Session 2

Networks with high level of renewables

Agenda for Session 2

- Background – networks with high level of renewables
- Distributed generation and its impact on power system losses
- Technology Development – International best practice

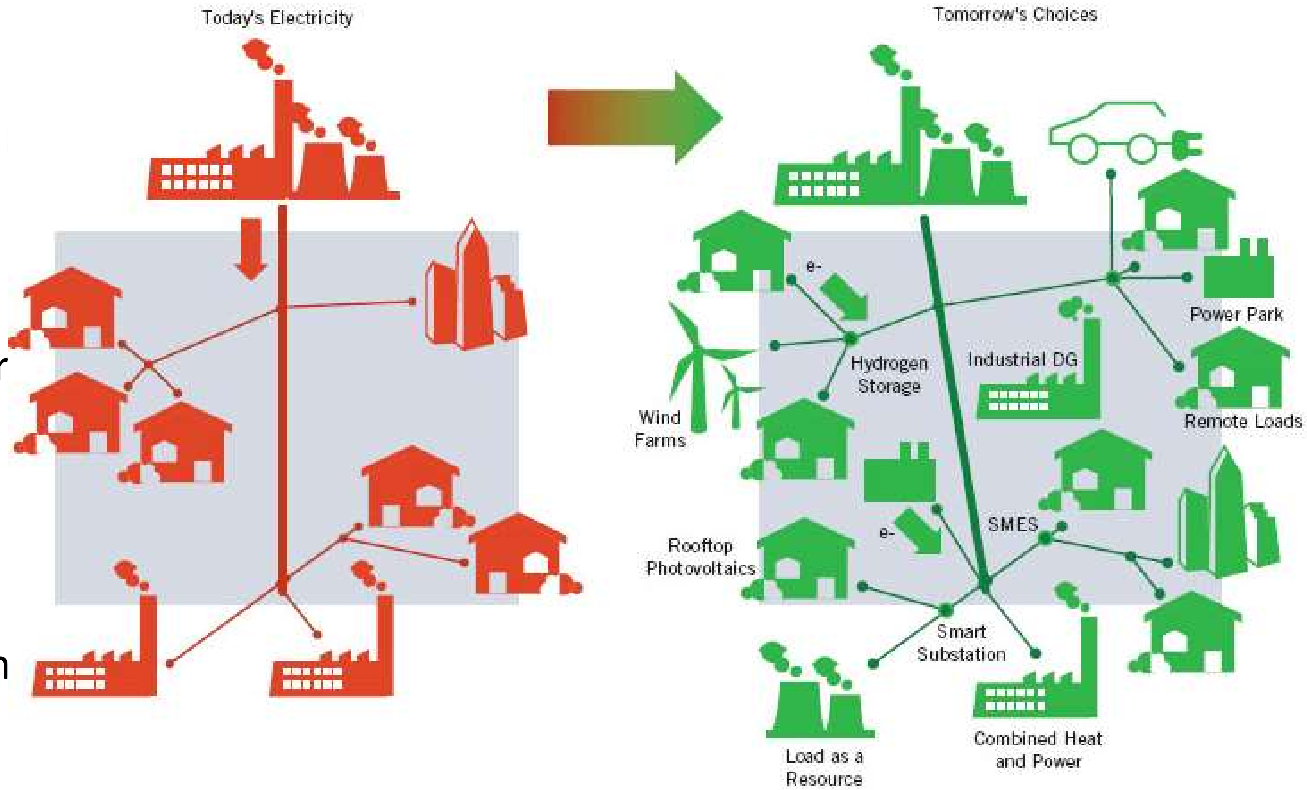
Eskom Danish Energy Agency COWI

Background – networks with high level of renewables

- Transition in South Africa
- Transition – benchmark figures

The new way..?

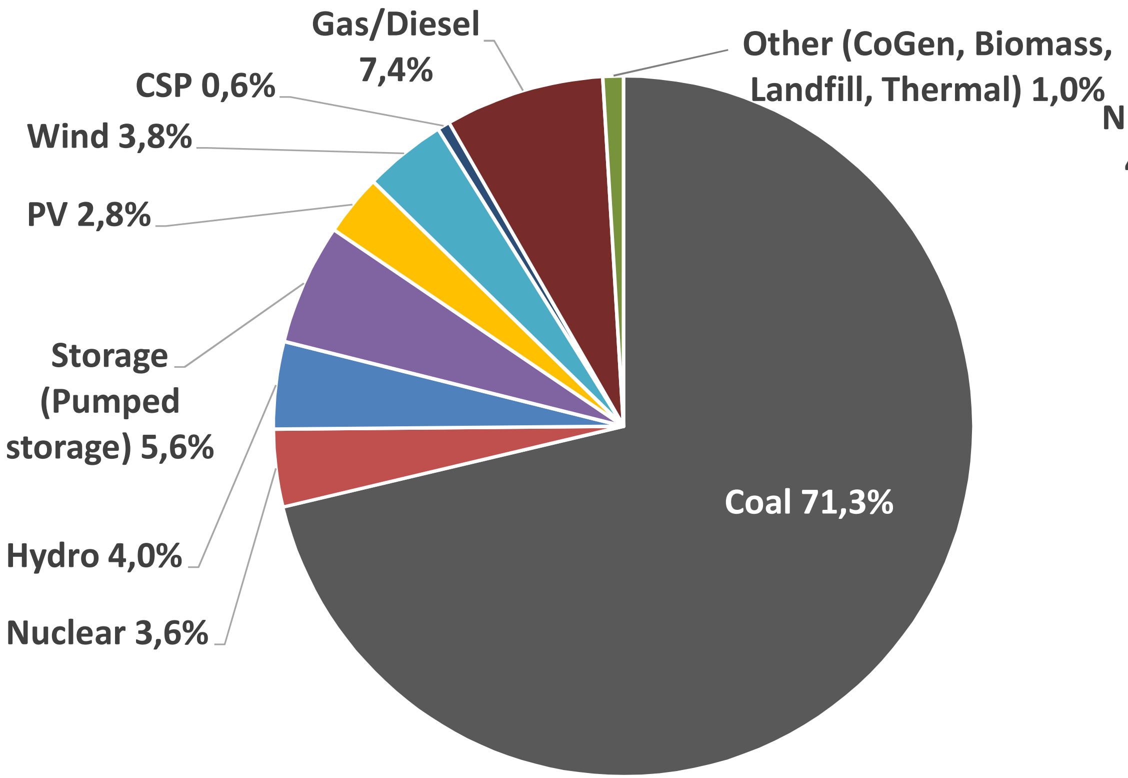
- The transmission have been passive and a one way exchange.
- Lately this behavior has shifted and the power generation is nowadays more diversified and distributed.
- The RE sources such as wind and solar power is more scalable than other energy sources. This gives that it can be adopted broadly, both commercial and privately at HV, MV and LV.
- Since RE is more easily scaled and available in all segments this leads to it being more distributed locally, often embedded. This increases the challenges with keeping the system in balance.



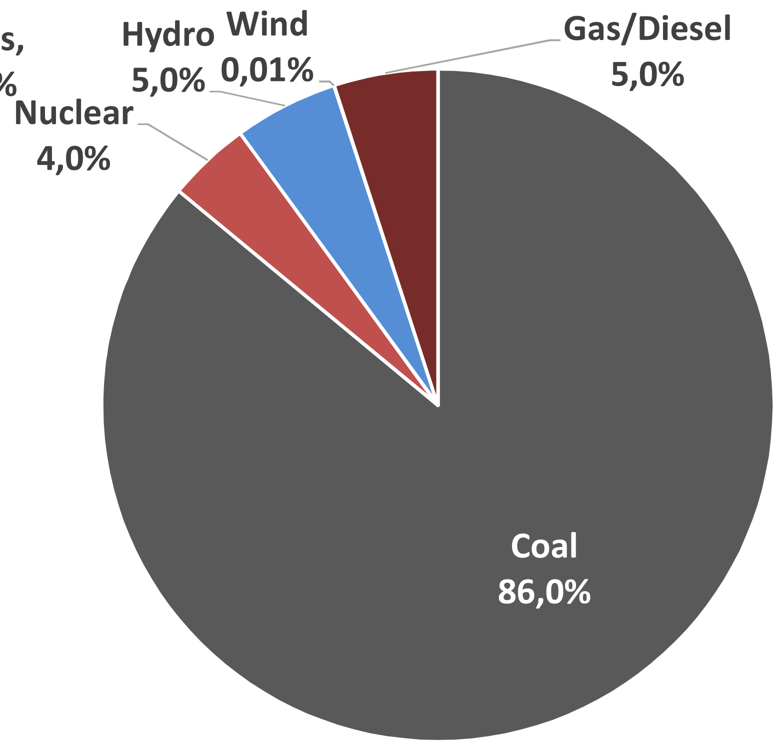
Transition in South Africa

- In 1998 White Paper of South African Government it is stated: *"Government believes that renewables can in many cases provide the least cost energy service". "Diversity of supply and primary energy carriers will be encouraged"*
  - In year 2000 – the first Wind Farm in SA was connected to the grid
  - Second farm connected during 2002 – 2003
- In 2003 White Paper of South African Government defined a ten year target on how RE could diversify the energy mix. It focused on four main objectives:
  - Ensure that an equitable level of national resources are invested in renewable technologies
  - Direct public resources to implementation of renewable energy technologies
  - Introduce suitable economical incentives for renewable energy and
  - Create an investment climate for the development of the renewable energy sector
- In the first two decades of 2000 several programmes have been rolled out with more ambitious targets
  - Programmes for diversifying of the energy production in several sectors
  - Feed-In Tariffs established in 2009 – 2011
  - In 2016 tax incentives for renewable energy was rolled out

What is the status of the transition in SA?



