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ISGAN
INTERNATIONAL SMART GRID ACTION NETWORK

Power Transmission & Distribution Systems

Network Planning and Decision-Making under Uncertainty

Discussion Paper

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ISGAN Work Group 6 and ISGAN Communication Working Group

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About ISGAN Discussion Papers

ISGAN discussion papers are meant as input documents to the global discussion about smart grids. Each is a statement by the author(s) regarding a topic of international interest. They reflect works in progress in the development of smart grids in the different regions of the world. Their aim is not to communicate a final outcome or to advise decision-makers, but rather to lay the ground work for further research and analysis.

Disclaimer

Acknowledgments

This ISGAN project has gathered 12 countries on 3 continents as well as the International Renewable Energy Association (IRENA). The project was leveraged through the ISGAN Knowledge Sharing Platform (KSP) and involved a year-long series of interactive workshops, consultations and analyses. A large number of skilled people have been involved throughout the project and their valuable experience, enthusiasm and insights is behind the project results and the content in this report. Our warmest gratitude to all of you:

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Executive Summary

Meeting the United Nations' Sustainable Development Goals (SDGs) necessitates a profound societal transformation. Electrical power grids play a central role not only in achieving *SDG 7 Affordable and Clean Energy* but also in directly supporting *SDG 8 Decent Work and Economic Growth* and *SDG 9 Industry, Innovation, and Infrastructure*. Grids are also crucial enablers for many other SDGs. The significance lies in the essential requirement for robust electrical grids to facilitate widespread electrification, crucial for achieving net-zero emissions and addressing a wide spectrum of ecological, social, and economic aspects of sustainable development.

Recognizing this pivotal role of electrical grids, ISGAN Working Group 6 joined forces with the ISGAN Communication Working Group Task 3, to spearhead a collaborative knowledge sharing project (KSP), involving researchers, policy makers and representatives from both transmission and distribution system operators. This initiative aimed to collate global insights on challenges and solutions in grid planning, ensuring that power grids can effectively contribute to the SDGs. The project's focal question encapsulated the overarching objective: *How can power grids be strategically developed to align with, and contribute to the global sustainable development goals?*

The project explored diverse long-term considerations in grid planning, addressing effective management of inherent uncertainty and complexity, the co-evolution of regulatory frameworks, workforce development, and heightened stakeholder coordination throughout the planning process. The one-year collaborative process that started in September 2022 involved a series of interactive co-creation workshops and analysis meetings, as well as an open consultation meeting and an ISGAN Virtual Learning Webinar[1].

To facilitate the co-creation of sound and solution-oriented policy recommendations, a substantial investment of time was dedicated to thoroughly exploring the challenges within current grid planning processes. This involved an in-depth analysis to understand their root causes and consequences across multiple dimensions, including, but not limited to, economic, political, and regulatory considerations. Following an effort of condensing and analyzing a large quantity of co-created material, the collective wisdom was synthesized into seven key policy messages, that were presented at an official side event of the Clean Energy Ministerial meeting (CEM#14) in Goa, India, in July 2023.

<u>The Seven Policy Messages:</u>

1. Develop comprehensive electrification scenarios aligning with net-zero emission goals.
2. Ensure grid development plans align with deep decarbonization scenarios.
3. Update cost-benefit analyses to reflect the values of grid capacity, incorporating social, environmental, and resilience metrics.
4. Foster regulatory frameworks supporting both conventional and smart grid solutions for a clean energy transition.
5. Establish strategies for recruiting and training a skilled workforce.
6. Promote stakeholder interaction at all stages of the grid planning process.
7. Increase awareness of the electrical grid's role in meeting SDGs.

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[1] https://www.youtube.com/watch?v=bgQP8oKU1C4

A central insight from the project underscores the urgent need to reconfigure grid planning processes, recognizing the imperative for a more holistic approach. This involves not only addressing technological, economic, and regulatory considerations but also integrating environmental sustainability, social equity, and long-term resilience into the planning framework. Additionally, the protracted lead times associated with grid investments demand swift action to dismantle barriers obstructing grids from fully realizing their role in the energy transition and contributing to the SDGs.

This report provides a detailed account of the collaborative process, the methodologies applied, and the outcomes achieved at each stage, with focus on explaining the meaning and context surrounding the policy messages.

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1. Introduction

Meeting the United Nations' Sustainability Development Goals (SDGs, see Figure 1) will require a transformation of the entire society. Electrical grids are an important enabler of SDG 7 Affordable and Clean Energy due to the needed electrification of many sectors to reach net zero emissions, as well as to other SDGs regarding climate action, poverty reduction, and innovation, among others.

Figure 1: United Nations' Sustainable Development Goals.

Electrification plays a pivotal role in facilitating the transition away from fossil fuels. In heating systems, electrical heat pumps are replacing combustion of oil, coal and gas. In the transportation sector, electrification serves as a cornerstone solution for decarbonization with an extended use of both batteries in electric vehicles and, particularly in the context of heavy maritime and aviation transport, electrofuels. Furthermore, the conversion of industrial processes into hydrogen-based production processes necessitates a substantial supply of electricity to produce the necessary green hydrogen. These instances exemplify the critical role of increased electricity usage in achieving the climate targets.

The share of electricity in total global final energy consumption is around 20% today. The IEA has estimated that this share needs to increase to 28% in 2030 and 50% by 2050 in their Net Zero Emissions scenario to enable the decarbonization of the energy system [1]. To meet this increase in electricity demand, the IEA has also estimated that average annual worldwide grid investments need to increase from around US$ 300 billion in the past years to US$ 630 billion in 2030 and US$ 830 billion in 2050. This includes investments in new grid capacity, reinvestments in aging grids and investments related to digitalization and smart grid technologies. These are unprecedented levels of investments. Ensuring that they realise in time will require revamping current grid planning processes.

ISGAN Working Group 6 initiated a project to gather experience from around the world on challenges and solutions regarding grid planning to ensure that grids can play their full role to meet the SDGs. This document reports on the findings of this project. The project was leveraged through the ISGAN Knowledge Sharing Platform (KSP), in close collaboration with Task 3 (Structured Knowledge Exchange) of the ISGAN Communications Working Group, and involved a year-long series of interactive workshops, consultations and analyses. The main conclusions of the project were summarized into a short policy brief containing seven policy messages. This Discussion Paper provides additional details and insights into the work and outcomes of the project.

The scope of the project has been to build a common understanding and to exchange knowledge on a wide variety of topics related to grid planning such as handling uncertainty and complexity, regulatory frameworks, developing and maintaining an adequate workforce and promoting stakeholder coordination and engagement. This has entailed gathering inputs about specific challenges faced by different types of actors in the participating countries. This paper summarizes these inputs; however, it has not been within the scope of this project to identify detailed and specific solutions to the many challenges faced by grid plannings within these topics. Some are documented in this report based on the inputs received from the project participants. However, they are not meant to be exhaustive. Rather, the project's diversity has been used to condense challenges and solutions at a higher level.

The following sections provides a documentation of these steps, starting with the importance of topic, introduction to ISGAN Knowledge Sharing Platform and project methodology in Section 2. Section 3 contains a review of the workshops and subsequent analyses on identifying first challenges and then a review of the solutions follows in Section 4. Examples on long term grid planning related challenges from some of the participating countries are provided in Section 5 together with practical examples on solutions studied or implemented. Section 6 lifts the perspectives by presenting the wider potential impacts an improved grid planning process could have. Finally, the conclusions are presented in Section 7 together with the policy messages which capture the gist of the recommendations developed in this project.

2. Background

2.1. A new era for power systems

Massive investments in grids will be required to achieve the SDGs and, in particular, to decarbonize the entire economy. Electricity systems have witnessed many changes in the past decades that have rendered grid planning processes very complex.

First, the deregulation of the electricity sector in many countries have separated decision-making processes for production and grid investments. While the two were co-planned in the past, they are today performed by different actors in many countries. The need for considering the investment decisions of external actors has resulted in increases in both complexity and uncertainty for grid owners.

Second, grids have been assumed to be close to completed in many advanced economies. Investment rates have stagnated in the past years. However, reaching net zero emissions will require fast increases in grid investment spendings to guarantee the realization of the electrification measures that are needed for the decarbonization of the energy system. This is often at odds with the long lead-times of grid deployment. These long lead-times result in turn in a high level of uncertainty and, therefore, complexity.

Third, while grid planners have in the past focused on being able to meet a few peak demand scenarios; the crucial role of intermittent and renewable energy in supplying fossil-free electricity entails an additional increase of uncertainty.

Finally, alternatives to grid-only investments, such as demand- and production-side flexibility and smart-grid technologies, exist in some cases. Grid planners must consider these alternatives, very often outside of their direct controllability area, to ensure cost-efficient grid expansion.

Many stakeholders are involved in the many aspects of grid planning activities. Grid planners propose plans for grid expansions. Regulators set the legal framework within which grid planners work and design incentives to promote certain qualities. Local populations are impacted by grid development projects. Governments propose new laws that shape how regulators and grid planners work. Industries require grid capacity to decarbonize and expand their activity. Societies need a high level of electricity security of supply and resiliency. New competences and skills will be needed to address the many changes identified above which puts new requirements and training and securing a resilient workforce and requires research efforts to achieve inclusive and cost-efficient grid planning processes.

The ISGAN activity on “Network planning under uncertainty” was started in order to compile experience from different actors and countries about the above challenges.

2.2. ISGAN Knowledge Sharing Platform

Since 2016 ISGAN has employed an impactful approach to leverage international peer-to-peer learning partnerships, focusing on key topics of relevance for the energy transition. The Network Planning under Uncertainty initiative constitutes the 9th ISGAN Knowledge Sharing Platform (KSP)[2], involving 12 countries on 3 continents as well as the International Renewable Energy Association (IRENA).

Key characteristics of the approach:

- Catalyzing the collective intelligence of a diversity of stakeholders (in this case policy makers, transmission system operators, distribution system operators and researchers) from many different countries to co-produce quality policy guidance to inform energy sector decision-making at international and national level.
- Structured and learning-focused process in several steps using different collaborative working methodologies (e.g. inspired by design thinking and systems mapping), gradually building insights through deep-dive and explorative dialogue.
- Sharing and reflecting on existing experiences from different countries and sector contexts as a basis for co-creation of new knowledge.
- Informal atmosphere and collaborative problem-solving on themes of mutual interest and importance: fostering capacity building and development of new working relationships and networks.

2.3. Project methodology

The methodology employed in this project included a number of activities, designed to gradually lead participants through the journey of identifying and exploring problems pertaining to the network planning process; co-creating ideas to make it more efficient, legitimate and transparent; and finally, to summarize findings into concrete policy messages relevant to policy makers and energy sector stakeholders globally. To prepare for an efficient and informed workshop dialogue and to capture the unique experiences and situations in individual participating countries, the process started with a detailed survey summarized into a pre-workshop report. Figure 2 shows the timeline of the project with its different activities, including dissemination efforts and deliverables.

[2] Information and results from previous KSP projects can be found **here**.

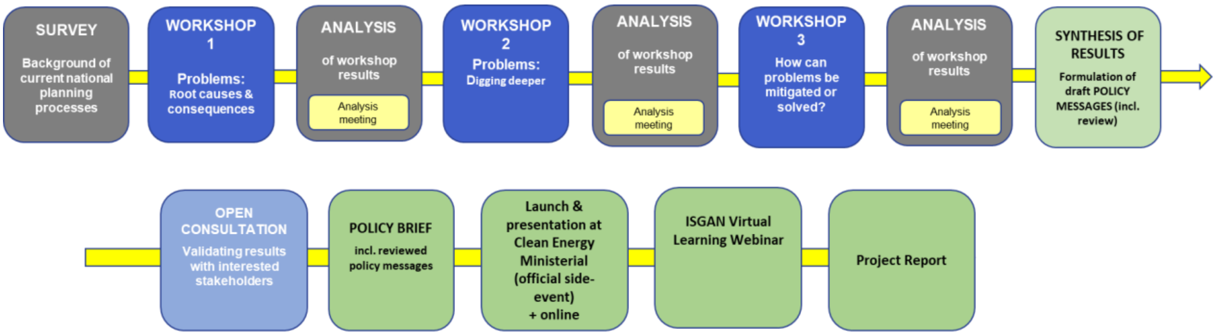

Figure 2: Overview of the project activities.

3. Identifying challenges

3.1. Process

The project started off by identifying problems and challenges related to network planning activities. This first part of the project is highlighted in Figure 3.

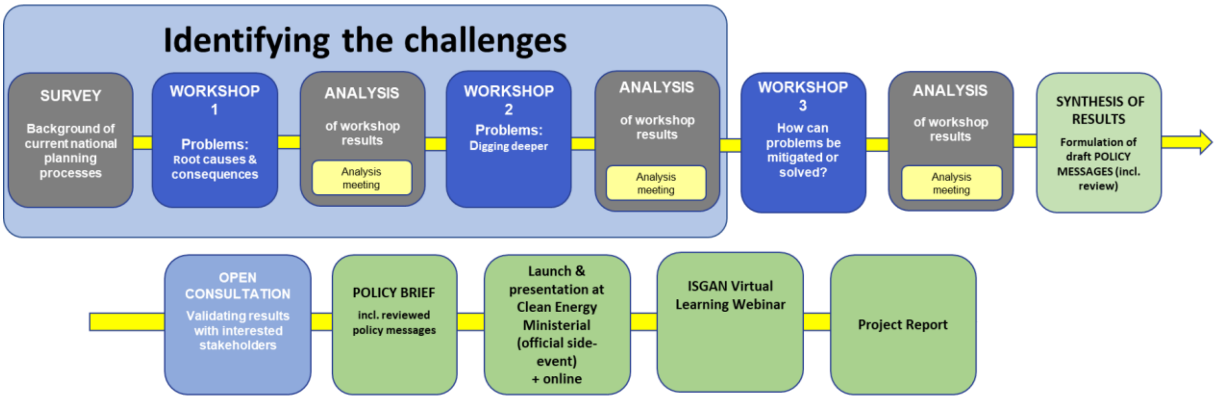

Figure 3: Activities to identify the challenges.

In a first step, a survey was conducted to gather information from the participating countries on the network planning processes in their respective national contexts. The list of questions included in the survey is presented in Appendix A. The questions related to the following topics: overall network planning process, steering mechanisms and regulation, methods and tools, stakeholder involvement, handling of uncertainties, public opinion about network planning and future development. The survey answers were compiled and analysed to identify recurring topics in the different countries. The analysis is documented in Section 3.2.

