Ref. Ares(2018)1137792 - 28/02/2018

NAVIGATING THE ROADMAP FOR CLEAN, SECURE AND EFFICIENT ENERGY INNOVATION

Issue Paper on

Scenarios of the global fossil fuel markets

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February 2018

A report compiled within the H2020 project SET-Nav
(work package 4, deliverable D4.3)

www.set-nav.eu

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Work Package Coordinator: DIW Berlin

SET-Nav
Strategic Energy Roadmap

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 691843 (SET-Nav).

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1 Introduction

Despite the European nature of the SET plan and the corresponding SET-Nav project, investigating global developments is essential for understanding pathways to a clean, secure, and efficient energy system. The global scope of climate change is not only an environmental problem, but also policy and economics connect domestic and regional climate policy to the international sphere.

In this regard, global fossil fuel markets are a central factor working through various channels, the most important one being their market prices. Different policies such as efforts to reduce GHG gas emissions have a direct effect on climate change (mitigation, green arrow in Figure 1). However, such policies also have another effect that may be disadvantageous. Indeed, through their effect on fossil fuel producers and consumers, fuel prices may be altered. This, in turn, will affect climate change mitigation, as economic behaviour of private actors is largely shaped by prices setting incentives. Whereas the availability of affordable fossil fuels may boost the economy in the short run, it will hamper the diffusion of renewable energies and slow the global energy transition – with eventually harmful consequences for the climate (red arrow in Figure 1).

The global order as a governing political theme is a major factor when elaborating on the prospects of climate change mitigation and a (global) energy transition. Economically, signals and incentives arising from such policy set a frame for energy markets to move in and to react on. Private investors have an essential effect on energy trajectories, as innovation, learning effects, and cost cutting will depend on them. Also, a more general impact of the state of the world is given, for instance by the possibilities for knowledge transfer as well as the availability of fossil fuels, which can depend on regional stability.

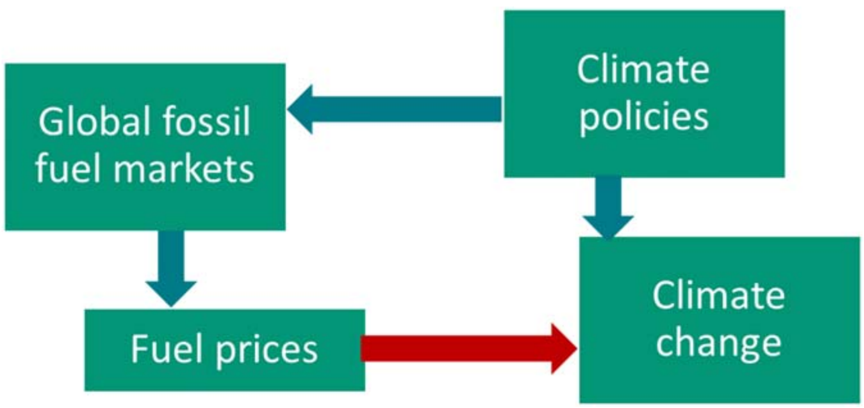

Figure 1: Illustration of the fuel price effect

Therefore, as part of the SET-Nav project, we have investigated four independent and novel scenarios for the global energy markets towards 2050. These will be the frame for the development of the energy markets and energy technologies in the European Union. Bridging between (qualitative) foresight analysis and (quantitative) modelling, we developed the scenarios as a group effort of project members and external experts.

The scenarios describe four very different and rather extreme yet plausible worlds which we believe to bring valuable insights for understanding if and how emerging trends nowadays may be weak signals of forthcoming threats and opportunities. The scenarios do, however, not attempt to predict the state of the global energy system by the year 2050, but they rather give bounds to the range of plausible alternative futures by defining certain trajectories, downside risks, new trends, and 'unknown unknowns' that could significantly affect the success of decarbonisation policies in the years to come. The study furthermore aims at highlighting the importance of an integration of qualitative and quantitative foresight techniques.

The abundance of relevant influences makes it inconceivable for analysts to focus on all developments equally. Hence, we – in contrast to previous work – focus on changes in the global order, on the behavioural perception of climate objectives for policy-makers, and on resulting technological pathways. The work reveals that a successful global renewable energy transition is strongly tied to the development of international relations and the global state of security as well as the integration of energy transition with wider economic objectives, such as poverty alleviation, infrastructure modernisation, and private investment.

Our four scenarios are:

- ***Business as Usual:*** Based on the Paris Agreement and the Nationally Determined Contributions by many polluting countries, but also taking into account recent political developments, this scenario sees a two-speed global energy transition which only picks up in the second half of the outlook period, but still fails to achieve the 2-degree target.
- ***Survival of the Fittest:*** This worst-case scenario sees international climate policy coming to a halt, mainly as a result of low diplomatic and economic cooperation between the large regional powers. Isolated initiatives for the deployment of renewable energy still take place to satisfy national energy agendas, but fail to prevent an intensification of climate-change-related catastrophes and large-scale crises.
- ***Green Democracy:*** Supported by a stabilisation of international relations and greater economic cooperation, this 'best-case' scenario sees an acceleration of the global energy transition. This large-scale system transformation is especially supported by various forms of bottom-up processes, as cities, non-state actors, and individuals play a noticeably more significant role in decarbonisation efforts.
- ***Climate Tech:*** Climate change mitigation efforts weaken as decision-makers anticipate promising technological advances, particularly in the field of geo-engineering. Ambiguous experiences with the new technologies, however, make new institutional frameworks necessary to accommodate the dual need for climate change mitigation and adaptation.

