EU Power Roadmap 2050

How to get to a prosperous, low-carbon Europe

partner in Smart Energy Collective

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KEMA DNV

The changing world of energy

Macro trends driving change

Complexity **Globalisation** **Energy transition**

The energy transition playing field

The energy transition is taking shape in the context of political, technological and economic trends.

Political

Political trends reflect the major elements of energy policies.

- Liberalization, Gas & Electricity Directives (and related legal and regulatory framework and arrangements)
- Regional integration and harmonization
- Climate policy (support of renewable energies, CO2 emission trading, energy efficiency)
- Security of supply

Technological

Technological trends are mainly driven by the climate policy and technological progress.

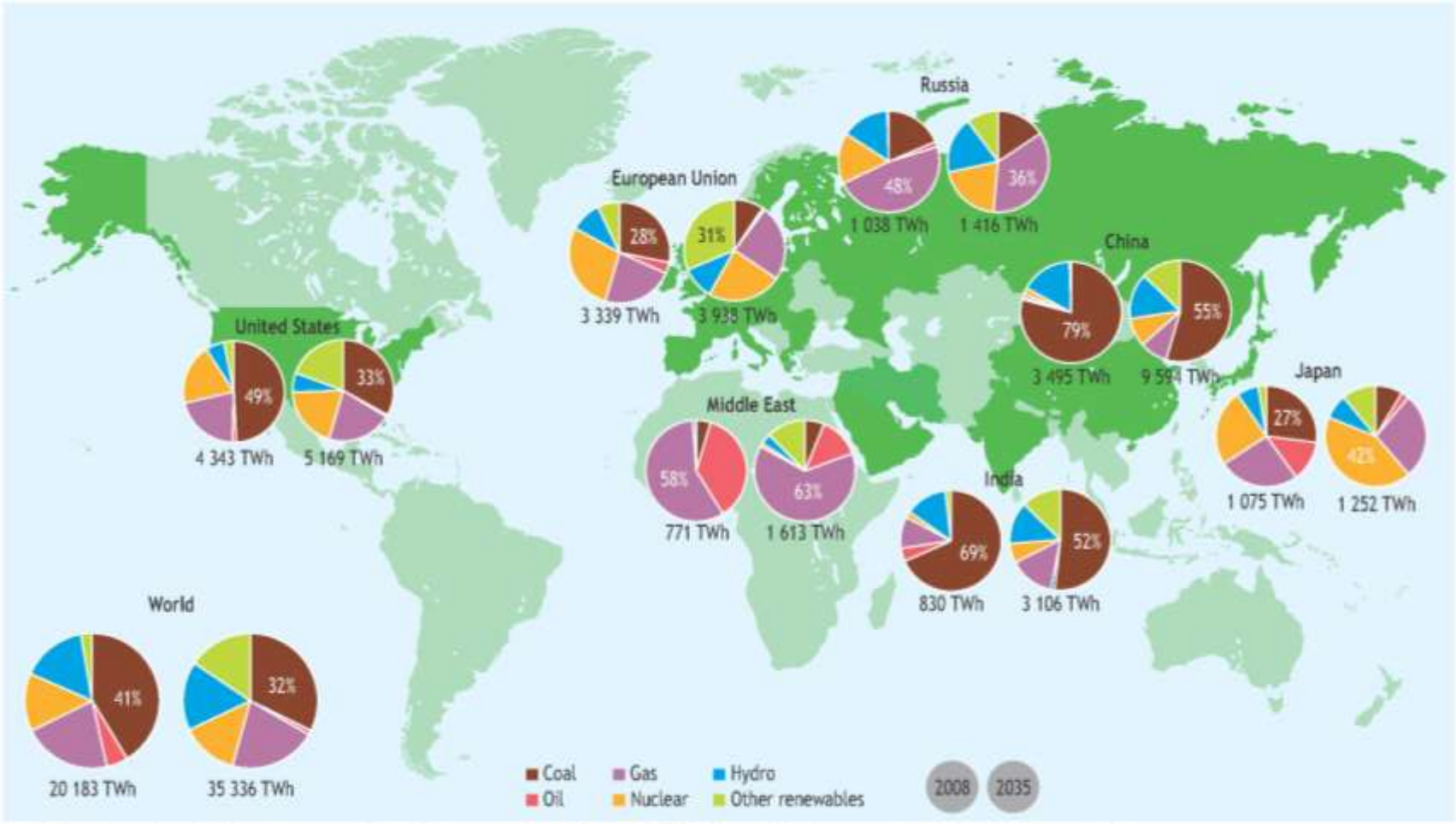
- Enhancement of renewable technologies
- Increasing efficiency (conventional generation)
- End-use energy efficiency
- Network technology (DC)
- Electric vehicles
- Dispersed generation
- Smart metering / smart grids
- Energy storage

Economic

Economic trends are mainly driven by general economic development, sector specifics and energy policy.

- Aging assets & replacement needs
- Increasing regional trade but still fragmented markets
- Demand growth
- Regional harmonization
- Corporate consolidation
- Convergence of gas and electricity markets

Electricity generation by fuel and region in IEA's New Policies Scenario in 2035 vs. 2008 (WEO 2010)

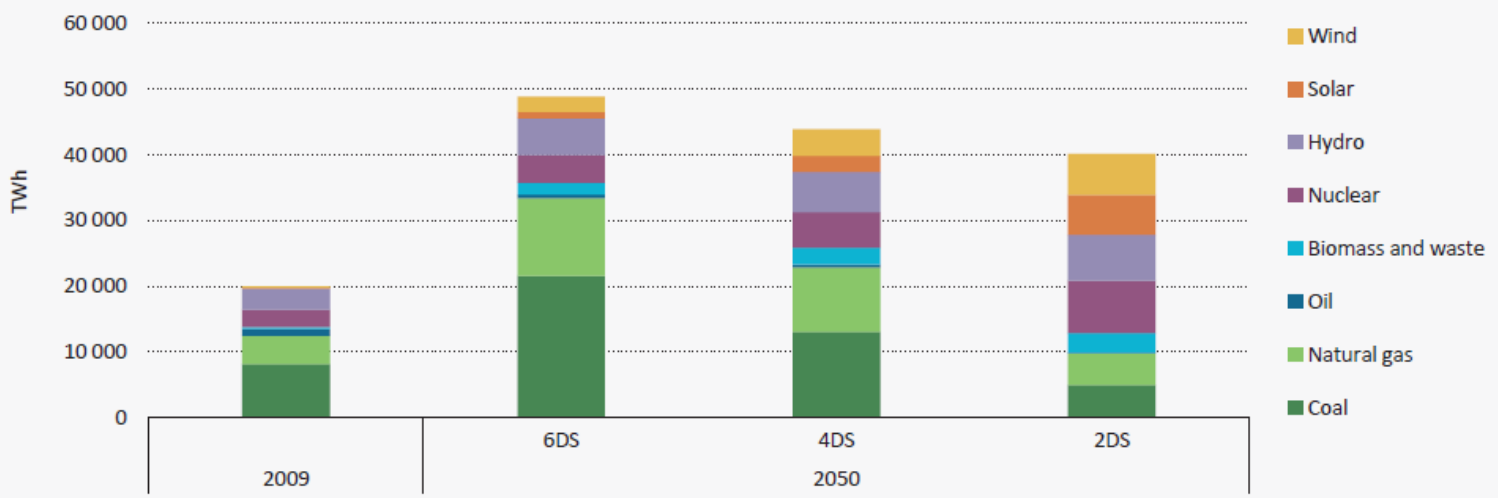


Note: For each region, the largest source of electricity generation in 2008 and 2035 is denoted by its percentage share of the overall mix.

Source: IEA World Energy Outlook 2010

Share of renewable energy sources in electricity generation

Fuel mix in electricity generation, by scenario



Key point *Diversification of fuels and increased use of low-carbon sources in the 2DS achieves a high degree of decarbonisation in electricity generation by 2050.*

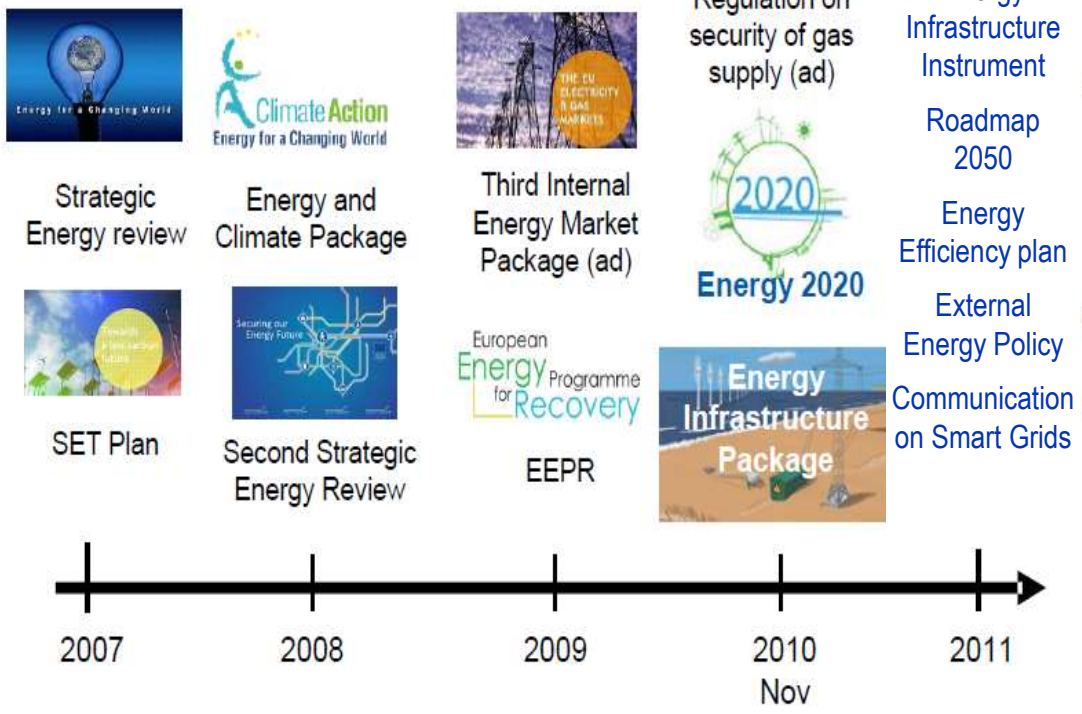
Source: IEA Energy Technology Perspective from 2012 (June 11)

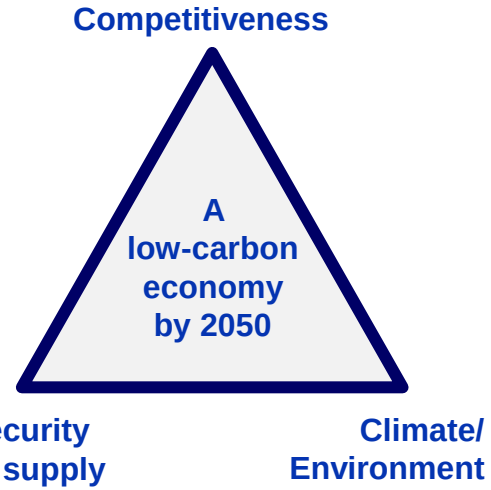
From fossil fuels to renewables

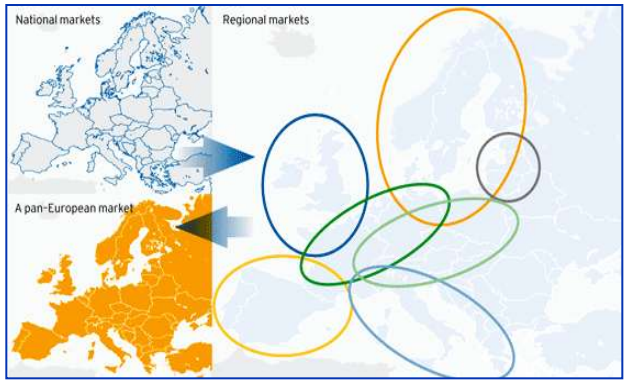
- Concerns about our global environment

- Europe wants to be less dependent on energy imports

EU Energy policy development







Europe's focuses

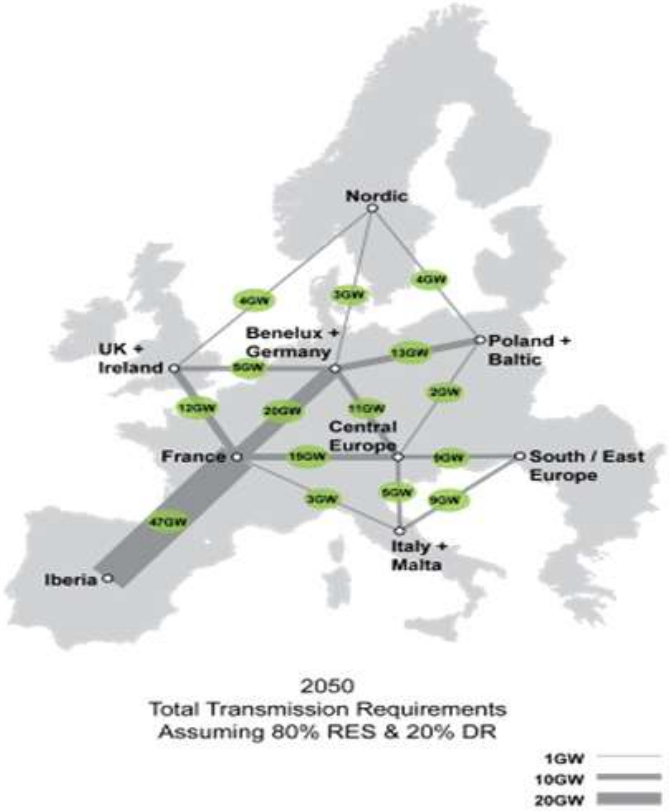
- Clear distinction between public and private activities: ***unbundling***

