SENTINEL

SUSTAINABLE ENERGY TRANSITIONS

"Pathways to climate neutrality in Europe with a spotlight in Greece: Challenges, uncertainties, solutions"

Workshop Synthesis Report

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By

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Background of the SENTINEL Project

While energy models have been useful tools for informing energy policymaking for many years, the increasing complexity of various dimensions of energy systems has resulted in a situation where existing tools do not capture enough of the details required for designing a decarbonised system. The European Commission-funded Horizon 2020 SENTINEL project aims to address this issue by developing a new energy system modelling suite in which different models can be combined in a modular way. Nonetheless, designing a multifaceted modelling suite presents some challenges. On the one hand, various energy models represent various technical functionalities and geographical and time resolutions. On the other hand, even the most well-designed modelling tool will be rendered obsolete if people's needs and concerns are not taken into account (Süsser et al., 2021). In this context, there is an additional risk that modelling outcomes and decisions based on them will be challenged by some social actors as long as they are carried out "*behind closed doors*".

For this reason, in SENTINEL, we followed a participatory approach based on stakeholder engagement. We established communication channels with stakeholders from the energy industry, the policymaking sphere, the civil society, and the field of science and research. We aimed to identify user needs for energy modelling and jointly specify the most critical and policy-relevant contextual questions that energy system models should be able to respond to (Kleanthis et al., 2022). As a next step, the SENTINEL energy models have been advanced and new tools were developed to meet user needs and to respond better to multiple transition issues and concrete research questions.

We tested the applicability and usefulness of the SENTINEL modelling suite in a set of case studies at three different geographical levels/contexts, namely: **i.** Continental (European Union, Norway, Switzerland, the United Kingdom, and some Balkan countries), **ii.** Regional (Nordic countries), and **iii.** National (Greece), with diverse energy transition issues and challenges that policymakers and other stakeholders will face in the future. The SENTINEL modelling results provide several implications with regards to the power sector's transformation, demand-side interventions, and sector coupling as well as the environmental and socioeconomic impacts of the energy transition in all the three case studies (Michas et al., 2022).

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Brief summary of the workshop

The workshop "Pathways to climate neutrality in Europe with a spotlight on Greece: Challenges, uncertainties, solutions" took place as a physical workshop in Greece on the 30th of June 2022. At the workshop, key experts from all the different stakeholder groups participated. The SENTINEL researchers presented key modelling results of the Continental and the National case studies and collected feedback on potential further model refinements and improvements required, the usefulness of the modelling insights and how to best disseminate them, as well as the identification of any further research questions that are needed to be answered. The document contains links to the presentations of the modellers.

This report serves as a summary of this SENTINEL stakeholder workshop and captures our discussion and findings tackling the different dimensions of the energy transition in Europe with a focus on Greece. Participants of the workshop stated a variety of different critical issues and challenges related to the energy transition of the Greek and European energy systems. These insights could further inform the research questions that had been identified in previous stakeholder engagement activities. Given the recent upheaval due to Russia's invasion of Ukraine and the consequent energy crisis that coincides with our work, these questions could be (re)considered by the SENTINEL consortium to accurately capture current developments in Europe. Finally, discussions and inputs from stakeholders revealed meaningful viewpoints that could be incorporated in the further development of the SENTINEL modelling platform.

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1. Stakeholder engagement approach and workshop proceedings

The workshop "*Pathways to climate neutrality in Europe with a spotlight on Greece: Challenges, uncertainties, solutions*" took place on the 30th of June 2022 in "Oasis" hotel apartments, in Glyfada, Greece, and was held back-to-back with the 3rd SENTINEL annual meeting. The workshop was co-organised with the European Commission (EC)-funded Horizon 2020 (H2020) PARIS REINFORCE project. Its overarching objective was to gather stakeholders and field experts on the Greek energy system to discuss critical issues of the energy transition in Europe and Greece based on energy modelling insights and to explore potential challenges and solutions moving forward, also considering recent geopolitical and policy developments around Europe.

Forty-five representatives of different stakeholder groups, namely energy industry, scientific/research community, policymaking, and non-governmental organisations and civil society, participated in this workshop. The full list of the participating institutions and organisations can be found in **Table 1**.

Table 1. Institutions & stakeholders participating in the consultation process.

Ministry of Environment and Energy (MEE)
Public Power Corporation S.A. (PPC S.A.)
PPC Renewables S.A. (PPCR S.A.)
Public Gas Company S.A. (DEPA S.A.)
Hellenic Electricity Distribution Network Operator (HEDNO)
Independent Power Transmission Operator (IPTO)
Regulatory Authority for Energy (RAE)
Hellenic Gas Transmission System Operator S.A. (DESFA S.A.)
Hellenic Energy Exchange S.A. (HEnEx S.A.)
Technical Chamber of Greece (TEE - TCG)
Hellenic Association of Independent Power Producers (haipp)
Hellenic Petroleum Marketing Companies Association (SEEPE)
Hellenic Association of Renewable Energy Sources Power Producers (hellasres)
Hellenic Wind Energy Association (HWEA/ELEATEN)
Hellenic Association of Photovoltaic Companies (HELAPCO)
Hellenic Small Hydropower Association (HSHA)
Centre for Renewable Energy Sources (CRES)
Institute of Zero Energy Buildings (INZEB)
National Technical University of Athens (NTUA)
Bruegel
Fraunhofer
Institute for European Energy and Climate Policy (IEECP)
Technical University of Mombasa (TUM)
Swiss Federal Institute of Technology in Zürich (ETHZ)
Utrecht University (UU)
Imperial College London
Delft University of Technology (TU Delft)
Aalborg University (AAU)
Hertie School of Governance (HSOG)
Central European University (CEU)
Universitat Autònoma de Barcelona (UAB)
Institute for Advanced Sustainability Studies (IASS)
Renewables Grid Initiative (RGI)

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University of Piraeus (UNIPI)
Private sector companies
Independent Energy Consultants
Greenpeace
WWF Greece

The workshop consisted of plenary and parallel breakout participation (**Table 2**).

The plenary participation was divided into three sessions: **(a).** the **opening** session in which stakeholders were introduced to both the SENTINEL and the PARIS REINFORCE projects, followed by **(b).** the **1st plenary** session and **(c).** the **2nd plenary** session. The objective of the 1st and 2nd plenary sessions was to present modelling results on low-carbon pathways for Europe and Greece to key stakeholders to receive their feedback regarding their usefulness. The plenary sessions were followed by a 45-minute Q&A session, where modellers were asked questions from stakeholders based on the presented modelling outcomes.

