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Challenges of decarbonisation to the electricity grid: demand side flexibility and distribution network issues

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Challenges to future electricity systems

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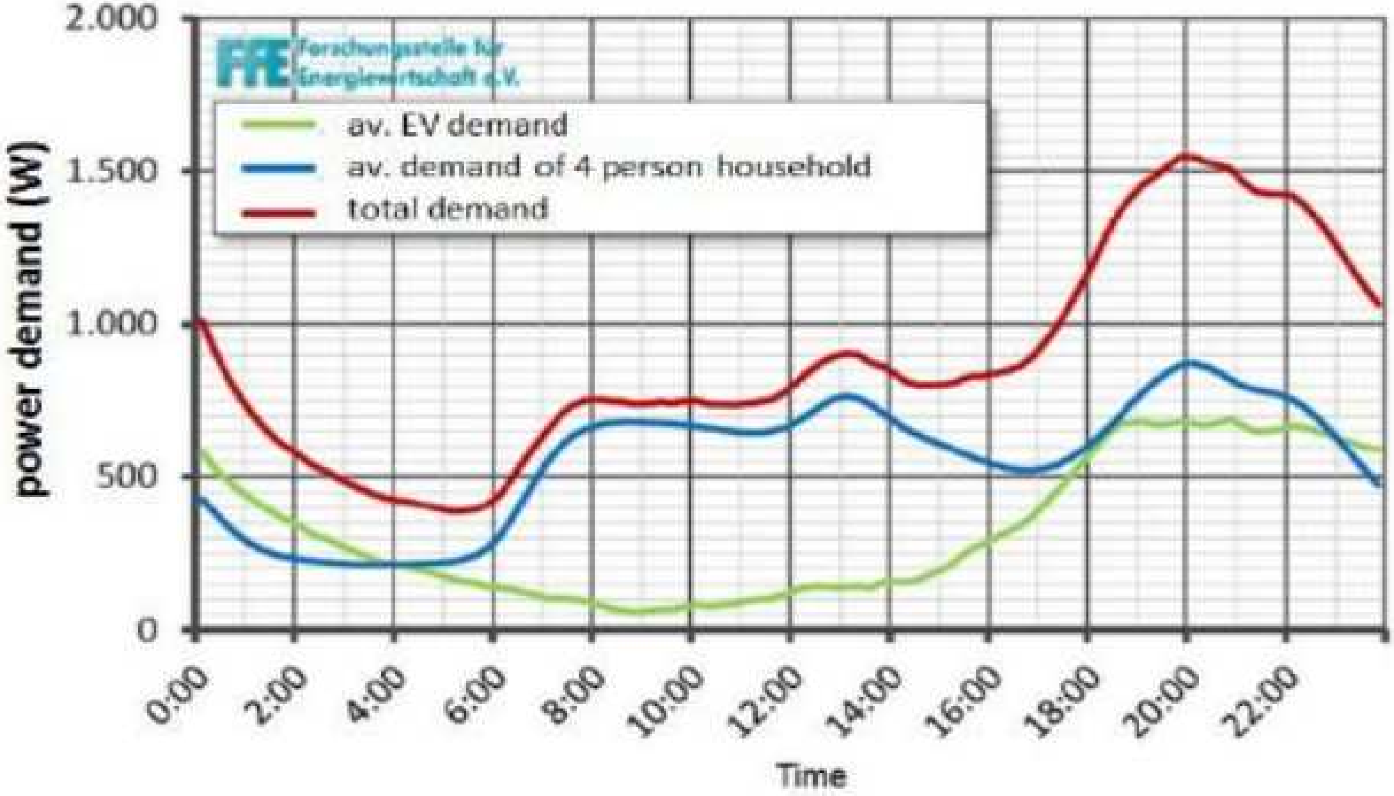
- Integration of large-scale RES (T&D level)
  - Variable and less predictable generation, partly away from load centres
- Distributed generation such as wind, PV (D level)
  - Electricity production at the end of distribution network designed for distributing centrally generated electricity (technical issues of bidirectional flows)
  - Less predictable and more variable load/supply (self consumption) at the grid: local congestion
- Electric vehicles (D level)
  - Potentially large and less predictable new load

Effect of Evs on load

Figure 2: Load curves (user-driven charging) of electric vehicle charging, private household and both aggregated (Germany)



Source: Nobis et al., 2011.

Consequence: need for system flexibility

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- What are the essential elements of a flexible system?
  - Sources of flexibility
  - Network able to operate these sources efficiently (smart grids and meters)
  - Market rules and regulations that incentive the flexibility sources to offer/sell their services
- Main questions about DSOs:
  - How to incentivise them to invest in the network to efficiently serve their users?
  - What are the potential new DSO roles?

Sources of flexibility

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	TSO	DSO
Supply	Power plants (fossils, CHP)	Distributed generation (RES and micro CHP)
Demand	Large industrial consumers	All industrial consumers and households
Storage	Pumped-storage and CAES	Batteries, EVs, heat pumps and water heaters

Demand side flexibility

What is demand response?

- Voluntary change by end consumers in their usual electricity use patterns due to
  - Price signals (implicit)
  - Incentives (explicit)
- Often accompanied by energy savings as well but this is not the purpose
- Always voluntary and remunerated!
- Need to be accompanied appropriate hardware: smart grids and meters
- Can operate at many markets: balancing, ancillary services, retail

What is smart metering (SM)?

