Cost-benefit analysis of a flexibility market model ("Ampelmodell") for the electricity market of Switzerland

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Topics of presentation

- The presentation is about the results of the project “cost-benefit analysis of a light-solution-model for the power market of Switzerland“
- Client: Federal Agency for Energy (BFE), joint project with ef.Ruhr
- Central topic: potential role of local flexibility markets in distribution grids in a future power market shaped by the Energy Strategy 2050
- Focus: “Ampelmodell”, flexibility market model proposed by BDEW
  - Distinguishes three states of the distribution grid: green, yellow and red, depending on shortage (related to voltage & thermal limits)
  - Yellow state: activation of local flexibility market
  - Technical requirements: smart grid technology for feed- and load management
  - Trade-off between benefits in efficiency by Smart Market and cost for the Smart Grids
- Project analyses cost and benefits of the “Ampelmodell” as well as drivers of change in Swiss distribution grids

Overview

- Background energy policy of Switzerland
- Challenges for future distribution grid
- “Ampelmodell”
  - o Setup and regulatory challenges
  - o Technical requirements
  - o Technical use cases
- Quantitative cost benefit analysis
  - o Modelling
  - o Results
- Conclusions & Recommendations

Background Energy policy of Switzerland

Swiss energy strategy based on target scenarios (“Energieperspektiven 2050”)

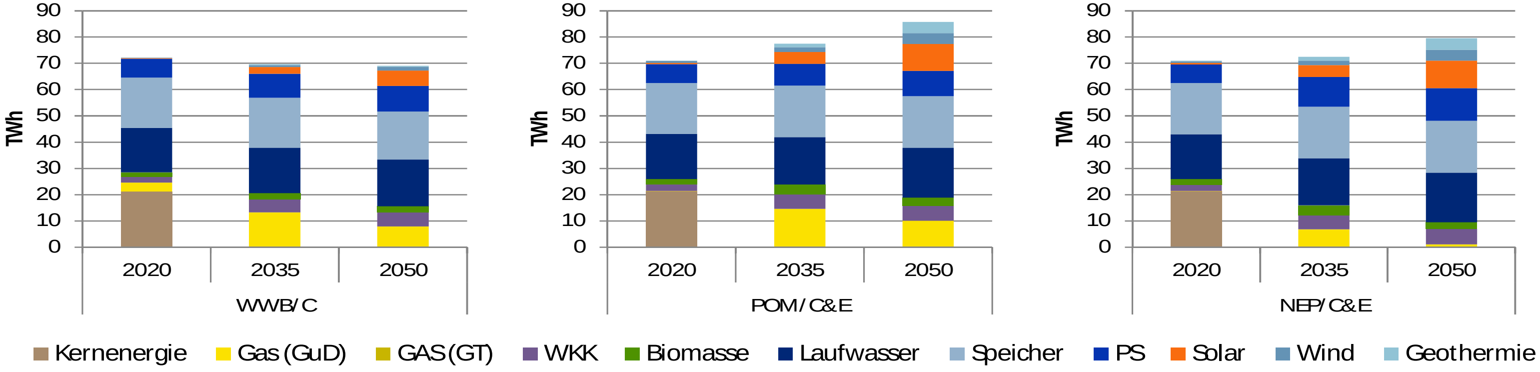
- Swiss energy policy is based on “Energiestrategie 2050”
- “Energieperspektiven 2050” are official target scenarios of the Swiss Federal Government
- Basis for further studies, including distribution grids or storage expansion
- Three main scenarios: NEP, POM, WWB

Scenarios Energy perspective 2050			
New energy policy	NEP	RES-expansion and Ambitious goals for energy saving	Solar wind expansion & CCGT, nuclear energy exit
Political package of measures	POM	RES-expansion	Solar wind expansion & CCGT, nuclear energy exit
Weiter wie bisher (continue like before)	WWB	Continue the trend	fossil central, nuclear energy exit delayed

Background Energy policy of Switzerland

Energy strategy focus on significant expansion of PV: Aim for 2050: share of approx. 30 %

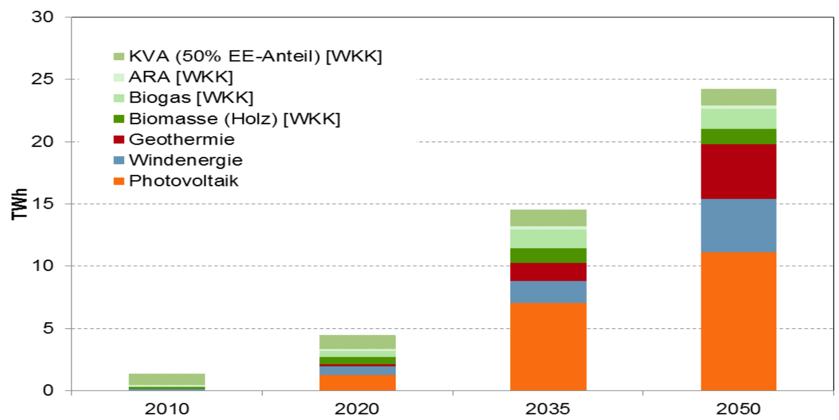
Forecast for the development of electricity production



Energy strategy 2050:

