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# Challenges of decarbonisation for 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

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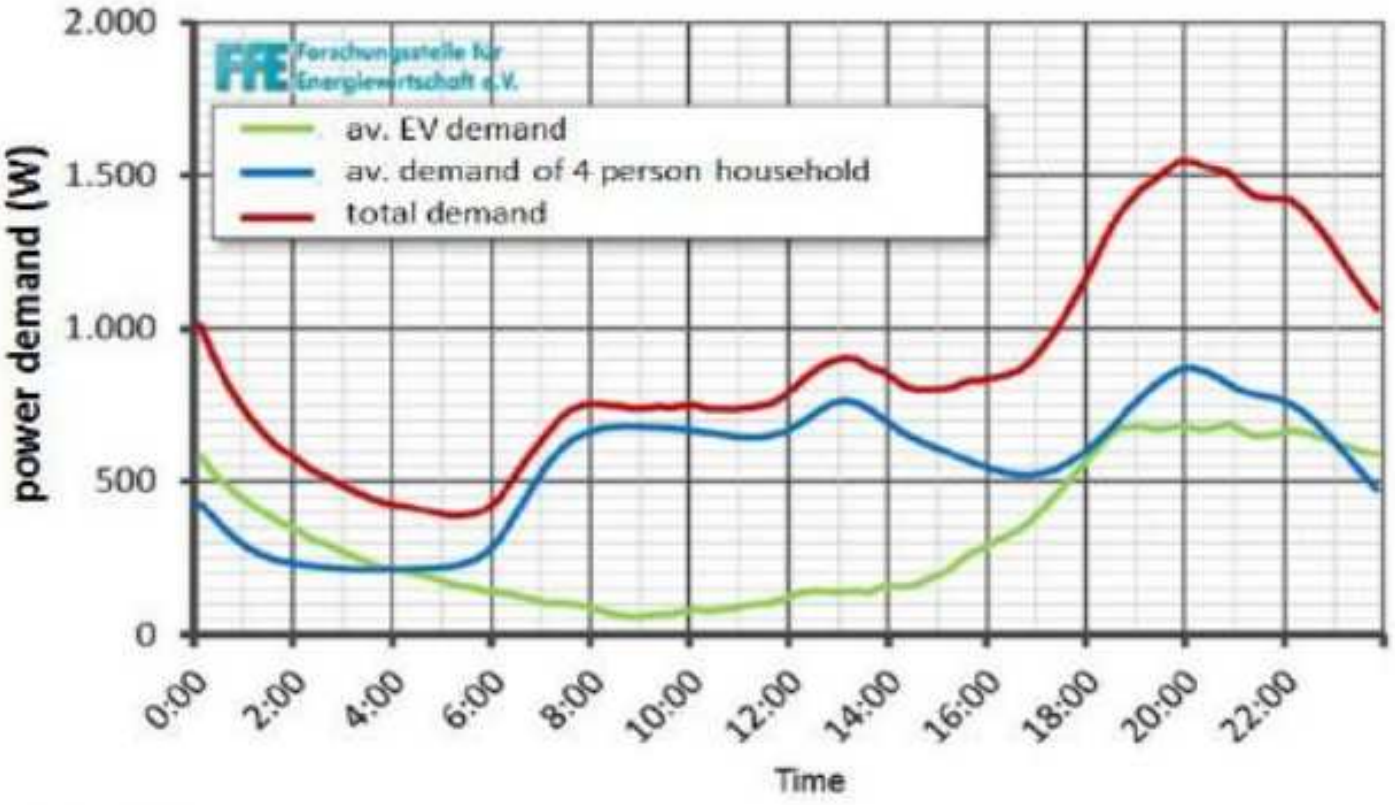
Figure 2: Load curves (user-driven charging) of electric vehicle charging, private household and both aggregated (Germany)




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 provide adequate incentives for 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?

What are the related proposals of the WP?

# Winter Package: „Clean Energy for all Europeans”

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- Package of measures for clean energy transition
- Main legislative proposals:
  - RED recast
  - EED
  - Governance
  - *Directive and Regulation on internal electricity market (IM Directive)*
    - *Chapter III: consumers*
    - *Chapter IV: tasks of DSOs*

# 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?

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- „Change of electricity load by final consumers from their normal or current patterns in response to market signals, including time-variable electricity prices or incentive payments, or in response to acceptance of the final consumer's bid to sell demand reduction or increase at a price in organised markets" (IM Directive)
- 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

# 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)
- Requires advanced metering: either several dials per day or smart meters
- Behavioural adaptation by choice or automatically (smart appliances)
- Various types: Time-of-use, critical peak pricing, real time pricing