The remainder of this paper proceeds as follows: First, we give a brief overview about other prominent scenarios of the global energy system. Then, we outline this study's methodology in a mostly non-technical manner. Afterwards, we give a synopsis of scenarios with a focus on our base-line scenario "*Business as Usual*". Lastly, we elaborate on some central lessons learnt from the study and conclusions for decision-makers.

2 Scenarios: An overview

In recent years, the global energy system has been marked by rapidly changing dominant trends and events, between the rapid expansion of shale oil and gas, the phase-out of nuclear energy, the drop in oil prices, and the internationally coordinated efforts to mitigate climate change since the November 2015 COP21 summit. This rapidly changing scenery in the energy sector significantly increases the need for decision-makers to understand the underlying inter-linkages and implications of these emerging trends. This rings particularly true for the European Energy Union and its efforts towards achieving the goals stated in the 2030 climate & energy framework.[1] An attempt to transition towards a decarbonised and fully-integrated single energy market necessarily looks several years, even decades ahead. It is therefore no surprise that a successful energy transition for Europe is contingent on understanding if and how emerging trends nowadays may actually be (weak) signals of forthcoming threats and opportunities. In order to successfully navigate towards a de-carbonized future and differentiate relevant signposts from 'white noise', it is more often than not necessary for decision-makers to rely on science to produce models that can estimate the long-term effects of individual policies and technologies on the energy system.

While scenarios have become more and more popular, they have at the same time been quite often misunderstood and misused (Godet and Roubelat, 1996). Even among the foresight analysis community, which focuses heavily on scenarios, there seems to be very little if any consensus even on how to define them, let alone how to best use them (Bradfield et al., 2005), which has led to a fair amount of scepticism on the usefulness of scenarios. Still, because of their value in capturing the complexities of the energy system and in including energy paths consistent with current and alternative (or, at the very least, feasible) policy trends, scenarios remain arguably the "best available tool to assess the magnitude of challenges that lie ahead" (Paltsev, 2016: 22). As Van Notten (2005:7) defines them, "scenarios are consistent and coherent descriptions of alternative hypothetical futures that reflect different perspectives on past, present, and future developments, which can serve as a basis for action".

The way in which scenarios differ from other planning methods such as contingency planning, sensitivity analysis and computer simulations lies mainly in the type of questions that each exercise poses. While contingency planning focuses on 'what if?' questions by presenting a base case and an exception (or contingency), "scenarios explore the joint impact of various uncertainties which stand side by side as equals" (Schoemaker, 1995:26). Moreover, scenario building exercises also differ from sensitivity analysis with regards to how uncertainty is approached. While the former generally considers simultaneous change across several variables, sensitivity analysis only focuses on the effect of a change in one variable while keeping everything else unchanged. Finally, in contrast to computer simulations, scenario analysis seeks to integrate subjective and non-quantifiable drivers, such as cultural and institutional change, which cannot be fully captured through computer models. This leads to an important difference between both techniques, as linear models, in contrast to scenario planning, will often overestimate the extent to which the future will resemble the past (Schoemaker 1995, Söderholm et al. 2011).

For the sake of clarity, this study establishes a seemingly small, yet important epistemological distinction between scenario building and scenario planning. We assume that "building scenarios means speculating about the uncertainty surrounding the future", while scenario planning is "a management technology used by managers to articulate their mental models about the future and thereby make better decisions" which therefore necessarily relies on the former as its foundation (Mietzner and Reger, 2004: 50). While scenario building and scenario planning share similar, if not the same origins and development, this distinction is nevertheless necessary for understanding the methodology and purpose underlying the scenarios presented in this study.

[1] See European Council Conclusions 23 and 24 October 2014, EUCO 169/14. Also see the corresponding documentation by the European Commission in COM/2014/015 final, and the impact assessment in SWD/2014/015 final and SWD/2014/016 final.

Scenario building exercises relying on a smart balance between qualitative and quantitative information inputs can tell "a story of how various elements might interact under uncertain conditions" (Schoemaker, 1995: 26). Furthermore, scenarios enable decision-makers to understand how certain disruptive events and trends, or 'black swans', can shake up the status quo and reshuffle the cards, whether for better or worse. In other words, scenario planning can be understood as 'reservoir thinking´ to better cope with unpredictable developments in times of rapid change and overwhelming complexity, and ultimately to develop strategies that are effective in a wide range of future conditions (Cann, 2010).

One of the most authoritative sources of forward-looking energy analysis is the annual **World Energy Outlook** (WEO), published by the **International Energy Agency** (IEA). It provides a projection of trends in energy demand and supply alongside explanations of their implications for energy security, environmental protection, and economic development. Recent issues of the WEO typically comprise three scenarios: 'New Policies' incorporates all existing and intended policies and measures at the time of publication, while a second scenario, 'Current Policies', only takes into consideration those policies that have already been implemented. Finally, a '450ppm' scenario looks at the necessary policies and measures for achieving the 2-degree Celsius target.

Several international oil companies also issue their own energy outlooks, projecting several decades ahead. **Shell** continues to periodically publish its scenarios for the global energy future, which, in the latest scenario study made public under the title 'New Lens', are mainly driven by the degree of rigidity and centralisation of the overall decision-making apparatus. For several years, **Statoil** has also been publishing a yearly scenario-based outlook, which very much follows similar principles as the WEO, with three scenarios inspired by the principles of 'reform', 'renewal', and 'rivalry'. **BP** and **ExxonMobil** are other examples of oil companies that produce their own outlooks, although these often rely on a single baseline projection.