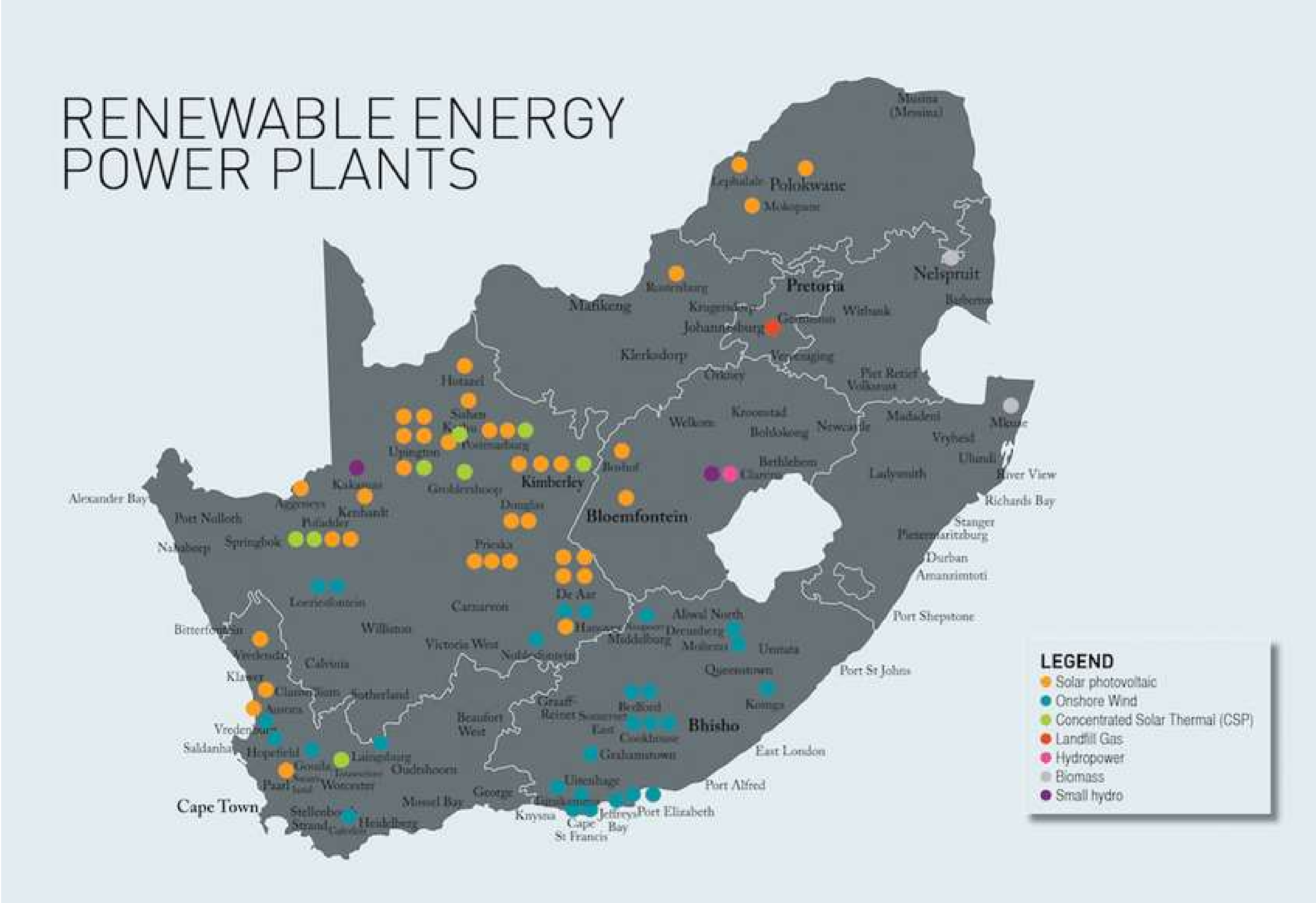
Power generation capacity 2018



Power generation capacity 2011

http://www.energy.gov.za/files/docs/IRP%202019.pdf

http://www.energy.gov.za/files



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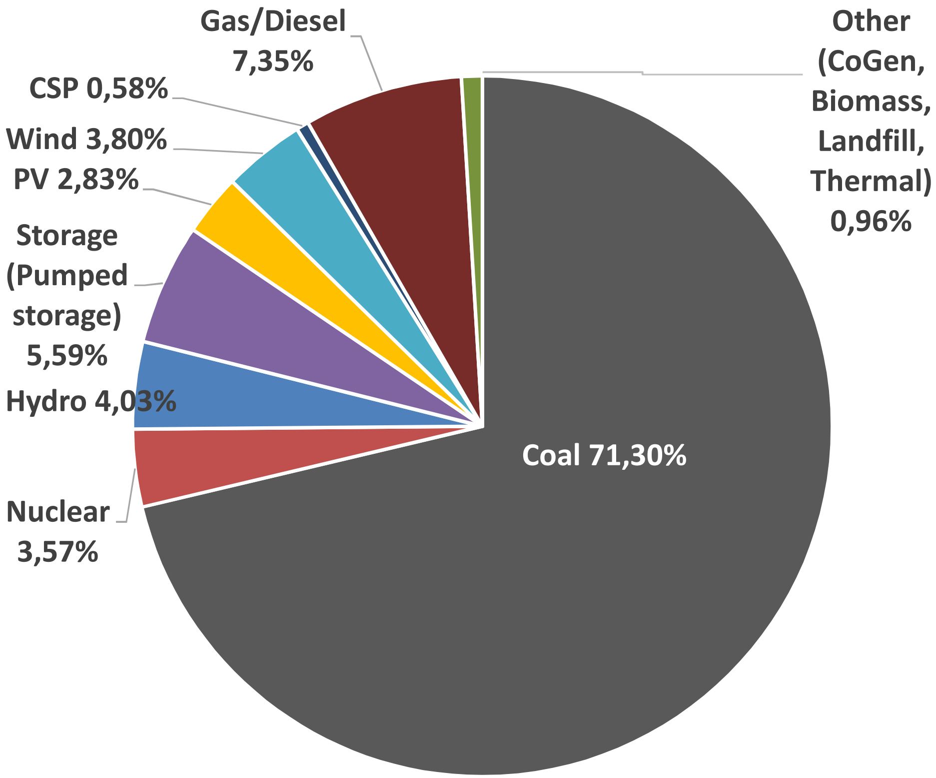
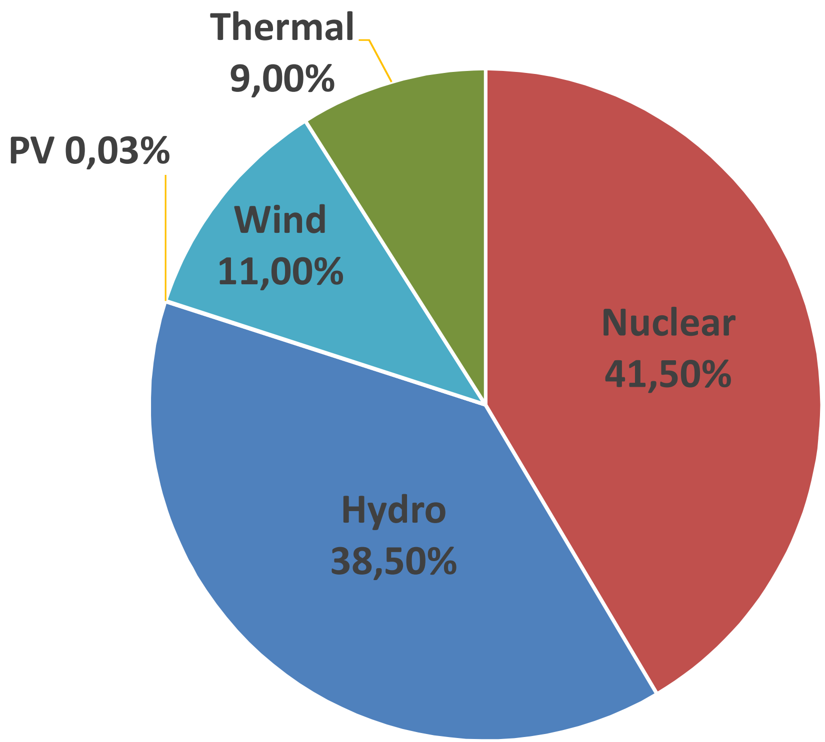