# What is smart metering (SM)?

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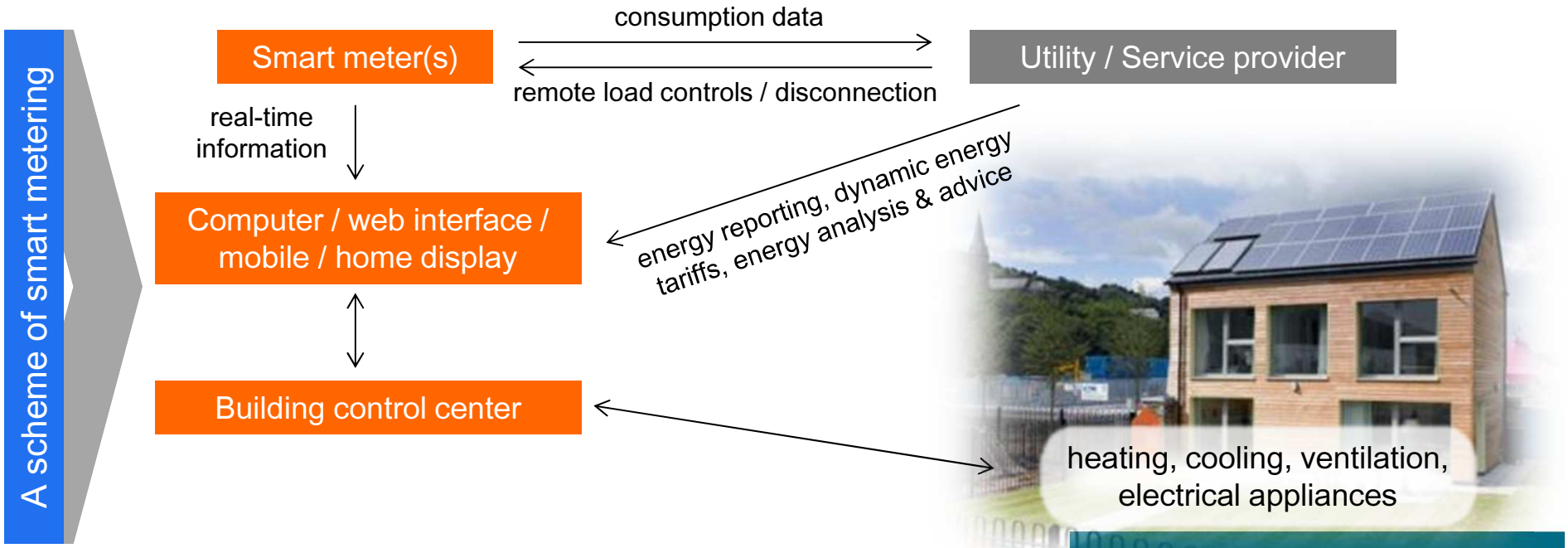
- Smart metering is more than just smart meters:
  - Electrical meters – instead of traditional electromechanical ones
  - Related hardware equipment (e.g. home displays)
  - Communications network
  - Data management and control center



# Smart meter roll-out by 2020

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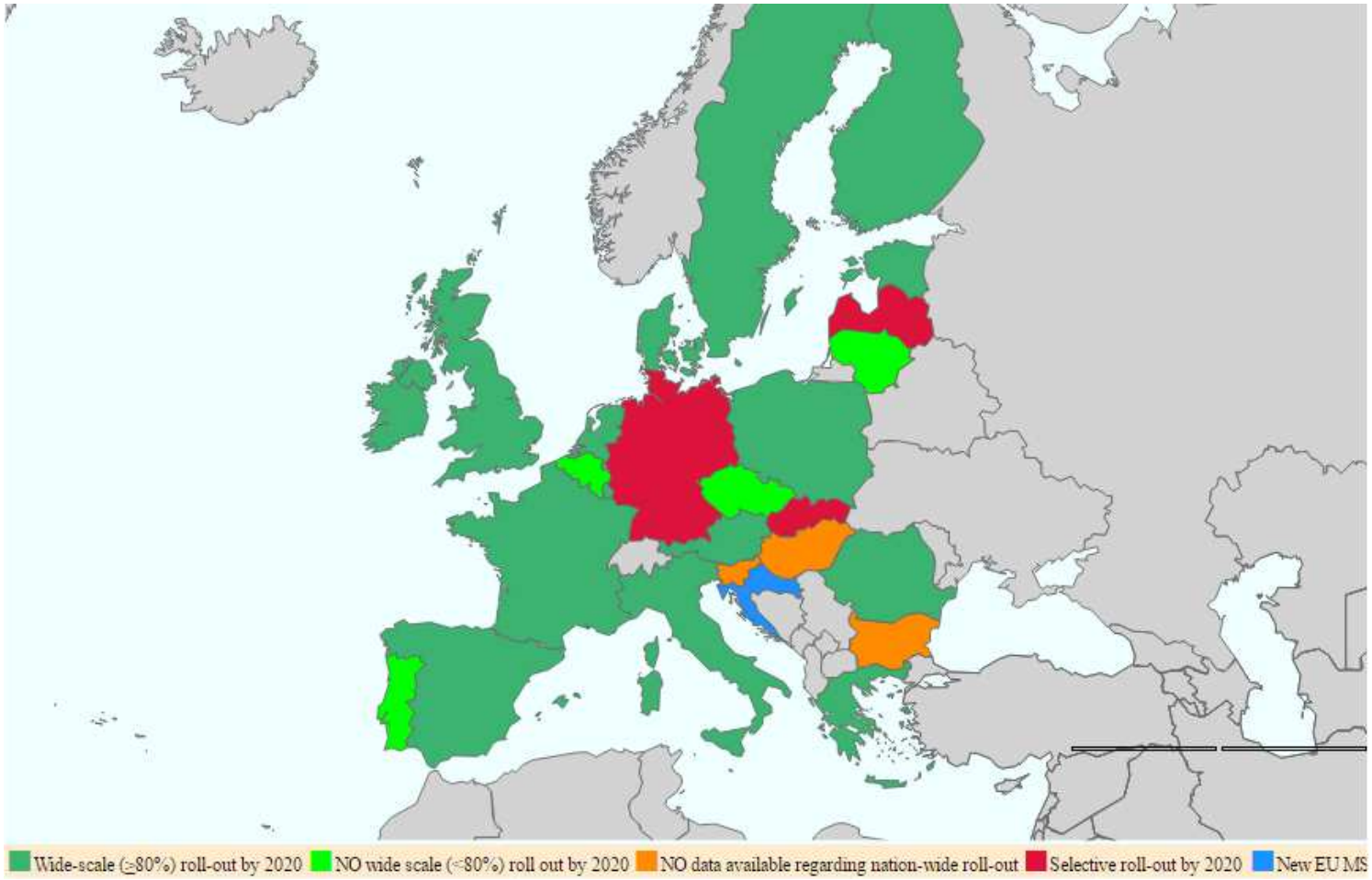


