Key steps to achieve 100% renewable electricity (Germany target 2050)

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Fraunhofer IWES

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- is the largest organization for applied research in Europe
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  - 70% of contract research revenue is derived from contracts with industry
  - 30% is contributed by the German federal and governments
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- Support Structures
- Turbine Simulation, Software Development and Aerodynamics
- Systems Engineering and Distribution Grids
- Energy Economy and Grid Operation
- Wind Farm Planning and Operation
- Bioenergy System Technology
- Control Engineering and Energy Storage Systems
- Marine Energy

Outline

- Timeline of electrical energy systems technology
- Do we have enough resource?
- Currently facing problems. How to handle?
- Conclusion and outlook

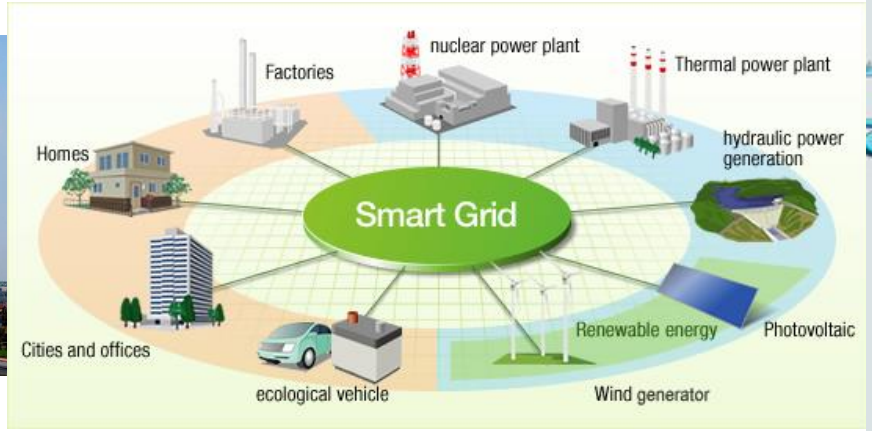
Timeline of electrical energy systems technology

- Less natural resources
- Energy harvesting
- Alternative energy e.g. nuclear or hydropower
- Renewable energy (RE)

- Investment of RE
- Policy
- Sell RE to main grid
- Increasing of decentralized generations (DG)

- Network problem!
  - Energy over capacity
  - Uncontrolable the large number of DG

