SENTINEL

SUSTAINABLE ENERGY TRANSITIONS

"The future of the European energy system: Unveiling the blueprint towards a climate-neutral economy"

Workshop Synthesis Report

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The SENTINEL project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 837089.

Background

To meet the goals outlined in the Paris Agreement and keep the global temperature increase below 1.5ºC, the transformation and decarbonisation of the current energy systems is of profound importance. However, deciding on how future energy systems shall be designed to guarantee energy security, social and environmental sustainability, as well as energy accessibility and affordability of energy across the population, is not an easy task.

While energy models have served for many years as useful tools to inform energy policymaking, the increasing complexity and interrelatedness of various dimensions of energy has led to a situation in which existing modelling tools do not capture enough of the technological, geographic, societal and environmental details important for designing a decarbonised energy system. The EC-funded H2020 project, SENTINEL, which stands for Sustainable Energy Transitions Laboratory, seeks to overcome this drawback and develop a new energy system modelling framework.

Nevertheless, designing a multifaceted modelling suite implies certain challenges. On the one hand, different energy models represent different technical functionalities and encompass different geographical and time resolutions. On the other hand, even the most solidly designed modelling tool, accommodating the newest and most innovative programming techniques, will become redundant if the needs and concerns of people are not considered. In particular, it is crucial that those who use energy models and their results in their professional life are involved in making decisions about energy futures. In this context, there exists an additional threat that the modelling runs, and decisions based thereon will be contested by some social actors, as long as they are conducted 'behind closed doors'.

In order to overcome these shortcomings, SENTINEL has applied a carefully defined, participatory approach. First, we are investigating how to adjust modelling tools and check their behaviour in different geographical and socio-cultural contexts. In that sense, we have selected three case studies: national (focusing on Greece), regional (dedicated to the Nordic region) and continental (Europe-wide). Second, from the earliest phases of the project, we have actively engaged stakeholders representing the policymaking sphere, energy industry, non-governmental organisations (NGOs) and scientific community, to understand what the needs of modelling users are. Finally, by involving external actors in SENTINEL models' application processes in a transparent way, we are aiming to give an overview about how the models work, and what kind of modelling outcomes can be driven by changes of different assumptions and parameters.

This document presents one of the steps undertaken to realise the actions described above. It summarises the online workshop "The Future of the European Energy System: Unveiling the blueprint towards a climate-neutral economy" that took place on 9 December 2020, with over 40 energy experts from throughout Europe and the SENTINEL consortium in attendance. This report captures the discussion and findings tackling the different dimensions of the EU's energy strategy, which show a complex mixture of points essential for delivering a decarbonised energy future for Europe. The results of this exchange indicate relevant issues of the European energy landscape, their accompanying challenges and implications, which should not only be considered by energy models, but also should constitute a base for further inspiring discussions among decision-makers and practitioners.

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1. Introduction

For the last two decades, the European Union (EU) has been a global leader in fighting climate change through its ambitious policies. This progressive approach is further accelerated by the 2019 European Green Deal, a comprehensive strategy navigating the EU to become the world's first climate-neutral continent by 2050. This strategic document outlines key actions needed to achieve carbon neutrality, which have been accompanied by a series of communications or action plans dedicated to concrete segments of energy system and economy, such as a Strategy for Energy System Integration, a New Industrial Strategy, or a Circular Economy Action Plan.

In December 2020, political attention concentrated around the European Council's agreement on a new EU greenhouse gas emissions (GHG) reduction target of at least 55% by 2030 compared to 1990 levels. This decision coincided with the approval of the EU Multiannual Budget for years 2021-2027, coupled with NextGeneration EU, the temporary instrument designed to boost the European recovery, after the unprecedented crisis caused by the COVID-19 pandemic in 2020. in Europe. The post-COVID-19 recovery funds, amounting to €1.8 trillion, can be an ideal opportunity to ensure a fair transition towards carbon neutrality.

Nevertheless, the practice of leading such a deep energy transformation encompasses a myriad of challenges and uncertainties. While for more than twenty years, energy system modelling has been at the heart of European future climate and energy scenarios and has helped European policymakers to unpack these challenges, it is unclear whether existing modelling tools fully reflect the concerns, needs and demands of affected stakeholders.

Against this backdrop and given that within SENTINEL we want to investigate how to best deliver suitable and applicable modelling solutions, it has been essential for us to discuss the relevance of our work with the representatives of the climate and energy realm. Recent developments at the EU level suggest an indicative list of critical topics, which modelling tools should be dealing with. Yet, we believe that a properly structured exchange with professionals making decisions about the energy future in their day-to-day work would enable us to gain first-hand insights into important issues, which should be considered in energy modelling to guarantee a successful implementation of technological and policy solutions leading to carbon neutrality.

To realise this objective, we organised an online workshop "The Future of the European Energy System: Unveiling the blueprint towards a climate-neutral economy". On the next pages of this report, we will present our approach to engaging stakeholders together with the workshop's proceedings. Then we will present the findings from this event, which, if not indicated otherwise, reflect the opinions of the participating stakeholders. The final part of this document outlines conclusions and the next steps.

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2. Stakeholder engagement approach and workshop's proceedings

The workshop "The Future of the European Energy System: Unveiling the blueprint towards a climate-neutral economy" took place on the 9th of December 2020. The initial idea for carrying out an exchange with stakeholders was to organise a physical meeting in September 2020. The outbreak of the COVID-19 pandemic required a change in our approach: the preparations shifted in time and the workshop was organised as an online event on Zoom. Altogether, over 40 representatives of the policymaking sphere, energy industry, NGOs, scientific community and the SENTINEL consortium participated. The list of participants can be found at the end of this report.