Source: JRC, 2014

# Smart appliances

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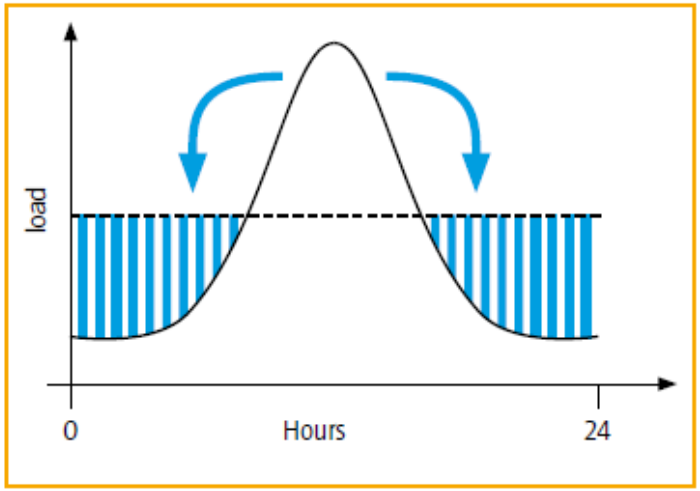
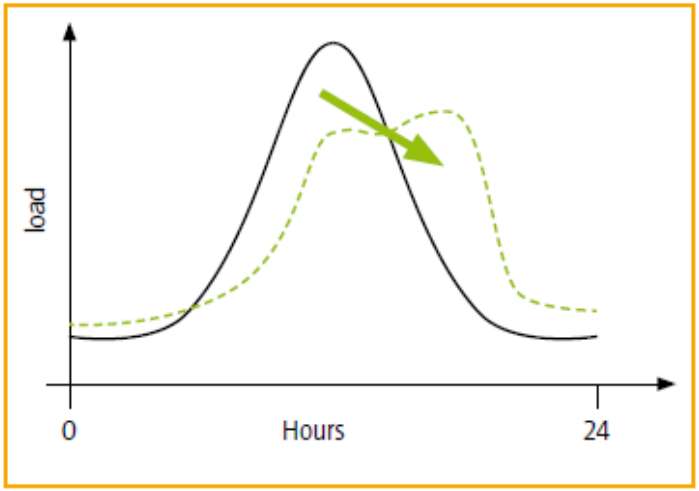
- No need for the active involvement of the consumer, activation based on pre-set parameters:
  - price
  - self-generation
- Factor determining load shift potential:
  - Total consumption of the device
  - The duration of load shift
  - Penetration of device



# 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

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# Peak load reduction with ToU pricing

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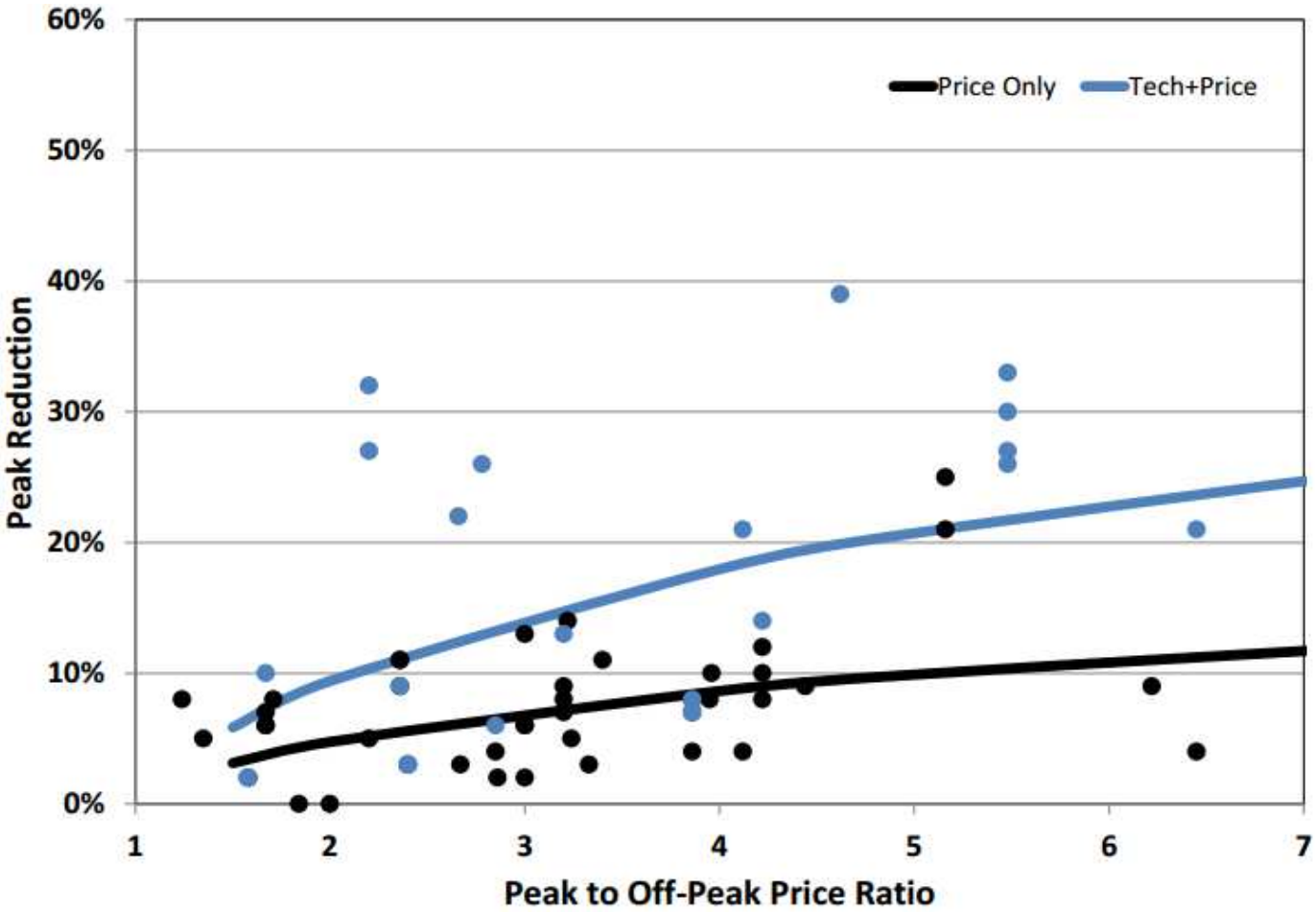


