4th International Forum

Long–term Energy Scenarios for the Clean Energy Transition

The role of long-term energy scenarios (LTES) in achieving net-zero commitments

7-9 December 2022 | Hybrid event

Event Proceedings (Day 2)

Contents

Event summary

The 4th LTES Forum hosted approximately 35 attendees at IRENA Innovation and Technology Center offices in Bonn, Germany, while 359 people participated in the Forum online. The participants represented a diverse array of stakeholders, such as government officials, intergovernmental organisations, development partners and non-profit organizations. The discussions conveyed during the Forum covered various topics including the alignment of long-term energy scenarios (LTES) with climate change strategies, demand-side assessment, hydrogen development strategies, and geopolitical issues, among others.

Through presentations, panel discussions, and attendees' interventions the Forum facilitated the exchange of knowledge and experiences on different aspects of the planning of LTES. An Interactive Workshop conducted on the final day of the Forum enriched the participants' understanding and perspectives on effective stakeholder engagement in the development of long-term energy scenarios (LTES).

Key takeaways

Session 1 - Aligning Long-Term Energy Scenarios (LTES) with Long-Term Low-Emission Development Strategies (LT-LEDS) to strengthen climate action

- **Energy Scenarios play a crucial role in the long-term planning for the energy transition** as they often capture the strategic dimensions of the energy sector while considering the alignment and interplay with other sectors and development strategies.

Session 2 - Demand-side assessments in Long-Term Energy Scenarios

- **A multidisciplinary approach is required to assess demand-side aspects on energy scenarios,** this approach allows the inclusion of quantitative results and narrative pathways in LTES. It is important to consider multiple techno-economic and societal factors to ensure effective long term energy planning.

Session 3 - Long-Term Energy Scenarios as an explorative tool for policymaking

- It is important to **understand the objectives and goals of decision-makers** to distill the right scenarios and concrete messages by technical experts to ensure the efficient use of scenarios in policymaking.
- To properly plan for the future, **LTES tools, techniques, and good practices** should be utilized to ensure a quick and efficient energy transition.

Session 4 - Role of 100% renewable electricity for the energy system transition in scenarios • **Accounting for 100% renewable electricity** in LTES is a challenging but necessary process. It is important to further interrogate key aspects in LTES such as sustainability metrics, measures for cleaning the power system, impacts of supply chains, materials and resources constraints, and societal impacts.
Session 5 - Incorporating global hydrogen insights for national LTES narratives • **Hydrogen is part of the bigger energy transition picture.** Setting the right priorities for hydrogen use will be essential for rapid scale-up and long-term contribution to decarbonization efforts. Scenarios help to assess different options for market development of hydrogen for national strategies.
Session 6 - Key geopolitical considerations in national LTES for planning a clean energy transition • **National long-term scenarios help governments navigate uncertainties globally.** The use of these scenarios is vital in addressing the latest socio-technical challenges and making the most of the opportunities offered by the transition to a low-carbon economy.
Workshop 1 - Participatory processes for developing national long-term energy scenarios • Refer to the section *Workshop 1: Group discussion session on participatory processes*
Workshop 2 - Country and expert cases on stakeholder consultations • **Proper participation and engagement** of the different stakeholder groups is vital in Long Term Energy Planning.

Session summaries

DAY 2 - Thursday December 8th, 2022

Session 4: Role of 100% renewable electricity for the energy system transition in scenarios

Jill Engel-Cox (U.S. National Renewable Energy Laboratory)— Introduced the session and presented on the role of 100 percent renewable electricity in energy scenarios. Engel-Cox noted that there has been tremendous progress in incorporating clean energy in the electricity sector. This can be attributed to the rapid growth of solar, wind, and other forms of renewable energy in the energy portfolio. Countries like Costa Rica and Iceland are close to achieving 100 percent renewable power through hydropower and geothermal. However, the share of renewables in the total energy mix (power, fuels, heat) has stagnated in most countries. The global increase in electricity demand and increased electrification means the rapid growth in renewables have still not been fast enough. This is evident in various sectors including the transport sector where there is a rapid increase in electric vehicle uptake and in the building sector with the growth of electrification of appliances. Given this background developing scenarios with 100 percent renewable electricity is challenging as the goal is a moving target on both the supply and demand side. Achieving a 100 percent renewable energy scenarios requires a multidisciplinary approach which takes into account grid flexibility, decentralization and scaling. At present, the modelling community is addressing these challenges on the local and global scale. The experts in this session shall discuss modelling methods, the successes in approaching 100 percent renewable power, and future challenges.

Scene-setting presentations

Christian Breyer (LUT University)— The presentation focused on ambitious industry transitions by mid-century. Breyer noted that countries use carbon budgeting to stay under the 1.5°C global temperature target for 2030, therefore mid-century targets and already quite late. Key drivers to consider when planning for the 1.5-degree target are the availability of technology, electrification, and cost implications.

Indicated primary energy demand, solar and wind energy can be harnessed to meet the expected demand. However, electrification remains key, and efficiency ensures its widespread impact. For instance, battery powered electric vehicles are three times more

efficient than internal combustion engines. The cost of electric vehicles has rapidly decreased as a direct consequence of rapid market expansion, and this trend will soon be replicated in the battery market. Solar energy production is the fastest-growing industry followed closely by wind energy. According to Bloomberg, approximately 1 terawatt of annual solar production shall be achieved globally by the end of the decade. Most energy scenarios structurally underestimate the potential of Solar energy and the cost savings accrued through using it.

All the studies in the presentation are published in scientific journals, however, there is a disconnect between the scientific community and policymakers. Nonetheless, there is strong growth in energy modelling research. The presentation also included a discussion of how several different kinds of raw materials and energy sources are used across sectors.

There should be a stronger regional focus on Africa as the continent has major potential for solar PV, wind energy and hydropower. There should also be a focus on India which has major potential for Solar PV. Currently, some Indian provinces have a capacity for 30 to 40 percent of renewable energy. There is an emphasis on knowledge exchange between stakeholders.

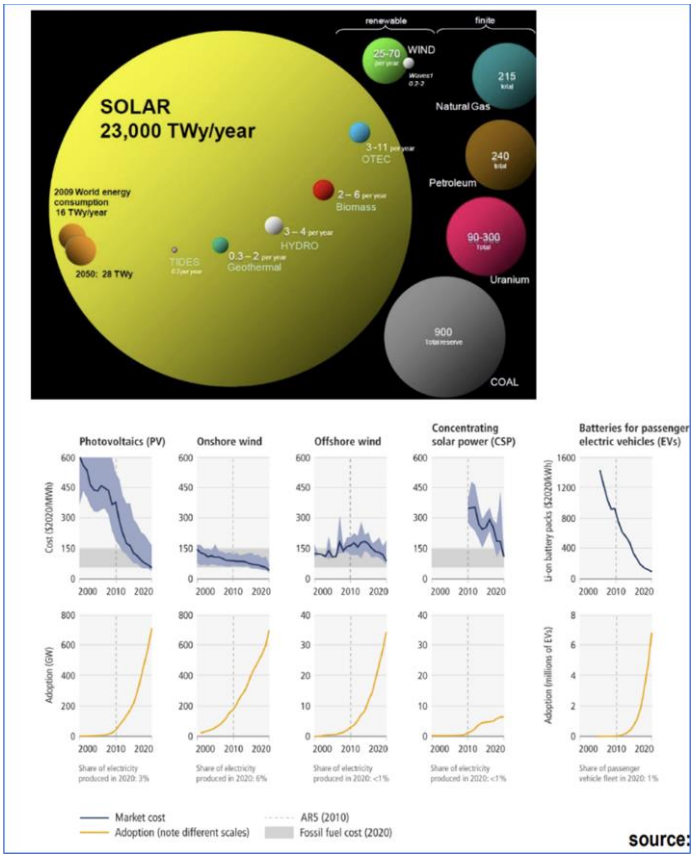


Figure 1: Key Drivers for 100% renewable electricity for ambitious energy and industry transitions by mid-century.

