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PORT METATRENDS

Impact of long term trends on business activities, spatial use and maritime infrastructure requirements in the Port of Rotterdam

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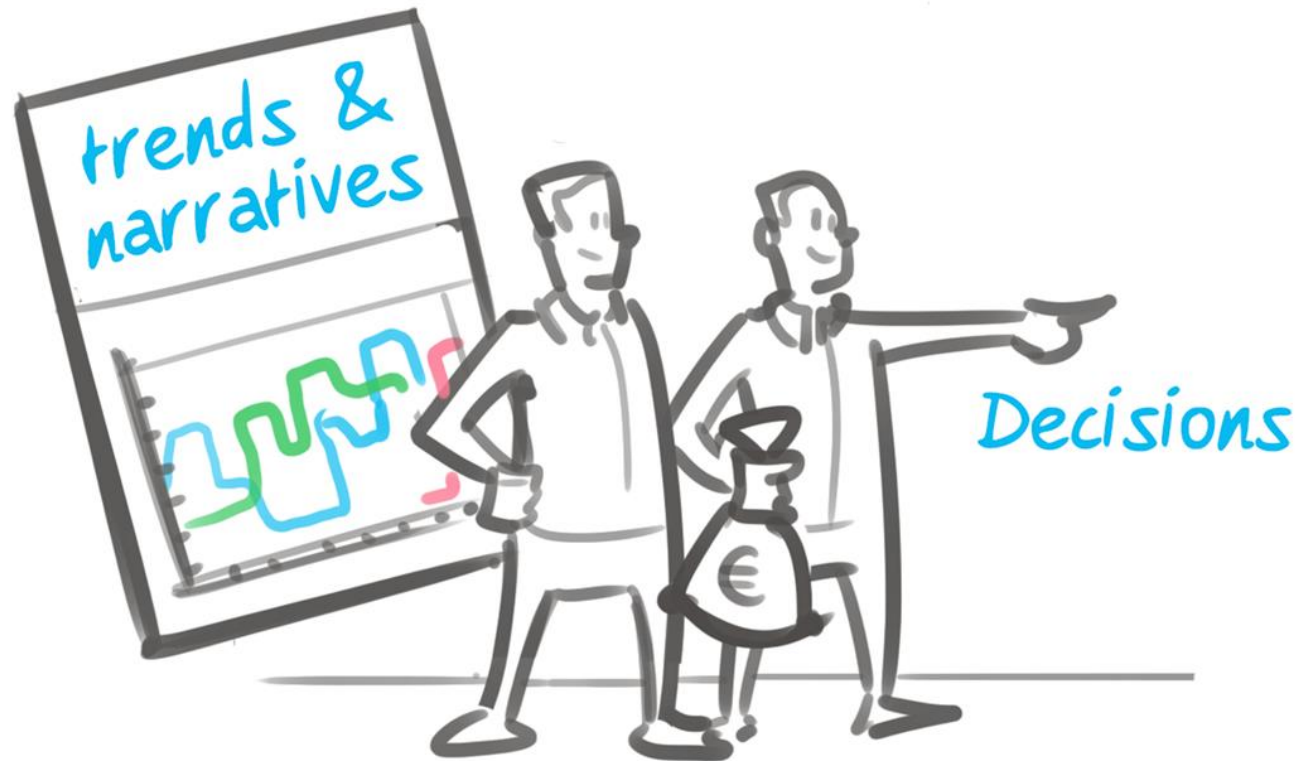
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S.1 Introduction

- This study demonstrates that through the use of a new scientific method that analyses long-term trends by placing them in a broader 'meta'-perspective, it is possible to identify the threats and opportunities for the port of Rotterdam.
- In face of the energy- and sustainability transition, new sustainable industrial activities are likely to take over the dominant position of the present fossil industry by the year 2040. By then, additional space is likely to become available in the port, and sustainable activities will start to scale up. Until that time, it is essential to utilise the scarce available space in the port optimally, so that the port serves as a breeding ground for promising sustainable industrial clusters.
- In order to achieve this, a clear view on what developments to expect and how to cluster future port activities is required. An exhaustive trend-analysis resulting in sixteen narratives that address the threats and opportunities for the port, as well as a port layout showing the possible locations of promising, future-proof clusters for the year 2040, is presented in this report.

Background

- The world is undergoing a major transition as a result of which the port of Rotterdam could lose up to 50% of its current throughput volumes, but the transition also offers many new business opportunities.
- To prepare the port for the future, use is generally made of forecasts and scenarios, but each of these methods has its own disadvantages. Forecasts perform well in stable times, but not in times of transition. Scenarios are well suited for analysing if the existing port activities are future-proof, but do not help in creating a shared vision that can provide guidance for seizing opportunities offered by the ongoing transition. In fact, if new investment decisions take into account a wide range of possible future scenarios, the result may be what the Dutch call 'a sheep with five legs', or a non-competitive port that can accommodate a wide range of activities at the cost of being non-competitive.
- The current forecasting and scenario methods are thus less suitable to adequately anticipate future developments in these times of major change, while port authorities are, especially now, in need of concrete guidelines for making investment decisions.
- To secure its position as a leading port in Europe and to ensure it in an uncertain future, the port of Rotterdam needs a clear and widely shared future vision, that recognises the threats and opportunities confronting the port.

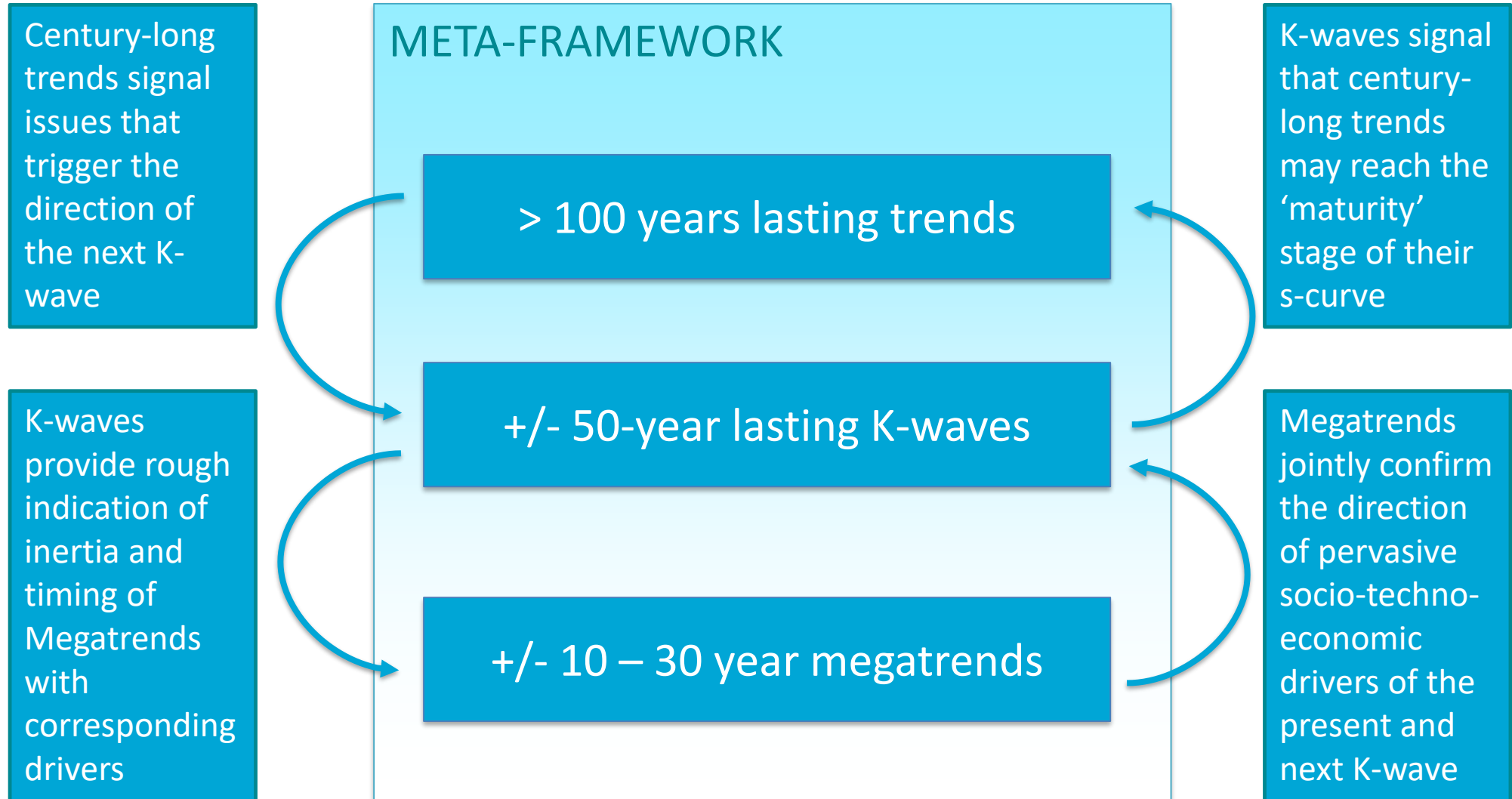
Three step approach

- This report presents a new three step approach for developing a shared vision on the future development of the port.
- The first step concerns a novel three layered framework for analysing future developments. In this step relevant trends are identified and placed in a broader 'meta'-perspective of a three layered framework, whereby different layers relate to trends of varying inertia (or duration). This multi-layered approach results in a sharper view of the future, which narrows down the 'plausible' future space.
- The second step concerns a new approach in which trend based narratives are used to identify threats and opportunities for the port. The insights from the three layered trend analysis are translated into sixteen well-structured storylines or 'narratives', that take the strengths and weaknesses of the port of Rotterdam as a starting point and thus address threats and opportunities specific to the port.
- The narratives indicate which activities are likely to claim scarce space in the port over the next two decades. They help to form ideas about a future-proof clustering of activities, the required space in the port, as well as the required infrastructure and utilities.
- The third step concerns creating a spatial development strategy based on the insights provided by the narratives.

S.2 Framework for analysing trends

- The future is uncertain and nobody possesses a crystal ball. However, by placing trends in a broader 'meta'-perspective, insights into plausible future developments and their implications, can be improved.
- The challenge is to reduce the set of futures that is considered plausible by improving our understanding of the dynamic behaviour of pervasive long-term trends and key uncertainties. To this end we introduce a novel three layered framework for assessing the course of future trends (see Figure 1).
- Each layer in this framework relates to trends with a different level of inertia and duration. The first layer concerns trends that have existed for more than a century, for which the direction is relatively clear. The second layer contains the movement of the so-called Kondratieff waves (or K-waves), that reflect an about 50 years long cyclical movement in the world economy. The third layer contains the remaining (mostly technology driven) megatrends such as autonomous sailing and 3D printing, of which the drivers are often closely linked to the pervasive drivers of the K-waves.
- The essence of analysing trends at three distinct levels of inertia is that by placing different layers of trends in a broader 'meta'-perspective of an overall framework, each layer provides added insights at the level of adjacent layers. This creates a sharper 'picture' of the future and improves our ability to anticipate on future developments

Figure 1: Three-layered meta-framework



Source: own representation.

S.3 Impact of trends on the port

- The systematic trend analysis offers clear insight in the direction of plausible future developments and their anticipated impact on the port.
- In total, nine centuries-long trends have been identified, each having an effect on the port of Rotterdam. On balance, these trends indicate a substantial reduction of future throughput volumes, including a stagnation and possible decline of future container volumes. Operational performance and port competitiveness are mostly affected in a negative way by climate change and benefit from the long-term trend in connectivity towards further connecting and optimising systems by means of data applications and the creation of the internet of things (IoT).
- The transition from the 5th K-wave to the 6th K-wave is reflected by a shift in its two primary drivers, namely: (1) a shift from globalisation to sustainability; and (2) a shift from ICT to IoT. Based on these drivers, the next 20 years are expected to be dominated by innovation and the development of new sustainable- and data driven technologies and business models. In the subsequent 30 years, the more successful technologies are expected to become dominant.
- The remaining megatrends tend to cluster around the primary drivers of the K-waves, i.e., data-driven developments and sustainable developments, with the data-driven developments acting as an enabler for the development of sustainable data-driven technologies.

S.4 Threats and opportunities

The extensive trend analysis performed in this study makes it possible to anticipate future developments and their expected impact on the port of Rotterdam. To this end, we have deliberately not used scenarios, but constructed a number of well-structured trend-based narratives that contribute to the creation of a shared future vision for the port. While constructing these narratives, a distinction is made between 'opportunities and threats' for the port-related activities and 'enabling technologies' that can serve as an enabler for improving the competitiveness of the port of Rotterdam. In total, the following sixteen trend-based narratives have been drafted:

Threats to existing activities:

1. Major decline in bulk fossil fuel throughput;
2. Possible decline in raw material throughput;
3. Stagnation or decline in deep-sea container transport;
4. Future loss of container cargo as a result of 3D printing;
5. Possible loss of market share due to climate change.

Opportunities for new activities:

6. Create production and blending area for renewable fuels, including production of synthetic fuels from imported hydrogen and carbon captured;
7. Create recycling and dismantling area for offshore rigs and ships;
8. Strengthen supply base for offshore energy production at sea;
9. Opportunity to increase short sea container transport;
10. Develop dedicated inland barge facilities at deepsea container terminals to increase the market share for deep-sea containers;
11. Develop aquaculture and fish farming in the port and at sea;
12. Expansion of cruise market for both maritime and inland shipping;
13. Increased navy presence to counter increased threats.

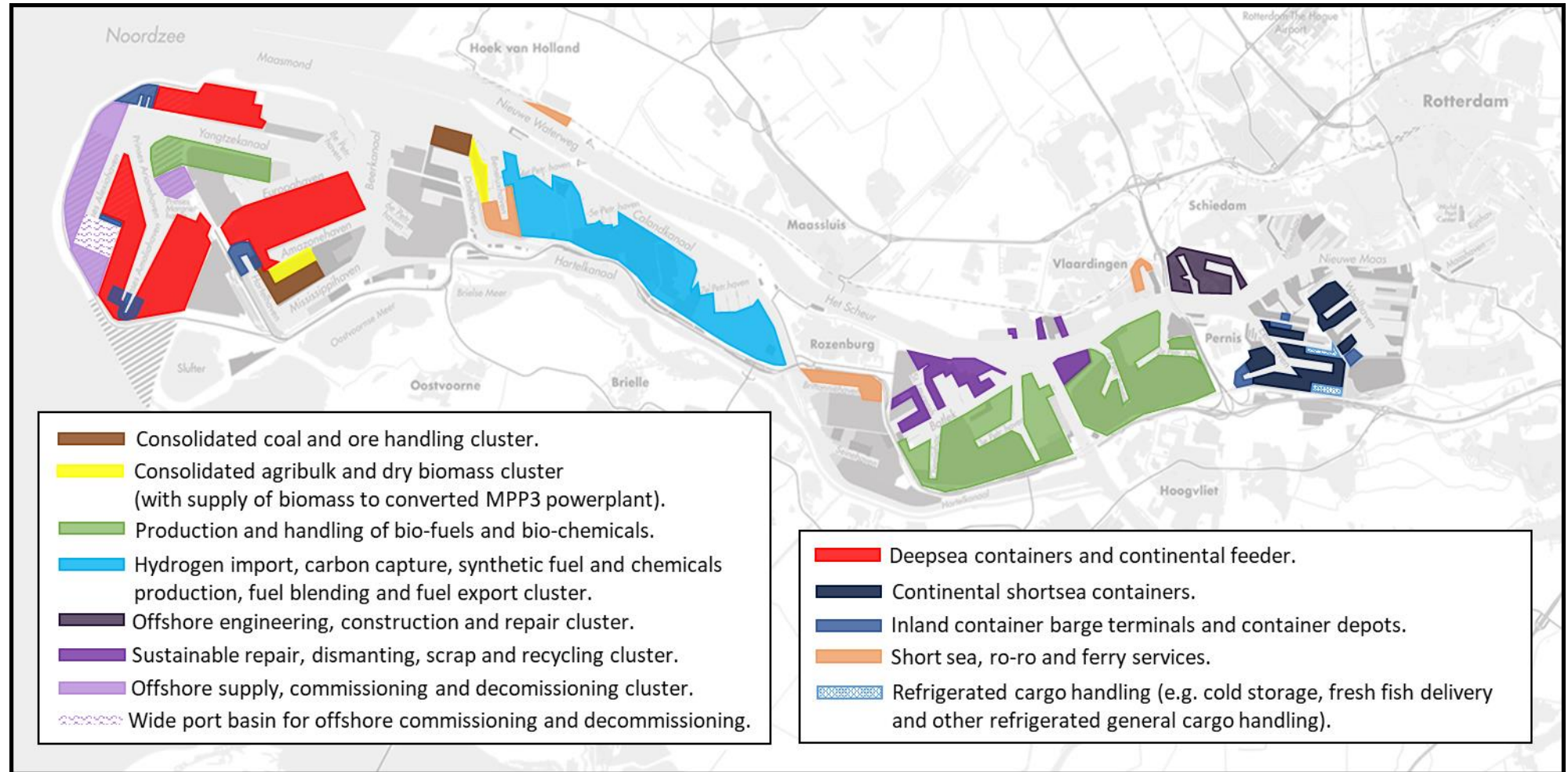
Enabling technologies:

14. Synchromodality as a catalyst for a more efficient hinterland connection;
15. Autonomous shipping changing maritime infra requirements, which enables the port of Rotterdam to gain market share if it acts as a first mover;
16. Optimization of port- and fairway infrastructure through the use of big-data and sensor technology.

S.5 Space and clustering

- It is expected that available space will remain scarce over the next 10 to 20 years despite the recent expansion at Maasvlakte 2. This is because the fossil industry may require another 10 to 20 years to phase out, while space is already required for new activities that are gradually starting to develop in line with the sustainability driver of the 6th Kondratieff wave.
- It is desirable for the port to facilitate these activities in order to ensure that it is ready for the future around the year 2040, when new sustainable activities take over the dominant position of the fossil industry and begin to scale-up.
- Through confronting the current port layout and location of activities with the future demand for space (indicated by narratives following from our trend analysis), a suggestion for possible clustering of future activities around the year of 2040 has been sketched (see Figure 2). Such a sketch can contribute towards formulating a successful spatial transition strategy for the port.

Figure 2: Outlined clustering of activities as suggested for the year 2040



Source: Author. Map received from Port of Rotterdam Authority (version 05 November 2018), adapted layout.

S.6 Conclusions and recommendations

- The world has entered a transition period that is characterised by a shift from an economic system driven by globalization and fossil raw materials to a sustainability-based system. As a result, the port of Rotterdam can lose up to 50% of its present cargo volumes, but the transition also offers plenty of new business opportunities. As it will take another 1 to 2 decades before the renewable system takes over the dominant position of the fossil-based system, the port is faced with a challenge to use the available space as efficiently as possible. This to achieve a smooth transition over the next 20 years and to create promising port clusters that are able to compete in a new more sustainable environment from 2040 onwards. Such a challenge requires a clear, practical and feasible strategy for spatial planning.
- This study shows that by placing trends in a broader 'meta'-perspective and analysing them in a structured way, it is possible to better anticipate future developments. By translating insights from trends into well-structured storylines (or narratives) and by taking into account the intrinsic strengths of the port, the future opportunities for the port can be made to surface. Based on the drafted narratives, a sketch indicating how the port can evolve to a new spatial layout, which anticipates on new future-proof industrial clusters is included.

Conclusions and recommendations

- This suggests keeping the existing infrastructure in use for another 10 to 20 years through refurbishment where required in order to buy time until the future structure and clustering manifests itself more clearly in the port so that new investment decisions can be made with less risk involved.
- Repurposing infrastructure for a less demanding use (lower draught vessels and lighter quay loads) could also be an effective way to extend the lifetime of existing infrastructures. Especially when it fits within the spatial framework.
- Additional studies are required to determine more specifically the use of space in the port and the required infrastructure investments. Such studies include:
 - New methods to forecast the expected stagnation in deepsea container transport;
 - New methods to forecast the expected impact of the energy transition on the fossil throughput volumes;
 - New insights into sustainable harbour clusters, the possible transition pathways towards the creation of these clusters, and the required port infrastructure;
 - New insights on how to prepare the port for the impacts of climate change.
 - Conceptual designs and business cases for new (more sustainable and climate proof) terminals and industrial production activities.

1. Introduction

- 1.1 Introduction
- 1.2 Background
- 1.3 Objective
- 1.4 Our philosophy
- 1.5 Some definitions
- 1.6 Methodology
- 1.7 Outline of the report

1.1 Introduction

- The world seems more uncertain than a few decades ago. Major transitions in the energy and transport system, such as reverse globalisation, a shift to renewable energy sources, the ambition to become CO₂ neutral, digitalization and use of big data, and the advancements in 3D printing will have a major impact on the future of port systems.
- Port managers, who decide on construction and maintenance of infrastructures with a technical lifetime of 50 years or more, are in need of guidance.
- Scenarios offer a possible way to deal with future uncertainty, but a strategy aimed at robust solutions entails high investments and the risk of becoming non-competitive.
- This study offers an alternative approach for handling uncertainty. It aims at reducing the perceived levels of uncertainty by integrating port-related trends, with varying levels of inertia, into a consistent framework at a meta-level.
- Integrating trends at a meta-level results in a more stable ‘picture’ of probable future developments that can pose **threats** or present **opportunities** for the maritime sector and the international port business.
- Subsequently, these insights into likely future developments, are translated into **narratives**. These narratives can guide the Port of Rotterdam as to strategies for spatial planning, land use, and infrastructure investments so that they can emerge as a market leader in an uncertain era.

1.2 Background

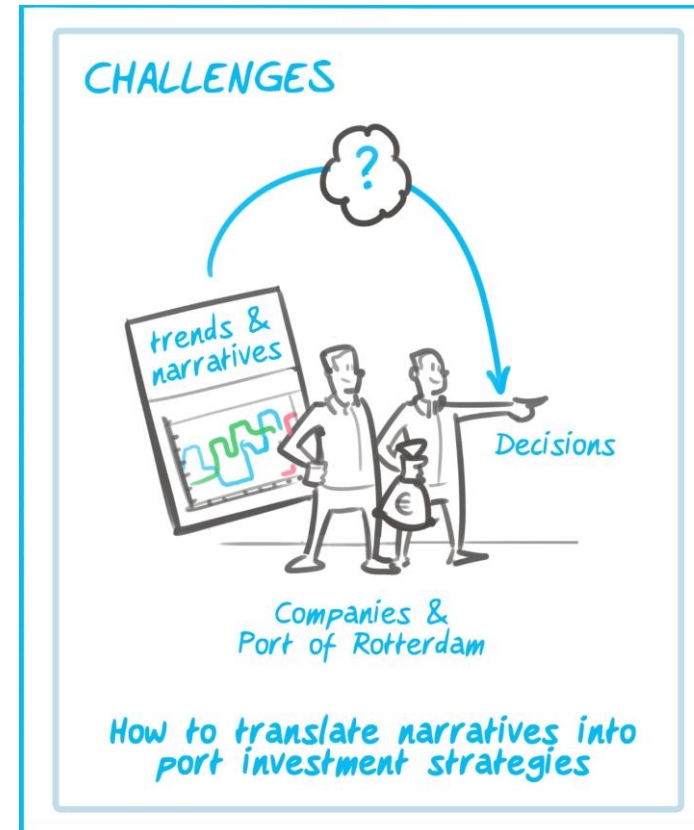
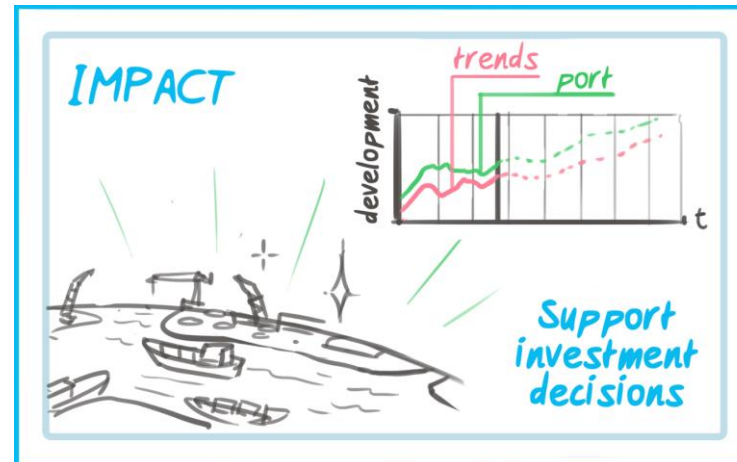
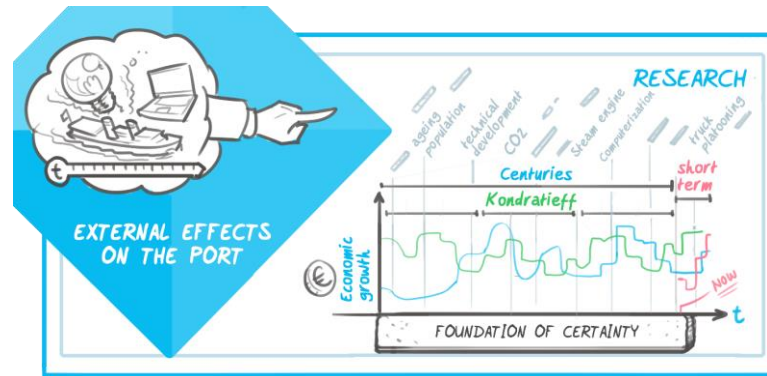
- The Port of Rotterdam is located at the mouth of the river Rhine that connects the world oceans with the German Ruhr area. It is one of the largest ports in the world and a champion in bulk handling of energy and raw material products.
- The handling of bulk energy and raw material products is closely linked to the prime drivers of, what Rifkin calls, the 1st and 2nd industrial revolution (Kuipers and Manshanden, 2015; The TIR Consulting Group LLC, 2016).
- The 1st Industrial Revolution originated from the invention of the steam engine. It was based on coal and gave rise to the train and rail infrastructure network.
- The 2nd Industrial Revolution was based on oil and the combustion engine led to cars and a road transport network.
- Rifkin predicts that when the digital connectivity and sustainable energy trends converge this will have a tremendous effect on our social and economic system.
- Ports such as Rotterdam that have a relatively large share in bulk energy and raw material handling, are extremely vulnerable to the impacts of the unfolding 3rd Industrial Revolution over the next few decades.
- Preparing for an uncertain future is a major challenge, and Port of Rotterdam needs to prepare to meet the challenge.

Background

- A focus on current and future trends and their impact on maritime transport infrastructure is one of the key themes at the section Ports & Waterways (faculty Civil Engineering and Geosciences) at the Delft University of Technology.
- The Section shares the vision that a successful port needs to be flexible and adaptive to face future changes, and that a clear and well thought out strategy is required in order for a port to remain competitive.
- There is a general perception that the rate of technological advancement will continue to accelerate, leading to an increasing uncertain future. However, based on a three-layered meta-approach for analysing future trends proposed in this study, *we argue that the future is more certain than one usually assumes.*
- The **PORT METATRENDS** framework developed in this study builds on the dissertation of Van Dorsser (2015) and scientific discussions with Prof. Robert U. Ayres of INSEAD Business School in France.
- This report, funded by **SmartPort**, presents the **PORT METATRENDS** framework and demonstrates how it can be used to anticipate long-term trends and facilitate the Port of Rotterdam in preparing for the future.

1.3 Objective

- The objective of this study is to use a scientific approach to obtain insights into long-term-trends and uncertainties and their implications for port development, thereby providing decision support for port investments, as illustrated in the figure.



1.4 Our philosophy

- The credibility of long-term projections is often questioned. This is due to examples of historical failures (e.g. Limits to Growth report published by the Club of Rome in 1972), as well as numerous recent cases of failed projections.
- The perception of increasing uncertainty is heightened by futurists such as Erik Brynjolfsson (The Second Machine Age, 2014) and Gerd Leonhard (Technology vs. Humanity, 2016), who propagate the notion of exponential technological growth.
- However, at a higher level of aggregation, the rate of change and the associated uncertainty level is not necessarily on the increase. For instance, though the rate of technological developments has become more rapid, the impact on economic growth, as measured by Gross Domestic Product (GDP), has been slowing down in technological frontier countries since the 1970's. This is paradoxical.
- If one moves beyond the neoclassical paradigm of exponential economic growth (discussed further in [Chapter 4](#)), it becomes possible to obtain more reliable long-term GDP and transport projections.
- **The view that the future is becoming ever more uncertain, therefore, does not necessarily apply at a more aggregated level.**

Our philosophy

- The following three principles are fundamental to our philosophy for anticipating long-term trends:
 1. The further one looks, the less one can see;
 2. Exponential growth can not last forever;
 3. A clearer insight into the evolution of a trend can be gained through understanding the context.
- The **first** principle states that while ‘looking’ further ahead, we can trade-off the time span with the level of detail. This is relevant since projections for the long term require a sufficiently high level of aggregation.
- The **second** principle follows from the laws of nature. It states that a trend can follow a transition curve (e.g. represented by the well known s-curve), a decline (e.g. fall back or gradual decline), or a combination of the two. This is particularly relevant for century-long trends.

Our philosophy

- The **third** principle leads us to a three-layered approach for analysing trends at the meta-level. In general, our understanding of individual events improves if we are able to grasp the broader context in which they take place. Similarly, we can improve our understanding of long-term trends by placing them in a framework of even longer pervasive trends identified at a higher level of aggregation.

1.5 Some definitions

- A **development** can be defined as an event or condition that: represents a change from today. Developments relate to trends and uncertainties that can either impose a threat or offer an opportunity for the port business.
- **Trends** are relatively stable demographic, social, environmental, economic, political and technological shifts that unfold over time.
- An **uncertainty (or uncertain development)** is a development that not follows a trend or for which a deviation of the trend is conceivable.
- **Threats** are developments that can have a negative effect on the success of an existing business activity in the port.
- **Opportunities** are developments that can either enable new business activities in the port or increase the success of an existing business activity.

Some definitions

- **Trend analysis** requires examining how a potential driver of change has developed over time, and how it is likely to develop in the future i.e., will the development show a trend or does it represent an uncertainty? A trend analysis thus covers trends as well as uncertain developments. Trends can exist at various levels of inertia that we refer to as layers.
- **Megatrends** [Layer 1] are trends that describe long-term processes of transformation with a broad scope and a dramatic impact that can be projected at least one or two decades into the future. They are global shifts that are reshaping the world we live in and have implications for organisations, industries and wider society, right now and in the future.
- **Kondratieff waves** (or K-waves) [Layer 2] are trends that follow an about 50 year lasting cyclical movement. Kondratieff waves can be related to the pervasive social, technological and economical drivers of our global society and the world economy ([see Chapter 3 for details](#)).
- **Century-long trends** [Layer 3] are the more pervasive megatrends that unfold over a period of one or more centuries.

Some definitions

- **Scenarios** are stories about the way the world might turn out tomorrow, stories that can help us recognise and adapt to changes of our present environment. Scenarios are commonly used to define all plausible futures in order to evaluate how susceptible a system is to future changes. Scenarios can be inductive or deductive. Inductive scenarios are true storyline scenarios whereas deductive scenarios are mainly used to investigate the extremes of possible future developments.
- A **narrative** is a story written or told, usually in great detail. A narrative is meant to include the "whole story". It differs from a deductive scenario in that it has a good storyline. Well-defined narratives have the ability to persuade people that the world is heading in a certain direction. They are therefore very useful for creating a collective or shared view over where the future is heading and what threats and business opportunities can be expected. In its broader use, narratives may also include fictive elements. This does not apply to trend-based narratives.

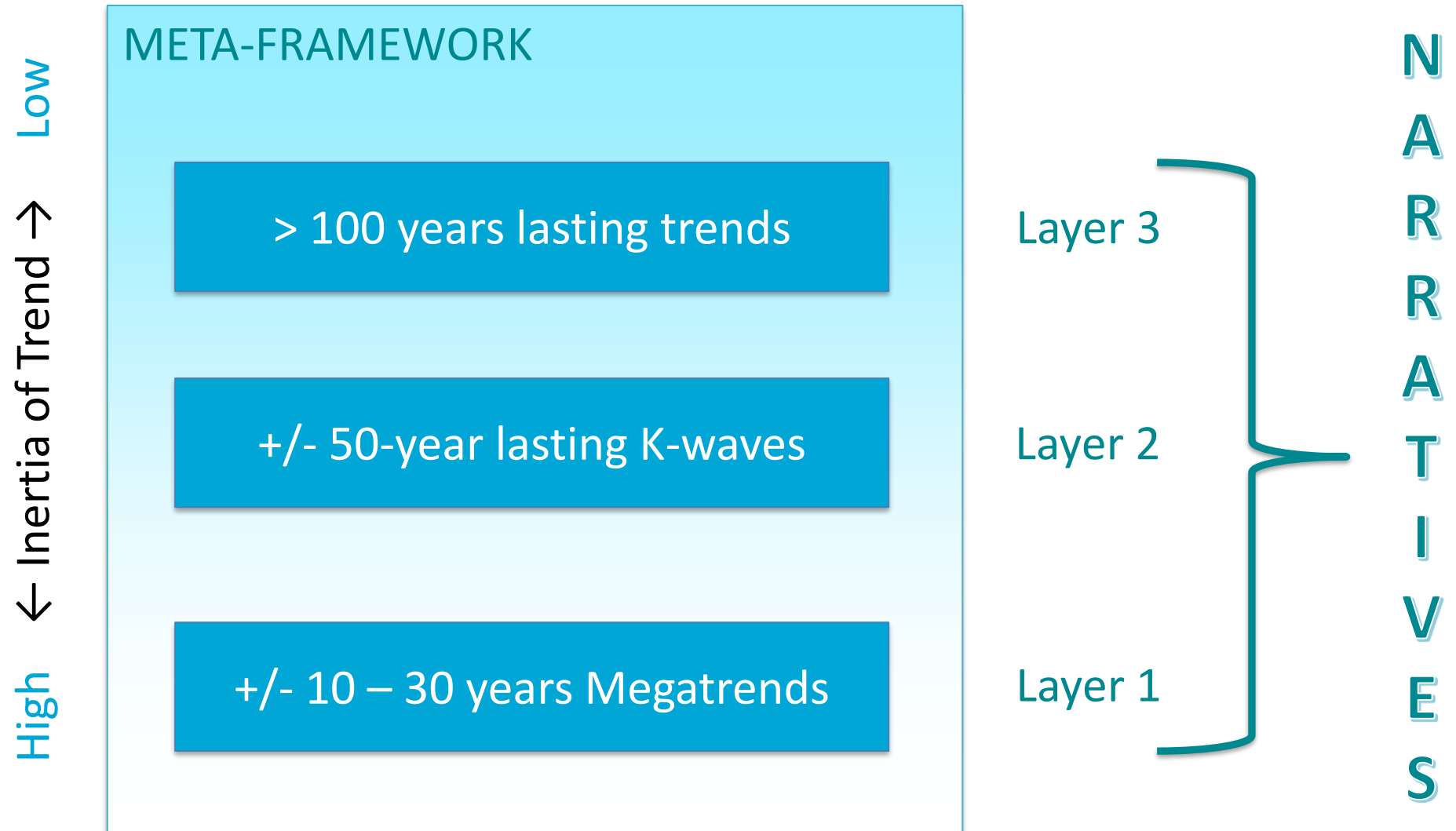
Some definitions

- **Trend-based narratives** contain a description of the direction in which the world is expected to be heading based on broader set of trends and uncertainties, that we refer to as a meta-framework. They indicate how this direction creates threats and opportunities for business. Trend-based narratives can be used to create a common view on which investment decisions can be made. They can be regarded as a subset of incremental storyline scenarios (not of deductive scenarios) that deal only with the more plausible or expected futures – rather than with all possible ones.
- The **meta-framework** integrates the insights from analysing related trends with different levels of inertia (or momentum). It consists of three layers: megatrends, Kondratieff waves and century-long trends. Through use of this framework, the understanding of the individual trends in each layer is augmented with insights from other layers. It, then becomes possible to place the trends in a broader perspective, and thereby helps to reduce uncertainty.

1.6 Methodology

- The methodology followed for this study consist of the [Steps A-C](#):
 - A. Carry out Port Meta-trend analysis using the three layered meta-framework. The methodology used for Port Meta-trend analysis is described in detail in the next section and consists of 3 steps.
 - B. Develop trend-based narratives. A trend-based narrative describes the potential future implications of a plausible and significant development that follows from meta-trend analysis in Step A; this development can represent either an opportunity or a threat for the port.
 - C. Examine the current system of clusters in the port, the characteristics and relative strengths (and vulnerabilities) of these clusters in the light of the identified trends (as presented in trend-based narratives in Step B), and develop a clear strategy over how to respond to the changes ahead by seizing opportunities.
- The conceptual 3 layered meta-framework for analysing long-term trends and developing ‘narratives’ (Step A and B) is presented in [Figure 1.1](#).

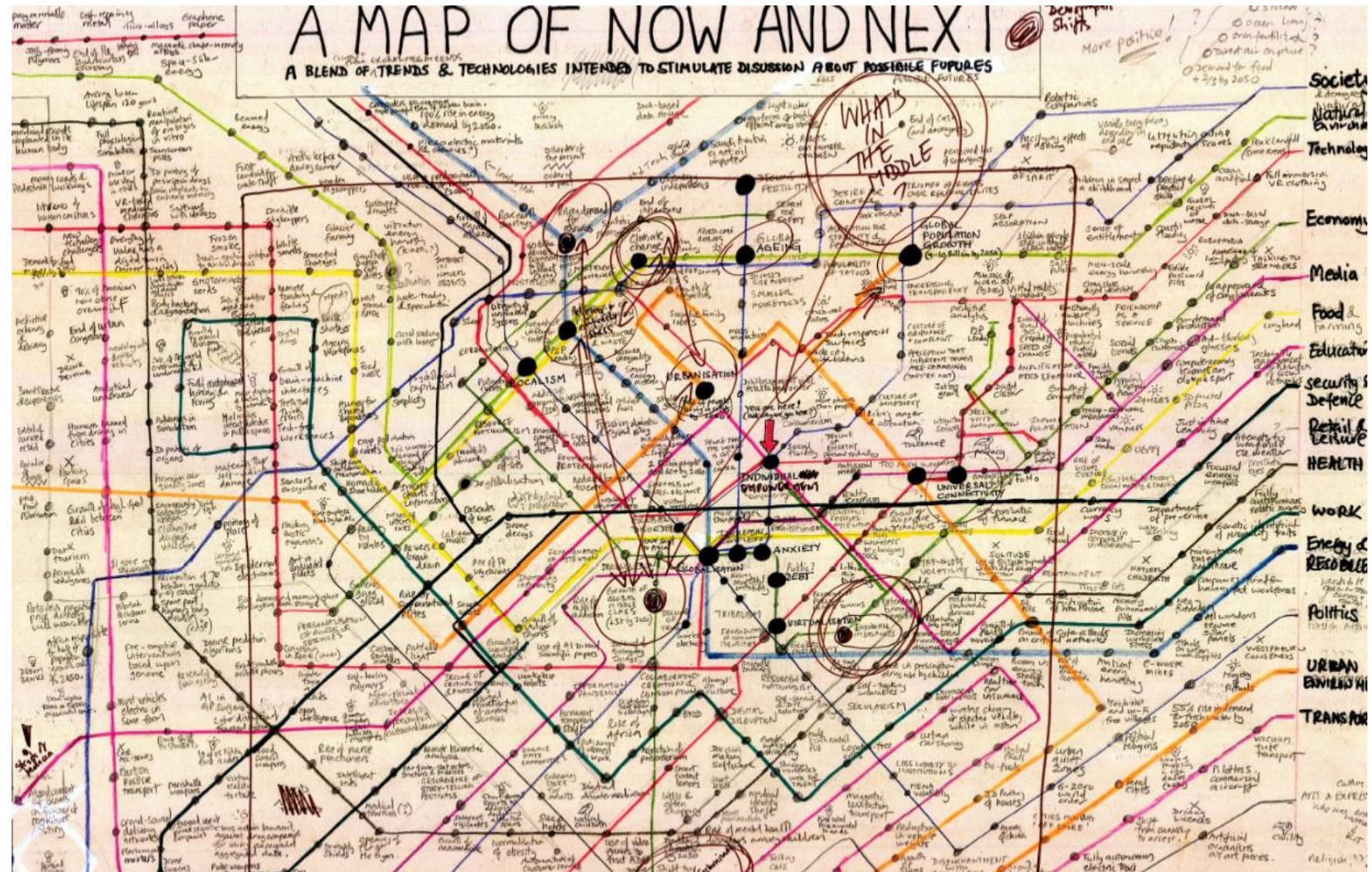
Figure 1.1: Conceptual meta-framework for analysing trends



Step A: Trend analysis methodology

- Trend analysis is complicated by the fact that a myriad of trends exists in the world. This makes it hard to see the forest for the trees. This complexity of our world stands out in Watson's map of the current trends (see [Figure 1.2](#)).
- To improve our ability to anticipate long-term developments we propose a new approach that consists of the following four steps:
 - **Step A1:** Identify megatrends with a duration of at least one or two decades and categorise these trends by topic.
 - **Step A2:** Study the dynamics of the about 50-year lasting economic waves (the Kondratieff waves or K-waves) and address how the primary drivers of the K-waves relate to the broader set of megatrends.
 - **Step A3:** Filter out trends with a duration of at least one century. These trends can be expected to remain relatively stable over the next few decades.
 - **Step A4:** Integrate all three layers into a broader meta-framework.

Figure 1.2: Watson's Map of the Current Trends

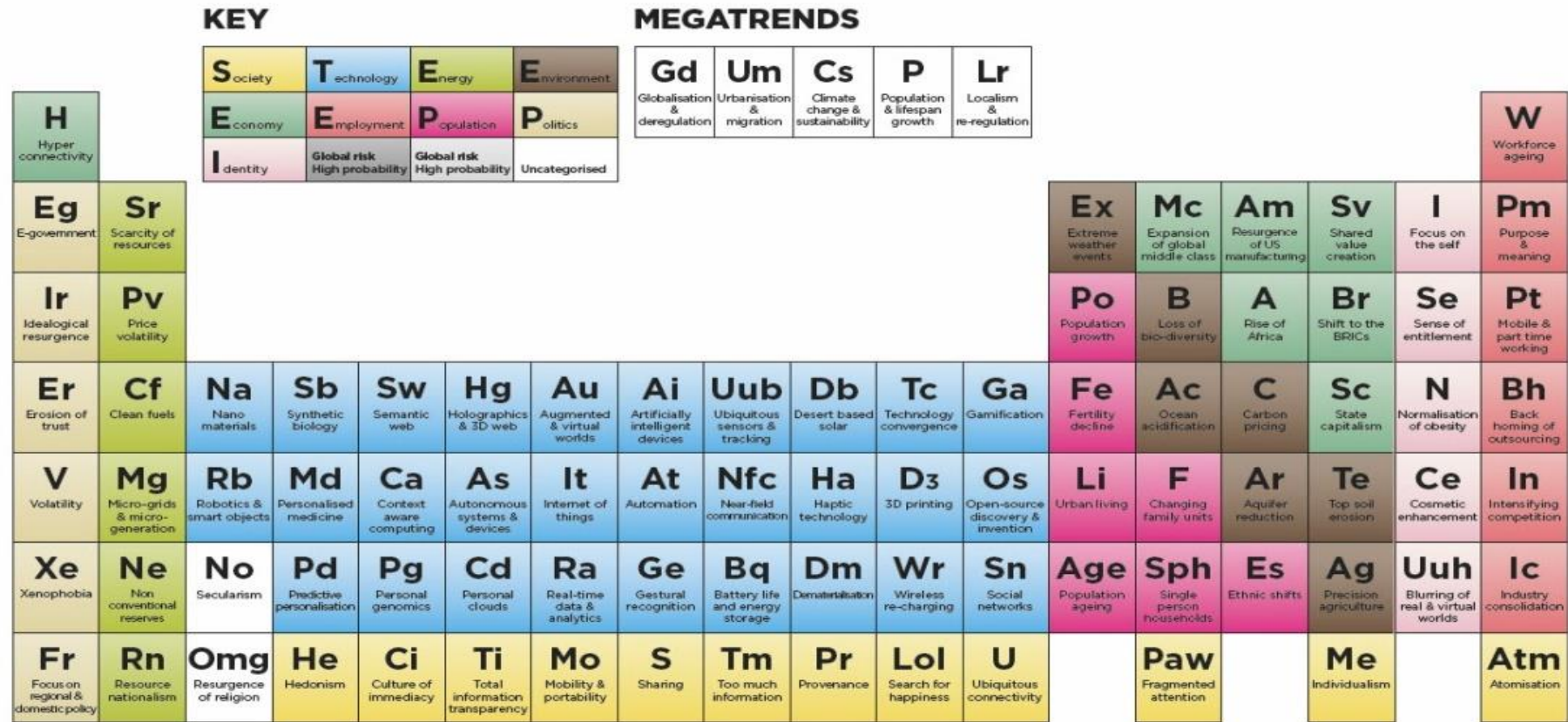


Source: Richard Watson, Blog: <http://toptrends.nowandnext.com>, 2016/12/14.

Step A1: Identify megatrends

- Step A1 involves a systematic screening of Megatrends with potential implications for the port system, without taking into account the inertia of these trends.
- Megatrends are named after a John Naisbitt's book published in 1982. Z-punkt (2008) explains that Megatrends can be distinguished from normal trends by their:
 - Time horizon:** Megatrends can be observed over decades. Quantitative, empirically unambiguous indicators are available for the present. They can be projected with high probabilities, at least 15 years into the future.
 - Reach:** Megatrends impact comprehensively on all regions, and result in multi-dimensional transformations of all societal subsystems, whether in politics, society, or economy. Their precise features vary according to the region in question.
 - Intensity of impact:** Megatrends impact powerfully and extensively on all actors, whether it is governments, individuals and their consumption patterns, or corporations and their strategies.
- The starting point for the identification of relevant Megatrends is Watson's 'periodic system of trends' (Figure 1.3).

Figure 1.3: Watson's periodic system of trends



Re Regulatory change	Bt Biological terrorism	Eu European incrementalism	Op Oil price spikes	Np Nationalism & protectionism	Sws Skilled worker shortages	Fp Food price volatility	Fi Fiscal imbalances	Gp Global pandemic	Cw Cyber viruses and data theft	Ua Uneven access to food & water	Si Severe income inequality	Rc Rogue employee	Mq Mega-quake in mega-city	High probability
Gg Global governance failure	Nt [△] Nuclear terrorism	Ed European disintegration	Up Unsustainable population growth	Mm Poorly managed migration	Kr [△] Explosion of North Korea	Csf Critical systems failure	Ws Collapse of welfare state	Pk [△] Collapse of Pakistan	Pi [△] Pakistan Vs India war	Cn Collapse of China	Oa Failure to treat obesity epidemic	Cc Failure to adapt to climate change	Vol Sure-volcano eruption	Low probability

Chart maker: Richard Watson

Source: Richard Watson, Blog: <http://toptrends.nowandnext.com>, 2013/02/14.

Identify megatrends

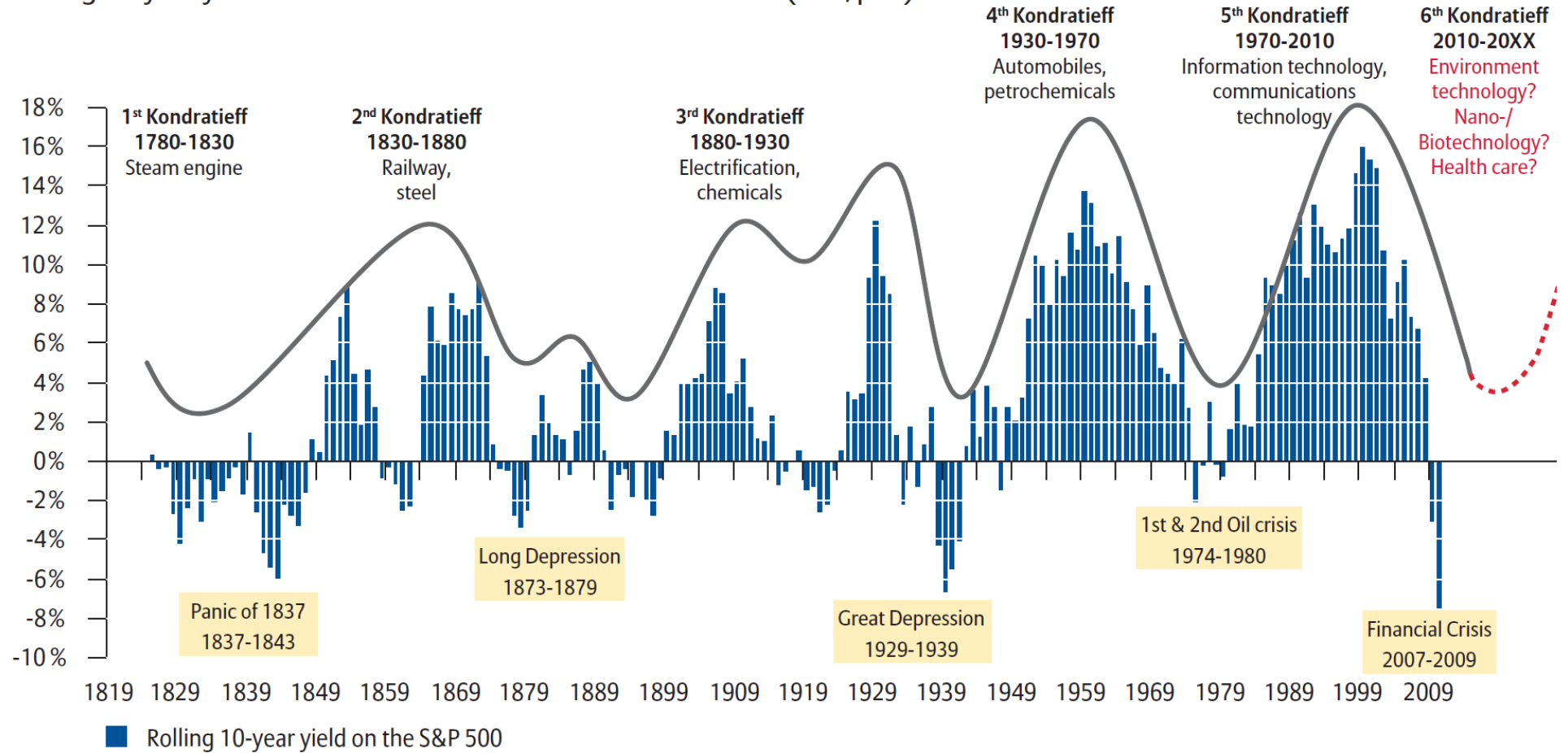
- Watson's periodic table allows for structuring and systematic assessment of what would otherwise be an almost endless list of trends. Trends are clustered around various categories using an extended version of STEEP, which stands for Social, Technological, Economic, Environmental, and Political.
- Watson recognises that some trends (referred to as megatrends in [Figure 1.3](#)) are more pervasive and longer lasting than others. This advocates analysing trends at different levels of inertia. He also indicates that anticipating future developments is not only about analysing trends, but also about identifying key uncertainties.
- We propose using **STEEEP** (**S**ocial, **T**echnological, **E**conomic, **E**nvironmental, **E**nergy, and **P**olitical) for identifying relevant megatrends and key uncertainties.
- The identified trends and uncertainties, as well as their expected impact on the business activities in the port are discussed further in [Chapter 2](#).

Step A2: Obtain insight from 50-year cycles

- Step A2 involves obtaining insight from 50-year economic cycles; a detailed description follows in [Chapter 3](#).
- The existence of long economic cycles in the world economy is widely acknowledged since the 1925 publication of Nikolay Kondratieff (Kondratieff, 1926). These cycles are called Kondratieff Waves or K-Waves.
- K-waves can be useful for looking far ahead since their main drivers are closely linked to the pervasive social, technological, and economic drivers of the world economy and therefore linked to many well-known megatrends (1st layer). Many important transitions take place over a period of two K-waves (about 100 years), whereby technology emerges in the first K-wave and becomes dominant in the next. Therefore, an analysis of K-waves and their underlying drivers provides insight into the dominant technologies of the next K-wave by way of assessing the promising technologies of the present K-wave.
- According to some, the financial crisis of 2008 marked the start of the downswing period of the 5th K-wave, but a closer look at the pattern could also hint at the year 2018E as the start of the downswing period. The upswing period of the next K-wave is expected to take place from about the year 2030/40 onwards.

Figure 1.4: K-waves and drivers of technological development

Rolling 10-year yield on the S&P 500 since 1814 till March 2009 (in %, p. a.)



Source: Datastream; Illustration: Allianz Global Investors Capital Market Analysis

Source: Allianz (2010) Analysis and Trends: The sixth Kondratieff – long waves of prosperity
https://www.allianz.com/v_1339501901000/media/press/document/other/kondratieff_en.pdf

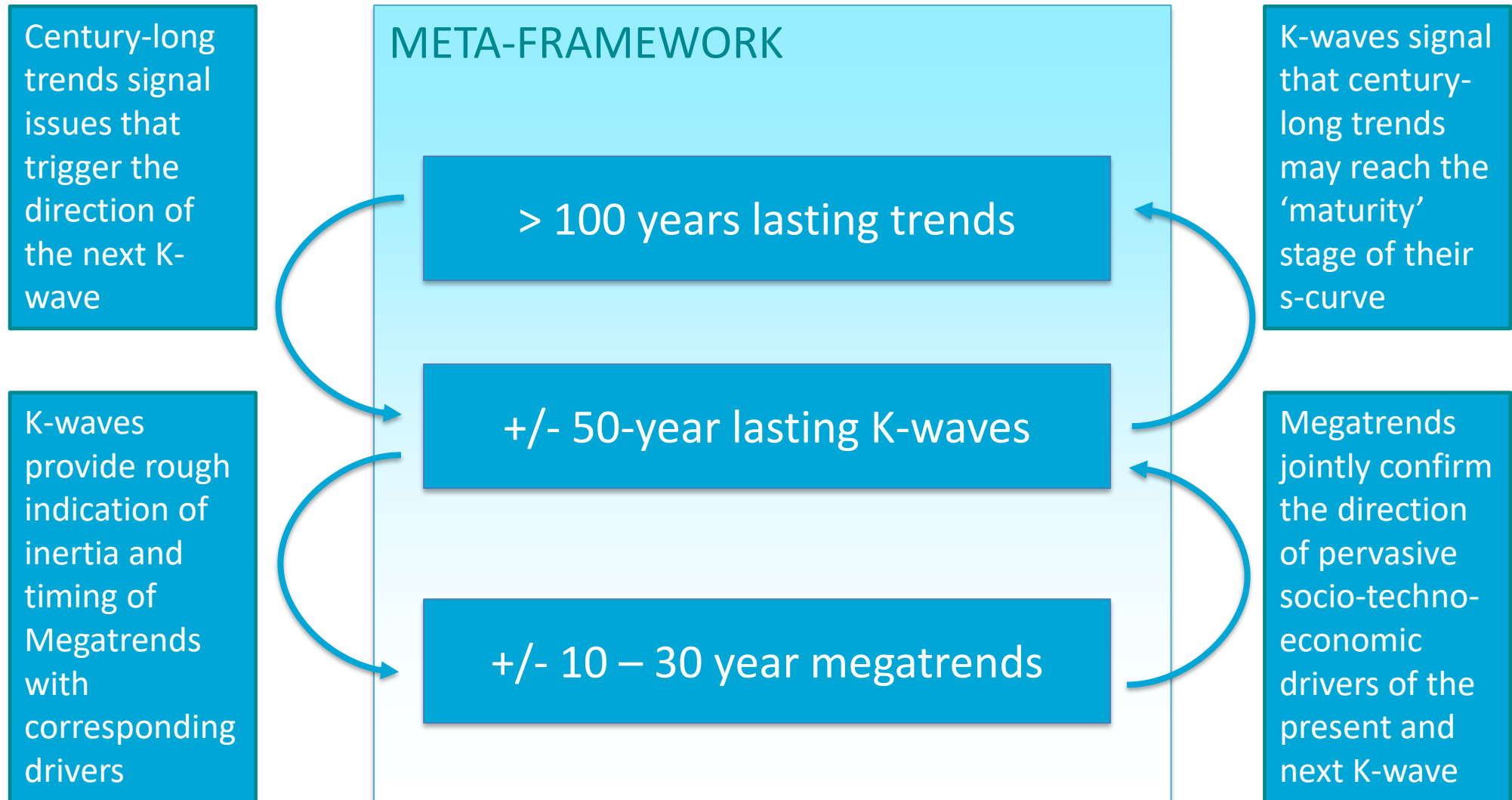
Step A3: Obtain insights from century-long trends

- When analysing long-term developments, it is useful to filter out the trends with a fairly low inertia, as these tend to be more stable.
- The identified century-long trends (discussed in [Chapter 4](#)) are:
 - Secularisation and individualisation;
 - Nature of activities and social power;
 - Population growth and urbanisation;
 - Energy and raw material use;
 - Technological progress and economic output;
 - Connectivity and information exchange;
 - Climate change and environmental degradation;
 - Transport costs and globalisation;
 - Shifts in geopolitical world order.
- Projections that anticipate developments a few decades ahead, are more certain if the underlying trend has existed for centuries, rather than decades.

Step A4: Create a meta-framework

- Essential to the idea of developing a multi-layered approach for analysing long-term trends, is that the knowledge gained at various layers can be applied to improve the understanding of trends with different levels of inertia.
- Each layer communicates with adjacent layers. The intermediate layer of about 50-year K-waves is essential, as it provides the link between the Megatrends in the bottom layer and the century-long trends in the top layer (Figure 1.5).
 - Megatrends are closely related to the primary socio-techno-economic drivers and technological developments of the present and next K-wave;
 - K-waves may indicate that a century-long trends has reached the 'maturity' stage of their s-curve, hinting at a discontinuation of exponential growth;
 - Century-long trends can signal issues that trigger the development of the next K-wave. (E.g., as a response to 200 year unsustainable resource exploitation, the next K-wave is likely to be driven by sustainability);
 - K-waves provide an indication of the timing and inertia of megatrends and their associated drivers. They can thus provide an indication of the timing of new ideas and technologies becoming dominant.

Figure 1.5: A meta-framework for an integrated trend analysis

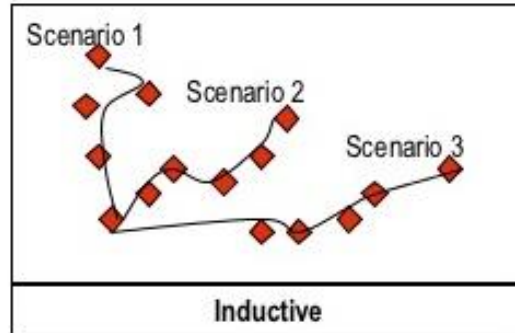


Source: own representation.

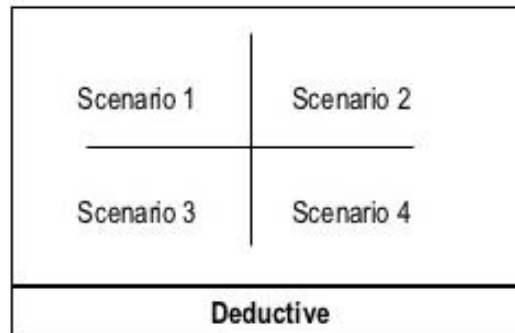
Step B: Trend-based narratives methodology

- In our opinion the **DNA** of a **SMART** port should not only be flexible and adaptive, but also able to create opportunities by enhancing desired cluster developments and utilising new technologies capable of giving a competitive advantage:
 - A smart port is **flexible** in order to **adapt** to changes in the world economy and the port environment;
 - A smart port has a sound **vision** on future developments and the dynamics of today's very long-term trends;
 - A smart port is able to **identify** tomorrows leading industrial **clusters** and define which of them suits the port best;
 - A smart port is aware of its **strengths** and the **opportunities** to accelerate the development of tomorrows leading clusters;
 - A smart port is aware of **new technologies** and invests in those that are able to create a competitive advantage and increase market share;
 - A **SMART** port is pro-active in creating a **strategy** for transforming the existing port complex into tomorrows leading port arena.
- A clear vision and competitive business strategy cannot be based on a broad set of scenarios. This would require the port to have almost innumerable capabilities and reduce its competitive advantage.

Intermezzo: Inductive and deductive scenarios



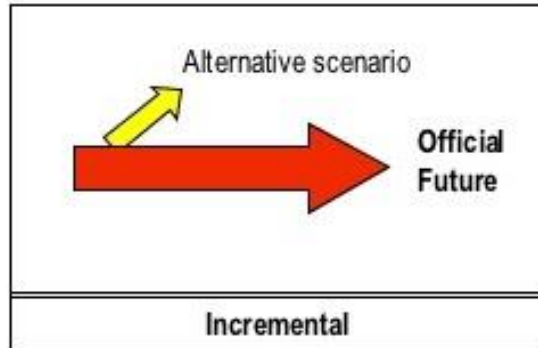
Inductive scenarios are storylines built around major uncertainties and well suited to think through their implications and thereby preparing for the future. Using these, responses can be set in place to deal with changes in case a scenario unfolds.



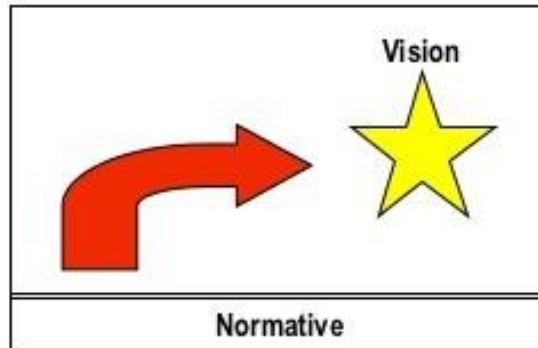
Deductive scenarios are well suited to anticipate possible developments. They explore their extremes of plausible future developments and consider two (or more) major uncertainties as a starting point, for which reason, the storylines are less insightful.

The **port vision 2030 scenarios** of the port of Rotterdam are in-between inductive and deductive (i.e. inductive with the intention to reasonably explore the extremes of plausible future developments). They are useful for examining the robustness of the system under uncertain developments and assessing which companies are likely to continue in certain port areas regardless of the unfolding future. But they are less suitable for identifying likely threats and opportunities for future port development.

Intermezzo: Incremental and normative scenarios



Incremental scenarios are used to explore a deviation from an official future. This approach is generally applied to investigate different policies or business strategies. But the concept is also interesting to address a trend that is exposed to certain identified uncertainties, such as the present trend towards a multi-polar world in which the alternative scenarios could be a war between US and China creating a (new) unipolar hegemony.



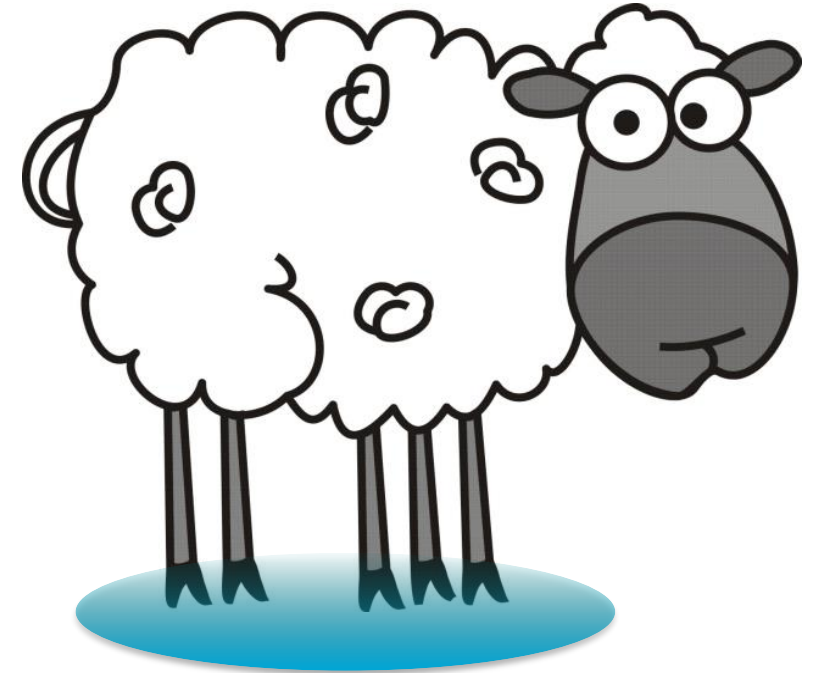
Normative scenarios are intended to envision a desired future based on a common vision. An example of such a normative scenario is the objective to keep climate change below two degrees over the next century.

Incremental and normative scenarios contain elements that can be useful for the development of new business models in the Rotterdam port area; we will explore these options by means of **narratives**.

Source: Figures retrieved from <https://www.slideshare.net/mkconway/rethinking-strategic-planning-a-futures-perspective>, initially adapted from Ged Davis, *Scenarios as a Tool for the 21st Century*, Shell International, 2002.

Use of narratives instead of scenarios

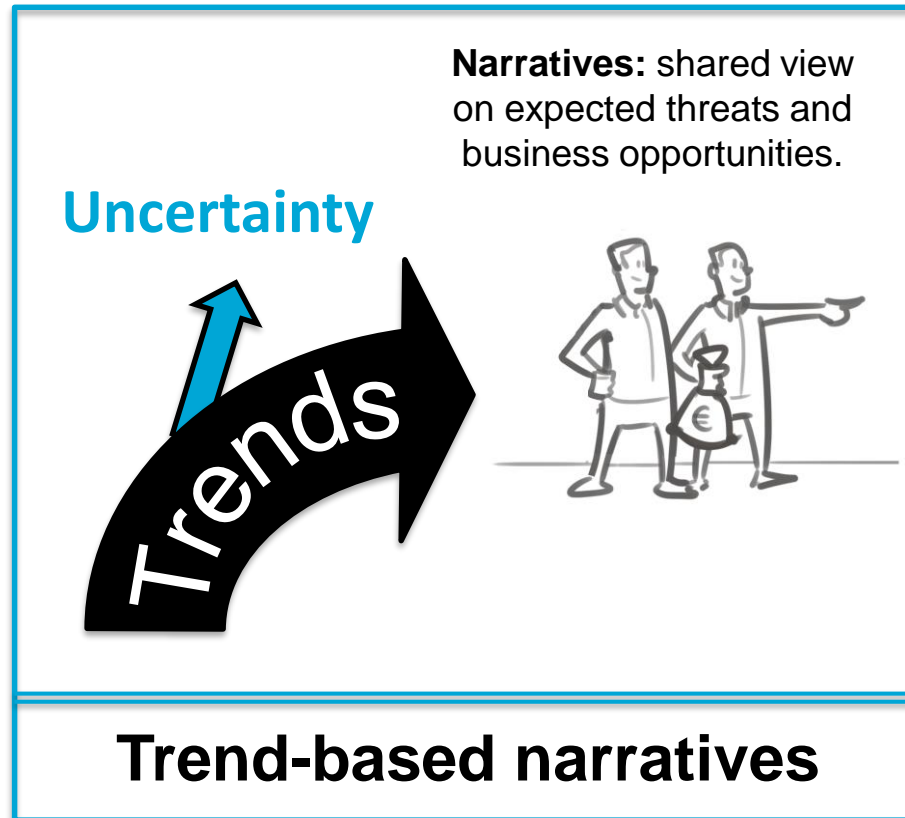
- Chapter 3 to 5 discuss in detail, long-term trends and their associated levels of inertia and uncertainties.
- These trends and uncertainties provide insight in the long term drivers of the world economy and transport system. These insights can enable the port of Rotterdam to prepare for its future.
- A common way to prepare for an uncertain future is to create scenarios, but though scenarios are well suited to analyse how well the system is likely to perform in different futures, they are less useful to seize opportunities and identify new business models.
- **We therefore introduce the use of trend-based narratives.**



Source: <http://glennvanderburg.nl/wp-content/uploads/2015/03/schaap-met-vijf-poten-lores.jpg>

Preparing for all plausible scenarios is like developing something capable of everything, but at costs of being non-competitive (i.e. creating a sheep with 5 legs).

Figure 1.6: Use of trend based narratives



Source: own representation.

- It is standard practice to develop a range of scenarios and examine the robustness of the port system in these plausible uncertain futures. This does not result in a clear vision of the future, nor in concrete strategies.
- Developing **trend-based Narratives** wherein new business opportunities as well as impending threats are identified, helps create a shared vision of the future of the port.
- Subsequently, strategies utilizing the strength of the port, can be set in place, to help the port become tomorrow's business leader.
- A shared vision is likely to attract new activities and new investors.

Step C: Developing a strategy for spatial planning

- In order to arrive at a clear strategy for responding to future developments and seizing opportunities, the following approach has been used:
 - **Step 1:** Link the present and future cargo segments and activities to the narratives presented in [Chapter 7](#).
 - **Step 2:** Identify the present strengths of the port of Rotterdam that can support the development of promising next generation port clusters.
 - **Step 3:** Discuss the developments signalled by the trends and narratives to assess their impact for creation of promising clusters.
 - **Step 4:** Define the considerations of these developments with respect to the implication for spatial planning of related port activities.
 - **Step 5:** Make suggestions for the logical clustering of future port activities at the stage when present transitions become stable – e.g. for year 2040 when port begins to seize the commercial opportunities of the next 6th K-wave after undergoing a critical stage.

1.10 Outline of the report

- **Chapter 2** deals with megatrends relevant for the port. A comprehensive list of trends and uncertainties and their potential impact on the port is included.
- **Chapter 3** discusses the historical movement and characteristics of the around 50-year economic cycles (i.e. Kondratieff waves). It further explains how these cycles give an indication of the momentum (or inertia/tempo) of identified trends.
- **Chapter 4** discusses the trends with a historical duration of over 100 years. These are considered relatively stable as compared to trends with a shorter duration, and form the basis for a long-term perspective.
- **Chapter 5** describes in detail, the 3-layered meta-framework for an integrated trend analysis towards identifying future developments significant for the port.
- **Chapter 6** describes the identified threats and opportunities for the Port of Rotterdam on the basis of the trend analysis in this study. The perceived impact on the port business is described via narratives that combine insights from various trends and can be applied for developing a clear business strategy.
- **Chapter 7** addresses the general impact of the trends on the development of the port.
- **Chapter 8** analyses the implications of the narratives for spatial planning in the Port of Rotterdam.
- **Chapter 9** draws conclusions over the applicability of the 3 layered meta-framework while planning for an uncertain future and illustrates how the framework can be used to advance port infrastructure planning.

2. Megatrends

- 2.1 Introduction
- 2.2 Societal megatrends
- 2.3 Technological megatrends
- 2.4 Economic megatrends
- 2.5 Environmental megatrends
- 2.6 Energy related megatrends
- 2.7 Geopolitical megatrends

2.1 Introduction

- This chapter discusses the first step in identifying developments with a potential impact on the port system.
- These developments either concern trends (or megatrends) or uncertainties, and can represent either threats or opportunities.
- The search for megatrends is conducted by first defining a number of relevant focal points, or categories, and then conducting specific searches within their scope. The categorisation is based on **STEEEP** and includes the following:
 - **S**ocietal megatrends;
 - **T**echnological megatrends;
 - **E**conomical megatrends;
 - **E**nvironmental megatrends;
 - **E**nergy megatrends;
 - **P**olitical megatrends.

Introduction

- The inertia of the identified trends (i.e. whether they last 10 or 200 years) is not taken into consideration in this chapter, but will be discussed in detail for the more pervasive trends in the two subsequent chapters.
- The next sections provide an overview of the identified developments and include the following
 - a summary of the most relevant developments;
 - a discussion of their potential impact for the Port of Rotterdam;
 - a table with a complete list of identified trends and uncertainties.
- A description of the trend, and the likely impact on important drivers for the transport system is also given in the table.

2.2 Societal megatrends

- **Trends**

- Booming population in many developing and more religious countries; stagnating population and aging in more secular developed countries.
- Urbanisation ongoing in both developed and developing countries.
- Strong increase in education and middle class income in newly industrialised countries like China and India; saturating education and decline of middle class income in more developed countries like US and Western Europe.
- Increasing inequality levels becoming extreme in US and China.
- Religiosity causing friction with those who want to become secular in Islamic states. High fertility of religious people increases impact of this friction.
- Migration from more religious and highly populated developing countries in for instance Africa to more developed and stable countries in Europe.
- Hyper connectivity, towards condition in which all people and systems are connected and global developments become more transparent.

- **Uncertainties**

- Social revolt due to deterioration of low and middle income classes, unemployment and inability to counter inequality.

Societal megatrends

- **Impact of trends**
 - Stagnating population growth and possible decline of population in western Europe results in lower consumption and transport volumes.
 - Urbanisation reduces material and energy consumption per capita.
 - Stagnation/decline in middle class income levels reduces consumption and enhances counter globalisation forces, both reducing international transport.
 - Increasing inequality reduces consumption, trade, and transport volumes.
 - Religious friction continuously add fuel to the fire of conflicts in the middle east and Africa. Conflicts directly result in lesser trade and indirectly are the cause of migration flows that, via enhanced populism, results in rise of trade barriers and fewer international trade (i.e. counter globalisation).
 - Hyper connectivity, thrives further economies of scale and further integration of intermodal networks (higher utilisation and lower transport costs); as well as diseconomies of scale due systems becoming too big to fail, causing shift somewhat back to smaller systems, and an increased focus on cyber security (which result in higher transport cost).
- **Impact of uncertainties:**
 - Takeover of government power by populist parties with a strong national agenda, creating trade barriers, reducing international trade and transport.

Table 2.1: Societal megatrends

Type	Development	Impact
Trend	Global population growth, due to high fertility rates and booming population in the more religious and less developed countries.	Growing population thrives economic activity in developing countries.
Trend	Aging and stagnating or even decreasing population due to low fertility rates in more secular developed countries.	Stagnating or decreasing population growth tempers economic production. Aging also tempers consumption.
Trend	Urbanisation, strong ongoing trend, not only in developing countries but also in developed world.	Enhanced stakeholder involvement, compact cities, low energy demand per capita (smaller living, less cars).
Trend	Increasing level of education in developing world.	Labour productivity and economic growth in developing countries.
Trend	Education levels reach point of saturation or even decline in western countries. Also because good education is no longer a guarantee for a well-paid job.	Saturation or even decline in level of education slows down technological progress and economic growth.
Trend	Loss of lower and middle income jobs due to ongoing technological development, such as automation, robotics, and artificial intelligence.	Enhance income inequality. Deterioration of middle class income group, reduced consumption, trade and transport.
Trend	Middle class increase in developing countries as a result of western offshoring practice.	Economic growth in developing countries that gradually become more powerful.
Trend	Rising inequality, to the extent that benefits of economic growth are almost entirely flowing into the pockets of the wealthiest minority of the population, in particular in US and China (even worse), but still also substantially in the Netherlands.	Large income growth for small group with relatively low consumption, low income growth or decline for majority of people. This reduces consumption and trade volumes. Enhances populism, nationalism and anti-globalisation forces.
Trend	Millennials are no longer expected to become wealthier than their parents and cope with this by changing their lifestyle.	Dematerialisation: shift away from owning goods to sharing them, consuming digital goods, and fostering experiences.

Table 2.1: Societal megatrends – continued

Type	Development	Impact
Trend	Secularisation and individualisation, which is a direct function of increased living standards (GDP per capita). Creating tension in Islamic countries with advancing economies.	Tension in Islamic world, because of intensifying religious and secular forces. Causing worldwide security issues, and fostering intolerance, anti-globalism, populism, and nationalism in the West.
Trend	Decrease of Christianity and increase of Islamic faith in Europe due to divergence in birth rates and immigration of Muslims.	Populism and nationalistic sentiments, resulting in more restrictive trade regimes (countering globalisation).
Trend	Continuous migration towards Europe as a result of geopolitical and religious conflicts and booming population in Africa and Middle-East.	Continuous migration of in particular Muslims to Europe thrives populism, nationalism, and anti-globalism.
Trend	Hyper Connectivity, by means of transportation, telecommunication, internet, social networks, and smart systems.	Connecting people thrives global trade and transport. Smart systems improve quality, but may also reduce transport volumes.
Trend	Intensified use of sensing and data applications by individuals, institutes and commercial enterprises.	Systems optimisation for all kind of activities including monitoring of civil infrastructures and transport optimisation.
Trend	Increased social awareness of the impact of industries on the environment (including effect on carbon footprint).	Stakeholders demanding transparency and corporate social responsibility.
Trend	Increasing expectations of adequate health, safety and security services.	Increasing demands with respect to environmental aspects and safety of port.
Trend	Enhanced focus on self-sustainability and use of local produced goods.	Counters globalisation, results in less international trade and transport.
Uncertainty	Major breakdown of essential services and infrastructures due to increase vulnerability to cyber crime and/or cyber terrorism.	Enhanced security regulations, redundancy of vital elements, smaller scale operations, higher transport prices.
Uncertainty	Social revolt, due to deterioration of low and middle income classes, unemployment and inability to counter inequality.	Tax regime adjustments, that can either have a positive or negative effect on trade and transport. Other unanticipated effects.

2.3 Technological megatrends

- **Trends**

- **Paradox** that at the **disaggregated** level, new developments follow each other at an **ever faster** rate, while at the **aggregated** level, technological growth (i.e. labour productivity growth) **slows down** in technological frontier countries.
- Knowledge is increasingly developed globally (and open source), while solutions are increasingly custom made and tailored to specific locations (using standard components).
- Focus on automation, robotics, and artificial intelligence.
- Focus on efficiency gains during production and lifetime use.
- Focus on shift towards renewable energy sources.
- Focus on using less materials, recycling, and renewable materials.
- Focus on miniaturisation (Nano-technology and DNA).
- Focus on digitalisation and integration of digital services.
- Focus on sensing and data driven applications.

- **Uncertainties**

- Digital obesity, failing internet security, failure of 'too big to fail' systems.

Technological megatrends

- **Impact of trends**
 - At an aggregated level, declining technological growth rates result in declining growth of labour productivity and declining economic output (from supply side). This tempers international trade and transport volumes.
 - At a disaggregated level technological progress results in many smart digital services that can be used to optimise the efficiency of operations (e.g. improve infrastructure utilisation; and monitoring the condition of equipment and infrastructure).
 - Ongoing automation and artificial intelligence change logistical and transport systems (e.g. automated terminals, 3D printing, autonomous driving).
 - Decline in throughput of fossil products; increase of renewable energy carriers; changing industrial and logistical activities.
 - Decline in transport of raw materials; increase in transport of recycled and renewable (often bio-based) materials.
 - Decline in transport of general cargo as a result of ongoing miniaturisation and shift towards digital services.
- **Impact of uncertainties**
 - Breakdown of port services due to malfunctioning of digital infrastructure.

Table 2.2: Technological megatrends

Type	Development	Impact
Trend	Knowledge developed and shared globally (often open source).	Technological growth and globalisation.
Trend	Declining technological growth rate in western technological forefront countries at aggregated level (measured by labour productivity growth).	Decline in per worker and per capita economic growth rates in western countries. Lower growth of middle income working class in western countries.
Trend	At disaggregated level new technologies seem to follow each other up at an ever faster rate.	Smart customised solutions, that improve the diversity of available products and enable further systems optimisation.
Trend	Energy transition: renewable energy, energy saving, smart-grids and electrification.	Decentralised energy production, reduced energy demand, electric cars and trucks.
Trend	Advanced recycling, urban mining.	Reuse of materials. Transport of used and upcycled materials.
Trend	Bio-based materials and biodegradable chemicals.	Sustainable closed material cycle. Local or regional production.
Trend	Biomimicry	New sustainable technologies, lighter production, new materials.
Trend	Advancing materials (e.g. stronger and lighter, Nano-sciences, bio-based, upcycling of used materials, etc.).	Lighter and more durable production, alternative for rare earth materials, bio-chemicals, reuse of materials.
Trend	Digitisation of processes, integration of digital systems, cloud technology, mobile Internet, and Internet of Things – in combination with advanced sensing and monitoring.	Smart solutions, supply-driven demand, energy transition, capacity optimisation (e.g. available berths/parking lots), infra-structure lifetime extension.
Trend	Block chain technology, building resistance against modification of data.	Secure data storage and exchange. Trust building.
Trend	Large scale implementation of customised local solutions based on global technology.	Self-sustainability at the local or regional level.

Table 2.2: Technological megatrends – continued

Type	Development	Impact
Trend	Ongoing automation and artificial intelligence.	Further digitisation, integration and optimisation of port systems. Also loss of employment and middle class consumption, that could result in lower throughput volumes.
Trend	Advanced robotics and autonomous vehicles.	Different use of vehicles and different infrastructure requirements. Also increase of labour productivity and loss of employment.
Trend	Use of drones and other unmanned devices. Increasingly used with autonomous operation and swarm technology.	Inspection, measurement, clean-up, defence and rapid delivery of small shipments with drones.
Trend	3D printing. Local custom made production based on globally available designs.	Self-sustainability, reduction of transport distances for final products, increase transport of bulk materials (i.e. printer 'ink').
Uncertainty	Quantum computing	Advanced optimisation and problem solving. Use of exact solutions.
Uncertainty	Leakage of classified information, spread via the internet.	Enhanced transparency and social corporate responsibility.
Uncertainty	Failing internet security and cyber crime	Political and business risks.
Uncertainty	Cyber terrorism and warfare	Major infrastructures sabotaged or used to create disaster.

2.4 Energy megatrends

- **Trends**
 - Long term decline in Energy Returns on Energy Invested (EROI). These have long been offset by advancements in mining technology, which are not likely to be sustained.
 - Strong causal relation between GDP and energy demand. Recently, the growth in energy demand shows signs of decoupling from increase in carbon emissions.
 - Strong growth of energy demand in developing and newly industrialised countries and a gradual decline of energy demand in western countries.
 - Chinese energy demand increased three fold between 2000 and 2015.
 - Levelized cost of renewable energy sources, such as wind and solar, has become lower than cost of fossil fuels at favourable locations.
 - Majority of investments in new energy generating capacity based on renewables.
 - Advancement in technology for bio-fuel and synthetic fuel production.
 - Decentralized energy production, electrification, and use of batteries (e.g. storage of energy in batteries of vehicles).
 - Peak oil and coal likely occurred around 2015. Peak gas expected around 2030.
- **Uncertainties**
 - Oil price likely to remain under pressure due to swift shift to renewables.
 - Uptake of carbon capture and storage technology (CCS) is slow.
 - Nuclear fission still awaiting technology breakthrough.

Energy megatrends

- **Impact of trends**

- Increasing EROI stimulates a shift from fossil to renewables as the latter become more cost effective compared to unconventional fossil fuels such as tar sands.
- Need for new energy sources in China has spurred development of cheap solar energy which is competing with fossil fuel in sunny countries. This may result in transport of 'solar farmed' hydrogen to ports in western Europe.
- German 'Energiewende' spurred development of cheap wind energy, now also competitive with fossil, creating a need for offshore supply bases.
- European policies and Paris agreement on reducing carbon emissions and advancing technology for bio-fuel and synthetic fuel production are likely to boost sustainable fuel production and blending activities in the port.
- Electrification of vehicles increases the licence to operate of the port due to lower emissions. In addition it creates demand for shipment of batteries.

- **Impact of uncertainties**

- Uncertain role of LNG as a transition fuel; uncertain investments in LNG facilities.
- Refurbishment of existing oil refineries instead of new investments. Facilities stay operational much longer, creating hybrid base for renewable fuel cluster.
- Potential to use captured carbon for synthetic fuel production.

Table 2.3: Energy megatrends

Type	Development	Impact
Trend	World energy consumption is closely linked to world GDP (linear trend between country GDP and energy demand). Energy use per unit of GDP is gradually decreasing over time.	Strong growth of world energy demand by about 1.9% per year since 1990. Energy intensity of world GDP reduces by about 1.5% per year since 1990.
Trend	Strong economic growth and consumption of energy in developing countries (about 3.3% annually energy increase since year 2007). Lower growth in OECD countries (In fact gradual decline since peak in 2007).	Energy consumption of developed countries (OECD) overtaken by non-OECD countries in 2008. Expected to become twice as large as OECD consumption over next 20 to 30 years.
Trend	Global energy-related CO2 emissions stayed flat over 2015 and 2016, despite 3%+ growth of global economy. Carbon intensity therefore drops by about 3% in 2015 and 2016.	Decoupling of global production and carbon emissions due to: decoupling of GDP and energy use; and decoupling of energy use and carbon emissions.
Trend	Tripling of Chinese energy consumption from 2000 to 2015, mainly produced with coal. To secure growth and reduce coal emissions China is now taking lead in development of renewable energy.	Mass production of renewable wind and solar energy creating steady demand for renewable energy production (mainly solar and wind) advancing cost levels for renewable energy further down.
Trend	Decreasing energy returns on energy invested (EROI) for fossil fuels. EROI on US oil and gas was e.g. over 100 in 1900, about 30 in 170, less than 10 for new discoveries, about 5 for shale oil, and about 2-4 for tar sands.	Fossil fuel production becoming less energy efficient. Cost of oil production becoming more expensive. This pushes production cost for unconventional oil production gradually up toward about 65 to 85 US\$ per barrel for tight oil.
Trend	Peak oil seems to have occurred in 2011 for conventional oil in and 2015 for conventional and unconventional oil combined.	New investments require long-term oil price at high cost levels for tight oil. If cost price for sustainable fuel is lower, new investments in unconventional oil production are put on hold.

Table 2.3: Energy megatrends – continued

Type	Development	Impact
Trend	Production costs for wind and solar energy are becoming cheaper than fossil energy, at least when ignoring intermittency costs. Year 2017 solar bid in Mexico at USD 1.77 cent per kWh.	Strong growth of renewables, but share of renewables still only about 2.8% of global energy consumption when excluding nuclear fusion and hydropower in 2014.
Trend	Sustainable energy investments overtake fossil energy investments. In 2015 about 70% of all investments in energy generation related to renewable energy.	Strong growth in installed renewable energy production capacity.
Trend	Increased global use of LNG as intermediate less unsustainable fuel.	Use of LNG as fuel for cars, truck, barges and seagoing vessels. LNG is regarded as intermediate fuel not as final solution. It is questioned if there is sufficient time for a full shift to gas, as more sustainable alternatives are already gaining ground.
Trend	Power to liquid (PtL) technology to transform water and CO ₂ to high-purity synthetic fuels (petrol, diesel, kerosene) with the aid of renewable electricity. Now becoming available and potentially being upscaled and implemented at industrial scale.	Carbon dioxide turned into a valuable commodity. Recycling of carbon as an alternative to underground storage.
Trend	Advanced biofuel production using all parts of plant material: not only oil and sugar (for production of bioethanol) but also cellulose. Production of bioethanol from cellulose now becoming feasible on industrial scale.	Increase in biofuel production due to ability to use all parts of plant material. Estimates indicate that biofuels can provide up to about 10% to 30% of world transport fuel by 2050.

Table 2.3: Energy megatrends – continued

Type	Development	Impact
Trend	Construction of large hydrogen production plants in oil producing countries such as Saudi-Arabia to blend with crude in order to reduce sulphur content. Note that Saudi-Arabia's oil production is declining and that they are planning to sell Aramco (the national oil production and refinery firm of Saudi-Arabia).	At present this has no effect on energy system, but once these factories start to produce a surplus one can expect transport of hydrogen instead of oil.
Trend	Advances in energy storage and battery technology.	Development of smart grid solutions and electrification of vehicles.
Trend	Electrification. By 2016 already globally 1 million electric vehicle on the road.	Reduces demand for fossil fuel as energy carrier and improves local air quality. Partial solution to intermittency problem when connected to smart electricity grid.
Trend	Development of smart electricity grids and cyber physical systems (CPSs) or systems that offer close integration of computation, networking, and physical processes.	Major changes in energy production and consumption. Shift away from fossil fuels.
Trend	Peak gas. Hubbert Linearization indicates peak gas to be occur around 2030, possibly somewhat delayed by unconventional shale gas. But shale gas production is expected to have peaked in US in 2015 already.	Gas is more sustainable than other fossil fuels and provides flexibility in energy production. Use of natural gas may grow as intermediate fuel for energy production and transportation for at least two to three decades, and possibly a few decades longer.
Trend	Peak coal. Estimates of recoverable coal reserves indicate that peak coal is to be expected between 2013 and 2045. Most sources indicate date around 2025 to 2030, but recent data also indicate that Chinese coal production (about half of global production) has, at least temporarily, peaked in 2013 followed by a likely peak in global coal production in 2014.	Accelerated decline of coal production. Increase in coal price. Accelerated closure of coal fired power plants. Reduced transport of coal. Enhanced decoupling of GDP and CO2 emissions.

Table 2.3: Energy megatrends – continued

Type	Development	Impact
Uncertainty	Oil price turbulence. Market prices dropped from over 140 US\$/barrel in 2008 to less than 40 US\$/barrel in 2009, recovered to about 100 to 120 US\$/barrel in period 2011 to 2014, fall about 50 US\$/barrel in 2015 and about 30 US\$/barrel and back at about 60 US\$/barrel in October 2017. Production costs range from less than 10 US\$/barrel for conventional middle east OPEC oil, to about 10 to 30 US\$/barrel for shallow water oil, 30 to 50 US\$/barrel for deep water oil, and 65 to 85 US\$/barrel for tight oil.	Increasing up- and downward pressure on oil price. Upward pressure due to peak oil and more costly production – as well as from substitution from coal to oil in China. Downward pressure from slowdown in world GDP and increasing of renewable energy production. For development of new unconventional oil fields the expectation of lower future renewable energy prices act as a barrier to investors.
Uncertainty	Nuclear fusion. Share of nuclear fusion in total energy production declining since mid-1990s. Use of nuclear energy may continue to decline or start to increase substantially in case of energy scarcity following an early fossil peak and/or slowdown in renewables.	Increase of nuclear fusion energy could either temper use of conventional fossil fuels, or use of renewable energy.
Uncertainty	Nuclear fission	Abundant cheap energy, but still in a very experimental development stage.
Uncertainty	Algae as the fuel of the future.	Solution for in particular heavier vehicles. Transport of algae fuels.
Uncertainty	Space based Solar power	Effect on transport system is unclear.

2.5 Environmental megatrends

- **Trends**

- Increasing global population putting pressure on the ecosystem.
- Degradation of natural resources and pollution, including pollution of the marine environment.
- Overfishing and shift from wild catch towards aquaculture production.
- Increased water scarcity, requiring energy to produce fresh water.
- Climate change, sea level rise, changing precipitation levels, increase in the number of extreme events.
- Growing pressure on ecosystems, due to pollution and effects of climate change, 25% of world food production at risk by 2050.

- **Uncertainties**

- Reduced carbon uptake of the oceans (no sign of this observed yet).
- Peak water, and impact on population in water scarce environments, likely to enhance geopolitical instability and water induced migration.
- Peak food, and impact on geopolitical stability and food induced migration.

Environmental megatrends

- **Impact of trends**

- Ecosystem degradation, decline of already insufficient natural resources in Europe, and a new focus on a circular economy; boosts recycling and upcycling activities, already a strong cluster in Rotterdam port area.
- Shift from wild catch towards aquaculture production may result in new offshore activities, new logistics related to food transport, and offers a potential for food production in unused port basins.
- Climate change affects accessibility and competitiveness of ports (sea level rise), downtime (extreme weather), and IWT hinterland connections (reduced loading capacity for e.g. bulk cargo in periods of drought and low water; and reduced loading capacity for e.g. containers in case high water reduces bridge vertical clearance).
- Growing pressure on ecosystems, due to pollution and effects of climate change, could result in increased food exports overseas.

- **Impact of uncertainties**

- Accelerated sea level rise may necessitate construction of flood barriers.
- Increased water scarcity could result in water becoming an export product, e.g. as return cargo for (anticipated) Hydrogen tankers from Saudi-Arabia.
- Peak food could result in enhanced social and geopolitical instability and increased migration, e.g. from Africa to Europe.

Table 2.4: Environmental megatrends

Type	Development	Impact
Trend	Population boom, pressure on ground use, and loss of biodiversity.	Growth of population from 1 billion in 1800 AD to 7 billion in 2016, with further growth on the horizon. Food and other material requirement compete with nature area. E.g. more than 80% of natural forest has been destroyed, to be replaced by urban areas and agri-monoculture.
Trend	Degradation of natural resource reserves, reaching peak output for some of them.	Constraint on economic output, trade and transport. Enhance global tension.
Trend	Intensified global competition on resources. Europe weak on critical raw materials, including rare earth metals. 9 of 14 most critical materials are for more than 50% dominated by China in production.	Strong European focus on renewables and advanced recycling methods. Not only from a sustainability, but also from a resource perspective.
Trend	Overfishing and shift to aquaculture production. Swift shift from wild capture to aquaculture production. According to FAO farmed volumes are now about 45% of total from about 10% in 1990.	Declining wild catch or at best stabilisation of fish catch just above present level if fishing efforts are reduced. Unable to meet demand of growing population. Shift towards fish farms.
Trend	Increased water scarcity on global scale. About 150 square kilometre of groundwater over pumped or withdrawn quicker than it can be replaced from underwater aquifers annually.	Increased geopolitical tensions, migration, reuse of water, and water production from seawater by means of reverse osmosis requiring energy.
Trend	Climate change, as becoming visible from carbon levels in atmosphere and from measurements of global temperature, shrinking ice sheets, etc.	Sea level rise, changing weather patterns, increase in impact of extreme weather events. Resulting in more frequent closure of port and increase effects of extreme precipitation and draught on inland waterway transport. On global scale also major impact on food security. Enhances social awareness on sustainability.

Table 2.4: Environmental megatrends – continued

Type	Development	Impact
Trend	Pollution shifting from a local to a global problem. Increased emissions, creating an increasingly complex mix of critical pollutants with interrelated environmental effects. Loss of biodiversity and increased rates of extinction due to pollution, chemical disposal, and climate change. Species extinction rate increased by as much as 1000 times over past centuries. Ecosystems at stake.	Persistent, bio-accumulative and toxic chemicals (PBTs) that remain in soil and sediment for a long time have emerged as an important environmental and health concern. Erode global food security, lower yields, increase global inequalities and adversely affect human health. Increases inequality and the displacement of people. Environment-induced migration.
Trend	Polluted marine environment, plastic soup, bleaching coral reefs.	Weaker, smaller and less diverse fish population. Reduced catch.
Trend	Growing pressure on ecosystems. Poorest population most depending on ecosystem services for food etc. Up to 25% of world food production at risk due to environmental breakdown by 2050.	Political instability and environment-induced migration (e.g. from Africa towards European Union).
Trend	Changes in health environment. Shift from communicable diseases to non-communicable diseases. Bacteria getting resistant. Increased persistent threat of pandemics.	Awareness that changes in lifestyle and use of antibiotics are required. Shift from intensive farming to biological farming, but within constraints of broader need to feed world population.
Trend	Improvement of local habitat in some areas due to regulation.	Improved water quality on river Rhine.
Uncertainty	Reduced carbon uptake of oceans.	Accelerated climate change.
Uncertainty	Water supply after peak water	Mass transport of water to water scarce areas. E.g. by means of intercontinental pipelines or in tanks of carriers from water scarce areas (e.g. return cargo for oil or future hydrogen carriers).

2.6 Economic megatrends

- **Trends**

- Decreasing labour productivity growth in technology frontier countries.
- Growing middle class in developing countries due to better education and rising labour productivity levels.
- Inequality reaching unsustainable levels, resulting in stagnation or decline of median income levels in western countries.
- Loss of jobs due to ongoing automation, robotics, and artificial intelligence.
- Offshoring of jobs to low wage countries, this trend is now changing direction but on balance, a shift of labour to low wage countries.
- Counter globalisation forces fostering the erection of new trade barriers.
- Low inflation rates as a result of technological progress and rising inequality (hence labour productivity growth does not result in higher wages).
- Declining interest rates as a result of monetary stimulation and rising levels of inequality (as richest people increasingly search for safe investments).

- **Uncertainties**

- Rising unemployment levels in western countries as a result of secular stagnation, when central banks are no longer be able to stimulate the economy and secure employment by lowering interest rates.

2.6 Economic megatrends

- **Impact of trends**

- Decreasing growth of economic output and transport volumes due to decline in labour productivity growth (supply side effect).
- Decline of consumption, economic output, and transport volumes due to stagnation and/or decline of middle class income as a result of ongoing automation and soaring inequality levels (demand side effect).
- Decline of trade and transport volumes as a result of counter globalisation forces (fostered by growing populism and nationalism).
- Growing middle class in developing countries increases export market for European manufactured products, reducing trade imbalance.
- Low inflation and interest rates foster investments in relatively low risk activities such as: windfarms, renewable fuel production facilities, as well as many other new investments (including port infrastructure investments).

- **Impact of uncertainties**

- Significant rise in unemployment (e.g. 20% - 40%) results in political unrest, populism, changes in tax regime, etc. In addition it lowers consumption levels and reduces transport volumes.

Table 2.5: Economic megatrends

Type	Development	Impact
Trend	Decreasing labour productivity growth in frontier technology economies	Slower economic growth in developed countries.
Trend	Decreasing labour productivity growth due to catch-up effect in some BRICS countries.	Slowdown of economic growth in Brazil, China, Russia and South-Africa (but not in India).
Trend	Increasing income and wealth inequality. Richest 8 people own more than 50% of world population at the bottom of the pyramid since 2017.	Lower consumption levels as richest tend to consume less. Higher level of capital invested, pressure on interest rates and returns on investment. Lower economic growth due to increasing income and wealth inequality.
Trend	Stagnating or even declining median family incomes in western countries since year 2000 despite growth of labour productivity.	Decline of middle class income group. Lower consumption levels. Reduced welfare, increased populism. Reverse globalisation.
Trend	Digitalisation of business processes.	Further optimisation and integration of processes. Higher risk of failure, cyber criminality, digital warfare and terrorism.
Trend	Loss of jobs due to ongoing automation, robotics and since recently also artificial intelligence.	Decline of middle class income group. Lower consumption levels. Reduced welfare, increased populism and nationalism. Reverse globalisation.
Trend	Reverse globalisation. Global trade lowers prices and boost consumption. But offshoring middle class jobs from western countries to developing countries without being able to create new ones foresters deterioration of middle-income class in western countries.	Globalisation, has long been a main driver of economic growth, but is now on its return, likely to create a double backlash on trade and transport, as a result of less trade per unit of production and less consumption due to loss of middle class.
Trend	Restrictive trade policy and increased wage costs in China.	Lower trade volumes with China, but shift to other Asian countries.

Table 2.5: Economic megatrends – continued

Type	Development	Impact
Trend	Offshoring, reshoring and nearshoring.	Increased focus on reshoring of labour, but on balance offshoring of production and services to developing countries still going on.
Trend	Decline of middle class jobs in western countries.	Social discontent, populism and nationalism in western countries. Lower demand for consumer products.
Trend	Increase of middle class in developing economies.	Increase of consumption and production levels in developing countries.
Trend	Decreasing 10 year risk free real interest rates from about 6% in the 1980s to near 0% in 2015 (both supply and demand curves for saving and investment shifted downward).	Reduction in nominal interest rates. Enhances investments in relatively safe new infrastructure, e.g. for renewable energy production.
Trend	Stable low core inflation rates of less than 1% in EU increased or decreased by cyclical effects in energy prices. Temporary increase in inflation due to rising energy price levels.	At present slight temporary increase in inflation and nominal interest rates due to increase in energy price levels.
Trend	Massive capital injections by central banks in attempt to restructure banking system, lower exchange rates and enhance economic growth.	Lower interest rates and creation of bubbles in exclusive luxury segment richest 1% of population.
Uncertainty	Secular stagnation, i.e. negative interest rates required to equate saving and investment at full-employment levels.	Inability to increase economic output and employment by lowering interest rates and expansionary economic policy. Potentially high unemployment rates.

2.7 Geopolitical megatrends

- **Trends**

- Shift away from US hegemony and western idealistic policies and institutions towards multipolar society that pursues global pragmatism.
- Russia collaborating with China in setting up Shanghai Cooperation Organisation (SCO) and other non-western institutions.
- Russia playing 'poker' game with the objective of restoring its former geopolitical dominance as world superpower.
- Turkey frustrated with slow (or absent) integration with EU as a result of incompilant democratic values, turns its face to the east, considers leaving NATO and moving towards SCO.
- NATO starting to restore its military power.

- **Uncertainties**

- How long will Putin be able to remain in power? Will Russia engage in a war in the Baltic?
- Where are the Korean conflict and other conflicts in the South and East Chinese sea leading to? Can these conflicts be resolved without war?
- Will Turkey drag into a conflict with NATO partners on Kurds in Syria?

2.7 Geopolitical megatrends

- **Impact of trends**
 - Shift towards global pragmatism of multipolar world intensifies conflicts, counters globalisation, and reduces trade and transport volumes.
 - Rising tension with Russia and threat of Turkey joining SCO drives building up of navy capacity, possibly requiring dedicated port facilities.
 - Increased threat of terrorism requires additional safety measures to be implemented in the port.
- **Impact of uncertainties**
 - Geopolitical tensions increase risk of cyber attacks and other terrorist or warfare attacks on the port.
 - Military encounter between NATO and Russia can be expected to result in economic sanctions affecting amongst others shipments of Russian oil to Port of Rotterdam and transshipment containers from Port of Rotterdam to Russian ports in Baltic sea.
 - US conflict with China could severely reduce (or bring to a hold) container volumes between China and Europe.

Table 2.6: Geopolitical megatrends

Type	Development	Impact
Trend	Growing economic and military power building up in the east. China taking over economically from US, India following suit. Russia, though economically small striving to regain its former dominant position as global superpower by teaming up smartly with Chinese and others.	Shift of economic activity towards Asia. Shift from western (former UK and present US) ideology and military and political hegemony towards new era with multipolar power play. Shift from perusing democracy to global pragmatism.
Trend	Growing aversion of western dominance by (former) communist counties (China, Russia, North Korea), Islamic Countries (Iran), and African Countries.	US political and military hegemony under pressure.
Trend	Long period of structural investments by Chinese and Russian government in African countries. Turning them into allies.	Strong ties between China and Russia and African countries. Giving them a strategic advantage internationally.
Trend	Undermining of democratic western institutions such as UN safety council (by veto rights) and rejecting International Criminal Court.	Shift of institutional power from west to east, or at least a decline in power of western institutes.
Trend	Development and strengthening of new Asian and BRICS institutions such as: Shanghai Cooperation Organization (SCO), Asian Infrastructure Investment Bank (AIIB), and BRICS's New Development Bank (NDB).	Shift from idealistic western politics (democracy and human rights) to a more pragmatic mind your own business approach.

Table 2.6: Geopolitical megatrends – continued

Type	Development	Impact
Trend	US Nationalism, Turkey facing East, raising tensions between NATO and Russia.	Restructuring NATO. Larger EU defence budgets. Military exposure in the port.
Trend	Multilateral trade agreements under pressure. Trans-Pacific Partnership (TPP) broken up before started, TTIP not likely to be realised.	Reverse globalisation and smaller role of influence of US in far east.
Trend	Brexit, D. Trump election, and upcoming nationalism in western countries (not necessary by ruling parties, but definitely affecting political landscape).	Reverse globalisation.
Trend	Growing influence of global climate policies, implemented in most countries. With China about to take the lead for resource securing purposes, EU gradually moving forward for sustainability reasons, and US partly off-track.	Shift towards renewable energy in an attempt to limit global warming to 2 degrees Celsius compared to 1990.
Uncertainty	Outcome of Brexit negotiations	EU trade with UK.
Uncertainty	Disintegration of European Union due to rising populism and nationalism.	Counters globalisation, results in less international trade and transport.
Uncertainty	Diplomatic conflict between EU and Russia.	Political sanctions on trade with Russia, affecting trade and transport volumes.
Uncertainty	Military escalation between NATO and Russia, with US and North Korea, or with US and allies in East and/or South Chinese see.	War.

Table 2.6: Geopolitical Megatrends – continued

Type	Development	Impact
Uncertainty	Economic and cyber warfare from China and Russia to destabilise US and allies.	Social unrest and instability. Fall of the dollar.
Uncertainty	Effect of China's aging population on growth of china's economic, political and military power.	Shift of power to other Asian and developing countries such as India.
Uncertainty	Russia economically under pressure due to sanctions and weak oil price.	Shift of power to other Asian and developing countries such as India.
Uncertainty	Potentially growing role of India on the long-term power balance in Asia.	More balanced and pro-western political development in Asia.

3. Economic cycles

- 3.1 Introduction to economic cycles
- 3.2 Empirical evidence vs. lack of theory
- 3.3 Historical overview of past K-waves
- 3.4 Expected timing of next down- and upswing period
- 3.5 K-waves and diffusion of technology
- 3.6 Anticipating drivers of next K-wave
- 3.7 K-waves and infrastructure development
- 3.8 Implication for direction of future trends
- 3.9 Summary of main conclusions

3.1 Introduction to economic cycles

- Social-, economic-, and technological developments follow a transition path that is usually not straight but subject to cyclical movements around a main trend.
- These cyclical movements have been studied ever since the industrial revolution started to cause social crises. Many cycles of varying lengths have been identified.
- Schumpeter, who devoted most of his life to the study of economic cycles, proposed a typology in which cycles are named after their discoverers. The most commonly reported cycles are:
 - 3-5 year inventory cycle of Joseph Kitchin;
 - 7-11 year business cycle of Clement Juglar;
 - 15-25 year infrastructure swing of Simon Kuznets;
 - 45-60 year long wave of Nikolay Kondratieff.
- Identification of economic cycles takes place by analysing various indicators related to price and production levels as well as other economic indicators.
- A trend is generally considered to be composed of the main trend plus the aggregate of the cyclical movements that act on it.

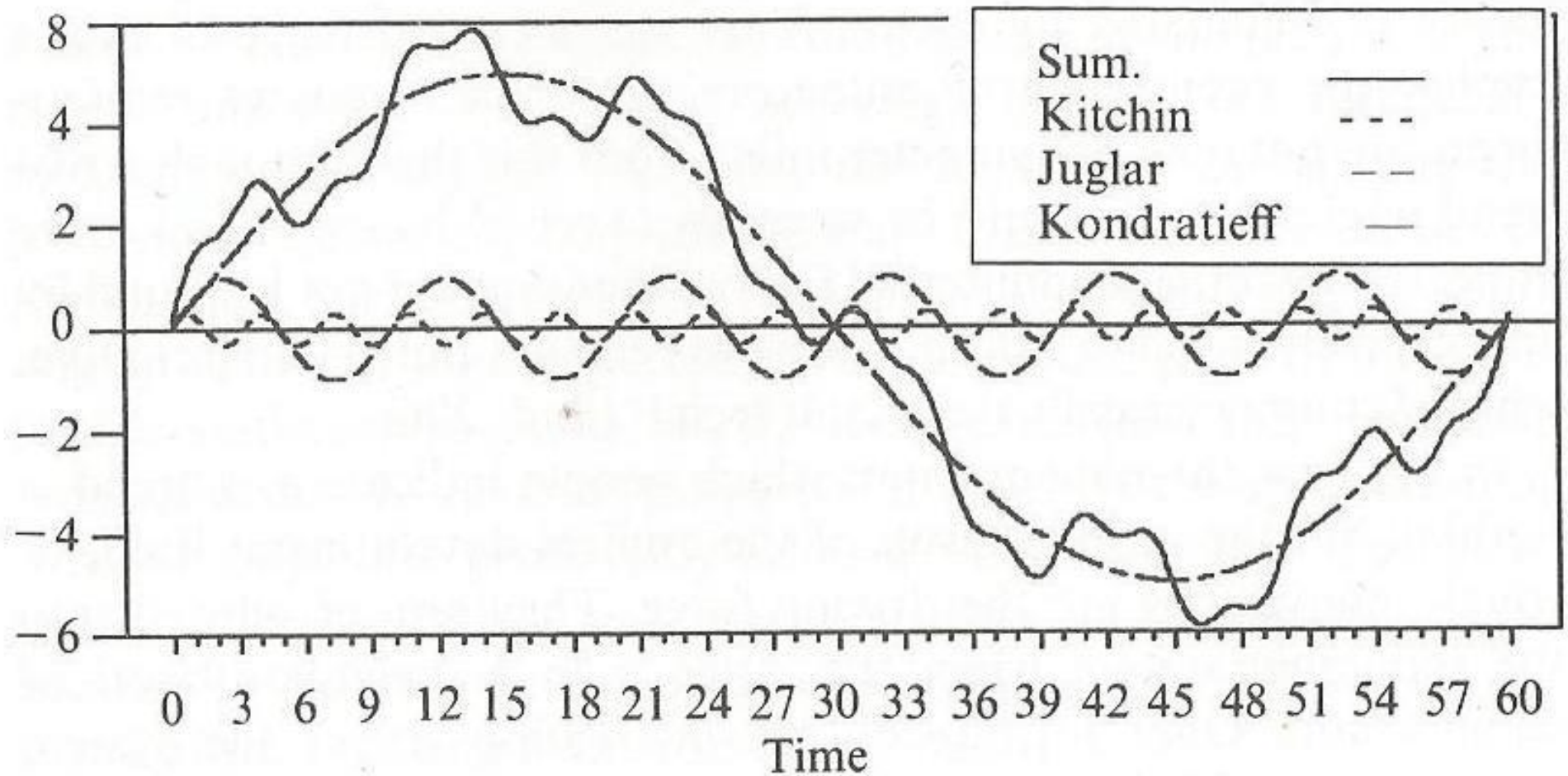
Introduction to economic cycles

- The **Kitchin cycle** are short, about 3-year inventory cycles, and therefore of little relevance to our broader framework for looking far ahead.
- The **Juglar cycle or (standard) business cycle** is the most well-known, as this cycle is related to the economic conjuncture.
- The **Kuznets swing** is connected with demographic processes, in particular immigrant inflows/outflows and their effect on construction intensity in the US. Its explanatory power for our purposes seems to be limited. However, the Kuznets swing is also claimed to be related to movements in income inequality and may be useful to investigate, but this is outside the present study scope.
- The **Kondratieff wave (or K-wave)** is the most relevant for the analysis of long-term trends. Kondratieff waves are related to the pervasive social, technological and economical drivers of our global society and the world economy. Their close relation with the diffusion of new technologies and the development of new infrastructure networks, make the K-wave very useful in identifying future trends and the inertia (or momentum/tempo/speed) of these trends.

Introduction to economic cycles

- Historical evidence shows that the movements of economic cycles of various lengths tend to align, making it easier to identify a pattern.
- Schumpeter (1939), who turned the study of cyclical movements into almost a religion, proposed a three cycle approach for which he concluded that:
 - *“Barring very few cases in which difficulties arise [...] it is possible to count off, historically as well as statistically, six Juglars [eight-to-ten-year cycles] to a Kondratieff [fifty to sixty years] and three Kitchins [forty months] to a Juglar – not as an average but in every individual case”.*
- Schumpeter’s three cycle pattern is depicted in [Figure 3.1](#), but though historical cycles can be fitted to this pattern (with some creativity), his three cycle pattern is not universally agreed upon.
- Kitchin (1923) for instance, indicated that a business cycle (or Juglar) can comprise of two or three Kitchin cycles.
- Van Duijn (1977) argues that Kondratieff waves, by definition, need not consist of six waves, but can also be composed of 5 periods (at least in cases where there is no war following a prosperity period).

Figure 3.1: Schumpeter's three cycle approach



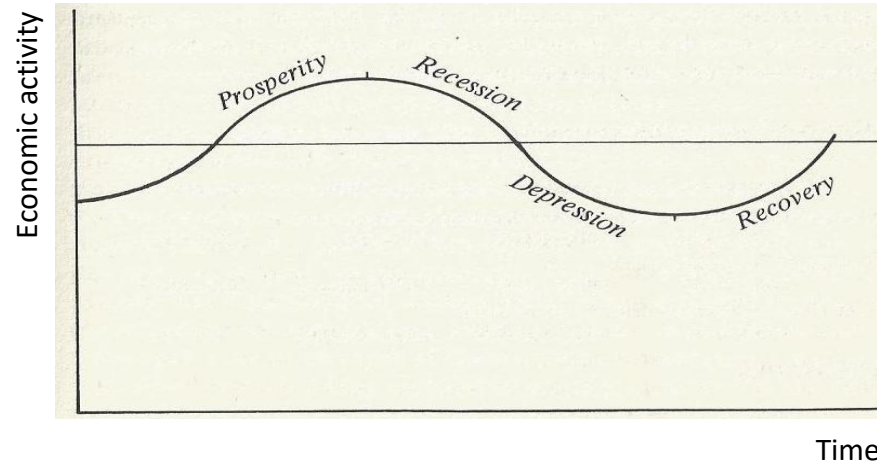
Source: Reijnders, J. (1990), based on Schumpeter (1939), retrieved from Narkus, S. (2012).

Introduction to economic cycles

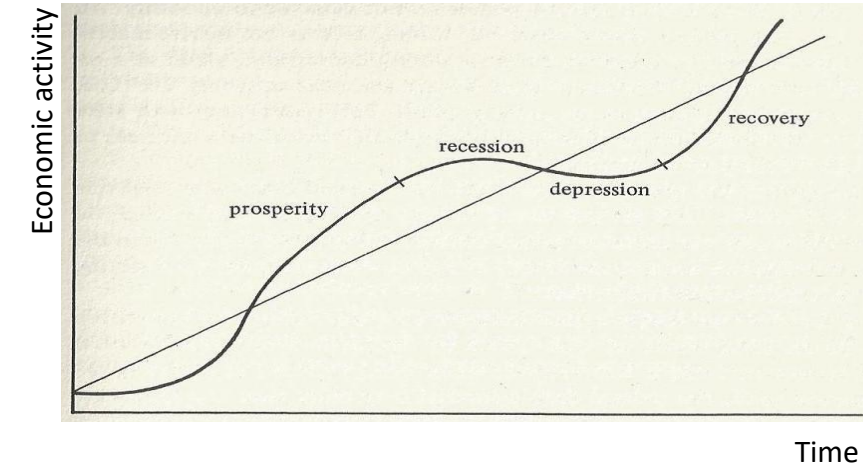
- The cyclical pattern of the K-waves can be represented in various ways. However, in all cases it involves a cyclical movement around a more stable long-term trend.
- The most universal representation of the K-waves is one with an upswing period followed by a downswing period. This representation is the easiest to compare amongst various researchers (see e.g. Van Duijn, 1983; Bosserelle, 2002).
- The movement of K-cycles is also related to industrial life cycles of technologies that 'belong' to the various K-waves, as clearly indicated by the Metamorphosis model of Mensch (1975).
- Schumpeter proposed a conceptual sinusoidal four-phase model, that comprises the phases prosperity, recession, depression, and recovery. This terminology is commonly used but hard to link to the movement of the Juglar cycles, as it would imply that each phase consists of a fractional number of Juglars.
- A revised version of Schumpeter's model was proposed by Kuznets (who had it checked by Schumpeter) because the phasing did not comply with the up- and downward movement of the waves. His revised scheme, that is also advocated and used by Van Duijn, differs by the fact that the lower point (i.e. the starting point of the upswing phase) is located at the beginning of the prosperity phase, and that the highest point (i.e. starting point of the downswing phase) is located at the end of the recession phase.