Meta-analysis of 163 ToU programs

Source: Faruqui et al, 2013

# The impact of EV charging tariffs on load

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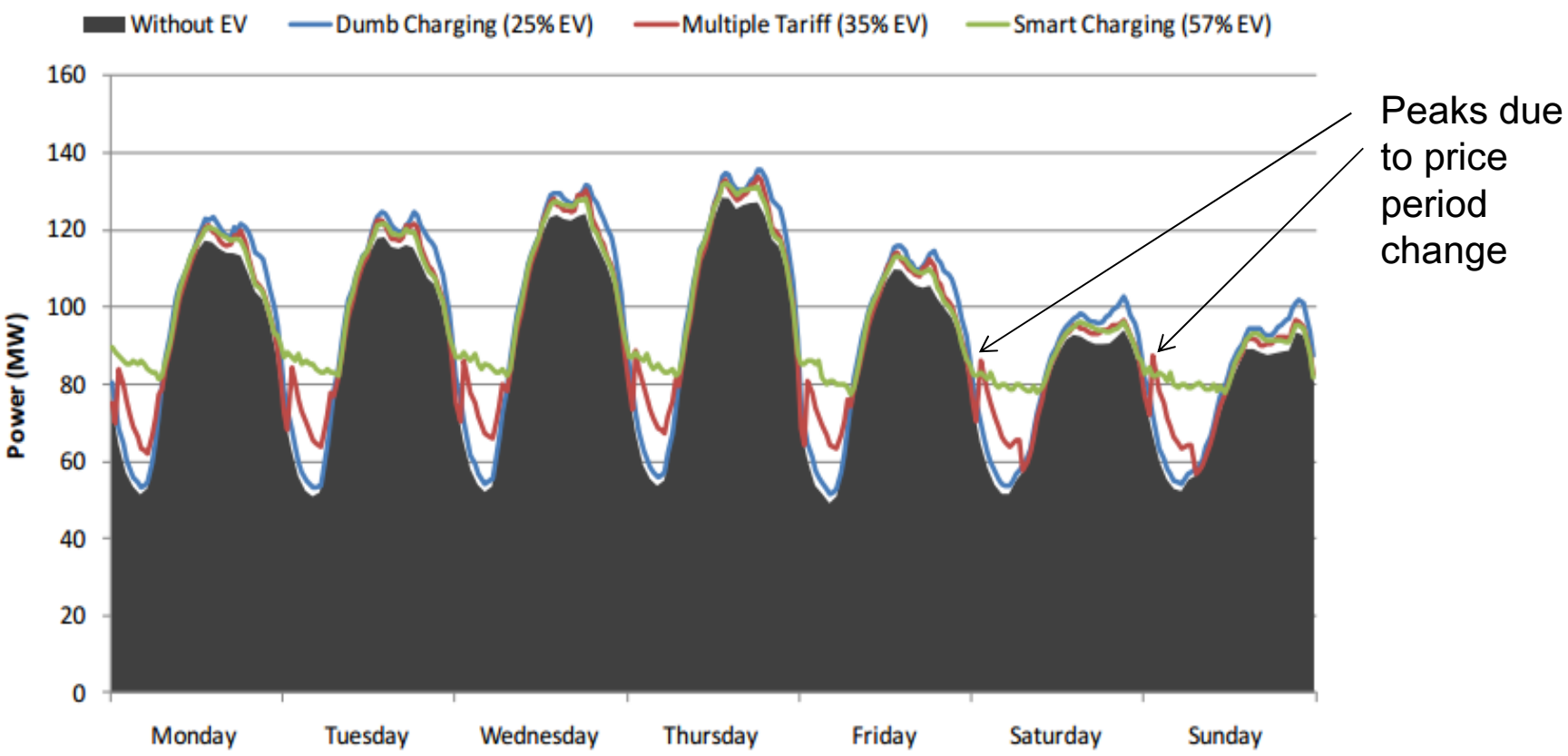