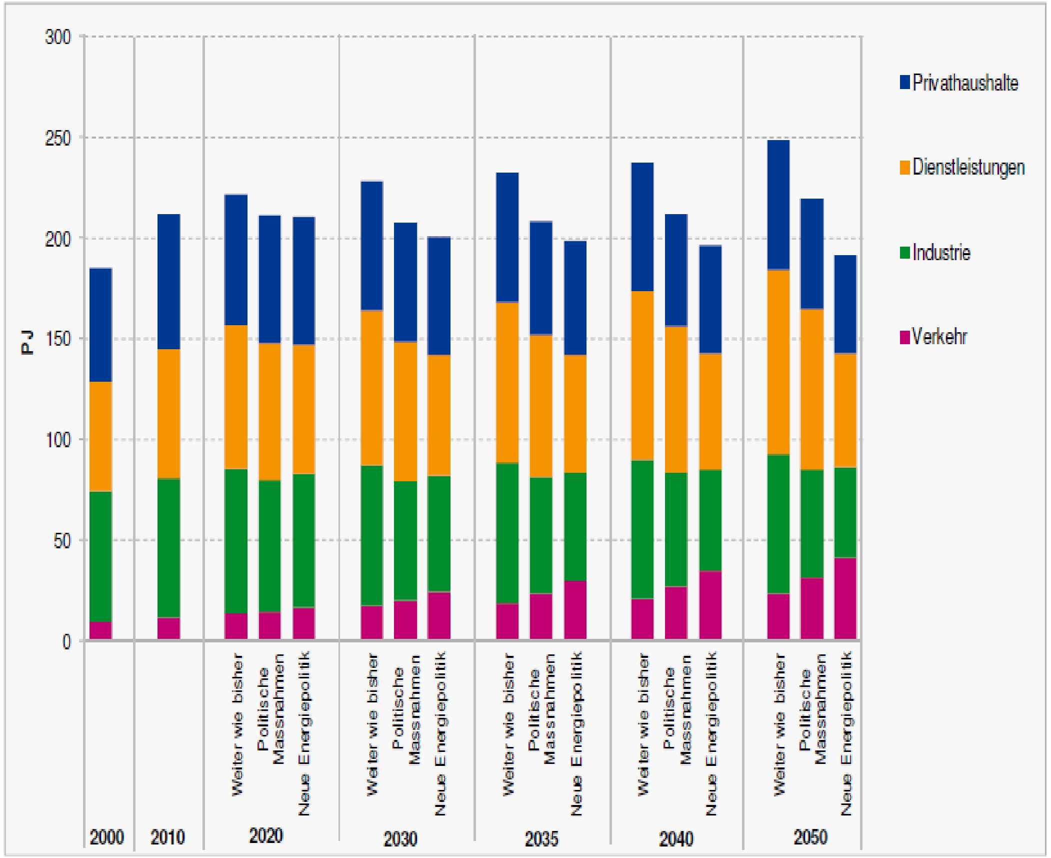
- nuclear phase-out by 2035
- Target scenarios assume strong increase of new renewable energies after 2035
- Photovoltaics dominates, Wind & Photovoltaics deliver two thirds of energy
- connection of Photovoltaics & Wind on low- and middle voltage level

New renewable energies in the scenarios (POM, NEP)



Background Energy policy of Switzerland

EP2050 scenarios



Quelle: Prognos 2012

- Figure shows the development of electricity demand for the scenarios from EP2050
  - WWB: Demand will rise
  - POM: Demand will be constant
  - NEP: Demand will decline
- But major changes are not predictable before 2020
- Decreasing of energy consumption by ambitious goals in regulation of efficiency
- Trend is uncertain – Climate policy goes along with higher usage of power utilities (electro mobility, heat pumps)

source: BfE/Prognos, EP 2050

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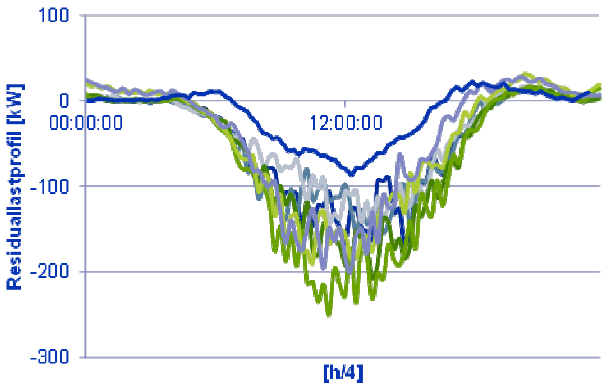
Challenges for the distribution grid

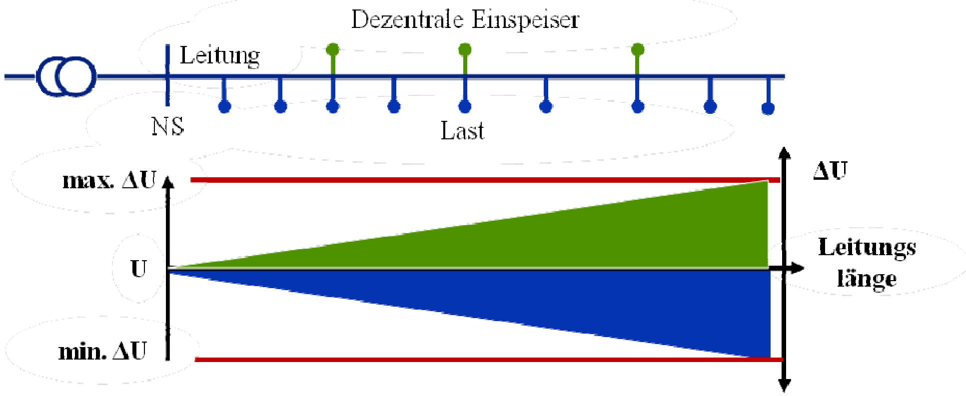
Increasing feed-in of intermittent RES-E leads to potential need for network expansion in distribution grid

- In the future, residual load in times of high solar PV feed-in will potentially exceed current thermal limits in low voltage grid
- Depending on distribution of installations, voltage problems could add to the challenges

Residual load exceeds thermal limit



Voltage problems in distribution grid



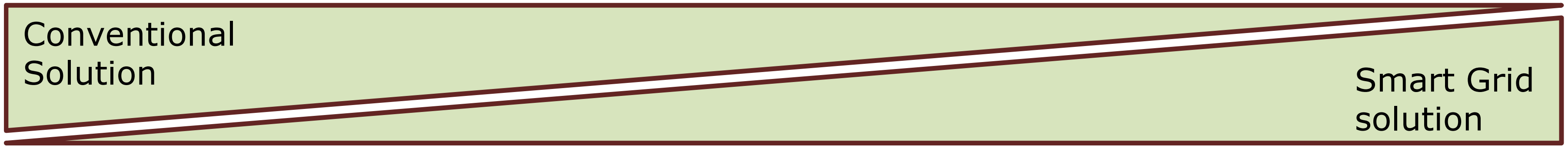
- Potential solution: (massive) conventional grid expansion
- Consentec Study on Swiss distribution grids: conventional expansion is expensive
  - 2035: distribution grid tariffs 35-40% higher than today
  - 2050: distribution grid tariffs 25-35% higher than today

Technical options for distribution grid operator

From the DSO‘s perspective conventional and smart grid solutions are competing technical options to tackle challenges

Distribution grid operators facing RES-E expansion dispose of different technical options

Construction of new infrastructure (lines & trafos) vs. Extension of existing infrastructure vs. Capacity expansion by optimized operation vs. Avoiding grid expansion by activation of flexibility



(Macro-)economic and DSO perspective are different:

- Econonomic perspective:
  - Minimization of total cost for a fixed level of
- DSO perspective :
  - Profit maximization (under given regulatory regime)
  - Ensure network stability & quality of supply

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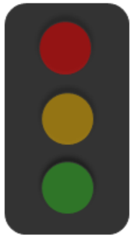
“Ampelmodell” by BDEW – decentral flexibility market

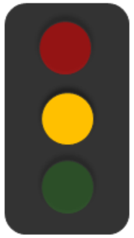
Model proposed by German Energy Association BDEW in 2012 , applied to Switzerland, is in the focus of the project.

