SENTINEL

SUSTAINABLE ENERGY TRANSITIONS

"Energy transition in Greece towards 2030 & 2050: Critical issues, challenges & research priorities"

Stakeholder Interview Meetings – A Synthesis Report

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Background

To meet the goals outlined in the Paris Agreement and keep the current trajectory of the global temperature increase below 1.5ºC, the transformation of the current energy systems into decarbonised ones is profound. However, deciding on how the 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 the energy policymaking, the increasing complexity and interrelatedness of various dimensions of energy 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 SENTINEL project, which stands for Sustainable Energy Transitions Laboratory, tries to overcome this drawback and develop a new energy system modelling framework.

Nevertheless, designing a multifaceted modelling suite brings along 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 remain redundant if the needs and concerns of people are not considered. In particular, those who are using energy models and their results in their professional life are crucial in making decisions about energy futures. In this context, there exists an additional threat that modelling runs, and decisions based on them, will be contested by some social actors, as long as they will be 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 (dealing with Europe). Second, from the early start 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 modelling users' needs are. Finally, by involving external actors into 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 interaction with stakeholders in the context of the SENTINEL national case study, for the identification of critical issues, challenges and research priorities for the energy transition towards 2030 & 2050 in Greece. The processes included physical meetings with stakeholders from the policymaking sphere, energy industry, non-governmental organisations (NGOs) and scientific community, to reflect on the national scenarios and targets suggested in the recent National Energy and Climate Plan and the Long-Term Strategy towards 2050. The report captures our discussion and findings tackling the different dimensions of the energy transition in Greece. The results of this exchange indicate relevant issues for the Greek energy system, 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

Greece is a transcontinental country with a diverse geographical landscape and a large potential in renewable energy (Michas, Stavrakas, Papadelis, & Flamos, 2020). It presents a case of a radical change in the planning of the energy system development. Although the introduction of renewable energy was actively promoted in the energy policy agenda over the past ten years (Nikas et al., 2018), indigenous lignite continued to play a major role in the electricity generation in all scenario analysis and policies formulated until 2019 (Stavrakas & Flamos, 2020). However, in the second half of 2019, the Greek government took the decision of phasing-out lignite-fired power plants in a short time horizon (by 2028) (Stavrakas, Kleanthis, & Flamos, 2020). This called for an extensive modelling work to analyse its effect on the further development of the energy system (Süsser et al., 2021). This modelling work resulted in the development of the:

1. National Energy Climate Plan (NECP) that summarises the country's climate and energy objectives, targets, policies, and measures for the upcoming decade, also considering the European Union's relevant targets for 2030, and United Nations Development Programme's Sustainable Development Goals (SDGs) (Ministry of Environment and Energy, 2019b), and

2. Long-Term Strategy towards 2050 (LTS 2050), which highlights the range of the available solutions and different scenarios for the upcoming energy transition, in the context of the long-term European energy strategy for 2050 (Ministry of Environment and Energy, 2019a).

However, additional modelling work is required to assess if climate-neutrality of 1.5°C, as promoted by both plans, is a feasible choice after all, maintaining the modernization and competitiveness of the national economy as key components, and creating an environment of social justice without 'winners and losers' for an energy transition with "no one being left behind."

Considering all these issues, the SENTINEL team reached out to several stakeholders form the power sector, fossil fuels industry, renewable energy sources (RES) and energy efficiency (EE) sectors, as well as to policymakers from the Ministry of Environment and Energy and representatives of NGOs to identify critical topics for the medium- and the long-term national strategy.