1980 → 2010 → 2040



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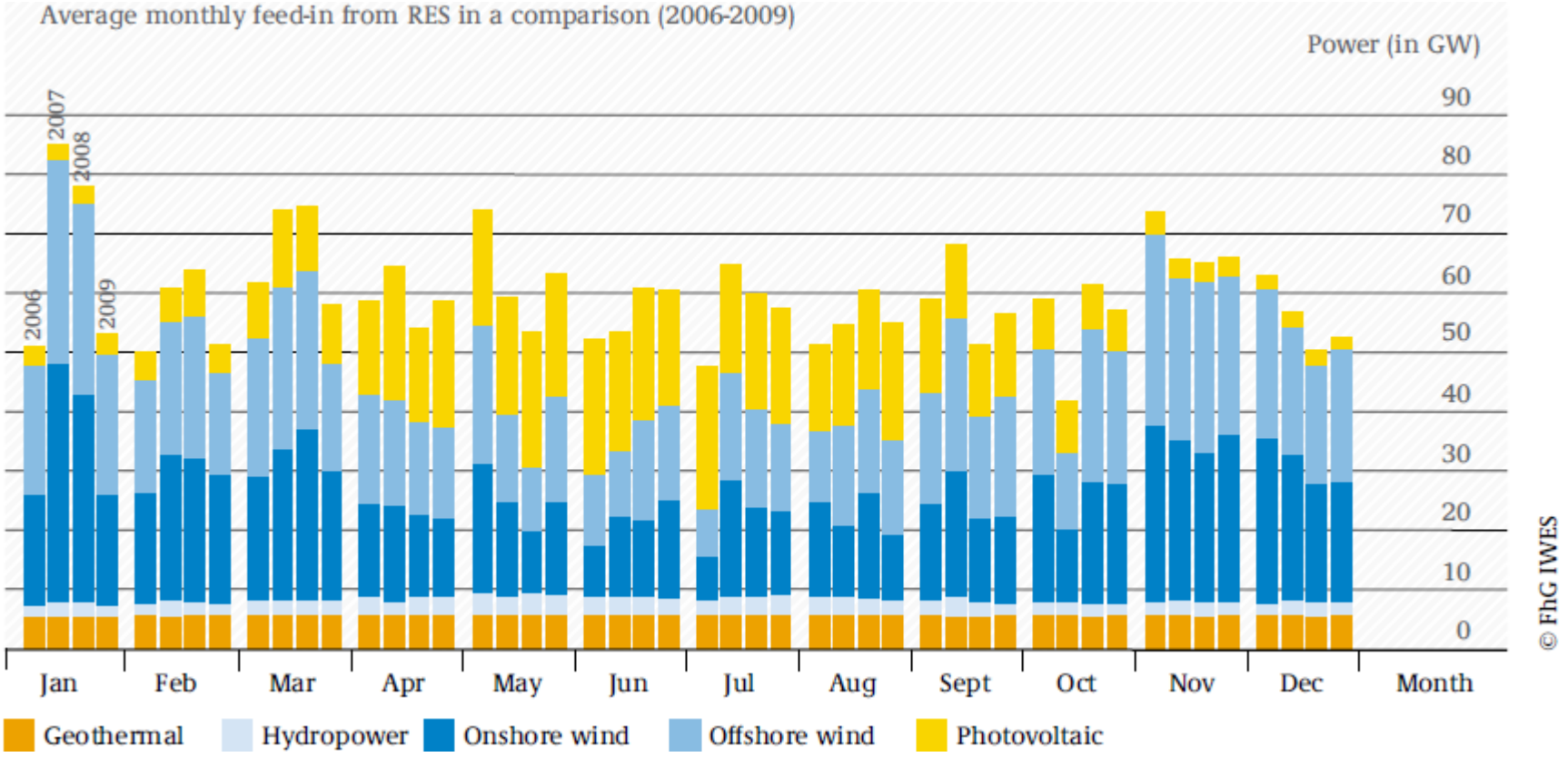
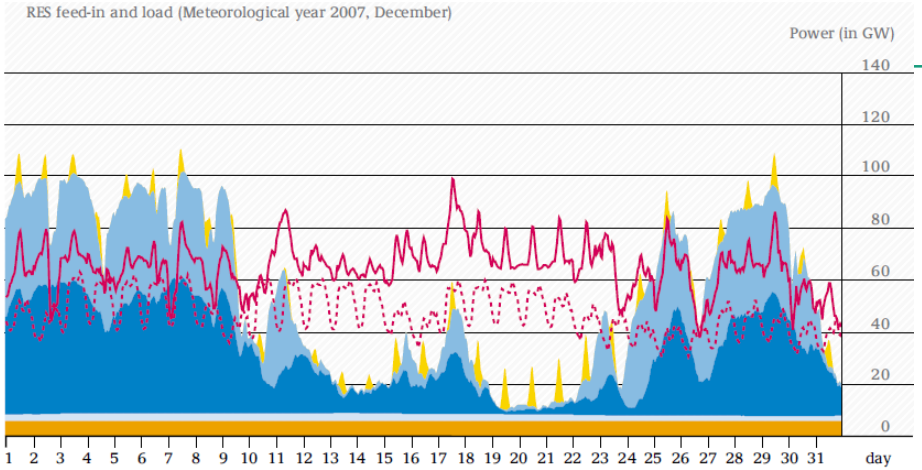
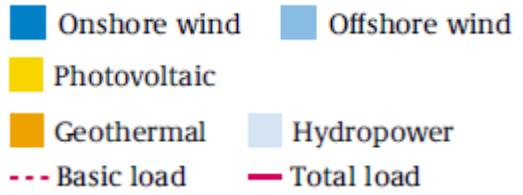
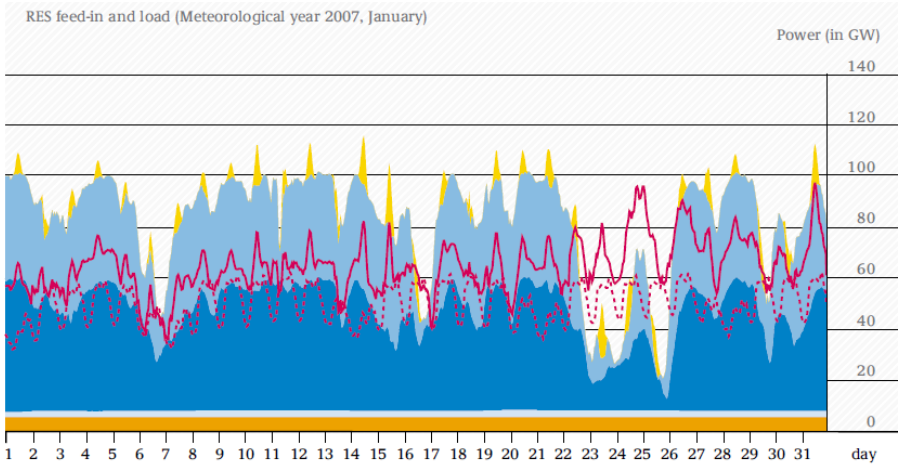
Do we have enough resource?
→ statistic of renewable energy generation (2006-2009)

