Resilience policy. What it means, how do we build it, what tools can we use to understand it

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RESILIENCE POLICY

WHAT IT MEANS / HOW DO WE BUILD IT / WHAT TOOLS CAN WE USE TO UNDERSTAND IT

Amit Ashkenazy-Garini

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Amit ASHKENAZY-GARINI

RESILIENCE POLICY

WHAT IT MEANS, HOW DO WE BUILD IT,
WHAT TOOLS CAN WE USE TO UNDERSTAND IT

Dissertation

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SUMMARY

INTRODUCTION AND PROBLEM DEFINITION

Governments all over the world have been searching for ways to build resilience to a myriad of risks, which seem to intensify in frequency and potential impact – from the Covid-19 pandemic to climate change, from AI running loose to economic crises that defy our expectations and understanding. Many have embraced concepts and ideas from resilience thinking, and applied them to particular shocks and stressors, or even as a holistic framework for city resilience in face of multiple shocks and stressors. Thus, a new policy domain emerged – resilience policy. However, unlike other policy domains, such as environmental policy or health policy, it lacks a clear definition of goals, methods of analysis, and trade-offs. This is the gap this dissertation will start to bridge.

RESEARCH QUESTIONS

The dissertation answers four main research questions:

- RQ1: What components of resilience policy can we identify in theory?
- RQ2: What components of resilience policy can we identify in practice?
- RQ3: What are the possible trade-offs inherent to resilience policy?
- RQ4: How can modelling be used to inform resilience policy analysis?

While each chapter focuses on a particular question and poses further sub-questions, the four main questions cut across the dissertation and are reflected on in each of the chapters.

STRUCTURE AND METHODS

As resilience has been taken up and developed by ecologists, social scientists, and engineers, to name a few, and applied to policy problems in every possible policy domain, its exploration and definition must employ a transdisciplinary approach:

The introduction and chapters 2+3 review resilience literature from two main schools of thoughts: social-ecological and socio-technical systems thinking. They present central concepts in resilience and operationalize them to define what policy goals resilience policy could and should pursue, and what methods can be used to build a resilience-oriented policy environment.

Chapter 4 presents a content analysis of 41 city resilience plans from all over the world, which were written as part of the '100 resilient cities' programme. The analysis builds on a bibliometric analysis of each plan, and a qualitative interpretation and comparison of the resulting clusters of concepts. The results of the analysis shed light on what resilience policies look like in practice, what components they include and highlight, and which similarities and differences we can identify across the plans.

Chapter 5 is based on a comparative analysis of empirical cases studies captured by 14 research teams across Europe and beyond, examining the resilience of rural regions and communities. It demonstrates the application of resilience thinking to actual and potential policies in a particular domain and reveals the possible trade-offs between different resilience policy goals in practice.

Chapters 6 and 7 focus on tools to analyse resilience policy, and specifically Agent Based Modelling (ABM). Chapter 6 makes the case for why ABM is particularly suited to analysing and supporting resilience policy making, and presents a model designed in support of an actual resilience policy in Israel in the domain of sustainable urban transport. Chapter 7 explores how we can endogenise policy evolution to ABM so that they capture both changes in the policy domain, as well as the policy environment.

RESULTS

Chapters 2 and 3 yielded a resilience policy framework. It consists of seven policy goals and three methods to create a resilience-oriented policy environments. The policy goals include maintaining diversity and variability, building in robustness, mitigating vulnerability, ensuring persistence, adaptability, and transformability, introducing redundancy, maximising flexibility and modularity, and governing connectivity. The three methods for a resilience-oriented policy environment include rethinking policy, enabling a resilience-oriented policy analysis, and facilitating transformations.

Analysing the resilience plans in chapter 4 presented five main components that appear in almost all of the city resilience policies in the programme: domain (which specific shocks and stressors does the policy deal with?), capacity building, institutional design, stakeholder engagement, and strategy design (reflecting on the policy document itself).

Observing the realities of resilience in the context of rural and agricultural development, chapter 5 shed light on the possible trade-offs between different resilience policy goals: flexibility and modularity on the one hand and redundancy on the other (a surprising result as flexibility and redundancy are often used interchangeably); decentralised policy-making and connectivity, diversification and transformability, adaptability and vulnerability, and persistence at different scales, to name a few. While capturing these particular trade-offs was case-specific, this analysis provides an important basis for the types of trade-off analysis to be included in analysing and designing any resilience policy.

Finally, chapters 6 and 7 presented an analysis of how ABM can be used to support resilience policy analysis through exogenous policy experimentation and endogenous policy evolution within the model. Both models discussed allow incorporation of the different facets of resilience policy presented in chapters 2-5: they can analyse how different policy scenarios support resilience policy goals from different agents' perspectives and at different scales represented in the model. They are both beneficial in engendering the kind of tools and policy environments described in chapter 2 - where cross scale interactions are looked at, interdisciplinary analysis is encouraged, and participation is broadened. They can both allow examination of the tradeoffs presented in chapter 5 as well.

CONCLUSIONS

This dissertation provides a toolbox for policy makers and researchers exploring resilience policies within domains or across the disciplinary and domain divide. It provides practitioners who wish to establish a new resilience office or scholars analysing a policy to confront a potential shock with specific goals they can pose for the policy or measure it against, concrete steps to follow to increase the generalised resilience of the policy system, specific components to be embedded in the policy, trade-offs to be identified and measured, and ideas for models that can support resilience policy design and analysis. It engenders resilience policy as an independent policy domain and lays the basic foundations to defining and understanding it in practice.

However, it also demonstrates that in contrast to other domains, where a degree of values and context specificity can impact policy goals and instruments, resilience policy is completely dependent on them. For example, while in environmental policy different tools can be suggested to dealing with waste – from promoting a circular economy to degrowth, both heavily value laden, their meaning is universally clear. Resilience policy goals can only be contextualised in reference to the specific system at hand, the values and visions for the system held by the policy-makers shaping it, and the scale at which they are considering its future. This ambiguity requires scholars researching resilience policy to provide even more clarity of the overarching ideas that define the field, a continual exploration of how they are implemented in different domains and geographies, and a reflection of the commonalities and differences that emerge so that they feed the theory of resilience policy and its useability for both science and policy.

SAMENVENTING

INLEIDING EN PROBLEEMSTELLING

Overheden over de hele wereld zijn op zoek naar manieren om resilience op te bouwen tegen een groot aantal risico's, die in frequentie en potentiële impact lijken toe te nemen - van de Covid-19 pandemie tot klimaatverandering, van AI die op hol slaat tot economische crises die onze verwachtingen en begrip tarten. Velen hebben begrippen en ideeën uit het resilience-denken omarmd en toegepast op specifieke schokken en stressfactoren, of zelfs als een holistisch raamwerk voor de resilience van steden in het licht van meerdere schokken en stressfactoren. Dit heeft geleid tot de opkomst van een nieuw beleidsdomein, namelijk resiliencebeleid. In tegenstelling tot andere beleidsdomeinen, zoals milieubeleid of gezondheidsbeleid, ontbreekt er echter aan een duidelijke definitie doelenstellingen, analysemethoden en afwegingen binnen het resilience beleidsdomein. Het doel van deze dissertatie is het dichten van deze kloof.

ONDERZOEKSVRAGEN

Het proefschrift beantwoordt vier hoofdonderzoeksvragen:

- RQ1: Welke componenten van resiliencebeleid kunnen we in theorie identificeren?
- RQ2: Welke componenten van resiliencebeleid kunnen we in de praktijk identificeren?
- RQ3: Wat zijn de mogelijke afwegingen die inherent zijn aan resiliencebeleid?
- RQ4: Hoe kan modellering worden gebruikt om resiliencebeleidsanalyse te informeren?

Terwijl elk hoofdstuk zich richt op een specifieke vraag en aanvullende subvragen stelt, doorsnijden de vier hoofdvragen het proefschrift en worden ze besproken in elk van de hoofdstukken.

STRUCTUUR EN METHODEN

Aangezien resilience is opgepakt en ontwikkeld door ecologen, sociale wetenschappers en ingenieurs, om er maar een paar te noemen, en is toegepast op beleidsproblemen in elke mogelijk beleidsdomein, moet de verkenning en definitie ervan gebruikmaken van een transdisciplinaire aanpak:

De inleiding en de hoofdstukken 2 en 3 bekijken de resilience literatuur vanuit twee hoofdstromingen: sociaalecologisch en socio-technische systeemdenken. Ze presenteren centrale concepten in resilience en operationaliseren deze om te definiëren welke beleidsdoelen resiliencebeleid zou kunnen en moeten nastreven, en welke methoden kunnen worden gebruikt om een beleidsomgeving te creëren die gericht is op resilience.

Hoofdstuk 4 presenteert een inhoudsanalyse van 41 plannen voor stads-resilienceplannen van over de hele wereld, die zijn opgesteld als onderdeel van het '100 resilient cities' programma. De analyse bouwt voort op een bibliometrische analyse van elk plan en een kwalitatieve interpretatie en vergelijking van de resulterende clusters van concepten. De resultaten van de analyse werpen licht op hoe resiliencebeleid er in de praktijk uitziet, welke componenten ze bevatten en benadrukken, en welke overeenkomsten en verschillen we kunnen identificeren tussen de plannen.

Hoofdstuk 5 is gebaseerd op een vergelijkende analyse van empirische casestudies verzameld door 14 onderzoeksteams uit heel Europa en daarbuiten, waarin de veerkracht van plattelandsregio's en -gemeenschappen wordt onderzocht. Het toont de toepassing van het resiliencedenken op feitelijk en potentieel beleid in een specifieke domein en onthult de mogelijke afwegingen tussen verschillende doelstellingen van resiliencebeleid in de praktijk.

Hoofdstukken 6 en 7 richten zich op instrumenten voor de analyse van resiliencebeleid, en specifiek op Agent Based Modelling (ABM). Hoofdstuk 6 beargumenteert waarom ABM bijzonder geschikt is voor het analyseren en ondersteunen resiliencebeleidsvorming en presenteert een model dat is ontworpen ter ondersteuning van een daadwerkelijk resiliencebeleid in Israël op het gebied van duurzaam stedelijk vervoer. Hoofdstuk 7 onderzoekt hoe we beleidsevoluties endogeen kunnen integreren in ABM, zodat ze zowel veranderingen in het beleidsdomein als in de beleidsomgeving vastleggen.

RESULTATEN

Hoofdstukken 2 en 3 hebben een resiliencebeleidskader opgeleverd. Het bestaat uit zeven beleidsdoelen en drie methoden om een beleidsomgeving te creëren die gericht is op resilience. De beleidsdoelen omvatten het handhaven van diversiteit en variabiliteit, het opbouwen van robuustheid, het verminderen van kwetsbaarheid, het waarborgen van persistentie, aanpassingsvermogen en transformeerbaarheid, het introduceren van redundantie, het maximaliseren van flexibiliteit en modulariteit, en het reguleren van connectiviteit. De drie methoden voor een beleidsomgeving gericht op resilience zijn het heroverwegen van beleid, het mogelijk maken van een resilience-gerichte beleidsanalyse en het faciliteren van transformaties.

De analyse van de resilienceplannen in hoofdstuk 4 presenteert vijf hoofdcomponenten die in bijna alle stadsresilienceplannen in het programma voorkomen: domein (met welke specifieke schokken en stressfactoren houdt het beleid rekening?), capaciteitsopbouw, institutioneel ontwerp, betrokkenheid van belanghebbenden en strategie ontwerp (reflecterend op het beleidsdocument zelf).

Door de realiteit van veerkracht in de context van plattelands- en landbouwontwikkeling te observeren, wierp hoofdstuk 5 op de mogelijke afwegingen tussen verschillende doelstellingen van het resiliencebeleid: flexibiliteit en modulariteit aan de ene kant en redundantie aan de andere kant (een verrassend resultaat, aangezien flexibiliteit en redundantie vaak door elkaar worden gebruikt); gedecentraliseerde beleidsvorming en connectiviteit, diversificatie en transformeerbaarheid, aanpassingsvermogen en kwetsbaarheid, en persistentie op verschillende schalen, om er een paar te noemen. Hoewel het vastleggen van deze specifieke afwegingen casusspecifiek was, biedt deze analyse een belangrijke basis voor de soorten afwegingsanalyse dat moet worden opgenomen bij het analyseren en ontwerpen van elk resiliencebeleid.

Ten slotte presenteerden hoofdstuk 6 en 7 een analyse van hoe ABM kan worden gebruikt om resiliencebeleidanalyse te ondersteunen door middel van exogene beleidsexperimenten en endogene beleidsevolutie binnen het model. Beide besproken modellen maken het mogelijk om de verschillende facetten van resiliencebeleid, zoals gepresenteerd in hoofdstuk 2-5, te integreren: ze kunnen analyseren hoe verschillende beleidsscenario's de doelen van resiliencebeleid ondersteunen vanuit het perspectief van verschillende actoren en op verschillende schalen die in het model worden vertegenwoordigd. Ze zijn beide waardevol voor het creëren van het soort instrumenten en een beleidsklimaat zoals beschreven in hoofdstuk 2 - waar schaaloverschrijdende interacties worden verkend, interdisciplinaire analyse wordt aangemoedigd en participatie wordt verbreed. Ze kunnen allebei ook onderzoek mogelijk maken naar de afwegingen die in hoofdstuk 5 worden beschreven.

CONCLUSIES

Dit proefschrift biedt een gereedschapskist voor beleidsmakers en onderzoekers die resiliencebeleid verkennen binnen domeinen of over de disciplinaire en domeingrenzen heen. Het voorziet praktijkmensen die een nieuw resiliencebureau willen opzetten, of wetenschappers die een beleid analyseren om een potentiële schok het hoofd te bieden, van specifieke doelen die ze voor het beleid kunnen stellen of waaraan ze het kunnen meten, concrete stappen om de algemene resilience van het beleidssysteem te vergroten, specifieke componenten die in het beleid moeten worden ingebed, afwegingen die moeten worden geïdentificeerd en gemeten, en ideeën voor modellen die resiliencebeleidsontwerp en -analyse kunnen ondersteunen. Het maakt resiliencebeleid tot een onafhankelijk beleidsdomein en legt de basis voor het definiëren en begrijpen ervan in de praktijk.

Het toont echter ook aan dat, in tegenstelling tot andere domeinen waar waarden en contextspecificiteit een zekere invloed kunnen hebben op beleidsdoelen en -instrumenten, het resiliencebeleid volledig afhankelijk is van deze waarden en contextspecificiteit. Bijvoorbeeld, in het milieubeleid kunnen verschillende instrumenten worden voorgesteld om met afval om te gaan - van het bevorderen van een circulaire economie tot de-growth, beide beladen begrippen, waarbij hun betekenis universeel duidelijk is. Beleidsdoelen op het gebied van resilience kunnen alleen worden begrepen in relatie tot het specifieke systeem, de waarden en visies van de beleidsmakers die het vormgeven, en de schaal waarop ze de toekomst ervan overwegen. Deze ambiguïteit vraagt van wetenschappers die onderzoek doen naar resiliencebeleid nog meer duidelijkheid te verschaffen over de overkoepelende ideeën die het vakgebied definiëren, een voortdurende verkenning van hoe ze worden geïmplementeerd in verschillende domeinen en regio's, en een reflectie op de overeenkomsten en verschillen die naar voren komen, zodat ze bijdragen aan de theorie van het resiliencebeleid en de toepasbaarheid ervan voor zowel wetenschap als beleid.

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CHAPTER ONE

01

RESILIENCE POLICY

RESILIENCE POLICY

01

INTRODUCTION

This chapter outlines the research questions, methodologies, and structure of the dissertation. It clarifies what we mean when we say resilience and describes how different disciplines found their own interpretation of it, even within the sphere of policy studies. It clarifies why resilience policy discourse is on the rise, and why resilience policy is needed now more than ever.

1.1 BACKGROUND

On January 23rd, 2020, the city of Wuhan in China was put in lockdown in response to a novel virus that seemed to be both contagious and especially harmful. Within three months, most of the world followed suit, and the global economy and our way of life came to a standstill. As our current economic system relies heavily on production and consumption, which often require physical interaction that puts people at risk, governments and societies were forced to find new ways, solutions, and policies for maintaining people's residence, sustenance, educational activities, and most importantly and urgently - their health. In other words, governments were looking for policies that allow a measure of resilience against this extreme event and its implications.

Furthermore, national governments and international organisations such as the OECD have been integrating the concept of resilience in policy documents, tools, and actions, and trying to clarify its meaning through expert advice. However, they often start with operational questions that relate, for example, to coping with disasters, neglecting the underlying theoretical and descriptive questions that resilience literature provides (Weichselgartner and Kelman, 2015). The result is that while the meaning of resilience policy in specific contexts such as climate change or security threats is well defined, what it stands for in and of itself or when applied to new resilience policies remains far from clear. This dissertation aims to bridge that gap.

The goal of this dissertation is to find new ways to define resilience policy, recognise its components, identify its inherent trade-offs, and build new tools to utilise this conceptualisation in policy research and practice.

1.2 RESEARCH QUESTIONS

To promote resilience policy as an independent domain of study, much as environmental or sustainability policy has done in the past half-century (Walker, 2017), there remains a need for conceptual clarification: What is resilience policy as an ontological object? What are its components and structure? And what may impede or facilitate resilience policy design and implementation? This dissertation will aim to answer these questions, formalised as follows:

- RQ1: What components of resilience policy can we identify in theory?
- RQ2: What components of resilience policy can we identify in practice?
- RQ3: What are the possible trade-offs inherent to resilience policy?
- RQ4: How can modelling be used to inform resilience policy analysis?

1.3 STRUCTURE AND METHODOLOGICAL APPROACH

Any study of resilience policy as an independent domain needs to be interdisciplinary in nature. Resilience crosses policy domains, disciplinary expertise, and scales of investigation, and thus studying it requires a wide range of tools and methodologies. To answer the research questions above, each chapter utlises a unique methodological approach, often implemented as part of collaborations with wide research teams and projects from different fields. Following is a short description of the methodologies used in every chapter and why they were selected.

Chapters 2-3 present a broad literature review of resilience thinking to achieve two goals: Chapter 2 extracts from the review central principles of resilience and translates them to concrete policy goals for resilience policy, which can be applied and operationalised regardless of the particular domain context. Chapter 3 finds in the review attributes that can be integrated in the way the policy system itself is built and operates to enhance resilience. The literature review brings together concepts and ideas from different strands of resilience thinking, mainly engineering resilience and socio-technical approaches applying it, and ecological resilience and the social-ecological approaches applying it. This integrated review connects insights from a field more than five decades in the making, resilience thinking, to the specific question at hand - what do these concepts mean in the context of policy. The outcome of these chapters is a framework used throughout the dissertation as a basis for analysis and discussion.

The fourth chapter moves from theory to practice, capturing what resilience policy looks like through the lens of actual policy documents. It utilises bibliometric and content analysis to find common components, structures, and themes in resilience policy plans from 41 cities around the world. While the bibliometric analysis allows identifying clusters of recurring concepts in each of the plans, the following structured content analysis was required to assign meaning to each cluster and to move from understanding the policy at a single city level to a cross-city analysis, and the emerging structure of resilience policy.

The fifth chapter delves into the meaning of resilience policy in a particular domain, rural and agricultural development, and the trade-offs it entails. It builds on a comparative analysis of fieldwork conducted by 14 teams from across Europe and the Middle East as part of an Eranet project, where researchers deployed interviews, focus groups, and content analysis to understand how rural stakeholders and regions in different geographical, economic, and social contexts perceive rural resilience and work to bolster it. The chapter provides a more concrete understanding of what resilience policy and strategies can look like in relation to particular shocks and stressors, and the trade-offs between different resilience policy goals when applied in practice.

The sixth and seventh chapter focus on agent-based modelling and how it can be used to analyse resilience policy. The sixth chapter presents a review of agent-based modelling and its utility in policy analysis in domains related to resilience, and an example of how an agent-based model of a real-life resilience policy challenge could be used to support policymakers in Israel, mainly on managing the transition to electric buses in the country's urban public transport fleets. The seventh chapter presents a new approach to researching and analysing resilience policy through a modelling approach that connects between theories of the policy process and different policy domains, thus allowing researchers and policy analysts to explore how policies may change over time within the model itself. The chapters also demonstrate why agent-based modelling is a tool especially useful for designing and analysing resilience policy: shared theoretical roots (complexity theory), shared assumptions (importance of representing heterogeneity), ability to represent the policy goals and tradeoffs presented in chapters 2 and 5, and their potential contribution to building a resilience oriented policy environment presented in chapter 3 and in operationalising the resilience policy components presented in chapter 4

The eighth chapter (conclusion) provides personal insights, based on the work conducted and the researcher's experience as a policy practitioner, about resilience policy as an ontological object, its limitations and potential, and the tools explored throughout the dissertation to better understand and explore it.

As has been mentioned, the chapters utilise quantitative and qualitative methodologies, from diverse disciplines such as rural sociology, systems engineering, political science, and environmental management. This stems from the practical nature of our work in diverse policy domains, the need to understand resilience policy at different scales of study, and the desire to design useful tools for researchers of resilience policy, resilience policy analysts and practitioners, and modellers who seek to expand the breadth of their models to include insights and dynamics crucial for capturing the evolution of resilience policy over time.

Furthermore, while chapters 6 and 7 focus explicitly on modelling resilience policy through agent-based models, each chapter builds a different kind of model to answer the research questions posed above - a conceptual model of resilience policy as a policy domain; a bibliometric model of resilience policy themes and components; a synthesis model of resilience strategies in rural development and the tradeoffs they present; an agent-based model of pathways for electrifying electric buses in Israel through an exogenous representation of the policy process, and finally an agent-based model that endogenises the policy process and can be coupled with any domain to explore resilience policy in multiple fields. Thus, the dissertation makes a contribution in considering different approaches to modelling, and how they can be used not only as tools in solving specific research and policy problems, but to define and integrate new knowledge domains.

Before delving into the research questions at hand in each of the chapters, we provide a short description of what resilience means in different disciplines and contexts, why it is being talked about in a policy context more and more in recent years, and why resilience policy is a policy domain worth pursuing.

1.4 WHAT DO WE MEAN WHEN WE SAY RESILIENCE?

Ecology recognises that sudden and unexpected change occurs in nature all the time: populations die, species invade or become extinct, and physical and biological disturbances change the whole dynamics of the ecosystem. In the social realm change is even more pervasive - in economy, society, and culture: local markets affect global markets and vice versa, market demand changes abruptly, and so do prices, profits, and loss. Values and culture can change, and with them whole societies, as people and nations move through time and space. But as systems transition between different states, or regimes, each with its unique characteristics, feedbacks, and rules, they often maintain or strive to maintain certain components that make up their identity. Resilience can thus be defined as the system's capacity to endure disturbances, endure change, while maintaining these core components, states, or regimes (Hughes et al., 2007).

While this definition gives us a general understanding of what resilience is, researchers and practitioners have offered many alternative definitions fitting different needs, perspectives, and theories. It is worthwhile to mention several definitions, to establish a shared understanding for the sake of this manuscript of what we mean when we use the term "resilience". In this section, I will briefly review a few approaches to defining resilience in different fields.

As resilience thinking is applied to a growing number of fields and disciplines it is better understood as a paradigm rather than a theory. It conveys a collection of ideas that facilitates discourse across disciplines on how systems can withstand and adapt to change over time (Tendall et al., 2015). The Latin etymological ancestor of the word resilience means to bounce back, reflecting the commonplace interpretation of resilience as the ability to recover from disruption and return to a normal state. This is a broad interpretation that allowed many fields to make use of resilience as an analytical prism – from natural science to social science, from infrastructure to material engineering. Indeed, many definitions of resilience mention the system's ability to maintain certain functions and structure while coping with pressures – either by preventing them, absorbing them, or recovering from them after they occur. These definitions have in common two elements – the system's performance levels normally and following a disruption, and the resources required to recover from it (Amarasinghe et al., 2012; Hosseini, Barker, and Ramirez-Marquez, 2016).

Hosseini et al. (2016) differentiate between four central domains for the application of resilience outside of the ecological sphere (which is described in detail in annex A) – organisational resilience, social resilience, economic resilience, and engineering resilience. While they all deal with one way or another of maintaining a certain normality in face of stress or disruption, each has a different subject as its focal point. Organisational resilience deals with a company or an enterprise seeking to resume operations in terms of its inventory, capacity, or service rate. Social resilience deals with individuals, groups, and communities who predict risk, try to limit its negative consequences, and survive and recover through collective action, adaptability, and growth. Economic resilience expands the scope of analysis from companies to regions, focusing on their utilisation of adaptive responses to refrain from maximum potential losses. Finally, engineering resilience brings to the fore technical systems – systems that are designed, and that interact with people and technology. In this sense, resilience represents the system's ability to survive passively through reliability, and proactively through restoration. These can be achieved through adjusting functionalities when facing unpredicted events, or through design that guarantees continuity in performance through factors such as minimising failure, limiting disruption effects, putting in place administrative procedures, increasing flexibility and controllability, and creating early detection mechanisms.

Resilience is associated with protection against both shocks, meaning extreme events, and stressors, meaning changes that may occur over time. Wright, Kiparoglou, Williams, and Hilton (2012) argued that ensuring asset or enterprise resilience is a process, rather than a trait: anticipating the threats, working to prevent them or mitigate their possible impacts, and, once they occur, minimising their duration, extent, and cost. This is followed by a process of recovery, learning, and adaptation. Disruptive events, they point out, can stem from the environment, from connectivity and interdependence between different systems, from a behaviour that emerges from within the enterprise, or from a possible conflict of priorities. In this sense, resilience goes further in its ambition and scope than risk management, which aims to quantify the probability and severity of different risk factors, helping the system plan and prepare for adverse events. By integrating time as a factor, resilience allows the system to absorb the shock, recover from it and adapt to it (Linkov et al., 2014).

Norris et al. (2008) similarly argues that resilience should be interpreted as a process rather than an outcome and that it is closer to a dynamic notion of adaptability than to static idealised stability. However, they further argue that adaptability itself is a complex notion, as it contains within it both engineering resilience that aims to bring back the system to the state or function that existed or was planned before the disruption, and ecological resilience that allows for multiple possible desired states to develop in accordance with the environment. Thus, they define resilience as a process that links certain capacities to adapt, to the desired pathway of functioning and adapting once a disturbance occurred. In their conceptualisation, resilience does not negate distress, which is a normative response to disruption, as long as it is followed by returning to a desired state of functioning. This can happen both on an individual level as well as on a community level by achieving what they term "population wellness".

Within the world of policy-making, resilience can also have multiple definitions. However, in analysing definitions for resilience from official national and international policy documents, Weichselgartner and Kelman (2015) found several common elements: the system's ability to withstand hazards through planning, resistance, absorption, preservation, adaptation, restoration, and even improvement of essential basic structures and functions. This is done by managing change on different scales (from national to household), changing living standards in face of shocks while maintaining their long-term prospects, and maintaining different components such as assets and networks in face of adverse events. In order to maintain these functions, structures, and feedbacks, the system needs to reorganise when disruptive events occur (Carpenter et al., 2012).

Social-ecological resilience thinking extends the definition of resilience beyond the rate at which the system can return to equilibrium or bounce back from a disruption, a characteristic of engineering resilience. It looks at the capacity of a system to persist when change occurs and to continue developing as the environment itself changes. It looks at how different social units – from individuals to societies can adapt to new conditions or transform the system so that it takes new pathways. These capacities can allow society to navigate between different thresholds and tipping points, even if that means breaking down existing perceptions and structures and replacing them with others that can build more general resilience (Folke, 2016). For more on the theoretical basis of social-ecological thinking see Appendix A.

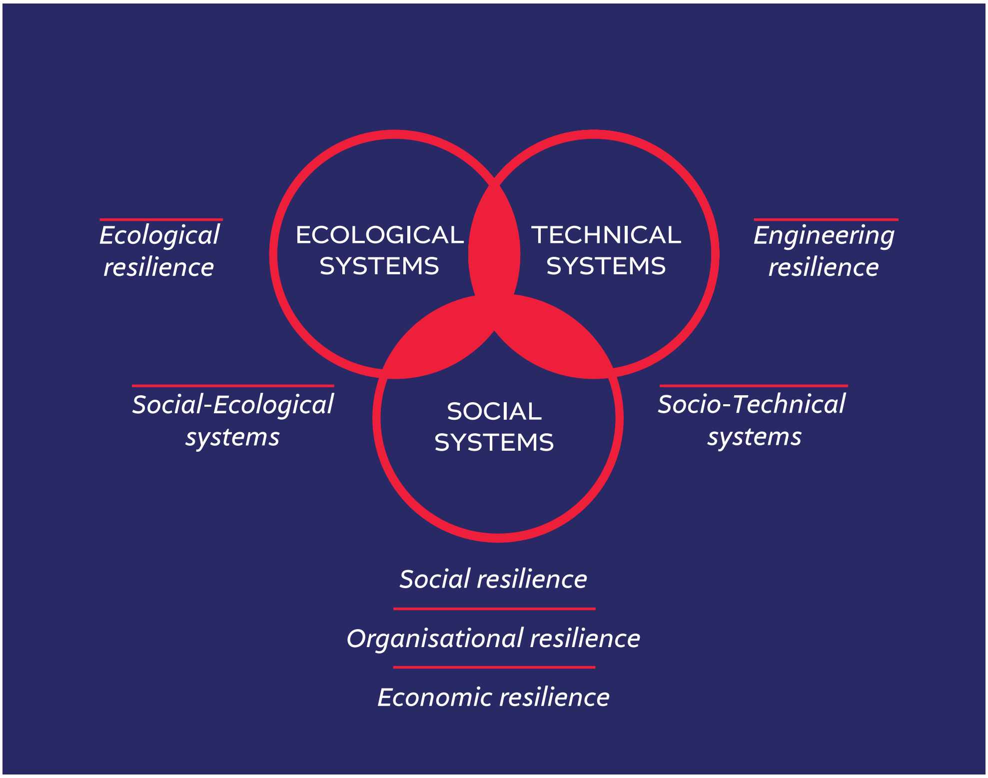
Comparing perceptions of resilience in international development and in social-ecological systems thinking, Bousquet et al. (2016) found that social-ecological thinkers focused on how to preserve system components such as identity, function, structure, and feedbacks. Development practitioners and scholars, on the other hand, focused on how quickly communities can recover from shocks after a disturbance, or more specifically disasters, have occurred. They demonstrate this through an examination of resilience in the food system, where social-ecological approaches look at facilitating social learning, putting in place early warning signals, and preparing for and creating buffers for the shock, while their development counterparts focused on households' ability to quickly respond to and recover from disruptions.

Similarly, in a broad meta-analysis of resilience policy documents, White and O'Hare (2014) found that they most frequently adhere to equilibrium-based approaches to resilience, and mostly engineering resilience at that. Ecological resilience is present to a lesser degree, and to an even lesser degree evolutionary approaches that seek, for example, responses to climate change that require transformations beyond traditional infrastructure, such as provisions of green infrastructure. Equilibrium-based approaches are often simplistic and fatalistic, aiming to preserve a status quo, and to find ways to return to it following a disturbance. In contrast, evolutionary approaches are focused on process, perceiving resilience as a deliberative practice that supports institutional and behavioural change. Furthermore, they found that while ecological approaches to resilience policy also aspire to reach a new normal state, it is for the aim of being better able to withstand shocks rather than transform the system altogether. Furthermore, detailed guidance is given to a greater extent in equilibrium approaches-based policies, facilitating rebound and recovery, and constraining the response to policy silos, endogenised and short-term risks. On the other hand, policies based on the evolutionary approach often remain abstract, imprecise, and lack definition and guidance.

One aspect of resilience and policy that is gaining traction in recent years is the question of equity – who stands to gain from resilience efforts and who gets left behind? For example, Siders and

Gerber-Chavez (2021) argued that Covid-19 demonstrated that people with financial means can make use of opportunities to avoid harm that are not available to lower income households, such as private health insurance, avoiding public transport, or stay in hotels when needed. Thus, they argue that resilience must be considered both at a societal level but also individually to expose the gaps in resilience within society, or in other words – "resilience for whom?".

FIGURE 1: APPROACHES TO RESILIENCE BY DISIPLINIRAY FOCUS



1.5 WHY IS RESILIENCE DISCOURSE ON THE RISE?

At this moment in time, resilience policy plays an ever-growing role in national debates - with climate change, war, ongoing pandemics, and economic instability on the rise. However, resilience has been gaining prominence in policy circles and in its academic following for years, especially in relation to climate change. As the climate crisis looms large, the notion of planetary boundaries, stemming from resilience theory, is extending its reach (Folke and Gunderson, 2010). Resilience has been invoked in response to myriad challenges: the need to secure infrastructure and the built environment in face of disruptions such as floods and sea level rise, national security threats, and supply chain instability to name a few. As energy and security policies become more intertwined, policies to bolster civil responses to emergencies further embed resilience in the policy discourse (Coaffee, 2008). Another driver of resilience policy discourse is the financial crisis, and its lasting impact on society, politics, and the economy, especially in certain European countries that have struggled to recuperate from its repercussions (Doyle, 2015).

Furthermore, stability is the basis for the social-economic system that allows national governments and firms in richer countries to continue on their current path of development. Ignoring extreme events and changes can put them at risk of litigation and liability, as happened, for example, with the deepwater horizon incident. In recent years we saw how crises such as the Covid-19 pandemic and the war in Ukraine can lead to supply chain failures, which can cause similar problems - shortages in labor, raw materials, and product availability (Hudson et al., 2012).

Another reason resilience is taking hold in policy discourse is recognition of the complex nature of our current economic and political system: policy domains and geographies are becoming more interconnected in a globalised society. Human impact is accelerating in breadth and speed, creating new cross-scale interactions and feedbacks (Folke, 2016). For example, despite the appearance of increasing human well-being, the loss of ecosystem services is undermining the conditions upon which that well-being depends (Raudsepp-Hearne, Peterson, Tengö, and Bennett, 2011).

The climate crisis is also opening new opportunities to integrate resilience in policy discourse, as individual scientists and institutions such as the IPCC are making it increasingly clearer to the public and policymakers, that current human development trajectories are untenable considering our dependence on the biosphere (Bousquet et al., 2016).

1.6 WHY DO WE NEED RESILIENCE POLICY?

Even if resilience is a useful prism for thinking about the world, why do we need dedicated policies to build resilience? While this section and the manuscript in general provide several answers to this question, it should be noted that it remains open-ended. The conclusions chapter looks back at the manuscript as a whole and tries to provide a subjective assessment of it, but in the meantime, we will take resilience policy at face value and describe how some of its proponents may describe it and its necessity.

Keeping in mind the challenges described in the previous section, advocates of resilience policy could argue that implementing resilience policy is necessary for several reasons: We need policies that explicitly provide stability in face of the growing interconnectedness of the systems that make up our current civilisation and the risks that interconnectedness entails; we need policies that steers us away from dangerous tipping points; we need policies that can help us face uncertainty in the shocks we may encounter and our overall development trajectories; policies that facilitate transformations in our systems; and policies that can manage the slow and fast processes that drive and govern our society and biosphere. Finally, resilience as a policy domain can serve as a boundary object that bridges the many disciplines and approaches required for tackling complex problems. Following is a short explanation of each of these reasons:

1.6.1 PROVIDING STABILITY IN FACE OF INTERCONNECTEDNESS

The complexity of ecosystems in spatial, temporal, and organisational scales, and human use of these systems, require complex human institutions to safeguard their functions. In other words - policies need to provide continual learning and a growing understanding of the changing conditions in the system. These should allow greater flexibility in adapting to surprises, and in creating greater capacity for new structures of innovation to take shape in response to the inherent unpredictability in the evolution of both the ecosystems and the societies to which they are linked (Folke et al., 2007). What it is we are trying to preserve, though, is a matter of interpretation.

While some look for ways to conserve the foundations of capitalist democracy as a predominant way to arrange state politics and economy (Iversen and Soskice, 2020), others contend more dramatic, even revolutionary change is needed to meet the social-ecological challenges capitalism has not only instigated but continues to exacerbate (Pelling, Manuel-Navarrete, and Redclift, 2012).

1.6.2 AVOIDING AND FACING THE CONSEQUENCES OF TIPPING POINTS

The need for resilience policy is becoming greater as humanity is approaching critical thresholds that are likely to affect consumption and production patterns, economic policy, and resource use (Folke et al., 2002). Climate change is perhaps the clearest case in point: stability in climate for the past 10,000 years has allowed the evolution of agriculture and human civilisation. Passing a critical threshold out of this stability would likely compromise human well-being as we know it. However, current development pathways are leading humanity toward those tipping points (Folke and Gunderson, 2010). Resilience policies are required to recognise them and cultivate alternative pathways. Alternatively, as years go by and governments fail to meet the necessary conditions to avoid these tipping points, adaptation to "the new normal" becomes increasingly urgent (Pörtner et al., 2022).

1.6.3 FACING UNCERTAINTY

Since we cannot yet accurately predict how climate change is going to affect extreme weather events in location and frequency, building resilience in critical infrastructure is regarded by some as the optimal course of action. In this case, resilience would mean trying to prevent adverse consequences and prepare for them at the same time, so systems can recover and adapt. Facilitating such capacities would require new ways to measure resilience, model infrastructure as complex systems, develop the field of resilience engineering, and expand methods of engagement with stakeholders, particularly with policymakers who are the ones that can push the system towards resilience management through legislation and regulation (Linkov et al., 2014).

Furthermore, assessing probabilities for extreme events and trends may be itself a difficult task, due to the lack of data that would allow fitting models, and a long tail of probability distributions for their occurrence, to the point of the chances of the event happening becoming an unknown, limiting policymakers' ability to make informed decisions and choices. (Carpenter et al., 2012). Resilience, while built on a theoretical foundation that appreciates a dynamic approach, is tilting toward a more radical understanding of risk. Rather than focusing on static capacities and capital, it is starting to look at trajectories. Rather than one possible scenario to avoid, it depicts alternatives where people may avoid the worst impacts of a shock, organise themselves to face its consequences, or rebuild and maintain their core assets. Resilience policy can also diminish the risk of the institutions themselves leading toward undesirable regime change when they become overly connected, self-reinforcing, and lacking flexibility - both in terms of function as well as discourse (Bousquet et al., 2016).

Importantly, fear of uncertainty and even resilience discourse itself can lead institutions to adopt solutions that strengthen the perception of control while in fact undermining resilience. For example, technological solutions in the food industry may create the illusion that nature can be contained, controlled, and ultimately ignored, preventing necessary changes not only in modes of production but in the very design of the food system (Stuart, 2008).

Facing the climate challenge, many nations are already looking for ways to engage in transformational decarbonisation. However, designing models and pathways that support it requires considering non-linear dynamics stemming from innovation, changes in human behaviour, and changes in the political sphere that may drive both policies that move the state from supporting fossil fuels to mitigating their use in the economy (as happened with coal in China between 2013-2015), and the other way around (as happened in the US under the Trump administration) (Rockström et al., 2017).

1.6.4 MANAGING FAST AND SLOW VARIABLES

Resilient systems and policies that aim to bolster them can respond to both slow and fast variables, meaning processes that occur at different time scales. For example, Troell et al. (2014) describe resilient food systems as susceptible to both risks that take long to manifest and evolve such as climate change, and risks that can fluctuate on a daily basis or even faster, as in the financial market. These two types of risks require very different capacities and responses among growers as well as policymakers. More broadly, resilience enables policymakers and scientists to analyse social-ecological systems' sustainability responses in the long term and make explicit the positive and negative impacts adaptive action may have on changes in the environment in the short term (Adger et al., 2011).

1.6.5 RESILIENCE AS A BOUNDARY OBJECT

Policymakers have been defining resilience as a distinct policy objective, especially in relation to sustainable development, despite the concept's ambiguity or multiplicity in interpretation Bousquet et al. (2016). In fact, its ambiguity probably contributes to its wide use as a boundary object, meaning that it can be easily used by different disciplines and to facilitate communication between scientists and practitioners. However, if it is to help design better policy interventions, resilience thinking should be operationalised in a way that helps shed light on interactions across scales and levels and moves analyses towards a whole system perspective (Tendall et al., 2015). Resilience policy can also shape institutions that help society overcome individual barriers to rational choice, creating aggregate decision-making that delivers better outcomes for the collective overall (Carpenter et al., 2012).

1.7 THE CHALLENGE AHEAD

In 2011, 50 Nobel Laureates discussed resilience as a central theme of a global symposium, looking at how to reconnect social-ecological resilience and development to the biosphere, spur social innovation to accelerate the transformation toward global sustainability, and encourage stewardship of the biosphere in the age of the Anthropocene (Folke and Rockström, 2011). This is not surprising as the past decade has seen extreme fluctuations in climate and weather, natural disasters such as the Tsunami in Japan, natural disasters of growing intensity and frequency, and social upheavals such as the Arab Spring. However, some say that while resilience scholarship has had an impact on management practices at the local and regional scale (Liu et al., 2007), it has not yet translated to the national and global scales (Gunderson and Folke, 2011).

Still, resilience can spur a change in the kinds of analyses, tools, and processes that underlie policy-making. Social-ecological resilience provides an outlet for planning theorists who are calling to focus on substance in conjunction with discussing issues of process. Its integration with complex-adaptive systems conceptualisation corresponds with current understandings of non-linearity and how it affects drivers of environmental considerations and concerns. It can also be a useful tool to frame problem setting and problem-solving (Wilkinson, 2012). Finally, resilience thinking provides policymakers with new metaphors for structural change in the complex systems we aim as a species to preserve and creates new tools for analysing their dynamics, thus helping expand adaptive governance (Wilkinson, Porter, and Colding, 2010).

1.8 RECOGNIZING CRITIQUE

While this manuscript inherently assumes a normative standpoint that resilience policy is a useful construct and tool, it is worth mentioning two prominent critiques of this approach.
First, perceptions of a system's resilience are observer-dependent, meaning that they are determined largely by the specific perspectives informing the analysis and within the context of the social system in which the analysis is taking place. Framing resilience as positive or negative is a normative determination, based on values of what is good for society and for individuals, though this is easier to identify when dealing with social conflicts rather than biophysical phenomena with dire implications such as drought and floods. In any case, we must take into account that the act of framing resilience one way or another is done by people with particular interests and access to resources. Thus, assessment of the system's resilience should consider the different groups within it, and how they are impacted by both disruptions and strategies to overcome them (Duit et al., 2010).

Second, applying notions from a natural science interpretation of resilience to society and politics can lead to normative and conceptual challenges. As resilience theory is predicated on ecological thinking and observations, applying them to social phenomena may create inherent problems in analysis. Assumptions about nature cannot be superimposed onto society, as the very categories of nature and society are socially constructed (Weichselgartner and Kelman, 2015). While limiting the use of resilience to understanding how social-ecological systems can maintain certain functions they deem essential can mitigate some of the conceptual difficulty, creating policies and institutions that are based on notions of resilience requires that we acknowledge they are value-laden and have distributional effects (Duit et al., 2010). Different people and groups have diverging views of the desirability of different states. They lead struggles over possible pathways through a plethora of institutional settings, and in multiple domains – from academia to party politics (Hughes et al., 2007). The capacity for resilience is itself not distributed evenly, both across social groups and within them. It is impacted by myriad factors in society, economy, and culture, and by decision makers' group affiliation (Weichselgartner and Kelman, 2015). As in any system analysis, defining the specific units being analysed and the system boundaries is critical, as increasing resilience for some may decrease it for others, and supporting certain dimensions (social or biophysical) may undermine others (Folke, 2016).

Third, while engineering resilience looks at the system as an object in need of fixing to return to its original state, and ecological resilience conceptualises the system as complex and natural, capable of reorganising and moving to different states following a perturbation, evolutionary resilience does not assume there is a desired state to return to or to progress toward, instead defining resilience as the system's capacity for adaptation and transformation (Uda and Kennedy, 2015). The tension between continuity and change is addressed when resilience is understood as the system's ability to reorganise in the face of change, so as to maintain certain elements within it such as function, structure, or feedbacks, allowing to safeguard its identity. In other words, it expresses both persistence and evolution (Folke, 2016).

In terms of the concrete policies resilience advances in practice, resilience is often used to focus policy interventions away from systemic interpretations and focus instead on the individuals and their ability to avoid risks such as poverty in face of different stressors and shocks. This has become a central concept in gaining access to funds for grants and development projects (Bousquet et al., 2016). An even more critical way to look at resilience policy is that it has no practical goals, other than reassuring voters that something is being done to confront unavoidable threats. Rather than prevent or mitigate risk, it projects the veneer of response to these threats, as their drivers are seeming too complex to address. It ensures voters that normalcy will be maintained and restored, even if the risk materialises. It is thus a coping mechanism that portrays action rather than inaction on part of the government, and a broad theme to which policy windows can be tailored (White and O'Hare, 2014).

1.9 CONCLUSION

Resilience means having the capacity to cope with change, whether it is expected or unexpected, gradual or immediate. Resilience thinking focuses on the way systems are governed and managed, so that they allow for flexibility and the emergence of innovative solutions when encountering shocks and stresses, whether it is at the level of the individual, the community, the organisation, the government, or even the world. It does not aim at preserving any particular status quo. This dynamic approach should allow systems to thrive in uncertain and complex situations, dealing with change at different scales and human dominated arenas. It integrates three paths for dealing with change: first, remaining in the current basin of attraction and path of development, second, adapting to changes through improvement and innovation while still maintaining the path, or third, overcoming possible traps and path dependencies by embracing a shift away from the current basin of attraction toward a different basin and development path. Rather than maintaining system resilience, this third option recognises the system when it has become too robust and rigid, and thus undermining its resilience can become a positive course of action (Folke, 2016).

While this chapter provided a general definition of resilience and its different disciplinary interpertations, the next chapter will delve to social-ecological and social-technical readings of resilience to identify possible policy goals for resilience policy across domains.

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CHAPTER TWO

02

CHAPTER TWO
POLICY GOALS

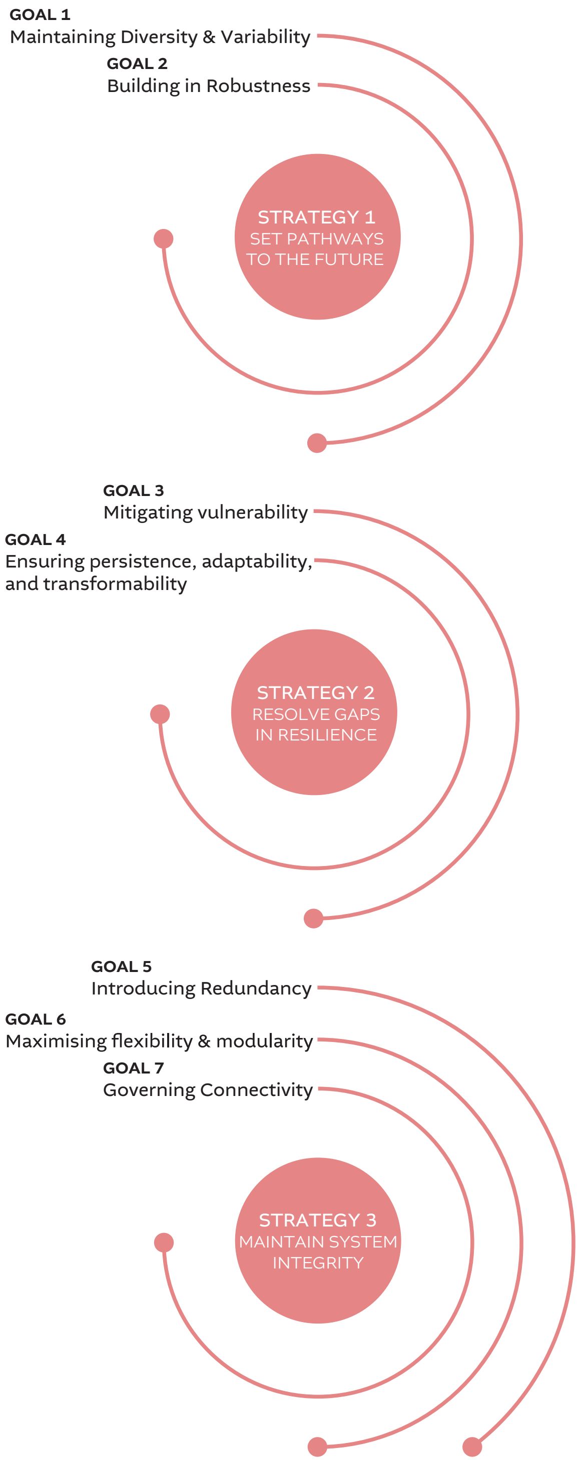
RESILIENCE POLICY

02

SETTING RESILIENCE POLICY GOALS

What is resilience policy? That is the basic question at the heart of this manuscript. While the introductory chapter gave a general review of different approaches to resilience, this chapter aims to answer the question by identifying in the literature the basic concepts that can be utilised to delineate resilience policy and specify the policy goals it entails.

FIGURE 2: RESILIENCE POLICY GOALS IDENTIFIED



2.1 INTRODUCTION

Resilience policies in specific policy domains have been widely explored– in environmental law (Garmestani et al., 2019), international development (Boyd et al., 2008), critical infrastructure (Hickford et al., 2018), urban planning (Rogers, 2018), transportation (Armstrong, Preston, and Hood, 2016; Green and Chmutina, 2019), disaster management (Flentje and Chowdhury, 2016), coastal management (Pontee and Tarrant, 2017), and agricultural development (Webb et al., 2017) to name a few.

However, framing resilience policy as an independent policy domain equivalent to environmental policy, health policy, or education policy, for example, requires clarification of what sets it apart from them. The literature on social-ecological and socio-technical systems provides a rich description of the overarching principles and qualities required to enhance resilience, which we can use to define specific policy goals. The literature also describes the kind of policy-making structures and analysis required to enhance resilience, or in other words what policy environments are most likely to bolster resilience. This chapter and the next review what we can learn from the literature on both of these dimensions of resilience policy – its policy goals and the policy environment it prescribes.

The chapter continues as follows: First, we present the methodological approach that guided the literature review in this chapter and the next. We then discuss how resilience qualities and principles can be translated into concrete policy goals. Finally, we dive into each proposed policy goal, forming a non-exhaustive list of goals that can serve policymakers in three ways: defining the ideal states they may choose to pursue, making policy evaluation and measurement more tractable, and understanding possible tradeoffs between different policy goals within the "resilience policy" domain. Detached from specific contexts these policy goals maintain a degree of ambiguity, and so examples from how governments dealt with the Covid-19 crisis will be used to demonstrate their possible meaning at different scales.

2.2 METHODOLOGICAL APPROACH

2.2.1 METHODOLOGY

The starting point for the discussion rests on previous work describing resilience principles and resilience governance, especially in this age of the Anthropocene (Carpenter et al., 2012; Folke, 2016; Jørgensen, Folke, and Carroll, 2019). For example, Folke identified several principles that according to research enhance resilience: maintaining diversity and redundancy, managing connectivity, managing feedbacks as well as the interplay of slow and fast variables, fostering complex adaptive systems thinking, encouraging learning, broadening participation, and promoting polycentric governance (Folke et al., 2016).

Much of this work was synthesised in 2012 when a group of resilience scholars held a workshop followed by a Delphi (multi-stage survey of resilience experts) to identify seven generic principles for enhancing the resilience of ecosystem services. The outcome was a seminal paper (Biggs et al., 2012) that was later expanded into a book titled "Principles for Building Resilience: Sustaining Ecosystem Services in Social-Ecological Systems" (Biggs, Schlüter, and Schoon, 2015). The group of experts defined seven principles of resilience – three were features of social-ecological systems (SES), and an additional four defined the attributes of SES governance systems. While the authors focused on how to enhance the resilience of ecosystem services, the basic structure they offered potential insight to resilience policy more broadly.

As this manuscript aims to build a broader bridge between different bodies of thought on resilience, and specifically between Ecological Resilience and Engineering Resilience, this chapter presents a literature review that integrates elements based on two central bodies of knowledge: First, the Stockholm Resilience Center, a hub and progenitor of social-ecological resilience. The second is the Proceedings of the Institution of Civil Engineers, representing a more socio-technical approach to resilience. In the former, papers with direct connection to governance were given more prevalence, as well as foundational papers on the centre's thinking about resilience in general. In the latter a wider net was cast, looking at papers discussing resilience in the context of infrastructure and planning. Recurrent themes were then identified, and insights from both sources were grouped under each. Additional resources were approached through focused searches in google scholar when the two main resources proved insufficient.

What most these papers and approaches had in common is that they compatible and even based on different notions of complexity theory. This is not surprising, as according Kreienkamp and Pegram (2021), global risks such as climate change are themselves complex, emerging from open systems as a result of interaction between different elements, and between those elements and their environment, and can only be analysed and understood in terms of these relations. However, the interactions between these elements are not linear and controllable, with feedback either magnifying or mitigating variations in initial input. This means that the system behaviour, or in this case the risks at hand, emerge from the bottom up, through self-organisation, adaptation, and co-evolution.

In order to make policy goals clear and relevant, we demonstrate how they manifested in government policy and policy debates in response to the ongoing Covid-19 crisis during its first 12 months in Israel. Israel was chosen due to the author's personal national affiliation, but also as a unique case: Israel achieved the quickest vaccine coverage in the world, but at the same time suffered high rates of infection per capita. Its high diversity in minority populations and lifestyles and past experience with emergency situations all contributed to a lively policy debate on the government's policy response to Covid.

2.2.2 RESILIENCE QUALITIES AS POLICY GOALS

Resilience policy can be seen as a tool for designing more resilient systems - resilient transportation systems, housing systems, farming systems, electricity grids, cities, or nations. The first step in designing complex systems, in this case, systems that have greater resilience, is defining functional requirements. In simple systems, these functions can be described relatively clearly and succinctly. For example, a sink's function is to drain water. However, the more complex the system, the more compounded the functions. For example, a national water pipeline needs to transport water efficiently, but also in a secure manner, with minimal disruption to the ecosystem in which it is laid, retaining water quality throughout. All these requirements translate to objectives and constraints that dictate the design space that delineates which solutions should be considered (Weijnen, Herder, and Bouwmans, 2008).

One way to conceptualise the design space for bolstering resilience through policy is with the concept of "ilities". ilities represent desired system properties, which frequently become visible after the system has begun its operation. They do not fulfil the primary functional requirements of the system, but rather their wider impacts on society and stakeholders, and do not include characteristics of the system that are continuously present such as an object's physical properties. Capturing the ilities most frequently mentioned in research and online, de Weck, Roos, Magee, and Vest (2011) identified, for example, quality, reliability, safety, and flexibility. Some ilities are more important than others (in terms of societal priorities), and their stature changes over time. Examining their co-appearance in webpages, De Weck found a hierarchical network, where some ilities are more connected to each other, some have a more central position in the network, and others are on its periphery, playing a supportive or enabling role for more central ilities.

De Weck identified resilience itself as an ility, one of the important emerging ones in our current design epoch. While De Weck conformed to the idea that resilience means bouncing back from unexpected disruptions, he mentioned other ilities that relate to it or can be included under its umbrella – agility, adaptability, reliability, and robustness to name a few. In order to ensure these ilities, he mentioned the use of policy tools such as standards and fines. These can be applied to push utilities, for example, to invest in necessary infrastructural changes and improvements that reduce the chances of cascading power failures (de Weck et al., 2011). Bauer and Herder (2009) offered a similar list of design goals for socio-technical systems and argued that these goals reflect public values. They describe the relations and mutual obligations of citizens and government, rights and benefits, and the principles at the basis of policies and government work. While these functionalities often need to translate to physical services provided, they are influenced by goals derived from the legal and political spheres, goals such as legality, justice, transparency, and accountability.

The next section of this chapter makes explicit the "ilities" that make up resilience or are connected to it, meaning properties that should emerge when resilience policy is applied in a system. This allows us to examine them as policy goals that delineate the design space for resilience policy.

2.2.3 RESILIENCE POLICY GOALS

While many possible principles and qualities for enhancing resilience are mentioned in the literature, we present a list of seven policy goals that help delineate the design space for resilience policies, clustered into three main strategies:

Set pathways to the future:

Goal 1: Maintaining diversity and variability,
Goal 2: Building in robustness.

Resolve gaps in resilience:

Goal 3: Mitigating vulnerability,
Goal 4: Ensuring persistence, adaptability, and transformability.

Maintain system integrity:

Goal 5: Introducing redundancy,
Goal 6: Maximising flexibility and modularity,
Goal 7: Governing connectivity.

For each policy goal, we will now ask what it means, how it can be strengthened, and what are its possible trade-offs.

2.3 STRATEGY 1: SET PATHWAYS TO THE FUTURE

The first strategy contains policy goals that increase the chances of prevention and recovery in the face of possible disturbances in the future, but also setting in place the potential for systemic transformation by maintaining diversity and variability and building in robustness.

2.3.1 GOAL 1: MAINTAINING DIVERSITY AND VARIABILITY

WHAT DOES IT MEAN?

Diversity in different components of social-ecological systems has many benefits to their resilience: it creates new opportunities for reorganisation to occur based on reserves of biological and social capacities such as species, knowledge, and skills (Carpenter et al., 2012; Folke, 2016); it spreads risks, introduces buffers to shocks and disturbances, and allows learning from various coping strategies (Wilkinson, Porter, and Colding, 2010). Diversity can also serve to bolster institutional robustness, as it allows for many small initiatives with similar purposes to persist in the current path despite possible disruptions (Bousquet et al., 2016).

Biggs et al. (2012) distinguished between three different components of diversity – variety, meaning the number of elements; balance, meaning how much of each element is present; and disparity, meaning the extent of difference between each of the elements. This definition can apply to biological elements such as genes, morphological and ecological elements such as landscapes, and social elements such as cultures, strategies, and institutions. Diversity in elements is the basis for system learning, innovation, and adaptation. This distinction also demonstrates why response diversity is critical for resilience, marking how different elements offer different responses to a disturbance, as is detailed below.

In ecosystem resilience, two types of diversity can be further distinguished: functional group diversity and functional response diversity. Functional group diversity refers to the persistence of species that generate services such as grazing, predating, or fixing nitrogen. Functions that are important for maintaining the system at its current equilibrium. Response diversity on the other hand refers to a richness of responses to environmental change in the ecosystem. This form of diversity allows for adaptation to changing conditions through new combinations and reorganisation of functions and interactions after disturbances. These definitions allow measuring resilience through four key attributes: Latitude, signifying how much change the system can absorb through reorganisation in the current state; resistance, meaning how big of a disruption is required to change the state of the system; precariousness, meaning the proximity of the current trajectory to the threshold after which reorganisation is impossible; and cross-scale relations, meaning how these attributes are influenced by dynamics in smaller and greater scales (Folke et al., 2004).

Response diversity can also apply to socio-technical systems. For example, in the financial system, portfolios hedge investment in one domain with investment in another in case changes in the market undermine the initial investment. However, in some socio-technical policy domains, diversity is all but gone. For example – global food production is based to a large extent on big mono-culture enterprises (Folke and Gunderson, 2010).

HOW CAN IT BE STRENGTHENED?

Complementing diversity with redundancy

In engineering resilience, diversity and redundancy represent complementary strategies: redundancy relies on duplication of function, meaning that if one component fails, others can serve the same purpose. Diversity, on the other hand, allows different components to reach the same effect through alternative means (Hudson et al., 2012). For example, Troell et al. (2014) argued that in order to make aquaculture more resilient, as part of the global food system resilience overall, policy needs to stimulate new heterogeneous and flexible production systems that take into account relative impacts on both local and global scales. This diversity is also central to what these systems can produce, by maintaining a large pool of aquaculture species.

Diversity in governance

According to Duit, Galaz, Eckerberg, and Ebbesson (2010), Ashby's law of requisite variety can be interpreted such that managers need to be able to provide specific and differentiated responses for every state the system can reach to manage the system. This kind of variety can already be seen in new approaches to governance:

- Partnerships between different government, private sector, and civil society representatives
- Different approaches to stakeholder engagement and self-organisation
- More complex forms of governance being experimented with, such as adaptive co-management, adaptive governance, and reflexive governance

The authors argue that all these emphasise localizing the policy context, taking into account the importance of networks, encouraging trial and error, and expanding the breadth of participation in policy making. Furthermore, adding additional actors of different kinds to the governance process and structure creates an institutional redundancy that allows better regulation of common pool resources. One reason for that is that having an overlap in hierarchies allows for crafting more complex policy solutions and governance mechanisms, fitting the growing complexity to the policy problems they address. The underlying rationale is that actors' and networks' diversity and flexibility will increase the number of viable alternatives open for policymakers, though an opposite contention has also been made that such structures lack coordination, communication, and resources compared to traditional hierarchic bureaucracies. Thus, there is a need to strike a balance between hierarchy and networks, and between the stability of institutions and the flexibility in adaptive governance systems, or rather fit the complexity of the proposed structure to the nature and scale of the problem at hand.

Enhancing response diversity

Walker et al. (2023) offered several strategies to enhance response diversity through policy and governance: encouraging substitutable options, for example developing alternative materials to critical minerals used in manufacturing but oftentimes rare and concentrated; complementing response options, continuing with the same example – developing systems for urban mining while securing material sourcing from additional countries; compensatory response options, meaning preparing responses that "kick in" when earlier measures fail, for example strategic reserves that can be used in case of price fluctuations in the global minerals market; and creating hybrid solutions that do not rely on a single solutions, for example moving away from grey to green infrastructure.

POSSIBLE TRADE-OFFS

While cultivating diversity is essential for bolstering resilience, it also poses new challenges for policy analysis and policy-making. First, it inherently increases uncertainty as it multiplies the number of variables and interactions in the system. Second, is may slow down the decision-making processes when differing interests and views make it harder to reach a consensus on policy solutions (as is demonstrated in the global efforts to reach an effective and binding climate agreement).

Diversity in elements can also increase variability in outcomes, leading to unexpected policy results in human-nature interaction, even when conditions are similar. People's socioeconomic differences, for example, can lead to different preferences, choices, and behaviours, which can cause different environmental outcomes. Preliminary differences in environmental conditions can also impact people's well-being and ability to sustain themselves (for example soil quality's impact on the potential for crops). Finally, the interactions are not static. Exogenous and endogenous factors can impact these interactions differently over time (Liu et al., 2007).

This complexity often primes policymakers to prefer to decrease variability as it makes planning more challenging and unpredictable. However, decreasing variability comes at a price for resilience, as it may change the boundaries for safe operating space, restricting information that adaptive management requires for continual decision-making, concealing signals and indicators of risks to resilience, and preventing pressures that are actually positive in building tolerance. Allowing a certain degree of variability encourages learning and builds the capacity to deal with different types of stressors. For example, traditional conservation policies aim at stabilising levels of human activity or natural stocks and services, and in many cases that is essential. However, this strategy may inadvertently increase vulnerability to new types of shocks. One way to balance these two contrasting needs is by defining a safe operation space within which variance is reduced (Carpenter et al., 2015).

Diversity can also pose challenges to promoting resilience policies and institutions. For example, describing the process of tackling environmental governance in the Baltic Sea, Österblom et al. (2010) argued that in some countries the environmental situation in the Baltic Sea was not perceived as a major policy problem, thus limiting the ability to create a shared governance framework or structure that would effectively tackle potential regime shifts in this joint space and resource. In other words, heterogeneity in the community of stakeholders dependent on the resource being managed and responsible for its management can lead to innovation and adaptation, but it can also limit communication, especially in face of ethnic, political, and resource-driven conflicts. Overcoming these challenges requires open discussion of policy trade-offs, which can in itself accelerate innovation (Fidelman et al., 2012).

EXAMPLE BOX 1

DIVERSITY AND VARIABILITY IN ISRAEL'S COVID-19 RESILIENCE POLICY

Diversity in policy design and implementation was a weakness and a strength at different points of the policy cycle in Israel. On the one hand, Israel made use of expertise and resources from different parts of the government system, even the security establishment, to bolster its civilian apparatus in responding to the pandemic. On the other hand, some of the perceived failures in Israel's handling of Covid could be attributed to a lack of diversity in the composition of its expert team established by the national security council, lacking representation for women, ultra-orthodox communities, and the Arab society in Israel (Kashti, 2020).

Israel has been legally in a state of emergency since its conception. As such, it developed an array of agencies that have the capacity to respond to emergency situations and facilitated implementation of the Covid response policy – from the IDF Home-front Command to intelligence units that gathered data and recommendations based on the spread of the disease in Israel and abroad, to reserve paramedics recruited to perform Covid tests at patients' homes, and military personnel running quarantine centres in converted hotels.

However, in terms of strategic policy design, the team initially established by the National Security Council to devise an exit strategy from the first quarantine was heavily lacking in diversity both demographically and in terms of disciplinary expertise. For example, the team had only 2 women out of more than 30 representatives overall. Considering the added burden and risks women had to face during the lockdown, this prevented an understanding of the problems faced and the solutions required. The team also initially lacked sufficient experts in education, culture, and even epidemiology, instead relying heavily on the participation of physicists who could, supposedly, advise on modelling the spread of the disease and so create better insight on policy alternatives from the narrow perspective of mitigating contagion (Weizmann Institute, 2020).

2.3.2 GOAL 2: BUILDING IN ROBUSTNESS

WHAT DOES IT MEAN?

Robustness is often used interchangeably with resilience, but it pertains to a more equilibrium-based view that is characteristic of engineering resilience: the ability of the system to continue functioning in face of internal or external disturbance without losing significant functionalities or structural integrity (Colding and Barthel, 2019; Das et al., 2016). Another way to look at robustness is that it represents the ability to withstand stress under a wide range of scenarios (Norris et al., 2008). Different from resilience, robustness analysis requires well-defined performance measures, understanding the uncertainty and boundaries in the system, and analysing the trade-offs between robustness and performance, and robustness and shocks of different kinds (Anderies et al, 2013).

