#Grids4Speed

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Executive summary: report overview

Grids for Speed (GfS) is a comprehensive examination of investments and enablers needed to ensure that our grids are fit and ready for a more electrified society.

Failure to invest in distribution grid modernisation will stall much-needed connections of technologies, such as renewables, heat pumps and electric vehicles (EVs). The anticipated upsides of reduced carbon emissions, greater energy efficiency and lower energy bills may not materialise, or at least not as quickly as the world needs. GfS sets outs the vision and framework for the distribution grid to achieve the energy transition by 2050 in the EU27 countries and Norway (EU27+Norway). It scrutinises the critical and sometimes underestimated role of distribution grid infrastructure in accelerating the shift towards sustainable, low-carbon energy systems.

Our starting point is Eurelectric's REPowerEU 2050 scenario. Described in Eurelectric's Decarbonisation Speedways report, the scenario integrates both the European Commission's Fit For 55 and REPowerEU policy packages. In GfS, we evaluate the scale of capital investment needed to:

- Increase the distribution grid's capacity to deploy renewables
- Replace ageing infrastructure
- Integrate advanced technologies for efficient grid management and control

Our analysis is informed by data from distribution system operators (DSOs) serving more than 60% of European energy users. It also includes National Energy and Climate Plans (NECPs), network development plans(NDP) and proprietary EY data. And it is modelled by EY and Imperial College London (ICL) through to 2050, using ICL's internationally acclaimed representative grid modelling methodology.

We identify the key enablers that must be in place to deliver the required investment and speed up grid development. In terms of regulation, we consider adjustments to the current incremental and backward-looking regulatory framework, to a true forward-looking approach that supports the grid acceleration required to realise the energy transition. And we determine how the supply chain, from materials to manufacturing, permitting and talent acquisition, must scale to deliver grids for speed.

In this report, we explore the societal benefits that will be made possible by investment, including energy bill savings, job creation opportunities and, crucially, decarbonisation.

In detailing investment needs, identifying appropriate regulations, formulating a supply chain action plan and addressing societal dividends, this GfS report becomes a valuable roadmap towards the energy transition. For policymakers, industry stakeholders and investors across the EU27+Norway, it offers insights and brings clarity to the strategic options they face, and their roles in facilitating a swift and efficient transition towards greener energy.

Executive summary: key findings

Policy

- The distribution grid must be central to energy policy and system design, not an afterthought.
- The distribution grid should develop at the speed of other societal mega shifts, such as decarbonisation, electrification and digitalisation.
- Electricity grid reliability and resilience are critical in an increasingly electrified society, where electricity will make up 60% of all energy demand, compared with just 20% today.

Investment

- €67 billion investment annually is needed to 2050 is needed to deliver a distribution grid that will enable the energy transition. Failure to get the grid ready in time will not only slow the energy transition but also jeopardise energy security and the benefits of decarbonisation.
- The electricity system is now in an exceptional period of growth, meaning that the investment profile is front-loaded. Investment must double until 2040 from roughly €36 billion today, then continue at 1.7 times today's levels through to 2050.
- Innovation in distribution grids is opening up new emerging grid strategies that can reduce the investment required by around 18% to €55 billion annually when supported by right regulatory environment.
- Those emerging grid strategies include anticipatory investment (i.e., proactively oversizing grid capacity when constraints and other works occur, in anticipation of increased demand), asset performance excellence (i.e., use of real-time data and artificial intelligence (AI) to optimise asset health) and grid-friendly flexibility (i.e., actively managing demand during peak times across voltage levels to defer grid growth).
- Anticipatory no-regrets investment is the most cost-effective strategy for building out distribution grid capabilities that are fit for a decarbonised future.

Societal benefits

- Efficiency gains from electrification will see energy bills almost halve by 2050 in a net-zero scenario, assuming that tax remains constant in relative terms.
- Today, direct and indirect jobs in the distribution grid sector represent around 0.4% of the EU workforce (835,000 jobs). Delivering the required GfS investment could create more than two million additional jobs.
- Reliable and resilient electricity supply has a massive societal value that far exceeds the cost of implementation.
- GfS investments in the distribution grid will support the connection of clean electricity technologies and the realisation of net zero. Stagnated investment will fail to connect three-quarters of these technologies.

€67bn/year
investment is required between 2025 and 2050 in the EU27+Norway

43%
of investment is for demand-driven reinforcement

2x
current investment between 2025 and 2040 in period of growth

1.7x
current investment between 2041 and 2050

Anticipatory
investment is a no-regrets approach to optimise investment

-18%
investment reduction to €55bn/year if emerging grid strategies are realised and supported by right regulatory environment

Executive summary: key findings

Regulatory enablement

- Though DSOs are regulated differently across the EU27+Norway, regulations have enabled them to jointly invest €33 billion annually between 2019 and 2023.
- Regulation must now transform if DSOs and national regulatory authorities (NRAs) are to be sufficiently flexible, agile and able to unlock early investment at a larger scale than in the past 30 years.
- Prioritisation is needed to deliver large-scale investment that creates most value for society.
- Capital expenditure (capex) for grid expansion must be accompanied by operating expenditure (opex) that enables continued and efficient operation.
- Reforms, such as the Electricity Market Design (EMD) agreement, that are already planned in European regulation must be implemented quickly. New initiatives must be developed and implemented as soon as possible this decade to support the acceleration of investment to 2040.

Supply chain enablement

- Increased volumes of critical grid materials, such as copper, aluminium and electric steel, are urgently needed.
- Anticipated global shortages in copper this decade may trigger price surges.
- Equipment manufacturing is under strain, with forecasts showing a need to double number of transformers and increase grid length by 70% to 2050.
- Policy support is critical to secure an agile and resilient supply chain, from mineral extraction to procurement, for distribution grid development.

Empowerment to scale investment

Measures to support DSOs in competition for investment by providing confidence and regulatory certainty should also enable an attractive risk/reward investment profile, with appropriate prioritisation and regulatory oversight.

Improved regulatory processes

By allowing decisions to be made quickly, transparently, objectively and with confidence, regulation supports DSOs and users with prioritisation.

2x transformers and 1.7x grid length to 2050

Keeps financing cost allowances up to date and minimises the lag between making the investment and the start of cost recovery.

Contents

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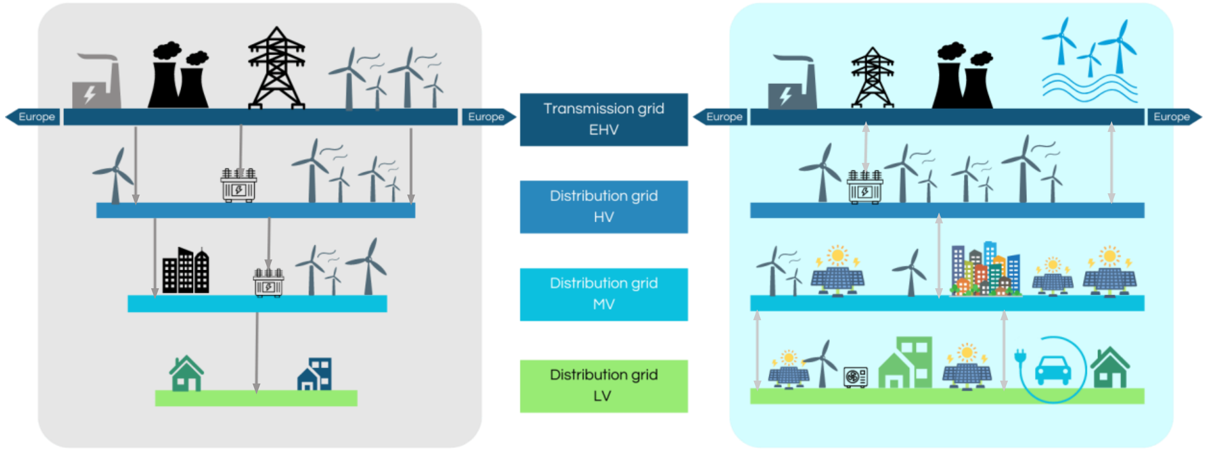
1

The need for GfS in the energy transition

Distribution grids are evolving but acceleration is needed as big changes reshape and disrupt society.

Electricity distribution grids: the forgotten giants of the energy transition

- Electricity distribution grids deliver electricity directly to homes, offices, businesses, factories and any other places that use electricity.
- Distribution grids connect customers with the transmission electricity grid, which in turn connects very large users and power plants.
- Distribution grids are owned, developed, maintained and operated by DSOs.
- Distribution grids comprise physical elements, such as substations, transformers, electric overhead and underground lines, smart meters and associated infrastructure. They also include digital control and management systems. For more on digitalisation, please see *Wired for Tomorrow* (2024), a new Eurelectric report on the digitalisation of DSOs.



Past

In the past, energy was generated at the transmission level and flowed down to the distribution level where it was consumed.

Future

Energy flows are now bi-directional, with generation and consumption happening at every level. This changes and increases DSOs’ responsibilities.

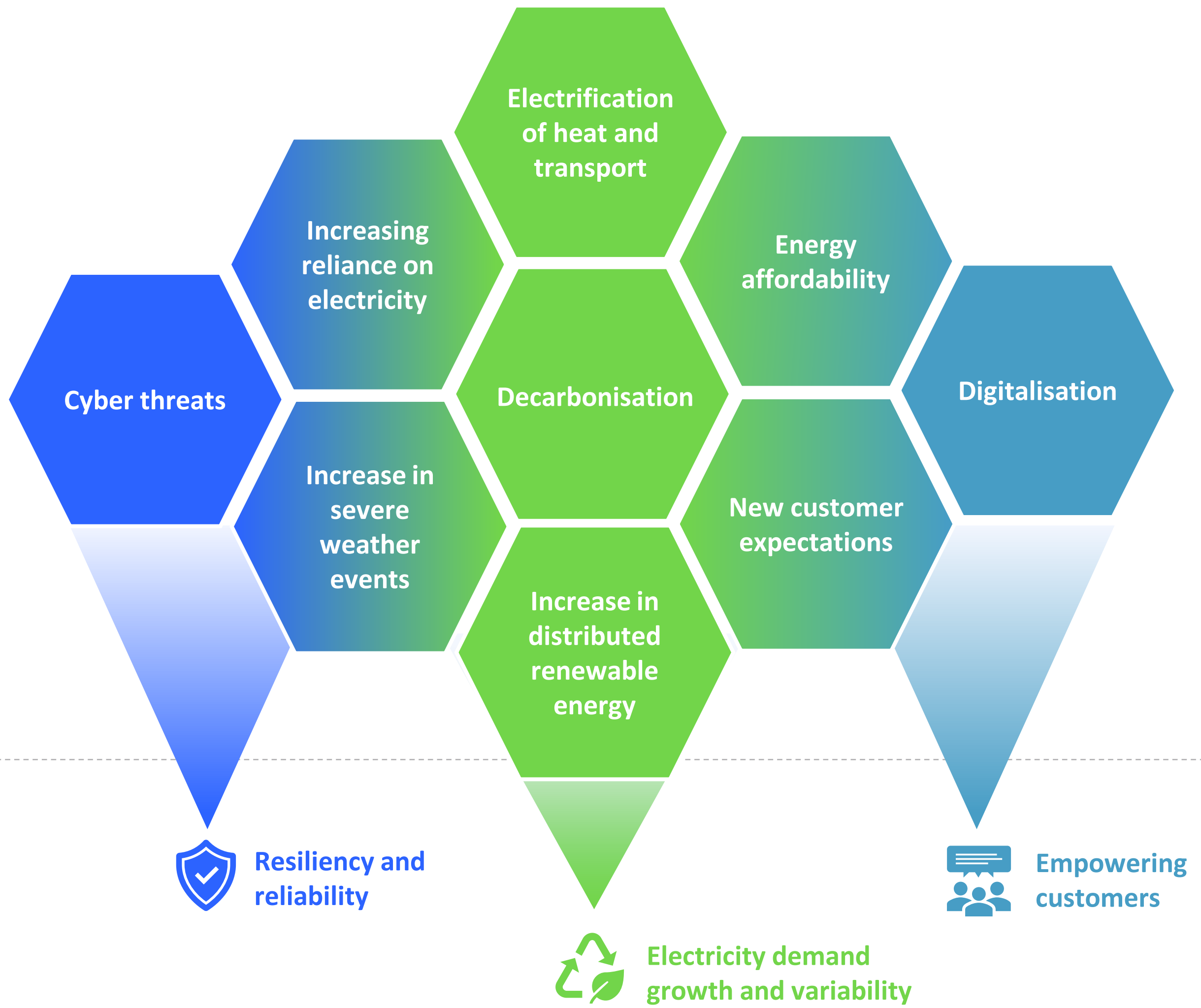
Transmission grid extra high voltage (EHV)	Above 150 kV
Distribution grid high voltage (HV)	Above 38 kV
Distribution grid medium voltage (MV)	Up to 38 kV
Distribution grid low voltage (LV)	400 V

Note: Voltage level definitions are indicative and may differ by country.

Major societal shifts bring new electricity grid priorities

Societal mega trends are changing energy systems at disruptive speed

Growing electricity distribution grid priorities

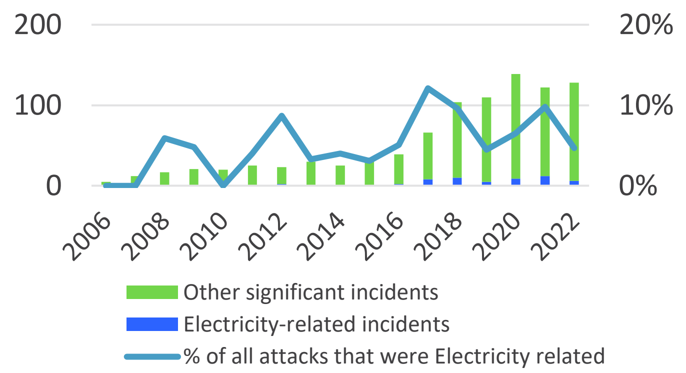


Resiliency and reliability

Cyber attacks lead to data and operational losses

The number of cyber incidents is increasing. For instance, a military cyber attack on a satellite in February 2022, killed the internet connection to approximately 5,800 wind turbines in Germany.

Number of cyber attacks

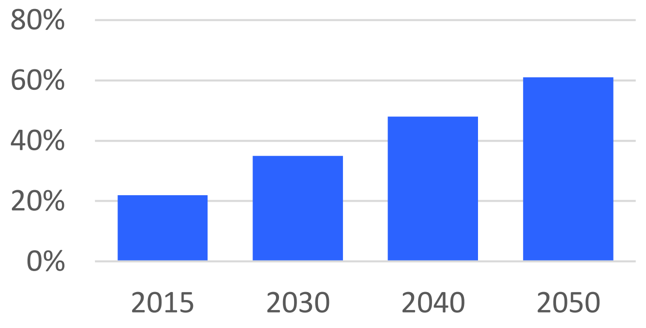


Source: Center for Strategic and International Studies (CSIS), International Energy Agency (IEA).

Rising reliance on electricity

As electricity will meet 60% of all energy demand by 2050, distribution grid infrastructure becomes the backbone of the economy and makes reliability and resilience critical.[1]

Electricity % in final energy demand

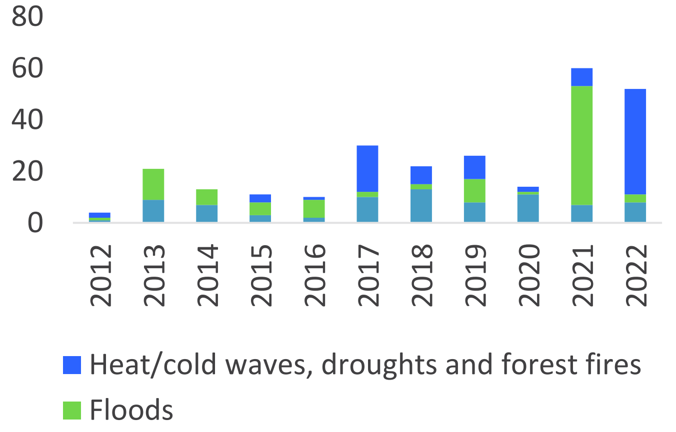


Source: Eurelectric.

More extreme weather events

Changing climate and more extreme weather events impact grid resilience[2]. In 2022, climate-related losses amounted to €650 billion in the EU.

Economic losses from natural disasters in EU (€bn)



Source: European Environment Agency (EEA).

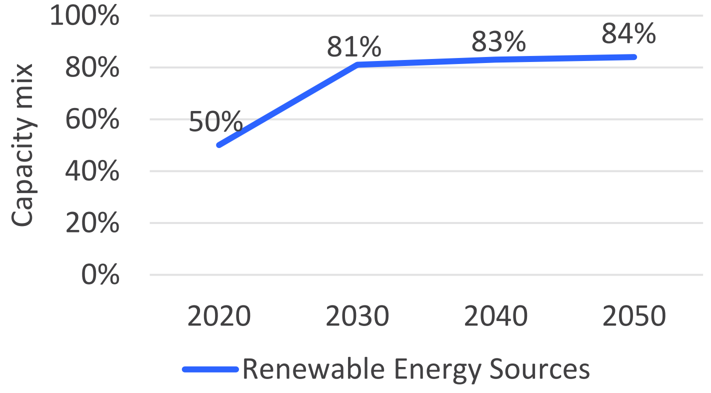
1. The renewable penetration forecast assumes a lower level of decarbonisation than the 45% targeted by the Renewable Energy Directive. Electricity's role in the energy mix is therefore likely to be higher should this target be met.
2. More information on grid impact of extreme weather events and Resilience is available in Eurelectric's *The coming storm : Building electricity resilience to extreme weather.*

Electricity demand growth and variability

Decarbonisation

By 2050, electricity generation will be largely decarbonised across the EU, requiring a rapid increase in intermittent renewables.

Renewable penetration in EU

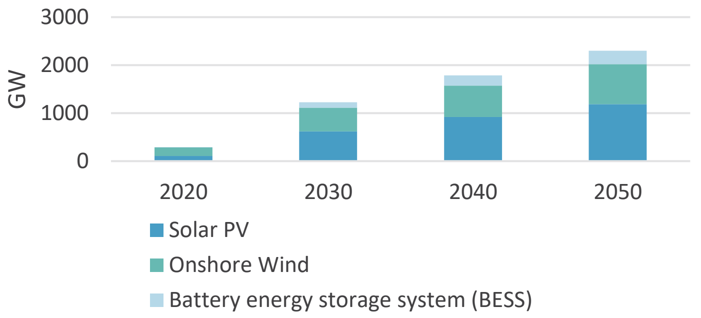


Source: Eurelectric.

Decentralisation

About 70% of future renewable generation and electricity storage will be connected to the distribution grid. Distributed renewable capacity in Europe will grow nearly six-fold fold from 2020 until 2050. This represents a massive increase in intermittent capacity to add to the distribution grid.

Renewable energy capacity in the EU

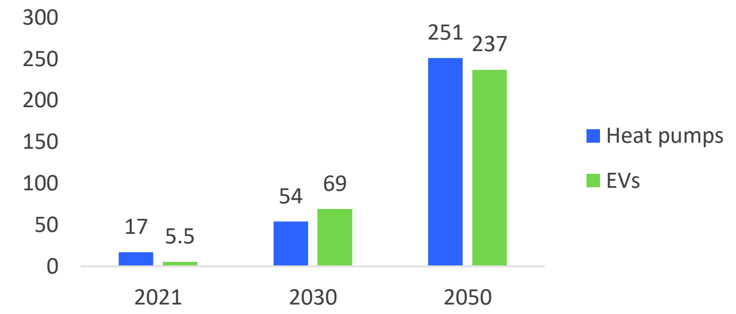


Source: Eurelectric.

Electrification of buildings, transport and industry

The electrification of buildings (heat), transport and industry will contribute significantly to growing electricity demand, both in terms of growing capacity and new connections. The deployment of EV chargers will require >15,000 new connections a day.

Heat pumps and EV in the EU (millions)



Source: Eurelectric, IEA.

Note: All analysis is REPower EU-inspired and does not factor in the 45% targeted by the recent Renewable Energy Directive. Renewable capacity, renewable penetration, heat pumps and EV demand in the EU are likely to be higher should this target be met.

Empowering customers

Rising customer expectation

Informed by their experiences in other sectors, such as retail and banking, customer expectations of critical infrastructure providers, such as grids, are increasing.

>50% EU consumers prefer to use digital channels for all interactions

>80% Daily internet use in the past decade has increased most in rural areas (45%), followed by towns (30%) and cities (29%)

~81% EU customers believe that everyone should try to reduce energy consumption during peak hours

Digital preferences must be met while retaining traditional channels, such as telephone, mail and public announcements, to serve all customers with same quality standards.

Source: EY Customer Experience Transformation (CXT) consumer research survey 2022 and EU Eurobarometer.

Rising affordability concerns

The average energy bill in 2022 was more than a month's wages for low-paid workers in most EU Member States.

~10% EU population lived in energy poverty in 2022

~7% EU population had arrears on their utility bills in 2022

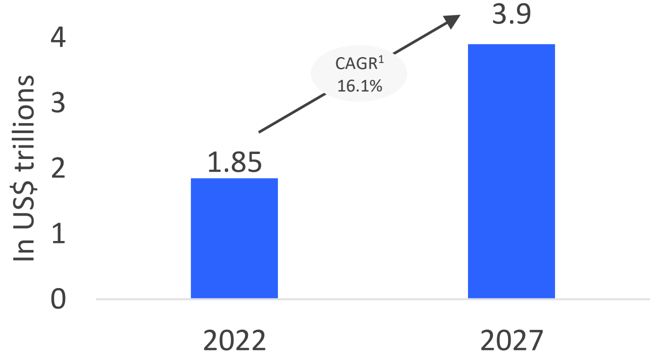
52% EU consumers said they spent more on electricity in 2022 than in 2023

Source: Eurostat, European Trade Union Confederation.

Digitalisation

Digital transformation is revolutionising processes, products, services and experiences across all industries, including the energy sector. Europe accounted for 22.7% of global digitalisation spending in 2023.

Global spending on digitalisation (US$ trillions)



Source: IDC Worldwide Digital Transformation Spending Guide 2023.

1. Compound Annual Growth Rate.

Progress on distribution grid connections and reliability, but must go faster

Customer requests

More requests for new or larger connections (both generation and demand) put significant strain on the grid.

+19% New customers connected in 2022 compared with 2019

56% Smart meter penetration in 2022

-11% Reduction in grid outages between 2018 and 2021

In some areas, the grid is already at capacity, and new connection requests will be turned down or significantly delayed. Waiting lists for HV connections can be up to eight years.

Number of substations

New substations are needed to keep the grid reliable, and able to accommodate growing customer numbers and integrate renewables into the system.

+1.5% Increase in primary substations between 2018 and 2021

+1.2% Increase in secondary substations between 2018 and 2021

This incremental increase will be insufficient to accommodate the energy transition.

Distribution line length

New lines are needed to ensure distribution grids can continue to connect customers.

+0.8% Increase in total length (km) between 2021 and 2022

+1.7% Increase in underground cables (km) between 2021 and 2022

+0.8% Increase in overhead lines (km) between 2021 and 2022

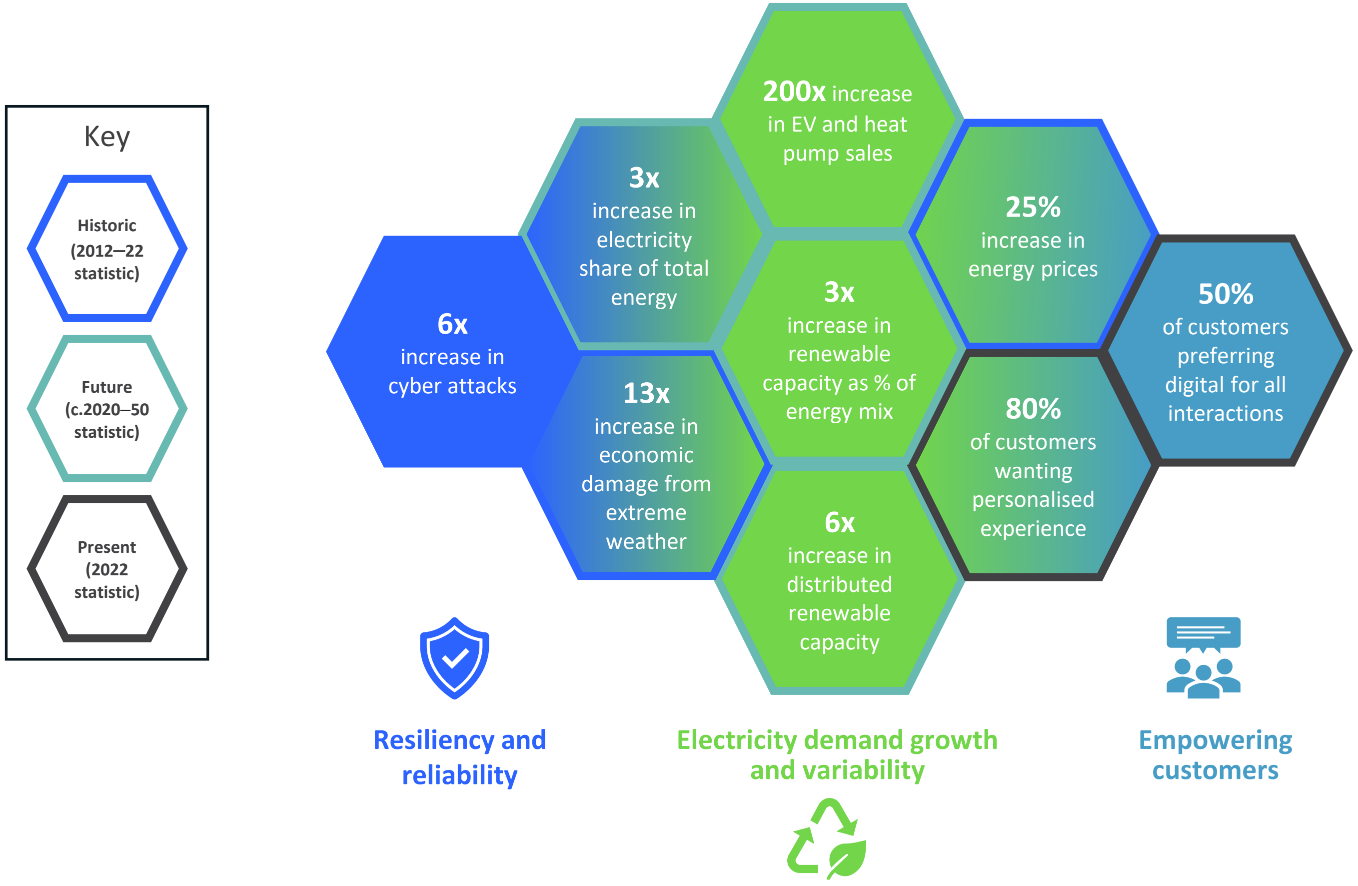
This increase in line length will be insufficient to accommodate the integration of renewables and more customers.

Source: Eurelectric Power Barometer 2023.

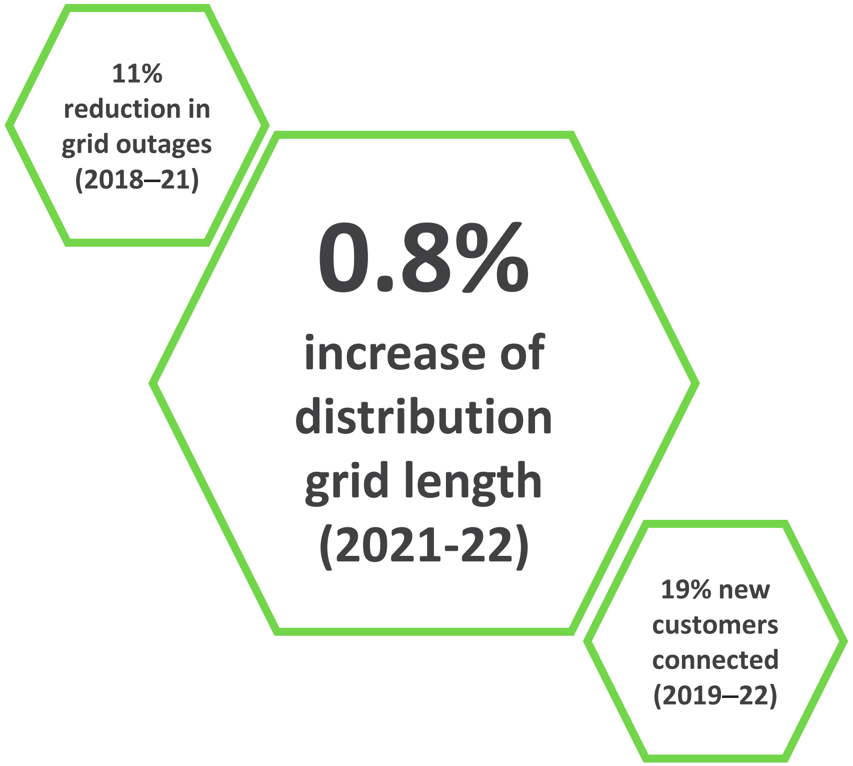
Grid investment must keep pace with societal shifts

Major societal shifts are underway. Grids are modernising but investment must accelerate to match the disruptive speed of change.

Mega trends are occurring at an exponential rate …



… the distribution grid is growing incrementally



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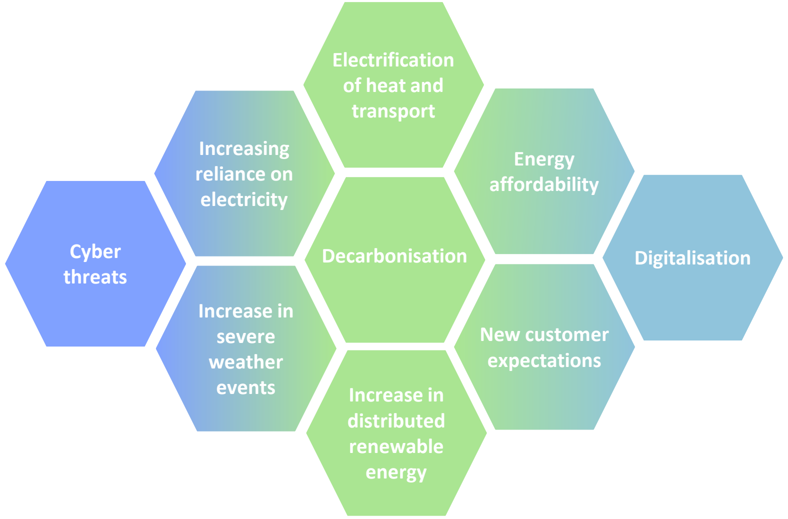
2

Revamping distribution grids for the energy transition

Shifting roles and investment priorities, escalating energy demand and the pursuit of net zero: DSOs take on transformative challenges.

To adequately respond to the societal shifts, enhanced grid requirements are needed

Societal mega trends



Growing grid priorities

- Resiliency and reliability
- Electricity demand growth and variability
- Empowering customers

GfS

Enhancements are needed across all grid business areas

Customer connections » Grid planning and asset management » Infrastructure delivery » Grid operations » Facilitation of markets and services

- Societal mega trends create internal and external challenges for DSOs.
- In response, DSOs must prioritise resiliency and reliability, electricity demand growth and variability, and empowerment of customers.
- To deliver the energy transition and resolve the challenges, grid operators must enhance the grid across all grid-related business areas.

The evolving role of the grid operator

Legacy responsibilities → **Evolving responsibilities**

Customer connections

Legacy responsibilities

- Facilitate the digitalisation of processes and requests to connect (contracts, signatures, opinions, etc.).
- Manage the steady flow of new connections for buildings, often in parallel with multi-year construction projects.

Evolving responsibilities

- Cater to high volumes of requests for new or expanded connections for distributed energy resources (DERs), including solar photovoltaic (PVs), EVs and heat pumps (HPs).
- Expedite customer site assessment decisions.
- Standardise diverse connection options and types(e.g., non-firm/flexible, etc.).

Grid planning and asset management

Legacy responsibilities

- Identify current and upcoming grid constraints and reinforce as required with grid solutions.
- Determine reliability of supply criteria and assessments.
- Manage and assess the condition of assets with little real-time operational information.

Evolving responsibilities

- Use bottom-up customer data and insights to forecast future demand.
- Harness probabilistic/risk-based reliability of supply criteria and assessments.
- Apply wired and non-wired flexibility solutions to address grid constraints and increase resilience.
- Adopt predictive asset management practices.

Infrastructure delivery

Legacy responsibilities

- Prioritise cost-efficient delivery of distribution infrastructure projects.
- Coordinate with other infrastructure projects.

Evolving responsibilities

- Increase collaboration with local planning authorities to manage permitting, and liaison with other utilities to address increasing underground congestion.
- Improve customer communications around planned/unplanned outages.
- Meet social and governance obligations in procurement.

Grid operations

Legacy responsibilities

- Conduct real-time operation and load balancing for the HV and MV distribution grid.
- Coordinate field crew intervention for manual switching and repair.
- Ensure power quality meets required thresholds.

Evolving responsibilities

- Increase grid visibility (real-time DER monitoring) down to the LV level.
- Increase automation or augment operation of assets or field-crew dispatch.
- Conduct real-time management of DERs (e.g., storage, wind).
- Procure, contract and activate flexibility resources.
- Increase coordination with the transmission system operator (TSO).
- Integrate operational technology cybersecurity operations centres.

Facilitation of markets and services

Legacy responsibilities

- Provide non-discriminatory access to the distribution grid for all customers and users (e.g., end users, power generators and service providers).
- Own and operate smart metering infrastructure, (including data exchanges for supplier switching) in some geographies.

Evolving responsibilities

- Facilitate customer participation (e.g., energy sharing) in the electricity markets, and incorporate new actors (such as aggregators and energy communities).
- Provide transparency on flexibility needs (i.e., type, location).

For more on how digitalisation is being used to meet these growing requirements, please see *Wired for Tomorrow* (2024), a report by Eurelectric.

New grid responsibilities require different investment needs

Investment categories
Different cost categories for stabilising, reinforcing or modernising the grid

Demand-driven reinforcement

Investment in the grid to accommodate growth in demand and connections due to:

- New or relocating customers
- Electrification of heat, transport and industry

Note: Savings from flexibility will be quantified by comparing scenarios with different levels of flexibility.

Renewal and replacement

Investment in replacing assets, either due to their age or condition, or because they are coming to the end of their useful lives. Excludes decommissioning costs.

Smart meter installations

Investment in:

- Initial rollout of smart meters at customer connection points and auxiliary systems
- Upgrade and renewal of smart metering infrastructure to deliver on growing demand from customers and DSOs
- Implement necessary information and communications technology (ICT) software

Generation-driven reinforcement

Investment in grid reinforcement to accommodate reverse power flow from renewable generation. This allows excess generation to move to wherever it is most needed.

Targeted resilience

Investment in targeted upgrades that are not addressed by other investment categories, such as:

- Undergrounding cables
- New feeder links to provide more backstop capability

Excludes measures that strengthen overhead grids (e.g., aerial bundled conductors).

System digitalisation[1] and substation automation

Investment in:

- Operational systems[2]
- Flexibility systems[3]
- Crew workforce and order management systems
- Core business systems[4]
- Data management/analytics
- Cybersecurity

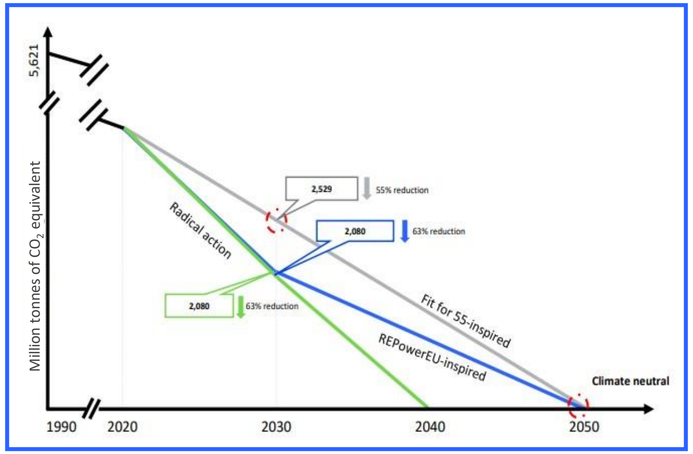
For more on digitalisation, see *Wired For Tomorrow* (2024), a report by Eurelectric.

1. For example, operational technology, cyber, AHM.
2. ADMS. GIS and data management or comms for RTUs and real-time monitoring.
3. Distributed energy resource management systems (DERMS) and DER gateway.
4. ERP, CIS and CRM systems.

EU policy goals: why operators must invest in modernising grid infrastructure

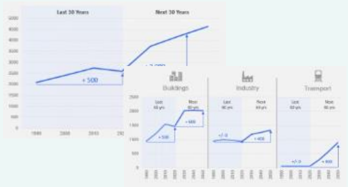
GfS determines what is needed from a grid investment and regulation perspective to deliver on EU policy

- Informed by the most recent political and market trends, Eurelectric's Decarbonisation Speedways depicts how Europe can achieve climate neutrality in or before 2050, as well as reach ambitious targets in 2030.
- Eurelectric's REPowerEU scenario adopts the EU's REPowerEU policy plan, which accelerates European independence from Russian energy and the transition to decarbonised energy sources. This scenario underpins the demand and generation forecasts for GfS.
- To achieve the EU's political goals, grid development and modernisation are essential. They will help to secure a cost-efficient, timely and secure delivery of the energy transition.
- GfS assesses related grid investment needs and the enabling regulatory framework.

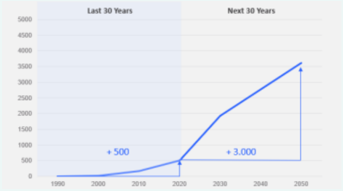


Based on the REPowerEU scenario, four indicators will impact future grid investment:

Change in electricity consumption (pages 20-21)

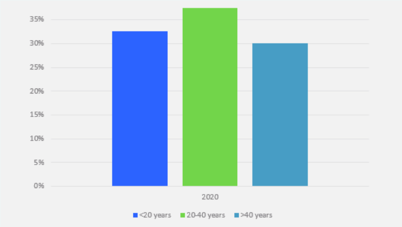


Connecting renewables (page 22)



Shift in peak demand (page 23)

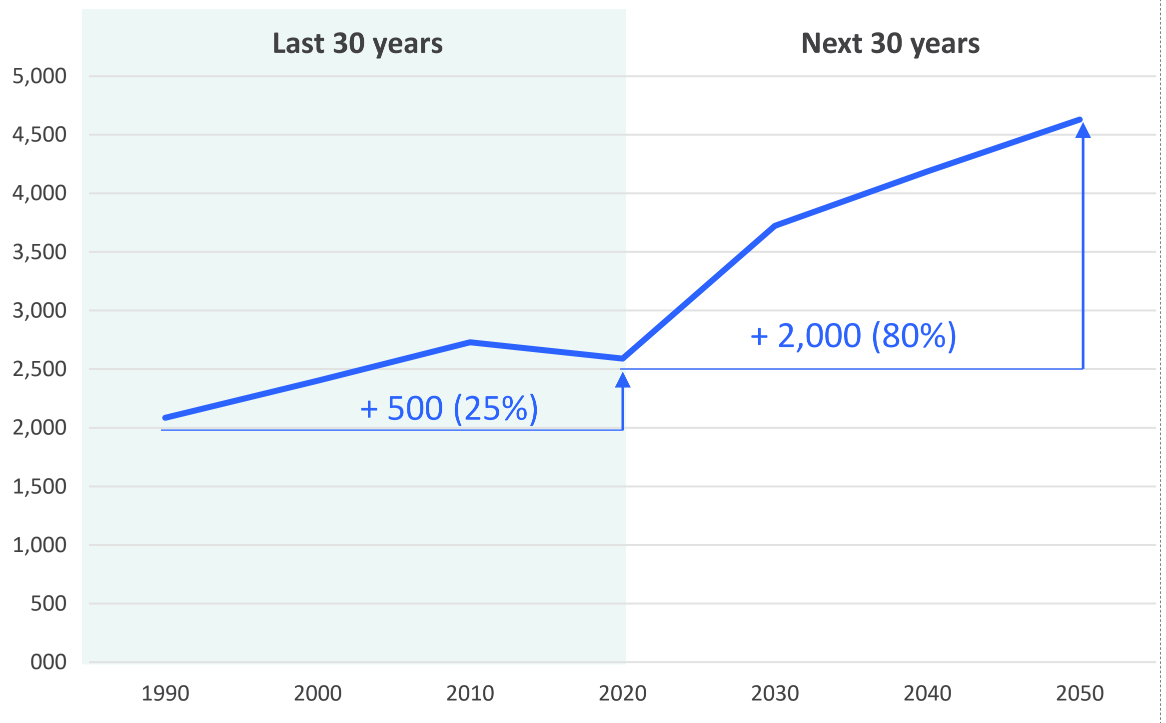
Grid age (page 24)



Surge in electrification and consumption demands greater grid reliability

Electricity consumption (TWh)

Rising consumption in the EU27+Norway



Observations and outlook

- After 20 years of stagnation, electricity demand will grow, becoming the dominant fuel of the economy. This is due to increased use by existing customers and new connections, as well as the electrification of transport, industry, heating, etc. The decrease seen between 2010 and 2020 reflects weather conditions, economic activity and greater energy efficiency.
- Reliable supply of electricity by distribution grids will become increasingly important to the economy. Greater reliance on automation across all voltage levels will identify faults and reconfigure the grid so that electricity can be restored and outage times minimised. Investment in meshing the grid and automating open points will deliver these benefits. In parallel, a seamless and secure supply chain will allow crews to intervene, access critical network assets and correct system faults.
- Increased grid resilience means it can withstand external threats, including natural disasters and cyber attacks.

Investment needed in …

- Renewal and replacement
- Targeted resilience
- Digital systems for crew workforce and order management for grid repairs and outages

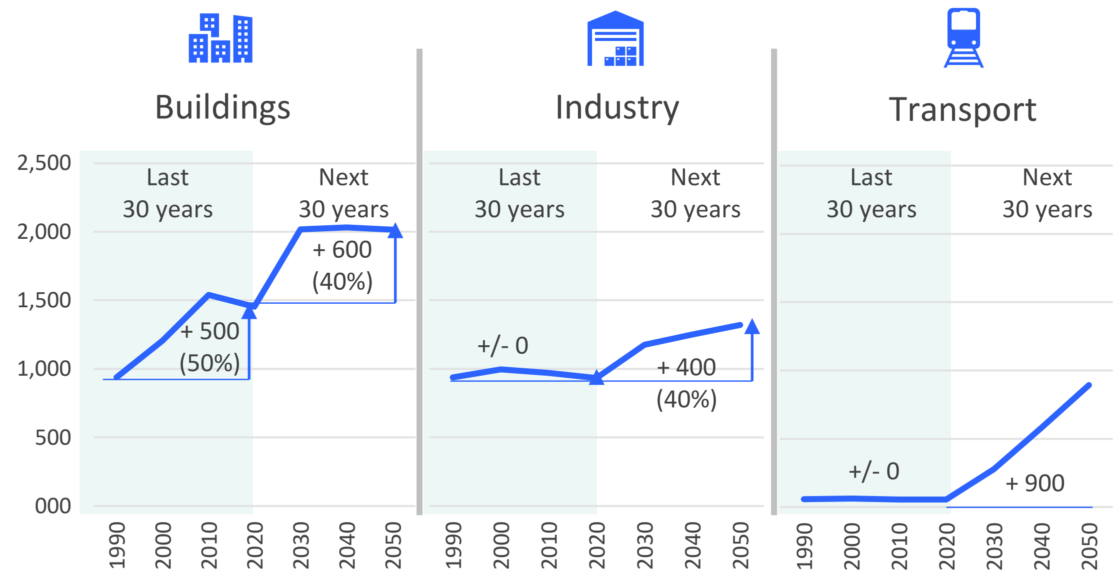
Source: Eurostat, *Supply, transformation and consumption of electricity*; Eurelectric, *Decarbonisation Speedways.*

Note: Annual electricity consumption variation in 2020 was not only affected by normal short-term variations such as weather and economic activity, but also restrictive measures to slow down the spread of COVID-19. For reference, electricity consumption was 3% lower in 2020 compared with 2019.