Ampelmodell by BDEW (2012)



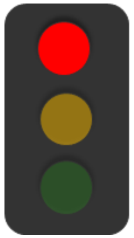
Green State

No congestion, market operations implement-ed as foreseen



Yellow State

Impending grid congestion, flexibility used by DSO to cope



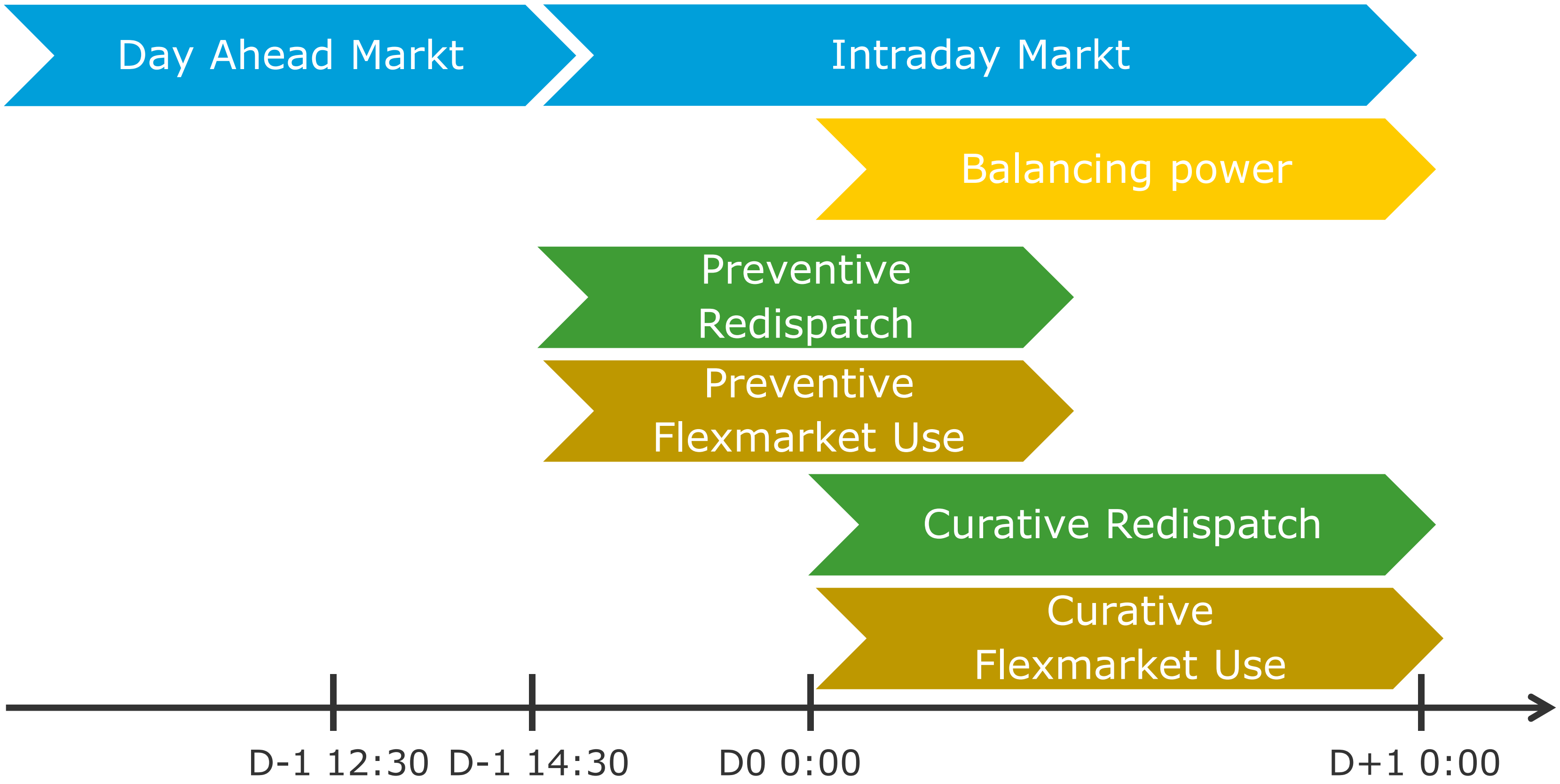
Red State

Grid stability in danger, technical intervention by DSO

- Goal: „ *DSOs should have a choice between grid expansion and flexibility provided in a separate market to ensure a cost-efficient expansion resp. operation of the grid as well as a high quality of supply .*"
- The green state today is represented by the normal market action and the red state by technical shortage- and disturbance management
- The yellow state is a new concept
  - Aim: Activation local /regional flexibility
  - Accounts for network constraints
  - Local market for flexibility: DSO is single buyer, flexibility offered by DSM, Storage or generation assets in distribution grid
  - Localizes the demand of system services, in particular demand for operating reserve

Comparison of „Ampelmodell“ with Redispatch

- Comparison of flexibility market in yellow state bears some resemblance to redispatch on transmission system level
- Flexibility market could be preventive and/or curative (design element)



