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# Helping Member States achieve their NECP goals through Innovative Grid Technologies

CurrENT
Enabling Network Technology throughout Europe

# Table of Contents

## Executive Summary

As Europe is facing severe challenges with regards to energy security, reliability and affordability, it is more important than ever to take ambitious steps towards Net Zero. Scaling up renewables is key here, both in reducing import dependency and fulfilling climate targets, and will require powerful electricity grids to be planned, optimised, developed and deployed.

The integrated National Energy and Climate Plans (NECPs) are a central instrument for planning, coordinating, and monitoring progress towards the EU 2030 energy and climate objectives, and Member States must submit draft updates of their national plan to the European Commission by June 2023, reflecting the EU's increased ambitions. currENT believes that it is timely for policy makers to guide Member States on the most cost-effective way to reach Net Zero in 2050: innovative grid technologies need to form part of this discussion.

Innovative grid technologies such as Dynamic Line Rating, Power Flow Control devices, grid monitoring and analytics, and superconducting cables allow the grid to function more efficiently. By using innovative grid technologies, the existing grid can transport more energy, react faster, and adapt to new circumstances more quickly, while reducing overall investment needs and delivering vast efficiency gains. Network expansion will be needed, and innovative grid technologies can complement these efforts.

currENT has reviewed all the NECPs and analyzed them with regard to their consideration of Innovative Grid Technologies. Our analysis shows that while smart grids are often mentioned, the term is used quite broadly, and often no details are provided. Some Member States do refer to storage, PSTs and DLR, yet there is much room for improvement, i.e. consideration of how the optimisation of existing grids can lead to fast, competitive and sustainable results. The next generation of NECPs should consider this potential in a deeper, more detailed and concrete manner. Our recommendations below list a number of points for the NECP guidance that EC, ACER, NRAs, and governments should take into account.

1. Efficient use of infrastructure through the application of the Energy Efficiency First Principle are paramount to achieve the EU Green Deal and REPowerEU targets: it needs to be enshrined in the NECPs.
2. Innovative Grid Technologies need to be considered part of the technology tool box.
3. The NOVA principle should be applied when talking about the electricity grid, and transparency in its implementation is key.
4. Better alignment between NECPs and Network Development Plans is needed.
5. NECPs should include emerging technologies, their expected impact and how investments can be made for their uptake
6. Working back from 2050 is vital.
7. NECPs must include non-binding agreements on offshore network development plans for renewables, established by Article 14 of the recently revised Trans-European Networks for Energy (TEN-E).
8. The European Commission should commission a study on the benefits of innovative grid technologies for reaching climate neutrality.

## Introduction

Two and a half years after the launch of Europe´s Green Deal and six months after the beginning of Russia´s war against Ukraine, it is more important than ever to take ambitious steps towards Net Zero. Europe is facing severe challenges with regards to energy security, reliability, and affordability, as well as challenges posed by unprecedented extreme weather. Despite these challenges, the EU has also managed to proceed with the emergency synchronisation of Ukraine into the Continental Europe Synchronous Area, and declared repeatedly and rightly that it will not deviate from its trajectory towards climate neutrality, and will accelerate the deployment of new renewables.

Renewables are key to reducing import dependency and fulfilling climate targets. This has been reconfirmed by the REPowerEU Action Plan that was presented by the European Commission on 18 May 2022, which had the three overall objectives of accelerating renewables, saving energy and diversifying supplies. Deployment of large-scale variable renewables requires powerful electricity grids to be planned, optimised, developed and deployed. Since time is of the essence, and massive investments will be needed, making use of all available solutions is crucial.

The Integrated National Energy and Climate Plans (NECPs) are a central instrument for planning, coordinating, and monitoring progress towards the EU 2030 energy and climate objectives. The NECPs covering 2021-2030 were finalised in 2019, and Member States must submit draft updates of their national plan to the European Commission by June 2023, reflecting the EU's increased ambitions under the European Green Deal, the European Climate Law and the REPowerEU Plan to end the EU's dependence on Russian fossil fuels. currENT believes that it is timely for policy makers to guide Member States on the most cost-effective way to reach Net Zero in 2050: innovative grid technologies need to form part of this discussion.

Innovative grid technologies such as Dynamic Line Rating, Power Flow Control devices, grid monitoring and analytics, and superconducting cables allow the grid to function more efficiently. By using innovative grid technologies, the existing grid can transport more energy, react faster, and adapt to new circumstances more quickly, while reducing overall investment needs and delivering vast efficiency gains. Network expansion will be needed, and innovative grid technologies can also complement these efforts. There are ample opportunities for boosting the efficiency of Europe's existing grid infrastructure by applying innovative grid technologies, which must also be reflected in new infrastructure projects. Innovative grid technologies can be deployed much more quickly than other solutions, and deliver results faster. Innovative grid technologies also enable grid operators to prioritise network needs with precision and efficiency. This is particularly important today, with European citizens heavily burdened by unusually high energy prices and Europe needs to do everything in its power to keep the energy transition affordable. Additionally, the ongoing supply chain crunch is already causing delays in delivering materials and equipment needed for grid expansion, and innovative grid technologies provide more timely and cost-effective options to ensure safe and reliable grid operations.

While the advantages of innovative grid technologies have already been demonstrated by various studies, they are too often overlooked. This is why currENT has analysed all EU27 NECPs with respect to innovative grid technologies. In this paper we first provide some background on the NECP process, then we provide a synthesis of how innovative grid technologies are considered in each NECP, and finally we provide several key recommendations for the upcoming revision of the NECPs.