Three sectors contribute to greater electricity consumption in the EU27+Norway

Electricity consumption by sectors (TWh)

Consumption in the EU27+Norway



Observations and outlook

- Buildings and industry currently represent 65%+ of electricity consumption. Given the increasing electrification of transport over the next 30 years, these three sectors will represent 90%+ by 2050.
- Buildings and industry electrify their heat production, and use more digital and IT services. However, increased consumption is partially offset by greater energy efficiency measures and the continuing shift from a manufacturing- to a knowledge-based economy.
- While marginal today, the transport sector will grow exponentially to become the third-largest electricity consumer within the next 30 years.
- To realise the benefits of energy security, decarbonisation and reduced local pollution, the electricity grid must be developed and reinforced so that it can both transport electricity to where it is needed and swiftly connect new loads from heat and transport.

Investment needed in …

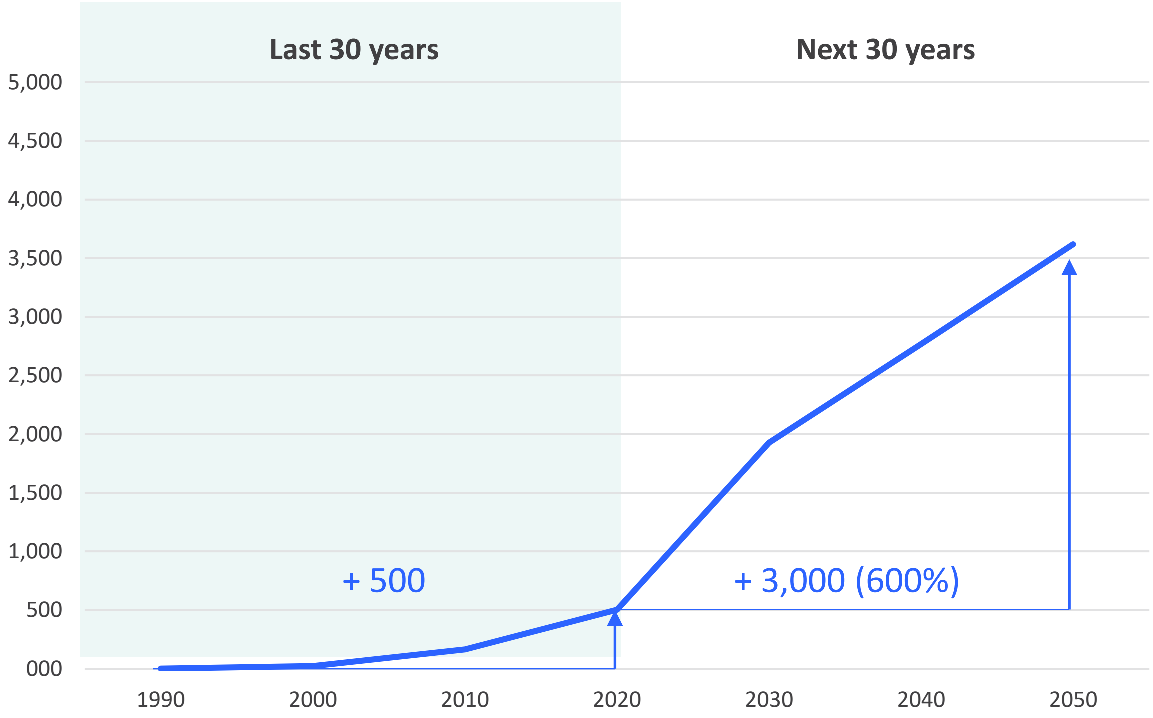
- System digitalisation and substation automation
- Demand-driven reinforcement
- Smart metering and increased grid visibility to know where growth occurs

Source: Eurostat, *Supply, transformation and consumption of electricity*; Eurelectric *Decarbonisation Speedways*

Connecting renewables to manage energy constraints, production and consumption

Renewables production (TWh)

How onshore wind and solar PV will impact distribution grids in the EU27+Norway



Observations and outlook

- Electricity markets operate across broad geographic zones or at national levels. Distribution grids, however, are not restricted by physical boundaries and can transport electricity beyond electricity markets.
- Most renewables are produced and consumed within the same distribution grid. This is more efficient as losses are lower with less distance between production and consumption.
- However, due to the intermittent nature of renewables, the distribution grid needs more real-time monitoring and management systems to maintain reliability and stability.
- The grid must be sized to ensure that electricity can flow from where it is produced to where it is consumed; otherwise, renewables production will be curtailed.
- Timely grid development is important to accommodate and connect accelerating renewables capacity.

Investment needed in …

System digitalisation and substation automation[1]

Generation-driven reinforcement

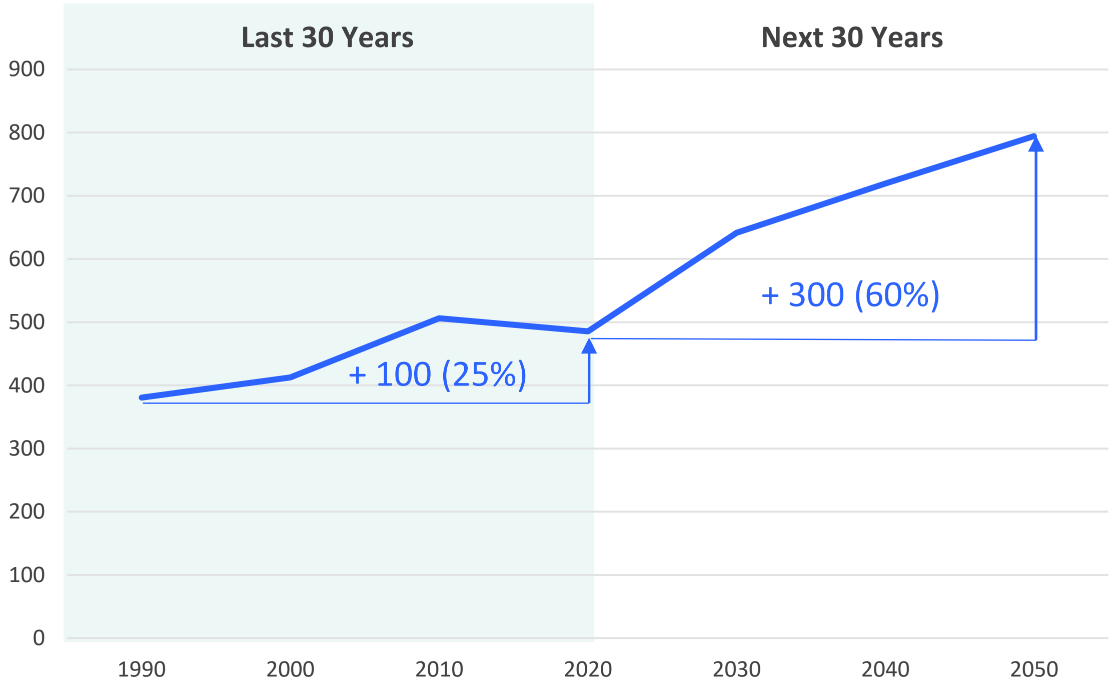
Source: Eurostat, *Supply, transformation and consumption of electricity*; Eurelectric *Decarbonisation Speedways*

1. ADMS to maximise the value of renewable energies

Peak visibility is critical due to the anticipated change in peak demand

Peak demand (GW)

Changing peak load in the EU27+Norway



Observations and outlook

- Peak demand or production denotes the maximum amount of electricity required during a specific moment of the year. It defines grid sizing at each voltage level. If peak demand can be lowered by shifting demand to another moment, while still meeting customer requirements, then it creates flexibility, which is a means to defer costly grid reinforcement.
- Electricity grid companies must be able to identify peak loading for each asset. This can be challenging, given the complexity of interconnected systems and switching mechanisms, and the need to forecast electricity demand for each asset.
- In the past, when demand was more predictable and steadier, DSOs relied on top-down forecasting and simulation models at higher voltage levels only. This will no longer be sufficient. DSOs now need bottom-up forecasting, using smart meter data and granular grid simulation tools, across all voltage levels and time horizons, from microseconds to years.

Investment needed in …

- System digitalisation and substation automation[1]
- Demand-driven reinforcement
- Smart meter installations

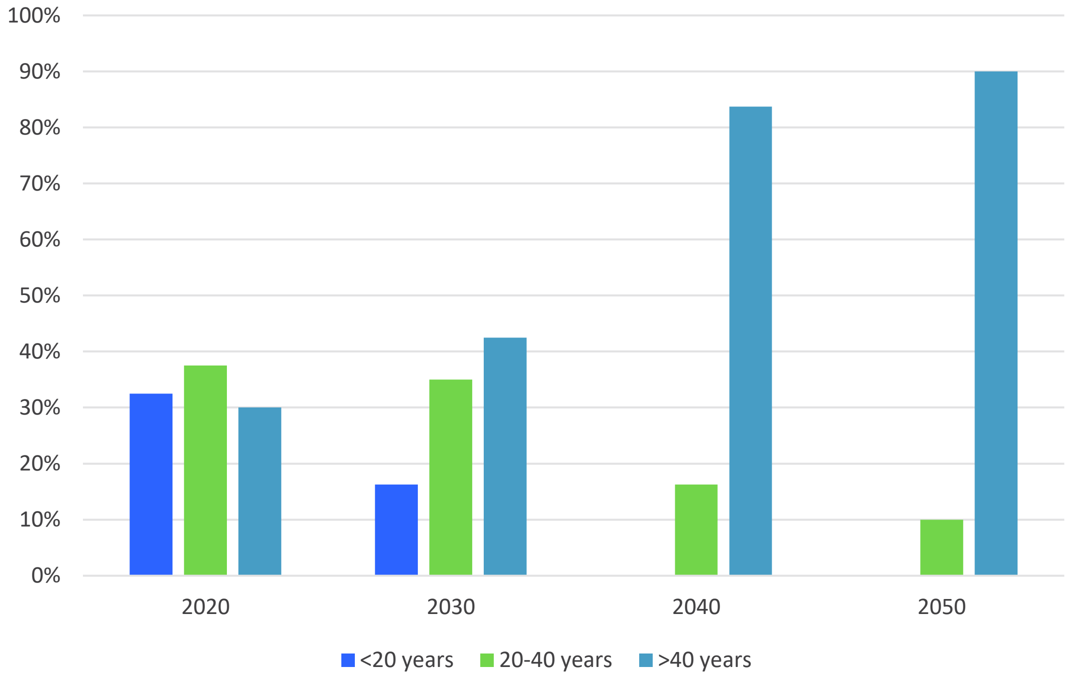
Source: European Network of Transmission System Operators for Electricity (ENTSO-E); Eurelectric *Decarbonisation Speedways*

1. Digital systems for data management, grid simulation and forecasting

30% of today's grid is more than 40 years old

Age of grid infrastructure (LV power lines)

Progressive asset ageing if none of the infrastructure is replaced after 2020 in the EU27+Norway



Observations and outlook

- 30% of today's grid is more than 40 years old on average, with some assets significantly older.
- To ensure resilient and reliable grids, investment in grid replacement and renewal is evaluated using a risk-based assessment and decision-making framework.
- When prioritising the replacement and renewal of assets, age is one factor in determining asset health. Other factors include the make, build, environment surrounding the asset, location, public risk, loading, impact of failure and inspection records.
- Advanced monitoring (including smart meter data) and maintenance data, combined with predictive algorithms and digital twins, can help to optimise asset health. However, periodic replacement and renewal remain essential.
- Overlaying grid expansion and customer connection requests with advanced forecasting and simulation tools also supports anticipatory investment.

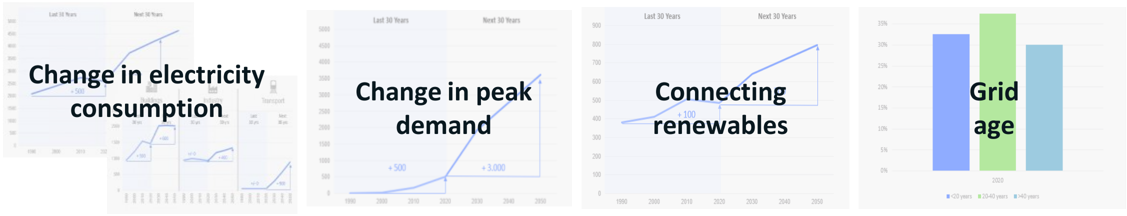
Investment needed in …

- System digitalisation and substation automation[1]
- Renewal and replacement[1]
- Targeted resilience

1. Renewing existing grid, while harnessing opportunities for strategic reinforcement, further monitoring (including smart meter data) and digital asset health management systems.

Various DSO investment is needed to enhance the rapidly changing electricity system

Main change indicators



Investment categories

Investment categories		
Demand-driven reinforcement	Renewal and replacement	Smart meter installations
Generation-driven reinforcement	Targeted resilience	System digitalization and substation automation

- Current state of play: The electricity grids of the EU27+Norway are entering a period of rapid change in terms of overall electricity consumption (kWh), renewable generation and peak demand (kW). At the same time, the existing grid is ageing.
- Enabling an electric future: To deliver on EU policy goals of carbon neutrality and energy security, GfS assesses distribution grid investment needs through to 2050. This investment analysis, presented in chapter 5, focuses on six investment categories, including physical grid growth, renewal, targeted resilience, and automation and digitalisation.

#Grids4Speed

3

Grid investment strategies enabling the energy transition

How DSOs can determine the right investment strategy and pathway to enable an electric future.

Grid investment needed to achieve REPowerEU and decarbonisation goals

Grids for Speed (GfS) uses the demand and generation outlook to 2050, considers the investment required for the distribution grid to manage the additional demand and generation and the impact of three key emerging investment strategies on this investment. Unlocking this investment and the physical realities of delivering the grid are considered in an action plan to support the scale out of the distribution grid and the benefits this will bring.

1. Demand and generation outlook

GfS is anchored in the demand and decarbonisation scenario REPowerEU, which is proposed in Eurelectric's Decarbonisation Speedways. This scenario delivers the EU's 2050 goals, as defined in the European Commission's REPowerEU and decarbonisation (Fit for 55) policies.

2. DSO investment strategies

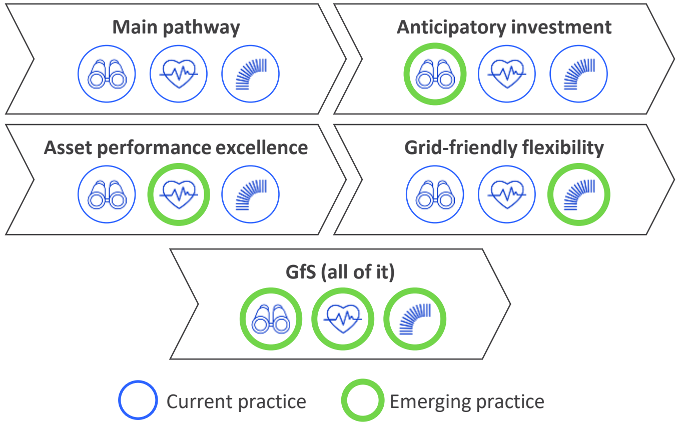
DSOs currently use multiple tried-and-tested investment strategies, such as increasing the capacity of grid sections or asset renewal cycles.

Additionally, GfS models three emerging grid investment strategies:

1. **Anticipatory investment** involves proactively expanding grid capacity when constraints and other works occur to meet the 2050 demands, rather than merely making incremental increases.
2. **Asset performance excellence** is achieved by using real-time data and AI to optimise asset health.
3. **Grid-friendly flexibility** means actively managing demand during peak times across voltage levels to defer grid growth.

3. DSO pathways

Pathways combine different investment strategies that DSOs can take to achieve net-zero goals. GfS examines how these three key emerging grid investment strategies interact with each other and current investment strategies. It explores the impact on the investment required.

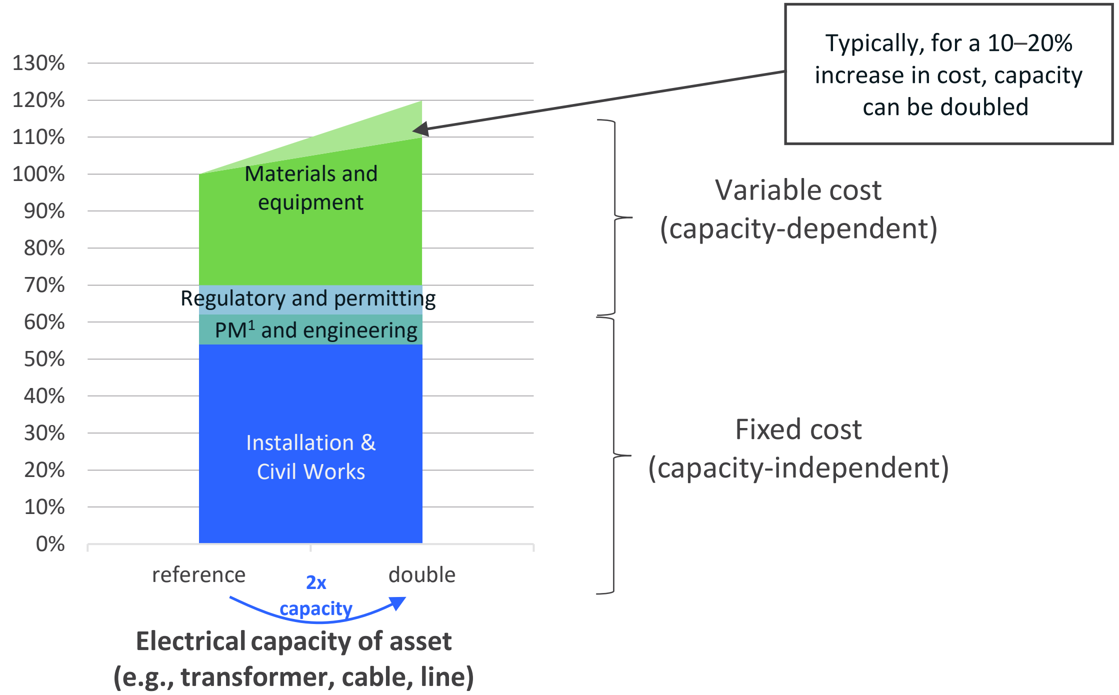


Economics supports anticipatory investment in distribution grid projects

Anticipatory investment

Cost breakdown for a grid asset reinforcement project

Indicative representation of the cost breakdown for a grid overhead line and cable installation project (other grid assets have similar characteristics)



Implication for distribution grid strategy

- Electricity grid projects are dominated by fixed costs for electrical installation and civil works, along with permitting, engineering and project management costs. Only material and equipment component costs are variable, as these are determined by the electrical size or capacity of the project.
- Typically, increasing the capacity of a grid project (e.g., line, cable or transformer installation) will only increase the cost of the project marginally, if within the same voltage level. For instance, doubling capacity may increase costs by around 10% to 20% yet provide additional capacity for planned future projects, such as renewables integration, new housing developments or heat electrification.
- Where future strong load growth is likely, it may be prudent to strategically size up capacity as an anticipatory investment during reinforcement or replacement projects. This will reduce the investment required in demand- and generation-driven reinforcement as additional capacity is available.

Investment impacted in …

Source: EY analysis, and ACER and PWC (2023), Unit Investment Cost Indicators

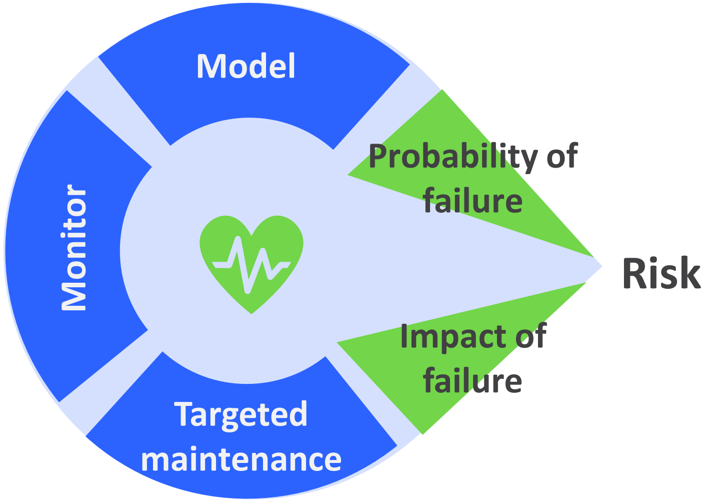
1. PM is project management

Asset performance excellence: optimising the use of the grid

Asset performance excellence entails using health and risk-based processes powered by data and AI

Advanced AI and machine learning (ML) algorithms dynamically predict asset health and probability of failure across extensive data sets of assets

Real-time monitoring of asset condition, such as load, temperature and pressure



Prepare condition-based asset maintenance schedule and harness field information to enrich asset health

Implication for distribution grid strategy

- Asset performance excellence harnesses the power of data, analytics and AI for asset management practices that consider the real health and condition of the asset.
- As a result, asset replacement is optimised to a just-in-time basis and investments are directed to the next most critical area.
- Additionally, unplanned outages from asset failure are proactively avoided, which improves reliability and customer outcomes.
- Asset maintenance schedules are reduced, evolving from reactive to condition-based maintenance, which further benefits reliability.
- Asset health simulation can be applied to decisions about distribution grid operations, further maximising asset lifespans.

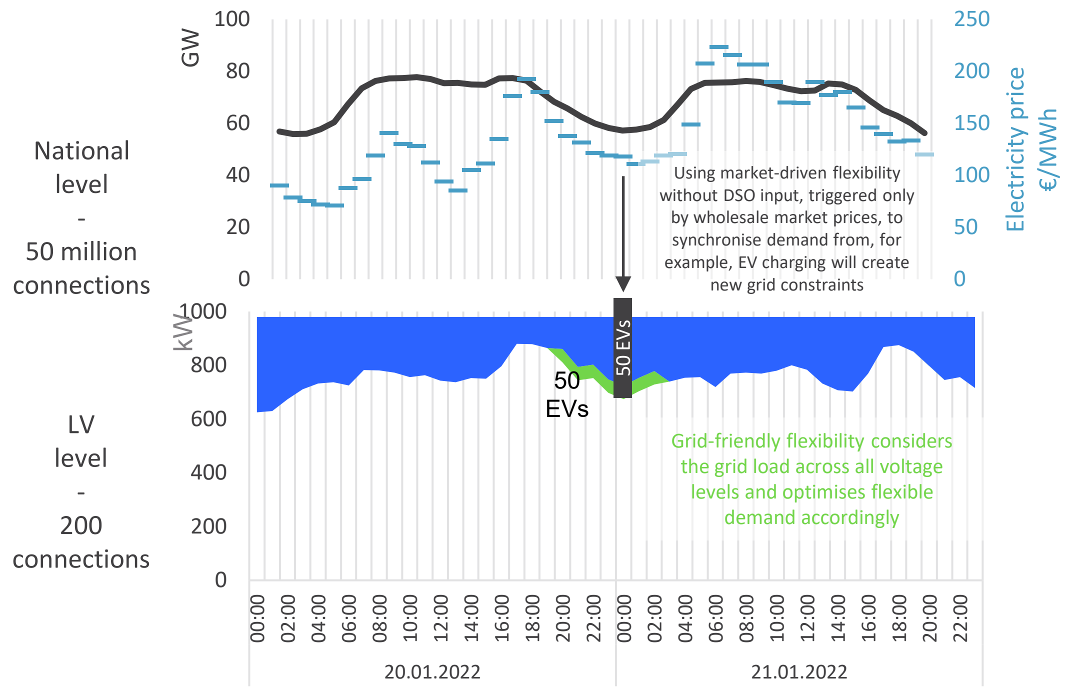
Investment impacted in …

- Renewal and replacement
- Digital systems for asset performance excellence

Grid-friendly flexibility is needed to reliably optimise grid investment

Grid-friendly flexibility

Static market-driven or non-regional flexibility will create new constraints and additional investment



Implication for distribution grid strategy

- The electricity system operates on international, national and regional levels, across HV, MV and LV grids.
- Flexibility actions taken at the national or wholesale market level can cause overloading and congestion in distribution grids, most importantly when bringing demand back (demand synchronisation through loss of diversity).
- The graphic illustrates a wholesale market actor that wants to optimise at the national and wholesale level. The actor dispatches demand after 21:00, but significant load remains at the LV levels, which must be considered.
- If all flexibility resources are dispatched simultaneously, demand will synchronise and local peaks will increase.
- To avoid the need for increased reinforcement in the distribution grid, near real-time monitoring of grid loading is needed.
- Grid-friendly flexibility optimises demand dynamically to defer grid reinforcement.

Investment impacted in …

Demand-driven reinforcement	Generation-driven reinforcement	Digital systems for flexibility

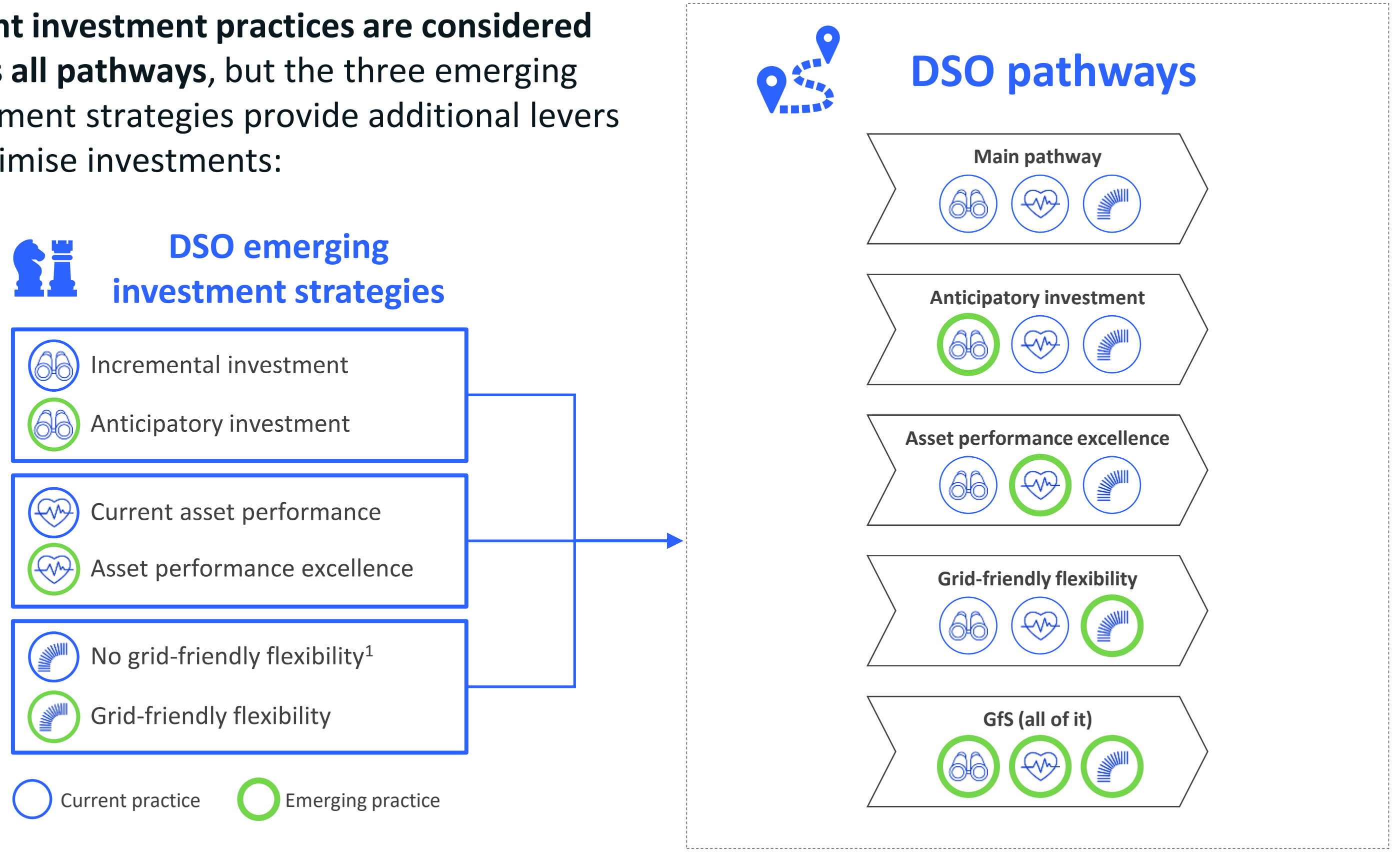
Real-world data from 20 and 21 January 2022 in Germany.
Source: MITNETZ STROM and SMARD market data.

How DSO pathways can interact to deliver REPowerEU

Decisions on grid investment strategies are dependent on regulation, technology and customer expectations:

- GfS estimates €67 billion grid investment is required annually to 2050 to deliver the energy transition, as described in REPowerEU.
- However, uncertainty stems from future electricity regulation and underlying incentives, evolving customer expectations and technology development.
- To address uncertainty, GfS analyses conventional distribution grid pathways, as well as three emerging grid strategies. Together, they illustrate the investment impact in reaching the REPowerEU target in 2050.
- Each investment pathway is capable of realising the REPowerEU EU targets, but at varying levels of cost, benefit and societal impact.

Current investment practices are considered across all pathways, but the three emerging investment strategies provide additional levers to optimise investments:



1. Assumption: Market-based flexibility may be used, but in ways that avoid synchronising customer demand and creating new peaks.

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4

GfS modelling methodology

Investment forecasting built on real-world grid data and world-class modelling and analysis.

GfS methodology overview

Data collation	Investment modelling	Action plan	Societal benefits
DSO data	ICL representative grid modelling	Regulatory tools	Societal benefit analysis
Publicly available reports	Investment analysis for EU27+ Norway	Supply chain scaling	
Eurelectric data	Emerging grid strategy optimisation		
EY insights and data			

Robust and comprehensive data sources underpin GfS

DSO grid plans

DSOs have provided EY with their grid development plans, which include:

- Extensive current-state information
- Future projections
- Regulatory compliance plans
- Investment plans

DSO data survey

The data survey had high representativeness, with more than 60% of connections in the EU27+Norway covered and representation from 21 countries (17 countries for regulatory assessment), with 10 countries covering more than 80% customers.

EU regulation and NECPs

Current and emerging European regulation were assessed.
EU NECPs were reviewed to understand:

- The 10-year plan of the Member State
- Energy mix insight
- Policy measures
- Infrastructure changes

EY data

EY has internal proprietary data and models, such as the ERTA model, heat pump and EV forecasting tools, power price forecasts and RECAI reports that were leveraged.

Public reports

Over 30 public reports have been used to support GfS. Sources such as Eurostat's databases and CEER's report on regulatory frameworks are invaluable for the up-to-date data they provide.

Eurelectric data

In the last year, Eurelectric has published 11 key reports, including positions on electricity market design and anticipatory investment. The data generated to create these reports was a rich source of industry information for GfS.

Calculating investment: ICL representative grid model and EY analysis

Imperial College London (ICL) developed a unique and internationally acclaimed methodology to realistically represent the distribution grid in whole-of-system investment planning models.
For each EU27+Norway country, the distribution grid is modelled, investment assessed and flexibility valued by creating a representative grid. Representative grids model each local geographic area based on its population density and assign a representative grid topology, adjusted for local conditions.

Investment categories

See page 18 for description of scope

Demand-driven reinforcement
The REPowerEU demand is overlaid in the representative grid models to understand the level of investment required to meet the scenario.

Generation-driven reinforcement
We calculated investment needed for reinforcement of the grid to accommodate reverse power flows from renewables to move electricity out of the area. We assumed that a local grid is only designed to export up to double peak demand. Beyond that, generation customers will be either curtailed, or choose to own storage or to connect in a more favourable location.

Renewal and replacement
Using the weighted average age of the top five asset classes, and their useful life, we calculated the annual depreciation of the asset base. This is assumed to be the level of investment required to renew and replace the assets.

Targeted resilience
We determined the number of cables underground, and additional feeder links used for targeted resilience upgrades. In parallel, we calculated resilience improvements from reinforcement and renewal investments. Investment was calculated based on DSO historical data, grid plans and current estimates.

Smart meter
Using historical data to set the baseline, we calculated how many smart meter installations are still required, as well as investment needed for ongoing renewal and upgrades of smart meter infrastructure. Using DSO data and EU Commission data, we calculated the required investment to meet countries' smart meter targets.

System digitalisation and substation automation
Using DSO input data and expert knowledge, we determined unit costs for the systems and calculated future investment (including replacement costs). We calculated the cost to automate one substation, multiplied by the number of stations to be automated.

Note: Smart grid technologies, such as on-load tap changers (OLTC) and dynamic line rating, are not modelled, but discussed on page 50. These technologies are alternatives to alleviate demand- and generation-driven reinforcement.

ICL internationally acclaimed representative grid model

ICL representative grid methodology

For each country, **ICL created representative grids** for LV, MV and HV, using fractal theory

Mapping/calibration to country level so that statistical parameters match real grids

Calibrated **representative grids** for rural, semi-rural, semi-urban and urban grid types

LV data

- Area size
- Desired customer distance/clustering parameter
- Distribution transformer density
- LV customer density
- Customer mix
- Average power from current loading

Additional MV and HV data

- MV customer density
- Matrix of LV grid tiles
- Number of HV/MV transformers per site and MV feeders per transformer

Statistical parameters for real grids (country level)

- Grid length (overhead, underground)
- Grid asset numbers (transformers) and voltage levels
- LV and MV customer numbers
- Customer type
- Grid branching rate factor
- Average power from current loading
- Active power losses

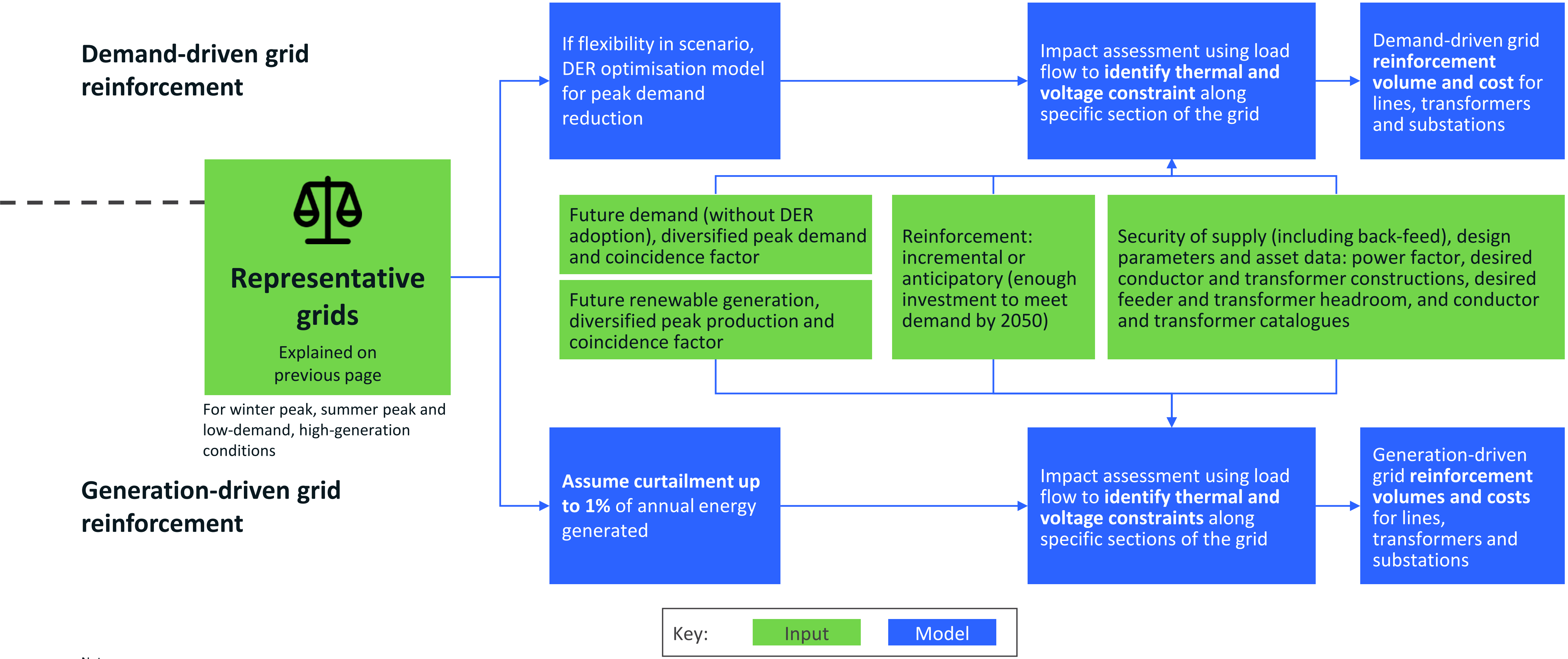
Allocation model

Baseline demand profiles and scenario inputs on DER adoption

- Distributed generation (DG)
- Energy storage
- EVs
- Heat pumps
- Other smart appliances

Key: Input Model

How representative grids calculate growth and curtailment



Notes:

- Attributing reinforcement to either demand or generation requires a convention as reinforcement effectively serves both. Here, demand-driven reinforcement is first determined by modelling for demand only. Then, the additional generation-driven reinforcement is derived by modelling the grid with demand and generation connected.
- Smart grid technologies, such as on-load tap changers (OLTC) and dynamic line rating, are not modelled, but discussed on page 50.

Other investment categories analysed by EY

Data collation
Combine public reports, DSO and EY data; identify discrepancies or inaccuracies.

Develop assumptions
Develop assumptions to underpin analysis, i.e., that replacement and renewal costs are equal to annual depreciation.

Calculate future investment
Use grid development plans, DSO data and public targets to understand the investment required to meet targets and demand.

Calibrate results
Use representative grids and historical DSO data to calibrate the future investment forecast.

Index investment forecast
Use the producer price index (PPI); turn investment forecasts into real figures.

Note: For full investment methodology per category, please see Appendix A.

Our approach to the regulatory assessment

Our regulatory assessment set out on section 7 focuses on the key blockers that must be removed to empower DSOs to deliver the investment in, and management of, the networks needed for GfS. We outline the structure of the regulatory analysis below.

Key investment analysis needs

- Our investment analysis highlights the key needs for the delivery of the GfS investment.
- The regulatory frameworks and regulatory tools are assessed against these key investment needs.

Regulatory challenges block GfS delivery

- Our review of regulatory frameworks builds on our DSO survey and identifies common regulatory challenges across the EU27+Norway.
- These common regulatory challenges are blockers to GfS. They must be addressed as part of the new regulatory GfS toolbox.

Solution

- We outline top regulatory tools needed to address or dismantle the regulatory blockers.
- These regulatory tools will empower DSOs to deliver the key investment needed for GfS.

Implementation and targeting

- We then assess how quickly these solutions can be implemented given the need to invest quickly in the grid.
- We also assess the targeting of regulatory reforms to the main driver of investment needs for different notional DSOs.

Our GfS regulatory analysis concludes that the GfS toolbox should both enforce of current legislation and regulation and develop new GfS policies to support DSOs. Regulations should empower national dialogue and decision-making between Member States, NRAs, TSOs and DSOs, and account for national differences.

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5

Grid investment pathways to 2050

Annual grid investment is front-loaded. It must double initially to 2040, but the success of emerging grid strategies could cut the cost by 18%.

Summary of investment forecast

- Electricity distribution grid investment of €67 billion annually is required to 2050 to build a distribution grid that can enable the energy transition. Failure to get the grid ready in time will not only slow the energy transition but also jeopardise energy security and the benefits of decarbonisation. The electricity system is in an exceptional decade of growth, meaning the investment profile is front-loaded. Investment must double until 2040 from roughly €36 billion today, continuing at about 1.7 times today's levels from 2040 onwards.
- Distribution grid demand-driven reinforcement is driving 43% of this investment, designed to alleviate both voltage and thermal constraints in LV, MV and HV grids. This highlights the importance of considering physical technical realities of the distribution grid in any policy and strategic assessment such as this.
- Emerging grid strategies, comprising anticipatory investment, asset performance excellence and grid-friendly flexibility, can reduce the investment required by around 18% to €55bn annually, but must be supported by a fit-for-purpose regulatory framework.
- Anticipatory investment is the most cost-effective emerging grid strategy.
- Grid-friendly flexibility appears to be an attractive option, from a societal perspective, for deferring investment in countries with rapid electrification. However, the business case, from the DSO perspective must take into account the compensation scheme for customers and aggregators.

€67bn/year
Of investment is required between 2025 and 2050 in the EU27+ Norway

43%
Investment is for demand-driven reinforcement

2x
Current investment between 2025-2040 in period of growth

1.7x
Current investment between 2041 and 2050

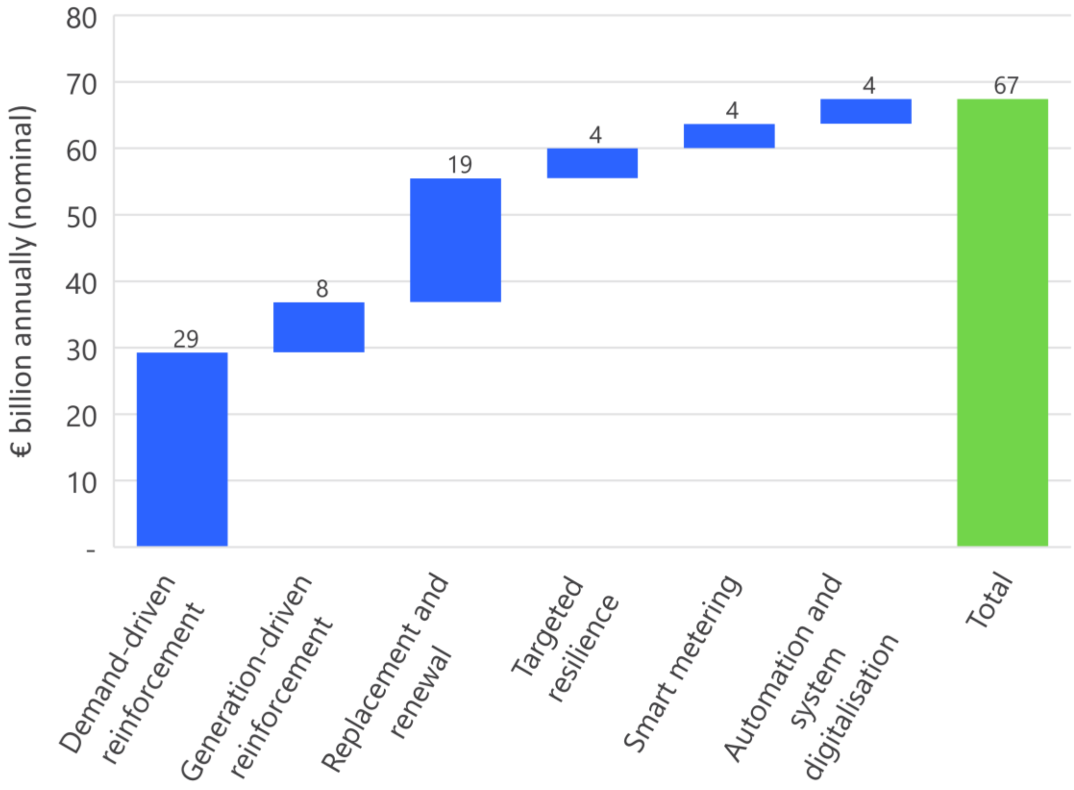
Anticipatory
investment is a no-regrets approach to optimise investment

-18%
investment reduction to €55bn/year if emerging grid strategies are realised and supported by right regulatory environment

Grid cost: €150 per capita annually to deliver the energy transition to 2050

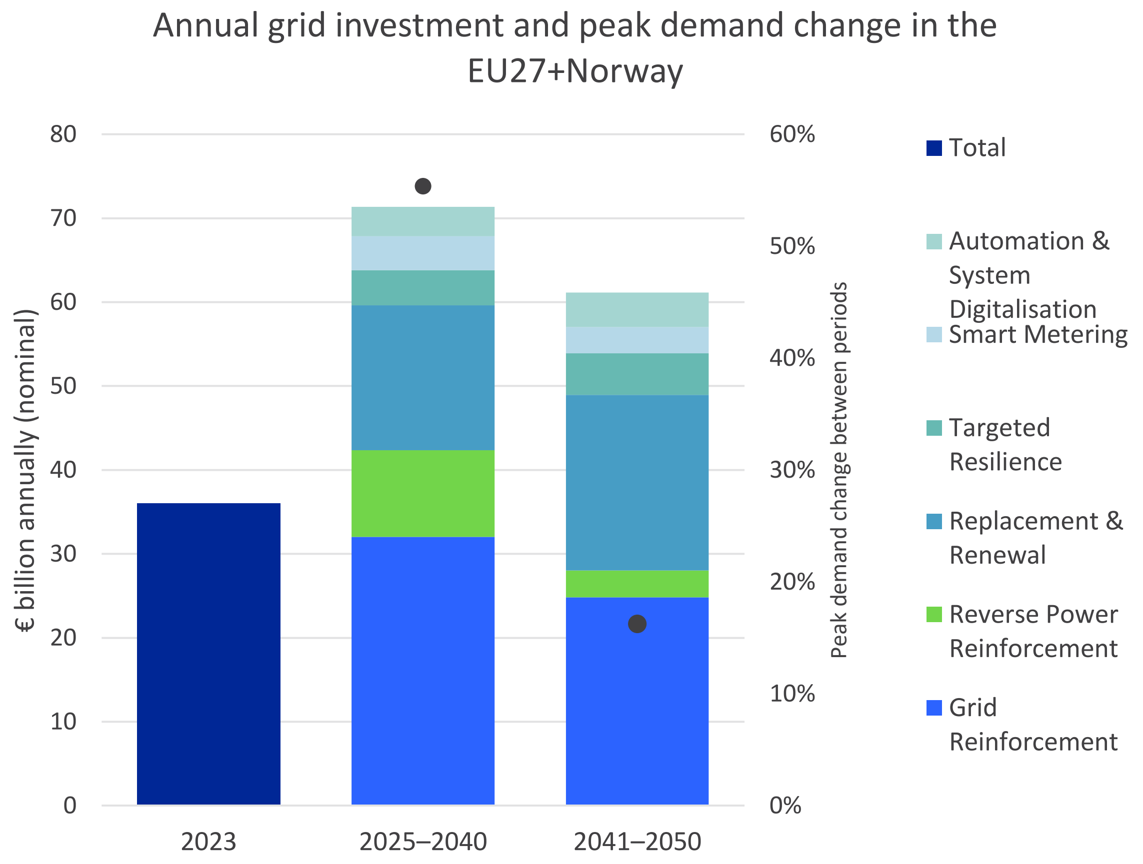
- To achieve the REPowerEU scenario across the EU27+Norway, around €67 billion annual investment is required, on average, between 2025 and 2050. This equates roughly to the amount paid on implicit fossil fuel subsidies in the EU — about €56 billion average annual spend (2008–2021), rising to €120 billion in 2022.
- To put this in perspective, €67 billion annual investment represents roughly 0.4% of gross domestic product (GDP) as of 2024 in the EU27, or €150 per capita annually.
- Failure to get the grid ready in time will slow down the energy transition and put energy security at risk. In 2021, the economic damage from power outages was a reported €50 billion.
- Demand-driven reinforcement accounts for 43% of the investment and will ensure the grid is sufficiently sized to deal with increased demand from the electrification of heat and transport. An estimated 237 million EVs and 251 million heat pumps are anticipated by 2050, which will facilitate market-driven flexibility via virtual power plants (VPPs).
- Replacement and renewal accounts for 27% of investment and will modernise ageing grid assets to optimise reliability and resilience.
- Generation-driven reinforcement represents 12% of annual investment and will allow excess renewable generation in one local area to be diverted to wherever it is needed.
- Additionally, targeted resilience will focus on strengthening the grid and building additional redundancy through meshing.