Hans-Christian Gils (German Aerospace Center)— Presented ongoing research which compares optimization and diversification approaches. It was noted that higher energy supply security can be achieved through diversification, to cushion the energy system from extreme weather events and terrorist attacks. In deciding on a scenario to work on countries must identify preferred parameters as illustrated as these results in different outcomes.

Diversity can be enhanced by utilizing various technologies including Concentrated Solar Power (CSP) and offshore technologies. Further, the trade-off between the implementation of a zero-emissions system and negative emissions needs to be explored in more detail. In conclusion it was noted that energy scenarios pay too little attention to risks associated with costs and availability of scarce materials.

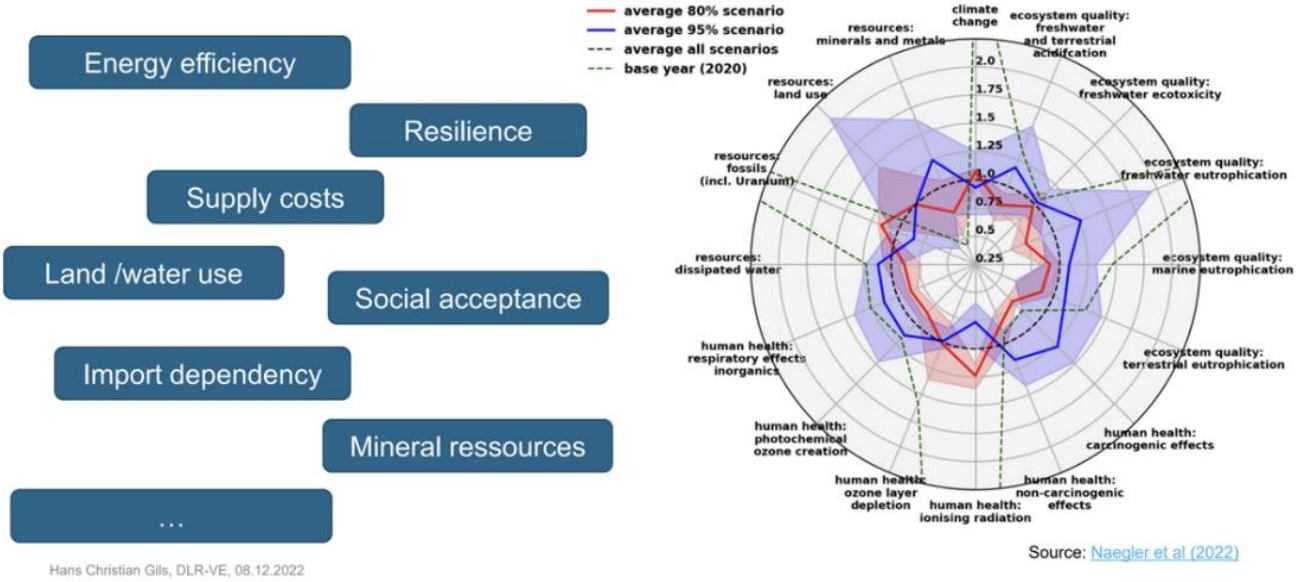


Figure 2: Illustration of different preferred target system considering multiple parameters which are weighted differently

Scene-setting questions from the audience

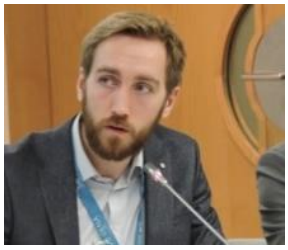
The specific guiding questions for this session included:

- *How far should one push for a 100% renewable energy system? To which extent should one consider other decarbonization options as carbon dioxide removal or also carbon capture and storage linked to industrial process emissions or fossil fuel use? -*

- *The relationship between energy efficiency and 100% renewable energy supply is interesting to explore more – what is the balance between efforts for energy efficiency and efforts to promote renewable energy supply? -*
- *A 100% renewable power or energy system will be much less dependent on fossil fuels. At the same time, clean energy technologies require critical minerals and other materials to produce them. How can supply chains for materials and technologies be better considered in energy system models and scenarios? -*
- *How to build synergies between centralized actors and decentralized prosumers? -*
- *How to ensure the best resource allocation across geographies? -*
- *What are the main constraints (technological, financial, social, environmental) for countries to formulate these types of scenarios? -*

Panel discussion with the moderator

Kaare Sandholt (Energy Research Institute of the Academy of Macroeconomic Research)— Discussed ongoing energy studies focusing on China where it was noted that the power sector model in China was constructed at a provincial level, therefore a lot of regional data is used when developing national models. There is a model in place that envisions a 100% percent renewable energy system, however, nuclear energy sources are categorised as renewable sources. Therefore the model's main limitation is the fact that nuclear plants cannot be constructed in mainland China due to the earthquakes. Currently, China's main concern is energy security and divesting from coal power production.



Christoph Wolter (Danish Energy Agency)— Noted that the next step in energy planning will be sectoral integration given that current climate-neutral scenarios also include fossil elements. The different renewable energy sources in the Danish energy system and their expected development were briefly described. It was noted that in Denmark different scenarios have been developed with different focal points across different energy sectors, however with an underlying basis on a high proportion of wind energy, as well as Power-to-X and e-fuels in the national energy mix.

Víctor Bazán (Executive Planning Secretariat, Sub-sector Energy, Costa Rica)— Hydropower is the main source of renewable energy in Costa Rica. Diversification happened after the 1980s which resulted in the inclusion of geothermal and more recently wind, solar power and biomass

Alex Santander (Ministry of Energy, Chile)— Noted that 100 percent renewable electricity is very important, however, this is often a challenge for countries. Chile aims to achieve a 100 percent zero-emission power system. To achieve this, proper public policies must be put in place to enable a smooth transition. Current projections show that in 2030, Chile will have more than 85 percent renewable energy power system, but to achieve this there must be significant investments in infrastructure. The main issue faced by Chile relates to land-use constraints as renewable energy projects take up major tracts of land.

Given that several presenters have highlighted constraints relating to critical materials in their presentations, panellists were asked to share their insights on the fact that China has major critical material reserves.

Kaare Sandholt — Noted that raw materials constraints are not a major issue in the energy modelling for China, however, the current model takes into account supply chain issues in the critical minerals sector.

Christian Breyer — Noted that resource availability was more of a geopolitical issue than an actual material supply issue. It was understandable that Chile and China prioritize local use of resources over exportation. On a global scale, these constraints can be minimized by having a 100 percent circular economy as is the case in several sectors including the steel sector.