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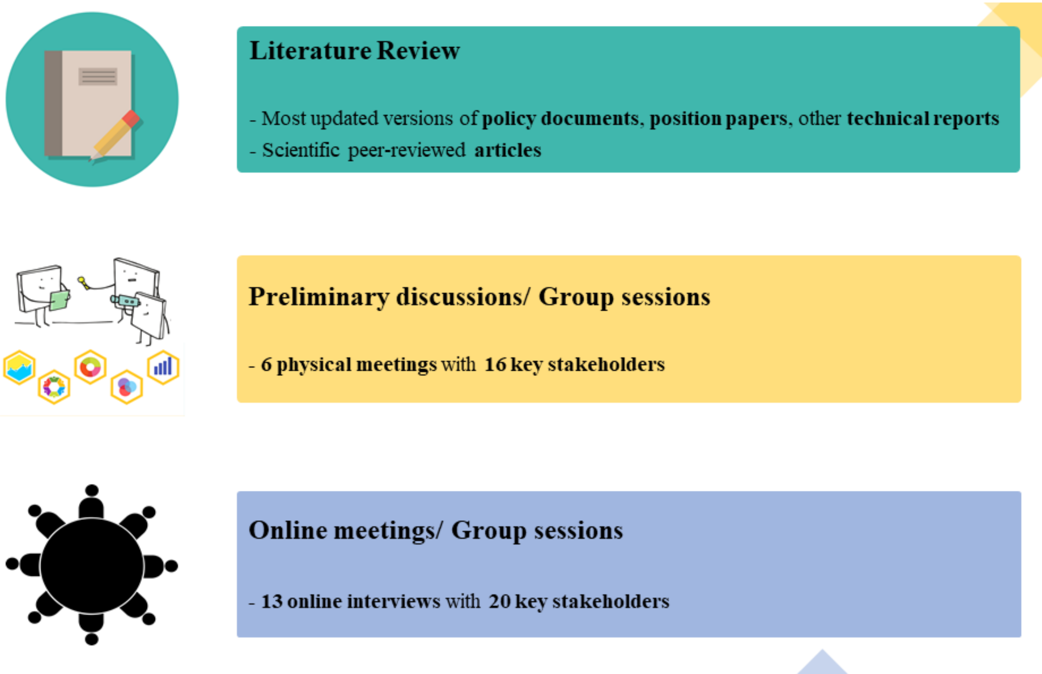
2. Stakeholder engagement



In order to collect stakeholders' input on the policy-relevant scenarios and the critical issues and challenges associated with them, we have applied a three-tier participatory multi-method approach. Tier 1 of our approach included a literature review of policy documents, scientific publications, technical reports and positions papers, in order to identify preliminary critical issues and challenges. The actual involvement of stakeholders took place in Tiers 2 and 3.

At the second Tier we conducted six physical meetings with sixteen stakeholders from policymaking, industry, and academia, to reflect on the national scenarios and targets suggested in the National Energy and Climate Plan, and the Long-Term Strategy 2050. This discussion included also specific assumptions for the three transition scenarios we have identified and will be considered in the modelling exercise of the case study analysis. The participants in the physical meetings represented the Greek Ministry of Environment and Energy (MEE), the Centre for Renewable Energy Sources (CRES), the Energy-Economy-Environment Modelling Laboratory (E3MLab) from the National Technical University of Athens (NTUA), and from different departments of the Public Power Corporation S.A. (PPC) and the Independent Power Transmission Operator S.A. (IPTO). All these entities played a key role in the development of the updated versions of the two policy documents mentioned above.

According to the initial planning, the third Tier of our approach included a National workshop in the spring of 2020. We made most of the arrangements for this: we reserved a venue for the 7th of April 2020 and invited relevant stakeholders, with more than 20 invitees having registered for the event. However, given the spread of the COVID-19 from late February 2020, we decided to cancel the physical event and host it as a webinar. However, representatives from the Ministry of Environment and Energy advised to postpone the online meeting, due to the uncertainty of the situation at the time and the total lockdown in Greece which started in mid-March 2020. This called for a complete restructuring of our initial approach. We used the period March-May 2020 to adapt to the new reality, investing additional resources to the design of specific online formats, which would allow us to organise interactive stakeholder engagement activities. As a first step, we shared with the stakeholders registered to the

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physical event, a narrative document. which synthesised all findings from Tier 1 and 2, and we collected their initial feedback, adding in this way an extra layer of validation. In the meantime, we also started organising bilateral online interviews with the same stakeholders. These meetings started in early June, because until then reaching out to them was difficult: many of them were either irresponsive or needed additional time to adapt to new circumstances of the COVID-19 pandemic. In the meantime, we shared our work with the SENTINEL modellers to receive their feedback on the simulation feasibility of the case study scenarios, on variables and assumptions necessary to calibrate/ parameterise their models, and on the contextual critical issues/ challenges and research questions to be replied by their models.

