FACULTY OF ENGINEERING AND ARCHITECTURE

FUTURE GRID FLEXIBILITY

ENERGY VERSUS POWER OF STORAGE

SUPPLY AND DEMAND

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CONTENT

- Energy versus Power
- Supply versus Demand in case of RES
- Consequences for Grid Balancing
- Challenges for Storage Systems
- Challenges by 2020/2035
- Conclusions

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ENERGY VERSUS POWER

1kWh ≠ 1kW

1kWh can equal: 10kW during 6 minutes
1kW during 1 hour
100W during 10 hour
All combinations of W.h=1.000

To be interpreted as:

- “Classical” power plant can deliver nominal power during a long time
- Renewable sources (sun/wind) only can deliver nominal power in case of sufficient sun/wind, so here, power is not related to energy
- Batteries cannot deliver or store arbitrary combinations of power in time for a given capacity (Ah) of energy content (kWh)

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ENERGY VERSUS POWER

Power versus Consumption
21GW vs 83TWh*/year

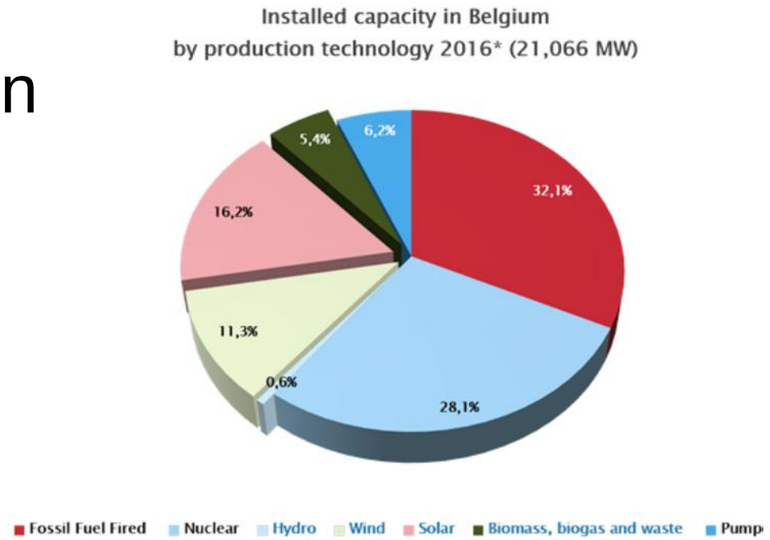
Wind: 2,3 GW delivers 6,4%

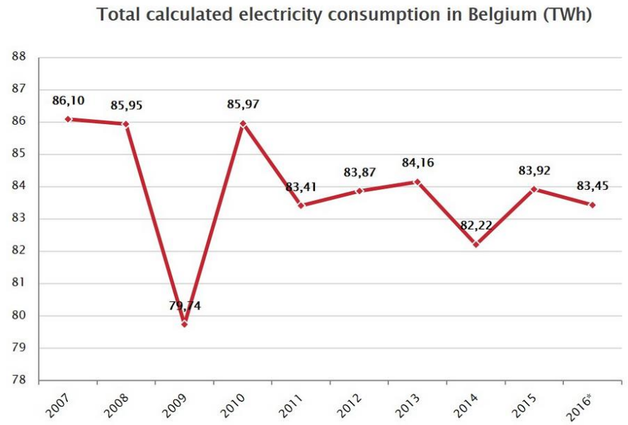
Water: 1,4 GW delivers 1,8%

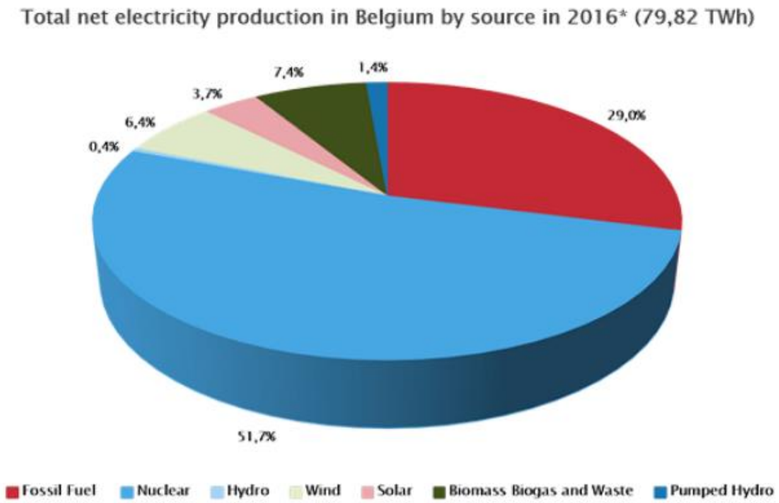
Sun: 3,3GW delivers 3,7%

Biomass: 1,1GW delivers 7,4%

“Classic”: 12,6GW is responsible for >80% of produced energy







Conclusion

Approximately 30% of the installed POWER of renewable energy sources guarantee only 10% of supply of demand ENERGY

