



Integrating renewables in the grid

One element of the flexibility sources
needed in a sustainable electricity system

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Is it an evolution? More of the same

 Context

 Power System Flexibility

 Flexible supply

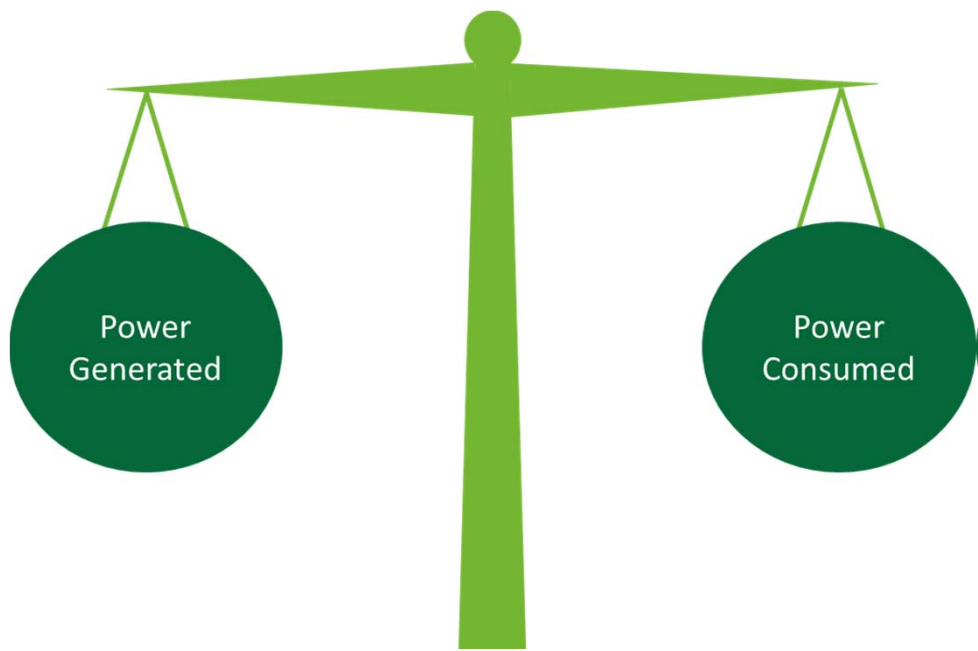
 Flexible demand

 Storage capacity

 Grid capacity

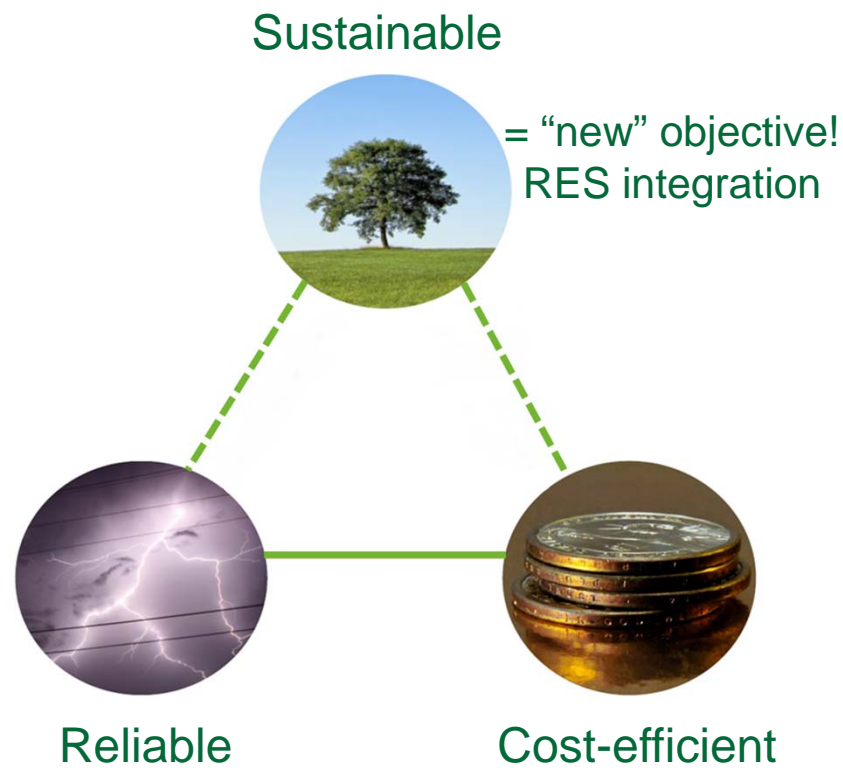
 Flexibility services

What are power systems all about?



Necessary balance in power systems

Objectives of current power systems



Satisfying 2 of these objectives is "fairly easy", satisfying all 3 is the big challenge!

The growing share of variable RES

Table 1: Installed capacity (GW) and annual electricity generation (TWh) of wind and PV in selected European countries by the end of 2013 (based on data published by ENTSO-E 2015).

	wind				solar (mostly PV ³)			
	[GW]	[TWh]	penetration [%]		[GW]	[TWh]	penetration [%]	
			mean ¹	max ²			mean ¹	max ²
Germany	33,1	50,8	9,16	101,85	35,9	31	5,59	110,46
Belgium	1,7	3,6	4,18	27,87	2,7	2,4	2,78	44,26
France	8,2	15,9	3,21	27,70	4,4	4,7	0,95	14,86
Denmark	4,8	11	33,95	436,36	0	0	0,00	0,00
Portugal	4,4	11,7	23,78	125,71	0,3	0,4	0,81	8,57
Spain	22,8	54,7	20,89	133,33	6,9	12,8	4,89	40,35
Ireland	1,8	4,5	17,31	105,88	0	0	0,00	0,00
Italy	8,5	14,8	4,69	44,50	18,4	21,2	6,71	96,34

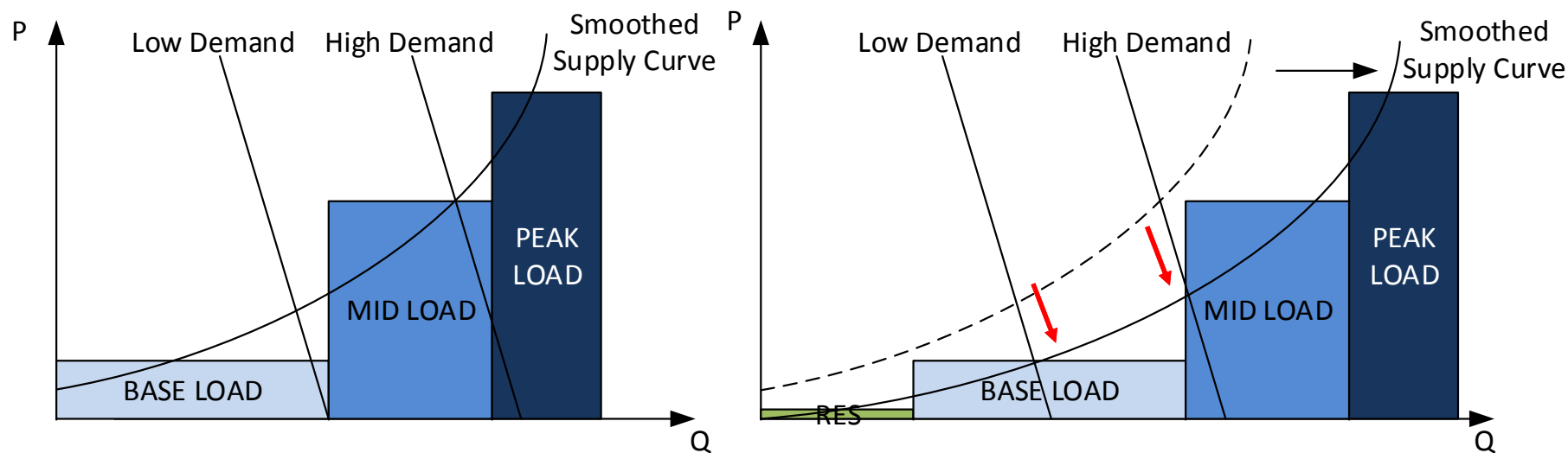
¹ average electric energy penetration: annual electricity generation in terms of total consumption; ² max penetration: installed capacity in terms of minimum consumption; ³ solar in Spain includes 2.3 GW Concentrated Solar Power (CSP).

De Vos, 2014

Market impact: theory

🌿 Twofold impact:

- ✦ Merit-order effect (due to close-to-zero marginal cost)
- ✦ Price volatility (due to variable nature)

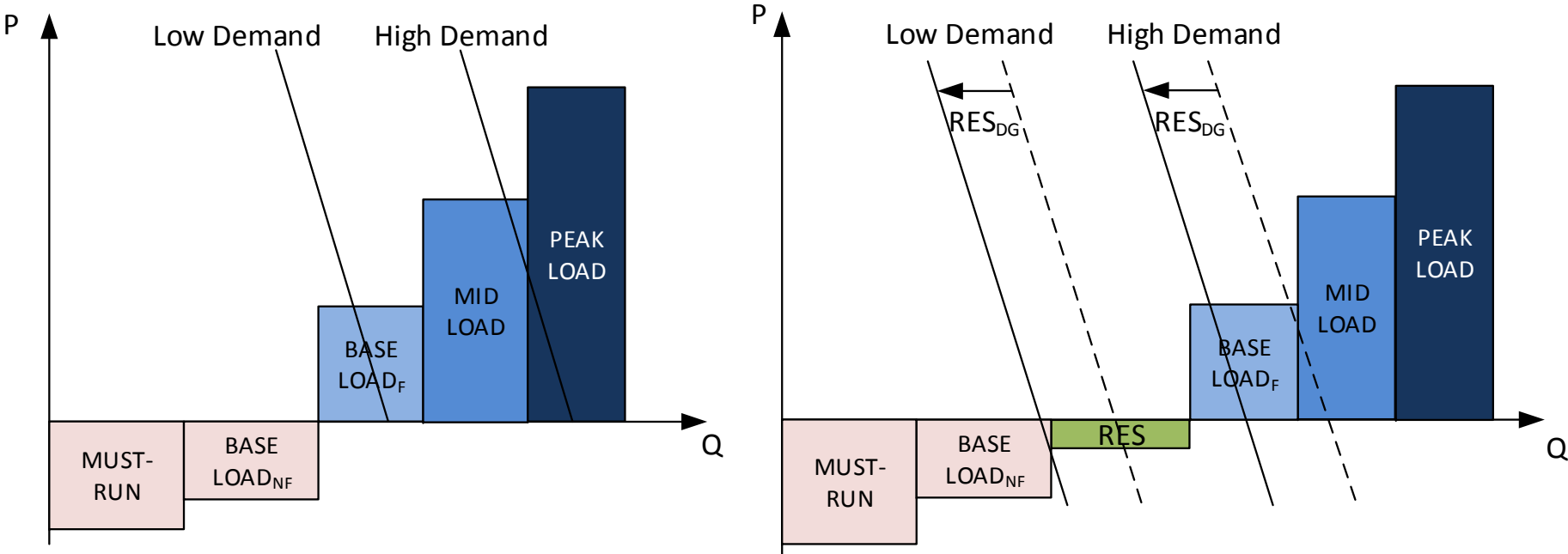


Price reduction depends on hourly scheduled RES and demand.