Figure 3.2: Various representation of K-wave model

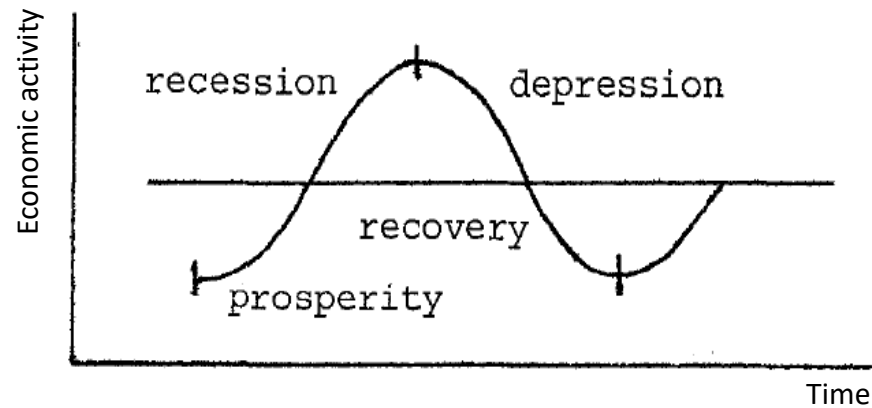
Conceptual model proposed by Schumpeter



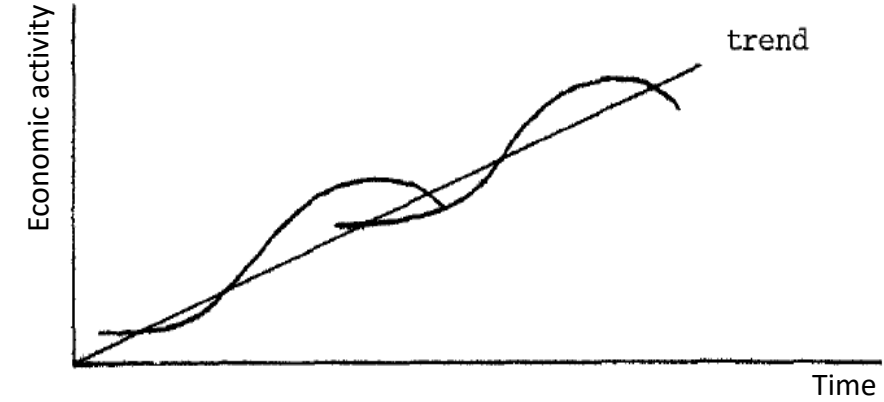
Model of Schumpeter with growth trend



Revised model representation



Model of Mensch with growth trend



Source: Above: unknown (probably Van Duijn, 1983), retrieved from Narkus, S. (2012). Below: Van Duijn (1977).

3.2 Empirical evidence vs. lack of theory

- There is ample empirical data supporting the historical existence of the K-waves, but a compelling theoretical explanation is still lacking.
- In absence of a compelling theory, the forecasting value of K-waves has been disputed – as there is no guarantee that a K-wave will be followed up by a subsequent wave. However, many (partial) explanations exist, and none of these provides any evidence that the K-wave patterns are likely to disappear within a relatively short time period of one or two wave lengths.
- Forrester's (1976) system-dynamics model indicated that the major mechanisms that seem to generate long waves in the model still occur even when the level of technology is constant and the rate of innovation is zero.
- In addition, others such as Modelski (1978) and Modelski and Thomson (1996), have proposed a long cycle that goes much further back in time, in which there is a shift in global leadership approximately every 100 years.
- **It is therefore reasonable to assume that the wavelike behaviour of the K-waves will continue for at least one or two more wave periods, i.e. up to about 100 years ahead.**

3.3 Historical overview of past K-waves

- There is no consensus as to the exact timing of the subsequent K-waves because:
 - Different economic parameters are examined to identify the waves;
 - The movement has not been synchronous in all countries, though in recent times, the world economy is tending to becoming more aligned;
 - Different interpretations and weights are given to the observed data.
- After studying and analysing more than 30 relevant publications and eliminating a few outliers, an indication of the periods in which the peaks and troughs occur is obtained. [Table 3.1](#) shows the chronology of the historical K-waves.
- Van Duijn (1977, 1983, 2007) argues that the K-waves are composed of 5 Juglar periods, of which two are prosperous periods. Occasionally, the length of K-waves was extended by a war period following the prosperous periods. (The war period created high geopolitical tension in the effort of securing countries needs.) WW2 was an exception as it took place in the recovery phase of the 3rd K-wave.
- **We adopt the 5 period scheme of Van Duijn as it seems to fit well with the historical data, and can thus provide valuable insights into likely future developments.**

Table 3.1: Chronologies of historical K-waves

Chronologies reported in literature of 1847 – 2012	1st Kondratieff	2nd Kondratieff	3rd Kondratieff	4th Kondratieff	5th Kondratieff
Trough	1782 - 1795	1842 - 1852	1890 - 1898	1932 - 1950	1984 - 1991
Peak	1808 - 1826	1864 - 1875	1911 - 1929	1967 - 1977	2008 - 2010*

* Note that 2008-2010 value is not in line with scheme provided by Van Duijn.

Chronology of Van Duijn (1983, 2007, extended by author)	1st Kondratieff	2nd Kondratieff	3rd Kondratieff	4th Kondratieff	5th Kondratieff
Trough	1782	1845	1892	1948	1992
Prosperous	1782 - 1792	1845 - 1856	1892 - 1903	1948 - 1957	1992* - 2000
Prosperous (war)	1792 - 1802 (1802 - 1815)	1856 - 1866	1903 - 1913 (1913 - 1920)	1957 - 1966	2000 - 2009**
Recession	1815 - 1825	1866 - 1872	1920 - 1929	1966 - 1973	2009** - 2018E
Peak	1825	1872	1929	1973	2018E
Depression	1825 - 1836	1872 - 1883	1929 - 1937	1973 - 1980	2018E - 2027E
Recovery	1836 - 1845	1883 - 1892	1937 - 1948	1980 - 1992*	2027E - 2036E
Total cycle time	63 years	47 years	56 years	44 years	44 years
Total cycle time excluding war	50 years	47 years	49 years	44 years	44 years
Upswing period duration	43 years	27 years	37 years	25 years	26 years
Upswing period duration excl. Wartime	30 years	27 years	30 years	25 years	26 years
Downswing eriod duration	20 years	20 years	19 years	19 years	18 years
Average upswing juglar (excl. war)	10.0 years	9.0 years	10.0 years	8.3 years	8.7 years
Average downswing juglar	10.0 years	10.0 years	9.5 years	9.5 years	9.0 years
Average juglar cycle (excl. War)	10.0 years	9.4 years	9.8 years	8.8 years	8.8 years

* Note: 1992 value listed to be 1990 in table on page 99 of Van Duijn (2007), but reported to be 1992 on page 195. ** Note: year 2009 suggested by author.

Note: expected values indicated with an E behind the year (e.g. 2018E).

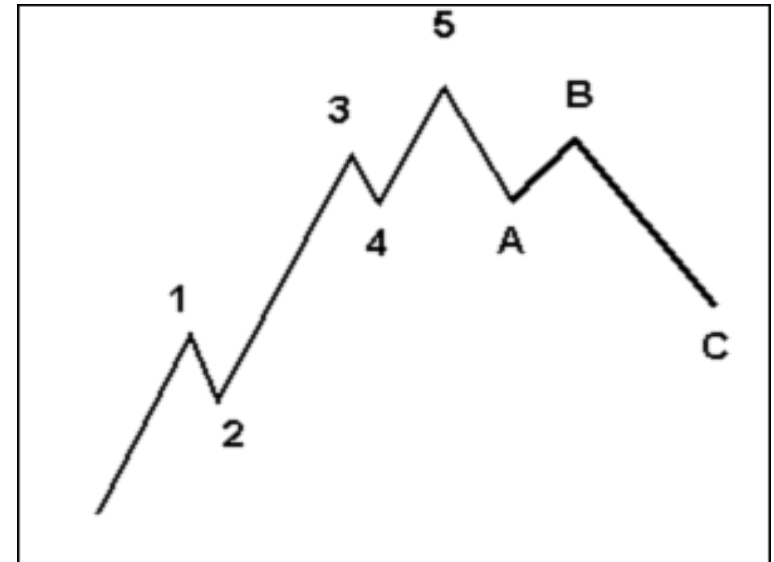
Source: Upper: own analysis based on over 30 publications, Lower: Chronology based on Van Duijn (1983, 2007, extended with estimates by author)

3.4 Expected timing of next down- and upswing period

- According to many, the downswing period is likely to have started around the year 2008 – 2010 (say 2009*), after the housing bubble and credit crisis. However, the assumption of K-wave to have peaked in the year 2009*, is not in line with Van Duijn. Based on Van Duijn, one could expect the K-wave to peak around the **year 2018E** or at least in the period from 2017E to 2020E (starting with today's date and taking into account a 7 to 11 year Juglar).
- For what it is worth, a technical analysis of stock indices also hints at a possible peak around 2017E – 2020E. If one imposes an Eliot Wave pattern that takes into account the psychological behaviour of traders, and the long-term trend of Dow Jones and S&P 500 indices, a new downward correction in the near future (e.g. in the period from 2017 to 2020) can be expected, but the potential link between K-waves and Eliot waves still requires fundamental research.
- The possible peak around 2017E – 2020E is further supported by long-term data on the movement of the stock value as compared to the output of the real economy. Based on Van Duijn's historical pattern, the next upswing period of the 6th K-wave can be expected around 2036E, though others indicate that upswing period could also be expected a business cycle earlier, i.e. around 2027E.
- **Based on this analysis it is concluded that new business models are likely to develop over the next 1 or 2 decades and become dominant by the year 2030 – 2040. This is when the nature of business has truly changed.**

Intermezzo: Elliot Waves

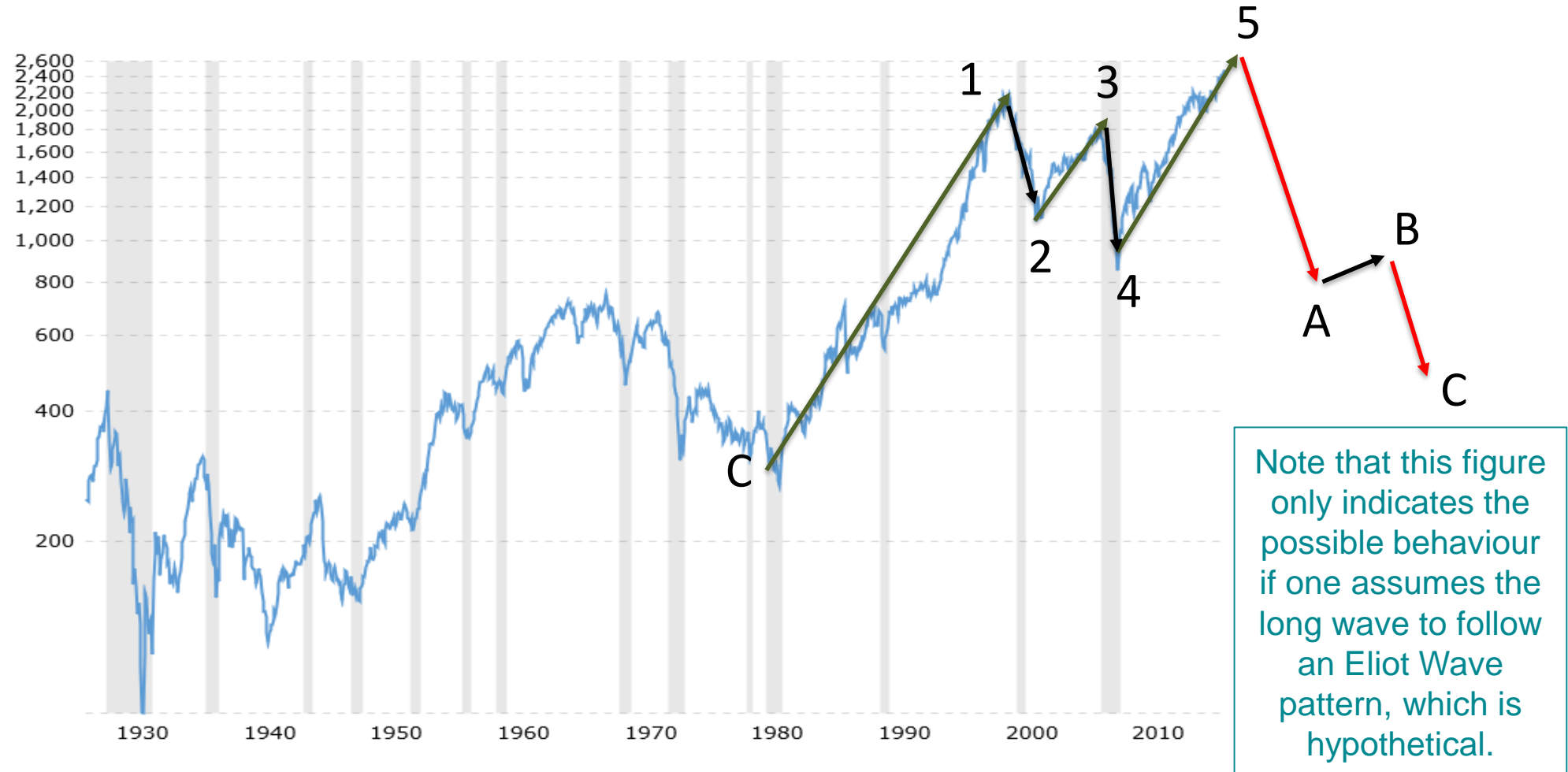
- The Elliot Wave Theory was developed by Ralph Nelson Elliot in the late 1920s.
- Elliott proposed that market cycles resulted from investors' reactions to outside influences, or the predominant psychology of the masses at the time.
- He found that the upward and downward swings of the mass psychology always showed up in the same repetitive patterns, which were then divided further into patterns he termed "waves".
- Elliot found a more or less standard wave pattern with 3 impulsive upward movements (bullish) and two impulsive downward movements (bearish), which are divided by a number of corrective movements (see figure).
- Bullish optimistic: C-1, 2-3, 4-5
- Bearish pessimistic: 5-A, BC
- Corrective: 1-2, 3-4, A-B.



Source: www.investopedia.com/articles/technical/111401.asp

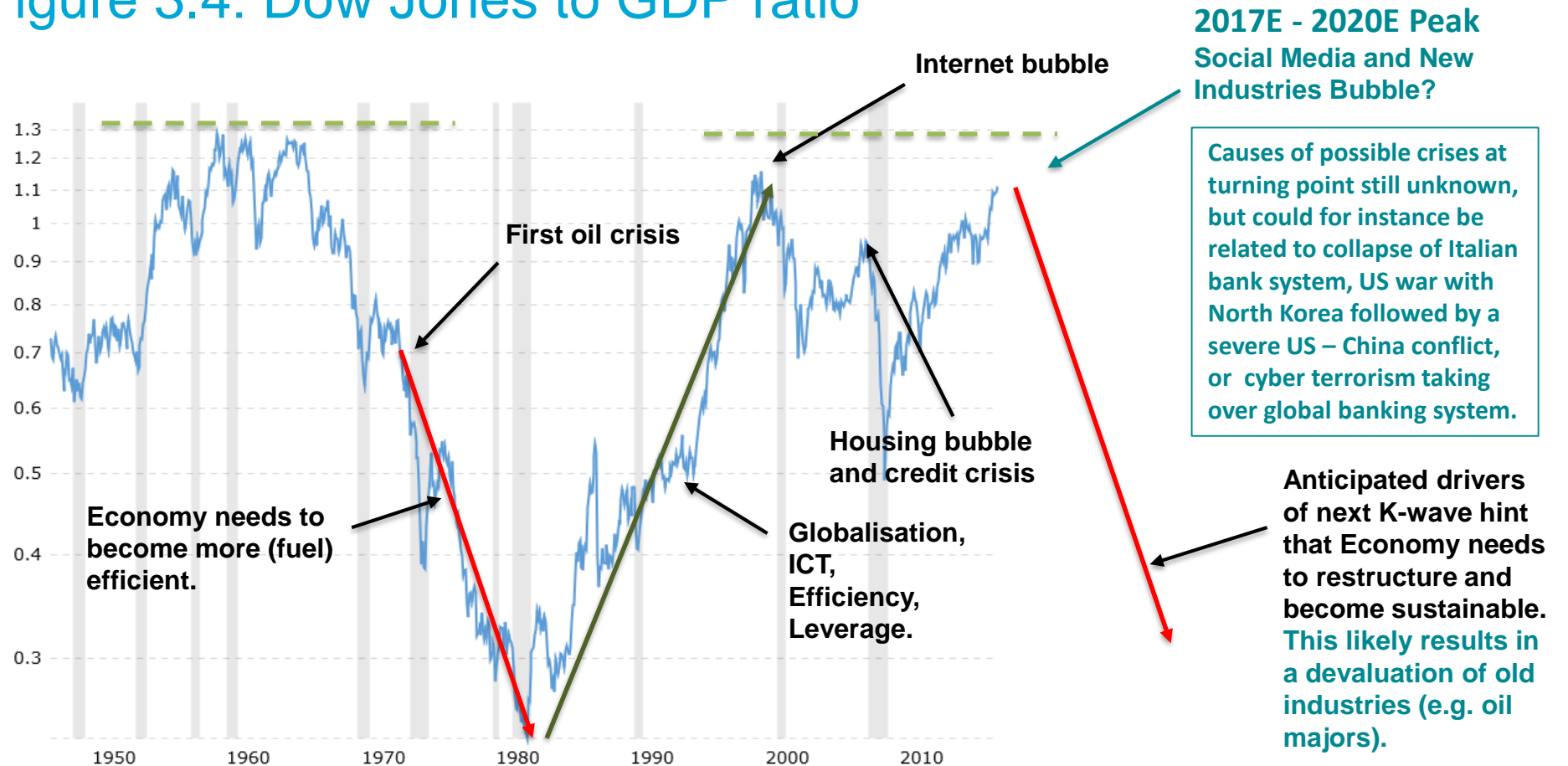
Figure 3.3: Inflation adjusted S&P 500 with Elliot Pattern

Elliot wave pattern could support peak in 2017E – 2020E



Source: figure with historical data from <http://www.macrotrends.net/>, technical analysis by author.

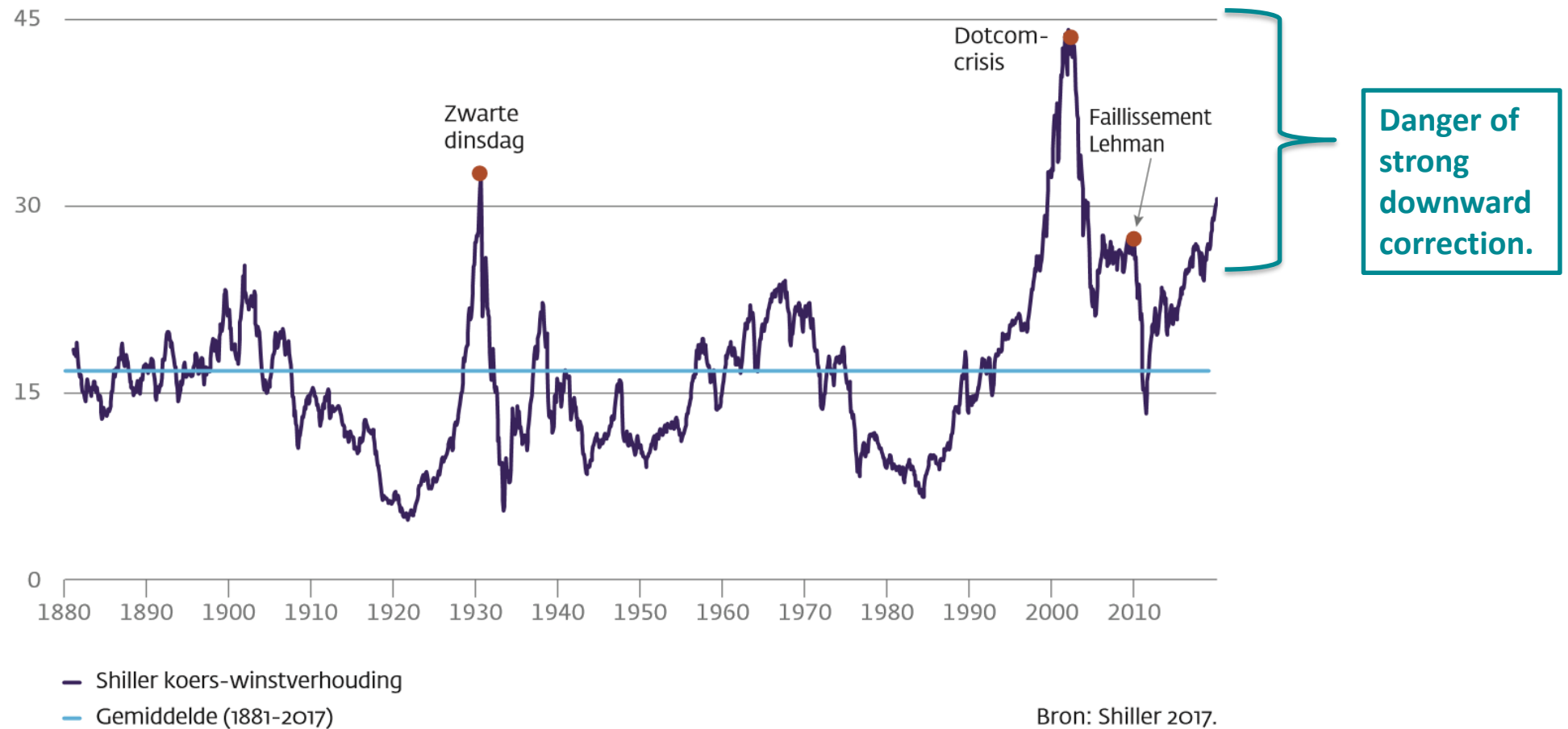
Figure 3.4: Dow Jones to GDP ratio



Points of Dow Jones Index divided by US GDP in billion. Figure provides indication of stock value (i.e. traders expectation of future added value) over added value created in the real economy, for which there may be a ceiling. Figure shows that present valuation of stocks is high compared to output of the real economy and that a downward correction can be expected in line with the shift of drivers from the 5th to the 6th K-wave.

Source: Source: figure with historical data from <http://www.macrotrends.net/>, interpretation by author.

Figure 3.5: US price-to-earnings ratio w.r.t. long year average



Note: Price-to-earnings ratio based on average profit over past 10 years

Source: Overzicht Financiële Stabiiteit, najaar 2017, DNB, https://www.dnb.nl/binaries/OFS_Najaar17%20WEB_tcm46-363954.pdf?2017100914

3.5 K-waves and diffusion of technology

- There is empirical evidence that social-, technological-, and economic change affect the cyclical behaviour of K-waves.
- Periods of growth and expansion of economic activities are punctuated with phases of fundamental change in the structure of the economy, the technology base, and many social- institutions and relations.
- After a certain stage, the dominating socio-techno-economic paradigm that has led to the previous upswing phase, reaches its limits of social acceptability, and the environmental compatibility begins to saturate.
- To quote Grübler and Nakćenović (1991): *“In this sense, each Kondratieff long wave portrays a barrier to diffusion. Most processes saturate during the end of the inflationary period and the onset of the disinvestment phase in the Kondratieff wave. Very few diffusion processes can tunnel through this barrier. If it is true that this marks the beginning of paradigm shifts, it is not surprising that further diffusion of systems associated with the old techno-economic development trajectory is blocked to make way for new. It is the disruptive crisis of the old that provides the fertile ground for new systems to develop. **It can be concluded that major innovations are likely to be developed during the downswing of the Kondratieff wave, but that it takes up to the next upswing period until they fully materialise as the main drivers of a new techno-economic paradigm”**.*

Linking innovation clusters to the five K-waves

- **1st Kondratieff wave** (about 1782 - 1845)
 - *Textile: Cotton Gin, Spinning Jenny;*
 - *Iron and Steel: Smelter, Puddling Process, Crucible Steel;*
 - *Steam Power: Watt's Steam Engine.*
- **2nd Kondratieff wave** (about 1845 – 1892)
 - *Railways: Locomotive, Bessemer Steel;*
 - *Other: Telegraph, Photography, Sewing Machine, Elevator.*
- **3rd Kondratieff wave** (about 1892 – 1948)
 - *Electricity: Edison's Lamp, Power Stations, Transformer;*
 - *Automobile: Combustion, Diesel Engine, Pneumatic Tyre, Assembly Line;*
 - *Other: Movie, Radio, Safety Razor, Fridge, Airplane, Telephone, Gramophone.*
- **4th Kondratieff wave** (about 1948 - 1992)
 - *Plastics: Polystyrene, PVC, Polyethylene, Silicone, Artificial Silk, Nylon;*
 - *Other: Television, Helicopter, Jet Plane, Photo Copy, Transistor.*
- **5th Kondratieff wave** (about 1992* – 2036E)
 - *Digitalizing: Integrated Circuits, Microprocessor, PC, Software, Internet;*
 - *Other: Biotechnology, Mobile Phone, Microwave.*

Figure 3.6: K-waves and trunk innovations

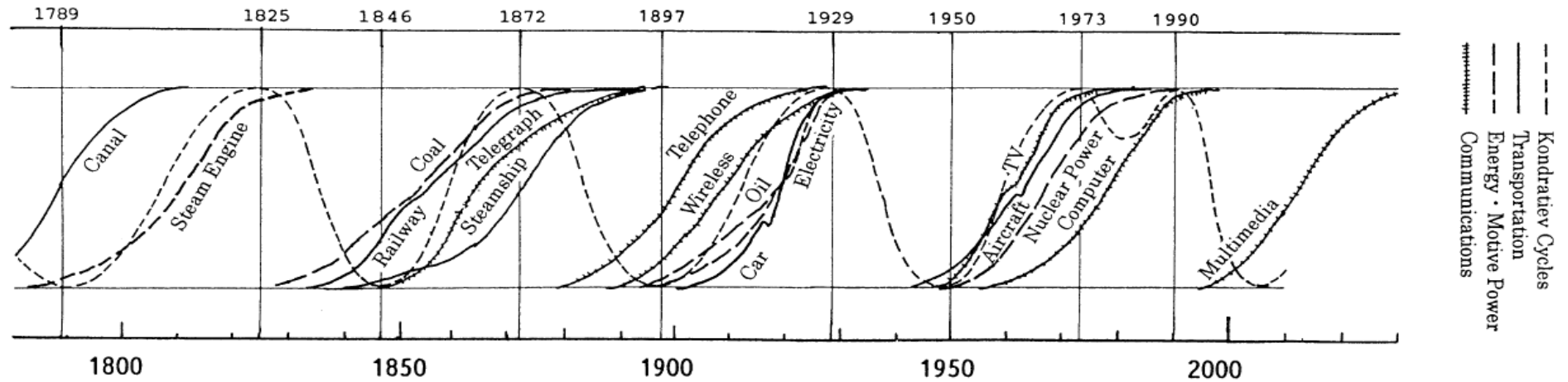


Fig. 10. Trunk innovations for infrastructures and business cycles

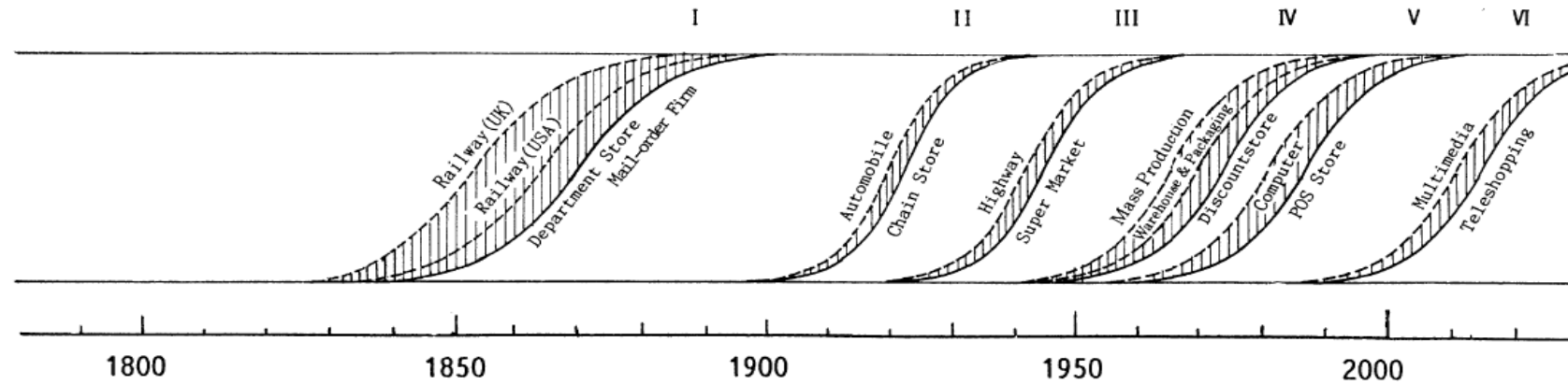
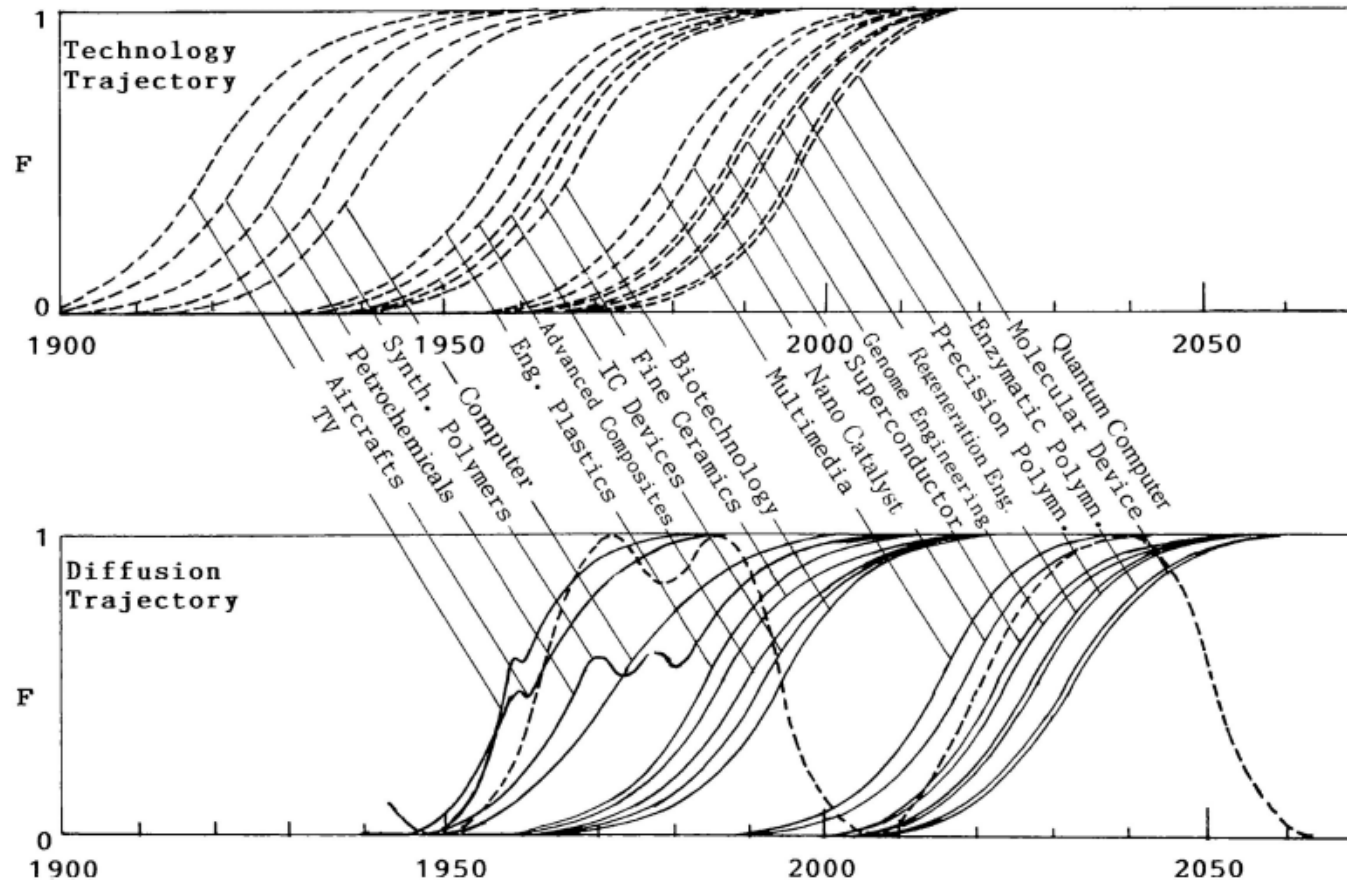


Fig. 11. Retail business evolving through trunk innovations

Source: M. Hirooka in E. Dinopoulos and R.F. Lanzillotti (Eds.) (2005)

Figure 3.7: Time lag between innovation and diffusion



About
40 to 50
year
time lag
(i.e. one
K-wave)

Fig. 13. Innovation clusters and 5th Kondratiev cycle

Source: M. Hirooka in E. Dinopoulos and R.F. Lanzillotti (Eds.) (2005)

K-waves and diffusion of technology

- A considerable amount of time is required for major innovations to become dominant drivers. First of all, the time from invention to an emerging innovation, can be long (For example: the basic principles of helicopter flight were already understood by Leonardo Da Vinci in the mid 15th century and proved by two French inventors in 1784, but it took until the early 20th century before the first piloted helicopter took off).
- Secondly, there is a substantial time lag before emerging technologies start to become more effective than the technologies that they replace. Ayres (1990) states that *“historical evidence suggests that in many cases the economic impact of an important innovation contributed little to the ‘next’ upswing but may have contributed significantly to subsequent ones”*.
- This implies that emerging technologies of the **nth wave** will not become dominant until the **n+1th wave**.
- **This valuable insight makes it possible to anticipate the dominant drivers of the next Kondratieff wave, through examining the promising and emerging new technologies of the present wave.**

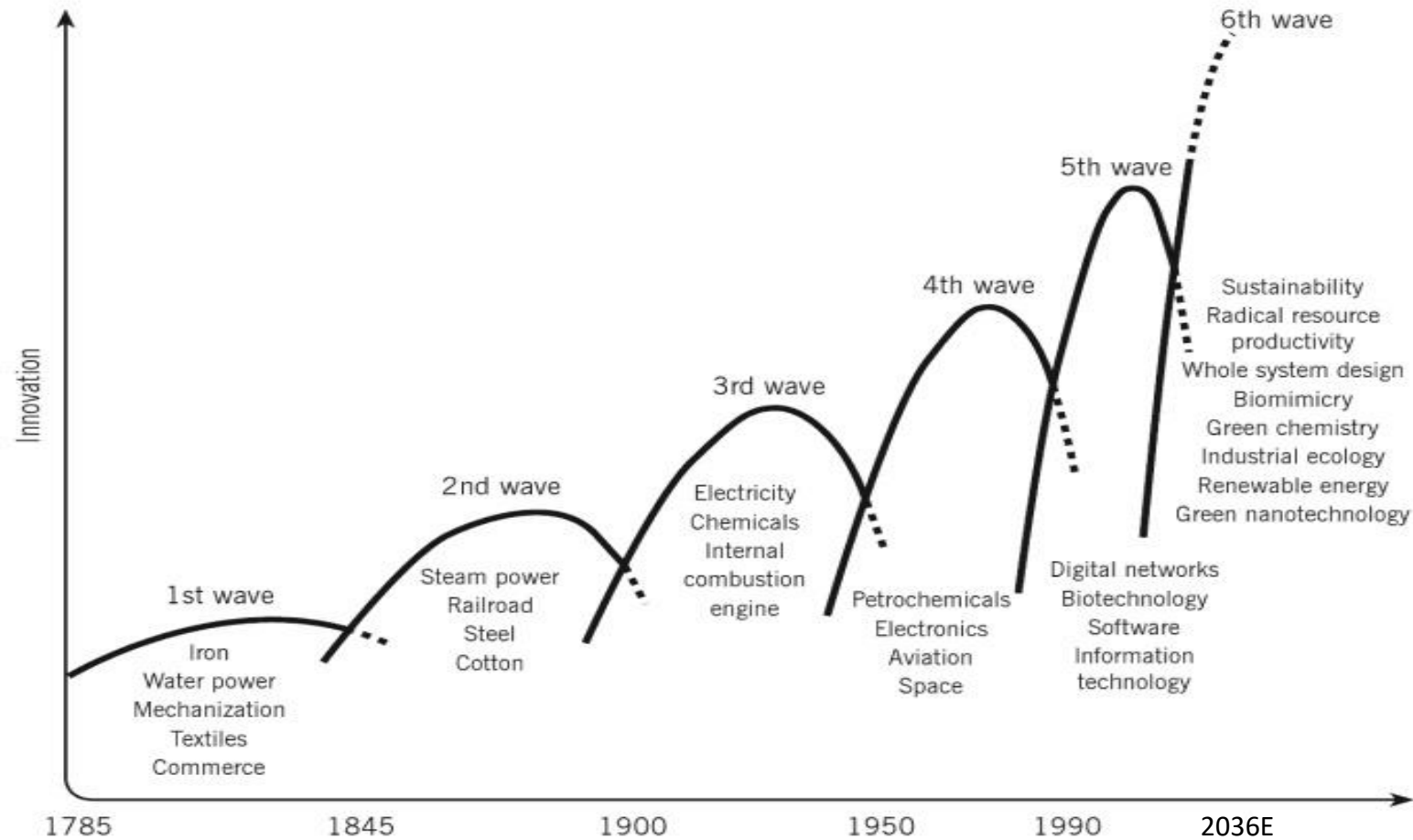
3.6 Anticipating drivers of next K-wave

- The **5th K-wave** was mainly driven by ongoing exploitation of fossil fuel resources, electrification, and ICT technologies. These driving forces have enabled far reaching integration of people, systems, and trade. We now live in a global economy with companies striving for profits by chasing new markets, through efficiency improvements, economies of scale, increased labour productivity, and outsourcing of production to low-wage countries. The overarching principal drivers of this broad development can be referred to as '**Globalization and ICT**'.
- It is interesting that the beginning of the **6th K-wave** coincides with the end of the "industrial age" (referring to what was once called "heavy industry") and the start of the "information age". The 6th K-wave is also different in another respect. The world is now confronted with a number of imminent crises. Among these are: environmental and climate change crisis (pollution, acid rain, the hole in the ozone layer, extinction of species, bleaching of coral reefs, loss of biodiversity, rise of sea-levels, melting of polar sea ice, increase of extreme events, changing precipitation levels); raw material and energy crisis (depletion of mineral resources and fossil fuels); potential food crisis (rise of food prices due to competition with biofuel production); financial, deficit, and debt crisis; and social crisis (repressive regimes, increasing income and wealth inequality).

Anticipating drivers of next K-wave

- In response to these crisis, there is an increasing need and desire for a more sustainable society (see also Jackson, 2009). The next K–wave is therefore, at least to some extent, expected to be driven by reactions to the above crises from an increasingly well-educated global population that is connected to internet and organised via social networks. In addition there is an ongoing trend of making things smarter and connecting them to the internet (i.e. the Internet of Things or IoT). The principal driver of the **6th K-wave** is thus linked to the broad concept of **‘Sustainability’** in combination with **‘IoT’**.
- The notion that ‘Sustainability’ is considered a principal driver of the next K-wave is broadly accepted (e.g. Figure 3.8). The critical problems of modern western society can indicate the direction of future megatrends. In line with these trends, the primary drivers of the 6th K-wave will be related to: burning less fossil fuels, enhancing corporate transparency and social responsibility, increasing energy efficiency, and holistic healthcare. However, increased network connectivity will also enhance threats of cybercrime and -terrorism.
- **The direction is clear but the extent to which sustainability and IoT will eventually change our world is impossible to foresee. K-waves provide a reasonable indication of the direction of future trends as well as a rough indication of their timing, but they can neither be used to define the magnitude of the effects, nor their precise timing.**

Figure 3.8 The anticipated drivers of the 6th K-wave



Note: we adjusted the timing of the starting point of the 6th wave, that was indicated by the year 2020 in the original figure, to put it in line with the extended framework of Van Duijn (see Table 4.1), the intersection between the 5th and 6th wave is in the year 2036E.

Source: Hargroves and Smith (2005), but with adjusted start date of upswing of 6th K-wave

“Educated guess” about the drivers of 7th K-wave

- Underlying trends that may affect the drivers of the 7th K-wave can be identified by analysing longer lasting trends such as:
 - Decreasing labour productivity growth in western countries.
 - Long period of (“uncontrolled”) monetary expansion to spur economic growth and create jobs, turning capital into an access commodity, and reducing real interest rates to an all time low;
 - Low inflation and zero bound on interest rates gradually makes monetary stimulation policies ineffective, disabling the ability of central banks to stimulate the economy and create new jobs;
 - Ongoing inequality towards more unsustainable levels, causing decline of the middle class population, which has a direct effect on consumption, economic output, and employment, as rich people tend to invest a large fraction of their money (and further reduce the risk free interest rates) while middle class income is mainly used for consumption purposes;
 - Ongoing automation, robotics and artificial intelligence reducing job opportunities for low and middle class workers;
 - Education levels reaching saturation or possibly starting to decline in the western world as good education can no longer guarantee a well paid job.

“Educated guess” about the drivers of 7th K-wave

- Following the wavelike motion of K-waves, it is sensible to assume new business models to develop over the next 1 or 2 decades. Once they become dominant (around year 2030 – 2040) a new upswing period sets in that spurs economic activity for another 20 to 30 years. Until then, loss of jobs due to computerization may be partially offset by new jobs as well as by some tax reforms that divert taxes away from the lower income segment. It is when the drivers of the 6th wave start to reach their limits, that one can expect a new major crisis.
- Assuming that income inequality continues to grow and computerization takes over an ever larger share of the jobs, it is sensible to “guess” that the next major crisis will be a social crisis in which people are no longer willing to accept large inequalities in income and wealth distribution. Once this foreseeable crisis is resolved, and if it is resolved without a major war, our descendants may create a world by the end of the 21st century that will start to care about the substantial ecological damage over the preceding three centuries of industrial growth (i.e. years 1800 to 2100). This society may aim for recovery of ecosystems and improvement of the quality of life.
- **Beyond this one starts to fantasize. It is impossible to foresee what may happen beyond the expected crisis at the end of the 6th K-wave. After this stage, K-waves can no longer provide any useful guidance on long-term developments, and one has to rely on insights from century-long trends.**

3.7 K-waves and infrastructure development

- Grübler (1990) identified clear patterns in the development of canal, rail and road infrastructure networks for the USA, Canada, USSR, France and Germany.
- He concluded that:
 - The midpoints between the individual infrastructure growth pulses (i.e., the time of their maximum growth rate) are spaced 55 years, as are their periods of saturation, which corresponds to the historical length of the K-waves;
 - The saturation and onset of decline of these infrastructures coincides with prolonged economic recessions (in 1870s, 1930s, and 1980s). At the same time, these periods of structural discontinuity show emergence of new transport systems: surfaced roads around 1870 and air transport in 1930s;
 - Each of these networks tend to be developed over a period of about 100 years, i.e. a period of about 2 K-waves. With infrastructures emerging in n^{th} wave and becoming dominant transport systems in the $n+1^{\text{th}}$ wave;
 - Each subsequent network is an order of magnitude larger (or better) than its predecessor, which can be explained by linking the networks to the drivers of the K-waves. At the end of the upswing phase the dominating transport system becomes increasingly unable to deal with the challenges that it is confronted with. To solve these issues, it is insufficient to provide more of the same infrastructure. An order of magnitude improvement of the transport system is then required to support the expansion period of the next K-wave.

K-waves and infrastructure development

- Grübler's observations allow us to identify patterns in existing infrastructure development cycles and to anticipate future developments. An update of the principal drivers and the emerging and dominating technologies of the K-waves was made by the author as presented in [Table 3.2](#).
- It can be concluded from the table that subsequent infrastructure development after air transport is intermodal transport. With respect to the intermodal system, it is not the increase in length of the network, but the number of possible connections, that will make it better. The phasing seems to be correct as it fits in with historical data. Intermodal transport started to emerge around 1966 with the arrival of the first cross Atlantic container vessel in Rotterdam (about 50 years ago) – and can further develop to become dominant in continental transport over the next 50 years.
- The next (and maybe the last) step in the evolution of transport networks may be 'avoiding transportation', or 'not transporting at all'. This may be partly made possible by advancements in 3D printing technology. 3D printing is at present, mainly applied for rapid prototyping and production of spare parts. However, it is likely to emerge to the extent that it reduces transport volumes over the next K-wave by 5% - 10%, and become dominant in the 7th wave when it may eventually reduce 20% - 50% of all freight transport. This is indicated in [Figure 3.9](#).

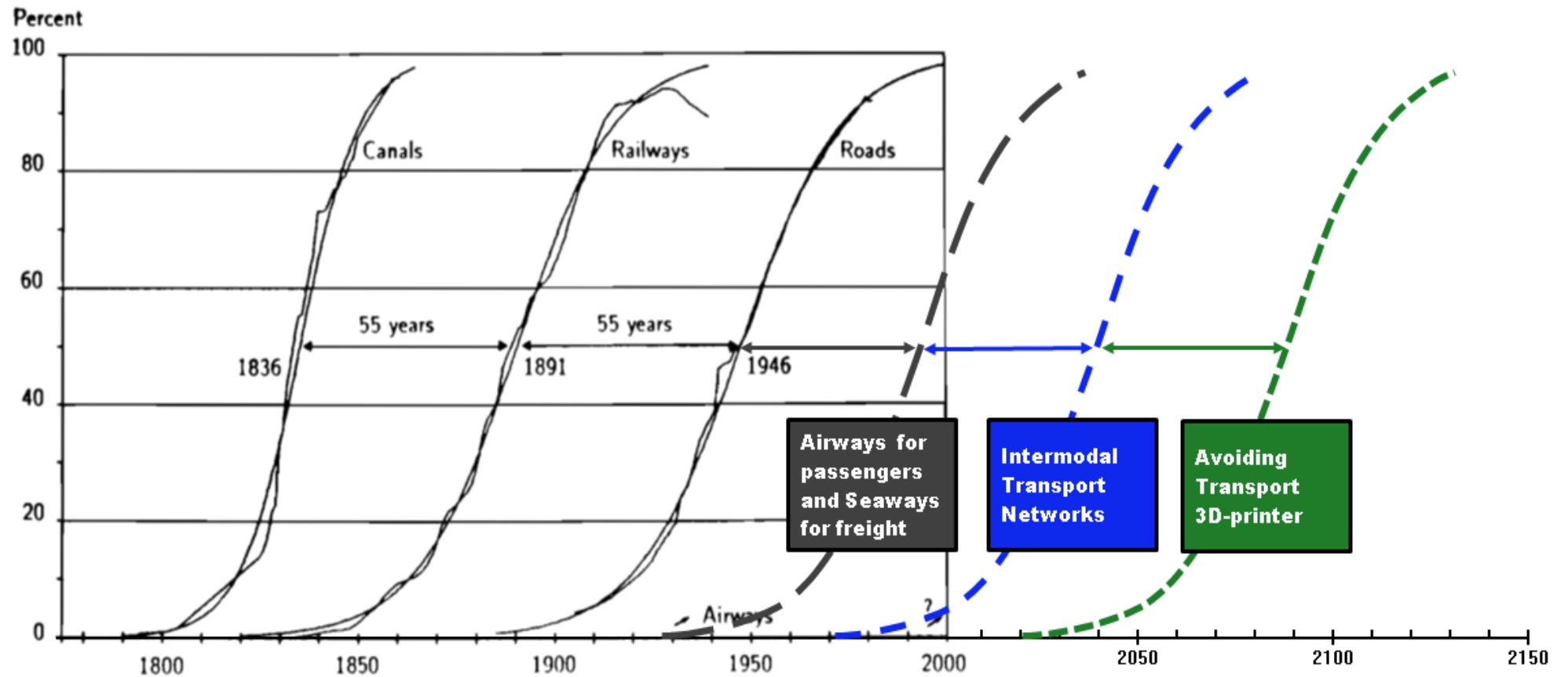
Table 3.2: K-waves and their primary transport divers

Kondratieff Timeframe	1st Wave 1782-1845	2nd Wave 1845-1892	3rd Wave 1892-1948	4th Wave 1948-1992	5th Wave 1992-2036E	6th Wave 2036E-2085E	7th Wave 2085E–2130E
Dominating technologies of indicated cycle	Water Power, Sails, Canals, Turnpikes , Iron Casting, Textiles	Coal, Iron, Steam Power, Mechanical Equipment, Canals	Railways , Steam Ships, Steel, Heavy Industry, Dyestuff, Telegraph	Electric Power, Oil, Cars , Radio, TV, Durables, Petrochemicals, Welding, Pipelines	Global Transport Systems , Mobile Phone, Internet, Social Media, Materials Science, Biotechnology	Probable: Recycling, Cradle to Cradle, Renewable Energy, Smart Integrated Systems, Intermodal Transport	Possible: New social standards and redistribution of wealth, Local bio-based manufacturing, 3D-printing with recyclable materials
Emerging technologies of next cycle	Mechanical Equipment, Coal, Stationary Steam Power Canals	Steel, City Gas, Indigo, Telegraph, Railways	Electricity, Cars , Trucks, Roads , Oil, Radio, Phone, Petrochemicals	Bulk Carriers, Containers, Container Vessels, Aircraft , Computers, Electronic Data Interchange, Space Flight, Telecommunication	Recycling, Cradle to Cradle, Renewable Energy, Smart Grids, Integrated Systems, Smart Customised Solutions, Intermodality	Plausible: Self-Sustainability, Local Production, Bio Based Materials, Decoupling of Economic Output, Wealth and Transport, 3D-Printer	Hopeful: Human Well-Being and Recovery of Ecosystems
Principal drivers	Manufacturing	Industrial production	Standardization	Ford-Taylorism	Globalisation	Sustainability	Quality of life

*Note: Estimated time line based on Extended Scheme of Van Duijn (see [Figure 3.1](#)) and a continuing K-wave consisting of about 5 Juglar of about 9 years each rounded at numbers of 5 years.

Source: Grübler, A. (1990) *The Rise and Fall of Infrastructures: Dynamics of Evolution and Technological Change in Transport*, Physica-Verlag Heidelberg; Van Dorsser (2015); further updated and extended by author.

Figure 3.9: K-waves in relation with infrastructure development



Source: Grübler, A. (1990) *The Rise and Fall of Infrastructures: Dynamics of Evolution and Technological Change in Transport*, Physica-Verlag Heidelberg (for historical data); updated by Van Dorsser (2015).

3.8 Conclusions and implications for port infrastructure development

- Economists have identified various economic cycles of which the most relevant ones for analysing long-term trends are the about 7 to 11 year lasting business cycle (or Juglar), and the 45 to 60 year lasting Kondratieff wave (or K-wave).
- Many representations and chronologies of the K-waves exist; among these Van Duijn (1983, 2007) provides the most detailed insights. Based on his chronology, K-waves consist of 5 subsequent Juglars with an optional extra war period following the prosperous period in the early waves.
- Further, the upswing period consists of three Juglars (i.e. two prosperous phases and one long wave recession phase) and the downswing period of two Juglars (i.e. the depression and recovery phase).
- Taking into account an average length of 9 years per Juglar, the overall length of the K-waves can be expected to be about 45 years in absence of a major war at the end of the prosperous period.
- Following Duijn's chronology the downswing period is expected from about 2018E to 2036E, but others assumed an earlier start of the downswing around 2009*. The downswing period is usually characterised by research and innovation to meet the needs of the new economic system of the next K-wave.

Conclusions and implications for port infrastructure development

- The subsequent upswing period can be expected from about 2036E onward, or according to some, possibly one business cycle earlier. The upswing period is normally characterised by implementation of new business models in line with the principles and drivers of the next K-wave.
- One can conclude that up to 2030E the world will be exploring – and that it is only from 2040E onwards that the new direction will become clear. **It is therefore advisable to postpone investments in new port infrastructure by one or two decades!**
- With respect to the main drivers of the K-waves, one can expect a movement from **‘Globalisation and ICT’ (i.e. primary drivers of the 5th K-wave that is now on the reverse)** to **‘Sustainability and IoT’ (i.e. envisaged primary drivers of the 6th K-wave)**. The shift from globalisation to sustainability is likely to cause a decline in existing container and bulk throughput volumes, but will also result in new business opportunities.
- With regard to the development of infrastructure networks, one can expect a further increase in the relative share of intermodal transport (strengthening short sea container shipping and continental inland container transport), as well as a gradual reduction in transportation volumes because of 3D printing, e.g. 5% - 10% reduction by 2050 and possibly 20% - 50% by the end of the century.

3.8 Summary of main conclusions

Next 10/20 years:

Downswing of 5th
Kondratieff wave

Drivers:

Globalisation and ICT

Period of innovation!

2030/2040 →

Upswing of 6th Kondratieff
wave

Drivers:

Sustainability and IoT

Period of implementation!

4. Century-long trends

- 4.1 Introduction to century-long trends
- 4.2 Secularisation and individualisation
- 4.3 Nature of activities and social power
- 4.4 Population growth and urbanisation
- 4.5 Energy and raw material use
- 4.6 Technological progress and economic growth
- 4.7 Connectivity and information exchange
- 4.8 Climate change and environmental degradation
- 4.9 Transport costs and globalisation
- 4.10 Shifts in geopolitical world order

4.1 Introduction to century-long trends

- Chapter 2 identified a broad range of Megatrends without paying attention to their inertia, but the inertia of trends is important to gain understanding of the relative level of uncertainty. The longer a trend lasts, the more likely it will remain heading in the same direction for a longer period of time.
- Century-long trends offer clear insight in the direction whereto the world is heading. Their slow inertia and long duration provides relatively 'certain' insights in what can be expected over the next few decades.
- When looking for instance 20 years ahead on a 200 year trend this only requires the time series to be extended (or extrapolated) for about 10% of the duration of the historical trend, which is relatively short.
- Century-long trends are therefore useful to identify the fundamental drivers that are likely to stay, with a relatively high level of certainty, for at least a few decades ahead.
- Some of the century-long trends have already been mentioned in the section on the identification of the expected drivers of the 7th K-wave.
- This chapter addresses the nine major century-long trends identified in this study.

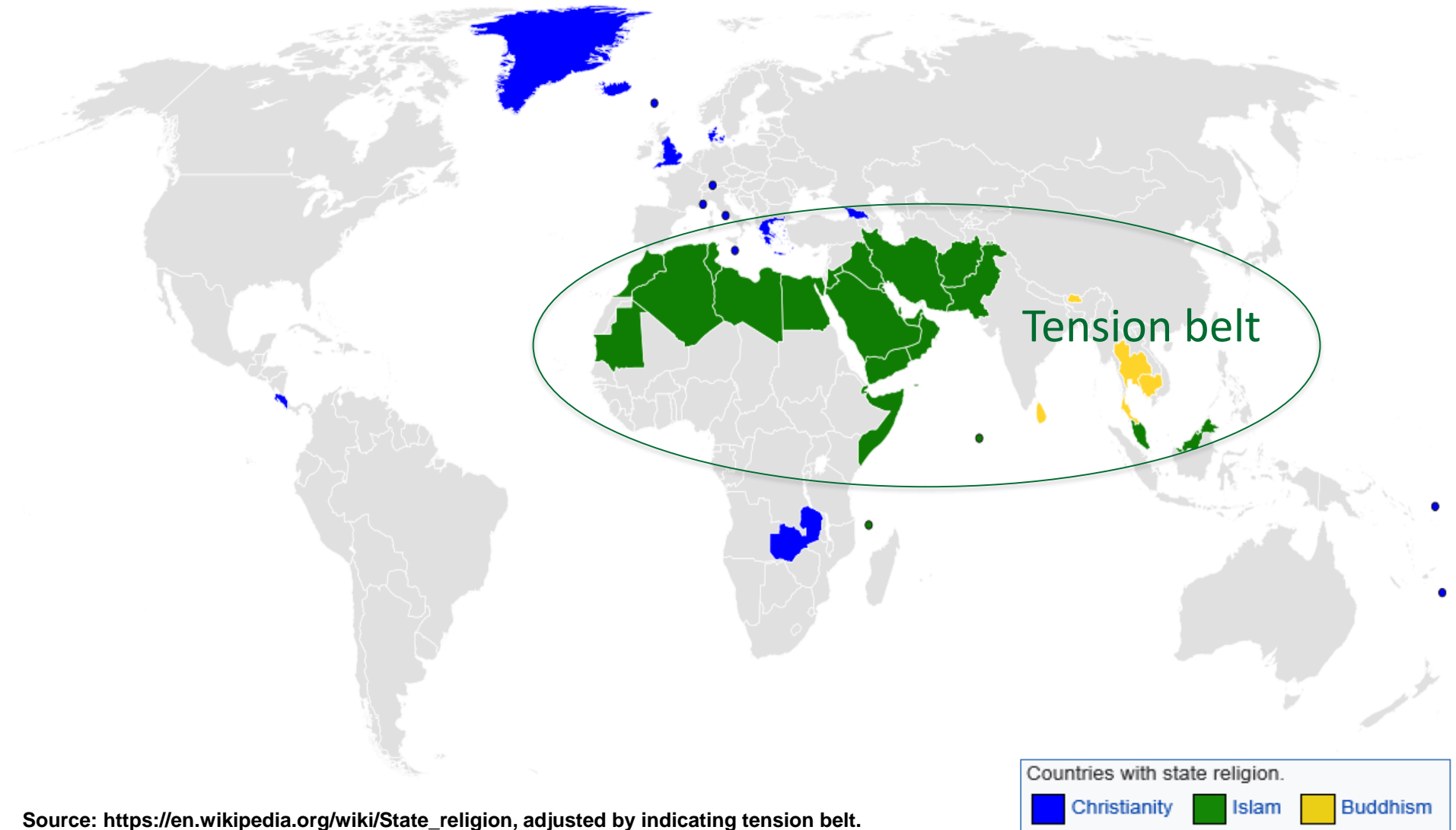
4.2 Secularisation and individualisation

- Secularisation stands for decline of religiosity and the religious organization that enforces it. Secularisation and individualisation have a major impact on **geopolitical stability** and **birth rates**.
- A secular nation applies a strict separation of the state from religious institutions and treats people of different religions and beliefs (including non-believers) equally by law. The separation of religion and state ensures that religious groups don't interfere in state affairs, and conversely, the state doesn't interfere in religious matters. The concept of secularism provides a framework for a tolerant democratic society in which all ideas and beliefs are open to discussion and in which people are free to express their beliefs. Secularism is therefore an essential cornerstone of democracy.
- Secularism is not self-evident. In the past, all European societies were ruled by two parallel hierarchies that vied for power. The secular hierarchy was based on feudal ranks, each owing allegiance to the one higher on the ladder, topped by kings and emperors and enforced by armed men. The religious hierarchy was equally rigid, ranging from the illiterate laity to the deacons, priests, bishops, archbishops, cardinals and the pope. Christianity was mandatory and questioning any of the Christian beliefs was exceedingly dangerous. The Church had an enforcement mechanism (the Inquisition), and had power of life and death over all (theoretically, even the king).

Secularisation and individualisation

- In Christian countries of Europe, it took a long time before the church was forced to give up power with respect to secular affairs. The fight for secular freedom took off after Martin Luther, who strongly disputed the claim that freedom from God's punishment for sin could be purchased with money, nailed 95 theses disputing church practices, on the door of All Saints Church in 1517 (now 500 years ago).
- Religions interference in state affairs remained common practice until the French Revolution converted France into a secular state, almost overnight in 1789. The change was welcomed and has never been questioned since. But it still took a long time for many other countries to follow. Italy, for instance, followed in the 19th century, Russia in 1917, and Spain in 1975. **It took almost five centuries from the time that Martin Luther started the revolution, to when virtually all European states became secular.**
- Today, most Christian countries are secular, with the exception of Vatican and a few other countries with state churches such as England, Iceland, and Denmark. In the latter, however, the democratic system has a say over Christianity, rather than the other way around. For example, the Danish parliament has enforced a law that obliges the Danish state church to marry gay couples as of 15 June 2012. **Christianity is no longer a source of geopolitical tensions.**

Figure 4.1: Countries with secular state religions



Source: https://en.wikipedia.org/wiki/State_religion, adjusted by indicating tension belt.

Secularisation and individualisation

- Secularisation is a major source of geopolitical unrest in Islamic countries. This has mainly to do with the fact that the **western democratic ideology was introduced (or imposed) too swiftly** causing tensions within the Islamic society.
- Iran became a secular state under the influence of the British in 1924, but once again became a theocratic republic after the Islamic Revolution of 1979.
- A similar movement from a secular to an Islamic state can be observed in Turkey today. At the time of founding of the republic, Atatürk turned Turkey into a state with a secular constitution that could call for military intervention if secularity was at stake. This is one of the reasons why the Republic of Turkey has weathered five successful military coups since 1923 (Ackerman, 2016). But with 95% of the population being Muslim, strong forces in favour of a more Islamic regime are in place. Following the failed coup of 2016, president Erdogan is now taking major steps towards a more totalitarian Islamic regime, distancing himself from the views of Ataturk and aligning more closely with the Ottoman past and Islamic heritage of Turkey.
- A major difference between the historical secularisation of Iran and Turkey in the early 20th century and the secularisation of the Christian countries is that in Islamic countries secularisation was imposed top down as a political ideology, whereas in the west it was attained bottom-up by the people.

Secularisation and individualisation

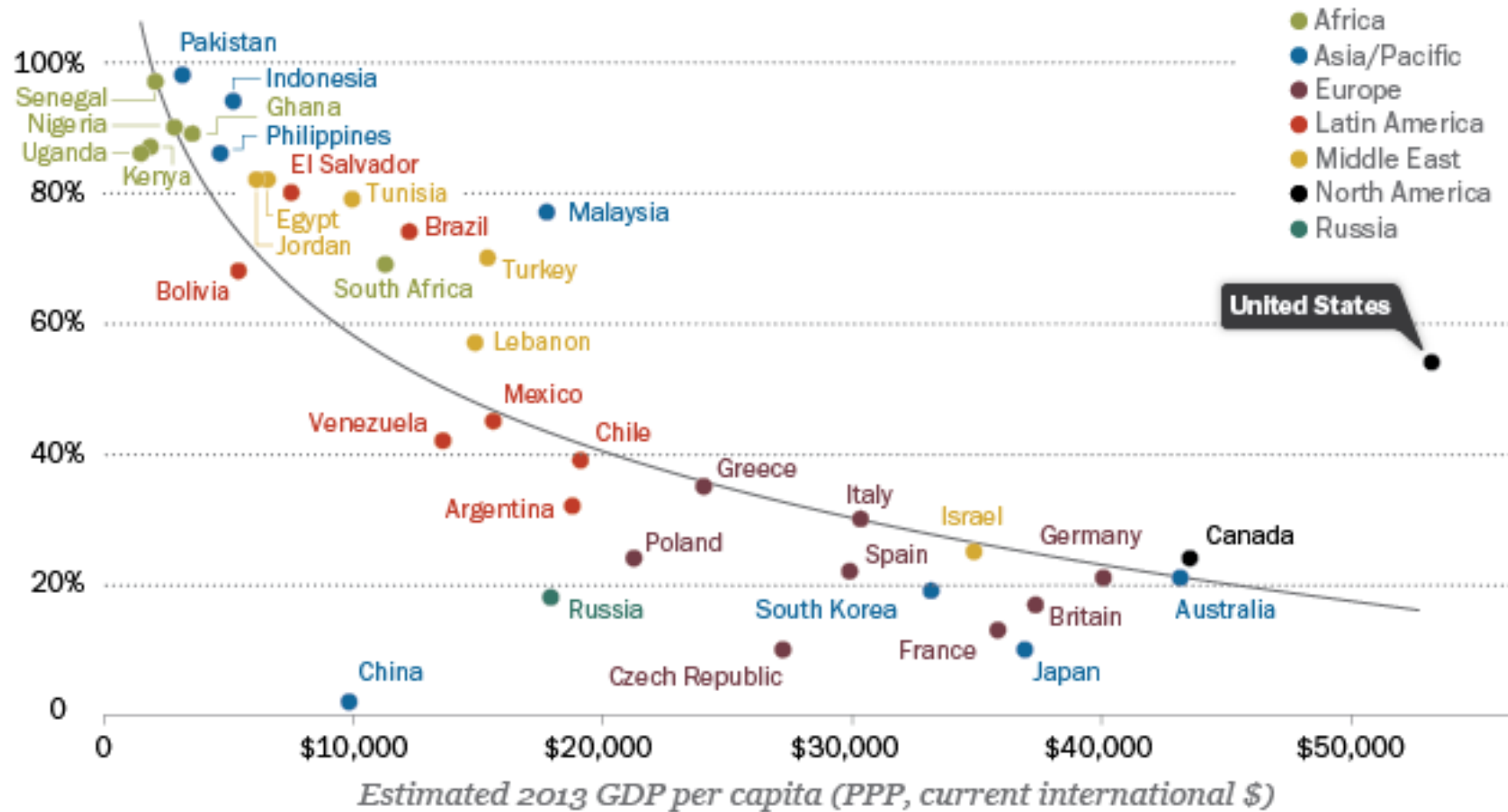
- Secularisation causes tension in Islamic countries like Turkey because on one hand, the population is unhappy and discontent with the strict secular regime, and on the other hand the people are becoming more secular at an individual level, wanting to adopt a more western lifestyle. This results in strong clashing forces.
- The Arabic spring movement aimed for a restoration of “*classic political demands of liberty, democracy and economic justice*” (Hoffman and Jamal, 2013). It also induced strong counter-forces aiming for a religious state, and resulted in political entities such as the Muslim Brotherhoods to terrorist organisations such as Al Qaida and IS.
- Religiosity typically changes very slowly over time. (E.g., the number of religious people in the Netherlands has decreased from nearly 100% in 1849 to about 75% in 1958, with the number of Muslims still being negligible; and about 49% in 2016, of which about 5% are Muslims and 2% belong to other non-Christian beliefs (Schmeets en van Mensvoort, 2015; Becker en de Hart, 2006; and Bernts and Bertghuijs, 2016)).
- **Therefore, Islamic religious tensions are to be expected to continue for at least another 50 to 100 years.**

Correlation between wealth, secularisation, and birth rates

- A strong negative correlation between the wealth level of a country and the importance of religion in peoples lives exists.
- As an exception to the rule that wealthier nations are less religious, are countries with strong socialist roots such as Russia and China, where religion only plays a very modest role, and the United States. US is far more religious than one would expect on the basis of their wealth level; but this may partly be explained by large inequalities in the income distribution.
- Apart from being a driver for social and political unrest, secularization also affects birth rates as birth rates tend to be higher in religious groups.
- The strong population growth in non-secular countries of the Middle East and North Africa, together with the increased wealth levels and individualism in these countries, is likely to intensify social and political tension in the Islamic world, and thereby remain fertile ground for conflicts and migration towards Europe.
- The combined effect of a relatively much stronger autonomous growth of Muslim population inside Europe, and an increased migration of Muslims into Europe, is to create a ground for continuous friction and an increase of nationalistic sentiments, for a long time to come.

Figure 4.2: Wealth and religiosity

% saying religion plays a very important role in their lives (2011-2013)

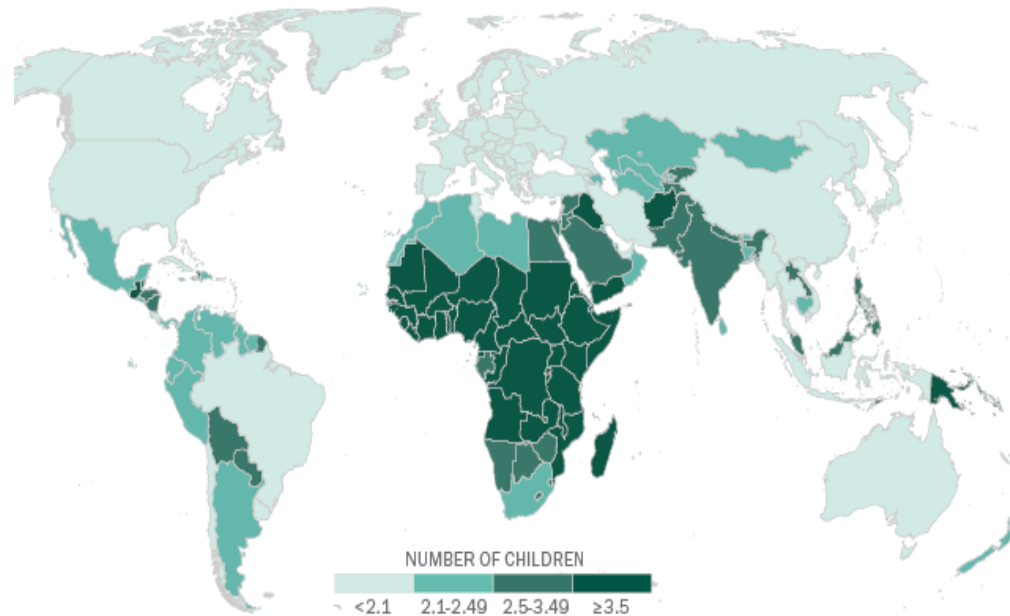


Source: PER Research Center, <http://www.pewresearch.org/fact-tank/2015/03/12/how-do-americans-stand-out-from-the-rest-of-the-world/>

Figure 4.3: Fertility rates per region and religion

Total Fertility Rates of All Religions, by Country

Number of children per woman, 2010-2015 estimate



Source: The Future of World Religions: Population Growth Projections, 2010-2050

Note: Only countries for which there are sufficient data are shown.

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Total Fertility Rates by Region and Religion, 2010-2015

Number of children an average woman is expected to have in her lifetime

	All Religions	Muslims	Christians	Unaffiliated
Sub-Saharan Africa	4.8	5.6	4.5	4.3
Middle East and North Africa	3.0	3.0	2.5	*
Latin America and the Caribbean	2.2	*	2.2	2.3
Asia-Pacific	2.1	2.6	2.3	1.6
North America	2.0	2.7	2.1	1.6
Europe	1.6	2.1	1.6	1.4
World	2.5	3.1	2.7	1.7

*Insufficient data for reliable estimates.

Regional differences in fertility rates for other religious groups are discussed in Chapter 2.

Source: The Future of World Religions: Population Growth Projections, 2010-2050

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Source (left): http://www.pewforum.org/2015/04/02/main-factors-driving-population-growth/pf_15-04-02_projectionsfertilitymaps4_all640px/

Source (right): http://www.pewforum.org/2015/04/02/main-factors-driving-population-growth/pf_15-04-02_ch1graphics_fertilityregion640px/

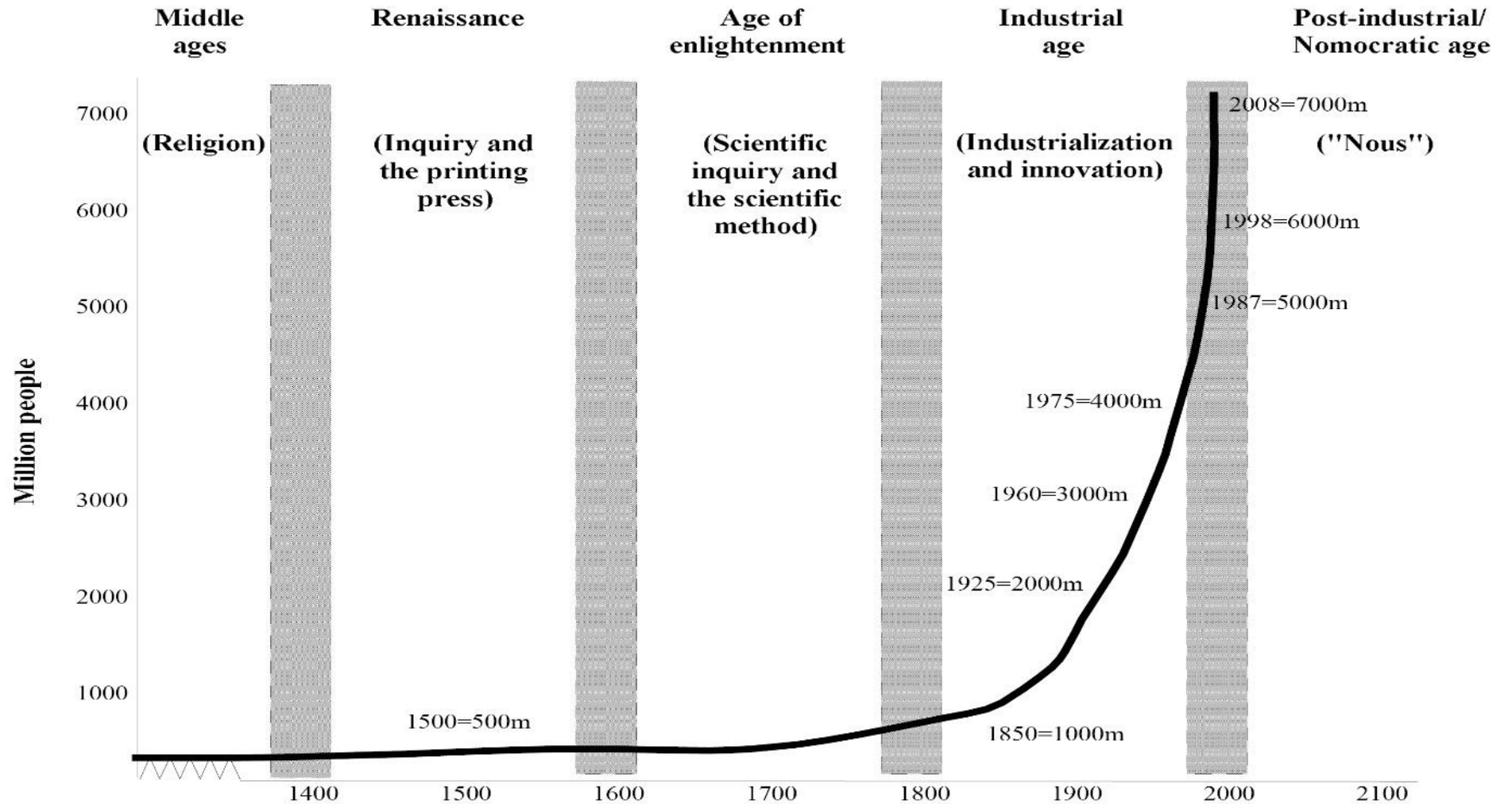
Recapitulation of secularization trend

- Islamic countries are also bearing the fruits of industrial progress, which implies that at least a part of the population desires more individual and political freedom and wants to discard religious rigidity, while others turn to fundamentalism.
- It can be argued that tensions in Islamic countries are largely due to conflicts between those who want to modernize (and secularize) and those who do not. Given the historical analogy with Christianity and the rise in overall wealth level, it seems inevitable that secularism will eventually prevail in Muslim countries. Because this is expected to take a long time, the unrest in the Islamic world can be expected to continue for at least few generations to come.
- **Islamic tensions that are threatening geopolitical stability and spur counter-globalisation forces (of growing nationalism), will be fuelled by differences in birth rates of religious and non-religious groups.**
- **Differences in religiosity and fertility rate will continue to drive migration from Africa to Europe throughout the century. This trend will be enhanced by ongoing secular tensions and increasing levels of starvation as a result of climate change (discussed in Section 4.8).**

4.3 Nature of economic activities and social power

- The secular movement in Europe has raised many questions that require a scientific clarification.
- According to Spies (1998), the religion based Middle Ages bred the information revolution of the Renaissance. The printing press developed during this revolution enabled the rapid diffusion of new ideas and scientific theories throughout Europe. This resulted in a scientific revolution during the Age of Enlightenment. The scientific revolution triggered the Industrial Revolution that enabled higher food production yields, increased living standards, and medical healthcare – and fuelled the rapid explosion of the world population from about 1.0 billion people in year 1820 to about 7.3 billion people in 2015.
- Over the ages, the nature of economic activities and the source of social power also changed. In the pre-industrial ages, the control of land formed the main basis of power, during the industrial ages, the power shifted to energy and capital, and nowadays it is moving to information, skills and knowledge.
- This shift in social power is illustrated by the MEI-evolution process of Van Wyk (1984, p.107) that describes the ages of man in terms of the nature of its society, namely, the power relations and the mode of operation. In the next era, a shift to a more information intensive and knowledge based society is expected.

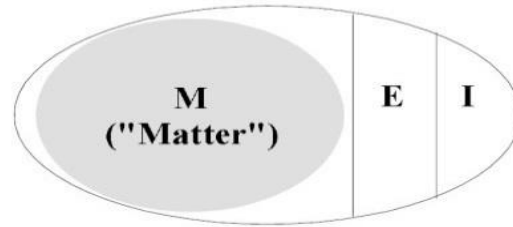
Figure 4.4: Human development over the ages



Source: Spies (1998, p.2), adjusted size.

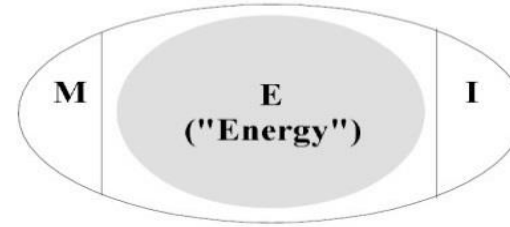
Figure 4.5: Shifts in mode of production and social power

MEI-Evolution Process of Van Wyk (1984)



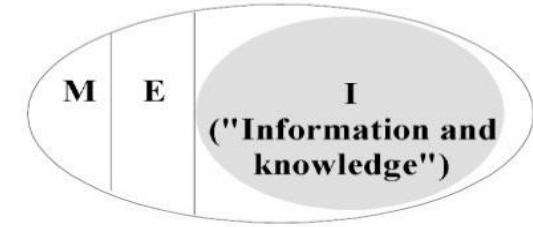
Pre-Industrial period

(Basis of social power: Control of land)



Industrial Age

(Basis of social power: Control of capital)



Post-Industrial Nomocratic Age

(Basis of social power: Information, skills and knowledge)

Key: ● Dominant characteristic of the technology of a period

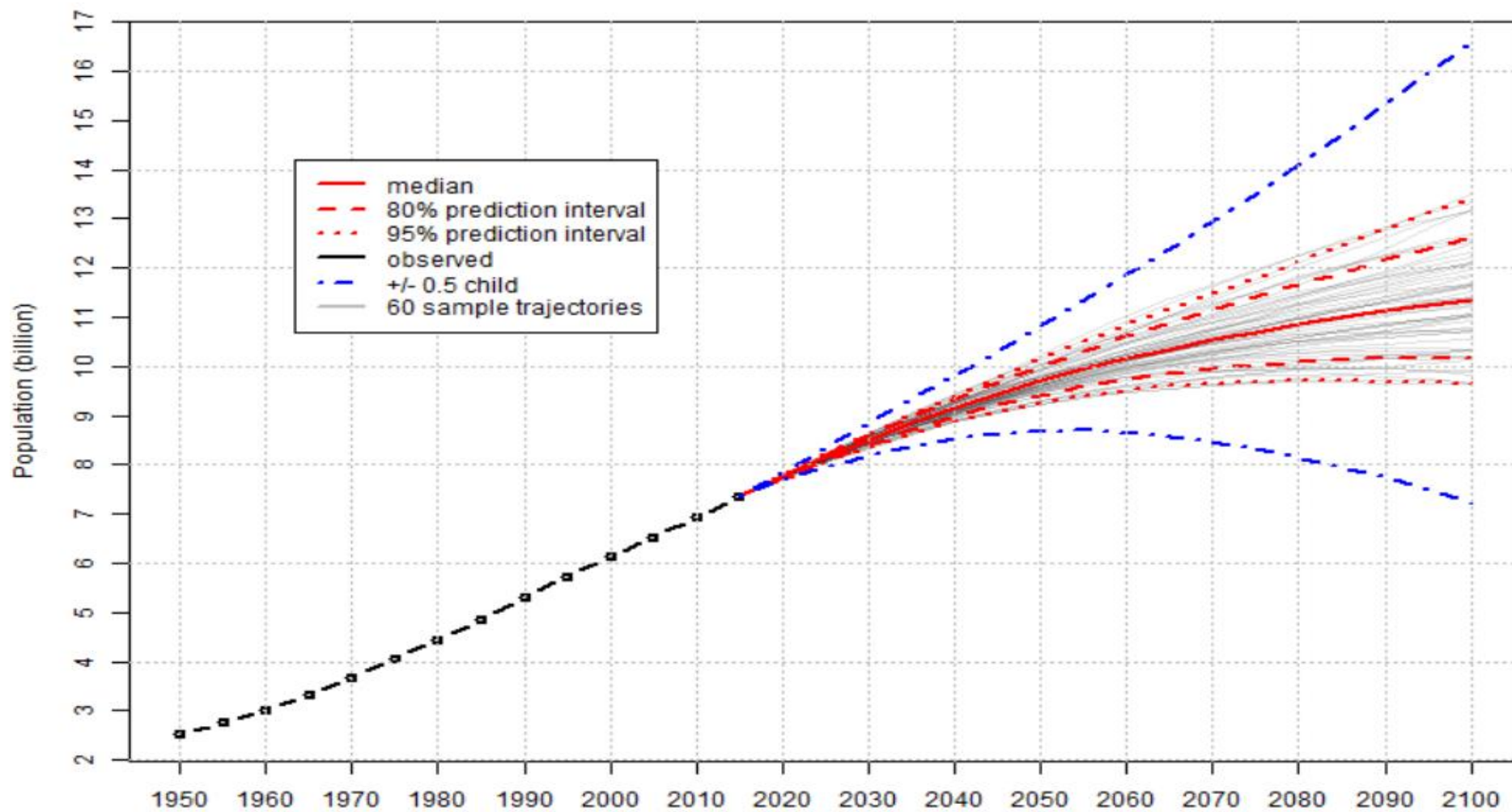
Age in History	Mode of Production	Nature of Social Power
Middle Ages (until 15 th century)	Agriculture and artisans	Church and landed gentry
Renaissance (until 17 th century)	Commerce, agriculture and artisans	Merchants, city states and landed gentry
Age of Enlightenment (until 19 th century)	Commerce, agriculture, artisans and small manufacturing	Capital, labour in nation states
Industrial Age (until 21 th century)	Manufacturing	Capital, labour in nation states
Post-Industrial Nomocratic Age	Services and networking	Embodied "capital" (knowledge, skills and information in a global society)

Source: Spies (1998, p.2 and 8).

4.4 Population growth and urbanisation

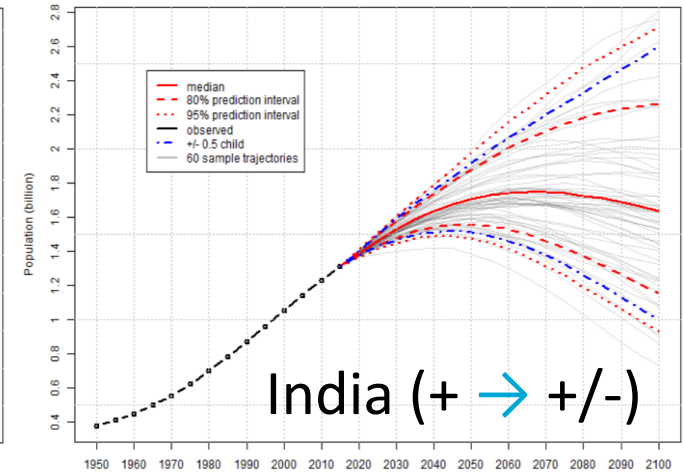
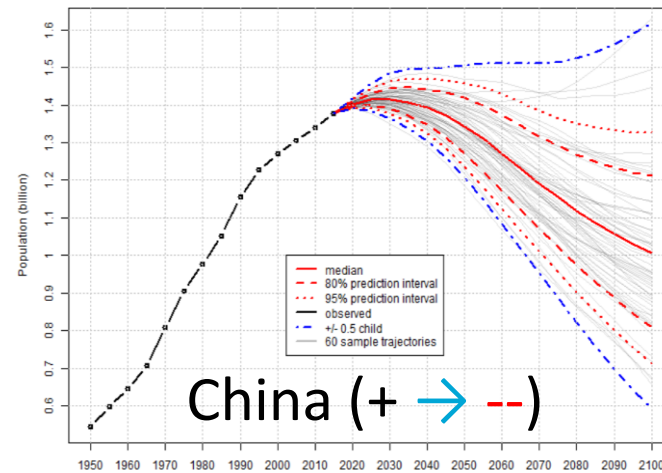
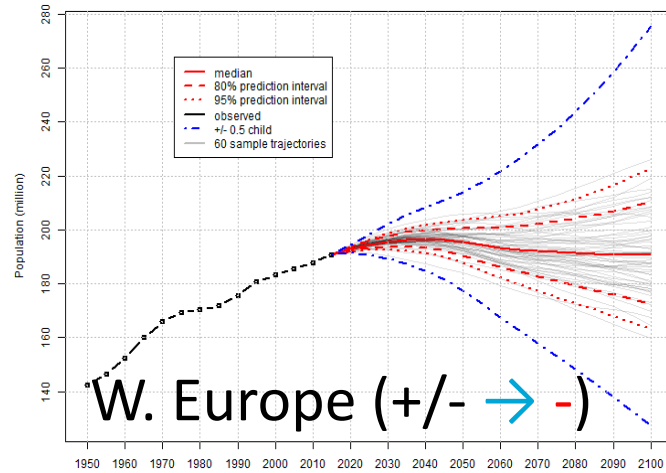
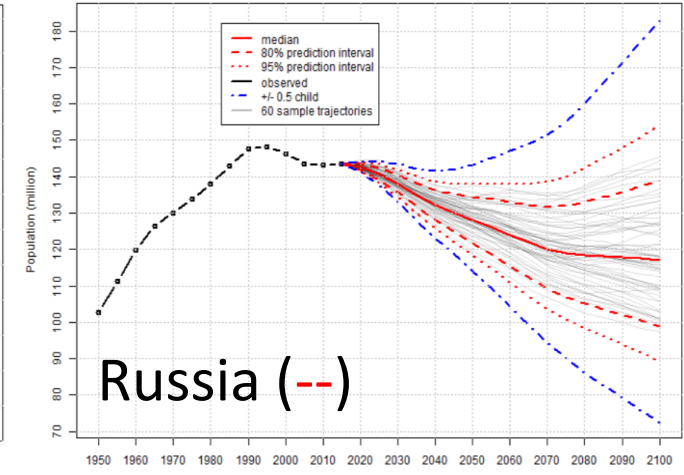
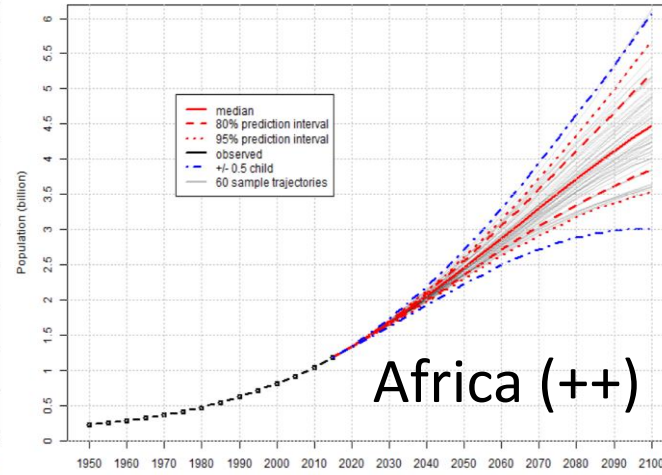
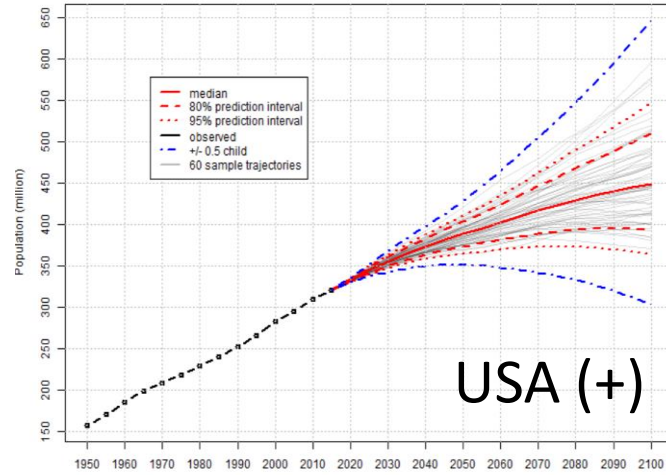
- The unprecedented exponential growth of the world population over the past few centuries has now slowed down and is likely to have reached an inflection point around the year 2000. Though growth rates are now slowing down, world population is still expected to reach about 8.5 billion in 2030, 9.7 billion in 2050 and 11.2 billion in 2100.
- Fertility rates vary substantially around the world. In the western world the population is still growing at a noticeable rate in the religious US, but it is beginning to decline in Europe and shows a significant decline in Japan. Interestingly, the populations in China and Russia, rivals of US for power, have or will have reached their peaks over the next decade, after which a sharp decline can be expected. This may restrict them from becoming a true superpower. By far, most population growth can be observed in India and Pakistan, and in African countries, most notably in Nigeria.
- According to UN DESA, India is expected to have the largest population size surpassing China around 2022, while Nigeria could surpass the US by 2050. The growth of African population is alarming as much of this growth is in the poorest countries, and likely to result in food shortages even in absence of the effects of climate change and environmental degradation on loss of food production. Population growth in Africa is a continuous driver for migration to Europe.

Figure 4.6: World population prospects



Source: UN DESA, World Population Prospects, <http://esa.un.org/undp/wpp/>.

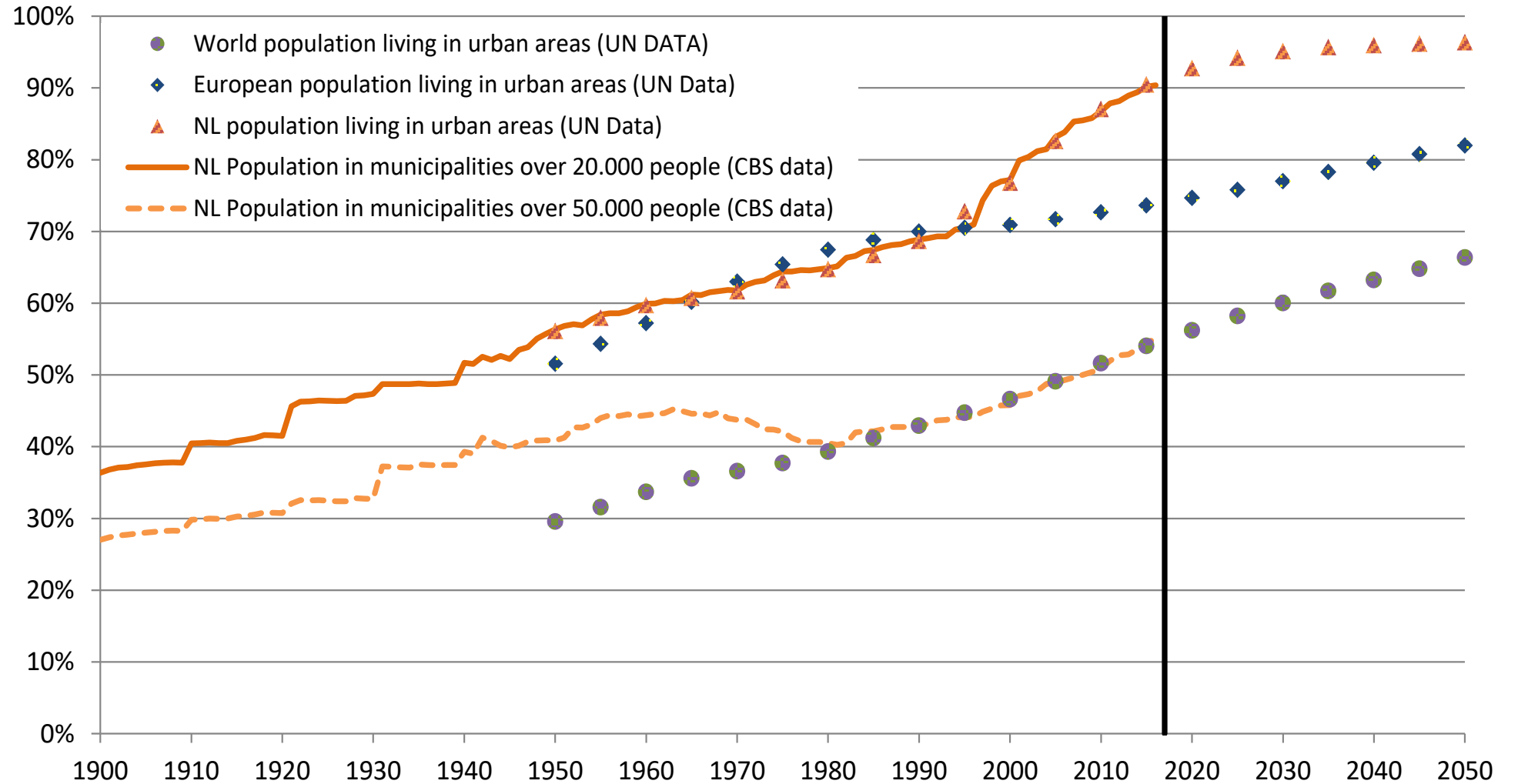
Figure 4.7: Regional population prospects



Urbanisation

- Over the past six decades, the planet has gone through a process of rapid urbanization and this is likely to continue over the next few decades. Since 2007, more people live in urban areas than in rural areas. In 1950, less than one-third (30 per cent) of the global population lived in urban settlements, and since 2016 almost 55% per cent of the world's population is urban. According to UN projections, the share of urban population is likely to continue to grow to about 2/3rd by 2050.
- Urbanisation is relatively higher in the western world compared to developing countries. In Europe, the share of people living in urban areas has increased from 50% in 1950 to almost 75% today, and is expected to continue to exceed 80% in 2050. UN statistics show that the share of urban population is large in the Netherlands. It has shown a substantial increase since the 1990s, when the trend that started in the 1960s, of living in municipalities at commuter distance from the cities seems to have reversed. This can be observed from statistics of people living in cities with over 50.000 inhabitants. Urbanisation is a main driver for compact living and reduced car use and ownership.

Figure 4.8: Ongoing urbanisation in World, Europe and NL



Source: UN, World Population Prospects, <http://esa.un.org/undp/wpp/>; CBS <http://statline.cbs.nl/>

4.5 Energy and raw material use

- When analysing energy and raw material trends one needs to consider both the demand and supply side. On the demand side, historical exponential growth in the annual per capita consumption rates for fossil fuel and raw materials over last 110 years, can be observed.
- However, per capita consumption cannot continue to grow at an exponential rate but is expected to follow some kind of transition s-curve followed by a decline. An analyses of various commodity trends shows some changes in the growth rate since the 1970s.
- With respect to the demand for cement, it seems that the exponential growth trend is ongoing, but if we examine the underlying drivers, it appears that growth since the late 1970s is purely a result of China's unsustainable growth spurt. This is unlikely to continue and will be influenced by demographic decline.
- Growth in per capita demand for ores and other industrial minerals has shown an exponential historical trend, but can be observed to have a lower growth rate since the 1980s.
- Growth in per capita demand for fossil fuels grew exponentially until the late 1970s, followed by a decline and a subsequent increase from the year 2000 onward. The question is if the per capita consumption has now stabilised.

Figure 4.9: Global raw material and fossil energy demand

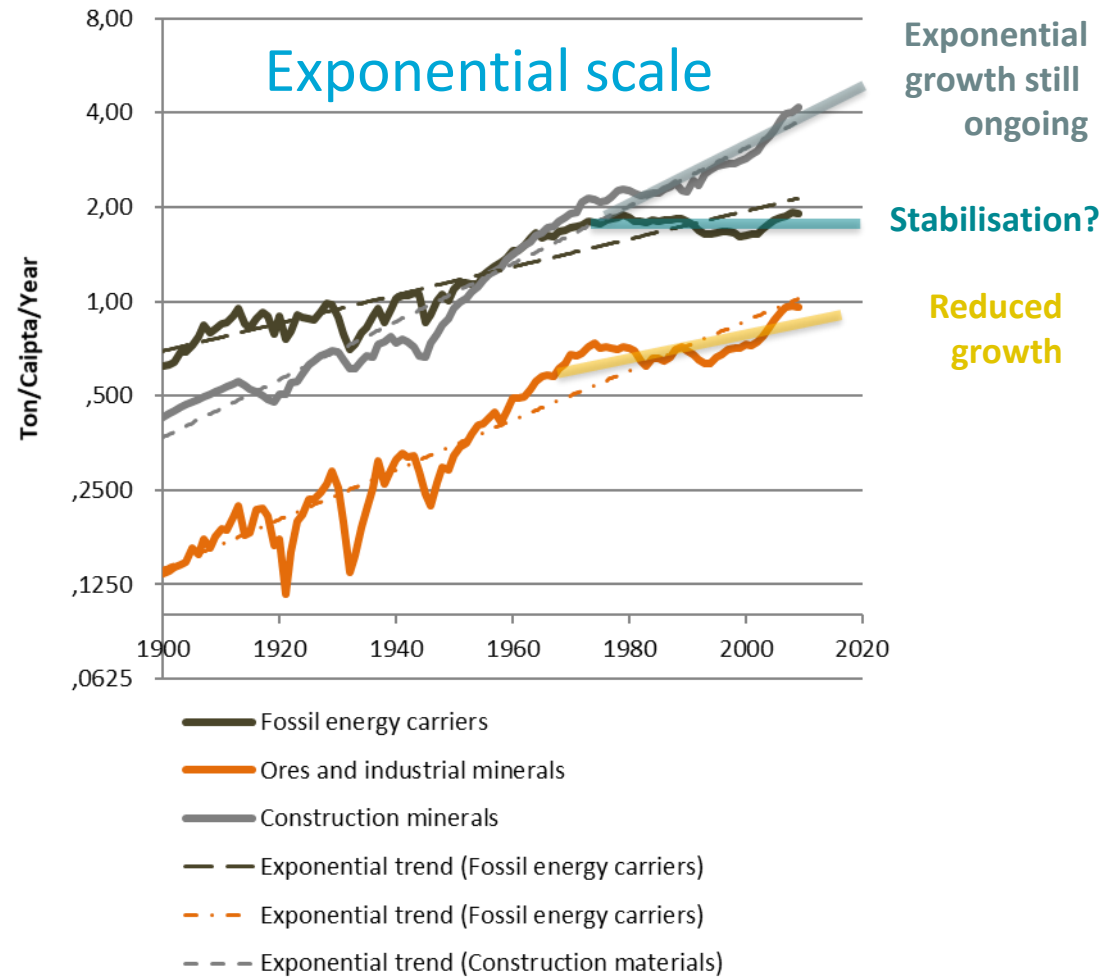
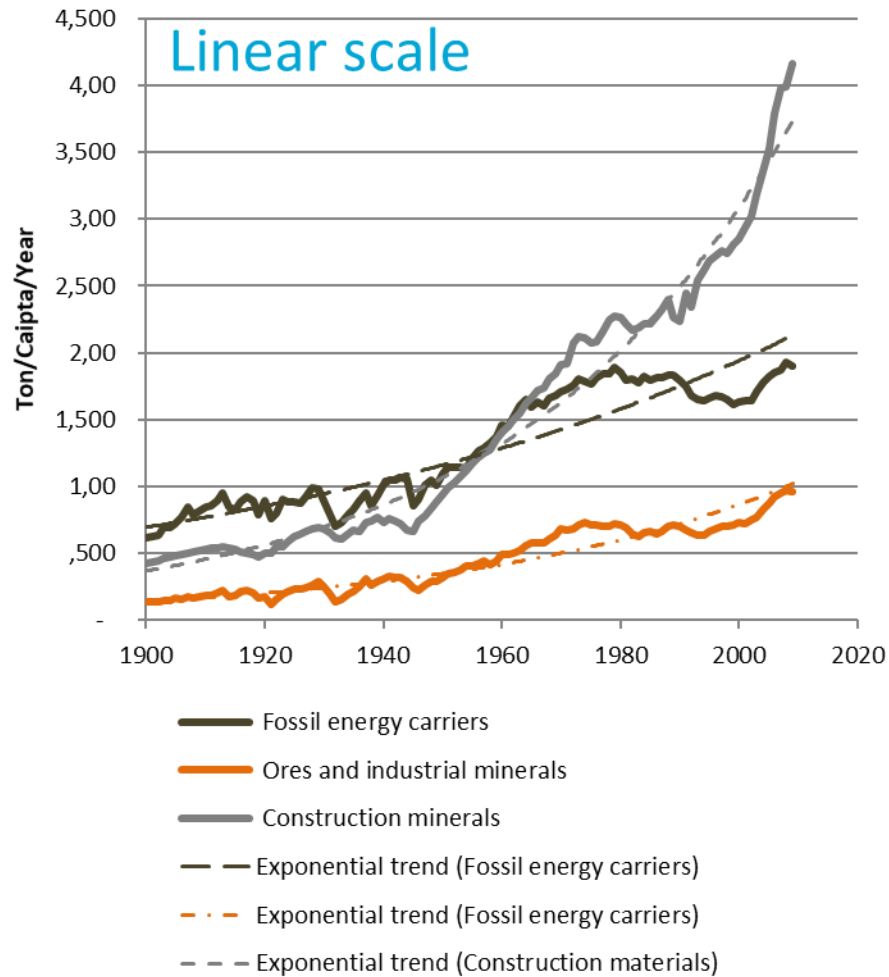


Figure 4.10: China's demand for construction materials

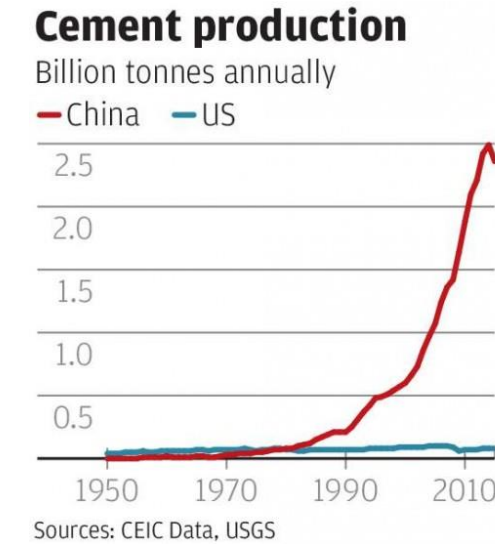
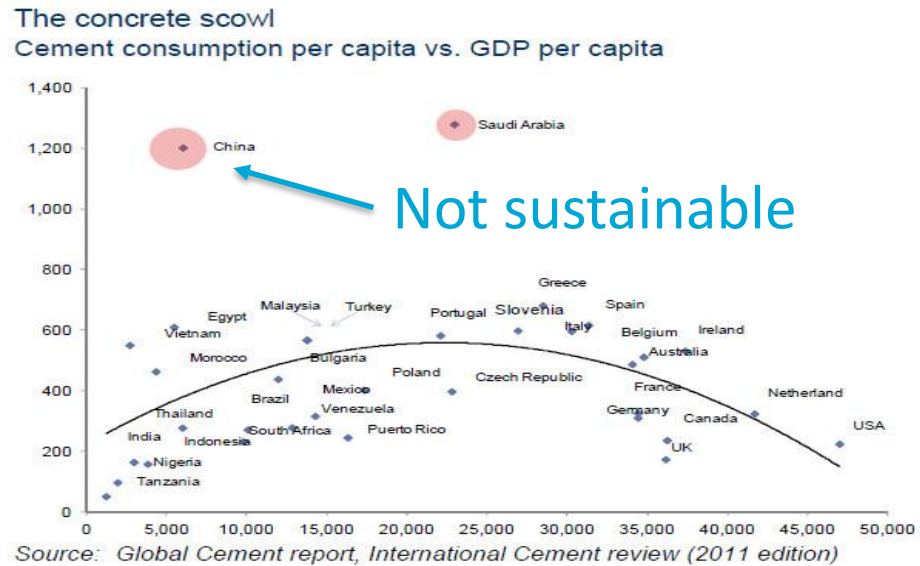
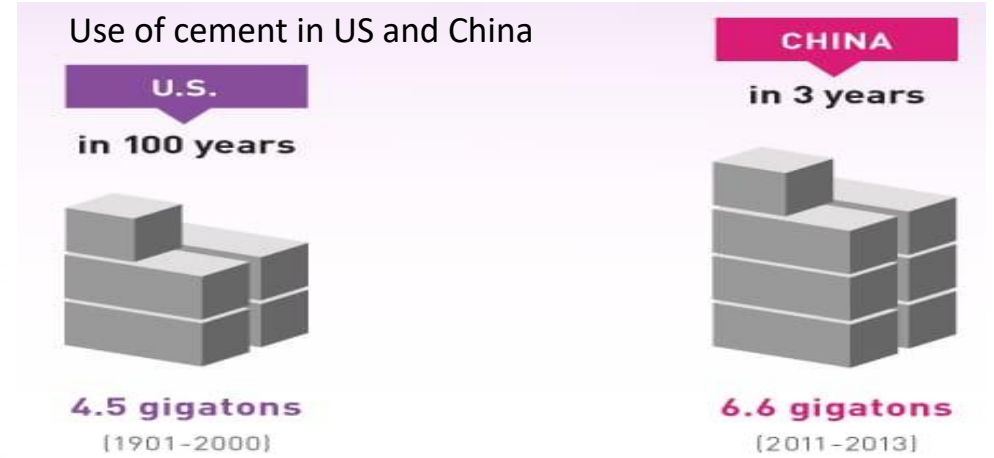
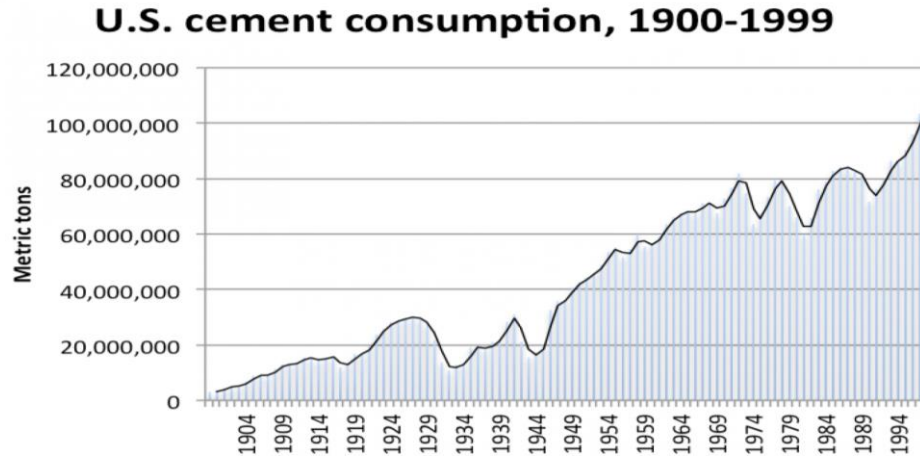
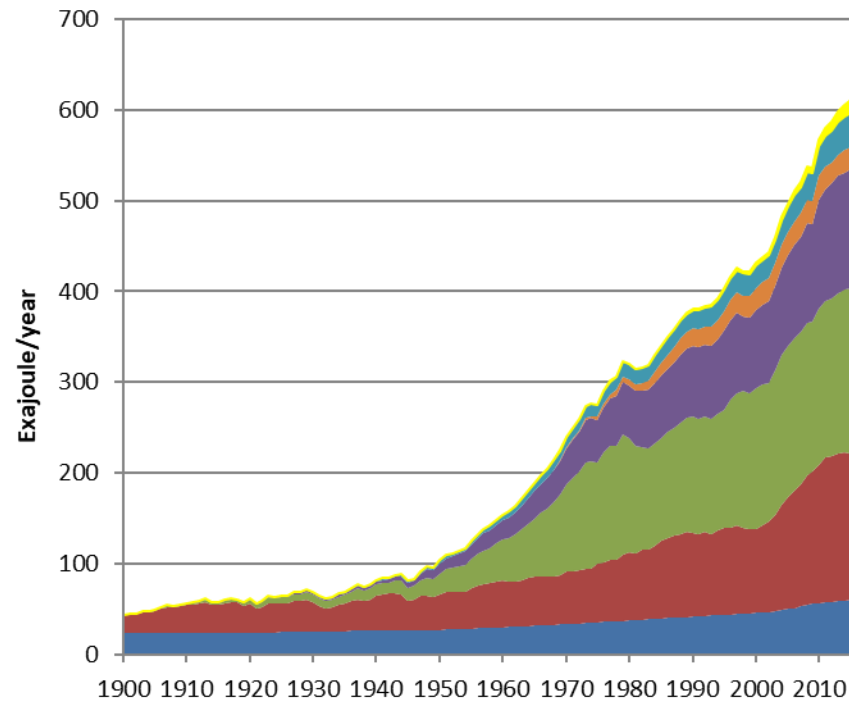
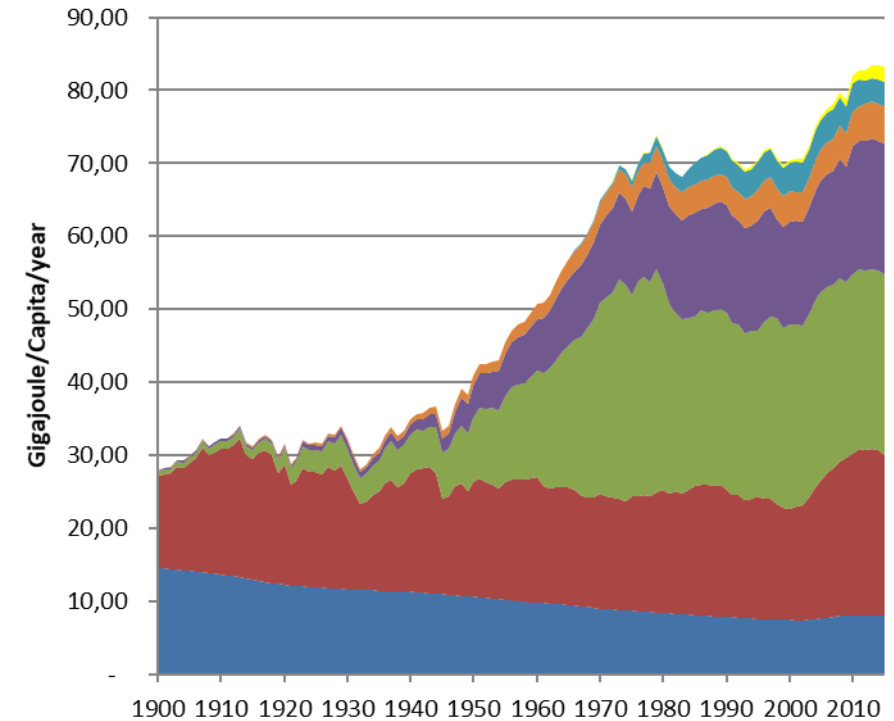


Figure 4.11: Global growth in overall energy demand



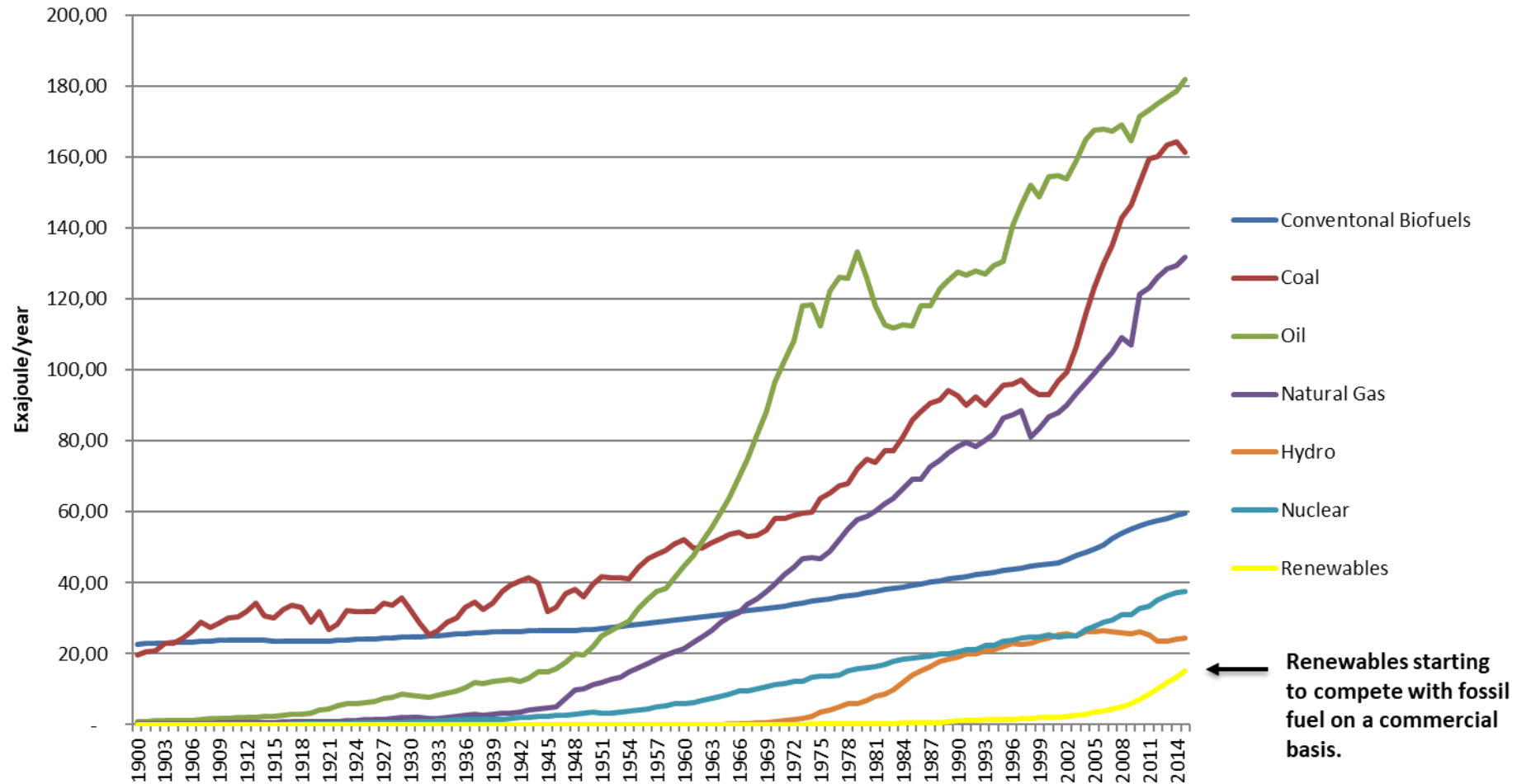
- Conventional Biofuels
- Coal
- Oil
- Natural Gas
- Hydro
- Nuclear
- Renewables



- Conventional Biofuels
- Coal
- Oil
- Natural Gas
- Hydro
- Nuclear
- Renewables

Source: own compilation based on (1): Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.H., Haberl, H., Fischer-Kowalski, M. (2009) Growth in global materials use, GDP and population during the 20th century, *Ecological Economics* 2009, Vol.68(10), 2696-2705; and (2) BP Statistical Review of World Energy June 2016.