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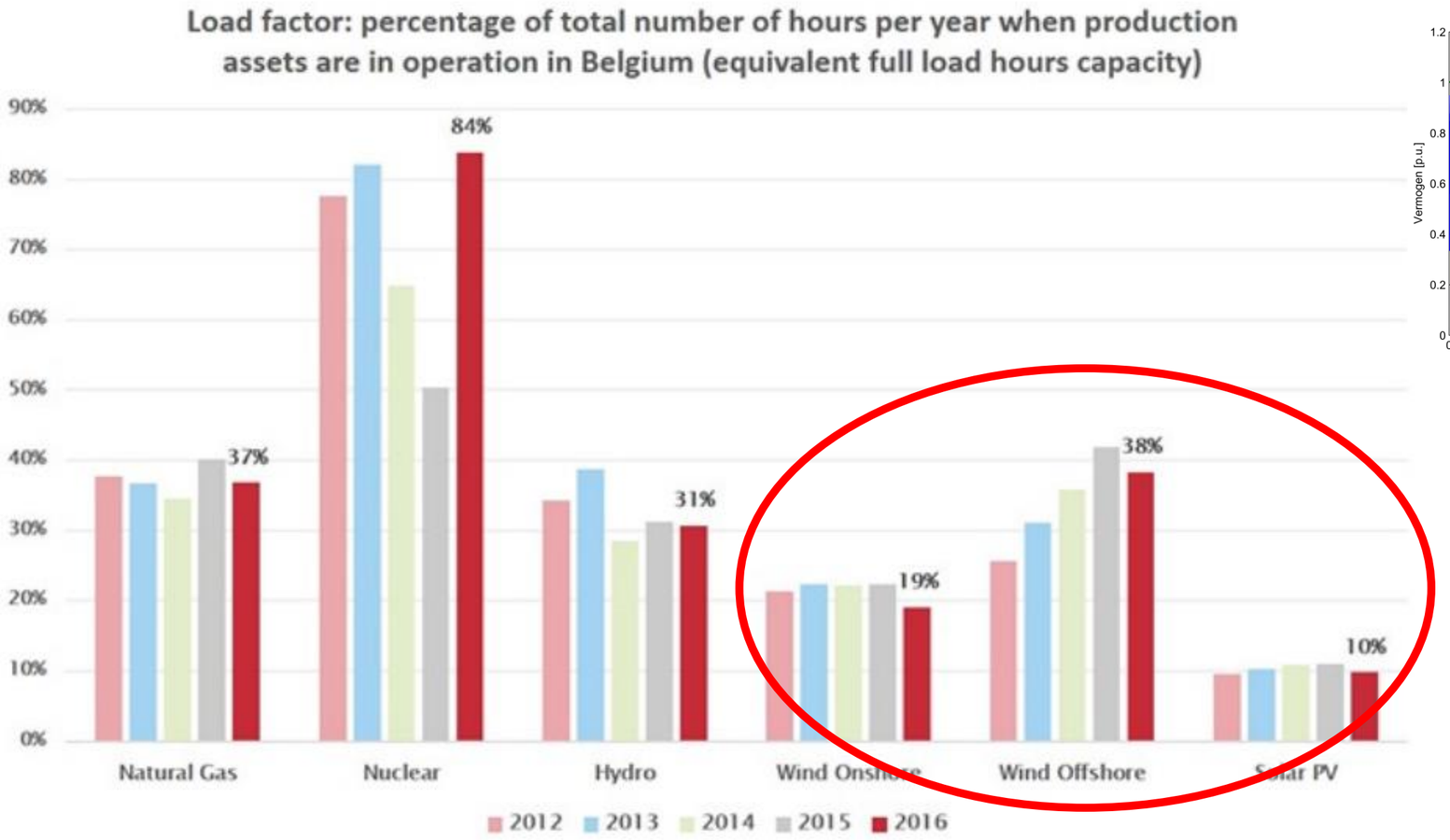
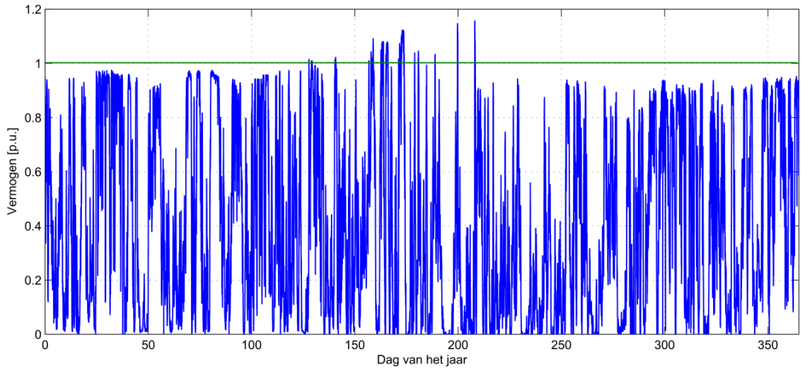
*1 TWh = 1.000 GWh = 1.000.000 MWh = 1.000.000.000 kWh

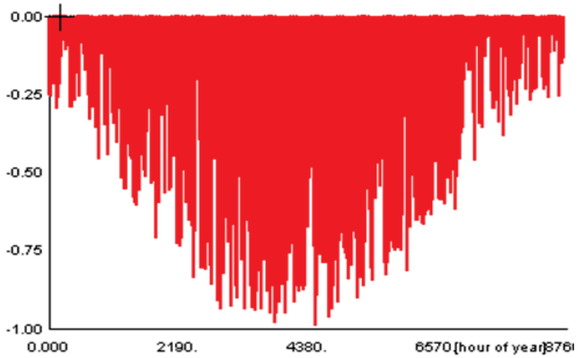
https://www.febeg.be/statistieken-elektriciteit

SUPPLY VERSUS DEMAND IN CASE OF RES





Normalised Off Shore Wind in BE



Standardised Yield of PV

Conclusion

Capacity factor of renewable energy sources varies between 10 and 40% max

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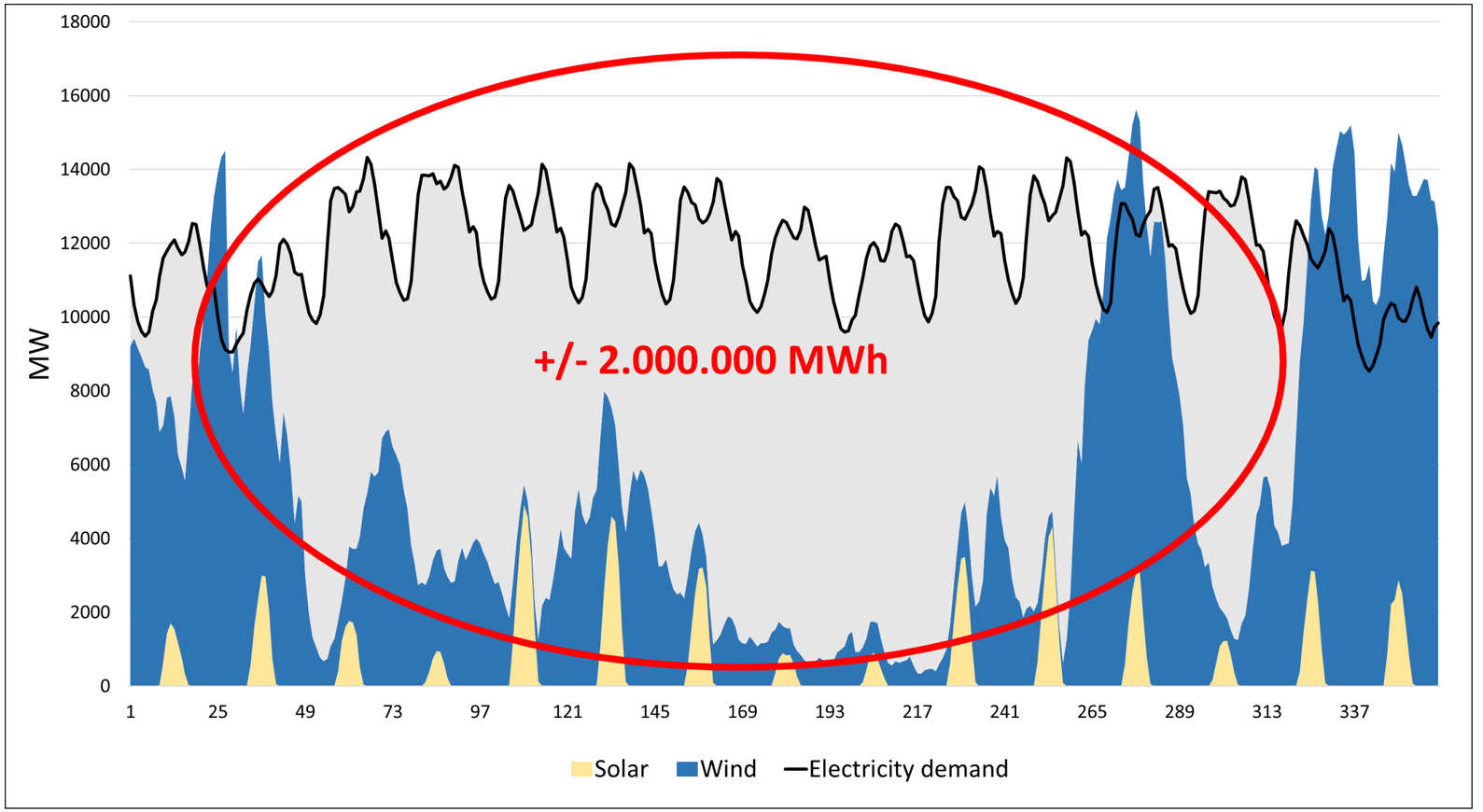
https://www.febeg.be/statistieken-elektriciteit