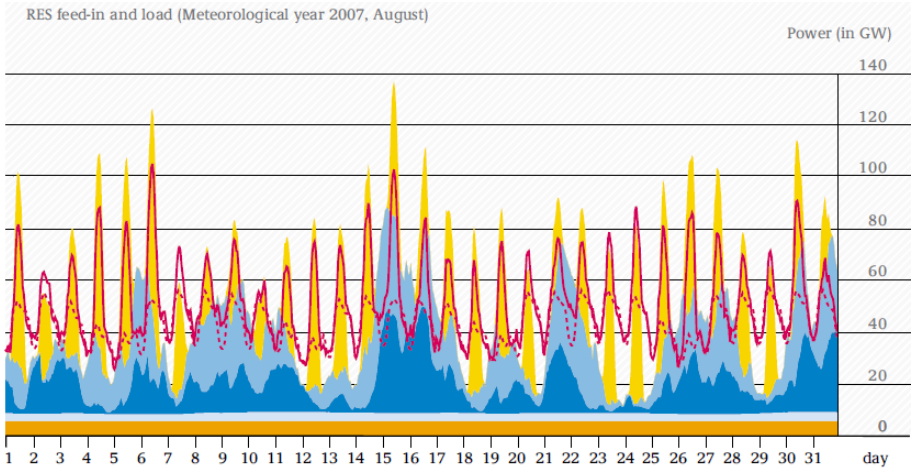


→ Generation VS Consumption (2007)

