WP 3.2
Control Architecture of Future Power System

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Overview

← how i'm going to answer the questions posed

Sections

I. Fundamentals
← *Q. 3*

II. Activities in WP3 / WP3.2
← *Q. 2*

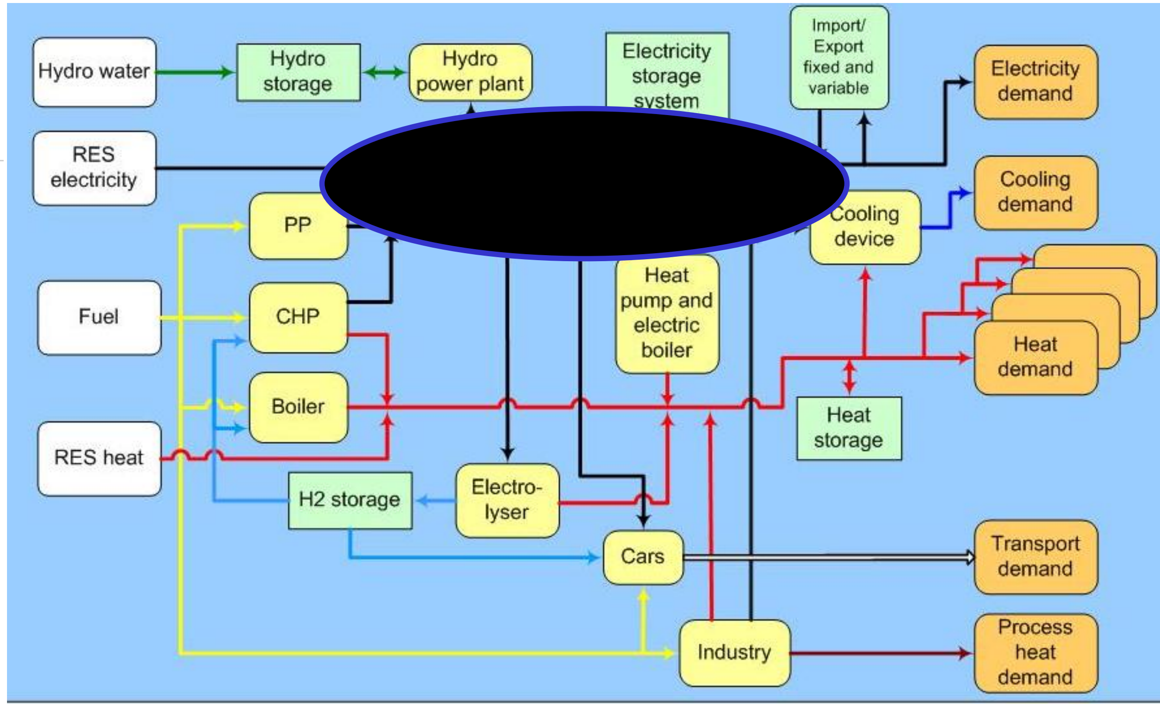
III. Integration within CEESA (WP1 and WP4)
← *Q. 1*

Questions we got:

1. What are the technical barriers and challenges for the grid and control system in […] scenarios […]?

2. How are we going to approach the task of analysing and solving the problems?

3. What feedback *are we able to come up with* in terms of modification that are needed to be made to the scenarios for electro-technical reasons?