The workshop was divided into four main parts: **(1)** Opening plenary session, **(2)** Parallel breakout sessions – round I, **(3)** Parallel breakout sessions – round II, and **(4)** Closing plenary session. Each of the parallel breakout sessions consisted of six thematic breakout rooms, which touched upon different aspects of the European energy system: **(i.)** Transforming the power sector: increasing ambitions for GHG emissions reduction & RES targets; **(ii.)** Sector coupling: implementing smart energy systems and accelerating the shift to sustainable mobility; **(iii.)** Decarbonisation of industry and Carbon Capture and Utilization and Storage (CCUS) & Bioenergy with Carbon Capture and Storage (BECCS); **(iv.)** Modelling energy demand of the building sector- a transition towards zero carbon society; **(v.)** Environmental aspects & implications, including the circular economy; and **(vi.)** Socio-economic aspects &implications, including recovery packages. **Table 1** below presents the structure of the workshop.

Time	Agenda item	
9:30-9:50	**Opening plenary session**	
9:50-10:55	**Parallel breakout sessions: Defining your needs regarding the models – round I**	Session 1: Transforming the power sector: increasing ambitions for GHG emissions reduction & RES targets
		Session 2: Sector coupling: implementing smart energy systems and accelerating the shift to sustainable mobility
		Session 3: Decarbonisation of industry and Carbon Capture and Utilization and Storage (CCUS) & Bioenergy with Carbon Capture and Storage (BECCS)
		Session 4: Modelling energy demand of the building sector- a transition towards zero carbon society
		Session 5: Environmental aspects & implications, including the circular economy
		Session 6: Socio-economic aspects &implications, including recovery packages
10:55-11:15	**Coffee break**	
11:15-12:20	**Parallel breakout sessions: Defining your needs regarding the models – round II**	Session 1: Transforming the power sector: increasing ambitions for GHG emissions reduction & RES targets
		Session 2: Sector coupling: implementing smart energy systems and accelerating the shift to sustainable mobility
		Session 3: Decarbonisation of industry and Carbon Capture and Utilization and Storage (CCUS) & Bioenergy with Carbon Capture and Storage (BECCS)
		Session 4: Modelling energy demand of the building sector- a transition towards zero carbon society
		Session 5: Environmental aspects & implications, including the circular economy
		Session 6: Socio-economic aspects &implications, including recovery packages
12:20-13:00	**Closing plenary session**	

Table 1. The structure of the workshop "The Future of the European Energy System: Unveiling the blueprint towards a climate-neutral economy"

In order to select the themes of the breakout sessions that were relevant from the perspective of the ongoing energy transition in Europe and from the modelling perspective, we undertook two steps. First, we reviewed existing literature to learn about energy policy priorities in the

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EU, concerning mostly the European Green Deal and its accompanying documents. Second, we discussed the prominence of our approach within the SENTINEL consortium to learn how the selected topics could be seized with the models applied in the project. As a result, each of the thematic sessions was facilitated by the SENTINEL modellers, who, in their own models, deal with various issues related to the scope of the selected themes.

It was important for us to invite stakeholders to the workshop who embody differentiated views on the critical issues of the future European Energy System. Thus, we sent numerous personalised invitations to representatives of the European climate and energy community. Our stakeholder mapping process encompassed literature and online research, included a snowball effect and was built upon a stakeholder involvement work carried out in SENTINEL in previous months. Again, the SENTINEL modellers were consulted and asked about their recommendations. A week before the workshop, we contacted registered participants and asked about their preferences regarding two thematic sessions, which they would like to attend during different rounds of the parallel breakout rooms. This information was compelling for us in order to guarantee that in two different rounds of thematic sessions, the created subgroups would be diverse and the exchange between their members multidimensional.

While contacting registered stakeholders we shared with them a short document produced in collaboration with SENTINEL modellers. It described the thematic scope of each of the sessions and research questions, which would guide stakeholders during the exchange. Inspired by the "*Three types of knowledge tool*" method (ProClim, 1997) we structured the proceedings of the thematic sessions around three questions relevant from a modelling point of view and the progress towards carbon neutrality in Europe. These questions were:

1. Where are we?
2. Where we want to get to?
3. How do we get there?

The objective behind answering the first question was to understand at which point, in the view of invited participants, the EU currently stands regarding the energy transition. Furthermore, it aimed at understanding current stakeholders' perception of specific processes and issues in the climate and energy realm in Europe. Sketching such contextualisation set the stage for further discussion.

The second objective of the European energy system transition – carbon neutrality – has been already defined and politically backed. Yet, we still wanted to use the second question to validate, whether there exists unanimity among the stakeholders regarding the plausibility of this goal and to learn their perspectives on the interim indicators leading to its realisation.

The aim of the last question was to identify crucial issues to be considered in order to achieve carbon neutrality. It was essential for us to comprehend and draw potential pathways, which will lead to this objective. These pathways should include technological developments, social processes, market and regulatory mechanisms as well as environmental aspects.

SENTINEL modellers had flexibility in facilitating their sessions, but they kept these three questions in mind while moderating the discussions. The following pages present the findings of each of the thematic session.