- Competitiveness of Europe in global market: ***sustainability***

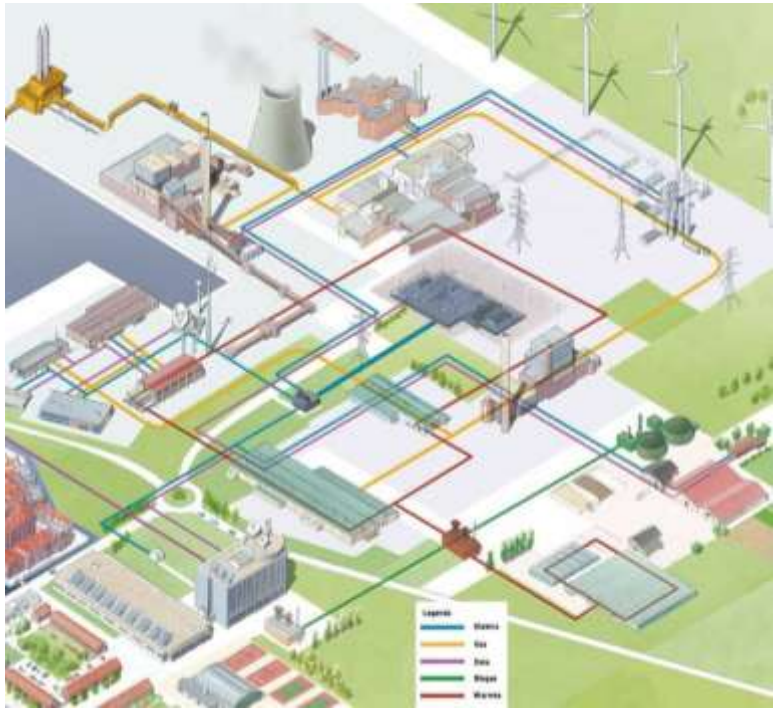
- Empowering customers: ***smartening***

The scale, and the priority of the business is shifting …

- **Europeanization**: increase of interconnection capacity and of cross-border trading; cooperation between European industries and institutions



- **Decentralization**: local energy (DG); new initiatives from small companies, citizens, and municipalities; innovative business models



… and dependency on data in a digital world is increasing

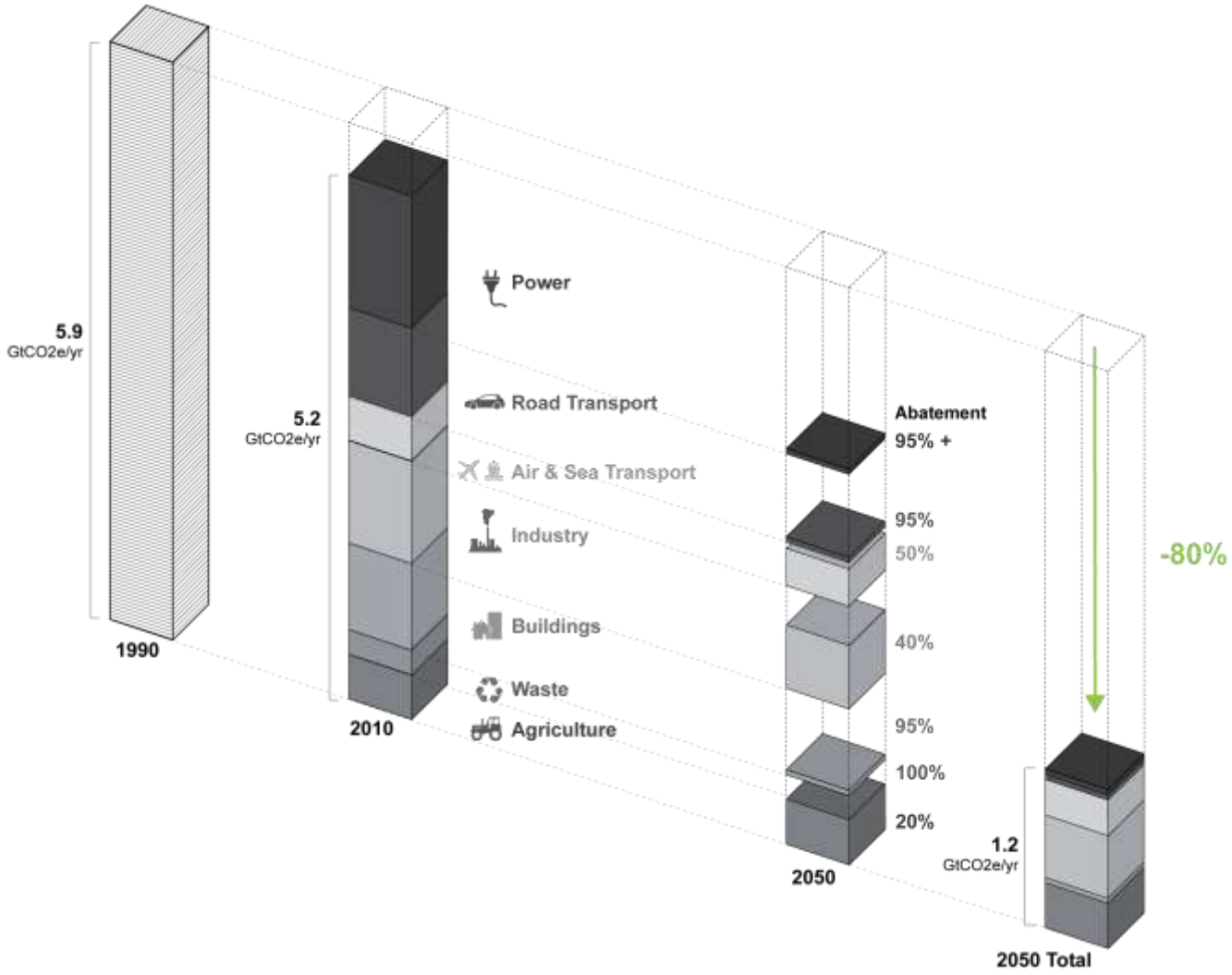
- Both work and private life has become digitalized which offers many advantages …
- … however, also creates larger dependencies on data or power interruptions

Many developments influencing the energy transition system

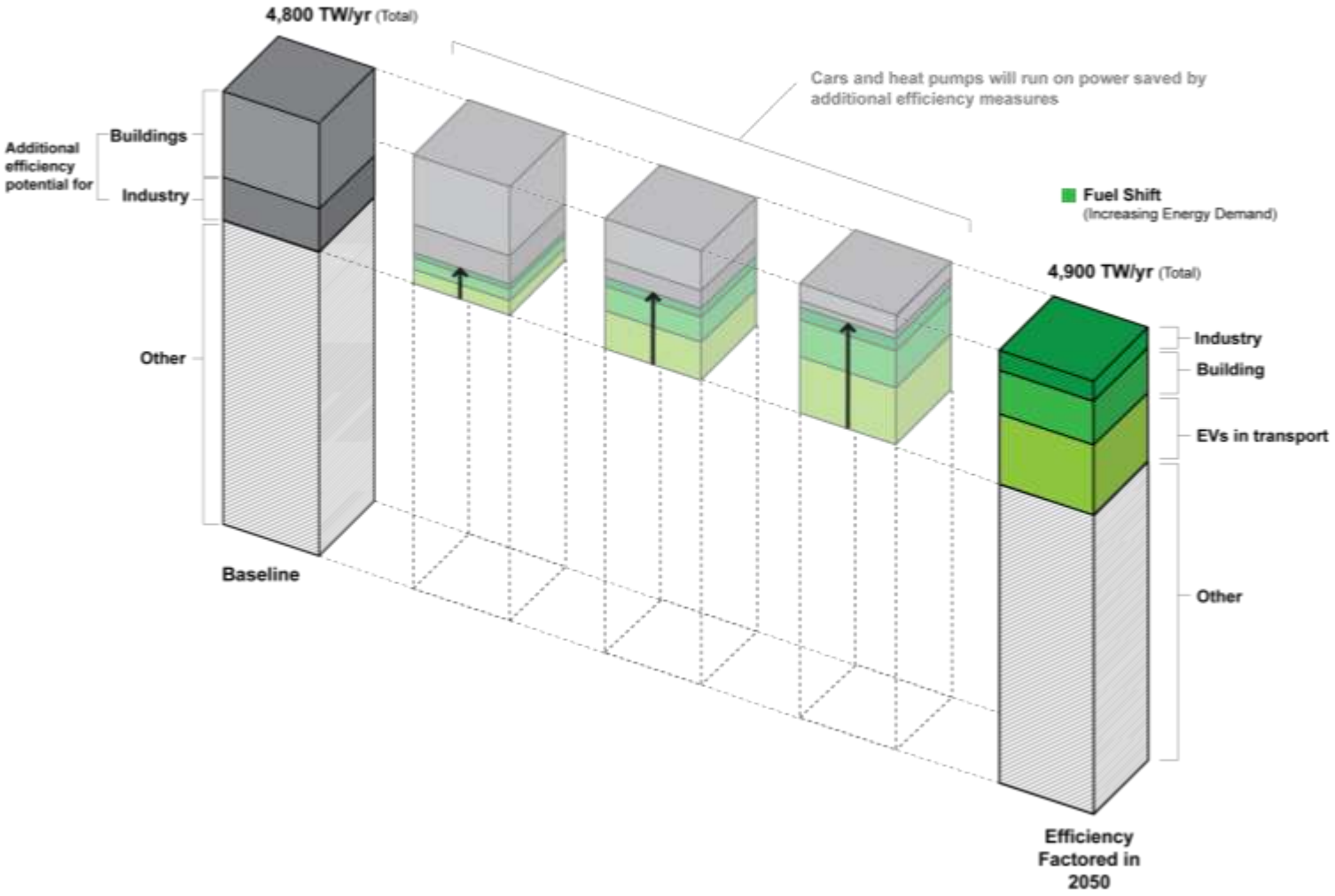
HOW DO WE GET THERE FROM HERE?

Europeanization: One internal market, decarbonization

80% Decarbonization overall means nearly full decarbonization in power, road transport and buildings

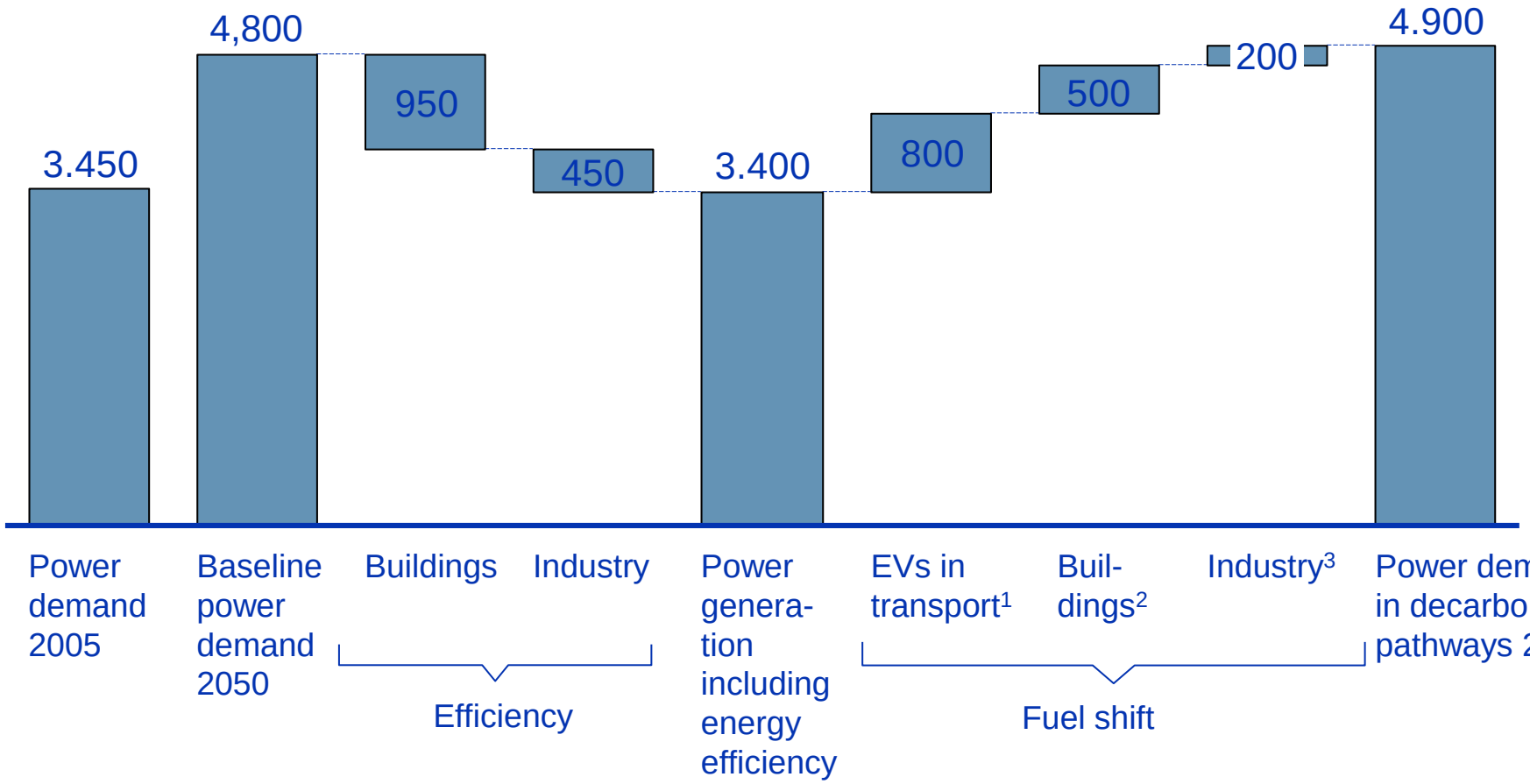


Power demand will go down due to higher efficiency and up due to additional demand from transport and building heating