Overall, during the period June - December 2020, we conducted thirteen online meetings with twenty key stakeholders, during which we validated our thematic research priorities and specified more than eighty research questions for the SENTINEL modelling suite. The interviews were based on a semi-structured design as well as an open discussion format, to allow stakeholders to freely express their opinions. The research questions identified through this approach were clustered in seven thematic priority areas, based on stakeholders' insights:

1. *Energy resource planning with a focus on security of supply*
2. *Distributed generation, storage & curtailment*
3. *RES business models*
4. *Direct and indirect electrification & energy efficiency*
5. *Demand-Response & digitalisation*
6. *Environmental impacts*
7. *Socioeconomic aspects & implications*

Each thematic priority area is discussed in the following sections, along with a series of contextual critical issues and challenges as were identified by stakeholders. Being inspired by the "*Three types of knowledge tool*" method (ProClim, 1997), we structured the output of the discussions around three guiding questions relevant from a modelling point of view:

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 stakeholders' perception on specific processes and issues about the energy transition in Greece and accompanying challenges. Sketching such contextualization was supposed to set the stage for further discussion. The final objective of the energy transition for Greece has been already defined and is politically backed. The second question was used to validate, whether there exists an unanimity among the stakeholders about this goal. The aim of the last question was to identify crucial issues to be considered to achieve the final target. 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.

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3. Insights from the interview meetings & group sessions with stakeholders in Greece

The following sections present the inputs we have received from stakeholders under each one of the thematic areas specified during preliminary discussions and group sessions.

3.1 Energy resource planning with a focus on security of supply

Long-term security of supply is an important issue for the Greek power system. During the interview meetings, stakeholders noted that energy planning should not only incorporate economic models, but also detailed technical models which will analyse the proper system operation under high RES penetration. According to them, "*The Greek power system has already operated some hours with zero marginal price due to the high generation of the existing renewables and the low levels of load during the period of the first total lockdown*" so this could offer a glimpse into the future operation of the system under a high share of RES.

The fact that the most of the lignite-fired power plants is decided to be decommissioned by 2023 (except for the 'Ptolemaida 5' plant, whose commissioning started in 2020 and will be retrofitted to generate electricity from natural gas from 2028 onwards), will offer a high advantage to the gas-fired units, which will operate as a transitional technology until the system is fully decarbonised. However, increasing carbon prices under the EU Emissions Trading System (ETS), and the large penetration of RES envisaged in all the scenarios of the NECP, may lead to the natural gas units becoming gradually less competitive in the wholesale market, limiting their contribution to the electricity mix.

However, representatives from the energy industry expressed their scepticism on the issue of high-RES penetration, from the point of view of the system operation as it stands today. However, there is some optimism, since they are expecting that within the next few years variable RES plants will be operated like conventional plants are operated today.

In addition, interviewees highlighted that interconnections will be a crucial parameter for the decarbonisation of the power system, as they contribute significantly to the security of supply. Therefore, the interconnection of the Greek system with neighbouring countries should be further increased, and, to this end, some domestic network upgrades will be also necessary. Cooperation with neighbouring countries could reduce the cost of the system's decarbonisation since interconnected countries could exploit RES electricity exports during periods of high RES generation.

However, on the other hand, the geographical placement of new RES installations, by simultaneously considering network constraints and the RES potential of certain regions, might be a challenge. As mentioned during discussions with stakeholders, the spatial distribution of RES in the case of extremely high RES penetration is a critical issue, and, to this end, proper land planning options should be explored.

