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Next Generation European Transmission Networks

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ENTSO-E R,D&I Planning WG Convenor

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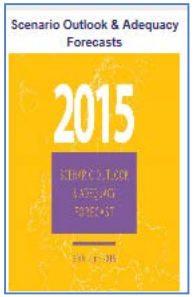
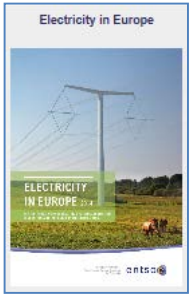
Reliable Sustainable Connected

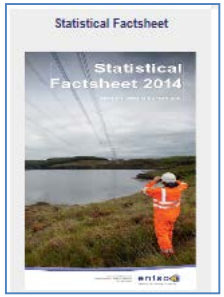
Flash info on ENTSO-E

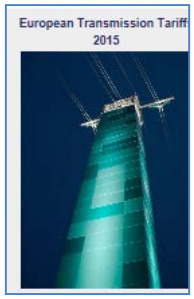
From volountary category association to EC-mandated body

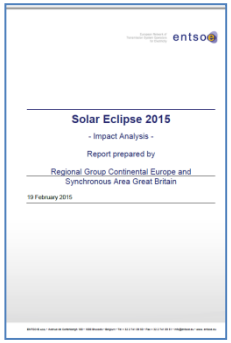
- ENTSO-E (European Network of Transmission System Operators) represents 41 TSOs from 34 countries
- Established and given legal mandates by the EU's Third Legislative Package in 2009
- Promotes and deploys close cooperation across Europe interconnected grids in:
  - ✓ Planning
  - ✓ Operation
  - ✓ Market integration
  - ✓ R&D coordination
  - ✓ Standards and statistics



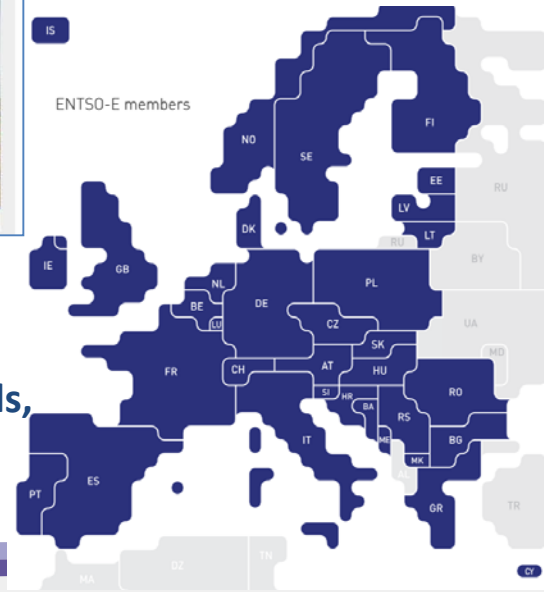




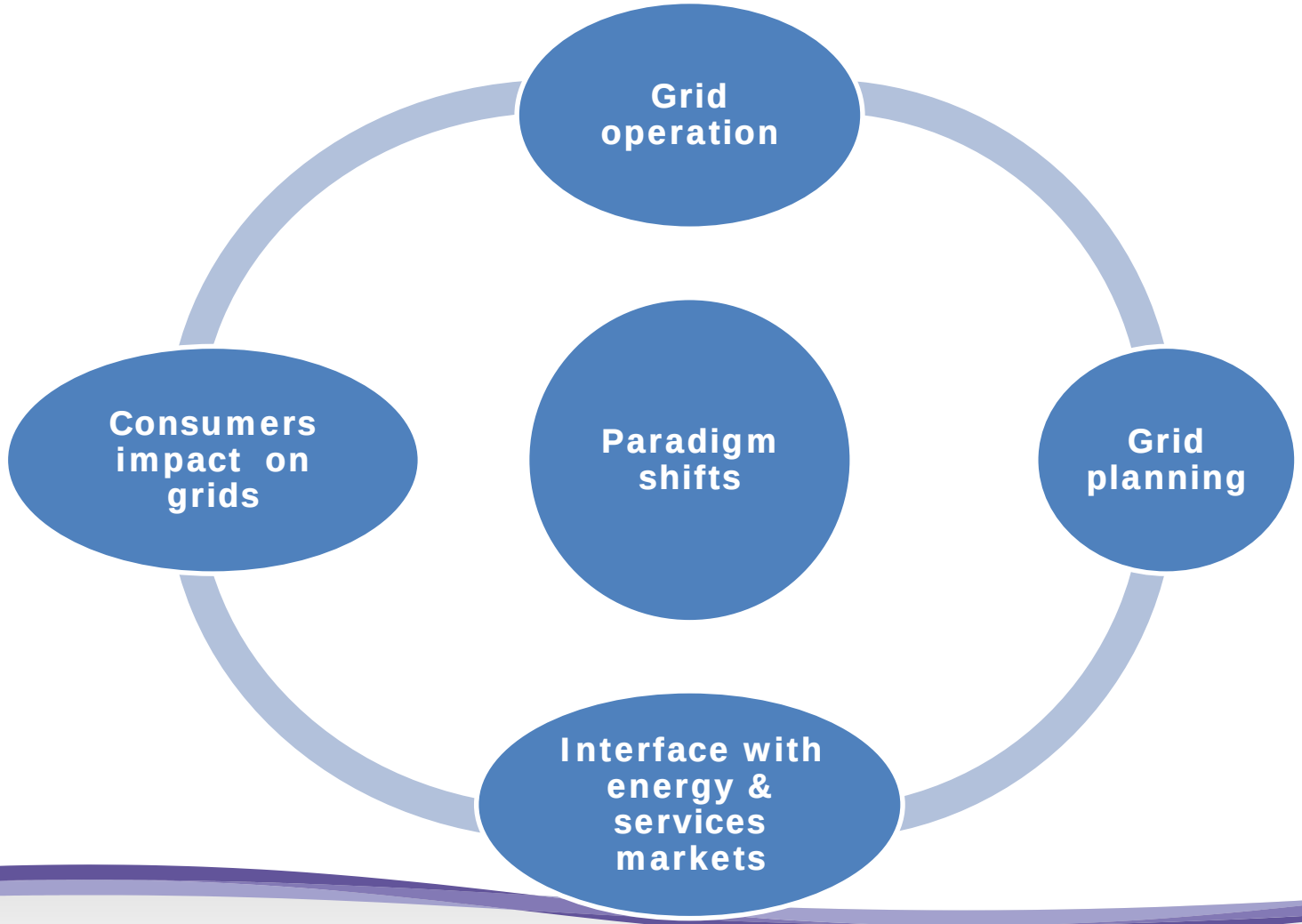




- Key actor to build world's largest electricity market, to support EU energy& climate policies, which are deeply re-modelling the power system
- Focal point for technical, market and policy issues relating to European grids, interfacing with industry, system users, EU institutions, regulators



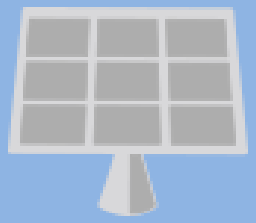
Multiple challenges for transmission networks



Multi-faceted paradigm shifts in power systems

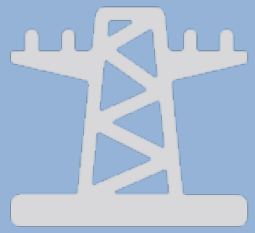
Energy source mix

- Electric sector is facing the major changes
- Electrification of transport, heat, processes
- Already here and now !



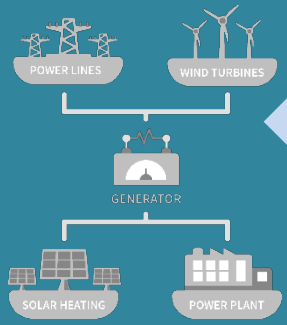
Supergrids & microgrids

- Supergrids for wider areas systems optimization
- Microgrids for self-consumption and local areas secondary optimisation
- Not mutually exclusive !



Consumers

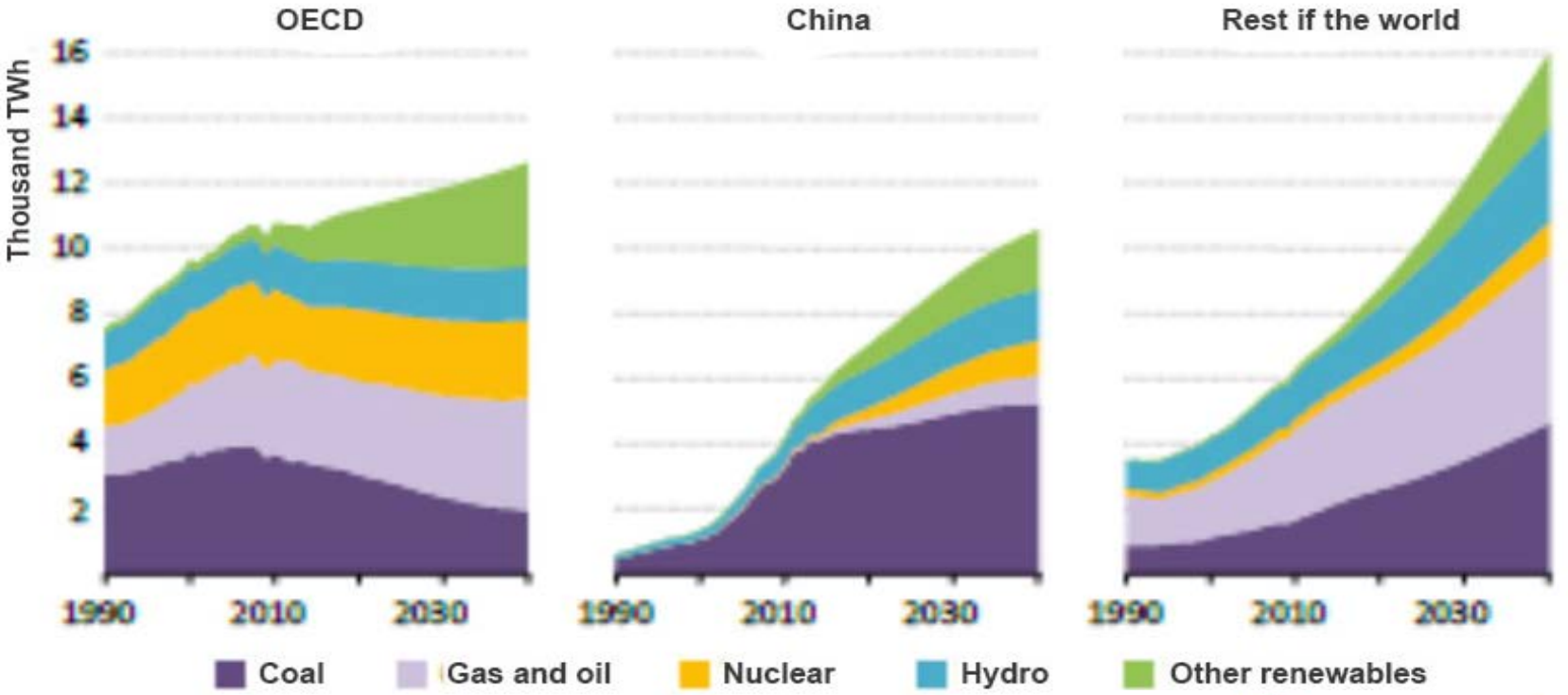
- Grids - and whole power systems - exist for them ...
- Passive and inelastic load idea is anachronistic in IoT era



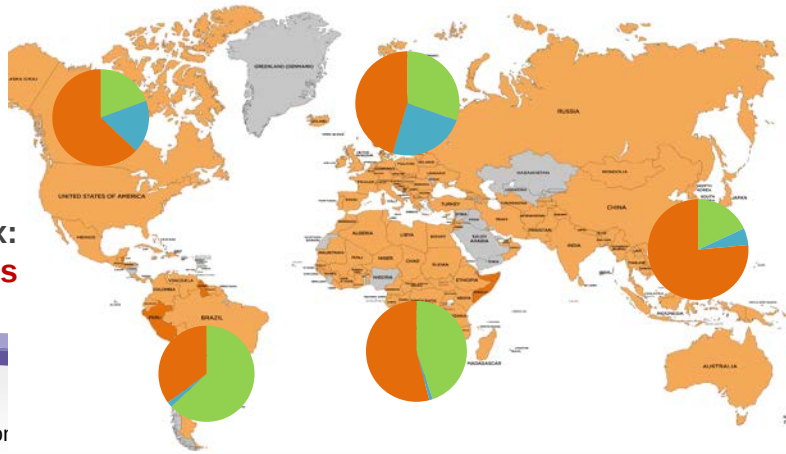
Markets

- Designed for competition among fossil fuel generation plants
- Now they strive to adapt to modified generation mix and to consumers empowerement

Paradigm Shift: Climate Protection → Renewables / Distributed Generation



Source: IEA WEO 2015 Electricity Generation 1990-2040; forecasts as per new policy scenario



However, still long way to go; see current generation mix: renewable energy, nuclear and fossil fuels