Figure 4.12: Contribution to global energy supply

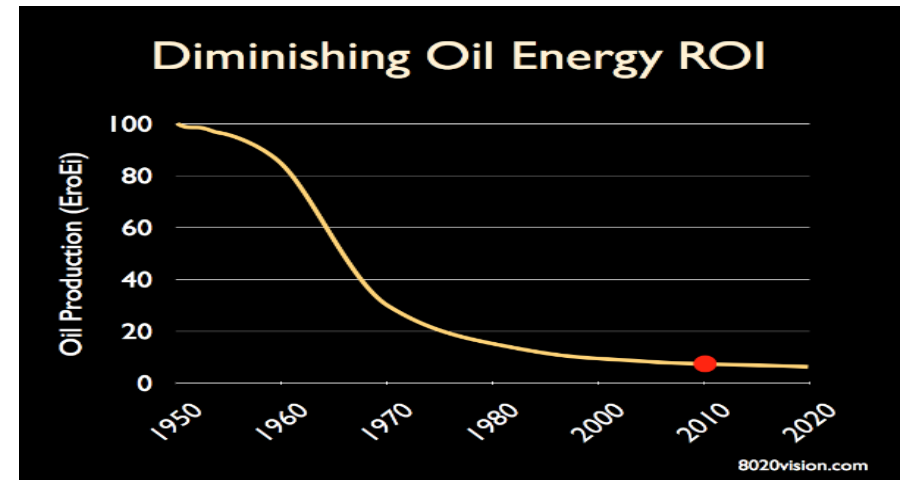
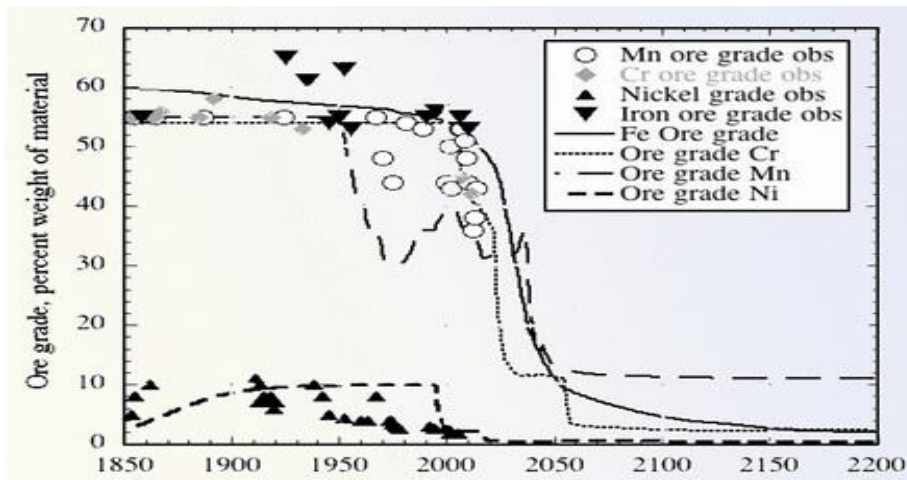
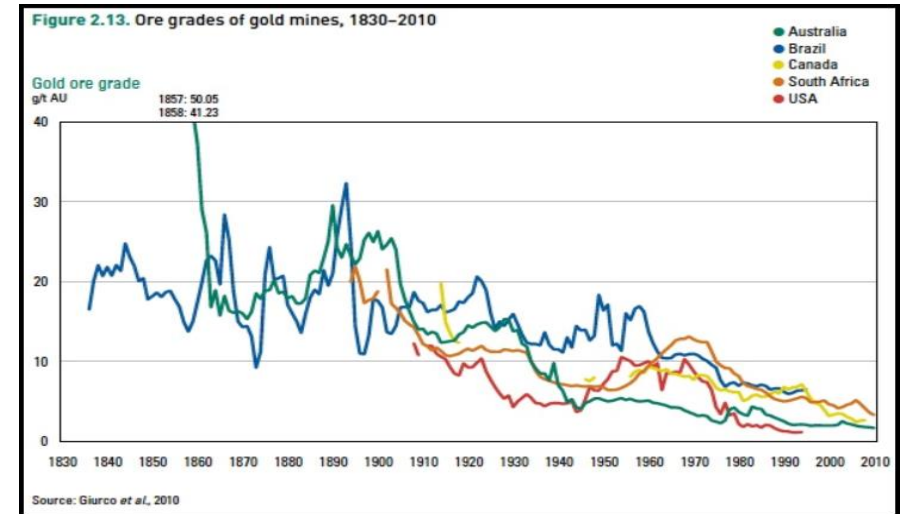
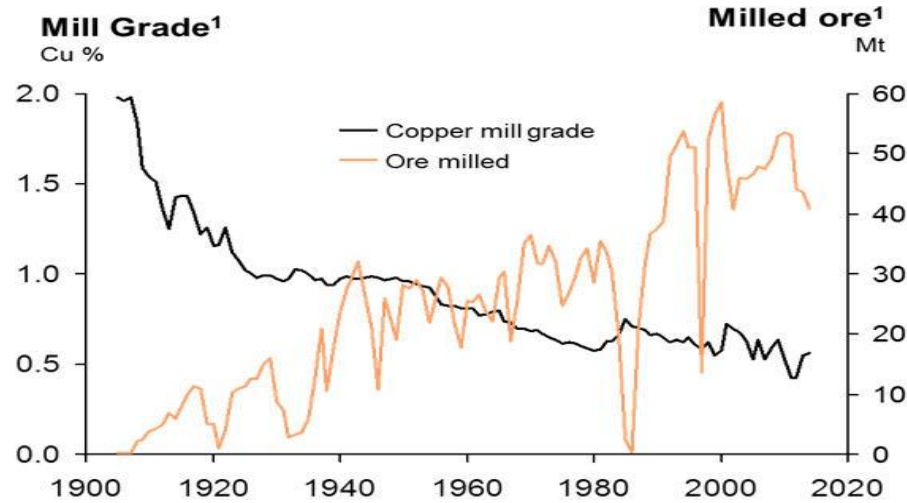


Source: own compilation based on (1): Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.H., Haberl, H., Fischer-Kowalski, M. (2009) Growth in global materials use, GDP and population during the 20th century, *Ecological Economics* 2009, Vol.68(10), 2696-2705; and (2) BP Statistical Review of World Energy June 2016.

Technological progress, mineral depletion, and price levels

- The previous figures indicated that the per capita demand for raw materials and energy is at best stabilising, which implies that overall demand is growing at the same rate as the world population.
- However, the exploitation of fossil fuels and raw materials is subject to depletion, which implies that the easily exploitable high grade mining areas are gradually being replaced by mining areas that are harder to exploit.
- This trend becomes most clear from analysing the ratio of energy returned on energy invested (EROI), which shows a sharp decline over the past century, Murphy and Hall (2010) indicate for the US that EROI on oil and gas was still over 100 in 1930, down to 30 in 1970, and only somewhere in-between 11-18 in 2005, while the EROI for new discoveries had already fallen below 8 in 1970 – and is only about 5 for shale oil and 2-4 for tar sands.
- Similar trends of declining ore grades are also observed for most mining products, which implies that more efforts (costs and energy) are required to mine a tonne of material.
- Until now, the advancements in mining techniques have been able to offset the effects of mineral depletion as to cost levels, but for many products the trend seems to have reversed around the year 2000.

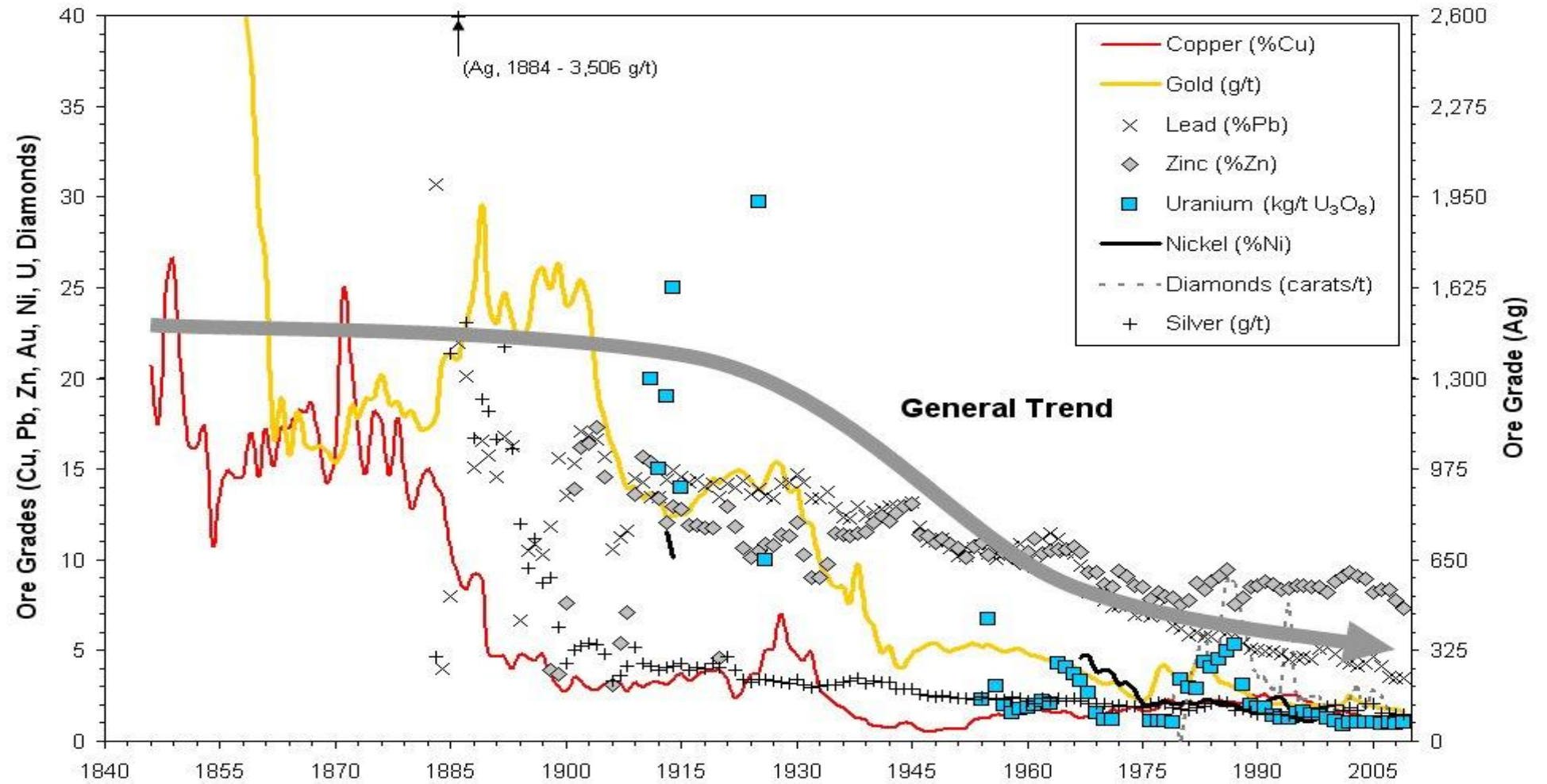
Figure 4.13: Illustration of declining EROI and ore grades



Note: Figure upper left relates to Bingham Canyon mine, USA. Other figure refer to global situation.

Source: <http://www.mining.com/heap-leach-minings-breakthrough-technology/>; <https://srsroccoreport.com/the-great-gold-supply-disconnect-market-severely-undervalues-price/>; <http://perspectives.geoscienceworld.org/content/gsgp/3/2/207/F19.medium.gif>.

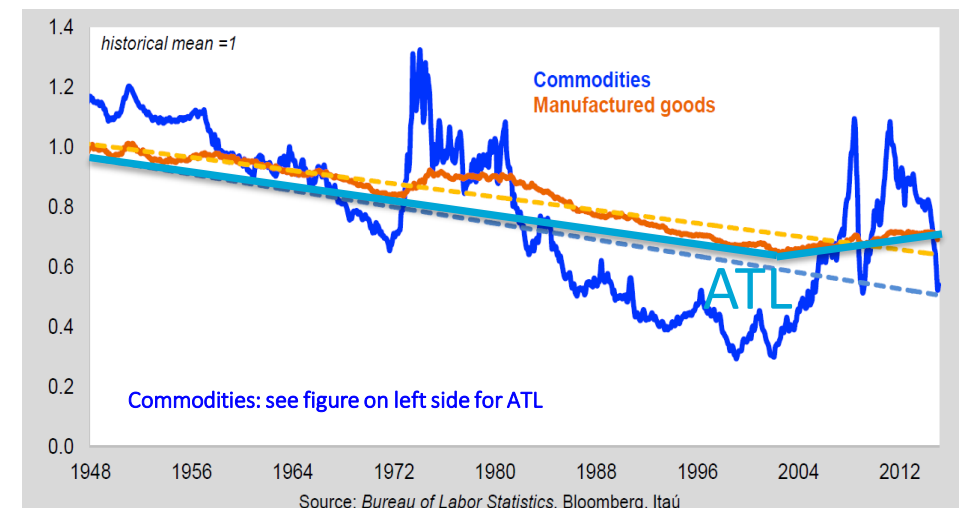
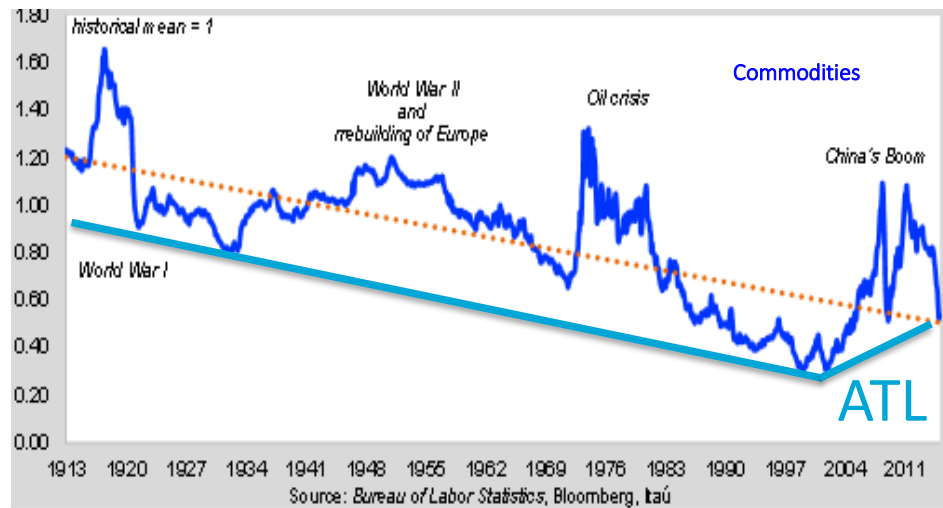
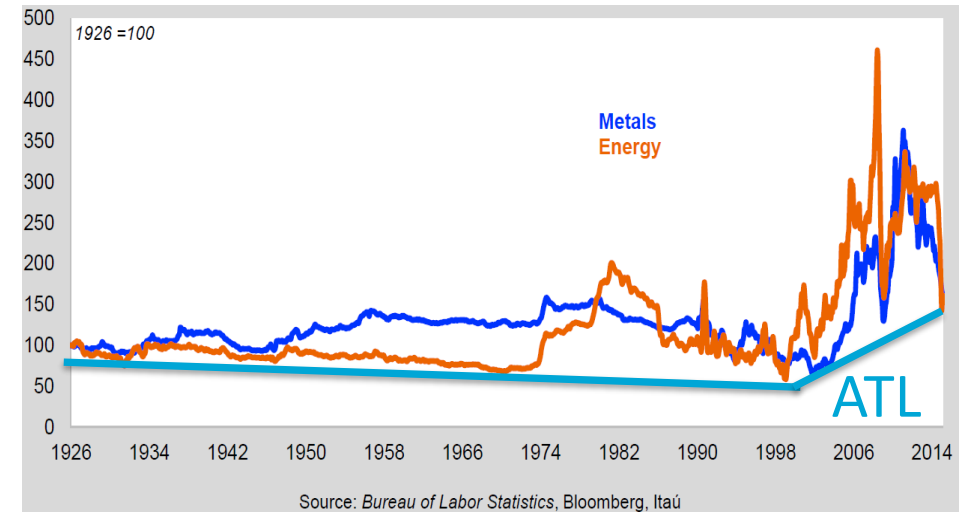
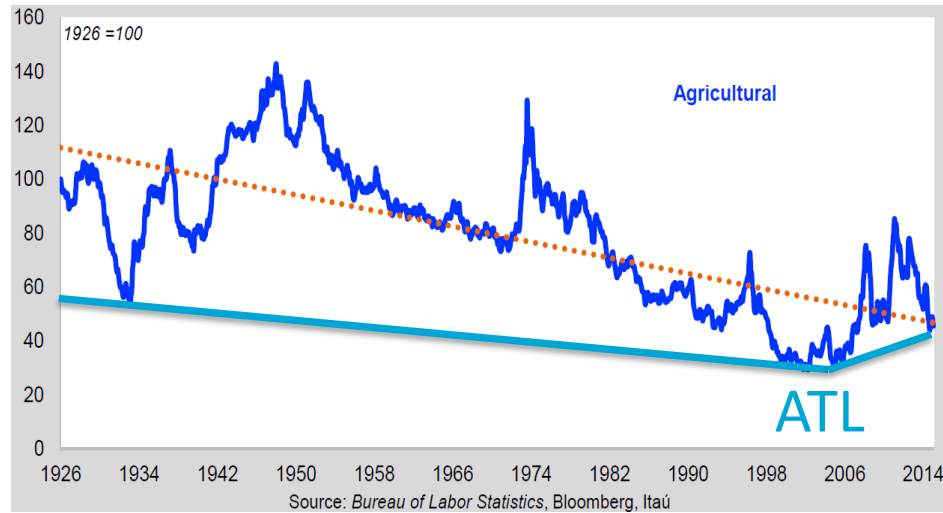
Figure 4.14: Further illustration of declining ore grades



Note: Figures relate to mining activities in Australia and are intended to indicate the general trend.

Source: <http://users.monash.edu.au/~gmudd/files/DecliningOreGrades.jpg>.

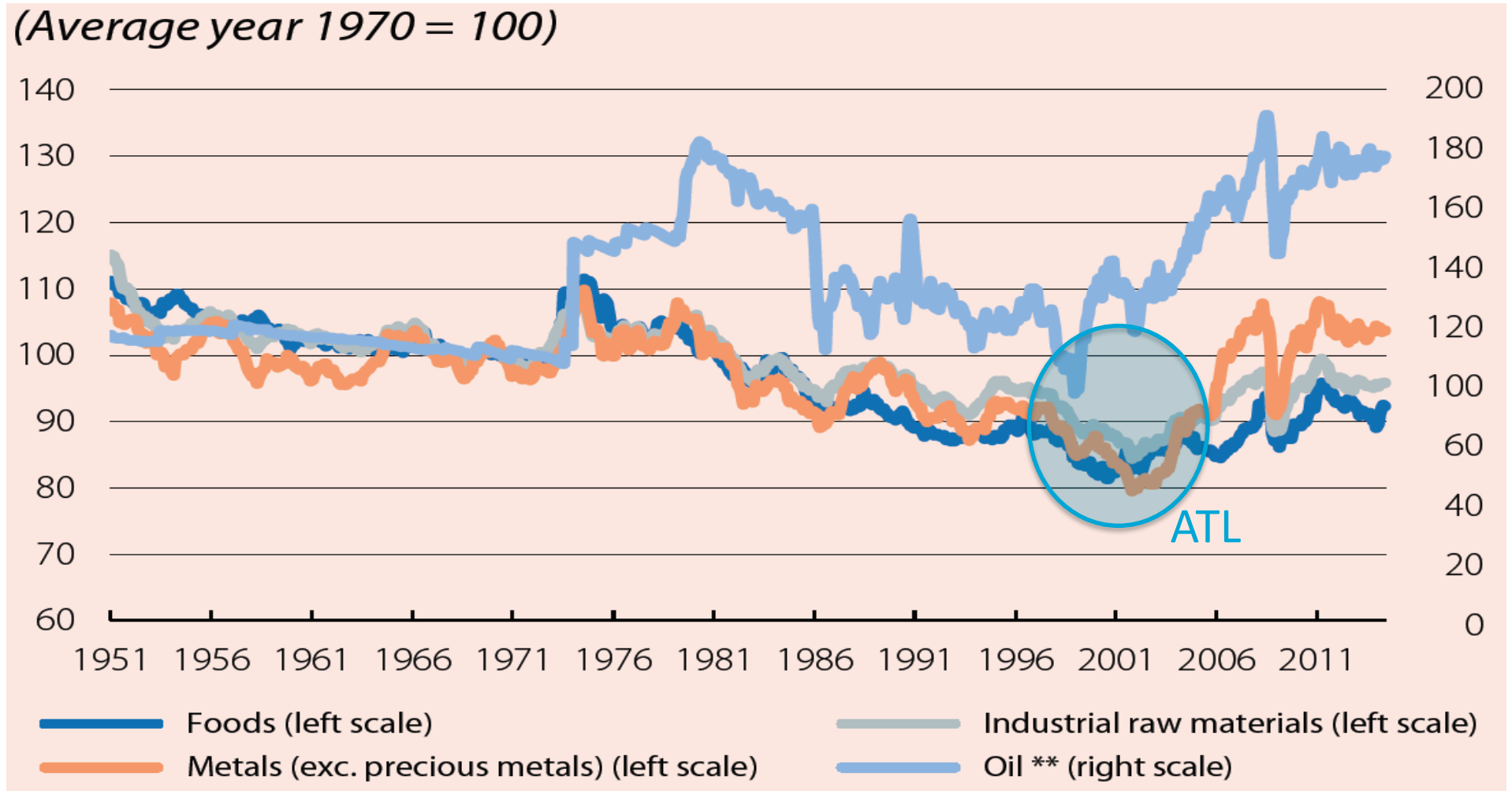
Figure 4.15: Year 2000 all time low in real commodity prices



ATL = All Time Low

Source: <https://www.itau.com.br/itaubba-en/economic-analysis/publications/macro-vision/commodities-in-a-secular-decline-are-we-back-to-the-trend;>

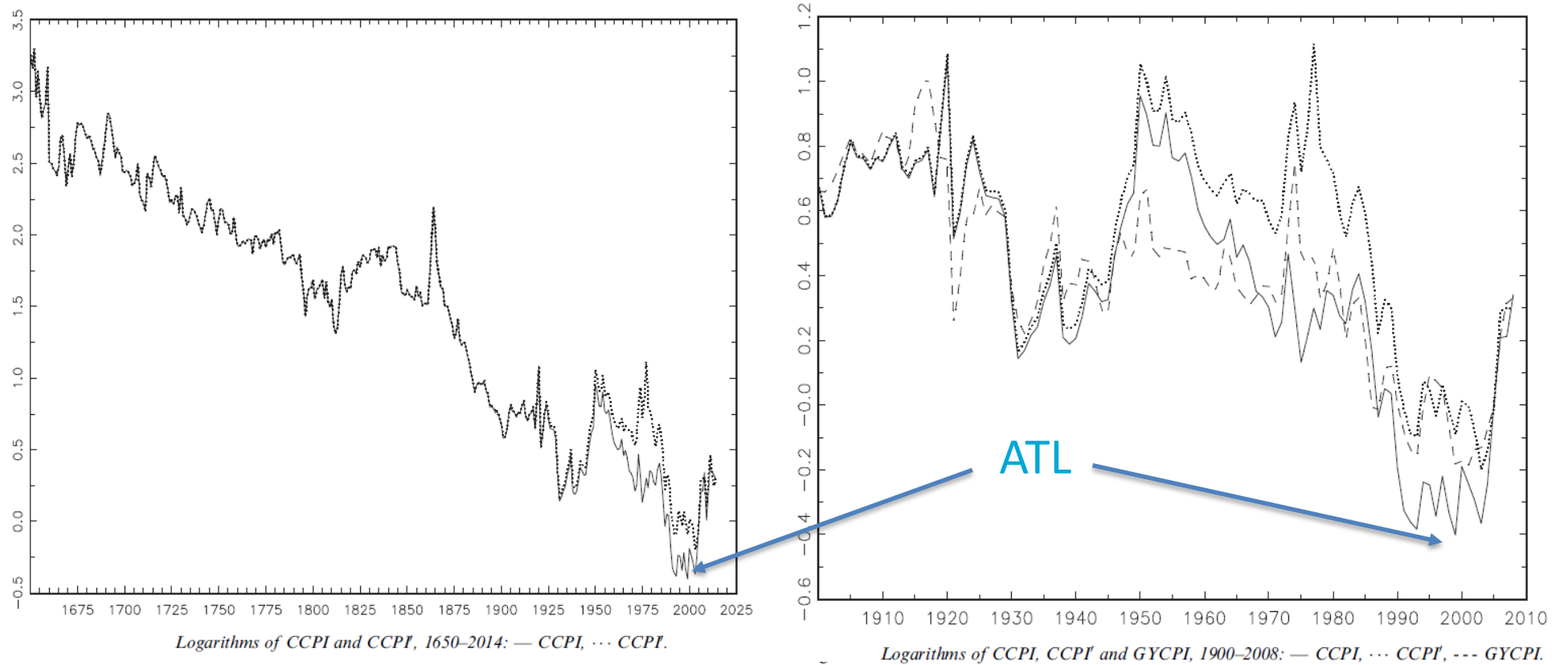
Figure 4.16: Year 2000 all time low in real commodity prices



ATL = All Time Low

Source: <http://www.caixabankresearch.com/documents/10180/470908/32-33%2BDossiers%2B1%2BING.pdf>

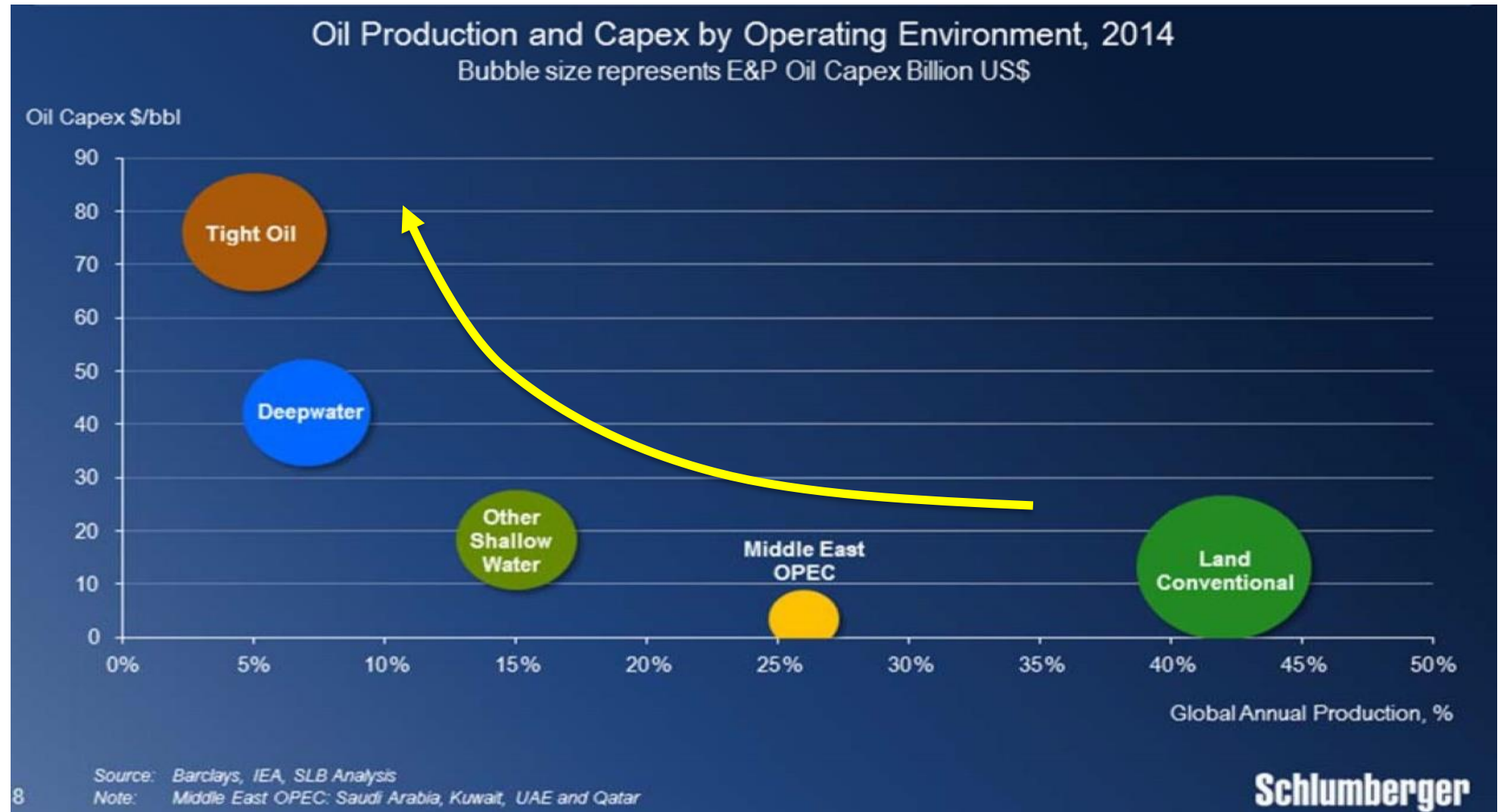
Figure 4.17: Year 2000 all time low in real commodity prices



Source: Harvey, D.I., N.M. Kellard, J.B. Madsen, M.E. Wohar (2017) Long-Run Commodity Prices, Economic Growth, and Interest Rates: 17th Century to the Present Day, *World Development*, vol. 89, pp.57-70. <https://doi.org/10.1016/j.worlddev.2016.07.012>

All Time Low (ATL) also confirmed by Composite Commodity Price Index (CCPI), CCPI excl. oil (CCPI'), and the comparable Grilli–Yang non-fuel weighted aggregate real index (GYCPI).

Figure 4.18: Increasing oil production cost levels



Fossil reserves and peak oil, peak gas, and peak coal

- Fossil fuel prices have long been expected to increase when the industry reaches peak oil, peak gas, and peak coal. However, this scenario will not necessarily materialize due to the discovery of shale gas and competition from renewables.
- Historical data on production volumes indicate that peak oil occurred in 2011 for conventional oil, but strange enough this has not resulted in soaring oil prices. It was instead followed by a period of overcapacity and increasing oil stocks due to the sudden increase in the production of shale gas and oil, which have led to overall oil production to peak in 2015.
- In contradiction to expectations, peak oil has occurred in a period with low and initially even declining prices. Peak oil and falling reserves could push up energy prices, but this does not have to happen, as renewables are beginning to become more competitive than fossil fuels.
- When analysing peak oil, not only production statistics, but also (trustworthy) resource statistics should be examined. Laherrere (2012) explains that BP statistical data on oil reserves indicating a growing reserve over time, is based on political data that could be misleading. Applying a technical approach leads to a different picture, hinting at a decline in resources since the 1980s.

Fossil reserves and peak oil, peak gas, and peak coal

- A technical approach seems trustworthy, since it not only accounts for the observed peak oil events, but is also in line with the following relevant developments:
 - OPEC has been able to sustain an agreement over output reduction. This was previously unthinkable;
 - Saudi-Arabia is investing in facilities to blend oil with hydrogen to reduce sulphur contents. The higher sulphur content could indicate depleting oil fields;
 - Saudi-Arabia is investing in solar energy to prevent the country from becoming net importer of oil over the next few decades;
 - Saudi-Arabia has announced its decision to bring a share of its state oil company Aramco to the stock exchange, presumably before it loses its value and in order to fund a shift towards renewables;
 - China is facing fuel shortage resulting in long rows at tank stations, which may result in social unrest.

Figure 4.19: The recent event of “peak oil”

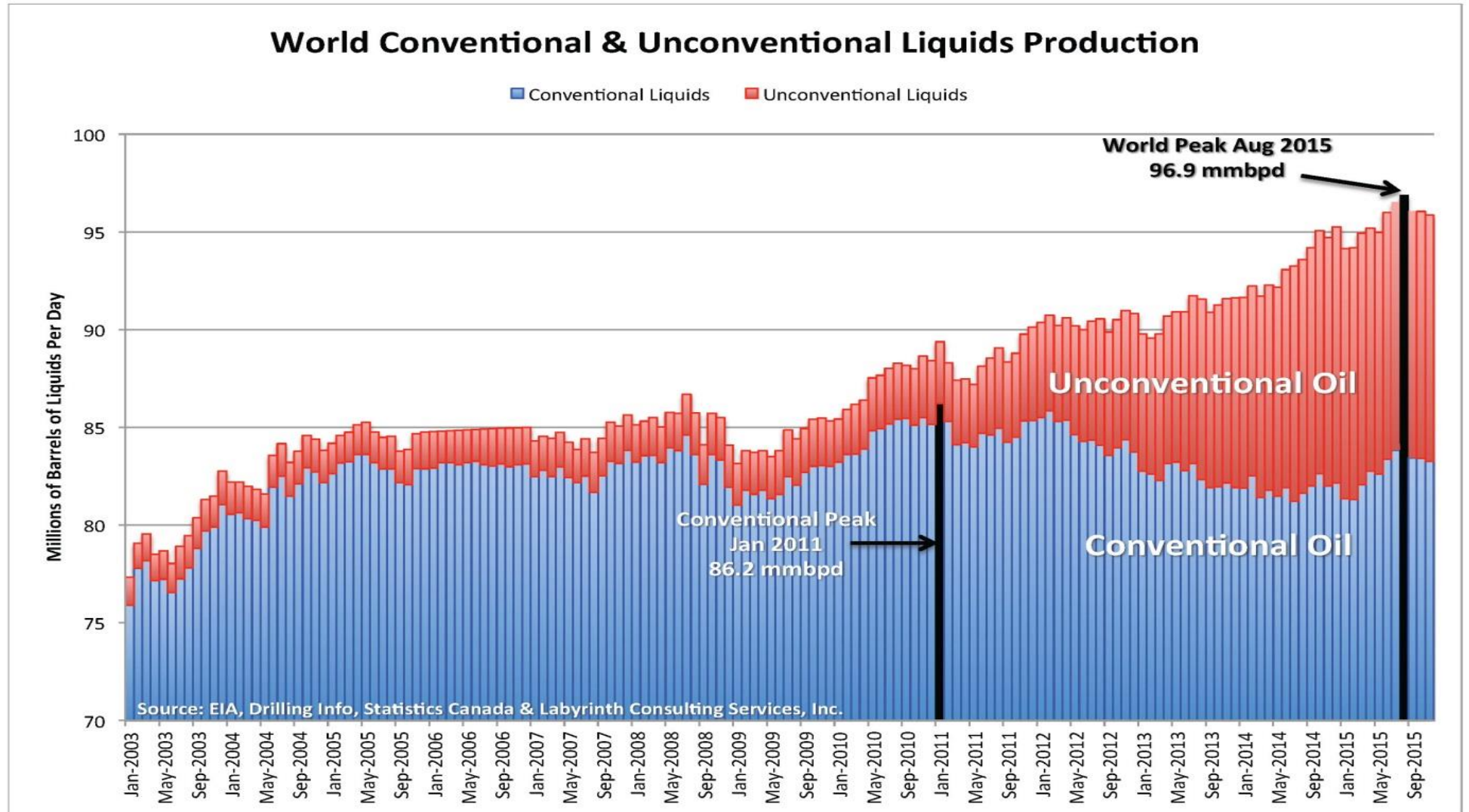


Figure 4.20: Official versus proven oil reserves

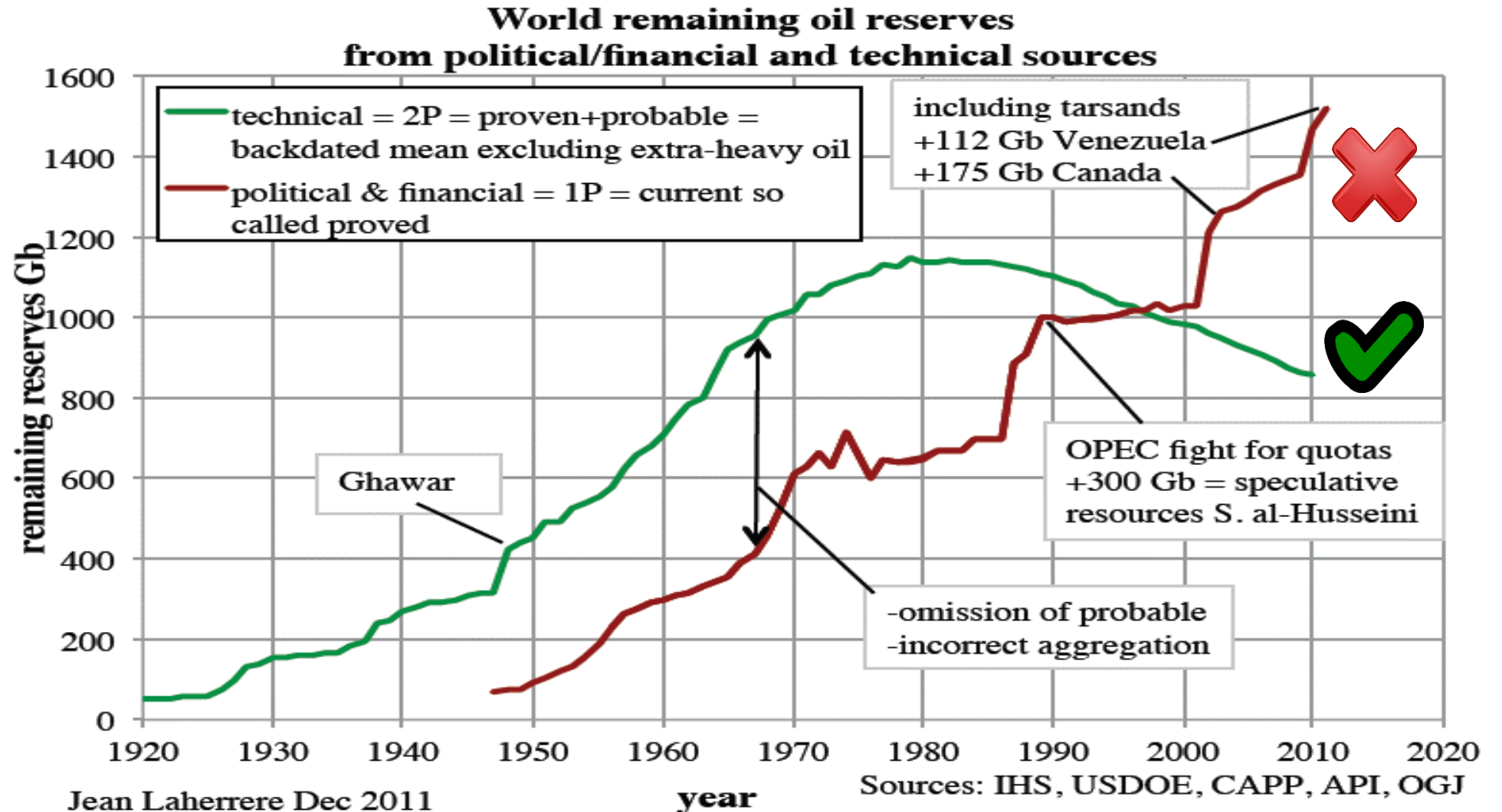


Figure 4.21: Absence of soaring oil prices with peak oil

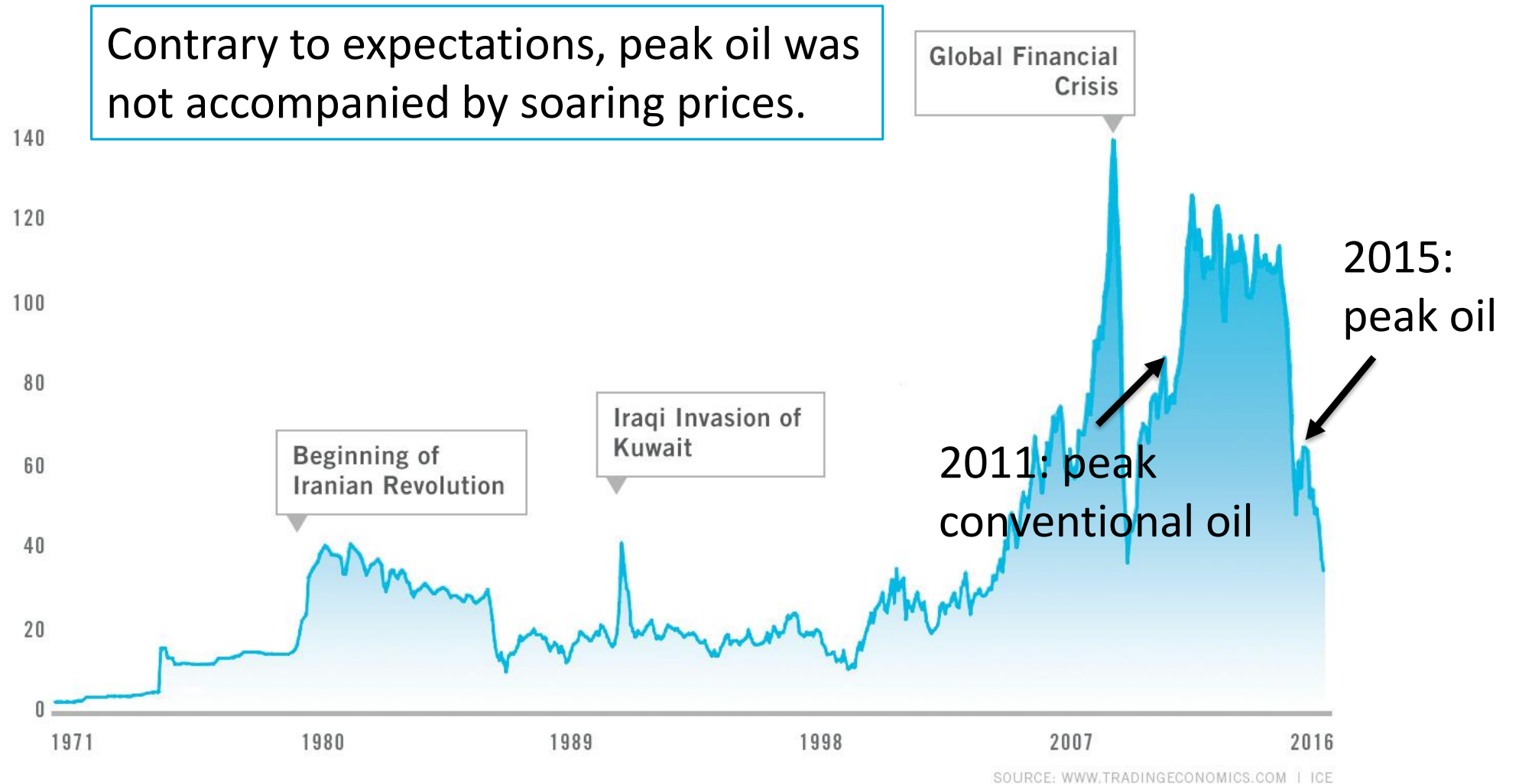
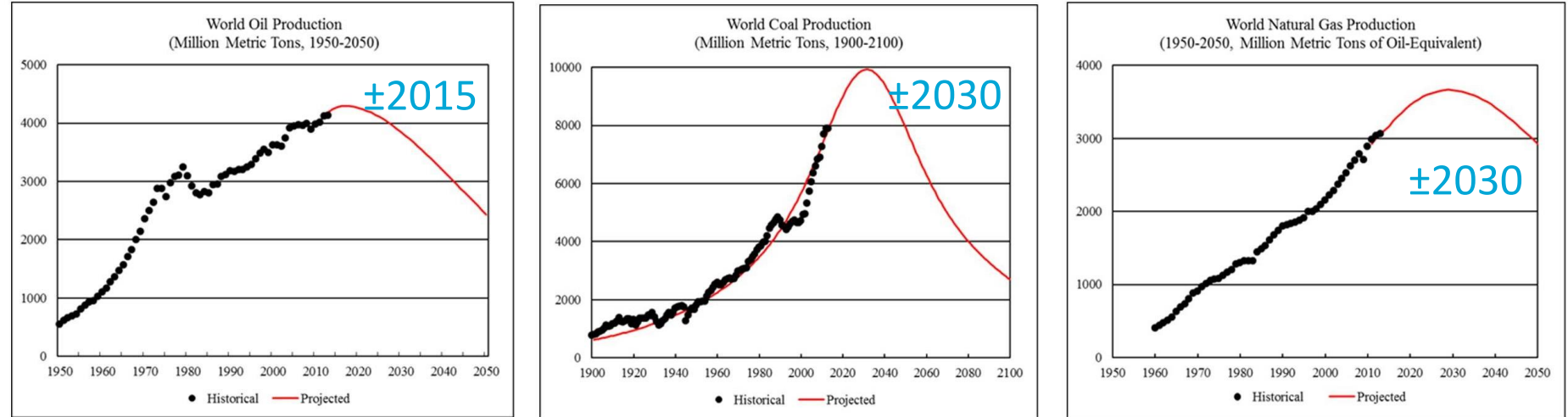


Figure 4.22: Peak estimates based on Hubbert linearisation

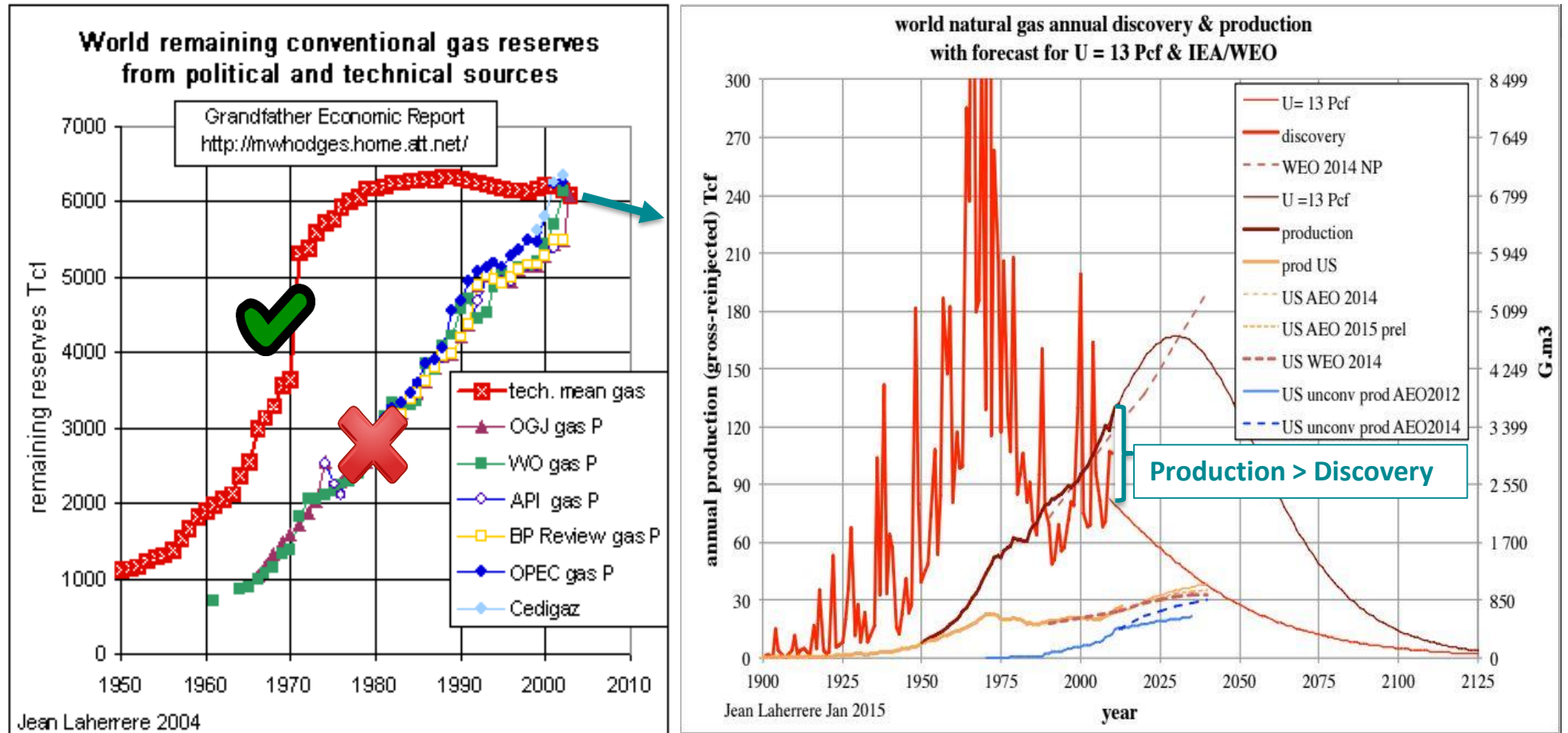
- In addition to peak oil, peak coal and peak gas may also be expected within a few decades, as forecasted on basis of Hubbert linearisation.



Source: <http://peakoilbarrel.com/world-energy-2014-2050-part-1-2/>

- Hubbert linearisation confirms that peak oil took place in year 2015 and expects peak coal and peak gas around 2030.
- The expectation of peak gas around 2030 is in line with the general perception that gas should be regarded as an intermediate (more sustainable fossil) fuel.
- Peak coal was expected around 2030 up till a few years ago, but now there are indications that it may have already occurred around the year 2014.

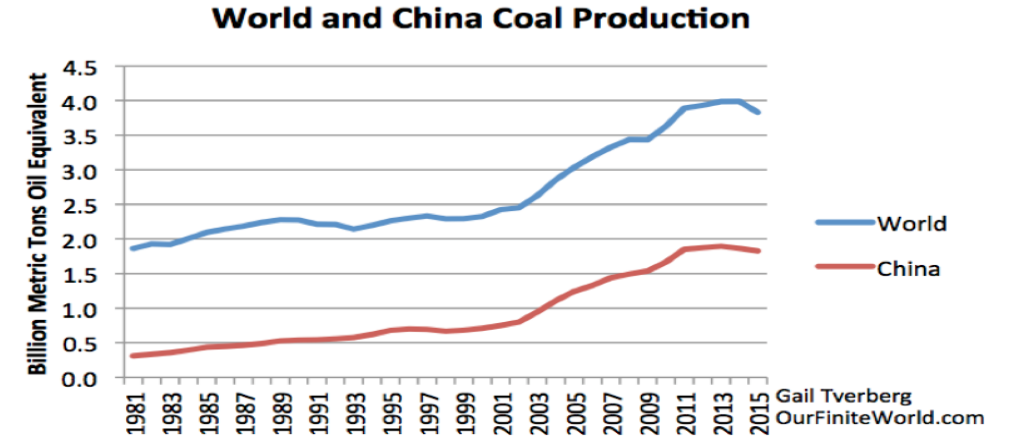
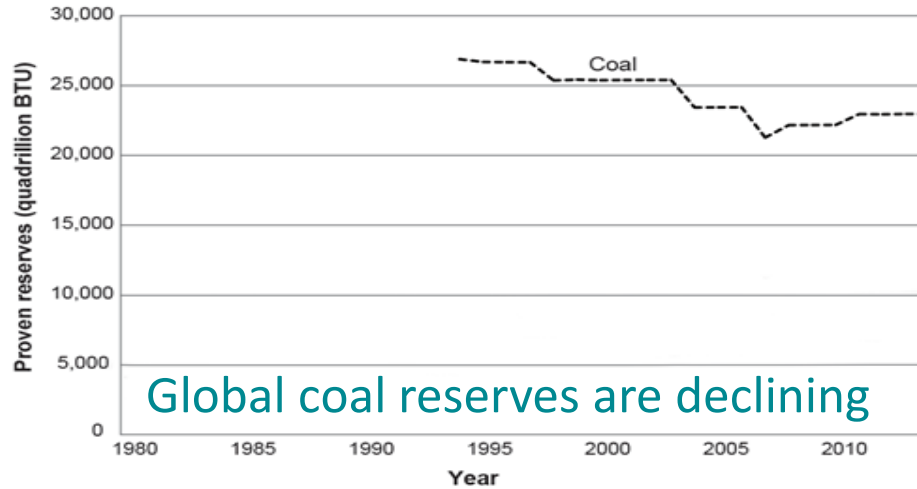
Figure 4.23: Natural gas reserves, discoveries and production



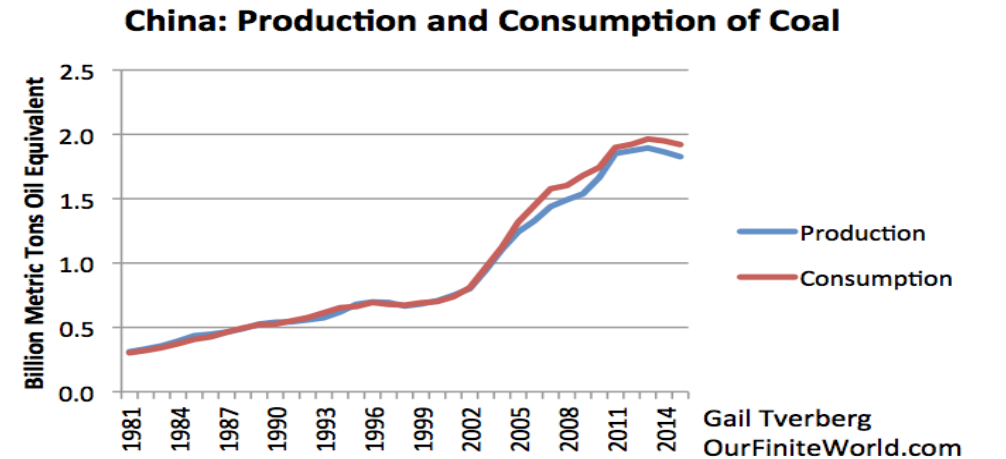
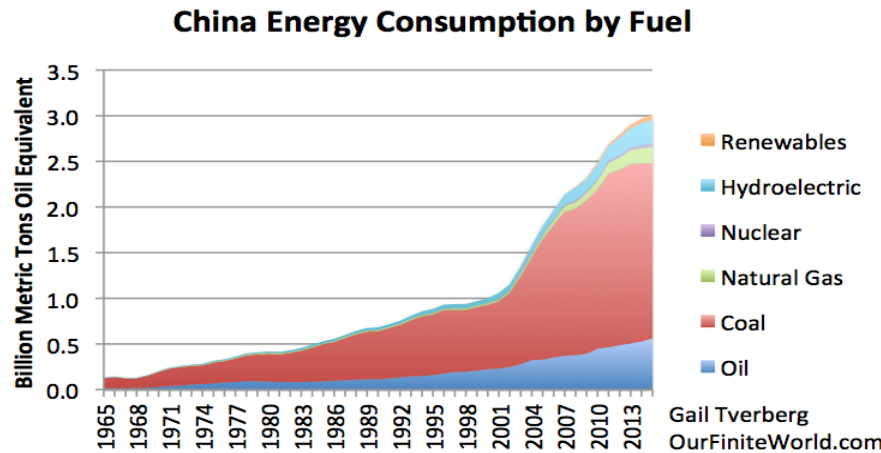
Source: <http://grandfather-economic-report.com/energy-b.htm>; <http://peakoilbarrel.com/eia-cc-reportm-plus-jeanlaherrere/>

- Peak gas estimated around 2030 confirmed by Laherrere, but could be delayed a few years due to increased unconventional gas production.

Figure 4.24: Coal reserves, production and consumption



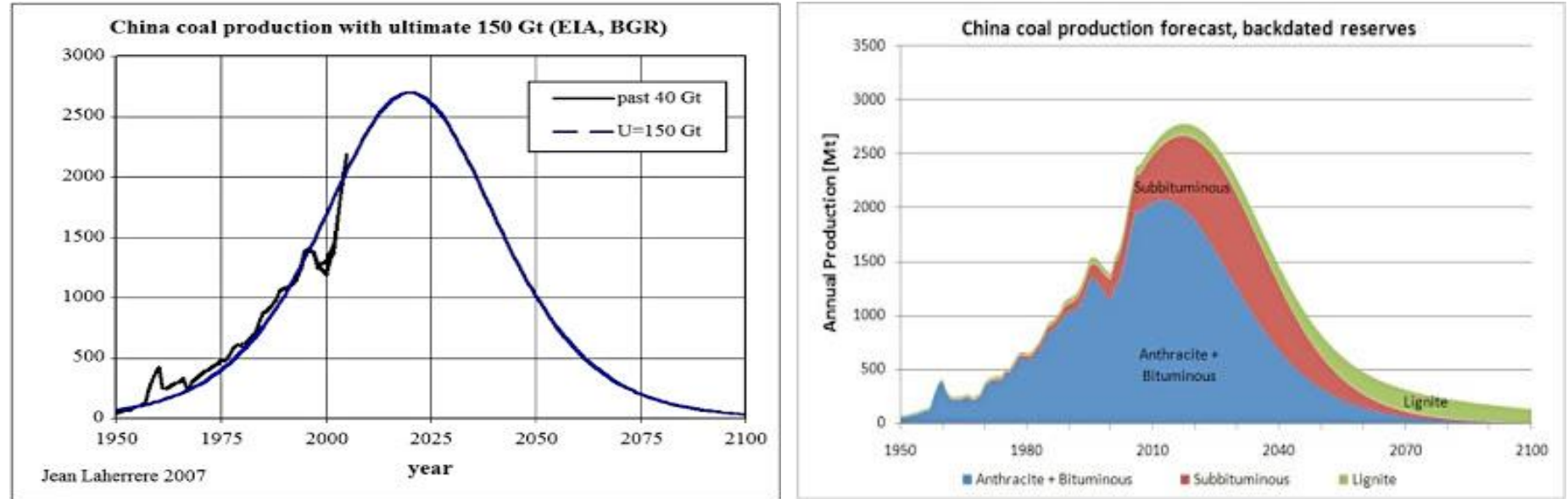
Based on BP 2016 Statistical Review of World Energy



China's energy demand requires all resources, likely to have hit peak coal in 2014.

Source: <https://energy.mit.edu/news/moving-away-fossil-fuel-energy-not-without-aggressive-policy-action/>; <http://www.theenergycollective.com/gail-tverberg/2242642/bp-data-suggests-we-are-reaching-peak-energy-demand>

Figure 4.25: Peak coal likely to have occurred in 2014



Source: <http://boloodoi.blogspot.nl/2008/07/coal-in-china.html>, based on report of Energy Watch Group published in 2007.

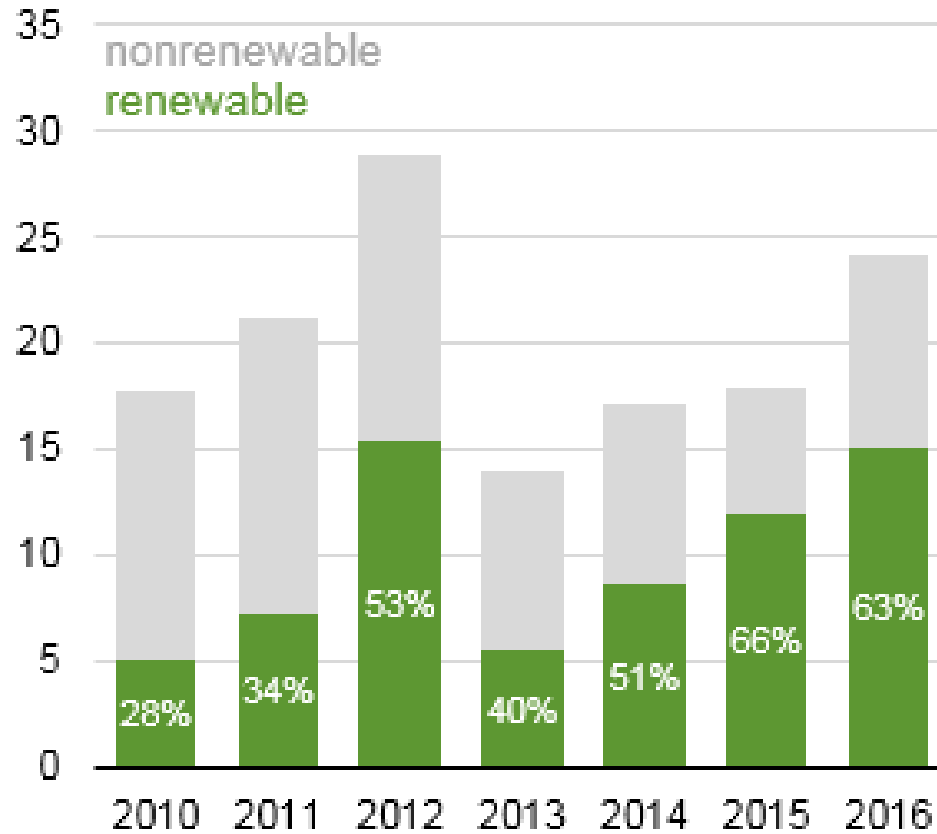
- Possible peak in Chinese coal production around 2015-2020 was already expected by critics who questioned the Chinese resource statistics in 2008.
- Following the massive surge in Chinese production of coal, the peak coal event has shifted forward and **peak coal is now likely to have occurred in 2014, not only in China, but worldwide.** (The worldwide coal peak aligns with peak in China since China accounts for half of global coal production and consumption).

Figure 4.26: Global investment in power capacity, \$billions.

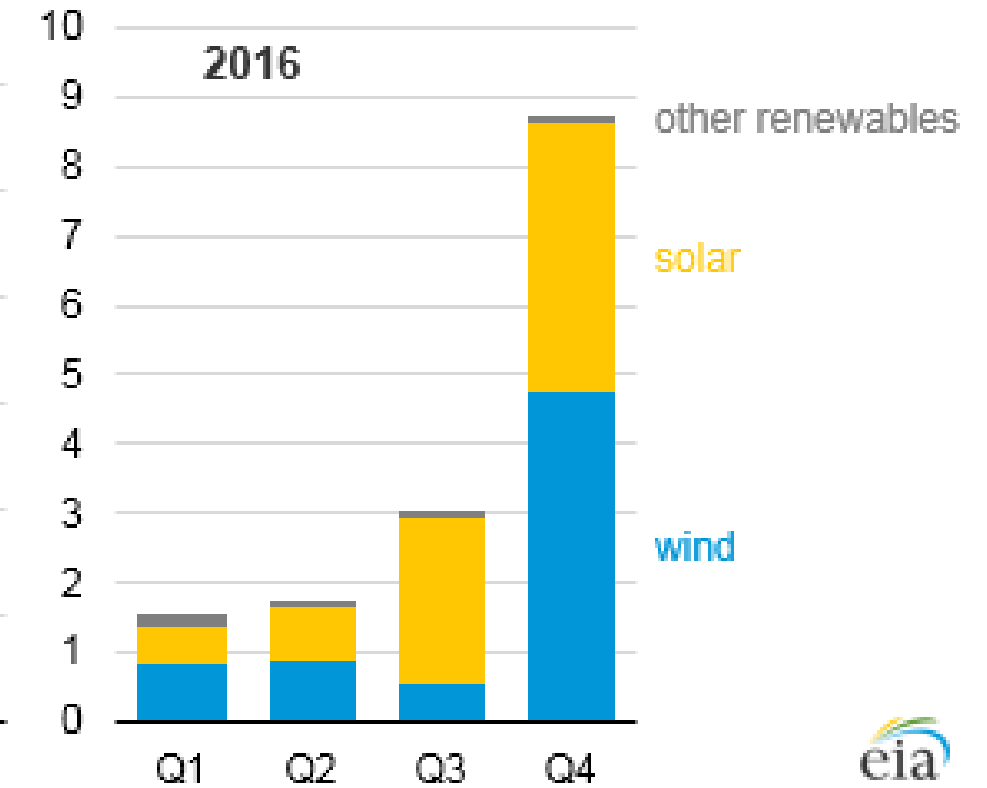


Figure 4.27: US investments in renewable power generation

Utility-scale capacity additions (2010-16) gigawatts



Utility-scale renewable capacity additions gigawatts



Renewable generation capacity expected to account for most 2016 capacity additions (in united states ?), January 2017.

Source: <https://www.eia.gov/todayinenergy/detail.php?id=29492>.

Figure 4.28: Optimistic views on sustainable energy growth

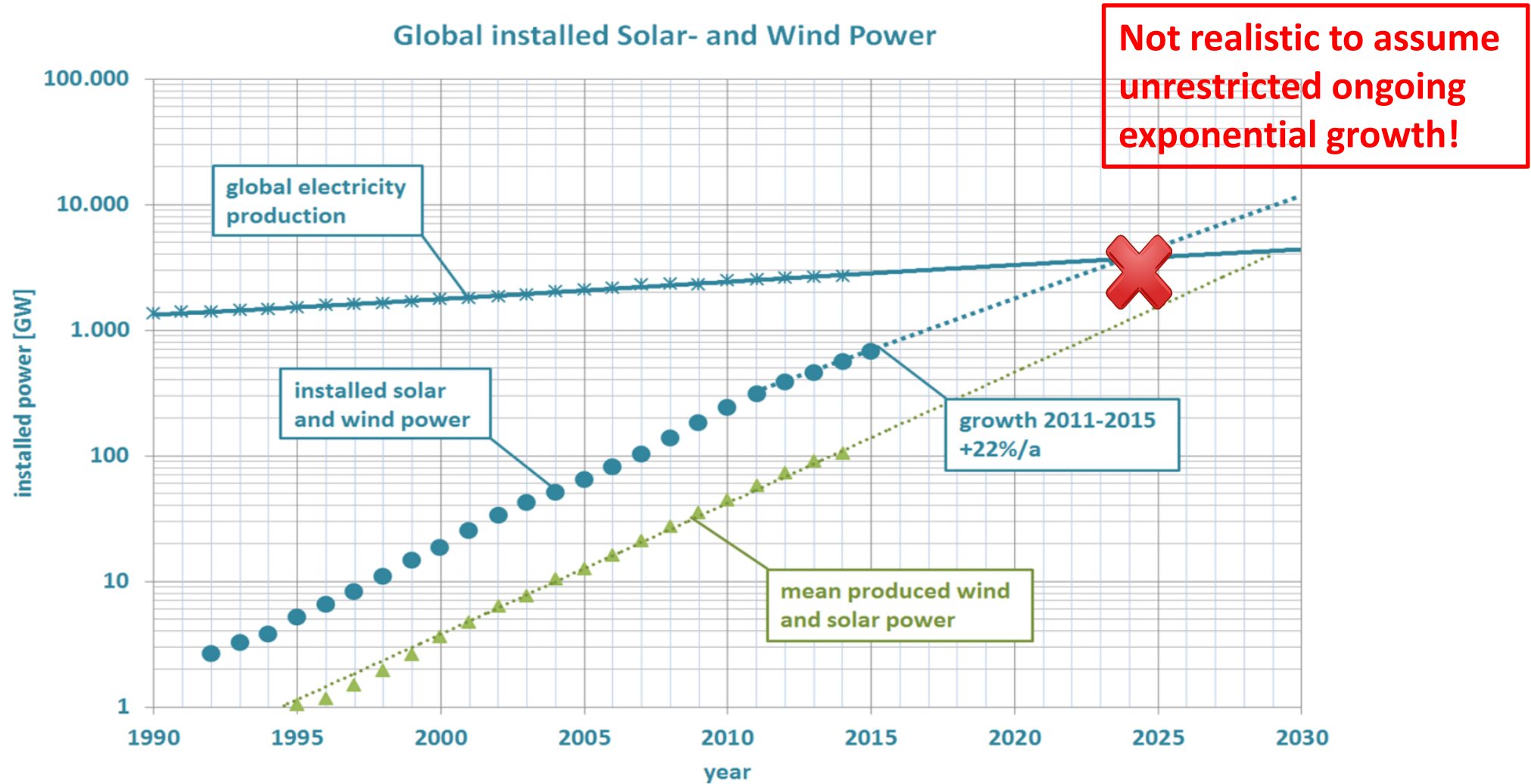
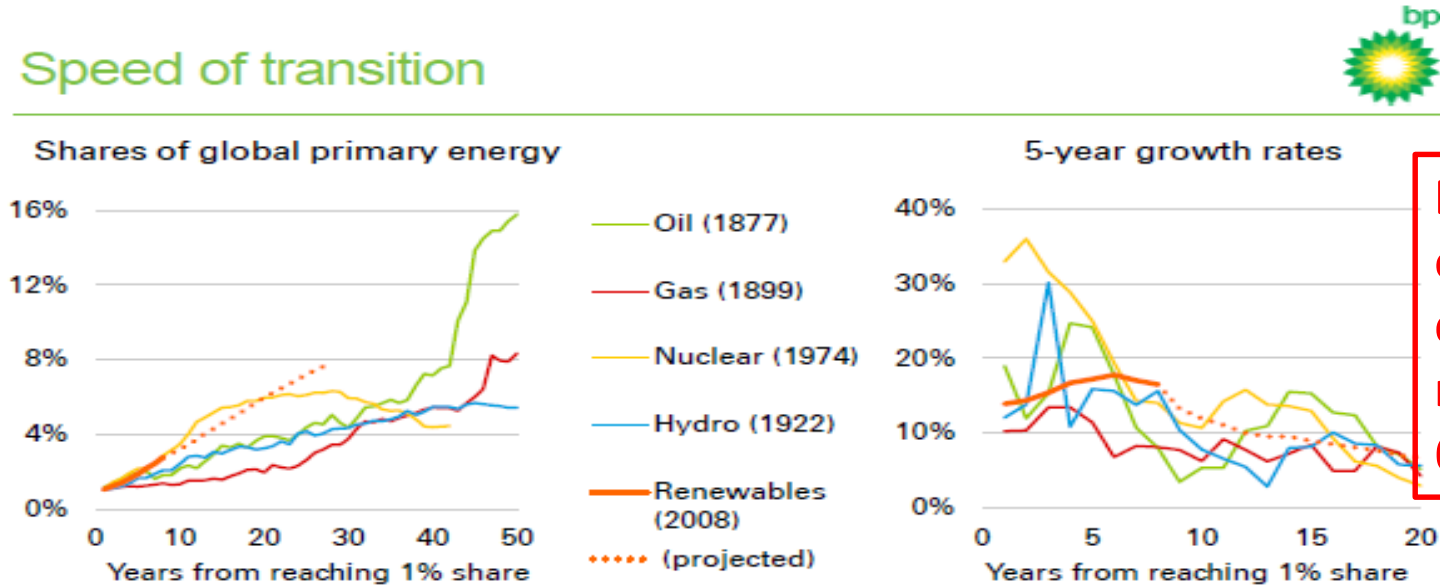


Figure 4.29: Pessimistic views on sustainable energy growth



Note: - For sources of data pre-1965 see "Economic development and the demand for energy" by Ruetli et al, Energy Policy, 2012.

BP Statistical Review of World Energy

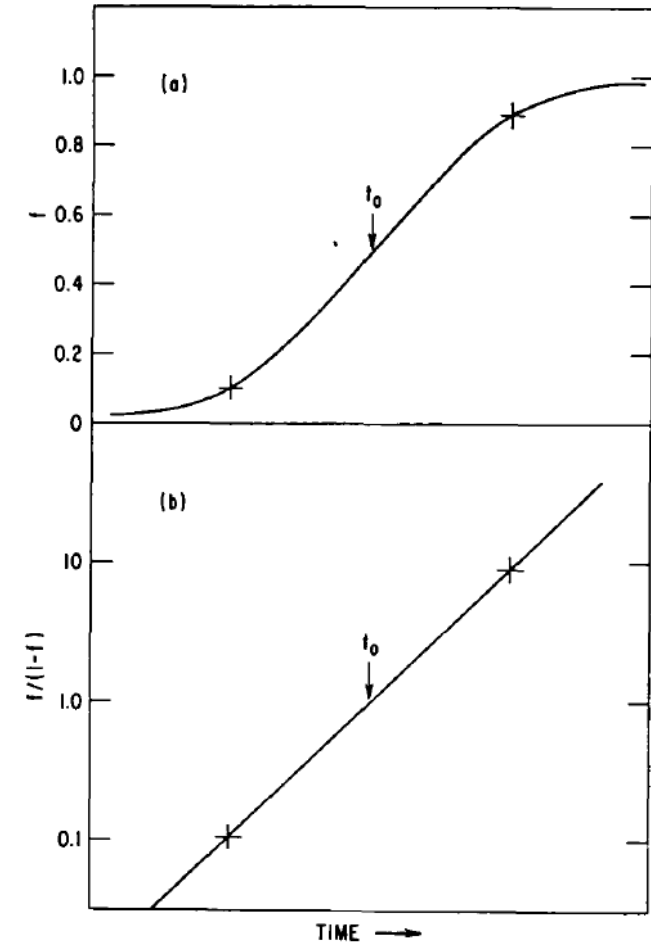
© BP p.l.c. 2016

Source: <http://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2016/bp-statistical-review-of-world-energy-2016-spencer-dale-presentation.pdf>

- Oil majors may have their own reasons for reporting low expectations.
- Irrelevant comparison with nuclear energy growth due to public opposition.
- Incomparable situation since the age with just three dominant fuels is ending; renewable fuels are a combination of many different energy solutions.
- **BP estimate would imply that it would take 50 years for renewable energy to reach 13% of global energy supply. This is considered unrealistically low given the present level of investments.**

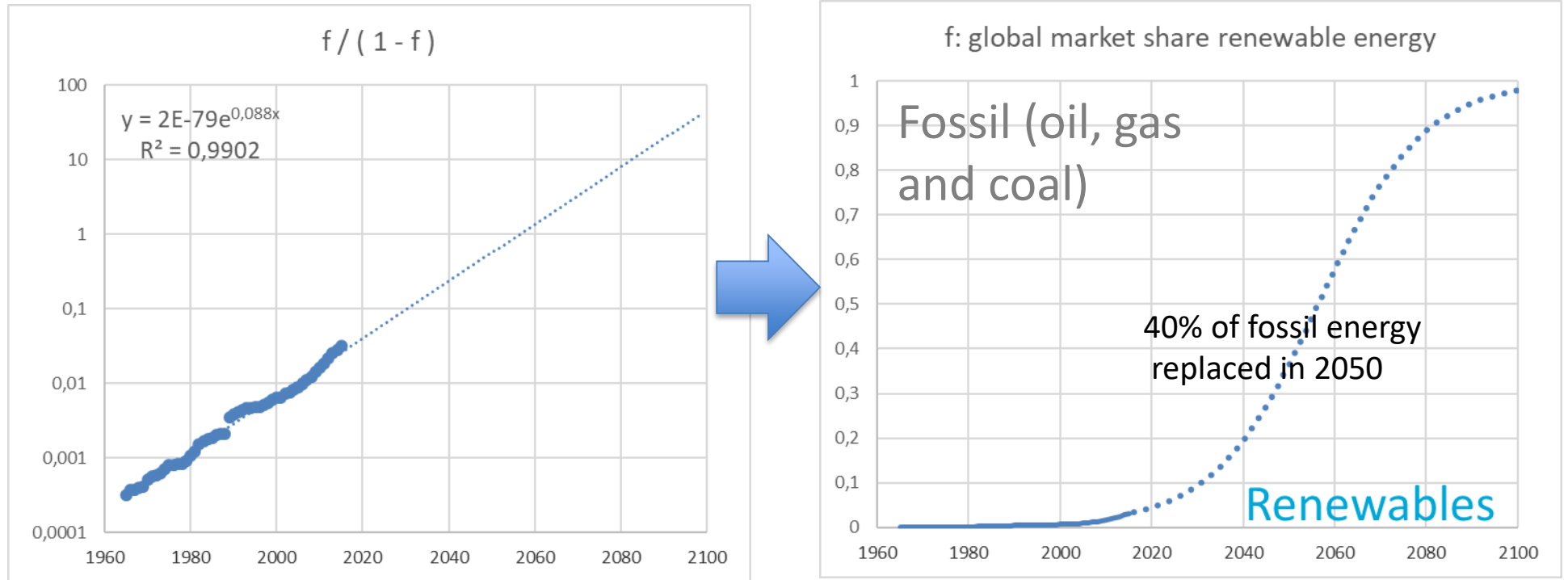
Alternative forecast based on Fisher & Pry model

- Fisher and Pry (1971) proposed a simple substitution model for technological change that is intended to describe the s-curve like substitution processes following the introduction of new technologies.
- The shape of the F&P model has been applied to many technologies and seems to fit quite well in many cases.
- The F&P model may also be suitable for describing the shift from fossil fuels to renewables. The shift from oil, gas and coal to renewables was analysed for the study; not included are conventional biofuels, nuclear- and hydro power.
- **Interestingly, the model indicates that it will take approx. 100 year (or about 2K waves) to complete the transition to renewable sources of energy.**



Source: Fisher and Pry (1971, p.76)

Figure 4.30: Forecast of shares based on Fisher and Pry model



ANALYSIS MADE FOR SUBSET EXCLUDING BIOMASS, HYDRO-POWER AND NUCLEAR.

100 years or about 2 Kondratieff waves

Source: own analysis based on (1): Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.H., Haberl, H., Fischer-Kowalski, M. (2009) Growth in global materials use, GDP and population during the 20th century, *Ecological Economics* 2009, Vol.68(10), 2696-2705; and (2) BP Statistical Review of World Energy June 2016.

Figure 4.31: Shell new lens scenarios

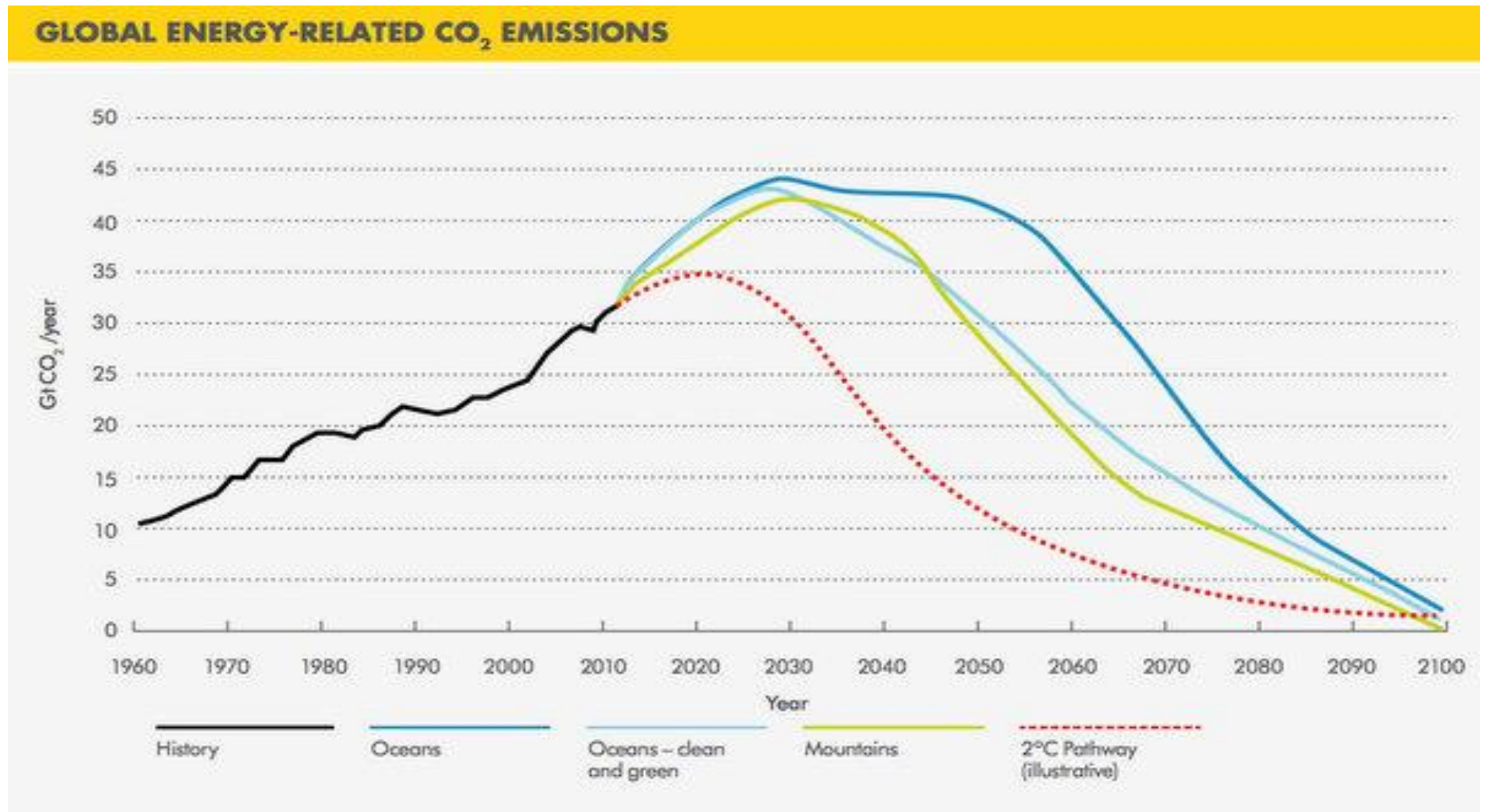


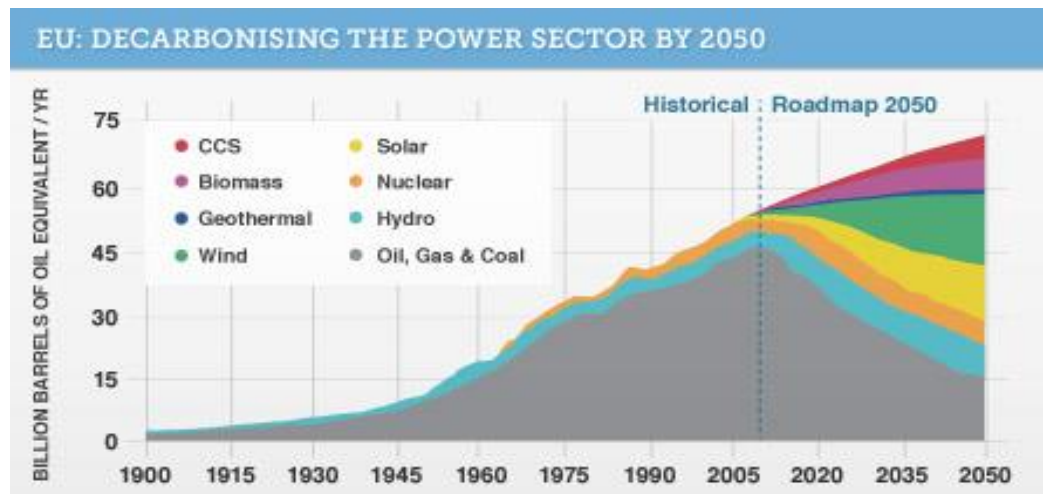
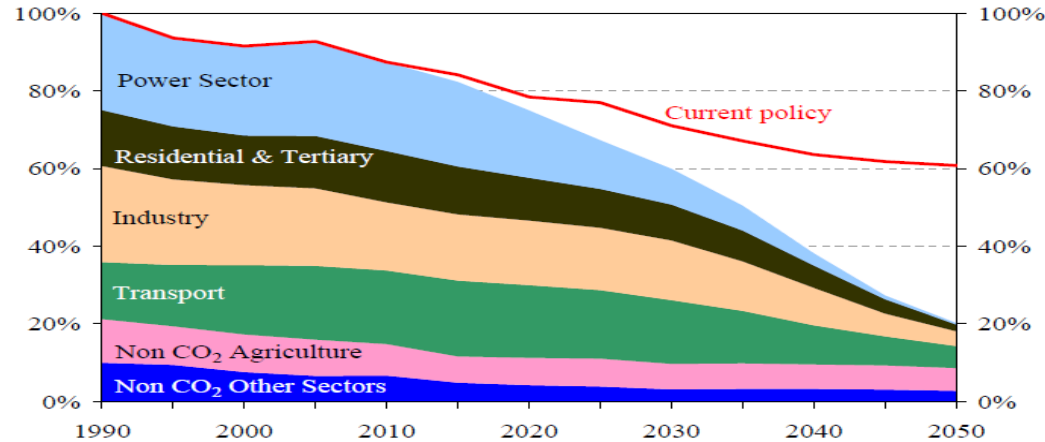
Table 4.1: Shell new lens scenarios

Shell new lens scenarios on primary energy demand

EJ/year Year	Historical						Mountains					Oceans				
	1960	1970	1980	1990	2000	2010	2020	2030	2040	2050	2060	2020	2030	2040	2050	2060
Fossil																
Oil	52	98	130.3	135.7	153.3	173.1	190.2	199.6	188.7	160.5	132.4	196.4	214	221.8	220.7	201.4
Natural Gas	18.9	35.3	51.6	70.2	87.3	114.8	149.7	188.8	226.2	237.7	234.8	147.9	169.2	187.3	185.6	175.4
Coal	52.2	61.6	75.9	94.2	100.1	146.2	184.8	199	191.4	211.8	247	202.7	222.3	201.7	218.6	204.2
<i>Subtotal</i>	<i>123.1</i>	<i>194.9</i>	<i>257.8</i>	<i>300.1</i>	<i>340.7</i>	<i>434.1</i>	<i>524.7</i>	<i>587.4</i>	<i>606.3</i>	<i>610</i>	<i>614.2</i>	<i>547</i>	<i>605.5</i>	<i>610.8</i>	<i>624.9</i>	<i>581</i>
Renewables																
Biofuels	0	0	0.1	0.3	0.5	2.5	6.6	8.6	10	10.2	13.5	4.6	5.5	7.2	14.2	25.9
Biofuels Gasified	0	0	0	0	0.2	1.3	5.4	11.5	18.2	33.9	41.7	7.8	19.8	20.4	22.1	26.8
Geothermal	0.1	0.2	0.5	1.4	2.1	2.4	4	6.1	9.4	14.7	30.8	5.1	9.7	18.9	26.4	34.1
Solar	0	0	0	0.1	0.2	0.8	3.6	11.3	19.5	32.1	51.3	4.4	25.2	70.1	132.6	209.6
Wind	0	0	0	0	0.1	1.2	3	5.2	11.5	21.8	34.3	4.7	13.2	24.7	42.4	59.3
Other Renewables	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0.1	0.2
<i>Subtotal</i>	<i>0.1</i>	<i>0.2</i>	<i>0.6</i>	<i>1.8</i>	<i>3.1</i>	<i>8.2</i>	<i>22.6</i>	<i>42.7</i>	<i>68.6</i>	<i>112.7</i>	<i>171.7</i>	<i>26.6</i>	<i>73.4</i>	<i>141.3</i>	<i>237.8</i>	<i>355.9</i>
Other																
Biomass/Waste solids	6.6	7.7	9.8	11.6	13.3	17.1	14	10.5	16.3	26.3	31.9	18.7	14.1	15.5	17.7	21.4
Biomass Traditional	14.9	18	21.5	26	29.3	33.2	35.1	37.6	39.9	42	45.9	28.9	26.9	24.2	24.3	22.5
Nuclear	0	0.9	7.8	22	28.3	30.1	37.5	55.6	74.6	91.9	107.5	33.3	42.1	47.2	52.4	54.7
Hydro-electricity	2.6	4.2	6.2	7.8	9.5	12.4	13.2	14.7	16.7	18.7	20.7	13.5	14.8	16.8	18.7	20.6
<i>Subtotal</i>	<i>24.1</i>	<i>30.8</i>	<i>45.3</i>	<i>67.4</i>	<i>80.4</i>	<i>92.8</i>	<i>99.8</i>	<i>118.4</i>	<i>147.5</i>	<i>178.9</i>	<i>206</i>	<i>94.4</i>	<i>97.9</i>	<i>103.7</i>	<i>113.1</i>	<i>119.2</i>
Total	147.3	225.9	303.7	369.3	424.2	535.1	647.1	748.5	822.4	901.6	991.9	668	776.8	855.8	975.8	1056.1
Share renewables, biomass and hydro.	16%	13%	13%	13%	13%	13%	13%	14%	17%	22%	27%	13%	17%	23%	31%	40%
Fossil substitution by renewables																
REN / (REN + FOS)	0%	0%	0%	1%	1%	2%	4%	7%	10%	16%	22%	5%	11%	19%	28%	38%

Source: own compilation of data from Royal Dutch Shell (2013) New Lens Scenarios.

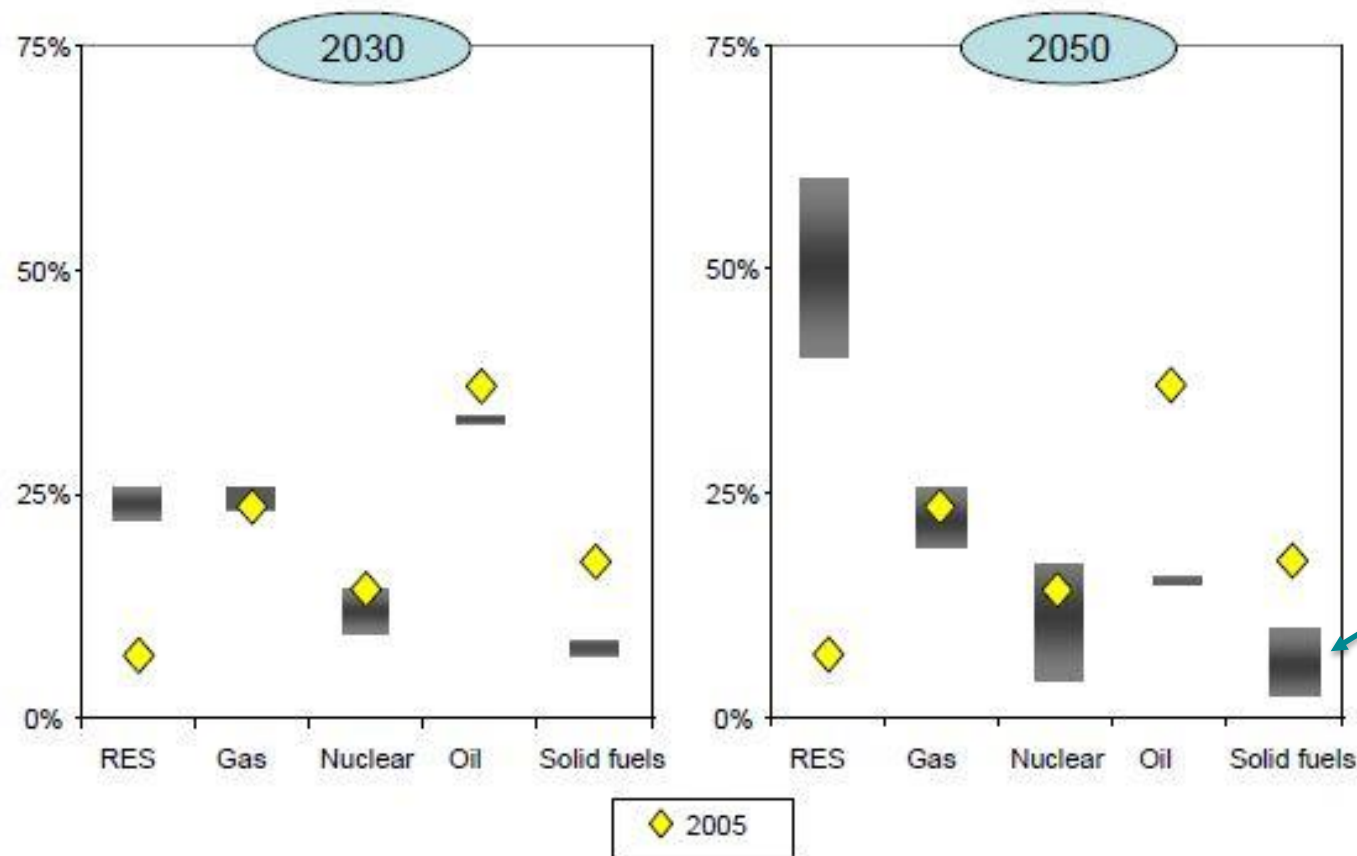
Figure 4.32: EU energy roadmap for 2050



Source: <https://ec.europa.eu/clima/sites/clima/files/strategies/2050/images/targets.png>; <http://www.raponline.org/wp-content/uploads/2016/06/roadmap-2050-designing-a-decarbonised-power-future.jpg>; http://kimatv.com/resources/media/5ab223ee-cd8c-48cd-abf5-dc5b1de67db3-FranceClimateCountd_Leak.jpg

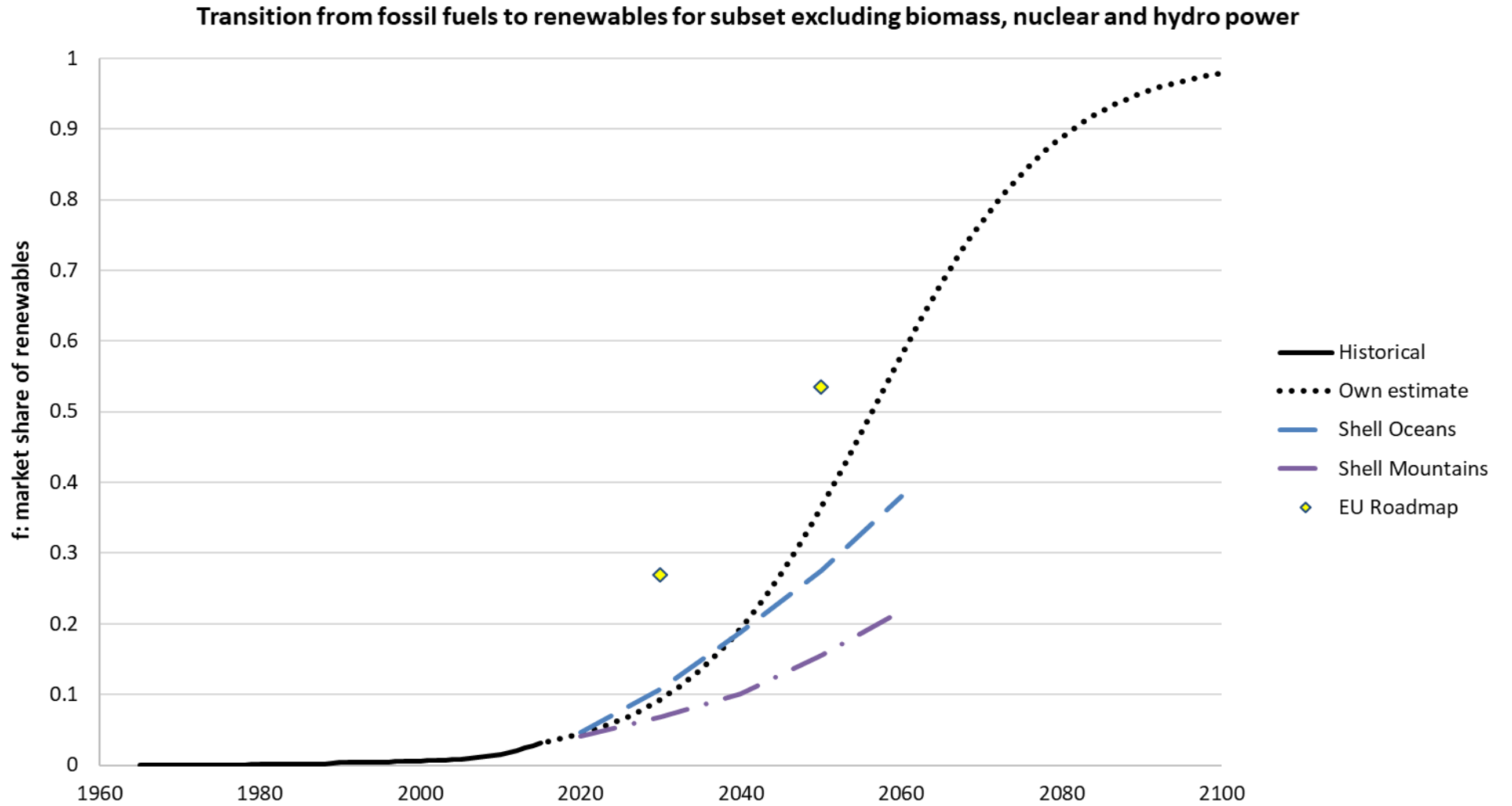
Figure 4.33: Implementation of EU energy roadmap

Graph 1: EU Decarbonisation scenarios - 2030 and 2050 range of fuel shares in primary energy consumption compared with 2005 outcome (in %)



Uncertainty over solid fuels due to uncertainty over carbon capture and storage (CCS).

Figure 4.34: Compilation of various projections

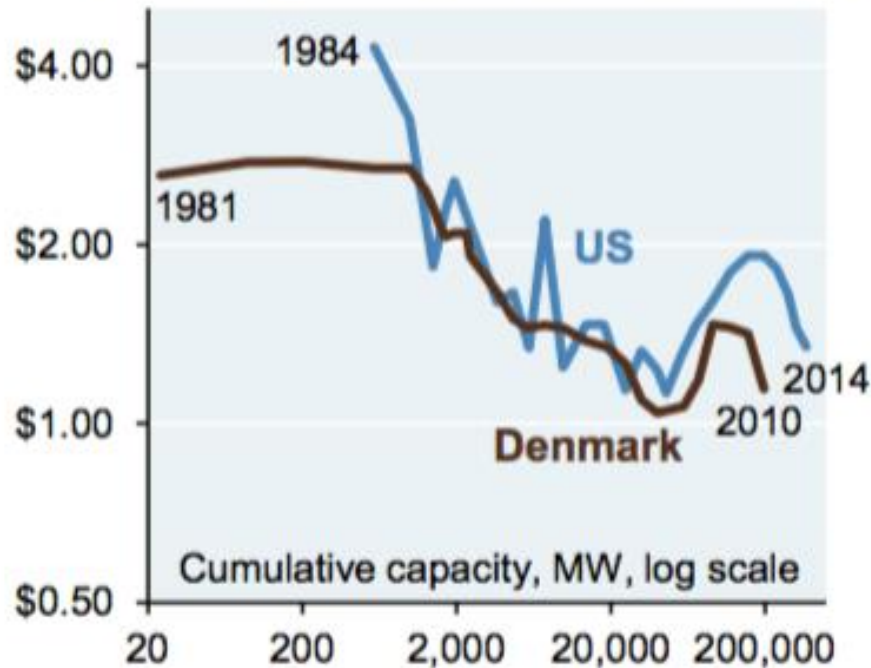


Source: own compilation based on previous mentioned sources

Figure 4.35: Falling unit costs for wind and photovoltaic energy

Wind learning curve

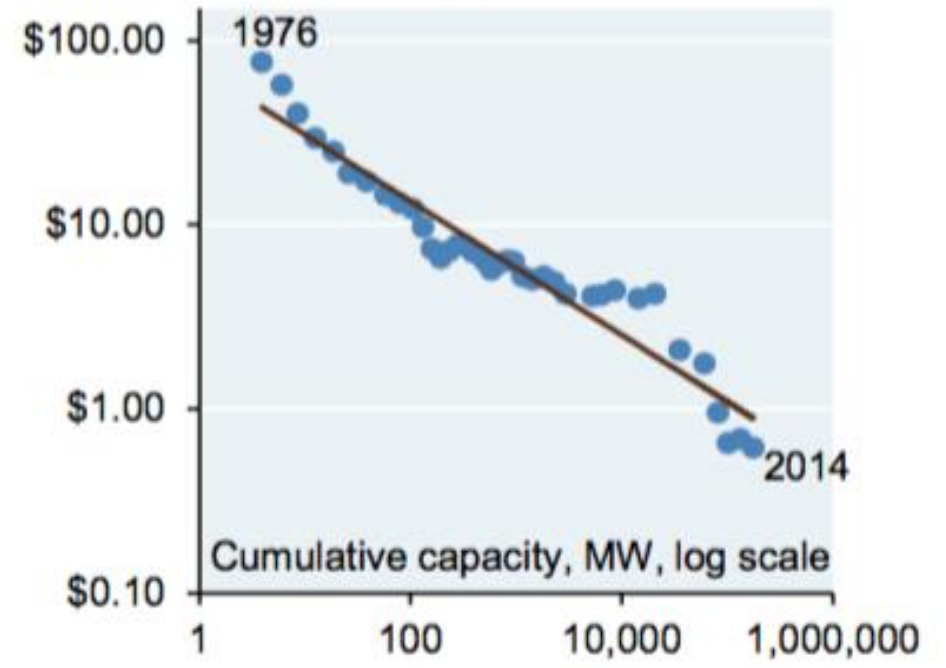
Capital cost, 2005 USD per watt, log scale



Source: NREL, GWEC. 2014.

Solar photovoltaic learning curve

Module* price, 2011 USD per watt, log scale

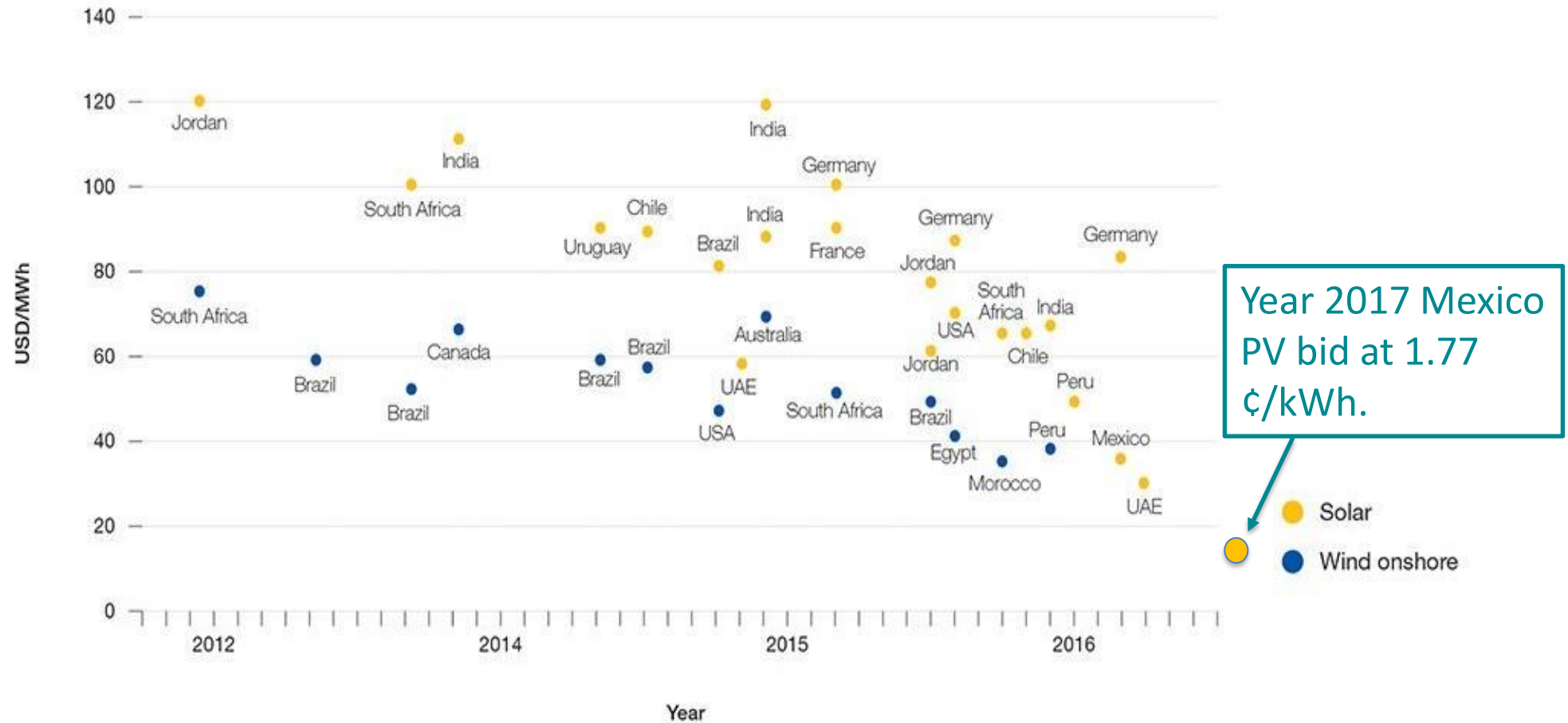


Source: Bloomberg, IEA. 2014. *Crystalline silicon

Note: The cost of wind and solar power generating capacity on a dollar-per-Watt basis has fallen with increasing deployments. The wind learning curve exhibits a bump corresponding to rising raw materials costs in 2004.

Source: <https://blogs.scientificamerican.com/plugged-in/deep-de-carbonization-would-increase-electricity-costs-20-90-percent-says-j-p-morgan/>

Figure 4.36: Photovoltaic bids now lower than wind energy



Source: International Energy Agency 2016

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Source: <https://twitter.com/solarpowereu/status/828609712635539456>, based on data from EIA 2016.

Figure 4.37: Solar energy costs fall below wind energy

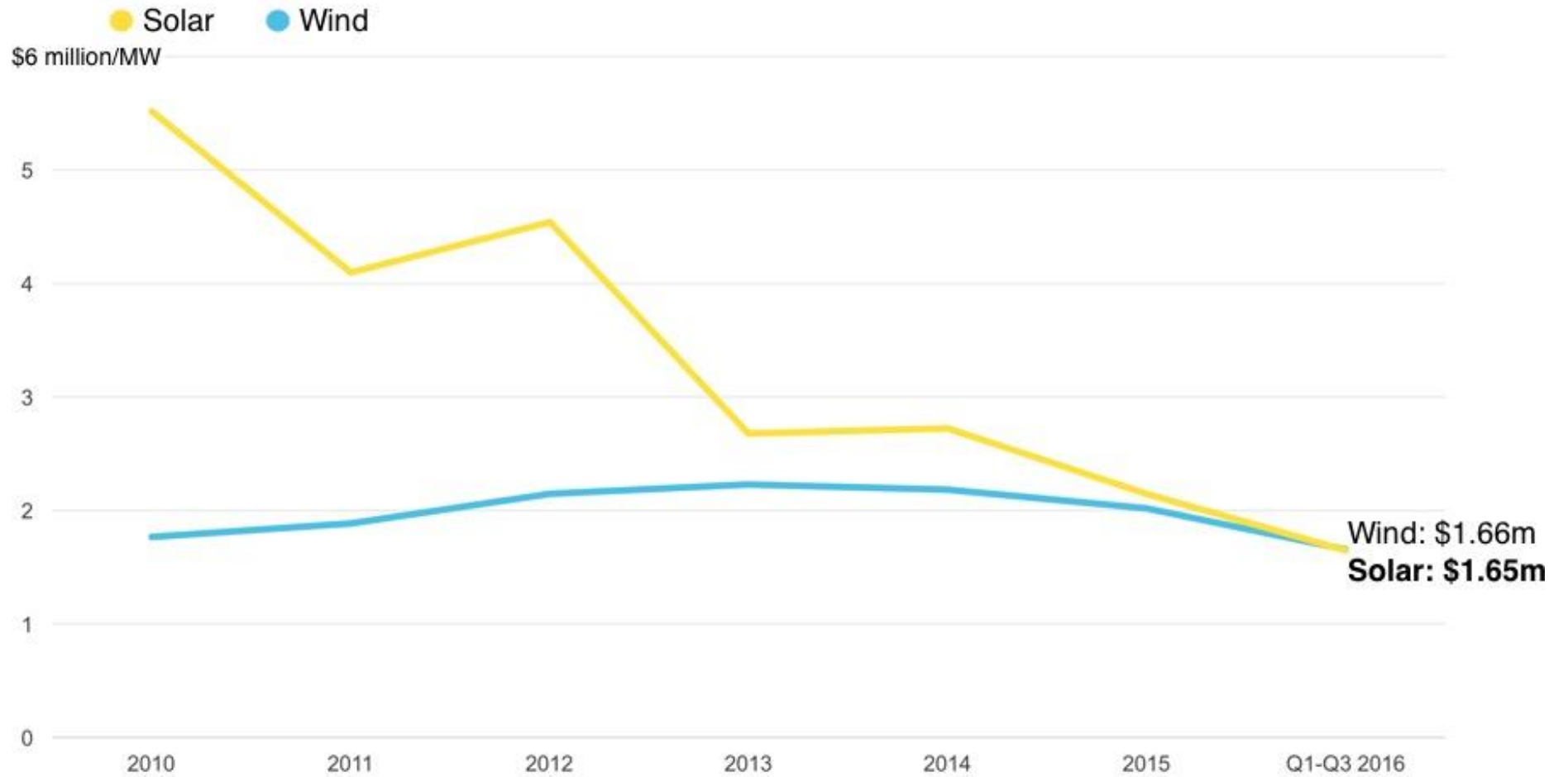
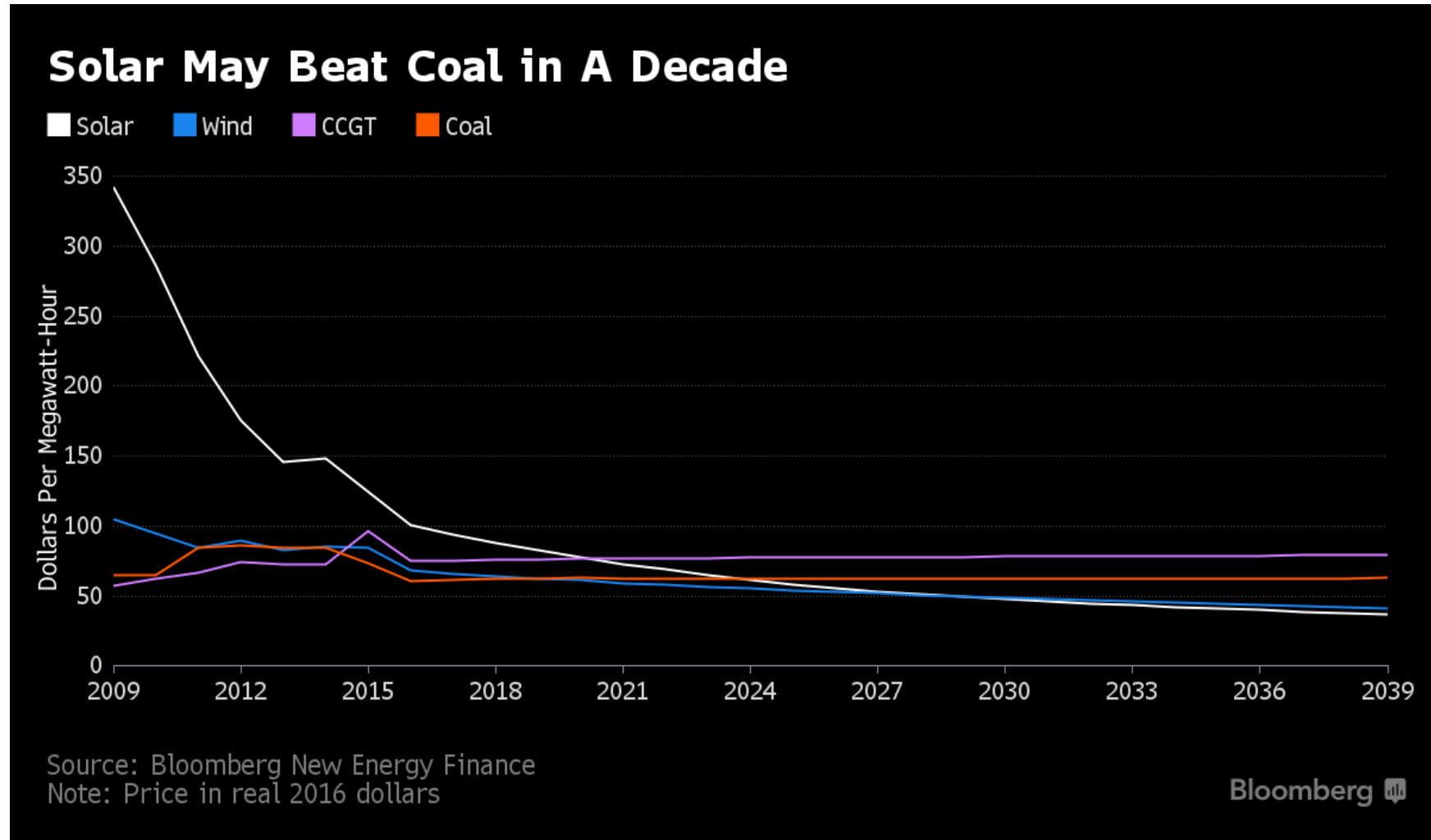


Figure 4.38: Solar & wind energy use may beat coal in a decade



Source: <https://www.bloomberg.com/news/articles/2017-01-03/for-cheapest-power-on-earth-look-skyward-as-coal-falls-to-solar>.