Market impact: theory

Twofold impact:

- ✦ Close-to-zero marginal cost (merit-order effect)
- ✦ Variable power output (price volatility)

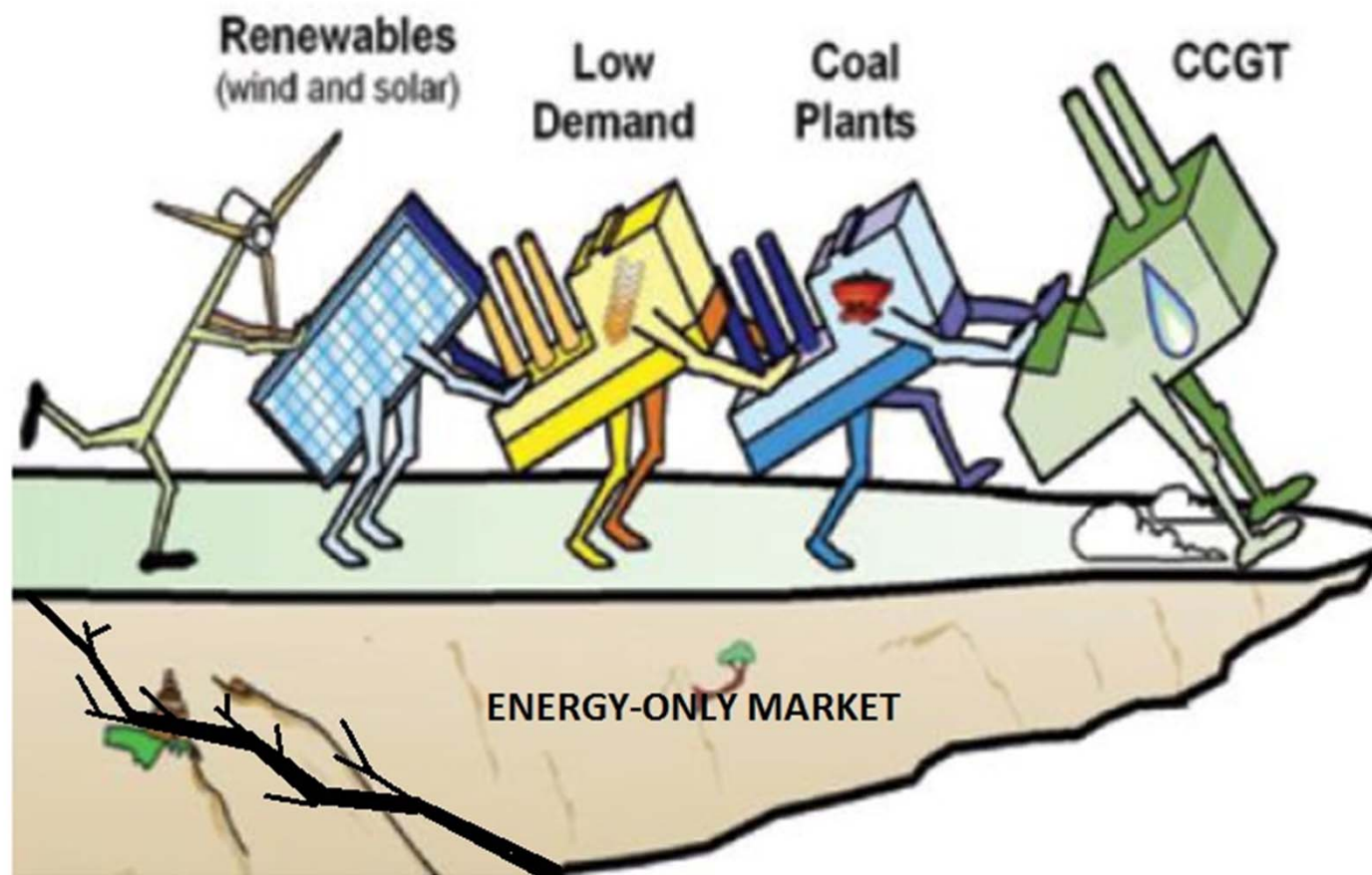


Occurrence of negative and positive price peaks (→ volatility) due to system inflexibility.

De Vos, 2014

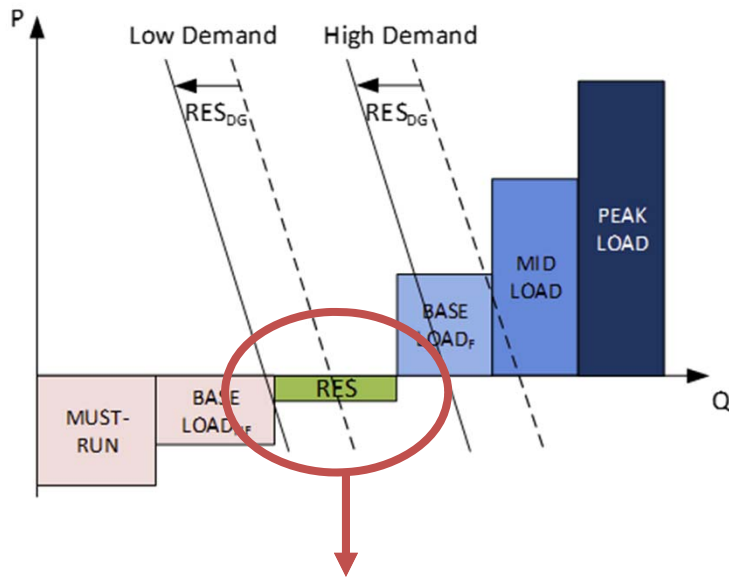
A. Merit-order effect

- Lower prices challenge the energy-only market, or at least some technologies in this market...



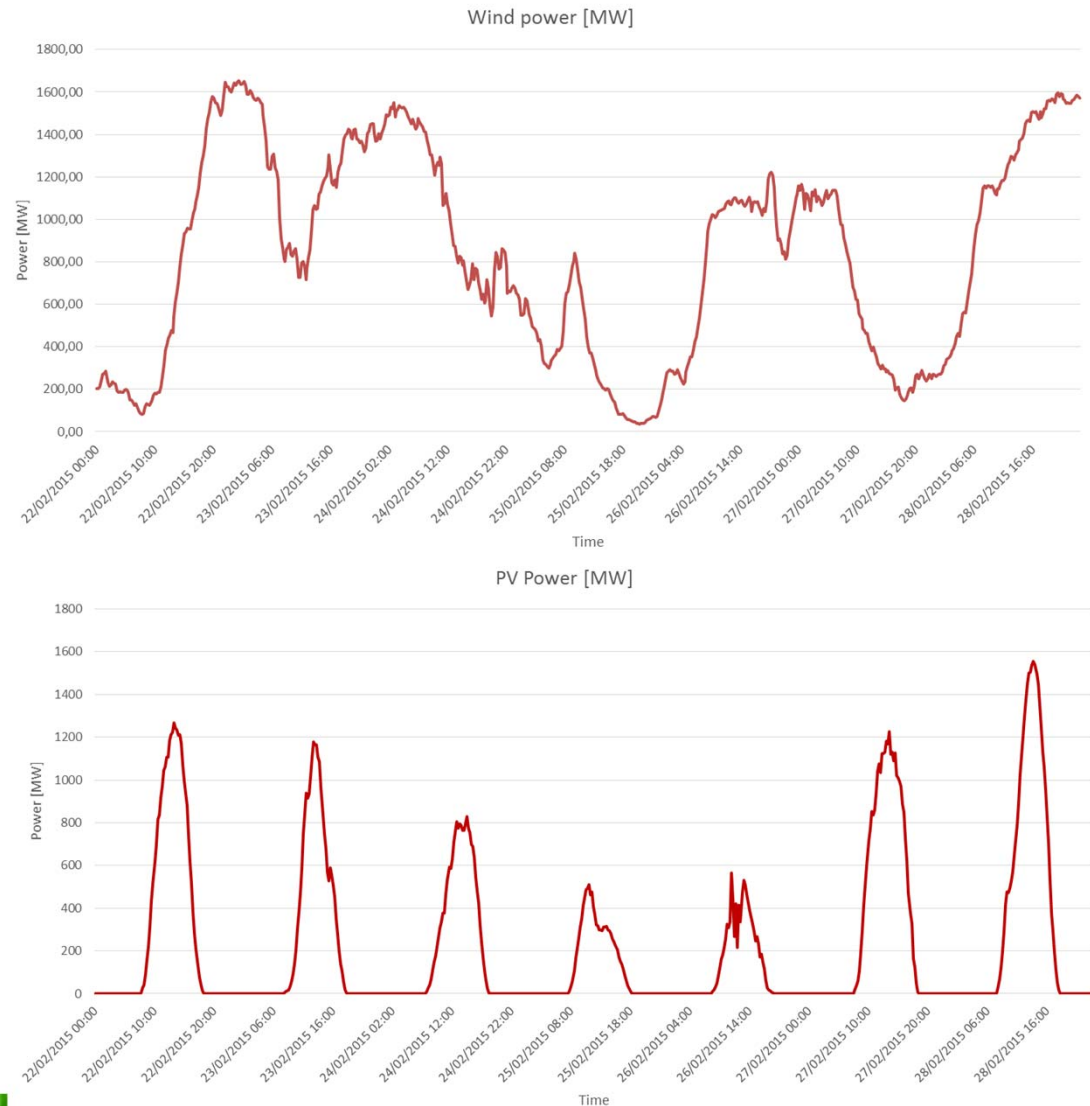
B. Price volatility

Wind and PV have a variable output profile.