HOW CAN IT BE STRENGTHENED?

Building systems that can withstand a wide range of possible futures

Robustness analysis aims to design fail-safe systems within a specific range of parametric uncertainty, despite a lack of information. It can help understand how for different adaptive pathways the set of expected dynamics may impact robustness-fragility trade-offs, meaning how to navigate short and mid-term dynamics. It can also reveal hidden fragilities that may be the basis for the need for transformation, allowing the system to reduce its sensitivity to shocks (Anderies et al., 2013). In certain cases, robustness analysis can identify optimal management strategies, for example, strategies that can manage resources in face of low growth rates, increasing growth rates, or fluctuating rates, with relatively marginal costs (Lindkvist, Ekeberg, and Norberg, 2017).

Supporting cooperation

Robustness analysis can also focus on specific traits such as cooperation. Policymakers and researchers can, for example, examine how cooperative strategies may persist under differing conditions of resource availability, environmental change, and biophysical system configurations such as more or less connected systems (Schl, Tavoni, Levin, et al., 2014). In common-pool resources, analysing the robustness of cooperative behaviour needs to take into account the incentives of selfish actors and how they may undermine cooperative behaviour. This may lead to a different goal than economic optimality, instead focusing on the ability to prevent invasion of non-cooperative harvesters for example (Tillman, Watson, and Levin, 2017).

Promoting participatory learning and design

Policy analysts and researchers can deploy participatory scenario planning to develop the different scenarios policies may need to address and be evaluated against, as well as proposed policy measures. Increasing the diversity of participants in these processes can bring to light interlinkages between factors that policymakers did not take previously into consideration. For example - how different technological requirements and innovations are dependent on and can impact social factors such as the likelihood of collective action, the necessary partners for collaboration under each intervention, potential beneficiaries and actors excluded by the strategy, and the interaction with environmental conditions that co-evolve with the policy (Enfors et al., 2008). Different tools for co-creation can build a 'shared conceptual repertoire' facilitating effective communication and knowledge synthesis among the different stakeholders. Stories are especially useful in constructing shared concepts and ideas that allow planning for a range of future scenarios (Galafassi et al., 2018).

POSSIBLE TRADE-OFFS

Levin et al. (2013) argued that a robust system can resist change or re-organise once it occurs to maintain its original functions. However, the authors also argued that universal robustness is impossible to achieve. Trade-offs in preparing for different uncertainties require choosing between different risks and responses, and between operating in the environment in which we are living, versus maintaining diversity that allows responding to new environmental conditions that may emerge.

Furthermore, robustness may become interchangeable with rigidity traps as institutional arrangements well suited to respond to specific shocks (otherwise known as specified resilience) may undermine the system's ability to respond to novel shocks (generalised resilience). However, social-ecological memory or the accumulated experiences of a community in a shared environment over time can bolster robustness. They allow for different functions to remain whichever pathway is chosen to face disturbances (Nykvist and Von Heland, 2014).

EXAMPLE BOX 2

ROBUSTNESS IN ISRAEL'S COVID-19 RESILIENCE POLICY

Israel's response to the Covid pandemic addressed robustness in two key ways: First, it enacted lockdown policies that aimed at efficacy in face of uncertainty regarding the virus behaviour. Second, it quickly moved to ensure vaccine preparedness as a long-term strategy in face of uncertainty regarding vaccine production. The government's first lockdown policy limited almost all movement outside of citizens' homes other than for medical reasons or for food supplies. Over time that policy changed, however initially, not knowing how dangerous the virus is or how quickly it may spread, the government's main message in terms of policy justification was maximising social distancing to a much larger degree than in many European countries. In other words, a distancing policy should be effective under a large range of epidemiological outcomes.

In terms of the government's vaccine policy – not knowing which vaccines would be approved, Israel had made early deals with Moderna and Pfizer, the latter being its core ingredient in vaccination strategy, but also invested in local vaccine development through the Israel Institute for Biological Research. It also built the required infrastructure to deliver the Pfizer vaccines, in contrast to the Netherlands, for example, which assumed vaccine distribution would be similar to regular seasonal vaccination efforts.

2.4 STRATEGY 2: RESOLVE GAPS IN RESILIENCE

The second strategy contains policy goals that address existing gaps in resilience: mitigating vulnerability, and ensuring persistence, adaptability, and transformability.

2.4.1 GOAL 3: MITIGATING VULNERABILITY

WHAT DOES IT MEAN?

Vulnerability is both an empirical reality and a perceived reality. People perceive risk differently based on whether they personally experienced it, their knowledge and understanding of it, their level of unrealistic optimism, and even based on their occupation (Crona et al., 2009). In the context of environmental change, vulnerability often denotes three key dimensions: Exposure, meaning the scale of stress experienced by the system in response to an event or changing conditions; sensitivity, meaning dependence on the natural resources being impacted; and adaptive capacity, meaning people's ability to adjust to the changes that occurred (Cinner et al., 2012).

From a socio-technical perspective - focusing on vulnerability can bolster resilient infrastructure design (O'Brien, 2009). For example, renewable energy is conceived as more resilient as it replaces the "supply on demand" approach with "capture when available" and "store until required". Rather than focusing on a particular fuel type it relies on a wide range of societal institutions and engagement mechanisms, reducing sensitivity to possible disruptions in supply of any one fuel.

HOW CAN IT BE STRENGTHENED?

Vulnerability is inherently linked to equity. Aiming to define "equitable resilience" Matin, Forrester, and Ensor (2018) argued that "Equitable resilience is that form of resilience which is increasingly likely when resilience practice takes into account issues of social vulnerability and differential access to power, knowledge, and resources; it requires starting from people's own perception of their position within their human-environmental system, and it accounts for their realities and for their need for a change of circumstance to avoid imbalances of power into the future". This is key in forming resilience policy, and requires proactive efforts by policymakers. This can be done in several ways, some of which we elaborate below: focusing on Justice, creating new approaches and tools to identify vulnerability, connecting human agency with system drivers, and facing vulnerability at multiple scales.

Focusing on Justice

Vulnerability is not merely an outcome of stressors or perturbations. It emerges in response to historical processes, differences in power relations between groups and their ensuing entitlements, and a larger context of political economy. In other words, different groups are affected differently by shocks, and changing the underlying causes of their vulnerability may require wider efforts than adaptation measures often offer (Miller et al., 2010).

From a global perspective, vulnerability to environmental stressors and hazards is not evenly distributed around the world, as is poverty. Some regions are sensitive to one but not the other, and some are prone to both (such as the middle parts of Asia) (Hall, Duit, and Caballero, 2008). Vulnerability can vary in spatial scale, with changes in reliance on specific sources of income, and distribution of physical and social capital. Even interventions to strengthen resilience can undermine certain groups' adaptive capacity as they restrict their access to resources and the choice of adaption strategies open for them to implement (Faraco et al., 2016).

Thus, interventions often need to make a concrete choice of whose vulnerability to target. For example, agricultural development projects could focus on established farmers that are attempting to start selling in new markets, or conversely with farmers who were left out of the market by choice or otherwise and are becoming increasingly marginalised (Enfors et al., 2008). Similarly, assessing infrastructure vulnerability requires considering hazards at different levels. For example, analysing vulnerabilities of water, sanitation, and hygiene systems can focus on risks to individual households, risks at a city level, or at a regional and river basin level (Johannessen et al., 2014).

Creating new approaches and tools to identify vulnerability

Since vulnerability is based on both social and physical concerns, assessing and addressing vulnerability requires integrative and interdisciplinary approaches. For example, assessing First Nation communities' water vulnerability in Canada, Plummer et al. (2013) examined water resources and supply, communities' access to water and water use, water quality, and infrastructure. They then analysed wider environmental pressures; economic factors such as livelihood, equity and human health; institutional factors such as governance, politics, and conflict; and social factors such as culture, perception, knowledge, technical capacity, and engagement. Analysing non-human organisms' vulnerability also requires wider nets. For example, In order to assess coral reefs' vulnerability to damage from anchors in the Great Barrier Reef in Australia, Kininmonth et al. (2014) had to factor in with their exposure models social variables such as familiarity of ship captains with different fishing sites, alongside different sites' safety and comfort, attractiveness, and accessibility.

As data requirements in assessing vulnerability may prove expansive, partnerships with other sectors, agencies, and governments facing similar risks, as well as academia, can prove crucial. For example, in Copenhagen, the insurance industry provided city planners data about private property vulnerability to cloudburst rain events to support their vulnerability assessment (Rosenzweig et al., 2019). However, the connections between different actors, industries, and countries may in themselves exacerbate vulnerability. For example, Hedlund et al. (2018) found that while several European countries are positioned well in their resilience to climate change, their position changes when taking into account their trade flows and dependence on globalised systems.

Connecting human agency with system drivers

Vulnerability focuses on human agency and as such it often examines shorter time frames than in traditional social-ecological resilience scholarship. Integrating the two concepts sheds a light on how long-term system drivers interact with local socioeconomic realities. Spatial scales also differ in the two strands of literature. While resilience scholars often focus on ecosystems and natural resource management in their policy domains, vulnerability assessment focuses on risks to human quality of life. Thus, as resilience solutions are defined at a system level, in vulnerability scholarship they are geared at the community and the individual actors involved. The two approaches are complementary, then, as they capture different dynamics and mechanisms – on the one hand interaction between social and ecological processes in resilience, and in vulnerability – actors' agency, power, conflict, and equity as they are expressed in decision making, action, and negotiation (Miller et al., 2010).

In practice, this linkage requires coupling risk reduction strategies with other policies that address the structural causes of the problems at hand. One way to achieve that is to mainstream risk reduction in different areas of policy-making, as the government of the Cayman Islands did in responding to climate-driven risks such as hurricanes. The government formally integrated risk reduction in the planning process by appointing members of the National Hurricane Committee to sit on different planning committees whose approval is required for land use changes (Tompkins, Lemos, and Boyd, 2008).

Facing vulnerability at multiple scales

Vulnerability can be addressed through local, national, and international policies that provide solutions in the short, medium, and long term. For example, in response to climate change and coral bleaching, fishing communities can evacuate highly vulnerable areas, diversify their fishing practices to help the reef reduce its sensitivity, and improve local ecosystem management through institutions and investment. National policies can provide fishers with safety nets that prevent falling into poverty traps, invest in new industries, or provide education and information that helps local actors understand the causes of change and adapt to it. Internationally, in the short term the international community may provide assistance and relief, but more importantly in the long term, this is a crucial arena for addressing the root causes of coral bleaching through climate negotiations and strengthened environmental governance and finance (Cinner et al., 2012).

POSSIBLE TRADE-OFFS

Planning for resilience requires understanding the trade-off between investing in reducing vulnerability to an extreme event and enhancing recoverability from it once it occurs (Hosseini, Barker, and Ramirez-Marquez, 2016). While resilience focuses on what is present, including adaptive capacities and resources, vulnerability makes clear what is missing. Resilience thinking can thus serve to mitigate vulnerability, enabling action to recognise and minimise it (O'Brien, 2009). For example, green infrastructure offers a way to mitigate vulnerability through transformational change in the system, in particular in cities where they can lower costs of adaptation to environmental change (Green et al., 2016). However, others reject the view that vulnerability is the inverse of resilience. Weichselgartner and Kelman (2015) argue that while resilience is described as shifts in system states between different domains of attraction, vulnerability represents a structural change, or rather a change in its stability landscape.

EXAMPLE BOX 3

MITIGATING VULNERABILITY IN ISRAEL'S COVID-19 RESILIENCE POLICY

While the physical threat of Covid-19 was identical across communities in Israel, the ability to avoid infection and cope with the quarantine measures set by the government was not. The ultra-orthodox community in Israel suffered objective conditions that made it much harder to social distance, such as a larger number of children per household, and smaller physical houses where separating infected family members is a greater challenge. Their ability to conduct remote education was also a challenge, as the number of computers required per household to sustain it was unattainable, and the type of studies in the autonomous ultra-orthodox education is built around communal studies rather than individual frontal teaching. This was compounded by religious and cultural traditions that were antithetical to social distancing, such as large funerals and weddings, and a dense urban fabric where much of life occurred in public spaces and communal institutions. All this required a dedicated "policy czar" that was charged with maintaining communication with the ultra-orthodox community and finding innovative and agreed-upon solutions that would safeguard their health and recognise the particular challenges they were facing.

2.4.2 GOAL 4: ENSURING PERSISTENCE, ADAPTABILITY, AND TRANSFORMABILITY

WHAT DOES IT MEAN?

Resilience represents social-ecological systems' tendency to remain within critical thresholds by constantly changing and adapting. In this sense, it is a balance or interaction between three different aspects of the system, or three capacities: persistence, adaptability, and transformability. Persistence represents a system or one of its components' tendencies to change to remain within a stability domain. Adaptability is the capacity to change external and internal processes and drivers to develop along the apparent trajectory within the stability domain. Transformability represents the ability to shape new stability domains, and deliberately cross thresholds into a new development trajectory (Folke et al., 2010).

The three capacities represent at a system level the degree of shock a system can absorb while maintaining its current state, the degree to which the system can self-organise, and the degree to which the system is open for creating space to learn and adapt (Folke and Gunderson, 2010). What is the practical difference between adaptability and transformability? Adaptability and transformability differ in the measure of change the system has undergone. Adaptability focuses on the social forces in the system working to maintain a desired regime or restore it, while transformability represents the capacity to create a completely new system configuration. In other words, adaptability maintains certain processes in face of change, transformability creates a new landscape altogether (Gunderson et al., 2006).

Still, differentiating between adaptation and transformation can be hard to pin down. Instead, they can be regarded as two different degrees of change along a continuum. When a change in the system components and their interaction is sufficiently radical, allowing new assumptions and practices to take root, it is easier to discern the system went through a transformation (Sinclair et al., 2014). Finally, Bousquet et al. (2016) differentiate between adaptation and transformation by looking at transformation as building on the accumulation or synergies of gradual changes, adaptations that occurred over time or at local scales, allowing for radical new combinations and settings to emerge. In this sense adaptation as an object has to be considered in relation to other objects, other adaptations in an integrated trajectory or pathway. Thus, policymakers can look for radical change through incremental actions of societal change.

HOW CAN THEY BE STRENGTHENED?

Much of chapter 5 deals with this exact question - how can the three different capacities be strengthened, while taking into consideration the inherent contradictions between them. Facilitating transformations is also the focus of method 3.4 for building resilience-oriented policy environments, discussed in the next chapter. However, it is worthwhile to mention that both adaptability and transformability build on experiments occurring on smaller scales, learning across scales, and the emergence of new initiatives. In this sense, transformations in social-ecological systems are reminiscent of transitions in socio-technical systems, which facilitate new spaces for experimentation. While in socio-technical transitions the goals and processes to achieve it are largely known in advance, in a social-ecological approach the new system's identity can emerge, being constrained only by the thresholds it does not wish to cross and the pathways it does not wish to follow (Folke and Gunderson, 2010).

Furthermore, transformability requires the ability to compare the current domain with its alternatives and to foster resilience in the new trajectory to navigate successfully to a new basin of attraction (Folke et al., 2010). Transformational change entails embedding new defining state variables, while others are lost, changing the nature of the stability landscape. It can be a proactive process or a forced process when conditions change. Transformability and general resilience have several commonalities, such as requiring different forms of capital, a diversity of institutions, support from governance structures at higher scales, and facilitating collective action and arenas for learning through different actor groups and networks. Transformability further requires changes in the attribution of meaning, in how actors and institutions interact and organise, and in the very configuration of the social network. However transformational change can begin at lower scales, mediated through actors and organisations that bridge learning and change at higher scales. That said, transformability at lower scales relies on resilience in higher scales as well (Folke and Gunderson, 2010).

POSSIBLE TRADE-OFFS

Persistence and adaptability are a manifestation of systems' attempts to avoid reaching tipping points that shift the system into undesirable situations. When such situations occur or seem inevitable, transformability is an expression of how society and nature change to fit the new conditions, especially through cooperative action to protect public commons that are vulnerable to exploitation (Folke and Gunderson, 2010). However, oftentimes, choosing to strengthen a particular capacity comes at the expanse of the others: Adaptability encapsulates actions taken by people and groups to ensure that the social-ecological system can continue developing in its existing pathway within the critical thresholds. It describes people's capacity to reshape their institutions so that they can cope with both internal and external change, through learning, a combination of experience and knowledge, and innovation. Transformability on the other hand launches the system on a new pathway rather than maintaining existing ones. It allows the system to cross critical thresholds into new basins of attraction and trajectories. It is in essence the ability to create a new system through new ways of thinking and operating, often in response to a crisis, when the current system can no longer be maintained. It builds on experiences that can be recombined to spark innovation and identify and manage opportunities (Folke, 2016). Chapter 5 will demonstrate how these contradictions come into sharp relief when policymakers look at different scales in terms of time and space.

EXAMPLE BOX 4

PERSISTENCE, ADAPTABILITY, AND TRANSFORMABILITY IN ISRAEL'S COVID19 RESILIENCE POLICY

The Israeli government moved quickly to ensure persistence in the most immediate and basic level - lowering exposure to the virus, infection rates and death, mainly through quarantine rules and new mechanisms and technologies for contact tracing. It also managed to be the first in the world to distribute vaccines to its citizens, thus allowing a measure of adaptability to the pandemic. However, in terms of transformability, in contrast to other countries that promoted a comprehensive policy package that aimed to leverage subsidies and government programs for economic rehabilitation for more profound transformations such as a decarbonisation of the economy, that was not the case in Israel. While Covid factored into other related policies that were published during the height of the pandemic, such as the energy ministry's energy efficiency plan for 2030 (Fisher, 2020.), it did not fundamentally change the country's economic or environmental policy.

2.5 STRATEGY 3: MAINTAIN SYSTEM INTEGRITY

The third strategy contains policy goals that ensure current systems are able to face stressors and shocks: Introducing redundancy, maximising flexibility and modularity, and governing connectivity.

2.5.1 GOAL 5: INTRODUCING REDUNDANCY

WHAT DOES IT MEAN?

Maintaining redundancies is considered a central mechanism for bolstering resilience (Carpenter et al., 2012; Folke, 2016). It marks the extent to which resources or other elements in the system can be replaced in face of disruption. Redundancies are built into technological products, infrastructure systems, and even our inner and social lives (Norris et al., 2008). Redundancy replicates elements and pathways in the system to compensate for the failure of existing elements in the system. (Biggs et al., 2012). Functional redundancy is considered especially important, meaning that several components in the system can fulfil the same function. Thus, if one is lost, others can take its place (Colding, Barthel, and Sörqvist, 2019).

HOW CAN IT BE STRENGTHENED?

When thinking of institutional design, redundancy can be bolstered not only by putting in place different systems with overlapping goals but also by allowing systems to have secondary roles that allow them to respond to disturbances beyond their primary occupation if the need arises. For example, during the second world war, the London underground system famously served as a refuge for residents looking for shelter from German bombings, a function underground rail systems still serve today as evident in the war in Ukraine. Similarly, Burkle, Delphia, and O'Neill (2017) suggested that farms should play a dual role in facing the multiple crises our food systems are facing - not only in producing food but also saving pollinator communities. Redundancy is further strengthened through response diversity, meaning that different components in the system adapt or respond differently to a disturbance, thus expanding the range of disruptions the system can withstand while maintaining its core functions (Colding et al., 2019).

POSSIBLE TRADE-OFFS

Gaining resilience through redundancy is not without costs. It usually comes at the expense of efficiency strategies that may save resources but increase exposure to risk. That said, facing climate change and other environmental challenges requires that efficiencies are in fact gained, either through technology or practices that allow normal operation despite dwindling resources and harsher conditions. One solution is to increase the capacity of existing infrastructure so that it can carry additional load, as well as design it with the recognition that both demand and environmental conditions might fluctuate throughout its lifetime. Another conflict that requires resolution in design is between efficient operations under normal circumstances, and resilience to extreme events, achieved through spare capacity (Hudson et al., 2012).

Thus, the value of redundancy and the means to achieve it are highly context-dependent. Social-ecological systems often have more flexibility and redundancy than technical systems, allowing more time and buffer to prevent shocks or withstand them (Amarasingheet al., 2012). Redundancy in technology may also present different levels of flexibility. For example, in addition to physical duplication, it can refer to having more or less technologically "advanced" alternatives to provide a particular service. For example, rather than having smart-phone based services provided to citizens, governments can create additional solutions that are accessible to communities that have less access to smartphones and digital technology – be it analog alternatives such as physical devices, cash, or digital alternatives including credit cards or dedicated communication channels (Colding et al., 2019).

In ecological systems, having greater diversity in species in a given system does not necessarily translate to high levels of functional diversity. Alternatively, even if species are clustered as functionally interchangeable, there may be differences between them based on how they consume resources, their specific interactions and roles in a given ecosystem, and their interaction with the particular environment in which they reside. Thus, losing certain species from within the cluster may lower functional redundancy disproportionately (Bejarano et al., 2017; Fetzer et al., 2015). This can lead to counter-intuitive strategies: In systems with low functional redundancy, invasive species that may be considered at certain policy contexts a negative disturbance or threat can serve to alleviate environmental shocks (Norkko et al., 2012).

EXAMPLE BOX 5

REDUNDANCY IN ISRAEL'S COVID-19 RESILIENCE POLICY

While some countries relied on a vaccine roll-out that is based on existing infrastructure and capacities, the Israeli government took a redundancy approach to its whole vaccination effort: First, it operated quickly to ensure the first supply of doses from Pfizer by agreeing to collaborate with the company on mapping the vaccine effects throughout the population. Second, the government signed contracts with additional companies to decrease the chances of supply disruptions. Third, the government allocated funding for developing a local vaccine (an effort that was eventually abandoned). Fourth, rather than relying on existing facilities and operations, the government created a designated plan for providing the vaccine throughout the population, avoiding issues such as IT inconsistencies and dose transport issues, which in the Netherlands, for example, remained an obstacle for months.

2.5.2 GOAL 6: MAXIMISING FLEXIBILITY

WHAT DOES IT MEAN?

Flexibility represents the system's ability to rapidly address distress or perceived disruptions in new and resourceful ways (Das et al., 2016). In other words, it means having the ability to organise different components of the system in new ways to create new solutions for emerging shocks and disturbances. One way to achieve greater flexibility is through the connected trait of modularity. In network theory modularity symbolises a large number of connections between nodes in a particular module, but few connections with nodes in other modules (Peña, Watson, González-Guzmán, and Keitt, 2017). For example, an electricity system comprised of independent energy communities is more modular than a centralised system where a small number of power plants supply power to the whole state. In a modular electricity system - if one source of electricity shuts down, the shock to the system is much smaller.

HOW CAN IT BE STRENGTHENED?

Flexibility in technical design

Flexibility can be introduced at different scales: Ivanov, Sokolov, and Dolgui (2014) suggested enhancing flexibility at a system, process, and product level. Planners can also increase system flexibility through evolutionary physical design. Gersonius et al. (2012) proposed a method for planning infrastructure systems in a way that allows different paths of evolution over time. Rather than having a single plan for long-term development, planners look for a range of scenarios and system configurations and devise a strategy that delivers an acceptable risk level through time. This requires quantifying the value of flexibility based on the distribution of uncertainty over time, and postponing investment decisions until more knowledge becomes available regarding which scenario emerges in practice.

Flexibility in institutional design

In contrast to the traditionally rigid nature of legislation and regulation, resilience requires a measure of flexibility in the structure and function of governance arrangements (Plummer, Armitage, and De Loë, 2013).

How can policymakers bridge that gap?

1. **Flexibility in policy networks**

   Flexibility is a policy necessity in co-evolving social-ecological systems where surprises are a basic part of the system's dynamic. Gunderson (1999) described three types of surprises that policymakers would have to confront: Local surprises that are created by previously unknown processes at a larger scale, cross-scale surprises where processes at larger scales intersect with internal slow variables to create an alternative stable state, and genuine novelty whereby new variables and processes transform the system, and no knowledge exists to understand the transformation or the actions required to cope with it.

   Designing policy that is able to provide adequate responses to such surprises requires institutional flexibility - going beyond narrow interpretations of legal mandates and allowing space for experimentation and policy adaptation when surprises occur. This may entail a need for flexibility in the linkages between actors in the policy network and in the power relations between them. One way to achieve this kind of flexibility in linkages is through novel ways to manage government organisations. For example, Olsson, Folke, and Hughes (2008) argued that the Great Barrier Reef Marine Park Authority was able to enhance the protection of the reef's biodiversity by creating a senior managers forum where different sections could take ownership of the agency's rezoning process to encourage innovative solutions to emergent problems, and through staff redeployment to enhance learning throughout the organisation.

2. **Flexibility in policy design and implementation**

   While flexibility in policy design is frequently hailed in resilience literature, policy advocates often aspire to reduce flexibility through stringent and universal obligations that don't leave space for loopholes and non-compliance. However, in certain cases, the lax application of binding resolutions, targets, and treaties, can contribute to policy success. For example, in the case of the Trilateral Wadden Sea Cooperation, flexibility in choosing to implement common solutions and using informal structures to allow new issues to be discussed and governed is considered a positive factor in the arrangements' success (Blenckner et al., 2015).

   Maintaining flexibility in the types of policy tools considered can also increase the range of responses and consequently the system's adaptability. For example, Hahn et al. (2015) designed a framework to differentiate between six degrees of ecosystem services and biodiversity commodification. At its extreme pole, commodification relies on explicit markets to govern biodiversity, in the form of instruments such as forest bonds, tradable conservation credits, biodiversity derivatives, etc. However, at the other end of the spectrum – policy instruments do not rely on the market but rather rely solely on subsidies, land use plans, and even policy analysis tools that recognise the economic, and thus the societal value of nature such as national funds to offset habitat loss in fisheries, coastal and marine environments (Sale et al., 2014).

3. **Flexibility in policy narratives**

   Discursive flexibility, meaning harnessing different narratives to capture the problems and solutions at hand, can be an asset in promoting transformative policy. For example, to persuade different audiences of the importance to establish a national urban park in Stockholm, activists utilised arguments from both landscape ecology (maintaining connectivity) and the cultural history of the area they advocated to conserve. This allowed to create a wider coalition with a more robust story about why the policy was needed (Biggs et al., 2012). They formed a 'protective story' that combined different sets of values, gaining the support of different audiences. It linked cultural history, conservation biology principles, and place-based and local aspects, increasing the park's legitimacy and the extent of stakeholder engagement (Ernstson and Sörlin, 2009).

POSSIBLE TRADE-OFFS

On the one hand, modular networks can adjust to stress more gradually as systems can be designed to contain disturbances through compartmentalisation (Carpenter et al., 2012; Folke, 2016; Peña et al., 2017). On the other hand, in analysing the resilience of the global food system, Troell et al. (2014) argued that achieving resilience through a modular, decentralised network comes at a cost: even if there is only a small probability of devising a global strategy to sustainably feed the growing world population, decentralising and "modularising" the solutions means that resilience needs to be built through millions of decisions made by consumers, producers, and national governments. Thus, while often decentralisation is considered key to bolstering resilience, it also presents a challenge for resilience policy. Similarly, flexibility often contradicts certainty, which is considered crucial in governance systems and can even hamper efforts for initiating transformations (shifting subsidies and support for renewable energy being case in point).

EXAMPLE BOX 6

FLEXIBILITY IN ISRAEL'S COVID-19 RESILIENCE POLICY

When Israel began distributing the Pfizer vaccines, which once opened have to be used within a certain time-frame otherwise they would go to waste, a specific organisational challenge emerged – what to do with doses that were not administered at the end of the day? While the government laid out clear instructions on prioritising vaccine roll-out based on age and other risk factors, some of the local HMOs decided to open up the vaccination centres to additional patients who were not included in that list. This was done through proactive messages inviting people to arrive at the vaccination centre, and also on a first come first serve basis at the end of the workday for anyone who arrived at the centre. This measure of flexibility allowed an accelerated rate of vaccination, and reduced vaccine waste.

Geographical modularity was also structured into the government's response strategy – the Ministry of Health and other government agencies decided which lockdown measures were necessary for each municipality based on a "stoplight model", whereby higher risks municipalities were faced with more stringent measures, while low-risk municipalities were allowed to open up more freely.

However, the government was also criticised for having both insufficient and excessive modularity in its strategy from a social standpoint: having two particular minorities exhibiting heightened risk of contracting Covid in the early months of the pandemic, mainly the Arab and Ultra-orthodox Jewish community, the "general public" demanded the government separate between policy in these communities and the rest of the country, essentially isolating them while allowing the rest of the economy to open up. The government decided against it and instead sought more unified responses nationally. On the other hand, when it came to enforcement – there was a perceived difference between how lockdown measures were implemented, as the government was unable or unwilling to send enforcement agents to stop events with high contagion potential such as mass weddings and funerals in ultra-orthodox cities and neighbourhoods, while at the same time having police fine and enforce lockdown and social distancing measures in much less risky situations elsewhere. Too little modularity in policy design, and too much modularity in policy implementation.

2.5.3 GOAL 7: GOVERNING CONNECTIVITY

WHAT DOES IT MEAN?

Connectivity means the ability of different actors or components in the system to interact with one another, or for resources and species to travel across social and ecological distances (Biggs et al., 2012). Thus, connectivity can have a physical, social, and organisational manifestation. Governing connectivity as a policy goal means looking for ways to bolster the ability of these different components to interact with one another within the system at a rate that increases the probability of staying within a certain regime or moving toward a different desired one. In some cases, this may mean finding ways to enable more interactions, and in others - limiting them.

Physical connectivity

Connectivity is particularly important in conservation policy, where ecologists and policymakers aim to measure the impact of habitat loss on the ability of different species to move between different patches and so remain viable (Blazquez-Cabrera, Bodin, and Saura, 2014). Protected areas can maintain existing habitats, but are also crucial to facilitate movement between different landscape patches to find new habitats in response to environmental change. This requires policymakers more complex thinking that goes beyond designating isolated reserves in land and sea (Bergsten, Bodin, and Ecke, 2013; Berkström et al., 2012).

Social and organisational connectivity

Connectivity can also facilitate social relations that enhance resilience. For example, in their study of fish value chains in Zanzibar, O'Neill and Crona (2017) revealed that in contrast to the often-exploitative image portrayed of the relations between fishers and middlemen, there is a host of connections built around these links in the value chain that create a crucial support structure between them, going beyond selling and buying produce. Furthermore, as resource flows increase in volume and speed, policies to enhance resilience should take into account social norms and informal institutions as a way to maintain stabilizing cooperation (Schl et al., 2014).

HOW CAN IT BE STRENGTHENED?

Institutions, and policy as a case in point, can play a crucial role in extending connectivity. Institutional connectivity can be achieved in many forms, here we highlight three distinct forms: First, Formal and informal institutions can connect between different policy and governance domains to allow policy impacts in fields not yet institutionalised. Second, bridging organisations can connect between different levels or scales in the system. Finally, new spaces for deliberation and collaboration can be opened through instruments such as multi-actor networks and platforms. We then highlight analytic tools that can help policy practitioners determine how connectivity can be strengthened to bolster resilience in a particular system.

Connecting regimes

As global connectivity grows, so does the need for new types of international institutions that can support national efforts to govern globally spreading problems such as antibiotic resistance (Folke et al., 2020). However, while the flow of material has become more extensive, its governance in international law has not grown at the same pace. One answer to this gap is 'connecting regimes', meaning organisations that were designed to govern other topics such as trade or certain sectors of the economy or environment and can indirectly regulate this flow (Cornell et al., 2017).

Bridging organisations

Another way to deepen institutional connectivity is through organisations and actors that connect actors in different parts of value chains, society, and governance hierarchies. These can direct credit flows, market demand, and access to the market, though often accelerating resource depletion when there are no institutions to counterbalance their economic incentive structure. They also present an opportunity to regulate at scales that are more manageable for government agencies, which may lack the resources to monitor individual producers or other actors (Crona et al., 2010).

Multi-actor networks
A third option for expanding the reach of institutional connectivity is by establishing multi-actor networks, meaning platforms that bring together representatives of different stakeholders to discuss a shared problem, goal, or interest. Building connectivity through multi-actor networks can support better policy design and implementation: it enhances coordination between different sectors and agencies, encourages information sharing, and tightens feedback loops between local monitoring and higher-level decision-making, increasing the fit between the scale of challenges and the institutions tackling them (Alexander et al., 2017). Collaboration is especially important to connect municipalities and other institutions that may have overlapping authorities over ecosystems, thus requiring coordinated and joint action for effective governance of social-ecological challenges (Bergsten, Galafassi, and Bodin, 2014). These multi-actor networks are particularly useful in creating hybrid spaces between top-down policy and on-the-ground community action. There, the connection between activists and policymakers can yield innovation and help make sense of policies being implemented (Beilin and Wilkinson, 2015).

Analysing connectivity
Network theory can be useful to reveal the connections between different social and environmental components in the system. Actors and resources are represented by nodes, and the way they interact (resource consumption, resource sharing, etc.) is represented as links. Network diagrams can reveal the interdependency within the system and the impact policy interventions may have on different actors and patches (Bodin and Tengö, 2012).

Not all components of the network are equally important for connectivity. Some are more central to ensure local flow within the system, and others are central for flow beyond its bounds (Estrada and Bodin, 2008). For example, Bodin (2009) offers three approaches to modelling connectivity between habitat patches – the degree to which a certain configuration of patches allows colonisation following local extinctions, finding clusters of patches that form habitats, and keystone patches that are crucial for connectivity.

Analysing connectivity also requires taking into consideration its impact and dynamics over time under different scenarios. For example, climate change can increase drought conditions, which in turn affect the abundance and distribution of water holes in and around reserves. Lacking the necessary network of resources to survive within the reserves, species may suffer or look for water outside it, increasing the risk for human-animal conflict (O'Farrill et al., 2014).

POSSIBLE TRADE-OFFS

Connectivity within a system can both facilitate and undermine resilience. Connectivity requires maintaining openness within the system and between systems, which allows material and information to move across larger scales. This can increase the risks of disease transmission, for example, but it can also bolster resilience in many ways, such as importing necessary resources when disturbances occur, including vaccines, food, finance, and raw material (Carpenter et al., 2012; Folke, 2016; Kummu et al., 2020). Furthermore, looking at the social and ecological parts of the system in tandem reveals how connectivity may trigger regime change or alternatively increase stability in human-governed landscapes. For example, remittances sent by urban workers back to rural areas can facilitate local investment in agriculture, thus strengthening a landscape regime that is in contest with reforestation (Ospina, Peterson, and Crépin, 2019).

Connectivity can also create new risks. This requires policymakers to put in place policy tools that are able, when necessary, to **decrease connectivity between different parts of the system**. Ecological models have shown that policies to constrain the movement of certain species, for example, can allow their prey more space to reproduce safely, increasing the ecosystem's resilience (Baggio et al., 2011). When connectivity and speed of flow create "hyper-functionality", meaning a subsystem that is over-performing, such as in the stock market, policymakers can use mechanisms to reduce it by increasing flow transparency, slowing it down, and decoupling different parts of the system to prevent cascades (Galaz and Pierre, 2017).

Modulating connectivity is particularly significant in the context of globalisation. Globalisation expanded and accelerated the flow of matter (commodities, people), energy, and information across the world, increasing integration and interdependence between places and markets (Crona et al., 2015). For example, international demand for fish can hamper the resilience of local fisheries. Political dynamics can disrupt supply and force unexpected changes in value chains. This requires policies that allow regulations and monitoring to decrease sensitivities to volatility in global markets (Niiranen et al., 2018). There is a need for policies and governance frameworks that account for resource flows, especially from rural areas where they are mined and produced to urban areas where they are consumed, and at a planetary rather than local scale (Seitzinger et al., 2012). Growing proximity between producers and consumers also opens new opportunities for policy mechanisms to enhance resilience such as global certification schemes (Österblom et al., 2017).

Connectivity between actors and resource bases can also increase or undermine their adaptive capacity. For example, fishers can adapt to changing environmental and market conditions by switching between fisheries based on considerations of market stability, specie value, stocks, and factors related to governance. These can be mediated through policy mechanisms such as licenses that delineate the range of adaptation strategies open for fishers to adopt (Stoll, Fuller, and Crona, 2017).

Multi-sectoral approaches (horizontal connectivity) are also crucial to mitigate risks from a liberalised and connected global market. This means that trade policies that increase connectivity must be analysed and designed in conjunction with policies governing natural resources, development, and social inequity (Crona et al., 2015). Even conservation policies that aim to increase resilience in certain parts of the system can unintentionally cause a loss of resilience in other parts of the system if a multi-sectoral approach is ignored. For example, in Sikkim, India, conservation policies that reduced access to forests, combined with agricultural intensification and subsidised food policies, deepened local dependency on external food flows and markets, at the expanse of formerly practiced subsistence farming that had produced greater food diversity (Gupta, Haider, and Österblom, 2020).

EXAMPLE BOX 7

CONNECTIVITY IN ISRAEL'S COVID-19 RESILIENCE POLICY

Connectivity was both a weakness and a strength of Israeli policy for handling Covid-19. Israel is a virtual island state as its borders with its neighbours are closed off completely (Syria, Lebanon), or highly guarded (West Bank, the Gaza Strip, Jordan, and Egypt). This allows the government to have a high degree of control over movement in and out of its international airports, maritime ports, and land borders.

However, throughout the first year of the pandemic, the Israeli government frequently changed its policy on entry into the country. Theoretically, it could seal off the skies completely, as it had in February 2020, or regulate entry in other ways such as compulsory Covid checks and quarantine (which were ongoing policies for much of the year). However, warding off variants and Covid infections were part of a wider array of presumed political considerations – from refraining from offending the US government, to encouraging travel to states with which Israel had just signed diplomatic accords (UAE), to accommodating constituents of parties in the coalition wishing to travel abroad or to Israel for religious purposes.

At the same time, connectivity facilitated Israel's becoming a test site for the Pfizer vaccine. One of Israel's strengths in terms of its health system is that in the past few years, the government invested billions of dollars in creating an IT system that centralised every citizen's health data regardless of their specific insurance provider. This meant that not only could medical service be provided more efficiently, but that the data collected can be used to study the safety and efficacy of the new vaccines at a highly granular resolution. This connectivity in health data allowed researchers in the health ministry, insurance providers, academia, and Pfizer to examine the epidemiology faster and more efficiently and became part of the agreement between the Israeli government and Pfizer (Yaffe-Hoffman, 2021).

2.6 CONCLUSIONS

This chapter reviewed the extensive literature on resilience principles, governance, and application in social-ecological and socio-technical systems to deduce explicitly what resilience policy means in terms of concrete policy goals. The review explored, mainly, two representative knowledge hubs on resilience, each reflecting a different understanding of the concept and its implications for policy making: The Stockholm Resilience Centre, and the Proceedings of the Institution of Civil Engineers. The review yielded seven policy goals: Maintaining diversity and variability, building in robustness, mitigating vulnerability, ensuring persistence, adaptability, and transformability, introducing redundancy, maximising flexibility and modularity, and governing connectivity.
In order to progress from resilience principles toward concrete policy goals, for each goal we provided a short description of its meaning (what are we striving for), how it can be strengthened (how can we get there), and possible trade-offs.

One important aspect to emphasise is the issue of temporality. Each resilience policy goal can translate to divergent tools and recommendations when the temporal scale changes. Chapter 5 focuses on the trade-offs this creates, especially between the three capacities of persistence, adaptability, and transformability. However, this tension is very much present in each of the goals and between them as the time horizon for different resilience goals can be quite different: While certain transformations can take decades, with society having extensive understanding on the rate at which they need to occur and the prices it would pay for delays, such as the move toward a circular economy or a zero-carbon economy, policies aimed at recovery operations after extreme events, for example, deal with much shorter time horizons – months, weeks, days, and even hours and minutes. This requires different capacities and policy processes to develop and maintain. It may also exacerbate the problem of fit, meaning in this case that institutions that are adept at dealing with problems at certain temporal scales are inadequate when the problems at hand are much slower or faster occurring.

Before moving on to exploring how resilience thinking can change the policy environment itself, we bring up a few suggestions for future work that could expand this effort.

OPERATIONALISING THE GOALS TO BOLSTER SPECIFIED RESILIENCE

The goals and strategies reviewed in this chapter do not provide specified answers, but rather questions and considerations that policymakers and researchers studying resilience policy should keep in mind and interpret. In order to operationalise them in a particular context, determinations must be made about values, priorities, and scales of analysis and intervention. That being said, policy goals and societal values are always in competition with one another. Even within well-defined policy domains such as environmental policy, policy options require a determination about priorities, managing risk, benefits, and cost.

ELUCIDATING TRADE-OFFS

The relations between the different resilience policy goals and strategies are also context dependent: They can be at odds with one another, support one another, or even conditional. This can be true of certain goals even within themselves as they are applied at different scales and in different facets of the system. This chapter pointed out some of these trade-offs when describing each goal, however when presented as concrete policy goals in policy processes, analysts and scholars could benefit from greater elucidation of these trade-offs. This is not a new effort in any way and has been applied in specific context domains. Kummu et al. (2020), for example, demonstrated that in the past thirty years expansion of international trade in the global food system on the one hand increased food supply diversity, but on the other hand created greater dependence on import from a diminishing number of import partners. It would be useful, however, to further explore what lessons we can learn across and beyond domains, as this chapter has tried to do. In chapter five of the dissertation we explore some of the trade-offs in resilience strategies in a specific domain (rural development), and see that these trade-offs only amplify when they are considered as part of national and international policy goals.

FURTHER EXPANDING AND INTERPRETING THE LIST OF GOALS

The sources selected for this review represent a wide range of domains, approaches, and applications of resilience theory, though mostly rooted in social-ecological and socio-technical thinking. As resilience is an ever-growing field, both in theory and in terms of application in different policy domains, the list of goals and strategies provided can be expanded to include additional policy goals, and re-interpreted so that it presents different ways to operationalise each of the goals in specific policy domains (what does connectivity mean in security, what does it mean in education). This ongoing effort to define new policy goals and reinterpret existing goals is essential in any emergent policy domain. In environmental policy, for example, new policy goals are set constantly, translated to new agencies, departments, and policy initiatives. The effort for expansion and reinterpretation of policy goals can build on the conceptual structure presented in this chapter, just as this chapter built on the conceptualisations of prominent resilience thinkers and experts.

BRIDGING THE GAP BETWEEN LEGAL STABILITY AND POLICY FLEXIBILITY

Flexibility and adaptability, core goals for resilience policy, pose a challenge to legal institutions, which usually prefer certainty and predictability to ensure equality in the justice system. It is useful for scholars and policymakers to explore how this inherent tension can be mitigated and overcome in practice. One possible answer could be embedding the practices that can lead to more flexibility and adaptability within existing policy frameworks. For example, stakeholder engagement and participatory scenario planning and policy design can promote openness and participation within existing legal frameworks while addressing some of the needs described for each goal. It is also possible to link flexibility and adaptability with notions of liability and accountability, which are highly institutionalised (Duit et al., 2010).

In the next chapter we extend the literature review to take up just such dilemmas, and ask how should policymakers shape the policy environment, meaning the processes and arenas in which policy is designed and implemented, so that it bolsters resilience.

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CHAPTER THREE

03

CHAPTER THREE
POLICY ENVIRONMENT

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03

CREATING A RESILIENCE ORIENTED POLICY ENVIRONMENT

How can policymakers instill resilience in the "way they do business" - the way they conduct policy analysis, build new institutions, set institutional boundaries, monitor shifting stressors and shocks, and prepare for transformations? This chapter continues to build on the literature review of resilience thinking in social-ecological and socio-technical research to explore the answers scholars in different disciplines provided.

3

3.1 INTRODUCTION

While the previous chapter described properties that resilience policy can bolster, meaning its desired policy goals, resilience thinkers point out the need to infuse resilience in governance structures at their core. In other words, regardless of the specific policy domain or individual policy being considered, resilience thinking aims to change the policy environment itself.
One way to think of the difference between resilience in policy goals and resilience in the policy environment is through two complementary frameworks in resilience thinking: specified resilience and general resilience. While specified resilience aims to build resilience to specific shocks, general resilience is broader in its ambition. It seeks to build the capacity to transform within the system so that it can adapt to any disturbance, whether it is yet known or not (Folke and Gunderson, 2010).

Specified resilience requires explicit definitions of what it is we wish to build resilience for and against, and whom it serves. General resilience, on the other hand, requires the policy system to nurture more basic resilience related traits. These allow gradual change but at the same time to cope with incalculable disturbances and surprise (Carpenter et al., 2012; Folke, 2016).
Specified resilience is intrinsically connected to the notion of vulnerability, as it describes how the lack of capacity to adapt can increase the system's susceptibility to harm from particular stresses that accompany environmental and social change (Carpenter et al., 2012). But fostering specified resilience may not be sufficient to prevent unexpected or willfully ignored regime shifts. That is why crisis or shocks are often required to overcome common existing thinking. These shocks can create new opportunities to face the underlying conditions, recruit new supporters and allies, build on existing knowledge and experience, and recombine them in novel ways to accelerate innovation, leading to new avenues of adaptation and transformation (Folke and Gunderson, 2010). Furthermore, while specified resilience can avert adversity by stabilizing a defined set of parameters, it can lead to a negative impact on the system as a whole. This tension between maintaining system resilience and achieving a specific resilience goal is mediated through governance. General resilience is supposed to build capacity in social-ecological systems to adapt to unforeseen changes, which are growing in rate and scale in the Anthropocene (Folke et al., 2016).

We offer in this chapter three main methods to incorporate resilience thinking in the policy environment:

Method 1 Redefining policy systems' boundaries and structures

Method 2 Enabling resilience-based policy analysis

Method 3 Facilitating transformations

For each method we review what changes resilience theorists argued needed to occur in thinking, organisation, and policy design and analysis processes in order to anchor resilience in the policy environment.

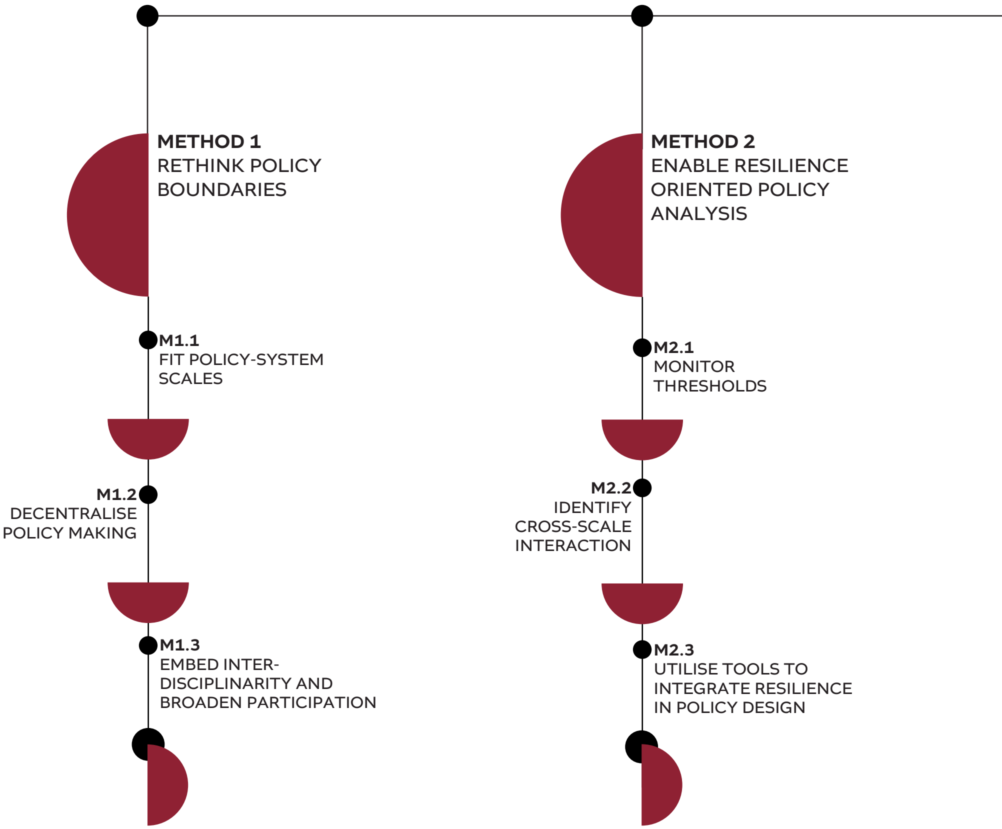
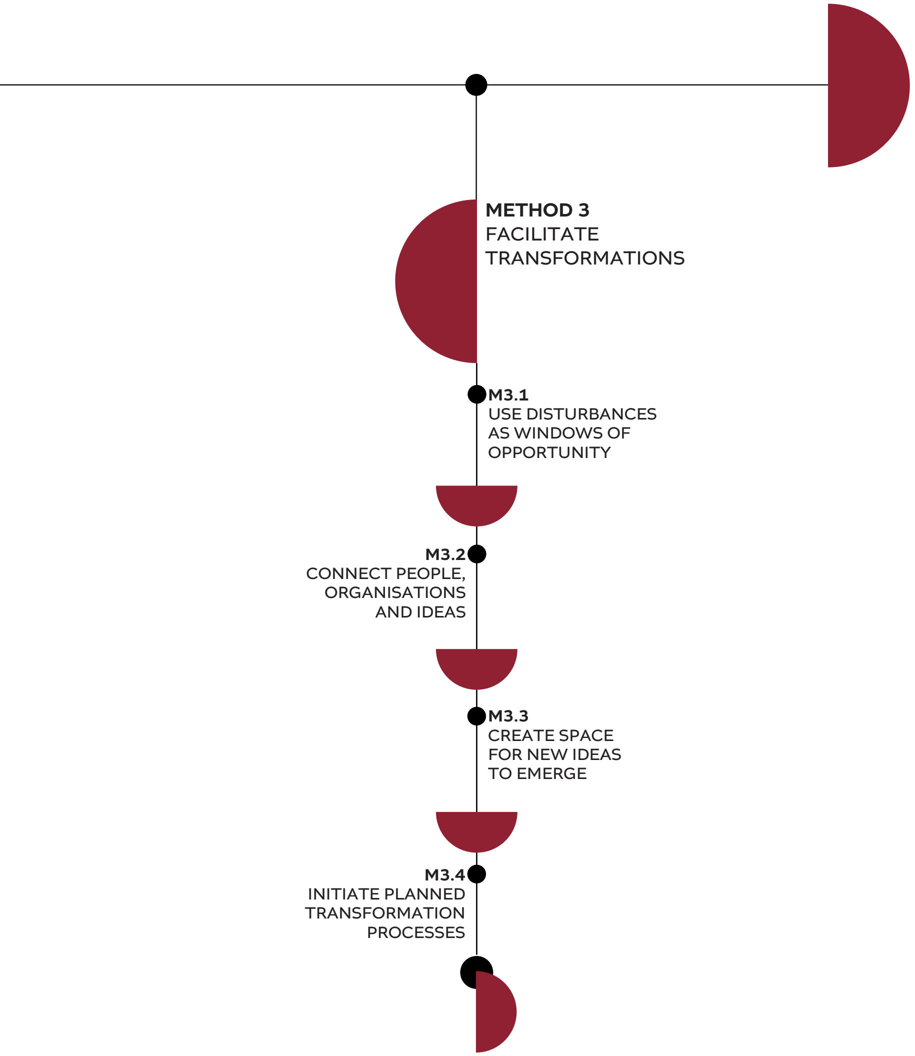


FIGURE 3: HOW TO BUILD A RESILIENCE-FOCUSED POLICY ENVIRONMENT



3.2 METHOD 1: RETHINK THE BOUNDARIES AND STRUCTURE OF THE POLICY SYSTEM

Resilience theorists proposed alternative ideals to dominant norms for policy making and policy system structures. They criticised current policy environments as being too centralised, prioritising certain types of knowledge and disciplines over others, siloed in different domains and perspectives, and often are out of step with the scale of the problems they are meant to govern. This section will review three main methods to rethink the boundaries and structure of the policy system based on resilience thinking:

M1.1 Fitting the scales between policy and ecosystems

M1.2 Decentralising policy making

M1.3 Embedding interdisciplinarity and broadening participation

3.2.1 METHOD 1.1: FIT THE SCALES BETWEEN POLICY AND ECOSYSTEMS

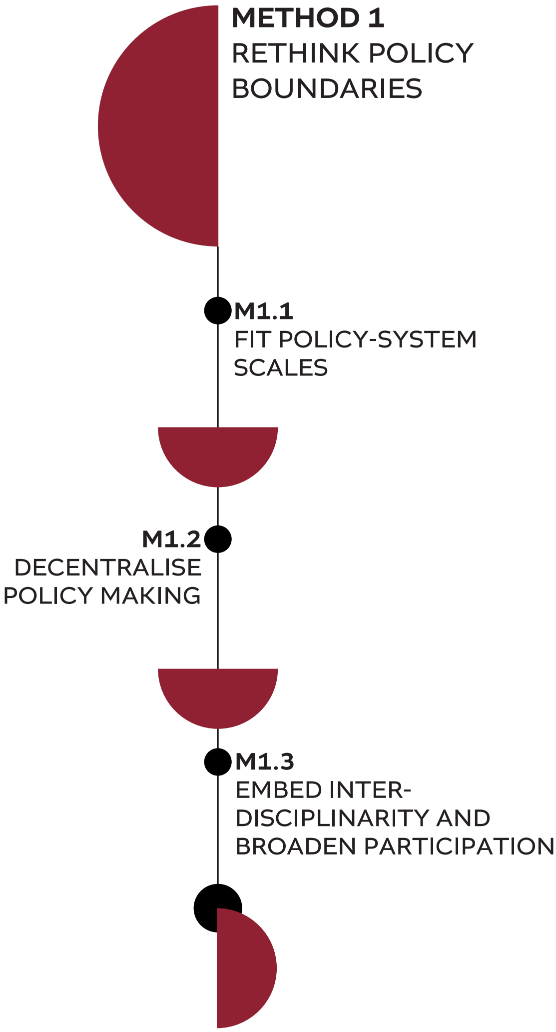
WHY DO WE NEED THIS?

Resilience is often undermined when there is a mismatch between ecosystems and the institutions governing them. This has been termed 'the problem of fit'. It can occur in three different dimensions – space, time, and function. A spatial mismatch occurs when the institution governing an ecosystem does not correspond with its geographical delineation. A temporal mismatch is characteristic in many policy arenas where planners and policymakers focus on shorter time-horizons than the ecological processes they regulate, or where systems are too slow to respond to social changes occurring at a much faster pace than policy-making and institutional change. Finally, functional mismatch describes a policy that is either too broad or too narrow relative to the regulated phenomenon, meaning that it ignores indirect effects, attempts to micro-manage, or uses large mechanisms to influence much smaller or local phenomena (Folke et al., 2007).

Another cause for ill-fitting institutions is the interaction between slow and fast variables. Slow variables determine the structure of the system. They set the conditions in which fast variables operate, variables that drive the dynamics of the system through interactions and feedbacks (Biggs et al., 2012). When dealing with ecosystems, fast variables usually include ecosystem services, such as water purification and crop production. These variables are significantly affected by system variables that take longer to fluctuate such as geological and hydrological dynamics over long periods of time (Walker et al., 2012). Managing these feedbacks is necessary to keep the system from reaching harmful thresholds (Carpenter et al., 2012; Folke, 2016).

Slow variables affect institutional design in the social sphere as well. For example, kinship, tradition, and religious norms change at a slower pace than legislation. Thus, changing the law may be insufficient in driving transformations in slower-moving phenomena. This mismatch is often ignored and can even cause conflict. This requires going beyond the economic incentives that regulation often attempts to change, focusing on the slow variables that drive social systems such as identity, values, world views, norms and cultural-cognitive aspects of the system (De la Torre-Castro and Lindström, 2010; Folke and Gunderson, 2010).

FIGURE 4: METHOD 1 FOR BUILDING A RESILIENCE-FOCUSED POLICY ENVIRONMENT



WHAT CAN BE DONE?

Fit the policy to the scale at which risk occurs

Start policy design with the unit where the risk is likely to occur, and intentionally fit the policy to that particular scale, while recognising how it is impacted by scales above or below it. For example, Uda and Kennedy (2015) built a framework for analysing neighbourhood resilience. They looked at the neighbourhood scale as a bounded complex system that is likely to cope with shocks and stresses in the future, while having to maintain certain functions, in this case fulfilling its residents' needs. Their analysis focused on two types of questions: first, how will future risks impact the system at hand, and how can they be prevented or faced at the neighbourhood level? Second, what happens if a service fails? Does the system have alternative services to provide? What happens if it can't, and how can the system survive as a whole?

Invite actors that represent different scales to design the policy

Initiate purposeful design of the actors invited to take part in policy formulation and implementation. This allows the integration of knowledge across scales and different environmental sectors, and to recognise and encourage the place of indigenous knowledge and community empowerment that bring not only different spatial scales but also temporal scales to the table (Fabricius et al., 2007).

Recognise the values at the basis of the policy's ideal state

The precise system state policymakers wish to restore or maintain reflects specific societal values, even if they are expressed in ecosystem terms. Policymakers should make explicit these values and put them up for debate in shaping it. For example, in evaluating the effects of farm abandonment on landscape and biodiversity, some researchers and policymakers look at an imagined past that is full of wilderness and untouched landscapes, especially where European forms of agriculture are rather recent. They disregard centuries of human-nature interaction shaped by native forms of cultivation and agriculture, focusing on a post-abandonment ideal where biodiversity can be restored to its former glory. In contrast, in European settings, the focus is often on pre-abandonment landscapes, in recognition of the way humans and nature are intertwined in creating valuable landscapes with distinct biodiversity and natural features (Queirozet al., 2014).

Reflect the dynamics between slow and fast variables

Policy analysis needs to reflect the dynamics between slow and fast variables and the feedbacks that drive the system toward different attraction basins. This requires monitoring systems that can reveal trends at different scales and where systems stand on different measurements, as well as making the information accessible and transparent for all actors in the policy system (Carpenter et al., 2012; Folke, 2016).

3.2.2 METHOD 1.2 DECENTRALISE POLICY MAKING

WHY DO WE NEED THIS?

Solving the problem of fit requires that governance systems are not only scaled appropriately to the problems they are charged with solving, but also polycentric and nested (Carpenter et al., 2012; Folke, 2016). This is in keeping with Elinor Ostrom's definition of polycentrism, meaning that there are "many centers of decision making that are formally independent of each other" (Ostrom, 2010). Large-scale institutions often need to be complemented by institutional arrangements at different scales that are linked together and allow the implementation of actions at local, national, and regional levels. This may favour a more polycentric governance structure rather than setting up new central agencies. It also entials subsidiarity, meaning that choices and actions should focus on the lowest possible level of governance while supporting collective-choice arrangements. This prevents rules from being instated at a system level that may only fit parts of it (Fidelman et al., 2012).

Polycentric governance is assumed to increase flexibility as it allows a diversity of approaches and mechanisms to be applied through experimentation. The overlap in authorities between governing bodies creates a redundancy that permits experiments to fail without risking the system as a whole (Biggs et al., 2011). This allows the policy to operate through networks that work in tandem to fulfil common objectives, as we can see, for example, with the different mechanisms to mitigate greenhouse gas emissions - policy tools, market tools, physical infrastructure, products, and research institutes to name a few. Even if some fail, others can still make headway in the collective action to fight climate change (Hudson et al., 2012).

This approach can be operationalised through a transition to 'adaptive governance', which creates a new balance between centralised and decentralised control by employing a network of agencies, organisations, institutions, and people that connect and coordinate voluntarily at different scales. They act somewhat autonomously, in a nested structure of polycentric institutional web (Folke, 2016).

WHAT CAN BE DONE?

Support community-based policies

While communities are sometimes forced to cope with shocks due to insufficient action on higher scales, they are also assumed to have an inherent disposition to enhance resilience for several reasons: first, communities with high social capital can mobilise and act; communities have attributes crucial for resilience, such as solidarity, reciprocity, cooperation, and networks; and their action can be facilitated and enabled through technological innovations (Bousquet et al., 2016). Norris et al. (2008) further described community resilience as emerging from a set of adaptive capacities – resource equity and equality in the distribution of environmental burdens; social capital and investment in networks of relationships, linkages between different networks and organisations, and the ability to form new associations and cooperative decision-making processes; providing both actual and perceived support through ever-expanding circles of proximity (family, friends, institutions etc.). Furthermore, they argued that communities provide social influence that allows for emergent norms; a sense of community, built on bonding and connection to it and the issues it faces; common meanings, views, and values, and the free flow of information through the community, building among other things on formal infrastructure to inform the public; a shared narrative and understanding of reality; and community competence where its members can jointly identify needs and challenges, agree on priorities and goals, on ways to reach those goals, and to implement them. Finally, communities have self-organisation and self-enforcement capacities and allow for flexibility and learning (Olsson et al., 2006).

Help communities become 'adaptive manager communities'

Fabricius et al. (2007) identified three types of adaptive communities. 'Powerless spectators' are communities that cannot cope with changes in policy, demographics, environment etc. They lack the financial means, the governance structures, the technology or natural resources, knowledge or networks. 'Coping actors' are communities where only short-term response is often possible as they lack leadership, motivation and vision. In contrast, 'adaptive manager communities' have the two crucial capacities for adaptation and governance: they have or develop polycentric institutions, knowledge networks, links between culture and management, and leadership and motivation for long-term solutions; and they can make hard choices between long and short term well-being and implement rules for managing the ecosystem. Enhancing communities' social capital can increase their chances of organisation in wake of disturbances, alongside support networks and even basic technologies such as mobile phones (Bousquet et al., 2016).

Complement national policies with a focus on local resilience

Decentralisation requires shifting the policy gaze onto local elements such as community and social resilience. Social resilience describes the capacity that groups and communities have to persist in face of the stressors that arise from environmental and social change. It can also be described as people's ability to change their own behaviour or the social structures that define the meaning of behaviour, and the ability of individuals and groups to ensure that desirable courses of action are taken when new circumstances dictate the need (Folke, 2016).

3.2.3 METHOD 1.3 EMBED INTERDISCIPLINARITY AND BROADEN PARTICIPATION

WHY DO WE NEED THIS?

One of the hallmarks of resilience thinking is dealing with surprises, meaning a perceived reality that is qualitatively different from expectations. The degree of inter-connectivity between systems we are currently experiencing means that surprises co-evolve along many dimensions – from the political to the biophysical. This requires an understanding and shared learning by scholars across many disciplines (Longstaff, 2009). However, While the interaction between humans and biophysical systems is often studied, social science and natural science remain traditionally separated, making it harder to understand how ecological and social systems behave as one coupled complex system (Liu et al., 2007).

Furthermore, considering only one side of social-ecological systems may lead to an overestimation of their adaptive capacities. While societies can change and adapt to a large extent, disregarding environmental constraints could lead to traps and breaking points. Interdisciplinary research makes clear that aiming to optimise a select number of economic or even ecological processes is likely to reduce capacity to deal with change and increase vulnerability, as it can cause loss of key ecological functions (Folke, 2007).

Finally, interdisciplinarity is also needed to confront complexity in resilience-related policy debates. Threats and risks are often masked by hidden assumptions framing these debates and other questions on the public's agenda. Complexity is ignored as society and policy focus on computable aspects of different problems, and because of a tendency to follow dominant models despite their incompleteness, filtering out inconsistent information. In order to reduce our vulnerability to these challenges, there is a need to include in the policy process a diversity of perspectives and models, and syntheses of knowledge from different, complementary, but at times conflicting viewpoints. It further requires taking in signals from a wide range of thinkers in a transparent manner, and recognising that extreme events will have physical, social, economic, ecological, and cultural impacts, interacting in ways that are hard to anticipate and compute. Ignoring these incomputable aspects leads to lacking models that nevertheless dominate policy prescriptions based on fragmented information (Carpenter et al., 2009).

However, the types of knowledge required in policy design and implementation go beyond formal scientific representation. Effective learning requires a diversity of stakeholders, jointly designing and understanding the institutional and organisational landscapes shaping these social-ecological processes (Olsson, Folke, and Berkes, 2004). Their participation can be enhanced at various stages of policymaking. For example, Eriksson et al. (2016) proposed the participatory diagnosis adaptive management framework as a way for non-experts to become involved in defining the system, its challenges, and what needs to change as part of the transition in governance. This process, they argue, connects the diagnosis phase with implementation, mobilizing the stakeholders who will affect its outcome.

WHAT CAN BE DONE?

Embed systems thinking in policy design

Social-ecological systems thinking allows resilience to serve as a bridge between disciplines, facilitating discussions about complex systems that consider a plethora of contexts and perspectives that may lead to theoretical and applied innovations. The nexus of resilience and sustainability particularly highlights the need for considering both the human dimension, including governance and practices, as well as an understanding of biophysical capacity and ecosystems processes and dynamics and how they interact (Folke, 2016). While in physical terms resilience represents the speed it takes to achieve homeostasis, it goes much further when it is used to analyse the adaptive capacities of human individuals, their communities, and society (Norris et al., 2008).

Invite different disciplinary interpretations of resilience when discussing resilience policy

Different disciplines provide different perspectives of resilience, focusing on complementary objects – ecology and the natural environment, psychology and people, engineering and built objects, and geography, aiming to integrate society, natural, and artificial environments. All dimensions are required for effective policy design. For example, geographers claim that they are particularly suited to study resilience as they inherently deal with different scales of time and space, and with society and the environment. Rather than interpretations of resilience as bouncing back from a disruption, geographic interpretations of resilience now suggest focusing on anticipation and bouncing forward (Weichselgartner and Kelman, 2015). Development studies bring their analysis of resilience from a political and institutional standpoint. They aim to reconcile developmental and humanitarian orientations and logic, integrating the two approaches. Rather than focusing solely on countries that are experiencing a momentary crisis and then moving on to the next, this marriage of approaches is hoped to keep the focus on countries beyond the peak of the crisis (Bousquet et al., 2016).