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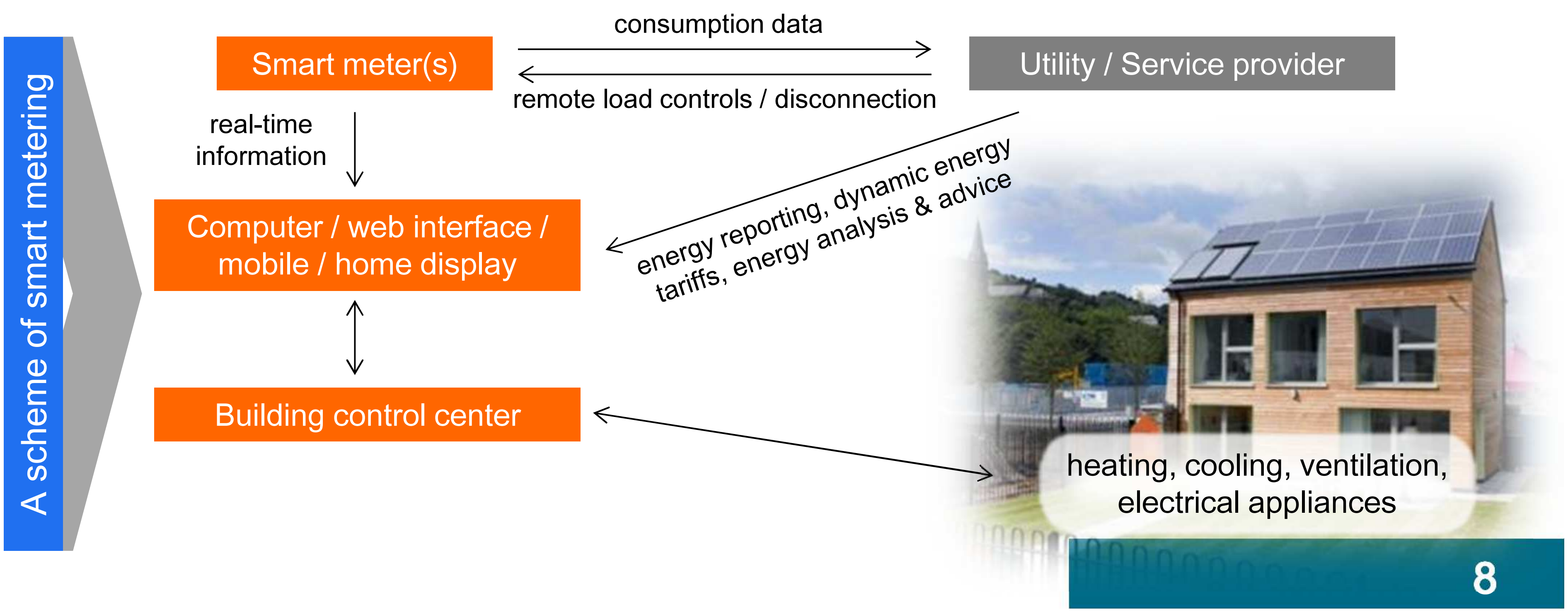
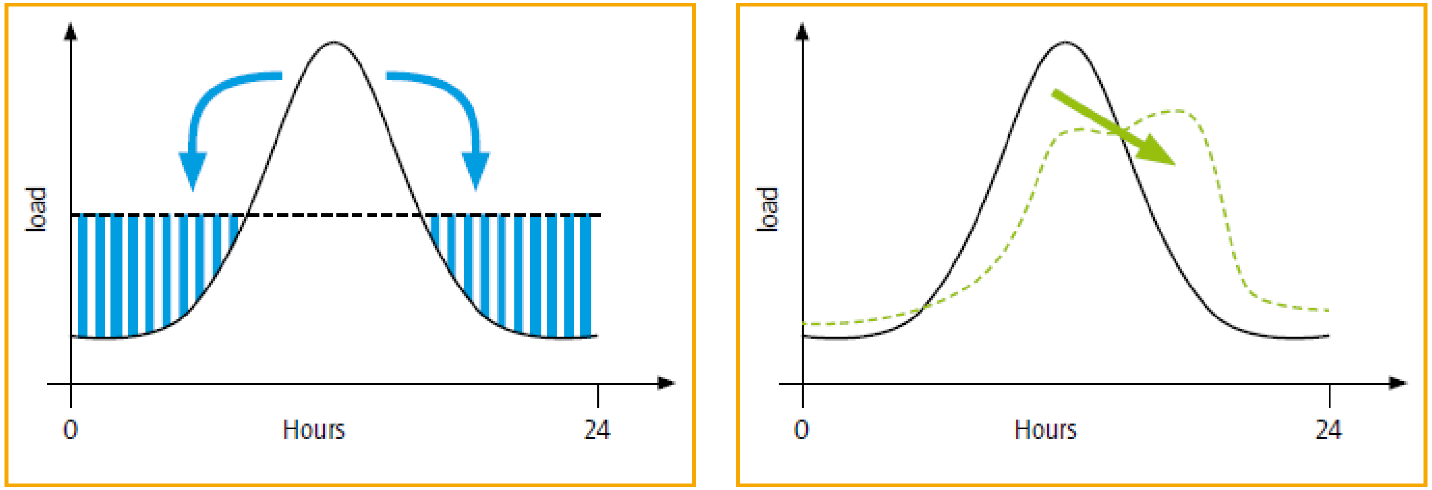
- Smart metering is more than just smart meters:
  - Electrical meters – instead of traditional electromechanical ones
  - Related hardware equipment (e.g. home displays)
  - Communications network
  - Data management and control center