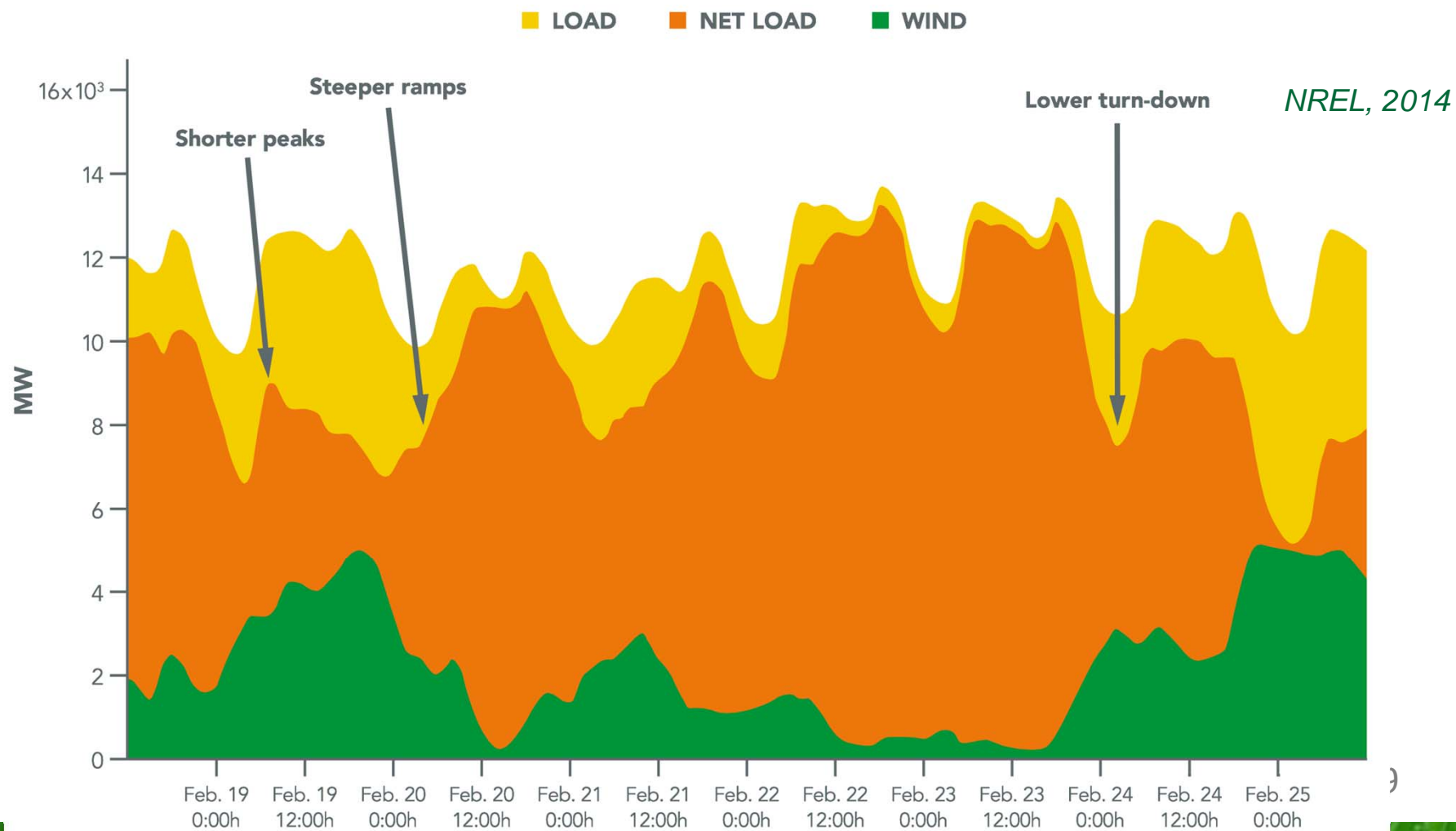
Supply of RES changes throughout the day => Net load, to be covered by conventional generation, becomes more volatile!

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Context conclusion: flexibility is key

RES variability requires flexibility.



Outline

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 Grid capacity

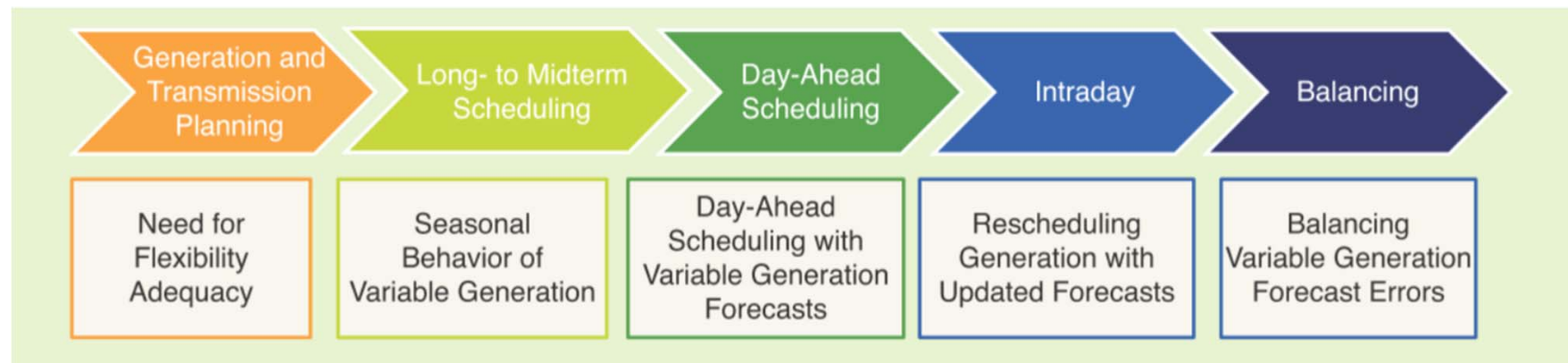
 Flexibility services

Power system flexibility

- Flexibility is the ability to quickly provide up- and downward power adjustments.
- Flexibility sources:
 - Flexible supply
 - Mainly through gas-fired power plants.
 - Flexible demand
 - Residential, commercial, and industrial consumption processes.
 - Storage
 - For example pumped-hydro storage, battery storage, power-to-gas storage.
 - Grid
 - Through improved control and additional transmission capacity.
- Paradigm shift: **supply follows demand to demand follows supply**, with the support of storage capacity and grid capacity.

Power system flexibility: timeline

- Ensuring system adequacy → ensuring flexibility adequacy.
- Need for flexibility in different time frames.
- Low RES penetration increases operational flexibility needs, while high RES penetration also affects long-term planning.



Holtinen, 2013

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Flexible supply

- Flexible power plants provide(d) largest share of flexibility.
- Ramp or start-up/shut-down.**
- Conventional** flexible supply sources: coal, gas, oil, CHP.
- But peak plants are hard to keep economically viable...



- New flexible supply sources:**
 - Wind farms** providing downward reserves. In the future also upward?
 - PV** providing flexibility in the future as well through improved control?



Flexible supply: observations

- ✎ Mostly provided by mid- and peak-load power plants.
 - ✎ These are bound by technical constraints:
 - 🏠 Start-up time, minimum load requirement, ramp rate, etc.
- ✎ Only a share of the installed capacity is able to offer flexibility.
- ✎ These power plants currently experience lacking profitability:
 - ✎ Low electricity prices
 - ✎ Limited number of operational hours
- ✎ Flexibility will in the future also be provided by variable RES.
 - ✎ Example Belgium: downward R2 wind project 'Estinnes'.
 - ✎ Wind providing upward reserve capacity as well in the future?
 - ✎ PV as flexibility provider through improved control and aggregation?

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Flexible demand

🌿 Definition:

- ✦ Change in electric usage pattern of end-users.
- ✦ In response to price signals or incentive payments.

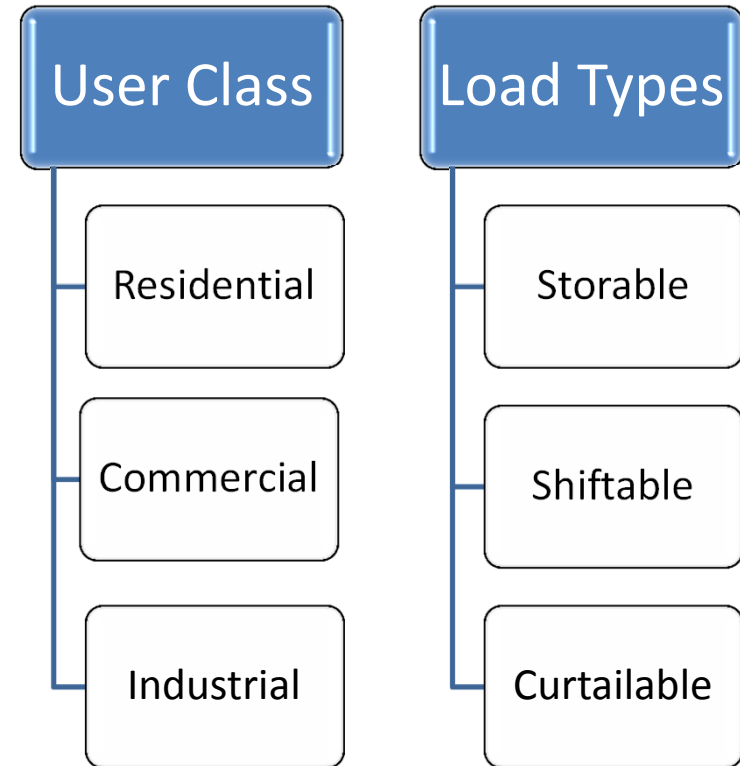
🌿 Increasing relevance due to:

Balancing variable generation requires flexible resources

Efficient way to cope with occasional peaks in demand

Market reform: liberalization and unbundling

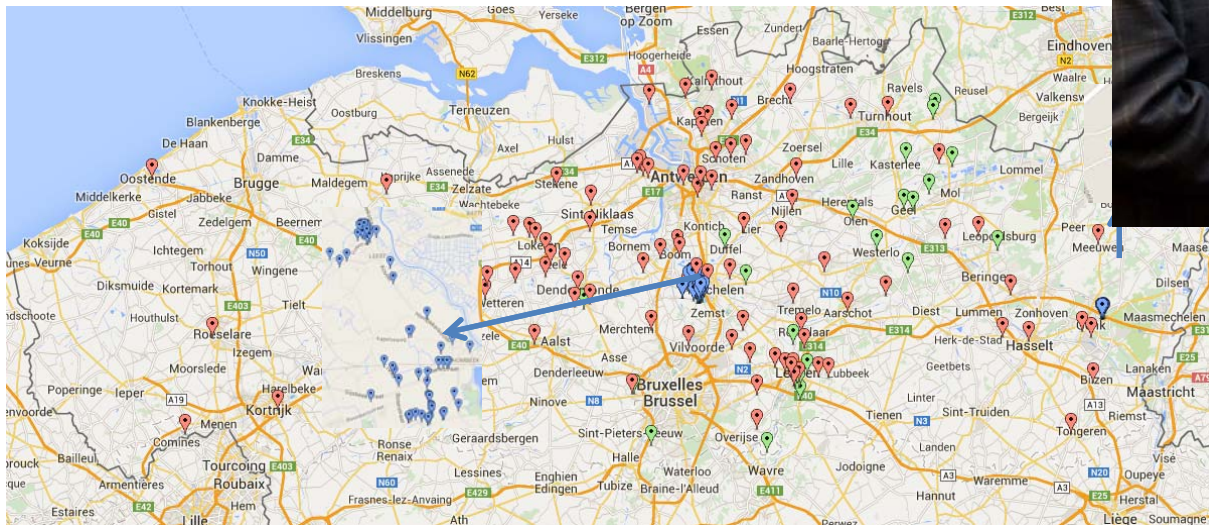
Cost reductions in telecom, control systems and computation



Flexible residential demand: case study Flanders

The Linear project

- 2009-2015
- 250 households participating
- Total budget € 30 million



Flexible demand: observations

- ✦ Share of flexible demand is increasing.
 - ✦ It is still the smallest flexibility provider today.
 - ✦ Will play a significant role with improving equipment.
- ✦ Still a relatively immature flexibility provider.
 - ✦ Its cost will decrease as more potential is tapped in.
 - ✦ However, current capacity may be “low hanging fruit”.
- ✦ Energy efficiency in the electricity sector may reduce potential.

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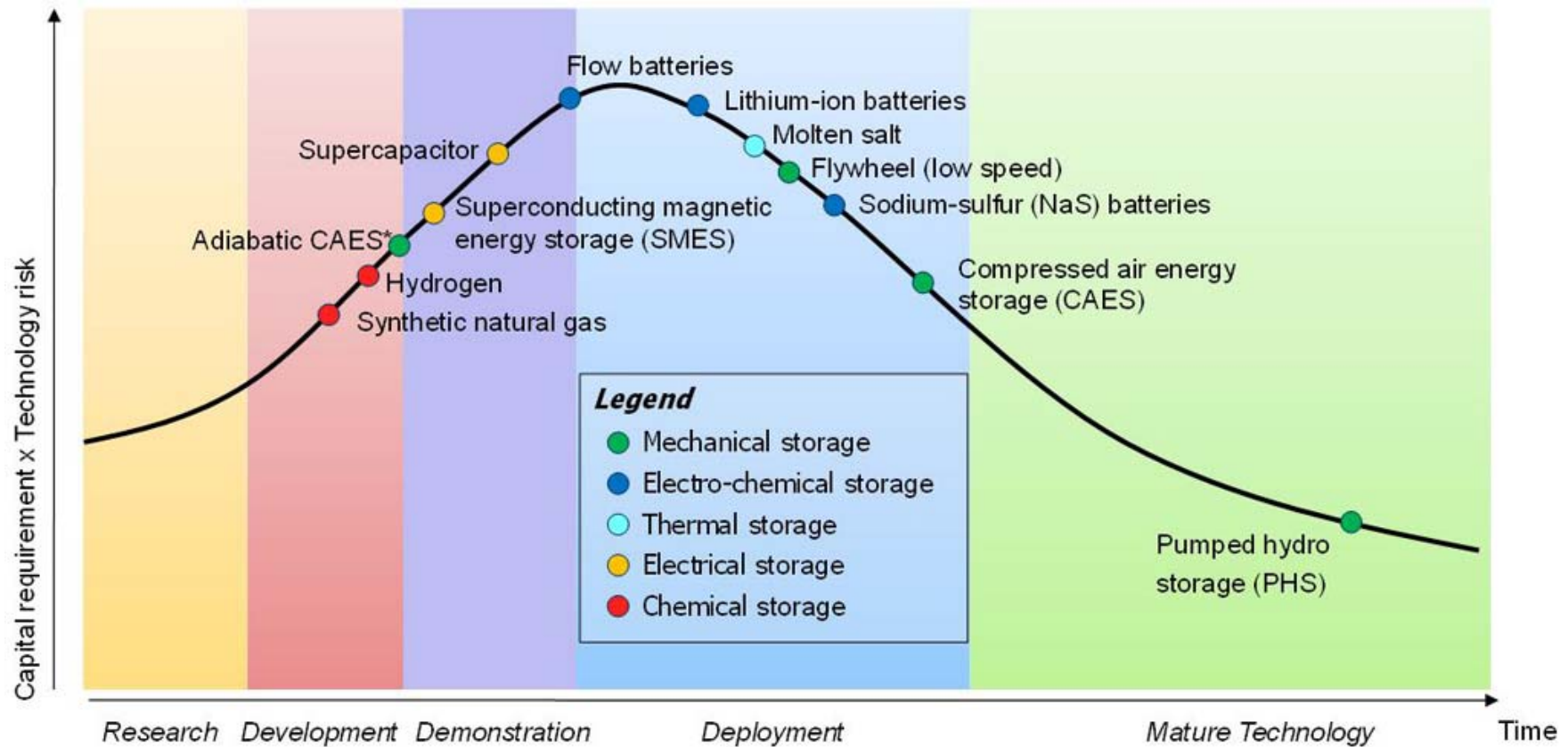
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Storage capacity: maturity



SBC Energy Institute Analysis

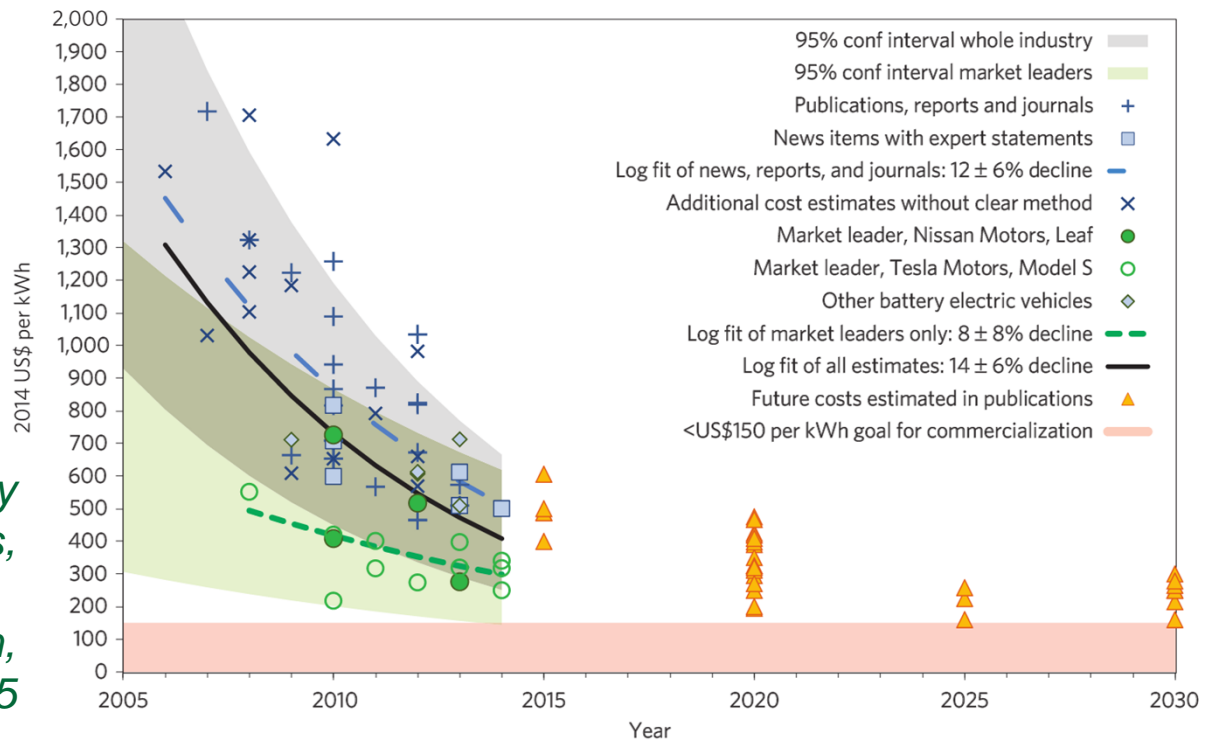
Storage capacity: batteries

Pro:

- ✦ Scalability
- ✦ Efficiency
- ✦ Energy Density
- ✦ Mass Production

Rapidly falling costs of battery packs for electric vehicles,

*Björn Nykvist and Måns Nilsson,
Nature Climate Change, 2015*



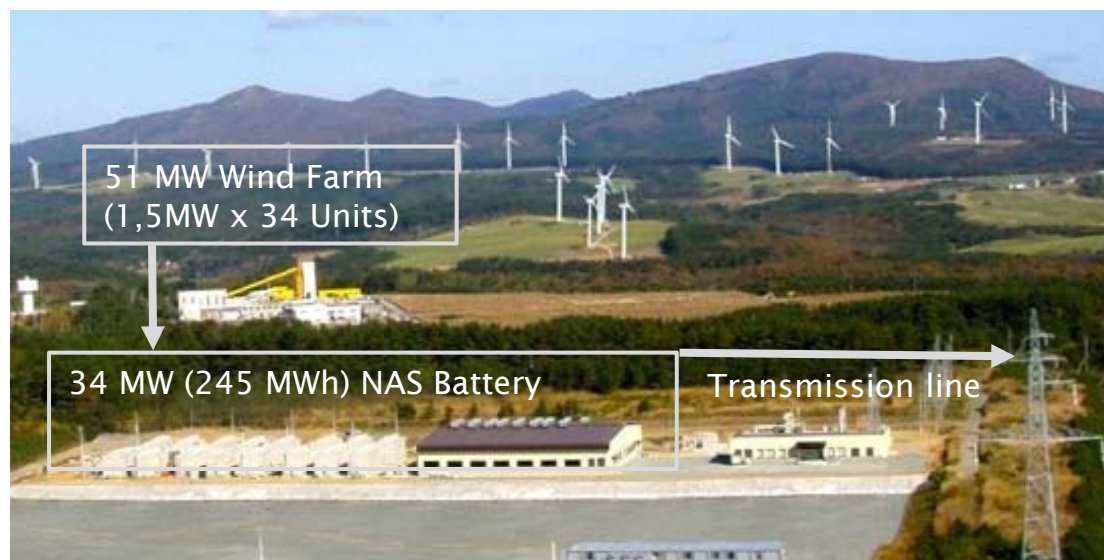
Storage capacity: batteries

Transmission Grid



West Mecklenburg, Germany

RES portfolio management

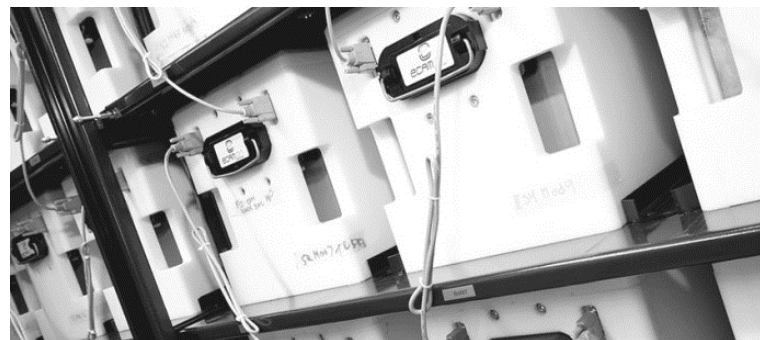


Rokkasho Futamata
Wind Farm, Japan

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Storage capacity: batteries

Community Energy Storage



Toronto, Canada

Residential level



SolarCity, Tesla Powerwall



Tesla Motors

Storage capacity: observations

≈ Pure flexibility providers

- ✦ Very few operational constraints
- ✦ Can use full power rating for both up- and downward power adjustments

A wide range of storage technologies

- ✦ Small-scale ↔ Bulk
- ✦ Power-based ↔ Energy-based

Challenges are mostly

- ✦ cost-related
- ✦ the limited cycle-life (batteries)
- ✦ the roundtrip efficiency

Most bulk storage is constrained by geographical requirements

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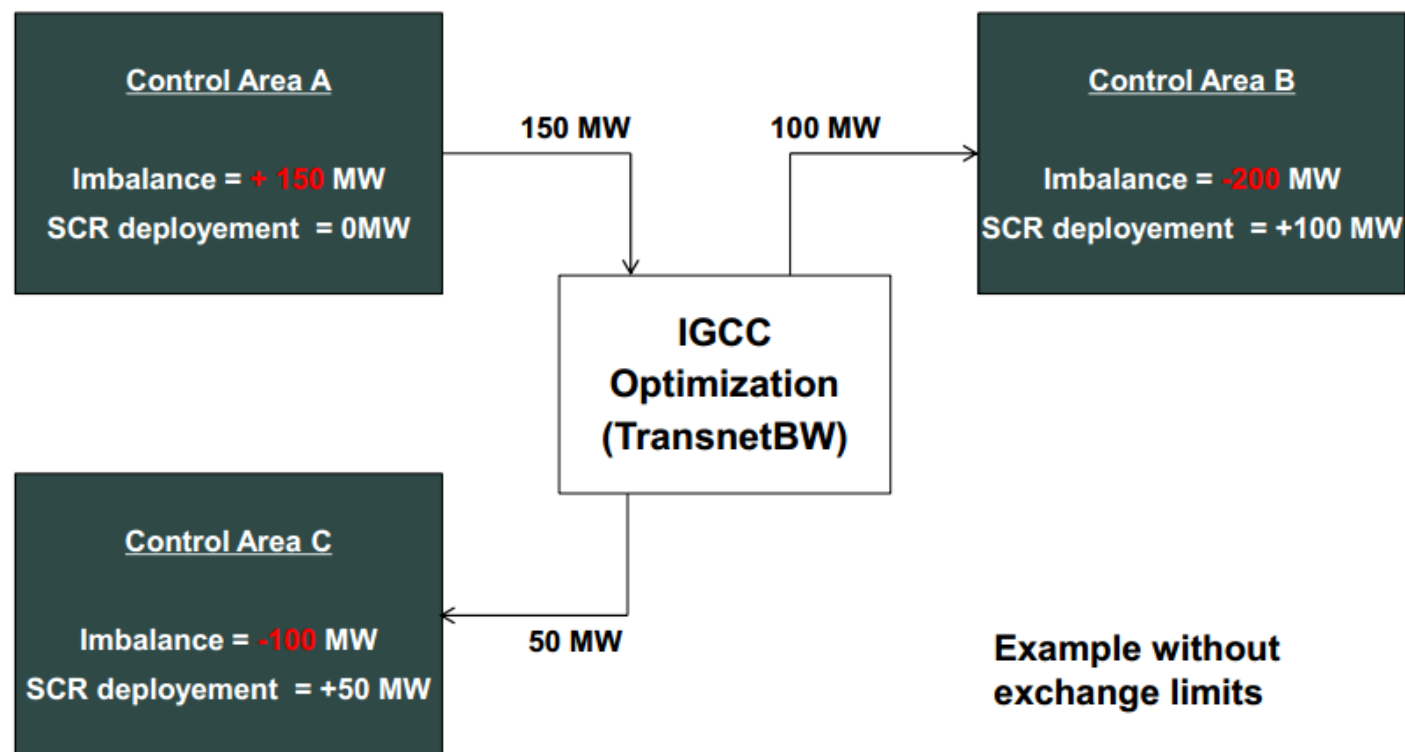
 Flexibility services

International Cooperation: IGCC

Netting of cross-border imbalance

✦ Germany, Belgium, The Netherlands

✦ Not guaranteed



Grid capacity: observations

- ✦ Grid capacity is a “vehicle” for flexibility.
 - ✦ Enables the activation of flexibility in neighboring regions.
- ✦ Can use full power rating for both up- and downward power adjustments.
- ✦ Import/export is not guaranteed at every moment.
- ✦ Not every installed MW grid capacity leads to a flexible MW.
 - ✦ Technical constraints (N-1, internal congestion, ...)
 - ✦ Commercial constraints (mid and long term contracting)
- ✦ Grid capacity can also be seen as an ally for other flexibility sources.
 - ✦ It can create additional flexibility needs by importing “problems”.
 - ✦ It allows flexibility to offer services towards other regions.

