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STRIDE Smart grid workshop

Lecture 5

Smart grid strategy and roadmap

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Smart grid strategy and roadmap

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Content

- Five Key Strategic Themes
- Smart Grid Framework
- Guiding Principles for Smart Grid Architecture and Design
- Grid Impacts and Issues
- Historical Grid vs. Future Grid

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5 key strategic themes

- Customer empowerment
- DER integration
- Power grid efficiency, reliability and resiliency
- Safety and workforce efficiency
- Innovation, information and connectivity

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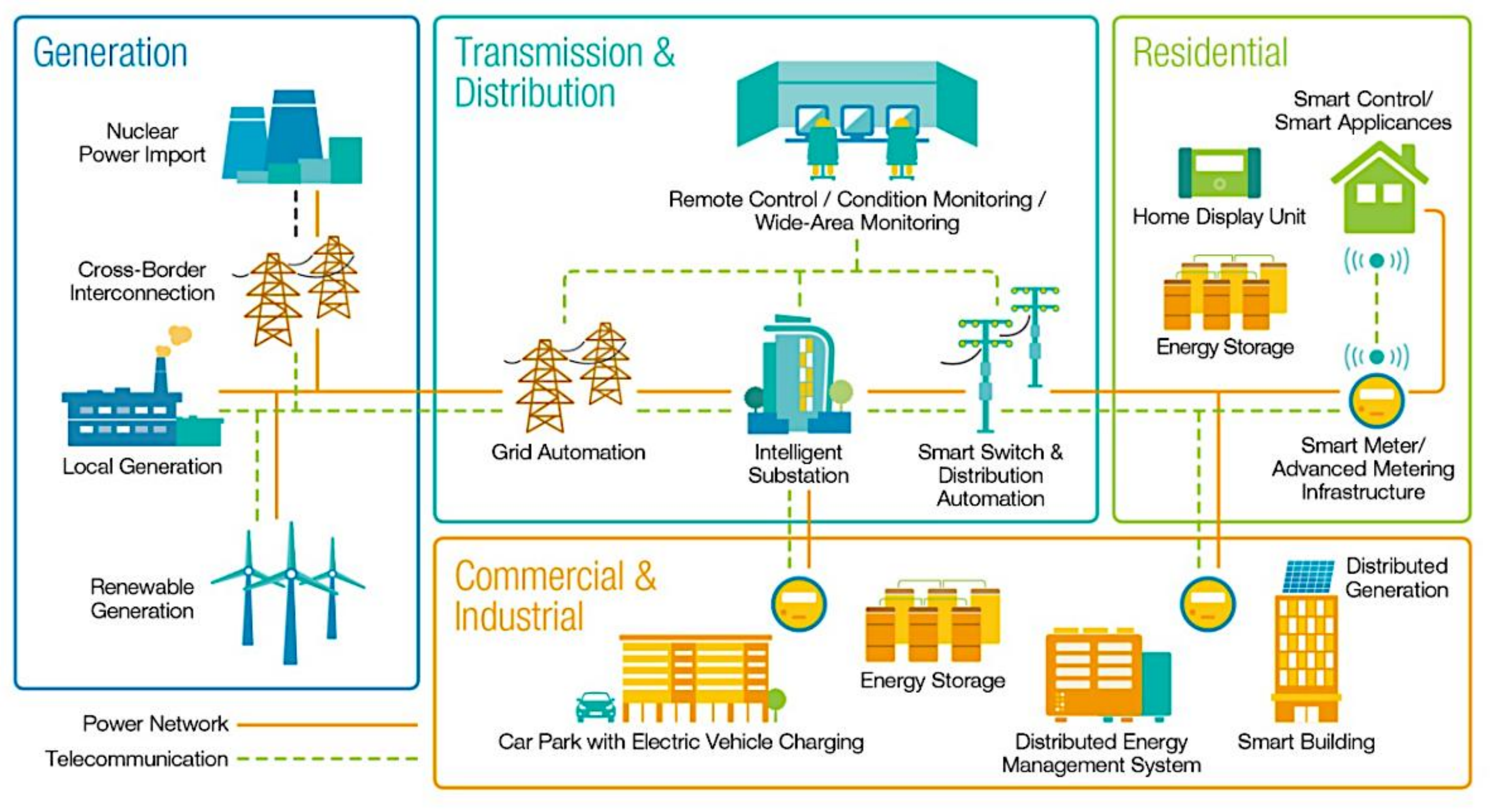
Smart Grid Framework



Source: https://www.clp.com.hk/en/about-clp/power-transmission-and-distribution/smart-grid

Project co-funded by the Europen Union (ERDF, IPA).

Customer Empowerment

- Enable customers to **participate** in, **monitor** and **control** their energy generation and consumption
- Multiple viable customer options
- Customer advocacy and trust
- Promote competition
- Smart meters
- Safety, security, privacy

Project co-funded by the Europen Union (ERDF, IPA).

Distributed Energy Resource Integration

- Collaborative DER policy framework development
- Timely access to and use of granular distribution and service location grid information
- Energy storage for regulation and for load shifting
- Capture and harness excess energy generation
- Real-time visibility and control of DER
- Gradually implement new smart devices and resources into the system

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Grid efficiency, reliability and resiliency (1)

- Advanced meter infrastructure will bring more effective and more efficient data analysis
  - real-time visibility and utility control of grid assets
  - proactive and timely grid data analysis and modelling
  - real-time visibility to manage and control voltages
  - self-healing/autonomous grid controls
  - automated and enhanced grid resiliency
- Devices: advanced inverters, in-line power regulators, etc.

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Grid efficiency, reliability and resiliency (2)

- Systems:
  - ADMS - Advanced distribution management system
  - DRMS - Demand response management system
  - DERMS - Distributed energy resource management system
  - MDMS - Meter data management system
  - OMS - Outage management system
  - DLC - Direct load control

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Safety and workforce efficiency

- Fully automate manual processes
- Remote readings
- The implementation of smart devices drastically reduces the time to act on some grid issues
- Re-focus workforce resources on critical tasks
- Training programs for workforce are of extreme importance

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Innovation, information and connectivity

- Innovative, robust and flexible Smart Grid architecture
- Relevant, cost-effective and timely innovation
- Timely massive data processing and analysis
- Secured, interconnected and efficient network communications
- Protection and automated response to threats

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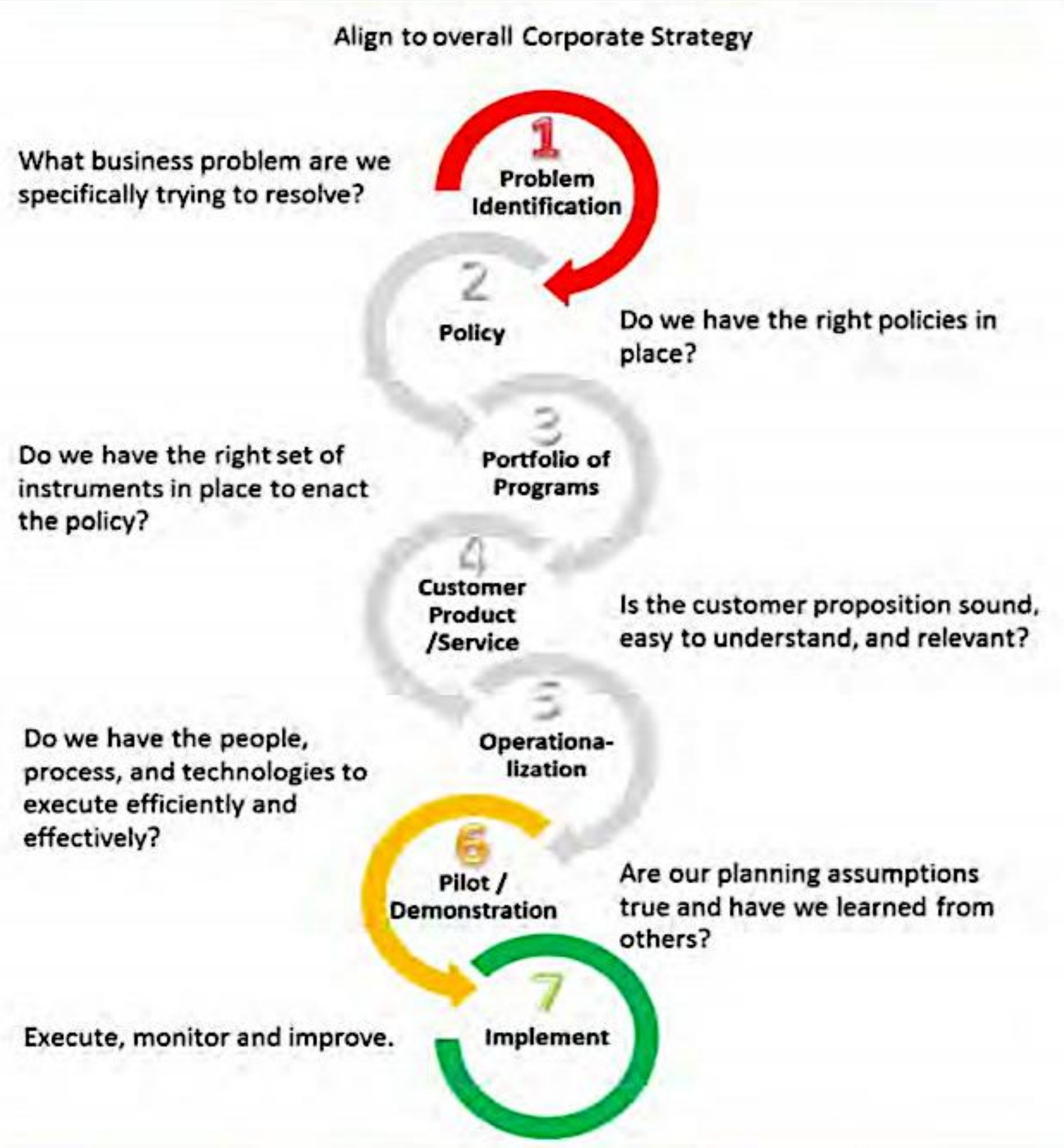
Overall process methodology



Project co-funded by the Europen Union (ERDF, IPA).