However, there is a challenge with lithium resources as current reserves can only sustain 1.2 Billion cars but these will soon be insufficient given the projected population growth and advances in the transport industry where by mid-century there will be 2.5- 5 Billion cars. To remedy this situation, it is necessary to explore alternative mobility options.

Jill Engel-Cox — Highlighted the fact that there is a lot of debate on the environmental sustainability of component manufacturing. It was noted that there must be a focus on the life cycle of renewable energy resources during scenario building.

Alex Santander — Noted that fossil fuels are important in Chile; therefore there ought to be more sustainable mining of these resources and critical materials to ensure a proper transition.

Jill Engel-Cox — Noted that there are metrics like Levelized Cost of Energy (LCOE) for energy models however there are no universally accepted metrics for sustainability, which makes it difficult to measure whether models are equitable, environmentally friendly, or sustainable.

Kaare Sandholt — Agreed that it is **i**mportant to explore a sustainability metric but advised that this was a moving target, as even LCOE will change in the next few years given various research advances.

Jill Engel-Cox — Reiterated that there are land constraints in Europe and elsewhere which hamper the renewable energy development.

Christoph Wolter — Noted that the biggest challenge in Denmark was the speed of deployment of renewable energy and resistance to projects by the local population and not land-use challenges. One way to remedy the situation is through proper cross-country collaboration as currently, the policy development predominantly occurs at the national level without taking advantage of collaboration benefits with the other 27 European Union countries.

Christian Breyer — Noted that there can be a mixed approach to modelling sustainability, where certain elements can be traced directly within energy models while others should be considered within the constraints. Carbon dioxide emissions can be modelled on their own, while biodiversity can be modelled within biofuels as a proxy variable as biofuels take up a lot of land and models can easily deduce the impact of a high proportion of biofuels in the national energy mix.

In the case of biofuels, it is possible to control the harmful impacts with proper land use planning. It is also possible to measure consumption by balancing geographical constraints between regions and subregions and ensuring adequate benefit-sharing. It is vital to increase the resilience of energy systems as this also ensures sustainability. Large hydropower facilities are linked with sustainability issues and these should be accounted for during energy planning.

Larger countries are typically able to either import more energy or have a bigger domestic supply, this ability of choice enables them to easily manage sustainability issues. Finally, on prospective Life Cycle Analysis (LCA), it is vital to explore how LCA metrics can be projected into the future when developing modelling methods, however, it is vital to note that we cannot draw conclusions for 2050 with 2010 solar PV data for instance.

How can unexpected events such as the current energy crisis in Europe be incorporated into long-term energy scenarios?

Christoph Wolter — Answered that it is possible to use models to plan for potential shocks. He noted that scenarios ought to consider macroeconomic shocks and extreme events. It will never be possible to capture all potential shocks, but it is vital to have scenarios based on extreme events, modelled on different pathways and proper potential solutions.

Given current geographical constraints, please share insight son the South American situation.

Alex Santander — Noted that Chile is a small country however the challenge is to continue connecting renewable energy power plants to the national grid given the security challenges. The other main issue relates to infrastructure, as the country needs to construct additional transmission power lines in order to meet its energy supply targets.

The institutional framework of the connection permit process out to be revamped to cater to the current energy sector needs. There ought to be more flexibility in energy modelling to account for the fact that at certain points of the day 85 percent of the national energy demand is met by renewable energy sources, therefore a nuanced approach must be taken in managing the power and electricity sector. It was noted that Chile has Independent System Operators (ISOs) which have two main legal mandates: first to maintain the security of the power grid and second to operate at minimum costs. It was proposed that a third mandate relating to innovation to enable a transition to a clean energy system through an increased share of variable renewable energy be included for ISOs. To achieve this goal, it is important to consider tariff protections and plan for additional investment while protecting the most vulnerable populations.

Víctor Bazán — Noted that Costa Rica is a small country hence they do not have distribution challenges. In Central America, there is a unitary system in place, and to ensure more sustainability countries should consider incorporating more long-term renewable energy.

How is the electrification of the transport sector proceeding in the different countries?

Víctor Bazán — Noted that the transport sector accounts for 40% of national emissions. Electrification efforts in the transport sector are moving ahead as there are approximately 3000 electric cars in Costa Rica.

Intervention from the audience

- **Miriam Bueno Lorenzo —** Asked Alex Santander & Christina Breyer what the main obstacles and concerns around energy security were. She asked whether governments consider the various scenarios for 100% RE scenarios when doing their planning. It was noted that energy efficiency and demand-response and flexibility and storage were not mentioned in the presentations and should be further discussed. It was noted that it is vital not to overestimate the capacity of power sector, as current production cannot always meet the demand.
- **Christian Breyer** — Responded that relating to the concern of energy security; countries with a large share of variable energy (reaching 100 percent in some hours and seasons) in their national energy mix should study feedback loops and track how the situation progresses. It was noted that the classical demand approach might be limited given the planned development of electrolysis plants offer a short-term solution, however, the more permanent solution is to phase out fossil fuels.

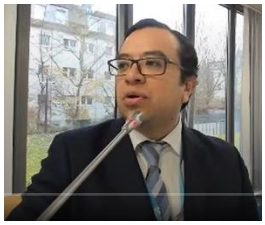
- **Kaare Sandholt —** Noted that the current challenge is to give the right incentives for renewables. China currently has a strong focus on developing the power market and giving consumers incentives to be flexible, however, this is a slow process. China has well-developed grids however the grid system is not flexible, which hampers expansion. The current analysis is focused on expanding the power sector.
- **ICLEI Representative —** Noted that they work with local partners on the transition to renewable energy and in some cases, local governments are way ahead of national governments. Participants were asked to comment on whether insights from local government are considered when developing local plans, given that in the past local contextual realities are not always considered.
- **Christoph Wolter —** Answered that in Denmark, local data of municipalities are taken into account when planning to determine how much renewable energy will be required to meet future demand. He noted that part of the governmental work on projecting renewable energy capacities is gathering data on all the municipalities' spatial planning and conducting assessments based on the data.
- **Jill Engel-Cox** — Noted that in the US several municipalities gather data on energy use however their efforts tend to be separate from state and federal level efforts.
- **Francisco Boshell** — Commented on critical materials demand. He noted that based on the research from IRENA there are 3 main factors taken into account; the circular economy, electrification of production and innovation fuelled by critical materials. IRENA is currently conducting research on environmental aspects and will share more information. Participants who work on critical materials and would like to collaborate were invited to reach out to him.
- **Ardian Islami** — Asked whether in their scenarios the panellists had considered the evolution of wind and solar. He further asked what happens with regard to the recycling process and to power plants, including solar PV and wind plants. at the end of their lifetime.
- **Hans-Christian Gils** — Highlighted that there were other technologies to consider, such as ocean energy and Concentrated Solar Power, to ensure a more diverse generation structure. These technologies are expensive in the short run but are beneficial over the long term.
- **Christian Breyer** — Noted that when it comes to the evolution of solar PV and wind energy uncertainties in their evolutionary process must be accounted for. This can be achieved using the learning curve approach to project future costs, as this has previously worked in economics. With regards to demand, aside from considering how terawatts of solar PV are required, it is most important to understand how the efficiency of solar PV evolves.