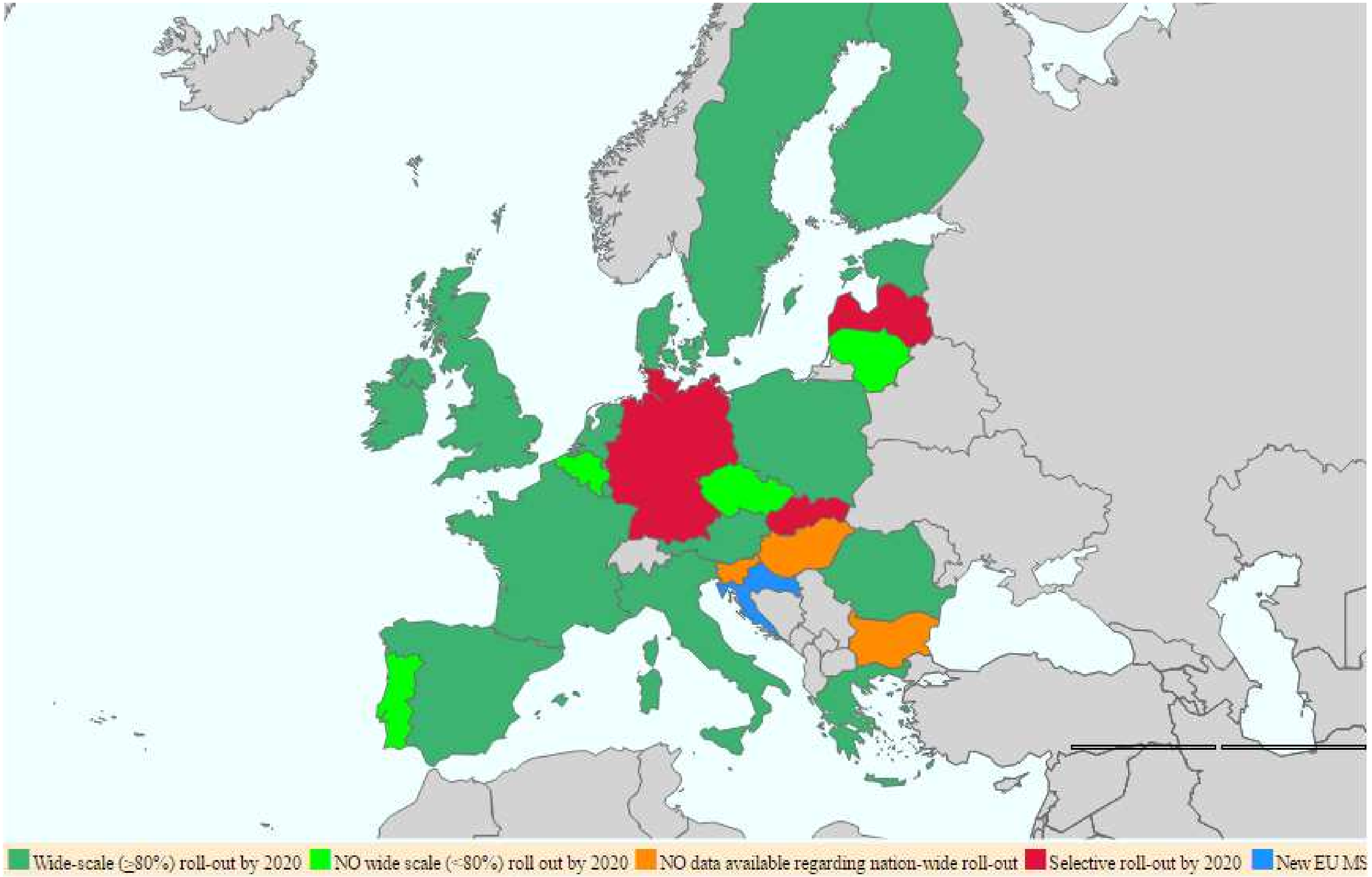


Smart appliances

- No need for the active involvement of the consumer, activation based on pre-set parameters:
  - price
  - self-generation
- Factor determining load shift potential:
  - Total consumption of the device
  - The duration of load shift
  - Penetration of device



Smart meter roll-out by 2020



Source: JRC, 2014

Implicit Demand-Side Flexibility

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- Traditional retail market and consumer:
  - Flat rate retail price irrespective to wholesale price
  - Low consumer awareness of usage due to monthly/yearly consumption metering
  - Q: would consumers accept price volatility in exchange for potentially lower bills (that requires active participation)?
- consumer's reaction to price signals but no firm commitment (if, how much and when)
- Behavioural adaptation by choice or automatically (smart appliances)
- Various types: Time-of-use, critical peak pricing, real time pricing

Time of Use (TOU) pricing: tariffs and meters

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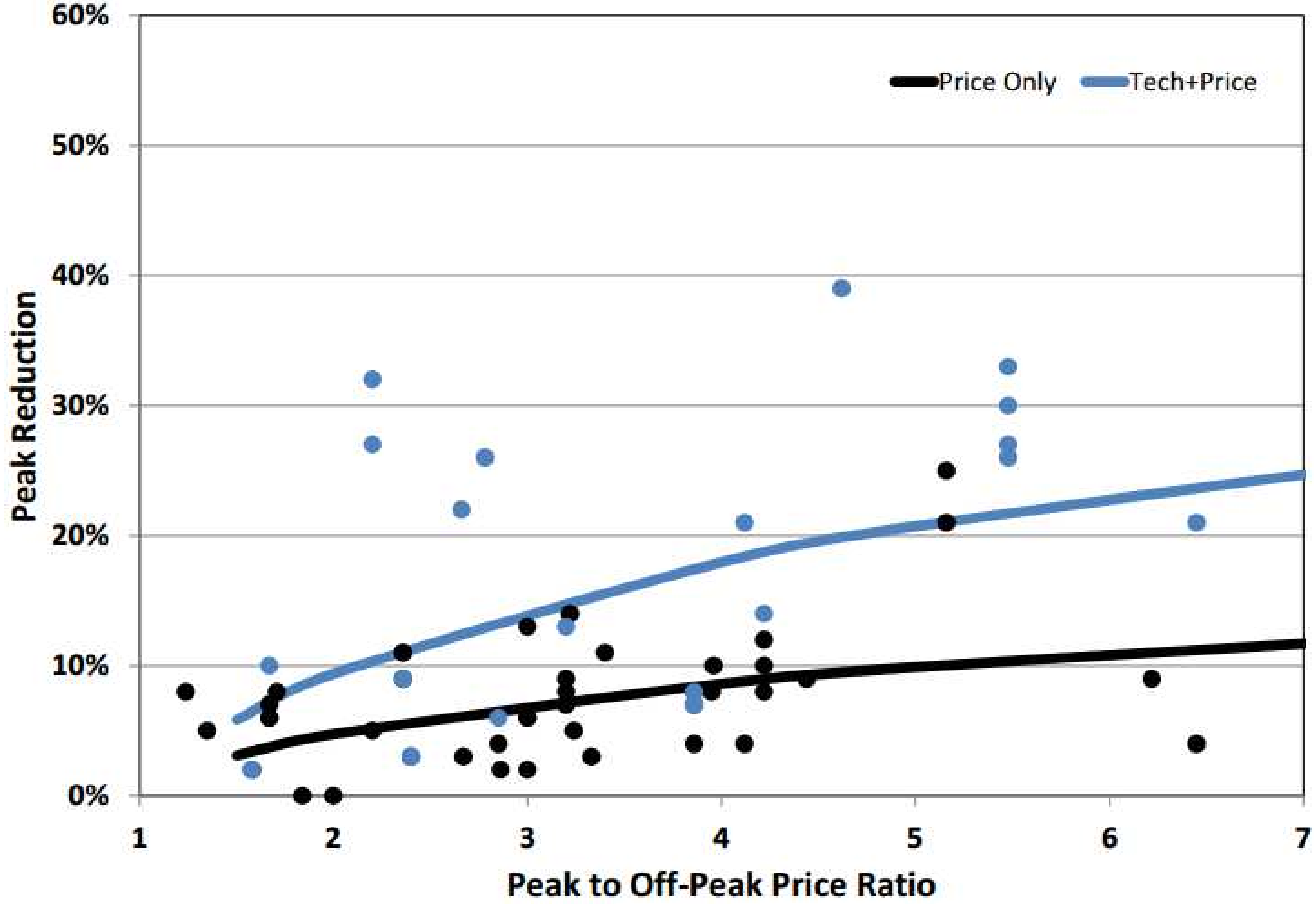
Tariff	Night	Day	Peak
T1	12	14	20
T2	11	13.5	26
T3	10	13	32
T4	9	12.5	38
T5 (W'end)*	10	14	38