Source: MERGE, 2012

# Enabling conditions for implicit demand response

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- Market-based retail pricing:
  - Problem of regulated prices
  - Price blunting effect of taxes and levies
- Competition of suppliers with (ToU) tariff packages and easy consumer switch
- Smart meter registering consumption at an hourly, or shorter basis
- 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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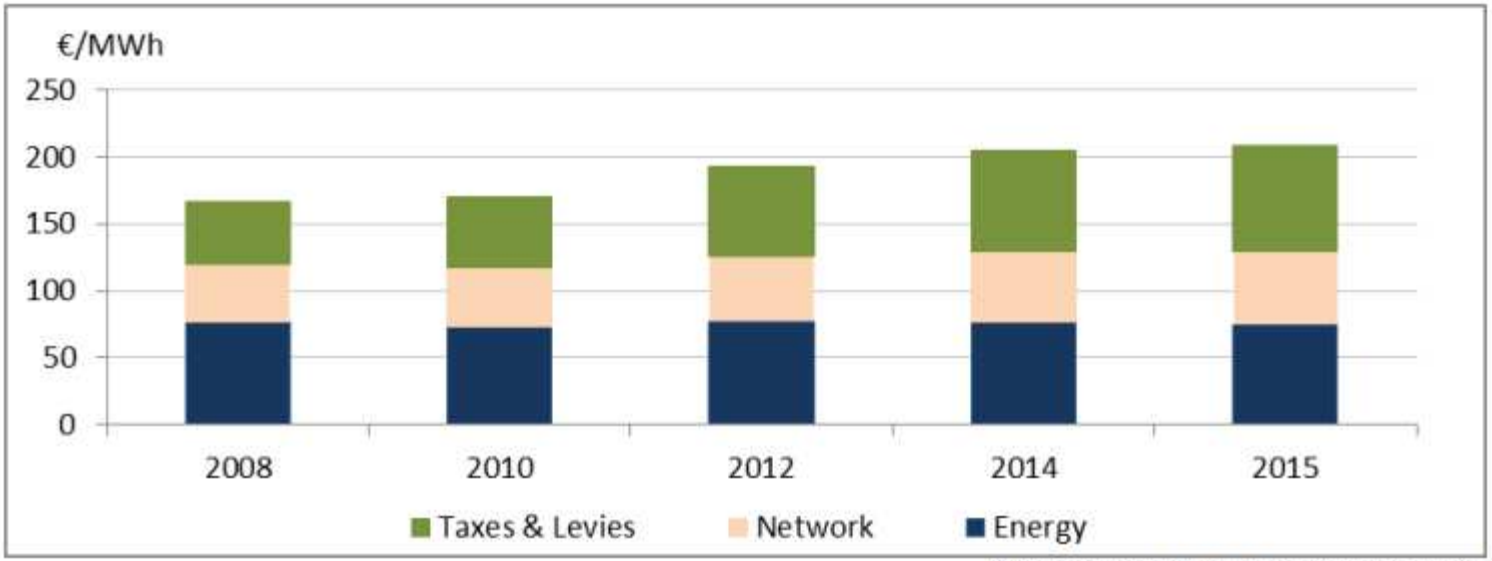
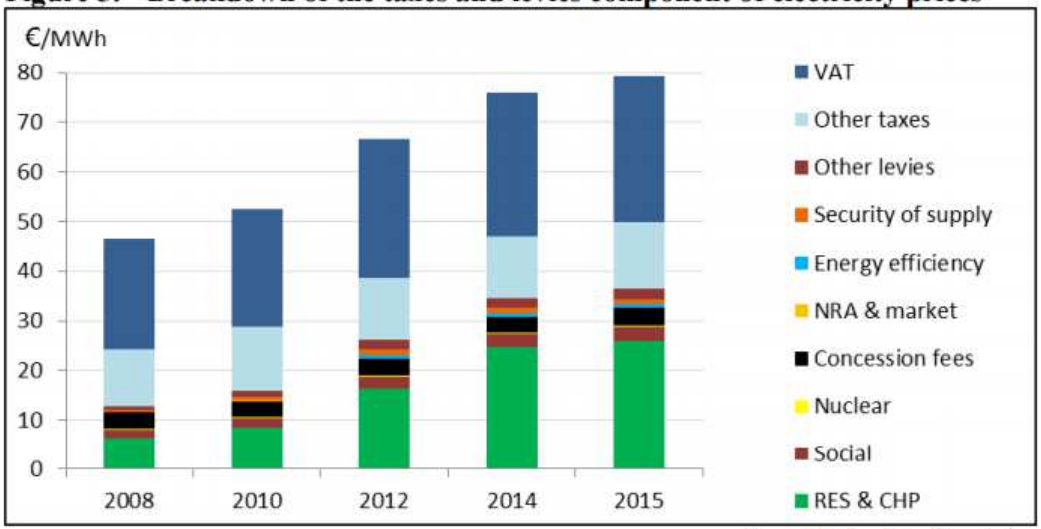
**Figure 3: Components of average EU household retail electricity prices**




Source: Member State, Commission data collection

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




Source: EC, 2016

# IM Directive on regulated prices (Art 5)

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- „Electricity suppliers are free to determine the price at which they supply”
- Energy poor and vulnerably consumers can be protected by other means than price setting public intervention

BUT

- Existing regulated prices for these groups can be maintained for 5 years (from entry into force) or longer in case of „extreme urgency” (?): Commission needs to be notified

# IM Directive on supplier competition (Art 11-12 and 14)

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- Consumer right to switch supplier within 3 weeks
- No charge for any switching related fees
  - Except in case of fixed term contracts: only if consumer received demonstrable economic advantage from having a fixed-term contract and not exceeding the economic loss of the supplier due to the lost consumer
- Comparison tool for offers of suppliers:
  - At least on, free-of-charge
  - Needs certification: criteria for comparison, easy-to-understand, up-to-date, covering a significant part of the market
- Final consumer is entitled to a dynamic price contract by his supplier and must be informed about the associated opportunities and risks