## A brief reminder: the NECP process

According to the 2018 Governance Regulation, adopted as part of the Clean Energy Package[1], all EU Member States are required to establish integrated 10-year National Energy and Climate Plans (NECPs) for 2021-2030. In these plans, Member States outline how they plan to address energy efficiency, renewables, greenhouse gas emissions reductions, interconnections, and research & innovation.

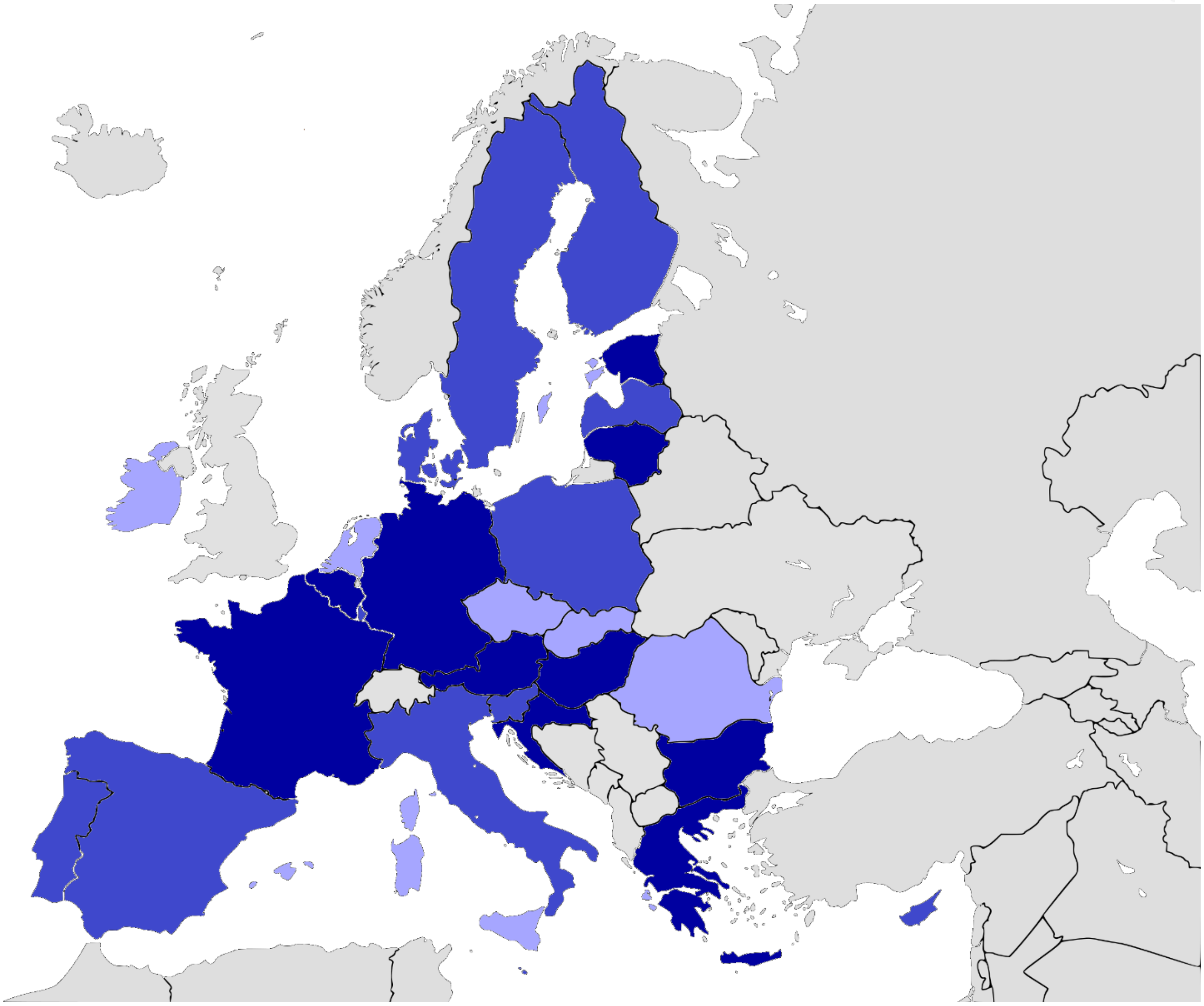
As stipulated in the Regulation, Member States submitted their draft NECPs before the end of 2018 and after feedback from the European Commission, submitted their final NECPs before the end of 2019. From March 2023, Member States are required to submit a progress report every two years, covering all five dimensions of the Energy Union.

However, under the European Green Deal, and the subsequent European Climate Law adopted on 30 June 2021, the EU committed to a more ambitious 2030 target of 55% CO2 reduction compared to 1990 levels. As a response to Russia's invasion of Ukraine, in May 2022 the European Commission presented its REPowerEU Plan, aimed at phasing out Russian fossil fuels, which proposes to accelerate the deployment of renewables as one of its three pillars. This means that the NECPs will need to be revised in order to reflect the new 2030 targets. Member States must each submit their draft revised NECP by June 2023, and their final revised NECP in 2024.

## Innovative grid technologies in the NECPs

currENT has reviewed all the NECPs and analyzed them with regard to their consideration of Innovative Grid Technologies. A short summary of this analysis by country is set forth in the list below, while full details by Member State, including the relevant NECP quotes, are in the Annex. Our analysis breaks down the Member States into three categories. First of all, there are Member States that do not refer to innovative grid technologies at all. Secondly, there are Member Countries that do mention technology, smart grids or innovation, but are not specific. In several cases, the efficient use of the existing grid is not mentioned. Thirdly, there are Member States that do mention innovative grid technologies.