Grid Impacts and Issues

- Variability and intermittency in renewable generation
- Decreased frequency response capability and decreasing system inertia
- Changing load patterns and unpredictability
- System dynamics becoming both faster and more unexpected
- The need to manage a vastly increasing number of generation points
- Growing cyber attack issues in the grid

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Variability and intermittency in renewable generation

- Intermittent energy resources: solar and wind
- Grid planning: storages, system flexibility, advanced control capabilities
- **Current: production follows consumption**
- **Future: consumption follows production**

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Decreased frequency response capability and decreasing system inertia

- Conventional spinning generation provided inertia – the ability to maintain the system frequency
- Wind and solar generators do not contribute to the system's inertia
- Higher number of renewable generators decreases the number of conventional generators that contribute to the inertia
- Solution: advanced inverters and power electronics

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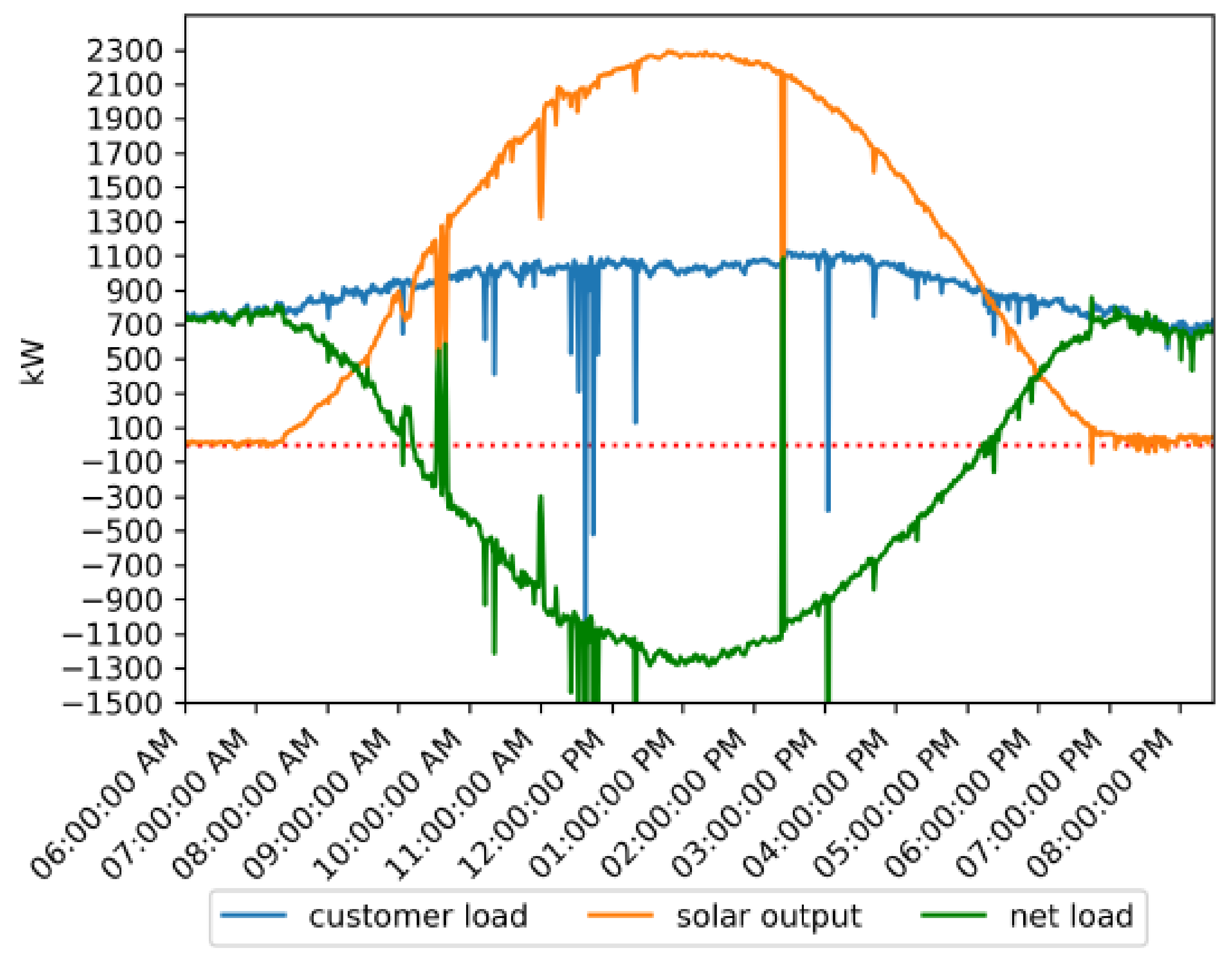
Changing load patterns and unpredictability

- Net load will be harder to predict due to the increase in the number and type of DERs
- Different impacts: some DERs give power to the grid, some store power, some reduce consumption
- Solution: sensing and control methods, observability strategies



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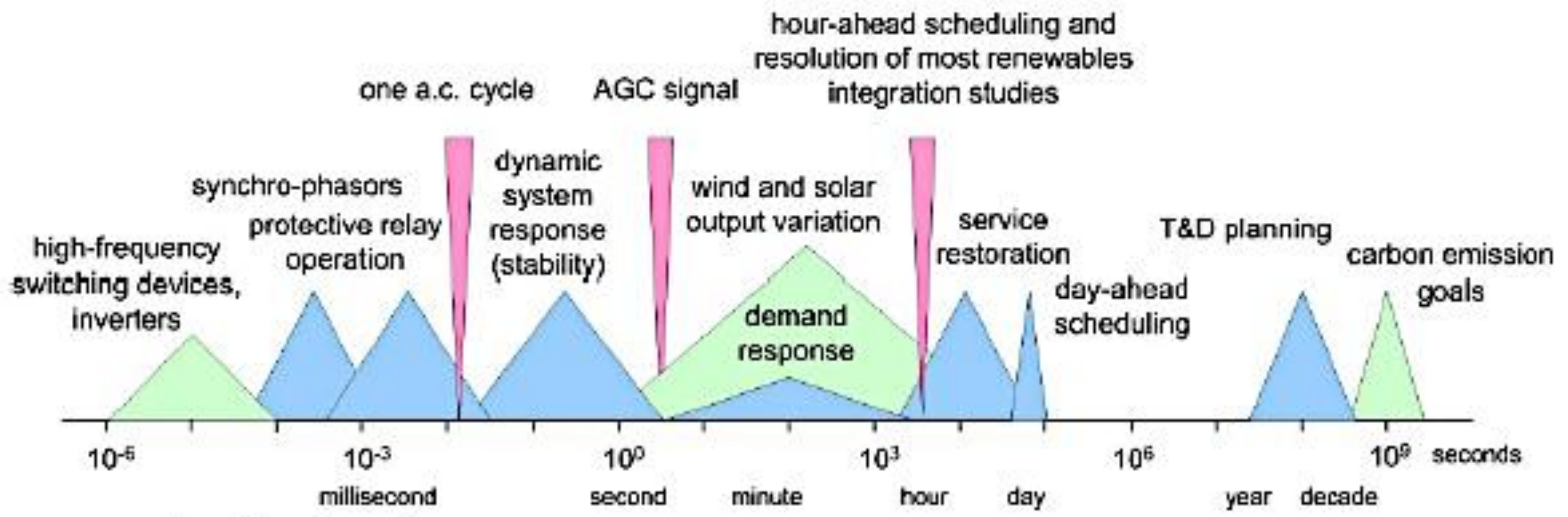
System dynamics becoming both faster and more unexpected

- Central challenge: generated power = consumed power + losses
- It is necessary to implement control methods appropriate to the grid changes



Source: Developed by Alexandra von Meier.

Project co-funded by the Europen Union (ERDF, IPA).

Management of a vast number of generation points

- A bigger number of generation points in the grid complicates the management of the grid
- Coordination and control strategies are important
- Substations have a bigger role in the system
- Cybersecurity

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Historical vs. ”New” Grid Characteristics

- **Historical**:
  - rotational inertia
  - dispatchable generation
  - passive/predictable loads
  - operator-based grid management
  - centralized control
  - SCADA
- **Challenge**: creating a design which can maintain a stable, coherent and manageable system

- **Emerging**:
  - reduced stability
  - faster dynamics
  - stochastic generation
  - engaged customers
  - sensors and data acquisition
  - extremely fast analysis
  - flexible and resilient systems
  - more precise control
  - decentralized control
  - PMU

Project co-funded by the Europen Union (ERDF, IPA).

Literature

- Solari Smart Grid Foundation Project on Hawaii; URL: http://solaricommunication.com/portfolio/Solari-Smart-Grid-Foundation-Project.pdf

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Smart Grids in the EU

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Content

- Sources of financing
- 2017 numbers
- Funding
- Investors
- Investing domains

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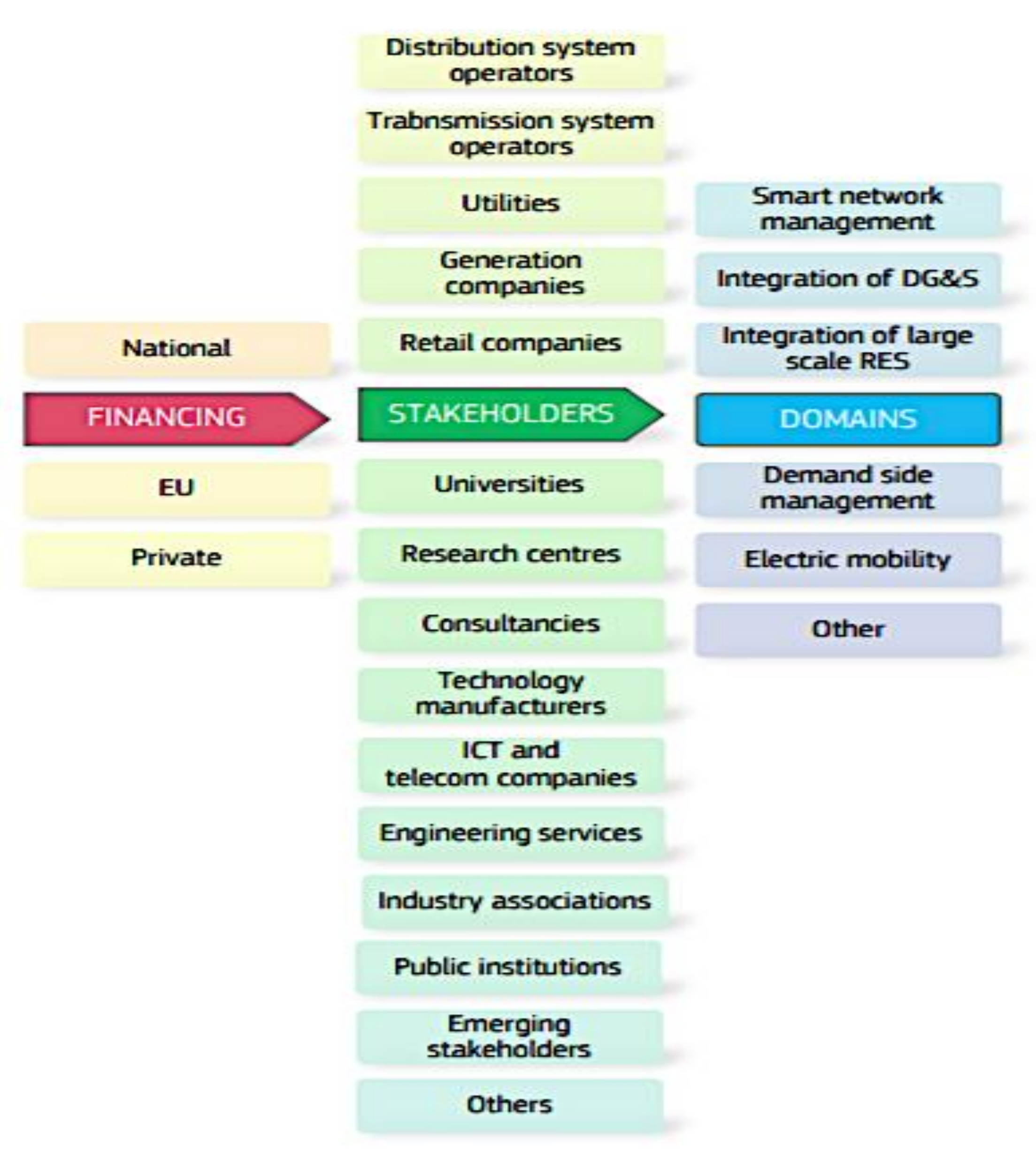
Sources of finan



Source: https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/u24/2017/sgp_outlook_2017-online.pdf

Project co-funded by the Europen Union (ERDF, IPA).