The survey had multiple purposes. First, it was a way to ease participants into the project by having them think about their local context and the related challenges. Second, it promoted knowledge sharing between project participants. Finally, it gave a solid and common ground on which the rest of the project could build upon.

In a second step, two virtual workshops were conducted to share knowledge on problems and challenges in different countries. The workshops gathered country representatives as well as key national stakeholders. The virtual collaboration platform Mural was used for brainstorming and co-creation. The knowledge sharing process and outcomes of the workshops are documented in Sections 3.3, 3.4 and 3.5.

3.2. Analysis of the survey answers

3.2.1. General aspects about the planning process

Planning processes are complex and differ between countries and network voltage levels. In general, they include different aspects such as network studies, formulation of future energy scenarios, market analysis and reinforcement plans, investment decisions etc. which traditionally define the needs for network-based solutions. The process is driven by the responsibilities of the grid operator in a framework of objectives and constraints. Historically, the planning process has been shaped by the traditional grid operator responsibilities such as security, adequacy, quality of supply, reliability, and efficiency. There has however been a shift from these traditional responsibilities towards decarbonisation, and more recently towards energy security and affordability.

Assessments of the planning processes are therefore done not only at a technical, and economic level but also at social and environmental level, upon which grid development projects are prioritised. These projects go through a process of consultation, permitting, procurement, and realisation.

3.2.2. Particularly challenging issues in the planning process

According to many respondents, this process needs updating to make multi-stage decisions through a scenarios-based approach to quantify the impact of uncertainties and strike a balance between risks and benefits. It is a big challenge to find robust and flexible solutions that can handle a variety of scenarios, which is needed in these situations with uncertainty, complexity, and long lead times.

Challenges or needs include:

1. Changing conditions that introduce increased complexity and uncertainty, e.g.
    - assumptions of load and generation characteristic (changing demand profile, high renewable generation, correlation between demand and generation at bulk supply points)
    - new grid aspects (new types of load, mutual interaction of new HVDC systems etc.)
    - forecasts (winter peak may no longer represent the most problematic system condition, assumptions for wind power production, uncertainty in national renewable deployment targets, long-term outlooks that depend on technologies that have yet to be developed etc.)
    - impact of climate change on network asset performance and lifetime
    - price evolutions (e.g. price of main commodities)
    - considering more heterogeneous connection requests of new renewable power plants
    - including sector-coupling aspects to consider interactions with the transport, heat and industry sectors (vehicle-to-grid, power2X, …).
2. Using more advanced methodologies
    - New tools for including opportunities from flexibility measures like storage and other local flexibility resources
    - modelling of uncertainties, for example uncertainty related to the availability of the flexibility resources
    - improving analytical capacity (e.g. the increase of inverter-based systems requires updating of grid codes and improving analytical capacity for network stability studies)
    - using probabilistic approaches (instead of deterministic ones) to model uncertainty in generation and demand profiles

- using new market capacity calculation methods to better reflect the effect on the available capacity of interconnectors
- new methods for assessing the stability of the electrical system as system inertia decreases and inverter-based systems become more widespread

3. Expanding granularity in time and space
    - consider heterogeneous location of renewable power plants
    - adapt lead times for grid users with shorter lead times, like solar farms or some industries

Furthermore, especially in the medium and low voltage levels, the lack of data and clearly defined processes can cause delays. In a large country like India, the non-availability of asset utilisation status and GIS[3] mapping of distribution infrastructure are amongst the major challenges in network planning.

The lack of local community acceptability is highlighted as a challenge, since it leads to further delays in the process. The long lead times are in themselves a challenge, since they increase the uncertainties even more due to the larger span between investigation and realisation.

In many countries, there are no or limited regulations, laws or processes concerning the network planning of DSOs[4]. There are often quite a large number of DSOs within a country, which sometimes fall under different regulators, leading to the use of several different methods, which causes additional challenges.

Coordination between DSO and TSO[5] grid expansions plans is also a very complex topic, and is all the more important in countries where the responsibilities are shared between different actors.

3.2.3. Steering mechanisms / Regulation

The objectives provided for the planning process and grid expansion are quite similar for most countries, where the grid needs to be safe, reliable, and affordable.

Most countries share similar constraints, including the technical limitations of the grid, minimising the overall cost of grid infrastructure, and the need to provide a good quality of supply. Generation, conversion, transmission, trading, distribution and use of energy should be conducted in a way that efficiently promotes the interests of the society, which includes taking into consideration any public and private interests that will be affected.

The way the economic incentives are designed differs somewhat, but they are often set up to ensure that network costs do not rise any more than they need to and to ensure a good standard by using performance targets, for example. Failure to meet requirements brings automatic penalties. Some countries reward network operators that innovate and operate their networks in a smarter way to better meet the needs of network users or take environmental sustainability measures, like reducing energy losses.

[3] Geographic Information System
[4] Distribution System Operators
[5] Transmission System Operator

3.2.4. Alternatives to traditional network expansion

Many countries currently do not consider alternatives to traditional network expansion in their long-term planning, but there are several ongoing projects looking into it.

The United Kingdom has a process split into two phases, where the first phase considers only network-based solutions to calculate the technical capabilities, whereas the second phase considers different market-based solutions, which are alternatives to traditional network expansion. These solutions are explored through pathfinder projects. The ongoing projects encompasses high voltage management, constraint management and stability management.

Including alternative smart grid solutions (voltage controllers, batteries, demand flexibility etc.) in the DSOs' grid planning procedure are often only done in pilots and trials.

Measures to increase the system capacity in the short term are considered in some countries. Italy, for example, has implemented a wide range of so-called "capital light" interventions (i.e., projects requiring only limited investments). Examples include dynamic line rating and deployment of new remote triggers and new grid defence strategies, which have been demonstrated to be excellent measures to enhance the system efficiency in the short term.

In Norway, it is possible since 2021 to use alternative connection agreements for connection of new customers to the grid. The DSO and the customer can agree on alternative connection agreements to reduce the cost of connection for the customer, often on the condition that the DSO can disconnect or reduce the capacity for the customer in some defined cases.

3.2.5. Need for increased stakeholder involvement

A common theme across the countries is the need for better stakeholder involvement, in particular closer DSO/TSO interactions.

More frequent dialogue between new players (distributed generation, consumers/loads) is seen as a way to help utilities "keep up", not only with new upcoming demands, but also to remain open to new possibilities for alternatives to grid expansion, for example using flexibility.

It was mentioned that diverging views of stakeholder groups often complicate and slow down the planning process. Improvements are needed to align the visions and agendas of different stakeholder groups around common goals.

A need for an increased dialogue between policy makers/regulators and TSO and DSOs are identified, which could lead to more realistic goals being set and/or feasible solutions found, e.g. realistic timelines, adequate funding, skills/personnel resources, and locational feasibility. Also, more efforts to facilitate proactive dialogues in the earlier planning stage, presenting the pros and cons of network upgrade options, might help improve acceptability, mitigating the delays in grid expansion. It is also desirable to define clear decision points early on in the process, thus avoiding the need for time-consuming re-assessments of different options later in the project.

Generally, there seems to be a shared need for stronger political or regulatory leadership to create a future-looking process instead of reacting to short-term needs. Increased collaboration with consultants and academics was pointed out as a way to develop more accurate methods in modelling uncertainties in demand and generation values. These collaborations could also help to develop more advanced tools that are capable of incorporating a probabilistic approach in the existing planning process, for example.

3.2.6. Uncertainties

There are fundamentally two sources of uncertainties in the system, the 'known unknowns' such as location of new renewable connections across a network and the 'unknown unknowns' (completely unexpected issues) such as geopolitical developments.

As already mentioned, there is considerable uncertainty related to the long-term planning process. The electrification of transport and other sectors, for example, as well as new generation, is often highly dependent on policies and technological development. There can be a lot of uncertainty related to when, where and how much additional load will be added to the system from new industries and electrification initiatives. Geopolitical aspects, the cost of the investments (commodity prices) etc., also play an important role.

In some countries, organizations others than grid owners, such as national energy agencies, create different scenarios for future decarbonized energy system. It is not clear, then, which scenario(s) grid planning activities should address.

Another source of uncertainty is the non-availability of accurate data of existing systems, causing uncertainty and inaccuracy in the final decision process.

3.2.7. Future development

There is a need to continue developing long-term network planning processes. Majority of the challenges are related to how the necessary infrastructure projects can be built in time; finding models/methods/tools to better address the growing and unavoidable uncertainties; and finding models/methods/tools that enable the network operators to include both network and non-network options in the long-term planning.

Another critical issue emphasised is the need to create appropriate incentives to attract and retain right skills in the energy sector.

Some other needs for future development lifted in the survey answers are listed below:

- Ensure that the process includes activities to continuously update network plans (important in today's fast-moving environment)
- Harmonize permitting procedures for grid development processes to reduce lead times.
- Highlight the role of flexibility in demand and production as a support to grid planning and clarify its potential.
- Expand the temporal and spatial considerations in transmission planning.
- Elaborate on mechanisms for coordinated TSO-DSO planning.
- Consider anticipatory network planning (both on transmission and distribution level) by creating a sound and robust framework for analysing how grid planning can capture different scenarios, while considering the long lead time of grid development projects.
- Look at more agile and more realistic network investment remuneration mechanism with less bureaucracy.
- Develop adequate remuneration schemes that justify the increased costs/risks implicit in the additional responsibilities of the DSOs to implement flexibility products.
- Create clear regulatory frameworks that encourage the cost-effective use of smart grid technologies.
- Consider a wider range of connection products where conditions define what can be expected and what to fulfil (such as alternative connection agreements).
- Consider investigating also in temporary short-term solutions in parallel of a decided grid expansion, to meet a need that occurs before the long-term solution is finalised (due to long lead times).

- Find tools/methods for integration of any type of flexibility.
- Investigate and develop methods to analyse new trends in power systems such as decreasing system inertia, more widespread use of inverter-based systems, and interaction between HVDC interconnectors.

3.2.8. Summary of the survey

The compilation and analysis of the survey answers gave the project participants the possibility to gain a basic understanding of the experience, challenges and proposed solutions in different countries. The project then moved on exploring these in more detail in a series of workshops as documented in the next sections.

3.3. Workshop 1 on identifying challenges

The first workshop was held digitally and gathered around 30 people from the organizing team and country representatives from Austria, Belgium, Canada, India, Italy, Norway, South Korea, Spain, Sweden, The Netherlands and United Kingdom. The workshop was designed to foster brainstorming and co-creation.

In a first step, a question storming session allowed participants to get familiar with the digital collaboration platform Mural and to ease into the topic of "Network planning under uncertainty". During this session, participants were asked to document any questions they could think of related to the topic. The main purpose of this session was the involvement of all participants and their introduction to the digital platform rather than the questions themselves.

After getting acquainted with the topic and the digital tool, the workshop focused on co-creating problem trees. Problem tree analysis is a tool to identify problems, their root causes and their causal relationships.

During the workshop, the participants worked with the following problem formulation: "*National long-term network planning and decision-making processes, in a "VUCA world", are generally not adequate given the ambition to reach the sustainable development goals*", were VUCA stands for Volatility, Uncertainty, Complexity and Ambiguity. The definitions of the VUCA categories are shown in Figure 4. In order to get inputs from different perspectives, participants were asked to use the PESTEL framework when creating the problem trees. PESTEL stands for Political, Economic, Socio-cultural, Technological, Environmental and Legal. Examples of different aspects included in the PESTEL categories can be found in Figure 5.

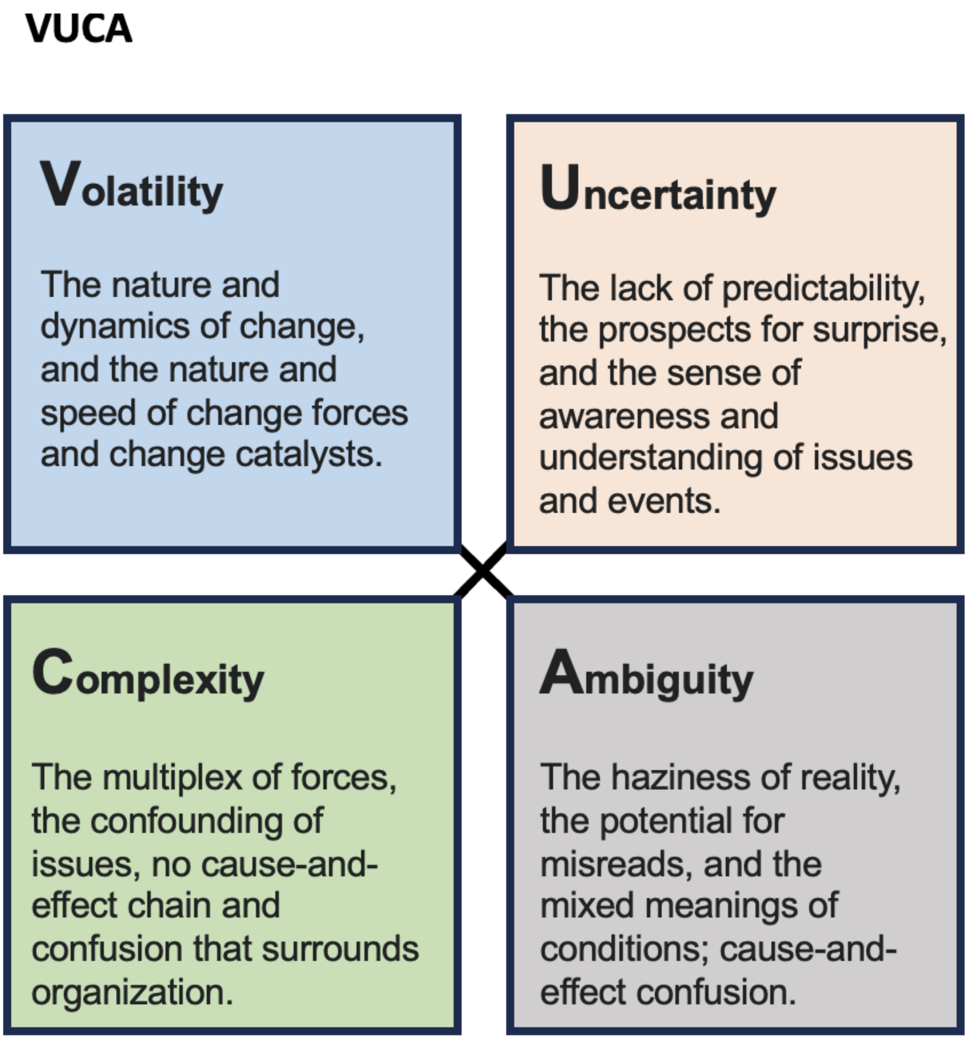

Figure 4: Definition of the VUCA categories..