Stimulate interdisciplinary collaboration in response to shocks

Following Hurricane Katrina, new collaborations sparked innovative thinking that brought together urban planners with experts in various fields such as coastal science, engineering, and ecology to ensure an effective response to future flooding and sea level rise (Ernstson et al., 2010).

Broaden participation in policymaking and in the policy mechanisms that emerge

Increasing participation and diversity in teams charged with solving complex problems, ensuring that there is a wealth of perspectives and experiences. This can improve the policy's effectiveness and legitimacy, as well as the influence of non-state actors as it allows them more direct access to policymakers and decision-making processes (Carpenter et al., 2012; Folke, 2016; Tallberg et al., 2018). When policies earn local legitimacy or allow local rule, natural resource users often are able to construct robust self-management schemes. This may occur through self-organising, or through initiated co-management facilitated through incentives and rules by higher governance scales (Takeuchi et al., 2014).

3.3. METHOD 2: ENABLE RESILIENCE-ORIENTED POLICY ANALYSIS

Policy analysis can strengthen resilience by integrating approaches, methods, and tools that enhance policymakers' understanding of the dynamics governing the system in question and the possible impact their policies may have on moving it from one state to another. Resilience is also an effective tool to foster complexity thinking in policy making. Using resilience terms, policies can be described as attractors that focus actors and social structures toward a desired equilibrium. Building on a complex adaptive systems approach to resilience policy, interventions can be more effectively designed to balance competing resilience values such as connectivity, redundancy, heterogeneity, and modularity (Levin et al., 2013).

Furthermore, the non-linearity of complex systems requires policy to take into consideration a much larger amount of information and the extent of dynamics. For example, Liu et al. (2007) described a forest conservation program that promised subsidies to residents for monitoring illegal harvesting but ended up increasing demand for land and fuel-wood, due to residents splitting up into smaller households to get a larger share of the subsidy.

Several basic components of resilience thinking prove particularly useful for shifting policy analysis toward complexity thinking and embedding resilience concepts into the practice of policy analysis itself. Three sub-methods to do this will be discussed:

M2.1 Monitoring thresholds

M2.2 Identifying cross-scale interactions

M2.3 Utilising existing tools to integrate resilience in policy analysis processes

M2.2

TOOLS FOR SOCIO-ECOLOGICAL RESILIENCE ANALYSIS

TOOLS FOR DECISION MAKING UNDER UNCERTAINTY

INCORPORATING LOCAL KNOWLEDGE AND BUILDING SHARED UNDERSTANDING

FIGURE 5: METHOD 2 FOR BUILDING A RESILIENCE-FOCUSED POLICY ENVIRONMENT

3.3.1 METHOD 2.1 MONITOR THRESHOLDS

WHY DO WE NEED THIS?

Systems usually operate within a stable range of parameters. When conditions exceed this range, the system might transition beyond its performance threshold. Resilience in this context represents the system's ability to maintain conditions away from its threshold values (Amarasinghe et al., 2012). Systems can reach thresholds, and points of transition between alternate regimes, both in time and space. In time they can occur, for example, as deforestation rates reach an upper boundary all at once as a result of demographic shifts. In space, thresholds can be reached, for example, as distances between activities reach a critical minimum (Liu et al., 2007). The idea of planetary boundaries, meaning the thresholds beyond which the biospheric system and our existence within it would be beyond a safe operation space, has spurred both scientists and policymakers to action in recent years. Domains such as biodiversity loss are particularly worrisome given the accelerating rate of extinction in recent centuries and decades (Mace et al., 2014).

Another complication is that certain ecosystems respond to changing environmental conditions in a relatively linear or at least discrete fashion. However, for some conditions, the change between two basins of attractions can occur at once, representing an unstable equilibrium, or a response curve that is folded backward. This state of bifurcation means that the transition between the two stable states is catastrophic. Monitoring change cannot tell us whether the system is nearing the threshold as there are no early warning signals. Furthermore, returning to the stable state that existed before the collapse requires conditions beyond those that were present when the collapse occurred. This kind of pattern in transitions, which occur at different critical points, is termed hysteresis. If there are more than one possible stable states in the system, the probability of moving from one to the other depends on the extent of each state's attraction basin. If it is small, a small disturbance may be sufficient in transitioning the system to another state. Gradual change can also alter the size of the attractor basins, making the system more vulnerable to shifts in response to stochastic events. This can be especially pronounced if the attractors are not equilibria, but rather cycles, or if the system is prone to internal fluctuations, even with no outside force moving it, thus nearing the boundaries of alternative attractors such that external fluctuations can drive the system over the edge through collision with its boundaries (this is known as strange attractors) (Scheffer et al., 2001).

WHAT CAN BE DONE?

Put in place monitoring systems to approximate and maintain distance from threshold

Policymakers need to identify clear thresholds, risk targets, and regime shifts, and maintain active and iterative learning processes where new information can be used to evaluate existing actions and assumptions. This kind of system can reveal early warning signals that often precede transformations in the system. While these signals are often weak, they are also persistent. Policymakers can shape systems and train leaders to identify and respond to them in time. Diverse teams can increase the range of responses developed, as they can rely on different information sources, and bring in expertise based on different types of experiences and scientific-based knowledge (Polasky et al., 2011).

Track changes in what is defined as a threshold level

Thresholds are not static points that can be easily identified and predicted. Instead, they are dynamic, impacted by processes, feedbacks, and interactions at different scales. Furthermore, adapting to slow change can be at times more easily attainable than rapid changes at larger scales, where existing experience and local information are not sufficient in creating the innovation needed for adaptation (Hughes et al., 2007).

Incorporate uncertainty due to social factors and dynamics

While people have agency, the ability to reflect and anticipate change, and choose whether to act or not, this does not guarantee that thresholds are not exceeded. In fact, nearing thresholds due to human decisions and social dynamics may be harder to identify. For example, in their description of Australian farmers' responses to the dairy market deregulation policy, Sinclair et al. (2014) have shown that intensifying production was not matched by the required knowledge and skills to handle new production systems and manage larger herds. The move created unexpected feedbacks such as increased sickness among the animals and poor pasture regrowth, causing sudden drops in milk production and cascading into crossing thresholds in different arenas, undermining farmers' economic viability altogether.

Allow disturbances below thresholds

Disturbances are an important part of ecosystem life cycles. They allow succession to occur and bolster system resilience. Denying disruptions from occurring through human intervention can lead to greater disruption later on, at a scale that could not have been predicted through linear system analysis (Folke et al., 2007).

3.3.2 METHOD 2.2 IDENTIFY CROSS-SCALE INTERACTION

WHY DO WE NEED THIS?

The problem of fit between biophysical and social institutions requires more than just a multi-scale analysis, which often means a simple synthesis of separate research done at different scales by different researchers and analysts. It requires a cross-scale analysis that recognises and analyses the linkages between the scales and how they affect one another (Folke et al., 2007). For example, local conservation actions can impact social and environmental conditions in adjacent or even economically linked regions, while policy change at a national and regional level can affect incentives and management practices locally (Österblom et al., 2010).

This cross-scale analysis is one of the central differences between resilience policy and traditional policy. Traditional policy tools and interventions, as well as their analysis, often focus on specific systems and scales: national or local, short-term or long-term, transport or energy, for example. In contrast, resilience thinking requires that policies be considered across temporal and spatial scales and across systems. These different scales are linked, and decisions made in one inherently affect others. Policy is particularly important in facilitating emerging governance systems, be it through legislation, economic incentives, or bridging organisations that connect the different scales (Folke, 2007).

WHAT CAN BE DONE?

Analysing policy across spatial scales

Thinking across spatial scales about resilience is challenging as drivers may present complex impacts and outcomes. For example, global trade can both increase and decrease resilience as it links the global with the local. On the one hand, it may decrease dependency on a single region or on local ecosystems, allowing balancing of consumption and local capacity. However, it also expands the distance between consumption and production, often masking social-environmental burdens and important signals regarding the state of the resource's source ecosystem. This can create a spillover of social-environmental effects when usage is detrimental, decreasing social capacity to respond to feedbacks (Deutsch et al., 2007). This spatial interaction is even more pronounced in a rapidly urbanising world, where consumption is often separated at large distances from the biospheres from which the products and resources originate. It is also shaped by the power structures that determine institutional and technological development, and the inequalities that shape consumption patterns. All these have an immense impact on landscape use and resulting changes in the biosphere (Folke et al., 2016).

Analysing policy across temporal scales

From a temporal standpoint - resilience policies are often hampered by a mismatch between the difference in time scales between drivers and impacts. Liu et al. (2007) describe this interaction through legacy effects and time lags. Legacy effects capture how human-nature interaction affects conditions many years after the fact, as can be seen, for example, in landscapes affected by human activities and demographics. Time lags, conversely, conceal the impacts of human-nature interactions for an initial time period until they can be visibly seen or understood.

Analysing policy across systems and sectors

The growth in inter-dependencies between different sectors in the economy means that managing risk and increasing resilience, especially when it comes to infrastructure, requires coordination and a clear definition of responsibility between agencies and operators. Otherwise, failures can cascade from water to ICT to transport to energy and so on (Metz, Darch, and Workman, 2016). In order to create a coherent policy, there needs to be a clear interpretation of resilience across the organisational scales. Equilibrium approaches would require more integration and coherence vertically – at neighbourhood, city, regional, and national levels for example, while evolutionary approaches would require more horizontal integration, meaning between different sectors. Furthermore, policy analysis should take into account that equilibrium approaches are often techno-rational, focusing on decreasing risk in an existing pathway but locking policy subjects in a passive strategy where only the impacts of risk are averted rather than the risk itself. They can also impede long-term adaptability, displacing exposure from one sector to another (White and O'Hare, 2014).

Consider trade-offs in cross-scale interaction

Policies must be evaluated at different scales to prevent shifting burdens and impact from one locale to another, or from short to medium-term time horizons. The adaptation itself sets pathways that can indirectly undermine diversity or certain elements of adaptive capacity if it locks in certain practices or technologies for example (Adger et al., 2011). Furthermore, while policies may erode resilience at one level of the system, the system can maintain resilience at larger scales. For example, while certain ports in England have suffered decline, the UK as a whole was not hurt by it since it happened gradually, and other ports continued extending services. (Hudson et al., 2012). Thus, rather than aiming to reach universal resilience, resilience policies can balance different gains and goals at different scales - to adapt at one scale, we must transform in others, and hurting resilience at one scale may actually bolster it in others (Olsson, Galaz, and Boonstra, 2014). Social-ecological resilience recognises these cross-scale interactions at the global and local levels and does not assume their impacts can be simply reversed (Wilkinson, 2012). These tradeoffs are more extensively discussed in chapter 5.

3.3.3 METHOD 2.3 UTILISE TOOLS TO INTEGRATE RESILIENCE IN POLICY DESIGN

WHY DO WE NEED THIS?

Elements of resilience thinking can be incorporated into policy analysis through decision support systems and methodologies. These kinds of tools allow policymakers to identify trigger points and what actions are required to avoid them under uncertain conditions at different time frames. However, the characteristics of the particular domain in which resilience is bolstered may require different types of indicators and parameters of system behaviour for monitoring and evaluation. They also prescribe different decision support systems based on the specific conditions and behaviours that can push the system and its functionalities beyond threshold conditions (Amarasinghe et al., 2012). Thus, it is useful to consider existing approaches and tools for incorporating resilience in policy analysis, allowing us to map practical instruments at our disposal and even possible gaps.

WHAT CAN BE DONE?

Tools for social-ecological resilience analysis

Bringing the social, ecological, and technical sides of the system into policy analysis requires tools that embed an understanding of the links between human well-being and ecosystem processes and structures within policy analysis and design, such as the ecosystem services policy cycle framework (Langemeyer et al., 2016). Furthermore, according to Folke et al. (2016), every policy mechanism considered should be analysed through the lens of those who benefit and those who stand to lose from either action or inaction, and how different policy decisions affect inequality. Ultimately the choice of policy mechanism should tie incentives to human actions that affect dwindling resources (Carpenter et al., 2012; Folke, 2016). One example of utilising decision support tools in the conservation sphere is the 'Optimisation for conservation' approach. It can help maintain key ecological processes, identify pathways for recreating certain broadly defined objectives, and manage controlling variables and drivers such as heterogeneity in landscapes, local biodiversity, and re-vegetation (Fischer et al., 2009).

Another way to look at the difference between traditional planning tools and resilience-based tools is that the latter attempt to identify and secure functionalities rather than components. They look for system functionalities that are critical for society, and for ways to ensure their ability to resist, adapt, and recover from different threats, thus sustaining them even in face of uncertainty. They do so by adopting components that reduce unanticipated risk and navigate recovery from it; building greater functional autonomy in different networks in case others are impacted; increasing inter-connectivity between different networks so that their functionalities can supply alternative solutions; and increasing social resilience to provide local, immediate, and perhaps unexpected solutions if necessary (Linkov et al., 2014).

Tools for decision making under uncertainty

In order to deal with the uncertainties involved in the kind of challenges resilience policy focuses on, more elaborate decision tools are required. In addition to traditional methods to assess projects' viability and potential, such as cost-benefit analysis or discounted cash flows analysis, Metz et al. (2016) proposed that both industry and regulators start implementing tools that have been developed in the academia to deal with uncertainty such as no regret options, win-win options, low regret options, or more complex tools such as real options analysis and robust decision making.

3

No-regret options represent situations in which the benefits of the project are greater than its costs regardless of how a particular risk evolves. Win-win options represent situations where the project has positive externalities that go beyond its impacts on reducing that particular risk. Low regrets options are situations where the cost is low relative to the benefit considering how the particular risk may evolve. Real options extend the cost-benefit analysis to allow for learning and changing decisions adaptively – abandoning assets, expanding them, or switching between them. Finally, robust decision-making tests each alternative against a large range of possible risk scenarios to see how each of them performs under uncertain conditions Metz et al. (2016).

Future-proofing

One way in which infrastructure planning utilises resilience is in designing structures that can adapt to uncertain future conditions such as growth in capacity, suitability, usability, and desirability, and reducing the impact of possible changes and drivers. This "future-proofing", meaning anticipating possible needs and constraints under different scenarios in different time scales, should help business and government both reduce adverse impacts and seize upcoming opportunities. But it can also orient planners to design their objects in a way that saves effort in redesign and in its overall life cycle costs (Masood et al., 2016). For example, Ingerslev and Fasce (2012) describe the kind of extreme events planners should keep in mind and design for when working on immersed and submerged floating tunnels with a transport system. They anticipate that extreme events that incur heavy load on the tunnels will occur – earthquakes, extreme floods or tsunamis, changing river flows etc. Thus, they ask to ensure resilience, in this case, the ability to recover from accidental overloads. They translate this functional requirement to a clear design requirement and go even further in imagining what may happen if the structure or its components fail, to ensure people's safety by guaranteeing their ability to escape for example.

Future-proofing can also focus on a specific threat or challenge such as climate change. For example, Armstrong, Preston, and Hood (2017) describe how the UK Department for Transport assessed its preparations for the railway industry to adapt to extreme weather events as a result of climate change. It looked at three different layers of resilience – ensuring a return to proper service once events have occurred, communicating disruptions to system users so as to minimise their impact, and perhaps most importantly - increasing the system's ability to cope with these events through infrastructure resilience and operational resilience. The former can be achieved through reinforcement of critical locations and identifying potential points of failure, and the latter by using existing assets such as network redundancy and diversionary routes to spread the risk and increase flexibility.

Another way to think of future-proofing is through the lens of institutional innovation: rather than assume that we can think in advance of all the countless scenarios that may arise and prepare for them, policymakers need to create a system that is capable of changing itself in face of crisis and disruption (Doyle, 2015). Furthermore, this institutional change expresses a tension between the need to adaptively respond to crises such as climate change or fishery collapse through central regulations, and the prohibitive nature of centralised knowledge and action. In order to mitigate that tension, Sandström (2011) proposes to allow certain space for local adaptation of the rules in different regional contexts, and to maintain a system that is open for new knowledge (in their case ecological knowledge) by, for example having personnel that can constantly revise the policy in response to it.

Using boundary objects to incorporate local knowledge and build a shared understanding
Boundary objects can facilitate policy transformations by allowing greater consensus on the problems at hand. For example, the NEST decision support system enabled a greater understanding of the effects of nutrients in the Baltic Sea, serving as a basis for a perceived fair allocation among the governments involved (Österblom et al., 2010). Policy analyses can also use local case studies to inform and scale up experiences and adaptive capacity (Larsen et al., 2012) or use scenario building to assess how actors may react to changes, and subsequently how their reactions might influence desirable or undesirable trends in the system. For example, Cinner et al. (2011) surveyed fishers to examine how they may react to different levels of decline in catch – continue fishing, adapt in a way that amplifies the decline, or adapt in a way that dampens the decline.

3.4 METHOD 3: FACILITATE TRANSFORMATIONS

WHY DO WE NEED THIS?

Transitions and transformations are central to resilience from both social-ecological and socio-technical system perspectives. This final method explores what transformation means in the context of resilience policy, and how it may be achieved through a proactive change in policy-making processes, institutions, and the environment in which they operate.

WHAT DO WE MEAN BY TRANSFORMATIONS?

While a previous section discussed the notion of transformation and transformability, Nykvist (2013) argued that looking at different scales may lead to divergent definitions of what a transformation is. For example, carbon capture and sequestration is an industry that some argue is an integral component of tackling climate change. From the industry's proponents' perspective, a transformation in the system would require a ten-fold increase in efforts – upscaling from pilot to commercial demonstration, building more demonstration plants, increasing funding for implementing these technologies and increasing taxes on carbon emissions. However, it also depends on the continued establishment and maintenance of coal power plants in conjunction with a more committed climate policy, a pathway most climate advocates would oppose calling 'transformational' in terms of the greater carbon-neutral economy. Thus, transformations are rooted in specific understandings of progress and development. In order to shape them and bring them about, change needs to occur in social relations, institutions, and practices (Bousquet et al., 2016).

WHAT CAN BE DONE?

While some authors look at the behaviour of specific agents as basis for transformations, others look at the structural drivers of change. For example, the concept of transformative adaptation focuses not on the individual decision maker looking for a satisfactory alternative that allows them to adapt to changing circumstances, but rather on the social process where social relations and dynamics determine people's adaptive capacity. An integrated approach would look at both the agency of particular actors and the system in which they operate. One example of such strategy would be collective action, and another is collaborative planning (Bousquet et al., 2016).

Gunderson et al. (2006) argued that systems can transform when the failure of past policy is acknowledged, when a crisis hits, or when there is a shift in societal values. They identify four components that seem necessary for adaptive and transformable change to occur – developing and maintaining open epistemic networks, facilitating different types of scientific and social learning, creating an arena for discourse where network members can exchange and develop knowledge, and fostering trust through leadership. Transformations require memory and understanding of social-ecological systems, but they are also limited by past decisions, policies, values, and system vulnerabilities. Maintaining an openness in institutional arrangements to allow linkages within the system and with other systems facilitates transformational learning across social and ecological scales, as well as encourages a tolerance to failure. Some transformation can also occur in closed institutional settings, where information is filtered out in order to support existing paradigms, but it will only occur when change is forced by a crisis or societal demands.

Olsson et al. (2004) suggested that new governance structures arise through a self-organising process that has several distinct features:

- Environmental events prompt a response that widens the scope of policy from managing a particular resource to a wider ecosystem perspective,
- Expanding the management from a few individuals to a group and then to multi-actor engagements,
- Evolving institutional structures that govern the new types of responses required,
- Collaboratively developing new knowledge of ecosystem dynamics and embedding it in these new structures,
- Developing new social networks that connect actors, allow information to flow, identify knowledge gaps, and create points of expertise,
- Leveraging these new networks to supplement local practices with knowledge and expertise across scales,
- Allowing the emergence of polycentric governance – multiple centres of governance that have the ability to cope with complex issues. Each of them is able to experiment and learn, creating new knowledge and feedback loops that reverberate throughout this networked governance structure. This decentralised system makes it easier to buffer against mismanagement and to increase desired domains of stability.

In Chapter 7 on endogenous modelling of resilience policy, some of these concepts are operationalised to model policy process theories. Thus, it is worth exploring in further detail what they mean and how policymakers can use them to bolster generalised resilience. In other words, what tools do we have to bring about transformation through policy change?

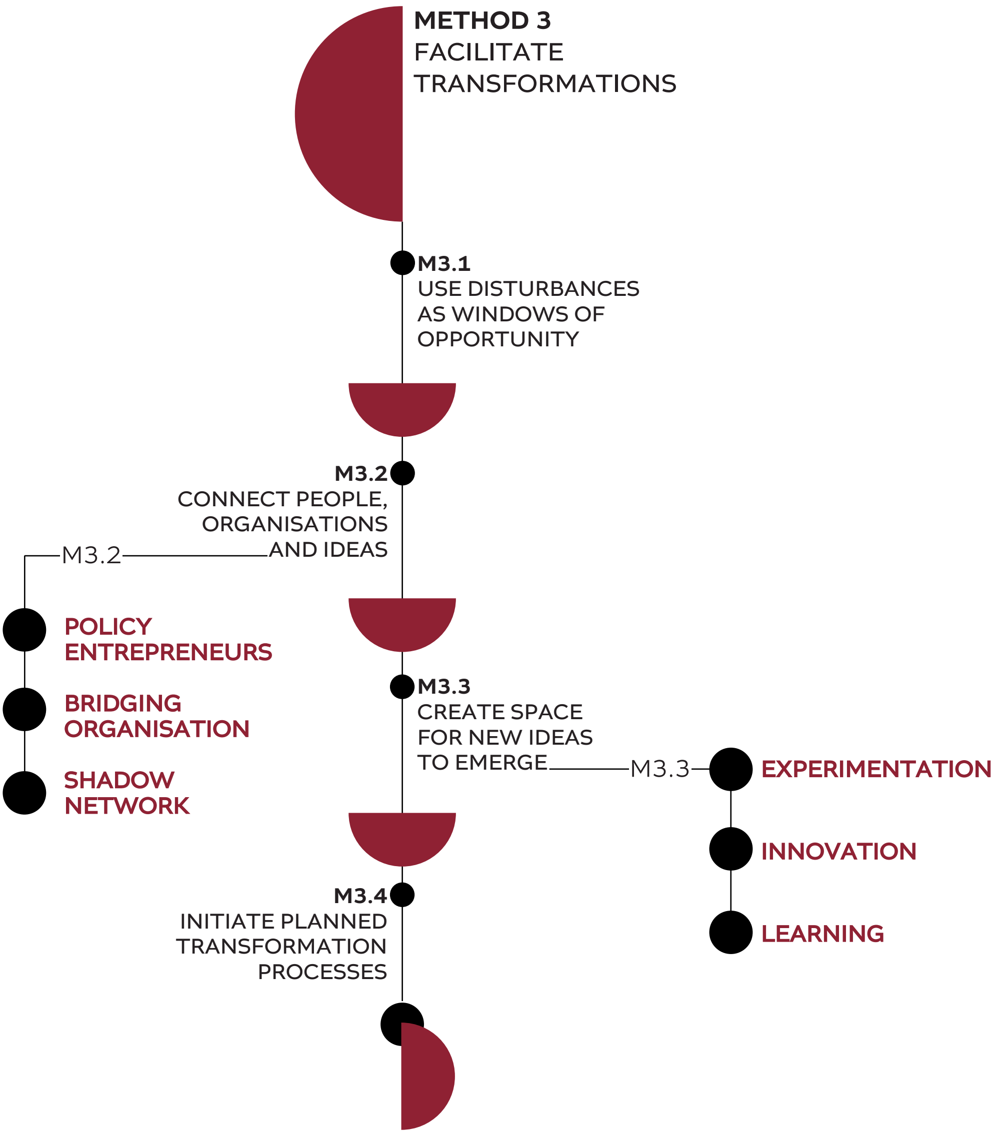
The following section will look at four ways policymakers can initiate, facilitate, and set the grounds for transformations in the system at hand:

M3.1 Using disturbances as windows of opportunity

M3.2 Connecting people, organisations, and ideas

M3.3 Creating space for new ideas to emerge

FIGURE 6: METHOD 3 FOR BUILDING A RESILIENCE-FOCUSED POLICY ENVIRONMENT



3

3.4.1 METHOD 3.1 USING DISTURBANCES AS WINDOWS OF OPPORTUNITY

WHY DO WE NEED THIS?

Transformations are often triggered by a crisis. This dynamic is embedded at the very core of resilience thinking. Folke (2010) defined resilience as the capacity of a system to cope with change and continue developing. He thus encapsulated two facets of resilience - withstanding disturbances, and actually using them to grow, innovate, and renew. They can also open a window for policy learning, as unexpected events can reveal an existing policy failure (Hughes et al., 2007). Finally, they can focus policy agenda on a particular problem that requires additional attention, resources, and political will. For example, hurricane Sandy demonstrated the disruptive power of extreme weather events and its effect on various networked systems such as transportation and energy (Hosseini, Barker, and Ramirez-Marquez, 2016).

WHAT CAN BE DONE?

Actors in the policy arena can embrace disturbances as a way to open up spaces for change and adaptation. In institutional terms, this translates to flexible institutions that can accommodate the necessary changes in response to the changing environment and have the knowledge to instruct the new practices that need to take root through an adaptive policy planning process (Wilkinson, Porter, and Colding, 2010). Furthermore, policy actors can actively prepare for windows of opportunity for transformation following disturbances to open up, and to learn from these disturbances - which processes at different scales facilitate transformations and which don't (Bousquet et al., 2016).

Similarly, Folke (2016) argued that in order to facilitate transformations policymakers and other actors should focus more on creating the conditions for opportunities to propel transformations to open up, and prepare for when they do, rather than control them or plan them out in advance. The new identity of the system is expected to emerge through interaction between different actors and communities, which is another reason to create conditions that allow experimentation and failure, cross-learning, and cross-scale initiatives, as long as they stay clear of known system thresholds.

3.4.2 METHOD 3.2 CONNECTING PEOPLE, ORGANISATIONS, AND IDEAS

WHY DO WE NEED THIS?

Transformations may be constrained by historical path dependencies or social-ecological traps whereby past decisions make it harder to push through certain types of policies and innovation (Boonstra and de Boer, 2014). Overcoming these barriers to transformation requires actors and organisations in the system to actively look for opportunities to create new pathways and help them emerge and spread at a different scales. This is often dependent on the success of three functions in the policy environment: policy entrepreneurs, bridging organisations, and shadow networks.

WHAT CAN BE DONE?

Supporting policy entrepreneurs

Transformations are more likely to occur in policy environments that allow institutional entrepreneurs to find and cultivate new trajectories and seize opportunities for transformations (Carpenter et al., 2012; Folke, 2016). Institutional entrepreneurs can play a vital role in initiating transformations by identifying political opportunities for creating new institutions or changing existing ones, framing problems in a way that advances change, linking different groups and allies, and creating new policy solutions. They take strategic action to advance transitions from one phase to the next, for example by managing key events that allow integration of transformational policy solutions in different policy processes and frameworks (Rosen and Olsson, 2013). The entrepreneurs operate in specific opportunity contexts, meaning they require institutional openness for innovation and for mobilising the necessary resources so that transformations can last (Järnberg et al., 2018).

Entrepreneurs' work focuses often on communication - they can build on their acquaintance with local actors to experiment with new practices, translate and implement external knowledge in local contexts, and integrate values in the work of local centres of governance. They can also build on local memory of crises to create new meaning, combining scientific knowledge and skills with those of local actors who have experienced the crisis and its impacts first-hand (Hahn et al., 2006).

Policy entrepreneurs also have an important role in creating coalitions and connecting different actors relevant to policy change. They connect and interact in unexpected ways, allowing new properties and patterns to emerge on broader scales, creating feedback, or adaptive waves, throughout the system (Folke, 2016). Policymakers, who often act as policy entrepreneurs themselves, can facilitate entrepreneurs' coalition-building efforts by, for example, taking a clear position on transformational policies, promoting strategic action through investment, enacting regulation, and providing advice that increases transformational coalitions' integration and effectiveness (Ulmanen, Swartling, and Wallgren, 2015). Policy entrepreneurs can also use legal structures, principles, and processes, to create new forms of social contracts, and allow the evolution of new concepts of rights and justice related to experiences of environmental change (Folke, 2016).

Enabling the work of bridging organisations

Bridging organisations link local stakeholders to actors in different organisational scales. They help build trust between actors, create collaborations both horizontally and vertically, resolve conflict, identify common interests, and provide social incentives to participate in transformative initiatives (Hahn et al., 2006). They link diverse groups and actors by increasing the number and types of social interactions between policymakers and scientists, using boundary objects, liaisons, and brokers who have a foot in both communities. They can also open neutral spaces where social networks can grow, and interests may align (Crona and Parker, 2012).

Cultivating shadow networks

Shadow networks are informal networks that can facilitate information flow, create 'nodes of expertise' that experiment with new solutions, and gather data and other tools required to institutionalise new approaches when windows of opportunity for transformations open up. They often emerge through individuals recognising the need for a new governance approach, slowly expanding into groups, and finally, a more coherent network that allows new knowledge to be embedded in institutions and institutional structures (Olsson et al., 2006).

These networks emerge through a process of agglomerating connections: individual actors meet people with similar interests, values, or causes. A social network emerges that can interact with other networks or formalise its activities in the form of organisations. These can clarify the nature of the problems they are trying to solve or bring up policy proposals in order to propel the system toward change. They can also gather information, accumulate knowledge, and create boundary objects such as reports, which build capacity and mobilisation within established governance structures and organisations, and facilitate horizontal and vertical cooperation (Österblom and Folke, 2013). Shadow networks can incorporate actors from different sectors. For example, the insurance industry has been approached by policy networks to access its information and assessments related to climate change, leveraging its ability to reduce risk or risky behaviour through its premium structures (Hudson et al., 2012).

3.4.3 METHOD 3.3 CREATING SPACE FOR NEW IDEAS TO EMERGE WHY DO WE NEED THIS?

Olsson et al. (2014) argued that in order to develop transformative capacity there is a need to open up new spaces for experimentation that can be coordinated across scales at critical times. These can explore and solve conflicts at local levels and broaden the range of ideas and practices that transform the system at hand. This requires building policy environments that encourage experimentation, innovation, and learning.

WHAT CAN BE DONE?

Allowing policy experimentation through adaptive co-management

Much of the focus on integrating resilience in governance mechanisms was put on the concept of adaptive co-management. The basic governance problem that adaptive co-management tries to overcome is that uncertainty is inherent in complex systems, due to its emergent, non-linear properties that arise from the interaction between different components in the system. However, decisions still need to be made, and so the approach aims to systemically incorporate learning in the management process (Folke, 2016).

Adaptive co-management as an idealised form of governance emerged out of natural resources management. It changes policy-making processes and structures by doing two things: First, increasing stakeholders' participation in decision-making and setting policies, and second, dealing with uncertainty by learning from practice, while upholding scientific observation and method. In order to implement this way of thinking, institutions need to adopt new norms and configurations – move toward polycentric governance, increase public participation, embrace an experimental approach, and fit the scales of governance to biophysical realities (Wilkinson et al., 2010).

According to Hahn et al. (2006), several factors contribute to the successful implementation of adaptive co-management as a governance model:

- Understanding and continually creating knowledge of ecosystem and resource dynamics by linking people in different organisations, capacities, and knowledge systems,
- Creating a learning environment that is based on constant testing and understanding of uncertainty rather than optimisation based on past records,
- Incentivising and institutionalising collaborations and linkages between communities, user groups, government agencies, and civil society organisations as the basis for polycentric governance,
- Coping with both natural and social external drivers

Adaptive co-management often requires embedding in broader governance systems to enable its large-scale implementation. For example, in the US and in Australia adaptive co-management has been integrated into legislation that makes it easier for resource managers to initiate preliminary experiments through participatory engagement with a diversity of stakeholders. Rather than have scientists try to educate policymakers and the other way around, this kind of arrangement creates a place for building trust and cooperation (Hughes et al., 2007).

Instill innovation

Transformations are inherently an outcome of innovation. While policy innovation is a topic in and of itself, several mechanisms and arenas for innovation are worth mentioning in this context:

1. **Local innovations -** The experiments adaptive co-management facilitates allow a policy to emerge from local innovations: Through a multitude of local projects, a macro effect can emerge reflecting the social and environmental values that generate the transformation. This allows for new institutions to emerge, including norms, values, and new ways in which actors perceive their environment, as well as formalising initiatives that may have started as voluntary (Hahn et al., 2006). In this context, enabling legislation can meet bottom-up practices to allow diffusion of innovation (Österblom et al., 2010).
2. **Policy transfer -** Implementing policies that have been designed in a different geographical context. Policy transfer allows policymakers to adopt new ideas and mechanisms in situations where time, resources, and information are constrained. It can be used to import ideas, inspiration, mechanisms, or institutions, or as a holistic strategy to confront the need for consistent or rapid transitions to new institutional regimes (De Loë et al., 2016).
3. **Social density -** Cities exemplify an ideal arena for innovation. Their density encourages more frequent encounters with people from different sectors and geographies, opening the potential for intentional collaborations that create new ideas on structuring technologies, institutions, and space to enhance resilience and sustainability (Ernstson et al., 2010).
4. **Combining different sources and types of knowledge-** Integrating socio-technical thinking that focuses on the role of technology in enhancing sustainability, and social-ecological thinking that focuses on the interplay of human society and ecological systems is particularly useful for facilitating transformations (Olsson et al., 2014). Furthermore, resilience policies can be integrated with different policy regimes that are attempting at achieving sustainable development, such as the sustainable development goals (Carpenter et al., 2012; Folke, 2016; Folke et al., 2002).

Institutionalise learning and communication

Information flow is pertinent to new strategies and policies that facilitate resilience, and in particular transformability. Expanding the scope of inquiry beyond adaptive management, resilience theorists looked at the social context in which it can emerge through the lens of adaptive governance – the processes that allow institutions and other forms of collective actions and decisions to occur, under conditions of uncertainty and lack of control. In these processes, people and groups with different interests and understanding of the world can reconcile their conflicts by bringing different kinds of information and knowledge (Österblom and Folke, 2013). Information can connect different temporal, spatial, and social scales. It can provide early warning on both immediate disruptions and long-term stressors. Information is also the basis for decision-making, even if it is not always available to vulnerable groups to act upon (Boyd et al., 2013).

Bousquet et al. (2016) mention two types of communication that facilitate resilient transformations: Institutional communication whereby the goal is to expose stakeholders to the concept of resilience and its associated terms, and communication among stakeholders that connects the science to their own experience and objectives. Thus, culture becomes a central factor in the shaping of social-ecological systems. It allows people to transmit meanings over generations, representing the ways people communicate and expand their knowledge of the world. However, the concepts that inhabit cultural systems can represent the system to different degrees of accuracy. Thus, identity and culture can both constrain and facilitate transformations (Folke, 2016).

3.4.4 METHOD 3.4 INITIATE PLANNED TRANSFORMATION PROCESSES WHY DO WE NEED THIS?

While previous sections on transformation and the broader policy environment discussed the necessary conditions for resilience and transformation to emerge, some scholars advocated for a more proactive approach. Resilience transformations can also occur intentionally and systematically, as other policies do. For example, reviewing how urban planners approach transformations toward a resilient city in a systemic manner, Wilkinson et al. (2010) found it had been done in two ways: First, identifying elements that contribute to a resilient city and deducing strategies that could materialise them, or second, engaging with practitioners and stakeholders to identify resilience principles in response to specific local challenges and testing their relevance for the specific system at hand.

WHAT CAN BE DONE?

Implement frameworks for planned transformations

Scholars proposed different models and frameworks for planned resilience transformations: Olsson et al. (2006) and Olsson et al. (2014) argued transformations occur in three phases: preparing for the change, transitioning to a new social context, and building resilience for the new trajectory. In the preparation phase agents of change work to open new pathways or trajectories for development by operating with their networks at larger institutional spaces. In the navigation phase what he termed 'cross-scale brokers' link actors at different scales in order to scale up initiatives and encourage innovation. The last phase is dedicated to building resilience, whereby bridging organisations encourage values and incentives to maintain the new state. They further argue that the transition itself can't be planned, only navigated. As windows of opportunity for policy change occur in different scales, they require cross-scale interactions that are made possible by connecting actors and organisations at different levels, allowing adaptive governance to emerge. The authors argue that when a transitions occurs, meaning that some externa or internal dynamic allows the system to break away from traditional governance regimes, new social structures emerge that can link different people, organization, and institutions, that allow new governance structures to be established. Furthermore, these events allow new linkages between solutions and problems from different domains, enabling composite policies to different problems. They mentions several concrete examples for these strategies, including having in advance a portfolio of potential projects that can be launched when a windor of opportunity appears, building institutions that can bring together different actors from diverse organizational levels, some policymakers, some researchers and activists, allowing translation of knowledge to occur between them and to appeal to new stakeholders, particularly potential funders.

Hudson et al. (2012) offered an iterative cycle of actions for initiating systemic response to risk: First, policymakers must identify risk owners, and for each of them determine the level of failure the system can tolerate and the risks that may lead to it. Second, they should assess the probability and severity of each risk and its impacts, and consider them relative to one another and to each stakeholder's tolerance levels. They can use methods such as single point of failure or event-tree

to analyse the process that may lead to system failure materialising. Third, they need to address vulnerabilities by defining for each risk whether it should be eliminated, reduced, isolated, or controlled based on each action's cost and the cost of system failure. Finally, they should look for response strategies for risks that cannot be removed or mitigated, through short-term protections and return to normalcy plans for example. This assessment exercise needs to happen if a failure has occurred, new risks have been identified, or on a routine basis.
Establish new institutions that govern resilience

Creating new institutions with comprehensive mandates of the issue at hand can lead to substantial transformations. However, it can also lead to loss of institutional memory, suffering from lasting organisational culture from previous agencies, and exacerbating institutional fragmentation that makes it harder to achieve policy revolution rather than evolution (Österblom et al., 2017).

Provide leadership for resilience transformations
The role of leadership is equally important in creating the required conditions for transformations, in building trust among actors, creating context through sense-making, managing conflicts that may emerge through new relationships and power dynamics, generating knowledge and making it accessible, formalising a vision and communicating it both internally and externally, gaining and mobilising support, and leveraging it to institutionalise the new approaches advocated (Olsson et al., 2006).

Embed solutions based on general resilience principles for specific risks
These could include, for example, building early warning systems, strengthening social-physical infrastructure through diversification or ecological buffers, distributing financial risk, and increasing preparedness through training or reserves. General resilience can be intentionally enhanced by making information about risk more accessible, incentivising residents and citizens with market measures to take appropriate action towards it, reducing vulnerability through public infrastructure and services, and strengthening oversight through proper institutions (Carpenter et al., 2012).

3.5 CONCLUSION

This chapter offered three broad methods to reshape policy environments so they foster generalised resilience regardless of the specific disturbance at hand, based on a broad literature review of social-ecological and socio-technical resilience:

Method 1 Redefining policy systems' boundaries

Method 2 Enabling resilience-based policy analysis

Method 3 Facilitating transformations

USEFULNESS OF THE ANALYSIS

The review provided concrete steps policymakers can take to implement each of the methods - from putting in place monitoring regimes to identify and avoid thresholds, to changing the division of power and responsibility so as to decentralise governance structures. While operationalising these methods can take different shapes in different contexts, and the real challenge may be how to actually gain support for implementing them, this chapter sheds light on the kind of best practices resilience policy professionals could promote as part of their work, whether in an agency's resilience office, as resilience officers, or even policy analysts tasked with bolstering specified resilience in a given field, as this review provides them diverse options to structure the analysis itself.

DIFFERENTIATING POLICY GOALS AND POLICY ENVIRONMENTS

While several of the concepts that appeared in this chapter overlap with ideas brought up in the previous chapter, which captured resilience policy goals, it is useful to distinguish between the two: The previous chapter set general goals toward which resilience policy should strive, best contextualised with a specific challenge in mind (how do I increase the connectivity here to ensure the persistence of this particular functionality, how do I mitigate vulnerability for this particular group to this particular disturbance). This chapter, on the other hand, set a roadmap for bolstering resilience regardless of the particular shock or disturbance at hand.

Furthermore, the differentiation between policy goals and policy environments can at times seem artificial. This reflects the porous boundaries between generalised and specified resilience. For example, diversity is a key policy goal, meaning that resilience policy should safeguard diversity within its target system. However, it is also prescribed as a key feature of the system creating the policy, which should reflect different disciplinary expertise, local knowledge, participation, and myriad stakeholders. This is not a bug in the analysis, but rather a feature. Indeed, the same qualities that resilience policy needs to install in its target system are important to maintain within the policy environment itself. However, the analysis aimed at differentiating between the two through the specific application of these principles in the two interlinked dimensions of goals and environment.

CHALLENGES FOR IMPLEMENTATION

Several methods proposed in this chapter, though widely popular in literature, can present a clear challenge for policymakers. For example, while experimentation is considered key in adaptive co-management, policymakers are often limited in their ability and willingness to experiment in the real world, where policy implementation has clear and present consequences. Some prefer modelling and monitoring to resolve uncertainty, assuming they are less costly and risky, an approach chapters 6 and 7 of this dissertation further develop. Some experiments can also face objections from different value groups and are not able to resolve conflicts between scientists and other stakeholders (Hughes et al., 2007).

Similarly, decentralisation is key in the new governance styles proposed in this chapter, particularly polycentric policymaking that acknowledges the role of communities. It opens up the possibility for appropriate institutional frameworks with equitable decision-making processes (Tendall et al., 2015). However, as the system decentralises and resembles more of a network, or nested systems that connect to one another and are dependent upon them, the advantages of central control and even a central understanding and ability to monitor and direct the system becomes harder to achieve (Hudson et al., 2012). Thus, none of the methods is universally appropriate or bolsters resilience in and of itself.

While chapters 2 and 3 aimed at defining what resilience policy means based on theory and literature, the next chapter examines resilience policy from an opposite approach - by analysing resilience policies from dozens of cities around the world, moving from theory to practice, from context independence to local interpretation.

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CHAPTER FOUR

04

INTRODUCTION

RESILIENCE POLICY FRAMEWORK

CHAPTER TWO
POLICY GOALS

CHAPTER THREE
POLICY ENVIRONMENT

RESILIENCE POLICY IN PRACTICE

CHAPTER FOUR
POLICY COMPONENTS

CHAPTER FIVE
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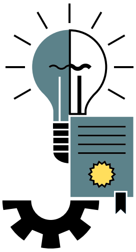
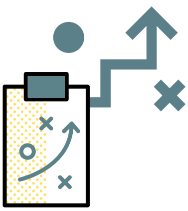
RESILIENCE POLICY

04

IDENTIFYING THE COMPONENTS OF RESILIENCE POLICY IN PRACTICE

Government agencies the world over have published and adopted official resilience policy documents and directives for the past two decades. This chapter focuses on a particular set of resilience policies created under the umbrella of the 100 resilient cities network. It deploys a quantitative content analysis methodology to dissect the commonalities and differences between them. Its results help us better understand the structure and content of resilience policies and plans in practice.

FIGURE 7: IDENTIFIED COMPONENTS OF RESILIENCE POLICY

	**DOMAIN**	Disasters, crisis and Emergency Environmental factors Inclusion Quality of life
	**CAPACITY BUILDING**	Community Life preparation Plan implementation Business Government
	**INSTITUTIONAL DESIGN**	System integration Demarcation Learning Enabling tools Partnerships
	**STAKEHOLDER ENGAGEMENT**	Involvement Multi - level Communication Responsibilities Coordination
	**STRATEGY DESGIN**	Policy design Time scales Values Analysis Goals

4.1 INTRODUCTION

Resilience policy has been codified in a wide range of policy documents directives, plans, laws, and regulations. These give us the opportunity to analyse the content, structure, and application of resilience policy. Rather than looking at how resilience policies implement the policy goals and environments proposed in the previous chapter (through deduction), here we will attempt to inductively explore the meaning of resilience policy.
Based on an analysis of 41 resilience plans created by cities that participated in the 100 resilient cities program, we aim to answer the following research questions:

1. Which disturbances and shocks do cities tackle through resilience policy?
2. Is there a common policy structure we can identify in resilience plans across the program?
3. What can we learn through quantitative content analysis about individual cities' resilience policies?

Synthesising the answers to these three questions yielded an emergent identification of resilience policy components, presented on the left, and explained throughout the chapter.

The chapter continues as follows: First, we provide a short overview of previous studies performed to analyse resilience policy documents at different scales and across domains. We describe the methodology used to perform a quantitative content analysis on a closed set of resilience plans - the urban resilience strategies that emerged out of the '100 resilient cities' program, which spanned dozens of cities all over the world, and provide a basis for inferring how resilience policy can be interpreted in highly divergent geographical contexts, and social, environmental, and economic conditions. Finally, we present the results of the analysis – first at a cross city scale, and then demonstrating what the analysis can teach us at an individual city scale as well. We conclude with a discussion of the methodology and results.

4.2 LITERATURE REVIEW – ANALYSING RESILIENCE POLICY DOCUMENTS

4.2.1 FROM CONCEPTS TO PLANS

Resilience policies have the potential to operationalise the theoretical concepts presented in the previous chapter. They can identify key agencies that are in charge of maintaining functions in face of crises and determine clear investment strategies that embed resilience in a cost-effective way throughout the system (Jerome et al., 2009). For example, resilience has become a central idea in organising and even replacing climate change adaptation policy in discourse and funding globally, with the multilateral global Climate Investment Funds investing 1.3 billion dollars in climate resilience through its Pilot Program for Climate Resilience, a move mirrored in places like the Caribbean placing resilience as a key concept in their climate investment strategy (Popke, Curtis, and Gamble 2016).

Resilience policies can be instigated by preparation or response to expected or unexpected shocks and disturbances. A multitude of resilience approaches can serve as a basis for the policy. International development and disaster management often rely on a social science based conceptualisation of resilience, while natural resources management policies build on social-ecological approaches. Resilience can be used by name only or as a central theoretical foundation for policy goals and measures. Since resilience is new to some stakeholders it may require champions in the organization that can cross boundaries and introduce the concept to new audiences (Parsons and Thoms, 2017).

4.2.2 CLIMATE CHANGE AS A DRIVING FORCE FOR RESILIENCE PLANS

In the US, resilience policy was codified by the federal government in 2013, when President Obama issued 'Policy Directive 21 on Critical Infrastructure Security and Resilience'. The directive defined resilience as the ability to prepare, adapt, withstand, and recover from disruptions caused by both human attacks and natural threats and incidents. This facilitated national security institutions such as the national security council to address matters of resilience explicitly. Two executive orders, 13653 and 13514 reflected further institutionalisation of resilience, outlining federal roles in supporting climate resilience through investment and planning, through land and water management, and by providing dedicated data and tools. The US Departments of Defense and State also contributed to mainstreaming resilience in a wide range of policies within the context of climate change, in conjunction with climate resilience growing in importance and usage at the federal level between 2011-2015 as part of the federal government's adaptation planning frameworks (Flood and Schechtman, 2014; Keenan, 2017).

At an agency level, the U.S. Army Corps of Engineers incorporated resilience in its official policy through an official climate resilience strategy, containing a climate preparedness and resilience policy statement. It mandated that climate change adaptation be considered in every phase of its projects' life cycles, to reduce vulnerability and improve resilience, specifically in water-related infrastructure (Hossain et al., 2017). Similarly, in the United Kingdom, a 2008 national security strategy document expanded security to beyond traditional military threats, dealing with questions of insecurity arising from climate change. It sets out explicit measures to increase resilience, such as defensive measures against sea-level rise and changes to agricultural practices to reduce water demand (Coaffee, 2008).

Mainstreaming resilience through the lens of climate adaptation drove resilience policy in Ireland as well: In 2012 the government published a national framework document titled 'The National Climate Change Adaptation Framework: Building Resilience to Climate Change'. It defined resilience from an engineering standpoint, highlighting anticipation, preparedness, and ability to respond to and recover from hazards. The EU similarly discussed the resilience of European coastlines in its 2013 strategy on climate adaptation, linking it to integrated coastal zone management (Flood and Schechtman, 2014). The Global South has adopted resilience in its climate change planning as well, with The Philippines, for example, creating a dedicated climate change commission to bolster climate resilience, and South Africa a strategy to build resilience and adaptive capacity in response to climate change (Parsons and Thoms, 2017).

4.2.3 RESILIENCE PLANS BEYOND THE CLIMATE

Resilience policy spread into a growing range of domains over time, especially in the context of disaster preparedness and natural resource management, in the US and the world over. In Oregon, for example, the House of Representatives required the provision of a resilience policy to meet the challenges of a possible earthquake and tsunami owing to the region's tectonic vulnerability. It directed the state's advisory commission in charge of seismic safety policy to produce a plan that would make recommendations on policy direction to protect life and commerce in case of an extreme event. The plan provided different time scales for restoration – from meeting basic needs in days and weeks, to more foundational modernisation over years, supporting both individual and community needs (Cutts, Wang, and Yu, 2015).

The EU strategy on adaptation to climate change sought to mainstream climate resilience in policies pertaining to health and society, biodiversity, production systems, and physical infrastructure. Several countries opened research centres developing agricultural resilience, and international development has been looking for ways to integrate resilience in different frameworks and programs. Resilience is a central concept in urban planning and in protecting infrastructure and has been incorporated in the New Urban Agenda presented in the UN-Habitat Medellin Declaration (Parsons and Thoms, 2017).

Resilience plans and policies have also been initiated through a sectoral focus. For example, the 'Italian Regulatory Authority for Energy, Networks and Environment (ARERA)' initiated a national resilience plan to be implemented jointly by the national transmission system operator and large distribution system operators in the country to ensure grid reliability (Ciasca et al., 2017).

Analysing resilience plans across the US federal government, Keenan (2017) found that almost half of the measures in the plans surveyed focused on coastal communities, mainly providing protection against floods. Most measures in general dealt with natural hazards, followed by technological and human-caused hazards. Their review found that the prevailing view of resilience is as a strategy for disaster risk reduction and post-disaster recovery, with risk mitigation and recovery missions comprising the bulk of interventions. A large proportion of the measures was dedicated to planning processes, including community planning and infrastructure risk analysis, with ecosystem resilience relatively underrepresented. In terms of sectors – the water and wastewater sector accounted for almost a quarter of the measures, followed by emergency services, and food and agricultural systems. A small number of measures (less than a tenth) dealt with the industrial sector, including chemical and commercial facilities, critical manufacturing, IT, and energy.

4.2.4 ENHANCING RESILIENCE THROUGH COMMUNITIES, BUSINESSES, AND CITY ACTION

National resilience policies often put much weight on the local level. For example, Australia's national strategy for disaster resilience acknowledged the role of communities and individuals, as well as businesses, in creating resilience to natural hazards (Parsons and Thoms, 2017). At the US federal level, most plans analysed in Keenan (2017) dealt with community resilience: ways to reduce vulnerability, planning for mitigation and recovery, and preserving cultural and natural resources. In the UK, communities and individuals are designated as responsible for resilience planning, preparedness, and response, though the central government retained much of the power to make decisions over priorities, procedures, and allocating the necessary funds to implement measures. This discrepancy raised concern over the use of resilience to promote neoliberal approaches and policies that devolve responsibility without authority and resources Chmutina et al. (2016).

The business sector is another central actor in resilience policies. For example, the Oregon resilience plan identified, among other factors, the need for better communication between the government and the private sector, which owns the great majority of infrastructure in the U.S. This requires collaboration with companies, and in particular owners of infrastructure facilities and networks in order to create redundancy, retrofit existing systems, replace them where needed, and implement other statewide resilience plans (Cutts et al., 2015).

Enhancing infrastructure resilience also requires action within the operator's broader organisational ecosystem. Labaka, Hernantes, and Sarriegi (2016) asked experts which activities are required to translate broad resilience principles into action to protect critical infrastructure. In addition to internal actions such as detecting warning signals and maintaining redundancies, the experts highlighted the need to provide guidance for other stakeholders in the infrastructure's ecosystem and to facilitate communication and joint decision-making with external stakeholders. They also argued that governments need to be able to coordinate the network of involved actors in case of a crisis and develop procedures to provide leadership and communication skills when it occurs. Similarly, creating trust among the network of stakeholders related to the infrastructure is crucial for sharing experience, knowledge, and lessons in crisis management, as well as formalising collaboration through official agreements.

Efforts to decentralise resilience emphasise the role of cities in operationalising resilience policy. Cities are a key focus in resilience policy discourse as they represent the growing challenges created through rapid migration to urban centres and global interconnectedness. Urban resilience aims to provide city residents with sufficient resources and capacities to mitigate risk, and to prepare, respond, and recover from shocks and disturbances as they occur (Coaffee et al., 2018). Furthermore, the meaning and understanding of resilience in national policy is shaped and influenced by the local context – the perceived risks in local institutions, the accepted responsibility for meeting them, historical policy developments, and specific governance structures that emerged over time (Doyle, 2015).

Resilience planning in cities is especially useful in the context of anticipatory adaptability, which looks at the possible risks and hazards a city may face as it grows and expands (Hudec, 2017). In this sense, urban resilience represents a meta-domain that integrates traditionally disparate policy domains - from urban planning to infrastructure, environmental management, social policy, and risk management to name a few (Huck, Monstadt, and Driessen, 2020). Conversely, resilience plans can serve to tackle specific local risks such as seismic risk (Vona, 2020) or climate change (Papa et al., 2015), in the entire city or in specific parts of it, such as the city centre or neighbourhoods particularly prone to damage (Santamouris, Cartalis, and Synnefa, 2015).

In order to operationalise resilience concepts in cities and local governance, researchers and practitioners developed a multitude of frameworks. Resilience action plans in particular have become focal points for policies to respond to expected and unexpected risks (Hernantes et al., 2019). Thus, different cities may have different approaches and entry points to resilience policy and planning. For example, in several municipalities in Spain, the resilience of critical infrastructure to climate change was evaluated through a local multi-stakeholder workshop series that mapped local risks, capacities, and policies to improve city resilience (Lomba-Fernández, Hernantes, and Labaka, 2019). Barcelona, Lisbon, and Bristol implemented a resilience action plan development process dedicated to climate change and related urban services such as mobility, waste, and water treatment and catchment (Cardoso et al., 2020). Other models for building local resilience plans and policies emphasise the need to integrate new sources of data built on technological advances with qualitative methodologies bringing in historical context and citizens' perspectives (Falco, 2015). However, one of the most far-reaching and systemic efforts to institutionalise resilience at a city level was the Rockefeller Foundation's '100 Resilient Cities' program, which operated between 2013-2019.

4.2.5 100 RESILIENT CITIES

In 2013, The Rockefeller Foundation established the '100 resilient cities' program to help cities build resilience to a wide range of challenges. The participating cities were given financial support to establish a position for resilience officers in city government. They were also given access to expert support in developing resilience strategies and to a network of partners and providers who could help them design and implement their local resilience policies. From more than 1,000 cities that applied - 100 were selected. The cities in the '100 resilient cities' network represented more than a fifth of the world's urban population. The member cities developed more than 50 resilience strategies, which outlined 1,800 actions and initiatives. They also pledged 230 million dollars toward implementation from the platform partners and 240 million from external sources. The program concluded on July 2019 (100 Resilient Cities, 2020).

In order to formulate their resilience strategies, participating cities led a resilience planning process engaging the different departments of city hall and other stakeholders throughout the city (Parsons and Thoms, 2017). The program embedded clear assumptions on what resilience is and how to act on it in its tools, and in particular in its core 'City Resilience Framework' developed by ARUP. However, participating cities maintained their agency and interpreted the dimensions and principles of resilience through local lens and priorities (Nielsen and Papin, 2020; Roberts, Douwes, Sutherland, and Sim, 2020). This interpretive dynamic mirrors processes occurring at national levels as well, as different US Federal agencies, for example, implemented centralised directives to integrate resilience in their assessment procedures (Larkin et al., 2015). Research of this rich corpus of resilience policy documents has been growing, as the plans express common themes in cities' resilience policies.

For example, analysing New York City and Melbourne's plans, Davidson et al. (2019) examined how policies within the plan manifest two central ideas in resilience strategy frameworks: planning for change and uncertainty, and nurturing conditions for self-organization, leading to recovery and renewal after disturbance. Other studies of 100 resilient cities went beyond policy design to identify, for example, challenges in its implementation, institutionalising the necessary governance networks, gaining political commitment and support, and engaging with decision-makers and citizens (Huck et al., 2020). Analysis has also been conducted to examine how the 100 resilient cities strategies fared in specific dimensions such as social equity and justice (Fitzgibbons and Mitchell, 2019; Meerow, Pajouhesh, and Miller, 2019) and climate change mitigation and adaptation (Elgendawy, Davies, and Chang, 2020).

The initiative was chosen as a basis for analysing resilience policy in this chapter as it represents a large network of cities, with resources to facilitate the resilience planning process and a clear reference framework that still leaves abundant space and ambiguity for local interpretation and meaning. This creates a useful basis for comparability between different cities' policies.
The chapter continues as follows: A brief description captures the methodology used to perform the quantitative content analysis of the cities' resilience plans. Next, the results of the analysis are presented - first through a wide comparative lens, then by focusing on the results that emerged in analysing individual cities. We conclude with a discussion on the validity and usefulness of the approach used and the insights it provides about resilience policy.

4.3 METHODOLOGY

Resilience discourse in policy has been integrating diverse fields and domains that go beyond emergency management. Keeping track of a resilience policy that is not place specific or domain specific requires innovative methodologies, as it needs to cut across different epistemologies unique to each domain (Keenan, 2017). Chmutina et al. (2016), for example, utilised quantitative tools to perform content analysis in policy documents related to the UK's resilience policy at different scales. In this chapter, a semi-automated inductive content analysis procedure was applied to a closed corpus of resilience policy documents. The following paragraphs will describe the methodology's rationale and the procedure followed.

4.3.1 CONTENT ANALYSIS

The aim of content analysis is to analyse material from different forms of communication, in this case policy documents, enabling a clear description of the text itself, its antecedents and its effects. It can be used to capture what is being explicitly said in the documents under investigation, but also the underlying structure of the text (Mayring, 2015). Content analysis aims to be positivist, to capture reality as it is while limiting the interpretative dimension of the methodology by relying on systemic and replicable techniques allowing other researchers to use the analytic categories and coding schemes to conduct the analysis (Saraisky, 2016).

Content analysis utilises two main techniques - frequency analysis and contingency analysis. Frequency analysis is based on counting how many times certain elements of the text appear compared with other elements, and contingency analysis examines which elements in the text are connected to one another, or appear in conjunction. These contingencies can reveal structures within the text of connected elements (Mayring, 2015). The growing number of online government documents, as well as other types of text useful for understanding political phenomena, creates a need for implementing new techniques that are able to automate the process (Hopkins and King, 2010). The technique used in this chapter is one such example.

4.3.2 AUTOMATING CONTENT ANALYSIS THROUGH 'VISUALISATION OF SIMILARITIES'

The technique applied in this chapter for content analysis is called 'Visualisation of Similarities' (VOS). It was originally developed as an alternative for 'Multidimensional Scaling', the traditional way of constructing 'science maps', meaning relations between keywords, documents, authors, and journals (Van Eck et al., 2010). However, it was also used for content analysis in several publications (Eriksson-Backa, Holmberg, and Ek, 2016; Popescu et al., 2017; Vaz, Rauen, and Lezana, 2017), and for mapping different policy domains such as public health (Chughtai and Blanchet, 2017), science policy (Wallace and Rafols, 2015), and development policy (Zuccala and van Eck, 2011), as well as policy process theories (Goyal, 2017; Wellstead, 2017).

Bibliometric mapping such as this was also used specifically to map resilience literature, for example in Mahajan et al. (2022), where researchers mapped not only the terms inhabiting resilience literature, but more specifically the concept of participatory resilience and how it is operationalised in both academic and policy documents.

VOS, using a dedicated software, builds the maps based on a co-occurrence matrix. Constructing the map consists of three steps: building a similarity matrix, creating a visual map based on the similarity index, and using an optimisation algorithm for the map. Building a similarity matrix means measuring the association strength between different concepts, resulting in their measure of similarity. It is obtained by calculating the number of co-occurrences of two distinct concepts, divided by the total number of their occurrence or co-occurrence. The matrix is then used to construct a two-dimensional map, which situates every two concepts in a distance that reflects their similarity. Items with high similarity are closer to one another, and items with low similarity are placed farther apart. An optimisation algorithm is implemented to prevent maps where all concepts are positioned in the same location. Finally, the method uses three types of transformations that ensure that the technique yields consistent results, or maps, at any number of runs of the program. The map can be presented in two modes - density view (see figure 11), where each point in the map is painted based on an item's density (meaning how many items are around it and how important they are), and a cluster-density view (see figure 12), where the item's density is calculated separately for each cluster (Van Eck and Waltman, 2010).

FIGURE 8: DENSITY VIEW OF THE CLUSTER MAP

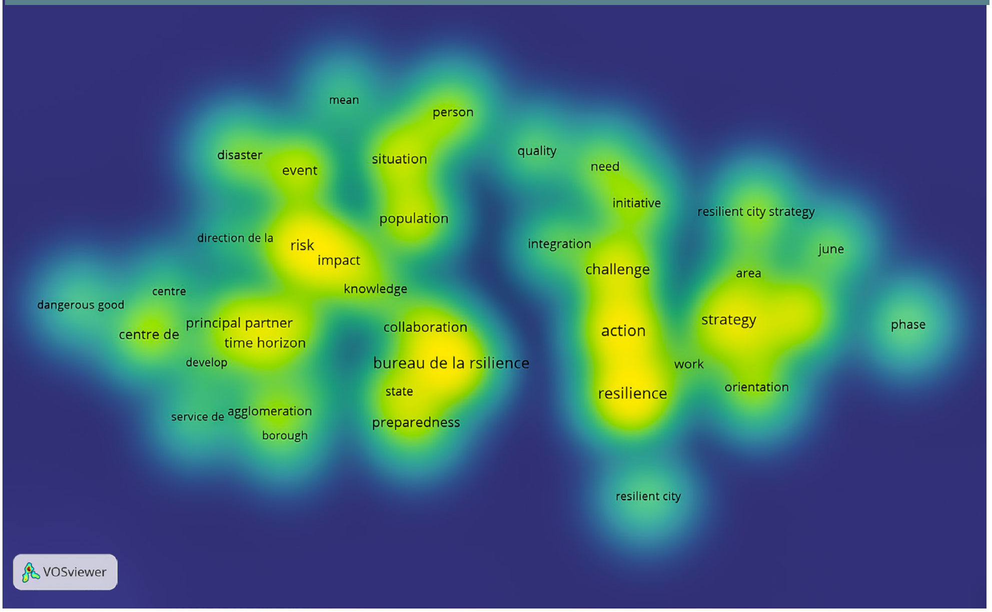
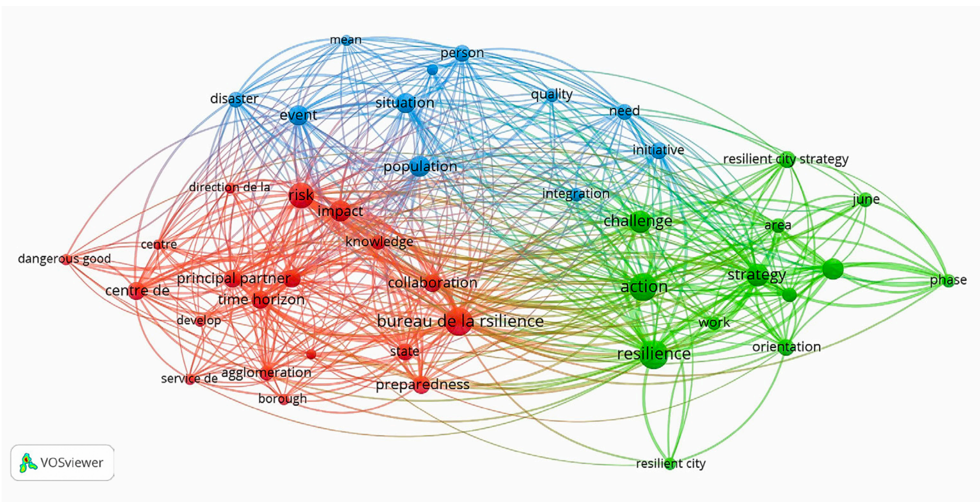


FIGURE 9: CLUSTER-DENSITY VIEW OF THE CLUSTER MAP



While the initial steps of the procedure require rather limited choice, every parameter configuration, assumption and coding decision made have been recorded to the best of our ability to allow rigorous inspection, replicability, and understanding of the resultant analysis, and are presented in Annex B.

4.3.3 OBJECT OF ANALYSIS - CITY RESILIENCE PLANS

In this chapter, VOS was used to perform content analysis on 41 resilience plans, each from a different city participating in the 100 resilient cities program. This is the number of plans available on the program website and are in English. These city plans represent countries all over the world, facing extremely different challenges and conditions from an economic, social, and environmental standpoint. While these strategies were formed at a city level, these are central cities and large population centres that embody a key arena for contending with stresses and shocks. Furthermore, they were formed based on an intentional process that created a shared baseline of understanding of resilience, though it was adapted by each city and evolved over the lifetime of the program. This allows a coherent analysis of these policy documents without having to question the specific interpretation of resilience as a foundational concept in each of the case studies, in this case the cities that wrote the resilience strategies analysed.

