A systemic approach to the energy transition in Europe

29 January 2021

Expert workshop report

SAPEA
Science Advice for Policy by European Academies

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About SAPEA

SAPEA brings together outstanding expertise from natural, applied, and social sciences and humanities, from over a hundred academies, young academies and learned societies in more than 40 countries across Europe.

SAPEA is part of the European Commission's Scientific Advice Mechanism. Together with the Group of Chief Scientific Advisors, we provide independent scientific advice to European Commissioners to support their decision-making.

We also work to strengthen connections between Europe's academies and Academy Networks, and to stimulate debate in Europe about the role of evidence in policymaking.

Europe's academies draw on the best scientific expertise to provide independent, balanced and authoritative scientific advice. This approach makes SAPEA a critical source of evidence for policymakers and the wider public.

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Introduction

The transition of the energy system is a key challenge and priority for the EU. It should be seen in the context of the European Green Deal which follows the principle of 'green and clean'. Most countries, including the US, Russia, Japan and China have joined the EU in the ambition of reaching net zero emissions by the middle of the century or soon after. But emissions are not the only issue. All the negative externalities of the energy system need to be considered, and also the social imbalances associated with the large number of people who are excluded and unable to afford their energy supply. Much work is needed to overcome the barriers and realise the opportunities presented by the energy transition and this report will provide a valuable contribution to that challenge.

This report is being produced as part of a project being carried out by the European Commission's Scientific Advice Mechanism on a systemic approach to the energy transition in Europe. The mechanism is composed of the Group of Chief Scientific Advisors, supported by the Science Policy, Advice and Ethics unit of DG RTD and by SAPEA.

This report is an integral part of the project. It is a summary of a SAPEA expert workshop which provided a critique of the draft SAPEA Evidence Review Report. Attendees included representatives from the wider expert community in the field of energy, including from industry, NGOs, universities and academies.

Scoping paper

Two important documents framed the project and guided the course of the work on the Evidence Review Report. These were the scoping document and an annex setting out relevant background questions. The key word in the title of the project is 'systemic' — the need to take a systems view of the challenge.

The main question of the scoping paper was:

> How can the European Commission contribute to the preparation for, acceleration, and facilitation of the energy transition in Europe given the present state of knowledge on the possible transition pathways?

The full scoping paper is available online:

- https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/scientific-support-eu-policies/group-chief-scientific-advisors/systemic-approach-energy-transition-europe_en

In answering this question, consideration should be given to constraints from technologies, services, energy sources, economics, raw materials, pathways, social issues and environmental boundaries, while previous work by the national academies should be taken into account.

The annex of background questions was an aid to support and guide the study. This highlighted the need to approach the main question as an interacting clockwork of social, economic and technical factors.

List of participants, programme and guiding questions

This expert workshop took place online on 29 January 2021 from 14:00—18:00 (CET).

SAPEA's expert workshop is a vital part of the evidence review process (see SAPEA Quality Assurance process: https://www.sapea.info/publications/quality-assurance/). Its purpose is to provide critique of the draft Evidence Review Report by the wider expert community. Feedback is given informally by the invited experts, offering constructive input to the Working Group. This workshop is also an opportunity to develop further the conclusions and evidence-based policy options in the Evidence Review Report.

Experts are invited in their capacity as expert in the field. All attendees gave their views in a personal capacity and not as representatives of their employer or any other organisation with which they are associated (including industry, NGOs, universities and academies). Chatham House rules were observed, with no attribution of any comments to any individual.

The list of participants, programme and guiding questions are attached as an annex to this report. The guiding questions were sent to the invited experts ahead of the workshop to help them prepare for the meeting and ask questions to the co-chairs of the working group on the draft report. The present report summarises the discussions and follows the different chapters of the draft report at the time of the meeting. Following the expert workshop meeting, the structure of the report was changed and therefore the different chapters presented below do not correspond to the final published report. However, the title of each chapter and its summary help to understand which issue was discussed. The input of the experts was discussed in subsequent meetings of the working groups and addressed in the Evidence Review Report.

Chapter 1: The EU in a global context

This chapter contains the systemic elements that appear as a common thread throughout all the subsequent chapters.

It points out that Europe has a huge responsibility to lead the way in decarbonisation, reflected in the fact that it has set ambitious targets in a tight timeframe. But climate change is a global problem and Europe must work towards a global solution, while recognising the heterogeneous nature of the EU's member states. Comparisons are made between the three major global economic blocs — the US, China and EU. The EU's favourable position in terms of progress in the energy transition is noted, but also that this means many of the easier 'low-hanging fruit' options have already been taken, making further progress potentially more difficult. It is therefore important that the EU adopts climate policies that encourage others to join in while maintaining open trade with the rest of the world.