Time of Use (TOU) pricing: consumer awareness

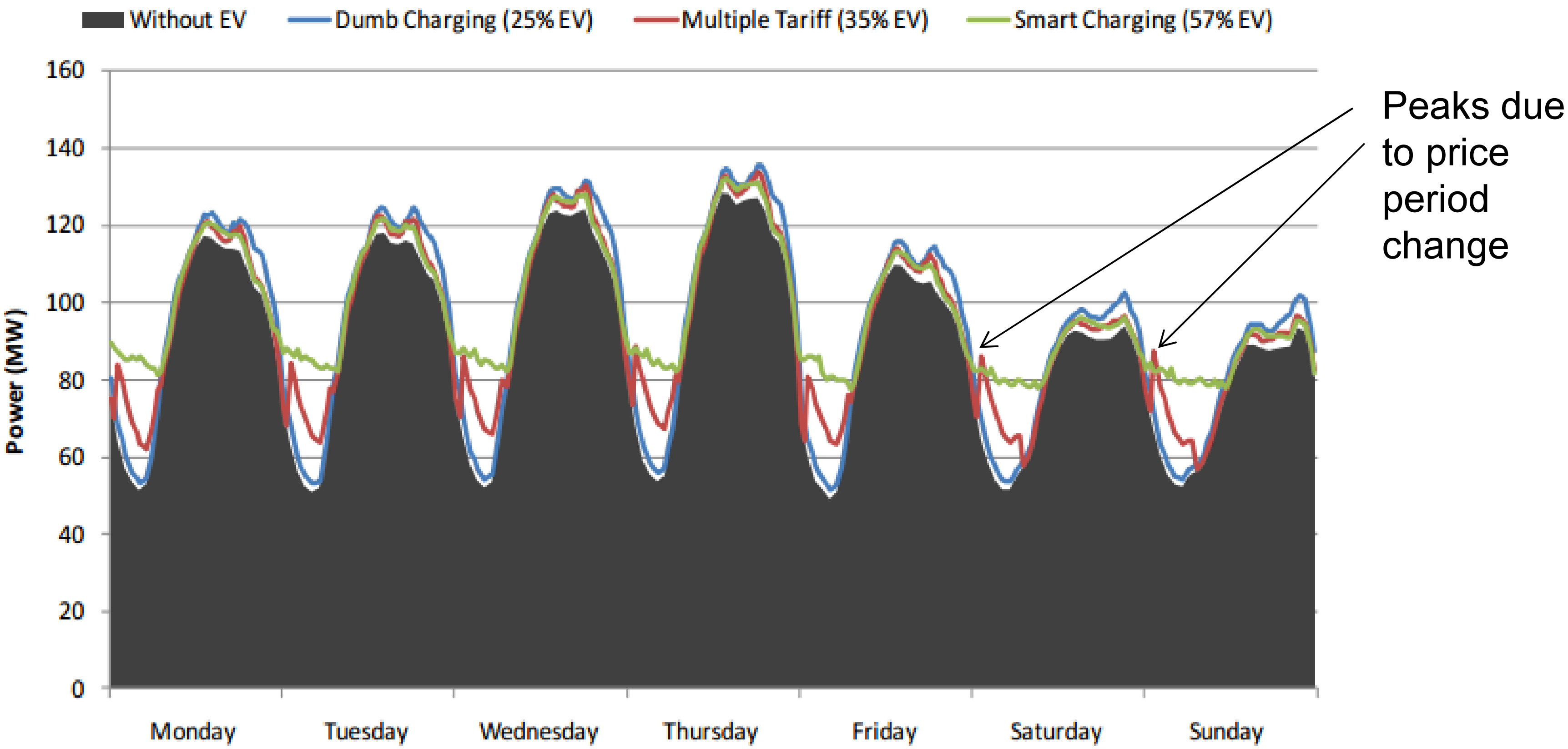
Peak load reduction with ToU pricing



Meta-analysis of 163 ToU programs

Source: Faruqui et al, 2013

The impact of EV charging tariffs on load



Source: MERGE, 2012

Enabling conditions for implicit demand response

- Market-based retail pricing:
  - Problem of regulated prices
  - Price blunting effect of taxes and levies
- Smart meter registering consumption at an hourly, or shorter basis
- Competition of suppliers with tariff packages and easy consumer switch
- Consumption data availability to the consumer and to third parties of his/her choice and data protection
- Market penetration of smart appliances