section I

FUNDAMENTAL ”BLIND SPOTS” OF ENERGY PLANNING

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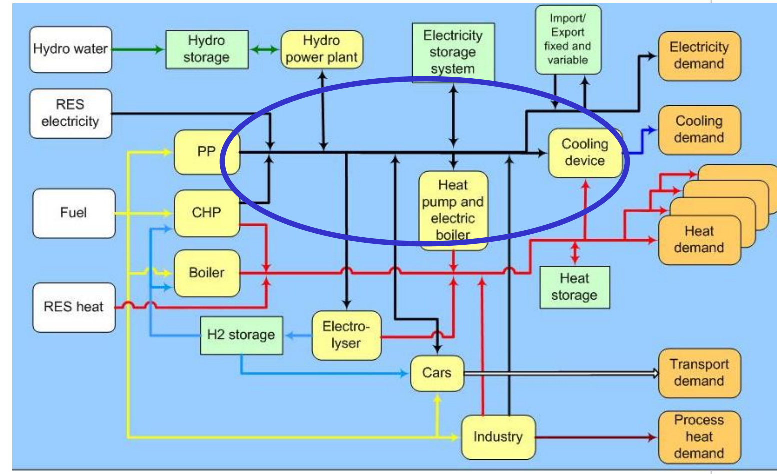
Three (Electrical) “Blind Spots”



- Time Resolution
  - ”What happens within the hour?”
  - → Fluctuations and balancing
- Granulation & spatial distribution
  - Big central or distributed generation?
  - Placement
  - → transmission capacities
- The future is uncertain! How to prepare?
  - E.g. Uncertainty of wind power prediction
  - → Market Design
  - → Control Architecture

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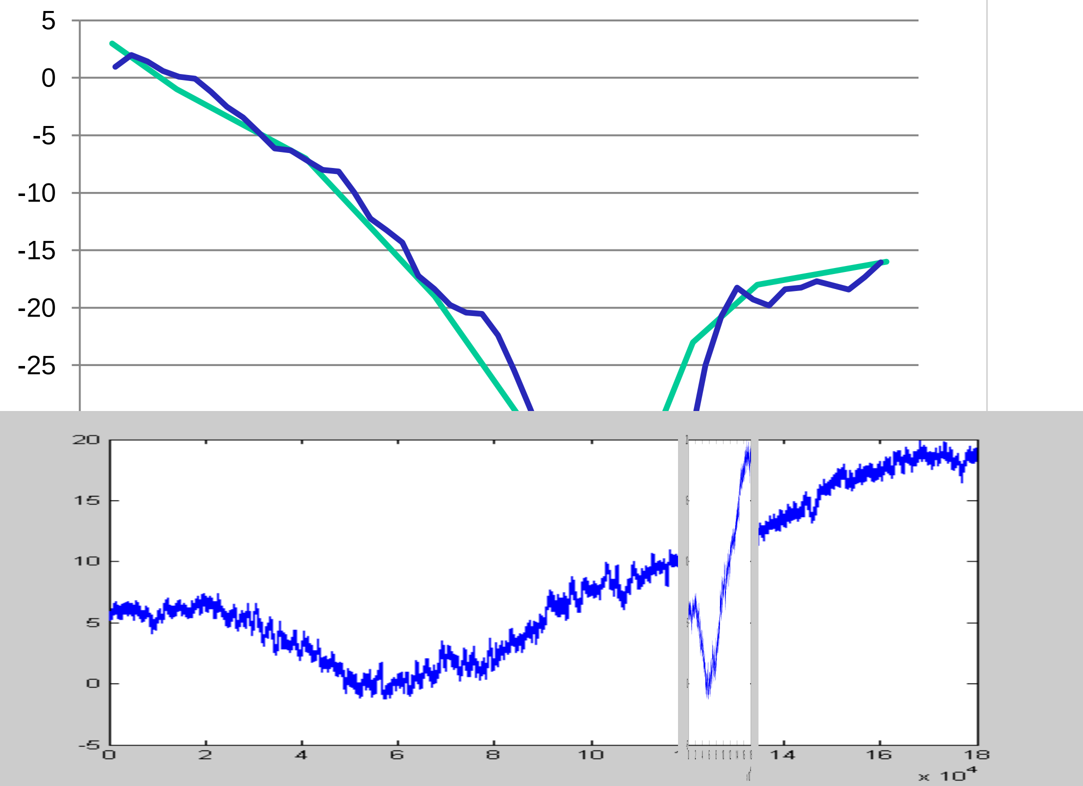
Time Resolution
– what happens within the hour?