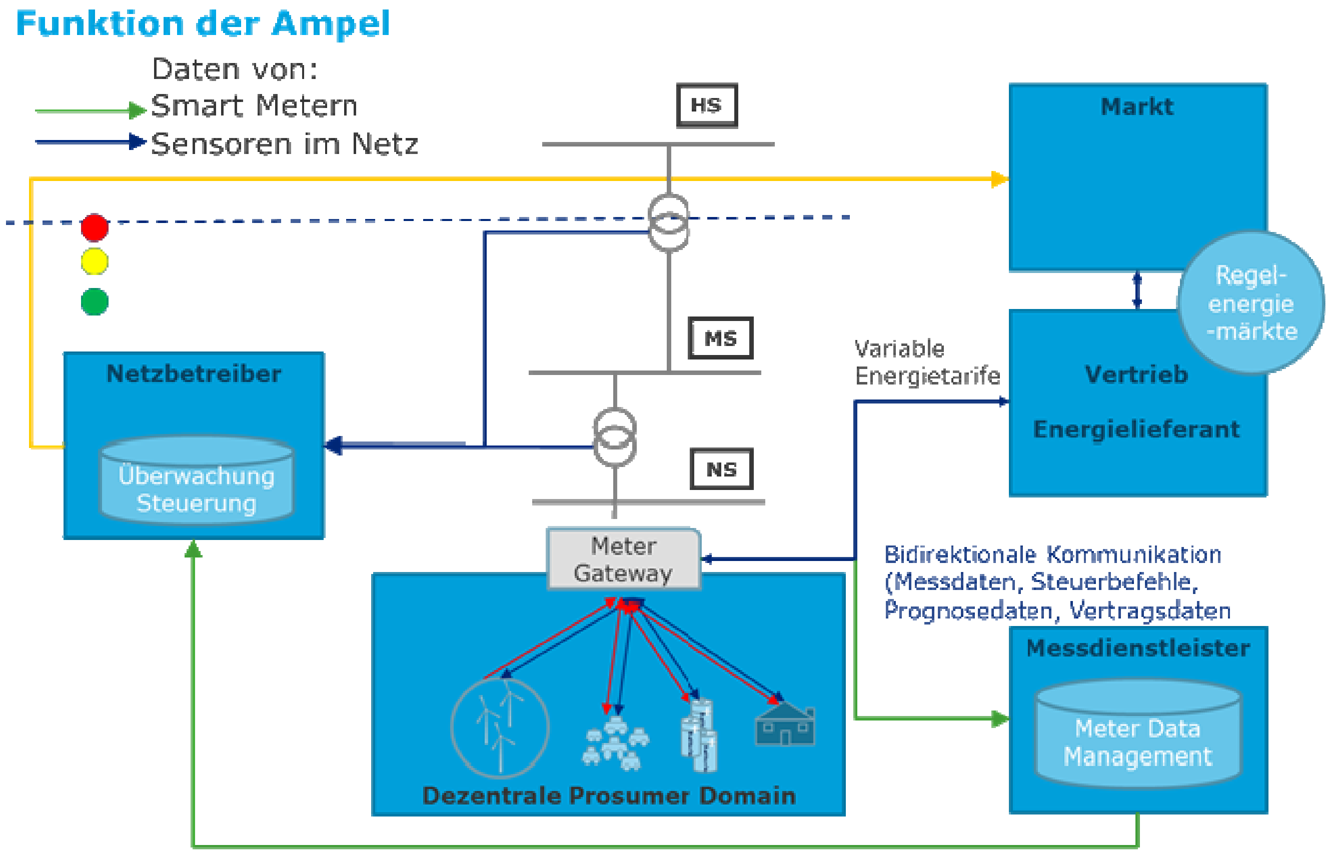
Regulatory challenges of „Ampelmodell“

- Introduction of a flexibility market as part of an „Ampelmodell“ entails a number of regulatory challenges (typical for smart grid solutions
  - DSO is Single Buyer – should he also be market operator?
  - How to organize market monitoring? How to deal with lack of / concentration of supply of flexibility?
  - How to regulate quality of supply (acceptance of red states)?
  - How to ensure balancing group of flexibility providers are observed? Who takes responsibility for balancing?
  - How treat CAPEX, how to treat OPEX associated with flexibility under grid regulation?
    - Specific problem for any „smart solution“: load maximum is key parameter in TOTEX based incentive regulation (not in Switzerland!, but in Germany)
  - Switzerland:
    - How to treat vertically integrated utilities at distribution grid level – how to prevent abuse of flexibility market?
    - What requirements to impose on DSO investment planning?

Technical requirements for Ampelmodell

Ampelmodell requires considerable investments into smart grid elements

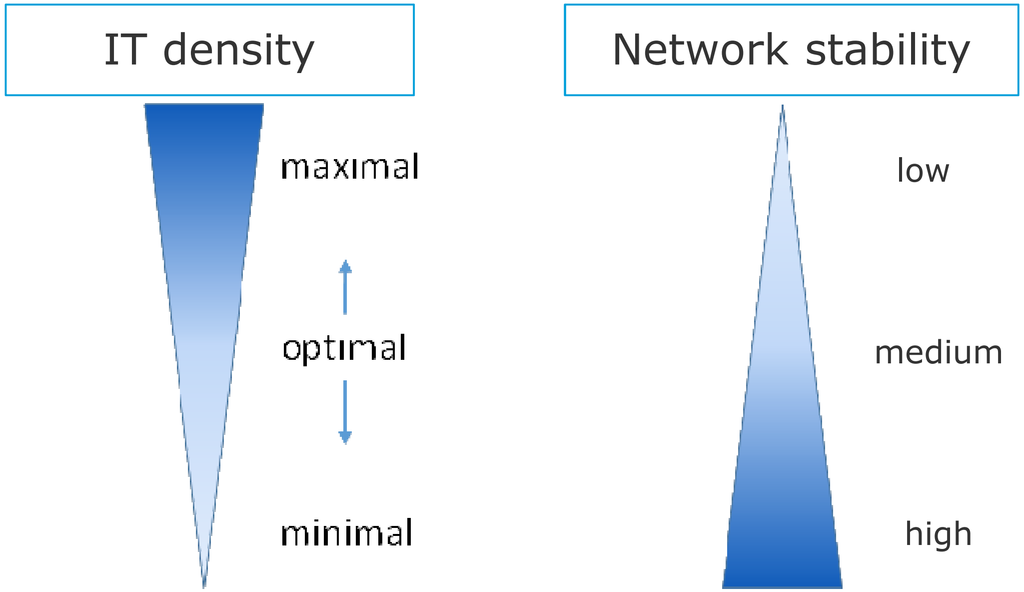
- ICT-requirements for the provision of flexibilities in yellow phase include both information and control elements
- Technical elements include:
  - Sensors
  - Meter Gateway
  - Control device DSM
  - Control device RES-E



Technical requirements for Ampelmodell

Ampelmodell requires considerable smart grid elements

- Inherent trade-off: Determination of trade-off between required rate of ICT and security margins within the distribution grid



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Technical Use Cases

The introduction of smart grid elements required for "Ampelmodell" yields a number of use cases. Not all are remunerated for in a potential flexibility market.