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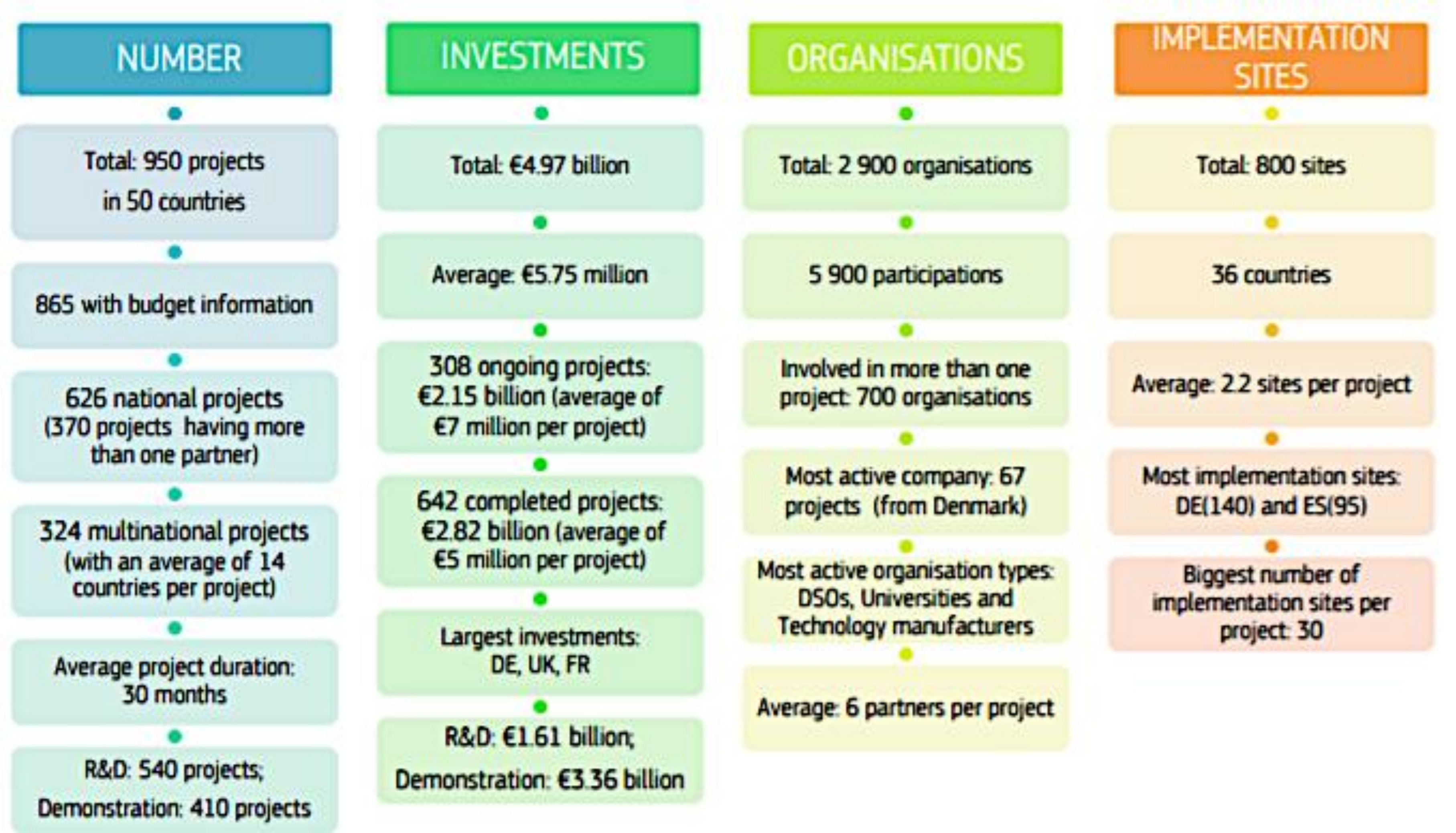
2017 database



Source: https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/u24/2017/sgp_outlook_2017-online.pdf

Project co-funded by the Europen Union (ERDF, IPA).

2017 database

- **Most in Germany**: around 325 projects
- SE Europe – high number of organisations, low level of investment
- Highest investments:
  - Smart network management
  - Distributed generation and storage
  - Together accounting for around 80% of the total investment

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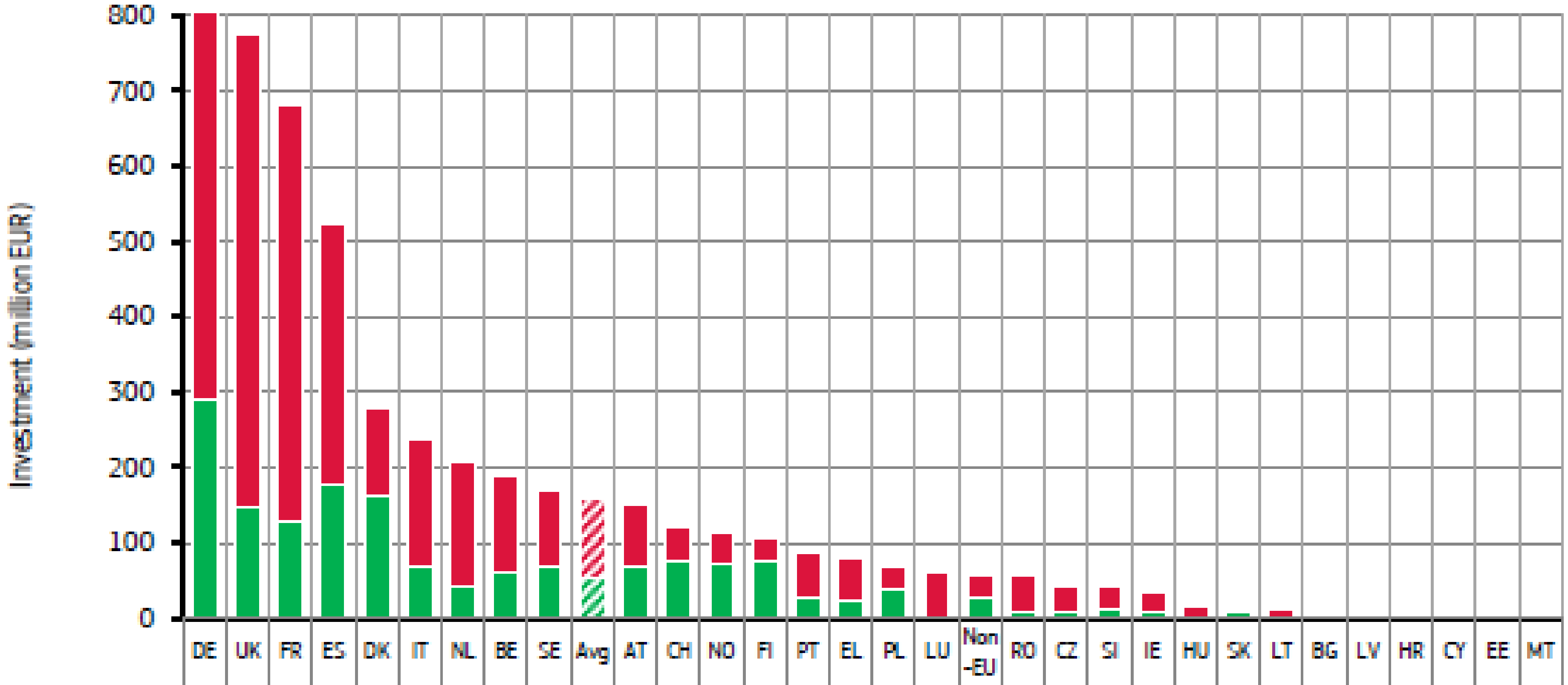
Total investment per country



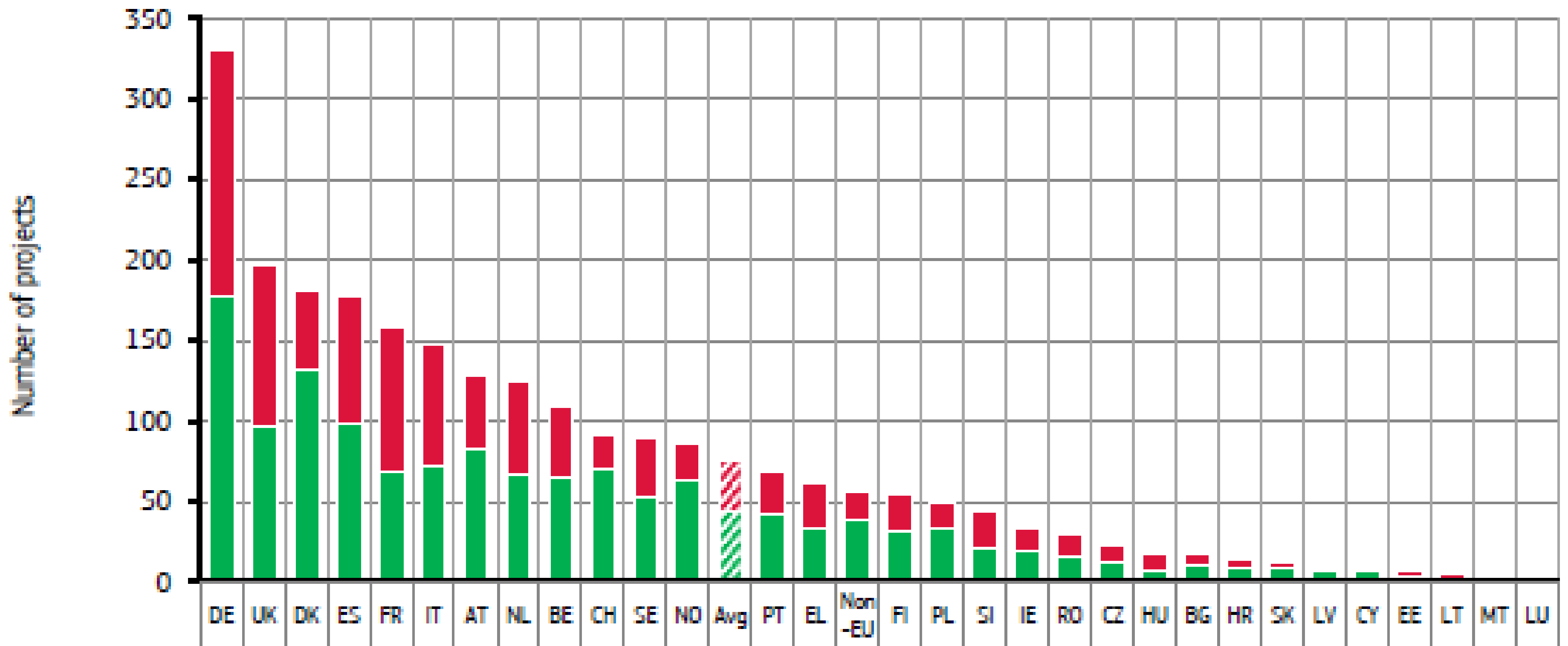
	DE	UK	FR	ES	DK	IT	NL	BE	SE	Avg	AT	CH	NO	FI	PT
Demonstration	520	628	550	344	117	172	166	128	102	108	84	47	41	29	62
R&D	289	146	130	177	161	67	43	62	69	52	68	76	71	77	27

	EL	PL	LU	Non-EU	RO	CZ	SI	IE	HU	SK	LT	BG	LV	HR	CY	EE	MT
Demonstration	53	32	61	30	49	36	28	25	14	3.7	8.9	5.1	3.5	2.4	1	2.3	1.2
R&D	25	36	0	28	9.1	7.1	13	8.8	1.8	8.2	1.2	2.9	4.2	3.8	3.7	1	1

Source: https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/u24/2017/sgp_outlook_2017-online.pdf

Project co-funded by the Europen Union (ERDF, IPA).