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3. Results of the parallel breakout sessions

Session 1: Transforming the power sector: increasing ambitions for GHG emissions reduction and RES targets

SENTINEL facilitators: Bryn Pickering and Arsam Aryandoust (ETH Zurich)

The discussion in the first thematic session focused on transforming the power sector, whose decarbonisation is pivotal for meeting the carbon neutrality objective. The share of renewable energy in electricity generation has increased considerably over the last decades. 2020 has become a breakthrough year, in which more electricity in the EU was produced from renewables than from fossil fuels (Agora Energiewende and Ember, 2021). The growth of renewables will continue to accelerate because it is politically supported. For instance, in December 2020, the European Council reached an agreement on a new EU greenhouse gas emissions (GHG) reduction target of at least 55% by 2030. This push could gather even more momentum, as the European Parliament also voted in 2020 for a 60% GHG emission reduction target by 2030. In that context, achieving decarbonisation of the power sector will need a complete transformation of the current system and utilisation of all possible technologies.

This session was structured around three indicative research questions: (i.) To what extent do we expect the system to be able to handle a large share of renewables in 10 years vs. 15/20 years?; (ii.) What is the future of the European transmission system in light of expected increases in total electricity demand and regionalisation of supply?; and (iii.) What power sector flexibility mechanisms should be in the focus of modelling as renewables increasingly become the dominant component of the power system? After discussing several aspects related to these questions, stakeholders shared their opinions concerning critical issues of the power sector transformation, which should be addressed by the models.

There was no general agreement among this session's participants with regard to when the European energy system will be capable of handling a large share (>70%) of renewables. In their view, the difference in achieving such a high percentage of renewables varies anywhere from 5-7 years up to even 25 years, due to intermittence and the uncertainties related to the supply of materials for batteries. Nevertheless, most of the stakeholders agreed that by 2040, more than 70% of energy in the EU can be produced from renewables, but with several stipulations. First, achieving that objective will depend on the advancement of a sector that is particularly dependent on fossil fuels, like aviation or some heavy industries. Second, this amount of energy could encompass the whole EU, but some specific countries and regions will be far off such a level of RES-penetration. Third, the main obstacle in achieving this goal will be the lack of flexibility mechanisms in place.

Participating stakeholders also presented different views regarding the role of the European transmission system. While some of the participants indicated that international HVDC transmission will become more important in the system by 2030, other participants indicated that it will become less relevant due to ongoing decentralisation. All in all, the stakeholders agreed that, by 2030, international HVDC transmission will be a more important component of the system than AC transmission. When discussing the longer timeframe of 2050 targets, stakeholders unanimously supported the claim that in 30 years the European power system will depend more on international HVDC transmission interconnectors to handle renewable variability.

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Stakeholders shared various opinions concerning power sector flexibility mechanisms. Among different options, they referred mostly to energy storage, especially in reference to the year 2030, which could be completed by conventional generation, hydro storage and geo-diversity enabled by transmission. While in the long-term perspective (by 2050) stakeholders emphasised the role of hydrogen, they raised some points regarding potential imports from Middle East and Africa, the time when it will become competitive and whether it is a synthetic fuel *per se* or an energy vector. Last but not least, the participants of this session also mentioned demand-side flexibility and heat storage.

With regard to the energy modelling, stakeholders defined the scope of its results, which are important from the policymakers' point of view. In that context, it became clear that policymakers need simplified, understandable and interactive models and results, instead of a large set of detailed modelling results. They especially value policy implications and insights, while being explicit about key assumptions.

Against this backdrop, stakeholders mentioned several critical issues that energy models should be dealing with. Alongside EU market design coordination, a prominent topic pointed out by most of the participants was that of social acceptance of energy infrastructure. While the electricity should be balanced according to regionalisation of supply, it can cause conflicts between continental and local interests. Good examples of this include the environmental impacts of small hydro power plants, local wind opposition fuelled by the 'NIMBY' mentality or concerns related to bioenergy, such as land use and actual net emissions. That led participants to question what the best way to account for environmental pressures and impacts could be.

Moreover, stakeholders voiced a need to model the use of decentralised production and building-level technologies to handle different timescales of renewables' variability. This addition could help in better understanding the system's stability and make it more predictable. That triggered a discussion about what degree of decentralisation is actually feasible and useful. This was followed by other points such as advancing digitalisation, the degree of electricity self-production, the level of electrification of industry, the role of hydrogen therein, technological locks-in as well as possibilities of power exchange with other jurisdictions, like Iceland or those located in North Africa. An additional, general point concerned the accuracy of modelling each sector.

In that context, a further question about modelling new modern venues for commercial transactions has raised a broader topic of a long-term modelling guidance in terms of technical, economic and regulatory information. In the case of the latter, stable and predictable governmental plans and regulations are required. However, it remains unclear what information is driving regulation-making and what are the principles behind it: are they based only on economic factors or do they also take into account equity aspects?

Furthermore, the discussion with stakeholders revealed that modelling of these critical issues would require additional information on expected costs evolution, estimation of self-production potential, risks related to the distribution grid, demand growth assumptions and application of backcasting scenarios. Last but not least, much of the discussion was dedicated to social and environmental constraints, such as export of emissions and acceptability regarding environmental issues. Since adding or removing them can shape the solution space differently, their inclusion should be clearly communicated in the models and modelling results.