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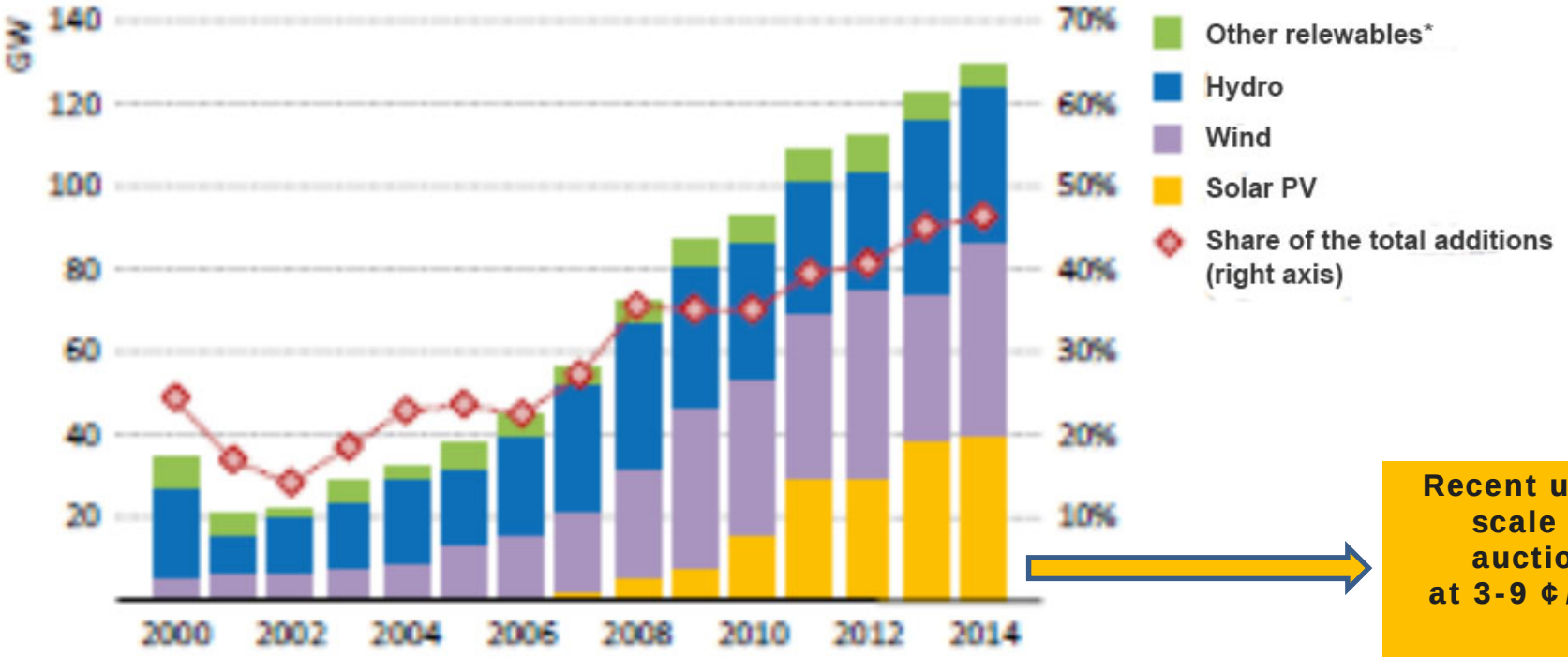
Half of capacity additions are renewables
Worldwide trend, albeit for different reasons



*Inclues geothermal, marine, bioenergy and concentrating solar power.

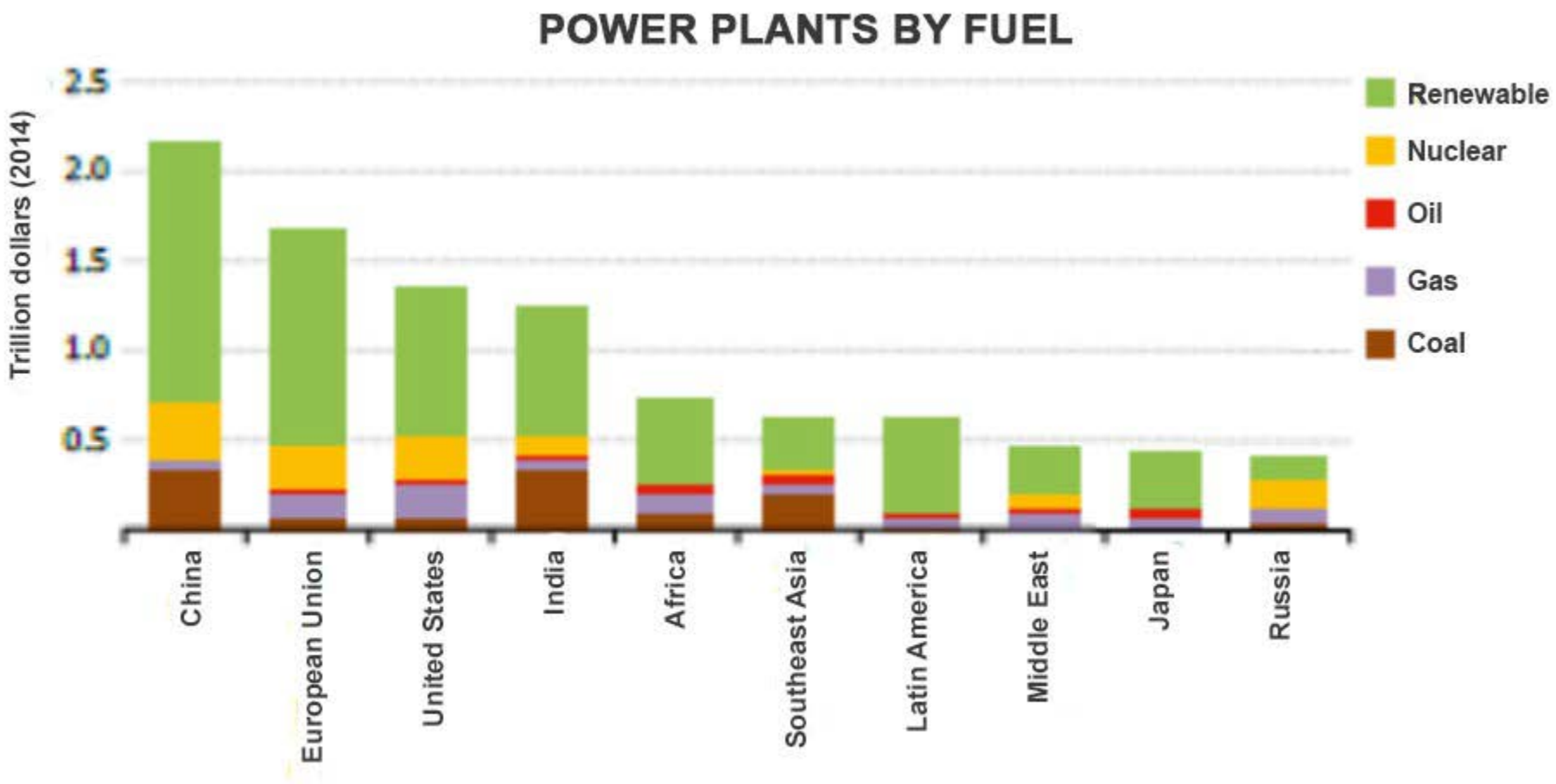
Recent utility-scale PV auctions at 3-9 ¢/kWh

(IRENA, Letting in the Light 2016)

Global renewables-based power capacity additions by type and share of total capacity additions

Source: IEA, WEO 2015 Special Report Energy and Climate

Money-wise, renewables dominate everywhere ; investors & finance made clear choice



Cumulative investment in energy supply by selected region in the New Policies Scenario, 2015-2040

Source: IEA, WEO 2015 Special Report Energy and Climate

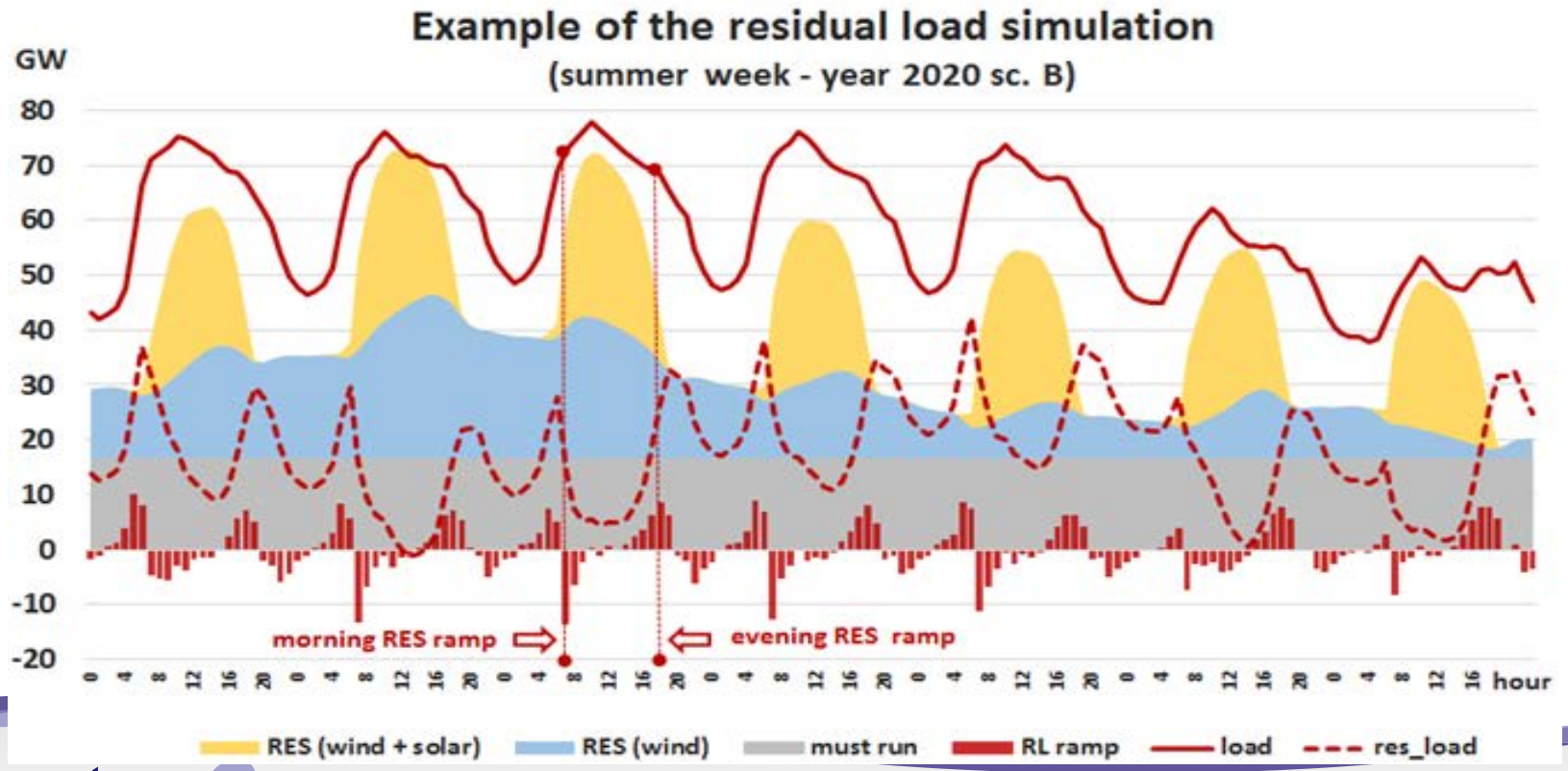
The rest of the story is on grid operators' shoulders …

Renewable electricity replaces fossil fuels

More efficient heating, transport, less CO_2

Cheaper to decarbonize

Flexible tools needed because of RE fluctuations



Limiting factors / challenges to overcome for higher variable renewable penetration

- **Grid Codes for Increasing Operational Scheduling and Dispatch Challenges**
  - ✓ **Dispatch, ramping, reactive power, fault ride through capabilities of all plants**
  - ✓ **At high levels of RES ancillary services need to be provided by RES also**
  - ✓ **Needs credible grid code enforcement.**

- **Forecasting: Key requirement for all penetration levels for efficient system operation.**

- **Voltage Stability, Transient Stability, Inertia, and Fault Levels; where studied, present binding limiting factor for high penetrations of variable RES**

- **Network epansion and investments:**
  - ✓ **For medium and high levels of variable RES, additional grid infrastructure required**
  - ✓ **In Europe, 80% of 150 billion € transmission investment until 2030 is driven by RES**

- **Governance: Need for greater information sharing and transparency between systems.**
- **Other observations on ancillary services, storage, offshore wind, transients, markets**

Source: Cigré TB 527 Feb. 2013

Evolution of grid operation: smarter criteria, new tools, TSO-DSO cooperation

Flexibility

- **Few** TSOs rely on DSO information
  - **Storage**: short term and reserve markets
  - **DR**: 5% of the electricity demand
  - Behind-meterPV affects system planning also

- **All** TSOs' grid & market tools rely on **data hubs** information ("distributed flexibility")
- **Storage** and **DR: Europe wide** for capacity and flexibility services

