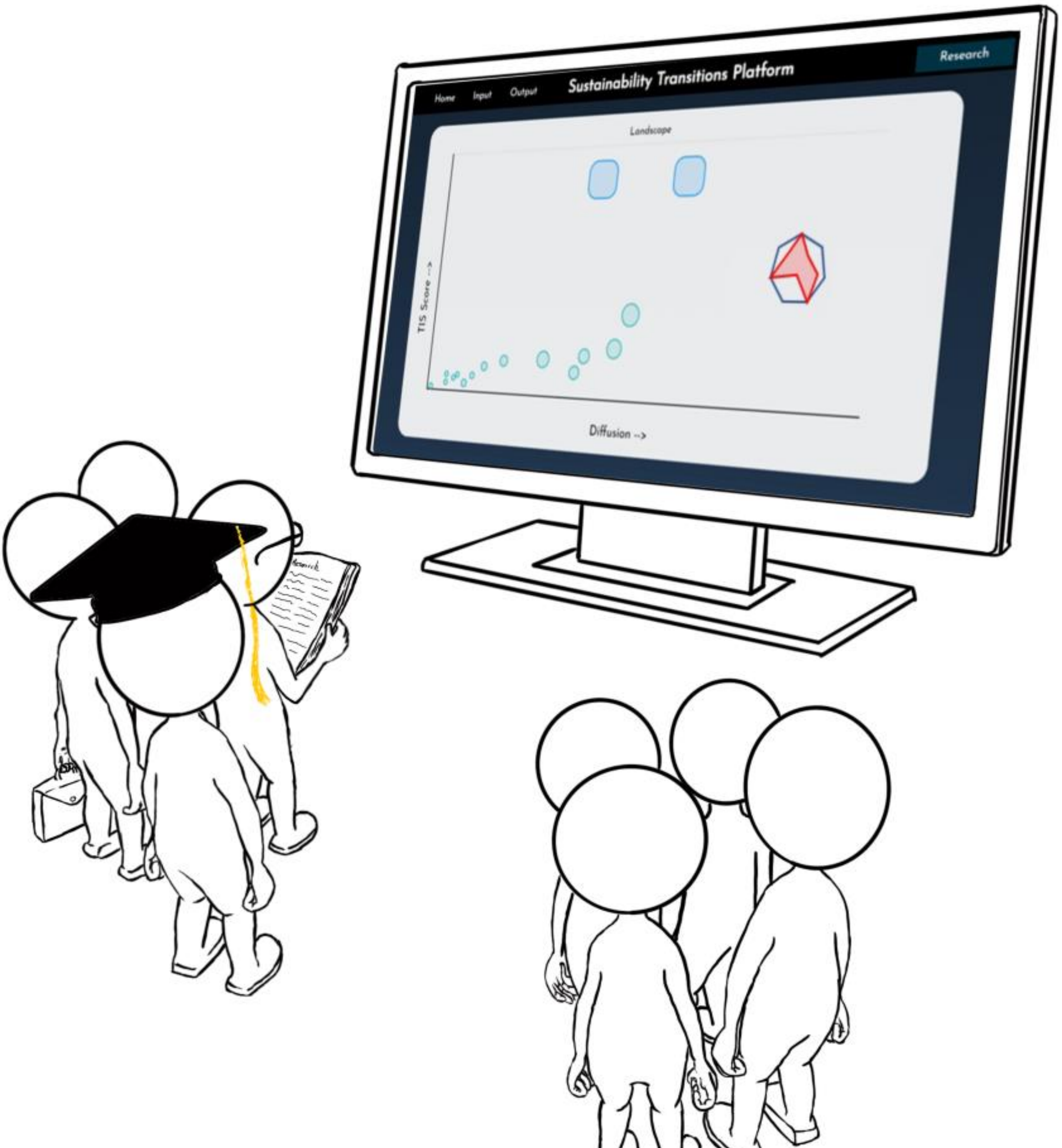
The Sustainability Transitions Platform

A digital innovation platform that serves as a tool for development of Sustainability Transitions research and as a bridge between theory and practice



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Front page image designed by Caroline Blom.

The Sustainability Transitions Platform

A digital innovation platform that serves as a tool for development of sustainability transitions research and as a bridge between theory and practice.

by

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in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in Sustainable Energy Technology
at the Faculty of Electrical Engineering, Mathematics and Computer Science
at Delft University of Technology

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December 12, 2022

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Acknowledgements

This research has been an intense rollercoaster ride. What started out as a straightforward idea that would be carried out as an internship in the tropical setting of Rio de Janeiro, Brazil, was drastically changed into a complex digital work-from-home experience. There were a lot of uncertainties regarding the project as a whole and how I should proceed in this changed setting. This I personally experienced as very challenging and more than once made me succumb to a lack of motivation. However, it also forced me to look at things from different perspectives – which often follows when one finds himself in a position that seems to be a dead end - which eventually lead me to discovering other personal interests.

The ups and downs of this ride did not go unnoticed and I am certain that I would not have been able to reach this point where I am now without the help of the people around me. That is why I want to thank those who have been there for me and helped me throughout this process.

To start off I would like to thank my research supervisor, Linda Kamp, who encouraged me to explore different routes and allowed me to experiment with some of the 'crazy' ideas that I found in these new perspectives. I also want to thank Roland Ortt who was introduced in a final phase of the project but was able to light another spark in it through his useful suggestions and enthusiasm.

Then I have whole other group of people to thank that were not directly involved with the contents of my project but most definitely had a big influence on keeping me going.
First of all, my parents, Frank and Ana Alice, who showed me nothing but support from start to end. Even when the choices I wanted to make were not the ones they had in mind (and which I was completely aware off but would still do anyway). Next to them I also want to thank my brother, Marc, and my sister, Caroline, who like no one else were able to relate to the struggles I was facing and made it easier to minify them when we were together. I also want to thank Julia for having been the silver lining in the stormiest of days and Beto for being an endless inspiration.

Peter H. Blom
The Hague, December 2022

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Abstract

Sustainability transitions is a complex multi-dimensional research field. In this field, different frameworks exist that have grown as separate strands while they actually contain many similarities and in some cases can even complement each other. In general, these frameworks try to present and clarify the processes related to transitions of socio-technical systems and the emergence, diffusion and utilization of technological innovations. To do so, researchers carry out historical event analyses for specific cases. This means that they gather, process and analyse data about events that have happened in the past to build a narrative of how an innovation has developed or a transition took place over time. Although there are guidelines in literature on how this should be done for each framework, the case results as presented in academic papers are often varied and the clarification behind the results and the used data can be unclear.

In this research an attempt has been made to reduce this variance and unclarity by building a tool in which the data gathering, categorizing and processing of sustainability transitions research cases is done structurally and the data itself is systemically presented through visualisations. This tool is a software based digital platform, referred to as the *Sustainability Transitions Platform* (STP). In the first draft of the platform functionalities have been limited and the sustainability transitions theory has been focused on the Multi-Level Perspective and Technological Innovation Systems. These are two of the most frequently used frameworks in the field and a combination of both is already being experimented with taking advantage of their commonalities and complementarities.

The combined framework contains three elements that are deemed important to build the system of the case. These are i) the environment in which the technological innovation system resides; ii) the actors, networks and institutions of the system; iii) the functions analysis tool to determine how the parts of the system are functioning.

These elements have been translated to the platform as three separate visualization tools, which are:

1. *Technology environment*, which presents the technology being analysed within a graph together with other technologies relevant for the analysis as comparison and landscape factors that influence the system.
2. *Structural components*, which presents all the actors, in a structured way through predefined groups, and their networks in the same graph and also present the relevant institutions in an adjacent table.
3. *TIS functions analysis*, which presents how the system is functioning in a radar chart based on a set of functions and their corresponding indicators.

These visualization tools are intended to present the case data in a structured way in order to help users of the platform better understand the system development process and make it comparable between cases.

The platform template has been tested through a case for offshore wind energy technology in Brazil. From this case we have seen that i) the data does indeed need to be implemented structurally; ii) the visualization tools in the platform present the system through the three required elements of the framework; and iii) the platform user is able to determine possible bottlenecks for further development of the system. Another advantage gained by carrying out the case in a platform instead of how they currently are in journals, is that the digital aspects of the platform allow users to interact with the visualization tools and the underlying data which can help clarify the reasoning behind the conclusions of analysis. From the case we have also learned that in the current version of the platform i) inputting the data can be very time consuming and should in the future be automated; and ii) some essential aspects of the case are still not presented in the visualization tools, for example, the power or influence specific actors have in a system, which should be taken into account in future versions.

The STP appears to have a positive effect on sustainability transitions case implementation and would be recommended to be further developed. Given its dynamic nature it should also be used as an experimentational tool to merge the strengths of other frameworks in sustainability transitions research to eventually generate a single more complete framework and act as a bridge between theory and practice.

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Chapter 1 – Introduction

Sustainability Transitions research is a complex field of study which has been built-up from many different research streams (Markard et al., 2012). The field is interested in understanding the shift from one socio-technical system to another through innovation (F. Geels, 2002). It is still very difficult to understand due to its multi-dimensional characteristics and partially also because there are multiple definitions of what exactly an innovation is (Klein & Sauer, 2016).[1]
A variety of frameworks have been constructed to study innovations and transitions. Some form of overlap was often encountered between the different frameworks. Through time attempts have been made to combine some of them to reduce parallel studies and strengthen each study by making use of the complementarities between the frameworks. In the last decade four frameworks have been identified as the most commonly used in sustainability transitions studies, these are, *Multi-Level Perspective* (MLP), *Technological Innovation Systems* (TIS), *Transition Management* (TM) and *Strategic Niche Management* (SNM) (Markard, 2020). Within these four and the other existing frameworks, there are two streams that stand out in the field, where one has the innovation (technology) itself as the focal point for change in the system and the other has a whole transition process (e.g. a whole sector) as the focal point in which multiple innovations (technologies) together change the existing system (Hekkert, 2020). Markard and Truffer (2008) have attempted to bring these two streams closer together by pointing out the differences and overlaps between the TIS and MLP frameworks and presented a suggestion for a combined framework. This combined framework is now being implemented by other scholars as well (Carstens & Cunha, 2019; Edsand, 2017; Nikas et al., 2022). There are however some differences in how the combined framework is being applied, so it still remains difficult to compare the different studies.

From reviewing literature in which the TIS, MLP or a combination of both framework is used, the following problems were encountered by the author:

1. It is difficult to determine what data is exactly being used for cases and how it is being categorized. This is important to know since these studies build a narrative or status based on historical data. Not being able to exactly identify the data also makes it difficult to reproduce or make new case studies in a very similar way.
2. There is limited use of data visualization, while data visualization is a strong tool for helping individuals understand information that comes from big amounts of data, especially if it can be used dynamically.
3. There is still much variation in the framework elements and how they are being used and analysed in studies.

To overcome these problems and get closer to understanding innovations and transitions it could be useful to i) standardize the framework elements, ii) centralize the data gathering and classifying process and iii) simplify the data through visualizations. To do this one could actually make use of a technological innovation with respect to publishing papers that are statically saved in a database, namely, implementing the study in a digital platform.

From a theoretical perspective two types of platforms can be found in literature. These are transaction platforms and innovation platforms (Gawer, 2014). Transaction platforms are regarded as intermediaries which allow participants to exchange goods and services or information, while innovation platforms consist of a core module on which other (innovative) components can be added

[1] As Klein and Sauer (2016) point out, there are different definitions for innovation. A more precise explanation of how an innovation will be defined for this research will be presented in section 3.3 together with the definition of *innovation systems*.

as complementarities (Cusumano et al., 2020; Gawer, 2014). From a technical perspective digital platforms are however built rather similarly. They consist of lines of code written by software developers that results in some specific output and functionalities facilitate or improve processes of specific actor groups. These could be functionalities such as data aggregation and structuring and outputs that help to visualize this data in a clear manner.

This research builds the idea of the *Sustainability Transitions Platform* (STP), which is a software based digital platform that acts as a bridge between researchers of sustainability transitions and actors who require the knowledge of this type of research and allows for innovation and improvements in its theoretical frameworks in order to help in this quest to accurately understand innovation and transition processes. It does so by demonstration through a simplified template of the platform that partially fulfils the requirements of the complete platform but sufficiently serves as a basis that guides towards the development of the fully functional STP. To test its functionality a case of offshore wind energy technology in Brazil will be implemented through the combined MLP and TIS frameworks. It will present the biggest advantages and disadvantages that might arise for sustainability transitions research in case such a platform would be used.

This lead to the formulation of the following research question:

'What elements should be present in a digital platform for the combined MLP and TIS frameworks and what could such a platform look like?'

The next chapter will explain the methodology used to answer this questions. This will be followed by four chapters which individually answer parts of the research question through a set of sub-questions as follows:

Chapter 3 – Theoretical Framework

- Sub-question 1: What are the Multi-Level Perspective and Innovation Systems frameworks and what are their most relevant elements?
- Sub-question 2: What are their commonalities and complementarities and how are they being combined?

The next chapter will further explain what is meant with the term platform and how exactly this combined framework will be placed within it.

Chapter 4 – Sustainability Transitions Platform (STP)

- Sub-question 3: What is a digital platform?
- Sub-question 4: How can the MLP and TIS framework elements be combined in a platform?

Chapter 5 – Case: Offshore Wind Energy Technology in Brazil

- Sub-question 5: What would a platform case implementation look like?

The last two chapters will be used for the discussion, future research possibilities and a conclusion for the findings from the research.

Chapter 2 – Methodology

In order to answer the sub-questions and the research question the following methodology has been used.
Firstly, a set of academic papers relating to either MLP, IS or a combination of both frameworks was analysed. This was done to understand on what commonalities and complementarities the combined framework is being constructed in literature and how it is being applied, but also to understand how each framework works individually. The main ideas and elements of the frameworks and their combination were identified and are presented in Chapter 3.
Secondly, the platform template was built by making use of web technologies. In this case the web technologies used were HTML, CSS & JavaScript. These are commonly used programming languages for building web pages and platforms and are often recommended for beginner level programmers (Stack Overflow, 2021). Given the author's limited skills with web technologies, it would not be feasible to construct a complete and fully operational platform within the given timeframe of the thesis project. For this reason the decision was made to limit the platform to a template with restricted functionalities which would sufficiently portray the idea of the complete platform. In this platform template the combined MLP and TIS framework was constructed based on the identified elements from literature. Since this research emphasizes the importance of using visualization tools for the framework, the platform elements used are also based on the visual representations that are being used in the framework literature. In order to accommodate all the relevant elements, including those that are not visually represented in literature, some adaptations have been made compared to the visualizations found in literature. In addition, some dynamic aspects have been added to the platform template in order to take full advantage of the functionalities available through web technologies compared to the static nature of papers and books. The exact elements used, how they were selected and which dynamic aspects were included will be further elaborated in Chapter 4.
Thirdly, data was gathered for the case of offshore wind energy technology in Brazil and implemented in the platform template. Part of the data gathering process was done in combination with an internship at the Consulate General of the Netherlands in Rio de Janeiro. The focus of the consulate was to determine what opportunities existed for Dutch companies in the emerging Brazilian offshore wind sector. In order to determine this, information had to be gathered relating to the current status of the offshore wind sector in both the Netherlands and Brazil. The internship experience and the knowledge obtained about the Brazilian offshore wind sector during the internship period inspired the author to use this case as the initial dataset for the platform template. The data gathering was done through desk research from different types of sources, such as, academic literature, news articles, books, webinars, conference papers and actor websites. The data itself is diverse and relates to a specific event, actor, network, institution, landscape factor or any other type of information that serves as an input to framework indicators and functions or to the technology environment. A more detailed explanation of the data gathering process will be presented in Chapter 4, as this is part of the functionality of the platform template. The data was saved in an Excel file which serves as a database from which the platform template inputs are retrieved to generate the necessary outputs.
Lastly, the results of this case implementation will be analysed analytically. This allows to discuss the pros and cons of the platform and its functionalities and also the future directions for research and platform development.

The methodologies used in this research consist of a variation and combination of literature research, analytical reasoning and hands-on experimentation. A summary of the methodologies used for each sub-question particularly can be seen in Table 1.

Table 1 - Methodology used to answer the five research sub-questions.

Sub-question	Methodology
1. What are the Multi-Level Perspective and Innovation Systems frameworks and what are their most relevant elements?	Analysis of the frameworks through literature research
2. What are their commonalities and complementarities and how are they being combined?	Analysis of literature in which the frameworks are already being combined and analytical reasoning as to which of their elements should be emphasized
3. What is a digital platform?	Literature research on the theory of platform and experimentation with existing digital platforms to understand how they work
4. How can the MLP and TIS framework elements be combined in a platform?	Through analytical reasoning of the theory and experimentation with platform software to determine the optimal outputs
5. What would a platform case implementation look like?	Through hands-on testing of the built platform template, where data of a case (offshore wind in Brazil) is inputted in the platform and the results obtained from it are analysed.

Chapter 3 – Theoretical Framework

In this chapter the theoretical framework will be presented on which the sustainability transitions platform will be based. The intention is to answer the first two sub-questions of this research, namely, *'what are the Multi-Level Perspective and Innovation Systems frameworks and what are their most relevant elements?'* and *'what are their commonalities and complementarities and how are they being combined?'*. To do so the chapter will be divided in four sections. The first section will focus on *Innovations & Transitions* which are the core concepts of the frameworks. The next two sections will focus on the *Multi-Level Perspective (MLP)* and the *Innovation Systems (IS)* frameworks individually. The last section will focus on the commonalities and complementarities of the frameworks.

3.1 Innovations & Transitions

At the basis of the theoretical frameworks are the notions of innovations and transitions. Simply put, innovation is something radically new and transition is the process of change from one state to another. These two notions go hand in hand because often the transition process from one state to the other happens through innovation. This transition process through innovation is the centre of analysis in much of the innovations research literature (Markard & Truffer, 2008). Innovation and transition studies have been around for more than 30 years and are linked from a variety of studies such as: management, sociology, policy, economic geography and modeling.
A technological innovation by itself is not able to cause a complete transition. Even if it is a great innovation from a technical perspective, there are also social, economic and institutional aspects that influence its development and the transition process. For that reason a technological innovation is regarded within a complete system, which in literature is also known as an innovation system or socio-technical system (Markard & Truffer, 2008).
There are differences in views regarding what the central point of the system is. Geels (2002) describes the socio-technical system as the interrelatedness of society and technology and connects the technology and all its artefacts to other societal aspects, such as, infrastructure, policies, regulations, markets, user practices, cultural value and symbolic meaning. In this case, the core of the system is a complete sector (e.g. transport, energy, agro-food, etc.) which fulfils a societal function. A transition then comprises of fundamental, multi-dimensional, long-term changes of socio-technical systems (Geels, 2002; Markard et al., 2012).

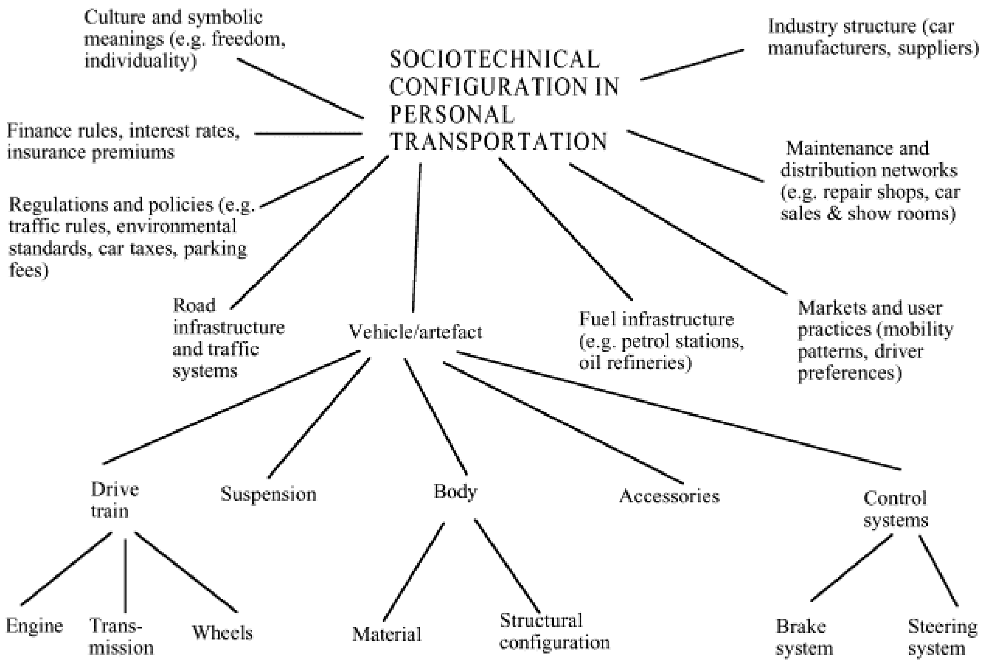

Figure 1 – Example of a socio-technical system for personal transportation (F. Geels, 2002)

In other cases the multiple aspects are still taken into account but the system is built closer to the technology itself. More attention is paid to the emergence, diffusion and utilization of a technology and which drivers or barriers exist that influence the transition process of the innovation from starting as a niche to becoming (a part of) the regime (Markard & Truffer, 2008). These are the two main research stream in innovations and transitions research. Around these streams the four commonly used frameworks for studying innovations and transitions are *Multi-Level Perspective (MLP), Technological Innovation Systems (TIS), Strategic Niche Management (SNM), Transition Management (TM)* (Markard et al., 2012).
The SNM and TM frameworks both stem from the MLP framework and the concept of technological regimes. The TIS framework stems from the broader defined *Innovation Systems (IS)* framework which has multiple research tracks defined from a different perspective.

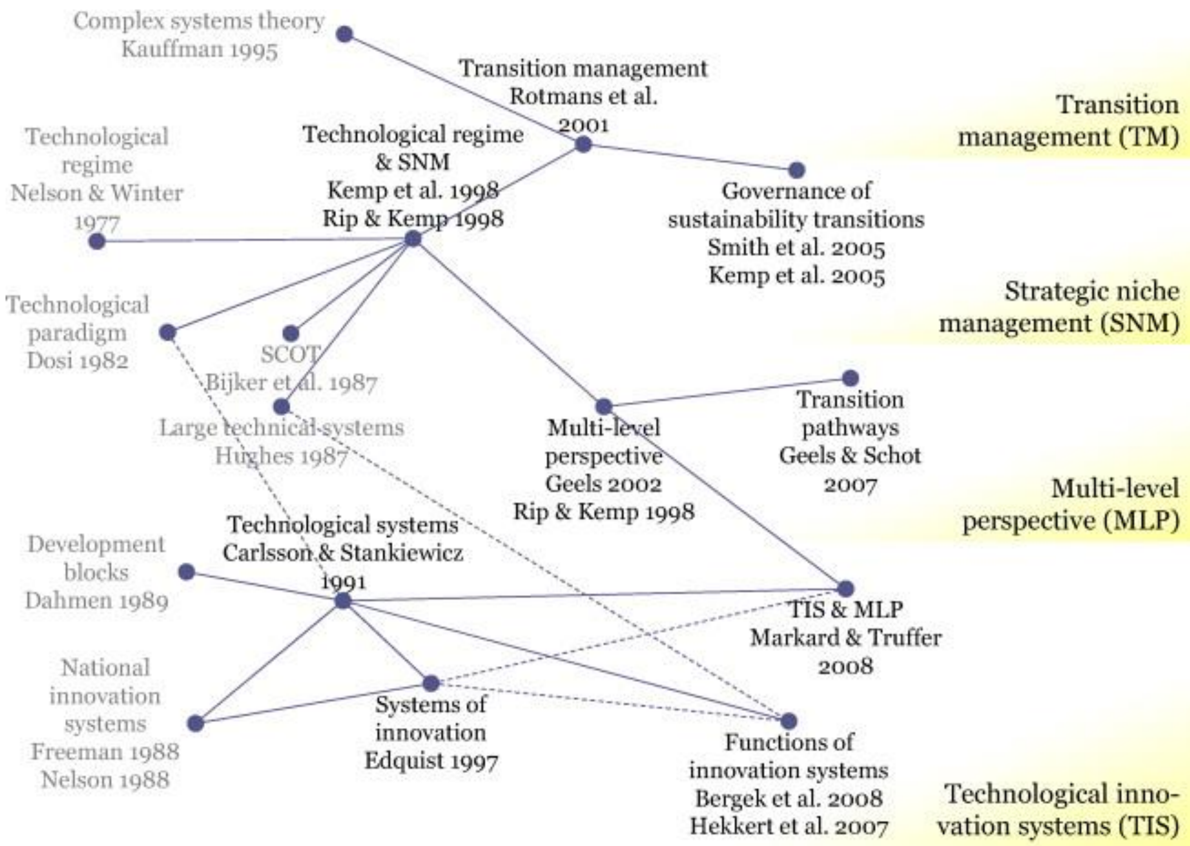

Figure 2 – Sustainability transitions research field (Markard et al., 2012)

There is no right or wrong framework. Choosing 'the best one' depends much on how the innovation and the surrounding system are defined and what the desired outcome is for the research. Moreover, there are some commonalities between the frameworks which indicate their close relatedness and in addition to that, the differences between the frameworks can sometimes even be seen as complementary to each other.
Markard and Truffer (2008) introduced the notion of a framework that combines the TIS and MLP frameworks by merging their commonalities and aims to strengthen the framework by emphasizing on their complementarities. The four major conceptual elements they specified for this combined framework are:

1. Niches or application contexts, in which radical innovations emerge and mature.
2. A technological innovation system, which might encompass niches and is characterized by emergent institutions and conjointly produced resources.
3. Socio-technical regimes that represent the dominant production structure, which challenges the TIS.

4. A landscape with parameters that influence regimes and innovations without being influenced in turn.

These conceptual elements fit well with the goal of this research, which is to design a platform template in which: i) the emergence of radical innovations can be analyzed; ii) the analysis will be done as described in the technological innovation systems theory; iii) the socio-technical regimes will be included in the analysis; iv) as will the landscape parameters that influence the regime and innovation. Given the points mentioned above the combined TIS & MLP framework as suggested by Markard and Truffer (2008) will be used as a basis for this research. This will give guidance to the process of developing the sustainability transitions platform and it also seems to be a relevant framework since multiple scholars have already been applying it to other studies as well (Carstens & Cunha, 2019; Edsand, 2017; Nikas et al., 2022). The exact way in which this combined framework will be implemented in the platform template will be explained in the following chapter, but first a more detailed description of the MLP and TIS frameworks will be given.

3.2 Multi-Level Perspective (MLP)

The multi-level perspective is a framework used to study technological transitions. As described in the framework, a technology is always embedded within a certain environment that consists of three different levels: landscape developments (macro), socio-technical regimes (meso) and technological niches (micro) (Geels, 2002). The landscape is the highest level of the environment and can have big influence on the regime and niche levels, these lower levels on the other hand have less influence on the landscape. The developments in the landscape are caused by, for example, political, cultural and demographic factors. The regime level is seen as the existing set of rules and group of actors embedded in the environment. These rules apply from both social and technological perspectives which bring stability but also make the entry for disruptive innovations very difficult (Markard & Truffer, 2008). The last level is where the niches are formed. The niche level is disruptive by nature and very unstable as innovations continuously emerge and disappear. It focuses on exploration and discovery of technological innovations which could become part of the whole environment (Geels, 2002).

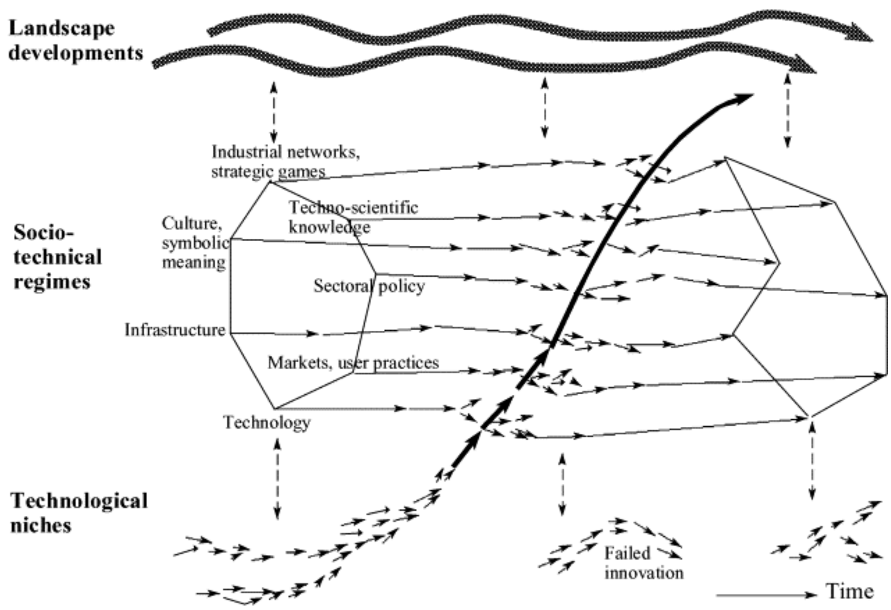

Figure 3 – Multi-Level Perspective: overview of the dynamic interaction between the landscape developments (macro), socio-technical regimes (meso) and technological niches (micro) as described by Geels (2002).

The framework is based on the interaction between the different levels and the changes that occur within them, yet at the core resides the concept of socio-technical regimes and identifying what drives

systemic change from one regime to another (Markard & Truffer, 2008). The change from one socio-technical regime to another, involving substitution of technology, regulation, infrastructure, user practices and symbolic meaning, is what defines a technological transition (Geels, 2002).
These socio-technical regimes consist of multiple actors and their networks and are regarded as multi-dimensional. This is depicted in the image below.

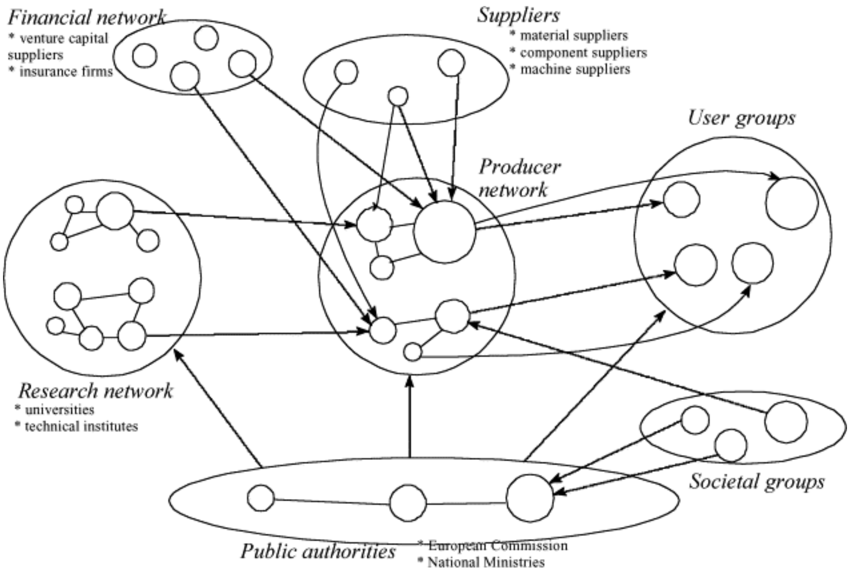

Figure 4 – The multi-actor network involved in sociotechnical regimes (F. Geels, 2002).

As Geels (2020) describes, regimes are locked-in path dependence through vested interest, sunk investments, scale advantages, cognitive routines, user practices or uneven playing fields. Niches are what pose a threat to these existing path dependencies of regimes. A pathway then has to be identified to overcome these barriers existent in the regime. Geels and Schot (2007) presented four different typologies of transition pathways based on the MLP, which are transformation, reconfiguration, technological substitution, and de-alignment and re-alignment. This insinuates that there is not one specific pathway for a transition to happen and gives another layer of complexity to transitions research.
Additionally, the description above leaves the impression that innovations are locked to a single regime, whereas in reality this could be a patchwork of regimes.

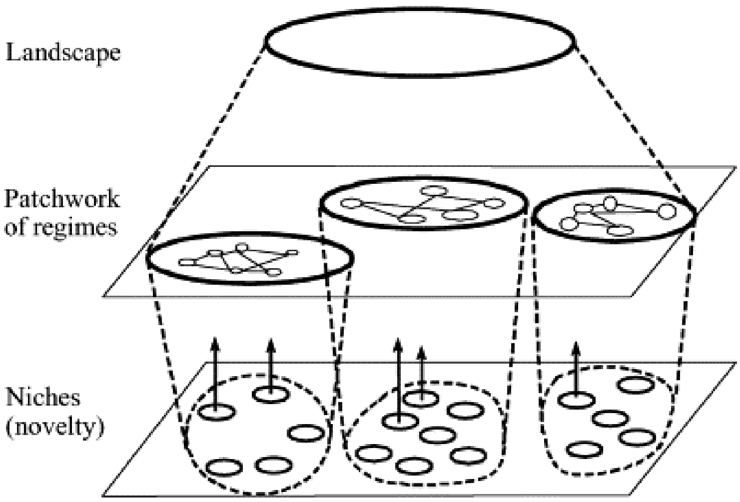

Figure 5 – Patchwork of regimes in MLP framework (Geels, 2002).

The MLP framework has been regarded as one of the main transitions research frameworks. This does not come as a surprise given its ability to capture this broad spectrum of elements involved in transitions.

3.3 Innovation Systems (IS)

Klein and Sauer published a paper in 2016 that celebrated the 30 years existence of innovation system research (Klein & Sauer, 2016). For this paper they did an extensive literature review on the innovation systems research field and presented their findings relating to the four main innovation system approaches used up till 2016, namely: National Innovation Systems (NIS), Regional Innovation Systems (RIS), Sectoral Innovation Systems (SIS) and Technological Innovation Systems (TIS). They point out that the foundations of Innovation system research were set around 1988 by Chris Freeman and Giovanni Dosi, who both lived in the age of the Cold War when nationalist thinking was very important for many countries given the circumstances. This nationalist thinking guided their research towards the National Innovation Systems approach (NIS). With this approach the innovation capacity of one nation could be compared to that of another country and help understand how innovations are developed and diffused. Over time this national perspective in research diversified to regional, global, sectoral and technological perspectives, which together are the commonly used and discussed approaches in innovation systems research.

Innovation systems has become a very large field of research and is being applied by policy makers (OECD, 2022). Even though the theory is finding its way into practice, the expansion of the research field and the multiple approaches that can be used has made the research field very confusing. Hence, studies such as the one done by Klein and Sauer (Klein & Sauer, 2016), that trace back the innovation systems research field and analyse the differences and similarities between the approaches, have appeared necessary to keep track of all the developments.

In general, innovation systems study the emergence of new technologies from complex interactions between actors (Binz & Truffer, 2017). As the name suggests, all the different approaches of innovation systems studies (regional, national, global, sectoral and technological) have two common underlying concepts, namely, *Innovation* and *Systems*. To understand the innovation systems research field these two concepts have to be further explained:

Innovation:

The term "Innovation" is being used in numerous scientific disciplines which nuance it in a different way and complicate the commitment to a single definition of the term (Klein & Sauer, 2016). A frequently used definition is the one described by the OECD: "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations". (OECD, 2005). For Innovation Systems research the central idea of *innovation* is that it introduces new knowledge or a combination of existing knowledge to the system and results from the interaction and learning process of actors within the system (Edquist, 1997). This idea of innovation has grown in two direction, where some authors concentrate on the development and diffusion of a technological innovation, while other authors took the idea in a broader sense and also take into account non-technological innovations. There is no strict definition for the term "innovation", and thus no right or wrong. There are however more useful and less useful definitions depending on what the intended purpose of use is (Edquist, 1997).

Systems:

As explained in Klein & Sauer (2016), "a system is a set of interrelated components that work towards a common purpose". As described by Carlsson et al. (2002), the systems consist of:

i) Components – the operating parts of the system. Can be actors/organizations (individuals, firms, associations, etc.) or technological artifacts (photovoltaic modules, batteries, other equipment) or institutional artifacts (laws, regulations, traditions, etc.).
ii) Relationships – the linkages between the components. One component is linked to at least one other component and the linkages strengthen the influence the system's behaviour has on the components. The relationships among the components varies for each case as it could be collaborative or competitive or even be a form of transaction (Edquist, 2006).
iii) Attributes – the characteristics of both components and relationships.

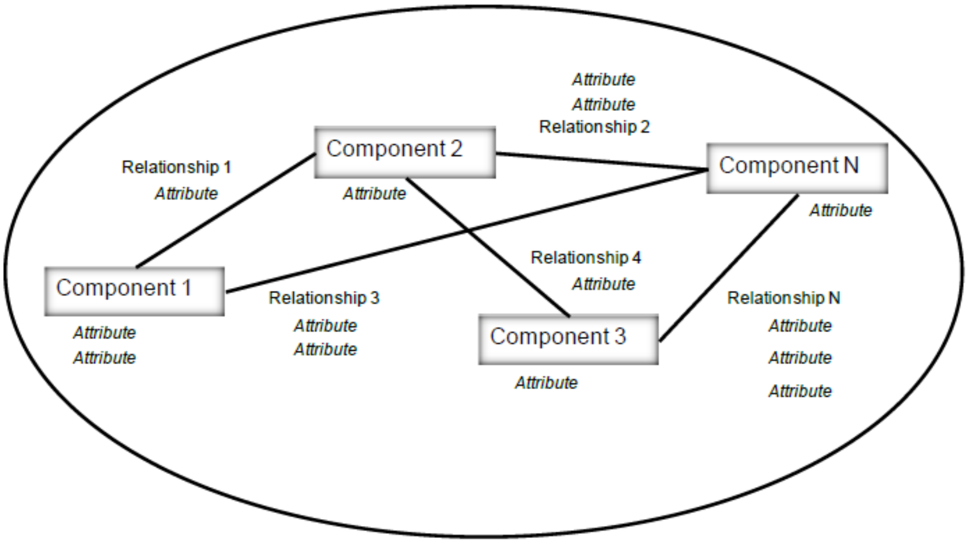

Figure 6 – Visual representation of a system including Components, Relationships and Attributes (Klein & Sauer, 2016).

The illustration above shows a single system but it should not be limited to one since multiple systems might exist in parallel and they could be connected to each other.

In Innovation System studies a set of functions is used to analyse the functionality of the system and the innovation process. Both the system components and functions vary between the frameworks. The different frameworks and their basic components and functions will be elaborated next.

3.3.1 National Innovation Systems (NIS)

Niosi et al. (1993) defined the National Innovation Systems (NIS) as "the system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, in as much as the goal of the interaction is the development, protection, financing, or regulation of new science and technology". This definition can be and has been broadened depending on the complexity level of the research (Klein & Sauer, 2016). Even in cases with a broader definition it is important to realize that generally the country's borders are determinant for the NIS research boundaries (Edquist, 2006).
Bounding the research to a country's border makes sense as generally the institutional and organization setup that influence an innovation are determined from a national perspective (Edquist, 2006). This also makes it a very useful tool to compare innovation development between countries due to their institutional variance.
The NIS remains and will continue to be one of the most relevant approaches within the Innovation Systems research field according to the analysis done by Klein and Sauer (2016). A visual representation of the NIS by Oh and Yi (2022) can be seen below.

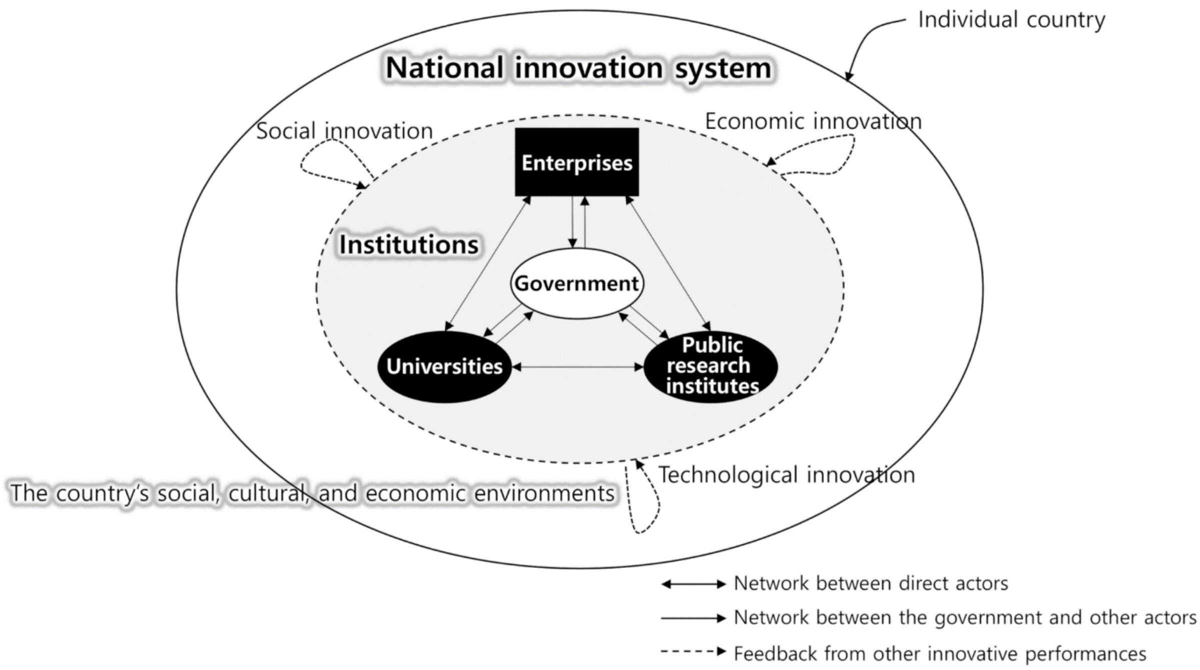

Figure 7 – Visual representation of a National Innovation System (Oh & Yi, 2022).

In the figure we can see an NIS comprising of the actors (government, enterprises, public research institutes and universities) their networks and their institutions bounded to a single country.

3.3.2 Regional Innovation Systems (RIS)

Different from the NIS, the spatial level for organizational and regulatory intervention in the RIS approach is bound to a region instead of a country. As explained in Cooke et al. (Cooke et al., 1997), a region is regarded as a subnational area where specific policies or technology transfer methods can be identified. The RIS provides an additional layer to the Innovation Systems studies which presents the possible differences in innovation development between regions within a country.
Although the RIS approach brings forward very valid discussion points regarding the nationalistic perspective dominating Innovation Systems research, it has also lead to further diversification in the units of analysis of the research field, because there is no unified definition of what the territorial boundaries are for a region (Doloreux & Parto, 2005). Among the territorial boundaries that have been used in case studies are cities, metropolitan regions, districts and areas on the supra-regional/sub-national scale (Klein & Sauer, 2016).
According to Doloreux (2005) the basic components of the RIS are:

- i) Firms
- ii) Institutions
- iii) knowledge infrastructures
- iv) Policy-oriented regional innovation

These components are analysed on a functional basis consisting of:

- i) Interactive learning
- ii) Knowledge production
- iii) Proximity
- iv) Social embeddedness

As is the case for NIS, through literature the components and functions have been expanded and diversified depending on the complexity of the research. A visual representation of the NIS by Cooke and Piccaluga (2004) can be seen below.

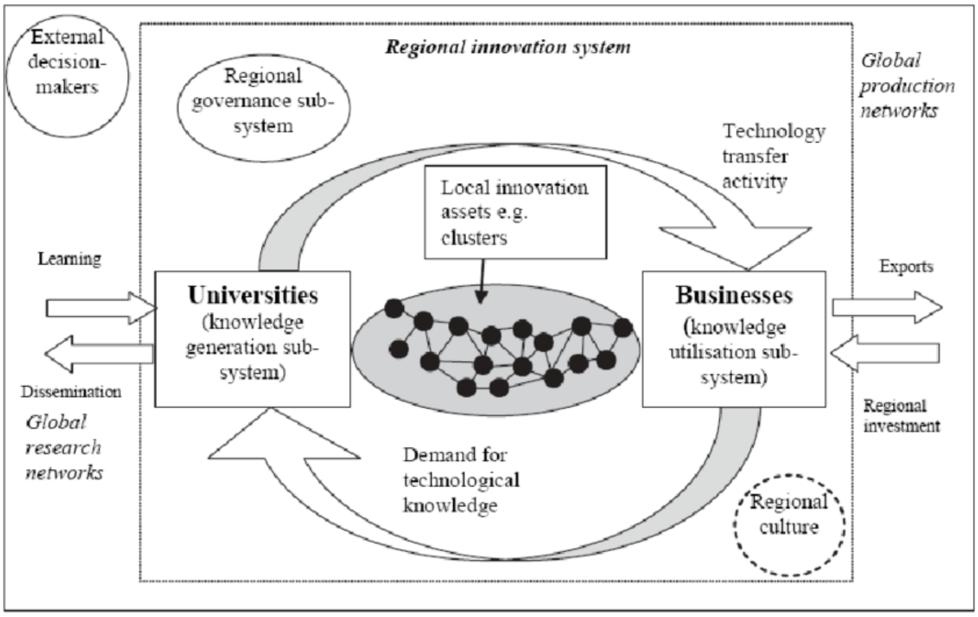

Figure 8 – Visual representation of a Regional Innovation System (Cooke & Piccaluga, 2004).

In the figure we can see an RIS with actors (universities and businesses), their networks and the regional institutions that are at play and external and global influences.

3.3.3 Sectoral Innovation Systems (SIS)

The SIS approach differs from the NIS and RIS by focussing research to a sector instead of a bound territory. Malerba (2004) defines a sector as "a set of activities which are unified by some related product groups for a given or emerging demand and which share some basic knowledge". In this sectoral approach the emphasis lies on the characteristics of the networks of actors, the factors that result in sectoral change and the influence the institutional framework has on the sector (Klein & Sauer, 2016). It explores the technological change and path dependencies of innovation which differ between sectors.

The main components of the framework are:

i) Institutions (norms, routines, laws, standards)
ii) Actors & Networks (can be a variety of different types of organizations and individuals such as, producers, suppliers, universities, financial institutions, government agencies, etc. and their connections)
iii) Knowledge & Technologies (the linkage and complementarity between multiple technologies within a sector and the accessibility, opportunity and cumulativeness of knowledge regarding these technologies)

The functions used in the SIS approach are:

i) Variety creation (such as the amount and type of new actors entering the sector which bring variety in approaches, behaviour and new knowledge to the system)
ii) Selection (brings convergence to the sector variety working towards the demanded sectoral product)

A visual representation of the SIS by Kim & Kang (2021), adapted from Malerba (2004), can be seen below.

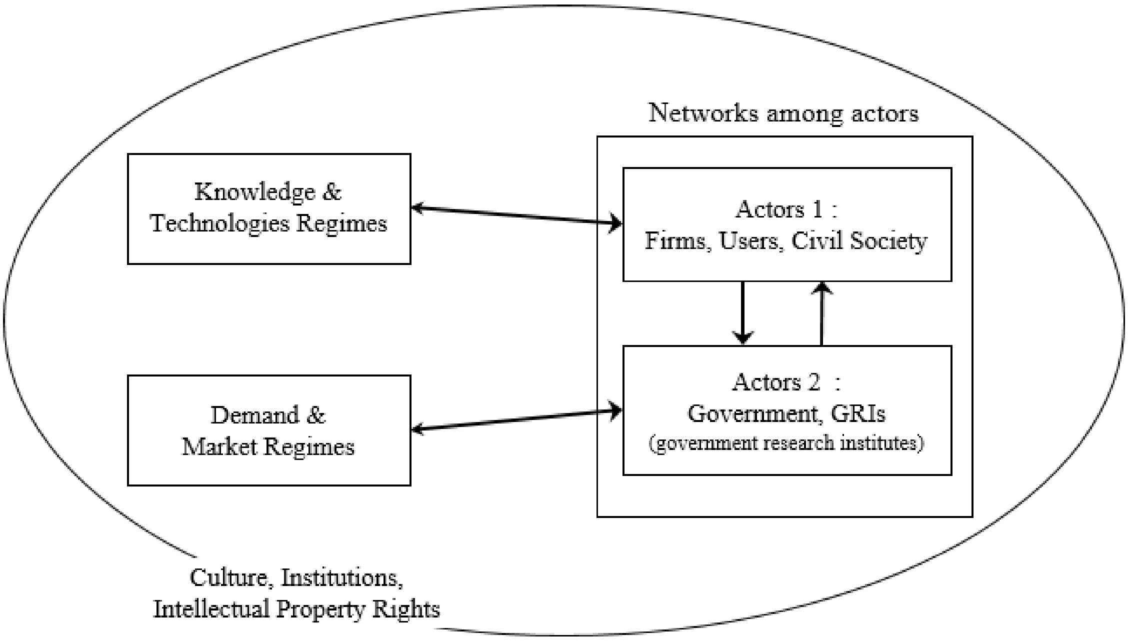

Figure 9 – Visual representation of a Sectoral Innovation System (Kim & Kang, 2021).

In the figure we se an SIS with actors (firms, users, civil society, government and GRIs), their networks and institutions in which they are bound and the internal influences from the regimes.

3.3.4 Technological Innovation Systems (TIS)

In the TIS approach a specific technology is the focal point of analysis. Carlsson and Stankiewicz (1991) defined the technological system as "a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology". The spatial boundaries vary between different studies and although TISs exhibit global characteristics commonly they are studied in a national or regional context.
The TIS framework as presented by Hekkert et al. (2007) and supplemented by Bergek et al. (2008) has increasingly been applied to specific case studies as it helps to systemically analyse the performance of the innovation system in question.
The basic components of the TIS approach are (Jacobsson & Johnson, 2000):

i) Actors (firms in the value chain, government bodies, NGOs, universities, technology users and other organisations)
ii) Networks (linkages between these actors)
iii) Institutions (the environment in which the networks and their actors legitimise the TIS and can be seen as the set of rules of the TIS)

The commonly used functions in TIS research as described by Hekkert et al. (2007):

i) Function 1: Entrepreneurial activities

Entrepreneurs are the ones that actually take action when a new opportunity arises, this makes their role essential in an innovation system. They are the ones that recognize and make use of a business opportunity which leads to the development of an innovation, either as a new entrant on the market or as an incumbent company diversifying its business strategy.

ii) Function 2: Knowledge development

Learning is an important mechanism in an innovation system. This function focuses on 'learning by searching' and 'learning by doing', which maps the R&D projects and investments related to the innovation system, but also patents and learning curves of the technology.

iii) *Function 3: Knowledge diffusion through networks*

Similar to the previous function, this function is also related to learning mechanisms. It focuses on ’learning by interacting’ and ’learning by doing’. Here the diffusion of knowledge through the innovation system network is the main concern, where knowledge exchange, contact, and openness between the different actors is mapped.

iv) *Function 4: Guidance of the search*

In general this function refers to the activities where different actors of the innovation system interact with each other and how they perceive the technology. For example: different ideas around a technology can be created during the R&D process, while in reality not all will be as effective. It is important to make a selection of what is most promising since usually resources, in the form of investments, are necessary for the development of the technology and these are often limited. From a societal perspective, the R&D sector can be guided towards the necessity of society.

v) *Function 5: Market formation*

An innovative technology might have to compete with different developed technologies which are embedded and already dominate a certain sector. The technology will thus need some initial protection to grow. This can found in the form of a market, where the new technology has an advantage with respect to previous technologies because of its characteristics.

vi) *Function 6: Resource mobilization*

As mentioned in function 4, resources are often limited. These resources are imperative for the development of the innovation. This function detects if actors have (sufficient) access to physical, financial and human resources.

vii) *Function 7: Creation of legitimacy/Counteract resistance to change*

Even though some innovations are essential for society in the long run they might not appear to be necessary from the start. Moreover, the innovation can even oppose the incumbent technologies in which some actors have vested interests. This can block the development and requires growth of actors supporting the innovation and their lobbying activities to counteract this resistance.

The set of functions are used to present the dynamic behaviour within an innovation system. This is done by mapping events and allocating them into specific indicators which are individually related to one of the respective system functions. If all functions are fulfilled this can be related to a well-functioning TIS. On the other hand, TIS can also encounter barriers which hamper one or multiple functions which can lead to a malfunctioning TIS, therefore identifying the barriers is the first step towards creating guidelines to overcome them and improve the innovation system.
A visual representation of the TIS by Haley (2018) can be seen below.