The parallel breakout sessions were implemented in the form of Climate-neutral World Café sessions/discussion tables (involve.org, 2018). A total of four parallel breakout sessions were available for stakeholders to attend. Their facilitation was equally distributed between the two projects.

The two PARIS REINFORCE Climate-neutral World Café sessions aimed at identifying bottlenecks hampering decarbonisation pathways in Greece and co-creating elements of a transformative policy mix that could overcome those bottlenecks, with a particular focus on the Greek power sector. Find more information about the PARIS REINFORCE Climate-neutral World Café sessions here.

The two SENTINEL Climate-neutral World Café sessions aimed at finding out what additional stakeholder questions should be addressed by energy system models to support policymaking in Greece and how modelling material should be integrated into the SENTINEL platform and disseminated to the different target groups.

Overall, stakeholders were asked to rotate between the four Climate-neutral World Café sessions to ensure equal participation across the discussion topics. After the completion of the parallel breakout sessions, each session's facilitator wrapped up the feedback received from stakeholders and presented it to the plenary (Climate-neutral World Café gallery).

Table 2. Structure (agenda) of the workshop "Pathways to climate neutrality in Europe with a spotlight on Greece: Challenges, uncertainties, solutions".

09.30-10.00	**Registration & Welcome coffee**
10.00-10.25	**Opening: Putting projects into context**
10.00-10.05	Welcome *Alexandros Flamos (University of Piraeus Research Centre)*
10.05-10.15	Introduction to the "SENTINEL" project *Anthony Patt (ETH Zurich)*
10.15-10.25	Introduction to the "PARIS REINFORCE" project *Haris Doukas (National Technical University of Athens)*
10.25-12.00	**Plenary Session I: Transition pathways to climate neutrality in Europe**
Session chair: *Alexandros Flamos* **Presentations:**	
10.25-10.35	"How can the decarbonisation of final energy uses contribute to meeting the European Union's emission reduction targets?" *Gabriel D. Oreggioni (Imperial College of London)*
10.35-10.45	"Towards a net-zero building sector: A European Dream?" *Souran Chatterjee (Central European University)*
10.45-10.55	"Using a global integrated assessment model to assess the policy environment in the European Union" *Mark Roelfsema (Utrecht University)*

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10.55-11.05	"Modelling of a smart energy system in Europe" *Jakob Zinck Thellufsen (Aalborg University)*
11.05-11.15	"Diversity of options to eliminate fossil fuels and reach carbon neutrality across the entire European energy system" *Stefan Pfenninger (TU Delft)*
11.15-12.00	Q&A session *Facilitation: Andrzej Ceglarz (Renewable Grid Initiative)*
12.00-12.15	**Coffee break**
12.15-13.30	**Plenary Session II: Decarbonisation pathways and the role of natural gas in Greece**
Session chair(s): *Haris Doukas* **Presentations:**	
12.15-12.25	"Energy transition in the residential sector in Greece: Investing in natural gas or in electrification?" *Vassilis Stavrakas (University of Piraeus Research Centre)*
12.25-12.35	"Greek NECP and Climate Law: are they ambitious enough? The role of natural gas en route to decarbonisation" *Alexandros Nikas (National Technical University of Athens)*
12.35-12.45	"Identifying bottlenecks for the decarbonisation of the Greek power sector" *Philine Warnke (Fraunhofer ISI)*
12.45-13.30	Q&A session & Interactive elaboration on the list of bottlenecks *Facilitation: Philine Warnke*
13.30-14.15	**Group photo & Lunch break**
14.15-15.45	**Climate-neutral World Café sessions**
Session facilitators: *Alexandros Nikas, Andrzej Ceglarz, Diana Süsser (IASS Potsdam), Philine Warnke, Vassilis Stavrakas*	
14.15-14.25	Live polling on "Which are the most relevant bottlenecks?" *Facilitation: Diana Süsser & Philine Warnke*
14.25-14.30	Explanation of proceedings & settling in tables
14.30-15.45	**Session 1: Bottleneck Specification** - "*What are the main aspects of the bottleneck and how is it hindering the transition?*" **Session 2: Policy Mixes & Interventions** - "*What policies and other interventions could overcome the bottlenecks?*" **Session 3: SENTINEL models to support policymaking** - "*What answers would you like to get from (energy) models?*" **Session 4: SENTINEL modelling platform** - "*What kind of energy modelling platform would you like to use?*"
15.45-16.00	**Climate-neutral World Café gallery & Final round of reflections**

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2. Insights from the plenary sessions

Plenary sessions

The plenary consisted of eight presentations with modelling results from both projects that were considered important for the participating stakeholders, as these addressed key research questions identified in the context of previous stakeholder engagement activities with Greek (Stavrakas et al., 2021) and European (Ceglarz & Schibline, 2021) experts.

In the **1st plenary** session, entitled "*Transition pathways to climate neutrality in Europe*", the SENTINEL project modelling teams made five presentations consisting of their modelling results for different transition pathways to climate neutrality by 2050 in Europe, also considering implications on the Greek energy system**.**

The 1st Plenary Session entitled "*Transition pathways to climate neutrality in Europe*" started with a presentation from Dr. Gabriel D. Oreggioni (Imperial College of London) on how the decarbonisation of final energy uses contributes to meeting the European Union's emission reduction targets. This study was conducted with the Demand for Energy Services, Supply and Transmission in EuropE (DESSTINEE) model, which reports results for 11 energy carriers, disaggregated according to key sectors and technologies, in 40 countries (Bobmann & Staffell, 2015). The presentation finished with conclusions about the role of electrification of road transport and industrial processes as well as energy efficiency improvements in buildings in meeting overall targets at the European level (**Fig. 1**).