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Session 2: Sector coupling: implementing smart energy systems and accelerating the shift to sustainable mobility

SENTINEL facilitators: Jakob Zinck Thellufsen and Miguel Chang (Aalborg University)

Electrification of demand sectors constitutes one of the building blocks towards carbon neutrality. In that context, advancing digitisation can help to successfully integrate the sector coupling approach into EU energy and climate policies, be it in regard to infrastructure planning, system and market operation, efficient designing of regulatory frameworks, or in the area of research, development, demonstration and deployment (Olczak, M. and Piebalgs, A., 2018). In previous years the European Union started a set of initiatives, which should facilitate sector coupling (European Parliamentary Research Service, 2019), but a real acceleration has come to be expected after the European Commission presented the Strategy for Energy System Integration in July 2020 (European Commission, 2020d).

The second session of the workshop aimed at discussing with stakeholders the critical issues related to sector coupling and identifying challenges of its implementation and inclusion in modelling. It was framed around five statements and accompanying guiding questions: (i.) Electric vehicles and P2X infrastructure have to be implemented to fit both passenger transport and heavy transport needs. How should P2X be used for industry and power plants?; (ii.) Heavy goods vehicles (HGV) need to be effectively decarbonised using electricity and batteries based on their technical requirements (i.e., weight, cargo and autonomy). To what extent is that feasible?; (iii.) The heating and cooling system needs to be designed to fit a development towards smart energy systems. This includes 4^{th} generation district heating; (iv.) Heat pumps, waste heat and thermal storage need to be implemented in district heating grids to accommodate for smart energy systems; and finally (v.) System integration will help lower the strain on the electricity grid coming from an increased demand for heating and transport supplied by electricity.

The discussion with stakeholders generated very relevant findings pertaining to hydrogen. The participants indicated that reversible fuel cells may be used to switch from H2 to electricity and that hydrogen can be used directly in thermal plants instead of going to gas. Nevertheless, it was difficult to find a clear answer to the question of whether some of the industrial processes will be able to rely solely on H2 or whether they will still need carbon-based fuels. Also, hydrogen poses potential risks, which could make it more relevant to include H2 in the production of e-methane and e-fuels. A possible solution would be to use heat pumps for lower-temperature industrial processes. An additional challenge arises in the high power demand of alternative fuel production for the aviation and marine industries. Such a large share of power will require a smart allocation of electricity production among different sectors, which should also be adequately reflected and improved in existing energy models.

Against this backdrop, stakeholders pointed out that electrifying freight through the use of battery electric trucks is feasible, since this technological option can cover most short distances. However, the answer remains open in regard to long distance trucking. The issue mentioned is that car technology drives the development in the whole road transport sector, and right now this looks to be purely electric going into 2050. Thus, hydrogen trucks are dependent on hydrogen cars being a widespread solution, which is not the outlook right now. Thus e-fuels might be a solution if direct electrification is not possible. Stakeholders also considered an important division between heavy and light trucks, because they have different

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options to shift away from fossil fuels. In the case of heavy trucks, additional factors determining the availability of technological choices will need to be considered. For example, some heavy trucks mainly drive short distances (e.g., between two cities), allowing them to use batteries more easily, as opposed to those driving long distances. A different solution could be to build electric roads. Stakeholders also raised a point regarding the role of the railway systems in the decarbonisation of the transport sector.

The participants of this session agreed that heating represents less uncertainty in modelling than e-fuels and the overall big picture of the transport sector. However, they signalled two relevant aspects related to the heating sector. First, the high-temperature heat can be used for electricity generation. Second, excess heat resulting from hydrogen production could be used in district heating grids.

These considerations bring direct implications for modelling. Stakeholders pointed out to the need to be careful with the naming of different technologies, to properly account energy flows in and between various sectors in order to better understand the outcomes. They emphasised the connection between geographical aspects and their impacts on the modelling representation and to challenges, such as the consequences of the COVID-19 pandemic. For example, stakeholders considered how the pandemic will affect transport patterns, such as the future demand and capacity of public transport. Furthermore, they voiced a need for flexibility in terms of time and geographical resolution: sometimes it is more appropriate to assume a high resolution, while other times it is more suitable to apply a lower resolution. Last but not least, stakeholders indicated that it is important to consider which sector will be the "recipient" of modelling results, as representatives of different sectors see different options for bearing the costs of transition to carbon neutrality. Limited resources of biomass and the CO_2 constraints related to electrification reflect these differences very well.

Session 3: Decarbonisation of industry and Carbon Capture and Utilisation and Storage (CCUS) & Bioenergy with Carbon Capture and Storage (BECCS)

SENTINEL facilitators: Gabriel David Oreggioni (Imperial College London) and Mark Roelfsema (Utrecht University)

The decarbonisation of industry might be one of the biggest challenges on the road to a climate neutral world. Challenges range from highly complex technological processes characteristic of this sector to the employment rates and GDP contributions it provides in the EU. In this context, in March 2020, the European Commission published "A New Industrial Strategy for Europe" (European Commission, 2020a). This document recognises the role of industry in achieving climate neutrality and brings attention to different aspects such as: supply security of clean, affordable energy and raw materials or the creation of leading markets in clean technologies.

Against this backdrop, the third session started by investigating stakeholders' expectations for industrial development in the next years. The participants agreed that industry will incrementally use less fuels, which will impact refineries and their expected declining capacity. Electrification of transport will only accelerate this trend. Nevertheless, since oil is also used for plastic production, some clusters will remain, as for example in Belgium. The industrial decarbonisation pathway will include electrification, the use of hydrogen, biomass as an input

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to produce new materials, utilising both mechanical and feedstock recycling of existing plastic, as well as Carbon Capture Utilisation and Storage (CCUS).