4.3.4 ANALYSING THE MAPS: INDUCTIVE CATEGORY FORMATION

A subsequent instrument utilised based on the concept maps created was categorisation, which is central in content analysis methodology. Categories can be constructed deductively, based on theory, as the previous chapter attempted, or inductively, based directly on the text at hand, which is implemented in this chapter (Mayring, 2015). Categorisation was conducted in several iterations: First, each cluster of concepts derived from each city plan was given a name that captured its possible meaning. Next, we identified central themes that arose out of similar clusters. Finally, each theme was analysed to identify sub-themes that gave a better sense of its substance, each consisting of several clusters.

The overall process for inductive category formation followed the stages below:

- Defining the goal of analysis
- Establishing a selection rule and abstraction level for the categories
- Going through the material line by line and formulating categories, while capturing the coding rules and preliminary examples
- With each new line decide whether the text fits with an existing category or requires a new one
- Revising the categories after an initial trial
- Working through the rest of the material
- Building the main categories
- Analysing and interpreting the categories and their occurrences (Mayring, 2015)

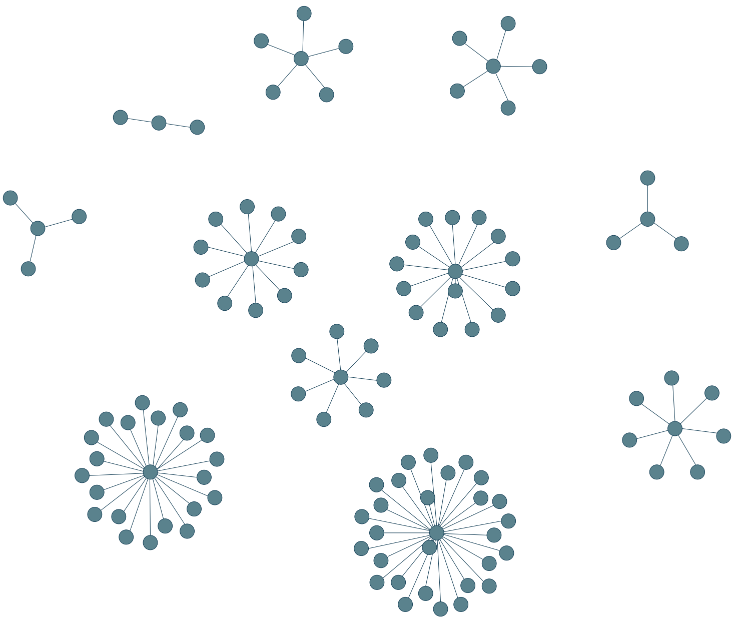
4.4 RESULTS

4.4.1 DESCRIPTIVE STATISTICS

All in all, the VOS analysis found 299 clusters in the 41 resilience plans used as input. Of those, 26 clusters were not categorised in any way, mostly due to the fact they only contained one concept, or if the concepts were too distinct to generalise (for example a name). The average plan contained 6 clusters with a standard deviation of 2.7, and half the cities had between 4-6 clusters. Only 3 cases in each extreme had more than 10 or less than 4 clusters.

Each cluster contained an average of five concepts as a basis for interpretation. Additional concepts that originally appeared in each city's map may have been omitted in the process of naming the clusters, which was based on the most relevant concepts for the naming process. However, in some cases many more concepts were included. For example, in New York, clusters contained 10 concepts on average with a standard deviation of 3.2, and 20 concepts in the extreme. However, for the most part, clusters in the plans analysed matched the average with 5 usable concepts per cluster.

FIGURE 10: DIFFERENT CLUSTER SIZES IN A CITY MAP



The categorisation process revealed five distinct categories:

1. **Domain** - These are clusters that focus on a particular topic or object of intervention, such as infrastructure, environment, disasters, etc. It is a good approximation of the city's view on specified resilience, meaning the specific shocks and stressors it aims to build resilience to.
2. **Capacity building** - This category includes clusters that describe how the city can enhance different actors' capacity to cope with stressors and shocks, and to build their generalised resilience.
3. **Institutional design** - This category best exemplifies how cities embed principles of generalised resilience in their governance systems and practices. It includes references to multi-level governance, leadership, finance, and policies that support resilience building in the city.
4. **Stakeholder engagement** - While this category overlaps somewhat with institutional design, it delves deeper into different ways to build partnerships and encourage participation in the resilience planning process and its implementation.
5. **Strategy design** - This final category reflects on the resilience policy document itself, and the planning process that it captures: which questions should be asked, objectives set, and how to deal with issues of measurements etc.

The two graphs below present the distribution of each category in each of the cities' plans, first in absolute numbers, then in relative terms. While the categories are not mutually exclusive in substance, each cluster was identified with only one category.

FIGURE 11: NUMBER OF CLUSTERS PER COMPONENT BY CITY

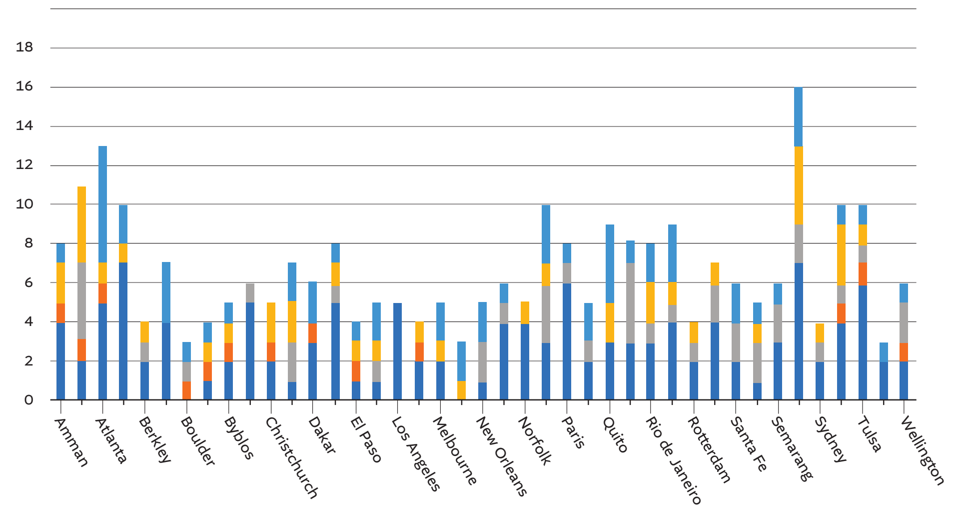
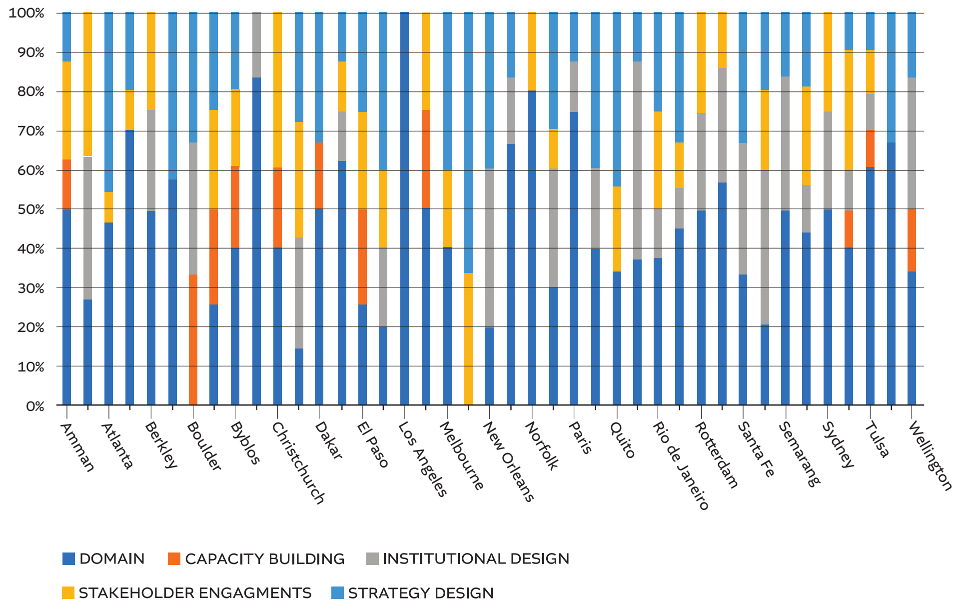


FIGURE 12: SHARE OF CLUSTERS PER COMPONENT BY CITY



This perhaps explains the uneven distribution between the different categories: The largest category is domain, with 44.6% of the clusters. It is followed by strategy design with 20.8% of the clusters, institutional design with 15%, stakeholder engagement with 14.6%, and finally capacity building with 4.7%.

As can be seen in the following table, most cities have representation of most categories:

TABLE 1: FREQUENCY OF NUMBER OF CATEGORIES PER CITY

NUMBER OF CATEGORIES	NUMBER OF CITIES
1	1
2	5
3	18
4	15
5	2

In Los Angeles, which has only one category, domain, each of its five clusters touches upon a different type of stressor - from climate change and the environment to violence and inclusion. Other than Montreal and Boulder, all cities have references to domain clusters. Montreal's clusters focus on stakeholder engagement and strategy design, and Boulder's on capacity building, institutional design, and strategy design. This could reflect, perhaps, greater weight assigned to generalised resilience in those cities, thinking about the process and structures yielding resilience more than the particular issues at stake.

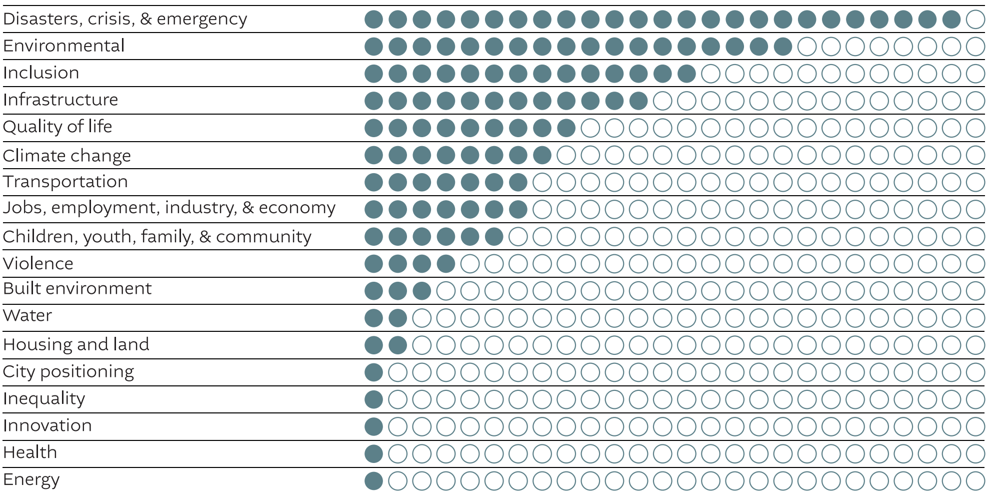
4.4.2 FINDING CROSS-CUTTING THEMES AND STRUCTURES

The following section answers the chapter's first two research questions: First, it explores which disturbances and shocks cities tackle through resilience policy by presenting the clusters associated with the 'Domain' category. Next, elaborating on the remaining four categories will give deeper insight into the common structure for resilience policy that emerged in the analysis.

DOMAIN

The 'Domain' category contained 18 subcategories, presented in the graph below.

FIGURE 13: NUMBER OF CLUSTERS IN EACH 'DOMAIN' SUBCATEGORY



The distribution of clusters aligned with each subcategory can be seen in the following table:

TABLE 2: TOP 5 DOMAIN STRESSORS IN THE PLANS

SUBCATEGORY	NUMBER OF CLUSTERS
Disasters, crises, and emergencies	16
Environmental factors	18
Inclusion	14
Quality of life	9
Climate change	8

'Disasters, crises, and emergencies' is the largest of all subcategories in the entire analysis (across all categories). It is not surprising, as resilience is first and foremost a policy issue connected with disaster preparedness and recovery. The clusters in this subcategory range from general references such as 'preparing for multiplicity (of) disasters' and 'facing local shocks and stresses' to specified risks such as flood protection, water stress, and climate risks. Some clusters focus on identifying and managing local vulnerabilities, while others on strengthening risk preparedness, bolstering protections, and facilitating recovery.

The 'Environmental' subcategory is the second biggest within the 'Domain' category. Clusters in the environmental subcategory ranged from risk-based approaches such as 'preparing for environmental crises' to solutions-oriented clusters such as 'introducing new environmental solutions', or 'forming a joint environmental strategy'. Health and environment are also a recurrent theme in these clusters ('fostering environmental health', 'meeting environmental health challenges'), as well as tackling emissions and pollution and maintaining natural capital and ecosystems.

The 'Environmental' subcategory is closely aligned with several others related to infrastructure and sustainability. For example, the climate change subcategory, which focuses on achieving climate goals and policies and preparing for climate risks, the infrastructure subcategory, which focuses on protecting and providing services, access, and facilities, the built environment subcategory, which is oriented to redesigning public space, and the transportation subcategory, which centres around sustainable mobility. Some cities actively aligned their targets with SDGs, focusing on how their pathways for change linked to achieving one or more goals (Croese, Green, and Morgan, 2020).

Having environmental factors almost at the top of the list corresponds with descriptions of the priorities emanating from specific cities' stories: In Rome the preliminary resilience assessment raised climate-related events and natural hazards such as earthquakes as the most prevalent shocks, and chronic stresses were correlated with environmental pressures as well – air pollution, debilitating ecosystem services, and inadequate public transport to name a few (Galderisi, Limongi, and Salata, 2020).

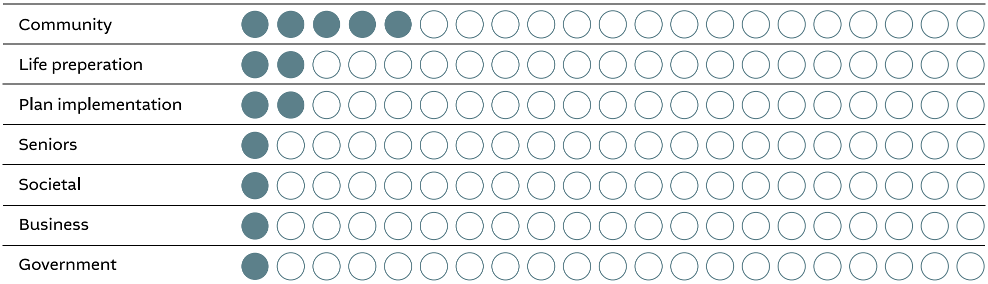
The 'Inclusion' subcategory refers to several layers of diversity and inclusion: acknowledging and addressing challenges by specific groups (immigrants, vulnerable populations), adopting justice-based frameworks and planning for inclusion, analysing multilevel vulnerabilities, and embracing diversity as a fundamental value for the community.

The 'Quality of life' subcategory contains clusters that bring together residents', families', and even tourists' standard of living and needs. It encourages an integrative approach and holistic perspective, looking at social, environmental, and economic dimensions including, for example, nature conservation, education, transportation, food, employment, and housing. It relates to other subcategories already mentioned, as well as smaller subcategories that focus on fostering economic growth and transitions, investing in youth, children, and families, tackling violence, and at a wider scope - gaining territorial advantage and promoting innovation.

CAPACITY BUILDING

Capacity is key to the 100 resilient cities definition of resilience, and in particular the capacity of individuals, communities, institutions, businesses and systems in the city to withstand, adapt and grow in face of shocks and disturbances (Flax, Armstrong, and Yee, 2016). This is reflected in the results, as the clusters included in this category describe capacity building for different types of stakeholders, including government, community, and businesses.

FIGURE 14: NUMBER OF CLUSTERS IN EACH 'CAPACITY BUILDING' SUBCATEGORY



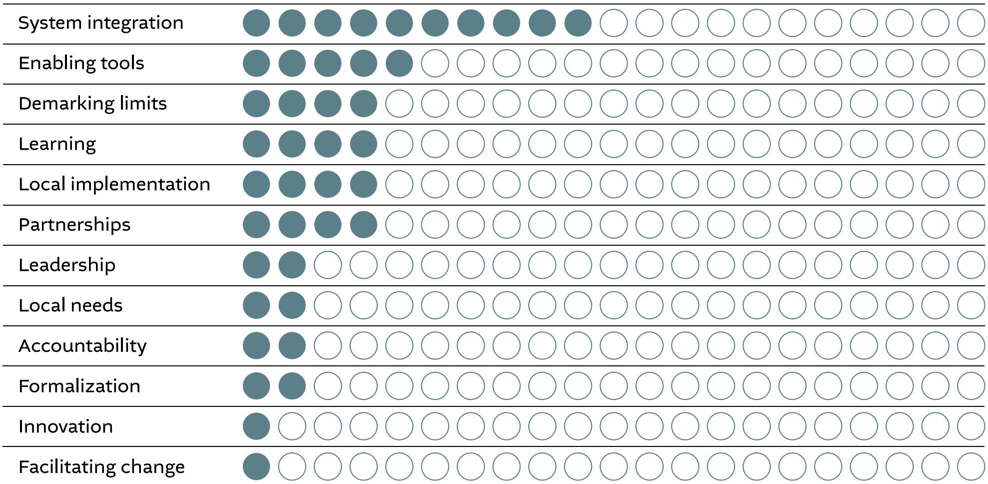
First, a 'Community' subcategory describes the types of resilience-related capacities the policy needs to build - community preparedness, shock absorption capacities, co-learning, and empowering diversity. A similar subcategory on society aims to build transformational capacity as an individual and cultural endeavour. Second, two subcategories focus on different age groups, with one subcategory devoted to youth, and another to senior citizens. Third, a business subcategory refers to supporting small businesses, and a government cluster looks at ways at increasing administrative efficiency and reach. Finally, a plan implementation subcategory looks for ways to enhance the capacity to build and implement the policy itself among the participating stakeholders.

One of the critiques of the resilience plans coming out of the program is that they are lacking in certain axes of justice and equity, and in particular in recognising systemic and persistent racism. However, the plans do discuss challenges experienced by marginalised communities, and many have specific objectives on increasing access to infrastructure, environmental amenities, and educational and economic opportunities (Meerow et al., 2019). For example, in Wellington, the cluster associated with capacity building mentions 'recommendations' and 'homelessness'.

INSTITUTIONAL DESIGN

The institutional design category describes different ways to embed resilience in formal governance networks, practices, and structures. It contains 12 subcategories: the biggest is system integration with 10 associated clusters, followed by several smaller subcategories (4-5 clusters each) on demarcation, learning, enabling tools, partnerships, and local implementation. Several other clusters deal with accountability, formalisation, local needs, innovation, and facilitating change.

FIGURE 15: NUMBER OF CLUSTERS IN EACH 'INSTITUTIONAL DESIGN' SUBCATEGORY



'System integration' refers to different ways to facilitate the kind of multi-level governance that resilience theory and adaptive co-governance prescribe: joint spatial planning, inter-departmental collaboration, multi-level governance, regional efforts to cope with climate change, dynamic system integration, and multi-sector partnerships. The enabling tools subcategory similarly suggests practical ways to operationalise resilience in policy terms - from designing supportive institutions and raising external funds, to facing the financial, social, and political challenges of threats such as sea-level rise.

The policy mechanisms described in the plans can also express an attempt to break away from existing governance structures through local governance experiments, disrupting institutional path dependencies through new forms of collective action. Melbourne, for example, sought to build a Metropolitan City Network through new collaborative workshops and coordination efforts between the state government transport agencies, metropolitan municipalities, NGOs, and the private sector (Fastenrath, Coenen, and Davidson, 2019).

The 'Demarcation' subcategory contends directly with the problems that may arise when different actors need to jointly form and implement policy. It suggests assigning clear institutional responsibilities, defining office holders, and relegating complementary roles if needed.

The 'Partnerships' clusters somewhat overlap with the stakeholder engagement category as it captures new initiatives to create institutional arrangements and initiatives between different stakeholders. For example, in New Orleans, this cluster includes the 'sewage and water board' as well as 'data centre'. In Santa Fe, this cluster mentions investment and strategic development in conjunction with health, education (school), transportation, urban planning, and public works, as well as the resilience office.

This reflects existing research on the plans at hand. For example, according to Spaans and Waterhout (2017), in Rotterdam, the plan expanded the institutional scope of resilience both in substance and participation. Prior to the initiative, resilience planning was limited to water management and flooding, governed by the city government with few initiatives reaching across the water sector. Following the plan, the city's resilience agenda included, among many topics, issues of cyber security, inclusion of socially marginalised groups, and preparedness for shocks in terms of access to food, energy, and data. This expansion required the participation of NGOs, companies, and more integration and communication between different departments within city government.

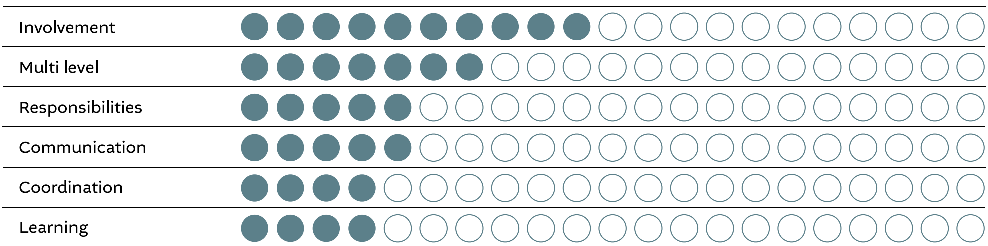
'Local implementation' discusses different pathways to execute the new initiatives: from funding and launching programs with different agencies such as the parks department and public works in the Berkley Plan, to enacting a range of policy mechanisms such as regulation, enforcement, and awareness-raising in the Surat plan.

Finally, the 'Learning' subcategory embeds learning as an inherent value and practice in resilience-based institutional design, aiming to encourage institutional learning, study emerging risks, make informed decisions, and implement informed policies. For example, the Oakland plan mentions collaborative government, and ties decision-making to goals, data, and principles. Da Nang mentions specific tools for learning, including models, research, and surveys.

STAKEHOLDER ENGAGEMENT

Cities can have different goals for their stakeholder engagement – from collaborative design of key performance indicators, open data collection, and leveraging funding, to seeking support for its initiatives throughout the implementation process (Komninos et al., 2019). Bolstering resilience through policy requires those impacted by the policy to be involved in decision-making to enhance its legitimacy, having change implemented at an acceptable rate, and finding ways to create a positive interpretation of the policy (Marshall, 2007). The analysis performed demonstrates this point as the stakeholder engagement category includes five subcategories: involvement, multi-level (action), communication, coordination, and learning.

FIGURE 16: NUMBER OF CLUSTERS IN EACH 'STAKEHOLDER ENGAGEMENT' SUBCATEGORY



'Involvement', the biggest subcategory in the stakeholder engagement category, suggests specific ways to expand the city's circle of partners. It describes different ways of bringing in individuals and organisations to take part in the full process of resilience policy-making - from conception to evaluation. It brings up, for example, fostering an active sense of stewardship, finding and maximising potential partners' participation, identifying stakeholders' values and interests, and building strategic partnerships. Other clusters related to involvement focus on cultivating cultural partnerships, bolstering civic participation, and gaining citizens' trust. Businesses and communities are explicitly considered as well in clusters that focus on collaborating with industry partners, trying to integrate residents and business needs, strengthening community dialogue, and providing local community assistance. However, while the plans demonstrate extensive efforts to increase participation, one of their critiques is that it is unclear how and to what extent they engaged with marginalised communities in particular (Meerow et al., 2019).

The 'Multilevel action' subcategory captures the different scales at which partners are sought: resident, household, neighbourhood, community organisations, region, state, national, and even international actors such as the world bank. It also describes different types of actors - from politicians to businesses, to government agencies and departments. Multilevel action allows the discovery and definition of the priorities different actors see and set for risks in the city. It can also form the basis for institutionalising resilience policy by establishing multi-sectoral mechanisms such as the Agua Capital Fund in Mexico City, which brings together NGOs, companies, and government agencies to increase water security by protecting the forest areas surrounding the city that replenish the city's aquifer (Berkowitz and Kramer, 2018). Stakeholder engagement through multilevel action can also allow co-design and co-creation of interventions, with even physical transformations at a particular site being developed with their potential users, as was the case in Vejle's train station resilience initiative (Taylor, Fitzgibbons, and Mitchell, 2020).

The 'Communication' subcategory includes four clusters that describe the need to communicate resilience projects, how to communicate, and possible goals for communication. For example, Atlanta's communication cluster mentions launching a platform, in conjunction with data, culture, and water measurements, interpreted as finding creative ways to communicate the content of the policy. Sydney's communication cluster focuses on the goals of communication - connecting, enhancing social cohesion, and creating awareness of policy solutions and directions.

The 'Coordination' subcategory emphasises the need to provide support to platform partners, coordinate citizen participation, develop synergies between stakeholders, and create collaborations to confront joint challenges.

Finally, the 'learning' subcategory describes different ways to share information between program partners and other stakeholders. This includes, for example, linking with other cities, performing workshops, conducting studies, and submitting proposals.

STRATEGY DESIGN

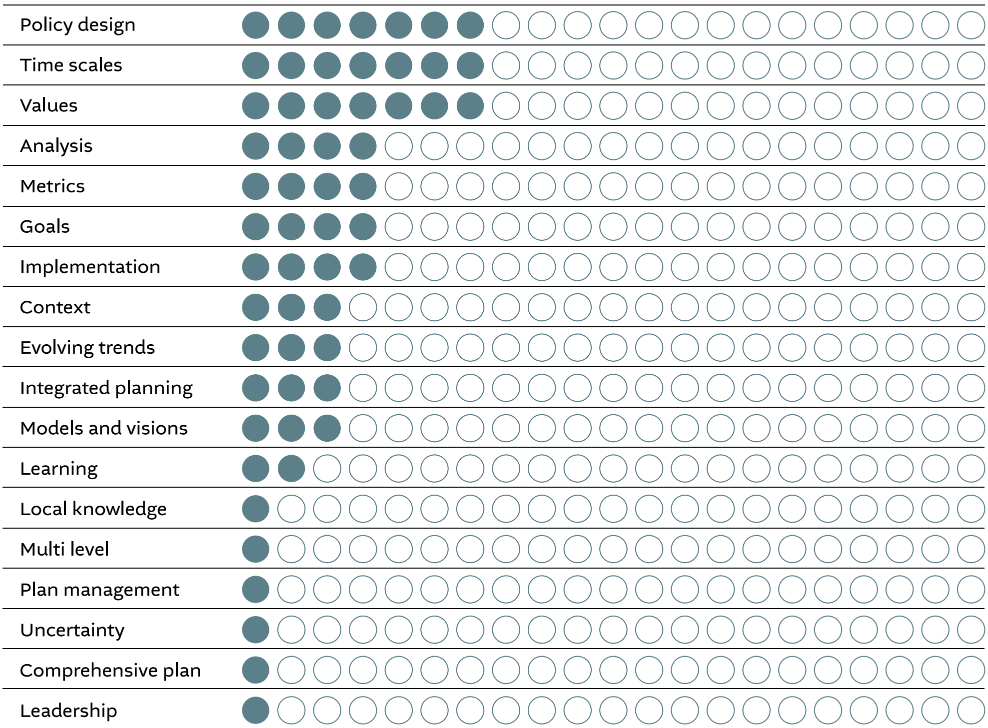
The final category, 'Strategy Design', contains 18 subcategories that capture the different facets, stages, and components of a resilience strategy document. Its three largest subcategories are policy design, time scales, and values, with 7 clusters each. It is followed by subcategories on analysis, goals, implementation, metrics, models and visions, implementation, context, and evolving trends, among others.

'Policy design' refers to clusters with distinct directions to creating a resilience strategy: identifying action-oriented challenges, inventing new types of initiatives, devising an actionable and structured plan and vision, and putting in place an effective policy and change strategy.

The 'Time scales' subcategory makes explicit and practical the temporal dimension of resilience thinking with clusters referring to considering diverse time scales, establishing multiple time scales, and balancing divergent time scales. Similarly, the values subcategory brings to the fore differences in spatial scales - looking for needs, values, and benefits of residents, neighbourhoods, and communities, for example, and articulating the specific resilience values the policy assumes and undertakes. This inherently depends on the choice of stakeholders in focus, their locations, and their size relative to other units of analysis (world, country, region, town for example). It also depends on the policymakers themselves and the worldview with which they design the policy.

The 'Analysis' subcategory emphasises specific issues resilience policy needs to examine - facets of inequality, gaps in performance, and socio-technical analysis. It also reinforces the need for utilising relevant information. Conversely, the 'Goals' subcategory is quite general and underlines the need to define clear goals, meet a multiplicity of goals, and prioritise both goals and actions.

FIGURE 17: NUMBER OF CLUSTERS IN EACH 'STRATEGY DESIGN' SUBCATEGORY



CONCLUSION: CROSS-CITY ANALYSIS

The five themes that emerged out of the cross-city analysis provide a clear structure for resilience policy. Within each of the themes, or policy components, we analysed how they provide policy goals and policy mechanisms, and express some of the principles and ideas mentioned in the theoretical discussions of resilience governance in the previous chapter. The domain theme opened a window into the wide range of shocks and disturbances the cities' resilience policies aimed to provide solutions for, from different environmental challenges to questions of inclusion, liveability, and infrastructure. The following section aims to answer the final research question - what can we learn through quantitative content analysis about individual cities' resilience policies?

4.4.3 ANALYSING AND COMPARING INDIVIDUAL CITIES' STRATEGIES

The previous section analysed the five themes that emerged when analysing the concept clusters across all 41 plans. This section takes a different approach: examining the clusters that emerged at a city scale. This scale of analysis demonstrates how particular cities interpret resilience policy, how they cope with similar challenges, and realise shared policy goals. Two useful ways to make sense of the list of clusters at this scale are by reviewing different clusters in a single city, and by comparing specific clusters that are similar in different cities. The first gives us a snapshot of the overall policy in individual cities, and the second provides a comparative perspective on the specific issues raised within them. Following is an example based on an analysis of the San Francisco resilience plan, and a city-to-city analysis of the partnerships and climate clusters.

CAPTURING RESILIENCE POLICY AT A CITY SCALE

San Francisco has seven clusters. Four of them are domain related, meaning they describe the shocks and disturbances the city's resilience policy aims to provide solutions for. These include threats to livability, preparing and dealing with disasters, adopting climate policies, and ensuring that buildings are robust, especially to earthquakes. Two additional clusters focus on cross-scale issues in terms of organisational action on resilience: fostering inter-departmental collaboration and increasing stakeholder access.

EXAMPLE BOX 8

SAN FRANCISCO RESILIENCE STRATEGY CLUSTERS

1. Tackling liveability threats: Climate, sea level rise, climate change, unaffordability, infrastructure, transportation, water, earthquake, transportation, response
2. Helping individual recovery: Disaster, individual, resident, neighbour, repair, training, organisation
3. Adopting climate policies: Mitigate, adapt, retrofit, prepare, ensure housing
4. Fostering inter-departmental collaboration: Mayors office, department, economic, resilient sf, AMI (area median income)
5. Increasing stakeholder access: Empower neighbourhoods, business, resource, access, connection
6. Ensuring robust buildings: Building, Building inspection, earthquake safety implementation program
7. Promoting multi-level collaboration: San Francisco, county

While the clusters have different focuses, they are not mutually exclusive in content. For example, while affordability is mentioned in the 'liveability' cluster, the concepts 'economic' and 'AMI', which stands for 'area median income', are mentioned in the inter-departmental collaboration cluster. This perhaps captures economic issues as being framed initially as policy problems, and then as part of the discourse on policy solutions and mechanisms. Similarly, different scales of intervention - from individual to resident, neighbourhood, and organisation, are mentioned in a cluster that focuses on building disaster resilience, rather than stakeholder engagement, reflecting a multi-scale approach throughout the themes that emerged.

Additional cross-over occurs between the clusters at a domain level. For example, adopting climate policies refers explicitly to housing, while the cluster focusing on livability mentions climate change and sea level rise in its list of threats. This demonstrates the multi-sectoral approach to resilience policy, which cuts across policy domains, requiring at certain cases to expand existing policy system boundaries.

Overall, the clusters capture in broad strokes what it is the city wishes to safeguard (livability in terms of housing, transportation, water, and affordability); what stresses and shocks it wishes to provide protection for (earthquakes, climate change, economic factors), and what is its basic approach in enacting resilience (engaging residents, businesses, and neighbourhoods, and putting in place dedicated safety and inspection programs).

SIMILARITY AND DIFFERENCES BETWEEN SIMILAR THEMES IN DIFFERENT CITIES

Zooming in on single clusters can focus our attention on differences between how different cities view specific issues that cut across the plans. For example, Bristol's 1st cluster, 'finding local partners' identifies similar actors to the ones mentioned above, but also 'university'. This may reflect a greater willingness to embrace research and researchers in resilience governance and policy, a role not necessarily envisioned by other cities.

Similarly, climate change is a recurring theme in several different cluster names. However, while Los Angeles' 1st cluster, 'responding to climate change threats', includes specific references to drought, water, wildfires, and extreme heat, Paris' 5th cluster, 'supporting climate, health, and social needs' links climate change to air pollution, social cohesion, and health. On the other hand, Da Nang's 7th cluster, 'tackling climate change vulnerabilities', refers to a specific tool, or platform called 'VCAP' (visual climate adaptation platform). These differences are telling in how cities may frame climate change as a resilience challenge, how climate interlinks with other challenges in the city, and what types of solutions or tools are being deployed, considered, or sought by the city.

4.5 DISCUSSION AND CONCLUSION

4.5.1 WHAT DOES THIS ANALYSIS TELL US ABOUT RESILIENCE POLICY?

This chapter presented a quantitative content analysis of 41 city resilience strategies. They represent a closed corpus of resilience policies rooted in a shared conceptual framework and initiative - the '100 resilient cities network'. By utilising a 'Visualisation of Similarities' technique that finds co-occurrences of concepts in each of the resilience policy documents and clusters them together, we employed an analytical process that is traceable and reproducible but is also inviting and open for future discussion and reinterpretation of the content at hand.

The results of the analysis shed light on the structure of resilience policy and its content in actual resilience policy documents. It revealed differences and similarities in how it is interpreted among different governments around the world, in this case, city governments, even when they share a conceptual framework, follow a similar process to design the policy, and are partners of a proactive network of cities working jointly towards resilience.

The analysis suggests that resilience policy has a shared structure of five pillars - domain (specific shocks, stresses, and changes government and society wish to prepare for), strategy design (reflection on how to shape the resilience policy), institutional design (what governance mechanisms the policy needs to establish), stakeholder engagement (building new partnerships and managing them), and capacity building (empowering specific groups and sectors to enable the transformations and adaptations the policy seeks to initiate).

The pillars are present to a different degree in each of the case study cities. This may represent divergent priorities, or differences in the interpretation and operationalisation of the key concepts that drove the policy design process, even though it was initiated by a single organisation with a unified methodology. Delving into each city's concept clusters revealed at a glance its own understanding of resilience, making sense of the process and the policy it delivered. Comparing similar clusters across cities provided further insight into different interpretations of the same concepts, diverging in the definition of both problems and solutions.

Importantly, while this analysis was not intended to implement the framework presented in chapters 2 and 3, however, it had some commonalities with both. While writing the policies was initiated and governed by the municipalities, the emerging structure demonstrates how polycentric the policies aim to be – in cultivating partnerships, building capacity among different stakeholders, and reflecting on the different institutions that are needed to cultivate resilience in the city. Furthermore, vulnerability is very much on the table, with many clusters voicing the concerns and risks to particular populations in the city, and proposing tailored solutions to them.

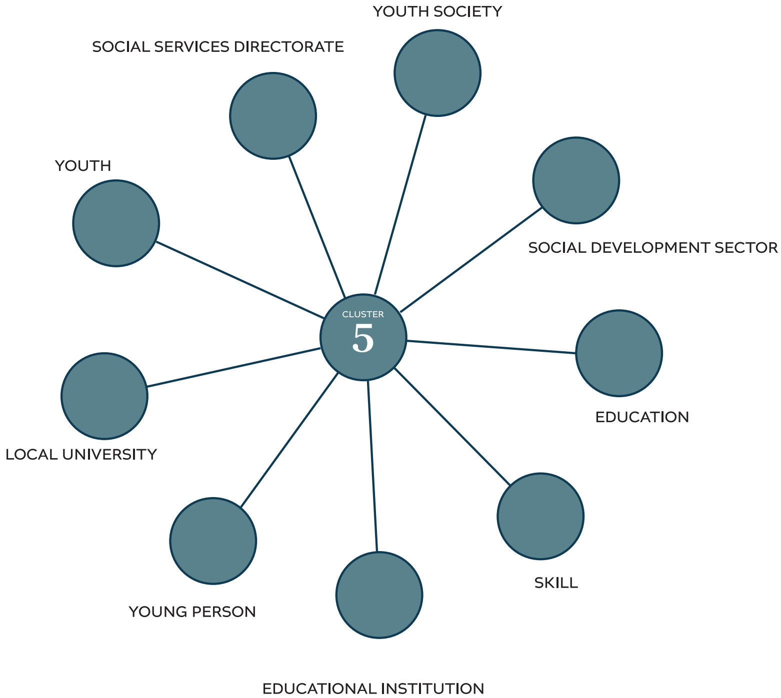
4.5.2 IS THE METHODOLOGY USEFUL FOR CAPTURING RESILIENCE POLICY?

The fact that resilience has been applied to a wide range of topics can undermine researchers' and policymakers' ability to view it as concise and well-founded. This gap is also apparent between the theoretical discussion of the topic and its application in practice by planners and policymakers (Tóth, 2015). This requires innovative methodologies and techniques to generalise observations of resilience policies in different places and contexts. In this chapter, this was achieved by combining algorithmic techniques such as 'visualisation of similarities' with a qualitative interpretation of the results. Following is a short discussion of the advantages and challenges of the methodology applied and its results.

CHALLENGES IN CLASSIFYING THE DATA

Some concept clusters were easier to classify than others. The meaning of the cluster was easier to identify when the target audience was mentioned (resilience of), or when it listed specific shocks and stresses (resilience to). For example, cluster number 5 in Amman was clearly describing questions that relate to youth in the city – providing them with education, social services, skills, and social development.

FIGURE 18: AMMAN CLUSTER NO.5



Similarly, Oakland's 5th cluster aimed to bolster youth and family resilience, and Melbourne's 1st cluster listed the specific disturbances the policy should build resilience towards. Several clusters also clearly dealt with the question of how to build resilience. For example, Boston's 4th cluster describes different visions for city governance that may increase resilience if implemented - a reflective city, an adaptive city, and proactive governance.

In contrast to the examples above, some clusters contained very few concepts altogether. But having more than one concept at a time allowed for a certain degree of speculation about what the cluster meant. For example, clusters 11 and 12 in Atlanta contained only two concepts each. However, cluster 11 with the words 'fosters long term' and 'integrated planning' can be characterised more easily and literally as fostering long-term integrated planning, and cluster 12 with the words 'supports livelihood' and 'employment' as 'supporting local jobs'.

Conversely, some clusters contained a very large number of concepts. While this is a challenge for coining a reductive statement that captures the meaning of the cluster, if the concepts are close to one another thematically the general idea becomes apparent. For example, New York's 3rd cluster contains 40 concepts. Seemingly these many concepts can inspire many interpretations. However, many of the concepts are directly linked to different ways to foster change in different environmental media – water, air, and land: improving air quality through public transportation, diverting waste away from landfill through recycling, improving water quality with wastewater treatment plants, and reducing greenhouse gas emissions.

FIGURE 19: NEW YORK CLUSTER NO.3

CHALLENGES IN RESEARCH DESIGN

The VOS technique employed is useful for the purposes mentioned above, but it relies on the assumption that the abstraction process it initiates can maintain and reflect the original meaning and intent of the original body of text, in this case, the cities' resilience strategies. In other words, it assumes the number of times each concept occurred and its co-occurrence with other concepts can reflect the substance of the original text. It further relies on a classification and interpretation procedure to analyse its output. These assumptions and dependencies allow processing a large amount of text and systemically comparing key concepts within it, but while the link between key concepts is empirically observable, its context and meaning are observer-dependent. Other researchers could arrive at different cluster names, themes, categories, and sub-categories, despite it being an inductive process.

However, providing full documentation of different stages in the analysis - from generating the maps to classifying the data, allows replication of the study and transparent discussion of the results. Future researchers can process the same data using another algorithmic technique, or take the output data from the VOS analysis and argue for different classifications. They can also accept certain levels of classification and reject others, or debate the conclusions made from the classification. This is not a weakness but rather a strength of the methodology, as it makes a scientific discussion of the results more feasible and approachable.

CHALLENGES IN CHOICE OF TEXTS

Finally, the source material is not necessarily representative of resilience policy more broadly. It is focused on cities rather than national agencies or governments, it excludes several plans that were written in languages other than English, and it is based on a conceptualisation of resilience grounded in a single initiative (100 resilient cities). However, the scale of the cities involved, their geographical spread, and the extent of resources invested in their planning processes reveal what resilience policy planning can be at its best and most extensive. Thus, taking this 'population' of policies tells us much about how these particular cities viewed resilience at a particular point in time, but it also reflects the scope and depth resilience policy can reach when it is based on a shared effort and approach, anchored in a rich theoretical background.

4.5.3 FUTURE WORK

The analysis presented in this chapter can be expanded in several useful ways: First, the analysis does not reveal much about the mechanisms each policy puts in place. It only paints with a broad brush the principles, topics, processes, and dimensions that come through in the text. Thus, it is complementary to more qualitative approaches for content analysis, opening a gate for comparison to the original texts, bringing up questions only the full texts can answer. Throughout the chapter, we referenced papers that took different approaches to analysing the cities participating in the 100 resilient cities program - from action research to case study analysis, but this effort can be further expanded.

A cross-methodology comparison could also help verify or challenge the results and answer questions that cannot be answered based solely on quantitative analysis. For example - what does the size of each category mean overall and in each city? Is the fact that a city has many more domain-related clusters only an artefact of the categorisation process, or does it reflect that the city is in fact facing more varied challenges?

Second, quantitative content analysis can be used further to look for correlations between different variables such as city characteristics and the policy elements it deployed. The weighting of connections between concepts can be utilised to examine the meaning of the clusters and re-examine their interpretation. Dynamic analysis could also be used to track the development and evolution of specific concepts and constructs over time, since we know when each plan was published.

In the next chapter, we take a different approach to understanding the context of resilience policy by going out to the field and observing how different actors work to improve resilience in a specific domain - rural development, and what that means for resilience policy design and trade-offs.

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4

CHAPTER FIVE

05

CHAPTER FIVE
POLICY TRADEOFFS

RESILIENCE POLICY

05

CONTEXTUALISING RESILIENCE POLICY AND TRADE-OFFS

Previous chapters looked to resilience literature and resilience policy documents to capture what resilience policy means. This chapter goes out to the field to see how resilience strategies are understood from the bottom up, meaning by their targets of intervention. It focuses on a specific domain: rural and agricultural development, building on insights from an extensive case study performed by the author and collaborators in the Arava region in Israel, and insights gained by research teams working in conjunction in 13 other countries across Europe and the Middle East as part of a European project. The chapter addresses two main questions: Firstly, how is the notion of resilience being operationalised on a farm and regional level? That is to say, what are the different strategies that farmers, rural residents, and other decision-makers in rural areas are using to enhance resilience? Secondly, how do the outcomes of these strategies complement and contrast one another when viewed in various spatial and temporal scales?

This chapter is based on the published paper "Operationalising resilience in farms and rural regions–Findings from fourteen case studies", Ashkenazy, A., Chebach, T. C., Knickel, K., Peter, S., Horowitz, B., and Offenbach, R. (2018). Journal of Rural Studies, 59, 211-221.

For purpose of brevity, some parts of the paper's literature review have been shortened as they were addressed in previous chapters of this dissertation. A conclusion has further been added to situate the chapter within the context of the dissertation. The paper was based on the ERA-NET project "Rethinking the links between farm modernisation, rural development, and resilience in a world of increasing demands and finite resources".

I would like to dedicate the chapter to Boaz Horowitz, blessed be his memory, who saw a different future for his region and many others.

5.1 INTRODUCTION

Effective policies for enhancing resilience need to explicitly specify what is the system or object they are meant to safeguard, and what risk are they protecting it from? In other words, resilience of what to what. Importantly, decisions about which functions should be conserved and protected are political, as different groups and people have different interests and values (Biggs et al., 2012). This adds another layer of investigation about resilience in its distributive form - resilience for whom? Furthermore, policy interventions to enhance resilience can be evaluated through three broad parameters – did they increase the system's capacity to absorb stressors, did they facilitate adaptation to the challenges being faced and predicted, and did they strengthen the ability to learn and create new pathways? (Adger et al., 2011)

This chapter evaluates how different stakeholders might offer differing answers to these questions, by exploring resilience policies and strategies in a specific domain - rural and agricultural development. It analyses how the concept of resilience (both short- and long-term) is operationalised through multiple strategies deployed by farmers, rural residents, and those in leadership positions in rural regions. The focus is on actual strategies deployed at these different levels, which we respectively refer to as farm and region.

5.1.1 THE RETHINK PROJECT

RETHINK was a European-initiated research project set out to investigate how resilience is operationalised in rural and agricultural development in 14 case studies across Europe and beyond. Researchers were asked to identify the way farms, communities, and rural regions perceive new economic, demographic, and environmental challenges, as well as more locally-specific changes in their region. In particular, the project aimed to identify strategies that these communities are deploying in their efforts to ensure their future well-being. Resilience should be seen in this context as the capacity to ensure the continuity of a particular value, in this case, the continuity of an agricultural practice, a family farm, or even the character of a region.

Factors that are likely to influence the future of European agriculture and of rural areas include expected demographic changes, the further development of food (value) chains, urban-rural relations, anticipated trends and perspectives in biotechnology, biomass energy, and bio-based products, and issues revolving around resource depletion Knickel, Zemeckis, and Tisenkopfs (2013). Thus, one of the central objectives of the project was to identify the way farms, communities, and rural regions perceive these as well as additional locally relevant challenges they are faced with at a systemic level, and which strategies they are deploying in their efforts to ensure their persistence and their quality of life. Each case study was different in nature, but through a shared conceptual framework, researchers were able to explore the local understanding of what resilience is, what farms and rural regions are doing to enhance it, and the effects these strategies may have on rural systems' viability.

RETHINK asked several research questions regarding farms' resilience and that of the rural regions in which they were situated, in order to identify how farmers, rural residents, and other decision-makers operationalise resilience, and how the outcomes of their strategies may change over time and space. For example, the project asked what are the key features of the different strategies used to strengthen resilience in rural regions; and how do market forces, societal demands, resource constraints, and place-based actions affect farms and rural regions' resilience over time.

The analysis is based on the observations made throughout the case studies, which combined shine a new light on the connections between farm modernisation, rural development, and resilience. We identified multiple strategies being deployed seeking to ensure short and long-term resilience. However, they also raise important political questions on a societal level regarding the implications of these strategies on the well-being of society as a whole. Finally, they allow us to apply the framework built in previous chapters, and deepen our understanding of the tradeoffs between different goals and methods.

5.1.2 APPLYING THE RESILIENCE POLICY FRAMEWORK TO RURAL AND AGRICULTURAL DEVELOPMENT

Resilience has become central in both academic discourse and policy agendas focusing on agriculture and rural development (see for example Lin (2011), Conger and Conger (2002), Herman (2015), Lamine (2015), Wilson (2010). In the analytical framework of RETHINK (Darnhofer et al., 2014), resilience was defined in the context of social-ecological systems. This was particularly suited to the analysis in the project, as it focuses on integrated systems in which human beings should be considered as a part of nature Folke and Berkes (1998). Within the context of food systems, social-ecological systems are interdependent and coevolutionary and they exist at many levels, from individual farms up to a global scale. The analysis of the interrelationship of these different levels, or "panarchy" Gunderson (2001), is essential to understanding them. Panarchy theory argues that processes at one scale affect those at other scales and thereby influence the overall dynamics of the system. Control can be exerted by both larger-scale processes (top-down) and by smaller-scale processes (bottom-up) (Berkes and Ross, 2016). The economic, social, and environment stressors affecting rural regions require farmers and policymakers to consider and strengthen the three capacities described in chapter 2 (goal 4): the capacity to buffer systemic shocks while conserving existing functions and structures (persistence); the capacity to deal with challenges such as uncertainty and surprise through renewal, reorganisation and learning within the current regime (adaptability); and the capacity to create a whole new trajectory that is rooted in a radical change in the very nature of the system (transformability) (Folke and Gunderson, 2010; Walkeret al., 2004). These three aspects of resilience also clarify the need for a diversity of behaviours in order for a system to remain 'dynamically stable'. Finally, they disentangle some of the contradictory aspects of the concept of a 'resilient system' and help account for scenarios in which one or more of the aspects may be dominant and negatively affect another. Following this rationale, for a rural region, community, or farm to be resilient, it should be able to display all three aspects and implement whichever is deems most appropriate (Darnhofer et al., 2014).

Davoudi, Brooks, and Mehmood (2013) maintain that the interplay between persistence, adaptability, and transformability is not deterministic but can be shaped by human intervention through the use of technologies, learning, ingenuities, and foresight. In the case of agriculture, these can take the form of agricultural input and extension services, for example. In other words, social learning capacity may determine whether a social-ecological system becomes more or less resilient when faced with disturbances of all sorts. However, Knickel et al. (2009) argue that the institutions, administrations, and extension services that are responsible for supporting changes in rural regions are often slow to react to new challenges and opportunities. Assuming that "today's research will guide tomorrow's farming solutions and approaches" (Commission, 2016), this slow pace may prove hugely detrimental, as these institutions generally offer a limited range of support, while the needs of farmers and society have already changed and diversified (de Roest, Ferrari, and Knickel, 2018; Knickel et al., 2009, 2018).

That said, while disturbances are usually considered to be 'negative' events, a shock can actually provide a 'window of opportunity' enabling a transformative change and the chance to re-evaluate the current situation, and socially mobilise and recombine sources of experience and knowledge to arrive at new strategies (Darnhofer et al., 2014), as described in chapter 3 M3.1. Additionally, some resilient systems in the rural sphere may not make a positive contribution to society at large, which raises important questions about system boundaries and definitions (as described in M1.1). This caveat emphasises the political nature of the question: what (and who) should be included (or excluded) from the definition of the system, or defining its ideal state, perhaps representing a tradeoff with M3.3 - broaden participation (Carpenter et al., 2001; Davoudi et al., 2012)?

Thus, applying resilience to rural and agricultural systems, and assessing its possible impacts, requires that it is examined over multiple scales (in this case, the farm, the and the region), and over time. The word resilience stems from the Latin root 'resilire', meaning to spring back Davoudi et al. (2012). But agricultural and rural systems in industrialised countries have been in a state of flux for decades if not more. Therefore, when we wish to preserve the rural system as it is or as it was – what precisely do we want to preserve, and why? Is it the one that existed before intensification occurred or after? Is it one where agriculture is the main driver of economic activity or an Arcadian rural landscape unencumbered by agricultural enterprises, big or small? Is it a state where farmers are independent and entrepreneurial, responding to the free market that exposes farmers to global fluctuations, or a rural state where subsidies enable a comfortable and attractive rural life in perpetuity? In other words, resilience of what in agricultural, rural, or food system do we wish to bolster, against which disturbances or change, and when?

McIntosh et al. (2008) note that 'rural resilience' has gained traction mainly in response to notions of rural decline. As such, rural resilience focuses on how rural residents and regions can improve their well-being through changes in their behaviour and adaptation to new circumstances, as opposed to feeling at the mercy of structural and external forces that appear to dictate their social and economic circumstances. In this chapter, we identify five strategies that rural residents, farmers, and regions are utilising to enhance their resilience, strengthen their sense of agency (and their actual agency), generate a sufficient (or desired) level of income and well-being, maintain a stable population base, and influence a wide range of policies and regulations that affect farms' operations, markets, and legitimacy within the rural space. Rather than ignoring the structural causes of 'rural decline', these strategies form part of the dynamic relationship between rural residents and these external forces.

In light of these conceptualisations of resilience, the systemic challenges faced by farmers and rural regions, and the myriad of ways in which farmers, rural residents, and regions may respond to and even benefit from these adversities, we structure the analysis around two key questions: (1) How is resilience operationalised on a farm and regional level, or, in other words, what are the different strategies that are being used to enhance resilience by farmers, rural residents and other decision-makers in rural areas? And (2) How may the outcomes of these strategies vary across spatial and temporal scales?

5.2 RESEARCH APPROACH AND METHODOLOGY

The analysis in this chapter consists of three layers:

1. In-depth case study performed in the Arava region in Israel by the author and his colleagues in the Israel case study research team.
2. Comparative analysis of the different case studies performed in the Rethink project to answer the research questions posed by the project, mainly how do farms and rural regions build resilience to shocks and stressors in Europe and its neighbouring regions.
3. Application of the resilience policy framework to the comparative case study analysis to identify potential trade-offs between the different goals of resilience policy.

The analysis is based on empirical data from 14 different case studies carried out in the European 'ERANET' research programme 'RETHINK'. These cases explored diverse pathways for farm modernisation and the connections between farm modernisation trajectories, rural development, and the resilience of agricultural and rural systems (see Table 3 below). The case studies utilised a common conceptual and analytical frameworks (Darnhofer, Lamine, and Knickel, 2013; Darnhofer et al., 2014). Within these frameworks, a common set of research questions was applied to each case study allowing a comparative analysis between case studies and drawing general conclusions at the international level while also highlighting the influence of contextual factors.

TABLE 3: OVERVIEW OF THE CASE STUDIES' KEY ASPECTS RELATED TO RESILIENCE

CASE	KEY CASE STUDY ASPECTS THAT ARE REALTED TO RESILIENCE
AUSTRIA	Potential contribution to farm-level resilience of organic farming, economies of scope and niche markets, new business models, selective use of technology, and an 'artisanal economy'.
BELGIUM	Opportunities for and barriers to developing alternative financing mechanisms to support and re-valorise a multifunctional agriculture that fits local needs and is less government dependent.
DENMARK	Resilience as an attribute that can be strengthened on a landscape scale through a joint visioning and design process, farmers' increased income opportunities, and local economy diversification.
FRANCE	Farm's short-term and long-term resilience strategies e.g. diversification of production, diversification in marketing, and optimising on-farm resource use.
GERMANY	Integrating agricultural and farm-based activities with the development of a bioeconomy through renewables and the reconfiguration of the agriculture-society nexus.

CASE	KEY CASE STUDY ASPECTS THAT ARE REALTED TO RESILIENCE
IRELAND	Farmers' use of new technologies to increase their economic efficiency and environmental performance, thus increasing their ability to persist in intensified production over time.
ISRAEL	Social resilience, the role of innovation and the dynamics between agricultural and non-agricultural economic activities under a major ongoing regional economic crisis.
ITALY	Regional initiative valorising extensive, outdoor pig production using local breeds, generating resilience at the farm and regional level, and social resilience, through a distinctly local product.
LATVIA	Impact of economic diversification on farm and enterprise resilience e.g. diversified smaller farms can be more profitable, resource efficient, and adaptable to consumer and visitor needs.
LITHUANIA	Economic diversification effects on farm resilience of farms and enterprises, e.g. young farmers develop farms on a step-by-step basis, sourcing locally and creating higher value-added products.
SPAIN	Innovation and social learning in organic vegetable production in Murcia through the creation of synergies between agents and sectors, promoting research and experimentation.
SWEDEN	Ways of safeguarding agricultural and rural land and lifestyles in the face of infringing urbanisation, through diversification and providing services to urban consumers.
SWITZERLAND	Suburban food production systems in a Swiss agglomeration with five different milk delivery channels illustrating the different dynamics between local farmers and urban populations.
TURKEY	Resilience and competitiveness of small ruminant farms in Isparta and the role of a farmers organisation in strengthening their standing in the regional economy.

The Israel case study was led by a research team that included the author and his colleagues in Israel, and its findings are reflected in the project report, available online (Hurwitz et al., 2015). The project consortium was built around a multi-disciplinary research team, including sociologists, economists, planners, and political scientists, as well as agricultural experts. This resulted in different methodologies being deployed in each case study, although they all aimed to answer the same research questions. The difference in methodologies may be seen as a limitation to generalisability (for example, the results of a survey in one country cannot be taken as representative of others), but they also allow for a broader understanding of the problem and overcome biases rooted in any one discipline or methodology.

Thus, information was gathered using a variety of tools, such as semi-structured interviews and multi-stakeholder group discussions, and involved a range of parties, including farmers, other key stakeholders from the private, public, and civil society sectors, as well as scholars. More specifically, the participants included agricultural advisors and experts, R&D experts, cooperatives and associations, managers, researchers, and policy-makers at national and local levels. Secondary data and information were gathered through desk research, including survey data, statistics, and previous literature, in addition to primary data such as agricultural reports. All the empirical data were gathered, analysed, and structured according to several predefined themes within the resilience framework (see section 2): persistence, adaptability, and transformability; the spatial variation in both the choice of resilience strategy and its subsequent impact (on the farm and region); and the temporal variation in the choice of resilience strategy and its impact (Darnhofer et al., 2014). These themes were also used as the basis of the comparative analysis.

In order to perform the comparative analysis we utilised a single linkage cluster analysis methodology, which maintains the richness of information contained in each case study but also allows for generalisability (Sahu, 2013). Going over each case study report, each reported rural resilience strategy was defined separately unless it closely resembled a strategy that had already been categorised. An additional round of clustering was then performed to find broader themes. Finally, we applied the framework for resilience policy goals and methods presented in chapters 2 and 3 to identify trade-offs within and between the strategies defined, in relation to the three capacities of resilience (persistence, adaptability, and transformability), and the different spatial and temporal scales resilience in rural regions can and should be considered through.

5.3 RESULTS

The strategies that we identified from the case studies can be classified into five main categories as listed below:

- Valuing traditions and local capacities,
- Promoting economic diversification,
- Utilising technological innovation and cost efficiency,
- Increasing cohesion with non-agricultural social groups within the region and outside,
- Optimising the use of public support.

Each category is introduced below through the rationale behind it, and analysed with respect to the way resilience is operationalised, first on a farm and then at a regional level. Each category discusses the extent to which it expresses (or affects) each of the three key dimensions of resilience (persistence, adaptability, and transformability) and how each category may affect the two different spatial scales (farm and region) at different time scales. While some strategies overlapped between categories, identifying these five distinct categories enabled to create a useful framework for discussing the inter-linkages between their different rationales and possible impacts, at times complementary and at others conflicting.

5.3.1 VALUING TRADITIONS AND LOCAL CAPACITIES

WHAT IS THE RATIONALE BEHIND THIS CATEGORY OF STRATEGIES?

Agricultural intensification often requires that farmers replace their traditional methods of production with 'more advanced' technologies and practices. While these may increase production volume and efficiency, they may also come at the price of standardisation and displacement of practices and products that are typical of a specific region, farm, or family. These practices and products hold great value to niche markets that prefer unique identities and stories to mass production and global brands. Thus, one 'alternative' strategy for increasing resilience focuses on creating added value through social constructs, meaning the unique symbolism and authenticity ascribed to products from particular places crafted with particular practices that are distinguished from any other place. This strategy often requires action at both farm and regional scales. While it is seemingly associated with persistence as it by definition aims to maintain the 'local way of doing things', it in fact symbolises a transition to the creative economy and thus is transformational in nature. It requires building a whole new set of skills that is necessary to embed farmers and their products within the creative economy, such as branding, social media marketing, or compliance with certification, for example. These features are best associated with transformability.

HOW IS THIS CATEGORY OPERATIONALISED IN THE CASE STUDIES ON A FARM AND REGIONAL LEVEL?

The Austrian case study illustrates how this category is operationalised at a farm level. Farmers in and around Salzburg are constantly looking for new business models in the 'artisanal economy', which, unlike mass production, does not rely on continual expansion. They may grow their business from micro-scale to small-scale, but not any further. Instead of dealing with generic, faceless supply chains, and supplying raw ingredients to agribusiness, they craft their goods based on personal acquaintance with local resources. They target specific customers, such as chefs and hotels who want to distinguish themselves by emphasising the locality of their ingredients. Such customers are willing to pay more for authentic products with clear origins, an appreciable, authentic story and roots, and local properties (in comparison with standardised products, which are often the antithesis of this description). This group of products includes luxury goods, but also products that are not necessarily based on exclusivity, but, because they cater to ethical criteria, are nonetheless regarded as more personal Darnhofer and Strauss (2015).

Establishing governance mechanisms is often an essential aspect of this resilience strategy, especially at a regional level. For example, in the Italian case study, stakeholders founded a consortium to protect the 'Cinta Senese', a special breed of pigs, successfully gaining a PDO (protected designation of origin) from the EU Commission De Roest and Ferrari (2015).
The German case study represents another way of operationalising this strategy on a regional level: developing and maintaining a local resource base. Rather than focusing on preserving tradition, the aim in southwestern Germany (The Hohenlohe and Schwäbisch Hall administrative districts) was to build new capabilities and knowledge in managing the flow of biomass in the region, as part of an initiative to generate 100 percent renewable locally-sourced energy. The energy supply itself, as well as the analysis and management of the flow of materials, are all under the control of local associations. This approach increases immunity to external pressures by reducing susceptibility to changes in energy policy regimes and global markets, and diminishes reliance on external knowledge and resources Peter, Pons, and Knickel (2015).

CONSIDERING RESILIENCE POLICY TRADE-OFFS

Flexibility and Modularity vs. Redundancy (goals 5 and 6)

The artisanal economy relies on farmers maintaining their local knowledge and investing more time in the crafting process, as slowness itself is valued (in contrast to the 'need for speed' in industrial agricultural systems and modern society in general). However, this does not mean that farmers can only market their traditional, local produce to a select few. They may also make use of large retailers and producers, for example, through distribution in a national organic supermarket chain or by supplying to a big brewery that uses the local ingredients for a specialty beer brand. Making use of different supply chains of different characters is expected to enhance both farm and regional resilience.

This kind of flexibility in supply chain design and modularity in its structure (local and decentralised in addition to big, centralised distributors such as supermarkets) requires more resources to implement - building systems that can supply for these two different types of customers, following different standardisation protocols, and adjusting farm products to each, all take time and money. While it creates a strategic redundancy between the different supply chains, the resources needed to support it diminish other kinds of redundancy such as financial savings or investment in scaling up one part of the supply chain over another.

Decentralise policy making vs. Governing connectivity (Method 1.2 and Goal 7)

While governance mechanisms can facilitate this strategy, they cannot replace voluntary cooperation among different farmers and other actors in the region. In Switzerland, some PDO registrations have been successful, including Gruyère and Vacherin Fribourgeois cheeses for example. But the Emmentaler cheese PDO has not brought about the expected economic and non-economic benefits. Bourdin et al. (2015) discovered that the private, inter-professional mechanism established to govern the Emmentaler supply chain was unable to create a joint marketing vision or to inspire coherence among its cheese processors. The disappointing performance of this initiative, which was established after the dissolution of the state-controlled market and a drop in milk prices, shows that structural factors can constitute very real obstacles to the success of a project. In other words, decentralising decision-making can actually undermine connectivity in that a centralised mechanism may give less voice to different actors but facilitate joint action.

5.3.2 PROMOTING ECONOMIC DIVERSIFICATION

WHAT IS THE RATIONALE BEHIND THIS CATEGORY OF STRATEGIES?

Relying on a single crop, produce or any other economic activity is inherently risky. Any change in the environment – be it pests, a rise in temperature, or even a temporary drought – can undermine years of effort and investment. When products are sold in the export market, these natural risks are compounded by unexpected changes in competition, preferences, and geopolitical events. Thus, farmers who value resilience often look to hedge their risks by expanding their range of activities: adding new crops and products, selling farm produce to new markets and niches, making use of their farms for non-agricultural activities, working off the farm, and even selling their land and continuing to work on the farm as employees Knickel, Lehmann, and Kröger (2011).

HOW IS THIS CATEGORY OPERATIONALISED IN THE CASE STUDIES ON A FARM AND REGIONAL LEVEL?

Case studies presented myriad paths for diversification on a farm level, which can be grouped into three main clusters: finding new product niches within the agricultural sphere, creating new ways to structure supply chains, and initiating new activities that may build on farmers' existing assets but go beyond traditional agricultural activities. All three pathways open new possibilities for change based on farmers' capacities and the markets in which they operate.

Finding new product niches within the agricultural sphere

One of the agricultural niches that came up in farmers' new portfolios throughout the case studies is that of 'environmental products'. It includes, for example, organic produce in France, and bio-energy crops in Germany. Both are examples of products that respond to emerging consumer preferences, policy shifts, and threatening geophysical changes such as climate change and land degradation.

Restructuring supply chains

The Swiss case study provides several examples for the second pathway: in this case by moving toward short food-supply chains in the regional food system. Trading within regionally-based short-supply chains helps farmers in the region retain more value by limiting the involvement of intermediaries. Consumers benefit from increased levels of trust and transparency, as they can trace the food to its source and, through ICT-based interaction with farmers and farms, they can better understand rural and agricultural realities Bourdin et al. (2015). Farmers implement this strategy through on-farm sales, farmers' markets, farm shops, delivery schemes, producer-consumer cooperatives and other collective organisations, regional certification labels, specialised shops and wholesalers, and public catering and restaurants.