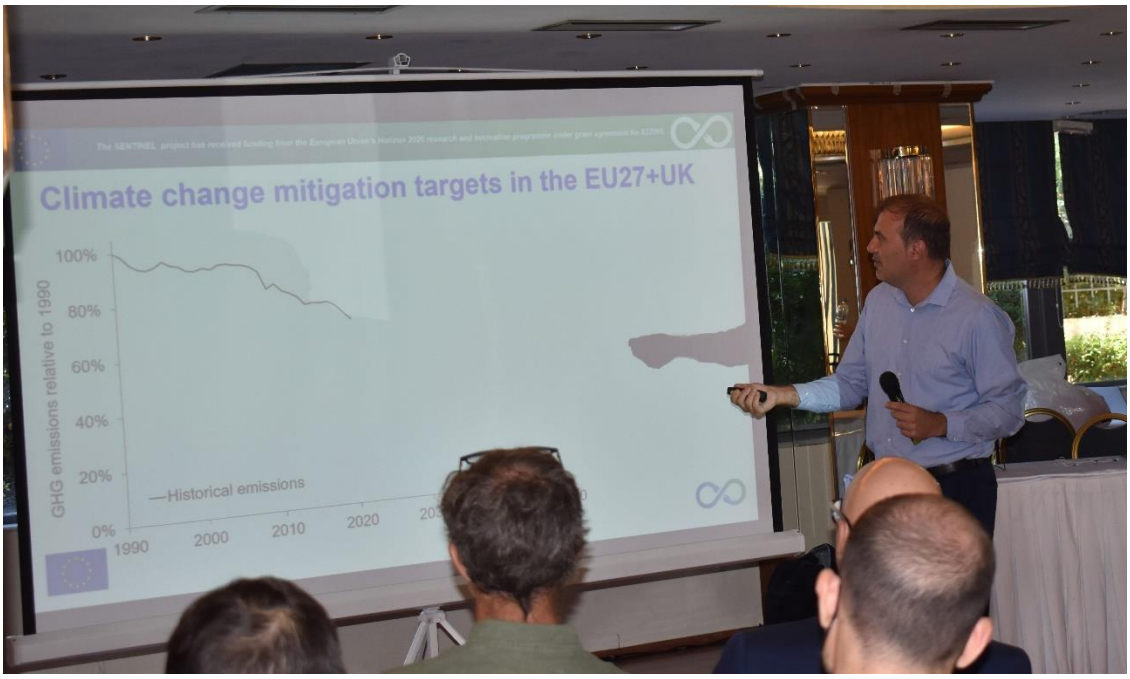

Fig. 1. Presentation with title "How can the decarbonisation of final energy uses contribute to meeting the European Union's emission reduction targets?".

Dr. Souran Chatterjee (Central European University) showed results in relation to reaching a net-zero building sector in the EU. This study was performed with the use of the High Efficiency Buildings (HEB) model that calculates energy demand in the residential and tertiary building sector based on macroeconomic indicators and technological development (Güneralp et al., 2017). The findings indicate that a 98% reduction in energy consumption of the residential building sector is possible, whereas the tertiary building sector can reduce its energy consumption up to 94% by 2060 under a net-zero scenario (**Fig. 2**). You can find more information about this presentation here.

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Fig. 2. Presentation with title "Towards a net-zero building sector: A European Dream?".

Dr. Mark Roelfsema and Ms. Hsing-Hsuan Chen (Utrecht University) utilised the Integrated Model to Assess the Global Environment (IMAGE) model (PBL Netherlands Environmental Assessment Agency, 2021) to assess different sectoral decarbonisation options by 2050. According to modelling outcomes, energy efficiency improvements have the highest impact in the passenger transport sector, mainly caused by a shift to electric cars. In the power generation sector, reducing CO_2 intensity in energy use and carbon capture and storage become more important measures to reach the net-zero emissions in 2050. For the industry sector, the highest potential of efficiency improvements come from the steel sector (**Fig. 3**).

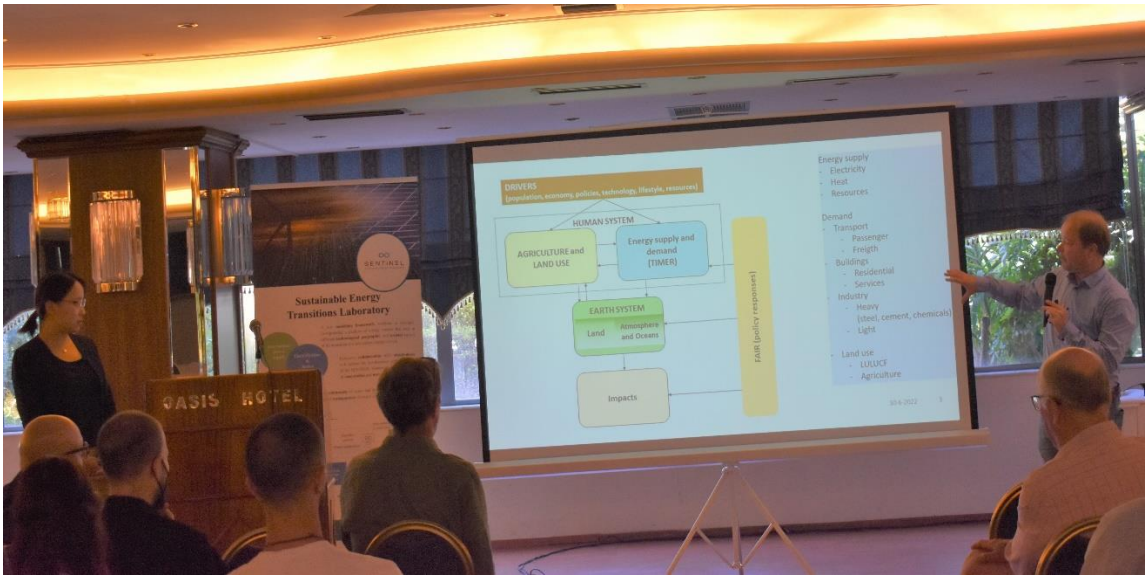

Fig. 3. Presentation with title"Using a global integrated assessment model to assess the policy environment in the European Union".

Assoc. Prof. Dr. Jakob Zinck Thellufsen (Aalborg University) used the EnergyPLAN model to simulate and design smart energy systems for Europe and Greece (Lund et al., 2021). The focus of EnergyPLAN was on simulating all parts of the energy system to capture the benefits of system integration. Various

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primary energy and total system cost scenarios for Greece were presented along with intercomparisons with other models' results (**Fig. 4**). You can find more information about this presentation here.