South Africa

2018

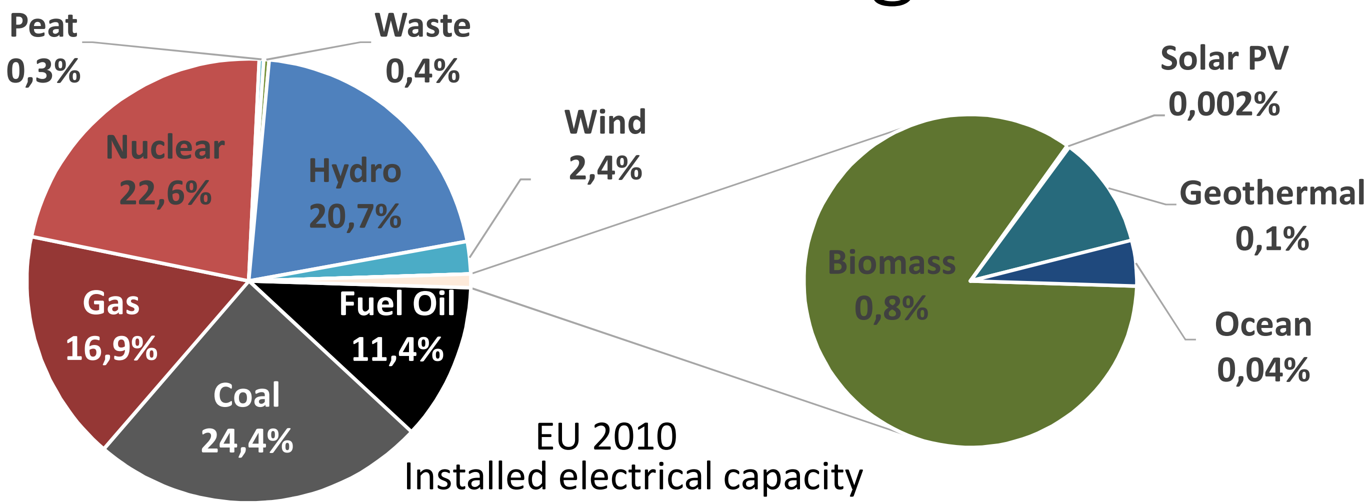


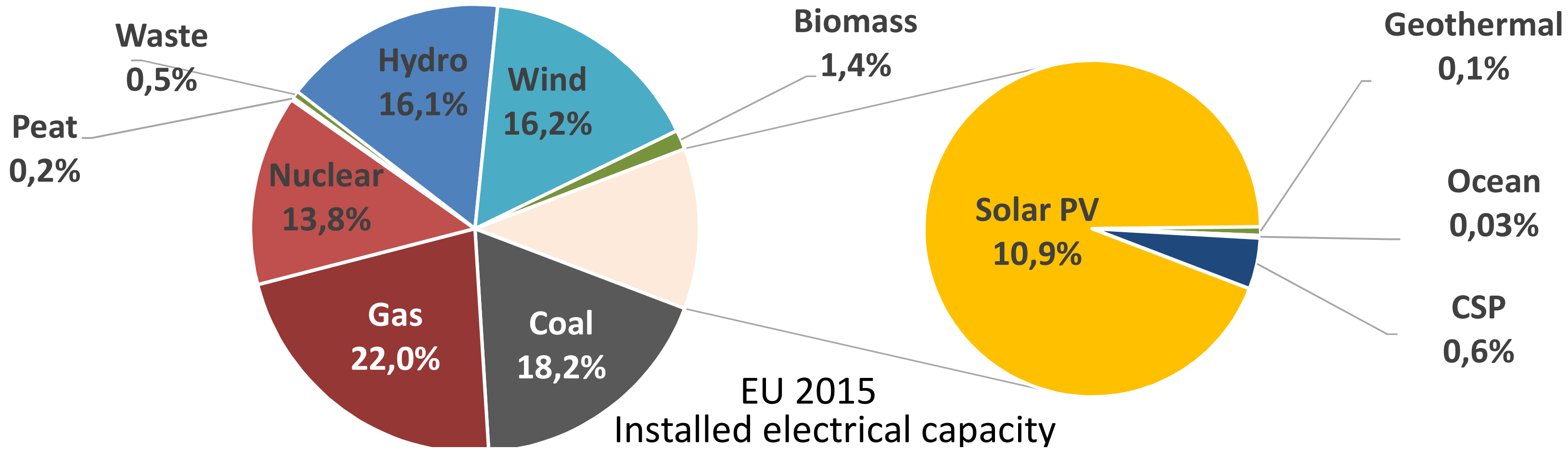
Sweden

Background – networks with high level of renewables

- Transition in South Africa
- Transition – benchmark figures

The transition in benchmark figures for EU

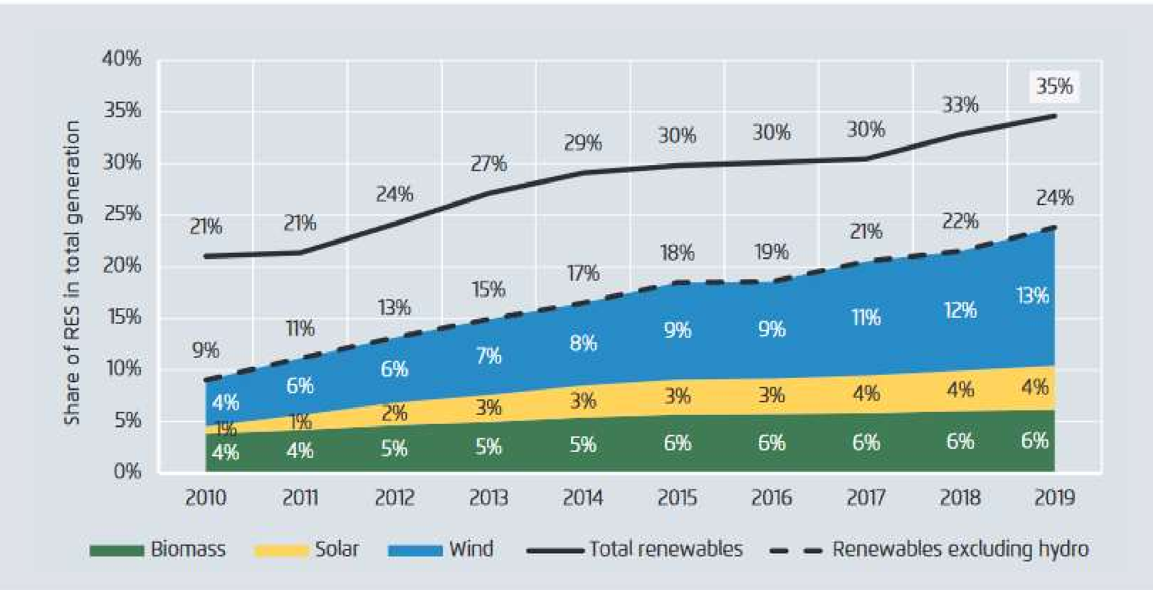




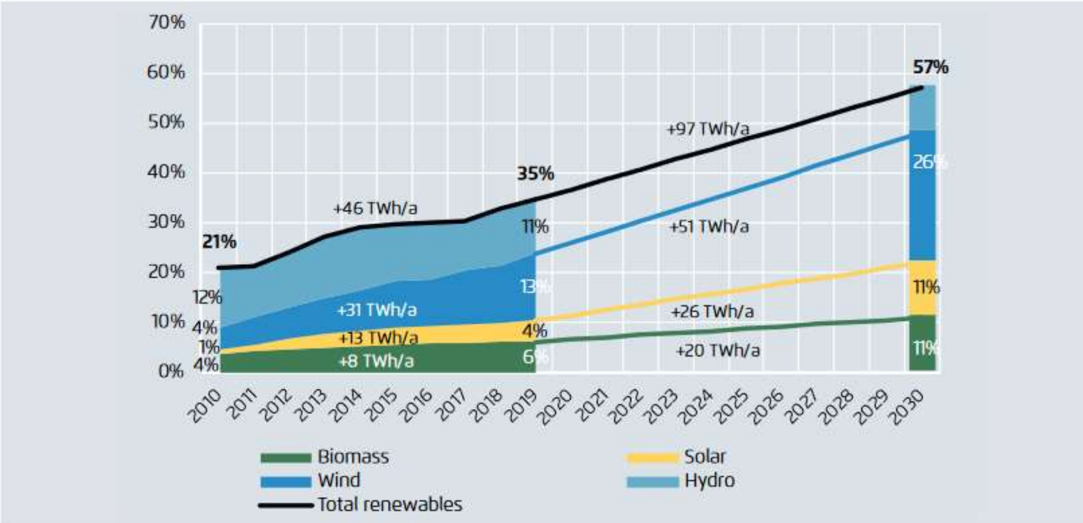
The transition in benchmark figures for EU 2019

- The power generation from coal collapsing and decreasing to 24%
- RE rose to a new record level, supplying 35% of EU electricity

EU 28 renewables share (as percentage of gross electricity production) Figure 3-1



2030 projection of renewable electricity share in European Commission's Long Term Strategy Figure 3-10



EUROSTAT data to 2017; Authors' calculations for 2018 and 2019; 2030 projection from "Long Term Strategy", European Commission 2018, dashed lines show projection

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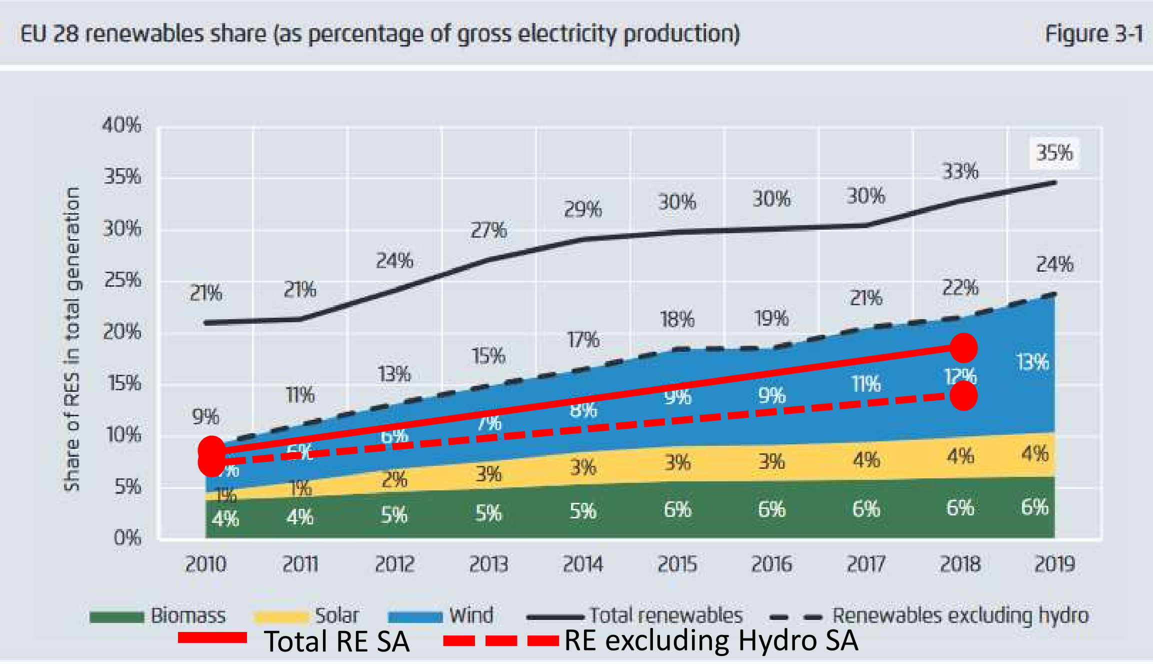
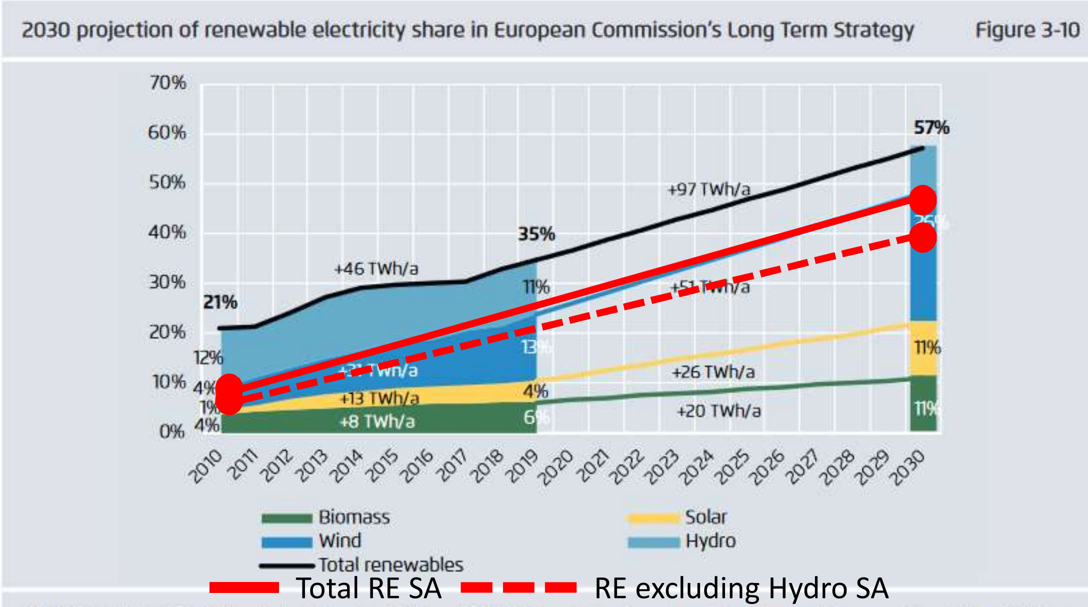