- 12hours:
  - 1h vs 15min

- 1h with higher resolution

  ... As the output of a larger windfarm



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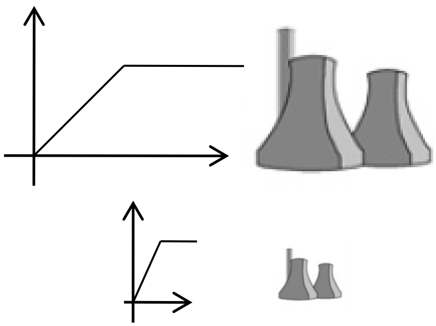
Granulation & spatial resolution

- The ramping capability of a generation unit is proportional to its size
  - Big units with inertia make ”friendly” (slow, controllable)
  - Small units make it more flexible but difficult to control
- Big central or distributed generation?
  → Ramping / Flexibility
- But also: Location
  - Will you balance wind power locally?

  → transmission capacities



Dealing with uncertain future ...

- Next *day / hour / minute / second*
- ”benefit -of-hindsight” used in EnergyPlan
  - Yearly distribution is optimally utilized with storage

- Following a plan under uncertainty when operating
  - Uncertainty of forecast cannot be eliminated!
  - prepare for the uncertain.

→What Can be known? (Theoretical limits?)

→ Allocation of balancing resources (Markets)

→ Connection of control architecture and short-term markets

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section II

ACTIVITIES IN WP3

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What is in the scenarios? (IDA 2030 / *2050*)

A. Central Generation

- Replace future power […] by fuel cell CHP plants, equal to 35-40 per cent of total power plants in 2030, (individual house heating →district heating CHP)
- Introduce 450 MWe large heat pumps
- *Replace all CHP and power plants by fuel cell-based or biogas or biomass gasification*

B. Renewable Electricity (uncontrolled)

- Increase wind power
  3000 MW to 6000 MW in 2030
  onshore@3000MW, 3000MW offshore)
- 500 MW wave; 700 MW PV
- *Increase wave power to 1000 MW*
- *Wind power (all offshore)*
  IDA2050: 7000MW //
  IDA2050Biomass: 3000MW //
  IDA2050Wind: 12000MW

C. (controllable) Distributed Generation

- Replace natural gas boilers by microCHP, ~10 per cent of house heating
- *Convert micro CHP systems from natural gas to hydrogen*

D. Electricity Demand Reduction

- … by 50 per cent in private households
- …by 30 per cent in industry

E. (controllable) Demand flexibility

- Flexible electricity demand in order to integrate wind power and CHP better in the energy system. (quantification?)
- *3TWh of industrial heat from heat pumps*

F. Transportation – V2G

- 20 per cent of fuel for road transportation by electricity (and 20 per cent by biofuels)
- *Stabilise the transportation demand at the 2030 level*

Initial comments / Apparent challenges

- The fundamental (frequency-forming) unit of power systems is the *synchronous generator*.
  Introduction of *fuel-cell CHP plants* means to remove stabilizing system inertia.

  →complete replacement of CHP plants by fuel cells seems most radical system change

- All measures are stated with reference to Ref2030 scenario*
  →scenario descriptions are only relative changes.
  A “business as usual” power system model does not exist.
  Further, a power system for the whole of Denmark is not available for us, neither tractable.