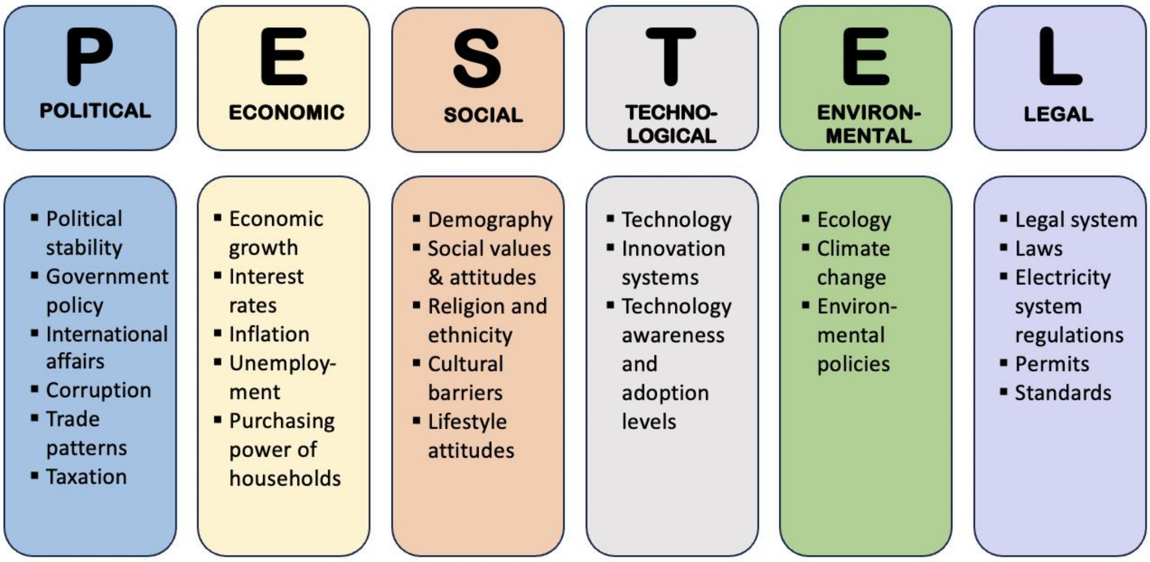

Figure 5: The PESTEL framework.

The use of the VUCA and PESTEL frameworks was a means to nudge participants into thinking about multiple aspects in order to collect as wide a range of inputs as possible. This part of the workshop was conducted in four smaller groups that focused on identifying, first, root causes and their causal relationships to the problem formulation (i.e. creating the bottom part of the problem tree) and, second, consequences and their causal relationships (i.e. creating the top part of the problem tree). It was followed by a discussion in the full group to share insights. Figure 6 shows a zoom into a section of one these trees.

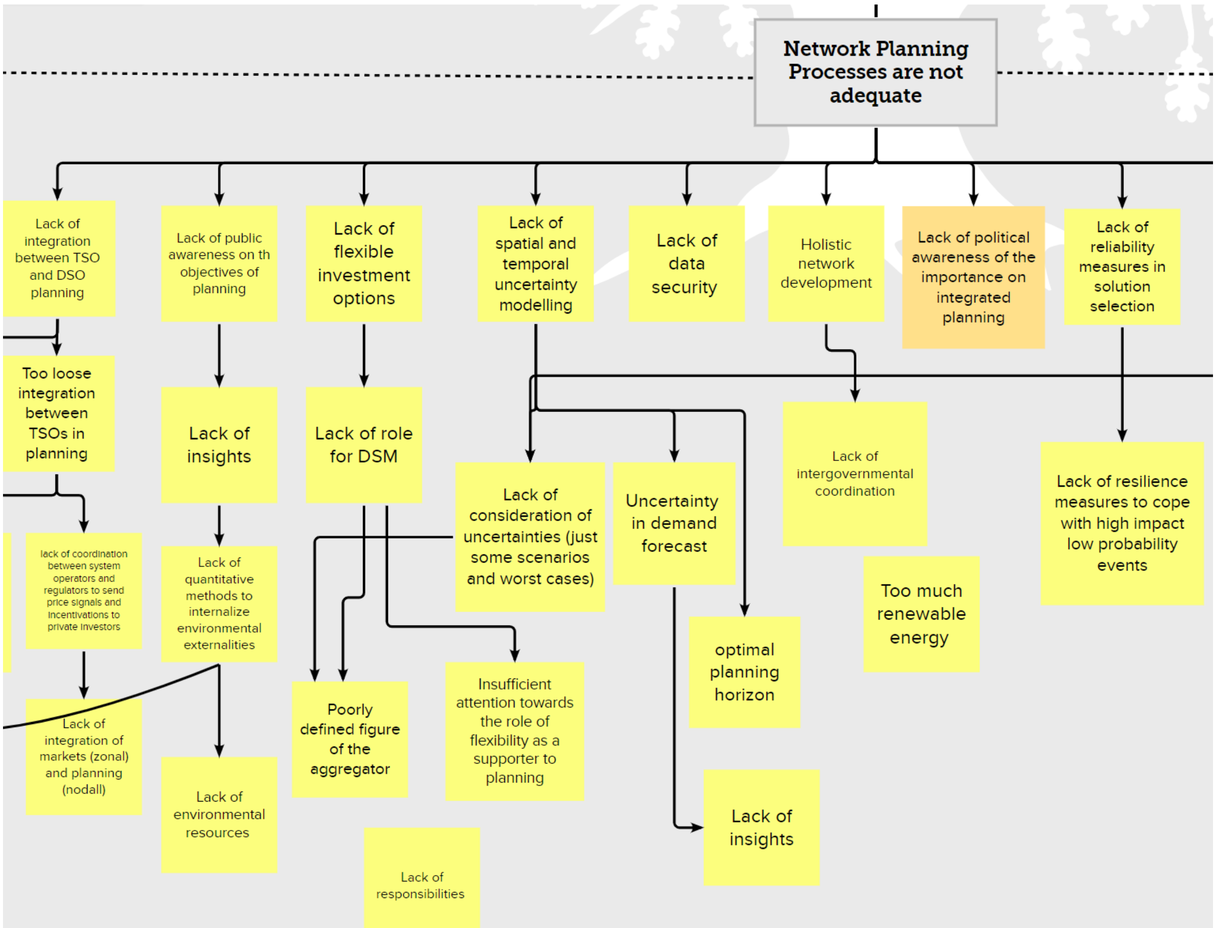

Figure 6: Zoom onto root causes.

The workshop was followed by an analysis by the organizing team to compile the outcomes and feed them into the rest of the project. The analysis included an optional workshop in which interested participants could give feedback on the analysis done by the organizing team.

This analysis allowed for the identification of some areas that needed further exploration in the upcoming workshop: deepening the understanding of how complexity and uncertainty impact network planning, and of the challenges faced and seen by different actors (TSO, DSO, regulators, researchers, …).

3.4. Workshop 2 on identifying challenges

The second workshop was organized in much the same way as the first one. A key difference was that key national stakeholders that didn't participate in the project earlier representing different actors (TSOs, DSOs, regulators, research institutions etc.) were invited to participate. In this workshop, the participants were asked once again to co-create problem trees keeping in mind the different aspects of the PESTEL framework and focusing this time on the key aspects of complexity and uncertainty.

Participants were divided into 3 levels depending on their background and interest: Policy and regulation, TSO, DSO. Participants in each level were divided into two groups, focusing on the PES and TEL aspects, respectively, for a total of six groups. The two groups in each level created problem trees with focus on their assigned aspects of the PESTEL framework.

This was followed by a discussion within their level to share their results and get feedback. Finally, new groups with participants from different levels were created to reflect on the outcomes of this workshop.

Figure 7 shows an example of one section of one of the problem trees.

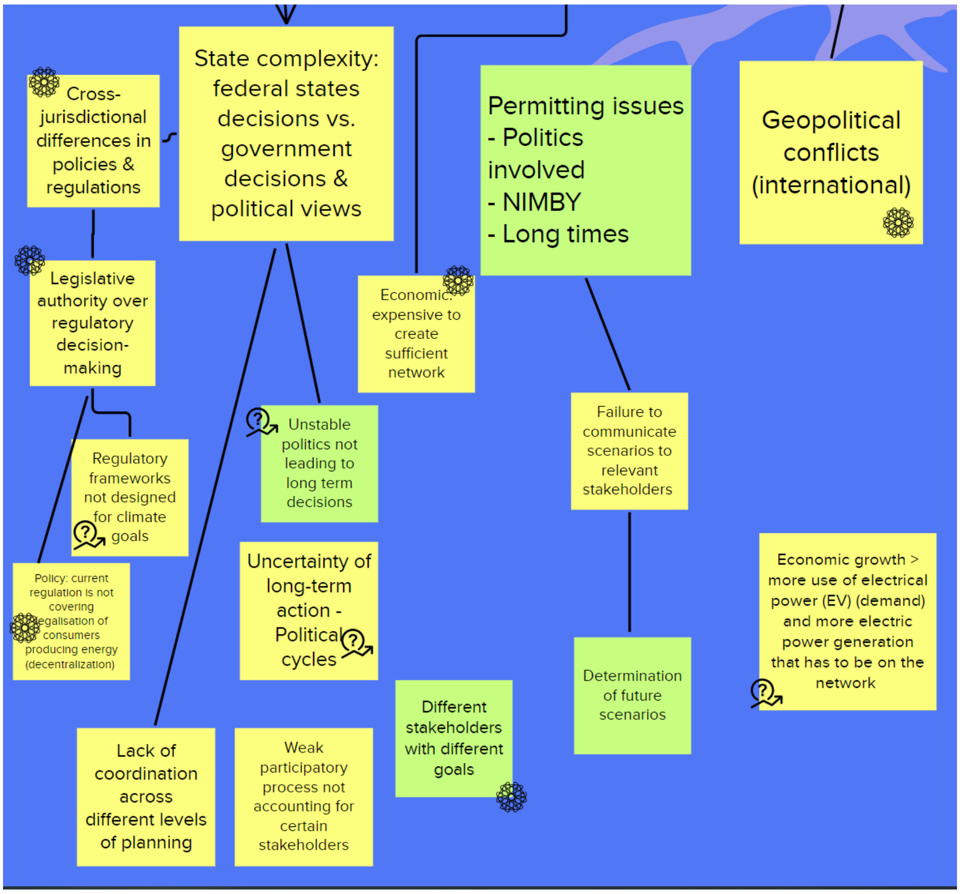

Figure 7: Zoom into one section of a problem tree.

An analysis of the problem trees of workshop 2 was done by the organizing team to identify recurring problems and challenges and categorize them in recurring themes. The purpose of this analysis was to prepare inputs to workshop 3 focusing on proposing solutions. As for workshop 1, an optional workshop was held in which participants could give feedback and inputs to the analysis performed by the organizing team.

This analysis concluded the part of the project related to identifying challenges. The outcome of this analysis is presented in next section.

3.5. Outcomes of workshops 1 and 2: Themes and identified challenges

The analysis of the outcomes of workshop 2 identified the following four recurring themes:

- Theme 1: How to handle uncertainty, complexity, new risks and threats?
- Theme 2: What regulatory adaptations are required?
- Theme 3: How to develop and maintain a competent, capable and resilient workforce?
- Theme 4: How to ensure efficient stakeholder coordination and engagement throughout the network planning process?

The following subsections summarise the workshop outcomes for each of these themes. The themes and their specific challenges were used as input for workshop 3 focusing on proposing solutions. This is presented in Section

Suggested Measures/Solutions.

3.5.1. Theme 1: How to handle uncertainty, complexity, new risks and threats?

This first theme is also the theme that received the most inputs from the workshop participants, thus emphasizing its importance. It relates to measuring the right metrics to capture the value of more grid capacity and to considering uncertainties and risks in an appropriate manner.

As already mentioned, grid development is subjected to a number of uncertain exogenous factors exacerbated by the long lead times and lifetimes of grid development projects. Among such factors, participants identified uncertainty in the amount, geography, location, type and timing of new production and consumption. In addition, while more intermittent generation is needed to fulfil climate goals, it also brings about additional uncertainty which must be addressed.

Furthermore, participants pointed out the need for including uncertain factors in the grid development studies. An example of these factors is the consideration of extreme weather events whose frequency is expected to increase due to rapid climate change. While these events may still occur with relatively low frequency in the future, they can have severe socio-economic consequences. The inclusion of such high-impact low-probability events in the network planning and assessment framework is important to take informed decisions resulting in an adequate level of resilience.

One important aspect that was raised during the workshops is the need for sector coupling between the electricity sector and other sectors such as industry and transport. This need arises from the necessity to electrify parts of other sectors to decarbonize them. This brings additional complexity and introduces new risks and threats to power systems originating from other sectors. The alignment of scenarios in different sectors is important to fully capture the potential and complexity of sector coupling aspects.

Another point that was raised often was the lack of a risk assessment framework that would allow to quantify risks, benefits and costs of different operational measures that could help increase the utilization of the existing grid capacity optimally. An example would be the possibility to load certain parts of the system at a higher level than allowed by the N-1 criterion, thus creating a risk for overload in case of contingencies, but also allowing for larger integration of renewable energy. Another example would be the increased use of corrective measures in which post-contingency overloads are allowed and dealt with by these corrective measures.

Alternatives to reinforcement exist, such as the use of flexibility and smart grid technologies. These can be cost-efficient alternatives for real-time or close-to-real-time operations. However, there is currently no appropriate way of assessing the risk ahead of real-time related to underperformance of these alternatives in actual operation. Overreliance on flexibility in grid planning processes as an alternative to building grid could result in challenging real-time operations should this flexibility not materialise. Participants also pointed out the fact that other operational practices such as network reconfiguration and utilization of the existing reserves must also be considered in planning processes.

Overall, participants emphasised the need for developing appropriate metrics that properly capture the benefits, costs and risks associated with more grid capacity.

Finally, participants agreed that not enough is done today to bridge the so-called technological valley of death, usually set at TRLs (Technology Readiness Levels) between 4 and 6. Many projects, with low TRLs, to upgrade current grid development assessment frameworks have been undertaken, but very few have made their way into TSOs and DSOs. One important aspect that was raised regarding this is the need to simplify the tools dealing with the inherent complexity and uncertainty.

3.5.2. Theme 2: What regulatory adaptations are required?

The second theme focuses on limitations in the current grid codes and national regulatory frameworks to foster grid development as a pillar of the energy transition.