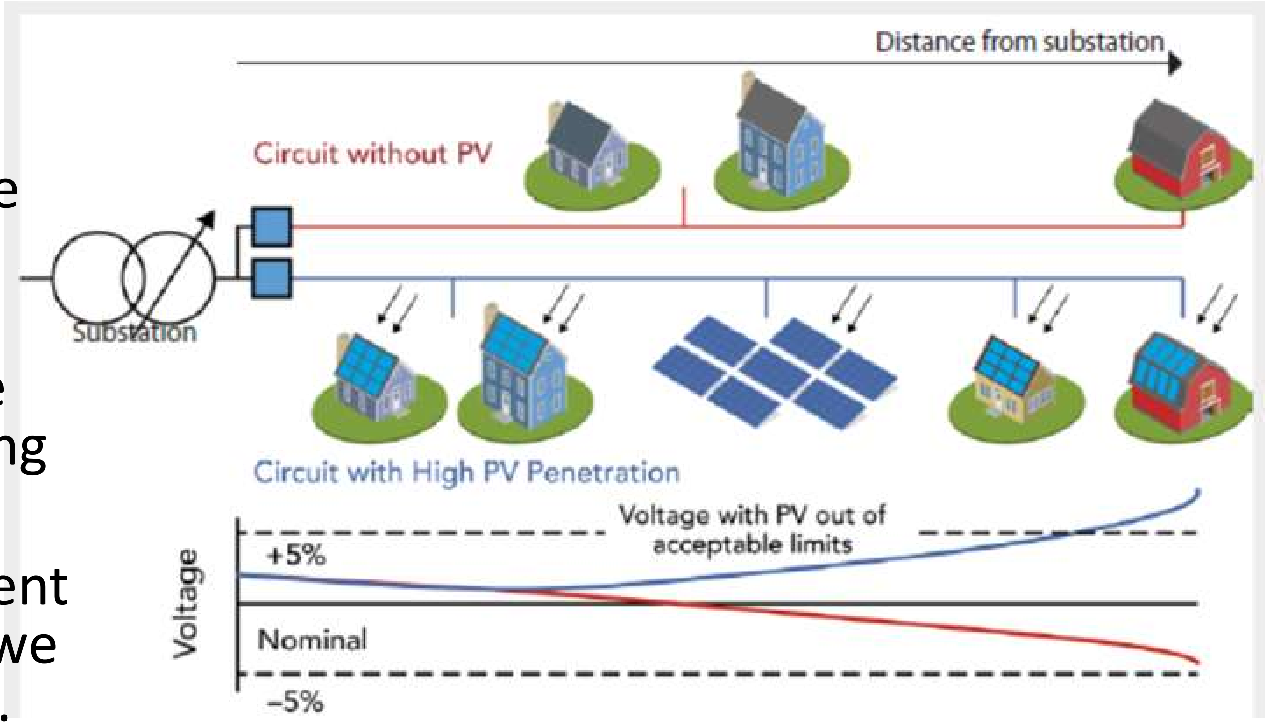
EUROSTAT data to 2017; Authors' calculations for 2018 and 2019; 2030 projection from "Long Term Strategy", European Commission 2018, dashed lines show projection

Distributed generation and its impact on power system losses

- Impact of DG on losses

Voltage impact

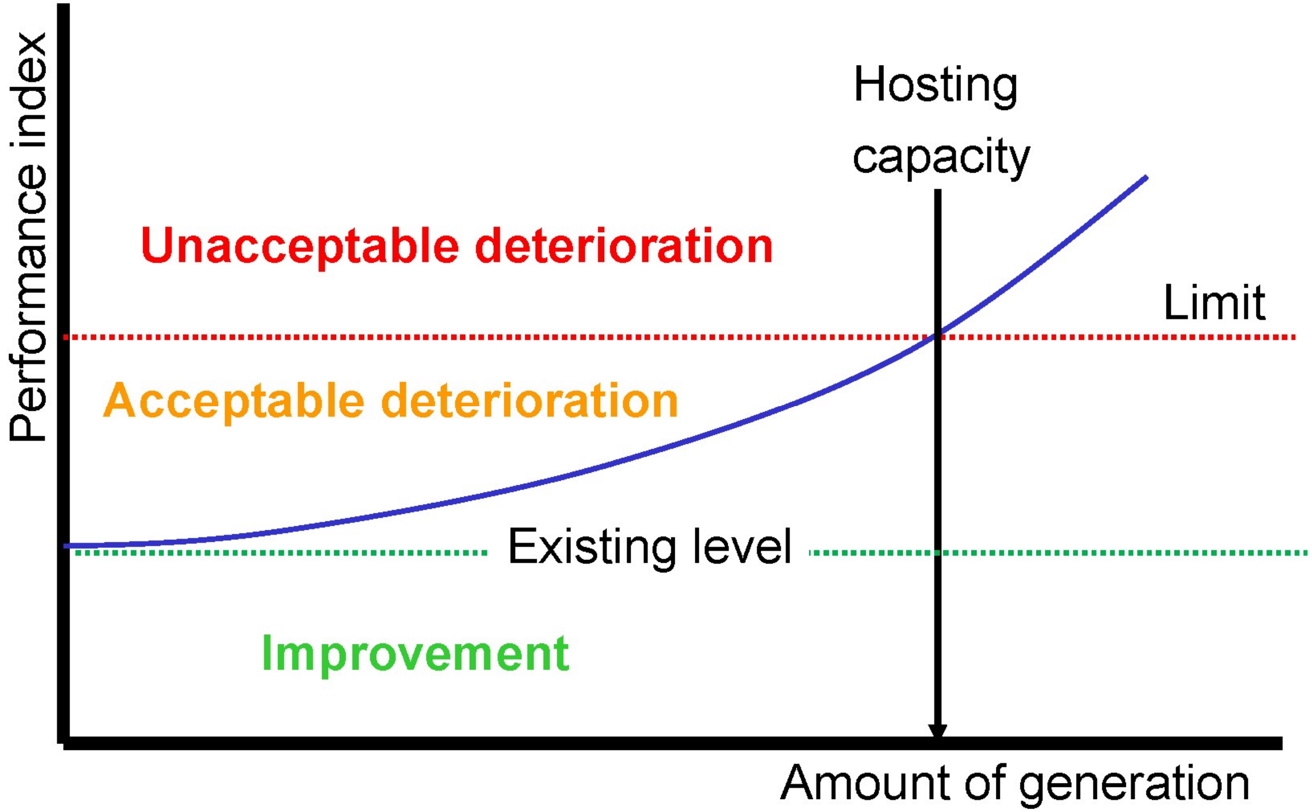
- The distribution network was previously operated in a passive way with little or no need to control the voltage.
- With the introduction of RE the distribution network is becoming an active system
- We have introduced a component that affects the voltage where we before had no or few problems.
-



Voltage impact

- The distribution network has a limit to how much RE that can be integrated due to voltage constraints.
- The limit is often referred to as *”hosting capacity”.*
- This is the limit to how much RE you can integrate in an existing network – when you reach the limit,
  - either we stop the integration
  - or we have to make a lot of grid investments