Going beyond agriculture

The third pathway for farm resilience through diversification builds on the understanding that diversification includes both agricultural and non-agricultural initiatives (e.g. Maye, Ilbery, and Watts (2009)). In the Latvian case study, for example, only 26 percent of small farms' income stems from farming, while off-farm economic activities account for 50 percent. On-farm activities other than growing crops or husbandry also play an important role: almost 40 percent of small farmers in the region reported providing agricultural services or non-farming related activities on their farms. These ranged from processing services for food and non-food products, to retail facilities, operating on-site restaurants and even providing recreational activities (such as fishing ponds and boating lakes). Some farms were open to the public for educational events, such as exhibitions of dairy production equipment, and others provided workshops for farmers Šumane et al. (2015). Similarly, farmers in the Austrian case study, especially those on smaller farms, rely a great deal on additional or alternative sources of income both on and off the farm. On-farm activities range from agri-tourism to the marketing of forest products, while off-farm activities include employment as teachers, factory workers, and carpenters, as well as working for the municipality or in local ski resorts Darnhofer and Strauss (2015).

Diversifying the regional economy

On a regional level, the Israeli case study provides an extreme example of the risks of a non-diversified regional agricultural economy. Starting in the early 2000s and for more than a decade, the region enjoyed several months of competition-free pepper export every year, thanks to its favourable local climatic conditions. The relative advantage led more and more farmers to adopt pepper production as their sole economic activity, resulting in nearly half of the region's economy relying on pepper exports. But in 2012, conditions changed, limiting the Israelis' competition-free window to mere weeks and initiating a regional economic crisis, with which it is still struggling Hurwitz et al. (2015).

In the past, when conditions in the market changed, the regional R&D Centre and the Israeli national agricultural export company directed farmers in the region toward another crop, but again as the sole focus. That allowed farmers to adapt to a new agricultural supply chain, while maintaining their basic agricultural structure. This structure was also maintained at a regional level, where the economy was not diversified as a whole, but rather replaced one homogeneous regime with another. As the pepper crisis started to unfold in 2012, the regional R&D Centre decided to take a different approach to diversification, this time looking for ways to establish a new regional economy based on a partnership between local farmers, residents, and biotechnology companies. These constitute a diversification strategy that may, in contrast to previous attempts that focused on persistence, strengthen both the region's and its residents' capacity for transformability. The regional council has also been engaged in efforts to increase the region's resilience through demographic diversification. It started building non-agricultural towns for non-farming residents that would bring in new skills and professions from outside the region, bolstering the region's adaptability and securing a positive population balance in face of diminishing income from agriculture.

CONSIDERING RESILIENCE POLICY TRADE-OFFS

Balancing Diversification, Robustness, and Persistence, Adaptability (Goals 1, 2, and 4)

Finding new strategies for production and marketing requires farmers to devote resources to developing completely new skills, and to undertake operations that were previously provided to them externally (by longer supply chains and dedicated service providers). They must acquire independent capacities for storage, trading, and processing. These reshape the balance between farmers' ability to sustain their current production regime (persistence) and their ability to shift to a new one (adaptability). For example, conversion to organic farming in the Spanish case study required the farms involved in the Camposeven cooperative to go through training on how to comply with European organic standards. Its members needed to learn new techniques both in actual farming practices (such as maintaining natural soil fertility and using natural predators instead of pesticides), as well as in marketing and design operations, such as conforming with labelling and certification processes (De los Ríos et al., 2015). All these translate to time, which as the authors of the Swiss case study highlight, was previously devoted to production.

Similarly, Šumane et al. (2018) have identified risk mitigation as an important consideration for farmers who wish to implement diversification strategies: farmers balance the potential benefits of engaging with new initiatives against the risk of increasing their dependency on external factors, such as banks or farmers' cooperatives. Thus, it is not surprising that farmers in Latvia, for example, prefer to minimise their required initial investment and base their choice of new activities on enhancing the use of existing resources and assets.

The extent of diversification and the spatial scale at which it is implemented can determine which capacity for resilience is bolstered. For example, looking for new but similar markets for existing produce, or even finding another crop altogether but still within a similar production system may enhance the persistence of the current regime at the expanse of activities strengthening transformability.

Diversification vs. Connectivity (Goals 1 and 7)

The Israeli case study provides an example of the conflict between the impacts of diversification activities on resilience at different scales: when farmers withdrew from the homogeneous pepper production in the region, regional resilience likely improved because the whole economy was less vulnerable to changes in prices for one single crop. That said, the ubiquitous production of pepper was an integral part of the community fabric in that it was a shared topic of discussion and allowed neighbours to help one another in input, labour, and knowledge. This sense of community, which may now be lost, was one of the prominent causes residents in the region identified for its resilience. Similarly, with one crop as a main regional crop farmers benefited from highly specialised and locally tailored guidance and institutional support in the form of crop-specific research for different aspects of crop management by the regional R&D Centre and the extension services. These same services under diversification may now be more limited in scope.

Diversification vs. Persistence (Goals 1 and 4)
Diversification can also affect resilience differently over time: when a region is homogeneous in its economic activity and its employment opportunities cater mostly for farming, its institutions may provide solutions for farmers in a much more effective and efficient manner, since challenges are common and easier to identify and solutions are much easier to implement. This may allow for a high level of persistence and even adaptability. However, in the long term, a region's homogeneity may hinder its ability to transform, potentially leading to high social and economic costs.

5.3.3 UTILISING TECHNOLOGICAL INNOVATION AND COST EFFICIENCY

WHAT IS THE RATIONALE BEHIND THIS CATEGORY OF STRATEGIES?

The rural and agricultural development policies that have dominated recent decades have been heavily influenced by conventional understandings of modernisation and progress (Ellis and Biggs, 2001; Knickel et al., 2018). Agricultural reforms and support schemes generally aim at turning farms and farmers into 'better' businesses and business people, for example, by giving them access to finance so that they can buy more advanced technology, thus lowering the cost of production (Bahrs, Fuhrmann, and Muziol, 2004). Such support is often meant to increase competitiveness in international markets and leverage opportunities associated with exports, thus improving farmers' ability to cope with arising challenges in domestic markets, labour costs and even in weather.

HOW IS THIS CATEGORY OPERATIONALISED IN THE CASE STUDIES?

The case studies from the two Baltic States explicitly demonstrate the hegemony of this development theory and the resulting resilience strategy it entails on the farm level. The Lithuanian report (Atkočiūnienė et al., 2015) proudly states that, over the past two decades, more than 2,000 farms have "switched to a 'Western' technology, modern management, high-tech, global economy". They are supported by the banks, which view agriculture as a funding priority: "Agribusiness... has become professionally planned, managed and developed". A similar situation exists in Latvia where most farms in the region have followed conventional ideas about farm modernisation, making investments in technological upgrades that allow them to reduce their level of manual labour and increase their output. Farmers and regional policy-makers who adopt this approach consider entrepreneurship, new business opportunities and comparative advantage to be important components of resilience (Šumane et al., 2015).

From a regional perspective, selling to high-volume international markets and higher-quality retailers can also strengthen resilience by improving the quality of production processes and even local environmental protection. For example, farmers in the Israeli case study export most of their produce to retailers overseas. In doing so, they are required to comply with stringent environmental standards that are stricter than the local ones in Israel, which led them to successfully switch to a more environmentally sound practice of biological control-based integrated pest management (Hurwitz et al., 2015).

CONSIDERING RESILIENCE POLICY TRADE-OFFS

Adaptability and Connectivity vs. Vulnerability (Goals 4, 6, and 3)

From a modernist perspective, farm modernisation should be a perpetual, unidirectional process – technology continues to progress and offer ever more efficient ways to produce agricultural value, which is then sold in a globalised market. According to the resulting theory of change, the best way to help farmers and improve their resilience is by safeguarding their access to credit, which allows them to acquire technology; provide them with the training and knowledge required to use the technology they bought; and ensure access to international markets where their produce can be sold. This group of strategies, therefore, focuses on the farm level and aims to increase persistence (producing the same thing, only more and better).

However, while the global market can offer farmers new opportunities for selling their produce, the RETHINK case studies revealed that this is often at a long-term cost to resilience. These costs include market volatility, the need to respond to distant markets and build trust with unknown consumers, the operational costs of building international supply chains, the transaction costs involved in marketing the produce, and perhaps most importantly, fierce competition with agricultural markets that are larger than those that exist at the regional or national level.

The opportunities offered by exports also come at the price of greater uncertainty and exposure to factors (such as price volatility) that have not played a role in farmers' decision-making and prosperity thus far. For example, Lithuania was very badly hit by the 2008-09 financial crisis. Almost 13 percent of its farms, more than thirty thousand in number, went out of business between 2007 and 2010. While economic crises are nothing new, the inter-linkages between different sectors and different national economies have led to a situation where the ability of individual farmers in Eastern Europe to persist may be undermined by financial leveraging practices half a world away. While the Lithuanian government's efforts to attract foreign investment and develop export markets enabled a quick recovery, they also deepened local farmers' exposure to geopolitical events, such as the Russian boycott of European goods, or to currency fluctuations that can hurt their profitability (Atkočiūnienė et al., 2015).

The impact of the Russian embargo created a similar problem in Latvia. It aggravated competition among neighbouring countries engaged in traditional branches of agriculture. This was particularly problematic for farms that had recently modernised their operations and had taken out bank loans that were based on business plans that unexpectedly became impracticable (Šumane et al., 2015). In other words, conventional capital-intensive modernisation adds another layer of reliance and vulnerability. Farmers' business models must take into account not only their predicted profit from selling their goods but also their anticipated ability to repay their debt, which in itself is dependent on external factors, such as interest and currency rates.

Adaptability vs. Flexibility (Goals 4 and 6)

Market volatility is an increasing problem not only in terms of farmers' income but also in terms of input price hikes for energy and other raw materials, which both Latvian and Lithuanian farmers mentioned as a major concern. Thus, as Knickel (2001) argues, the viability of highly industrialised, often highly specialised agricultural production has gradually lost some of its allure and credibility.

It is not surprising then that resistance to new technologies and international markets was also found to be a valid strategy for increasing farmers' resilience, as was the case in the Turkish case study. Unlike their Baltic counterparts, most farms in the Turkish case study region still rely on traditional production methods, mostly grazing in public range lands and pastures. While some farms utilise new technologies for feeding livestock and milking, acquiring the necessary funds for such an upgrade is beyond the reach of many farmers, especially those who are older or with limited education. The 2013 drought in the region gave an opportunity to compare the two types of farms – modernised (in the capitalist sense described above) and traditional. The traditional farms actually turned out to have more flexibility in responding to the crisis, since they did not have the fixed costs associated with farm modernisation. Thus, they were able to respond by selling some of their livestock and reducing their costs. In contrast, the modernised farms were obliged to increase their level of debt to continue paying hired labour and to purchase additional feed for their stock (Giray, et al., 2015).

Adaptability vs. identifying cross-scale interaction (Goal 4 and Method 2.2)

Finally, agricultural intensification can undermine resilience for environmental reasons if policy focuses only on one scale (farm vs. region), and one dimension (volume of production vs. environmental impact). The use of fertilisers and pesticides, for example, can negatively impact local biodiversity and the quality of soil and water in the region (Henneron et al., 2015). However, the intensification framework itself also offers new ways to decrease these environmental effects. The Irish case study, for example, introduced a "slurry hydrometer" that can improve farmers' decision-making process regarding nutrient management. Using such technologies can improve farmers' legal compliance with environmental regulations, their economic performance and efficiency, and their ecosystem's ability to support agricultural activity over time (Buckley and Shortle, 2015).

5.3.4 INCREASING COHESION BETWEEN DIFFERENT SOCIAL GROUPS WITHIN THE REGION AND OUTSIDE

WHAT IS THE RATIONALE BEHIND THIS CATEGORY OF STRATEGIES?

The physical and demographic changes occurring in rural regions require a continual and dynamic response to ensure the region's viability – finding a new mix of spatial uses, safeguarding the region's natural integrity, and finding the right balance between farmers, other rural residents, and their urban counterparts. Thus, building and strengthening new kinds of relationships between farmers, rural residents, and urban centres, enhances farmers' and rural regions' resilience on multiple dimensions: Increasing social cohesion, maintaining traditional landscapes and restoring local ecosystems, expanding economic opportunities, and creating a new appeal in rural regions that may counteract depopulation trends, all of which enhance rural regions' ability to persist in one form or another.

HOW IS THIS CATEGORY OPERATIONALISED IN THE CASE STUDIES ON A FARM AND REGIONAL LEVEL?

The case studies offered several strategies that build on co-dependencies between different populations within the region and outside it to enhance its capacity to manage changes in rural regions' demographics and economies successfully.

Internal social cohesion

The first group of strategies in this category focuses on increasing social cohesion between different actors within the region such as farmers and non-farmers. It is based on the fact that farmers and their managed landscapes can provide multiple functions and play a significant role in the local community, such as possessing local ecological knowledge, providing meeting places, and maintaining open landscapes (Milestad, Ahnström, and Björklund, 2011). This was achieved in the case studies through joint planning activities and a rethinking of certain aspects of farm and land management. These practices can improve farmers' relations with other rural residents, reshape non-farmers perceptions of agriculture, and also reflect the different ways in which multi-functional agriculture can enhance stronger social and environmental resilience (Dessein, Bock, and De Krom, 2013; Knickel et al., 2011).

From a farm-level perspective, this strategy mitigates the risk of opposition to agricultural activities, in what used to be a more homogeneous agricultural space. One example of this strategy being deployed was in the Belgian case study. It was set in a peri-urban part of Flanders where the agricultural sector has already shrunk and farmland now effectively serves as a buffer between the local industrial seaport and residential areas. Local farmers were concerned about the prospect of losing their land to other uses and were increasingly coming into legal conflict with non-farming residents, who often object to basic farm-related operations such as building a new barn. Aware of these conflicting interests, the Flemish Land Agency developed a programme called ECO2, whereby they guaranteed not to expropriate farmland in the buffer zone if the farmers would agree to plant hedges and trees along the edges of their fields. This was done to improve landscape aesthetics and hide industrial facilities, which was of interest to non-farming residents in the region as well. The project was collaboratively planned by farmers and non-farmers. Both parties were also charged with governing the dedicated fund that financed the initiative. In other words, an environmental challenge, in this case, a visual and cultural one more than an ecological one, became a driver for resolving a social conflict in the region or at least ameliorating it (Koopmans et al., 2015).

Ecosystem restoration can be another focal point to rally farmers and other actors in the region in joint cause and action. It also demonstrates how this strategy can strengthen ecological resilience, which is inherently a regional challenge that cannot be resolved by individual farms or residents. In the Danish case study, for example, farmers and other groups got together to restore a local watercourse that had suffered severe changes due to agricultural intensification. The project's main objectives were to ensure the stream's ecological integrity and a steady flow of water, to restore the watershed's biodiversity, and to publicise the watershed's natural and cultural history as well as its new management regime. This collaborative venture was institutionalised through the Odderbæk Stream Association, which brokers formal and informal agreements between farmers, other landowners, and municipal agencies (Pears, Kristensen, and Primdahl, 2015).

The association initiated a range of activities to improve the relationship between the stream's biophysical quality and structure and its place alongside agriculture in the landscape. The association drew up a set of rules for maintaining the stream, which was approved by the municipal and regional authorities. In 2004, it produced a strategic plan that mapped areas of particular natural importance surrounding the stream that required preservation or even a change in land-use. Several farmers went beyond the original plan and experimented with projects such as wetland preservation. As such, this case provides an interesting example of a strategy that is a departure from the traditional planning approach and a move towards one that includes farmers' experiential knowledge (Knickel et al., 2018).

External social cohesion

A second group of strategies in this category focuses on leveraging relations with urban residents and centres to increase rural resilience. Urbanisation and rural depopulation are often perceived as posing an existential challenge to continued rural prosperity (Collantes et al., 2014). However, while cities compete with rural regions, they are also an important hub of activity where rural residents can sell their produce and find off-farm jobs, and from where urban residents can embark on visits to the countryside, which can create a myriad of new revenue streams (Knickel, 2001; Knickel et al., 2011).

Furthermore, the distinct differences between urban and rural lifestyles can in some cases generate counter-urbanisation, a migration stream from the city to rural areas, which can provide both tangible and intangible benefits for rural areas. Based on research in small towns in Australia's inland rural areas, McManus et al. (2012) argue that robust engagement between farmers and town communities is important in maintaining rural populations and services as well as a strong local economy and environment. Thus, while rural regions' resilience may be destabilised by a dwindling population, rural residents and regions also deploy resilience strategies that depend on proximity to strong urban centres. Farmers and rural residents are also dependent on the resources available in city centres for their on-farm agricultural activities.

Thus, for example, the Lithuanian case study mentioned the importance of farmers' proximity to Vilnius, the capital city, for maintaining good access to human capital, natural resources, infrastructure, and financial resources (Atkočiūnienė et al., 2015). Proximity to the city is also of indirect importance, offering farmers the ability to complement on-farm activities with off-farm income. In the Danish case study for example, a large proportion of farm owners were found to have off-farm jobs, meaning that they need to regularly commute to nearby cities or industrial centres (Pears et al., 2015). Cities also offer a larger range of educational possibilities. This is especially important considering the education gap between rural and urban regions: in Lithuania, the proportion of college and university employees in the city is twice as high as in rural regions.

Nurturing social and economic ties with an urban customer base can also enhance resilience among farmers who plan to diversify their marketing methods or income-generating activities. This is exemplified by the recent proliferation of short food-supply chains, such as farmers' markets. Proximity to cities opens up new marketing possibilities at low cost and can contribute to a local sense of pride, with the added value to consumers of knowing the place where their produce came from. The Lithuanian case study, for example, shows that farmers' markets help build and encourage the appreciation of local produce.

Rural residents and farmers also make use of their proximity to cities by offering on-farm services that cannot be provided within the urban centre: agro-tourism, hosting farm events, offering the chance to experience farm work, or sheltering city dwellers' horses, which has become a central economic activity in many peri-urban areas, as in the peri-urban area described in the Gothenburg case study in Sweden (Olsson, Bruckmeier, and Wästfeld, 2015).

Lastly, some rural regions look for ways to attract new residents, marketing themselves through the benefits of rural living and lifestyles. For example, the Arava region in Israel is located in a remote desert, but in recent years it has enjoyed an influx of people, some returning to the region and others as newcomers. The Arava has both economic and social attractions including land available for agricultural and non-agricultural purposes, housing that is significantly cheaper than in Israel's urban centres, and a sense of community that some residents argue is lacking in larger cities.

CONSIDERING RESILIENCE POLICY TRADE-OFFS

Persistence at different scales (Goal 4)

As the Swedish case study points out, farmers taking part in initiatives that integrate non-farming activities and populations in the region may also be increasing the risk that the landscape will be transformed from a mostly production-oriented landscape (agriculture) to a consumption-oriented landscape (Olsson et al., 2015). Thus, while this group of strategies may enhance persistence at the farm level, in the long term it could place community and farm resilience at odds as they can undermine the region's agricultural viability over time.

For example, in the Gothenburg peri-urban region, the increase in the number of horse farms led to a rise in land prices with which conventional agriculture could not compete. Moreover, the shift from agriculture to recreation has facilitated, or at least coincided with, wider changes in land-use, such as rural gentrification, which has led to former farms and summer houses becoming inhabited by non-farming ex-urban residents (Olsson et al. , 2015). Such changes may mean that rural regions become an extension of the city, changing their social fabric and putting them at risk of subsequent real-estate development. This is yet another example of the tension between the two different scales of farm and region; while the region's ability to change its character allows it to withstand population and economic changes, at a farm level, these changes may be prohibitive, discontinuing long-held agricultural traditions and character.

5.3.5 OPTIMISING THE USE OF PUBLIC SUPPORT

WHAT IS THE RATIONALE BEHIND THIS CATEGORY OF STRATEGIES?

Across Europe governments provide direct financial support to farmers. In addition, the government also subsidises the much higher costs which are usually involved with providing public goods and services in remote areas and with allocating land and water to agricultural and non-agricultural rural land-use. It is no surprise then that farmers and rural regions take an active interest in maintaining or improving these different kinds of support, to ensure their persistence. This becomes especially important when changing social values or political priorities may place these support systems at risk.

HOW IS THIS CATEGORY OPERATIONALISED IN THE CASE STUDIES?

The effect of public support mechanisms on farms' and regions' resilience depends on their design, their timing (and termination) and on the attitudes of the farmers themselves. For example, the farmers in the Spanish Camposeven cooperative tried to avoid public subsidies as much as possible in order to maintain their autonomy and, even more so, the quality of their produce (De los Ríos et al., 2015). However, they are still dependent on public support for the provision of water, as they operate in a water-scarce region. The Latvian case study demonstrates that this is not a binary question, an all-or-nothing situation. Around 26 per cent of the income of small farms in Latvia is derived from farming; agricultural subsidies and social allowances provide another 27 per cent; and the remaining 50 per cent originates from off-farm economic activities (Šumane et al., 2015). This form of income combination may require farmers to adapt and transform but also provides them with the means to persist.

On a regional level, government subsidies can help adapt to new business models and economic structures, while maintaining local traditions. For example, the provincial government of Sienna in the Italian case study used subsidies to protect the tradition of breeding high-value Cinta

Senese pigs in the late 1970s. They also led a promotional campaign to inform consumers of the quality of Cinta Senese produce and contributed to building a new market for the farmers' produce. Finally, they initiated the establishment of a consortium to bring together all the stakeholders interested in safeguarding the breed and helped the consortium to prepare the necessary documentation to apply for a PDO label. These initiatives helped transform the local farming system, moving participating farms away from a focus on production volume to an extensive free-range pig farming system based on a model that carries symbolic, cultural and environmental value (De Roest and Ferrari, 2015).

CONSIDERING RESILIENCE POLICY TRADE-OFFS

Persistence vs. Adaptability and Transformability (Goal 4)

While short-term persistence often benefits from governmental support mechanisms, their long-term effect on adaptability and transformability may result in counterproductive outcomes. Across the EU, it is common for around half of a farm's income to comprise subsidies and payments for public goods provision. In less-favoured areas, where the maintenance of the cultural landscape and highly valued natural environments are more important than primary production, this proportion can easily be 70 percent (Bryden et al., 2012; Knickel, 2001). These subsidies allow farmers and rural regions to maintain agricultural production and a certain threshold of population base even in the face of external economic pressures. However, they may undermine their long-term persistence in two central ways: First, subsidies are linked to political preferences that may change. For example, between 2000-2009 the Israeli government limited its support of the agricultural sector in favour of other values such as consumer protection and increasing competition within the local market as well as with imports (OECD, 2010). Second, relying on subsidies to persist reduces farmers' motivation to seek new ways to diversify, as discussed in previous sections.

That said, adaptability and transformability can be strengthened by, and usually, even require public assistance. In the Italian case study described above, moving toward valorised local products and business models would not have been possible without initiatives fostered by regional governments: raising local awareness about existing local food traditions, supporting the establishment of partnerships to codify quality characteristics, linking up with existing marketing schemes, conducting new marketing operations and even adjusting local legislation to accommodate the emerging business models (Knickel et al., 2009). In the Israeli case study, the efforts led by the regional R&D Centre to create a new biotechnology economy in the region cannot occur on an individual farm level, as farms lack the financial resources, expertise, and manpower allocated by this semi-governmental agency.

5

5.4 DISCUSSION

The findings in this chapter are intended to shed light on three important aspects of resilience: First, how is resilience operationalised on a farm and regional level in rural contexts? Second, we asked how we asked how the outcome of these strategies may change across spatial and temporal scales. Third, we looked at trade-offs between different resilience policy goals and methods.

To address this, we identified strategies to bolster resilience deployed by farmers, rural residents and regions, and national policy-makers in 14 case studies across Europe and beyond. We then classified the different strategies using five distinct categories, exploring in each category the short-term and long-term effects of these strategies on different actors' and systems' capacity to persist, adapt, and transform. While the classification into categories was a useful analytical construct, the strategies themselves can overlap, complement or conflict with one another within and across categories.

Davoudi et al. (2012) warn that "resilience thinking highlights the fundamental futility of preparing 'blueprint' type strategies for systems that are non-linear, complex and intrinsically dynamic. Such an 'engineering' mode of operation is still deeply embedded in planning policy, practice, and methods." Indeed, the analysis demonstrated that any account of rural resilience needs to be defined in relation to its particular context. Furthermore, the use of the term "strategies" should not be taken at face value, meaning that while actors' agency is very much present when implementing the interventions and initiatives described in each of the five categories, the actors are not necessarily attempting to increase resilience. They are more often than not pursuing a multitude of specific objectives that may have a direct positive or negative impact on resilience, which we tried to capture in the analysis.

Furthermore, operationalising resilience in a rural and agricultural setting requires the ability to define and preserve certain properties of farms, communities, regions, or their residents, at predetermined time scales, with clear system boundaries, through the facilitation of change in other parts of the system. Which properties or 'anchors' of the system should be maintained? These anchors may include, for example, the makeup of people who live in a certain village, the landscapes that govern the terrain, the predominance of certain professions such as farming, the perceived quality of life, or the cultures and communities that flourish in the region. Each of the five categories in this chapter contains several strategies designed to maintain these anchors, by strengthening their persistence, adaptability, or transformability. Based on the results of the analysis we, therefore, discuss how the goals and outcomes of the strategies may change over space and time and the consequent contradictions arising when these two dimensions are taken into account when assessing the contribution of a strategy to the resilience of a farm or a region. Finally, we discuss some of the policy implications for the design of resilience strategies in light of these insights.

5.4.1 TRADE-OFFS IN STRATEGIES, GOALS, AND OUTCOMES OVER SPACE, TIME, AND SYSTEM SCALES

Trade-offs in resilience at different spatial scales

Rural systems have many anchors, which not only exist at different spatial scales but are also likely to be valued differently by the various stakeholders at disparate levels. Using the two levels of farm and region helped clarify some of the differences between anchors. For example, enhancing the regional economy's ability to withstand price volatility through diversification could require actions that undermine farmers' ability to help one another based on common production methods and inputs. Equally, increasing farmers' ability to persist by intensifying operations could undermine the region's environmental viability and its capacity to withstand bio-physical shocks such as climate change.

Trade-offs in resilience at different temporal scales

It is crucial to define the time scale when analysing different anchors' ability to maintain stability. When we include the time dimension in the analysis, strategies that seemed to enhance resilience in the short term were deemed less attractive in the long run and vice versa. For example, lobbying for subsidies that strengthen farms' persistence in response to a sudden financial crisis may lock farmers into a manufacturing scheme that, in the long run, undermines their own transformability. Similarly, opening to global markets and intensifying farm operations did create lucrative economic opportunities for farmers in Latvia, Lithuania, and Israel, but these initiatives also increased their debt and exposure to international market fluctuations, which undermined their ability to cope with international economic shocks.

Trade-offs in resilience at different system scales

In a holistic approach that incorporates the aforementioned scale factors (spatial and temporal), it becomes even more important to clearly define system boundaries. For example, does the resilience of farm households equate to rural resilience, and does this equate to societal resilience? Not necessarily. In an increasingly urbanised world, the interests and needs of rural regions and nation-states do not necessarily coincide. Given the higher per capita costs of providing social services in remote areas, many resilient rural regions may actually undermine, rather than contribute to, national resilience. However, if the value of rural communities, with their rich local history and culture, is acknowledged in its own right, then finding ways to maintain their social and economic viability may be a valid policy goal, albeit a very different one from promoting the resilience of individual residents or farmers in the region. The boundaries of the target system delineate the range of anchors that interventions should focus on, and consequently, the values used to design and evaluate successful strategies. These values include metrics in the social, economic, and ecological realms.

5.4.2 CONTRADICTIONS IN STRATEGIES IN SUPPORT OF RURAL RESILIENCE

The analysis reveals that operationalising rural and agricultural resilience involves making explicit the values we use to judge the system components that are to be 'maintained' and safeguarded. Consequently, goals may include safeguarding local knowledge and traditions, conserving landscapes that society holds dear, ensuring the livelihoods of rural dwellers, or protecting the ecosystems in which rural communities live. In some situations, these disparate objectives may be aligned, but in others, they may conflict. For example, we demonstrated that while increasing productivity by means of intensification can increase a farm's income, it can also mean a loss of authenticity, which in turn may undermine the farmer's ability to create added value through regional identity, traditional farming practices, or the unique stories behind the produce.

On a regional level, if rural regions encourage newcomers to bring non-agricultural jobs to the region, in effect transforming it into a rural suburb with higher-income residents, this may help preserve rural landscapes, keep towns intact, or increase their economic security, but it could also imply that parts of the agricultural heritage may be lost. Conversely, if agriculture is preserved, even when local farmers have lost their ability to compete in open markets, traditions may be safe, but at the expense of economic self-reliance. Highly industrialised agriculture, on the other hand, could deter people from wanting to visit or live in the area.

Thus, it is crucial to acknowledge the values and priorities that underlie any 'resilience interventions' and related policy tools. This acknowledgment should, at the very least, allow those considering strategies and interventions, be they academics, policy-makers, or residents of the target regions, to accept or dispute the normative assumptions of the rural resilience discourse, its implicit problematisation, and the solutions it proposes.

The inherent contradiction in rural resilience interventions may become harder to resolve now that rural regions are becoming more diverse than ever before. They contain both farming and non-farming households and the balance is changing. Some farms are large and industrial, others small and artisanal. Thus, any intervention needs to define whose resilience it aims to enhance even within the set system boundaries. This is fundamental to understanding the specific contextual meaning of rural resilience. It might produce some counterintuitive results. For example, if the aim of resilience policy is to support the resilience of younger rural residents regardless of what they do or where they live, it could involve supporting them to move to urban centres where there are likely to find more employment (and social) opportunities. Similarly, non-farming residents are likely to be interested in strengthening ecological resilience by restoring ecosystem features and landscapes lost to industrialised agriculture, even if at the expense of farmers' economic interests. Such analyses expose the issues of power that Cote and Nightingale (2012) argue need to be made explicit in resilience studies and interventions by asking the key question "resilience for whom and at what cost to which others?"

5.4.3 IMPLICATIONS FOR RESEARCH, POLICY, AND PRACTICE

While persistence, adaptability, and transformability can co-exist, they can also undermine one another. Investing in programmes that make farm production more efficient or expanding the markets for a certain crop can increase economic welfare, but these strategies (which can be classified as "persistence") may also prevent farmers or regions from investing in transforming the regional economy. In addition, they do not pay sufficient attention to broader, longer-term, non-economic aspects of welfare (de Roest et al., 2018). On the other hand, helping farmers develop their entrepreneurial skills can increase their adaptability, but the additional time spent on 'running a business' may be spent at the expense of running basic farm operations. These and a myriad of other examples show that no single strategy can amplify all three aspects of resilience.

Ploeg, Marsden, et al. (2008) and Wilson (2010) have argued that places with strongly developed economic, social, and environmental capital are likely to be more resilient than places where only one, or none, of these factors, is present. The analysis has demonstrated that the three dimensions are not necessarily commensurate in any given region or farm. Moving beyond productivism and towards rural resilience requires cooperation among local communities and regional leadership, not only in practical matters but also in the story they tell themselves and the outside world about their region. A strong regional identity would allow them to present a narrative that is appealing to potential visitors, residents, and consumers of local services and products.

Furthermore, while conflicts between farmers and non-farmers can be resolved through individual farmers changing their management practices, they are more likely to be resolved through concerted efforts in which formal and/or informal networks play key roles (Koopmanset al., 2018). Hence, improving the integration between rural development plans and agricultural support schemes could help design policy packages supporting resilience strategies that best suit local circumstances. Finally, any proposed solution would also need to be regarded and structured in dynamic terms, to reflect different potential outcomes at different spatial and temporal scales, and account for potential future changes in circumstances.

5.5 CONCLUSION

This chapter illustrated how resilience is operationalised on a farm and regional level by suggesting five different categories of resilience strategies that are being used to enhance resilience: Recognising the economic as well as social value of local traditions and capacities; finding new ways to diversify rural residents' economic activities and sources of income; utilising new technologies and the scales of a globalised market economy while keeping in minds the vulnerabilities associated with it; bringing together different communities, residents, and actors in rural regions and in cities to build greater social cohesion; and utilising government assistance to farmers and rural regions to maintain public goods that may otherwise fade away. Furthermore, it demonstrated the trade-offs between different resilience policy goals and methods, when they are considered from the point of view of different stakeholders, visions of the system, and different scales.

The distinctive contribution that this chapter makes to the rural social science literature is that it demonstrates how the disparate spatial and temporal scales used to assess and plan for bolstering resilience may result in contradictory goals and outcomes. It, therefore, argues that when designing resilience policies, strategies, and interventions in rural and agricultural development, it is imperative not only to ensure that these interventions are well-integrated and clearly defined, but also to keep in mind that they are situated in a particular context, understanding, and set of values and needs that will by definition change, at particular scales of time and space. Thus, it is only possible to maintain certain elements of the system as they are, and almost always at the expense of others.

Finally, it also raises important political questions beyond each region. Rural interventions can have implications for the well-being of other groups, including society as a whole, meriting future research questioning the singular nature of rural resilience in a 21st-century context.

This chapter relied on a qualitative empirical approach to contextualising resilience in a particular policy domain. It presented the conflicts and trade-offs in policy goals and effects that become apparent when applying some of the goals suggested in chapter 2 and methods presented in chapter 3. It showed the difference in interpretation of what resilience policy is and should be that arises when delving into particular case studies and comparing them across cultures, geographies, and political-economic frameworks. The next chapter asks how we can analyse resilience policy and the rate of change it prescribes in a socio-technical system, using an agent based model.

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CHAPTER SIX

06

RESILIENCE POLICY

06

MODELLING RESILIENCE POLICY WITH AGENT-BASED MODELS

As previous chapters demonstrated, while resilience thinking calls for greater freedom to experiment with new governance structures and alternatives, resilience policy often provides a response to problems at scales too big, complex, and costly to experiment with. Modelling, and in particular agent-based modelling can provide a way to examine the different ways the system at hand could evolve over time in silico and to represent the different facets of resilience previously explored. In this chapter, we explain why agent-based modelling is a useful tool for analysing resilience policy, demonstrate how it can be applied with a real-life policy example from Israel, where policymakers asked to prepare for electrifying Tel-Aviv's bus fleets, and examine how the principles and concepts raised in previous chapters can be supported by concrete tools such as ABM.

This chapter builds on the Master's thesis of Hensley Djoe, with whom I worked as supervisor on this project. Specific attributions to his work will be mentioned throughout the chapter. Full model documentation can be found in Hensley's thesis, available at the TU Delft Repository: Djoe, (2015). Under what conditions do clean fuel buses prosper.

http://resolver.tudelft.nl/uuid:9c03dde8-558d-4982-a363-b78132340102

6.1 INTRODUCTION

Agent-based modelling has become an essential tool for policy analysis. Resilience policy in particular requires modelling tools that go beyond linear and static statistical analysis, since it by definition copes with uncertain and often unknown shocks and disturbances and an environment that changes over time. Designing resilience policy is further based on an understanding of the policy system as a complex adaptive system, requiring methodologies and tools that are tailored to analyse complex systems and phenomena. Finally, fostering generalised resilience requires that policy itself constantly adapts, co-evolving with the technical, ecological, and social systems in which it is embedded. This means that describing its possible pathways cannot rely on tools and models that assume an equilibrium end state for the policy at hand.

This chapter explores the potential of agent-based models (ABM) to answer these challenges. It first reviews the distinct features that engender ABM useful for analysing resilience policy, and how it is already being used for policy analysis in different domains related to resilience policy. Then it presents an Agent-Based Model that analyses the effects of a specified resilience policy in the transport sector - electrification of urban public transport bus fleets in Israel, exploring how it can be used to analyse the different components of resilience policy presented in previous chapters.

While this chapter presents the basic mechanics of the model, the model itself is not the focus of the chapter, instead it aims to demonstrate how ABMs can support resilience policy analysis, and specifically the components of resilience policy described in chapters 2-5. In depth description of the model can be found in Djoe (2015), available online at the TU Delft repository: http://resolver.tudelft.nl/uuid:9c03dde8-558d-4982-a363-b78132340102

6.2 USING ABM FOR RESILIENCE POLICY ANALYSIS

Policy analysis as a field has long relied on quantitative methods for solving problems. In the 1970s, greater demand for policy analysis, growing computing capabilities and advances in economic modelling and simulation further increased the role they played in policy evaluation. Simulations became a useful tool for policy analysts, allowing them to run a series of organised trial and error experiments in order to observe how the system may behave and change over time (Yang, 2006). However, it took several decades for simulations to gain traction in policy research. Incorporating ABM in policy research represented a methodological evolution, allowing simulated agents to adjust their plans of action through learning, interaction, and institutions (Johnson, 1999).

Following is a short description of what an agent-based model is, why it is useful for analysing resilience policy, and how agent-based modelling has been applied to enhance policy analysis in different policy domains closely related to resilience policy in the past.

6.2.1 WHAT IS ABM, AND WHY IS IT USEFUL FOR RESILIENCE POLICY ANALYSIS?

ABM DEFINITION AND SUITABILITY

Agent-based models (ABM) are simulations that represent social entities such as people and organisations, technical objects such as infrastructure or cars, and the interactions between them. The agents in the model can observe their environment, communicate with other agents, learn, and make decisions. Based on these interactions between different agents and between agents and their environments, system-level behaviours emerge, and the system changes and evolves (Nikolic and Lukszo, 2013).

ABM has proved to be a useful tool for policy analysis. It can help policymakers make sense of complicated and complex problems and systems, as they contain many factors and agents that interact with one another, and heterogeneous populations of actors that can learn and adapt (Johnson, 2015). ABM has an advantage over more traditional quantitative methods for policy analysis, such as differential equations, statistical forecasts or system dynamics models, in that they are able to relate this heterogeneity in behaviours. Furthermore, they can delineate what information is available to which actors, their decision rules, and the environments in which they operate at a system level (Lempert, 2002).

ABM also allows the explicit representation of the interactions between actors and their environment. All these allow modellers and policy analysts to conduct relatively "cheap" experiments that increase their understanding of how different interaction structures, institutional settings, environmental conditions and agents' characteristics may impact the system's evolution over time (Squazzoni, 2008). These qualities may explain the growing abundance of ABM used to investigate policy questions in multiple fields – from education planning and crime to energy systems, natural park management, electric cars diffusion and industrial clustering (Crooks and Heppenstall, 2012; Jager and Edmonds, 2015).

Its prominence in political science research was further evidenced in the fact that the American Journal of Political Science chose a research paper weighing policy outcomes based on agent-based modelling Bhavnani et al. (2014) as the best published in 2014.

Several attributes make ABM a natural choice for analysing resilience policy in particular: They help bridge the disciplinary divide and represent both social and physical realities in the model; they provide a practical methodology to operationalise complexity theory; and they are inherently dynamic and do not require any equilibrium to function effectively. Each of these qualities is essential for resilience policy, especially when it integrates both socio-technical and social-ecological systems thinking. Following is a short explanation of how each of these attributes of ABM is commensurate with the challenges resilience policy poses.

Bridging the disciplinary divide

The first attribute that makes ABM highly suited for analysing resilience policy is its ability to represent theories of social science and exact sciences alike. Scholars of social-ecological and socio-technical approaches to resilience acknowledge the need to incorporate more social science research and findings in any attempt to understand how physical systems change over time. ABM can serve as a boundary object – a practical tool that allows researchers from different disciplines to discuss the system at hand, provide their different perspectives of it, resolve conflicts in interpretation, and translate their shared understanding into a formal model.

This is largely due to the fact that it is easier to represent the concepts and insights social science provides in ABM, as it focuses on individuals and their behaviour. It creates a more natural way to describe and capture actors' activities, especially when their behaviour is complex, and when it is important to apply randomness to particular parts of the system rather than the model as a whole (Bonabeau, 2002). This allows expressing a great deal of knowledge and data accumulated in social science research about the behaviour and relationships between people and institutions (Bankes, 2002).

Furthermore, differential equations and statistical modelling often impose restrictive and unrealistic assumptions such as linearity, homogeneity, normality and a lack of dynamism. ABM allows us to relax these assumptions. It enables exploring bounded rationality, learning, and institutional and social structure (Bankes, 2002). ABM can incorporate data about network structure and relationships, and interactions between network actors, based on qualitative and quantitative measurements and concepts, thus allowing researchers to capture their progression and change over time (Johnson, 2015). Thus, in contrast to traditional models that work best with static, homogeneous problems that tend to reach equilibrium states, ABM allows researchers to create and explore complex scenarios and worlds with greater fidelity (Muis et al., 2010).

These limitations in modelling are not limited to exact sciences. More than any other discipline in social science, economics has relied on the use of models to both theorise and demonstrate the mechanics of the field. However, Axtell (2007) pointed out that some of neoclassical economics' "sweet spots" are caused by constraints and that ABM can more easily overcome: The assumption of rational agents that are capable of maximising their own welfare, which does not take into account the empirical evidence of people's bounded rationality; the homogeneity of agents in many economic models, especially in macroeconomics; a lack of direct interaction among agents, replaced by interaction with "abstract economic objects like price vectors and aggregate economic statistics"; and the pursuit of agent level equilibrium which is unrealisable in reality.

In 2015, the OECD's assessment synthesis of New Approaches to Economic Challenges (NAEC) reflected this challenge to policy analysis more broadly, stating that "the OECD is also developing a more systematic use of micro-data to design policies which reflect the heterogeneity of agents and is more systematically considering the entire distribution of outcomes to better understand the sources of growth and tackle inequality. The OECD is also reviewing some of its fundamental assumptions, approaching risk and behaviour with greater realism, and is updating its models, deploying increasingly integrated and versatile approaches that are able to translate the findings of social research and behavioural science into policy design and implementation" (Ramos, 2015).

Finally, ABM allows a great measure of transparency about model assumptions, especially when following dedicated protocols for describing the model such as ODD. In addition to facilitating communication of the model, it enables its replication, comparing it with other models of the same phenomenon, and is critical in facilitating dialogue between different disciplines, such as policy scientists and experts in the policy domain (ecologists, economists, etc.) (Grimm, Polhill, and Touza, 2017).

Operationalising complexity theory

The second attribute that makes ABM an important tool for analysing resilience policy is its roots in complexity theory. Resilience as a discipline draws on many aspects of complexity theory. Complexity theorists describe a problem or a system as composed of a number of components that interact with one another and create numerous possible combinations of behaviour and states that are hard to predict Jager and Edmonds (2015). Complexity theory lends new tools and methodologies, such as ABM, which allow us to view the interaction between the different components of the policy system and their change over time. It can help us identify phases of stability and instability in policy processes and compare the outcomes of our models with our knowledge of previous theories of how policy works (Haynes, 2008). These are foundational notions in resilience thinking and resilience policy, which aims to provide solutions to these unpredictable changes and risks.

In addition to analysing the complex systems on which policies need to operate and affect, 'policy' is in and of itself a complex phenomenon. ABM enables the representation of political and policy systems that are by nature non-linear, unstable, and unpredictable (Elliot, 2003). Thus, complexity-based models can depart from traditional static representations that look at policy impact at a specific point in time, instead focusing on how different policies and institutions can evolve under different conditions, allowing actors in the model to have agency and engage in self-organization. They shape their own perceptions, goals, and subsequent behaviours based on changes in their environment and interactions with other actors around them, leading to adaptive behaviour. The interactions between these agents and their environments can also give rise to emergent phenomena such as policy (Teisman and Klijn, 2008). In other words, ABM allows researchers to observe in the model how transitions in policy and the broader system that it shapes can emerge as a result of micro-macro mechanisms that are operating in different sectors and at different levels (Squazzoni, 2008).

How does this micro-macro dynamic come about? Another key element in both resilience thinking and complexity modelling is heterogeneity. Resilience thinkers emphasise the need for diversity in elements in the system providing similar functions, and in how elements in the system may respond to changes in order to withstand shocks and stresses. When modelling the system that requires representing agents, objects, and environments that are different from one another by design, ABM allows the modeller to embed unique agent profiles, interaction structures, and environments in which agents operate. These differences give rise to generative explanations of social phenomena such as transitions (Squazzoni, 2008). These capacities create an additional layer of exploration in policy design and evaluation, by enabling second-order considerations of the ways in which policies may develop and win support over time (Jager and Edmonds, 2015), a key element in resilience policy, as was mentioned in chapter 3.

Finally, and as a result, ABM as a complexity methodology defies the deterministic nature of policy analysis. Policy planning and analysis have long relied on the notion that the relationship between government action and external consequences is linear and proportional, meaning that a certain level of incentives will trigger a certain level of response and that that level can be predicted by an all-knowing planner. This view pertained to the way public administration envisioned itself as well, as a deterministic structure where institutions issue orders that are then carried out as planned further down the hierarchy. However, with the advance of complexity theory, this view has begun to change (Morçöl, 2005). Complexity research acknowledges that rather than simple cause and effect, policy analysis must deal with non-deterministic probabilities, which are a hallmark of decision-making under uncertainty (OECD, 2009), and also a basic tenet of resilience policy. This underscores the importance of the third attribute that requires policy analysts designing resilience policy to make use of ABM: moving toward a dynamic practice of policy analysis.

Moving from a policy optimum to dynamic scenarios

While policymakers at times look for models to reliably depict the future so that they can plan accordingly, ABM does not purport to predict the most likely outcome. Instead, it offers "robustness". That is to say that instead of hoping for a reliable depiction of a specific, probable future, ABM allows the development of robust strategies – strategies that "perform relatively well, compared with the alternatives, across a wide range of plausible futures" (Lempert, 2002). This approach supports resilience policy planning, which itself aims to prepare policymakers to a wide range of eventualities.

Johnson (2015) supported this reserved approach, stating that simulations do not offer a high degree of accuracy for the outcomes of policy events, but they do offer valuable insights for policy analysts and scholars: the ability to detect the evolution of large-scale regularities, evaluating the possible effects of different policy designs, and exploring the causal mechanisms in policy systems. ABM allows us to create new worlds where modellers can modify certain parameters or assumptions, examining their effects on emergent behaviour, and explaining how changes in simple decision rules can lead to divergent policy outcomes (Berry, Kiel, and Elliott, 2002).

Furthermore, rather than examining policy at a particular point in time in a singular spatial unit, ABM can look at policy across different scales of time, space, and of the policy system itself, linking individual behaviour to the resulting policy outcomes. ABM can incorporate data about network structure and relationships and interactions between network actors, based on qualitative and quantitative measurements and concepts, thus allowing researchers to capture their progression and change over time (Johnson, 2015).

How can policy analysts operationalise this approach in practice? Performing policy analysis in complex systems presents unique challenges, with which ABM can effectively cope: complex systems are sensitive to particular assumptions in certain regions of activity, and deep uncertainty that emanates from a lack of knowledge or agreement on certain input parameters or even how to model the system as a whole. In these cases, Lempert (2002) suggests that ABM provides policy analysts and policymakers the opportunity to gain insight by watching different model runs unfold, as part of an effort for computer-assisted reasoning. Rather than optimal solutions, alternatives are evaluated based on their robustness and on a satisficing criterion. Modellers use uncertainties to create an ensemble of scenarios, representing different views on how the world works and what choices for action may arise. These ensembles can then be visually represented in what Lempert terms “landscapes of plausible futures”, and compare different policy strategies across the landscape, in an attempt to find strategies that perform well in a wide range of scenarios, that can adapt over time, or in particular regions that are of interest to policymakers. These in-silico experiments present a viable option to implement the kind of adaptive governance approaches resilience scholars to advocate for, which are not always possible in real life due to cost, safety concerns, or a limited time frame in decision-making.

Finally, this dynamic quality in ABM is useful in another field resilience thinkers proposed to increase their own interaction with – transition studies. Timmermans, de Haan, and Squazzoni (2008) demonstrated that while policy sciences do not explicitly use transition studies conceptualisation and terminology, they have much in common – focusing on gradual changes happening over time, and short periods of radical change. ABM allows studying such transition processes by interpreting concepts such as regimes and niches to agents who have different strategies, can transform, and be influenced by the landscape signals and the strategies controlled by the modeller.

HOW ABM WAS USED FOR POLICY ANALYSIS IN RELATED DOMAINS

ABM has been used to inform and analyse policy in a wide range of domains (see for example Zehra and Urooj (2022) for a review of its use in economic policy, Ornstein and Hammond (2021) in public health policy, Castro et al. (2020) in climate-energy policy, Kremmydas, Athanasiadis, and Rozakis (2018) in agricultural policy, and Cubeddu (2020) in environmental policy analysis). As resilience policy needs to provide solutions for challenges in various domains it is useful to review past applications of ABM in domains that are closely related to resilience policy, or where questions of persistence and transformation are of special importance.

Following are several examples of agent-based models developed to support policy design in arenas closely related to issues of resilience - emergency response and public safety, economic planning, conflict resolution and social justice, and infrastructure design and spatial planning, including in public transport. For brevity's sake we provide only a short description of each topic. Annex C provides a fuller account of the different examples.

Emergency response and public safety

In some situations, experimenting with policy is not just difficult to execute or financially costly for trial and error, it could lead to loss of life and serious crisis. This is the case in domains such as emergency preparedness and response and public health and safety. Researchers in these domains built ABM's to help with questions such as how to best support refugees (Anderson, Chaturvedi, and Cibulskis, 2007), reduce harm from gun ownership (Hayes and Hayes, 2014) and alcohol consumption (Scott et al., 2016), and how to reduce contagion through regulation (McPhee-Knowles, 2015).

Economic planning

Economic planning has become a vital domain for enabling transformations and ameliorating crises. Through budgetary allocations, monetary decisions and taxation instruments policymakers can alter people's and corporations' behaviours in advance, and provide necessary relief when a crisis hits. Researchers have used ABM to explore the effects of micro-economic policy, macroeconomic policy, and diffusion and innovation.

For examples, ABM was used to examine how the geographical distribution of policies that improve labour skills can affect technological change and growth in a regional and in super-regional context (Dawid et al., 2009), and the potential impacts of policies for supporting Small and Medium Enterprises (SMEs) (Pablo-Martí et al., 2013). Ogibayashi and Takashima (2014) incorporated the government as an explicit actor in an agent-based model that explores the impact of the corporation tax rate on GDP. ABM has also been used to simulate emerging macro-economic phenomena and mechanisms, as well as multiple market economies that are grounded in actual economic structure and details (for example Ogibayashi and Takashima (2013)).

ABM is particularly useful in simulating consumer attributes and decisions, helping policymakers evaluate policy tools' impact on technological diffusion, and its desired rate and extent. This has been used to simulate future diffusion scenarios and counterfactual diffusion scenarios (without policy incentives or other incentives in their place) in different products and fields, such as solar power (Zhang et al., 2016; Zhao et al., 2011), smart metering (Zhang and Nuttall, 2011), and electric vehicles (Querini and Benetto, 2014) among others. In addition to analysing policy impact on new technologies' diffusion, agent-based models have also been used to analyse policy's impact on the very process of innovation (Ahrweiler et al., 2015; Schilperoord and Ahrweiler, 2014).

Conflict resolution and social justice

One of the growing strands of resilience literature tackles the question of justice. Rather than enshrining an existing reality, it asks what kind of transformations should the system strive for to bolster the resilience of vulnerable members and groups in society, and create a more equitable community and state. ABMs simulated how a policy may resolve or aggravate conflict and violence between Israelis and Palestinians under different scenarios for territorial settlement in Jerusalem (Bhavnani et al., 2014), decrease or increase social segregation in cities (Feitosa et al., 2012), and create a more equitable education system (Maroulis, 2016).

Infrastructure design and spatial planning

ABM is particularly suited to explore questions that combine physical space and social interactions. Many ABMs explore how policies affect the resilience of public infrastructure, natural resource management, and urban design. For example, Shi, Thanos, and Antmann (2013) designed a model that simulates a single-stream recycling system and a dual-stream recycling system on a local level (county and region) to compare their effectiveness in reaching recycling goals. Zellner (2008) created a model that explores possible policies for sustainable groundwater use. The model brings together policy, infrastructure, people's behaviour and decisions, and bio-physical components. The interaction between these different layers can shed new light on the complexity of the groundwater depletion problem, and on the possible indirect effects competing policies may have on solving or exacerbating it. The energy system has been an especially prolific arena for ABM, with models that analyse electricity markets design and efficiency, carbon emission trading and renewable energy supply among others (Sensfuß et al., 2007).

Urban planning has also made use of ABM's ability to bring together spatial, economic and behavioural analysis, particularly in the context of sustainable urban development. For example, Vallejo, Rieser, and Corne (2015) simulated an urban environment where real estate consumers look to maximise their utility through a set of criteria that varies among different agents, showing emerging rates of accessibility to urban parks. Similarly, Brown et al. (2004) built an ABM to assess the effectiveness of different configurations of greenbelts. Others looked at more direct policy interventions, such as compact city planning. One such example is the Household Residential Relocation Model, which visualises the impact of a government policy to encourage households to move from suburban areas into downtown, in order to increase population density in urban areas in Japan (Ma, Zhenjiang, and Kawakami, 2013).

Transport planning

Any attempt to model a socio-technical system requires to grasp, by definition, the technological aspects of the systems at hand, and the social institutions, actors, and decisions that impact its evolution over time. In the model described in the coming sections, that entails the buses and charging infrastructure on the technical side, and the different factors impacting the bus operators' decision to buy and deploy electric buses versus more traditional alternatives on the social side. Before delving into the actual model, it is worth mentioning that modelling the transition to electric vehicles has been widely implemented, both in ABM and other model types. These models provide useful insights and inspiration for both sides of the socio-technical equation. Following are a few examples that were helpful in the preliminary stages of designing the model.

Kokkinogenis et al. (2014) populated a model with an artificial society of commuters in order to observe the potential effects of market-based and incentive-based instruments on commuters' choice of public versus private transport modes. Levy, Render, and Benenson (2015) built PARKAGENT - a spatially explicit ABM that was developed to evaluate multiple parking policies and solutions under different development scenarios in the Tel-Aviv metropolitan region in Israel. Each agent in the model is a driver with a set destination looking for parking, with the capacity to decide whether to park or not based on their own location, that of the parking spot and other properties. It uses real-world information on road structure, traffic limitation and parking facilities based on available municipal data.

A multitude of ABMs was built to predict the diffusion of electrical power drives, though mostly in the context of private cars. For example, Eppsteinet al. (2011) built a model exploring different factors impacting plugin hybrid electric vehicles market penetration, including gasoline prices, market instruments such as rebates, consumers' willingness to pay for fuel efficiency, information availability, and interaction with other consumers. Köhler et al. (2009) used concepts from transition theory to build a model that assesses future adoption rates of alternative power drive technologies and mobility practices, based on the inter-dependency of existing institutions and infrastructure. ABMs were also used as decision support tools that may help both industry and government better plan charging infrastructure and forecast EV charging demand (Olivella-Rosell et al., 2015; Pagani et al., 2019).

6.3 MODELLING RESILIENCE POLICY EXOGENOUSLY

6.3.1 BACKGROUND

This section will present a model designed to support resilience policy design in the transport-energy domain in Israel, specifically the electrification of public transport buses in the Tel-Aviv metro region. The model incorporates policy as an exogenous factor, meaning that modellers decide which policies should be implemented in the model, rather than letting the agents in the model decide for themselves.

While important in and of itself, we will only provide a basic description of the model and its results, as the objective of this chapter is to examine how ABM can be used to analyse resilience policy in light of the frameworks and concepts offered in previous chapters. Thus, it is the model's useability that is of interest to us. Additional details about the model can be found in Djoe (2015), which developed and presented the modelling work upon which this chapter is based, and is available online at the TU Delft repository.

The section proceeds as follows: First, we present the case description. Second, we explore what can be learnt from the models described in the previous section and more general literature on electric buses, as well as the resilience policy framework presented in earlier chapters to build the model at hand. Third, we present the model itself, illustrating how an ABM can integrate the different aspects of resilience policy in practice to support policy design. Finally, we draw lessons about the potential and limitations this approach presents to resilience policy analysis.

6.3.2 CASE DESCRIPTION

Over the past decade, Israelis have become increasingly agitated at the state of public transport in the country, especially within the Dan metropolitan area with Tel-Aviv at its core. Demands for better infrastructure grew as the problem of traffic became ever more apparent and severe. While many important solutions have been in the works – from a light rail train network to rapid transit lanes, one solution, in particular, has become synonymous with better quality vehicles in public transport fleets: bus electrification.

While not necessarily the reason for their popular appeal, electric buses offer a triple win for sustainable transport, following a simple strategy and priority coined by sustainable mobility experts: Avoid-Shift-Improve. The first part of the approach refers to means by which the need to travel can be avoided, to begin with, such as more dense and mixed-use urban design and promoting teleworking. The second part aims to shift travellers from individual car use to more sustainable transportation modes such as public transport, bicycles, and walking. The last part aims to improve the performance of remaining vehicles so that their malignant environmental effects are minimised GIZ (2014). According to its protagonists, electrification of the urban bus system offers an opportunity to promote all three strategies – create a more public transit-oriented urban design, encourage more widespread use of the public transport system, and eliminate tailpipe emissions while facilitating the transformation to renewable energy production (des Transports Publics, 2011). However, in its initial stages, E-Bus technology requires active efforts among policymakers, bus operators, planners, and the public in order to gain equal standing as a viable alternative to existing bus fleets on the one hand and private transport investment on the other.

Furthermore, the global bus industry has proven over the years to be a convenient test bed for new fuels and power technologies, as it led the adoption of new solutions such as compressed natural gas. Bus fleets' centralised storage, maintenance, and powering, as well as their regular routes, facilitate the planning and implementation of vehicle replacement and infrastructure installation. While they often face budgetary constraints, especially in municipal arenas, subsidies from national governments supported by public agencies can encourage innovation and experimentation with new, in this case, electric power drives (Ealey and Gross, 2008). In fact, electric-powered vehicles (EVs) are already an integral part of public transportation systems around the world, albeit in different forms: Battery E-Buses, trolleybuses, trams, metro, and light rail are all in use, though differing in infrastructure needs, costs, and capacity (Barrero, Van Mierlo, and Tackoen, 2008).

In Israel, electric buses gained traction for several reasons: First, they represented a leapfrog in technology that was appealing to the public regardless of specific impacts. It was considered newer, and thus better. But it also provided specific solutions to environmental challenges on the agenda. For many residents of Tel-Aviv and other dense cities in Israel, electric buses represent a way to address their plight of street-level air pollution, which had become especially unbearable in the southern neighbourhoods of Tel Aviv, where the central bus station had been located for decades. For climate activists and policymakers seeking ways to mitigate GHG emissions, electric buses offer a tangible and immediate intervention, while also building a pathway for the long-term transformation of the energy-transport system.

However, for the Ministry of Energy in Israel, this possible change in bus fleet composition represented a challenge. First, it meant that electricity production in Israel, which at certain times of the year runs on relatively low margins of reserve capacity, may need to increase to be able to provide for the additional demands by charging buses. Second, local distribution infrastructure may be required to facilitate charging facilities in depots, stations, and other central locations. Preparing for an electrified portfolio seemed additionally challenging due to uncertainty on the rate of electrification over the coming years, and how public transport operations will change as a result on a daily basis. In order to answer some of these questions, the ministry commissioned a study on the possible implications of bus electrification in Tel Aviv. The model described next was developed as part of that study.

6.3.3 INCORPORATING INSIGHTS FROM EXISTING ABMs, THE RESILIENCE POLICY FRAMEWORK, AND FROM TRANSPORT PLANNING LITERATURE

In order to design an ABM to help the Ministry of Energy prepare and design its policy, we built on the ABM review and resilience policy framework presented, as well as transport planning literature. Following is a short description of the insights gained from reviewing each of these fields.

ELEMENTS TO INCORPORATE FROM ABM EXPLORING RESILIENCE-RELATED POLICIES

The ABMs presented in the previous section helped inform the design of the model's temporal configuration, environment, and policy setup.

Temporal configuration

As the mass shooting simulation demonstrated (Hayes and Hayes, 2014), finding the time scale most relevant for the policy question at hand is key. While the policy experimented with in the model affected purchasing capacity, meaning hours or days before the actual shooting, the simulation focused on the mass shooting event itself meaning at a time scale of seconds to minutes. Similarly, electrifying the public transport fleet requires simulating purchase decisions occurring every few years, but also fleet operations (buses driving and charging) occurring at an hourly scale.

Furthermore, while the model needs to simulate the path from the current attraction basin (mostly diesel-based buses in the fleet) toward a new attraction basin (mostly electrified buses), policymakers need to know what happens once the shift has occurred. As in the Jerusalem model (Bhavnani et al., 2014), which looks at the ramifications of different scenarios to divide the city on intergroup violence, the bus model needs to demonstrate what will happen to the city's energy demand patterns under different scenarios for electric bus penetration over time.

Environment

The social justice models mentioned above highlighted the value of building a spatially explicit model in order to consider the disparate distribution of effects throughout the city. In the Tel Aviv case study, the negative health effects associated with air pollution caused by buses near the current central station is a case in point. Thus, the model places the buses in a simplified grid representing their movement between different transportation hubs in different corners of the city. While the model does not consider the way air pollution may spread or diminish under different electrification scenarios, as some of the natural resource ABMs have done, it allows an approximation of changing conditions in neighbourhoods adjacent to the central station based on the amount of diesel buses left compared with the baseline scenario.

Policy setup

The models reviewed bring up three important points on incorporating resilience policy in an ABM, and in the current model in particular:

Experimenting with crucial policy parameters

Models can both identify which policy parameters have the most impact on the desired behaviour, and allow policy analysts to experiment with different configurations of parameters they know to be impactful to begin-with. For example, the mass shooting simulation found that bans on magazine purchase was most effective in limiting the rate of fire (Hayes and Hayes, 2014). Similarly, Kugleta (2017) experimented with the different parameters that go into Horizon2020 call design to see how they impact the overall number of calls and consortium composition. In the current model, we deployed different types of policy tools at changing levels that can potentially impact the bus operators' purchasing decisions, including the number of years vehicles are allowed to remain in operation, and different tender rankings for electric versus diesel buses.

Observing market share as an emergent phenomenon

Both the microeconomic and macroeconomic models reviewed simulated how wide economic phenomena such as market share and GDP emerge as a result of different policy incentives and personal preferences. In the current model, market share emerges based on individual choices companies make, which are influenced by the interplay between tendering incentives, companies preferences, and broader market conditions such as energy costs.

Including government as an agent

Ogibayashi and Takashima (2014) incorporated the government as an explicit agent in their simulation of the impact of the corporation tax rate on the GDP. In their model, government agents were tasked with collecting taxes and spending revenue. In the current model – a government agent issues a tender for operating clusters of public transport lines, decides which companies can participate, weighs the proposals, and picks a winner.

ELEMENTS TO INCORPORATE FROM THE RESILIENCE POLICY FRAMEWORK

Modelling resilience policy with ABM allows policy analysts to incorporate many of the different aspects the previous chapters explored. We illustrate how they were used to design the model at hand. The results section of this chapter will provide an in-depth analysis of how the model enhances each of these elements.

- Explicitly represent resilience policy goals and strengthening resilience-oriented policy environments as described in chapters 2 and 3
- Create the kind of communication, reflection, transparency, and inclusion that are crucial to resilience policy as described in chapter 4
- Examine the policy at different temporal and spatial scales, and infer tradeoffs to different stakeholders as described in chapter 5

ELEMENTS TO INCORPORATE FROM TRANSPORT PLANNING LITERATURE

Before delving into the actual model, it is worth mentioning that modelling the transition to electric vehicles has been widely implemented, both in ABM and other model types. These models provide useful insights and inspiration for both sides of the socio-technical equation. Following are a few examples that were helpful in the preliminary stages of designing the model.

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In terms of technological considerations - in order to estimate the operational implications of adopting electric buses in the fleet, it is necessary to define and evaluate their charging properties: How much power will they consume? When will charging occur, and how frequently will buses require recharging? Luo et al. (2013) suggested that in order to calculate the demands and characteristics of charging, data must be gathered regarding the average daily travel distance of buses, the normal operation time of buses, the peak periods of bus operation, the intervals between buses in peak and off-peak hours, the rated travel distance of an E-Bus, and the expected travel distance of an E-Bus per charge. In order to predict charging loads, Luo et al. (2011) argued the need to characterise the type of electric drive, charging times, type of charging (fast vs. slow), and other charging needs and data. At a spatial level - the physical aspects of charging must also be taken into account, mainly the location and distribution of charging stations. While easier to plan with centralised public transportation systems, according to Song, Yang, and Lu (2010) determining the location of charging stations must ensure the needs of buses and the road network, and also take into account the state of distribution and transmission grids in the region. In this case, some of the data was already known from the early adoption of electric buses in Tel-Aviv, narrowing the parameters of the physical attributes of the system.

6.3.4 MODEL DESCRIPTION

TIME SCALE

The goal of the model is to explore different scenarios for electric bus diffusion in Tel-Aviv over a period of 16 years. The model simulates three different time scales: The first time scale is a "tick", meaning a round in which the computer executes all the listed tasks. Each tick of the model represents an hour, allowing the simulation of electric buses' charging patterns. The second time scale is a day (24 ticks), in which the simulation can explore the way individual buses and the fleet as a whole behave throughout the day and night. The third time scale is a year, allowing the model to explore how the bus fleet changes by responding to new public transport tenders that come out every year. While within a "tick" all the activities are assumed to take place at the same time in real life, meaning in parallel, the computing limitations of a simulation entail an ordering of certain activities, or in other words the model runs sequentially, and actions do not occur "all at once". In order to avoid biassing the results of the simulation, it uses a randomiser that changes the order of who does what within a tick every time the simulation is run.

AGENTS

The model consists of three types of agents: Buses driving around the city, the bus operators that own them, and the public transport authority, representing in this case the Israel Ministry of Transport, which is responsible for setting the terms of the tenders for different clusters of bus routes every several years, choosing the operator that proposed the best bid, and monitoring the ongoing needs of transport users in each cluster.