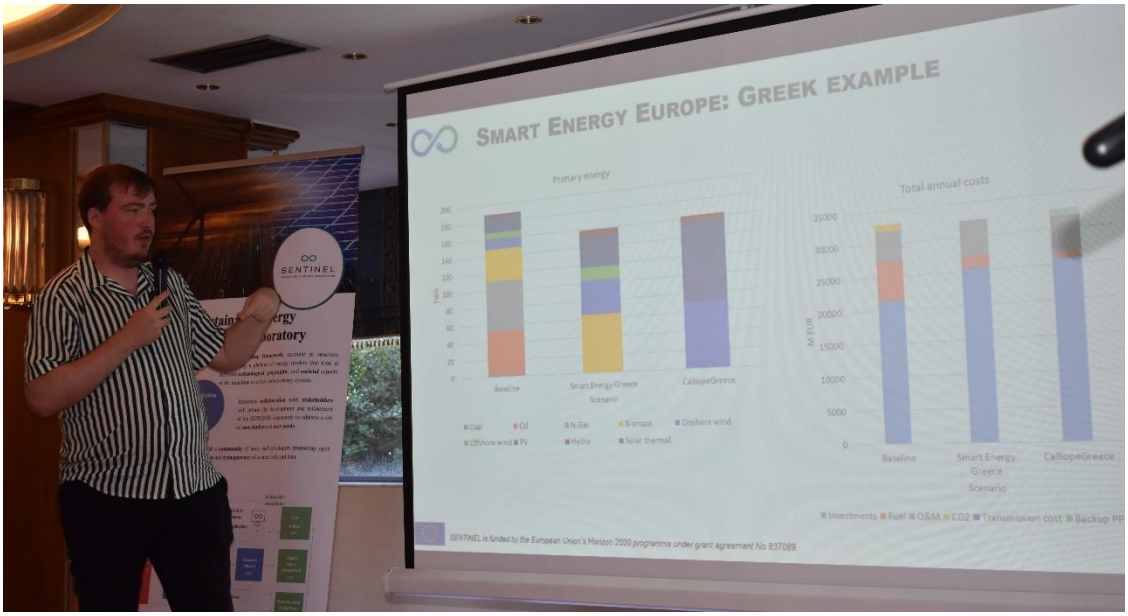

Fig. 4. Presentation with title "Modelling of a smart energy system in Europe".

Assist. Prof. Dr. Stefan Pfenninger (Delft University of Technology) presented the diversity of options to eliminate fossil fuels and reach carbon neutrality across the entire European energy system. This work employed the Euro-Calliope model, which simulates the greenfield deployment of components of the energy system at a sub-national level, in 98 regions across 35 countries in Europe (Pfenninger & Pickering, 2018). The findings highlighted the variety of cost-effective options and spatial configurations for an energy self-sufficient, carbon-neutral Europe. An interactive interface based on the modelling results is available for further exploration of the trade-offs between the energy system components here (**Fig. 5**). You can find more information about this presentation here.

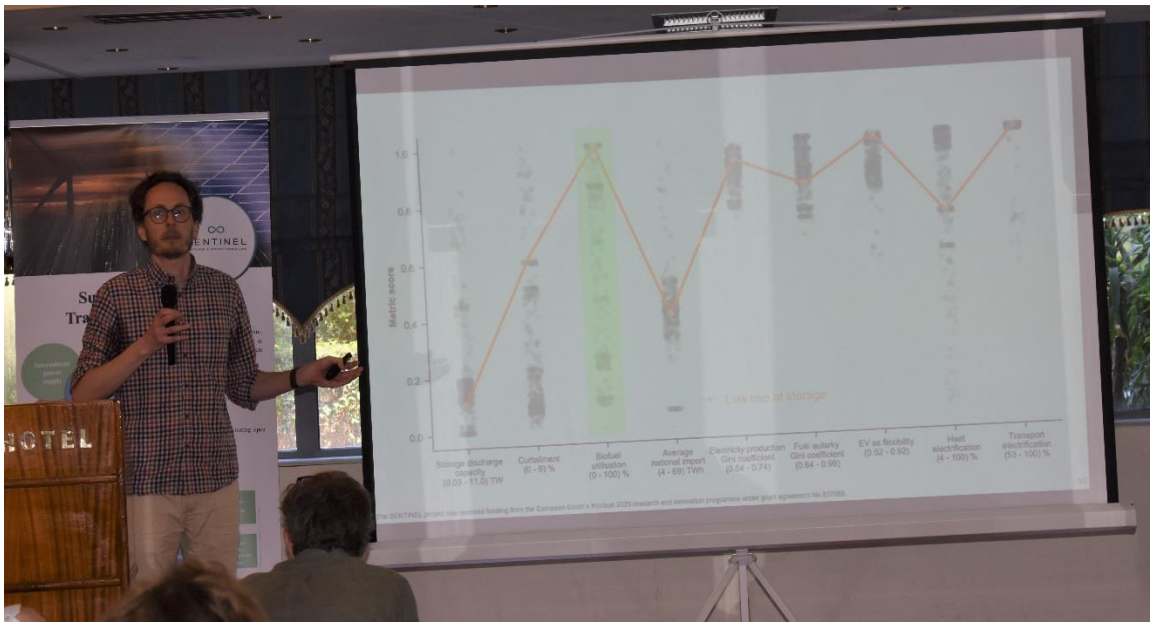

Fig. 5. Presentation with title "Diversity of options to eliminate fossil fuels and reach carbon neutrality across the entire European energy system".

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In the **2nd plenary** session, entitled "*Decarbonisation pathways and the role of natural gas in Greece*", SENTINEL and PARIS REINFORCE project modelling teams gave three presentations regarding project results for different decarbonisation pathways in Greece.

Dr. Vassilis Stavrakas (Technoeconomics of Energy Systems laboratory (TEESlab), University of Piraeus Research Centre (UPRC)) opened the 2nd Plenary Session with a presentation about future options for the energy transition in the residential sector in Greece. This study utilised the Dynamic high-Resolution dEmand-sidE Management (DREEM) model (Stavrakas & Flamos, 2020), which not only calculates energy demand in the building sector, but also assesses the benefits and limitations of demand-flexibility. Key conclusions of this work are that by following the renovation rates dictated by the existing National Energy and Climate Plan (NECP) in Greece, decarbonisation in the residential sector cannot be achieved by 2050. The study also showed that to achieve decarbonisation in the Greek residential sector, investing in electrification leads to lower fuel and renovation costs, and, thus, lower total costs at both the household and the national level, compared to investing in natural gas as a transition fuel, which is the existing national planning (**Fig. 6**). You can find more information about this presentation here.

Fig. 6. Presentation with title "Energy transition in the residential sector in Greece: Investing in natural gas or in electrification?".

After a series of presentations based on modelling results from the SENTINEL project, colleagues from the PARIS REINFORCE project provided two presentations with a focus on the Greek power sector. Dr. Alexandros Nikas (National Technical University of Athens (NTUA)) presented three scenarios for the decarbonisation of the Greek power sector by 2050 (**Fig. 7**) and Mr. Konstantinos Koasidis (NTUA) and Dr. Philine Warnke (Fraunofer) presented insights from the PARIS REINFORCE qualitative analysis of the Greek power sector. More information about both presentations are available here.