Taxes and levies

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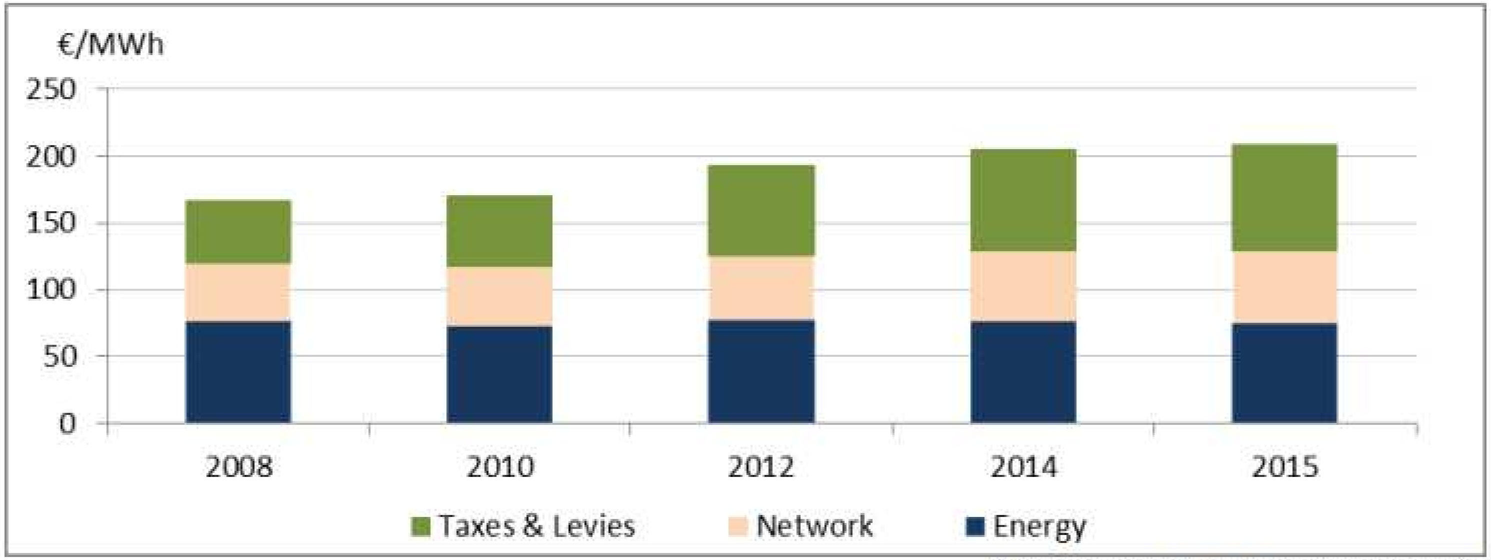
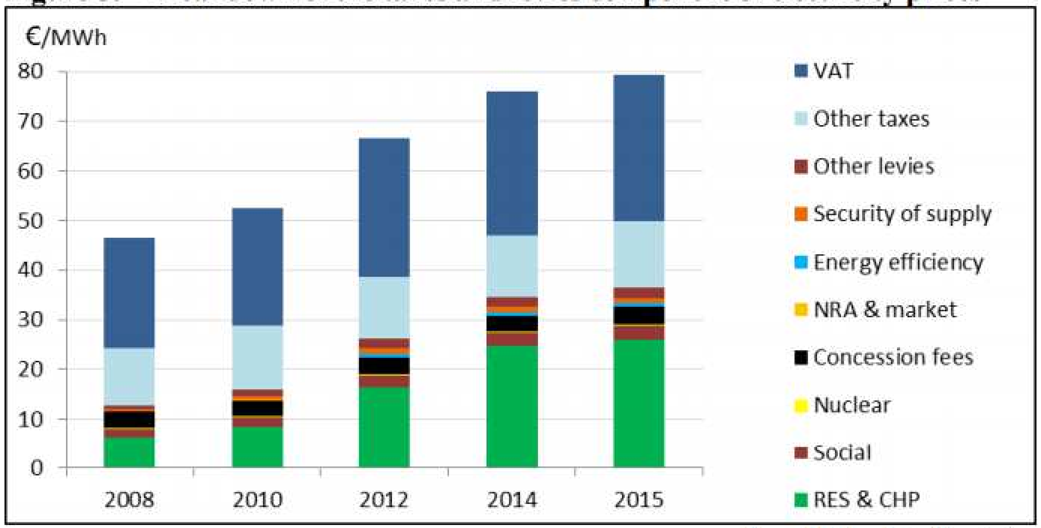
Figure 3: Components of average EU household retail electricity prices



Source: Member State, Commission data collection

Figure 5: Breakdown of the taxes and levies component of electricity prices



Source: EC, 2016

Implicit Demand-Side Flexibility: Critical Peak Pricing (CPP)

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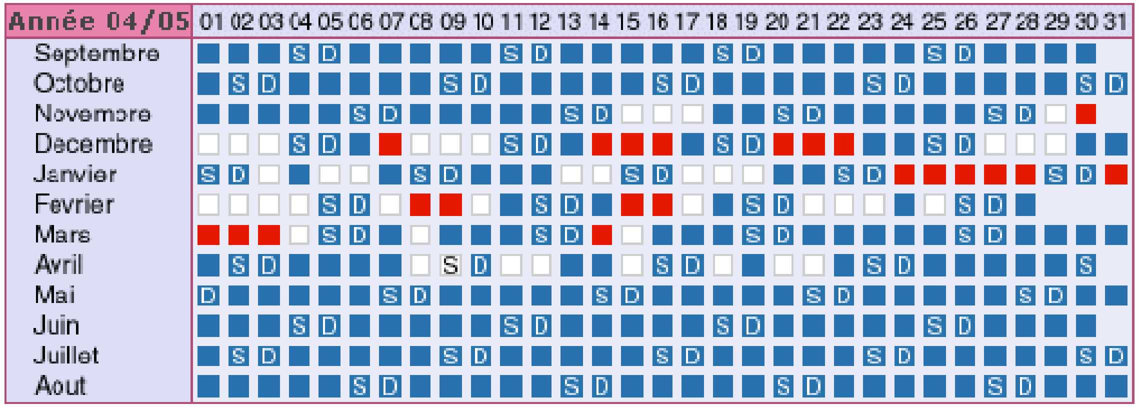
- Very high price for certain critical periods in flat rate or ToU tariff schemes
- CPP can be set in advance or linked to wholesale price but much higher than peak price in ToU
- Critical periods defined by system security or high wholesale price
- Periods are announced in advance but limited in number

CPP example: EDF Tempo tariff

- For households and small enterprises
  - Three types of day: blue, white and red
  - Announced day ahead (on meter+ email/sms/web)
- Two time zones:
  - Normal and peak



Consumer type (kVA)	Fix tariff (Euro/year)	Price (Euro/kWh)					
		Blue days		White days		Red days	
		normal	peak	normal	peak	normal	peak
9 kVA	162,42	0,0446	0,0553	0,0907	0,1075	0,1682	0,4702
12-15-18 kVA	222,36						
24-30 kVA	409,06						
36 kVA	549,72						