The chapter goes on to discuss the need to ensure that the energy transition does not compromise the economic viability or competitiveness of the EU economy. Climate policies need to be effective in reaching their goals, but economically efficient in terms of not wasting resources and implemented in a way that creates as little social distortion as possible. Prosperity and climate policy must be combined at the global level, meaning diplomacy to help build a global alliance will be a critical part of EU policies going forward. This will have geopolitical implications, particularly with regard to countries with large fossil fuel resources. Ultimately, it is the majority view that this will need to be tied together through the introduction of carbon pricing.

The chapter also includes a discussion of the implications of the COVID-19 crisis. In the short term, this was a major shock to society and led to reductions in energy demand. But, in the long term, the challenge remains the same: to completely decarbonise the economy.

Discussion

Along with general approval for the overall content of the report, the following points were made regarding the content of chapter 1:

- The criteria proposed for the ambitious emissions reduction targets — that they are economically efficient, without social distortion and do not harm competitiveness —

should factor in the desired outcomes. It would be useful to define the concept of 'economic prosperity' in terms of endpoints or goals. In particular, it is important to understand how to weigh short-term prosperity against long-term prosperity and the sensitivities around this issue in climate policies.

- Consideration should also be given to the possible co-benefits from reducing emissions, such as increased circularity of materials and less air pollution, that could have significant economic value. Including a criterion that there should be no harm to the environment could also be considered.
- The geopolitics of the energy transition should not be underestimated. On the potential of fossil fuel reserves becoming stranded assets, this is not a risk but a necessity if targets are to be met. Although alternative sources of revenue might be developed by fossil-fuel-rich nations, there will inevitably be winners and losers which leads to political resistance and a possible drive to lower the ambition for the targets by some countries. The issue is addressed in the report but could maybe be emphasised.
- It would be helpful to point out the enormous scale of the challenge faced by the EU to reach net zero emissions by 2050. Currently, there are no scenarios for the energy transition that indicate that the EU is now on a pathway that will meet either the 2030 or 2050 targets. Evidence, either from the EU or globally, on why emissions reductions are needed and the timeframe in which these need to occur would be useful to include. This is important in respect to when technologies will need to be deployed or how long it would take to introduce a global carbon price.
- There is no mention of EU citizens in the chapter. It would be advisable to include them in this chapter and indicate what it is that they do, or do not, expect from the energy transition. Citizen engagement will be critical to the energy transition and a greater emphasis on behavioural economics is needed.
- It is important to be precise in the language used in an evidence-based report. For example, the terms clean energy, renewable energy and low-carbon energy are not equivalent, particularly in the case of nuclear energy.
- Although the need to take a systemic approach is made clear in the scoping paper, this does not come through clearly in the framework of the report. An introduction to explain the structure of the report would help in this regard, including a more consistent approach to how policy options appear in the report, which is currently quite varied. In general, the report would benefit from a clearer narrative.
- Taking a systems approach is always challenging, but the report could be bolder in its recommendations. Possible options would be: the expansion of the EU ETS scheme to new sectors and to tighten the cap on emissions allowances; development of the electricity markets to include all options for balancing and flexibility to support wind and solar power; and funding of first-of-a-kind energy projects that will balance risks and ensure learning.

- A clearer link to the literature review would also be beneficial.
- Any link to the Sustainable Development Goals in the global context is missing.
- It is not clear why the heterogeneity of EU member states is included in a chapter on the global context.
- In terms of global cooperation, some indication on possible ways to foster this cooperation would be helpful and in which areas it is important. Further discussion on energy security could be added to make it more comprehensive.
- The chapter needs to emphasise the question from the scoping paper on what the EU can do to facilitate the energy transition. The evidence presented in the report should support the need for a multi-level-governance approach.
- The concept of 'effective value of carbon' or 'shadow price of carbon' should be included. If targets are to be met by 2050, the value of carbon will need to increase significantly. This will need to be factored into economic forecasts by businesses when making investment decisions.

Chapter 2: Energy transition pathways and electrification

This chapter starts with the technical basis for the report, which flows from a consensus of how most experts and scenarios expect the energy transition broadly to unfold. The main features of this consensus are a significant increase in variable renewable energy, mainly wind and solar power, that will decarbonise the electricity system. In turn, this will lead to large-scale electrification of other sectors such as transport, industry and buildings. Demand reduction and management will play a major role along with sector integration. There will be other supporting low-carbon technologies including carbon capture and storage, nuclear power and bioenergy and all of this will depend on the systemic issues already discussed. This summarises the general position adopted throughout the report with differences in the possible pathways towards the end goal expected. Supporting evidence for this consensus is provided, mainly derived from EU policies and communications.