InterReg IV: CO2 en CH4 als dragers van Regionale ontwikkeling

SUPPLY VERSUS DEMAND IN CASE OF RES

“Dunkelflaute/Darkless/Donker luwte” means the coincidence of lack of sun and wind and is a composition of ‘Dunkelheit’ (darkness/donker) and ‘Windflaute’ (windslessness/luwte).

An installed 20 GW PV solar plant and a 20 GW windfarm creating hardly (each) 3 GW, while demand in this period is2.000.000GWh



Conclusion

Need for over dimensioning and storage

Back-up needed to guarantee a LOLE <3u

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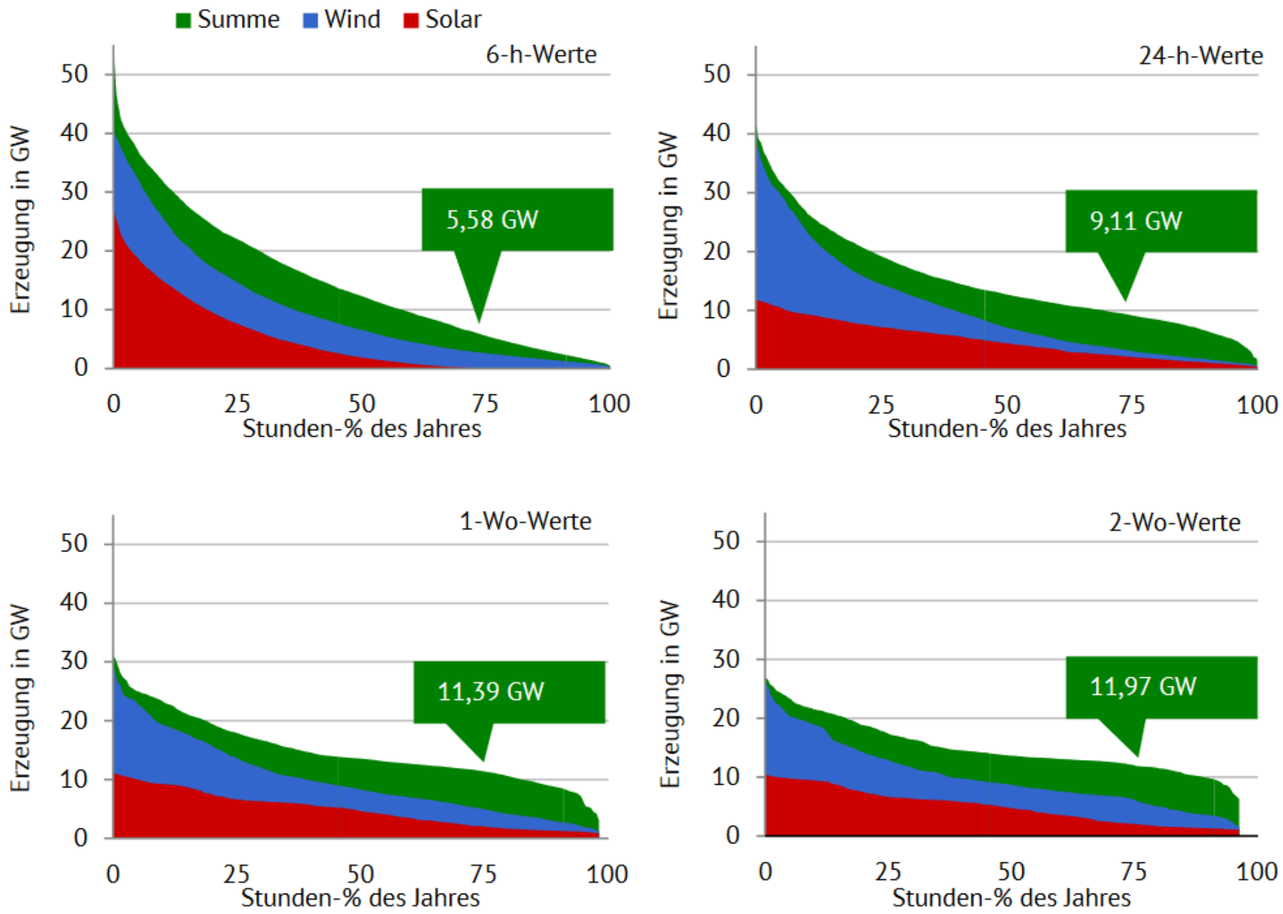
SUPPLY VERSUS DEMAND IN CASE OF RES

Summation of sun and wind production based on different time scales of averaging.

The higher the scale of averaging, the “better” the equability of the produced energy, but the more hidden the instantaneous peak production of the installed RES.



Conclusion

Need for power control, storage and flexibility

Feasibility storage: → Urge of Hybrid solutions

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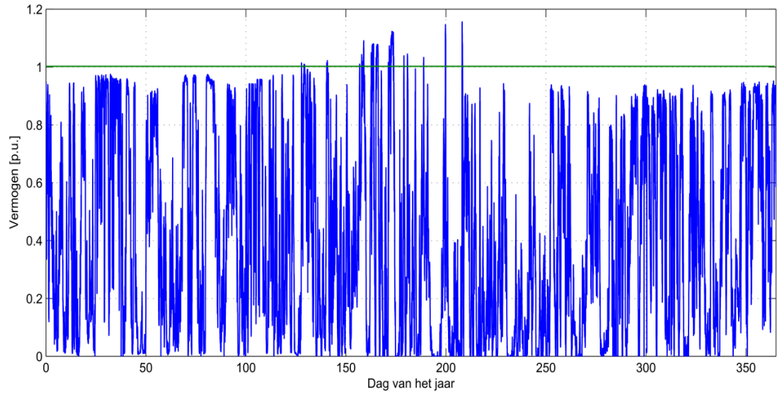
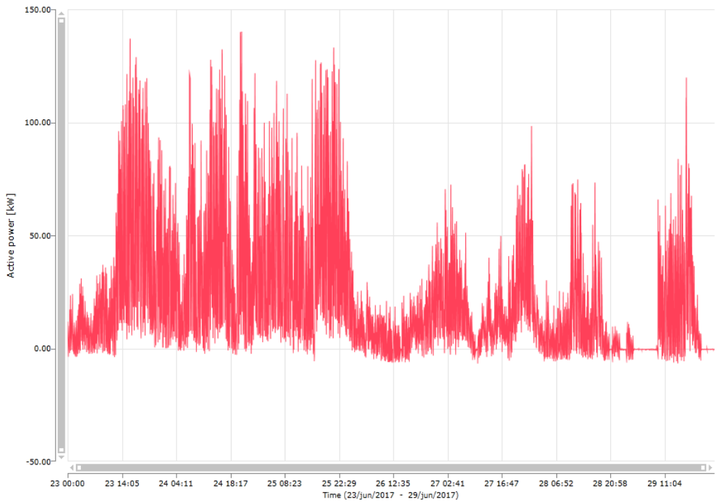
170629_GPE_Studie_Kalte-Dunkelflaute_Energy-Brainpool.pdf