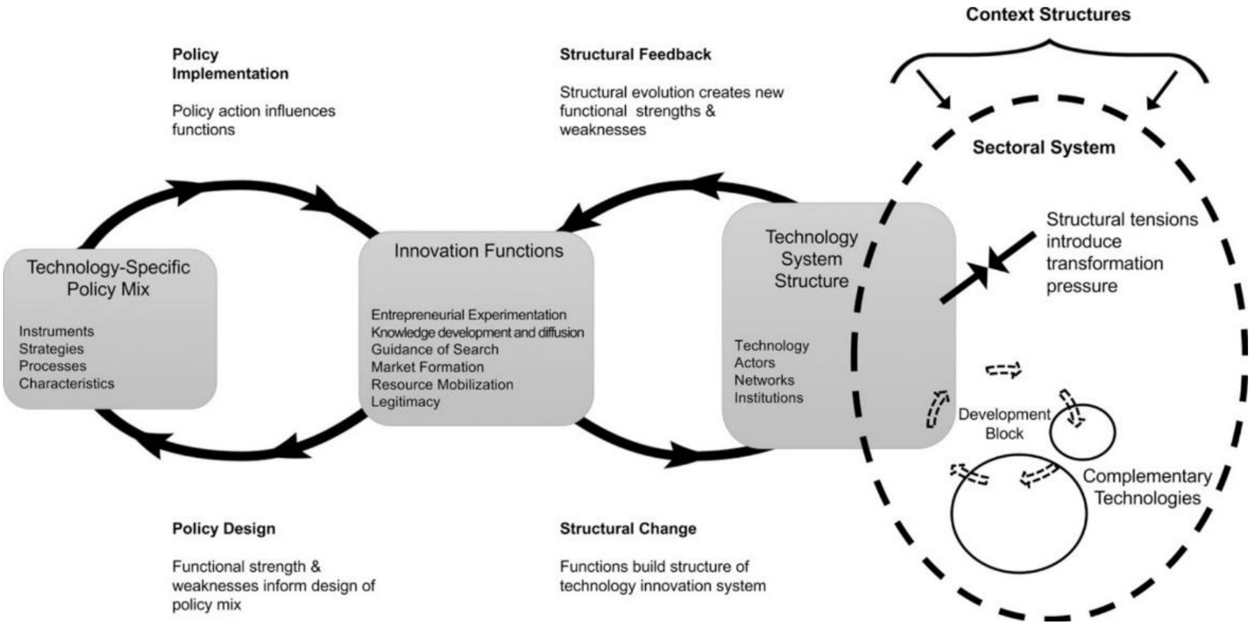

Figure 10 – Visual representation of a Technological Innovation System (Haley, 2018).

In this figure we see the linkage between the structural components and the functions of the TIS and how the policies influence the functions. A complete overview of the TIS analysis as described by Bergek et al. (2008) can be seen in the figure below.

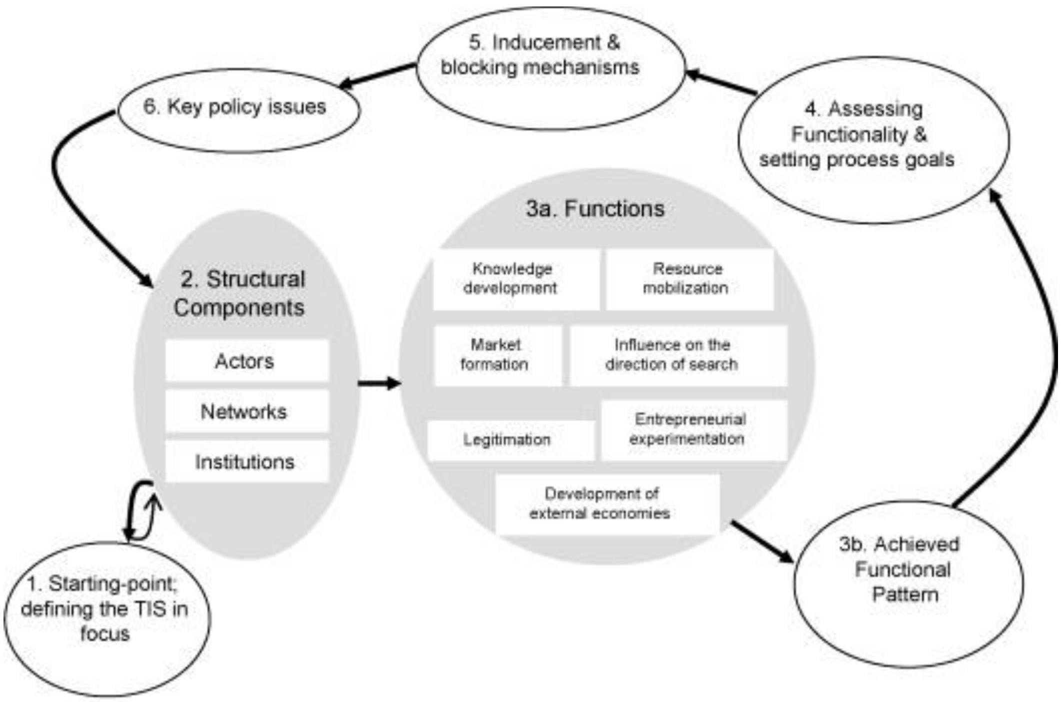

Figure 11 – TIS scheme of analysis (Bergek et al., 2008).

3.3.5 Global Innovation Systems (GIS)

The GIS framework tries to enhance the innovation systems literature by adding an explanatory stance with respect to the spatial complexity of innovation processes (Binz & Truffer, 2017). By this is meant that events in the innovation process more often take place in multiple spatial locations (e.g. different countries or regions) and should be taken into account in innovation systems analysis.

There are two key mechanisms in the GIS framework which are the generation of resources in multi-locational subsystems and the establishment of structural couplings among the systems
Basic components for the GIS are:

i) Actors
ii) Networks
iii) Institutions

Functions:

i) Knowledge
ii) Financial investment
iii) Market formation
iv) Legitimation
v) Structural couplings

A visual representation of the GIS by Tsouri et al. (2021) can be seen below.

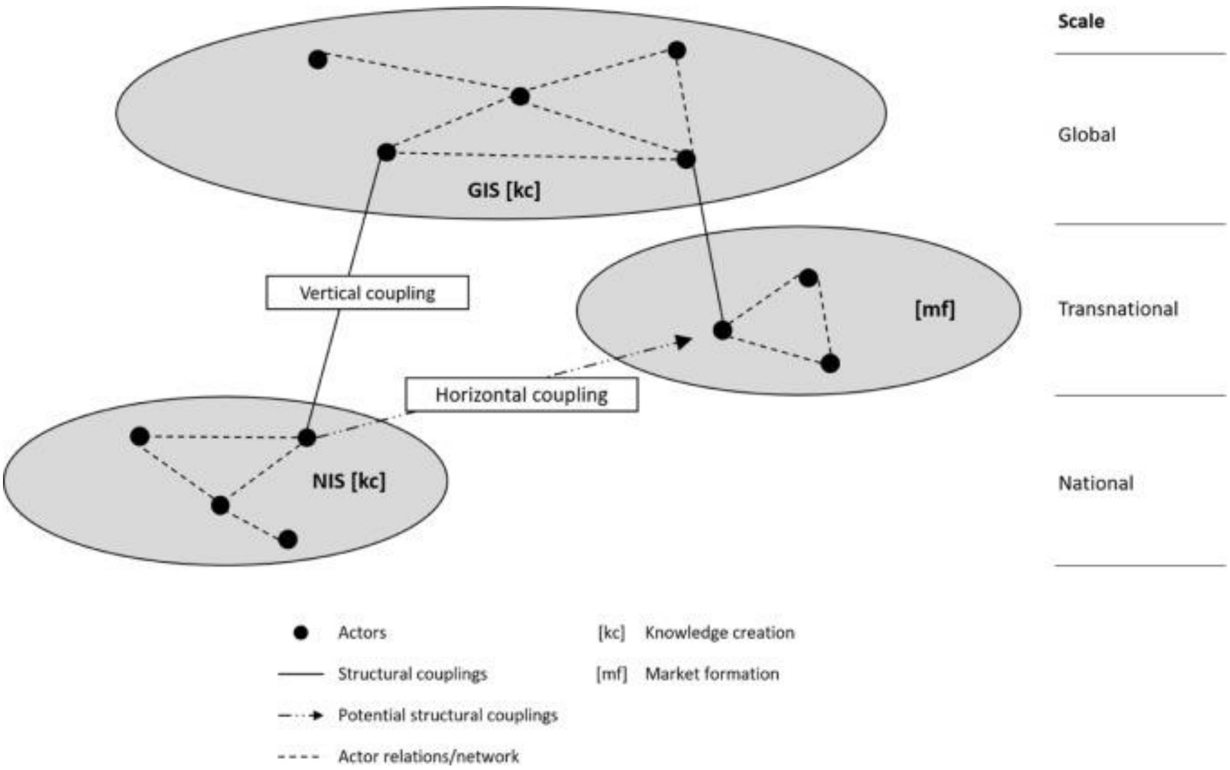

Figure 12 – Visual representation of a Global Innovation System (Tsouri et al., 2021).

In this figure we see linkages between the global and national IS and the transnational couplings between them.

3.3.6 Relationships Between Innovation Systems Frameworks

The different innovation systems frameworks have some overlaps and relationships. This can be seen in the similarities between in basic components and functions used. The national and regional innovation systems are spatially based and are primarily differed by the extent of the spatial boundary, but their basic components remain the same. Sectoral and technological innovation systems on the other hand, cross geographic borders. TISs can also cross sectoral borders. This is to be expected since "different technologies or knowledge fields are empirically intertwined" (Markard & Truffer, 2008). Markard and Truffer (2008) have created a visualization for these potential relationships as can be seen below. Keeping in mind that the TIS could be split into different sub-TISs where one sub-TIS could be limited to one specific NIS or SIS.

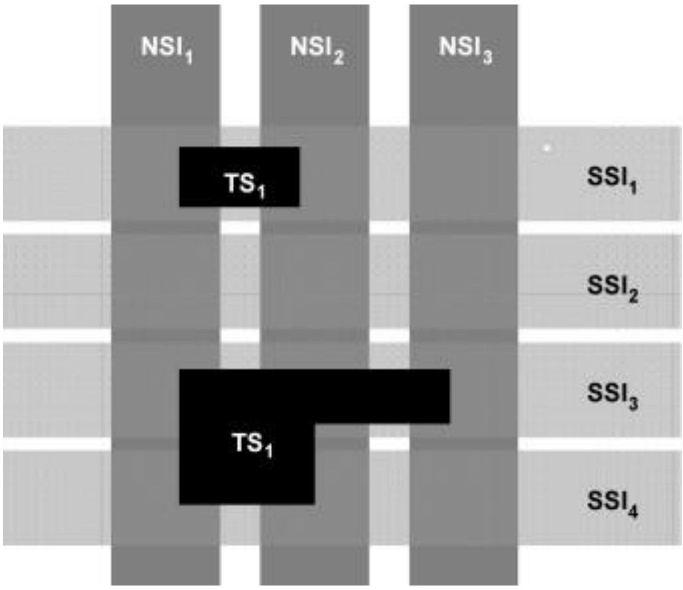

Figure 13 – Visual representation of potential relationship between multiple national (NSI) and sectoral (SSI) innovation systems and a technological innovation system (TS) (Markard & Truffer, 2008).

The image shows that each framework can be seen individually but once put inside a single frame there are clear conceptual overlaps between them. As already mentioned there is no right or wrong framework, they can all form a basis for the same innovation system that will be dependent on the research context and boundaries.

This same reasoning was also adhered by Asheim et al. (2011) and Schrempf et al. (2013). The visualization presented by Asheim et al. (2011) can be seen below and additionally includes the global and regional innovation systems to portray the innovation systems relationships.

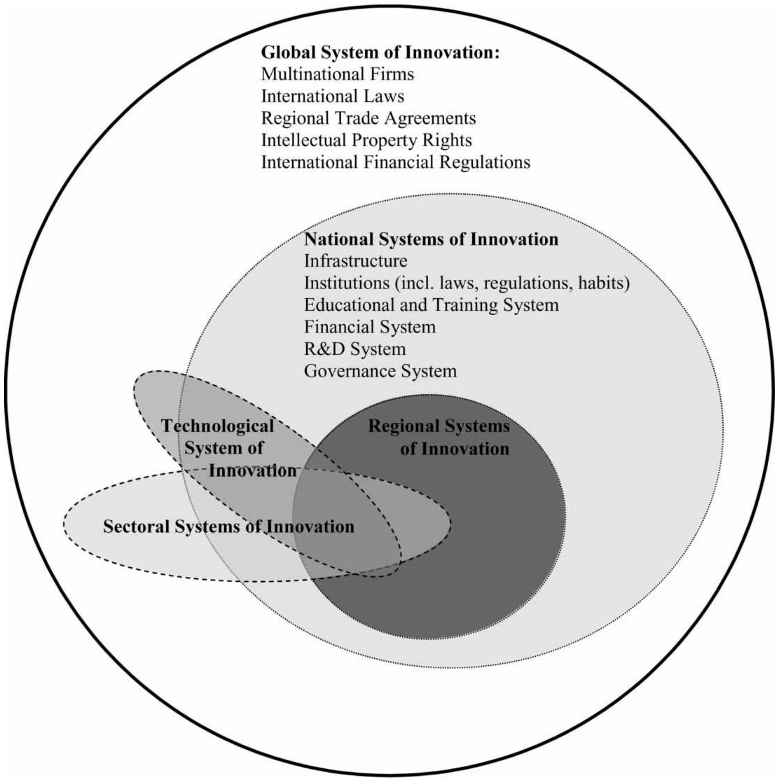

Figure 14 – Visual representation of potential relationship between different innovation system frameworks (Asheim et al., 2011).

3.4 Commonalities and Complementarities Between the Frameworks

There are also commonalities and complementarities between the MLP and IS frameworks. First of all is that both frameworks regard actors, networks and institutions as important conceptual components (Markard & Truffer, 2008). The MLP framework is however less detailed on the actor roles, strategies and interactions which can influence innovation processes. Secondly, the Niche and Regime levels are present in both frameworks. Although they are clearly distinguished in the MLP, in the TIS it depends on the technology maturity whether it will be viewed as niche- or regime-like. An immature TIS with an early stage technology mostly resembles the innovative and protected role encountered in niches of the MLP, while a more mature TIS resembles a regime since it provides guidance to innovation processes to support established technologies. The regime of the SIS approach is defined similarly to the MLP approach, which is on an industry or sector level. Markard and Truffer (2008) translated the commonalities between the frameworks to the image below which points out the segments in which the frameworks overlap.

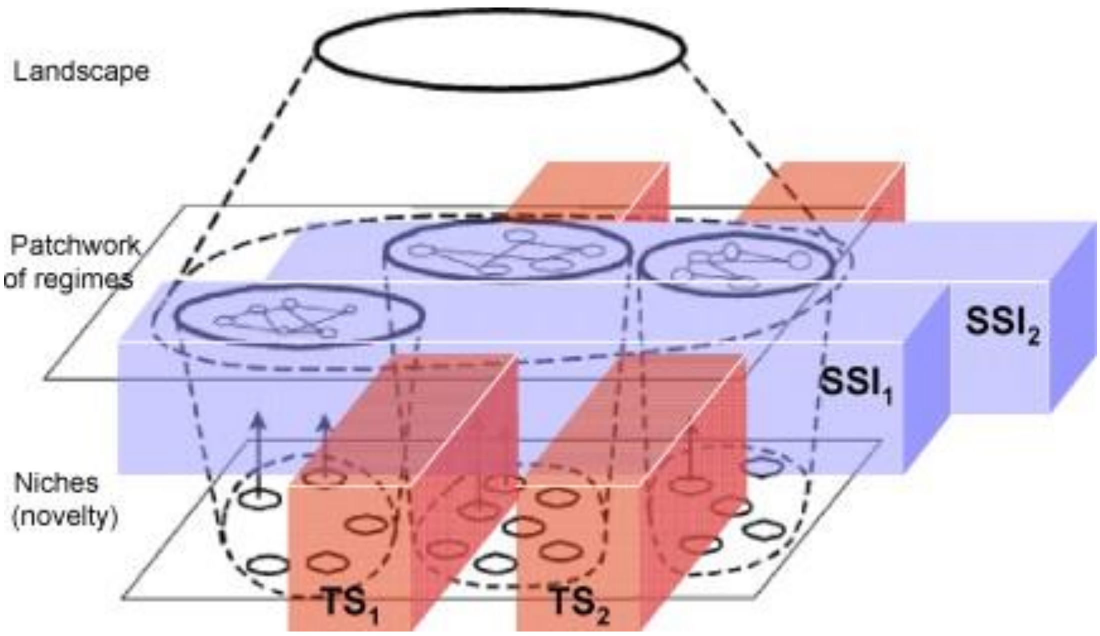

Figure 15 – Interrelation between MLP and IS frameworks as presented by Markard and Truffer (2008).

As already discussed in Section 3.2 and can be seen in the image above, the MLP framework is built on the landscape, regime and niche levels. Its strength lies in that the framework allows to analyse innovation and transition processes through the interplay of stable regimes and destabilizing external shocks from the niches and landscape levels. The IS framework on the other hand is very inward looking, meaning that the success of the innovation corresponds to the system in which it resides and does not structurally take its environment and influences into account. It does not fully include landscape parameters to the analysis and cannot completely explain a technological transition. The MLP falls behind compared to the IS frameworks on the concepts and tools available to analyse innovation dynamics at the niche level and in cases of complementarity between multiple niches (Markard & Truffer, 2008). The IS framework is more elaborated in this aspect and its structural and functional analyses allow for better actor and niche representation (Bergek et al., 2005).

Given these points there appear to be opportunities in which these two frameworks could complement each other. Markard and Truffer (2008) have presented this complementary framework as the *technological innovation systems* and defined it as “a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology and/or a new product”. The design of the concept is based on i) the innovation function of the system; ii) being technology (or product) centred; iii) the actors, networks and institutions being supportive to the innovation process (Markard & Truffer, 2008). This framework focusses on using the strengths of the TIS, which allow for functional analysis of innovation dynamics and cases of complementarity between multiple niches, and of the MLP, by including the external shocks present in landscape parameters. An example visualization of the framework can be seen below.

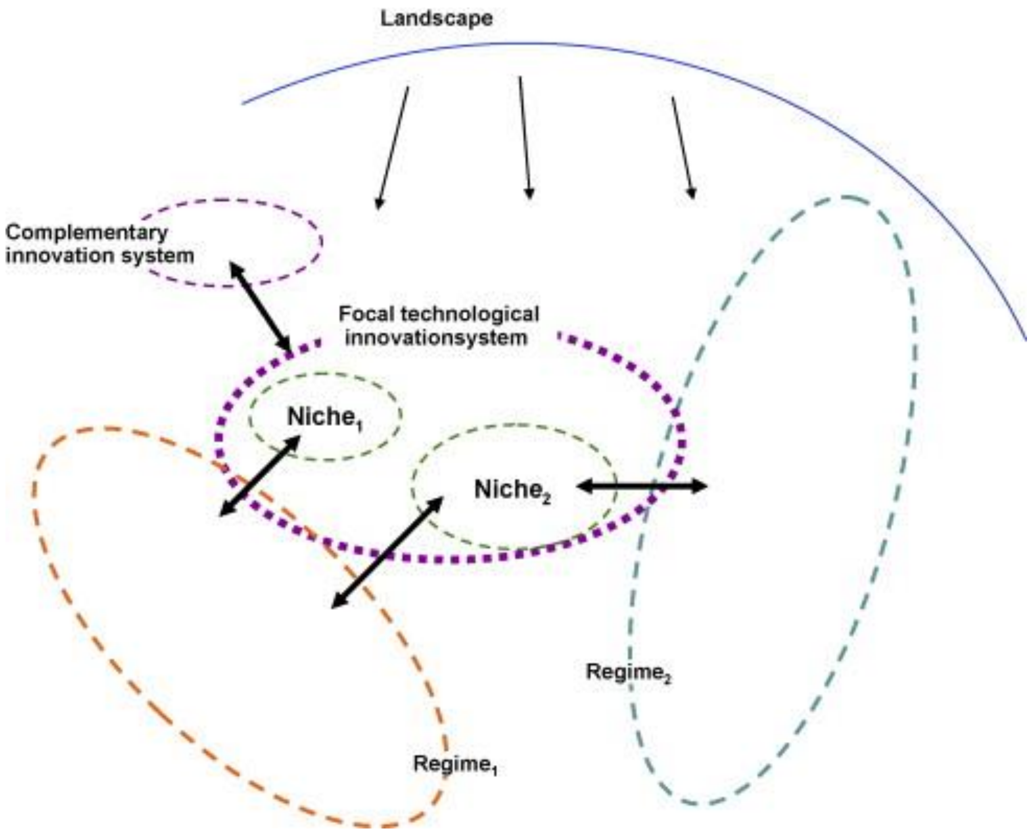

Figure 16 – Example of the combined TIS and MLP framework as described by Markard and Truffer (2008).

The construction of this combined frameworks was one of the first steps towards converging the existing frameworks and bringing the already related research fields even closer together. The following table summarizes how the two frameworks serve as commonalities or complementarities.

Table 2 - Summary of the commonalities and complementarities between the MLP and TIS frameworks.

	MLP	TIS	Combination effect
Scope of analysis	Sector	Technology	Complementary
Levels of analysis	Landscape, Regime and Niche	Regime and Niche	Complementary
Conceptual components	Actors, Networks and Institutions	Actors, Networks and Institutions	Commonality
Tools of analysis	-	Functions	Complementarity

The convergence of these frameworks fits very well with the author's desire, which is to build a platform that is based on the core concepts of sustainability transitions research. With this platform the author hopes that the case analysis and presentation of sustainability transitions research is facilitated and structured and that the convergence of the frameworks progresses. Building a separate platform for each framework would defeat the purpose of fully understanding sustainable transitions and as is being seen in research, there are ways of combining them in theory, but hopefully also in a platform. Although the author’s desire is to have a platform with a single framework that has been constructed through convergence of the already existing ones, it would be unrealistic to do so within the timeframe and available resources of an MSc. thesis. As has been explained in Section 3.1, the combined MLP and TIS framework as presented by Markard and Truffer (2008) for a large part coincides with the author’s vision for the platform. That is why the platform template of this research will be built based on their combined framework, and will not include other frameworks since research on how to combine those to this combined framework would be a whole other thesis research on itself. The next chapter will further explain what is meant with the term platform and how exactly this combined framework will be placed within it.

Chapter 4 – Sustainability Transitions Platform

In this chapter the concept of the *Sustainability Transitions Platform* (STP) will be explained and the particular elements that will be used for the platform template will presented. This will be done by answering the following two sub-questions: '*What is a digital platform?*' and *'How can the framework elements be combined in a platform?'*

4.1 Defining the Platform

Defining what exactly a platform is can be a bit confusing since the word platform is not new and it is being used in different sorts of context (Gawer, 2014, 2016). Depending on the context in which it is being used, different definitions can be applicable. Gawer (2014) has presented two different perspective on how platforms can be defined based on what has been described in literature. These are the i) economics perspective and the ii) engineering design perspective of platforms.

From the **economics perspective** a platform can be seen as a particular kind of intermediary between two actor groups. It is an essential bridge or pass way between two types of customers of the platform. From this perspective the platform is seen as a triangular business model, which is different compared to the traditional linear business model which relies on a serried supply chain for value or product creation. Platforms allow the direct flow of value between different actor groups that were not directly connected in the linear model, making it a triangular business model which in literature is also referred to as *transaction platforms* (Cusumano et al., 2020). The platform facilitates the interaction and transaction between actor groups, such as producers and consumers. It also serves as a mean to give the actor groups insights on their activities which can be used for self-improvement.

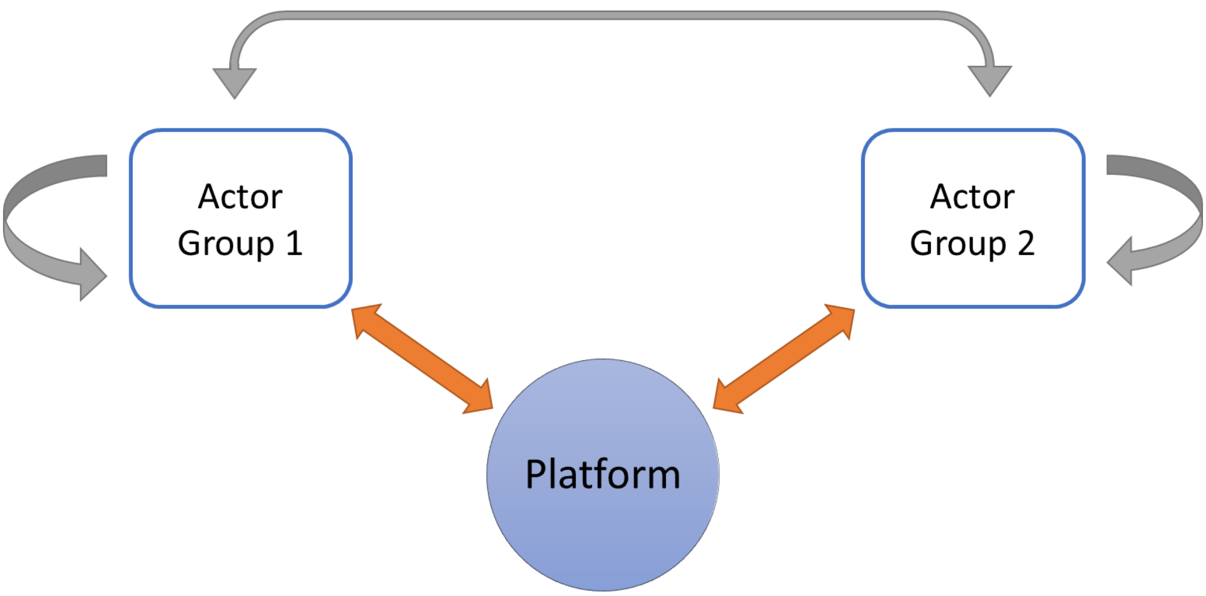

Figure 17 - The platform triangular business model from the economics perspective. The platform serves as an intermediary between actor groups which facilitates transactions between them but also allows them to innovate and improve their own products, services and processes (image adapted from Gawer (2016)*.*

Some examples of these transaction platforms are Spotify, Netflix, Uber, Airbnb, Deliveroo. Each one of them has two actor groups that benefit from using the platform. In Spotify, which is a music platform, the actors that produce music are able to reach a large group of music listeners that are subscribed to the platform and music listeners are able to listen to a large variety of songs as many producers upload them to the platform. More producers and listeners are then inclined to enter the platform as this number increases on both sides generating a self-strengthening loop which is known as the network effect. This principle of network effects is central in platform literature and holds for the other platforms mentioned as well (Cusumano et al., 2020; Gawer, 2014). Besides this benefit for producers to be able to reach many customers in one place, they also gain the advantage of not needing a long supply chain of multiple intermediaries that interfere in their product and business and are able to reach their customers more directly.

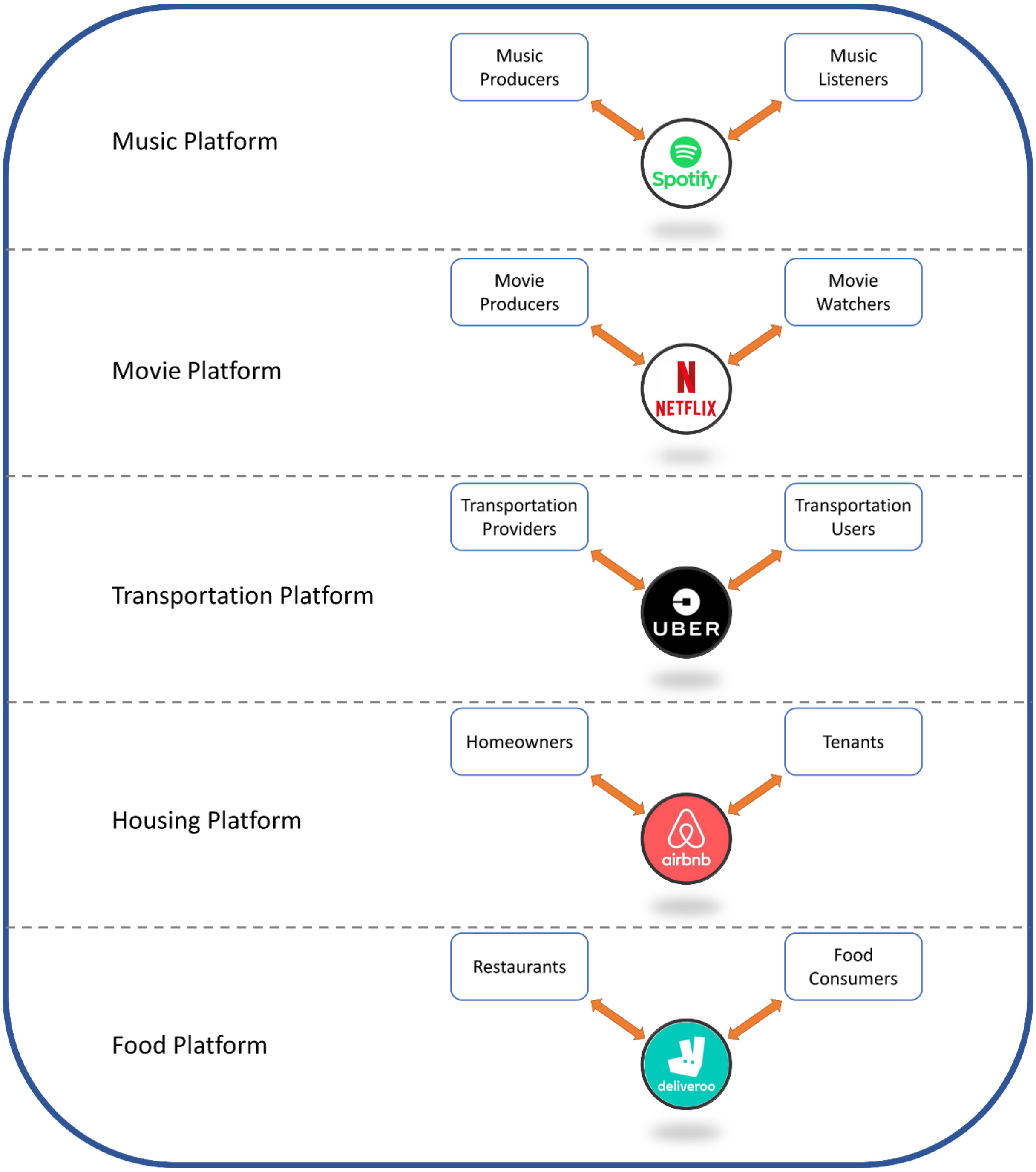

Figure 18 - Examples of the triangular business models of transaction platforms.

This representation is however limited to only one part of the complete operations and capabilities of these platform companies. In reality these companies are continuously trying to improve and diversify their platform in such ways that new types of actors also start to make use of it and that the experience of their current user base is improved. Using the same example, Spotify has branched out to also include podcast and video services besides the music industry it started on. Other examples are Netflix, which included series and games, and Uber, which added food delivery services to its platform.

From the economics perspective the platforms is thus seen as a market for transactions between two actor groups.

From the **engineering design perspective** a platform can be seen as a core module or a set of core modules on top of which innovation can happen by having compatible modules (or peripherals) that are complementary to it. In literature it is also referred to as an *innovation platform* (Cusumano et al., 2020). One of the older examples of such a platform can be seen in the automotive industry. Car companies design core components (e.g. the chassis) that form the basis or template of the to be produced cars. On top of these core components other parts can be added which results in a variety of different car models as final products. In their core they are the same however the final product can differ depending on what components are added. By doing this the manufacturing process can be accelerated, which saves costs while maintaining product quality, and also allows the pace of innovation to be increased.

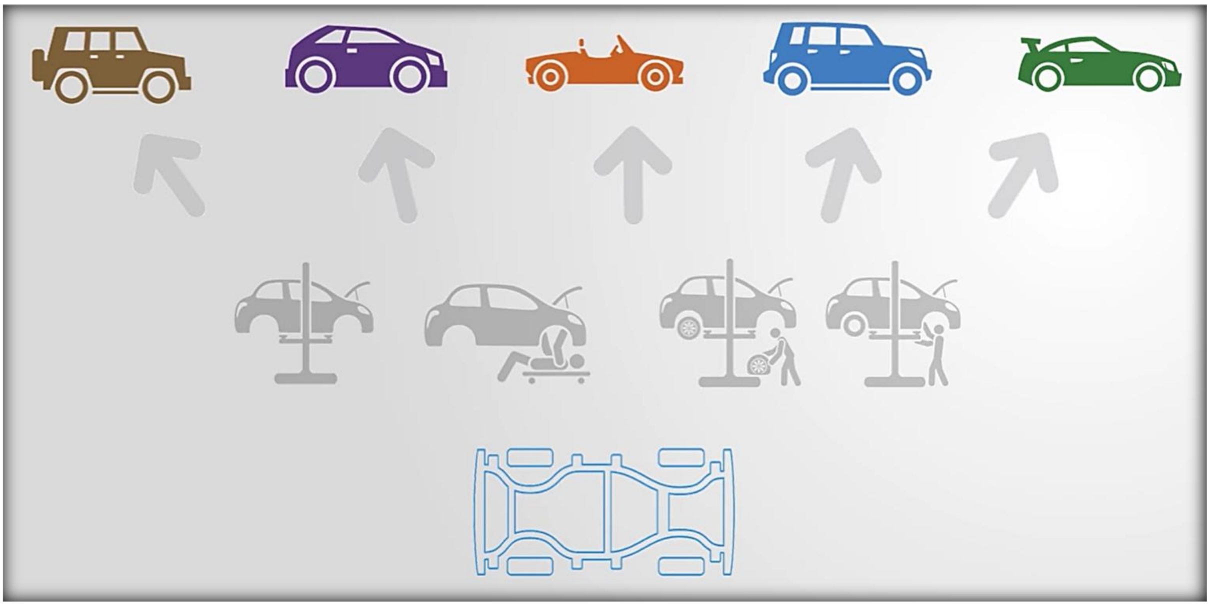

Figure 19 - Example of a car manufacturing platform where different car models are built based on the same core components. In this case all the cars are built on the same type of chassis (Systems Innovation, 2015).

Nowadays, this concept of having a core module where other components can be added is more frequently being encountered in a digital form and is referred to as a digital platform. A digital platform is a software based platform which exists of a core module on which other software innovations can be added. An example of this is what has been produced by the company Apple. They have built the iPhone and the digital platform Apple iOS that is required to operate it. What makes it be regarded as a platform is that independent software developers are able to develop products (apps) which are compatible with the requirements of the apple software and are thus able to add innovations to the core of the apple product. Apple iOS is then seen as the innovation platform that allows other applications (e.g. Spotify, Netflix, Uber, Airbnb, Deliveroo) to operate in its environment. The Apple core product improves as innovators add their products while the innovators are incentivised to add their products to the apple ecosystem as it has a large pool of users. This also shows that the company Apple as a whole and the platform it has been developing also presents characteristics as described in the economics perspective in which Apple works as an intermediary between application developers and application users. This overlap is also pointed out in literature where the companies that operate in both perspectives of innovation and transaction platforms are being labelled as hybrid companies (Cusumano et al., 2020). In this hybrid form of a platform both the economics and engineering design perspective are applicable, thus the platform as a total should allow both transactions and innovation to happen.

From a theoretical point of view, the transaction and innovation platforms are the two types of existing platforms. When looking at digital platforms in particular, from a technical point of view these two types of platforms are built rather similarly. When diving deeper into the technical aspects of digital platforms we see that they consist of lines of code written in programming software. These lines of code are what make a platform i) look the way it has to and ii) do what it is intended to do. These lines of code are programmed by software developers with a focus on optimal use for the users of the platform.

The functionality a platform can vary depending on what the developers program it to do. In some cases the functionality of the platform is related to data which is gathered during the building process of the platform and to the user activity once the platform becomes operational. The platform developers then have the option to use the data as an internal source for improvement but also as an improvement source for the platform users or third parties interested in certain parts of the data. It allows, whoever required, to digitally interact with data in several ways. The data can for example be ordered, grouped and/or filtered through specific commands embedded in a platform. This functionality can in many cases simplify the analysis of the data and can be a huge advantage as the size of the dataset increases. In some cases datasets can be so extensive that it becomes almost impossible to analyse them without the help of computational devices.

The frameworks used in transition studies rely very much on available information, in other words, data. This data can for example be the actors active in a specific technology and the networks between them; indicator information to determine function fulfilment; applicable rules and culture in a country and the requirements for a technology. This data is gathered from different sources, which often come as text (you read it: e.g. papers, articles, books), visuals (you see it: e.g. videos, images, prototypes) or audio (you hear it: e.g. interviews, lectures, podcasts, webinars, presentations).

In transition studies data is gathered and categorized. Afterwards, conclusions are drawn based on this data. Different conclusions can be drawn from similar studies as the data gathering process and interpretation can be different for each researcher, which is why a more structural and standardizes process would be beneficial. A digital platform could provide this structured and standardized environment and it can go even further by presenting the data in a visually easy to understand and dynamic way. This can help in the challenge of accurately understanding the data for innovations and transitions. Visualizations in particular are something that could be used to improve innovation and transition research. As Munzer (2014) wrote in her book about visualization analysis and design: "Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more effectively". In this case the task would be to use datasets to help understand innovation and transition processes. Having a platform that includes visualizations representing the data related to the transition frameworks could help researchers carry out their task more effectively as it augments the researcher's data processing capabilities.

The author's ambition is that a platform is created that is specifically designed for sustainability transitions research. This would be categorized as a research platform driven by the need to understand innovation and transition processes which are determined by making use of different components, in this case frameworks, which contain tools that improve the understanding of the theory. The theory is continuously tested by applying them in cases, which in the platform are regarded as the end products. From what is learned in the implementation of cases, knowledge should be gained on improvements for the existing frameworks or the creation of new ones, which should in turn also lead to improvements in understanding innovation and transition processes. This would classify the platform as an innovation platform type in which an interface is present where innovation in sustainability transitions research can be experimented and applied.

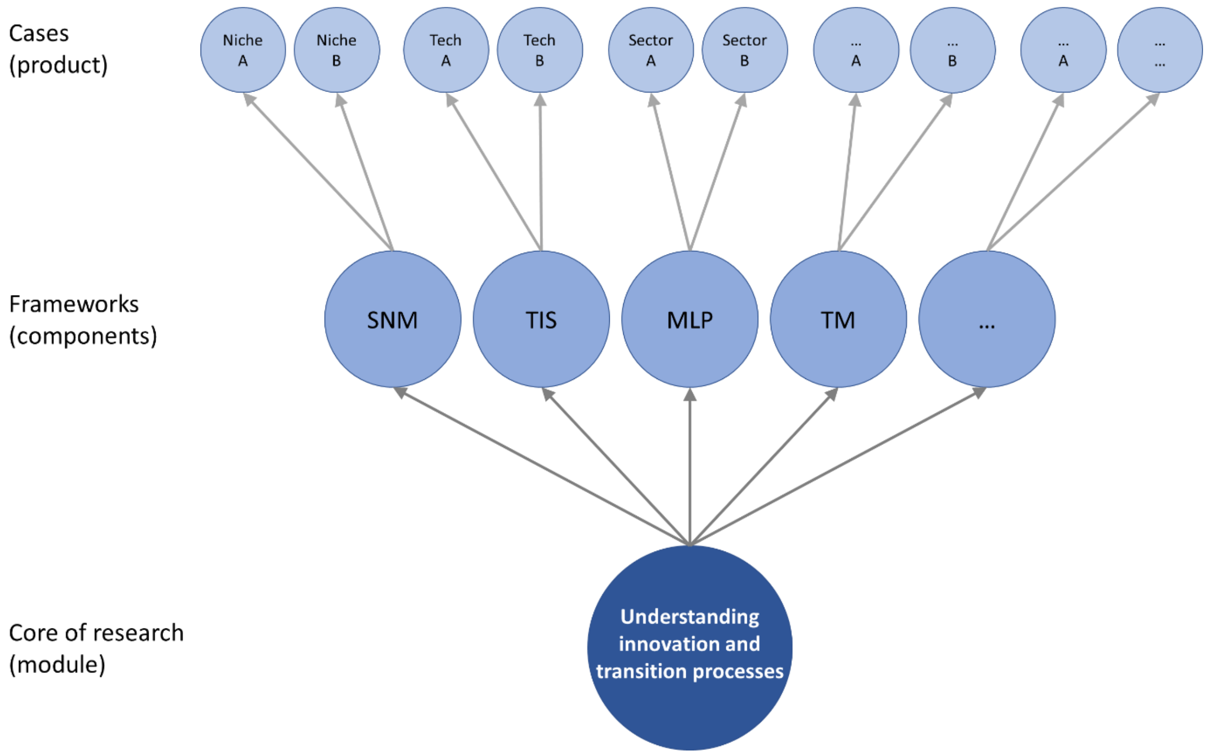

Figure 20 - Sustainability transitions research as an innovation platform. Understanding innovation and transition processes is the core (module) of the research, this is being done through different sets of frameworks (components) and being implemented in various cases (product).

Nevertheless, the ambition is that this digital platform will not only be useful for research purposes, but that it will also be useful for society to be able to make decisions that lead to sustainable transitions. As mentioned in Chapter 3, sustainability transitions research has primarily focused on generating policy advise for policy makers (Köhler et al., 2019). Thus, in the research field itself we already encounter two different actor groups interested in the matter, where one group contains the researchers that develop the frameworks, gather the data, implement cases and generate policy advice, and the other group contains the policy makers, which use the knowledge gained from the advice to implement policies that in turn influence innovations and transitions. By creating a platform where these two actor groups would be able to interact with each other a triangular business model would be created which would also make the platform resemble a transaction platform. The platform would then become a bridge between researchers and policy makers. In the author's view the data generated in cases for sustainability transitions research is also valuable for other types of actors such as organisations working on international trade or companies trying to enter new markets (more on this in Section 6.3.5). This would also allow other groups interested in the knowledge created by the researchers to use it directly from the platform, turning the platform into a bridge between knowledge producers and knowledge users. A bridge between theory and practice.

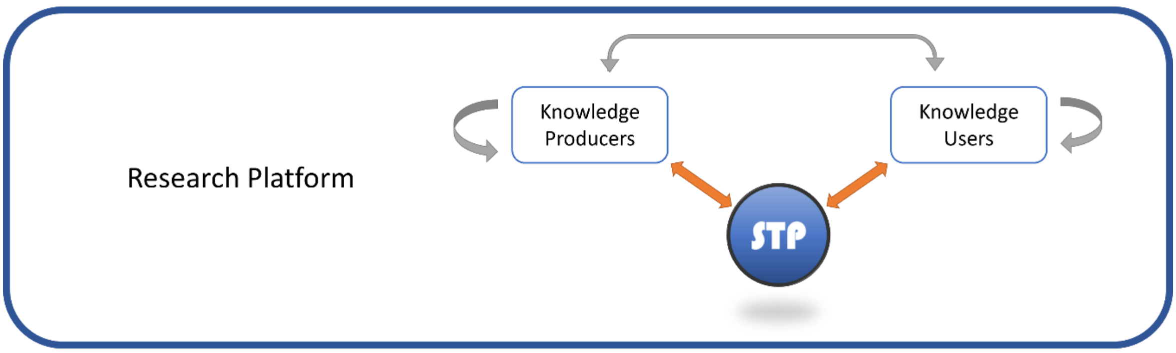

Figure 21 - The triangular business model for the STP as a research platform.

Based on this the fully functional *Sustainability Transitions Platform* (STP) would be defined as:

a software based digital platform that acts as a bridge between researchers of sustainability transitions and actors who make decisions that influence innovations and transitions, in which researchers are able to input gathered data and are able to interact and analyse it generating knowledge related to innovations and transitions which can be used by policy makers or other actors to guide them in their decisions towards a sustainable future. Hereby a community is created in the platform of researchers who are able to see and interact with each other's work allowing them to continuously evaluate the sustainability transitions theory making it possible to structurally and efficiently improve and innovate the theory and its frameworks resulting in a more accurate understanding of innovation and transition processes.

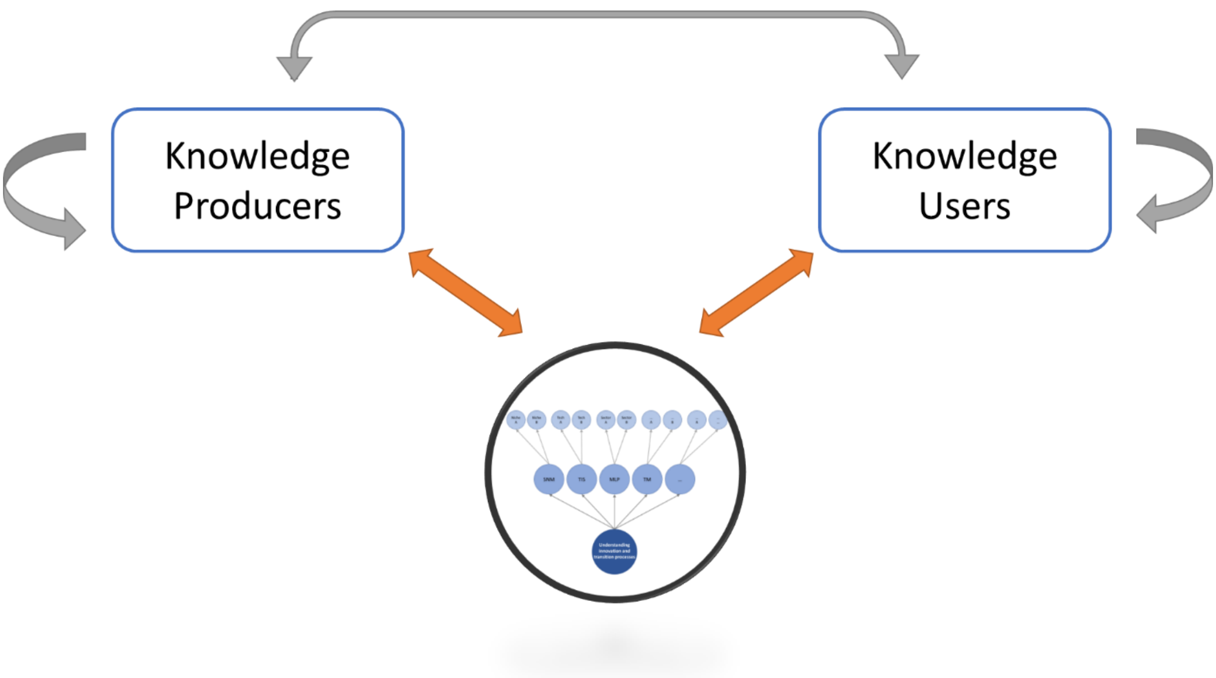

Figure 22 - Visualization of the complete sustainability transitions platform as a hybrid model including both the economics and engineering design platform perspectives.

This is the idea for the fully functional *Sustainability Transitions Platform* (STP). Developing this complete version of the platform would however require more resources, time and experience in both software development and business than the author alone has and would also go beyond the requirements of an MSc. thesis. That is why for this research only a first draft or template (as is referred to in this document) will be made which only fulfils part of the complete platform but sufficiently serves as a basis for the STP and the further ideas behind it. The boundaries to which this research and the platform template abide will be discussed in the coming section.

4.2 Platform Template

The platform template of this research will be limited to a specific part of the complete idea of the STP. What the author explicitly wants to bring forward in this research is:

i) The theoretical side to demonstrate how theoretical knowledge relating to sustainability transitions could be translated to visualizations in digital platforms and how the theory could be further developed within it.

ii) The technical side of platform development for research, meaning that through hands-on experimentation the platform template will be built with software.

iii) The practical side showing how the actual implementation of a case in the platform would take place, in other words, how a researcher would experience the interaction with inputting data in the platform and conducting an analysis based on the outputs generated by the platform.

Thus, from a platform theory perspective the template would primarily be presented as a product making it resemble more an innovation platform. Even though in this research the interface for knowledge producers and knowledge users will be demonstrated, it can not yet be qualified as a transactions platform since the community building through network effects and transactions opportunities between them, which make it a triangular business model, will not be tested or further analysed (Gawer, 2014, 2016). This should be taken into consideration for future research and in the next steps of development of the STP.

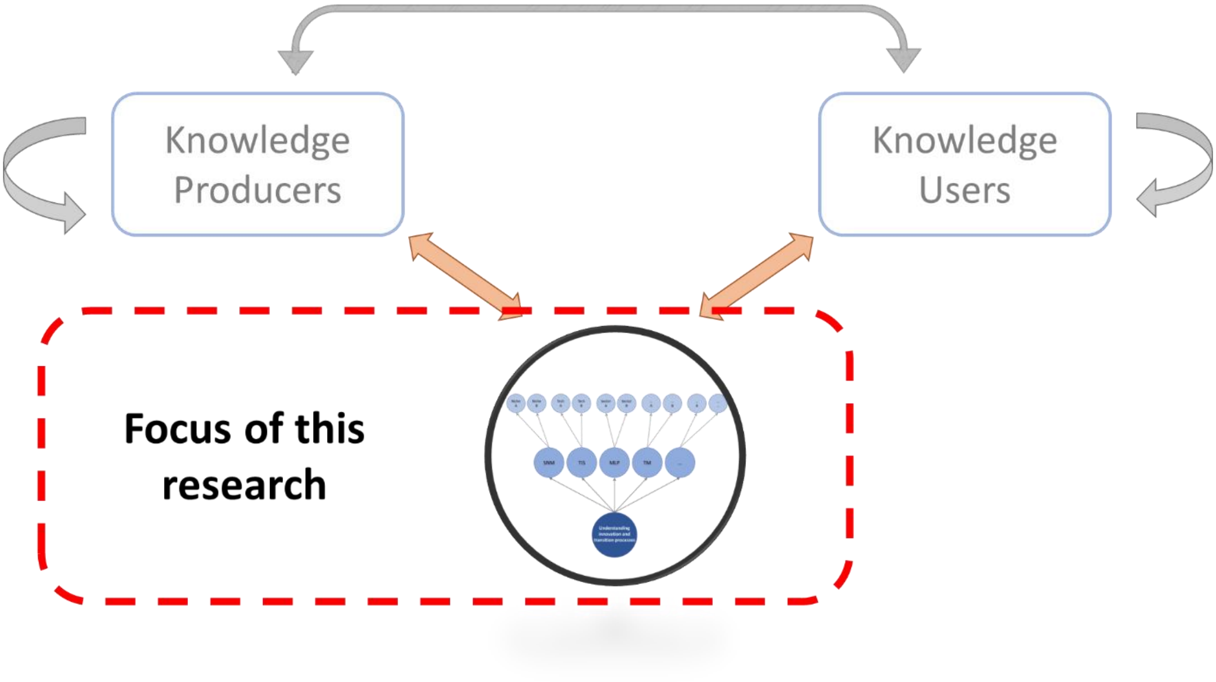

Figure 23 - Visualization of the focus of this research. A platform template will be built for this research that will serve as a guiding tool to look at the engineering design perspective of this research. It will work as a sample to show how theory implementation and innovation of it happens on the platform.

From the technical perspective a platform will be built using the web technologies (software) HTML, CSS and JavaScript that will allow the creation of an interface for data inputs and generating outputs that are relevant for sustainability transitions theory. The platform will have different functionalities that help users understand the theory and interact with the data. The functionalities that could be present in the outputs can be numerous, which is why the template has been limited to some specific ones. The outputs of this template are aligned with the core of sustainability transitions research and are based on the available visualizations from existing studies. In this case, these will be visualizations from studies that apply the MLP & TIS frameworks, which are commonly used frameworks in the research field as has been explained in Section 3.4. The template is also narrowed down to the case study of this research: Offshore Wind Energy Technology in Brazil. As mentioned in Chapter 3, there are multiple topics that fall within sustainability transitions research, such as, energy, transport, water and food (Markard, 2020). In principle, every case applied to any of the different topics should apply the core of sustainability transitions research and its frameworks, yet the inputs and outputs might differ to a certain extent. Even within a single topic there might also be differences in inputs and outputs depending on the central point of research, e.g. between different technologies. Nevertheless, the ultimate goal for the platform is that it should allow all cases to be applicable. This template is intentionally built as a first example of what the platform could look like and the digital aspects of it should allow for adaptations and improvements were needed. So, for this research the assumption is made that the platform design, inputs and outputs are the same for all the different technologies of sustainability transitions research. Meaning that this template built for an offshore wind case would also be applicable for a solar PV or Oil & Gas case, albeit some differences are in place in reality. The differences and how the platform should be updated conformably are topics for future research.