Regarding future bidding offers and capacity investments, stakeholders highlighted that, in a system with high RES penetration (65% by 2030 as foreseen by the NECP), it would be difficult for investors to bid, if they do not have a portfolio of variable RES, thermal power plants, and storage, so that they can securely offer their bid despite RES variability. Also, natural gas units should be kept for grid security reasons, as in the longer-term horizon they are expected to remain in operation for balancing services. In the case of high RES penetration, it is difficult to calculate the flexibility of power plants, as, the higher the RES penetration, the higher the

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residual load volatility that must be met by dispatchable power plants. All these technical specifications and constraints make the planning of the energy system extremely complex.

3.2 Distributed generation, storage & curtailment

In the case of high RES penetration, storage systems are needed to minimise curtailment and cover part of the system's increased needs for flexibility (Nanaki & Xydis, 2018). Pumped storage hydropower is an obvious option for Greece, as pointed out by stakeholders, but newly emerging technologies, like utility scale batteries, should be also considered. Overall, storage systems could help absorbing more electricity from RES, enabling RES to become the main source of energy in the country. This is why stakeholders argued that it is difficult to reach a 100% RES system in Greece, without storage infrastructures and without improving the technical capacities of the available storage technologies. On the other hand, stakeholders from the industry highlighted that conventional units will be needed for reserve requirements at least until 2030, and that, after 2030, hydrogen could be a more preferable way of storage than batteries in remote or non-interconnected electricity systems. They also stated that hydrogen production could also be an alternative to electricity grid expansions, and remote or non-interconnected sites with high RES potential could be exploited for hydrogen production.

Another important particularity of the Greek power system are the non-interconnected islands, in which electricity is generated using oil products at a high cost. The integration of high shares of RES in these non-interconnected systems can be an option once issues of variability are addressed. RES combined with storage infrastructure could be a solution alternative to the interconnection of islands to the mainland. As a showcase of the viability of this approach, the island of Agios Efstratios is planned to achieve an 85% level of RES penetration until 2030.

In the case where RES capacity increases significantly, a key challenge will be the mitigation of curtailment. Stakeholders pointed out that, after 2030, it is expected to have high levels of curtailment due to the high RES generation expected during hours of low demand. In general, curtailment could be due to dynamic stability issues and the technical minimum of conventional power plants already in the system. These two factors will determine the need for reserves and storage. The necessary storage installations could either be aggregated, considered as a virtual power plant with centralised scheduling, or they can be installed in homes and offices as a decentralised option. However, Greece still lacks a regulatory framework for storage, which according to stakeholders should be introduced as soon as possible.

Finally, specific suggestions on this issue were made by an independent energy consultant, who mentioned that *"the operation of the system in the island of Crete can offer significant know-how for the operation of the interconnected system under high RES penetration. Currently, in the control area of Crete, each wind park has a set point determining the amount of electricity that it provides, also ensuring the overall balance of the system. RES curtailment is in the range of 8-10%, which is acceptable and agreed among RES producers. On the other hand, the power system in the island of Rhodes has very high curtailment levels, which could be reduced if RES producers created a central storage unit in the island."*

3.3 RES business models

As the RES capacity increases, each RES producer will aim at maximising profits, thus the selection of the most economically attractive business model will be of primary importance. Regarding this issue, stakeholders noted that net-metering has been very profitable so far for residential customers, however, the directive for the internal electricity market mentions that, after 2023, injected energy will be metered at the wholesale price, instead of the retail price

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(European Parliament, 2019). Even though net-metering could be very profitable if implemented in the tertiary sector, its potential has not been exploited yet. The latter is mainly due to dimensioning mistakes, as, initial attempts to cover the 100% of the annual needs of enterprises were made without proper sizing of the systems, aiming at the maximisation of the simultaneity between generation and consumption.

For the case of participation of RES in the wholesale market, RES technologies have low operation and maintenance requirements and, thus, much lower variable costs compared to conventional generating units. In the long run, the cost of electricity is expected to be reduced because of RES penetration, which will be a direct benefit for consumers.