Annual average grid investment in the EU27+Norway (2025–50)



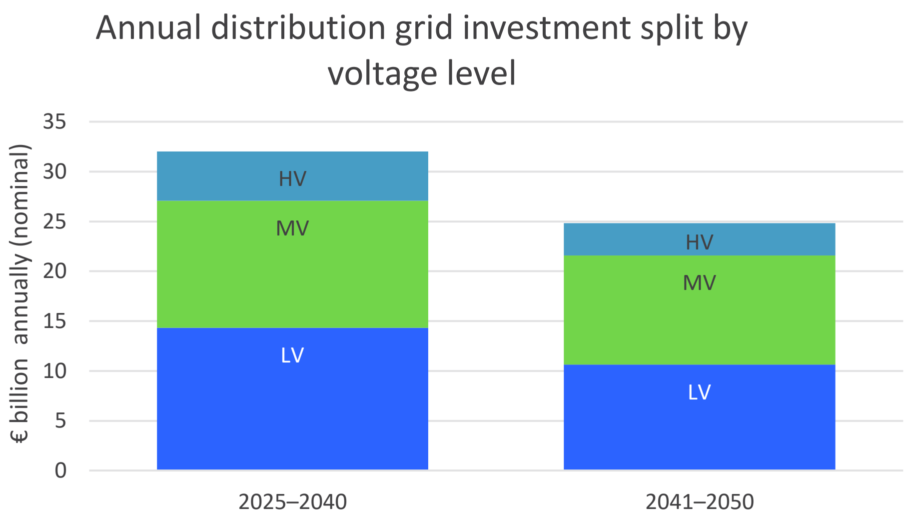
Note: All investment numbers shown in this section are in nominal terms and are derived using a standard PPI at country level. The PPI used is shown in Appendix D. The investment per capita is derived based on a population of 452 million for EU27+Norway..

Investment must accelerate now to enable net zero

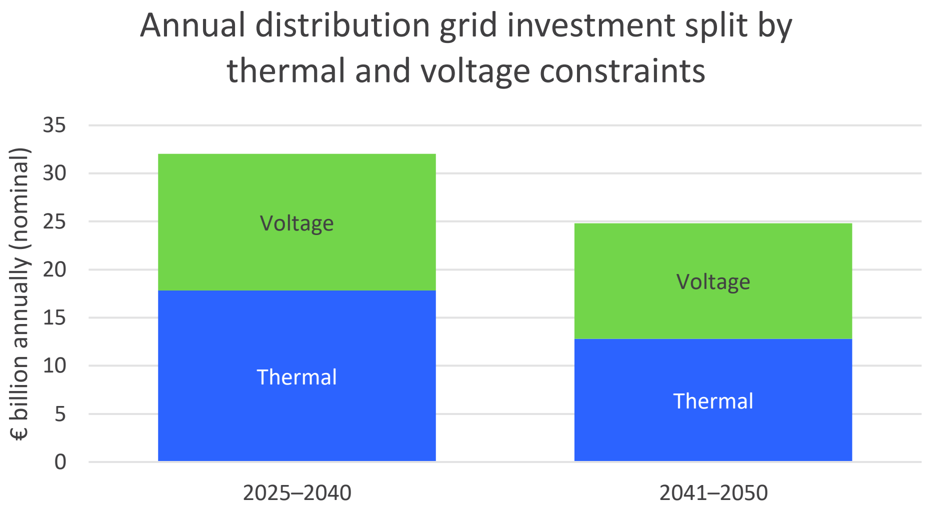


- Investment will need 2x current investment in the next 15 years and 1.7x current investment in the final decade to 2050.
- The current decade of electricity growth is extraordinary, akin to the inter-war and post-war period.
- Current demand growth to 2040 is driven by rapid electrification of the economy in general, and of the transport and heat sectors in particular. But the backward-looking regulatory investment framework means that grid investment has not yet accelerated sufficiently, leading to significant grid congestion.
- Due to current demand growth, immediate acceleration in grid investment is needed to develop the grid to 2040. Failure will result in connection delays and greater grid congestion, which will slow the energy transition.

Grid reinforcements needed to mitigate thermal and voltage constraints



- LV investment accounts for 44% of the €67 billion annual investment, MV for 41% and HV for 15%. In terms of unit costs, HV projects are more expensive due to technical complexity and scale.
- The LV grid accounts for 60% of grid length today. This is where the majority of new EV and heat pump loads connect, adding substantial load to the grid. By 2050, the LV grid will serve not only 250 million homes but also a similar number of heat pumps and EVs.



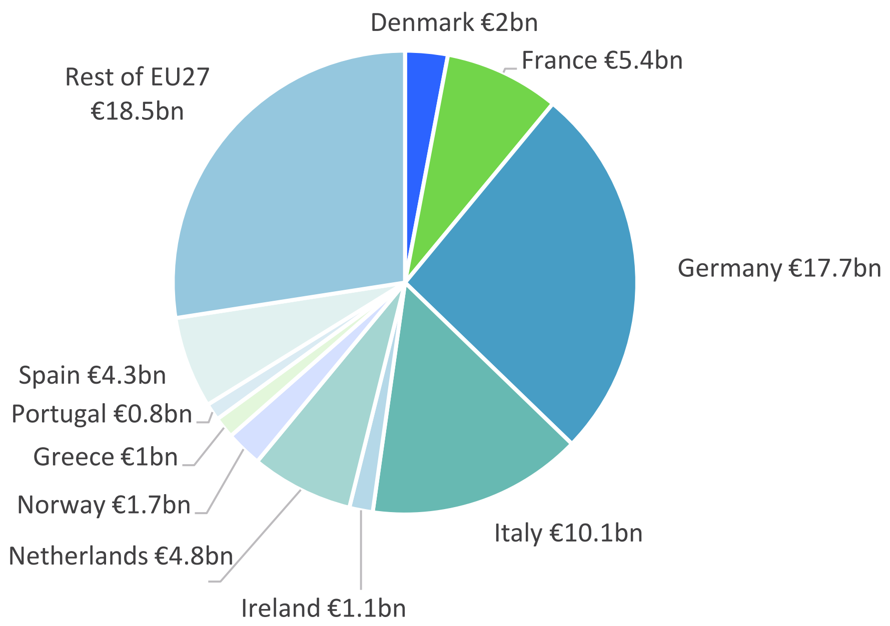
- Reinforcement is required to address thermal and voltage constraints. Thermal represents 60% of reinforcement to 2030; voltage is similar.
- Thermal constraints are well understood and occur when load exceeds capacity. They are behind just over half of all investments.
- However, the electricity grid can only operate if voltage remains within certain parameters. Voltage drops along the power line and cable, as a function of conductor, length and load.

Notes:
- LV is defined here as 400V, MV up to 38 kV, and HV above that
- Transformers are classified based on their secondary voltage side i.e., HV/MV transformers are included in MV investment costs.
- Voltage constraints can be partially addressed by regulators and capacity banks, which are not modelled here.

France, Germany and Italy represent 50% of the grid investment

- Investment varies greatly across the EU27+Norway. Key driving forces are population density, increases in peak demand and the speed of the energy transition.
- France, Germany and Italy represent 50% of investment through to 2050. This is higher than their share of energy consumption (40%), but similar to their GDP (50%).
- Investment per capita, is highest in Norway, Denmark and the Netherlands.
- Some countries invested significantly in their distribution grids in the past five years. However, the incremental backward-looking regulatory framework does not sufficiently cater for the transformational stage of investment, which will likely extend over the next 30 years.
- Countries with multiple and diverse DSOs tend to have higher investment requirements.

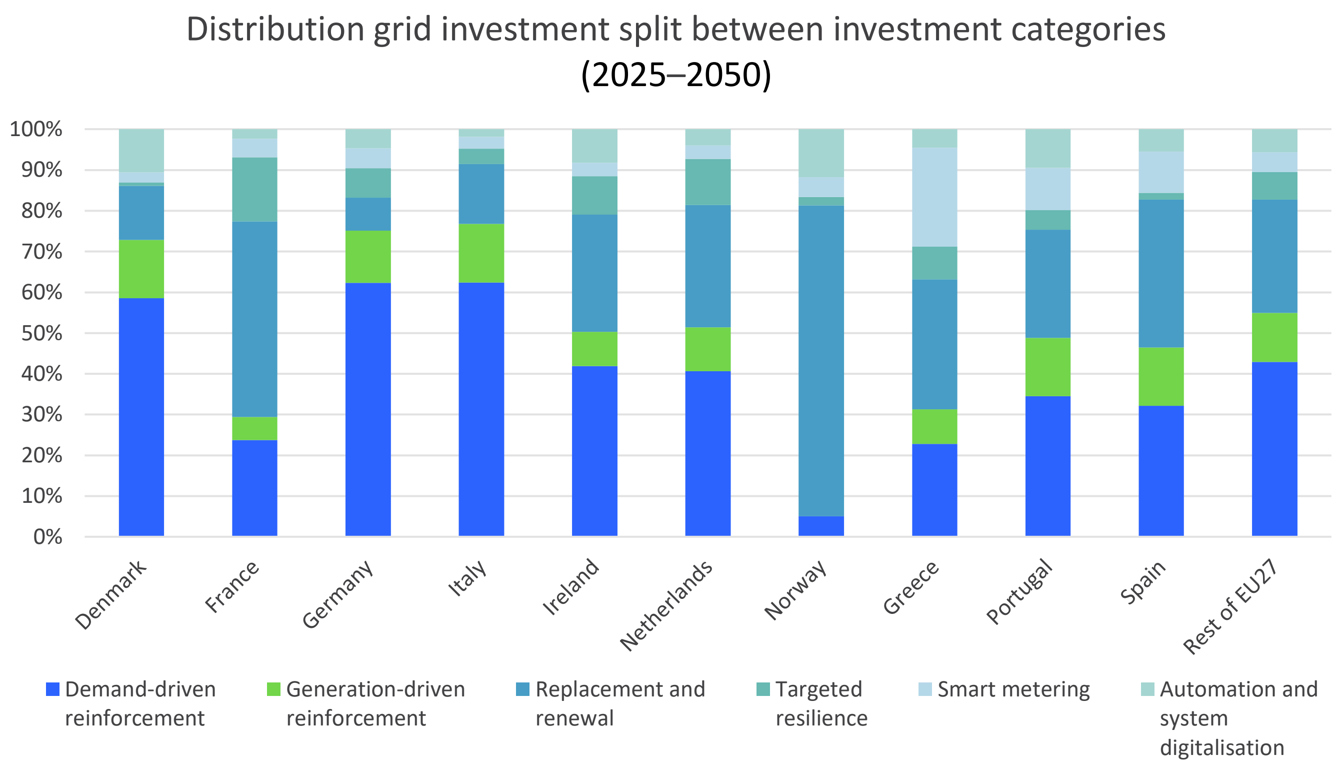
Total annual distribution grid investment in the EU27+Norway split by country (2025–2050)



All numbers are nominal in average annual investment to 2050

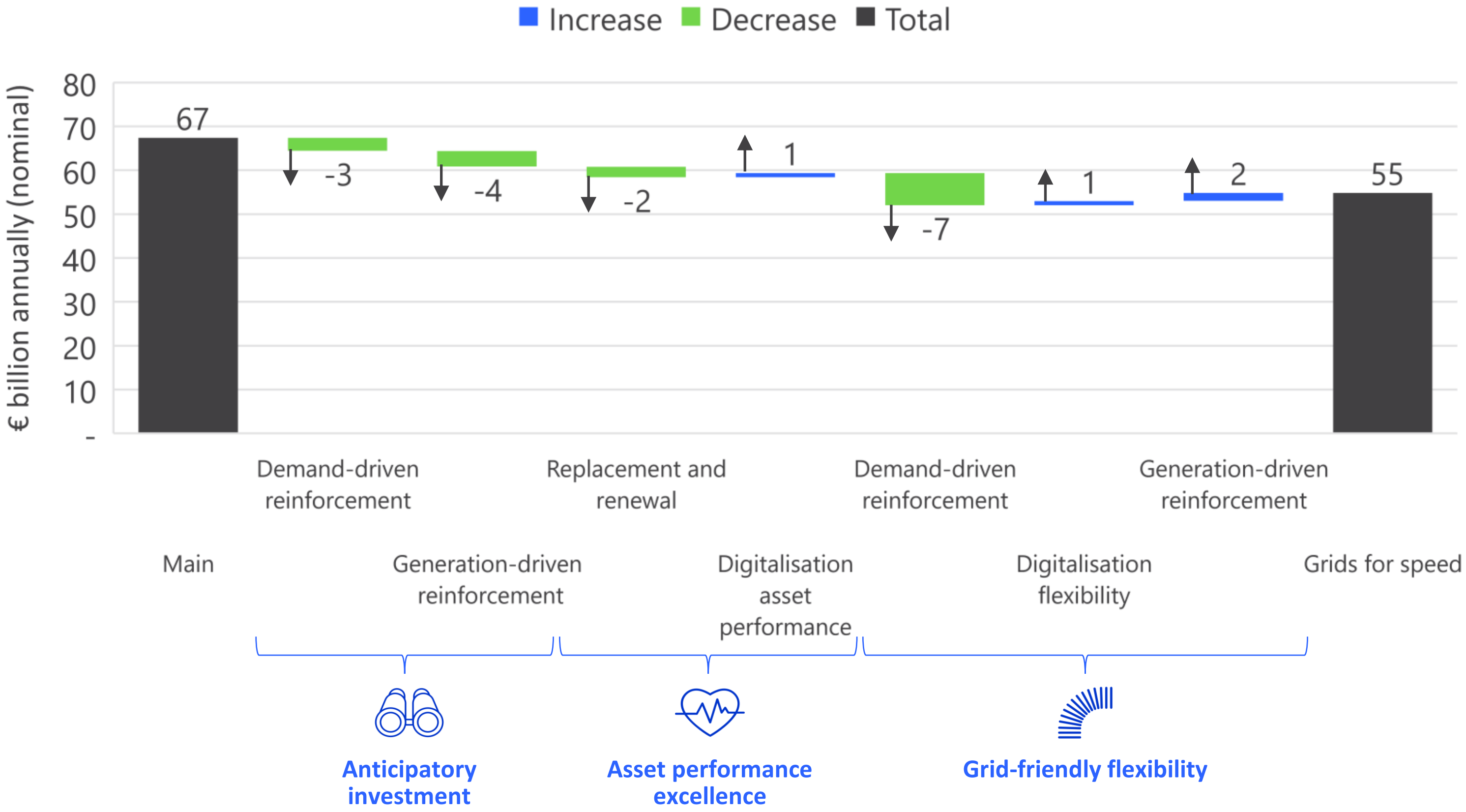
There are diverse investment demands from the EU27+Norway

- Each country has its own starting point, environment and future challenges, which dictate the type of investment that is most needed.
- The investment pathways reflect the uniqueness of each grid. For instance, Italy, Germany and Denmark require a greater share of demand-driven reinforcement; Norway, France and the rest of the EU27 must invest more heavily in grid replacement and renewal.
- A subsection in Appendix C of this report provides a detailed view on country-level pathways and explains the rationale for investments.



Three grid strategies could reduce investment by 18% to €55 billion annually

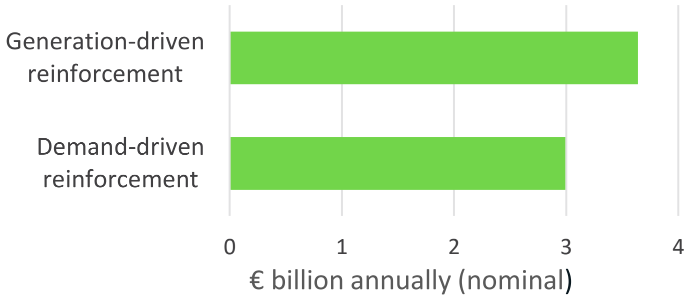
The impact of emerging investment strategies on distribution grid investment (2025–2050)



- If all emerging grid strategies were combined, investment to 2050 could be reduced by 18%, or €12 billion annually.
- Anticipatory investment is the most cost-effective strategy, as it only creates cost reductions. Its success hinges on regulatory support and granular load forecasting, which is informed by data.
- Asset performance excellence creates additional benefits, such as enhanced reliability and resilience, and lower opex costs.
- Grid-friendly flexibility brings a positive societal cost-benefit ratio, keeping in mind that the necessary activity payment has not been considered.
- Potential for deferred network reinforcement capacity means more investment is required to integrate generation-driven reinforcement from renewables. The alternative is higher curtailment, which would slow the benefits of decarbonisation.

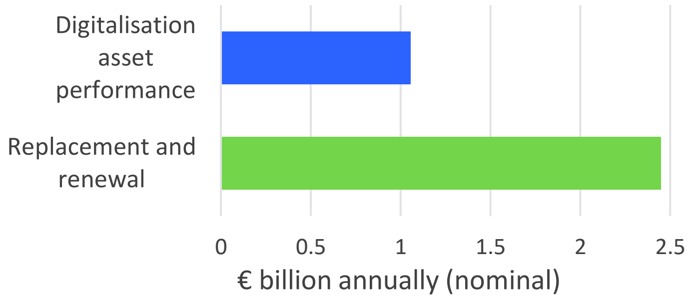
Advanced grid strategies do more than optimise investment

Anticipatory investment



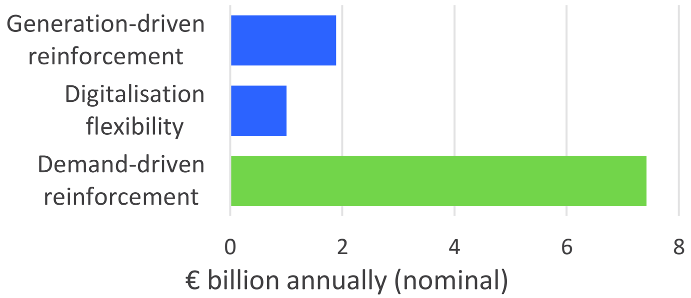
- When assets are up-sized, grid reinforcement project costs increase only marginally. This is because most costs are fixed and are not dependent on electrical capacity or equipment size (see page 28 for more details).
- All countries can benefit from anticipatory investment over the forecast window. However, DSOs must have excellent long-term forecasting capabilities, informed by smart meter data and an understanding of customer behaviours.
- Anticipatory investment also offers additional headroom for generation-driven reinforcement from renewables. This allows electricity to be transported to wherever it is needed, reducing the need for curtailment.

Asset performance excellence



- Optimised condition and health monitoring and modelling deliver a 2.4:1 cost benefit ratio across the EU27+Norway.
- At the national level, the cost-benefit is positive in 21 countries.
- Additional benefits, which are not captured, include higher grid resilience and reliability, fewer unplanned outages, fewer public security risks, and reduced operational costs due to streamlined maintenance schedules.

Grid-friendly flexibility

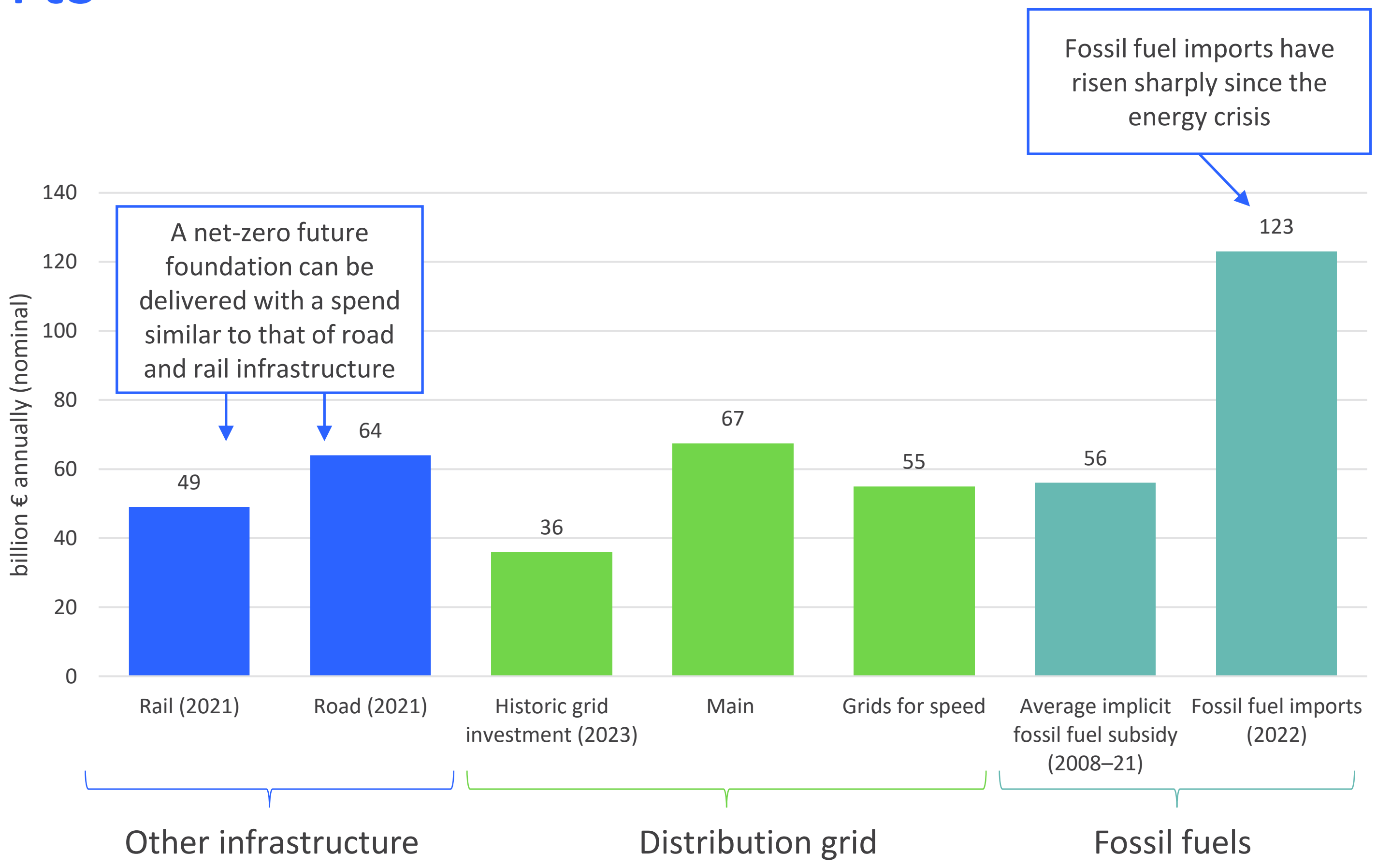


- Grid-friendly flexibility delivers a 2.5:1 cost-benefit ratio across the EU27+Norway. The cost-benefit of a smaller network is offset by the need to accommodate generation-driven reinforcement from renewables or to accept higher curtailment.
- At a national level, the cost-benefit is positive in 19 countries with strong peak-demand growth.
- Grid-friendly flexibility will deliver a €4+ billion net benefit, which will be societal. An activation payment for flexibility is required by market actors.
- Greater interoperability and standardisation of heat pumps, EV chargers, etc. will support cost efficiency.
- Flexibility systems can be used to enable faster connections of clean technologies (renewables, electric charging hubs, etc.). These so-called flexible connections can deliver additional decarbonisation and customer satisfaction benefits.

Legend: Benefit (green), Cost (blue)

€55 billion distribution grid investment needed; less than current spend on fossil fuels imports

- GfS investment required for grids is comparable with historical spend on rail and road networks. Currently, investment in grid infrastructure is below investment in rail and roads.
- €55 billion is less than the spend on implicit fossil fuel subsidies, and far below the amount spent on fossil fuel imports.
- The graph considers pre-energy-crisis spend on fossil fuels, which has since risen sharply. Fossil fuel imports stood at €277.2 billion in 2022 and implicit fossil fuel subsidies rose to €122 billion.
- The investment required is significant, but it is not without precedent for critical infrastructure.
- Lifting grid investment to match road investment is required to deliver the net-zero-ready grid, if emerging grid strategies are harnessed.



Source: EEA (2023), Fossil fuel subsidies; Organisation for Economic Co-operation and Development (OECD) infrastructure investment.

Smart grid technologies further optimise reinforcement investments in targeted applications

Smart grid technologies are part of today's distribution grid planning toolbox, to address grid constraints by optimising the use of the grid without physical reinforcement. Grid engineers are assessing these technologies against reinforcement as part of the technical, economic and benefit assessment of a specific constraint, and the outcome is highly dependent on local conditions (i.e., asset health, exact load profile, demand forecast, customer mix, topology). This detail is beyond the investment focus of GfS. However, the capability and application of key technologies are introduced to illustrate how smart grid technologies can contribute to refining reinforcement investments and ensure a more targeted and efficient allocation of resources, which is an important asset for DSOs to manage the transition.

On-load tap changers (OLTC)

Capability: A transformer modifies voltage between its primary (higher) and secondary (lower) voltage sides through varying core windings. If primary windings are reduced, secondary voltage increases, and vice versa. All grid transformers use multiple primary winding taps to adjust the voltage adjustments on the secondary side. OLTCs enable voltage level adjustments during transformer operation, and with the assistance of advanced distribution grid management systems, this can be done remotely to optimise the grid in response to real-time conditions. While this practice is common at higher voltage substations, it is not typically implemented at MV and LV substations.

Application: Expanded use of OLTCs in MV/LV networks to broaden the voltage envelope dynamically and maximise integration of LV-connected generation (mainly PV) and, to a lesser degree, demand.

GfS investment benefit: Optimise LV generation-driven reinforcement caused by voltage constraints.

Line voltage regulator (LVR)

Capability: An LVR (also called voltage stabiliser or voltage conditioner) stabilises the voltage level of an electrical circuit. An LVR is essentially a transformer connected in a series that employs sensors and control to make voltage adjustments.

Application: LVRs are frequently implemented in MV and LV networks — particularly in rural areas with extensive feeders or significant generation — where pronounced voltage fluctuations are a common challenge. LVRs dynamically adjust voltage levels, effectively smoothing out small voltage irregularities and, consequently, deferring the need for grid reinforcement.

GfS investment benefit: Optimise MV and LV generation-driven and demand-driven reinforcement by managing voltage constraints.

Dynamic line rating (DLR)

Capability: Grid line limits are generally set based on static environmental conditions (e.g., weather). DLR uses multiple sensors and measurement data, such as wind speed and temperature, to determine the real-time safe capacity of overhead lines. The results allow grid operators to safely increase conductor limits temporarily.

Application: DLR is especially well suited to maximising line capacity for wind power integration as, during windy periods, the wind cooling effect on the conductor allows the thermal limit of the line to be increased. DLR can therefore offset generation-driven reinforcement.

GfS investment benefit: Optimise HV generation-driven reinforcement caused by thermal constraints.

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6

Societal benefits of GfS

Grids for speed set to have a significant impact on household energy bills, reliability, job creation and, critically, decarbonisation.

How grids for speed can deliver society-changing opportunities

Energy bills and affordability

- Efficiency gains from direct electrification can reduce household energy consumption significantly.
- Electricity distribution fees are expected to stay flat to 2050 as increased GfS investment is offset by an overall increase in electricity consumption volumes.
- By 2050, European household energy bills could halve in a net-zero scenario.

Job creation

- Direct and indirect jobs in electricity distribution represent around 0.4% of the EU workforce (835,000 jobs), but structural challenges around age, diversity and skill gaps must be addressed urgently to ensure success.
- GfS can create more than two million additional direct and indirect jobs.

Reliability and resilience

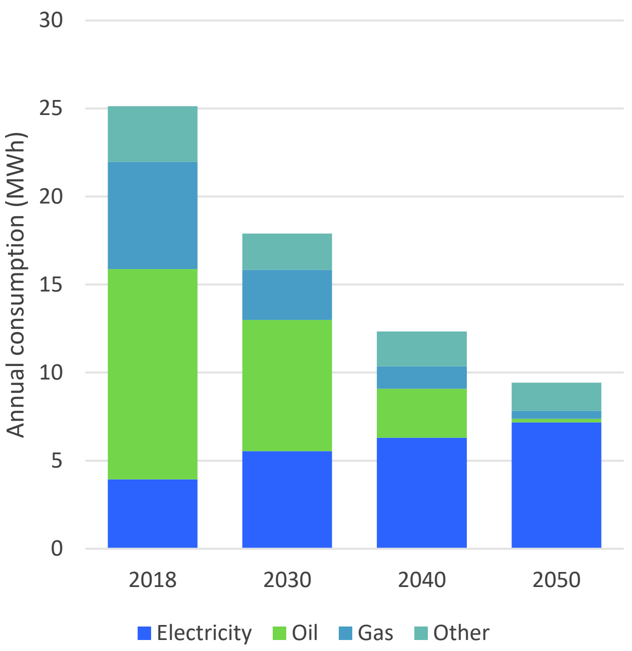
- Reliable and resilient energy supply is paramount in an electric society.
- Already today, the value of electricity when it is unavailable is 100 times higher than its purchase price for residential customers and much higher for businesses.
- In 2021, the economic damage from power outages was a reported €50 billion.

Decarbonisation

- To meet net-zero goals, GfS investment must be accelerated.
- Stagnated grid investment would mean that almost three-quarters of connections for key decarbonisation technologies, such as heat pumps, EV and renewable generation, and for use in low-carbon industries, do not materialise. And that will jeopardise the pursuit of net zero.

Efficiency gains from direct electrification will slash household energy consumption

Average EU household energy consumption for home and car usage

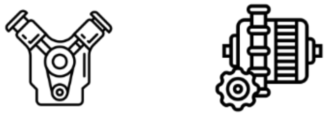


Delivering the grids for speed will pave the way to net zero by 2050 (as set out in the REPowerEU scenario) by securing reliability and resilience.

In a net-zero scenario, direct electrification will deliver three- to fivefold energy-efficiency gains to end users, on top of the decarbonisation benefits that accompany an increasingly renewable energy mix.

Car usage

Petrol engine | **Electric engine**



30% | 90%+, including charger losses

3x
Energy efficiency

Home heating[1]

Gas boiler | **Electric heat pump**

98% | 300–500%[2]

3x–5x
Energy efficiency

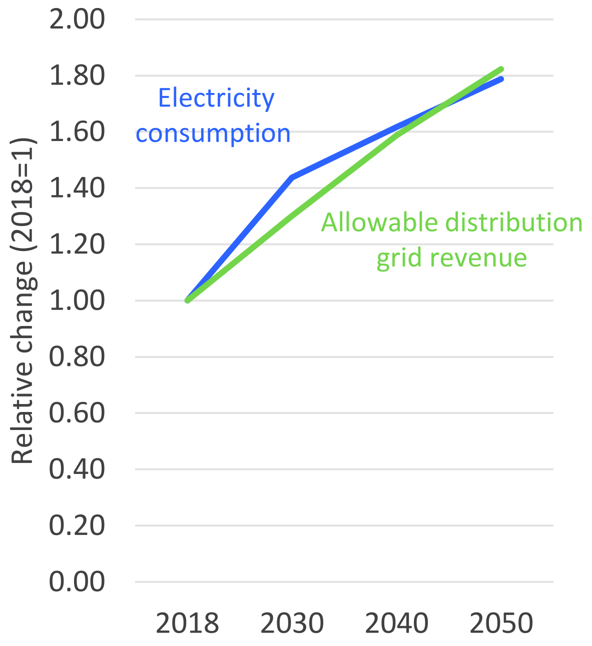
Other energy-efficiency gains will come from improvements to building envelopes and reduced kilometers travelled as behavioural shifts, such as the use of shared or light mobility alternatives, become more entrenched. Though electricity consumption will go up overall — a consequence of the electrification of everything — the net result of energy efficiencies will be a significant reduction in household energy consumption.

Source: Household energy consumption from Eurelectric Decarbonisation Speedways; Heat pump efficiency from IEA, The Future of Heat Pumps (2022).

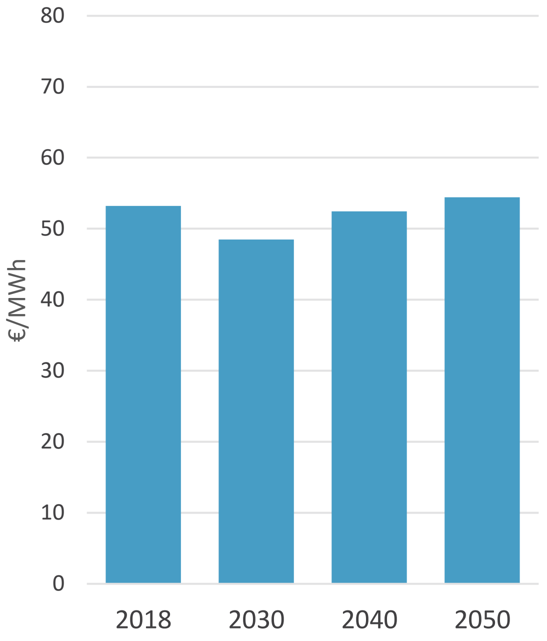
1. Bioenergy-fuelled combined heat and power (CHP) and district heating are other key technologies to decarbonise heat.
2. The efficiency of heat pumps is typically expressed as coefficient of performance (COP), but here, a percentage is used to make the number comparable. For the efficiency range stated, air-source heat pumps are on lower and ground-source heat pumps in the upper side. The efficiency of a heat pump varies with the temperature lift (i.e., difference between input and output temperature) and is therefore lower during colder ambient temperatures.

Distribution grid fees stay flat to 2050: investment costs offset by higher overall electricity consumption

Estimated distribution revenue requirement and distribution electricity consumption

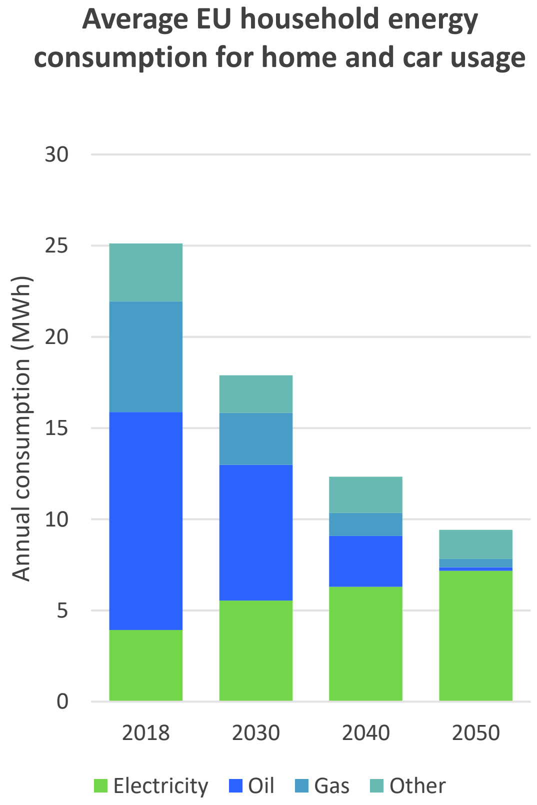


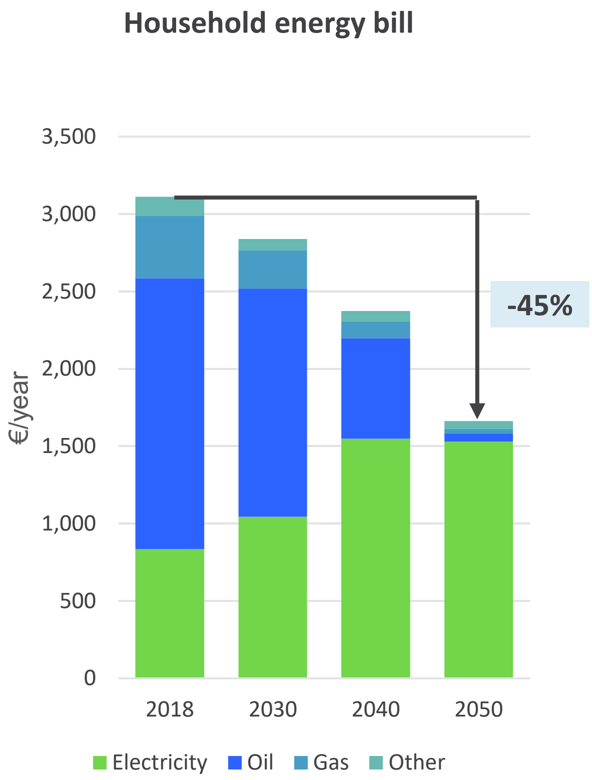
Estimated distribution fees



- This GfS report establishes that about €67 billion annually, roughly twice the current level of investment, is needed to 2050 to build the distribution infrastructure to enable REPowerEU.
- As new investments are recovered progressively over 40 years or more, electricity distribution fees do not directly go up as new investment is added. The amount that distribution grids can recover is called allowable revenue and is composed of the following factors. (allowable revenue = capex return + depreciation + operations and maintenance)
- However, the electricity distribution fee is affected by electricity consumption. As investment goes up, electricity distribution consumption increases in parallel due to electrification, meaning that investment is shared across a larger customer base.
- This analysis finds that electricity distribution fees are expected to remain flat to 2050, as the increase in allowable revenue from higher grid investment is offset by the increase in electricity consumption.

European household energy bills could halve by 2050 in a net-zero scenario





The net-zero REPowerEU scenario for Europe assesses all energy fuel sources and includes high end-use electrification. GfS investment, along with other electricity supply investments, could reduce the average EU household bill by 45% across all energy sources by 2050.

Furthermore:

- Total energy need is reduced due to direct electrification and other energy-efficiency gains (see page 53).
- The growing volume of electricity offsets investment in the distribution grid and other supply infrastructure.

The extent of future energy bill reductions will vary across countries. It will depend on:

- The level of electrification and energy-efficiency gains achieved
- The retail electricity price determined by the unique characteristics of a country's electricity system and mix
- The costs of investment in assets needed to deploy the energy transition

Note: The electricity bill calculation includes supply, transmission, distribution and tax. The methodology is described in Appendix F . Price models for Small and medium-sized enterprises and industrial customers are not available.

Grids for speed will boost job creation

Today

250–280k
direct jobs

Direct jobs in planning, operating and maintaining distribution networks, which make up around a quarter of direct energy sector jobs in EU27

500–640k
indirect jobs

Indirect jobs in manufacturing electricity distribution equipment (transformers, control equipment, lines, etc.) and in the construction of utility projects

750–920k
direct and indirect jobs
0.42%
EU27 workforce

Combined, direct and indirect jobs in electricity distribution account for 0.38-0.46% of the EU27 workforce

Tomorrow

To deliver the 21st century distribution grid and meet DSOs' evolving requirements (see page 17) for planning, building and operating the distribution grid, existing job profiles are expanding.

At the same time, new jobs are being created to strengthen engagement with new customers (e.g., in the transportation and heat sectors) and with stakeholders, as well as in meeting new customer expectations and delivering new market services.

Digitalisation will play a key role in enabling utility processes to scale. Digital innovation will help to:

- Increase LV visibility using more sensors and by harnessing smart meter data, supported by data analytics and algorithms
- Manage customer engagement and connection processes for rapidly increasing volumes of new connections

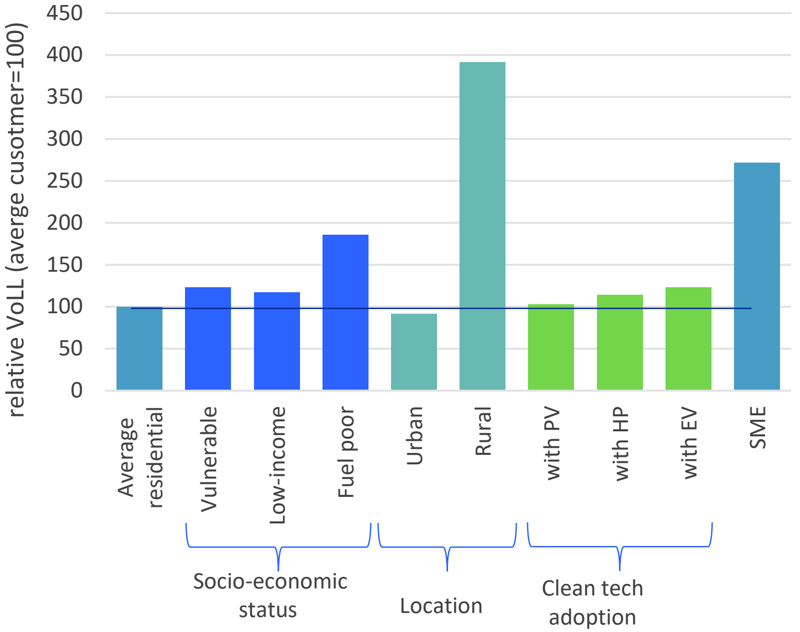
> 2 M
additional direct and indirect jobs by 2050 in distribution grids

Digitalisation will also increase productivity in the manufacturing and construction sectors and create new digital jobs. However, digitalisation cannot offset the increase in workforce that is needed to deliver increased grid investment needs.