For the remainder of this section the platform template interface will be demonstrated, as knowledge producers and knowledge users would perceive it, and the scope for the template and this research will be defined. In Section 4.3 the implementation of the theory in the platform will be further explained and this will be demonstrated through a case in Chapter 5.

4.2.1 Interface

There are two different interface to be distinguished in the platform template. One interface is for the knowledge users and the other is for the knowledge producers.

Knowledge user is anyone who is interested in the information related to sustainability transitions. In the platform template the user has to be able to easily **extract** information on a desired technology-country combination (e.g. Offshore wind – Brazil). To achieve this two steps should be taken by the user, namely i) select a technology and ii) select a country. Additionally, the user has the option to select a specific year to be analysed.
Once selection is made the relevant TIS & MLP information should appear on the device screen as outputs. After the users receive the information they should also be able to focus on specific parts of the information to better understand the logic behind it (e.g. by selecting a specific TIS function score the platform should show which indicators were used).

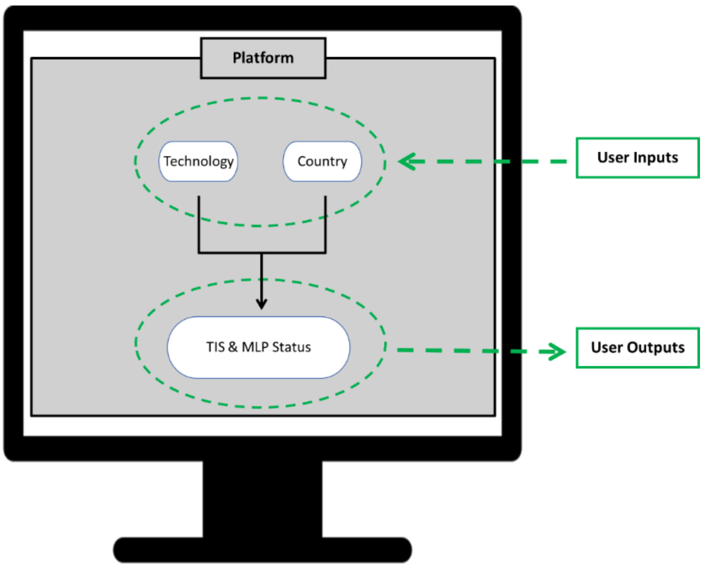

Figure 24 – Platform template logic for knowledge users.

To give an impression of the platform template, two snapshots have been included next. The first shows the input side for the knowledge user (Figure 25), the second shows the outputs (Figure 26).

Knowledge User Inputs:

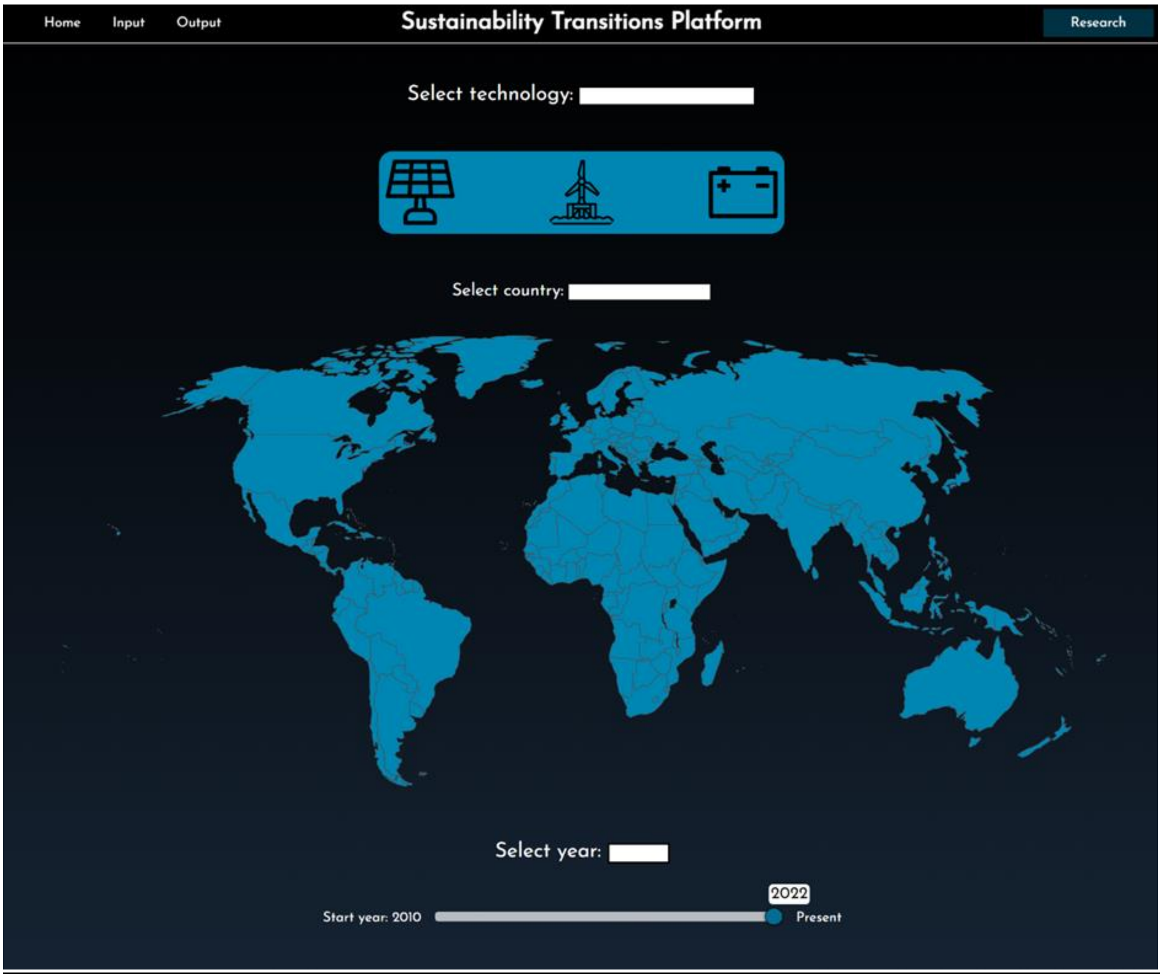

Figure 25 – Snapshot of the input side of the platform template for knowledge users.

Knowledge User Outputs:

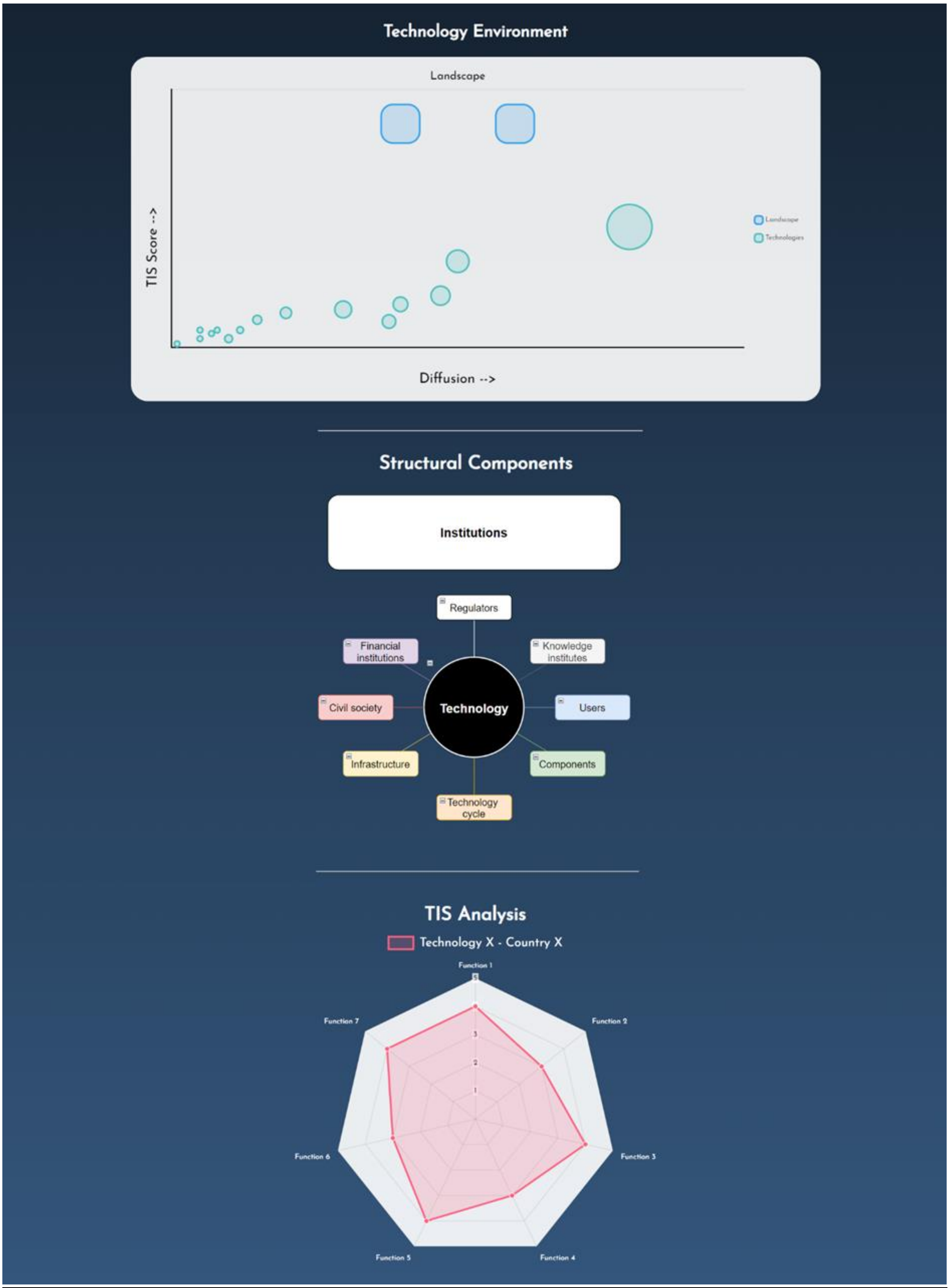

Figure 26 – Snapshot of the outputs of the platform template for the knowledge users.

Knowledge producer is anyone conducting sustainability transitions research. In the platform template the knowledge producer has to be able to easily **insert** information on the desired technology-country combination (e.g. Offshore wind – Brazil).
The input data for the platform template comes in the form of chains of information. This data is linked in the platform based primarily on two questions: i) what is the event? and ii) who are the actors? If the actors cannot specifically be defined the information will be related to a landscape event.

<u>Examples</u>

Information 1: Government entity X opens new tender that allows technology Y to be developed in a specific zone.

Event (what?): new tender that allows technology Y to be developed in a specific zone.
Actors (who?): Government entity X

Information 2: Company X hands in environmental assessment documents for development of technology Y in specified zone to Government entity Z.

Event (what?): hands in environmental assessment documents for development of technology Y in specified zone
Actors (who?): Company X, Government entity Z

Information 3: Environmentalist group X says that development of technology Y in specified zone is problematic for the environment.

Event (what?): development of technology Y in specified zone is problematic for the environment
Actors (who?): Environmentalist group X

Information 4: User X signs offtake agreement for technology Y with Company Z.

Event (what?): signs offtake agreement for technology Y
Actors (who?): User X, Company Z

Information 5: Financial institution X invests in technology Y project of Company Z.

Event (what?): invests in technology Y project
Actors (who?): Financial institution X, Company Z

Information 6: Research institute X publishes paper about technology Y.

Event (what?): publishes paper about technology Y
Actors (who?): Research institute X

Information 6: Global pandemic caused by Covid-19 virus.

Event (what?): Global pandemic caused by Covid-19 virus
Actors (who?): - (Landscape event)

Each event is also linked to a single date or a start and end date because the order of events is also relevant to understand the innovation process. This is important because one event can trigger another and switching around the order can give a false interpretation of the process.

For the platform template the data is being gathered in an EXCEL file which could be converted into a CSV or JSON file that can directly be imported into the platform. Eventually the inputs should be made inside the platform, however designing a complete interactive input page goes beyond the goal of this thesis. The image below gives a very simple representation of what the researcher side would look like. It is a table where researchers can input and filter on data. In the actual platform a more appealing interface would of course be required.

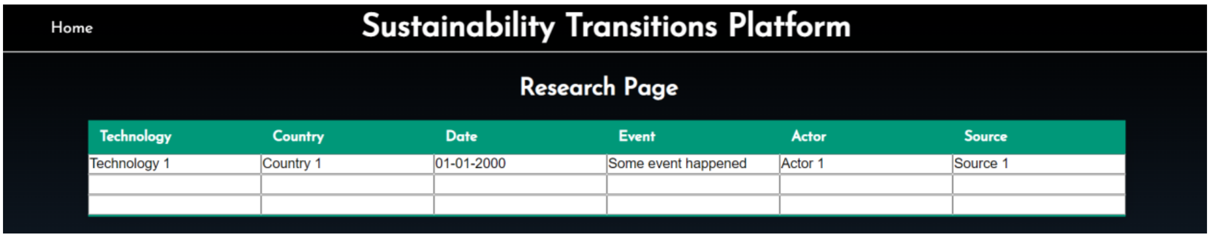

Figure 27 – Platform snapshot of basic researcher input interface

It is important to realize that in the early stages of the platform all knowledge producers are also knowledge users but not all knowledge users are knowledge producers. Reason being that the used frameworks and their functions and indicators are still a work in progress within research itself, hence it would make it very difficult to converge them if anyone can add data without the necessary theoretical background. In a later stage, when transition research frameworks and indicators are more converged and well defined, the intention is that also more knowledge users have the option to become knowledge producers in the platform. This would be beneficial for keeping data in the research up to date. For example, if a study was conducted on offshore wind in the Netherlands in 2021 and if in 2022 a new event happens related to this technology-country combination (e.g. a new regulation or new target for the technology) this should be able to be entered by anyone, preferably someone close to the source of the information, and not depend on the one person who did the initial 2021 study. Of course a system has to be developed that not any random information can be added, removed or edited. There has to be some kind of control to confirm these changes are correct. Being able to transform all knowledge users to knowledge producers can be a big step towards bringing together research and practice and will be further discussed in Chapter 6.

4.2.2 Scope

There are many research areas in which sustainability transitions studies are being applied. Part of transition studies is understanding that all the areas are probably connected in some way. Take for example energy and transport: transportation needs fuel that comes in a form of energy such as electrical energy for electric vehicles or chemical energy (in the form of kerosene) for airplanes. At the same time, the energy sector needs transportation in order to transport components to build new energy power plants. These are only two of many linkages that show the dependency between sectors. Although we know these linkages exist, mapping and connecting all of them between all sectors and determining what influences a transition still remains an immense task.

In transition studies often a research is bounded to a specific area, of which the most common ones are energy, transport, water and food (Markard, 2020). In some cases this area is even narrowed down further in technology-centred research where the goal is to understand the differences in diffusion of technologies of a specific research area. For example by looking at the diffusion of fuel cell technology for cars which are only part of the whole transportation sector. The diffusion of this technology can be compared more easily with other car technologies, such as combustion engines or EV's but it is a lot harder to compare its diffusion with other transportation methods, like bicycles or airplanes. To understand and measure the diffusion of a technology a reference frame or scope has to be set.

This research is technology centred since one technology, offshore wind, is the focus of the research. Nevertheless, in order to understand if this technology will diffuse in a specific country it is important to place the technology in context and compare it with other technologies of this country. In this case offshore wind, an electricity generating technology, will be compared with other electricity generating technologies, hence the scope will be electricity generating technologies. The other technologies will then be part of the output, but they will not be analysed as in depth as offshore wind will. This is because each technology can be done as a separate case and doing all these cases would require a lot more time than available during an MSc. thesis, hence, the 'data' for the other technologies will be assumed in a reasonable way. And if at some point the case studies for these other technologies are actually done, these cases could be inputted in the platform so that they are linked to each other to form the complete picture of the electricity generating technologies in a country or even the whole energy sector.

The following example will try to explain how the electricity scope sits inside the energy sector more precisely:

> In general a country has its own energy sector which is composed of different forms of energy, such as electrical-, thermal- and chemical energy. Each form of energy can have a different use, like the use of electrical energy to power up home appliances, thermal energy to heat up buildings, and chemical energy as fuel for cars. The total share each form of energy has can differ between countries, where for example a very cold country might be more reliant on thermal energy for heating up homes and buildings with radiators while a very warm country might be more reliant on electrical energy to cool down homes and buildings with air-conditioners. Each of these forms of energy can be generated from multiple different sources, meaning that there are different types of technologies that could generate a specific form of energy. Offshore wind energy technology is a technology that generates electrical energy from wind at sea. It takes the kinetic energy available in wind and converts it into a rotational motion which allows for electricity generation at the generator. Hence, offshore wind is a source for electrical energy generation which can be used to supply (part of) a country's energy demand. Other known technologies for electricity generation are for example PV, hydropower, onshore wind, nuclear, tidal and fuel fired power plants from coal, oil, biomass and gas. It is important to note that some of these sources are used for multiple forms of energy. Take gas for example: a gas fired power plant uses gas as its fuel to heat up water and create steam to rotate a steam turbine which generates electricity, it transform chemical energy to thermal energy and eventually to electrical energy. At the same time gas is also used in home boilers to heat up water which can then be used for showers or to run through radiators in order to disperse the heat inside a building, so it transforms chemical energy to thermal energy. Gas fuelled technology can in these cases serve both for thermal as for electrical energy and this is one of the reasons why defining a scope for transition research is of relevance. Suppose a country has a specific energy demand of 50% thermal energy and 50% electrical energy. If no electrical energy is produced with gas but all of the thermal energy is, gas has a 50% share in the energy sector scope, however it has 0% in the electrical energy scope and 100% in the thermal energy scope. If the country shifts its energy consumption to 1% thermal energy and 99% electrical energy, gas can still have the 100% share in the thermal energy scope, however this only counts for 1% of the energy scope. Understanding the scope of research is important in transition studies especially if diffusion of technologies is being analysed. Because if we would be looking at the transition of the energy sector in a country of which 1% is demanded from thermal energy and a single technology covers that whole demand, has the technology diffused in the thermal energy scope? It would seem so, since it is the only technology and covers the demand 100%. But from the energy sector scope, has it diffused if it only accounts for 1% of the total energy sector? Defining the scope is important as the whole picture of transitions is very dynamic. Sectors are often linked and determining if a specific technology is diffusing depends on what it is being compared to, or in other words, what the scope is. In this example the scope is merely divided between energy and electricity, however the scope can be adjusted in many more ways. Looking back at offshore wind energy technology, which can reside both in the energy or electricity scope, it can also be regarded within the renewable energy scope: what is the demand for renewable energies and how does the technology compare to other renewable energy technologies? Or even the wind energy scope: how does it compare to onshore, airborne or floating wind energy technologies?

As explained at the beginning of Section 4.2, the assumption has been made that all technologies being analysed in sustainability transitions research are built based on the same types of elements. These elements should thus be constructed as general as possible in the platform to be applicable to all technologies. At the same time this first draft of the platform has been designed to be tested on the Brazilian offshore wind case. Which is why specific terms and concepts from offshore wind TISs can be present in the platform design and why this research will be limited to the electricity generation scope of Brazil as this should generate sufficient information for a platform template that helps understand the environment in which the technology resides.

Indeed, other technologies within the whole energy sector (e.g. batteries and hydrogen) or technologies of other sectors can also have an influence on the development of offshore wind, however, analysing and taking all of them into account would go beyond the requirements of an MSc. thesis and beyond the purpose of this research to build a platform template. Nevertheless, once a fully developed platform exists, adding the data relating to these other technologies should be possible and a feature to allow selection of different and multiple scopes should also be available since this allows for comparison from multiple perspectives and gives an even broader understanding of the complete environment.

4.3 TIS & MLP Elements for Platform Template

Looking at the knowledge user side of the platform, we have seen that the input for the users is rather straightforward. A user only has to select the technology and country for which he wants the information. The output, on the other hand, requires more theoretical background to be understood. The output of the platform is divided in three parts. These are: i) technology environment, which is primarily based on the MLP framework and strengthens the TIS framework; ii) structural components, which is a part of the TIS framework and can also partly be found in the MLP framework; iii) TIS analysis, from the TIS framework.

These three parts have been constructed in the platform template based on the theory discussed in Chapter 3 and used a set of existing papers that also implement this theory and have similarities to the case being implemented in this research as guidance. The case of this research has three main characteristics:

i) Technology: Offshore Wind
ii) Country: Brazil
iii) Theory: Combined MLP & TIS Framework

The set of papers that were used were chosen through a search in the search engine Scopus. Firstly, a search was done that combined all three of these characteristics (Offshore wind + Brazil + MLP & TIS), however no applicable papers were found. Secondly, a search was done that combined two characteristics (Offshore wind + MLP & TIS; Brazil + MLP & TIS), of which two papers were found that had a case that used the combined MLP & TIS framework and had Brazil as the country of research. Thirdly, a search was done in which offshore wind was used as the case technology and that either the MLP or the TIS frameworks were implemented. This last search produced 32 hits in Scopus, and after filtering these studies to only the ones that contained explicit information about actors, networks, institutions, functions and indicators, 11 remained which were selected to be further analysed. So, in total 13 different papers were used as a guidance to build the platform template. These studies can be seen in the following table.

Table 3 – Papers analysed and used as guidance for creation of the TIS & MLP elements in the platform template.

#	Title	Authors	Year	Characteristics
1	Technological learning in offshore wind energy: Different roles of the government	Smit T., Junginger M., Smits R.	2007	Offshore Wind
2	A Systemic Assessment of the European Offshore Wind Innovation	Luo, L., Lacal-Arantegui, R., Wieczorek, A. J., Negro, S. O., Harmsen, R., Heimeriks, G. J., & Hekkert, M.P.	2012	Offshore Wind
3	A review of the European offshore wind innovation system	Wieczorek A.J., Negro S.O., Harmsen R., Heimeriks G.J., Luo L., Hekkert M.P.	2013	Offshore Wind
4	Mechanisms blocking the dynamics of the European offshore wind energy innovation system - Challenges for policy intervention	Jacobsson S., Karltorp K.	2013	Offshore Wind
5	Broadening the national focus in technological innovation system analysis: The case of offshore wind	Wieczorek A.J., Hekkert M.P., Coenen L., Harmsen R.	2015	Offshore Wind
6	Analyzing interdependencies between policy mixes and technological innovation systems: The case of offshore wind in Germany	Reichardt K., Negro S.O., Rogge K.S., Hekkert M.P.	2016	Offshore Wind
7	Unpacking policy processes for addressing systemic problems in technological innovation systems: The case of offshore wind in Germany	Reichardt K., Rogge K.S., Negro S.O.	2017	Offshore Wind
8	Established sectors expediting clean technology industries? The Norwegian oil and gas sector's influence on offshore wind power	Mäkitie T., Andersen A.D., Hanson J., Normann H.E., Thune T.M.	2018	Offshore Wind
9	Challenges and opportunities for the growth of solar photovoltaic energy in Brazil	dos Santos Carstens, D. D., & da Cunha, S. K.	2019	Combined Framework + Brazil
10	Emergence of floating offshore wind energy: Technology and industry	Bento N., Fontes M.	2019	Offshore Wind
11	Technological innovation system analysis in a follower country – The case of offshore wind in Poland	Sawulski J., Gałczyński M., Zajdler R.	2019	Offshore Wind
12	Validating the "seven functions" model of technological innovations systems theory with industry stakeholders—a review from UK offshore renewables	Aldersey-Williams J., Strachan P.A., Broadbent I.D.	2020	Offshore Wind
13	A comparative study of biodiesel in Brazil and Argentina: An integrated systems of innovation perspective	Nikas, A., Koasidis, K., Köberle, A. C., Kourtesi, G., & Doukas, H.	2022	Combined Framework + Brazil

This set of papers (Aldersey-Williams et al., 2020; Bento & Fontes, 2019; Carstens & Cunha, 2019; Jacobsson & Karltorp, 2013; Luo et al., 2012; Mäkitie et al., 2018; Nikas et al., 2022; Reichardt et al., 2016, 2017; Sawulski et al., 2019; Smit et al., 2007; Wieczorek et al., 2013, 2015) together gives a varied mix of ways in which TIS and MLP elements have been used in studies. Although the majority of the papers relates to offshore wind and not other technologies, the assumption was made for this research that the elements encountered for all technologies would be similar, as was discussed in Section 4.2. Furthermore, the two papers that implement the combined framework and were included in the analysis process did use other technologies as case, namely solar PV and biodiesel. This helps to broaden the perspective towards the elements but is not the main goal of this research and could be studied in the future. The three different parts of the platform template, *Technology Environment*, *Structural Components* and *TIS Functions Analysis,* each contain different parts of the TIS & MLP elements and will be discussed individually next.

4.3.1 Technology Environment

The technology environment part is based on the MLP framework from Geels (2002) (see Section 3.2) and uses a part of the TIS framework (see Section 3.3.4) as an input. The MLP framework describes a technological transition through three levels, namely, the landscape (macro-level), the regime (meso-level) and the niches (micro-level) and places them on a timescale where the technology goes through the emergence, diffusion and reconfiguration phases. There is an interplay between the three levels, where the regime is the focal level of the framework and can be influenced by landscape pressures allowing opportunities for niches to emerge, diffuse and even become the new regime. The framework itself is often depicted through an image showing these levels (see Figure 3). However, visual interpretation of how the technology being studied fits in its environment and in the framework image is hard to encounter in literature, while this could be a very useful, clear and compact way of presenting the information. Besides, building the framework in the platform allows for dynamic interaction which can also show interesting information that cannot easily be interpreted on paper.
The image below is a representation of how the original framework from Geels (2002) could look in a platform that portrays the framework's hypothetical trajectory of changes between the three levels (x-axis) over time (y-axis). In other words, over time things can happen in the landscape which

influence and destabilize the current regime, this opens opportunities for niches to develop, diffuse and maybe even become the new regime.

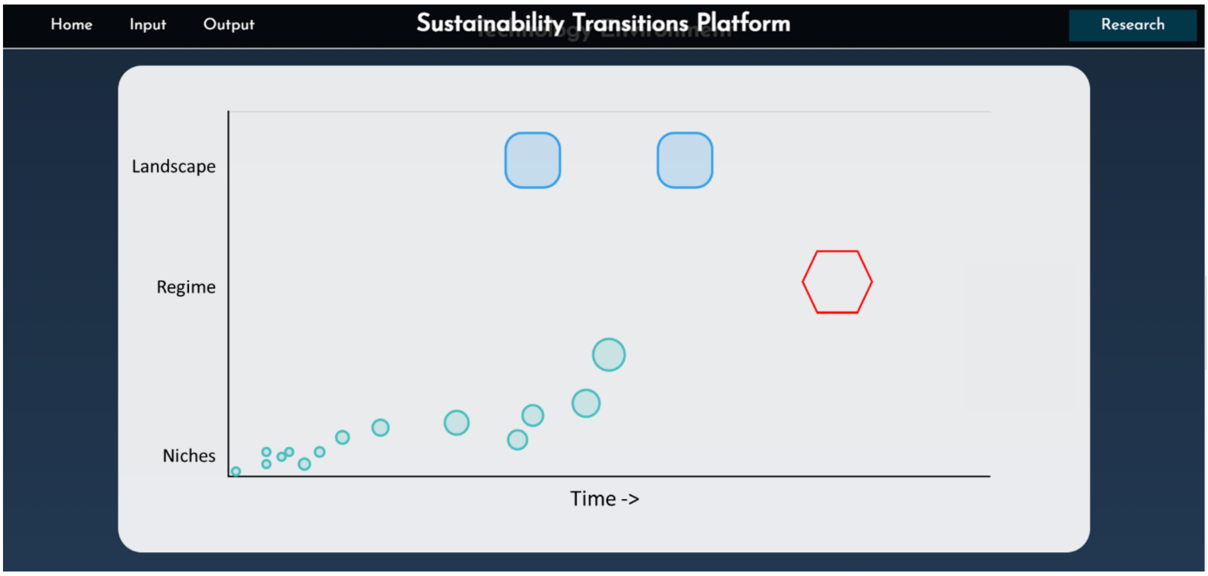

Figure 28 – Example of how the MLP framework would look in the platform template if directly copied from theory as presented in Geels (Geels, 2002).

There are a couple of adaptations that have to be made to this graph in the platform template in order to make it applicable for the purpose of this thesis. Specifically, these adaptations will be made to the *x-axis*, *y-axis* and the *graph area* and will be explained and visualized next:

X-axis: **Time** will be decoupled from graph and **diffusion** will be placed on the x-axis.

- **Time:** instead of having a complete timescale on the axis showing the hypothetical time trajectory of the technology environment, one single point in time will be displayed on the graph that shows what the current status is of the technology environment. This helps to make the user understand which technology forms the regime, which other technologies/niches are present and what landscape factors are influencing these technologies at this moment. The transformation over time is of course still very relevant. As can be seen in both papers that used the combined TIS & MLP frameworks (Carstens & Cunha, 2019; Nikas et al., 2022), the cases are portrayed over time through analysis of historic events. Nikas et al. (2022) present their results in a graph with multiple tables where the events are divided over three time periods, while dos Santos Carstens & da Cunha (2019) presents the events as a sequence in time written in text separate for each part of the analysis. By taking advantage of the dynamic aspects of the platform, time can be decoupled from the graph (not removed), meaning that a separate button is made that allows the user to select the specific year or period that the user wishes to analyse. This keeps the historic structure of analysis in place as could be seen in the papers and helps the user, for example, to see how long the dominant technology has been the regime or how long it took for it to go from niche to regime. Or from a landscape perspective, if the country is suffering from a crisis, how long has that been taking place?

- **Diffusion:** since the timescale will not be used on the x-axis, it becomes possible to insert another scale which can quantify the technologies based on their position on the graph, which in this case will be their diffusion. Diffusion can be measured differently depending on the type of technology or sector and is not always a simple quantifiable value. In this case, where an electricity generating technology is being studied, the diffusion will be measured based on the total installed electricity capacity of a country. The bigger the share of a technology is of the total installation the more diffused it is and the smaller the share the less diffused. Completely diffused technologies are at the right-hand side of the graph where 100% share of the installed capacity is the maximum and would indicate that a single technology covers all installed capacity, while emerging or phased-out technologies cover 0% share and are at the left-hand side of the graph. Using total installed capacity as the diffusion scale allows the users to see how the technology being studied compares to other technologies in the field.

Y-axis: **TIS score** will be used on y-axis, **landscape** will be decoupled into own segment, **regime and niches** will take internal graph positions.

- **TIS score:** as described in the TIS framework theory (see Section 3.3.4), the fulfilment of functions can determine if the technology will diffuse fast/easily. The more fulfilled the functions the faster the technology will probably diffuse. Knowing the function fulfilment is interesting for two reasons, namely, i) in theory it says something about which technologies will probably diffuse the most in the coming years and ii) it tells which technological systems require improvements and in which parts. The TIS score will be the average of the function scores ranging from 1 (absent) to 5 (excellent). High TIS scores mean that on average the functions are being fulfilled and the technology is placed on the top side of the graph, while low scores come from unfulfilled functions and show the technology at the bottom of the graph. A fundamental statement of the TIS literature is that all functions must be fulfilled in order to have an easy and fast diffusion of the technology (Aldersey-Williams et al., 2020; Hekkert et al., 2007). Averaging the function scores as a single score fades this notion away since the score does not explicitly tell if a single function is unfulfilled. Yet, this average score still gives an initial indication of how well the functions are doing on average and can be further examined in the TIS analysis section of the platform.
  Another point that requires attention regarding the TIS Score particularly in this research, is that only the TIS of offshore wind in Brazil will be fully analysed (see a more detailed explanation for this choice in Section 4.2.2). This means that, although other electricity generation technologies are included in the technology environment part of the platform template, their TIS Scores have not accurately been determined through the functional analysis steps of the TIS but rather been estimated based on how the installation capacity increases or decreases. Here the assumption is that: the higher the installation of new capacity is, the higher the TIS score is. So, in the technology environment part of the platform template multiple technologies will be present but for this research only the TIS Score of offshore wind will have been determined through the TIS functional analysis. Ideally the TIS functional analysis will also be applied to the other technologies through the platform in future research, to give a more complete representation of the case.
  The TIS score and functions will be explained in more detail in Section 4.3.3 of this chapter.

- **Landscape:** in the platform the landscape will be regarded as external factors that influence both the regime and niche technologies. These could for example be economic, environmental or geopolitical crisis, but also cultural factors (see more on this in Section 3.2). Since there are different types of landscape factors of which some influence all and others influence some of the relevant technologies the landscape can better be regarded as an independent block. This separation of the landscape can also be seen in the paper of Nikas et al. (2022) which uses the combined MLP & TIS framework.

- **Regime and niches:** These two layers of the MLP framework will be placed within the graph as reference points for the combination of TIS score (y-axis) and diffusion (x-axis). As previously mentioned, the TIS score will reflect how well the functions of a system are being fulfilled and these functions represent essential parts of socio-technical systems. The more these functions are fulfilled the more this socio-technical system has regime characteristics. In the platform this translates as follows: technologies that are in the lower-left corner (low TIS score and low diffusion) have niche characteristics and technologies on the top-right corner (high TIS score and high diffusion) have more regime-like characteristics. Although sustainability transitions scholars are still discussing how exactly the TIS and MLP frameworks fit between each other there is a consensus that the TIS resides somewhere between niches and regime of the MLP framework (Aldersey-Williams et al., 2020; Hekkert et al., 2007). By placing the niche and regime in the graph and associating it with a TIS score allows for visual interpretation of this thought.

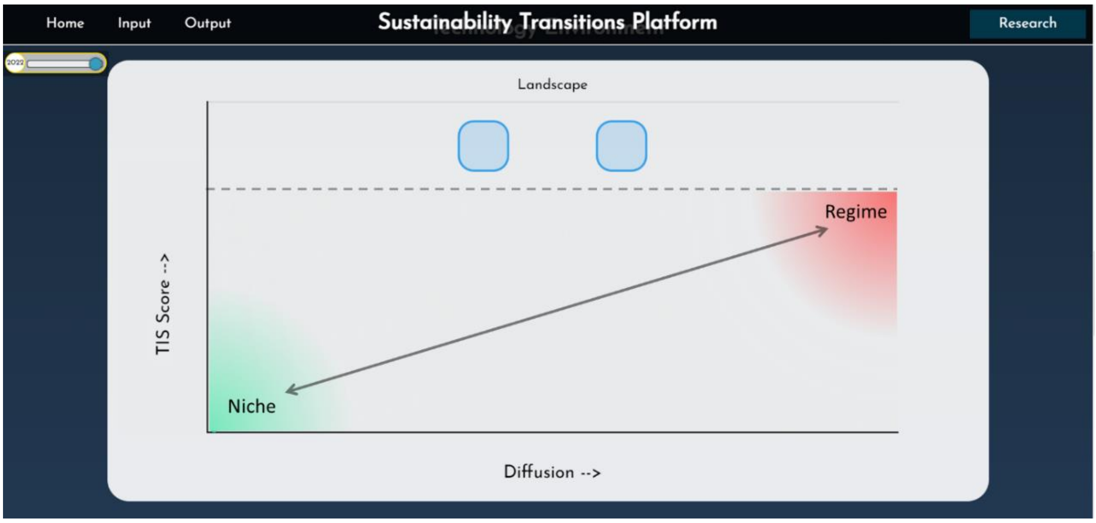

Figure 29 – Technology environment from Geels (2002) *with adaptations for platform to present status at a specific moment in time with an option to change the time (slider button on top left of screen). TIS score and diffusion on axes to represent technologies within the MLP framework.*

Graph area: Inside the graph area the relevant technologies will be placed according to their TIS scores and diffusion. Besides these two there are more parameters that could be of relevance for users when comparing technologies within the same environment or even between different environments. For this template two other parameters were added which become visible when hovering over the technology. These are the installed capacity in MW and the levelized cost of electricity (LCOE) in $/MWh.

- The installed capacity is indeed related to the diffusion (share of total installed capacity) yet this value has more meaning when comparing technologies between different countries. A technology might have an 80% share in installed capacity in one country and 20% in another, but they could both have the same absolute value. This could be interesting for research that compares between countries.
- The LCOE is a measure to determine the cost-effectiveness of a technology and allows for price comparison between different technologies over their lifetime at a specific location (Raikar & Adamson, 2020).

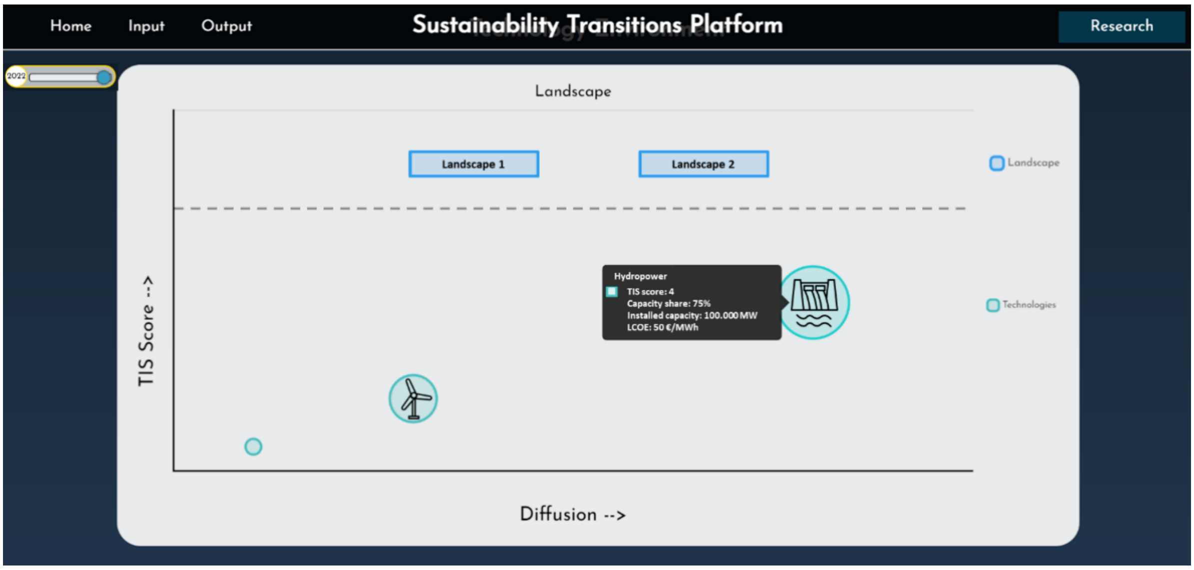

Figure 30 – Platform snapshot showing visual representation of the Technology Environment with example of the dynamic options of platform to make information appear if necessary.

These parameters have been added to the platform template (as can be seen in Figure 1) because they hold information that is deemed relevant for technology development in comparison with other technologies. Keeping in mind that the platform gives this flexibility to let researchers choose what data they believe is relevant and wish to add. For other cases even other or more parameters could be added as long as the data is available and inputted. Another essential advantage of the complete platform is that any data that has been added should be clickable and trace the user directly back to the source of the data. This also allows users to validate, change or compare datasets if required.

4.3.2 Structural Components

The structural components form the pillars of the technology and are present in both the MLP and TIS frameworks. In the MLP they are portrayed as the multi-actor network involved in sociotechnical regimes where the regime is the set of rules around the technology. In the TIS they are described as *actors, networks & institutions* where the institutions are the set of rules. Different visual representation of parts of the actor, network and institutions are shown in literature. Geels (2002) presented the actor-network as can be seen in Figure 4 and below is an example of how the actors and networks were presented in Sawulski et al. (2019) (the institutions were presented in text).

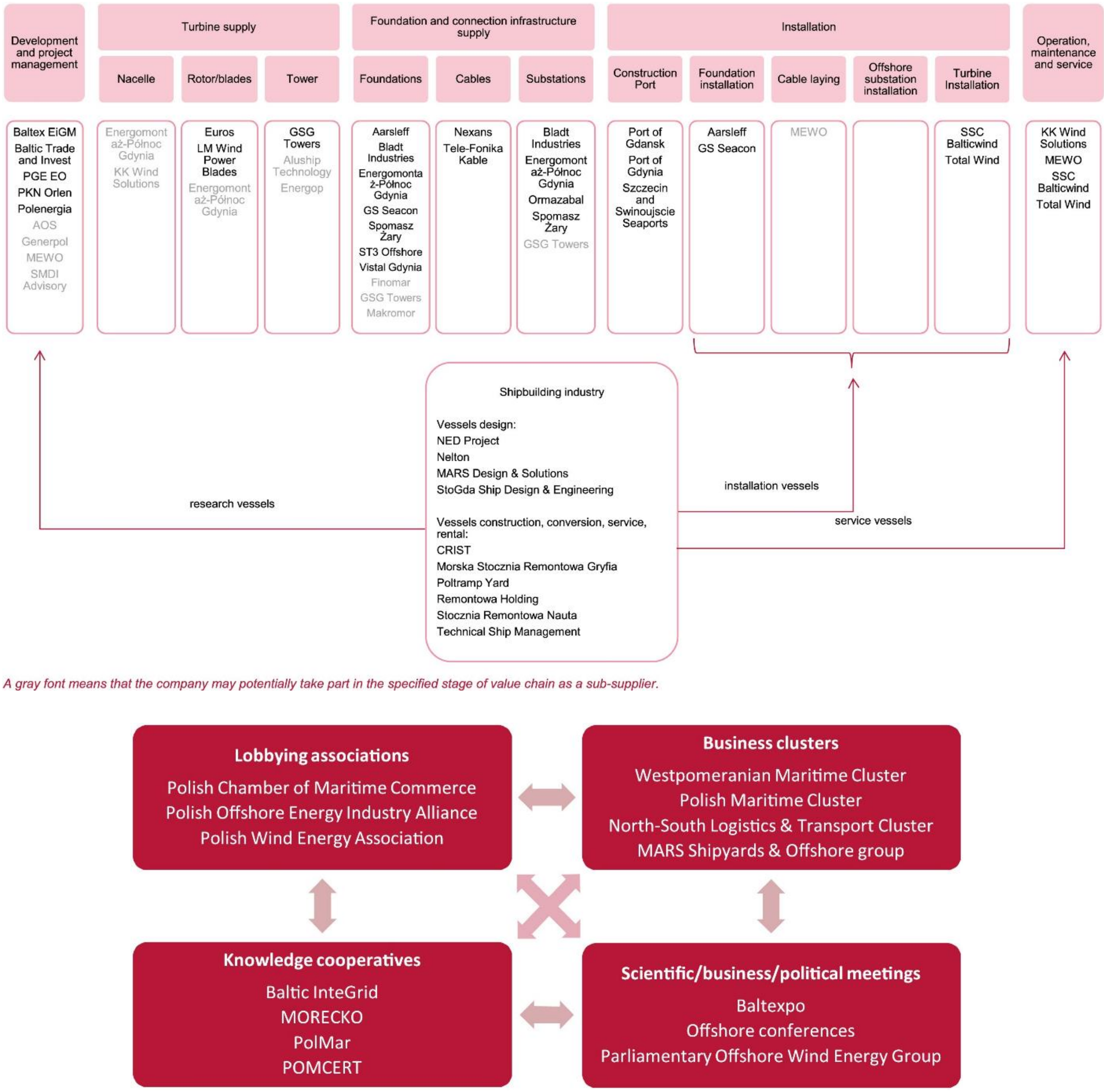

Figure 31 – Actors and networks as presented by Sawulski et al. (Sawulski et al., 2019) *for offshore wind in Poland.*

In the platform template the structural components will also be included. The author's intention is to present the actors, networks and institutions in the platform in a visually clear way. Meaning that any user that inputs a specific technology-country combination should see the corresponding actors, networks and institutions in a clear and structured way in the output. Making a table or a list with all the actors and networks would not make the outputs visually clear, since many actors can be involved in the technological system. This would generate a very extensive list or an overwhelming table. It can sometimes, for example, make it very difficult for the user to understand what different types of actors are involved and how they are clustered. That is why for the platform template it was opted to combine both the design for multi-actor network (Figure 4) and that of the socio-technical system (Figure 1) from Geels (2002) into a single output that could clearly represent this for the users visually. How this combined output looks like in the platform will be presented in the following sections for each part individually, which in this case are the actors, networks and institutions.

4.3.2.1 Actors

There is reason to structure the way actors are included in transition studies if we want to say something about the completeness of the system. This can be important in cases where a single

technology in one region is evaluated at different points in time, or a single technology is compared for different regions or different technologies are compared in the same region. In all these cases mapping all the actors tells much about the system itself and the differences compared to others.
The actor presentation differed between the studies that were analysed (see Table 3). In many cases the actors were plainly found in text, in other cases they could be found in a table and in few occasions they were found in a graph with actor division.

Table 2. Important actors involved in the TSIS for offshore wind energy, with their nation of origin in brackets (DK=Denmark, NL=The Netherlands, DE=Germany, GR=Greece, UK=United Kingdom, CA=Canada, US=United States)

	Knowledge institutes	**Turbine manufacturers**	**Project operators**	**Component suppliers**
Denmark	Risø (DK)	Bonus (DK)	Elsam (DK)	Big role for Wind Power Hub (DK)[a]
		Vestas (DK)	Energi E2 (DK)	
United Kingdom	a.o.[b]	Vestas (DK)	Shell (UK/NL)	a.o.
	Risø (DK)	Repower (DE)	Npower (UK)	Wind Power Hub (DK)
	ECN (NL)		E.ON (DE)	KBR (US)
	ISET (DE)		Centrica (UK)	MPI (UK)
	CRES (GR)		Dong (DK)	
			Talisman (CA)	

Figure 32 - Example of actors in a table for offshore wind energy TIS (Smit et al., 2007).

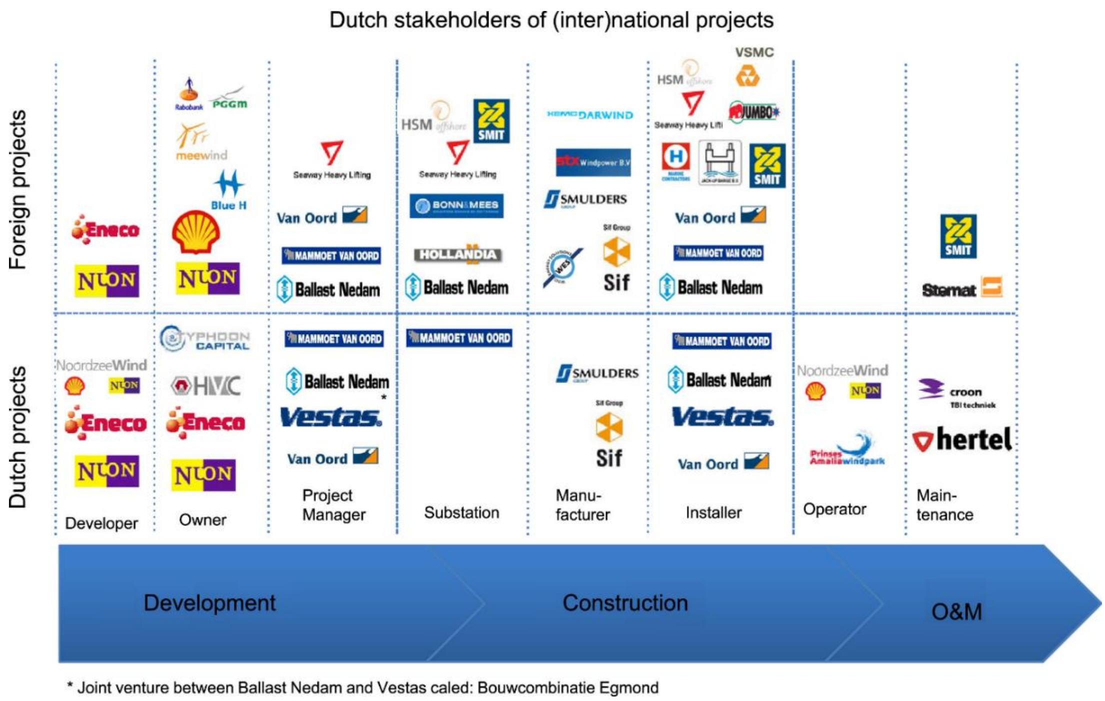

Figure 33 - Example of actors in a graph for offshore wind energy TIS (Wieczorek et al., 2013).

Besides the way in which the actors are presented, there is also unclarity in actor selection for the cases. Sometimes actors appear to be selected on importance but it remains unclear why one actor is important and the other is not. In other cases only specific actor groups are shown, such as technology developers and supply chain, while little is mentioned about actors in other groups such as knowledge institutes or infrastructure. This could suggest that some cases are incomplete or that some studies are too detailed. In the author's view, a more detailed analysis is preferred over an incomplete analysis as this gives a more precise view of the system and in the case it is too detailed the surplus information could always be filtered out afterwards.

To prevent the selective choice of actors, in the platform template the actors will be split into predefined divisions. Where, for example, an actor that regulates the technology will be placed in the regulators division, or an actor that uses the technology will be placed in the users division and so on. The thought being that in order for a technology to diffuse all actors should be in place regardless of the country or region being studied. The actors from all regions combined form the pool of the global innovation system of the technology. It is expected that there might be some differences between types of actors in different regions or for different technologies but for this research it will be limited to using the same division for the actors as it is expected that most regions will require the same types of actors in the socio-technical system and it is for now assumed that for different technologies these divisions are also the same. For technologies that serve a similar purpose (e.g. generating electricity) the actor divisions will probably be very similar, the differences might increase when looking at a broader perspective or between technologies of different sectors. Nevertheless, in this research only electricity generating technologies will be taken into account and it is assumed that their actor divisions are the same. This assumption is strengthened by considering that a big chunk of the actors overlap between these electricity generating technologies in a specific region. This actor overlap between different technologies was also pointed out in the research by Mäkitie et al. (2018) between Offshore wind and Oil & Gas in Norway.

To clarify the actor division a layered construction has been made in the platform template which can be seen in Figure 34.

Layer 1 – The main actors division for any electricity generating technology.

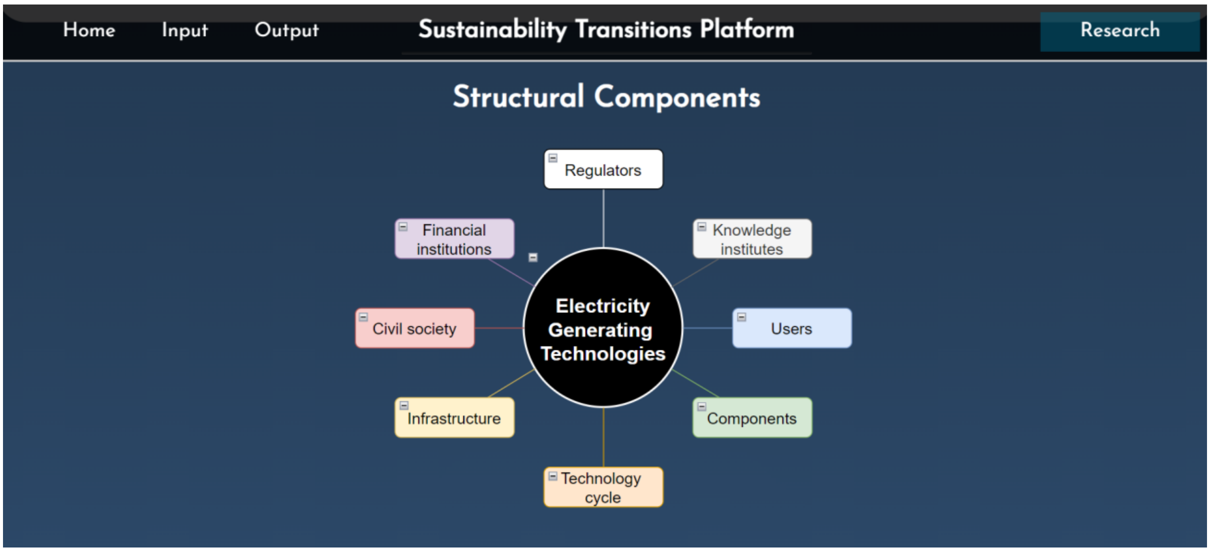

Figure 34 – Platform snapshot of the layer 1 actors division for electricity generating technologies.