Power demand will go down due to higher efficiency and up due to additional demand from transport and building heating

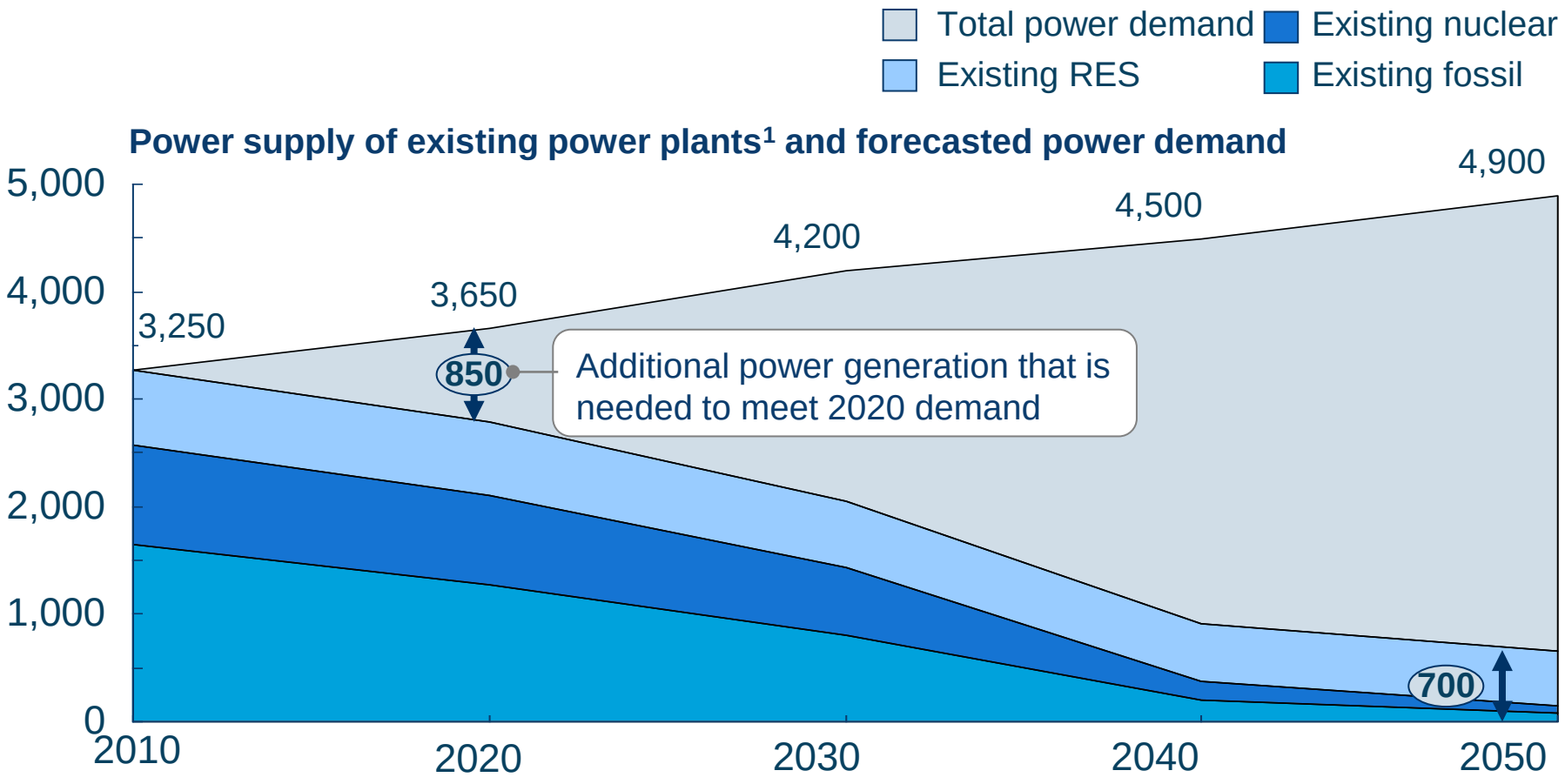
EU-27 plus Norway and Switzerland power demand, TWh per year



1 Electrification of 100% LDVs and MDVs (partially plug-in hybrids); HDVs remain emitting ~10% while switching largely to biofuel or hydrogen fuel cells
2 90% of remaining primary energy demand converted to electricity (heating/cooling from heat pumps); assumed 4 times as efficient as primary fuel
3 10% of remaining primary energy demand for combustion converted to electricity (heating from heat pumps); assumed 2.5 times as efficient as primary fuel

Additional 850 TWh/yr of production is required by 2020, and even 4,200 TWh/yr in 2050

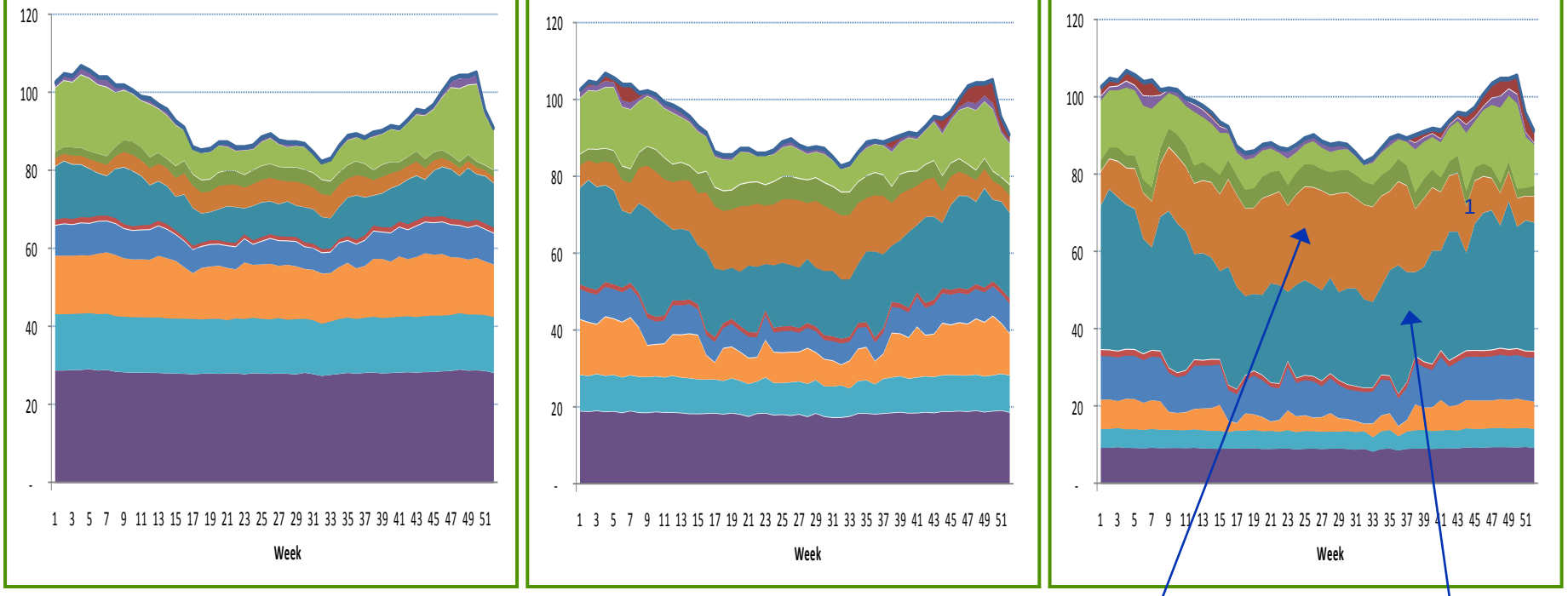
EU-27 plus Norway and Switzerland, TWh[1]



1 Assumes no change in reserve margin from 2010 to 2050
2 Existing capacity includes new builds until 2010

A combination of solar & wind is beneficial for balancing purposes

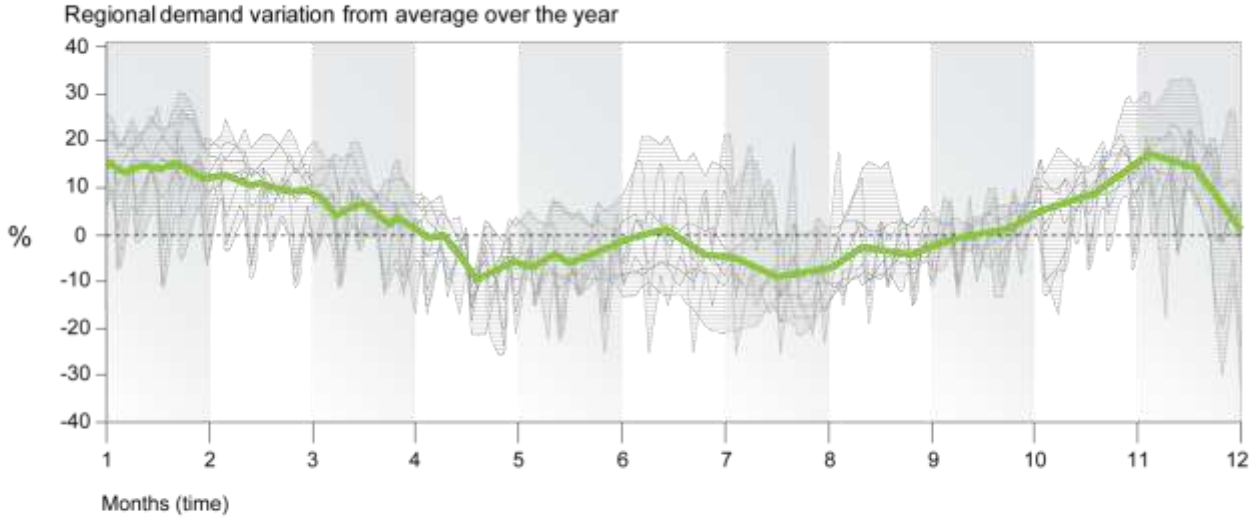
40% RES 30% CCS 30% nuclear	60% RES 20% CCS 20% nuclear	80% RES 10% CCS 10% nuclear