  It was noted that India, with a population of 1.7 billion people and the highest population density in the world, will face land resource constraints, to remedy this, land area-efficient technologies are necessary. Further, there should be more

regulation to support long lifetimes as current solar PV models last 40 years. Finally, there is the possibility of future wave power solutions which could compete with offshore wind and potentially have lower costs being developed. There are viable wave sites in Europe, on the entire Atlantic Ocean bordering Morocco, Portugal, Norway, Ireland, New England states, East Coast in the US and in Indonesia.

- **Christoph Wolter —** Noted that ongoing screening on technology development is decisive and that models should consider up-to-date techno-economic data which is determined in a transparent process, which Denmark prioritizes as part of energy systems analyses. Finally, it was noted that it is important to consider different technologies that have the potential to decarbonize the energy systems and update energy models based on these.

Session 5: Incorporating global hydrogen insights for national LTES narratives



Moderator: Francisco Boshell (International Renewable Energy Agency) Introduced the session and noted the need for transport and planning for hydrogen infrastructure.

The specific guiding questions for this session included:

- *How can the use of LTES support the formulation of policies and strategies for hydrogen development and infrastructure investment?*
- *What are the benefits of using national hydrogen strategies in the development of LTES?*
- *What are the key considerations/assumptions to develop different LTES for hydrogen?*
- *What are the key constraints for developing hydrogen scenarios?*
- *Do you estimate hydrogen-related economic growth (GDP impact, job creation, welfare) in your hydrogen scenarios?*
- *Which approach do you lean more towards with respect to hydrogen and why - technological neutrality or priority of green (renewable) hydrogen?*
- *What are the main priority areas for hydrogen generation (color) and consumption (end use sectors)?*
- *What energy security and geopolitical considerations did you consider during discussions on importing/exporting strategy? (if any)*

Scene-setting presentations

Benjamin Gibson (International Renewable Energy Agency)— His presentation focused on the geopolitics of energy transition given the ongoing work on hydrogen. It was noted that if countries are to achieve themed century Paris Agreement goals, green hydrogen production should amount to 200 million tonnes by mid-century. To accomplish this there will be a shift in global trade with and hydrogen will account for 20% of global commodities. He noted that while different industry groups and experts may disagree on the exact details there's a consensus that hydrogen will impact global trade. The hydrogen industry contributes to the feedstock and chemical industries and potentially replace about 100 million tons of the fossil fuel base used in these sectors. Various national hydrogen strategies and initiatives were discussed. Japan has a very advanced national hydrogen policy framework and following this example, approximately 60 countries have developed their own hydrogen strategies. Owing to the dynamic nature of the sector many hydrogen projects have been announced over the past few years.

In conclusion, the importance of harmonizing sectoral planning and accounting for carbon emissions from hydrogen energy was highlighted. Further, countries must keep in mind that hydrogen production may also cause massive regional and local water stress; therefore when evaluating investments and projects historical data and the latest climate science must be used. From a purely technical point of view, there is a lot of potential for growth in green hydrogen production. Given that hydrogen plays a key role in international trade continued investment in green hydrogen will contribute to economic growth.

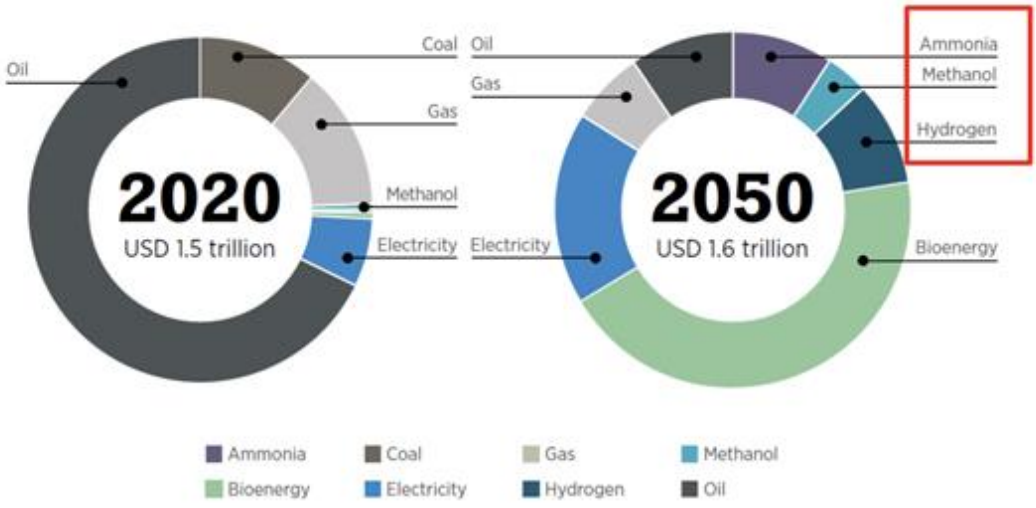
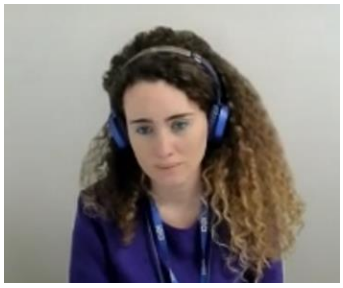


Figure 3: Hydrogen and its derivatives could grow from negligible amounts today to 20% of global trade in energy commodities by 2050



Amalia Pizarro (International Energy Agency)— The presentation was based on the global hydrogen review published in September 2022 under the auspices of the Clean Energy Ministerial Hydrogen Initiative. The major momentum in the development of hydrogen can be attributed to two factors. The first is the recognition of hydrogen's potential to increase energy security given that it is faster to produce than fossil fuels, energy security targets can be easily achieved. The second major factor is based on the role that hydrogen plays in decarbonizing key emitting sectors, specifically the transportation and manufacturing industry sectors.

According to the research, there are 26 National Hydrogen Strategies in place and consequently numerous large low-emission hydrogen production projects. However, given the increasing number of trade agreements to buy low-emission hydrogen products, there ought to be better regulation regarding the stability of these agreements in the face of sectoral uncertainties. While hydrogen production is on course, it is vital that countries track the growth of the industry to ensure a fast transition to align with the 2050 climate targets. When categorizing a hydrogen project as low emission it is vital to consider the emissions occasioned by projection and supply to users. Demand for hydrogen is fast growing and by 2030, considering the current trends, there will be demand for about 150 million tons of hydrogen. Current IEA modelling shows that considering current government pledges, there will be a higher consumption of hydrogen by 2030.

Currently, production is concentrated in Europe and China, with potential additional development in North America. While there are numerous planned hydrogen projects, many uncertainties hinder their takeoff. To resolve this, innovation in the hydrogen value chain is necessary as there are very few commercially viable hydrogen technologies in use globally. It is important to note that most hydrogen projects rely on ammonia as a raw material, however, ammonia production is carbon intensive. It is vital that proper policies are vital in enabling the growth of emerging low-carbon hydrogen production technologies by 2050.