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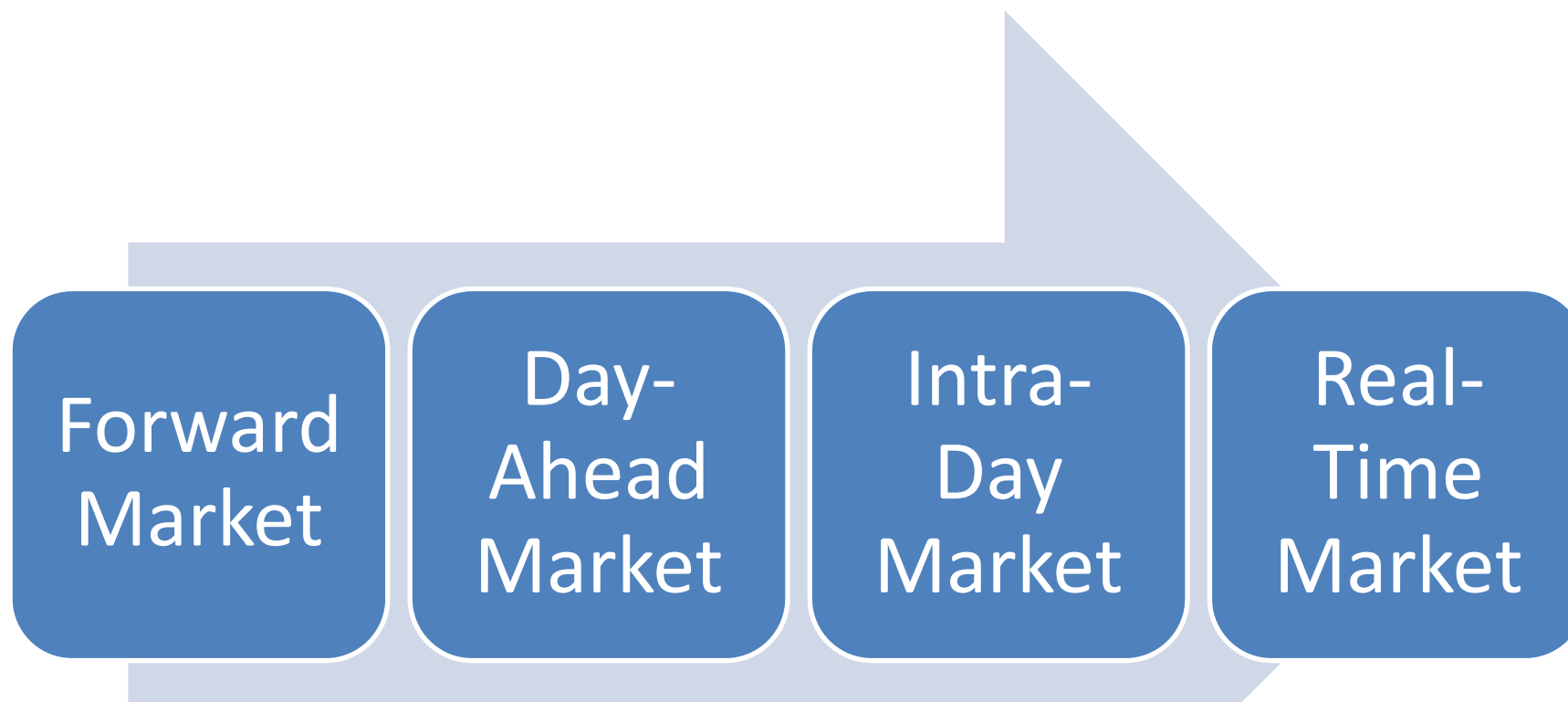
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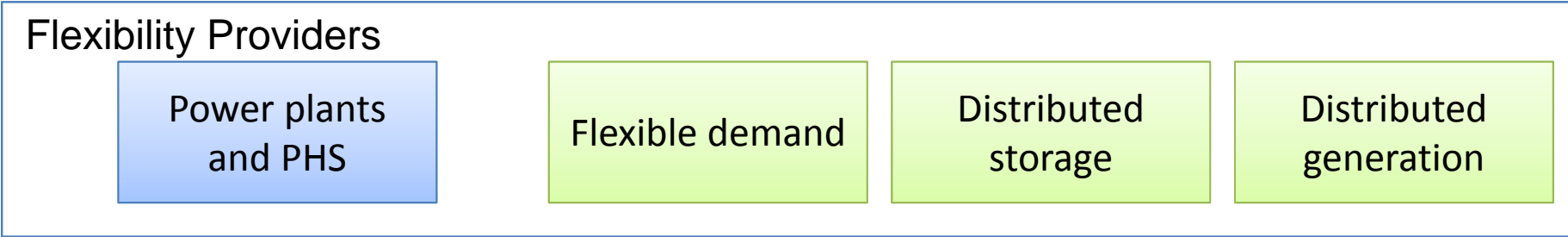
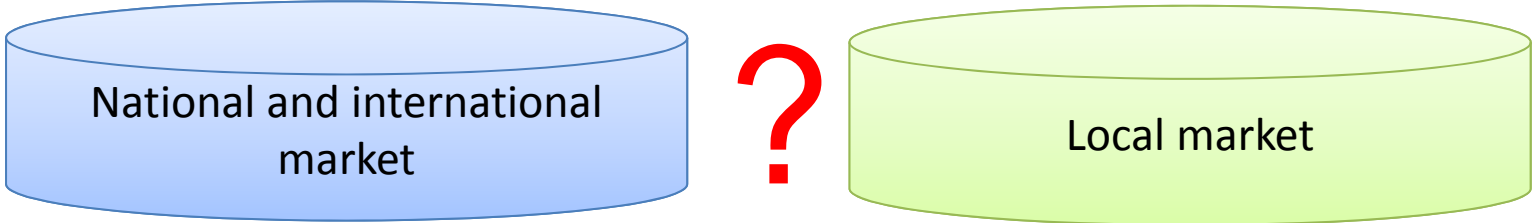
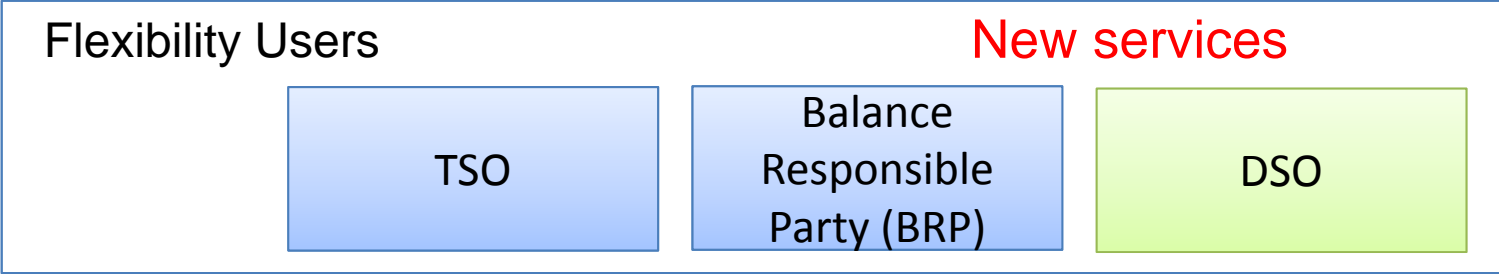
 Flexibility services

Flexibility services: energy services



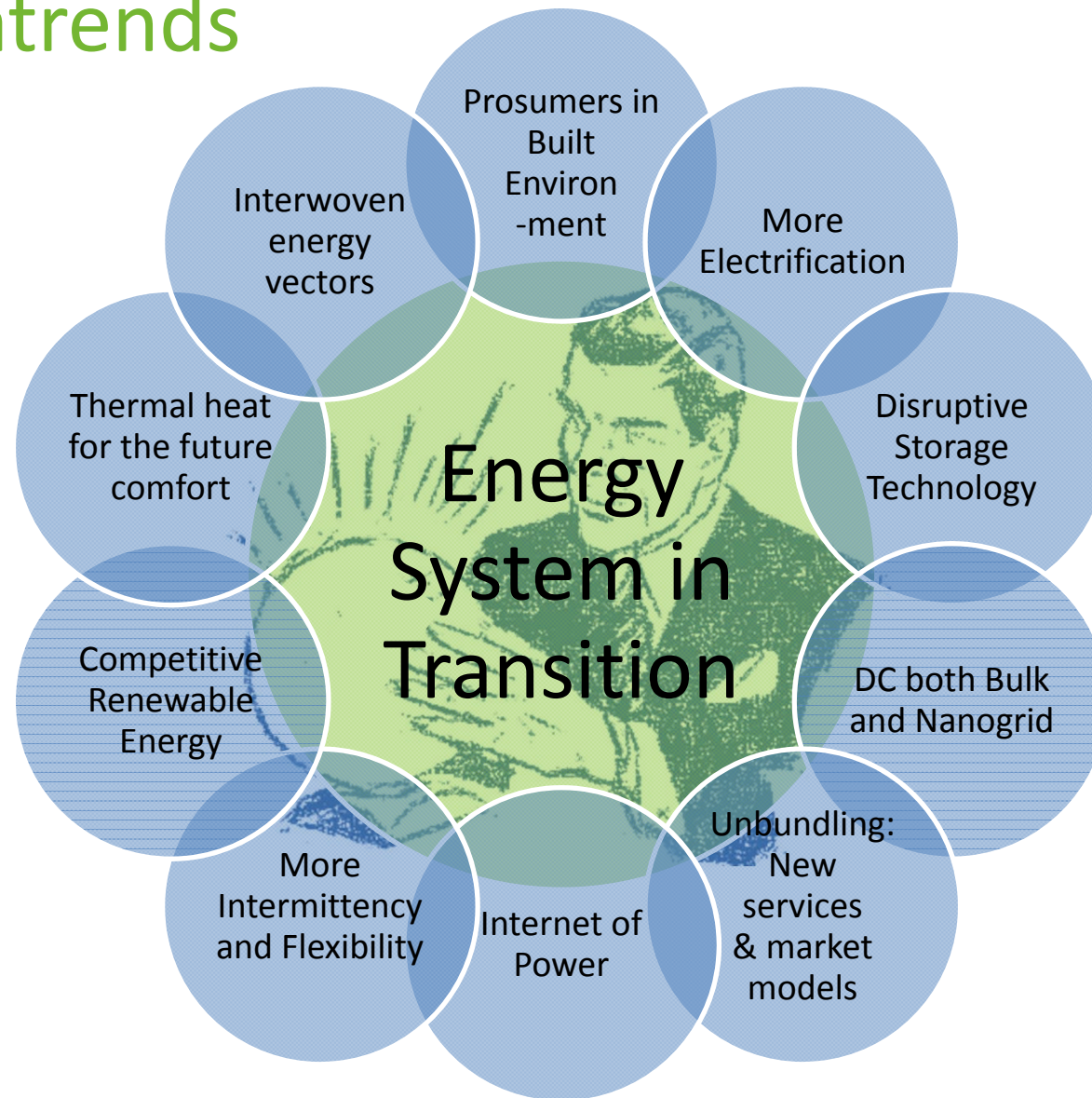
Participating in consecutive electricity markets, moving towards more complex operation strategies closer to real-time.

Flexibility services: flexibility markets



Is it an Revolution? You ain't seen nothing yet

Megatrends



Two markets

Large Energy Consumers

- ✦ Commodity
- ✦ PRICE, PRICE, PRICE and reliability
- ✦ Electricity and gas are products
- ✦ Europe based

Service for Small Consumers

- ✦ Energy sources: do not care
- ✦ Comfort, well-being
- ✦ SME: Sit back and relax
- ✦ Local-based (Flanders,)

Small Energy Consumers

- 🌿 Home: gas, heat, electricity
- 🌿 SME: manufacturing
- 🌿 Office Buildings
- 🌿 Specific buildings (hospitals, education, ...)
- 🌿 Ownership is critical

Is Energy Efficiency THE Issue?

- Comfort or efficiency
- What if marginal cost is zero?
- Capex versus Opex
- Flexibility may cause energy loss
(cooling warehouses)
- Quality of energy:
low temperature heat versus electricity
- Better efficiency, less flexibility

Less energy – More electricity – Smart Heat

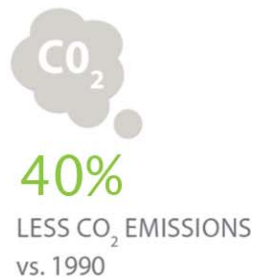
- ✦ Better insulation: electric heating & increased potential for renewables
- ✦ Heat pumps: combination of green electricity and green heat
- ✦ Advanced heat networks (4th generation)
- ✦ Renewables: common carrier is electricity
- ✦ Transport
- ✦ Gas demand goes down

The end of the kWh as billing unit for energy

- 🌿 30 % is commodity (energy) cost
- 🌿 40 % grid
- 🌿 30 % levies
- 🌿 Only for commodity kWh is relevant
- 🌿 Grid: capacity
- 🌿 Levies: policy
- 🌿 Commodity is marginal cost, goes to zero
- 🌿 Capacity for grid service
- 🌿 Local generation/storage: disconnection feasible?
- 🌿 Insurance contracts

The world is changing

Europe:



The world is changing

Europe:



40%

LESS CO₂ EMISSIONS
vs. 1990

27%

MORE RENEWABLE
ENERGY USE

The world is changing

Europe:



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LESS CO₂ EMISSIONS
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MORE RENEWABLE
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LESS PRIMARY
ENERGY USE vs. BAU*