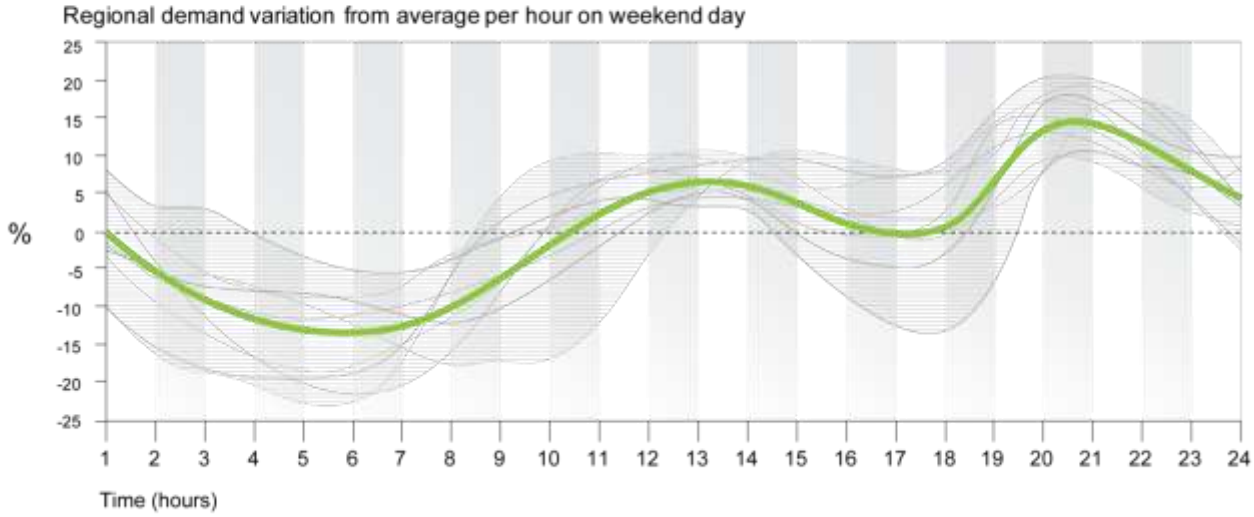


Energy production mix over the year, TWh per week

Demand
OCGT
CSP
Geothermal
Gas
Storage[1]
PV
Biomass
Coal
Hydro
Wind
Oil
Nuclear

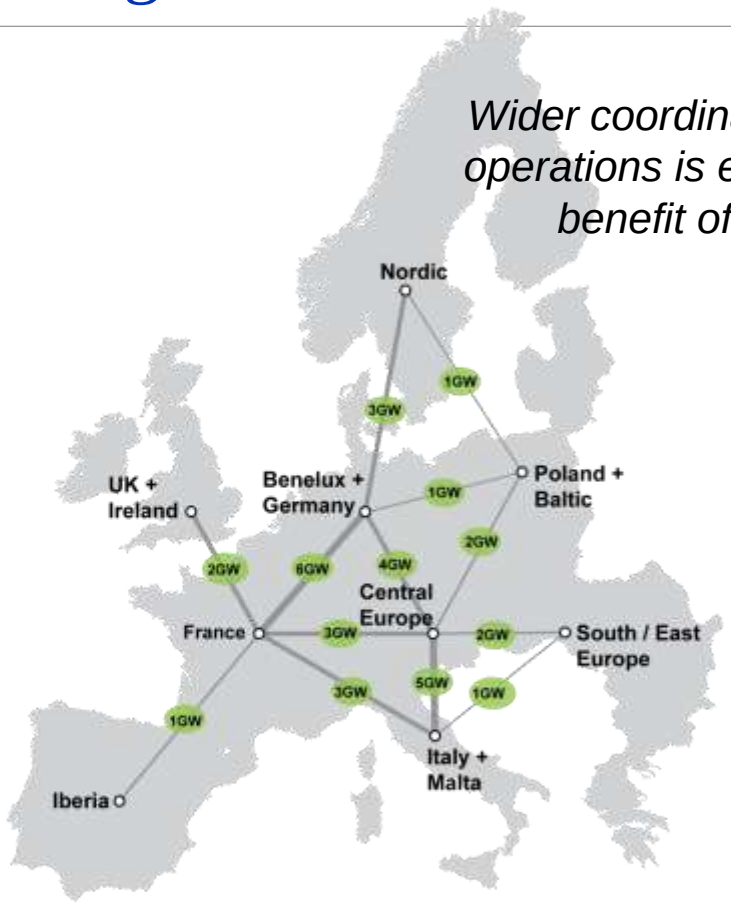
Grid capacity reduces variability in both daily & seasonal demand fluctuations



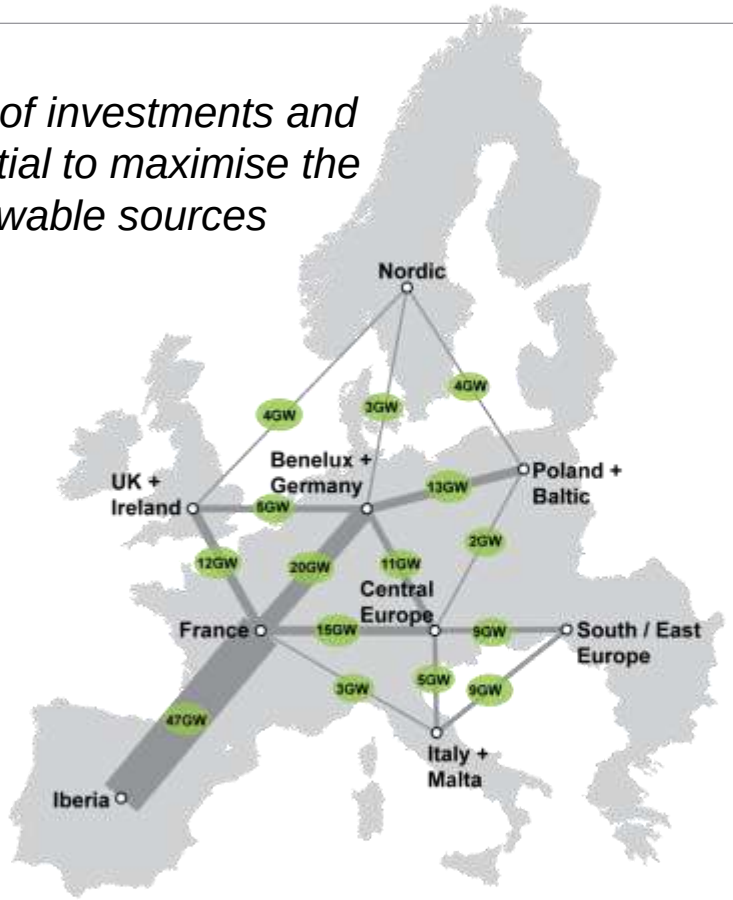


Inter-regional transmission requirements

Wider coordination of investments and operations is essential to maximise the benefit of renewable sources



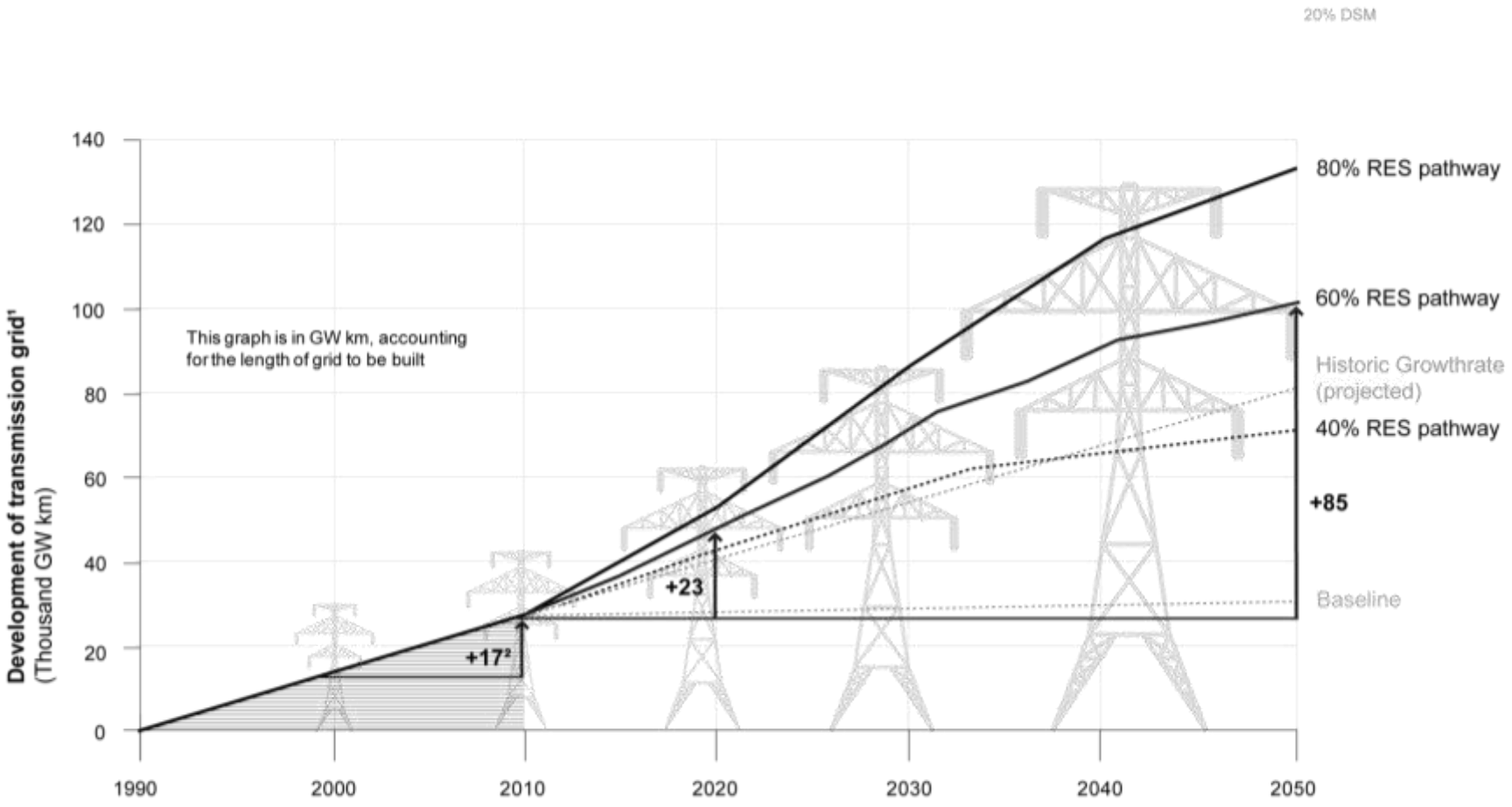
2010
Existing Capacity



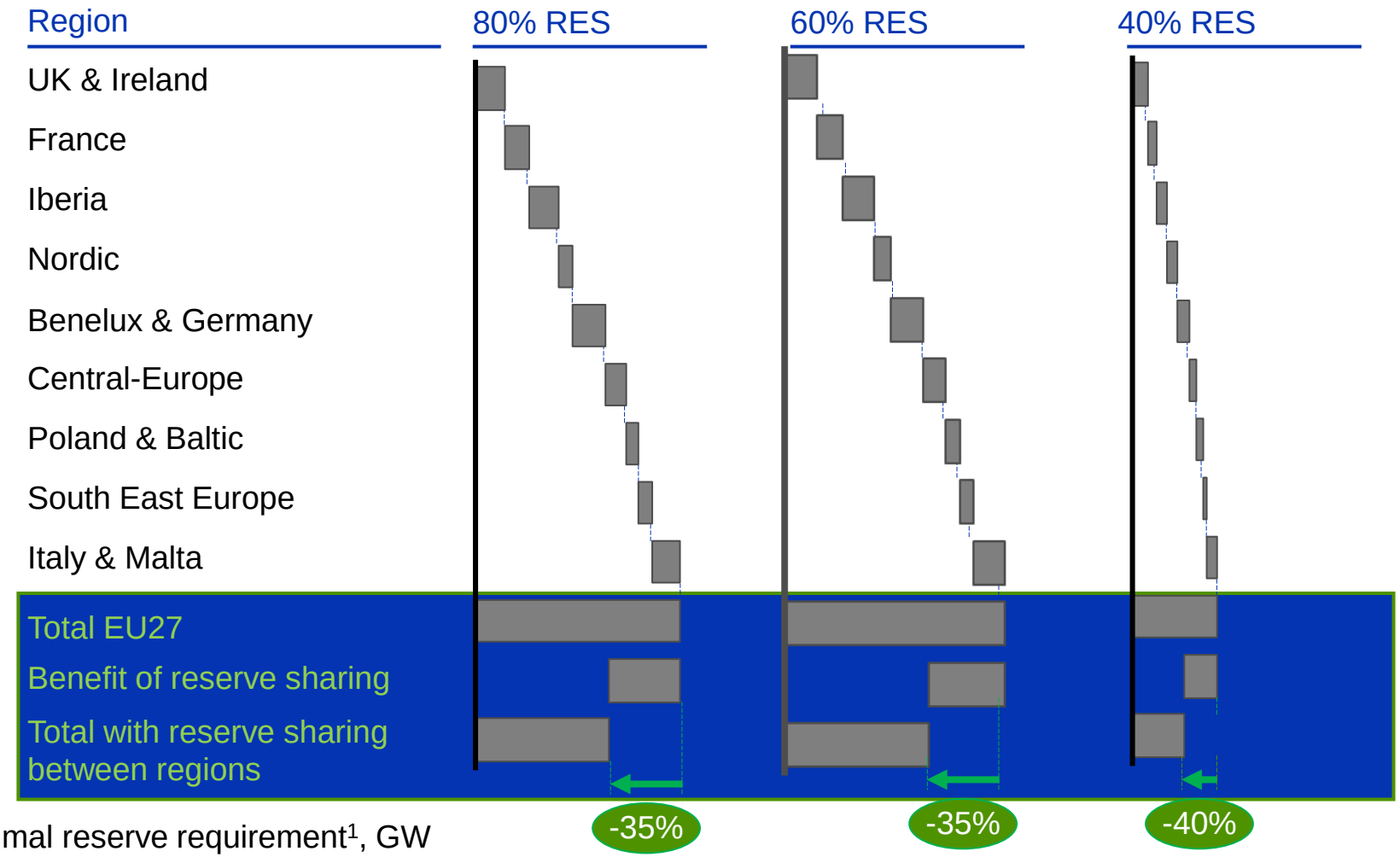
2050
Total Transmission Requirements
Assuming 80% RES & 20% DR