The consideration of new actors (such as aggregators and flexibility service providers) and new technologies (such as smart-grid technologies and storage) has been pointed out as lacking in the most current regulation, thus slowing down the adoption of innovative solutions.

In addition, the inappropriateness of the N-1 criterion in a context of rising uncertainties has been raised several times. Moving away from the deterministic N-1 criterion and to more risk-based planning and operations would allow system owners and operators to capture more clearly risks associated with different system states.

Furthermore, it was raised several times that the current regulation should be updated to reward grid development decisions that contribute to fulfilling the UN Sustainable Development Goals (SDGs). Improved network planning processes can of course contribute to SDG7 regarding Affordable and clean energy but can also have a positive impact on other goals like for example SDG 1 on No poverty and SDG 8 on Decent work and economic growth, both since access to energy is one contributing factor and improved network planning processes are a mean to ensure this. One important aspect here is the key role of grids to fulfil the climate goals. However, increased grid capacity has more benefits, such as industry expansion, job creation and resiliency towards extreme weather. This is very much in line with the points raised under theme 1 on using the right metrics to take appropriate decisions. The regulatory framework should incentivize solutions in line with these benefits.

Finally, it was pointed out that the availability of a skilled workforce to work on these topics is an issue for regulators and policymakers.

3.5.3. Theme 3: How to develop and retain a competent, capable, and resilient workforce?

The third theme relates to ensuring an adequate workforce for grid development with the right skills.

Participants raised several times the issues that there will not only be a need for an increased workforce to carry out today's grid planning activities across all involved actors (TSOs, DSOs, regulators, …) but also a need for a workforce with new skills related to, for example, uncertainty and risk management, digitalisation, and cross-sectoral assessment. A solution would be the development of upskilling and reskilling programs which are lacking today.

In addition, training is of utmost importance, but it should be underlined that it also requires the creation of adequate training environments relying on resources such as proper datasets and scenarios. The limited availability of these resources is a hinder today.

3.5.4. Theme 4: How to ensure efficient stakeholder coordination throughout the network planning process?

The last theme identified in the analysis of the workshop results relates to fostering stakeholder engagement, coordination and collaboration.

Grid planning is an activity involving and impacting many stakeholders and groups throughout the society. Different government levels (at the municipal, regional, provincial and national levels) can have different goals and interests. Local communities may not value country-wide benefits enough to accept local consequences of grid projects. Different social groups are impacted differently by grid projects. It is therefore of utmost importance to engage all stakeholders to understand these different value systems and objectives in order to take appropriate decisions. Engaging stakeholders also has a positive effect when it comes to ensuring acceptance and delivering value for the society at its different levels. Valuable inputs can arise from more stakeholder interaction. For example, involving local municipalities can help identify possible grid routes as well as have better communication. It is also crucial to inform on benefits of grid development at different geographical levels and in terms of the value created towards the fulfilment of the UN SDGs. Platforms for stakeholder engagement exist today but are sometimes inadequate.

In addition, grid planning occurs at different voltage levels and is done by different actors working very often in silos, although these voltage levels are interconnected. Inadequate TSO/DSO coordination leads to solutions that are not cost effective. Furthermore, different authorities may be responsible for different topics that overlap but, again, may work in silos. An example is the creation of scenarios for different sectors such as transport, industry, energy and electricity. In many countries, this work is spread across multiple authorities with limited coordination. The development of standards for different actors to work together, such as data-sharing standards for TSOs and DSOs, is important to ensure effective collaboration.

An overarching concern raised during the workshops is the lack of transparency in grid development processes, which makes it hard for impacted stakeholders to understand the final decisions. Information confidentiality should be weighed against the benefits in terms of understanding, acceptance and co-creation generated by more transparency.

4. Suggested Measures/Solutions

4.1. Process

The next phase in the project was to identify solutions and formulate recommendations, as indicated in Figure 8. The main activity in this phase was a physical workshop with country representatives and national stakeholders. The outcome of the workshop was processed and condensed into a policy brief containing seven key messages, see [2]. The post-workshop analysis included an open consultation workshop in which project participants and the ISGAN ExCo representatives were invited to comment on an early proposal for the policy brief.

The sections below document this phase in more detail.

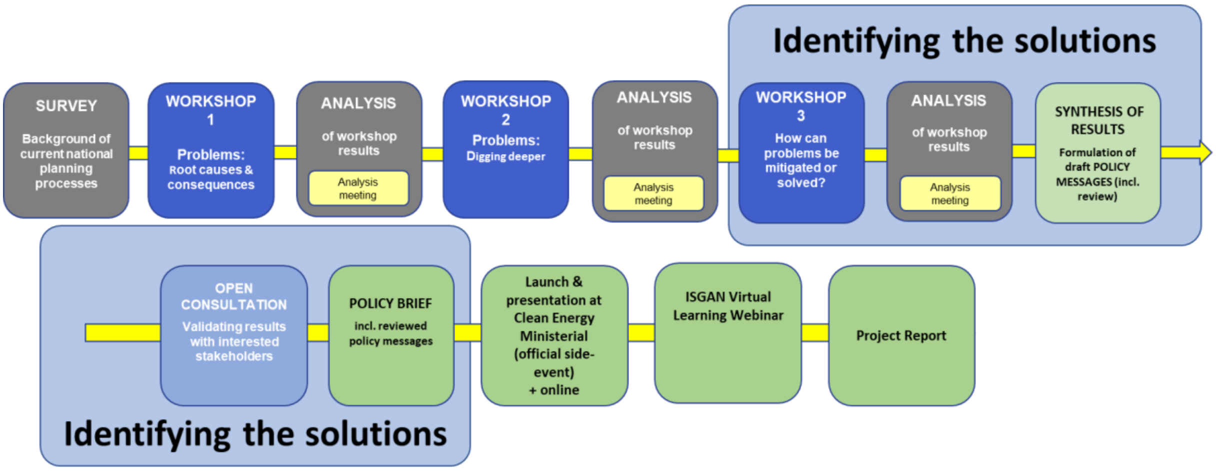

Figure 8: Activities to identify the solutions.

4.2. Workshop 3 on identifying solutions

A pre-workshop preparation material was compiled for the third workshop focusing on “How can problems be mitigated or solved?”. The preparation material was based on the outcomes of the first two workshops containing (on top of a reminder of the project background, scope and goal) the problem trees from the three (Policy- , TSO- and DSO-) perspectives together with four themes that were identified for further discussions (see Section 3.5). Each theme was presented with some overarching questions relevant to that theme as well as some selected issues that had been pointed out in the problem trees.

As an additional preparation and knowledge-sharing activity, each participating country was asked to prepare a short video presentation discussing:

- One challenge the country experiences related to long-term network planning
- One measure the country has implemented (or is piloting) to improve long-term network planning

Participants were asked to choose a challenge and a measure relating to one or several of the identified themes. As was the case for the survey performed early in project, the videos had several purposes. The primary purpose was to share knowledge and concrete examples between the participating country representatives and the project, but they also served the purpose to start processing questions related to what would be discussed at the workshop. Some highlights from the video examples are provided in Section 0.

The third workshop was held as a physical workshop. The workshop gathered around 20 people from the organizing team, representatives from IRENA and country representatives from Austria, Belgium, Germany, Italy, Norway, Republic of Korea, Republic of South Africa, Spain, Sweden, The Netherlands and United Kingdom.

In parallel, two shorter digital sessions were arranged for project participants that did not have the possibility to join physically. The digital sessions hosted representatives from Canada, Italy, Spain and IRENA.

In the workshop, the aim was to go from problem trees to solution trees as illustrated in Figure 9. The solution tree framework is similar to the problem tree framework presented in Section 3.3 but where the roots of the tree are solutions or mitigations through which a goal can be achieved. The branches represent potential positive impacts as of achieving this goal. The goal of the solution trees in this workshop 3 was set to “Future-proof network planning processes”.

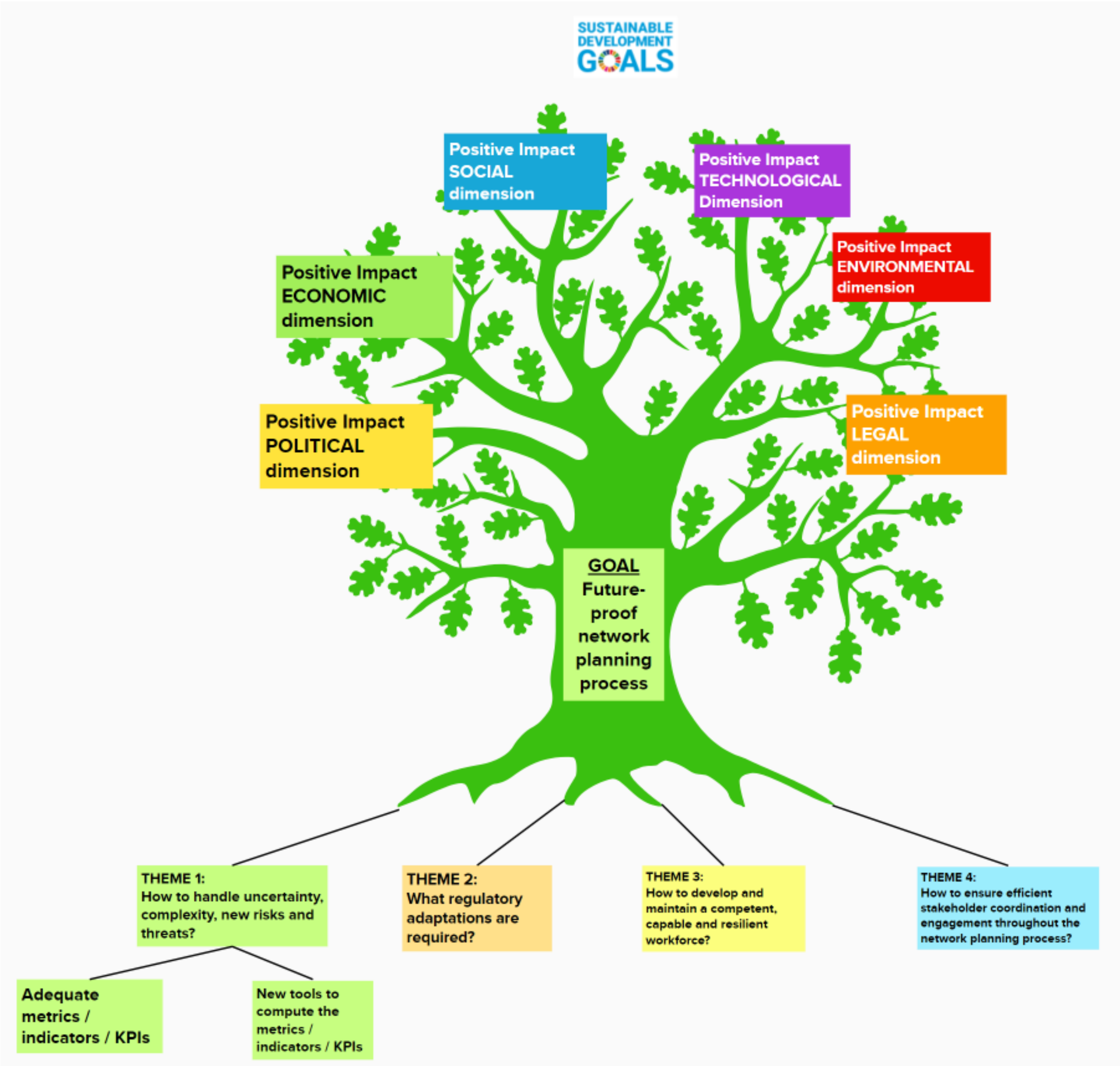

Figure 9: Empty solution tree

The third workshop was divided into several interactive sessions in which the participants worked in smaller groups to co-create solutions. There was one session for each of the four themes from Section 3.5, one session that focused on the impacts of a future-proof network planning process, i.e. on vision and objectives and one session had the goal to start writing policy messages that could be identified from the solution trees. The theme-specific sessions were guided by the outcomes of the previous two workshops, documented in Section 3.5.

4.3. Outcomes of workshop 3: Suggested solutions

Four groups worked in parallel and thus created four different solution trees. Figure 10 presents the solution trees co-created by the four groups to get an understanding of the work and Figure 11 shows a zoom into a section of one these trees.

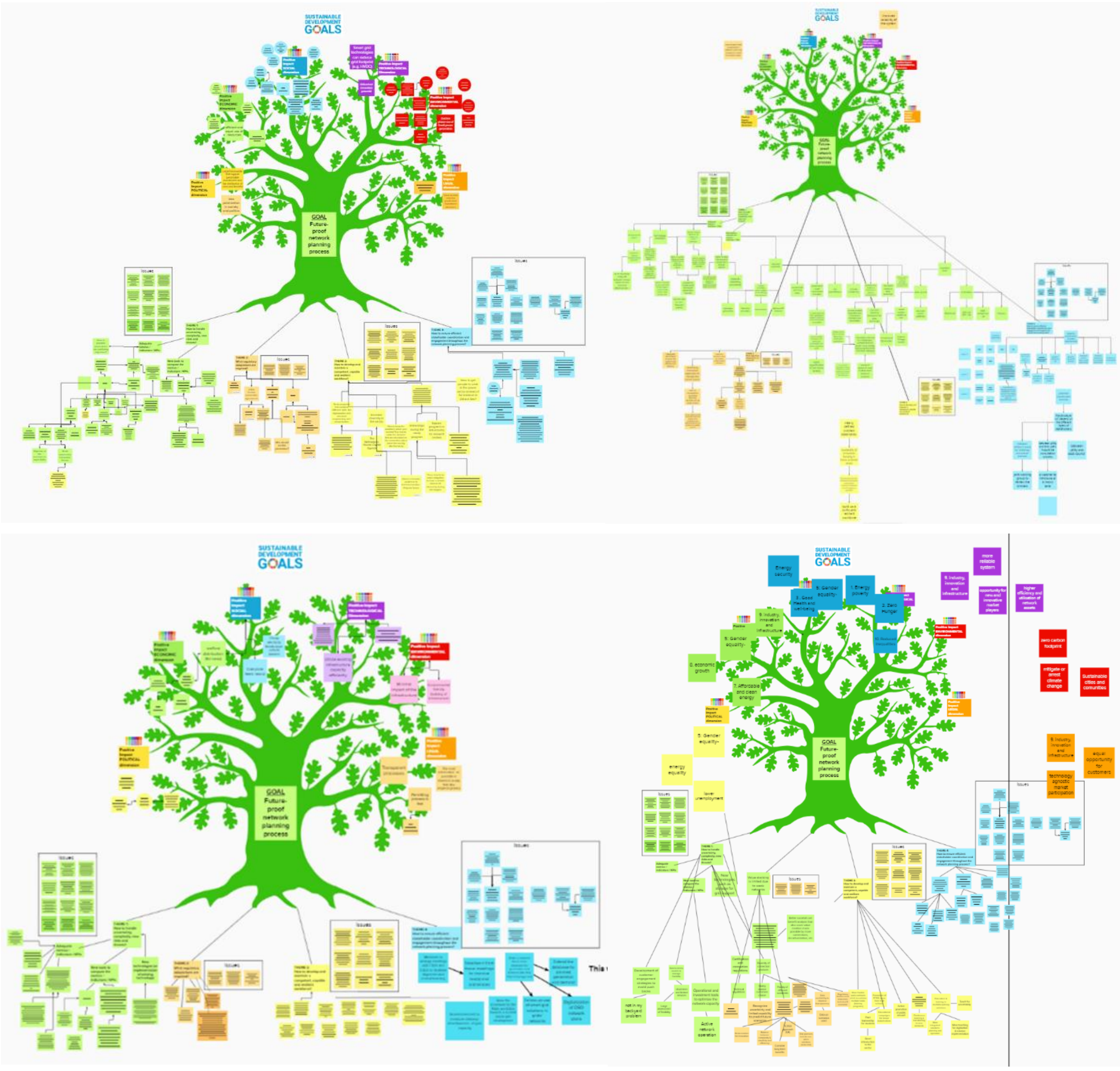

Figure 10: Solution trees from the four different groups.