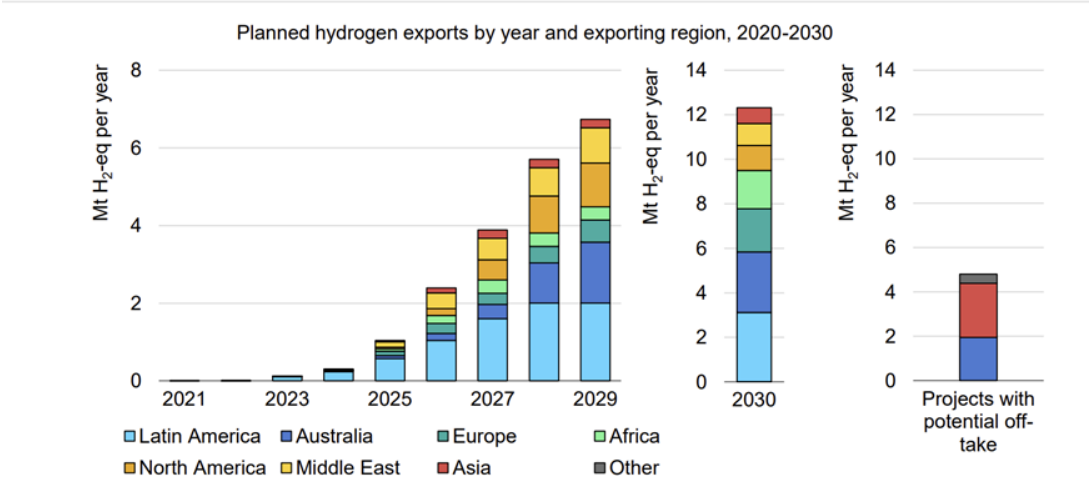


Figure 4: Hydrogen trade can kick start soon, but barriers remain

Mario Ragwitz (Fraunhofer IEG)— In addressing the question of hydrogen infrastructure, the research conducted on behalf of the German hydrogen council looked at hydrogen demand in Europe generally with a focus on Germany. In the research 20 scenarios from the European Commission were studied and their possible contribution to climate mitigation pathways. As per the scenarios assessed it emerged that the direct use of electricity dominates in all scenarios. Hydrogen and e-fuel demand in Green House Gas neutral scenarios varies between 3% and 20%, and hydrogen and e-fuel demand increase with more ambitions Green House Gas targets. Finally, it emerged that biomass potentials and deployment have a strong impact on hydrogen demand. It was noted that factors related to demand, infrastructure and supply will define future hydrogen transportation options.

In conclusion it was highlighted that sector coupling will be a dominant property of future climate neutral energy systems. According to the scenarios studied, the share of electricity-based sector coupling, hydrogen and synthetic fuels is characterized by high uncertainty. Besides uncertainties in general input data, another reason for the broad spectrum of results is the challenge of fully integrated modelling of sector-coupled infrastructure.

Most models and studies show a projected high demand of hydrogen; therefore dedicated hydrogen infrastructure will be necessary. Further, a detailed assessment of hydrogen demand and supply at high spatial resolution is needed to determine the topology of the infrastructures. Fully integrated modelling of demand, supply and electricity,

gas/hydrogen/heat infrastructures at high resolution are required to assess the optimal energy infrastructures. Therefore, models for grid-based multi-energy-systems are needed

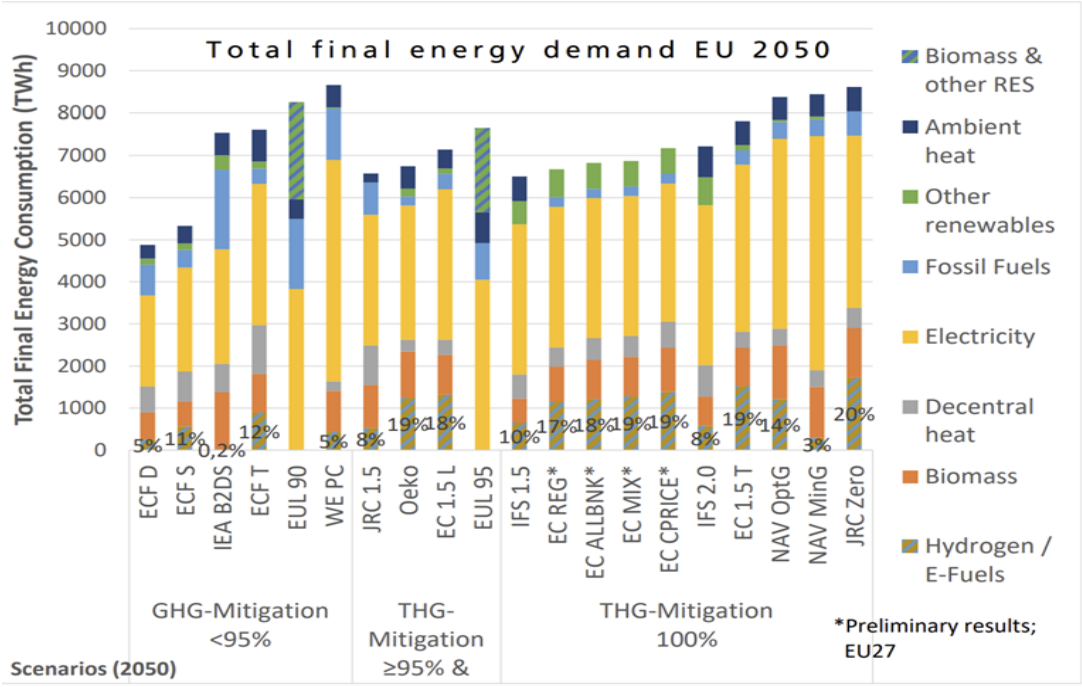


Figure 5: Meta-Analysis of main recent European Union scenarios on Green House Gas- neutral energy systems

Country Presentations

Miriam Bueno Lorenzo (Ministry for Ecological Transition and Demographic Challenge, Spain)— Noted that Spain has 3 strategic policy documents for the hydrogen sector: (i) The Integrated National Energy and Climate Plan, (ii) The Long-term Decarbonisation Strategy 2050 and (iii) Hydrogen Roadmap: A Commitment To Renewable Hydrogen. Spain has the installation potential to operationalise a 4-gigawatt electrolysis plant, this can potentially fulfil 25% of hydrogen demand in the industrial sector. Spain uses the TIMES model in energy modelling which enables emission calculations while planning for the security of supply. Additionally, the country conducted a complementary socio-economic impact analysis using GDP and a second analysis on the health impact of the energy transition as key indicators.