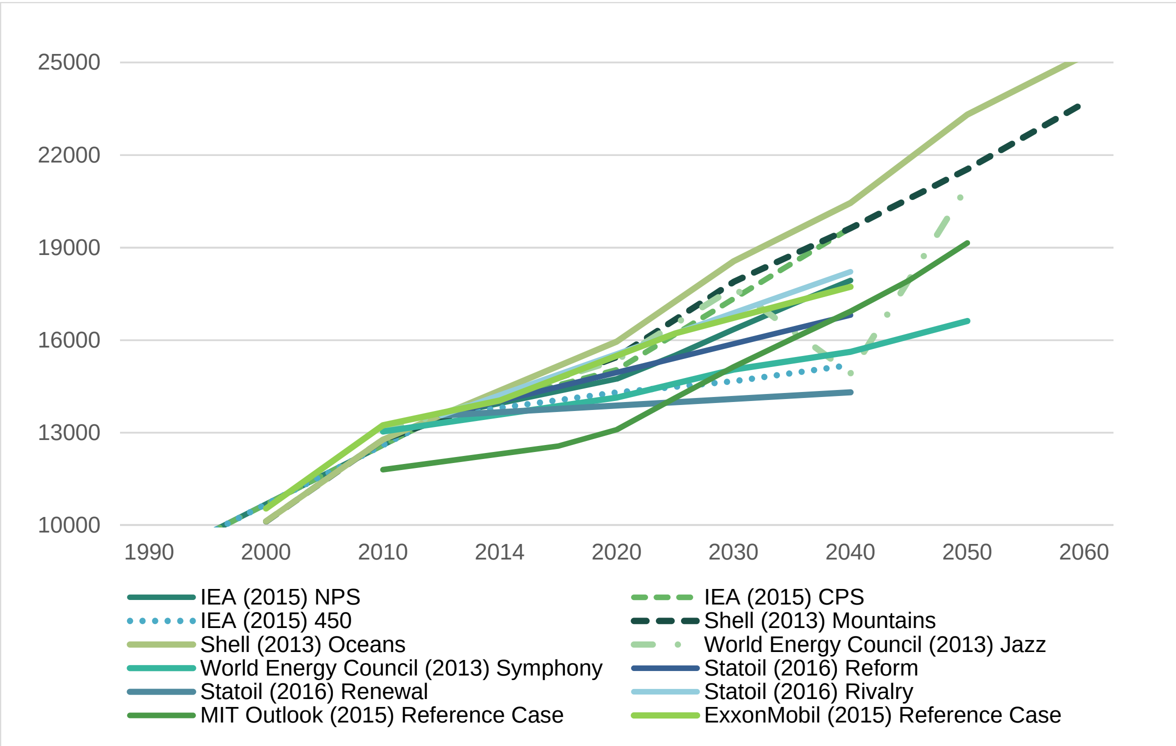

Figure 2: Total primary energy demand across 12 world outlooks (Mtoe)

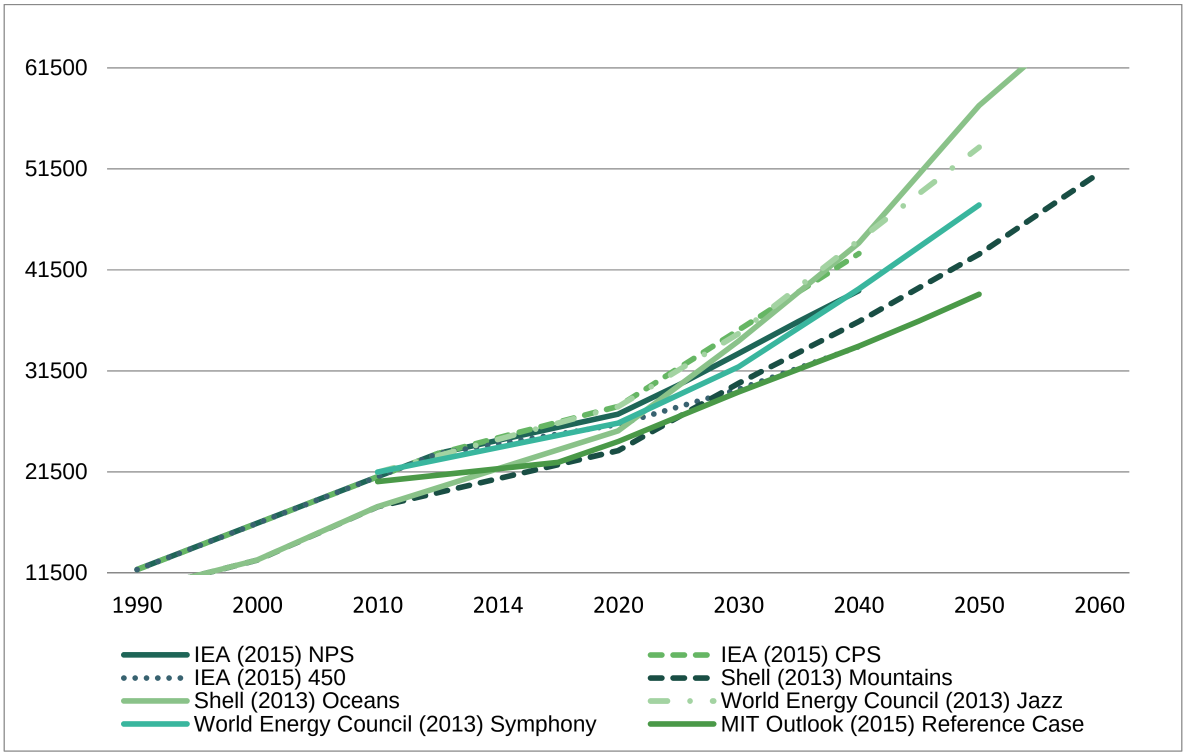

Figure 3: World electricity generation across eight world outlooks (TWh)