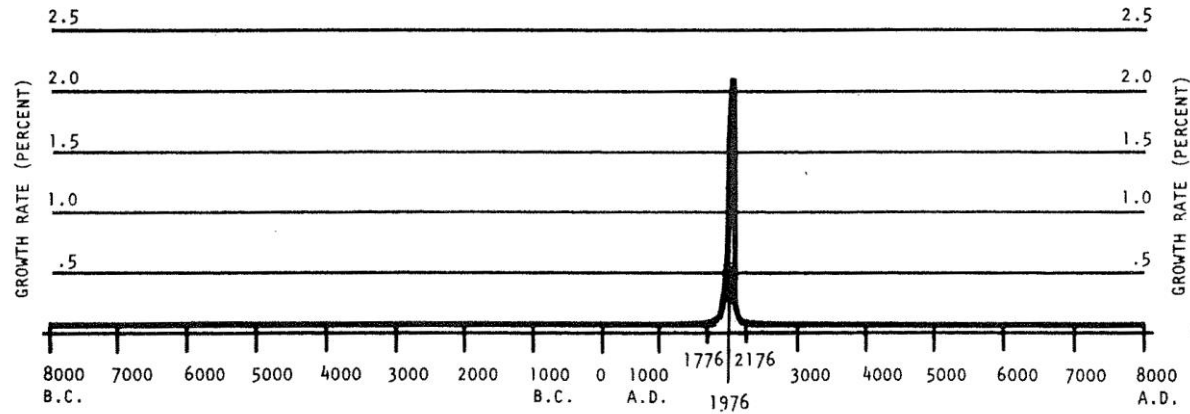
Recapitulation of renewable energy growth

- Fossil fuel reserves are gradually declining, reducing the quality of the remaining stocks (lower energy return on energy invested and lower grade mineral ores).
- For over a century, the rate of technological progress has been able to offset the cost increases due to mineral depletion, but this trend has now come to an end.
- Fossil fuel reserves have now come to the point that productions starting to decline. Peak oil is likely to have occurred in 2015, but the event remained relatively unnoticed as oil prices have not (yet) surged. This could be explained by the increased supply of shale oil and reduced demand since the end of the 2008 crisis.
- The need for energy sources in China has spurred the use of coal to the extent that peak coal is likely to have taken place around the year 2015.
- Peak gas is expected to occur around year 2030 or slightly beyond.
- China has invested so much in renewable energy that the price of, in particular, solar energy has plunged to the extent that it has now become cheaper than fossil in sun rich countries.
- Renewables are now expected to become more cost effective than fossil fuel (including coal) over the next 10 to 20 years.
- New investments in energy production capacity mainly concern renewables. The business model for fossil energy is no longer applicable.

4.6 Technological progress and economic growth

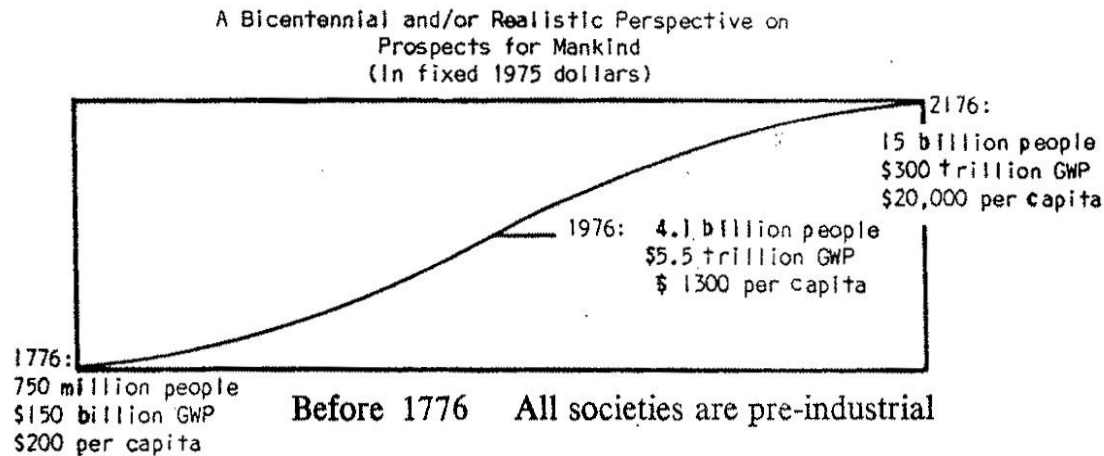
- Since the dawn of human mankind, we have been developing tools and methods to make operations smarter, but the pace of these developments remained slow until the beginning of the Industrial Revolution (see [Chapter 3](#)).
- According to Kahn et al. (1977) there have been two great watersheds in human history, namely, the agricultural revolution that started in the Middle East's Fertile Crescent period some 10,000 years ago and the Industrial Revolution that began in Holland and England about 200 years ago.
- Over the impact of the second watershed, Kahn et al. (1977, p.1) write: *“[T]hat 200 years ago almost everywhere human beings were comparatively few, poor and at mercy of the forces of nature, and that 200 years from now, we expect, almost everywhere they will be numerous, rich and in control of the forces of nature. The 400-year period will thus have been as dramatic and important in the history of mankind as was the 10,000-year period that preceded it”*.
- The ‘Great Transition’ is said to take the following path: *“[T]he growth first of population and later of GWP (Gross World Product) will approximate a flattened s-shaped, or logistical curve, passing from an earlier era of slow growth through the present period of exponential growth to a final levelling-off”*.

Figure 4.39: Technical view of 'Great Transition'



On a very long time scale, the change over the past (and next) about 200 years, is just a spike.

Source: Kahn et al. (1977, p.29) originally adopted from Freeman and Berelson (1974).



Essential to this view is that the physical system (i.e. technological development) follows an s-curve.

Note: The figure presents a conceptual framework. The time frame indicated on the x-axis ranges from the year 1776 to the year 2176. The y-axis represents World Population, GWP, and GWP per capita.

Source: Kahn et al. (1977, p.6).

Intermezzo: Solow's neo-classical growth model

- Economist agree that technological development spurs economic growth.
- According to Robert Solow (1956), a founding father of today's neoclassical growth theory, economic output can be regarded as a function of the production factors labour and capital as well as of the state of technology that is generally referred to as total factor productivity (TFP).
- Solow's model assumes constant returns to scale in case all factors are increased by a similar percentage, and diminishing returns to scale in case only labour or capital are increased. Due to the diminishing returns to scale for individual factors, there is an optimum capital stock to labour ratio that he refers to as the steady state or balanced growth path (hence capital is subject to depreciation, so the maximum amount of capital per worker is limited).
- Once a country has reached its balanced growth path, it can only raise its output per worker by raising the state of technology.
- The growth in the state of technology (i.e. growth of TFP) was initially assumed to be exogenous and defined by means of technological forecasting. Economists later proposed the endogenous growth theory in which economic growth is defined as a function of research efforts.

Solow's neo-classical growth model

- Solow's neo-classical growth model is written as:

$$Y = A * F(K, L)$$

or

$$Y/L = A * F(K/L)$$

with:

Y = Economic output

A = State of technology (or TFP)

K = Capital

L = Labour

with:

Y/L = Economic output per worker

A = State of technology

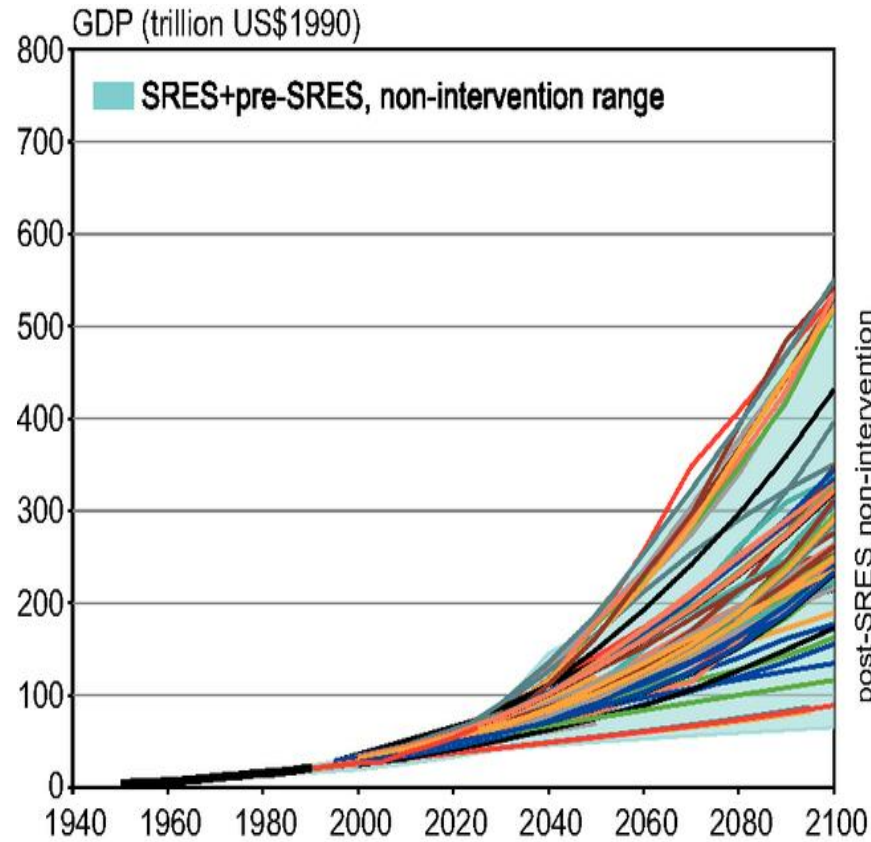
K/L = Capital intensity of labour

- When a country reaches its optimal long-term path for a capital to labour ratio K/L^* , it can only continue to increase its output per worker by improving its state of technology A (i.e. its total factor productivity).
- In order to anticipate a country's long-term growth path, estimates of changes in total factor productivity (TFP) and the size of the labour force, are required; these are a function of working age population and the degree of labour participation (which in turn is linked to the unemployment rate).
- Later models also include the quality of labour (i.e. the human capital).

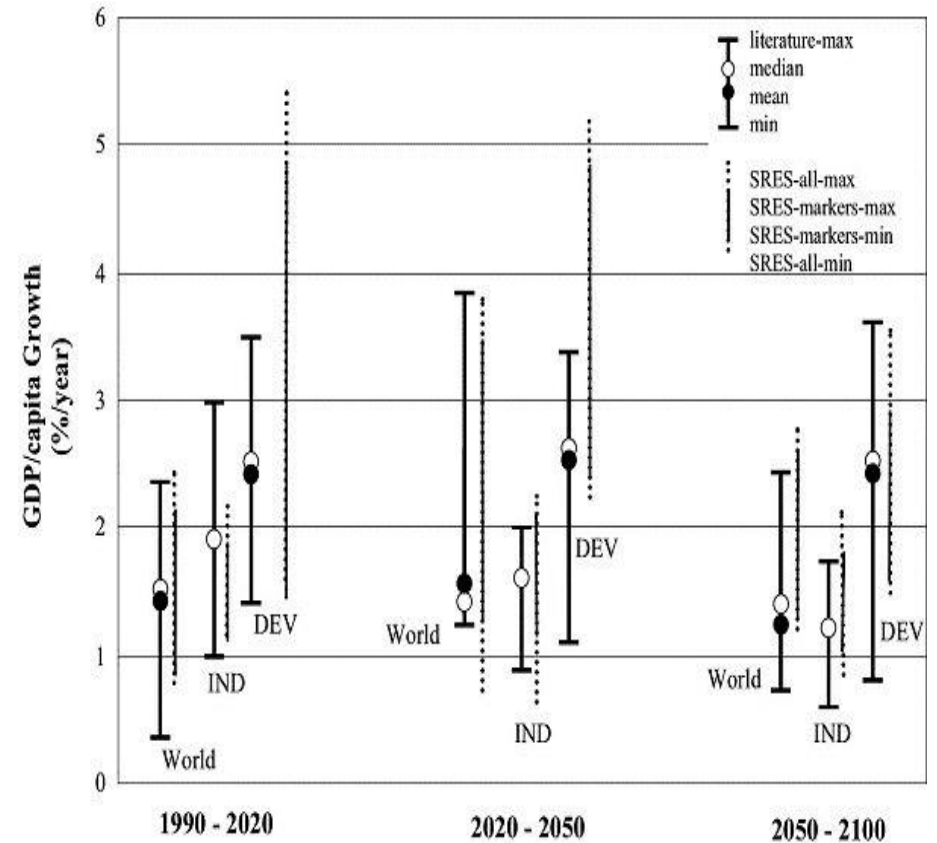
Mainstream neo-classical growth assumptions

- Without intending to create a strawman (and with our excuses if partly doing so), we argue that the present neo-classical paradigm for economic growth is not in line with the “great transition” and violates the laws of physics.
- The neoclassical growth paradigm is based on the following assumptions:
 1. It more or less assumes that the economy will remain growing at an exponential rate. Neoclassical economists argue that the lower growth rates over the past (few) decade(s) are exceptional from a long-term perspective (last 200 years since the beginning of the Industrial Revolution), and that higher growth rates are likely to be restored in the next decades. It ignores the physical constraint that technological development follows a centuries-long transition process, i.e. an s-curve.
 2. It further assumes that in the long run, price adjustments will incline towards a situation of full employment, ignoring the existence of minimum wages. This implies that economic output is considered supply driven i.e. economic output follows technological progress and labour productivity. It ignores the possible effects of increasing unemployment, due to ongoing automation and increasing inequality, on the demand side of the economy.

Figure 4.40: Mainstream assumption of exponential GDP growth



Source: IPCC (2007, p.180).



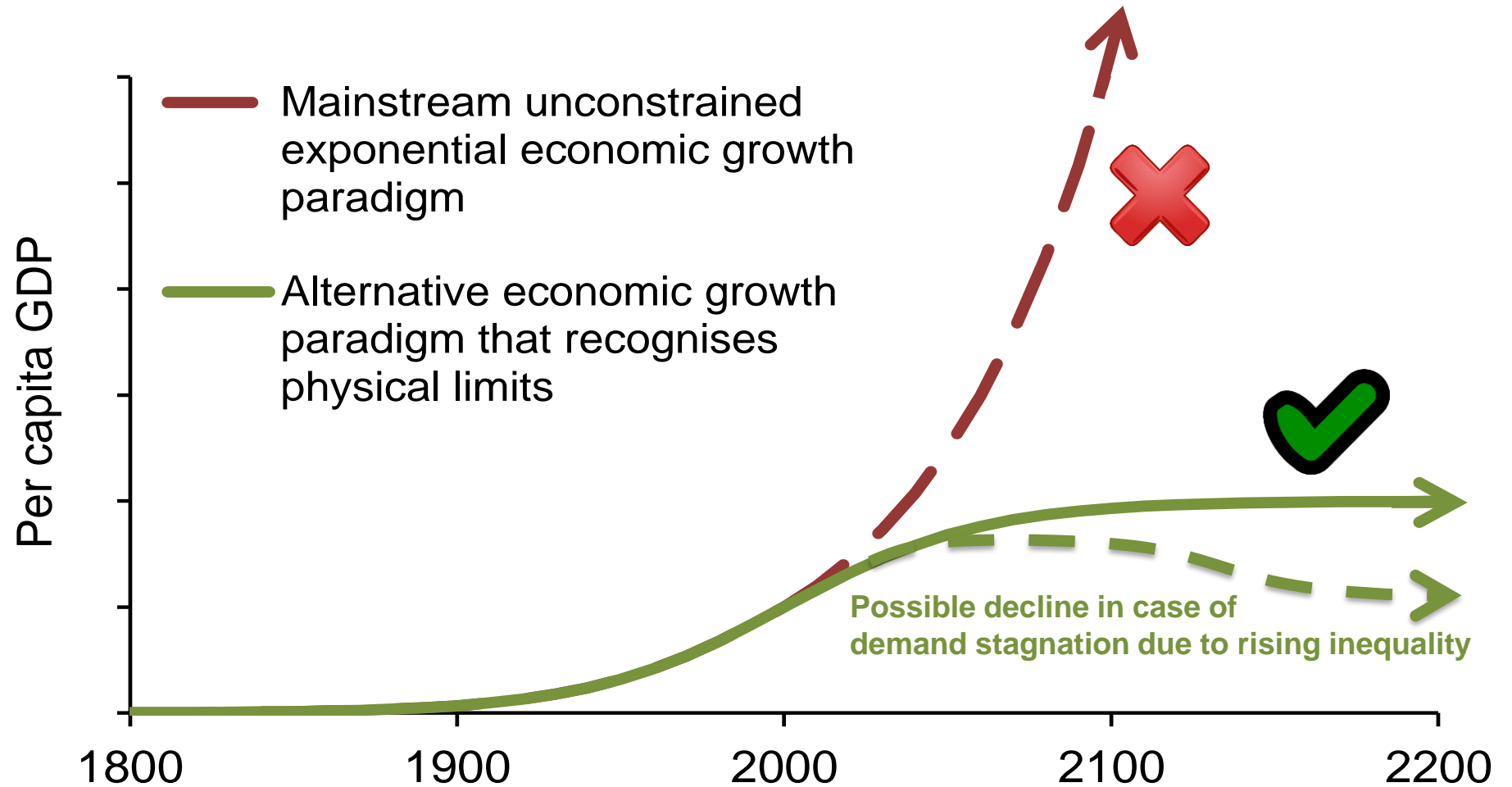
IPCC (2000, p.119).

The exponential nature of official growth scenarios is clearly illustrated by IPCC scenarios as well as other official scenarios published by governmental institutes.

Reasoning behind an alternative paradigm on economic growth

- From a very long-term perspective, ongoing exponential growth seems illogical.
- With respect to the **supply side** of economic output, Van Dorsser (2015, p.113) concluded that: *“For the preparation of very long term economic growth projections I propose to define a new post-neo-classical paradigm on economic growth that departs from the same neo-classical Solow (1956) model but imposes one additional restriction namely that the state-of-the-art labour productivity in technological frontier countries is ultimately constrained by physical limits and therefore follows some kind of s-shaped transition curve that moves towards a still unknown (and unpredictable) horizontal asymptote on the very long term (say a few hundred to a thousand years from now). This paradigm is in line with the physical views on economic growth and the more recent insights from the field of semi-endogenous economic growth modelling, but it clearly breaks with the mainstream neo-classical view of ongoing exponential growth that has been widely adopted since the development of the first generation of endogenous growth models in the 1980s.”*
- With respect to the **demand side** of the economy, more recent insights Van Dorsser, 2016), indicate the risk of much higher levels of unemployment and lower economic output due to ‘secular stagnation’ (i.e. inability to enhance economic output by lowering interest rates) and increasing levels of inequality.

Figure 4.41: Different paradigms on economic growth



Note: figure shows authors view on how to interpret the very long term trend in the per capita GDP output. Figure based on further elaboration of Van Dorsser (2015)

Supply-side considerations

- Economists state that whether the growth of knowledge and TFP is subject to increasing, constant or decreasing returns to scale, is an empirical question (CPB, 2015). We argue that this only applies on a temporary time scale. Our physical reality is bound by limits, and our understanding of the physical system and our capacity for technological development (and TFP growth) is ultimately bound to move towards this limit – and therefore subject to diminishing returns.
- As explained by Fernald and Jones (2014), we have been able to offset the effects of decreasing returns to scale in knowledge development over the past 200 years (characterised by unprecedented labour productivity growth), by an increase in education and research output. However, exponential growth of useful knowledge cannot continue endlessly due to the existence of physical reality.
- Eventually, due to diminishing returns on knowledge development, even linear growth will require exponential knowledge growth, whereas until now it required an exponential growth in education and research efforts. So even if we succeed in making our brains ‘obsolete’ and successfully shift to research based on artificial intelligence (assuming that this is feasible), the amount of energy required will continue to grow exponentially, until it reaches the limits of our universe.

Supply-side considerations

- For those who consider the argument of ultimate limits to ever advancing knowledge development irrelevant for assessing a time period of a few hundred to a thousand years ahead (e.g. those of the opinion that we are just awaiting a new breakthrough technology), the assumption that the economy is moving towards a steady non-zero growth rate, is also not realistic.
- To give an example based on Van Dorsser (2015). If the 2.1% growth rates used in the high scenario of the Dutch Delta Programme (defined up to the year 2100) are extrapolated for the remainder of this millennium, it would imply that some 770 years from now, the entire output of today's Dutch economy is produced by just one person, which is hard to believe.
- Even Leonhard (2016), who claims that we are nearing the point of accelerated exponential technological growth (or “the Singularity”), distinguishes between aspects that **can** and **cannot** be automated.
- Leonhard makes a distinction between two different processes. He refers to the processes that can be automated as STEM (Science, Technology, Engineering, and Mathematics) and to processes that require human capabilities as CORE (Creativity/Compassion, Originality, Reciprocity/Responsibility, and Empathy). This distinction is very important.

Supply-side considerations

- If we assume two workflows STEM and CORE, and assuming that STEM workflows can be improved at an exponential rate (disregarding decreasing returns), and CORE workflows cannot be improved (assuming zero growth), the share of CORE workflows will gradually increase until the share of STEM becomes insignificant – ultimately leading to a zero growth rate.
- This argument is similar to an argument often used to explain the decrease in labour productivity growth since the 1970s, namely that productivity growth is harder to achieve in the newer service sector of the economy.
- Summing up, we would expect decreasing technological growth rates (i.e. TFP growth rates) over time, which is confirmed by empirical data.
- Other factors directly contributing to the growth of labour productivity (and hence economic output from the supply side), are the capital goods available and the quality of labour (or human capital).
- In advanced nations the level of capital per worker is already high and subject to decreasing economies of scale. Moreover, the level of education is already high and possibly about to reach a ceiling (as good education is no longer a guarantee for a well paid job and not worth the risk of taking a loan).

Figure 4.42: 200 years exponential growth in per capita GDP

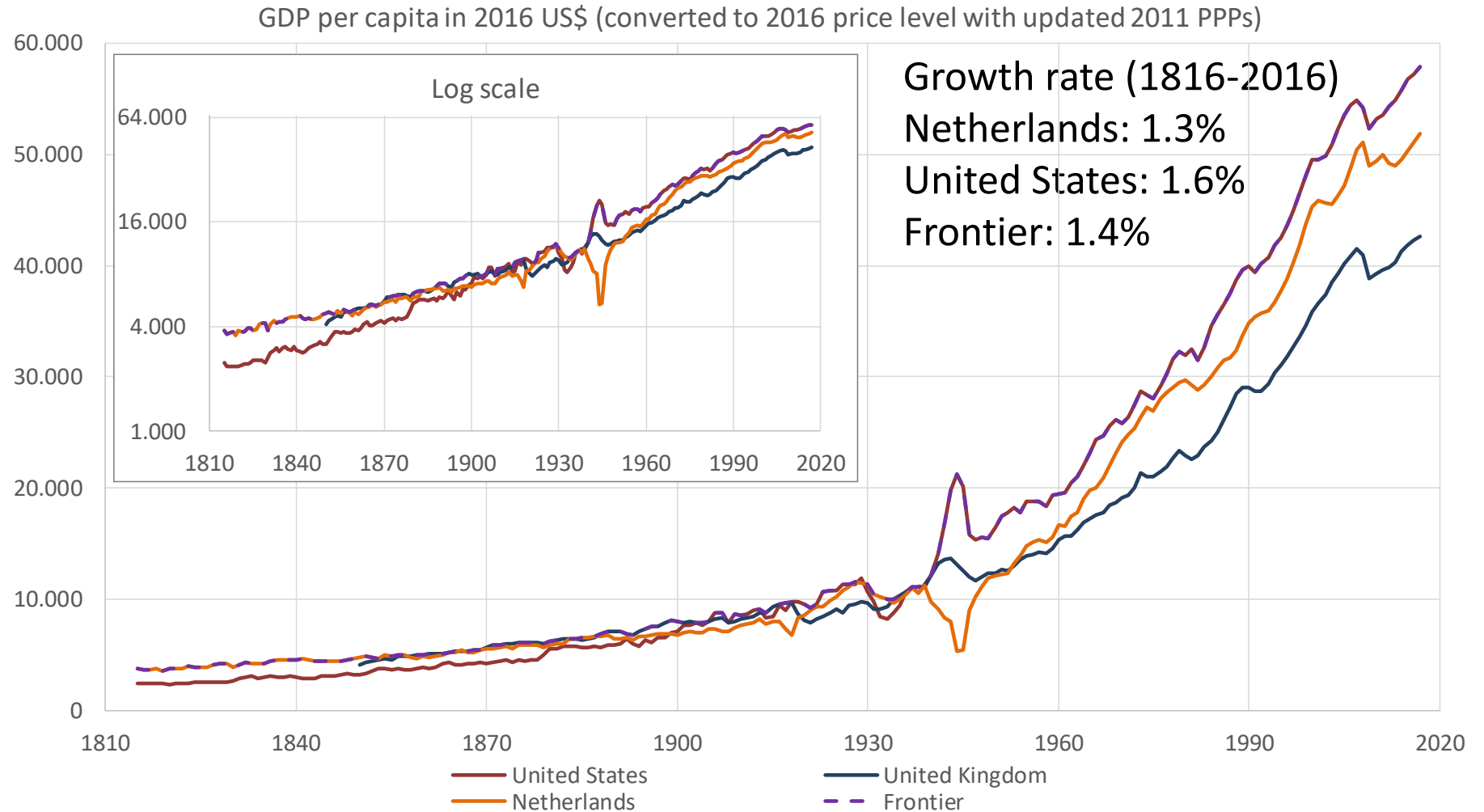


Figure 4.43: Per capita GDP growth at technological frontier

Frontier per capita GDP growth in 2016 US\$ (converted to 2016 price level with updated 2011 PPPs)

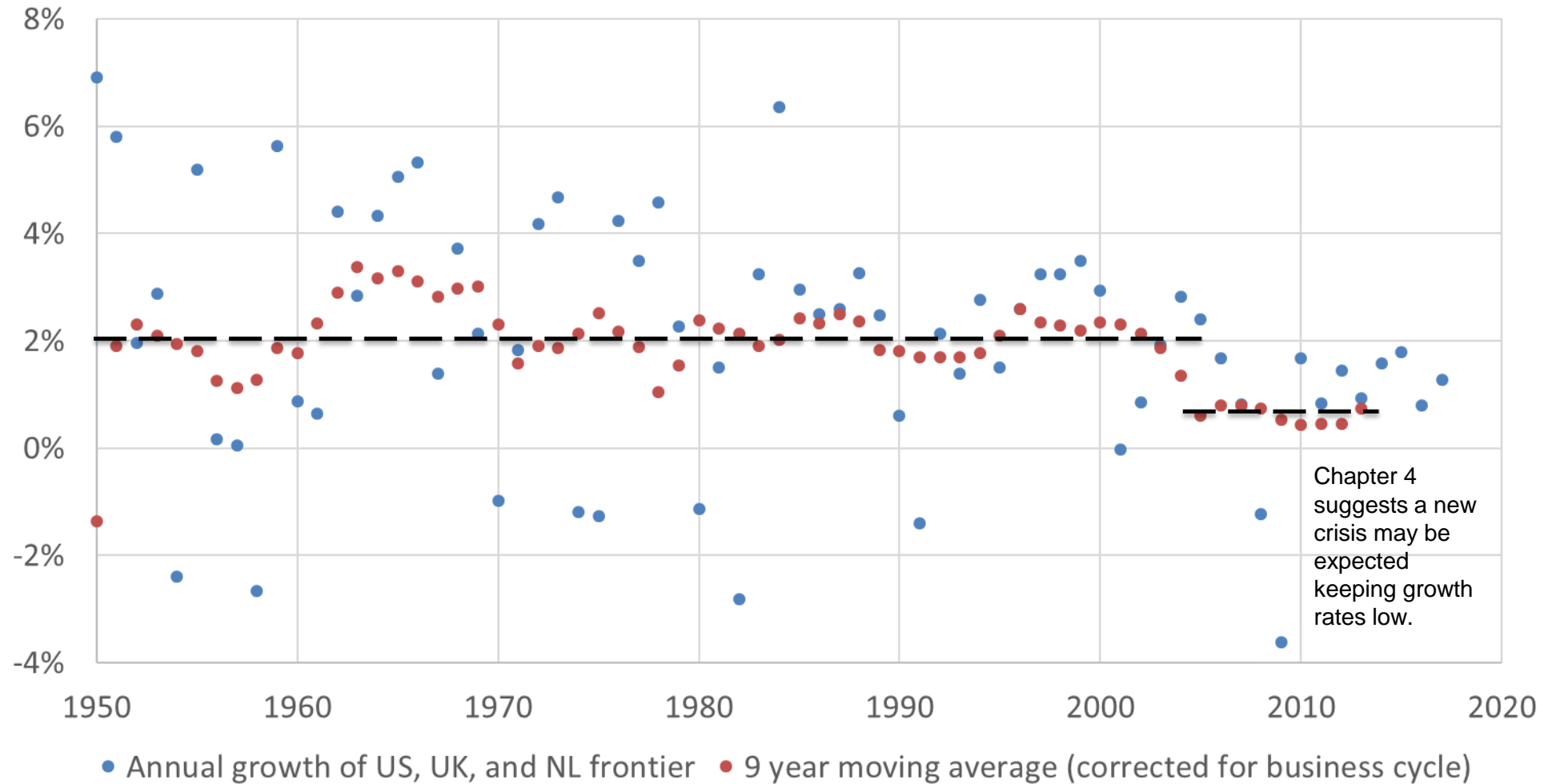


Figure 4.44: Per hour work GDP output at technological frontier

Technological frontier output per worked hour, OECD Countries
in 2016 US\$ (converted to 2016 price level with updated 2011 PPPs)

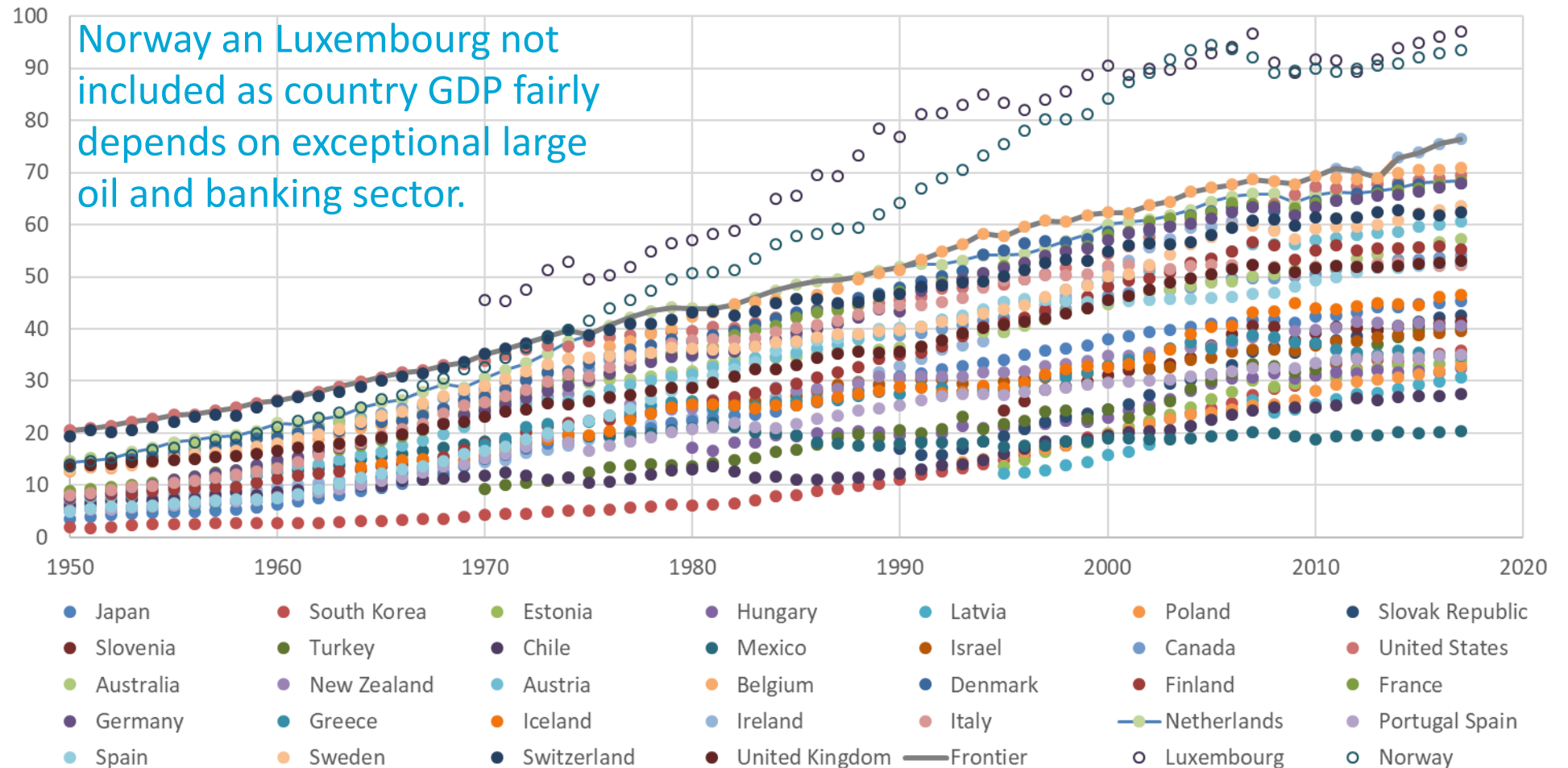
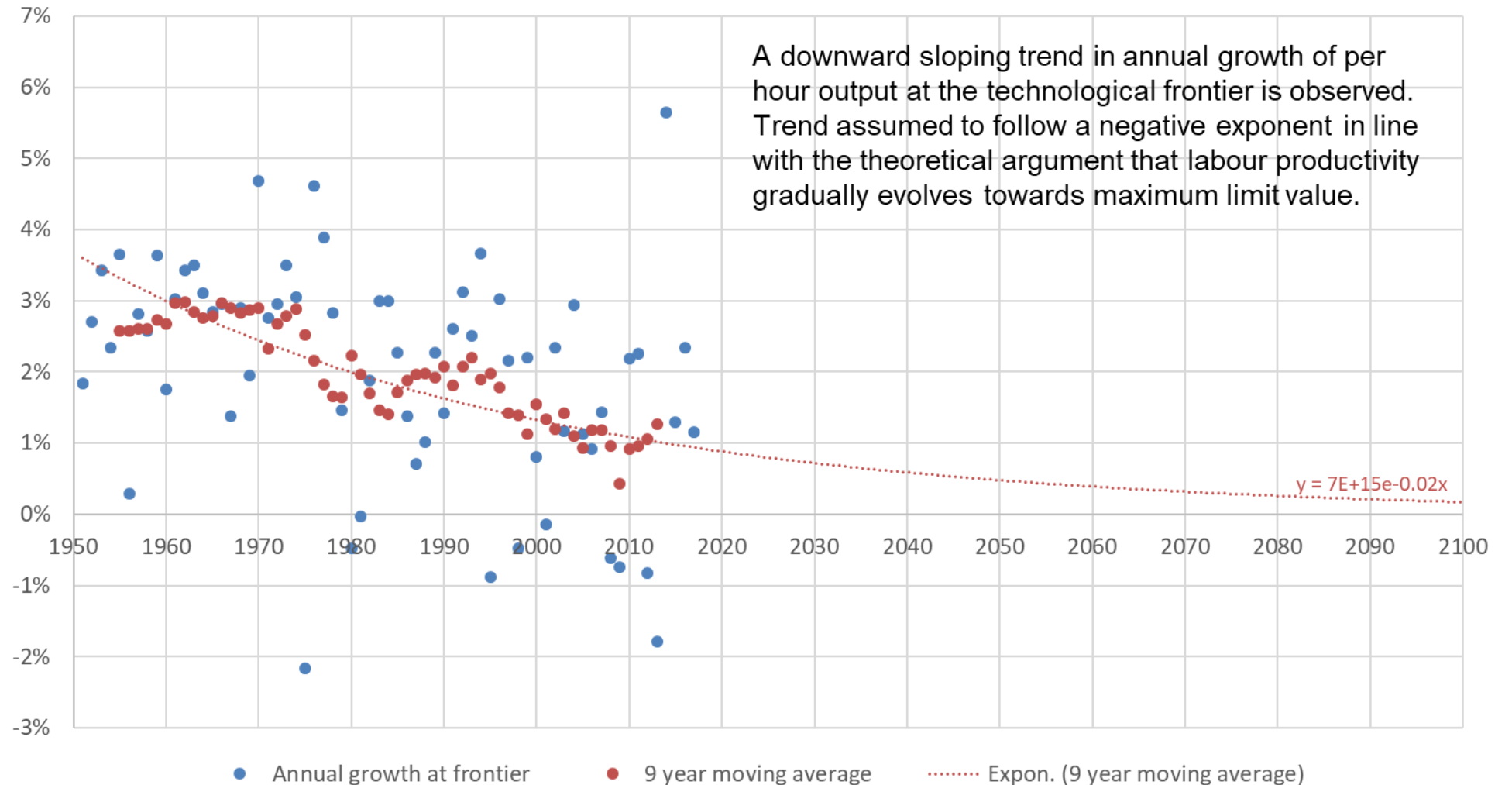


Figure 4.45: Per hour GDP growth at technological frontier

Annual growth of labour productivity at frontier of OECD countries (excl. Norway and Luxembourg)



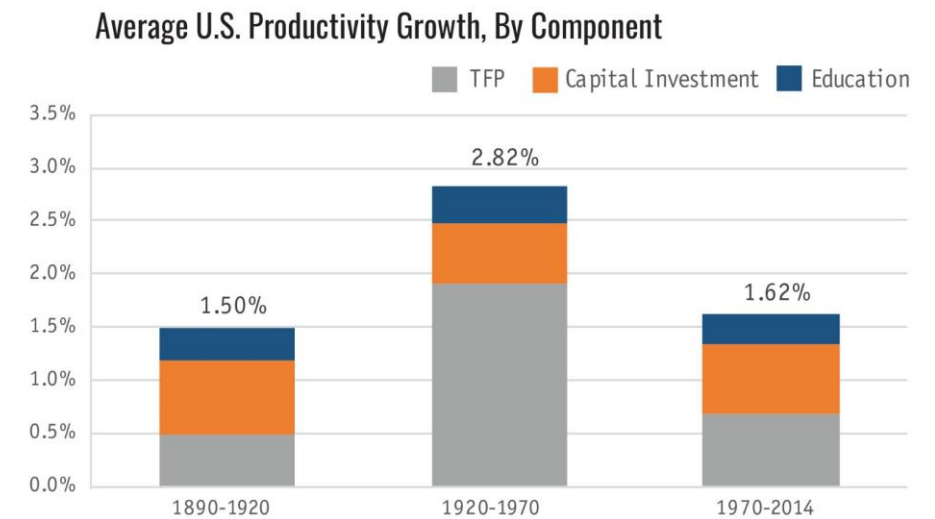
Data: The Conference Board Total Economy Database™ (Original version), May 2017

Figure 4.46: Growth of labour productivity in United States



Main drivers

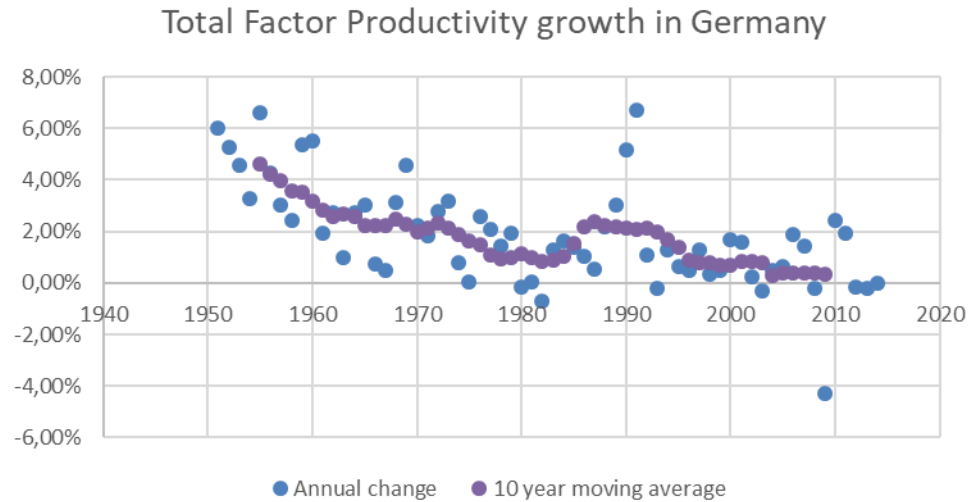
- Total Factor Productivity
- Real capital accumulation
- Human capital accumulation



Source: Data obtained from Gordon (2016)

Source: <http://s3.amazonaws.com/content.thirdway.org/publishing/images/files/000/001/941/Productivity-charts-new.jpg?1456869880>; Based on Gordon (2016).

Figure 4.47: Trend in growth of total factor productivity



Clear decline in growth of total factor productivity in Germany and the Netherlands since 1950. Trend less clear for USA, but also clear decline over last decade.

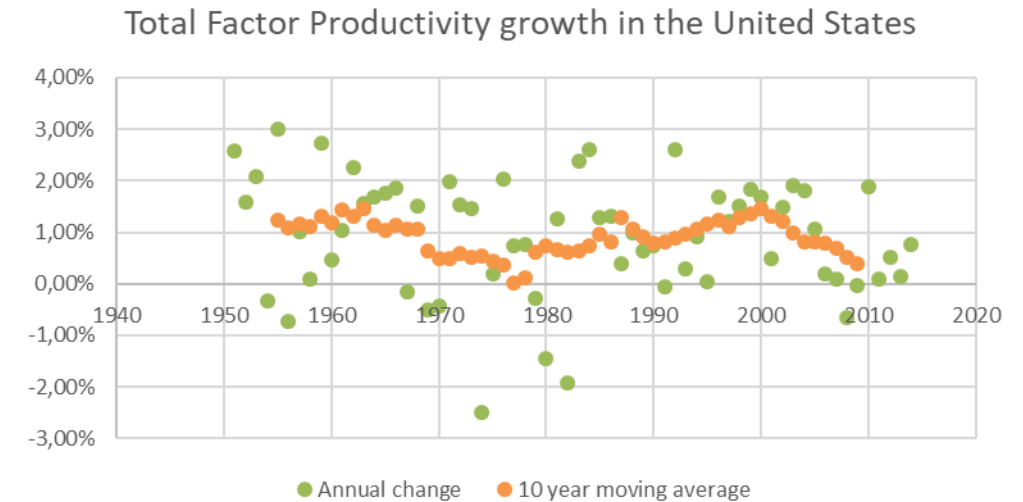
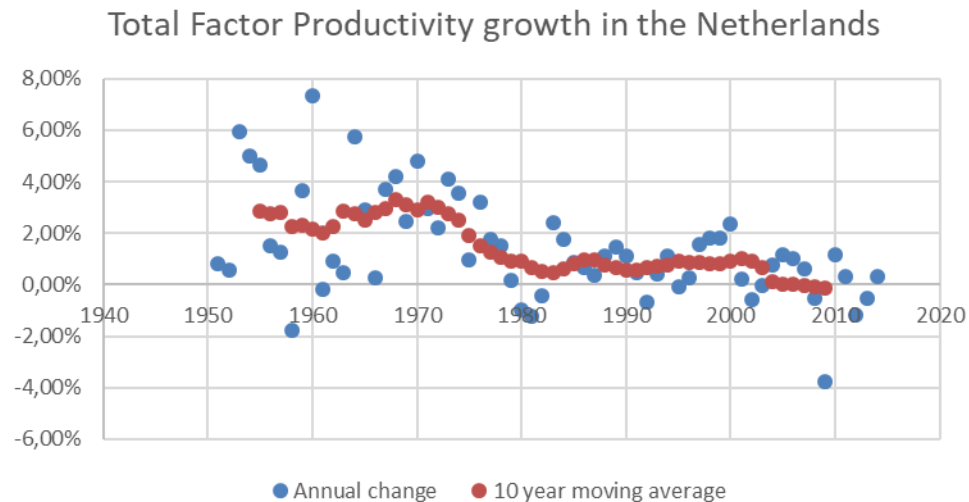


Figure 4.48: Total Factor Productivity growth since 1990

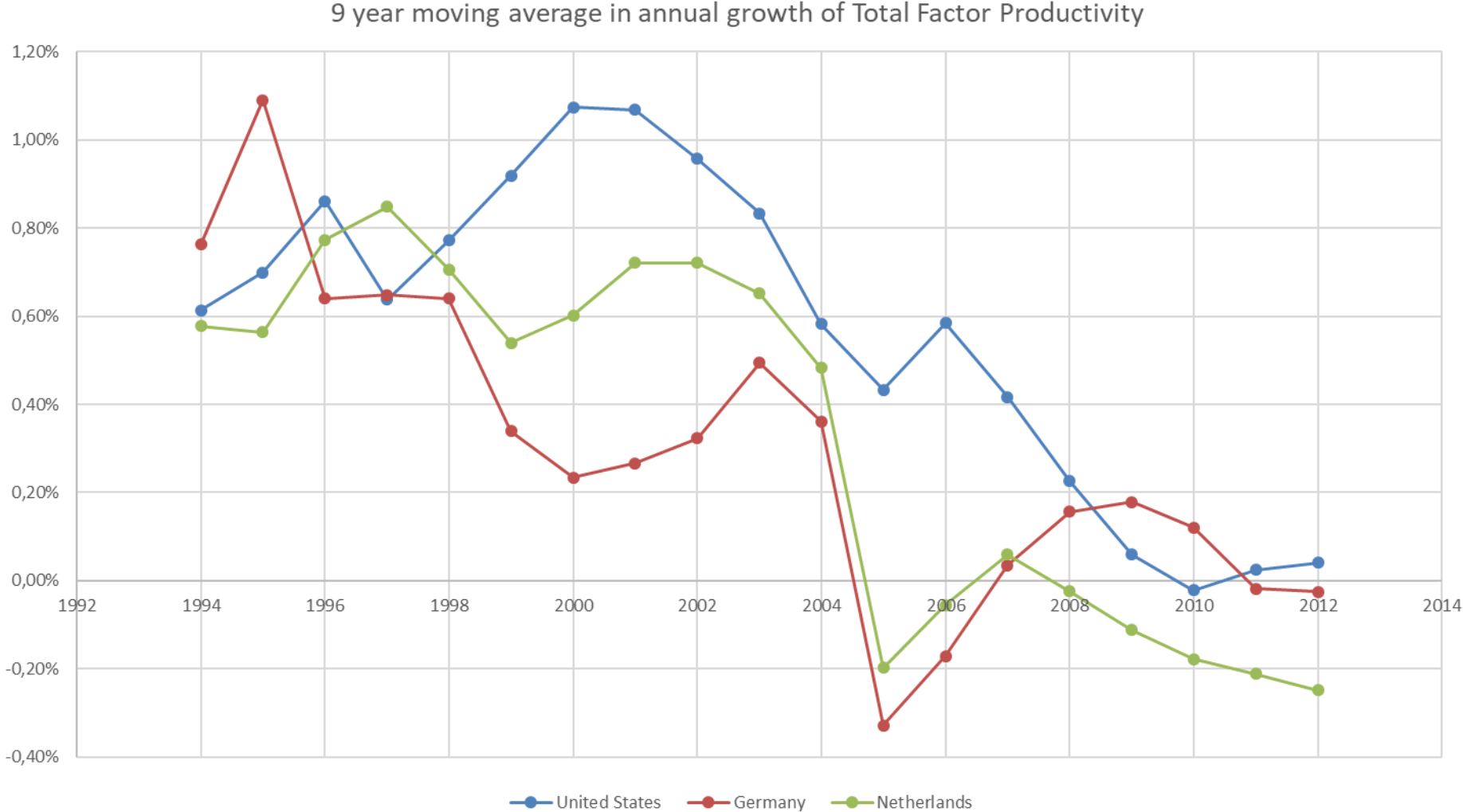
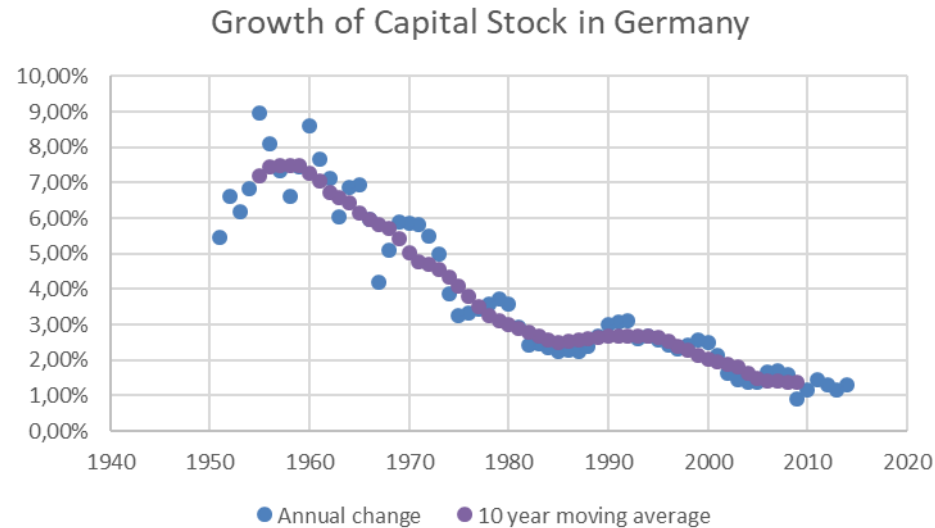


Figure 4.49: Trend in growth of capital



Steady decline in growth of capital stock in Germany and the Netherlands since 1950. Sharp decline in growth of capital stock for USA over last decade.

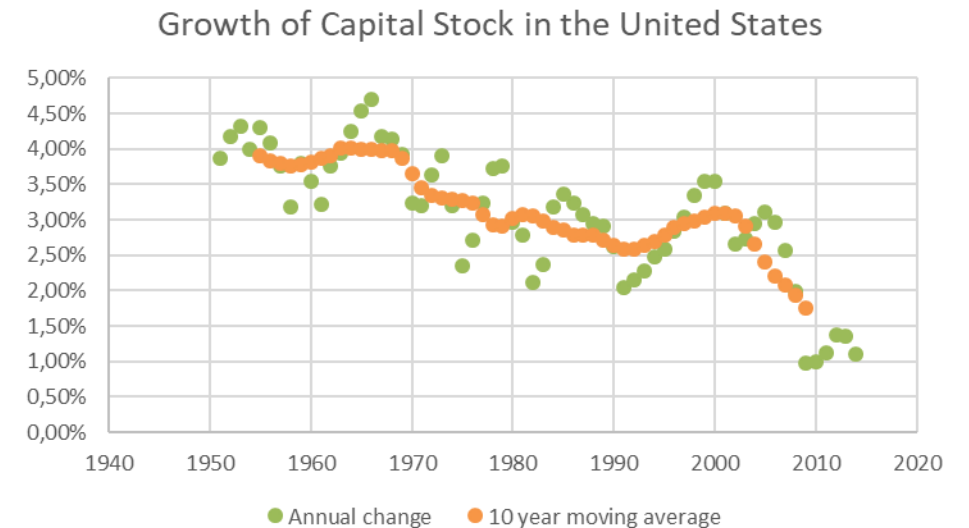
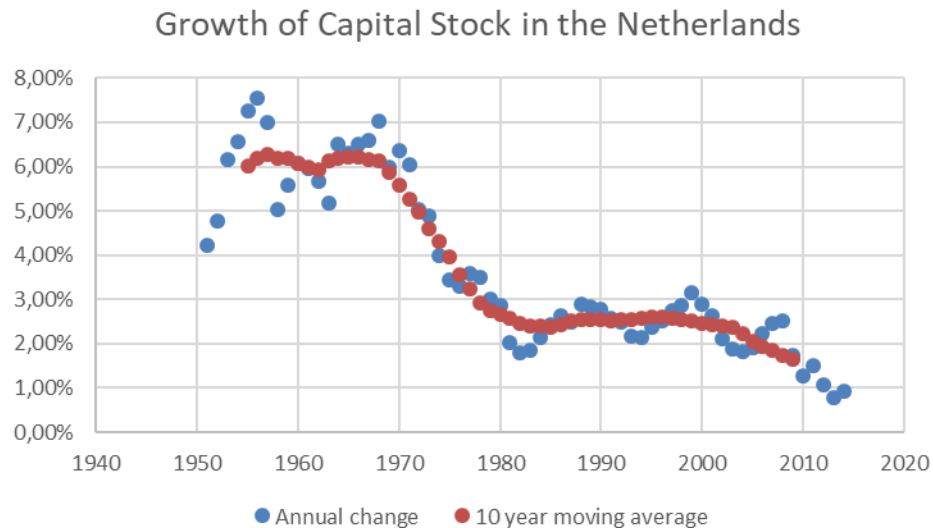
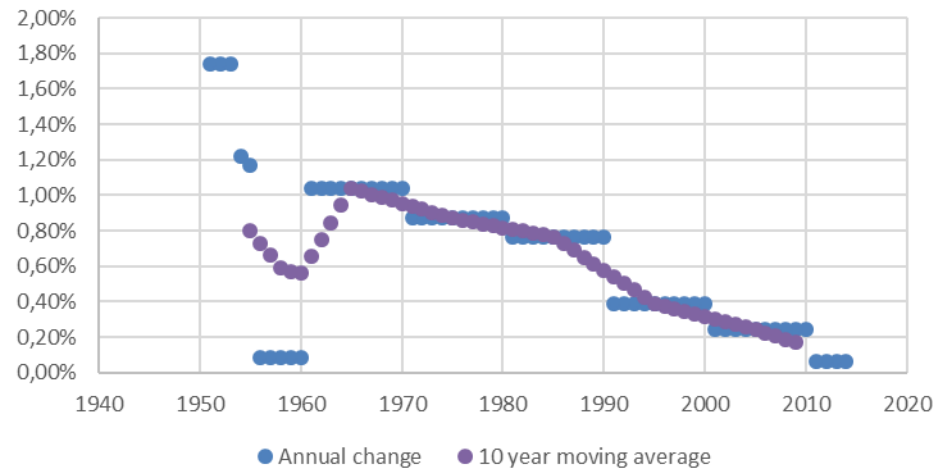


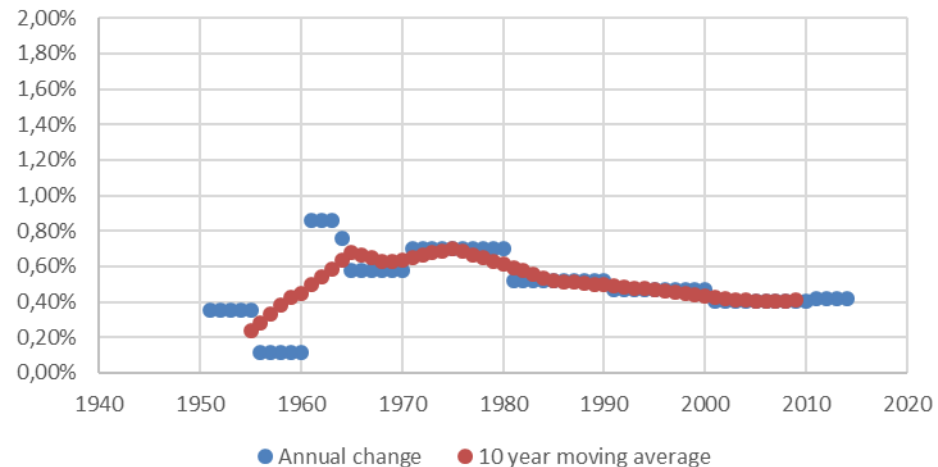
Figure 4.50: Trend in growth of human capital

Growth of Human Capital in Germany

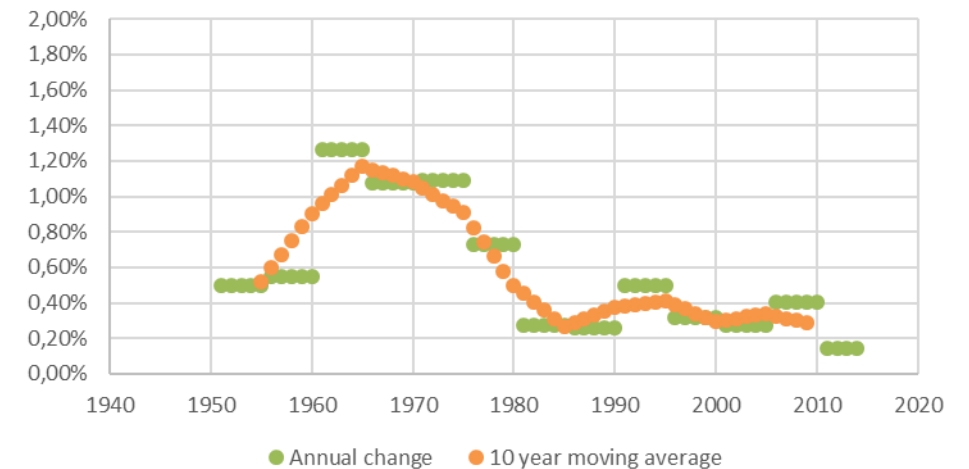


Growth of human capital index, based on years of schooling and return to education, has shown a substantial decline since the 1970s, but may now temporarily stabilise at low growth rate.

Growth of Human Capital in the Netherlands



Growth of Human Capital in the United States



Demand-side considerations

From the demand side of the economy, the following considerations on the growth of economic output are important:

1. Automation, robotics and artificial intelligence are lowering the demand for unskilled and middle income labour.
2. Share of labour compensation in GDP is declining, resulting in a decline of middle class income and growing levels of inequality, ultimately reducing demand for economic goods and thereby reducing economic output and labour demand.
3. As wealthy people trend to consume only a small fraction of their income, growing levels of inequality increases the demand for (low risk) investment opportunities – thereby ‘pushing’ interest rates down.
4. Central banks have long been able to pursue economic growth by increasing the money supply and lowering interest rates. But with interest rates near or even below zero (i.e. near secular stagnation, or inability to enhance economic output by lowering interest rates) in Europe and Japan, the end of this practice is in sight meaning that unemployment rates may increase considerably in the future due to inability of central banks to stimulate the economy. This signals a possible trend breach from a long period of relatively high levels of employment.

Threat of automation, robotics and artificial intelligence

- Frey and Osborne (2013) indicate that 47% of the jobs in the USA is at risk of being automated over next 2 decades.
- Deloitte (2014) estimated for the Netherlands that at least 2 million (28%), and up to 3 million (42%) of the 7,2 million workers are at a risk of losing jobs due to automation.

INNOVATION

Chinese factory replaces 90% of humans with robots, production soars

Changing Precision Technology Company in Dongguan city has set up an unmanned factory run almost entirely by robots. The factory has since seen fewer defects and a higher rate of production.

By Conner Forrest | July 30, 2015, 11:30 AM PST

<http://www.techrepublic.com/article/chinese-factory-replaces-90-of-humans-with-robots-production-soars/>

Pandit Says 30% of Bank Jobs May Disappear in Next Five Years

By Chanyaporn Chanjaroen

13 september 2017 05:57 CEST Updated on 13 september 2017 08:18 CEST

<https://www.bloomberg.com/news/articles/2017-09-13/ex-citi-ceo-pandit-says-30-of-bank-jobs-at-risk-from-technology>

Japanese company replaces office workers with artificial intelligence

Insurance firm Fukoku Mutual Life Insurance is making 34 employees redundant and replacing them with IBM's Watson Explorer AI

<https://www.theguardian.com/technology/2017/jan/05/japanese-company-replaces-office-workers-artificial-intelligence-ai-fukoku-mutual-life-insurance>

AI will soon replace hundreds of thousands of public sector workers – and that's a good thing

ANDREW HALDENBY

5 FEBRUARY 2017 • 10:00PM

<http://www.telegraph.co.uk/news/2017/02/05/ai-will-soon-replace-hundreds-thousands-public-sector-workers/>

Figure 4.51: Declining share of labour compensation in GDP

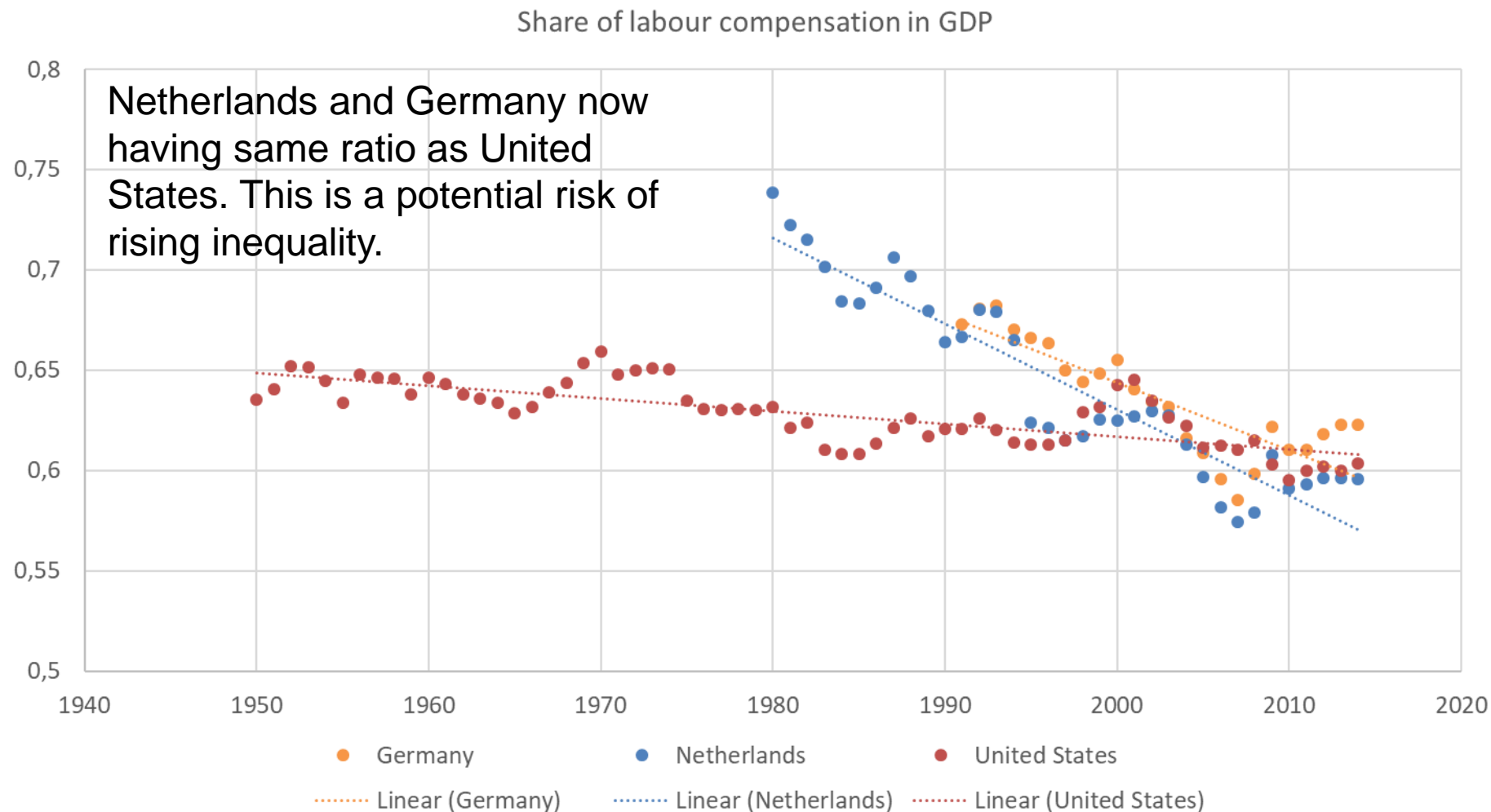
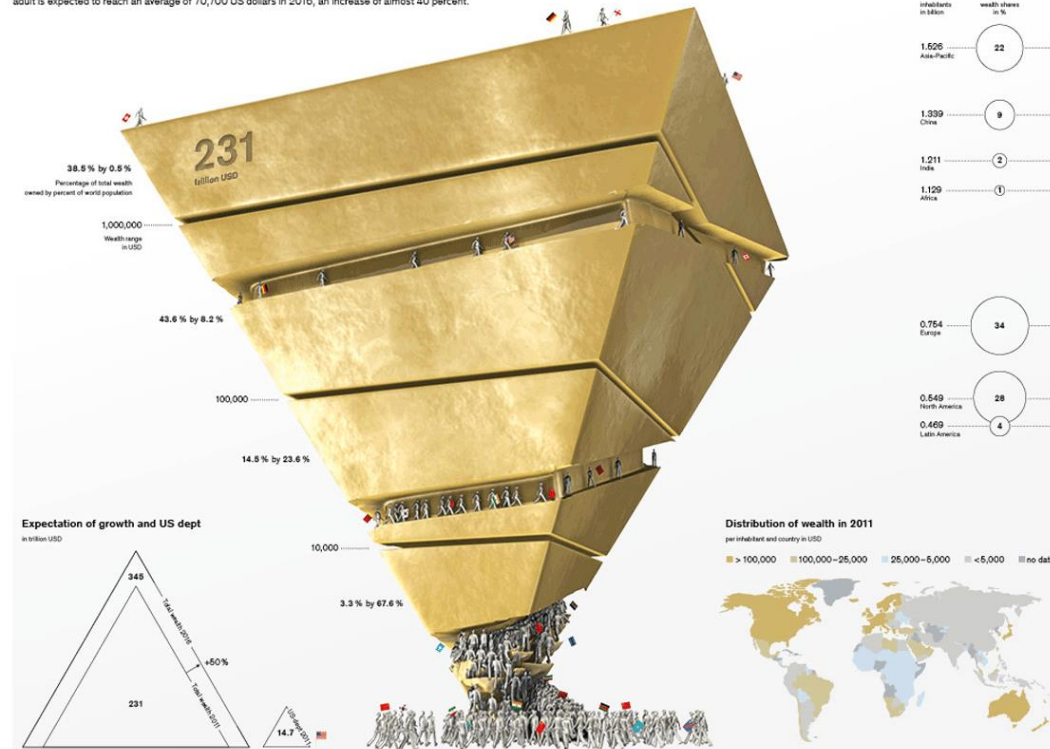


Figure 4.52: Global income and wealth inequality

World's 8 richest billionaires have same wealth as poorest 50%. This was still 63 people in 2016, but now only 8 in 2017 (Oxfam international, 2017).

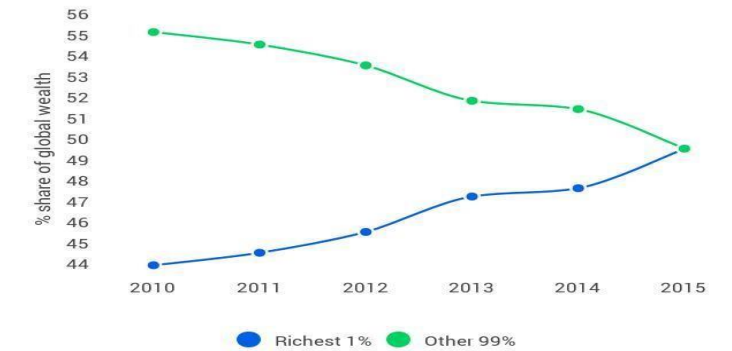
Global Wealth Pyramid

An estimated 4.5 billion adults' personal wealth totaled 231 trillion US dollars in 2011. The number of wealthy people at the top of the pyramid equals about one percent of the global population. Total household wealth is expected to rise by 50 percent in the next five years to 345 trillion US dollars, an increase equal to 8.4 percent growth per year. Net worth per adult is expected to reach an average of 70,700 US dollars in 2016, an increase of almost 40 percent.



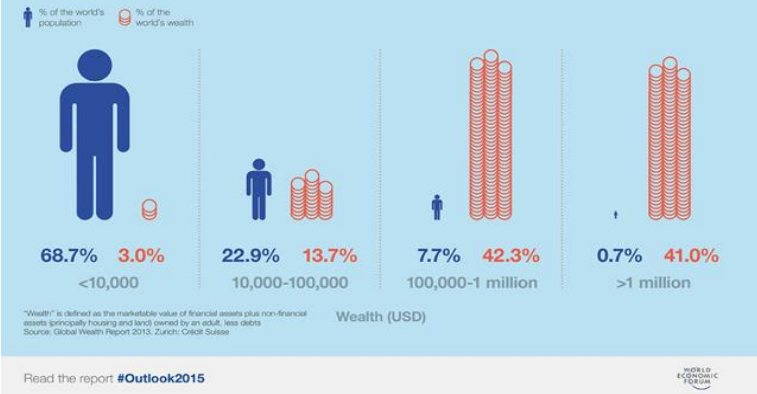
<https://i.pinimg.com/originals/b6/7a/c0/b67ac0b3a6dde1f0e1d47af81d8899df.jpg>

Share of global wealth 2010-2015



<https://weforum-assets-production.s3-eu-west-1.amazonaws.com/editor/Tvkf1fE7KasBTIGlv78BrJKad6FncJKO4luXuNCnE7I.JPG>

How is the world's wealth shared amongst its population?

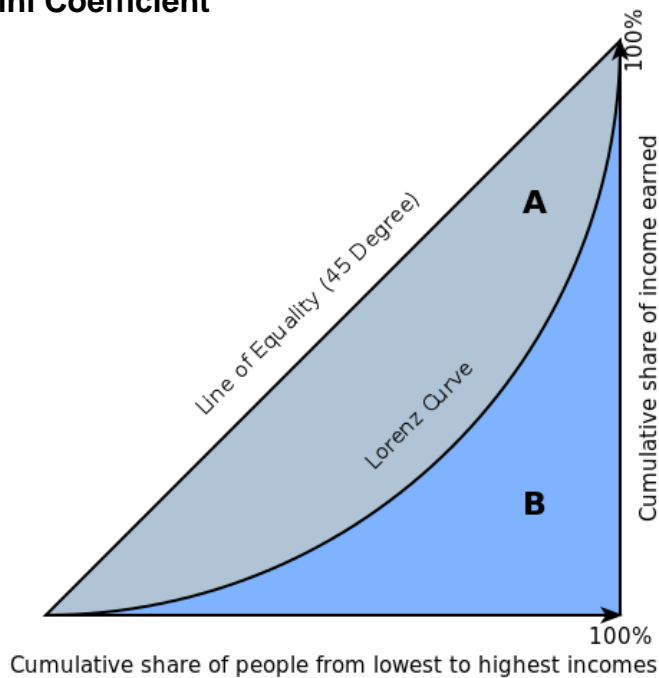


http://assets.pewresearch.org/wp-content/uploads/sites/12/2014/11/FT_WEF-inequality.jpg

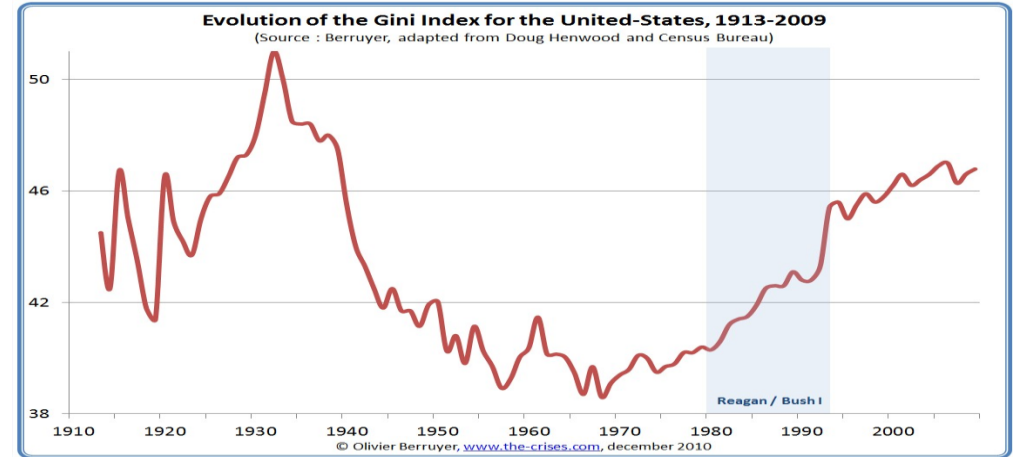
Intermezzo Gini-coefficient

Gini-coefficient is used to measure inequality in a country. The function is defined as $A / A+B$ in figure below.

Gini Coefficient



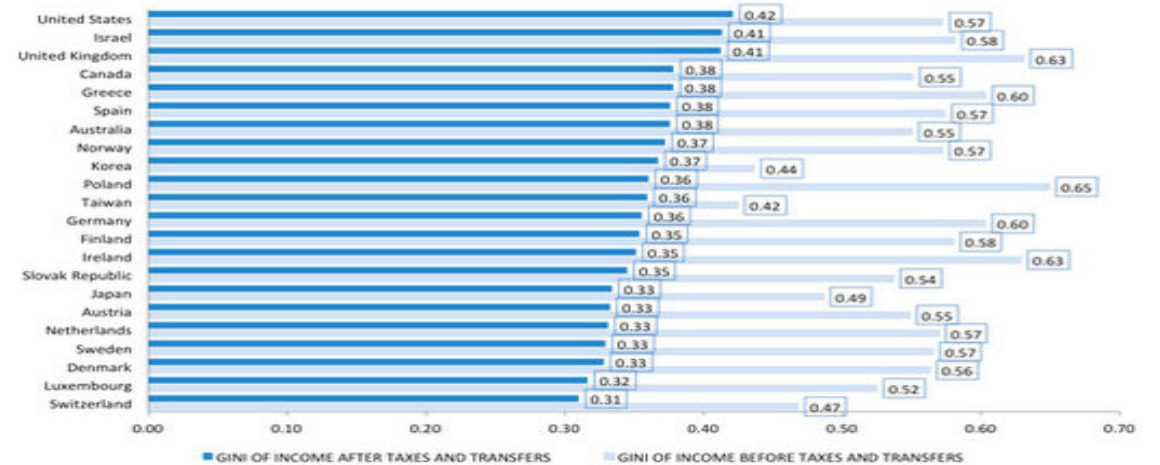
<https://nl.wikipedia.org/wiki/Gini-co%C3%ABffici%C3%ABnt>



<http://www.the-crises.com/wp-content/uploads/2010/12/gini-index-usa.jpg>

Income Inequality and Redistribution

The U.S. government does less than many other rich countries to reduce market-generated income inequality.



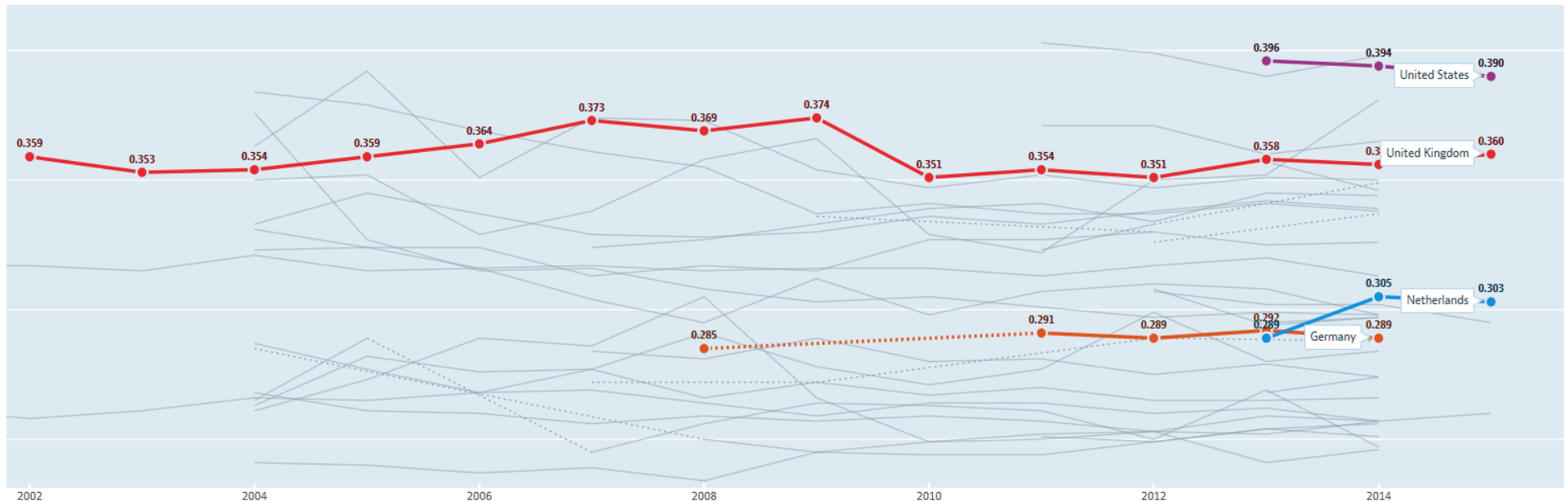
Source: Author's calculations, 2013, based on LIS microdata, most recent datasets available (early to mid-2000s)

https://cdn.static-economist.com/sites/default/files/images/2013/11/blogs/democracy-america/screen_shot_2013-11-027.jpg

Figure 4.53: Effect of inequality on GDP output

- Brueckner, M and D Lederman (2015) find that on average, a 1 percentage point increase in the Gini coefficient reduces GDP per capita by around 1.1% over a five-year period; the long-run (cumulative) effect is larger and amounts to about -4.5%.
- If we “bluntly” use this number, it would imply that the long-term effect of an increase from the Dutch situation (Gini of 0.303) to the U.S. situation (Gini of 0.390), would result in an almost 40% loss of economic production (8.7 percent points * 4.5% = 39.15%). **Inequality can thus have a severe impact on GDP!**

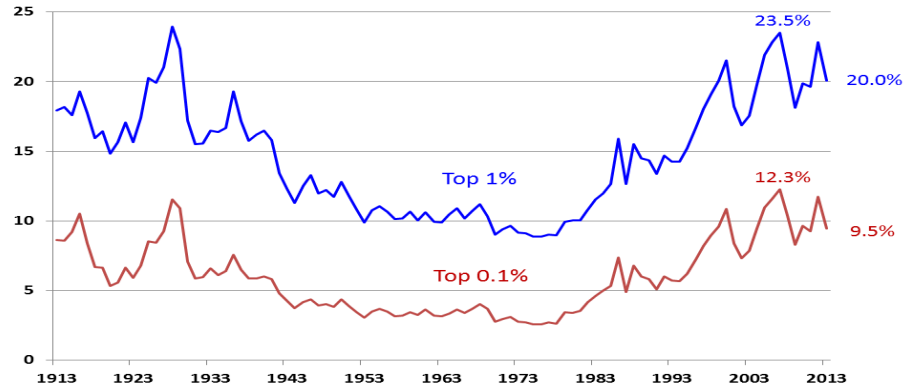
Gini coefficients for selection of OECD countries



Source: <https://data.oecd.org/inequality/income-inequality.htm>

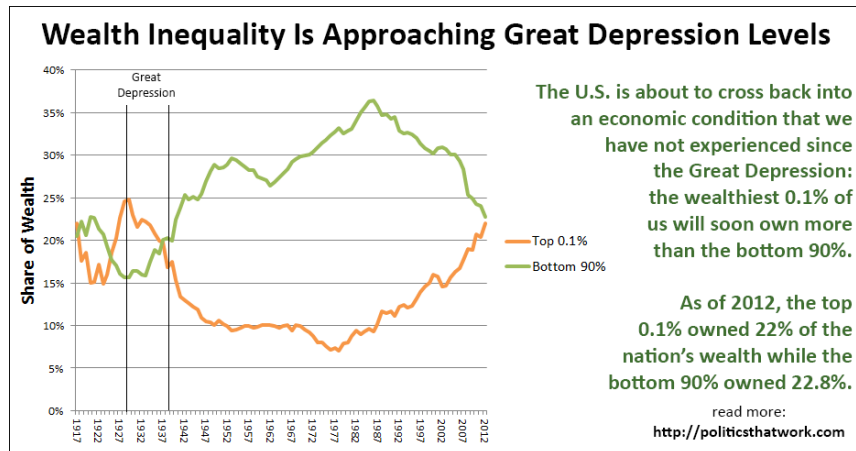
Figure 4.54: US income and wealth inequality

U.S. Income Shares of Top 1% and Top 0.1% Households – Incl. Capital Gains (1913-2013)



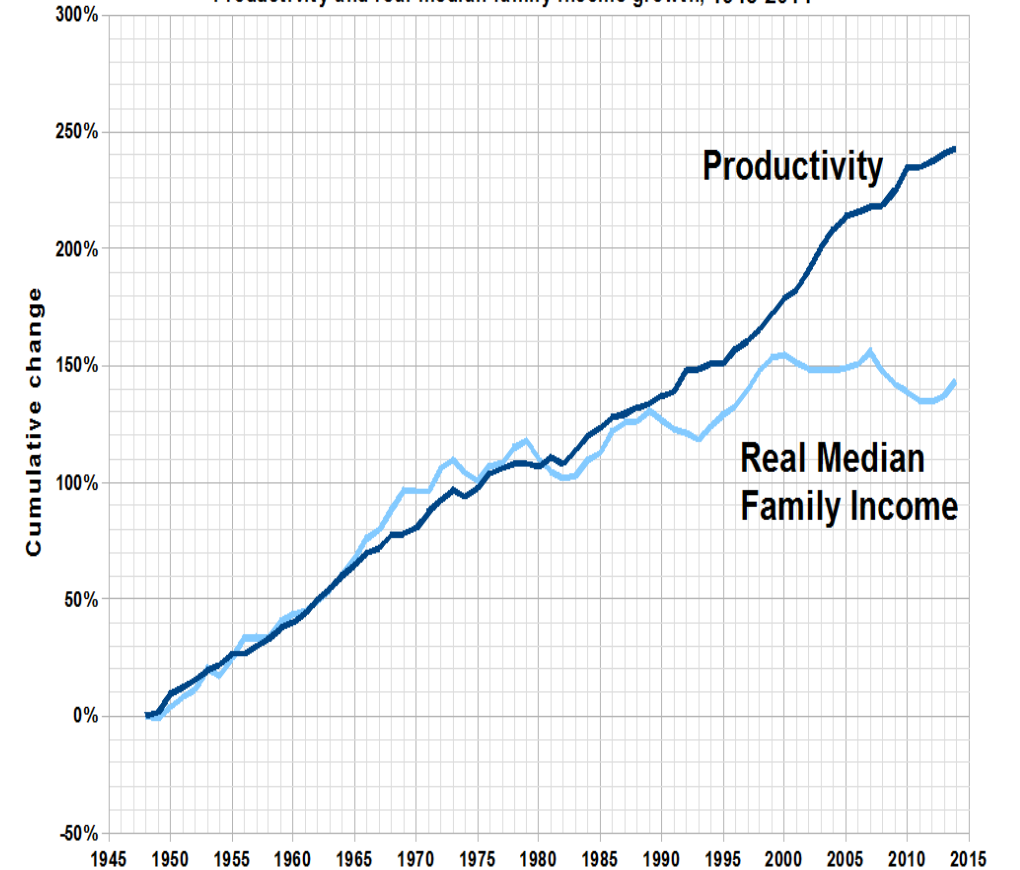
Source: Piketty & Saez – January 2015

https://upload.wikimedia.org/wikipedia/commons/e/e7/U.S._Income_Shares_of_Top_1%25_and_0.1%25_1913-2013.png



<http://politicsthatwork.com/img/x137.gif.pagespeed.ic.KyVBjNUqRF.png>

The benefits of increased productivity over the last 35 years have not gone to the middle class
Productivity and real median family income growth, 1948-2014



Source: Analysis of Current Population Survey Annual Social and Economic Supplement *Historical Income Tables* (Table F-5) and Bureau of Labor Statistics, *Productivity – Major Sector Productivity and Costs Database* (2012)

Source: https://en.wikipedia.org/wiki/Income_inequality_in_the_United_States#media/File:Productivity_and_Real_Median_Family_Income_Growth_in_the_United_States.png

Figure 4.55: Inequality in China substantially above US

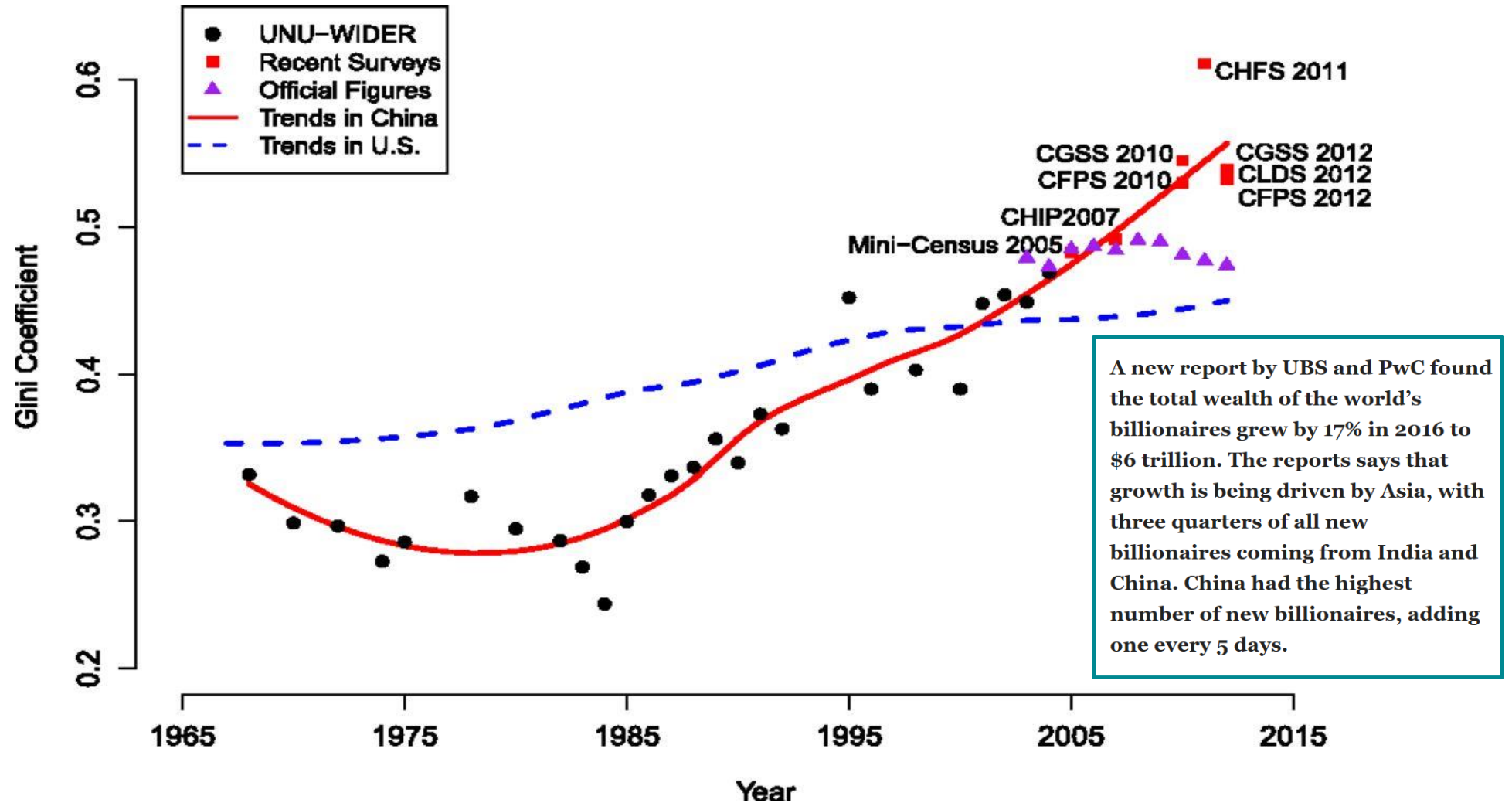
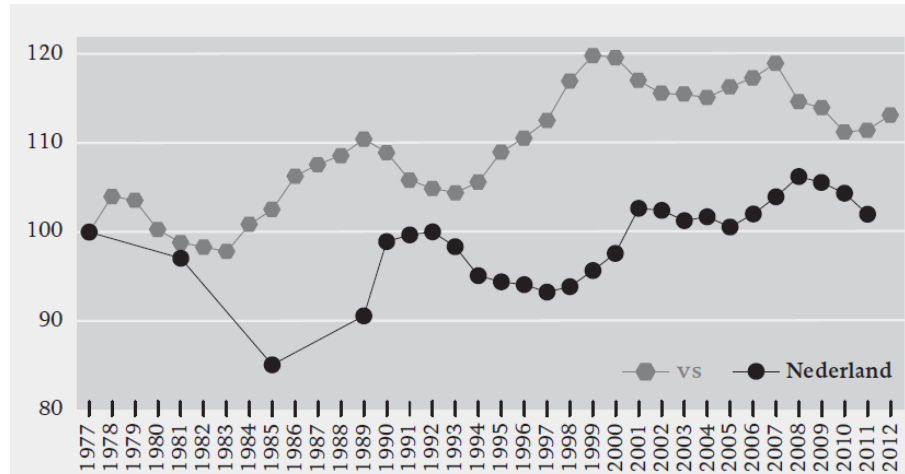


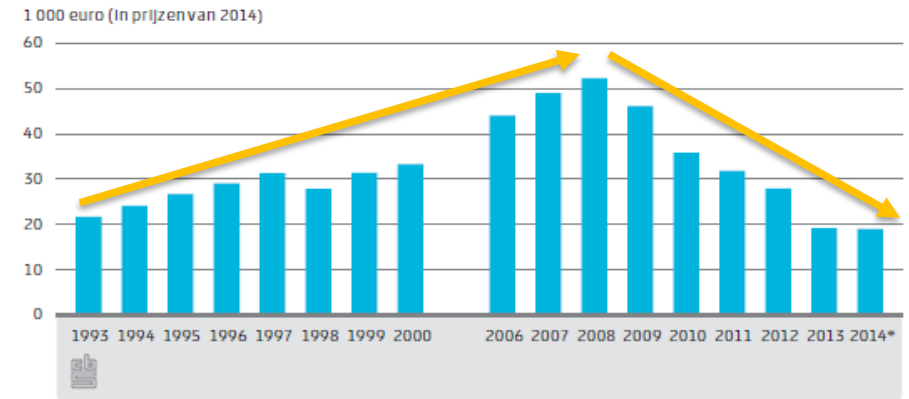
Figure 4.56: Dutch income inequality and effect of financial crisis

Development of median income (1977 – 2012)



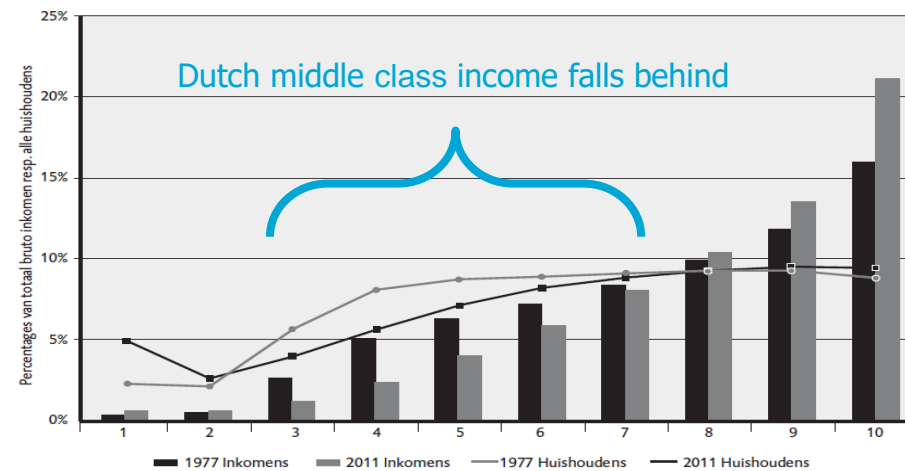
Source: WRR (2014) Hoe ongelijk is Nederland?

Development of median income (1977 – 2012)



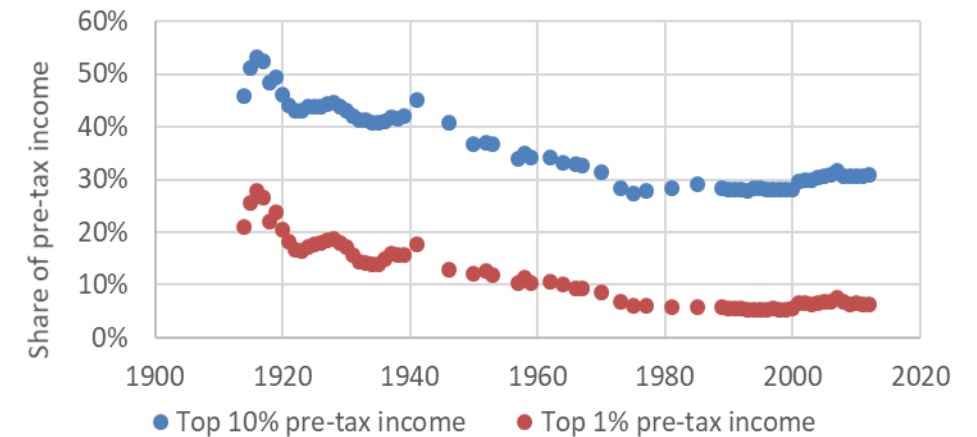
Source: CBS (2016) Welvaart in Nederland, <https://www.cbs.nl/nl-nl/publicatie/2016/26/welvaart-in-nederland-2016>

Distribution of income over income classes and households



Source: WRR (2014) Hoe ongelijk is Nederland?

Slight increase in share of GDP going to highest incomes

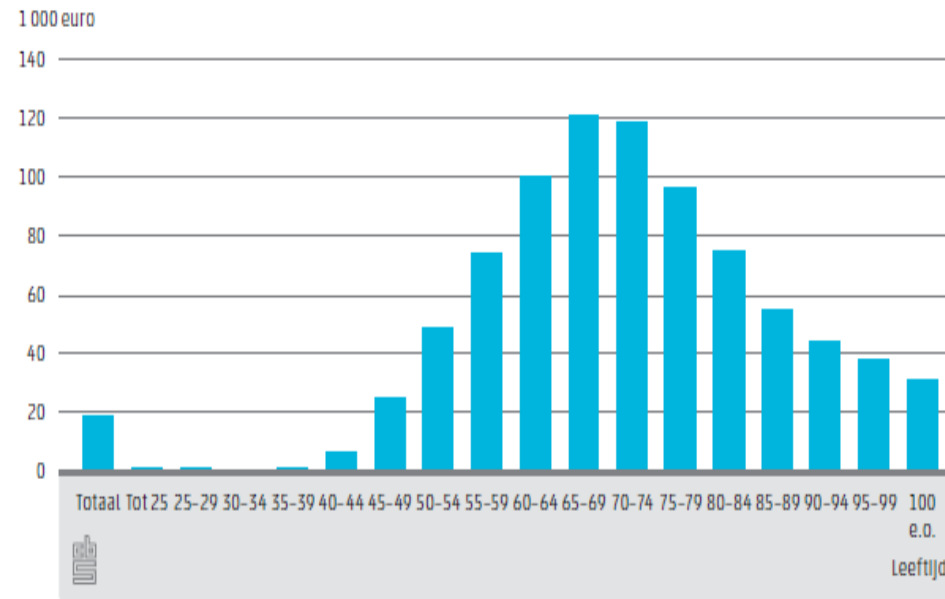


Source: World wealth and income database, <http://wid.world/data/>

Figure 4.57: Unequal wealth distribution in the Netherlands

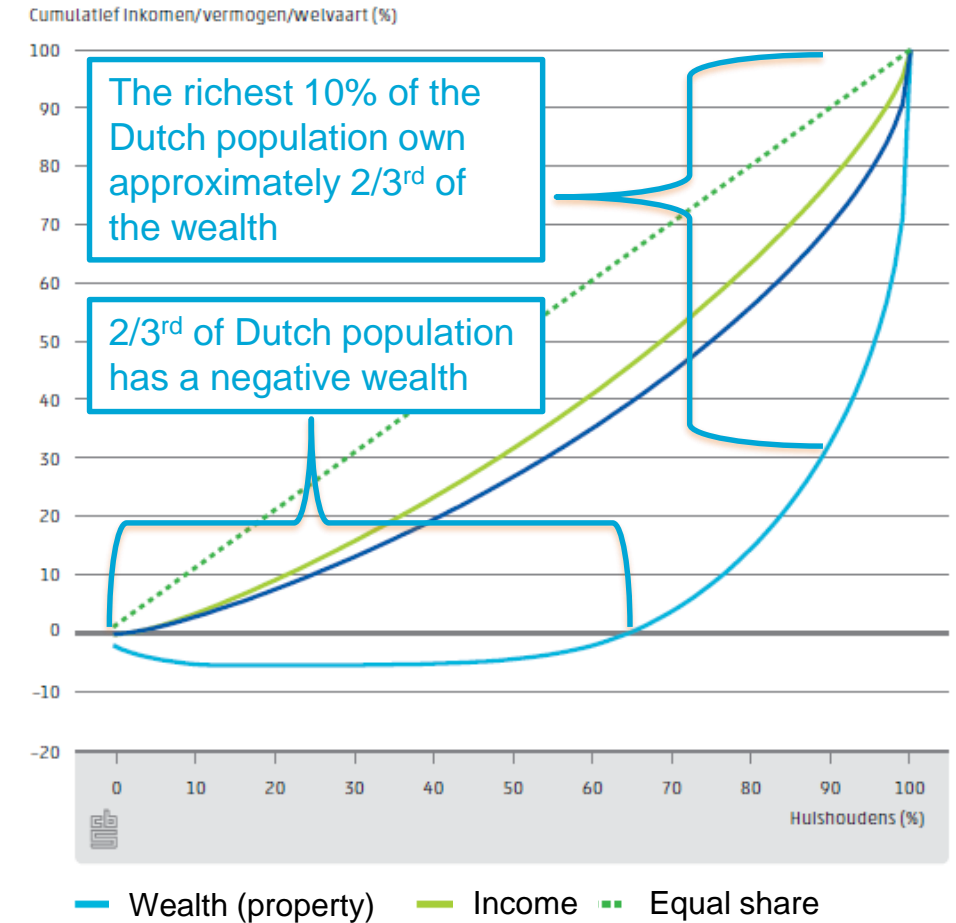
Wealth distribution is also very unequal in the Netherlands with 2/3rd of population having a negative wealth, making them exceedingly vulnerable to loss of income, e.g. due to automation.

Distribution of wealth according to age of main breadwinner



Source: CBS (2016) Welvaart in Nederland, <https://www.cbs.nl/nl-nl/publicatie/2016/26/welvaart-in-nederland-2016>

Lorenz curve for inequality



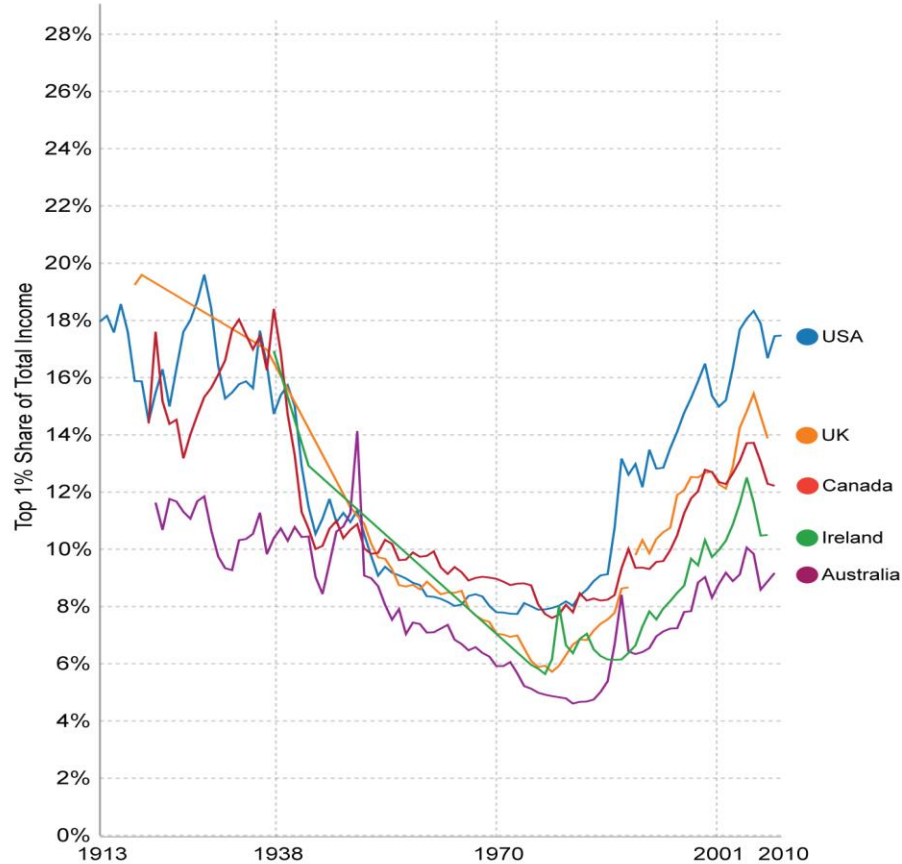
Source: CBS (2016) Welvaart in Nederland, <https://www.cbs.nl/nl-nl/publicatie/2016/26/welvaart-in-nederland-2016>

Figure 4.58: Increasing inequality in different economic regions

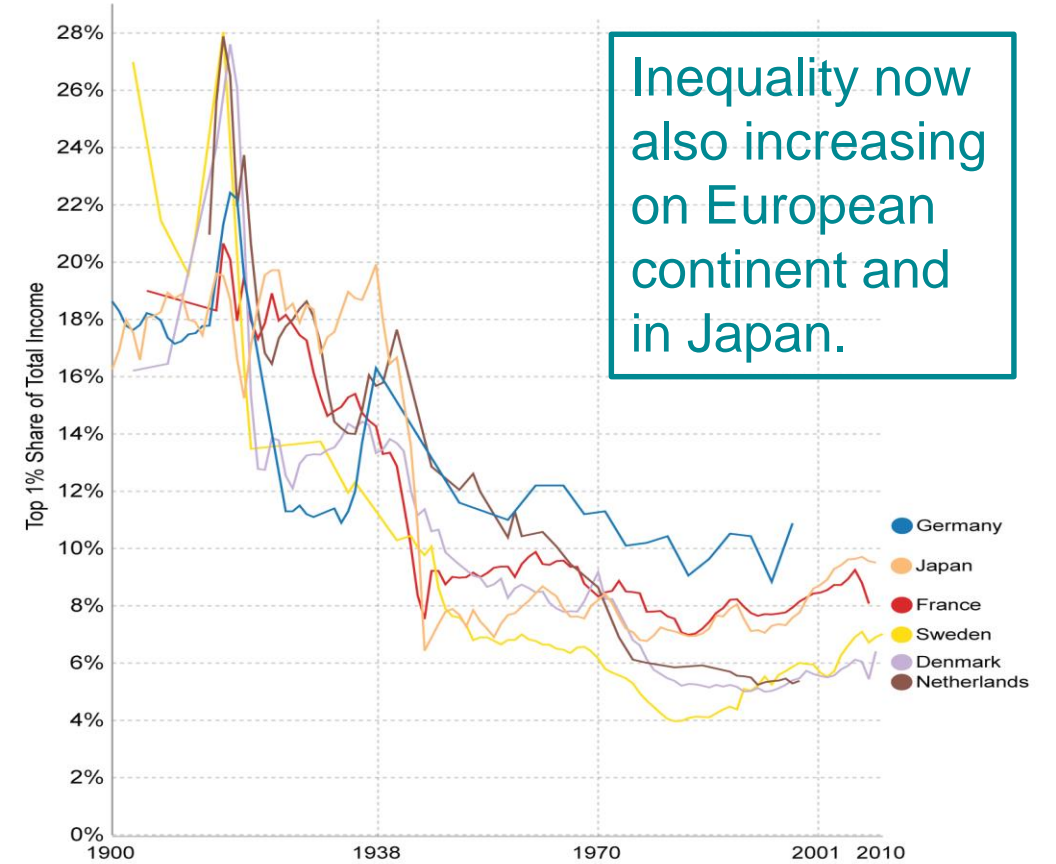
Our World
in Data

Share of Total Income going to the Top 1%, 1900-2010

The evolution of inequality in English speaking countries followed a U-shape



The evolution of inequality in continental Europe and Japan followed an L-shape



Data source: The World Top Incomes Database.

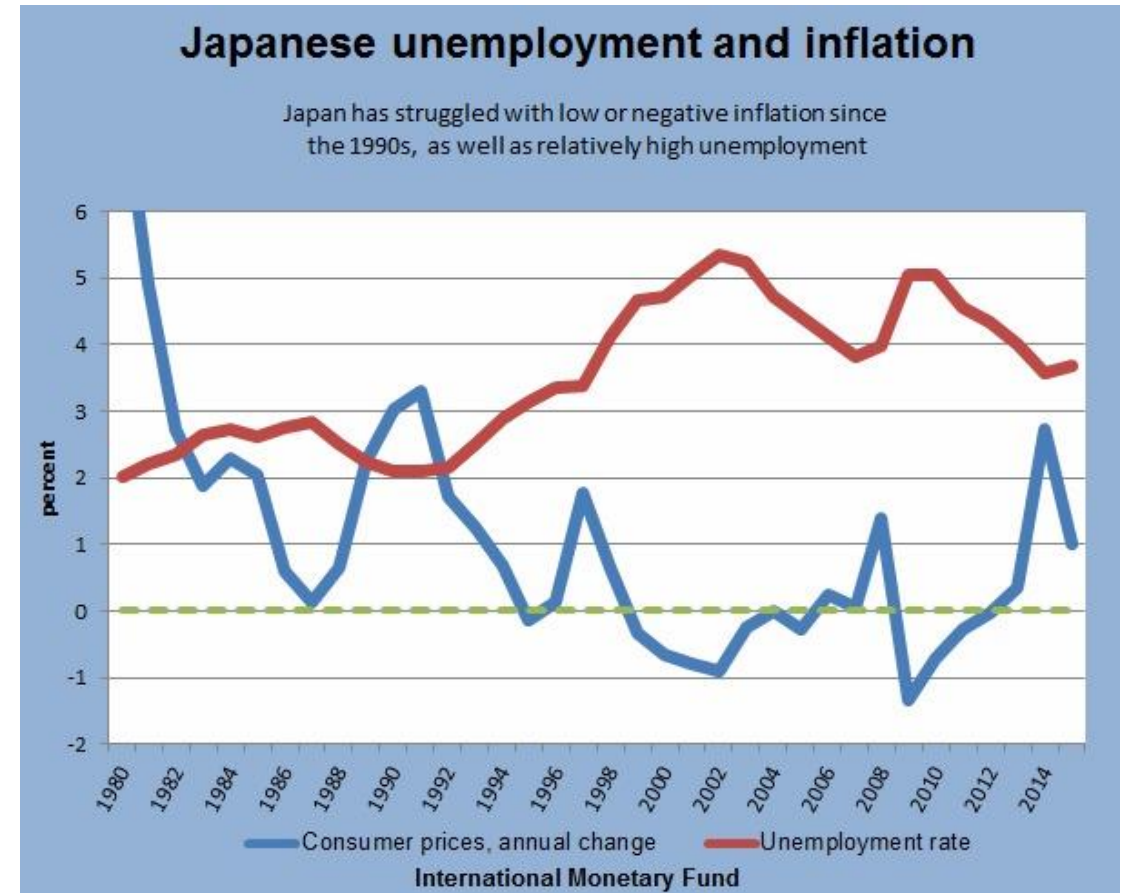
The interactive data visualisation is available at OurWorldinData.org. There you find the raw data and more visualisations on this topic.

Licensed under CC-BY-SA by the author Max Roser.

Figure 4.59: Effect of decreasing real interest rates

- Decreasing real interest rates normally boost GDP growth, but with low inflation they become a drag because of the **lower zero bound**, which disables central banks from fighting unemployment by lowering interest rates (i.e. risk of **secular stagnation**).
- Low inflation and near zero interest rates are expected to result in **rising unemployment levels** (EU and US may follow Japan).

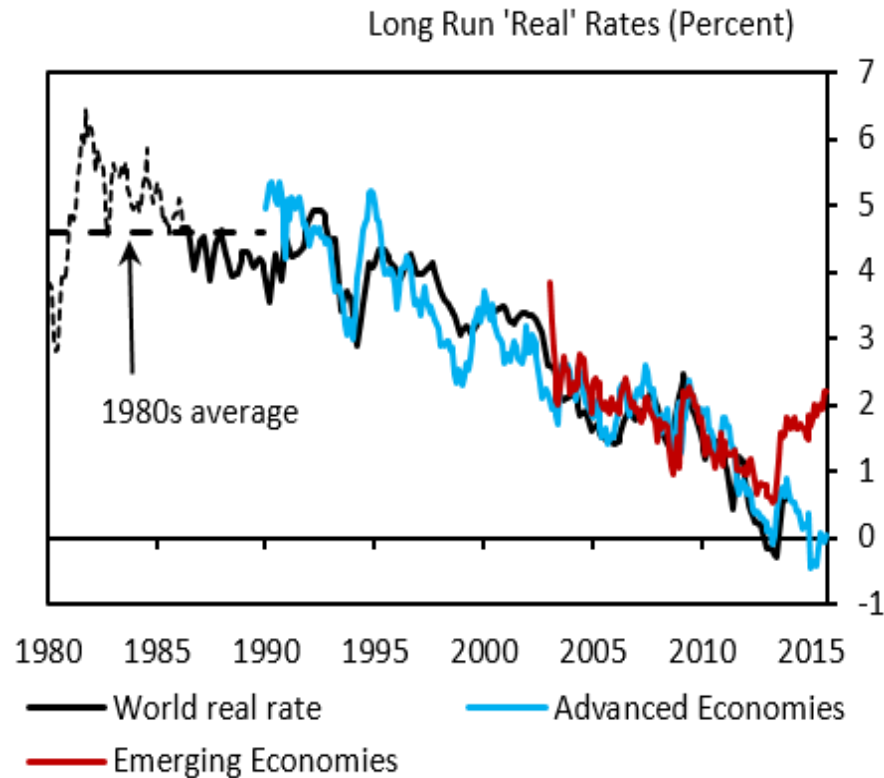
Negative correlation between low inflation rates and high levels of unemployment.



<http://s3.amazonaws.com/content.washingtonexaminer.biz/JapanUnemp.jpg>

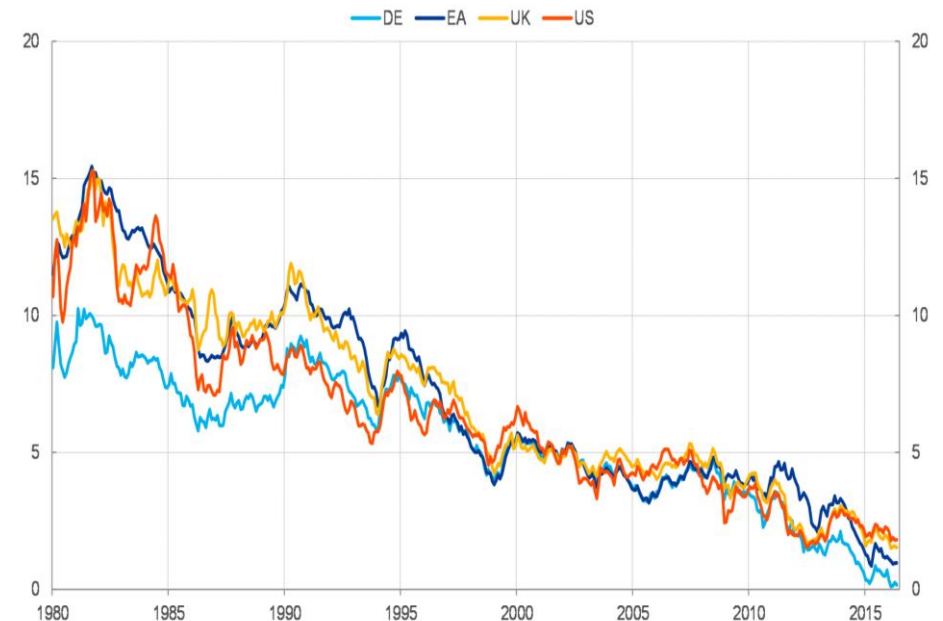
Figure 4.60: Effect of decreasing real interest rates

- Decreasing real interest rates can potentially result in much higher levels of unemployment (i.e. trend breach from today's mainstream neoclassical assumption of full employment).



<http://voxeu.org/article/towards-global-narrative-long-term-real-interest-rates>

Long-term government bond yields
(10-years; % p.a.)



Source: ECB, Deutsche Bundesbank, Bank of England and Federal Reserve Board.
Latest observation: May 2016.