Source: Eurostat (2021), Structural business statistics
Note: The job creation estimate is likely conservative, an IMF working paper finds that each €1 million invested in the energy sector creates four to thirteen jobs. Based on this assumption, the additional investment of €600 billion EUR in grid investment by 2050 will create two million to seven million jobs. Source: IMF (2021), The Direct Employment Impact of Public Investment.
For more on jobs, see Eurelectric (2024), Wired for Tomorrow.

Ongoing reliability and resiliency from grids for speed

VoLL values for specific DSO in function of socio-economics, location and clean tech adoption



In 2021, power outages cost the European economy more than €50 billion (EEA). The growing role of electricity in the energy mix, up from 20% today to 60% by 2050, and the increasing prevalence of adverse weather events are set to increase the cost of outages and the value of reliable supply to customers.

The value of lost load (VoLL) denotes the monetary cost that electricity customers place on unserved electricity, which happens when supply fails to meet demand (e.g., due to outages or insufficient capacity).

The exact value of VoLL varies, dependent on methodology, time of day, type of customer, etc.

Crucially, however, unserved electricity is valued at 100 times more than the actual cost of electricity itself (around 0.28€/kWh in 2021) for residential connections, and significantly more for SMEs and industrial customers.

Among residential customers, the socio-economically challenged, rural communities, and those using heat pumps and EVs, etc., value reliability more highly than other groups.

For as long as lost electricity is valued more highly than it costs, and while outages continue to cost the economy billions, a reliable electricity supply remains imperative.

Source: Electricity North West, The Value of Lost Load (2018).

Note: A detailed assessment of value of security of supply is beyond the scope of this report. VoLL represents a typical customer, but individual businesses and households can experience significantly different impacts from electricity outages. For instance, a power cut might be a slight inconvenience for a residential home during holidays, but it could cause significant financial harm to a domestic customer running a business from home or a business customer that relies on continuous power supply, such as a data centre or a manufacturing plant. Also, VoLL does not capture broader non-monetary costs, such as loss of customer trust, stress, inconvenience and even health risks. Finally, VoLL does not necessarily increase linearly with the duration of the outage. Short interruptions might cause minor disruptions, while prolonged outages can result in exponentially greater damage, as systems fail and products or materials are spoiled.

Grids for speed: the massive risk of underinvestment for decarbonisation

Without the grids for speed investment, even a grid investment growth stagnating at 1.5% annually will create a €605 billion shortfall in distribution grid investment by 2050. This would mean that connections for three-quarters of all heat pumps, EVs, renewables and low-carbon industry technologies would not materialise meaning carbon emissions would go up and decarbonisation targets would be missed.

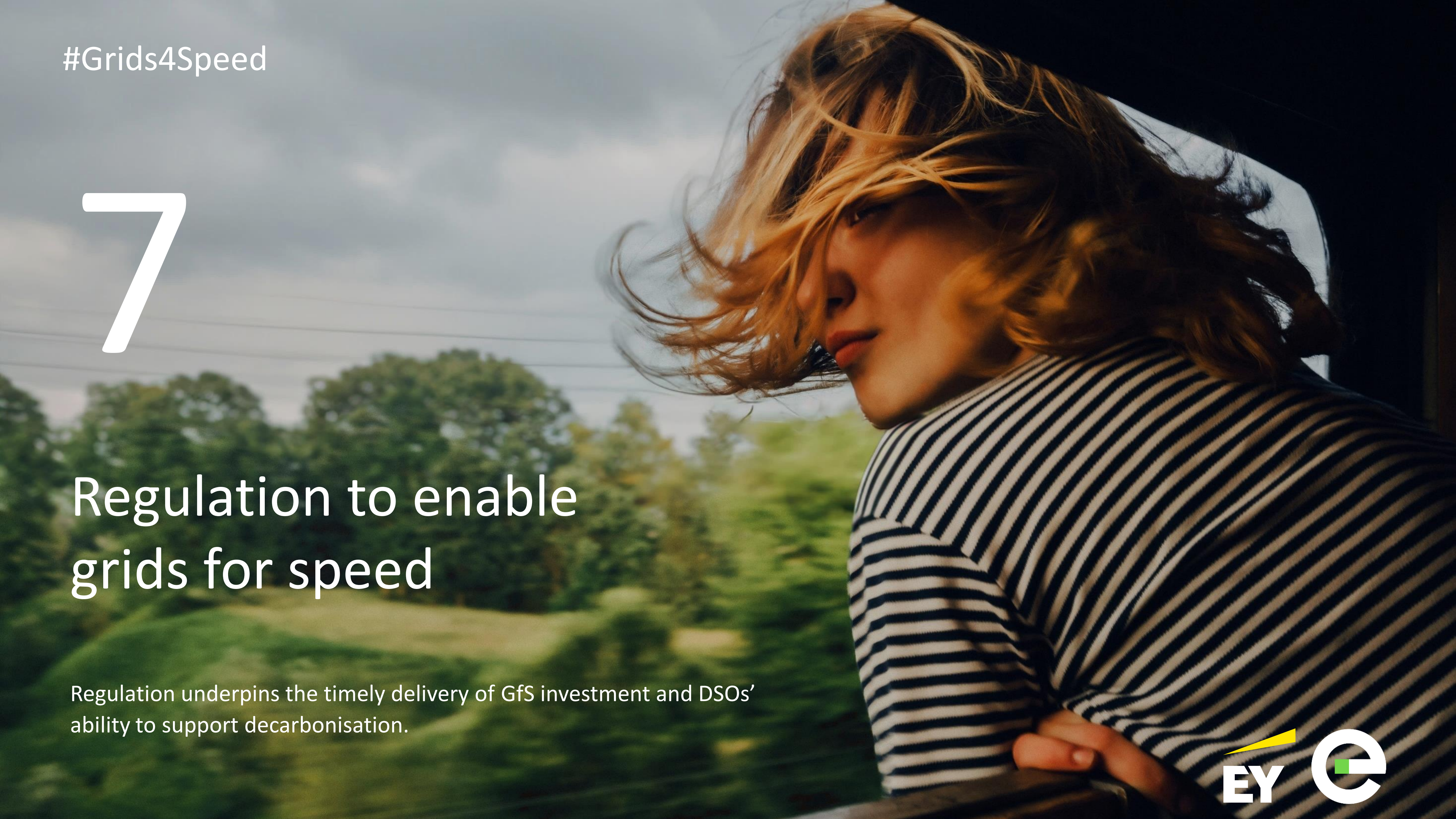
Failure to accelerate gris for speed investment means 74% of connections in key technologies would be missed:

- 190 million heat pumps not connected
- 120 million EV chargers not connected
- 1220 GW of distributed renewables not connected
- 240 TWh of missed industrial electrification

32%–37% of total emission reductions required to achieve decarbonisation

1800–2060 Mt CO_2eq additional CO_2 emissions by 2050

Note: The percentage of emission reductions is relative to 1990 emissions.



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7

Regulation to enable grids for speed

Regulation underpins the timely delivery of GfS investment and DSOs' ability to support decarbonisation.

Summary regulatory analysis

Regulatory enablement

- Though DSOs are regulated differently across the EU27+Norway, regulations have enabled them to jointly invest €33 billion annually between 2019 and 2023.
- Regulation must now transform if DSOs and NRAs are to deliver investment at a larger scale than in the past 30 years.
- Regulation must focus on empowering DSOs to confidently make investment choices.
- Regulation must support emerging grid strategies (e.g., anticipatory investment and grid-friendly flexibility) that can reduce the investment required by around 18% from €67 billion to €55 billion annually.

Regulation to fit DSO needs

- DSO investment will be driven by growth in either demand or in DG, or a mix of both drivers (at the same or different voltage levels).
- Most GfS regulatory reforms will benefit all DSOs. However, to be most effective, regulatory change should also target the main investment drivers.
- Regulation must empower national dialogue and decision-making between Member States (MS), NRAs, TSOs and DSOs to account for national variations.

Implementation of a new regulatory framework

- Regulatory change must be implemented quickly to reflect incoming reforms in European regulation, such as the EMD agreement. New initiatives must be developed and implemented as soon as possible this decade to support the acceleration of investment through to 2040.

Regulatory changes for grids for speed

Empowerment to scale investment

Measures support DSOs in competition for investment by providing confidence and regulatory certainty. They include an attractive risk/reward profile on investment, with appropriate prioritisation and regulatory oversight.

Improved regulatory and enabling processes

By allowing decisions to be made quickly, transparently, objectively and with confidence, regulation supports DSOs and users in prioritising decisions.

Financial support for network investment

By keeping financing costs allowances up to date, the gap between investment and start of cost recovery is minimised.

1. An anticipatory investment is one that proactively addresses expected developments, looking beyond immediate needs of generation or demand, assuming with sufficient level of certainty that new generation and demand will materialise, notwithstanding potential low utilisation in the short term. (2) Flexible solutions refer to contracts or other operational mechanisms that provide voluntary adjustment of the generation injection and/or the consumption power in response to an external signal.

The assessment of regulatory analysis builds on key investment needs for DSOs

Our regulatory assessment set out on this section focuses on the key blockers that must be removed to empower DSOs to deliver the investment and management of the networks needed for GfS. We outline the structure of the regulatory analysis below.

Key investment analysis needs

- Input to regulatory analysis and discussed in sections 2 to 5 of this report

Current regulatory landscape

- Input to regulatory analysis based on DSO experiences and published reports

Regulatory challenges block GfS delivery

- Outline of macro challenges to delivery of GfS and the DSO needs

Solution

- Outline of top regulatory tools to address the regulatory blockers to build the GfS regulatory toolbox.

Implementation and targeting

- Implementation of solutions
- Targeting of regulatory reforms
- Focus areas on new regulatory tools implementation

Regulatory environment integral to DSOs' ability to invest

Regulatory framework

- Regulatory frameworks are the rules, principles and processes set up by the EU, MS and NRAs. They guide, control or influence the behaviour, actions and operations of regulated businesses, such as DSOs.

Incentives and obligations

- Incentives and obligations are regulatory tools that often form part of remuneration frameworks to encourage or require DSOs to deliver on requirements that are deemed beneficial to society. These incentives have a financial impact on DSOs.

Remuneration framework

- Remuneration frameworks are systems or structures outlining how DSOs are compensated for their services.
- They regulates how DSOs recover investment and operational costs, and make profit through grid tariffs on consumers and electricity producers.

Regulatory asset base (RAB)

- RAB denotes the value of the capital investment of a regulated company.
- The depreciation of the RAB allows for recovery of investment costs over the life of an asset.
- The cost-recovery profile influences the attractiveness and financeability of the investment.

Investment cycle

- For DSOs, the investment process starts with grid planning and concludes at the end of asset life.
- The investment cycle is informed by regulatory requirements, restrictions and processes.
- Subject to approval/ benchmarking, investment costs are added to the RAB for cost recovery and assessed for efficiency.

Regulatory system

- Regulatory systems in GfS are either:
  - Incentive-based systems, which use incentives and outputs to incentivise the regulated company
  - Cost+ systems, which aims to return a stable rate of return above costs to the regulated company

Types of remuneration framework

- There are three main types of regulatory frameworks:
  - Revenue cap – sets the maximum revenue a DSO can earn in a year
  - Price cap – sets the maximum user charge for a DSO in a year
  - Hybrid – Sets remuneration based on cost+ system and other regulatory tools

Regulatory period (RP)

- A regulatory period is the timeframe determined by an NRA during which:
  - Terms and conditions for grid tariffs are set
  - Revenues, outputs, and incentive mechanisms for DSOs are also set

Separate and joint treatment of capex/opex

- Remuneration frameworks can benchmark or consider allowances for capex and opex either individually or combined. These allowances can then be used either for capex or opex separately or interchangeably.

Please see Appendix E for additionally defined terms.

Regulation today across the EU27+Norway

Wide-ranging DSO regulatory frameworks have been adopted across the EU27+Norway. Despite these differences (outlined in the table below), DSOs experience common challenges in expanding investment to deliver GfS.

Remuneration Framework	System	Duration of RP	Countries	Sub-categories		
				Treatment of capex and opex	Adjustments to capex	Adjustments to opex
Revenue Cap	Incentive-based	1–5 Years	Austria, Czechia, Denmark, Estonia, Germany, Ireland, Netherlands, Portugal, Spain, Sweden and Norway,	**Separate capex and opex**: Czechia, Estonia, Ireland, Spain and Sweden	**Yes:** Czechia, Denmark, Germany, Ireland, Netherlands, Norway and Spain	**Yes**: Austria, Czechia, Denmark, Ireland, Norway, Portugal and Spain
				Joint capex and opex: Austria, Denmark, Germany, Netherlands, Norway and Portugal	**No:** Portugal and Sweden	**No:** Estonia, Germany and Sweden
Price Cap	Incentive-based	1–5 Years	Hungary, Lithuania, Poland and Romania	**Separate capex and opex** for all	**Yes:** Hungary, Lithuania, Poland and Romania	**Yes:** Hungary, Lithuania, Poland and Romania
					No: 0	**No:** 0
Hybrid	Cost+[1] with incentive regulation elements	1–4 years	Greece and Italy[2]	**Separate capex and opex** for all	**Yes:** Greece and Italy	**Yes:** Greece and Italy
					No: 0	**No:** 0
Prevailing models[3]	**Incentive based regulation is most widely adopted**			**Separate capex and opex: 58%**	**Yes: 93%**	**No: 68%**

1. Cost+ remuneration framework, which is followed in some EU countries such as Belgium and Croatia, is out of the scope of this report as none of the survey respondents indicated using the approach.
2. From 2024 onwards, Italy will shift to a totex framework, jointly considering capex and opex.
3. 'Prevailing model' defined as the model that applies to DSOs that serve the largest share of customers in aggregate across EU27+Norway from our sample data.

Existing regulation challenges scale and pace of GfS investment

Key investment analysis needs for GfS

- **€67 billion investment annually until 2050 to enable energy transition**
- **Anticipatory investment is the most cost-effective emerging grid strategy**
- **Grid investment is front-loaded**
- **Grid-friendly flexibility to support DSO grid management**

Common macro challenges for GfS

- Regulatory and other processes could slow delivery of needed investment in some geographies
- Financial and regulatory constraints and/or investment disincentives over allocates risks to DSOs unless additional network demand is certain
- Economic and societal benefit not prioritised for connections
- Insufficient regulation, incentives or allowances to support grid friendly flexibility

Please see Appendix E for description of the common regulatory challenges within each macro challenge.

Changes to regulatory regime to deliver GfS

What GfS needs

€67 billion investment annually until 2050 to enable energy transition	Anticipatory investment is the most cost-effective emerging grid strategy	Grid investment is front-loaded	Grid-friendly flexibility to support DSO grid management
• Access to capital at a competitive rate of return • DSO confidence for DSOs of cost recovery through appropriate risk and reward mechanisms commensurate with the scale of investment needed • Confidence for DSOs that costs assessments reflects their true cost • Adjustments to opex to reflect higher capex and growth of the grid, including digital solutions • Financial support to invest in new asset performance excellence	• Ability to invest ahead of need where there is a strong supporting rationale. This includes capex for the grid and for digitalisation as well as supporting opex • Ability to consider events and connections far into the future and to streamline investment • Freedom for Member States to prioritise investment to connect new demand and DG to areas where investment will deliver greatest societal benefit • Clarity on the actual number of grid connection requests to support effective DSO decision-making on investment	• Timely recognition of capex needs to support financing • Streamlined regulatory processes and other enablers (such as permitting for grid investment) for DSOs to invest in and meet surging grid requirements • Agile and timely amendments to regulatory frameworks to support a surge in investment	• Remuneration framework allowances to enable DSOs to make best use of grid-friendly flexible solutions • Standardisation of tariff methodologies to generate an effective level of grid-friendly flexibility from market participants and support a rapid and cost-effective energy transition • Flexible connection charges/options • Ability to manage increase in demand driven by greater electrification

Regulatory tools to deliver €67 billion investment annually

Key finding from investment analysis

€67 billion investment annually until 2050 to enable energy transition

Linked regulatory challenge

- **Timeliness of capex and opex recognition in investment mechanism**
- **Affordability concerns**
- **Adapt weighted average cost of capital (WACC) to macroeconomic conditions**
- **Need for additional opex to reflect higher capex**
- **Benchmarking relies on historical costs**
- **Efficiency targets limiting maintenance to achieve operational excellence**

Top tools to address regulatory challenge

- **Regularly monitor and recognise investment at pre-determined points in time,** so that capex and opex are adjusted and accounted for in a timely, transparent, and regulatory certain manner.
- **Make greater use** of non-tariff funding for investment to allow for projects to develop and be implemented that will have a significant impact in enabling the EU27+Norway to meet its overarching decarbonisation targets.[1]
- Update expected cost of debt measures in the remuneration framework to **reflect** the current cost of capital environment and **pace of investment** in expansionary phase of the grid, with a balance towards encouraging rather than dampening investment.
- **Update or delay cost benchmarking** to capture current costs and prices or allow demand for grid investment to materialise.
- **Increase efficient allowances for operational excellence to** enable DSOs to make best use of existing grid.

1. Please see focus discussion on role of non-tariff funding on page 78.

Regulatory tools for anticipatory investment

Key finding from investment analysis

Anticipatory investment is the most cost-effective emerging grid strategy

Linked regulatory challenge

- **Lack of anticipatory investment mechanisms**
- **Short investment horizon**
- **Economic and societal benefits not prioritised for connections**
- **Lack of mechanism to reduce overasking for capacity**

Top tools to address regulatory challenge

- **Fast-track and streamline approvals and permitting of projects ahead of confirmed need,** based on expected future DSO grids needs given renewable energy targets, with continued monitoring and ability to respond to evolution of the plan.
- **Link efficiency benchmarks[1] to the estimated societal benefits of investment,** including whole energy system, system security and decarbonisation targets, so that innovation is still possible and more focused on when it has most impact.
- **Link investment horizon projections** to 10- to 15-year DSO NDPs, with adequate mechanisms, including strong cooperation between DSOs and TSOs without increasing bureaucracy.
- **Allow** Member States, where needed, to set connection prioritisation through appropriate cooperation between Member States, NRAs and DSOs linked to societal benefit of new connection tailormade to local challenges without increasing bureaucracy.[2]
- **Include in** connection regime mechanism that **incentivises users to only request connections that are** needed and not benefit from overasking capacity.

1. Efficiency benchmarks is a standard or point of reference used by NRAs within remuneration frameworks to assess efficiency of operational and economic performance of electricity utilities.
2. As part of this solution, the EU Commission should clarify that non-discrimination requirements enable prioritisation of connections by Member States based on objective criteria defined at national level via amendment to Article 31 paragraph 2 of electricity directive as amended by EMD.

Regulatory tools for front-loading grid investment

Key finding from investment analysis	Linked regulatory challenge	Top tools to address regulatory challenge
Grid investment is front-loaded	Cost of delays in capex recognition	**Regularly monitor and recognise investment at pre-determined points in time,** and adjust revenue to reflect the cost of any gap between investment made and cost recovery.
	Lack of efficient and agile approval/permission processes	**Expedite investment approval process for strategic grid projects** and allow adjustments to the RAB to prevent the risk of financial disallowance.
	Insufficient ability to amend investment plans	Create agile provisions **to amend investment plans post approval on a need/timely basis.**
	Lack of coordination among RES development and grid development	**Streamline permitting for grid development with a 'bundled' approach (for example, RES project permit linked to grid extension permit).**

Regulatory tools to support grid-friendly flexibility

Key finding from investment analysis	Linked regulatory challenge	Top tools to address regulatory challenge
Grid-friendly flexibility to support DSO grid management	Insufficient allowances for grid-friendly flexibility	Include **allowed expenditure for grid-friendly flexibility** as well as create **targeted incentives and outputs for grid-friendly flexibility and smart grids** in the remuneration framework.
		Increase efficient DSO allowances in the regulatory period and set targets to enable DSOs to best decide when to invest in capex/opex solutions.
	Active grid management through tariff variation not always applied	**Review** current tariff constraints and standardise tariff methodologies. This should include the **introduction of time-variant charges** and consideration of defining tariffs by customer type to better reflect costs.[1]
	Connection agreements often do not reflect grid capacity	**Introduce flexible connection agreements** with a transparent process for converting to a firm connection. Permanent flexible connection agreements may also be offered, only when agreed by both parties and where fair market alternatives for other connection agreements exist.[2]

1. National discussions are needed on the appropriate balance between cost reflectivity and complexity of time-variant charges to ensure underlying level of grid-friendly flexibility from system users.
2. Please see focus area on flexible connection (page 81) for description of approach on using flexible connections agreements to accommodate greater grid connection demands.

The GfS regulatory toolbox

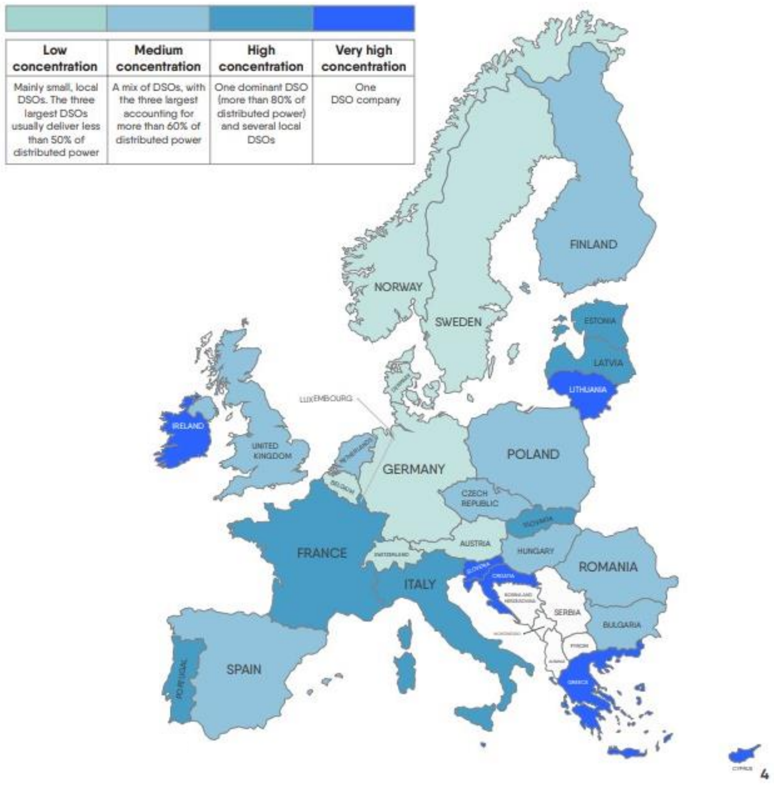
The regulatory tools described in previous slides can be grouped into three categories.

	Empowerment to scale investment (ESI)	Improved regulatory and enabling processes (IRP)	Financial support for grid investment (FSG)
Need to enforce existing legislation	• **ESI1 –** Include **allowed expenditure for grid-friendly flexibility** as well as create targeted incentives and outputs for grid-friendly flexibility and smart grids in the remuneration framework. • **ESI2 – Increase efficient DSO allowances and set targets** to enable DSOs to best decide when to invest in capex/opex solutions.	• **IRP1 – Review current tariff constraints and the standardisation of tariff methodologies.** Include the **introduction of time-variant charges** and consider defining tariffs by customer type to better reflect costs. • **IRP2 – Introduce flexible connection agreements** with transparent process for converting from flexible to firm connection Permanent flexible connection agreements may also be offered where agreed by both parties and fair market alternatives exist. (see page 80). • **IRP3 – Link investment horizon projections** to DSOs' 10- to 15-year NDPs.	• **FSG1 – Update expected cost of debt measures** to reflect macro-economic conditions. • **FSG2 – Update or delay cost benchmarking** to capture current costs or allow demand to materialise. • **FSG3 – Regularly monitor and recognise investment** needs at pre-determined points, so that capex and opex are adjusted and accounted for, in a timely manner. • **FSG4 –** Increase **efficient allowances** for operational excellence. • **FSG5** – Adjust **revenue** to reflect the cost of any gap between investment made and cost recovery.
New legislation needed	• **ESI3 – Link efficiency benchmarks to the estimated societal benefits of investment,** enabling innovation in areas where it can have the most impact. • **ESI4 – Allow** Member States**,** as needed, **to set their own connection priorities (see page 81)** tailormade to local challenges without increasing bureaucracy**.**	• **IRP4 – Fast-track and streamline approvals of grid projects** ahead of confirmed need based on expected future DSO grid needs (see page 79). • **IRP5 – Include** in connection regime mechanism that **incentivises users to only request connections that are needed** and not benefit from overasking capacity. • **IRP6 – Expedite the investment approval process for strategic projects** and allow adjustments to the RAB to mitigate financial disallowance risk. • **IRP7 –** Create agile provisions to **amend investment plans post-approval** on a need/timely basis. • **IRP8 –** Streamline permitting for grid development with 'bundled' approach for grid and project.	• **FSG6 – Make greater use of** non-tariff funding for investment to allow for projects to be developed and implemented (see page 78).

Please note that top solution numbering does not represent a ranking between options.

DSO archetypes differentiate challenges across the EU27+Norway

GfS investment will not be uniform across the EU27+Norway. GfS uses DSO archetypes to assess these different challenges and articulate the importance of targeted regulation.[1]



Source: Eurelectric , 2020.

Observations

- There are more than 2,600 DSOs in the EU27+Norway.[2] DSOs vary by number, level of demand served, amount of DG in their networks, ownership (private or publicly owned by national or municipal governments), and size (depending on whether they are national or regional DSOs).
- Uniform regulatory solutions may not fit every DSO type in every location.
- Some solutions must be targeted to where they are most relevant.

Implications for regulatory analysis

The use of DSO archetypes allows GfS to better articulate the specific regulatory needs of diverse DSO types across the EU27+Norway.

1. We note that, in specific areas, including islands, regulation may need to be further targeted. More on specific challenges of islands in Appendix E.
2. Eurelectric 2020 and updates on number of Norway DSOs.

Why the regulatory needs differs across archetypes

All DSOs will experience growth in demand and DG. However, the impact on DSOs will be dictated by the main driver[1] of growth. They are illustrated here as three archetypes.

Archetype A: Primarily demand-led drivers

Description of driver

Growth in demand due to electrification of heating, transport, etc. is the main driver, in relative terms, for investment to 2050.

Unique challenge

Investment is driven by the individual decisions made by large numbers of customers, over which the DSO has little visibility or control.

Relevant tools

Tools that incentivise behaviour across multiple market participants.

Archetype B: Primarily DG-led drivers

Description of driver

Growth in DG due to new wind and solar producers, batteries and electrolysers, etc. is the main driver, in relative terms, for investment to 2050.

Unique challenge

Connecting multiple market participants while ensuring that the grid operates within its technical parameters despite significant increases in load.

Relevant tools

Tools that focus on grid access and redistribution of costs.

Archetype C: Mixed demand- and DG-led drivers, operating at the same or different voltage levels

Description of driver

Both demand and DG (which may occur at different voltage levels) will equally drive investment need to 2050.

Unique challenge

The need to invest at scale and optimise growth in both DG and demand on grid assets.

Relevant tools

Tools that balance both demand and DG growth, and are agile.

1. We note that in specific areas, including islands, regulation may need to be further targeted.

Archetype A: characteristics of demand-led DSOs

This DSO will mostly invest to increase its capacity to meet growth in demand rather than to support increased DG resources. This will impact network visibility and the tools needed by DSOs to deliver GfS.

Description of driver

- Growth in demand from consumers is the primary driver for DSO investment until 2050.
- Demand growth comes from increased electrification of heating, transport, etc.
- Large numbers of consumers (including residential, commercial and industrial) will likely drive the demand growth, with a smaller impact (relative to other archetypes) from each consumer on overarching DSO investment needs.

Unique challenge

- This DSO will have reduced DSO visibility over the main driver of its investment needs.
- Investment is likely to be driven by demand decisions made by large numbers of customers, which are unlikely to be reported to the DSO.
- Increased demand from electrification is unlikely to be distributed uniformly across geographical areas, requiring DSOs to invest in several parts of the grid.

Relevant tools

- This DSO is more likely to require tools that incentivise the behaviour of a large number of consumers.
- Incentivising behaviour of market participants is more important than setting specific requirements for individual consumers.

Archetype B: characteristics of DG-led DSOs

This DSO will mostly invest to increase its capacity to connect new DG resources rather than to meet growth in demand to 2050.

Description of driver

- The main driver for investment to 2050 is growth in DG.
- Increases in DG could come from new wind and solar producers, batteries and electrolysers.
- The location of DG is likely to be driven by both the availability of renewable resources (greater incidence of solar or higher/more constant wind speeds) as well as its ability to connect to the grid.

Unique challenge

- This DSO will have to connect large numbers of market participants, bringing significant increases in system load, while ensuring that the grid continues to operate within its technical parameters.
- Greater availability of renewable resources increases investment needs in specific areas of the network.

Relevant tools

- This DSO is more likely to need tools that support grid access, enabling it to manage new connections in advance of network reinforcements.
- As new connection requests are more likely to come from individual DG projects, this DSO can target DG projects rather than its wider consumer base.

Archetype C: characteristics of demand- and DG-led DSOs

This DSO will mostly invest to increase its capacity to meet both growth in demand and connect new sources of DG, which may occur at the same or different voltage levels (e.g., demand in LV, and DG in MV).

Description of driver

- Demand and DG will equally drive investment needed to 2050. However, this growth in demand and DG may or may not occur at the same voltage levels.
- Large numbers of consumers (including residential, commercial and industrial) will drive demand growth. DG growth will be geographically influenced by the availability and constancy of renewable resources and their ability to connect to the grid.

Unique challenge

- This DSO will have to invest at scale and optimise investment to meet growth in both demand and DG.
- To the extent that demand and DG connect at the same voltage level, it is likely that this DSO will have to optimise investment to meet more uncertain load level.
- To the extent that demand and DG connect at different voltage levels, it is likely that this DSO will have to invest in both areas of its network at the same time.

Relevant tools

- This DSO will need tools that enable it to balance both demand and DG growth.
- Given the uncertain impact of load on connections, this DSO is likely to need agile regulation that will allow it to respond to changes as they occur during the regulatory period.

Top tools for DSO archetypes

Archetype A: primarily demand-led drivers

Archetype B: primarily distributed generation-led drivers

Archetype C: mixed demand and DG-led drivers, operating at the same or different voltage levels

Common tool: IRP4 – Anticipatory investment mechanism
Fast-track and streamline approvals of projects ahead of confirmed need based on expected future DSO grid needs.

Common tool: ESI2 – Efficient allowances for network management
Increase efficient allowances to enable DSOs to best decide when to invest in capex/opex solutions.

Common tool: FSG1 – Reflect changes in cost of debt
Update expected cost of debt measures to reflect macro-economic conditions.

Common tool: FSG6 – Non-tariff funding
Make greater use of non-tariff funding to minimise burden on demand tariffs.

Archetype A	Archetype B	Archetype C
Targeted tool: IRP1 – Grid tariff review Review current tariff constraints and standardisation of tariff methodologies.	**Targeted tool: IRP2 – Flexible connection** Introduce flexible connection agreements where appropriate.	**Targeted tool: ESI3 – Maximise benefit** Link efficiency benchmarks to estimated societal benefits from investment.
Targeted tool: ESI4 – Connection prioritisation Allow MS, where needed, to set connection prioritisation.	**Targeted tool: IRP5 – Connection regime** Connection regime incentivises only request connections that are needed.	**Targeted tool: IRP7 – Plan adaptability** Create agile provisions to amend investment plans on a timely basis.

Regulatory toolbox needs quick implementation

Given grid investment will be front-loaded, proposed changes to the new regulatory framework must be implemented as soon as possible. The green box below highlights opportunities to use the DSO remuneration reviews to implement reforms. These are scheduled in **more than 15 countries** in or before 2027, and across all countries by 2030. Where reviews occur after 2027, **in-period reviews** may be needed.

Indicative start of DSO regulatory periods based on RP length

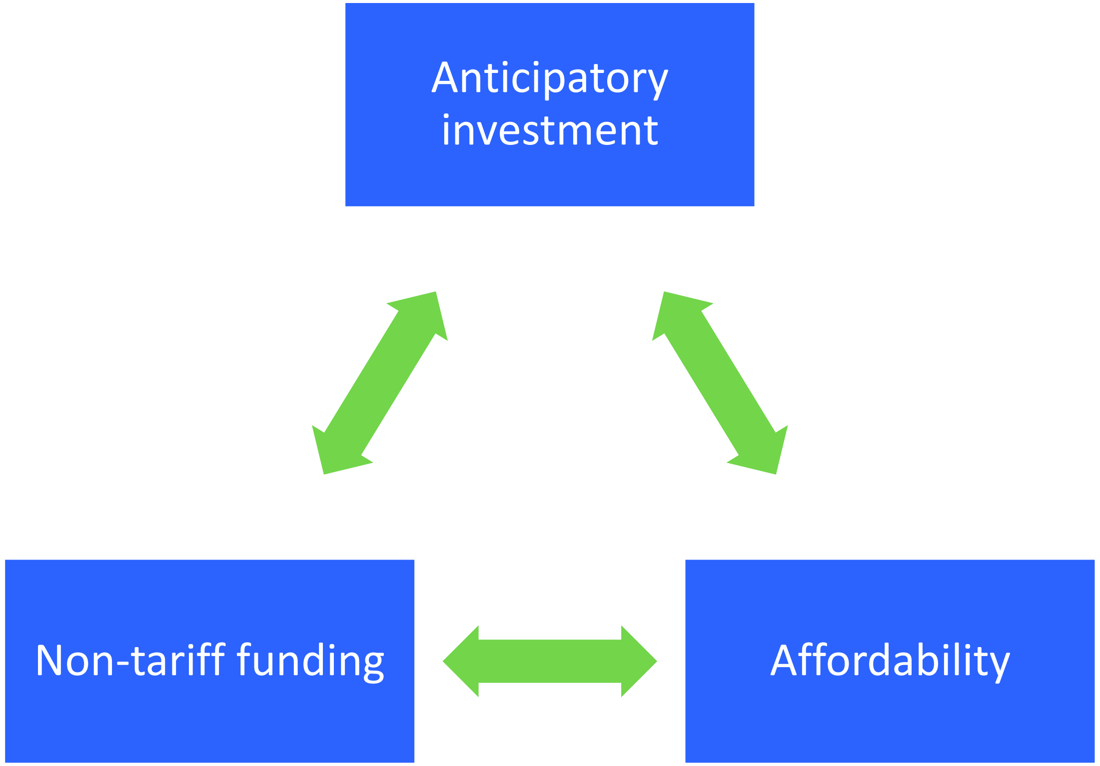
Country	RP length	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Austria	5 years				■					■					■					■		
Belgium	5 years					■					■					■					■	
Croatia	1 year	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Cyprus	5 years			■					■													
Czechia	5 years		■					■					■					■				
Denmark	5 years				■					■					■					■		
Finland	4 years	■				■				■				■								
France	4 years		■				■				■				■				■			
Germany	5 years					■					■					■					■	
Greece	3–5 years		■				■				■				■				■			
Hungary	4 years		■				■				■				■				■			
Ireland	5 years		■					■					■					■				
Italy	4 years	■				■				■				■				■				■
Lithuania	5 years	■ (small)		■			■ (small)		■			■ (small)		■			■ (small)		■			■ (small)
Luxembourg	4 years		■				■				■				■				■			
Netherlands	3–5 years			■					■					■					■			
Poland	Annual	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Portugal	4 years			■				■				■				■				■		
Romania	5 years					■					■					■					■	
Slovakia	5 years				■					■					■					■		
Slovenia	1 year	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Spain	6 calendar years	■						■						■						■		
Sweden	4 years	■				■				■				■				■				■
Norway	Annual	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Source: CEER, Report on Regulatory Frameworks for European Energy Networks 2023.

Notes: Start of new regulatory periods for large DSOs: ■; small DSOs: ■; current RP of Latvia and Estonia are not explicitly stated; Bulgaria and Malta are excluded as their RP information is not available. Depending on national legislation, the remuneration framework may be fixed for multiple regulatory periods.

Focus area: DSOs must optimise tariff-based investments with non-tariff funding support

Our analysis focuses on regulatory policy, but it is important to note the impact that non-tariff funding[1] on top of tariff-based investment can have in supporting anticipatory investment.



Observations

- Investment ahead of need is the most cost-efficient grid investment strategy.
- However, the risk of investing early is that existing EU27+Norway customers are burdened with investment costs ahead of the forecast increase in grid tariff-payer numbers.
- This can increase customer bills and negatively affect affordability in the short term.
- Non-tariff funding removes some costs from current bill payers, while retaining the societal benefit of decarbonisation.

Implications for regulatory analysis

Non-tariff funding can be an enabler to anticipatory investment. Mechanisms must be transparent and carefully designed to avoid unjustified market distortions. This approach should not compromise DSO returns that are needed to support required investments.

1. Non-tariff funding relates to any funding for grid investment that is not recovered from system users via grid tariffs. This could be for example from public sources (both European and national) and private avenues.

Focus area: regulatory changes to support anticipatory investment

Challenge: lack of anticipatory investment mechanisms

- GfS highlights the key role that anticipatory investment (notably strategic up-sizing) must play in delivering the EU's REPowerEU and the Fit for 55 targets.
- The EMD reforms require tariff methodologies to reflect anticipatory investment and allow for costs to be recovered.

New regulatory approach

- We recommend that approvals and permitting for anticipatory investment are fast-tracked and streamlined to secure project go-ahead in advance of confirmed need. Investment will be informed by DSOs' expected future grid needs in order to meet renewable energy targets. Continual monitoring will enable adjustments as projects evolve:
  - Once transposed into national legislation, DSOs' NDPs should become the primary mechanism for projecting anticipatory investment.
  - A fast-tracked and streamlined process must provide adequate incentives for DSOs to make anticipatory investments in a stable and predictable investment environment.
  - Risk assessment must focus on ensuring that the grid is always available, rather than temporarily underused.

Policy actions needed to deliver anticipatory investment as soon as practicable:

1. EU Commission and ACER

- Publish recommendations and guidelines to remove investment caps.
- Allow and incentivise anticipatory investments at DSO and TSO level.
- Confirm regular treatment of investments in tariff regulation.

2. Member States

- Appoint adequate governance organisations.
- Develop indicators to align policies, investments and existing plans.
- Allocate EU funds to DSO and TSO network investment to enable delivery against targets.

3. NRAs

- Revise regulatory frameworks to include and define anticipatory investment.
- Enable fast-tracked and streamlined approval processes for investments ahead of need.

Focus area: flexible connections to address network capacity shortages

Challenge: insufficient grid capacity to offer firm connections to all users

- Shortages in grid capacity can delay connection for new users if all connections need to be firm from the start.
- Flexible connections allow more connections to be made ahead of grid investment. This can undermine business plans for system users if there is no certainty of supply and no compensation mechanism to reflect the value of the flexibility provided to the grid.

Use of flexible connections

- Article 32 of the EMD states that flexible connections can be introduced on a temporary basis ahead of physical reinforcement of the grid to support increased connection to the grid.
- Clear contractual agreements between users and DSOs can mitigate some risks and set out the conditions for when the flexibility can be used.
- Remuneration frameworks must support timely investment in the grid, with a clear timetable for the provision of firm capacity. This should be supported by integrated planning cooperation between Member States, TSOs, DSOs and NRAs, facilitated by European legislation. Permanent flexible connection agreements may also be offered, only when agreed by both parties and where fair market alternatives for other connection agreements exist.

A successful flexible connection framework must address:

1. Transparency

Clarify on application, time limitations, compensation and usage of mechanisms to inform user business plans.

2. Voluntary option

Make flexible connections an option rather than a requirement, with consequential impact on connection times.

3. Compensation

Compensate users that accept a flexible connection for providing flexibility to the system. This can be achieved with discounts or rebates on grid tariffs, or improved connection conditions (e.g., faster connection times) reflecting the value of their flexibility.

Focus area: Dutch case study on prioritising connections

Challenge: connection queues

- Shortage of capacity within the Dutch electricity grid led to connection delays or cancellation for:
  - Businesses, leading to reduced economic activity
  - Hospitals, schools and housing, leading to societal costs.
- Resolving grid congestion requires long-term investment across several areas of the grid over many years.
- Currently, connections are delivered on a first-come, first-served basis.

New approach

- The Dutch regulator published a network code amendment in April 2024 to prioritise grid connections based on societal needs. This reform prevents connections to essential projects, such as hospitals, schools and housing, from being delayed. It also prioritises connections that improve grid constraints.
- Prioritisation is based on clear guidelines developed in conjunction with national and local governments, as well as with TSOs and DSOs.
- Discussions continue on whether grid capacity should be reserved for future, but not yet submitted, connection requests for essential projects, or to accommodate increased demand from households.

Dutch regulation aims to prioritise projects that resolve constraints or deliver societal benefits through three processes:

1. Integrated energy planning

Integrated plan across TSO, DSO, national and local governments and regulators with a community and regional focus.

2. Multi-year investment programme

Agreed plan across TSO, DSO, national and local governments, and regulators for investment on key grid projects.

3. Flexible connections agreements

Flexible connection agreements offered to all customers. However, upcoming EMD regulation requires that a flexible connection is converted into a firm connection after grid reinforcement, which may limit available capacity and may not be optimal in all markets, including in the Netherlands.

GfS hinges on timely regulatory transformation to deliver the required investment

Transformation of regulatory toolbox for GfS

- Current regulation has delivered significant benefits to the EU27+Norway customer, but transformation is needed for GfS to address four main challenges:
- Speed – regulatory and enabling processes could slow the delivery of investment that is needed in some geographies.
- Finance – Financial and regulatory constraints and/or investment disincentives over allocates risks to DSOs unless additional network demand is certain.
- Connections – economic and societal benefit not prioritised for connections.
- Grid-friendly flexibility – insufficient incentives or allowances to support grid-friendly flexibility.

New regulatory toolbox to reflect different DSO needs

- The GfS regulatory toolbox must address three DSO needs:
  - Investment – empower DSOs to scale investment
  - Processes – improved regulatory and enabling processes
  - Finance – financial support for grid investment
- The new regulatory toolbox will comprise measures already supported by legislation as well as new policies yet to be implemented.
- Many tools will benefit all DSOs; others will define specific measures for certain DSOs with unique needs.

Regulatory reforms must be implemented at pace

- The new regulatory toolbox must be implemented as soon as possible to support front-loaded investment:
- Scheduled reviews until 2027 – more than 15 countries in our study have a remuneration framework review up to and including 2027. Reforms should be implemented at scheduled reviews and in all countries by 2030.
- Other countries – implementation must be within regulatory periods to support growth in investment needed today.

#Grids4Speed

8

Scaling and innovating the supply chain

How to scale the supply chain, from materials to manufacturing, permitting to talent acquisition, to deliver grids for speed.

Grid supply chain challenges beyond DSOs' direct control

Collaboration is needed to resolve bottlenecks across the supply chain that cannot be fixed by DSOs alone. Failure to address these challenges will compromise DSOs' ability to deliver grids for speed on time, even if investment is realised.

Materials

- The distribution grid in the EU27+Norway is currently 10 million km long. It will need to grow around 1.7x to 16.8 million km by 2050 to achieve the energy transition.
- The number of transformers must double to 2050.
- To 2030, about 2.5 million metric tonnes of copper and aluminium will be consumed annually to build out the distribution grid.

Equipment manufacturing

- The material supply chain is not very secure. Only a very small amount of material extraction and processing takes place within the EU.
- Lead times for components are increasing, with some increasing twofold in the last two years.
- Prices for components have also risen—on average, 64%.

Procurement

- Public procurement processes for infrastructure projects in the EU27+Norway are governed by principles of transparency, competition, accountability, quality, competition and fairness.
- However, by not prioritising speed, procurement processes for simple projects can take 1–1.5 years and around 1.5–2.5 years for complex projects.
- Procurement can take around half the time of the project itself.

Permitting

- Permitting, similar to procurement, is governed by strict regulation. This has led to lengthy permitting processes; it can take 4 to 10 years for a permit to reinforce the grid.
- If grids are to expand in the way required to achieve climate goals, this process will have to be accelerated.

Talent

- The lack of talent across the supply chain must be addressed to ensure grids can deliver at speed.
- Recent labour surveys show there is a shortage of electrical mechanics and fitters in 15 EU countries.