SUPPLY VERSUS DEMAND IN CASE OF RES



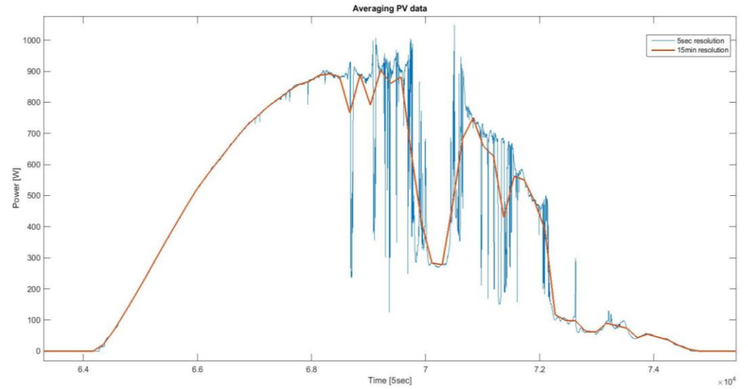
Normalised 15 min values Off Shore Wind in BE



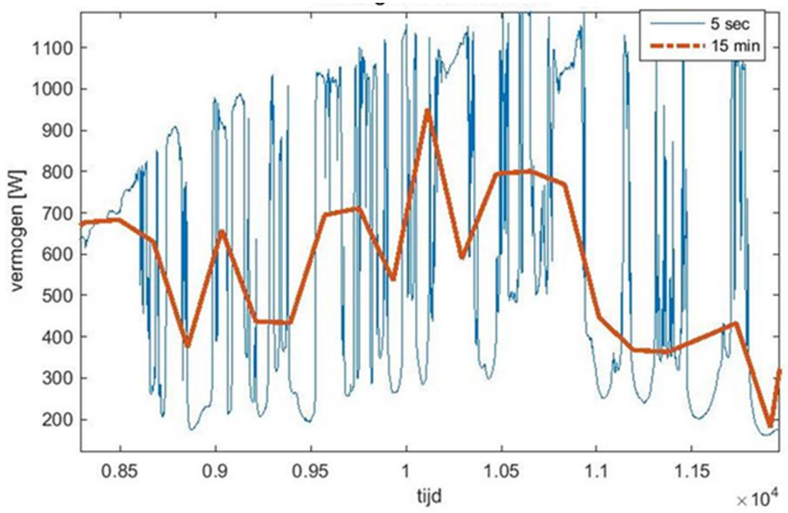
1 min values of a 150kVA Wind turbine

Yield of PV and Sun not only a function of location and emplacement, but even more strongly depending on (local) weather conditions.

The instantaneous yield can be strongly differ from the averaged 15 minute values, who are usually handled for yield calculations.



Daily and 5 minute variations of PV



15 minutes and 5 second variations of PV

Conclusion

Need for fast control systems to handle dynamic power changes of RES

Rotating inertia of the system decreases

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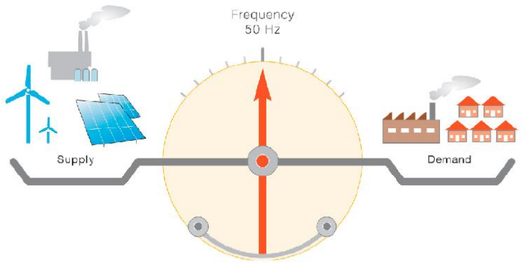
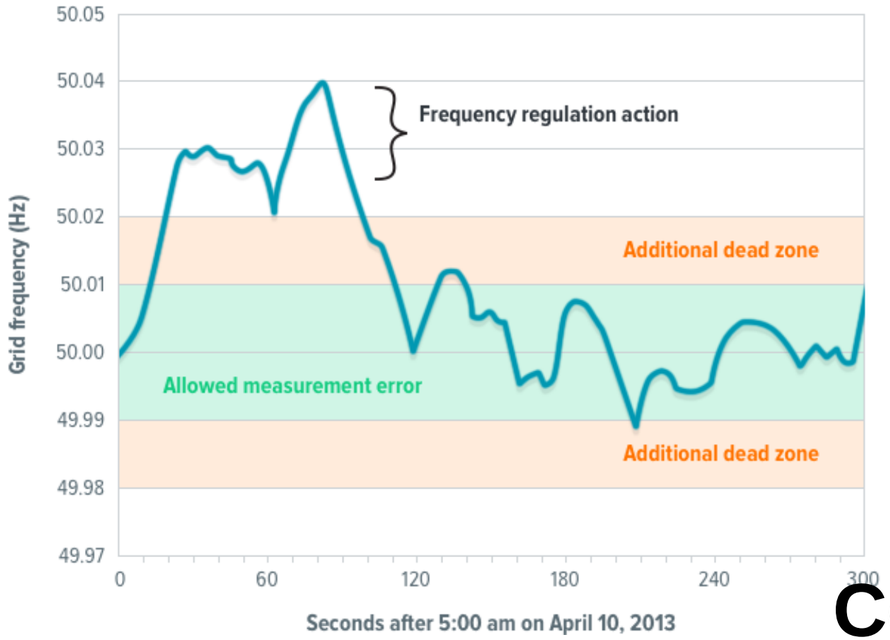
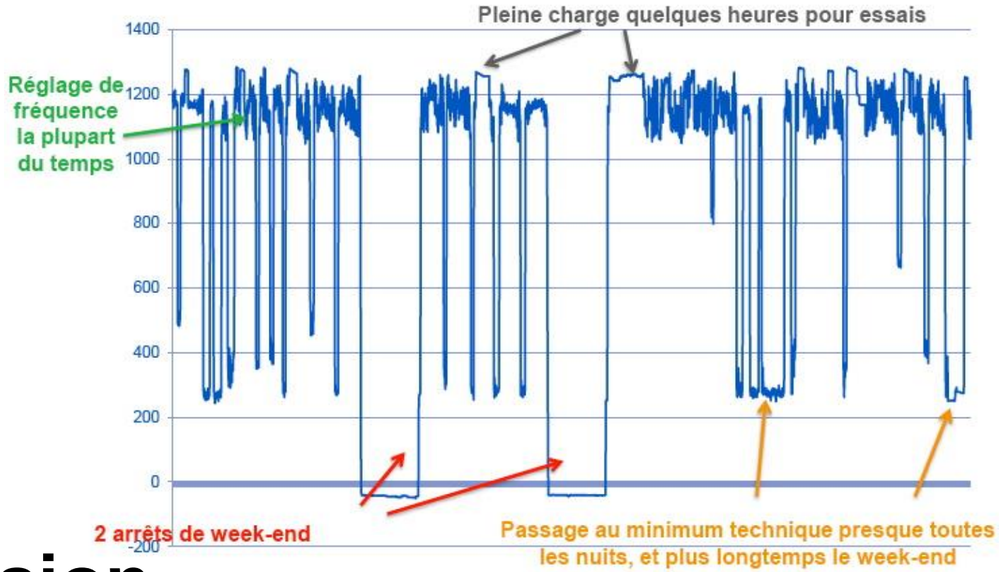
CONSEQUENCES FOR GRID BALANCING