# IM Directive on smart metering (Art 19-21)

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- Smart metering roll-out is still linked to CBA (revised periodically!) but MS should safeguard minimum functional requirements:
  - Able to provide info on actual time of use that is available at no cost and near-real time
  - Able to measure electricity fed into the grid (active consumers)
  - enable final consumers to be metered and settled at the same time resolution as the imbalance period of the national market
- Final customers shall contribute to the cost of rollout that needs to monitored by the MS
- If no roll-out: final consumers still entitled to smart meters on request:
  - the offer should contain the functionalities and cost
  - Installed within 3 months

# IM Directive on data access (Art 23-24)

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- Final consumers should access its own consumption data at no cost
- MS should specify eligible parties (at least: consumers, suppliers, TSO, DSOs, aggregators, energy service companies) which may have access to data
- Data can be accessed by them at the explicit consent of the final consumer
- Common European data format will be designed
- Data service provision should be a non-profit activity

# 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

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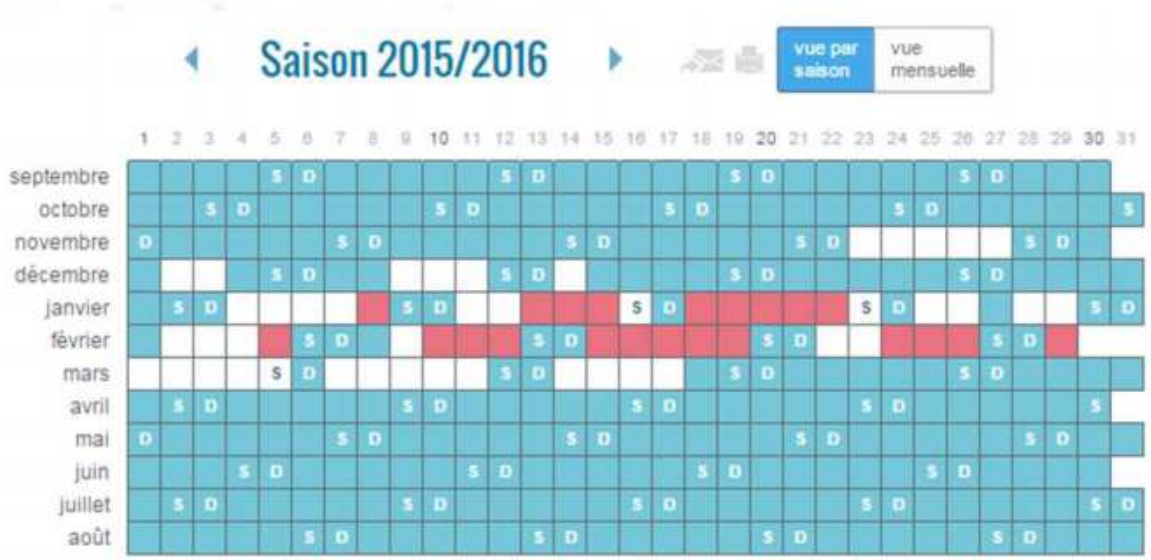
- For households and small enterprises
  - Three types of day: blue, white and red
  - Announced day ahead between 11 and 12 am (on meter+ email/sms/web)
- Two time zones:
  - Normal and peak




| Option | Puissance | Subscription (€/year) | "Blue" day Offpeak hours (c€/kWh) | "Blue" day Peak hours (c€/kWh) | "White" day Offpeak hours (c€/kWh) | "White" day Peak hours (c€/kWh) | "Red" day Offpeak hours (c€/kWh) | "Red" day Peak hours (c€/kWh) |
|---|---|---|---|---|---|---|---|---|
| TEMPO | 9 | 92,04 | 5,75 | 7,44 | 8,46 | 10,74 | 14,80 | 40,26 |
| | 12 | 141,12 | 5,75 | 7,44 | 8,46 | 10,74 | 14,80 | 40,26 |
| | 15 | 161,76 | 5,75 | 7,44 | 8,46 | 10,74 | 14,80 | 40,26 |
| | 18 | 181,44 | 5,75 | 7,44 | 8,46 | 10,74 | 14,80 | 40,26 |
| | 30 | 452,28 | 5,75 | 7,44 | 8,46 | 10,74 | 14,80 | 40,26 |
| | 36 | 529,44 | 5,75 | 7,44 | 8,46 | 10,74 | 14,80 | 40,26 |