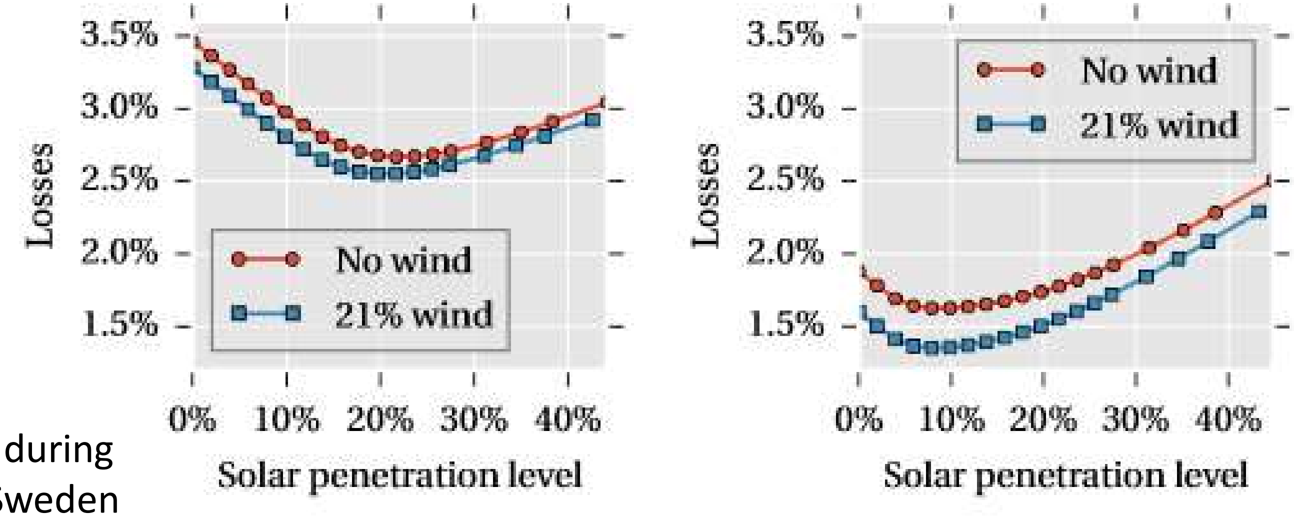
Limitations in the power grid for distributed power generation - Hosting capacity



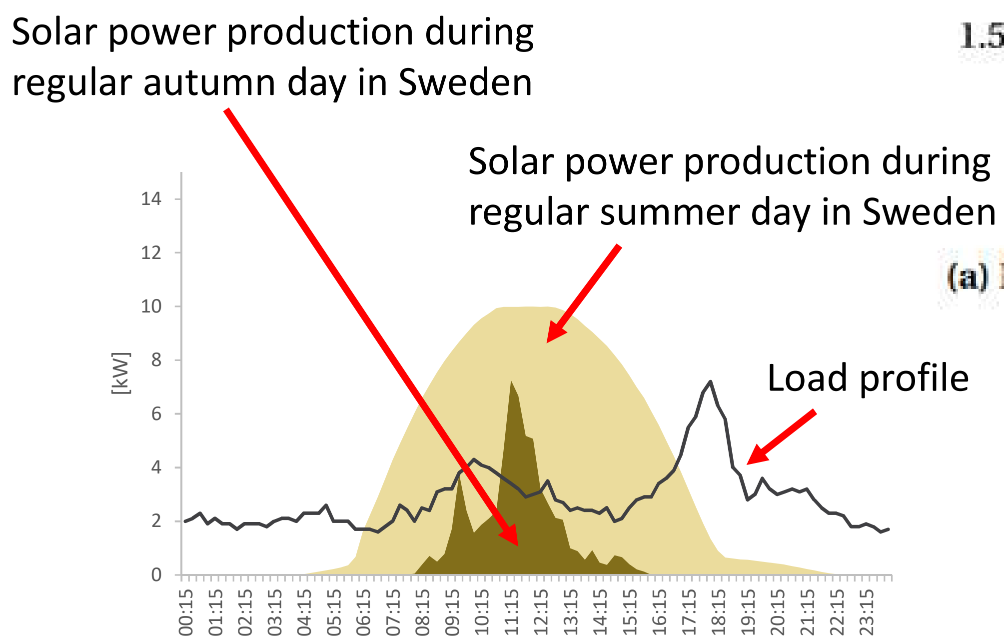
How is increased share of RE affecting the power grid losses?

- Locally distributed RE - reduces losses up to a certain level
- When power is locally produced and also locally consumed the power grid losses (mainly low voltage level) is reduced till certain level of RE penetration.
- But when the RE increases further, power production and demand is not in harmony. This leads to mismatch between production and consumption and a larger amount of power production is transmitted over the power grid. This leads to increased losses.

Impact of DG on Losses



(a) Load mainly at low voltage. (b) Load mainly at medium voltage.



CEER Recommendations for reducing electricity network losses

Technical losses:

- 1) Increase voltage levels
- 2) Apply less transformational steps to deliver electricity to consumers
- 3) Utilise new and improved equipment
- 4) Employ distributed generation in a more efficient manner, including combining it with local storage
- 5) Optimise network flows – reduce peaking
- 6) In general, pursue network architecture and management that promote the highest efficiency

Non-Technical losses:

1) All countries should collect data on these types of losses

2) Focus on more accurate recording of electricity consumptions through improved metering and the use of smart meters

3) Reduce theft and other hidden losses

What can be done to accommodate more DG in the distribution networks?

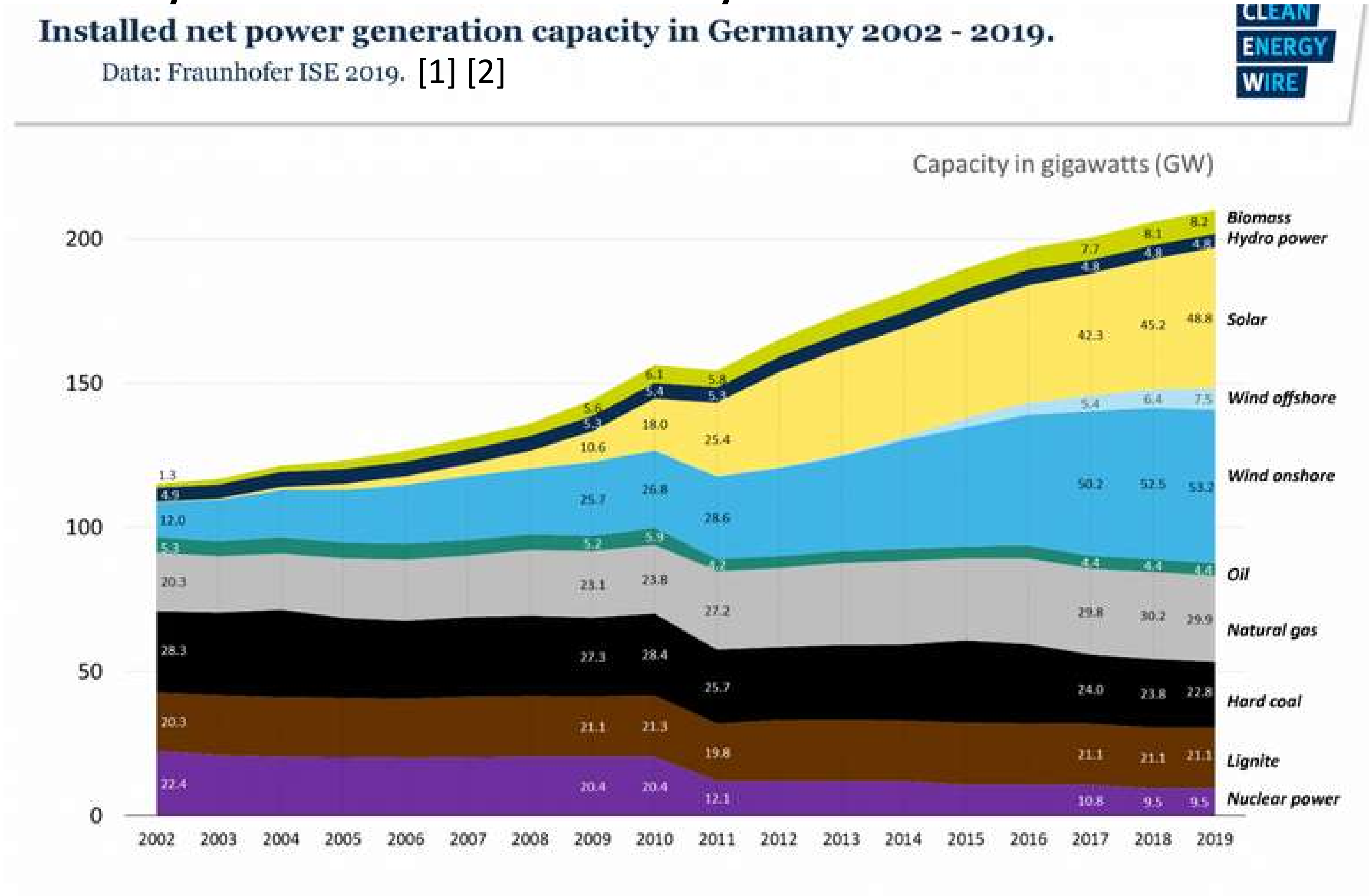
- Modify tap-changing transformer regulation
- Expand and strengthen the grid
- Curtail photovoltaic (active) power generation
- Inverter reactive power compensation
- Local storage or increased peak self-consumption

- Adjust tap changer setting at the distribution transformer
- Automatic tap changers in distribution transformers
- Step-down transformer halfway
- Higher cross-section
- Shorter LV-lines
- Meshed LV-system
- Limit PV-connections
- FACTS/capacitor/reactor bank in MV-substation
- DSM – Demand Side Management
- Flexibility services

Technology Development – International best practice

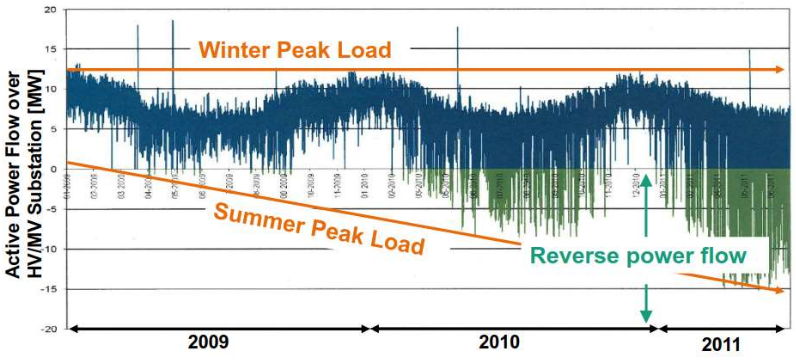
- Germany as a case study
- Flexibility services