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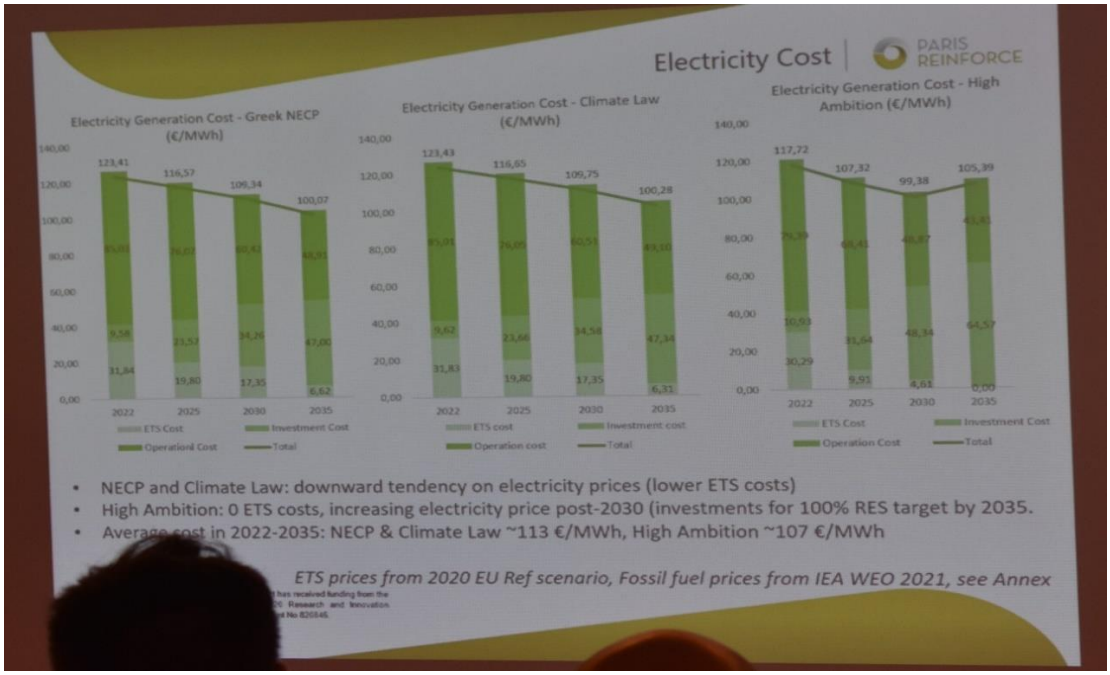

Fig. 7. Presentation with title "Greek NECP and Climate Law: are they ambitious enough? The role of natural gas en route to decarbonisation".

The 2nd plenary session was followed by an interactive elaboration on the list of bottlenecks for the decarbonisation of the Greek power sector (**Fig. 8**), facilitated by PARIS REINFORCE colleagues. Find more information about the interactive discussion here.

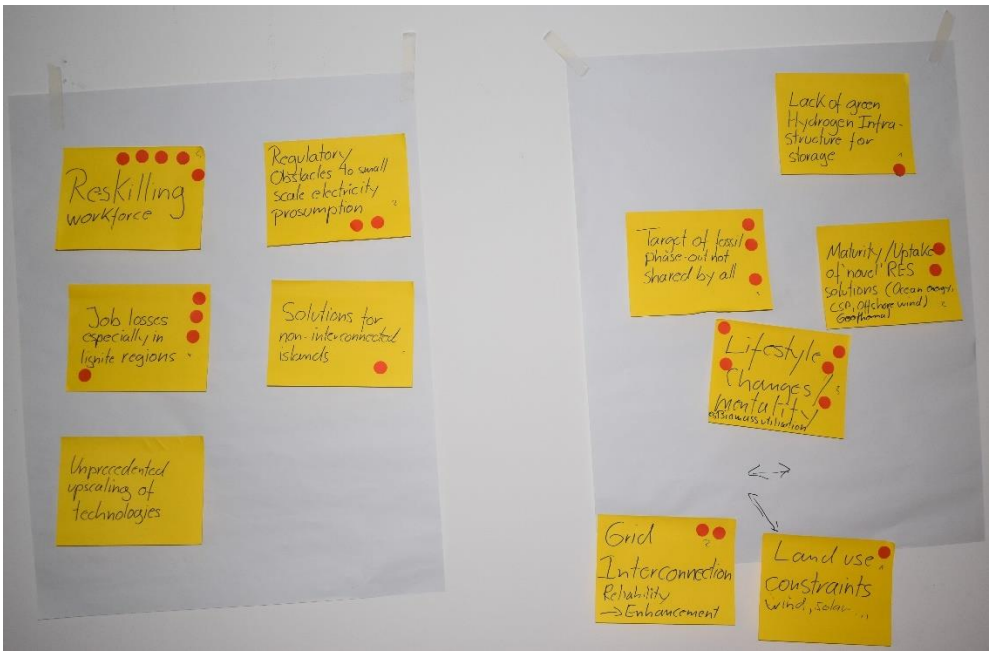

Fig. 8. Example of elaboration on bottlenecks for the decarbonisation of the Greek power sector.

Q&A session

After the two plenary sessions and presentation rounds, stakeholders had the opportunity to ask modellers with regards to the presented modelling insights (**Fig. 9**). The main discussion topics were **(i).** the usefulness of and feedback on modelling results, **(ii).** the model integration and comparability, and **(iii).** modelling challenges and further research areas.

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Fig. 9. Q&A session with SENTINEL modellers.

Usefulness of and feedback on modelling results

Stakeholders posed specific questions with regards to the SENTINEL modelling results. They were interested to learn more about the decarbonisation potential and the availability of biomass. Modellers argued that biomass growth is estimated according to specific land-use constraints considered in the IMAGE model, which has a detailed method of modelling land use and agriculture. They also highlighted that, at the European level, without carbon capture technologies, such as bioenergy with carbon capture and storage, behavioural change is necessary to reach the target of the 1.5°.

Stakeholders also mentioned that modelling scenarios usually result in labour markets and supply chains with radically different implications and asked for these aspects to be further taken into consideration by the SENTINEL modelling suite. Modellers noted that models which consider macroeconomic impacts, such as the WEGDYN computable general equilibrium (CGE) model and IMAGE, could provide some further relevant socioeconomic implications.

In addition, stakeholders argued that offshore wind will play a critical role in the Greek energy transition but were sceptical about the very large increase in new onshore wind projects required. Modellers responded that they have considered different scenarios for the wind capacity mix, which should be further adapted to the Greek reality based on the feasibility of implementing wind projects, e.g., considering public acceptance, spatial concerns, etc. According to outcomes from the EnergyPLAN model, an advantage of offshore wind projects is their quicker implementation; however, they result in higher costs due to more challenging installation, maintenance, and electricity transmission processes.