Mapping to Electricity perspective

1. Generation Units ←*more renewables, less inertia?*
2. Grid Design ← *transmission network, components?*
3. Balancing Control ←*Intermittency*
    1. Controllability issues
    2. Balancing resources (time scales/ volume)
4. Network Control (Operational stability) ←*Changing flows*
    1. Voltage Control
    2. Distributed inputs
    3. Reactive flows and congestion management
5. (Protection Systems)

Measures / Tech. Areas	A. Central Generation	B. renewable Electricity	C. Distributed Generation	D. Demand reduction	E. Demand Flexibility	F. Transportation	WP3.1	WP3.2
I.	X	x		-	-	-	?	?
i.	X	x	x	?				
II.	X	X		x	X	X	X	X
i.	x	X		?	X	X	X	X
ii.		X	X		X	X		X
III.		x	X	-	X	?	X	x?
i.		x			X		?	x
ii.			X		X		X	x
iii.	X				x	x	x	
IV.	?	?		-	?		X?	?
X – major, x – minor, ? – unclear, - – none								

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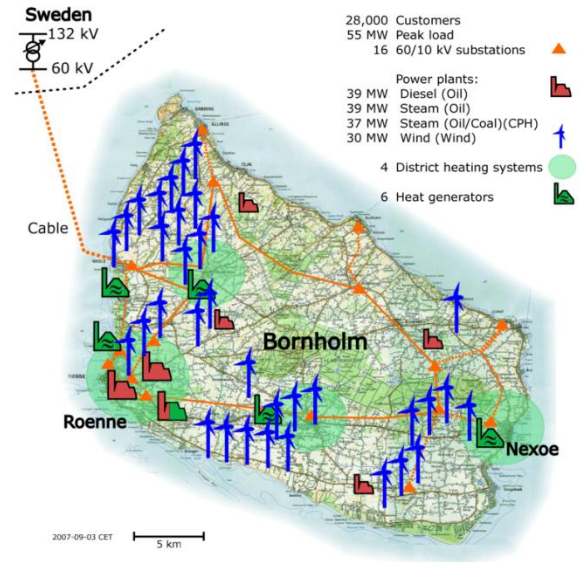
Bornholm as a Model for Denmark

Approach:

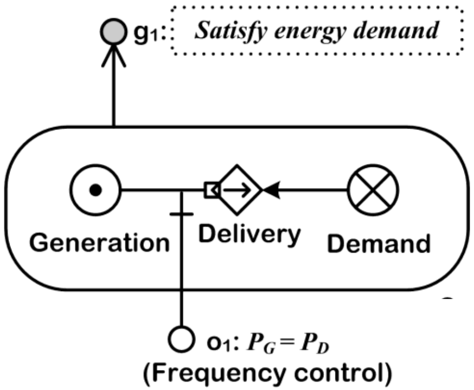
- scaling of CEESA scenarios to Bornholm (see WP3.1-presentation)
- Implementation of CEESA measures
- EnergyPlan Model + Dynamic models