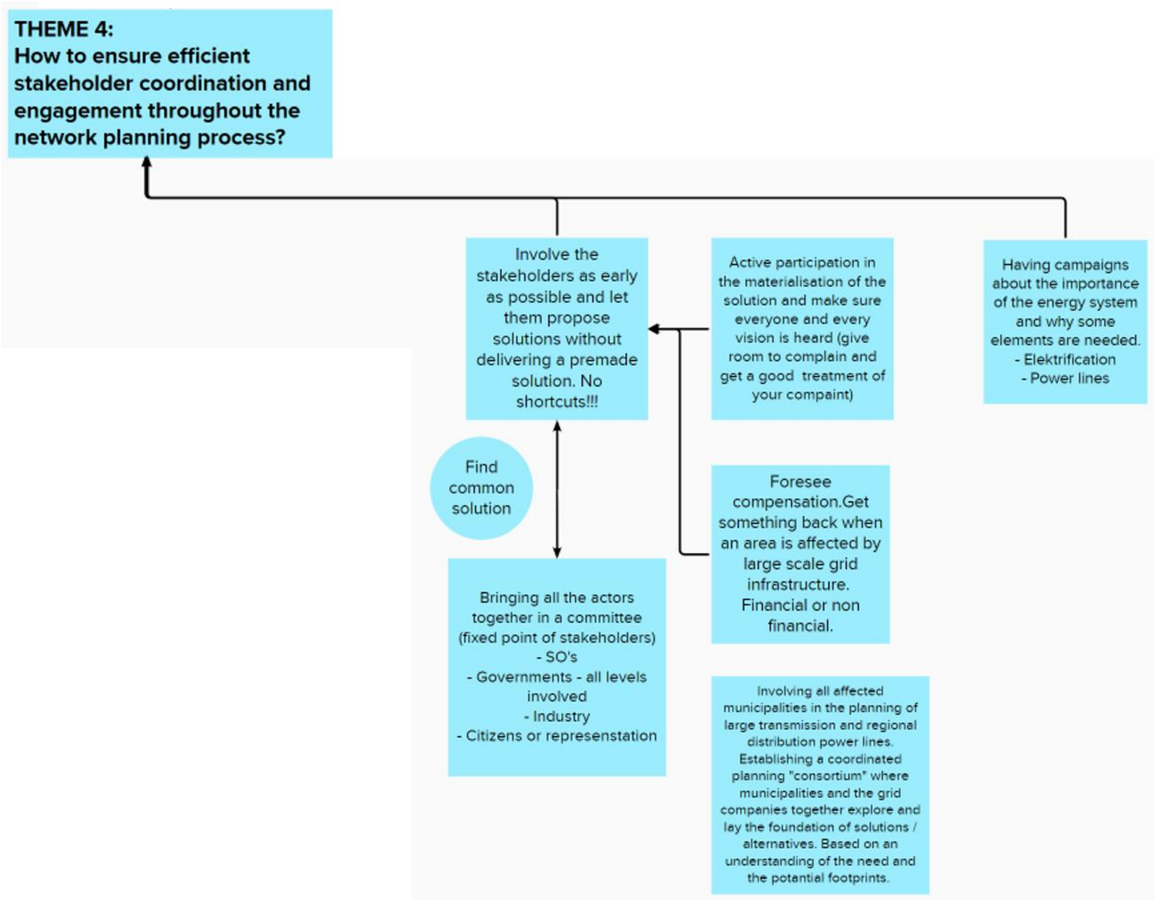

Figure 11 Zoomed in view of Theme 4 for one of the Solution trees

Each group decided what specific issue(s) within each theme to focus on, either selecting one or several of the specific challenges identified in earlier workshops or starting from an issue identified by the group. The following subsections document the proposed solutions and measures under each theme.

4.3.1. Theme 1: How to handle uncertainty, complexity, new risks and threats?

The first theme addressed challenges regarding the uncertainty and complexity inherent in grid planning processes. The theme was further divided into two subthemes. The first subtheme, *Adequate metrics / indicators /KPIs,* focused on how to choose adequate metrics to properly evaluate different dimensions of grid development projects. The second, *New tools to compute the metrics / indicators /KPIs*, focused on the actual tools needed i.e. how to evaluate the metrics.

4.3.1.1. Adequate metrics / indicators /KPIs

Grid planning, in simple words, can be described as identifying a need, analysing the requirements for the solution, evaluating the different grid development options that can meet the need, deciding upon which option is the best solution and planning for the realisation.

Identifying needs for grid development

Identifying needs for grid development should be based on multiple scenarios of expected demand (quantity and location) and what type of production that would meet the demand. Historically, generation expansion planning and grid planning have been done together. However, in many countries, these activities have been separated following the deregulation of the electricity sector. This greatly increases the uncertainty and complexity faced by system planners. Careful creation of these scenarios is crucial. It is also important that production planning and grid planning are aligned and that production planners are involved in the grid scenario development, and vice versa. The set of scenarios that grid planning activities rely upon should be updated regularly to reflect changes in forecasts.

Furthermore, it is also of utmost importance to design effective stakeholder interaction forums to involve as many impacted stakeholders as possible in the grid planning process. This helps collect, identify, and coordinate needs across different levels (TSO / DSO / industry / municipalities, …). It also helps to increase public acceptance later on during the process. Such interaction forums, for example, have been set up in Sweden where regional collaboration forums has been created to accelerate the energy transition. By working together, with the same view on the target, co-created solutions can be suggested that speeds up the permitting process for grid expansion [3].

Scenarios must be created in line with agreed-upon objectives. In particular, the United Nations' Sustainable Development Goals should guide the scenario creation phase so scenarios can support achieving these goals. A wide societal, environmental and economic perspective should be considered in the scenario creation. This means not restricting scenarios to enable achieving UN SDG 7 on Affordable and Clean Energy but setting grid planning in its larger societal context considering its benefits and impacts beyond the electricity sector. In particular, it is important that scenarios consider sector coupling and value creation in the whole economy.

It is desirable to provide guidelines and methodologies for developing long-term load scenarios to set a stable and agreed-upon scenario framework that can be used when updating scenarios. Agreed-upon scenarios can be used by multiple stakeholders beyond the authorities and organisations creating them. Therefore, in addition to the scenarios themselves, documentation and guidelines on how to use the scenarios must be published, including their scope, underlying assumptions, limitations and applications. Which further contributes to transparency and a sense of trust in the scenario results.

Policy message 1:

Develop cohesive scenarios for the electricity sector that show the necessary electrification measures required to achieve net zero emissions

Comprehensive scenarios of electricity generation and demand to reach net zero emissions across the entire energy system are critical in determining future grid development needs. Nationally and, where possible, regionally coordinated scenarios, developed in a transparent and inclusive manner with key sector stakeholders, are crucial to facilitate effective planning and decision-making.

Evaluating grid development options

To be able to do a proper evaluation before an investment, it is important to base the evaluation on as many aspects impacted by the investment as possible. In other words: to use adequate metrics / indicators or KPIs in the analysis. Important aspects to include when evaluating are for example environmental impacts, investment costs, cost of energy not supplied, cost of losses, risk of blackouts and its related costs to society (as potential consequence of inadequate grid development), value creation outside the energy sector (recognized for example through cross-sectorial socioeconomic analyses) and operational cost or indirect costs for alternatives (such as storage, demand-side flexibility) to pure grid investments.

The evaluation is often done by using some sort of cost benefit analysis (CBA) and/or multi-criteria analysis tools (MCA), comparing the cost of a solution with the benefit the solution would bring. Some aspects can be evaluated quantitatively while some others can only be assessed qualitatively. The CBA standards developed by ENTSO-E in Europe is one example of how to perform a cost benefit analysis of Grid Development Projects [4]. Various

CBA and MCA tools are available, e.g. the ISGAN Smart Grid Evaluation Toolkit [5], an open access tool supporting decision makers in identifying the best smart grid planning options.

While today's CBA analyses consider traditional metrics related to power systems, such as operational security, they usually don't capture the wider value of grid development from a societal point of view. An example could be value creation in society when industrial centres can be developed thanks to appropriate grid capacity. In contrast, too little grid capacity may lead to socioeconomic opportunity losses. These must be captured appropriately when doing CBA analyses.

Due to grid being a long-lived and critical infrastructure, it is important to carefully identify risk and resilience factors and assess their impact on grids. This includes considering the effect of climate change during the lifetime of grid projects, such as how changes in temperatures or climate events can impact the grid capacity.

Grid planning activities should not be seen as separate and non-interacting with grid activities on shorter timescales such as maintenance planning, operations planning and operations. Today, these activities are partly done in silos with no coherent and overarching framework guiding decisions across the different timescales. As an example, operational practices must in some way be considered in the planning processes in order to appropriately measure the need of grid development. In this wider power system planning and operation context, it is important to define and agree on right operational risk levels by considering resulting impacts and benefits to the society. An illustration of this is that accepting higher operational risk levels in terms of, e.g., violation of traditional power system security criterion (such as the N-1 criterion) may in some cases result in socioeconomic benefits with little consequences in terms of sustained outages and customer disconnections. Allowing this in operations and considering this in grid planning activities would most likely decrease the need for grid reinforcement to manage these situations and thus in some cases allow faster connections of new grid users.

Policy message 2:

Ensure that grid development plans enable deep decarbonization in line with the developed scenarios

Grid development plans enabling the entire energy system transformation in line with the developed set of scenarios require coordinated involvement of all impacted stakeholders. Balancing conflicting goals between local and national levels as well as between economic, social, and environmental considerations will require political guidance.

4.3.1.2. New tools to compute the metrics / indicators / KPIs

Since grid planning processes are highly complex, there is no standalone tool that can be used to perform the evaluation of all the different metrics. Instead, different tools are used in the grid planning process. This includes, for example, tools for cost benefit analysis (CBA) and for multicriteria analysis (MCA), power system simulation tools and electricity market analysis tools.

For the power system operators and planners to be able to manage the grid planning in the increasingly complex and uncertain environment, some tools need to be updated and some new tools will need to be developed. It is important to develop and use an appropriate set of methods and tools that complement and are integrated with each other in a coherent process to be able to capture all aspects that should be considered (as discussed in Section 4.3.1.1).

Some functional needs were identified during the project and are loosely listed below:

- Capture changes in new types of loads with electricity-consuming equipment based on new technologies.
- Have the capability to model incremental changes.
- Have the capability to consider that customers load profiles not necessarily coincides and to have more appropriate ways investing if more customers can access than summing up all peak loads (regardless of when and for how long they appear).
- Manage stochastic models.
- Use probabilistic modelling approaches.
- Be able to model uncertainty of renewable generation sources.
- Develop suitable models capable of taking into account different needs and behaviours.
- Reflect smart grid solutions that are in operation today (like dynamic line rating or system integrity protection schemes) to have the right information on required grid capacity.
- Include market-based solutions as an alternative to traditional grid reinforcement.
- Consider new services, actors, and available flexibility (e.g., hydrogen generation, flexibility providers, aggregators, interconnectors and offshore DC networks). It is also important to be able to capture flexibility from technical network solutions like, grid reconfiguration possibilities.
- Capture value creation made possible by the increased capacity in terms of resilience, achievement of climate goals, industry establishment, city growth, among others.
- Define and quantify appropriate risk measures capturing threats and uncertainties and considering societal benefits achieved by allowing increased levels of the traditional risk metrics (N-1 criterion, …).
- Model climate change and its impact on grid development.
- Assess if increasing the use of existing asset utilisation or off grid arrangements can serve as an alternative to grid expansion.
- Capability of considering off grid arrangements.
- Build tools and evaluation frameworks that allow for reproducibility and regular updates of the evaluation outcomes to consider new information.
- Include multiple alternative solutions and not only the one optimal one chosen by grid planners to inform and foster stakeholder interaction.

With the increasing complexity related to new tools and interactions between an increasing number of actors, adequate ways of managing data and information exchange are crucial. This includes:

- Common interfaces to exchange information across different standalone tools.
- Standards and tools for data exchange between TSOs and DSOs.
- Open APIs for easy data exchange and publication.

While it is important to capture as much of the inherent uncertainty and complexity as possible, complex tools may be a barrier for their fast adoption within organisations working with grid planning. The effort needed for the tool users to understand and use new tools, and to make sense and analyse the tool outcomes must be considered in the tool design process. Simple solutions can in this respect provide high value compared to more complex alternatives.

A proper risk assessment framework should recognise that not all risk and uncertainty factors are known and, therefore, that the resulting metrics do have some blind spots. Also, optimality in terms of socioeconomic benefits should consider the pace at which identified alternatives can be implemented and the effort (e.g., in terms of monetary and human resources and stakeholder interactions) required to do so. In this respect, sub-optimal solutions with minimum effort should be accepted.

Policy message 3:

Update existing cost-benefit analyses to properly capture the values of sufficient grid capacity and account for social, environmental, and resilience metrics

Planning is fraught with uncertainty and complexity, magnified by the long lead times of grid development projects. It is imperative to establish a clear, standardised, and transparent grid planning assessment framework that is embraced by all relevant stakeholders and is capable of assessing and weighing multiple metrics. Key factors to consider include economic, social, and environmental dimensions of grid development while also addressing risk and resilience factors. It is also vital to incorporate all of the benefits of increasing grid capacity to properly value grid development projects and also capture the consequences of inadequate grid development in the context of deep decarbonization of the economy.