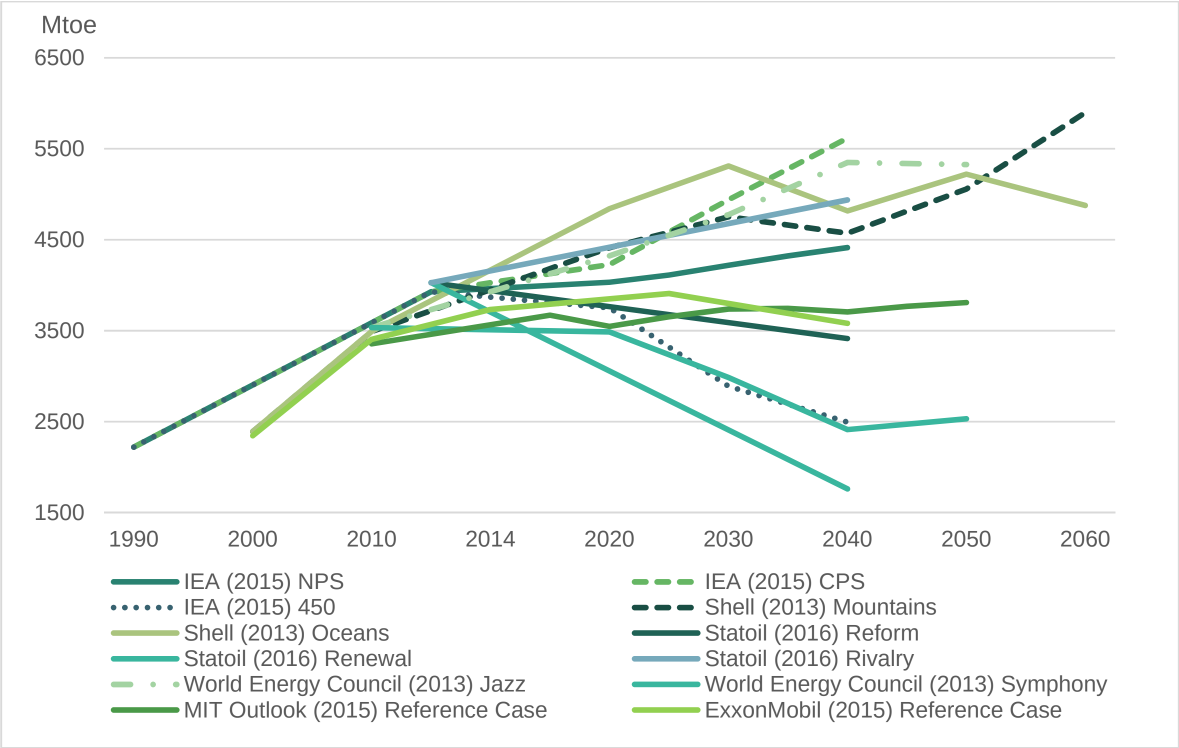

Figure 4: World coal demand across twelve world outlooks (Mtoe)

Although each organisation makes long-term energy projections using their own model assumptions and historical databases, it appears that, on aggregate and especially for certain variables such as world energy demand and renewable electricity generation, the results shown vary only little in scope. However, the permanence of several key uncertainties characterising the global energy system suggests that other plausible alternative futures exist outside of this restricted range and can bring additional insights to the consumer of these 'classical' scenarios.

In recent years, the generation of scenarios for the world energy system has also been widely popularised among other non-state actors, such as interest groups or research institutes. The **World Energy Council** (WEC) has, based on a mix of qualitative foresight analysis and quantitative modelling, produced two scenarios. These are 'Symphony' and 'Jazz', which are driven by a dichotomy between coordinated and uncoordinated energy and climate policy. Finally, the **Massachusetts Institute of Technology** (MIT) also provides a yearly single reference case which assesses the pledges made by the signatory countries at the Paris 2015 summit.

Figure 2, **Fehler! Verweisquelle konnte nicht gefunden werden.**, and Figure 4 show the projections of a selection of scenarios for global total energy demand, electricity generation, and coal demand respectively. Besides differences in the magnitude, there seems to be a consensus that the demand for electricity is going to decrease sharply throughout the next four decades. Projections for primary energy demand show a slight divergence, yet all show a modest to strong increase. Analysing the forecasts for coal demand, however, reveals significant differences between the outlooks, even strongly varying in the overall trend. While some see continued increases in their references cases, other also "conservative" ones foresee a stagnation of demand while more progressive scenarios predict an even sharp decrease.

This offers the conclusion that, despite similarity in total energy and electricity figures, the question how these demands will be met is largely debated. That, in turn, emphasises the role of fossil fuels, being an open question when comparing these outlooks. While an expansion of global energy demand could be answered by green growth, i.e. relying on renewable energies, energy efficiency, and alternative concepts of transport, it could also be met with the status quo of the energy portfolio, fuelling climate change, and result an overshooting of fossil fuel consumption and GHGs. Loosing prospects from these narrow binary images, also numerous solutions with low-emitting technologies such as carbon capture and storage (CCS) or different climate change adaption are possible. Which way will be finally chosen depends on numerous variables that shape the global techno-economic system and policy.