The chapter continues with an assessment of the implications of increased levels of variable renewable energy and how this needs to be managed efficiently in a way that maintains a secure, balanced and flexible power system. Consideration is given to the advantages of an enhanced electricity transmission network that allows the efficient placement of renewable energy generation and the market implications of the shift to variable renewable energy.

Discussion

- The two most important points on integration are not emphasised enough. First, how does the system cope with periods of low output from wind and solar energy? This is mentioned in the chapter but does not have sufficient prominence and there is no clear systemic solution given. Secondly, the issue of system stability and cost is not explained in enough detail with supporting evidence and more could be said about synchronous inertia and capacity markets. Furthermore, the issue of integration is also dealt with in chapter 4 but there is not a clear reason why this topic is split between these two chapters.
- The chapter lacks the scientific evidence to support the position being adopted. There is a focus on the electricity system, but renewable electricity alone will not be enough to meet the 2050 targets. An enhanced hydrogen system will also be needed and, although this is covered in the report, it is not given enough prominence. In addition, the contribution of the industrial sector is underplayed, in particular the

need for long-term investment decisions to be made. Energy sources from outside the EU will also be important (e.g. solar power from North Africa) and the political implications of this should be considered.

- The chapter, and more broadly the report in its entirety, should include more discussion on the role of decentralised energy production and storage. This is important as a potential source of finance and it encourages vital citizen engagement which can link production and consumption of energy.
- There should be more weight on how to secure the massive increase of market-based renewables to support electrification.
- More detail could be provided on the EU decarbonisation strategies rather than what is currently a list of the legal acts with too much emphasis on the electricity sector.
- A transition period of "several decades" seems to be a bit general. Including a more explicit time element would be helpful to make clear the point that decisions need to be made within a strategy in order to reach the goals in a timely fashion. This is important given the long lead times for many of the investments that will be needed in the energy system.

Chapter 3: Demand for energy and the role of energy efficiency

This chapter focuses on the demand side of the energy system and the expectation that a much more dynamic relationship between supply and demand will evolve as part of the energy transition from the more passive arrangement that currently exists. This can deliver 'win-win' outcomes with demand acting as a fuel within the system and reductions in demand meaning cheaper energy costs to consumers and less generating capacity being required.

The chapter covers the overall role of demand in reaching the EU's climate goals and the progress that has already been made in reducing demand. The future outlook for how energy demand is likely to evolve is then considered along with an assessment of the necessary demand reductions from a range of scenarios that meet net zero emissions goals. Also considered is the 'rebound effect' that is observed following the introduction of energy efficiency measures. The chapter concludes with an assessment of measures that could help contribute to reducing energy demand in the EU energy system.

Discussion

- The general inclusion and approach of the chapter was commended. Given the importance of the role of energy demand, it was felt that the issue could be introduced even earlier in the report as part of chapters 1 or 2. In addition, the issue of energy efficiency is also considered in section 4.2.1 which could potentially be better placed in this chapter.
- The concept of 'directionality' was raised which highlights the fact that within the system there are many different actors making decisions and, if the climate goals are to be met, these decisions need to be directed towards that final goal. In this respect, visionary scenarios are important and although these are considered in the report, more emphasis could be placed on them.
- The importance of instilling a sense of realism in terms of the results that energy efficiency measures can deliver was highlighted, particularly in terms of what can be expected from the engagement of 'prosumers' who will only make up a small proportion of the population.

- The economic efficiency of energy efficiency measures was questioned with regard to the payback periods that consumers will face.
- In general, the need to decouple energy use and carbon emissions was highlighted given the fact that demand reductions will inevitably be limited.
- There was a sense that the chapter took an ambivalent position on energy efficiency and the role it could play in reducing energy demand and that it could be clearer on the different positions that exist and their drivers. For example, there was a lot of detail on the Fraunhofer study but not others.
- The issue of 'sufficiency' is considered in the chapter, but the precise meaning of this approach could be made clearer in terms of how it can be implemented as a tool to reduce demand. The concept of growth is also brought up at this point in the report but could be expanded to explain whether economic growth is compatible with emissions reductions and, if so, under what conditions.
- The role of households in energy demand is critical and it is a welcome addition to the report to see the progress made in this sector highlighted. It will be important to draw this through into the policy implications, in particular the contribution that eco design regulations can play as an effective means of managing demand and that these are applied to products globally.
- The example chosen to illustrate the 'rebound effect' is not necessarily the most appropriate as vehicle efficiency standards can work in conjunction with a carbon price. In fact, a high carbon price, imposed on primary fuel providers, combined with high efficiency standards and other policies such as air quality regulations, would be an effective means of managing demand for mobility services. This highlights the need to understand how the range of policy interventions work together in a systemic way.
- Generational behaviour changes will be an important factor to consider, given that the end date of 2050 for climate targets is more than a generation away. The effect of this will be significant as changes in the norms and behaviours of different generations can already be seen. For example, the younger generation are less likely to own cars but more likely to buy smart devices. Patterns of consumption (as shown in figure 10 of the report) will therefore be different for different age groups. This will also give time to change the behaviour of consumers through policy interventions beyond just price incentives, with value for the environment becoming more of a factor.
- In response, it was noted that the effectiveness of energy efficiency standards as a tool to meet climate targets is complex and will need to be clarified in the report.