Investments in RES depend on the attractiveness of the applied business models. To avoid sudden impacts on electricity prices, the level of the RES investments required should be steady and continuous. Furthermore, even if new business models tend to be subsidy-free (Psomas, 2019), when state support is included in a business model, the liquidity of the RES special account should be considered during its design in order to avoid deficits, such as the ones occurred with the introduction of the Feed-in Tariffs scheme during the period 2008-2013 (Stavrakas, Papadelis, & Flamos, 2019). In this context, stakeholders acknowledged the importance of legal issues. For example, the existing legal framework for small-scale PV systems is rather complicated and does not contribute to the wider penetration of the technology.

On the other hand, most of the stakeholders agreed that for small-scale, decentralised RES projects, and particularly PV, self-consumption models could emerge, in which prosumers would consume most of the electricity generated at the local level and sell the excess to the grid. The main challenge of decentralised generation and prosuming is that initial costs of RES technologies may be prohibitive for investments, despite the benefits over the technologies' lifetime. This fact is even more obvious in the case of economically vulnerable consumers. As a stakeholder pointed out *"if leasing models are offered to consumers by electricity providers, who will own the central storage systems and act as aggregators, then, in this case, the prosumer model would not be attractive."*

3.4 Direct and indirect electrification & energy efficiency

When it comes to the electrification of the transport sector, there are, currently, several barriers to electric mobility that should be overcome in order to achieve the ambitious targets dictated by the NECP. On the one hand, the high initial investment cost of electric vehicles (EVs) is an impeding factor to their dissemination. On the other hand, even though, according to literature, almost 85% of the EVs' users currently charge their vehicles at home (Perellis, Mezartasoglou, & Stambolis, 2018), their limited range autonomy means that the lack of appropriate charging infrastructure will pose a further problem for the promotion of this technology. Stakeholders highlighted that the electrification of transport is expected to change completely the form of the load curve and could deteriorate the imbalance between RES generation and demand, which is a major technological challenge that makes the contribution of RES to transport a challenging task.

Furthermore, regarding the electrification of the heating sector, barriers such as the high investment cost of heat pumps, or the lack of expertise in designing and installing them, could be impeding factors to their dissemination, according to one interviewee. Synergies between RES (especially PV) and heating/ cooling have been studied in literature as a means of

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reducing the cost and energy requirements of heating and cooling applications (Michas et al., 2019).

In regard to EE, and according to the NECP, selecting cost-effective applications, simplifying existing processes, the lack of incentives for EE measures, and the difficulty in implementing EE projects via innovative financing schemes, can be barriers to the exploitation of existing funding mechanisms. Regarding challenges for the implementation of EE projects, a stakeholder pointed out that Energy Service Companies (ESCOs) are still extremely limited in Greece. Therefore, there is a need for setting up loan schemes for EE interventions, which could support the creation of ESCOs, maybe even under the activities of the European Investment Bank (EIB).

EE obligation schemes, which are the most widespread market mechanism and can lead to the implementation of cost optimal energy efficiency measures, the transitioning from behavioural to technical measures as well as expanding the scheme by trading certified energy savings are considered as important steps towards the mainstreaming of EE projects. As stated by a stakeholder *"a key incentive for EE could be the provision of subsidies coupled with obligations for a minimum level of energy savings achieved by the intervention. In the same line of thought, the amount of funding which is offered for residential building renovations should be increased, since it is estimated that something close to 1 billion Euros per year are needed to achieve the EE targets foreseen by the NECP."* The new "Exoikonomo-Aftonomo" programme, deriving from the EU Recovery Fund, a mechanism to mitigate COVID-19 effects, could facilitate the sustainability of household refurbishments in the residential sector (Hellenic Ministry of Environment and Energy, 2020).

Finally, hydrogen could provide low-carbon energy at peak demand, substituting natural gas in the industry sector. As stated by stakeholders, hydrogen will be mainly used in industry, but heat recovery should be explored before we move on to the next step of hydrogen economy. Stakeholders during physical meetings mentioned that the replacement of natural gas for industrial uses would be a difficult part of decarbonisation. Nevertheless, existing equipment could be adapted for alternative use (e.g., hydrogen gas boiler for space heating).