Total number of projects per country



	DE	UK	DK	ES	FR	IT	AT	NL	BE	CH	SE	NO	Avg	PT	EL	Non-EU	FI	PL	SI	IE	RO	CZ	HU	BG	HR	SK	LV	CY	EE	LT	MT	LU
Demonstration	152	101	50	79	91	77	46	58	44	21	37	22	32	26	29	18	24	16	22	14	14	9	10	7	5	4	3	3	3	3	2	2
R&D	178	96	131	99	68	71	82	66	65	70	53	64	43	42	33	39	31	34	21	20	16	13	7	10	9	8	6	6	3	2	3	0

Source: https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/u24/2017/sgp_outlook_2017-online.pdf

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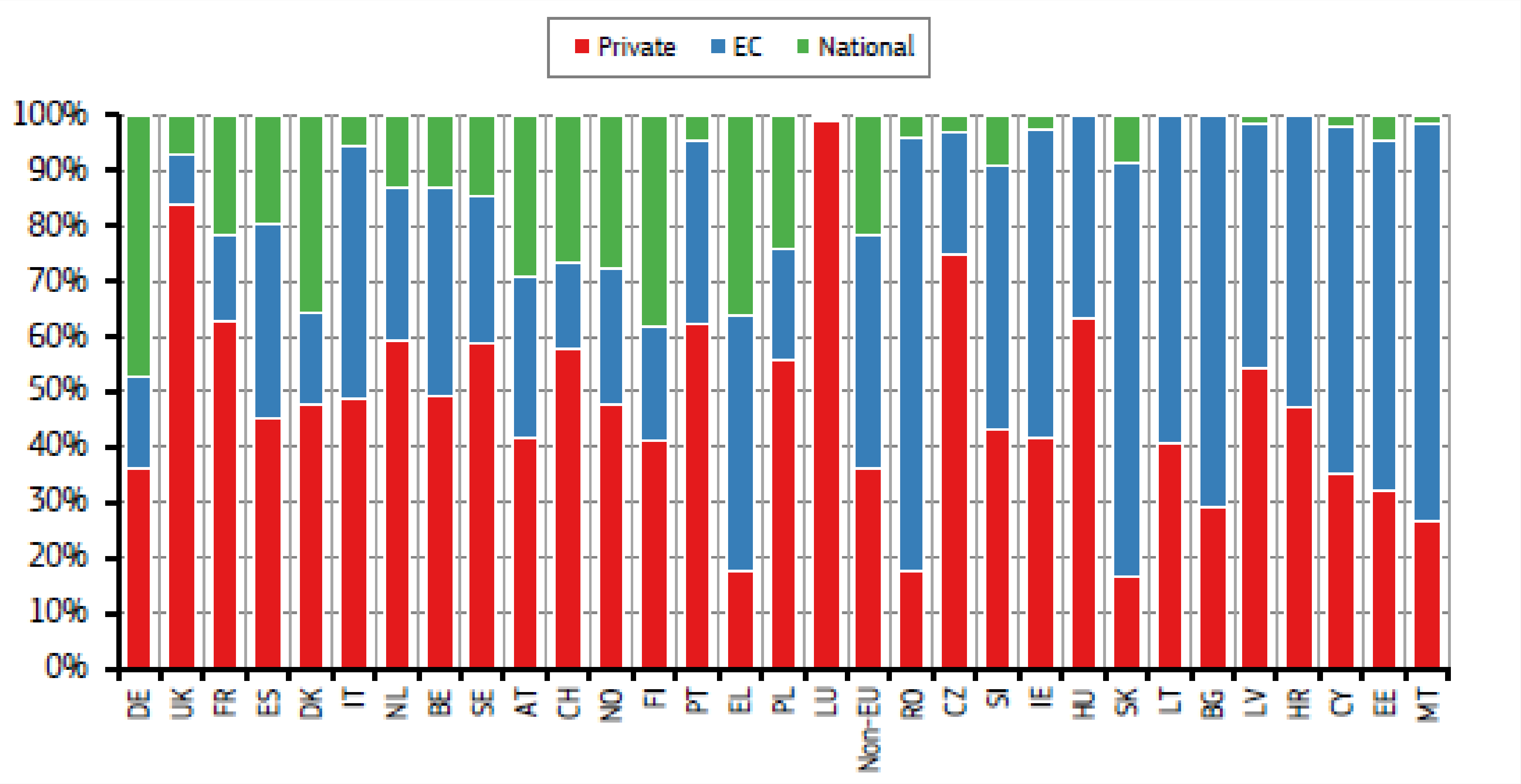
Share by financing source per country



Project co-funded by the Europen Union (ERDF, IPA).

Source: https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/u24/2017/sgp_outlook_2017-online.pdf

Main factors affecting the number of projects

GENERAL CHARACTERISTICS	Country's size, population and electricity consumption	State of the electricity grids	Number and company culture of DSOs
REGULATORY FRAMEWORK	Favourable regulatory framework	Specific regulatory funding for innovation projects	RES supporting mechanisms and policies
NATIONAL CONTEXT	National co-funding mechanisms	Adoption of Smart grid Action Plans/National priorities	Creation of Smart Grid Platforms
EUROPEAN CONTEXT	Accessibility to European co-funding mechanisms	Smart grids as priorities in the regional Smart Specialization Strategies	Participation in EU Working Groups and Platforms
MARKET ENVIRONMENT	Number and size of established market actors	Existence of a national smart grid value chain	Overall climate for innovation

Source: https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/u24/2017/sgp_outlook_2017-online.pdf

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Sources on financing of smart grid innovation projects

- Private investment, national and EU funding
- DSOs are the main investors in the smart grid environment
- How and why companies invest?

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National funding

- 49% of total projects received some sort of national funding
- In most of the Member States – under 10% of overall level of investment
- In 7 countries (DE, DK, GR, FR, AU, PO, FI) – over 20%

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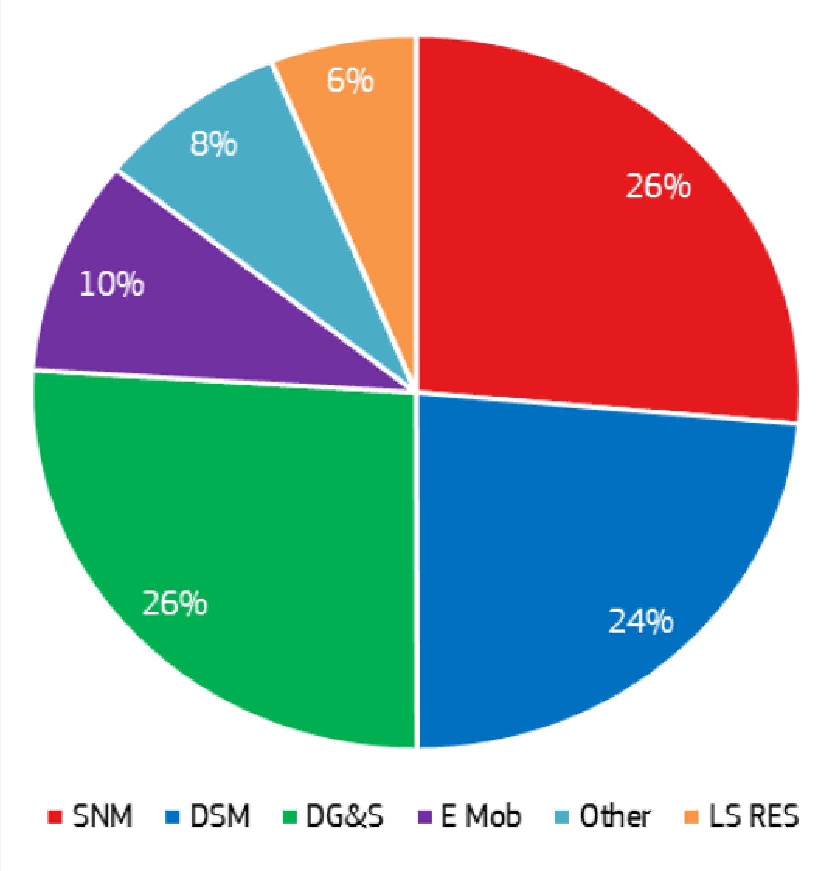
EU funding

- around 30% of projects in total
- 55% R&D, 45% Demonstration
- funding:
  - 39% R&D
  - 61% Demonstration



Source: https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/u24/2017/sgp_outlook_2017-online.pdf

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Who is investing?

- DSOs
- Universities
- Technology manufacturers
- Public institutions
- Emerging stakeholders

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Stakeholder categories

- Generation companies
- TSOs and DSOs
- Utilities
- Retail companies
- ICT and telecom companies
- Technology manufacturers
- Industry associations
- Engineering services
- Universities
- Research center
- Consultancies
- Public institutions
- Emerging stakeholders
- Other

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Role of DSOs

- Their traditional role is swiftly evolving towards neutral market facilitators or information providers
  - Granting consumers with the possibility to opt for better energy contracts
  - Allowing retail companies to offer options and services best tailored to customer needs

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Domains

- Highest investment domains:
  - Smart network management (34 %)
  - Demand-side management (25 %)
  - Integration of DG&S (22 %)
  - Together > 80%

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Smart Network Management (SNM)

- Increasing the flexibility of the electricity grid
- Enhancing grid monitoring and control capabilities
- **Key applications**:
  - WAMS
  - Advanced sensors to detect faults
  - Tools for self-controlling and self-healing grids
  - New tools for frequency, reactive and power-flow controls
  - Smart inverters

Project co-funded by the Europen Union (ERDF, IPA).

Demand Side Management (DSM)

- Demand response
- Energy conservation/efficiency
- **Key applications**:
  - Development of ICT solutions and services
  - Encourage consumers to modify their consumption
  - Empowerment of energy consumers through initiatives

Project co-funded by the Europen Union (ERDF, IPA).

Integration of Distributed Generation & Storage

- Advanced-control schemes and new ICT solutions
- **Key applications**:
  - Network planning and analysis tools
  - Active grid support
  - Integration of storage systems

Project co-funded by the Europen Union (ERDF, IPA).

Integration of Large-scale Renewable Energy Resources

- To integrate RES at transmission or high-voltage distribution network
- **Key applications:**
  - New grid technologies
  - Offshore networks for wind power integration
  - Forecasting tools for RES production

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E-mobility

- Smart integration of EVs into the electricity network
- **Key applications**:
  - Development of smart charging infrastructure
  - Integration of EV for provision of ancillary services
  - Development of V2G interfaces

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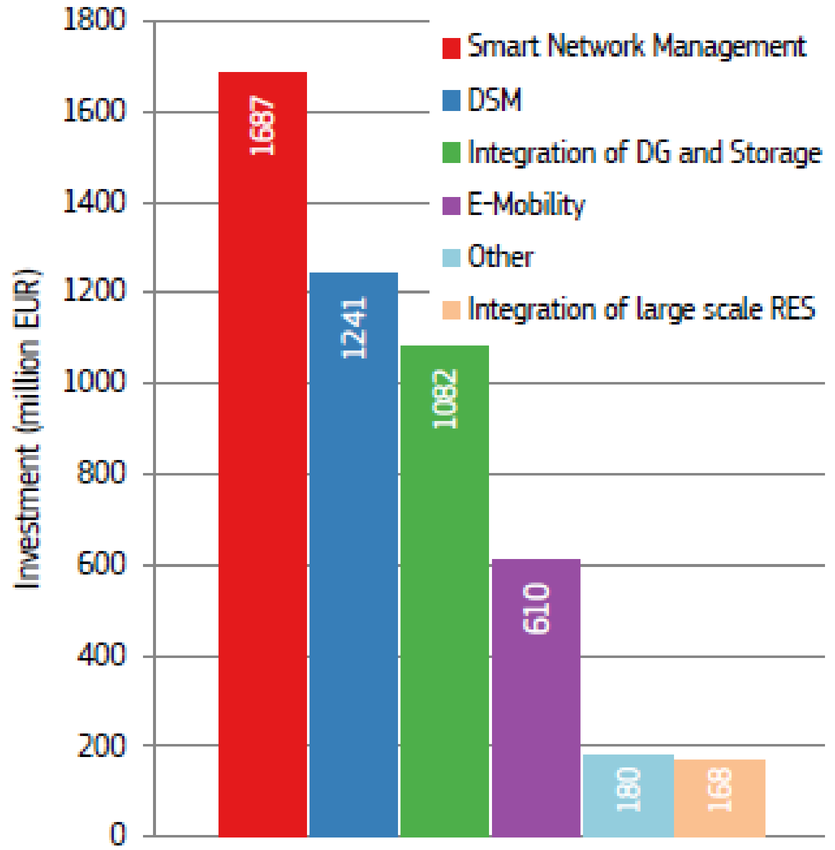
Financing per smart grid domain (1)