While most popular scenarios set their lines of division across the set of climate policies assumed, our scenarios begin on a more general level. Global policy and geopolitics set the broad frame for action to take place in. Climate policy itself exists in an ambiguous relationship with other political objectives, and decision-makers will favour certain objectives in certain environments. Due to the global nature of climate change, international coordination is a crucial issue, and the perception of the importance of climate issues may vary for both politicians and citizens if facing different security environments. Of course, economic actors such as investors and firms are not unaffected by these developments. Different states of the world create different incentives and possibilities to engage in novel technologies, affecting their costs and trajectories in turn. The diffusion of technologies can hence not be disentangled from their surrounding parameters. Obviously, necessity, availability and tradability of fossil resource behave likewise and alter the system's needs and permissions significantly. This is why have decided to build our scenarios on assumptions regarding changes in the global order, the behavioural perception of climate objectives, and resulting technological pathways.

3 Methodology

The future development of global energy and fossil fuel markets is subject to numerous uncertainties, which is why researchers make use of forecasting to predict possible pathways (see Krey (2014) for an overview of methods and examples). Qualitative forecasting, on the one hand, allows for the inclusion of a wide range of possibilities and factors but fails to estimate the system-wide consequences and to produce reliable numbers. Quantitative forecasting, on the other hand, delivers consistent and precise numerical results, but it is inherently bound by the assumptions and rules of the underlying model.

This study is also intended to show a possible synthesis of qualitative and quantitative scenario building. It demonstrates how storylines can help simplify the complex interactions and dynamics that make up the global energy system and can, hence, contribute to successfully navigating our economies towards a decarbonised future. This navigation, yet, requires precise numbers for validation and guidance. For this, we show how the results of a multi-sector multi-fuel model, parametrised according to the storylines, can provide a stable background for the storylines to be used for decision-making.

First, we developed qualitative scenarios using strategic foresight. Multiple scenario generation was conducted in three fundamental steps: (a) identifying key drivers, (b) generating mutually exclusive scenarios, and (c) defining indicators of each pathway. The first two steps were carried out in an expert workshop with practitioners, analysts, and academics. Led by a specialist scenario-workshop facilitator, participants constructed initial scenario themes. Storylines for all four scenarios were elaborated via additional desk-research, and indicators were defined by generating several objectives and observable hypotheses for each alternative scenario.

For the quantitative part, DIW-maintained MULTIMOD is used, which is a multi-fuel multi-sector model of the global energy system with a particular emphasis on the inclusion of imperfect competition, endogenous investments, and endogenous fuel substitution via computationally-calibrated end-use costs (see e.g. Huppman & Egging, 2014; Langer et al., 2016; Oke et al., 2016). Based on the storylines, critical input parameters for MULTIMOD (e.g. reference demand, parameters for future technologies, transport possibilities) were quantified and fed into the model with base year 2015. Key variables to support the storylines and attach numbers to them are obtained from the model in ten-year steps (2015, 2025, 2035, 2045, 2055).

4 The energy system towards 2050: four scenarios

Using the methodology outlined above, we have developed four distinct scenarios of the global energy system towards 2050. Table 1 gives a comparative overview about them regarding selected central dimensions. In our *Business as Usual* scenario, we foresee a continuation of current mitigation efforts alongside persisting geopolitical tensions, leading to insufficient efforts to achieve the 2-degree Celsius result. More severely, *Survival of the Fittest* is a worst-case scenario that considers a paralysation of global governance and cooperation, leading to a rapid exhaustion of the carbon budget and large-scale crisis. Contrasting to that, *Green Democracy* accounts for a state of international cooperation and interlinkage of sustainable development goals, which achieves a global green energy transition. *ClimateTech*, lastly, considers the ambiguous effect of advances in promising new technologies on the dual-necessity for mitigation and adaptation efforts. In more detail:

- ***Business as Usual:*** The prolongation of (geo-)political tensions diverts resources and interest from climate issues, such that COP21 is widely respected and fulfilled but not succeeded by more ambitious aims. Increasing, carbon-intensive energy demand, especially driven by the developing world, can only partly be offset by progress towards decarbonisation in emerging economies and the EU. The pace of global energy transition only starts to accelerate towards 2030, but these efforts fail to remain under the 2-degree Celsius threshold, leading to an intensification of localised climate change-related catastrophes toward the end of the period.

- ***Survival of the Fittest:*** Low diplomatic and economic cooperation between the large regional powers brings international climate policy to a halt, albeit isolated initiatives for the deployment of renewable energy for satisfying national energy agendas. The carbon budget is filled towards the end of the 2020s, leading to an intensification of climate-change-related catastrophes and large-scale crises. These new crises and the resulting tensions furthermore hinder government responsiveness in many host countries, thereby drastically delaying even further any concerted adaptation measures and increasing their costs.
- ***Green Democracy:*** Supported by a stabilisation of international relations and greater economic cooperation, global energy transition accelerates due to support from various forms of bottom-up processes. Cities, non-state actors, and individuals play a noticeably more significant role in the deployment of renewable energy sources and energy-efficient technologies. More generally, a greater integration of energy and climate policy with other economic and social objectives takes place and enables governments to tackle energy poverty, while the 2-degree Celsius threshold is respected and climate change has only localised impacts in the medium-run.
- ***ClimateTech:*** Decarbonisation efforts weaken as decision-makers anticipate promising technological advances, particularly in the field of geo-engineering, that are considered sufficient for delaying the overrun of the carbon budget. Technologies such as carbon capture and storage and solar radiation management are deployed around 2030 and enable better control over carbon emissions in the long-run, despite environmental complications. However, they only buy time for developing structural solutions based on low carbon-emitting energy sources which is why the dual-need for climate change mitigation and adaptation arises.