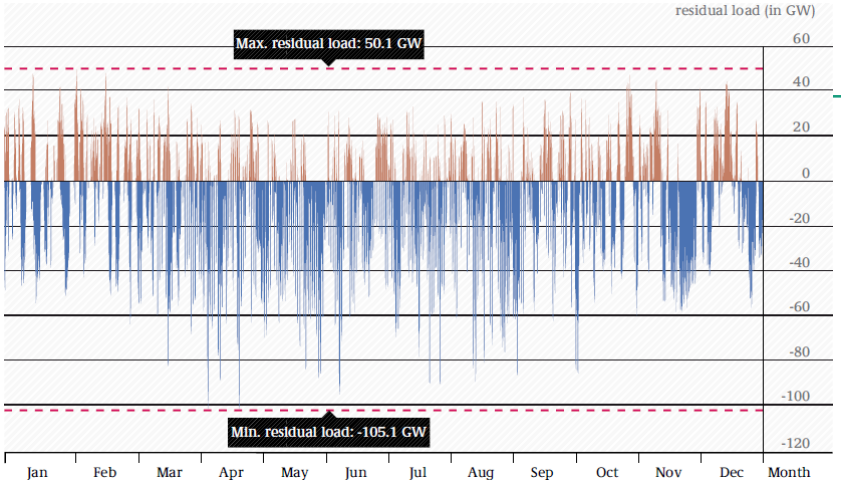


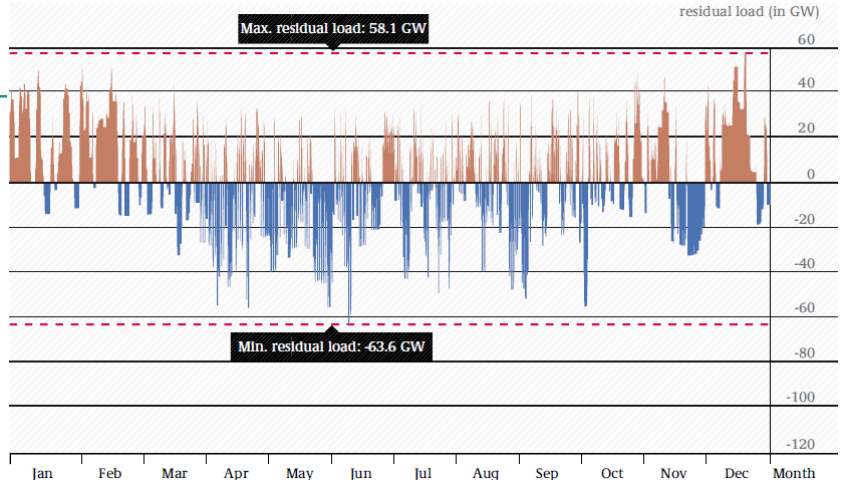






→ Residual loads with load management and storage

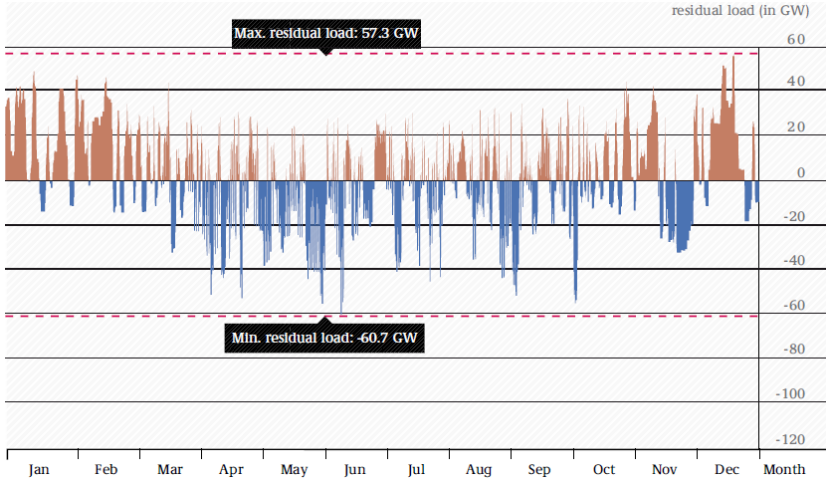