Having active research and development is crucial. When it comes to the interaction between research and development on the one hand and implementation at end-users (grid planners) on the other hand, it is important to ensure that proposed methodologies and solutions at the research level reach the intended users by travelling through the higher TRLs. The so-called TRL valley of death (technologies and solutions reaching TRL of 4 to 6 and getting "stuck" there) should be bridged by focusing fundings on elevating solutions' TRL above TRL 4 to 6. In this respect, promoting bidirectional interactions between research bodies and need owners is of utmost importance, not only across organisations but also within them. Clearly defined needs by need owners (grid planners) will foster research and development activities in the right direction.

To actively work with research and development is of utmost importance to identify and create good methodologies and solutions.

References to some projects and measures proposed are listed in Appendix B: Relevant projects and R&D outcomes.

4.3.2. Theme 2: What regulatory adaptations are required?

Laws and regulations provide a steering mechanism for what grid planners are allowed and must do. Therefore, in addition to ensuring that grid planners use the right tools, it is of utmost importance that laws and regulations provide incentives to achieve the right results in terms of supporting the energy transition and, more generally, the fulfilment of all UN SDGs.

Some regulatory adaptions needed are provided:

- Regulatory frameworks should foster both conventional and smart grid solutions contributing to the achievement of these goals. The regulations should be technology agnostic to be fair to all solutions (also non-wire).
- The regulatory frameworks must adjust to the emergence of new actors and define their new roles with their rights and obligations. Currently, this is relevant for, e.g., aggregators, flexibility service providers (FSPs), local energy communities and distribution system operators (DSO).

- Regulation must also adapt to the increasing amount of data that is and will be available. The risks related to privacy issues and cyber security must be evaluated and weighed against the value creation possible from data utilisation.
- When grid capacity is scarce and due to the long lead times of grid development, allowing for a diversity of connection products such as flexible connection agreements could be considered. This could allow giving different priorities to connection requests depending on type of customer and their flexibility potential. Examples on countries that allow flexible connection agreements are UK, Ireland, Norway, and Belgium. If providing different priorities to connection requests, it is important that regulation clearly defines how this prioritisation should be done considering the associated benefits in terms of, e.g., job creation, emissions reductions.
- The political level has an important role to set goals and ensure that grid planning aligns with and acts as an enabler for the UN Sustainable Development Goals. They should also incentivise grid capacity.
- The energy transition needs grid capability and end-users cannot wait, why creating conditions for anticipatory grid development is spoken for, to manage long lead times considering the value that access to network capacity brings to society.
- In the same way that simplicity can be beneficial in tools and methods, it is also important for the regulatory framework to find a balance between complexity, simplicity, stability and efficiency.

Policy message 4:

Ensure that regulatory frameworks foster both conventional and smart grid solutions contributing to the clean energy transition

Regulatory frameworks should be responsive to meet the needs of the rapidly evolving electricity sector, including accommodating the emergence of new actors, increased use of generation and demand flexibility, and new technologies like battery storage. This must be balanced with providing long-term regulatory stability for sector stakeholders. It is also crucial to weigh the socioeconomic benefits of rapid grid development against potential implications for security of supply and quality of service. Tools such as regulatory sandboxes should be extensively used to support the deployment of innovative solutions and to help the sector to meet net zero emission targets.

Finally, the rapid energy transition and needed adaptions will put some strain on regulatory bodies and grid planners in terms of human, technical and economic resources. This is addressed in the next section.

4.3.3. Theme 3: How to maintain a competent, capable, and resilient workforce?

The lack of a resilient workforce with the right skills can be a bottleneck in achieving a grid planning processes able to deal with the challenges caused by increasing complexity and uncertainties.

Solutions to this challenge include the need for developing educational programs teaching the right skills not only for new entries in the workforce but also for existing staff for them to gain new knowledge from research and other industries. Part of the solution is also related to the need to attract needs to identify ways to increase attractiveness of technical studies in general and the electricity sector in particular. One example is Terna in Italy who has created Podcast Terna, with educational campaigns for broad stakeholders.

Ways to have the right type of education include:

- Creating study programs that combine different skills, like digitalisation, electrical engineering and social studies.
- Developing strategies skills supply and education needed for the energy transition.
- Increase teaching in new areas like uncertainty, risk assessment, digitalisation and integrated solutions.

Creating new expertise includes capitalising on completed innovation projects. Dissemination of both the experience and knowledge gained during such projects as well as identified challenges will contribute to expanding the required expertise. Fostering this knowledge dissemination could be very beneficial. This can be encouraged by including requirements in research funding calls and research programs to include knowledge transfer as part of their dissemination activities, in terms of contribution to education, updating education programs and courses, skill development etc.

Furthermore, multiple education forms should be used including internships during study programs, sponsorship from governments or companies for students, mentorship programs and trainee programs to link industry and research centres.

Finally, knowledge transfer strategies prior to retirement should be developed to avoid losing valuable expertise.

Policy message 5:

Develop strategies to recruit and train a skilled workforce to satisfy short- and long-term competence needs

To effectively address the challenges of an uncertain and complex grid planning environment, substantial investments and collaboration among education, government, research, and industry stakeholders are imperative for attracting and nurturing a skilled workforce. Experts from diverse backgrounds and with distinct competencies are required throughout the planning process. These backgrounds and competencies include policy and regulation, engineering, environmental impact assessment, and urban and rural planning as well as expertise in behavioral sciences.

4.3.4. Theme 4: How to ensure efficient stakeholder coordination and engagement throughout the network planning process?

As already mentioned, the grid planning process is complex and involves many different stakeholders such as system and network operators, regulators, producers/developers, local councils, environmental agencies and end-users (industry and citizens). Opportunities to bring stakeholders together should be created in order to ensure synergy between interacting organisations (such as TSOs and DSOs) to reach cost-effective solutions and to increase understanding and acceptance of grid development. One example, already mentioned, is the regional collaboration forums initiated in Sweden [3].

The structure on the coordination and involvement process depends on the involved stakeholders:

- Laws and regulations can foster interactions between TSOs and DSOs to facilitate alignment and mutual learning and create joint working groups to co-create grid development options synergistically.
- Clear and well-defined stakeholder forums and consultation processes can be set up between utilities and their stakeholders. This should be bidirectional processes in which stakeholders raise their values and interests and can propose solutions to ease

grid development projects considering local aspects. In some cases, recognizing the local and regional impacts of grid development projects may lead to the need for compensation, monetary or non-monetary.

- Institutional transformation strategies can be developed within organisations to align the different parts of a DSO/TSO such as research, planning and operations departments.

In stakeholder interaction, it is important to consider different aspects, including:

- Customer needs and values (grid as a public service). As lifted in Section 4.3.1.2, it is important to have appropriate risk metrics in the grid planning process. Discussions regarding risks and what, from a socioeconomical perspective, should be considered an acceptable level of security of supply are also important to consider in forums with different stakeholders.
- DSO needs (need to unlock distribution flexibility and local balance responsibility).
- TSO needs (in terms of, e.g., power system security).

Also, data exchange is important and practical solutions must manage data utilisation, for example by:

- Defining a standard and a well-defined set of information to be exchanged among stakeholders.
- Creating a database for planned generation and demand as well as for DSO network development plans that stakeholders can use to follow up grid development projects.

The project identified various specific and general requirements to consider when designing interaction processes at different levels. Some examples are loosely listed below:

- Coordination of scenarios (on foreseen temporal and spatial need of demand and production) between DSOs and TSO as well as between DSOs and DSOs.
- Interaction design should be fair and efficient in terms of time, monetary and human resources.
- Every actor should be given equal opportunity to get involved.
- Digitalisation of connection requests to system operators to simplify preparatory work for both system operators and end-users.
- Clear and well-defined timeline of coordination for specific grid development projects, including visualisation of the timeline and decision points (milestones).

Policy message 6:

Promote stakeholder interaction at all levels of the grid planning process

Enhanced collaboration between government, industry, research and other societal actors should be promoted to efficiently share knowledge and co-create solutions for effective grid development. In specific grid planning projects, dedicated platforms for public engagement and stakeholder interaction, in particular with local communities, should be established to ensure productive collaboration, permitting, and decision-making.

Communication is challenging but crucial. Well-developed communication strategies towards impacted communities and stakeholders on specific grid development project should shed some lights on how these projects align with the overall country goals and what are the alternatives (including the costs and impacts of doing nothing). More generally, communication campaigns should not focus only on the need of generation, but also on transmission and distribution capacity. Carefully worded communication campaigns must recognise different target groups and be concrete enough to be relatable by the targeted stakeholders.

One proactive approach to stakeholder communication and involvement could be to create early-stage mapping of relevant and vulnerable areas for transmission (and generation) development.

Finally, to mitigate polarised political discussions, the communication efforts must recognize that grid development is a multi-criteria problem and involve stakeholders in defining the relevant criteria to consider and weigh against each other.

Policy message 7:

Increase awareness and understanding of the role of the electrical grid for meeting the Sustainable Development Goals

Highlighting the central and transformative role of electricity systems in achieving the UN Sustainable Development Goals (SDGs) can help gain acceptance for necessary grid investments. More specifically, grid planning outcomes that may directly impact SDG 7: Clean and Affordable Energy, should be more clearly linked to potential benefits to other SDGs regarding climate action, poverty reduction, and innovation, among others.

5. Country-specific challenges and solutions

As mentioned in Section 4.2 each participating country was, as additional preparation and knowledge-sharing activity for workshop 3, asked to prepare a short video presentation discussing:

- A challenge the country experiences related to long-term network planning
- A measure the country has implemented (or is piloting) to improve long-term network planning

Participants were asked to choose a challenge and a measure relating to one or several of the identified themes in Section 3.5. The publicly available videos can be downloaded from the ISGAN web page [6]. Short descriptions are also provided below:

5.1. Austria

In Austria, one of the major challenging issues regarding network planning is how to envision and quantify what the future may look like in terms of the energy transition.

In the short term, there is, on top of the technical challenge, a need for qualified personnel. On a longer term, one of the biggest challenges is that there currently is no long-term planning process at the DSO level, why the expected renewable energy expansion on lower voltage levels is unknown and thus so are the reinforcement requirements. The risk is that ad-hoc planning is performed instead on strategic planning.

In the project “567”, methods and scenarios for strategic grid planning in distribution networks were developed as a help to empowering the DSOs in their decision-making processes. The project was performed by AIT together with three large Austrian DSOs. The framework developed are illustrated in Figure 12.

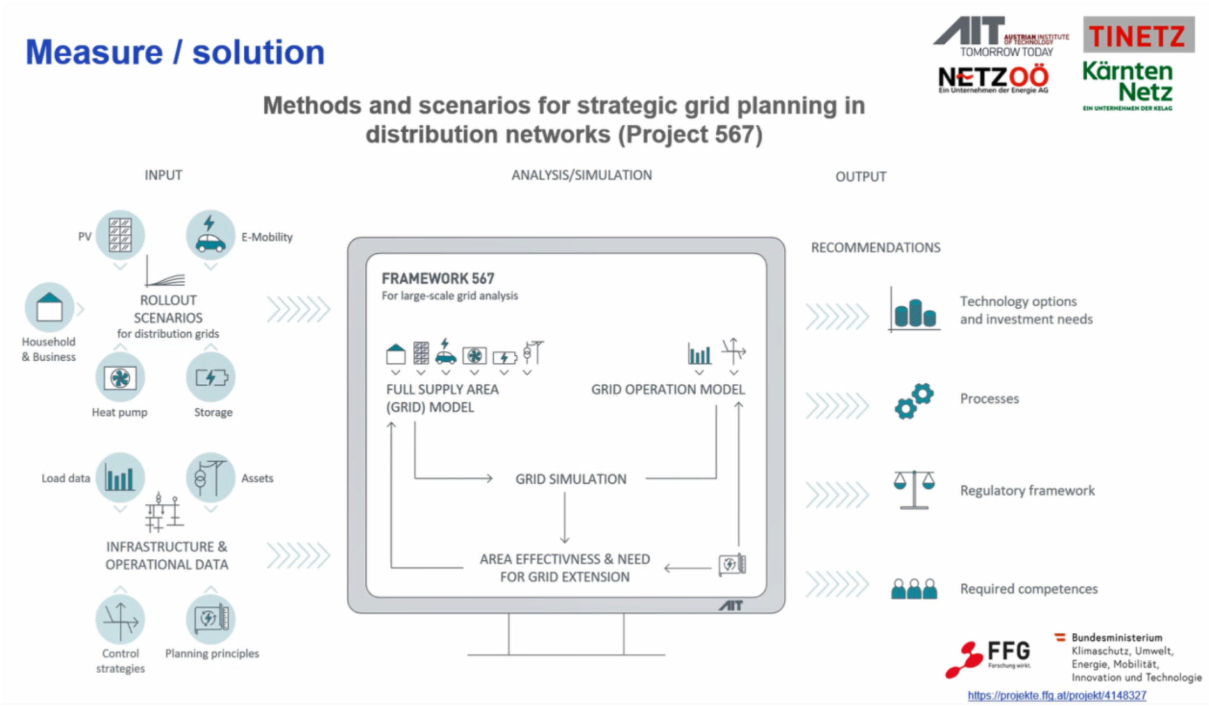

Figure 12 Illustration of the framework for strategic grid planning in distribution networks developed in the "567" project.

Reference attached in Appendix B: Relevant projects and R&D outcomes (#2).

5.2. Belgium

The issue lifted by Belgium is the need to expand their grid with extra transmission lines to meet the offshore wind target. Without this grid expansion, the benefits for the market are limited. The major challenge for the grid expansion is regarding permitting and the fact that the transmission network development plan is produced on a federal level but permitting is performed on regional level. Belgium experiences that performing necessary grid expansions on transmission level is nowadays very difficult. There is currently no solution to the challenging situation presented, but ideas of possible measures lifted are more collaboration between different state levels and for the TSOs to offer multiple technological solutions.

As a measure to find solutions to general energy transition related challenges, Belgium has created the Energy Transition Fund (ETF). The fund wishes to encourage and support research, development and innovation related to the energy transition. The fund is also a way to ensure more concrete R&D output for policy makers, as well as possible further commercialization of innovative technologies and concrete investments.