2020 → 

→ 2025

Security

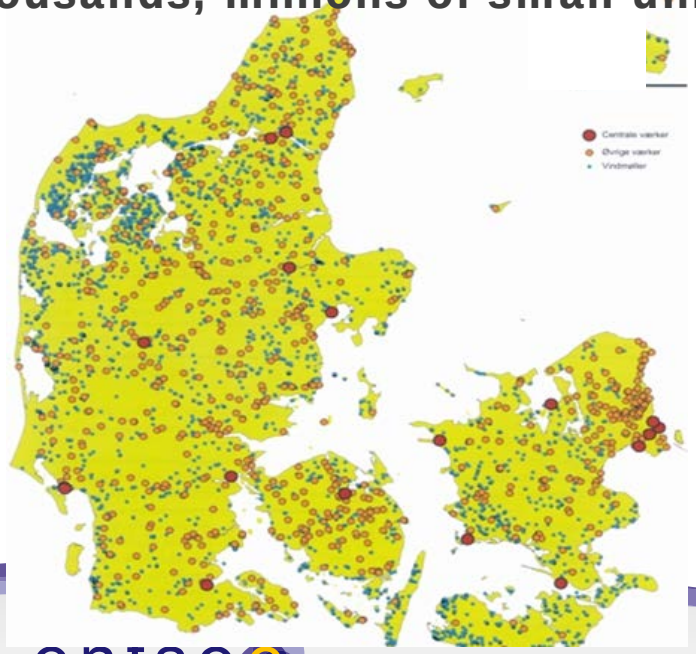
- **New tools** for regional security assessment (e.g. from iTesla, Umbrella, other EU projects)
- Limited interaction with **other energy network**
- Planning based on **a modular methodology** (eHighway2050)

- Interaction TSO security assessment – data hubs
- **EU wide** coordinated planning based on **overall energy system** view

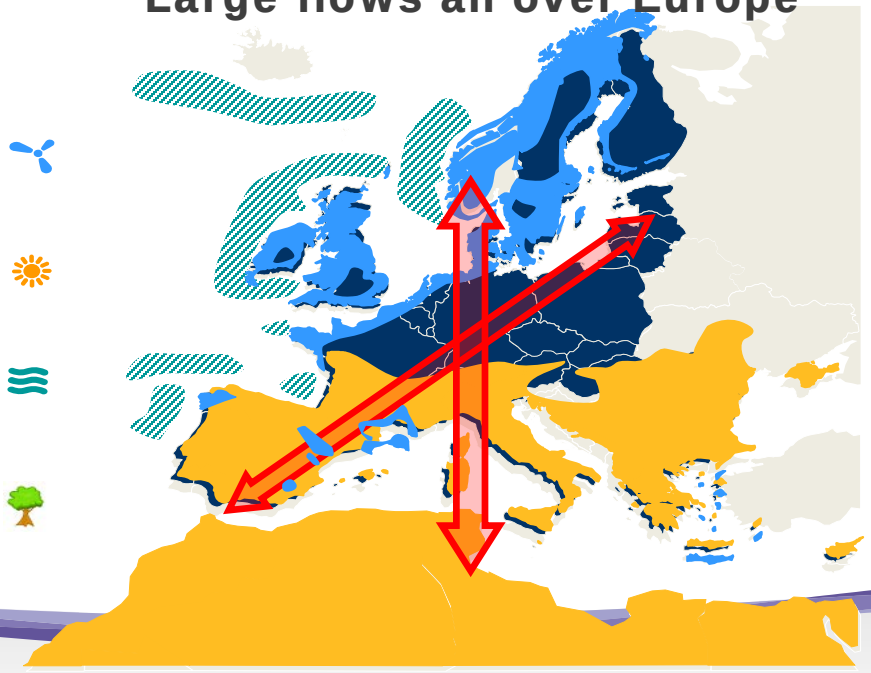
Increased needs and scope for cooperation distribution – transmission

- Fluctuating RES with low capacity factors need strong, continental size grids
- Distributed generation needs smart grids
- Both need stronger cooperation transmission – distribution
- These needs appear wherever in the world the RE contribution grows
- Distribution reliability in much of the world needs to improve a lot – smart grids and microgrids can help

Thousands, millions of small units



Large flows all over Europe



Areas for enhancing TSO / DSO cooperation

MARKETS

- Ensure consistency between wholesale and retail market
- Unlock DSR potential
- One single market

OPERATIONS

- Define needs around observability
- Active power mgt actions with impact on balancing + congestion in transmission should be overseen by TSOs
- Define roles of TSOs and DSOs

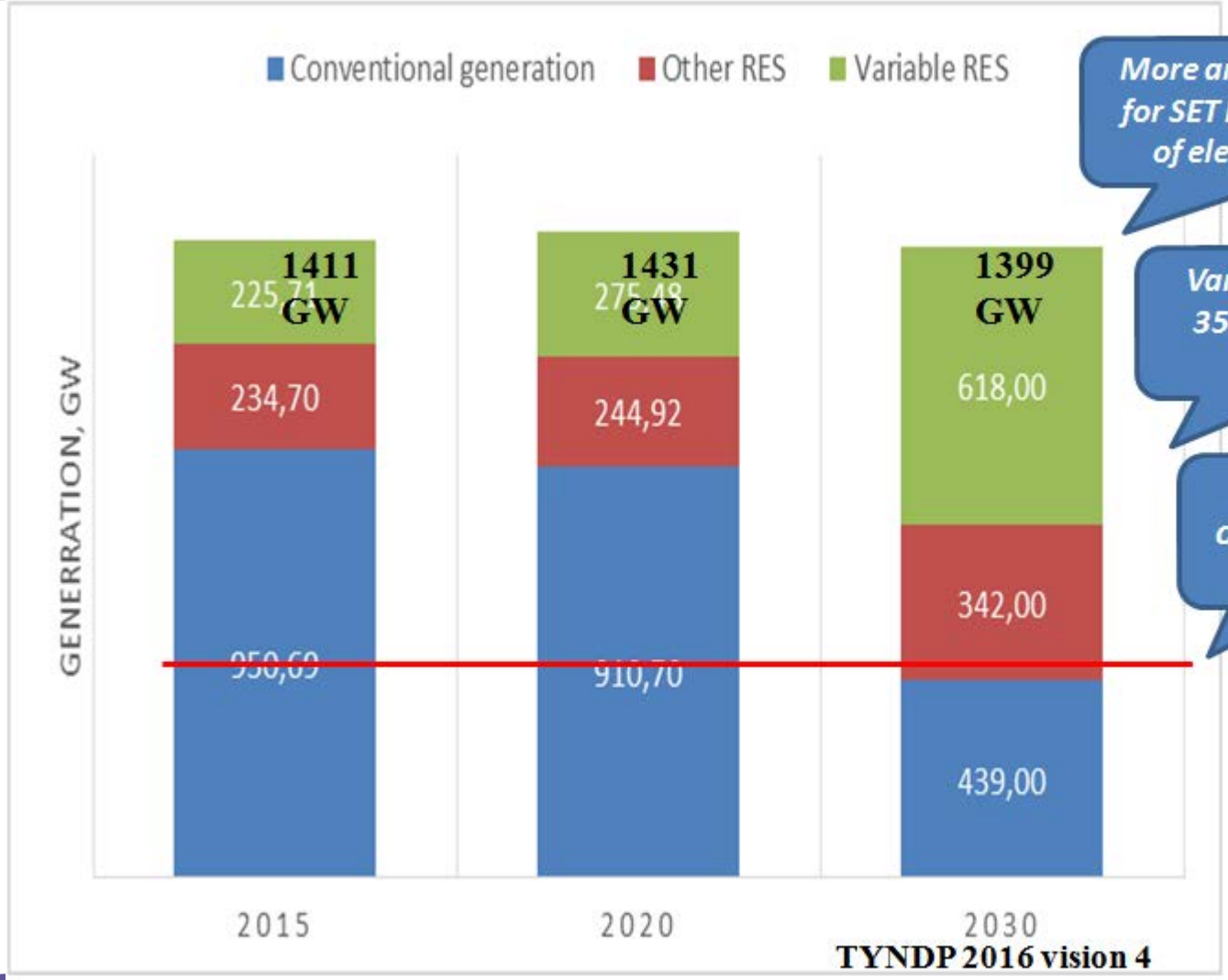
DATA

- Define data needs to fulfil regulated tasks
- Using existing standard developed at EU level (CIM format)
- IT architecture for data management

PLANNING

- Enhance the information exchange
- Coordination of the assessment of connection capacity
- Enhance resilience

The generation mix challenge in Europe



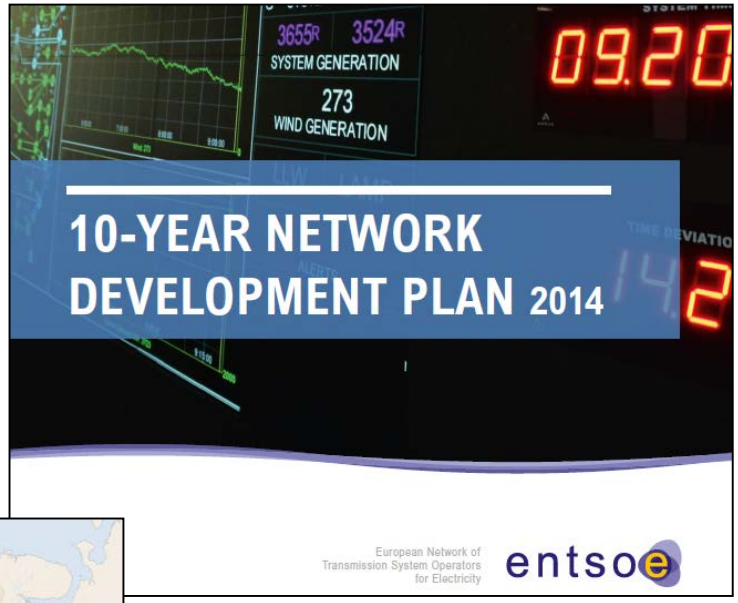
More ambitious objective for SET Plan var.RES : 45% of electricity demand

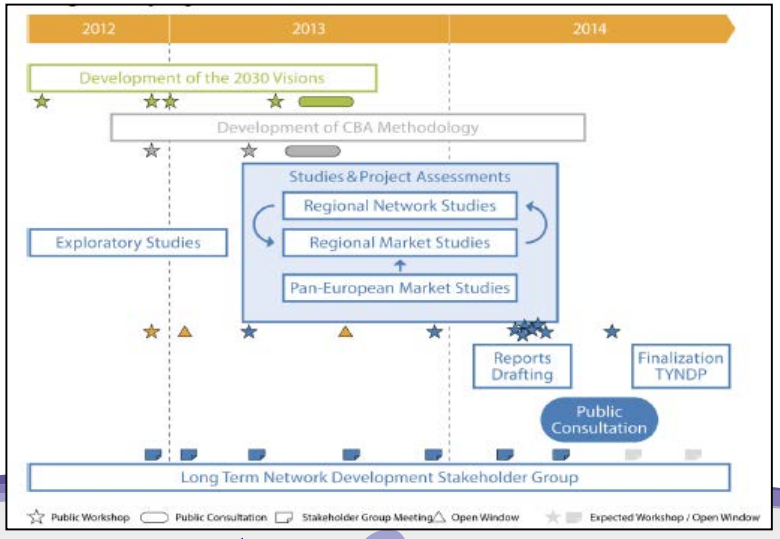
Var. RES represent 35% of electricity demand

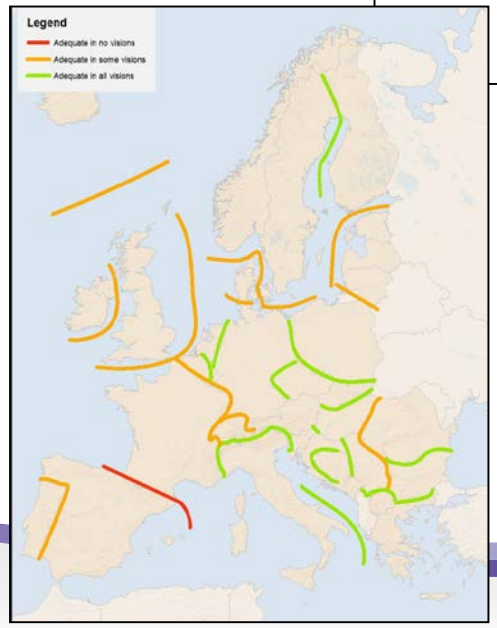
Load varies only from 530 to 574 GW

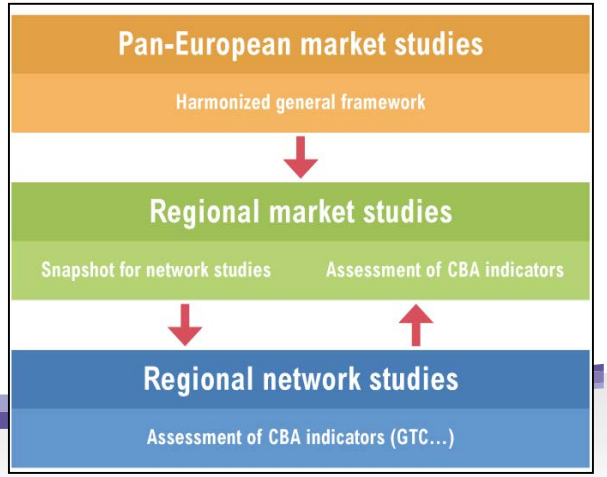
Evolution of grid planning: from national to continental planning and beyond