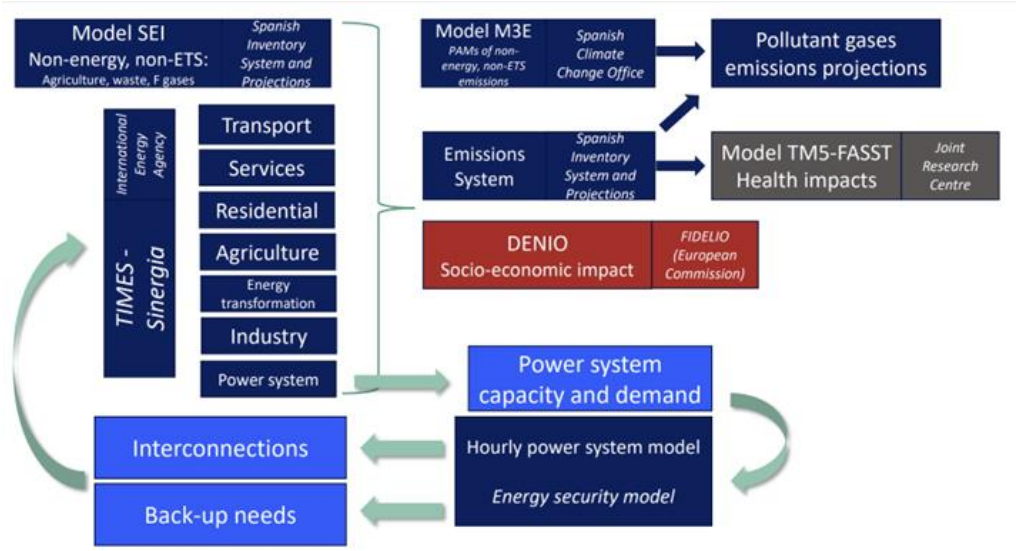


Figure 6: Spain's models on incorporating global hydrogen insights for national LTES narratives.

Alex Santander (Ministry of Energy, Chile)— In Chile the energy sector is responsible for almost 80% of GHG emissions, of the 80% the electricity sector contributes 30% and the transport sector 26%, therefore it is important to reduce the GHG intensity of these sectors. In contrast, Chile has a high availability of renewable energy specifically solar and wind and can potentially increase generation by 80 times the installed capacity. The country strives to achieve carbon neutrality by 2050. In line with this, there is a Climate Change Framework Law and various energy policies and guidelines in place.

The country uses the Long-Term Energy Planning (LTEP) process where they define 3 scenarios which take into account the energy supply, the demand, the infrastructure and the evolution of the energy sector. The 3 main scenarios are the Recovery scenario, the Carbon Neutrality scenario, and the Accelerated Transition scenario. Using this, the country created around 200 simulations to find the most effective solution and made projections to achieve carbon neutrality. In 2019 green hydrogen emerged as a key technology necessary in achieving Chile's carbon neutrality commitments. Additionally, carbon capture has a very important role in decarbonisation. The current carbon neutrality plan contains a roadmap to the electrification of various energy uses given that Chile currently imports almost 75 percent of fossil fuels that cover energy uses.

To achieve carbon neutrality various coal plants are being phased out and there are various reconversion agreements in place for coal plants in Tarapacá, Tocopilla, Mejillones, Huasco, Puchuncaví and Coronel. The goal is not only to retire coal power plants but to create an

alternative for people who currently depend on coal production and coal consumption to ensure a just transition while ensuring energy security.

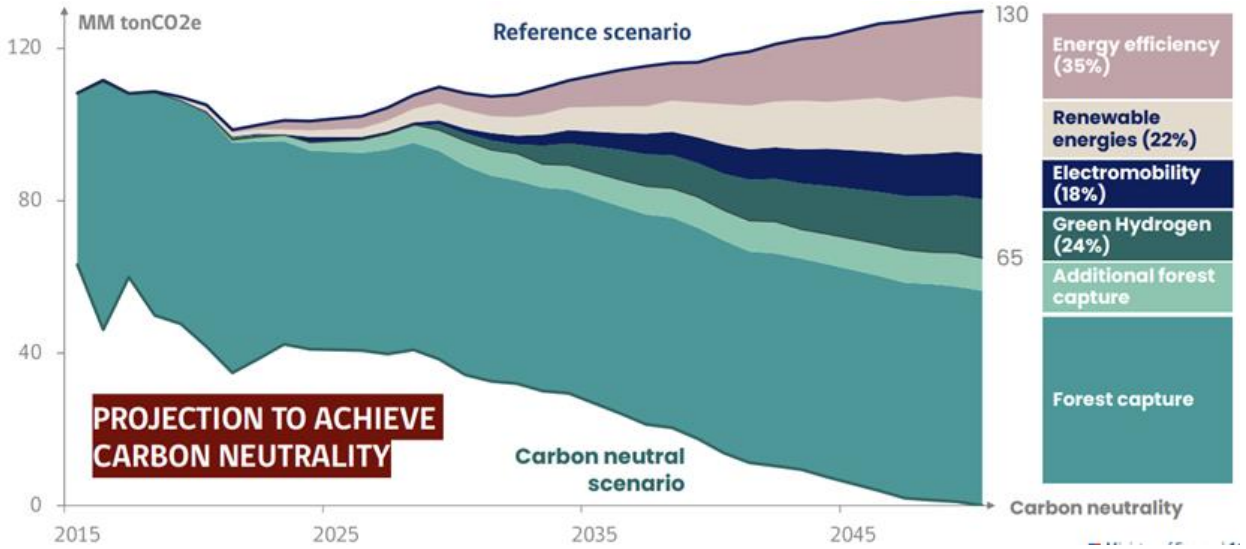


Figure 7: Future vision to face new challenges. Carbon neutrality commitments before 2050.

Panel discussion with the moderator

Given that in Spain and Chile, there is a need for concurrent energy planning and hydrogen planning, what has changed in the past five years in terms of long-term energy planning? Further what new topics have emerged, and which new stakeholders are being engaged?

Miriam Bueno Lorenzo — Noted that the main change was the aspiration to achieve carbon neutrality and in line with the Paris Agreement limit global warming to below 1.5° Celsius. As such the country is planning for carbon neutrality and decarbonizing the whole energy sector specifically the cement and steel sectors. Currently, the country has more integrated planning while ensuring proper stakeholder consultation and ensuring international cooperation with the European Union. Spain also has developed several participatory processes where they included industry stakeholders to discuss demand-side processes.

Alex Santander — Chile's understanding of all energy uses has improved. Chile has an open-market and ultraliberal economy; however, the government needs to make additional efforts to understand energy uses within the country. There is a need to understand how to electrify more sectors of the economy. Regarding green hydrogen there is a need to include territorial planning as renewable energy projects tend to take up a lot of land. Further, it is necessary to ensure proper citizen participation and develop multisectoral scenarios. Finally, it is vital to integrate internal and international energy demand in planning.

What bottlenecks exist when it comes to issues of grid stability?

Alex Santander – Stated that in Chile the government models hydrogen in their projections and definines which production projects ought to be connected to existing grids and which can be relatively isolated from the grid. In future the analysis should also incorporate Solar PV, wind energy and explore hydrogen storage solutions to facilitate the transition and ensure sustainability.

How can policy makers overcome resistance and skepticism surrounding green hydrogen while supporting international cooperation.

Amalia Pizarro — Noted that the main barrier faced in the hydrogen sector is the lack of a standard for low-emission hydrogen certification as a common standard will protect against a race to the bottom in the sector. Additionally, it is necessary to avoid market fragmentation and this can be achieved by ensuring common standards and international cooperation.. Additional barriers in the sector relate to infrastructure and technology constraints as currently, the widespread trade of ammonia is not practical due to its flammable nature.

Given that in the integrated modelling approach parties are looking to decarbonise ammonia, is it possible to use methanol instead? In that case, where would the facilities be located to ensure access to proper transportation links?