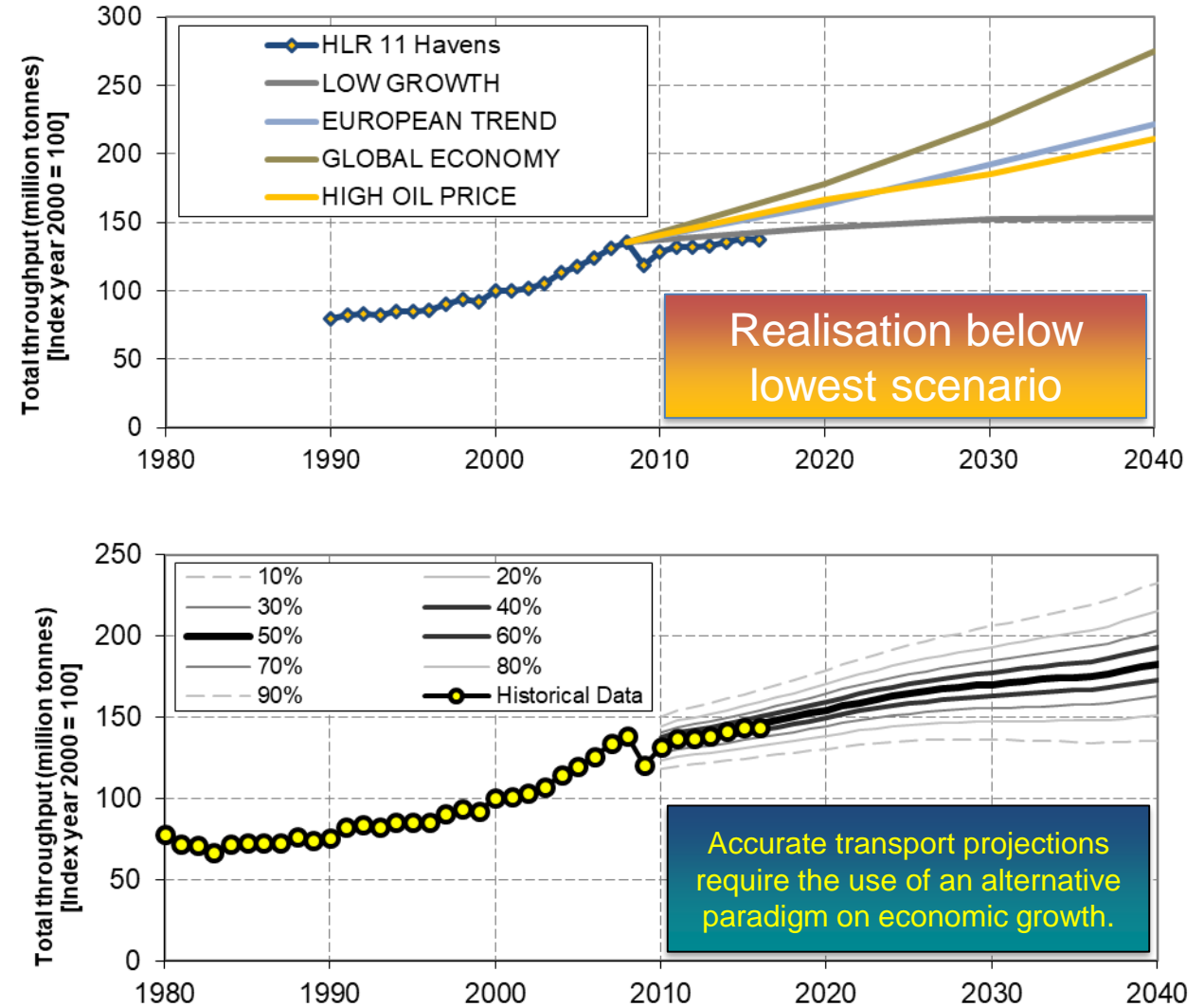
https://www.ecb.europa.eu/press/key/date/2016/html/sp160615_chart1.png

Recapitulation of economic growth development

- Mainstream neo-classical views on economic growth tend to assume that:
 - the economy moves towards an exponential growth rate in the long run (sometimes mistakenly called ‘balanced growth path’);
 - by means of price adjustments the labour market will, in the long run, incline towards a situation of full employment.
- This paradigm does not take into account the secular long-term characteristics of economic growth from the supply and demand side.
 1. Supply side characteristics are: (1) existence of limits to the maximum attainable physical and human capital per employee, and (2) limitations on total factor productivity growth as a result of declining marginal returns on additional research efforts.
 2. Demand side characteristics are: (1) gradual loss of lower and middle income jobs as a result of automation, robotics, and artificial intelligence (2) effect of unemployment and increasing inequality on the demand for economic goods; (3) inability of central banks to lower interest rates and stimulate the economy in order to create new employment opportunities as a result of the lower zero bound on interest rates.

Figure 4.61: Impact of GDP assumptions on transport projections

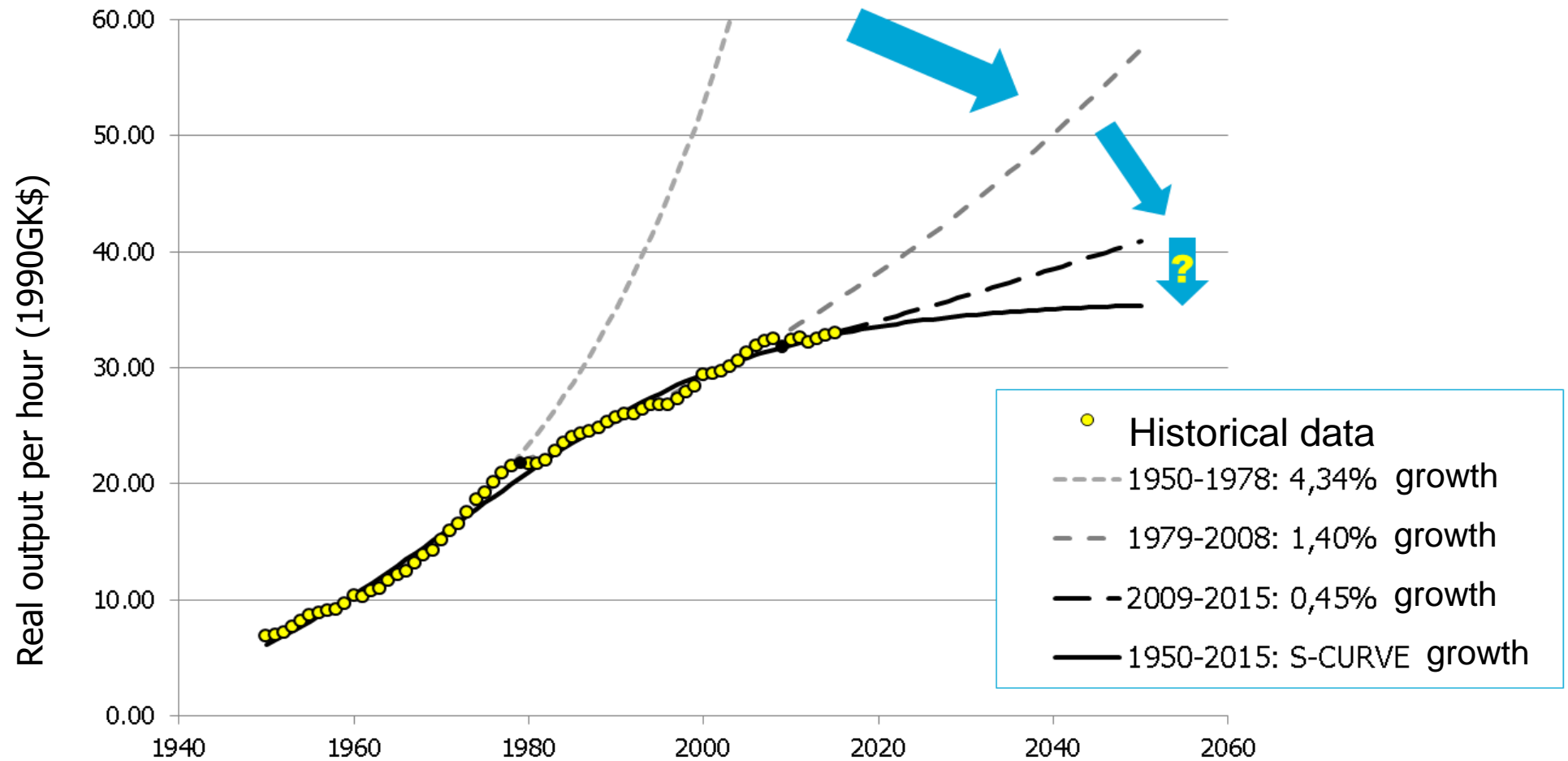
- Use of the right growth paradigm is fundamental to obtaining realistic transport projections.
- PoR Port Vision 2030 scenarios (published in 2010), were overestimates because of faulty GDP growth assumptions in line with CPB.
- Projections of Van Dorsser (2015), based on the alternative paradigm and the author's growth projections still prove to be quite accurate.



Reflection on GDP scenarios of Dutch Central Planning Agency

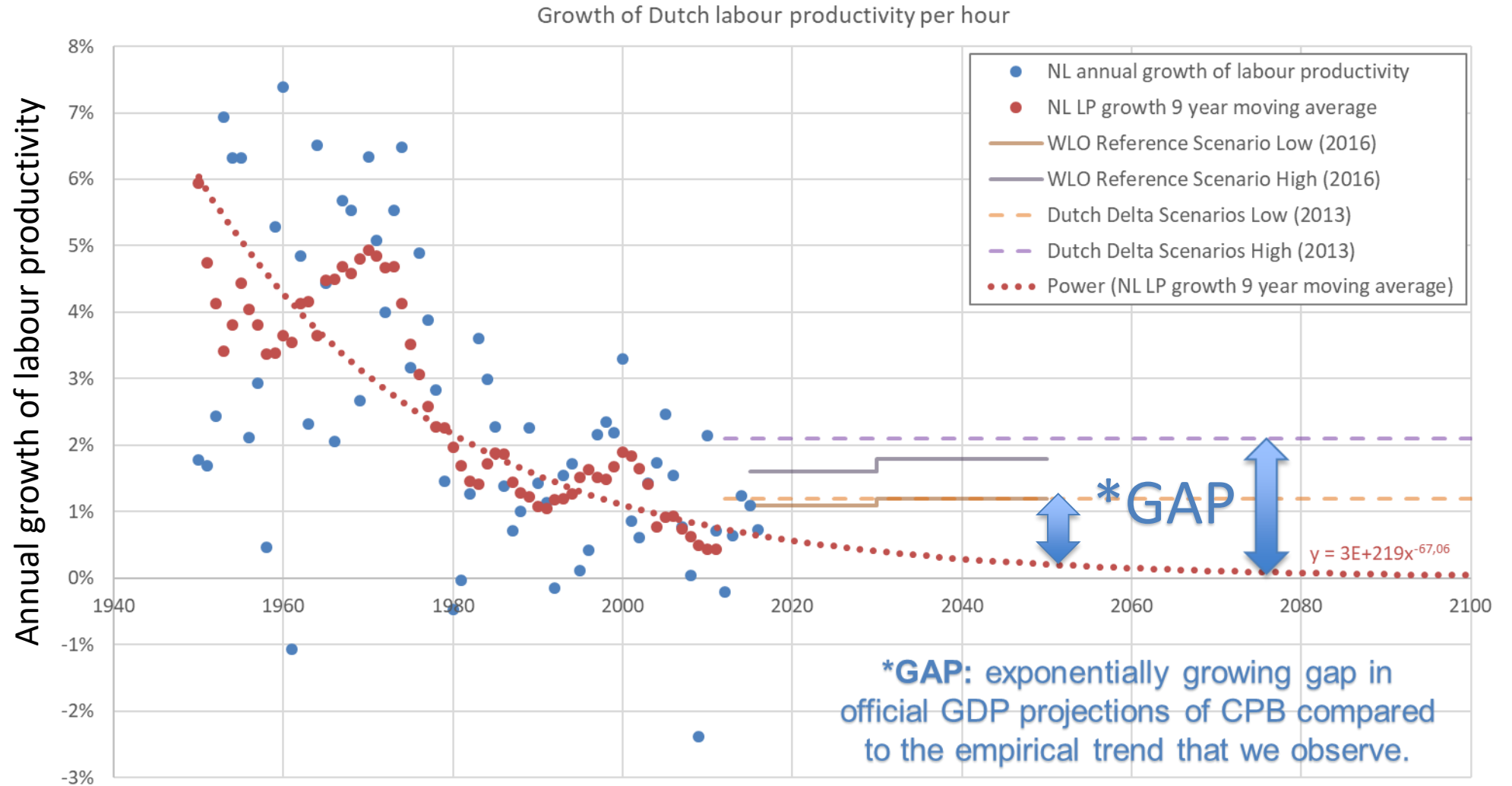
- Views of Dutch central planning agency are in line with mainstream neoclassical view of ongoing exponential economic growth.
- They assume:
 1. Labour productivity to remain growing at fixed non-negative growth rate.
 2. A situation of more or less full employment to continue in the long run.
- As discussed earlier, assuming a growth rate of 2.1% for labour productivity (also assumed up to year 2100 in high Delta scenarios published in 2013), would imply that in about 770 years we can produce the entire output of today's Dutch economy with just 1 person. This is hard to believe.
- We consider the ongoing exponential growth a '**perpetuum mobile**', a misperception of our age. Since we are so used to (exponential) growth, we can hardly imagine a world without growth; moreover we are afraid that an end to growth might result in everything comes to a stand still. Nonetheless, in order to obtain realistic projections, we need to question this paradigm.
- We have therefore started a discussion with Dutch central planning agency (CPB) on the economic growth assumptions applied in official scenario studies.

Figure 4.62: Empirical data shows decreasing productivity growth



Data: The Conference Board Total Economy Database™ (Original version), 2015.

Figure 4.63: Decreasing labour productivity vs. growth assumptions



Data: Primarily: The Conference Board Total Economy Database™ (Original version), May 2017. Extended with other sources.

Figure 4.64: We initiated discussion on GDP growth assumptions

BRIEVEN

Tunnelvisie bij CPB

Scenariostudies gaan doorgaans uit van de in mijn ogen onjuiste en achterhaalde veronderstelling van aanhoudende exponentiële economische groei. Het is positief dat het CPB in zijn dinsdag gepubliceerde referentiescenario's probeert een genuanceerder beeld te schetsen. Hierbij baseert het zich niet alleen op de gangbare opvatting van aanhoudende exponentiële groei, maar houdt het ook rekening met de in kracht winnende opvatting dat de arbeidsproductiviteit — en dus ook de economische productie — op lange termijn een blijvend dalende trend zal laten zien. Deze nieuwe aanpak resulteert in een tweetal eenvoudige scenario's. Beleidsmakers kunnen uitgaan van 1% groei in het lage en 2% groei in het hoge scenario. In tegenstelling tot het gedachtegoed van een geleidelijk afnemende groei wordt in het lage scenario nog steeds een exponentiële groei verondersteld. Ook lijkt het erop dat de arbeidsproductiviteitsgroei niet geraamd is, maar als sluitpost fungeert om mooie ronde groeicijfers te krijgen. Hierdoor is er in beide scenario's vanaf 2030 juist weer sprake van een hogere arbeidsproductiviteitsgroei, wat lijnrecht ingaat tegen het gedachtegoed dat bij het lage scenario hoort. In dat opzicht is helaas nog steeds sprake van enige tunnelvisie.



Dr.ir. Cornelis van Dorsser, TU Delft

Redactie: Jacqueline Bosboom, Michiel Goudswaard, Ronald van de Krol, Rijk Timmer. T

Initiated discussion with Dutch central planning agency (CPB) on economic growth assumptions applied in official scenario studies.

Figure 4.65: It is imperative to continue the discussion

ESB Mening Reactie ESB

Mening: Planbureaus overschatten economische groei

CORNELIS VAN DORSSER
Onderzoeker aan de TU Delft

Politici en beleidsmakers hebben behoefte aan inzicht in mogelijke toekomstscenario's bij het opstellen en evalueren van nieuw overheidsbeleid. Daarom ontwikkelen de Nederlandse planbureaus (thans het CPB en het PBL) al decennialang evenwichtige beleidsscenario's rondom belangrijke thema's als demografie, economische productie, transport en mobiliteit, energie, klimaatverandering en waterveiligheid. Op dit moment kent Nederland scenario's: de Delta Scenario's voor 2100 vooruitblikken (Bruggeman *et al.*, 2010) referentiescenario's Wetsaart en Leefomgeving 2050 vooruitblikken (Manders en Kool, 2010) deze scenario's worden belangrijke politieke maakt over bijvoorbeeld de aanleg van nieuwe Ramingen voor de groei van de economie be de ramingen voor onder andere de vraag naar en vervoer. Voor het goederenvervoer is er z nageen-opp-opp-relatie (Van Dorsser, 2010) teconoom ben ik daarom genoodzaakt kritische liggende groeiramingen te kijken.

Het CPB hanteert bij zijn langetermijnprogr men die gangbaar zijn in de economie. De eerste de arbeidsproductiviteit (en dus ook de econo tie) op lange termijn een min of meer constan zien als gevolg van aanhoudende technologie. De tweede aanname betreft de veronderstellin volledige werkgelegenheid. Hoewel beide a deels stroken met de trend over de laatste 200 economen van het CPB zich hiermee toch op De eerste aanname doet geen recht aan de w is op lange termijn niet vol te houden. Een co van 2.1 procent per jaar (zoals verondersteld riorio's tot het jaar 2100 impliceert dat de huil productie over 800 jaar met slechts één part gerealiseerd. Technici weten heel goed dat al een transitiecurve doorlopen, maar vreemd gomen halstaring in een constante groei gelo (1995) al twintig jaar geleden heeft vastgesteld dat er bij ken-nisontwikkeling sprake is van afnemende meetopbrengsten en Fernald en Jones (2014) recentelijk nog hebben aangetoond dat de technologische vooruitgang sinds het begin van de industri- e revolutie vooral een gevolg is van een toename in het aantal jaren onderwijs en het aantal onderzoekers. Aan deze toename lijkt in westerse landen nu echter een einde te komen (Gordon, 2014). Dit betekent dat de arbeidsproductiviteitsgroei op lange termijn een blijvend dalende trend zal laten zien. De aanname van een redelijk volledige werkgelegenheid is ook niet vanzelfsprekend. Automatisering leidt in veel gevallen tot een groter verlies aan banen dan dat er nieuwe bijkomen (Went *et al.*, 2014). Dit effect wordt versterkt doordat het minimumloon substitutie tussen kapitaal en arbeid aan de onderkant van de markt verhindert. Verder zijn er nog zorgen over seculaire stagnatie, die het voor centrale banken onmogelijk maakt om economische groei te stimuleren door nog ruim-

Van Dorsser meent dat het CPB en het PBL de bbp-groei in de langetermijnscenario's van hun recent verschenen studie *Wetsaart en Leefomgeving* (WLO) overschatten (CPB en PBL, 2015). De WLO

TON MANDERS
Sectorhoofd bij het Planbureau van de Leefomgeving

PETER ZWANEVELD
Programmaleider bij het Centraal Planbureau

cognitieve technologie – de zogeheten NBIC-technologieën – al geruime tijd als veelbelovend gezien (Franklin en Andrews, 2012). Dit betreft onder andere de vooruitgang in de medische wetenschap, die potentieel kan leiden tot een sterke van het aantal gezonde le- en. De optimisten geven ove- voor hun groeiprognoses. elisingen is het zinnol om lipen de Deltascenario's voor 2100 waterveiligheid wordt gero- omdat voor vrijwel alle dijken verhoging tot na 2050 een se- meer informatie beschikbaar groei en over de fetteijke stij- op dat moment een beter ge- worden dan nu (Zwaneveld ter vooruitkijken heeft zelden ter wordt, waardoor de kwalite- sionen moeten worden er niet

van den Born *et al.* (2013) Deltascen- werking 2012–2013, Deltares, KNMI, (2014) The second machine age: work, brilliant technologies. New York: WW

ing welvaart en leefomgeving. Cahier al Planbureau/Planbureau voor de

development of the Dutch inland waterway transport system: policy analysis, transport projections, shipping scenarios, and a new perspective on economic growth and future discus- sion. Delft: TRAIL Research School.

Franklin, D. en J. Andrews (red.) (2012) *Megachanges: the world in 2025*. London: The Economist in association with Profile Books Ltd.

Gordon, R.J. (2012) Is U.S. economic growth over? NBER Working Paper, 18195.

Zwaneveld, P. en G. Verweij (2014) Economisch optimale waterveiligheid in het IJsselmeergebied. CPB Note, 14 januari.

Reactie op: Planbureaus overschatten economische groei

Realistic transport projections cannot be obtained without realistic GDP projections.

270 271

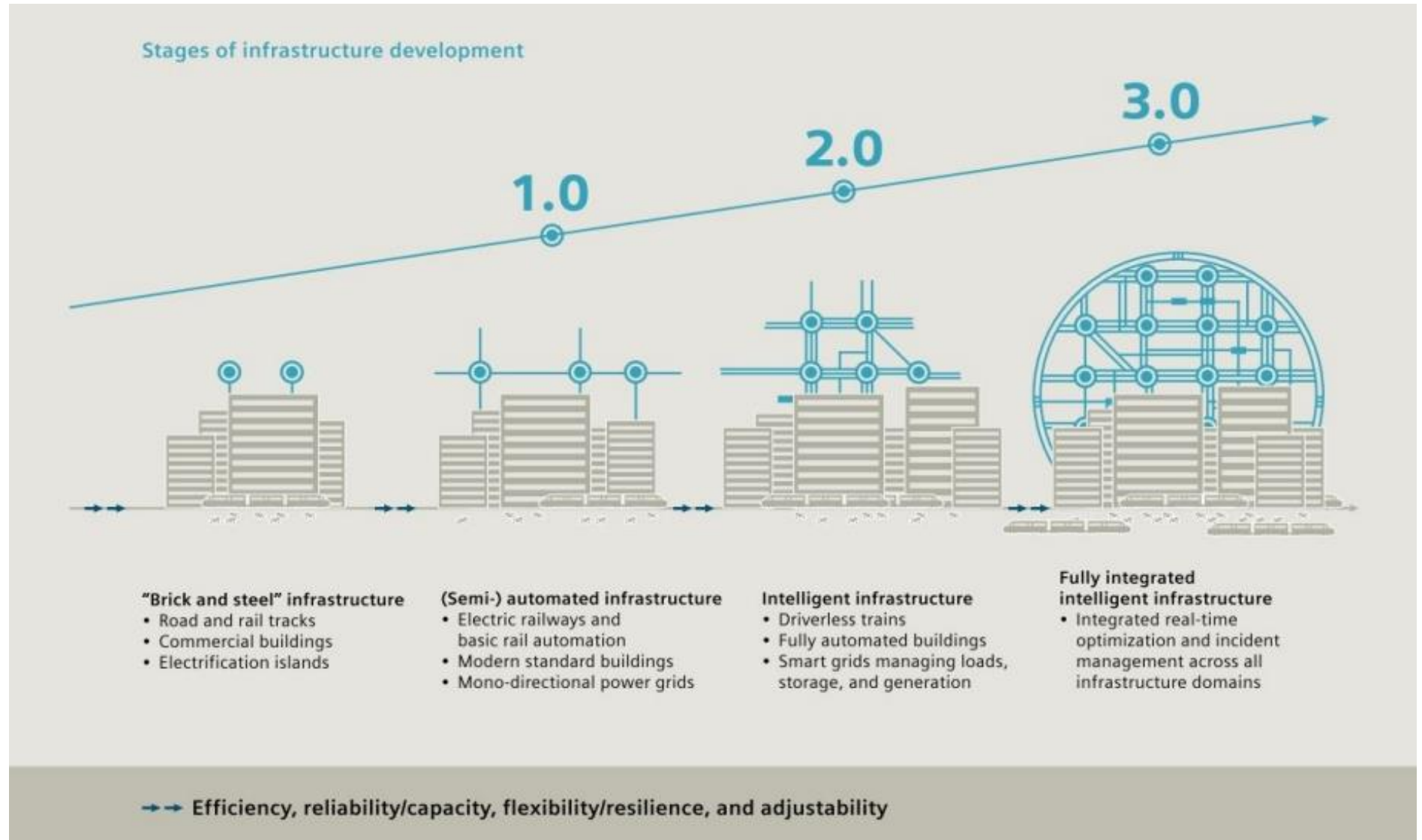
Jaargang 101 (4732) 14 april 2016 Jaargang 101 (4732) 14 april 2016

Source: Economisch Statistische Berichten (ESB), Jaargang 101 (4732), 14 april 2016.

4.7 Connectivity and information exchange

- Enormous progress has been made with respect to connectivity since the rise of maritime nations including the invention of printing, development of mass transportation (turnpikes, canals, railways, roads, airways, hyperloops), telecommunication (telegraph, telephone, broadcasting), and the introduction of the internet.
- Almost everyone on earth can be contacted instantly by phone or internet, and one can travel anywhere within one or two days. But this is not the end. With the introduction of smart systems we have now also started to connect individual devices and it is not unlikely that some 100 years from now (or even much earlier) virtually all devices will communicate with each other.
- Working environments are already organized so that one can connect to the cloud virtually anywhere so that the world becomes our office. Furthermore, innovations such as 3D printing and the physical internet will make long-distance shipping of physical objects (e.g., spare parts) unnecessary. The next step could be to create cyborgs as we move towards a 4th industrial revolution wherein physical, digital and biological worlds converge.
- In short, we are moving towards a state of hyper-connectivity in which almost all systems are or can be connected to one another.

Figure 4.66: Connectivity and infrastructure development



Source: <http://corporate.siemens.com.au/en/home/news-centre/blogs/the-journey-to-intelligent-infrastructure.html>

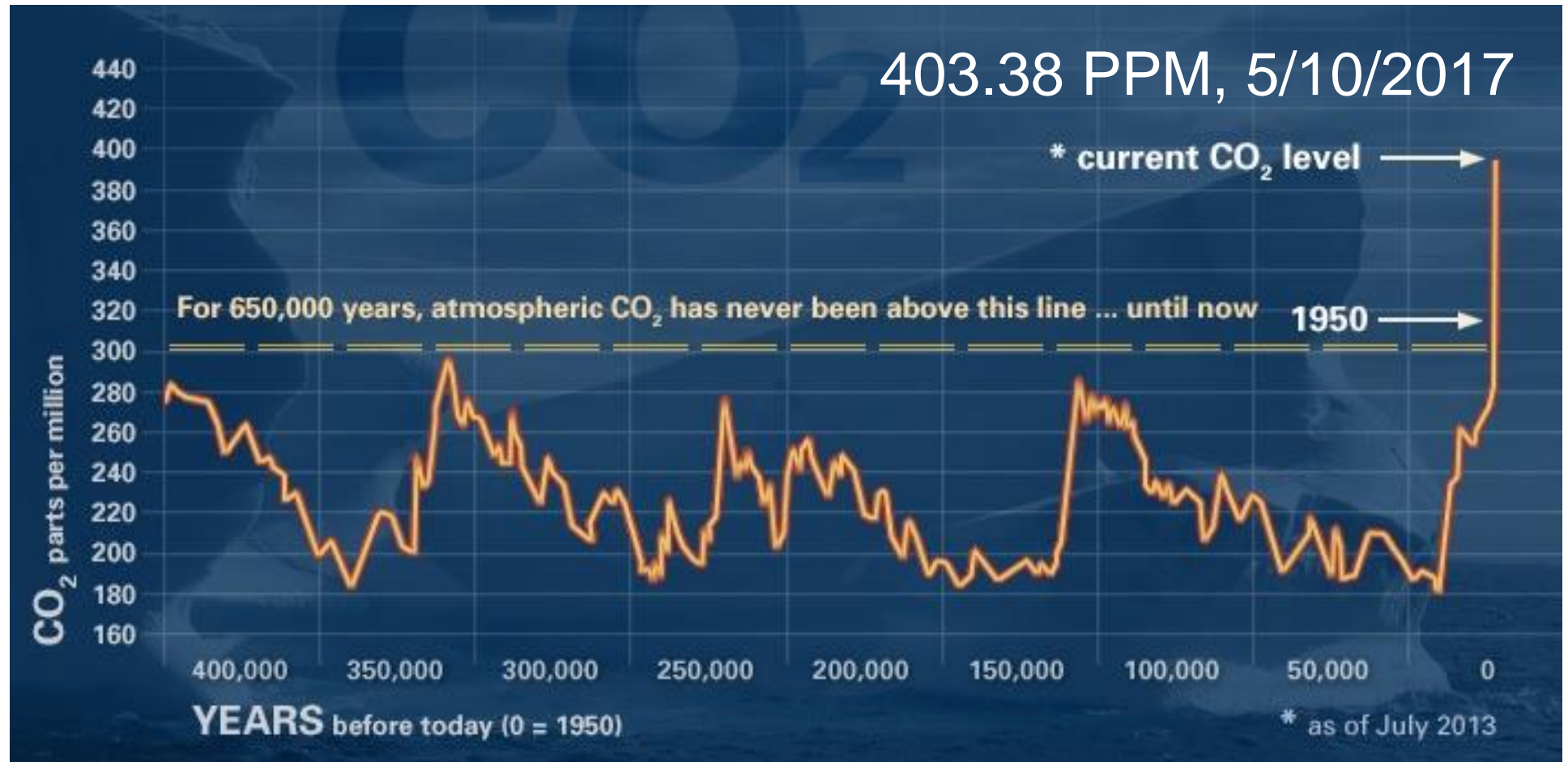
Connectivity and information exchange

- Increasing connectivity enables far reaching integration of systems and the development of many useful new services and applications.
- But is also makes our global society vulnerable to failure of critical systems due to cyber criminology, cyber terrorism and cyber warfare.
- In addition there is a risk of digital obesity. Digital systems are supposed to bring us freedom and happiness, but we are becoming immobilised by the sheer amount of content and the fear of being off-line.
- Summing up, the ongoing trend in the direction of further connectivity and integration of systems will continue, accompanied by a counter movement to make systems smaller, less critical, redundant, and more secure. This counter movement can be regarded as a second order feedback loop.

4.8 Climate change and environmental degradation

- There is overwhelming evidence and growing social awareness of the increased levels of carbon dioxide in the atmosphere and its effect on the climate. Climate change is a major social and political driver towards greening of the economy, that is (temporarily) hampered in the US by president Donald Trump, who calls climate change a hoax and proposes to withdraw from international agreements and stop related research efforts.
- Evidence of climate change stands out from:
 - Carbon measurements in the atmosphere;
 - Global temperature rise and warming oceans;
 - Shrinking ice sheets and declining arctic sea ice;
 - Glacial retreat and decreased snow cover;
 - Increase in number and intensity of extreme events;
 - Ocean acidification.
- The climate change challenge feeds the main driver of the upcoming 6th Kondratieff wave, i.e., sustainability.
- Environmental degradation is having devastating effects on our ecosystems (e.g. effect of plastic microfibers in sea- and drinking water, resistance to antibiotics, and dying corral reefs).

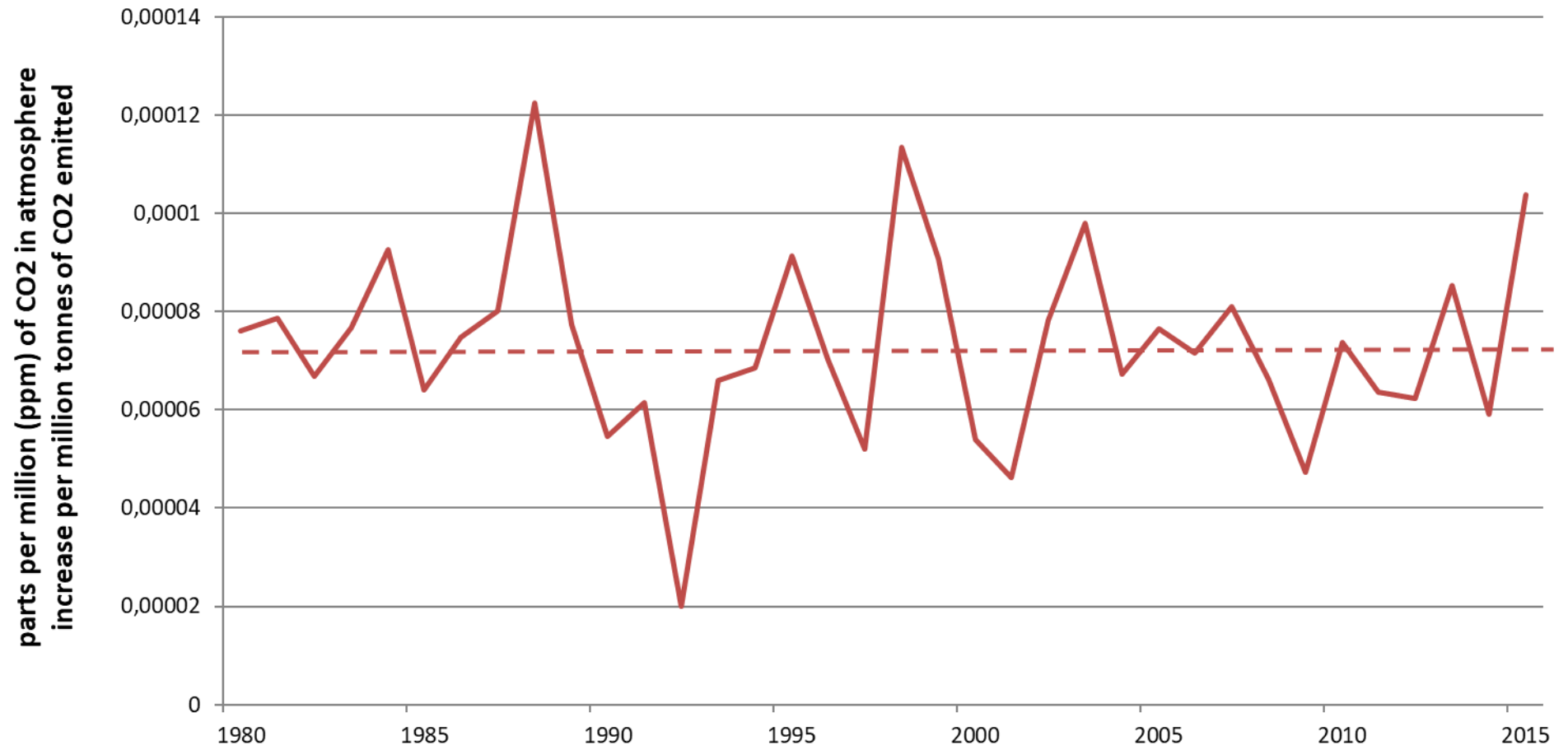
Figure 4.67: Atmospheric carbon dioxide levels



Source: Global climate change, climate.nasa.gov, https://climate.nasa.gov/climate_resources/24/

- Clear measurable evidence of climate change from CO₂ levels in atmosphere.

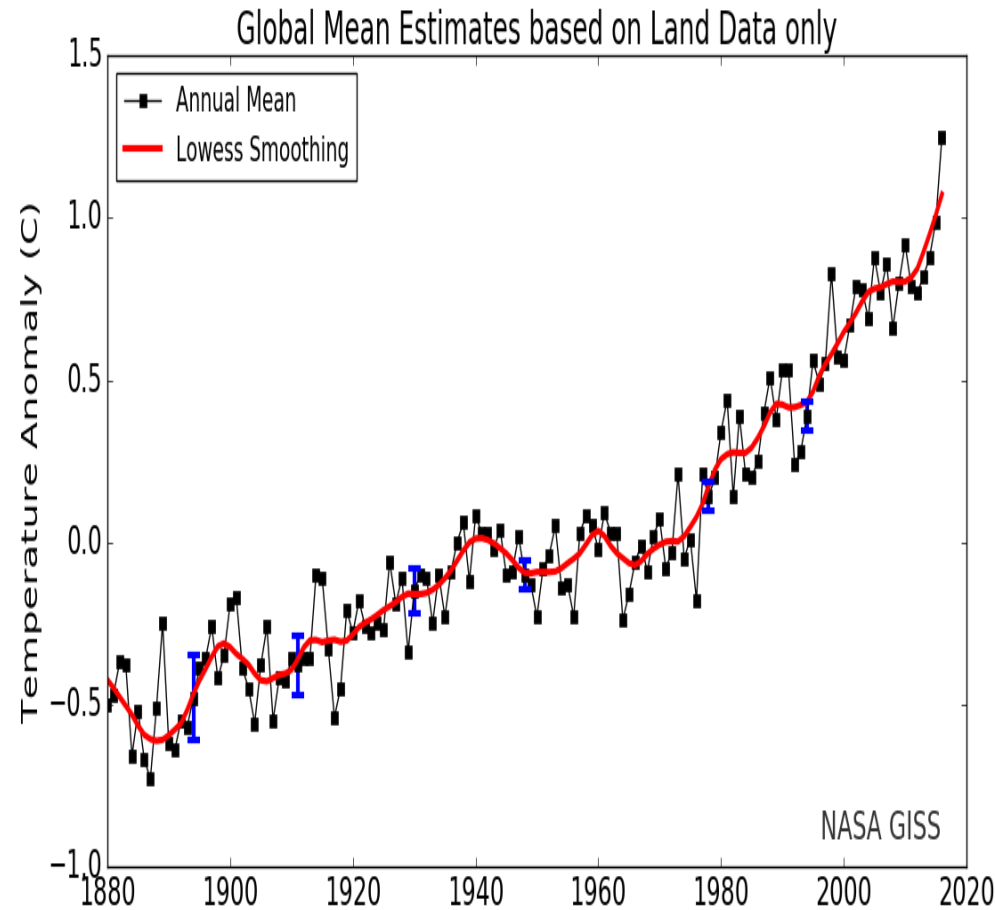
Figure 4.68: Increase of carbon levels per tonne carbon emitted



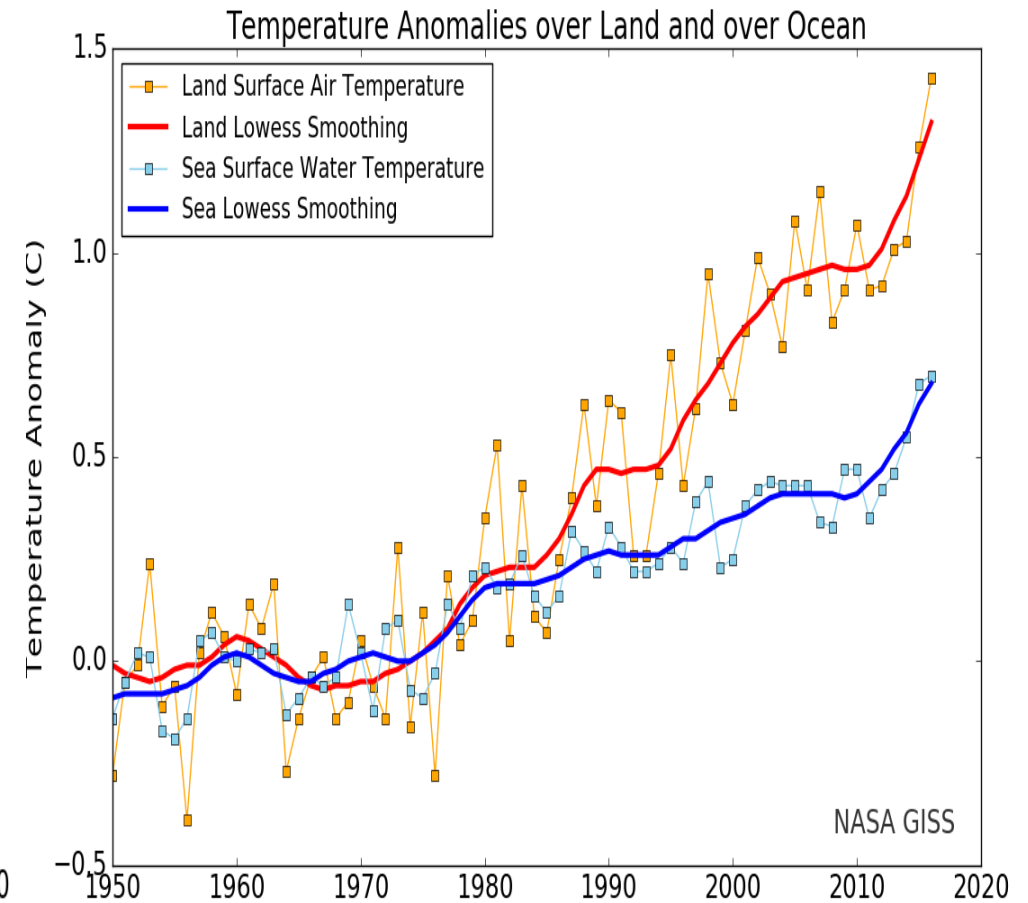
Source: Own analysis based on BP Statistical Review of World Energy June 2016 on carbon emissions and reported CO2 measurements.

- No signs that atmospheric CO2 increase per tonne CO2 emitted is increasing. This suggest that absorption capacity of the ocean is still in place.

Figure 4.69: Steady rise of global land and sea temperature



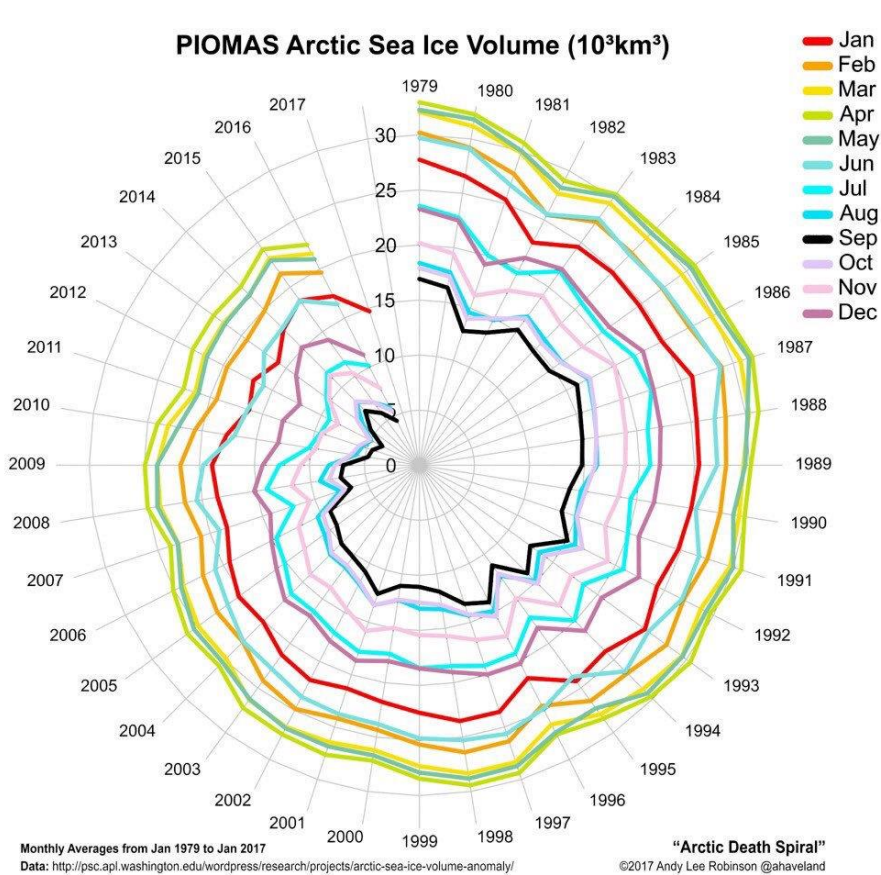
Source: https://data.giss.nasa.gov/gistemp/graphs/graph_data/Temperature_Anomalies_over_Land_and_over_Ocean/graph.png



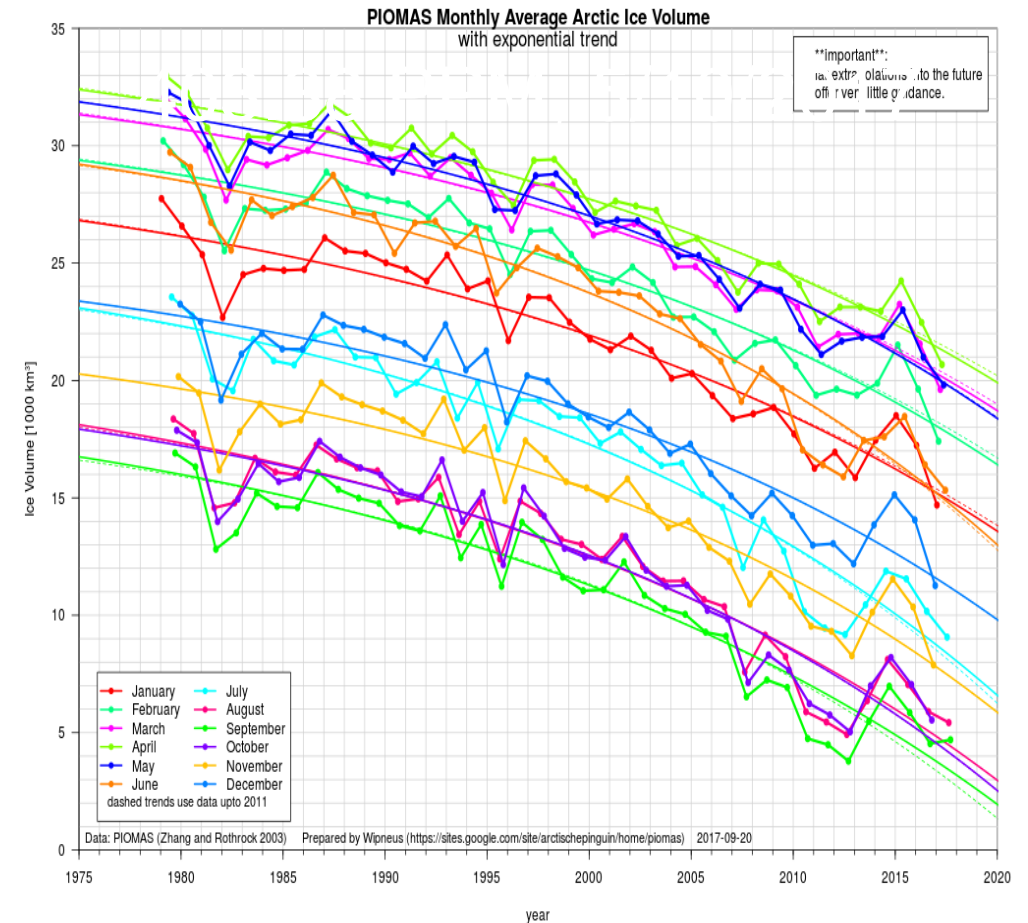
Source: https://data.giss.nasa.gov/gistemp/graphs/graph_data/Global_Mean_Estimates_based_on_Land_Data_only/graph.png

- The planet's average surface temperature has risen about 2.0 degrees Fahrenheit (1.1 degrees Celsius) since the late 19th century.⁵ Most of the warming occurred in the past 35 years, with 16 of the 17 warmest years on record occurring since 2001. Not only was 2016 the warmest year on record, but eight of the 12 months that make up the year — from January through September, with the exception of June — were the warmest on record for those respective months. (<https://climate.nasa.gov/evidence/>).

Figure 4.70: Decline of Arctic sea ice



Source: <https://pbs.twimg.com/media/C4sClniWQAAOd0h.jpg>



Source: <https://sites.google.com/site/arctischepinguin/home/piomas/grf/piomas-trnd2.png>

- A strong decline of arctic sea ice is observed over the past 40 years. Some already indicate that arctic sea may be free of ice within a few years.

Figure 4.71: First passage in Arctic without an ice breaker

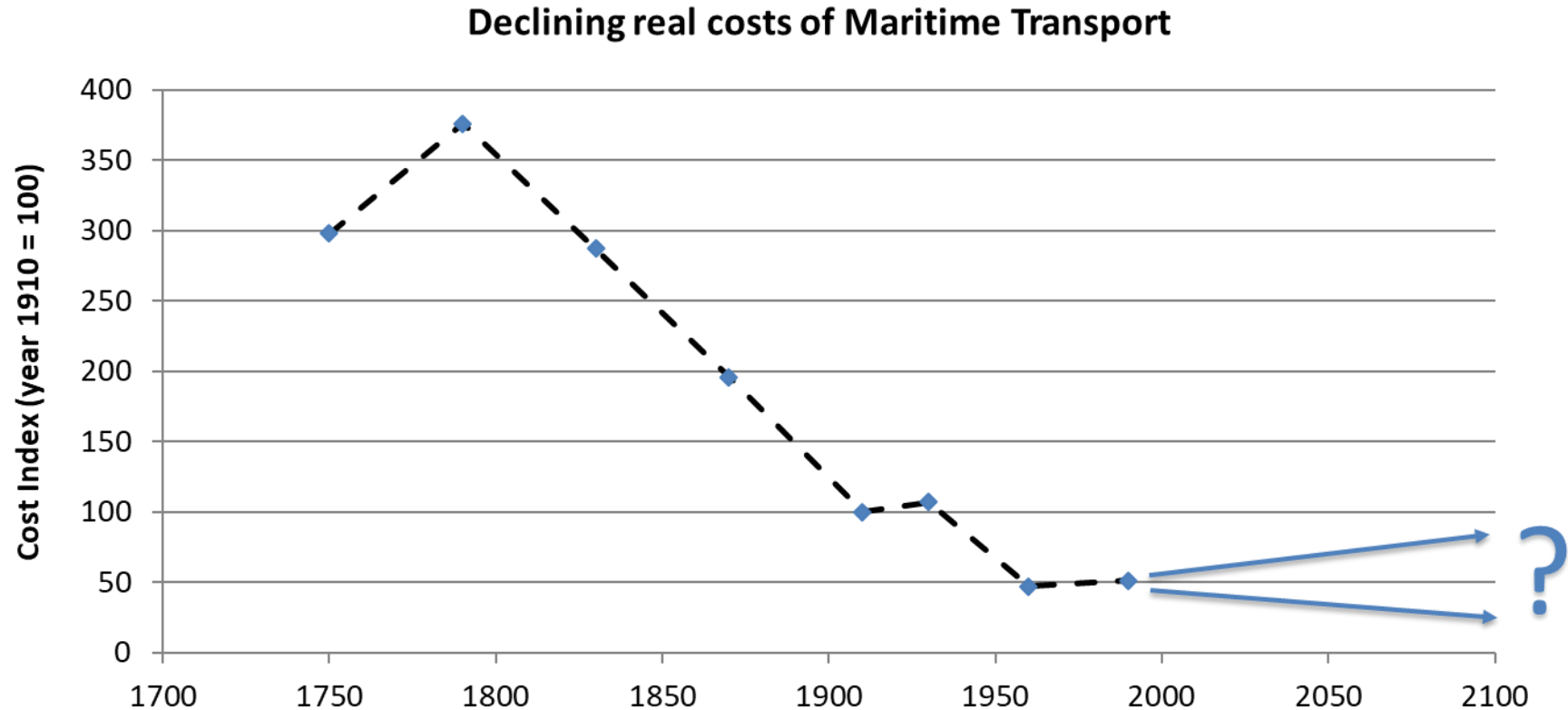


The Guardian (24-08-2017): “On its maiden voyage, the innovative tanker used its integral icebreaker to cross ice fields 1.2m thick, passing along the northern sea section of the route in the Russian Arctic in a record six-and-a-half days.”

4.9 Transport costs and globalisation

- Due to technological progress and economies of scale and scope, costs of transport have declined dramatically over the past two centuries.
- This dramatic decline in real transport costs has been one of the main drivers of the globalisation K-wave of the 20th century (i.e the 5th K-wave).
- At present, the options to further reduce the costs of seaborne freight are almost exhausted and focus is increasingly shifting towards reduction of pré- and end haulage costs of inland transport (between the port and the producing end/or receiving company).
- The present slow down in cost reduction of freight transport and the increase in costs of sea transport (as of now) and inland transport (expected within few decades), acts as a driving force for counter-globalisation.
- Declining freight transport costs are no longer a major driver of globalisation and by slowing down they no longer counterforce the sustainability and reverse globalisation movement.
- The shift in the main driver of the K-waves from globalisation to sustainability is thus also to be expected from the trend breach of century-long trend of declining transport costs.

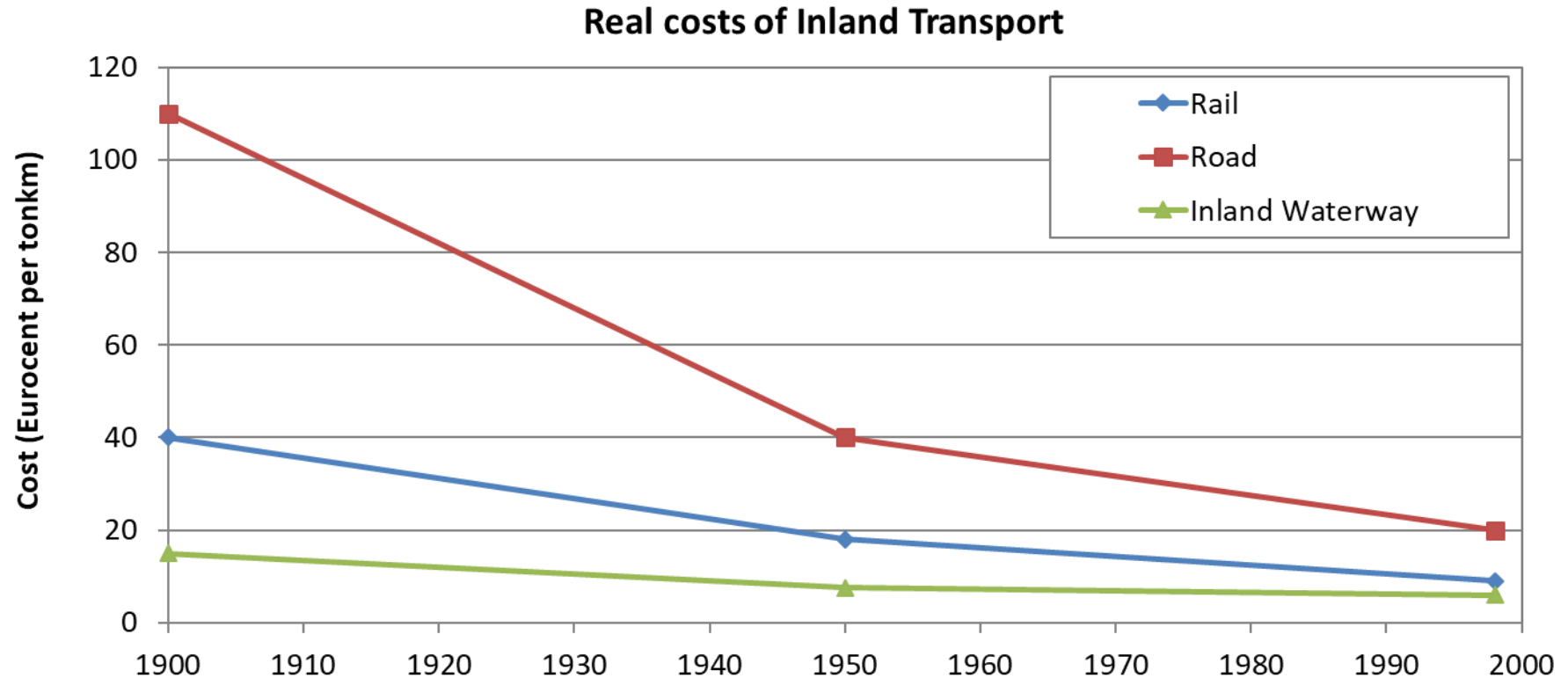
Figure 4.72: Maritime transport costs



Source: Oosterhaven, J. and P. Rietveld (2003) *Transportkosten, Locatie en Economie*, KVS paper, http://www.rug.nl/staff/j.oosterhaven/kvs_paper.pdf.

- After a dramatic decline in in the real costs of seaborne trade, there is little room for further cost reductions. In analogy with the cost development of commodities (see Figure 4.15 to 4.17) costs may now increase.

Figure 4.73: Inland transport costs



Source: Oosterhaven, J. and P. Rietveld (2003) *Transportkosten, Locatie en Economie*, KVS paper, http://www.rug.nl/staff/j.oosterhaven/kvs_paper.pdf.

- After a dramatic decline in real costs of inland transport over the 20th century, there is less margin for further cost reductions. However, the potential for inland transport costs decline is larger than for maritime sea transport. Decline of costs may thus continue for a few decades at a slower rate, after which an increase may follow.

Reverse globalisation

- Reverse globalisation trend can be observed from historical data on 'Trade over GDP' ratio, that indicates that globalisation trend follows a cyclical pattern.
- Data for the Netherlands show that someone forecasting trade volumes back in the 1865s, would have projected an ongoing exponential growth (e.g. doubling of trade volumes in a few decades time) whereas globalisation peaked shortly thereafter resulting in a stable ratio, later on followed by a decline.
- It therefore appears that there are limits to the openness of the world economy and we have once again reached these limits. This view is supported by the end of the era of declining transport costs (that drive globalisation), by the shift of the main driver of the K-wave towards sustainability, by the rising tensions in the world, and by the effect of increasing inequality, social exclusion and joblessness that fosters populism, nationalism, and reshoring of labour.
- Reverse globalisation trend can also be observed from the global 'Trade over GDP' statistics, though longer time series are harder to obtain globally.

Figure 4.74: 'Limits' to globalisation in Dutch history

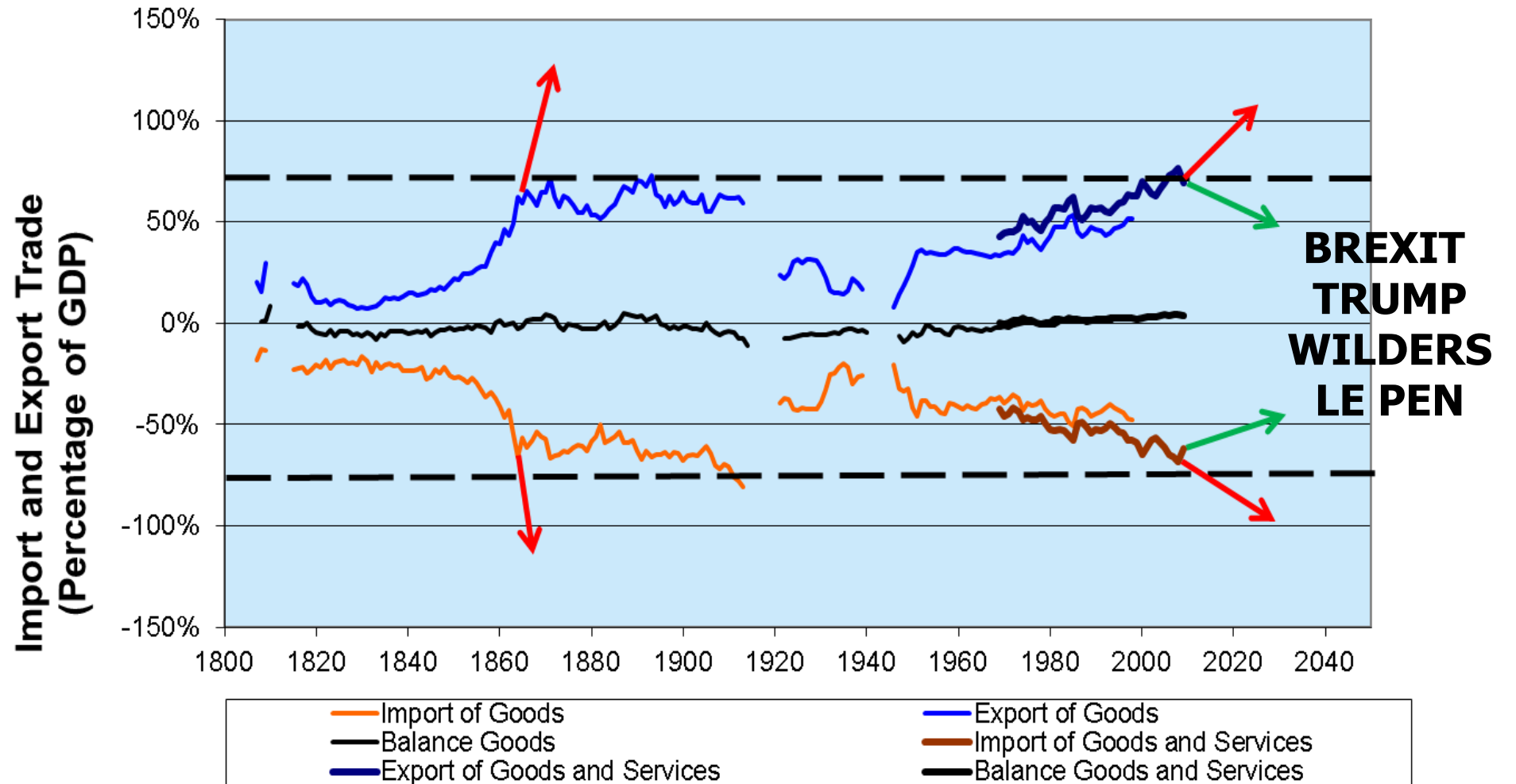


Figure 4.75: World merchandise trade over World GDP



4.10 Shifts in geopolitical world order

- Ancient history tells about great empires that lasted for centuries. Following the middle ages, countries started to challenge each other on a global scale. Shifts in global leadership, since the end of the middle ages, seem to appear almost every 100 years (Modelski, 1978; Modelski and Thompson, 1996).
- Modelski proposed a long cycle in which there is a shift of global leadership (based on maritime power) following a major conflict approximately every 100 years. Starting in 1517, the leading maritime power was Portugal (until about 1580). Portugal was first challenged by the Netherlands and England. The next cycle, starting in 1609 and continuing until 1713, was led by the Dutch and challenged by France and England. After the merger of England with Scotland, Britain, still challenged by the French, led from 1714 until 1815. After the Napoleonic wars, Britain continued to lead, challenged by Germany, from 1816 until 1914 (WW I) when Britain's maritime lead was again challenged by Germany, the United States and Japan. WW II followed. After 1946, the US became and remains the leading maritime power (but increasingly challenged by China).
- Rastler and Thomson (1983) took the cyclical theory of Modelski a step further by attempting to explain the decline of each successive dominant world power in terms of credit and debt (mismanagement). Debt levels can thus be seen as indicators of a possible shift in global power.

Shifts in geopolitical world order

- It can be concluded that shifts in power have taken place since the middle ages about once every century. Generally, such shifts were accompanied by financial mismanagement.
- The economic hegemony of the US and its allies, and the democratic ideology propagated by the Western world is now contested. This is apparent from the military built-up in potential conflict zones:
 - Russian military activities and orchestrated rebelism in Black Sea countries;
 - Fear of Russian invasion and/or orchestrated rebelism in Baltic States;
 - Chinese enforcing major claims in South-Chinese sea;
 - Chinese enforcing major claims in East-Chinese sea;
 - Chinese increasing military presence in Indian ocean;
 - Korean conflict on Yellow Sea and Kim Yong Un's nuclear ambitions.
- Though the incidence of major wars between world leading power has fallen significantly over past 500 years, tensions are building up and unpredictable leadership in both East and West, form a real threat of a potential conflict.

Figure 4.76: Occurrence of War amongst great powers

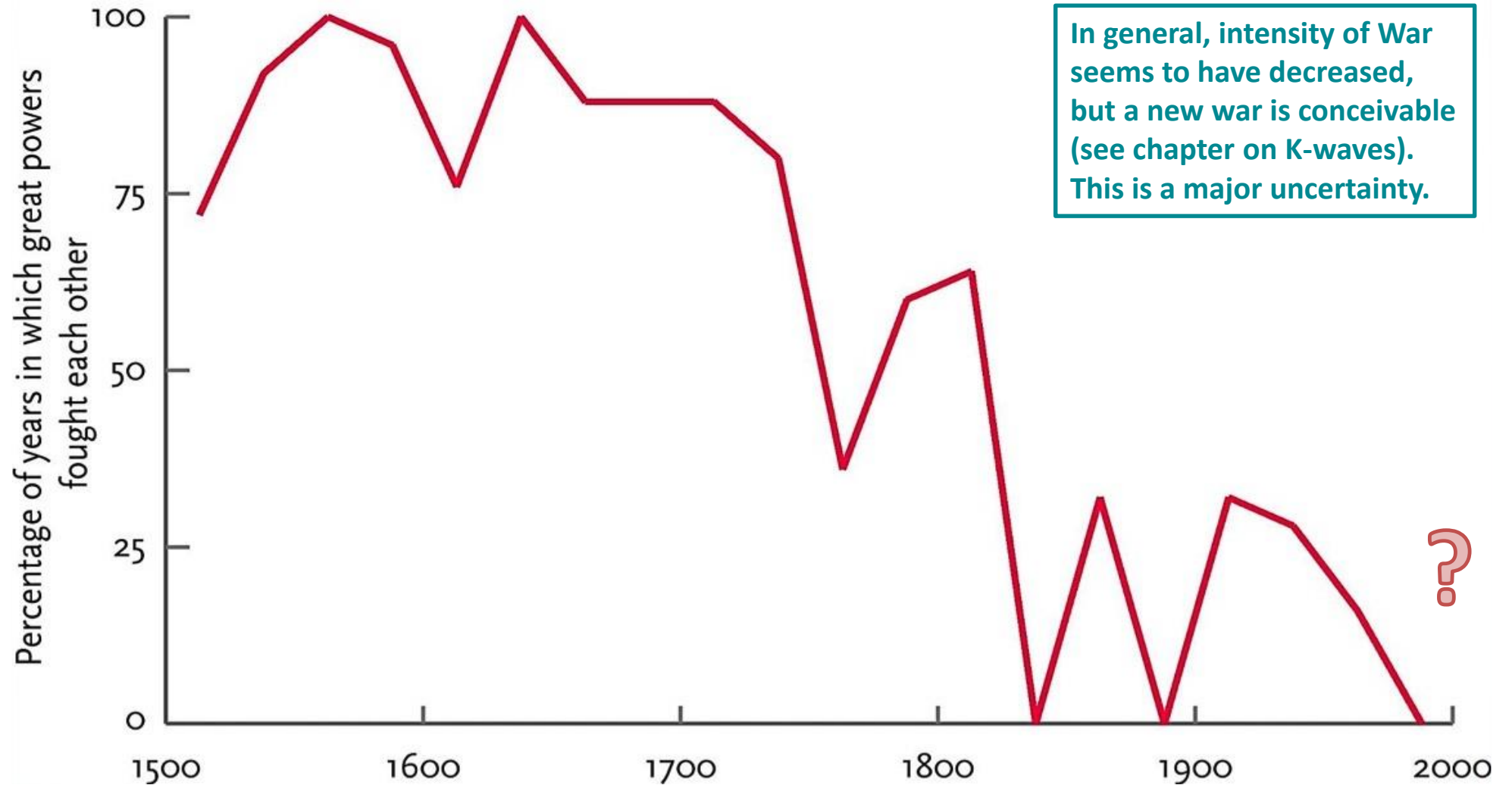
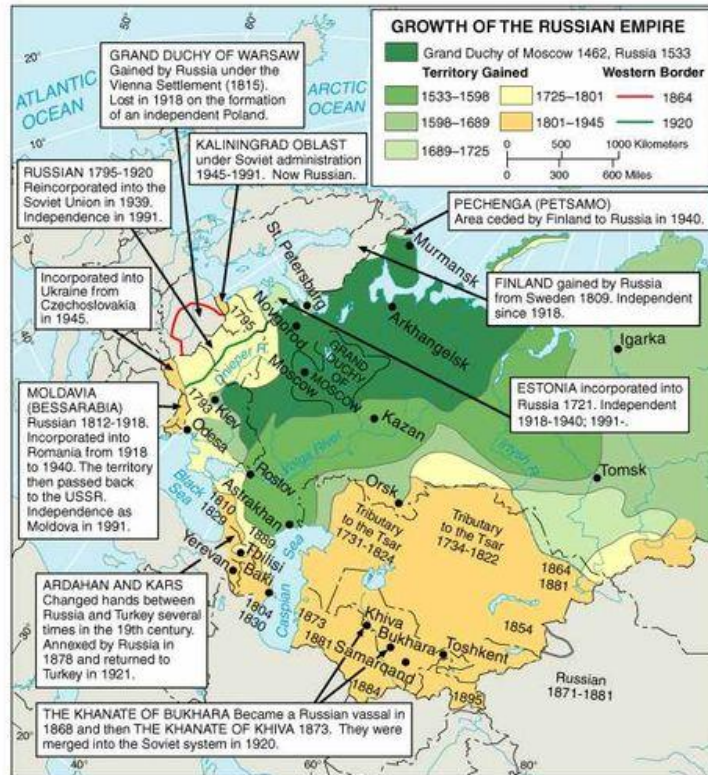


Figure 4.77: Russian drift for militaristic expansionism

- Numerous potential conflicts on Russian federal territory, as Russians desire to restore historical situation before the collapse of the USSR superpower.
- Many disputes over past decades since Putin came into power. Main objective seems to be securing Russia's vulnerable seaways and claiming reserves.



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<https://nl.pinterest.com/pin/5840674490630238/>

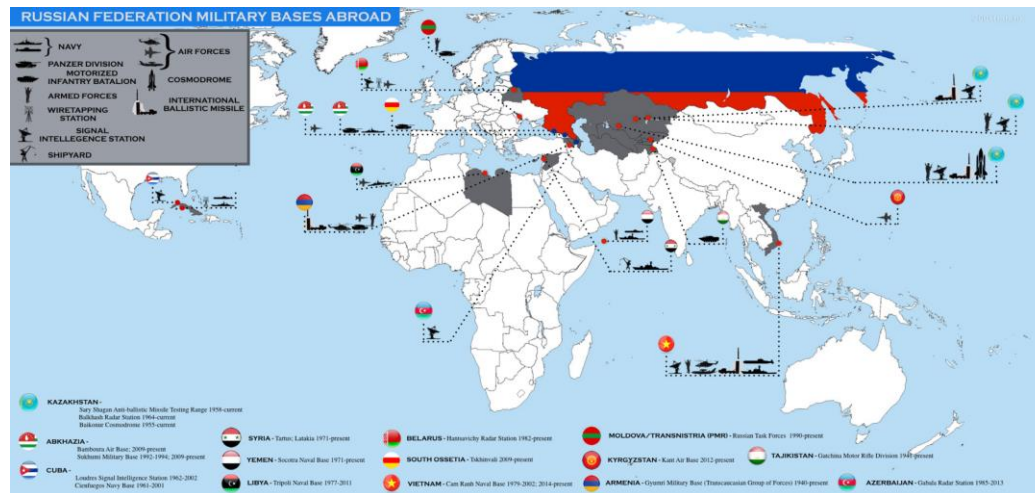


<https://thenypost.files.wordpress.com/2014/05/russiajdsfkfskfsf.jpg?quality=90&strip=all>

Figure 4.78: Russian expansionism restrained by NATO



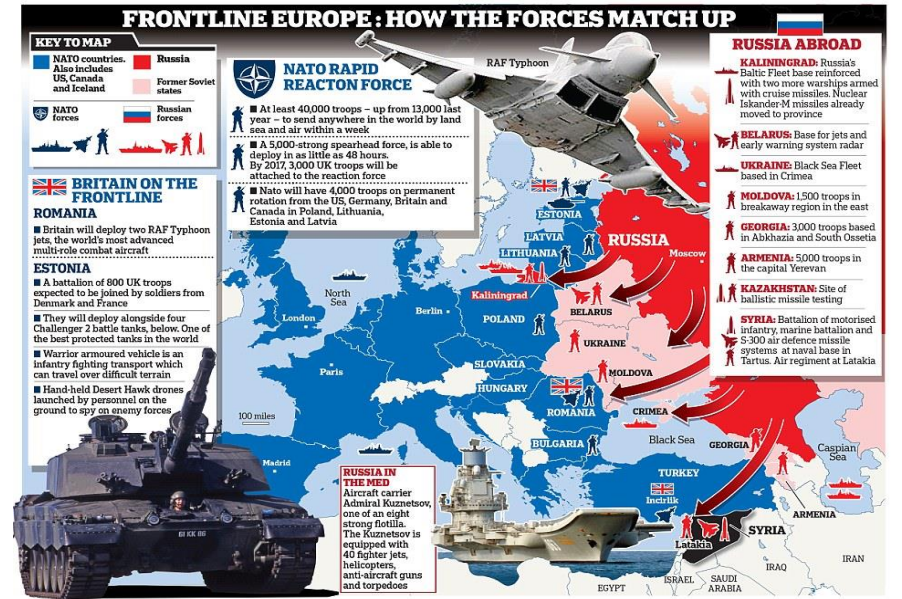
Source: <https://antioligarch.files.wordpress.com/2012/05/russia-nato-bases.jpg>



Source: <https://i2.wp.com/www.numbers-stations.com/wp-content/uploads/2017/05/RASHKA.png>

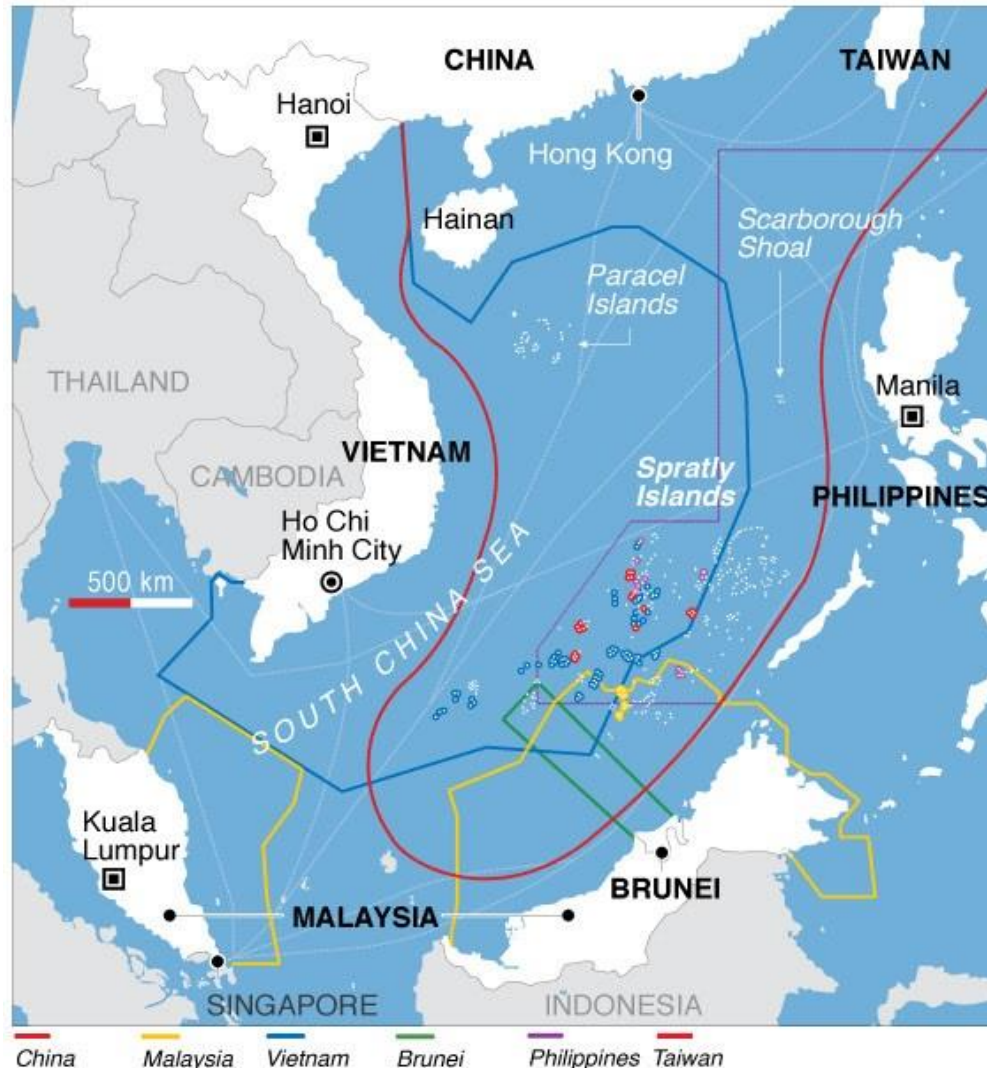


Source: <http://euromaidanpress.com/wp-content/uploads/2014/11/russia-native-lands-.jpg>

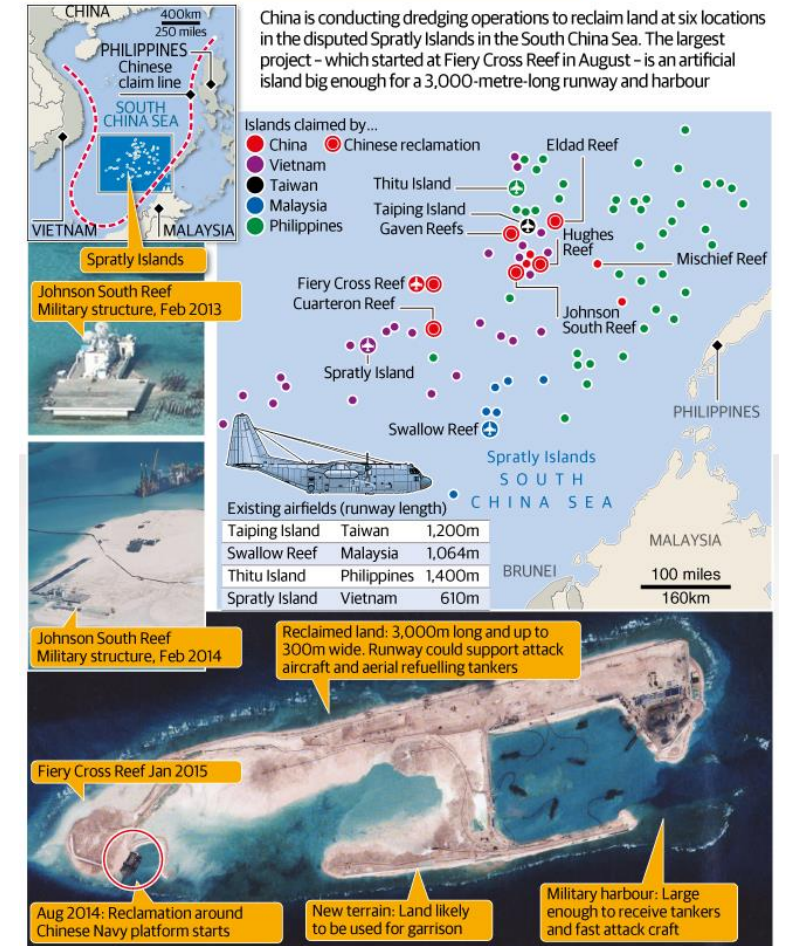


Source: http://i.dailymail.co.uk/i/pix/2016/10/27/00/39C011910000578-0-image-a-39_1477523068722.jpg

Figure 4.79: China's claim and disputes on South China Sea



CHINA'S ISLAND-BUILDING PROJECTS



© GRAPHIC NEWS
Source: IHS Jane's Defence Weekly
Pictures: Associated Press, Philippine Armed Forces, Airbus Defence and Space satellite imagery

<http://warnewsupdates.blogspot.nl/2017/08/has-china-finished-its-island-building.html>

Figure 4.80: Disputes on East China Sea and Yellow Sea

Issue is complicated by Korean nuclear threat.



Source: <http://www.china-briefing.com/news/wp-content/uploads/2011/05/East-China-Sea-Map.jpg>

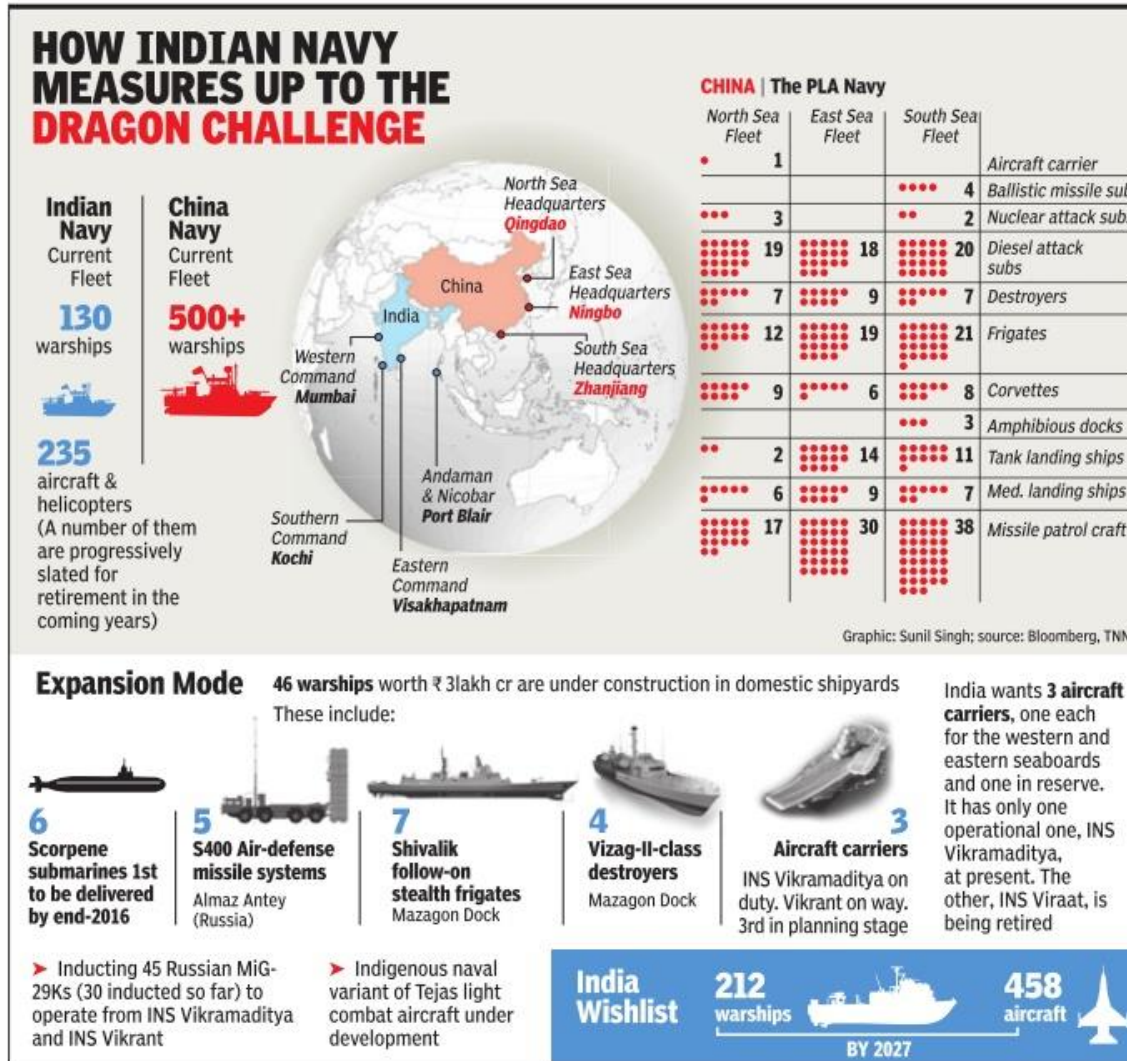


Source: http://www.aljazeera.com/mritems/Images/2017/9/4/3537a0495f904ad29ca35dd250b12bf1_18.jpg



<https://www.britannica.com/media/full/322222/151908>

Figure 4.81: China's presence in Indian ocean



Source: <https://www.quora.com/What-are-the-main-conflicts-between-India-and-China>



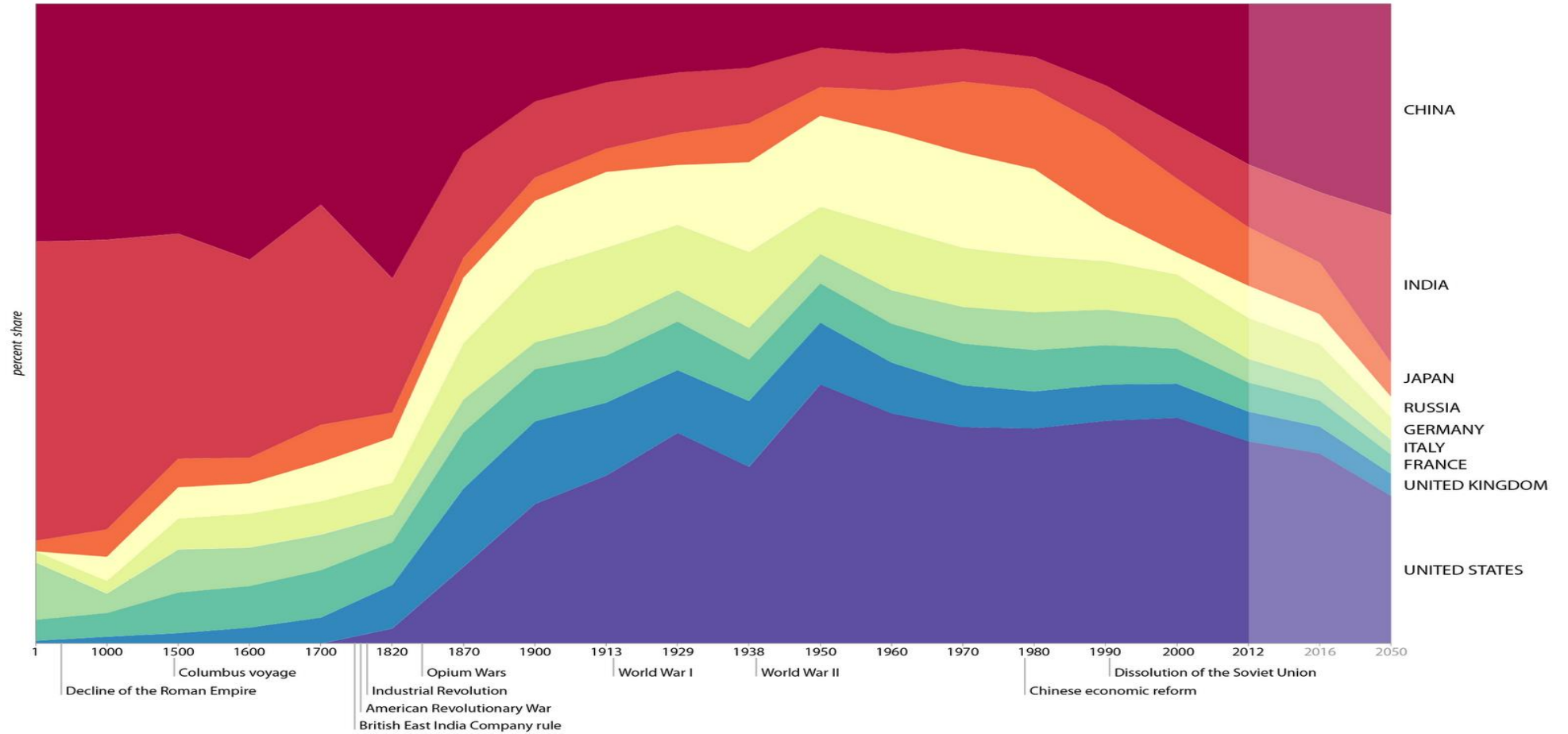
Source: <https://commons.wikimedia.org/wiki/File:Collardeperlaschino.png>

Considerations over power shift from west to east

- Countries seeking territorial expansion such as China (claiming the South and East Chinese Sea and increasing its dominance in the Indian Ocean) and Russia (exploiting all possibilities to restore the former USSR empire) have shaped a new alliance, the Shanghai Cooperation Organisation (SCO) to avoid US interference in what they call 'domestic' affairs. Turkey is supporting this ideology and considering leaving NATO to join the SCO.
- In our opinion the main geopolitical uncertainties are:
 - Is power fully shifting from western hegemony to eastern hegemony, or is power only partly shifting towards a multipolar geopolitical situation?
 - Will the shift of power be resolved without war or not? War can be expected to lead to a definite shift from west to the east, or a prolonged US hegemony.
- Putting aside the unpredictability of political leaders, a few trends indicate that Russia and China will be reluctant to strive for military hegemony. Both are facing demographic decline and decline in economic growth, while the religious American population show a steady population growth and ongoing technological progress. In addition, the (potentially neutralising) role of the more western oriented country of India in the SCO, is still to be discovered.

Figure 4.82: China and India are recovering their ancient position

A history of balance of power based on percentage share of combined GDP (PPP) of the 9 great powers

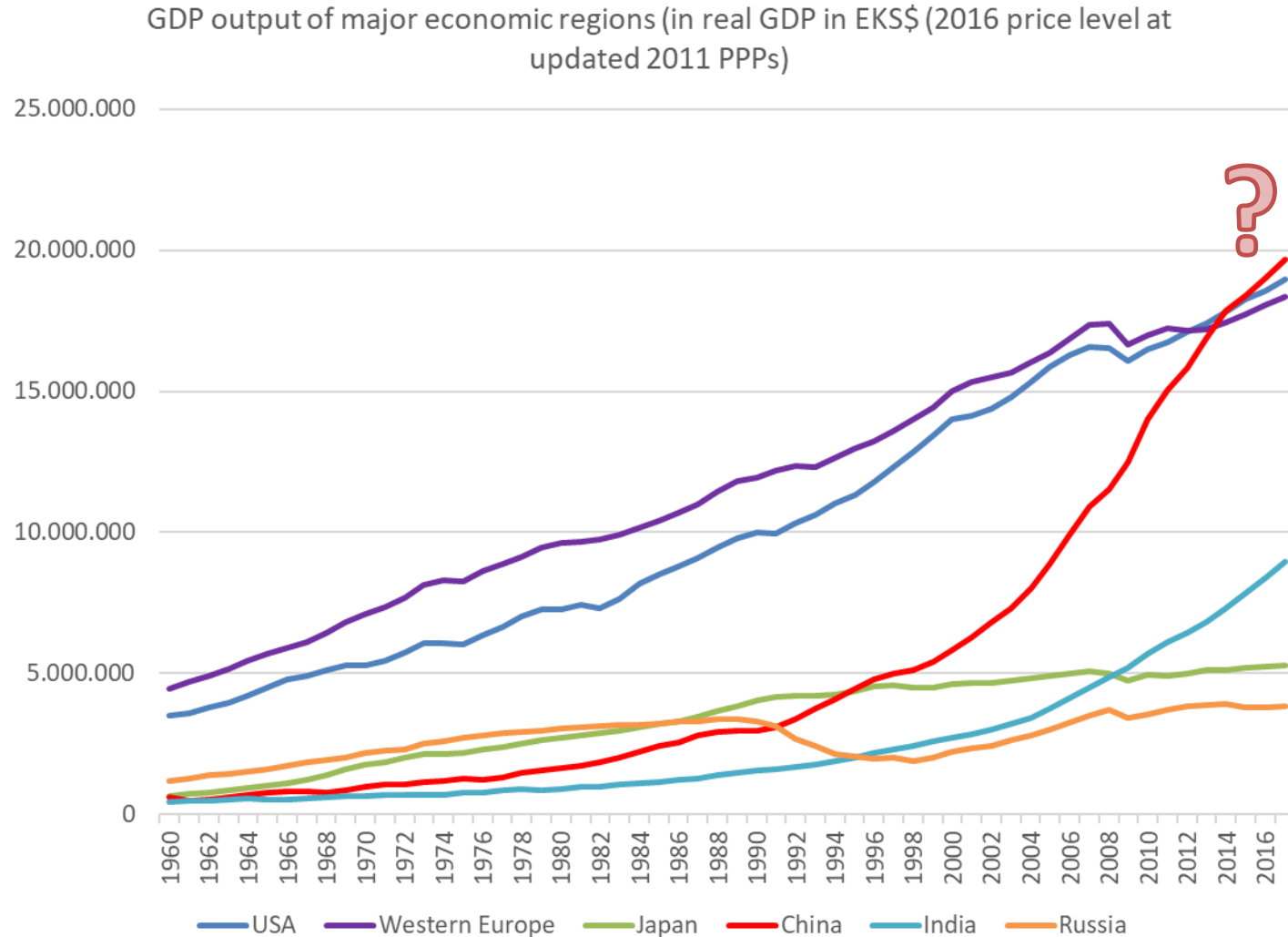


Author: Sasha Nikitin, 2012, <http://nalilord.livejournal.com>

Sources: GDP data for years 1 - 2000 Angus Maddison, University of Groningen; 2016 IMF projected; 2050 PWC projected

Source: <http://wiredbrazil.blogspot.nl/2012/03/graphic-gdp-history-history-of-balance.html>

Figure 4.83: Shifts in political world order



China has set in a gradual slow-down of population and per capita output growth;

US has a strong population growth and a gradual per capita output growth;

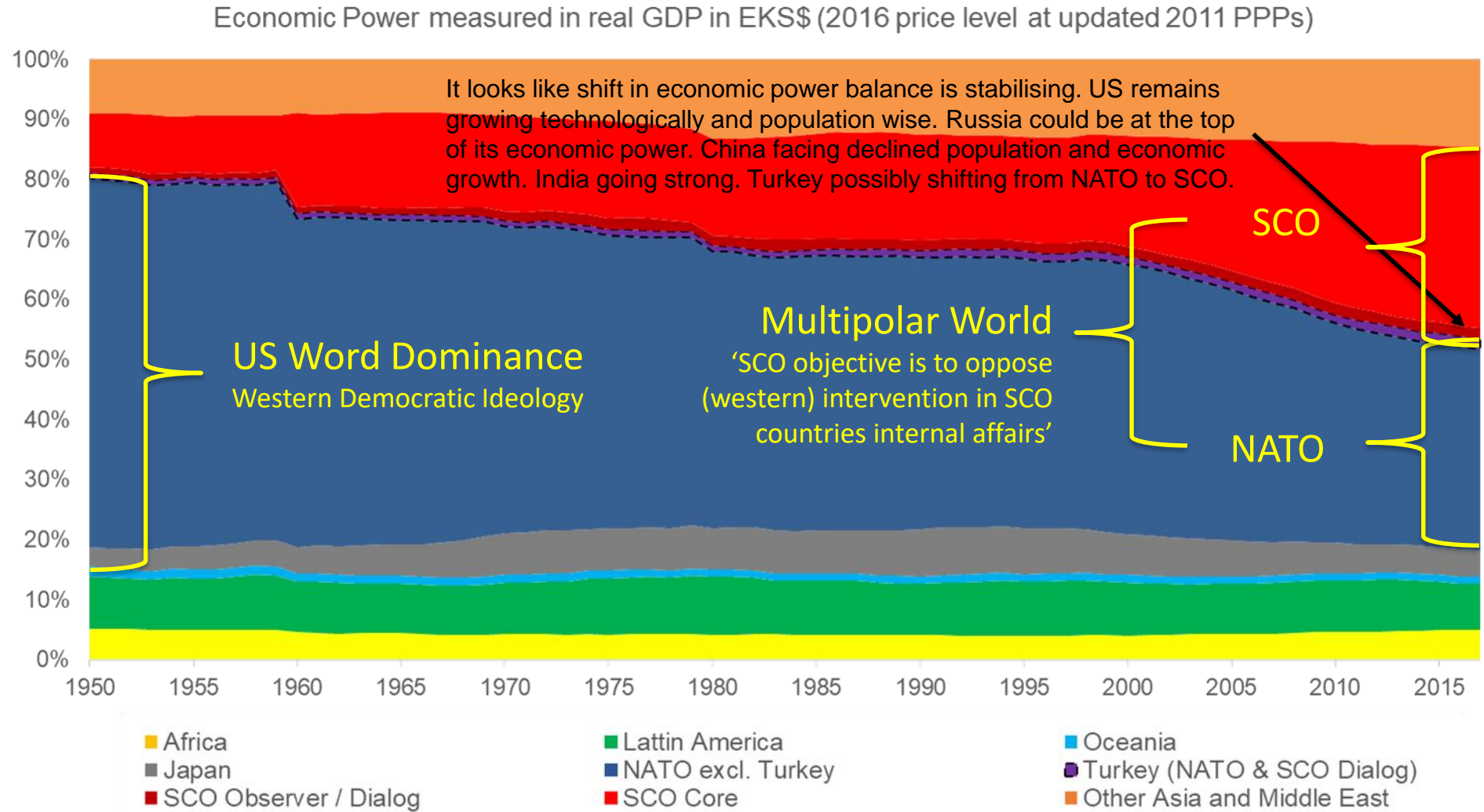
European population and per capita output are falling behind;

India has a strong growth of population and per capita output;

Japan faces stagnation in population and per capita output;

Russia faces population decline and per capita output is vulnerable to possibility of renewables forcing oil price down.

Figure 4.84: Stabilising economic power in a multipolar world

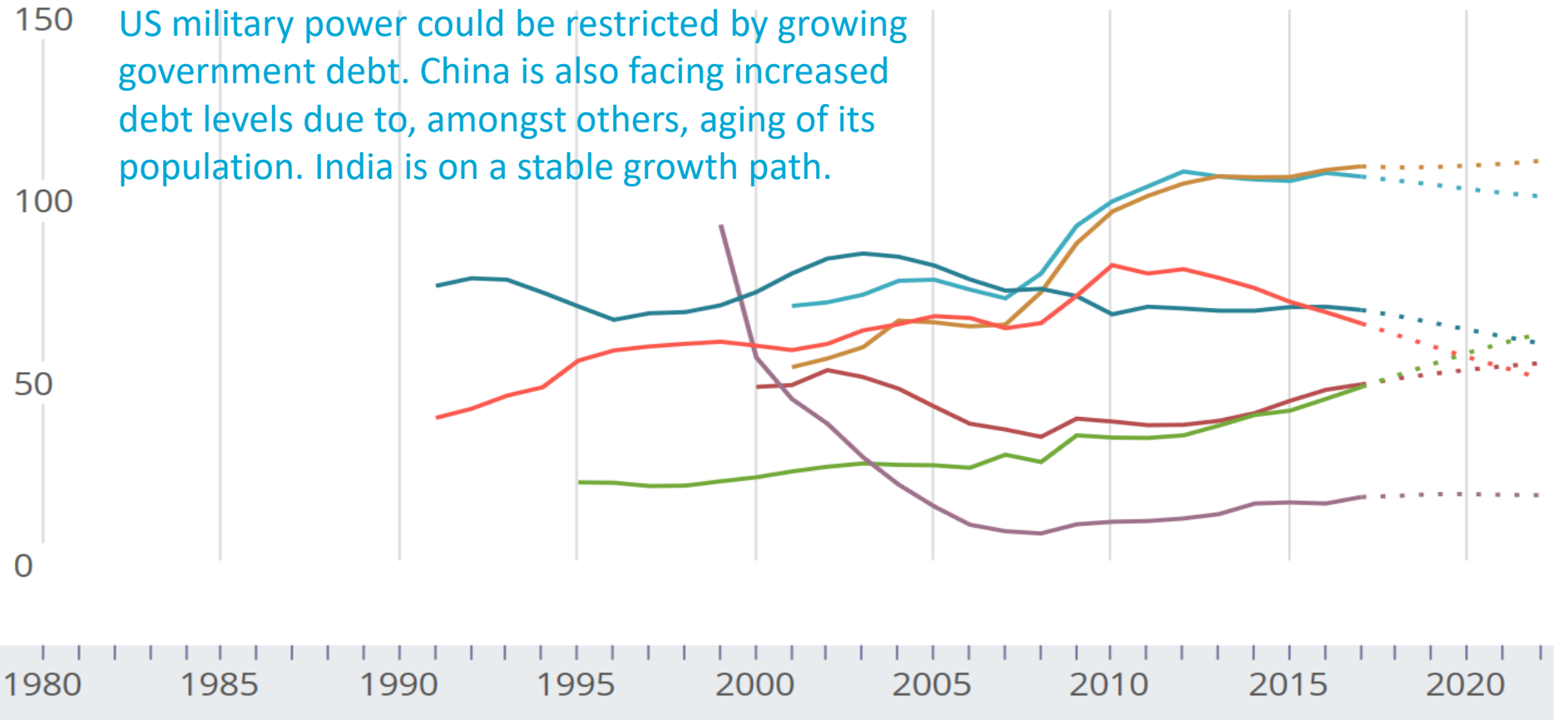


Data: The Conference Board Total Economy Database™ (Original version), May 2017. China (Alternative) dataset used.

Figure 4.85: Development of public debt ratios

IMF DataMapper

General government gross debt (Percent of GDP)



● Emerging market and developing economies ● Advanced economies ● United States ● China, People's Republic of ● Russian Federation
● India ● Germany

Source: http://www.imf.org/external/datamapper/GGXWDG_NGDP@WEO/OEMDC/ADVEC/USA/CHN/RUS/IND/DEU

Recapitulation of geopolitical trends

- In the past few decades, demographics and economic power have been building up significantly in the east, with China and India reclaiming their position as ancient world powers. Russia is cooperating with China to set up the SCO and other non-western institutions.
- As a result, the western US hegemony, and dominant western democratic ideology is now being challenged. The result will be a multipolar world in which geo-pragmatism and a mind your own business attitude prevails.
- In view of the ongoing demographic and economic developments, a full shift towards eastern hegemony is unlikely. Russia has a declining population and is economically weak and vulnerable due to economic sanctions and pressure on oil prices created by the energy transition. China is aging and facing a population decline over the next few decades. The one child policy could result in fierce opposition to go to war (one loses the entire family if the only son is lost). India, which is more pro-western, is likely to gain power. In the US, birth rate and economic progress are high enough for it to potentially maintain its position as a leading power.
- In absence of a major war, a prolonged period of multipolar power in which democratic principles of international justice are sacrificed, can be expected.

5. The meta-framework

- 5.1 Description of an integrated meta-framework
- 5.2 Century-long trends as drivers of next K-wave
- 5.3 K-waves and impact on century-long trends
- 5.4 K-waves and confirmation from megatrends
- 5.5 K-waves and inertia of megatrends
- 5.6 Conclusions on use of meta-framework

5.1 Description of the meta-framework

- In the present volatile times, a ‘binocular’ is insufficient to obtain a sharp view of the future. Far more sophisticated tools are required to ‘see’ better and improve our understanding of what we see. Looking far ahead and anticipating future developments requires an equivalent of a Hubble telescope.
- The meta-framework proposed in this study, builds on the basic principle that in order to understand the direction of future developments, an understanding of the broader context in which individual developments take place is essential. Once the context is understood, the direction of future trends can be estimated with more certainty.
- This chapter elaborates on the additional insight created by the meta-framework.



http://silva.se/app/uploads/2016/11/binoculars_tromsoe.jpg



https://californiasciencecenter.org/sites/default/files/styles/meta/public/media/image/hubble-telescope.jpg?it ok =u_vuyGB9

Description of the meta-framework

- If trends are analysed without placing them in a broader context, the deviations in the trend can be observed but one cannot be sure if it is a trend breach. The trends too can't be anticipated.
- Example 1: a current trend is the focus on optimising costs for hinterland transport. Without understanding the underlying trends, it is difficult to say if the trend is important for port authorities. However, in view of the knowledge that the real costs of sea transport have (nearly) reached an all time low, the need to increase the competitiveness of hinterland transport becomes obvious.
- Example 2: without placing it in a broader context, it is not possible to determine the direction of the trend in Figure 4.75 i.e. red or blue arrows?

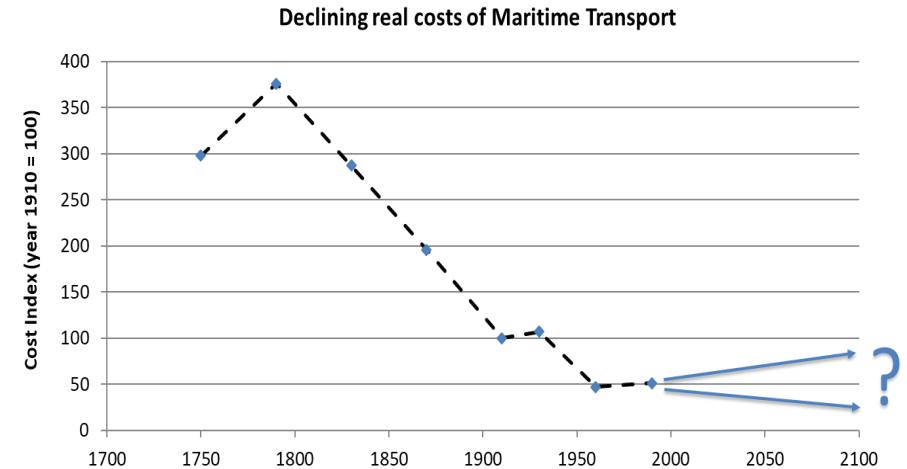
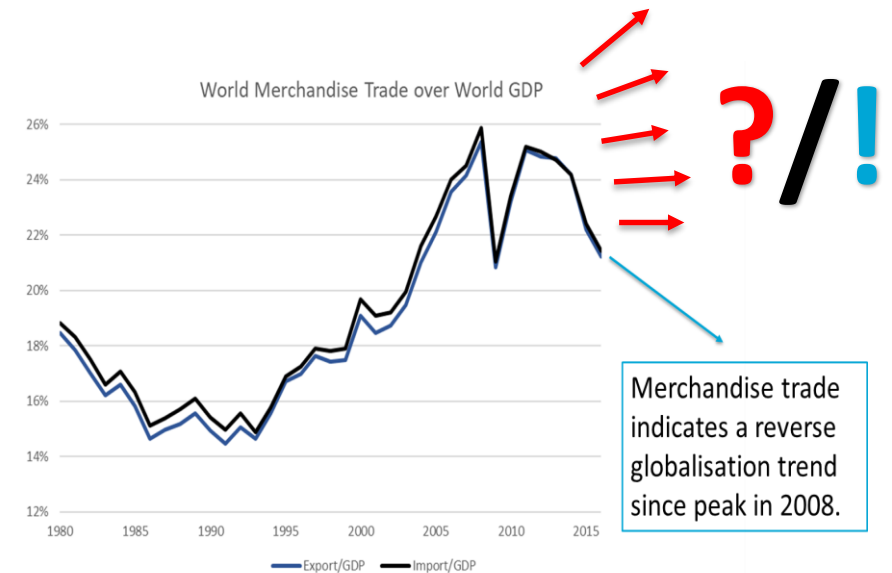


Figure 4.72: The integrated meta-framework for analysing trends



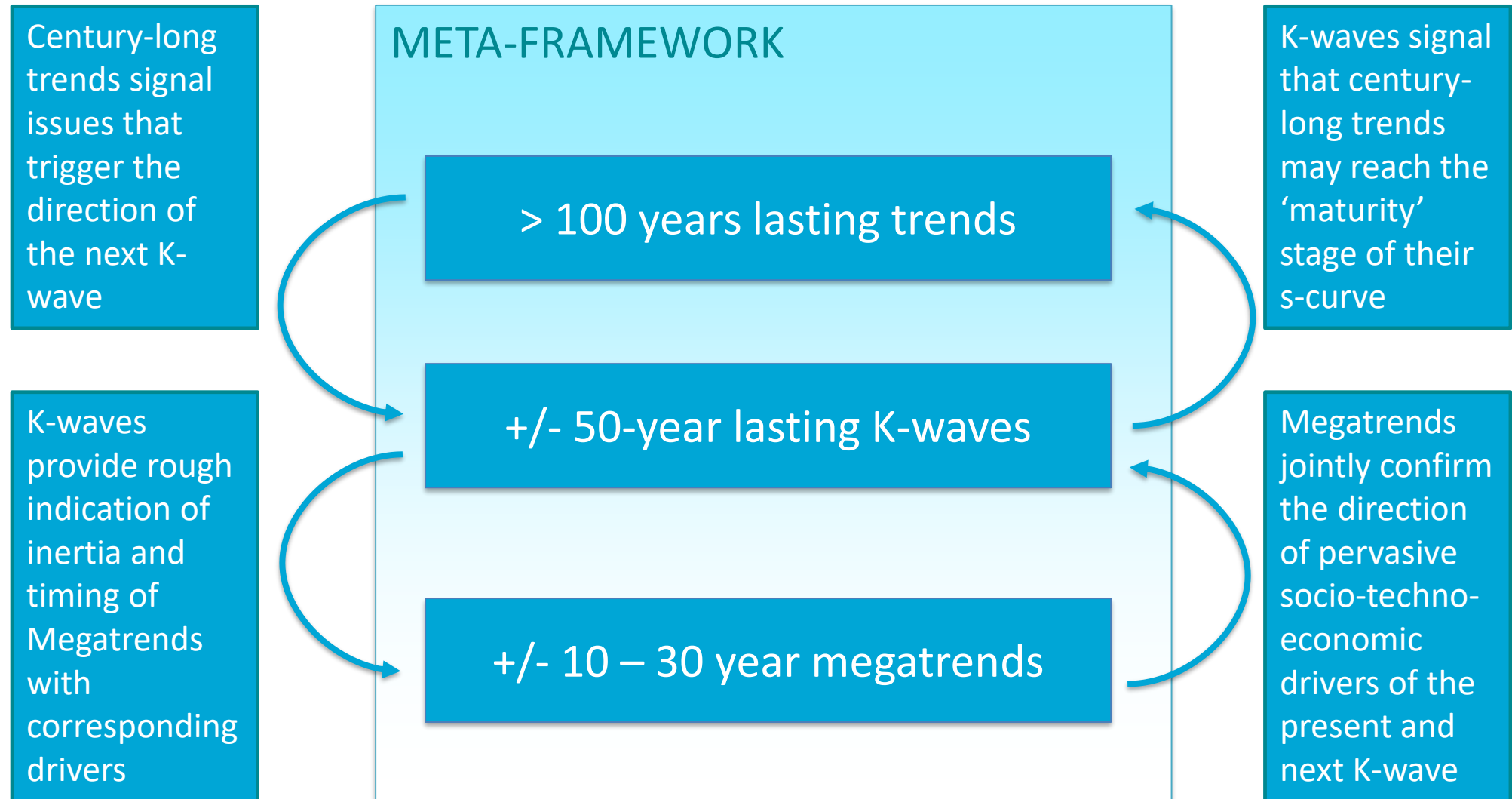
Merchandise trade indicates a reverse globalisation trend since peak in 2008.

Figure 4.75: World merchandise trade over World GDP

Description of the meta-framework

- For understanding the broader context in which individual trends take place, a framework that augments insights from individual trends with insights from related trends, is required. This principle works in two directions.
 1. Independent, well-known megatrends can be placed in a broader context of more fundamental trends from which they emerge.
 2. Fundamental trends with a large inertia can be identified and validated by various ongoing developments heading in the same direction. For example, numerous ongoing developments (megatrends and uncertainties) validate the more fundamental trend toward sustainability.
- Therefore it is useful to analyse trends at different levels of inertia, and integrate the insights using the meta-framework. The proposed meta-framework, therefore, consist of three layers with different levels of inertia (see Figure 1.5, repeated as Figure 5.1).
- The top layer comprises relatively stable trends with a duration of over a century; the middle layer relates to the cyclical movement of the about 50 years Kondratieff waves and its associated pervasive trends (or drivers); and the bottom layer includes 'standard' megatrends with a duration of one or two decades.

Figure 5.1: A meta-framework for an integrated trend analysis



Source: Figure 1.5 (repeated).

Description of the meta-framework

- The presented meta-framework links the trends in the three layers resulting in deeper insights than can be obtained by analysing individual trends. The middle connecting layer, contains the cyclical movement of the K-waves and describes their fundamental drivers. Therefore, K-wave analysis is very significant for anticipating future developments.
- For major transitions (e.g., energy transition), it is not advisable to apply a standard quantitative forecasting model that extrapolates historical trends and uses expert opinion. All related trends need to be placed in a broader qualitative framework that improves our understanding of the fundamental drivers, and ensures that deviations of the trend (i.e. breaches) are not overlooked.
- The calibration of ‘our Hubble telescope’ comes from the augmented insights provided through use of layers with varying inertia. Century-long trends signal issues that are likely to trigger the direction of the next K-wave and help identify pervasive drivers with more certainty. Once identified, the direction of the pervasive drivers of the next K-wave can be validated by analysing the current megatrends (and their enablers, such as emerging technologies).

Description of the meta-framework

- Once the pervasive drivers of the next K-wave are established, the position of century-long trends on the transition s-curve can be perceived. This is important to establish if the inflection point on the curve has been passed.
- Insight in pervasive drivers of the K-waves and their corresponding levels of inertia is useful for obtaining an indication of the period when emerging technologies can become dominant, as explained in [Chapter 3](#).
- An identification of the pervasive drivers of the K-waves is thus essential for understanding the direction of future trends.
- The main drivers of the 5th K-wave (now in its downswing phase) are **Globalisation** and **ICT**. The expected drivers of the next K-wave are **Sustainability** and **IoT**.
- Note that the drivers of the 6th K-wave emerge during the downswing period at the end of the 5th K-wave.



Period of Innovation!



Period of Implementation!

Source: Conclusion of Chapter 3, repeated.

5.2 Century-long trends as drivers of next K-wave

Nine century-long trends were identified in Chapter 4. All these trends contribute to the fundamental shift from **globalisation** towards **sustainability** and the continuing rise in hyperconnectivity reflected by the shift from **ICT** towards **IoT**. The forces exerted by the nine century-long trends that act in the direction of countering globalisation, enhancing sustainability, and increasing connectivity are discussed below:

- The **secularisation and individualisation** trend explains the tensions within the Islamic world resulting in nationalistic and populist forces in the west resulting in reverse globalisation through protectionist policies, and signal the end of the globalisation era (symptoms: Brexit, Trump, etc..).
- The **nature of activities and social power** trend indicates a shift from energy to information as a major source of power. The implications are twofold.
 - First, the shift from energy to information implies that the world will no longer be energy constrained (reduced fossil dependency as renewables offer a potential for abundant energy in the future). This relates to the sustainability driver.
 - Second, the shift towards information as prime source of power relates to the rise in hyperconnectivity.

Century-long trends as drivers of next K-wave

- The **population and urbanisation** trend amplifies the trends in energy- and raw material use as increased population requires a vast amount of resources and spurs demand for renewables and recycling. Urbanisation also increases social awareness of pollution and unsustainable exploitation of earth resources, thus driving sustainability. Urban population lives in more compact houses and is less likely to own a car, acting as an enabler for reduced energy and raw material consumption (sharing goods instead of owning them). This trend is therefore, a major driver for sustainability. Moreover (educated) urban population is likely to accelerate the shift from ICT to IoT.
- The **energy and raw material use** trend implies that mining efforts in terms of cost and energy are on the increase, which fosters sustainable development of energy and raw material use (i.e. refuse, reduce, reuse, recycle, etc...) as a cost effective alternative. This effect is enhanced by the growth of the world population and the strong economic growth in developing and newly industrialised countries (NICs) accompanied by increasing demand for material input. The difficulty in meeting resource demand, acts as a major driver for renewable energy and recycling. This is becoming obvious e.g. in China where there is an increase in imports of scrap metal and efforts to boost sustainable energy production (mostly solar, but also wind etc.).