1GW
10GW
20GW

The rate of grid investments compared to historic levels

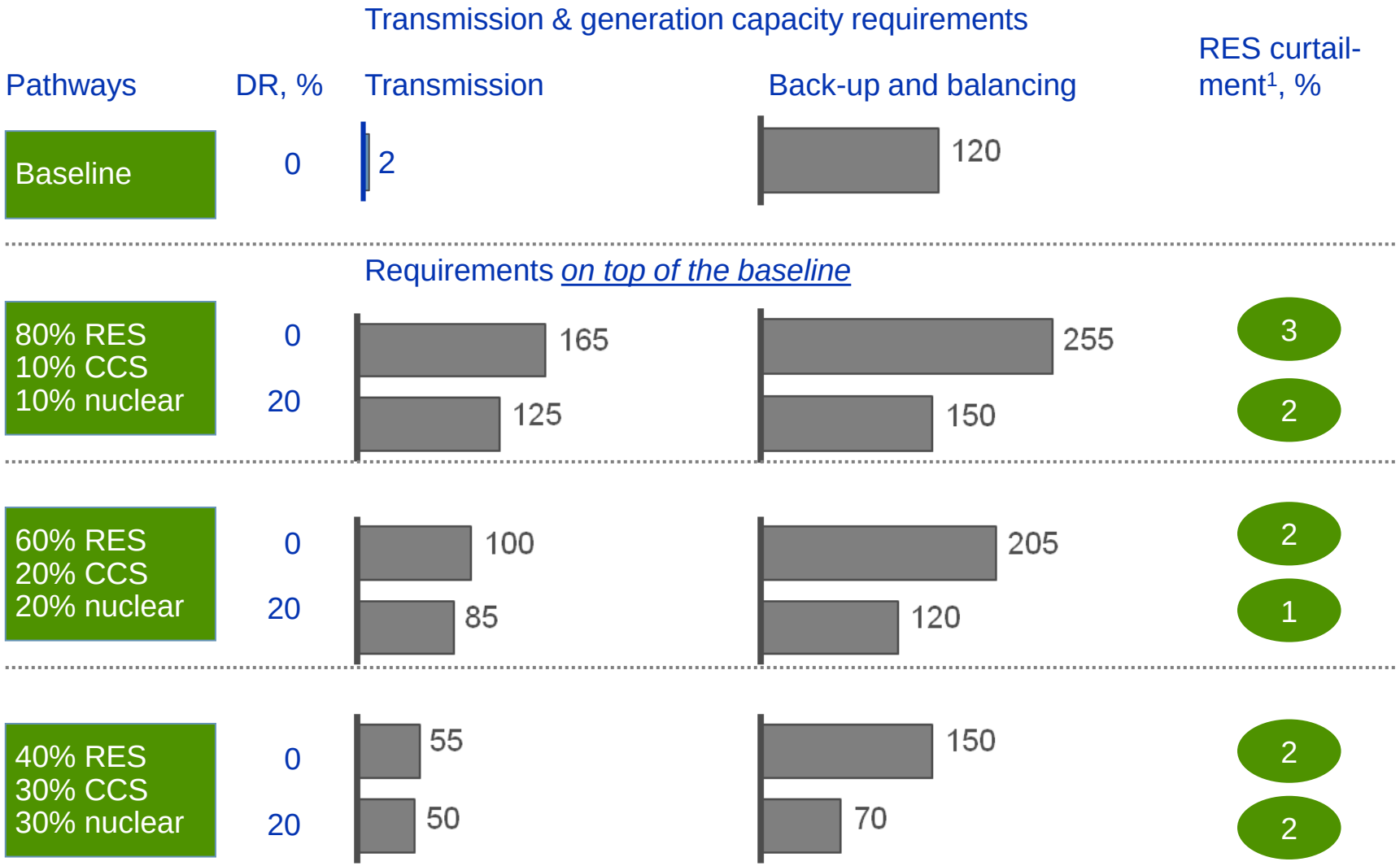


An EU approach requires about 40% less reserve capacity



Maximal reserve requirement[1], GW

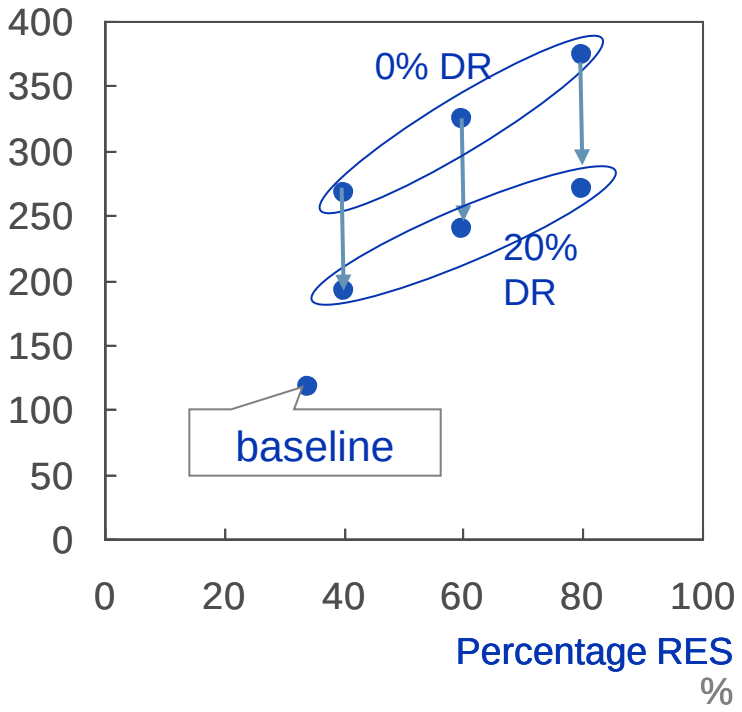
Curtailment is kept low through grid expansion and back-up capacity