[1] Regulation on the governance of the energy union and climate action (EU)2018/1999



Category 1: Does not refer to innovative grid technologies in NECP (light blue)

1. Czech Republic: No mention of innovative grid technologies, and only reinforcement and building more lines are mentioned.
2. Ireland: No mention of grid efficiency and innovative grid solutions.
3. Netherlands: Challenges such as congestion, the need for flexibility, and the need for affordable costs for customers are identified, no innovative grid technologies are mentioned.
4. Romania: General mention of the need for digitalisation, but no further details are provided.
5. Slovakia: General mention of digitalisation, but no further details are provided.

## Category 2: There is some mention of innovative grid technologies, but it is very general or incomplete (medium blue)

1. **Cyprus**: Some projects mentioned to improve the level of smartness of the grid.
2. **Denmark**: Mentions smart grids and planning for offshore renewables.
3. **Finland**: Mentions renovation and expansion of the network as well as the Finnish Funding Agency for Innovation, but no systematic mentioning of the role of optimisation and innovative network technologies.
4. **Italy**: Mention of technology investment needed for the energy system, but no explanation of which technologies are meant.
5. **Latvia**: Mention of optimisation in the context of energy efficiency, extensive section on clean energy techs in the RD section, but no mention of clean techs for power grids.
6. **Luxemburg**: Detailed RD, innovation and competitiveness section mentioning PST and DLR, but more technologies should be mentioned here.
7. **Malta**: Mention of upgrading the system with very limited general mentioning of new solutions, but no details on which ones.
8. **Poland**: Mention of 2030 interconnection targets with PST as well as other optimizing grid solutions, but not specified other than storage. Mention of need for reactive power compensation.
9. **Portugal**: Mention of modernisation of grid infrastructure and the need for smart grids, but no details on which techs are meant.
10. **Slovenia**: Statement that TSO is looking for answers to RES upscale and the need for cost-effective grid operation, but no details provided.
11. **Spain**: Storage and general mention of need for maximizing existing grids, but no further details what is meant.
12. **Sweden**: Mention of Smart Grids existing through the Smart Grid forum, but no details on technologies.

## Category 3: Consideration of innovative grid technologies is included (dark blue)

1. **Austria**: Recognizes the need for smart grid solutions, and emphasizes the role of storage.
2. **Belgium**: Implementation of DLR and high-performance conductors are mentioned as fundamental to enhancing grid efficiency.
3. **Bulgaria**: Development of smart grid and reinforcement of existing grids are mentioned.
4. **Estonia**: Mention of RES integration, innovation, technologies.
5. **France**: Mention of innovative grid technologies in the context of RD, but smart grids are not explained.
6. **Germany**: Mention of the need for optimizing power grids and their more efficient use.
7. **Greece**: Key priorities for RD include Smart Grids with reference to storage and digitalisation.
8. **Hungary**: Insists on the need for innovative and smart solutions, DLR is mentioned.
9. **Lithuania**: Mention of storage for the power system, as well as need for innovative grid technologies.

## Conclusions and Recommendations

All solutions are needed to deliver the energy transition, and even more so, these days and very short term, to ensure security of supply and affordability. Our analysis shows that while smart grids are often mentioned, the term is used quite broadly, and often no details are provided. Some Member States do refer to storage, PSTs and DLR, yet there is much room for improvement, i.e., consideration of how the optimisation of existing grids can lead to fast, competitive and sustainable results. The next generation of NECPs should consider this potential in a deeper, more detailed and concrete manner. Our recommendations below list a number of points for the NECP guidance that EC, ACER, NRAs, and governments should take into account.

### 1. Efficient use of infrastructure through the application of the Energy Efficiency First Principle are paramount to achieve the EU Green Deal and REPowerEU targets: it needs to be enshrined in the NECPs.

Member States should include specific innovative grid technologies into the revised version, grid chapter, of the NECPs. when revising their NECPs, in order to help achieve the goals of the Paris agreement, the EU Green Deal and the REPowerEU Action Plan. In order for grids to not become a bottleneck in achieving the EU's ambitious renewables targets, it is important to make the most of our existing grids and to build new grids as efficiently as possible.

The updated NECPs should reflect the Energy Efficiency First Principle (EEFP), defined in EU Regulation 2018/1999 on Governance of the Energy Union and Climate Action:

> "energy efficiency first' means taking utmost account in energy planning, and in policy and investment decisions, of alternative cost-efficient energy efficiency measures to make energy demand and energy supply more efficient, in particular by means of cost-effective end-use energy savings, demand response initiatives and more efficient conversion, transmission and distribution of energy, whilst still achieving the objectives of those decisions"

The updated NCEPs should also reflect the assessments in relation to the application of the (EEFP) made by the European Commission's recast Energy efficiency Directive, article 25. This includes an obligation to consider energy efficiency solutions in policy and investment decisions in energy systems:

> "Member States shall ensure that gas and electricity transmission and distribution network operators apply the energy efficiency first principle (…)
> in their network planning, network development and investment decisions. (…)
> Member States shall ensure that transmission and distribution network operators map network losses and take cost-effective measures to reduce network losses. (…)
> National energy regulatory authorities shall limit the possibility for transmission and distribution network operators to recover avoidable network losses from tariffs paid by consumers"

## 2. Innovative Grid Technologies need to be considered part of the technology tool box.

A variety of reports describe the innovative grid technologies that are available, how they function, what their Technology Readiness level is, and where they have been deployed: ENTSO-E Technopedia[2], the BMWI Operational devices study[3], the IEA Technology Guide[4], IRENA's Innovation Landscape Report on Enabling Technologies[5], ETIP SNET's Knowledge Sharing Platform[6], and RGI's best practices database[7]. Furthermore, there are a number of highly respected studies, such as those by Consentec[8], Brattle[9], the WindEurope Paper on Grid Optimisation[10], THEMA Consulting[11], RWTH Aachen[12], IEEE, and the ACER paper on infrastructure efficiency[13], which shed light on the contribution of innovative grid technologies to security of supply, sustainability and market integration.