Century-long trends as drivers of next K-wave

- ... The energy and raw material use trend is also influenced by climate change related policies that aim to speed up renewable energy development. The decline in costs of renewables is already so dramatic that investments in new fossil energy production and refining capacity is declining. The supply of renewable energy requires smart grids, which in turn drives the shift from ICT to IoT.
- The **technological progress and economic growth** trend fosters reverse globalisation, sustainability and the development of IoT in several ways. At the disaggregated level, many new technologies are being developed in fields of sustainability, big data and IoT. At the aggregated level, technological progress (automation, robotics, and artificial intelligence), will displace workers. In the present economic reality where corporate taxes are low compared to taxes on wages (and still being lowered by e.g. Mark Rutte and Donald Trump), this displacement will cause a decline of the middle class in western countries. Unemployment and inequality foster populism, nationalism and reverse globalisation. Some undercurrent forces countering the inequality trend are gaining strength (e.g. the Bernie Sanders movement in the US).

Century-long trends as drivers of next K-wave

- The **connectivity and information exchange** trend aligns with the trend towards hyperconnectivity, i.e., connecting devices to the IoT. Availability of sensor data e.g. over pollution levels, helps to create transparency and drives sustainability initiatives. The next step beyond IoT, is to connect the human body to the 'internet'. This fusion of technologies in the physical, digital and biological worlds is referred to as the fourth industrial revolution.
- **Climate change and environmental degradation** are both strong drivers of sustainability and act in two ways. First top-down via environmental and climate policies, and second bottom up whereby consumer awareness and corporate responsibility contribute to increased environmental compliance (sustainability and reducing footprint is becoming a core objective for major brands). Climate change and pollution result in lower agriculture yield and fish catch; this could result in mass starvation and migration, further triggering populism and nationalistic sentiments and reversing globalisation.
- Intercontinental **transport costs** (at sea) have now reached a point of no further decline. Declining transport costs thus no longer serve as a driver for globalisation.

Century-long trends as drivers of next K-wave

- **Shifts in political world order**, or more specific the shift from US hegemony to a multi-polar (or bi-polar) world in which NATO and SCO both vie for power, can make the world less stable. This instability and malfunctioning of western institutes (such as the UN safety council) increases geopolitical tensions and reverses globalisation. E.g. disagreements over the Syrian crisis causing refugees to flee to Europe and increasing populism and nationalism, which in turn results in raised trade barriers. Another example is the sanctions imposed on Russia reducing trade volumes between Russia and EU member states. The consequences of dissensions over North Korea could be dramatic, especially if followed by a trade conflict between the US and its allies and China. Shifts in the political world order will, almost by definition, reduce international trade.

To conclude, each of these nine trends drive reverse globalisation, sustainability, and hyperconnectivity. The century-long trends therefore establish that globalisation is indeed on its reverse. This implies that trade volumes will follow the **blue** line in the Figure 4.75 – and that the main driver of the next K-wave are sustainability and IoT, in combination with transitions in socially relevant systems, e.g. energy transition.

5.3 K-waves and impact on century-long trends

Similarly, the primary drivers of the K-wave will influence the direction of long-term trends, but it can take time to change (or bend) the curve of a very long-term trend. The influence of the K-wave drivers on the century-long trends is probably not as large as the other way around and can be compared to the continuous force exerted by a small rudder on a super tanker. The shift from globalisation to sustainability creates forces that tend to align the century-long trends making them co-dependent. As a result, the entire system moves into a certain direction. The impact of the K-wave drivers on the century-long trends is as follows:

- **Secularisation and individualisation:** ongoing digitalisation and interconnected world act as an amplifier for secular tensions (i.e. a positive feedback loop).
- **Nature of activities and social power:** sustainability trend stimulates production of (cheap) renewable energy reducing the need for fossil reserves. This undermines the role of fossil energy resources as a global power source. Research and development of knowledge is required in the field of renewables, and supports the shift from energy to knowledge as a source of power (i.e. a positive feedback loop).

K-waves and impact on century-long trends

- **Population and urbanisation:** sustainability (including income and wealth equality) and a healthy life style are all drivers with a positive effect on population growth. Taxes on carbon footprint, digitalisation and increasing connectivity are drivers of further urbanisation. In turn, sustainability and increasing connectivity are drivers for population growth and ongoing urbanisation (i.e. two positive feedback loops).
- **Energy and raw material use:** sustainability is a major driver for the transition from fossil fuel exploitation to harvesting renewable energy. Technological development in the renewable energy field is starting to undermine the business case for new fossil mining and refinery investments (too little time left to recover capital expenditures). Cost of energy may temporarily go up in the medium term but is expected to decline and then stabilise with advancing technology. Recycling gains importance as resource for manufacturing materials (i.e. negative feedback loop on energy and raw material exploitation).

K-waves and impact on century-long trends

- **Technological progress and economic growth:** at disaggregated level sustainability acts as a main driver for many technological developments. Inventions like 3D printing foster local or regional production. Sustainability temporarily spurs economic output (for a few decades) as the energy and raw material transition creates new markets. On long term, sustainability may increase economic output by reducing inequality levels (i.e. sustainability has positive feedback loop on both medium and long term economic growth).
- **Connectivity and information exchange:** this long term driver is fully aligned with the indicated driver of the K-wave towards more connectivity (i.e. it is similar to shift from ICT to IoT).
- **Climate change and environmental degradation:** though the inertia of the climate change trend is much larger than the inertia of the pervasive socio-techno-economic drivers of the K-waves, the sustainability driver of the 6th K-wave will slow down climate change. Hopefully, this will help maintain the global temperature rise between 1.5 to 2.0 degrees as stated in the Paris agreement. (i.e. sustainability has a negative feedback loop on climate change, pollution and environmental degradation).

K-waves and impact on century-long trends

- **Transport costs and globalisation:** sustainability affects transport cost and globalisation in various ways. In short term, it adds to transport cost by demanding sustainable operations (reducing carbon emissions, reducing pollution, enhancing safety, etc.). In the long run, sustainability may reduce transport costs, as it makes processes more cost effective and renewable energy will eventually result in lower fuel costs. (i.e. sustainability may have a short term negative feedback loop and a long term positive feedback loop on transport cost and globalisation).
- **Shifts in political world order:** sustainability reduces the need for raw materials and fossil fuels, thereby reducing global tensions. This results in an increase in trade and transport volumes. (i.e. sustainability creates a negative feedback loop on the raising tensions).

It can be concluded that the main drivers of the next Kondratieff wave (sustainability and increased connectivity) impact all century-long trends. The largest effects are: change in direction of the energy and raw material trend, the climate change and environmental degradation trend, and the increasing tensions from the shift in political world order.

5.4 K-waves and confirmation from megatrends

- Megatrends and emerging technologies show an alignment with the primary drivers of the present K-wave and confirm the movement of pervasive K-wave drivers.
- As indicated in Table 3.2 (see right), many of the emerging technologies of the present 5th K-wave are related to sustainability and increased network connectivity. These trends are expected to be dominant drivers of the next K-wave.
- Technologies that aim to advance sustainability have also been listed as (enablers and) drivers for the next K-wave in Figure 3.8.
- Table 5.1 shows the alignment of megatrends with the K-wave drivers (i.e. sustainability and increased connectivity).

Kondratieff Timeframe	5 th Wave 1992-2036E	6 th Wave 2036E-2085E
Dominating technologies of indicated cycle	Global Transport Systems, Mobile Phone, Internet, Social Media, Materials Science, Biotechnology	Probable: Recycling, Cradle to Cradle, Renewable Energy, Smart Integrated Systems, Intermodal Transport
Emerging technologies of next cycle	Recycling, Cradle to Cradle, Renewable Energy, Smart Grids, Integrated Systems, Smart Customised Solutions, Intermodality	Plausible: Self-Sustainability, Local Production, Bio Based Materials, Decoupling of Economic Output, Wealth and Transport, 3D-Printer
Principal drivers	Globalisation	Sustainability

Source: Table 3.2, partly repeated.

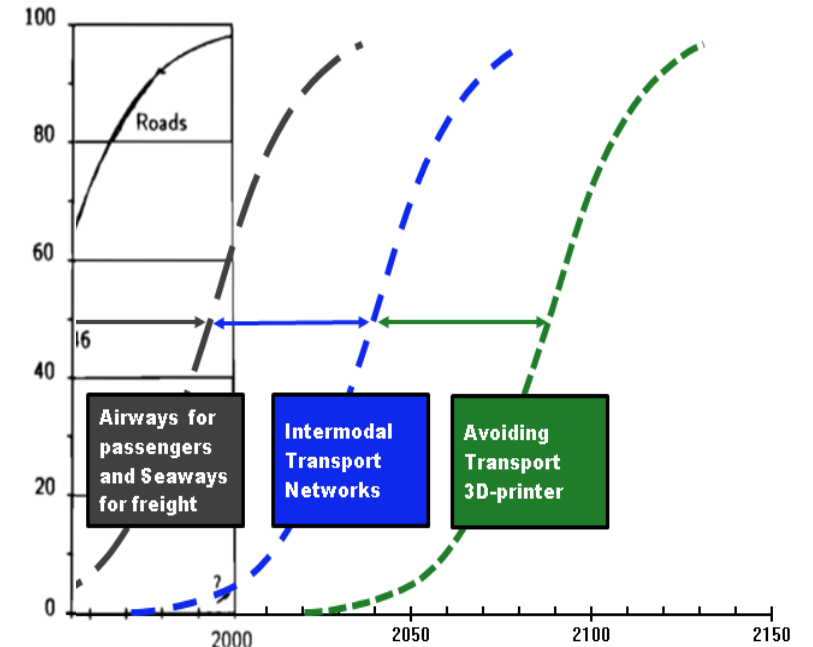
Table 5.1 Megatrends connected to 6th K-wave drivers

Type	Trend
Social	<ul style="list-style-type: none"> • Hyper connectivity, towards condition in which all people and systems are connected.
Technological	<ul style="list-style-type: none"> • Major focus on renewable energy, smart grids, recycling, and use of renewable materials. Ongoing miniaturisation (Nano-technology and DNA), bio-based, and avoiding transport with 3D printing. • Shift towards digital services, digitalisation and further integration of systems. Shift from ICT to IoT. • Social media spreading information (but also disinformation) making global developments more transparent (and hopefully more sustainable).
Economic	<ul style="list-style-type: none"> • Automation, robotics, and artificial intelligence causing loss of jobs and decline of middle income class in western world. Together with opposition against offshoring of workflow to low wage countries and increasing income and wealth inequality this creates discontent amongst population resulting in strong counter globalisation forces (populism and nationalism) and the possible erect of new trade barriers.
Environmental	<ul style="list-style-type: none"> • Various trends with respect to pollution and climate change that indicate the imminent need for more sustainability.
Energy	<ul style="list-style-type: none"> • Levelized cost of renewable energy sources, such as wind and solar, becoming lower than cost of fossil fuels at favourable locations. Majority of investments in new energy generating capacity already based on renewables. • Decentralized energy production, electrification, and use of batteries (e.g. storage of energy in batteries of vehicles). • Advancement in technology for bio-fuel and synthetic fuel production.
Political	<ul style="list-style-type: none"> • Various trends indicating a period of increased tension due to change in global power balance, resulting in reduced power of western institutions (such as United Nations), increased number and intensity of conflicts, and reduced global trade volumes.

Source: own representation based on input from Chapter 2.

5.5 K-waves and inertia of megatrends

- Chapter 3 mentioned that major innovations are likely to take place during the downswing period of the Kondratieff wave (i.e. the next 10 to 20 years), but that it will take up to the next upswing period before they materialise as main drivers of a new socio-techno-economic paradigm (Grübler and Nakćenović, 1991).
- This implies that many developments with a large expected impact, such as autonomous driving and virtual reality will evolve from a novelty to a standard commodity over the next few decades.
- It was further discussed that new infrastructure developments tend to take place over a period of two K-waves, with basic inventions already in an earlier period. In line with this, 3D printing developed in downswing period 5th K-wave will emerge to the extent of influencing transport volumes during 6th K-wave, and will become dominant in reducing transport volumes in 7th K-wave.



Source: Figure 3.9, reduced content.

5.6 Conclusions on use of meta-framework

- By placing individual trends in a broader meta-framework, the basic drivers for developments over the next few decades can be identified with more certainty.
- Each of the nine identified century-long trends confirmed a shift of the pervasive drivers of the K-wave from globalisation (at least partly), towards increased sustainability and increased systems connectivity.
- These pervasive drivers can be corroborated by a range of 'standard' well-known megatrends with a duration of at least one or two decades and by a number of emerging technologies.
- The pervasive sustainability and systems integration trends, that characterise the next 6th K-wave will affect the direction of century-long trends through positive or negative feedback loops. A positive feedback loop reinforces the original trend, while a negative feedback loop weakens it.
- The inertia of the more general trends (i.e. well-known megatrends) and the timing of emerging technologies tends to align with the drivers of the broader K-waves. Insight in the inertia of the K-waves therefore provides guidance on the inertia of individual megatrends.

6. Impact of trends on the port

- 6.1 Introduction
- 6.2 Impact of centuries long trends
- 6.3 Impact of drivers of next K-wave
- 6.4 Impact of individual megatrends
- 6.5 Conclusion

6.1 Introduction

- So far, the report has focused the identification of long term megatrends and the functioning of a 3 layered framework of trends. Explicit reference to the impact of the trends on the port has only been made in Chapter 2, where the megatrends were identified, but no longer in the subsequent chapters on the Kondratieff waves, the century long trends, and the way the trends interact.
- This chapter explicitly addresses the impact of the framework of trends on the maritime transport system and the port in particular. It shows how the systematic approach of the applied trend analysis offers clear insight in the general direction of plausible future developments and their anticipated impact on various systems related to the port, such as the energy and transport system.
- A separate discussion on the impact of the trends for the port is provided for each of the layers in the overall framework, starting with century-long trends, followed by the drivers of the K-waves, and concluding with the impact of megatrends that relate to new upcoming technologies.

6.2 Impact of centuries long trends

- 1. Secularisation and individualisation:** The creation of a truly secular and democratic western society has been a bottom-up process that took almost 500 years since Martin Luther. The attempts in 20th century to impose western democratic and secular values on Islamic states top-down have moved too fast, creating tensions between those who want to reform and modernise and those who don't. The inertia of the secularisation process ensures these frictions to stay for many future generations, guaranteeing a continuous source of tension, conflicts, and refugee flows. Adding the fact that religious communities have a higher birth rate than secular ones, pressure will continuously build up enhancing populistic, nationalistic, and anti-globalisation sentiments. This all has a tempering effect on international trade and maritime transport.
- 2. Nature of activities and social power:** There has been a shift of power from control of land in the pre-industrial age to the control of capital and energy over past 200 years of industrialisation and to control of data, information and knowledge today. This has resulted in more data-intensive processes that influence supply chains by allowing consumers to buy directly overseas (with increasing global shipments of final goods). But it also resulted in rising inequality levels that can be expected to have a reducing effect on consumption levels and transport demand.

Impact of centuries long trends

- 3. Population growth and urbanization:** The population growth varies considerable over the world. In Europe, the population is aging and stabilising. For the rather religious US, the population remains growing steadily. The population in Asia has been booming, but many Asian countries are now facing severe aging and population decline, e.g. Russia and Japan. This is also expected in China some 10 years from now. India is likely to show a continued population growth until the second half of the century. Population is also booming in Africa. European demographics have a tempering effect on production, consumption, trade and transport, while the aging of the US, European and Asian population has an increasing effect on the cruise market. Ongoing urbanisation is a universal trend that continuous. It results in a denser lifestyle (i.e. fewer cars, smaller houses, less energy per capita) and a shift to services, both reducing transport.
- 4. Energy and raw material use:** The industrial revolution resulted in an ever growing demand for energy and raw materials. Unprecedented exploitation of raw materials resulted in degradation of available resources as reflected by a strong decline in energy return on energy invested (EROI) and mineral ore grades. Until recently, technological progress was able to outweigh the effect of declining resources, but around the year 2000 this trend reversed, resulting in rising real cost levels. Rising real cost levels have a reducing effect on consumption levels

Impact of centuries long trends

... and transport volumes and stimulate use of fewer materials, reuse of materials, and renewable energy sources. These trends have a major impact on the types of goods and volumes shipped through the port.

- 4. Technological progress and economic output:** Knowledge development and technological progress (as measured by labour productivity) have for almost 200 years grown at an exponential rate. This growth can be explained by the growing population, rising education levels, and increased research efforts. But labour productivity cannot continue to grow indefinitely at an exponential or even linear rate, due to diminishing returns on knowledge development. In fact labour productivity can be thought of as a transition process that moves towards a maximum attainable limit state, for which the inflection point now seems to have been surpassed in the western industrial world. For a stabilising population (like in Europe) the supply side of the economy is thus subject to a continuous declining growth rate. But constraints are also expected from the demand side of the economy. On balance, technological progress results in a net loss of employment due to automation, robotics and artificial intelligence. In the past 50 years this loss of jobs was countered by central banks that applied quantitative easing to stimulate the economy. However, the limit of these measures has been

Impact of centuries long trends

... reached (i.e. negative interest rates) and rising unemployment rates may be expected. Increasing unemployment fuels nationalistic anti-globalisation sentiments and adds to the current trend of growing inequality. Inequality substantially reduces purchasing power for the majority of the population (also in the Netherlands), resulting in lower economic output, consumption, and transport.

6. **Connectivity and information exchange:** This trend has been prevalent for thousands of years. It is fundamental to human nature and will inevitably continue. Following historical inventions in transportation (e.g. ships, canals, railways, highways, and aviation) and information exchange (e.g. writing, book print, telecommunication, and internet) the world is continuously pushing the limits towards full connectivity of all people and systems. Forefront developments now concern the creation of the internet of things (IoT) and cybernetics. The IoT will, supported by advanced sensors and big-data applications, allow the port to be utilised in a more cost-effective way, increasing the potential for improving its competitive position.
7. **Climate change and environmental degradation:** Climate change is a pervasive trend that can be clearly observed from rising carbon levels in the atmosphere, global temperatures, shrinking arctic ice coverage, sea level rise, changing ecosystems, more frequent tropical storms, etc. Climate change has, together with pollution and loss of biodiversity, a major impact on the living

Impact of centuries long trends

... environment and food supply and is expected to cause mass migration. Climate change affects the port transport system in two ways. It directly affects the transport performance of the port by e.g. more frequent closure of storm surge barriers, increased downtime of terminals, and worsened inland waterway connections to the hinterland, but it also results in less ice on rivers and an open arctic sailing route. It indirectly affects the way of doing business due to increased regulations, increasing transparency and social pressure on corporate sustainability, and growing consumer demand for sustainable products like renewable energy, recycled materials, biodegradable plastics, and sustainably grown fish.

- 8. Transport costs and globalization:** Technological progress, economies of scale and declining real costs of material and energy use over the past few hundred years have facilitated globalisation and resulted in a continuous decline of costs for seagoing freight. However, the bottom price seems to have been reached and price levels may now start to go up in response to rising material and energy costs. Declining transport cost can therefore no longer be regarded as the main driver of ongoing globalisation. In fact, rising transport cost may even counter globalisation. With costs of sea freight hitting the bottom, the logistical focus is increasingly shifting towards the optimisation of hinterland transport and reduction of last mile transport costs.

Impact of centuries long trends

- 9. Shifts in geopolitical world order:** Over the past decades, the economic and military power balance has shifted gradually from the west to the east. Russia and China have disabled the functioning of western institutions such as the United Nations safety council and created their own alliance, the Shanghai Cooperation Organisation (SCO) to reduce US influence in what they call domestic affairs (i.e. territorial expansions). Turkey is supporting this ideology and considering leaving NATO to join the SCO. As a result, the western US hegemony, and dominant western democratic ideology is now being challenged. The result will be a multipolar world in which political-pragmatism and a mind your own business attitude prevails. With China being confronted with near population decline and economic slowdown it is less likely to rival the US for world domination. In the absence of a major war, a prolonged period of multipolar power in which democratic principles of international justices are sacrificed, can be expected. These geopolitical tensions affect trade in a negative way, as already observed from European sanctions on Russia and the US trade war with China. This also affects port throughput volumes of e.g. oil from Russia and containerised goods from China to Rotterdam.

6.3 Impact of drivers of next K-wave

Kondratieff waves move through subsequent stages of innovation and implementation. During the downswing period that recently started, many new innovations are introduced. It usually takes up to the following upswing period before these innovations become truly competitive and take over the dominant position of the present system. The transition from 5th K-wave to the 6th K-wave mainly concerns a shift in two primary drivers:

- 1. The first shift in primary drivers concerns a shift from globalisation (and unsustainable exploitation of resources) to sustainability**, which clearly links to ongoing transitions in sustainable energy and material use and corresponds to reverse-globalisation (backward movement from hyper-globalisation to more sustainable levels of globalisation), as observed from back shoring, local food production, etc. This driver has severe impact on types of goods and volumes shipped through the port.
- 2. The second primary driver links to the hyperconnectivity trend, which is shifting from ICT to IoT**, aimed at making things more transparent (e.g. via blockchain technology), more convenient, and energy efficient, thus aligning

Impact of drivers of next K-wave

... with the first objective. This driver has various pervasive impacts on the port business such as improved vessel routing and terminal planning, autonomous transport, use of sensor techniques, and smart infrastructure. It offers the port the potential to become more cost-effective.

Based on the movement of these drivers, the next 20 years are expected to be dominated by innovation and the development of new sustainable- and data driven technologies and business models. In the subsequent 30 years, the successful technologies are expected become dominant.

6.4 Impact of individual megatrends

- Megatrends relate to technological developments that are often linked to the pervasive drivers of the upcoming Kondratieff wave, which are nowadays often related to achieving efficiency gains through the use of data applications and sustainability.
- The movement of these trends usually aligns with the inertia of the K-waves, which roughly suggests technology development over the next two decades and upscaling of matured technologies in the period thereafter.
- The identified megatrends seem clustered around two major types of development, being data-driven developments and sustainable developments, of which data-driven developments often act as an enabler for the development of sustainable data-driven technologies.

Impact of individual megatrends

- 1. Data-driven developments** include the use of sensor techniques; real time data; big data; artificial intelligence; autonomous decision making; systems optimisation through data exchange and data sharing. In addition internet shopping also affects the organisation of the logistical system. All these technologies have a pervasive impact on the utilisation and life cycle maintenance of port infrastructure, operational planning of port activities, the organisation of port logistics, autonomous vehicles, synchro modal transport, etc.
- 2. Sustainable developments** include many trends and technologies related to recycling of materials, shift to renewable energy and fuels (including electrification, hydrogen, and power to x); biochemicals and biodegradable plastics; carbon optimised logistics; local production and 3D printing. These megatrends have a major impact on the port operations, types of goods handled, and the logistical footprint.

6.5 Conclusion

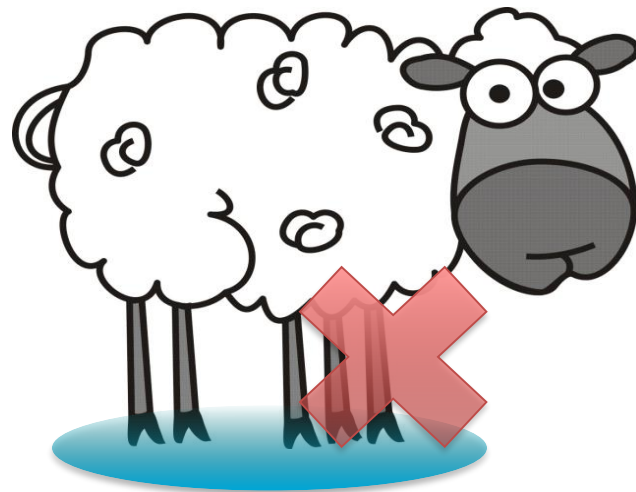
- Altogether, these trends have a pervasive impact on the port business, that is reflected in an expected decline in transport of energy products and raw materials, an anticipated stagnation or even decline of container volumes, and a potential growth of renewable energy and fuel production activities, recycling activities, and sustainable offshore fish farming activities.

7. Trend-based narratives

- 7.1 Use of trend-based narratives
- 7.2 Narratives on identified threats
- 7.3 Narratives on identified opportunities
- 7.4 Narratives on enabling technologies

7.1 Use of trend-based narratives

- Scenarios are not considered appropriate for identifying new business opportunities (see [Chapter 1](#)), because the use of scenarios to prepare for all possible business developments is like creating a ‘sheep with 5 legs’ (i.e. something that is capable of almost everything, but at the cost of being non-competitive). We therefore introduce the use of trend-based narratives so as to create a shared view on expected threats and business opportunities.



Source: <http://glennvanderburg.nl/wp-content/uploads/2015/03/schaap-met-vijf-poten-lores.jpg>



Uncertainty



Narratives: shared view on expected threats and business opportunities.



Trend-based narratives

Source: authors representation.

3 types of T-shirt based narratives

Note: Narratives presented as T-shirts, for T-shirts are the stories we wear.

Port of
choice

Cargo flows &
activities



Threats to existing activities: e.g., decline of existing bulk and container volumes.



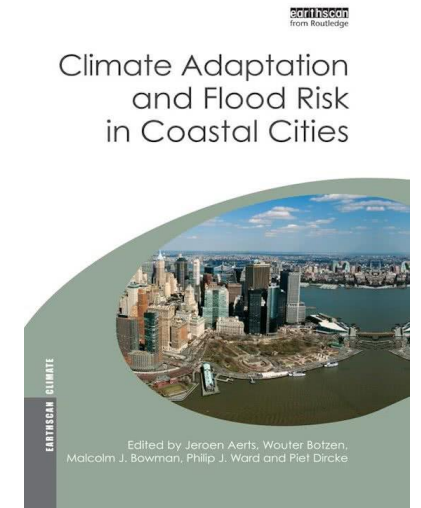
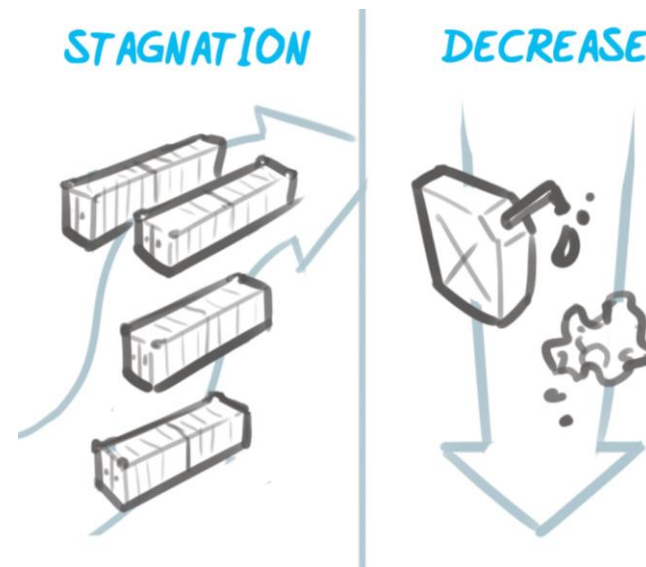
Opportunities for new activities: e.g., developing new cargo flows and port activities.



Enabling technologies: new technologies that enable future competitiveness.

7.2 Narratives on identified threats for Port of Rotterdam

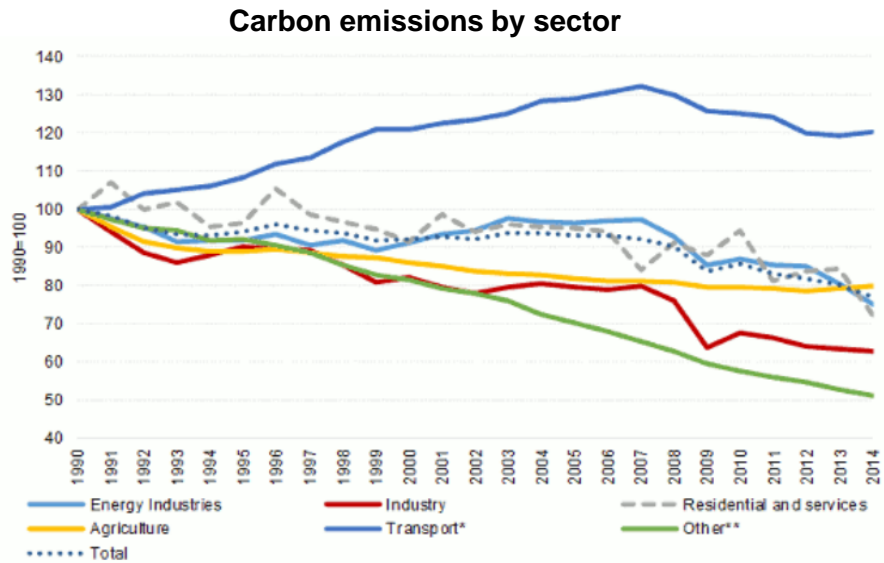
- #1 Major decline in bulk fossil fuel throughput;
- #2 Possible decline in raw material throughput;
- #3 Stagnation or decline in deep-sea container transport;
- #4 Future loss of container cargo as a result of 3D printing;
- #5 Possible loss of market share due to climate change.



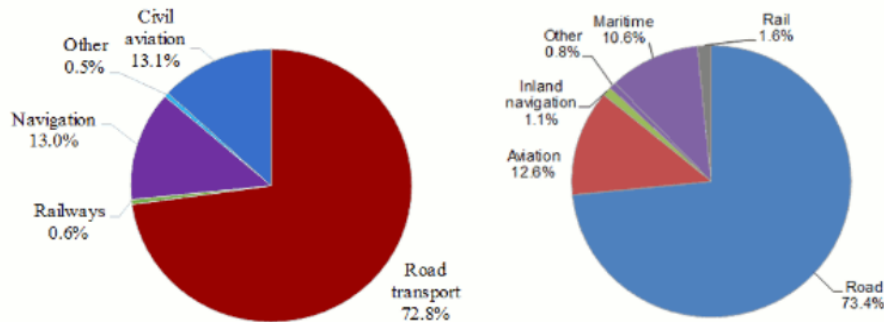
#1 Major decline in bulk fossil fuel throughput

- Energy transition results in a shift from first coal, then oil and last from LNG to renewables.
- Energy carriers (e.g. Coal, Oil, LNG) lose share as a result of electrification. In principle, all energy required for road vehicles and electric power can be supplied by electric weirs and batteries from central and decentralised production (at industrial scale and by prosumers).
- The extent of the shift towards **electrification** is unclear and depends on advancements in renewable fuels technology. A shift towards use of hydrogen is also possible. Hydrogen can either be stored and used directly (which is complicated), or used to develop synthetic renewable fuels such as ammonia, formic acid, renewable methanol, or renewable gasoil. When converted into **synthetic fuels**, it can also be blended with biofuels.
- Shift to renewable energy not only affects the influx of energy carriers, but also the in- and outgoing flows of mineral oil products. Future market for renewable fuels (e.g. synthetic and bio-based) is likely to be a fraction smaller than today, depending on the adoption of electrification. Vehicles with a high energy demand, such as ships and airplanes, are less likely to shift towards battery power and more likely to favour renewable fuels.

Figure 7.1: Over 70% of oil throughput at risk



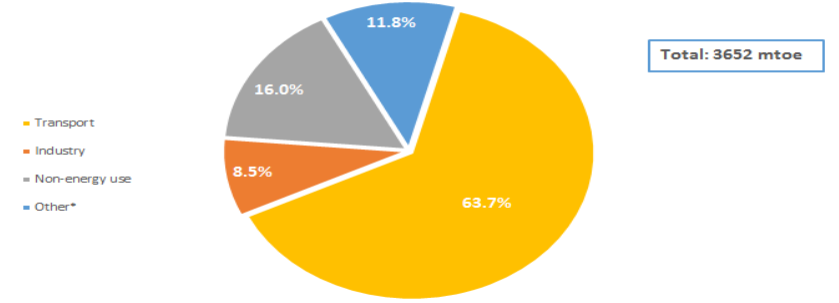
Note: * Transport includes international aviation but excludes international maritime; ** Other include fugitive emissions from fuels, waste management and indirect CO2 emissions
Source: EEA



Greenhouse gas emissions from transport by mode in 2014
Share of transport energy demand by mode in 2014 (%)

https://ec.europa.eu/clima/policies/transport_en

Global crude oil consumption in 2012, breakdown by sector

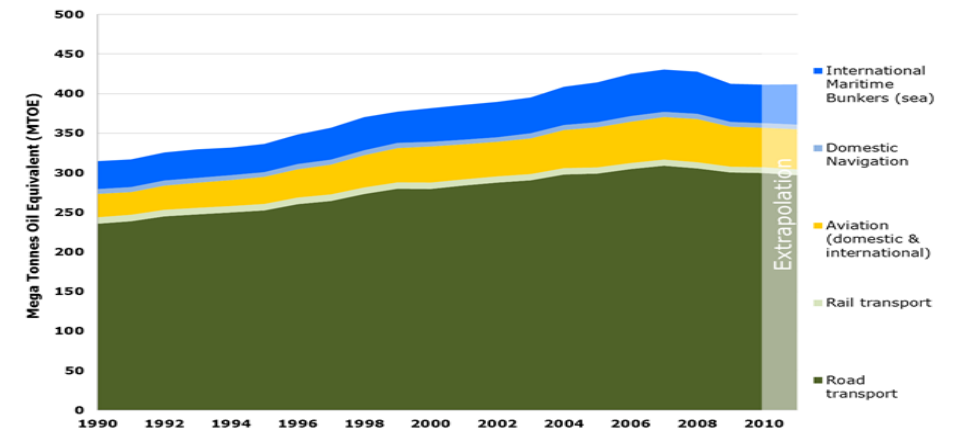


*Agriculture, buildings, commercial & public services, and others.

Source: IEA Key World Energy Statistics 2014

Source: http://www.globalpetrolprices.com/common_images/articles/39/World%20oil%20demand%20by%20sector%202012.png

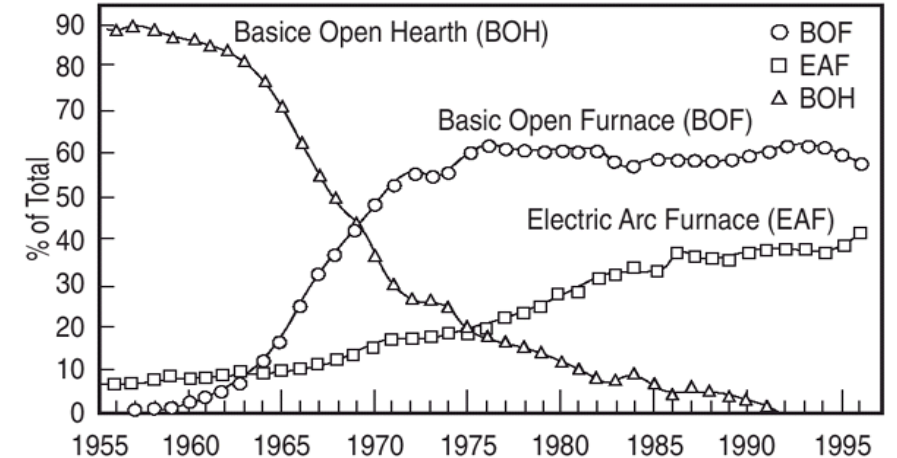
Final energy consumption by transport modes in EU27



<https://www.eea.europa.eu/data-and-maps/indicators/transport-final-energy-consumption-by-mode/assessment-2>

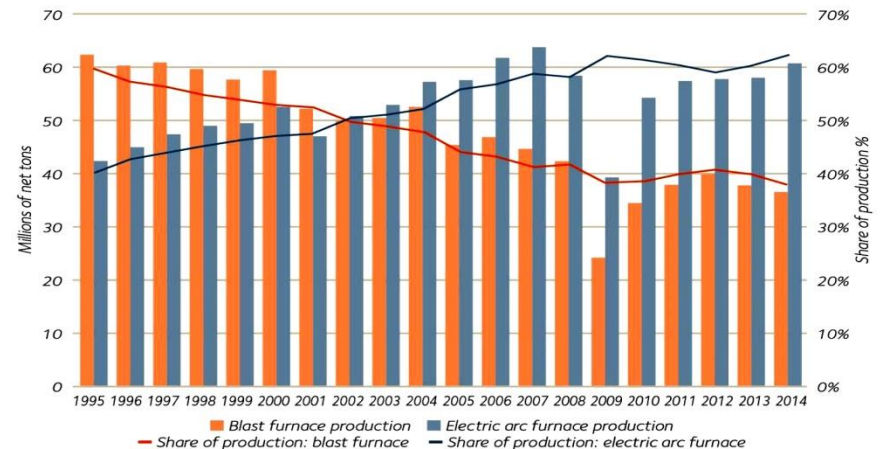
Figure 7.2: Use of coal in steel production

- There are various ways to produce iron and steel. The conventional processes (BOH and BOF) use coal as an energy source. BOH process has now been replaced by the more efficient BOF process.
- The use of electricity instead of coal has been increasing gradually. It was 8% in 1955 and is about 60% currently (data for US). The share of Electric Arc Furnace (EAF) is increasing at a rate of approx. 10% per decade. At this pace, coal-based processes could be fully replaced within 4 decades.
- Sustainability initiatives might speed up the shift to EAF. The steel industry is now investigating the options to shift towards use of Hydrogen as an energy source for iron production.



Note: data refer to the US

<http://www.tms.org/pubs/journals/JOM/0110/fig3.gif>



Source: AISI

Note: Data refer to the US

https://energy.gov/sites/prod/files/2017/05/f34/fcto_may_2017_h2_scale_wkshp_ripke.pdf

Figure 7.3: Various steel production processes

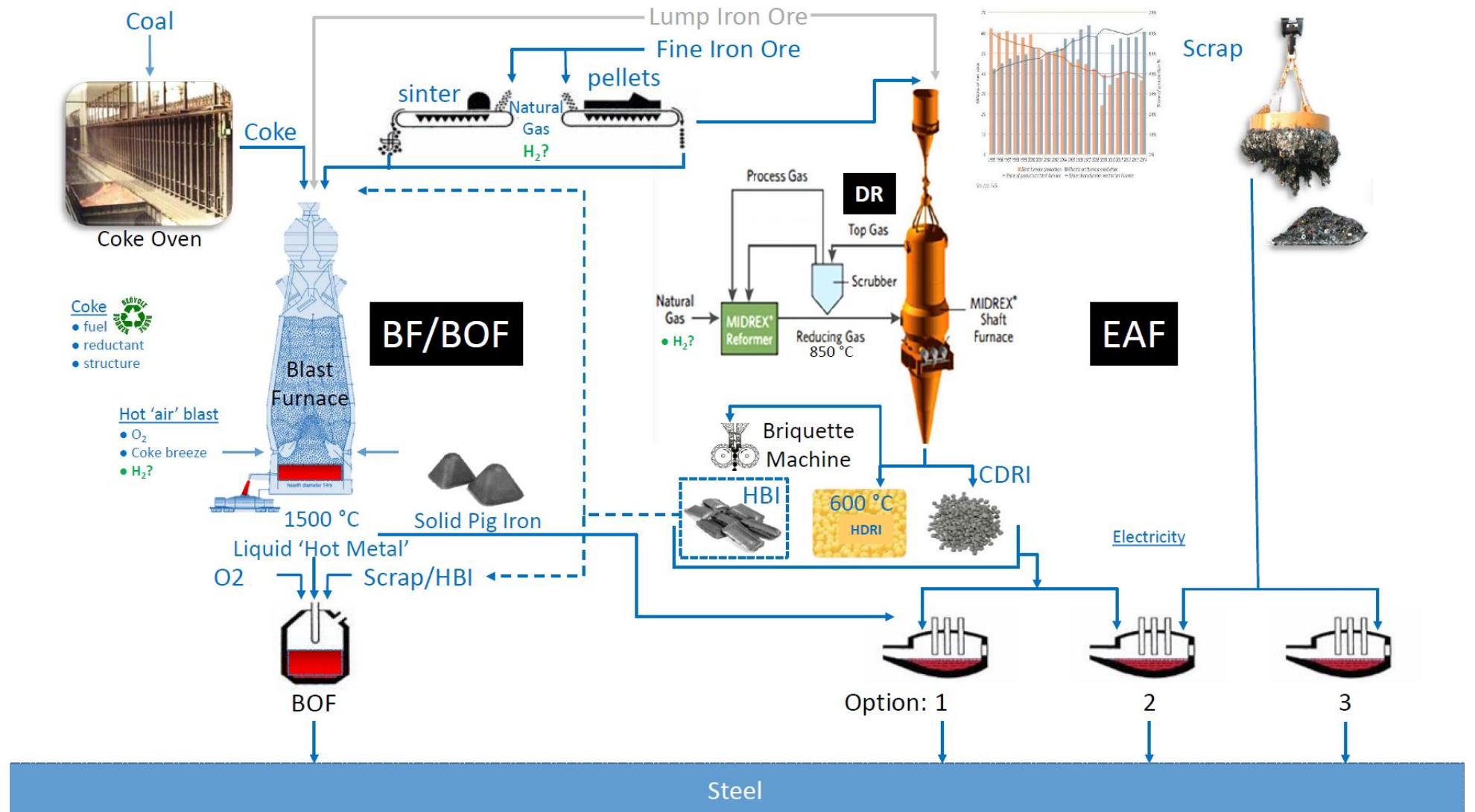
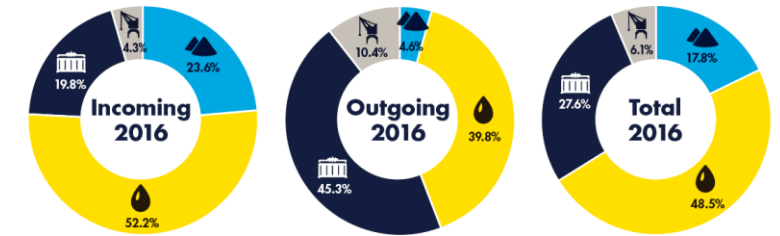


Figure 7.4: Impact of fossil fuel decline on port throughput

- The energy transition fosters a shift from first coal, then oil and LNG to renewable energy.
- Current energy carriers will, to a major extent, be replaced by direct delivery or local production of electric power. In addition one might expect import of hydrogen.
- Shift to renewable energy not only affects raw energy carriers, but also in- and outgoing flows of mineral oil products.
- About 60% to 70% of coal is used for energy production and is at direct risk of being replaced. 30% - 40% of coal throughput is used by steel industry, which is gradually moving towards use of electricity and hydrogen.
- Over 70% of oil throughput and a large share of mineral oil products are at a risk of being replaced by renewable energy.
- **Overall effects of energy transition could be a decline of total port throughput by 35% to 50% within a few decades.**



INCOMING AND OUTGOING BY COMMODITY

Iron ore and scrap	29.3	1.9	31.2
Coal	28.2	0.2	28.4
Agribulk	9.7	0.7	10.4
Other dry bulk	8.7	3.5	12.2
Subtotal dry bulk	75.9	6.4	82.3
Crude oil	100.8	1.1	101.9
Mineral oil products	47.0	41.8	88.8
LNG	1.0	0.7	1.7
Other liquid bulk	19.0	12.2	31.2
Subtotal liquid bulk	167.8	55.7	223.5
Total bulk goods	243.7	62.1	305.8
Containers	63.7	63.4	127.1
Roll-on/Roll-off	9.6	12.8	22.4
Other general cargo	4.1	1.7	5.9
Total breakbulk	13.8	14.5	28.3
Total throughput	321.2	140.0	461.2

Unit: Gross weight x 1 million metric tons

Source: Port of Rotterdam

<https://www.portofrotterdam.com/sites/default/files/facts-and-figures-port-of-rotterdam-2016.pdf>

Considerations for future infrastructure development

This section examines the possible implications for port infrastructure development due to [decline in bulk fossil fuel throughput \(narrative 1\)](#).

- Impact on ship type / size / number
 - Gradual decline in number (but not necessarily size) of large oil carriers initially, and almost entirely over next 3 decades);
 - Gradual decline in number of smaller vessels supplying Russian oil;
 - Gradual decline of crude oil transport with and storage in inland barges;
 - Swift decline in number (but not necessarily size) of large coal carriers (e.g. about 80% over next 2 decades and possibly last 20% in subsequent 2 decades);
 - Major decline in inland waterway transport of coal to German Ruhr area;
 - Intensified import of LNG initially, possibly in larger carriers, followed by a decline from about 2040 onward.

Considerations for infrastructure development

- Impact on infra loads / demand / alternative use
 - Similar loads on oil jetty structure, but less frequently. Jetty and storage infrastructure may be adapted for alternative use such as alternative hydrogen based liquids as well as liquid carbon dioxide;
 - Comparable loads on quay of coal terminal, but less frequent. Quay infrastructure could be used for handling of deepsea containers or bio-bulk;
 - Potential demand for expansion of LNG terminals.
- Impact on cargo handing and storage requirements
 - Gradual decline in crude oil storage capacity (e.g. almost entirely over next 3 decades, with majority between 2 and 3 decades from now);
 - Swift decline in size of coal storage (substantial decline, but the assumed 80% decline in volume will not result in an 80% decline of storage capacity as the terminal has to smoothen peaks in the unloading of bulk carriers; it is therefore conceivable that coal storage areas may be e.g. reduced by 60% in 2040, but more specific analysis is required to define likely impact);
 - Potential demand for expansion of LNG terminals.

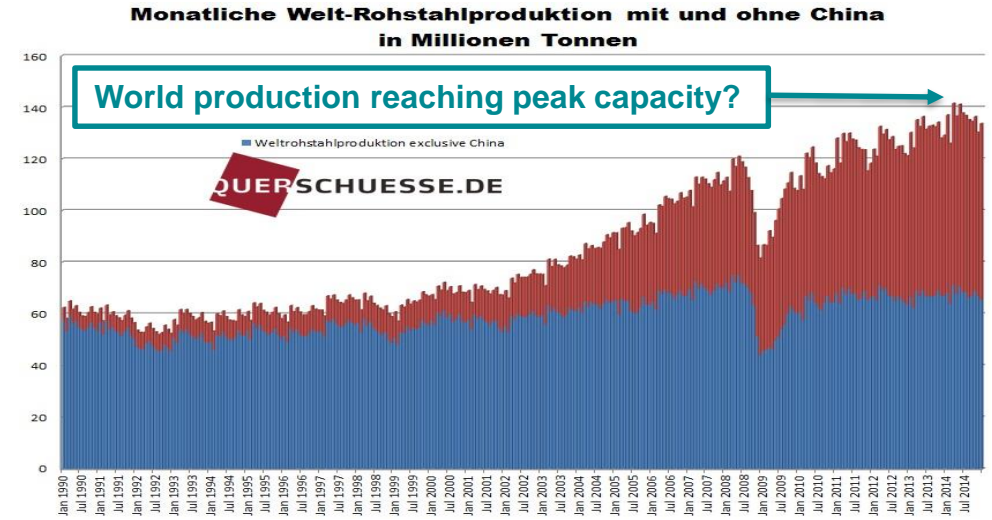
#2 Possible decline in raw material throughput

- Possible shift of raw material production, and in particular steel production, to countries with lower overall costs. Logical movements are future shifts towards areas where raw materials are mined (creating added value for the country) or towards areas where renewable energy is cheaply available (e.g. the middle east).
- Since the financial crisis, there is global overproduction of steel, possibly due to increased steel production in China. This has led to closure of less cost efficient steel companies outside China (e.g. in the United Kingdom). At present, steel prices are increasing in response to the boom of the present business cycle. Due to relatively high efficiency of continental steel companies, and demand from German car manufacturers, a swift decline of German steel production is not expected.
- German raw steel production has shown a gradual decline over the past decade (with a trough in 2009). It is unclear if this decline will continue over next decade in case higher carbon emission rights are imposed, reducing the high cost efficiency of European steel factories.
- Strong social and political focus on reduction and reuse of materials in 6th K-wave. Import of ore and coal for steel production could reduce due to increase in reuse material waste (or scrap).

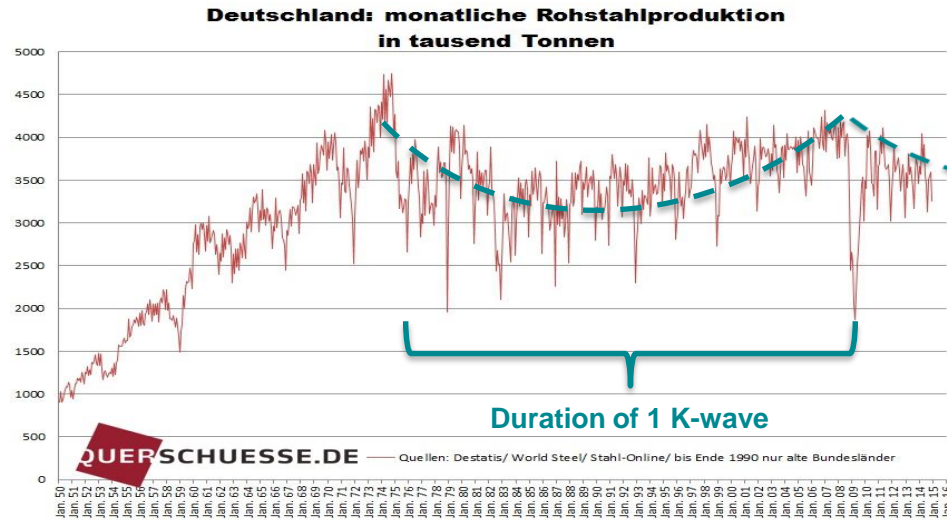
Figure 7.5: No indication that German steel industry disappears



<https://www.qlerschuesse.de/wp-content/uploads/2015/01/A1457.jpg>

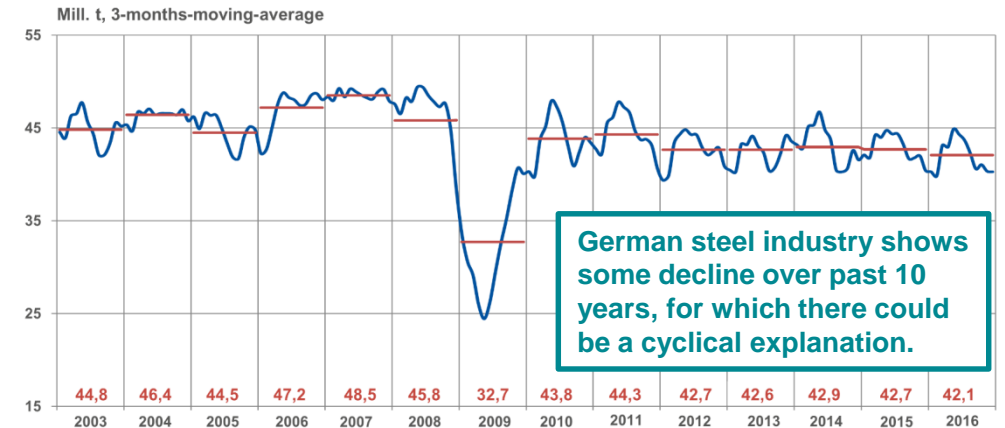


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<https://www.qlerschuesse.de/weltrohstahlproduktion-dezember-2015/>

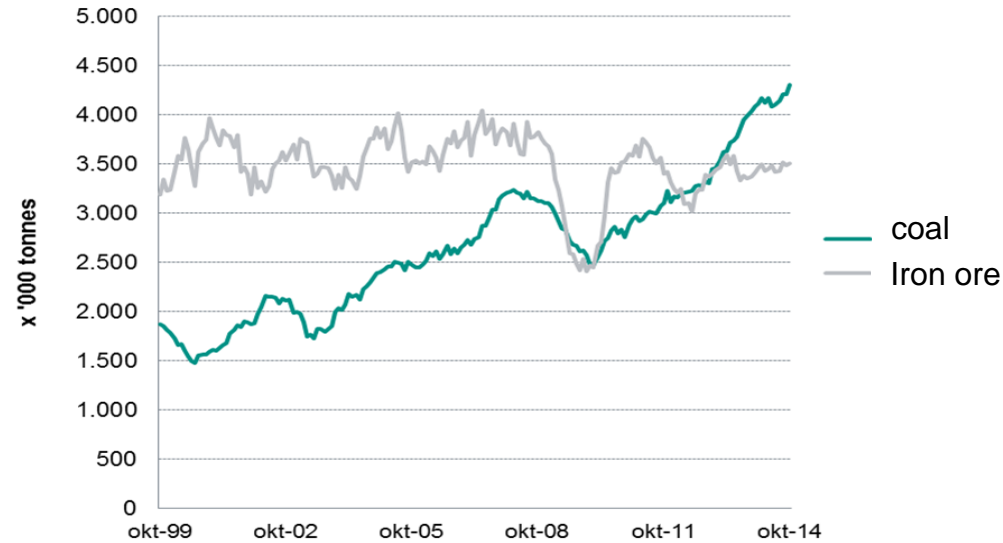
Crude Steel Production in Germany



http://en.stahl-online.de/wp-content/uploads/2013/08/201701_Crude_Steel_Production_GER.png

Figure 7.6: Impact of iron production on port throughput

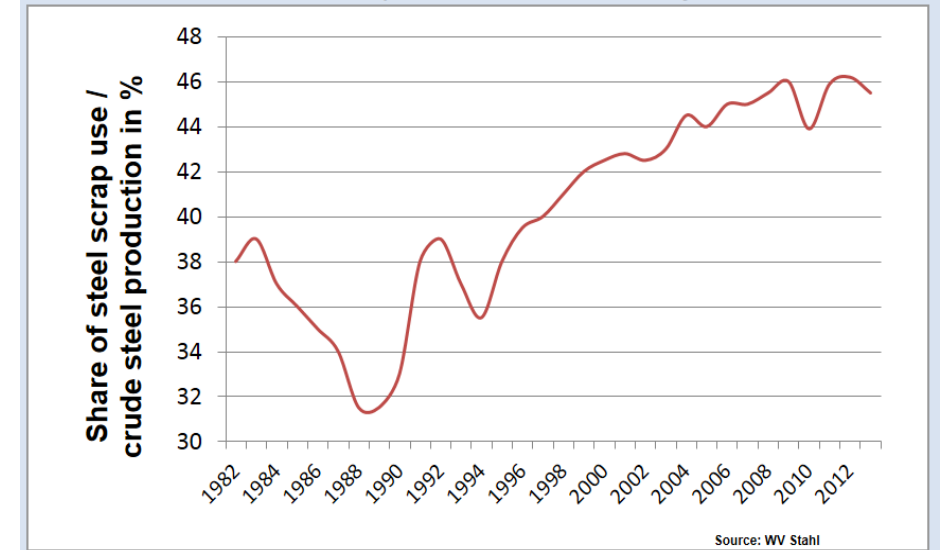
German import of iron ore and coal



Source: <https://insights.abnamro.nl/2015/02/structurele-trends-vormen-uitdaging-droge-ladingvaart/>

Resource efficiency by using steel scrap:

Share of total crude steel production in Germany



http://en.stahl-online.de/wp-content/uploads/2013/08/201403_Share_Scrap_Crude_Steel_Production_Germany.png

- The share of scrap in steel production is about 45%. Further increase can reduce iron ore demand, but not dramatically.
- This is confirmed by iron ore import volumes, that approximately follow the crude iron production trend as presented on previous page.
- Outlook for next decade is rather uncertain (say +10% to -20% growth of iron ore throughput). Sustainability drivers may gradually reduce volumes in the long run. **Effects of climate change on inland shipping could result in closure of industry.**

Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to [expected decline in raw material throughput \(narrative 2\)](#).

- Impact on ship type / size / number
 - Slow gradual decline in number of ore carriers due to increase share of scrap in steel production. Maybe a slight decrease in size of vessels due to changes in sourcing of materials as well as the ending of charter contract with Berge Stahl in September 2016.
- Impact on infra loads / demand / alternative use
 - Similar loads, but lower than when Berge Stahl was handled at the port. This implies reserve strength in the quays, which offers additional flexibility in selecting the quays for bulk handling.
- Impact on cargo handling and storage requirements
 - Unlike coal storage, the storage capacity for iron ore can be assumed to remain more or less unchanged over the next few decades, implying that the relative share of ore in the dry bulk terminals increases.

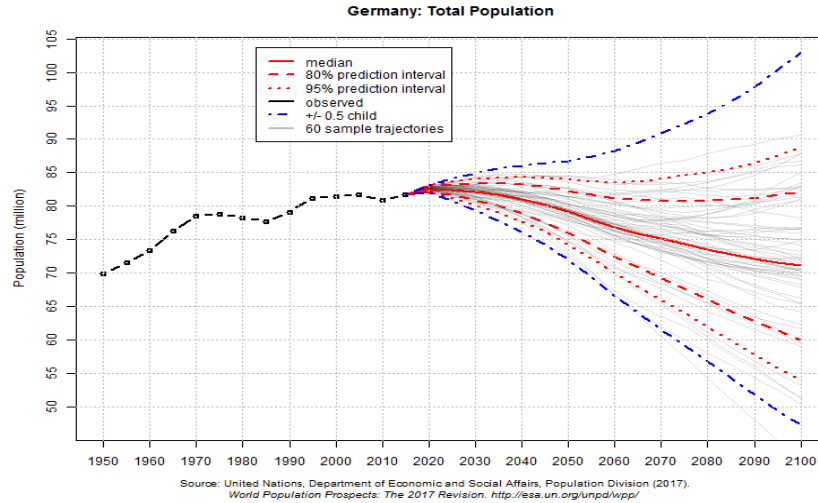
#3 Stagnation or decline in deep-sea container transport

- The latest statistics show a large growth of container volumes in the Port of Rotterdam: container throughput grew with 9.3% in TEU and 10.4% in tonnage over the first half of 2017. This can, to a large extent, be explained by a growth of market share in the Le-Havre Hamburg range from 29.0% to 30.9% (6.6% increase) over Q1 2017. The remainder can be related to the present economic boom that may reverse in the period 2018 - 2020 (see [Chapter 4](#)).
- The long-term outlook for container sector is less optimistic. Container throughput is a function of the size of the population, the consumptive spending and industrial production in the hinterland, the material intensity of the economy and the extent to which intermediate goods are shipped around.
- This is represented in the following simplified formula:
 - $$\text{Container throughput} = \text{population} \cdot \frac{\text{Labour}}{\text{Population}} \cdot \frac{\text{GDP}}{\text{Labour}} \cdot \frac{\text{Trade}}{\text{GDP}} \cdot \frac{\text{Cargo}}{\text{Trade}} \cdot \frac{\text{Containers}}{\text{Cargo}}$$
- As discussed on the next page, the long-term trend for each of these parameters is likely to change, resulting in an overall decline in container throughput.

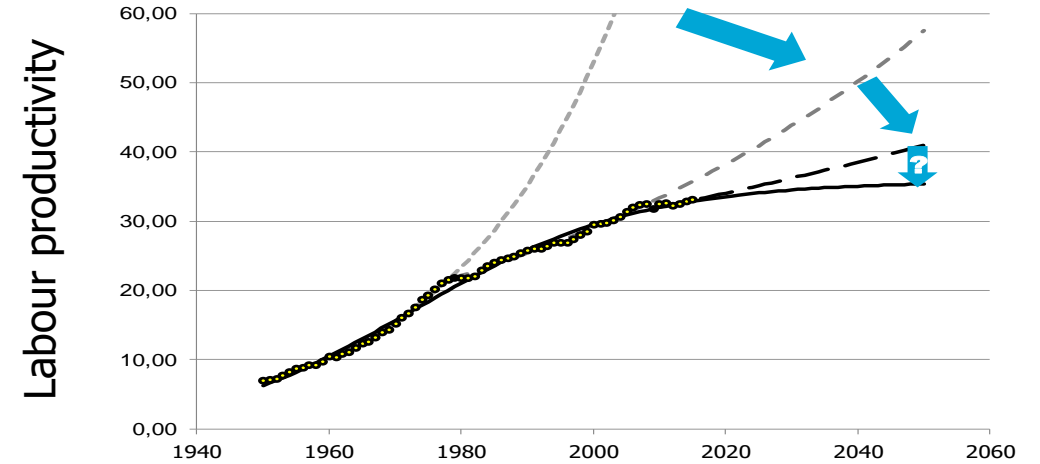
Long term drivers of container transport slowing down

- **Population:** The UN DESA, World Population Prospects indicate a **stagnation** and possible long term decline of west European population. In Germany, the decline of population is expected to set in as early as 2025.
- **Labour/Population:** Fraction of population contributing to the output of the economy is declining as a result of **aging** and retirement of the baby boom generation. Another trend is the **loss of jobs** due to automation, robotics and artificial intelligence. Some 40% - 50% of jobs are at stake. Rising **inequality** is expected to further add to unemployment due to lowered consumer demand.
- **GDP/Labour:** **Reduced labour productivity** growth as a result of decreasing economies of scale in technological development; this can be observed in technology frontier countries.
- **Trade/GDP:** **Reverse globalization** reduces trade and transport per unit of good produced and consumed (e.g. local production and fewer intermediate goods).
- **Cargo/Trade:** **Dematerialization** (i.e. doing more with less; for instance by means of lighter products, miniaturization, digital technologies, and sectoral shifts to services) will result in lower transport volumes per unit of production and trade.
- **Containers/Cargo:** **Containerisation** is reaching its limit, and may no longer be a major driver for increased container transport.

Figure 7.7: Impact of various trends on container throughput



<https://esa.un.org/unpd/wpp/Graphs/Probabilistic/POP/TOT/>



Source: see Figure 4.62



https://www.portofrotterdam.com/sites/default/files/styles/port_is_content_image/public/Maasvlakte%202-juni2015_0.jpg?itok=tN8dlhry



Source: see Figure 4.75

Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to expected stagnation or decline in deep-sea container transport (narrative 3).

- Impact on ship type / size / number
 - Size of deepsea vessels will reach a plafond, but still hard to say at what size;
 - Throughput and number of vessels is likely to show a continued slow gradual growth until about 2040/50, but at a reducing pace. Container volumes can be expected to stabilise and possibly even decline some 2 to 3 decades from now. However, further research on the primary drivers and the use of appropriate economic growth assumptions is recommended to gain more specific insights.
- Impact on infra loads / demand / alternative use
 - Less space will be required at Maasvlakte II than initially planned for. This frees up space for alternative use, such as for offshore installation and decommissioning activities;
 - Space could also be made available for the creation of dedicated container barge handling facilities at the deepsea container terminals.

Considerations for infrastructure development

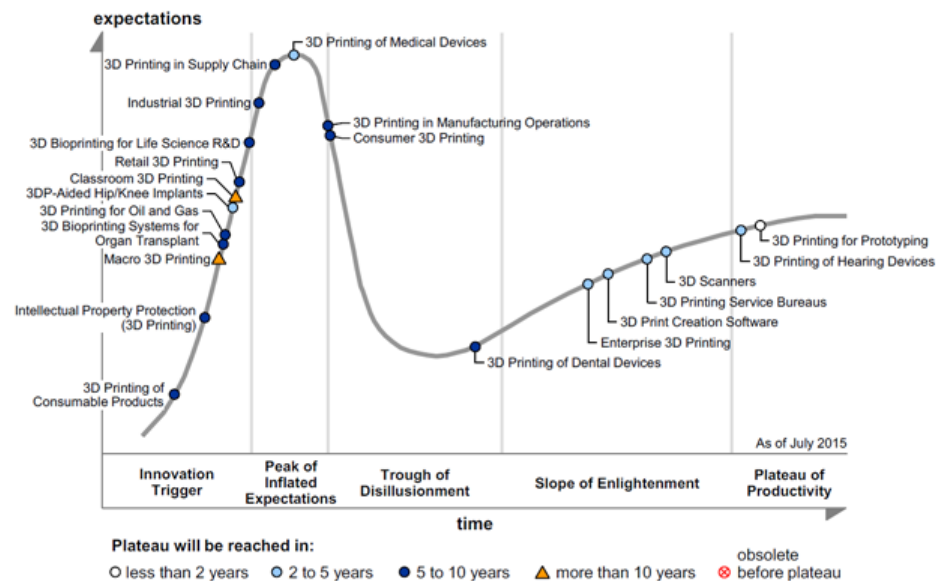
- Impact on cargo handling and storage requirements
 - In order to enable growth in a stabilising or declining market, the focus needs to shift to increasing market share within the region;
 - An increase in market share could be obtained by strengthening the hinterland connection, and especially the hinterland container barge connection;
 - Development of dedicated barge handling facilities can be expected to improve reliability of barge services, thereby improving quality of hinterland service, which helps to strengthen deepsea market share;
 - Tempered demand for future road capacity. Less urgent to plan for further expansion of road system.

#4 Future loss of container cargo as a result of 3D printing

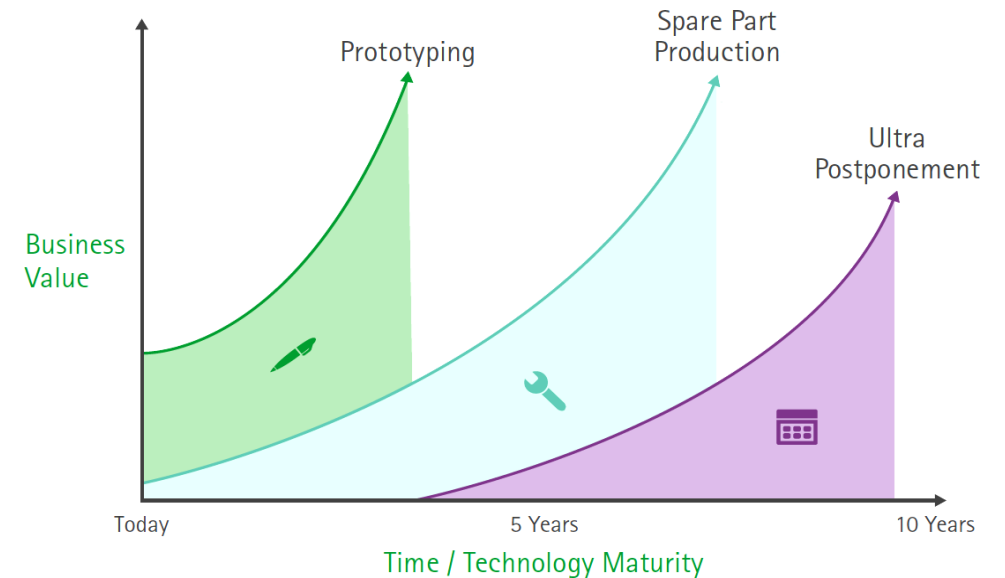
- 3D Printing has the potential to redesign the supply chain and reduce:
 - material use for products (lighter production and thus less tonnes);
 - the need for storage of slow moving stock (such as spare parts);
 - intermediate goods during production process;
 - transport of printed material (3D ink), which is shipped in bulk or in containers, but requires less space as compared to finished products (i.e. less volume but not necessarily less tonnes).
- 3D printing technology is developing rapidly in many fields, for various types of goods, using different materials.
- For most consumers, the range of materials is limited to various plastics, wood based filaments and pastes. For more advanced materials such as metals, expensive and sophisticated printers are required.
- 3D printing is now finding application in spare part replacement. Next step is ultra postponement of production (e.g. as already introduced in production process of Nike shoes).

Figure 7.8: Forefront development

- Many of the technologies related to 3D printing are gradually reaching maturity. Though the technology is ready for adoption, it is still not wide-spread.
- Application of 3D printing is now shifting from rapid prototyping to spare part production and production of high durability products (e.g. medical, aviation).
- 3D printing for local production will change supply chains, possibly enhancing reshoring.



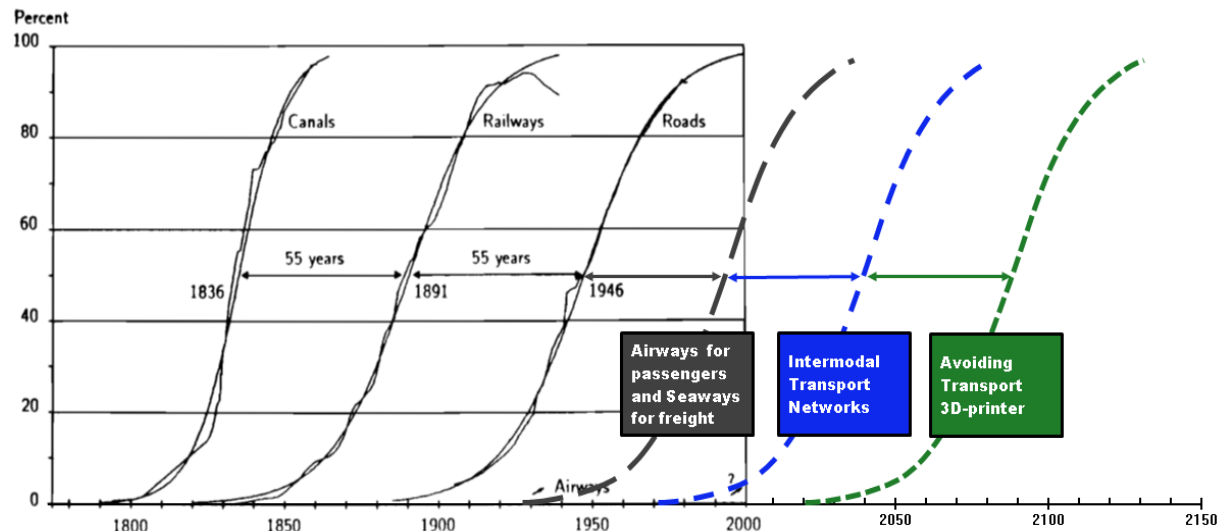
<https://www.sculpteo.com/blog/2017/08/01/the-3d-printing-hype-cycle-by-gartner-what-does-the-2017-edition-say/>



<http://www.dima3d.com/en/market-impact-perspectives-3d-printing-technologies/>

Figure 7.9: Impact of 3D printing on port throughput

- 3D Printing is expected to impact supply chains over time, but the effect on port throughput volumes is not to be overestimated.
- Impact will be via reshoring of activities (production back to Europe / reverse globalisation), smaller intermediate product flows, and shift to transport of 3D ink (in bulk).
- Over long term, a reduction in international transport volumes due to use of locally produced printing materials (e.g. bio-based or recycled materials) is expected.



Source: Grübler, A. (1990) *The Rise and Fall of Infrastructures: Dynamics of Evolution and Technological Change in Transport*, Physica-Verlag Heidelberg (for historical data); updated by Van Dorsser (2015).



Source: <http://www.industryweek.com/emerging-technologies/impact-3-d-printing-supply-chains-infographic>

Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to the expected **future loss of container cargo as a result of 3D printing (narrative 4)**.

- Impact on ship type / size / number
 - Gradual change in trade patterns from trade with China to trade with resource producing countries (that produce ‘ink’ for 3D printers) could result in a more diversified container fleet with less mega carriers, e.g. from 2050 onwards. In addition 3D-printing causes an expected decline on container volumes and possibly causes a shift to bulk.
- Impact on infra loads / demand / alternative use
 - Shipping ‘ink’ instead of products reduces (air) volume of cargoes shipped in containers causing an increase in ratio of tonnes per TEU. Also possible that shift results in a change of containers used. Likely to increase relative number of bulk containers.
- Impact on cargo handling and storage requirements
 - Using denser loaded containers reduces the space required for shipping containers, and especially for empty containers. Denser loading of containers may also reduce the container imbalance between Asia and Europe.

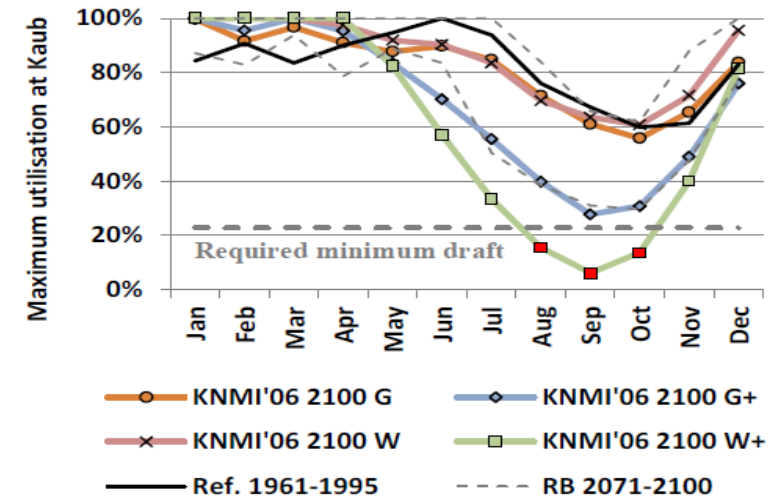
#5 Possible loss of market share due to climate change

- The ongoing climate change is affecting our weather system (global temperature has risen by 1 °C since industrialisation). It can affect the market share of the Port of Rotterdam within the Hamburg – Le-Havre range in various ways.
 - Climate change could impact IWT hinterland connections with long periods of low water depth during draughts and lower air draft for container ships during high water periods. The overall effect depends on political interventions to improve waterway system (e.g. by canalisation of free flowing rivers, see also Van Dorsser, 2015).
 - Sea level rise could cause a more frequent closure of the Maesland barrier, and ultimately also require an investment in a new barrier and sea locks. Closure of the port entrance will have a negative effect on the market share of the Port of Rotterdam vis à vis other ports in the region.
 - Another impact of sea level rise could be to decrease the competitive advantage of the deep water channel of the ‘Nieuwe waterweg’. With rising water levels, the access channel for other ports will become deeper. Also, a decline in fossil and raw material bulk throughput will lessen the need for a deep water canal, since container vessels require lesser water depth.

Figure 7.10: Effects of climate change on accessibility



Source: <http://lh3.ggpht.com/-mHLcvlgiXs/U1JxKWk7SLI/AAAAAAAAxmg/FhZqvefJTEg/maeslantkering12%25255B7%25255D.jpg?imgmax=800>



Note: Figure concerns maximum barge utilisation in tonnes.
Source: Van Dorsser (2015, p.272)



Foto: Twitteraccount: Merel Langeveld



<https://beeldbank.rws.nl/RuimtevoordeRivier/Home/DisplayDetail/273275>

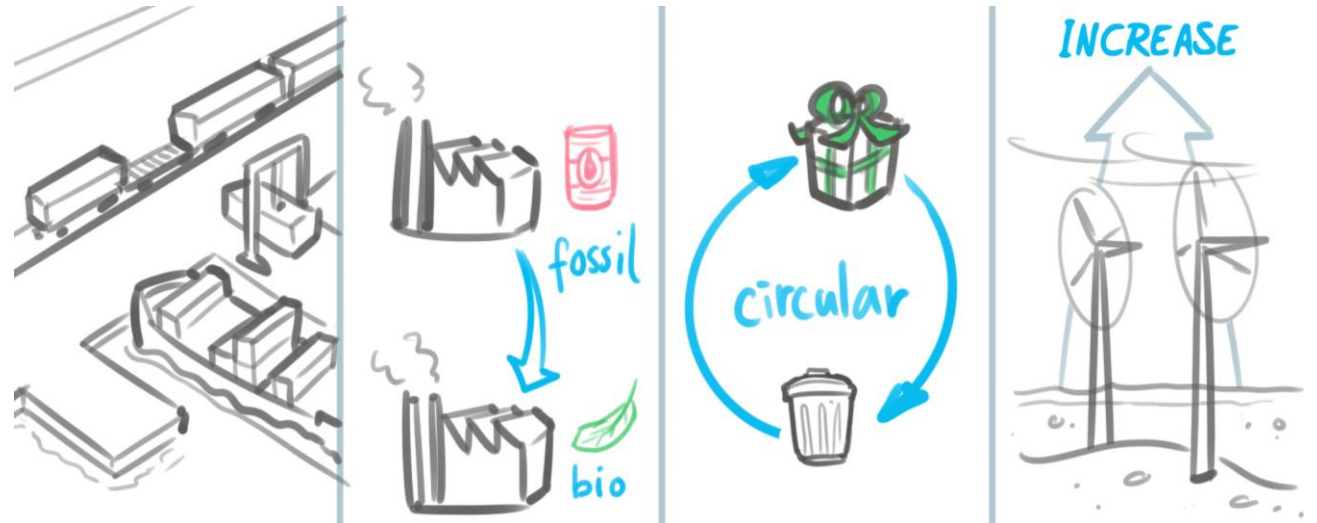
Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to [expected loss of market share due to climate change \(narrative 5\)](#).

- Impact on ship type / size / number
 - Reduction in number of vessels in case of more frequent closure of Maeslant barrier and/or possible future construction of ship locks;
 - Increase in ice reinforced vessels that are sailing via northern hemisphere to China and Japan;
 - Development of shallow draft barges, with lower capacity or increased width.
- Impact on infra loads / demand / alternative use
 - Ice reinforced vessels have stronger hull, but may also be smaller than their counterparts due to reduced roundtrip time (i.e. larger time spend in port);
 - Sea level rise has effect on natural depth at quays.
- Impact on cargo handling and storage requirements
 - Increased number of extreme weather events has effect on terminal operations, downtime and required equipment;
 - Extreme weather events may require lower stacking of empty containers.

7.3 Narratives on identified opportunities

- #6 Create production and blending area for renewable fuels;
- #7 Create recycling and dismantling area for offshore rigs and ships;
- #8 Strengthen supply base for offshore energy production at sea;
- #9 Opportunity to increase short sea container transport;
- #10 Develop dedicated barge facilities at deep-sea container terminals;
- #11 Develop aquaculture and fish farming in the port and at sea;
- #12 Expansion of cruise market for both maritime and inland shipping;
- #13 Increase navy presence to counter increased threats.



#6 Create production and blending area for renewable fuels

- Several ongoing trends point towards the possibility of transformation of present fossil oil industrial complex into a renewable fuel production and blending area.
- First the port of Rotterdam is a petrochemical hub locating **major fossil fuel refinery plants**. Major investments are presently being made to refurbish the existing complexes. The investments in this 'old' fossil industry instead of new installations are logical as the shift towards renewables does not guarantee cost recovery for new installations.
- The existence of 'old' petrochemical industry is a major asset when it comes to the development of new green industries since **biochemical** products can be combined with fossil products, enabling a gradual shift from fossil to renewable.
- Development of a renewable biochemical complex can be aided by the supply of raw materials via shipping and inland waterway transport. In addition ships are (together with airplanes) the entities most likely to require **biofuels** in the future. It is advantageous that the market for biofuels can be located in the port, and that the fuel can easily be shipped overseas by ship and to the hinterland airports (such as Schiphol airport) by inland waterway transport.
- Recent technological developments have increased the options for production of biofuels. For instance, in addition to the oil and sugar components, the cellulose component can now also be used for fuel production.

Create production and blending area for renewable fuels

- Biofuels can thus be produced from solid materials (i.e. wood pellets). This is promising as the port of Rotterdam already houses a cluster for transshipment of (solid) biomaterial.
- Considerable progress in the field of **synthetic fuels** (i.e. combining hydrogen and carbon to create synthetic hydrocarbon fuels by adding renewable energy) is being made and could provide the opportunity for production of synthetic fuels in the port area (for instance by importing hydrogen from sunny areas with cheap renewable energy or from offshore wind farms).
- Synthetic fuel production in the existing port area would generate synergies: existing berths could be converted for **hydrogen import** (if possible), carbon for production of synthetic fuels can be made available from port industry, energy is available from offshore windfarms, fuel can be blended with fossil fuels and bio-fuels, future demand from shipping industry can be catered to.
- Import of hydrogen is not unlikely as Chinas energy demand boosted decline in cost of solar energy down to less than 2 dollar cent/kWh in sun rich countries. Saudi-Arabia is building hydrogen plants, to add hydrogen to crude oil in order to improve quality of crude oil that has high sulphur content (due to depletion of oil fields). It may only be a matter of time before producing hydrogen is more cost effective than mining crude oil.

Figure 7.11: Refurbishment of existing oil refineries

NEWS 22 August 2016

Gunvor invests in Rotterdam refinery

Gunvor Petroleum Rotterdam has secured a project finance facility of USD 200 million to invest in further developing its Europoort refinery and improving the refinery's infrastructure. The facility is being provided by Rabobank, ING, ABN Amro and other banks. There was a considerable amount of interest. The facility was oversubscribed by 40%.



<https://www.portofrotterdam.com/en/news-and-press-releases/gunvor-invests-in-rotterdam-refinery>

ExxonMobil to Invest 1 Billion Dollars in Rotterdam Refinery

AmCham is honored to announce that one of its founding members, ExxonMobil is going to massively invest in its Rotterdam Refinery. The investment pertains to the Hydrocracker Unit. AmCham is excited that ExxonMobil which is the oldest US industrial to invest in the Netherlands stays loyal to the Netherlands and keeps on investing in this country. Please find the press release [here](#).



<https://amcham.nl/news/exxonmobil-invest-1-billion-dollars-rotterdam-refinery>

June 2016



Het voortbestaan van de olie-raffinaderijen is nodig om schone fabrieken van de grond te krijgen

- Allard Castelein

“The continued existence of the oil refineries is necessary to get clean factories off the ground”.

Allard Castelein

<https://www.ad.nl/rotterdam/groene-haven-draait-op-aardolie~aa1bf33c/>

Figure 7.12: Shift to renewable fuels (closing the carbon cycle)

Different solutions for different types of vehicles.

1. Bicycles, cars, trucks and busses can use batteries or hydrogen.
2. Trains can be electrified.
3. Ships and airplanes can shift to n^{th} generation biofuels and synthetic renewable fuels (with an anticipated revival of turboprops in aviation).

Scientific estimates indicate that some 10% to 30% of global energy demand can be supplied with biofuels. This may be enough to supply shipping and aviation with renewable fuel.



https://i2.wp.com/images.hgmsites.net/med/tesla-model-3-design-prototype--reveal-event--march-2016_100551199_m.jpg?resize=640%2C480&strip=all



<https://i.pinimg.com/736x/9b/63/a6/9b63a6e42f3e6f8da8f005f3ebcb4ed0--hydrogen-fuel-costa-rica.jpg>



Source: <https://insideevs.com/wp-content/uploads/2013/08/ev-train-2.jpg>



https://en.wikipedia.org/wiki/Electric_truck#/media/File:Iveco_Stralis_AD_190_E-Truck._Lidl._Spielvogel.jpg



<http://blogs.edf.org/texascleanairmatters/files/2013/03/hydrogen-fuel-cell-trucks-source-earth-techling.jpg>

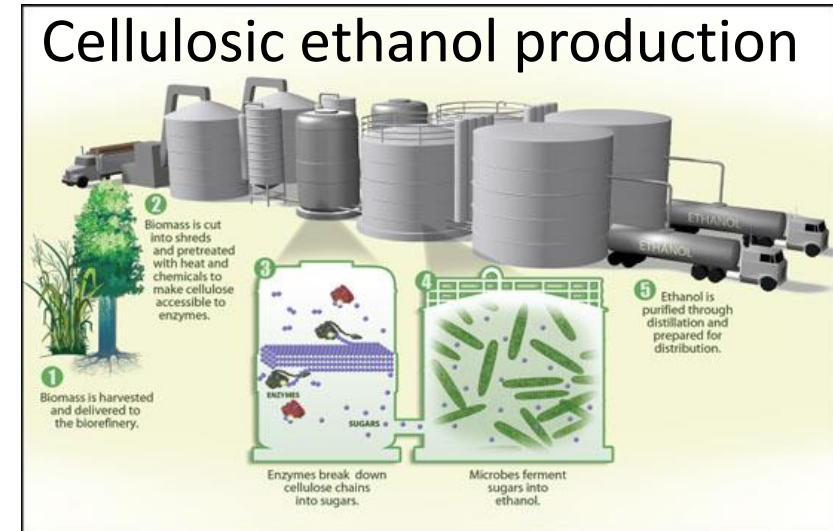


<https://www.economist.com/blogs/gulliver/2012/02/air-travel-and-turboprop-revival>

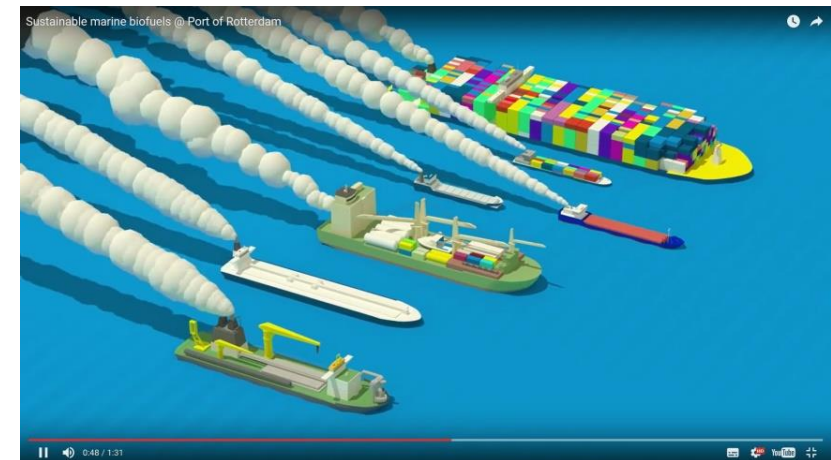
Figure 7.13: Production of marine biofuels

Opportunity for the port to create large biofuel cluster:

1. Sustainable energy source for ships and aviation.
2. Technology available to not only use 'sugar' and 'oil' but also 'cellulose' component of plant material for fuel production.
3. **Large bio cluster already present in the Port of Rotterdam.**
4. The port can be an ideal location for **fuel blending**. Intermediate products can be transported with short sea and IWT and directly supplied to sea ships.



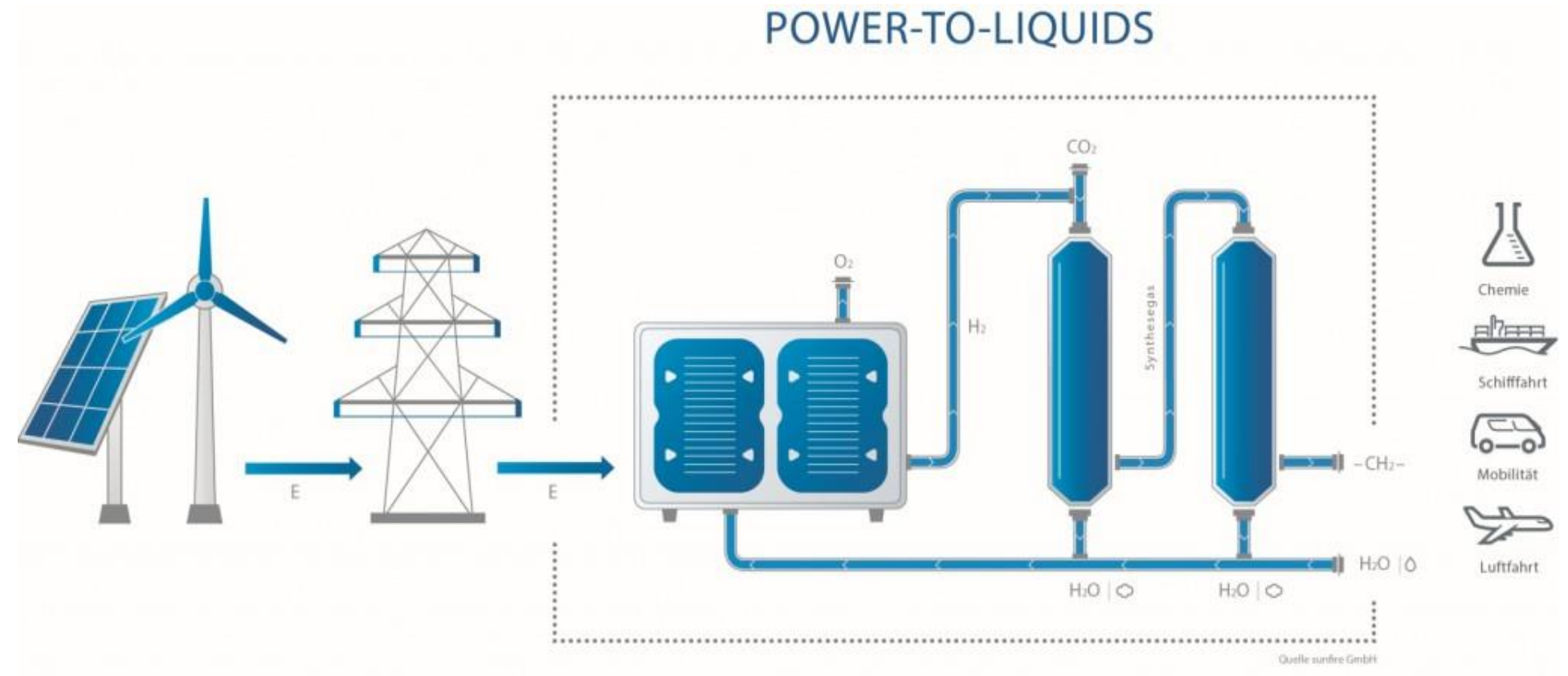
https://public.ornl.gov/site/gallery/thumbnails/How_Cellulosic_Ethanol_is_Made_-_original.jpg



<https://www.vesselfinder.com/news/4477-Sustainable-marine-biofuels-programme-launched-Video>

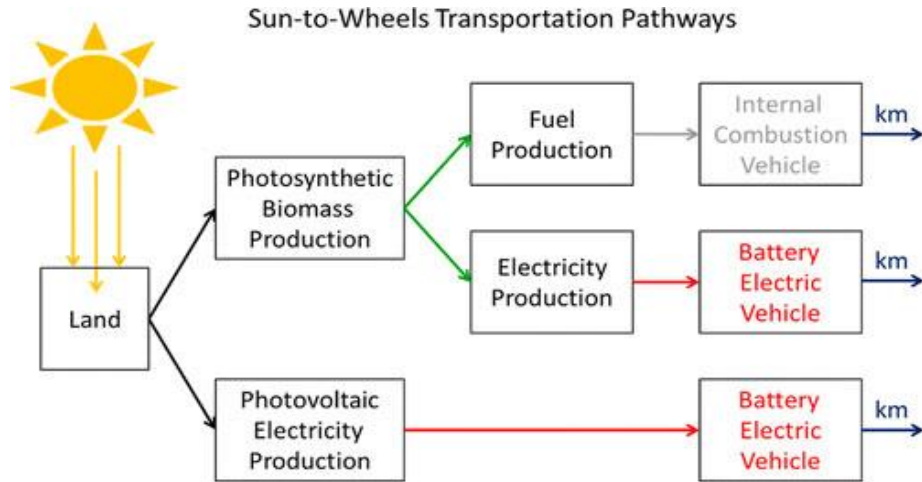
Figure 7.14: Power to liquid (PtL)

Fuel production from solar energy is more energy efficient than growing of biomass. PtL technology about to scale up to produce synthetic diesel at an industrial scale.



Source: <http://www.energypost.eu/worlds-first-power-liquids-production-plant-opened-dresden/>

Figure 7.15: Efficiency of solar vs. biofuel



<http://cfnewsads.thomasnet.com/images/sites/3/2013/02/santabarbara.greenandcleanphoto2.jpg>

There are various ways to harvest sustainable energy. It is more efficient to harvest solar energy directly than by growing biomass.

Highest energy output per m²



Lowest cost per energy unit

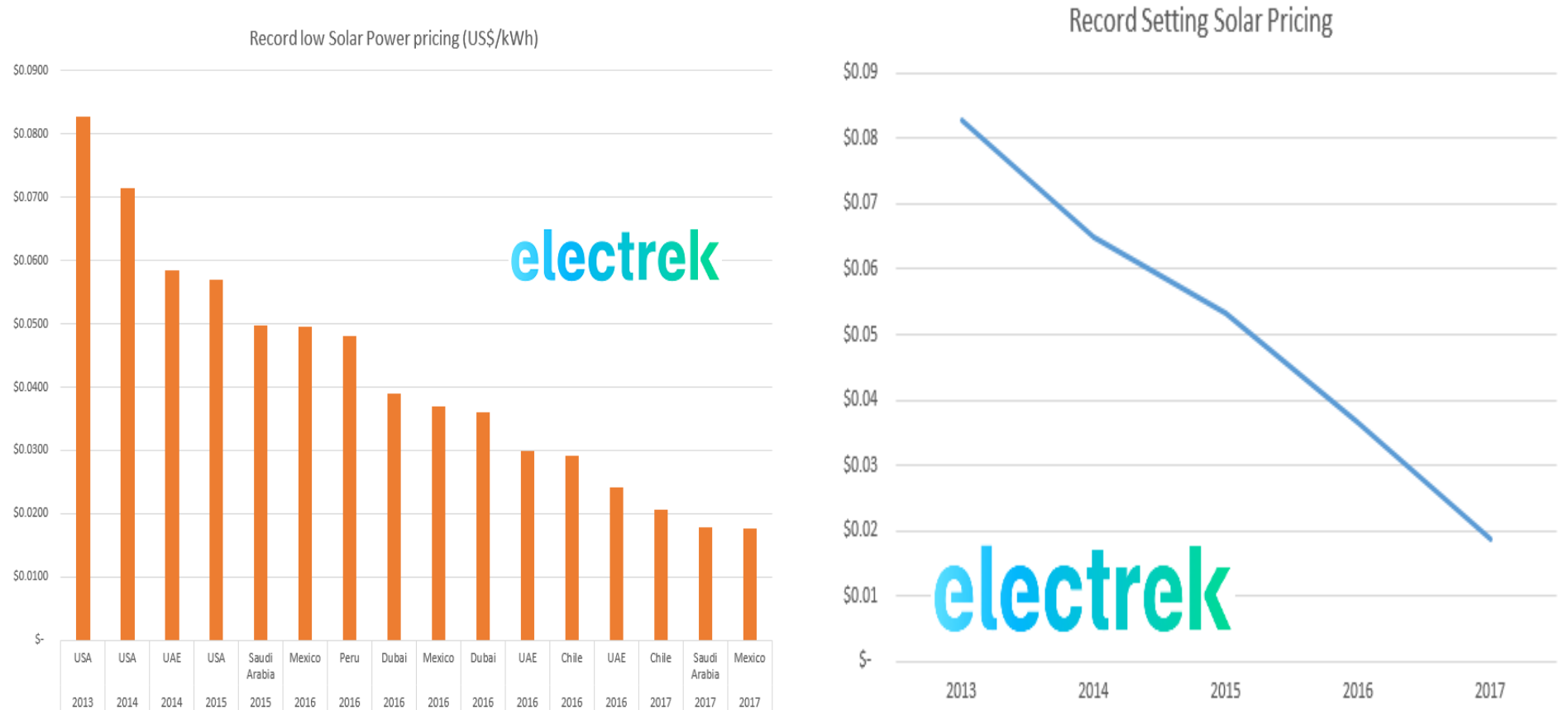


Note: this was in the year 2013, Cost price of solar now already much lower!

M. Pogson, A. Hastings, P. Smith (2013) How does bioenergy compare with other land-based renewable energy sources globally? *Global Change Biology Bioenergy*, 5, 513–524, doi: 10.1111/gcbb.12013.

Figure 7.16: Reducing cost of solar power

Record low solar bid in Mexico at 1.77¢/kWh (16 November 2017)



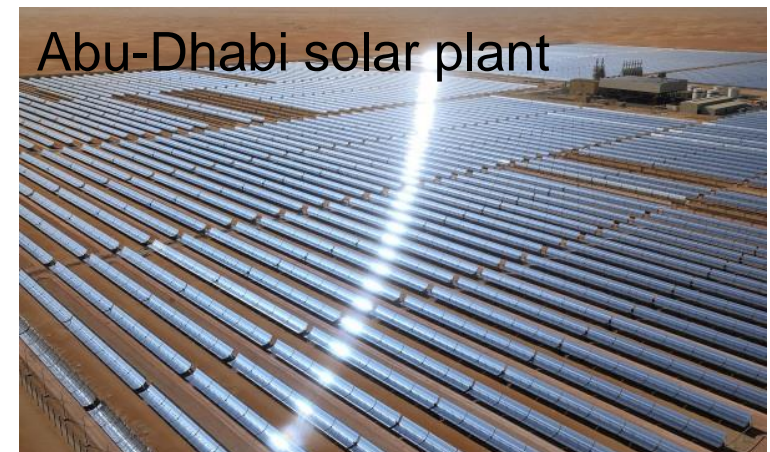
<https://electrek.co/2017/11/16/cheapest-electricity-on-the-planet-mexican-solar-power/>

Figure 7.17: Import of Hydrogen

1. Saudi-Arabia has announced plan to invest \$50 billion in renewable energy. Energy developers have been asked to bid on some 700 megawatts worth of solar and wind projects.
2. Saudi-Arabia is producing hydrogen to blend with depleting crude oil in order to reduce Sulphur content.
3. Cheapest solar energy now below 0.02 \$/kWh in middle east. **At 50\$ per barrel fuel cost of energy from oil > 0.07 US\$.**
4. With solar energy 2-3 times cheaper than in Germany (leader within Europe), a viable option could be to produce Hydrogen in the Middle east, Mexico or North Africa and ship it to the port of Rotterdam.



http://www.motorship.com/_data/assets/image/0028/423667/LH2-Carrierpilot_edited-1.jpg



http://www.masdar.ae/assets/images/content/1001/jan_2013_aerial_francois_site_photoshooting_0208_bb_cloud.jpg

Figure 7.18: Carbon capture for synthetic fuel production

1. Production of sustainable synthetic fuels requires CO₂ produced by a renewable source of energy.
2. This carbon dioxide could be harvested from carbon capture in MPP3, which is the most advanced coal and biomass power plant in the world.
3. For this purpose, the 1.7 billion euro power plant needs to be converted into a full biomass plant.
4. Biomass is well available as the Port of Rotterdam houses a large biomass cluster.
5. If not used for synthetic fuel production, the captured carbon can be stored in old gas fields, resulting in a negative CO₂ production.



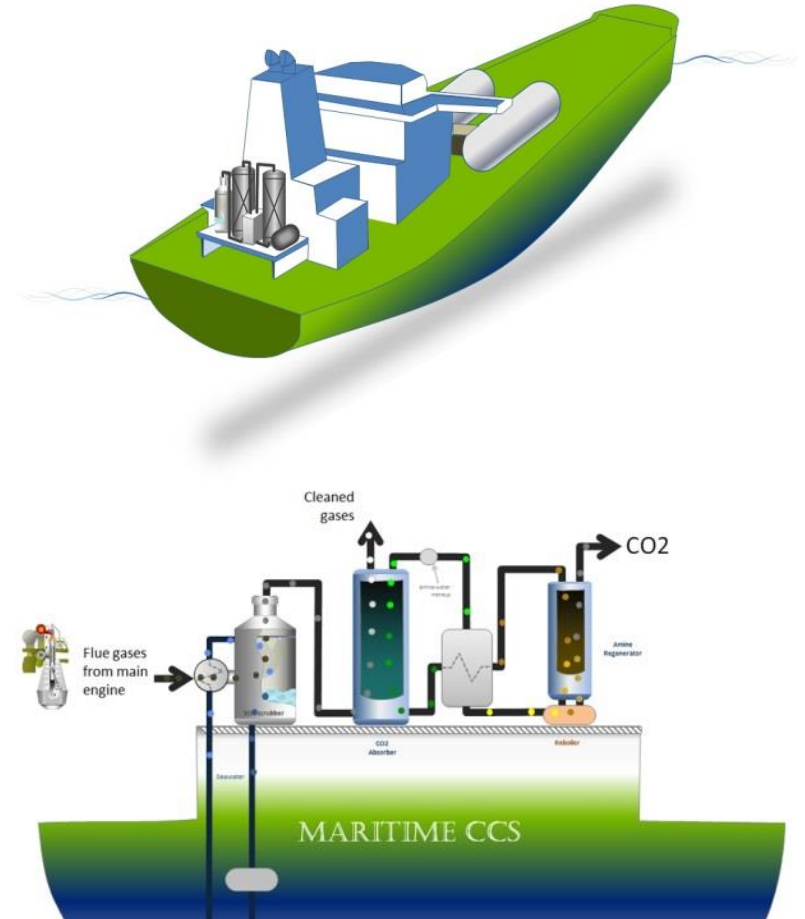
<https://www.fluxenergie.nl/gloednieuwe-kolencentrale-op-maasvlakte/>



https://www.portofrotterdam.com/sites/default/files/styles/por_is_content_image/public/Wood-pellets%2C-biomass.jpg?itok=Wrbvait1

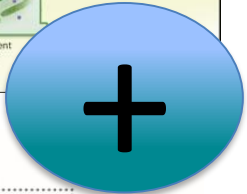
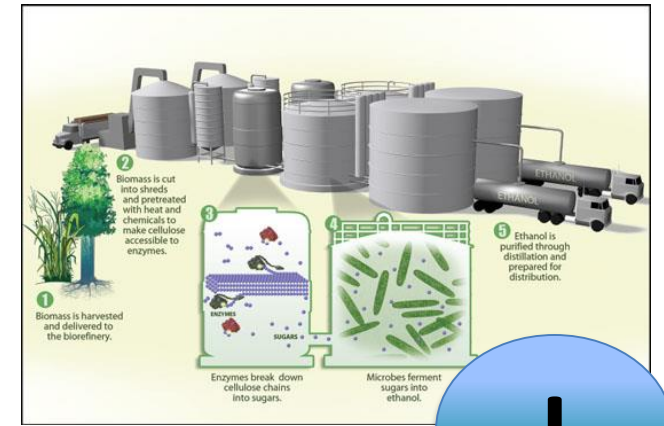
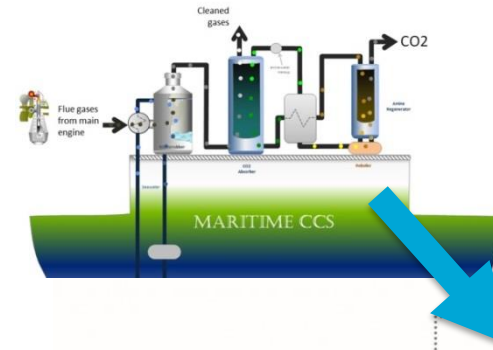
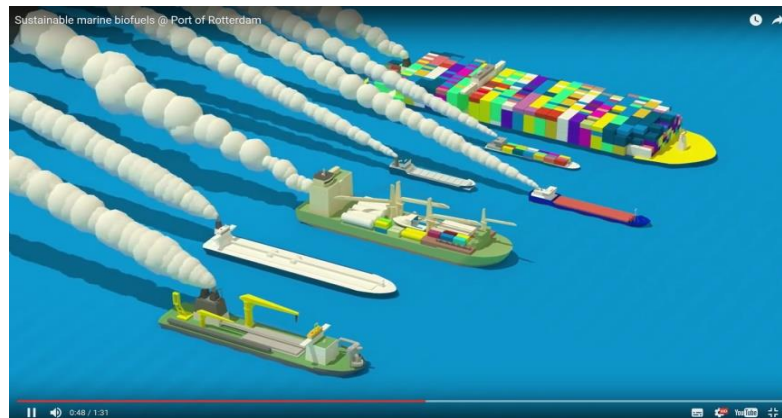
Figure 7.19: On board carbon capture and storage

1. Synthetic fuel production requires carbon captured from industrial complexes and power generation plants.
2. Ships may also be fitted with carbon capture technology in the more distant future. A DNV study indicates that up to approx. 65% of CO₂ can be recovered.
3. Once PtL facilities are developed and operational in the port, CO₂ can be an important feed stock for synthetic fuel production.
4. Ships would be able to return captured carbon exhaust to the PtL factories in the port, especially if given a financial incentive.

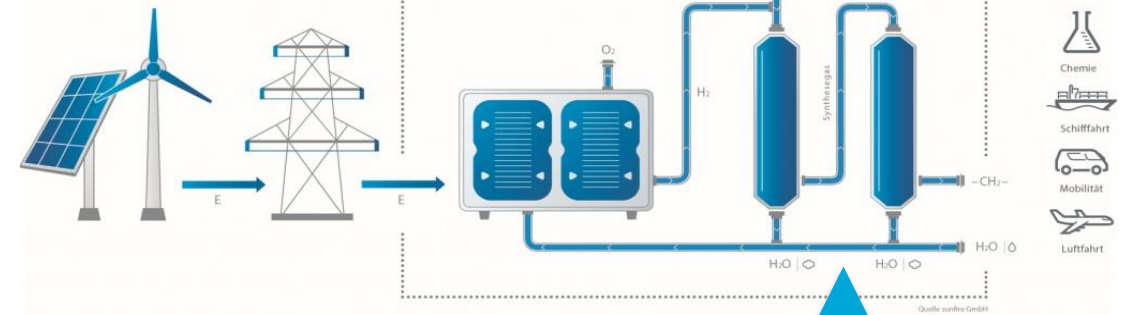


On-board Carbon Capture and Storage.
<http://articles.maritimepropulsion.com/?page=20>

Figure 7.20: A potential fuel blending cluster



POWER-TO-LIQUIDS



Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to the expected opportunity for [creating a production and blending area for renewable fuels \(narrative 6\)](#).

- Impact on ship type / size / number
 - For bio-based cluster a larger number of reactively smaller vessels is expected compared to present oil cluster. In addition there may be a substantial number of inland barges shipping bio-materials and bio-fuels to/from the port;
 - For hydrogen imports one may expect coastal sized vessels on short trips (e.g. to Doggersbank) and larger vessels to sun rich countries like Saudi-Arabia or Morocco. The size of long distance hydrogen carriers is likely to start relatively small and to increase rapidly over a period of few decades;
 - For export of fuel products there may be a decline due to the global shift to renewables. Over time, the size of vessels could become smaller due to the smaller size of the market, but this effect is uncertain and speculative;
 - Fuel export is likely to shift from fossil based fuels to a blend of bio-based and synthetic fuels (power to X).

Considerations for infrastructure development

- Impact on infra loads / demand / alternative use
 - Lifetime of existing oil jetties along Caland Canal may be extended as loading forces will be reduced with the gradual phasing out of major oil carriers. Jetties may possibly also serve slightly smaller mineral product carriers;
 - Incoming cargoes (bio-fuels, hydrogen) likely to require more and smaller jetty facilities. Also an increased demand for inland tanker barges possible.
- Impact on cargo handling and storage requirements
 - Completely different loading facilities are required for unloading of smaller ships with hydrogen and bio-fuels. Loading rates for these commodities are also likely to be lower than for crude oil vessels;
 - In case renewable fuel blends are going to serve as fuel for seagoing vessels (as anticipated in narrative) this will also require sufficient bunkering capacity. Possibly existing facilities for loading bunker barges may be converted.

#7 Create recycling and dismantling area for offshore rigs and ships

- Recycling is, especially for Europe, of major importance to secure sufficient (raw) material and continue industrial production.
- Rhine connected countries (Germany, Switzerland, Austria, Belgium and Netherlands) are front-runners in recycling of municipal waste.
- A large recycling industry is present in the ports of Rotterdam, Antwerp, and Amsterdam and many connected inland ports.
- With raw materials becoming scarcer, demand for circular use of goods is expected to remain growing in line with 10Rs of Jacqueline Cramer (see [Figure 6.21](#)).
- The first two Rs (refuse and reduce) will tend to lower port throughput as discussed in section on threats. The last two (recycle and recover) can provide opportunities for diversifying port activities.
- In addition to building up the existing recycling and energy recovery activities in the port, there is an opportunity to strengthen the recycling cluster by developing a major sustainable scrap facility for offshore units and ships.
- The outlook for the ship scrapping market is improving with an expected boom around 2030. The expected decommissioning of offshore units in the Brent field will likely increase from 2019 onwards and peak around 2030.
- Ship scrapping is expected to recover and reach a peak around 2035 – 2040 globally.

Figure 7.21: Impact of circular economy on port business

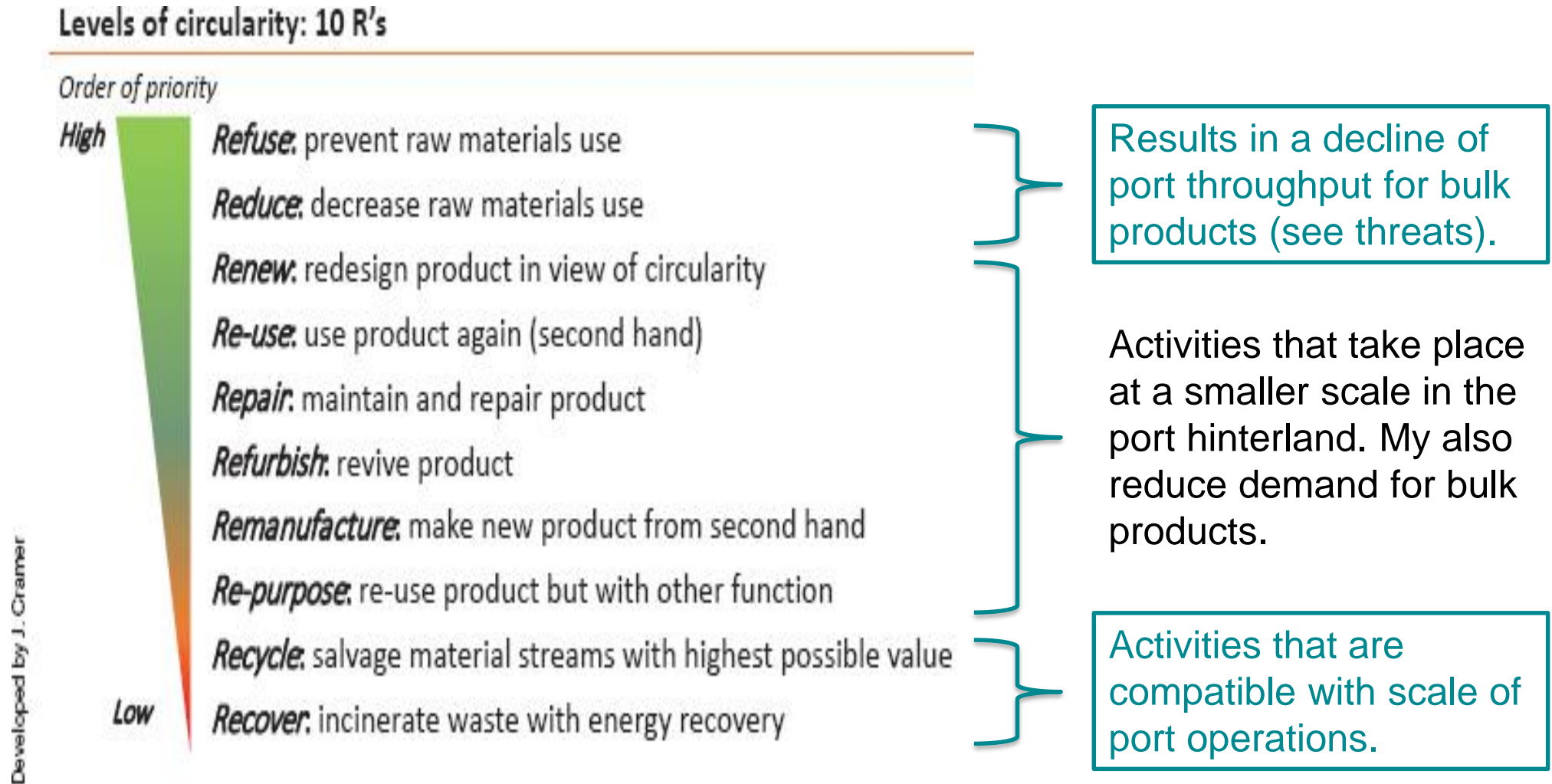
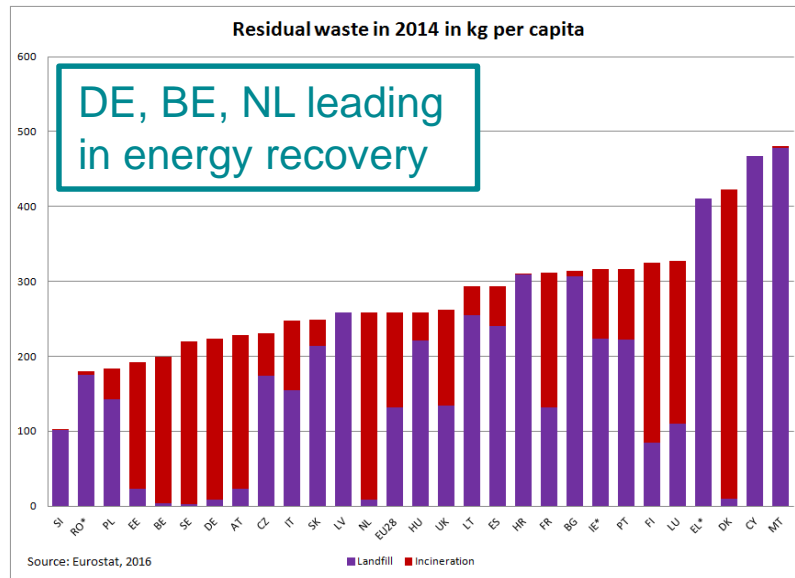


Figure 7.22: Strength of Rhineland's recycling cluster

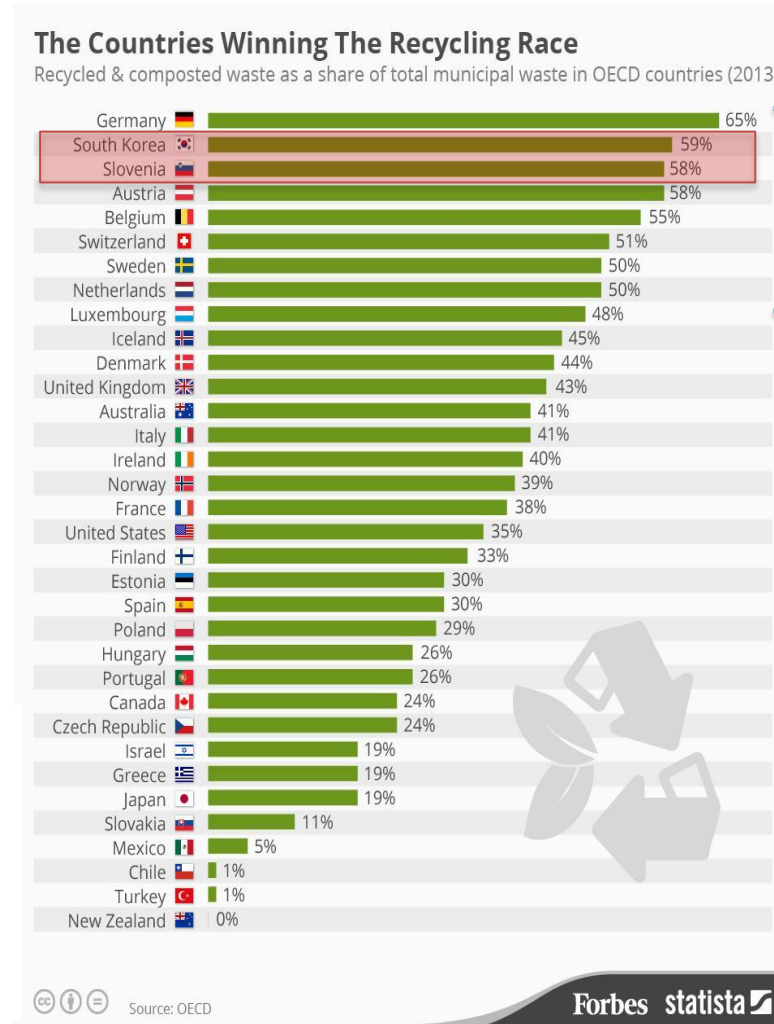


<https://www.zerowasteurope.eu/wp-content/uploads/2016/03/residualwaste.png>

Materiaal	Doelstellingen Europa vanaf 2005	Doelstellingen Nederland 2005-2012	Resultaten Nederland 2013	Doelstellingen Nederland 2013-2022
Glas	60%	90%	79%	90%
Papier/Karton	60%	75%	89%	75%
Hout	15%	25%	22%	43%
Metaal	50%	85%	93%	85%
Kunststof	22,5%	42%	46%	51%

Percentages hergebruik per materiaal

https://www.kidv.nl/item/6865/afbeelding_2.PNG.png&width=1000&maxheight=1000



https://blogs-images.forbes.com/niallmccarthy/files/2016/03/20160303_Recycling-01.jpg

Figure 7.23: Opportunity for a major decommissioning facility

1. Many companies are already active in recycling of metals, plastics and other materials.
2. Recycling companies are well connected with each other by IWT infrastructure.
3. Heavy lift vessels, pontoons and other installation equipment required for decommissioning of offshore units in the North Sea is located in the port.
4. Port contains several large drydocks such as Damen Verolme (405 x 90 m).
5. Existing offshore supply base on 2nd Maasvlakte, and second to be completed by 2019.



https://lh6.googleusercontent.com/-N7VR9LPyMDI/Uqn7eb5fXNI/AAAAAAAAACU/_g7WFCkEw68Mcn8Ancuw3oMHVWrBWkXbwCJkC/s1600-w640/



<https://pbs.twimg.com/media/CMYVShnVAAAYGxb.jpg>

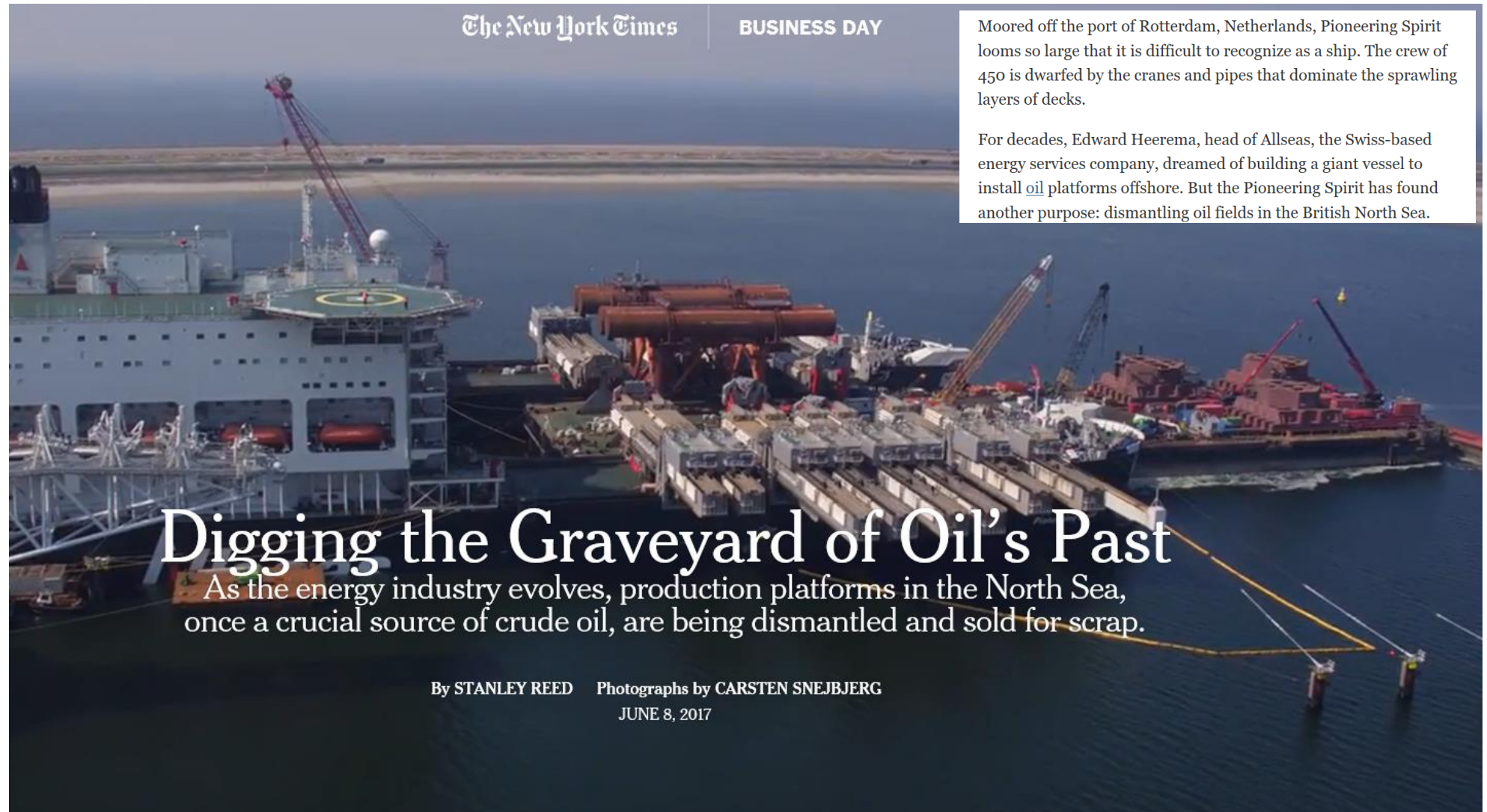


<http://www.trucks-cranes.nl/nederlands/hijskranen/hijsklussen/schiedamboten.html>



<https://pbs.twimg.com/media/CDg7CrMWgAEQwcv.jpg>

Figure 7.24: Large market for offshore decommissioning



The New York Times

BUSINESS DAY

Moored off the port of Rotterdam, Netherlands, Pioneering Spirit looms so large that it is difficult to recognize as a ship. The crew of 450 is dwarfed by the cranes and pipes that dominate the sprawling layers of decks.