Mario Ragwitz — Noted that there is no single answer to the question as parties must consider the existing infrastructure and grid connectivity as hydrogen transport is cheaper than electricity transport. In typical situations, it makes more sense to transport molecules and then to electrolyze but it is hard to generalize this answer as it depends on infrastructure and integrated sector coupling technologies.

Francisco Boshell — Asked whether the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems (IEG) was commissioned by the German government to support scenario development, or if the IRENA LTES are supporting their endeavours from an academic perspective.

Mario Ragwitz — Answered that the IEG is the biggest research institution in Europe which was commissioned by the German government to support scenario development as well as conduct research.

Is it a priority to develop all green hydrogen resources or are there are more pressing issues like electricity access in developing countries. Additionally, are developing countries exploring the investment potential that hydrogen brings to their economies? This was asked in light of

the fact that developing countries like Namibia where hydrogen production ranges between 2 and 5 gigawatts but national electricity production amounts to 0.5 gigawatts

Benjamin Gibson — Responded that there are still many people in sub-Saharan Africa without access to electricity. To remedy this there are a lot of projects to allow more access to electricity including green hydrogen projects. In Africa, there are multiple opportunities for investments and green hydrogen export.

Intervention from the audience

- **Francisco Boshell** — Asked participants to raise their hands if they are integrating hydrogen in their energy systems. Half of the room raised their hands, and the floor was opened for participants to comment on integrating hydrogen in their long-term energy planning.
- **George Partasides** — Noted that every country has specific technical potential. For instance, Chile has Concentrated Solar Power and Hydrogen Power for future developments, but this is not the case in all countries. It was noted that CSP is best produced in countries with favourable environments, while the development of hydrogen will depend on access to shipping and infrastructure and these must be considered during long-term energy planning.
- **Malene Hagaard Vested** — Commented on the regional and global export of hydrogen. The Danish strategy on hydrogen and e-fuels considers the global price of hydrogen and transportation costs. It was noted that Denmark has the potential to export hydrogen and e-fuels to countries within the EU including Germany. Participants were invited to share their views on exporting hydrogen and e-fuels considering transport constraints and other infrastructural issues.
- **Mario Ragwitz —** Noted that transport and trade should be assessed when considering export and import of hydrogen and e-fuels. It was noted that Europe does not have a large trade potential as compared to countries like Japan and China where inter-continental hydrogen trade will be viable.
- **Amalia Pizarro** — Noted that they would shortly release a report which highlights the fact that in some places it is relatively cheap to transport hydrogen over long distances while in other places it will be practically impossible. Hence hydrogen trade and production should be considered on a case-by-case basis given the different contextual realities, uncertainties and the evolution of new technologies.
- **Christoph Wolter** — Noted that Denmark's 2030 Power-to-X strategy takes into account current resources, however the country is now looking to expand the strategy to 2050.
- **Mario Ragwitz —** Noted that when considering the potential use of methanol, carbon costs are taken into account. The IEG accounts for the carbon cost by considering the regulation of biomass and the availability of renewable energy. In

the modelling and assessment, ammonia is one of the most promising raw materials as it can be used for hydrogen production and directly in many industrial processes.

Session 6: Key geopolitical considerations in national LTES for planning a clean energy transition

Scene Setting

Roland Roesch (International Renewable Energy Agency)— Participants were thanked for their attendance, and it was noted that the IRENA IITC has for the past 3 years set up collaborative frameworks to engage the private sector, policymakers and other stakeholders. When discussing the energy transition issues Liquified Natural Gas (LNG) is seen as an alternative for countries that rely on fossil fuel resources. To ensure energy security hydrogen energy plays a key role consequently IRENA has conducted research on this. Additionally, IRENA has conducted research on critical materials which are necessary for the energy transition given their role in enabling technologies specifically the building of electrolyzers and batteries. The current session will focus on how countries can best address the geopolitical dimension of energy planning.

Scene-setting presentations

Uwe Remme (International Energy Agency)— The presentation focused on insights that countries should consider during long-term energy modelling. It was noted that the recent energy shock was of unprecedented magnitude and had resulted in price shocks in energy markets and commodity markets in general. Energy scenarios are vital as they can approximately model the impact of current and future shocks and predict crises. In the models assessed it emerged that consumer behaviour changes can reduce CO_2 emissions while ensuring energy security. Finally, it was noted that the vulnerability of supply chains for clean energy technologies can be traced through price development on selected critical minerals whose prices rapidly rose since January 2021.

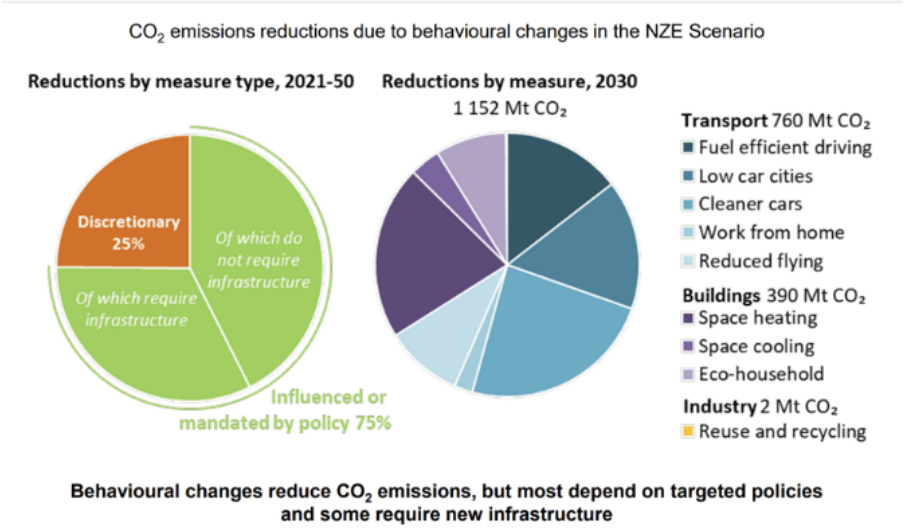


Figure 8: Behavioural changes can cut CO_2 emissions and improve energy security.

Marius Oosthuizen (World Energy Council)— Briefly shared background on the scenario work done by the World Energy Council but noted that it was not closely linked with politics. A detailed conceptual analysis to frame the discussion was provided. It was noted that the scenarios developed enable actors to predict the impact of major geopolitical shifts while integrating them into consecutive scenarios. The scenario development process enables strategic conversation within the sector. The World Energy Council is exploring using scenarios as a process tool in modelling uncertainties.