Finally, another critical issue mentioned by stakeholders is that the grey energy of building materials should be considered while renovating towards a net zero building sector. HEB modellers highlighted that carbon embodiment is accounted for the calculation of carbon emissions and that in net zero/passive houses, carbon due to construction is higher, while operational carbon is much lower, resulting in total carbon emissions going down.

Model integration and comparability

Stakeholders were also interested to learn about the extent to which SENTINEL modellers achieved integration of the different models by performing validity checks at the sectoral level, also noting that some of the models have system-wide scope, and, thus, their results can be compared more easily, while this might be more difficult for sectoral models.

Modellers noted that sectoral comparisons were conducted between the modelling teams. For instance, results from the HEB model were validated with results coming from the DESTINEE and the DREEM

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models. Modellers also referred to the SENTINEL intercomparison database that has been developed to enable comparisons of modelling results (Oreggioni et al., 2022). A key challenge to this is that models have different definitions of sectors, and thus more clarifications on the models' energy use classifications (e.g., P2X, hydrogen) are needed in some cases to compare their results. Furthermore, modellers argued that a lot of effort has been made to harmonise input data of the models so that differences in modelling results can be mainly attributed to intrinsic modelling approaches. For example, system design models were fed with the same input data from sectoral models in terms of service demand and final energy consumption.

Modelling challenges and further research areas

Moreover, stakeholders asked what areas should be further researched to improve the models and modelling insights. According to SENTINEL modellers, key challenges to improving the models are the lack of transparency of data and the difficulty in accessing them, forcing the modellers to go further than the available macro data categories (e.g., by making necessary assumptions).

Furthermore, modellers indicated that the aftermaths of the Russia's invasion of Ukraine shows how important it is to quickly achieve the independence from Russian gas and other fossil fuels and given this situation gas cannot be considered as an intermediate solution, thus suggesting looking into other solutions to replace gas, e.g., by lowering energy demand. In this regard, a relevant topic would be identifying the time and investment needed to decarbonise the building sector.

Modelling results also showcased that there are various technically and at aggregate level economically achievable pathways toward climate neutrality. The next step is to find out what options and timing are most desirable instead of what is possible. Given that the decarbonisation time frame runs out, and that infrastructure and building retrofits take time, decisions need to be taken by policymakers soon enough.

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3. Insights from the Climate-neutral World Café sessions

The following two sections present the detailed feedback we have received from stakeholders participating in the SENTINEL Climate-neutral World Café sessions, i.e., Session 3 (**Section 3.1**) and Session 4 (**Section 3.2**). Detailed insights from the PARIS REINFORCE Climate-neutral World Café sessions can be found here.

3.1. Climate-neutral World Café Session 3: SENTINEL modelling tools to support policymaking in Greece

Facilitators: Ms. Amanda Schibline & Mr. Andrzej Ceglarz (Renewables Grid Initiative)

Objective

The objective of the Climate-neutral World Café Session 3 entitled "*SENTINEL models to support policymaking*" was to identify and generate a set of updated research questions to pinpoint what aspects should be answered by energy system models to support policymaking in Greece. Participants were prompted to write down either a question, topic, or comment regarding the energy transition in Greece that they believe is relevant for energy system models to answer, also considering recent geopolitical developments (i.e., Russia's invasion of Ukraine and energy crisis in Europe). Having each stakeholder at the table write down a question or idea brought us closer to understanding the current needs of the policymaking sphere and reflects whether the SENTINEL modelling suite can fulfil the expectations of the modelling results' users in a short-term manner.

Method

To meet the objectives of this session, the "Idea Tree Exercise" method (Stokols et al., 2019) was followed. According to this method, each stakeholder received a large sticky note and marker to ideate one or more questions/comments that are relevant for models to answer for the Greek energy transition. Unlike other brainwriting methodologies, the second step of the process enabled another stakeholder to comment, elaborate, or ask follow-up questions to the original stakeholder's input. Finally, the sticky notes were all placed on a board and the participants used dot voting to prioritise the most urgent input to support policymaking. During this Climate-neutral World Café session, in two rounds of the "Idea Tree Exercise" method, two separate stakeholder groups contributed their ideas to the board, leading to 18 different insights being generated in total, commented on, and prioritised. **Fig. 10** shows the "Idea Tree Exercise" method as it was implemented during the first round of the Climate-neutral World Café Session 3.

Fig. 10. Implementation of the "Idea Tree Exercise" method during the first round of the Climate-neutral World Café Session 3 "SENTINEL models to support policymaking".

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Results

Results from this session provided an interesting mix of economic, technical, political, and social research questions about critical issues and challenges towards a decarbonised energy system in Greece, also reflecting the importance of having stakeholders of different groups and backgrounds involved in the exercise to deliver multifaceted answers. Additionally, stakeholders prioritised different urgencies in all the three stages of the "Idea Tree Exercise" method. As summarised in **Fig. 11**, the questions and comments generated by the stakeholders concerned mostly the topics relevant to the Greek political context, which were clustered into five categories: **(i).** *Costs of the net-zero transition*, **(ii).** *Energy system needs and considerations*, **(iii).** *Modelling capabilities and user needs*, **(iv).** *Policy implementation realities*, and **(v).** *Citizen-led and prioritised energy transition*.

Fig. 11. Clustering of stakeholder questions about the critical issues and challenges towards a decarbonised energy system in Greece.

During the first round of the Climate-neutral World Café Session 3, stakeholders generally had a more technical background and were much more experienced in the energy system modelling process. Due to this, in the first stage of the "Idea Tree Exercise" method, questions and comments they wanted to be answered by energy system models reflected their advanced understanding of what energy system models do, and more importantly, what they are not yet doing well enough for the Greek context. For example, questions focused less on costs and policies, but more on novel innovative solutions and modelling capabilities. Indeed, the second stage of the "Idea Tree Exercise" method, where each individual's sticky notes were rotated to the participating stakeholders, resulted in follow-up questions

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and comments about the scientific preciseness of the original input from the first step, or they provided more data to agree with the original input. For the prioritisation stage of the "Idea Tree Exercise" method, "technical" stakeholders favoured citizen-led, innovative solutions.