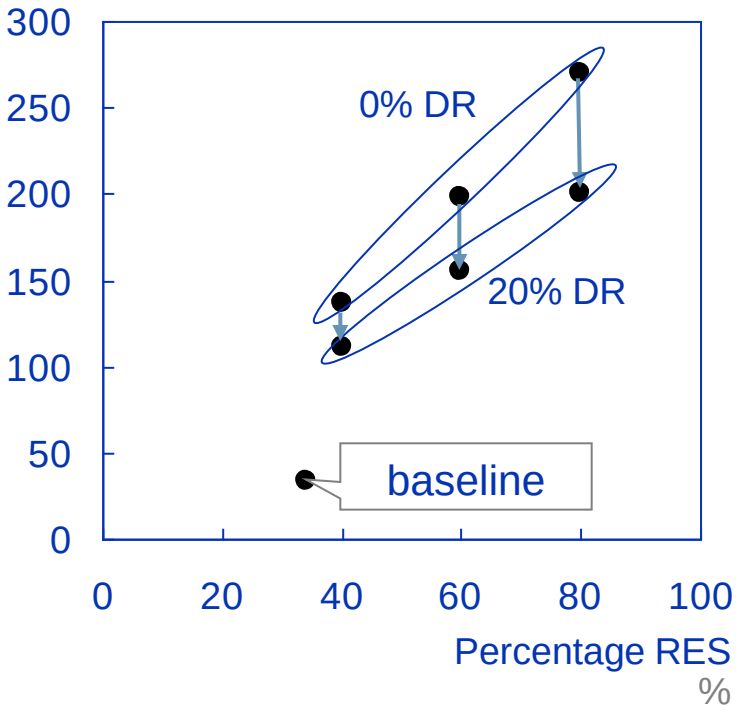
2050 figures, in GW

Demand response can reduce grid and back up investments by 20–30%

Additional back up capacity
GW

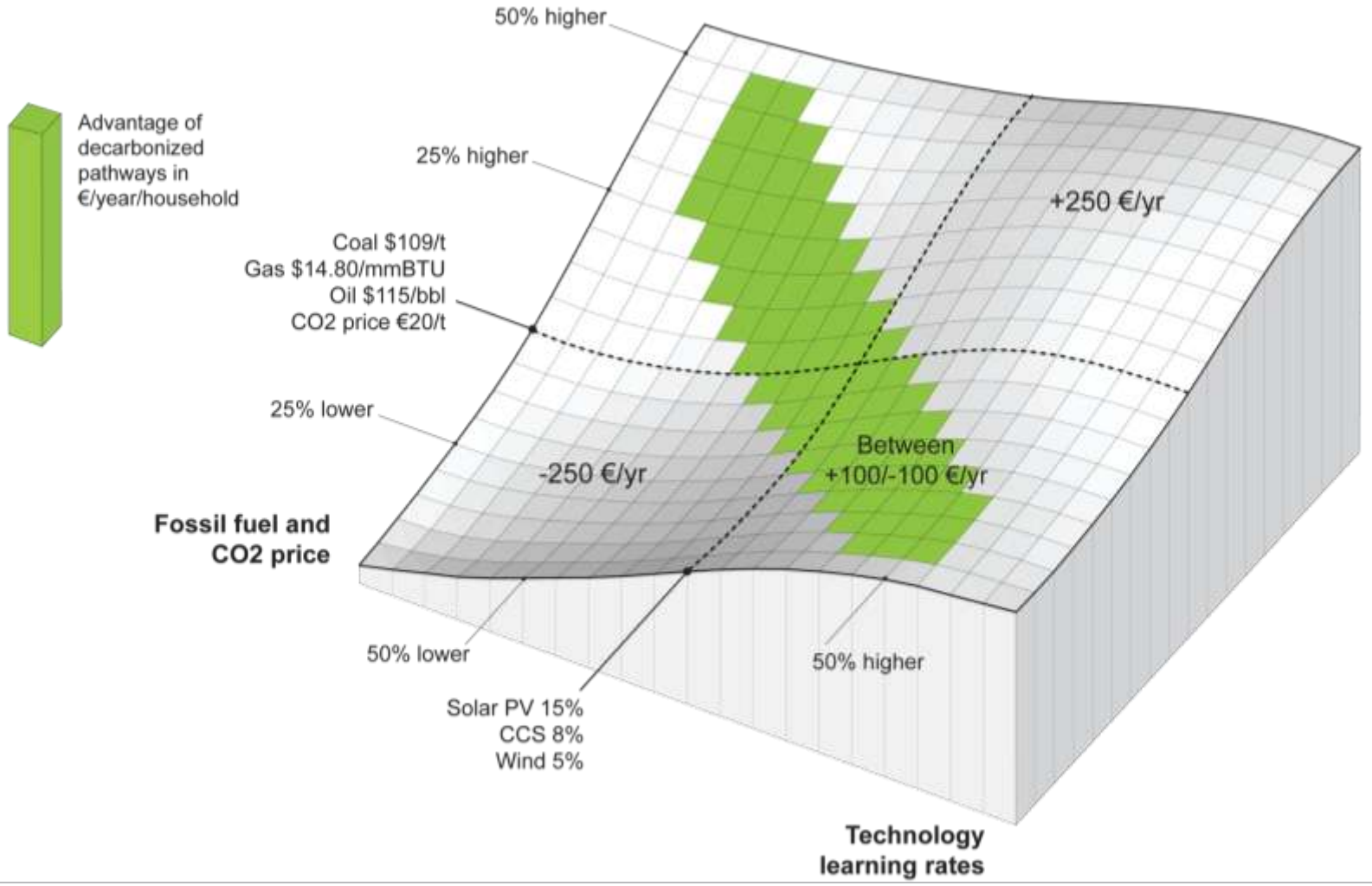


Additional transmission and and back up capex
EUR bn over 40 years

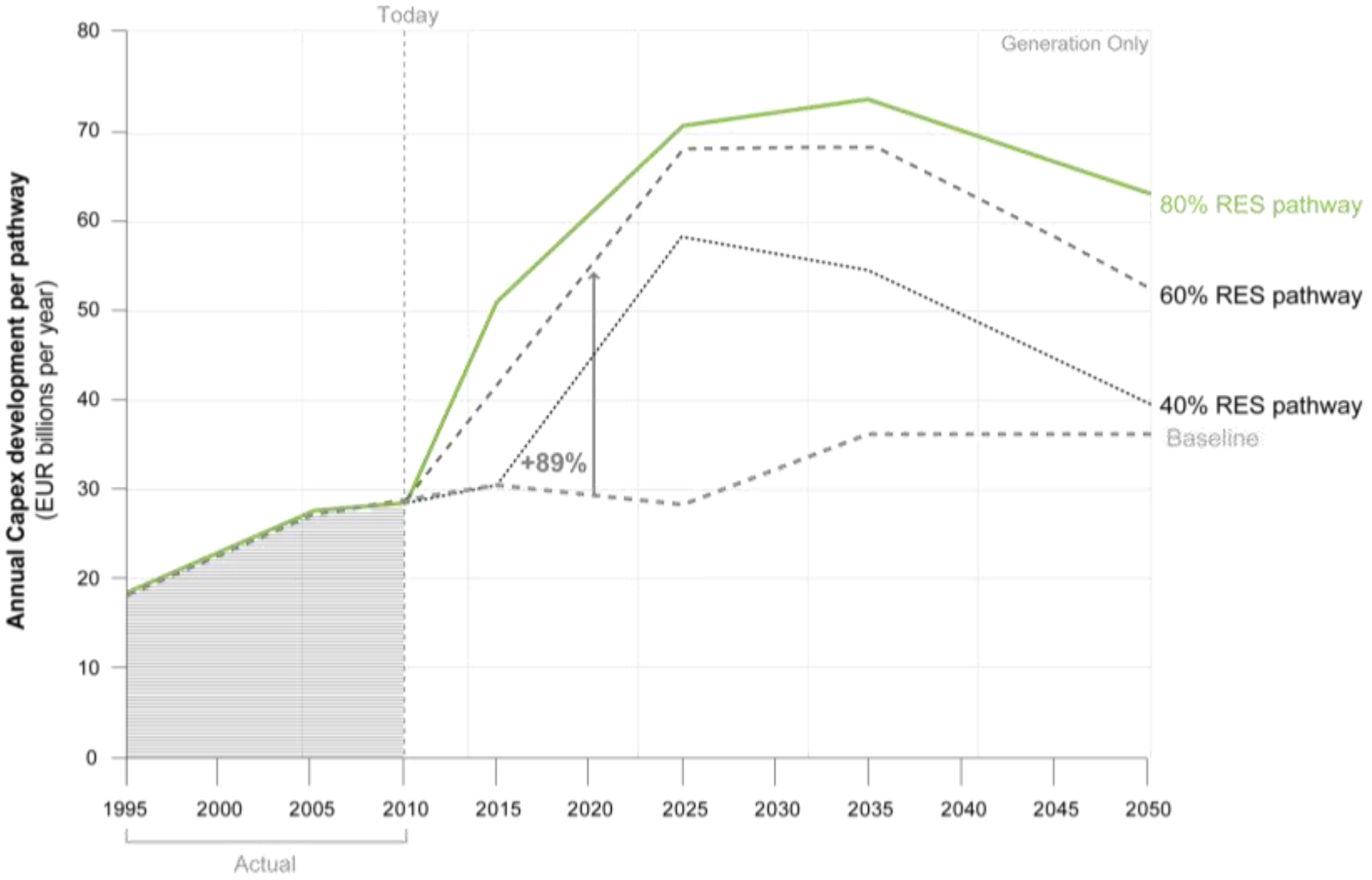


Optimized, DR assumptions: Baseline – 0%, 40, 60 & 80% RES - 0% to 20%

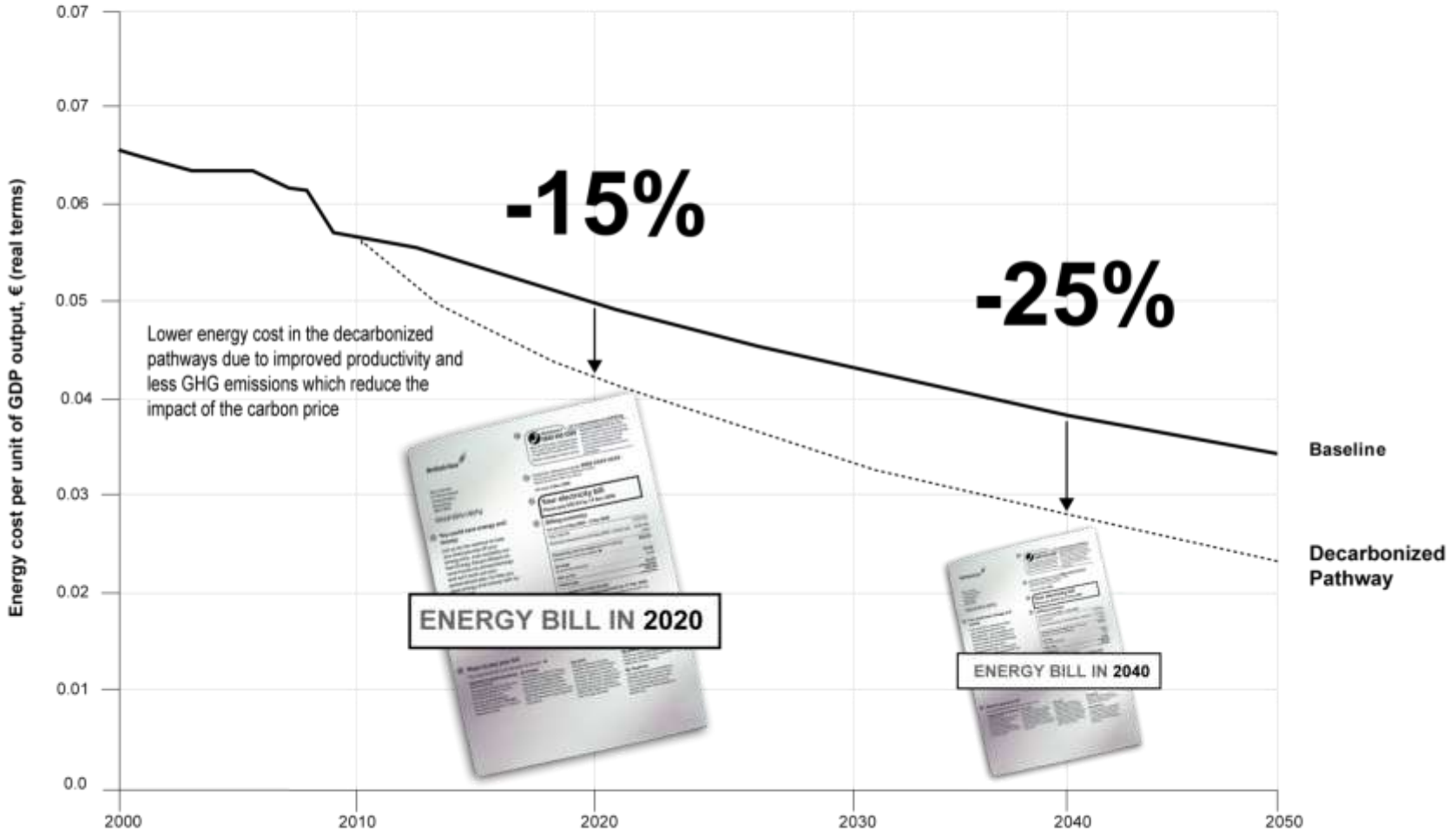
The cost of the decarbonized pathways and the baseline are likely to differ less than € 250 per year per household



Capital for power generation would more than double in the next 15 years

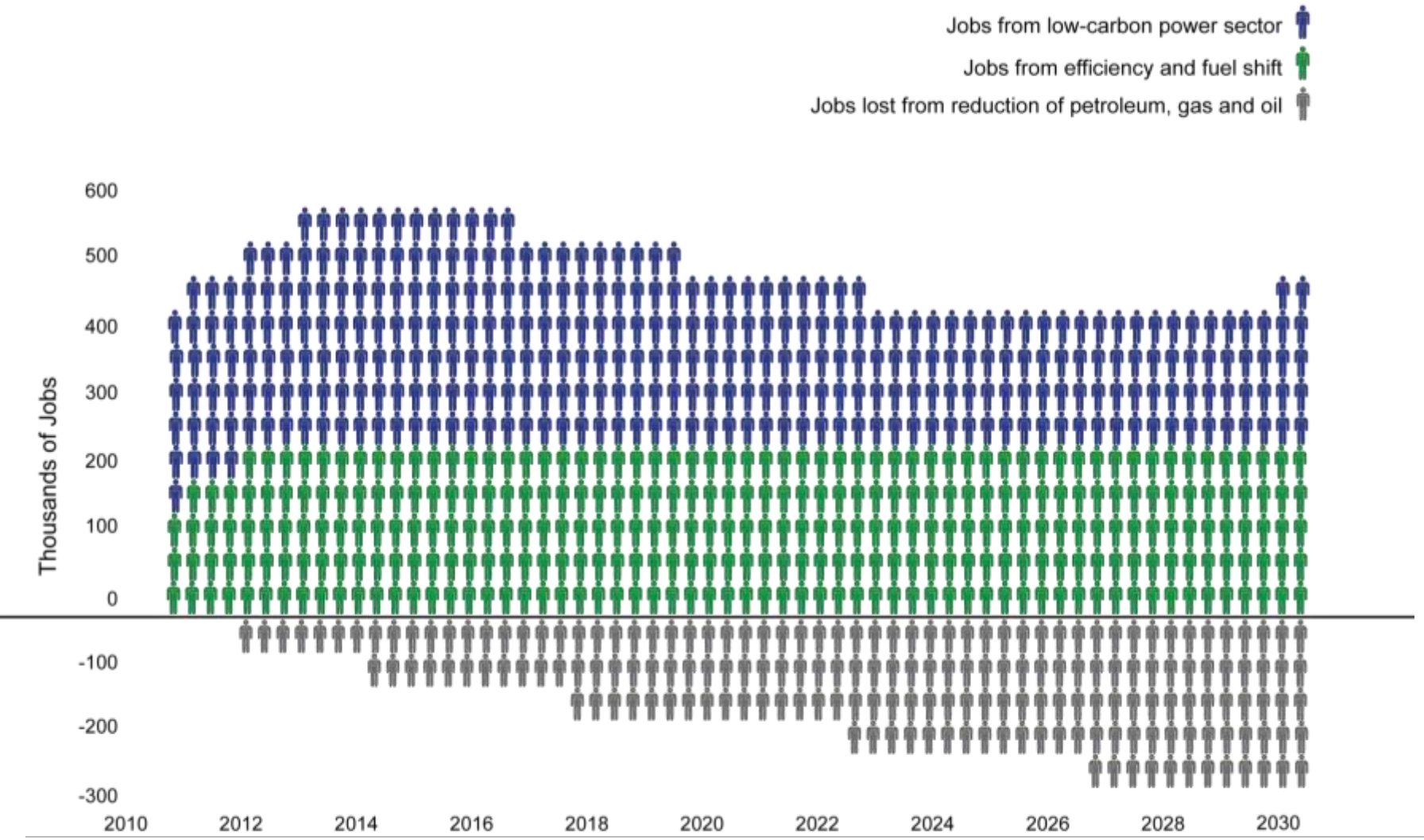


Efficiency and fuel shift could result in a lower energy bill on the long term



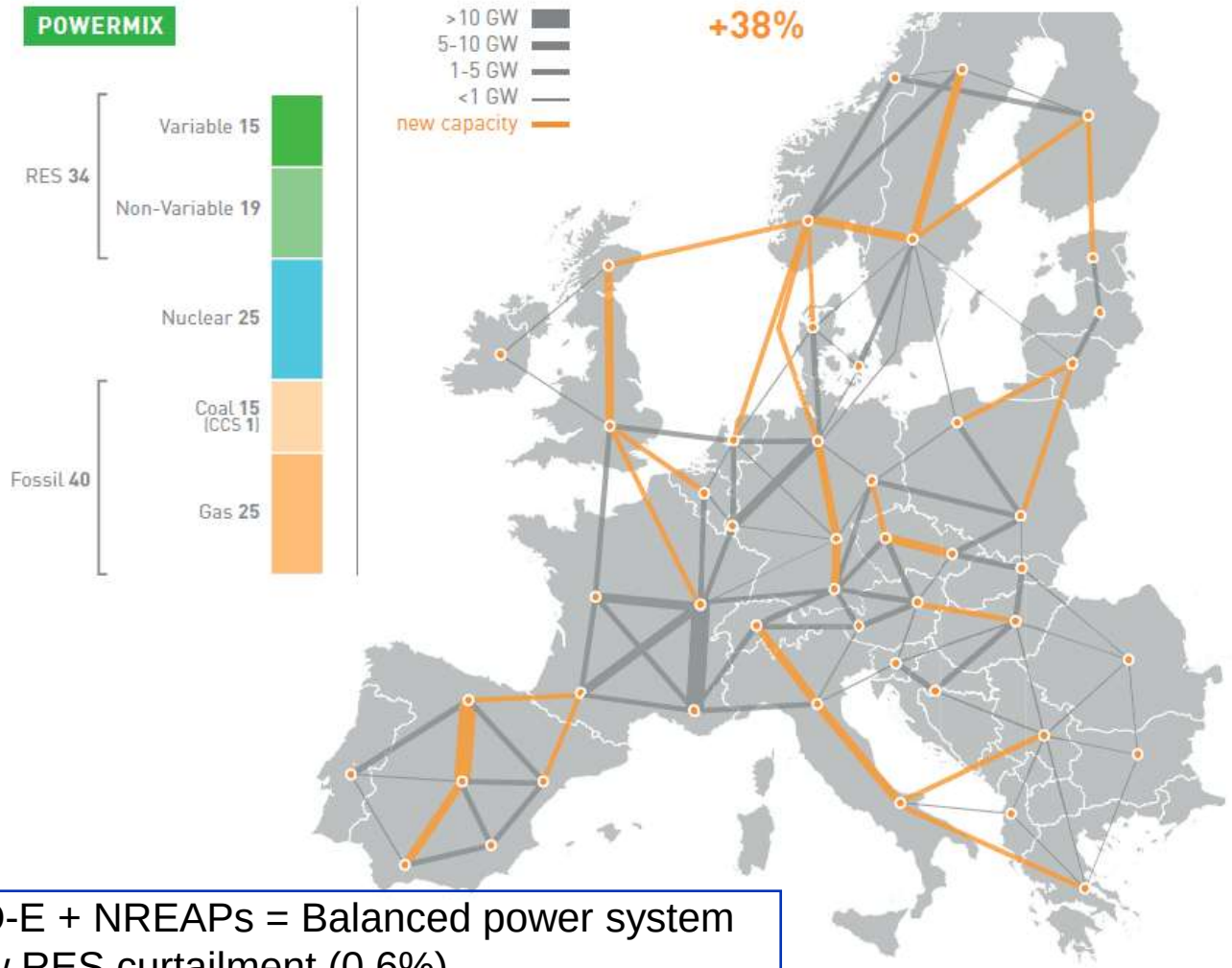
NOTE: Energy prices are a weighted average of prices faced by consumers weighted by the shares of consumption of different fuels