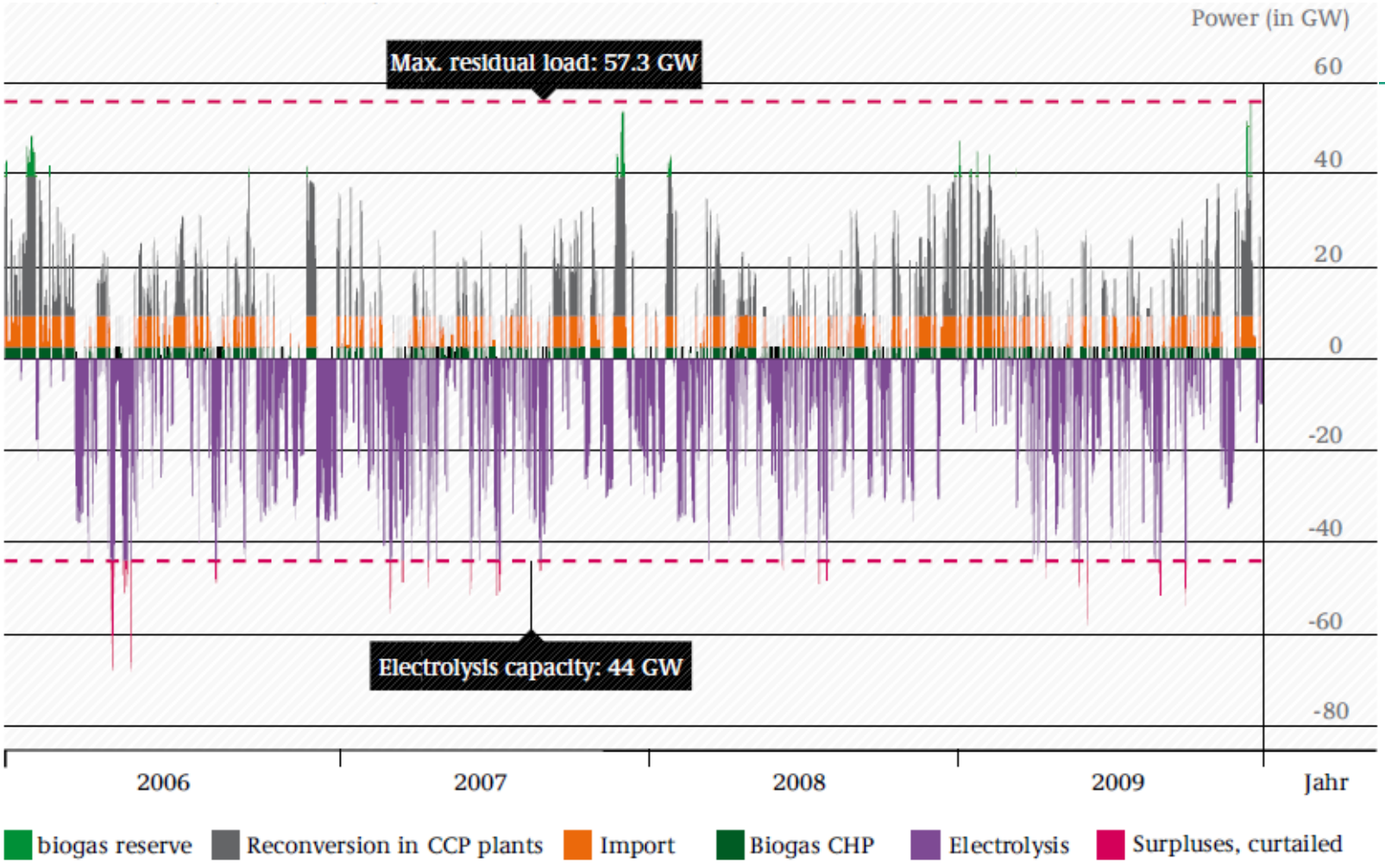
1. Basic residual load
2. Residual load with load management
3. Residual load with load management & storage

Deficit (load > feed-in from RES)