As previously mentioned, in the platform it is assumed that all technologies that generate electricity encounter the same actor groups, which in this case are:

- Regulators: Actors that impose and control the rules
- Knowledge institutes: Actors that generate and pass on knowledge
- Users: Actors that use the technology
- Components: Actors that make/deliver technology components
- Technology cycle: Actors that implement and operate the technology
- Infrastructure: Actors that facilitate the infrastructure to implement the technology
- Civil society: Actors from society that influence or are influenced by the technology implementation
- Financial institutions: Actors involved in financial aspect of the technology

It may even be possible that this holds for all energy technologies or even technologies of other sectors however this has not been further investigated in this research and could be of interest for further research.
These presented actor layers can be divided into smaller actor groups or divisions (layer 2) and those can in turn be divided into smaller groups again (layer 3). This is visualized in the platform as can be seen in Figure 35.

Layer 2 – Technology specific layer where subdivisions are made from the layer 1 types of actors that relate more closely to the technology being studied. In this case for offshore wind as can be seen in the image below.

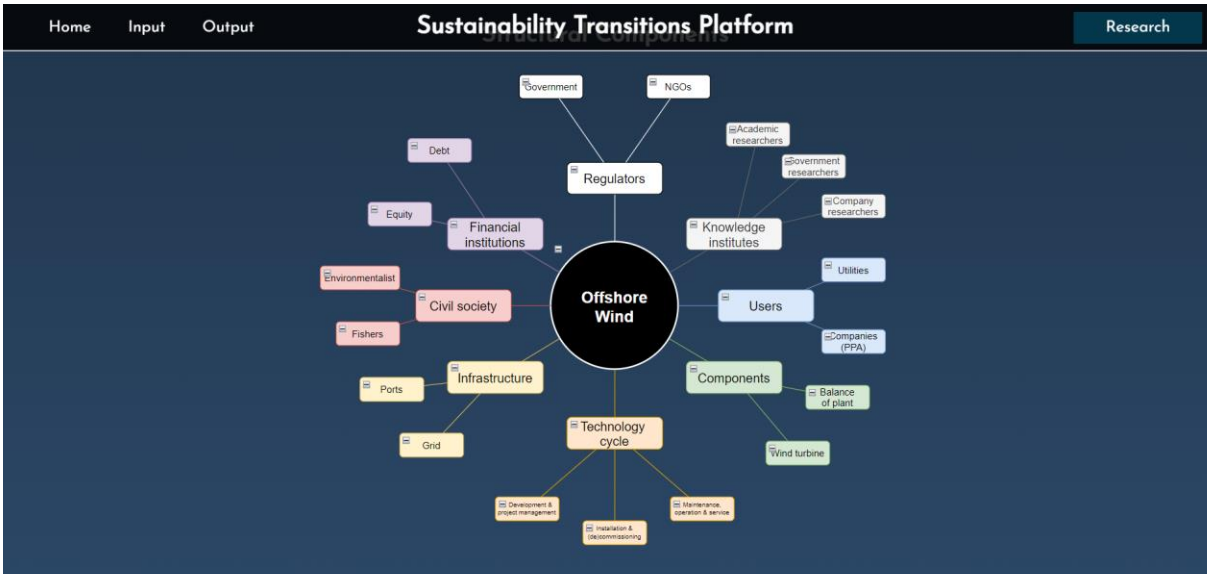

Figure 35 – Platform snapshot of the layer 2 actors division for offshore wind energy technology.

- Regulators:
  i) Government
  ii) NGOs
- Knowledge institutes:
  i) Academic researchers
  ii) Company researchers
  iii) Government researchers
- Users:
  i) Utilities

    ii) Companies (PPA)
- Components:
    i) Wind turbine
    ii) Balance of Plant (BoP)
- Technology cycle:
    i) Development & project management
    ii) Installation & (de)commissioning
    iii) Operation, maintenance & service
- Infrastructure:
    i) Ports
    ii) Electricity grid
- Civil society:
    i) Environmentalists
    ii) Fishers
- Financial institutions
    i) Debt
    ii) Equity

Layer 3+ – It is possible to continue adding layers to get more detailed information about all actors and their role in the technology chain. For example components is divided between wind turbine and Balance of Plant. Wind turbine could then be further subdivided as follows:

- Components:
    i) Wind turbine
        i. Rotor
            - Blades
            - Hub
        ii. Nacelle
            - Generator
            - Gearbox (not always)
            - Shafts (if gearbox)
        iii. Tower

Although these following layers exist and contain actors that have a specific function for the development of the technology, the actors of these layers are commonly bound to the previous layers. For example the wind turbines which are supplied by companies such as Vestas or Siemens Gamesa require independent parts such as the blades and generators which can again be supplied by other companies. While generally the companies that deliver the wind turbine are responsible for delivering the final product and are thus responsible for the following layers. This responsibility construction for offshore wind technology is in most cases established through multi-contracting or engineer, procure and construct (EPC) contracts (ORE Catapult/BVG Associates). The image below shows an EPC contract structure for the NoordzeeWind project where Vestas was the company responsible for the wind turbines.

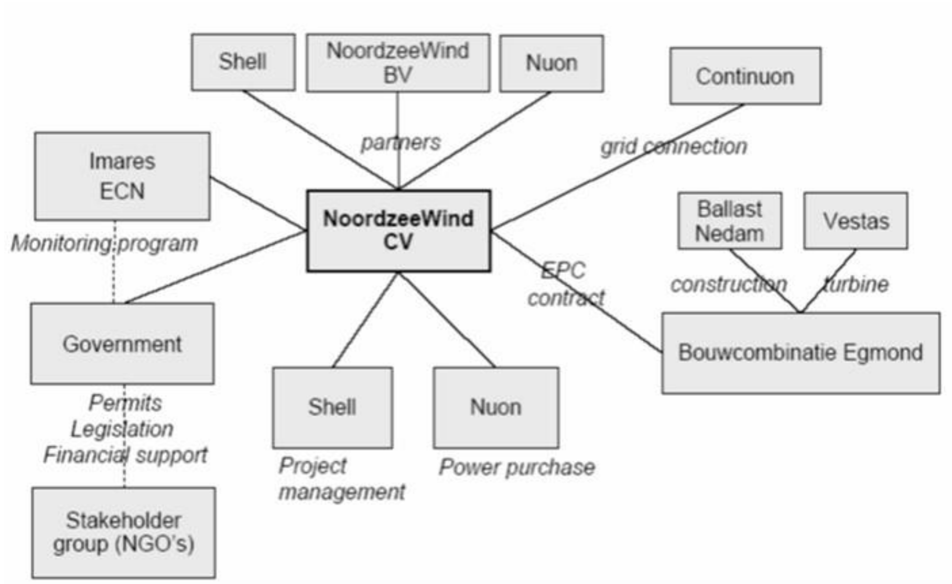

Figure 36 - NoordzeeWind stakeholder structure as presented in the general report for offshore wind farm Egmond aan Zee (NoordzeeWind, 2008).

The next image shows the companies in the following layers for Vestas (the turbine supplier) in combination with Ballast Nedam (the main constructor).

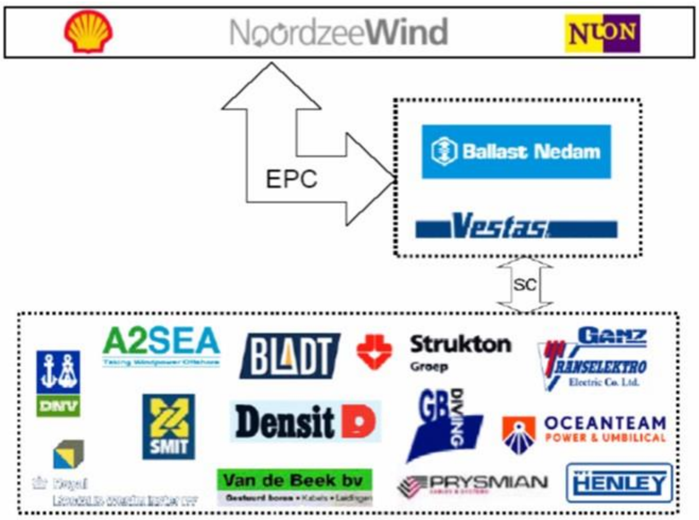

Figure 37 - NoordzeeWind contract structure as presented in the general report for offshore wind farm Egmond aan Zee (NoordzeeWind, 2008).

For this research and the platform template the structural components will be presented until layer 2. In the full platform it would be encouraged to add more layers as this gives a more complete picture and can also give more insights between the connection of actors and other TISs. Where for example a layer 3 company is part of both offshore wind and oil TISs.

Complete actor layout – Once all the divisions until layer 2 have been established, the actors for each division can be added. This can already present possible gaps in the structural components of the technology.

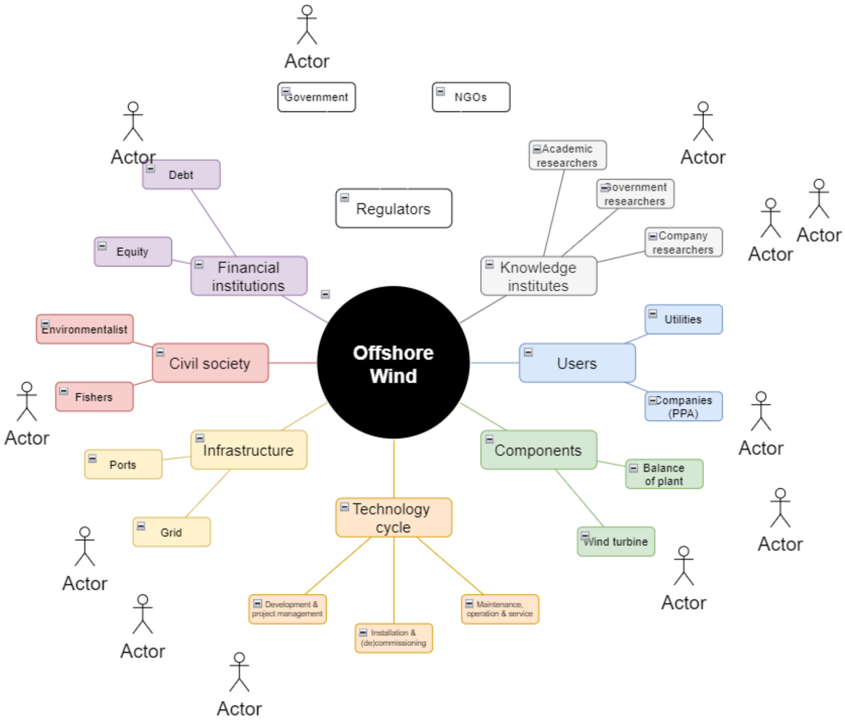

Figure 38 - Example of actors in the actor division of the platform template.

4.3.2.2 Networks

The networks are the linkages between different actors. These linkages come in many forms, such as cooperation agreements for exchange of knowledge, services or resources. In the studies pointed out in Table 3, the network presentation and the emphasis put on the linkages also differed. In most of the cases the networks were explained in text. Often merged with the part where the actors were presented. One example of a visual representation of networks has already been shown in Figure 31, from the research done by Sawulski et al. (2019). Another visual representation was found in the paper of Wieczorek et al. (2013). The visual representation shows the actors and their network linkages for offshore wind in European countries and can be seen below.

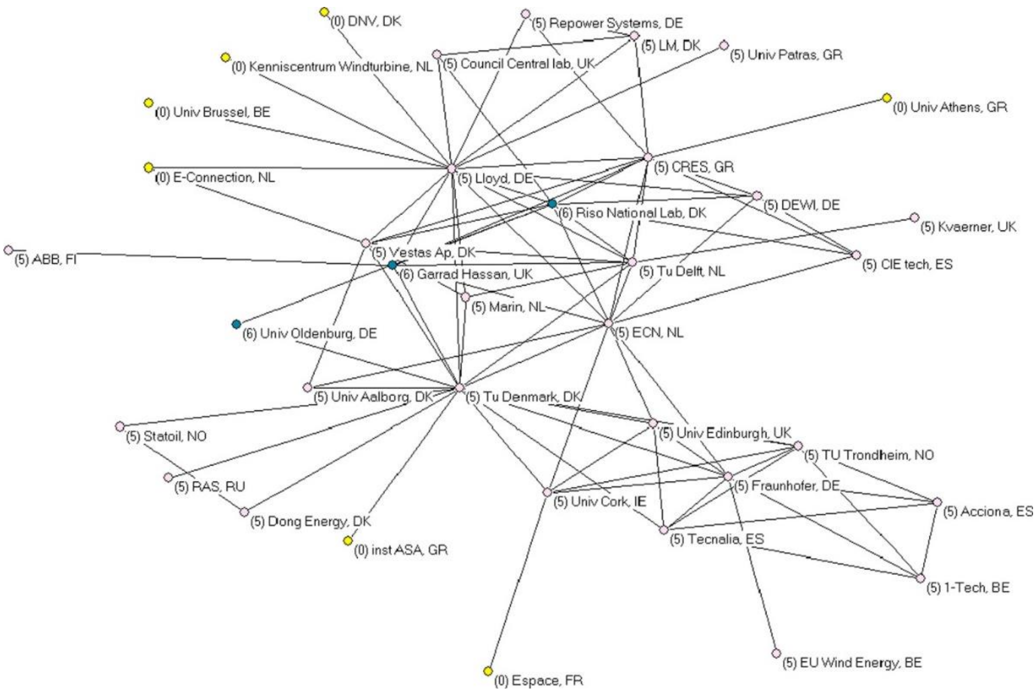

Figure 39 - Network linkages between actors of offshore wind in Europe (Wieczorek et al., 2013).

The image does indeed show the actor names and their linkages with other actors. It even goes beyond the presentation of these two parameters by adding additional data: i) the country of origin of each actor; ii) the linkage value. It does however remain unclear what types of actors they are and what types of linkages have been made.

To clarify the types of actors it makes sense to take advatange of the already existing actor structure of the platform template (as described in Section 4.3.2.1). That is why the networks will be presented in the same place as the actors themselves in the platform, as is also mostly done in the papers from Table 3. The platform then allows for interactivity in which the user can select if the networks or only the actor divisions are visible. Additionally, other interactive aspects can be added to the platform which can help the users understand the networks better:

i) By hovering over an actor the linkages between that actor and other actors within the system are highlighted.
ii) By hovering over a linkage the specific information about that linkage is shown.

By making use of these interactivity options of the platform, a user can get detailed information about the networks of the system. This could help improve accuracy and consistency of research.

The images below demonstrate how the networks and the interactivity options would be seen in the platform.

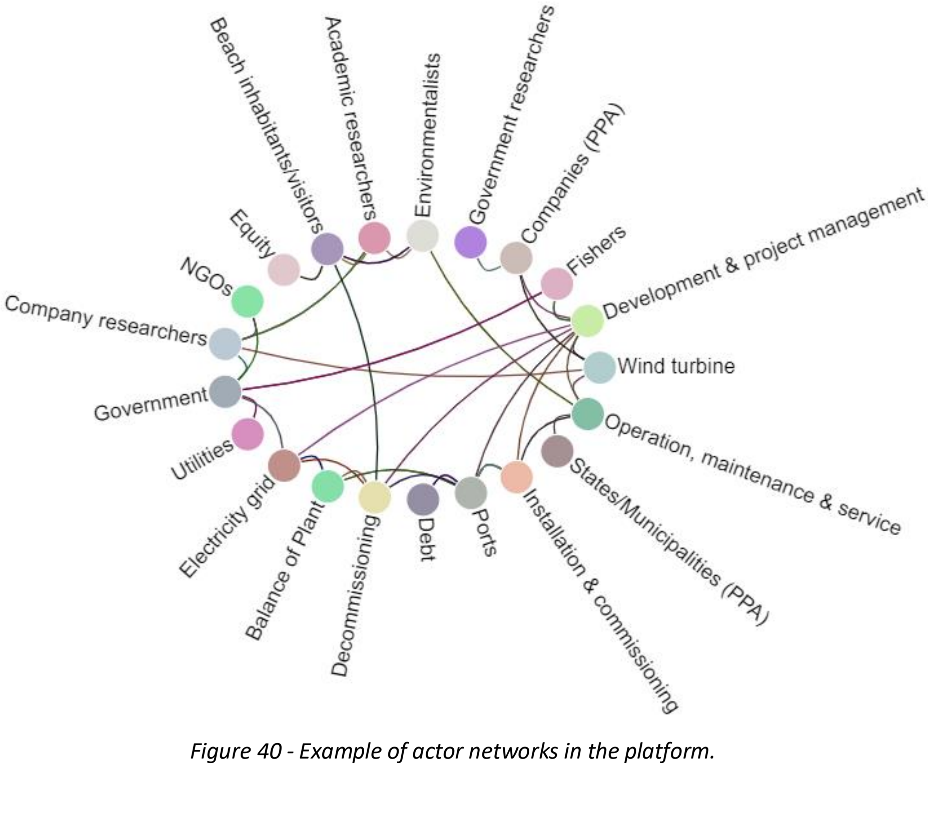

Figure 40 - Example of actor networks in the platform.

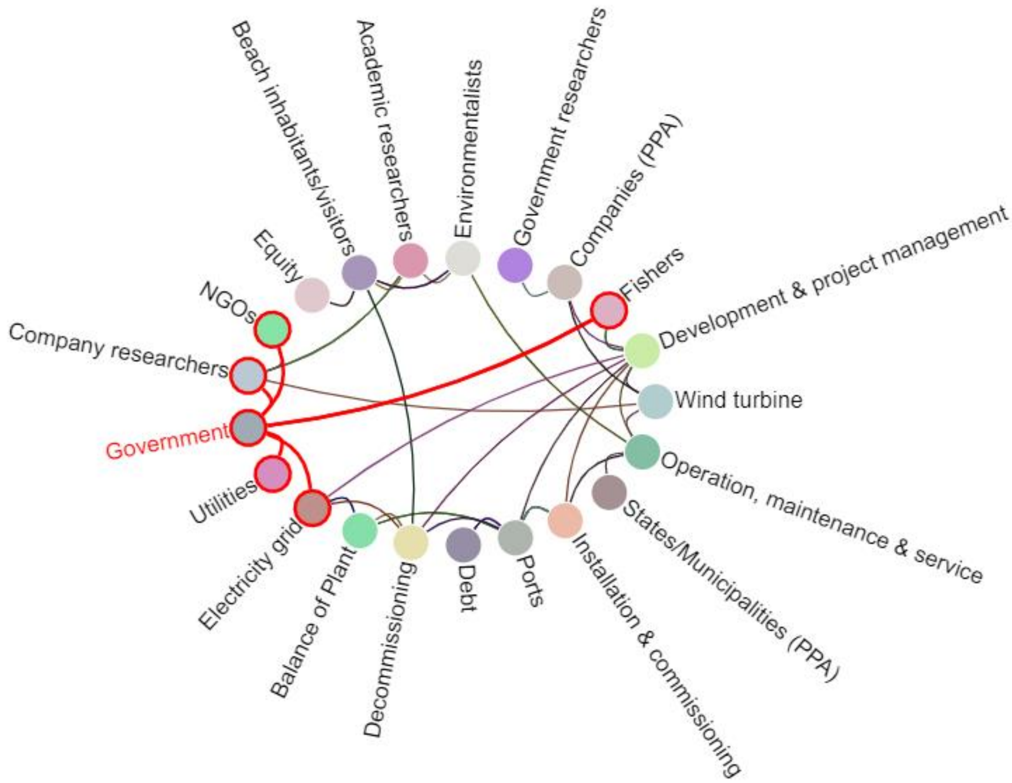

Figure 41 - Example of highlighted actor and linkages through interactivity in the platform. In this case the user has hovered over the actor 'government'. The platform then highlights all the 'government' linkages and the corresponding actors to those linkages.

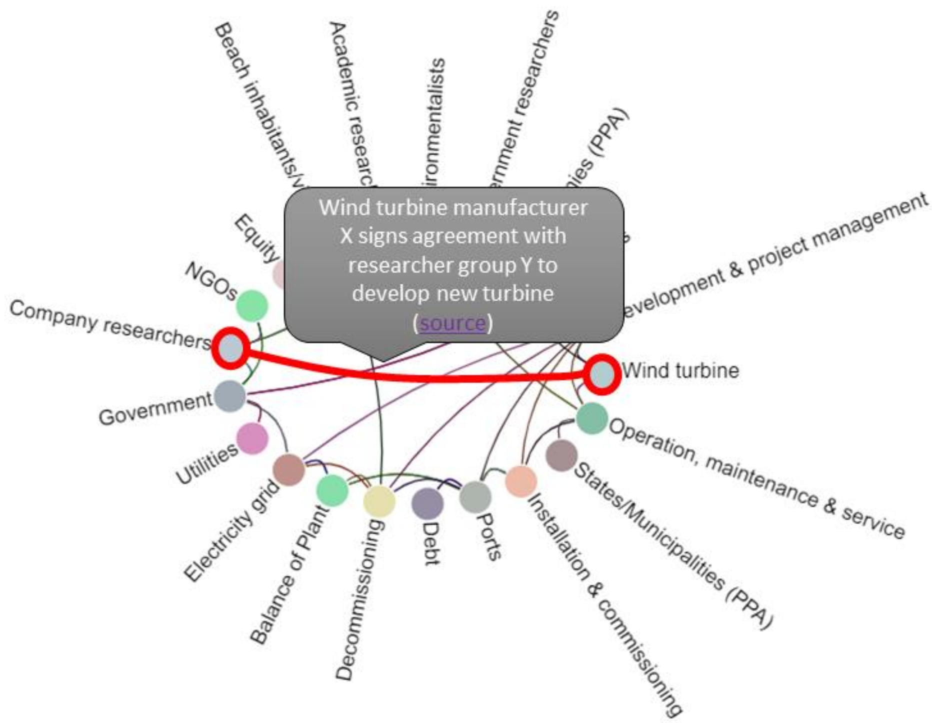

Figure 42 - Example of platform interactivity in the networks. In this case the user has selected a linkage between 'researchers' and 'wind turbine' manufacturers. This makes the linkage and the corresponding actors be highlighted and makes a tooltip pop-up with a description of the linkage and a link to the source of the information.

4.3.2.3 Institutions

The institutions are the "rules of the game". These rules can be *regulative* (laws; regulations), *normative* (social/professional standards; social/professional expectations; values) and *cultural-cognitive* (beliefs) (Fünfschilling, 2020). In the Table 3 studies analysed (see beginning of Section 4.3), the institutions were mostly embedded in text. Since the platform will be designed to present MLP & TIS information visually, it was opted to present the institutions in a table where the existing "rules of the game" and their explanations are compactly presented to the user. Hence, a table has been included to the structural components of the platform template.

Although not implemented in the platform template, interactivity could be implemented in future versions. For example, i) by selecting a specific institutions the actors that are directly influenced by them could be highlighted; or ii) by selecting a specific actor or actor group their specific values/beliefs/views with respect to the technology or other actors could be shown. This would give an even more complete picture of the structural components. This specific information could be obtained through interviews or (ideally) be inputted by the actors themselves.

The actors, networks and institutions together form the structural components and are presented in the platform template as a single part. How this is visualized in the platform template can be seen in the following figure.

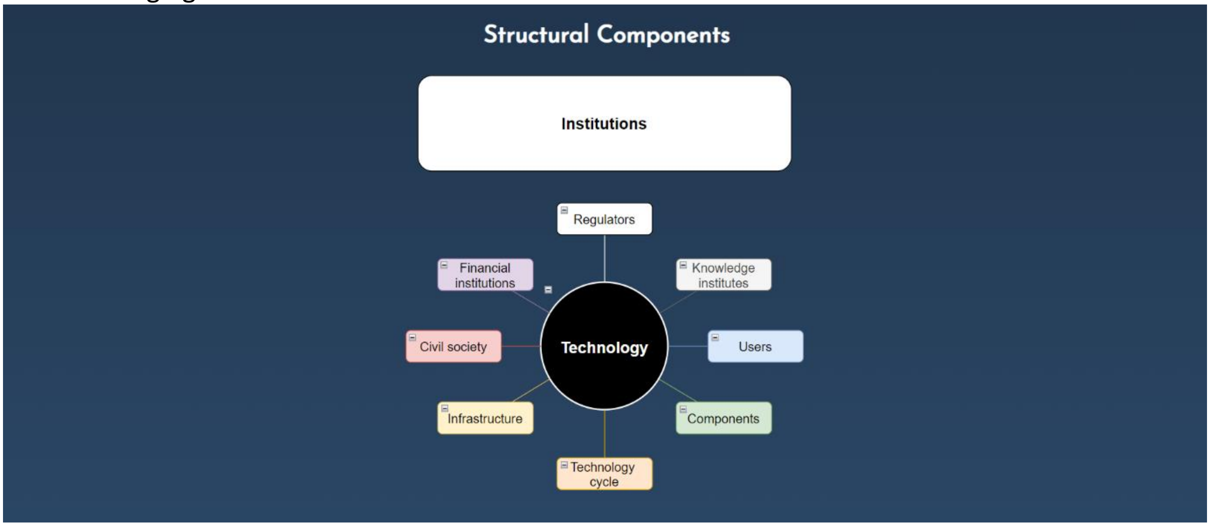

Figure 43 - Platform snapshot of the structural components (actors, networks and institutions where no case has been implemented.

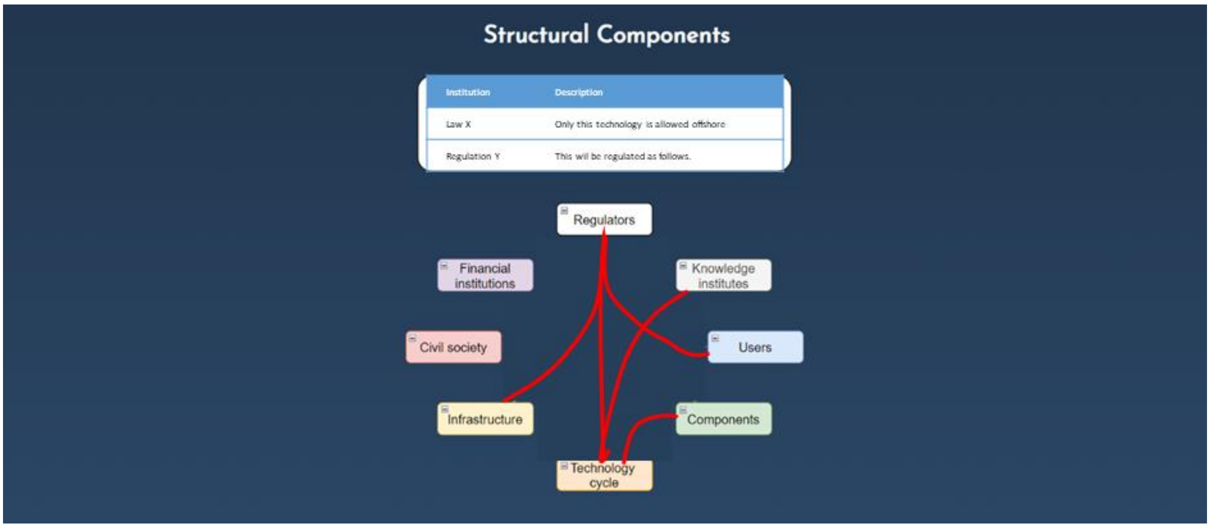

Figure 44 - Example of structural components in the platform with dummy data. It shows a table with the institutions and their description and the networks of the actor groups.

4.3.3 TIS Functions Analysis

As the name suggests, the TIS Functions Analysis for the platform template is based on the TIS framework. As described in Section 3.3.4 the framework uses a set of functions which if fulfilled result in easier/faster diffusion of the technology. The fulfilment of these functions is determined by a score which in its turn is determined through indicators. Each of these indicators represents some form of data related to the technology and partially tells whether a function is being fulfilled. If all functions are fulfilled the structural components should in theory be complete and working well, otherwise, if one or multiple functions are not fulfilled, this can be linked back to a problem in the structural components.

In TIS studies the '*TIS Snapshot*' is in some cases being used to visualize function fulfilment (Hekkert, 2020). In some of the studies presented in Table 3, this has indeed been included to the results of the analysis (Luo et al., 2012; Sawulski et al., 2019; Wieczorek et al., 2013, 2015). An example of such a TIS Snapshot (from the Wieczorek et al. (2013) paper) can be seen in the following figure.

Figure 45 - TIS snapshot for offshore wind in the Netherlands in 2011 (Wieczorek et al., 2013).

The TIS Snapshot will also be present in the platform template as this is one of the strong points of visual data representation in sustainability transitions research. A snapshot of how this looks in the platform template can be seen in the image below.

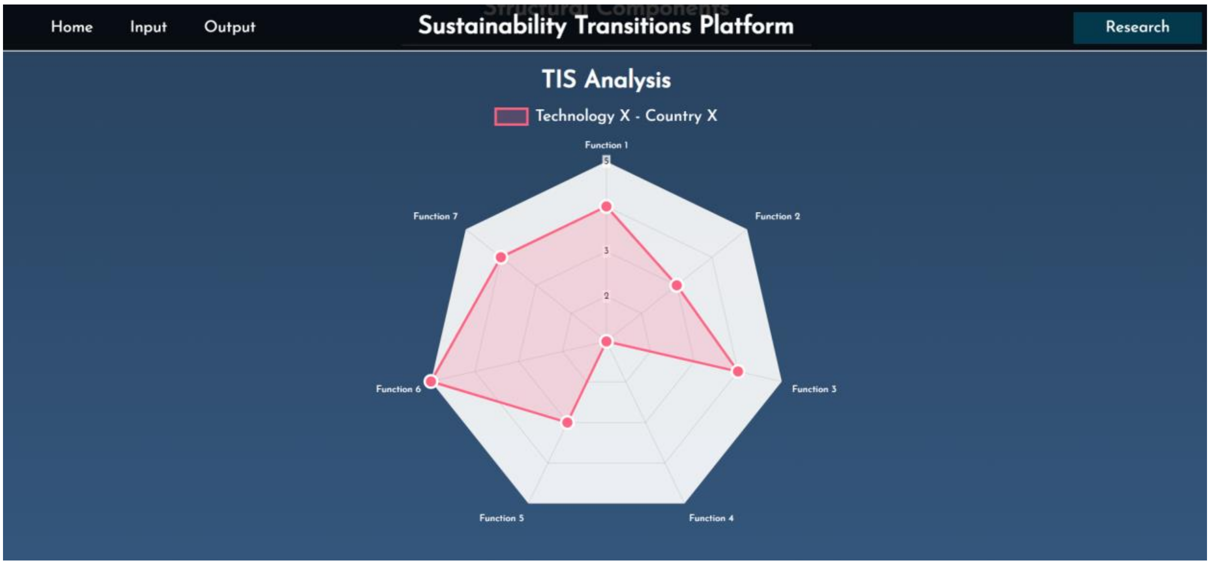

Figure 46 - Platform snapshot of the TIS analysis section.

A big difference between having the TIS Snapshot on paper or in a platform is once more the interactivity. In the platform template a user has the possibility to see directly which indicators were used to determine the function score by hovering on the specific function. The image below shows an example where function 2 is selected and we see that 'Technology X – Country X' has a function score of 3 which was determined from data of 4 different indicators.
Additionally, in a more developed version of the platform, the user should be able to click on the indicators and their data to be directly redirected to the source of the information since this helps verifying the information and is relevant for research.

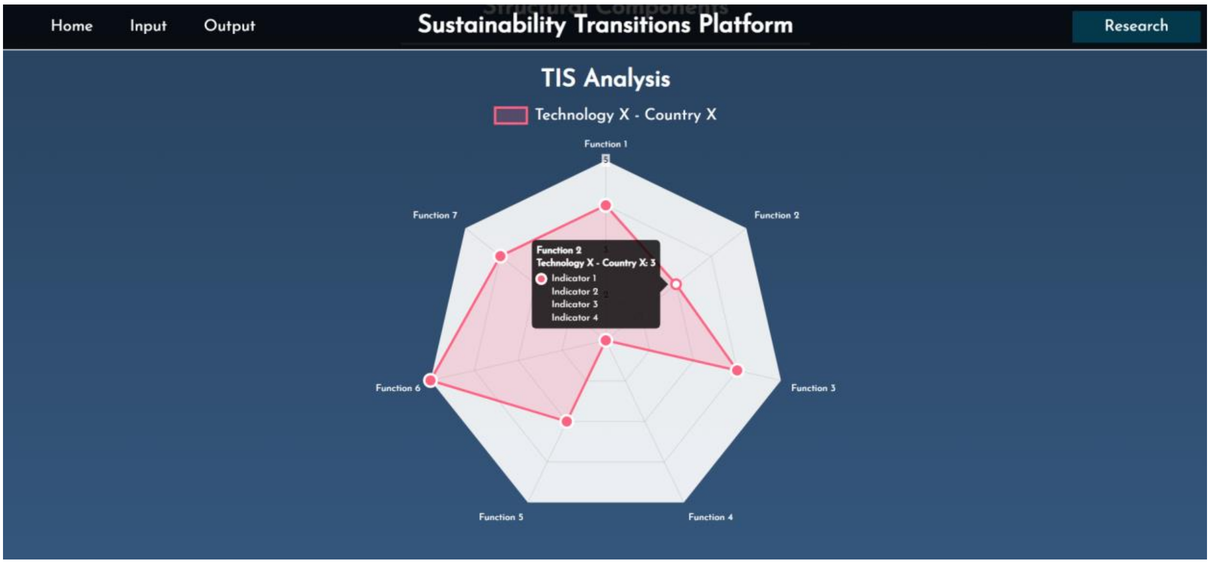

Figure 47 - Platform snapshot of TIS analysis with interactive feature. By hovering over the function score a tooltip pops-up in which the specific indicators used and their corresponding results are shown.

The functions and indicators for the TIS Analysis of this research will also be based on what is being used in the papers of Table 3. Almost all of the papers utilized the functions as described by Hekkert et al. (2007). In a few cases (Bento & Fontes, 2019; Jacobsson & Karltorp, 2013) it was opted to utilize the functions as described by Bergek et al. (2008). One of the studies in particular (Aldersey-Williams et al., 2020) focussed on validating the functions through an offshore wind case in the United Kingdom. Their study pointed out that the functions of Bergek and Hekkert are in principle very similar and showed that the seven functions of Hekkert et al. (2007) are necessary and that there is no direct

necessity for using the eight functions as is done in Bergek et al. (2008), the choice would mostly depend on the researchers preference. They further concluded that an additional function should be added in both cases, which relates to contextual factors which in the case of the platform template can be found back in the *technology environment* section. Besides these two there are other sets of functions being used in literature, such as, the functions as described by van Alphen et al. (2007) which are designed to better incorporate the TISs of developing countries; and the functions as described by Edsand (2017) which divided some functions in a national and an international part to grasp the difference between these two parts more precisely. Even though Brazil is still regarded as a developing country which would fit with the description of the van Alphen et al. (2008) or Edsand (2017) functions, it would not make sense to present the first template of the sustainability transitions platform through a set of more case specific functions. The idea of this research is to have a first general template which can then be further developed and adding and editing other functions is most definitely a feature that is desired, but should be looked at better in a further stage. In addition, splitting up the national and international functions has in some cases not been necessary as these parameters have been presented as separate indicators within the functions of Hekkert et al. (2007) or Bergek et al. (2008) (Bento & Fontes, 2015; Gosens & Lu, 2013; Vasseur et al., 2013). Similarly, separate indicators have been used within the Hekkert or Bergek functions which focus on the aspects of developing countries (Esmailzadeh et al., 2020; Kebede & Mitsufuji, 2017; Wandera, 2020). Furthermore, the two papers that have used Brazil as the case country from Table 3 utilized the seven functions of Hekkert et al. (2007), which indicates that a case in Brazil does not necessarily need to be tied to functions specifically designed for developing countries.
Given these findings, the seven functions as described by Hekkert et al. (2007) will be used as the basis for the case in this research. These are *1) Entrepreneurial activities, 2) Knowledge development, 3) Knowledge diffusion, 4) Guidance of the search, 5) Market formation, 6) Resources mobilization, 7) Creation of legitimacy*. Detailed descriptions of each individual function can be found in Section 3.3.4. It is important to realize that in a future stage, when the platform is fully operational, researchers should be able to make use of its dynamic properties in the functions as well, meaning that they should be able to select and input a different set of functions if they desire to for their research.

In order to determine if the functions are fulfilled a set of indicators will be used for each function. These indicators can be qualitative or quantitative and will give a measure as to how strong a function is in the innovation system. For example, an indicator for entrepreneurial activities (F1) could be the number of new entrants in the TIS, for resource mobilization (F6) it could be the availability of specialized training programs. Wieczorek et al. (2012) created a table with a set of possible indicators for each function. This table can be seen below.

Table 4 - TIS functions and example indicators (Wieczorek, 2012).

Function	Indicators are for example:
F1 entrepreneurial activities	New entrants, experiments, start-ups, diversification activities
F2 knowledge development	R&D projects, demonstration projects , patents, journal publications, reports, prototypes
F3 knowledge diffusion	Workshops, conferences, network activities
F4 guidance of the search	Long-term targets of governments and industries, expressed visions, alignment of expectations of relevant actors, Visions, expectations, policy documents, demand articulation by leading customers
F5 market formation	The number of niche markets, specific tax regimes , new environmental standards that improve the chances for new environmental technologies
F6 resources mobilisation:	Human capital: education, specialized training programs Financial capital: venture capital, public seed money, private investments Physical: natural resources, infrastructure
F7 creation of legitimacy:	Size and growth of interest groups/advocacy coalitions and their lobby activities, size of network around technology, actions that legitimize technology, number of exhibitions / workshops, technology platforms

This table is a good starting point, but even now, 30 years after the first steps in sustainability transitions research have been set, there is no exact or predefined set of indicators that should be used in a case. The choice of indicators varies between papers. What makes indicator selection even more complex is that although some indicators are more recurring and easier to point out in papers, some appear to be either encrypted in text, mixed up with other indicators or plainly left out.
For this research the table with example indicators from Wieczorek et al. (2012) has been used as a basis and has been updated with the indicators that were found in the papers from Table 1. This resulted in the following set of indicators being used for this research case:

Table 5 - Specific indicators used for this research case.

Functions	Indicator 1	Indicator 2	Indicator 3	Indicator 4	Indicator 5
F1 entrepreneurial activities	New entrants	Experiments	Start-ups	Diversification activities	
F2 knowledge Development	R&D projects	Demonstration projects	Patents	Journal publications	Prototypes
F3 knowledge diffusion	Workshops	Conferences	Network activities	Webinars	
F4 guidance of the search	Long-term targets of governments and industries	Expressed visions	Expectations	Demand articulation by leading customers	
F5 market formation	Specific tax regimes	Policy instruments	Size of the market		
F6 resources mobilisation	**Human capital:** Education	**Human capital:** Specialized training programs	**Financial capital:** Public seed money	**Financial capital:** Private investments	**Physical:** Infrastructure
F7 creation of legitimacy	Actions that legitimize technology	Level of competition between technologies			

The main differences in indicators compared to the basis of Wieczorek et al. (2012) are that:

- ‘Reports’ (F2) was removed, since this indicator would be difficult to precisely measure and has not been used in any of the papers in Table 3.
- ‘Webinars’ (F3) was included, this was a personal addition of the author given the global change of information exchange due to social distancing during the COVID-19 pandemic.
- ‘Policy documents’ (F4) was removed, as this indicator seemed unclear as to what it would measure and was not encountered in any of the papers in Table 3.
- ‘Number of niche markets’ (F5) was replaced by size of niche markets, this was more clearly found in other papers of Table 3.
- ‘New environmental standards that improve the chances for new environmental technologies’ (F5) was replaced by policy instruments, which was also more frequently used in papers of Table 3 and gives a broader perspective.
- ‘Natural resources’ (F6) was removed, as this would be difficult to precisely measure and has not been used in any of the papers in Table 3.
- ‘Size and growth of interest groups/advocacy coalitions and their lobby activities’, ‘Size of network around technology’ (F7) were removed, as these would be difficult to precisely measure and have not been used in any of the papers in Table 3.
- ‘Number of exhibitions / workshops’ (F7) was removed, as this is too similar to the workshops indicators of F2.
- ‘Technology platforms’ (F7) was removed, as none of the papers in Table 3 used this indicator.
- ‘Level of competition between technologies’ (F7) was added, as this was implemented in some of the Table 3 studies and would nicely relate back to the technology environment section of the platform.

These indicators are used to determine the final score of each function. In literature the scoring of the functions remains slightly unclear.
Building on the point previously made, that it sometimes is difficult to determine which indicators have exactly been used and to which part of the text the answer is directly linked, the scoring has also become quite vague to determine since a score is given based on the chunk of text presented for the function. Often the scoring of the functions is done on a 5-point scale (1 = absent; 2 = weak; 3 = moderate; 4 = good; 5 = excellent). Although it should in most cases be possible to differentiate between a 1 and a 5 from the text, it can become quite difficult to differentiate between a 3 and a 4, for example. The score can differ between researchers depending on how they interpret and weigh different parts of the information.
To reduce this variance in function scores the platform template will be built so that each indicator is processed individually and that each of the indicators gets its own score. The final function score will be based on the average of all the function’s respective indicator scores together. This ensures that all the indicators are weighed equally an clarifies better which indicators within the function are weak or strong. This approach has also been implemented by the Table 3 paper Sawulksi et al. (2019).
The indicators will thus be scored on a 5-point scale, where 1 = absent; 2 = weak; 3 = moderate; 4 = strong; 5 = excellent, and this score will be based by analysing the result for each indicator and comparing it to the results of the Table 3 papers where possible. So if for example from analysis it is perceived that there are 10 ‘new entrants’ (F1) and that one paper had 20 ‘new entrants’ with a score of 4 and another study had 4 ‘new entrants’ with a score of 2, then the score for the 10 ‘new entrants’ in this case will be a 3. This does indeed not completely remove all the variance since the indicator scores will be based on what the researcher sees as weak or strong. That is why scoring indicators instead of the functions directly will only reduce the variance. The platform should eventually help the scoring system, because in the end it is better to score indicators compared to what is seen in other cases. Firstly, by comparing the same technology in different countries and secondly by comparing the technology to different technologies. This gives a much better approximation of what the score should be without personal bias. This is however something that will only exist in a future development stage

of the platform, since more cases should be implemented to be able to compare them. This will be treated further in Chapter 6.

Once the indicators have been scored, the functions scores are automatically calculated, and once these scores are available the final 'TIS Score' can be generated by taking the average of all the function scores. This 'TIS Score' is then coupled back to the technology environment section of the platform (see Section 4.3.1) and is, strictly speaking, not a recommended way of presenting the TIS functionality, since each function should be fulfilled individually. By averaging the score the unfulfilled functions are masked and could induce the user to believe that a TIS is functioning well. The 'TIS Score' does however present the average functioning of the TIS simply which makes it a nice addition to the *technology environment* graph by coupling the TIS to its environment if used consciously.

4.4 Summary of the Platform

In this chapter the idea of the complete Sustainability Transitions Platform (STP) has been presented. The STP comprises the two theoretical perspectives existent in platform literature, namely:

i) *Engineering design perspective*, where the platform serves as a digital data interface built on computer software where researchers are able to input and analyse data related to sustainability transitions which also allows them to improve and innovate the theory within the platform itself.

ii) *Economics perspective*, where the platform is regarded as a triangular business model forming a bridge between sustainability transitions researchers and policy makers, or more broadly between knowledge producers and knowledge users that exponentially can grow through network effects.

The scope of such a platform, including all the different frameworks and aspects of sustainability transitions research, is huge and will require a lot of time for development, testing and application. That is why for this thesis research only a template of the platform has been designed which only considers part of the whole sustainability transitions research and functionalities of the platform and should serve as an initial step towards the development of the complete STP.

In this research a platform template has been built that mostly resembles an innovation platform in which only a combination of the MLP and TIS frameworks has been implemented. The combination of these two frameworks has been selected to present cases of technological innovation system including their external factors. The platform template has been designed based on what is described in the theory of the frameworks, how it is being applied in cases and how it has already been visualized. Since the platform template is meant to simplify the theory and bring it closer to practitioners, it has been divided in an input and an output section (see Figure 25 and Figure 26, respectively). The input section is meant for users of the platform template to select which technology and country information they require. The output section shows the information related to the technology and country the user selected.

The output section has been divided in three different parts, which are:

1. *Technology environment*, in which the technology of interest is shown within an environment that contains the competing technologies including some technology specific data and landscape events that influence the technology.
2. *Structural components*, in which the actors, networks and institutions of the innovation system are presented.
3. *TIS Functions* Analysis, in which the status of the TIS is shown based on the fulfilment of the seven functions as described by Hekkert (2007).

Each of these parts should present information to the users of the platform template that should help them understand what factors are inducing or blocking for the development and diffusion of the

technology in the country at hand. The three parts of the output are built based on case related data that has been found through research and inputted in the platform template database.
The platform template will be used in this research as a first draft to show how case data could be inputted into the platform template and what the obtained outputs would mean from a researcher's perspective. This will be done through a case for offshore wind in Brazil with a boundary where only electricity generating technologies in Brazil will be considered for the analysis. This case will be presented in the next chapter.

Chapter 5 – Case: Offshore Wind Energy Technology in Brazil

Now that the theory behind the platform and the functionalities of the platform template have been explained, a case will be presented in this chapter to demonstrate how the platform template actually works. This will give a better understanding of how case implementation takes place and what the resulting outputs look like in the platform viewed from a user perspective. This in turn will present discussion points of what works well and what could be improved by implementing sustainability transitions research in a platform.

The case of this research is offshore wind energy technology in Brazil. This case was chosen because various actors of the Brazilian energy sector have stressed the necessity for diversification from the hydropower dominated energy regime and even though offshore wind energy technology has not been installed in Brazil yet, it appears to have a very high technical potential and it has been gaining a lot attention from national and international actors in the last couple of years (GWEC, 2020).

The first step for this case entailed gathering data that is directly or indirectly related to offshore wind energy technology in Brazil. This data varies from development companies signing agreements with suppliers or government agencies, to universities publishing research articles, to government agencies applying new regulations, to price competitiveness with other technologies, to landscape effects on the technology, and so on. This data is then decomposed through the questions *what & who* as has been explained in Section 4.2.1. The *what* question represents the specific event. The *who* questions represents the actors that were involved in the event. As explained in the previous chapter, this data should represents all the events around the technology and country being analysed and due to it being historical it should not change over time and should in theory not differ between two different studies on the same technology-country combination.

The second step is to allocate the gathered data into the specific TIS and/or MLP framework elements in the platform. These elements can be found in one of the three sections in the platform: *Technology Environment, Structural Components & TIS Functions Analysis*. Keeping in mind that a single event can hold data for multiple sections (e.g. new entering actor is data for both Structural Components and TIS Functions Analysis – function 1).

Once these steps have been completed the platform should render the outputs that give a visual representation of the TIS and MLP framework elements that tell something about the development of the technology. The platform users should be able to interact with the outputs and the underlying data in multiple manners to increase their understanding of the case.

For this research the data and the platform outputs will be split up in three time periods that mark significant changes in activity of offshore wind development in Brazil according to the author. These periods are:

- 2002 to 2010
- 2011 to 2016
- 2017 to 2021

Although the full periods are analysed, only snapshots of the platform from the first year (2002) and the last year of the periods (2010, 2016 and 2021) will be presented as these represent the starting point and the final status of the periods. In a more developed stage of the platform the user should be able to select the periods directly according to their interests instead of the predefined yearly range as is the case for the platform template. The user should, for example, be able to select a single period from 2002 to 2021 or even more different periods than the three selected for this research with a smaller range.

The data and corresponding outputs as seen in the platform template will be presented next for each of the three specified periods.

5.1 Period 2002-2010

5.1.1 Technology Environment

To understand how offshore wind energy technology is developing over the years in Brazil, it is important to take contextual factors into consideration. This includes looking at other technologies and landscape factors that could influence it. For many years, hydropower has been the dominant electricity generating technology in Brazil. The first Brazilian hydroelectric power plant was already installed as early as 1889, having a potential of 250 kW (Esfera Energia, 2021). From that point on the amount of hydropower installations only increased and so did their capacities. In 1984 the 14 GW Itaipu hydroelectric plant was installed which was the largest of its kind in the world at that time. According to the data published by the ONS, Brazil's national electricity system operator, almost 70 GW of hydroelectric plants had been installed in Brazil by 2002, which accounted for 88% of the total installed capacity in the country (ONS, 2022). Other technologies were also part of the electricity mix, but their shares in installed capacity were far lower than that of hydropower. As presented in the ONS data, the biggest competitors where primarily fossil fuel based thermal power plants which together had an installed capacity of around 8.7 GW (Coal 1.3 GW; Gas 3.5 GW; Oil 1.2 GW; Other thermal 2.7 GW). Besides the fossil fuel intensive power plants also nuclear energy was introduced to the mix with a single plant of 640 MW and Biomass with three plants that together had a capacity of 31 MW. Other renewable technologies such as solar PV, onshore- and offshore wind energy had not made an entry to the electricity mix yet. A summary of the most relevant values for these technologies for the year 2002 has been made based on the ONS dataset and can be seen in the following table.

Table 6 - Brazilian electricity generating technologies data for the year 2002. (ONS, 2022)

Technology	Total Installed Capacity (cumulative) [MW]	Installed Capacity (year) [MW]	Electricity Generated (year) [GWh]	LCOE [$/MWh]
Hydropower	69,769 (88.1%)	2,780 (47.6%)	317,902 (91.0%)	No data
Gas	3,484 (4.4%)	1,326 (22.7)	6,652 (1.9%)	No data
Coal	1,308 (1.7%)	0 (0%)	2,826 (0.8%)	No data
Oil	1,217 (1.5%)	50 (0.9%)	2,760 (0.8%)	No data
Nuclear	640 (0.8%)	0 (0%)	13,837 (4.0%)	No data
Biofuels	31 (0.0%)	1 (0.0%)	115 (0.0%)	No data
Onshore Wind	0 (0%)	0 (0%)	0 (0%)	No data
Solar PV	0 (0%)	0 (0%)	0 (0%)	No data
Offshore Wind	0 (0%)	0 (0%)	0 (0%)	No data
Other	2,716 (3.4%)	1,685 (28.8%)	5,151 (1.5%)	
Total	**79,165 (100%)**	**5,842 (100%)**	**349,243 (100%)**	

The beginning of this period marked a change in the Brazilian electricity system. Brazil had suffered from extreme droughts in 2001 and 2002 and had at the same time seen the rate of electricity consumption increase at 4%, which was well above the increase rate of electricity production. Given that at that time Brazilian electricity was largely dependent on hydropower, and consequently the water levels of the dams, the combination of droughts and increasing electricity consumption lead to an energy crisis (UOL, 2005).
The information above represents the input data for the '*technology environment*' section of the platform template for a case of electricity generating technologies in Brazil. By inputting the data in the platform template the following visualization (Figure 48) can be seen in the platform:

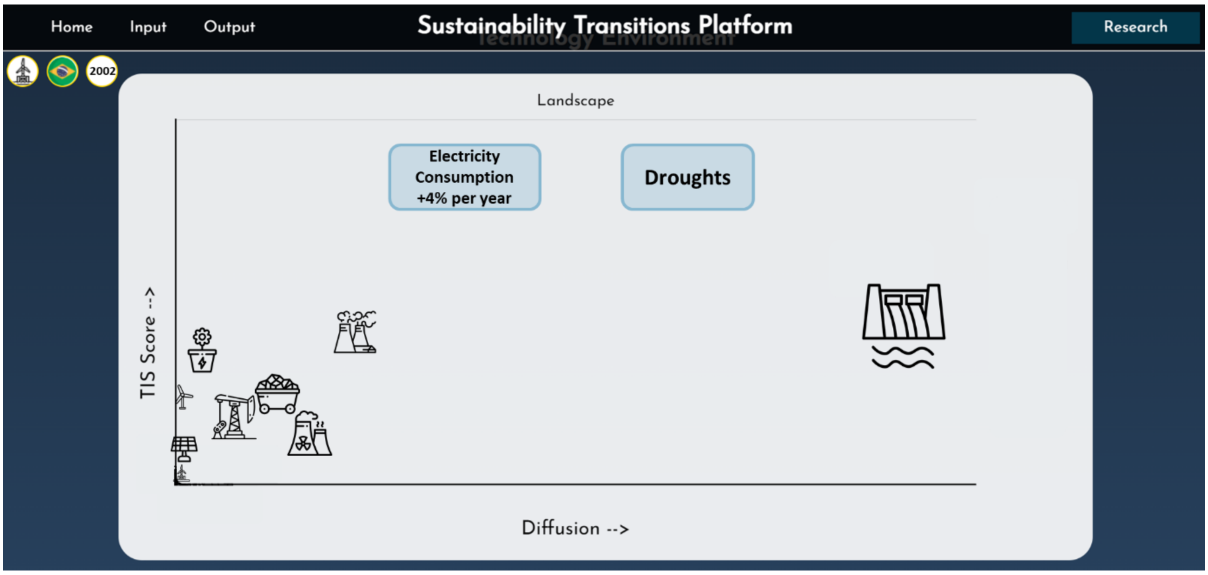

Figure 48 - Platform snapshot that represents the technology environment section. Includes technologies and landscape factors influencing offshore wind energy in Brazil in the year 2002.