The world is changing

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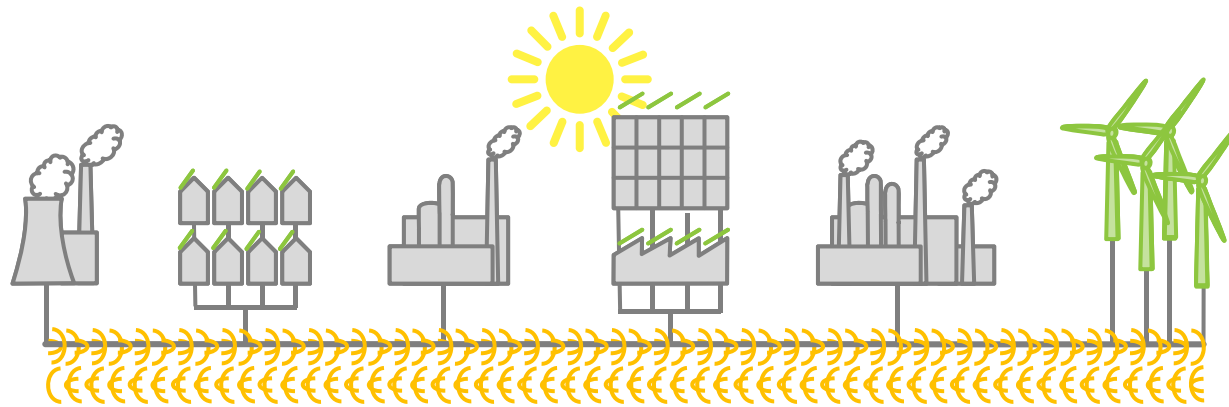
LESS PRIMARY
ENERGY USE vs. BAU*

By the year

2030

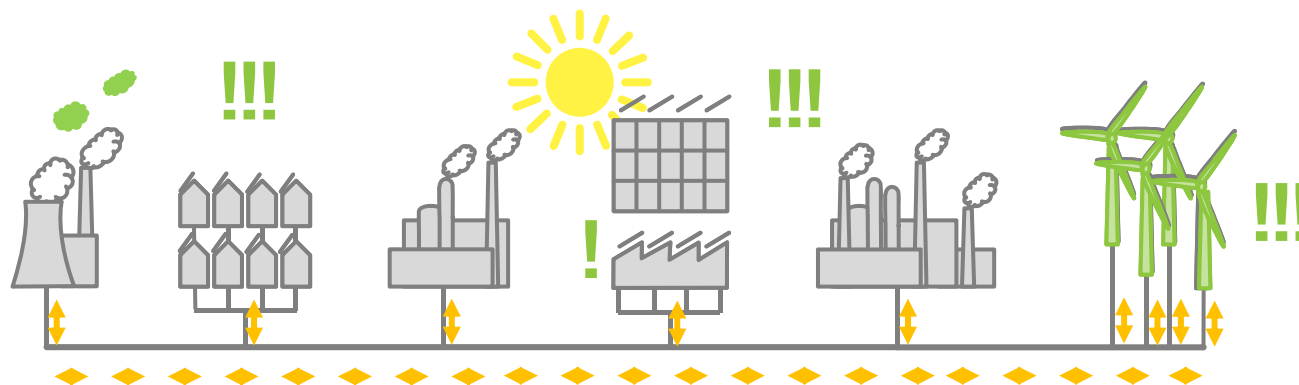
*Business As Usual

Trends



- Large-scale integration of Renewable Energy Sources
- Large-scale integration of Distributed Energy Resources
- Evolution towards smart grids

Challenges



- Demand drives generation ↔ generation drives demand
- Bidirectional flows
- Techno-economical puzzle:
coordinated grid actions with all the players involved

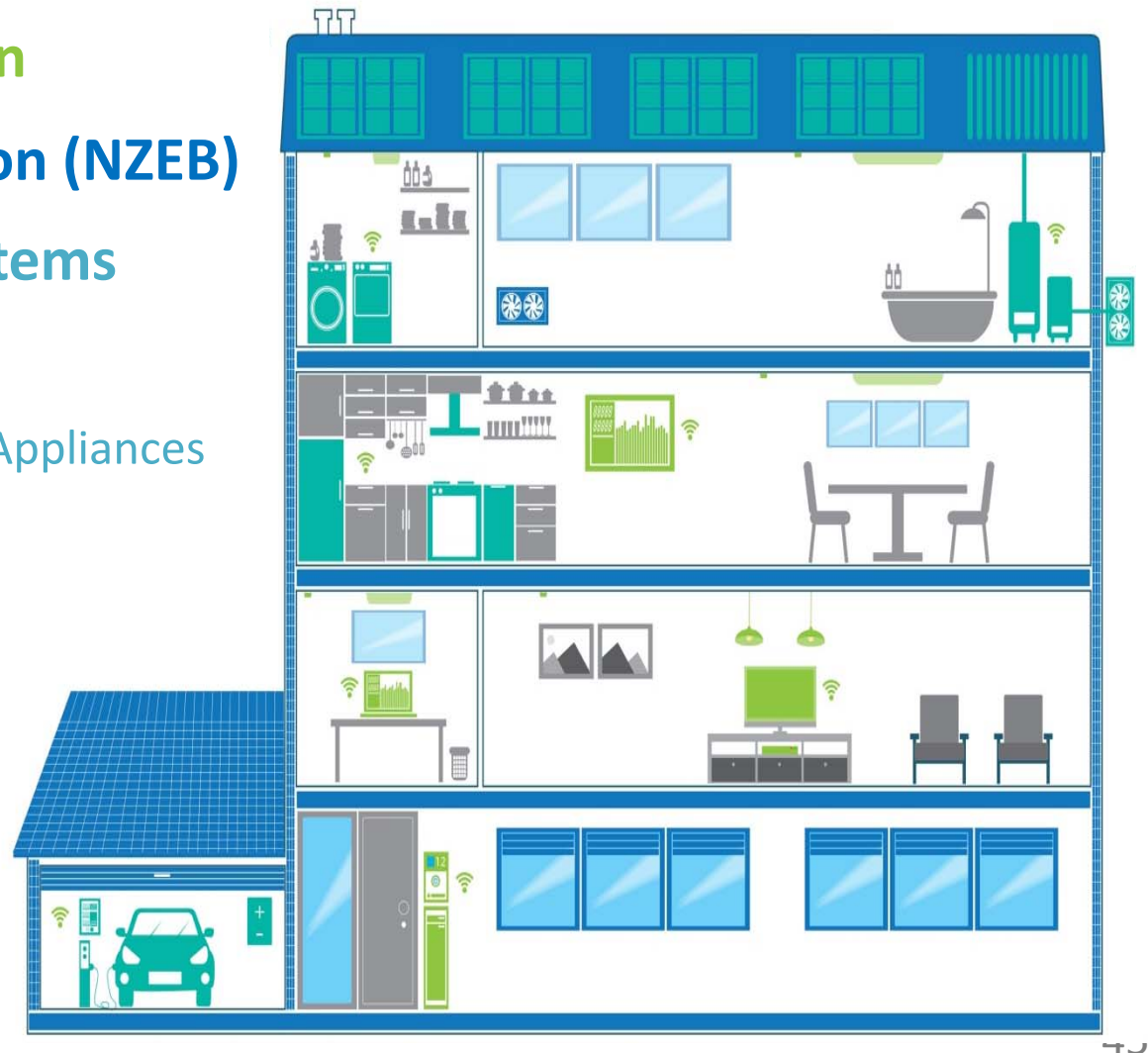
Smart Homes ... from which perspective?

🌿 Home Automation

🌿 Smart Construction (NZEB)

🌿 Smart Energy Systems

- 🌿 Smart heat Pump
- 🌿 Solar panels
- 🌿 Smart Household Appliances
- 🌿 EV Charging

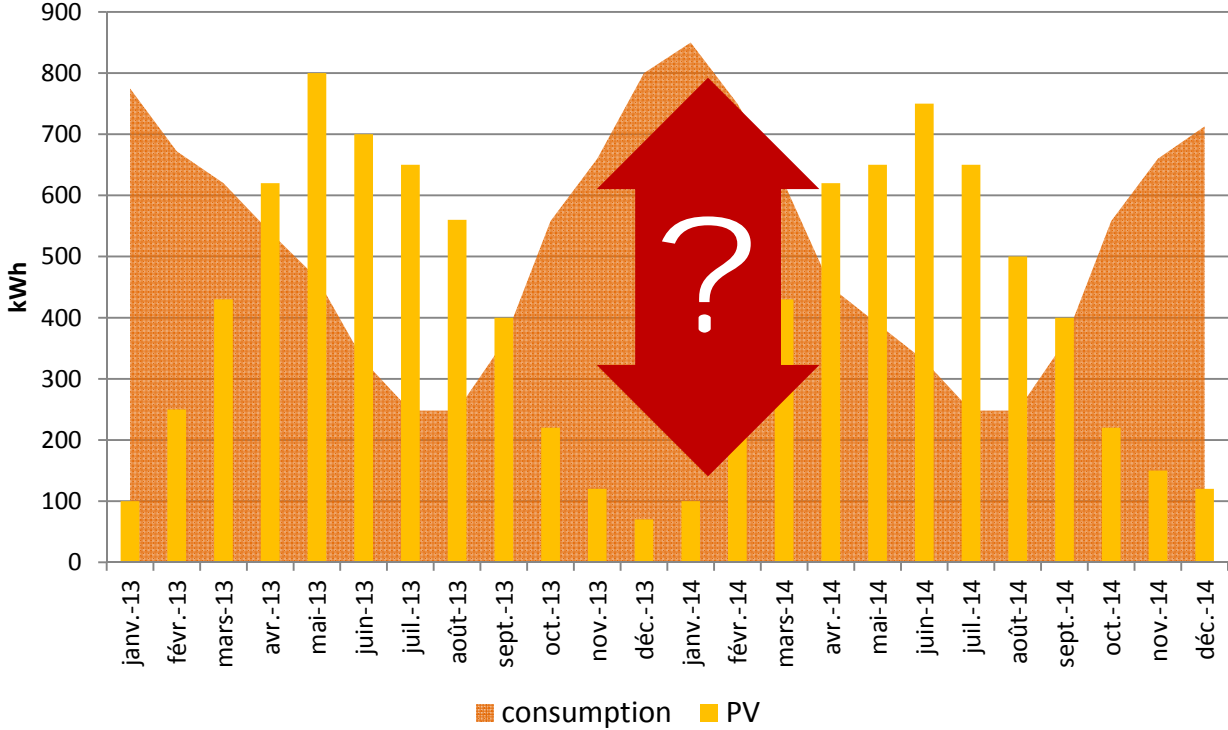


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Nearly Zero Energy Buildings