In that context, participants shared the opinion that hydrogen and electrification will play an important role in the fuel basket of the industrial sector. This can be accomplished on a large scale, helping to transition away from coal and coke feedstock in heavy industries, such as steel manufacturing. A good example of this is in Luleå, Sweden, where a plant is using hydrogen for steel production. Additional investments are planned to produce sponge iron from pellets, which could also help to get rid of blast furnaces.

In the view of stakeholders, the hydrogen economy is progressively accelerating and reaching to maturity. For example, Siemens Energy is developing the industrial hydrogen fuel cell system to provide Combined Heat and Power (CHP). The European Commission is carrying out studies investigating how to adjust natural gas pipes for hydrogen and is also working on the legal aspects accompanying these technological developments.

Nevertheless, the foreseen increased hydrogen production creates a competition between the means of its use. On the one hand, it can be utilised for electricity production, however, it can also be used as energy carrier to replace natural gas, as in the transport sector and in stationary combustion sources. Yet, stakeholders pointed out that hydrogen use creates other opportunities, as in the case of conversion back to electricity with fuel cells or use as an intermediate for chemical and fuel production. In that process, water is produced to be used as a feedstock in other industries, such as in textile production, instead of depleting ground water. A different opportunity stemming from the electrolysis process relates to pure oxygen production.

The participants of this session agreed that it is very difficult to foresee the shares of different fuels for the whole industrial sector in Europe, because it greatly depends on the industry type. For example, CCS will not be developed in the paper and pulp industry, as they will mostly utilise biomass with a minor share of additional fuels. The steel sector will likely be decarbonised through hydrogen, but the full share depends on the levels of recycling. In the chemical sector, it will be impossible to fully retreat from carbon, but decarbonisation will probably come from biomass use. Currently, different sectors and different countries are testing and developing different options, but it is not clear which choices will become mainstream.

In case of CCS technologies, the stakeholders noticed that there are already projects being developed in the North Sea, which have potential to utilise CO_2 produced in industrial clusters in Norway, Belgium, the Netherlands, Germany and the United Kingdom. If that is the case, CO_2 could be transported either by pipelines or by ships. There are certain risks related to CCS technology and some of the countries are not keen to invest in it, but this technology will presumably become commercially viable. Furthermore, CCS technology can be combined with hydrogen as a complementary technology in order to decarbonise, such as in the cement sector. To what extent CCS will be used depends on regulation and accounting of emissions. Last but not least, in the future the captured CO_2 could be used for fuel production.

Stakeholders commented that the industrial sector is currently asking governments for financial support and funds to invest in new technological solutions, as in the example of using plastic as a feedstock. Nevertheless, there is a lack of a clear commitment from the side of industry to share such costs, because the industries want to remain competitive. Furthermore, the session's participants indicated, that from a policy advocacy perspective, it would be

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beneficial if energy models would make a clear sectoral breakdown that indicates separate numbers for cement, steel, chemicals, pulp and paper and others.

The discussion showed that it is very challenging to explicitly evaluate whether some European countries will push for an early decarbonisation (by 2040), because different EU member states represent different “decarbonisation speeds”. The decarbonisation commitment will depend on levels of industrialisation, the available potential of renewables, the spatial dimension, and the characteristics of the current electricity markets. A question remains open regarding how nuclear energy can contribute to decarbonisation. For example, although in Belgium the decision about the nuclear phase-out was made in 2003, its implementation was insufficient. Furthermore, in the Netherlands, some voices advocate building new nuclear power plants by 2030. All in all, the stakeholders agreed that the European Green Deal is the main driver pushing the industry towards decarbonisation and the introduction of a carbon border adjustment tax or a labelling system could contribute to that.

Session 4: Modelling energy demand of the building sector – a transition towards zero carbon society

SENTINEL facilitators: Souran Chatterjee (Central European University), Vassilis Stavrakas and Georgios Giannakidis (University of Piraeus Research Center)

Decarbonising the energy sector by 2050 will require better balancing of energy demand. The fourth thematic session concentrated on energy efficiency measures and smart building features that will be instrumental in reaching 2050 decarbonisation. The building sector is one of the EU’s largest energy consumers, accounting for 36% of total GHG emissions (European Commission, 2020b). Considering that the EU has a relatively high share of old and inefficient building stock, this sector plays a crucial role in achieving climate neutrality.

The participants of this thematic session first discussed how energy demand can be modelled for 2050, assuming no further actions or policies are taken. The participants generally agreed that demand modelling by 2050 will follow the 2030 trend, as long as the 2030-specific policies and targets are always included. That said, the participants did advise that the level of detail will impact models. In addition, one stakeholder noted that National Energy and Climate Plans (NECPs) could be utilised to help define the Baseline scenario. Specifically, heating and cooling were noted as the most important aspects for targeting energy consumption, as CO_2 is expected to reduce by 60% by 2030 in this sector. The emergence of new appliances could also affect energy consumption trends.

Looking at the EU as a whole is important, but there are significant region-specific needs that also need to be addressed by energy demand models. Participants noted several region-specific factors including weather differences and effect on technology, traditional architecture, renewable energy potential for heating and PV panels, electrification trends, developments in population and urbanisation, and consumer behaviour. The myriad of region-specific needs that should be addressed by energy demand models shows the complexity of the energy sector decarbonisation target in the EU.