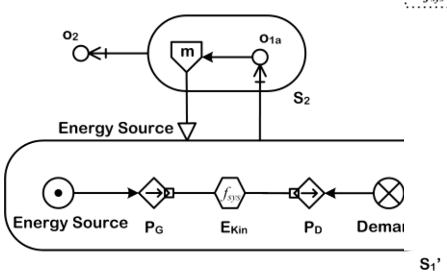


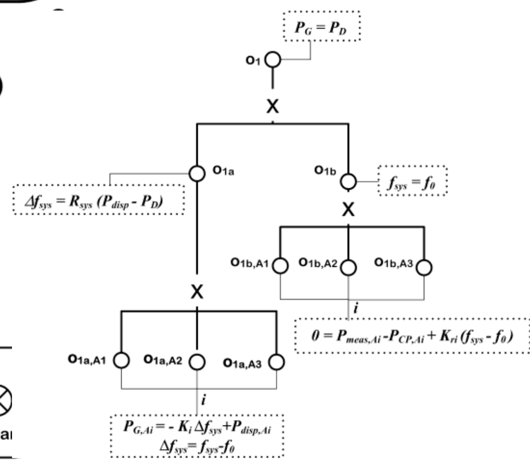
Goals

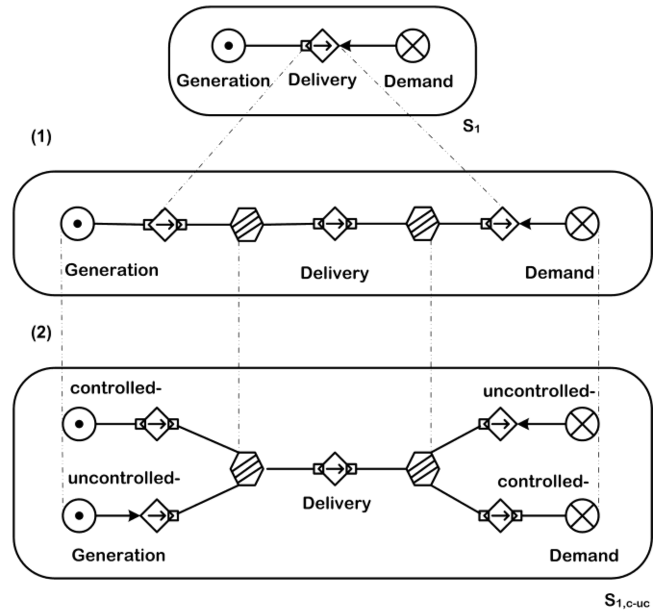
- Validate model results → how much wind can be intergrated
- Evaluate ”possible futures” in terms of alternatives control approaches

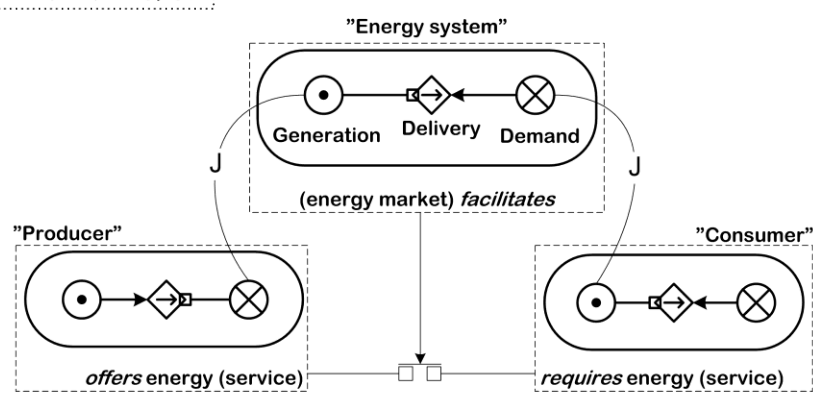
Functional Modeling of Control Architecture











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section III

INTEGRATION WITH CEESA

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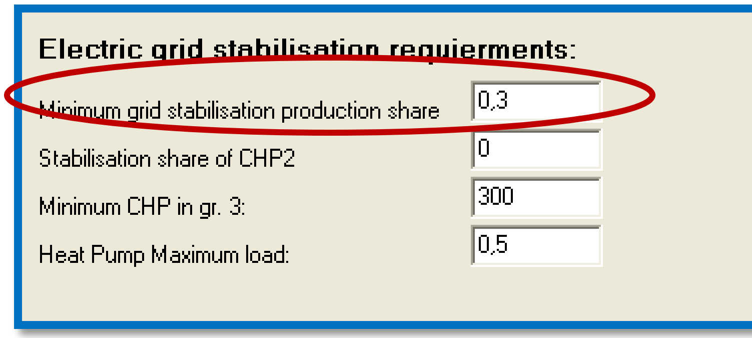
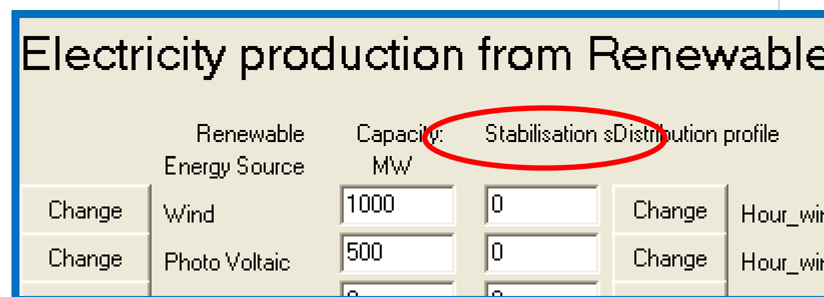
Integration with WP 1 / EnergyPlan