3.5 Demand-Response & digitalisation

In a sustainable energy system with high electrification and high RES penetration, load management and energy storage will be required alongside flexible conventional generation methods (Nanaki & Xydis, 2018). Stakeholders mentioned that regional control services could contribute to a better operation of the system offering a control area at the neighbourhood level. Also, a remote measurement in the demand sector is necessary to obtain a clear picture of the load, which should be managed.

Digitalisation (e.g., smart meters, RES aggregation, virtual power plant management, etc.) would enable better system management and create opportunities for active consumer participation (e.g., prosuming, demand-response, etc.). A stakeholder noted that the installation of smart meters will have an added value for consumers, but the cost will be covered by them. Furthermore, it would be useful, if part of the cost of smart meters was subsidised, to achieve a wide deployment as soon as possible. Financial incentives, as, for example, time-of-use (TOU) tariffs, or even more adaptive tariff schemes, which could contribute to the smoothening of peaks, should be created by utilities to maximise the advantages of smart meters. Overall, stakeholders indicated that proper demand-response

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with the use of smart meters can achieve the necessary peak shaving in the system's operation.

Moving towards digitalisation, an interviewee noted that a software tool that monitors data and calculates CO_2 emissions per type of energy, and total CO_2 emissions per period in the residential sector, could be particularly useful for consumers. Moreover, digital platforms, supported by user-friendly interfaces for consumers, could also offer benefits to electricity producers and utilities, also contributing to demand management.

Against this backdrop, some stakeholders stated that demand-response could be competitive to storage, and it would be desirable to combine these approaches, while only one stakeholder argued that demand-response, in general, is not expected to cause large changes to the needs for investments in storage installations. The latter shows that both suggestions should be evaluated thoroughly before identifying the best solution to move forward.

Finally, Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) models could also be used to increase the flexibility of a smart grid through the aggregation of many EVs and the management of their energy flows as a virtual power plant. Stakeholders suggested that utilities should further contribute to the deployment of charging stations, and that consumers could have a flat tariff for a variety of electricity usages including EV charging. They also acknowledged that EV charging stations could operate as aggregators or utilities, regulating the timing of charging, and that the latter could be the initial structure of a V2G model.

3.6 Environmental impacts

Policymakers and civil society organisations are deeply concerned about the environmental impacts of energy system transitions and consider that environmental impacts should be addressed in modelling exercises with the introduction of externality costs. This would differentiate the prioritisation of investments based on, firstly, their environmental, and, secondly, their social impact, while the overall process will aim at selecting the best approach for achieving social prosperity. Therefore, the ability to incorporate environmental factors into the energy planning process, especially in the case of extreme decarbonisation scenarios, is crucial.

Average GHG emissions from electricity generation in Greece so far are relatively high, due to the dominance of fossil-fuelled power plants in the electricity mix. After the planned decommissioning of most of the lignite-fired power plants by 2023, gas units are expected to play a significant role in electricity generation. However, decarbonising these units using carbon capture and storage (CCS) and hydrogen fuel cells is a challenging process. Furthermore, CCS plants are not capable of capturing their total emissions and their capture rates will need to be high enough to avoid high overall emission levels. Furthermore, stakeholders highlighted that CCS technologies still have a low technology adoption rate and are very costly.

Consideration of the full life-cycle effects of storage technologies has shown that using, reusing, remaking, and recycling batteries is more challenging than simply disposing of them. With the expected high demand for storage batteries, one of the main environmental issues is what happens with the batteries at the end of their lifetime. In this context, a representative from academia mentioned that *"The clear message is that all materials used in energy technologies should be recycled."* Therefore, the disposal of batteries is not environmentally sound, and, thus, unacceptable from a circular-economy standpoint. To this point, stakeholders reached a consensus, pointing out that other technologies are also recyclable

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“as for example, 90% of the wind turbine materials can be recycled, with only their blades not being recyclable; however, their material is environmentally neutral and can be used as construction aggregate.”