## 3. The NOVA principle should be applied when talking about the electricity grid, and transparency in its implementation is key.

The NOVA principle states that optimisation of the existing grid should happen before reinforcement before expansion of the grid. currENT believes that NOVA should become a general regulatory principle across EU and European grid-related legislation, including transparency and monitoring on implementation. Hence it should be applied systematically in the upcoming revision of NECPs, as well as in all grid planning exercises, from NDPs to TYNDPs, as well as in 70% action plans and monitoring. Additionally, it is important that the next version of the ENTSO-E dynamic model includes those tools as well.

## 4. Better alignment between NECPs and Network Development Plans is needed.

Many countries are currently basing their Network Development Plans on the targets in the NECPs. However, as Europe is rapidly increasing its ambition in many areas, this means that NDPs are sometimes based on outdated targets. NDPs should consider the most up to date targets.
In some instances, the opposite is true. For example, according to the German NDP[14], Superconductors have “great potential, and grid deployment in the gigawatt range in 2030 is realistic”. However, the German NECP does not refer to the technology.
There needs to be a better alignment between the NECP process and the NDPs.

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[2] https://www.entsoe.eu/Technopedia/
[3] https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/netzbetriebsmittel-und-systemdienstleistungen-im-hoch-und-hoechstspannungsnetz.html
[4] https://www.iea.org/articles/etp-clean-energy-technology-guide
[5] https://www.irena.org/publications/2019/Sep/Enabling-Technologies
[6] https://tools.etip-snet.eu/search.html
[7] https://renewables-grid.eu/activities/best-practices/database.html?L=0
[8] cosentec. 2021. *The Benefits of Innovative Grid Technologies.*
[9] https://watt-transmission.org/wp-content/uploads/2021/02/Brattle__Unlocking-the-Queue-with-Grid-Enhancing-Technologies__Final-Report_Public-Version.pdf90.pdf
[10] https://windeurope.org/wp-content/uploads/files/policy/position-papers/20200922-WindEurope-Grid-optimisation-technologies-to-build-a-greener-Europe.pdf
[11] https://heimdallpower.com/wp-content/uploads/2021/08/Report_Thema_Consulting_Group.pdf
[12] https://www.iaew.rwth-aachen.de/go/id/hyjix
[13] Infrastructure efficiency: the role of regulation in incentivising smart investments and enabling the energy transition | www.acer.europa.eu
[14] https://www.netzentwicklungsplan.de/de/netzentwicklungsplaene/netzentwicklungsplan-2035-2021

### 5. NECPs should include emerging technologies, their expected impact and how investments can be made for their uptake

Innovative grid technologies and other technologies that are expected to mature in the coming years, such as transmission technology based on superconductors, can significantly improve the efficiency of grids, affecting both the willingness to invest in new grids and the questions of when and where to invest in what kind of grid components. The updated NECPs must consider the application and use of both existing and emerging technologies within the 2050 timeframe, when socioeconomically beneficial to apply them.

### 6. Working back from 2050 is vital.

It is important to take a long-term approach and consider what kind of electricity grid will be needed in 2050 and beyond. Working backwards from that, it is also important to consider investment in innovative grid technologies with a lower technology readiness level, in order to have a grid that is fit for purpose in 2050. Having a long-term perspective will also inform grid operators to choose innovative grid technologies that provide a solid foundation and flexible infrastructure for future grid needs.

The updated NECPs must reflect what is necessary for economy-wide carbon neutrality in 2050 and work back from there. That entails planning and designing a transition to a fit for purpose power grid infrastructure to support economy-wide decarbonisation, including through electrification of the transport, building and industrial sectors. Therefore, the NECPs need to be based on demand scenarios that ensure the net zero greenhouse gas emissions (GHG) scenarios are reached. Modifications to include the following issues could be made: flexibility, complementarity of solutions, redeployability, scalability, fast deployment, and modularity.

Conventional copper-based HVDC technology is unlikely to be able to transfer more than 2 GW of power. New innovative transmission technology based on superconductors, promise the ability to carry several times more power in a much smaller surface area and at lower voltages than conventional copper-based cables. They also require significantly less infrastructure, materials and space.

The impact of enlarged DC networks on the overall stability and security of supply of the European synchronous systems needs to be considered at an aggregate pan-European level to make sure proposals are viable. This is a task the Commission should carry out at an aggregated European level, but the necessary information to conduct it must be made available in the updated NECPs. This is vitally important as to date no one has done an assessment of all plans' combined impacts rather than piecemeal analysis. Notably the combined losses, controller interaction risk and impact on system strength of conventional DC needs to be assessed compared to other technologies (be they DC or AC alternatives).

### 7. NECPs must include non-binding agreements on offshore network development plans for renewables, established by Article 14 of the recently revised Trans-European Networks for Energy (TEN-E).