Behavioural aspects substantially affect energy demand and should be captured in the models. Participants emphasised the importance of identifying the relationship between cause and effect. They discussed the demographic factors of aging populations and the percentage of building owners versus renters. Behavioural aspects affect energy usage in regard to

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temperature settings for heating and cooling, so it is important that this behaviour is included in models, like EUCalc.[1] Behavioural aspects should also be sector-specific. This is important when looking at behaviour of prosumers vs. consumers, the effect of smart metering, and the efficacy of increasing consumer awareness. Naturally, participants also asked what types of policy measures could best influence positive actions on behavioural and lifestyle changes. Should the focus be on incentivising consumers or is it more effective to pursue other actions?

Stakeholders also discussed the role of integrated energy production toward the 2050 energy demand models. From PV panel integration on or around buildings to net zero buildings, the advantage is that users become prosumers and there is the possibility to create Positive Energy Districts. Creating the building as an energy hub not only optimises the network but also provides greater advantages outside of the building sector. For example, it provides electric car charging and appliances with local electricity, enabling some to act as electricity storage facilities. The energy demand model will need a data source to measure and monitor the current and new trends. Hourly models would be necessary to model in detail how building demand is covered by RES generation. The advantage of integrating local energy production into the models is to show when the distribution network is modelled.

Digitalisation will be instrumental for the future decarbonisation in the EU building sector. Digitalisation enables the user to easily control their heating, cooling and appliances, increasing both energy efficiency and consumer awareness. The participants stressed that the first step toward digitalisation should be the introduction of smart metering throughout the EU, and to monitor its effects on consumer awareness and behaviour. After smart metering, participants also considered demand-response applications, time-of-use incentives, Pay-for-Performance (P4P) schemes and third-party investments as further digitalisation applications. Finally, it is important to utilise digitalisation in relation to EV's charging-discharging patterns.

Stakeholders felt that there were multiple policy scenarios that also should be addressed by the energy demand models. Resilience and adaptation of infrastructure are paramount to withstand the unprecedented events brought on by climate change. Upgrading old building systems to digitalised versions will create more balanced consumption. The societal drivers for renovating old buildings also have distribution effects on household spending and savings, as well as macroeconomic effects for the public, such as the fuel tax. Ultimately, the participants felt that market influences, as in real estate, would have the most influence on whether energy efficiency measures are taken up and on their success. Business models need to incentivise people to invest in the necessary technological infrastructure.

Session 5: Environmental aspects and implications, including the circular economy

SENTINEL facilitators: Cristina Madrid-López and Nicholas Martin (Autonomous University of Barcelona)

Energy and ecological systems are strongly interrelated. For example, an increase in biomass production or the development of solar and wind farms can lead to externalised environmental impacts related to land use constraints. Furthermore, the development of new energy technologies is linked to an intensified extraction of resources. This brings with it serious

[1] The EUCalc: http://tool.european-calculator.eu/app/buildings/energyuses/?levers=1j12112ffl11211mp2b111fffffpppppp11f411111e3211r211l21n221 (22.02.2021)

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repercussions: as presented in the "Circular Economy Action Plan", 50% of total GHG emissions and 90% of biodiversity loss and water scarcity comes from the extraction and processing of different resources (European Commission, 2020c). The fifth session of the workshop was dedicated to the environmental impacts of the energy system and opened a discussion about how these impacts and implications should be included in energy models.

In the first part of this session, the stakeholders brainstormed about the direction into which the future EU energy system should go, taking into account environmental constraints and societal needs. They indicated relevant topics that encompass specific issues. In the case of the European low-carbon economy, they discussed a 60% GHG emission reduction in comparison to 1990 levels as policy target. CCU technology could be helpful in achieving that goal and it also has potential to reduce resource demand, as in the case of using a bio-based carbon for plastic production. The participants of this session mentioned that following the targets to achieve a low-carbon economy will require more grids.

Concerning circular economy and raw material use, the stakeholders pointed to a reduction of plastic waste, interrelated with the application of CCU, that could contribute to a 90% recycling rate in industry. Furthermore, while the attendees indicated that the increasing lifetime of technologies and appliances would substantiate the circular economy goals, they also agreed that it is important to secure the supply of raw materials. In the case of the green economy, the participants referred not only to water use, but also to land use, in which 100% sustainable forestry would play an important role. Moreover, a specific point was raised about the air pollution hotspots, in which the ambient air is polluted by NOx, SOx and particulate matters' emissions. These substances cause severe human health problems.

Stakeholders further pointed out a need to investigate the relation between the future EU energy system and the Sustainable Development Goals (SDGs), i.e., what are the linkages between them and what could the potential trade-offs be. Participants also discussed topics related to the type of energy system and its scalability (big vs. small). This discussion included storage, ranging from large systems such as hydro to systems focusing on domestic, small-scale solutions. In that context, they indicated that small-scale solutions (such as batteries or prosumerism) could bring large-scale consequences related to employment and investment rates, participation in the market, and the security and stability of the whole system. The stakeholders determined that it would be beneficial to compare the environmental effects of centralised vs. decentralised systems. Finally, there was an emphasis on changing and adapting specific energy infrastructure related to the risk issues and possible accidents, as in the case of gas and hydrogen grids.