3.7 Socioeconomic aspects & implications

Socio-technical factors, such as social acceptance of energy technologies, are critical for the transition to carbon-neutral energy systems, since these factors can constrain, or accelerate, the pace of diffusion of new technologies. As noted by one interviewee: *“The success of the energy transition is hindered by the fact that people who live close to RES installations are reacting, and they do not directly see the benefits of RES.”* Stakeholders noted that, so far, lobbying against RES has been highly successful, thus, it is not easy to change the way people think about renewables, and that awareness raising campaigns have an effect only, if they are spread over longer periods of time. However, awareness raising should be combined with incentives, according to one stakeholder, *“since the main issue is the lack of incentives towards sustainability, while the lack of information is a secondary barrier.”*

It is important to understand the ways in which societal actors interact and shape the energy future. Such actors often contribute in far-from-cost-optimal ways, especially in how they react to energy system developments, and create pressures that redirect policies and the overall energy trajectory. Stakeholders mentioned that an interesting question to which models could try to provide answers is the willingness to participate in support schemes as a function of the level of subsidies offered. In another example, consumers both value a higher percentage of renewables in electricity generation and penalize interruptions to supply, but they are also sensitive to the effect these have on the cost of energy.

Stakeholders also stated that the effects of a RES-based transition on vulnerable consumers should always be considered since energy poverty is an existing problem and instead of solving it, the energy transition might create new vulnerable groups of consumers, especially after the total shutdown of lignite-fired power plants. As it was highlighted by one stakeholder *“Vulnerable social groups should be included in the energy transition.”*

Within a wider social aspect, the implications of the energy transition can span a large landscape. The shutdown of thermal power generation resources will be at the cost of job losses, especially in regions where the economic activity is largely dependent on fossil resources. Specifically, according to one stakeholder *“It is expected that 4,500 jobs will be lost due to the shutdown of the lignite-fired power plants in Greece.”* Also, a post-lignite ‘cleaner’ development trajectory in such regions should be socially ‘just’ (Nikas, Neofytou, Karamaneas, Koasidis, & Psarras, 2020). Therefore, stakeholders highlighted that it is important to discuss how those which are currently working in the lignite industry will participate in the energy transition. They indicated that the villages close to the lignite-fired plants could be turned into showcase energy communities, and a “Just Transition Fund” should be utilised for the creation of clean energy start-up communities in these areas. Finally, an important point that was raised is that even though the energy transition will have a positive overall impact, the designed policies might not be based on citizens’ needs.

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4. Conclusions & outlook

Discussions and inputs from stakeholders revealed meaningful viewpoints that should be considered in future work in SENTINEL. The approach of using the seven thematic sessions proved to be appropriate in better understanding the current critical issues energy transition in Greece, in confirming the agreement about the need to achieve carbon neutrality, and in uncovering the components of the potential pathways leading to this objective.

The main themes related to the power sector and its decarbonisation, are the requirements for secure supply, system flexibility and storage, which stem from the announcement of shutting-down the lignite-fired power plants, coupled with high penetration of RES. In this context, the role of interconnection capacities in securing supply and the system's operation, needs to be further investigated. Furthermore, demand electrification with a focus on transport and development of the necessary infrastructure is a critical issue that needs to be further studied. Finally, novel regulatory frameworks, to ensure that the post-lignite development trajectory in the coal regions is socially just, are required. The latter also includes social innovations relevant to the concept of energy citizenship, such as energy communities, ecovillages, and others.

Finally, from a modelling perspective, our findings reflect a need for further improvement of existing modelling tools. Current energy system models cannot answer all the questions and concerns raised by the stakeholders. That motivates us to continue working on development of the SENTINEL suite. Yet, the uncertainties remain, whether some of the questions will ever be feasible to be answered by energy system models. Probably not, therefore, we think that in those cases modelling should serve as an additional tool for stimulating a transparent and inclusive public debate towards holistic decision-making.

Based on the information generated from the consultation process with stakeholders, we will shift into a models' application stage. Once the first round of modelling runs is completed, we will be happy to share them with key experts and stakeholders and consult them on how 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	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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Institutions & stakeholders participating in the consultation process

Ministry of Environment and Energy (MEE)

Public Power Corporation S.A. (PPC 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 Associatio (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)

Center for Renewable Energy Sources (CRES)

Institute of Zero Energy Buildings (INZEB)

Independent Energy Consultants

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