The remainder of this section will elaborate the *Business as Usual* scenario and provide an overview of key variables. The other scenarios are highlighted in the detailed case study report (SET-Nav Deliverable D4.4.).

4.1 Business as Usual

Driving forces

The scenario relies on two key driving forces: first, a continuation of geopolitical tensions consolidated by the multiplication of localised conflicts and an entrenchment of diplomatic positions by the main actors on the international scene (US, EU, Russia, China). Second, and despite the aforementioned, the fulfilment of the National Determined Contributions (NDCs) as issued by the majority of countries signatories of the Paris Agreement, albeit with practically no overshoot. Given the geopolitical environment, the extent to which renewed support for multilateral responses to climate change in the years beyond 2025 and 2030 can affect a global energy transition in line with the 2° Celsius target is contingent on economic growth and openness.

Key uncertainties to 2050	Business as Usual	Survival of the Fittest	Green Democracy	Climate Tech
Geopolitical forces	Prolongation of current conflicts, but no escalation	Intensification and expansion of current conflicts	Quick de-escalation of major conflicts and tensions	Prolongation of current conflicts, but no escalation
Technological innovation	Investments lead to cost-cuts of renewables and the diffusion of electric vehicles but do not suffice to decouple growth and CO^2	Isolationism depresses investments and, thus, innovation in energy generation, efficiency, and end-use technologies	Strong decarbonisation policies motivate R&D, leading to strong cost-cuts in green technologies; CCS is available in an early stage.	Sudden advances in various generation and decarbonisation technologies, which are deployed after 2030
Support for Renewables	National, non-coordinated support schemes for RES (with the exception of the EU)	Dependent on domestic endowment in resources; coordination, at most, happens in regional blocks	Strongly driven by ambitious multilateral carbon emission reductions programs	Support schemes are slow to pick up; renewables are mostly market-driven
Evolution of fossil fuel markets	Persistence of FF in most parts of the world (with the exception of EU and China)	Fossil fuels are consolidated by low prices amid large natural endowments	Coal is phased out by 2030, while oil only remains in a few key industries	Persistence of FF in most parts of the world (with the exception of EU and China)
Carbon intensity of the Global South	Rising carbon emissions in Africa are partly offset by a push for green growth in other emerging regions	Rising energy demand in the Global South almost exclusively satisfied by dirty fuels	Green-growth in the global south including smart cities and decentralised sustainable generation	International slowdown of energy transition efforts includes the Global South
International climate policy	Mostly state-driven, operating under the UNFCCC; new multilateral initiatives are delayed until the 2030s	UNFCCC has lost legitimacy; climate policy is driven by informal alliances with an emphasis on adaptation	Multi-level cooperation regimes promoting bottom-up initiatives; climate targets are tightened and become binding in the 2020s	Climate change mitigation is less preponderant; parallel institutions arise due to new technologies
Dominant dimension of the energy trilemma	Energy accessibility and affordability	Energy security	Environmental sustainability	Energy accessibility and affordability

Table 1: Overview of the four scenarios

The Paris promise: between targets and ambitions

The late 2010s and early 2020s see a prolongation of geopolitical tensions and localised conflict that worsen human and economic conditions not only in the Middle East and Africa but also in OECD countries. While this geopolitical situation does not directly impact the achievement of climate targets set by countries in their respective NDCs, political priorities are diverted from climate and energy issues.

While the Paris Agreement constitutes an important attempt at coordinating national agendas with regards to climate and energy policy, the aggregation of NDCs does not suffice to achieve the necessary reduction of emissions that would reach the 2° Celsius target. The agreement is only a first step and poses several additional challenges. While national ambitions on mitigation objectives are converging, much still needs to be done with regards to adaptation measures. Further questions relating to financing schemes to support developing countries' plans as well as frameworks that could foster technology transfers have yet to be addressed effectively.

Climate targets announced in the countries' NDCs in the aftermath of the Paris Agreement are all met in the *Business As Usual* scenario. However, the re-evaluation of those targets and associated measures, requested to take place every five years, brings only very modest changes to the original ambitions of the signatory countries. Between 2018 and 2025, among the top 10 GHG emitters that signed the Paris Agreement, only the EU and China will effectively scale up their efforts in comparison to what was pledged in 2015 and immediately thereafter.

Carbon pricing and taxation is not enforced globally but instead relies on regional, national, and local implementation. In the mid-2020s, the EU and China make their policies even more stringent. While under Republican leadership, the United States do not witness much change with regards to carbon pricing, and mostly rely on a handful of cap-and-trade initiatives at the state and regional level.