Classification of use cases of smart grid required for "Ampelmodell"

		TSO	DSO	BGM
UC 1	Voltage control & blind power compensation		√	
UC 2	Vertical congestion management (thermal limits		√	
UC 3	Avoidance & Shortening of supply interruption		√	
UC 4	Availability of data / information in distribution network		√	
UC 5	Optimization of flexibility in system markets	√		√
UC 6	Optimization of flexibility in local market	√	√	√
UC 7	E-Mobility infrastructure		√	√

Modeling prerequisites

Prior to modelling costs & benefits of the „Ampelmodel", scenarios of development have to be selected and tframework assumptions have to be fixed.

- Scenarios
  - Expansion of renewable energy sources and conventional generation as in Energy perspectives 2050 scenarios WWB, POM & NEP
  - We simulate stylized distribution grids for 2020 and 2035
- Assumption on stylized distribution grid
  - Distinction between rural and urban network as of today
  - Includes network levels 5-7, with simplified network topology
  - "typical" Swiss network in terms of grid and transformer capacity
  - Load connected in line with Swiss average
  - Variation of connected RES-E (in line with EP2050 scenarios)

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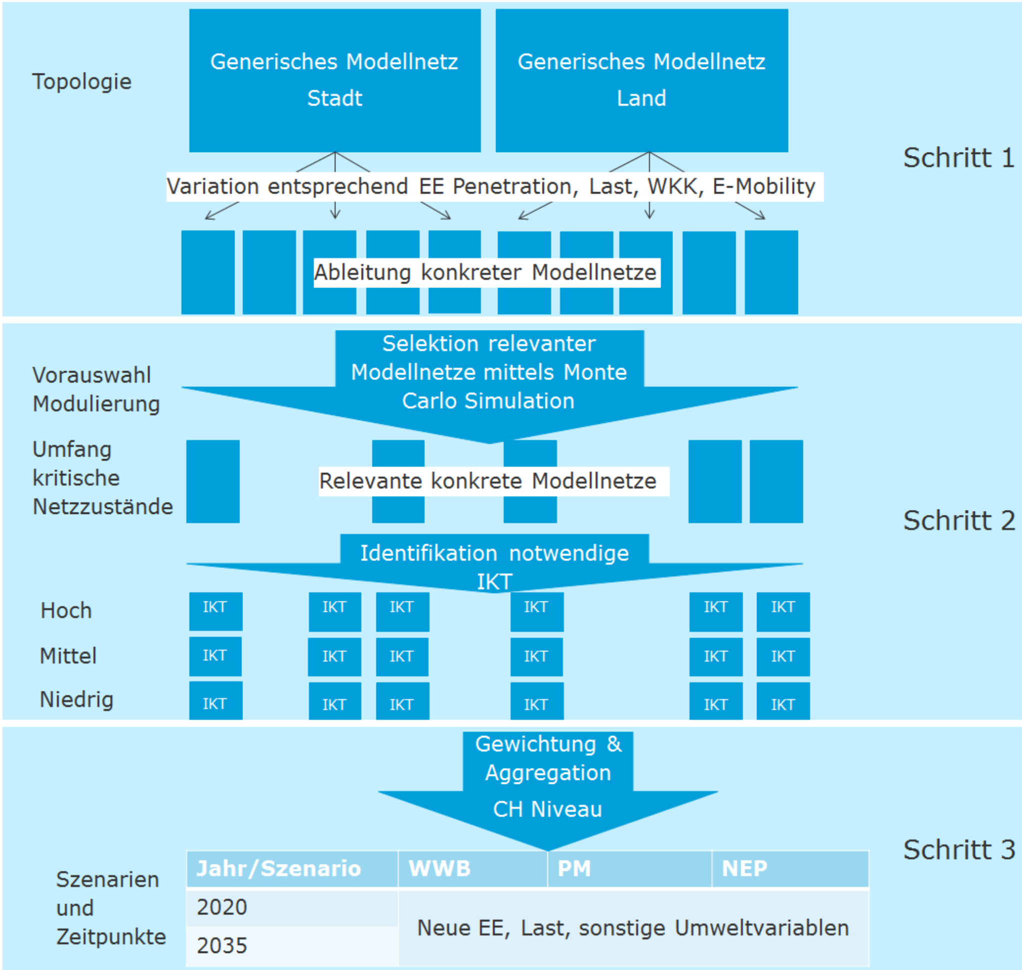
Structure of the cost-benefit-analysis for Ampelmodell

Modeling include three steps.

1. Identification of potential yellow states in the distribution grid
   a) Rural and urban grids modelled according to MC simulation over RES-E
   b) In parallel calculation of system price
2. Generic simulation of cost & benefits of "Ampelmodell" in smart market (ef.Ruhr Modell)
3. Extrapolation of "Ampelmodel" simulation to Swiss electricity system

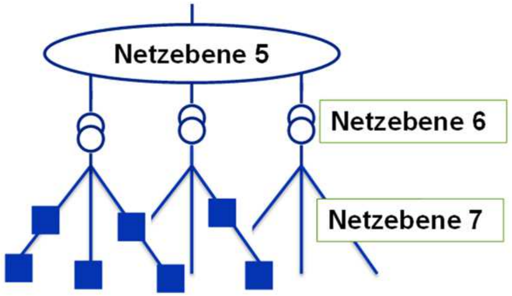


Modeling step 1a: Configuration of stylized network

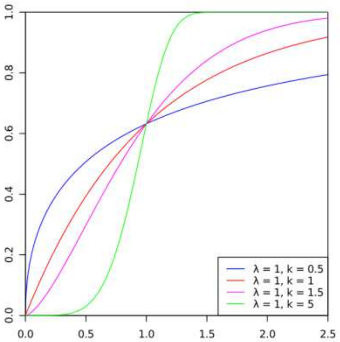
Configuration of stylized distribution grid for Monte-Carlo-simulation.