It is vital that the updated NECPs are capable of capturing the benefits of a truly meshed approach to offshore grid planning. That means going beyond the assumption that only two markets are involved in a cross-border transmission project. The full benefits of sea basin-wide planning only emerge if power flows to more than two markets – and possibly incorporating renewable production assets in hybrid applications. The NECPs must be able to consider and capture the benefits of a meshed approach to grid planning by referencing the political agreements on offshore renewables for each sea basin established by the new TEN-E regulation, Article 14.

**8. The European Commission should commission a study on the benefits of innovative grid technologies for reaching climate neutrality.**

In order to realize the full benefit of innovative grid technologies, the European Commission, possibly with ACER, should commission a study on the benefits of Innovative grid technologies for network efficiency. Benefits of these technologies in terms of improving security of supply and creating welfare savings through market trade are clearly reported in Europe by ARERA, Consentec, RWTH Aachen, and Thema for the Nordics, and actual deployments have been described by Elia, RTE and ELES.

## Annex: Detailed NECP Analysis

| Country | Summary | Are Innovative GRID Solutions explicitly mentioned? | Quotes from the NECP |
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| Austria | Austria recognizes the need for smart grid solutions, emphasizes the role of storage | Yes | • P 93 The title of the paragraph itself underlines that, besides the PCIs, the projects on the transmission line are focused on the infrastructure development<br>• P 175 *Dimension 3: Security of energy supply* – storage capacity is promoted at both small and large scale<br>• P 179 For the development of energy transmission infrastructure, the importance of a suitable framework for innovation and investments is recognized<br>• P 183 Among the actions to make the energy systems more flexible there are storage and the smart grid management<br>• P 188 Smart systems and grids are considered as enablers to local and regional energy supply to become up to 100% dominated by RES |

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| Belgium<br>Part A<br>Part B | Implementation of DLR and high performance conductors is mentioned as fundamental to enhance grid efficiency | YES | PART A<br>• P 26 Concerning the Internal Energy Market section, it is underlined how Belgium have already 21 % of interconnection rate by 2020, thus achieving the 2030 EU Interconnection targets. The interconnection rate was increased till late 2020 through additional investments also including SVC.<br>• P 176 A table is presented with all the investments needed for the Belgian energy transition. Particularly, 17 billion Euros through private investments are required for improving transmission and distribution grid and developing smart grids.<br>• P 293 Among the DSOs measures to improve the efficiency in operations of their distribution systems there is DLR technology<br>• P 300 Three ways of developing the 380 kV transmission lines are listed including the reinforcement of the existing grid in order to boost energy flows and make it more flexible<br>• P 303 The implementation of DLR and high-performance conductors in the transmission and distribution grid are underlined as fundamental measures to enhance the existing grid potential |
| Bulgaria | Development of smart grid and reinforcement of existing grids is mentioned | Yes | • P 18 Grid security and flexibility are increased by the development of energy infrastructures such as new transmission lines and interconnections<br>• P 41 The integration of RES is supported by upgrading of the existing grid and the development of smart grids. |

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| [Croatia]() | Optimisation of power flow is mentioned as well as compensation devices | YES | • P 72 The key infrastructure projects are presented including not only traditional development of transmission lines but also the revitalization of old power lines by using HTLS.<br>• P 153 In the short- and long-term development of the transmission grid, the substitution of conductors with HTLS is further underlined and, for the operation of the energy system, greater importance is given to voltage management and the optimization of power flows.<br>• P 153 A very useful table is outlined with a list of measures for the grid and their corresponding contribution to the reduction of transmission losses. Among the measures listed, HTLS, compensation devices and the optimization of power flows are included. |
| [Cyprus]() | Some projects are mentioned to improve the level of smartness of the grid | Yes/partly | • P 22 The promotion of the PCI EuroAsia Interconnector, which consists of a submarine HVDC cable connecting Greece, Cyprus and Israel, and the investments for development and secure operation of the transmission electricity system are the priorities for increasing Cyprus internal energy market.<br>• P 139 The need for increasing the observability of the distribution system is recognized and, as a starting project, the implementation of a SCADA through a tender is outlined.<br>• P 281 EU competitive programs related to energy and climate for the period 2014 – 2020 are listed including some projects which aim to reach the optimal integration of RES by increasing the level of smartness of the lines. |

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| Czech Republic | There is no evidence of using innovative grid technologies. Reinforcement and building more lines is mentioned exclusively | NO | • P 135 A new line between Czech Republic and Slovenia is planned, as well as a general uprating of 220kV network to 400kV.<br>• P 251 A PST is located near the border with Germany since 2017 to prevent domestic lines being overloaded by loop flows. |
| Denmark | RES | YES, partly | • P 124 Under the Green Labs DK program, some new technologies are going to be tested in the field of smart grids, which are particularly relevant for the Danish energy system as there is a large share of intermittent wind energy to be integrated into the grid.<br>• P 127 Among the seven Areas that could enhance joint Nordic Electricity Grid, the Digitalization of the Nordic Electricity Grid is listed.<br>• P 161 The traditional development of the transmission grid is expected due to the rapid expansion of onshore wind and solar energy sources. |
| Estonia | Mention of RES integration, innovation, technologies | Yes | • P 111: Green Technology Investment program mentioned as a measure; explained on p 64 The intended aim of the measure 'Green technology investment programme' is to boost start-up and scale-up companies whose activities are directed towards developing and bringing to market new products, services and technologies for reducing or capturing greenhouse gas emissions. The aim of the investment programme is to bring additional private equity to the field of green technology via investments with state equity capital. |