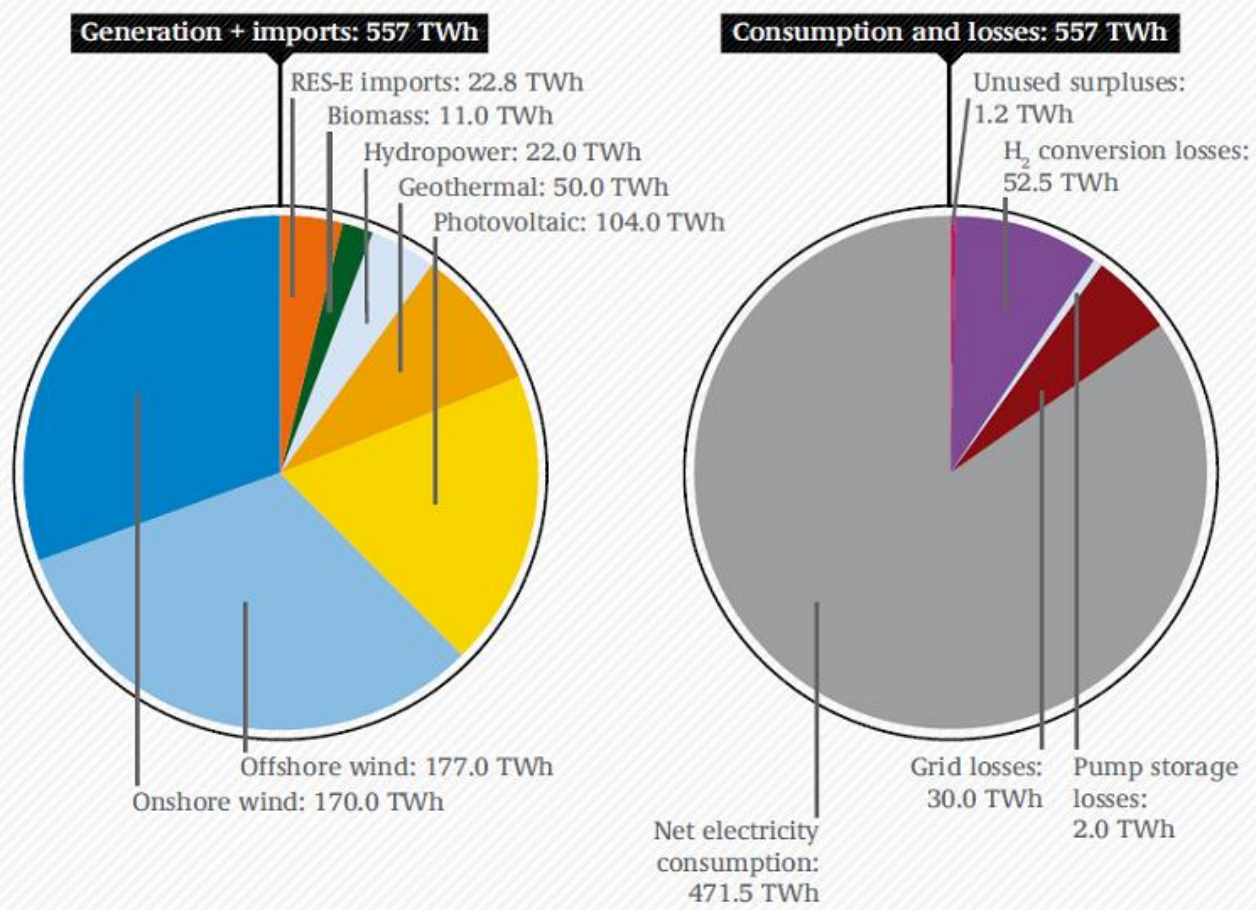
Surpluses (feed-in from RES > load)