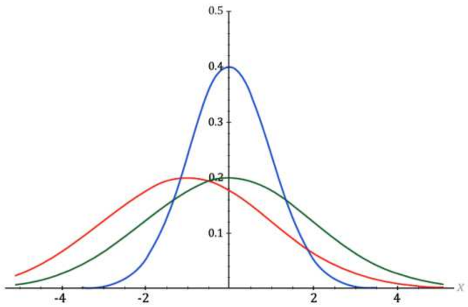
- Configuration of low voltage grid
  - Number of HH, farms, commerce, electric vehicles, heat pumps (with standard load profiles)
  - Power of transformer
- Configuration of medium voltage grid
  - Connection of low voltage grids
  - Connection of wind power plants (feed-in profile based on weather year 2011)
- Monte-Carlo-Simulation
  - Variation around mean for low voltage grid
  - 250 realizations (weather year 2011)
  - PV: Weibull-Distribution
  - CHP: normal distribution
  - Small hydro: uniform distribution

Connection of low and medium voltage grids



Weibull- and normal distribution (exemplary)



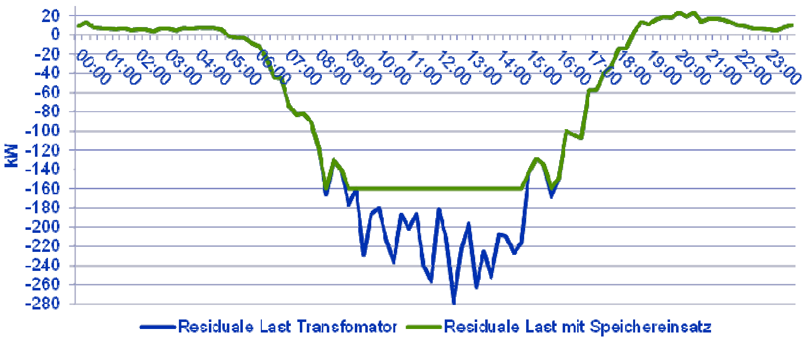


Modeling step 1a: Identification of red & yellow states

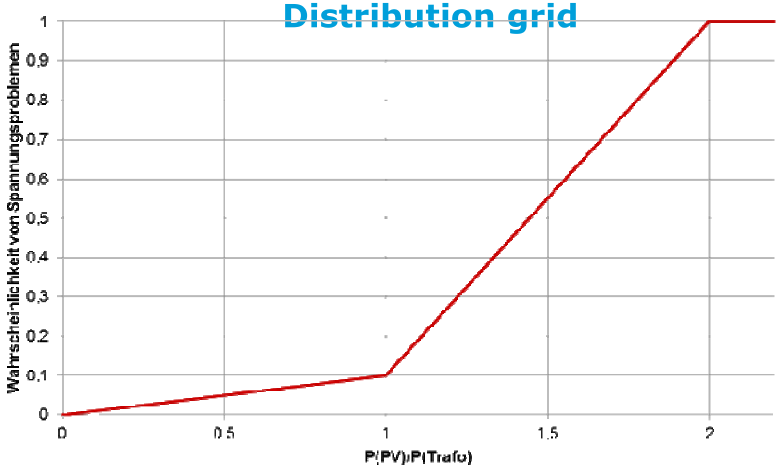
Identification of network problems, including both excess of thermal limits and voltage problems, in stylized grids

- Simplified approach, detailed calculation of load flows and economic reactions in step 2
- Identification of red & yellow states
  - Exceeding thermal limit (Transformer) □E□F > □E□F
  - Voltage problems → Prob(Voltage problem)

Residual load exceeds thermal limit



Probabilty of voltage problem in Distribution grid



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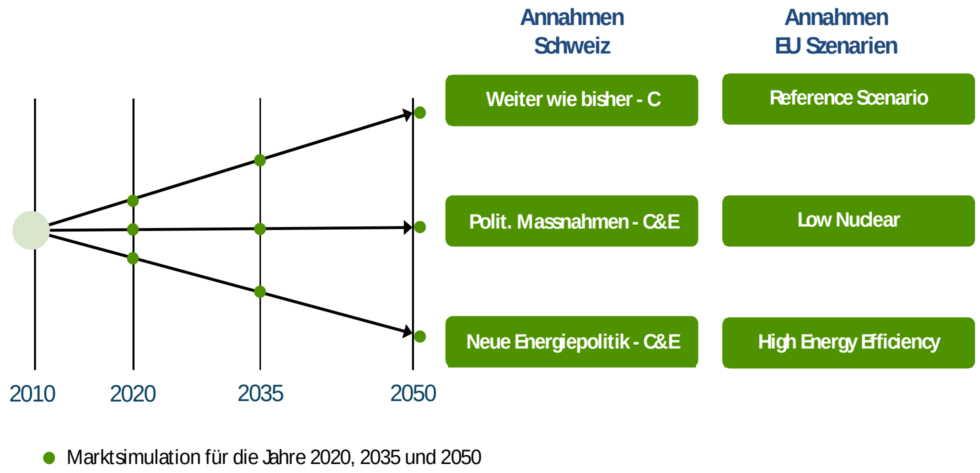
Modelling step 1b – simulation of system prices

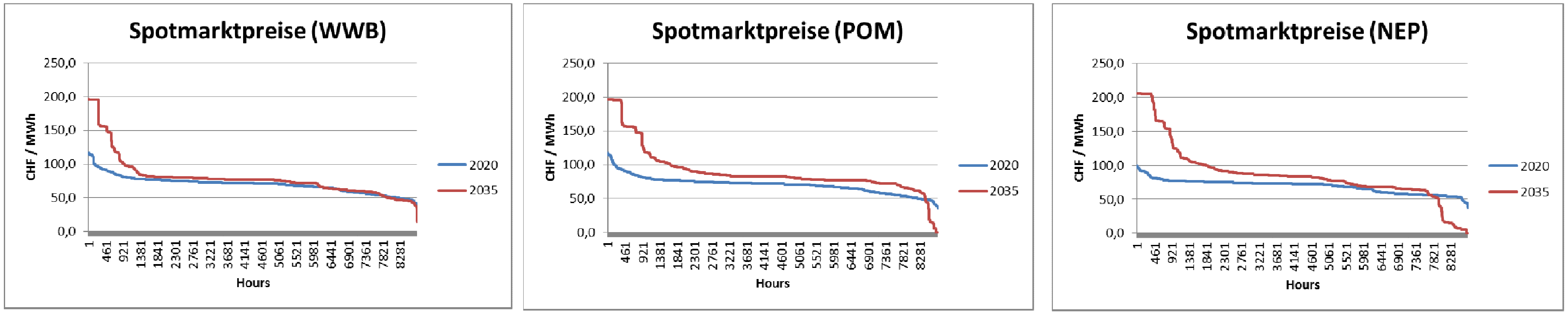
Simulation of wholesale & balancing market prices as basis for flexibility market price calculation in step 2