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| | | | • P 54: priority on synchronisation and here RD an important part of it<br>• p 113: chapter on electricity infrastructure:<br>• P 117: innovation and RES integration Electricity system The sufficiency and flexibility of the electricity system will be safeguarded through measures 1.1 (Developing the electrical energy production;) and 1.2 (Transmission eligible for electrical energy sector needs and efficient transmission) of the NDPES 2030 security of supply sub-target (Table 18). The barometers of these measures direct network operators to make necessary investments and develop solutions for more efficient integration of renewable energy into the Estonian electrical system. A good example of this innovation is the map application developed by the Estonian TSO (Elering AS), which shows the available capacities in the electricity grid belonging to the company on a year-by-year basis and enables renewable energy producers to plan their projects more effectively.<br>• P 125: reference to innovation as part of H 2020 projects that Estonia has applied for, reference to smart electricity grid Energy-related priorities under the Horizon 2020 programme are a reduction in energy consumption and carbon footprints through smart and sustainable use; supplying customers with electricity which is affordable and produces low carbon emissions; alternative fuels and mobile energy sources; |

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| | | | a single, smart European electricity grid; new knowledge and next generation technology; robust decision-making and public engagement; market uptake of energy innovations;<br>• P 163: storage and ultra capacitors, Tallinn university of technology |
| Finland | Finland mentions renovation and expansion of the network, as well as the Finnish Funding Agency for Innovation; no systematic mentioning of the role of optimisation and innovation network techs. | Yes, partly | • P 126 Finnish Funding Agency for Innovation Tekes invested in multiple programs: the SGEM (Smart Grid and Energy Markets) which has developed the right competencies for developing more intelligent energy networks and smart controls, the FLEXe which investigates on the requirements for a flexible energy system.<br>• P 151 Fingrid, Finnish TSO, has initially invested in renovating ageing transmission lines, substation and increasing interconnections for better integration of RES in the system. |
| France | Mention of innovative grid technologies in the context of RD, smart grids are not explained | YES | • P 11 – Measures to guarantee the security of supply for electricity: *According to analytical work carried out by RTE when working on the provisional balance sheet, the system is flexible enough to handle the integration of extensive renewable energy capacities (over 100 GW installed by 2035 based on the Ampère scenario) without any disruption to the supply/demand balance. It will be possible to use* ***all the existing flexibility tools****, in particular* ***demand flexibility, storage*** *and* ***interconnections****, to handle the new challenges that will arise in connection with the increase in electricity produced from non-controllable renewable sources* |

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| | | | • P 74 – 2.5.1.1. Guideline 1: focusing on key topics for the energy transition: brief list in brackets of **flexibility solutions** that have been developed such as curtailment and production management, storage, coupling of networks and vectors, etc.<br>• P 261 – Major investment guidelines*: awareness of the importance of the transmission grid for integration of RES and which aspect RTE is focusing on in its 2019 grid* transformation strategy, no technology solutions are presented clearly<br>• P 265 – 4.5.1.1. Smart grids: technical solutions are not explained<br>• P 268 – The smart meter: a major asset<br>• P 301 – 4.6.1. Current public funding of R&D in the energy sphere*: €515 million on **new energy technologies** (44%) which include **energy efficiency** (in industry, tertiary, housing and transport), renewable energies (solar, wind, marine, bioenergies, geothermal and hydroelectricity), CO2 capture, **energy storage**, **electricity grids** and **hydrogen and fuel cells**, and fundamental science.* |

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| Germany | Mention of need for optimizing power grids and their more efficient use | YES | • P 108 – 3.4.2.i.1. Electricity Grid Action Plan: *Firstly, existing grids will be optimized and utilized more effectively. This includes technical optimization and modernization measures, new technologies and operating concepts and improved congestion management.* (No clear evidence of which technologies are considered)<br>• P 108 – 3.4.2.i.4. Optimization and utilization of the existing grids: *overhead line monitoring, short-term interim measures, optimization of re-dispatching processes and the introduction / further development of modern digital technologies and system management concepts.*<br>• P 111 – 3.4.3.i.3. Measures in the Action Plan for Reducing Grid Congestion: *predictive controlling as well as new technologies in the areas of grid elements and grid management, with the aid of which the grids can be more fully utilized, meaning more electricity can be transported*<br>• P 114 – 3.4.3.ii.9. Optimization measures relating to re-dispatching: Higher level of utilization of the existing grid to increase transport capacities by more actively controlling electricity flows using phase shifters in conjunction with weather-dependent overhead line operation |

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| Greece | Key priorities for RD include Smart Grids with reference to storage and digitalisation | Yes | • P 30 Among the key policy priorities of research and innovation there are smart grids and new technologies, but no further details are present on which innovative solutions are considered.<br>• P 127 The best technical and cost-effective enhancement of energy infrastructure is considered as one of the main measures to be implemented in order to ensure the optimal RES integration.<br>• P 202 Digitalization, demand response, more interconnections and new storage systems are the main measures considered to increase the flexibility of the energy system.<br>• P 236 Developing smart grids by increasing the level of digitalization is one of the key priorities in the research and innovation field. |
| Hungary | Insists on the need for innovative and smart solutions, DLR is mentioned | YES | • P 28 The promotion of innovative and smart solutions is required to transform the energy sector by ensuring greater flexibility<br>• P 71 It is underlined and encouraged the use of innovative solutions for smoothing the transformation of the electricity markets<br>• P 94 Enhanced intelligence of transmission and distribution networks is considered fundamental for preparing the grid to the increasing of the decentralized generation. Among the specific measures, the DLR is mentioned for more accurate monitoring of the available capacity of the lines. |