For decades, Edward Heerema, head of Allseas, the Swiss-based energy services company, dreamed of building a giant vessel to install oil platforms offshore. But the Pioneering Spirit has found another purpose: dismantling oil fields in the British North Sea.

Digging the Graveyard of Oil's Past

As the energy industry evolves, production platforms in the North Sea, once a crucial source of crude oil, are being dismantled and sold for scrap.

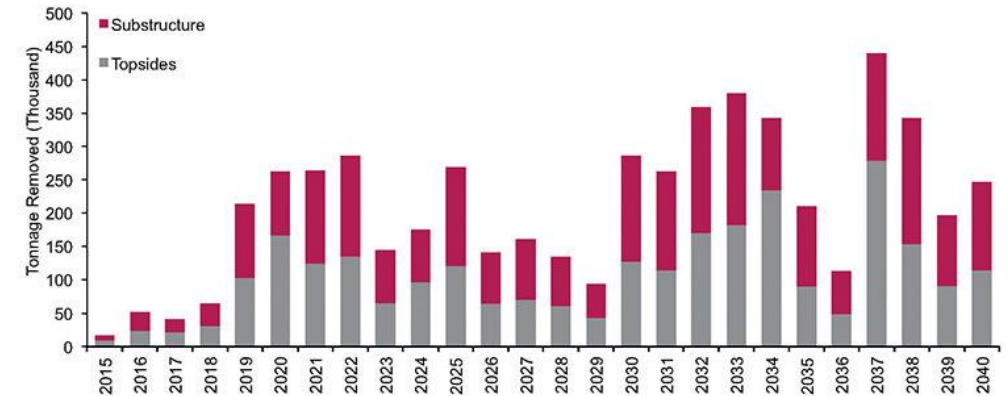
By STANLEY REED Photographs by CARSTEN SNEJBJERG

JUNE 8, 2017

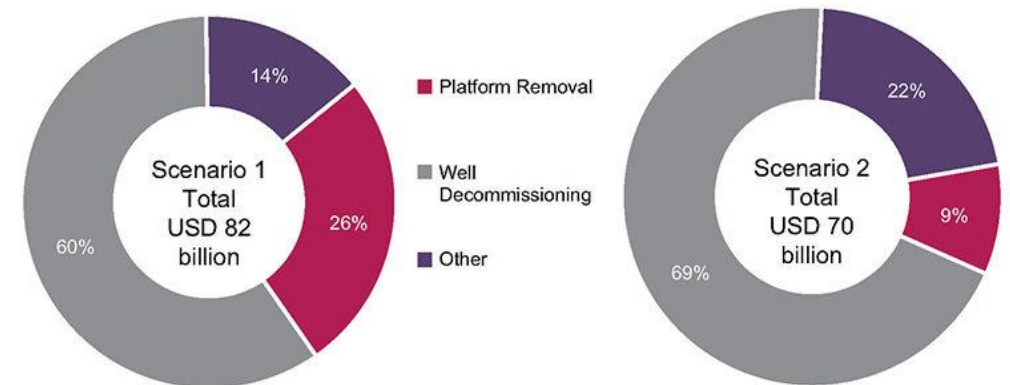
Figure 7.25: Decommissioning market outlook up to 2040

- Douglas-Westwood expects boom in North Sea decommission market (Wilby, 2016).
- Removal of 285 platforms and more than 400 wells in UK; and some 146 platforms in Denmark, Germany and Norway, is expected in the period 2016-2040.
- Total decommissioning market has expected value of 70 – 82 billion US\$ depending on success of single lift vessels (SVLs) like the Pioneering Spirit that can complete removal of heaviest platforms with just one lift rather than via reverse installation methods.
- There is a large market for vessels capable of closing subsea wells. This links to growing business for offshore supply bases.

Volume of decommissioning work in United Kingdom, Germany, Denmark and Norway.



Size of decommissioning market from 2016 to 2040 In United Kingdom, Germany Denmark and Norway.



Note: Scenario 1 with conventional methods; Scenario2 with Single Lift Vessels
Source: <https://www.spe.org/en/print-article/?art=4>

Figure 7.26: Decommissioning of oil fields in North Sea

- Shell has over 100 platforms to be dismantled over next decade.
- Cheaper and safer to lift them with Pioneering Spirit than to dismantle them at sea.
- Oil companies do not want to repeat mid-1990s confrontation with environmentalist (about sinking Brent Spar).



<https://www.nytimes.com/2017/06/08/business/energy-environment/oil-north-sea-shell.html>

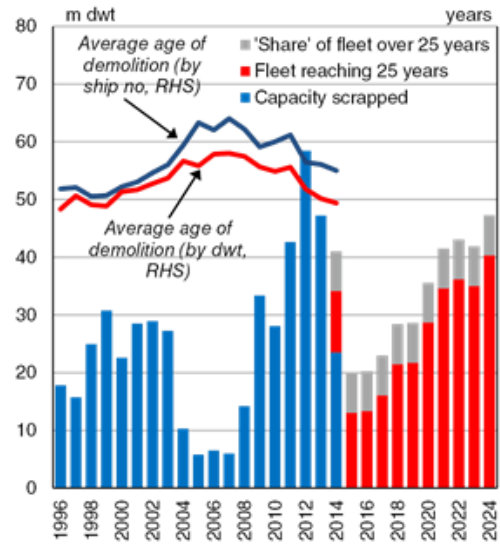
Figure 7.27: Growing market for (sustainable?) ship demolition

- With society becoming more aware and demanding over sustainability issues and corporate responsibility, a shift of ship demolition to western countries is gradually becoming more likely.
- The foreseen demolition activities offshore and the need to secure material resources could strengthen business case for vessel scrapping in Europe.
- Scrapping industry is recovering and expected to peak around 2035-2040 globally.

Graph of the Week

Demolition - More Ups Than Downs?

The lines on the graph show the development of the average age of vessels and dwt demolished. The bars on the graph show historical scrapping in dwt (in blue), along with fleet capacity reaching 25 years old each year (in red) and a share of the 'tail' of the capacity in the fleet over 25 years old spread across a period of 15 years (which might be considered cautious in today's fuel price and regulatory environment).

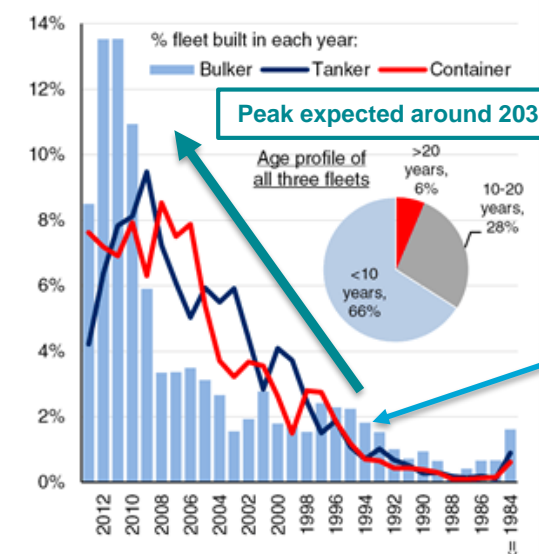


Source : Clarkson Research Services

Graph of the Week

The Bulk & Box Fleet's Difficult Demographics

Graph shows the percentage of the bulker, tanker and container-ship fleets built in each year up to 2013. Data in terms of dwt for bulkers and tankers and teu for container-ships. Inset pie chart shows age of dwt capacity in all three sectors combined.

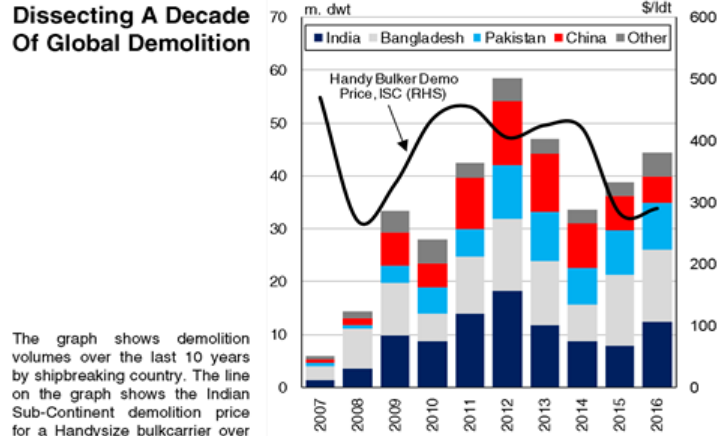


Source : Clarkson Research Services

Figure 7.28: Social need for sustainable scrapping business

Graph of the Month

Dissecting A Decade Of Global Demolition



The graph shows demolition volumes over the last 10 years by shipbreaking country. The line on the graph shows the Indian Sub-Continent demolition price for a Handysize bulkcarrier over this period in terms of \$/dwt.

Source : Clarksons Research

https://www.clarksons.net/wfr2/News/GetImage?Type=Image&FileName=BackPageImages%2F2017-02-17_upload_4941802_WSMT_2017_02.png

Table 6.7. Top 10 ship-scraping nations, 2010

Country	Scrapped amount, dwt	Accumulated market share, as a percentage	Number of ships scrapped	Rank	Scrapped ships, percentage of total volume				
					Bulk carriers	Dry cargo / passenger	Offshore	Tankers	Others
India	9 287 775	32.4	451	1	9.7	32.8	5.3	46.2	5.9
Bangladesh	6 839 207	56.3	110	2	15.1	5.5	5.7	71.1	2.5
China	5 769 227	76.5	189	3	46.6	36.3	2.5	12.2	2.4
Pakistan	5 100 606	94.3	111	4	8.1	2.9	6.2	80.6	2.2
Turkey	1 082 446	98.1	226	5	24.3	48.7	0.2	14.1	12.8
United States	217 980	98.8	15	6	0.0	19.9	0.0	80.1	0.0
Romania	16 064	98.9	4	7	0.0	100.0	0.0	0.0	0.0
Denmark	15 802	98.9	25	8	0.0	53.4	22.7	0.0	23.9
Japan	13 684	99.0	1	9	0.0	100.0	0.0	0.0	0.0
Belgium	8 807	99.0	12	10	0.0	100.0	0.0	0.0	0.0
World	28 637 092	100.0	1 324		18.6	22.7	4.7	50.0	4.1

<https://www.shipbreakingbd.info/images/top10ScrapingNations.jpg>



http://i.dailymail.co.uk/i/pix/2013/05/14/article-232433_9-19C5EDAB000005DC-821_1024x615_large.jpg



https://www.nature.com/polopoly_fs/7.34061.1455570171/image/HighRes_42-70296894.jpg_gen/derivatives/landscape_630/HighRes_42-70296894.jpg



http://i.dailymail.co.uk/i/pix/2013/05/14/article-0-19C50AA6000005DC-236_964x660.jpg

Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to the expected opportunity for **creating recycling and dismantling area for offshore rigs and ships (narrative 7)**.

Impact on ship type / size / number

- Shipment of offshore platforms to decommissioning areas. E.g. shipped on seagoing barges or single lift vessels like the *Pioneering Spirit*;
- Increase in number of intra port shipments with decommissioned parts from decommissioning area towards recycling industry;
- Impact of enhanced material recycling on recycled cargo volumes is hard to anticipate as different developments can be expected:
 - Possible increase in export volumes to material hungry countries like China (e.g. in larger bulk carriers or in containers);
 - Possible increase of inland bulk shipping with collected recycling material from hinterland to port of Rotterdam;
 - Possible increase of inland bulk shipping with sorted scrap material to in particular the German hinterland.

Considerations for infrastructure development

- Impact on infra loads / demand / alternative use
 - Impact depends fairly on applied decommissioning procedures. Are ships and offshore constructions scrapped at a single location (such as they are beached in e.g. India and Bangladesh now), or are they swiftly decommissioned or cut into several pieces and shipped towards the recycling industries. The latter model would probably fit better with the Port of Rotterdam;
 - Assuming a swift decommissioning of offshore installations, operations will benefit from a sheltered open water space with berthing facilities where offshore decommissioning activities can take place with large crane vessels. Given the irregular and temporary basis of decommissioning activities co-sharing of these berths and the port basin area could be beneficial.
- Impact on cargo handling and storage requirements
 - Need to accommodate lifting activities with large cranes. E.g. at waterfront areas or at decommissioning shipyards (such as potentially Damen Verolme);
 - Need to prepare space for recycling/scrapping industry, including sufficient space for receiving material, scrapping, storing and blending, as well as for shipping material via quay side and land side (e.g. in containers).

#8 Strengthen supply base for offshore energy production at sea

- Sustainable energy transition is, with approx. 5% renewables, still at the beginning of the s-curve but expected to show acceleration.
- The energy transition has gained political momentum since Paris agreement. Clear EU and national energy policies are in place.
- The Dutch national energy agreement now aims to increase wind energy generation at sea from less than 400 MW in 2015 to 4500 MW in 2023.
- Neighbouring countries are also building major wind farms at sea. For instance, Belgium has plans for new wind farms near the Westerschelde, Germany in its entire North Sea region and UK not far from the Port of Rotterdam.
- These developments validate the increasing demand for offshore supply bases, such as the Maasvlakte 2 Terminal that opened in 2017 and the Offshore Center Maasvlakte 2 planned for 2019.
- Offshore supply bases can also provide room for well closing/decommissioning activities, construction and commissioning of offshore fish farms, and installation of offshore solar farms in-between wind farms.

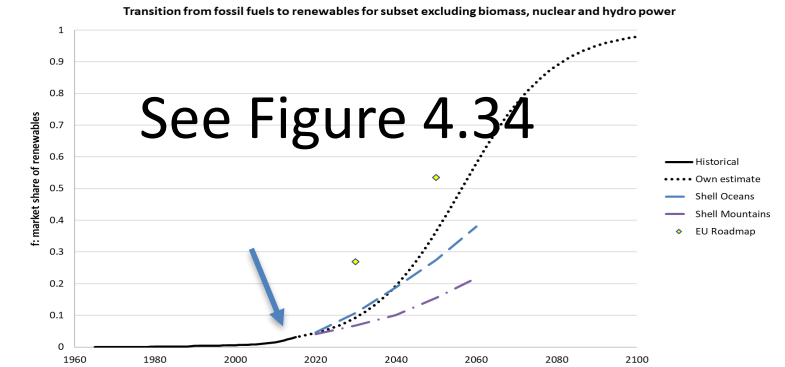
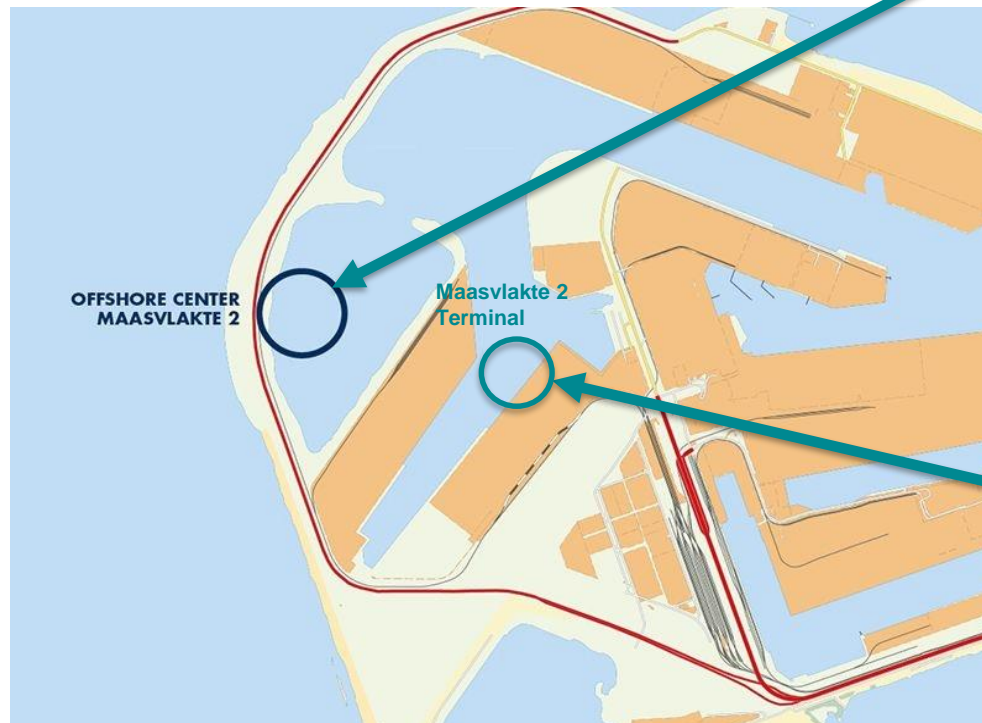


Figure 7.29: Development of offshore supply bases

- Offshore supply bases in ARA region have advantage over other supply bases due to their excellent IWT connection to equipment supply and production areas in hinterland.



<https://www.portofrotterdam.com/nl/nieuws-en-persberichten/offshore-center-rotterdam-ocr-nieuw-land-voor-windparken-op-zee>

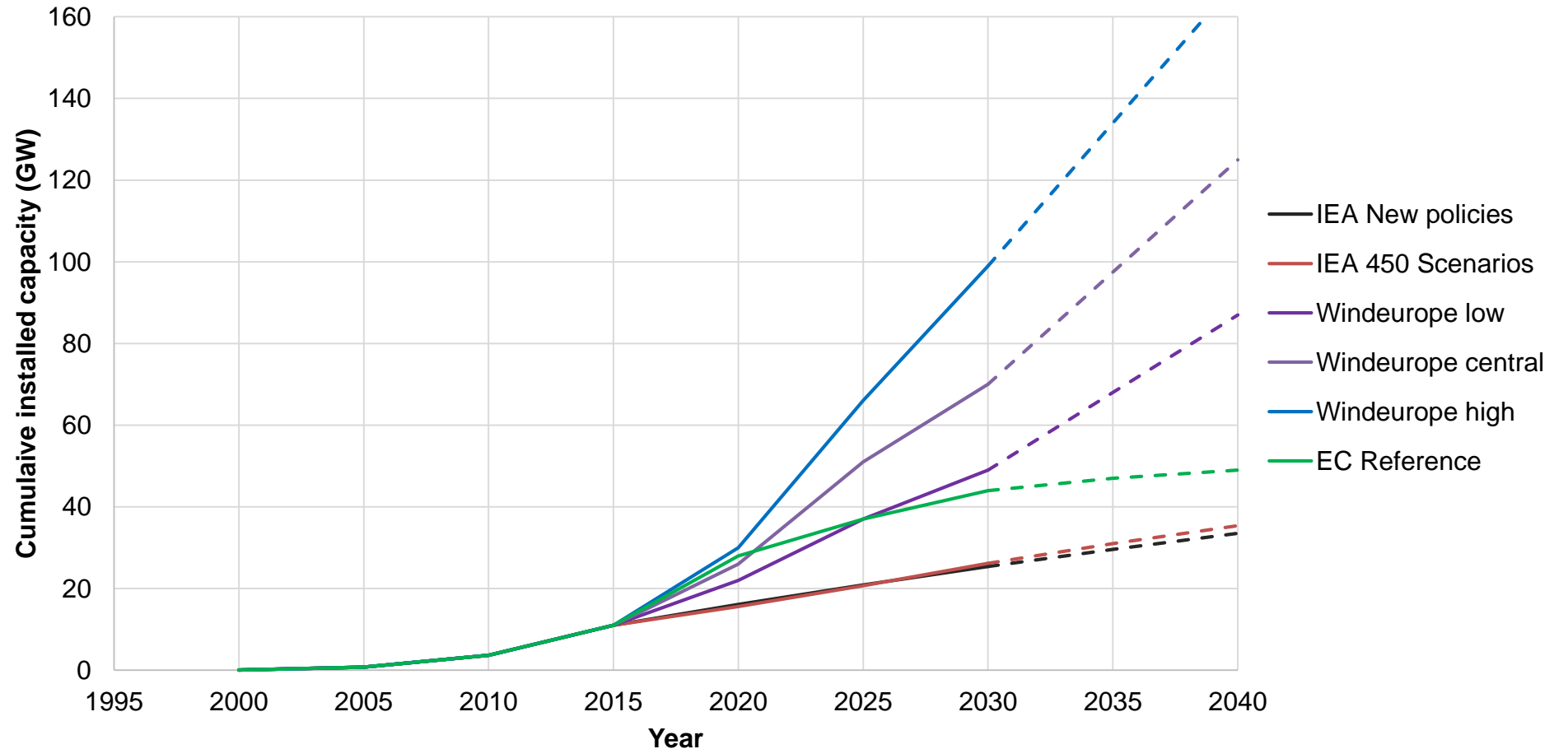


<https://www.portofrotterdam.com/nl/nieuws-en-persberichten/offshore-center-rotterdam-ocr-nieuw-land-voor-windparken-op-zee>



<http://www.4coffshore.com/windfarms/maasvlakte-2-terminal-officially-opened-nid6480.html>

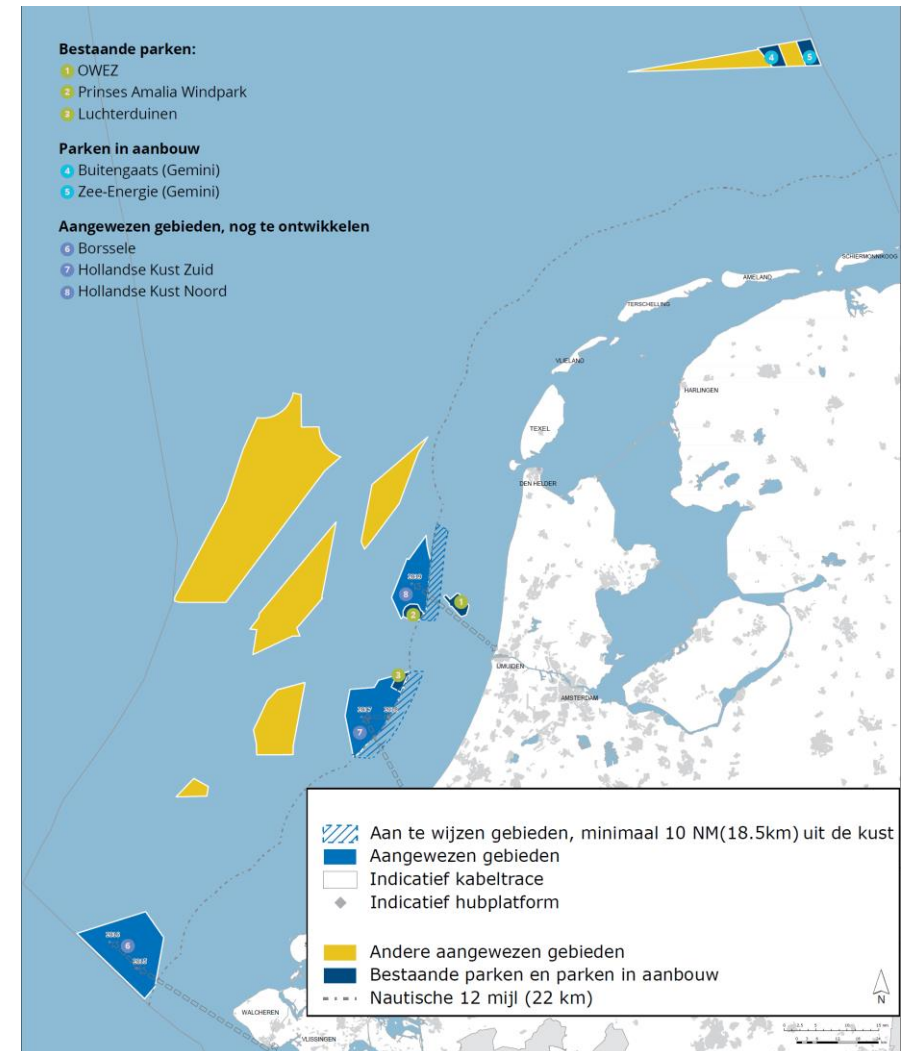
Figure 7.30: Projections for offshore wind power in EU



Source: (1): Windeurope (2017), Wind energy in Europe: Scenarios for 2030, from: <https://windeurope.org/wp-content/uploads/files/about-wind/reports/Wind-energy-in-Europe-Scenarios-for-2030.pdf>; (2): IEA (2016), World energy outlook 2016: Special focus on renewable energy, from: <https://www.iea.org/media/publications/weo/WEO2016SpecialFocusonRenewableEnergy.pdf>; (3): European Commission (2016) Energy, transport and GHG emissions trends to 2050, from: https://ec.europa.eu/energy/sites/ener/files/documents/20160712_Summary_Ref_scenario_MAIN_RESULTS%20%282%29-web.pdf

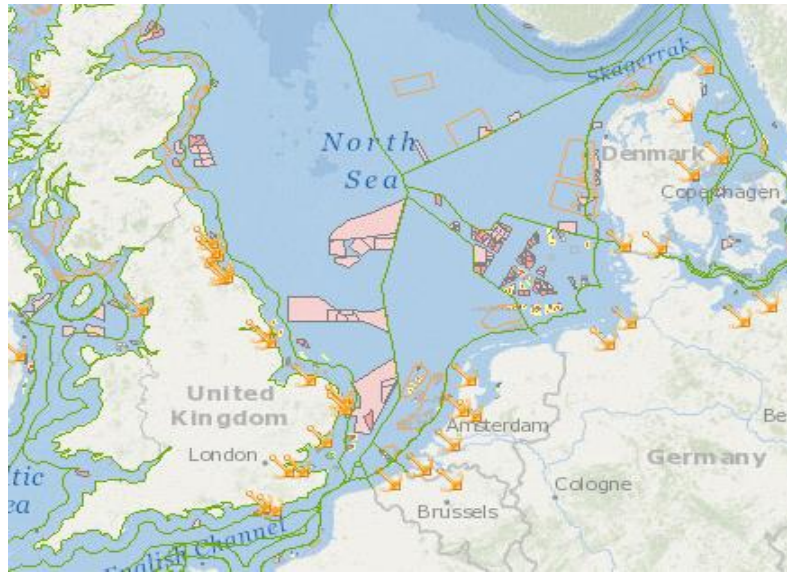
Figure 7.31: Dutch wind park expansion in period 2016 to 2023

Windpark	Locatie	Afstand van de kust	Vermogen
Bestaande parken			
OWEZ	Egmond aan Zee	11 km	108 MW
Prinses Amalia Windpark	IJmuiden	23 km	120 MW
Luchterduinen	Noordwijk	23 km	130 MW
Parken in aanbouw			
Buitengaats (Gemini) -	Ten noorden van de Waddeneilanden	60 km	300 MW
Zee-Energie (Gemini) -	Ten noorden van de Waddeneilanden	60 km	300 MW
Aangewezen gebieden, nog te ontwikkelen			
Borssele	Zuiden van Zeeland	Vanaf 22 km	1400 MW
Hollandse Kust Zuid	Regio Den Haag	Vanaf 18.5 of 22 km	1400 MW
Hollandse Kust Noord	Regio IJmuiden	Vanaf 18.5 of 22 km	700 MW



<https://www.energieakkoordser.nl/~media/files/energieakkoord/nieuwsberichten/2016/factsheet-windopzee.ashx>

Figure 7.32: Development of offshore wind power

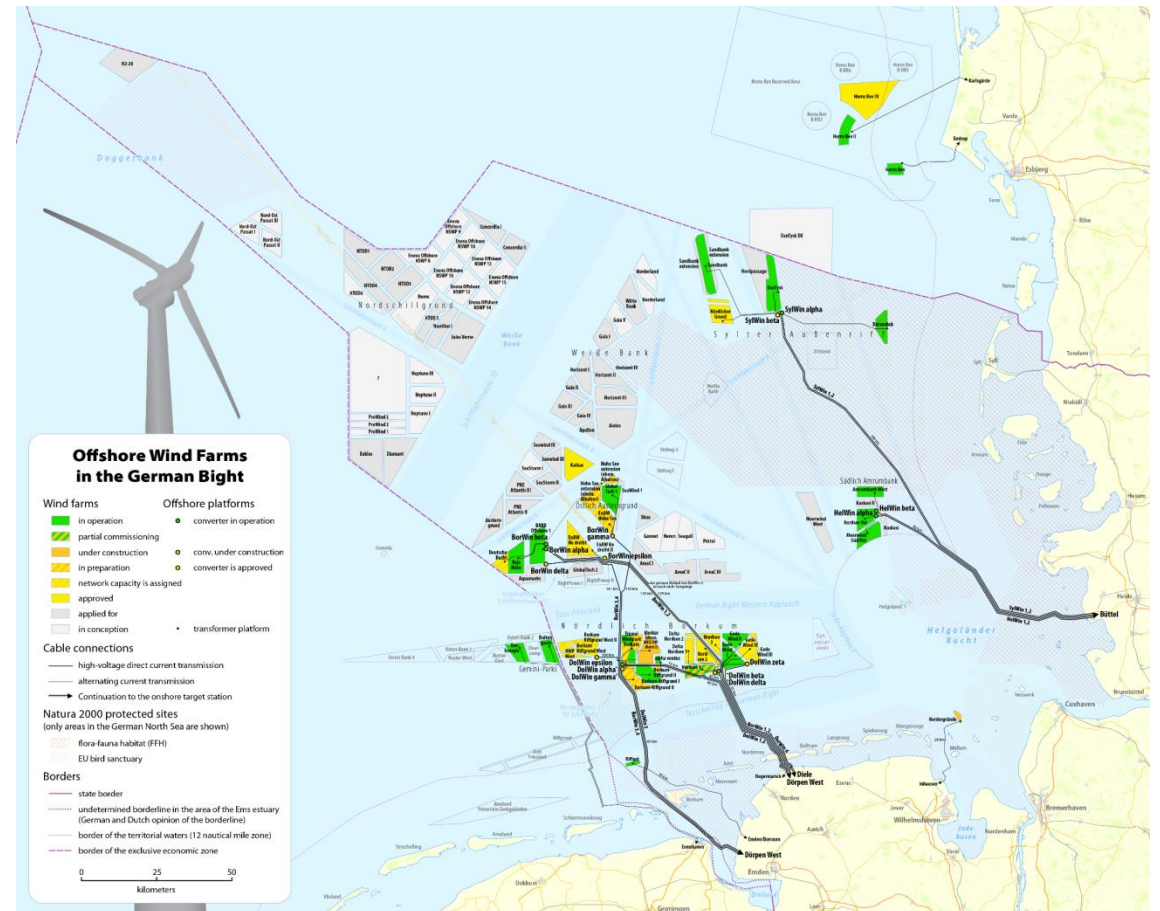


<https://www.energy-watch.nl/nl/18-artikelen-nl/40-ontwikkeling-van-offshore-wind-nl>



<https://corporate.vattenfall.co.uk/globalassets/uk/project-s/vattenfall-windpower.jpg>

German North Sea area almost completely covered by shipping lanes and wind farms.



https://upload.wikimedia.org/wikipedia/commons/a/a1/Map_of_the_offshore_wind_power_farms_in_the_German_Bight.png

Figure 7.33: North sea hubs

- In addition to the use of substations and subsea cables plans are being made for the creation of a power hub island to which the energy is supplied. The artificial island hubs are intended to be equipped with power to X (P2X) facilities, that for instance produce hydrogen from energy and seawater.



Figure 7.34: Next step could be solar panels between windmills



<https://www.japantimes.co.jp/wp-content/uploads/2017/06/f-chinasolar-a-20170612.jpg>



<https://www.walldevil.com/wallpapers/a38/sea-wind-turbine.jpg>



<http://cdn.nowitcounts.com/wp-content/uploads/2016/04/Floating-Solar-Power-Plants.jpg>



<http://www.dutchnews.nl/news/archives/2017/06/shell-step-up-building-huge-north-sea-offshore-wind-farms/>

Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to the expected opportunity for [strengthening the supply base for offshore energy production at sea \(narrative 8\)](#).

Impact on ship type / size / number

- Various types of ships including specialized installation vessels and vessels specially designed for transport of windmills. Later possibly also vessels for transport of floating solar energy devices and offshore fish farms. Terminals may further be used for decommissioning of offshore installation units. Relatively few calls but substantial added value at the terminal;
- Wind energy development market presumably expands for another 2 to 3 decades; Solar possibly for another one or two decades, starting somewhat later e.g. from 2030 onwards; offshore fish farm development could e.g. also start from e.g. 2030/2040 onwards. Offshore decommissioning also expected to become substantial from about 2030/40 onwards;
- Note: above estimates with respect to likely timing are based on a rough intuitive understanding of momentum of trends.

Considerations for infrastructure development

- Impact on infra loads / demand / alternative use
 - Supply base terminals need to be flexible in design. Loads vary from large voluminous cargoes like the blades and tower of a windmill, to heavy but relatively small items like windmill rotors, to very heavy superstructures of dismantled oil rigs. Important is to make sure that the quay is designed for both vertical and horizontal loading of units (lifting and rolling). It should also be designed to support both mobile cranes and floating cranes;
 - Terminal should ideally be designed for processes supporting simultaneous use of quay by seagoing and inland vessels. This holds both for outbound cargoes (e.g. windmill construction components) and for inbound cargoes (e.g. components of disassembled offshore units).
- Impact on cargo handling and storage requirements
 - Terminal should be designed to provide sufficient space for various types of voluminous cargo such as wind mills, solar panels, and fish farm structures;
 - Terminal should be developed such that it enables efficient assembling and disassembling activities.

#9 Opportunity to increase short sea container transport

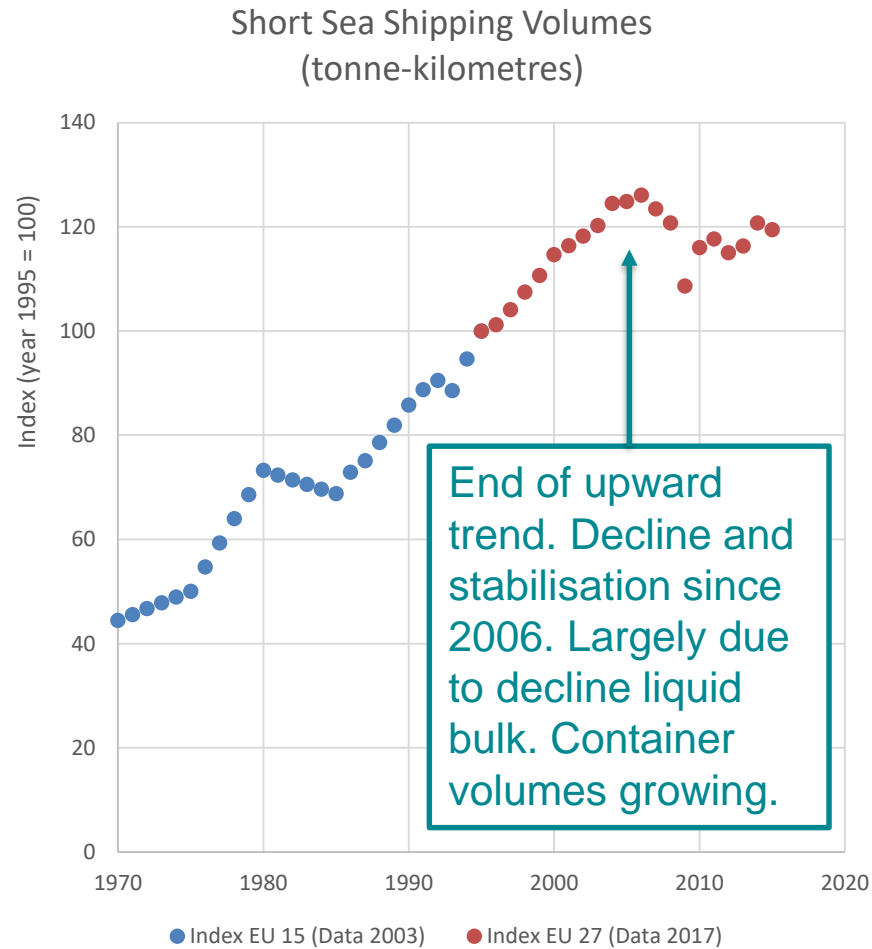
- Short sea shipping showed a significant increase between 1970 to 2006, followed by a fall-back, and thereafter a flat recovery.
- Main reasons for decline of short sea shipping volume is a decline, in particular, of liquid bulk transport. Short sea container transport is still growing.
- European Union aims at shift of 30% of all unimodal road transport over 300 km to intermodal transport by 2030 and 50% by 2050.
- This ambition is supported by the EU climate objective to reduce overall carbon emissions by 40% in 2030 and by 80% in the year 2050.
- Continental cargo usually shipped in continental pallet wide, high cube and 45 foot containers.
- The benefit of this container is that it has similar inner dimensions (and cargo volume) as a standard truck trailer.
- Expected stagnation in deepsea container volumes creates space for short sea shipping. This offers an opportunity to improve the Market share for short sea container shipping.



45 foot

Continental
loading unit

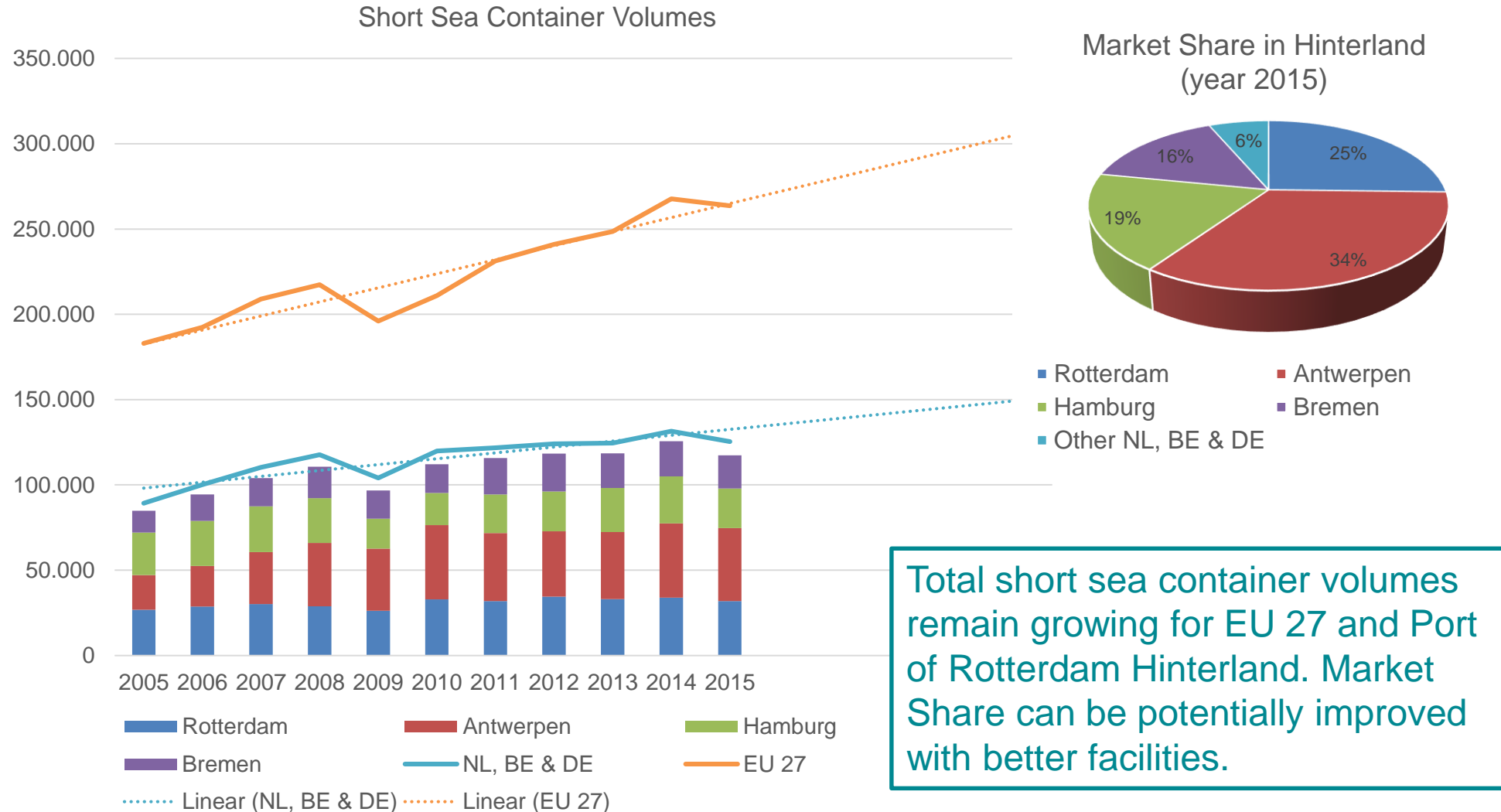
Figure 7.35: Stagnation in Short Sea Shipping since 2006



Source: European Commission (2003) EU energy in Figures; European Union (2017) EU Transport in Figures – Statistical Pocketbook 2017. <https://ec.europa.eu/transport/sites/transport/files/pocketbook2017.pdf>

Source: Eurostat data (retrieved November 2017) Maritime transport – short sea shipping – main annual results.

Figure 7.36: Ongoing growth in short sea container volumes



Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to the expected opportunity for [increasing short sea container transport \(narrative 9\)](#).

- Impact on ship type / size / number
 - Increased number of short sea connections results in more frequent calls of relatively small short sea container and possibly also ferry vessels;
 - Possibly a slight increase in the size of the short sea vessels as a result of larger cargo flows. However, since increase in volumes will provide a strong incentive for improving the network size (i.e. more frequent calls and more direct destinations served), focus may not be on increasing the ship size
- Impact on infra loads / demand / alternative use
 - Intensified use of short sea facilities;
 - Short sea containers have a relatively light weight per TEU (due to larger size of common used 45 foot containers), which could mean extended lifetime of existing storage yards at former deepsea terminals in city.
- Impact on cargo handling and storage requirements
 - Short sea cargo has relatively high share of road pre- and end haulage. Short sea development thus requires sufficient capacity of access roads.

#10 Dedicated barge facilities at deepsea container terminals

- With deepsea container growth expected to slow down space may be available for dedicated inland barge terminals next to the deepsea terminals. This could give a boost to deepsea container volumes by increasing the market share.
- The long term trend in the development of transport costs indicates that there is little margin to reduce the costs of international sea freight further. Focus is now on reduction of costs for hinterland transportation.
- Rotterdam and Antwerp have a competitive advantage over other ports in the Hamburg – Le-Havre range due to excellent inland waterway connections.
- Inland waterway transport is cost competitive for hinterland transport, but has issues with reliability and lead time due to unavailability of sufficient quay capacity and lack of priority for inland ships at deepsea terminals. (Inland ships have to wait for deepsea ships). Inland shipping now frequently encounters severe congestion and long waiting times, thereby losing market share to road and rail cargo.
- The development of dedicated inland barge terminals at the deepsea terminals can increase the port's market share for deepsea containers, in particular due to the creation of more reliable hinterland connections.
- Note: if the targeted 45% of containers are shipped to the hinterland by IWT, this would relate to 31% of all container moves at the terminals. For such volumes it seems logical to develop dedicated inland barge facilities.

Figure 7.37: IWT faces severe terminal congestion


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Barge operators and shipping lines apply Rotterdam and Antwerp congestion surcharges


CONTAINER SUPPLY CHAIN CONFERENCE at TOC AFRICA

5-6 December 2017

Durban ICC South Africa

Conference, Exhibition & Networking event

Find out more



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By Alexander Whiteman 17/07/2017

Delays of up to 120 hours have led European barge operator Contargo to impose a congestion surcharge on all operations at the ports of Antwerp and Rotterdam.

The €19.50 per container charge came into effect on Friday and will be levied until 31 August, amid a worsening situation for loading and unloading throughput times at North Europe's major import hubs.

"For weeks now the barges of Contargo's fleet have had to wait increasingly long for unloading and loading," said the operator.

"Throughput times of 50 hours, peaking at up to 120 hours, are no longer an exception and, unfortunately, we must now pass on a part of the costs to our customers."

Contargo said the surcharge applied irrespective of the navigational area of the Rhine for all loads and terminals.

"If the situation has not substantially improved, we shall also have to extend the surcharge beyond 31 August 2017," it added.



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Rotterdam and Antwerp ports tackle congestion, but it's 'too little, too late'


CONTAINER SUPPLY CHAIN CONFERENCE at TOC AFRICA

5-6 December 2017

Durban ICC South Africa

Conference, Exhibition & Networking event

Find out more



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By Mike Wackelt 12/09/2017

Barge companies using the Benelux container ports of Antwerp and Rotterdam believe congestion there will get worse before it gets better, as North Europe's two biggest hubs prepare to receive ultra-large ships brimming with peak season goods.

One senior manager of a Duisburg-headquartered barge operator told *The Loadstar* today that recent initiatives by the Antwerp and Rotterdam port authorities had been "too little, too late".

He said: "We have been suffering with severe congestion all through the summer, and now in the last weeks of the peak season they decide to try and help us."

Privately, the ports blame the massive influx of ultra-large container vessels by ocean carriers and their "cavalier regard" to schedules.

However, last week the port of Antwerp commenced a series of four weekly workshops, which the authority said was aimed at "optimising" barge handling at the port.

President of the Belgium Shippers Council Lennart Hiep told *The Loadstar* last week it would be participating in the workshops, but was not optimistic for a quick solution.



MOST POPURECENT COM



Figure 7.38: Suggestions for creating adequate IWT capacity



Source: Google Earth (retrieved 2017); <http://imgw.rgcdn.nl/9d4ebee0a77e4a6ab7e2e40d7678e55a/opener/2905935.jpg> (picture left); http://logistiek.nl.s3-eu-central-1.amazonaws.com/app/uploads/2016/03/brabant_overslag.jpg (picture right)

Considerations for infrastructure development

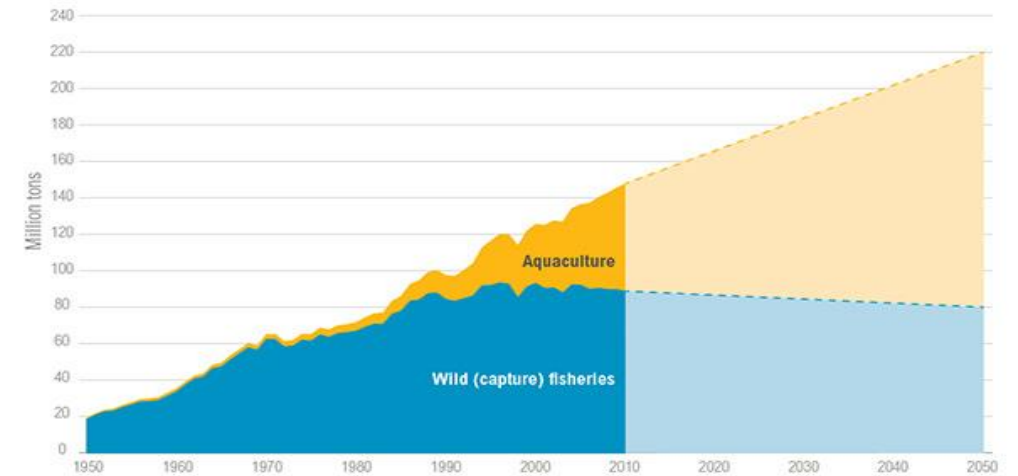
This section examines the possible implications for port infrastructure development due to the expected opportunity for **developing dedicated barge facilities at deepsea container terminals (narrative 10)**.

- Impact on ship type / size / number
 - Increased number of inland vessels together with a potentially reduced number of inland barge movements within the port as a result of improved and more reliable planning of inland barges at the deepsea terminals;
 - Potential increase in size of inland barges due to reduced time spent in the port making larger barges more cost effective. Size can go up to 135 x 22.8 meter;
 - Increased number of deepsea container volumes as a result of an increased overall market share within the Hamburg – le Havre region.
- Impact on infra loads / demand / alternative use
 - Little change in infra loads, but potential to reduce water depth requirements at quay to 5.0 meters for inland barges. Suits well at the end of port basin.
- Impact on cargo handing and storage requirements
 - Requires changes in internal terminal processes including possibly longer transport distances from the stack to the barge handling facility.

#11 Develop aquaculture and fish farming activities

- The global fish stock is insufficient to feed the growing world population.
- Peak fish from wild catch occurred around the mid 1990s after which catch volumes have started to decline.
- Over past two decades a major shift to aquaculture and fish farming occurred.
- Aquaculture is widespread in Asia, and Europe is likely to follow.
- Aquaculture and fish farming provide opportunities for new business both on land and in the North sea.
- Offshore farming could generate additional activities for offshore supply bases at the second Maasvlakte.
- Offshore farming could provide an opportunity to develop fish terminals and cold store warehousing.
- Aquaculture may also increase short- and deepsea container shipping.

Aquaculture Is Expanding to Meet World Fish Demand



Source: Historical data 1950–2010: FAO, 2014. "FishStatJ." Rome: FAO. Projections 2011–2050: Calculated at WRI, assumes 10 percent reduction in wild fish catch between 2010 and 2050, and linear growth of aquaculture production at an additional 2 million tons per year between 2010 and 2050.

See www.wri.org/publication/improving-aquaculture for full paper.

WORLD RESOURCES INSTITUTE

http://www.wri.org/sites/default/files/uploads/wrr5_figure10_web.jpg



<http://www.gettyimages.nl/detail/nieuwsfoto's/rotterdam-netherlands-to-go-with-afp-story-lifestyle-nieuwsfotos/75278752?#rotterdam-netherlands-to-go-with-afp-story-by-alix-rijckaert-two-picture-id75278752>

Figure 7.39: Kingfish fish farm at Eastern Scheldt opened in 2017



Figure 7.40: Plans for farming of seaweed in the North Sea

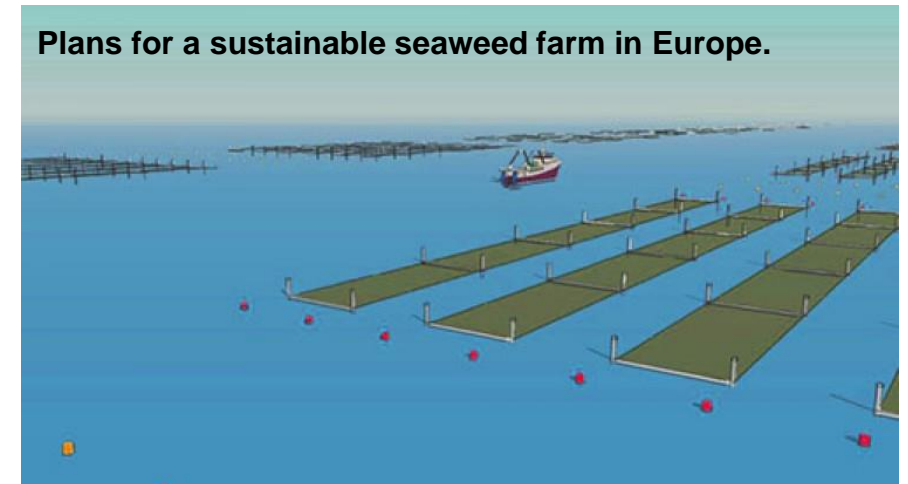
Towards a European seaweed industry

Seaweed forms the basis for a promising blue-green economy; local, sustainable, healthy and new opportunity for the European economy. It offers an extraordinary offshore and onshore opportunity and is applicable to a wide variety of categories such as tasty food, renewable resources and important ecosystem services.

The North Sea Farm Foundation is a non-profit organisation aimed at realising a sustainable seaweed industry in the Netherlands and surrounding EU countries. The growing global population and synchronic demand for food challenges us to transit from animal proteins to plant based proteins and to change where we source our food. The urgency for this transition has caused a trend with a growing number of consumers that wishes to eat healthy and sustainably. Seaweed fits perfectly in this new demand as it does not require farmland, fresh water or fertilizer. It also takes up nutrients that would otherwise disappear into the oceans which makes it an important link in developing a circular economy. Seaweed converts the greenhouse gas CO₂ into biomass and oxygen which helps counteract oceanic acidification and climate change. The seaweed farms also create excellent shelters and nurseries for juvenile fish, shellfish and crustaceans. Moreover, seaweed farms can be engineered to share space with wind farms, fisheries and shellfish cultivation. Cultivation of seaweed is feasible in salty marshes, near coastal areas and offshore areas. The seaweed industry has the potential to become a new blue-green economy and Europe has an excellent position to become a high-tech frontrunner.



<http://www.globalmaritime.com/erko-seafood-and-global-maritime-develop-north-sea-fishfarm-concept>



Plans for a sustainable seaweed farm in Europe.

<https://i.pinimg.com/originals/26/b5/1e/26b51e33e12caac306ee07540a5cbc79.jpg>



A diver inspects seaweed growing at test site near Galway, Ireland.

http://europa.eu/rapid/press-release_IP-14-962_en.htm

Figure 7.41: Plans for salmon farming in the North sea

By MARK PRIGG

PUBLISHED: 19:57 GMT, 6 March 2014 | UPDATED: 10:20 GMT, 7 March 2014

12

[View comments](#)

It may at first glance look like an oil rig, but according to a Norwegian firm, this giant structure is the future of fish farming.

Each of the 5,600 tonne, 670-metre-high steel rigs can house eight times as many salmon as conventional cages.

They have a 245 square metre pen for the salmon, space in the offices above for 600 tonnes of feed, and accommodation for up to four people - although they can be operated remotely.



Each of the 5,600 tonne, 670-metre-high steel rigs can house eight times as many salmon as conventional cages, and the design is based on oil rigs

<http://www.dailymail.co.uk/sciencetech/article-2575030/The-automated-fish-rigs-farm-Salmon-North-Sea.html>

Press Releases



Erko Seafood and Global Maritime Develop "North Sea Fishfarm" Concept

Stavanger & Bergen, Norway; May 19 2017: Erko Seafood AS, a leading producer of high quality salmon and trout, and Global Maritime AS, a leading provider of engineering services to the offshore sector and an innovator in offshore fish farming, have developed a new concept for offshore salmon farming, called the «NORTH SEA FISH FARM». The concept plans to use a stationary base which will act as a fish farming platform and which will be located in the open sea.

<http://www.globalmaritime.com/erko-seafood-and-global-maritime-develop-north-sea-fishfarm-concept>

Figure 7.42: Fish farming at decommissioned offshore platforms

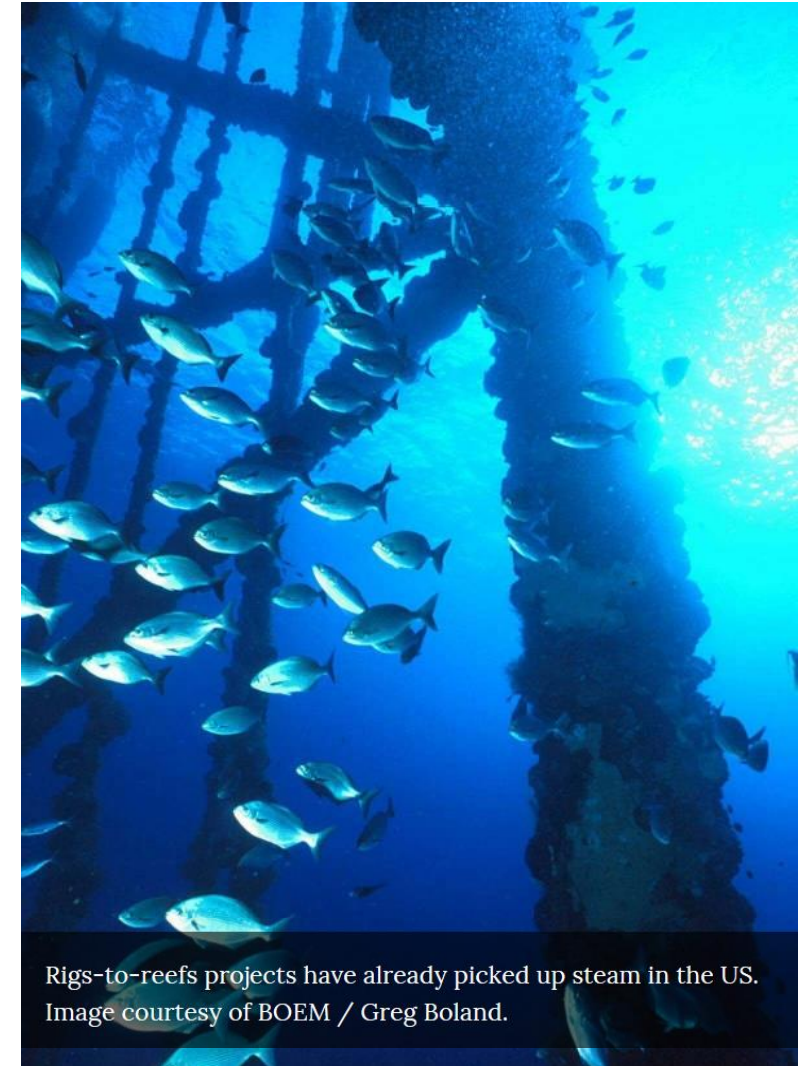
17 JUNE 2014 ANALYSIS

From offshore oil to deep-sea fish farming

By Chris Lo

SHARE

With decommissioning costs a major concern for the oil and gas industry, new ideas for converting old platforms have begun to emerge. Dr. Ulugbek Azimov of Northumbria University discusses his research into using old oil platforms as self-sustaining hubs for deep-sea fishing, an idea that could make both financial and environmental sense.



Rigs-to-reefs projects have already picked up steam in the US.
Image courtesy of BOEM / Greg Boland.

<http://www.offshore-technology.com/features/featurefrom-offshore-oil-to-deep-sea-fish-farming-4293827/>

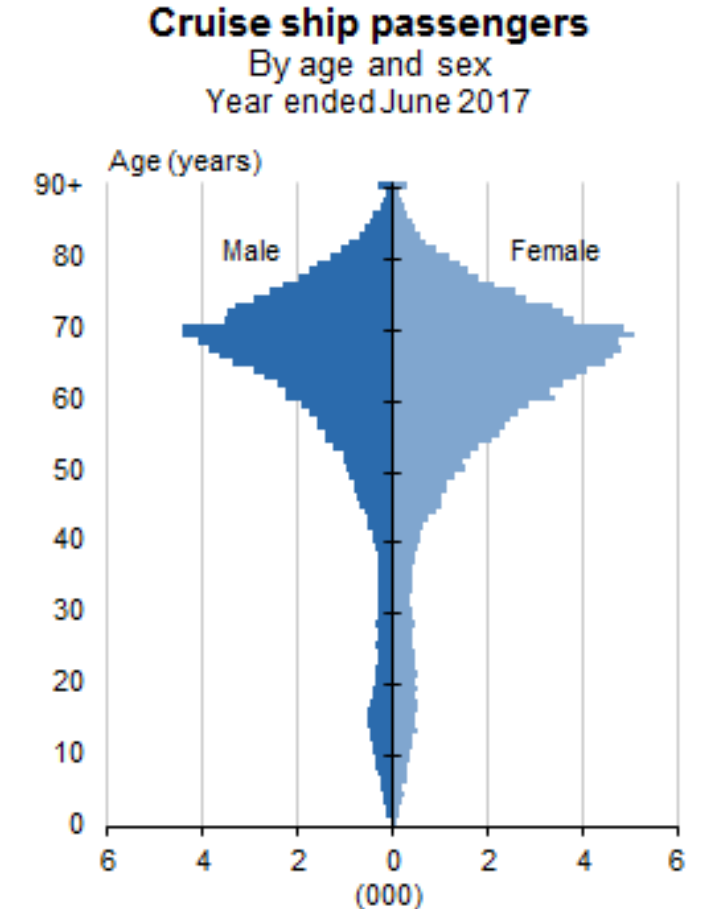
Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to the expected opportunity for [developing aquaculture and fish farming activities](#) (narrative 11).

- Impact on ship type / size / no
 - Apart from installation and maintenance of offshore fish farms (see section on offshore supply basis), there may be a demand for fish landing in combination with stuffing of refer containers to be shipped by IWT, shortsea and deepsea;
 - Where it concerns fish imported for an auction, other ports may be more logical, such as Flushing, Scheveningen, Stellendam and Ijmuiden.
- Impact on infra loads / demand / alternative use
 - Requires water bound unloading and cross docking facilities for receipt of fish and supply to container terminals;
 - Relatively small draught of fishing vessels as well as relatively small loads imply that lifetime of existing quays may be extended if used for this purpose.
- Impact on cargo handing and storage requirements
 - Requires refrigerated storage and cross docking facilities next to the quay.

#12 Expansion of cruise market for maritime and inland shipping

- The change in demographics and the rising inequality will drive the boom in cruise market for at least another 10 to 20 years. There will be a gradual shift of passengers from North America to Asia.
- Geopolitical unrests could further boost the European cruise market, since the majority of Europe is relatively safe and stable compared to potential conflict areas such as e.g. the South China Sea.
- Statistics over the age of passengers in New-Zealand (likely to be indicative for other regions as well) shows that the majority of the cruising population is about 70 years old. The aging population in North-America, Europe, and Asia thus provides business opportunities.

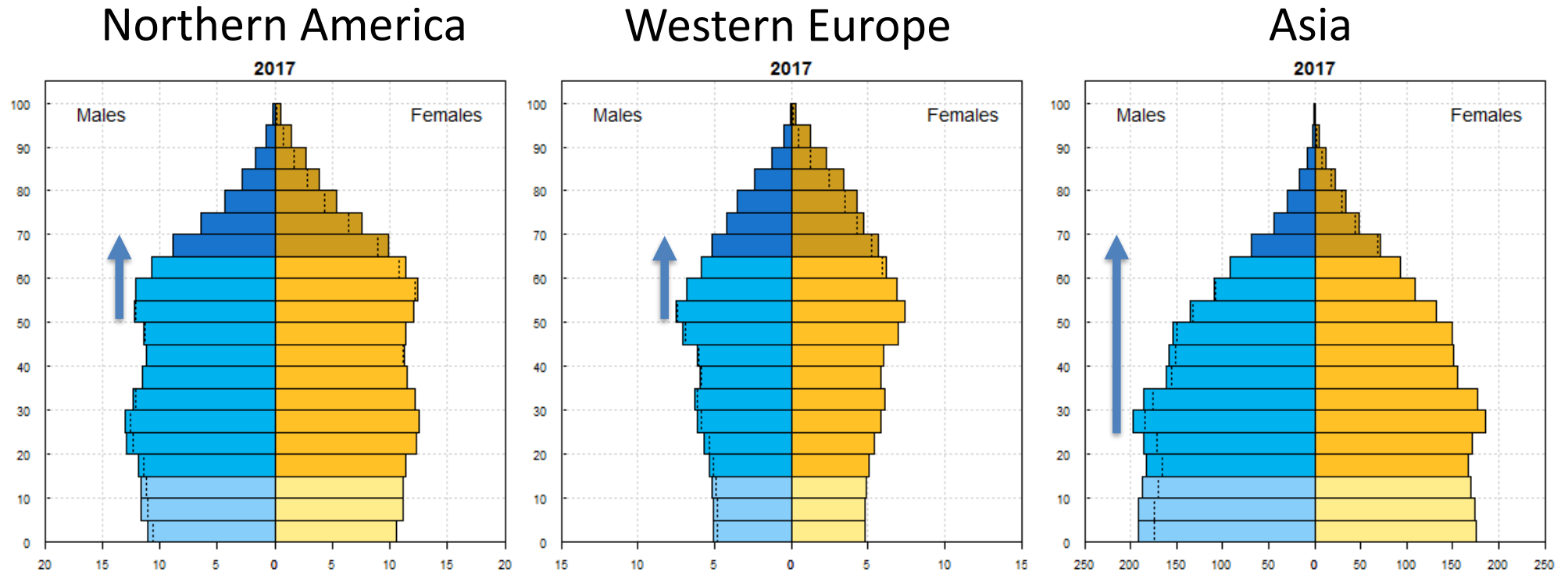


Source: Stats NZ

Note: Data for New-Zealand
http://www.stats.govt.nz/browse_for_stats/industry_sectors/Tourism/cruise-ship-stats.aspx

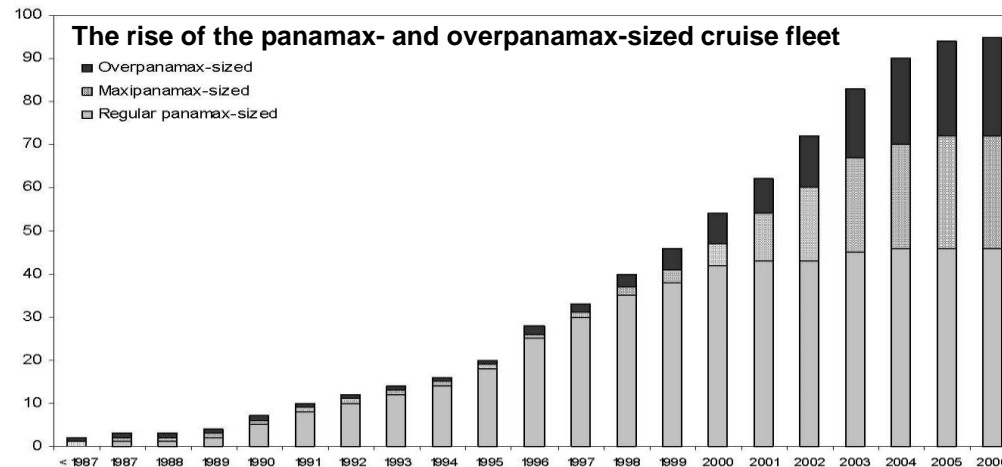
Figure 7.43: Demographic drivers of increasing cruise volume

- Age of cruise passengers is around 70 years. An increase in number of passengers from North America and Western Europe can be expected over next 10 to 20 years driven by changing demographics. For the much larger Asian market, this increase will continue for another 45 years.

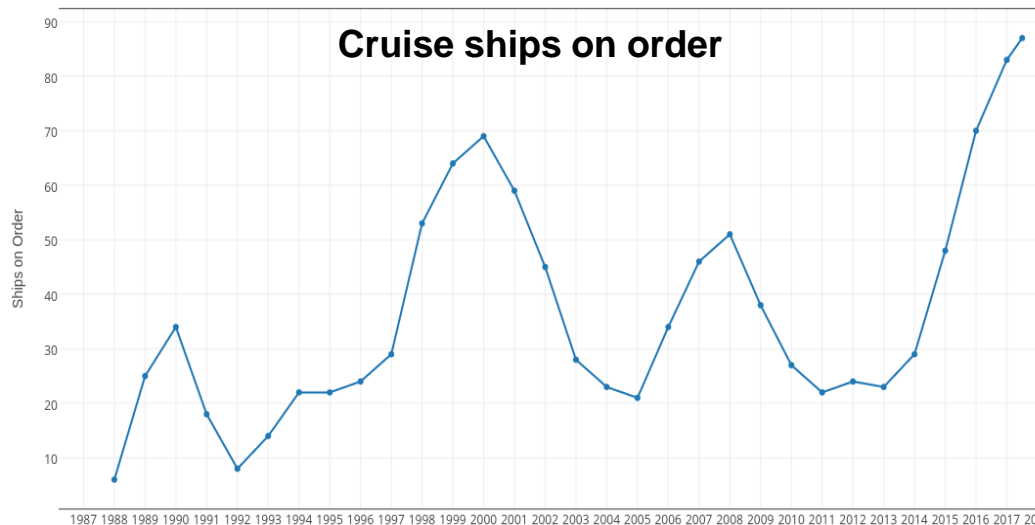


Population pyramids for year 2017 retrieved from UN World Populations Prospects 2017, y-axis shows age, x-axis shows population in millions.
<https://esa.un.org/unpd/wpp/Graphs/DemographicProfiles/>

Figure 7.44: Increasing size and number of cruise ships

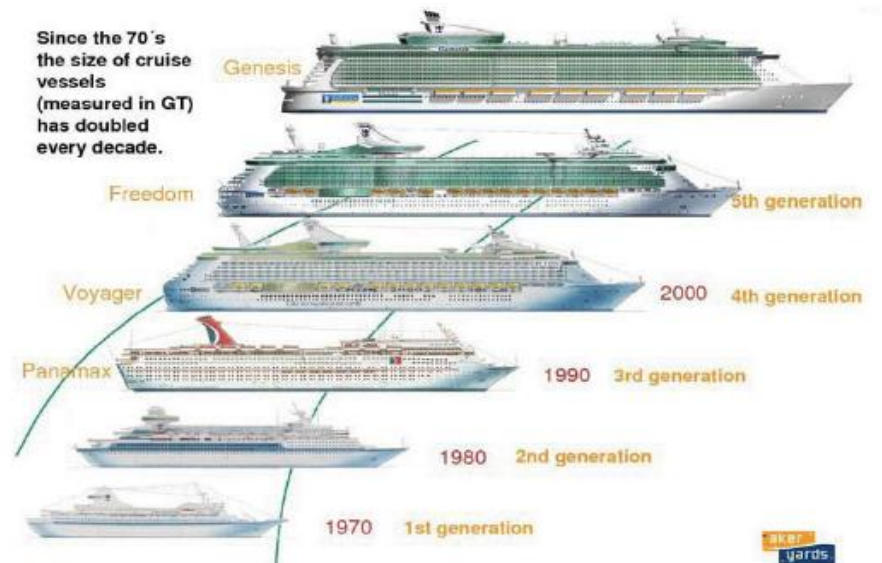


<https://belgeo.revues.org/docannexe/image/13517/img-11.jpg>



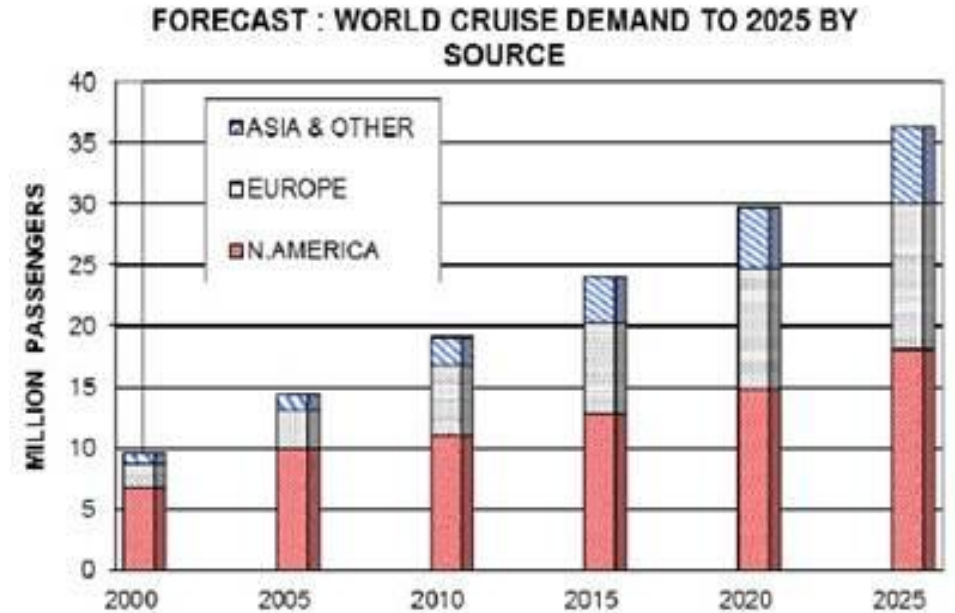
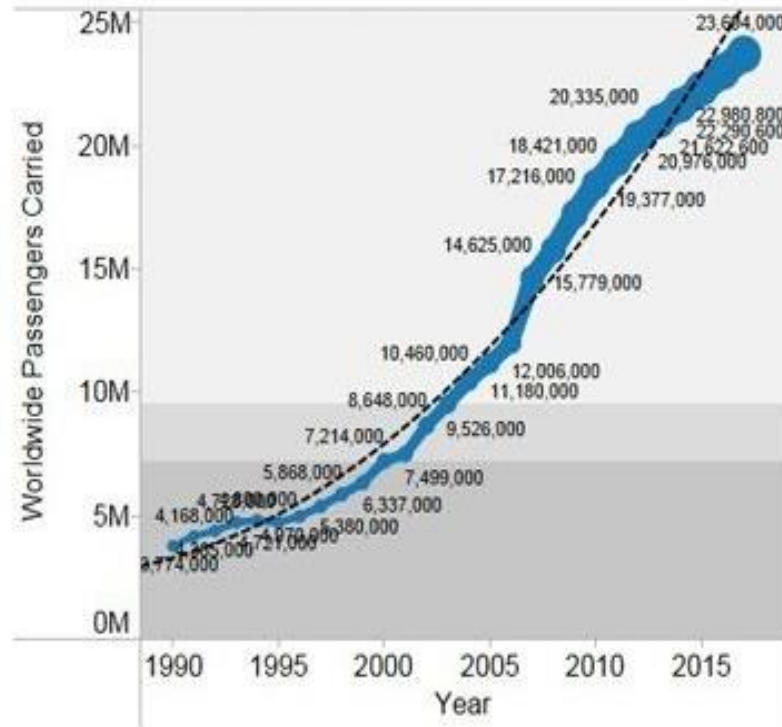
https://www.cruiseindustrynews.com/images/stories/wire/2017/july/Plot_2.png

Substantial increase in size and number of cruise ships. At present also a newbuilding peak. Fleet reached about 300 vessels by end of 2015
 (http://www.cruisemarketwatch.com/capacity/)



https://www.researchgate.net/publication/259693087_GOALDS_-_Goal_Based_Damage_Stability_for_Passenger_Ships/figures?lo=1

Figure 7.45: Increasing global and European passenger volumes



Source: Ocean shipping consultants (2013)
<https://www.marinelink.com/news/prospects-outlines357897>

Year	North America	Europe	Other	Worldwide Passengers Carried
2013	12,690,500	5,663,500	2,622,000	20,976,000
2014	13,007,800	5,861,700	2,753,100	21,622,600
2015	13,332,900	6,066,900	2,890,800	22,290,600
2016	13,666,300	6,279,300	3,035,300	22,980,800
2017	14,007,900	6,499,000	3,187,100	23,694,000

<http://www.repositioncruises.com/cruise-industry/>

Strong growth of cruise market, not only in North America, but especially also in Europe and Asia.

Figure 7.46: Cruise market growth on inland waterways

Europese riviercruisevaart weet groei - ondanks langdurig laagwater - vast te houden Meer dan 1,3 miljoen passagiers in 2015

In 2015 is de vraag naar riviercruises in Europa naar nieuwe recordhoogte gegroeid. 423.635 Duitsers maakten een cruise. Dat was 1,9% meer dan het jaar ervoor. Nog sterker was de groei vanuit Noord-Amerika, waardoor het totaal aantal passagiers in de Europese cruisevaart naar 1.330.000 groeide. Dat was ruim 20% meer dan in 2014.

De cijfers komen uit een studie van IG RiverCruise (de vereniging van Europese riviercruiserebedrijven), en het Duitse Reisverbond DRV. Een riviercruise kostte vorig jaar gemiddeld 1.027 euro. De gemiddelde reisduur was 7,18 dagen.

De groei had nog hoger kunnen uitvallen, als het extreme en langdurige laagwater op de Rijn en de Donau geen roet in het eten had gegoooid, zo schrijven IG RiverCruise en DRV. Daardoor moesten touroperators geplande flink wat cruises annuleren of vervangende vaarkanties aanbieden.

De Donau en de Rijn blijven de favoriete vaargebieden. Onder Duitsers versloeg de Rijn voor het eerst de Donau in populariteit (38,2 om 38,0%).

VS en Canada

In de Verenigde Staten en Canada groeit de interesse voor een cruise over de Europese binnenwateren



(foto Fotolyse/Fotolla)

jaar na jaar. Vorig jaar nam het aantal cruisevaarders uit die landen met maar liefst 42,9% toe. Het aandeel Noord-Amerikaanse gasten is inmiddels groter dan het Duitse.

De blijvend groeiende vraag naar riviercruises vanuit de VS en Canada weerspiegelt zich volgens IG RiverCruise en DRV in de nieuwe schepen die jaarlijks in de vaart

komen. Meer dan de helft van de nieuwbouw in 2015 - goed voor een gezamenlijke bedden capaciteit van 3.160 - werd voor Noord-Amerikaanse touroperators en rederijen gebouwd.

In totaal werden vorig seizoen 27 nieuwe riviercruiseschepen opgeleverd. De investering die daarmee gemoeid was, was ongeveer 585 miljoenen euro.

Op de riviercruiseschepen werken 13.097 mensen. De Europese riviercruisesector levert op de wal verder nog 3.514 mensen werk, die in dienst zijn bij de rederijen. Daarnaast zijn er nog circa 11.000 indirecte banen afhankelijk van de sector: bij toeleveranciers, havens, aanbieders van excursies enzovoort.

Voor jong en oud

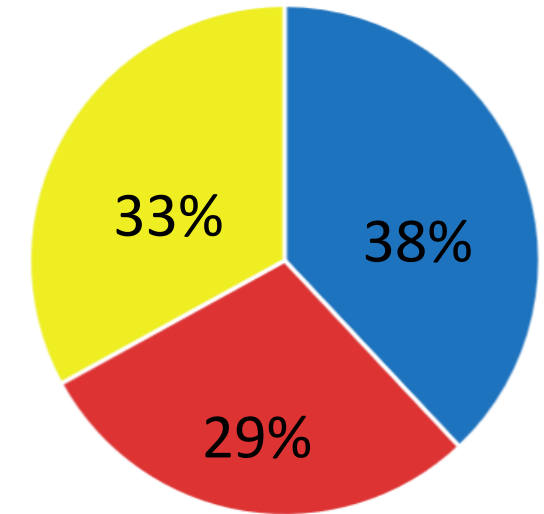
DOOR NOUD VAN DER ZEE

Op een riviercruise zit je als vakantiegevoel op de eerste rang. Varend over een rivier zie je de wereld aan je voorbij glijden: pittoreske dorpjes, prachtige landschappen en - soms - wereldsteden. Het mooie van een riviercruise is het gemoedelijke karakter. Binnen en buiten Nederland bestaat een groeiende belangstelling voor riviercruises. Het oubollige imago is inmiddels wel afgeworpen. De gemiddelde leeftijd van de passagiers is weliswaar nog rond de 50 jaar, maar binnen het aanbod van rederijen en touroperators zijn steeds meer nieuwe mogelijkheden.

Rijn en Moezel zijn ingesteld op gezelligheid; populair bij ouderen, maar minder bij jongeren. Een riviercruise over de Donau, door Duitsland en Oostenrijk, maar ook Slowakije en Hongarije met hun geheel eigen sfeer, spreekt een jonger publiek wel aan.

Split of Passengers by nationality (%) - 2015

Source : IG River Cruise / German Travel Association (DRV)



- US Americans & Canadians
- Germans
- French, British, Swiss

<http://www.inland-navigation-market.org/en/rapports/2017/q2/8-passenger-transport/>

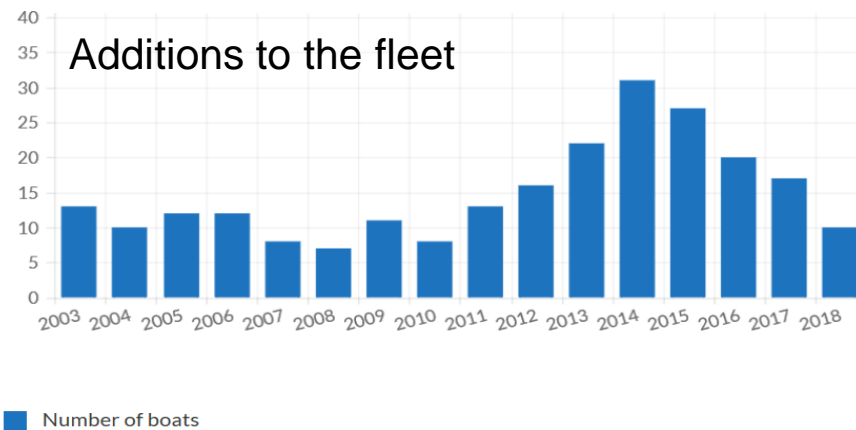
http://www.binnenvaartkrant.nl/wp-content/uploads/2016/03/krant_201607-thema.pdf

Figure 7.47: River cruise market stabilises after strong growth

- Increase in river cruise capacity seems to have stabilized.
- Cause of stabilisation may be market saturation or an increase in vessel costs and lack of trained staff available for these vessels.

New River Cruise vessels for the European market (2003-2018)*

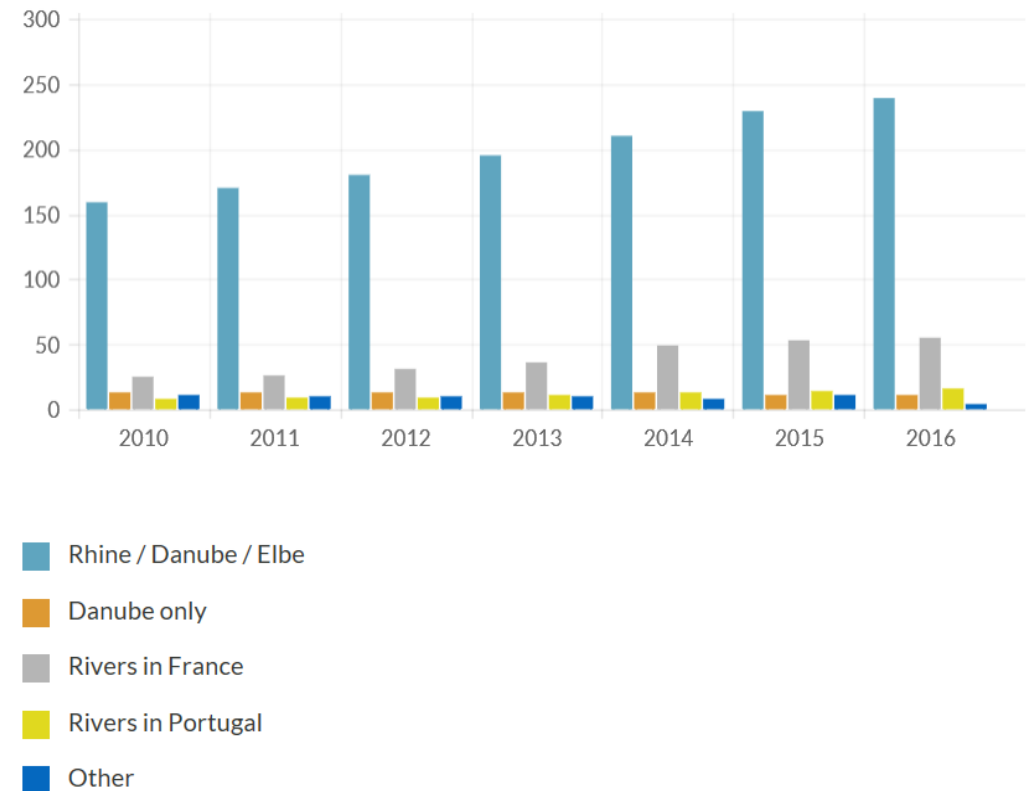
Source : Hader & Hader 2016 * values for 2017 and 2018 : forecast based on order books



Source of both figures: <http://www.inland-navigation-market.org/en/rapports/2017/q2/8-passenger-transport/>

Number of river cruise vessels in Europe by region of operation (2010 – 2016)

Source : CCNR



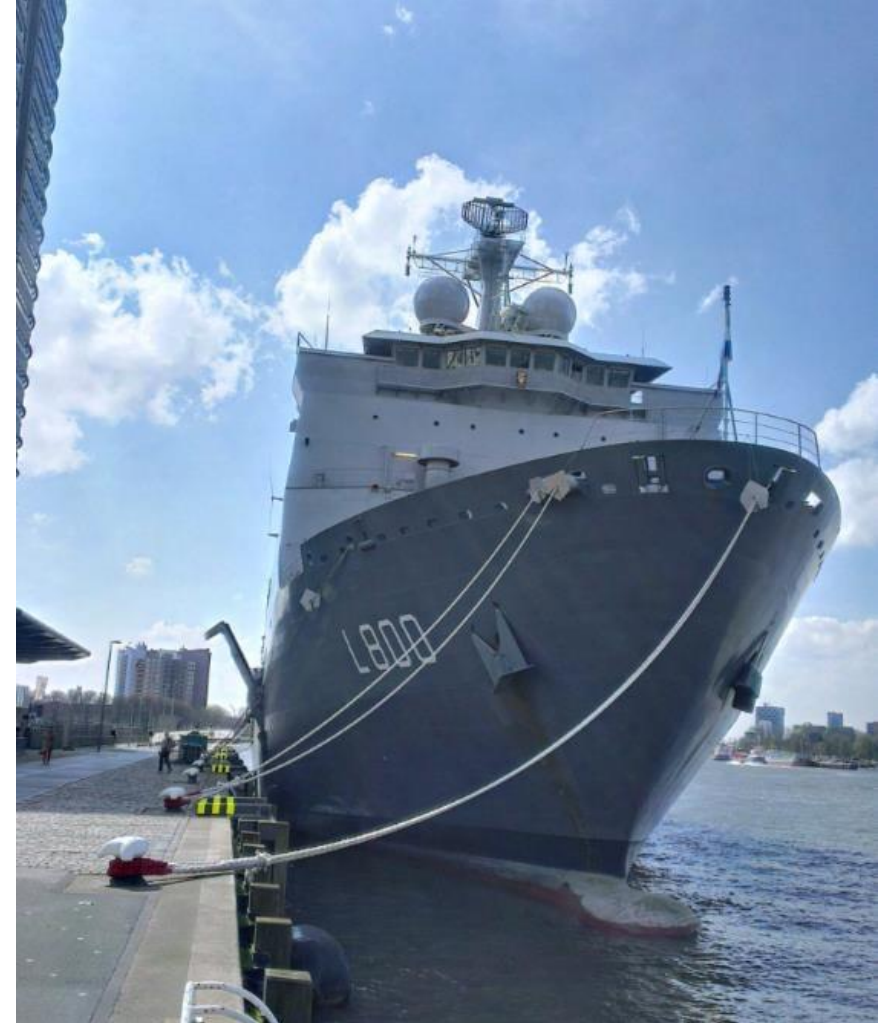
Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to the expected opportunity for [expanding the cruise market for maritime and inland shipping \(narrative 12\)](#).

- Impact on ship type / size / number
 - Increased number of large deepsea cruise vessels;
 - Increased number of 110 to 135 meter long Rhine cruise barges.
- Impact on infra loads / demand / alternative use
 - Seagoing cruises require major terminal facilities at an appealing location;
 - Inland cruise barges offer an interesting opportunity for urban development around Merwehaven & Vlaardingen. The advantage at Merwehaven is that reduced depth requirement at quays may extend the useful lifetime of quays.
- Impact on cargo handing and storage requirements
 - Seagoing cruises require supporting landside activities, such as utility services and busses for transport of passengers to major Dutch attractions that are often located North of Rotterdam (e.g. Keukenhof);
 - Inland cruises create demand for local activities, such as e.g. excursions to Schiedam's wind mills or KETEL 1 distillery, or a local lunch.

#13 Increased navy presence to counter increased threats

- The changing geopolitical environment emphasizes the need to rebuild Europe's military strength including the Dutch navy.
- Due to increased geopolitical tension, it may be desirable to spread the fleet over several ports in order to prevent a 'Pearl Harbour attack'.
- After Den Helder, Flushing (in Dutch Vlissingen) is a logical second port, but it may also be strategic to station a part of the Dutch and/or NATO fleet in Rotterdam as well.
- It may, in combination with other measures, also be necessary to increase navy presence in the Port of Rotterdam to protect the area from possible terroristic activities.



<http://navaltoday.com/2016/04/13/gallery-port-protection-drill-in-rotterdam/>

Figure 7.48: Royal Dutch navy plans for replacement of vessels

The Netherlands and Belgium jointly purchase 16 new navy vessels

Door: [Jaime Karremann](#)

Bericht geplaatst: 14-11-2016 | Laatst aangepast: 14-11-2016

Nederland en België gaan samen vier fregatten en twaalf mijnenjagers kopen. Dat melden Belgische media vanochtend. Met de aankoop zou in totaal 4 miljard euro gemoeid zijn.



Een vroege artist impression van de toekomstige Belgisch-Nederlandse fregatten. (Beeld: DMO, bewerking: Jaime Karremann/ Marineschepen.nl)

<https://marineschepen.nl/nieuws/Nederland-en-Belgie-kopen-samen-16-nieuwe-marineschepen-141116.html>

Dutch Minister of Defense seeks to replace submarines by 2025

Posted on 2014-11-04 by [mrkoot](#)

UPDATE 2017-06-17: updates moved to *bottom*.



Dutch S803 Zeeleeuw submarine at SAIL Amsterdam 2005.

Courtesy of Björn Hamels. Source (BY-SA 2.5).

Unchanged.

<https://blog.cyberwar.nl/2014/11/dutch-minister-of-defense-seeks-to-replace-dutch-submarines-by-2025/>

Geopolitical instability, Russian threat over Baltic states and Trump effect on NATO spending demand bigger role of navy in protecting the country and valuable port assets.

Figure 7.49: Navy protection of port against terrorism

English: Navy assesses safety Port of Rotterdam Marine test veiligheid Rotterdamse haven

16 september 2014

Van het afzoeken van de Maashaven met duikrobot REMUS (Remote Environmental Monitoring System) tot het onderzoeken van de romp van een vrachtschip op explosieven. Deze week oefent de Duik- en Demontegroep van de Koninklijke Marine in Rotterdam aan de hand van tal van scenario's op het gebied van havenbeveiliging.

Om de veiligheid in de haven van Rotterdam te testen, houdt de Koninklijke Marine tot en met vrijdag realistische oefeningen. Zo onderzoeken duikers de scheepsromp van het historische stoomschip De Rotterdam en zoekt een onderwaterrobot de bodem van de Rijnhaven af. Dat meldt het ministerie van Defensie.

Bij een verhoogde terroristische dreiging levert de marine speciale pelotons die de havens moeten bewaken. Zo'n duikpeloton kan objecten, zoals een schip of een deel van de haven, beschermen tegen aanvallen door terroristen.

Tijdens de oefeningen wordt het duikpeloton geconfronteerd met allerlei opdrachten in de haven van Rotterdam. De robot REMUS (Remote Environmental Monitoring System) wordt met zijn hoogwaardige sonarapparatuur ingezet om geheel zelfstandig en veel sneller dan duikers de (zee-)bodem in kaart brengen. Het duikpeloton oefent in Rotterdam vanaf het duikvaartuig Zr.Ms. Nautilus, dat met een decompressietank speciaal hiervoor is uitgerust.

<https://www.beveiliging.nl/nieuws/marine-test-veiligheid-rotterdamse-haven>



The Royal Netherlands Navy, Police, Port of Rotterdam authority and other Dutch agencies are taking part in exercise 'Port Defender' in Rotterdam.

Special navy and police forces are practicing harbor protection against major incidents and terror threats.

The two-day exercise started April 12 at the Wilhelminapier where the Dutch Navy landing platform dock ship HNLMs Rotterdam will be docked throughout the exercise.

As part of the exercise, special forces of the Marine Corps and the Special Intervention Service (Dienst Speciale Interventies DSI) freed a ship hijacked by terrorists with explosives on board.

Navy divers and military maritime bomb squad were also put through their paces.

Posted on April 13, 2016 with tags [HNLMs Rotterdam](#), [Port Defender](#), [Royal Netherlands Navy](#).

<http://navaltoday.com/2016/04/13/gallery-port-protection-drill-in-rotterdam/>

Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to the expected opportunity for **increased navy presence to counter increased global threat levels** (narrative 13).

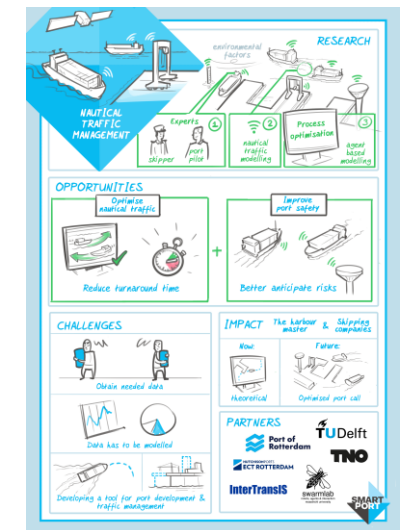
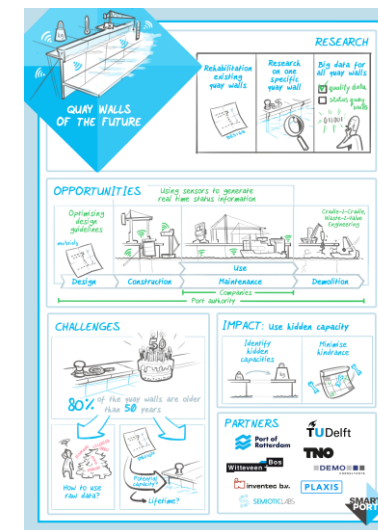
- Impact on ship type / size / number
 - Increased presence of navy vessels, including smaller patrol size vessels to secure entry of Nieuwe Waterweg (possibly in combination with autonomous sailing and use of swarm technology, see also narrative #16).
- Impact on infra loads / demand / alternative use
 - Possible requirement of secure navy areas.
- Impact on cargo handling and storage requirements
 - Use of smaller patrol vessels may require dedicated secure areas with little wave penetration. Larger navy vessels may be located at standard locations such as at the Parkkade or in front of Port Authority building.

7.4 Narratives on enabling technologies

- # 14 Sychromodality as a catalyst for a more efficient hinterland connection.
- # 15 Autonomous shipping changing the maritime environment, which enables the Port of Rotterdam to gain market share if it acts as a first mover.
- # 16 Optimization of port and fairway infrastructure through use of big-data and sensor technology.



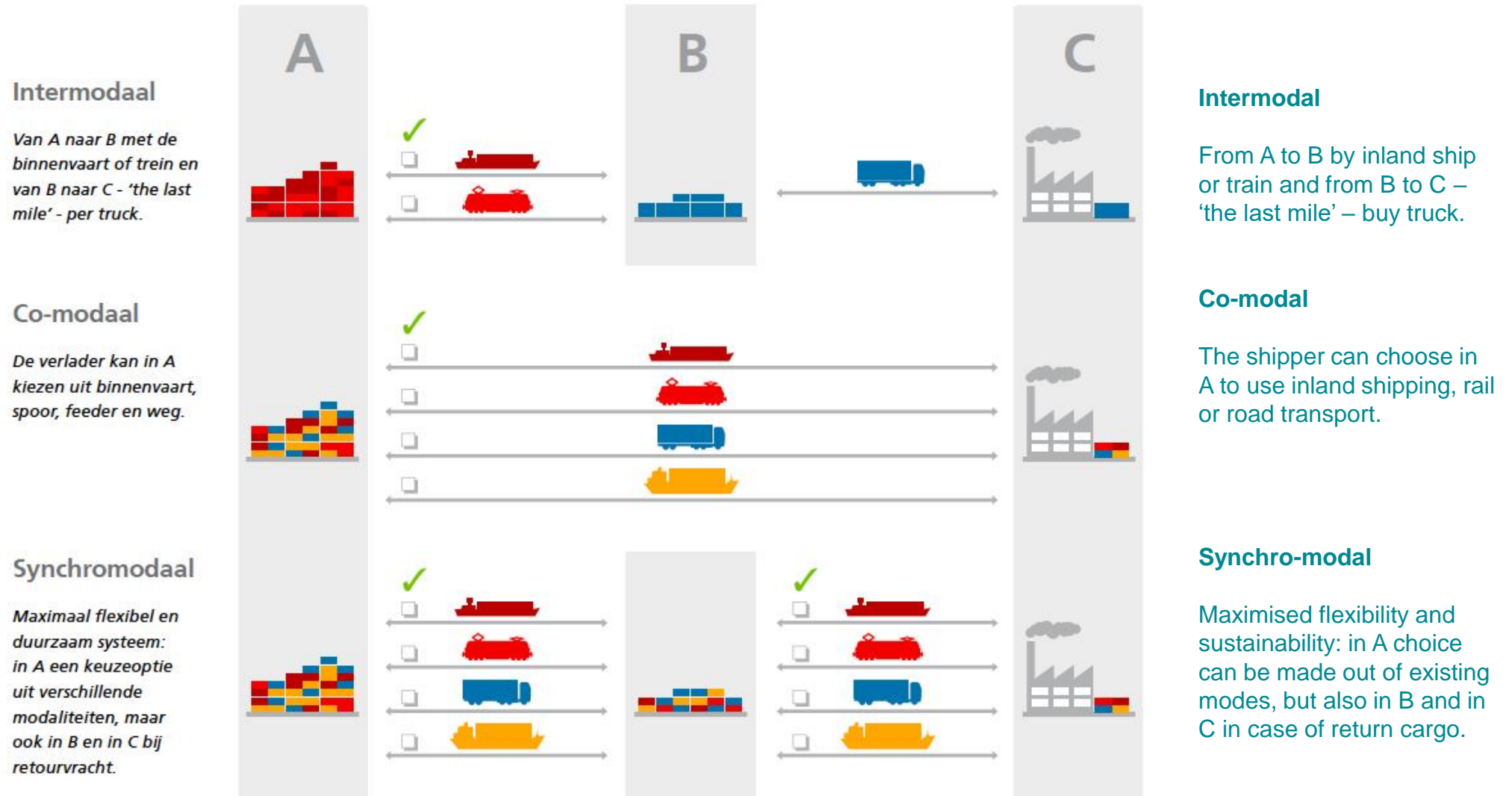
Link to many other SmartPort projects



#14 Develop synchro-modal hinterland connections

- The market share for deepsea containers depends largely on the quality of the hinterland connections. This can be supported by a shift from intermodal, to co-modal and eventually synchro-modal transport.
 - Intermodal: transport of single loading unit by more than one transport means;
 - Co-modality: efficient use of different modes on their own and in combination;
 - Synchro-modal: optimal use of a combination of transport modes based on real time information regarding the available transport capacity.
- Investing in synchro-modality is of particular interest for the ports of Rotterdam and Antwerp, as they have good road and rail connections as well as an excellent IWT network (unlike other ports that lack a good IWT connection).
- Scaling up the concept of A-modal booking (whereby the modes of transport are not determined by the client, but dynamically assigned by the synchro-modal service provider) to include sea transport can further boost the market share of Dutch and Belgium ports (e.g., German cargoes for which Asian shippers assume that it is more logical to ship them via a German port than via Rotterdam).

Figure 7.50: Intermodal, co-modal and synchro-modal



Intermodaal

Van A naar B met de binnenvaart of trein en van B naar C - 'the last mile' - per truck.

Co-modaal

De verlader kan in A kiezen uit binnenvaart, spoor, feeder en weg.

Synchromodaal

Maximaal flexibel en duurzaam systeem: in A een keuzeoptie uit verschillende modaliteiten, maar ook in B en in C bij retourvracht.

Intermodal

From A to B by inland ship or train and from B to C – 'the last mile' – by truck.

Co-modal

The shipper can choose in A to use inland shipping, rail or road transport.

Synchro-modal

Maximised flexibility and sustainability: in A a choice can be made out of existing modes, but also in B and in C in case of return cargo.

Figure 7.51: Synchro-modal service providers in Rotterdam

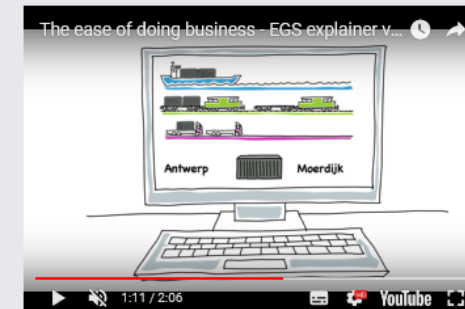


Synchromodal network: reliable & sustainable

CONTROL TOWERS

As a logistics service provider you are always operating to the best of your ability. You save time and money and ease the strain on the environment with measures such as making sure that lorries and vans don't drive around with an insufficient load. Wayz utilizes Control Towers to optimize transport and distribution logic. From the Control Tower, we can take care of the management of the entire chain and improve the application of synchro-modal transport. The shipper books the shipment amodally and leaves the decision of which modalities to use entirely to the independent Control Tower. In this way it becomes possible to switch seamlessly between the various modalities and to respond quickly to unexpected conditions before or during transport.

<http://wayz.nu/coordination/control-towers/?lang=en>



Our view on 'the ease of doing business'

Synchromodal, is optimal

European Gateway Services stands for optimal reliability and security of delivery. We make sure that your container always cost-efficiently reaches its destination right on time. To achieve this, European Gateway Services operates synchro-modally. This approach offers the efficiency and sustainability that logistics requires, both today and tomorrow. Synchro-modal transport is a continuation of intermodal transport, in which the mode(s) of transport and route(s) are consistently selected based on current circumstances and with the customer's required delivery time as a starting point. EGS always selects the optimal transport combination for you, carefully weighing all variables - available modes of transport, occupancy rates, routes, transit times, possible disruptions. If necessary, the modality is even changed while the cargo is already en route. Synchro-modal transport ultimately yields a reliable service provision at competitive costs in which optimum use is made of modes of transport and infrastructure whilst drastically reducing CO₂ emissions.

<http://www.europeangatewayservices.com/en/#view=home>

Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to the expected opportunity for [developing synchro-modal hinterland connections](#) (narrative 14).

- Impact on ship type / size / number
 - Possible increase in number of inland barges and inland container trains.
- Impact on infra loads / demand / alternative use
 - Possible increased utilisation of barge and rail handling facilities.
- Impact on cargo handling and storage requirements
 - Possible increase in overall container handling at deepsea terminals due to increased market share for containers in Hamburg – le Havre region;
 - Possible decrease in required area for container storage at deepsea terminal due to use of floating stock and reduction of dwell time at the terminal.

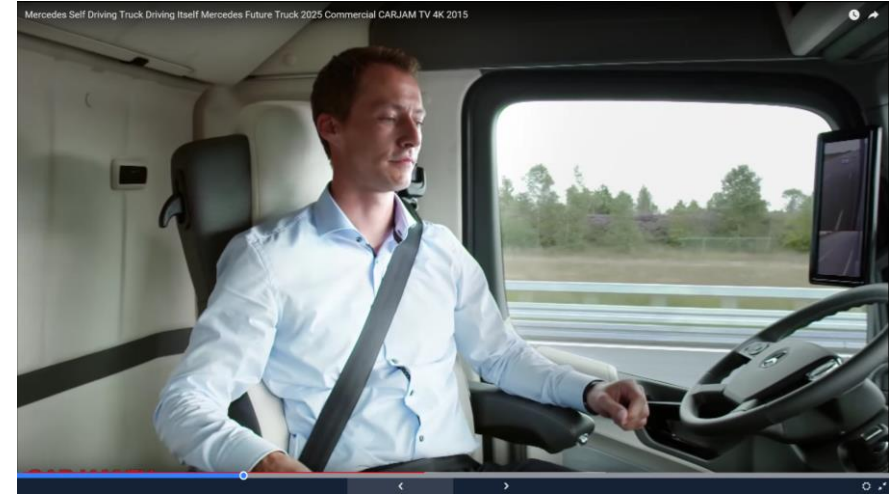
#15 Autonomous shipping changing the maritime environment

- Autonomous shipping is on its way to transform the nature of the shipping industry. There are many challenges ahead requiring more time for advancements than for autonomous road vehicles and drones.
- Benefits of autonomous shipping could be twofold. First, a port that is equipped for autonomous shipping is likely to have a better position to gain (or remain) market share. Second, the introduction of autonomous shipping may reduce costs of inland shipping. This could provide competitive advantage for Dutch and Belgium ports. However, autonomous road and rail transport will be more beneficial for German ports (without major inland waterway connections) in comparison to Dutch and Belgium ports.
- Autonomous shipping will require an increased amount of (preventive) ship maintenance. This may generate additional work for shipyards in the Rotterdam port arena.

Figure 7.52: Rapid autonomous technology development



https://www.tesla.com/nl_NL/videos/autopilot-self-driving-hardware-neighborhood-long



<https://www.youtube.com/watch?v=XZxZC0lgOlc&feature=youtu.be>



<https://i.ytimg.com/vi/2rNWbpOsOvI/maxresdefault.jpg>



https://en.wikipedia.org/wiki/Fleet-class_unmanned_surface_vessel

Figure 7.53: Big plans for the future



<http://www.identity-theft-awareness.com/images/self-driving-car.jpg>



https://s1.cdn.autoevolution.com/images/news/gallery/if-audi-did-trucks-we-wish-they-looked-like-these-two_16.jpg



<https://spectrum.ieee.org/image/Mjg1Njc0Nw.jpeg>



http://www.seatrade-maritime.com/media/k2/items/cache/706ad81e522d47ce22a60a00e01ef96e_XL.jpg

Figure 7.54: Some issues are hard to solve



<http://www.mirror.co.uk/tech/watch-horrifying-moment-tesla-car-8839739>

Safety



http://assets4.bigthink.com/system/idea_thumbnails/60075/size_1024/google_car_cops.jpg?1447423060

Legal

Figure 7.55: Gartner hype cycle

2013 vs 2014 vs 2015

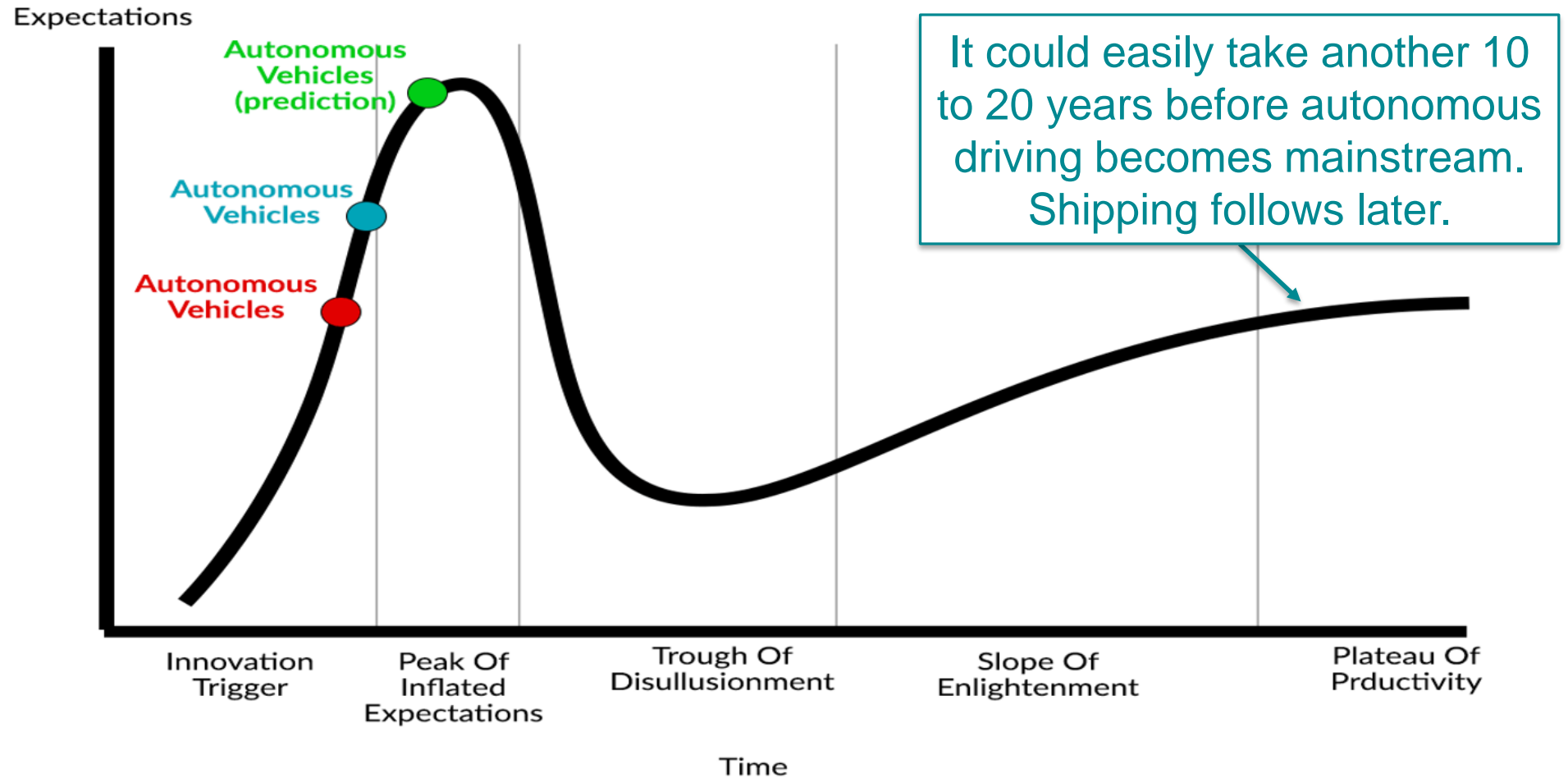


Figure 7.56: Consequences of failure



https://www.stimva.nl/Portals/2/Afbeeldingen/watisimlandeljikeregeling_enlvr.jpg



http://www.cargolaw.com/2011nightmare_mv_rena2.html

Figure 7.57: Ships require on board maintenance unlike cars



http://i.telegraph.co.uk/multimedia/archive/01671/china_1671896c.jpg



<https://i1.wp.com/www.licensedtransportuncovered.com/wp-content/uploads/2015/03/Chauffeur.jpg?fit=889%2C667&ssl=1>

On board a seagoing vessel, only a part of the crew is involved with navigation. The rest of the crew carries out inspection, maintenance, repair, cargo handling, mooring activities, etc.