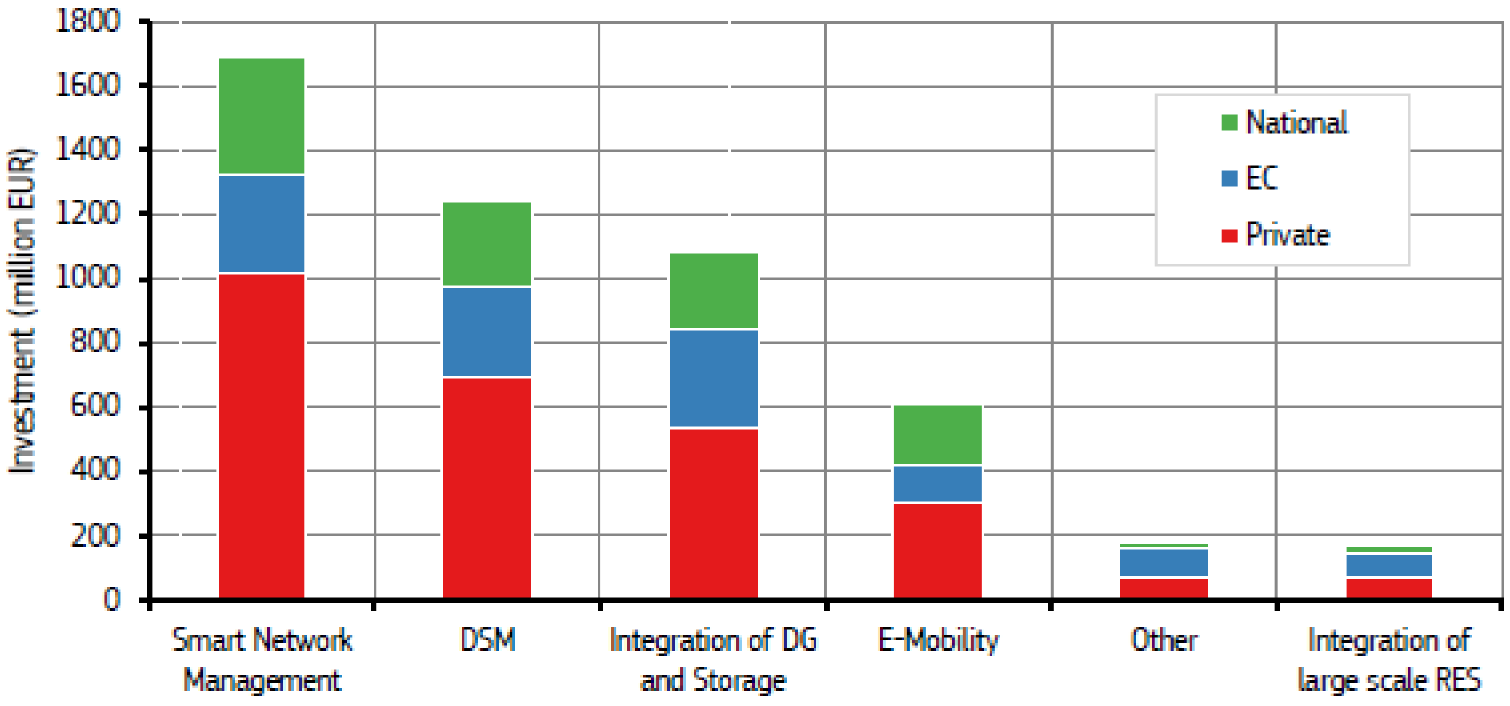
Figure 39. Total investment per smart grid domain



Source: https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/u24/2017/sgp_outlook_2017-online.pdf

Financing per smart grid domain (2)

Figure 40. Total investment per smart grid domain and source of funding



Source: https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/u24/2017/sgp_outlook_2017-online.pdf

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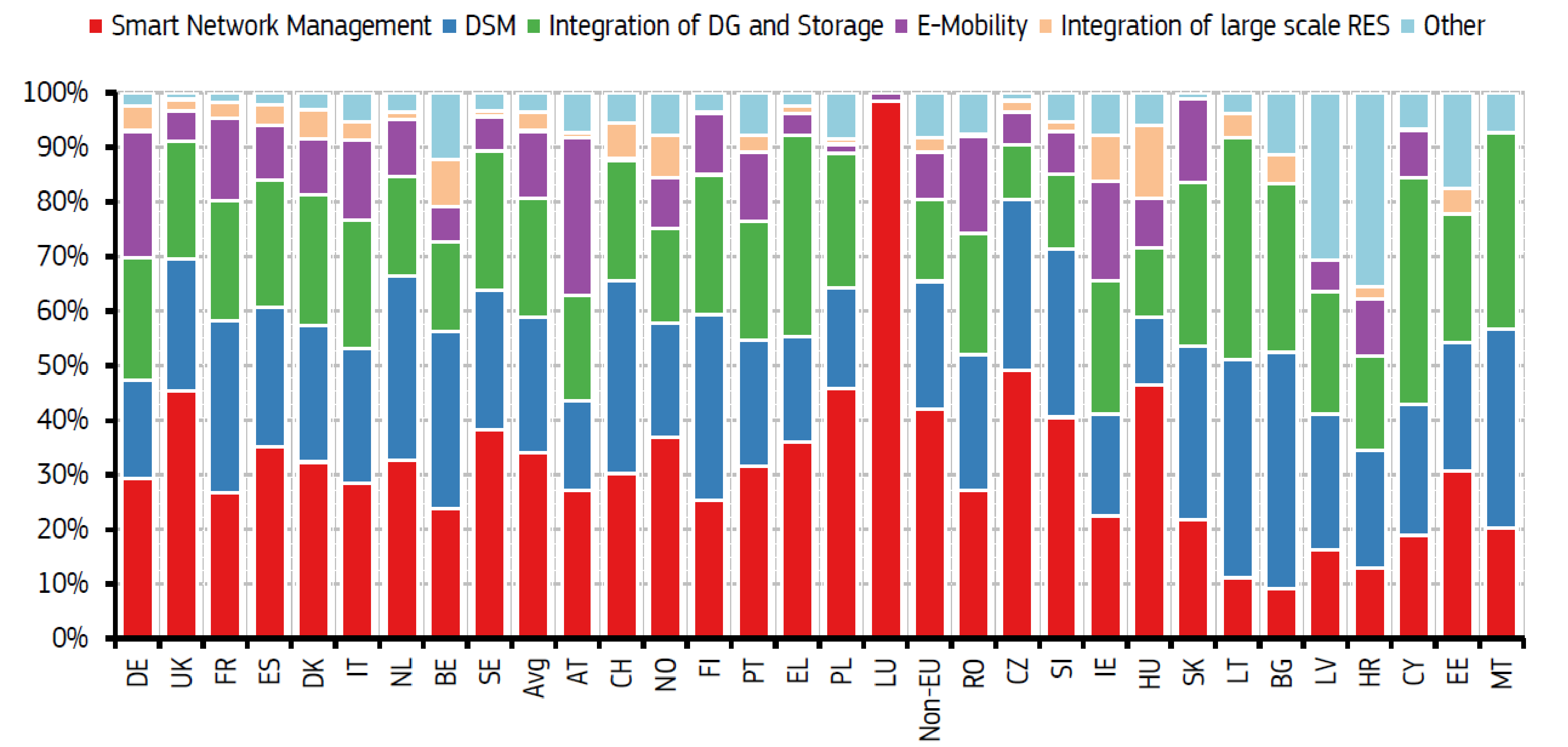
Percentage distribution of total investment per smart grid domain and country



Project co-funded by the Europen Union (ERDF, IPA).

Smart Grid Projects in Europe

- SINCRO GRID (SI, HR)
- ACON (CZ, SK)
- Smart Border Initiative (FR, DE)
- Danube InGrid (HU, SK)
- Data Bridge (EE, LV, LT, DK, FI, FR)
- Cross-border flexibility project (EE, FI)

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Literature

- European Commission; Smart grid projects outlook 2017; URL: https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/u24/2017/sgp_outlook_2017-online.pdf
- Smart Grid and Meters; URL: https://ec.europa.eu/energy/topics/markets-and-consumers/smart-grids-and-meters/overview_en

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Smart Grids in the USA

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Content

- Investments in the USA
- Review of energy in the USA
- SG technology: deployment trends and benefits
- Drivers of grid transformation
- Energy storages, EVs

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Investments in the USA

- $144.5 bn
- investor-owned utilities (IOUs), public power providers and cooperatives
- reasons for investment:
  - declining wind and solar generation costs
  - growing supplies of natural gas
  - extreme weather

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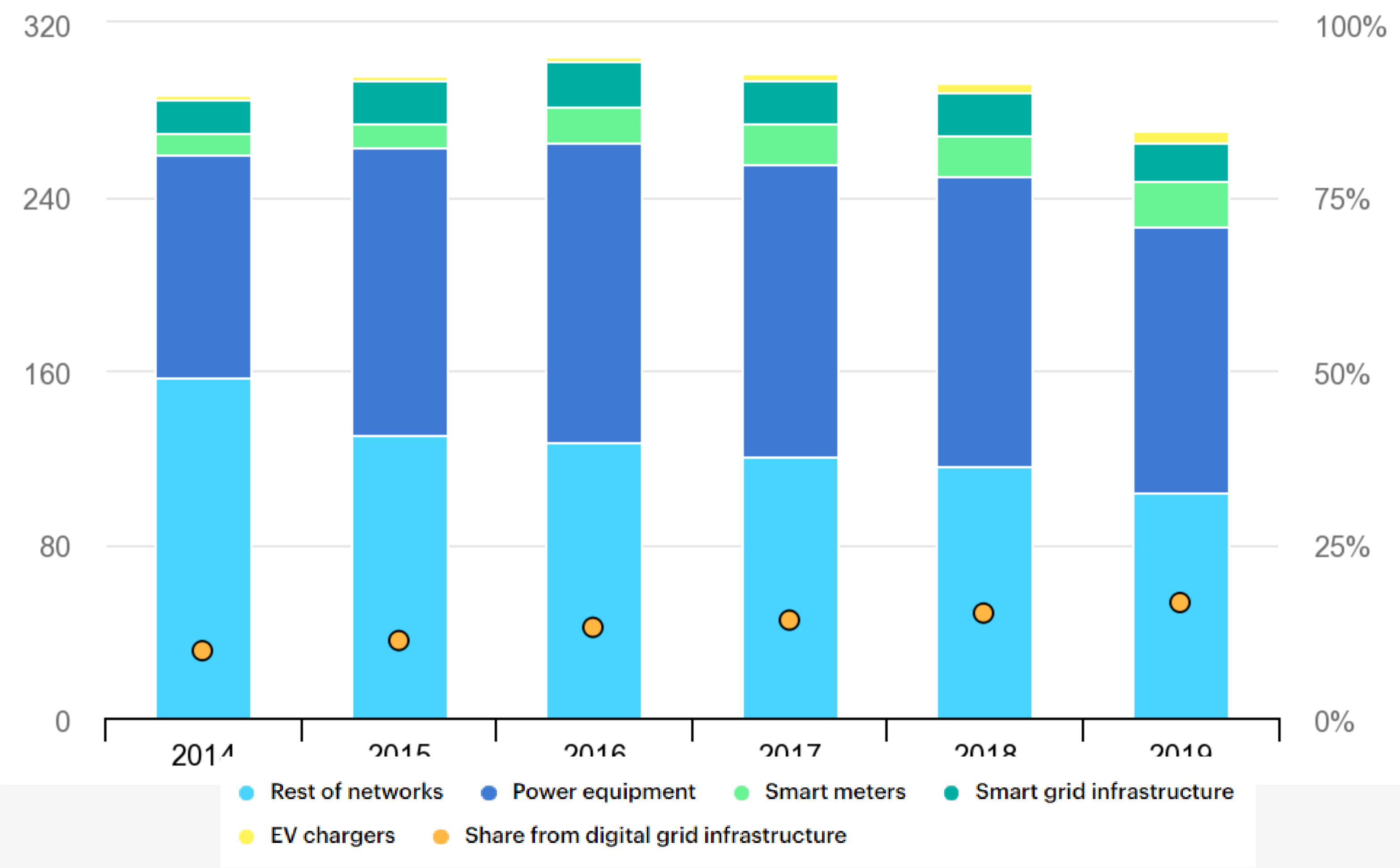
Investment in smart grids by technology area