Germany as a case study



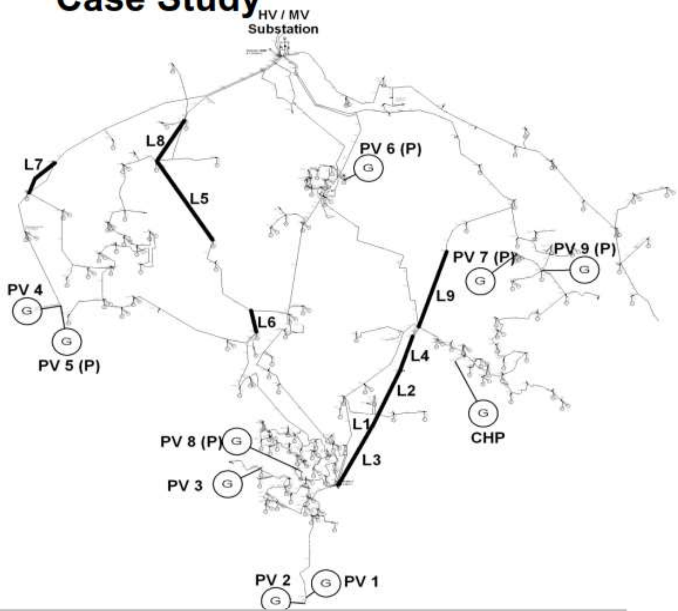
Germany as a case study

Rapid Change from Consumption to Supply Grid



Source: E.ON Bayern AG

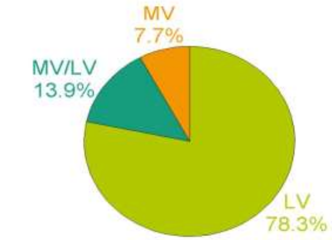
Smart Grid „Seebach“– Germany‘s High PV Penetration Case Study



Installed Generation Capacity:

PV	32.8 MWp
Biomass	0.73 MWp
Water Power	0.55 MWp

Point of Common Coupling:



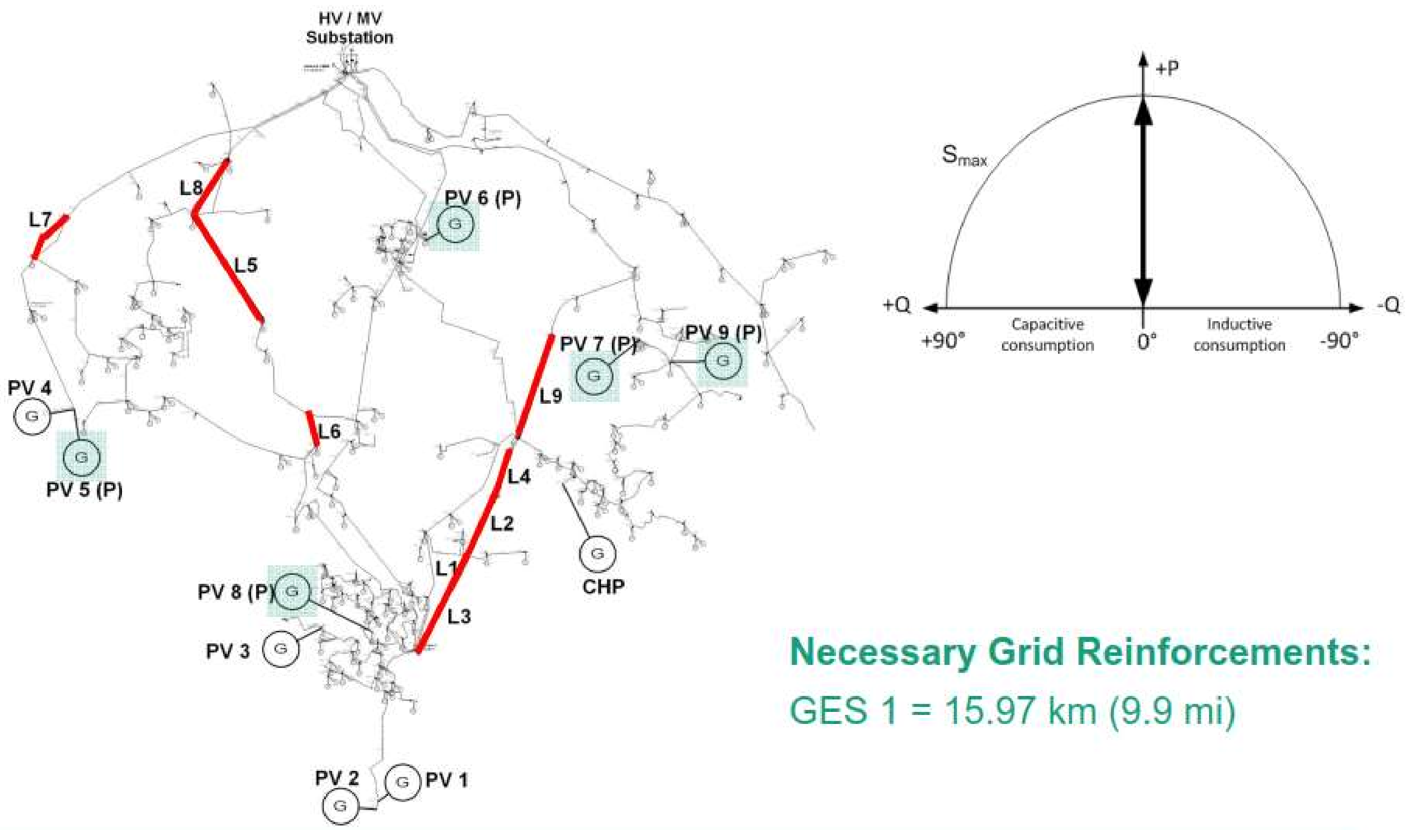
Investigated Scenarios (local control strategies only):

1. Pure active power feed-in (base scenario)
2. Reactive power provision by PV inverters
3. Automated voltage limitation: Active/Reactive power control by PV inverters

[3]

Germany as a case study

Scenario1: Pure Active Power Feed-In (Base Scenario)



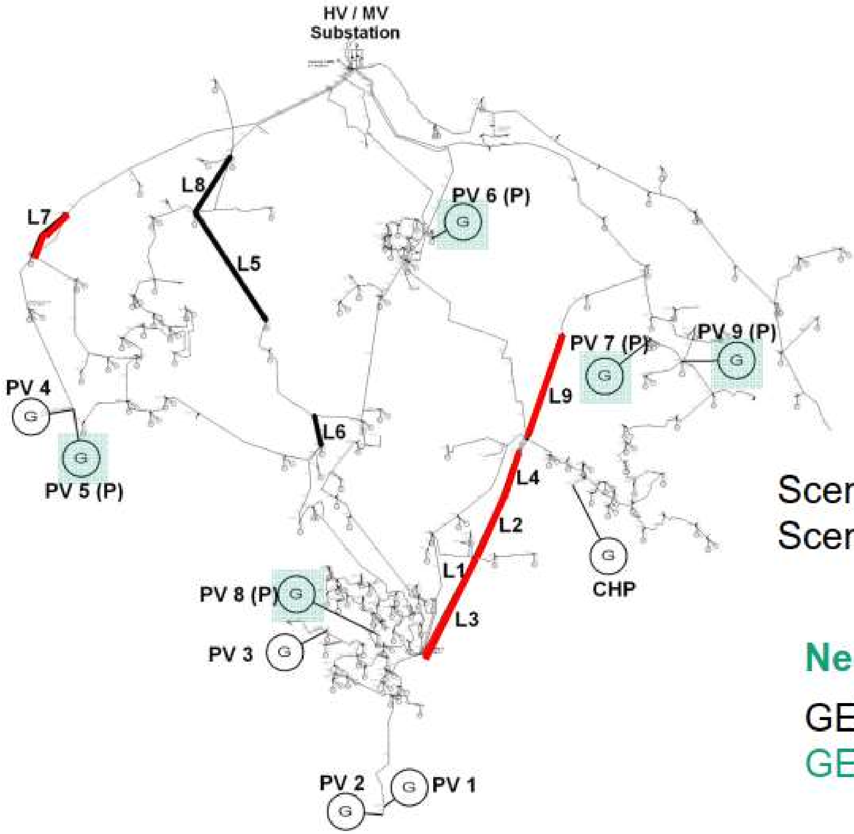
Necessary Grid Reinforcements:

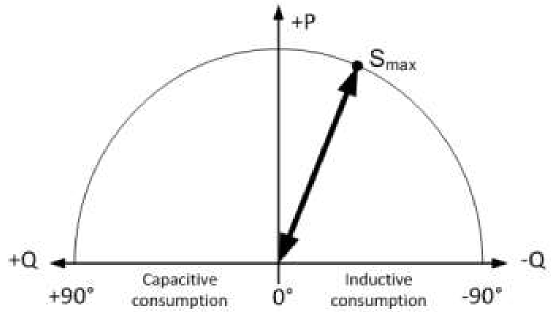
GES 1 = 15.97 km (9.9 mi)

— Cable Reinforcements

Germany as a case study

Scenario2: Reactive Power Provision





Scenario 2.1: Fixed Power Factor 0.95
Scenario 2.2: Q(U)