In the second part of this session, the stakeholders reflected about the information needed to model the envisioned EU energy system, taking into account societal, political, research and data dimensions. With this in mind, the participants indicated that in order to meet the 60% GHG emission reduction target, ambitious climate targets will need to give a strong political message to the society. That also relates to the renewable energy and energy efficiency targets. From the stakeholders' perspective, it would be important to model how much each policy is contributing to the realisation of the overall target. They remarked, however, that industrial actors might not provide the modellers with relevant data because of competition issues. Regarding air pollution hot spots, they expressed that it would be beneficial to include the specificities of the pollutants coming from different technologies and sectors into the model. This could raise additional concerns amongst policymakers, especially in the context of new emerging technologies, and the risk of accidents related to them.

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Moreover, the stakeholders voiced a need to create a method that would integrate different indicators stemming from the SDGs. Modelling the links between the energy system and different SDGs would allow for a more robust analysis that includes social and political factors. For example, modelling these linkages would allow the models to calculate water impacts of different technologies or to quantify the links between energy prices under different scenarios and their impacts on poverty. The participants of this session drew attention to communication challenges in presenting and adequately weighing different environmental indicators, taking into account all uncertainties, especially if different actors have different preferences. Concerning circular economy, the stakeholders expressed an interest in models which capture the whole lifecycle: from raw materials to the end use application.

In the case of the sustainable biomass issue, many different elements were mentioned, such as fine chemicals, food, fibre, fertilisers and fuels. Also, the stakeholders remarked that different sectors compete for biomass use and some industries are still strongly dependent on bioenergy. Thus, it would be useful to consider the competition for biomass in the modelling as well as the relation of different kinds of biomass to the land use constraints, such as forestry, food crops and energy crops. Additionally, that includes the biomass imports from countries outside of the EU. Furthermore, it would also be relevant to acknowledge in the modelling the impacts of acidification and eutrophication. Referring to the electricity storage, the attendees pointed out that there are substantial differences in environmental impacts when it comes to installing batteries behind the meter or front the meter. That relates to the system efficiency and type of technologies avoided by the storage (e.g., gas plants). Additionally, putting batteries behind the meter is more difficult to control, therefore it is better to connect the PV systems in the buildings to the grids, rather than storing with batteries.

Session 6: Socio-economic aspects and implications, including recovery packages

SENTINEL facilitators: Diana Süsser and Hannes Gaschnig (Institute for Advanced Sustainability Studies) and Jakob Mayer (University of Graz)

The last of the thematic sessions looked at the European energy transition through the lenses of the social and economic aspects. The European Green Deal has devoted much space to both dimensions: the pathway towards carbon neutrality by 2050 should be socially just and not leave anyone behind, and at the same time create millions of new green jobs and guarantee economic growth (European Commission, 2019). The significance of these issues moved even higher up the political agenda as a consequence of severe effects caused by the COVID-19 pandemic, which began affecting European societies and economies in 2020.

In that context, the participants of this session were especially interested in: what kind of impact will the EU recovery packages have on the energy transition; how should the “just transition” look and whether energy poverty will increase during the energy transition; how should local communities be involved; what are the socio-economic chances and risks of the energy transition and how can these be included in the energy models.

With regard to the key characteristics of a climate neutral energy supply in Europe by 2050, the stakeholders noted that a successful transition is a matter of incentives, as in the case of demand-side management. At the same time, they shared the opinion that the current GHG emission target of 55% by 2030 is not ambitious enough, and that if we want to achieve climate neutrality, it should be increased to 60%. However, having an EU-wide target means different

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repercussions for different member states. While setting a 100% RES target would be helpful in further reduction of GHG, it would require adequately designed regulatory frameworks for all sectors as well as more interconnections between the EU member states.

That, in turn, would require an adoption of a different approach and tasks by member states. Currently, there is a competition among the member states based on the natural split of renewables, whereas more cooperation and coordination would be needed to fulfil higher targets. Stakeholders shared that this process is visible in Sweden, who would prefer to have more ambitious climate targets for the whole EU, but does not have enough influence on other member states. Although all Nordic countries are perceived as frontrunners in achieving carbon neutrality, they are facing internal challenges and conflicts in that manner. For example, in Norway the energy industry is keen to decarbonise, whereas other industrial sectors are rather sceptical. These considerations led the stakeholders to pose additional questions regarding a common European energy system, such as: Where should the storage for Europe be – in the Nordics?; where is it most economically efficient to build RES and storage units?; and finally, what would be the benefits for different regions?

The stakeholders expressed positive opinions on the job creation resulting from the European Green Deal's implementation. They referred to new jobs related to demand-side management (especially to storage and operation of electricity), net metering, services related to the hydrogen technologies, and development of RES technologies and grids. However, the attendees of this session also mentioned specific challenges related to a low-carbon transition. For example, phasing out coal would mean that unemployment among coal sector workers will increase before they will be able to find jobs in the low-carbon sector. That will have additional effects on the income of whole regions and consequently, on other subsectors of local economies. Thus, future modelling studies should investigate regional effects on unemployment and job creation (including their spatial dimension), instead of aggregating them at the national or the European level. This is particularly important due to the uneven distribution of costs and benefits that co-determine the acceptance of the energy transition and specific technologies.