Chapter 4: Differences in the transition pathways

This chapter focuses on the systemic issues that impinge on the energy transition and how these will play out in the possible pathways going forward. This includes aspects of the technical components of the energy systems and sectoral issues, of which, transport, industry and buildings are considered in the chapter along with the electricity system. The chapter considers how all these elements will interact at a systemic level and their interdependencies.

In terms of the technical issues, the chapter first considers the role of demand reduction (as noted in the previous chapter) given its importance and prominence. Advances in digitalisation are also addressed that are expected to deliver significant innovations in the energy system. A number of particular technologies and fuels are then discussed that are expected to provide potentially sizable amounts of low-carbon energy and have an impact on the transition pathways. This includes nuclear power, carbon capture, utilisation and storage (CCUS), hydrogen and synthetic fuels, and bioenergy. The chapter also includes sections on grid balancing and the challenges related to the scaling-up of energy technologies.

Discussion

- It is important to be clear that the electrification of sectors such as mobility and heating will lead to an increase in demand for electricity and that this will not be offset by energy efficiency measures, although this is still an important issue. This is recognised by the IEA and EU and is a key point to consider when discussing the efficient integration of renewable energy.
- The section on nuclear power only takes into account first-of-a-kind, generation III plants that have long lead times and high costs. However, a mature design and a multi-unit build programme could significantly reduce build times and costs, such as in discussed in a report by the OECD[1] on levelised cost of generating electricity. It is also worth noting that nuclear fuel accounts for only a small proportion of the costs of nuclear power and is unlikely to have an impact on security of supply. Nuclear power can also be used in the manufacture of low-carbon hydrogen — so-called 'pink hydrogen'. This, along with the related local employment, means that nuclear power can play a significant role in the energy transition up to 2050.

1 https://www.oecd-nea.org/jcms/pl_51110/projected-costs-of-generating-electricity-2020-edition

- The technical discussions in the chapter are, in some instances, too general but in others they have a high degree of detail. This needs to be balanced out. For example, the sections on energy demand and digitalisation would benefit from more evidence to support the claims being made.
- The concept of technology readiness levels (TRLs) would be helpful to include when discussing the various technologies as this is an important factor in the deployment of the technologies and will necessitate different policy interventions.
- For the section on synthetic fuels, it would be helpful to point out that the conversion of electricity to hydrogen and then to the synthetic fuel means a low overall efficiency. This increases the cost of the fuel and is likely to limit their use to sectors with few low-carbon alternatives such as aviation or long-distance transport.
- The section on transport is missing any mention of electrified rail transport which is already a major mode of transport in the EU for goods and passengers that has scope to be expanded relatively easily.
- There is a significant risk associated with any reliance on BECCS and other negative emissions technology, given that this is currently empirically unproved. In addition, there are issues relating to supply chain emissions, land use tensions, biodiversity and water demand, high energy consumption, costs, and potential scale of deployment. Overall, there is a need for rigorous evaluation of these technologies.
- The area of the bioeconomy is also very challenging. There are developments of first-of-a-kind bioenergy refining plants where biomass is being used for high-value products. This leads to the concept of a hierarchy for biomass products that would be helpful to consider. Issues relating to biodiversity and sustainability mean that the total amount of bioenergy available for the energy transition needs to be considered very carefully. Clarity on negative emissions is also needed in relation to carbon debt.
- Despite the mention of 'pathways' in the title of the chapter, a clear pathways view is lacking. It might be useful to plot each of the technologies against the criteria set out for the energy transition in chapter 1 as it would be beneficial to understand how they compare in terms of social factors, economic efficiency, and competitiveness, as well as other environmental impacts. This, along with a discussion of possible combinations of technologies, could help provide a better pathways view.
- There is an issue with the structure of the report which means that there is too much focus on the technologies and not on the possible pathways that the energy transition could follow, which is meant to be the main subject of this chapter. A clearer distinction within the report between the pathways and the different technologies would provide a clearer narrative and bring out the systemic issues more easily.
- The trend in combined heat and power (CHP) is currently seen to be declining in Nordic counties as it is no longer seen as being feasible.
- There is a major question regarding the future of natural gas as it relates to the decarbonisation of heating. This has a limited life but is supported by a valuable grid

network. There is no clear consensus on the future of the gas grid, but it is an issue that needs to be addressed, particularly in terms of the timing of the energy transition and the risk of stranded assets. There are opportunities to introduce a blend of hydrogen into the gas grid that are, perhaps, more promising than is suggested in the report.