Figure 7.58: Increasing system complexity

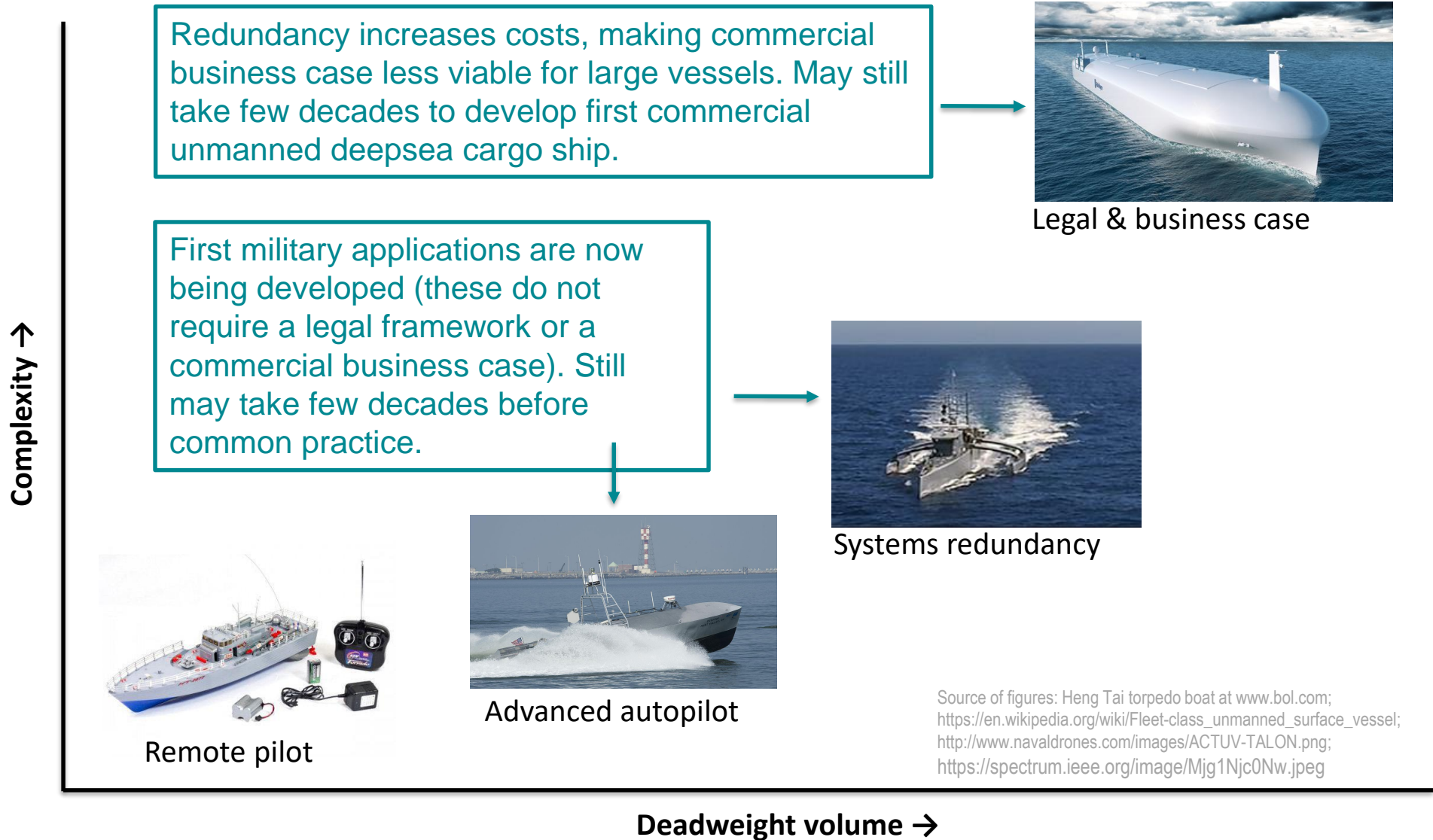
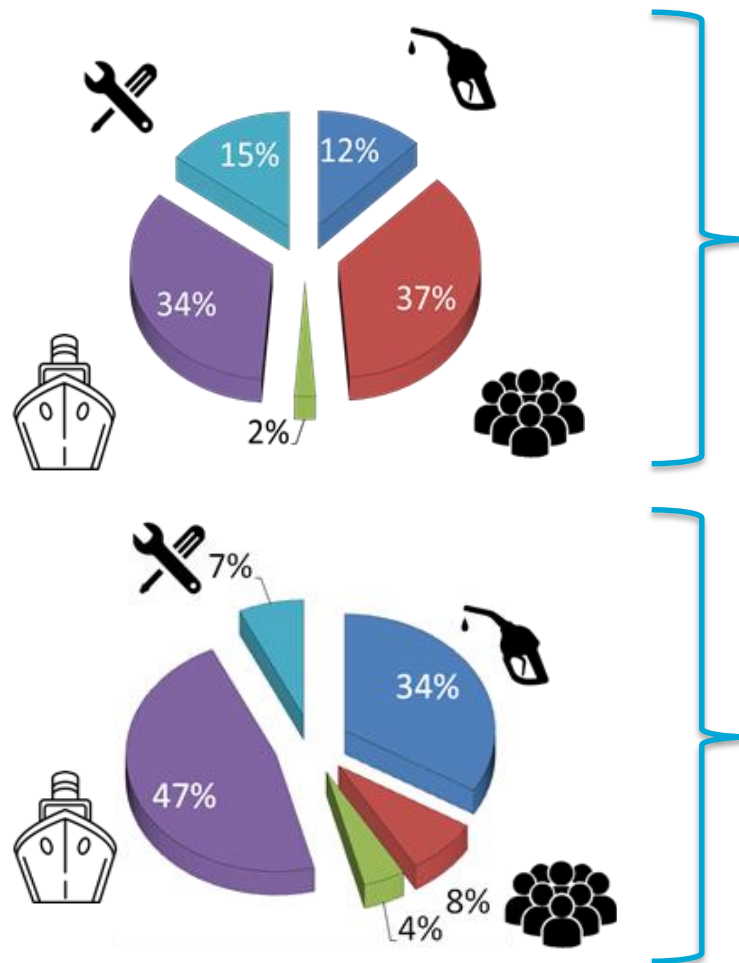
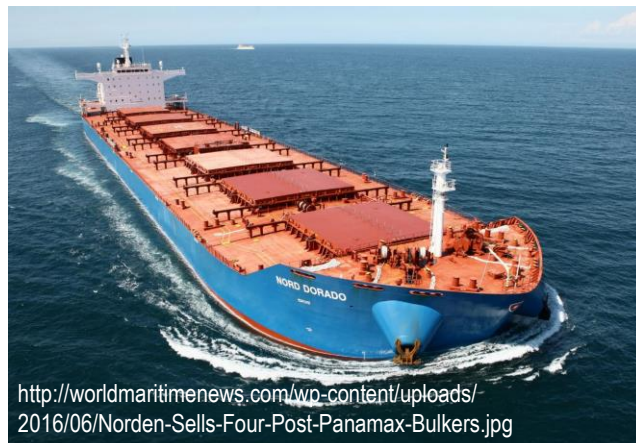


Figure 7.59: Business case for autonomous shipping

Business case for large deepsea carriers more complicated than for small coasters



- Coastal journey;
- Close distance to emergency support;
- Smaller engines (lower cost of redundancy);
- Relatively good manoeuvrability;
- Potential for 37% saving on crew.

- Deepsea journey;
- Long distance to emergency support;
- 1 large expensive engine (high cost of redundancy);
- Large inertia & poor manoeuvrability;
- Potential for 8% saving on crew.

Source: Cost figures provided by Dr. Ir. Robert Hekkenberg, TU Delft.

Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to the expected opportunity for [the development of autonomous shipping \(narrative 15\)](#).

- Impact on ship type / size / number
 - Same cargoes but in different ships with less or no crew;
 - Slight reduction in vessel calls due to larger cargo space of vessel when no accommodation is provided.
- Impact on infra loads / demand / alternative use
 - Possibly more gentle operations with lower peak loads on infra, which implies that larger ships could be accommodated at existing quays or that the lifetime of existing quays could be expanded;
 - Additional measures and requirements to secure safe operations, such as additional safety areas surrounding tug operations or use of advanced mooring facilities like Cavotec automated mooring system.
 - Possibly more intensified use of bow (and stern) thrusters and pods/schottels.
- Impact on cargo handing and storage requirements
 - Less movements with utility vessels (fresh water and food supply, waste etc.);
 - Simplified loading operation when accommodation is eliminated.

#15 Big data and sensors for port infra and fairway optimization

- Big data and sensor technology offers opportunities to optimise transport logistics (including IWT to hinterland), terminals and waterway infrastructures. Optimising the system provides the port with a competitive advantage.
- Continuous monitoring of ship movements in combination with tidal information and nautical traffic simulation can be used to improve the operational windows of the vessels entering the port.
- AIS systems, cameras and sensors can be used to identify free berth locations. This helps avoid unnecessary ship movements within the port and to timely adjust vessel speed, instead of following the usual practice of sailing fast and waiting at location (see e.g. apps developed for port of Amsterdam and Rotterdam).
- Combining hydrographical data with real time depth measurements allows for improved real time maps of the entrance channel and hinterland waterways. This enables optimisation of loading draft, especially in combination with water level predictions (see e.g. Covadem project).
- Sharing information amongst various port users and integrating planning data for inland barges and terminals results in a more efficient planning for all stakeholders (see e.g. Nextlogic Project).

Big data and sensors for port infra and fairway optimization

- Enables use of sensor techniques to improve reliability of ships and infrastructure components (e.g. early discovery of component failure of ship engine; early discovery of possible problems with functioning of bridges and ship locks; early discovery of potential failure for terminal equipment such as cranes).
- Use of sensing technology and big data can be used to improve understanding of failure mechanisms and real loading conditions. This can result in a longer residual lifetime for existing infrastructures (e.g. quay walls) as well as in improved design rules for new infrastructures.

Figure 7.60: Application to optimise berth availability information



[EN](#)

NEWS 25 June 2014

« ARTICLES

Port of Amsterdam launches all-new, Android-compatible app

25-09-2013

Port of Amsterdam launched its all-new lamPort App, the first Android-compatible app of its kind. The app, which was previously available for Apple's iOS devices, can now also be used on Android smartphones. The app has been enhanced with many new features, including information on the expected times at which ships arrive at the pilot station and pass the sea lock at IJmuiden. The new lamPort app also indicates the time when the ship is in its berth, while another new feature tells the user when a ship is actually ready for departure.

As the first port company to launch its own app, Port of Amsterdam is an industry trailblazer when it comes to mobile digital services. The app was enhanced and expanded based on feedback from shipping agents, pilotage agencies and other maritime services providers.

The free app allows interested users to track information relating to shipping in the North Sea Canal Area, including data on navigation, sea cruises and river cruise ships. lamPort provides details on the size, type and berth of all ships moored in the port, as well as on the shipping agent. In addition, users have the option to track individual ships. The app also contains a Port of Amsterdam newsfeed.

[@havenamsterdam](#)

Port of Amsterdam launched the first version of the lamPort app in 2011.

<https://www.portofamsterdam.com/en/press-release/port-amsterdam-launches-all-new-android-compatible-app>

Prizewinning app shows available berths in Rotterdam

Source: Port of Rotterdam Authority

Finding a place to berth in the biggest port of Europe, will be a piece of cake for inland shippers with the soon-to-be-launched 'Berth Available' app. With this new app shippers will be able to see at a glance which berths are available and which ones are taken.



Entrepreneur Léon Gommans came up with this application that combines data from the Automatic Identification System (AIS) with the coordinates of berths in the port of Rotterdam. Gommans recently won the National App Prize with his idea. He expects that the app will be available in the App Store by October.

<https://www.portofrotterdam.com/en/news-and-press-releases/prizewinning-app-shows-available-berths-in-rotterdam-0>

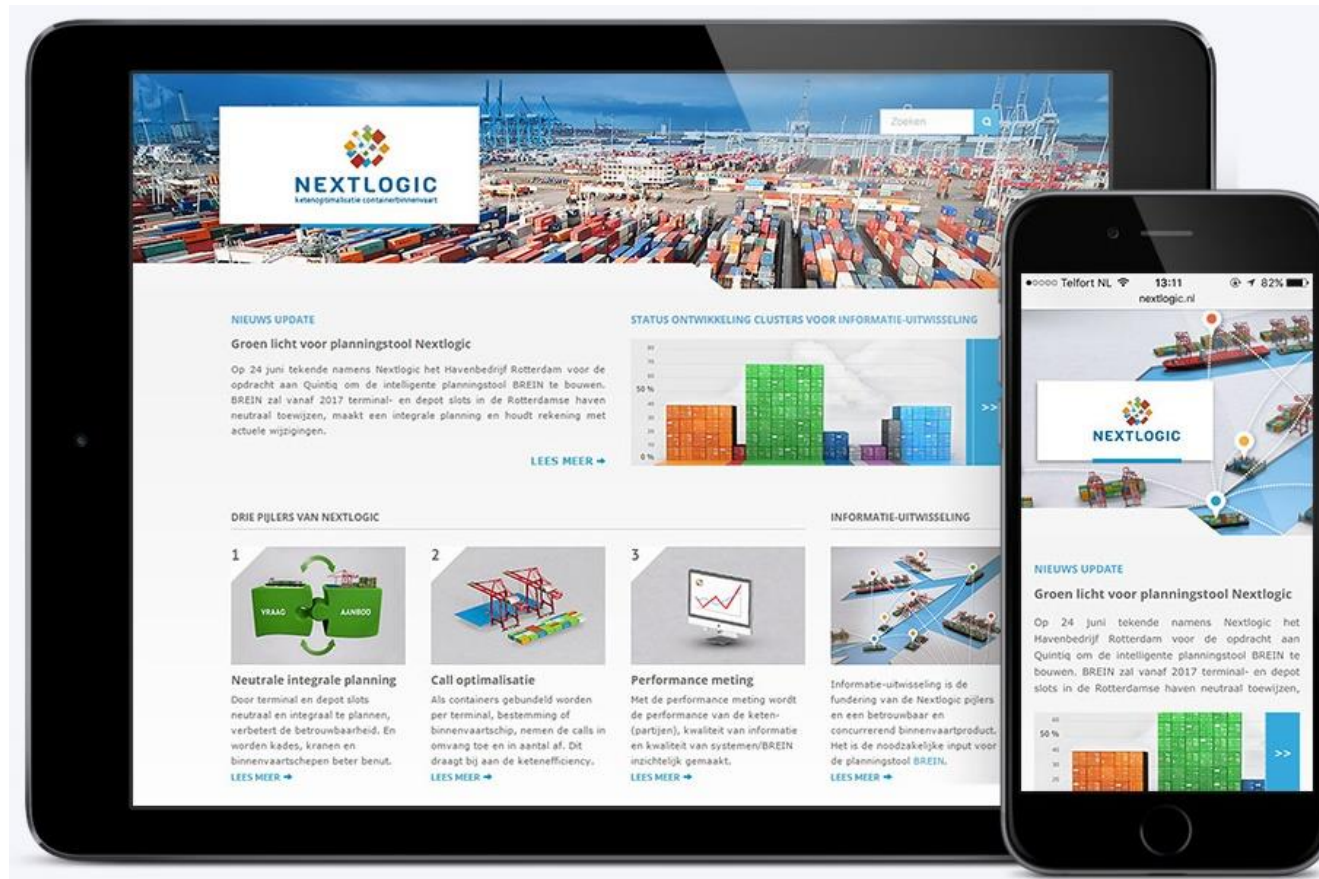
Figure 7.61: Covadem: Cooperative depth measurements.



Continuous depth sounding and data sharing enables vessels to optimise loading capacity, optimise vessel track and speed thereby reducing fuel consumption and improving arrival time reliability.

https://i.ytimg.com/vi/il_8ptDTvXQ/maxresdefault.jpg

Figure 7.62: Nextlogic: Central integrated planning for inland vessels



Integration of terminal and ship information systems into a central planning tool would increase transparency and efficiency of cargo handling system for inland vessels in the port of Rotterdam.

Figure 7.63: Predictive maintenance solutions

REDS
MARITIME

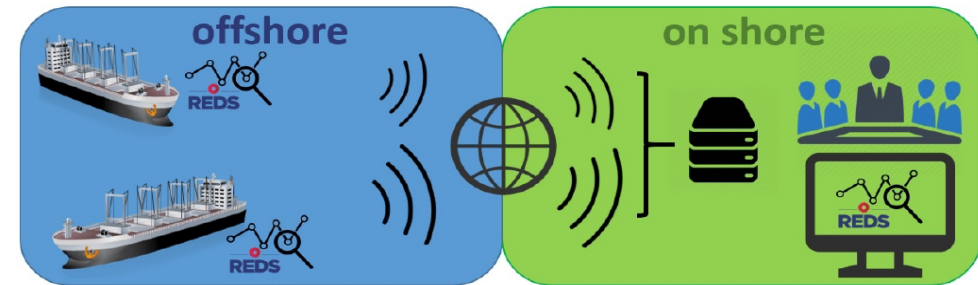
**Engine monitoring & Predictive maintenance:
a cost saving solution**

- Insight in error development weeks or months before component or engine failure.
- Reducing fuel use, thereby lowering emission levels.
- Engine condition monitoring enables data driven maintenance.
- Early detection prevents damages and consequential damages.
- Condition based maintenance increases the availability of your ship and reduces maintenance costs.
- Online availability of measurement data enables remote monitoring and benchmarking.

The advertisement features a large image of a container ship at sea, with a smaller inset image of a tablet displaying a monitoring dashboard with various charts and graphs.

REDS MARITIME, THE NEW STANDARD IN ENGINE CONDITION MONITORING: WEEKS IN ADVANCE INSIGHT IN ERROR DEVELOPMENT

REDS Maritime is an engine monitoring system that gives stakeholders 24/7 insight in the status and efficiency of their marine engines. Deviations in engine performance are detected three weeks in advance. This enables the user to take appropriate action to prevent damages, component failure and ship downtime. This makes REDS Maritime the ultimate software tool to carry out planned maintenance.

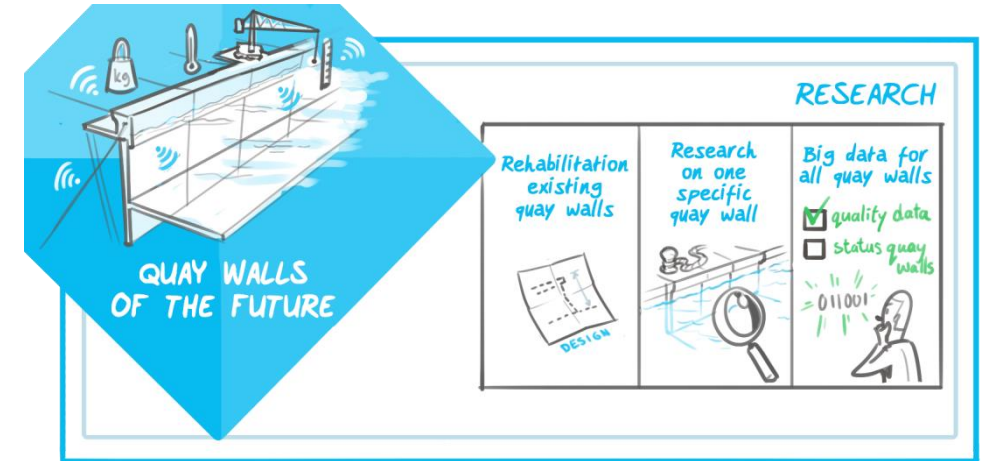


Measurement data 24/7 accessible offshore and on shore. Real-time and available for trend analysis. Please watch our video about the importance of real-time engine insight and trend analysis (<https://www.youtube.com/watch?v=wUz-P5TrQUA&t=4s>).

Predictive maintenance solutions enable ships and infra objects to early detect and replace failing components.

Figure 7.64: Intelligent quay walls

- Sensor technology allows for improved evaluation of the condition of port infrastructures such as quay walls.
- Infrastructure providers can better assess if preventive maintenance is required and allow structures to be used longer since residual strength is better known.
- This provides an opportunity to extend the useful lifetime of existing port infrastructures and to postpone decisions on infrastructure upgrading and replacement up to the time where the impact of ongoing transitions becomes clear.



<http://smart-port.nl/en/project/kademuren-van-de-toekomst/>

Witteveen + Bos



<https://pbs.twimg.com/media/DLTIVQTXoAUBwNI.jpg>

Considerations for infrastructure development

This section examines the possible implications for port infrastructure development due to the expected opportunity for [implementing big data and sensing \(narrative 16\)](#).

- Impact on ship type / size / number
 - Slight increase in vessel calls due to increased market share of port.
- Impact on infra loads / demand / alternative use
 - Intensified use of waterway with less restrictions for shipping.
 - Reduced ship waiting times at anchorage area;
 - Extended lifetime of terminal equipment and quay infrastructure.
- Impact on cargo handling and storage requirements
 - More reliable, efficient and cost effective use of terminal handling equipment;
 - More reliable, efficient and cost effective loading of cargoes in port storage areas;
 - Better information sharing between ships and terminals (as e.g. also aimed for by Nextlogic) intended to result in better terminal crane utilisation and more effective vessel routing (in particular also for inland shipping).

8. Spatial implications for the port

- 8.1 Introduction
- 8.2 Liquid bulk and chemicals
- 8.3 Dry Bulk
- 8.4 Containers
- 8.5 Offshore construction and recycling
- 8.6 Aquaculture
- 8.7 Seagoing and inland cruise activities
- 8.8 Increase of navy presence
- 8.9 Conclusions and suggested layout

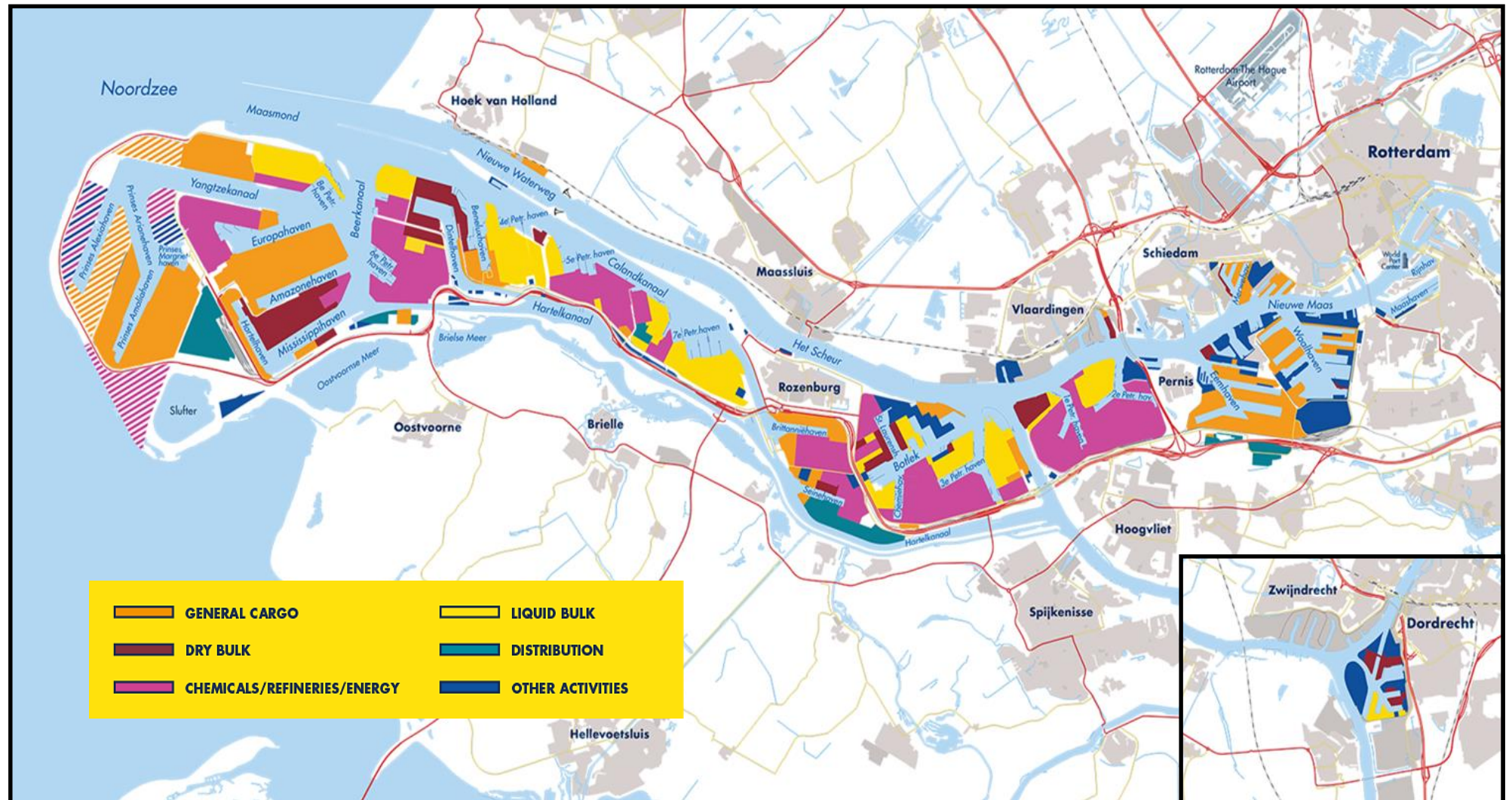
8.1 Introduction

- Figure 8.1 shows the present cargo segments and activities in the port. Anticipated future developments, described in the narratives in Chapter 6, have significant spatial implications for port areas and infrastructure.
- Though a large decline in bulk handling volumes is anticipated (30% - 50% of total throughput), the space for creating new clusters is expected to become available only gradually. This is because the existing clients are likely to continue their present operation as long as it generates cash and to postpone costs of demolition and cleaning up as much as possible (or even until they go bankrupt).
- The need for space over the next one or two decades is urgent if the port is to remain competitive after the transition (i.e. from about 2040 onwards). Smart choices as to the effective use of scarce available space must be made, so that port is a pioneer for the next generation industrial clusters (as indicated by the sustainability drivers of the next K-wave in our trend analysis).
- This chapter studies the spatial implications of the narratives on the port with the objective of locating areas where decline or consolidation of existing activities is expected, as well as areas where promising new clusters can be created. The methodology used is described in [Step C](#) of [Section 1.9](#).

Introduction

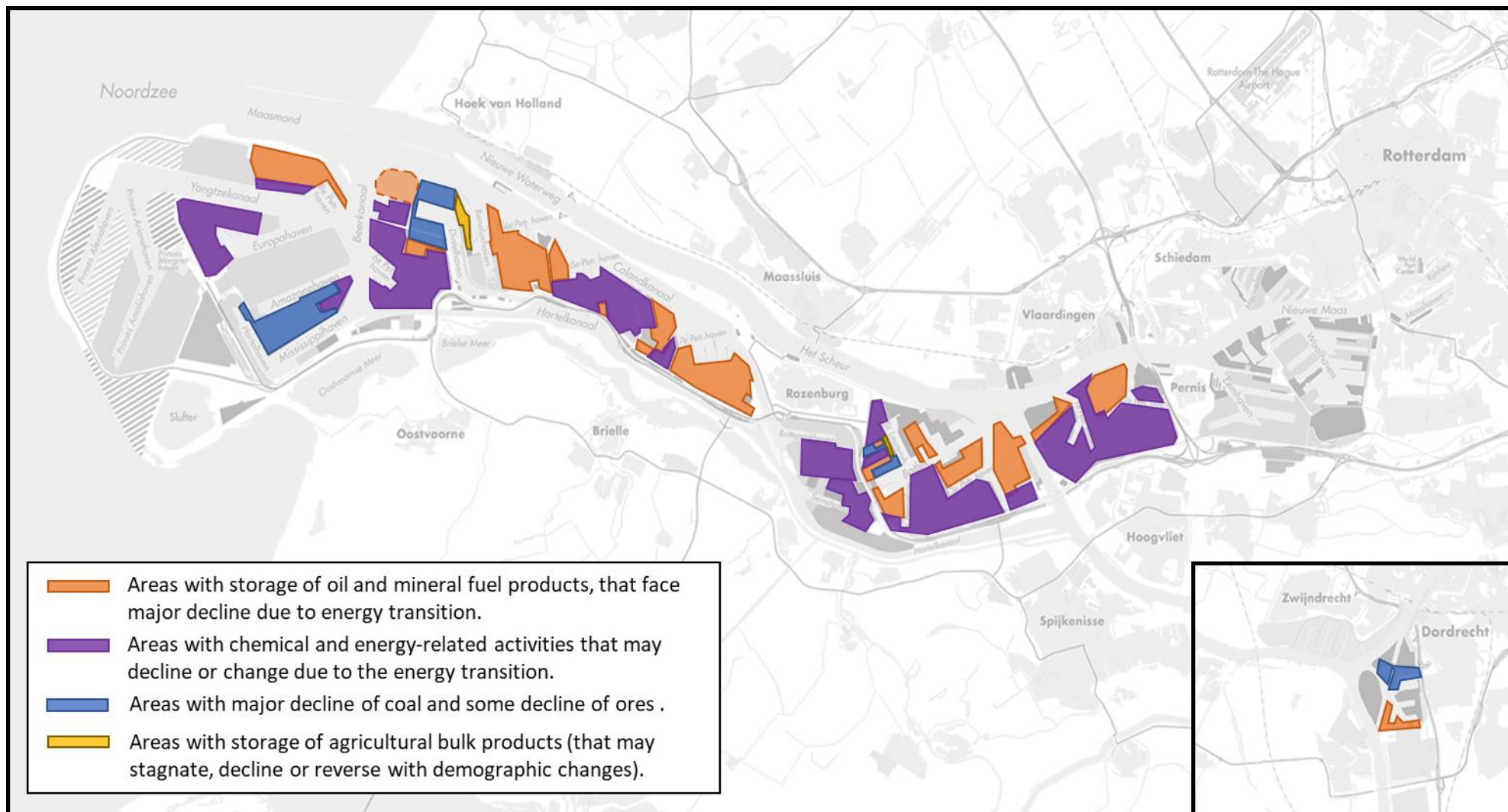
- The applied methodology results in suggestions for clusters of activities, that are combined and presented in Figure 8.20: *Suggested spatial clustering of activities (year 2040)*. The year 2040 is chosen since it marks the point where the transition has passed its critical stage, and new clusters determine future port activities.
- The interpretation of the narratives for spatial planning is of a qualitative nature and the suggestions put forward in the report are primarily intended to facilitate an open discussion on the logical clustering of future port areas (and not on the exact space required for individual activities). Detailed studies into the infrastructure requirements and the corresponding investments for the creation of suggested clusters is therefore recommended.
- Considering the huge costs of infrastructure (deep water quays cost about 70 million euros per km), the effective use and reuse of existing port assets is a major consideration for assigning new activities to available port areas.
- The suggested clustering of activities is based on available information for existing port areas and activities (e.g. a GIS based port map) as well as our interpretation of the narratives and input received from, amongst others, Cees Pons, senior staff from Department of Port Development, Port of Rotterdam.

Figure 8.1: Port of Rotterdam – layout and cargo segments



Source: Port of Rotterdam Authority (version 05 November 2018), adapted layout.

Figure 8.2: Port areas with anticipated decline of activities



Source: Author. Map received from Port of Rotterdam Authority (version 05 November 2018), adapted layout.

8.2 Liquid bulk and chemicals

- Port activities link to narratives:
 - #1 Major decline in bulk fossil fuel throughput (with respect to liquid fuels)
 - #6 Create production and blending area for renewable fuels.
- Present strengths of Port of Rotterdam:
 - Port of Rotterdam has a strong (petro)chemical cluster with mass storage, facilities, refineries, chemical industries at various locations. There is ongoing refurbishment of existing oil refinery complexes in the port and the creation of new oil tank storage capacity at the Maasvlakte. The port is likely to emerge as a consolidation area of fossil fuel related activities in a declining fossil market. This provides a strong base for an evolutionary development of the (petro)chemical industrial cluster into a bio-based cluster.
- Developments signalled by trends and narratives:
 - Decline of crude oil and oil products (mainly fuels) throughput and storage;
 - Transition of existing 'fossil' fuel complex into renewable fuel production and blending area (e.g. biofuels, hydrogen + CO₂ → synthetic fuels, formic acid);
 - Transition of fossil based chemical industrial cluster into industrial complex based on renewables and bio-based chemicals.

Liquid bulk and chemicals

- Considerations with respect to spatial planning:
 - As discussed earlier, space may be a serious issue over next 20 years as companies try to launch renewable activities while continuing fossil-based activities, especially if PoR becomes consolidation area for fossil industry;
 - With electrification of road vehicles, fossil fuel storage will gradually decline, freeing up space in the port. However, new space is required to establish renewable fuel and chemical cluster, which is more diverse and probably more area intensive compared to the fossil industry;
 - Probably more but smaller vessels. Crude oil tankers may be used for e.g. import of hydrogen and biomaterials. Mineral oil tankers (that can also ship renewable fuels) may remain the same size or become smaller in response to a declining market. Hydrogen may be shipped in coastal vessels from offshore production facilities at e.g. Doggerbank or in larger deepsea carriers from e.g. Middle East or Morocco. Bio-material is probably shipped in smaller vessels due to supply in smaller commercial parcel sizes.

Liquid bulk and chemicals

- Suggestions for clustering of future activities:
 - Planned expansions at MV1 can serve to free up space for renewable fuel and chemicals cluster timely, if cargo is relocated from older chemical complexes in Botlek & Petroleum harbours and Caland Canal;
 - Planned area (see Figure 8.7) can also be used for biofuel, synthetic fuel, and sustainable chemicals (e.g. degradable bio-chemicals) to kickstart sustainable fuel/chemical cluster development in the port. However, space is limited at MV2 and also needed for other purposes. It is therefore advisable to seek for space for these new activities in the existing liquid and petrochemical areas;
 - Aim for creation a bio-fuel and bio-chemical cluster at Botlek & Petroleum harbours (as intended by PoR) rather than around the Caland Canal. This is logical as bio-based activities will involve smaller sized vessels as compared to mineral oil products and deepsea hydrogen imports;
 - It is logical to transform the deep water Caland Canal area into a renewable fuel production, storage and blending area. Renewable fuels can be shipped to export markets in similar bulk carriers, using similar facilities as for mineral oils. Crude oil facilities may gradually be converted into hydrogen receiving facilities. Connection can be made to (planned) CO₂ pipelines.

Liquid bulk and chemicals

- Considerations for infrastructure development:
 - Use of existing crude oil receipt facilities (jetties, pipelines and storage tanks) likely to be continued up to about the year 2040, thereafter rapid decline in crude volumes handled expected, possibly leading to smaller ships that require smaller water depth in the Caland Canal (and possibly in the main entrance channel of the port, i.e. the Eurogeul and Maasgeul);
 - Handling facilities for existing mineral oil products are expected to remain in use even after the energy transition, but then for export of e.g. synthetic fuels, bio-fuels, other renewable fuels and/or blends of renewable fuels;
 - Size of future fuel tankers is uncertain, but they may become smaller in response to a global decline in liquid fuel consumption due to electrification;
 - New terminal facilities are likely to be required for import and/or export of alternative energy carriers and chemical base materials, such as hydrogen, synthetic fuels, bio fuels, ammonia, formic acid, etc. Space for these new activities is required from about 2020 to 2040;
 - Scaleup of these activities is expected from about 2040 onwards.

Liquid bulk and chemicals

- Considerations for infrastructure development (continued):
 - Sustainable fuels are likely to be shipped in smaller vessels, though the size of these vessels can be assumed to increase over time and to be a function of the distance. E.g. hydrogen shipped from Doggersbank is likely to be shipped in smaller vessels than hydrogen from the Middle East.
 - The future may show intensified shipment of liquid bio-base materials by inland barges, where bio-material are collected and processed into base materials at the hinterland location and then shipped to the port for further processing into high quality fuel/chemical products.

Figure 8.3: Location of existing oil, fuel, and chemical storage



Source: presentation of Ronald Backers (Advisor Business Intelligence Liquid Bulk at Port of Rotterdam), Gasoline, Naphta & LPG Conference, 9 November 2016, <https://www.slideshare.net/PortofRotterdam/rotterdam-the-1hub-at-the-heart-of-the-trade>

Figure 8.4: Location of existing chemical companies



Figure 8.5: Strategic development of bio-based cluster

Strategic development of chemical cluster

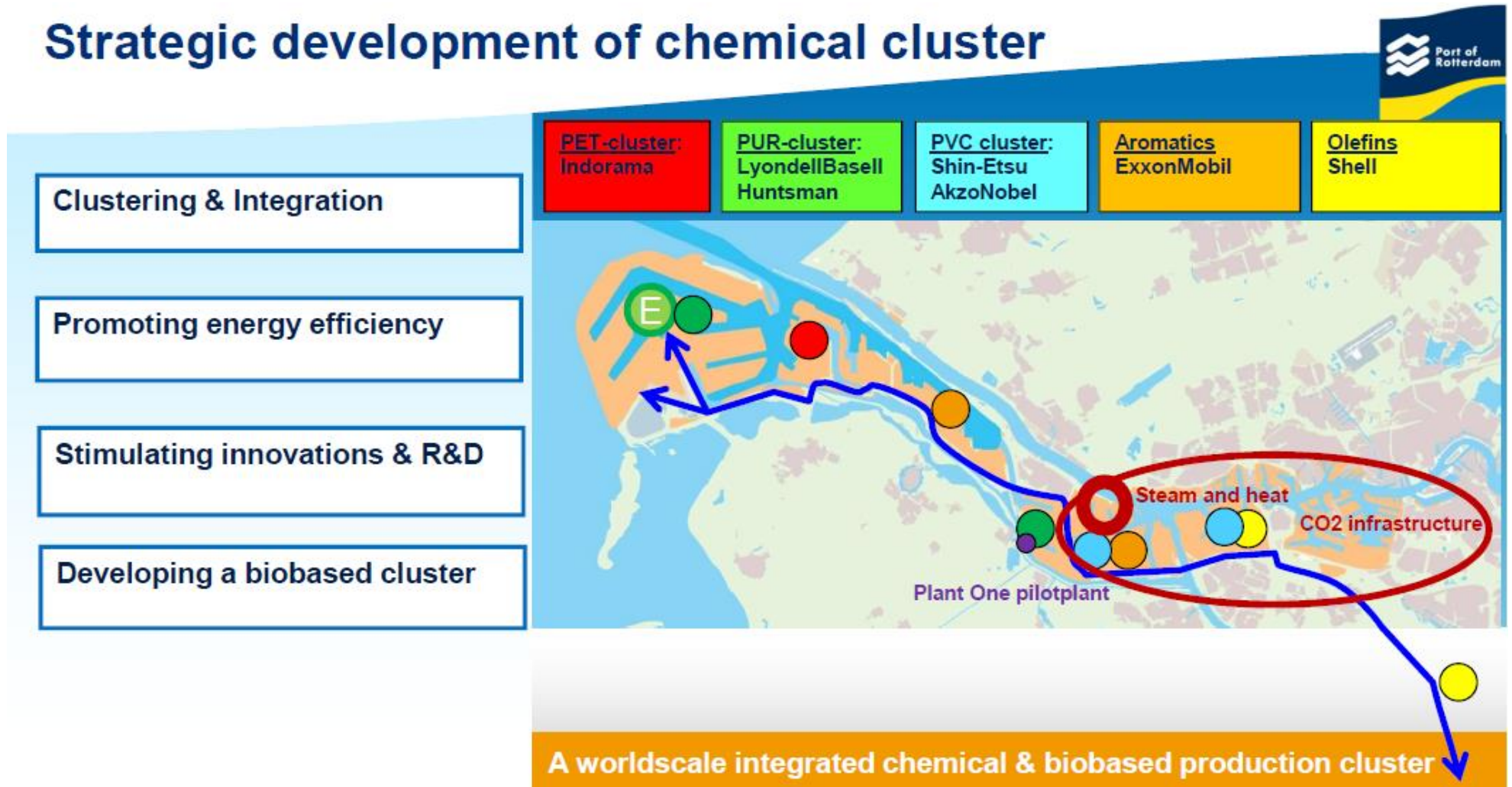


Figure 8.6: Location of existing bio-related companies

BioPort Rotterdam

- **Agri- and biomass terminals**

ADM, EBS, EMO, Marcor, RBT, ZHD

- **Tankstorage for chemicals, biofuels, vegetable oils**

Caldic, Vopak, Rubis, Odfjell, LBC, Koole, Standic

- **Biomass co-firing**

E.On, GDF-Suez, AVR

- **Biofuels production**

Neste Oil, Abengoa, Biopetrol

- **Biobased production plant**

IOI, ADM, Lyondell, Cargill, Wilmar, Unimills

- **New opportunities for biobased industry**



Source: presentation of Ronald Backers and F.J. Hellenthal, Biofuels International, 21-22 November 2012, <https://www.slideshare.net/PortofRotterdam/port-of-rotterdam-port-integration-biofuels>.

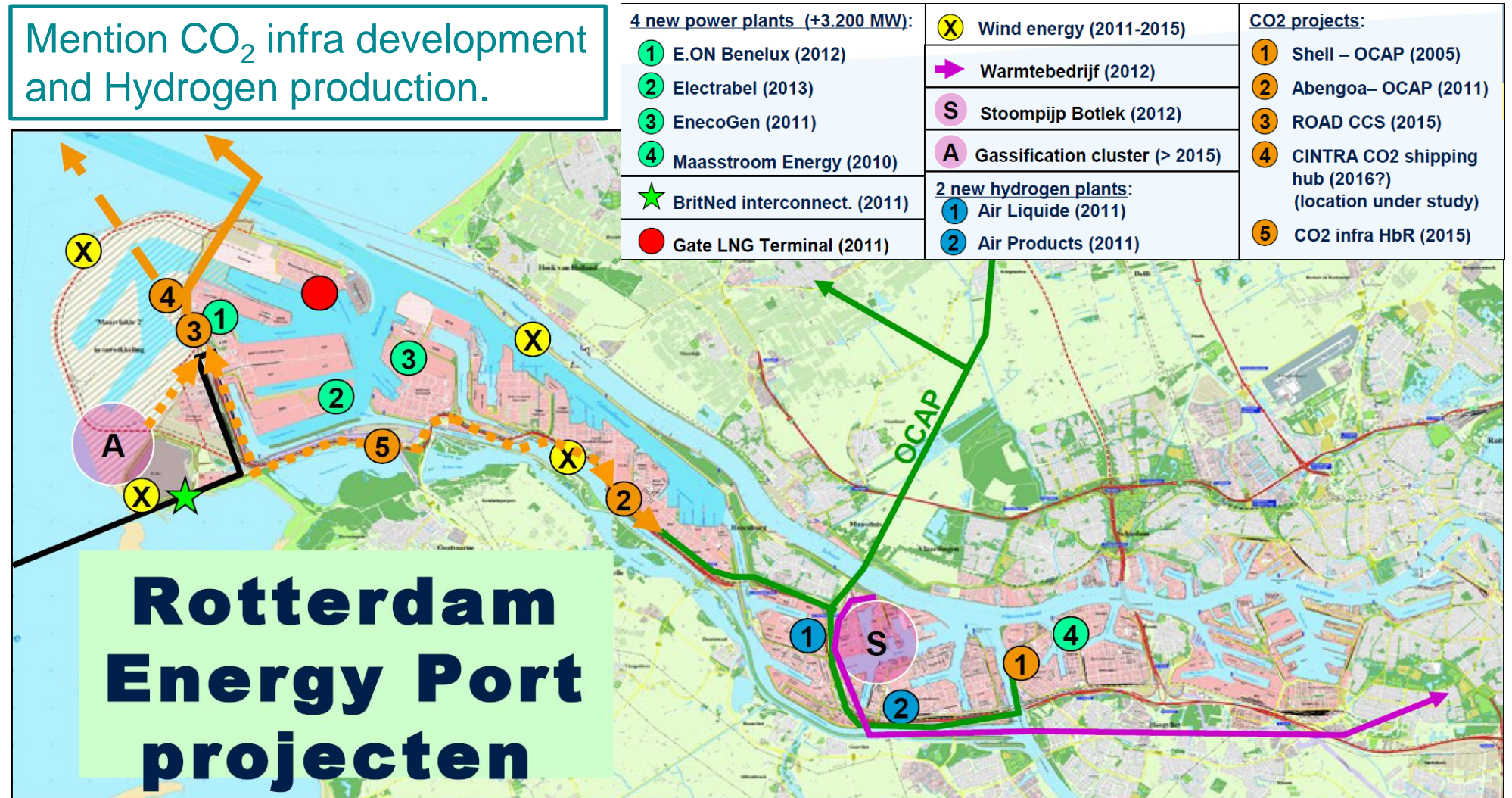
Figure 8.7: Suggested location for bio-based activities

Developing a Biobased Cluster

- Biobased Cluster Maasvlakte dedicated to biobased chemical industry
- Ca. 80 hectares
- Available from 2013
- Waterfront with deep water
- Integration & Clustering with existing industries
- Connected to road / rail / pipeline infrastructure

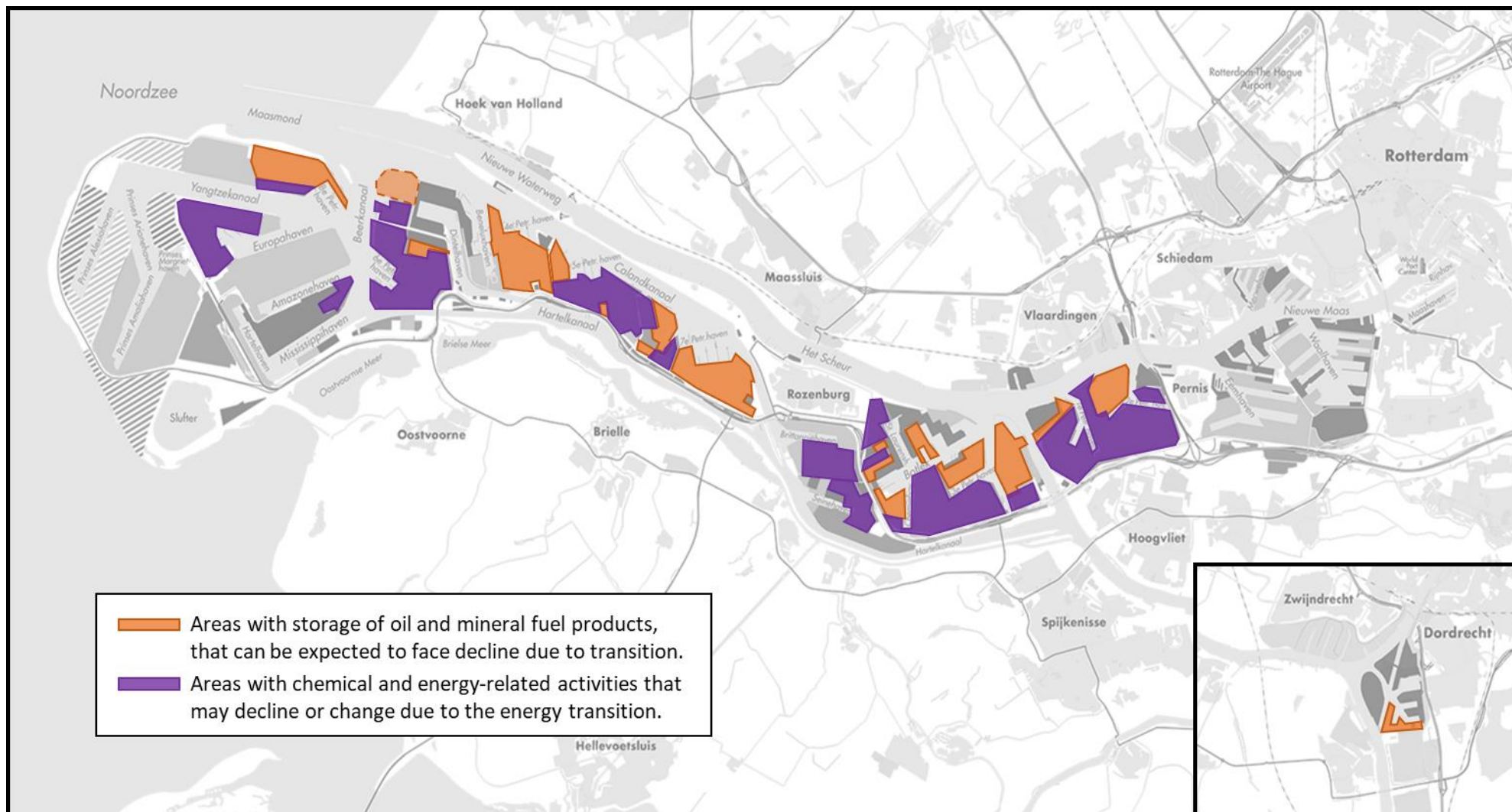


Figure 8.8: Carbon infrastructure and hydrogen production



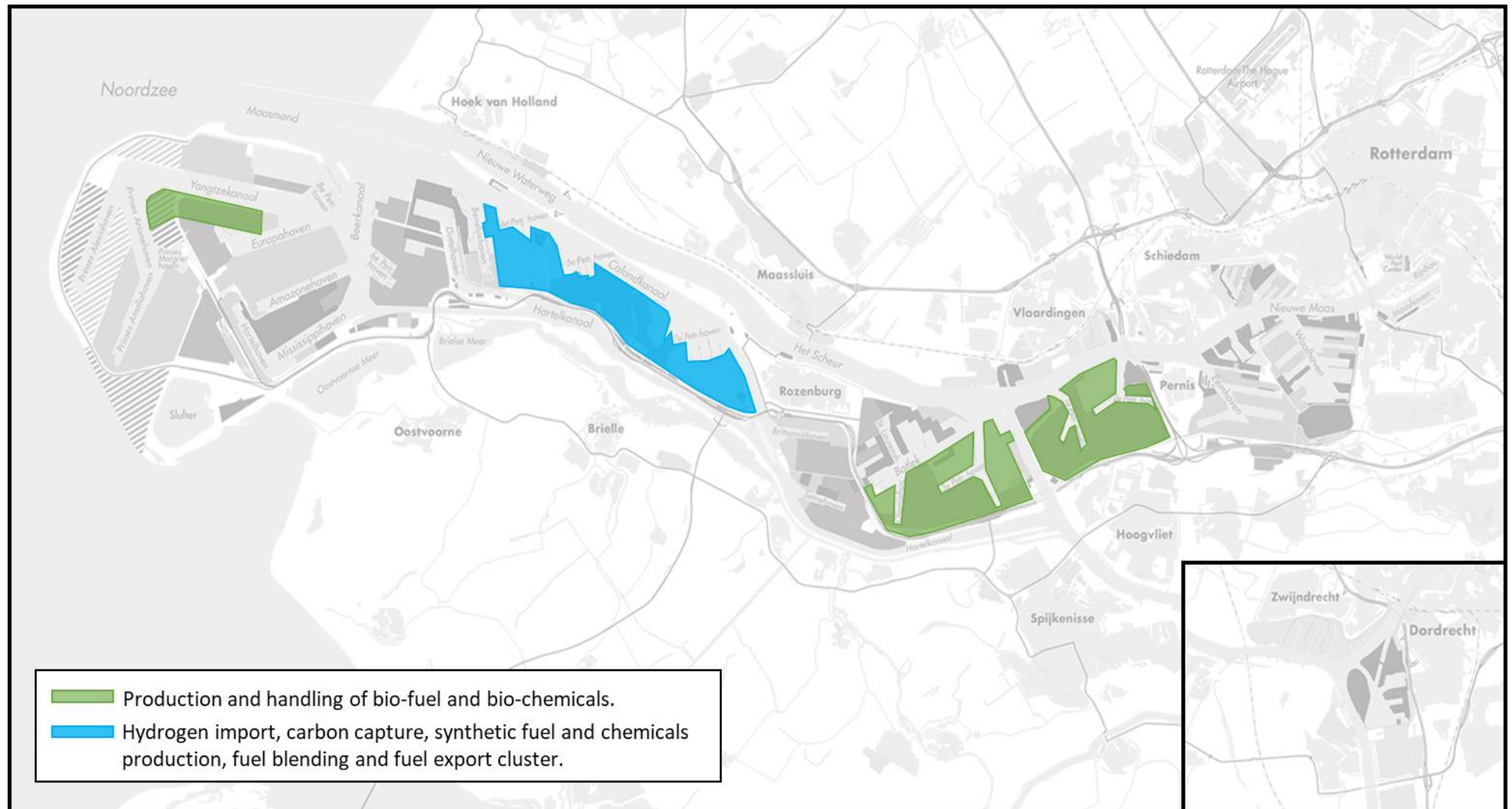
Source: presentation of Jaap Jelle Feenstra (Director Public Affairs at Port of Rotterdam), Gasoline, Naphta & LPG Conference, January 2013, https://www.slideshare.net/hcss_hsd/port-of-rotterdam-16216997.

Figure 8.9: Areas potentially affected by shift from fossil fuels



Source: Author. Map received from Port of Rotterdam Authority (version 05 November 2018), adapted layout.

Figure 8.10: Suggested clustering of renewable fuel/chemical activities



Source: Author. Map received from Port of Rotterdam Authority (version 05 November 2018), adapted layout.

8.3 Dry Bulk

- Port activities link to narratives:
 - #1 Major decline in bulk fossil fuel throughput (with respect to solid fuels)
 - #2 Possible decline in raw material throughput (also shift from ore to scrap)
- Present strengths of Port of Rotterdam:
 - Port already handles a substantial amount of solid biomass;
 - New MPP3 power plant partially fuelled with biomass; may be converted into a full biomass plant.
- Developments signalled by trends and narratives:
 - Phasing out of coal for energy use over next few decades;
 - Phasing out of coal for iron production within 30 to 40 years;
 - Gradual shift of ore for steel production to intermediate products and scrap;
 - Gradual stagnation or decline of population could result in reduced import (and possibly increased export) of agri-bulk products;
 - Energy transition likely to increase demand for nth generation biofuels.

Dry Bulk

- Considerations with respect to spatial planning:
 - Declining coal volumes likely to result in consolidation, especially since EBS and EMO terminals are owned by the same group;
 - Ore for steel production is likely to remain (no indication otherwise), and become backbone of consolidated bulk handling activities;
 - In addition, there may be a substantial increase in solid bio-mass volumes depending on future policies regarding use of biomass;
 - Coal is now transported via an underground conveyer belt from the EMO port to the MPP3 power plant. According to a consulted material handling expert, such a conveyer could also be used to supply the plant with bio-mass.
- Suggestions for clustering of future activities:
 - Consolidate bulk handling at Europort and Maasvlakte and free up space for other activities in other areas such as the Botlek;
 - Develop new solid-biomass storage areas with a dedicated quay at EMO terminal in the Amazonehaven and connect it to MPP3 via the conveyer system, if the plant is fully converted to biomass.

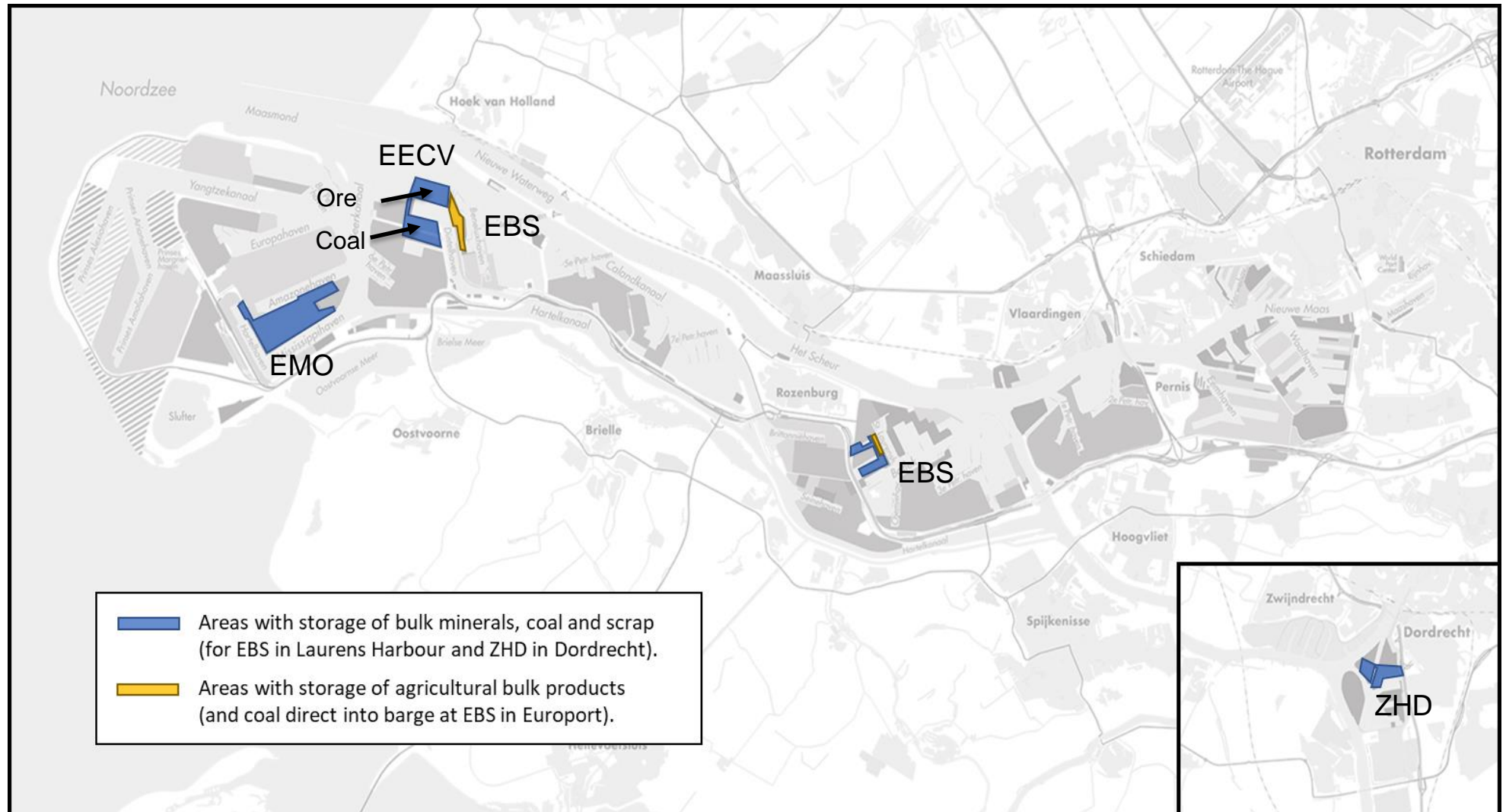
Dry bulk

- Considerations for infrastructure development:
 - Likely need to consolidate bulk handling areas as coal is expected to show a major decline over next two decades. Especially quays in Botlek area (i.e. Laurens harbour) could be used otherwise, e.g. shift to scrap handling.
 - No clear signals that ore will phase out swiftly. Ore handling facilities might be used for another 40 years or more. Unclear if there will be any changes in the future size of ore carriers. End of contract with the Berge Stahl in 2016 hints at possible step back in size of largest vessels, which could provide some room for extending the lifetime of existing quays.
 - Indication that share of scrap used in steel production will gradually increase, but unclear if scrap will remain largely exported (to e.g. China) or will be used more intensively in European steel industry (e.g. in Ruhr area). Possibility that scrap import will be added to portfolio of present dry bulk terminals.
 - New space may be required for handling of bio-bulk materials. The parcel size of bio-solids is smaller than for coal and ore minerals and the specific weight is also smaller. Therefore smaller and lower draught vessels can be expected for bio-bulk shipments than for coal. This may provide some room for lifetime extension at present dry bulk berths.

Dry bulk

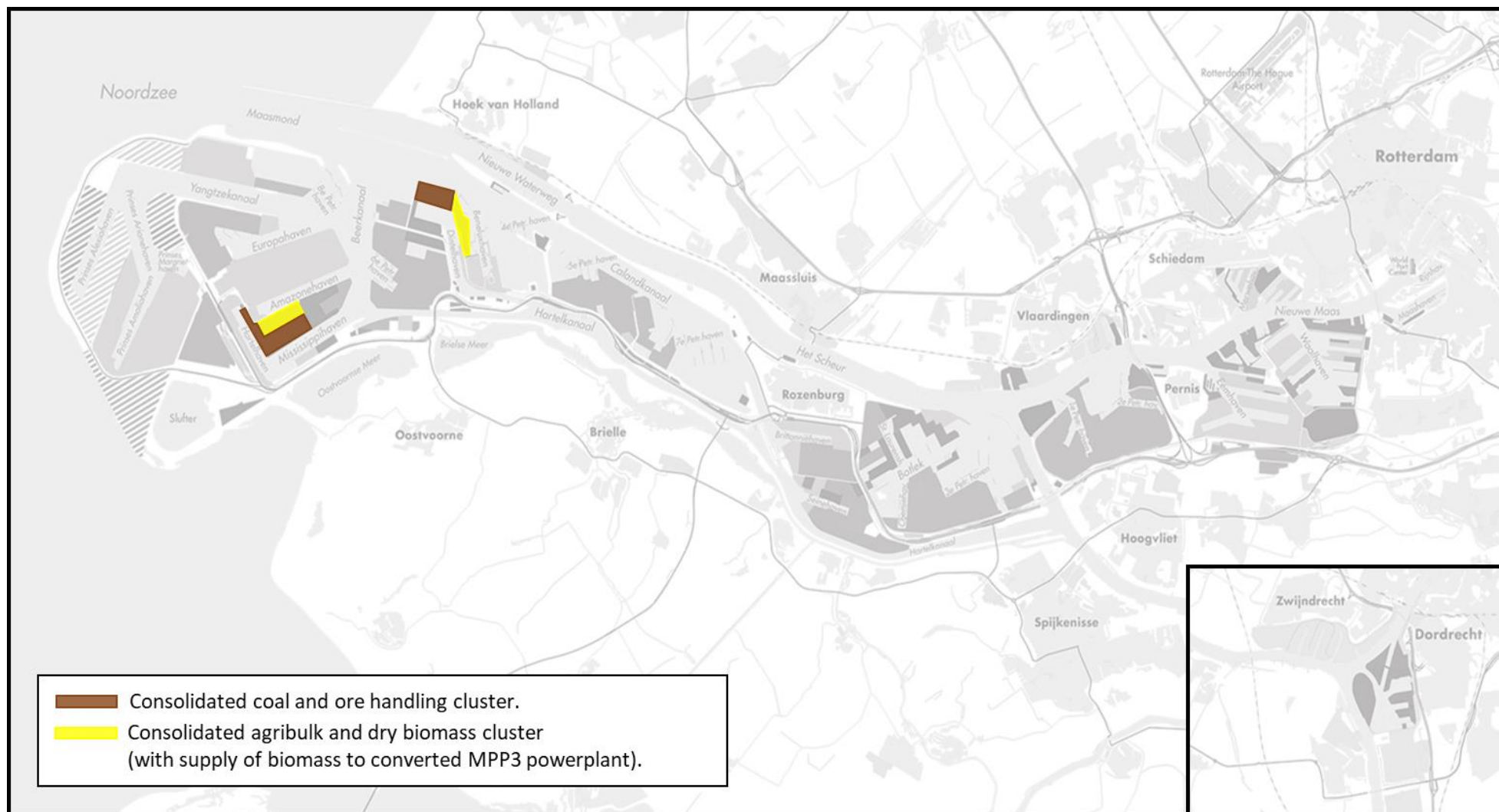
- Considerations for infrastructure development (continued):
 - If the MPP3 powerplant is converted into a fully biomass-fired power plant, space will be required for discharge of solid bio-materials. It may be possible to locate the storage of bio-material at the existing coal facility of EMO using the same underground conveyor belt as now used for coal. Due to smaller size and lower depth of the supplying sea ships and/or barges a new quay facility could be considered at the Amazonehaven, at least in case it is necessary to separate the bio-material flows from the ore flows at the EMO facility (this requirement has not been further assessed in this study).

Figure 8.11: Areas potentially affected by decline in dry bulk



Source: Author. Map received from Port of Rotterdam Authority (version 05 November 2018), adapted layout.

Figure 8.12: Suggested clustering of dry bulk activities



Source: Author. Map received from Port of Rotterdam Authority (version 05 November 2018), adapted layout.

8.4 Containers

- Port activities link to narratives:
 - #3 Stagnation or decline in deep-sea container transport;
 - #4 Future loss of container cargo as a result of 3D printing;
 - #5 Possible loss of market share due to climate change;
 - #9 Opportunity to increase short sea container transport;
 - #10 Develop dedicated inland barge facilities at deepsea container terminals to increase the market share for deep-sea containers.
- Present strengths of Port of Rotterdam:
 - Port of Rotterdam is Europe's largest container port and financial crisis indicated potential to be port of consolidation for containers;
 - IWT hinterland connection is major asset with potential to improve.
- Developments signalled by trends and narratives:
 - Recent increase in market share due to new efficient capacity at MV2;
 - Expected stagnation and/or decline of throughput volumes in HLR;
 - Expected continuation of growth in continental container volumes.

Containers

- Considerations with respect to spatial planning:
 - Not all space presently allocated for containers may be required for future container terminal expansions. Other activities such as offshore construction and decommissioning can be accommodated here;
 - In a stagnating market, the growth of deepsea container volumes requires a growing market share. This can be fostered by improving the quality of the container barge transport services to the hinterland, for which reliability is more important than cost. Reliability improvements require a better handling of IWT barges at deepsea terminals, ideally by means of dedicated high capacity container barge quays at or near the deepsea terminals;
 - The performance and costs of IWT can further be improved by consolidating and reducing the number of empty depots;
 - Feeder volumes may be increased by creating additional feeder facilities at deepsea terminals. Though transshipment is footloose and feeder handlings provide relatively little added value to the overall port revenues, feeder cargo could serve as baseload for shortsea lines;

Containers

- Considerations with respect to spatial planning (continued):
 - There is a potential to increase continental short sea container volumes, which are often shipped in pallet wide, high cube, 45 foot containers;
 - Continental short sea ships can be handled in areas with less water depth i.e., in city port area of Waal/Eemhaven. This city area is also beneficial as it reduces road transport cost of pre/end haulage compared to cargo that is shipped via the Maasvlakte (i.e. city is located closer to the hinterland);
 - Ro-Ro faces fierce competition from continental container transport. Ro-Ro benefits from locations at the port entry due to shorter sailing times. For Ro-Ro cargo sailing time is more important than trucking distance.
- Suggestions for clustering of future activities:
 - Consolidate primary deepsea and feeder volumes at the Maasvlakte;
 - It is a major question if one should use all planned space at the Maasvlake for further expansion of deepsea container handling activities. In particular the availability of a wider offshore basin in the Alexiahaven may be valuable for enabling offshore activities with large cranes in sheltered water, such as commissioning and decommissioning of offshore units.

Containers

- Suggestions for clustering of activities (continued):
 - Create dedicated barge terminals adjacent to the deepsea terminals. With a targeted modal share of 45% for IWT at the 2nd Maasvlakte, almost 1/3rd of all handlings are barge handlings. Dedicated barge cranes are cheaper and more efficient than deepsea cranes, so that the creation of new barge facilities is likely to increase overall terminal capacity and reduce cost levels;
 - Consolidate and expand short sea container shipping activities in the Waal/Eemhaven area;
 - Consolidate barge depot landscape (from many depots at various locations with limited opening times to fewer depots at strategic locations close to terminals with 24/7 opening times) and create sufficient depot capacity close to deepsea terminals, to avoid the need to relocate outgoing empties from inland depots to outgoing deepsea terminals;
 - Maintain ro-ro activities at their present location, as these locations are quite effective in serving short turnaround time in the port (ideally close to port entrance with good road accessibility).

Containers

- Considerations to infrastructure development:
 - Reduced pace in growth of deepsea container volumes and possible growth stagnation (e.g. from 2030 onwards) and/or decline (e.g. from 2050 onwards) imply that less space is required for new deepsea container handling infra. In line with this development road infra demand may also grow less quickly.
 - Possible shift to short sea transport creates opportunity to redefine function of container terminals at Waal/Eemhaven area (no longer deepsea). As short sea vessels have a smaller draught than deepsea vessels, smaller depth is required in the port basins. This could reduce dredging cost and also provide options to extend the lifetime of the existing container quays.
 - Shift of Waal/Eemhaven area to short sea shipping may increase road congestion at the Heijplaat as most continental 45 foot containers are shipped by road and relatively few 45 foot containers are shipped by intermodal barge transport compared to 20 and 40 foot containers.
 - Shift to transport of 45 foot containers may reduce loads on stacking yard as 45 foot containers tend to have a lighter relative weight per m² than 20 and 40 foot containers. This may increase remaining lifetime of the yard paving.

Containers

- Considerations for infrastructure development (continued):
 - Proposed development of inland barge facility next to deepsea terminals requires some capital investments as well as a principled decision to locate shallow draught berths in the deepsea port area of MV2. The expected effects of developing dedicated barge facilities at the terminals are:
 - An expected modal shift from inland road transport to inland barge transport (as a result of the substantially improved reliability and lower costs for barge operations);
 - An increase in overall market share for deepsea containers to the Port of Rotterdam due to improved hinterland connections and lower terminal handling costs.
 - The inland barge facility is suggested to be located at the end of the basin in order to avoid the need to dredge up to the water depth required for seagoing vessels entering the port basin. In some cases one may consider to develop a multiple user terminal, e.g. a combined terminal that serves inland barges for both APM and RWG terminals in Prinses Amaliahaven. This will reduce barge planning complexity as well as the need to provide additional waiting berths for inland container barges in the vicinity of these terminals.

Figure 8.13: Existing container terminals and depots

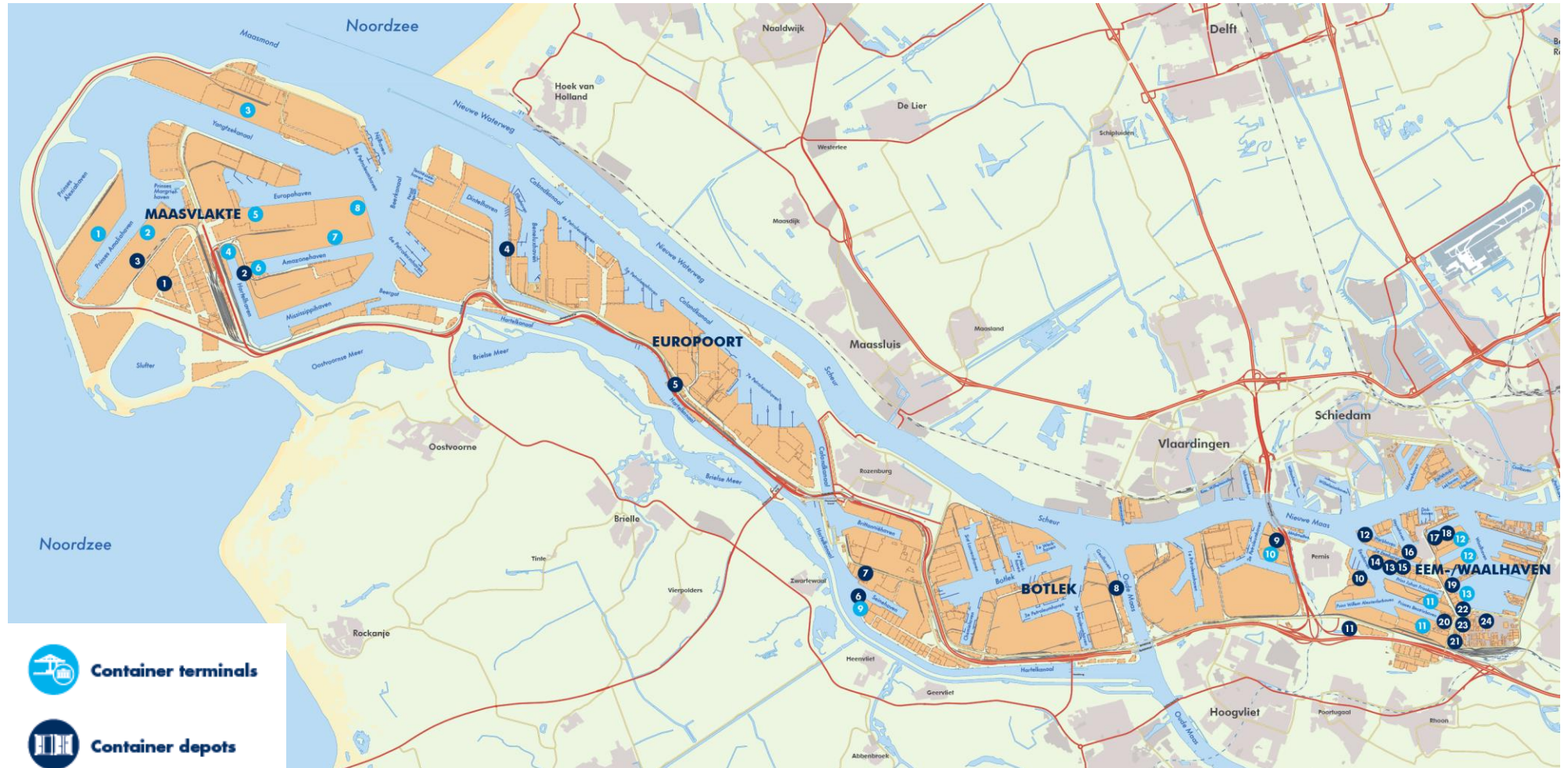
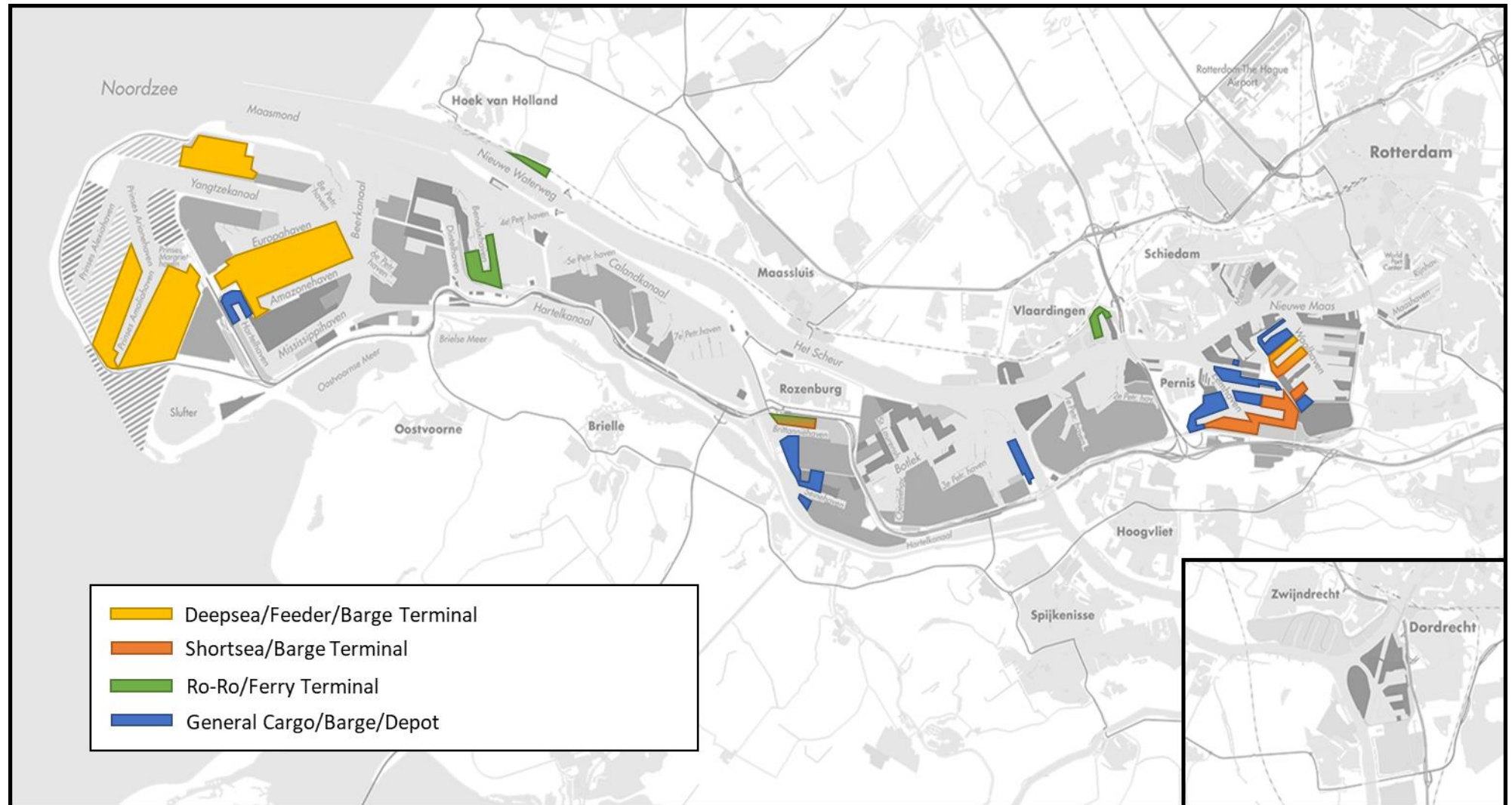
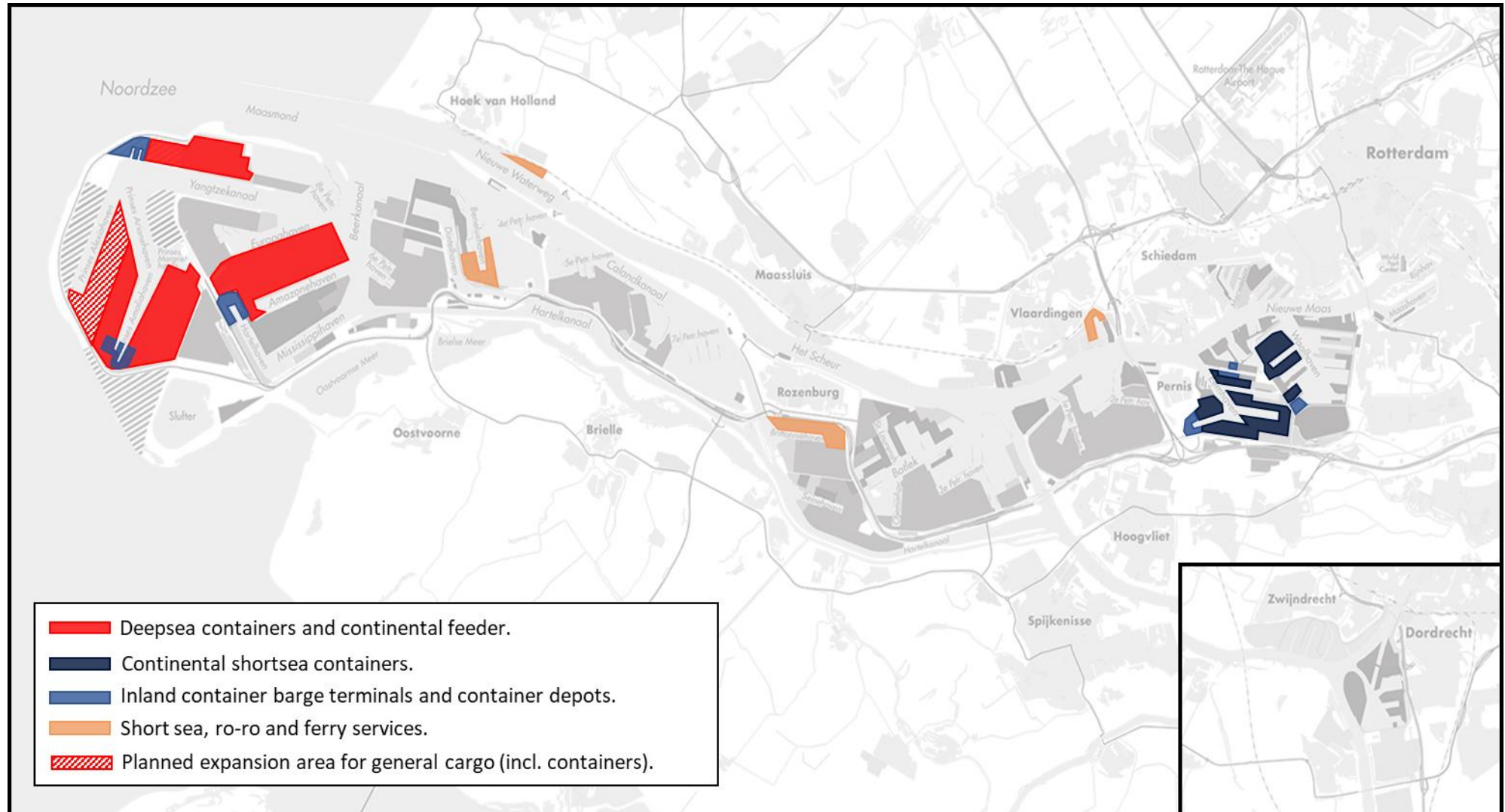


Figure 8.14: Areas where containers are handled (incl. Ro-Ro)



Source: Author. Map received from Port of Rotterdam Authority (version 05 November 2018), adapted layout.

Figure 8.15: Suggested clustering of container handling activities



Source: Author. Map received from Port of Rotterdam Authority (version 05 November 2018), adapted layout.

8.5 Offshore construction and recycling

- Port activities link to narratives:
 - #7 Create recycling and dismantling area for offshore rigs and ships;
 - #8 Strengthen supply base for offshore energy production at sea (not only wind, but possibly also solar at sea);
 - #11 Develop aquaculture and fish farming in the port and at sea (via construction an installation of offshore farm facilities).
- Present strengths of Port of Rotterdam:
 - Presence of world class engineering, construction and repair cluster;
 - Presence of companies that own worlds largest floating cranes (e.g. Heerema's Thialf) and the world's only single lift vessel (i.e. Allsea's Pioneering Spirit);
 - Presence of major shipyards with large docks for newbuilding and repair;
 - Presence of existing recycling cluster within and around the port, that is well connected by means of inland shipping;
 - Presence and ongoing development of new offshore supply bases at MV2 to support, in particular, the construction of offshore wind farms.

Offshore construction and recycling

- Developments signalled by trends and narratives:
 - Major demand for offshore facilities due to development of large offshore wind farms over next 2 to 3 decades;
 - Growing demand for offshore decommissioning facilities over next few decades as a result of dismantling of Northsea oil and gas fields;
 - Potential demand for offshore facilities in case of development of offshore solar farms in addition to wind over next 2 to 3 decades;
 - Potential demand for sustainable decommissioning of seagoing ships as a result of increasing social corporate responsibility and need for recycling as an essential material resource for Europe;
 - Potential demand for offshore facilities to support the commissioning of offshore fish farms in the north sea, a market that may now start to develop and could become more substantial one or two decades from now (i.e. after the main construction peak in offshore wind energy);
 - Potential demand for offshore activities to facilitate maintenance of offshore wind farms and other offshore units.

Offshore construction and recycling

- Considerations with respect to spatial planning:
 - The offshore commissioning and decommissioning industry may benefit from the availability of a sheltered deep water open space such as the ‘pool’ in which the Pioneering Spirit has been constructed. It can be useful to preserve extra wet area in the Alexiahaven to support and enable major offshore lifting activities in a sheltered deep water environment;
 - A sheltered offshore lifting area may not only support the commissioning of new offshore units (e.g. offshore switchgears and transformers; floating solar panels; and floating fish farms), but also the decommissioning of offshore oil and gas production units into smaller pieces that can then subsequently be shipped to recycling companies on pontoons and inland barges;
 - Many recycling activities are located around the Botlek area and Vlaardingen (as well as in Dordrecht and ‘s-Gravendeel). The Damen Verolme shipyard has potential to become a major (repair and) offshore decommissioning facility that is positioned next to a number of steel recycling companies;
 - For offshore construction and recycling activities environmental aspects (e.g. noise) require operations to keep sufficient distance from residential areas.

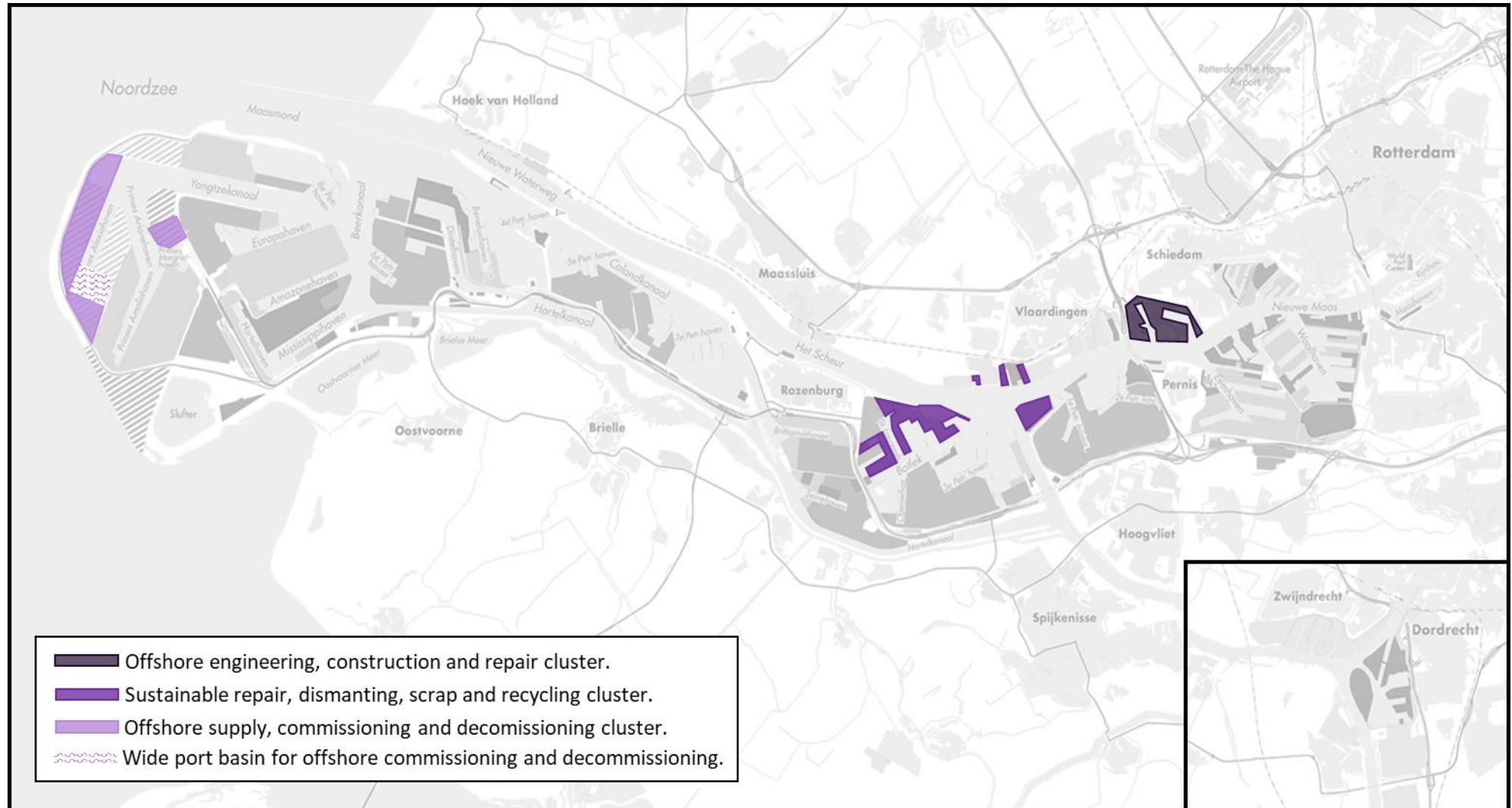
Offshore construction and recycling

- Suggestions for clustering of future activities:
 - Develop major offshore cluster at MV2, in line with present actions of port authority to create second offshore terminal in Alexiahaven, but with the explicit intention to reserve sufficient sheltered deep water space for offshore commissioning and decommissioning activities with large floating equipment;
 - Preservation of world class offshore construction, engineering and repair cluster in Botlek (Damen Verolme) and Schiedam (e.g. Mammoet, Huisman, and Damen);
 - Enhancing existing recycling and scrap handling activities in and around the northern part of the Botlek area and Vlaardingen (Zeemanshaven). With the potential development of the Damen Verolme shipyard into a combined ship and offshore (repair and) decommissioning facility;
 - Possible development of a dedicated ship dismantling facility at for instance the present location of the EBS coal terminal if this area becomes available following a consolidation of bulk terminals in Rotterdam.

Offshore construction and recycling

- Considerations to infrastructure development:
 - Commissioning and decommissioning of offshore platforms and installations requires sufficient deep sheltered water area to support floating crane operations as well as sufficient strong quays to support mobile cranes.
 - Offshore installation of wind farms, solar farms, and fish farms require sufficient space in the port for preassembling and loading (rolling or lifting). Space requirements include dry and wet storage/assembly areas.
 - Shipyards may enter into the market for decommissioning of seagoing ships and offshore platforms. This may, amongst others, require dismantling berths, cranes with high lifting capacity, covered scrap facilities, seagoing and inland transport barges, and areas where entire objects or sections can be stripped into steel scrap and other useful recycling materials.
 - The recycling market is likely to require additional space and quay length at metal scrap handling facilities, in order to be able to receive barges with decommissioned subsections, while maintaining sufficient capacity to serve seagoing vessels (e.g. for export of scrap).

Figure 8.16: Suggested areas for offshore construction and recycling



Source: Author. Map received from Port of Rotterdam Authority (version 05 November 2018), adapted layout.

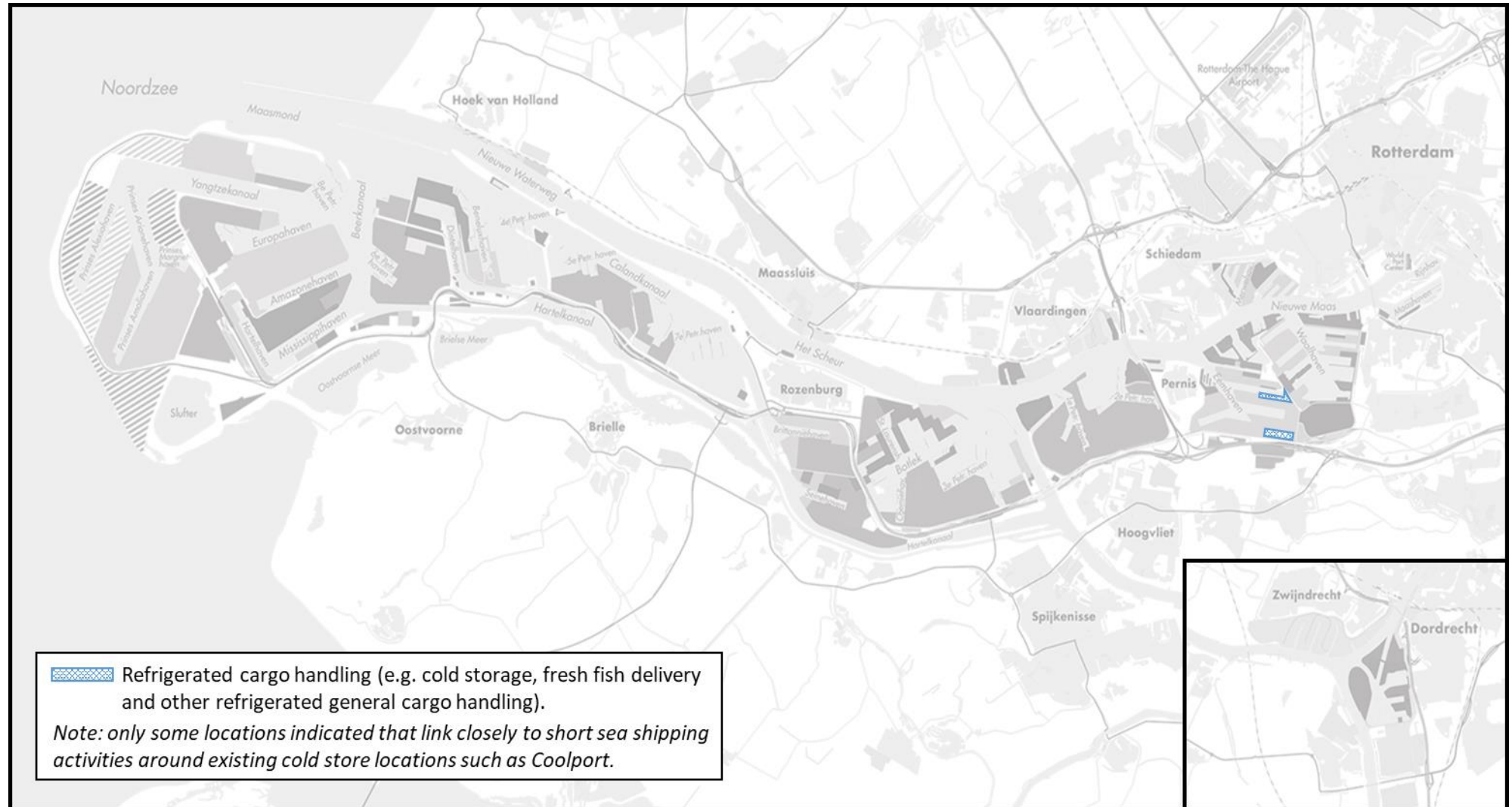
8.6 Aquaculture

- Port activities link to narratives:
 - #11 Develop aquaculture and fish farming in the port and at sea.
- Present strengths of Port of Rotterdam:
 - Older port basins (that are no longer actively used for shipping) may offer space for small scale urban fish farming activities;
 - Heat waste of industrial complexes may offer opportunities for commercial fish farming activities (e.g. comparable to former happy shrimp farm).
- Developments signalled by trends and narratives:
 - Growing interest in sustainable fish farming and urban food production.
- Considerations with respect to spatial planning:
 - Needs to fit in logically with other industrial and urban developments in the port and city area. May fit with city development in Merwehaven that already houses the urban food initiative “Uit je eigen stad” (food from your own city).

Aquaculture

- Suggestions for clustering of future activities:
 - Not a focal point from a port perspective, but could become relevant from a municipality perspective;
 - Offshore fish farming may require landing space for farmed fish (for this, facilities may be integrated with other refrigerated general cargoes).
- Considerations for infrastructure development:
 - Space may be required near offshore supply terminals or shipyards for the construction and installation works of new offshore fish farms;
 - Fish landing facilities could be located in Waal/Eemhaven area making effective use of existing quay infrastructure for which the lifetime may be extended if fewer depth is provided. However, fish landing facilities may also be accommodated by other Northsea ports;
 - Possible future location for receipt of farmed fish could e.g. be the berth and cold storage facility of Kloosterboer in the Prins Johan Frisohaven;
 - There is a future possibility for farmed fish to be processed and stored into containers at sea, in which case they could be served by e.g., Coolport.

Figure 8.17: Suggested areas for refrigerated cargo handling



Source: Author. Map received from Port of Rotterdam Authority (version 05 November 2018), adapted layout.

Figure 8.18: Urban food initiative at Merwehaven in Rotterdam



Uit Je Eigen Stad ENGLISH



Alessandro MAMMUT FILM

Gepubliceerd op 22 mrt. 2017

Uit je Eigen Stad is one of the biggest urban farms in Europe. It is located in the harbour area of Rotterdam (NL). The key aim of Uit Je Eigen Stad is to connect urban consumers with urban producers. They want to show how food is produced using various techniques and products ranging from mushroom cultivation, poultry production, aquaculture and horticulture.

Sources: https://daks2k3a4ib2z.cloudfront.net/585d1cd0a25e6be93c168faa/5a048692289d66000119fb0c_1500-wonen-in-rotterdam-uit-je-eigen-stad-03.jpg (top left); http://versestad.nl/wpdir/wp-content/uploads/2014/05/DSC_0053.jpg (bottom left) https://www.youtube.com/watch?v=QQ_c7v-wVxl (right)

8.7 Seagoing and inland cruise activities

- Port activities link to narratives:
 - #12 Expansion of cruise market for both maritime and inland shipping.
- Present strengths of Port of Rotterdam:
 - Attractive city that already contains appealing cruise terminal;
 - Especially for inland waterway cruises, port is endpoint of the Rhine.
- Developments signalled by trends and narratives:
 - Expected growth of cruise and river cruise market over next decades.
- Considerations with respect to spatial planning:
 - Growing public opposition against environmental impact of large seagoing cruise vessels on air quality and congestion in city area.

Seagoing and inland cruise activities

- Suggestions for clustering of future activities:
 - From a logistical perspective it would be logical to consider the development of a future sea cruise terminal in Vlaardingen (close to the A4 motorway);
 - From a city development perspective one may consider developing a cruise terminal in the Merwehaven that is already intended for urban development;
 - The Merwehaven may also fit well with development of inland cruises for which logistical operations are far less demanding;
 - We have not plotted future cruise activities in our imaginable port layout, as it is not clearly linked to existing industries and potentially fits at various locations.
- Considerations to infrastructure development:
 - A cruise terminal requires an appealing location and good accessibility for busses towards typical Dutch attractions (mostly in north of Rotterdam);
 - Inland cruises may provide an opportunity for development of Merwehaven. This not only extends the useful lifetime of existing quay infrastructure, but makes it possible to reduce dredging costs due to the low draught of inland barges.

Figure 8.19: City considers new cruise terminal at Merwehaven



DONDERDAG 24 MAART 2016, 00:07

DEEL DIT ARTIKEL:



Merwehaven meest geschikt voor nieuwe cruiseterminal



Cruiseschip Royal Princess (Foto: Tom van Vark)

De Merwehaven zou volgens de gemeente Rotterdam de meest geschikte plek zijn voor een nieuwe cruiseterminal in 2025. Ook wordt onderzocht of de omgeving van huidige terminal aan de Wilhelminapier kan worden aangepast, waardoor de schepen in het centrum kunnen blijven liggen.

In het onderzoek van de gemeente naar een mogelijke nieuwe locatie voor de cruiseterminal, zijn de Parkhaven en Katendrecht afgevalen. Volgens wethouder Adriaan Visser bleken deze ongeschikt voor het ontvangen van meerdere cruiseschepen.

Bereikbaarheid

Het aantal cruiseschepen dat Rotterdam bezoekt neemt jaarlijks toe, maar volgens de gemeente is de Wilhelminapier te klein voor twee schepen tegelijkertijd. Ook is de bereikbaarheid van de huidige cruiseterminal niet voldoende en zijn de mogelijkheden voor uitbreiding beperkt.

Derde stadsbrug

Ook wil wethouder Visser voor de EXPO 2025 er een derde stadsbrug bij, van Schiedam naar Rotterdam-Zuid, waardoor cruiseschepen niet meer naar het centrum van de stad kunnen varen.

"Het liefst zouden we als college de Wilhelminapier aanhouden als locatie voor cruiseschepen, maar ik moet ook naar de toekomst kijken," vertelt Visser.

"De Merwehaven heeft alle ruimte, de bereikbaarheid is daar goed en dat biedt natuurlijk heel veel perspectief. Nu is dat nog industriegebied, maar over 10 jaar ziet het er daar misschien wel heel anders uit."

De gemeente gaat de mogelijkheden de komende periode onderzoeken en zal vervolgens een voorstel doen aan de gemeenteraad.

Source: <https://www.rijnmond.nl/nieuws/140089/Merwehaven-meest-geschikt-voor-nieuwe-cruiseterminal>.

8.8 Increase of navy presence

- Port activities link to narratives:
 - #13 Increased navy presence to counter increased threats.
- Present strengths of Port of Rotterdam:
 - Port is used to accommodate navy vessels on an incidental basis;
 - Port already preparing for terrorist activities together with the Navy.
- Developments signalled by trends and narratives:
 - Growing global tensions and strengthening of NATO forces in Europe.
- Considerations with respect to spatial planning:
 - Counter terrorism will generally involve use of smaller navy vessels;
 - Existing quays along waterway (e.g. at Parkkade) could be sufficient.

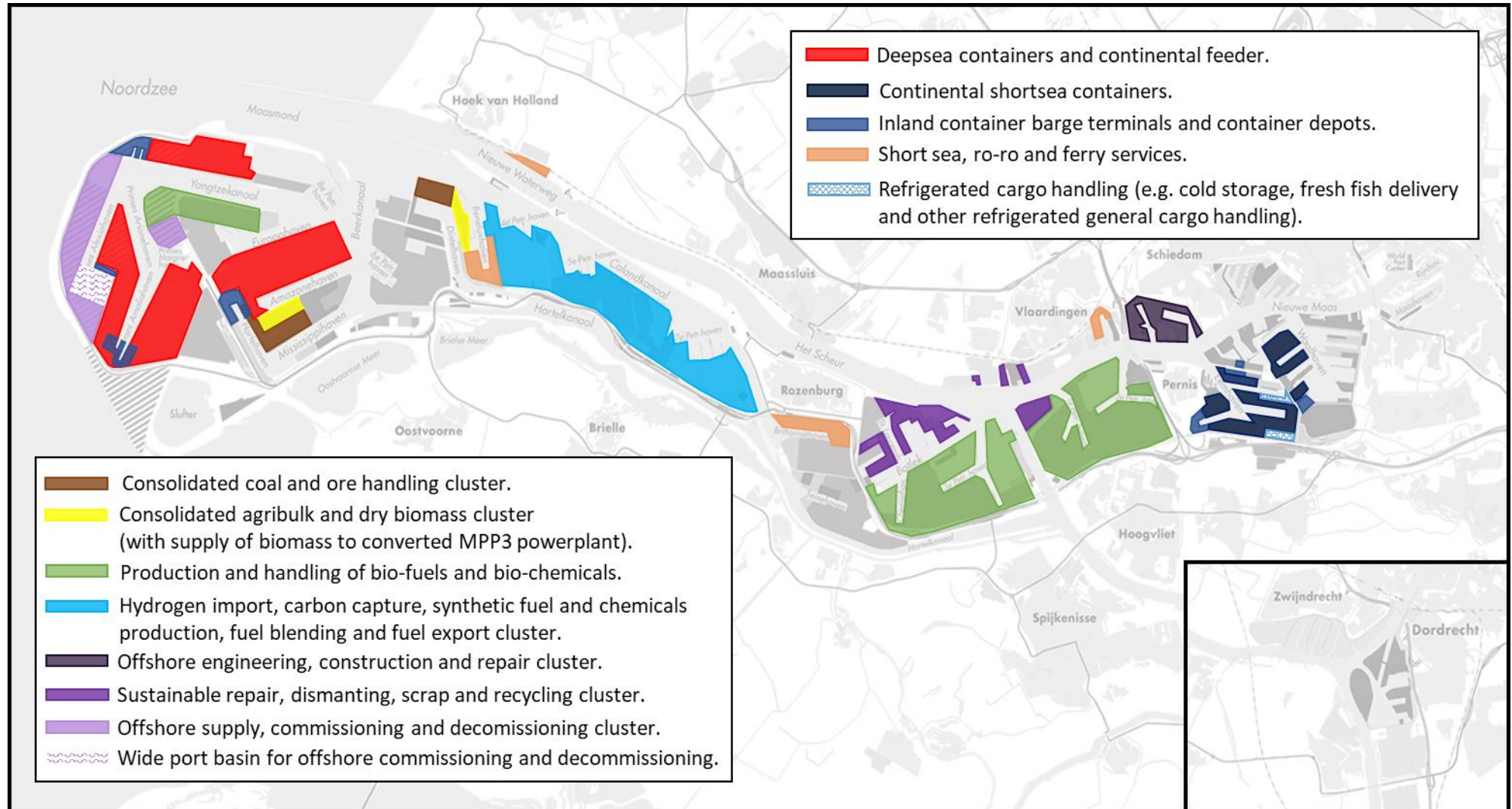
Increase of navy presence

- Suggestions for clustering of future activities:
 - No suggestions made on facilitating navy activities in this report. This needs to be further investigated together with Royal Dutch Navy.
- Considerations for infrastructure development:
 - Possibility of increased demand for secured mooring of NATO fleet.
 - Possible need for secured area that provides a base for small patrol vessels used to secure the port from threat of terrorist attacks.

8.9 Conclusions and suggested layout

- Future trends will have spatial implications for the port. The threats (identified by our trend-based narratives) will lead to declined activity and free up space in the port, while new opportunities for developing clusters with promising futureproof port activities will demand space.
- The decline in spatial demand for fossil activities will create extra space, but this will become available only gradually over the next 20 to 30 years. However, the new activities towards the creation of promising clusters of the next K-wave (i.e. from about 2040 onwards) require space urgently.
- Though MV2 has space for expansion, space is likely to become scarce over the next two decades. Existing clients are expected to invest in sustainable activities while still continuing current operations (thereby postponing decommissioning and cleaning activities to maximise their cash flow). This manner of operation is likely to continue for the next 20 to 30 years.
- New sustainable port activities and clusters are, in line with the drivers of the next 50 years lasting K-wave, expected to develop over next 20 years and become dominant in the subsequent period of 50+ years.
- Port of Rotterdam needs to have the renewable clusters effectively in place by year 2040 in order to take a leading position as a world class port for these new sustainable activities. Figure 8.20 indicates how this may be achieved spatially.

Figure 8.20: Suggested spatial clustering of activities (year 2040)



Source: Author. Map received from Port of Rotterdam Authority (version 05 November 2018), adapted layout.

Considerations with respect to suggested layout

Some of the considerations with respect to the suggested clustering of activities and layout in Figure 8.20 are:

1. As a result of the anticipated stagnation in deep-sea container transport in the region, only limited space is required for further growth of deepsea container activities. In order to pursue continued growth in a stagnating market, efforts could be made to increase market share, for instance by improving the container handling facilities for inland barges and feeder traffic.
2. To take full advantage of the opportunities in the offshore installation and dismantling market, a sufficiently wide harbour basin where large crane vessels and submersible pontoons can operate in a sheltered deep water environment, should be considered.
3. The conversion of the MPP3 power plant on the Maasvlakte into a fully biomass-fired power plant can make a positive contribution to the carbon-neutralization of the port. After conversion, the required biomass flow could, in principle, be supplied via the existing underground conveyor belt from the EMO terminal through a new transfer facility in the Amazonehaven.

Considerations with respect to suggested layout

4. The possibility of supply of hydrogen, both in smaller ships from e.g. the Dogger Bank and in large carriers from e.g. the Middle East, should be taken into account. It is quite conceivable that this hydrogen, together with carbon captured in the port, is processed into synthetic fuels that can subsequently be exported via the existing infrastructure. The present industry and existing port infrastructure around the Caland Canal seem best suited to accommodate this development.
5. In addition to hydrogen, there is a clear trend towards biomass-based fuels and biochemicals. Because the parcel sizes for biomass are likely to be smaller than for refined fuels, it is logical to establish the production, storage and handling of biofuels and biochemicals in the petroleum port, since the port basins have smaller depths compared to the basins around the Caland Canal.
6. Society is increasingly demanding reuse of materials and Europe has relatively few raw material resources. This can provide opportunities for expansion of existing recycling activities already well established in and around the Botlek area. The Damen Verolme shipyard could play an important role in the sustainable dismantling of oil rigs and seagoing vessels and act as a catalyst for the recycling cluster.

Considerations with respect to suggested layout

7. It is logical to develop the Waal/Eemhaven area into a container handling area for short sea container shipping. The basins are smaller than at the Maasvlakte and also located close to the hinterland, which saves road transport cost.

9. Conclusions and recommendations

9.1 Main conclusions

9.2 Recommendations

9.1 Main conclusions

This report presents a comprehensive list of individual trends and structural uncertainties in Chapters 2 & 4. These are integrated into a broader 'meta'-framework by linking them to the so called Kondratieff waves. Conclusions over insights obtained from K-waves and a broader 'meta'-framework are presented in Chapters 3 & 5. Chapter 6 addresses the impact of the trends on the port environment. Chapter 7 presents the narratives on threats and opportunities for port development following from a trend analysis using the 'meta'-framework. These narratives are translated into spatial impacts for the port in Chapter 8.

The main conclusions of Chapters 2-8 are summarised below:

- The world is undergoing a transition that is characterised by a shift from a system based on globalisation and fossil material use, to a system based on sustainability and use of renewable resources. Due to this transition, the present throughput volumes in the Port of Rotterdam could be halved over the next few decades. However, this transition also offers many new opportunities.
- The shift to a renewable system will still require another 1 to 2 decades and this provides a challenge to utilise the available space as efficiently as possible, and smoothen the transition by timely creating promising, desired clusters in the port. By doing so, Port of Rotterdam will remain competitive in a future sustainable business environment (from about 2040 onward).

Main conclusions

- Efficient use of space, now and in the future, requires a clear strategy. However taking all possible future scenarios into account would mean preparing for all possible business developments and creating what the Dutch call a 'sheep with 5 legs' (i.e. something that is capable of almost everything, but at the cost of being non-competitive). A different approach is therefore suggested.
- This study demonstrates that it is possible to anticipate future developments better by analysing trends in an integrated and structured manner. These trends are then translated into narratives, and subsequently, based on the present strengths of the port, the future business opportunities (i.e. new cargoes and activities) are brought into picture. The spatial implications as to promising new clusters, are depicted in Figure 8.20. The figure suggests new futureproof port clusters and indicates their logical location in the port area.
- Clearly the figure is indicative and detailed plan studies are required to determine the needed space, infrastructure, utilities and investments for each activity and cluster. The qualitative approach applied in this study requires detailed studies. However, the information presented and the outcomes of the study provide a good starting point for follow-up studies.

Main conclusions

- We conclude, on the basis of insights obtained from the cyclical movement of the Kondratieff waves, that it is worthwhile to postpone major investments in renewal of existing port infrastructure by about 10 to 20 years. This enables the port to buy time until there is more clarity over future activities and cluster forming, reducing the market risks of developing new capital-intensive infrastructure.
- However, investments in port activities associated with new opportunities as identified in Chapter 7 should not be postponed. The port is advised to act as a pioneer and invest in these activities to create tomorrows leading port clusters.
- To some extent the trend based narratives can also be used to anticipate possible implications for infrastructure development, such as related to the: (1) Impact on ship type / size / no; (2) Impact on infra loads / demand / alternative use; and (3) Impact on cargo handling and storage requirements.
- Repurposing infrastructure for less demanding use (lower draught vessels and/or lighter quay loads) can be a cost effective way to extend the lifetime of existing infrastructures. Especially when it fits within the spatial clustering framework. Possibilities to extended the use of existing infrastructures have amongst others been identified for bio-bulk, shortsea container shipping, and inland cruises.

9.2 Recommendations

- Based on this study the following recommendations are made:
 - Apply 3 layered meta-framework for analysing trends in order to improve understanding of future developments compared to a flat trend analysis.
 - Use insights from trend based narratives to develop a spatial vision for the clustering of future port activities, such as e.g. presented in Figure 8.20.
 - Postpone investment in complete renewal of existing infrastructure by about 10 to 20 years until there is more clarity over future activities and cluster forming. Instead apply necessary life extending refurbishment.
 - At the same time, seize the opportunities for development of promising activities that may become tomorrows leading port clusters that may be expected scale up from about 2040 onwards.
 - Take into account the options to repurpose and extend the lifetime of existing infrastructure while taking decisions as to the future use of existing infrastructure and desired clustering of future activities.
 - Extend the qualitative insights presented in this report with complementary follow-up studies aimed at quantifying the identified impacts.

Recommendations

- Follow-up studies are recommended to cover following aspects:
 - Development of improved long-term projection methods to assess the impact of the anticipated stagnation in the deepsea container segment, taking into account the need for revised economic growth projections;
 - Development of improved long-term projection methods to assess the impact of energy transition on fossil bulk throughput volumes;
 - Creation of clusters of sustainable futureproof business activities, study over the probable transition paths, as well as required space and infrastructure;
 - Conceptual terminal/industrial designs and business models to explore the feasibility of the identified activities within the desired clusters, in order to attract commercial parties and accelerate the transition.
 - Detailed assessments on the impact of climate change on the port environment and the options to prepare the port for these changes.
 - Detailed assessments of the possible implications of the narratives for port infrastructure development (e.g. number, type and size of ships, cargo types and parcel sizes, as well as berthing, mooring and cargo handling requirements).

List of references

- This section contains a list of all references made in the main text.
- References of figures are not included unless they have been specified by author name and date only. These references are indicated below the figures in the main text.
- Not included are also innumerable references that can be linked to the trends listed in the tables of Chapter 2. Including a scientific discussion on how these trends were identified and how they link to the available sources would be an heroic quest.

List of references

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