In contrast, the second round of the Climate-neutral World Café Session 3 included diverse stakeholders from Greece that encompassed more political and economic backgrounds in industry and policy. These stakeholders highlighted that both policies and the energy system requirements of Greece are quickly changing, and energy system models need to keep up with these changes. For example, the topic of security of supply was brought up by several stakeholders that prioritised increased storage capacity and additional liquid natural gas investments. From a policy perspective, stakeholders also wanted models to stay contemporary with the rapidly changing policies, asking about REPowerEU plan's implications on Greece's energy security, renewable energy sources (RES), and storage. In the second stage of the "Idea Tree Exercise" method, the participating stakeholders mostly agreed with their peer's original comments. Notably, an inquiry about model inputs and assumptions underscored an insightful answer: "Stakeholders need transparency". Therefore, models need to be open-access and modelling assumptions need to be clearly explained. During the final prioritisation round, the stakeholders agreed that transparency is the most relevant modelling aspect to consider for the future, which echoes and confirms previous findings generated in SENTINEL regarding user needs for modelling (Gaschnig et al., 2020).

3.2. Climate-neutral World Café Session 4: SENTINEL modelling platform

Facilitators: Dr. Vassilis Stavrakas, Mr. Serafeim Michas & Mr. Nikos Kleanthis (TEESlab UPRC)

Objective

The objectives of the SENTINEL Climate-neutral World Café Session 4 entitled "*SENTINEL modelling platform*" were to discuss **(i).** how to disseminate best modelling results via the SENTINEL platform, **(ii).** issues related to dissemination, exploitation, and sustainability of the SENTINEL platform, and **(iii).** what type of information stakeholders would prefer to find in the SENTINEL platform as well as how it should be structured. The main purpose of this session was to gather ideas that could help the SENTINEL consortium to prioritise the most significant issues that should be considered during the development, the operation, and the maintenance of the platform.

Method

In this session, an open discussion format was followed. To solicit the feedback from experts, each participant received a large sticky note and marker to ideate one or more comments relevant to the set objectives. During the two discussion rounds of the session, two separate stakeholder groups contributed their ideas by placing the sticky notes to a board (**Fig. 12**).

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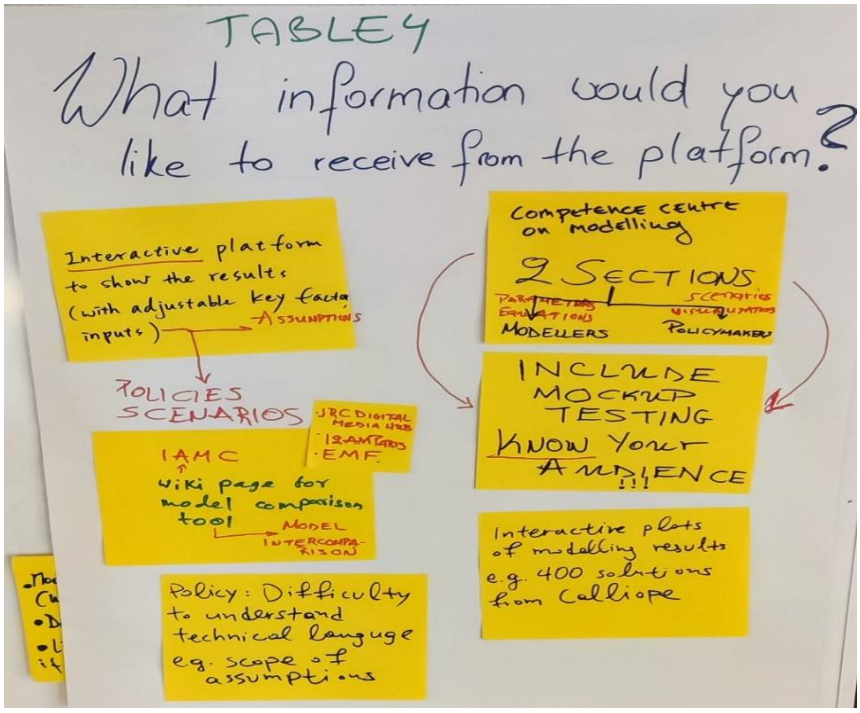

Fig. 12. Clustering of stakeholder feedback received during the two discussion rounds of the Climate-neutral World Café Session 4 "SENTINEL modelling platform".

Results

After grouping together and further analysing the feedback received from the stakeholders, summaries with the key insights based on the discussion topics concerning the platform were developed and are presented in **Fig. 13**.

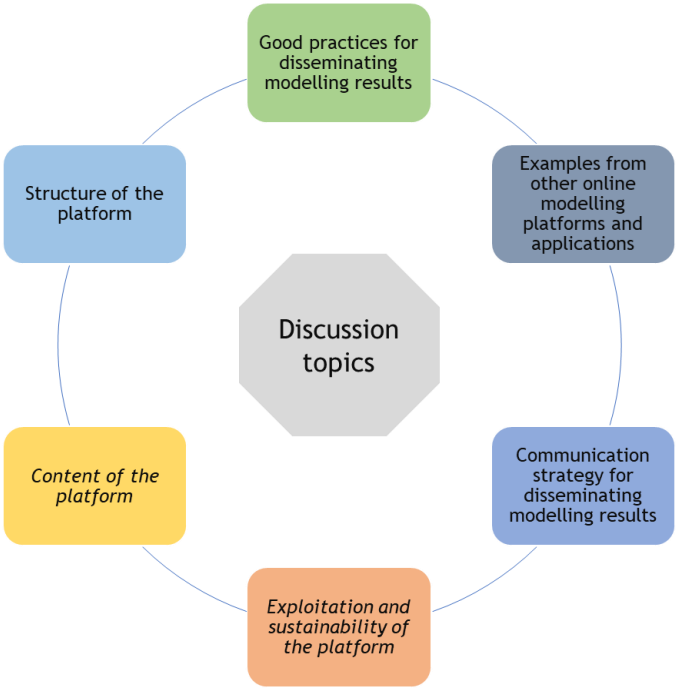

Fig. 13. Discussion topics with regards to the SENTINEL modelling platform.

Good practices for disseminating modelling results

Stakeholders provided useful feedback with regards to the dissemination of key modelling results via the SENTINEL modelling platform, highlighting the need for making the results simple,

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comprehensible, transparent, and visually appealing. They suggested that technical language should be adapted in a way that promotes user-friendly and digestible dissemination of modelling results to all interested parties, like, for example to policy experts, by translating them into targeted policy recommendations. As they highlighted, policy experts often find it difficult to properly understand the technical specifications provided by modelling teams, which can often lead to misinterpretations and misunderstandings.

Stakeholders argued that the presentation of modelling results, as included in the online platform, should be easily understandable to different types of users, i.e., to people who are not familiar with energy modelling, but also for those, who are looking to dive deeper into the data and modelling details.