- BFE Project: Energy storage for Switzerland (2013)
  - Simulation of wholesale and balancing market prices
  - Combination of EP2050 with EU 2050 roadmap scenarios
  - Wholesale market prices calculated in PLEXOS based European market model
  - Derivation of balancing market prices by opportunity cost analysis

Scenarios



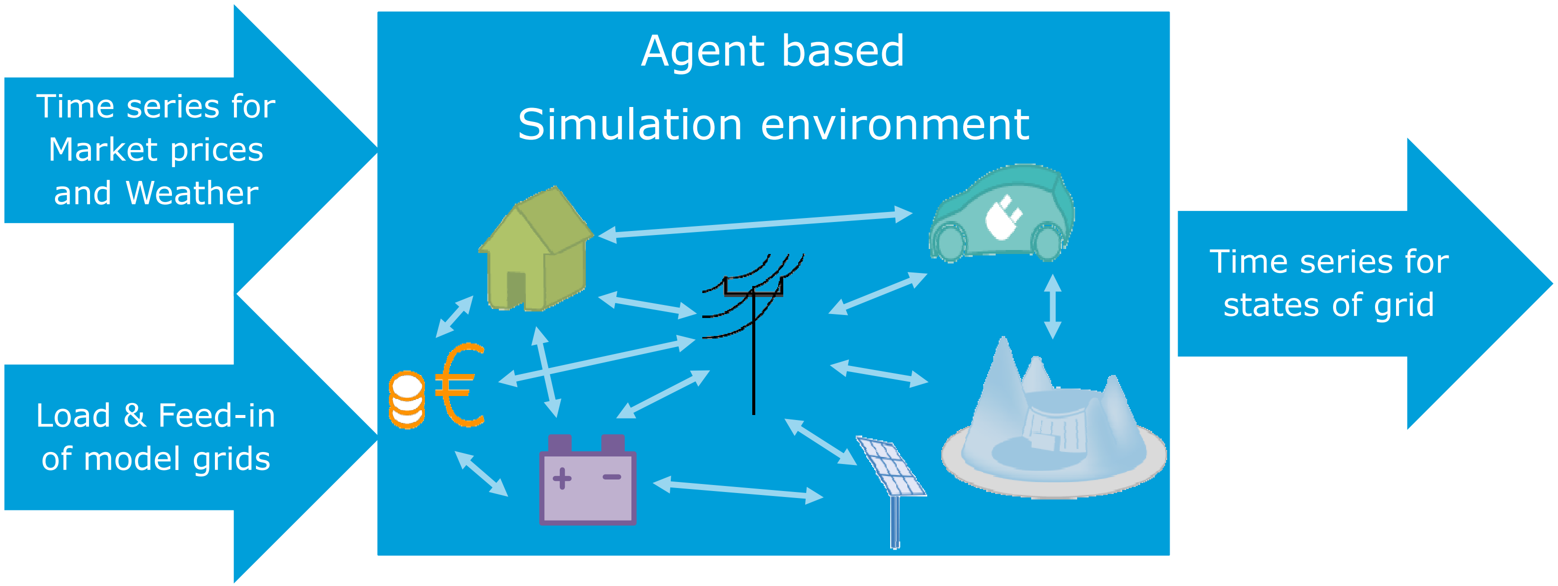
Simulated price duration curves for Swiss spotmarket



Modeling step 2: agent based grid model

Detailed simulation of selected model grids with an agent based model

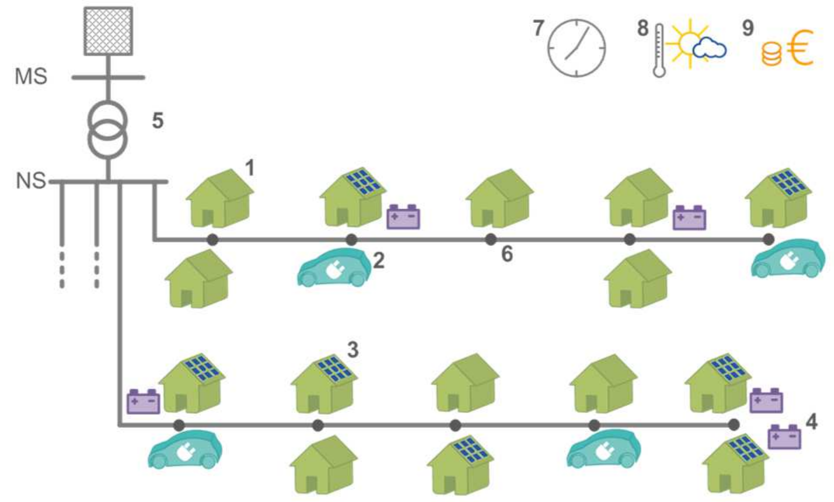
- Agent based simulation for certain grids (in yellow states), which are chosen by the Monte-Carlo-simulation
- System prices are taken from the market simulation from step 1b



Modeling step 2 – details of network model

Umfassendes exemplarisches Netzmodell mit MS- und NS-Ebene.

- Basic setup
  - Simulation of a MV-network with LV-networks (Cigré Benchmark-Netz)
  - All network users are parameterized individually and located in grid.
  - Network users have individual utility functions and react to prices
  - System price is underlying simulation
- Interpretation of „Ampel“ states:
  - „green“: unlimited market activity
  - „yellow“: network problems identified, flexibility price (as deviating from system price) is
  - „red“: introduction of flexibility price does ot solve problem