- It is agreed that CCS was considered a more promising technology in the early 2000s but has since become less popular. But there is now something of a revival because of the urgency of the climate challenge and the probable need for negative emissions technologies. Medium sized regional projects of the order of 100,000 tonnes of CO2 per year that use deep saline aquifers for storage could be considered as economically viable options such as waste incinerators in urban areas.
- The chapter in general takes the dogmatic position of technology neutrality that is common in current discussions on energy policy that does not present pros and cons beyond the cost of a technology and the carbon footprint. This misses the full story that would include, among other things, material circularity and type, waste, air pollution, water use, and environmental impact that should be factored in for each technology and drive investment decisions. A full assessment of the technologies along life-cycle assessment terms would be useful to fully understand their broader economic, social and environmental impacts. This is also important in terms of embodied emissions and the part that the EU could play in global negotiations to ensure that that emissions are reduced regardless of where goods are manufactured.
- The manner in which digitalisation is presented in the chapter is limited to mainly its ability to improve energy efficiency and not its full potential to achieve the climate goals. There are many additional benefits it can provide such as benchmarking the performance of goods or services where the data exists but is not being shared.
- The various processes to produce hydrogen needs greater explanation as there are fundamental differences in these approaches that could, in certain circumstances, have a detrimental impact on the energy transition.
- The section on heating and cooling could include more on heat pumps. Heat networks are clearly important but may not be an option in certain regions where they do not exist, and they would be difficult and expensive to build. Heat pumps offer a simpler solution that will still be effective at reducing emissions if coupled with decarbonised electricity supplies and they can be used in reverse mode to provide cooling when necessary.
- The report needs to be consistent in its treatment of the fact that, to date, emissions have not been significantly reduced despite advances in the deployment of renewable energy (as noted in chapter 1) but that this is the policy that is expected to produce such reductions in emissions in the future. More discussion on this point would be helpful.

Chapters 5 & 6

Fuel aspects in the energy transition & Resource efficiency, critical raw materials and the circular economy

Chapter 5 looks in more detail at some of the fuels that are important to the energy transition including synthetic fuels and hydrogen, and bioenergy. Also included is energy storage and batteries as the function these perform in the power system means that they act as a fuel, particularly in the case of dealing with periods of low output from wind and solar energy. Within the section on bioenergy is a discussion on the hierarchy of use and there is a description of the pros and cons of a range of the fuels in terms of production costs, storage, transportation and distribution, along with the applications in different sectors such as heating and cooling, industry and transport.

Chapter 6 moves beyond energy requirements and considers critical raw materials and resources and issues relating to the fact that the energy transition involves a switch from a fuel-based system to one based on renewable energy and the infrastructure that will be needed to deliver that energy. This will involve the global supply of raw materials and greater emphasis on recycling and reuse and, ultimately, a more circular economy. Also included is a discussion on material use in the construction sector.

Discussion

- There was an important report published recently by the Joint Research Centre on the use of woody biomass for energy production in the EU[2] that discusses some of the issues being debated in this area. This report would be worth considering in the context of this chapter.

2 https://publications.jrc.ec.europa.eu/repository/handle/JRC122719

- Also in relation to bioenergy are issues relating to NOx and particle emissions, as well as agricultural emissions linked to the use of manure and biogas that requires specific considerations that are currently lacking in the text.
- On batteries, too much emphasis is given to second-life use cases for which there is limited evidence for its economic viability and potential business cases. A more critical assessment of this aspect would be advisable. Whereas too little emphasis is given to hydrogen storage that utilises the existing natural gas network.

Chapter 7: Economic and regulatory aspects of the energy transition

This chapter considers the economic and regulatory aspects of the energy transition. It starts out from the observation that the increase in ambition of the climate targets is substantial, meaning that investments and innovations will be needed at an unprecedented scale. Moreover, this needs to happen in a relatively short timescale. Consequently, the longer the EU takes to set out the strategic route the more difficult the challenge will become.

To anchor the discussion in this chapter, reference is made to the recent Impact Assessment (IA) provided by the European Commission. This is used as a starting point, but the quantitative analysis is not replicated. The chapter takes the key characteristics of three of the six scenarios from the IA to provide a framework for a discussion on the possible options available to policy makers. Inspiration is also taken from the Kopernikus Project Ariadne.[3]

In principle there are two polar approaches that could be taken. The first option would be to extend the current approach that focuses on regulatory measures as the primary instrument with carbon pricing playing a supporting role. Alternatively, the carbon price takes the leading role, largely through the extension of the EU-ETS, with regulatory measures playing the supporting role. The former approach is labelled the REG scenario and the latter the CPRICE scenario. In addition, there is a middle ground that is labelled the MIX scenario which can be difficult to define as the implementation of this scenario could vary considerably. For this reason, the MIX scenario is further divided into one which is, in general, well implemented in the sense that it provides a consistent and complimentary set of policies and one which is less well implemented.