Production and consumption of energy has to be in balance on each time window

- R0 = rotating reserve (statism) - Duration <1 sec
- R1 = FCR – Scale 100 MW - Duration: sec
- R2 = FCCa - Scale +100 MW - Duration: min
- R3 = FCCm (?) - Scale 1000 MW - Duration: hours
- R4 = Darkless – Scale +GW??? - Duration: days?







Conclusion

R1: Distributed, Autonomous, V2G? Anyway: very fast

R4: Classic PP, Hydro, STEG, TLS → hybrid solutions needed

https://jancovici.com/transition-energetique/renouvelables/100-renouvelable-pour-pas-plus-cher-fastoche/

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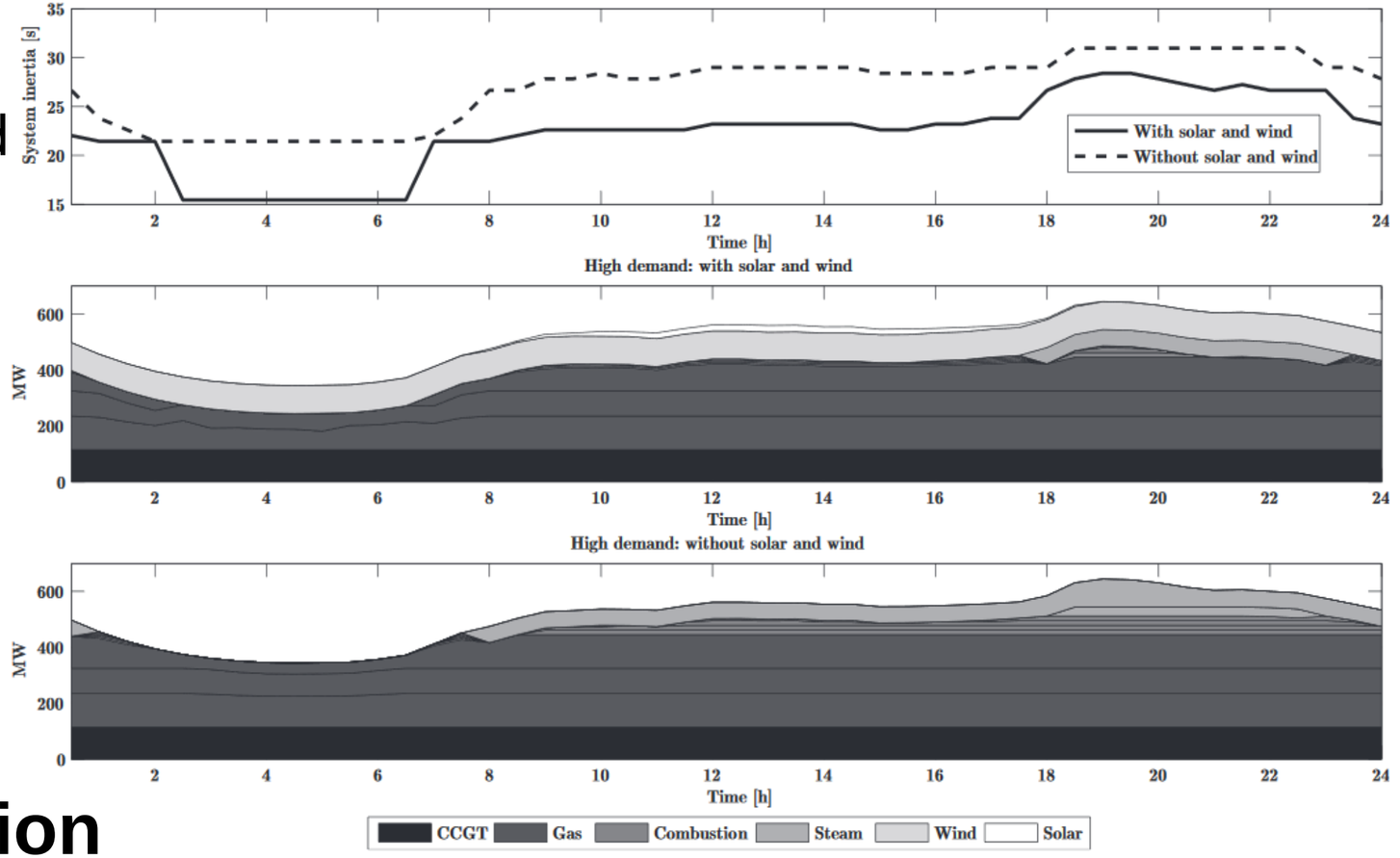
CONSEQUENCES FOR GRID BALANCING

- Increase of RES have a vast impact on grid stability
- Both “rotating inertia”, as FCR* and FCC** will be affected due to low inertia of RES and cannot maintain frequency stability
- Effects increase with increasing penetration of RES.
- Frequency control has to be redesigned in order to cover this issue.