And the reality of energy markets

Insulation
Ventilation
Heat pumps
+ PV



Your Home, an Intelligent Energy Cluster

Investments

† ROI
(financial)



reduce CONNECTION CAPACITY, while
increasing total electricity consumption

† Peace of mind
(insurance)



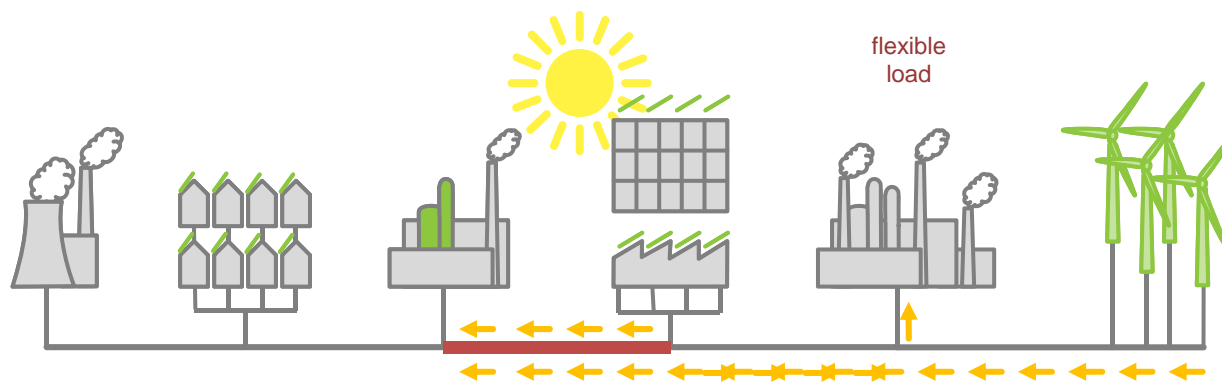
Back-up = STORAGE
HEATING + DC (LED, multimedia, mobility,
...)

† Time Management
(comfort)



AUTOMATED SYSTEMS
climate control, cost savings ToU prices

Consumer Flexibility: demand response



When
overload

Active



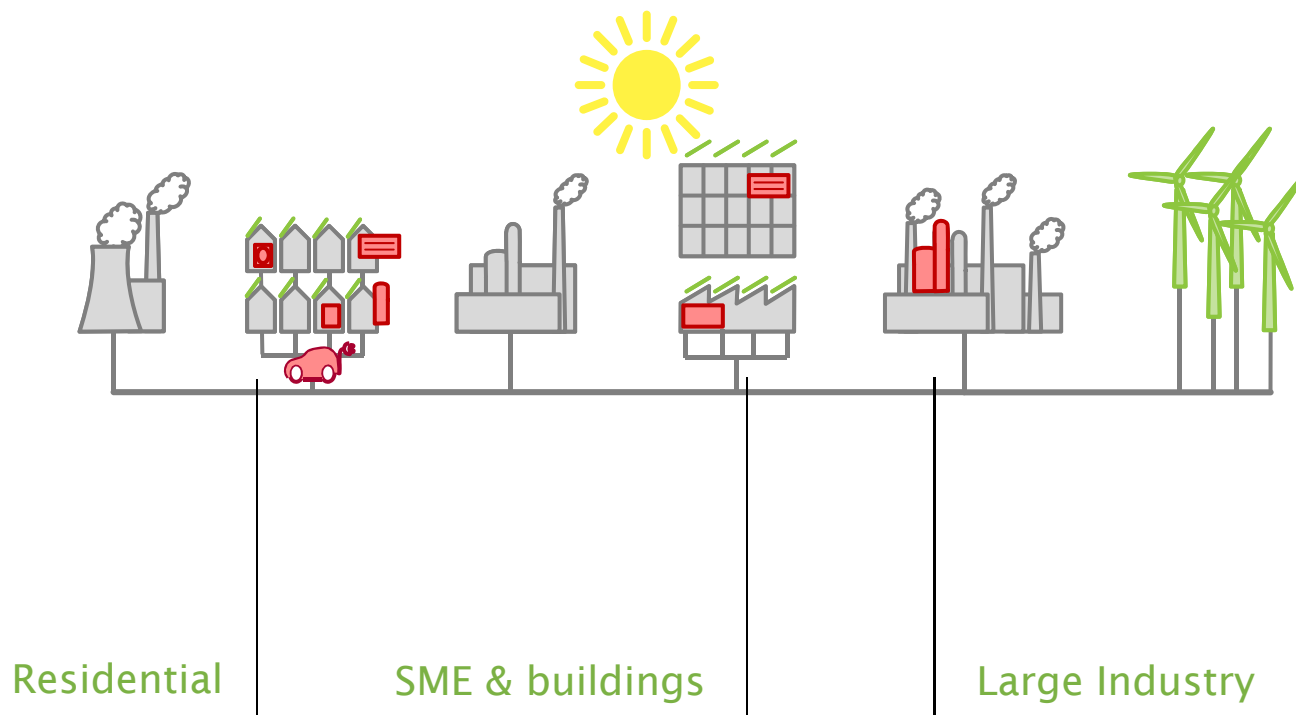
lots of renewable energy are injected, grid
is possible

flexible demand can solve this

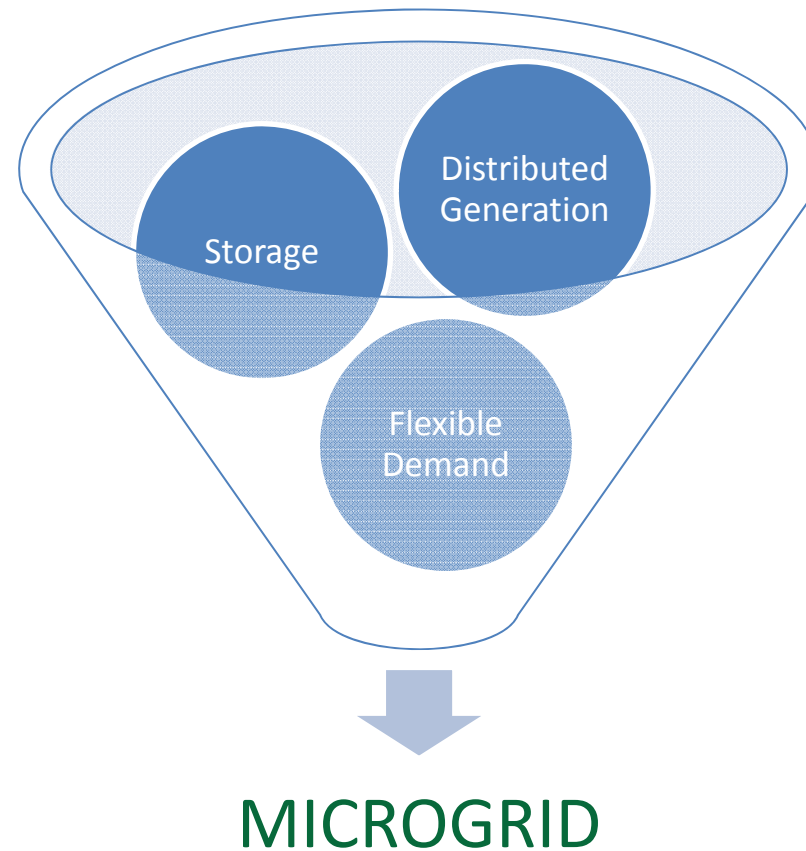
Quote (Art. 15.8) from the European Commission Energy Efficiency Directive (2012/27/EU):

“Member states shall promote access to and participation of Demand Response in balancing, reserves and other system services markets”

Sources of Consumer Flexibility






Back to the future: Decentralised Supply



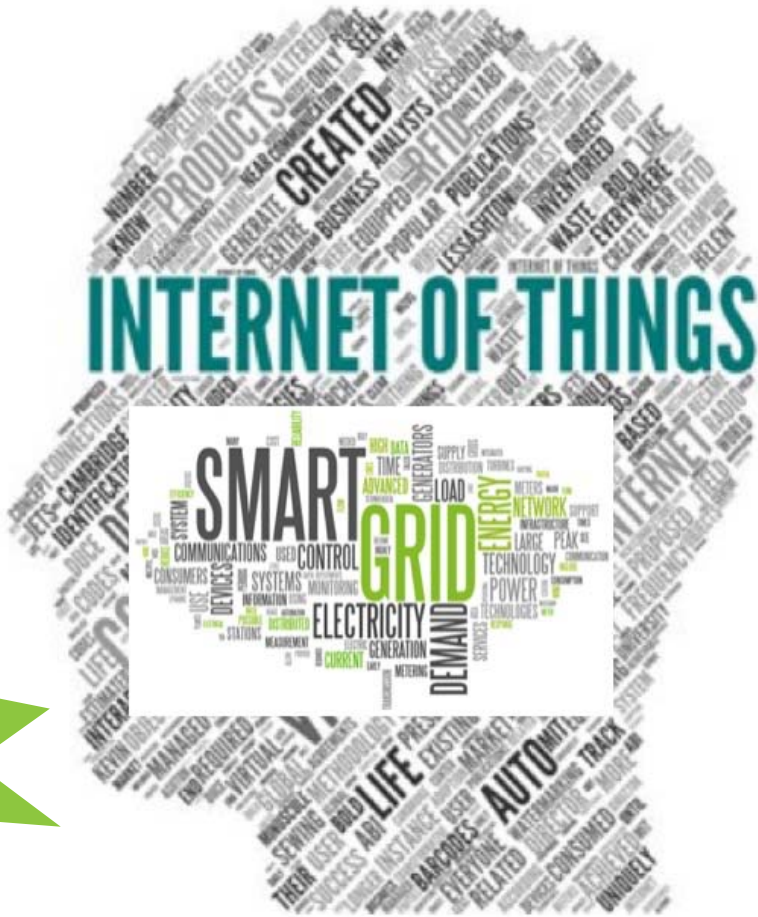
Why would flexibility work now?

 We've already seen:

-  Demand-side management
-  Decentralised systems
-  Electrical vehicles

Why would flexibility work now?

-  All devices communicate with each other
-  Share information
-  Greater efficiency
-  Automation
-  Security
-  Comfort





More info?

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