Buses

The buses in the model belong to three different public transport operators, representing the lion's share of the market in the city – Egged, Dan, and Kavim. Each bus is either an electric bus or a diesel bus. Each technology has different properties: range, recharge time, emissions, costs of purchase, cost of operations, and life spans. The data upon which the buses were modelled was based on actual attributes of buses used at the time in Tel-Aviv, or on global industry standards.

Every morning at 5 am each bus "wakes up" and checks if it has a shift, meaning that their operator needs them for one of the clusters they operate. If it does – it leaves the station according to their predetermined shift time (between 5 am-1 pm), and starts driving around the city at a speed of 20 km/h for 10 hours (for a total of 200 km a day, the daily average for buses in Tel Aviv). Every passing hour buses lose energy from fuel or electricity at a realistic rate, and so they must conserve sufficient energy to reach the station before the end of their shift. Upon return to the station – diesel buses refuel within minutes, while electric buses recharge at a rate of 60 kWh per hour. Buses can only leave the station the next day if their energy is fully restored. If a bus becomes too old to meet the terms of the tender – it is discounted from the model (the agent dies). If the bus still qualifies for operation but is not a part of the active fleet (which size depends on how many tenders the specific operator won) – it remains in the station.

Every year the buses' costs of operation are updated based on different scenarios for the cost of energy and technological development.

Bus operators

Out of the host of public transport operators (companies) working in Israel, we focus in this model on three of the largest companies with the biggest market in Tel-Aviv: Dan, Egged, and

Kavim. The operators own the buses and are responsible for all aspects of their operations including maintenance and energy costs. In reality, in order to operate bus routes, each company must win every few years a tender set by the Ministry of Transport. The tender specifies the level of service the company must provide, and the subsidy it will receive in return, based on the km driven by the fleet as well as the number of passengers on board. In the model, operators must similarly win the tenders they are invited to bid on by the Public Transport Authority.

The two main variables the operators need to take into consideration in the model in terms of their bid are the total cost of ownership they'd present in the bid and their level of innovation through the introduction of electric buses. While cost accounts for 80 percent of the tender's weighting and innovation accounts for only 20 percent, the model experiments with different levels of subsidy granted to electric buses, affecting their total cost of ownership compared with diesel buses. Another constraint in this optimisation procedure is each operator's willingness to innovate, a predetermined parameter for each company that changes over time, representing the operators' willingness to adopt the new technology as time passes. This parameter is used to cap the number of electric buses operators can integrate into their tender, a cap that diminishes over time.

The operator must also decide how many new buses they will need to acquire overall to meet the requirements of the tender, meaning how many buses in addition to the ones it has in stock will it need to travel the new routes it may win. Since buses are limited in allowed age – introducing new busses to the fleet may be a gradual process. In the model, while electric buses are awarded better scores in the bid, they have a smaller range than diesel buses, thus requiring additional purchases.

Public Transport Authority

Every year the Public Transport Authority measures the difference between existing bus capacity as served by valid contracts, and the growing demands for ridership, based on a set population growth rate of 1%. It takes into consideration tenders that expired and determines how many km the new tender will need to fill. It then invites the operators to submit a bid and finally evaluates the competing offers. The higher the price offered by a bid, the more penalty points it receives. However, a higher proportion of electric buses in the fleet awards tenders with a reduction in penalty points. Once the authority determines the winning bid, the operator assigns old buses and purchases new buses to fulfil the new quota required in the tender it won, in addition to its ongoing contracts.

Emergent phenomena in the model

The model allows several phenomena to emerge based on the interaction between environmental factors such as energy prices, actor properties such as openness to innovation, and the preferences and demands set out by the regulator: First, the mix of buses in the fleet at any given moment and over time, meaning the trajectory of electrification over a time span of 16 years. Second, energy demand based on the rate of electrification at any given moment of the day in different hubs, as the mix of buses change. Third, the impact of the urban bus fleet on decarbonisation goals as buses switch from diesel to electric drive with their respective emission coefficients. Finally, the fleet's changing operational profile emerges over time, meaning shift structure and time requirements based on charging length, shift timing, and fleet composition.

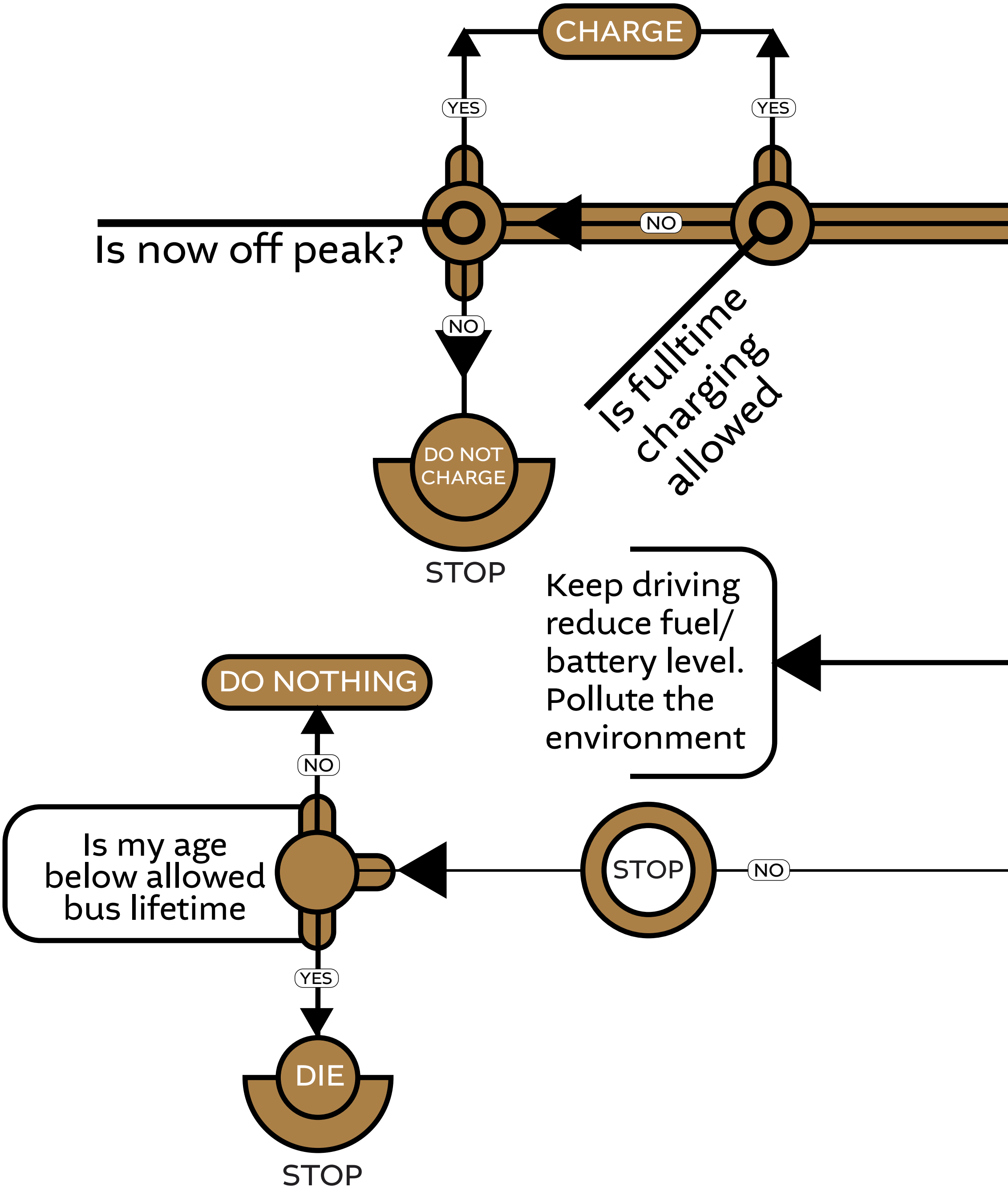
CHARGE
YES
YES
NO
Is now off peak?
NO
DO NOT CHARGE
STOP
Is fulltime charging allowed
Keep driving reduce fuel/ battery level. Pollute the environment
DO NOTHING
NO
Is my age below allowed bus lifetime
STOP
NO
YES
DIE
STOP

FIGURE 20: DAILY SEQUENCE OF EVENTS FOR BUSES IN THE MODEL, FROM DJOE (2015)

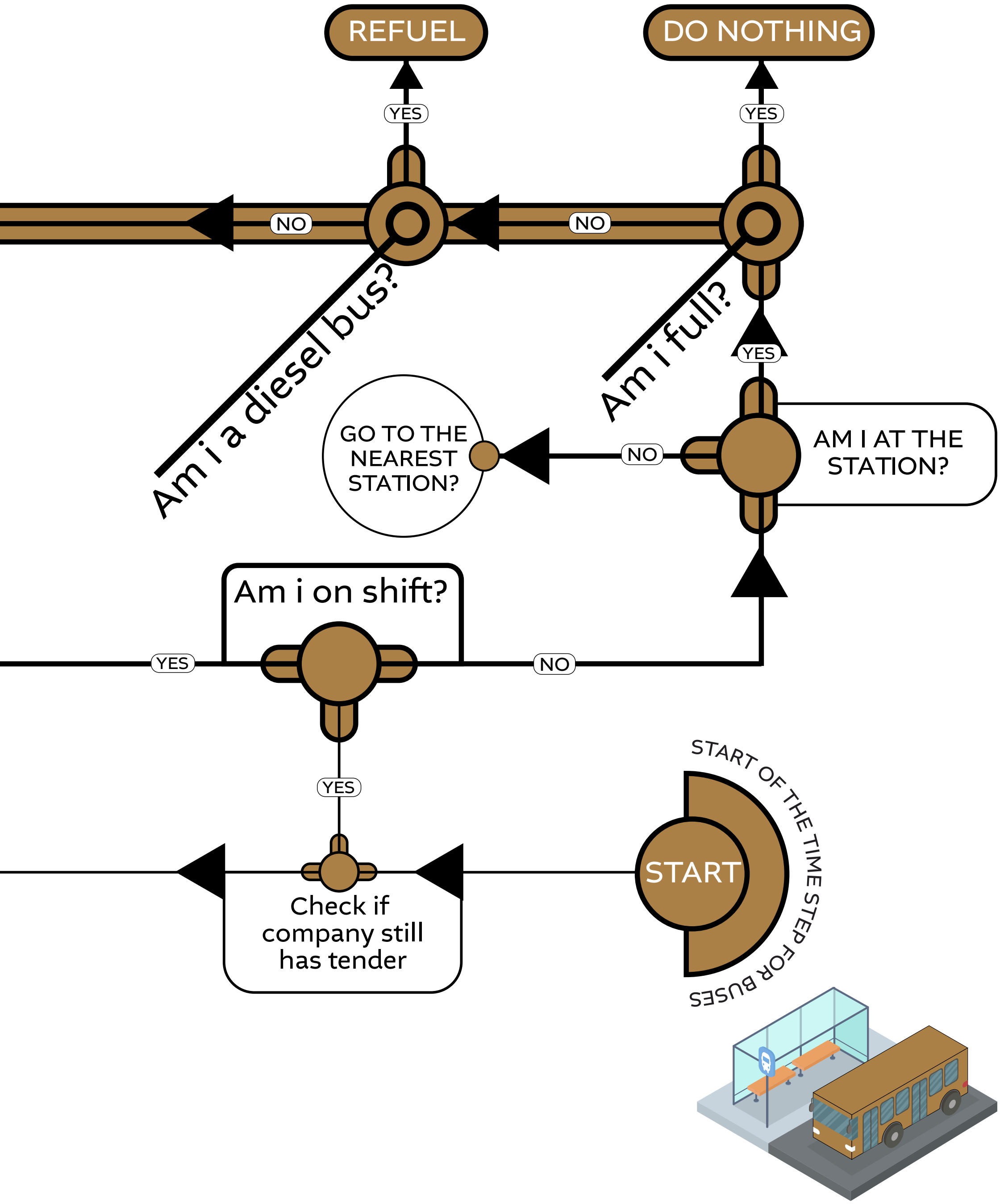

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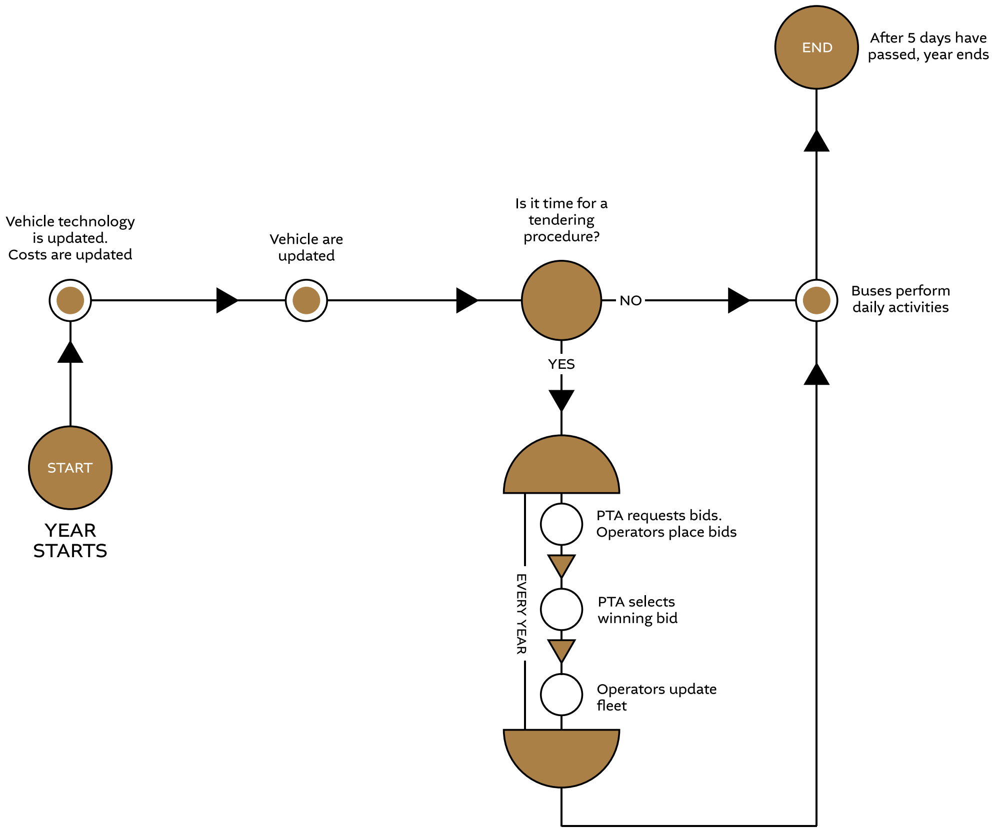
FIGURE 21: MODEL OVERVIEW: ANNUAL TIME FRAME, FROM DJOE (2015)



MODEL CALLIBRATION AND VALIDATION

The model used real world data of the Israeli electricity grid usage at a regional scale, cost of operation figures for different bus types, fleet size and company share in the Dan Metropolitan Area, and charging times and intensity based on the electric bus just entering the market at the time in Tel Aviv. This allowed the model to reflect the situation at year zero as reflected on the ground.

Model validation occurred in two phases – first, a first stage simplified model was created based on expert elicitation in Israel. Then, based on consultation and structured interviews with bus operators, public transport authorities representatives and public transport NGO's and consultants in the Netherlands, the second stage model was built and revised. This resulted in changes made to the tendering algorithm and to the government agent's behavioural design, as well as to the bus operators agents decision rules.

The PTAs assisted in improving the tendering mechanisms and the behaviour of The consultants and NGO's then validated the model overall, including the different components in the model, their interactions, and the tendering process simulated.

6.3.5 EXPERIMENTATION AND RESULTS

PARAMETER SETTINGS

While there is a long list of pre-determined parameters in the model, certain values were changed each run so as to assess the impacts of various policies, incentives, and market conditions.

TABLE 4: BUS MODEL EXPERIMENTS PARAMETER SETTING

PARAMETER	VALUE
Bonus for electric bus integration	0, 6000, 12000
Diesel price scenario	1-Drop in prices 2-Moderate increase in price (BAU) 3-Accelerated increase in price
Development speed Egged	0.05, 0.1
Development speed Dan	0.05, 0.1
Development speed Kavim	0.05, 0.1
Charging the bus is allowed at peak hours as well	true, false
Maximum allowed age of buses	8, 12
Initial maintenance cost per km of ebus	0.25, 0.38

The model was run with each configuration of the parameters (these ones in addition to the set parameters) 10 times to account for variations and deviations due to software implementation and interaction between variables. This allows statistical presentation of average, minimal and maximal results, and standard deviations, as can be seen in the whisker plot in figure 25.

THE IMPACT OF TENDERING POLICY ON EBUS MARKET SHARE

Under all scenarios, electric buses increased in number to a position of dominating the local bus fleet with over 1200 buses at year 16 of the model. Figure 22 presents the number of electric buses in the fleet over time under the three different subsidy regimes (on the top row of the matrix - from no subsidy to maximal subsidy), and three different scenarios for diesel prices (on the right side of the matrix – from a decrease in diesel prices to growing increase in price). The exception was that the scenario on the top left corner of the facet grid, with no subsidy and decreasing diesel prices will extend diesel buses' competitiveness compared with electric buses. Indeed, that scenario presents the slowest rate of market penetration for electric buses, though even then electric buses are the majority of the fleet by the end of the simulation.

6

The facet grid in Figure 23 presents the same figures, but compared with the number of diesel buses in the fleet. It shows that under most scenarios electric buses overcome diesel buses in prominence around year 13 of the simulation. While not unsurprising as year 12 was set as the maximum allowed age of buses in half of the simulation runs, this result underscores the importance of tendering requirements compared with market pricing for different components of fleet ownership and operation. Furthermore, the transition is gradual and builds up at a similar but not identical rate under different scenarios, allowing regulators to match the rate of infrastructure development with potential uptake.

FIGURE 22: NUMBER OF ELECTRIC BUSES IN THE FLEET OVER TIME UNDER DIFFERENT SUBSIDY REGIMES AND DIESEL PRICE SCENARIOS, FROM DJOE (2015)

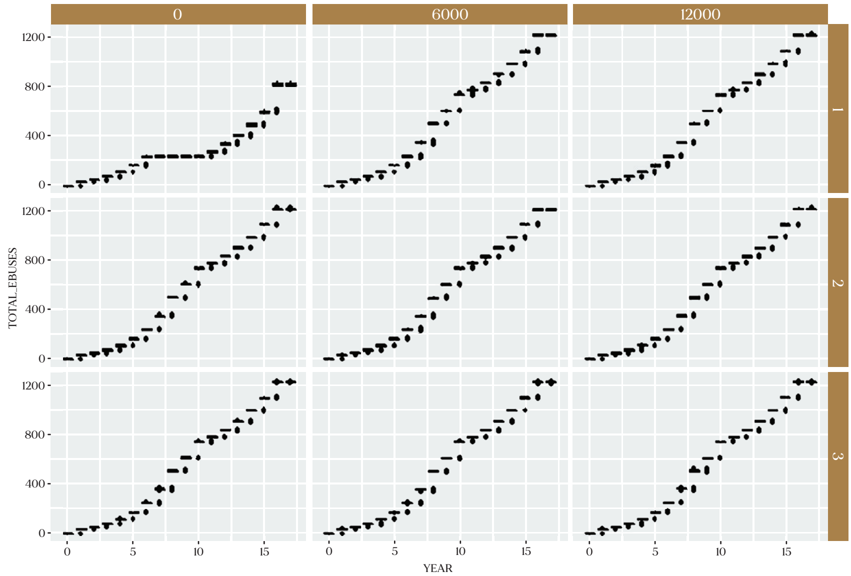
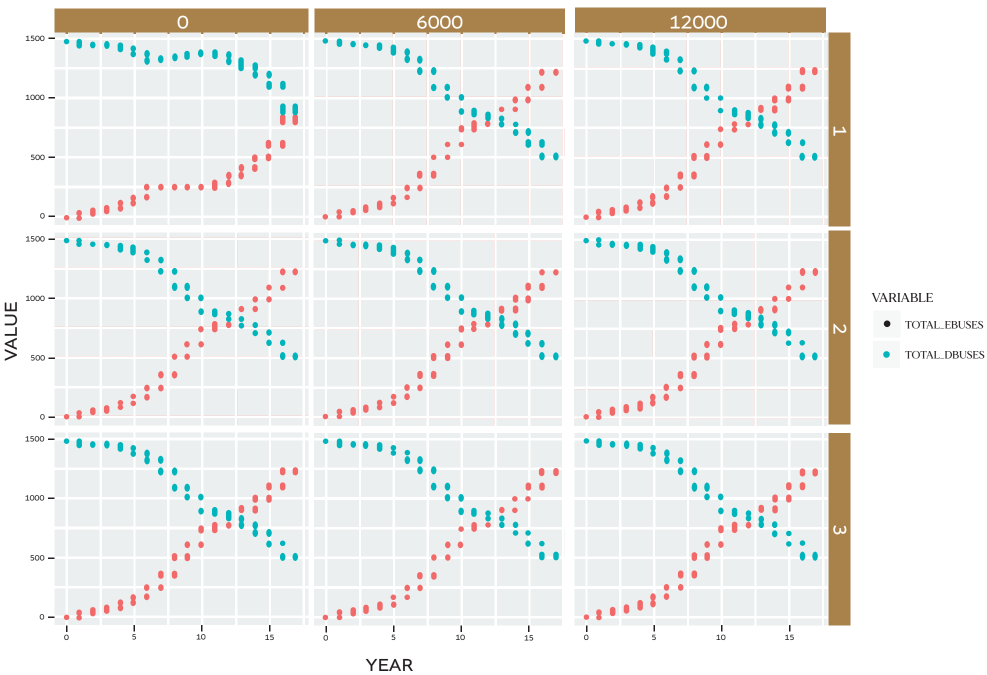
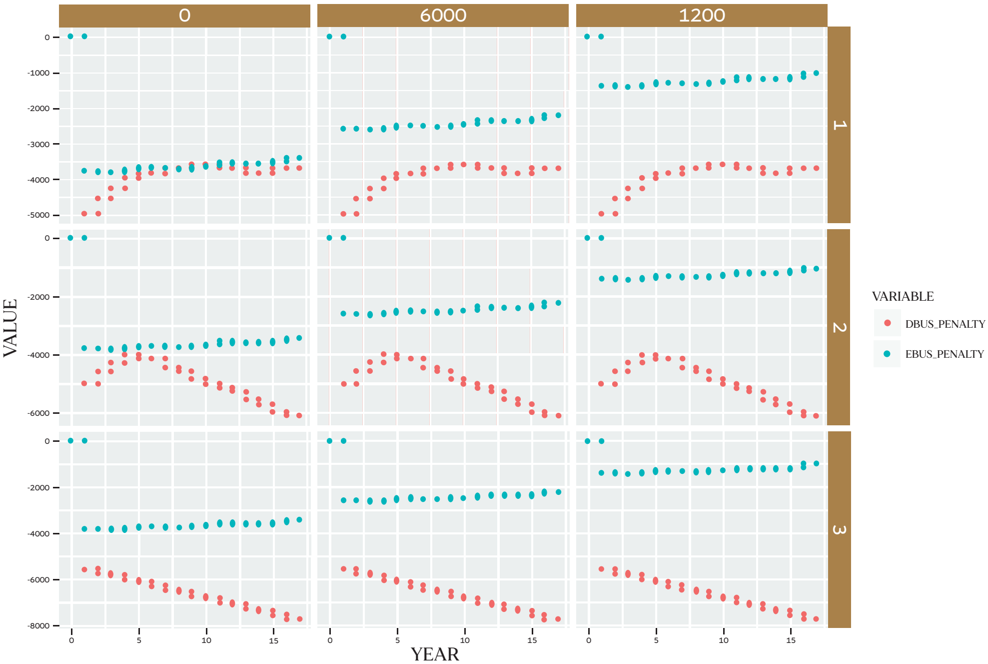


FIGURE 23: NUMBER OF ELECTRIC BUSES VS DIESEL BUSES IN THE FLEET OVER TIME UNDER DIFFERENT SUBSIDY REGIMES AND DIESEL PRICE SCENARIOS, FIGURE FROM DJOE (2015)



In terms of policy design, in this case a resilience policy aimed at ensuring the stability of the transport-energy system while promoting its transformation through electrification, three key points arise from the model: On the effectiveness of policy instruments, their desirability, and their limitation in changing industry behaviour. First, how effective is the subsidy, and how big should it be in order to tip the balance in favour of electrification? The Total Cost of Ownership of electric buses in the model, based on market analysis, is designed such that it goes down over time. Thus, it should make no difference at a certain point whether subsidies are in place. However, as mentioned above, while there is little difference in terms of outcome between a 25% subsidy for the buses' total cost of ownership and a 50% subsidy, there is a sizeable difference between no subsidy at all and a 25% subsidy. This observation is also visible in the facet grid below that shows the "penalty points" given to electric versus diesel buses in evaluating each tender, which correspond, basically, to the weighted cost of ownership of each type of bus.

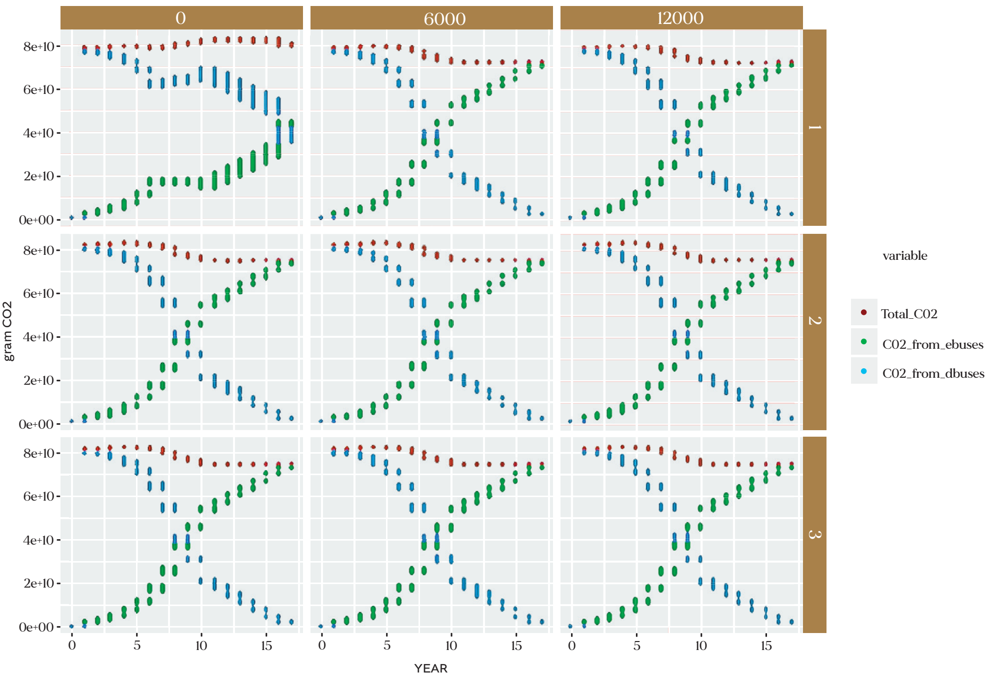
FIGURE 24: RELATIVE COST OF OWNERSHIP UNDER DIFFERENT COST OF OWNERSHIP SCENARIOS FROM DJOE (2015)



While under all diesel price scenarios, electric buses are preferable to diesel buses with a subsidy of 25% of cost and above, decreasing diesel prices with a zero-subsidy scenario creates parity between the technologies, possibly tilting the balance in favour of diesel buses. Since the total cost of ownership for electric buses versus diesel buses changes over time with fluctuations in electricity prices, diesel prices, and technology prices, using a subsidy (or alternatively different weighting of innovation) should be calibrated to the actual cost, desired rate of penetration, and the point beyond which the marginal benefit of subsidies is no longer justified in terms of added penetration.

The second point of contention is policy desirability. We mentioned before the different reasons the government may pursue a policy of electrifying buses in Israel – from consumer desirability to decreasing street-level air pollution. Currently, the government is promoting electrification as part of its effort to decrease the transport sector's carbon emissions under Israel's commitment to the UNFCCC. However, the model shows that while full adoption of electric buses decreases emissions from 80ktCO2/year to 70ktCO2/year, it does not contribute significantly to Israel's overall climate mitigation goals. These numbers would of course change with the scale of adoption nationwide and with a deepening transition from natural gas and coal toward renewable energy production in Israel, however as buses comprise only 1% of Israel's GHG emissions – even at full adoption the change would be perhaps important yet not considerable in and of itself. It could, however, lead to greater savings in emissions if it is able to impact the modal split by attracting commuters away from their car and toward public transport, especially commuters who reach the metropolitan centres from towns farther out, and could be perhaps persuaded to use the new local buses in combination with the train. That, however, requires further investigation beyond the scope of the model.

FIGURE 25: CO2 EMISSIONS FROM BUSES IN THE FLEET, FROM DJOE (2015)



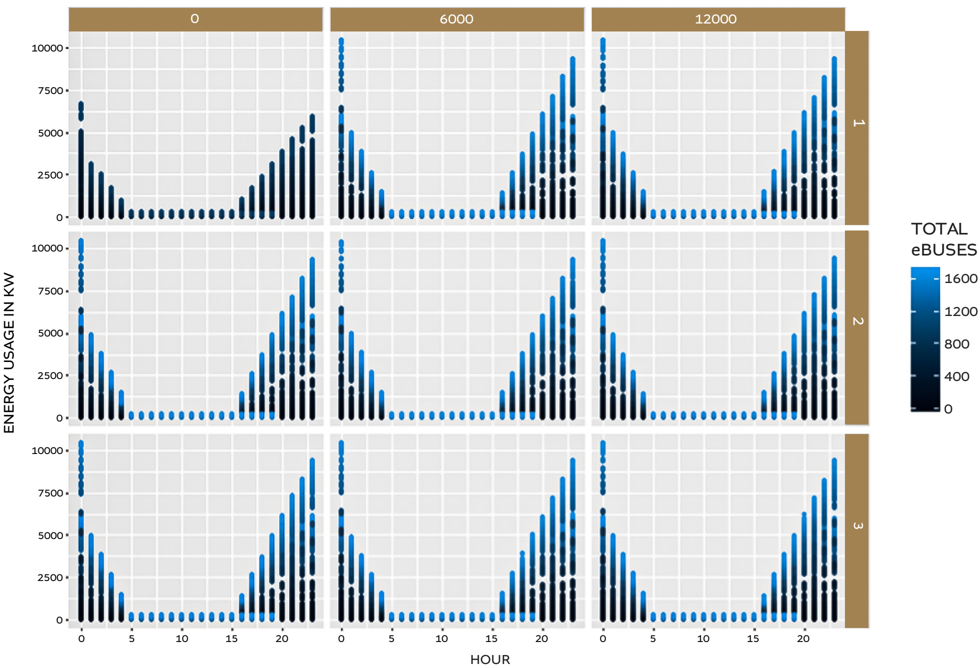
This result begs the question of whether a subsidy is worth the investment. From a resilience standpoint, the answer depends on how policymakers frame the policy goal. If the goal is the long-term transition to a low-carbon economy where the transport system is completely electrified, then perhaps providing a preliminary push to change the market balance toward electric buses is necessary. If the goal is to provide immediate relief to air pollution – the difference between zero tailpipe emissions and the relatively small amount of emissions from newer euro bus standards may not be justifiable.

However, examining emissions at a sub-municipal scale, some neighbourhoods, especially in the south of Tel Aviv suffer much of the brunt of tailpipe emissions due to the historic location of the central station. Thus, any immediate relief would be more than justifiable, but necessary. On the other hand – as long as Israel is dependent on fossil fuels for electricity production, the health implication of relocating emissions from the tailpipe to power plants must be examined more closely. Finally, in terms of increasing ridership, there may be a trade-off between the desirability of electric buses in the eyes of consumers, and the alternative costs of electric buses. Instead of subsidising the more expansive technology, the ministry could, for example, invest the money in expanding the network of existing lines' frequency. Thus, the exact kind of transformation desired, the spatial and temporal scales most important to policymakers, and the desired rate of change are all crucial variables to compare these different pathways toward an alternative equilibrium where electric buses gain market prominence.

THE IMPACT OF ELECTRIFICATION ON ENERGY DEMAND

In terms of impact on the energy grid, which was the main driver of this analysis for our policy stakeholder, the Israel Ministry of Energy, the following facet grid shows the additional load created by electric bus recharging at different hours of the day under the different scenarios of market penetration. Assuming the actual operation of the buses will follow a similar logic to the one presented in the model – electricity demand starts increasing from late afternoon until midnight, gradually decreasing until buses start leaving for their morning shifts. Under the most optimistic predictions in the model, the load would just exceed 10 MW at peak time, which should not pose a challenge for Israel's unitary electricity production system. However, it would probably require installing additional distribution infrastructure at the night depots/ stations where charging takes place. Examining the number of expected buses in each location and corresponding usage throughout the day could help planners design a resilient charging infrastructure, possibly using different market penetration scenarios to determine the rate at which infrastructure should be upgraded or supplanted over time.

FIGURE 26: ELECTRICITY CONSUMPTION BY EBUS FLEET THROUGHOUT THE DAY UNDER DIFFERENT ELECTRIFICATION OUTCOMES, FROM DJOE (2015)

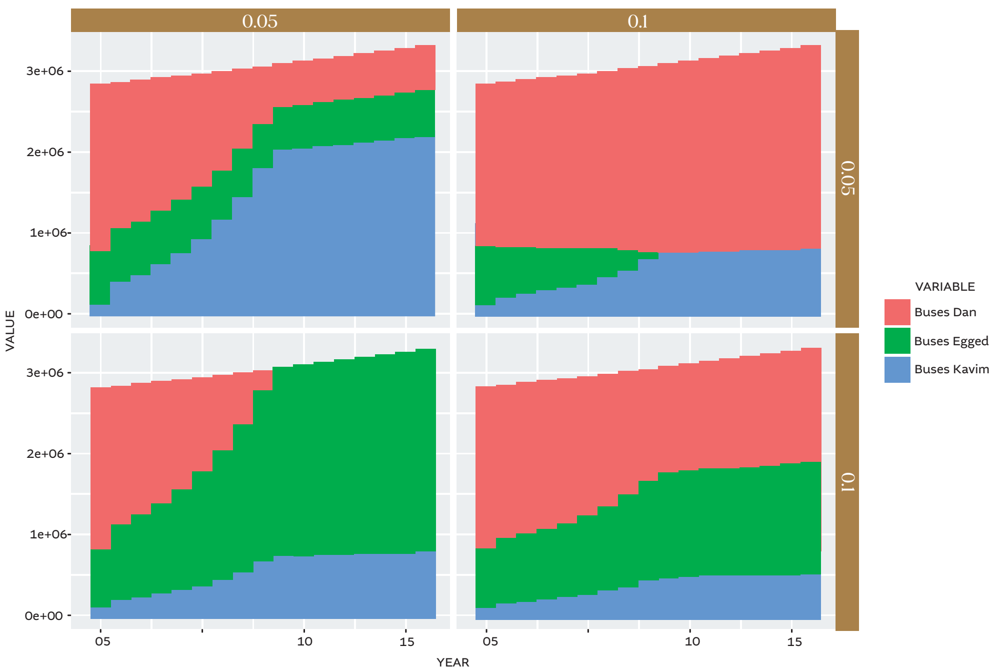


THE BENEFITS OF WILLINGNESS TO INNOVATE TO MARKET ACTORS

Finally, the model shows a clear market advantage to early adopters of the technology. In the facet grid below – the top and right side variables represent Egged and Dan's willingness to adopt electric buses, and their market share over time. On the top right – Dan is twice ahead of Egged in its adoption speed, gaining almost complete control of the market by the end of the model run. The bottom left is an inverse of the same scenario, with Egged gaining control of the market, despite the fact that its initial share is much smaller. Of course, that depends on the validity of the total cost of ownership figures over time, but it also reflects two important factors for policymakers: First, perhaps other policy instruments besides pricing mechanisms could accelerate diffusion, by working with industry to facilitate the transition: training employees, helping in new supply chain design, applying pressure to senior management, or creating new paths for knowledge transfer between companies abroad and in Israel, or even different companies within the market. Alternatively, the ministry has already begun including mandated minimums for the number of electric buses that have to be purchased in its tenders, essentially forcing bus operators to initiate a process of adopting this new technology and build the necessary capacities within the company to support it.

Secondly, the pathways that emerged in the model can serve as a sort of early warning system. If the total cost of ownership is indeed in favour of electric buses as assumed in the model, but companies do not increase the share of electric buses in the fleet beyond what is mandated – there might be a need for further intervention in the market – either by increasing mandated minimums, finding barriers for adoption of the new technology, or re-calibrating the financial calculus for both technologies at both industry and government.

FIGURE 27: MARKET SHARE BY COMPANY AND WILLINGNESS TO ADOPT EBUSES, FROM DJOE (2015)



6.4 HOW DOES THE MODEL INCORPORATE THE DIFFERENT ELEMENTS OF RESILIENCE POLICY PREVIOUSLY EXPLORED

The model presented above was not predefined as a model of resilience policy. It seeked a specific answer to a specific policy challenge and could be defined as a model for transportation policy planning, climate policy analysis, or indeed an energy policy model. However, the very nature of the policy question at hand – preparing for a change in the system's landscape and moving toward a new socio-technical equilibrium – positions it as a clear resilience policy in the domains of energy, transport, and climate.
Thus, it is worth examining how the model manifests some of the aspects of resilience policy captured in previous chapters of this dissertation: How does it facilitate achieving the resilience policy goals and environment described in chapter 2 and 3? How does it correspond with the shared components of resilience policy identified in chapter 4? And how does its interaction of different scales help understand the interests and needs of different stakeholders, and the trade-offs between them, as described in chapter 5?

6.4.1 RESILIENCE POLICY GOALS AND ENVIRONMENT

HOW DOES THE MODEL HELP ANALYSE AND PROMOTE RESILIENCE POLICY GOALS?

The model was originally designed to support one explicit policy goal – to ensure that the electricity system can withstand and support any transition that may occur over the coming decade to electrified public transport in Tel Aviv. However, as a classic resilience objective, the model helps uncover the different goals that comprise it:

Connectivity

The model enhances connectivity across domains as well as actors by tying together operational decisions about bus fleet logistics, tactical decisions on electricity infrastructure, and strategic decisions about investment in new transport technologies. These decisions belong to at least three different ministries – the Ministry of Energy, the Ministry of Transport, and the Ministry of Finance. The model creates a new decision space between them, poring substance to the growing domain of energy-transport as a unified system. The model makes concrete the actual demands of electrification, showing the system's ability to carry the additional load, and reassuring actors of the transition's viability in terms of the electric grid. However, it also allows actors to cast doubt about the transition's climate mitigation potential, possibly undermining the alignment of the transition as a policy solution to the climate policy problem.

Flexibility and redundancy

At an operational level the model explores which redundancies in electricity infrastructure would be required to fulfil the new needs of electric buses. It also allows the fleet managers to see the implications of electrification on shifts allocation, range, and the timing of charging, which at the moment is significantly less flexible than refuelling in terms of the space-time it requires: as long as it takes several hours rather than minutes, buses require multiple parallel chargers or a more intricate timing of the charging operation.

At a tactical level – it allows policymakers to explore alternative instruments to achieve electrification, taking into account different eventualities in technology prices, energy prices, and companies' willingness to adopt new technologies: changing the terms of the contract, offering different levels of subsidy, or creating non-tangible support schemes to facilitate electric bus adoption.

At a strategic level – the model allows policymakers to compare electrification with other policies for improving climate mitigation and air quality that may achieve similar results at a reduced cost, or alternatively – ask what else is needed in order to achieve the full potential of electrification as part of a larger transition in the transport-energy system.

Diversity and Variability

The model brings to the table and is intended to inform actors from across the energy-transport system: public transport operators, regulators, finance officers, environmental planners, infrastructure engineers, and the public that uses the system and is affected by its performance. However, it somewhat undermines the functional redundancy in policy framing promoting bus electrification so far. While in the past, civil servants in different ministries rejected electrification as a worthwhile effort as there were other alternatives deemed more worthy of investment to achieve particular policy goals (GHG mitigation, air quality, level of service), in terms of agenda-setting - electrification benefited from a degree of ambiguity that gained it support as a solution to all these different policy problems. However, while this was not the primary goal of the model, modelling the transition to electric buses makes it possible to examine each of these policy goals in and of itself, possibly compared with other alternatives (lower impact diesel buses, other mitigation activities), thus dissolving some of the ambiguity electrification enjoyed as a policy solution.

Robustness

The model looks at different scenarios for market evolution in terms of energy prices, technological development, and technology diffusion, and allows policymakers to tailor their interventions to optimally adjust the rate of electrification. This is intended to ensure that the transport and energy components of the systems are in sync in their rate of development, but it also allows policymakers to consider what changes they need to make in their tendering procedures, the conditions they set for the operators, and the support they provide them in order to reach the electrification goal they set.

Mitigating vulnerability

Several vulnerabilities are confronted in the model: first and foremost the energy-transport system's. The primary objective of the model is to ensure that if installed, electric buses have the electricity infrastructure in place to ensure seamless operation and that the wider electricity system is not undermined by the additional load. Second, and perhaps more in line with the need to consider social justice and equity, the model examines how the transition affects vulnerable populations in the city that suffer from air pollution, especially around transportation hubs (though it does not consider possible pollution at source – whether in power plants or further back in the electric vehicles' value chain). That said, as the budget for electrification may be directed at the expanse of increasing bus frequency, for example, other vulnerable populations (such as elderly users of public transport) may have different priorities and conclusions on what equity means in this particular policy problem. Finally, the model allows policymakers to face the vulnerability of the electrification policy itself to changes in the market and other barriers that may require changes to the parameters of interventions included in the model, or additional interventions that were not.

HOW DOES THE MODEL HELP DESIGN A RESILIENCE-ORIENTED POLICY ENVIRONMENT?

Many of the attributes and functions of a resilience-oriented policy environment can be strengthened and supported by this model in the transport-energy ecosystem. First, it breaks traditional boundaries between agencies, fitting the scale of problems and institutions, and creating space for learning and innovation. In this case, whereas traditionally the ministries of transport and finance design and monitor public operators tendering processes and operations and the ministry of energy the electricity grid, this model redefines the system boundaries so they are all required to provide their expertise and decision-making power. It further brings into the fold the ministry of environmental protection in considering the desirability of the transition from a climate and air pollution perspective. The model is also based on conversations, interviews, and data collection from these various agencies and actors that helped shaped the design of the model and the data at its core.

Second, the model provides a new method for complexity-oriented policy analysis – it examines the move from one equilibrium (diesel buses dominating the fleet) to another (electric buses dominating the fleet). It demonstrates what policy and market conditions can trigger this change of state based on the operators' own decisions, their "rational" analysis of costs, how it is affected by different configurations of the tender (such as maximum age allowed for buses and weighting of innovation versus cost), by financial incentives, and other barriers to diffusion that may hold them back. It also considers the implications of actually reaching the new equilibrium in terms of the energy and operational needs (though it does not explore what happens if incentives change back after full adoption had occurred).

Third, the model examines cross-scale interactions – how changes in the global industry affect local decision-making, how decisions by individual bus companies affect the country's climate goals or the city's exposure to air pollution, and how incentives structured over a time-frame of years (in the tender) affect operations at a logistical scale of days and hours (through charging and shifts). This also allows policymakers to better understand how to manage slow and fast variables in the transport-energy system, with tenders occurring once every few years setting the tone for more frequent bus acquisition and replacement, and the daily operation of the electricity grid.

Fourth, the model makes it easier to make decisions under uncertainty, as it reveals strategies that can work under different development paths in the market, and that provide a win-win situation for regulators, bus operators, and public transportation users. This also facilitates a planned transformation toward full electrification, as the model explicitly represents the actions different actors need to take in order to facilitate it, from tender design to rethinking of the supply chain, allocating space for charging stations, installing the necessary infrastructure, and even making possible changes to shift times or routines. It also gives a direction for how best to use positive disturbances such as the annual climate negotiations as a window of opportunity to promote electrification, by clarifying the extent of resources required to expedite the transition.

6.4.2 HOW DOES THE MODEL SUPPORT THE COMMON COMPONENTS OF RESILIENCE POLICY?

The model operationalises many of the components of resilience policy mentioned in chapter 4, mainly domain, strategy, institutions, stakeholder engagement, and capacity building: It carves out a new space for resilience thinking in the specific domain of transport-energy. It makes clearer the resilience implications of electrification for both bus operators and the electricity grid, going from operational and daily factors to the strategic factors impacting full-scale transformation. In terms of strategy – it lays out the road plan to transformation and allows discussions of the pillars of operation required to implement it by each of the actors. This is also essential in terms of building new institutions to support the transformation – from new subsidies and forms of support to operators to joint operations of the ministries involved. The model helps to build each of their respective capacities in analysing the transitions and understanding the challenges the others face in supporting it. In this sense, the model is a tool for stakeholder engagement non-hierarchically.

6.4.3 HOW DOES THE MODEL HELP US UNDERSTAND TRADEOFFS FOR DIFFERENT STAKEHOLDERS ACROSS TIME AND SPACE?

Chapter 5 demonstrated how different strategies for bolstering resilience entail trade-offs for competing policy goals and perspectives across time and space. This model operationalised that approach in examining how a transformation in the bus fleet as part of a larger understanding of climate resilience may affect the much shorter-term resilience of daily operations in both public transport fleets and the electricity system. It also brings up the question of whose resilience is improved and whose is undermined by accelerating or abstaining from the transition to electric buses. For example, one of the determinants of the speed of adoption in the model is openness to innovation. While the model only represents this quality as a general factor, it represents more than just an approach of "sticking to what you know" or avoidance of transaction costs when finding new suppliers and value chains.

It also represents employees that may need to go through training to be able to handle the new technology (for example mechanics), or even lose their job if indeed maintenance needs are considerably lesser when switching to electric power drives. It could also mean that operators lacking the initial capital to transition find it harder to compete with the larger operators, leading to a market consolidation that some may view as less desirable. On the other hand, delaying electrification has very real consequences for residents in certain parts of the city that are suffering from extensive air pollution from public transport, though perhaps the transition to electric vehicles could undermine their plea to remove a local transportation hub that increases their exposure to air pollution, among other environmental harms. Furthermore, the costs of the transition for the state, as exposed by the differences in tender offers, could be used for evaluating other measures to mitigate both air pollution and climate change, as well as extending public transport service.

6.5 CONCLUSION

This chapter demonstrated how an agent based model of a particular policy can incorporate the different aspects of resilience policy previous chapters explored. Modellers could test and experiment with what happens at different levels of subsidy, though it remained static throughout the simulation, and it wasn't impacted by developments in the policy system. While for some types of policy that is not a crucial impediment, resilience policy is by definition dynamic in nature. It must respond to changes in the environment, in technology, and in society, and evolve over time. This requires adding a layer of complexity to the model, which will be explored in the next chapter.

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CHAPTER SEVEN

07

CHAPTER SEVEN

ENDOGENOUS

07

ADDING POLICY EVOLUTION TO RESILIENCE POLICY MODELS

This chapter takes agent based modelling of resilience policy a step further, looking at ways the policy process can be endogenised within the model itself, allowing the domain side of the system to co-evolve with the policy system itself and the policies it decides to implement.

This chapter builds on the Master's thesis of Raphael Klein, with whom I worked as supervisor on this project. Full model documentation can be found in Raphael's thesis, available at the TU Delft Repository: Klein, R. (2017) Policy emergence: An agent-based approach: http://resolver.tudelft.nl/uuid:1dd6d1d1-fec3-4aa7-b952-7b208b410750

It also presents results of the honour's project by Lotte Lourens and Anna Noteboom, supervised by Raphael and myself. Specific attributions of their work will be mentioned throughout the chapter.

7.1 INTRODUCTION

The previous chapter demonstrated that ABM can be highly useful for analysing resilience policy. However, while most agent-based models grant agents the ability to make autonomous decisions and react to changing environments, they often rely on modellers determining beforehand which policies the model should examine. The modeller then chooses which policies are going to be implemented in the model either as environmental factors that agents can respond to, or as predefined choices coded into the agents that can be activated in face of an external event. However, analysing resilience policy requires much more flexibility in modelling. It requires agents to be able to formulate a policy not based on predefined modeller decisions, but rather as the result of interaction between different social forces and actors, and between them and the physical and social environment in which they operate. In other words, it requires endogenous policy creation within the model.

This chapter offers a new approach that aims to resolve this gap. It explores ways to endogenise the policy in ABM, so that the models policy analysts use can demonstrate how the policy may evolve in conjunction with the changes occurring in the system it is trying to impact. This will be achieved through a detailed review of approaches taken in the past to represent different components of policy making in ABM, followed by a proposal for how to conceptualise the policy process in ABM and analyse the data it produces.

Finally, while this chapter presents sufficient details about the new modelling approach to convey its overall rationale and mechanisms, its goal is not to provide an in-depth analysis of the proof of concept model. Instead, its goal is to assess its usability to resilience policy analysis, which is the focus of the final section of this chapter: examining how the different elements of the resilience policy framework, structure, and trade-offs presented in chapters 2-5 can be incorporated or supported by this new modelling approach. The model itself is presented and documented in full in Klein (2017), available online at the TU Delft repository: http://resolver.tudelft.nl/uuid:1dd6d1d1-fec3-4aa7-b952-7b208b410750

7.2 MAKING THE CASE FOR ENDOGENISING POLICY IN ABM

INCREASING LEVELS OF POLICY REPRESENTATION IN THE MODEL

When we talk about endogenising policy in ABM, we do not propose this is a binary determination. Rather, there are degrees to which policy can be incorporated as part of the model. Chappin and Dijkema (2010) offered a useful classification for policy representation in ABM: they defined four levels of complexity for modelling 'transition assemblages', which is a term they defined as a set of policies, regulations and R&D strategies. The four levels can be more broadly interpreted as the extent to which the policy process itself is endogenous to the model: Level 1 refers to models that use a fixed set of policies and regulations that are implicit in the model, rather than represented explicitly. In level 2, policies become a fixed system parameter, meaning that agents can base their decisions on its settings, but the policy itself cannot be changed as it is unrelated to other system properties. It is still exogenous to the model. In level 3 – policy is represented as an exogenous scenario parameter, meaning that the policy process itself is not yet modelled but different policy options can be implemented in the same model. In this level "policy" can have parameter values that vary between runs, draw on trends that develop after several runs of the simulations, or on external system dynamics models. In level 4 models policy development is endogenous, meaning that government is an actor in the model, and it decides what its policies will be during and as part of the simulation.

According to the authors, at this level "Government's actions are the outcome of its decision rules and the state of the system, i.e., past, current and expected values on system parameters. Since the system's state depends on the agent's reaction to government policy, the government's behaviour would be a result of its own behaviour in the past in relation to the behaviour of other agents. As a consequence, the policy setting is an emerging property of the system." (Chappin and Dijkema, 2010)

Building level 4 models, or models that endogenise the policy process, increases their complexity significantly. This requires additional data, design and programming effort, capacity for data analysis, and coping with uncertainty in interpreting model results that could be affected by additional variables and interactions. So why is this effort worthwhile, and why is it especially useful when analysing resilience policy? First, it helps us better understand how both society and the environment we live in co-evolve over time. Second, endogenous policy models can help policy scientists explore policy itself in new ways.

MODELS BETTER SUITED FOR (RESILIENCE) POLICY ANALYSIS

Resilience policy, by definition, is not static. It changes in response to new shocks and stresses society identifies or nature imposes. Furthermore, if effective, it also shapes both nature and society. For example, a heavy storm like Hurricane Ida in 2021 that cost dozens of lives on the eastern coast of the United States focused attention on vulnerabilities to floods, especially in urban areas and low cost below ground-level housing. It also brought to the fore the imminent dangers of climate change, just as the debate over climate change legislation was in the airwaves and the climate talks in Dublin were about to commence. Thus, US climate policy, a specified resilience policy, was both affected by this natural disaster and affected the future environment in which similar disasters are more or less likely to occur through mitigation and adaptation efforts. Models supporting decision-making not representing these possible shifts in policy are less likely to capture the pathways for both resilience policy evolution and the evolution of the system as a whole. Furthermore, endogenising policy in ABM presents an alternative to empirical statistical models that extrapolate past data to predict the close future, assuming a linearity of events that doesn't apply in times of great change (Farmer and Foley, 2009).

In addition, different actors in the political system – politicians, voters, and even the system itself are prone to change over time. ABM allows this change to be incorporated into the model, as actors can learn, remember, and be affected by their environment. Instead of finding just the end state of the system, we can learn how it evolved, and what happened within the political process itself. ABMs are better suited to represent the way these actors actually think and behave: with a lack of knowledge about certain aspects of the world or other actors, with limited time and capacity for calculation, and with a value structure that can change, is inconsistent or even contradictory. They instead use trial and error and look for satisfactory rather than optimal solutions and outcomes. Modelling how these actors change and change the system over time also allows better model validation, by comparing the evolution observed in the model to real-world observations (Muis et al., 2010).

SUPPORTING POLICY RESEARCH

Political scientists have long used formal modelling techniques to study the ins and outs of the political system – from the effect of allocation of responsibilities and appointments to ministries on a Prime Minister's ability to implement her policies (Dewan and Hortala-Vallve, 2011), to the ways "civil service systems of personnel management interact with bureaucratic discretion to create expert bureaucracies populated by policy-motivated agents" (Gailmard and Patty, 2007), how certain ideologies characterise government agencies (Bertelli and Grose, 2011), or how political contributions affect elected officials' ideological positions (Bonica, 2013).

However, agent-based modelling enables a much more intricate model design, allowing patterns to emerge, and agents to interact with one another and with existing political structures. Thus, the range of hypotheses tested can be significantly widened, providing new methodologies for political and policy processmtheory demonstration and validation.

ENHANCING THE POLICY-SCIENCE INTERFACE

ABM offers a possible bridge between policymakers and policy scholars. Cairney (2015) argued that translating the language of policy process theories is crucial to foster a debate that builds on scholars' ability to generalise conclusions across government, as well as practitioners' expertise in developing a particular policy for several years. This debate is important for improving our analysis of the policy arena, and also for providing policy advice. While some argued that trying to objectify reality through overly formalistic mathematical models can be dangerous to our connection with reality and the lived experiences of others, others have pointed to the contextual nature of complexity theory, which actually ties knowledge with greater participation MORÇÖL (2005).

7.3 REVIEWING DIFFERENT APPROACHES TO ENDOGENISING POLICY IN ABM

Before moving on to describing the new modelling approach it is worthwhile to review past attempts at endogenising policy emergence in ABM. We categorised these models under six broad categories:

1. Goal-seeking policy making,
2. Building tailored profiles for decision-makers and government organisations,
3. Policy packaging,
4. Modelling political parties' behaviours,
5. Modelling stakeholder dynamics,
6. Using theory to design agents and models.

The final category of theory-based models also inspired the approach proposed in the final section of the chapter. For the purposes of brevity, more detailed explanations about some of the models mentioned in this section are presented in annex D.

7.3.1 GOAL SEEKING POLICY MAKING

One of the traditional ways to model policymakers' decision-making process is to focus on the somewhat rational process of weighing the efficacy of policy alternatives, in an attempt to either optimise decisions or satisfy some goal or agreed-upon indicator of success, similar to the electric bus model presented in the previous chapter. For example, Carrillo-Hermosilla (2006), Zhou and Mi (2014), and Tang et al. (2015), all included agents representing government agencies that used different optimization techniques to adjust their policy decision in order to optimise their strategy for meeting a predetermined goal: they look at the potential outcomes of implementing a certain level of tax, quota, or a subsidy, and choose the instrument and beneficiaries that most efficiently achieve that goal.

7.3.2 BUILDING TAILORED PROFILES FOR DECISION MAKERS AND ORGANISATIONS

Policymakers can utilise different types of decision rules, or procedures, in choosing one policy alternative over another: while they can apply a rational calculus by which they compare each of the alternatives at hand with their expected values based on probable cost and benefits, they may also use heuristics, or mental shortcuts to reach a decision without having to consider all the information at hand. For example, they can use a categorical imperative such as "no new taxes", or a historical precedent that fits the current situation to their past experiences (Thorngate and Tavakoli, 2009).

ABM's computational strength allows researchers to use tailored profiles to simulate interactions amongst agents, between them and their environments, and even between them and the problems they encounter. For example, Davies et al. (2014) examined how regulators' personal traits may affect their willingness to consider evidence delivered by the actors they are regulating, while Chang and Harrington Jr (2006) on modelled the effects of organisational norms and culture. ABM was also used to represent differences in how different government groups and organisations responded to policy through a more abstract conceptualisation, where models were populated with agents that represent different approaches to policy acceptance rather than actual agencies (e.g. Wu et al., 2008).

7.3.3 POLICY PACKAGING

Policies often consist of assemblages of tools and instruments, or by another name – policy packages. Taeihagh and Bañares-Alcántara (2014) proposed a methodology for constructing policy packages using an ABM that represent the interaction between relevant stakeholders and decision-makers. The model allows agents representing policy makers and other stakeholders to evaluate which policy measures would meet performance and feasibility criteria, choose policy measures that amplify one another in achieving their policy goal, and negotiate with other agents for policy consensus.

7.3.4 MODELLING POLITICAL PARTIES' BEHAVIOURS

Political parties have a great deal of influence over policy as party members are elected for policy-making positions, and party leaders impact how voters understand and perceive different policy issues. Political scientists have utilised ABM to simulate shifts in party preferences. This strand of ABM captures decision rules that aim to optimise electoral support for the party through different strategies such as complying with demands from the party base or imitating government positions (Schumacher and Vis, 2012). They also simulate voter reaction to these strategies (Muis et al., 2010), and allow voters to interact and influence each other's voting behaviour (Fowler and Smirnov, 2005).

7.3.5 MODELLING STAKEHOLDER DYNAMICS

Modellers can capture the policy environment in which the policy emerges by focusing on the relations between stakeholders – their different power positions, the interests and beliefs that drive their decisions, their impact on policy actors across different scales (local-national-international), and engagement efforts policymakers have initiated to include them in the policy process. Some models focus on stakeholders' power balance in relation to one another and how they may compete based on game theory calculations (Abdollahian et al., 2006), personal and familial networks and affinity (Kuznar and Frederick, 2007), mutual respect and acquaintance (Zellner et al., 2014), and beliefs and attitudes toward policy proposals (Pahl-Wostl, 2002; Valkering et al., 2005). Some policy models linked different scales of policy making and outcome, such as international climate negotiations with household decisions and behaviour (Gerst et al., 2013), or iterative planning processes based on proposals from local stakeholder agents (Svalestuen et al., 2015). Finally, ABM can be used to engage with stakeholders either during the modelling process through participatory modelling so as to shape agent rules (d'Aquino and Bah, 2013), generate scenarios, and analyse model output (Scherer et al., 2015)

7.3.6 USING THEORY TO DESIGN AGENTS AND MODELS

Zia and Koliba (2015) argued that simulation models should play an essential role in describing the mechanisms of complex policy and governance systems, based on theories of the policy process that are inherently complexity friendly. These theories look at the holistic properties of complex systems in order to avoid reductionism. They describe the emergence of new structures and functions, they take into account feedback dynamics where clear cause and effect relationships are not readily apparent, they allow self-organization to play a part in shaping the system or parts of it, and they contain path dependencies in the system's evolution. For example, the multiple streams theory views the policy system as constantly evolving rather than reaching a static equilibrium, it assumes that the three streams' coupling occurs through generative processes, and it acknowledges that actors work to actively align them to achieve a policy goal.

In the last decade, several researchers designed agent-based modelling frameworks and simulations that bring to digital life the formalisations suggested by such institutional theorists as Elinor Ostrom. Balke, De Vos, and Padget (2013) viewed institutions as an effective vantage point to describe and ultimately simulate policies, as policies, they argued, are simply a combination of norms (definitions of what society expects us to do) and enforcement mechanisms that are expected to increase compliance with those norms. They went on to propose the InstitutionalABM methodology (I-ABM), and a prototype simulation called J-InstAL to demonstrate the applicability of their approach, exploring the effects of fines and detection probabilities on agents' adherence to contracts. Ghorbani et al. (2013) and Ghorbani (2013) further built on Ostrom's work and created the MAIA meta-model. It uses the rationale and language of the Ostrom's Institutional Analysis and Development Framework to describe systems where individuals and institutions are key components. Its development is a sound basis for using insights from the theoretical world of policy processes to create a modelling-compatible syntax for evolving decision processes. It was applied in numerous simulations, effectively capturing situations where institutions play a vital role in resolving societal challenges – from the effects of corruption on flood risk (Abebe et al., 2019), to the expansion of bio-gas infrastructure (Verhoog, Ghorbani, and Dijkema, 2016). While MAIA does not target the policy process per se, it explicitly models structures in the social system as a dynamic property that both affects and is affected by interactions between different actors.

However, the reason that institutional theory is a clear match for ABM may also present an obstacle with the challenge at hand – it was designed as a framework that can encapsulate many different theories and approaches through a universal set of rules and grammar relevant for analyzing institutional dynamics (Schaler, 2014). Thus, it may not be sufficient in leveraging the particular explanatory strength that theories depicting the policy process were able to amass throughout the years, with a large body of case study analysis.

Theories of the policy process were utilized as such, for example, in the SimPol model – a generic model of a basic polity at three different resolutions. In order to build the model structure, Cioffi-Revilla (2009) combined selected features from the work of political science theorists such as D. Easton, R.A. Dahl, K.W. Deutsch, K.V. Flannery, G. Johnson, J.W. Kingdon, and H. Wright. However, in his description of the model the author does not go into great detail regarding how each theory influenced model design. In subsequent work, Cioffi-Revilla and Rouleau (2010) used ABM to extend the theoretical understanding of civil unrest through the explicit representation of micro-level dynamics between society and government, aiming to not only draw on political science theories but also enrich them.

Some models focused on particular parts of the policy process, filling gaps in the original theory. For example, Waldherr (2014) built a model that simulates the emergence of news-waves in the media arena, a key aspect in the agenda-setting phase of the policy process. The model, named AMMA, aimed to reproduce the dynamics by which reporters choose which stories to report, how these stories affect a topic's perceived news-worthiness, and how the reporting affects policymakers and other actors in the policy arena, who in turn can heighten the topic's news value by initiating events that are related to it.

The following section describes a novel approach developed to simulate the policy process with ABM, based on an explicit and transparent representation of policy process theories. It is based on the work of Dr. Raphael Klein's master's thesis (Klein, 2017) which we have supervised and participated in ideation and development.

7.4 A NEW APPROACH TO ENDOGENISING POLICY IN ABM

7.4.1 MODEL ARCHITECTURE

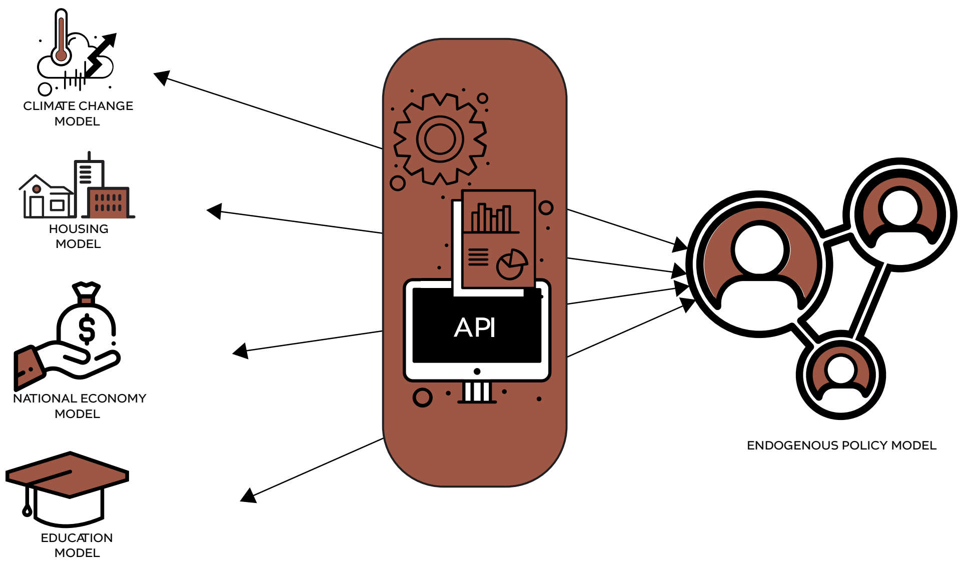
ABM, just like resilience itself, is often a boundary object. It serves as a bridge between different disciplines, practitioners of different professions, and even sectors in society. Using the model they can discuss their different understandings of a common problem, sharpen their gaps in approach and perception, dispute each other's data and assumptions, and the conclusions that arise from the model output.

Thus, rather than building one specific model that examines how policy might change in one specific policy domain, we set out to build a basic concept and infrastructure. These would allow any modeller, policy analyst, or researcher with a model that includes a policy element to plug into a ready-made component that adds a layer of policy evolution. This was the basis for the model architecture proposed: the policy process model presented in this section does not stand on its own. Instead, it can connect to any other model that represents "the world" and the way it is impacted by policy over time.

This structure also corresponds with the resilience policy framework presented in previous chapters. The framework, as this ABM, allows analysing the different facets of resilience policy regardless of the particular domain in which it is applied. In a sense, both are an expression or a tool for promoting "generalised resilience", creating a platform to analyse and promote specified resilience to the particular shocks and stressors at hand.

A special interface (API) transmits the data between these two separate models (the specific domain model, and the policy process model), with output from one serving as input for the other and vice versa, over and over again. The policy model will "ask" the domain model what is happening on the domain side (for example how much has electricity demand grown or what new technologies are available), and in return provide the domain model with a policy decision on what should be done next. Researchers and modellers can take an available ABM in whatever topic they are interested in, plug it into the policy process model, collect the necessary data to configure the policy side and transform their original model into an endogenous policy model. This can be applied to new models while they are being designed or to existing models.