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| Ireland | No mention of grid efficiency and innovative grid solutions | NO | • P 203 The following projects are considered for the extension of the Greater Dublin Area transmission line: the installation of a gas insulation switchgear, a new 400/110 kV substation near Portlaoise, a new 110kV/38kV substation in Kilkenny and new110kV overhead lines.<br>• P 204 Three interconnection projects are listed for fulfilling the network extension requirements. |
| Italy (Ver. December 2019) | Mention of technology investment needed for energy system, but no explanation which technologies are meant | YES, but | • P 323 - Table 78 – Investment in the technologies, processes and infrastructure needed for the development of the energy system: it is reported the number for Electrical System, but no explanation of which technology solutions are included<br>• P 324 - Table 79 – Investment needed to update the electrical system: there is a list of items but no focus on technological solutions |
| Latvia | Mention of optimisation in the context of energy efficiency, extensive section on clean energy techs in the RD section, but no mention of clean techs for power grids | YES, BUT | • Mention of optimisation, RD often in context of energy efficiency.<br>• P 32 synchronisation with ENTSO-E system for Security of supply<br>• P 40: Research and Innovation, with extensive section on clean energy technologies; no specific mention on clean techs for power grids<br>• P 36 Smart meter roll out by TSO AST and here general mentioning of smart grid: AS Sadales tīkls is continuing to install smart electricity meters in the framework of developing a smart grid based on digital technologies. A gradual expansion of the smart grid will |

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| | | | reduce the costs of servicing and maintenance of electricity meters and ensure that the information on consumption, load, and interruptions in the electricity grid is available quickly, at any time, and from any location<br>• P 56: energy transmission infrastructure: mentioning the use of **synchronous condensers:** According to this scenario, synchronisation will be ensured by using the existing Lithuania–Poland interconnection LitPol Link and an additional submarine cable between Lithuania and Poland, as well as synchronous condensers in the hydroelectric power plants of all Baltic countries.<br>• P 119 mentions in page on RD. Optimisation of energy system development planning, energy production, trade, and distribution; |
| Lithuania | Mention of storage for the power system, as well as need for innovative grid techs | YES | • P 154: electricity sector: Litgrid is currently conducting a **pilot battery project** to test the potential of battery storage systems under realistic operating conditions of the Lithuanian power system. The test results will help you to evaluate the applications of such batteries and to determine the technical parameters of these devices that best meet the system needs. The project is being implemented to increase frequency management and to ensure system stability and security. Battery storage systems can contribute to maintaining the required level of inertia (function of synthetic inertia) and to ensuring very fast |

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| | | | reserves of control power, which would contribute to improving system adequacy in the preparation for synchronous operation with continental European networks. A total of 11 areas where such a battery system could be useful have been identified, most of which are related to frequency management, as well as rapid compensation of power changes, management of network congestion, improvement of energy quality and a dynamic stability and emergency reserve. P 169: dimensions research and development, actions:<br>• P 170 actions include: to modernise and **expand the electricity grid system through the deployment of advanced and innovative technologies (**32 newly built or reconstructed transformer substations built and 350 km (inclusive) of built/reconstructed power lines 2023) mention **of new substations and repowering** |
| Luxembourg | Detailed RD, Innovation and competitiveness section mentioning PST and DLR: more techs should be mentioned here | YES, but | • P 10: Research, Innovation and competitiveness section<br>• P 47: **energy transmission infrastructure: mention of PST and DLR as well as repowering:** In the electricity sector, apart from the fact that the Creos public grid is located in the same bidding zone as the German Amprion grid, the integration of Luxembourg into the European electricity grid has been significantly improved by the commissioning of a phase-shifting transformer and the establishment of a permanent |

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| | | | line connection between the Luxembourg and Belgian transmission systems. Testing of the phase-shifting transformer has now been completed. Currently, the phase-shifting transformer is used to optimise the load flows in Luxembourg and the surrounding regions. Luxembourg aims to further strengthen this meshed integration over the medium term. Since an increase in the demand for electricity and peak load is expected in Luxembourg, in part due to the expected population increase, diversification of economic activities and general economic growth, it is necessary to expand the existing interconnections. The transmission system operator Creos is therefore planning to convert an existing 220 kV interconnection towards Germany to high-temperature conductors by 2020 and, in the medium to long term, to upgrade/reinforce the 220 kV line towards Germany. There are still no plans to connect the Luxembourg public grid to the French grid.<br>• P 116: electricity infrastructure: mention of **repowering**: Creos, is actively promoting the **reinforcement and upgrading** of the high and medium voltage levels to enable and support the transition from fossil fuels to renewable energies. In particular, the aim is to enable the production of electricity (especially wind and photovoltaics) to be continually increased in the north of the country and to allow for high consumption in the centre and |