About 400,000 jobs are created in clean tech, versus potentially 250,000 job losses in fossil fuel supply chains



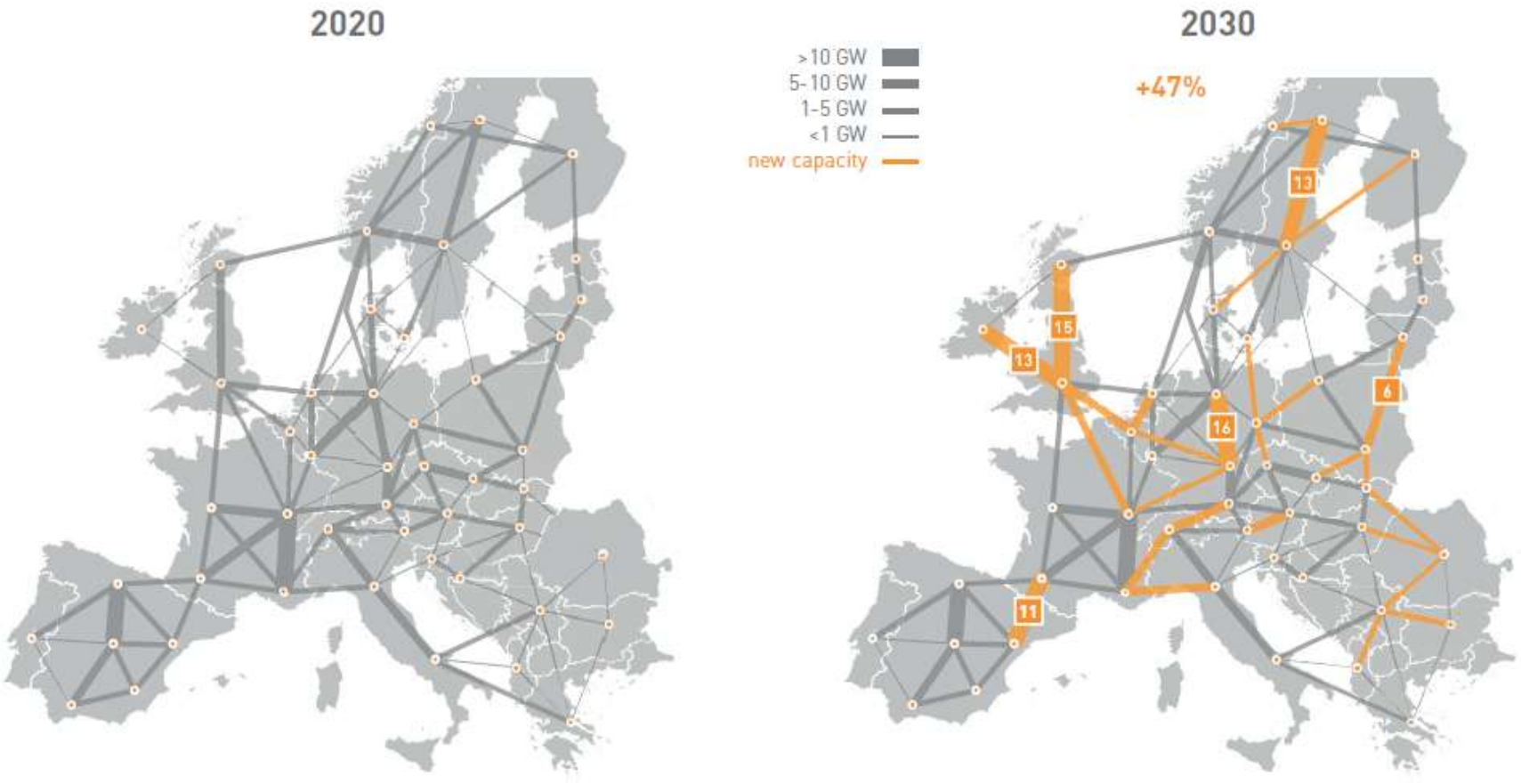
Power perspectives 2030

Current plans for 2020 are an adequate first step

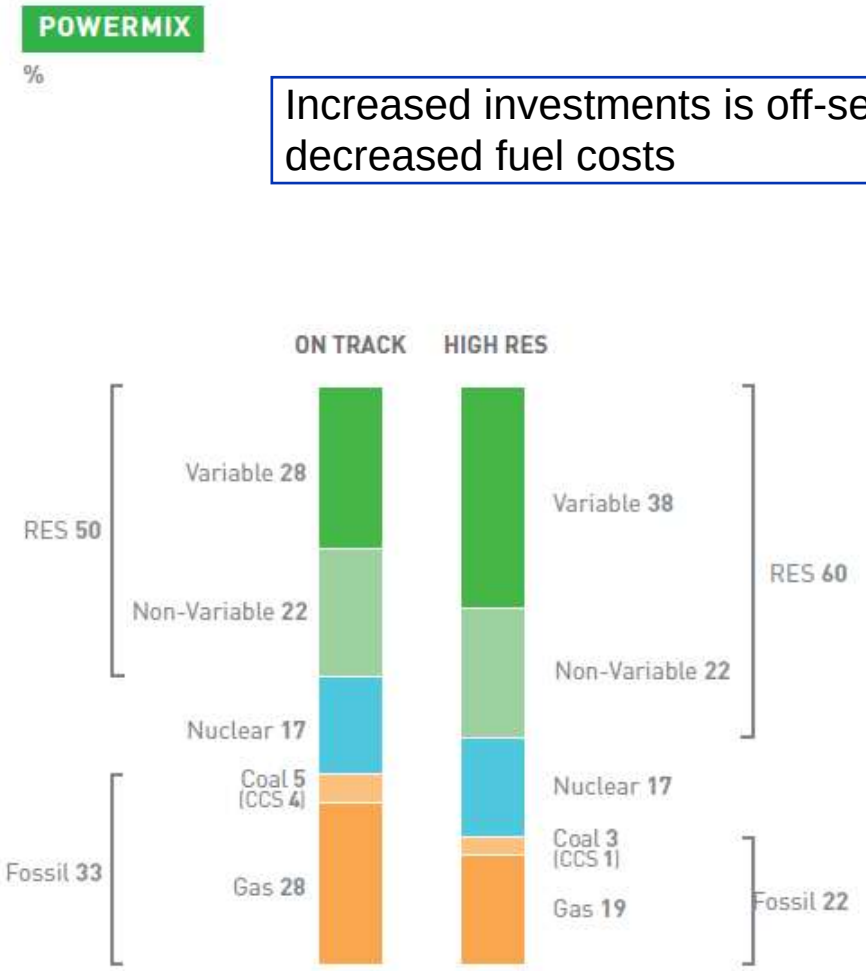


ENTSO-E + NREAPs = Balanced power system with low RES curtailment (0.6%)

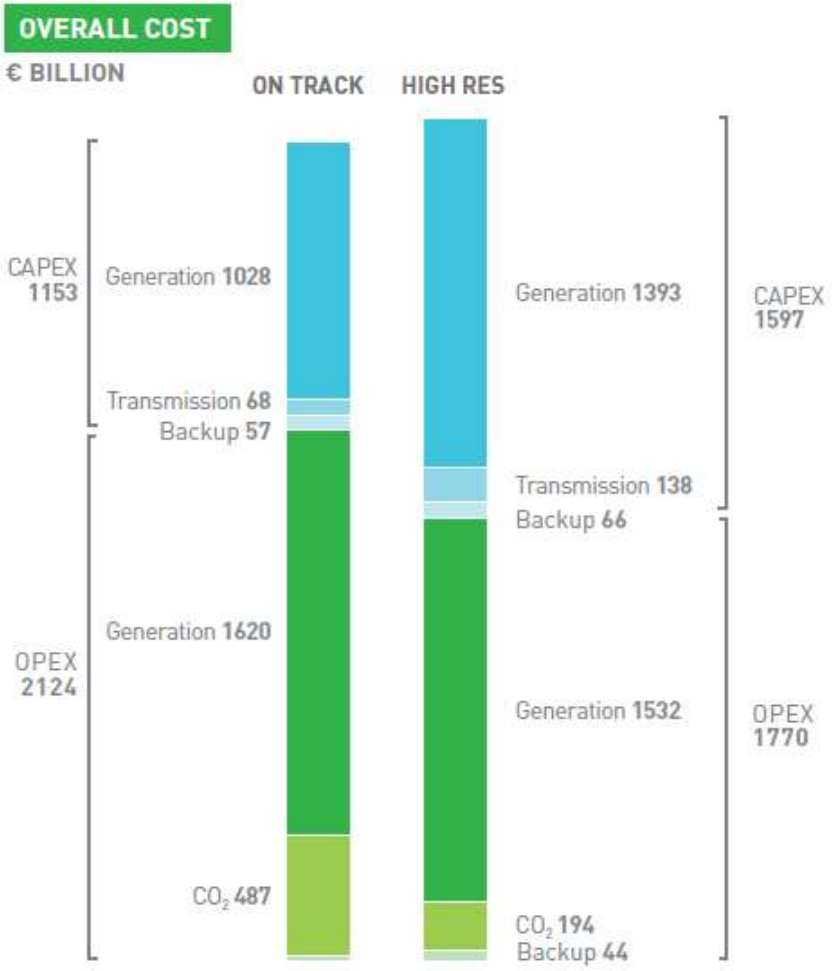
Transmission grid needs to be extended by another 47% in the next decade



Higher shares of RES is technically possible at similar cost



Increased investments is off-set by decreased fuel costs



Demand response and energy efficiency make a real difference in overall cost

Decentralization: Flexibility, cooperation, interoperability, consumer participation

Flexibility of our energy system

- Fast controllable power generation, including curtailment of e.g. wind power
- More grid capacity, including interconnection capacity, and cross-border trading
- Energy storage, small-scale and large-scale systems and services
- Smart local energy, including integration of DG, demand response, and active participation of end-users

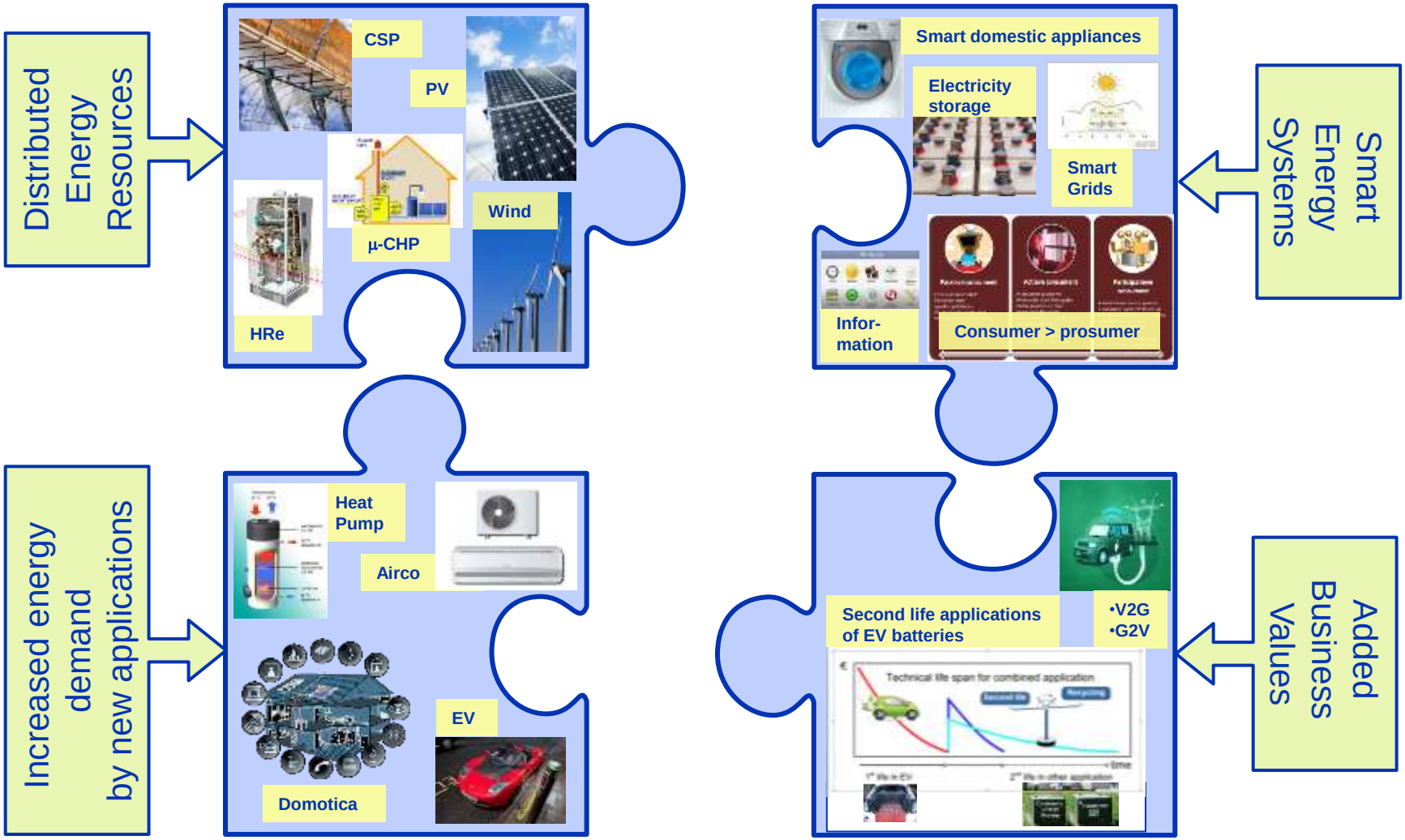
Cooperation, e.g. between energy industry, housing & transportation

Transportation	Local energy	Housing
Electric vehicles will become mainstream	E.g. micro CHP's: local heating and electricity production	Smart home appliances, innovative services, etc.