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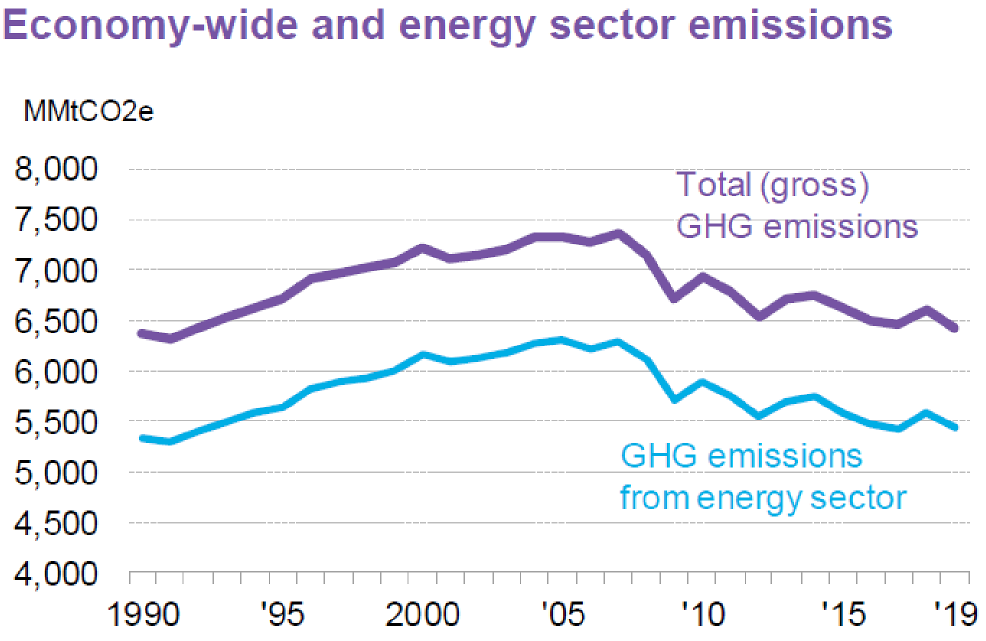
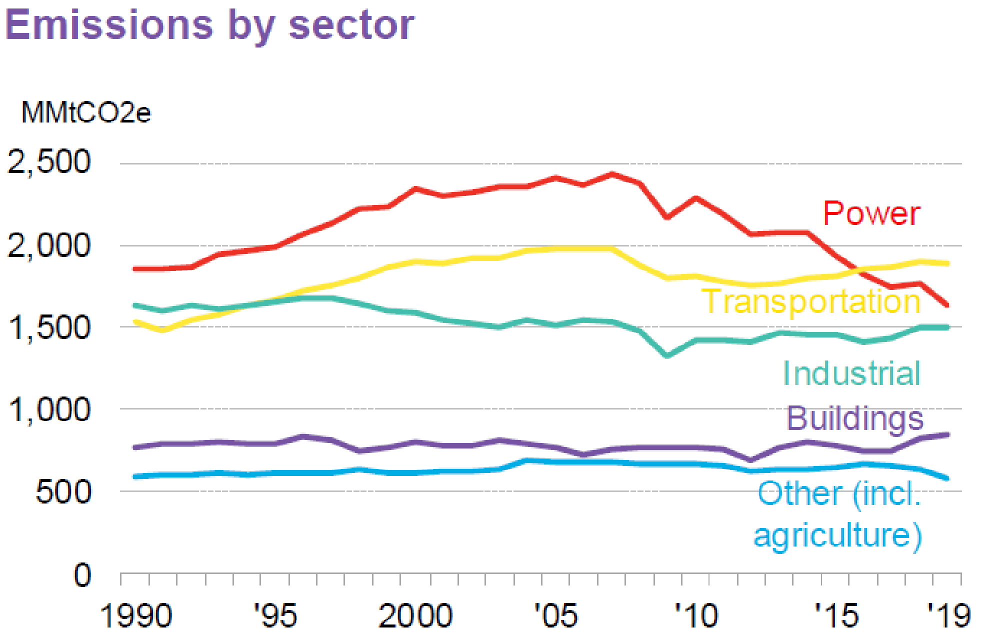
U.S. Energy overview



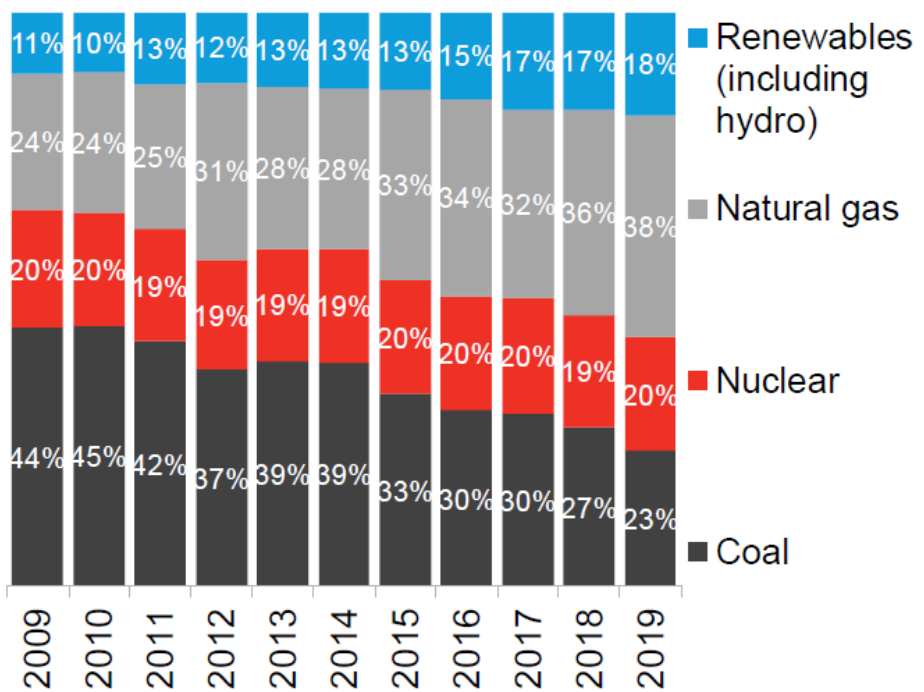


Source: BloombergNEF, EIA, EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016 Notes: "Sinks" refer to forests and green areas which absorb carbon dioxide. Values for 2019 are projected, accounting for seasonality, based on monthly values from EIA available through September 2019.

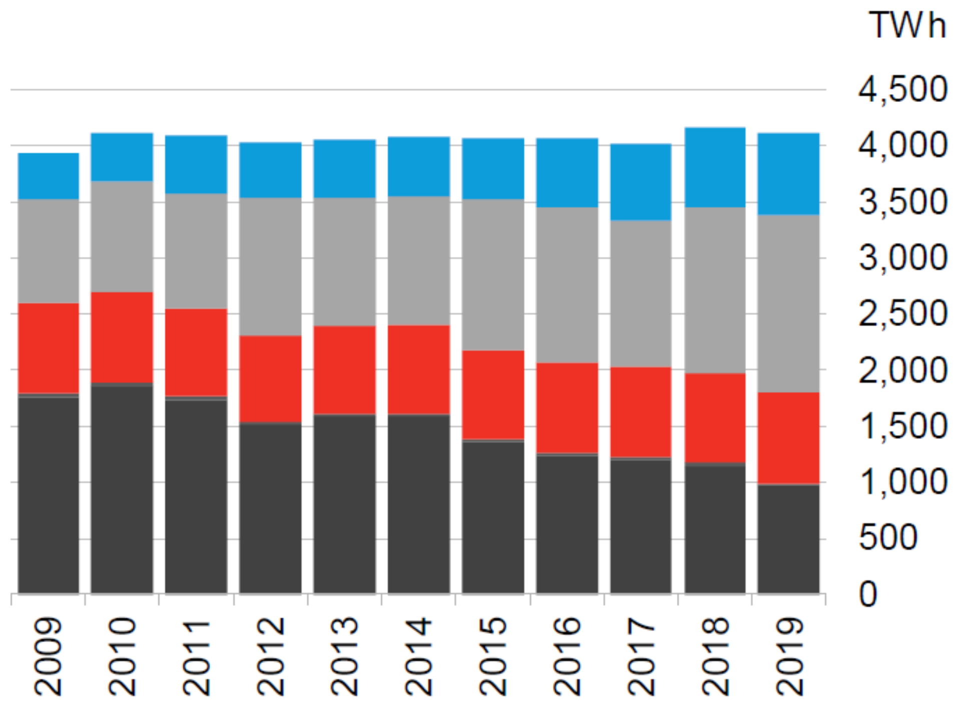
Project co-funded by the Europen Union (ERDF, IPA).