A net-zero distribution grid hinges on the supply chain's capability to scale

Though this report focuses on conductors and transformers, success hinges on scaling the supply of all component parts, including, for example, switchgear, reclosers, sectionalisers and switches. Ultimately, the strength of the supply chain is determined by its weakest link.

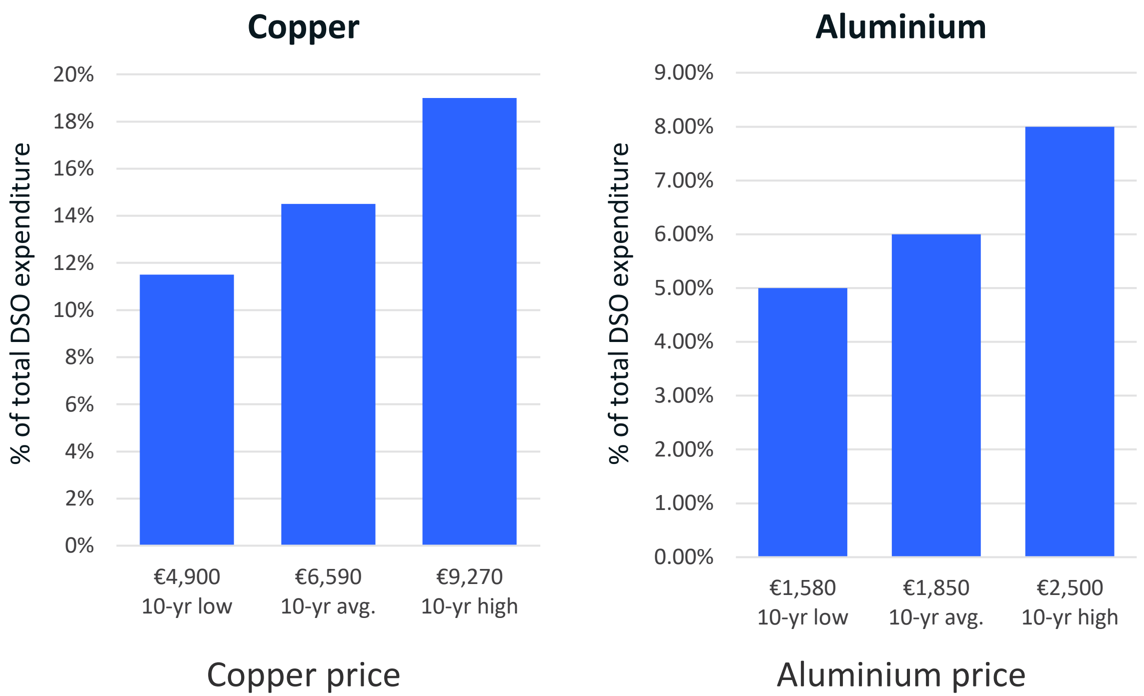
Today		Annual additions 2025–50		2050 net-zero distribution grid	Key materials
4.5mn Transformers	+	+172,000/yr Transformers to 2050	=	9mn Transformers in 2050	Cu, Steel
10mn km Conductor	+	+262,000 km/yr Conductor to 2050	=	16.8mn km Conductor in 2050	Cu or Al, Steel

Note: Al = aluminium; Cu = copper

Demand for copper, aluminium and electrical steel to build out the distribution grid

- Copper conductivity is around 60% higher than aluminium; however, aluminium is about 30% lighter than copper. Overall, it is commonly accepted that aluminium is the best electrical conductive metal by weight, and copper the best by volume.
- For transformers, copper is expected to remain the go-to metal. For electricity lines, aluminium use is expanding significantly, making it already the go-to metal for HV cabling and other use cases.
- From a price perspective, aluminium supply is abundant and therefore more cost-efficient.
- Aluminium represents 6%, and copper 14%, of DSO investments historically. Volatility of the material prices presents a risk to grid development. If not managed properly, it will delay the energy transition. Over the last 10 years, the average price for copper was €6,590, versus a maximum price of €9,270. Conversely, for aluminium, the hike was less severe: €1,850 on average, versus a maximum €2,500.
- The importance of industrial grade steel and electrical steel for the distribution grid cannot be understated either. Significant amounts of steel core are also needed in conductors and transformers.

Share of copper and aluminium costs in new grid investment under different historic price assumptions

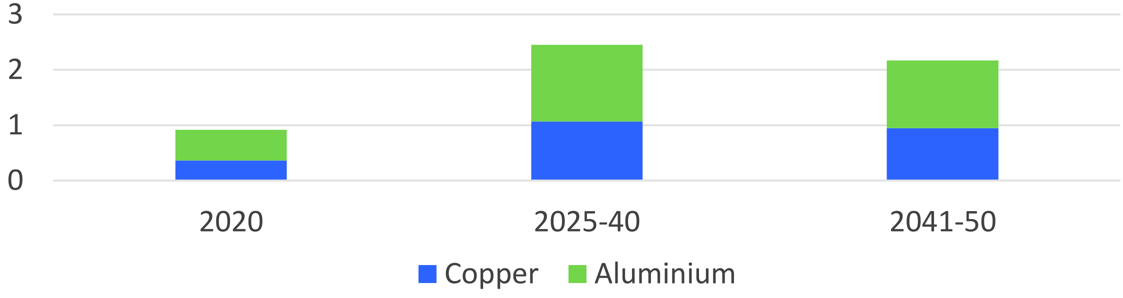


Source: IEA, The Role of Critical Minerals in Clean Energy Transitions (2021).
Note: The shares have been calculated according to total electricity grid investment in 2019, with raw material prices adjusted. Costs are in EUR per tonne.

Note: All commodity prices, including aluminium and copper, were more volatile in (2020–2023) due to the disruption caused by the COVID-19 pandemic.

Energy transition to create potential shortfall in copper supply within the next decade

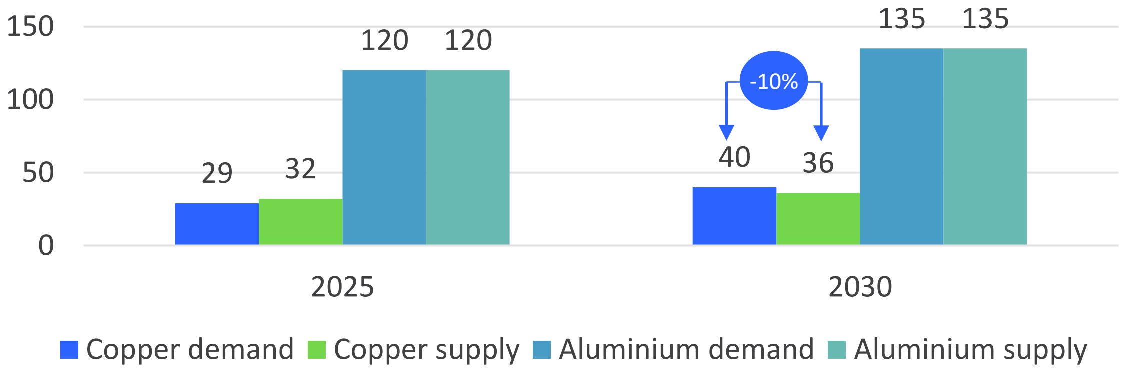
Annual EU27+Norway distribution grid demand for copper and aluminium (million metric tonnes)



- Globally distribution grids account today for around 10% of copper demand and 7% of aluminium demand.[1]
- A sharp increase in DSOs' copper and aluminium needs coincides with a large uplift in global demand in general, not least for other clean energy technology applications.
- Rebuilding the damaged grid in Ukraine may further add to demand for equipment once the war ceases.

- Though global demand for aluminium is increasing, supply can keep up. However, within the current decade, a shortfall in copper is anticipated, unless the industry ramps up capacity quickly.
- A copper shortfall would complicate the immediate acceleration in grid development and GfS. While new copper mines are under construction today, lead times are, on average, 17 years from discovery to production. Integrated supply chain planning across the full material lifecycle is critical. Greater use of secondary sources, including recycling, could help to fill the gap.

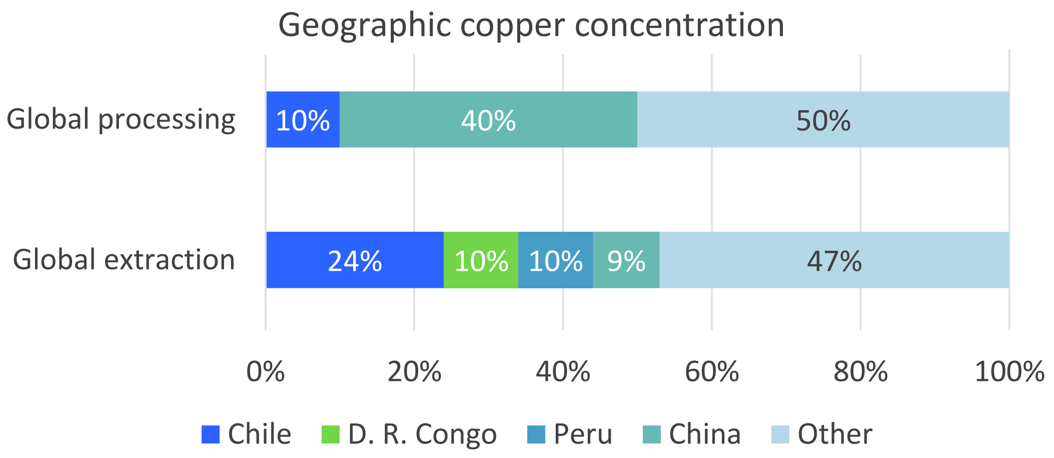
Annual global supply and demand of copper and aluminium (million metric tonnes)

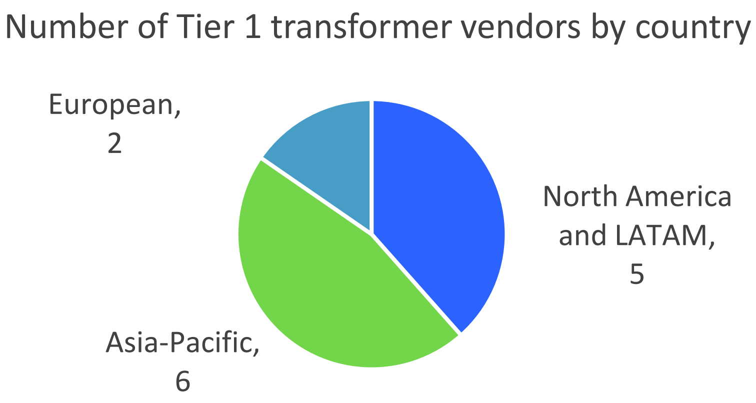


Source: Energy Transitions Commission, Material and Resource Requirements for the Energy Transition (2023).
Note: All commodity prices, including aluminium and copper, were more volatile in (2020–2023) due to the disruption caused by the COVID-19 pandemic.
1. IEA, The Role of Critical Minerals in Clean Energy Transitions (2021).

EU27+Norway exposed reliance on copper

- Copper extraction and mining is concentrated geographically in a certain countries, which increases the risk of supply shortages relative to demand. Geopolitical tensions can generate policy responses that have a disproportionate impact on copper prices.
- The EU27+Norway is exposed to supply chain disruptions as it consumes 15% of refined copper globally. Ongoing global collaboration and fair trade remain critical to Europe's grid development.



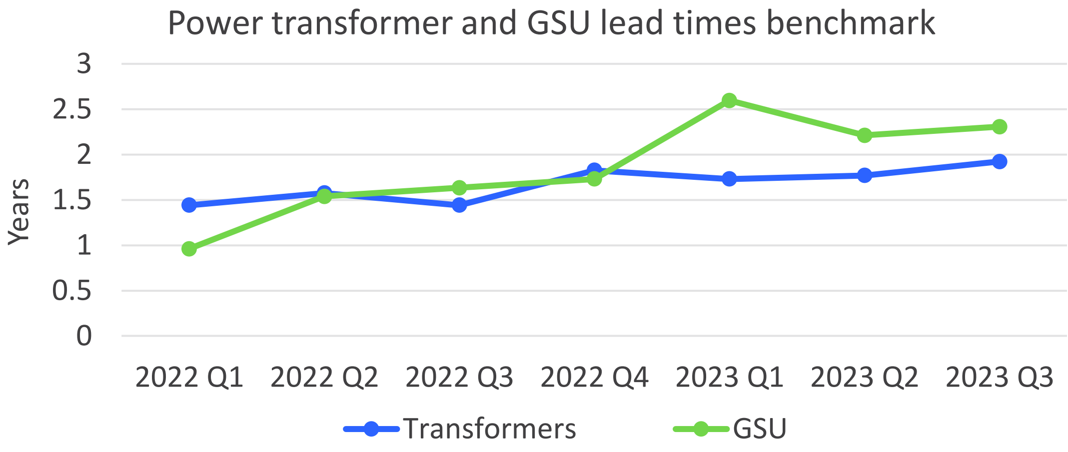


- Manufacturing also carries risks too. Bottlenecks in the manufacturing supply chain are compounded by labour or skill shortages.
- As Europe is not self-sufficient in terms of manufacturing equipment, it must maintain good international trade relations and import, increasingly, fully assembled electrical grid components, such as transformers.

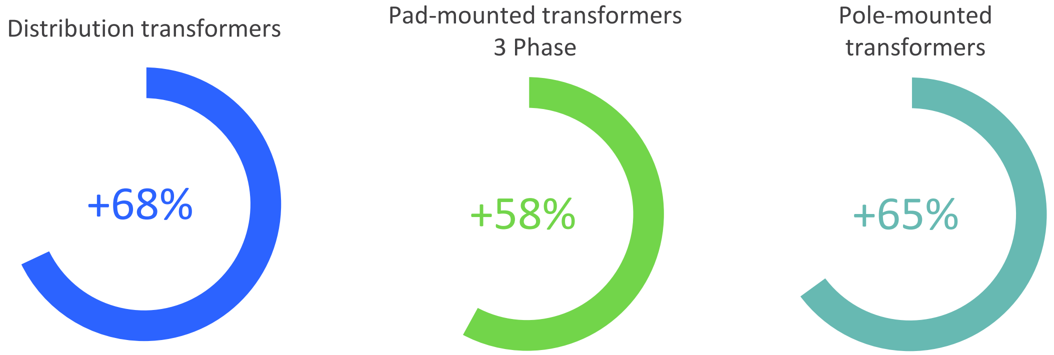
Source: Energy Transitions Commission, Material and Resource Requirements for the Energy Transition (2023); Wood Mackenzie, Power transformers: Supply shortage and high lead times (2023).

Current reality: surge in transformer lead times and costs hinders grid development

- Transformer lead times have risen to 2.2–2.5 years on average in the last couple of years.
- Large transformers, both substation power transformers and generator step-up (GSU) transformers, have lead times ranging from 1.5 –4 years.
- Manufacturers, aware of growing demand from grid companies and developers, and the shortage of transformers and other assets, are announcing increases in manufacturing capacity. The SGB-SMIT Group, for instance, has announced a new production site in Botoșani, Romania.



Transformer price increase (January 2020 – December 2023)



- Transformer prices, dependent on size and applications, have risen 60%–70 % on average since January 2020. This is due to supply chain issues, manufacturing shortfalls and increased commodity prices.
- 45% of transformer costs are soft costs, such as labour logistics and margin. The rest are material costs such as steel, copper and fuel oils.
- Without rapid action, these costs will rise further, making acceleration in GfS unattainable.
- There is an urgent need for collaboration and strategic planning across European policymakers and industries to tackle the challenges collectively.

Source: Wood Mackenzie, Power transformers: Supply shortage and high lead times (2023).

Lengthy public procurement processes not fit for grids for speed

Public procurement processes for infrastructure projects are governed by principles of:

Transparency **Quality** **Accountability** **Competition** **Fairness** **but not** **Speed**

The EU defines the legislative framework for public procurement, but detailed implementation is undertaken at the national level. Though the procurement principles remain critical, the actual rules must be revised to shorten grid delivery projects. Public procurement can easily take 1 to 1.5 years for simple grid construction project, rising to 1.5 to 2.5 years for complex projects, such as the procurement of an advanced distribution management system (ADMS). Procurement times account for roughly half of actual construction or delivery time.

Ways to accelerate procurement without introducing new risks:

- **Time-limited procurement procedures:** A maximum timeframe for the public procurement of strategically important distribution grid projects could speed up development. A similar approach was used at EU level in the Trans-European Networks for Energy policy (TEN-E) for permit granting procedure of projects classified as Projects of Common Interest (PCI).
- **Dynamically updated monetary thresholds:** When inflationary pressures or hikes in supply prices impact DSOs, a greater proportion of projects can fall within the thresholds for more tightly controlled procurement. These additional requirements can delay project delivery. Dynamically updating EU thresholds, or automatically indexing them to the respective (industrial) inflation rate, could accelerate procurement.

Note: Entities operating in the water, energy, transport and postal services sectors are subject to Directive 2014/25/EU on procurement.

The need for speed: permitting for green infrastructure

The problem:

- Accelerated permitting is needed to ensure that the investments recommended in this report can deliver the level of grid build-out that is required.
- Depending on technology type and voltage, permitting can take between four and 12 years. In Germany, for instance, nine to 12 years is typical for a 110 kV line.[1]
- Grid owners and operators need a clear long-term perspective, which translates into demand for the supply chain.

Recommendations:

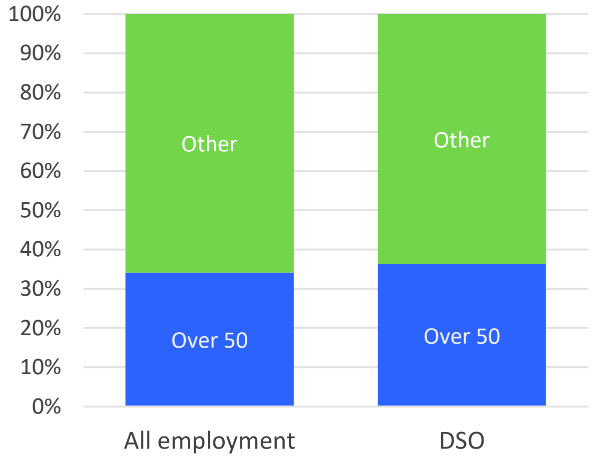
- Expedite permitting process: Explore ways to accelerate the permitting procedures for distribution grids. Germany, for instance, expedites the process and balances varying interests by enforcing strict deadlines for consultations among stakeholders.
- Increase permitting oversight: Escalate permitting decisions to a higher administrative tier, which is better equipped to weigh both local and broader societal considerations, keeping in mind the persistent urgency dictated by the climate crisis.
- Streamline land designation for grid projects: Streamline the process and requirement that DSOs acquiring property for grid expansion reclassify the land for electrical industry use. This is a lengthy process and adds to the overall timeline for launching new projects.

1. ERT (2024), Strengthening Europe's Energy Infrastructure.

Urgent need to recruit, train and upskill workforce

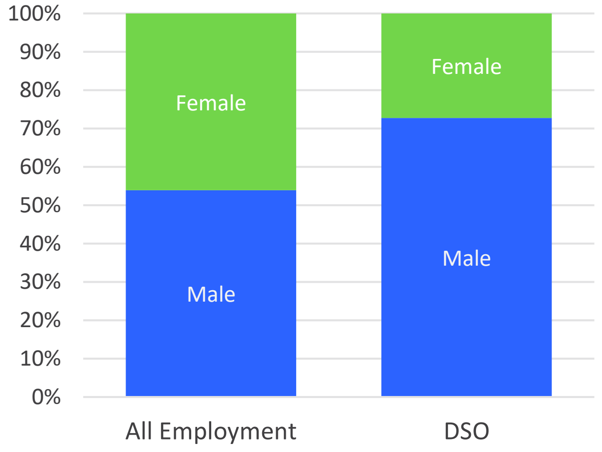
Converting the GfS grid investment into infrastructure will hinge on the availability of people with the passion, skill, experience and training to get the job done.

Age



Ageing workforce: DSOs must plan recruitment, as 36% of workers in the sector are more than 50 years old, slightly higher than in all other employment.

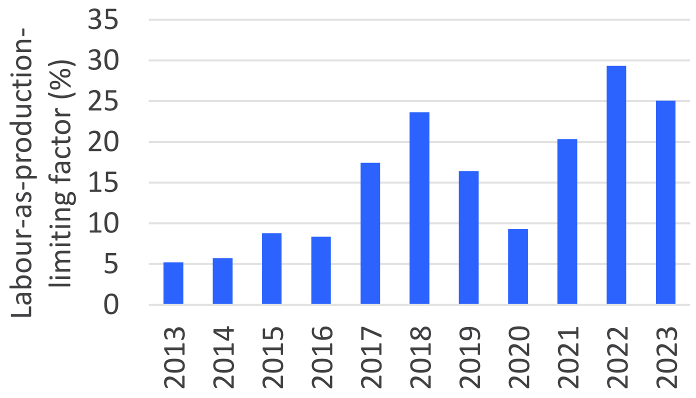
Gender



Diversity: DSOs must expand diversity in the talent pool. Women represent only 27% of the DSO workforce. In engineering and technical roles, the share is significantly lower.

Electrical skill shortage

EU27 electrical equipment manufacturing—labour shortage



Electrical skill shortages in manufacturing: DSOs must recruit, train and upskill. Recent labour shortage surveys show there are already shortages of electrical mechanics and fitters in 15 EU countries.

Sources: Eurostat, Age and Gender Statistics, Employment by sex, age and detailed economic activity (2021); Skill shortage data from European Commission, DG EFIN, Business Survey, subsector data, seasonally adjusted data.

Action plan to boost supply chain efficiency

Heightened material demand from the clean energy sector, anticipated shortfalls in copper, skills deficits and extended manufacturing lead times are stretching the distribution grid supply chain. Enhanced collaboration and strategic planning, across European policymakers and industries, are crucial to boost the supply chain. An action plan for efficiency includes:

Materials

- The EU27+Norway needs to consider its relationships with resource-rich countries, including co-investing in mines and partnering.
- Driving innovation will help accelerate development of new materials, transform production methods and establish new recycling processes that will optimise manufacturing.

Equipment manufacturing

- Championing free trade policy globally is crucial in facilitating the import of materials, components and assembled equipment for the energy transition.
- In manufacturing policy, the EU can progress its recent efforts to develop a competitive industrial strategy that matches instruments recently adopted by other global powers.
- The adoption of asset performance excellence and grid-friendly flexibility will not only optimise investment but also enhance manufacturing requirements for grid equipment.

Procurement

- A maximum timeframe for public procurement of strategic distribution grid projects will expedite grid development.
- Dynamic adjustments to EU procurement thresholds will help the sector to tolerate inflation/supply price spikes and reduce project delays.

Permitting

- National interest projects will benefit from a fast-tracked, centralised and government-coordinated permitting process. This will simplify permitting and support faster planning to achieve an earlier operation date.
- Accelerated permitting will shorten consultation deadlines between parties, reducing potential for conflict and delays.

Talent

- Expand talent pool by embracing diversity and training programmes.
- Leverage process automation and digitalisation where possible to create more than two million jobs required to deliver grids for speed.

Source: Energy Transitions Commission, Material and Resource Requirements for the Energy Transition (2023); Wood Mackenzie, Power transformers: Supply shortage and high lead times (2023); IEA The Role of Critical Minerals in Clean Energy Transitions (2021).

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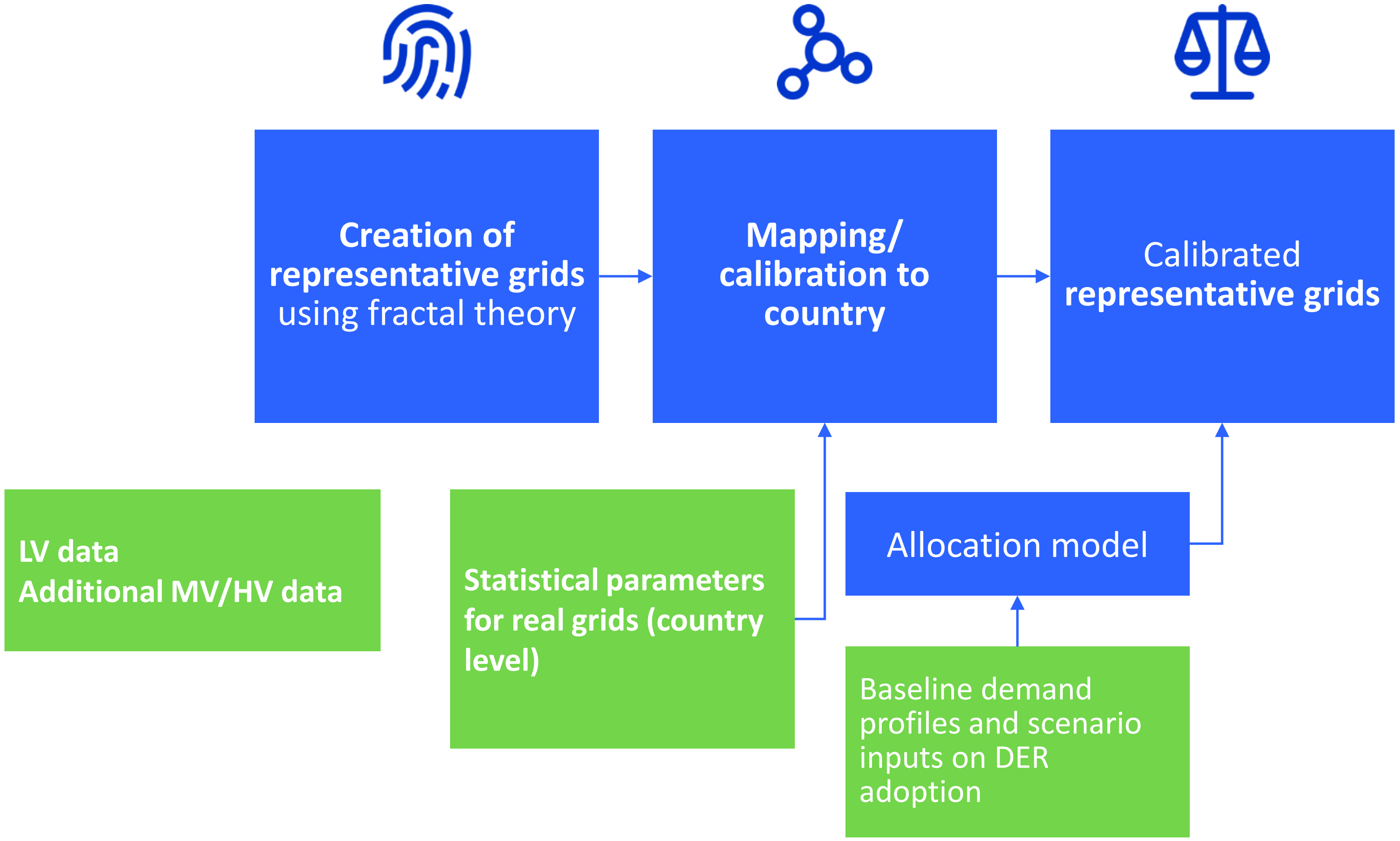
Appendices

Appendix A: Methodology details

Example: Spain's representative grids



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12 rural grids

+

9 suburban grids

+

9 urban grids

10 representative grids for each of the following three voltage-level distribution grids:

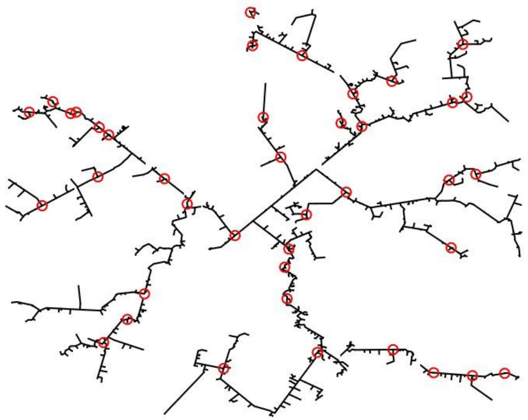
- 110 – 10 – 0.4 kV
- 35 – 10 – 0.4 kV
- 66 – 20 – 0.4 kV

Spain’s rural representative grids

Customers/ km^2	Transformers/ km^2	Area size (km^2)	Number of customers	LV grid length (km)	Number of DTs	MV grid length (km)	Number of primaries
5	0.5	400	2,000	266 / 272 / 259	200	1434 / 1371 / 1389	1
25	1	80	2,000	121 / 122 / 120	80	443 / 431 / 401	1
50	1.5	40	2,000	81 / 78 / 88	60	273 / 275 / 265	1
100	2	20	2,000	57 / 59 / 57	40	157 / 152 / 161	1

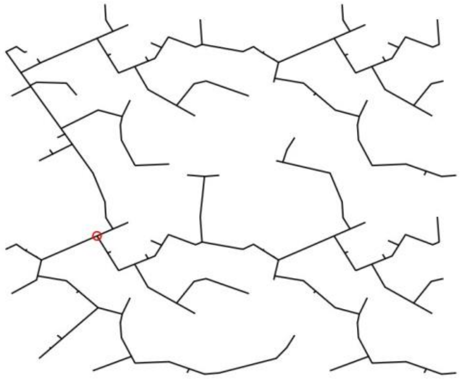
Visualisation of one grid with 100 customers per km^2

4.5 km



LV grid 4

8.9 km



MV grid 4

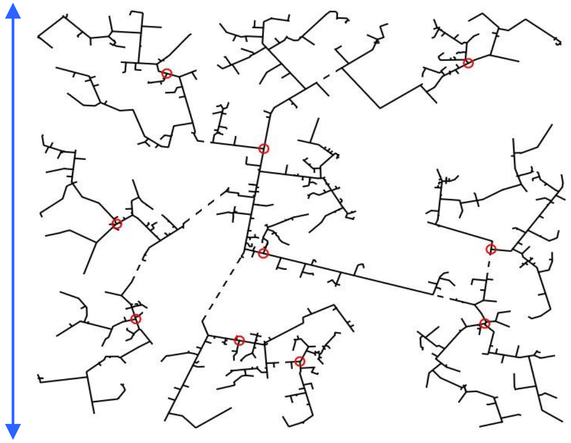
Note: DT= distribution transformer

Spain's suburban representative grids

Customers/ km^2	Transformers/ km^2	Area size (km^2)	Number of customers	LV grid length (km)	Number of DTs	MV grid length (km)	Number of primaries
200	2	12.5	2,500	58 / 56 / 61	25	92 / 87 / 102	1
400	3.2	6.3	2,500	46 / 48 / 43	20	69 / 70 / 71	1
800	2.1	4.9	3,900	37 / 39 / 38	10	46 / 50 / 44	1

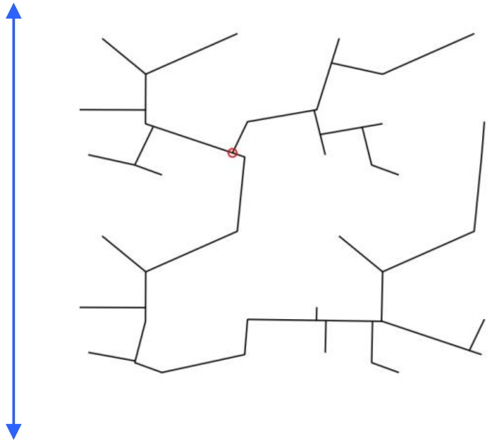
Visualisation of one grid with 800 customers per km^2

2.2 km



LV grid 7

4.4 km



MV grid 7

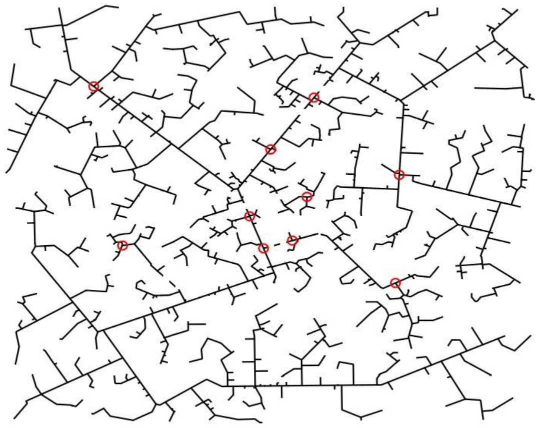
Note: DT= distribution transformer

Spain’s Urban Representative Grids

Customers/ km²	Transformers/ km²	Area size (km²)	Number of customers	LV grid length (km)	Number of DTs	MV grid length (km)	Number of primaries
1,600	3.3	2.4	3,900	25 / 26 / 29	8	25 / 28 / 26	1
3,200	7.7	1.7	5,400	30 / 29 / 29	13	29 / 25 / 27	1
6,400	11.9	0.8	5,400	21 / 20 / 20	10	15 / 17 / 17	1

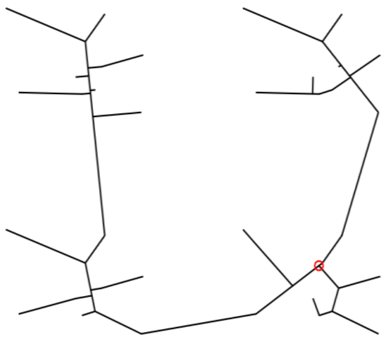
Visualisation of one grid with 6,400 customers per km^2

0.9 km



LV grid 10

1.8 km



MV grid 10

Note: DT= distribution transformer

Germany's representative grids

Customers / km²	Transformers / km²	Area size (km²)	Number of customers	LV grid length (km)	Number of DTs	MV grid length (km)	Number of primaries
10.7	1.1	187.6	2,000	183.4 / 182.2	200	933.7 / 924.8	1
27.5	2.2	72.9	2,000	108.5 / 111.3	160	415.1 / 429.2	1
56.2	3.4	35.6	2,000	78.8 / 78.9	120	265.6 / 252.7	1
109.2	4.4	18.3	2,000	52.5 / 59.3	80	160.3 / 147.8	1
230	2.9	10.9	2,500	53 / 56.3	32	89.1 / 97.6	1
467.4	5.6	5.35	2,500	40.7 / 42	30	65.5 / 68.2	1
906.5	2.3	4.3	3,900	37.2 / 36.1	10	35.5 / 35	1
1,728.3	4.4	2.26	3,900	24.5 / 21.2	10	22.9 / 22.4	1
3,200	7.7	1.69	5,400	29.3 / 29.3	13	28 / 19	1
6,400	15.4	0.84	5,400	21.1 / 20.6	13	17.5 / 17.4	1

20 representative grids are created: 10 of each of 110 – 20 – 0.4 kV and 110 – 10 – 0.4 kV. MV area size is fourfold the LV area size.

Note: DT= distribution transformer

France's representative grids

Customers / km^2	Transformers / km^2	Area size (km^2)	Number of customers	LV grid length (km)	Number of DTs	MV grid length (km)	Number of primaries
6.0	0.6	335.5	2,000	245.7	200	1,230.5	1
25.4	1.0	78.6	2,000	111.2	80	393.0	1
55.1	1.7	36.3	2,000	75.2	60	249.5	1
109.3	2.2	18.3	2,000	51.3	40	152.9	1
230.3	2.3	10.9	2,500	58.5	25	90.4	1
454.1	3.6	5.50	2,500	44.4	20	66.0	1
908.7	2.3	4.29	3,900	33.3	10	39.3	1
1,855.2	3.8	2.10	3,900	24.5	8	24.9	1
3,158.4	7.6	1.71	5,400	29.4	13	28.9	1
7,716.6	14.3	0.70	5,400	18.8	10	16.1	1

10 representative grids, 20 – 0.4 kV, are created. MV area size is fourfold the LV area size.

Note: DT= distribution transformer

Mapping of Spain’s grids

Parameter			Statistical data	Representative network data	Discrepancy (%)
Number of domestic customers		≤15	1,614,631	1,614,631	0.00
		≤37.5	2,860,151	2,860,151	0.00
		≤75	2,881,041	2,881,041	0.00
		≤150	3,127,865	3,127,865	0.00
		≤300	3,222,568	3,222,568	0.00
		≤600	3,506,045	3,506,045	0.00
		≤1200	3,390,881	3,390,881	0.00
		≤2400	2,598,195	2,598,195	0.00
		≤4800	913,423	913,423	0.00
		>4800	362,480	362,480	0.00
Conductor length (km)	LV	OH	245,827	245,462	-0.15
		UG	143,862	143,941	0.06
		Total	**389,688**	**389,403**	**-0.07**
	MV	**Total**	**258,399**	**258,389**	**0.00**
	HV	**Total**	**59,111**	**59,101**	**-0.02**
	MV and HV	OH	237,542	237,060	-0.20
		UG	79,968	80,431	0.58
Number of transformers	MV/LV		289,593	289,292	-0.10
	HV/MV		5,120	5,116	-0.10
	HV/HV		517	517	-0.15

Country local administrative units (LAUs) are grouped by household density (HD) (households per km^2) by dividing number of persons with average household size, for example:

- 0 < HD ≤ 15
- 15 < HD ≤ 37.5
- 37.5 < HD ≤ 75
- 75 < HD ≤ 150
- 150 < HD ≤ 300
- 300 < HD ≤ 600
- 600 < HD ≤ 1,200
- 1,200 < HD ≤ 2,400
- 2,400 < HD ≤ 4,800
- HD > 4,800
- The average number of persons per household is calculated from total number persons and total number of households per country.
- The number of households in mainland Spain was 19,320,000 in 2023.
- For Spain, population statistics per LAU are not available from Eurostat census data. An estimate is done based on the weighted average of the rest of EU countries for which data is available.

Representative grids are mapped to minimise deviation for:

- Countries’ number of domestic customers.
- Countries’ distribution statistics:
  - Grid length per construction (overhead (OH) lines / underground (UG) cables / total)
  - Number of transformers
- Data is split by voltage level: LV, MV and HV.