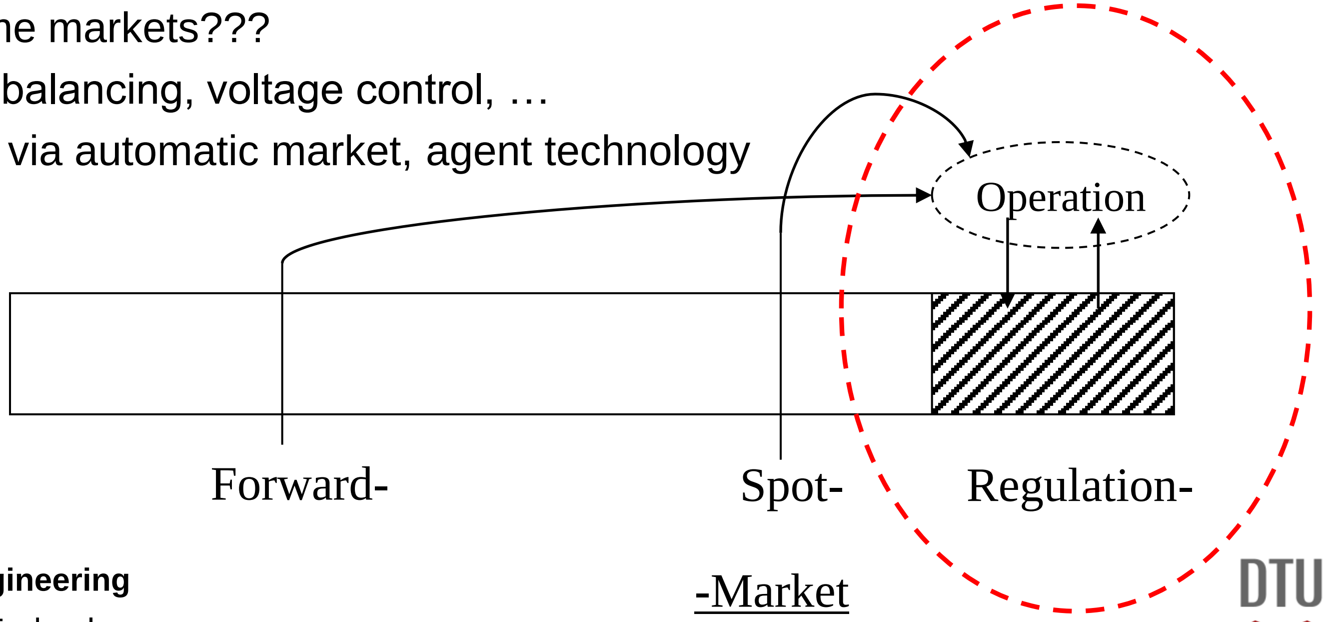
- EnergyPlan adresses some grid requiremnts
- Required *”stabilization share”* (connected large synchronous generation):
  - Estimated 30% according to experience from system operators
  - CEESA calcualtes with 0%
  - *Theoretical minimum* unknown
- stabilizing contribution from renewable energies
  - Possible, to be investigated...





Possible communication with WP4

- Requirements for *market design*
- Toward *markets* for flexible allocation of balancing resources,
  - Realtime markets???
  - Power balancing, voltage control, …
  - control via automatic market, agent technology



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Summary

- A careful mapping between between work packages is needed to achieve consistent results
- Most challenging questions with regards to the electricity system remain in the ”blind spot” of EnergyPlan
- Integration with WP4: questions of market design
- Bornholm island central ”mapping tool”
- Moving forward on the Functional Modeling

Thanks for your Attention!

Questions? Welcome!

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