- Since 2009 the European legislator has tasked ENTSO-E with the delivery of a European network development plan which builds on national plans and includes specific regional investment plans
- Having a European approach to grid planning ensures consistency and cost-efficiency









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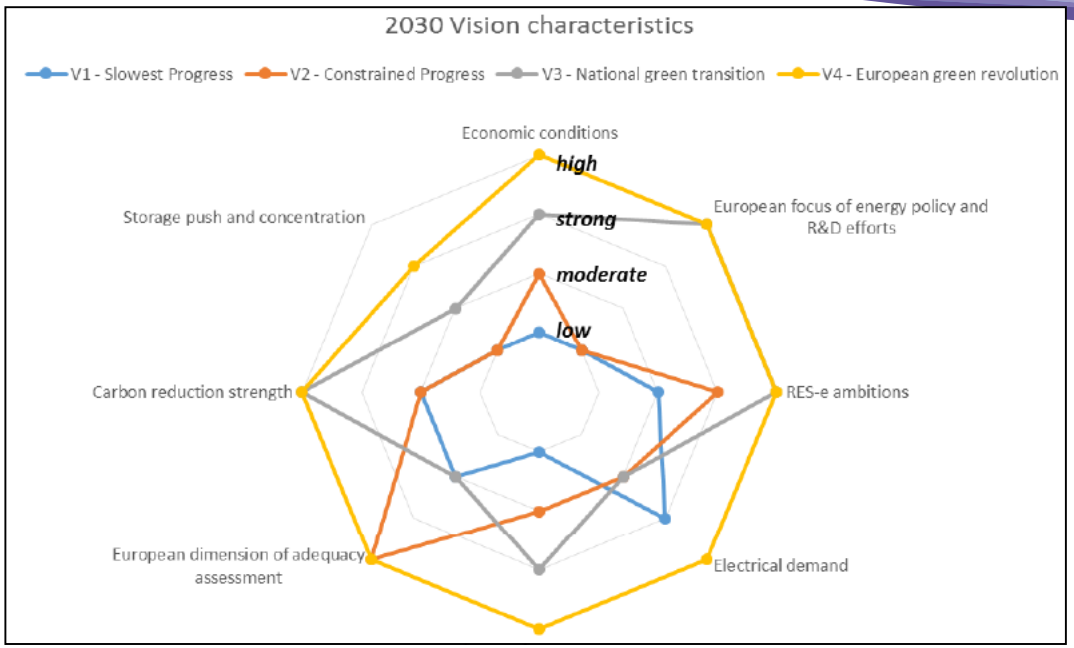
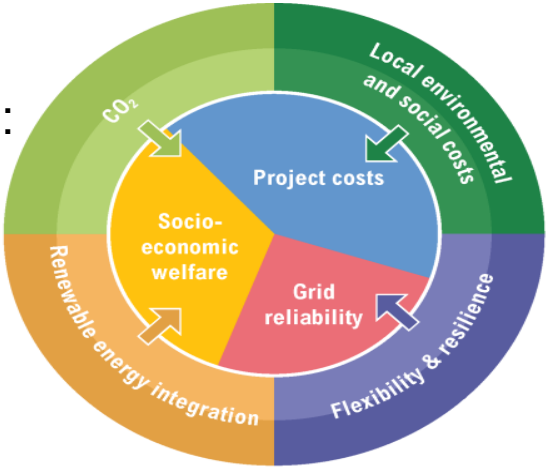
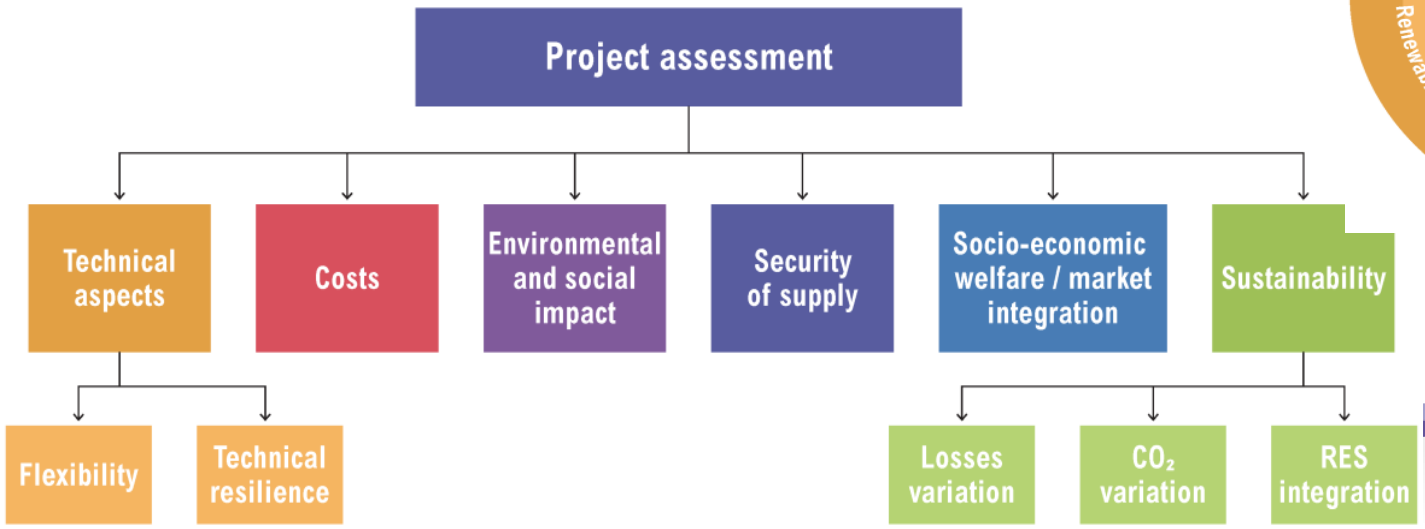
Visions, scenarios, evaluation metrics, assessment methodologies



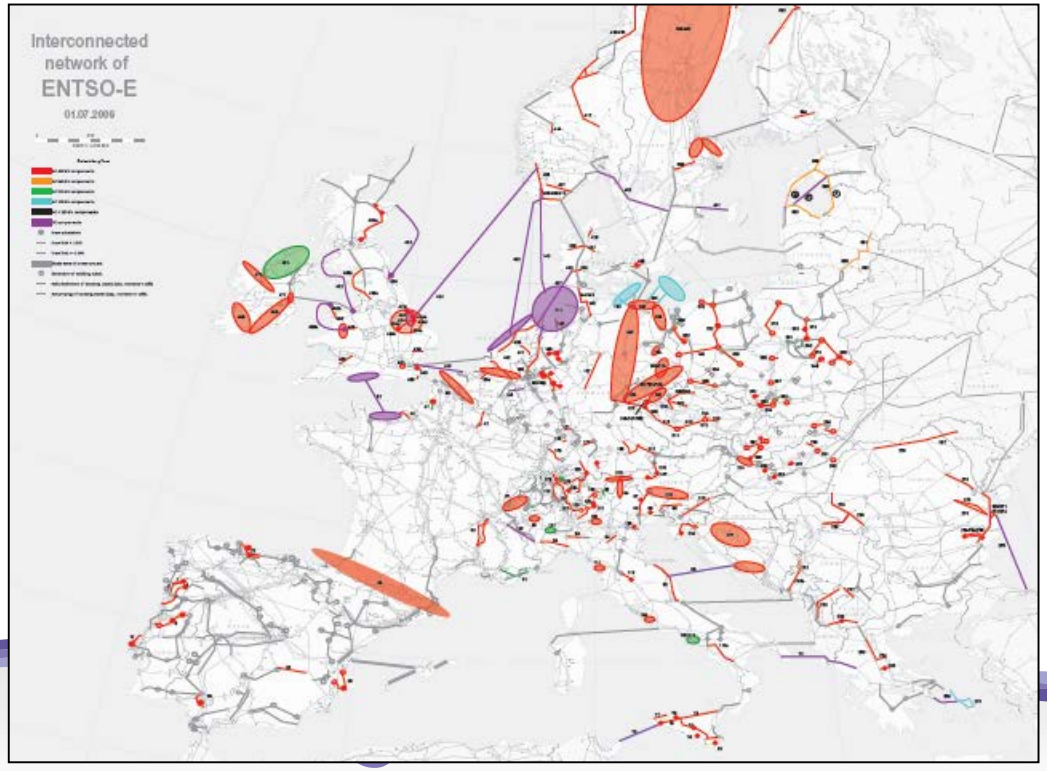
CBA Analysis:

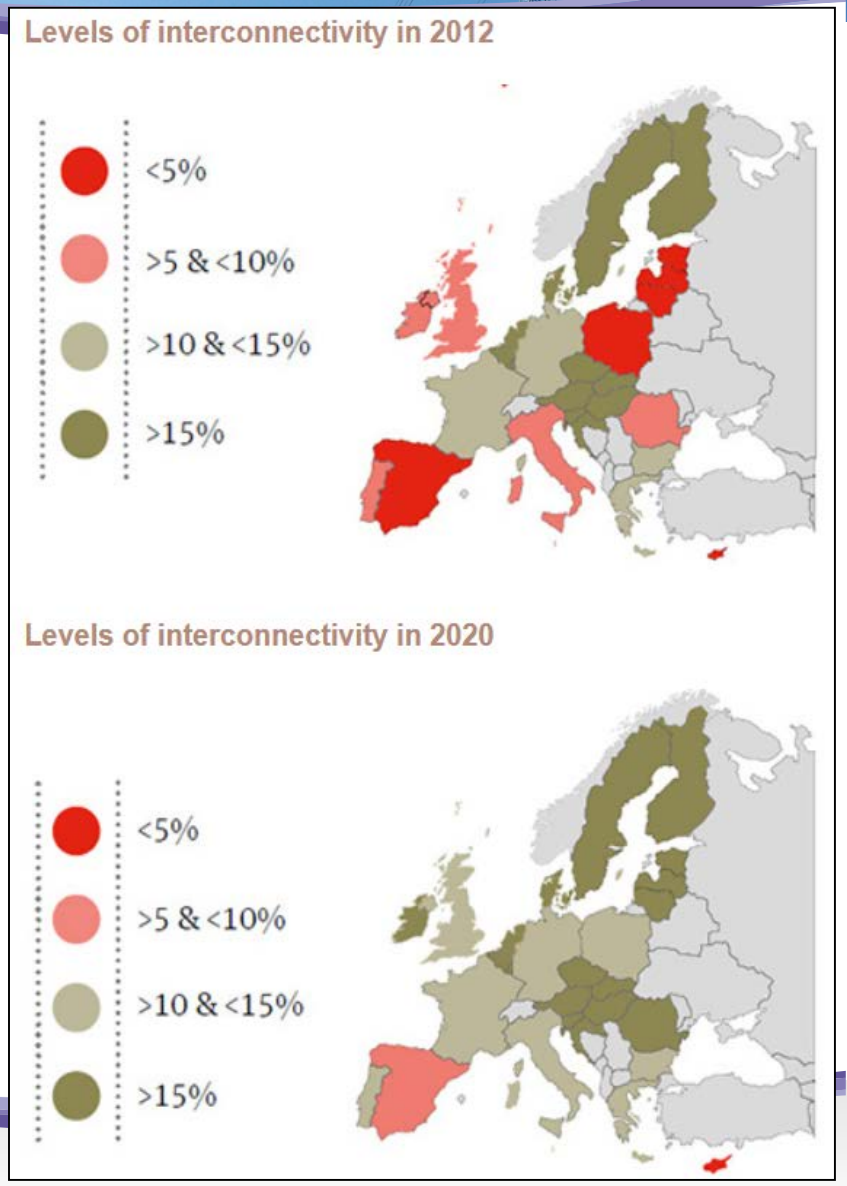




Interconnections are one main focus of EU-wide infrastructures planning, and shall shape future grids