Conclusion

Need for a greater volume and speed of frequency response to keep the system stable → EFCC

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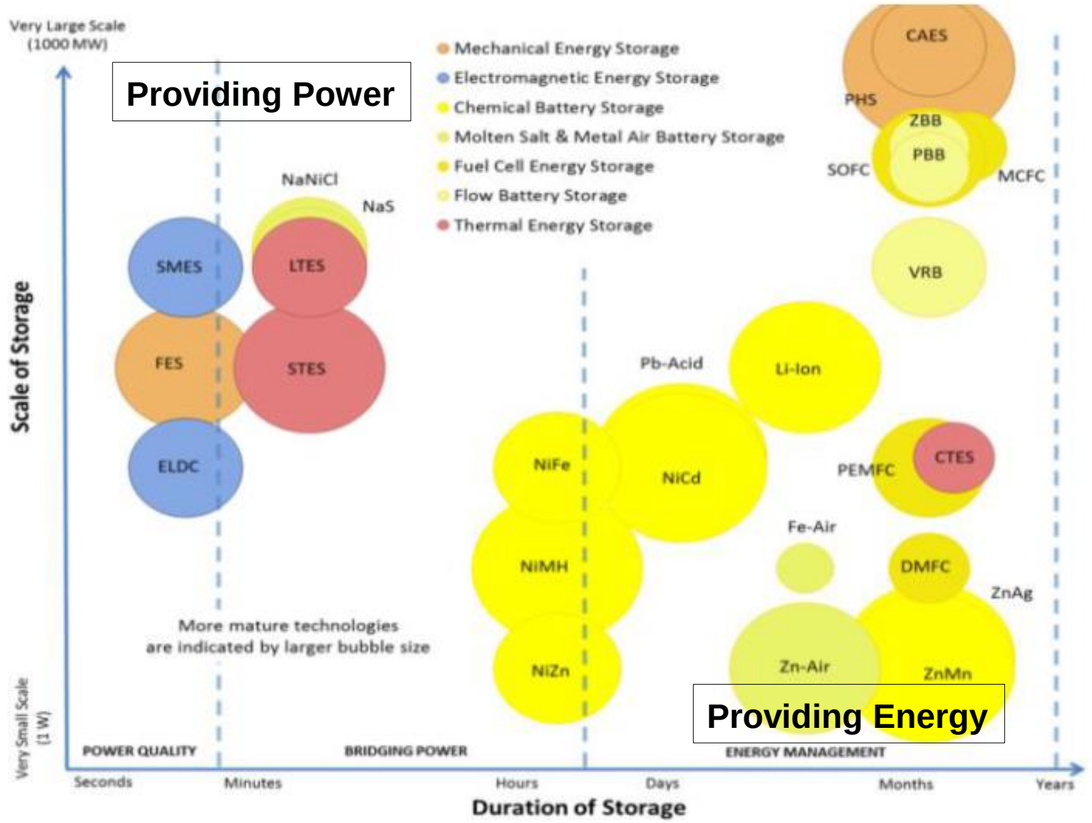
https://pdfs.semanticscholar.org/1cd1/9e3ae4b3ff6919570cf6faa693a13d21652a.pdf
Grid Inertia and Frequency Control in Power Systems with High Penetration of Renewables

CHALLENGES FOR STORAGE SYSTEMS

- Combining energy and power in load/production profiles
- “Merit order” of storage (cf. production sites): Ragone plot
- **How long and how fast do I have to store how much energy?**



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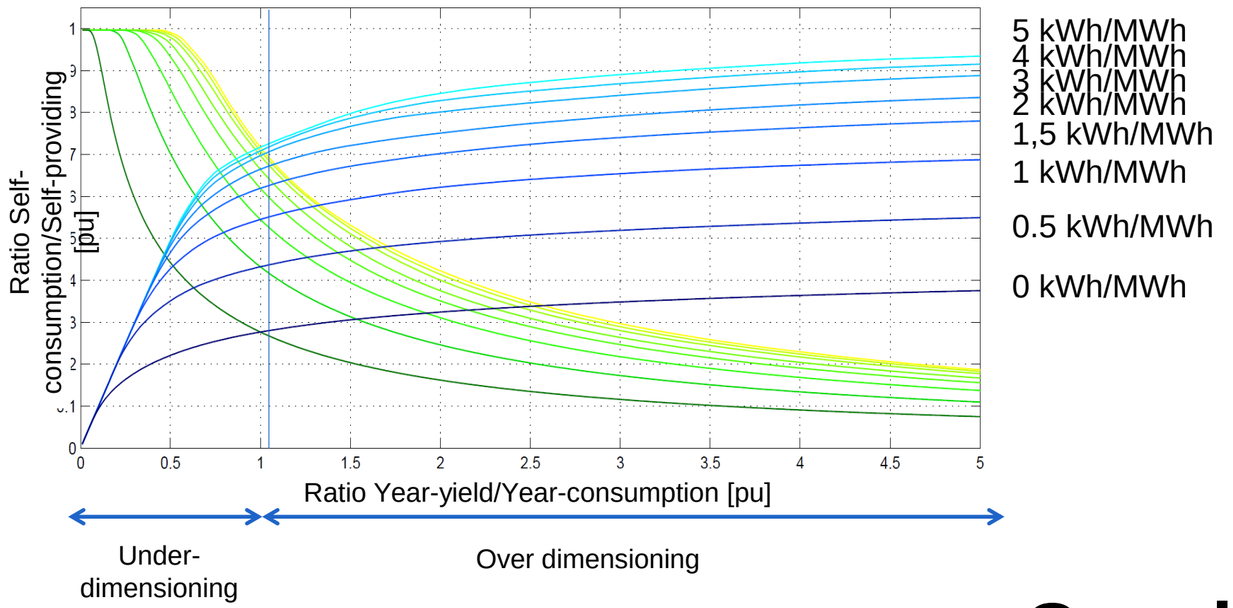
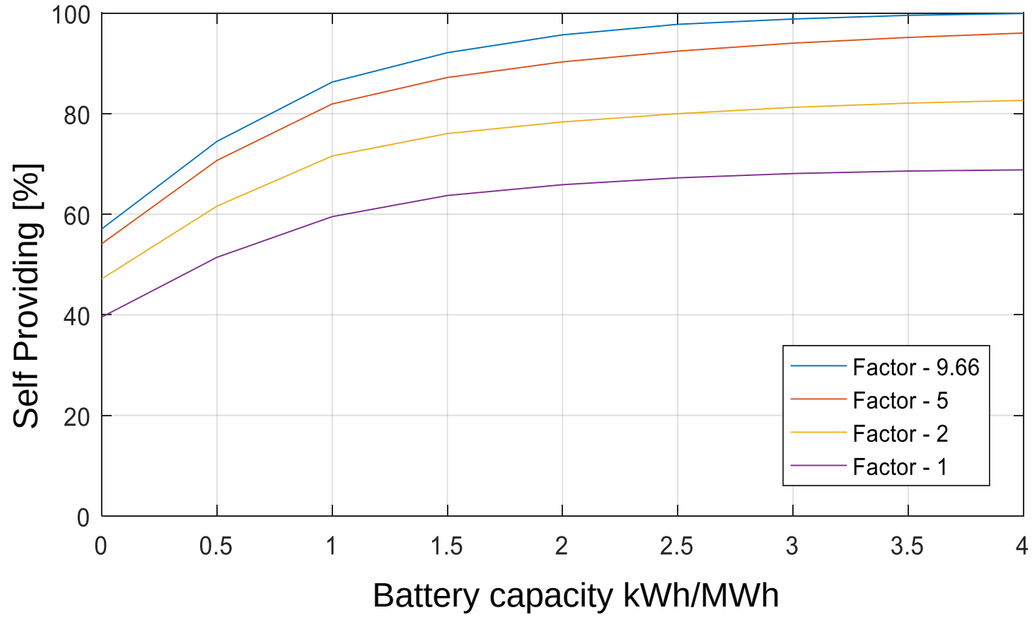
CHALLENGES FOR STORAGE SYSTEMS

Added Value over dimensioning PV/Wind?