# 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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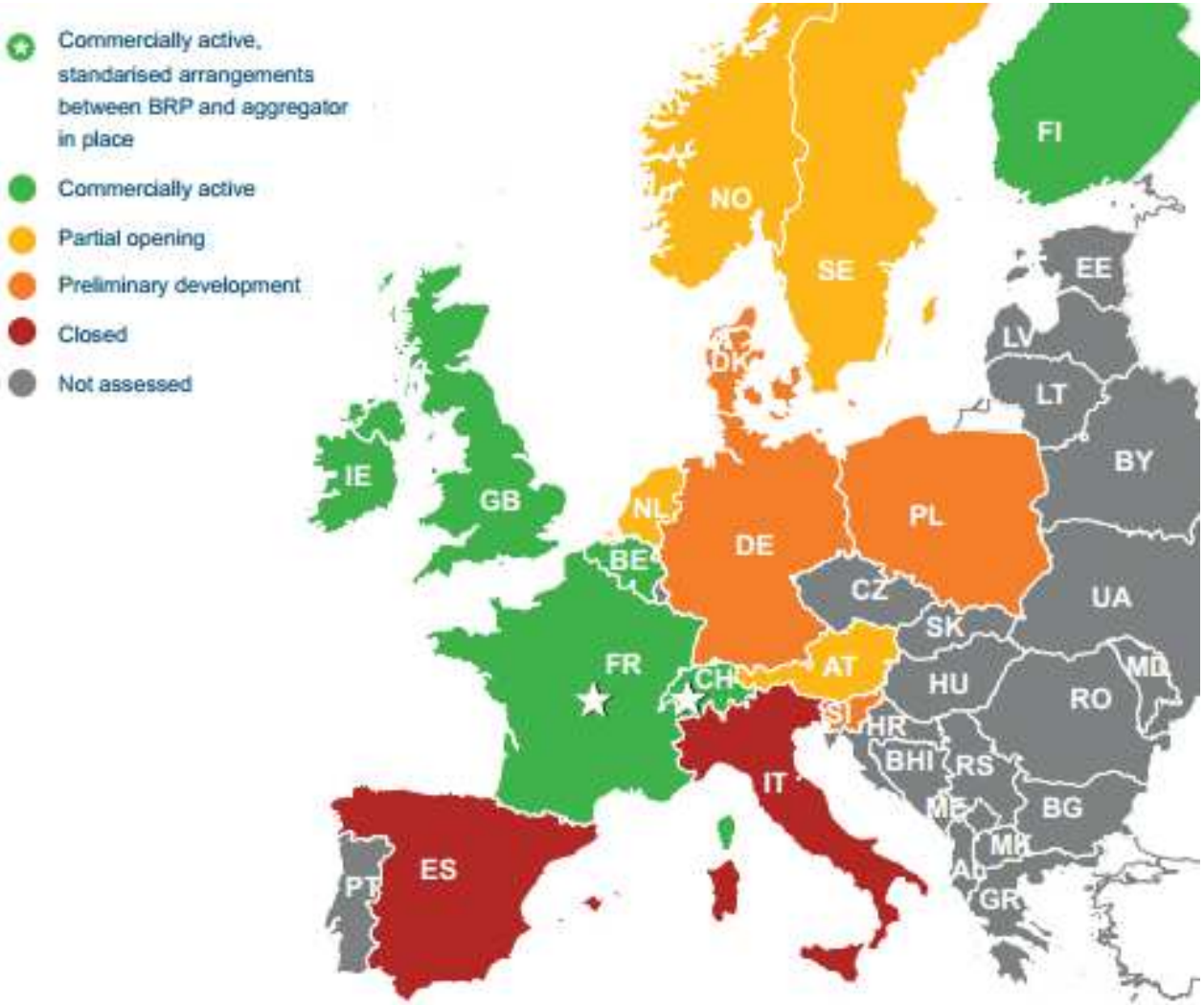


Source: SEDC, 2015

# Enabling conditions for explicit DR

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- Demand Response should be accepted as a resource in balancing/ancillary markets: not true in many countries
- 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

# IM Directive on demand response and aggregators (Art 13 and 17)

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- „MS shall ensure access to and foster participation of demand response in all organised markets”
  - TSOs in balancing market and (unless justified by CBA) non-frequency ancillary markets
- MS shall ensure that NRA or TSO/DSOs in cooperation with DR providers define the technical modalities for participation
- Final consumer can contract an aggregator without the consent of his supplier
- Aggregator right to enter the market without the consent of other market actors
- TSO/DSOs should treat aggregators and demand response providers on a non-discriminatory manner

# 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

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| RTO/ISO | 2013 Potential Peak Reduction (MW) | 2013 Percent of Peak Demand [8] | 2014 Potential Peak Reduction (MW) | 2014 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)

# DSOs

# DSO funding

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- 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

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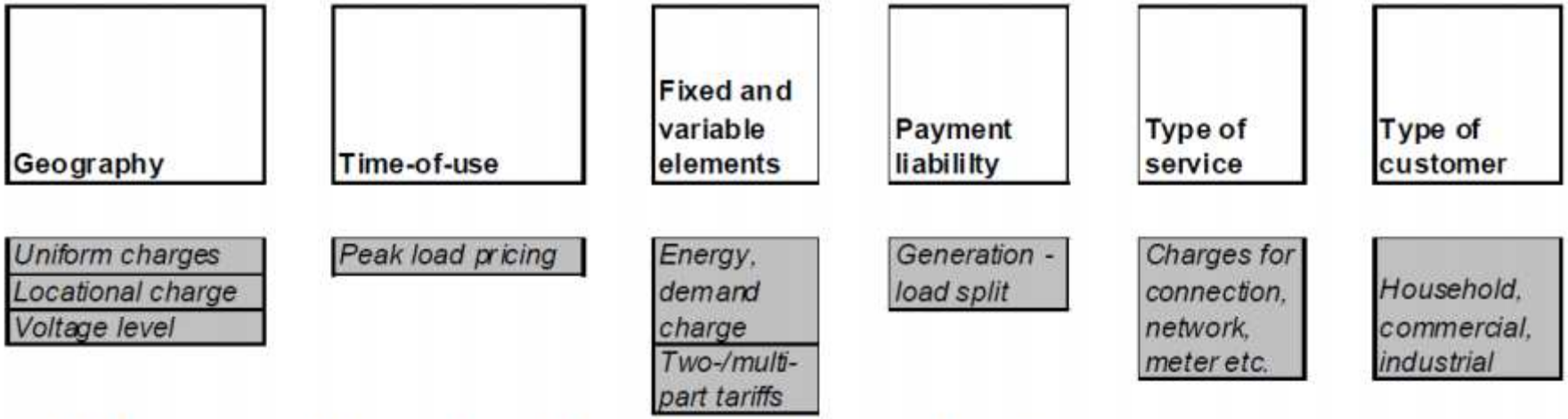