The different policy scenarios are assessed according to three criteria: effectiveness in realising the climate targets through consistency and enforcement; economic efficiency to ensure that resources are not wasted; and the political feasibility of enacting the package of measures. In general, the CPRICE scenario performs better in terms of effectiveness and economic efficiency. In terms of political feasibility, both the REG and CPRICE scenarios face challenges with the MIX scenarios being more achievable, but all scenarios will face difficulties and require trade-offs between competing interests. The

3 https://www.iass-potsdam.de/en/research/kopernikus-project-ariadne

fact that this will be a dynamic challenge is noted with policy measures evolving over time.

Also considered in the chapter are measures to rectify economic imbalances that result in the fact that climate policies often work in a regressive fashion, meaning that those on low income can face a higher burden of compliance. Finally, the issue of global competitiveness and carbon border adjustments are discussed.

Discussion

- The chapter was thought to be well argued and a vital component of the whole report. However, the detail of the text was considered to be potentially difficult for non-experts to understand. In the context of the whole report, this chapter (and chapter 8) takes a more transition-oriented approach compared to the previous, technology-oriented chapters. The transitional approach includes aspects of directionality such as roadmaps, communication and engagement. It also addresses behaviour, testing and risks, and the scaling-up of new technologies. In terms of the systemic assessment of the energy transition these aspects are perhaps more important and consideration should be given to making them more prominent in the report by amending the overall structure. There could be better linkages made between the different chapters to bring out the systemic aspects of the topics discussed.
- There is a strong focus on carbon pricing in the chapter which, although important, misses some broader aspects. Possible omissions from the chapter were suggested that included multi-level governance structures and the need to coordinate across local, national, EU and global levels. Linked to this are regulatory instruments that aim to control other aspects of energy systems that could reinforce emission controls. For example, air pollution regulations, if enforced, could accelerate reductions in the use of coal in parts of the EU. Consideration of regulations that address such externalities and their associated costs to the environment could be included in the chapter. Furthermore, the impact of European standards being applied at a global level should not be underestimated.
- Networking and collaboration could also be addressed as this can be a critical component that needs to be supported alongside policy measures. Financing, R&D and sustainable investments could be considered in more detail as well as a broader assessment beyond just economic considerations to include the circular economy and behaviour.
- Carbon pricing coupled with measures to avoid carbon leakage were seen as being the most effective means of meeting the climate targets. In terms of the criteria used to assess the different scenarios, the addition of complexity would be useful as this is an important factor in their likelihood of success. The social dimension could also be expanded, being only included briefly in the economic efficiency section. How each

of the scenarios perform over the long term is not fully discussed and their ability to set the energy transition on the right pathway and deliver the ultimate goals could be developed more. The political feasibility criterion focused mostly on legal aspects but could include broader challenges around acceptance and distributional effects between member states.

- More discussion on the Impact Assessment could be included that considers the consequences on each of the scenarios such as the likely increase in the carbon price or the competitiveness of exports.
- The importance of accompanying political decisions with a long-term roadmap was noted to enable the necessary investment decisions by industry.
- Taxonomy was highlighted as being of particular importance in driving the political narrative and investment decisions. The report could usefully clarify what is meant by decarbonisation, including embedded and operational carbon, and the distinction between energy and carbon targets.
- The section on regressivity of energy policies could be more enthusiastic on possible measures to address this problem.

Chapter 8: Embedding the energy transition into society

This chapter begins from the position that all technologies exist within society and can be assessed from a socio-technical or political point of view. For a technology to be embraced takes more than just an investment decision, it comprises of a range of factors that must all be fulfilled if it is to be accepted. Acceptance does not necessarily mean that a technology delivers sufficient advantages, but rather that the alternatives are comparatively less acceptable.

The chapter considers in detail the EU's just transition mechanism. This has a particularly regional dimension, and it is important for policy makers to determine the mechanisms to drive the energy transition that will be effective for each region in order to make changes that would not have happened without intervention. In doing so, it is then important to consider whether local interventions may lead to social imbalances at the level of the individual.

Social acceptance is also discussed, moving beyond the usual considerations of the acceptance of particular technologies or infrastructure to consider the issue in a broader sense. This is expanded further with a section on public engagement, deliberation and ecologies of participation. This will include experimentation, innovation and citizen ownership.