Mapping of German and French grids

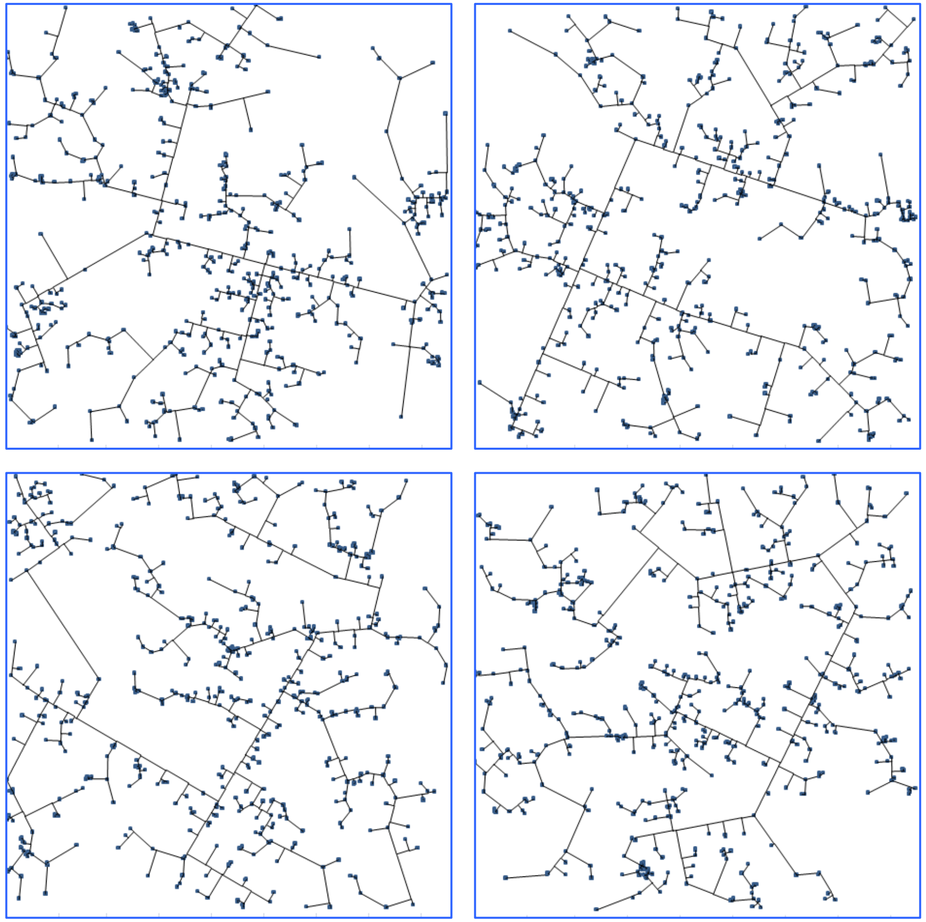
Germany

Parameter			Statistical data	Representative networks data	Discrepancy (%)
Number of domestic customers		≤15	402,123	402,123	0.00
		≤37.5	2,554,205	2,554,205	-0.00
		≤75	4,971,914	4,971,914	0.00
		≤150	6,509,308	6,509,308	0.00
		≤300	6,618,265	6,618,265	0.00
		≤600	6,913,277	6,913,277	0.00
		≤1200	6,878,018	6,878,018	-0.00
		≤2400	6,421,790	6,421,790	0.00
Conductor length (km)	LV	OH	145,945	147,476	0.01
		UG	1,025,695	1,025,760	0.00
		Total	**1,171,640**	**1,173,236**	**0.00**
	MV	**Total**	**515,247**	**515,022**	**-0.00**
	HV	**Total**	**115,815**	**115,833**	**0.00**
	MV and HV	OH	232,973	233,382	0.00
		UG	398,089	397,472	-0.00
Number of transformers	MV/LV		459,868	459,485	-0.00
	HV/MV		9,850	9,847	-0.00
	HV/HV		4,488	4,488	-0.00

France

Parameter			Statistical data	Representative networks data	Discrepancy (%)
Number of domestic customers		≤15	1,992,998	1,992,998	-0.00
		≤37.5	3,614,976	3,614,976	0.00
		≤75	3,572,208	3,572,208	-0.00
		≤150	3,716,558	3,716,558	0.00
		≤300	3,527,277	3,527,277	0.00
		≤600	3,415,533	3,415,533	-0.00
		≤1200	3,246,239	3,246,239	0.00
		≤2400	4,299,172	4,299,172	0.00
		≤4800	2,218,816	2,218,816	-0.00
		>4800	2,205,424	2,205,424	-0.00
Conductor length (km)	LV	OH	426,153	426,803	0.00
		UG	270,862	269,882	-0.00
		Total	**697,015**	**696,685**	**-0.00**
	MV	OH	362,293	362,309	0.00
		UG	256,052	255,622	-0.00
		Total	**618,345**	**617,930**	**-0.00**
Number of transformers	MV/LV		744,467	740,857	-0.00
	HV/MV		19,246	19,224	-0.00

Example of four statistically similar LV grids



Investment assessment methodology for other categories

Investment category	Inputs	Process	Output
Renewal and replacement due to age and condition	• Average annual investment in the last five years required for asset replacement and renewal due to age (€) • The present net book value (nominal €), weighted average age (years) and useful life (years) of the top five main asset classes	• Determine depreciation rate of asset class. • Use depreciation rate and weighted average useful life to determine original cost. • Determine cost of rebuilding today by applying inflation. • Determine annual value depreciation. • Use annual depreciation to determine future depreciation. • This is the value required to continue to replace and renew assets. • Validate this against the amount spent in the preceding five years.	Replacement and renewable investment required (2025–40 and 2041–50)
Digitalisation of systems (e.g., OT, cyber, AHM) and automation of primary and secondary substations	• Average annual investment in the last five years required for automation of substations and number of substations • Investment in different types of system	**System digitalisation** • Determine useful life of each type of system. • Distribute the total investment over the period of asset life. • Scale forecast values based on DSO energy consumption and include inflation effect to capture price volatility. **Grid automation** • Determine number of substations to be automated, and investment, based on historical data. • Determine unit investment for automating one substation. • Apply rate of change in automation over forecast period on substations. • Use unit investment on number of substations automated to calculate forecast values for investment. • Include inflation effect and scale based on energy consumption of DSOs.	Digitalisation investment required each year (2025–40 and 2041–50)

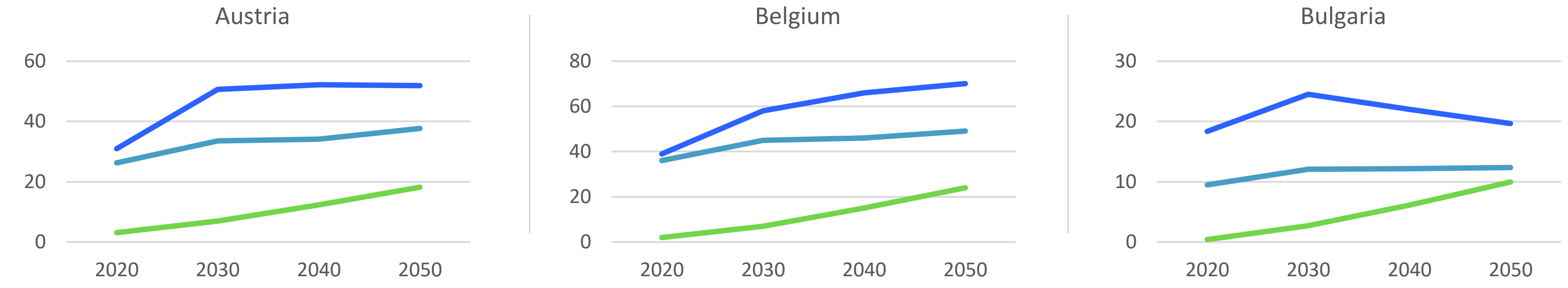
Investment assessment methodology for other categories

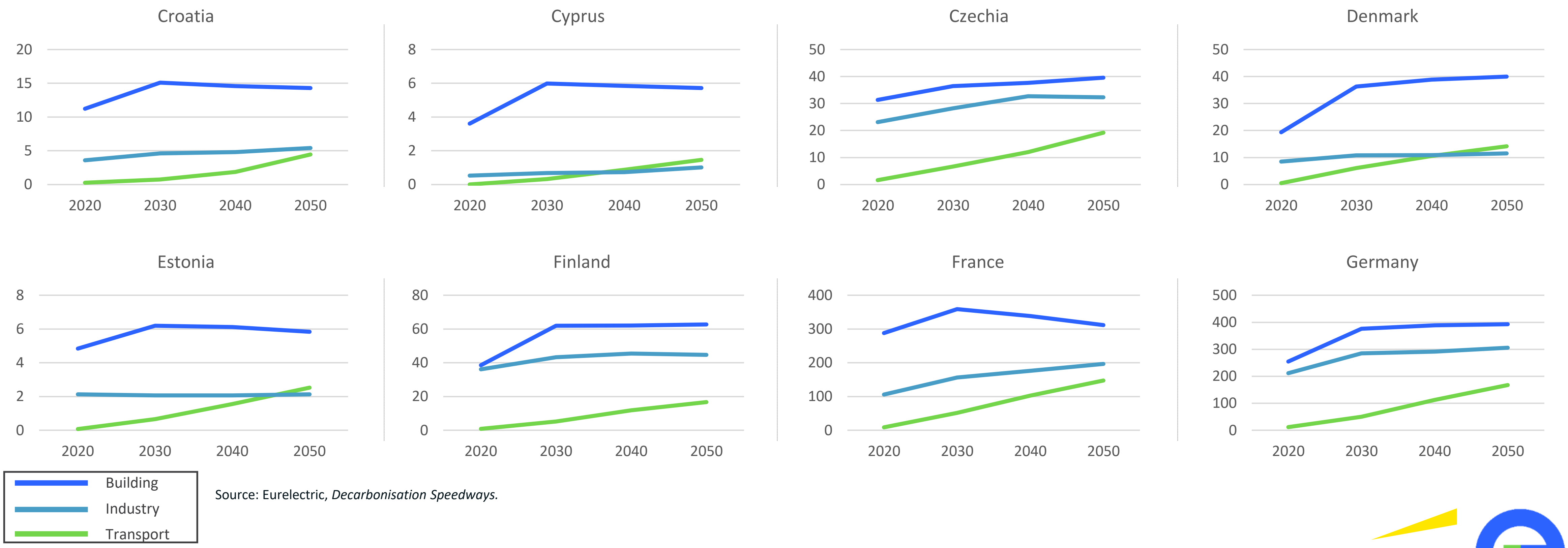
Investment category	Inputs	Process	Output
Smart meter installations	• Investment to deploy smart meters at customer level (€ millions) • Deployment of smart meters (millions) • Average annual investment in the last five years required for smart meter installations	• Determine smart meter installation investment based on historical data. • Obtain unit investment based on European Commission reports and DSO data. • Determine number of smart meters and split it over useful lifetime of meters. • Use unit investment on number of meters installed to calculate forecast values for investment. • Include inflation effect and scale based on customers of DSOs.	Investment required for the country to reach its smart meter deployment plans (2025–40 and 2041–50)
Resilience to harden grid through under-grounding and new feeder links	• Overhead lines converted to underground lines (km and €/km) • New feeder links added (number and €/feeder)	• Determine total grid length, overhead and underground lines (km) for current year based on historical data. • Determine overhead lines converted to underground based on historical data and similarity in grid length with other DSOs. • Evaluate unit cost per km of grid line based on PPI and grid length. • Determine total investment value for forecast period, taking inflation into consideration. • Scale forecast values based on grid coverage of DSOs.	Investment required for the country to make its grid more resilient against disruptions and extreme weather events (2025–40 and 2041–50)

Appendix B: Country-level demand and generation assumptions

Electricity consumption by sector (TWh)

Key countries

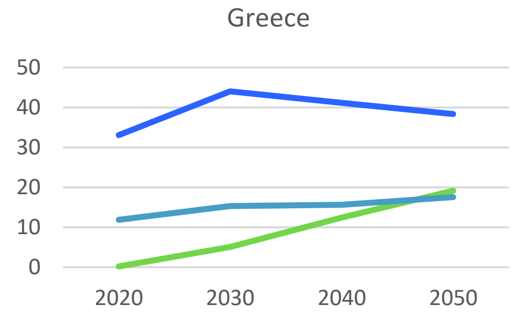


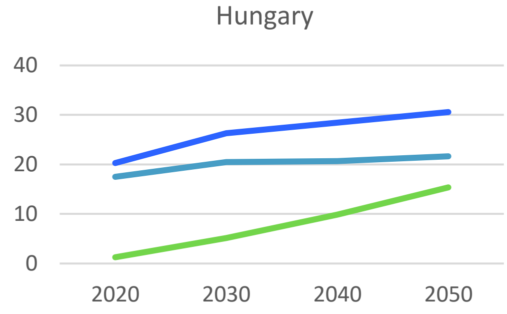


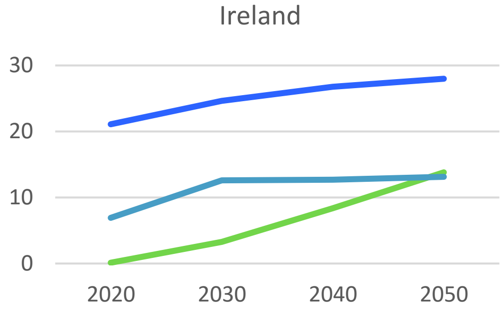
Source: Eurelectric, *Decarbonisation Speedways.*

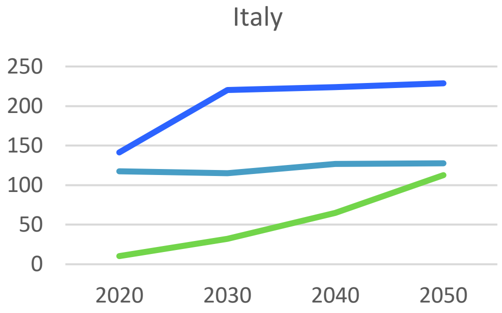
Electricity consumption by sector (TWh)

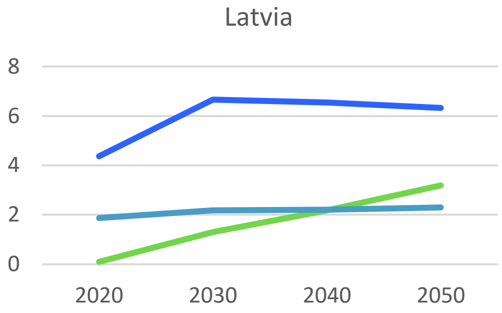
Key countries

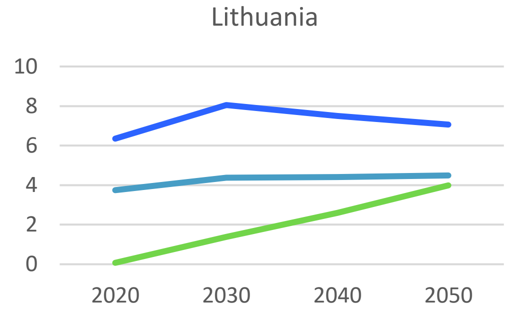


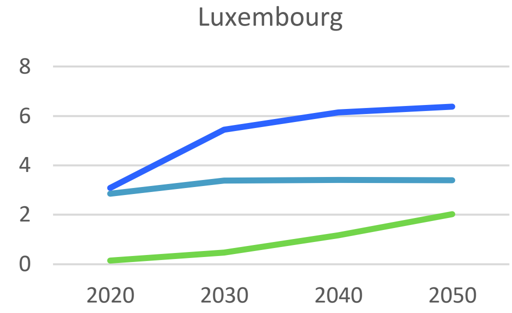


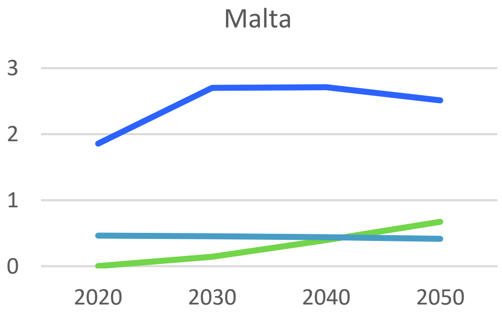


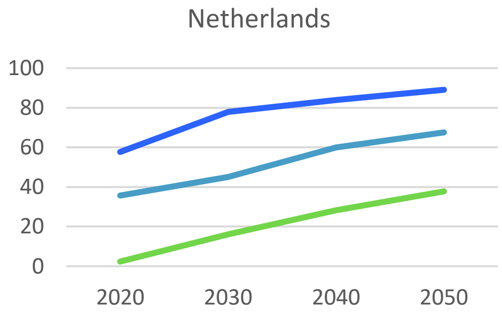


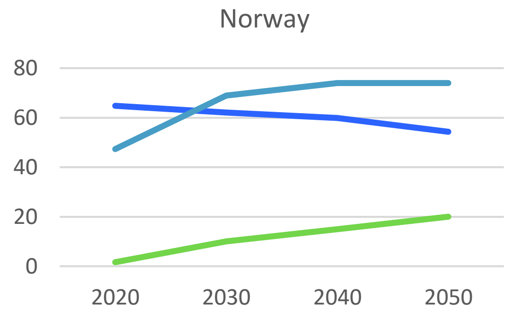


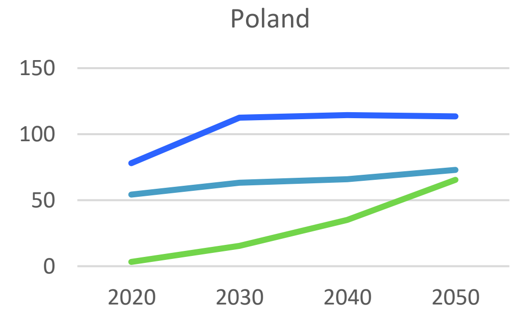










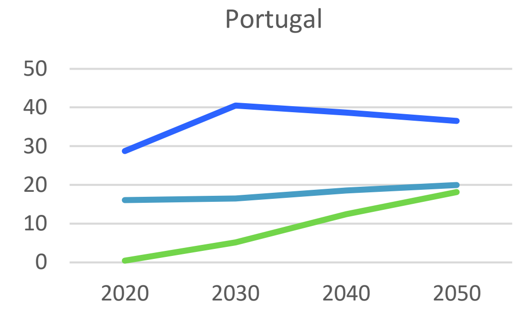


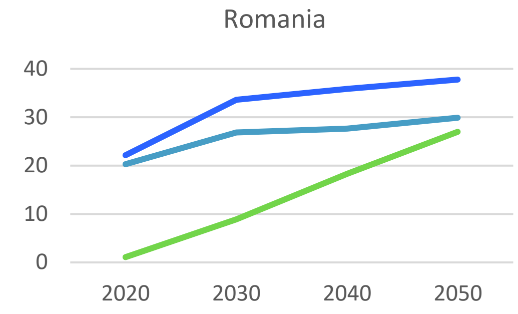
Building
Industry
Transport

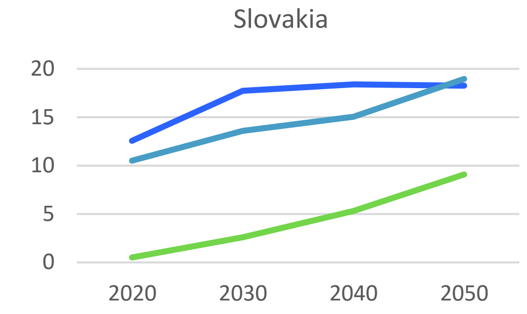
Source: Eurelectric, *Decarbonisation Speedways.*

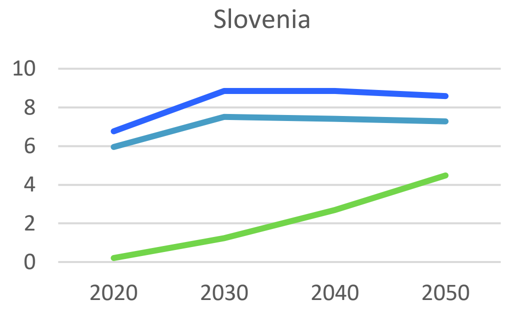
Electricity consumption by sector (TWh)

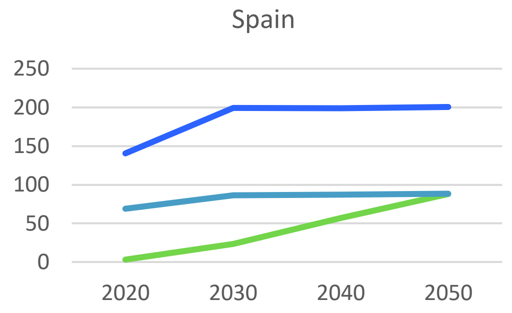
Key countries

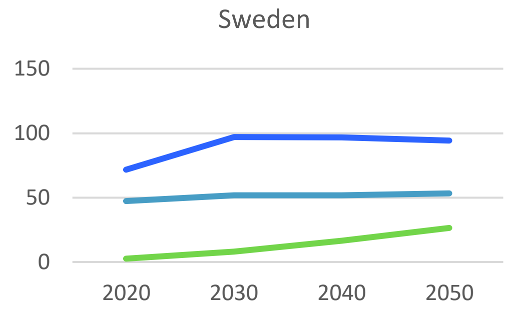










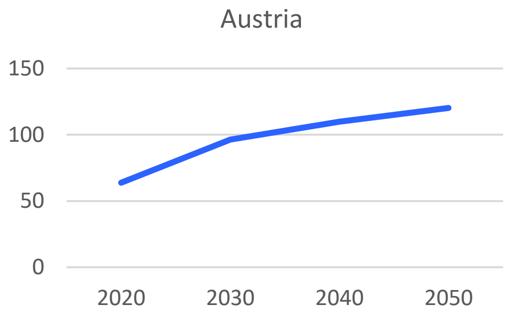


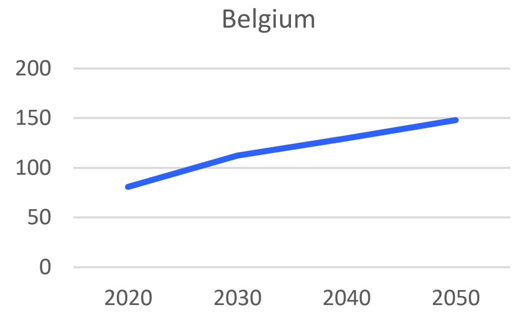
Building
Industry
Transport

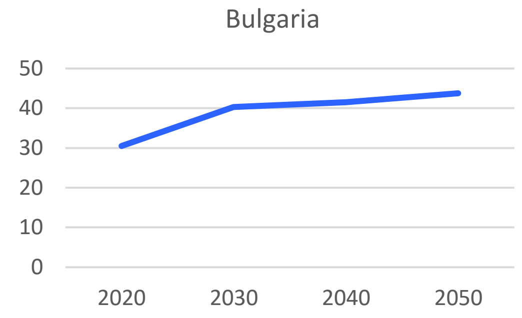
Source: Eurelectric, *Decarbonisation Speedways.*

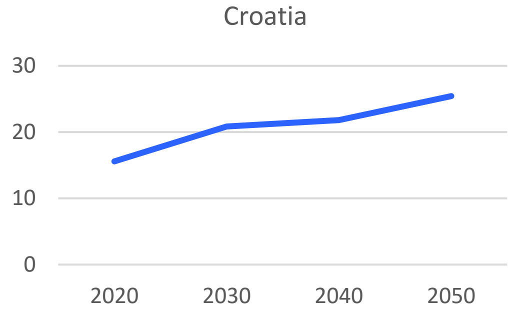
Total electricity consumption (TWh)

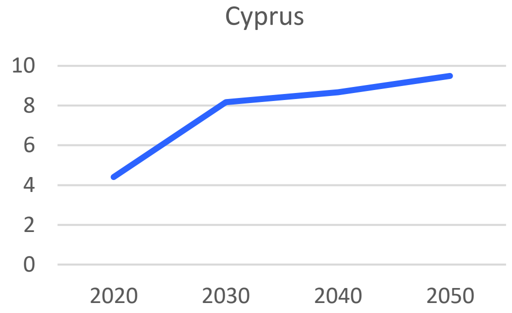
Key countries

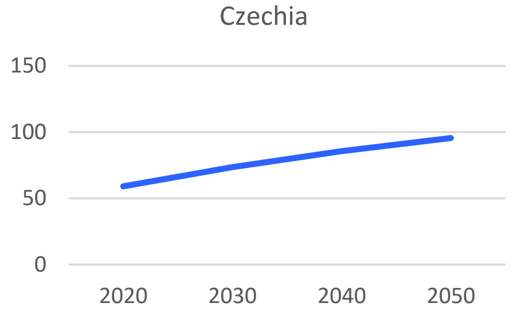


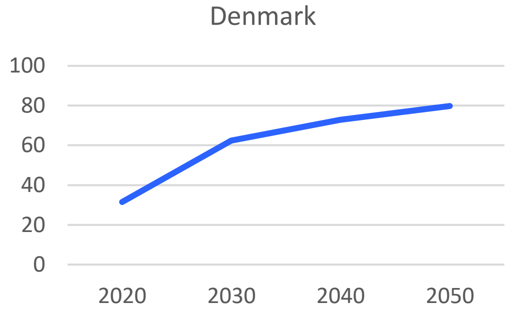


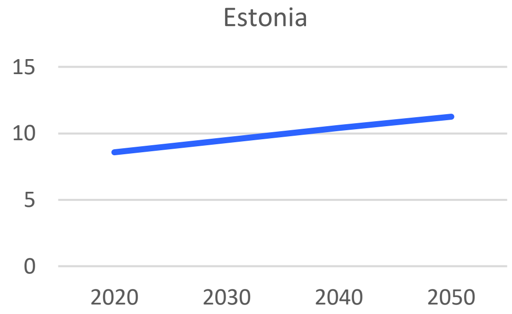


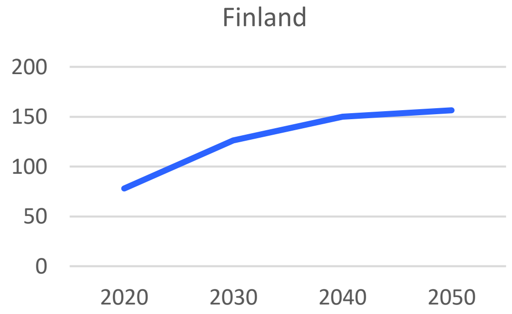


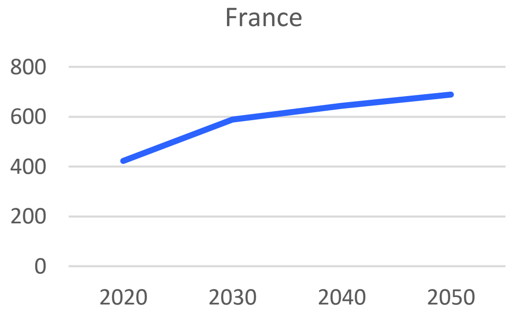


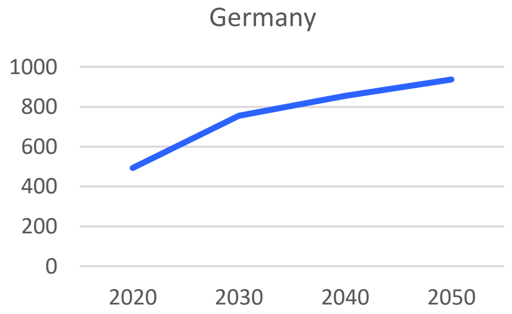










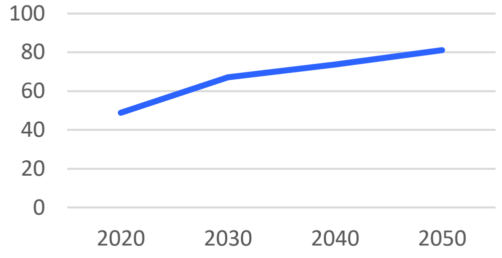


Source: Eurelectric, *Decarbonisation Speedways.*

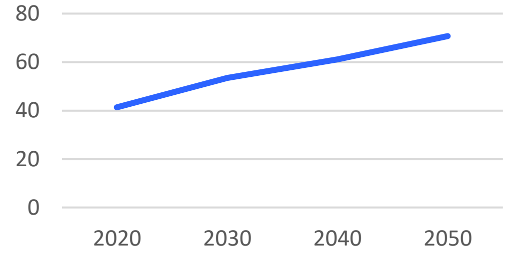
Total electricity consumption (TWh)

Key countries

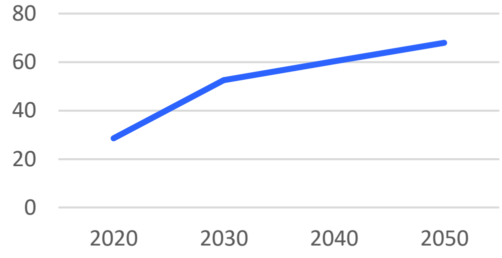
Greece



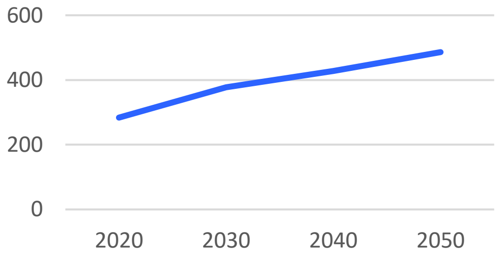
Hungary



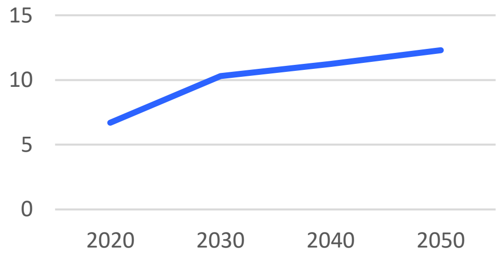
Ireland



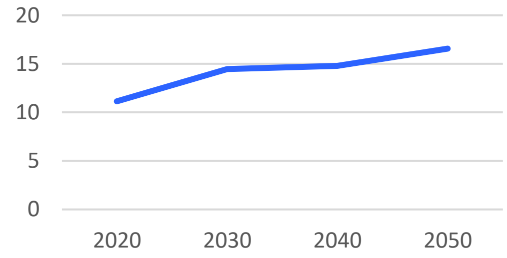
Italy



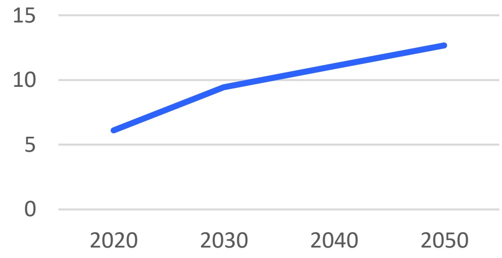
Latvia



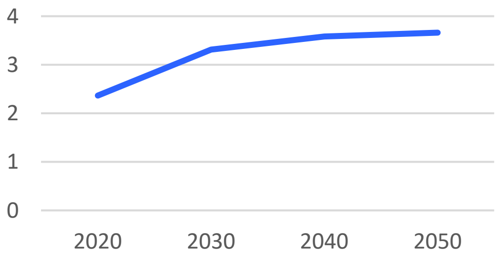
Lithuania



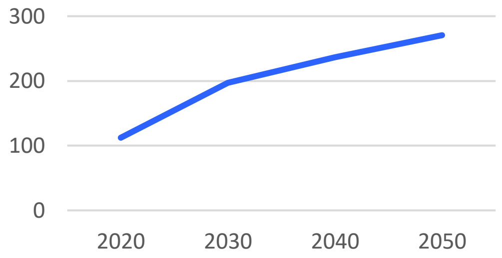
Luxembourg



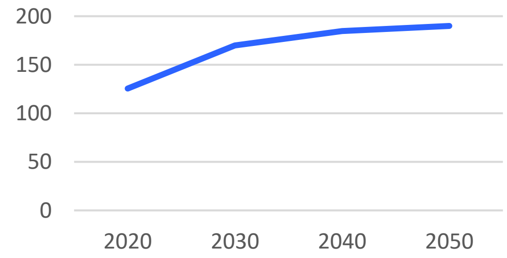
Malta



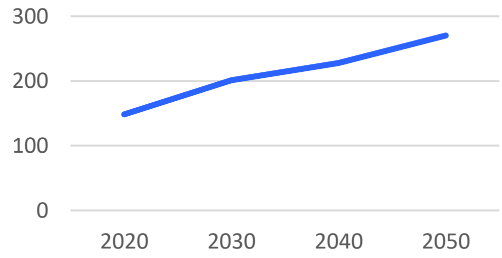
Netherlands



Norway



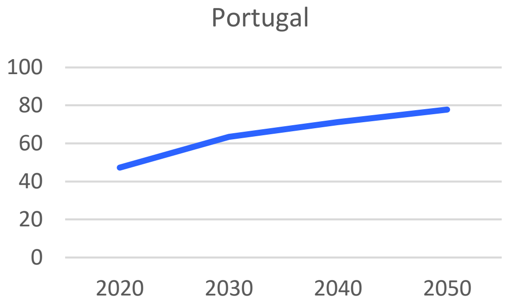
Poland

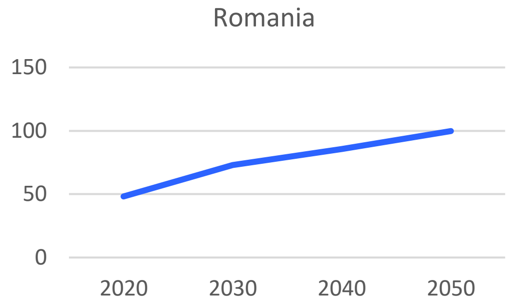


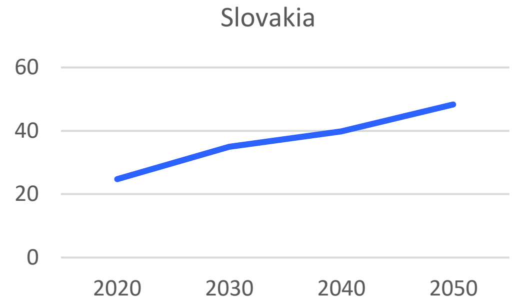
Source: Eurelectric, *Decarbonisation Speedways.*

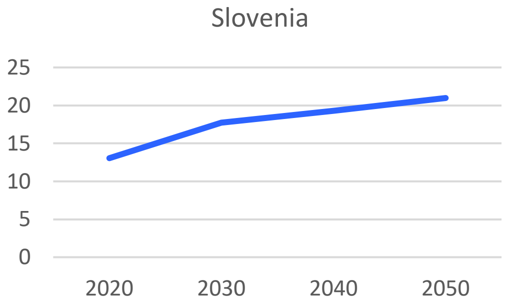
Total electricity consumption (TWh)

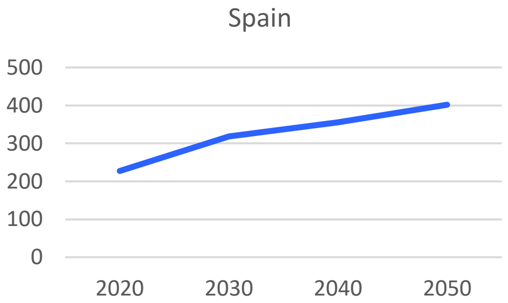
Key countries

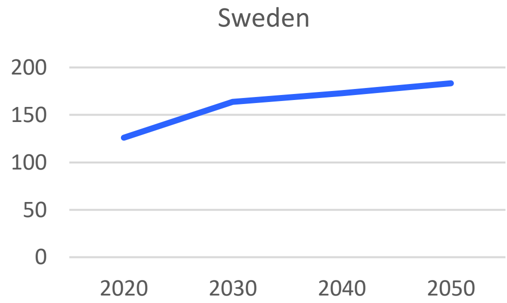








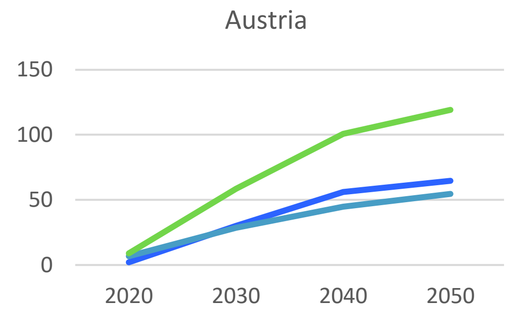


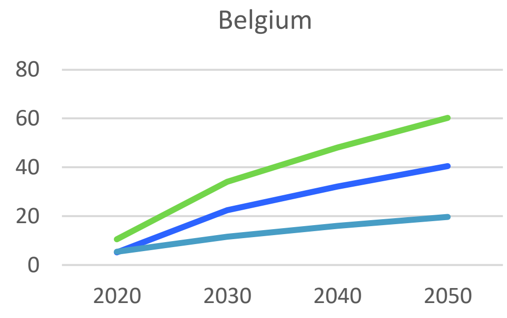


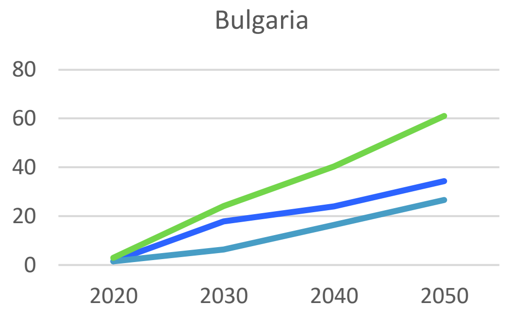
Source: Eurelectric, *Decarbonisation Speedways.*

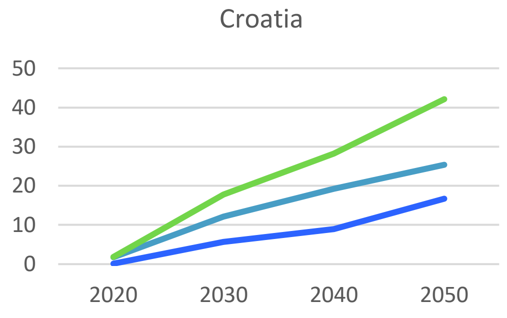
Renewables production (TWh)

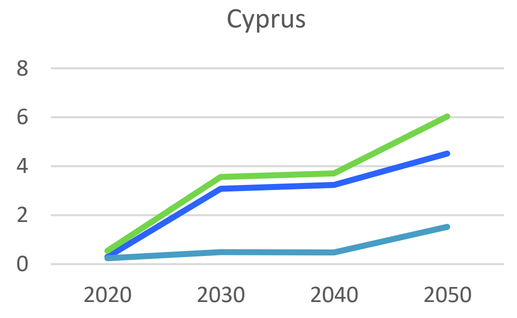
Key countries

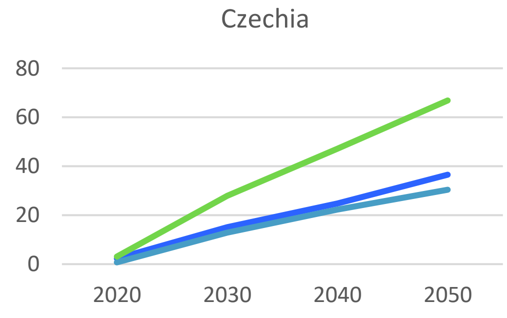


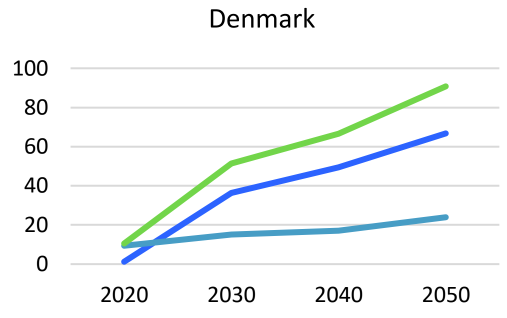


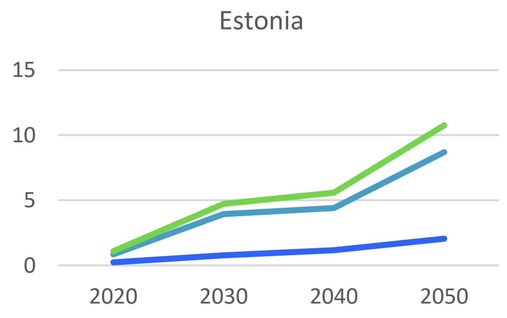


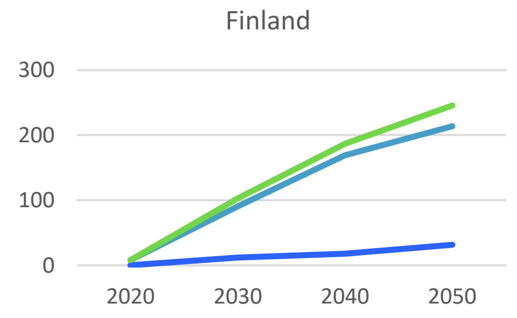


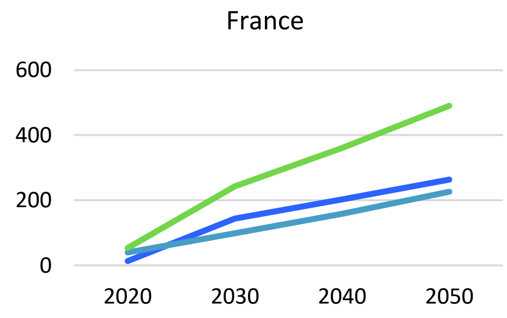


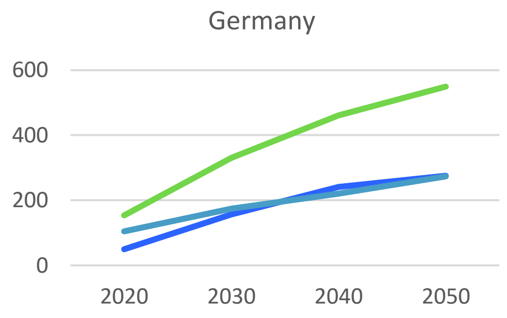










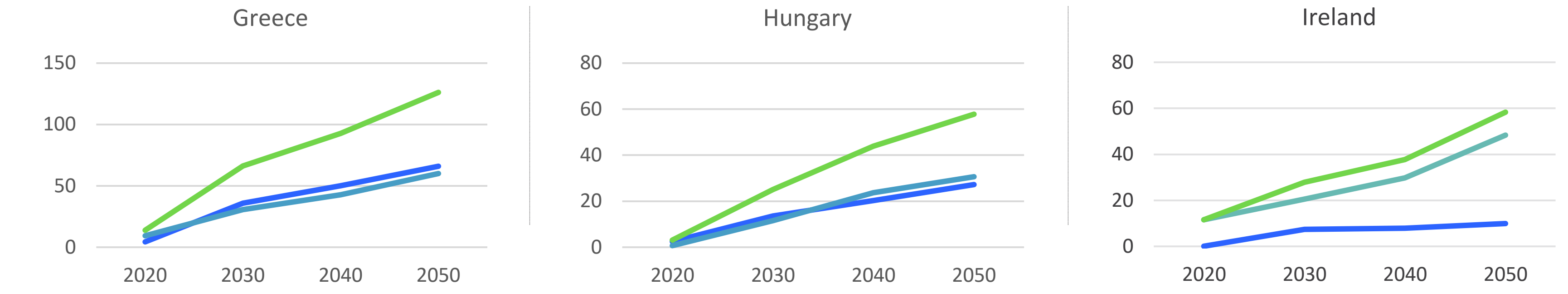


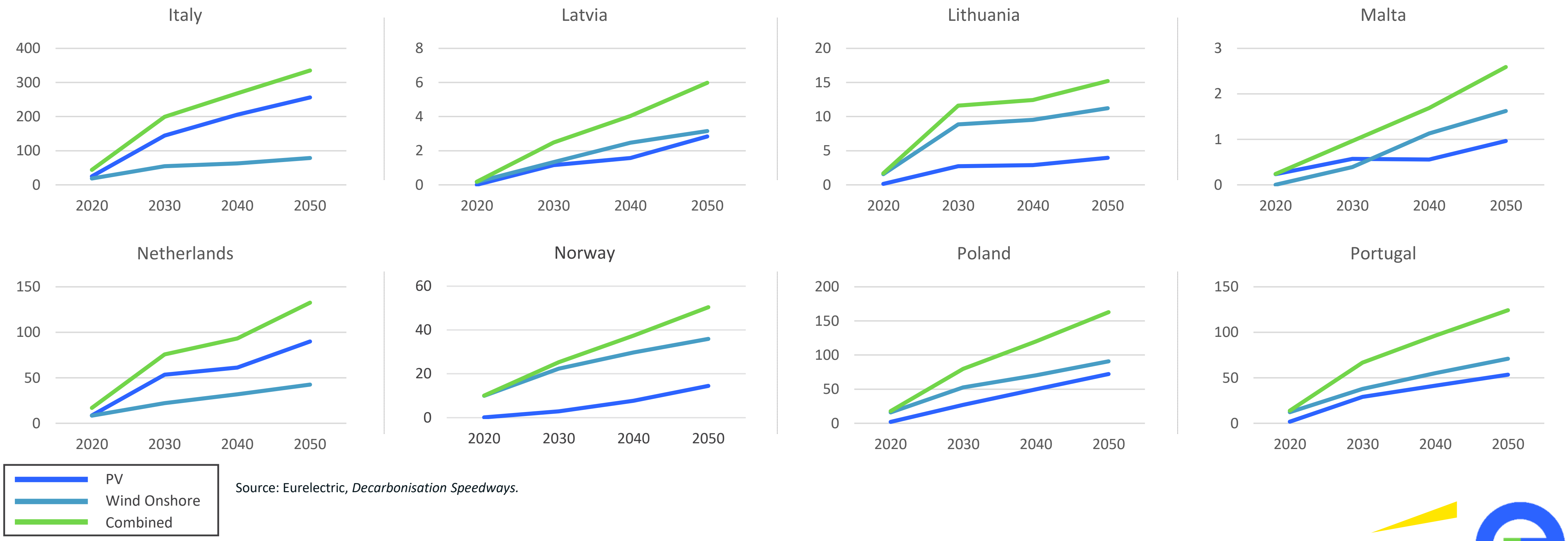
PV
Wind Onshore
Combined

Source: Eurelectric, *Decarbonisation Speedways.*

Renewables production (TWh)

Key countries

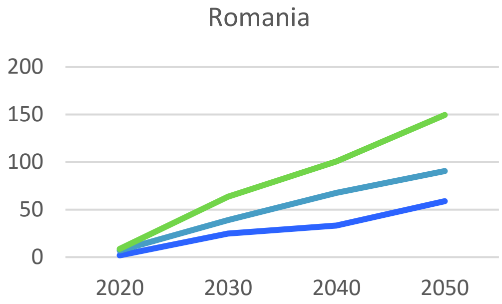


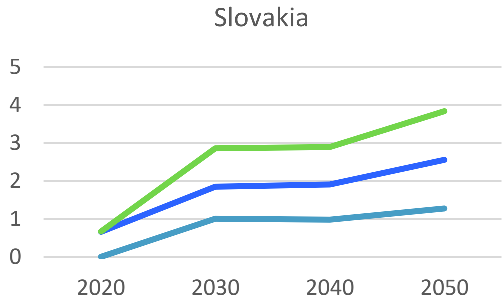


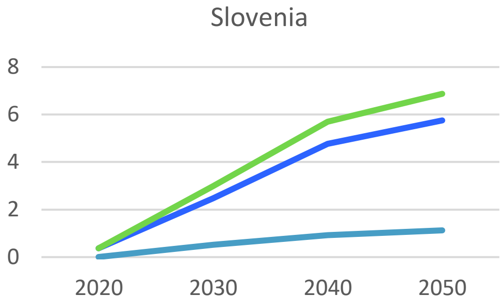
Source: Eurelectric, *Decarbonisation Speedways*.