Explicit Demand-Side Flexibility

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- Committed, dispatchable flexibility that can be traded (similar to generation flexibility) on the different energy markets (balancing and ancillary services)
- Often managed by independent aggregators that pool the capability of energy users (industrial, commercial, residential) to sell this as a single resource
- Aggregators assess the flexibility capacity of member and provide the infrastructure for activation
- Voluntary to joint the programs but then compulsory service provision
- Various types of programs: Direct load control, Interruptible/curtailable service, Emergency DR

Explicit demand response market development in Europe

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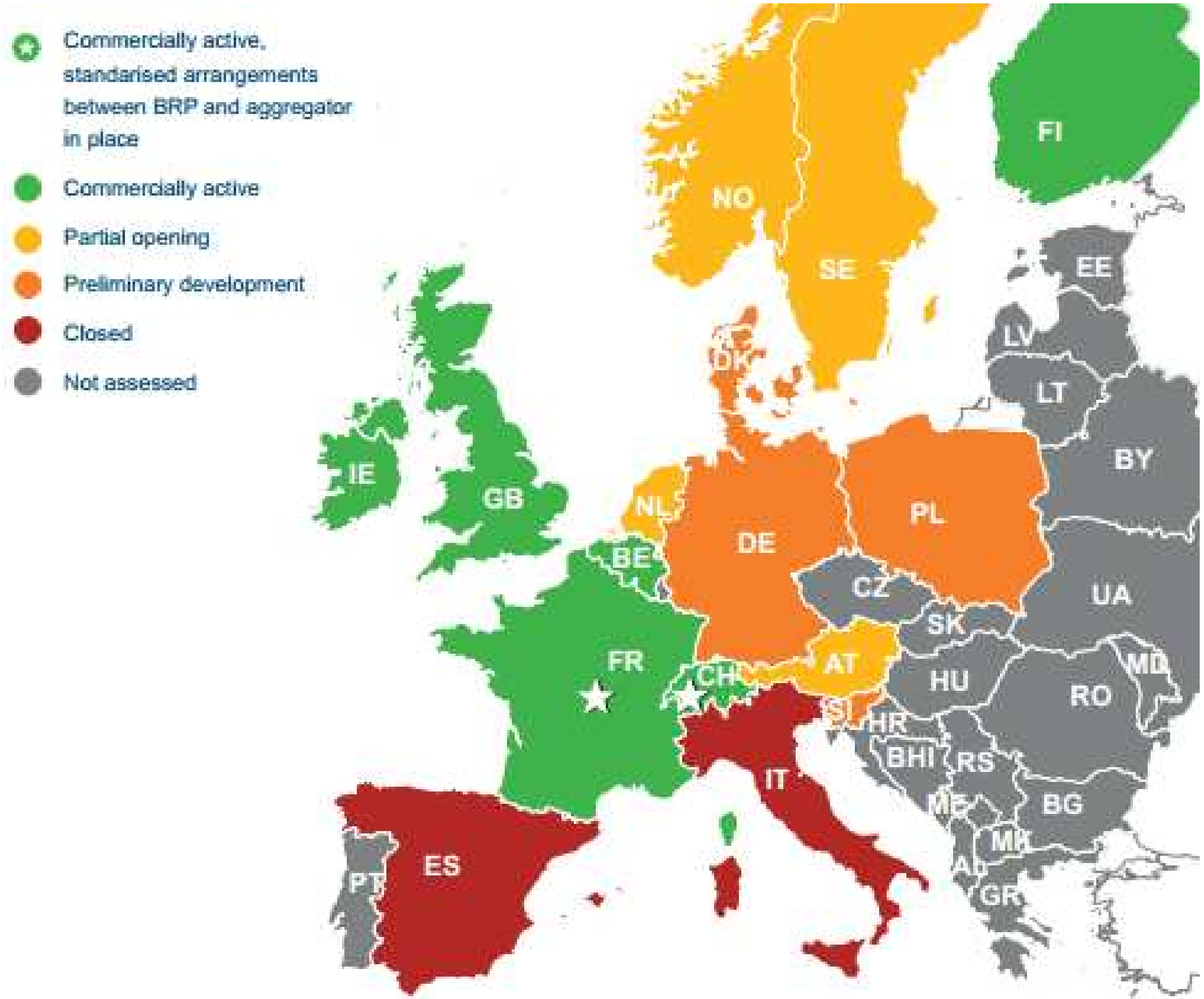

Source: SEDC, 2015)

Enabling conditions for explicit DR

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- Demand Response should be accepted as a resource in balancing/capacity markets
  - Not true in many countries, despite EED Art 15.8: „Member States shall ensure that transmission system operators and distribution system operators, in meeting requirements for balancing and ancillary services, treat demand response providers, including aggregators, in a non-discriminatory manner, on the basis of their technical capabilities."
- Aggregated load and independent aggregators should be allowed to enter the markets
  - Q: should consumer flexibility be unbundled from sales of electricity?
- Viable product specification
  - Size of bid: 3-5 MW
  - Different availability requirements: e.g. weekday-weekend
  - Ban on symmetric bid requirement

Benefits of demand response

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- cost effective balancing resource for variable renewable generation
- Monetary savings of end users by shifting consumption to low-tariff periods
- Reducing total generation capacity in peak hours; various estimations:
  - 14% of peak demand in the EU by explicit DR (Gils, 2014)
  - 10% of peak load by industry and tertiary sectors in Germany (Stede, 2016)
  - 16% of UK peak demand by manufacturing, hospitals and retail stores (Association of Decentralised Energy, 2016)
  - 10% of peak demand in the EU (European Commission)
- Avoided network investment especially during demand growth (risk of stranded assets if growth is not persistent)