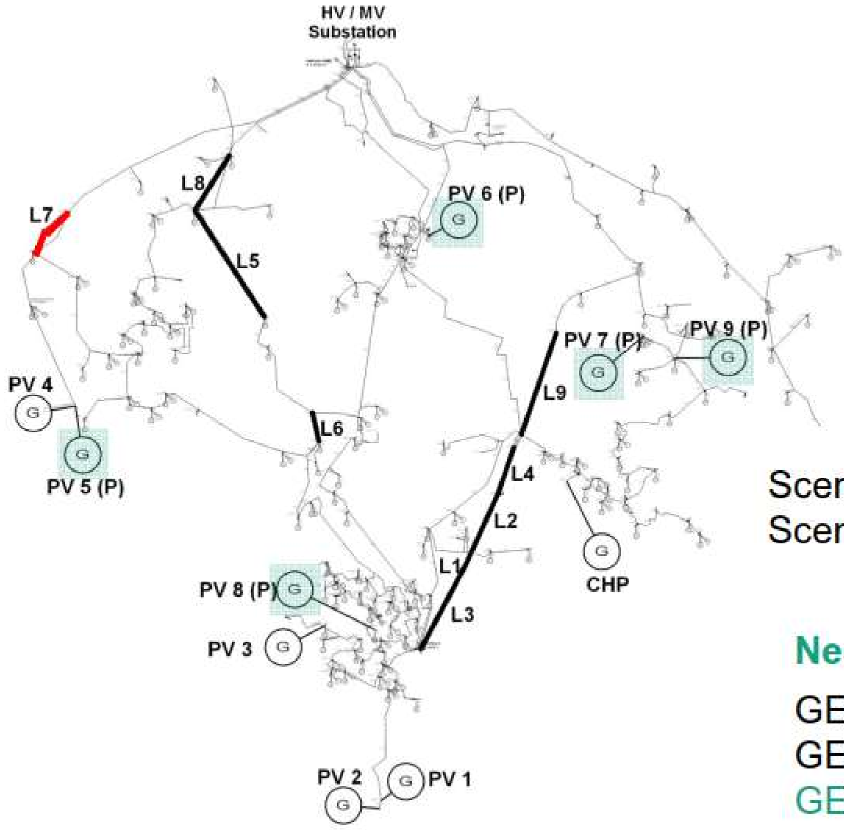
Necessary Grid Reinforcements:

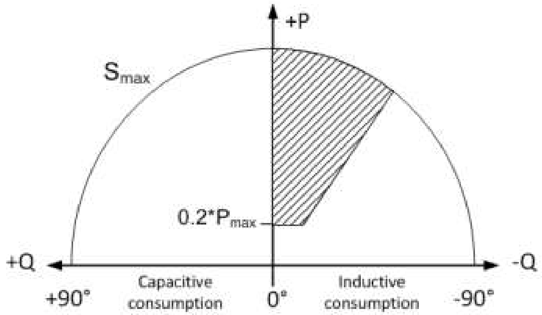
GES 1 = 15.97 km (9.9 mi)
GES 2 = 11.44 km (7.1 mi)

Cable Reinforcements

Germany as a case study

Scenario3: Automated Voltage Limitation





Scenario 3.1: Max. Voltage = 1.07p.u.
Scenario 3.2: Max. Voltage = 1.06p.u.

Necessary Grid Reinforcements:

GES 1 = 15.97 km (9.9 mi)
GES 2 = 11.44 km (7.1 mi)
GES 3 = 1 km (0.62 mi)

— Cable Reinforcements

Germany as a case study

- Today Germany uses this strategy in areas with high penetration of PV
- Subsidy scheme for energy-storage batteries [4]
- Flexibility services and PPAs (Power Purchase Agreement)

Technology Development – International best practice

- Germany as a case study
- Flexibility services

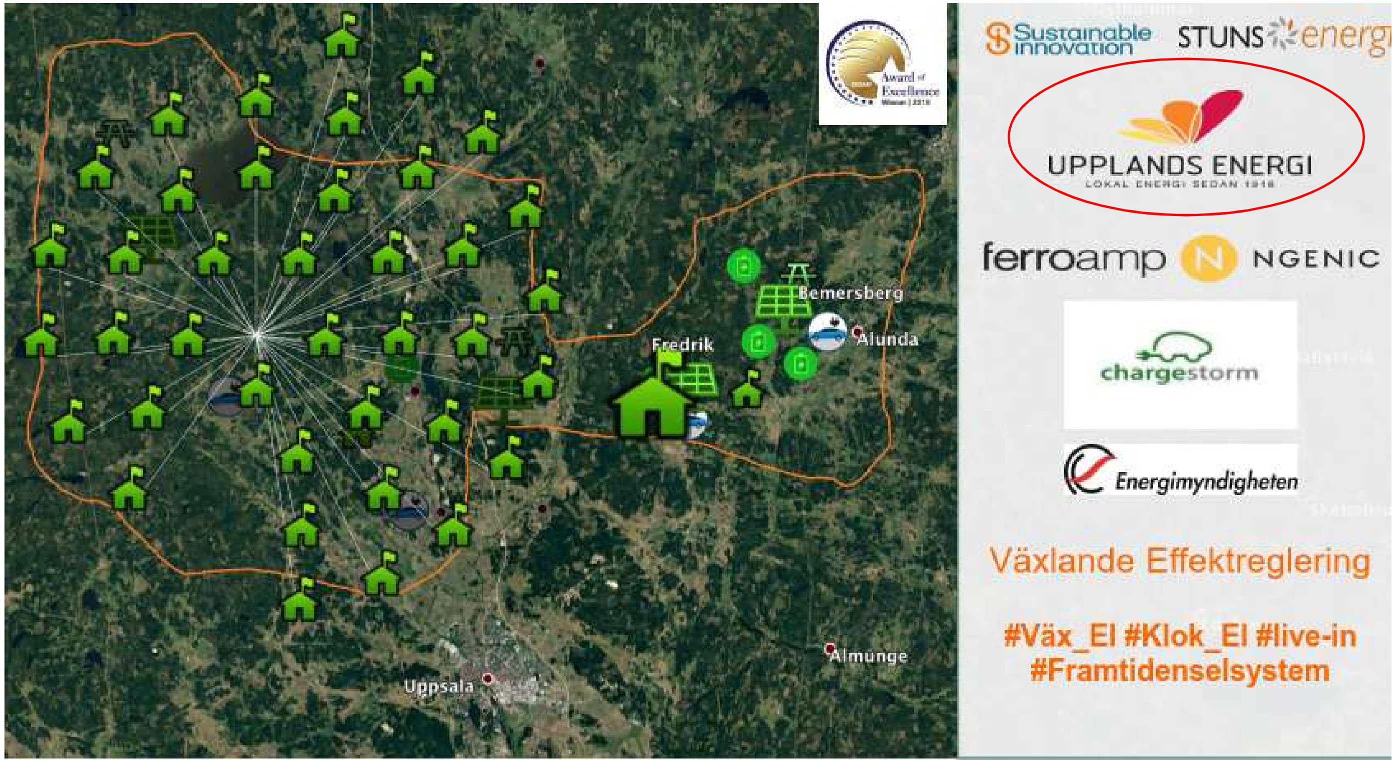
Flexibility services

- There is a large number of flexibility services both on the market and discussed on top of the agenda
  - Battery storage
  - Pumped storage
  - Hydrogen storage
  - Micro grids
  - Nano grids
  - New market models
  - Virtual Power Plants (VPP)

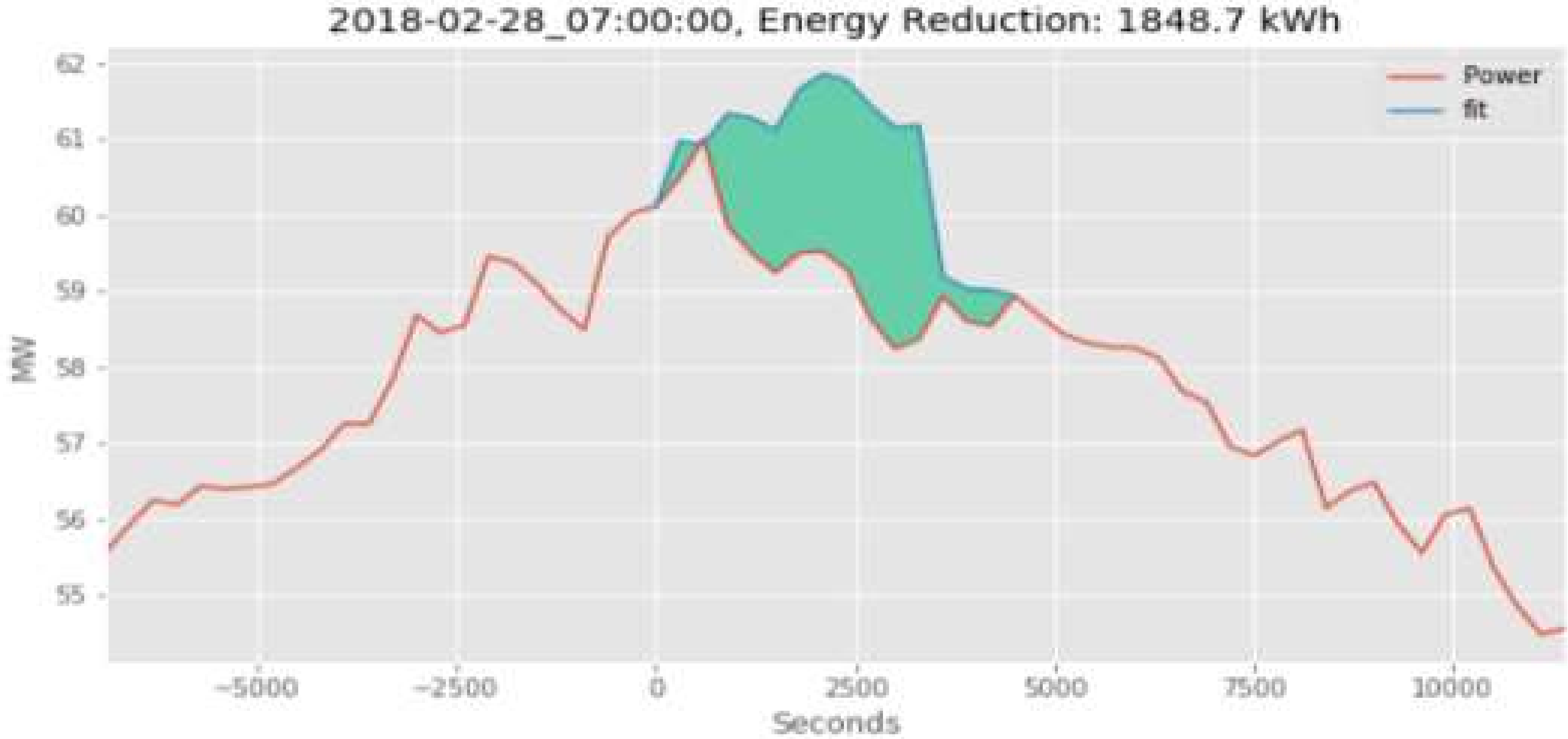
Virtual Power Plants (VPP)