FIGURE 28: MODEL ARCHITECTURE



Another central facet of the system's modularity is that it should allow examination of how policy may evolve according to different theories of the policy process and even different interpretations of the same theory. As a proof of concept, we began with two central theories – the "multiple streams approach" and the "advocacy coalition framework" (ACF).

7

These two theories focus on different elements and dimensions of policymaking and offer a different explanation for how a policy may emerge: The multiple streams approach, theorized by Kingdon (1984), argues that three central streams drive policy choice – problems, policies, and politics. The problems stream captures conditions that are interpreted as requiring attention and action; the policies stream contains actions that different actors in the policy arena would like to advance (and could be portrayed as solutions to different problems); and the politics stream refers to the mood and priorities of the electorate, different campaigns to affect policy, and the changes in the composition of the different branches of government due to elections for example. Policy entrepreneurs work to couple the three streams together, sometimes in conjunction with a critical event that diverts attention to a particular policy domain, thus opening a policy window where the streams' particular combination comprises a package that increases the chances of passing a particular policy (Zahariadis, 2014).

The advocacy coalition framework describes the networks at play in the policy process, their characteristics and ways of operation and interaction, how they facilitate learning, and how the interaction of different groups in the network contributes to policy stasis or change (Jenkins-Smith et al., 2014).

The model allows several phonemena to emerge: First and foremost, the policy choices emerging from the interaction between the different policy stakeholders. Second, changes in individual actors' beliefs and affiliations over time. Third, it allows actor networks to change, and so the networks of joint action, meaning the teams and coalitions through which the agents operate or more basically the networks of interactions leading to collective action or change are an emergent phenomenon. Fourth, the changes in the domain system, meaning the model that is linked to the policy process model, are a direct emergent outcome of the policy choices made in the policy model, as is true in the opposite direction as well.

7.4.2 HOW THE MODEL WORKS

The model is based on a shared general rationale: policymakers are tasked with setting the agenda for the policy arena, and later on with formulating the policies that correspond with whichever issue was placed on the agenda. They can try to influence one another in order to change each other's decisions on what should be placed on the agenda and which policies should be selected. Policymakers can also be influenced by policy entrepreneurs, who are agents that are not necessarily policymakers themselves but are trying to shape the policy process, such as lobbyists or representatives of different social movements. The third type of agent is external parties, who represent media organizations, research institutes, and other actors that mediate and translate their knowledge of what is happening in the world for the other actors in the policy arena. A final class of agents in the model is the policy makers' constituents, representing the voters, party donors, and others who may form the policy makers' "base". Constituents don't have any "actions" but they can be influenced, with their final beliefs and goals indirectly affecting those of policymakers in the arena.

While our initial intent was to maintain a strict separation between the representation of the different theories in the model, certain crucial elements had to be incorporated from both the Multiple Streams Framework and the Advocacy Coalition Framework in order to achieve the requisite variety that allows the model to operate. For example, the multiple streams framework does not specify each actor's internal thought structure, which the ACF does. Alternatively, while the ACF describes how coalitions interact with one another, it does not specify the different types of actions individuals may do to impact other individuals they interact with, which the multiple streams do. Thus, our basic model had to build on both for functioning. However, the model also allows users to activate each of the theories, creating variations in some of the actors' behaviours and even decision structure. In order to simplify the explanation we will first present what each actor does in the general model when neither theory is activated. We will then depict how each theory affects the agents in the model and their possible interactions.

7.4.3 HOW DO AGENTS "THINK" IN THE MODEL?

Each actor in the model has a belief hierarchy. At its top tier, one might place general values such as economic development, environmental conservation, or similarly abstract ideals. At the bottom – very tangible issues such as putting in place recycling infrastructure, funding better public transport, or limiting access to guns through background checks. For each of these issues, actors perceive their current state and the desired state they would like to achieve. Furthermore, the different levels of the hierarchy are connected through causal relations. For example, some actors in the model could perceive increasing funds for public transport as positively linked to greenhouse gas emission mitigation, which positively affects climate change, which positively affects environmental conservation. In other actors' minds increasing funds for public transport could be negatively connected to the ability to own a car in the city, which they may think negatively affects employment potential, which they perceive to negatively affect economic development.

7.4.4 HOW DO AGENTS CONVINCE OTHER AGENTS IN THE MODEL?

Based on this belief structure, agents in the model can try to affect one another's perceptions through the equivalent of "framing" in three different ways: First, they can change another actor's mind on how the world works, meaning their causal relations between different levels in the hierarchy. For example, using terms like "green jobs" or "environmental security" the environmental movement has tried over the years to connect environmental issues and measures to other domains such as economic development and defence policy. Second, agents can try to impact how other agents perceive the state of the world. For example, climate campaigners repeatedly try to explain that while we may think the world is decades away from a climate catastrophe, we are in fact only years away from a tipping point. Third, agents can try to impact each other's desired states. For example, European political actors may try to convince one another that an annual expenditure of 1% of GDP on defence is crucial to maintain NATO or alternatively wasteful and belligerent.

In order to determine which of the actions the agent is going to perform, they first have to choose which actor they will perform the action on. They are more likely to try to influence policymakers rather than other agents who do not hold decision-making power over policy; agents who are closer to them in the policy network; agents who are more similar to them in their political affiliation; and those that are perceived to have lesser levels of conflict with the agent on the issue at hand (that perception could be wrong, as agents have partial knowledge of others, which becomes less partial with every interaction they have). The type of persuasion tactic the agent uses is chosen based on their calculation of which one has the best likelihood of success. Once the persuasion tactic has been activated, its impact is determined by the extent of resources the persuading agent has, which in turn depends on their political affiliation (reflecting for example, whether they are in the coalition or the opposition, representing a big block of voters or small).

7.4.5 WHAT CAN EACH TYPE OF AGENT DO?

While the basic actions available to policymakers, policy entrepreneurs, and external parties are similar, there are some important differences that determine the flow of the model:

POLICYMAKERS

In addition to convincing other policymakers to join their cause, policy makers have actual decision-making power over which policy is taken up in the model. This is done in two stages: In the agenda-setting stage – a count is performed of policy makers' view of which issue on their belief hierarchy is the most urgent, meaning the gap between its state and goal is the widest. This is done by focusing on issues not in the lowest branch of the tree but at rather more abstract levels, representing a wider agenda issue. The issue receiving majority support is selected as the issue "on the agenda".

After the agenda has been set, a new stage of policy formulation commences, in which policymakers are asked to decide which policy instrument should be used to act on the issue selected in the previous round. That means the selection available to the policymakers is of instruments that are connected to the selected issue in the belief tree but are located at a lower branch. The agents can again try to impact one another's beliefs, and eventually make a decision based on two factors – the expected impact of each proposed policy instrument, and the urgency of each particular issue. The voting rules for policy selection is set in advance by the modeller. It can be a simple majority, a two-thirds majority, or unanimity, representing the particular policy system at hand.

POLICY ENTREPRENEURS

Policy entrepreneurs have the same function as policy makers other than the ability to actually make a decision on the agenda at hand and the instrument chosen. This means they try to convince other actors in the model on which issues should be put on the agenda and what instrument should be chosen once an agenda has been set. Similarly to policymakers, their resources are based on their political affiliation.

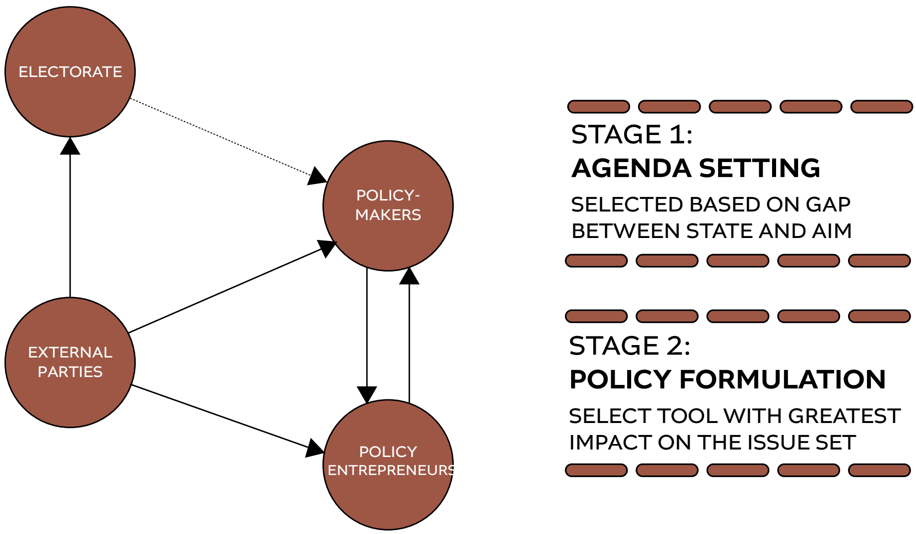
EXTERNAL PARTIES

In addition to the different framing actions shared by other actors, external parties have direct access to the state of the world and can transmit the information to all other actors, including the constituents. However, they may focus on certain issues and not others, and their ability to transmit the information successfully to other actors depends on their proximity to the other actor in their policy network, as well as their affiliations, which may affect the level of trust other actors put in them. This represents a situation where Fox News, for example, will be able to "inform" conservative voters, but when looking at the state of the world in terms of the environment might not look at climate change altogether. Since external parties represent actors with immediate access to mass media, they can also perform "blanket actions", which means trying to convince all the actors in the model (the calculation remains the same, but aggregates all the agents they are trying to perform the action on). Blanket actions also allow external parties to impact the goals of different constituencies, with their impact depending on resources and the difference in beliefs between them and the constituents.

CONSTITUENTS

The constituents represent a certain share of the voting population and are tied to a particular political affiliation. While they do not make active decisions or choices, they impact the number of resources other actors have (bigger constituencies translate to more resources), and they affect the goals of their affiliated policymakers, who try to remain close to their constituents' goals to remain in office.

FIGURE 29: STRUCTURE OF INTERACTIONS AND STAGES IN THE MODEL



7.4.6 REPRESENTING MULTIPLE STREAMS THEORY

Activating the multiple streams theory mode slightly changes the model's routines. While the politics stream is inherently represented in the model through the concept of resources, the problems and policies streams need now to be made more explicit. Thus, the belief tree is split in two – one tree representing problems, and another tree representing policies, or solutions. The instruments in the policy tree are connected to one another at different levels and to the problems in the problems hierarchy. Each agent starts with choosing either a policy or a problem to promote. Problems are selected based on their urgency, while policies are selected based on their perceived impact. The policy or problem with the highest score is chosen by the agent. Then, agents must choose a corresponding problem or policy. If an agent chose a policy to begin with – all actions they will perform on others during the simulation will focus on impacting other agents' beliefs on that policy or its corresponding problem.

While this may seem puzzling to policy analysts accustomed to thinking of the policy process through the linearity of the policy cycle and its stage-by-stage approach, this representation of the multiple streams theory corresponds with the natural evolution of policy. Take for example the electric bus diffusion which we considered in the previous section of this chapter. It is a policy solution that can fit many different problems: air pollution, climate change, passenger comfort, energy security, and many more. However, its proponents usually start with the desirability of the solution itself, rather than the urgency of each of these problems in and of itself. Alternatively, climate activists often focus on the problem at hand, rather than any one solution. In this sense, the model operationalises the theory in a way that can help researchers and policy analysts explore alternative procedures for policy analysis: On the one hand it allows them to explore the freedom in interactions between actors that yields policy agendas, as proposed by the multiple streams theory, on the other hand it introduces, or even forces, a temporal dimension that requires analysts to think how the policy could emerge based on these interactions.

The theory argues that policy windows open up when problems are coupled with particular solutions and have the support of a particular political situation which allows the policy to emerge. This is represented in the model's revised decision process as well. In the first round (agenda setting), policymakers are asked to choose both a policy and a problem. In the second round (policy formulation) policymakers have to choose both problem and policy once more, but this time they must choose a policy and problem that are subsidiary to the ones chosen in the first round. For example, if in the first round policymakers chose "need for better public transport" as a policy problem and "electric bus acquisition" as a policy solution, in the second round they will have to choose instruments that improve electric bus acquisition and are related to the problem chosen by most.

Another concept introduced from the multiple streams theory is "teams". This means that agents with similar beliefs on a policy and a problem are able to form a short-lived small group that provides its members access to each other's networks, meaning they can act on agents outside their own immediate network. Members of the team can also contribute resources to the team and agree on actions that the team performs on other teams or internally to increase team cohesion. When the team influenced a sufficient number of agents in the model, it disbands.

7.4.7 REPRESENTING THE ADVOCACY COALITION FRAMEWORK

In the ACF mode of the model, agents band into larger and more permanent "coalitions" – groups where agents share beliefs, and only leave if there is a change in the highest level of belief in their belief hierarchy. The coalitions can act similarly to teams, meaning act on their own members or on agents in their collective network, while using shared resources. However, unlike teams, coalitions are centralised, and their actions are determined by the coalition leader, who is the agent in the coalition with the largest policy network. The number of coalitions in the policy arena is relatively limited.

Another role added in the ACF mode in accordance with the literature is that of a policy broker. This is an agent who can connect two other agents through one of two actions: creating a new connection altogether between agents that had none, or raising their awareness levels of each other, meaning that they have a better understanding of each other's beliefs. Policy broker roles can be assigned to policymakers, entrepreneurs, and external parties, and they can be either neutral or in an advocacy position, meaning they will only connect agents who share their beliefs.

7.4.8 HOW CAN THE MODEL HELP US ANALYSE RESILIENCE POLICY?

Resilience policy is by definition a policy that deals with an expected change in the world: preventing it, adjusting to it, or recovering from it. This means the policy and the world it affects should co-evolve over time. For example, climate goals might become more stringent as the climate crisis deepens, and adaptation policy may expand as its effects are more pronounced. The model allows for these two sides of the system, meaning the physical side and the social side (in the form of the policy system) to affect one another and change as a result. While the model is not meant to be predictive of policy outcomes, it does allow a more in-depth understanding of how specific policy outcomes may emerge, and the underlying social dynamics that may contribute to any particular outcome.

Preliminary experiments performed with the first implementation of the model present several such opportunities for analysis in two central applications: understanding how particular agents and groups of agents may perceive an issue and what policy choices they would make over time, and what changes we might see to teams or coalitions active in a particular policy domain, which could affect not only policy outcome but the policy's wider perception in society. In order to demonstrate the model's potential usefulness, following is a description of these experiments and visualisations of results that outline different insights that can be generated based on their analysis.

7.4.9 EXPERIMENTAL DESIGN AND MODEL VALIDATION

The model was run in four versions, each adding additional features corresponding with the specific theory it aims to represent. All versions used the same "external" model coupling, representing the potential spread of forest fire based on policy decisions about forest management made in the endogenous policy side of the model. Within the policy module, the number and makeup of agents remained constant throughout the experiments: six policymakers, six external parties, and 18 policy entrepreneurs.

PARAMETERS CONFIGURATION - BACKBONE MODEL

The simplest version of the policy model requires configuration for four main variables:

1. Belief Hierarchy profile

Each agent is assigned an affiliation, capturing their aims and how they perceive causal relations between different levels of the hierarchy. Three sets of experiments were run, each setting different parameters for each of the three available affiliations:

TABLE 5: PARAMETER SETTINGS FOR EACH BELIEF HIERARCHY PROFILE

		ISSUES	CASUAL RELATIONS
	Affiliation 0	1	1
	Affiliation 1	-1	-1
PROFILE 1	Affiliation 2	0	0
	Affiliation 0	0	1
	Affiliation 1	0	-1
PROFILE 2	Affiliation 2	0	0
	Affiliation 0	1	1
	Affiliation 1	-1	-1
PROFILE 3	Affiliation 2	0	1

2. The affiliation weight

This parameter defines how much impact each agent has over agents with different affiliations. Each two affiliations have a different weight, varying from 0 to 1. This parameter allows testing how changing the influence of different affiliations over one another impacts policy learning and change. Configuration: Interval 0.8-0.9

3. Affiliation distribution

This parameter represents what share of the population identifies with each particular affiliation, defining what representation they have in the policy system. This affects the resources assigned to each of the agents based on their affiliations. Within the model exploration, this parameter was set such that in one configuration all affiliations have the same representation, while in the second configuration, only two affiliations have a large representation. Configuration: Interval 0.01-0.5

4. Electorate influence on the policymakers

This coefficient defines how much each policymaker's aims can change as a result of their electorate's change in beliefs. In order to test whether the electorate influence is working as intended and if these values have unexpected consequences, the coefficient was set to 0 and to 1 in specific runs of simulations, and in others it was at an interval. Configuration: Interval 0.001-0.010

PARAMETERS CONFIGURATION - BACKBONE+ MODEL

The same parameters configuration from the backbone model is kept, in addition to the following parameters:

Resources potency parameter

This parameter changes the impact of actions agents perform on each other. Configuration: Interval 1-10

Resources weight action

This coefficient defines the share of each agent's resources that they can spend on each action they perform, and as a consequence how many actions they can perform. Configuration: Interval 0.05-0.20

Awareness decay coefficient

This coefficient defines the speed at which agents' awareness of each others' beliefs decreases over time. Configuration: Interval 0.01-0.10

Conflict level

These coefficients define the level of conflict between agents of different affiliations. Configuration: Interval 0.8-0.9

PARAMETERS CONFIGURATION - MULTIPLE STREAMS MODEL

The same parameters configuration from the backbone+ model is kept, in addition to the following parameters:

The team creation threshold - problem magnitude

When forming teams, all agents in the team must have a similar perspective regarding the gap between their perceived state of the world and their desired aim. This is translated to a minimal gap between these two parameters, or in other words a threshold gap regarding the magnitude of the problem the team aims to solve, which each agent joining the team must share. Configuration: Interval 0.2-0.7

The team creation threshold - belief gap

Agents joining teams based on problems must meet a certain threshold regarding the connection between the problem at hand and its wider implications (for example - we need to tackle the problem of urban GHG emissions, so that we can mitigate climate change). This means that the causal relation between the policy core issue the team selected as a problem and the starting agent's deep core issue is kept within a maximal value for all members when the model is at an agenda-setting stage. When the model moves to the policy formulation stage, the same value must be kept among all team members for the causal relations between the problem selected to be on the agenda and the secondary issue selected as the problem by the agent starting the team. Configuration: Interval 0.6-1.0

The team creation threshold - policy impact

When forming teams to promote a policy, all agents joining the team still need to meet the problem magnitude threshold. However, instead of the belief gap, which focuses on the problem side, agents joining the team must have similar views on the impact their chosen policy will have (for example - we should promote electric buses because they lower urban GHG emissions). This means that the impact parameter of the team's selected policy on the secondary issue selected as the problem by the agent that started the team must be within a certain maximal gap for every agent joining the team. Configuration: Interval 0.2-0.7

PARAMETERS CONFIGURATION (ACF MODEL)

The same parameters configuration from the backbone+ model is kept, in addition to the Coalition Formation Threshold. This means that the agents joining the coalition must be within a certain distance of the leading agent's state belief for the issue they selected. Interval 0.15-0.55

MODEL VALIDATION

Once an initial conceptualization was in place, leading researchers in the field of policy process theories were contacted, sent the suggested approach and conceptualization, and consulted on the approach as a whole, and the degree to which the model accurately represents each theory as a whole, the behaviour of specific actors in the policy arena, and its interaction with other theories included in the model. These interviews and correspondences led to certain changes in the way the model was initially structured, but it also proved a useful two way dialogue on the concretisation of the theories to the level required for formalization and implementation in a simulation. Some limitations could not be avoided, such as a certain level of linearity that is inherent in computer simulations. Full documentation of the validation process and results is available at Klein (2017).

7.4.10 VISUALISING RESULTS AND POTENTIAL PATHS FOR ANALYSIS

As a proof of concept model, the experiments described above were meant to explore how different characteristics of the policy system and its individual components may yield different policy results over time. This evolutionary dynamism is the linchpin of resilience policy analysis - examining not only how initial policies affect their intervention domain, but also how they may be affected by the way it changes over time (for example if a policy fails to achieve its intended purposes), or by factors intrinsic to the policy system in and of itself (for example a change in the makeup of the ruling coalition), and due to external factors and forces that can shape it in unexpected directions (such as an extreme weather event, accident, or a war between a rival power and an ally).

A further goal of this proof of concept model was to design tools that can "open the black box" of policy change, by visualising the internal dynamics of the policy system over time. For example, support for a particular policy can be plotted over time comparing all agents, a subgroup of agents, or even an individual agent. Thus, in figure 32 each line represents a different agent's leading policy goal over 500 'ticks' of a single simulation run. Moving from one number on the y axis to another shows how an agent changed their mind, or moved their support to a different policy goal.

Changes in agents' support for policy can be further analysed based on their different characteristics, such as their initial political affiliation. This is demonstrated in figure 33, where agents' change of support to different policies is shown to either remain stable over time in agents with political affiliations 1 and 2, or change around tick 350 for agents with political affiliation 3. Finally, we can analyse one particular agent to see how different policy goals they hold change over time compared to one another, as is demonstrated in figure 34. In this last figure, each policy goal is outlined in a separate line that shows the standard deviation derived from multiple runs of the model.

In each of these cases, the model allows us to identify points in time where changes occurred in actors' support for different policies. While these tools don't provide us an explanation to the cause of change, they can suggest how views held by different groups in society might evolve over time, as well as the people representing them in different institutions. They also provide an insight to where we should look for the causes of such inflection points, using additional analysis tools based on model data. Modellers can then analyse how these positions change in response to different events that may happen both "in the world" and "in the policy system". For example, what happens to constituents' views and to political coalitions if a natural disaster occurs, if a certain political party gains control of the government, or if a new social movement or institution emerges, all events we can simulate in the model.

FIGURE 30: POLICY GOALS BY ALL AGENTS OVER A SIMULATION RUN, FROM LOURENS AND NOTEBOOM (2018); NOTEBOOM (2018)

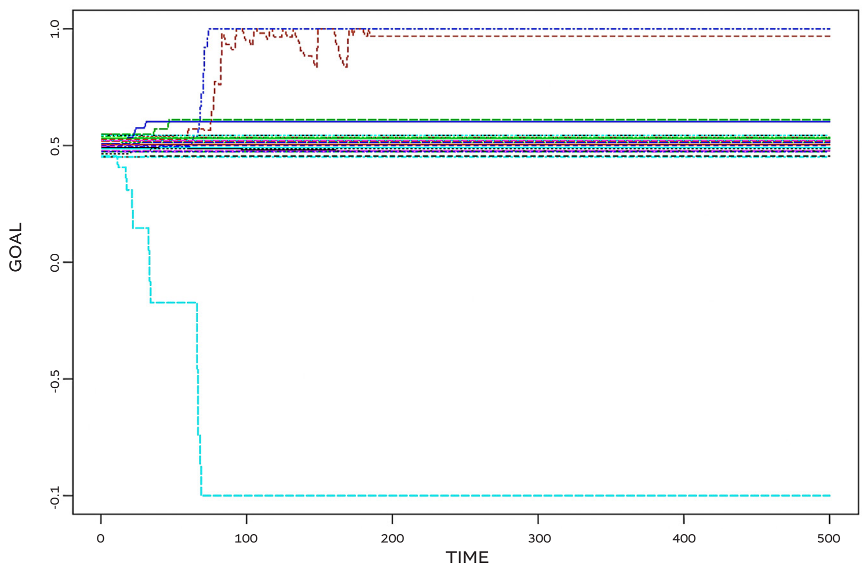


FIGURE 31: SUPPORT FOR POLICY AT THE AGENDA-SETTING STAGE BY AGENTS BASED ON THEIR INITIAL POLITICAL AFFILIATION, FROM LOURENS AND NOTEBOOM (2018); NOTEBOOM (2018)

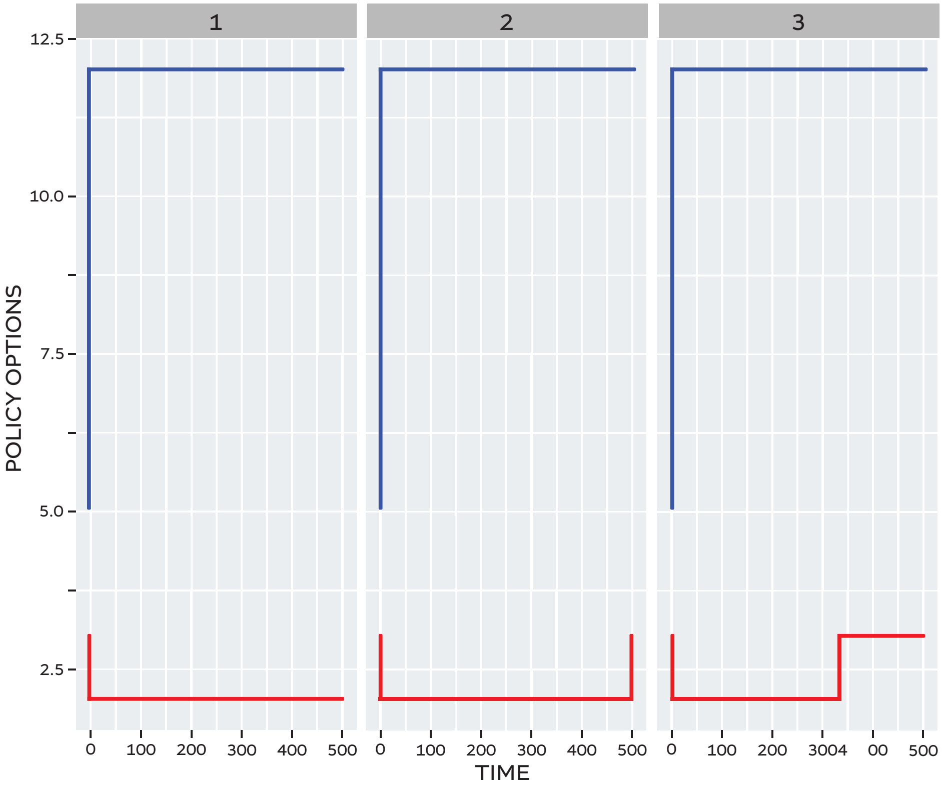
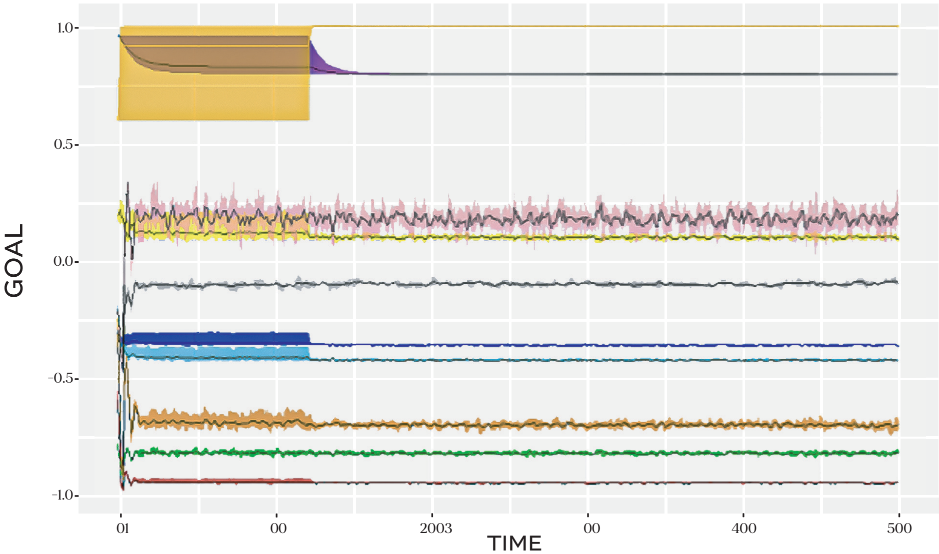


FIGURE 32: POLICY GOALS BY A PARTICULAR AGENT OVER SEVERAL SIMULATION RUNS (WITH STANDARD DEVIATION FOR EACH GOAL), FROM LOURENS AND NOTEBOOM (2018); NOTEBOOM (2018)



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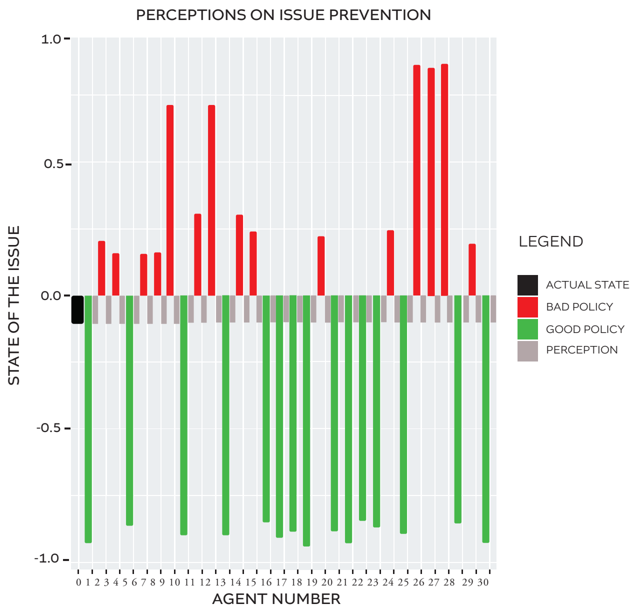
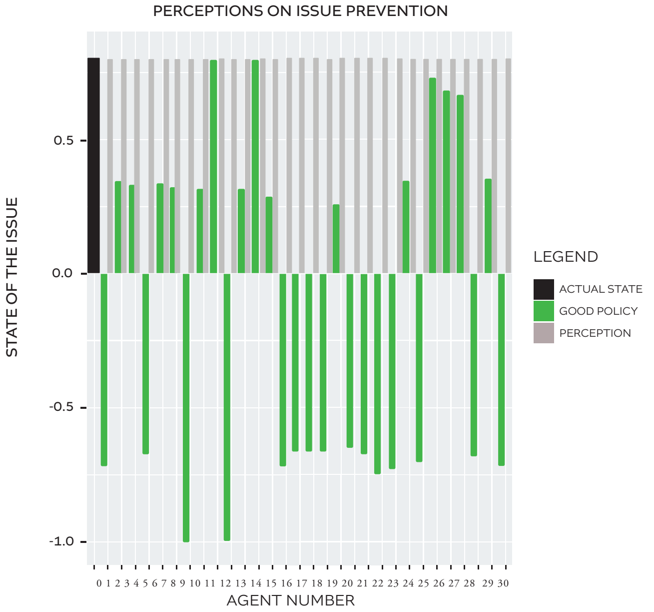
The model can also highlight the difference between people's perceptions of the state of the system at hand, the actual state of the system, and how the policies selected correspond with their beliefs. For example, in figure 35, the actual state of the world is presented at the leftmost bar in black. Next, each agent's perception of the state of the world is presented in grey, and in red and green whether the selected policy helps achieve their policy aim or undermines it. This tool allows us to capture the impact of the disconnect between perceived reality and actual reality on policy, and how this dynamic then impacts the state of the world. This is a major challenge in issues such as climate change, where different political groups have developed resistance to seeing its severe consequences, thus limiting their support for mitigation and even adaptation policies. Thus, analysing how resilience policy in this domain might evolve over time must be able to simulate this dynamic.

FIGURE 33: COMPARING AGENTS' BELIEFS ON THE STATE OF THE SYSTEM, THE ACTUAL STATE OF THE SYSTEM, AND POLICY IMPACT ON THEIR POLICY GOALS, FROM LOURENS AND NOTEBOOM (2018); NOTEBOOM (2018)

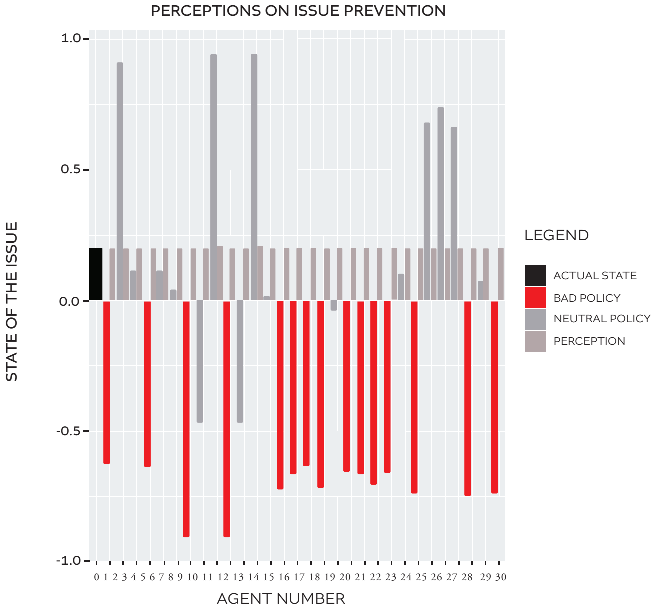
(a)



(b)


PERCEPTIONS ON ISSUE PREVENTION
STATE OF THE ISSUE
0.5
0.0
-0.5
-1.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
AGENT NUMBER
LEGEND
ACTUAL STATE
GOOD POLICY
PERCEPTION

(c)


PERCEPTIONS ON ISSUE PREVENTION
STATE OF THE ISSUE
1.0
0.5
0.0
-0.5
-1.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
AGENT NUMBER
LEGEND
ACTUAL STATE
BAD POLICY
NEUTRAL POLICY
PERCEPTION

7

The model can also represent the affiliations that might form between different actors in the policy system, and how these connections may give rise to changes in policy beliefs and outcomes. For example, figure 36 presents the composition of all coalitions in a particular point. This allows policy analysts to compare the forces working for and against certain policies, what beliefs drive their decisions, and what is the power balance between them. Figure 37 takes a longitudinal approach, showing at each tick of the simulation which agents belong in a particular coalition. This allows analysts to ask why certain actors may drop in and out of coalitions, based on changes in the policy domain, in their individual constituents, or in coalition dynamics. Thus, when studying, for example, opposition to nitrogen policy, the model may be able to show the formation of a coalition between farmers and other forces in the political system based on a shared policy approach, which can then impact not only nitrogen policy but the formation of new governing coalitions or ad-hoc support for related policy domains.

FIGURE 34: COMPOSITION OF COALITIONS IN THE MODEL AT A PARTICULAR POINT IN TIME, FROM LOURENS AND NOTEBOOM (2018); NOTEBOOM (2018)

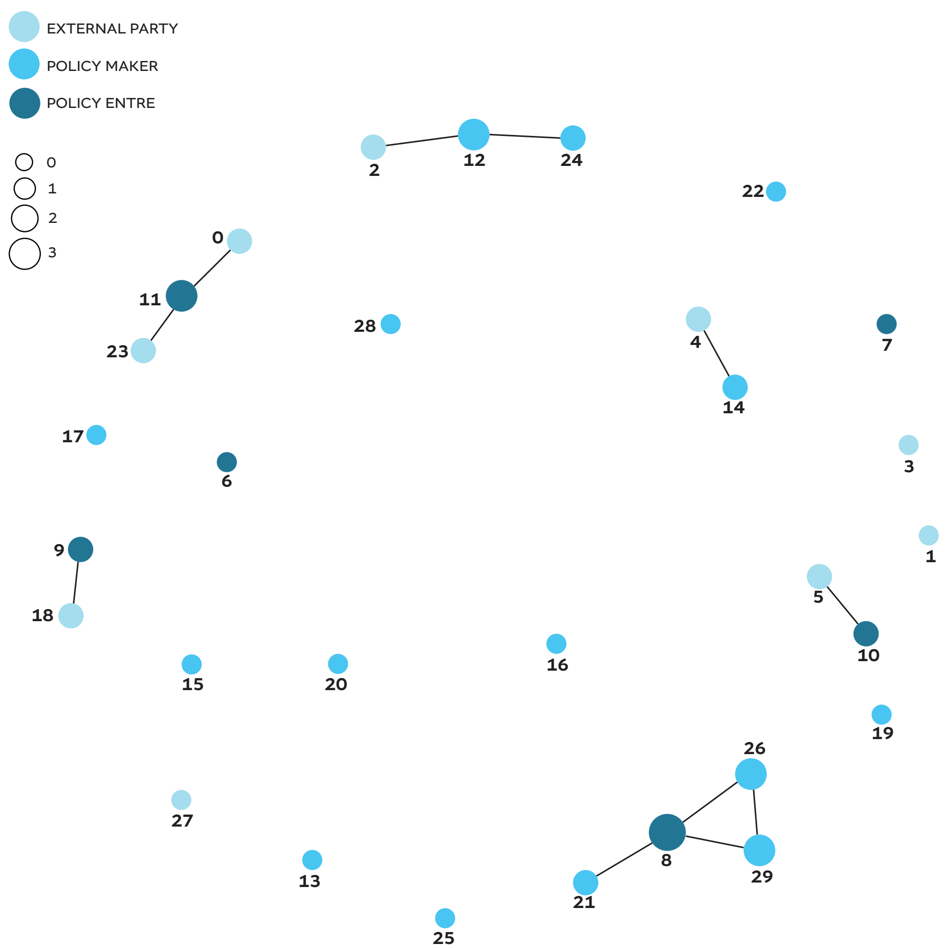
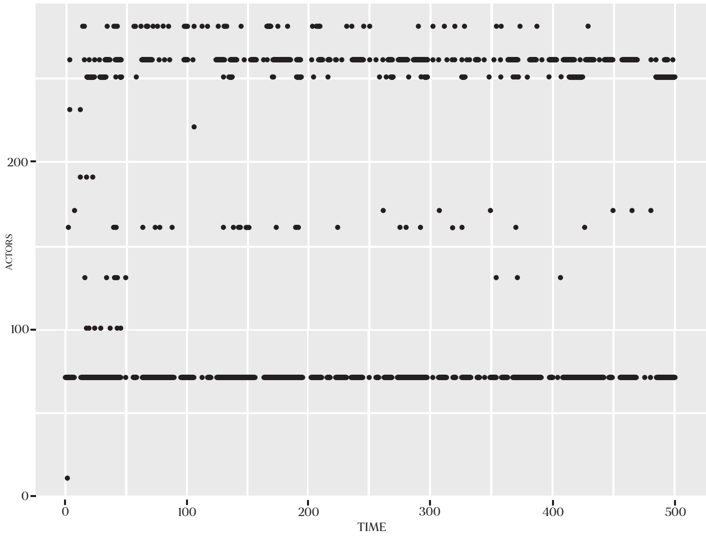
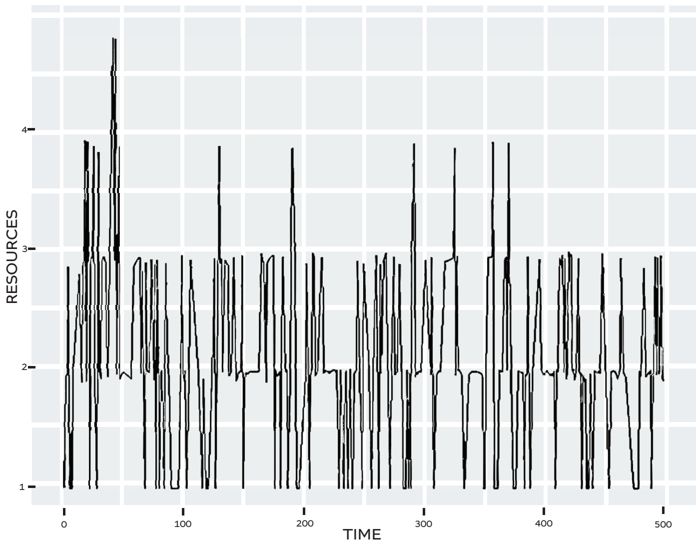


FIGURE 35: COMPOSITION OF A SPECIFIC COALITION OVER THE WHOLE SIMULATION RUN, FROM LOURENS AND NOTEBOOM (2018); NOTEBOOM (2018)



One last example of how model output can inform resilience policy analysis is in its representation of resource distribution. Figure 38 presents the amount of resources a coalition has throughout an entire simulation run. This reflects its popular support, power, and ability to impact policymakers and the public. By following the resources available to coalitions (in the ACF model) teams (in the Multiple Streams Model) and individual agents (in all versions of the model), policy analysts can observe how changes in the policy domain and external events can impact the influence different groups have on the emergent policy, and how the distribution of resources between these different groups can evolve itself over time with policy changes.

FIGURE 36: AMOUNT OF RESOURCES AVAILABLE TO A COALITION OVER A WHOLE SIMULATION RUN, FROM LOURENS AND NOTEBOOM (2018); NOTEBOOM (2018)



7

7.5 HOW DOES THE MODEL INCORPORATE THE DIFFERENT ELEMENTS OF RESILIENCE POLICY PREVIOUSLY EXPLORED

What is the added value of endogenising the policy process for analyzing resilience policy? The previous chapters of this dissertation give an outline for how this model can be used to support resilience policy-making:

- It allows exploration and experimentation with different policy configurations to see whether the emergent policy correlates with the policy goals defined in chapter 2
- The model can help form a policy environment more conducive to resilience (chapter 3)
- It contributes to a more reflexive and communicative policy process (chapter 4)
- It allows exploring the different scales and dimensions at which the policy operates, and how they may conflict with one another and affect resilience over time (chapter 5)
- It expands the capacity of traditional ABMs to incorporate and reflect a change in the environment and the agents represented in the model (chapter 6)

7.5.1 HOW DOES THE MODEL HELP INCORPORATE RESILIENCE POLICY GOALS IN POLICY ANALYSIS?

CONNECTIVITY

The model allows exploring new types of connectivity that are crucial for ABMs simulating policy in general, and even more so policies revolving resilience: between the policy process and the policy domain it tries to impact, between different actors and groups in the policy network, and between different policy solutions and policy problems under different political scenarios.

FLEXIBILITY AND MODULARITY

The model makes it easier to experiment with modular policy design: It allows the modeller to observe what happens when different policy tools are introduced under diverse social, ecological, and technological conditions. It reflects how flexibility increases and decreases in both the policy system and the policy domain. For example, it can show that a subsidy to persist in certain crop production systems allows farmers to continue production in the short term, but makes it harder for them to switch to other crops or economic activities altogether in the mid-long term, based not only on the conditions in the domain side of the model (crop and input prices to name a few), but also on how the policy itself may get "locked in" due to farmer coalitions rallying to maintain it. Thus, the model can show how policy affects flexibility in its own evolution over time, creating expected or unexpected path dependencies that make it harder for it to change when needed. By allowing the policy system represented in the model to choose different combinations of policy tools, analysing its results can also increase flexibility in designing policy packages – combining policy tools at different times and circumstances so that they work to enhance each other.

Finally, the model itself is flexible and modular in two central ways: It allows exploring different theories, as it is intended to be a platform for theory deliberation and representation, bringing together policy process theorists and modellers. Second, it can connect to an infinite number of policy domains, as long as the modellers can map the necessary data for capturing that domain's policy system.

REDUNDANCY

The model can help policymakers and analysts identify different strategies to achieve their desired policy outcomes and maintain them over time – different ways to frame the issue, build coalitions, or make use of changing political circumstances to ensure the policy at hand survives. In other words, while exogenous ABMs allow exploring a redundancy in policy tools, an endogenous model can reveal necessary redundancies in policy strategies, and help policy entrepreneurs choose how to invest their resources and frame their policy proposals to increase their chances of implementation. In terms of specific policy goals – as the environment in the model (and in reality) changes in tandem with people's perception of it, different policy mechanisms may be used to ensure similar resilience outcomes. The model allows the choice of these different mechanisms to emerge, and shape the environment in different ways.

DIVERSITY AND VARIABILITY

Endogenising the policy process means that the analysis represents a greater diversity of actors, beliefs, interactions, coalitions, and mechanisms that affect how the policy system operates and evolves. In this sense, an endogenous policy model, differently from an exogenous policy model, asks what the requisite variability is for models considering a policy system. This question is particularly salient with resilience policy, which inherently deals with change over time and how policymakers and communities respond to change. Furthermore, the model allows actors' beliefs and policy choices to change, responding not only to actual changes in the environment but to their changing perception of it, the information they receive, and persuasion tactics used by other actors in the network. This variability is crucial when considering how policy might be shaped after extreme events in the environment (earthquakes, heatwaves, mass shootings) or in the policy arena itself (supreme court verdict outlawing abortion for example).

ROBUSTNESS

Robustness analysis aims at finding policies and strategies that work under a wide range of scenarios. The endogenous policy model extends the type of scenarios that can be examined with a model. In addition to the technological, economic, and environmental conditions that affect policy outcomes, the model allows analysts to examine the political and institutional conditions under which the policy emerges, works, and evolves over time. All these allow exploration of how the policy at hand may need to change based on external pressures or pressures arising from changing social values, perceptions, understandings, and shifts in power.

MITIGATING VULNERABILITY

The model exposes two classes of vulnerabilities important for analysing resilience policy: First, while vulnerabilities in the current state of the system may be easier to detect, the model allows the detection of emergent vulnerabilities based on interactions with the policies selected by agents in the model over time. Certain groups could be made more vulnerable based on policy decisions that occur throughout the simulation, or different components and aspects of the system. Second, the model reveals vulnerabilities in the policy itself - not only how effective it is in terms of its stated goals, but can it withstand political and environmental tribulations.

As discussed in previous chapters, vulnerability is directly tied to social equity and justice. Williams et al. (2022) offered three pathways to integrating equity considerations in ABM, all supported by the modelling approach proposed in this chapter: First, it allows better stakeholder engagement, as it brings into the fore different groups in society working toward different policy goals, and allows those groups to inform modellers on how they should be represented in terms of their belief trees, networks, and power relations with other groups (resources). To the extent that the model is used as a basis for policy formation, it thus increases their ability to impact policy outcomes and the considerations being made through policy and modelling assumptions. Second, it makes clear the biases and positionality of the modellers, as their perception of different groups and their values is clearly translated to the way the configure agent settings and even causality between different issues and policy instruments. Third, it incorporates different forms of equity in the model design itself, particularly issues of distributional justice that are made transparent through the identification of the policies chosen with the preferences and views of different groups of voters and policy entrepreneurs represented in the model.

PERSISTENCE, ADAPTABILITY, AND TRANSFORMABILITY

The interplay between the three capacities depends on the way policy may change over time. For example, if the government and the public see the subsidy given to the farmers to maintain their original crops doesn't actually work over time - they may back an alternative policy that requires farmers to invest more in alternative strategies. Thus, only by looking at resilience pathways over time is it possible to evaluate the effectiveness of any given policy a-priori. This requires not only a model that has the appropriate time horizon, but a model that can simulate the dynamic changes in policy, the environment, and the subjects of the policy, as the endogenous policy model does.

7.5.2 HOW DOES THE MODEL HELP DESIGN A RESILIENCE-ORIENTED POLICY ENVIRONMENT?

Endogenising the policy process in the model can facilitate general resilience in the policy system in several different ways: First, it allows representation of the institutions and governance structures resilience aims to instill. Second, it invites the integration of new types of knowledge, including local knowledge and interdisciplinary collaborations. Third, it provides necessary tools for supporting ongoing analysis of resilience policy.

REPRESENTING RESILIENCE GOVERNANCE

Endogenous policy models such as the one presented in this chapter allow researchers and policy analysts to simulate different types of decision-making structures and procedures: decentralised governance arrangements, policies that expand or narrow the boundaries of the policy-making mechanism to that of the social-ecological system at hand, add or remove actors from the policy network, and change the rules to allow priority to different communities and levels of governance.

EMBEDDING NEW FORMS OF KNOWLEDGE

Agent-Based Modelling in general is highly useful for integrating knowledge from different disciplines. The modelling approach presented extends the ability to incorporate existing knowledge about how policy evolves over time, about the particular policy networks and systems being considered, and local knowledge both about the institutions and the domain system they govern. Finally, the model can build a shared understanding of risks and development pathways among elected officials, civil servants, and their constituents.

PROVIDING NECESSARY TOOLS FOR RESILIENCE POLICY ANALYSIS

The model introduces new ways to support designing and monitoring resilience policy: **First, it enhances policymakers' ability to identify cross-scale interaction** on both the domain side and the policy side - showing what happens, for example, at the national level if new knowledge about the system at a local or international level comes out. A case in point could be a new report from the IPCC or, or a report of mass floods or fires. How would that cause a possible shift in policy? who would oppose or ignore it? How would the resulting policy affect GHG emissions in the state, and how would that, in turn, affect the country's emissions policy at a later round?

Second, the model can support the system by monitoring thresholds. This could mean examining how alternative policies would evolve over time and how close that may bring the system to its known thresholds, identifying possible thresholds to begin with, or looking at policy thresholds, meaning at what point would it become impossible to change policy course one way or another.

Third, the model can uncover the slow and fast variables working on both sides of the system - the policy side and the domain side, how they interact, and how policymakers can manage them.

Fourth, if incorporated in collaborative modelling processes, the model has the potential to **establish a common language for different stakeholders** working on resilience policy and open a space for policy deliberation where everyone's assumptions about resilience are made explicit. This is a key step in the future development of endogenous policy models, and their incorporation in multi-modelling environments.

Fifth, the model can facilitate transformations by identifying possible windows of opportunity for policy change, and even helping policy entrepreneurs open them up by revealing possible trajectories for proposed policies or policies left out of the debate.

Finally, the model creates the ability to experiment not only with different policy mechanisms, but with whole governance structures, the way policies are presented and framed to the public, and strategies for advancing the policy at different scales and networks.

7.5.3 HOW DOES THE MODEL SUPPORT THE COMMON COMPONENTS OF RESILIENCE POLICY?

The model supports each of the five components found in strategy, capacity, communication, stakeholders, and domain:

STRATEGY

The model can create a reflexive strategy or policy by allowing policymakers to experiment in advance with the mechanisms they propose, their possible evolution scenarios, and their impact on select dimensions in the system they are trying to affect (city, country, sector, etc.). They can compare these results to the goals they set, or even use the model to determine which indicators they need to put in place to ensure greater resilience has been reached in the particular way they intended, or alternately to trigger action in case of increased risk.

CAPACITY

The model builds capacity for analysing change among different stakeholders and groups in society - it can be used not only by policymakers, but by non-governmental organisations, scholars, and officials from competing ministries or agencies to "raise the alarm" on different policy trajectories, and dispute assumptions made about the rate of change, how it affects different places and people, and the proper response to it.

COMMUNICATION

The model allows policymakers to communicate to different constituents the risks they may be facing in upcoming years, the way different policies may affect them, and what they can do to take part in instilling change - either through political participation, making individual choices, or other types of collective action. These same features also open more space for opposing proposed policies, either because constituents disagree with policymakers' assumptions and thinking revealed by the model, because they may contest the validity of the model itself, or because they may wish to avoid certain dynamics and possible consequences emerging from the model.

STAKEHOLDERS

The model can help bring together different stakeholders to the table to discuss and make explicit the risks being discussed in the policy, the way that risk may affect each of them, proposed solutions, and most importantly the assumptions about each of these, which can be latent and conflicting. One way to increase the model's impact in this arena is through a collaborative process for building the model or populating its basic structure, where each stakeholder can explain their choices, interests, behaviours, and concerns.

DOMAIN

The model can focus on a narrow set of issues in the resilience domain being considered, or on an integrated web of domains as it applies to the system. One way to tie different domains is through the use of a multi-model environment that connects the policy side of the model to different models, each representing a different yet related domain.

7.5.4 HOW DOES THE MODEL MEASURE DIFFERENT CAPACITIES FOR RESILIENCE IN THE SYSTEM AND THEIR TRADE-OFFS?

While traditional ABMs allow measuring how different agents or system traits react to changes in the environment, including policy changes, it requires modellers to predefine the specific mechanisms being implemented in each run of the simulation. The endogenous model can measure how different policies that emerge at different times along the "lifetime" of the simulation affect policy subjects, taking into account that they can affect policy design and outcome. In other words, whether farmers, for example, are actually better off with a subsidy over 5, 10, and 20 years, how it would impact their lobbying efforts, and what future policies it may lead to, considering not only the farmers but different constituents in the region and at a national level.

7.6 CONCLUSION

This chapter examined how endogenous policy modelling can be used to analyse resilience policy. It reviewed the potential of agent-based modelling that builds on policy process theories to enhance the analysis, allowing analysts and researchers to examine many of the essential components of resilience policy, including heterogeneity, co-evolution, and cross-scale interactions. The modelling approach presented provides an illustration for how policy can be endogenised in ABM, growing and changing within the model, rather than predetermined by the modeler, allowing new types of analyses that are crucial to resilience policy, which by definition may change over the years, in response to its effects and to different social dynamics in the policy system.

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CHAPTER EIGHT

08

RESIL
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08

CONCLUSIONS

In this chapter, we reflect on the outcome of this dissertation, its relevance to actual policy-making, and what we can do as scientists hoping to affect resilience policy.

The concluding chapter outlines the main insights gained from the dissertation. It starts by answering the research questions posed in chapter 1, and follows with personal insights gained in the process of writing this dissertation as a researcher examining resilience policy and a practitioner involved in shaping it. After a review of concrete answers to each research question, I will reflect on the following topics:

1. Is and should resilience policy be an independent policy domain?
2. Is ambiguity necessary for resilience policy?
3. What did I learn about the usefulness of modelling and the advanced tools proposed in this dissertation for resilience policy analysis?
4. What can scientists do to advance resilience in the policy arena?
5. What are the next steps that emerge from the outcomes of this dissertation?

8.1 ANSWERING THE RESEARCH QUESTIONS

This dissertation implemented myriad qualitative and quantitative methodologies to capture what resilience policy means beyond any particular domain. It gave answers to several concrete questions based on resilience theory, resilience policy documents, field observation, and modelling efforts:

- Which policy goals we can pose for resilience policy?
- How we can structure the policy environment so that it supports both the policy system's resilience as well as the policy subject at hand?
- What common components can we identify in resilience policy documents and plans?
- What tradeoffs should we consider when designing resilience policy?
- How can technical tools such as agent based models support these efforts?

8.1.1 RQ1: WHAT COMPONENTS OF RESILIENCE POLICY CAN WE IDENTIFY IN THEORY?

Reviewing the rich literature on resilience thinking through different disciplinary approaches yielded a set of principles that we have reformulated as policy goals (presented in chapter 2), and a set of strategies to integrate resilience in the policy environment (presented in chapter 3). These offer a useful framework for resilience policy researchers and practitioners who look to define which systemic attributes resilience policy in any domain should advance, and how to structure the policy environment so that it promotes them. In other words - what should a resilience unit do, and how should it do it?

POLICY GOALS

The literature review identified seven concrete goals that can be posed as overarching resilience policy goals:

1. **Maintaining Diversity and Variability** - ensuring a richness of system components that increase its ability to prevent, adapt to, and recover from shocks and transform the system itself through new combinations
2. **Building in Robustness** - advancing policy instruments that allow the system to withstand a wide range of possible futures
3. **Mitigating Vulnerability** - identifying system components and traits that require strengthening through a combination of perspectives, from bolstering individual and social agency to bolstering parts of the system itself that are sensitive to the shocks and stressors at hand
4. **Ensuring Persistence, Adaptability, and Transformability** - finding the right balance between these three capacities, each strengthening resilience at different temporal and spatial scales
5. **Introducing Redundancy** - investing in overlapping policy instruments that ensure the system and its different components can continue functioning and even transform if one of them ceases to function temporarily or permanently
6. **Maximising Flexibility and Modularity** - designing the system in a way that allows policymakers to respond in different ways and rearrange policy resources so that the system can meet the challenge at hand
7. **Governing Connectivity** - regulating the level of connectivity between different parts of the system, or between the system at hand and external systems, so that the flow of energy, resources, information, and any other component reinforces the system's ability to persist and transform rather than undermine it.

However, in contrast to some domains where policy goals can be understood in absolute terms, for example - we need to mitigate GHG emissions as much as possible, we need to ensure access to healthcare to as many people as possible etc., in resilience policy the goals only offer possible directions rather than clear destinations. Their directionality is itself context dependent even within a certain domain application: more connectivity can be a good thing for the food system as it allows trade in inputs and produce to support agricultural production and nutrition, but it also creates a dependence that, faced with crises such as the war in Ukraine, can undermine the food security of entire nations.

POLICY ENVIRONMENT

While the policy goals can help policymakers build specified resilience to particular stressors and shocks, generalised resilience is mostly built through the policy environment itself. This means that the way policy is made needs to follow certain principles that engender resilience thinking and practice. We identified in the literature three main methods to achieve that:

1. **Method 1:** Rethink policy boundaries - while traditional policies are often siloed by domains,scales, and institutions, a resilience-oriented policy environment requires fitting the scales of the policy instruments and institutions governing them to the scales of the problem; to decentralise policy-making so that the places, communities, and people experiencing the problem can experiment with different ways to confront it; and to broaden participation so that the policy is shaped through a diversity of disciplines, perspectives, expertise, lived experience, and potential partners to implementation.

2. **Method 2**: Enable resilience-oriented policy analysis - policymakers should monitor thresholds in the domain they are responsible for, identify cross-scale interactions both in time and space, and utilise tools to integrate resilience in policy design (such as the tools presented in Chapter 6 and 7, but of course there are many more).
3. **Method 3**: Facilitate transformations - rather than wait for the right time to induce change, policymakers and policy entrepreneurs need to be proactive in instigating the transformations required to ensure system resilience. They can do this by using disturbances as windows of opportunity for policy change, connect people, organisations, and ideas to form networks that actively drive policy change, find institutional ways to create space for new ideas to emerge, and initiate planned transformation processes (such as the move to a circular economy, net-zero economy, or a world with safe operating space for AI).

8.1.2 RQ2: WHAT COMPONENTS OF RESILIENCE POLICY CAN WE IDENTIFY IN PRACTICE?

By systematically analysing 41 resilience plans from cities around the world, we identified five components that recur in most plans in one way or another:

1. **Domain** - which specific shocks and stressors does the policy deal with?
2. **Capacity building** - how can we strengthen different actors and system components to \ handle these shocks and stressors, and to implement the resilience policy developed?
3. **Institutional design** - How can we structure the institutions governing resilience to enhance it over time, including their integration and demarcation, the tools they require, and the partnerships necessary for their success?
4. **Stakeholder engagement** - How can policymakers involve different parts of the community in policy design and implementation, and in coordinated efforts to ensure resilience is continually strengthened?
5. **Strategy design** - How can policymakers build the resilience policy itself so that it is effective and efficient? What kind of values must it promote? At what time scales should it be determined? What kind of analysis needs to be employed? And what goals should it set?

These can help guide policymakers, analysts and researchers in designing new resilience policies, and to compare resilience policies to one another based on common dimensions and functionalities.

A different type of analysis was presented in chapter 5, where field observations from teams in 14 different countries were used to derive insights into which components are implemented or should be implemented to support rural and agricultural resilience from the perspective of different stakeholders in each region: Valuing traditions and local capacities; promoting economic diversification; utilising technological innovation and cost efficiency; increasing cohesion between different social groups within the region and outside; and optimising the use of public support. These were found to be often conflicting in nature, reflecting that even when there may be agreement on what kind of system we wish to preserve, the pathways and policies to reaching it can still contrast.

8.1.3 RQ3: WHAT ARE THE POSSIBLE TRADE-OFFS INHERENT TO RESILIENCE POLICY?

The analysis in chapter 5 allowed us to identify a myriad of trade-offs between the policy goals and methods presented in the framework developed in chapters 2 and 3. By examining each strategy at different time scales and spatial scales (community, region, country, world), value preferences, and stakeholders perspectives, we found trade-offs between flexibility and modularity on the one hand and redundancy on the other (a surprising result as flexibility and redundancy are often used interchangeably); decentralised policy-making and connectivity, diversification and transformability, adaptability and vulnerability, and persistence at different scales, to name a few. While capturing these particular trade-offs was case-specific, this analysis provides an important basis for the types of trade-off analysis to be included in analysing and designing any resilience policy.

8.1.4 RQ4: HOW CAN MODELLING BE USED TO INFORM RESILIENCE POLICY ANALYSIS?

Chapters 6 and 7 presented the way agent-based models can support resilience policy analysis through exogenous policy experimentation and endogenous policy evolution within the model. Both modelling approaches allow incorporation of the different facets of resilience policy presented in chapters 2-5: they can analyse how different policy scenarios support resilience policy goals from different agents' perspectives and at different scales represented in the model. They are both beneficial in engendering the kind policy environments described in chapter 2 - where cross scale interactions are looked at, interdisciplinary analysis is encouraged, and participation is broadened. They can both allow examination of the tradeoffs presented in chapter 5 as well. However, each has their own benefits: the exogenous model (and others like it) maintains a level of coherence and simplicity that is easier to both design and trace in conceptualisation, implementation, and analysis, making it more readily available and operable on its own. The endogenous model is more of a platform that allows policy analysts to enrich their existing "technical models" of the domain at hand with an understanding of how the policy system may evolve over time, impacting the domain side and impacted by it as well. This modelling approach, however, requires many more resources and capacity to populate with data, tailor to the specific situation, and analyse, due to its breadth and complexity.

8.2 PERSONAL REFLECTION

8.2.1 DOES RESILIENCE POLICY EXIST? SHOULD IT?

In my many years of work with policymakers and different government agencies, I was asked to tackle countless topics - from agricultural waste to the value of urban densification. The brief I would get from policymakers I worked with, however, was never about resilience, and always about resilience. It was never about resilience since that was never the language they used. They never asked me "What should we do to bolster connectivity or modularity or robustness?". Even when they asked about resilience, it was often in a particular context - climate resilience as a pseudonym for climate adaptation, or rural resilience when they actually meant rural development. It was always about resilience, however, because what they really wanted to know was how they should deal with this change that has happened, or prepare for a change that they know is on the horizon. So is resilience policy everything, nothing, or something in between?

My initial intuition about resilience policy was, indeed, that it was nothing. Every resilience policy I encountered was actually part of a different domain - security policy, social welfare policy, environmental policy, etc. As I delved deeper and deeper into the world of resilience, as often happens with theoretical crushes, I began to see resilience in every policy: Land policy was resilience policy as it had to weigh the needs of cities to expand while providing proper housing and income sources for new residents. Landscapes needed to balance contrasting needs of connectivity in habitats versus a decentralised energy system with its intensified land usage. Airport noise standards were based on modularity in time slots, runway design, and technological advances while safeguarding the persistence of adjacent neighbourhoods and their residents' ability to maintain a normal life. Basically, every policy is meant to either respond to change or induce change, and that is what resilience is all about. So, if every policy is resilience policy, what does resilience policy actually mean?

This dissertation tried to break resilience policy as an independent term into the basic units that make up a policy domain - its goals, the conditions it requires to thrive, its functional requirements, its expected outcomes, its internal trade-offs, and contradictions, what indicators we might use to measure it, what tools we might use to analyse it. In doing so, it set some boundaries between resilience as a policy domain and others.

However, while in every policy domain there are trade-offs to be considered, there are also bottom lines. Value-laden, certainly, but clear answers either way. For example, when asked recently by colleagues of mine what I thought about a certain agricultural reform as an expert in environmental policy, it was quite easy for me to answer. I weighed the GHG emissions associated with each alternative, the water footprint, land requirements, effects on biodiversity, and so on. I used Life Cycle Assessment and Material Flow Analysis and could say with a certain degree of certainty which alternative was preferable from an environmental standpoint. Different people may assign greater weight to one environmental value over another, but overall the analysis is clear.

But no such clarity exists with resilience policy. There is never a clear bottom line, no determination outside of context. For example, if we take connectivity as a policy goal - do we want more or less of it? There's no way of answering that question generically. Even within a certain policy domain, let's say health policy, it could mean so many different things - connectivity between places, between scientists, and between the IT systems that administer vaccines. Even if we want greater connectivity in all these categories (which we don't), how does that play out over time? The past three years have proven the value of breaking connectivity through social distancing, quarantine, and closed borders.

Variability, then. Surely more diversity, and more variability, are always a good thing. Are they though? The language of variability was used by certain political actors in recent years to justify expanding fossil fuel production and exploration to maintain an "all of the above" energy mix. For scientists and climate activists who understand the urgency of transforming our energy system, we might advocate for more heterogeneity in our energy sources, but not in all of them. In other words, there's no rule of thumb of "more is better than less", or if you want more resilience this is what you have to do.

8

Furthermore, what can I advise outside of my expertise in environmental policy? In order to say anything coherent about resilience in any given topic, I have to study that topic in detail. Yes, I can guide other experts and practitioners in thinking about their policy domain or the particular problem at hand, offer useful questions, and suggest a process for coming up with solutions and weighing them. I can even help them critique and evaluate the options they came up with, but I wouldn't presume to be able to prescribe them policy options unless I studied the specific domain in depth.

One question I kept asking myself as a way to understand the validity of resilience as an independent policy domain was - do we need a ministry of resilience? Resilience officers have already established themselves in cities (though at least some of this inertia was spurred by the 100 resilient cities program that has since closed), and I've met in my research journey with resilience officers in government agencies, who were responsible for bridging between different disciplinary expertise, such as climate science and transportation infrastructure. But would it make sense to have a whole ministry dedicated to resilience, the same way we do for the environment, economy, or education? The answer is not straightforward. Just because it doesn't exist doesn't mean it shouldn't. The US EPA was founded in 1970, in Israel the first Minister for the Environment was appointed 18 years later. In both cases, their responsibilities grew over time, as well as their understanding of policy problems, solutions, and goals. To be frank I'm still not sure of the answer. Perhaps a resilience department in every ministry? resilience officer in every department? Or maybe we just need a seminar on resilience thinking every now and then?