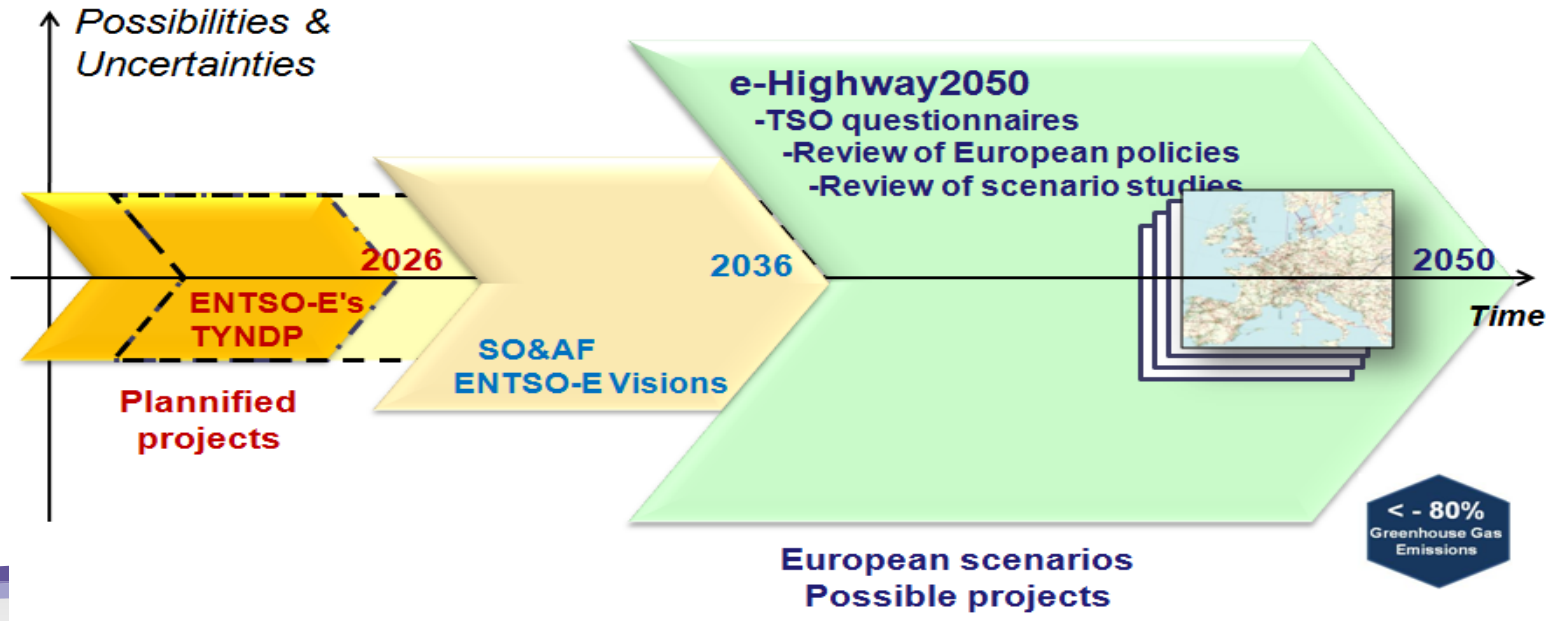
- **The TEN-E Guidelines identify nine strategic geographic infrastructure priority corridors in the domains of electricity, gas and oil, and three EU-wide infrastructure priority areas for electricity highways, smart grids and CO2 CCS**



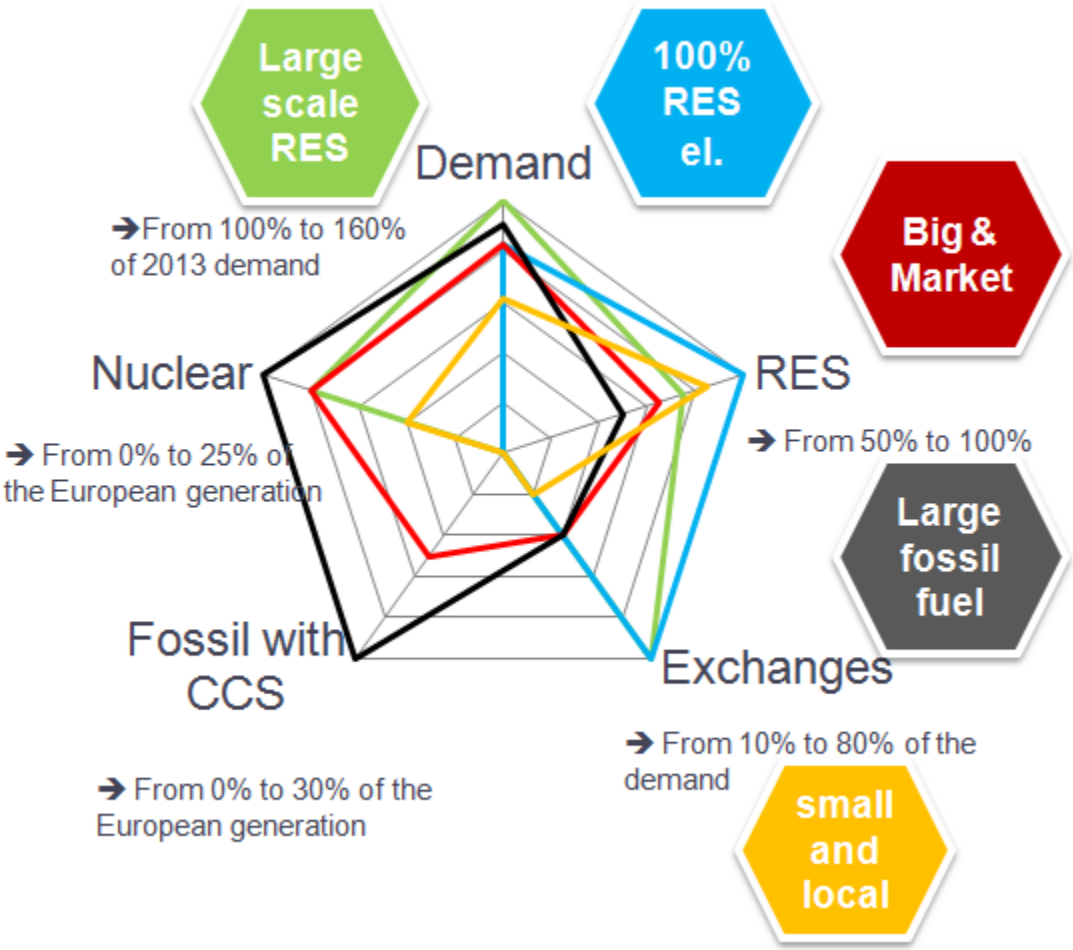


Planning the next generation network: e-Highway project

- **Wide range of options / scenario / sensitivities, for comprehensiveness of projections**
- **No super-imposed DC supergrid has been applied**
- **Priority corridors common to several scenarios are no-regret investment reccomendations**



E-Highway scenarios and identified set of invariant grid expansions



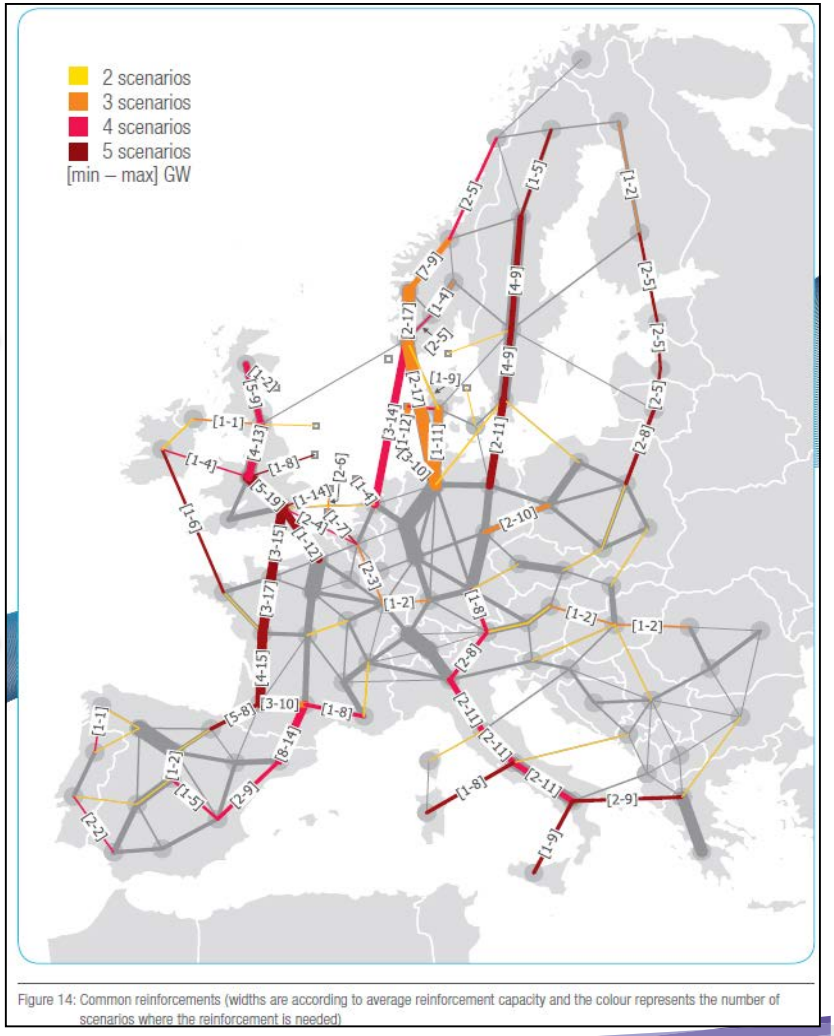


Figure 14: Common reinforcements (widths are according to average reinforcement capacity and the colour represents the number of scenarios where the reinforcement is needed)

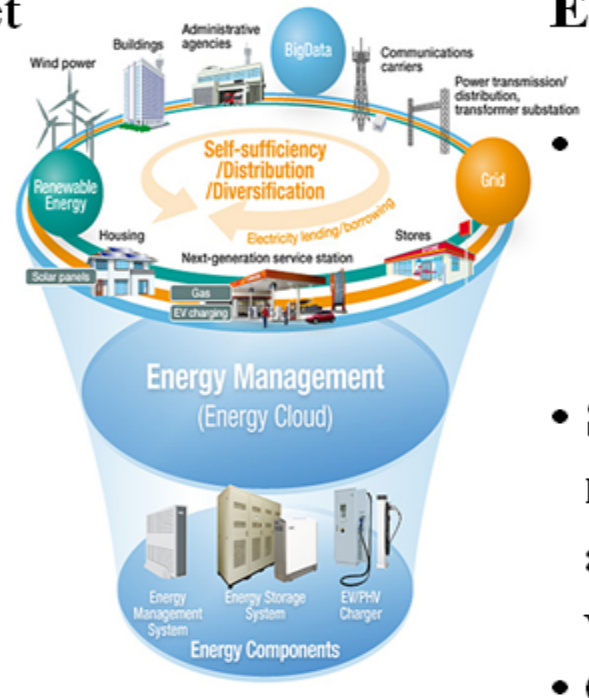
Evolution of grids to cope with market design, regulation and consumers' empowerement

Implementation of:

- Europe wide market coupling (CACM)
- Balancing network code as basis for DSR/DER

- **Data privacy and security**

- Providing data in time and form to those with need and authorisation



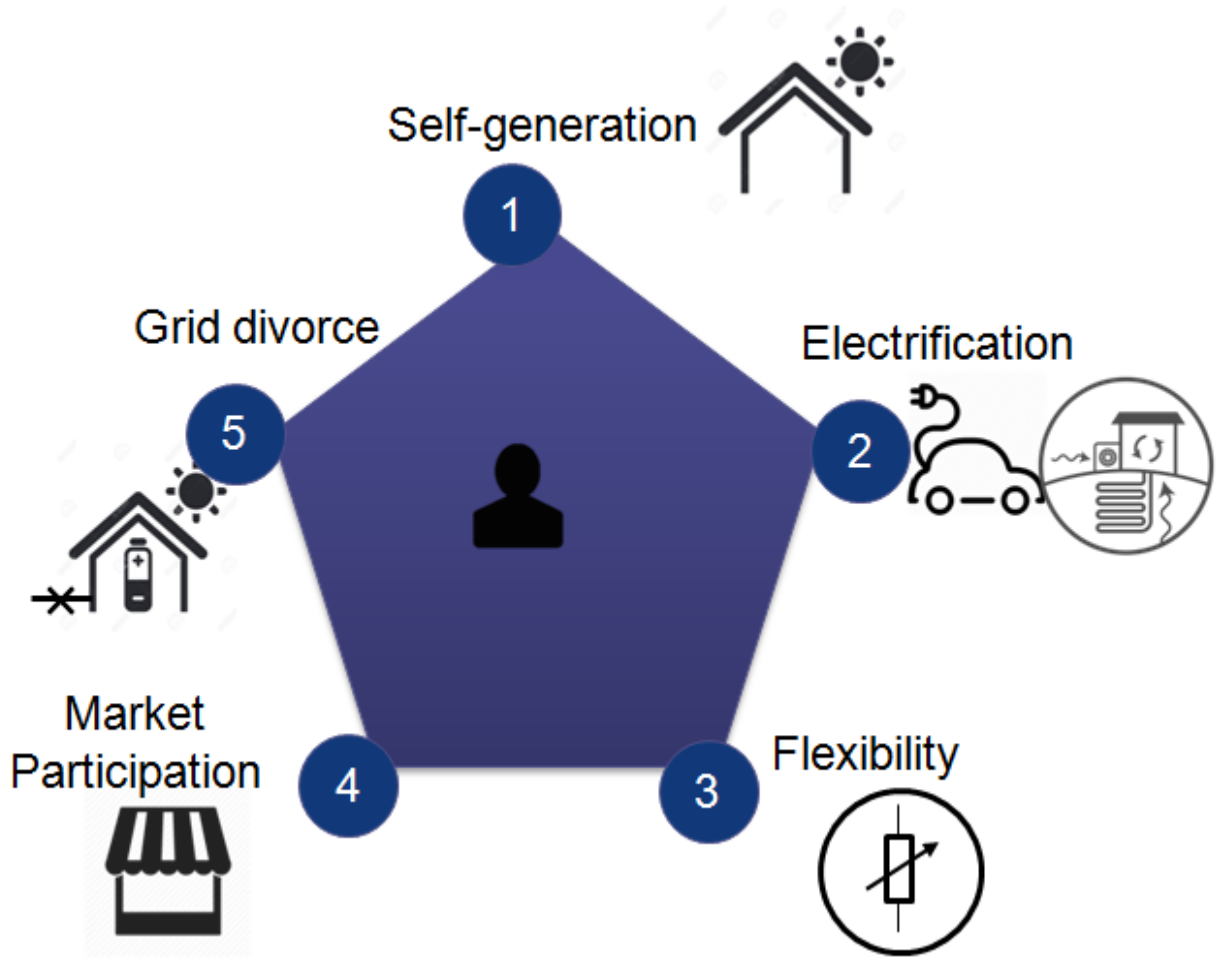
Dynamic retail pricing in **EU legislation**