The fund tackles many challenges and has many positive effects, like:

- Need for more labour force, training, and education.
- The energy sector benefits from the outcome of the different projects. A knowledge sector is created to tackle the technological challenges and market issues related to the energy transition.
- Technology and market instruments are being developed to soften extreme network investments by using the network in a more efficient way.

Also, results are disseminated in a variety of ways and the funded projects contribute with their research results to a common knowledge base. As an example, one project had the goal to create different expertise centres in Belgium. This led to start-ups, in collaboration with other partners, being able to develop their product.

Reference attached in Appendix B: Relevant projects and R&D outcomes (#24).

5.3. Canada

Canada´s electricity system is governed at the provincial and territorial level with some responsibilities on the federal level. Some regulatory responsibilities are shared, as shown in Figure 13.

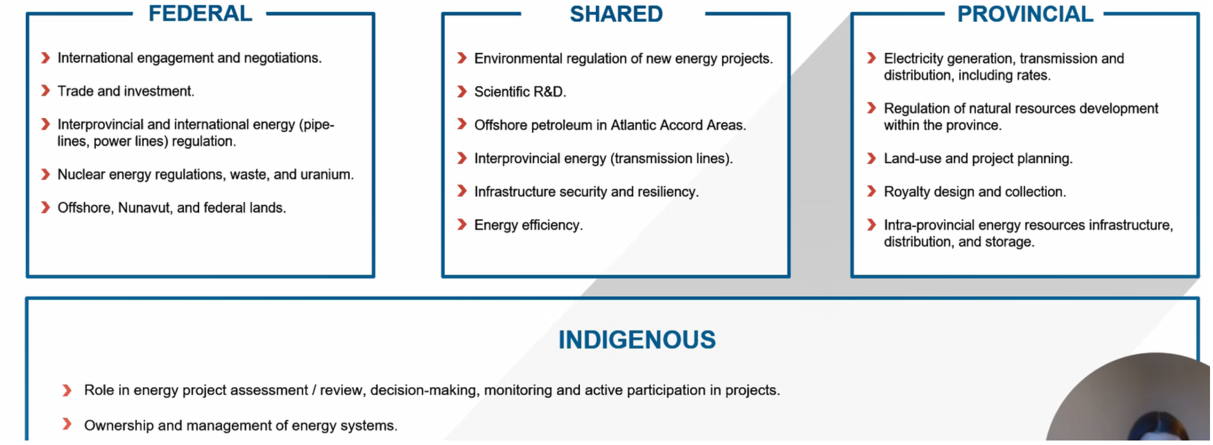

Figure 13 Overview of how jurisdictional responsibilities are divided between federal level and provincial.

Each province has its own set of regulations and legislation for energy production, transmission, and distribution. Multiple climate goals are however set on a national level, which can complicate things. There are many jurisdictional perspectives to consider regarding network planning in Canada and one of their major obstacles are institutional inertia which makes it hard to face the speed necessary to meet the Net Zero goals. Coordination and new models of working with industry are required. This challenge has an impact on many different stakeholders such as: policy makers; utilities; system operators; regulators; innovators and businesses.

Potential to influence is determined by jurisdictional mandates. Some activity areas which can be influenced on a federal level are shown in Figure 14, where the "Innovation and Electricity Regulation Initiative" is lifted as one good example on measure taken.

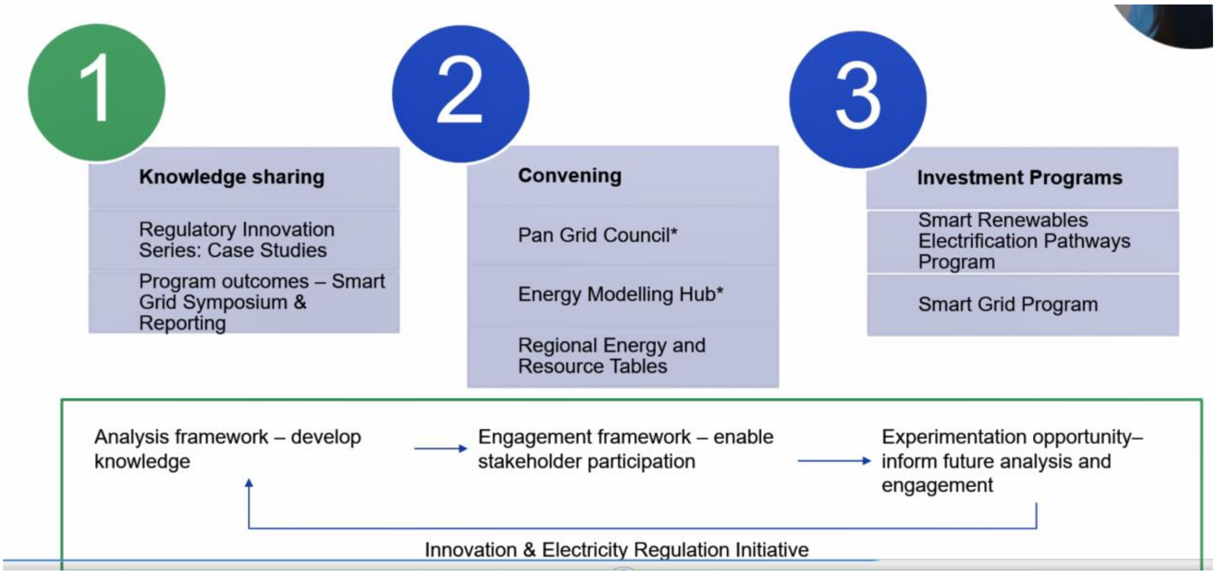

Figure 14 Measures organized in activity areas where the federal level can influence.

The three objectives of the initiative are to:

- Learn from jurisdictions across Canada what others are doing to support grid modernisation and innovative smart grid technology implementation.
- Identify common regulatory challenges, possible solutions and opportunities to advance market deployment of smart grid technology.
- Consider approaches to potential federal program development.

The initiative has the goal to find pathways to reach the Net Zero target and is primarily in phase one but is intended to expand across the framework *inform*, *convene* and *invest*.

Under the *convene* category, there are some initiatives supported by the government. For example, the Electricity advisory council has the mandate to advise the provincial and territorial governments bringing together external experts. The Electricity advisory council is a temporary body external to government. Other initiatives are ongoing under the different categories.

This approach is the federal strategy to provide support in a space with the federal government has limited authorities, in order to support the jurisdictions to meet the Net Zero needs.

5.4. Italy

A big challenge for Italy is related to how to manage the need for coordination on a high level to, in the most effective way, meet the energy transition.

Several factors need to be considered:

- Strong interdependency
  - TSOs and DSOs infrastructures are getting more and more coupled and to run the grid in an optimal a high amount of data, often sensitive, needs to be shared in a secure way.
- Electrification trend
  - New types of loads like electrical vehicles and heat pumps changes the ways the distribution grids need to be planned.
- Observability
  - The increase in distributed generation is one example that results in increased challenges related to observability.
- Coordination in Emergency situation
  - To be able to manage situations with extreme events, coordination and planning must be done ahead of such potential situation.

One solution that Italy is working on to address this challenge, is to open channels that foster new structures for collaboration amongst stakeholders.

Examples on both national and international level are provided:

- Equigy:
  - A joint venture between the TSO, Terna, and other stakeholders developing a Crowd Balancing Platform based on blockchain for trusted data sharing among stakeholders.
- TSO/DSO collaboration:
  - Terna's pilot project to implement traffic light mechanisms for global grid services and sharing static and dynamic data between Terna and the DSOs.

- Flexplan:
  - A Horizon 2020 funded project that has developed an innovative grid planning methodology that allow to account flexibility resources. Flexplan has also developed ways to test integrated T&D planning, by sharing only TSO-DSO-interface data.
- TSO/DSO coordination protocol:
  - Definition of actions and methods of coordination between Terna and the DSOs and implementation of the procedures defined in the respective Emergency Plans.

Reference attached in Appendix B: Relevant projects and R&D outcomes (#5).

5.5. Korea

The single biggest challenge in Korea is increasing delays in transmission expansion, for example due to decreasing acceptance of affected communities. Also, the much shorter lead time of renewables, particularly solar, compared to transmission expansion results in an interconnection backlog with the interconnection-driven, passive network development approach that Korea currently applies. The fact that demand is mainly concentrated in the capital, with limited production capacity, causes network constraints. The situation has worsened by an increase in the development of energy-intensive data centres who want to locate close to the capital area.

The mentioned challenge impacts all the TSOs, the National Regulation Authority and policy makers.

As a solution, the Korean government recently announced a shift towards more anticipatory network planning, especially in corridors into the capital area.

- A transmission extension plan for timely interconnection of renewables is under establishment which is based on assessing the construction plans and deployment potentials (i.e. forecast-based planning ahead of interconnection requests).
- Also, a grid impact assessment scheme for energy intensive facilities will be legally formalised where measures to mitigate adverse effect from the facility are required or the connection will be delayed.
- Other measures than grid expansion, like for example installing flexible AC transmission systems (FACTS), have been used to increase the transfer capacity in existing and new transmission lines.

Also measures to improve public acceptance are under development, like improving the financial compensation scheme for affected local communities.

5.6. Norway

As many other countries, Norway lifts the challenge of the accelerating rate of electrification and decarbonization which results in an increase in the need for both more and larger grid connections.

Today, Norwegian grid companies have incentives to

- be reactive and wait with investments in network capacity until they are triggered by requests from end-users (also in cases where the "lead time" for establishing new capacity is very long, e.g. 3-15 years), and
- operate their networks in a "low-risk" manner (maintaining good operational margins, e.g. N-1, by limiting new and larger grid connections until more network capacity is in place).

This raises two questions relevant for policy makers, NRAs, grid companies, etc.:

- What is the optimal approach to investments in network capacity and operational margins / risks when one takes all the costs and benefits that are relevant for society into consideration? (Including the economic value creation, social development and decarbonization that is made possible by having access to network capacity).
- Should society accept higher power supply interruption rates (operational risk), higher operational network costs and more proactive investments in network capacity (investment risk) to rapidly realize more and larger grid connections that can create benefits for society?

One measure recently launched in Norway is a scheme called “Connection with conditions of disconnection or reduction of consumption” (flexible / alternative / non-firm connection). The scheme allows grid companies to establish connection agreements with end-users that have conditions related to disconnection and reduction of demand, e.g. in case of faults / outages and work on / maintenance of network assets. Disconnection and reduction of demand according to the conditions of a flexible / alternative / non-firm connection does not cause interruption costs (energy not supplied). It is voluntary to accept an alternative / non-firm grid connection temporarily or permanent. Potential customers are: Electrical ferries, hybrid ships, shore-to-ship power facilities, data centres, industry, charging facilities, etc.

Another measure is the Cost of Energy Not Supplied (CENS) scheme, implemented years ago, to incentivise a socio-economic rational development and operation of the grid. The scheme is a part of the income cap regulation of the grid companies and makes power supply interruptions affect their income. The scheme is intended to lead to a socio-economic optimal approach to fault / outage restoration, maintenance work, reinvestments, etc. However, the measure can cause an unintended challenge since it disincentivizes grid companies from taking higher operational risks.

5.7. Sweden

The challenge lifted for Sweden are the very high foreseen growth of demand, driven mainly by a large-scale electrification of industry such as green steel, battery manufacturing etc. Also, the increasing price differences between the electrical price bidding zones within the country is challenging. The increasing price differences is, to a large extent, a result of transmission grid congestions in combination with very high energy prices in continental Europe.

To meet the increasing need of grid capacity, there is a change in how grid planning is considered moving towards adapting a more anticipatory network planning. The requirement for bi-yearly network development plans is implemented in the electricity law and the Swedish TSO is correspondingly making system development plans.

Several initiatives are taken to manage the need of limiting grid capacities, as presented in Figure 15.

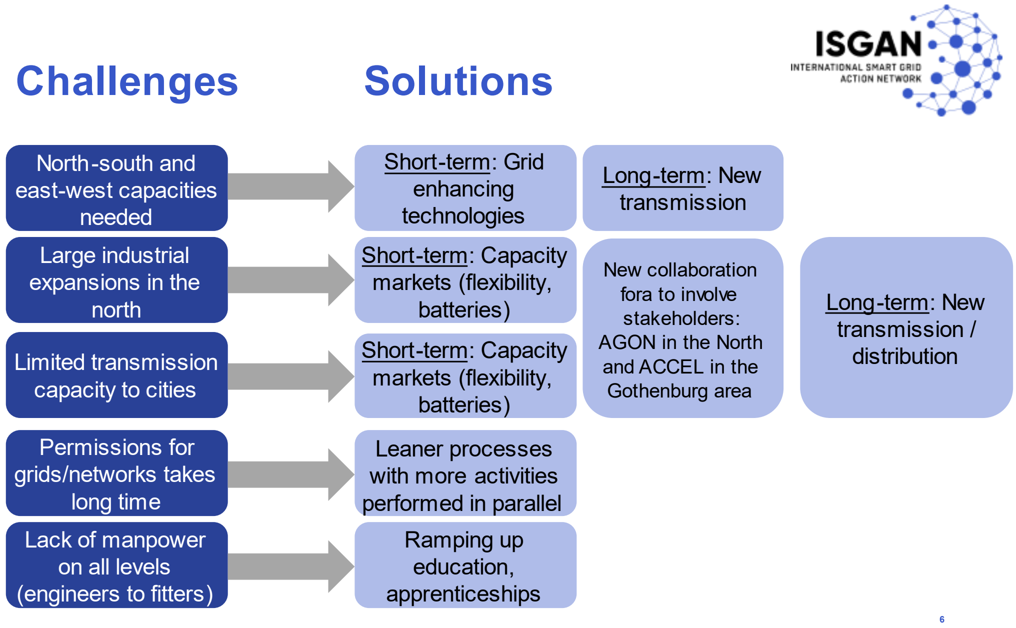

Figure 15 Challenges and solutions related to lack of grid capacity in Sweden.

5.8. United Kingdom

United Kingdom currently uses a deterministic analysis when determining the transfer capacity. Due to time restrictions, this only allows for studying selected (few) number of boundaries and selected (few) number of scenarios. It is thus not possible to consider all possibilities resulting from for example uncertainties (the most onerous scenario might not coincide with the demand peak), nor to look at all boundaries of interest.

Even though there is a good understanding of what changes need to be done in the planning process, like to use a probabilistic approach, the improvements are still difficult to achieve for example due to the computational burden the changes imply.

The measure taken by NGESO in collaboration with TNEI to address this challenge is to develop a stability assessment framework to enable large volumes of analysis for system planning purposes. Combinations of machine learning and statistical methods have been evaluated to improve speed of analysis and best capture uncertainty. The most promising methods will be developed further in trials with the full system model.