Moreover, stakeholders exclaimed that the transparent dissemination of the results, including model assumptions, uncertainties, and what model results can say (and what not) is essential. They highlighted the need for assumptions, scenarios, and data used to be clearly explained, and that the presentation of modelling results is executed in a coherent manner, which includes simple and eye-catching visualisations. According to their preferences, modelling results should be presented interactively, i.e., with adjustable key factor inputs in terms of assumptions and policy scenarios and be facilitated by standardised approaches.

Examples of other online modelling platforms and applications

Stakeholders encouraged additional research of existing web-based interactive modelling platforms and applications as good practices that could be used as inspiration during the development of the SENTINEL platform. They offered the following examples:

I. GitHub and GitLab, online software development platforms that enable software developers to upload their own code files and to collaborate with fellow developers on open-source projects.

II. The Open Energy Platform, a web interface to access energy related data with proper documentation (metadata) and links to source code and underlying assumptions.

III. The open energy mod list/wiki, an initiative fostering open source and open data in energy modelling.

IV. The Strategic Energy Roadmap Scenario Explorer that shows selected energy modelling results based on the impact analysis of multiple future paths and policies.

V. The I^{2}AM PARIS platform developed under PARIS REINFORCE project, an open-access, data exchange platform hosting detailed documentation, inputs and outputs of energy- and climate-economy modelling.

VI. The Integrated Assessment Consortium (IAMC) Wiki that provides an overview of integrated assessment models using a transparent wiki-based approach that has consistently been used across a range of models, also including a model comparison functionality that allows for direct comparisons between these models.

VII. The Modelling Inventory and Knowledge Management System (MIDAS) of the European Commission's Competence Centre on Modelling (CC-MOD), which documents models that are used to quantify the environmental, economic, and social impacts of policy options and their contributions to Commission's impact assessments.

Stakeholders also mentioned the Energy Scenarios website of the Joint Research Centre's (JRC) Digital Media Hub as a means of presenting modelling results in a simplified way. They also added that interactive plots, such as the online application of the Euro-Calliope model which enables users to identify trade-offs among energy system key performance indicators, would be very useful for the visualisation of modelling results.

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Strategy for effective communication and dissemination of modelling results

Experts noted that correctly identifying the target audiences of the SENTINEL modelling platform would be the key to adapting content according to their preferences. Web developers should design a platform that provides added value for different user groups, but when designing the platform, the target group that will form the majority of users should be defined. They also suggested that it would be beneficial to receive feedback from the target audiences on whether the content and structure of the platform are understandable to them.

Strategy for exploitation and sustainability of the platform

Stakeholders suggested reaching out to the identified target audiences to highlight the unique selling points of the SENTINEL modelling platform, e.g., user-friendliness, front-end oriented modular platform design to fit various purposes and research questions of different stakeholder groups, etc. They claimed that several similar online modelling hubs have already been created and that it would be useful to develop the SENTINEL platform in a way that it has some competitive advantages compared to other existing online applications. Furthermore, they argued that maintaining the modelling platform, especially after the end of the SENTINEL project, is very important. In this sense, they proposed creating a simple platform that is well structured and easy to manage and will work smoothly after the project end. In this context, they also stressed out the importance of identifying synergies with other projects and initiatives in the field of energy system modelling.

Content of the SENTINEL platform

Stakeholders prioritised model intercomparisons, asking for explanations of model differences by comparing specific model outputs when inputting the same parameters, and applications in case studies, requiring specific information about the functionality and use cases of specific models as well as descriptions of the relation and linkages of different compatible models. They noted that mock-up model testing for the replication of results, accompanied by training material for model application, would be a useful feature to include in the platform. Experts also asked for the incorporation of well described and open-source model overviews and documentations, download options of models and output data, historical, and projected input data, and key model assumptions used, as well as uploading their sources, if available, and a contact point to reach out to in case of technical difficulties. They also asked for a timeline of updated model versions and a track record that will include all reports and publications referring to these versions.

Stakeholders also referred to the need for including policy descriptions in cases where specific policies were analysed by the models to derive their outputs. An interesting point of discussion was related to what might happen if we do not reach the targets set by energy policy documents, with some stakeholders asking for the presentation of such cases to be also informed about negative energy system implications.

Structure of the SENTINEL platform

Stakeholders argued that it is important to distinguish the platform's interfaces in two sections; one for visitors that are interested in the key messages and visualisations of results, e.g., policymakers, technical users and another for modellers looking for higher granularity and input data, etc.

Moreover, they proposed two different menus within the platform's structure. The first is related to the SENTINEL intercomparison database (Oreggioni et al., 2022), which could include searching functionalities to find variable values for selected key performance indicators of the energy system. The second concerns the research questions of the SENTINEL case studies (Stavrakas et al., 2021) that could also incorporate a keyword search to find relevant research questions and read the respective modelling results based on the case study model applications (Michas et al., 2022). For example, users interested in learning more about the use of biomass across different sectors could type "biomass" and

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navigate themselves through relevant research questions about biomass, where responses based on modelling results could be available.

Key take-aways

The main suggestions from the participating stakeholders regarding the development of the SENTINEL modelling platform are summarised below:

- Need for model intercomparisons, well described and open-source model overviews, and documentations of models.
- Clarity on assumptions, scenarios, and data and coherence on the presentation of modelling results.
- Utilisation of user-friendly language and inclusion of policy descriptions in cases where specific policies were analysed by the models to derive their outputs.
- Definition of key target groups and constant communication with them for their feedback on the platform.
- Identification of competitive advantages compared to other existing online applications and synergies with other projects and initiatives in the field of energy system modelling.

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4. Conclusions and outlook

The stakeholder workshop did not only enable the SENTINEL researchers to present the key results of the SENTINEL modelling work for the Continental and the National case studies, but it also provided us with the opportunity to receive feedback on the modelling approaches and results, as well as the SENTINEL modelling platform. We conclude that there are multifaceted European- and Greek-specific challenges and issues of the transition to climate neutrality to which energy modelling can provide important insights. The perspectives from the workshop will help us to further advance the SENTINEL modelling tools and provide a user-friendly online platform. In addition to that, we identified, together with the stakeholders, new transition challenges and research questions that could be addressed in future modelling work.

The SENTINEL project will end in November 2022. Formed focus groups on various energy system modelling topics, such as energy demand, environmental implications, and socio-economic transition aspects modelling will continue to exist, and new stakeholders are invited to join the discussion. You can find information about the SENTINEL modelling suite and publications on our website.

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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	High-resolution demand-side management	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

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