- DSR and DER are used for balancing and **other markets**

- **Smart apps, data hubs, non-discriminatory access**– well integrated with DSOs/TSOs' software
- Compliance with **data protection regulation**

Active end-users

- With smart meters, homes, businesses and factories become a resource for the system
- With prosumers and active consumers , also grid reliability could become individualized
- Digitalisation of consumer-side power system opens up pletora of services, both for end users benefit and for grid operation



Topics for next 10 years innovation actions are identified in ENTSO-E R,D&I Roadmap, issued in July 2016

Clusters	Functional Objectives		FO contents
C1 Modernization of the Network	T1	Optimal grid design	Optimal grid design: planning, adequacy, tools
	T2	Smart Asset Management	Smart Asset Management; predictive and on-condition maintenance; capex optmisation
	T3	New materials & technologies	Use of new materials and power technologies; new construction and maintenenance methods
	T4	Environmental challenges & stakeholders	Environmental impact, public acceptance, stakeholders participation
C2 Security and System Stability	T5	Grid observability	Observability of the grid: PMUs, WAM, Sensors, DSO information exchange
	T6	Grid controllability	Controllability of the grid: frequency and voltage stability, power quality, synthetic inertia
	T7	Expert systems and tools	Decision support tools, automatic control and expert systems
	T8	Reliability and resilience	Reliability and resilience: defense and restauration plans, probabilistic approach, risk assessment, self healing
	T9	Enhanced ancillary services	Enhanced ancillary services for network operation; cross-border supply of services
C3 Flexibility of Power System	T10	Storage integration	Storage integration, definition and use of storage services; system added value from storage
	T11	Demand Response	Demand Response, tools to use DSR; Load profile, EV impact
	T12	RES forecast	Improved RES forecast and optimal capacity operation
	T13	Flexible grid use	Flexible grid use: dynamic rating equipment, power electronic devices; use of interconnectors
	T14	Interaction with non electrical energy networks	Interaction/coordination with other energy networks (gas, heat, transport)
C4 Economy & Efficiency of Power System	T15	Market - grid integration	Integration of market and grid operation across timeframes (up to real time)
	T16	Business models	Business models (for storage, grid extension, distributed generation) for optimal investments in the network
	T17	Flexible market design	Market design for adequacy, flexibility use, cross border exchanges, rationale use of RES, demand management
C5 ICT & Digitalization of Power System	T18	Big data management	Big data, data mining, data management
	T19	Standardization & data exchange	Standardization, protocols for communications and data exchange with DSOs and other grid operators
	T20	Internet of Things	New communication technologies, Internet of Things
	T21	Cybersecurity	Cybersecurity

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Grid planning

Asset management

Grid observability and controllability

Adequacy, reliability, resilience

Flexible operation

Market and business models

Big Data, IoT, ICT applications

BACK-UPS

Future developments for the power system

Data hubs information: TSO/DSO grid & market tools

Storage: Services to TSOs/DSOs , prosumers

Demand Response : capacity, balancing services

Distributed generation: visibility and remote control and system services

Electrical vehicles : connections and deploying of charging points

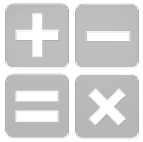
Security and stability : New tools for regional security assessment and interaction with other energy networks

Energy system view: market, operation, planning

Digitalisation of energy (ICT trends)

Hyper-Connectivity

Manage the energy service from any device, anywhere
Creates new channels from users to service providers
Enabling communities in creating new energy services



Super-Computation

Inferring relations between user-generated and other Information, beyond the capabilities today, as to improve existing or creating new energy services

Cloud

Computation and data storage resources offered by 3rd parties as enabling platform for energy services

IoT

Pervasive access to a variety of sensing and control devices

Cyber-security

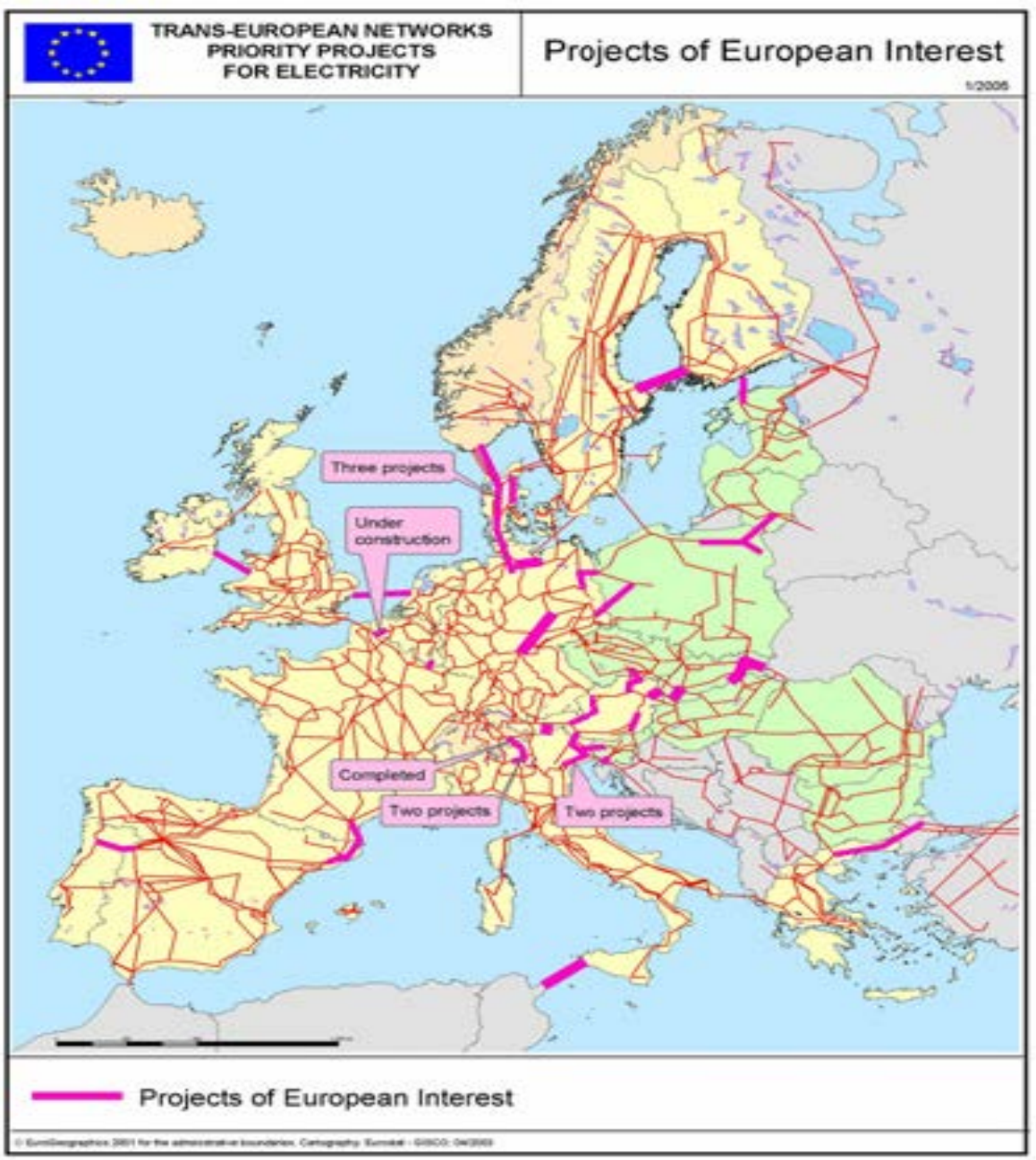
Privacy, 3rd party access to user data only by consent.
Protects energy system against failure from cyber attacks

Projects of European Interest

The projects of European interest are of utmost importance to achieve climate–energy policies objectives

Projects may deal with:

- ✓ Internal network reinforcements
- ✓ Interconnection within member states
- ✓ Interconnection with neighboring countries