→ Simulation of covering the residual load

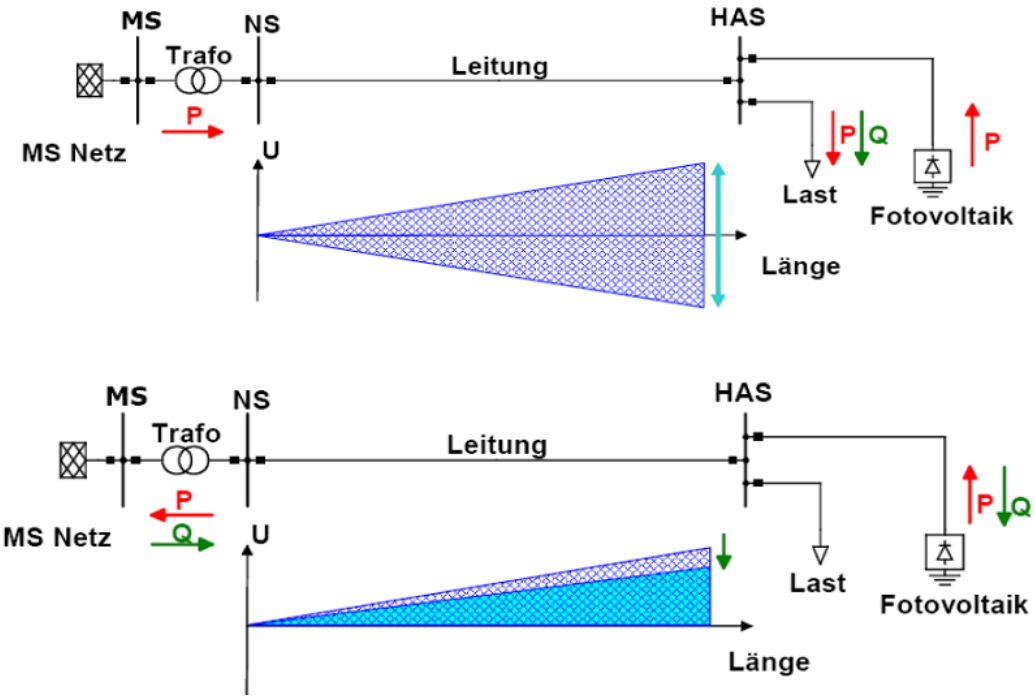


→ Energy balance – prediction of year 2050 based on statistic of 2006-2009



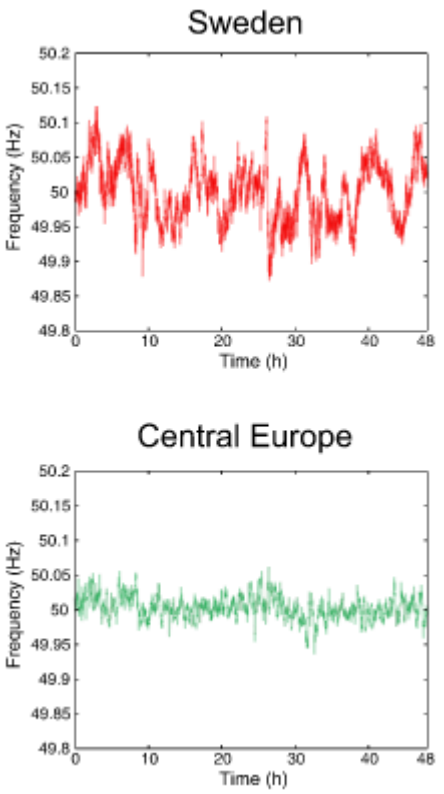
Current situations and facing problems
→ What happen on the network?

Situations	Problems
Small DGs sell electricity to grid	• Over energy in the pool • No energy balance • Black out
If they do not consider about grid stability	• Over frequency • Over voltage • System fault
If they consider about grid stability	• Over dimension design for generators • But how can network providers give them the information to follow?