On the top left of the figure we can see three circles representing i) offshore wind technology, ii) Brazil and iii) the year 2002. At the top of the graph we seen two landscape factors in blue blocks, namely i) the electricity consumption of 4% per year and ii) droughts encountered in Brazil. The figure above also presents the technologies on specific positions in the graph based on their diffusion and their TIS Scores. Here the niche technologies are located at the bottom left of the graph and the regime on the top right of the graph, in this case being hydropower. As has been explained in Section 4.3.1, the diffusion is based on the technology's share in total installed capacity and the TIS score is the average of the function scores determined in the TIS Functions Analysis. In this research the TIS functions analysis has only been carried out for offshore wind while the TIS scores of the other technologies has been estimated based on their increase in installed capacity.
Figure 49 illustrates the dynamic features that can be used in the platform. By hovering over hydropower the technology data (from Table 6) can be visualized next to the technology. The data that is visualized can vary depending on the users preferences. This selection has been made by the author because it was deemed relevant as explained in Section 4.3.1.

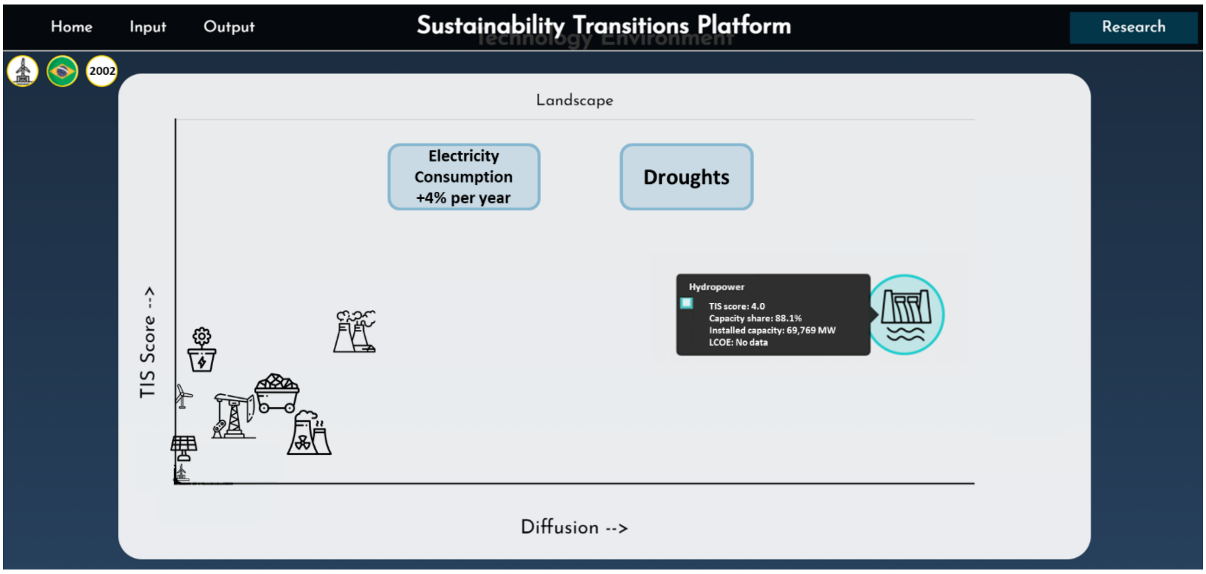

Figure 49 – Platform snapshot with example of the dynamic features. By hovering over a technology more information can be retrieved. In this case the TIS Score, capacity share, installed capacity and LCOE of hydropower in 2002 are presented. Note that there is no data available for the LCOE in this period.

The experience of the energy crisis brought a new perspective on how the energy system in Brazil should be handled. From a regulatory perspective new laws and programs were being set up that would protect the energy system. One example is the PROINFA program, which was developed to incentivize electricity production through alternative sources. This led to the entry of onshore wind energy technology to the mix and gave a boost in new biomass installations.

According to the ONS data (ONS, 2022), between 2002 and 2010 Brazil had increased its installed capacity from around 80 GW to 105 GW (33% increase). Gas installations had increased by more than 4 GW, while biomass, nuclear and oil had increased slightly more than 1 GW. Nevertheless, the biggest increase was still found in hydropower which accounted for around 14 GW, which is more than half of the newly installed capacity. By the end of this period (2010) hydropower was still by far the dominant technology but had seen its total share in the electricity mix decrease from 88.1% to 79.6%. The selected data for the technologies at the end of the period can be seen in the table below.

Table 7 - Brazilian electricity generating technologies data for the year 2010. (ONS, 2022)

Technology	Total Installed Capacity (cumulative) [MW]	Installed Capacity (year) [MW]	Electricity Generated (year) [GWh]	LCOE [$/MWh]
Hydropower	83,794 (79.6%)	1,716 (40.9%)	426,207 (88.6%)	No data
Gas	7,650 (7.3%)	254 (6.1%)	15,531 (3.2%)	No data
Oil	2,805 (2.7%)	1,289 (30.7%)	5,177 (1.1%)	No data
Nuclear	1,990 (1.9%)	0 (0%)	14,524 (3.0%)	No data
Coal	1,308 (1.2%)	0 (0%)	2,085 (0.4%)	No data
Biofuels	1,252 (1.2%)	675 (16.1%)	3,093 (0.6%)	No data
Onshore Wind	568 (0.5%)	258 (6.2%)	1,448 (0.3%)	No data
Solar PV	0 (0%)	0 (0%)	0 (0%)	No data
Offshore Wind	0 (0%)	0 (0%)	0 (0%)	No data
Other	5,887 (5.6%)	1,685 (28.8%)	12,943 (2.7%)	
Total	**105,254 (100%)**	**4,191 (100%)**	**481,007 (100%)**	

During this period between 2002 and 2010, Brazil was doing economically well which was reflected in an average GDP growth rate of 4% (The World Bank, 2022). In the year 2010 GDP growth rate even hit as high as 7.5%, which had not been seen in the country since the mid 80’s. Brazil did however continue to suffer from droughts during this period of which the ones in 2005 and 2010 again lead to instability in the electricity system (Câmara dos Deputados, 2022). The 2010 data within the platform looks as follows.

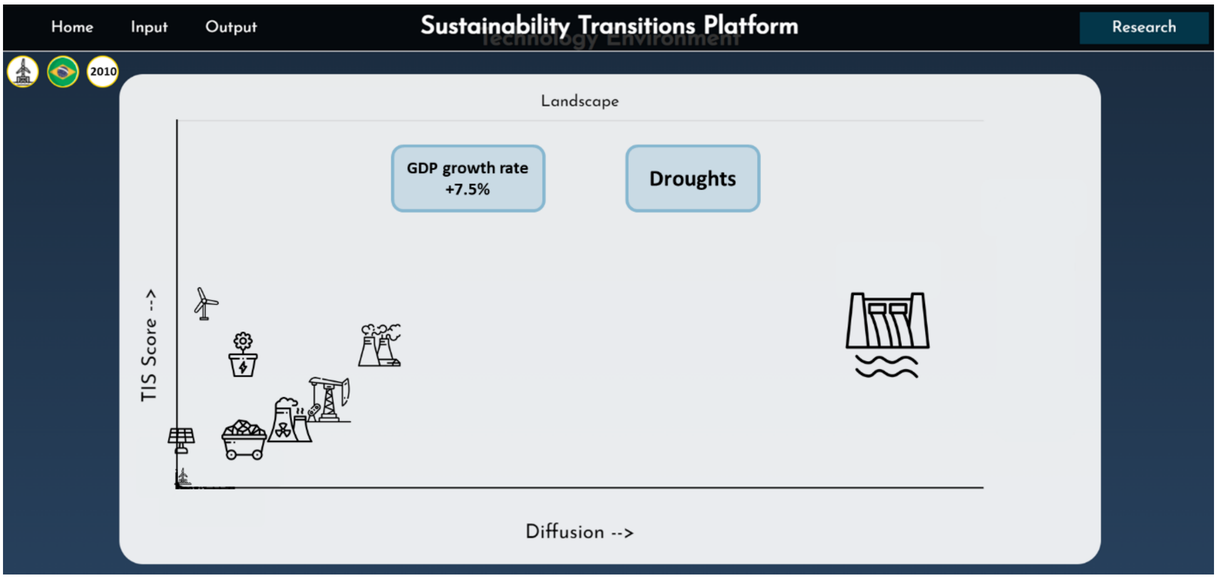

Figure 50 - Platform snapshot that represents the technology environment section. Includes technologies and landscape factors influencing offshore wind energy in Brazil in the year 2010.

In the platform figure for 2010 we again see two landscape factors in the blue boxes at the top, which are i) GDP growth rate of 7.5% and ii) droughts again. Within the graph the technology positions on the x-axis has remained rather similar except that hydropower has slightly decreased its diffusion share, moving it to the left, and the niches have gained some, moving them to the right. On the y-axis, one movement that particularly stands out is that of onshore wind. It has risen above the TIS Score of the other niches which places it further at the top of the graph. Even though the TIS analysis for this technology has not been carried out, according to the theory the function fulfilment should be working well in order for a technology to diffuse. This change in TIS Score has been estimated based on what is known about the future development of the technology. As we will see in the next period the installed capacity of offshore wind increases a lot compared to that of the other niches.

5.1.2 TIS Structural Components

The structural components are the pillars of the technology being studied, which in this case is offshore wind. Data was gathered relating specifically to this technology. The first event encountered in the data dates back to 2002 when the company Eólica Brasil was officially registered with the specific purpose of developing an offshore wind energy project in Brazil. The following event identified only happened in 2008 when a research paper was published by the University of Delaware (UD from the United States), titled: *'Combining meteorological stations and satellite data to evaluate the offshore wind power resource of Southeastern Brazil'*. This was followed by another research paper published in 2009 that was conducted by the Federal University of Rio de Janeiro (UFRJ) and CEPEL, a subsidiary of state-owned electricity company Eletrobras. The final event identified in this period relates to the memorandum of understanding (MoU) signed between Brazilian utility company Neoenergia and Spanish company Iberdrola[2]. In this MoU the companies pointed out their interest in codeveloping both onshore and offshore wind in Brazil.
In the platform, the actors are divided in their respective actor divisions and are presented through their logos[3]. Their visualization in the platform template at the end of the period (2010) is as follows.

[2] Neoenergia is a subsidiary of Iberdrola. (https://www.iberdrola.com/press-room/news/detail/neoenergia-subsidiary-iberdrola-debuts-paulo-stock-exchange-brazil-s-largest-energy-sector-placement-since-2000)
[3] In some cases the actor logos could not be found and have been exchanged for the actor name.

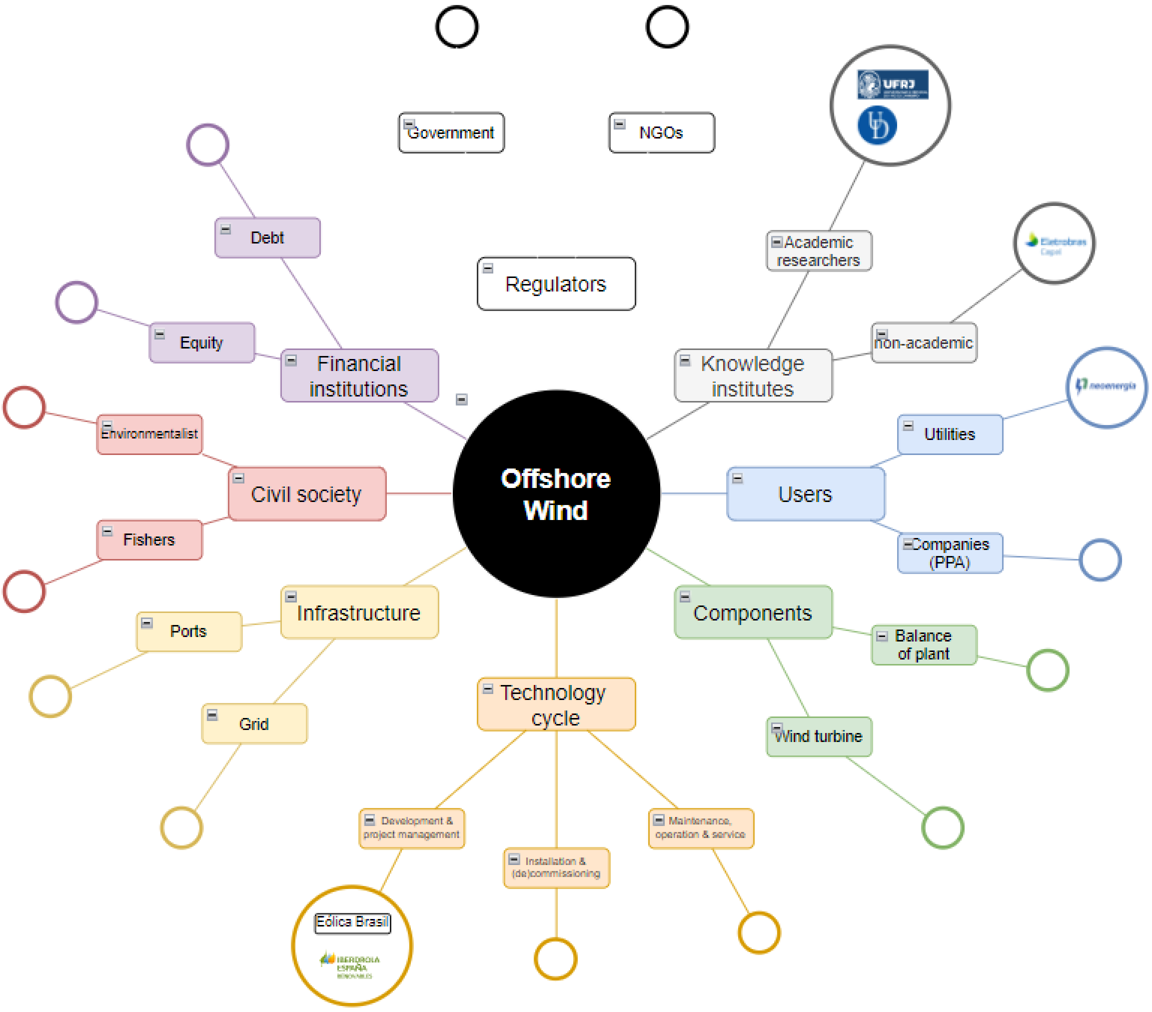

Figure 51 – Snapshot of offshore wind energy technology actors in Brazil in 2010.

From the figure we can see that six actors (Federal University of Rio de Janeiro; University of Delaware; CEPEL; Neoenergia; Eólica Brasil; Iberdrola) have been identified over four different actor divisions (academic researchers; non-academic; utilities; Development & project management). Many of the actor divisions remain empty, which can be identified by the empty ring with no actor logos.

From the data in this period the two networks that could be identified where the published article by UFRJ in cooperation with CEPEL (linkage between academic and non-academic research) and the MoU signed between Neoenergia and Iberdrola (Developer and electricity distribution company). In the platform template these networks are visualized as follows.

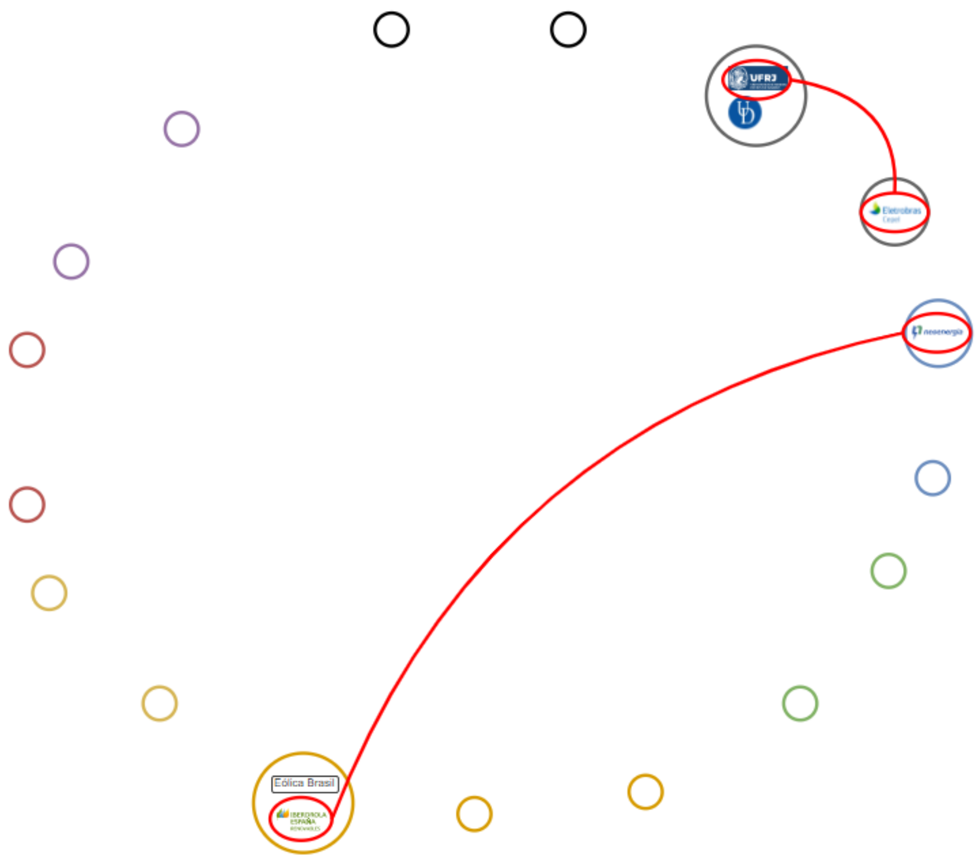

Figure 52 – Snapshot of offshore wind energy technology networks in Brazil in 2010.

As already mentioned in the *technology environment* section of this period, the energy crisis of 2001-2002 had pushed the creation of new regulations. An important one in this period was the PROINFA program which incentivizes the implementation of alternative electric energy sources to the Brazilian electricity matrix. This did indeed lead to the installation of the first onshore wind energy project in Brazil as an alternative source (ONS, 2022). Although this program did not lead to the installation of offshore wind projects, it helped as an incentive to look at the technology as the first start-up was set up during that period.
The energy crisis also gave a better perspective on the effects of extreme weather conditions and their relation to climate change. This has incentivized auctions specifically designed for renewable energy generators and the National Climate Change Policy. The identified institutions for this time period can be seen below as they are presented in the platform template.

Institutions	Description
Laws 8.987/1995 and 9.074/1995	Address the process of granting concessions and authorizations for power generation.
Law 10.438/2002	Institutes the Incentive Program for Alternative Sources of Electric Energy PROINFA, being the first legislative act to encourage the implementation of renewable sources in the Brazilian matrix.
Law 10.848/2004 and Decree 5.163/2004	Allow the participation of wind sources in the auctions of energy in the Regulated Contracting Environment (ACR) to serve the distributors.
Law 6.048/2007	Amended for auctions specifically designed for renewable energy generators.
Law 12.187/2009	National Climate Change Policy to reduce emissions of greenhouse gases and mitigate climate change.

Figure 53 – Snapshot of offshore wind energy technology institutions in Brazil in 2010.

5.1.3 TIS Functions Analysis

Data has been gathered relating to offshore wind in Brazil and where possible each datapoint has been attributed to a function, or more specifically, an indicator. A summary of the found data and their respective indicators can be seen below as well as the final TIS snapshot for the year 2010 as is seen in the platform template.

Function 1 – Entrepreneurial activities			**Score (1 to 5)**
1	New entrants	1 → Iberdrola (OffshoreWind.biz, 2010); New entrants are rated as weak.	2
2	Experiments	0; Experiments are rated as absent.	1
3	Start-ups	1 → Eólica Brasil (CNPJ, 2002); Start-ups are rated as weak.	2
4	Diversification activities	1 → Neoenergia (OffshoreWind.biz, 2010); Diversification activities are rated as weak.	2
	Total Score Function 1	Based on the average score of the indicators, the function fulfilment of *entrepreneurial activities* is *weak*. There are too few new entrants, start-ups and diversification activities and experiments are absent. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Germany a 5 for having high quantity of all necessary actors in the value chain and for having some experimental projects. They have given the Netherlands and Denmark a 4 for missing a few actors in some parts of the value chain. They have given the UK a 3 for missing even more actors in the value chain compared to the previous two countries. Sawulski et al. (2019) scored offshore wind in Poland with a 4 because "the number of companies who are active and ready-to-be active is significant" and "companies are active in almost all elements of value chains". Nothing was further mentioned about experimental projects but they made use of other indicators related to innovation capacity.	**2**

Function 2 – Knowledge development			**Score (1 to 5)**
1	R&D projects	0; R&D Project are rated as absent.	1
2	Demonstration projects	0; Demonstration projects are rated as absent.	1
3	Patents	0; Patents are rated as absent.	1
4	Journal publications	2 → UD, UFRJ (Scopus, 2022); Journal publications are rated as weak.	2
5	Prototypes	0; Prototypes are rated as absent.	1
	Total Score Function 2	Based on the average score of the indicators, the function fulfilment of *knowledge development* is *absent*. There are too few journal publications and R&D projects, demonstration project, patents and prototypes are absent. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Denmark a 5, Germany and the Netherlands a 4 and UK a 3. All four countries had enough competent actors for knowledge development and had running R&D projects. In Germany and UK the knowledge production was spread out over a large number of organizations while in Denmark and the Netherlands this was concentrated in a smaller number of institutes. The knowledge generation sources and outputs were in larger amounts in Denmark, followed Germany with a large amount specifically on patents and the Netherlands with a large number of publications. The UK lagged behind a bit in these aspects. Sawulski et al. (2019) scored offshore wind in Poland with a 2. This score is based on 55 publications from multiple research institutes and companies, 2 patents and the absence of R&D and demonstration projects. The rest of the score is base on the quality of knowledge which was also regarded as weak.	**1**

Function 3 – Knowledge diffusion			Score (1 to 5)
1	Workshops	0; Workshops are rated as absent.	1
2	Conferences	0; Conferences are rated as absent.	1
3	Network activities	0; Network activities are rated as absent.	1
4	Webinars	0; Webinars are rated as absent.	1
	Total Score Function 3	Based on the average score of the indicators, the function fulfilment of *knowledge diffusion* is *absent*. The workshops, conferences, networks activities and webinars are all absent. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Denmark and Germany a 5, Netherlands a 4 and UK a 3. In all four countries there were strong national research networks, good industrial cooperation and strong lobby/political networks. These points were perceived as excellent in Denmark and Germany and good in the Netherlands and the UK. The UK also fell behind on linkages between knowledge institutes and industry which pushed its score further down compared to the other countries. Sawulski et al. (2019) scored offshore wind in Poland with a 3. This score is based on that stakeholders are able to acquire knowledge relating to the technology through a lot of different channels, however the ties between knowledge institutes and industry do not appear to be so strong as industry gets most of its knowledge from foreign sources.	**1**

Function 4 – Guidance of the search			Score (1 to 5)
1	Long term targets	No data; Long term targets are rated as absent.	1
2	Expressed visions	No data; Expressed visions are rated as absent.	1
3	Expectations	No data; Expectations are rated as absent.	1
4	Demand articulation	No data; Demand articulations are rated as absent.	1
	Total Score Function 4	Based on the average score of the indicators, the function fulfilment of *guidance of the search* is *absent*. Long term targets, expressed visions, expectations and demand articulation are all absent. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Denmark a 3, Germany a 5, Netherlands a 2 and UK a 4. In all countries offshore wind was still expensive compared to fossil fuel technologies and would depend on nationally-financed schemes. The expectation in all of them was that there was a big market and potentially a great return on investment. The difference in grades were mainly due to the clear commitment of the German government to offshore wind and the well-functioning feed-in tariff they applied, the UK government's plans to reduce the carbon intensity of the power sector with offshore wind as a crucial element, the Danish heavy energy taxation on renewable electricity and the Dutch government's unclear and unstable framework to support the technology. Sawulski et al. (2019) scored offshore wind in Poland with a 2. This was because there was a "lack of a clear vision for the development of the Polish offshore wind sector", the expectations varied between actor groups and there used to be a target for the technology of 500MW but this had gone out of date.	**1**

Function 5 – Market formation			Score (1 to 5)
1	Specific tax regimes	No data; Specific tax regimes are rated as absent.	1
2	Policy instruments	PROINFA (Eletrobras, 2022), National Climate Change Policy (IEA, 2022); Although offshore wind gained some form of advantage over fossil fuel intensive technologies, the instruments did not help sufficiently compared to other more developed technologies that also benefited from the policies. Policy instruments are rated as weak.	2
3	Size of the market	No data; Size of the market is rated as absent.	1
	Total Score Function 5	Based on the average score of the indicators, the function fulfilment of *market formation* is *weak*. The policy instruments that have been introduced, insufficiently help the development of offshore wind. Specific tax regimes and the size of the market are absent. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Germany a 5, UK a 4, Denmark and Netherlands a 2. Denmark and the Netherlands both had low numbers in new installations and planned projects. The taxes for offshore wind in Denmark were problematic and the Policies in the Netherlands were not favourable for offshore wind. Germany had high ambitions and consented projects for the coming years, as did the UK but in a smaller amount. Sawulski et al. (2019) scored offshore wind in Poland with a 2. This is because there were no installed and consented projects, the tax regime is inexistent and there were unclear policies with respect to the development of the technology.	**1**

Function 6 – Resources mobilization			Score (1 to 5)
1	Education	No data; Education is rated as absent.	1
2	Specialized training programs	No data; Specialized training programs are rated as absent.	1
3	Public seed money	No data; Public seed money is rated as absent.	1
4	Private investments	No data; Private investments is rated as weak.	1
5	Infrastructure	The ports are not yet equipped to house offshore wind projects and the grid has to be expanded to allow new connections of high capacity without congestion (EPE, 2020); Infrastructure is rated as weak.	2
	Total Score Function 6	Based on the average score of the indicators, the function fulfilment of *market formation* is *absent*. Although the infrastructure exists it is not able to house offshore wind and there have been no sign of port or grid actors involvement in the technology. Education, specialized training programs, public seed money and private investments are absent. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given the financial resources for offshore wind in Germany and UK a 4, Denmark a 3 and Netherlands a 2. There was “no strong evidence that the availability of financial resources (capital costs) has been very problematic”, however they would all need increased levels of investments in the projects, technology development, grid and ports. In Germany a state-owned development bank provided €5 billion of financing to 10 offshore wind farms. UK had a commitment to offshore wind of 2 billion pound per annum. The Netherlands had seen its subsidy being removed until the price of the technology would decrease. The Human resources for Germany and Denmark were given a 4, Netherlands a 3 and the UK a 2. All four had to make an attempt to increase the number of courses and trainings. In Germany and Denmark the field was attractive for professionals, while in the Netherlands there were doubts about the career prospects and in the UK it was more beneficial to work in the oil and gas sector. For physical resources all countries scored moderate except for the UK which had scored weak. Primarily the problems for all countries related to the cost of the technology due to the materials, the variety of manufacturing processes and the required upgrades to the grid. Sawulski et al. (2019) scored offshore wind in Poland with a 3. This score is based on the availability of well trained polish engineers who are operating in offshore wind markets outside of Poland which could potentially operate in the market once it gets started and that “there is a general consent, that the money is available on the market” however no specific amount and were it would come from is mentioned.	**1**

Function 7 – Creation of legitimacy			Score (1 to 5)
1	Actions that legitimize technology	No data; Actions that legitimize technology are rated as absent.	1
2	Level of competition between technologies	No data; Level of competition between technologies are rated as absent	1
	Total Score Function 7	Based on the average score of the indicators, the function fulfilment of *market formation* is *absent*. No data could be found, relating to actions that legitimize the technology and the level of competition between the technologies, specifically for offshore wind. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Germany, UK and Denmark a 4 and Netherlands a 3. All four countries had national renewable energy targets which were implemented to reduce the share of fossil fuels. This was advantageous for offshore wind compared to fossil fuel technologies, however other renewable technologies also benefited from these targets. In Germany and the UK clear national targets and well developed support programmes were present for offshore wind specifically. In Denmark, offshore wind was also seen as a major future contributor to the energy production, while in the Netherlands “the lack of vision, absence of any consistent programme and poor subsidy scheme, are the factors most limiting the legitimacy of this renewable”. Furthermore, “in none of the analysed countries is there significant opposition to offshore wind farms as long as the wind turbines are not visible from the shore and there is no huge impact of construction on the local public”. Sawulski et al. (2019) scored offshore wind in Poland with a 2. This was based on that social resistance against investments in offshore wind seemed marginal, only a few remarks had been made by particular interest groups (e.g. maritime fishing industry and sea traffic controllers), companies expected actions by environmental activists, but most importantly weighing the score down was because of “the complexity of the permission procedures and the costs associated with this issue”.	**1**

Below a snapshot of the TIS Functions Analysis section is given for offshore wind in Brazil in the year 2010 as can be seen in the platform template.

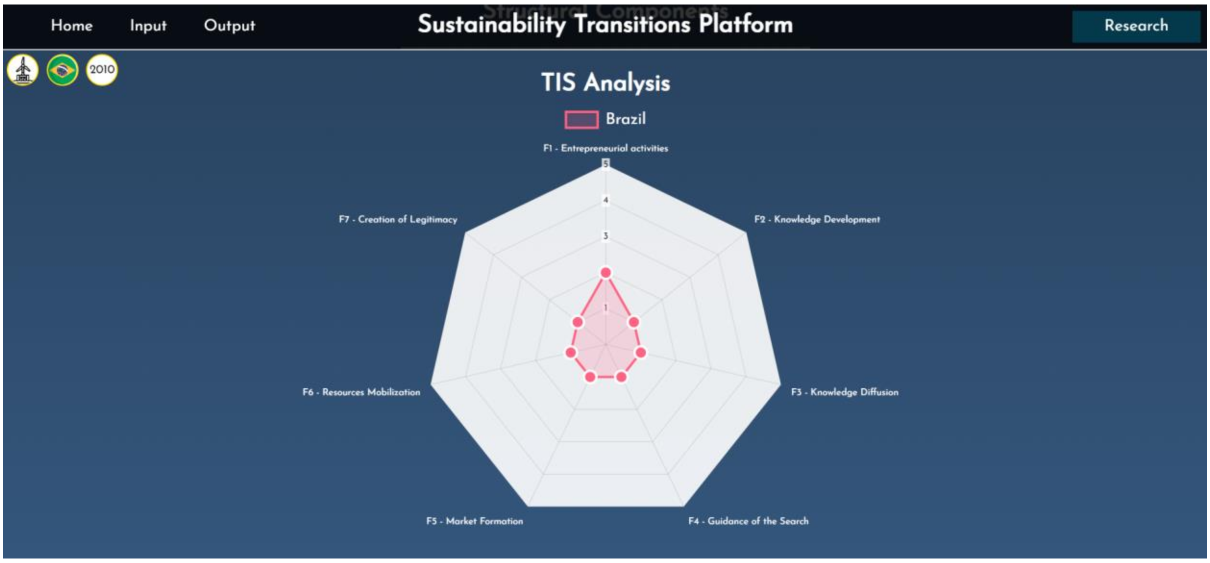

Figure 54 - Platform Snapshot of Brazilian Offshore Wind TIS in 2010.

Here again we see the technology-country combination (offshore wind – Brazil) and the specific year (2010) depicted on the top left and in the centre the spider diagram as is being used in TIS studies to present the results of the functions analysis. Each extremity of the diagram represents one of the functions being used in the research and the red dots represent the score of each function for offshore wind in Brazil. In this case we can see that only function 1 – entrepreneurial activities received a score of 2 (weak) and the rest of the functions, from 2 to 7, all scored a 1 (absent).
Through the functions analysis a score for each function has been determined. The average of these function scores determines the final TIS score that gets inputted in the *technology environment* section of the platform. For this period the TIS score for offshore wind in Brazil equals 1.1. This value has determined the vertical position for offshore wind on the graph in Figure 50.
As discussed in Section 4.3.3, taking the average value of the functions does not represent the functionality of the system correctly, since each function individually should be fulfilled. It does however give a simple and visually easy way of representing how the system is doing on average.

5.1.4 Period Results

By looking at the results as presented in the platform template, for this period from 2002 to 2010, the following points stand out.

Technology environment
Electricity generation in Brazil has been dominated by hydropower. Given the extreme droughts that the country has been experiencing, which have a negative effect on the hydropower reservoirs, and the increasing demand for electricity, opportunities have opened for other technologies to increase their share or enter in the Brazilian electricity mix. This opportunity was seized by onshore wind technology, which entered as a new technology, and nuclear, biomass, gas and oil, which increased their share of total installed capacity. Nevertheless, during the whole period more than half of all new installed capacity still came from hydropower. Offshore wind was not able to take advantage of this opportunity as it would appear.

Structural components
By looking at the structural components it becomes clearer why offshore wind has not been able to take advantage of this window of opportunity yet. There are very few actors involved in the technology. A few knowledge institutes have started to generate and share knowledge about the technology, however the limited number is insufficient to give a sufficient understanding of the technology. The first entrepreneur, has seen the opportunity and decided to act on it by starting up a company specific for offshore wind in Brazil (Eólica Brasil), and an existing foreign company (Iberdrola) has taken first steps to enter the market through a linkage with utility company (Neoenergia). However, no activity has been seen with respect to the technology from regulators, financial institutions, civil society, infrastructure and component suppliers. From the institutions it can be seen that there is a desire to diversify the electricity mix to reduce the dependency on hydropower and that preferably this diversification happens through other renewable sources, however none of the institutions are specifically designed for offshore wind which leaves it competing with other more developed renewable energy technologies.

TIS analysis
These shortcomings in the structural components are in line with the fulfilment of the functions as all of them are either weak or absent. Only a few indicator have shown some form of data from the analysis. This of course can be expected from a newly developing technology. From the platform results it can be seen that in all aspects improvements have to made for the technology to develop.

5.2 Period 2011-2016

5.2.1 Technology Environment

Entering this new period the landscape pressures had taken a turn. The consecutive droughts were followed by intense localized rainfalls between 2011 and 2014 which resulted in floods and mudslides, which in turn caused many casualties (Câmara dos Deputados, 2022). In 2014 and 2015 droughts started to come again (Getirana et al., 2021), making Brazil juggle between extreme weather conditions.

The electricity consumption was still growing at a 4% rate at the beginning of the period, but in 2015 and 2016 the consumption slightly decreased (IEA, 2022). In this case not only because the water basin levels were low, but also because Brazil had entered an economic unfavourable period with GDP hitting -3.5% and -3.3% in 2015 and 2016, respectively (The World Bank, 2022). The consumption levels can be seen in the figure below.

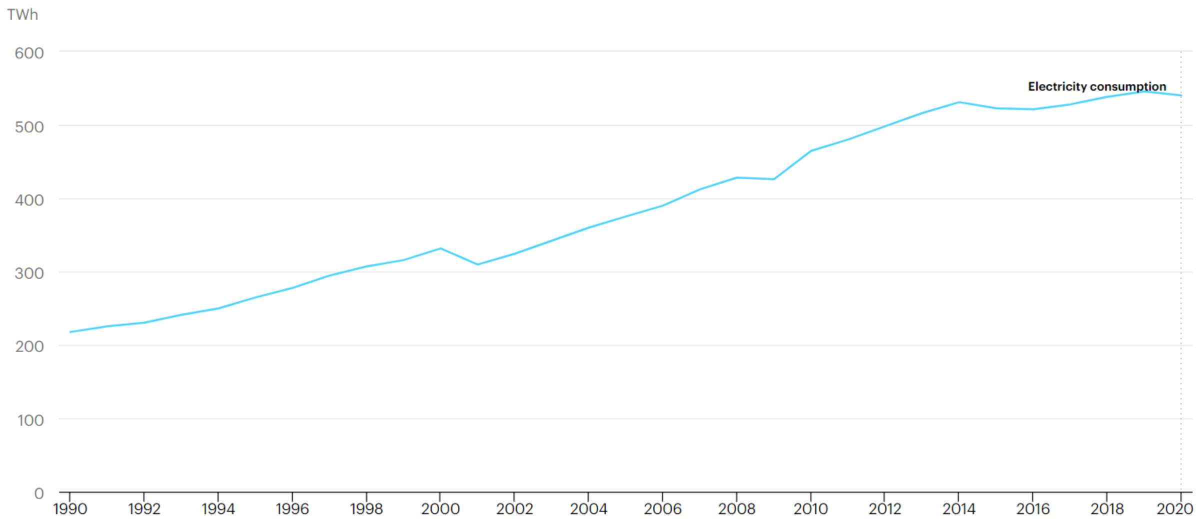

Figure 55 - Electricity consumption in Brazil between 1990 and 2020 (IEA, 2022).

Another landscape factor that Brazil has suffered from is the high corruption activities, specifically involving state-owned enterprises (The World Bank, 2019). In 2014, an investigation was started which eventually exposed one of the largest corruption scandals in the world. It was known as Operation Car Wash (Operação Lava Jato in Portuguese) and involved construction companies and state-owned companies which had embezzled billions of dollars in contracts and money laundering schemes (The World Bank, 2019). Two highlighted companies in this scandal are Odebrecht and Petrobras, which were two of the worst offenders among the many other companies involved. Corruption has been deeply rooted in the regulatory and political framework of Brazil. Luiz Inácio Lula da Silva (better known as Lula), the Brazilian President from 2003 to 2010, was convicted in 2017 for his involvement in money laundering and corruption, among which his involvement in operation car wash, and was eventually arrested in 2018 (OAB, 2018). The same corruption scandal also resulted in the impeachment of then President Dilma Rousseff in 2016 (Watts, 2016). Following this scandal Brazilian state-owned enterprises are required to publish reports about their corporate governance and sustainability according to the Global Reporting Initiative. Transparency International yearly divulges the 'corruption perceptions index'. This is an "indicator of perceptions of public sector corruption, i.e. administrative and political corruption" rated from 0 = highly corrupt to 100 = clean. In 2015 Brazil had a score of 38 on this index. The global average was then 43.

During this period hydropower remained by far the technology with the largest installed capacity and also had the largest amount of new installed capacity. It did however lose share in total installed capacity as onshore wind got a huge boost in installations and grew from 0.5% in 2010 to 6.8% in 2016.

The other technologies saw some slight increases but their share remained almost the same and Solar PV was able to enter the market with a first 10 MW project. Offshore wind remains with no installed capacity, however the first project consisting 576 MW has entered the pipeline for development and is running through the environmental assessment. The main data relating to the technologies can be seen in the following table.

Table 8 - Brazilian electricity generating technologies data for the year 2016. (ONS, 2022)

Technology	Total Installed Capacity (cumulative) [MW]	Installed Capacity (year) [MW]	Electricity Generated (year) [GWh]	LCOE [$/MWh]
Hydropower	98,721 (71.4%)	5,029 (57.6%)	406,024 (74.4%)	No data
Gas	9,911 (7.2%)	338 (3.9%)	34,613 (7.2%)	No data
Onshore Wind	9,390 (6.8%)	2,494 (28.6%)	31,383 (5.8%)	No data
Oil	3,727 (2.7%)	0 (0%)	11,940 (2.5%)	No data
Biofuels	3,379 (2.4%)	144 (1.6%)	11,538 (2.4%)	No data
Coal	3,103 (2.2%)	0 (0%)	11,135 (2.3%)	No data
Nuclear	1,990 (1.4%)	0 (0%)	15,864 (2.9%)	No data
Solar PV	10 (0.0%)	0 (0%)	31 (0.0%)	No data
Offshore Wind	0 (0%)	0 (0%)	0 (0%)	No data
Other	8,056 (5.8%)	729 (8.3%)	23,075 (4.8%)	
Total	**138,287 (100%)**	**8,734 (100%)**	**545,602 (100%)**	

By compiling all this data into the platform template, the *technology environment* section gets presented in the outputs as can be seen in the figure below.

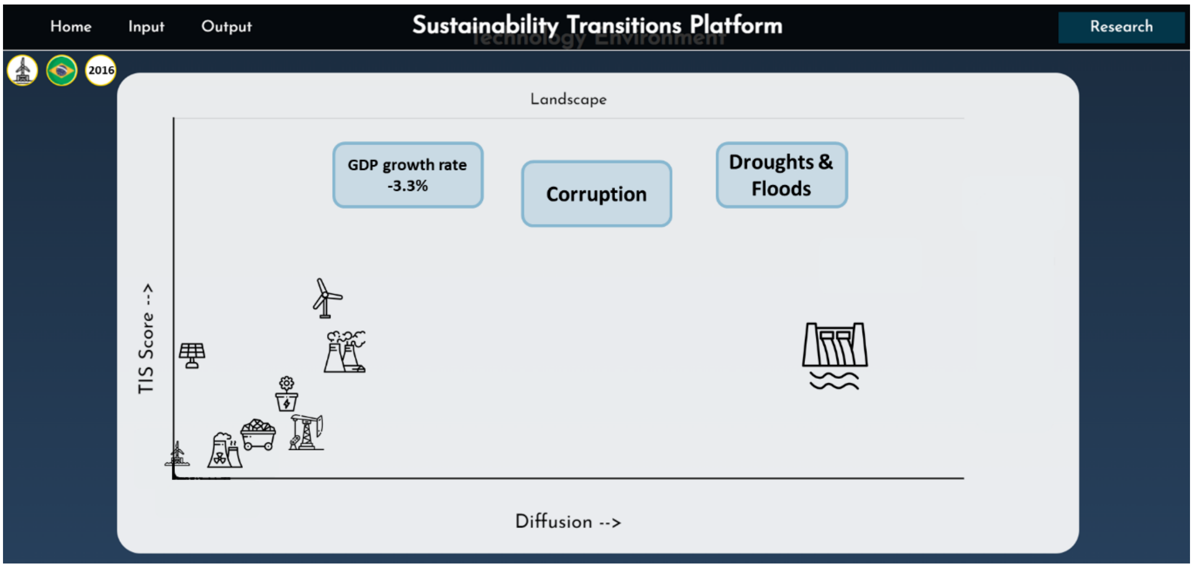

Figure 56 - Platform representation of the Technology Environment. Includes all technologies and landscape factors influencing offshore wind energy in Brazil in the year 2016.

Here, once again, we see the landscape factors represented at the top of the graph in the blue boxes. In this case three landscape factors are presented, being i) GDP growth rate at -3.3%, ii) droughts and iii) corruption. Although corruption could probably also have been included in the previous period, since corruption had also been a problem then, it was only included in this one period because of the scale 'operation car wash' had and the effect it had on Brazil as a whole.

The technology positions on the graph have had some shifts compared to the previous period. Onshore wind has moved to the right becoming the second most diffused niche behind gas. This would be in accordance with the high estimated TIS score it already had. Coal, oil and nuclear remain at the bottom side of the graph with low TIS scores, although their installed capacity increases in the next period, it is far less than the other technologies increase. Hydropower continues to diffuse but the rate at which it is happening is slowing down, pushing the technology a bit towards the left again. Solar PV has started to diffuse with its first installation and as we know from the following years the new installations with substantially increase relating to a higher TIS score in this graph for the technology.

5.2.2 TIS Structural Components

During this period some initial activity was identified from actors that supply components, work on installation and commissioning and deliver other technology services. Such as, Offshore Wind Power Systems of Texas who signed an MoU with Eólica Brasil over the supply of a mobile offshore jack-up platform for meteorological testing (Navingo, 2022) and Keppel Corporation building offshore support vessels in anticipation of demand for offshore wind (Navingo, 2022). It also marked the first moment in which an offshore wind project was submitted for environmental assessment, which is one of the first steps towards developing a project. This project was submitted by BI Energia to the governmental agency IBAMA (who is responsible for the environmental assessment) and consists of a 576 MW wind farm of 48x12MW GE Haliade-X wind turbines (IBAMA, 2022). Nevertheless, most of the events identified where linked to research institutes. There was an increase in both academic (mostly Brazilian universities) and non-academic (international research companies) actors which generated knowledge with respect to the technology in Brazil and presented them in the form of papers and reports. Also important to highlight in this period is the increased activity from regulators with respect to the technology. In 2015 Brazil had sworn in the new energy minister, Eduardo Braga, who said he wanted to open the doors for ocean energies and push the federal government to begin studies on offshore wind. Other regulating actors that marked their initial presence are the Global Wind Energy

Council (GWEC), who developed a roadmap for offshore wind in upcoming markets such as Brazil and India, and the International Energy Agency (IEA) who researched and presented the estimated costs of renewable energies for different countries among which offshore wind in Brazil. The visual representation of the actors at the end of this period are as follows.

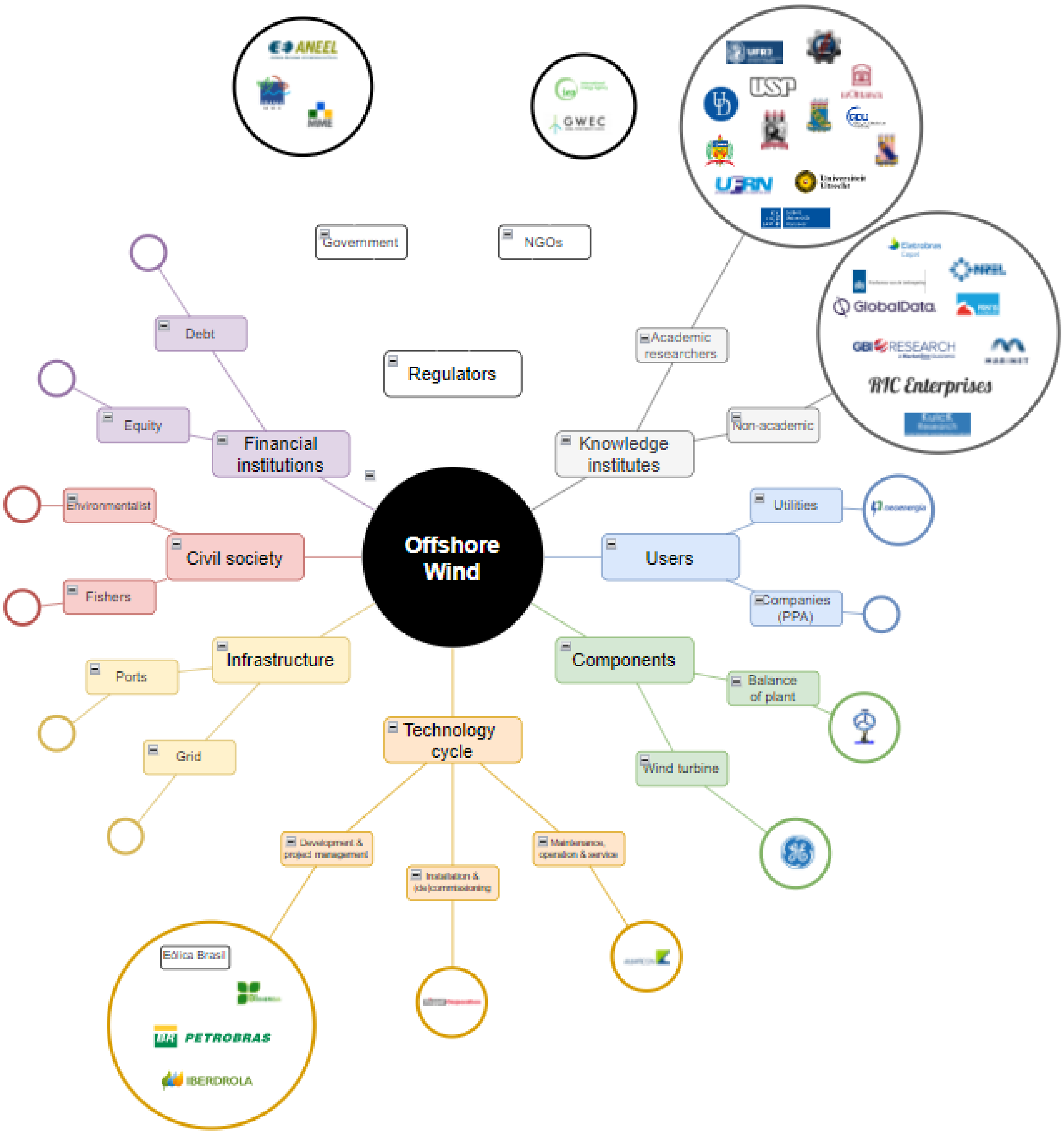

Figure 57 - Snapshot of offshore wind energy technology actors in Brazil in 2016.

Compared to the previous period (see Figure 51) we see that the amount of actors has been increasing. Most of them in the knowledge institutes actor group, being an equal distribution between academic and non-academic researchers, but we can also see that other actor groups, such as regulators, component manufacturers/suppliers and technology cycle, have entered the Brazilian offshore wind TIS. There are however still actor groups missing, such as financial institutions, civil society and infrastructure.

Most of the networking activity in this period was encountered with and within academic research actors. This is something that might also be expected when there is still much not known relating to a technology in a specific environment. Other networks were between developers and component suppliers and a government institute.

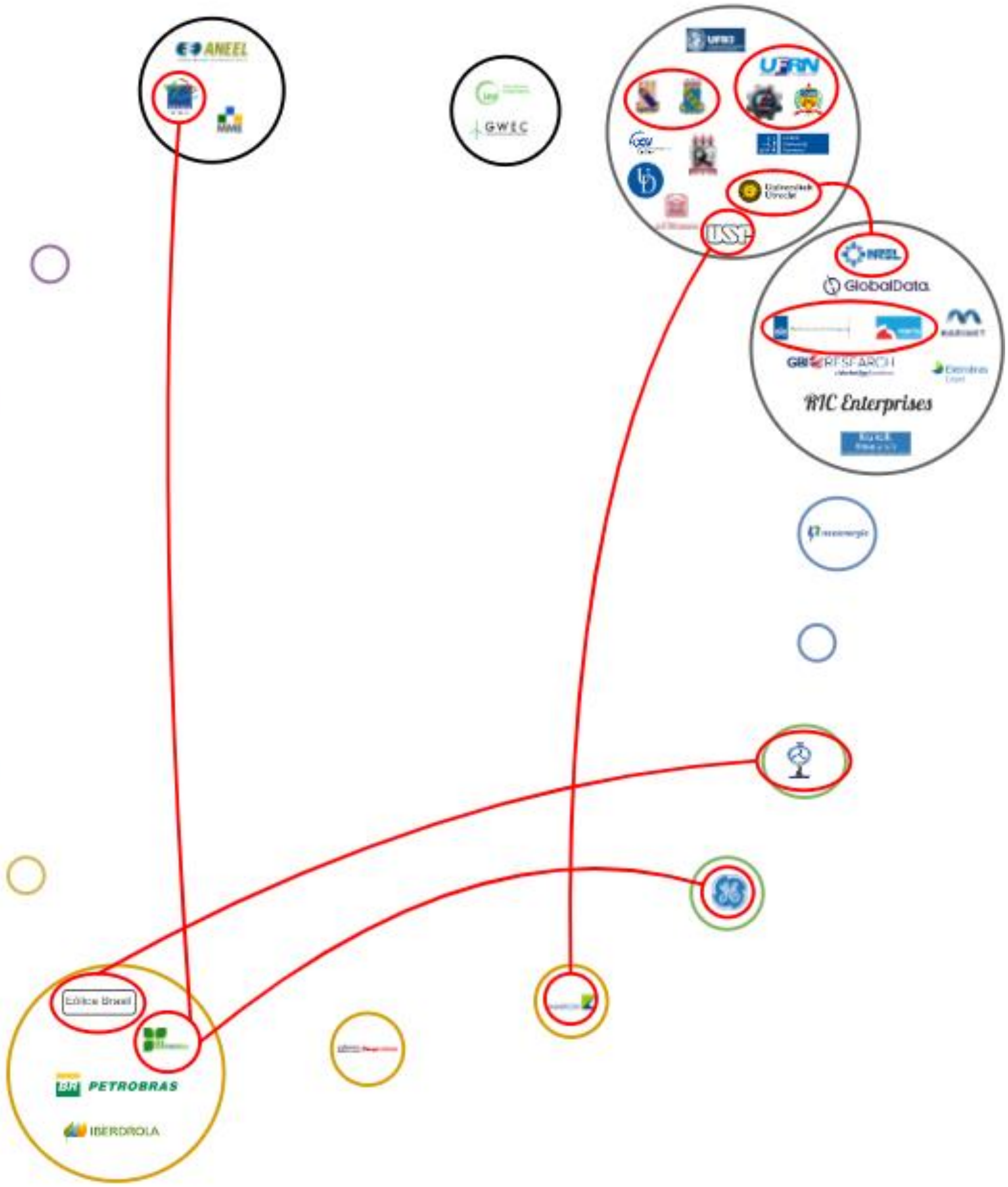

Figure 58 - Snapshot of offshore wind energy technology networks in Brazil in 2016.