In order to guarantee a just distribution of costs and benefits, stakeholders suggested that significant funding will be needed. In their opinion, however, a substantial share of money (70-75%) should be mobilised by private funds, then the states should guarantee the rest (20-25%). Additionally, some of these funds should be redirected to incentivise reskilling of the workers, in the light of fast RES deployment and coal, gas and nuclear phase-outs.

The stakeholders reflected that such changes will be similarly relevant for energy communities that are expected to develop in the next decades. Nevertheless, in order not to hinder their growth, increased investment in digitalisation is needed. For example, in some European regions the internet connection is still weak, and a reliable and fast internet will be essential to efficiently manage energy flows (which is also relevant for the municipal energy providers) and enable an effective demand-side management.

Furthermore, the participants of this session indicated that for the modelling of a decarbonised energy system it is important to consider overall negative and positive effects for consumers, which can be reflected, for example, in increasing number of unpaid energy bills. In order to avoid that, stakeholders proposed incentives for storage investments, which could harmonise the electricity market and prevent electricity price fluctuation (e.g., in winter, when sun does not shine or when wind does not blow). Other issues that could be modelled in the context of

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the affordability of the energy transition could relate to social housing, in which energy poverty is decreased by increasing efficiency and renovating buildings.

Finally, the stakeholders reflected on the effects of the COVID-19 pandemic that caused specific behavioural changes in the context of the energy system. For example, working from home reduced the overall transportation and changed its patterns, while at the same time caused higher demand for gas needed for heating of the houses. It means that the COVID-19 impact allows for "non-conventional" scenario analysis, in which, e.g., travel demand reductions have non-linear distributional effects, because of diverse housing quality.

4. Conclusions and outlook

The viewpoints presented by the workshop's participants revealed important aspects that should be considered in the future work of SENTINEL. The approach applied to engage stakeholders proved appropriate in harvesting diversified insights from representatives having diverse perspectives regarding climate and energy pathways, to enable a constructive exchange between them and to better understand opinions on multiple dimensions of the future European energy system. Based on the findings collected at the workshop we are able to draw the following conclusions:

First, as each of the thematic sessions showed, different aspects of the European energy transition cannot be analysed separately. Developments and actions in one part of the energy system trigger changes in its other elements, unveiling new, and sometimes even unexpected, interlinkages. It clearly shows the increasing complexity of current energy realities, which should not be understood as compilation of adjusted technological components, but as multidimensional systems, encompassing social, economic, political, environmental and regulatory facets.

Second, while one of our ambitions of this workshop was to embrace the whole European Union, the results of the exchange with stakeholders reminded us that there are significant differences between the EU's member states as well as between specific European regions. On the one hand, such differences must be considered while thinking, for example, about varied renewables potentials or societal capabilities included in the energy models. On the other hand, these diversities can foster numerous opportunities to strengthen the energy transition at multiple levels. This, in turn, may create a multi-level reinforcement loop.

Finally, from a modelling perspective, our findings reflect a need to further improve modelling tools applied in SENTINEL and beyond. The current energy system models cannot answer all the questions and concerns raised by the stakeholders. While we are motivated to continue developing the SENTINEL framework, uncertainties remain as to whether it will ever be feasible to answer some of them through energy system models. This is especially relevant if considering a dynamic energy political environment at the EU level. Hence, we further acknowledge a need to discuss these issues directly with stakeholders confronted with these developments in their everyday work.

Overall, evaluation after the workshop showed that participants were satisfied in joining this event. The collected feedback and lessons learned will help us realise the next steps in the SENTINEL project. Based on the information generated at the workshop, we will shift into a model application stage. Once the first round of modelling runs is completed, we will share the outputs and consult them with energy experts to further improve our work.

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About SENTINEL

The transition to a low-carbon energy system will involve a major redesign of the energy system, primarily around renewable sources, in accordance with 2030 and 2050 targets that the European Commission has defined. The interdisciplinary consortium develops an open-source platform SENTINEL, which stands for the Sustainable Energy Transitions Laboratory. This platform will consist of well-suited energy models to support the European Energy Transition. Please find an overview of project partners and modules below.

Please find further information about SENTINEL here.

Module	Model	Focus	Developer
Social and Environmental Transition Constraints	QTDIAN*	Drivers of technology diffusion	Institute of Advanced Sustainability Studies (IASS), Germany
	ENVIRO*	Life-cycle analysis of energy technologies	Autonomous University of Barcelona (UAB), Spain
	ATOM	Technology adoption by individual agents	University of Piraeus Research Center (UPRC), Greece
Energy Demand	DESTINEE	Electricity demand generator	Imperial College London, UK
	BEVPO	E-mobility diffusion, utilisation, and charging	ETH Zürich, Switzerland
	HEB	Technology-specific building sector demand	Central European University (CEU), Hungary
	DREEM	Electricity demand response and flexibility	University of Piraeus Research Center (UPRC), Greece
System Design	EnergyPLAN	Energy supply: focus on sectoral integration	Aalborg University (AAU), Denmark
	Calliope	Energy supply: focus on geographical integration	ETH Zürich, Switzerland
	IMAGE	Global integrated assessment model	Utrecht University (UU), Netherlands
Economic Impact	EMMA	Top-down electricity market simulation	Hertie School (HSG), Germany
	BSAM	Agent-based capacity bidding simulation	University of Piraeus Research Center (UPRC), Greece
	WEDGYN	Computable general equilibrium impacts	University of Graz (UGR), Austria

* new model to be developed within the project

Table 2. The SENTINEL models and consortium partners

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