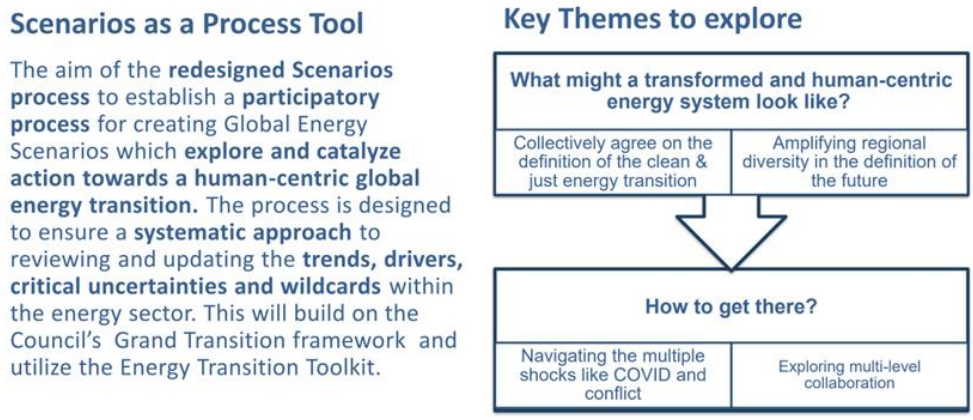
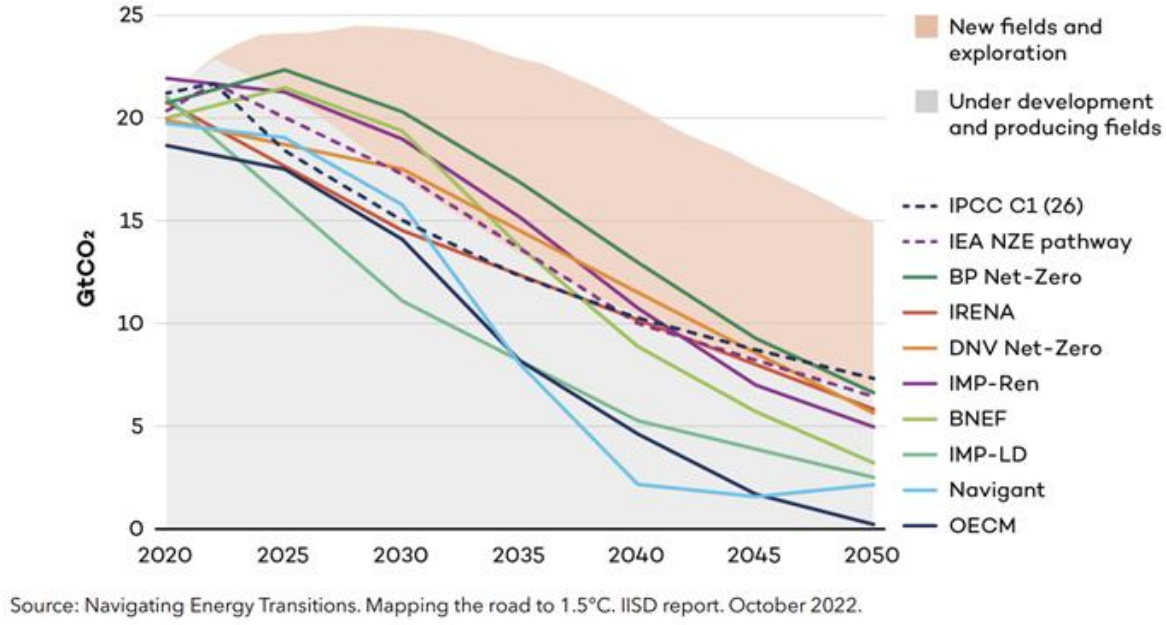


Figure 9: Scenarios in service of the World Energy Council mission: Scenarios as a process tool.

Angela Picciariello (International Institute for Sustainable Development)— Based on IISD's Navigating Energy Transitions: Mapping the road to 1.5°C report, it emerged that there is no room for new oil and gas developments. on the other hand, there is a huge gap in solar and wind deployment globally. It was noted that the war in Ukraine has had so far three main consequences: first, that gas prices in Europe have dramatically increased; second, that there is an increased dash for gas by the European Union that risks seriously hampering the energy transition; finally, there likely will be short and long-term impacts on renewable energy deployment, especially because of issues within the renewables supply chains. It was finally reiterated that, in a 1.5-degree-aligned scenario, except for an immediate two years gas supply crunch, European gas consumption can and should be met without building new gas infrastructure.



Source: Navigating Energy Transitions. Mapping the road to 1.5°C. IISD report. October 2022.

Figure 10: Illustration of the fact that there is no room for new oil and gas development.

Panel discussion with moderator

What key geopolitical drivers are considered when formulating long-term energy scenarios? Additionally, are there disruptions identified that are relevant for long term energy planning?

Angela Picciariello (International Institute for Sustainable Development)— Oil and gas extraction faces the same challenges as those seen in the mining sector, however, the growth of the renewable energy sector changes the discourse. Typically, renewable energy is pitched as locally available energy as the sun shines everywhere and the wind blows everywhere,

however, the narrative often fails to note that the critical minerals necessary for these technologies are not equally distributed. To remedy this energy models should incorporate critical mineral supply chain issues.

Ardian Islami (Ministry of Infrastructure and Energy, Albania)— Albania has one of the highest shares of renewable energy in south-east Europe, however the country is highly dependent on rainfall for its hydropower projects. It was noted that there are plans for grid interconnection between Albania and North Macedonia to allow for the uptake of solar energy in the country.

George Partasides (Permanent Secretary Office Ministry of Energy, Commerce and Industry, Cyprus)— Noted that there has been a radical change in Cyprus and now 90 percent of households will have access to some form of renewable energy technology.

Intervention from the audience

- **Christian Breyer** — Commented on term "Black swan" noting that when we talk about endogenous optimization models it is difficult to model geopolitical risk. Unexpected changes often lead to fundamental supply chain disruptions as seen with the war in Ukraine and the Covid-19 pandemic. Countries could consider conducting stress tests to optimise their planning. This approach is easy to take as many sensitivities are already included in models. It was noted that while it is easy to test these scenarios for scientific risks, modelling political disruptions is more complex.
- **Brad Little** — Noted the need to develop a new community working on policy uncertainties as is the case in Canada. Natural Resources Canada uses a cone of uncertainty as part of the energy models, and this should be replicated in other countries.
- **Miriam Bueno Lorenzo —** Stated that all new energy strategies should incorporate geopolitics issues related to critical materials given the projected increased demand. Additionally, when discussing energy transition countries should focus on reducing external energy dependence and conduct relevant stress tests to ensure stability of the energy systems. It was noted that climate change will be the biggest stress test for the world and countries should adequately plan for that.

- **Roland Roesch** — Regarding critical materials the global approach should be on how to produce more components with fewer and more diverse materials. As such the circular economy is of utmost importance. Additionally, countries must ensure that

the mining of critical materials in environmentally friendly as failing to do so will raise additional environment, social and governance (ESG) issues.

- **George Partasides** — Noted that from a national perspective, some countries wish to limit the importation of critical material and instead find local sources as this protects from geopolitical issues. Therefore, politicians should either front policies that reduce energy demand or find ways to import energy and these options should be reflected in the models.
- **Miriam Bueno Lorenzo** — Noted that there ought to be stress tests based on the fact that less intensive carbon energy sources such as natural gas emit greenhouse gases. As such potential solutions on reducing the concentration of greenhouse gases should also be included in models.
- **Nadeem Goussous —** Noted that there are ongoing discussions with the financial sector on scenario use. One of the problems arising is that models sometimes do not account for the base year due to the fluidity of situations making it difficult to come up with accurate scenarios. It is also vital to frequently update scenarios in real time as was the case for the World Energy Council when they developed a Covid-19 scenario in the early days of the pandemic as this ensures a better policy response.