Peak reduction: US examples

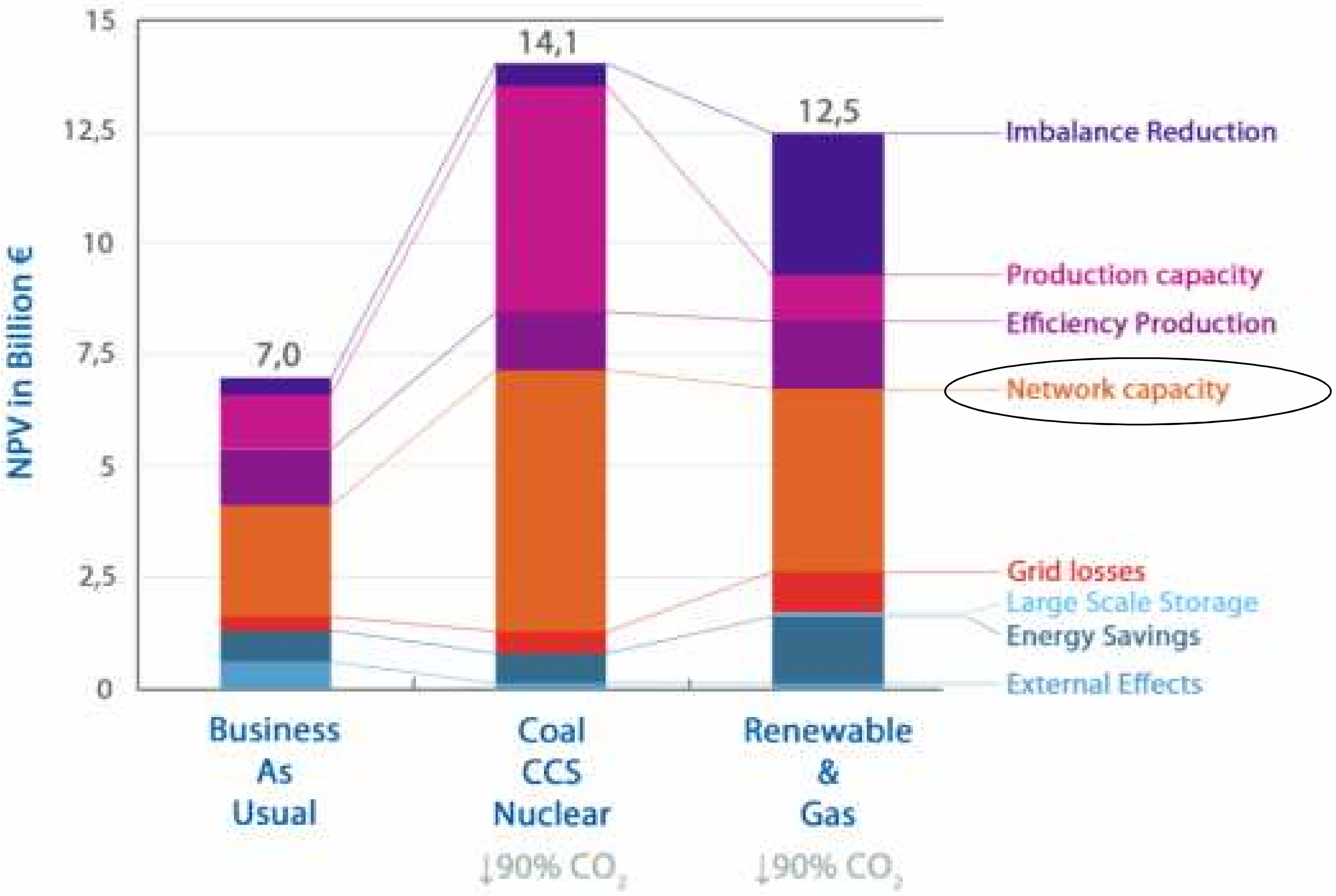
RTO/ISO	2013		2014	
	Potential Peak Reduction (MW)	Percent of Peak Demand [8]	Potential Peak Reduction (MW)	Percent of Peak Demand [8]
California ISO (CAISO)	2,180 [1]	4.8%	2,316 [9]	5.1%
Electric Reliability Council of Texas (ERCOT)	1,950 [2]	2.9%	2,100 [10]	3.2%
ISO New England, Inc. (ISO-NE)	2,100 [3]	7.7%	2,487 [11]	10.2%
Midcontinent Independent System Operator (MISO)	9,797 [4]	10.2%	10,356 [12]	9.0%
New York Independent System Operator (NYISO)	1,307 [5]	3.8%	1,211 [13]	4.1%
PJM Interconnection, LLC (PJM)	9,901 [6]	6.3%	10,416 [14]	7.4%
Southwest Power Pool, Inc. (SPP)	1,563 [7]	3.5%	48 [15]	0.1%
Total ISO/RTO	**28,798**	**6.1%**	**28,934**	**6.2%**

Table 1: Potential Peak Reduction from U.S. ISO and RTO Demand Response Programs

Source: FERC, 2015

As reliable source of flexibility as generation: above 90% delivery (NERC)

Social benefits of smart grids: NL, 2011-2050



Source: Delft and DNV GL, 2012

DSOs

DSO funding

- Task: maintain and operate the distribution network and integrate all users
- Investment requirement in the European distribution network is 480 bn EUR up to 2035 (IEA estimate)
- Funding: connection charges and network tariffs
  - Connection charges: To what extent should it be socialised or borne by the new network user? Should it be differentiated by location to reflect the true cost of connection – deep connection charge?
  - Network tariffs: charges on system users
    - Most often paid only by the load (now it is only load)
    - Elements: capacity and energy consumption linked (volumetric) charge
    - The most commonly used volumetric tariffs designed for stable or growing demand

Network tariffs design options

Geography	Time-of-use	Fixed and variable elements	Payment liability	Type of service	Type of customer
Uniform charges *Locational charge* *Voltage level*	*Peak load pricing*	*Energy, demand charge* *Two-/multi-part tariffs*	*Generation - load split*	*Charges for connection, network, meter etc.*	*Household, commercial, industrial*

Figure 1: Alternative criterion and ways levels of differentiation of tariffs

Source: VTT (2011) modified from[4] Petrov and Keller (2009)

Network tariffs are economic signals and determine how and to which extent grid users can influence their energy bill by changing their behaviour:

- short-term use of the network to avoid risk of overload
- long-term decisions such as whether to install PV capacity at home

Network tariffs should provide full cost recovery for DSOs

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- High share of DG and energy efficiency measures result in lower consumption
- EVs and heat pumps increase consumption but probably peak load as well and the network should be able to serve it
- Volumetric charges paid after net consumption but constant use of the network: problem of equity and cost recovery for DSOs (disincentive to connect new prosumers)
- Few countries apply capacity charge at LV: FI, NL, ES
- Should the tariff base extended to generation as well?