- No Storage – Added value rather small
- Complete independency possible but highly over dimensioning and expensive
- Increase of Z_v with increasing "yield/consumption" decreases with increasing capacity





Conclusion

Self providing increases by huge increase of installed of RES (x10)
Must be combined with hybrid storage to reach goals

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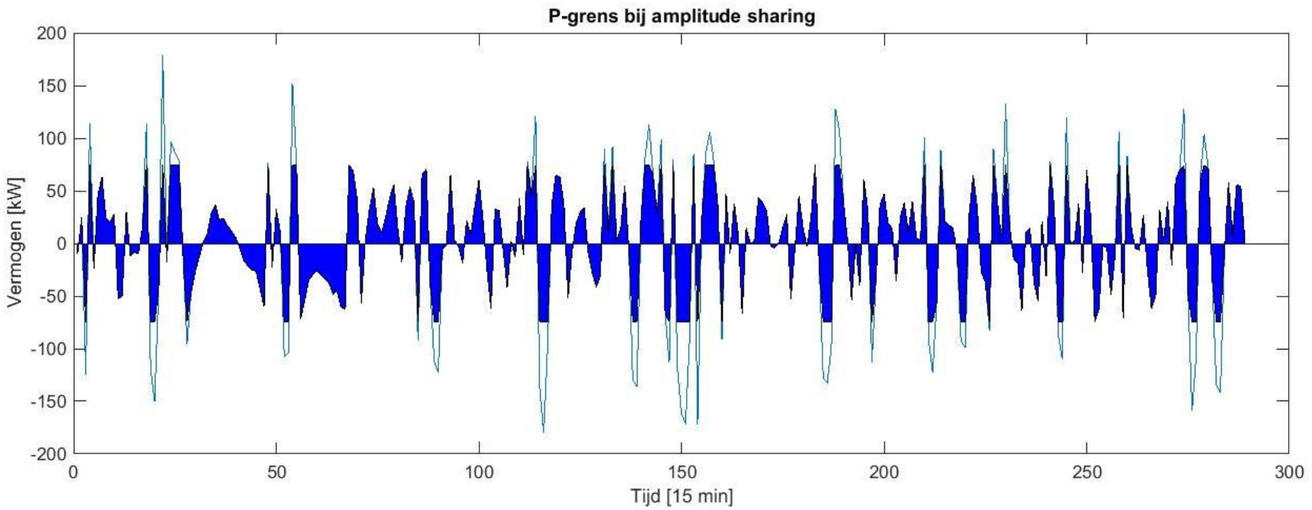
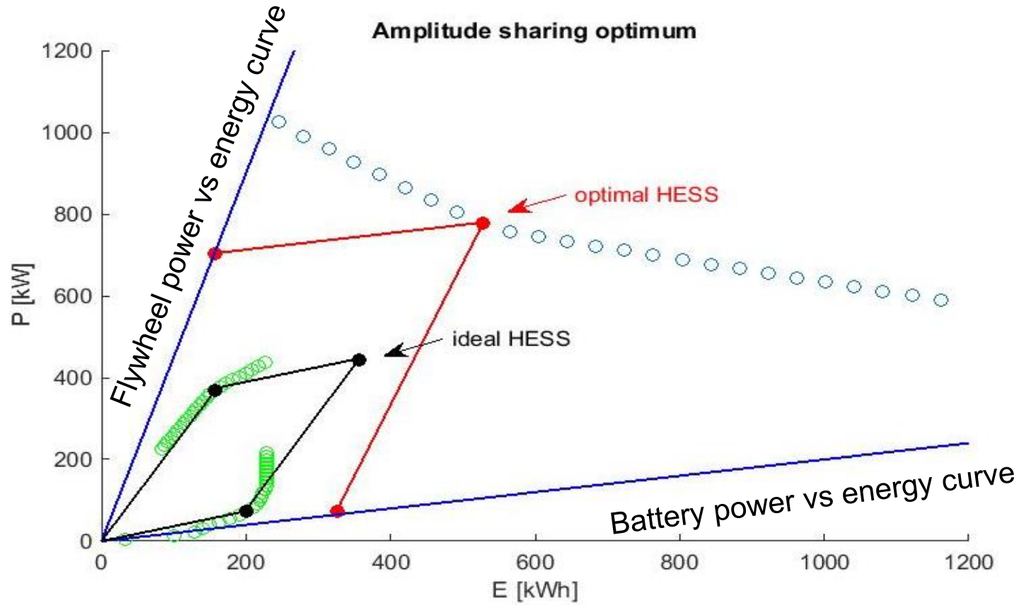
CHALLENGES FOR STORAGE SYSTEMS

Hybridisation in storage as key solution

- Oversizing energy or power using one single technology
- Combine energy provider with power provider → Cover fast power variations
- Drawbacks compensated by strengths of multiple technologies





Conclusion

Hybrid storage is need to cover both Energy and Power capability of the storage systems

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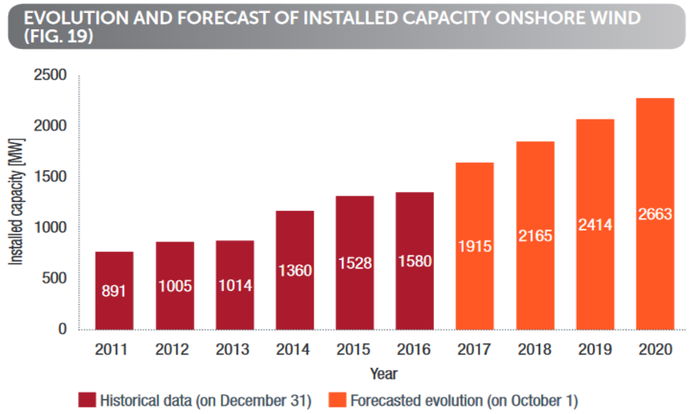
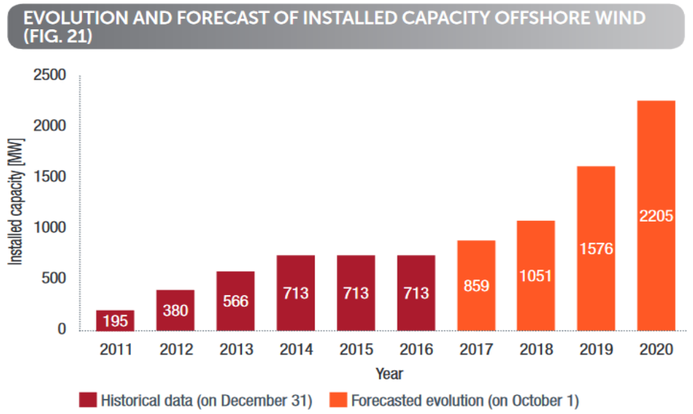
CHALLENGES BY 2020/2025