U.S. Energy overview

U.S. electricity generation, by fuel type



U.S. electricity generation, by fuel type



Source: EIA, BloombergNEF Note: Values for 2019 are projected, accounting for seasonality, based on latest monthly values from EIA (data available through October 2019)

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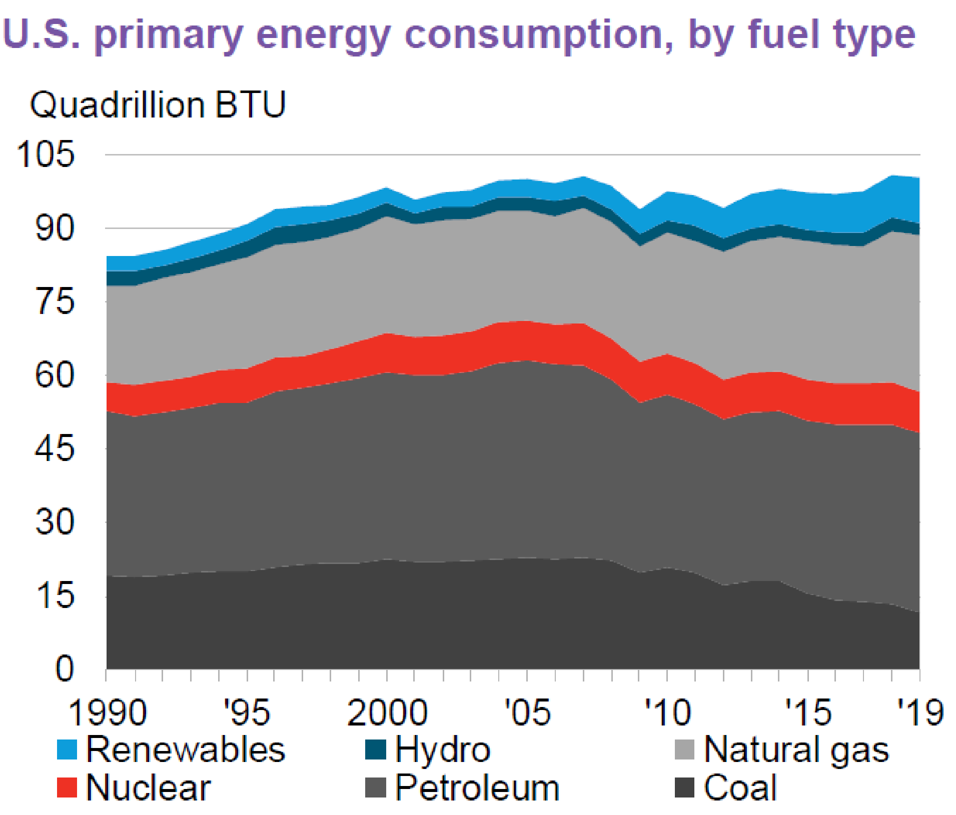
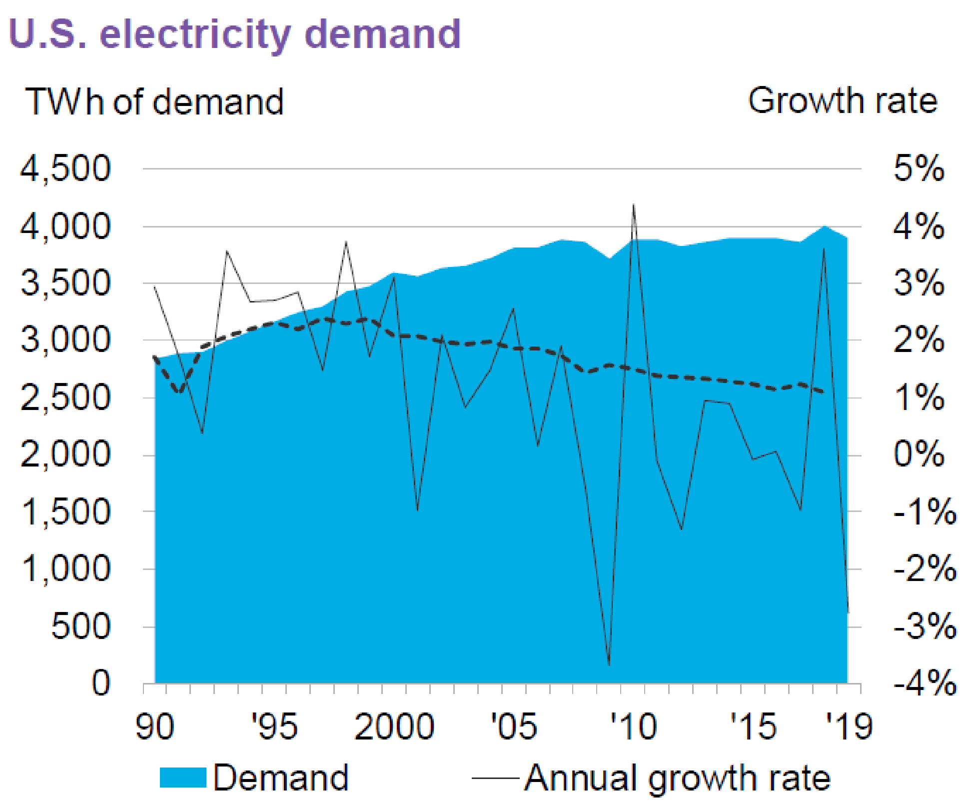
U.S. Energy overview





Source: EIA, BNEF Notes: "CAGR" on the right hand side graph is compound annual growth rate. Values for 2019 are projected, accounting for seasonality, based on the latest monthly values from EIA (data available through September 2019). BTU stands for British thermal units.

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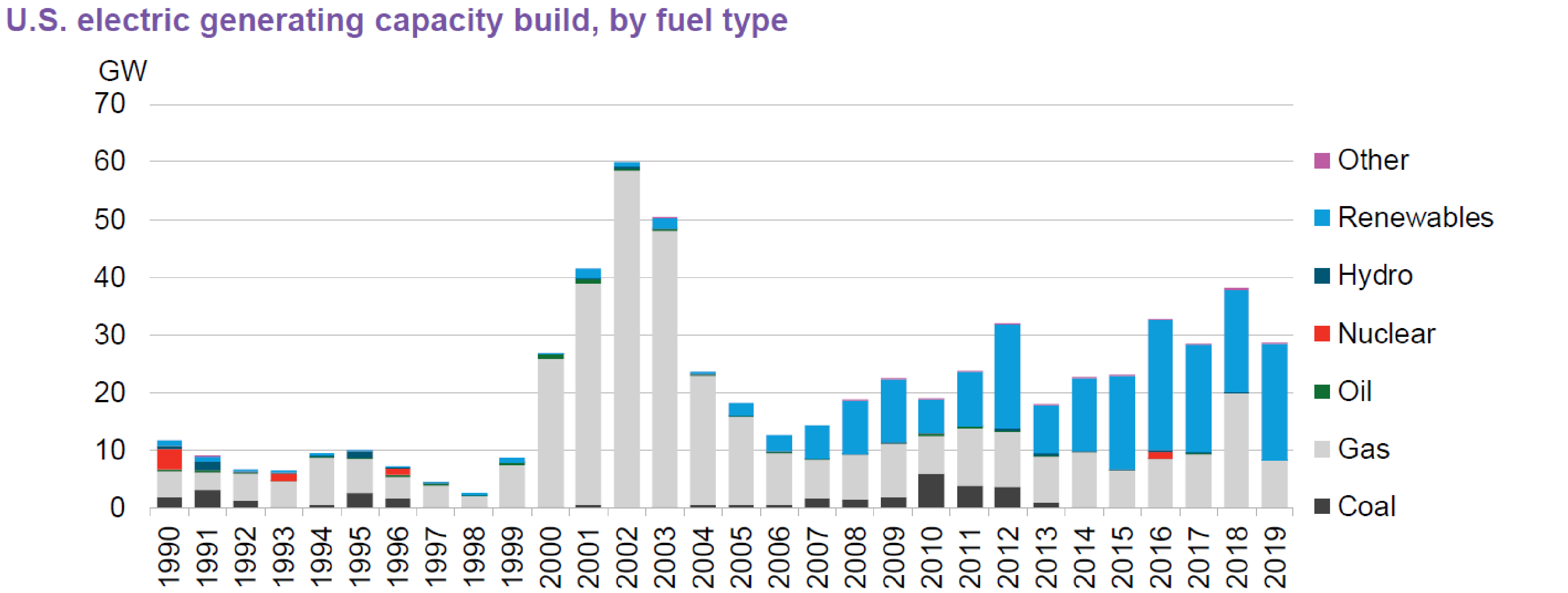
U.S. Energy overview



Source: EIA, BloombergNEF Note: All values are shown in AC except solar, which is included as DC capacity. "Renewables" here does not include hydro, which is shown separately. All capacity figures represent summer generating capacity. Includes installations or planned installations reported to the EIA through October 2019, as well as BloombergNEF projections.

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Investments in smart grids in the USA

- **Key factors** which have driven smart technology investment:
  - Cost-shared deployment under the recovery act reduced the risk of early investment
  - New digital technologies and operational systems on the grid
  - Training of the workforce
  - Developing of standards
  - Weather conditions and cyber threats
  - Declining prices in distribution – PVs and wind

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SG Technology: Deployment Trends and Benefits

- Advanced transmission system technologies for wide-area visibility and control
- Advanced distribution system technologies for self-healing automation, equipment, health monitoring, and voltage optimization
- Advanced metering infrastructure
- Smart customer devices and energy management systems that enable demand response

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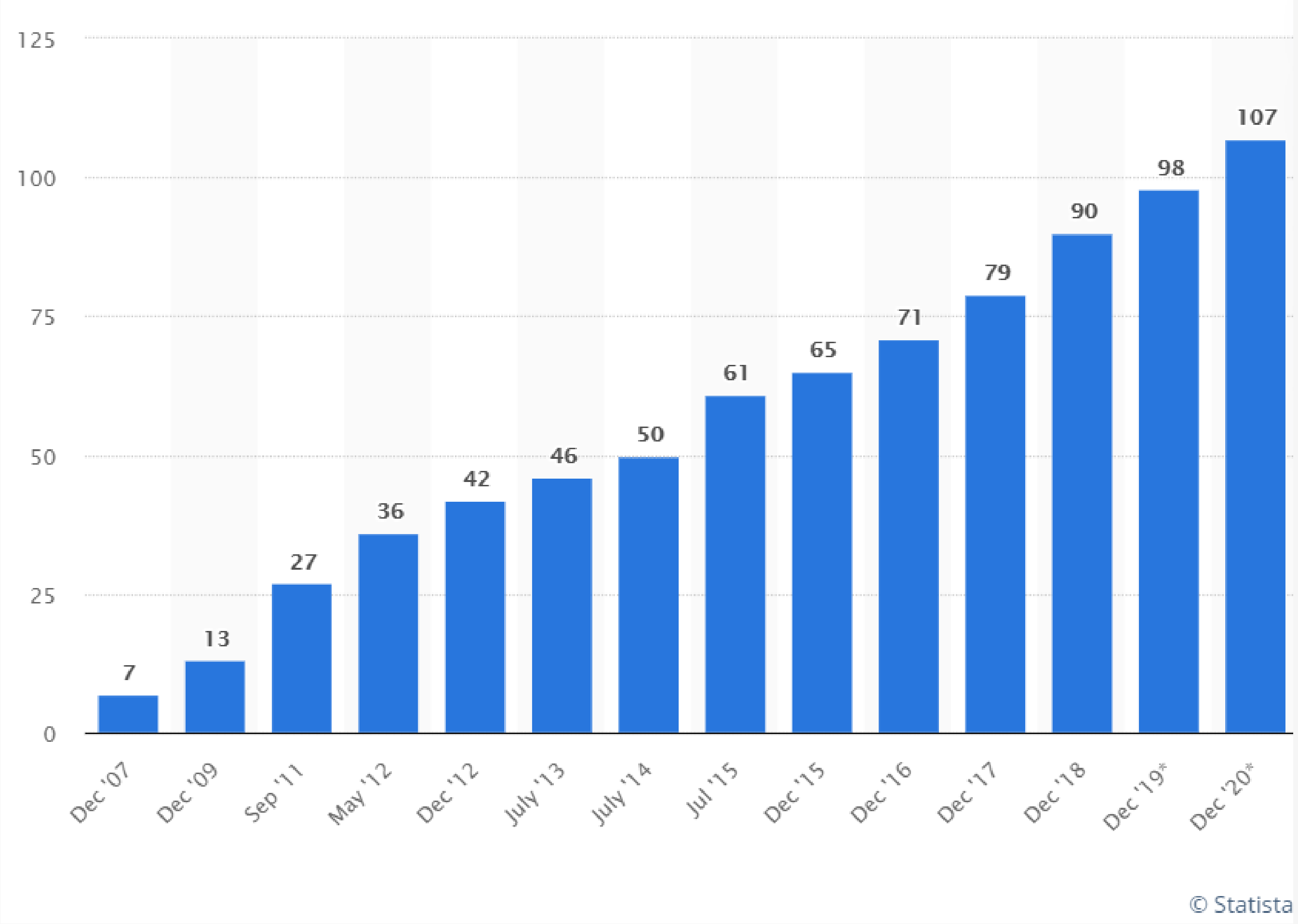
Number of smart meters in millions in the U.S.