From the figure we can see that also the amount of network linkages has increased. Still, there appears to be only one actor (BI Energia) which has a linkage with more than one different actor group. Another thing that stands out is that the linkages between the knowledge institutes actor group are amongst themselves.

During this period the same institutions were applicable as the previous period except that the PROINFA program was closed on 31st December 2011 because the two goals were met:

- Goal 1: 3,300 MW of renewable energy installed before the end of 2007 through a system of subsidies and incentives.
- Goal 2: increasing the share of electricity produced by three renewable sources to 10% of annual consumption within 20 years. This happened in 2011 already through wind, biomass and small hydroelectric sources.

Decree 656 was introduced which exempts manufacturers from paying tax on components for wind turbines. The tax exemption would hold for both on- and offshore wind turbines (Presidência da República, 2014).

Institutions	Description
Laws 8.987/1995 and 9.074/1995	Address the process of granting concessions and authorizations for power generation.
Law 10.438/2002	Institutes the Incentive Program for Alternative Sources of Electric Energy PROINFA, being the first legislative act to encourage the implementation of renewable sources in the Brazilian matrix.
Law 10.848/2004 and Decree 5.163/2004	Allow the participation of wind sources in the auctions of energy in the Regulated Contracting Environment (ACR) to serve the distributors.
Law 6.048/2007	Amended for auctions specifically designed for renewable energy generators.
Law 12.187/2009	National Climate Change Policy to reduce emissions of greenhouse gases and mitigate climate change.
Executive Decree 656/2014	exempts manufacturers to pay Social Integration Program (PIS) and Contribution to Social Security Ficing (COFINS) tax on components purchased for wind turbines production.

Figure 59 - Snapshot of offshore wind energy technology institutions in Brazil in 2016.

5.2.3 TIS Functions Analysis

The data until 2016 has been gathered and divided into functions and indicators as presented in the following tables. Based on the data a TIS snapshot has been built in the platform template that represents the status of the Brazilian offshore wind TIS in 2016.

	Function 1 – Entrepreneurial activities		Score (1 to 5)
1	New entrants	4 → GE, Keppel Corporation, Offshore Wind Power Systems of Texas, Iberdrola (OffshoreWind.biz, 2010); New entrants are rated as moderate.	3
2	Experiments	0; Experiments are rated as absent.	1
3	Start-ups	1 → Eólica Brasil (CNPJ, 2002); Start-ups are rated as weak.	2
4	Diversification activities	2 → Petrobras (Scopus, 2016), Neoenergia (OffshoreWind.biz, 2010); Diversification activities are rated as weak.	2
	Total Score Function 1	Based on the average score of the indicators, the function fulfilment of *entrepreneurial activities* is *weak*. Although new entrants are at a moderate level and one of the leading O&G companies in Brazil (Petrobras) has started to look at its options in offshore wind, there are too few diversification activities and start-ups entering the market and experiments are absent. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Germany a 5 for having high quantity of all necessary actors in the value chain and for having some experimental projects. They have given the Netherlands and Denmark a 4 for missing a few actors in some parts of the value chain. They have given the UK a 3 for missing even more actors in the value chain compared to the previous two countries. Sawulski et al. (2019) scored offshore wind in Poland with a 4 because "the number of companies who are active and ready-to-be active is significant" and "companies are active in almost all elements of value chains". Nothing was further mentioned about experimental projects but they made use of other indicators related to innovation capacity.	**2**

Function 2 – Knowledge development			Score (1 to 5)
1	R&D projects	0; R&D Project are rated as absent.	1
2	Demonstration projects	0; Demonstration projects are rated as absent.	1
3	Patents	0; Patents are rated as absent.	1
4	Journal publications	11 → UFRN, USP, UU, LUH, UO, PBL, NREL, UFPE, RIC Enterprises, UNIFEI, UFSC, UFC, GCU, UD, UFRJ (Scopus, 2022); Journal publications are rated as moderate.	3
5	Prototypes	0; Prototypes are rated as absent.	1
	Total Score Function 2	Based on the average score of the indicators, the function fulfilment of *knowledge development* is *weak*. There are some journal publications that have been carried out by different actors, but R&D projects, demonstration project, patents and prototypes are absent. Relative to other papers this score seems to be acceptable because Wieczorek et al. (2013) have given offshore wind in Denmark a 5, Germany and the Netherlands a 4 and UK a 3. All four countries had enough competent actors for knowledge development and had running R&D projects. In Germany and UK the knowledge production was spread out over a large number of organizations while in Denmark and the Netherlands this was concentrated in a smaller number of institutes. The knowledge generation sources and outputs were in larger amounts in Denmark, followed Germany with a large amount specifically on patents and the Netherlands with a large number of publications. The UK lagged behind a bit in these aspects. Sawulski et al. (2019) scored offshore wind in Poland with a 2. This score is based on 55 publications from multiple research institutes and companies, 2 patents and the absence of R&D and demonstration projects. The rest of the score is base on the quality of knowledge which was also regarded as weak.	**1**

Function 3 – Knowledge diffusion			Score (1 to 5)
1	Workshops	1 → GWEC (GWEC, 2016); Workshops are rated as weak.	2
2	Conferences	0; Conferences are rated as absent.	1
3	Network activities	0; Network activities are rated as absent.	1
4	Webinars	0; Webinars are rated as absent.	1
	Total Score Function 3	Based on the average score of the indicators, the function fulfilment of *knowledge diffusion* is *absent*. Only one workshops has been given and conferences, networks activities and webinars are absent. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Denmark and Germany a 5, Netherlands a 4 and UK a 3. In all four countries there were strong national research networks, good industrial cooperation and strong lobby/political networks. These points were perceived as excellent in Denmark and Germany and good in the Netherlands and the UK. The UK also fell behind on linkages between knowledge institutes and industry which pushed its score further down compared to the other countries. Sawulski et al. (2019) scored offshore wind in Poland with a 3. This score is based on that stakeholders are able to acquire knowledge relating to the technology through a lot of different channels, however the ties between knowledge institutes and industry do not appear to be so strong as industry gets most of its knowledge from foreign sources.	**1**

Function 4 – Guidance of the search			Score (1 to 5)
1	Long term targets	No data; Long term targets are rated as absent.	1
2	Expressed visions	The in 2015 appointed minister of MME had expressed that there lie many opportunities for offshore technologies along the Brazilian coast and that more research should be carried out. They did however expect that offshore wind would not be competitive with other sources before 2030 (Offshorewind.biz, 2015); The technology has made an entrance in the political agenda and is expected to have a future in the country, but it will take a very long time and the focus will be on research. Expressed visions are rated as weak.	2
3	Expectations	No data; Expectations are rated as absent.	1
4	Demand articulation	No data; Demand articulations are rated as absent.	1
	Total Score Function 4	Based on the average score of the indicators, the function fulfilment of *guidance of the search* is *absent*. There are expressed visions about offshore wind entering the market but in a distant future. Long term targets, expectations and demand articulation are absent. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Denmark a 3, Germany a 5, Netherlands a 2 and UK a 4. In all countries offshore wind was still expensive compared to fossil fuel technologies and would depend on nationally-financed schemes. The expectation in all of them was that there was a big market and potentially a great return on investment. The difference in grades were mainly due to the clear commitment of the German government to offshore wind and the well-functioning feed-in tariff they applied, the UK government's plans to reduce the carbon intensity of the power sector with offshore wind as a crucial element, the Danish heavy energy taxation on renewable electricity and the Dutch government's unclear and unstable framework to support the technology. Sawulski et al. (2019) scored offshore wind in Poland with a 2. This was because there was a "lack of a clear vision for the development of the Polish offshore wind sector", the expectations varied between actor groups and there used to be a target for the technology of 500MW but this had gone out of date.	**1**

Function 5 – Market formation			Score (1 to 5)
1	Specific tax regimes	Decree 656 → exempts manufacturers from paying tax on components for wind turbines. The tax exemption holds for all types of wind turbines (Presidência da República, 2014); This gives offshore wind a small advantage over other technologies except the fast developing onshore wind technology. Specific tax regimes are rated as weak.	2
2	Policy instruments	National Climate Change Policy (IEA, 2022); The PROINFA program that gave renewables an advantage over fossil fuel intensive technologies has been terminated since the goals had been reached. Only the National Climate Change Policy remained. Policy instruments are rated as weak.	2
3	Size of the market	No data; Size of the market is rated as absent.	1
	Total Score Function 5	Based on the average score of the indicators, the function fulfilment of *market formation* is *weak*. A specific tax regime has been introduced which marginally helps offshore wind compared to renewable competitors, however the policy instruments are weak and the size of the market is absent. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Germany a 5, UK a 4, Denmark and Netherlands a 2. Denmark and the Netherlands both had low numbers in new installations and planned projects. The taxes for offshore wind in Denmark were problematic and the Policies in the Netherlands were not favourable for offshore wind. Germany had high ambitions and consented projects for the coming years, as did the UK but in a smaller amount. Sawulski et al. (2019) scored offshore wind in Poland with a 2. This is because there were no installed and consented projects, the tax regime is inexistent and there were unclear policies with respect to the development of the technology.	**2**

Function 6 – Resources mobilization			Score (1 to 5)
1	Education	No data; Education is rated as absent.	1
2	Specialized training programs	No data; Specialized training programs are rated as absent.	1
3	Public seed money	No data; Public seed money is rated as absent.	1
4	Private investments	No data; Private investments is rated as weak.	1
5	Infrastructure	The ports are not yet equipped to house offshore wind projects and the grid has to be expanded to allow new connections of high capacity without congestion (EPE, 2020); Infrastructure is rated as weak.	2
	Total Score Function 6	Based on the average score of the indicators, the function fulfilment of *market formation* is *absent*. Although the infrastructure exists it is not able to house offshore wind and there have been no sign of port or grid actors involvement in the technology. Education, specialized training programs, public seed money and private investments are absent. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given the financial resources for offshore wind in Germany and UK a 4, Denmark a 3 and Netherlands a 2. There was "no strong evidence that the availability of financial resources (capital costs) has been very problematic", however they would all need increased levels of investments in the projects, technology development, grid and ports. In Germany a state-owned development bank provided €5 billion of financing to 10 offshore wind farms. UK had a commitment to offshore wind of 2 billion pound per annum. The Netherlands had seen its subsidy being removed until the price of the technology would decrease. The Human resources for Germany and Denmark were given a 4, Netherlands a 3 and the UK a 2. All four had to make an attempt to increase the number of courses and trainings. In Germany and Denmark the field was attractive for professionals, while in the Netherlands there were doubts about the career prospects and in the UK it was more beneficial to work in the oil and gas sector. For physical resources all countries scored moderate except for the UK which had scored weak. Primarily the problems for all countries related to the cost of the technology due to the materials, the variety of manufacturing processes and the required upgrades to the grid. Sawulski et al. (2019) scored offshore wind in Poland with a 3. This score is based on the availability of well trained polish engineers who are operating in offshore wind markets outside of Poland which could potentially operate in the market once it gets started and that "there is a general consent, that the money is available on the market" however no specific amount and were it would come from is mentioned.	**1**

	Function 7 – Creation of legitimacy		Score (1 to 5)
1	Actions that legitimize technology	GWEC was lobbying for the start of development of offshore wind in Brazil, which could be perceived through a workshop they organized (GWEC, 2016); Actions that legitimize technology are rated as weak.	2
2	Level of competition between technologies	Although little information was still available about the competitiveness of offshore wind, the expectation from the MME was that it was far from being competitive with other sources (Offshorewind.biz, 2015); Level of competition between technologies is rated as weak.	2
	Total Score Function 7	Based on the average score of the indicators, the function fulfilment of *market formation* is *absent*. The actions that legitimize the technology are few and information is lacking regarding the level of competition between offshore wind and the other technologies albeit that the expectations are low. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Germany, UK and Denmark a 4 and Netherlands a 3. All four countries had national renewable energy targets which were implemented to reduce the share of fossil fuels. This was advantageous for offshore wind compared to fossil fuel technologies, however other renewable technologies also benefited from these targets. In Germany and the UK clear national targets and well developed support programmes were present for offshore wind specifically. In Denmark, offshore wind was also seen as a major future contributor to the energy production, while in the Netherlands "the lack of vision, absence of any consistent programme and poor subsidy scheme, are the factors most limiting the legitimacy of this renewable". Furthermore, "in none of the analysed countries is there significant opposition to offshore wind farms as long as the wind turbines are not visible from the shore and there is no huge impact of construction on the local public". Sawulski et al. (2019) scored offshore wind in Poland with a 2. This was based on that social resistance against investments in offshore wind seemed marginal, only a few remarks had been made by particular interest groups (e.g. maritime fishing industry and sea traffic controllers), companies expected actions by environmental activists, but most importantly weighing the score down was because of "the complexity of the permission procedures and the costs associated with this issue".	**2**

The 2016 TIS functions analysis for offshore wind in Brazil is represented as a TIS snapshot in the platform template and can be seen in the figure below. Here again we see that the red dots portray the score for each function in that specific year. In this case functions 1, 5 and 7 received a score of 2 (weak) and the other functions a score of 1 (absent). This indicates that still a lot has to happen to the TIS in order to speed-up and smoothen the technology generation, diffusion and utilization.

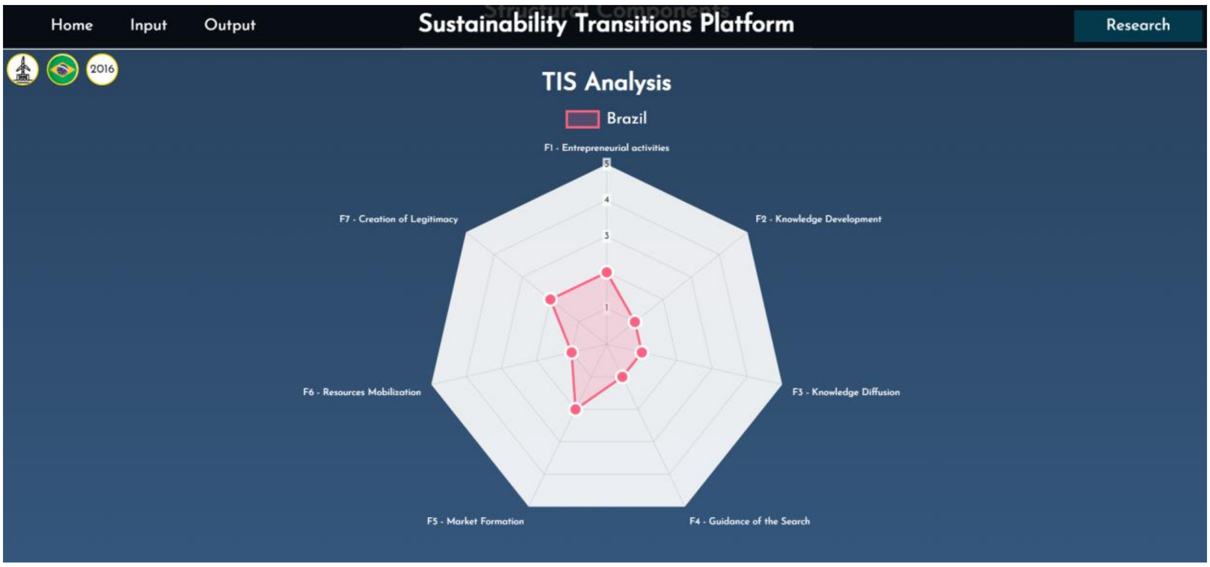

Figure 60 - Platform Snapshot of Brazilian Offshore Wind TIS in 2016.

Through the functional analysis a score for each function has been determined. The average of these function scores determines the final TIS score that gets inputted in the technology environment. For this period the TIS score for offshore wind in Brazil equals 1.4.

5.2.4 Period Results

Looking at the results of this period as presented in the platform, the following points stand out.

Technology environment

The country still continues to suffer from extreme weather conditions alternating between localized intense rainfalls and droughts. In addition, the country has been agonized with corruption including one of the biggest scandals seen in the world known under the name 'operation car wash' which came to light in 2014. During this period Brazil entered a politically unstable and economic unfavourable period with the president being impeached and the GDP growth rate hitting as low as -3.5%.
As for the technologies, the biggest winner of the niche technologies during this period was onshore wind. About 26% of all the newly installed capacity came from onshore wind installations. This was nevertheless still far off from the 45% installed in hydropower (ONS, 2022). During this period a new renewable technology made its entry to the electricity market in Brazil, namely, Solar PV.

Structural components

During this period more actors started to take part in the Brazilian offshore wind TIS. The biggest increase could be seen in knowledge institutes, followed by actors in the technology cycle. Other actor types also started to make an entry, such as regulators and component suppliers/manufacturers. These actors are forming some linkages however the amount and variety in actor groups are still minimal. There are still actor divisions and whole groups missing in the TIS, specifically within financial institutions, civil society, infrastructure and users.
The main changes in the institutions is that the PROINFA program has been terminated which was beneficial for renewables. Offshore wind did not get an opportunity to take advantage of this program. A tax exemption was created for wind turbine components, which is applicable to both on- and offshore wind turbines. From a governmental perspective a belief has risen that there is a future for offshore wind, however it is expected to take a long while and that more research is necessary.

TIS analysis

These shortcomings in the structural components are in line with the fulfilment of the functions as many are still absent with the exception of entrepreneurial activities, market formation and creation of legitimacy which are weak. The latter two have seen new event and increasing scores compared to the previous period. From the platform results it can be seen that in all aspects improvements have to made for the technology to easily emerge and diffuse.

5.3 Period 2017-2021

5.3.1 Technology Environment

Coming into the next and last period of the analysis, Brazil continues to suffer from extreme weather conditions. In May of 2021 the minister of mines an d energy informed that Brazil had to prepare for one of the worst droughts the country has seen in the last century and declared that the country would be in a state of emergency from June until September (Câmara dos Deputados, 2021).
Although the county had seen positive GDP growth rates at the beginning of the period, in 2020 the rate took a steep decline towards -3.9% (The World Bank, 2022). This can for a big part be linked to Brazil (and the rest of the world) being impacted by the COVID-19 pandemic. Many, if not all, customs

and processes were impacted by this landscape effect resulting in insecurity and unknowingness across the different sectors of the country.

By the end of this period, and no different from the previous two periods, hydropower still remained the biggest technology in total installed capacity having now reached around 110 GW. Interesting to point out is that during this 5 year period the newly installed capacity of hydropower and onshore wind were rather similar, namely 36,7% and 33,0%. Following these two came Solar PV with 13.1% and Gas with 10.4%. This showing that the diffusion rate of the alternative renewables onshore wind and solar PV is higher than that of the other technologies. Until now offshore wind remains without installed capacity, however at the end of this period the project pipeline had already increased to 55 GW, which is a lot considering this was only 0.5 GW five years before. The table below represents some of the core figures for the technologies.

Table 9 - Brazilian electricity generating technologies data for the year 2021. (ONS, 2022)

Technology		Total Installed Capacity (cumulative) [MW]	Installed Capacity (year) [MW]	Electricity Generated (year) [GWh]	LCOE [$/MWh]
	Hydropower	110,291 (65.0%)	0 (0%)	365,592 (63.3%)	46.12
	Onshore Wind	19,793 (11.7%)	3,718 (53.0%)	68,887 (11.9%)	33.59
	Gas	13,172 (7.8%)	1,049 (15.0%)	45,140 (9.4%)	51.66
	Solar PV	4,141 (2.4%)	1,206 (17.2%)	7,682 (1.3%)	46.02
	Biofuels	4,080 (2.4%)	479 (6.8%)	16,504 (3.4%)	53.52
	Oil	3,892 (2.3%)	0 (0%)	15,047 (3.1%)	No data
	Coal	3,448 (2.0%)	0 (0%)	13,589 (2.8%)	96.94
	Nuclear	1,990 (1.2%)	0 (0%)	14,704 (2.5%)	No data
	Offshore Wind	0 (0%)	0 (0%)	0 (0%)	59.37
	Other	8,986 (5.3%)	560 (8.0%)	30,093 (6.3%)	
Total		**169,793 (100%)**	**7,012 (100%)**	**577,239 (100%)**	

By compiling all this data into the platform template, the *technology environment* section gets presented in the outputs as can be seen in the figure below.

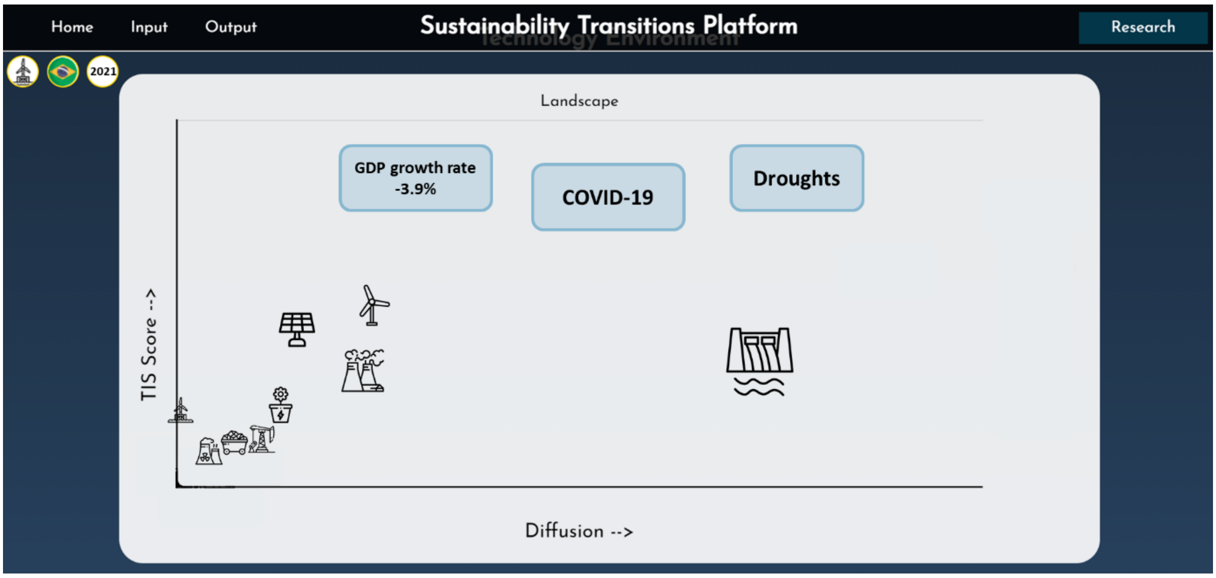

Figure 61 - Platform representation of the Technology Environment. Includes all technologies and landscape factors influencing offshore wind energy in Brazil in the year 2021.

As we can see, the landscape factors have been added in the blue boxes at the top again, being i) droughts, ii) GDP growth rate -3.9% and iii) COVID-19. Hydropower has again slightly lost some shares in total installed capacity and has moved to the left (away from being a full regime). Onshore wind has moved to the right becoming the second most diffused technology and biggest among the niches. Also Solar PV has moved to the left and is now the fourth technology with most installation behind gas, which has also increased. The other technologies have stayed similar in diffusion or slightly lost shares, moving them to the left.

5.3.2 TIS Structural Components

During this period many changes happened in the Brazilian offshore wind TIS. In 2017 the Brazilian senate presented regulation PLS 484/2017 which intended to push the expansion of current regulations to include specific requirements for offshore wind energy. By 2020 the Ministry of Mines and Energy (MME) had announced that regulations specific for offshore wind would be implemented by the end of 2021. In this period a surge of new actors entered the Brazilian offshore wind energy system. Many national (Petrobras, Eólica Brasil, Votu Winds, Bosford Participações, Prumo Logistica, Bravo Vento) and international (Enterprize Energy, Qair, Ocean Winds, Equinor, Sowitec) developers submitted project proposals for environmental licensing at IBAMA. Prumo Logistica signed financing agreements with private equity investors EIG Global Energy Partners and Mubadala and agreements with and port owners Porto do Açu.

This increase in developers also resulted in an increase of turbine suppliers such as Vestas, Siemens Gamesa and MingYang. Even the company Seatwirl which is developing a relative new concept wind turbine decided to explore its chances in the Brazilian market given the good technical conditions and market interest.

Another very important development for offshore wind happened during this period and relates to the users of the technology. The companies Enegix, Fortescue Future Industries and Ammpower saw the large potential in offshore wind as an opportunity to develop their business of generating green hydrogen and ammonia. Different from the other renewable energy technologies in Brazil, the market seems to be forming based on the demand for another type of energy source (hydrogen and ammonia) instead of direct injection to the national electricity grid. This would make the offshore wind TIS very dependent on the hydrogen TIS which is still in an early stage of development globally. Nevertheless, this has boosted the activity around offshore wind as agreements have been signed between hydrogen producers, ports, offshore wind developers and state governments of Ceará and Rio Grande

do Norte, which were the states with highest concentration of submitted offshore wind projects by the end of 2021.
This period also highlighted the technical potential of offshore wind available in the country as both The World Bank and the government energy research company (EPE) released reports highlighting this vast potential, where based on their own analysis The World Bank estimates a technical potential of over 1.000 GW (The World Bank, 2019) and EPE estimates around 700 GW (EPE, 2019b). The roadmap for offshore wind in Brazil published by EPE also presented possible bottlenecks for development of (part of) the 700 GW and included suggestions to overcome these. Furthermore, for the first time the EPE included offshore wind as part of the electricity generating technologies of which the future electricity matrix might consist in its 10 year energy expansion plan (EPE, 2019a). Besides the government energy research company many other academic and non-academic research actors also continued research related to this particular TIS.
An actor specific activity worth mentioning for this period is that of state-owned oil & gas giant Petrobras. In 2018 the company had submitted a single turbine offshore pilot project for environmental licensing at IBAMA (IBAMA, 2022). They had previously been expanding their business model by adding PV and wind energy projects to their portfolio and had been researching the possibility to power their offshore oil & gas platforms with offshore wind turbines. In that same year they also signed an MoU with the Norwegian company Equinor for the development of offshore wind in Brazil. By 2020, Petrobras had withdrawn the pilot project and announced that it would put a halt to its operational activities in renewable technologies and divest the assets it had in that sector. The CEO gave as statement that “if we decide to enter the game [of the renewable energy sector] we want to enter to win, we will not rush in without thinking just because other oil majors are doing so. We don’t want to lose money”. Pointing out that they assume the business was not profitable at that time (Spattuzza, 2019). The company’s involvement in the Lava Jato corruption scandal, and the resulting image and financial problems could also be seen as part of the reason for the change in course of the company.
Another peculiarity during this time period relates to the wind associations active in Brazil. ABEEólica is the biggest wind energy association in Brazil and has helped in the development of onshore wind energy in Brazil partially to its strong ties with the Ministry of Mines and Energy and the Global Wind Energy Council (GWEC). Marcello Storrer, CEO of the Brazilian offshore wind development company Eólica Brasil who had been trying to set up the first Brazilian project since 2002, suggested that the focus of ABEEólica was solely directed towards onshore wind and that its lobbying activities towards the MME were actually hampering progress for offshore wind. He went on to set up a new association in 2017 called ABEMAR, who’s purpose was to lobby specifically in favour of offshore wind energy in Brazil (ABEMAR, 2020). One of the core statements from the association is that the existing legal framework is sufficient for development of offshore wind in Brazilian waters and that the plan of the MME to create a new framework is unnecessary and is delaying development of the technology. Around 2020 ABEEólica started to promote itself more as the association of both onshore and offshore wind as big part of its associates were involved in both technologies and were looking to develop further in both directions[4] (ABEEólica, 2022).

An overview of the actors as seen in the platform template can be seen in Figure 62. At a first glance we can see that most of the actor divisions have at least one actor present. The divisions in which no actor activities were identified for offshore wind are *debt*, *environmentalist*, *fishers* and *grid*. Compared to the previous period we see that the amount of actors in *knowledge institutes* has continued to increase. The amount of developers has also seen a big increase, but the most interesting actors that have appeared for this period are the *companies (PPA)* from the *users* group, which differently from utility companies that distribute energy to customers on the grid, use the electricity generated by the technology for their own business purposes and can increase the security of their

[4] In 2022 the association eventually changed its logo to encompass both onshore and offshore wind equally and included new technologies to its operational field in order to include hydrogen.

energy costs through long term agreements with the electricity providers at a fixed price. This reduces the risk for both the electricity producing and consuming parties. This is interesting for a technology that has to compete with other more developed and cheaper renewable technologies for grid injection.

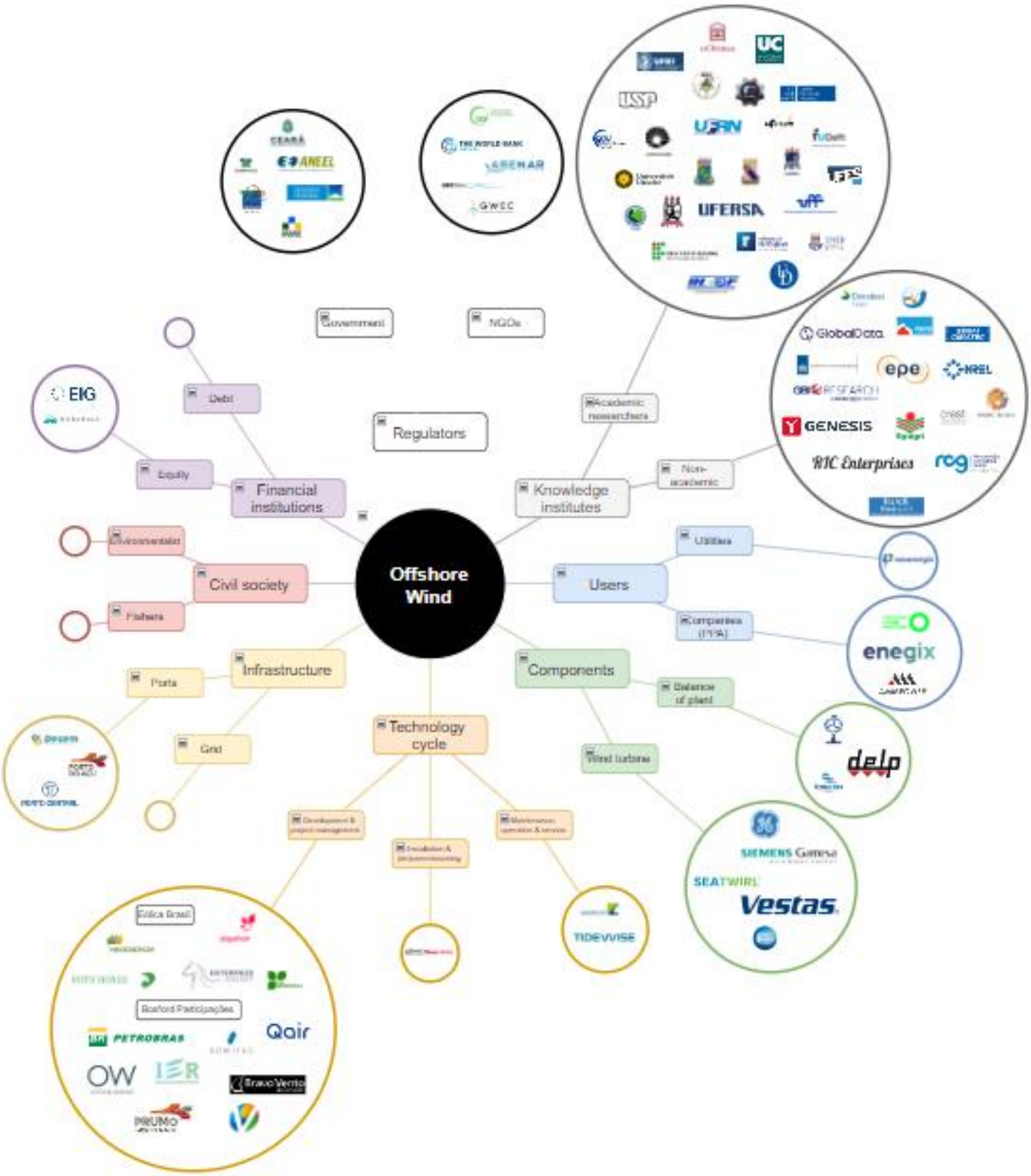

Figure 62 - Snapshot of offshore wind energy technology actors in Brazil in 2021.

Based on the data, the network linkages between the actors are presented in the platform template as shown in Figure 63. From the figure we can see that in quantity the linkages have increased compared to the previous period, but more importantly is that many of the new linkages are between different actor groups. This strengthens the TIS because different perspectives that relate to the technology development and diffusion are brought closer together. Another thing that stands out is that many non-academic researchers do not appear to be forming linkages. The exact reason for this is not clear, but what could be expected is that the data on the actors has been found based on reports and papers they have published, these are sometimes publicly available to all actors, which would link them to everyone in the TIS, and sometimes privately sold without information to who has acquired the research. This makes it in some cases difficult to determine exactly how the researchers are linked to other actors and might be misleadingly represented in the figure.

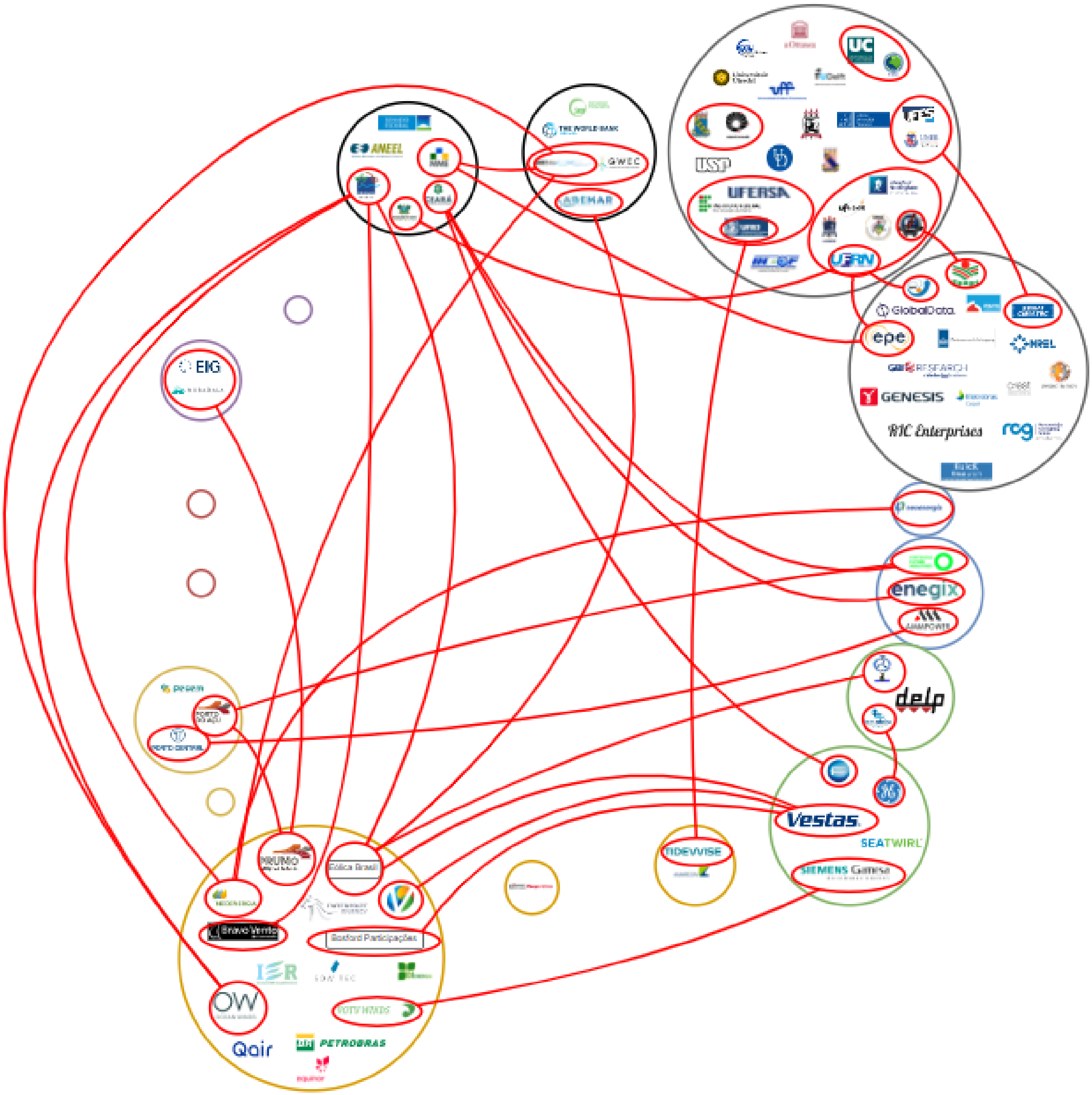

Figure 63 - Snapshot of offshore wind energy technology networks in Brazil in 2021.

More institutions have been identified that relate to offshore wind energy in Brazil compared to the previous period. The first new institution is the already mentioned regulation PLS 484/2017 which intended to push the expansion of current regulations to include specific requirements for offshore wind energy. This was followed by Law 11.247/2018 which related to the expansion of the existing energy policy to include and promote wind energy generation on water surfaces. By 2020 the Brazilian ministry of mines and energy had announced that clear regulations for offshore wind in Brazilian territorial waters would be presented by the end of 2021. In this period also a roadmap was presented for the development of offshore wind in Brazil by the Brazilian energy research agency, EPE. This roadmap included the potential for the technology and existing bottlenecks that could hamper the development of the technology. The full list of active institutions that have been identified are presented in the table below.

Institutions	Description
Laws 8.987/1995 and 9.074/1995	Address the process of granting concessions and authorizations for power generation.
Law 10.848/2004 and Decree 5.163/2004	Allow the participation of wind sources in the auctions of energy in the Regulated Contracting Environment (ACR) to serve the distributors.
Law 6.048/2007	Amended for auctions specifically designed for renewable energy generators.
Law 12.187/2009	National Climate Change Policy to reduce emissions of greenhouse gases and mitigate climate change.
Executive Decree 656/2014	Exempts manufacturers to pay Social Integration Program (PIS) and Contribution to Social Security Financing (COFINS) tax on components purchased for wind turbines production.
Regulation PLS 484/2017	Intended to push the expansion of current regulations to include specific requirements for offshore wind energy
Law 11.247/2018	Focuses on the enlargement of the energy policy institutional attributions with the objective of promoting the development of the generation of electric energy from a wind source located in the interior waters, in the territorial sea and in the exclusive economic zone.
EPE Roadmap 2019	Addresses the current status of offshore wind in Brazil, such as potential and infrastructure and regulatory problems.
IBAMA EIA 2020	Required Environmental assessment for development of offshore wind farms.
Normative resolution 876/2020 from MME / ANEEL	Addresses, among other aspects, the requirements and procedures necessary to obtain an authorization to operate and / or expand the installed capacity of wind farms. As for obtaining the authorization (DOR), the interested party may request the registration of the Authorization Granting Application for Wind Energy Exploration, submitting documents that demonstrate fiscal regularity, and legal and technical qualifications.
Normative Instruction SPU 87/2020	Provides for administrative, inspection, management and contract acts, establishing procedures inherent to the processes of assignments of use, in free, onerous regimes or under special conditions of real estate and areas of the Union's domain and property, and other measures.
New power sector law 14.120/2021	New criteria for auctions; Allows to use R&D and EE funds to contra covid; Reduces the discounts on usage tariffs for renewable energy; Establishes the need to define ways to value the environmental benefit of new valorisation mechanisms for renewable energy

Figure 64 - Snapshot of offshore wind energy technology institutions in Brazil in 2021.

5.3.3 TIS Functions Analysis

The data until 2021 has been gathered and divided into functions and indicators as presented in the following tables. Based on the data a TIS snapshot has been built in the platform template that represents the status of the Brazilian offshore wind TIS in 2021.

Function 1 – Entrepreneurial activities			**Score (1 to 5)**
1	New entrants	16 → Enterprize Energy, Sowitec, Qair, Ocean Winds, Equinor, GE, Tidewise, Siemens Gamesa, SEATWIRL, Vestas, Goldwind, Delp, IE Madeira, Keppel Corporation, Offshore Wind Power Systems of Texas, Iberdrola (IBAMA, 2022; 4C offshore, 2022; OffshoreWind.biz, 2002-2021); There is a high amount of new entrants and they are also of different actor types. New entrants are rated as good.	4
2	Experiments	0; One experimental project had been planned by Petrobras but was cancelled in 2020 (IBAMA, 2022), leaving the mark at zero experiments. Experiments are rated as absent.	1
3	Start-ups	5 → Bosford Participações, Bravo Vento, Votu Winds, BI Energia, Eólica Brasil (IBAMA, 2022; CNPJ, 2022); The amount of start-ups that are being seen for the technology is good, however they are limited to one specific actor group, namely, developers. Start-ups are rated as moderate.	3
4	Diversification activities	8 → Prumo Logistica Global, Pecem, Porto do Açu, Porto Central, Veritas Grupo, Petrobras, Internacional Energias Renovaveis, Neoenergia (IBAMA, 2022; OffshoreWind.biz, 2002-2021); Diversification activities of different actor groups has been perceived which is good. Petrobras, one of the major Brazilian energy companies with strong ties to the government, did however back-out from offshore wind projects. Diversification activities are rated as moderate.	3
	Total Score Function 1	Based on the average score of the indicators, the function fulfilment of *entrepreneurial activities* is *moderate*. The strongest activities are seen in new entrants, which are of a high quantity and varied. The activities in start-ups and diversification of incumbents are seen as moderate and experiments are still absent. Relative to other papers this score seems to be acceptable because Wieczorek et al. (2013) have given offshore wind in Germany a 5 for having high quantity of all necessary actors in the value chain and for having some experimental projects. They have given the Netherlands and Denmark a 4 for missing a few actors in some parts of the value chain. They have given the UK a 3 for missing even more actors in the value chain compared to the previous two countries. Sawulski et al. (2019) scored offshore wind in Poland with a 4 because "the number of companies who are active and ready-to-be active is significant" and "companies are active in almost all elements of value chains". Nothing was further mentioned about experimental but they made use of other indicators related to innovation capacity.	**3**

Function 2 – Knowledge development			Score (1 to 5)
1	R&D projects	0; R&D Project are rated as absent.	1
2	Demonstration projects	0; Demonstration projects are rated as absent.	1
3	Patents	3 → WO2017049376, WO2019222825A1, WO2021237323A1; This is a low amount of patents. Patents are rated as weak.	2
4	Journal publications	36 → UFMA, UNICAMP, UFSCAR, UFRPE, UFF, UFERSA, UN, INPE, Pontis, SENAI, GlobalData, GBI Research, EPE, Genesis, Epagri, RCG, Crest, Rystad Energy, TU Delft, UNEB, UC, UFRN, USP, UU, LUH, UO, PBL, NREL, UFPE, RIC Enterprises, UNIFEI, UFSC, UFC, GCU, UD, UFRJ (Scopus, 2022); The quantity of publications is adequate and the quantity and variety in publishing actors is good. Journal publications are rated as good.	4
5	Prototypes	0; Prototypes are rated as absent.	1
	Total Score Function 2	Based on the average score of the indicators, the function fulfilment of *knowledge development* is *weak*. The strongest activities are seen in journal publications, which are of an adequate quantity and being published by various actors. Few patents have been published which is rated as weak and prototypes, R&D and demonstration projects are still absent. Relative to other papers this score seems to be acceptable because Wieczorek et al. (2013) have given offshore wind in Denmark a 5, Germany and the Netherlands a 4 and UK a 3. All four countries had enough competent actors for knowledge development and had running R&D projects. In Germany and UK the knowledge production was spread out over a large number of organizations while in Denmark and the Netherlands this was concentrated in a smaller number of institutes. The knowledge generation sources and outputs were in larger amounts in Denmark, followed Germany with a large amount specifically on patents and the Netherlands with a large number of publications. The UK lagged behind a bit in these aspects. Sawulski et al. (2019) scored offshore wind in Poland with a 2. This score is based on 55 publications from multiple research institutes and companies, 2 patents and the absence of R&D and demonstration projects. The rest of the score is base on the quality of knowledge which was also regarded as weak.	**2**

Function 3 – Knowledge diffusion			Score (1 to 5)
1	Workshops	2 → EPE (2019), IBAMA (2019); Workshops are rated as weak.	2
2	Conferences	2 → World Renewable Energy Congress (2019), Global Offshore Brazil Summit (Quest Offshore, 2020); Conferences are rated as weak.	2
3	Network activities	0; Network activities are rated as absent.	1
4	Webinars	22 → Firjan, BRATECC Houston, UK in Brazil, GWEC/World bank/IBAMA, epbr, TV BrasilGov, ABEEolica, Ibama, Windpower Oportunidades, OAB Nacional, Saneamento Ambiental, Diálogos UE-Brasil, Arcadis Brasil, Cultura e Eventos - OAB SP, Projeto Amazônia Azul UFRN, CEBRI, UFRJ, Engenharia de Energias UFRB; Webinars are rated as good.	4
	Total Score Function 3	Based on the average score of the indicators, the function fulfilment of *knowledge diffusion* is *weak*. The strongest activities are seen in webinars, which are of an adequate quantity and been organized by various actor types. Few workshops and conferences were given which rated as weak and specific network events are still absent. Important to note is that due to the COVID-19 pandemic restrictions to physical events were put in place. That has had influence on how the knowledge is diffused as can be seen in the spike of digital events (webinars) and the lack of networking activities. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Denmark and Germany a 5, Netherlands a 4 and UK a 3. In all four countries there were strong national research networks, good industrial cooperation and strong lobby/political networks. These points were perceived as excellent in Denmark and Germany and good in the Netherlands and the UK. The UK also fell behind on linkages between knowledge institutes and industry which pushed its score further down compared to the other countries. Sawulski et al. (2019) scored offshore wind in Poland with a 3. This score is based on that stakeholders are able to acquire knowledge relating to the technology through a lot of different channels, however the ties between knowledge institutes and industry do not appear to be so strong as industry gets most of its knowledge from foreign sources.	**2**

Function 4 – Guidance of the search			Score (1 to 5)
1	Long term targets	No concrete targets, only introduction to the long term 2050 national energy plan (PNE, 2020) and the medium term decennial energy plan for 2030 (PDE, 2020) with possible installed capacity and potential in the Brazilian energy system; Long term targets are rated as weak.	2
2	Expressed visions	ABEEólica expressed they would expand their operational scope to include offshore wind and other sources because it expects that these will play a big role in Brazil's future (ABEEólica, 2022). The MME has expressed that clear regulations for offshore wind in the country would be released and that by the end of the decade the first projects might be operational (MME, 2021); The technology has made an entrance in the political agenda and is expected to have a future in the country, but it will still require some time and research and many actor groups have not expressed their visions. Expressed visions are rated as weak.	2
3	Expectations	In both the PNE 2050 and the PDE 2030, the expectation is that offshore wind will make its first entry in the energy system in 2027, but that it will have difficulties to compete with other renewable technologies given its high CAPEX and OPEX prices. Petrobras cancelled its pilot project due to low expectations for the technology in the near future (Recharge News, 2019). EPE expects that the prices will decrease fast given the global scale of development of the technology (EPE, 2020). MME expects that the regulatory framework, that is expected to be released beginning of 2022, will boost technology development (MME, 2021); Expectations are rated as moderate.	3
4	Demand articulation	There is no demand from the grid, only from hydrogen producers; Demand articulation is rated as weak.	2
	Total Score Function 4	Based on the average score of the indicators, the function fulfilment of *guidance of the search* is *weak*. The strongest activities are seen in the expectations, which are mostly positive from governmental and lobbying actors, but was also doubted for the near future by industry incumbent Petrobras. The other indicators are still weak because no specific targets have been presented and nothing was expressed about assisting the technology in its competitive position towards other renewables. The demand for the technology is mainly dependent on the hydrogen production. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Denmark a 3, Germany a 5, Netherlands a 2 and UK a 4. In all countries offshore wind was still expensive compared to fossil fuel technologies and would depend on nationally-financed schemes. The expectation in all of them was that there was a big market and potentially a great return on investment. The difference in grades were mainly due to the clear commitment of the German government to offshore wind and the well-functioning feed-in tariff they applied, the UK government's plans to reduce the carbon intensity of the power sector with offshore wind as a crucial element, the Danish heavy energy taxation on renewable electricity and the Dutch government's unclear and unstable framework to support the technology. Sawulski et al. (2019) scored offshore wind in Poland with a 2. This was because there was a "lack of a clear vision for the development of the Polish offshore wind sector", the expectations varied between actor groups and there used to be a target for the technology of 500MW but this had gone out of date.	**2**

Function 5 – Market formation			Score (1 to 5)
1	Specific tax regimes	Law 13.097 → exempts manufacturers from paying tax on components for wind turbines. The tax exemption holds for any type of wind turbines (Presidência da República, 2015); This gives offshore wind an advantage over other technologies except the fast developing onshore wind technology. Specific tax regimes are rated as weak.	2
2	Policy instruments	National Climate Change Policy (IEA, 2022); Policy instruments are considered very weak for offshore wind energy, the PROINFA program that gave renewables an advantage over fossil fuel intensive technologies has been terminated since the goals have been reached. Only the National Climate Change Policy remains. Policy instruments are rated as weak.	2
3	Size of the market	0 Projects installed, 0 wind farms consented, 23 projects with a total of 55 GW in environmental licensing (IBAMA, 2022). EPE estimates 700 GW technical potential is available for projects up to 50m water depth (EPE, 2020), The World Bank estimates this at 480 GW (and 748 GW for floating wind) (ESMAP, 2019); The potential size of the market is huge and new large projects are being submitted at a very fast pace, yet no projects are operational and none of the potential projects being revised is guaranteed to be constructed. Size of the market is rated as moderate.	3
	Total Score Function 5	Based on the average score of the indicators, the function fulfilment of *market formation* is *weak*. The strongest activities are seen in the size of the market, which has been estimated to have a huge potential and many developers are handing in project proposals for environmental assessment. There are however still no operational projects and none have been consented. The specific tax regime, comprised of the tax exempting law for turbine components, and the policy instruments, comprising of only the national climate change policy, are seen as weak. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Germany a 5, UK a 4, Denmark and Netherlands a 2. Denmark and the Netherlands both had low numbers in new installations and planned projects. The taxes for offshore wind in Denmark were problematic and the Policies in the Netherlands were not favourable for offshore wind. Germany had high ambitions and consented projects for the coming years, as did the UK but in a smaller amount. Sawulski et al. (2019) scored offshore wind in Poland with a 2. This is because there were no installed and consented projects, the tax regime is inexistent and there were unclear policies with respect to the development of the technology.	**2**

Function 6 – Resources mobilization			Score (1 to 5)
1	Education	3 offshore wind educational courses (USP, 2018; UFRN, 2020; UFRJ, 2021); Education is rated as weak.	2
2	Specialized training programs	No data; Specialized training programs are rated as absent.	1
3	Public seed money	No data; Public seed money is rated as absent.	1
4	Private investments	R$ 50 billion → investment from Macquarie Group for 3.48 GW of projects with Servtec (Diario do Nordeste, 2022); Private investments is rated as weak.	2
5	Infrastructure	Ports have started to get involved in the offshore wind development process, they are however not yet equipped to house offshore wind projects (Porto do Açu, 2021; OffshoreWind.biz, 2021). The grid has to be expanded to allow new connections of high capacity without congestion (EPE, 2020); Infrastructure is rated as weak.	2
	Total Score Function 6	Based on the average score of the indicators, the function fulfilment of *market formation* is *weak*. All the indicators will require improvements for the function to be fulfilled. There are only a handful of educational courses an no specialized trainings. The investments for a set of projects of one specific developer have been clarified however how the other 52 GW that are being assessed will be financed has not been publicly presented. Besides the human and financial resources also the physical resources such as the ports and grid will require substantial upgrades. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given the financial resources for offshore wind in Germany and UK a 4, Denmark a 3 and Netherlands a 2. There was "no strong evidence that the availability of financial resources (capital costs) has been very problematic", however they would all need increased levels of investments in the projects, technology development, grid and ports. In Germany a state-owned development bank provided €5 billion of financing to 10 offshore wind farms. UK had a commitment to offshore wind of 2 billion pound per annum. The Netherlands had seen its subsidy being removed until the price of the technology would decrease. The Human resources for Germany and Denmark were given a 4, Netherlands a 3 and the UK a 2. All four had to make an attempt to increase the number of courses and trainings. In Germany and Denmark the field was attractive for professionals, while in the Netherlands there were doubts about the career prospects and in the UK it was more beneficial to work in the oil and gas sector. For physical resources all countries scored moderate except for the UK which had scored weak. Primarily the problems for all countries related to the cost of the technology due to the materials, the variety of manufacturing processes and the required upgrades to the grid. Sawulski et al. (2019) scored offshore wind in Poland with a 3. This score is based on the availability of well trained polish engineers who are operating in offshore wind markets outside of Poland which could potentially operate in the market once it gets started and that "there is a general consent, that the money is available on the market" however no specific amount and were it would come from is mentioned.	**2**

	Function 7 – Creation of legitimacy		Score (1 to 5)
1	Actions that legitimize technology	The lobbying activities for offshore wind were increasing in a positive way. ABEEólica had amplified its focus to include offshore wind (ABEEólica, 2020). Through their strong ties with the MME they have been able to push the ministry to speed up the regulatory framework. IBAMA also presented the Environmental Impact Assessment (EIA) procedure which was developed to clarify and speed up the environmental licensing process (IBAMA, 2020). There is a general proudness in having a clean electricity matrix compared to the rest of the world, which pushes the desire to keep it that way. No social resistance has been identified against offshore wind; Actions that legitimize technology are rated as good.	4
2	Level of competition between technologies	The level of competition between technologies is high. Most of the programs that had been set up benefited renewables over fossil fuel technologies, however no distinction was made between specific technologies. Offshore wind had to compete with other more developed and cheaper renewable technologies. There were no specific targets for offshore wind and no intentions of subsidizing the technology (GWEC, 2020); Level of competition between technologies is rated as weak.	2
	Total Score Function 7	Based on the average score of the indicators, the function fulfilment of *market formation* is *moderate*. There have been strong lobbying activities by important players in the sector, the permit procedures are being simplified and there have been no oppositions from civil society so far, however, the technology still lags behind other competing sources and there is no outlook for a subsidy scheme to help the technology. Relative to other papers this score seems to be acceptable. Wieczorek et al. (2013) have given offshore wind in Germany, UK and Denmark a 4 and Netherlands a 3. All four countries had national renewable energy targets which were implemented to reduce the share of fossil fuels. This was advantageous for offshore wind compared to fossil fuel technologies, however other renewable technologies also benefited from these targets. In Germany and the UK clear national targets and well developed support programmes were present for offshore wind specifically. In Denmark, offshore wind was also seen as a major future contributor to the energy production, while in the Netherlands "the lack of vision, absence of any consistent programme and poor subsidy scheme, are the factors most limiting the legitimacy of this renewable". Furthermore, "in none of the analysed countries is there significant opposition to offshore wind farms as long as the wind turbines are not visible from the shore and there is no huge impact of construction on the local public". Sawulski et al. (2019) scored offshore wind in Poland with a 2. This was based on that social resistance against investments in offshore wind seemed marginal, only a few remarks had been made by particular interest groups (e.g. maritime fishing industry and sea traffic controllers), companies expected actions by environmental activists, but most importantly weighing the score down was because of "the complexity of the permission procedures and the costs associated with this issue".	**3**

The 2021 TIS functions analysis for offshore wind in Brazil is represented as a TIS snapshot in the platform template and can be seen in the figure below. Here again we see that the red dots portray the score for each function in that specific year. In this case all functions got a score of 2 (weak) except for function 1 – Entrepreneurial Activities and function 7 – Creation of Legitimacy, which got a score of 3 (moderate). This indicates that still a lot has to happen to the TIS in order to speed-up and smoothen the technology generation, diffusion and utilization.