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| | | | south of the country. Due to its dependence on imports, a further expansion of the existing interconnectors is also planned in order to continue to guarantee the security of supply for Luxembourg. For example, the upgrade/reinforcement of the existing 220 kV line towards Germany is already part of the network development plans of both Luxembourg and Germany.<br>• P 156: enhancement measures on DLR and repowering, as well as PST: Creos is currently envisaging the following cross-border network expansion and enhancement measures:  Targeted replacement of existing lines with high-temperature conductors (HTC) using existing masts  Equipping/strengthening of the 220-kV line towards Germany, with a prospective maximum increase of around 2,600 MW in nominal transmission capacity in existing corridors |
| Malta | Mention of upgrading the system with very limited general mentioning of new solutions, no details on which | YES, but | • P 15 Malta's electricity grid is linked to the European grid via 200 MW Malta-Italy subsea interconnector. It does not have a transmission system, so the measures included in the plan are mainly referred to the distribution grid.<br>• P 46 Unlocking the Malta's RES potential is limited by the grid integration constraints: the need for significant spinning capacity, utility scale battery storage or flexible balancing services are underlined for ensuring system stability.<br>• P 70 Enemalta, the leading energy services provider in the Maltese Islands, is focusing on upgrading its substations with |

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| | | | new transformers as well as implementing new technologies, but no clear mentioning of which solutions are considered besides storage systems. |
| Netherlands | While the challenges such as congestion and need for flexibility, need for affordable costs for customers are identified no innovative technologies are mentioned. | NO | • P 43 Electricity infrastructure and its development are essential for accommodating the increasing share of RES (onshore and offshore) in the Dutch electricity mix, but coordination is required to keep those investments and their spatial impacts at their minimum. In parallel with traditional grid expansion projects, some studies are investigating how the use of flexibility, energy storage and congestion management can make the best use of the available capacity of the network at the lower social costs.<br>• P 71 The key interconnections projects are COBRA cable to Denmark for 0.7 GW and the increase of the interconnection capacity with Belgium from 2 to 3.4 GW.<br>• P 118 It is underlined how the Dutch transmission electricity grid is one of the most reliable in the world, with 99.99 % reliability. |
| Poland<br>Part 1-3<br>Part 4<br>Part 5 | Mention of 2030 interconnection targets with PST as well as other optimizing grid solutions, not specified other than storage. Mention of need for reactive power compensation | YES, but | Part 1-3<br>• P 37 The 2030 electricity interconnectivity targets are presented with remarks on optimizing the available interconnection capacity by adopting different remedial measures as phase shifters or other devices optimizing grid transmission.<br>• P 104 Supporting for development of large-scale storage facilities is considered crucial for balancing energy demand and generation |

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| | | | Part 5<br>• P 70 Among the TSO's tasks there is the modernization of grid devices including those used for reactive power compensation.<br>• P 80 In the Energy Security section, not only the development of the transmission infrastructure is stressed but also the modernization of the existing lines. |
| Portugal | Mention of modernization of grid infrastructure and need for smart grids, which no details on which techs are meant | YES, but | • P 54 The reinforcement of interconnections, particularly in the priority corridor 'North-South Electricity Interconnections in Western Europe (NSI West Electricity)' are the key electricity infrastructure projects.<br>• P 103 The Strategic Actions are listed which also include the modernization of transmission infrastructure and the development of smart grids. |
| Romania | General mentioning of need for digitalisation, with no further details | NO | • P 100 Digitization of the national energy system in the transmission, distribution and consumption segments and introduction of the IoT and AI in the transport and distribution systems‟ management; |
| Slovakia | General mention of digitalisation with no further details | NO | • Slovakia already meets interconnection targets<br>• The ACON smart grid project includes "digitization of over 200 kilometres of 22kV lines." The implementation of smart elements will provide adequate capacity for all grid users and allow for better monitoring. Easier identification of potential failures will reduce the time it takes to clear them. This will provide customers with a more stable distribution system with |

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| | | | minimum downtime and high supply quality.<br>• Danube InGrid smart grid project: The main goal of the Danube InGrid (Danube Intelligent Grid) project is to increase the integration of renewable energy sources into the grid through the use of intelligent technologies at transmission and distribution level, including their smart management.<br>• General uprating of the 220kV network to 400kV is planned. |
| Slovenia | Statement that TSO is looking for answers to RES upscale and the need for cost-effective grid operation; no details provided | Yes, but | • The transmission system operator is looking for answers and modern approaches to the challenges of accelerated introduction of production from renewable energy sources and the requirements of ensuring flexibility. Thus, in accordance with comparative studies and in comparison, with other European transmission system operators, Slovenia's transmission network is currently a leader in terms of cost-effective maintenance and operation. |
| Spain | Storage and general mention of need for maximizing existing grids, with no further details what is meant | YES but | • P 18 Flexibility of the system should be ensured by all the storage types and e-mobility<br>• P 86 Among the measures for the *Adaptation of electricity grids to integrate renewables* there is the maximization of the existing grid capacity but without listing possible solutions available on the market<br>• P 178-179 *Electricity transmission infrastructure other than the 'Projects of Common Interest' (PCIs), […] in order to minimise the environmental impact, to optimise the investments already made and to* |

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| | | | *maximise the use of the existing electricity corridors, priority should be given to the improvement and updating of the existing network as opposed to new routes and infrastructure. These actions can be carried out by increasing the capacity of the network through repowering, setting up multiple circuits and using new technologies.* Grid enhancing solutions are not listed. |
| Sweden | Mention of Smart Grids, through the Smart Grid forum existing, no details on technologies | YES, but | • The Smartgrid Forum, a joint enterprise to promote smarter energy use set up in spring 2016 by a Government decision, has developed a strategy for using smart grids to increase the flexibility of the electricity system. The Forum has produced 20 recommendations for activities in the following four areas: • establishing the conditions for new business models for flexible services; • developing the markets for system services; • carrying out IT-security and integrity measures; and • carrying out information and awareness-raising measures. |