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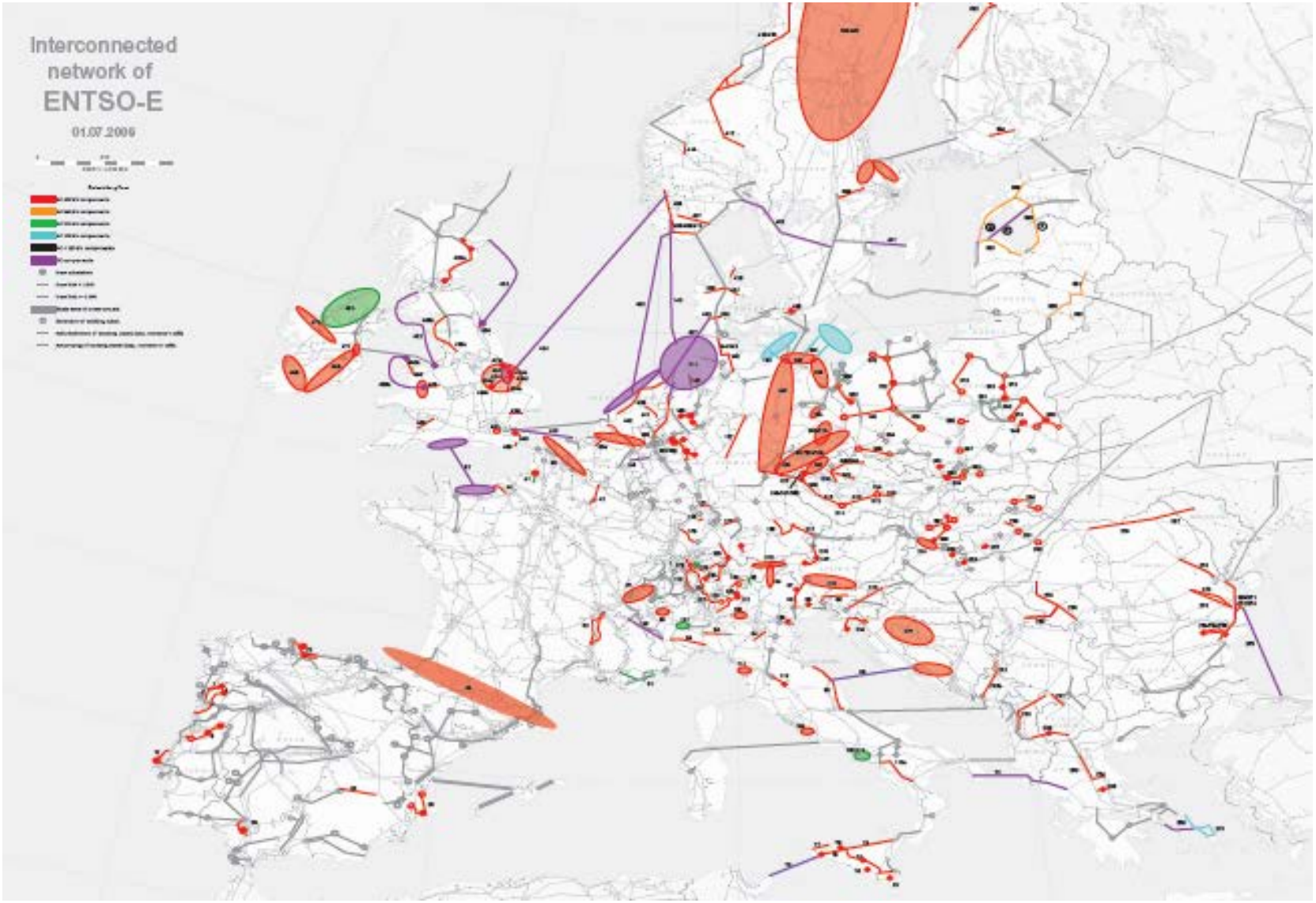
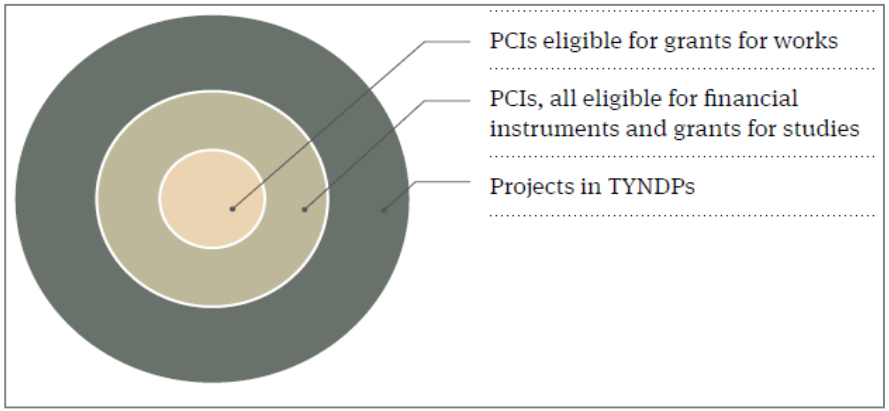
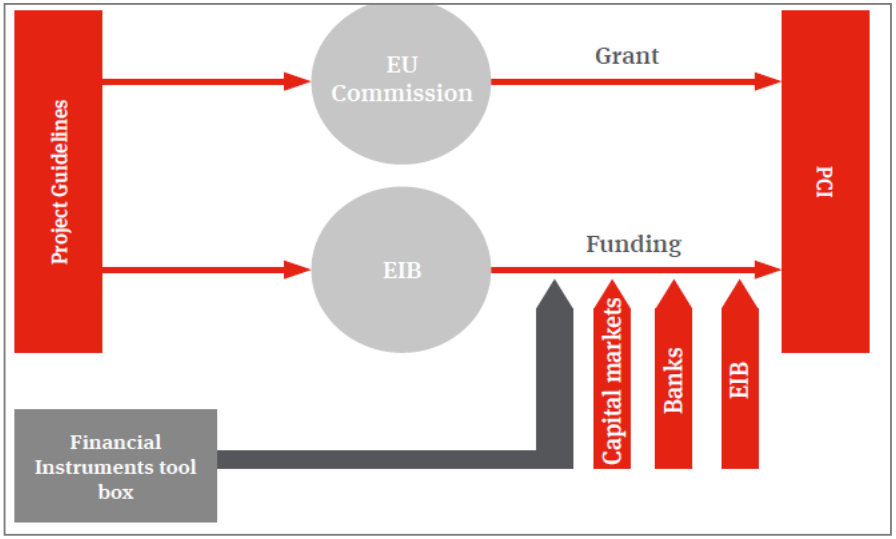
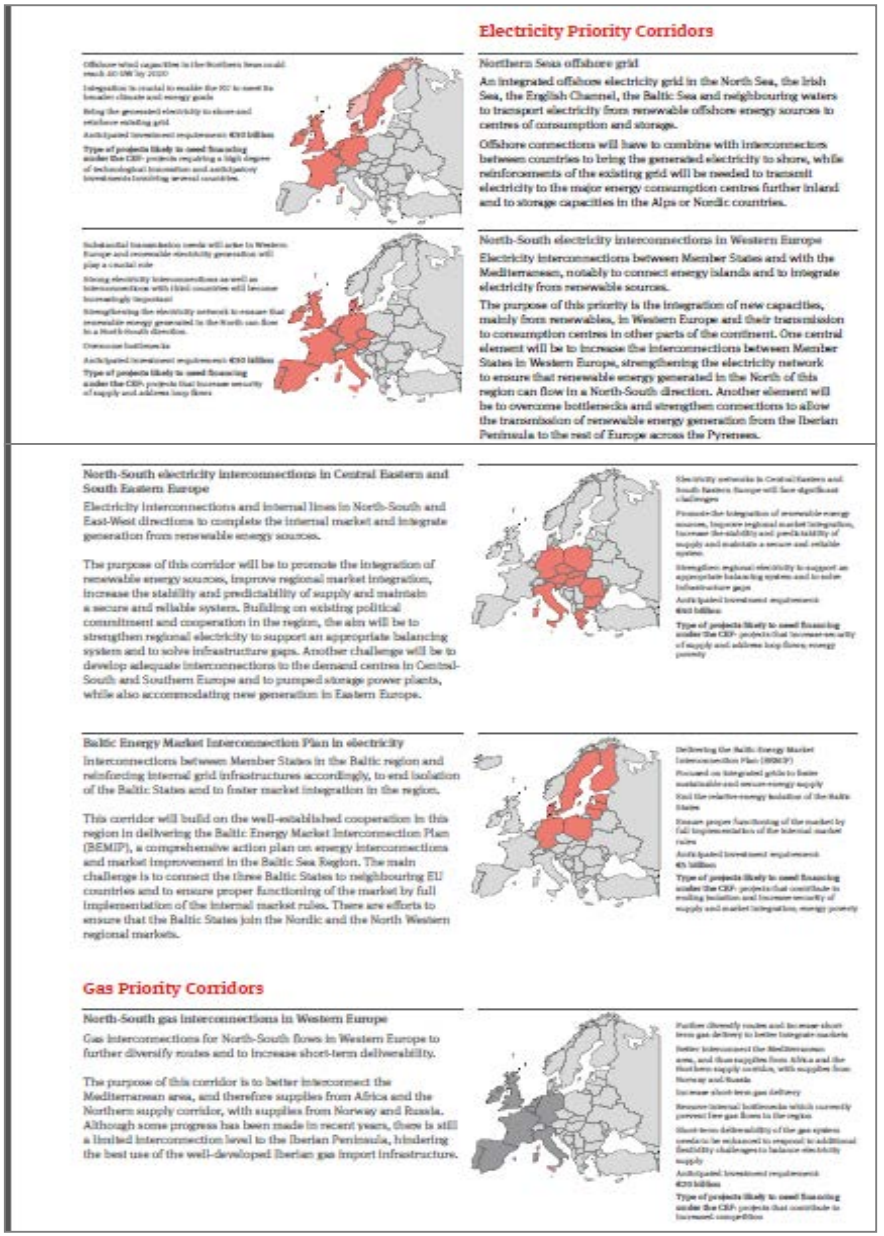


I corridioi prioritari

- **The TEN-E Guidelines identify nine strategic geographic infrastructure priority corridors in the domains of electricity, gas and oil, and three EU-wide infrastructure priority areas for electricity highways, smart grids and CO2 transportation networks**







Gli scenari di lungo periodo

- **Individuati dal progetto europe e-Highway**
- Rappresentano un ampio ventaglio di possibilità
- **Lo scenario che si realizzerà sarà una combinazone lineare degli scenari-base**

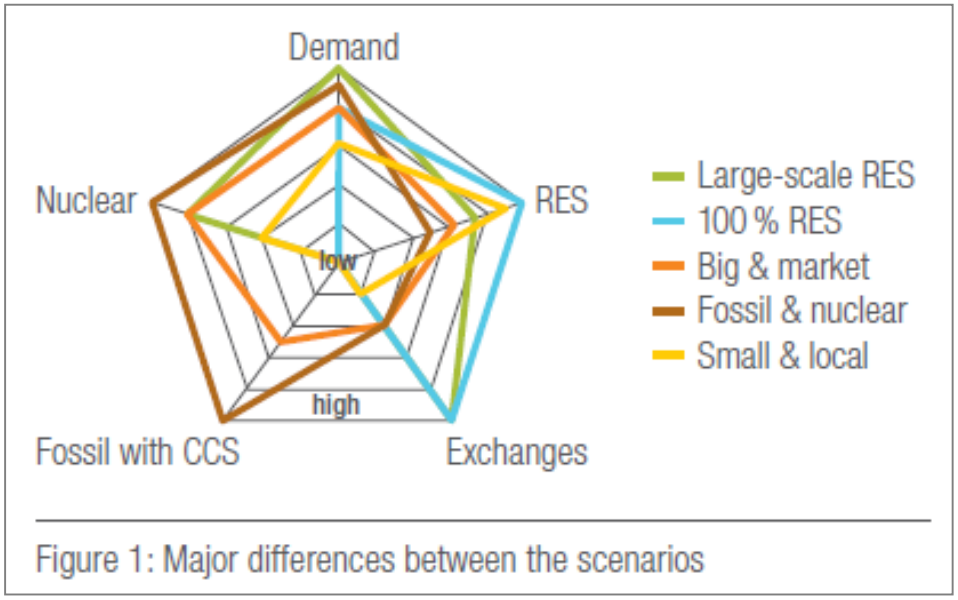
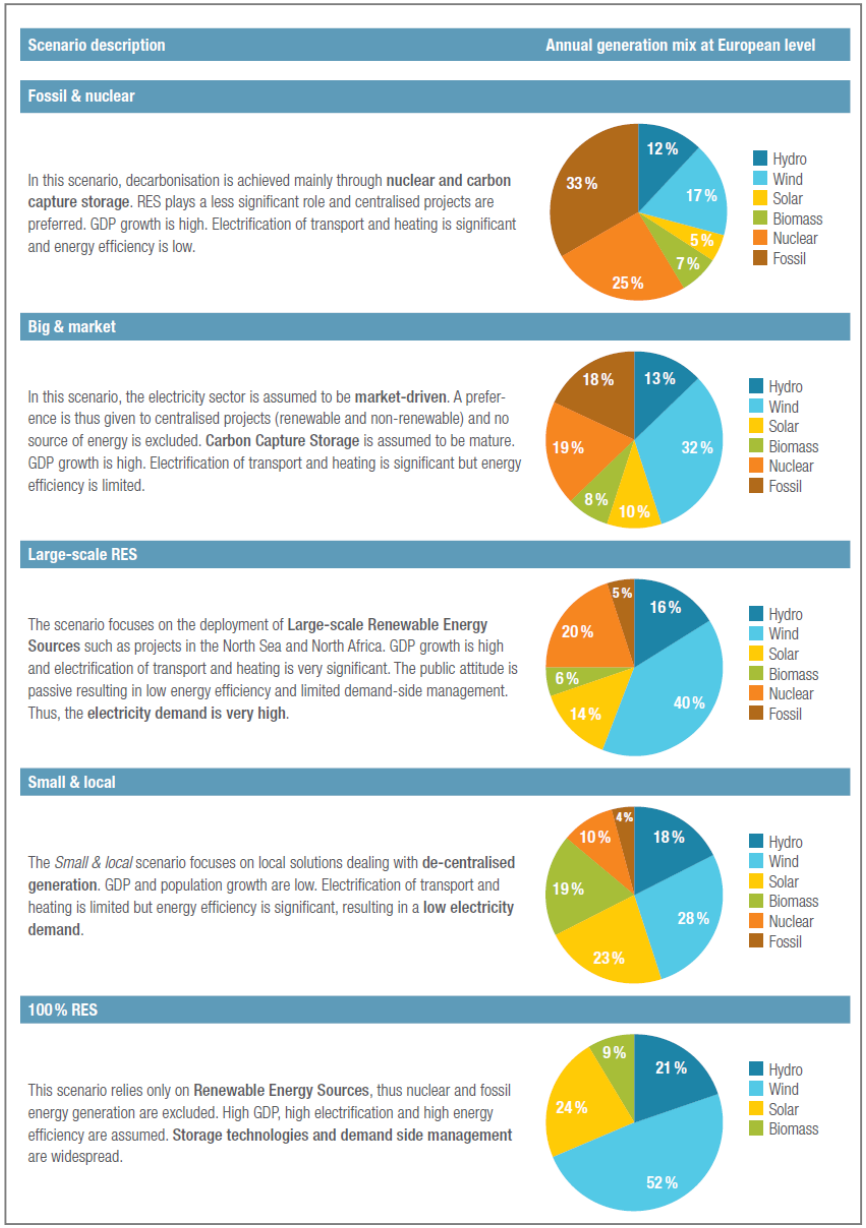
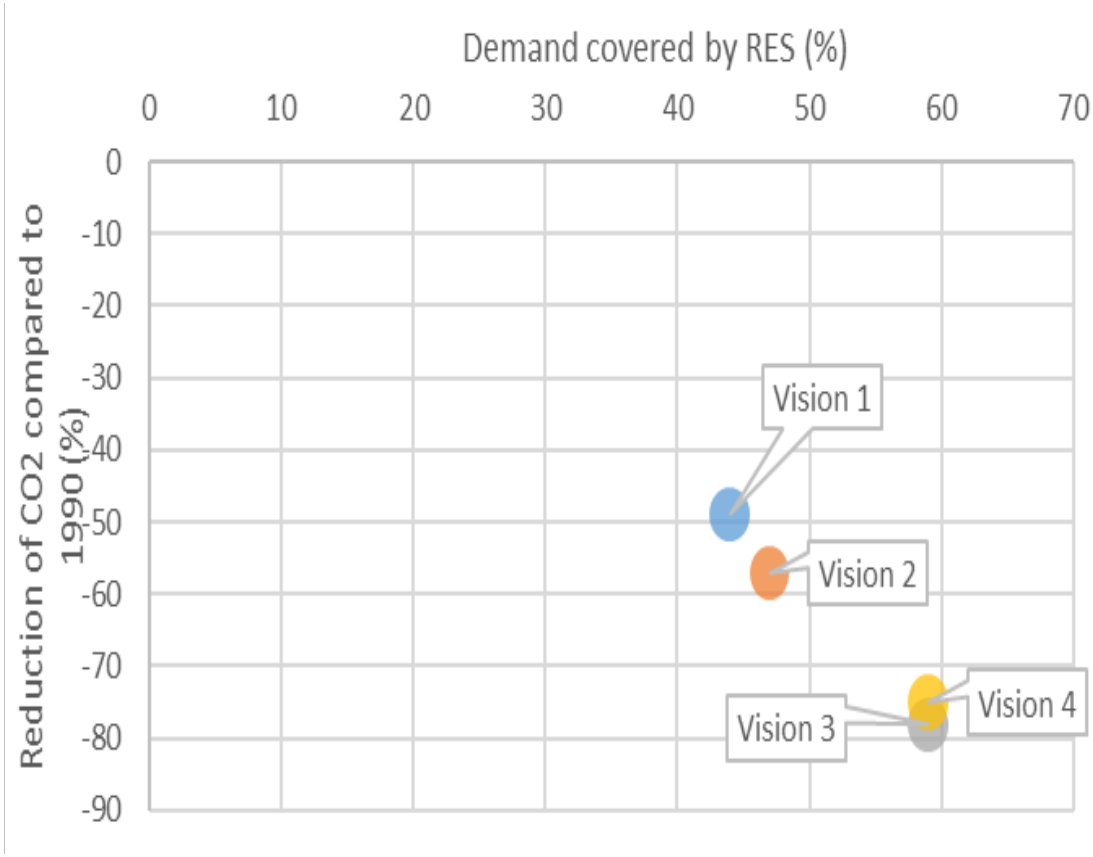