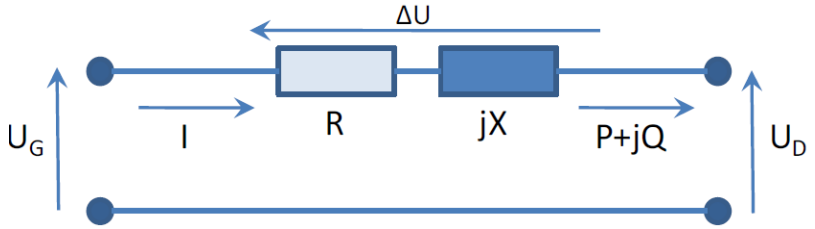
→ General problems of grid integration

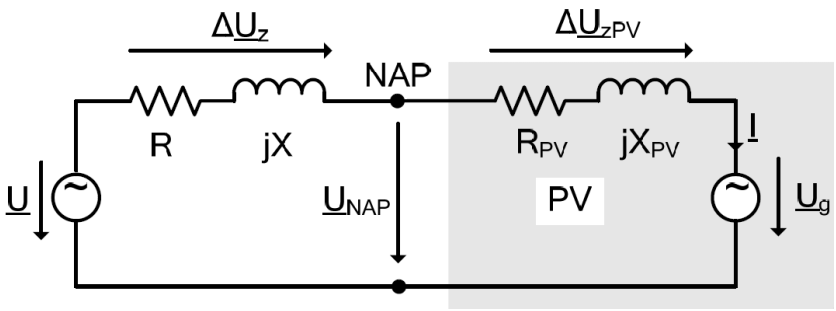
Grid integration problems	Note
Power quality	Guarantee of frequency and phase → $50\ \mathrm{Hz} \pm 2\%$, 120° phase shift → Synchronization btw clusters
Voltage stability	Guarantee of voltage level e.g. $230\ V_{RMS} \pm 10\%$ → Voltage drop or peak
Harmonics distortion	Caused by nonlinear loads or electronic generators e.g. inverters which result to the bad power quality
Reliability	Stable or fault
Protection	New system structure → New protection rules
Control	Centralized VS decentraliced control

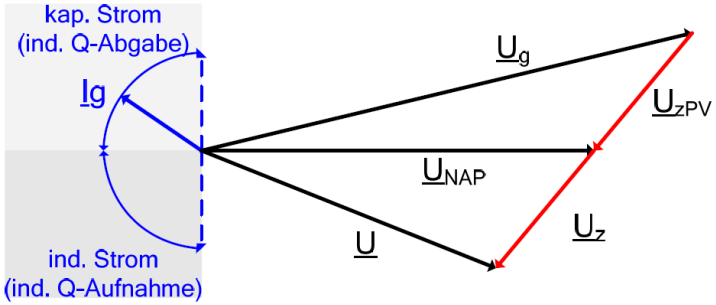


→ Power network stability and control

- Frequency stability
  - Draw active power (P) from grid → freq. drops
  - Feed-in P into grid → freq. increases
- Voltage stability
  - Inject reactive power (Q) into grid → V drops
  - Consume Q → V increases
- Angle stability
  - Synchronization at point of common coupling
  - Synchronization method e.g. phase-locked loop (PLL)
- Control methods
  - Centralized control (traditional)
  - Decentralized control

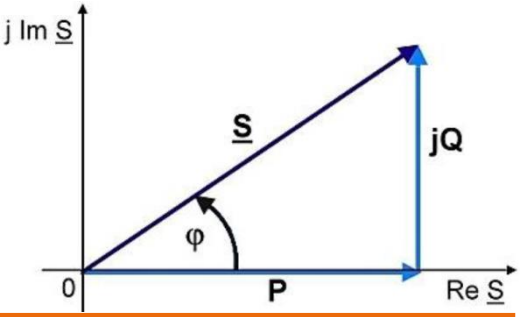






How to know?
How many P and Q should be injected into the grid?

→ Grid supporting (decentralized contr
by setting of power factor



Techniques	Details
$cos(\varphi) = const$	Means, if they want to sell more P, they have also to inject more Q More Q means more heat loss
$cos(\varphi) = f(P)$	The power factor depends on P The curve is given by network providers Depends on network characteristic, not flexible
$P = f(freq)$	It does not allow to inject further P if the frequency is out of band The curve is given by network providers Depends on network characteristic, not flexible
$Q = f(U_{PCC})$	Injected reactive power depends on voltage at the point of common coupling (PCC) The curve is given by network providers Depends on network characteristic, not flexible
$Q = const$	Q is always injected even no energy on offer Heat loss and poor durability
$P = f(U_{PCC}, I_{PCC})$ $Q = f(U_{PCC}, I_{PCC})$	Automatic detection algorithm Intelligent, redundance, heat loss reduction Oscillation can be easily occured

Conclusion and outlook

- From the statistics and simulation results, the electricity generated by renewable sources is enough to provide loads in the whole country
- Peak loads can be covered by technique of load management and energy storage
- If there are a lot of DGs, grid integration is not easy. Network instability occurs
- To support networks, varying of P and Q injection can help to maintain the frequency and voltage in the stability band
- The automatic detection and control of P, Q for decentralized DGs (droop control) has a high potential for the future grid structure (microgrid cluster)
- The droop control method VS the network oscillation is a ongoing research


Thank you for your attention
Any question?