Still, the types of questions resilience policy lends, and the values and practices it aspires to instill should not be easily dismissed. When my professional partner Tzruya and I started working with the Arava region in Israel and other rural regions as part of the project I described in chapter 5, we were met with agricultural experts on the one hand and rural sociologists on the other. As experts in environmental policy, the glasses we used to understand the problems they were describing were quite different than their own. One of the recurring problems rural experts described was that of rural depopulation. Indeed, it is one of the main challenges European rural policy contends with. But for us, having as a prime concern lowering GHG emissions and avoiding habitat fragmentation and biodiversity loss, having more and more people move to the city was always the solution, never the problem. When we conveyed that analysis to our counterparts in academic conferences and rural think tanks, it was often met with shock and anger. But once we deployed concepts from resilience thinking, anger slowly turned to confusion, and in that confusion, a narrow space was opened for questions that were considered taboo at best, or never considered at worst.

For example - if the region is trying to attract new residents to de-populating villages, what is it exactly that we are trying to preserve? Is it the landscape of the village? The structure of a community even though the original residents have already left? Is it people who might take up agriculture? What is the justification for the surplus emissions, spending, and infrastructure the government needs to allow and support? Conversely, if those we care about are the original residents of the community - shouldn't we help them move somewhere more viable so they can be closer to potential workplaces, public services, and other people? Are they actually farmers or landowners if most of the workers in their fields are migrant workers? Or perhaps we need to think about them through the lens of transformability, in the sense that their most important value is to knowledge creation on new methods for agricultural production, or adding complexity to the food system? Through an analysis of resilience policy, I myself found many exclamation marks I had as an environmentalist turned to question marks, and so did my rural counterparts. Perhaps that is the true meaning of resilience policy as a boundary object. It does not provide absolute truths and prescriptions, but the questions it raises create a whole new way to examine the policy domain or problem in which they are applied.

Still, some scholars, such as Renn (2020) see sustainability and resilience as inherently interlinked, and thus prescriptive of at least directions for operation, if not specific policy objectives. For example, maintaining humane living conditions for present and future generations, whether through preventing the worst of climate change, preserving ecosystem services, or ensuring that covid recovery measures are fairly distributed and support lower income groups. While this approach is hard to argue with, it perhaps dilutes the independence of resilience as a domain in favour of existing domain in social-environmental policy.

8.2.2 IS AMBIGUITY DANGEROUS OR NECESSARY FOR RESILIENCE POLICY?

One of the conclusions of the previous section is that resilience policy is inherently ambiguous, at least until its specific domain context is clarified, and out of the policy process emerge clearer policy goals and measures. But is this conceptual clarification a necessary condition for an effective resilience policy, or does it actually undermine its purpose?

Mosse (2004), reflecting on his time as a consultant for the UK Department of International Development, asked "Is good policy unimplementable?". He argued that policy is in fact a communication tool, which primary purpose is to facilitate an agreement between disparate actors and parties. The more detailed and concrete it is, the harder it is to reach a consensus. Thus, ambiguity is not a bug in policy design, it is a feature.

The point of this dissertation, however, was to demystify, and decrease the ambiguity of the term "resilience policy". It was intended to provide conceptual tools for researchers, policymakers, and other actors in the policy arena, to clarify what they mean when they say resilience. It looked at literature and policy documents to refine the objectives resilience policy should aspire to, the types of themes or components it should include as a document, and the processes and structures it should put in place. In other words, if effective, it should make it harder to describe a policy as 'promoting resilience' without a proper explanation for what specific resilience values it promotes, at what temporal and spatial scales, at the expanse of what trade-offs. Exactly the kind of clarifications that make it harder to recruit support for action.

For example, as we discussed in chapter 5, when the EU Commission talks about supporting agricultural resilience, they often mean promoting intensification. However, intensification comes at a price. It often facilitates centralisation of operations, thus rewarding capital accumulation at the expanse of small farms; it further entrenches the kind of agricultural practices that created many of the social-environmental problems associated with modern farming in terms of nitrogen emissions, GHG emissions, and biodiversity loss. It also creates greater dependency on the global market as well as debt, which could undermine farmers' resilience over time. Creating the kind of policy environment described in chapters 2 and 3 or even a policy document resembling the resilience strategies in chapter 4 would invite contrasting interpretations of agricultural resilience, as well as critique from groups that may have been hitherto excluded from the debate, and thus destabilise the policy as a rhetorical tool that coalesces interests.

Following this logic, resilience could be more useful as a metaphor than an operable framework. And indeed, when reading the literature about resilience governance as a policy practitioner, it sometimes seems impracticable. The dream of a truly polycentric policy-making structure, which not only allows but demands experimentation, constantly adapting not just to circumstances but to what we learn from local experience as well as others is more than ambitious. It is antithetical to the Weberian state. It also assumes the supremacy of the local for determining policy, an assumption that ignores the fact that local interests and needs are not necessarily aligned with goals that cannot be perceived at that level. Thus, the problem of fit is turned on its head, pitting the local against the national or even super-national.

Indeed, resilience as a project seems intent on extending its ambiguity and conceptual confusion as it expands into more and more fields. I remember the anger I confronted when as a student with a background in political science, hearing professors who are world leaders in ecology as they discussed using resilience to solve real-world problems, then asking them how they could apply basic concepts in ecology to complex societal questions where 'optimums' had no place. For them, applying resilience not only as a metaphor but as an actual way society works and should work seemed not just natural but desirable. In that sense, resilience perhaps wasn't designed to deal with the ambiguity inherent to it once it is applied beyond the narrow confines of landscape ecology, where its concepts could be empirically observed, measured, and tested.

So, should we refrain from reducing ambiguity in a policy domain that is growing in importance? I don't believe so. In this case, ambiguity leads to depoliticisation. Who could argue with a policy that promotes resilience? Who should argue with a policy based on a technical term and theory that seems so 'natural' in its roots? But of course, the specifics of resilience policy look quite different. They bolster resilience for some and undermine it for others. They lock in certain pathways while uprooting others. Clearly defining which specific resilience policy goals were defined, at what temporal and spatial scales, with which trade-offs and for whom, following what kind of process or by what governance structure - could make all the difference between what each of us determines as good policy or bad. That is the basis of informed democratic choice.

8.2.3 ON TOOLS

One of the purposes of this dissertation was to provide concrete and practical tools for policy analysts to design resilience policy. I'd like to focus on the models described in chapters 6 and 7 to ask, for a moment, are they in fact usable in policy analysis? If so - for what purpose? If not - how can they be made more usable for and by different constituents?

The most frequent question I get when approached by policymakers to address a new policy problem is 'What did others do?'. In that sense, the kind of mapping that came out of chapter 4, looking at as many policy documents as possible and taking stock of what came up would be the most useful way I could answer their questions about resilience policy. While the categorisation process rests on a degree of interpretation, having the original tables with the actual phrases used in each plan allows policymakers to make their determination about the categories that came up, or even just focus on the least abstract level of analysis, meaning the domains and policy mechanisms captured in the plans. Most likely this would entail going back to the actual plans and finding the original description of specific problems and solutions of interest. Being able to base an argument in favour of a certain policy tool on the actual experience of others lends it both power and credibility.

Creating an agent-based model, on the other hand, is a different story altogether. Firstly, it takes quite some time and expertise to build. It thus most likely requires outsourcing to researchers, whose time-frames are wholly incompatible with the pace of policy-making. Even the endogenous model we proposed and built requires a policy domain model to connect to, and a mapping of the policy system that is not readily available to policymakers.

Second, what goes on inside the model requires much interpretation, which compounds as the model's complexity grows, adding to the inherent uncertainty in any kind of modelling. The endogenous policy model thus requires not only effort to set up and populate, but also to process and make sense of. These are resources not often available to policymakers. But even if they were - is the value of the model in the model itself or in its making? Is it not in engaging with different affected groups and experts to better understand the problem and the policy system affecting it, understanding each other's assumptions and needs? Most modellers would indicate the latter. In resilience policy that is surely the case. But these efforts make the chances of being able to use a political window of opportunity to promote a certain policy even smaller. Whether that is a positive or negative attribute of the model is utterly observer dependent - for certain policy entrepreneurs, this would be counterproductive. However, as we strive to politicise resilience policy and reveal the distributional divides it may amplify, this understanding of policymakers' and other actors' interpretation of reality and intended action is an important source of resistance and ability to bring up alternative interpretations and solutions.

The other direction could be then to automate and simplify the model as much as possible, and instead of building new models - connect it with other existing models as part of a multi-model ecology. To a certain degree that was indeed the approach we took with the endogenous model. It was designed to connect with whichever model captures the policy domain debated, as long as it can be configured to transmit the data about the state of the system to the policy agents on the policy system side, and translate the decisions these policy agents make to changes in the domain side environment. The graphs depicting changes in policy coalitions, beliefs, and other choices presented in chapter 7 showcase the kind of automation of data processing that could help policymakers make their own determinations about the model and what its results teach us. But of course, the simpler the model and the more automated the procedures, the fewer freedom users have to learn from the model and its proximity to their interpretation of how the world works.

Another value we should consider for the model is Latourian in nature, meaning its value of persuasion. Latour described the importance of objects of calculation scientists build to persuade different audiences of their claims and proposals (Latour, 1986). In policy, such tools hold great value. When I was director of the Social-Environmental Caucus in the Israeli Parliament, we held a session once on the McKinsey GHG abatement cost curve. It was a simple graph that showed how much money each ton of CO_2 equivalent would cost to mitigate for different policy tools being considered. However, while the McKinsey report briefly mentioned the potential mitigation from a modal shift, the curve largely excluded any policies that required behavioural change or systemic change such as building a bus rapid transit lane or creating mixed-use neighbourhoods (McKinsey, 2023).

Still, since it was the only graph on the board, with actual numbers allowing comparison of the tools, it defined the government's scope of analysis, and accordingly its priorities and plans. Having a tool like the one proposed in chapter 7, which can represent possible dynamics and pathways for the policy system and policy itself over time could allow proponents of competing policies to challenge more simplistic, static, or narrow analyses often relying on much more basic economic models. Finally, making the assumptions in the model explicit allows a richer debate that brings in experts from different fields as well as non-experts, who may not be able to contend with traditional models whose assumptions are rarely discussed.

8.2.4 WHAT CAN SCIENTISTS DO?

Over the past few years, I had the privilege of working on projects that bring together scientists, practitioners, and policymakers. As someone who has a foot in both worlds, academia and government, I believe scientists have much more potential for affecting policy than they realise, resilience policy in particular. This can be done through several routes: telling policymakers what to do, inserting complexity into the debate, creating opportunities to initiate policy, taking part in ongoing policy debates, participating in multi-stakeholder platforms, and acting as translators in between disciplines, and between academia and the outside world.

PROVIDE ANSWERS WHEN POLICY-MAKERS ASK

One of the recurring messages in resilience policy is that we need to integrate new kinds of knowledge into the policy debate, with scientists being a crucial voice in the debate. However, my colleagues in academia are often surprised by just how much policymakers ask to be told what to do about a certain issue. As I mentioned, the first question I'm asked as a policy analyst almost always is "What do other countries do". Yet, rather than calling scientific experts in the field, policymakers often rely on external consultants and NGOs to form policy proposals. This is not a critique of policymakers, whose time is limited, and whose networks are naturally confined. It is, however, an indication, that at least in certain policy domains and problems - if scientists become readily available for consultation and proactively network with the right civil servants, they can save civil servants much time, while affecting policy trajectory from early stages of policy conception. While their advice would not be necessarily welcome under all administrations, it would provide a critical basis for science-based policy-making, which scientists the world over are calling for profusely.

PROACTIVELY AFFECT THE POLICY PROCESS

As was mentioned in chapter 7, the multiple streams framework argued that policy entrepreneurs open policy windows by finding and framing the right combination of problems, policies, and politics. Scientists can affect all three. They are often the ones to come up with problems and policies in the first place, but they do not necessarily know how to operate in the policy sphere.

One way to do so is to leverage the power of scientific organisations - not only the traditional structures such as universities and disciplinary associations, though they have a large role to play as well, but also through NGOs such as the Union of Concerned Scientists who promote an agenda of inserting scientific debate and representation into formal policy structures.

While some may wish to refrain from taking an active part in the policy process as it may undermine their social trust and acceptability by some members or parts of society, they must keep in mind that policy will be advanced with or without their participation, even if that policy is zero action. When tackling the global challenges resilience thinking often addresses, such as the need to rapidly de-carbonise and provide tangible adaptation solutions to the effects of climate change, keeping to the sidelines is not a viable alternative.

Another way is to effectively connect with policy entrepreneurs and help them find alternative framing for problems and solutions that could translate to the kind of policy scientists support. Integrating with the policy process could be quite time-consuming, as it requires following what legislation is being considered in Parliament, speaking with Parliament members and civil servants on a permanent basis, taking an active part in formal policy deliberations, and recruiting other experts to bolster the case for the policy proposed. These activities are not usually recognised or rewarded by universities, but they hold the potential for much impact on policy discourse and outcome.

ADDING COMPLEXITY TO THE DEBATE

Researchers have access to tools policymakers lack, and the time and knowledge to use them. This allows them to enrich the debate with nuances and alternatives it sorely lacks. For example, when considering the agricultural reform in Israel, the debate mostly touched on the price of produce versus the profits of farmers, with some environmental NGOs bringing up the issue of food sovereignty. However, from a resilience standpoint, there are so many more dimensions to be discussed - from the types of subsidies given to farmers and their ability to affect environmental performance, to the kinds of agricultural products it makes sense to grow locally versus importing based on supply chain stability, cost, and social-environmental considerations, the ability to develop agro-tech in Israel as part of an innovation ecosystem where researchers, farmers, and entrepreneurs work hand in hand, land allocation to crops by type, what kind of agricultural landscapes we want to preserve and where, and many more. Only through direct interaction with think tanks, civil servants, and even the media, was it possible to start enriching the public debate and expand the boundaries of the policy being considered.

PARTICIPATING IN MULTI-STAKEHOLDER PLATFORMS

Multi-stakeholder platforms have become a staple in Horizon Europe projects. In a project I am currently working on, focusing on six different countries in Africa, I saw firsthand the challenge and potential of taking part in such platforms. In many places, they can bring together local activists, policymakers from the local up to national and even international levels, people directly affected by the problem everyone together is trying to tackle, and researchers supporting them by providing their expertise. By providing knowledge from elsewhere, as well as frameworks for thinking about the problem and tools for analysing it and building informed solutions, scientists can not only help shape better policies but also establish research that is based on the initiatives and needs that come up in the platform. From a resilience policy standpoint, these platforms are the most practical way I've encountered of creating the kind of policy environment and structures described in chapter 3, creating a direct connection between different communities and levels of governance.

ACTING AS TRANSLATORS

Coming to a school of systems engineering as a social scientist I had to learn how to think like an engineer, and how to explain myself to them. This disciplinary divide is of course not unique. Explaining to political scientists why modelling could be useful for enriching theory, or even why policy theory should be used for practical analysis was and remains just as much a challenge. However, it is still internal to academia. In order to engage with the public and ingrain a systems thinking approach in the policy process, scientists need to know how to act as translators between different disciplines, and between researchers and policymakers. This is not just a conceptual challenge, but a very practical one - how do you create a powerpoint presentation for a parliamentary committee hearing where you only get three minutes to talk? what do you say? what kind of terms do you use? what kind of material do you bring to the committee? How do you persuade the committee chair to let you participate in the discussion in the first place and once it started? what messages do you want the media to use afterward? These are crucial skills to be able to participate in policy debates and eventually affect policy outcomes.

8.3 WHAT'S NEXT?

The research presented in this dissertation is ongoing. Some of the chapters are in process of publication, while others remain more of a conceptual foundation for our work. Chapter 4, reviewing resilience policy plans, has become particularly relevant over the past few months, as I've been advising several organisations in Israel on how to support climate resilience planning in Israeli municipalities. Studying what the participating cities did to prepare for specific shocks and stresses within the domain of climate change clarified for me the need to map and compare specified resilience policies in different domains across the plans.

Through the project I described earlier taking place in African cities, I am working on building new methodologies for establishing and operating multi-stakeholder platforms for sustainability transformations, and hope to build on the insights from chapters 1 and 2 as a basis for the empirical research we are conducting on the platforms our partners. Finally, the endogenous modelling approach presented in chapter 7 is of particular importance to me. We hope to be able to make it accessible to different academic and practice communities: policy theorists who may continue to help it grow by formalising and exploring their theories in the model, domain specialists and modellers who may wish to connect their existing domain models to the policy system model in order to enrich their model's complexity, and policymakers as well as other actors in the policy arena who may wish to use the model to explore concrete policy problems, though that may require further simplification of the model.

8.4 FINAL REMARKS

Resilience policies have been sprouting in every policy domain in every corner of the world. Resilience officers and professionals have been appointed at government ministries and agencies, municipalities, businesses, and NGOs. But thus far, the concept of resilience policy as an independent policy domain, equivalent to environmental policy or health policy, remained quite open for interpretation. This dissertation laid the groundwork to change that. It proposed clear goals for resilience policies, methodologies for integrating them in government work, illustrated the trade-offs policymakers must consider when they propose such policies, and offered concrete tools to help analyse resilience policy through modelling, and go even beyond traditional ABMs in allowing policies and policy arenas to evolve within the model. This toolbox should serve any resilience professional looking to understand what their job entails, researchers of resilience policy and resilience in general who can use this analysis as a common language to debate over and develop, and even modellers and researchers in policy disciplines hoping to extend their analysis to embed the dynamic approach of resilience thinking.

We wish to thank you for reading this manuscript and invite you to open a discussion and collaboration on resilience, policy, and everything in between.

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ANNEX A:
THE THEORETICAL BASIS FOR SOCIAL-ECOLOGICAL RESILIENCE

APPENDIX TO CHAPTER 1

The concept of resilience was originally introduced by the Canadian ecologist C.S. Holling (Holling, 1973) as a way to explain how ecological systems can persist in their original state when perturbations occur, rather than move to another attractor, or alternative stable state. For example, when will a forest remain a forest if a fire occurs, and when will it become barren? Holling differentiated between engineering resilience, which focuses on returning to equilibrium, and ecological resilience, which describes complex systems that have multiple basins of attraction, or multiple equilibria. Disturbances can cause the system to cross a threshold and move to an alternative basin or attractor. Attractors can be either fixtures of stability or cycles that occur. The attractors themselves are dynamic, as their properties and thresholds are affected by embedded randomness and trends in the system. When fluctuations close to the trends turn into more explicit shifts, the system can be described as undergoing a regime shift. If these shifts move the system from one stability domain to another they can be termed critical transitions. This interplay between change and stability informed Folke's definition of resilience as the capacity of a system to cope with change and disturbances by both absorbing them and reorganising so that the system can maintain its functions, structure, feedback, and overall identity (Folke and Gunderson, 2010).

Holling's original conceptualisation of resilience was based on four basic functions of ecosystem behaviour, and how they sequentially interact with one another: First, exploitation, meaning processes where organisms can capture readily available resources, usually after some disturbance has occurred in the ecosystem. Second, conservation, is the process by which these resources are accumulated and complex structures start appearing in the system. During these two stages, there is an increase in connectedness and stability. When these connected structures become over-connected, a creative destruction process is likely to happen (a forest fire for example). The system is vulnerable and easily changed, as the stored capital is released and organisation is lost. This represents internal destruction triggered by an external event. However, this release sets the stage for a fourth function, process, or stage - reorganisation. The released materials become available for the next "exploiters" and a new cycle can begin. Resilience, thus, is the capacity of a system to experience stress and recover. In other words - how well is the system able to self-organise? (Folke et al., 2007)

When Holling applied the concept of resilience to analyse ecosystems, he aimed to explain how ecosystems can absorb change, or continue developing in a preliminary state when the system is disturbed or when its conditions change. In contrast to the prevailing view at the time, he proposed that ecosystems can have several basins of attraction. Thus, he defined resilience as a system's ability to persist by absorbing fluctuations in different parameters and variables (such as state variables and driving variables). He observed the effects of random events on ecosystems, as well as their heterogeneity at different scales of time and space (Folke, 2016). However, society was not the focus of Holling's analysis. That changed in 1998 when Folke and Berkes introduced the social-ecological systems approach to the field.

In describing the birth of resilience theory, Folke (2010) emphasised two assumptions made by Holling: First, that humans and nature must be considered as one co-evolving social-ecological system. Second, the systems do not respond to change in a linear fashion. Instead, they are unpredictable, constantly shifting, self-organising, and responding to feedback loops across scales in both time and space. Or in other words, these are complex adaptive systems. The social-ecological systems approach erases the boundaries between social systems and natural systems. It points out that the social and the ecological are in constant interplay, shaping each other, delineating trajectories and determining each other's evolution. The social sphere includes technologies, institutions, economy, and culture, among the many facets of human activity. The ecological component contains the biosphere and the dynamics driving the earth – biogeochemical cycles, the atmosphere, water cycles, the interlinkages between living beings and so on. Thus, studying resilience requires integrating the analysis across scales of time and space, and across artificial disciplinary boundaries. People, communities, and societies shape ecosystems and the biosphere, are dependent on it, and are shaped by it (Folke et al., 2016). Social-ecological resilience focuses on three dimensions: how much disturbance can a system absorb before changing its state, how capable is it of self-organising, and how much capacity does it have to learn and adapt? (Wilkinson, Porter, and Colding, 2010)

Social-ecological resilience thinkers look at the interplay between times of stability or gradual change and times of rapid change. Their system boundaries are social-ecological systems, where uncertainty is prevalent: these are complex-adaptive systems where people interact with one another in unpredictable ways, leading to the emergence of macro-level phenomena that can in turn affect people's behaviour itself. This interaction may cause changes to the system's properties as a whole. Thus, complex adaptive systems display non-linear dynamics, with shifts between different attractor states that can become irreversible (Folke et al., 2016).

In order to better clarify resilience analysis, Walker et al. (2012) suggested the following distinctions between different elements of social-ecological systems: First, the system is based on state variables and the relationship between them. Change in the system occurs either as a result of these relationships or due to the impact of external drivers, meaning variables that are outside the scope of the system and are not affected by its internal dynamics, as they are at a higher scale, for example. Within social-ecological systems, humans can be either an exogenous factor when the issue at hand is purely ecological in nature, or endogenous when what is being examined is a social-ecological interface. Conversely, ecological processes can be considered external drivers of social processes, or endogenous factors if the process involves interaction between the social and the ecological parts of the system. Another important distinction is between behavioural rules and control variables. Control variables often signify variables people can change in order to affect the system, such as policies, for example. If, however, people are considered an endogenous part of the system, the rules by which they decide which control variables to act upon need to be identified and defined explicitly. In other words, differentiating between exogenous and endogenous variables, and specifically people's behaviours as either one is crucial to analysing social-ecological systems. Similarly, distinguishing between internal system variables and external drivers regardless of people's behaviour and choices is important. The variables driving and controlling system behaviour have thresholds beyond which it moves from one stable state to another. These variables may change slowly, allowing gradual change that then pushes the system beyond the system in a relatively short time period (Sinclair et al., 2014).

Since one of the goals of this dissertation is to bring together insights and tools from different schools of thought on resilience, it is worth reviewing how Holling himself looked at the way ecological resilience and engineering resilience translate to policy and institutions, and their implications on increasing or undermining the system's resilience over time.

Holling (1996) described two definitions for resilience in ecological literature: the first definition, which is closer to engineers' understanding of resilience, emphasises efficiency, constancy, and predictability. It focuses on how fast a system can return to a steady state equilibrium following a disturbance. Holling termed it "engineering resilience". The second definition closer to biologists' interpretation of resilience emphasised persistence, change, and unpredictability. This view focuses on conditions that can transition systems from one equilibrium to another. It measures resilience by the amount of disturbance that a system can absorb before changing its structure, by changing the processes and variables that control behaviour. He termed this approach "ecological resilience". Holling argued that these two views can be described as alternative paradigms to resilience. Ecological resilience, he said, can decrease, even if engineering resilience is maintained: when agencies manage ecosystems seeking constancy of production, they may undermine resilience, encouraging industry to become static and dependent on particular conditions that may change at one time or another. This, he argued, is likely to lead to a crisis triggered by an unexpected external event, which in turn may lead to policy change. The fundamental difference between the two approaches, he argued is in the belief of whether only one or more stable states are possible. If only one is possible, then resilience can only be measured by the time it takes to return to that state.

However, in nature, more than one stable state is possible, and so resilience can also describe the constructive role of instability such that it allows diversity as well as persistence, and designs that maintain functions in face of disturbance. Holling captures two features that increase ecological resilience: First, functional diversity, meaning that different mechanisms regulate the same function. While they are not efficient in and of themselves, their overlap redundancy ensures robustness to the regulation process, and thus system resilience. The second feature is the tendency in nature to operate close to the limits of instability, where information and opportunity are most abundant, different from engineering resilience that operates near the equilibrium. Ecological resilience, he argued, requires three main features that comprise adaptive management: First, having a diverse, flexible, and redundant regulation. Second, error signals can drive corrective action. Third, it requires constant experimental probing of changes in the environment. This would become the basis, he suggested, for institutional regimes that can maintain and increase system resilience. These would avoid controlling a single target variable, ignoring its wider social, environmental, and economic context. Rather than focusing on yield, we would focus on the interrelations between people and resources in face of uncertainty, rather than short-term - a long-term perspective; and rather than local settings regional settings would take precedence. He then translated this approach to a clear policy prescription: integrating knowledge across scales, engaging the public to explore future scenarios, embracing adaptive design that acknowledges and tests the unknown, and involving citizens in monitoring and interpreting results (Holling, 1996).

An alternative approach to the single or multiple equilibria of engineering and ecological resilience is evolutionary resilience. This approach resists the desire to maintain an equilibrium or find ways to cope with disturbances. Instead, it looks for new forms and functions that can accommodate the shocks and stresses the system is facing (White and O'Hare, 2014). In other words, rather than looking for an old or new equilibrium, evolutionary resilience requires constant adaptation, describing the ability of a complex system to change and transform in reaction to the stresses it endures. It is in fact these changes and fluctuations that allow the system to persist over time (Doyle, 2015).

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ANNEX B: EXTENDED METHODOLOGY FOR THE BIBLIOMETRIC AND CONTENT ANALYSIS

APPENDIX TO CHAPTER 4

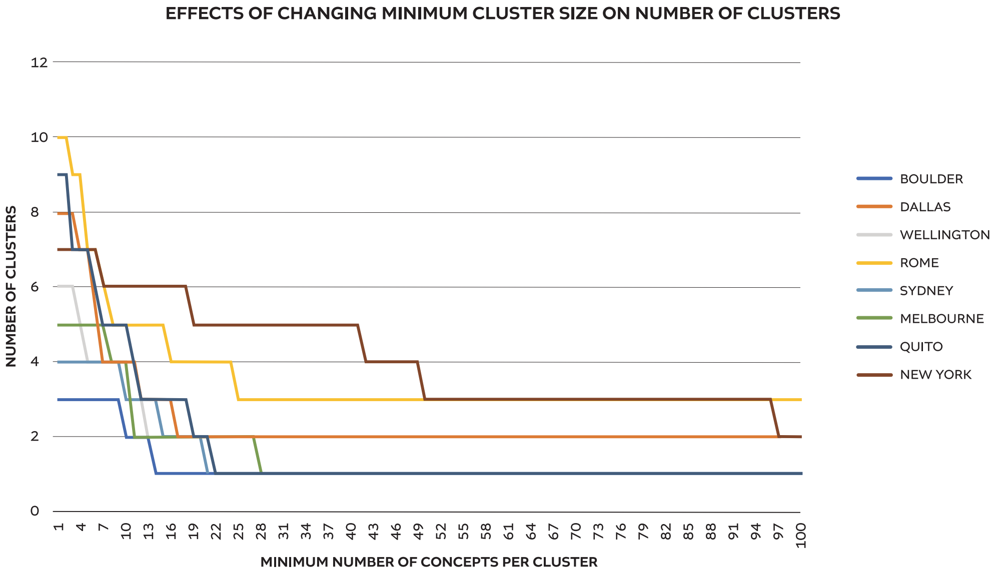
FILE PREPARATION AND PARAMETER CONFIGURATION

First, each of the 41 plans in the English language available at the time on the program's website were downloaded in PDF form. Next, they were converted to a .txt file as required by VOSviewer by an online converter (http:// convertonlinefree.com/PDFToTXTEN.aspx).

Next, each plain txt file was uploaded to VOSviewer separately. This initial stage consists of several choices and parameter settings prompted by the software:

1. Create a map
2. Create a map based on text data
3. Upload the txt file as the VOSviewer corpus file
4. Ignore structured abstract labels and copyright statements
5. Full counting - This means that all occurrences of terms selected are counted, compared with a binary count where only their presence or absence matters
6. Set minimum number of occurrences of a term - At this stage the software begins choosing the terms to be included in the co-occurrence matrix. Since each city's plan is of a different size, there was a need to standardise this variable. In small plans with a smaller overall word-count, the number of occurrences for each term is expected to be smaller as well. Thus, rather than using a benchmark absolute value, a percentage threshold value of 0.03% was calculated for each plan. For example, in Amman the software identified 3554 independent terms. In order to reach the threshold, a minimum number of 9 occurrences per term was set, yielding 108 terms overall.
7. Select the 60% most relevant terms - The software automatically attributes a relevance score for each term, and based on it advises to maintain only the top 60 percent of terms. This setting was kept.
8. Verify selected terms - The final step before producing the map was taking out any terms that are not of substance, such as "n a" (not available), "visit http", unidentified duplicates and so on. Each exemption, as well as the variable configuration for each city was documented in a designated methodology file.
9. Minimal cluster size - The software allows users to increase or decrease cluster sizes by \ choosing the minimum number of terms that a cluster must include. While having fewer clusters may facilitate analysis, it risks a loss in richness and detail. In order to determine the optimal setting, several experiments were conducted with plans representing different percentiles of number of terms (meaning different plan sizes). The graph below shows that the change in minimum cluster size is not linear, it is a steps chart. This means that the change in cluster size mostly occurs in increments of 2-3 terms per cluster. Thus, the chosen parameter setting was 1, meaning that there was no filter on the software's matrix. However, during the analysis itself, clusters with only 1 term were not named or categorised since the categorisation process required a combination of at least two terms to create a reasonable context for the term.
10. Robustness analysis - Several txt files were ran three times through this process to ensure the software produces the same output each time (concepts and clusters).

FIGURE 37: EXPERIMENT RESULTS - MINIMUM CLUSTER SIZE



Following is the final configuration for each of the city files:

TABLE 6: PARAMETER CONFIGURATION PER CITY PLAN

CITY	OVERALL TERMS	PERCENTILE	MIN. NUMBER OF OCCURRENCES TO MEET 0.03% THRESHOLD
amman	3554	585	9
athens	6099	975	13
atlanta	5073	902	13
bangkok	3634	658	14
berkley	2097	24	8
boston	5218	926	9
boulder	1892	0	7
bristol	2812	268	8
byblos	2630	195	8
cdmx	4834	829	10
christchurch	4727	804	11
da nang	2383	0.17	13
dakar	3301	487	11
dallas	2372	146	13
el paso	2848	292	8
glasgow	2228	97	8

CITY	OVERALL TERMS	PERCENTILE	MIN. NUMBER OF OCCURRENCES TO MEET 0.03% THRESHOLD
los angeles	6025	951	10
medellin	2166	48	10
melbourne	4025	756	10
montreal	2368	121	10
new orleans	2646	219	8
new york	14825	1	9
norfolk	2207	73	8
oakland	3720	707	11
paris	3549	0.56	11
pittsburgh	3901	731	10
quito	4911	878	16
ramallah	3244	463	11
rio de janeiro	3120	414	13
rome	3308	512	12
rotterdam	2862	317	9
san francisco	3007	365	8
santa fe	3618	634	11
santiago	4905	853	10
semarang	3214	439	10
surat	3592	609	13
sydney	3500	536	11
thessaloniki	4714	0.78	11
toyama	3059	0.39	9
tulsa	3708	682	12
vejles	2882	341	8
wellington	2653	243	9

The result of this process were 41 maps. This output has three aspects - a visual map, a map file and a network file. A map file includes information about each term, most importantly which cluster it belongs to. The network file includes information about the links items in the map (Van Eck and Waltman, 2013). In order to capture the broader themes that emerged in the analysis rather than focus on specific terms, the map files were used for the rest of the analysis, and specifically the terms identified under every cluster. The clusters mostly include more than one coupling of terms, making clearer the context in which the terms are situated.

CLUSTER VISUALISATION

While there is significance and value in the visual maps offered by the software, it is oriented toward exploring terms rather than clusters. That is why a simpler way to represent each city's clusters and terms was required, facilitating the cognitive process of categorization. In order to create the simplified maps an R code was created based on the visNetwork package (Thieurmel, 2019). The result was an html file for each of the maps, presenting the clusters and their associated terms.

MAKING SENSE OF THE CLUSTERS

The process of categorising the clusters that emerged from VOS-viewer's analysis of each city's resilience plan included three stages: First, naming the clusters, second, creating meta-categories, and third, defining sub-categories that describe the categories in detail. The questions guiding the analysis served as reference points for the categorization process - what is the policy about? What elements of the policy process does it address as they relate to different descriptions of resilience and resilience policy? How were these elements operationalised?

NAMING THE CLUSTERS

Naming the cluster is an interpretive act. Each cluster can have more than one definition, description, or name. In order to engender maximal transparency to how each cluster was coded, the process was broken down to steps and procedures, and documented in full.

To begin with, each city's map was inspected in the html file cluster by cluster. After looking at the cluster's affiliated concepts, a name was given to the cluster based on an "action-descriptor-object" format. For example, "planning for changing environmental conditions", whereas the action is "planning", the object is "environmental conditions", and the descriptor is "changing". The names were based on a specific combination of concepts in the cluster, read in a specific order to make sense as a sentence or a structure. The concepts included in the final naming were documented, as well as the order in which reading them led to the specific naming choice for the cluster. For example, the concepts "platform partner", "supportive community", "ngo", "relevant department", "private sector" "actions", and "action owner" in this particular order gave rise to the cluster name "defining clear partners'responsibilities" (Athens cluster number 3).

By including or omitting certain concepts, or by changing their order, different interpretations and naming choices can be reached. Our goal was to include as much information as possible in the resulting "clusters table" to explain the choices made. This creates the basis for a detailed and informed discussion with others about them, allowing a structured process of dispute and reinterpretation.

Once each cluster was given a name and documented next to the concepts engendering it, it became apparent that analysing across plans requires a higher level of abstraction or categorization. While the first level of abstraction, naming the clusters, described what each city's resilience plan was about and how it was built, the meta-categories aimed to describe this phenomenon of resilience policy across geographies and domains. Each line in the clusters table was read and given a one or two word descriptor. If the next cluster name fit the descriptor it was kept, and if not - a new descriptor was assigned. In the end, seven meta-categories were found. However, two of them - communicating the plan and leadership, were folded into other related categories: stakeholder engagement and institutional design. This somewhat evened out the cluster frequency in each category, but the final distribution is still not homogeneous.

DEFINING SUB-CATEGORIES

While the categories yielded overarching descriptions of the structure of the policies, ascribing meaning that explained what they meant in more detail required an intermediate level of abstraction in between each specific cluster and the meta-categories. Thus, an additional analysis was conducted that combined these two levels: A new filtered list was created for each category displaying its affiliated clusters. Each cluster name and concepts were read in relation to the meta-category, and a more detailed description of it was created containing one or more single words comprising the sub-category name. If the next cluster fit the sub-category it was given the same affiliation, and if not - a new sub-category was created.

The result was a list of meta-categories describing what resilience policy is, subcategories capturing what each meta-category actually means in the context of resilience policy, and cluster names describing how these different elements manifest on a local level in each plan.

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ANNEX C:
FURTHER DETAILS ON ABMs RELATED TO RESILIENCE

APPENDIX TO CHAPTER 6

REVIEW OF ABMs IN RELATED POLICY DOMAINS

ABM has been used to inform and analyse policy in a wide range of domains (see for example Zehra and Urooj (2022) for a review of its use in economic policy, Ornstein and Hammond (2021) in public health policy, Castro et al. (2020) in energy policy, Kremmydas, Athanasiadis, and Rozakis (2018) in agricultural policy, and Cubeddu (2020) in environmental policy analysis). As resilience policy needs to provide solutions for challenges in various domains it is useful to review past applications of ABM in domains that are closely related to resilience policy, or where questions of persistence and transformation are of special importance.

Following are several examples of ABM developed to support policy closely related to issues of resilience - emergency response and public safety, economic planning, conflict resolution and social justice, and infrastructure design, including in public transport.

EMERGENCY RESPONSE AND PUBLIC SAFETY

In some situations, experimenting with policy is not just difficult to execute or financially costly for trial and error, it could lead to loss of life and serious crises. This is the case in domains such as emergency preparedness and response and public health and safety. Researchers in these domains built ABMs to help with questions such as how to best support refugees, reduce harm from gun ownership and alcohol consumption, and how to reduce contagion through regulation.

1. Supporting refugees - Anderson, Chaturvedi, and Cibulskis (2007) created a model that simulates the effects of policy makers' decisions regarding the level of sanitation, security, availability of food, water, and medical resources and personnel, on the response and possible behaviour of refugee communities, their health and well-being.
2. Public health and safety - Hayes and Hayes (2014) simulated a mass shooting scenario, using different parameters based on a bill to restrict the sales of assault weapons and high-capacity magazines. The simulation found that the rate of fire is the most influential variable on the number of people wounded or killed, and that banning high-capacity magazines will therefore be an effective policy instrument (in contrast to the assault weapon ban which they argued does not decrease the rate of fire). Another model, Vir-pox, explored different containment measures to block the spread of smallpox. The researchers found that different policy options, in this case, various vaccination strategies, were subject to uncontrollable influences beyond their expected "objective impact", such as identity and group behaviour. The model then estimated the number of deaths each strategy could yield (Eidelson and Lustick, 2004). Other models focused on how regulators act. For example, McPhee-Knowles (2015) developed a food safety model that examined the interaction between government inspectors, retailers, and consumers. The model simulated different inspection scenarios, comparing different search strategies inspectors deploy to identify contaminated stores.

ECONOMIC PLANNING

Economic planning has become a vital domain for enabling transformations and ameliorating crises. Through budgetary allocations, monetary decisions and taxation instruments policymakers can alter people's and corporations' behaviours in advance, and provide necessary relief when a crisis hits. Researchers have used ABM to explore the effects of micro-economic policy, macroeconomic policy, and diffusion and innovation, as presented below.

Micro-Economic Policy

ABM seems particularly suited for simulating micro-economic phenomena and policies, representing individual consumers', workers', and businesses' behaviour, knowledge and choices, and their effects on the economy as an emergent pattern. Dawid, Gemkow, Harting, and Neugart (2009) designed a model, for example, that examines how the geographical distribution of policies that improve labour skills can affect technological change and growth in a regional and in super-regional context. Pablo-Martí et al. (2013) used a model called MOSIPS to examine the potential impacts of policies for supporting Small and Medium Enterprises (SMEs). It forecasts the evolution of an economic system over several years, based on the interactions and behaviour of two types of agents: Households and firms. Government regulations, as well as access to finance and other factors, influence agents' decision of whether to start their own company. Through their relations with other households and firms – an economy emerges where companies can compete or cooperate with one another, grow, employ, sell and trade. The public sector's rules thus modify agents' behaviour and decisions and as a result the market itself.

Similarly, Ogibayashi and Takashima (2014) incorporated the government as an explicit actor in an ABM that explores the impact of the corporation tax rate on the GDP. The authors designated two main roles for their government agent – collecting taxes, set in a constant rate for companies and progressive for consumers, and spending money on public expenditure – from wages to public purchasing of goods – using market purchasing and subsidies as demonstrative policies. The policies themselves, however, are set externally to explore the outcomes of their different combinations.

Macro-Economic Policy

ABM has also been used to simulate emerging macro-economic phenomena and mechanisms, as well as multiple market economies that are grounded in actual economic structure and details. Ogibayashi and Takashima (2013) for example used macro-economic simulation to investigate public policies' effects on GDP. Their model represents consumers, producers, a bank, and government agents, exchanging money, giving rise to such macro-level factors as GDP, wage gaps (measured in the Gini coefficient), and average market prices. The government in this case collects taxes, pays wages to its employees, and spends money on public foods. The model then tests the effects of expenditure policies and subsidies for the private sector, as well as combinations of both.

Diffusion And Innovation

ABM is particularly useful in simulating consumer attributes and decisions, helping policymakers evaluate policy tools' impact on technological diffusion, and its desired rate and extent. This has been used to simulate future diffusion scenarios and counterfactual diffusion scenarios (without policy incentives or other incentives in their place) in different products and fields, such as solar power (H. Zhang, Vorobeychik, Letchford, and Lakkaraju, 2016; Zhao, Mazhari, Celik, and Son, 2011), smart metering (T. Zhang and Nuttall, 2011), and electric vehicles (Querini and Benetto, 2014) among others.

In addition to analysing policy impact on new technologies' diffusion, agent-based models have also been used to analyse policy's impact on the very process of innovation. Such is for example the INFO-SKIN model. The EU invests heavily in academic and commercial research and development programs. Through them, the European Commission aims to spur innovation and discoveries that will secure Europe's competitiveness and economic growth. The previous scheme, Horizon 2020, allocated nearly 80 billion euros of funding over seven years (Kugleta, 2017).

The model simulated the impacts of policy design choices expressed in the Commission's calls for proposals on the number of proposals received and their composition: Narrowing or widening their scope, changing the amount of funding per call or project, changing the required consortium size, and requiring greater levels of SME participation in the consortium. The model also demonstrated that using ABM for ex-ante policy evaluation can be useful in measuring the sub-components or the configuration of policy alternatives (Ahrweiler, Schilperoord, Pyka, and Gilbert, 2015).

On a national level, the IPSE-SKIN model was developed to facilitate an innovation ecosystem in the economy of Ireland, through structured networks consisting of academia, government, and industry. Once the model was able to emulate the observed structures that have emerged in reality, through simulated processes that have been empirically observed as well, it was used to explore policy interventions into these processes. Thus, it requires a calibration procedure that matches the structure of innovation networks that appear in data and those artificially generated using the model, an initial configuration of starting conditions and policies, in effect reproducing the researchers' data sets before it is utilised for policy analysis (Schilperoord and Ahrweiler, 2014).

CONFLICT RESOLUTION AND SOCIAL JUSTICE

One of the growing strands of resilience literature tackles the question of justice. Rather than enshrining an existing reality, it asks what kind of transformations the system should strive for to bolster the resilience of vulnerable members and groups in society, and create a more equitable community and state. Following are several such models, simulating how a policy may resolve or aggravate conflict and violence, decrease segregation, and create a more equitable education system.

Resolving Diplomatic Conflicts

One of the most intractable conflicts in the international arena is that of Israelis and Palestinians. At its core is the question of sovereignty over Jerusalem, which both sides consider their rightful capital city. Many offers have been made for how to divide the city as part of a future peace plan. ABM has been used to measure the impacts of these different policy proposals on one of the most important indicators of peace on a micro level – inter-group violence. The researchers created a spatially explicit model that used empirical data to seed agents in actual neighbourhoods in the city, and to determine their probability to engage in violent behaviour toward surrounding agents. They validated their model based on existing data on inter-group violent occurrences in the city and then set out to examine what would happen if one of three different proposals for the division of the city were implemented compared with a business-as-usual scenario – the Clinton parameters, the Palestinian proposal, and a return to the 1967 borders. The model demonstrated that barring a fundamental change in Israeli policy toward East Jerusalem and its residents, the return to 1967 borders decreases violent events to the largest degree (Bhavnani, Donnay, Miodownik, Mor, and Helbing, 2014).

Tackling Social Injustice

The impacts of urban policy on the emergence of social segregation were also tested using ABM. Feitosa et al. (2012) built the MASUS model, which is composed of an urban population and an urban landscape. Every few "years" household agents in the model decide whether to move to a different location or stay put, with alternative scenarios simulating social mix policies that disperse poor and rich families throughout the city.

One of the determinants of housing choices and equity is the quality of local education systems. Designing effective school systems and educational institutions, in general, requires making a multitude of policy decisions, and deploying a wide range of policy tools. Their success often depends upon the interaction between teachers, parents, children, their physical learning environments, education budgets, and both centralised and decentralised strategies to attain educational goals, all of which can be represented in ABM. For example, Maroulis et al. (2014) created a model to examine the repercussions of switching from a form of student allocation where they are sent to a school in their neighbourhood, to a more open choice system where they can choose between different public schools in their district. The researchers used actual enrolment data from the Chicago school system, allowing policymakers to track changes in enrolment in each school, school performance, and school closures in the city.

In a later study, Maroulis (2016) used the model to review the sensitivity of policy interventions, in this case, student assignment lottery, as part of a popular methodology in education policy evaluation – randomised field trials. Experimenting with the model revealed that rising participation rates in school choice programs lead to a decrease in treatment effect, meaning that comparing the treatment in different districts requires that policy analysts take into consideration its participation rate and capacity. Thus, ABM can be used not only as a standalone tool but as a way to support, calibrate, validate, and even integrate different available assessment methods.

INFRASTRUCTURE DESIGN AND SPATIAL PLANNING

ABM is particularly suited to explore questions that combine physical space and social interactions. It can simulate still objects such as wind turbines, the market that determines their cost and benefits over time, the social actors that build them, use them, and interact with them, and the environment in which they all exist and operate. Thus, it is unsurprising that many ABMs explore how policies affect the resilience of public infrastructure, natural resource management, urban design, and transport planning, as presented below.

Public Service And Infrastructure Provision

Waste management systems are another type of infrastructure where human choice, perception, and interaction with their surroundings can affect a desired emergent policy outcome, such as recycling rates or waste diversion from landfills, and thus highly compatible with ABM. For example, Shi, Thanos, and Antmann (2013) designed a model that simulates a single-stream recycling system and a dual-stream recycling system on a local level (county and region) to compare their effectiveness in reaching recycling goals. The ABM was further linked to an optimization model, that allowed the researchers to provide policy recommendations on waste management fleet vehicle routes, and for resource allocation considering different objectives for the system as a whole.

According to Chappin and Dijkema (2008) ABM are especially useful in understanding the transition to new energy regimes, as they contain populations of agents who are adaptive rather than fully rational, and they have a demonstrated ability to incorporate physical subsystem models (such as energy and road infrastructure). And indeed, the energy system has been a prolific arena for ABM, with models that analyse electricity markets design and efficiency, carbon emission trading and renewable energy supply among others (Sensfuß et al., 2007).

Natural Resource Management

ABM can help design policies to contend with depleting natural resources. For example, Zellner (2008) created a generic model that explores possible policies for sustainable groundwater use. She examined the decision to convert farmland into residential development, based on the extent of residential development in neighbouring lands and agricultural soil quality. Development is also constrained, in the model, by zoning of levels of residential density. Residents then choose a location to reside in based on different preferences such as the quality of schools and proximity to employment centres. Water consumption per resident is then calculated based on their type and location. Other agents represent farmers, who use groundwater for irrigation. The groundwater itself is also represented as a diffusion model. Thus, the model brings together policy, infrastructure, people's behaviour and decisions, and bio-physical components. The interaction between these different layers can shed new light on the complexity of the groundwater depletion problem, and on the possible indirect effects competing policies may have on solving or exacerbating it.

Urban Design

Numerous ABMs examine the effects different policies may have on people's interactions with the built and natural environment. For example, Brown et al. (2004) built an ABM to assess the effectiveness of different configurations of greenbelts, areas in the city outskirts where development is restricted, on development patterns outside the greenbelt, based on residential choice of location. Malik et al. (2015) mentions several ABMs used for studying urban issues and policies in the past few years – from land use policy and slum formation, to urban growth and evolving landscapes in cities. He created a model that simulates a theoretical city, allowing planners and researchers to examine how agents interact in response to different policy tools such as investment in transport infrastructure and different land use regulations. He then applied the tool to Karachi, looking for the best policies to foster creativity led economic growth.

Urban planning has made use of ABM's ability to bring together spatial, economic and behavioural analysis, particularly in sustainable urban development contexts. One way to do that is to simulate the different ways by which a neighbourhood or a city may expand and change, based on its residents' demographics and preferences. For example, Vallejo, Rieser, and Corne (2015) simulated an urban environment where real estate consumers look to maximise their utility through a set of criteria that varies among different agents, including the value they ascribe to living next to open spaces. Based on their purchase decisions, the model shows different rates of accessibility to urban parks, taking into consideration distance from the park, considered a determining factor in visitation frequency. While this model is more demand driven, assuming market forces will shape urban form, others looked at more direct policy interventions, such as compact city planning. One such example is the Household Residential Relocation Model, which visualises the impact of a government policy to encourage households to move from suburban areas to downtown in order to increase population density in urban areas in Japan (Ma, Zhenjiang, and Kawakami, 2013).

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ANNEX D:
FURTHER DETAILS ON ABMs ENDOGENISING POLICY

APPENDIX TO CHAPTER 7

GOAL SEEKING POLICY MAKING

Carrillo-Hermosilla (2006) built a model that measured the impact of environmental prevention and transition policies on the evolution of a sustainable technologies market. The author included policymakers in the form of an agency with bounded rationality. The agency, which represents both public and private interests, can offer support for certain technologies that help solve environmental problems. In order to do so it employs an evolutionary strategy, which consists of two parts: First, it provides a dynamic level of support that changes over time based on its assessment of current levels of environmental damage caused by companies in the model, the level of support offered last time environmental damage had changed its course, and the time that had passed since the change occurred. Second, through a modelled participatory process the agency sets a threshold level for required sustainable change. It then iteratively evaluates each technology's ability to reach the threshold, providing finance only to those technologies that met the threshold. If more than one technology meets it – only the best-performing technology wins its support. Once the process is over the threshold the policy gradually changes to more demanding levels, based on the agency's ability to find more satisfactory alternatives.

Zhou and Mi (2014) utilised this approach in modelling China's oil pricing policy: The researchers explicitly represented the Finance Ministry and the Development and Reform Commission, each with its own optimization function for controlling taxes and eventual pricing through reference time and percentage, impacting manufacturers as well as consumers.

Tang, Wu, Yu, and Bao (2015), researchers built a model to study the effectiveness of carbon emissions trading in China. The government agent in the model allocates free carbon emissions quotas to firms and designs the carbon emission trade market in terms of regulation, penalties and subsidies. Allocation is determined according to two pre-established rules: grandfathering - based on the firm's historical performance, and benchmarking - based on the sectoral level of carbon emissions intensity.

BUILDING TAILORED PROFILES FOR DECISION MAKERS AND ORGANISATIONS

Davies et al. (2014) adapted a model called TESLA, whereby the different agents' receptivity to the information offered and their willingness to share information was calculated based on personality traits such as openness, conscientiousness, extroversion, agreeableness, and emotional stability. The modellers allowed two agents to speak to one another in the simulation, with values of power also affecting the outcome, determining dialogue length for example. Furthermore, receptivity was estimated in each of the three stages considered part of brokering evidence – receiving evidence, processing it, and passing it on. The transaction was considered successful if the two actors' expectations of the evidence matched, based on the characteristics of the evidence itself (qualitative/quantitative, political/social/technical, and cost). Success in the model meant that the regulator has confidence in the evidence presented. If confidence is not sufficient, the regulators can then consult once again with the evidence provider. The provider can then adjust the evidence they offer to the regulator based on their own receptivity. This process repeated until the regulated entities had no more power left, or alternatively if it succeeded in instilling confidence in the regulator's assessment of the evidence they provided.

Similarly, Bozkurt (2015) created a model that determines the probability that individuals will be able to solve complex problems, based on their philosophical profiles in three axes: ontology, meaning their definition or representation of reality; epistemology, their means of acquiring new information and knowledge; and teleology, whether they are goal oriented or not. The model then triggers random encounters between the different agents, each with one of eight resulting profiles, with problems of different properties such as information availability, ambiguity, time sensitivity, stability, and its number of components. The results of the model made explicit the differences between actors of different profiles' ability to solve problems of different kinds and complexity, with clear implications for team building considerations.

Researchers have also built tailored profiles for government agencies and organisations. Chang and Harrington Jr (2006) argued in favour of modelling organisational structure based on three dimensions: the allocation of information, meaning how information moves within the system; allocation of authority, meaning who makes decisions; and organisational norms and culture, meaning shared beliefs and values regarding how the world works, and how present norms can shape future behaviour.

Wu, Hu, Zhang, and Fang (2008) used the E-Government Group Behavior Model to explore the acceptance of information technology within government agencies. Each agent in the model is represented by a circle with a number. Blue circles represent support of the technology, red circles represent opposition, and green circles neutrality. Each agent has a different level of technology acceptance, a power attribute determined by his group affiliation, and a degree of obtaining interest among other attributes. Agents can move freely in the world but are constrained and driven by environmental attributes that include structural inertia, administrative measures, and incentives. Finally, Bonabeau (2002) demonstrated that it is possible to model the emergent collective behaviour of an organization or a part of it. For example, John, McCormick, McCormick, and Boardman (2011); and John, McCormick, McCormick, McNeill, and Boardman (2011) built a model of the flow of information in the intelligence agencies community in the US government, in order to understand how to increase inter-departmental cooperation despite diverging interests and missions.

POLICY PACKAGING

Another approach that allows policies to emerge endogenously in agent based models was presented by Taeihagh and Bañares-Alcántara (2014), who proposed a methodology for creating policy packages using ABMs.

The ABM builds on an extensive process that researchers employ before the simulation part of the model begins: policymakers and experts are asked to build a library of relevant policy tools, and asses the relations between them – is one precondition for the other, does it facilitate it, are they in synergy with one another, or do they potentially or actually contradict? The matrix is then uploaded as input to the ABM, which has three main stages: First, a "policy packer agent" selects policy measures that have the highest level of positive interactions with other measures, resulting in a proposed package. Second, "assessor agents" evaluate alternative policy packages according to a specific set of criteria representing policymakers' and other stakeholders' priorities, including difficulty of implementation, stability, and package performance. Third, the assessor agents negotiate to reach a consensus on which package to choose.

In the policy packing stage, the agent first selects a best-performing measure based on random or predefined criteria as the basis of the package. If that measure has any preconditions those measures are added as well. Then it adds measures that perform best with that measure, based on the measures relations matrix. Any precondition measures required for other measures selected are added to the package as well, however before adding any measure and its precondition the packer evaluates their impact on the size of the existing package, its cost, how long it will take to implement, and whether these proposed measures and pre-conditions contradict any existing measures in the package. The packer repeats this process until the full package is formed.

After the policy packer agent selects the most effective policy measures to create the alternative packages, the different assessor agents rank each package based on their individual assessment criteria. They sum up the weighted score for each measure, yielding their subjective package score. These agents may have competing goals, which means that their choice of package could diverge significantly from one another. They then look at other assessor agents' choice of packages, and attempt to reach a consensus on which package to adopt through negotiation: If more than half of the agents chose a similar package, the assessor agents maintain their original choice. If a consensus cannot be reached, they will check if choosing the next best solution will allow for greater consensus with the other agents and if so, adopt that one. If not, they maintain their original choice.

PARTIES' BEHAVIOURS

Schumacher and Vis (2012) simulated parties' expected utility using three main decision strategies – policy seeking (changing policies in accordance with party activists), vote-seeking (shifting toward the mean voter), and office seeking (shifting toward the position of the government). They analysed which combination of environmental incentives and decision strategies leads social-democratic parties to retrench the welfare state, i.e. narrow its scope of services to citizens. They incorporated within the model economic data that may affect voters' preferences and parties' decision rules based on studies on party position shifts, allowing each party in the simulation to decide their policy positions, and whether or not to join a coalition government.

Muis et al. (2010) argued that ABMs of political party competition allow the representation of adaptive learning by party leaders. In their own model of political parties in the Netherlands, they incorporated two basic categories of agents – voters and candidates. Each party and voters' position was situated spatially with reference to two dominant political dimensions in the Dutch political system: raising taxes to improve public services versus the opposite, and accepting immigration and promoting policies that help them versus the opposite. Each time period voters measure the distance in positions between themselves and each party and choose the party that is closest to their own ideological preference. Voters' preferences are assumed to be fixed, and the salience of each issue is also fixed and equal. During the simulation setup, 10,000 voter agents are created and randomly assigned political preferences, following a normal distribution around the mean party position in the policy space.

In Muis' model, parties utilise three strategies to decide what their position will be each time period: 'sticker', representing a party leader who maintains policy positions regardless of their popularity among voters; 'aggregator', representing a party leader who sets the party at the mean position of its voters every time period, thus representing a "democratically inclined" party; and a 'hunter' party leader, who compares support for the party position in the current and last time periods. If it has grown, the leader moves forward in the same direction. If it diminished, the leader moves in the opposite direction at a random value between 90 and 270 degrees. Thus, the hunter is a party leader who constantly looks to expand its electorate. Muis also introduces a 'media distortion' variable that impacts voters' perceived distance from party positions. Greater media attention to a party reduces media distortion, allowing voters to accurately measure the distance between them and the party. When attention is lacking, voters will perceive the distance to be greater than it actually is. Thus, maximum media attention allows the party to appeal to all potential voters, and minimum media attention to none. Beyond 40% media attention, media distortion ceases to impact the voters. In order to validate the model, Muis compared the simulated party size with the actual party sizes in the Dutch parliament.

Fowler and Smirnov (2005) added an additional layer of complexity to modelling party-voter behaviour, and specifically voter turnout, by creating a social context to the voter agents. In their model, two parties compete for votes in recurring elections. Each election cycle parties estimate the location of the median voter, based on previous election results. They can then update their platforms to optimise their expected payoffs, though both parties prefer to win elections with policy positions close to their actual ideal points. Voters are also attributed ideal policy positions, which they compare to each party's platform before the elections to measure the distance between the party's position and their own. However, in this model voters are placed on a spatial grid that allows them to interact with their closest neighbours. They ask other agents in their neighbourhood whether they voted or not, and how satisfied they were with the results. They divide the neighbourhood into voters and abstainers, identify which type is more satisfied, and imitate their behaviour.

MODELLING STAKEHOLDER DYNAMICS

Power, Interest, Competition, And Beliefs

Kuznar and Frederick (2007) incorporated more mechanistic views of power in a model named RiskTaker, which simulates coalition formation and the effects of nepotism. In their model, agents have the choice of joining a rebellion or defect (meaning refraining from joining it). Agents who defect earn moderate payoffs, while those who join earn larger ones if they are joined by others. Nepotism is then simulated in two ways: First, agents with larger kin networks gain better access to wealth, and off-springs inherit 50% of their parents' wealth at birth.

Zellner et al. (2014) delved into the organizational structures and mechanisms that governed stakeholders' interaction in their case study model. The researchers built a model that focused on ecological restoration in the Chicago Wilderness, to better understand how decisions may emerge more broadly. The model was based on ethnographic data, which was used to formalise the behaviour of two local member groups. The model revealed their patterns of interaction, taking into account both formal and informal meetings. The model revealed, for example, that agents that interact more frequently and have high levels of mutual respect are helpful in facilitating the decision process, but less so in changing collective positions on specific restoration practices (Zellner et al., 2014).

Other models focused on stakeholders' beliefs and attitudes toward policy. SIRCH, for example, simulated water demand in southern England, and how it may be impacted by climate change. The simulation examined how consumers may respond to warnings about water shortages from a policy agent, based on their consumption tendencies, knowledge of their neighbours' consumption, and attitudes toward the policy agent (Pahl-Wostl, 2002). Another stakeholder-based water management model was presented by Valkering et al. (2005). In their model, different strategies for river management are considered by inhabitants, farmers, nature organizations, and gravel extraction companies. Each type of agent has its own goal, and quantitative standards to measure whether these goals are achieved. They also have differing beliefs, which affect their calculation of cost and benefit as well as uncertainty regarding the impact of each strategy proposed. These belief settings correspond with each stakeholder's worldview. The policy with the most total agent support is calculated and eventually picked in the model.

Cross-Scale Stakeholder Interaction

Gerst et al. (2013) aimed to represent the complex interaction between the different scales through which policy emerges through a model of climate policy-making called ENGAGE. The model ties the international climate negotiation process to the micro-decisions made by businesses and households in the national arena. Each climate negotiator in the model has a utility function that is linked to the aggregate preferences of the domestic agents in their home country. These preferences are dynamic and are affected by different agents' beliefs and economic conditions. These conditions themselves are dynamic, as the model explicitly represents energy as an input, impacting the cost of production and use of goods. The amount of energy used is subject to change through improvements in R&D. While their first version of the model focuses on the domestic level, they propose that in order to link the negotiators to the domestic arena, households' and firms' policy preferences should be represented, as well as their influence over national policy-making. Furthermore, each agent will require a measurement of belief regarding the extent of damages climate change will inflict on them and the perceived efficacy of different policy measures. If more than one country is represented then issues of trade will also need to be taken into account.

The policy process, especially at more local levels of government, can entail direct and iterative engagement with stakeholders that may be impacted by policy outcomes. Thus, ABM can endogenise policy emergence by allowing citizens and government agents to propose alternatives, react to proposals, and decide and learn from implementation based on their individual and collective interests, preferences, and goals. For example, Svalestuen, Öztürk, Tidemann, and Tiller (2015) created a model that simulates the development of coastal plans to determine aquaculture expansion in a small municipality in Norway. In the model, the plan is formalised by a government agent and sent to different types of stakeholders who can then file complaints about it. Complaints can trigger a re-planning procedure, or the plan can be approved, determining the fishing licenses the municipality can distribute. Following license provision, fishermen can learn from one another's successful strategies using algorithms based on evolutionary game theory.

Stakeholder Engagement And Participatory Modelling

Policy making aims today more than ever to be inclusive both in process as well as outcome. Urban planners as well as other policymakers and analysts depend on new voices representing different groups and interests to shed light on their understanding of the problem, and to increase public ownership of the proposed solutions. However, designing polycentric governance schemes may require new tools that are able to better engage stakeholders and facilitate deliberation among them. In this context, ABM has a dual use: representing different stakeholders' behaviours and beliefs to build a more valid representation of reality for policy analysis purposes, and as a platform that structures the deliberation process among the different stakeholders, policy analysts, and policymakers. ABMs can simulate how different people in the policy arena behave and interact, and the result of their interaction. They can thus represent decision-making as social learning, rather than simply an exercise of separate individuals maximising their own utility. Formal stakeholder participation in the modelling process can also yield a more valid result by combining different layers of objective data and subjective perceptions (Pahl-Wostl, 2002).

d'Aquino and Bah (2013) designed a participatory modelling platform that investigated Senegalese climate adaptation policies that are based on changes in land use. The researchers asked participants, both farmers and policymakers, to take part in a board game where they must choose certain types of land use based on different interests, rules governing the game, and access to natural resources. The choices made throughout the game were then used to characterise each agent type's strategies, behaviours and needs.

In the OCOPOMO project, Scherer et al. (2015) asked stakeholders related to different policy proposals to generate scenarios for particular policy aspects, adding to insights gained from policy documents and other evidence gathered. These scenarios were then modelled, and stakeholders were asked to analyse their output so as to change their scenarios or adopt the insights the model had generated. The model thus enabled greater transparency in policy analysis, as well as traceability for different arguments presented in the scenarios and elsewhere Scherer and Wimmer (2011). That said, involving the stakeholders in the modelling process can also lead to their formal representation in the model itself. In OCOPOMO, for example, stakeholders' input resulted in capturing which stakeholder agents should be included in the model, the relationships between them, and the rules that capture their behaviours and interactions.

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LIST OF PUBLICATIONS

CURRICULUM VITAE

LIST OF PUBLICATIONS

Journal articles and book chapters

Blass, V., Chebach, T. C., & Ashkenazy, A. (2024). Sustainable non-renewable materials management. In Sustainable Supply Chains, A Research-Based Textbook on Operations and Strategy Second Edition. Springer (upcoming).

Chebach, T. C., Ashkenazy, A., Tchetchik, A., & Blass, V. (2022). What Makes Farmers Follow the Standard? The Role of Regional Characteristics, Local Alternatives, and Policy Support in Non-State Market Driven Governance in the Arava, Israel. In Geography Research Forum (Vol. 41, pp. 117-151).

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CURRICULUM VITAE

Amit Ashkenazy-Garini was born in 1981 in Israel. After graduating his BA cum laude from an honours programme in "Government, Diplomacy, and Strategy" at the IDC Heryzlyia (Reichman University), he started his career as a policy practitioner and researcher as director of the Social-Environmental Caucus at the Knesset (Israel's Parliament), and fellow at the Milken Fellows Program. He later served as fellow in the Ministry of Transport, promoting legislation and projects on sustainable and equitable transport.

In 2010 Amit embarked on a master's degree at Yale University's School of Forestry and Environmental Studies (now School of Environment), where he focused on environmental policy at multiple levels of governance – from local to national and the international arena. He also served as sustainability fellow at the New York City Parks Department.

In 2012 Amit returned to Israel, where he worked as a consultant at the Praxis institute and served as spokesperson for Hadash party at the national 2013 elections. Later that year he joined Meidata as a senior environmental analyst, working with government ministries, NGOs, foundations, and commercial companies to capture insights on environmental policies in various domains around the world.

In 2013 Amit and his husband, Ido, moved to the Netherlands. In conjunction to his ongoing work as policy analyst, Amit embarked on his PhD journey at TU Delft. In 2019 Amit became co-founder and director of MV, a company specialised in applied sustainability research. Amit took part in writing multiple grant proposals, and since 2020 has been a leading partner in the Horizon2020 project "HealthyFoodAfrica", promoting sustainability transformations in food systems through 10 living labs established in cities in Sub-Sahara Africa.

In addition, Amit is working with multiple initiatives to promote resilience at the local and national levels in Israel, focusing on climate resilience planning, and building tailored decision support tools that facilitate design and adoption of new resilience policies.

חֶלֶד

RESILIENCE POLICY