Example from Sweden

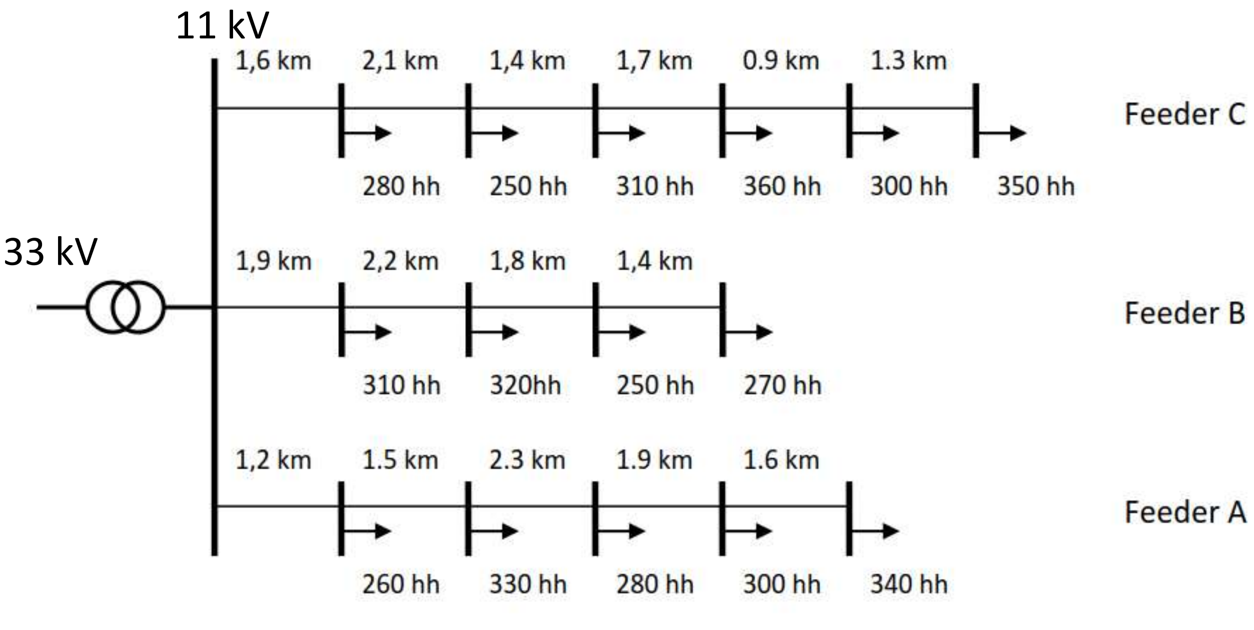
- 250 customers
- Heat pumps
- Reduced heat



Example from Sweden



Home work to perform before watching Session 3

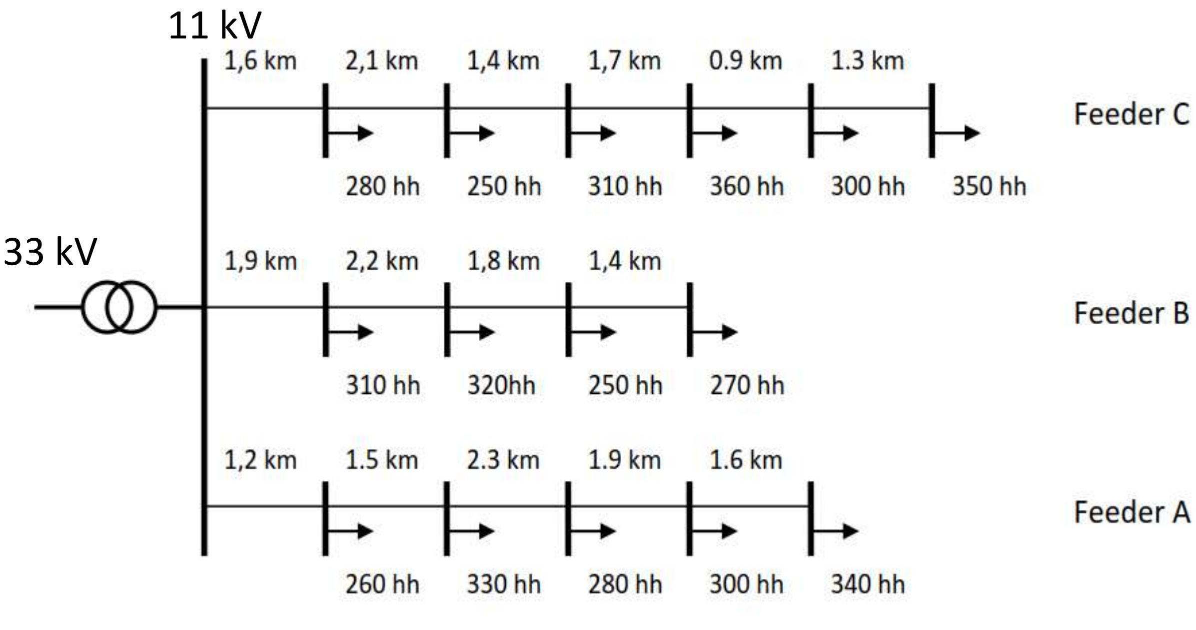


hh = Household

Lets study what will happen to the system losses at MV-level when the households at three 11 kV radials (Feeder A, B and C) starts to install small scale PV systems at their roof tops.

All the households in the same radial has the same kind of heating/colling system and therefore the same assumed electricity consumption. The PV system size is determined of the household yearly consumption of energy.

Home work

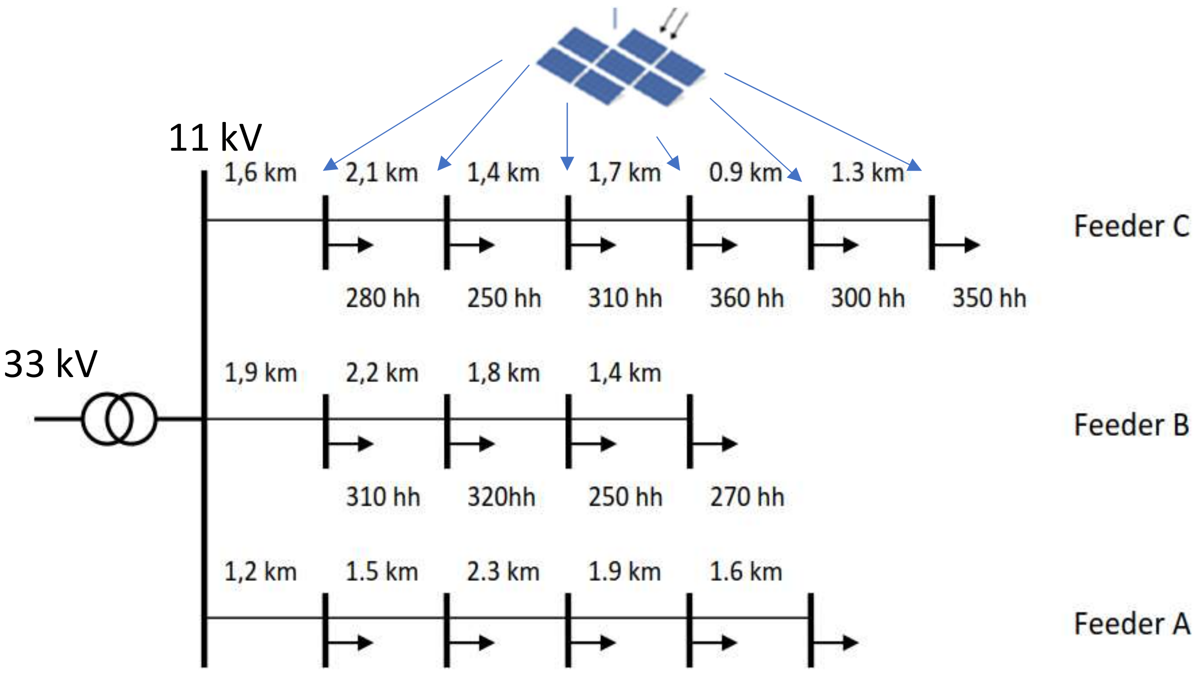


hh = Household

Assume that 10, 50 resp. 100% of all the hhin each feeder invests in SSEG and consider what will happened with:

1. The voltages at the MV-busses for different share of SSEG?
   a) Sketch a curve showing what you think will happen to the bus voltage as a function of SSEG share in the grid and
      i. During high load
      ii. During low load
2. System losses for different share of SSEG?
   a) Sketch a curve showing what you think will happen to the system losses as a function of SSEG share in the grid
3. Based on your assumptions, which suggestions do you have for improvements to accommodate more SSEG in the grid and retain power quality? Discuss.
   a) Technical improvements
   b) Flexibility services
4. Can you think of an "optimal" SSEG level?
5. Is there any benefits with SSEG?

Home work



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Refrences - Background

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[3]https://www.researchgate.net/publication/224601813_Energy_loss_estimation_in_distribution_networks_for_planning_purposes
[4] CEER Report on Power Losses, https://www.ceer.eu/documents/104400/-/-/09ecee88-e877-3305-6767-e75404637087
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[6] Photovoltaic energy barometer 2007-2018, Wikipedia
[7] Eskom presentations by Naniki Lukhele, Nicolaas Esterhuysen
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