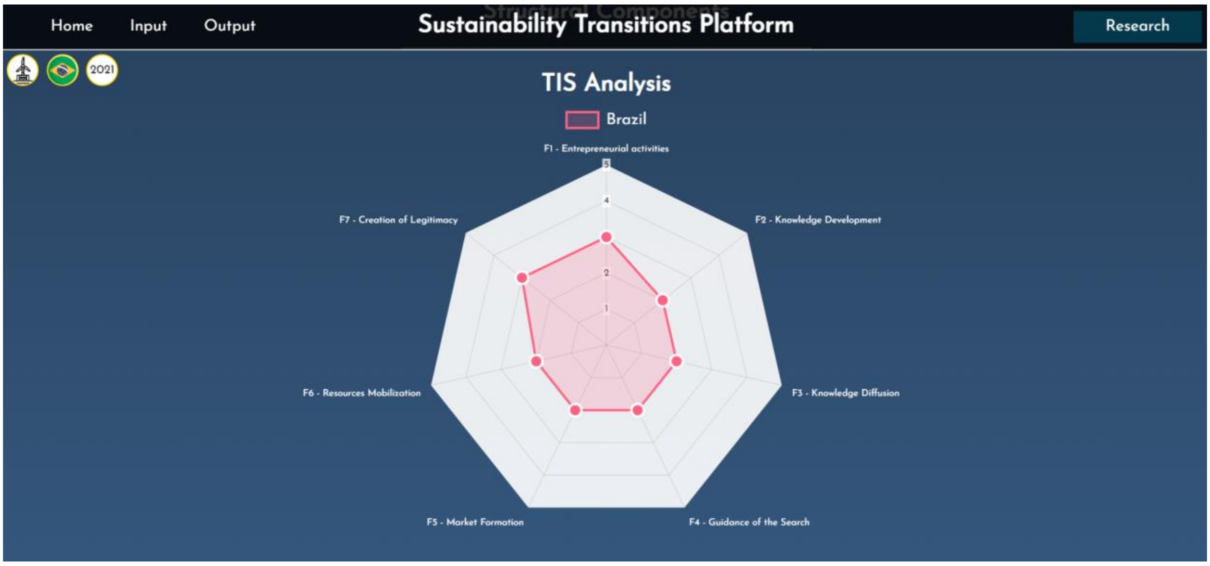

Figure 65 - Platform Snapshot of Brazilian Offshore Wind TIS in 2021.

Through the functional analysis a score for each function has been determined. The average of these function scores determines the final TIS score that gets inputted in the technology environment. For this period the TIS score for offshore wind in Brazil equals 2.3.

5.3.4 Period Results

Looking at the results of this period as presented in the platform, the following points stand out.

Technology environment

The country still continues to suffer from extreme weather conditions and was in 2021 experiencing one of the worst drought it had seen in decades. In addition, the country suffered from a new phenomenon, the COVID-19 pandemic. The pandemic had a global impact and brought insecurity to the whole world. The impact from this pandemic was also noticeable in the GDP growth rate of Brazil which was as low as -3.9% in the year that the pandemic hit.

As for the technologies, the biggest winner of the niche technologies during this period continued to be onshore wind. The ONS (2022) data shows that the newly installed capacity for onshore wind was similar to that of hydropower during the period. Another technology that stood out this period was Solar PV, which has grown to become the fourth largest electricity technology based on installed capacity behind gas. This should be reflected in good fulfilment of the function scores. The other technologies also had new installations but fewer during the period except for nuclear energy, which had no new installations. Despite that hydrogen still had the most installations it continued to lose shares in total installed capacity during this period due to the growth of the other technologies.

Structural components

During this period a spurt of new actors entered the offshore wind TIS. Many new developers have seen potential in the market and have handed in project proposals for environmental licensing. Ports have also started to get involved in the technology development process. There was an increase in

turbine suppliers, knowledge institutes and regulating agencies. Also the first private investors showed their interest in financing Brazilian offshore wind projects. Another actor group that gained some new players are the users. Many of which are actors from the hydrogen TIS. Nevertheless, there are still some actor divisions missing, these are debt financers, civil society and grid actors.
A huge increase is also seen in the networks between these actors. This is to be expected with an increasing number of actors, however more linkages are between different actor groups as well. This is important to get knowledge and practice through all actor groups to facilitate the diffusion process. Also in the institutions changes were perceived as offshore wind is being taken more seriously as an individual technology with potential in Brazil. Among the institutions are PLS 484/2017 and Law 11.247/2018, that pushed towards regulation and policy expansion for electricity generation on territorial sea waters. Furthermore, IBAMA released the required Environmental Impact Assessment which should now clarify and speed up the environmental assessment process. Lastly, the MME had announced that specific regulations for offshore wind would be provided by the end of 2021. They did not manage to deliver these by the end of the year, only at the beginning of 2022. The expectation is that the first Brazilian offshore wind projects will start construction by 2027.

TIS functions analysis
The shortcomings in the structural components are in line with the fulfilment of the functions as most of the functions are still weak with the exception of entrepreneurial activities and creation of legitimacy which are now being scored moderate. Most of the functions have improved compared to the previous period however there is still a lot of improvement necessary in the system for the technology to easily emerge and diffuse.

5.4 Case Results

Offshore wind is a technology with a huge technical potential in Brazil. The technology is however at a very early stage in the country and by the end of 2021 there were still no projects in operation or even being constructed. Yet, there is a growing interest visible given the huge project pipeline that has been lining-up for environmental assessment. The pipeline by itself does however not present the complete picture of what the future for Brazilian offshore wind will be. Through insertion of the historical analysis data in the platform template the following points became visible for the development of offshore wind energy technology in Brazil:

- There was **no market** for the technology. The Brazilian electricity matrix is one of the cleanest in the world due to the large share in hydropower. As can be seen in in the technology environment figures (Figure 48, Figure 50, Figure 56 and Figure 61), hydropower has been the dominant technology throughout the periods being analysed, which is reflected in its position on the top-right of the graph. The dominance it had has however been slightly decreasing over the years (hydropower has slowly been moving to the left on the graph), which is for a big part stimulated by the droughts Brazil has been suffering from, which is a landscape event also visible in the technology environment graph. From the structural components section we can see that in the first period institutions were introduced (e.g. PROINFA) that pushed towards diversification of the electricity matrix in order to reduce the hydropower dependency. This opened opportunities for technologies from other sources like wind-, solar energy and biomass, which are also very abundant in the country. Onshore wind energy technology has taken full advantage of this situation and has started to diffuse at a quick pace, as can be seen from its rightward movement from Figure 56 and Figure 61. It has been able to drive its cost down making it the cheapest technology in the country based on LCOE (Table 9). The cost of offshore wind is high compared to that of its renewable competitors if it were to be injected to the grid. This can be seen in the technology environment section of the platform which shows the 59.37 $/MWh LCOE of offshore wind in 2021, which is higher than the LCOE of onshore wind (33.59 $/MWh), solar PV (46.02 $/MWh), hydropower (46.12 $/MWh) and biofuels (53.52 $/MWh), leaving the technology uncompetitive in the market. This was also reflected in the lack of actors in the *user* group for the technology as can be seen in the structural components section of the platform of the two first periods (Figure 51 and Figure 57). This did change around 2020/2021 when the potential of Brazilian offshore wind was taken into consideration for hydrogen and ammonia production and actors from the user group entered the offshore wind TIS (Figure 62) and started to build networks with other actors in the offshore wind TIS (Figure 63). This could be a good development for market formation of offshore wind in Brazil, but it could also make the offshore wind TIS very dependent on the hydrogen TIS which could be a risk for its long term development. It would be recommended to take this development opportunity in synergy with hydrogen, but making sure that the technology can also operate within the national grid. From the development in combination with hydrogen, offshore wind technology could gain experience in the country which could lead to cost reduction and make it more competitive on the grid. If by some reason the hydrogen market would malfunction or collapse, offshore wind energy technology would not completely come to a halt in the county.

- There is **no protected space** and there seems to be no necessity whatsoever to create specific advantages for offshore wind which falls behind in competition with the other renewable technologies in the country. This can be seen in the institutions of the structural components section of the platform template (Figure 53, Figure 59 and Figure 64). In a 2020 GWEC webinar (which is one of the data inputs in the platform template) Elbia Ganoum, CEO of the biggest Brazilian wind energy association (ABEEólica) pointed out that onshore wind has been growing very fast but is not even at 10% of the 800 GW potential in the country. It would seem peculiar to subsidize offshore wind energy technology if other renewable technologies such as PV and onshore wind are cheaper and still have a huge amount of available potential in the country (GWEC, 2020). The focus seemed to go completely to renewables on land, which also lead to the creation of a new association focused on solely offshore wind, ABEMAR (Figure 62). This association was created by one of the Brazilian offshore wind project developers. Nevertheless, by 2021 ABEEólica had changed its focus and decided to put more effort into the development of offshore wind and remained the bigger association for this technology as well. Although nothing about the necessity of a protected space or some form of advantage for the technology was mentioned during this change. Neither from the government actors there appears to be a necessity for a sort of financial advantage for the technology.

- There were still **no clear regulations** for the technology by the end of 2021. These regulations are lacking in the institutions of the structural components section of the platform template (Figure 53, Figure 59 and Figure 64). This lack of regulations can be traced back to the low level in numbers and involvement of regulating actors in the structural components (Figure 51, Figure 52, Figure 57 and Figure 58). Only in the third period this increased as can be seen in the platform snapshots (Figure 62 and Figure 63). In this last period multiple projects had been handed in for environmental assessment, however at the beginning there still was insecurity as to whether the existing legal framework (mostly designed for offshore structures of Oil & Gas projects) was sufficiently defined in order to allow development of offshore wind projects. This worried many developers and investors since the initial investment for these types of projects are too high to start without being absolutely sure about their legal rights. The ministry of mines and energy announced that by the end of 2021 clear regulations would be presented, which was delayed until the beginning of 2022. The announcement of the regulations was warmly welcomed as a lot of new actors entered the offshore wind TIS (Figure 62) and can be seen in the market size indicator of function 5. The developers of the Asa Branca and Caucaia projects, which were pioneers in the Brazilian offshore wind TIS, had some doubts about the effects these new regulations would have. Given that they had already entered the environmental assessment phase, they feared that the new regulations would give the government the authority over the project space allocation in Brazilian waters and that the government would be allowed to give their project locations to other developers. The announcement of a regulatory framework being made was enough to wake the interest of many different and mostly international actors to enter the Brazilian offshore wind market (Figure 62). This appears to be beneficial for the development of offshore wind as this portrays more security to the TIS and also results in more knowledge and resources flowing into it. Nevertheless, the native actors which have been in the development process for years are sceptical and a bit worried that foreign companies will be favoured with the new regulations. This can be very problematic for the national development of the technology as native actors can become reluctant to participate in the TIS out of fear of being unable to compete with large international companies. It would be recommended to keep native actors involved in the development process as much as possible and regulations that require national actors and/or resources to be a part of it in order to avoid that no benefits of the technology are perceived nationally and that any form of further development will be solely dependent on international players.

- There is a need for improvements in the **infrastructure**. Although the supply chain for wind turbines is mostly in place and there is quite some experience with offshore environment from the oil & gas sector, the infrastructure still needs to be improved. No information could be found that relates actors from the grid to the offshore wind TIS and, as can be seen in the platform snapshot (Figure 62) and from the function resources mobilization (indicator: infrastructure), it was not until the last period that actors from the ports got involved. The main takeaways for the ports is that they need to be upgraded and expanded to be able to house the facilities necessary for offshore wind projects (EPE, 2019b). The availability of vessels for transportation and installation of offshore wind turbines and components might become an issue given the global demand and limited amount of vessels. Furthermore, some of the projects in the pipeline have opted to develop projects 15+ MW turbines, while no projects have yet been installed with turbines of that size. These bigger turbines are built of bigger components and there is a limit to the size of the component which current vessels would be able to transport (Bloomberg, 2019). Lastly, the electricity grid would also need improvements. Indeed this would depend on whether projects are developed strictly for direct hydrogen production or if they are designed to be connected to the national grid and would from there deliver the 'promised' energy to the hydrogen facilities as agreed on the PPAs. In both cases suitable electrical installations will be necessary which are currently not present. From a business case perspective it would make the project less risky if the connection to the grid would exist to prevent the sole dependency on the hydrogen demand, as has been mentioned earlier. That is why at least more involvement of grid actors would be required for future development of offshore wind.

- There are **missing actor groups**. Following on the previous point that grid actors should be involved, there are more actors types that have not been identified from the analysis that could be of influence to the development of the technology. As can be seen in Figure 62, debt financers are missing which are often banks that lend money to the project developers to build the project on a non-recourse basis (PWC, 2020). As has been seen in Luo et al. (2012), there are many (international) banks involved in the offshore wind sector and they have played an important role in the development of the technology as the initial investment costs of these types of projects are very high and require large amounts of financial resources. Another actor group that is missing in the platform results is the civil society. Although there is no direct indication that the technology will not develop if these actors are not actively

involved in the TIS, these actors could eventually be of influence to the development of offshore wind by for example bringing the construction of projects to a halt through lawsuits or protests if the projects do not meet certain requirements or neglect specific cultural values. This has been experienced in some European countries (Luo et al., 2012).
In the technology cycle actor group we see that the division with developers and project managers contains many actors, however, the actor divisions for installation & commissioning and operation, maintenance & services only had one actor each by the end of 2021. Here it is expected that many more actors should be present for the development of the TIS. This could have something to do with the early stage development offshore wind still is in Brazil, where as long as no permits for project development are released to the developers, no agreements are signed with other actors of the technology cycle. Yet the author expects that these actors are already involved but in a not publicly shown way.

- Although very slow, there is **progression in the TIS**. From the TIS snapshots of each period, visible in Figure 54, Figure 60 and Figure 65, it can be seen that, albeit at a very slow rate, all the functions are increasing. We see that at from 2010, when almost all functions were still absent, to the end of 2021, the functions have been able to reach a weak or even moderate score. Although there is already a huge amount of planned projects to be developed, these scores would indicate that a lot still has to happen in all functions of the system in order for the technology to diffuse easily and fast.

All in all, offshore wind in Brazil has had problems entering the market which is already dominated by a renewable technology, hydropower. Given the extreme climatic conditions that work averse to hydropower a necessity grew to diversify the energy matrix which created opportunities for other technologies. The abundance in natural resources and available space on land resulted in onshore wind and solar PV being able to diffuse at a very fast pace leaving offshore wind, which is a slightly newer technology, behind. It remains unclear if the cost of offshore wind energy technology will be able to decrease any time soon, such that it will become competitive with the other renewable technologies on the grid. On a global scale offshore wind is becoming more mature. It is seeing its costs decline rapidly and has been able to prove its operations. Because of this the technology is being seen as an interesting investment opportunity for private investors, banks and pension funds. This decreasing cost in technology and having a group of interested international financial institutes will probably incentivize the future development of the technology in Brazil. But, the biggest catalyst that appears to be making offshore wind being pushed for development in Brazil now, is the possibility to combine it with hydrogen production facilities and exporting the hydrogen to other countries. This could speed up the diffusion of offshore wind in Brazil drastically but precaution should be taken with its dependency on the hydrogen TIS.

Chapter 6 – Discussion & Future Research

This chapter will be used to look back at what has been experienced from using the platform template for sustainability transition research and also to present possibilities for future research and the platform itself. To do so the chapter will be divided into a couple of segments. These are:

i) Data Inputs, which relate to the data that is gathered, categorized and inputted in the platform template.
ii) Platform Outputs, which relate to the results that are outputted in the platform template.
iii) Sustainability Transitions Theory and Platform, in which the theoretical aspects of sustainability transitions research in combination with the platform template will be discussed. This includes other existing frameworks that have not been included in this research.
iv) Platform Theory, which places this particular platform in context of the theoretical aspects of platforms.
v) Practical Implications, in which the practical aspects of this research and for the development of such a platform will be highlighted.

By taking these points in discussion we are able to see how some of the issues present in sustainability transitions studies, that were presented in Chapter 1, are being tackled in this research. To recap, the pointed out issues are:

1. It is difficult to determine what data is exactly being used for cases and how it is being categorized. This is important to know since these studies build a narrative or status based on historical data. Not being able to exactly identify the data also makes it difficult to reproduce or make new case studies in a very similar way.
2. There is limited use of data visualization, while data visualization is a strong tool for helping people understand information that comes from big amounts of data, especially if it can be used dynamically.
3. There is still much variation in the framework elements and how they are being used and analysed in studies.

The discussion should also present the main advantages and disadvantages of implementing sustainability transitions research in the platform template. At the same time new questions and ideas should arise for continuation of this research. This will construct the basis for future developments of the sustainability transitions platform and will serve as guidance for additional advantages that could be gained and possible bottlenecks that could be encountered in a more developed phase of both the platform and the theoretical frameworks.

6.1 Data Inputs

The data inputs relate to the data gathering and categorizing process of sustainability transitions research (**issue nr. 1**). As discussed in Chapter 3, the process to understand why transitions happen or why certain technologies develop or not is often analysed on the basis of historical events. Within the research field this is referred to as historical event analysis. In practice this means that researchers gather data relating to their case based on events that have happened in the past by looking through different sources. The data sources can, for example, be found in the form of literature, books, reports, webinars, interviews, webpages, blogs and magazines. Since the data that is gathered is historical, in theory this should mean that the data should not differ between two studies treating the same case.

What could differ is the source of the data. Some studies could opt to emphasize on interviews while others could focus more on the data gathered through desk research or a combination of both. Another point of difference between research papers, that has been discussed in Chapter 4, is that the amount and level of detail of the data gathered also differs. For example: one study names all the specific actors that have been identified during the event analysis while another only names the largest or most influential actors and concludes that either sufficient or insufficient actors are active in the TIS. Although sometimes it may seem sufficient to name only the largest or most influential actors it still leaves room for doubt about the completeness of the analysis and makes the reader wonder if nothing has been overlooked or if some form of bias towards the data is in place. On the other hand, writing down every piece of data found can become a very exhaustive and time consuming exercise and could potentially lead to confusion and unclarity about the main points of the case. Nevertheless, studies are being applied in different detail levels which makes it difficult to compare the data that has been used and thus it is also difficult to interpret the indicators, functions and the TIS analysis results between different studies.

A possible **solution** for this problem could be to standardize and automate the data gathering and categorizing process of sustainability transitions studies. By standardizing is meant that the way in which data is structured should become similar for everyone implementing such a sustainability transitions case study. Events should in a standard way be decomposed in *who* and *what* segments and this again should be categorized in a standard way in functions and their indicators including their sources. This should help reduce the selectivity of researchers on how detailed the data should be. By automating is meant the process of data gathering and categorization which should not be done manually but through computational algorithms. Platforms can nowadays function well enough to do the desk research algorithmically and return and categorize the required data as priorly programmed. This would help remove the exhaustive manual labour of endlessly searching for data and having to categorize it yourself and would allow the researcher to spend more time on the analysis of the data and case. Another advantage of doing this work algorithmically is that it in theory the type of data gathered should be similar for different studies. This could reduce bias in research and reduce the possibility of overlooking relevant data.

What has been **achieved** in this research is the construction of a platform template which serves as a first draft for the sustainability transitions platform in which data can be inputted in a structured manner. This helps researchers in gathering and categorizing historical data for research cases in a clear, pre-defined and structured way. The used data has to be decomposed in *who* and *what* segments and in turn also has to be categorized in a standard way in functions and their respective indicators and includes their sources. This does not imply that all research cases have to use the same pre-defined functions and indicators, but it requires them to specify directly which ones are being used and which data is eventually linked to it, which helps clarifying the argumentation for the results and reduce variance between researches based on similar data. This flexibility in used functions/indicators is necessary as there is no fixed set of functions and indicators that should be used in cases yet. This is still a point of discussion in literature which can also be tackled with a digital platform given that they can cope better with flexibility than paper written cases.

What has **not been achieved** in this research is solving the problem of the time consuming process of data gathering and categorizing. Given the initial state of the platform (and the limited computational skills of the author), the data gathering and categorizing was done manually instead of automated. A lot of work and time was required to i) build up a database in which the data would be categorized and stored; ii) search through different sources for data that could be relevant for the case; iii) decompose and input the data in the corresponding parts of the database. In reality it was sometimes also difficult to decide how exactly to categorize events or actors. For example, the Brazilian energy research agency (EPE) is a government entity which could in principle be seen as part of the *regulators* actor group, however, in this research EPE was placed within the *knowledge institutes* actor group in the end because their inputs for offshore wind have primarily been creation and diffusion of knowledge. This multi-agency problem can also be found in literature (Köhler et al., 2019). Furthermore, by having inputted the data manually in the database mistakes could have been made which for example might have led to data being misplaced in the database. Besides that, searching through different data sources manually might have resulted in some of the relevant data being overlooked, meaning that the database of the case could be incomplete.

In **future research** the data gathering and categorizing process should be done automatically in the platform instead of manually. This could be achieved by further developing the platform and including algorithms designed to search for the data and store it as required. If this can be achieved i) researchers would have to spend less time searching for the case data; ii) the data used starts to become more comparable between cases; iii) data bias would be reduced; iv) mistakes in the datasets of overlooking of data will be reduced. Truth is that, in any way it is difficult to gather all existing data, even for algorithms. In the beginning they have to continuously be optimized and updated to search all the possible variables and different forms of data. Even then it might happen that not all the data for the case can be found through algorithms, if for example the data is not available through desk research but only though interviews, or if the information is not publicly available. That is why in a futuristic and idealistic phase of the platform the actors relating to a specific part of the data should themselves add the data into the platform instead of having an algorithm searching through different sources to find the same second-hand data and eventually inputting it. This would for example mean that a governmental actor would input data relating to a new regulation in the platform; or that the person who published a paper relating to the technology would update the information in the platform; or in case a company signs an agreement to supply components to a developer they themselves would input this information into the platform. This could make the process more efficient and accurate and would also bring the theory of sustainability transitions research closer to practice. This is however still far from being realistically applicable, while platforms with algorithms that search for data already exist (e.g. Google, Yahoo, Bing, Scopus). Most probably algorithms that execute commands similar to the ones necessary for sustainability transitions research already exists and it should be possible to copy and adapt them to the research requirements. The first recommendation for future research would then be to start developing a platform that includes an algorithm that gathers sustainability transitions relevant data and eventually would also able to categorize it. By looking at existing models and experimenting with the requirements for sustainability research a huge step could be made towards speeding up the data gathering process and increasing the similarity and reproducibility of case studies. Once this phase of the platform is reached, at least the following checks should be performed with existing case studies:

- How different is the data from the one gathered manually for this research (offshore wind in Brazil)? Does the algorithm retrieve more or less data? Is most of the data similar or does one dataset include a lot more different data?
- If the algorithm is applied to different cases which have already been carried out previously, how different would the results be in this case? Would the final analysis of the case result in different conclusions about the bottlenecks for technology development and the presented policy strategies?
- Is the difference between the algorithmically obtained desk research data substantially different from data that has been gathered through interviews? If so, could the interview data then be logged digitally so that algorithms are able to find them as well?

There are two **other advantages** for sustainability transitions research in relation to the data inputs for cases within a platform, namely, adaptability and continuity. This means that wherever the case has been left off, data can still be changed or added. Whether this is new data found through interviews for example or simply another source that has been overlooked. The existing data could even be edited so that faulty data could be removed and the platform could automatically update and re-render the outputs accordingly to the new situation. This adaptability is a lot harder once papers have been published and new data arises. The effect the new data has on the TIS would have to be changed manually as would the resulting outputs for analysis. Besides, case studies that have been published on paper are difficult to update for future events, meaning that continuation of the case is difficult. If, for example, a researcher would decide to look at the development of offshore wind in the Netherlands for the year 2023, the researcher could either start the whole data gathering and categorizing from scratch or use an existing paper that contains the TIS data for offshore wind in the Netherlands for a previous year, the paper by Wieczorek et al. (2013) for example which contains the TIS data until 2011. Starting from scratch can be very time consuming, especially for technologies that are already more developed and have experienced more events (thus, contain more data points), and building the TIS based on a previous study in which the data is not clearly structure can become quite difficult and awkward. If the platform had already existed and the data from the previous research had been inputted there, the researcher would merely have to update the database with data from the following years and could conduct his analysis through the results in the platform outputs based on the whole dataset, without having to puzzle the data in a paper. In a future phase of the platform, once the algorithms are included, the data would automatically be added, saving the researcher even more time for result analysis.

6.2 Platform Outputs

The platform outputs relate to the visualization of large amounts of data in sustainability transitions research (**issue nr. 2**). As discussed in Chapter 4, visualization tools are hardly used in sustainability transitions research and when they are, they are not used in their full capacity because of the static nature of visualizations on paper. Digital visualization tools help individuals interpret large amounts of data and as has been discussed in Section 6.1, sustainability transitions research is built on large amounts of data generated through historical event analysis. Moreover, the fundamental idea behind sustainability transitions research is trying to understand why and how transitions happen, or from a technological perspective, understanding what results in technology generation, diffusion and utilization, based on the available data. Hence, more the reason to have visualizations that clarify and simplify large amounts data which helps researchers in this quest to understanding it.

A possible **solution** for this issue could be to create a digital platform in which the sustainability transitions research data can be aggregated and presented through visualization tools. The visualizations should present the core information required in the research in a clear way based on the data. Also, By making use of the interactive aspects of digital visualization tools and dynamic characteristics of the digital platform different levels of detail regarding specific parts of the data and their sources should be retrievable.

What has been **achieved** in this research is the construction of a platform template that contains three different visualization tools which have been designed based on the theory of the MLP and TIS frameworks. By inputting the gathered data in the platform, the visualization tools have been able to construct the results that present relevant information about the Brazilian offshore wind TIS and its contextual features.

What has **not been achieved** in this research is the creation of a fully working platform in which all the interactive aspects of the visualizations tools and the platform can be utilized. These interactive and dynamic features are limited in the platform template. The strengths and limitations differ between each of the three different output sections of the platform template and require a more elaborate discussion as will be done next.

6.2.1 Technology Environment

What has been **achieved** in the first output section of the platform, the *technology environment*, is presenting the technology being analysed within a graph that contains the contextual factors that lack in the TIS framework. This output was designed based on the MLP representation of Geels (2002), as can be seen in Figure 3, and in this case shows the landscape factors and competing technologies. The relevance of including landscape factors is that external or macro events can have effects on the development of technologies. In this research for example we have seen that the droughts in Brazil (landscape event) have had a significant influence on its energy system. If this factor would not have been considered in the analysis, there would be no clear linkage to the announced necessity to decrease dependency on hydropower through diversification of the energy matrix which resulted in the growth of onshore wind and solar PV. The relevance of competing technologies, such as onshore wind and solar PV, is that it helps to put the technology being analysed into perspective. The more information there is available about the competing environment the technology is being placed in, the better it becomes to understand how easy or difficult it might be for the technology to diffuse. Results can be obtained by analysing a technology by itself, but only by comparing it with other technologies will the results gain meaning. That is how we can distinguish between one technology being part of the regime and the other only a niche, or even distinguish which technology is the most developed within the niche technologies and which one is expected to develop the fastest in the following years. This comparative stance is important within the technology environment section and brings forward one of the shortcomings of the case analysis in this research, namely, that only offshore wind energy technology has been fully analysed and not the other competing technologies present in Brazil.

This research case analysis has **not achieved** to accurately present how offshore wind is developing in Brazil compared to other electricity generating technologies in the country. Because, instead of carrying out a complete analysis on the other technologies, a less extensive method has been used that allows the author to place the technology into perspective and simulate its development compared with other technologies in this section of the platform template. This simulation has been done through two values, namely:

- *TIS score,* which is based on the average of the TIS functions scores which in theory is not a correct way of measuring how well a TIS is functioning since all functions should be fulfilled. The average can blur out unfulfilled functions. Nevertheless, by using this average a single value is created of how the TIS of a specific technology is doing on average. This value has been determined for offshore wind in Brazil for the three different periods and for the other technologies these values have been ‘rationally’ assumed based on already known information about how quickly they have diffused in the following years after the period of analysis.
- *Diffusion*, which relates back to the TIS score. The exact definition of diffusion is rather vague in literature. Although it is clear that one speaks of diffusion as the technology starts to grow, it remains unclear how much growth and within what timeframe it should happen to call a diffusion slow or fast. That is why in this research and the platform template an attempt has been made to quantify the diffusion. In the platform template the diffusion has been measured based on the total installed capacity of the technology in relation to the total installed capacity of all competing technologies together. This measure again gives an indication of how the technology is doing compared to others.

For **future research** it would be recommended that more cases are implemented in the platform where a complete TIS analysis of the technology within a specific country is carried out. Perhaps this could be done for the other technologies that have already been taken into consideration (and assumed) in this research to give this specific case continuation. By placing the technologies on a graph from top to bottom, top being high TIS scores and bottom being lower TIS scores, with accurately determined TIS scores it should in theory be possible to easily distinguish which technologies are expected to diffuse faster in the coming years from an average point of view. This visual presentation of how the technologies are moving based on their function score also works as a feedback model to the TIS theory and how all functions must be fulfilled as the functions themselves are still being discussed in literature meaning there is still more that has to be understood about the theoretical claims. The options for a high TIS score have been presented in the table below.

TIS Score	All functions fulfilled	Technology diffuses	Concurs with theory
High	Yes	Yes	**Yes**
High	Yes	No	**No**
High	No	Yes	**No**
High	No	No	**Yes**

If the TIS score is high, all functions are fulfilled and the technology diffuses, this would concur with the TIS theory, however, if the technology does not diffuse this could indicate that another technology (or technologies) is performing better or that something is incorrect in the applied functions and or indicators. If the TIS score is high, not all functions are fulfilled and the technology does not diffuse, this would again concur with the TIS theory, however, if the technology does diffuse this indicates that something is incorrect about the applied functions and indicators since not all functions necessarily had to be fulfilled in order for the technology to diffuse.
As for measuring diffusion, the share in installed capacity is not necessarily the only way it could be measured. Another option could be to look at the share of electricity generated, or the change rate of installed capacity, or the number of new projects. More research could be done into defining how to measure diffusion or in what occasions the different units would be more suitable. The clue remains that in sustainability transitions research something is trying to be said about the change in development state of technologies and at which pace it happens. By quantifying this and comparing it between technologies more meaning is given to how far a technology has actually diffused based on the scale used. Independently, the platform's interactive characteristics can again be of use by having the axis adapted to the requirements of the user as long as the data required is inputted.

6.2.2 TIS Structural Components

As pointed out in Chapter 4, the **problem** in the structural components of research papers is that they are often presented in a text format with a structure that makes it easy or pleasant to read and not necessarily an orderly (and probably boring) structure. In the cases that they are presented visually in papers this tends to happens in varied, and sometimes awkward, ways.

What has been **achieved** in this output is that a single section has been created within the platform template in which a visualization shows the three pillars of the technological system, namely, the actors, networks and institutions, in a structured manner. Actors have been divided in groups which directly show what actor types are present and which ones are not. Networks can be presented in the same graph containing the actors, showing precisely which actors are involved in the linkages. The relevant institutions have been included in the graph in the form of a table.

What has **not been achieved** in this output is a visual representation of the importance of individual actors and networks in the TIS. As mentioned in Section 4.3.2, some papers only point out the biggest or most important actors and networks of the system which can indeed sometimes be sufficient and can say a lot about the system itself as some actors are more influential with respect to the development of the technology than others. This distinctions is not directly visible in the current version of the platform. Also, the actor groups have been built on a case for offshore wind. For this research the assumption has been made that these actor groups would also hold for the other electricity generating technologies and maybe even other technologies in the whole energy sector or other sectors. This has however not been tested.

For **future research** a couple of things would be recommended for this specific output. Firstly, cases for other electricity generating technologies, technologies from the energy sector and from other sectors should be carried out to see if the specified actor groups do indeed hold for all of them. Secondly, more advantage should be taken from the interactive capabilities of the platform, such as the layer depth in which actors are presented which could go a lot further down in detail of the supply chain of components all the way to the material usage. This would allow the platform to also indicate blocking mechanisms in resources. Also the importance of actors could be visually improved by for example making more important actors bigger in the graph and by clicking on actors making more information about them appear (e.g. country of origin; latest activity with respect to the TIS; # of people; financial figures). Thirdly, the networks from the Brazilian offshore wind case became visually more complex with each period that passed. In future periods the amount of linkages might become overwhelming and unclear which is why a more organised network visualisation structure should be used. An example of a more structured version can be seen in the figure below.

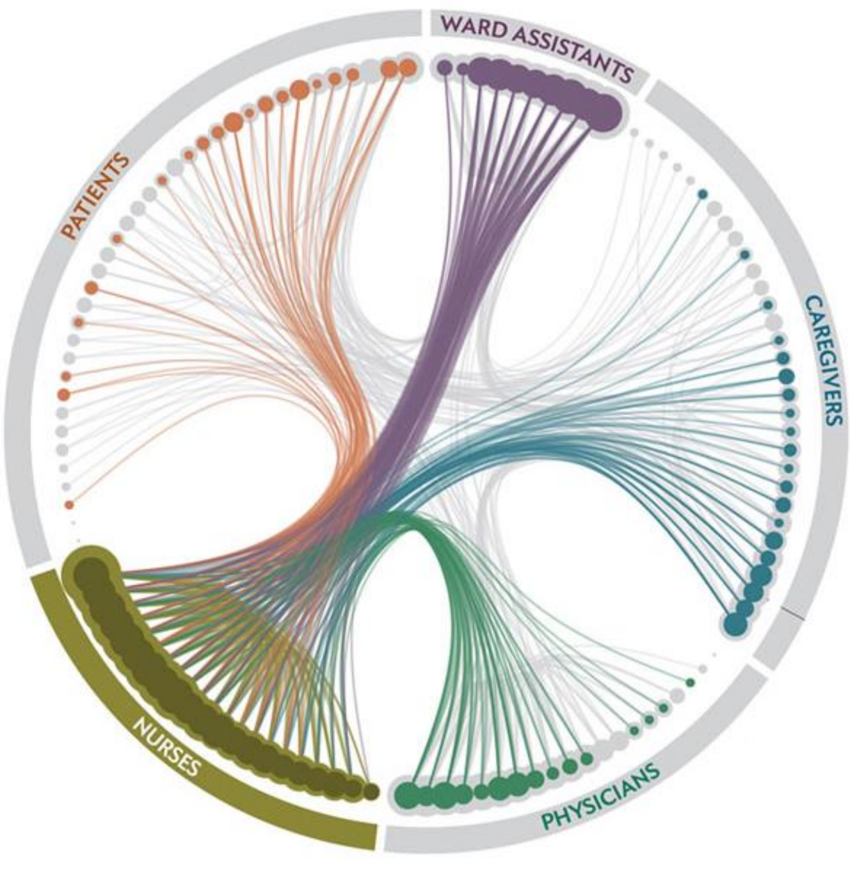

Figure 66 - Example of a more structured representation of large amounts of linkages. (Graphic by Jan Willem Tulp, retrieved from www.scientificamerican.com)

Fourthly, the current presentation of institutions is limited to formal and general rules of the game while the interactivity of the platform would also allow a more in depth presentation on the institutions, specifically the soft types, such as beliefs, expressed visions and culture. These could be built based on individual actors and actor groups and be brought forward through interaction in the platform. An example of this is shown in the following figure.

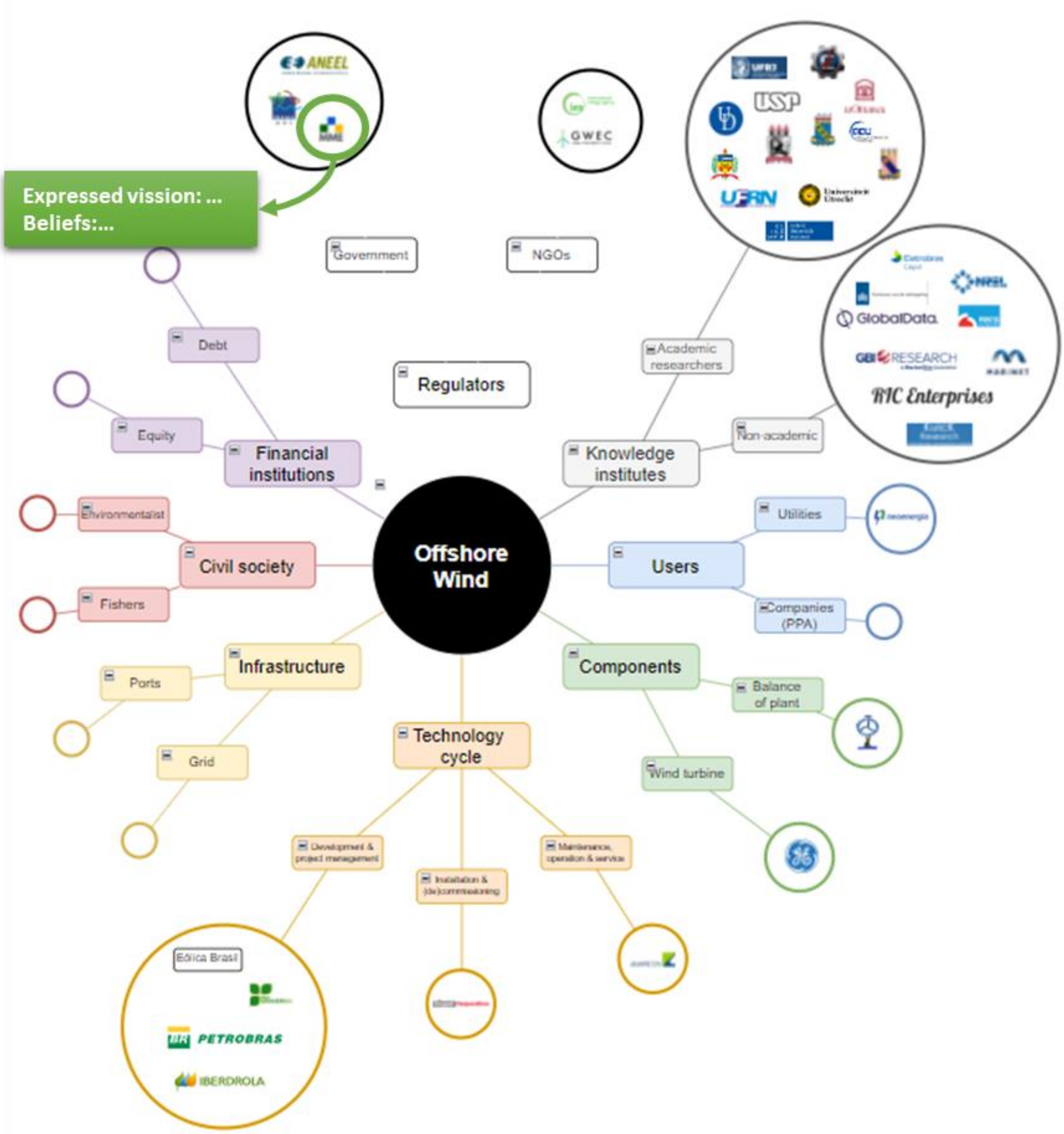

Figure 67 - Example of inclusion of institutions to the actor-networks graph. By hovering over an actor specific institutions could show up.

6.2.3 TIS Functions Analysis

The TIS snapshot is one of the recurring visualizations in sustainability transitions research papers. The **problem** being encountered is that in TIS studies it is still difficult to determine when a function is viewed as absent, weak, moderate, strong or excellent. Currently this is done through analytical reasoning based on the used indicators and their results. This can sometimes lead to inconsistencies in function scoring. For readers of the research the reasoning behind the final function score can be rather unclear because the indicators are often presented in chunks of text making it difficult to determine exactly which indicators are being used, what exactly the resulting data is for each indicator and how influential each indicator is.

What has been **achieved** in this output is that a visualization tool has been built in the platform template in which TIS Snapshots can be presented. At first this is similar to what can be seen in some of the TIS research papers, however, the dynamic characteristic of the platform come to play as the user of the platform can gather additional information about the TIS Snapshot. The platform user can find specific information about how exactly each function score has been determined. By hovering over or clicking on a function score in the TIS snapshot a tooltip pops-up which shows the exact indicators that have been used to determine the resulting score. The user should then see the indicator name and the respective data for that indicator. In addition, instead of only giving the function a final score, each indicator has been scored individually and the average of the indicator scores is what determines the function score. This helps researchers or any other kind of user of the platform to exactly identify what indicators have been used and the corresponding data relating to the indicator that have resulted in the presented function score.

Although the indicator based system presents clarity about the data being used for scoring, what has **not been achieved** in this output is accurately determining why indicators and functions receive a specific score (absent, weak, moderate, strong or excellent), clarifying which indicators should be used in research and if they have to be weighed.

For **future research** it would be recommended to work on the clarification of the scoring of indicators through a comparative stance between case studies. Take the example of this research about the Brazilian offshore wind TIS. The scoring of the indicators, and eventually functions, should be comparable to that of other technologies it is being compared to. In this case: hydropower, onshore wind, gas, oil, solar PV, biofuels, coal and nuclear. If cases are carried out for these technologies as well, a range is created between the technologies for each indicator that shows a maximum and a minimum. Take for example the indicator papers published from function 2 and the example values in the table below.

Function 2	Papers published
Hydropower	100
Onshore wind	80
Gas	80
Oil	60
Solar PV	55
Biofuels	52
Coal	30
Nuclear	20
Offshore wind	3

Here hydropower would score 5 (excellent) as it is the maximum and offshore wind would score 1 (absent) as it is the minimum. This does of course not completely remove the unclarity since the difference between a 3 and 4 or a 4 and 5 has not been defined, it does however clarify that in this example onshore wind and gas should receive the same score, only hydropower should receive at least the same score or higher and that solar PV should receive an equal score to oil or lower. The scoring can then be done through an equal distribution between the maximum and minimum. This type of scoring is however easier for quantitative indicators and more difficult for qualitative ones and should be worked on in the future. Another option would be to score the technology in comparison to how it is doing in different countries. The scoring principle would be the same as comparing between technologies, except that now a single technology is compared between different countries instead of compared to different technologies in the same county. This could say something about how the technology is doing on a global level. Furthermore, as discussed in Section 6.1, the dynamic characteristics of the platform allow adaptability, meaning that insertion and removal of indicators and the weighing of them could also be tested out for different cases and help understand more precisely which indicators should be used and how they should be weighed.

Two **other advantages** relating to the TIS snapshot being used on the platform instead of in paper versions are i) the user should also be able to click on the indicators or results and be redirected to the dataset or source of the data, and ii) by having the TIS snapshot in the platform template the user has the option to use a *time slider* to see how the TIS Snapshot looks like at any point in time and can also easily see how it changes over time, given the data has been inputted. This can help researcher see which functions are the motors of change and push the other functions towards fulfilment. The paper versions of these researches limits the possibilities for the user (or in that case the reader). The person reading the paper is bound to the time period TIS Snapshot the author has chosen to present. As is the demonstration case presented in this research for the three selected periods. In none of the analysed papers in Table 3 (Section 4.3), TIS snapshots have been presented for different time periods of the case, giving little information about what the TIS of the case looked like at the beginning or at the middle of the analysis and how it has been changing over time.

6.3 Sustainability Transitions Theory and Platform

The theory and platform discussion relates to the varying use of frameworks and their elements in sustainability transitions research (**issue nr. 3**). The goal of sustainability transitions theory is to fully understand transition processes. Knowing why certain technological innovations are able to diffuse and others not or not as fast, what the systems around innovations are composed of, and how technological system are situated in the bigger picture including socio-technical regimes and landscape influences. Many frameworks exist within sustainability transitions research of which now four have been used more frequently. These are MLP, IS, SNM and TM. There are strengths and weaknesses in each framework and between them commonalities and complementarities can be found. There is no right or wrong framework, choosing the 'best' one mostly depend on the application of the research. Unfortunately, in some cases the frameworks are regarded as completely separate research directions while the strengths of each framework independently which could serve well as a complementarity to another framework. Ideally all the different frameworks would be merged into a single one that contains all the strengths of the different frameworks. This is however not an easy task.

A possible **solution** to create the ultimate framework could be to gradually merge single frameworks or parts of them at a time. Some attempts to bring the frameworks closer together step by step have already been made in literature, for example the Markard & Truffer (2008) paper discussed in Section 3.4 which brings together the TIS and MLP frameworks. Cases are already being carried out with this combined framework, however, the value of these cases would increase if the data used for them would be stored in a platform environment which would also allow to continue building these cases with aspects from other frameworks.

What has been **achieved** in this research is the creation of a platform template based on the combined MLP and TIS frameworks that is designed as a tool to facilitate inclusion and experimentation of these two and other frameworks in a structured way.

What has **not been achieved** in this research is experimenting with other frameworks by adding (parts of) them to the platform and the research case.

This would be recommended for **future research**, as the drive of this research is to continue building on this basis of framework convergence as presented by Markard and Truffer (2008). The following sections will demonstrate how this framework development in a platform played out in this research and could be continued on in future research.

6.3.1 MLP and TIS

The **problem** with the platform template of this research is that this version only contains parts the MLP and TIS frameworks. As explained in Section 3.4 these are two of the most used frameworks in sustainability transitions research and their combination is already being tested in different case studies. The TIS is based on the structural components and uses the functions analysis to indicate possible weaknesses in the structural components. The framework, by itself, does however lack external factors in the analysis, which is one of the strengths of the MLP framework. Furthermore, the TIS is criticized for not reflecting on broad transition processes and rather used to clarify the diffusion of specific technologies (Wieczorek et al., 2015). These technologies are only a piece of transitions. As pointed out by Hekkert (2020) and presented by Aldersey-Williams et al. (2020) the TIS framework sits somewhere within the MLP framework.

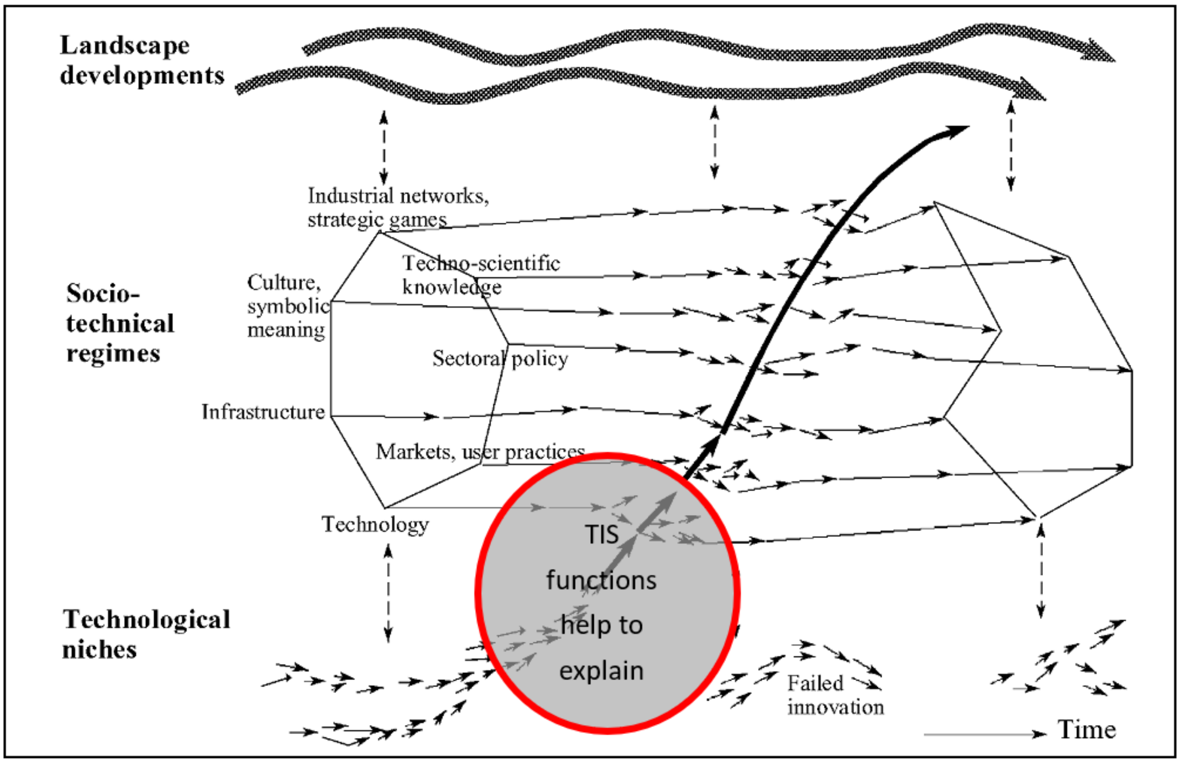

Figure 68 - Visualization of how the TIS framework sits within the MLP framework as presented by Aldersey-Williams et al. (2020).