Project co-funded by the Europen Union (ERDF, IPA).

Customer automation and energy management systems

- **Customer awareness** – access to energy usage information and making of smarter energy decisions
- NEST, Amazon’s Echo, Google’s Home – **smart home devices**
- Currently **over 1,5 million** smart home devices have been installed

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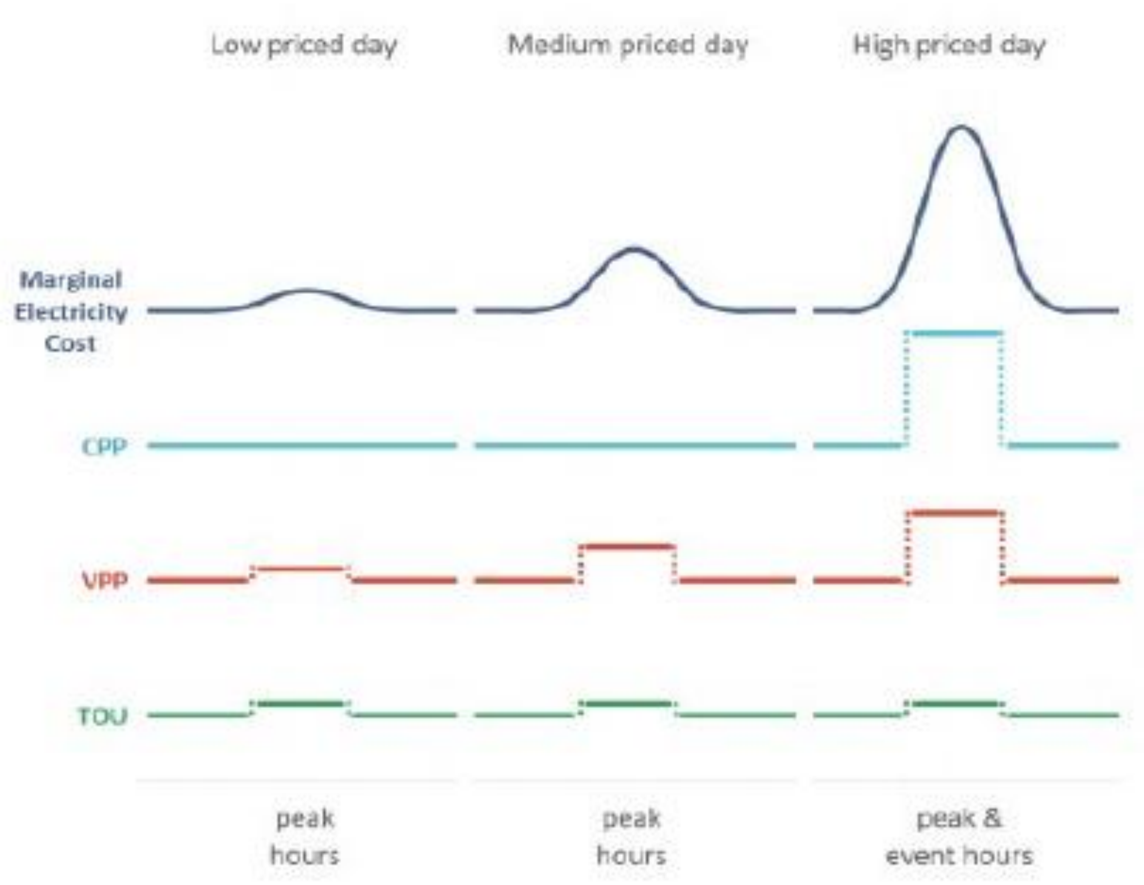
Dynamic pricing and Demand response

- Dynamic rates (peak and off-peak)
- CPP, VPP, TOU



Source: DOE, Customer Acceptance, Retention, and Response, 2016.

Project co-funded by the Europen Union (ERDF, IPA).

Drivers of Grid Transformation

- Federal and State policies
- Information management, communication technology
- New participants in the energy market
- Larger domestic gas resources
- RES capacity in total generation is 20%

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Policies and Incentives

- Federal, state and local levels
- Renewable portfolio standards
- Energy efficiency resource standards
- New net energy metering rules

Energy Storage Technologies

- **Flexible resource**
- Declining battery prices and state incentives
- Total installed battery storage power capacity: 869 MW
- Total installed battery storage energy capacity: 1236 MW
- Total number of operational battery storage systems: 125

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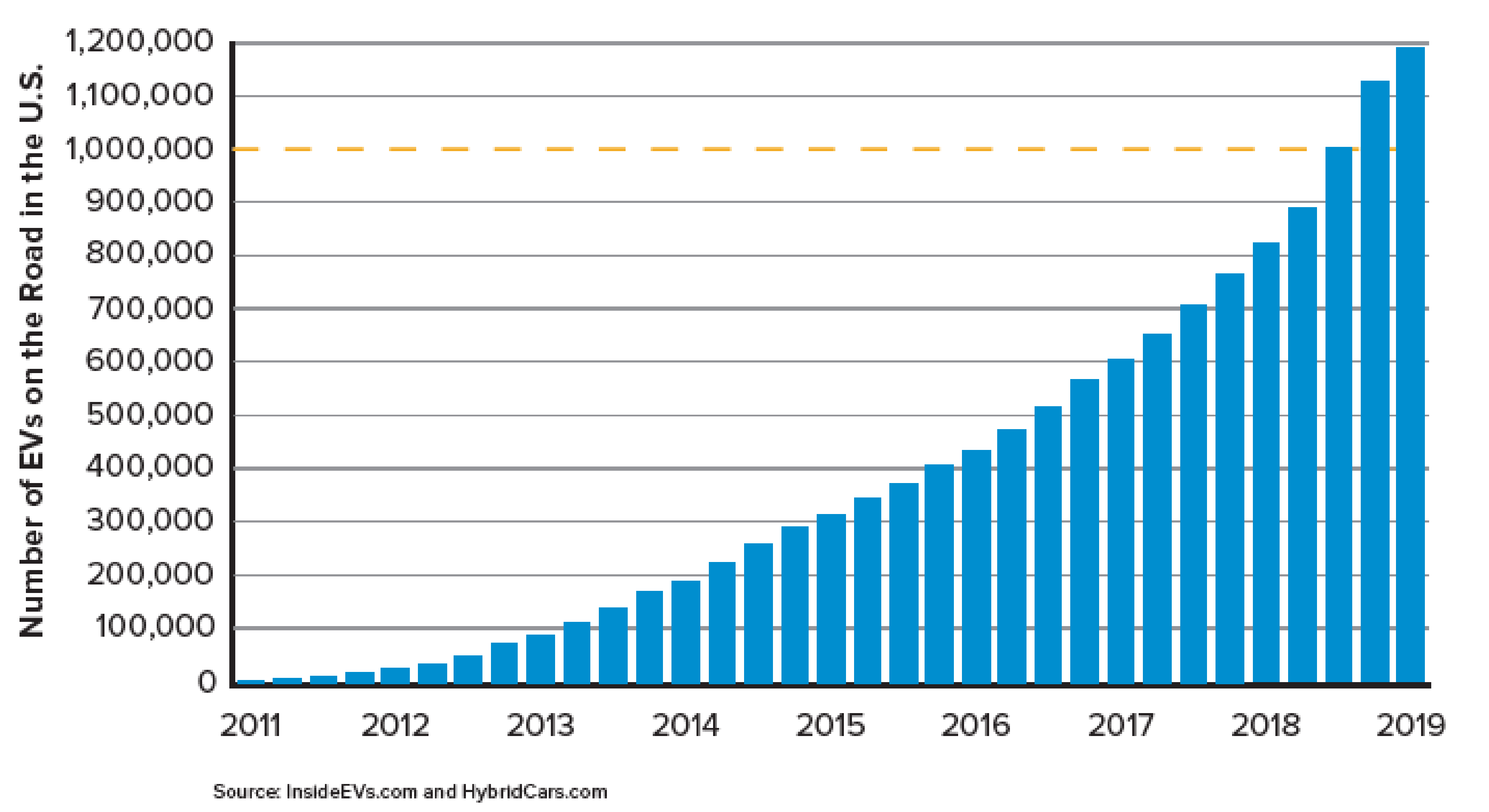
Electric Vehicles

- Rapidly decreasing prices of Li-ion batteries
- Energy density improvements
- Incentives: tax credits and rebates, reduced license and registration fees
- Potential storage units
- Automakers: Tesla, General Motors, Nissan, Ford, Toyota

Project co-funded by the Europen Union (ERDF, IPA).

Number of EVs on the road in the U.S.



Project co-funded by the Europen Union (ERDF, IPA).

Literature

- U.S. Department of Energy; Smart Grid System Report to Congress 2018; URL: https://www.energy.gov/sites/prod/files/2019/02/f59/Smart%20Grid%20System%20Report%20November%202018_1.pdf
- BloombergNEF; URL: https://www.bcse.org/wp-content/uploads/2020-Sustainable-Energy-in-America-Factbook-Overview-.pdf
- Utility-scale battery storage capacity continued its upward trend in 2018; URL: https://www.eia.gov/todayinenergy/detail.php?id=44696

Project co-funded by the Europen Union (ERDF, IPA).

Interreg
Danube Transnational Programme
STRIDE

The development process for the NAP - Sweden example

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Content

- Political framework and market terms and conditions
- Customer participation and societal aspects
- R&D, innovation and growth

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Recommendations and proposals

- Coordination Council Action Plan
- **3 main areas:**
  - Political framework and market terms and conditions
  - Customer participation and societal aspects
  - R&D, innovation and growth

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Danube Transnational Programme
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Political framework and market terms and conditions

- Upcoming challenges:
  - **Intermittent renewable energy generation**
  - **Need for new demands for balance in the system**
  - **Fast changes in generation can cause voltage disruptions**
- Solution: market ground rules and design to meet the upcoming challenges

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Political framework and market terms and conditions

- **Ground rules on the electricity market**
  - system balance, output variations, flexibility, energy storage
- **New conditions for the electricity grid**
  - cost-effective investments, incentives, security
- **Cooperation with other parts of the energy market**
  - coordination of transport and power sectors for electrification
- **Long-term development of the policy framework and market conditions**
  - increase knowledge of the system and RES, monitor new demands

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Customer participation and societal aspects

- **Smart grid from a customer perspective**
  - protection of private data
  - public opinion
- **Customers' access to measurement data and information**
  - easier access and transparent information
  - customer participation on the electricity market
- **Synergies between smart grids and other societal development**
  - enable greater connection between energy sector and other sectors

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R&D, innovation and growth

- **Knowledge and skills development**
  - Develop knowledge and skills to meet future demands
- **Research priorities and cooperation**
  - Define priorities for research and strengthen cooperation
- **An integrated smart grid innovation strategy**
  - Stimulate smart grid development and innovation
- **Conditions for pilot and demonstration projects**
  - Adapt conditions for pilot and demonstration projects and their funding
- **A smart grid on a global market**
  - Utilise standardisation and interoperability
  - Develop national promotion strategies and promote international cooperation

Project co-funded by the Europen Union (ERDF, IPA).

Literature

- The Swedish Coordination Council for Smart Grid; Summary of recommendations and proposals; URL: https://www.ei.se/Documents/Publikationer/ovriga_engelska_publikationer/Summary_of_recommendations.pdf

Project co-funded by the Europen Union (ERDF, IPA).