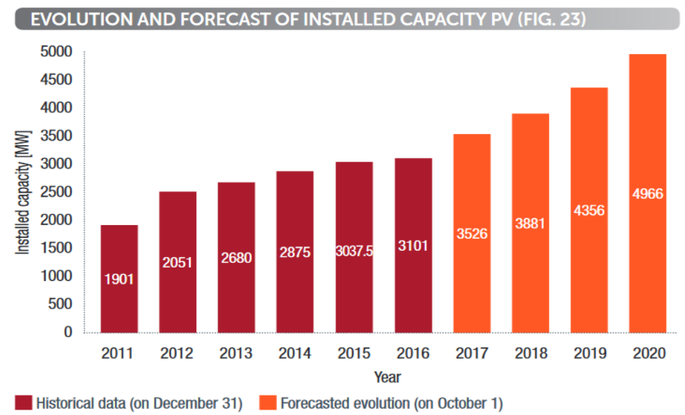
- Increase of 40% On Shore => 700MW provides 1,2TWh
- Increase of 260% Off Shore => 1350MW provides 4,5TWh
- Increase of 40% PV => 1450 MW provides 1,3TWh

→ 3,5 GW extra (+/-15%) installed power generates only 8% extra energy

→ Increasing consumption due to electrification: 124TWh (+50%) by 2050*







Conclusion

Giant investments in RES, R4, including LT storage will be imposed

The conservation of conventional power plants remains needed → UF???

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http://www.elia.be/~/Products-and-services/Strategic-Reserve/171129_ELIA%20AR-Winter_UK.pdf
*information_kaderinfo_inforcadre_307.nl

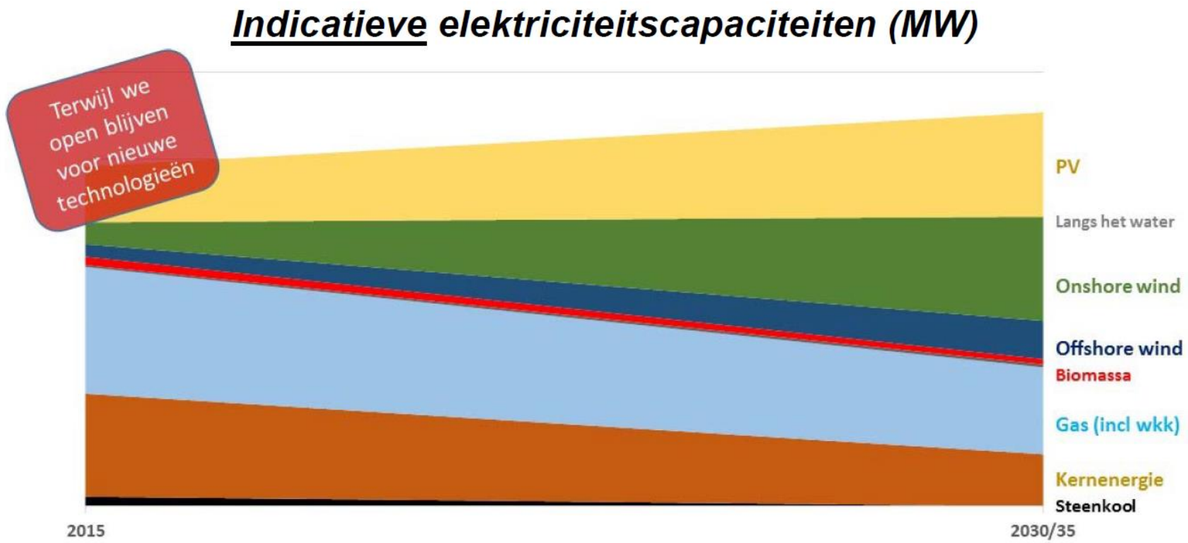
CHALLENGES BY 2020/2035

Increase of off shore: technological (connectivity, power exchange, transport, variability of yield,…) and physical/legal (locations, free space, …) constraints – Curtailment rules?

Increase of on shore: Societal (location, power range, shadow, noise…) and Technological (CF, maintenance, grid congestion,…) constraints

Increase of PV: low capacity factor, challenges for DG and storage, congestion, … - Curtailment rules?

Conventional power plants: to maintain, to increase? Anyway back-up must be installed to avoid outages. Cost of variability of production – Utilisation factor



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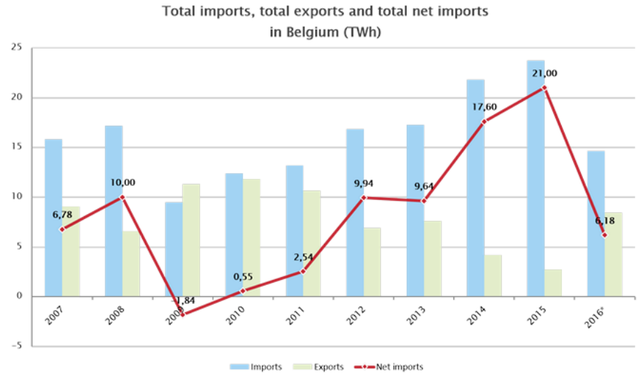
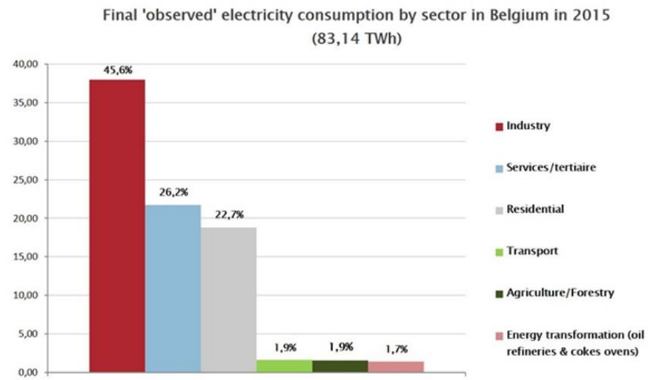
CONCLUSIONS

- Import or export of our neighbour countries is no option for backing up lack of energy production (except on short term) since they have the same challenges.
- 100% RES is possible, however investments will be huge and curtailment will be needed.
- In parallel with the increase of RES, both back-up power plants and (LT/Gas) storage must be deployed.
- Flexibility becomes the future, not only for industry but also for end users → Prosumactor
- Permanent power supply for large industry remains important (in fact also for small end-users), since massive storage (in power and energy) is not feasible for longer periods.





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