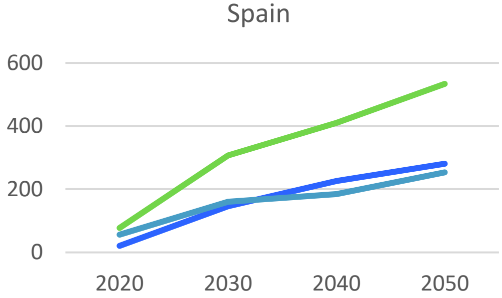
Renewables production (TWh)

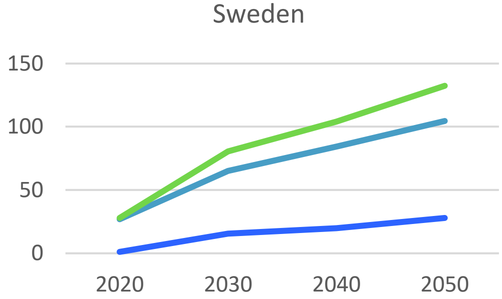
Key countries









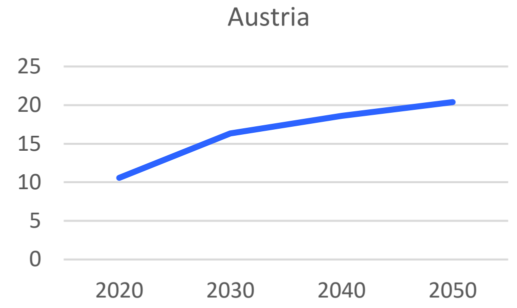


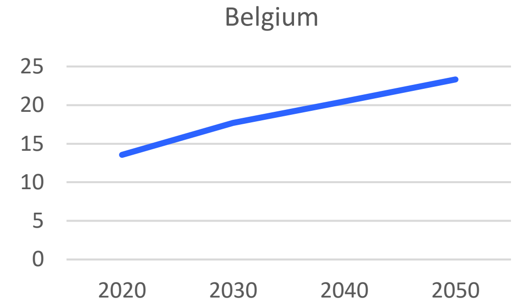
PV
Wind Onshore
Combined

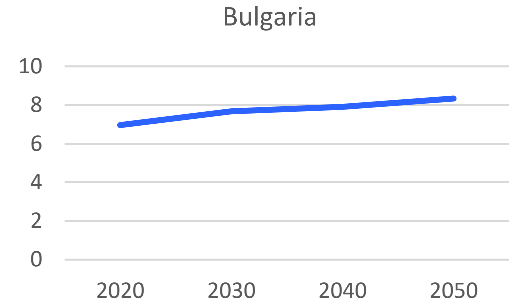
Source: Eurelectric, *Decarbonisation Speedways.*

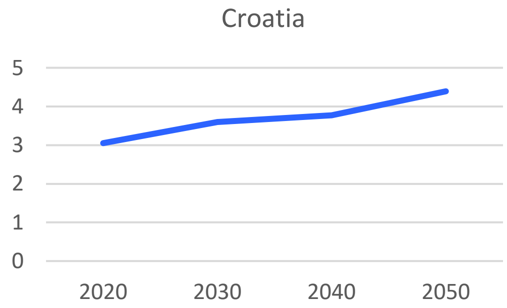
Change in peak load (GW)

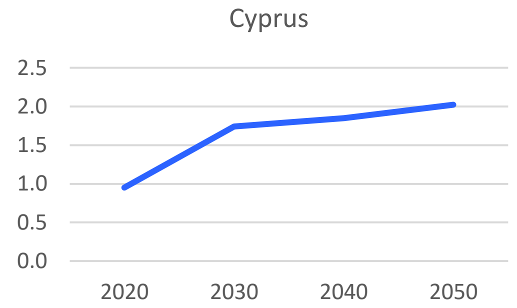
Key countries

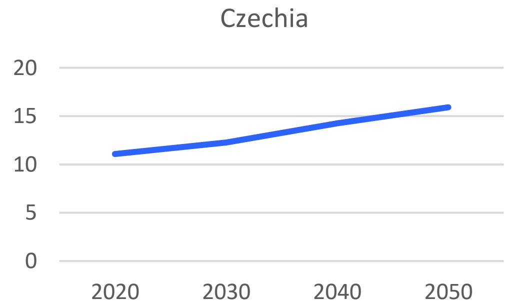


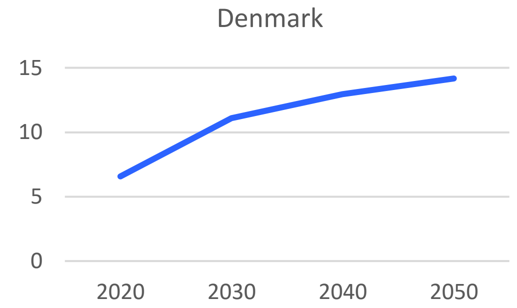


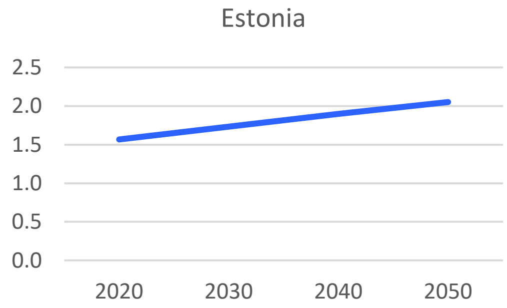


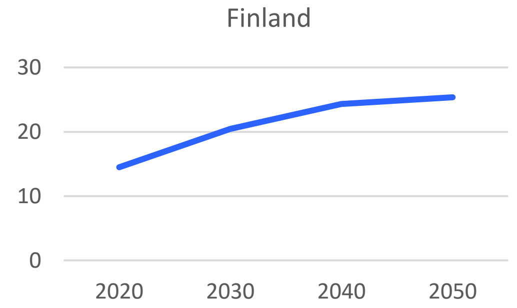


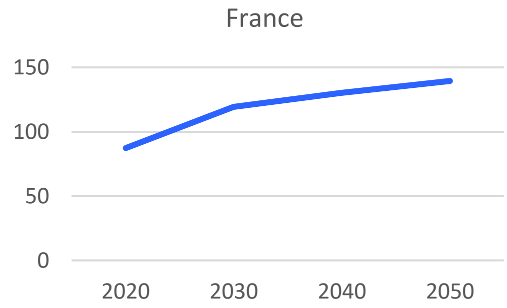


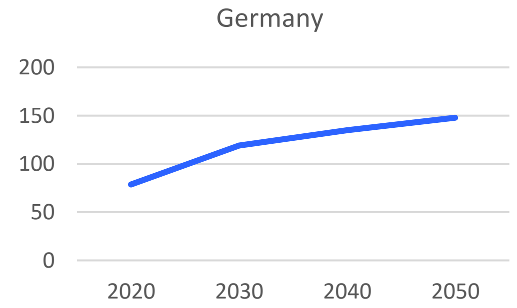








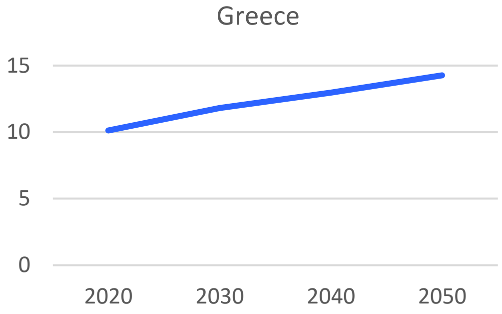


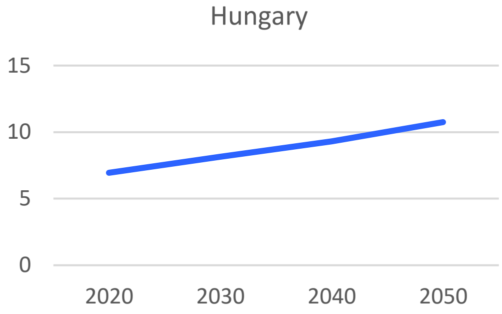


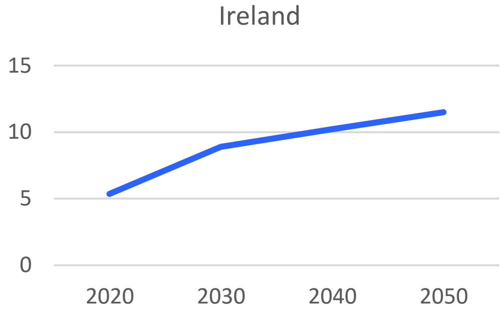
Source: Eurelectric, *Decarbonisation Speedways.*

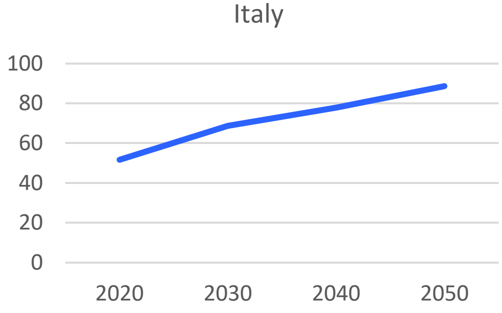
Change in peak load (GW)

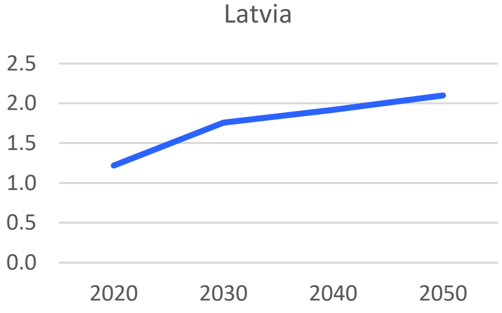
Key countries

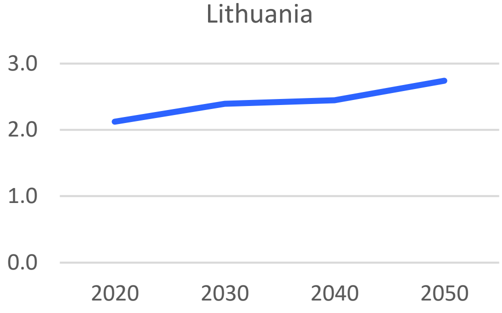


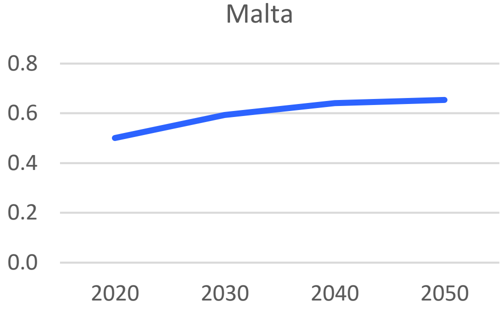


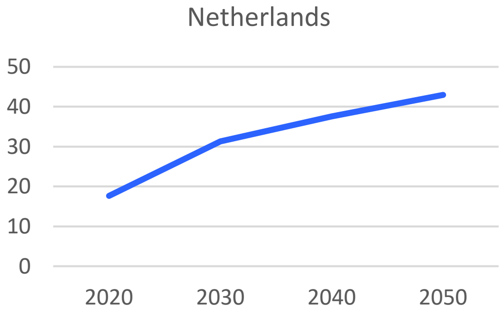


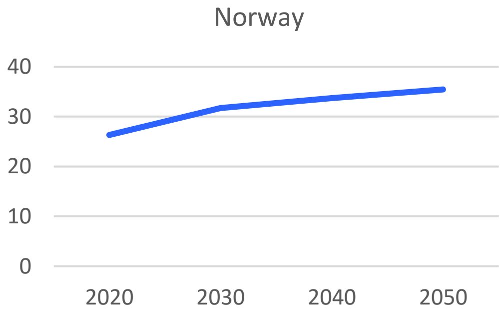


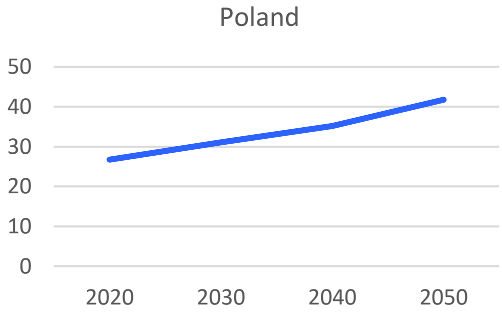


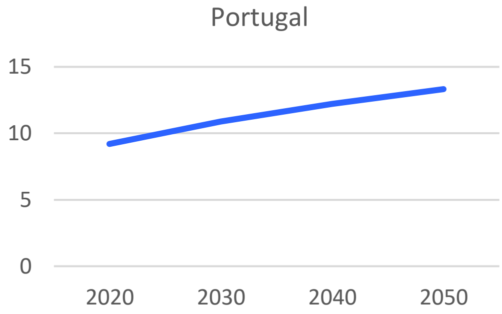








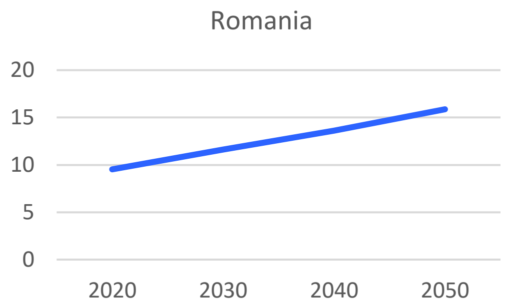


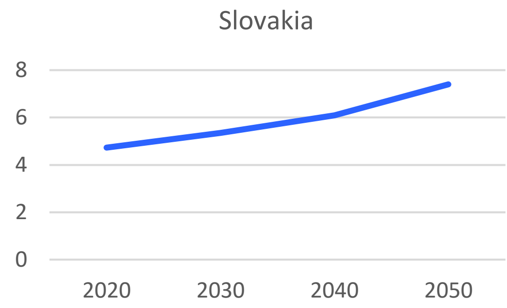


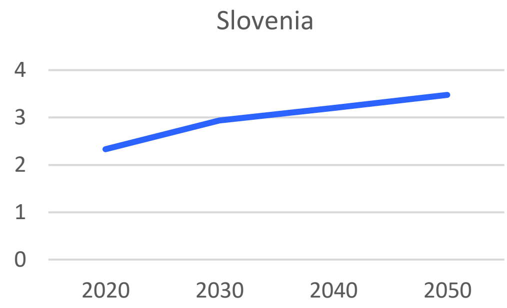
Source: Eurelectric, *Decarbonisation Speedways.*

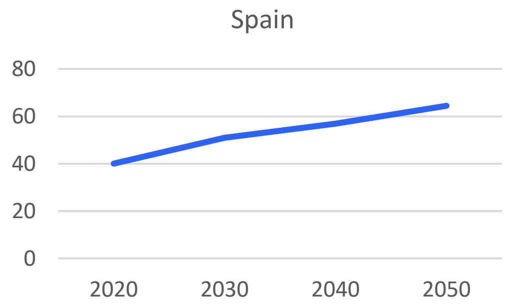
Change in peak load (GW)

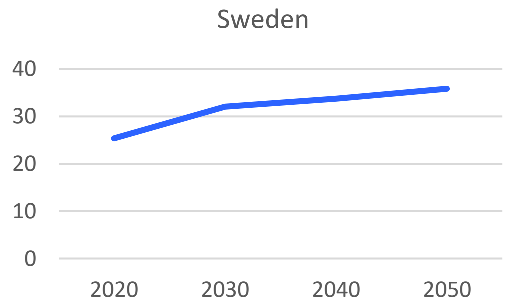
Key countries









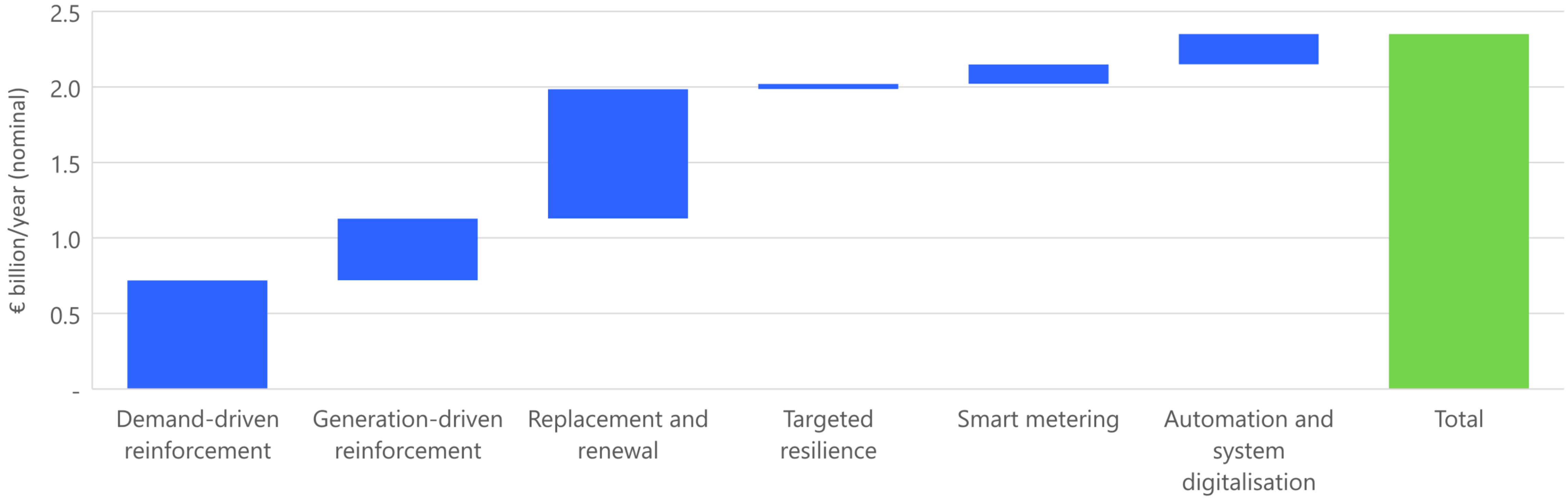


Source: Eurelectric, *Decarbonisation Speedways.*

Appendix C: Country-level investment requirements to 2050

Austria

33% CAGR for EV electricity (2025–30) and aggressive conversion to renewable heat via heat pumps	Austrian Renewable Energy Expansion Act aims for 100% renewable generation by 2030	Replacement of grids assets to maintain reliable supply	Aggressive renewables targets necessitating targeted grid resilience	Smart meter rollout scheduled to conclude by 2026 – 2.6 million deployed to date	Automating secondary (MV/LV) substations and transformer subs



Czechia

Share of EV in total electricity demand will grow from 1%–23% (2025– 40)

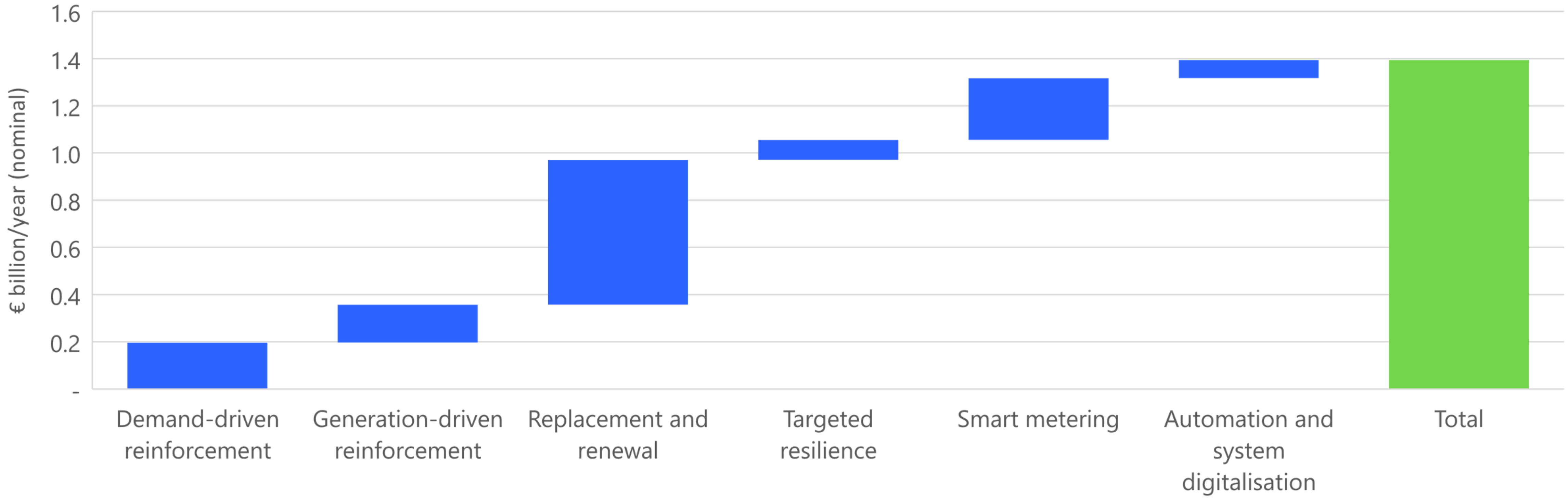
PV capacity to reach approximately 36 TWh by 2050

Modernising grid infrastructure

Two billion investment required in grid resilience to increase share of renewables

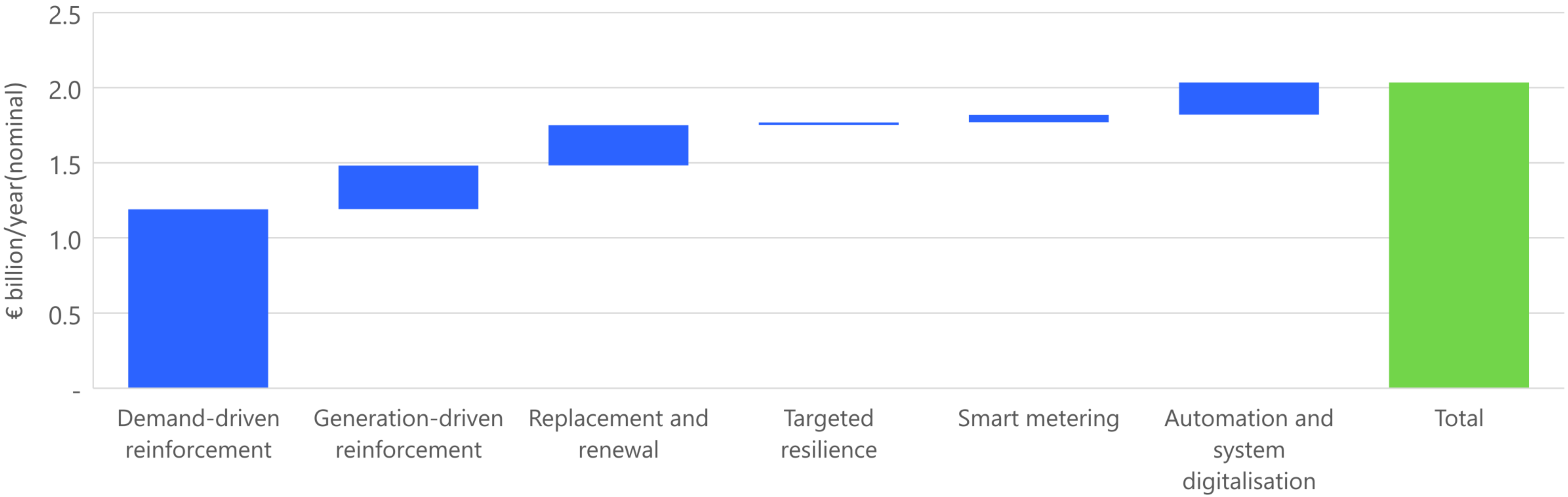
Less than 10% smart meter penetration to date – a number of small-scale deployments continuing

System data management, cyber, workforce management



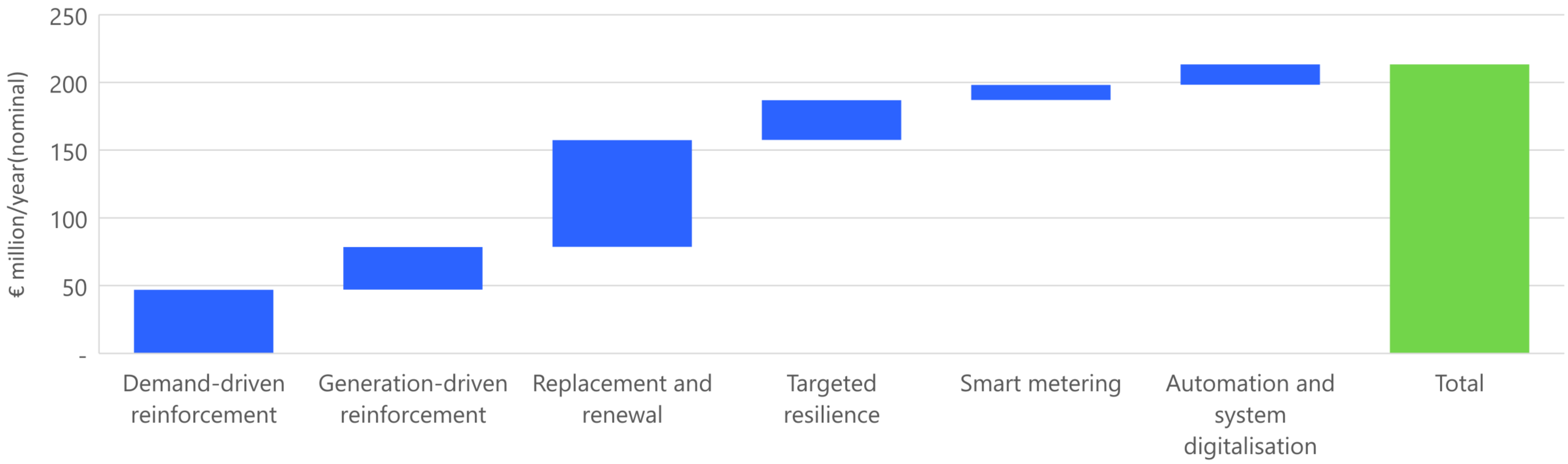
Denmark

CAGR for EV electricity demand will be 24% (2025–30) and 14% (2030–35)	PV and onshore wind production to increase 900% by 2050	Low population density with relatively high asset base per capita	93% of grid underground by 2033 – resilience improvement from reinforcement investments	Approximately €1.3 billion investment in smart metering required before 2050	Primarily in cybersecurity, grid maintenance and flexibility services



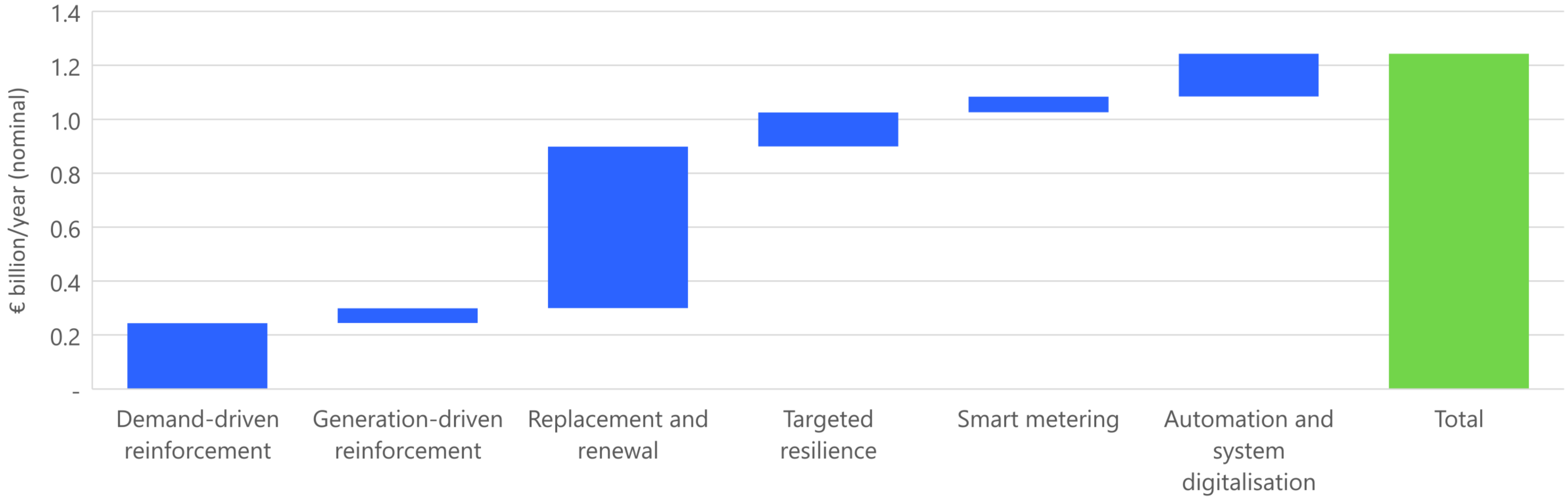
Estonia

25% CAGR for EV electricity demand (2025–30). And railway electrification in progress	Onshore wind capacity to grow 8x (2020–50), electric cogeneration also grows	Replacing underground cables, substations and overhead lines	Significant targeted investment in grid infrastructure	Smart meter replacements underway	Majority investment in system data management



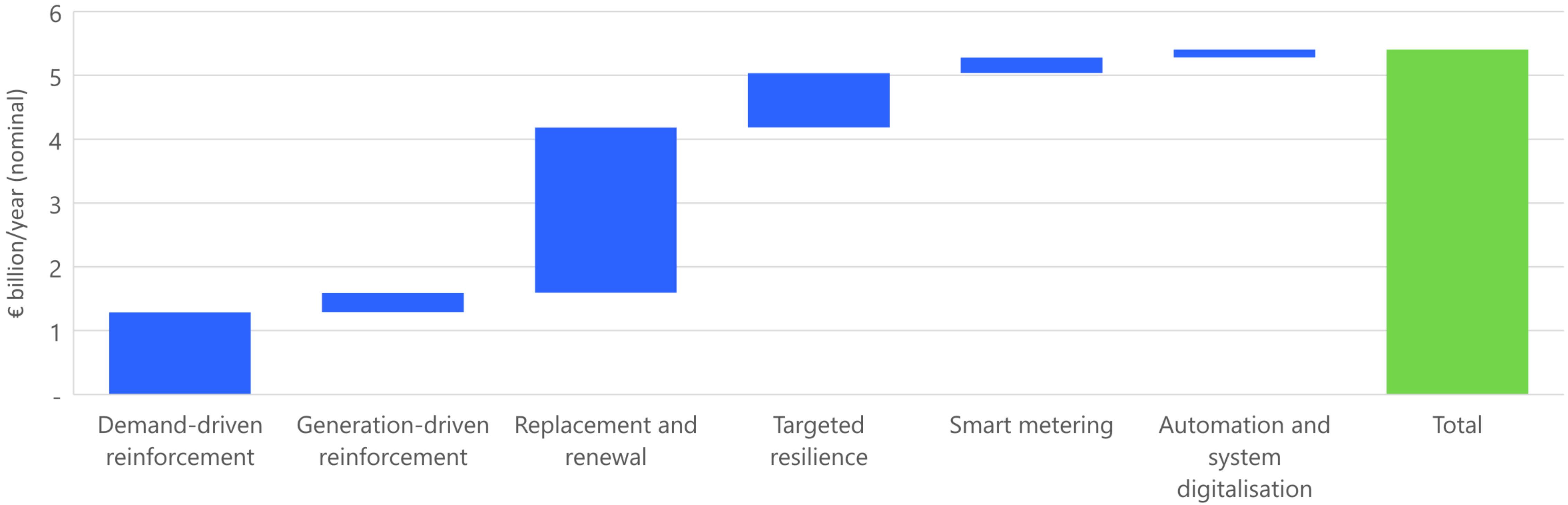
Finland

30% CAGR for EV electricity consumption to 2030 and rapid heat electrification (including district heating)	Continue significant investments in PV and onshore wind capacity	Low population density with relatively high asset base per capita	Higher security by moving lines away from forests, widening corridors and undergrounding	Completed first-generation rollout in 2013; second-generation rollouts in progress	Developing smart grid technologies



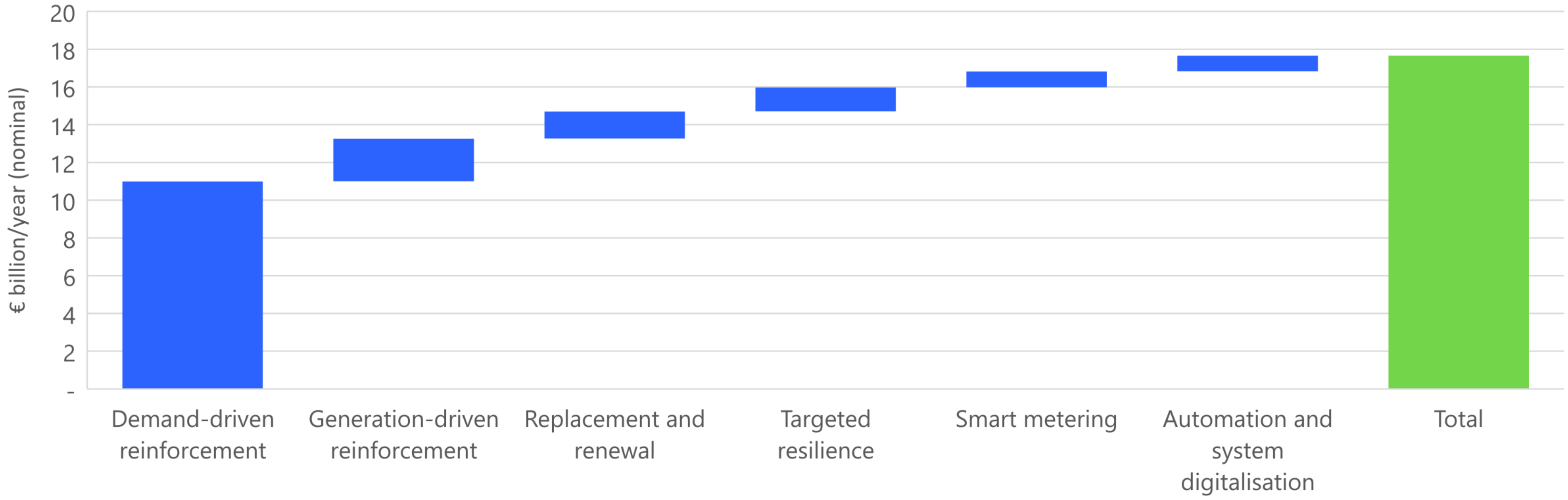
France

39 % CAGR for EV electricity (2025–30) and management of already highly electrified heat demand	PV and onshore wind production to grow 9x between 2020 and 2050	Renewal of ageing infrastructure	50% of total grid length is underground; further strengthening in of exposed grids	Delivery for smart meter holdouts, small number of new installs and replacement	Primarily in cybersecurity, flexibility services and digitising control centres



Germany

Aggressive policies for EV and heat pump deployment – EV will total 17% of total electricity demand by 2040	Wind addition drives HV/MV reinforcement and PV drives MV/LV reinforcement	Replacement of underground and overground cables	Continued investment in overhead to underground conversion with new feeder links	2023 legislation mandated installations, with full smart meter rollout targeted by 2030	Workforce management, condition-based maintenance, GIS and cyber checks



Greece

Strong EV growth, with EV electricity demand expected to equal 28% of total electricity demand by 2040

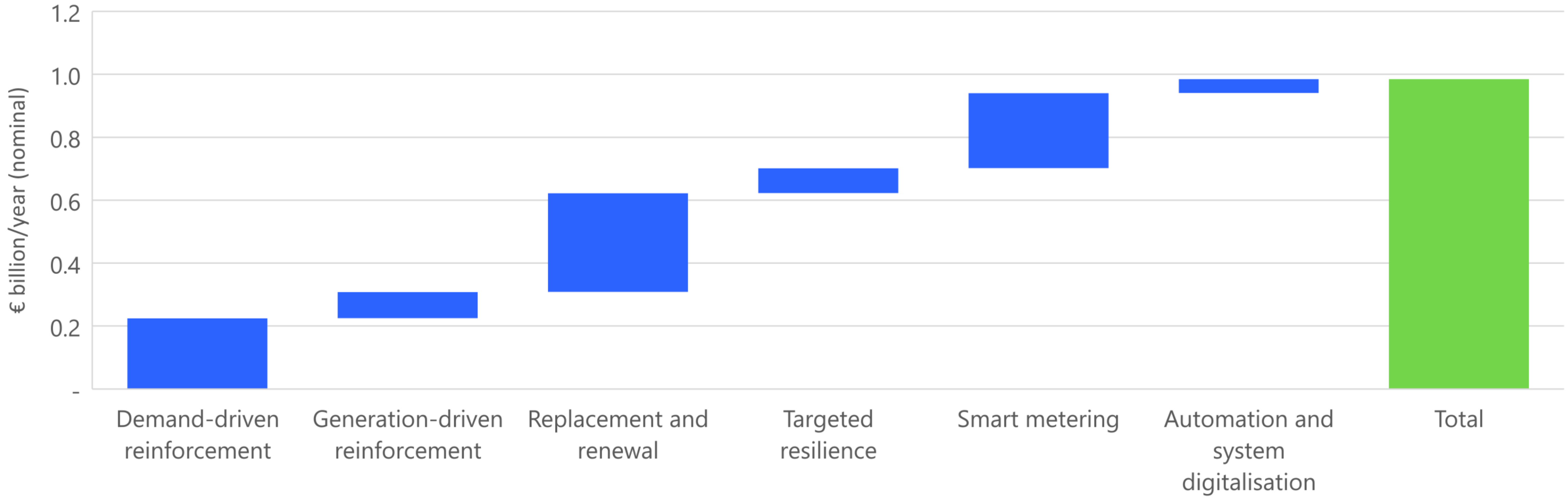
Integration of both onshore wind and solar PV

LV and MV grid upgrades, including substations

Targeted grid investment to reduce wildfire risk from overhead lines

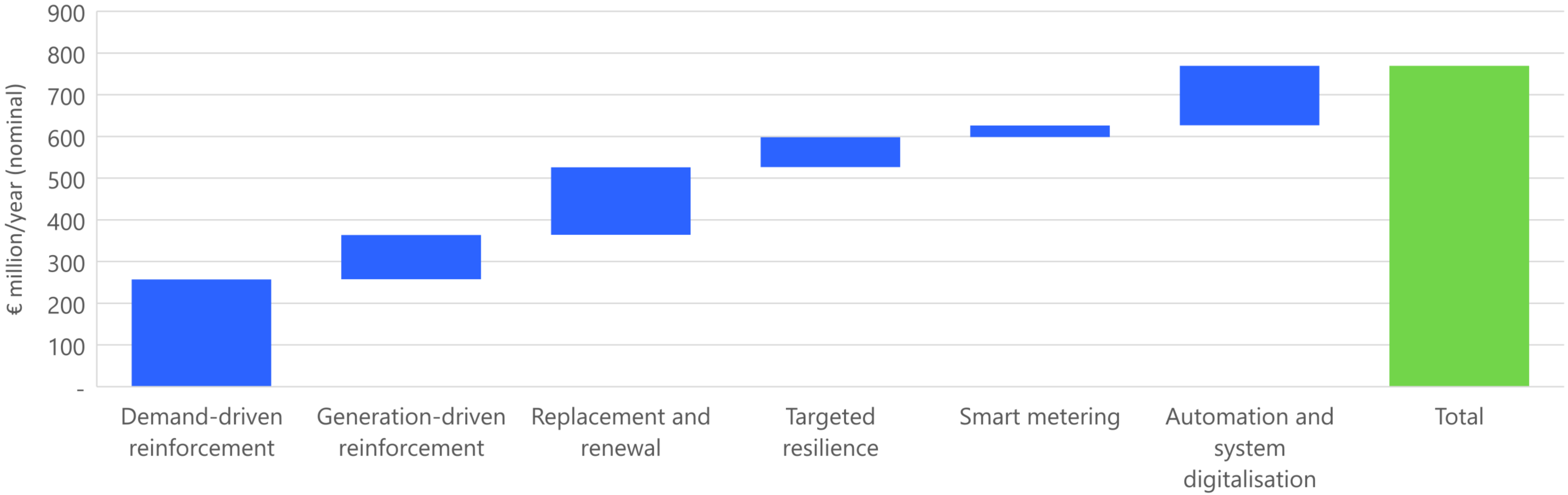
Full smart meter rollout being tendered; scheduled through 2030

SCADA/ADMS system installation and enhancement



Hungary

EV electricity demand as share of total electricity demand expected to reach 21% (2040)	PV capacity to grow from about 2.5TWh to 27TWh (2020–50)	Replacement of ageing assets to maintain reliable supply	Grid hardening, redundancy and disaster recovery plans	Low penetration of smart meters to date	Majority of investment in predictive maintenance and cyber risk



Ireland

EV electricity demand as share of total electricity demand will reach 19% in 2040

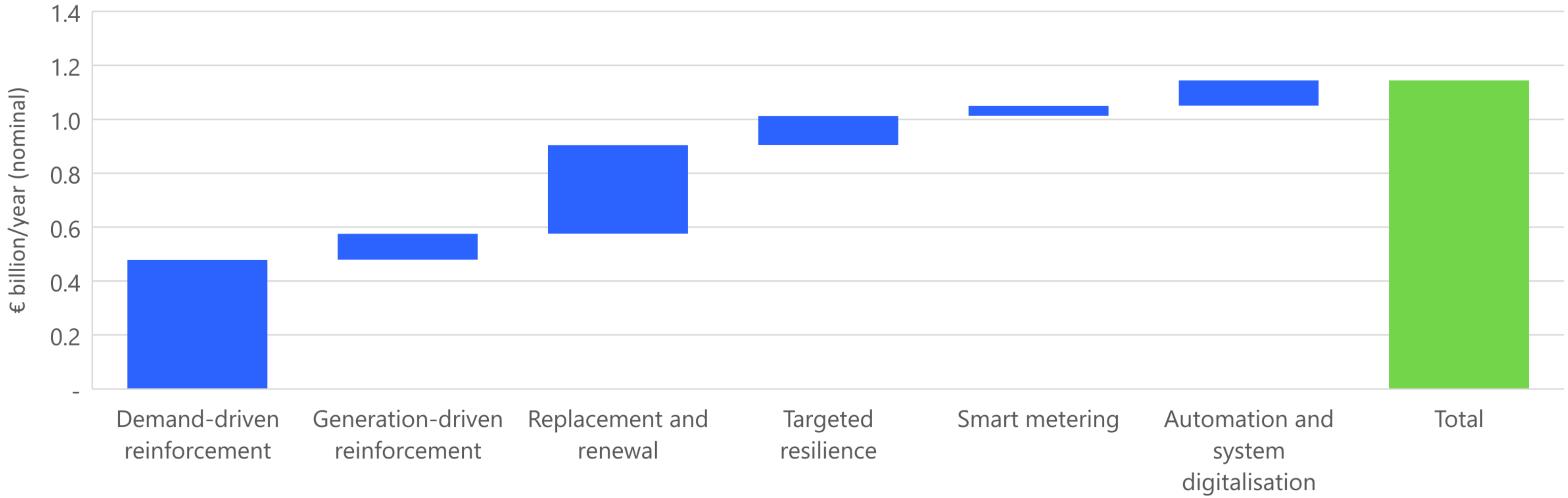
Continued integration in large onshore wind and also growing distribution connected PV (over 5GW expected by 2030)

Investment to renew ageing grid infrastructure

Approximately €2.8 billion in targeted grid resilience to harden grid exposed to weather hazards between 2025 and 2050

First time rollout underway with more than 1.5 million smart meter installs

Developing data management and cyber capabilities



Italy

Total electricity demand from heat pumps will reach 21TWh by 2050

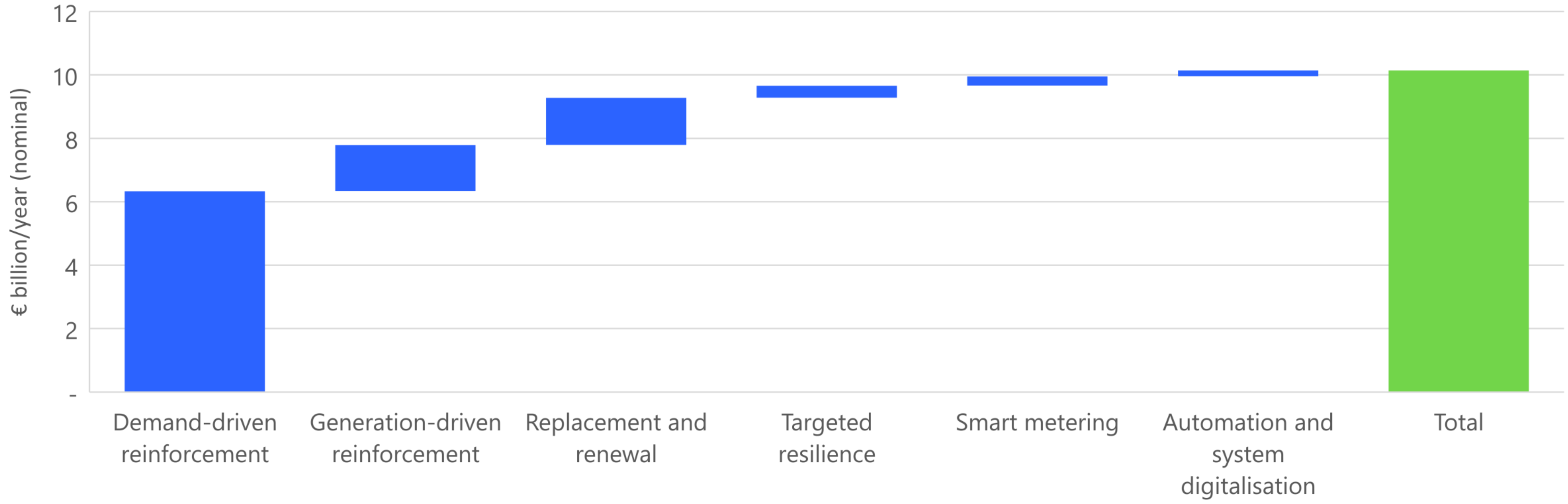
PV and onshore wind production to grow by 770% between 2020 and 2050w

Replacement of ageing asset base and further investment in smart grid advancements