Green gas application

- Significant reduction in CO_2 emissions globally (e.g. in Europe 80% by 2050)
- Electricity makes up half of our total energy demand
- Energy use is reduced overall
- Renewable energy sources compose the majority of our portfolio
- Fossil fuels are used in the most efficient and clean way possible

Interoperability



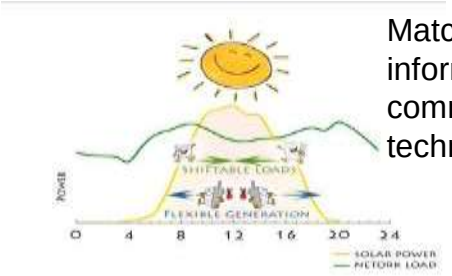
Interoperability

Consumer participation

We like electric cars

Smart home appliances

We are participating producers of energy (prosumers)



Matched by information and communication technology

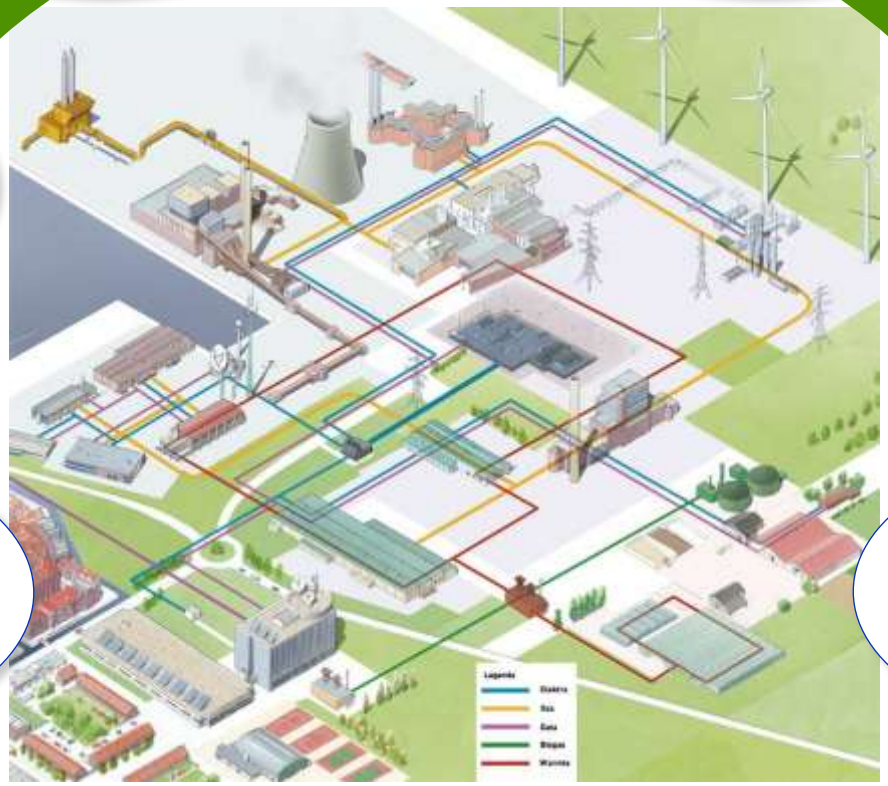
Save money with smart use of energy

Ultimately moving to Smart Energy Cities

Integrate energy infrastructures

Apply ‘open innovation’ to accelerate developments

Transfer energy consumers to energy down- and uploaders

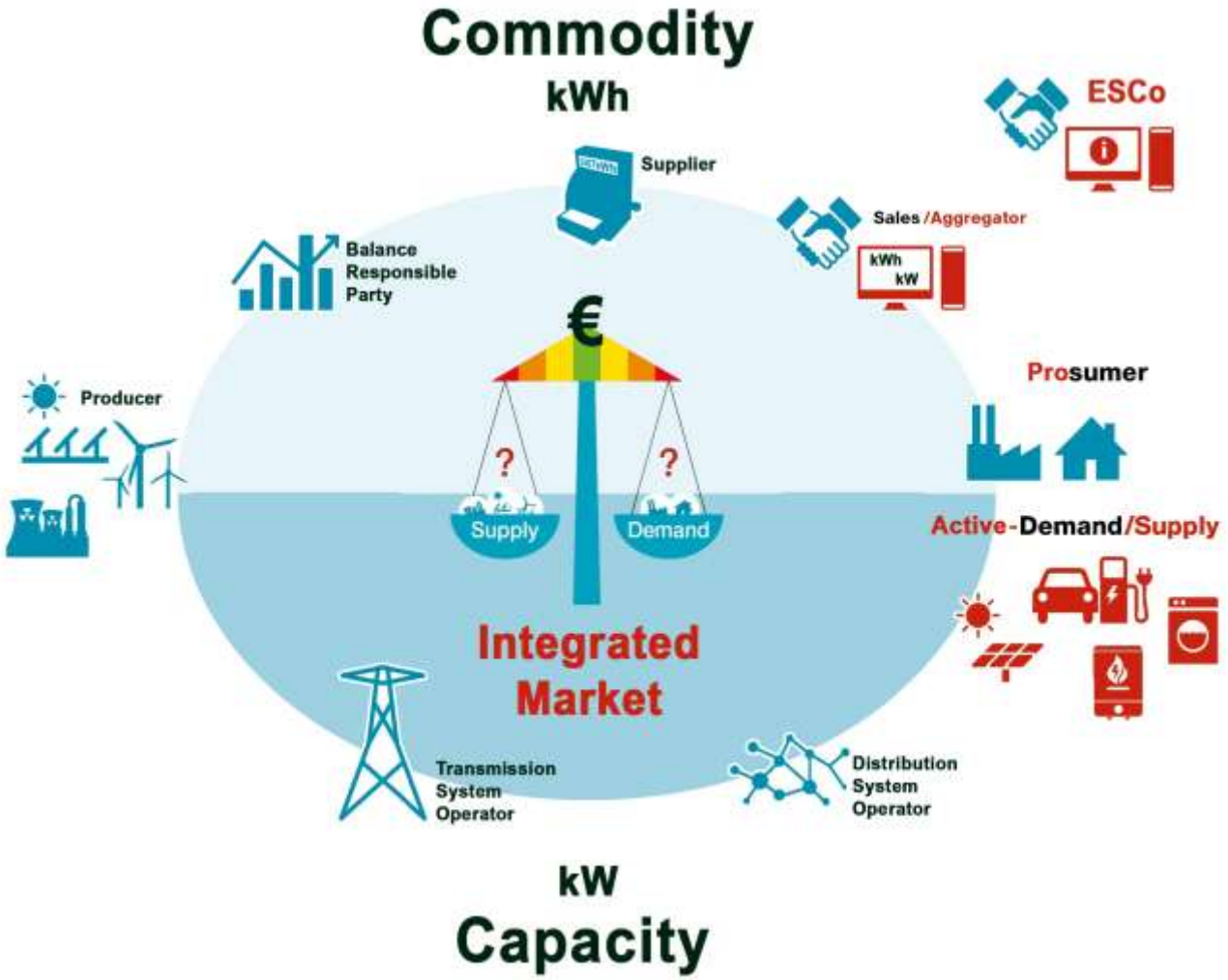


Organize local energy markets

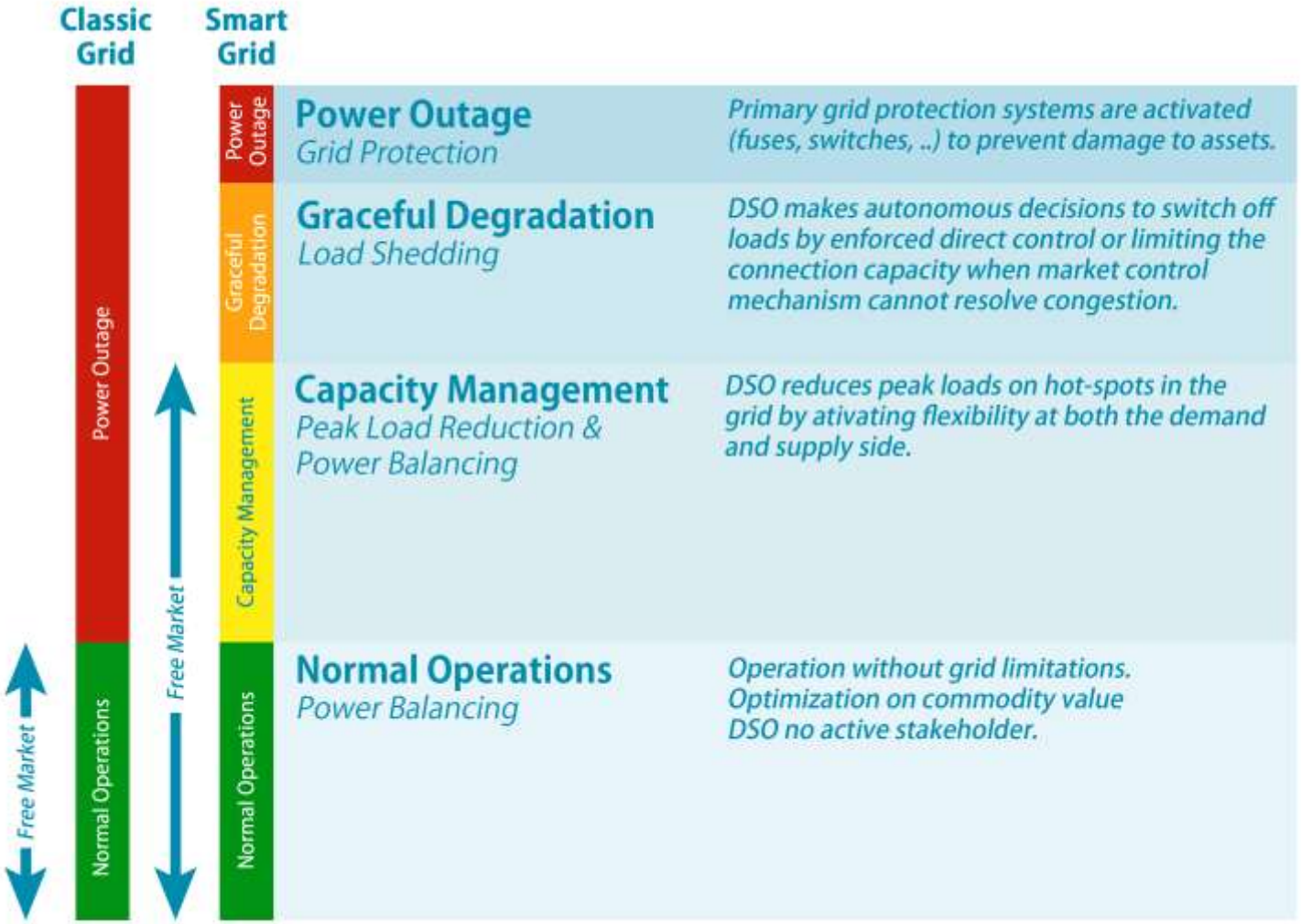
Join forces, and be willing to really cooperate

Install ICT systems to enable local control

New Market Roles



‘Yellow is the new green’



Concluding remarks

Energy Transition

- From a centralized, one-directional energy system
- To a partly decentralized, two-directional system

Energy Sector

- The future energy system will embrace
  - Automotive industry and transportation sector
  - Building industry
  - End-users, and its behavior

'Soft' Enablers

- A common vision
- Collaboration, and open innovation
- Societal permission

Thank you

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