Discussion

- It was stressed that this is a very important chapter which is central to the overall topic of the systemic approach to the energy transition. It could be expanded further and related more closely to the previous chapter on policy measures.
- In particular, the issue of public acceptance and engagement could include more innovative approaches such as citizens assemblies which have been shown to be very effective in a number of energy projects that might otherwise have proved difficult to deliver. Education was also suggested as an important issue that is not covered, especially given that the energy transition will occur over an extended period of time and effect a generation of the population that is currently very young.

Chapter 9: Policy options

This chapter presents a set of evidence-based policy options that are drawn from the rest of the report. As noted in the introduction, these will be considered by the Advisors when they formulate their Scientific Opinion for the Commission and the related policy recommendations. It was stressed that in their current form the options are still in development and do not include an option that deals with carbon pricing.

Four options have so far been considered:

- **Supporting technical innovation and industrial competitiveness.** This draws on the issues relating to the EU in the global context and its role in global efforts to tackle climate change. It considers the dependencies that will arise from the deployment of new technologies and how the EU can take advantage of its favourable position in regard to natural resources, innovation and commercialisation of technologies or where it can seek to improve its position in areas where it is currently lagging behind its competitors.
- **The geopolitical perspective.** This addresses the need for the EU to take a lead in decarbonisation and to encourage other developed economies to drive towards the goals of the Paris Agreement. It also considers the heterogeneous nature of member states within the EU and the different approaches that will need to be taken to ensure an equitable and economically efficient transition for all parts of the EU.
- **System integration.** This focuses on the technical aspects of the energy transition, particularly with respect to electrification and variable renewable energy. This will result in a move from a fuel-based system to a weather-based system and will introduce a range of uncertainties in the delivery of services that will need to be managed. This will be a dynamic process that will require the integration of both short-term and long-term technological, political and market developments.
- **Technology diversity.** This addresses the fact that the full range of technologies will be needed to deliver the energy transition. Policies will be required that are inclusive for all the potential technologies such that they foster diversity, enhance capabilities and provide platforms for innovation and the successful scaling-up of technologies.

Discussion

- The inclusion of an introductory paragraph for the chapter could be helpful that sets out a timetable for the distribution of actions, specifying which actions are needed urgently and which could be built up over time.

- The current set of options focuses heavy on the technologies. A greater emphasis on the transition of the energy system would be preferable to stress the need for directionality towards the climate goals and the need for broad stakeholder engagement. This could also bring in issues such as multi-level governance, sustainable finance, behaviour, circular economy, institutional change and the role of the European commission.
- On the system integration option, the need to ensure security of supply was highlighted as a critical issue. Hydropower is listed as a source of decarbonised, dispatchable power that increases the security of the power system, but there is limited potential for this source of power to be expanded in the EU. Nuclear power, however, does offer a similar function which should be noted in this option.
- In terms of technology innovation, there could be a distinction made in the taxonomy between short, medium and long-term opportunities that require different support mechanisms to develop the technologies. Technologies that are relatively well-advanced need support to be scaled up whereas less well-advanced technologies need support for basic science and R&D.
- The question of who is going to pay for the energy transition was raised. Significant funds will be required to develop a decarbonised energy system. This will be challenging, particularly following the global coronavirus pandemic. It will be important for the costs to be distributed in an equitable fashion which may require new or revised sources of taxation that do not place an unfair burden on lower income citizens. Similarly, the EU should recognise its legacy contribution to climate change and contribute its fair share in redressing this in relation to developing countries which did not benefit from early industrialisation.

Annexes

Programme

All times are given in Central European Time.

14:00	Welcome *Antoine Blonce, Scientific Policy Officer, SAPEA*
14:05	The European Commission's Scientific Advice Mechanism and the Group of Chief Scientific Advisors *Nebojsa Nakicenovic, Member of the Group of Chief Scientific Advisors*
14:10	Euro-CASE and SAPEA *Yves Caristan, Secretary-General of Euro-CASE*
14:15	Scoping paper and background questions *Peter Lund, Working Group co-chair*
14:25	Presentation and discussion: Chapter 1 *Christoph Schmidt, Working Group co-chair, and all*
14:45	Presentation and discussion: Chapter 2 *Alan Walker, SAPEA scientific writer, and all*
15:05	Presentation and discussion: Chapter 3 *Alan Walker, SAPEA scientific writer, and all*
15:25	Presentation and discussion: Chapter 4 *Alan Walker, SAPEA scientific writer, and all*
15:45	Break
16:00	Presentation and discussion: Chapter 5 *Alan Walker, SAPEA scientific writer, and all*
16:20	Presentation and discussion: Chapter 6 *Alan Walker, SAPEA scientific writer, and all*
16:40	Presentation and discussion: Chapter 7 *Alan Walker, SAPEA scientific writer, and all*
17:00	Presentation and discussion: Chapter 8 *Alan Walker, SAPEA scientific writer, and all*
17:20	Presentation and discussion: Chapter 9 *Alan Walker, SAPEA scientific writer, and all*
17:50	Closing remarks *Peter Lund and Yves Caristan*