In this research this technology specific analysis was adhered, namely, for offshore wind. This would induce that the TIS is the core framework of this research. However, the bigger picture of a transition was brought into perspective by including landscape factors and the competing technologies with estimates of how their TISs are functioning.
The technologies presented are however still limited to the electricity generating technologies scope which are still only a piece of a full transition as is looked at in the MLP framework. Here, often a transition is seen on a whole sector basis, which means that the transition should happen for the complete energy sector. That would include other innovation systems to the mix, amongst which storage and electricity transportation technologies.
The platform template of this research does already allow the inclusion of these other technologies and a more complete picture of the energy sector transition could be presented. It only would require the data of those technologies to be inputted in the platform.

For **future research** more advantage should also be taken from this detailed aspect of the platform in which complete sectors are built based on smaller pieces, in this case TISs. This can for example present the existing overlap between the structural components of different TISs. This overlap has been studied by Mäkitie et al. (2018) and can for example signal the presence and power actors have across the whole sector and not only in specific TISs, it can also show the displacement of actors from one TIS to another and it can also show the dependency between TISs. These three examples can have a significant impact on transitions as they present the status, dependency and changes of structural components of multiple TISs.

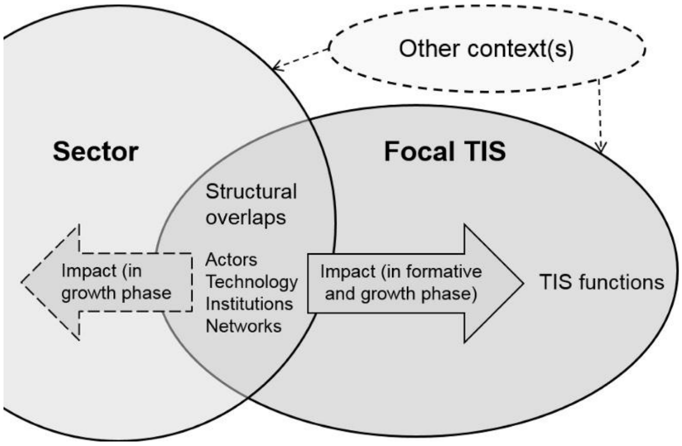

Figure 69 - Overlap of strcutural components of the focal TIS with the sector. (Mäkitie et al., 2018)

This overlap is also present in this research for the Brazilian offshore wind TIS. Some examples can be seen in the governmental actors, such as the ministry of mines and energy which is the responsible regulator for all energy technologies and ANEEL which is the national electrical energy agency that monitors the activities of these technologies. Their imposed rules or institutions often apply to all sector technologies or some of them, as was the case of PROINFA.
Another example present in this case is shown by the dependency of offshore wind power to hydrogen. Offshore wind was not able to find actors in the *user* group since it had to compete for users with other more developed, cheaper and sustainable technologies. This was not until actors from the hydrogen TIS saw the potential for synergy between the two technologies in which offshore wind would be competitive as an electricity generating technology for their hydrogen production process.

For a first draft of the platform this combined MLP and TIS framework should sufficiently serve as an example of the possibilities available in combining different frameworks. It should also help future research in presenting the overlaps between different TISs and the depth of transition that is being analysed. There are however many other frameworks with different aspects that could improve the platform for use in sustainability transitions research. One example that follows up on the transition perspective is the *deep transitions* framework, which has a multi system (or multiple sector) outlook as will be discussed next.

6.3.2 Deep Transitions

"A deep transition is a transition that happens across multiple systems and changes society in a fundamental way" (Deeptransitions.net, 2022). Here, by systems are meant sectors such as the energy-, food- and mobility sector. Meaning that deep transitions looks at transitions that happen through all these different sectors together. The theory behind this framework is that different systems are all bound to a meta-regime. This meta-regime is a standard or model accepted across a wider range of socio-technical systems. It is a preferred way and common sense for improving the system, supported by sanctions, beliefs and values (Schot, 2021). The meta-regime pushes the different systems towards common rules. An example would be sustainability, which besides in the energy system is also being implemented as a core value in the food and mobility system.
The deep transitions framework has two different research directions. One direction is *deep transitions history*, which looks at transitions from a historical perspective. The other direction is the *deep transitions futures*, which gathers the knowledge gained from the historical direction and based on this tries to determine the transition options for the future.
Deep transitions history has a very similar process to that of the MLP and TIS frameworks and to that of this research. Simply put, it comes down to gathering historical data, but instead of one system at

a time it goes for multiple systems. This historical data gathering is one of the core functions to be applied in the platform making the *deep transitions* framework a good match to be included. The difference would be found in the output presentation of the results, which for a part could still be implemented in the current platform design. A simple example of how it could be visualized can be seen in the figure below.

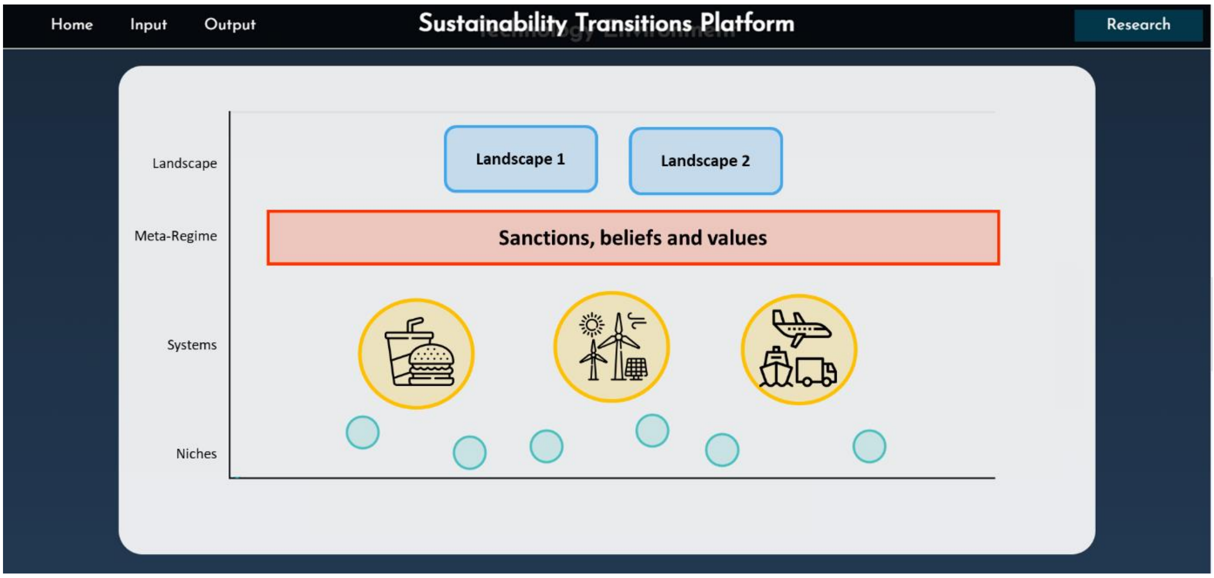

Figure 70 - Platform snapshot presenting an example of deep transitions implementation.

By having the deep transitions historical direction implemented in the platform, a full view of the historical transitions should be available which in turn should help in the analysis and recommendations of deep transitions futures. Perhaps one day the platform reaches a stage in which it can itself analyse the data gathered and give its own recommendations for deep transition futures through artificial intelligence. The version of the platform in this research already functions as a basis for adding parts of the deep transitions framework.

6.3.3 Geography of Sustainability Transitions

The next framework that could have strong applicability in the platform is *geography of sustainability transitions*. In this framework spatial perspectives on sustainability transitions are developed by looking at the spaces, places and scales at which they unfold (GeoST, 2022). One of the core points brought forward in this theory is that the context-specific structural conditions in which technologies diffuse or transitions take place can vary significantly. Take the development of offshore wind for example. Although the wind resources are very good in Brazil, there are no projects operational there, whereas they are in European countries of which most have less good wind resources offshore compared to Brazil. This has to do with differences in the contextual aspects of the countries. The level of development of the country can already play a role, as well as the actors, networks and institutions in place in each of them.

In some studies this difference between countries has been brought forward by comparing them with each other (Nikas et al., 2022; Vasseur et al., 2013; Wieczorek et al., 2013). The study by Wieczorek et al. (2013) did this for offshore wind in four different European countries: Netherlands, Denmark, United Kingdom and Germany. The results of their TIS analysis can be seen below.

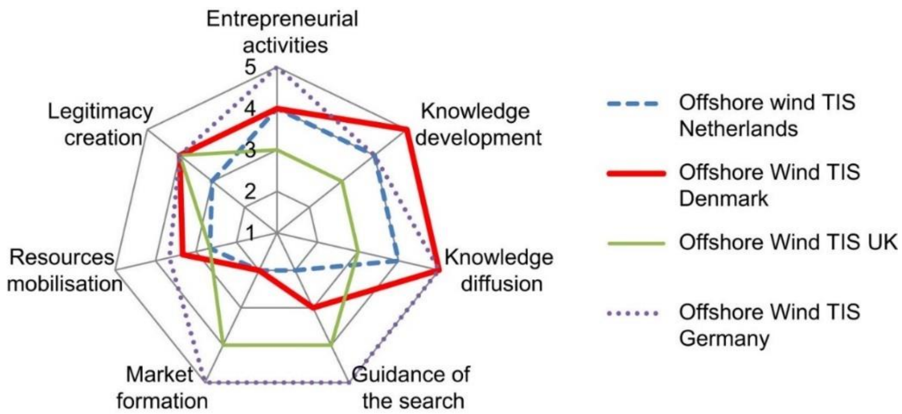

Figure 71 - TIS snapshots for offshore wind in European countries (Wieczorek et al., 2013).

There are clear differences visible in the functions fulfilment between the countries. Knowledge development is very strong in Denmark while it is moderate in the UK, and market formation is very strong in Germany while it is weak in Denmark and the Netherlands.
Wieczorek et al. (2015) point out that "the countries together seem to have all necessary ingredients for well-functioning North-Western European TIS. Weaknesses in one country are compensated by strengths in other countries". This presents some initial perspective to the possibility of collaboration between TIS development opposed to multiple perfectly fulfilled TISs on a country level. They continue to argue that "solutions to these problems [within unfulfilled functions] may not always be addressed effectively through national policy interventions as they need to 'work against the system' and are thus easily victim to policy-failure". Implying that sometimes the countries themselves might not directly be able to solve the existing problems in the TIS, which leads to their conclusion that "stimulating or strengthening transnational linkages may offer a more conducive way to approach domestic problems in the innovation system."
In light of these thoughts another functionality for the platform and future research lies at hand. This functionality would be to determine possible exchange opportunities between different TISs. By this is meant that where possible bottlenecks or gaps exist in the function fulfilment of one country, another country might have its strengths. By putting the TISs side by side and being able to compare on specific data, opportunities for exchange might be perceived. This function exchange has not been tested in this research, but the platform template could be a handy tool to select the first cases and functions that could be tested, as can be seen in the following example figure.

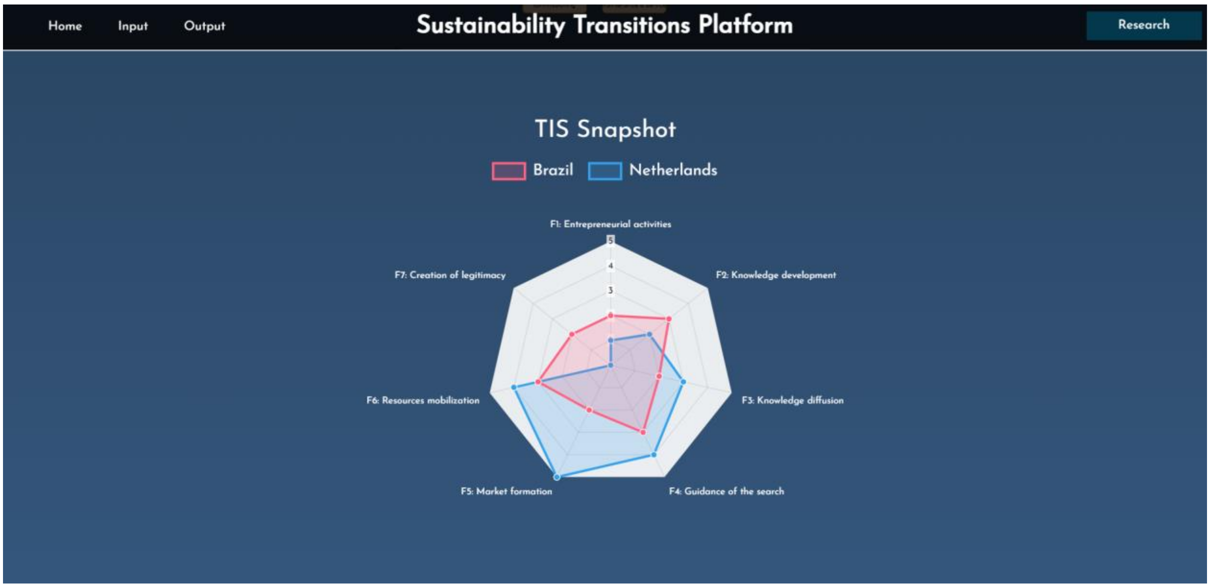

Figure 72 - Platform snapshot of the TIS Functions Analysis with example of a case where two different countries are analysed simultaneously to determine possible exchange opportunities.

The figure above relates back to the work that had been done during the internship at the consulate in which the consulate had a role in finding information relating to the development of offshore wind energy technology in Brazil and be able to point out the strengths of offshore wind in the Netherlands and find possible opportunities for Dutch companies in the Brazilian market.
There are of course other things that have to be taken into consideration in this international exchange as the conditions in which the Dutch companies are used to operate might be different in Brazil. Also, much thought should be given from the Brazilian side as to which parts of the TIS could be outsourced to other countries without having a significant national impact or having the national TIS too dependent on an international TIS.
To a certain extent, adding multiple country cases for a specific technology in the STP also provides parts of the *global innovation system* of that specific technology. This could allow researchers to zoom out of the specific country cases and see how the technology is developing on a global level but still based on very detailed levels.

6.4 Platform Theory

As discussed in Chapter 4, the Sustainability Transitions Platform should be designed as both an innovation and a transaction platform in order for it to reach its maximal potential. The design of the platform template for this research has primarily been focussed on the innovation platform perspective of it. This decision has partially been made because the sustainability transitions research field on itself already appears to be operating on the same concepts as innovation platforms do. Namely, innovation platforms consist of a core module on top of which components can be added, that complement the core, through which a variety of products can be created. This results in an innovation inducing environment on the component layer while maintaining structure and quality with respect to the core. On a conceptual level the sustainability transitions research field tries to understand innovation and transition processes (core) by making use of theoretical frameworks (components) and testing them through cases (products). Through research and publications innovation is continuously introduced to the endlessly growing theoretical framework of sustainability transitions research.
The static nature through which this is happening does however make it somewhat difficult or overwhelming to keep track of all the theoretical innovations and how they are precisely structured within the core of understanding innovation and transition processes or to what extent they complement or overlap existing frameworks, which in turn can lead to loss of quality in the research field. A digital variant for this research field would require more deterministic linkages of where the innovation precisely fits in the core of the field and its already existing frameworks. Consequentially, this would also allow to automatically track the variances in innovation given the computational environment of inputs and outputs on which digital platforms are based. That is why a digital variant of this innovation platform in research could already be useful to structure the progress in theoretical innovation and secure the quality of the research field.

Turning to the other platform perspective, this research has not presented how the STP would precisely function as a transaction platform, while it is expected that this perspective will be essential to make the platform progress.
Transaction platforms are regarded as triangular business models in which the platform functions as an intermediary between two actor groups. This does not mean that only two specific actor groups are able to use the platform, instead it means that the platform serves as a facilitating tool for exchanging something of value between two actors groups of a value chain that were initially not, or not easily, able to. This allows them to exchange their product of value directly with the required party without being dependent on other multiple intermediaries of the value chain to interact between them as is usually the case in 'standard' businesses. This dependency on a supply chain with multiple intermediaries that partake in the transfer of value from producer to user is known as a linear business model.

The business model for sustainability transitions research has not been studied in particular. However two different angles to a business model appear to be in place.
One angle relates back to the platform as an innovation platform where researchers have a double function. On the one hand they are the ones that produce the cases (products) and on the other hand they are the ones that use the cases (products) to find ways to improve the frameworks (components) and with the gained knowledge are able to produce new cases to better understand innovation and transition processes (core). From this perspective researchers are both the knowledge producers and consumers which makes knowledge the exchangeable value that leads to improvements in the core and components of sustainability transitions research, making it a self-sustaining loop but not particularly a good business. That has to do with this inward looking perspective relying on researchers themselves to continuously keep growing the research field.
The other angle has a more outward perspective, where the knowledge produced in the sustainability transitions research field would support practitioners in policy making or sustainable business development. This serves as a much bigger incentive to continue to improve the theory as the theoretical knowledge gains practical value. This transfer of knowledge from researchers to policy makers is already happening and can for example be seen in Luo et al. (2012).

The process in which the initial knowledge gets generated and transferred to the policy makers does currently resemble a linear business model, containing the following chain:

i) Data: the raw material of the value chain
ii) Researchers: individuals or groups of individuals who gather data and transform it to knowledge through designed frameworks and case experimentation.
iii) Intermediary institutions: the organizations for which the researchers work or the organisations that are financing the research project and the publishing groups that are able to present the research papers to a larger network.
iv) Policy makers: individuals or institutions that use the available knowledge to decide on and implement policies.
v) Public: individuals and businesses influenced by the policies which in turn act responsively to the new set of rules.

The new policies trigger a reaction from individuals and businesses which act in a particular way resulting in a new set of data for sustainability transitions analysis. This chain has been depicted in the following figure.

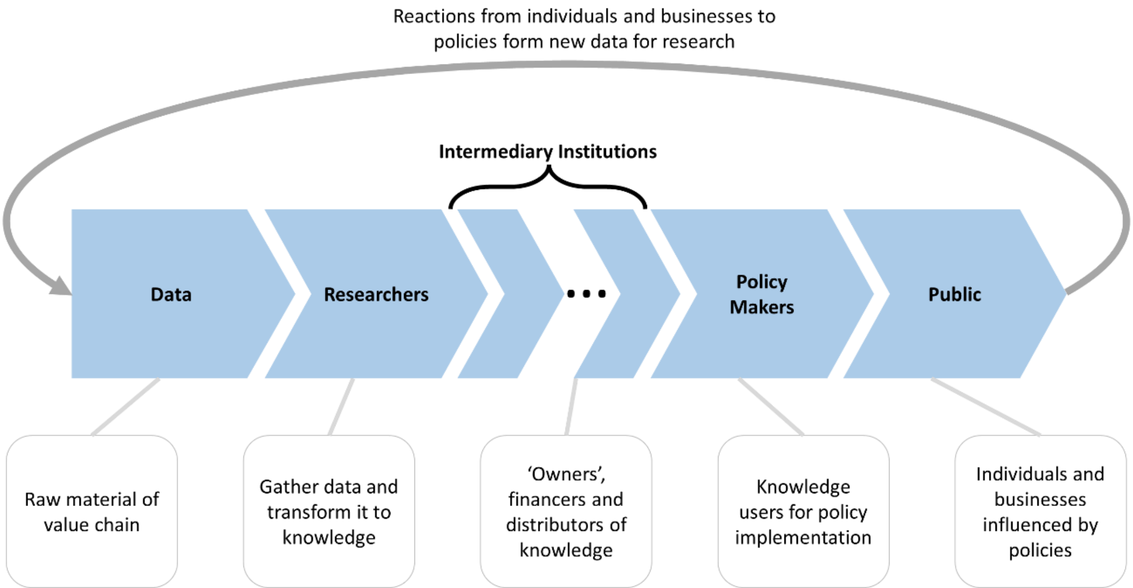

Figure 73 - The perceived linear business model for sustainability transitions research.

From a transaction platform perspective the sustainability transitions business model would change from a linear to a triangular form in which the platform would take the role as an intermediary connecting the individual researchers, as knowledge producers, and the policy makers, as knowledge users (see Figure 21). By doing this a direct connection can be made between the over 3000 members of the sustainability transitions research network ((STRN, 2022) and the global pool of policy makers.
The platform itself would function as a data gathering, categorizing and processing tool for researchers which they can then use to analyse and create knowledge about cases and would function as a knowledge database for policy makers. If taken full advantage of the digital possibilities, the platform could be further developed to algorithmically do the data gathering, categorizing and processing saving the researchers time to analyse the cases and improve the theory. Nevertheless, the question remains if this triangular business model would generate enough interest on both sides of the users of the platform to actually create a network effect bringing the platform to its full potential.
These are points that should be dived into in future research and especially be experimented with to get a feeling of how the different platform perspective and business models work for sustainability transitions research in practice.

6.5 Practical Implications

This research has tried to present the idea of a digital platform for sustainability transitions research, which is referred to as the *Sustainability Transitions Platform* (STP). To present this idea a template of the STP has been built on which future versions can be developed. As we have seen from this research there are many advantages to building a fully operational version of the platform but there are also some implications regarding how the platform should be built and how it should function with respect to the elements present in sustainability transitions and platform theory. To add to this, there are also other more practical implications to building such a platform which have to be taken into consideration if the development of the platform is to be proceeded. These will be treated next through a series of questions.

First of all, there are already existing 'digital platforms' in sustainability transitions research (e.g. Deeptransitions.net, 2022; DRIFT, 2022; GEIST, 2022; GeoST, 2022; NEST, 2022; STRN, 2022; Transitiepraktijk, 2022). So, what makes this one different and what should it be used for?

> Other platforms seem to focus on presenting the core concepts in sustainability transitions research or their specific areas within the research field and making available or referencing to the most important papers and other forms of academic literature. Making these more a type of theoretical knowledge base about the theoretical frameworks of sustainability transitions.
> The STP has a more hands-on utility, where the intention is to make researchers interact digitally with actual case applications. This would also make it a knowledge based platform but with a more practical aspect that should help them in the process of applying the theory in practice, making it more of a playground to experiment with the existing sustainability transitions theory. Once a platform version has been developed that is perceived as accurate and appropriate by researchers a step can be taken to allow actors from outside the research field to use the platform as well. Because of the user friendly interface digital platforms have compared to academic papers, it should make it easier for people outside of research to also experiment with the theory behind sustainability transitions, bringing theory and practice closer together.

Getting this platform to actually be developed and functional for researchers seem like a difficult task. How would that happen?

> That would require software developers to build a version that can actually be rolled-out for testing. At first it should be tested by a small group of sustainability transition experts which will lead to an iterative process that should result in a version that could be put online for

other researchers to use as well. This step could also be done in combination with academic courses on sustainability transitions where students would try out the platform to test and learn about cases and the theory.

Once a version is rolled-out which all researchers could use, more cases would be implemented at a faster pace and this would most probably generate more feedback points for the platform. This will indeed be a long process of iteration which in a sense will be continuous as long as sustainability transitions theory itself is being worked on. This will require a delicate interplay between what is important to grasp from theory and how that can be converted to digital visualization.

Here it seems to be assumed that researchers are willingly going to use and implement cases in the platform. What would their incentive be to do so?

The Sustainability Transitions Research Network has over 3000 members according to their website (STRN, 2022). Hopefully, many or at least some of these scholars will be incentivised by the idea of structured and simplified data processing for their cases. Nevertheless, it would not hurt to also add a financial incentive to it. The author does not have a background in business, finance or economics but a suggestion could be to build a similar business model to that of Spotify (the music platform).

In short, the business model of Spotify is a two-sided music marketplace for users and artists. Spotify users pay a monthly subscriptions fee to have an account and be able to listen to music. The artists receive a part of this fee (royalties) as their content is listened to. The more users listen to an artist the more royalties the artist receives. This stimulates the artist to provide more content. Which gets more users interested in getting Spotify subscriptions if they are the only/best/cheapest providers of the content they want. Which again stimulates more artist to upload content to Spotify as the pool of music listeners gets bigger and can give them more royalties. In addition, through software the Spotify platform also provides data analytics to the artist about their listeners which they can again use to improve their own businesses.

Translating this business model to the STP: the artist that upload music on Spotify are the researchers that upload their cases (data and analysis) on the STP and the users that listen to music on Spotify are individuals or organisations that use the STP to extract case information. STP users pay a monthly subscriptions fee to have and account and gain access to sustainability transitions studies and their data. The researcher receives a part of this fee (royalties) as their content is accessed. The more users access a researcher’s data and analysis the more royalties the researcher receives. This stimulates researchers to provide more content, which stimulates more individuals/companies to get STP subscriptions if this is the only/best/easiest way to get the required data. Which again stimulates more researchers to upload content to STP as the pool of users gets bigger and can give them more royalties. In addition, through software the STP also provides data analytics to the researcher about the users that access their data which they can again use to improve their own research.

What information does the platform deliver that could be of interest to companies or individuals outside of the research field and would this incentivise them to get a subscription fee?

With the STP complete systems around a technology are being built. Users of the platform are able to see all the actors, their networks, the institutions and the environment in which the technology is or will be operating. The first group of interest for the platform from a practical perspective would be policy makers, as these frameworks are mostly being used for policy advise. Policy makers can then see where the structural bottlenecks are in the system and introduce policies directed to overcome them.

From a different perspective, which was personally experienced during the internship at the Dutch Consulate General in Rio de Janeiro, inquiries would come in from companies (in this case a wind turbine maintenance company and an offshore network organisation) to the consulate about the Brazilian offshore wind market, regulations and actors. If this case had been carried out and implemented in the platform, these companies could directly access it by getting a subscription and would not have to wait for someone else to present them the information or have to do the analysis themselves. From the consulates perspective it could be interesting to have the subscription and be able to present the information to the inquiring companies if they were not willing to get a subscription themselves, instead of hiring a costly team of consultant to carry out a research on the case and generate a report (which was done in this case during the internship). Continuing on this thought, also the consultants could use the STP as a tool to first gain knowledge about the case and eventually also use it to present results to their clients. These are some hypothetical cases and no statements can be made yet if these or other individuals or companies willing to get subscriptions and pay for the STP.

If users are paying subscription fees and researchers receive more royalties once the users access their data, would it not compromise the quality of the research as researchers would be driven by the financial incentive and want to have as many users accessing their data even if incorrect or incomplete?

This can indeed happen and that is why researcher accounts have to be verified. First of all, to prevent random persons inputting random data just to get royalties and, secondly, preventing actual researchers from taking advantage of the royalties system. A controlling group would be necessary to check if data and cases being inputted are indeed valid. That would require a board of controllers that are experienced with sustainability transitions theory and would be willing to check the cases. This would of course not be too different from checking cases that are being carried out on paper and presented in academic journals.

Could the data input system be rigged so that one researcher is able to input many cases very fast though automated software which makes use of artificial intelligence?

Absolutely! To some extent that is also what is trying to be reached at a more developed stage of the platform, namely, making the STP autonomously gather and categorize case data through artificial intelligence to reduce this time-consuming process for researchers. The controlling group should be able to prevent 'bad' cases from being uploaded but once the AI software has improved enough to automatically generate good quality data and cases a step can be taken to have automated cases as the standard.

Could AI also improve the STP in other ways?

Indeed it could. One example could be that if enough cases and the corresponding analysis are implemented in the STP, AI can learn from the database and already generate policy suggestions for new cases that have no analysis yet. Another possibility could be that the STP already presents suitable new markets for companies looking to expand their business abroad. In other words, the wind turbine maintenance company, previously mentioned, could directly receive indications of suitable markets for their business instead of having to reach out to multiple consulates or hiring consultants to get information about the different markets.

Will the STP not require a lot of data which has to be stored in data centres which are considered unsustainable because they require a lot of energy?

This remains unclear as indeed a lot of data is required and is continuously going to increase as each year new data is generated. The data can however mostly be saved in a CSV format which is a small sized data format, while many other platforms also store large sized data formats (e.g. JPEG, PNG and MP4) that are used for images and videos. This would already indicate that the amount of data that has to be stored in the STP is smaller than that of some other platforms. In addition, the data for the cases is mostly already available on the internet (or an intranet) which means it is already being stored in some database which in theory should be retrievable to the platform, meaning that there would in principle be no need to build new data centres. How this would exactly be done is outside the expertise of the author but should definitely be looked at.

To finalize this discussion one last thought will be shared: It is interesting to realize that what seems to be happening is that a technological innovation system for the sustainability transitions platform is being constructed and that the complete analysis presenting the technology environment, structural components and TIS functions analysis should be further carried out to fully understand the existing bottlenecks in the TIS of the STP and what would be required to make the platform technology diffuse.

Chapter 7 – Conclusion

This research has tried to present the idea of the *Sustainability Transitions Platform* (STP), which is a digital platform for sustainability transitions research. It has done so by building a first draft of the platform (referred to as platform template) limited to the *Multi-Level Perspective* (MLP) and the *Technological Innovation Systems* (TIS) frameworks of the sustainability transitions theory. To build this platform template the following research question has been tried to answer:

'What elements should be present in a digital platform for the combined MLP and TIS frameworks and what could such a platform look like?'

The research question has been split up in a set of sub-questions which have been used as guidance to answer this research question. The answers to each sub-question are as follows.

Sub-question 1: *What are the Multi-Level Perspective and Technological Innovation Systems frameworks and what are their most relevant elements?*

Both the MLP and TIS are frameworks within the sustainability transitions research field. This research field is built on the notions of innovations and transitions, and tries to understand how something radically new can become (a part of) the regime by considering the multi-dimensional aspects of the process.

The MLP framework is used to study technological transitions. It tries to understand and present the influencing factors of change in systems (e.g. in energy, transportation, food). It does so by building the system based on three different levels. These are the i) landscape developments (macro), which are the highest level of influence and are for example, political, cultural and demographic factors that influence the system; ii) socio-technical regimes (meso), which are the existing set of rules, and the group of actors and their networks embedded in the environment; and iii) technological niches (micro), which are the disruptive and unstable innovations trying to develop and enter the regime (Geels, 2002).

The TIS framework is used to study technological innovation systems. It tries to understand and present the influencing factors that result in the emergence, diffusion and utilization of technological innovations (Markard & Truffer, 2008). It does so by, firstly, building the structural components of the system, composed of: i) actors, which can be individuals, companies, organisations that are involved or influence the technological system; ii) networks, which are the linkages between the different actors of the technological system; and iii) institutions, which are the 'rules of the game' by which the actors abide and contain laws, policies, regulations but also soft rules, such as culture and beliefs. Secondly, through a set of functions the operationality of the system is assessed, also known as the functions analysis. Different sets of functions can be found in literature, but a frequently used set is the one as described by Hekkert et al. (2007). This set contains seven functions: F1-entrepreneurial activities, F2-knowledge development, F3-knowledge diffusion, F4-guidance of the search, F5-market formation, F6-resources mobilization and F7-creation of legitimacy. By making use of indicators the fulfilment of each function can be determined and scored on a 5 point-scale where 1 is absent and 5 is excellent. An unfulfilled function indicates a possible bottleneck in the TIS which relates to a problem in the structural components that could hamper the generation, diffusion and utilization of the technology.

Sub-question 2: *What are their commonalities and complementarities and how are they being combined?*

Both these frameworks are designed to help understand the influencing factors that result in changes in technological systems and could lead to transitions. This is done by gathering, processing and analysing historical data related to the system for specific periods in time and presenting their conclusions in academic papers or reports. In both frameworks data is gathered related to the actors, networks and rules of the system, which are regarded as important components of the analysis.

The main difference between the frameworks is that, the TIS has a more complete grasp on actor roles, strategies and interactions which can influence innovation processes and better tools to analyse innovation dynamics at the niche level, while the MLP has a more outward view of the system and also takes the environment or context in which the system resides into the analysis. Their differences allow for a possible combination of the frameworks where the tools of the TIS framework can be complemented with the outward looking environmental or contextual factors of the MLP frameworks. This combined framework has already been suggested and presented in the study of Markard and Truffer (2008) and is being experimented with in different cases.

The way in which data relating to the cases is gathered, processed, analysed and presented differs substantially in literature. This can make the analysis and the following result presentation vary between cases and make it difficult to fully understand changes in systems and transitions. That is why a structured and simplified method of case analysis should be found for sustainability transitions research. There are already existing technological tools that could help improve this process. These technological tools are commonly known as digital platforms.

Sub-question 3: *What is a digital platform?*

In literature two types of platforms can be found, which are innovation platforms and transaction platforms. Transaction platforms are regarded as intermediaries which allow participants to exchange goods and services or information, while innovation platforms consist of a core module on which other (innovative) components can be added as complementarities (Cusumano et al., 2020; Gawer, 2014). The most successful platforms contain both perspectives and are recommended for the fully operational STP, thus the definition would be translated to:

a software based digital platform that acts as a bridge between researchers of sustainability transitions and actors who make decisions that influence innovations and transitions, in which researchers are able to input gathered data and are able to interact and analyse it generating knowledge related to innovations and transitions which can be used by policy makers or other actors to guide them in their decisions towards a sustainable future. Hereby a community is created in the platform of researchers who are able to see and interact with each other's work allowing them to continuously evaluate the sustainability transitions theory making it possible to structurally and efficiently improve and innovate the theory and its frameworks resulting in a more accurate understanding of innovation and transition processes.

The word 'digital' refers to the platform being built through software making it a coded digital interface with various functionalities. An example of a functionality would be that the platform allows different types of actors to interact with and analyse some form of data. In the case of the music platform Spotify, it allows artist to upload their music and users to listen to the music. Users can search for the songs they want to hear and save them in playlists while artist receive royalties for their work and obtain knowledge about their listeners through data analytics delivered by the platform. These are only a few of the functionalities that a platform has for music platform. The possibilities in functionalities for different types of platform are immense and for a big part only limited to the imagination of the platform developers.
To achieve the goals desired in this research, a platform would be required to at least,

1. allow researchers to input case data into the platform in a structured way and save this data in a database,
2. convert the inputted data through predefined software logic into clear presentable results by making use of data visualization tools,
3. allow users to access and interact with the visualization tools in order to understand cases and their underlying data.

Compared to conducting and presenting research cases on paper a digital platform can provide i) structure, which helps to clarify for both researchers and users which data should and has been used in cases; ii) adaptability, which allows researchers to adapt existing cases in accordance with changes happening in the underlying theory; and iii) interactivity, which allows researchers and user to better analyse and understand the relevance of specific parts of the data. These points present some of the advantages that could be gained for sustainability transitions research in the quest to fully understand technology development and transitions through the use of a digital platform.

Sub-question 4: *How can the MLP and TIS framework elements be combined in a platform?*

Based on the points discussed in sub-questions 1, 2 and 3, a platform designed on the MLP and TIS frameworks should contain the following elements:

1. the environment in which the technological innovation system resides,
2. the actors, networks and institutions of the system,
3. the functions analysis tool to determine how the parts of the system are functioning,

By taking these three points a platform template has been built that contains three different visualization tools that each represent one of these elements. These elements and their visualization tools are, in the platform template, referred to as i) technology environment, ii) structural components and iii) TIS functions analysis, and present the following:

Technology environment, presents the technology being analysed within a graph together with other technologies relevant for the analysis as comparison and landscape factors that influence the system.

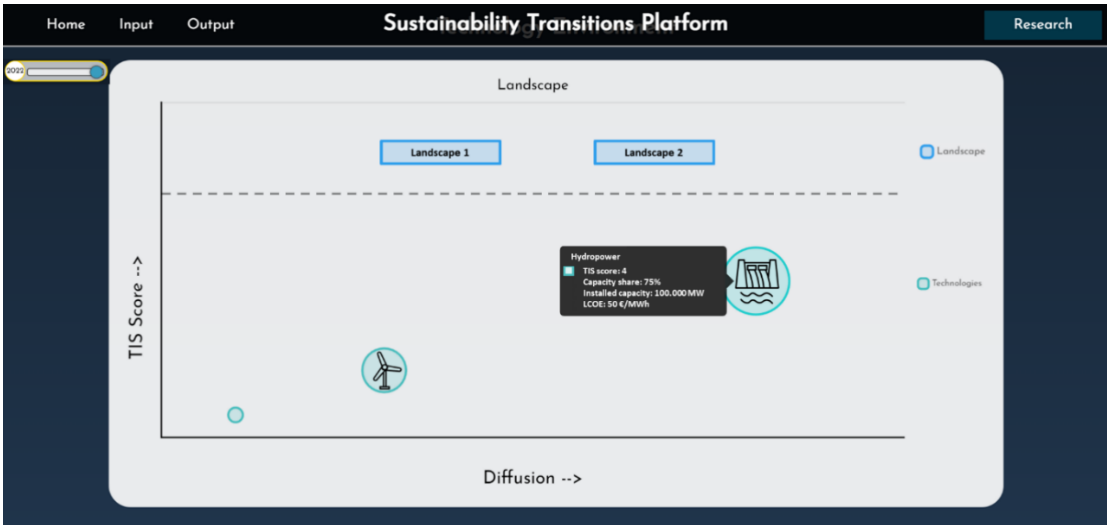

Figure 74 – Platform snapshot showing the visualisation tool representing the Technology Environment. This includes the technology being analysed in context with other technologies and the influencing landscape factors. Additional data is also presented for a technology by making use of the interactivity of the platform.

Structural components, presents all the actors in a structured way through predefined groups and their networks all in the same graph and the relevant institutions in a table.

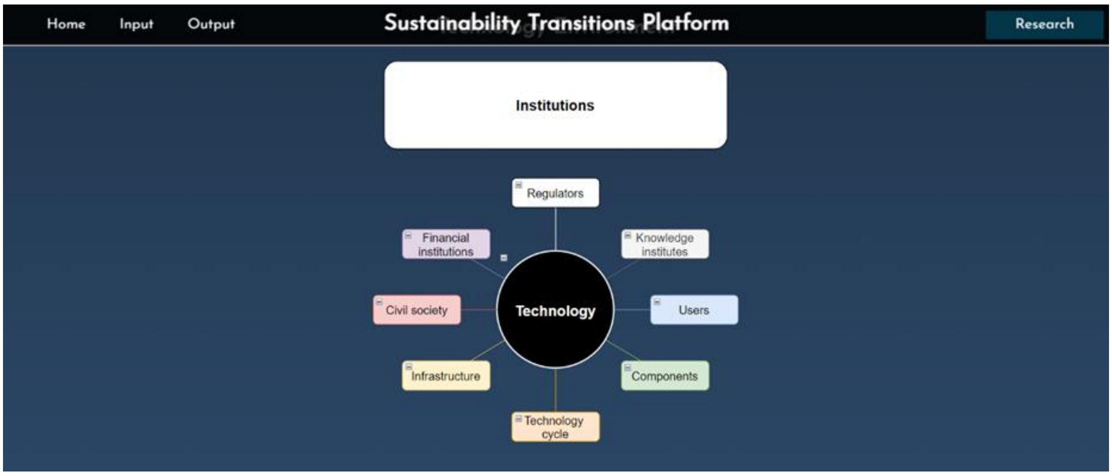

Figure 75 – Platform snapshot showing the visualisation tool representing the Structural Components. It shows the actor group division for a technology and a table space for the institutions. The networks also become visible in this visualization once the data is inputted.

TIS functions analysis, presents how the system is functioning in a radar chart based on a set of functions and their corresponding indicators. In the platform template it was opted to score the indicators individually and having their average determine the function score instead of scoring the function directly. This was done to maintain clarity in the influence each indicator has for the function score.

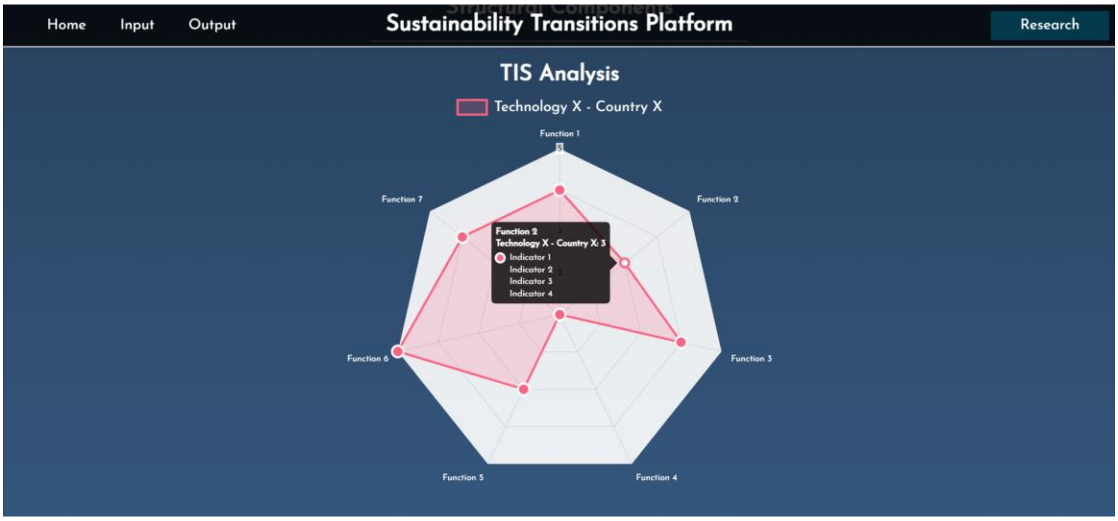

Figure 76 – Platform snapshot showing the visualisation tool representing the TIS Functions Analysis. It shows the score each function has received based on a set of indicators which can be retrieved by making use of the interactivity of the platform.

These visualization tools are designed to portray the most important parts of a case with respect to the used MLP and TIS frameworks and allows user of the platform template to interact with the tools to better understand the system and its changes but also the underlying data applicable to the case.

Sub-question 5: *What would a platform case implementation look like?*

To test the platform functionality a case for offshore wind energy technology in Brazil has been carried out and inputted in the platform template. Data was gathered from 2002, which was the year in which the first data point was found specifically for offshore wind in Brazil, until 2021. This data was then decomposed in *who* and *what* questions and inputted in the database also adding the required additional points (e.g. date of occurrence, actor type, indicator type). For the paper version of this research (which is required in an MSc. thesis) the case was analysed for three different periods and snapshots of the platform during the last period (year 2021) will be used as clarification of what a case implementation would look like.

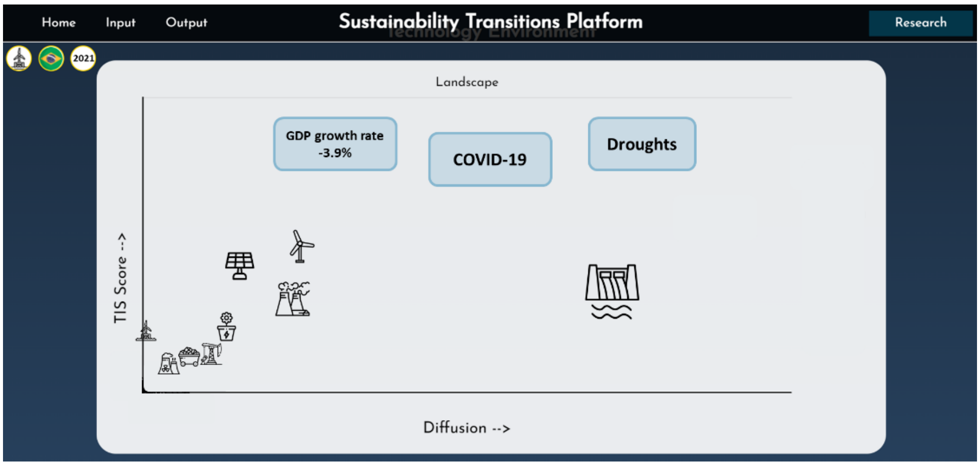

Figure 77 - Snapshot of the technology environment section of the platform template for the case of offshore wind energy technology in Brazil in 2021.

From the snapshot above we can see that hydropower is the dominant electricity generating technology in Brazil. It has however been struggling due to landscape events such as COVID-19, economic stability and droughts. These landscape event (droughts in particular) have given opportunity to other technologies to start diffusing in the market, especially onshore wind and solar PV, which had not started to diffuse yet at the beginning period of the analysis. We can see that offshore wind still lags behind in competition and has not yet been able to enter the market.

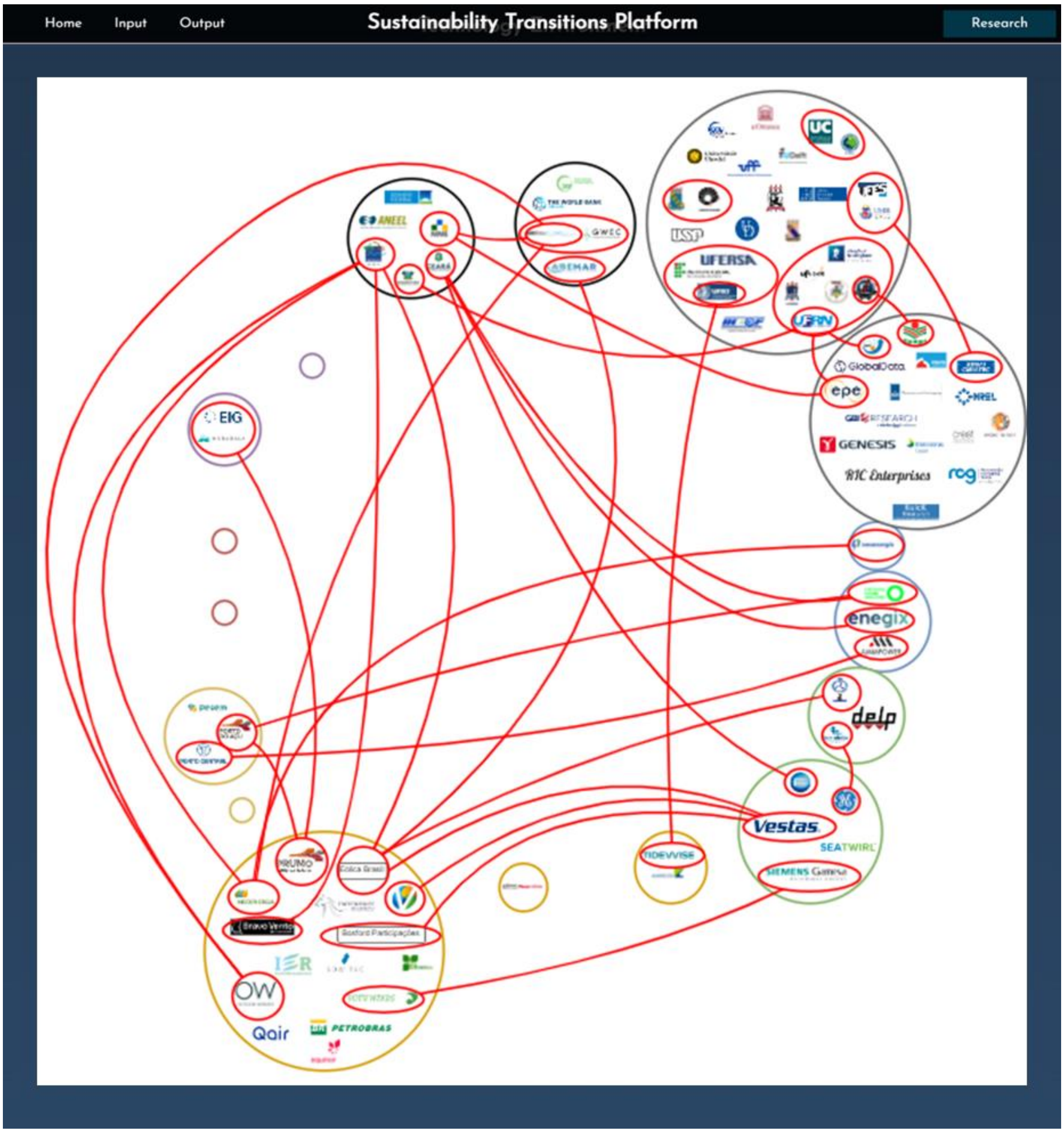

Figure 78 - Snapshot of the Structural Components section of the platform template for the case of offshore wind energy technology in Brazil in 2021.

From the snapshot above we can see that most of the actor groups are present, some more than others, but there are also some groups still missing (debt financers, civil society and grid actors). We can also see that multiple linkages have been formed between different actor groups, which are the red lines on the graph. A lot fewer actors and networks were present in the periods before, because of the high competition with other technologies (can be seen in the technology environment), and this increase in the last period can for a big part be linked to the entry of actors in the users group, which are primarily hydrogen developers who saw the potential in synergy of the two technologies in the country.

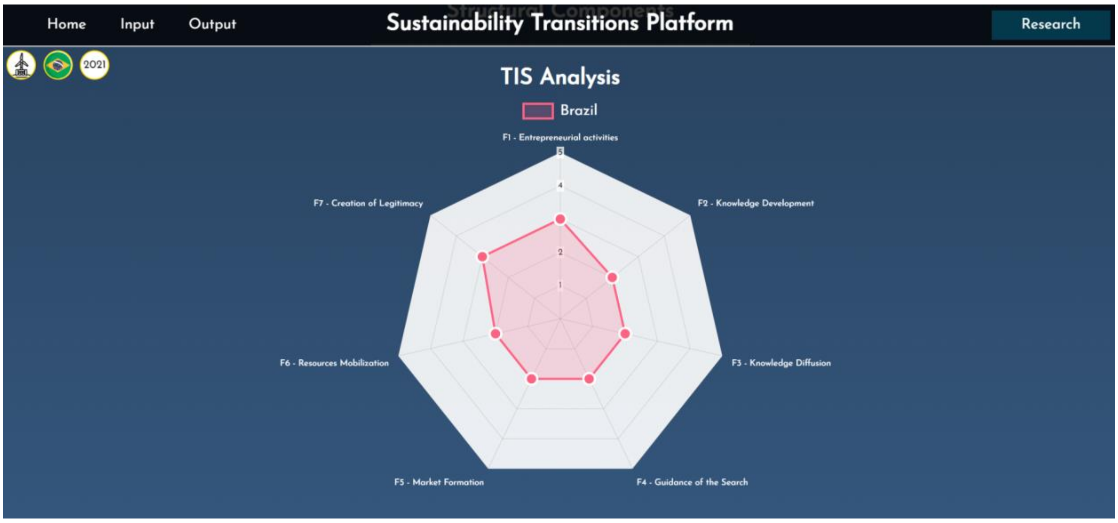

Figure 79 - Snapshot of the TIS Functions Analysis section of the platform template for the case of offshore wind energy technology in Brazil in 2021.

From the snapshot above we can see that function 1 (entrepreneurial activities) and function 7 (guidance of the search) are the most fulfilled functions with a score of 3 (moderate). The moderate score for function 1 has come to place by the moderate and good scores of the indicators 'new entrants', 'start-ups' and 'diversification activities', while for function 7 it was because of the good score for the indicator 'activities that legitimize the technology'. The other functions are still lagging behind and are considered as weak. All functions still require attention and a lot of improvements if the technology is to diffuse easily and quickly.

This brings us back to the main question of this research, namely, 'what elements should be present in a digital platform for the combined MLP and TIS frameworks and what could such a platform look like?'. This research has shown that a digital platform designed with elements of the combined MLP and TIS frameworks should present i) the environment in which the technological innovation resides, ii) the actors, networks and institutions of the system, and iii) the functions analysis tool to determine how the parts of the system are functioning. These elements have been transformed into visualization tools in the platform template as can be seen in Figure 74 (technology environment), Figure 75 (structural components) and Figure 76 (TIS functions analysis). Through the implementation of a case we can also see that the platform template does indeed present the desired outputs of the data in the visualization tools and allows researchers to draw conclusions on what is influencing the development of the technology in a specific country. This would suggest that more cases could be tried out in the platform template.
However, this version of the platform template is far from complete as i) the data gathering and categorizing process is very time consuming and is prone to errors, which is why it should be automated; and ii) there are still aspects from the MLP and TIS literature that bring essence to the analysis and are not being grasped in the visualization tools. For example, the power or influence individual actors have within a TIS, or if specific indicators should be weighed heavier than others to determine the function score. These are aspects that should be taken into consideration and could probably in some form be implemented in the platform as well due to its dynamic nature.
As a concluding remark, the author's intention with this research is to build the idea of a platform that works for the whole sustainability transitions research field and not only for two of its frameworks. This platform template is only a first draft of the platform envisioned which consists of a complete sustainability transitions framework that has been merged together from already existing and new frameworks by joining their commonalities and adding their complementarities. This could be easier, or perhaps clearer, if done digitally with the help of the dynamic aspects of a platform instead of only through the static build of papers. This could also help researchers compress their knowledge and

thoughts into a digitally complex but visually simpler form that can also be used by individuals outside of the research field bringing theory and practice closer together.

It is time for some technological innovation
in research about technological innovations.

Appendix A – Link to STP

Link to the *Sustainability Transitions Platform* (STP)[5]:

https://sustainability-transitions-platform.on.drv.tw/STPTest/

[5] This is only a demo version for readers to be able to see how the platform looks on their laptops. The Interactivity is limited.

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