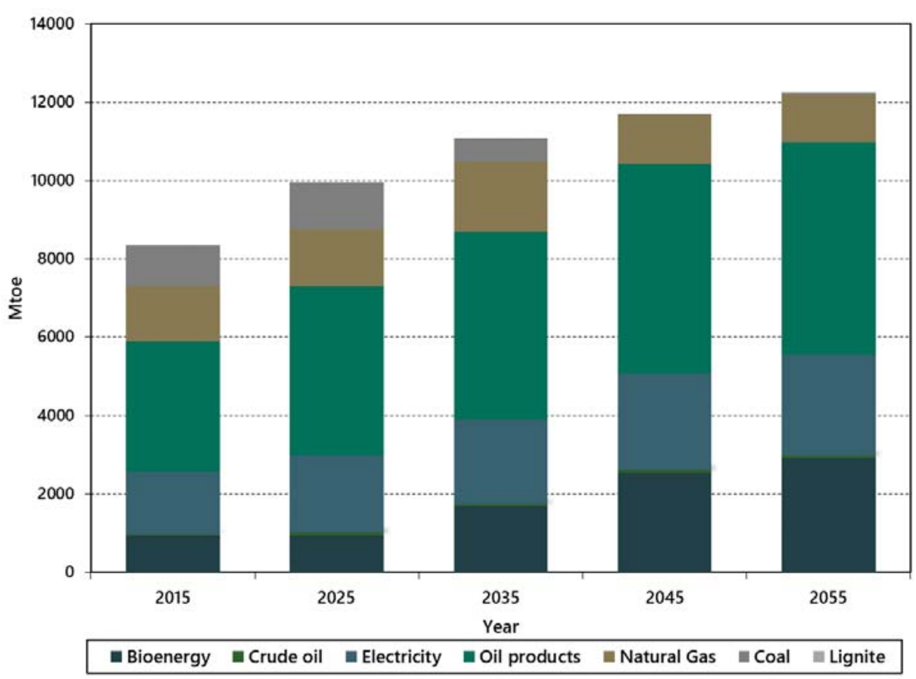

Figure 5: Results from Multimod for global final energy demand in *Business as Usual*

These initiatives, being more modest than initially hoped for, do not spur the necessary investment in renewable energy generation and end-use efficiency for effectively tackling the growth in energy demand from much of the developing world, which is notably driven by a doubling of Africa's population over the period 2017-2050. In addition, the carbon intensity of the African continent increases continuously, resulting from the continent's coal and oil dependency for electricity generation and mobility, while biomass continues to be widely used for cooking. India's climate policy makes incipient progress through stricter vehicle standards and a number of gas power plants. But emissions from coal-fired electricity generation rise steeply and make India one of the world's largest polluters. More generally, despite a diffusion of micro-grid installations, targeted green investment programs, and a significant amount of new hydropower projects in the Global South, whether through private actors or multilateral development banks, these do not suffice to curb carbon emissions in these regions.

This trend is partly offset by more positive developments among several other large polluters. For one, Chinese coal consumption continues to fall throughout the entire period, thus contributing in the short-term to carbon emissions peaking in the first half of the 2020s and further consolidating China's role as a pillar for future international climate cooperation. The MENA region also takes a more positive stance towards decarbonisation, although progress is still constrained by conflicting interests with the regional fossil fuel sector that becomes ever more dependent on domestic consumption.

Despite the absence of a global carbon pricing mechanism and the insufficient schemes for supporting growth of renewable energy production in the first decade of the scenario, developments in certain key areas of the global economy awaken hope for renewed action towards mitigating climate change and transforming the world energy sector further in later years. For example, while global demand does not yet switch away from coal in the 2020s, new solutions start to emerge at the turn of the 2030s.

All in all, the 2020s see renewable energy and fossil fuels co-exist with geographical variation. Transport in the Global South is virtually entirely using fossil fuels, whereas the diffusion of electric vehicles accelerates slowly in many industrialised economies. A similar picture emerges for electricity generation: Europe and China make significant advances towards decarbonisation, while fossils still dominate in the rest of the world, supported by the absence of joint political action or technological advances.

Catching up in 2030

The pace of the global energy transition does indeed accelerate in the 2030s and 2040s, helped both by renewed action taken by the United States which are invigorated by a new, more climate-friendly political leadership, and by technological advances that become widely accessible.

Concerning technological advances, the transport sector is subject to important changes, with electric vehicles experiencing significant cost decreases by the mid-2020s, although wide-scale deployment only takes place in the following decade. Traditional combustion-engine cars continue to persist in many parts of the globe. Freight and air travel do not undergo any major changes. Renewable electricity generation becomes increasingly cheaper relatively to electricity from coal and gas due to declining generation costs following both public and private investment in research and large-scale deployment. Carbon capture and storage (CCS) becomes available and enters power generation, yet the technology stays expensive and efficiency stays below expectations. Other technologies, such as nuclear fusion, are still far from being available, although research in those technologies nevertheless continues.

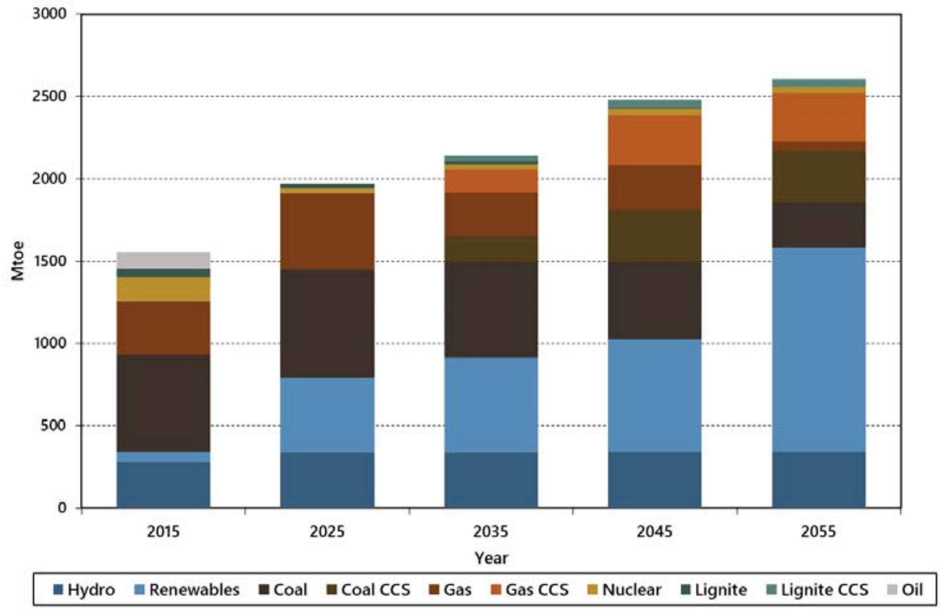

Figure 6: Results from Multimod for global power generation fuel mix in *Business as Usual*

The catch-up in climate policy by the United States, which already begins in the second half of the 2020s, enables a new and significant multilateral push towards decarbonisation in which all large emitting countries take part. This effort comprises stricter limitations on coal production, coordinated action against carbon leakage, and the set-up of important financing schemes for supporting climate adaptation.