Problem of lower electricity consumption

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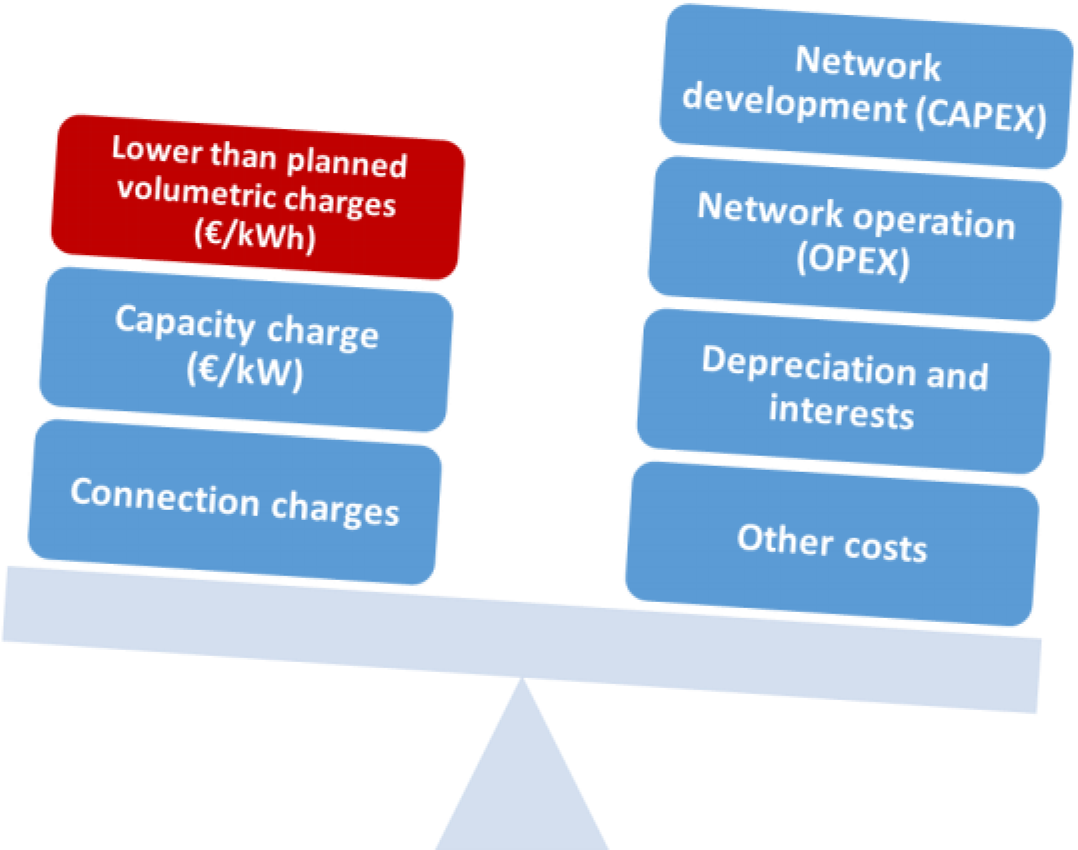

Network tariffs should result in optimal investment mix

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- Traditional versus innovative grid solutions
- Smart grids investment:
  - more OPEX than CAPEX and today often there is rate of return on CAPEX but not OPEX, plus OPEX involves an efficiency improvement factor
  - need for TOTEX approach for an optimal mix of expenditure (earning an equal return on supply and demand side solutions)
  - Risk premium in WACC to recognise higher investment risk

Incentive regulation in Italy

- Additional 2% WACC for 12 years for DSOs
- Eligibility:
  - Only network sections where reverse power flow is more than 1% within a year and test more technical solutions
- Assessment:
  - 4 technical score (A)
  - Cost (C)
  - Increase of DG capacity (P_{smart})

$$PI = \frac{Psmart \sum_{n=1}^{4} An}{C}$$

Network tariffs should allow consumers to provide flexibility to price signals

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- by not penalising consumers for participating in Demand Response, and changing their consumption profile:
  - Austrian DSOs separate balancing energy from normal consumption when calculating network charges, and charge for the balancing energy at a much lower rate
  - France: Time Of Use Tariffs are available (day/night) but both EDF and others consider that critical peak pricing should also be introduced
  - German distribution tariffs encourage large consumers to keep their consumption stable and hence indirectly penalizing them for participating in DR

Conclusions on network tariffs

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- No smart meters available:
  - Predominantly flat rate capacity charge that gives revenue certainty
  - But lack of volumetric charge evaporates incentives for energy efficiency (should this be the vehicle of EE or energy price?)
- With smart meters:
  - ToU charge in addition to the flat capacity charge
  - Smart contracts: DSO is able to limit the consumption or production of a grid user a certain number of times a year, for a limited duration, at critical moments under agreed conditions in exchange for a rebate

Changing role of DSOs?

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- Core activity: grid operation (natural monopoly)
- Non-core activities (competitive markets):
  - Flexibility services
  - Infrastructure for storage and EVs
  - Energy efficiency services/advice
- Question: Should DSOs be limited to their core activity or may get involved in others?
  - Synergies among the activities but problem of fair competition: unbundling as a solution? (Norway: DSO can own but cannot operate storage)
  - DSOs are neutral data managers: share commercial data on energy use to facilitate competition; rules on what data and to whom
  - Transitionary involvement of DSOs: in NL to accelerate the rollout of EVs charging infrastructure but third party access

Conclusions

- The flexibility that can be provided by demand response is an increasingly valuable asset
- Different consumers fit to different types of programs
- DR potential is significant but largely untapped in Europe
- Legal provisions (Third Package, EED) are in place and the technological solutions are available commercially
- Markets is only partially opened and entry barriers exists
- DSOs face an increasingly complex task of grid operation accompanied by less predictable tariff revenue
- Need for rethinking network tariffs that provide revenue certainty for DSOs, incentive to engage in innovative investment but also provide signals to network users on the efficient use of the grid
- DSOs could engage in new grid related activities but fair competition should be safeguarded by regulation