Figure 1: Major differences between the scenarios

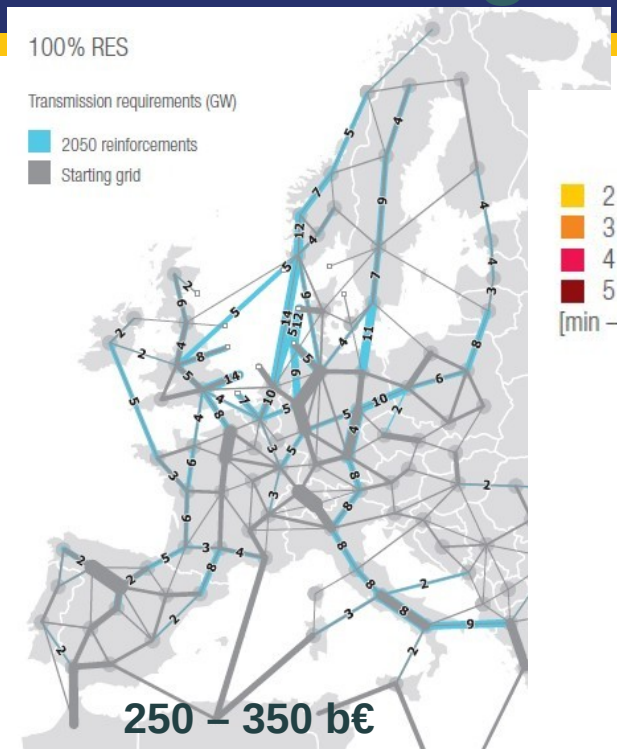


TYNDP scenarios: a wide range of plausible futures

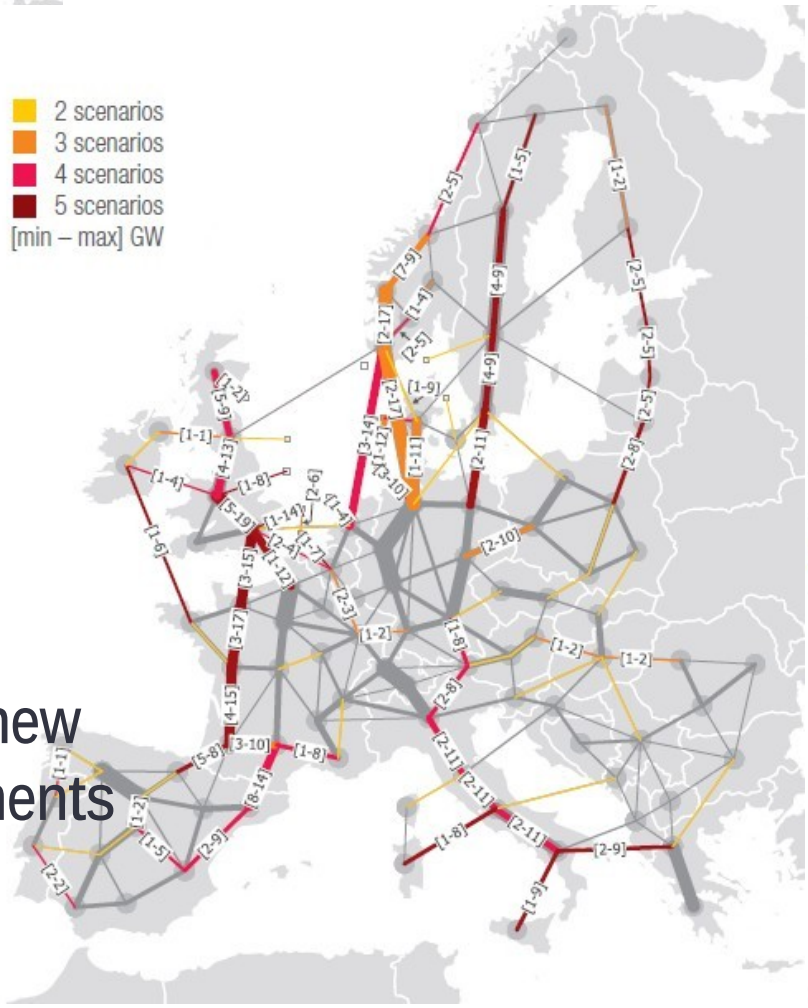


All 2030 Visions matching the renewables objectives of the electricity system.
(V1-2 and V3-4 show a strong differentiation in spatial distribution of generation)

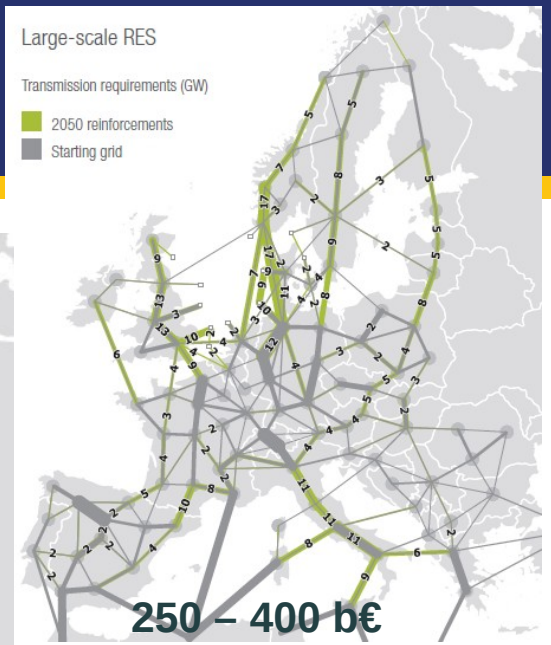
The 2050 grid architectures



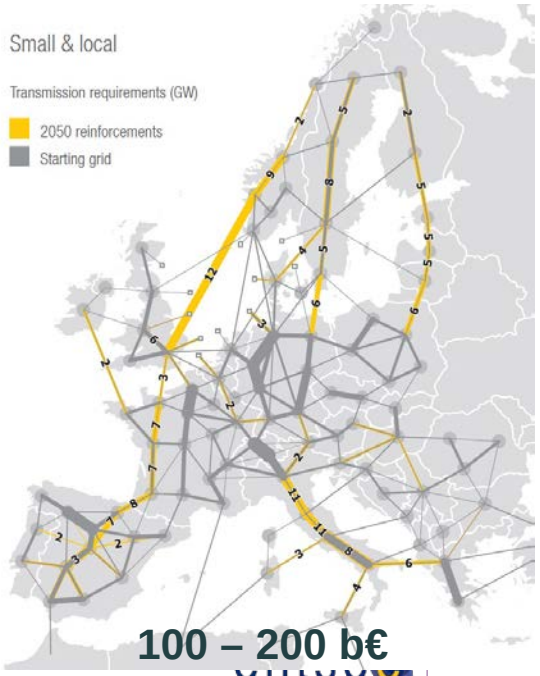
250 – 350 b€



100 – 400 b€



250 – 400 b€



100 – 200 b€

- An invariant set of new lines and reinforcements has been identified.

Reliable Sustainable Connected

User Impact on System Operators

	Revenue Model	User value proposition	Operations
Self-generation	declining revenue from energy based distribution tariffs	storage capabilities	Technical statuary limit and PQ violations
Electrification	increased revenue from load growth	enabling platform for e-mobility charging	network expansion and congestion management
Flexibility	alternative for procurement of system services (TSO)	Facilitating user flexibility and markets (load mgnt, generation mgnt, accounting)	use customer flexibility for operations and asset optimization
Market participation	new value network requiring new business processes	Dynamic pricing, connection management and accounting	TSOs/DSOs cooperation
Grid divorce	hedging /lost customer	Dynamic pricing/re-connection management, maintenance/emergency power	?

ENTSO-E activities on R&D and Innovation

Strategy 2016 and change of name

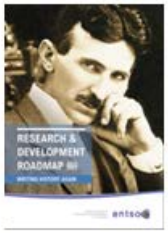
- R&D more and more necesary to cope with system paradigm shift
- Research, Development & Innovation Committee (RDIC) aims at co-ordinating actions and projects of TSOs, notably towards smarter grids, maximising added value between national and international level
- Main deliverables are built combining top-down and bottom-up approaches , plus extensive stakeholders consultation

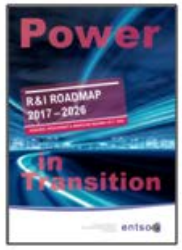
- 2 main pillars:
  - Incubator of consortia for answering EC calls, together with research institutes and other stakeholders
  - Inter-TSO cooperation on best practices, knowledge sharing, addressing short-term challenges not covered by large programs
- 3 dimensions addressed:
  - Technology
  - Processes
  - Business models
- Active participation in the European energy research structures and platforms (now ETIP)

Overview and interplay of ENTSO-E R&D mandated deliverables on R,D&I

ENTSO-E Publications 2012 2013 2014 2015 2016 2017

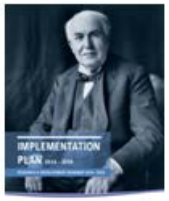
R&D Roadmap

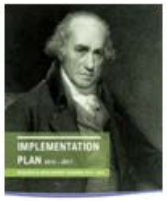


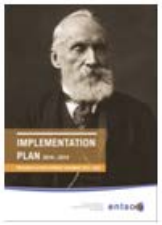


Sets a framework for medium and long term with defined targets

Implementation Plan



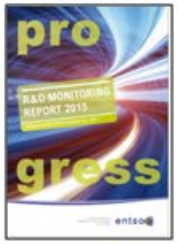




ENTSO-E R,D&I Imlementation Plan 2017-2019

Lists projects and actions for next 3 years (yearly update)

Monitoring / Application Report



Assesses progress, gaps and deployment of R&D activities (yearly update)

Role of grids in R&D processes

- **Pivotal role of grids:**
  - ✓ Backbone of the whole power system
  - ✓ Indispensable enabler to low-carbon-systems → increased need of power transfer for RES generation optimisation
  - ✓ Traditionally a centre of technical excellence and prone to continuos learning & improvement
- **Role of grid operators for deployment of R&D results:**
  - ✓ Although not primary R&D institutions, they own and manage the assets and systems where most innovation has to be deployed or connected
  - ✓ Only and obligated location for projects at demo stage
  - ✓ Natural interface and data provider towards both traditional actors (DSOs, power market players, equipment manufacturers, research institutes, univeristies) and also newcomers (storage operators, aggregators, balance services providers, service companies, ITC apps providers, etc.)
  - ✓ In charge of introducing and integrating - under optimal system view - several proposed new technologies and solutions

Grid operators should have a key involvment in early stage of R&D concepts to ensure proper system perspective, integration aspects, operator's requirements

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Grids and ENTSO-E role in European R&D arena

➢ **Main overarching trends:**

- ✓ Integration of different energy systems: gas, heating, transport, but also ICT, new materials
- ✓ Challenges and solutions tend to stretch over borders, hence higher level view is needed
- ✓ Strong political pressure towards innovation and smart grids/cities to maintain European competitive advantage on relevant technologies
- ✓ EU and all grid users expect ENTSO-E and other actors to anticipate the challenges, to timely identify and deploy cost-effective solutions in order to consolidate the European front-runner role on energy&climate issues
- ✓ Still various R&D activities related to grids are performed by several stakeholders, often with little coordination

TSOs mandated to coordinate efforts, to share priorities, to avoid overlaps, to achieve more-value-for-investment
Both among them and vs the Research Community

Current TSO involvement in EU projects

23 European funded R&D projects

Active participation of 25 out of 41 TSOs from ENTSO-E