A global substitution between fossils and renewables only takes place in the 2030s and 2040s. Thus, the importance of fossils decreases substantially, and global collective action for climate change mitigation still operates within a UNFCCC-type framework. However, the associated targets are mostly binding.

Still, this re-invigoration of climate change mitigation efforts fails to remain under the 2° Celsius threshold, leading to an intensification of localised climate change-related catastrophes toward the end of the period.

Indicators

- The Paris Agreement is respected, but is not followed by more ambitious multilateral decisions until the 2030s. Despite isolated progress on national level, there is no global carbon price.
- Current political tensions on both global and regional level continue to exist but do not escalate and proceed to cool down during the 2020s.
- Clean energy solutions fail to meet growing energy demand in developing economies, mostly supplied by fossil fuels.
- Fossil fuels and renewables coexist, with electricity and transport decarbonisation not ascending substantially before 2030.

5 Discussion and Policy Recommendations

Despite the prominence of the scenarios by institutions such as IEA, the lack of robustness of forecasts to changes in either data or modelling approach makes new scenario research anything but superfluous. A comparison of well-established scenarios shows that while global electricity demand projections are similar across different studies, pathways for fossil fuels show significant divergence over time.

Global energy transition is particularly sensitive to three main forces, namely: i) the state of international politics which itself is to a large extent contingent on security matters; ii) the integration of economic and energy-related objectives and incentives; and, iii), the balancing between climate change mitigation and adaptation responses. International relations and the state of security are strongly tied to the renewable energy transition in the long-run, while energy transition needs to be integrated with wider economic objectives, such as poverty alleviation, infrastructure modernisation, and private investment. Moreover, it is crucial to develop an inclusive approach to policy-making that combines both mitigation and adaptation options.

Particularly, decision-makers should be aware of the following:

- **International relations and the state of security are strongly tied to the renewable energy transition in the long-run.** Regional conflicts and resulting humanitarian crises have fuelled the re-emergence of protectionist policies and represent a risk not only for European integration, but also for the effectiveness of the European Union's energy and climate policies in the absence of multilateral climate cooperation. However, as some recent examples have shown, too, greater cooperation between countries in the form of investments as well as technological and financial transfers could well spur a new dynamic for international climate policy.
- **Energy transition needs to be integrated with wider economic objectives such as poverty alleviation, infrastructure modernisation, and private investment.** While that relationship appears to already hold in today's world, it is easily strained by political tensions and protectionist policies. Growing energy demand from the developing world can easily jeopardise mitigation efforts if coordination between economic and energy-related objectives is absent. The 'Green Democracy' storyline, however, conversely highlights the opportunities to be seized in the energy transition.
- **It is crucial to develop an inclusive approach to policy-making that combines both mitigation and adaptation options.** Adaptation technologies are not necessarily risk-free and failure to adopt a comprehensive approach could very well lead to new environmental, societal, and political problems that would further hinder the global energy transition. At the other end of the spectrum, balancing the use of both options can encourage new investments, stakeholders, and more dynamic relationships between the relevant actors.

The scenarios make clear that is necessary to look beyond the economics of energy markets for a comprehensive understanding of climate policy. Indeed, several factors can be influential – and can therefore be tackled by policy-makers. While the complexity of drivers of climate policy and emissions may be discouraging, the variety of tuning parameters for policy-makers to convince their partners of ambitious climate policy should actually be viewed as an advantage. The realm of tuning parameters goes from technology and innovation support over (regional) geopolitics to trade policy and, of course, energy policy.

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Project duration:	April 2016 – March 2019
Funding programme:	European Commission, Innovation and Networks Executive Agency (INEA), Horizon 2020 research and innovation programme, grant agreement no. 691843 (SET-Nav).
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About the project

SET-Nav aims for supporting strategic decision making in Europe's energy sector, enhancing innovation towards a clean, secure and efficient energy system. Our research will enable the European Commission, national governments and regulators to facilitate the development of optimal technology portfolios by market actors. We will comprehensively address critical uncertainties facing technology developers and investors, and derive appropriate policy and market responses. Our findings will support the further development of the SET-Plan and its implementation by continuous stakeholder engagement.

These contributions of the SET-Nav project rest on three pillars: modelling, policy and pathway analysis, and dissemination. The call for proposals sets out a wide range of objectives and analytical challenges that can only be met by developing a broad and technically-advanced modelling portfolio. Advancing this portfolio is our first pillar. The EU's energy, innovation and climate challenges define the direction of a future EU energy system, but the specific technology pathways are policy sensitive and need careful comparative evaluation. This is our second pillar. Ensuring our research is policy-relevant while meeting the needs of diverse actors with their particular perspectives requires continuous engagement with stakeholder community. This is our third pillar.

Who we are?

The project is coordinated by Technische Universität Wien (TU Wien) and being implemented by a multinational consortium of European organisations, with partners from Austria, Germany, Norway, Greece, France, Switzerland, the United Kingdom, France, Hungary, Spain and Belgium.

The project partners come from both the research and the industrial sectors. They represent the wide range of expertise necessary for the implementation of the project: policy research, energy technology, systems modelling, and simulation.

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