Less exposure to extreme weather events

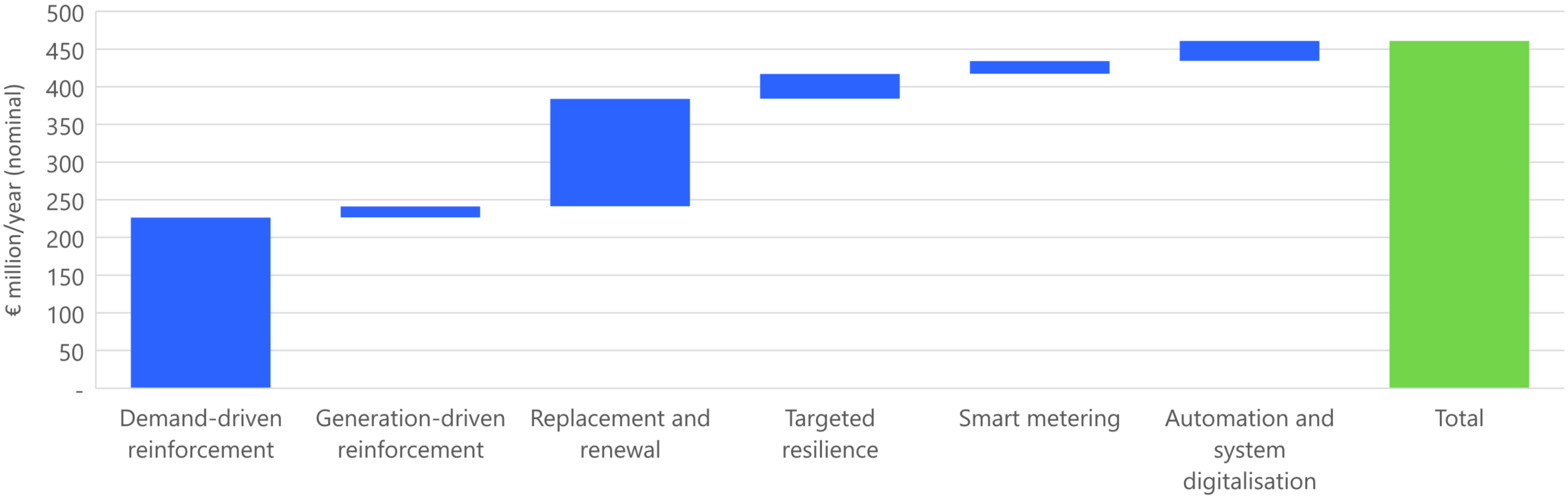
Second-generation smart meter rollout finished – future installs limited to new building constructions

Pioneering smart grid with investment in grid monitoring solutions



Lithuania

29% CAGR for EV electricity demand (2025–30) and 17% EV share in total electricity demand by 2040	Majority of renewables investment in onshore wind	Replacement for ageing grid infrastructure	Grid expansion to cater for renewable energy sources – focus on wind and solar capacity	Smart meter rollout underway	Grid monitoring systems, workforce management, substation automation



Luxembourg

Share of EV in total electricity demand will reach 16% in 2040

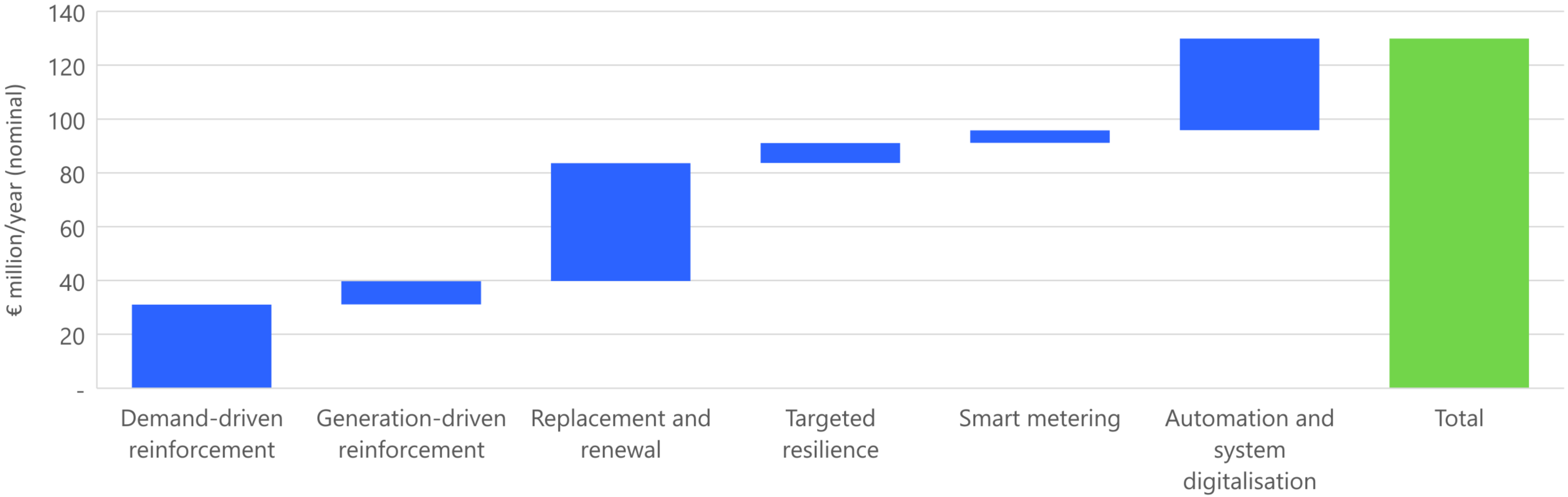
Strong investment requirements in renewables to meet national energy and climate plan (PNEC) targets

Upgrades to grid infrastructure to support reliability and improve efficiency

Grid expansion and interconnection

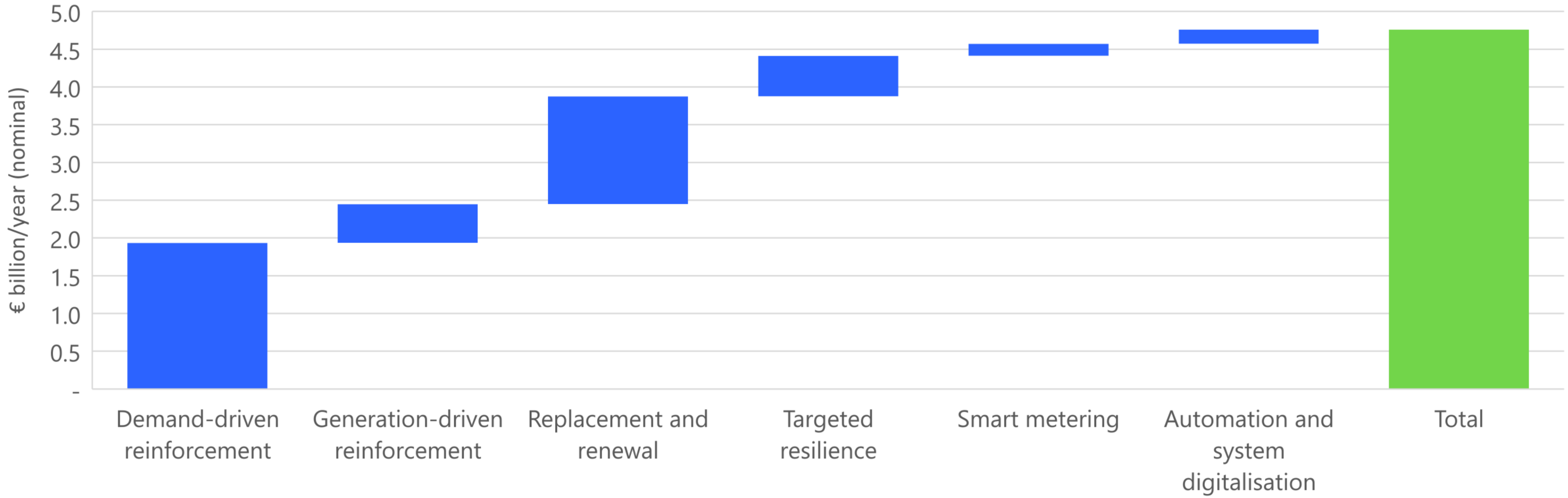
Greater than 80% smart meter penetration to date

Majority of investment in system data management and cyber risk management



Netherlands

EV electricity demand will total 16% of total elec. demand by 2040	Distribution-connected PV and onshore wind production to grow significantly	Replacement of ageing asset base	Approximately €14 billion forecast for investment in grid resilience between 2025 and 2050	€4.1 billion required for investment in smart metering before 2050	Primarily control centre digitisation and cybersecurity



Norway

Combustion engine ban planned for 2025 – CAGR for EV electricity demand will be 13% (2025–30) + additional electrification (trucks, ferries, etc.)

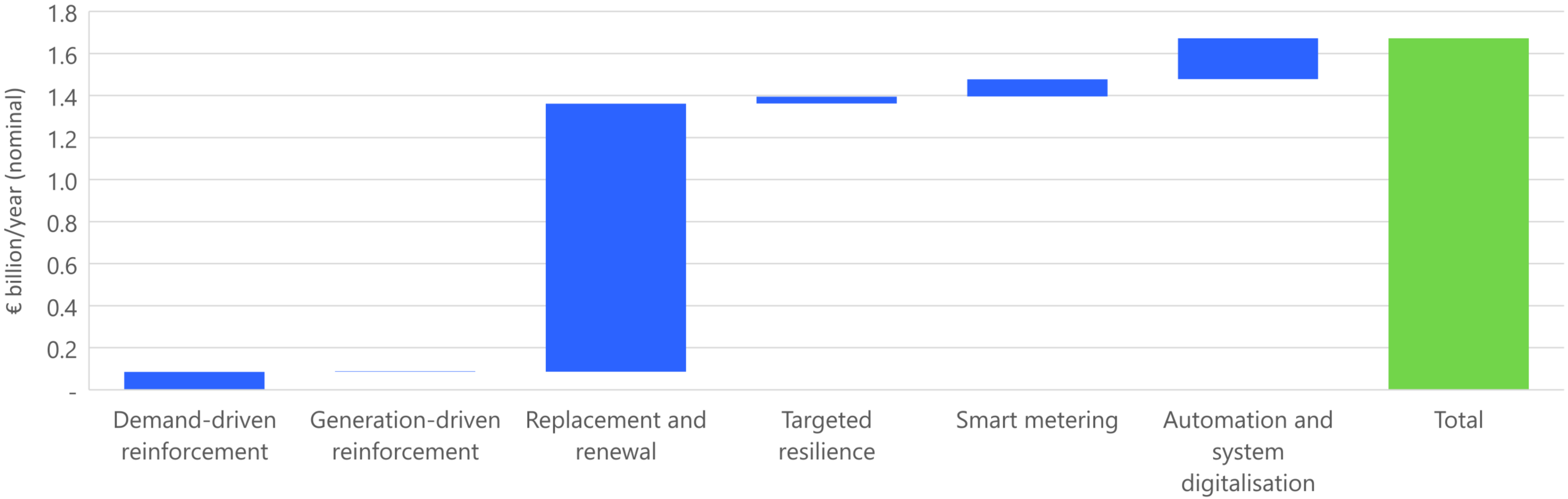
Relatively low PV additions on distribution grid, but new government target of 8TWh solar by 2030 could change this.

Lower population density with large asset base

Overhead line reconductoring and cable undergrounding

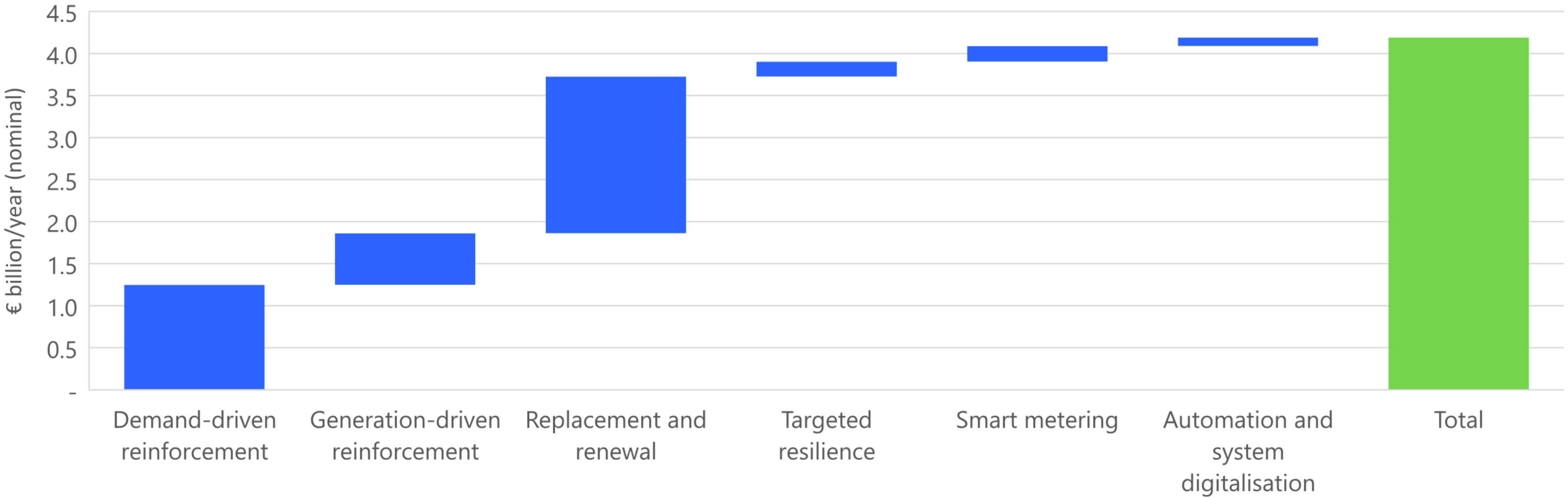
First-generation smart meter rollout complete

Majority of investment in grid operations and monitoring including ADMS, GIS, SCADA and DERMS



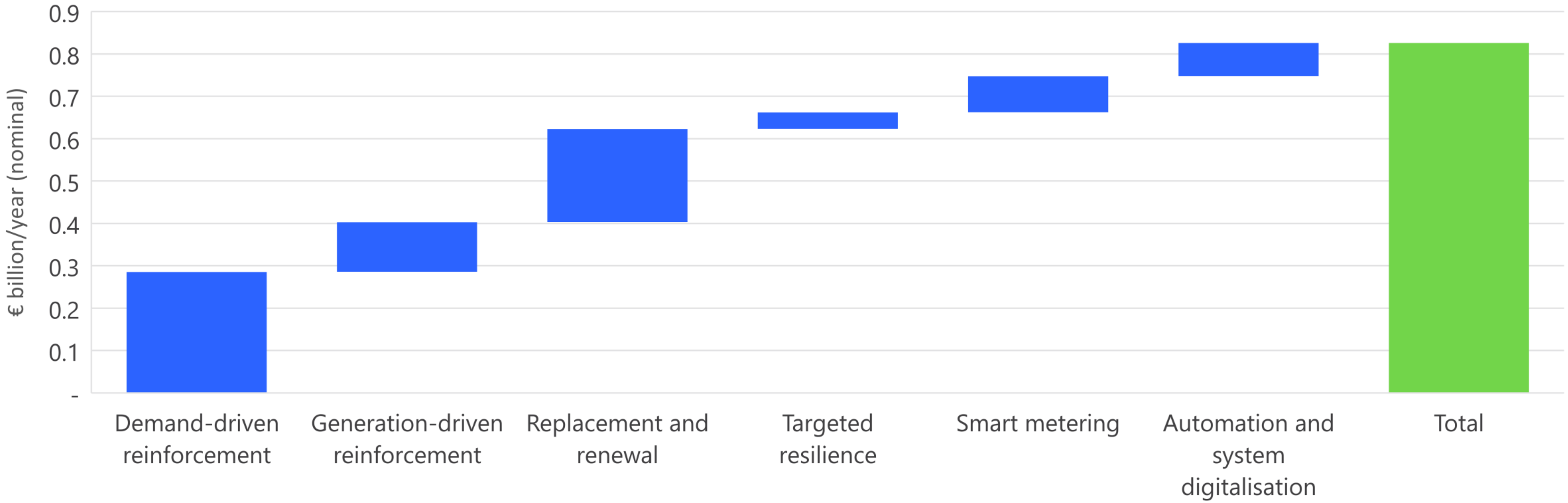
Poland

66% CAGR for EV electricity demand between (2025–30)	Significant investment in PV with capacity to grow from approximately 2 TWh to 72 TWh (2020–50)	Upgrading ageing grid infrastructure	Targeted grid hardening to cope with extreme weather events	Rollout underway since 2010s — 80% smart meter deployment expected by 2028	Substation upgrades and automation



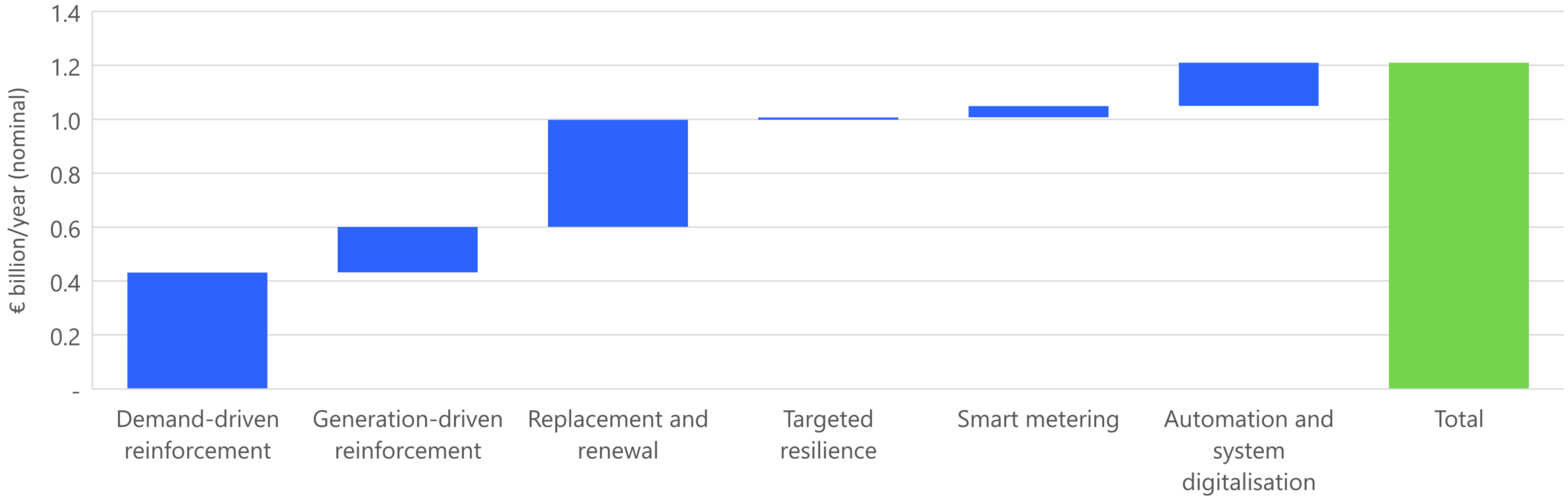
Portugal

40% CAGR for EV electricity demand expected (2025–30)	Renewables target of 80% by 2026 — significant growth of solar and wind capacity	Renewal of conductors, substations, switchgear, etc. due to condition	Creation of new grid corridors to improve resilience	First rollout to conclude in 2024, but ongoing investment in renewal and replacement	Established smart grid programme in place



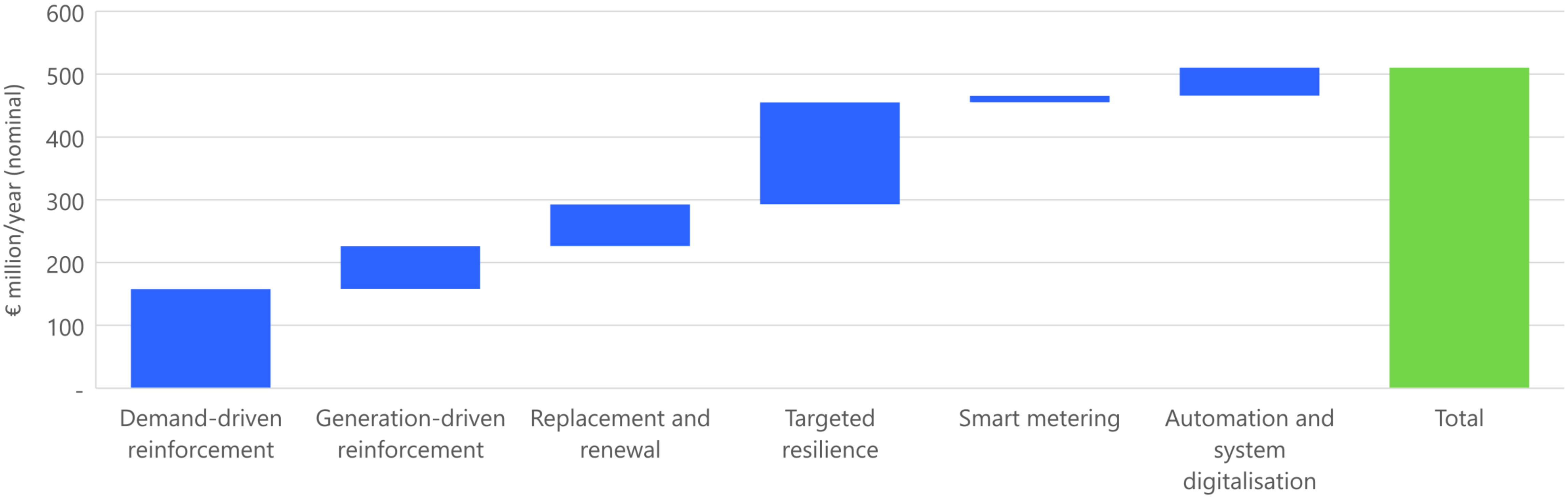
Romania

High EV share of total demand expected by 2040 (nearly 40%)	Significant investment in PV and onshore wind	Upgrading ageing infrastructure	Expanding grid capacity	Smart meter rollout to continue, with greater than 25% smart meter penetration to date	Workforce management, substation automation and developing data capabilities



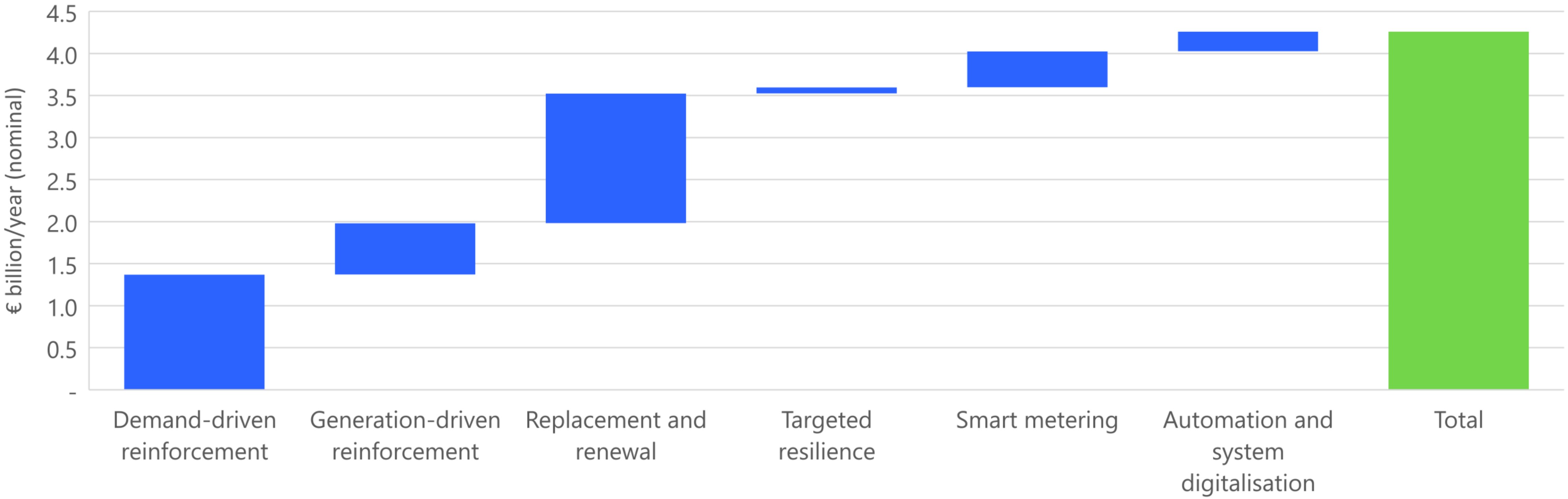
Slovenia

Strong growth in EV electricity demand expected — 24% CAGR (2025–30)	Majority of renewables capacity will come from PV	Replacement of ageing infrastructure	Targeted grid hardening to cope with extreme weather events	Smart meter penetration rate currently over 80% — further first-time rollouts required	Substation automation and workforce management



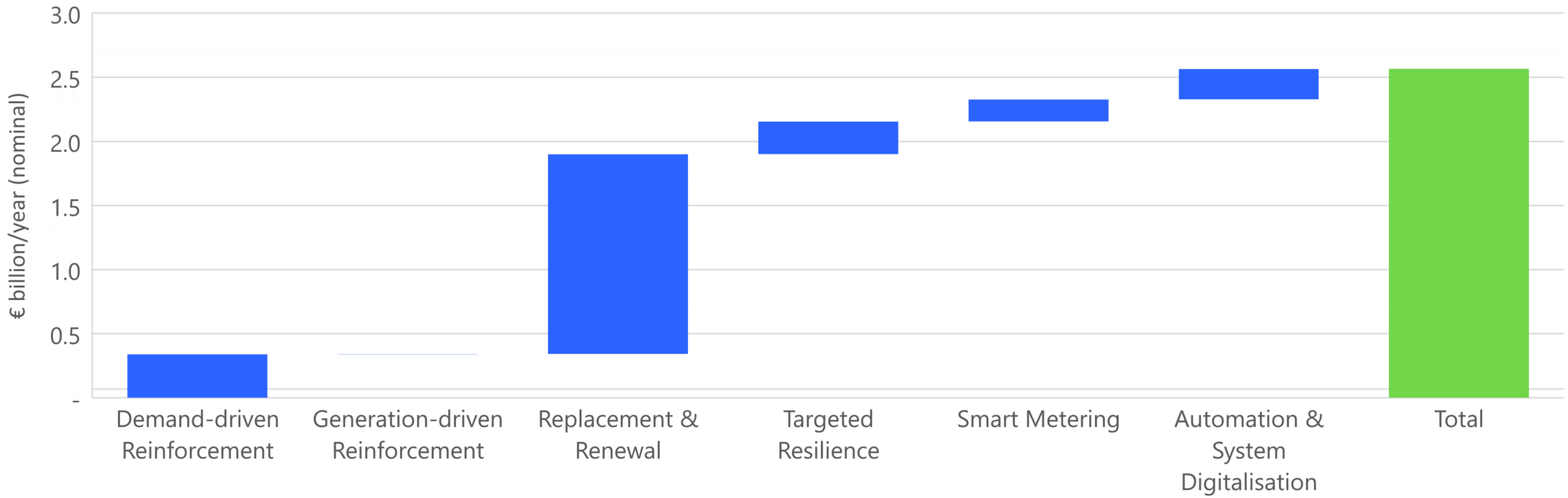
Spain

Heat pump share in total electricity demand to reach 4.5% by 2050	PV and onshore wind production to grow by 622% between 2020 and 2050	LV, HV and MV investment to support NECP, fix quality issues and improve yield	Approximately €1.9 billion forecast for investment in grid resilience (2025–50)	Smart meter rollout completed in 2019 — refresh rollouts expected in next five years	Majority of investment in workforce/crew management and digitising control centres



Sweden

Heat pump share in total electricity demand to grow to 11% (2050)	Wind onshore capacity to reach 104 TWh by 2050	Investment in renewing assets due to condition	Approximately €6 billion required in targeted resilience before 2050	Refresh rollouts are pending for all Swedish utilities	Workforce management, substation automation and data management



Appendix D: Inflation assumptions

Producer Price Index (PPI)

The GfS investment numbers presented are shown in nominal terms and were calculated using the following country-level PPI.

Country	2023	2025	2030	2035	2040	2045	2050
Austria	100	98	100	106	114	123	133
Belgium	100	81	82	90	99	109	120
Bulgaria	100	93	97	106	118	130	143
Croatia	100	99	97	98	102	108	115
Cyprus	100	102	108	119	131	145	160
Czechia	100	98	104	116	130	144	161
Denmark	100	93	86	83	85	90	96
Estonia	100	92	98	109	122	135	150
Finland	100	92	93	98	105	113	122
France	100	83	84	89	95	101	108
Germany	100	90	85	85	88	94	101
Greece	100	92	95	106	116	128	140
Hungary	100	99	106	123	143	166	193
Ireland	100	102	109	120	133	147	162
Italy	100	94	87	83	85	91	97
Latvia	100	90	82	77	79	84	91
Lithuania	100	87	89	95	104	114	126
Luxembourg	100	93	99	109	121	134	147
Malta	100	100	106	117	129	142	157
Netherlands	100	95	94	96	101	107	115
Norway	100	78	83	92	101	112	124
Poland	100	94	98	105	114	124	135
Portugal	100	99	106	117	129	143	157
Romania	100	103	111	126	142	160	181
Slovakia	100	97	103	114	126	139	153
Slovenia	100	95	101	111	123	136	151
Spain	100	87	83	87	95	102	109
Sweden	100	92	95	104	114	126	138

Source: Oxford Economics, Databank.

Appendix E: Regulatory analysis

Overview

This appendix provides additional information on topics discussed in the regulatory section:

- Summary of common regulatory challenges that the regulatory tools will need to address
- Overview of key survey responses to our consultation
- Key regulatory definitions
- Considerations for island grids

The regulatory toolbox will need to address common regulatory challenges

DSOs currently face four main challenges in accelerating investment to deliver.

Regulatory and other processes could slow delivery of necessary investment in some geographies

- Lack of mechanisms to de-risk DSO investment in areas of high need
- Benchmarking relies on historical costs
- Lack of anticipatory investment mechanisms
- Short investment horizon
- Lack of efficient and agile approval/permission processes
- Insufficient ability to amend investment plans
- Lack of coordination among RES development and grid development

Financial and regulatory constraints and/or investment disincentives over allocates risks to DSOs unless additional network demand is certain

- Timeliness of capex and opex recognition in investment mechanism
- Adapt WACC to macroeconomic conditions
- Affordability concerns
- Cost of delays in capex recognition
- Efficiency targets limiting maintenance to achieve operational excellence

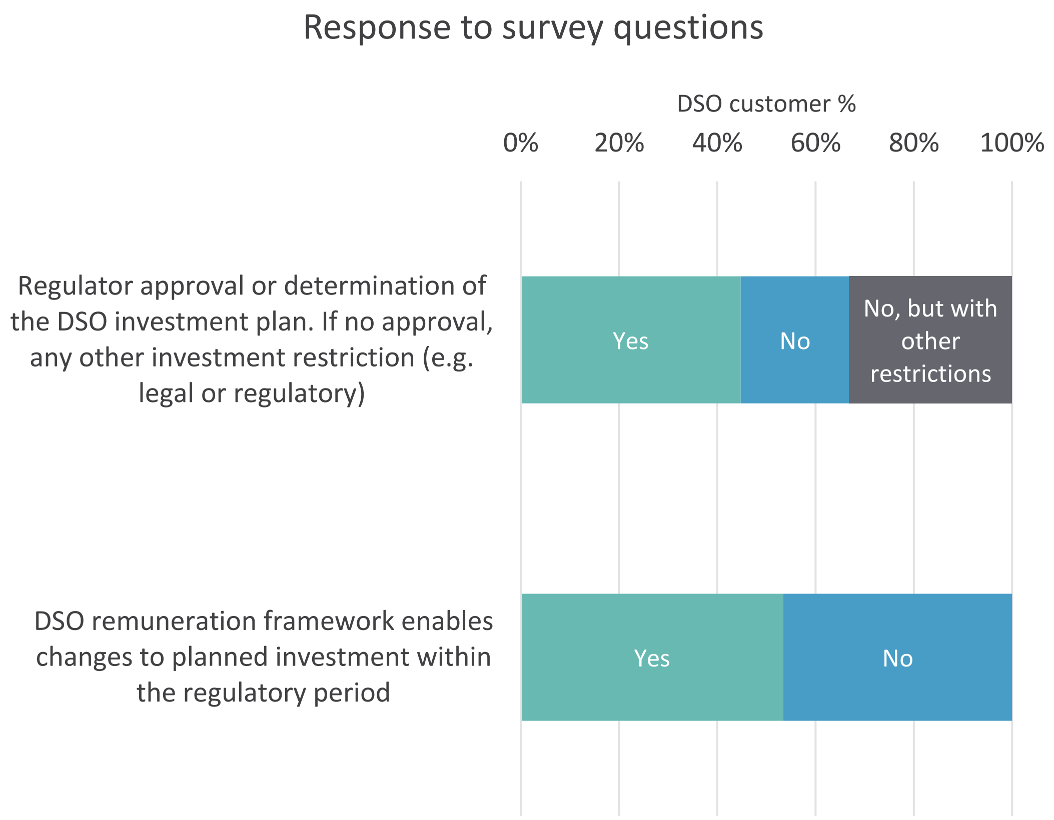
Economic and societal benefit not prioritised for connections

- Lack of mechanism to reduce overasking for capacity
- Connection agreements often do not reflect grid capacity

Insufficient incentives or allowances to support grid-friendly flexibility

- Need for additional opex to reflect higher capex
- Active grid management through tariff variation not always applied

Regulatory processes and other enablers are key determinants of a DSO's ability to invest



Observations

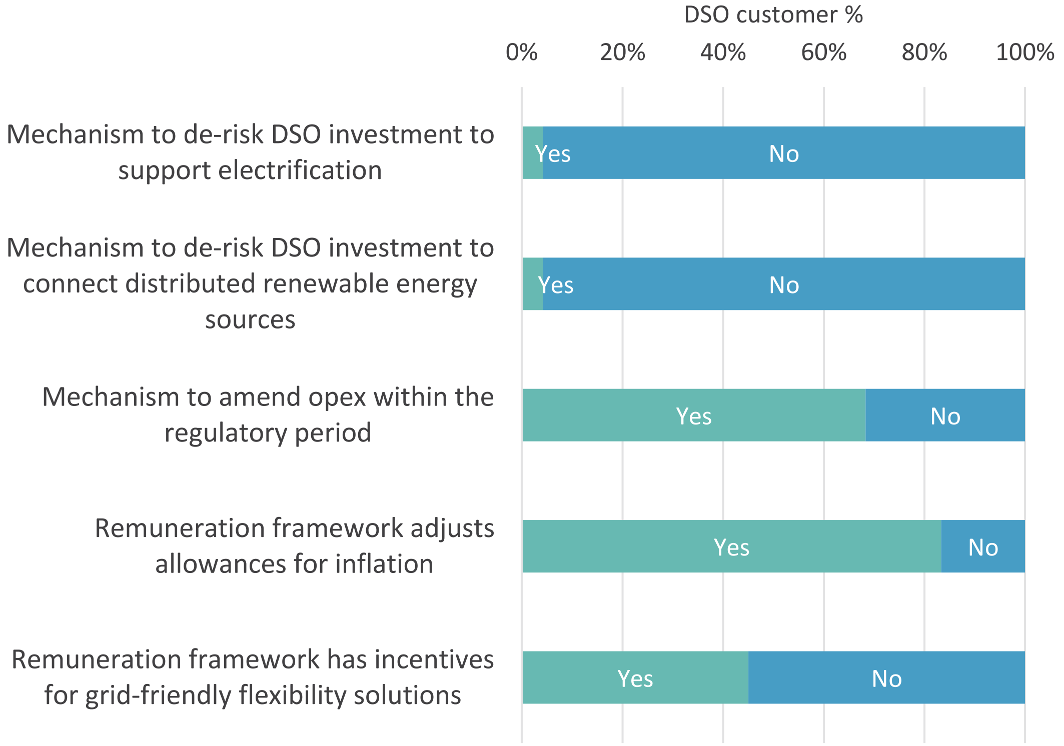
- For most DSOs, the regulatory framework or other legal or regulatory processes play a key role in determining the ability of the DSO to attract private investment to the grid.
- Approval of investment (either ex-ante or ex-post) is an additional hurdle that can impact when investments occur.
- This is particularly the case for DSOs with a revenue or price cap, although also present in hybrid frameworks.
- However, in the majority of cases, there are regulatory mechanisms that enable DSOs to amend their investment plans to respond to changing investment needs.
- This is relevant across remuneration frameworks, with greater prevalence under a revenue or price cap.
- Transparent, consultative, objective, apolitical and evidence-based decision-making is key to reduce risk.

Implications for regulatory analysis

The importance of regulatory processes in enabling investment at pace and scale.

Incentives and restrictions in today's regulation will impact DSO investment decisions

Response to survey questions on existing regulation



Observations

- The majority of remuneration frameworks do not differentiate the level of risk[1] to DSO for investments needed to support decarbonisation, such as electrification of heating or connecting distributed renewable energy sources, compared with traditional DSO deliverables.
- While capex can generally be amended in a regulatory period, this is not generally the case for opex, which is commonly fixed for the duration of the regulatory period.
- DSO frameworks are adjusted for inflation, ensuring they reflect general changes in price inflation. This protects DSOs to the extent that DSO costs move in line with this metric.
- Approximately half of DSOs are incentivised to procure grid-friendly flexibility solutions.

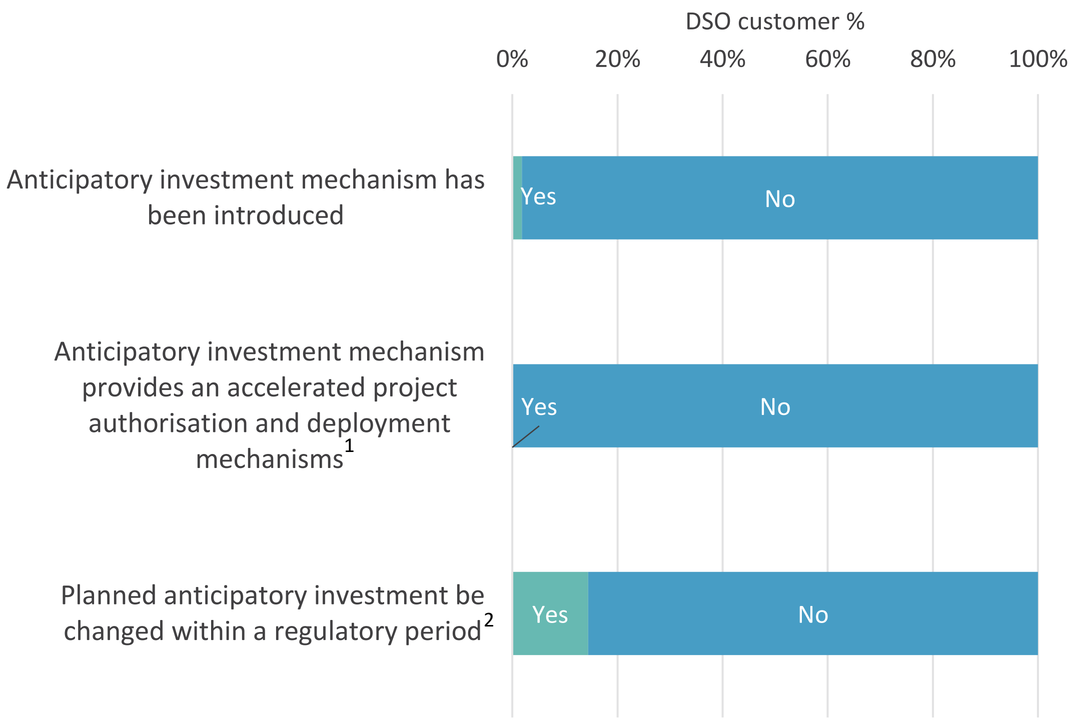
Implications for regulatory analysis

Mechanisms that adequately de-risk and incentivise some type of DSO investments are lacking.

1. In this context, de-risking refers to practices within a regulatory framework that reduce the economic risk to DSOs of losses via penalties or disallowed costs for investing to meet the grid requirements

Anticipatory investment mechanisms still need to be implemented in most regulatory frameworks

Response to survey questions on existing regulation



Observations

- The majority of DSOs do not currently have a targeted regime for anticipatory investment. However, it is noted that this is likely to change following implementation of the EMD regulation following EU Parliament and EU Council approval.
- Current anticipatory investment mechanisms do not include an expedited approval process compared with traditional investment.
- Current anticipatory investments do not generally enable DSOs to amend their anticipatory investment plans in response to new information.

Implications for regulatory analysis

The importance of enabling anticipatory investment given its identification as the most cost-effective emerging grid strategy in GfS.

1. Share of respondents with current anticipatory investment mechanisms.
2. Share of respondents with current anticipatory investment mechanisms.

Key regulatory terms

Below, a few key terms used in the report are defined

Term	Description
DSO opex and capex	DSO operating expenditure (opex) relates to the ongoing costs for operating the DSO grid, which includes system maintenance, repairs and customer service. DSO capital expenditure (capex) refers to the infrastructure investments, such as power lines, transformers or grid automation equipment. It could also refer to the expenses for upgrading existing infrastructure to improve service quality and reliability, or to meet regulatory requirements.
Grid tariffs	Grid tariffs relate to the charge that energy users (households or businesses) have to pay for using the distribution grid of the DSO. This tariff is designed to cover the costs that a DSO incurs for the operation, maintenance, and development of the energy distribution grid. The specific structure of these tariffs varies depending, for instance, on national or subnational regulation and level of incentivisation.
Remuneration framework	The framework that outlines how DSOs are compensated for their services. It regulates how DSOs recover investment and operational costs, and make profit through service tariffs charged to electricity consumers and generators. Remuneration frameworks may also include incentives for achieving specific targets such as reliability and quality of supply, the integration of renewable energy sources and the reduction of losses in the grid. Remuneration frameworks normally include benchmarking of capex and opex, which may be done separately or together. When capex and opex are benchmarked together, it is sometimes referred to as a totex regime.

Increased planning uncertainty and grid stability services for island electricity grids

The insularity and weak interconnectivity of island electricity grids present unique challenges that necessitate distinct regulatory and financial approaches to their energy transition.

Higher planning uncertainty

- In island grids, electricity demand fluctuates more significantly across seasons as islands are often popular leisure and tourism destinations with heightened activity in a limited period (e.g., during the high season).
- Additionally, the actual number of grid users is generally much higher than the number of customers due to factors such as day visitors or large customer loads with a high number of users (e.g., hotel complexes).
- Consequently, planning uncertainty and risk are elevated, which is reflected in financial performance and should therefore be taken into account in regulatory considerations.

Need for grid stability services

- Island grids required enhanced grid management to ensure secure and stable electricity supply compared to highly interconnected regions.
- Grid inertia and rapid fault current (also called, short circuit level) are necessary to maintain power system stability. However, synchronous generators, which traditionally provide these services, are replaced by an increasing numbers of asynchronous renewable generation sources.
- Thus, additional investments in grid stability management and technology (e.g., batteries, flywheels, synchronous condensers) will be essential for island grids (our proposed islands grid stability toolbox could help address this challenge).

Appendix F: Energy price analysis

Methodology for estimating future household energy bills

Scope

The scope is the total energy bill of residential homes, including heating and private car usage, in Europe (EU27).
The GfS distribution investment forecast to 2050 is used to estimate impact the future DSO tariff.
Additional assumptions on electricity and energy supply is from Eurelectric's Decarbonisation Speedways:

- Household consumption trends up to 2050 per country
- Wholesale electricity prices up to 2050 per country
- Energy prices trends up to 2050 for EU-27[1]

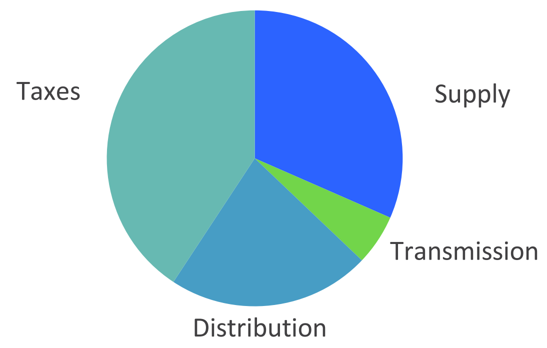
Approach

- Supply is derived from the wholesale market simulations completed in Decarbonisation Speedways.
- The DSO tariff is modelled on GfS investment forecasts and a simplified building block model (allowed revenues =capex return + depreciation + operations and maintenance).
- The TSO tariff consists of existing investment expenses, augmented by costs for offshore wind development.
- The proportion of tax included in electricity tariffs is expected to remain constant in relative terms through to the year 2050.

Limitations

- The evolution of DSO and TSO tariffs is calculated at EU27-level, without distinguishing between individual countries.
- Household DSO and TSO tariffs are based on electricity consumption only and do not consider their point of connection.
- The supply portion of the tariff is not tailored to customers' load types (e.g., residential, services, industrial customers).
- Wholesale electricity price simulations are conducted for three climate years.

Electricity tariff components in EU27



1. Except for electricity, assumptions are derived from external sources.