**Figure 1: Alternative criterion and ways levels of differentiation of tariffs**

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

NRAs has to publish the methodology and the underlying cost assumptions for the calculation of network tariffs (IM Directive)

# 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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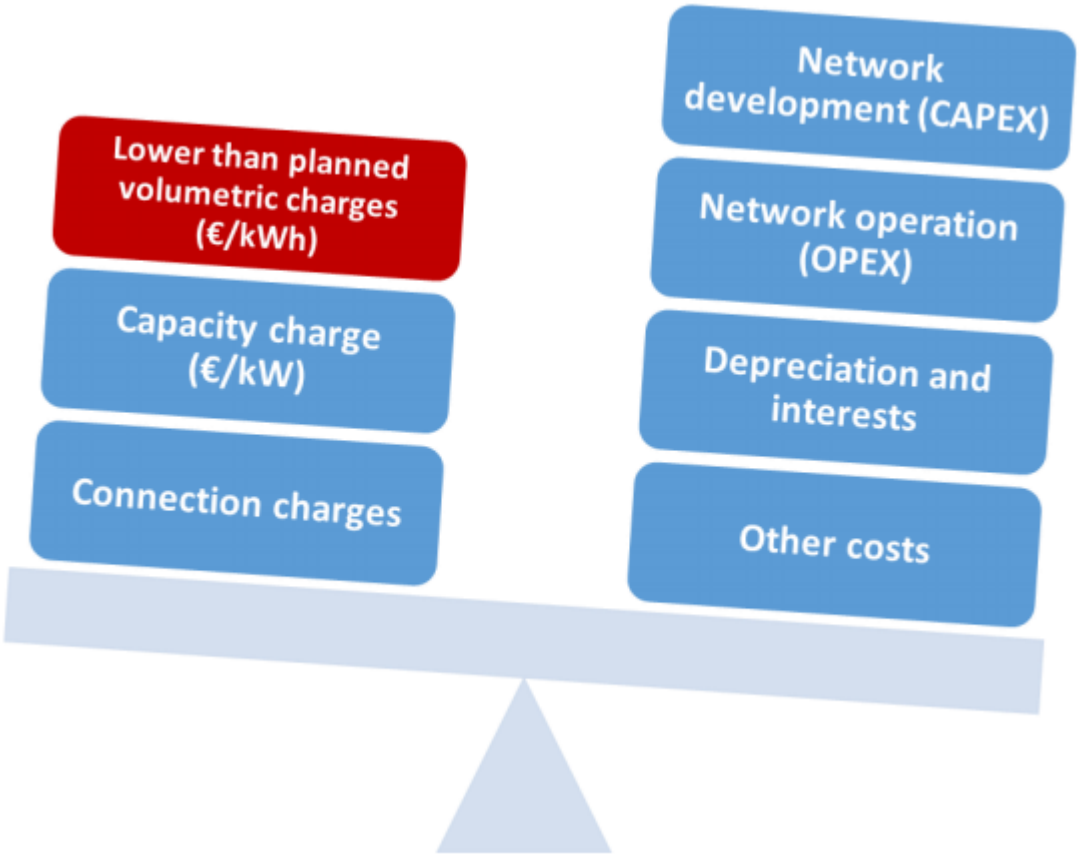

# Network tariffs should result in optimal investment mix

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- Traditional versus innovative grid solutions
- Smart grids investment:
  - would involve more OPEX than CAPEX compared to current grid investments
  - current bias towards capital investment: capitalisation to maximise revenue
    - CAPEX increase asset value
    - rate of return on CAPEX
  - need for TOTEX approach for an optimal mix of expenditure (earning an equal return on supply and demand side solutions): buying cloud based IT solution from a third party or own and implement itself?
  - More risky CAPEX: risk premium in WACC to recognise higher investment risk
- NRAs have to measure the performance of TSO/DSOs on smart grid development based on Union wide indicators every two years (IM Directive)

# Incentive regulation in Italy

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- 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 ($P_{smart}$)

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

# IM Regulation on network tariffs (Art 16)

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- NRA may introduce ToU tariff reflecting the use of network in a foreseeable manner
- NRAs should recognise all cost of DSOs needed to incentivise them to raise efficiencies in network operation and introduce performance targets as well
- ACER task to harmonise national tariff methodologies addressing:
  - Ratio of tariffs applied to consumer and producers
  - Cost to be recovered by the tariff
  - ToU tariff levels
  - Location signals
- Examples:
  - Austrian DSOs separate balancing energy from normal consumption when calculating network charges, and charge for the balancing energy at a much lower rate
  - 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

# IM Directive on the role of DSOs (Art 31-34)

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- MS have to create the regulation that allows and incentivises DSOs to procure (!) flexibility services to substitute for network upgrade
- Standardised products must be defined
- The cost borne by DSOs must be remunerated
- Network development plan every two years for the next 5-10 years (new generation and load, including EV re-charging points) and must demonstrate that these developments could not be avoided by demand response, energy efficiency or storage
- DSO cannot own, develop or operate recharging points or storage only if:
  - No one was interested in the tender and NRA approves
  - Legal unbundling
  - Must be re-tendered every 5 years
  - Necessary for the reliable and secure operation of the grid (additional condition in case of storage)

# Conclusions

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- 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
- Technological solutions are available commercially and legal provisions will be enhanced once the IM Directive is adopted
- New entitlement of final consumers:
  - Smart meter
  - ToU tariff
  - Aggregator
- 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 should keep themselves to their core business