As part of the project a couple of tools have been developed, see Figure 16.

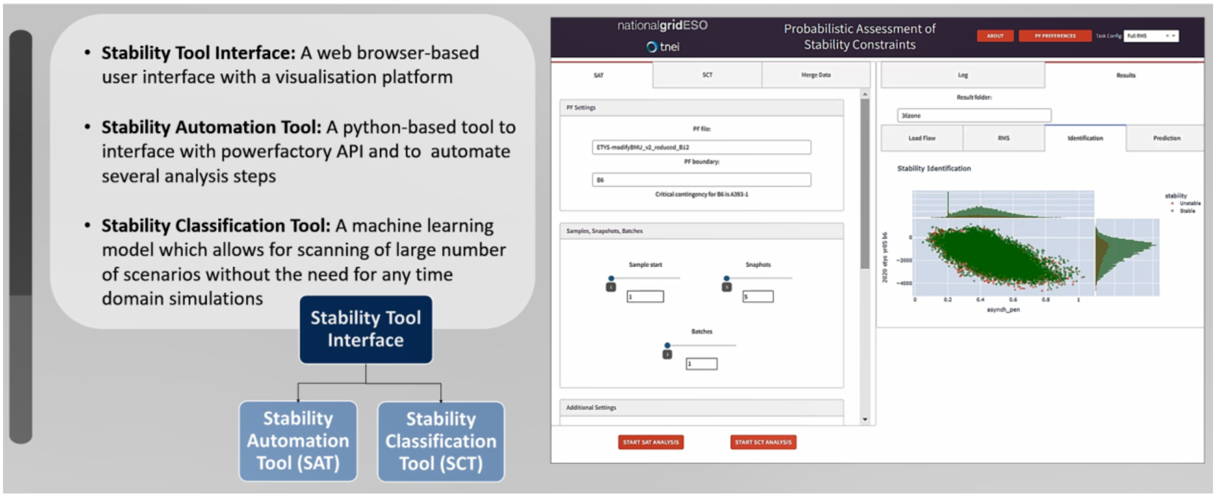

Figure 16 Example of tools developed within the stability assessment framework.

The framework allows scanning through a wide range of scenarios without manual intervention and helps dealing with uncertainty. The tools are currently being tested.

Reference attached in Appendix B: Relevant projects and R&D outcomes (#1).

6. Wider potential impacts of improved planning processes

In order to contextualize the impact of the proposed solutions and demonstrate how an enhanced network planning process can contribute positively to various SDGs, a session of the in-person workshop was dedicated to exploring such visionary linkages. Through this discussion, it became clear that network planning possesses the potential to play a pivotal role as a catalyst, especially in the realms of, but not confined to, the following SDGs:

SDG 7: Affordable and clean energy

SDG 8: Decent work and economic growth

SDG 9: Industry, innovation and infrastructure

To help explore potential positive impacts across various dimensions, the PESTEL framework was employed once more, see Figure 5. Examples of outcomes gleaned from this workshop dialogue include:

- Political dimension:
  A more transparent and democratic planning process, in which stakeholders' concerns and needs are taken into account, may contribute to more predictable investments and a more equitable distribution of costs and benefits.
- Economic dimension:
  An improved planning process may enhance economic efficiency, support industrial development, and competitiveness, as well as streamline investments, thereby avoiding stranded assets. Enabling access to affordable and reliable renewable energy in optimal locations may also contribute to job creation.
- Social dimension:
  A legitimate planning process that engages all interested stakeholders may have significant positive social impacts. It may promote economic welfare distribution, foster inclusivity by ensuring everyone's voice is heard, enhance energy security and affordability, encourage grid technology adoption with minimal local disruption, and raise public awareness about the societal importance of grid development, contributing to a more informed and engaged citizenry.

- Technological dimension:
  Significant technological benefits can be expected from an improved grid planning process, including the adoption of smart grid technologies to reduce grid footprint (e.g. HVDC). It may optimize the utilization of existing infrastructure and network assets, enhance system reliability and open doors for innovative market players offering solutions that support and strengthen the grid's capacity in various ways.
- Environmental dimension:
  A more efficient approach to adopting new methods and technologies may boost capacity, accelerating the electrification of industries and end-use sectors, reducing emissions, and curbing renewable energy curtailment. Efficient grid planning is critical for managing increased renewable energy levels, expediting the phasing out of fossil power generation. Sound grid planning should also contribute to a more balanced trade-off between land use (onshore transmission grid development) and seabed use (offshore grid development), helping to conserve both aquatic and terrestrial ecosystems.
- Legal dimension:
  A future-proof grid planning process is characterized by swiftness without sacrificing transparency, ensuring that all voices are heard. Permitting procedures should not only be clear and expedient but also just, governed by fair and predictable rules that encourage sound investment decisions. Such a process would guarantee equal opportunities for customers, allowing technology-agnostic market participation. Moreover, it would facilitate the sharing of pertinent and valuable information while upholding privacy rights.

7. Conclusions

This report documents the findings of an ISGAN project on "Network planning under uncertainty". Electricity networks have a pivotal role to play as enablers of a deep decarbonization of the entire energy system. Furthermore, electricity networks are value creators for the entire society and therefore are important contributors to many of the United Nations' Sustainable Development Goals such as climate action, poverty reduction, industry, innovation and infrastructure, sustainable cities and communities, among others.

This ISGAN project has gathered 12 countries on 3 continents as well as the International Renewable Energy Association (IRENA). The project was leveraged through the ISGAN Knowledge Sharing Platform (KSP) and involved a year-long series of interactive workshops, consultations and analyses.

These activities have resulted in a set of seven policy messages aimed to support policy makers and energy sector stakeholders to tackle the barriers preventing electricity grids to successfully play their role as enablers of the energy transitions and important contributors to many of the SDGs. These seven policy messages are:

1. Develop cohesive scenarios for the electricity sector that show the necessary electrification measures required to achieve net zero emissions
2. Ensure that grid development plans enable deep decarbonization in line with the developed scenarios
3. Update existing cost-benefit analyses to properly capture the values of sufficient grid capacity and account for social, environmental, and resilience metrics
4. Ensure that regulatory frameworks foster both conventional and smart grid solutions contributing to the clean energy transition
5. Develop strategies to recruit and train a skilled workforce to satisfy short- and long-term competence needs
6. Promote stakeholder interaction at all levels of the grid planning process
7. Increase awareness and understanding of the role of the electrical grid for meeting the Sustainable Development Goals

This report serves as a supplement to the previously published policy brief (attached herein) encompassing the seven key policy messages. Its primary purpose is to provide a comprehensive documentation of the knowledge sharing process and its outcomes. Included in this documentation are country-specific challenges and solutions gathered from the project participants, which can offer valuable insights and inspiration to other countries facing similar challenges.

A central takeaway from this report is the imperative recognition that the protracted lead times associated with grid investments demand swift action to overhaul grid planning processes, ensuring their alignment with the evolving energy transition.

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Appendix A: Survey questions

Process

A. Please give a high-level (simplified) overview of the network planning process in your country.

- If possible involving both TSOs and DSOs.
- If possible, please visualize the process – see example *(separate ppt)*.

Answer:

B. Is there something in the current network planning process you would consider particularly challenging? Please elaborate.

Answer:

Steering mechanisms / Regulation

C. What are the main steering mechanisms/regulatory frameworks?

- Objectives (and who defines these)?
- Constraints (and who defines these)?
- How are economic incentives designed?

Answer:

D. Is it generally considered to be feasible to meet all objectives and constraints?

- If not, or if too generally defined, are the priorities clear (for all the relevant stakeholders involved)?

Answer:

Methods / Tools

E. What methods are used to comply with the steering mechanisms?

Answer:

F. At which stage(s) of the process, and how are alternatives to traditional network expansion, evaluated and considered?

Answer:

G. How are network planning decisions evaluated (*ex-post*) to ensure process improvements and the capture of key learnings?

Answer:

H. Are there any mechanisms for providing feedback to the regulators and other actors defining the steering mechanisms? If yes, please elaborate.

Answer:

Stakeholder involvement

I. Who are the main stakeholders involved in the network planning process?

   Answer:

J. At which stage(s) of the process are these stakeholders involved?

   Answer:

K. Do you see a need for increased stakeholder involvement?

   - What kind of dialogue/stakeholder interaction is needed to improve network expansion planning process?

   Answer:

Uncertainties

L. What stage(s) of the planning process are based on or influenced by predictions/assumptions of future conditions?

   - E.g. when are scenarios or forecasts of generation and demand used?
   - How is quality assurance of input data and methods used secured?

   Answer:

Perception

- What is the experienced "general opinion" of the network planning and expansion process?

  - Should the process and its objectives/constraints be clarified to avoid ambiguity for the involved stakeholders (and to ensure transparency for society at large)?

  Answer:

Future development

- What need for new frameworks/methods/regulation do you see in regard to network planning and decision-making to enable the energy transition in your country – in line with, and supporting, the realization of the global sustainable development goals (The 2030 Agenda)?

  - Targeting different perspectives and system actors.

  Answer:

- Are you aware of any new R&D experience in this field?

  - Links to, or copies of relevant material, are most welcome!

  Answer:

Additional comments

- Please add here any other information that you consider relevant in the exploration of this topic!

  Answer:

Appendix B: Relevant projects and R&D outcomes

This appendix lists relevant project including tips provided in the survey answers regarding new R&D experience.

#	Project / Publication	Link
1	A probabilistic approach to stability analysis for boundary transfer capability assessment	https://cse.cigre.org/cse-n027/c1-a-probabilistic-approach-to-stability-analysis-for-boundary-transfer-capability-assessment.html
2	P567: Methods and future scenarios for strategic grid development in distribution grid levels 5, 6 and 7	https://projekte.ffg.at/projekt/4148327
3	Leafs: Integrating local storage systems and variable loading into low-voltage networks	https://www.energy-innovation-austria.at/article/leafs-2/?lang=en
4	DG DemoNetz-Concept: Innovative voltage control concepts for active network management	https://nachhaltigwirtschaften.at/resources/edz_pdf/1012_dg_demonetz_konzept.pdf
5	FlexPlan: An innovative grid planning methodology considering the opportunity to introduce new storage and flexibility resources in electricity transmission and distribution grids as an alternative to building new grid elements	https://flexplan-project.eu/the-project/
6	Plan4RES: Synergistic Approach of Multi-Energy Models for an European Optimal Energy System Management Tool	https://www.plan4res.eu
7	PlaMES: Integrated planning of Multi-Energy Systems	https://plames.eu/
8	CoordiNet: Collaboration schemes between TSOs, DSOs and consumers for the procurement of grid services	https://coordinet-project.eu/
9	DT4Flex: Digital Twin of the Distribution Network to manage resources flexibility	https://ingelectus.com/dt4flex/
10	OneNet: One Network for Europe, seamless integration of all the actors in the electricity network across Europe for the optimization of the overall energy system	https://onenet-project.eu
11	IEEE Transmission & distribution committee, HVDC & FACTS committee, Working group 15.05.18, "Studies for planning HVDC", 2021	https://resourcecenter.ieee-pes.org/publications/technical-reports/PES_TP_TR86_TD_022521.html
12	BeFlexible: increasing the flexibility of energy systems, improving cooperation among distribution system operators (DSOs) and transmission system operators (TSOs), and encouraging all energy-related stakeholders to participate	https://beflexible.eu/

13	C. Mosca, E. Bompard, B. Aluisio, M. Migliori, C. Vergine and P. Cuccia, "HVDC for frequency stability under RES penetration: the Sardinia island case,", 2019 AEIT HVDC International Conference (AEIT HVDC), Florence, Italy, 2019	https://ieeexplore.ieee.org/document/8740577/
14	E. M. Carlini et al., "Static and Dynamic Evaluation of Different Architectures for an Actual HVDC Link Project," in IEEE Transactions on Power Delivery, vol. 35, no. 6, pp. 2782-2790, Dec. 2020	https://ieeexplore.ieee.org/document/9217983
15	Gianni Celli, Fabrizio Pilo, Giuditta Pisano, Simona Ruggeri, Gian Giuseppe Soma, “Risk-oriented planning for flexibility-based distribution system development,” in Sustainable Energy, Grids and Networks, Volume 30, 2022	https://www.sciencedirect.com/science/article/pii/S235246772100151X
16	I. B. Sperstad, E. Solvang and O. Gjerde, "Framework and methodology for active distribution grid planning in Norway," 2020 International Conference on Probabilistic Methods Applied to Power Systems (PMAPS), Liege, Belgium, 2020	https://ieeexplore.ieee.org/abstract/document/9183711
17	LIFE AreAPoort: developing a district-scale energy management platform to resolve grid problems while integrating local stakeholder interests in its design and implementation	https://www.energielabzuidoost.nl/life-arenapoort/
18	SmoothEMS: researching and testing technology with which we can accelerate the energy transition by making optimal use of the existing power grid	https://elaad.nl/projecten/smoothems-met-gridshield/
19	Smart Planning: gaining insight into how Smart Grids can make optimal use of the flexibility of the connected parties, given the conflicting interests of users, suppliers and network operators	https://projecten.topsectorenergie.nl/projecten/smart-planning-16589
20	TROEF: A new layered energy ecosystem, accelerating the transition to renewable energy in built environments by developing a new energy ecosystem	https://www.troef-energy.nl/en
21	ROBUST, a future-proof and affordable electricity grid, integrated solutions for local congestion problems in city regions	https://tki-robust.nl/
22	CIGRE Working group C1.39, “Optimal power system planning under growing uncertainty”, 2020	https://e-cigre.org/publication/820-optimal-power-system-planning-under-growing-uncertainty
23	Local inertia - Belgian project looking at analysis tools that are able to rapidly detect low inertia areas	https://innovation.eliagroup.eu/projects/local-inertia/
24	Information about the Beligan Energy Transition Fund (ETF)	https://economie.fgov.be/nl/themas/energie/energietransitie/energietransitiefonds https://economie.fgov.be/fr/themes/energie/transition-energetique/fonds-de-transition

25	CEER Paper on Alternative Connection Agreements, Council of European Energy Regulators (CEER), Brussels, Report C23-DS-83–06, 2023	**https://www.ceer.eu/documents/104400/-/-/e473b6de-03c9-61aa-2c6a-86f2e3aa8f08**
26	CEER Paper on DSO Procedures of Procurement of Flexibility, Distribution Systems Working Group, Report C19-DS-55–05, 2020	**https://www.ceer.eu/documents/104400/-/-/e436ca7f-a0df-addb-c1de-5a3a5e4fc22b.**