List of participants

Invited experts

- Dr Heli Antila, Fortum Power and Heat Oy (Finland)
- Prof Yves Bamberger, National Academy of Technologies of France - NATF (France)
- Antony Froggatt, Chatham House (United Kingdom)
- Dr William Gillett, The European Academies' Science Advisory Council - EASAC (United Kingdom)
- Patrick Ledermann, National Academy of Technologies of France - NATF (France)
- Prof. Dr. Jürgen Leohold, Volkswagen AG - retired (Germany)
- Imke Luebbeke, World Wide Fund for Nature - WWF European Policy Office (Belgium)
- Prof Lena Neij, Lund University (Sweden)
- Dr Jerôme Perrin, Renault (France)
- Prof Karen Pittel, University of Munich & ifo Institute (Germany)
- Patrick J Rudden, Royal Irish Academy (Ireland)
- Christian Schaible, European Environmental Bureau - EEB (Belgium)
- Dr Stephan Singer, Climate Action Network International (Belgium)
- Dr Leena Srivastava, International Institute for Applied Systems Analysis - IIASA (Austria)
- Pierre Trémolières, Accenta (France)

Working group members

- Dr Carlos Alejaldre, Center for Research on Energy, Environment and Technology - CIEMAT (Spain)
- Prof Ronnie Belmans, KU Leuven & EnergyVille (Belgium)
- Frank Carre, The French Alternative Energies and Atomic Energy Commission - CEA (France)
- Dr Ana Estanqueiro, National Laboratory for Energy and Geology - LNEG (Portugal)
- Prof Lidia Gawlik, Mineral and Energy Economy Research Institute of the Polish Academy of Sciences (Poland)
- Prof Filip Johnsson, Chalmers University of Technology (Sweden)
- Prof Andreas Löschel, University of Münster (Germany)
- Prof Peter Lund, Aalto University (Finland) – Co-Chair
- Prof Marianne Ryghaug, Norwegian University of Science and Technology (Norway)
- Dr Alessandra Sanson, National Research Council (Italy)
- Prof Sabine Schlacke, University of Münster (Germany)
- Prof. Dr. Dr. h.c. Christoph M. Schmidt, RWI - Leibniz Institute for Economic Research (Germany) – Co-Chair

- Prof Benjamin Sovacool, Sussex University (United Kingdom) & Aarhus University (Denmark)
- Prof Goran Strbac, Imperial College London (United Kingdom)
- Prof Diana Urge-Vorsatz, Central European University (Hungary)
- Prof Brian Vad Mathiesen, Aalborg University (Denmark)
- Prof Richard van de Sanden, Eindhoven University of Technology - TU/e & The Netherlands' energy research institute - DIFFER (The Netherlands)

SAPEA

- Antoine Blonce, Scientific Policy Officer, Euro-CASE
- Dr Yves Caristan, Secretary General, Euro-CASE
- Dr Nina Hobbhahn, Scientific Policy Officer, EASAC
- Dr Alan Walker, Scientific Writer (United Kingdom)

Observers

- Group of Chief Scientific Advisors
  - Prof Carina Keskitalo (member)
  - Prof Nebojsa Nakicenovic (member)
  - Prof Rolf Heuer (former Chair)
- Science Policy, Advice and Ethics unit of DG RTD
  - Dulce Boavida (Policy Officer)
  - Nicola Magnani (Policy Officer)
  - Jacques Verraes (Deputy Head of Unit)
- Other observers
  - Jonas Knapp, Potsdam Institute for Climate Impact, PIK (Germany)
  - Dr Gerhard Kussel, Leibniz Institute for Economic Research - RWI (Germany)

Guiding questions for workshop participants

Invited experts are requested to read and discuss the draft SAPEA Evidence Review Report with these questions in mind. There is no need to specifically answer each question.

General questions

- Does the report answer all aspects of the question asked in the scoping paper and the background questions? Are there any crucial gaps?
- Does the report use the appropriate and up-to-date evidence?
- Is the content of the draft report presented in an objective, evidence-based way?
- Is the report clearly structured?

Questions linked to the report's conclusions and policy implications

- Are the conclusions and policy implications presented in the report sufficiently backed up by scientific evidence and follow logically the evidence presented in the text?
- Can the conclusions and policy implications presented in the report relevantly inform policy making? At what level are they relevant - at EU level? National level? And within what timeframe?
- Are there important trade-offs to consider that may not have been covered?
- Are some options more realistic than others, or should be considered more urgently, by policymakers?

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