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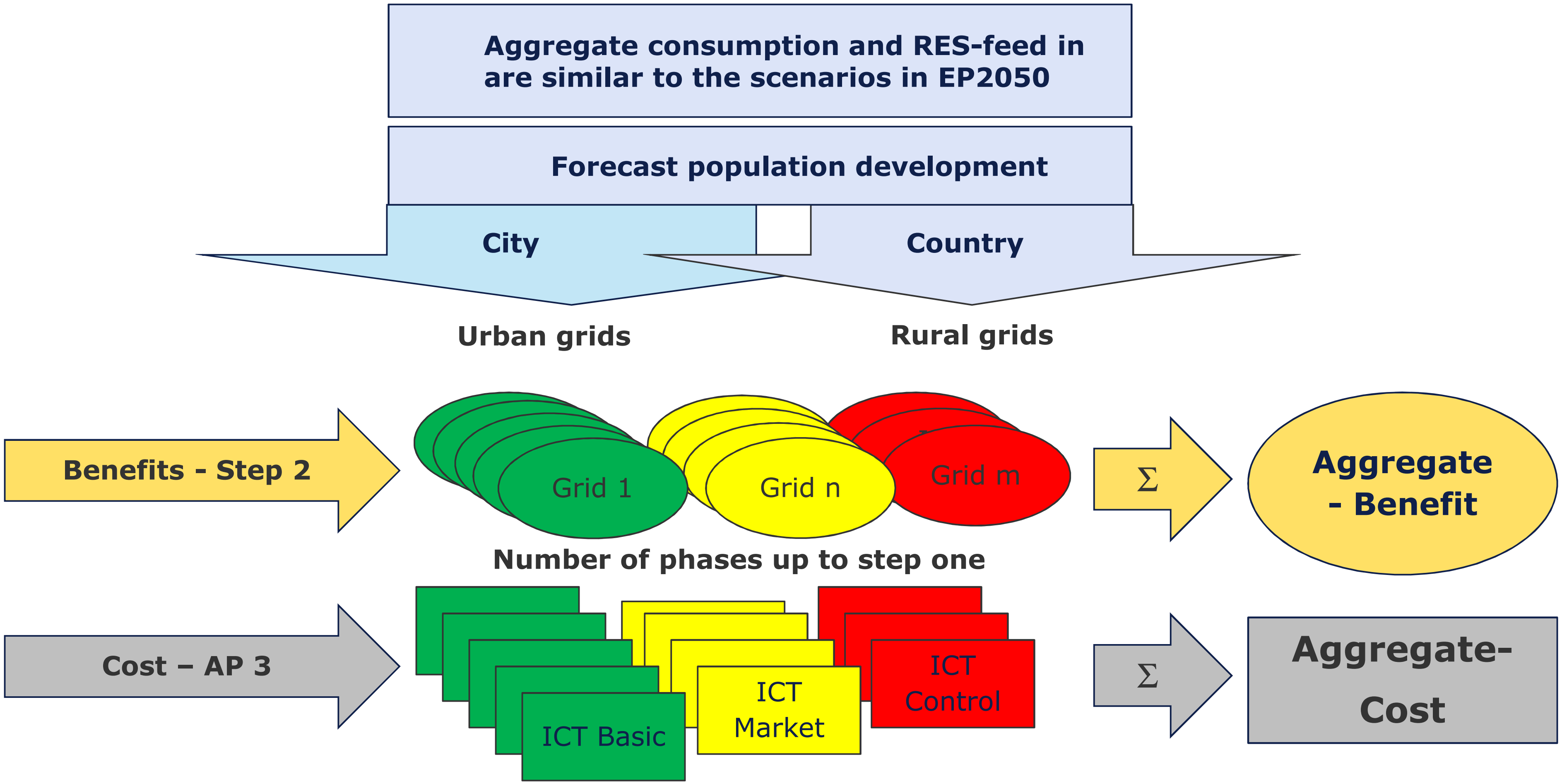
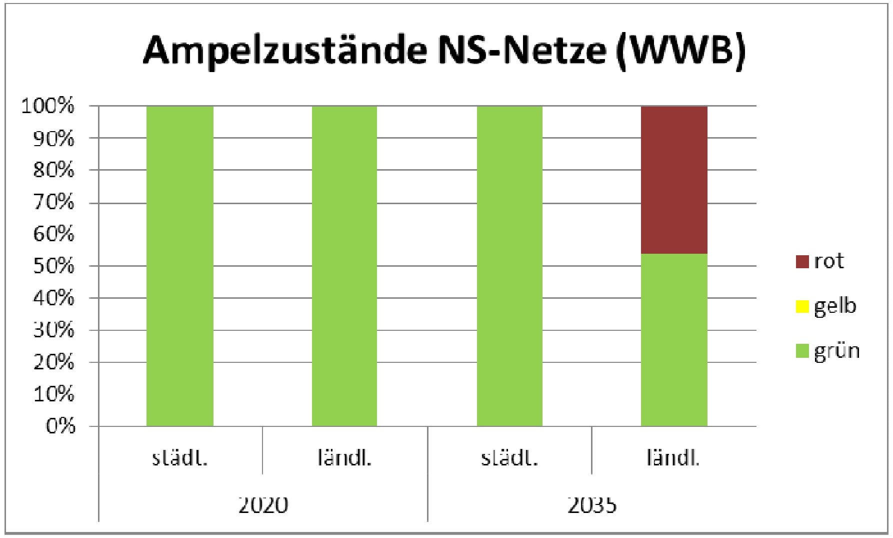
Modeling step 3 - aggregation of results

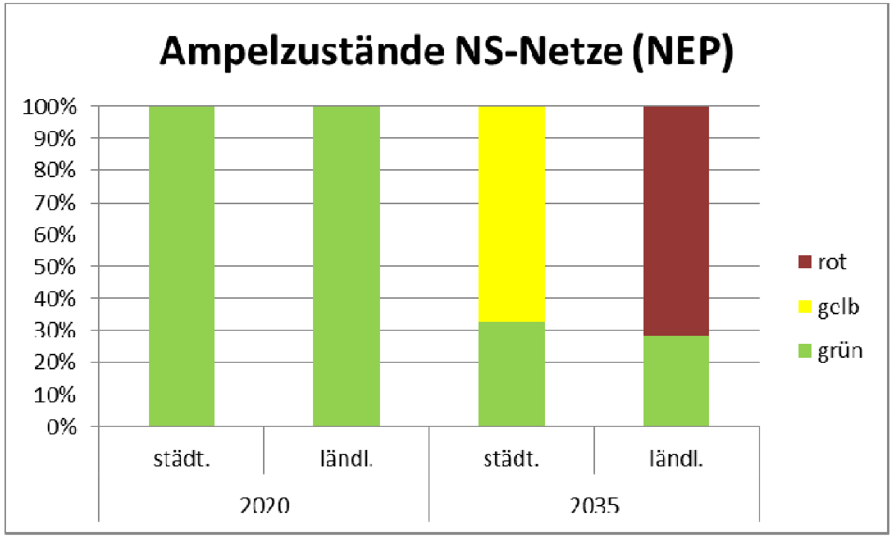
Aggregation of local Cost and Benefits leads to an aggregate picture for the Swiss electricity system



Results of MC-simulation of distribution networks

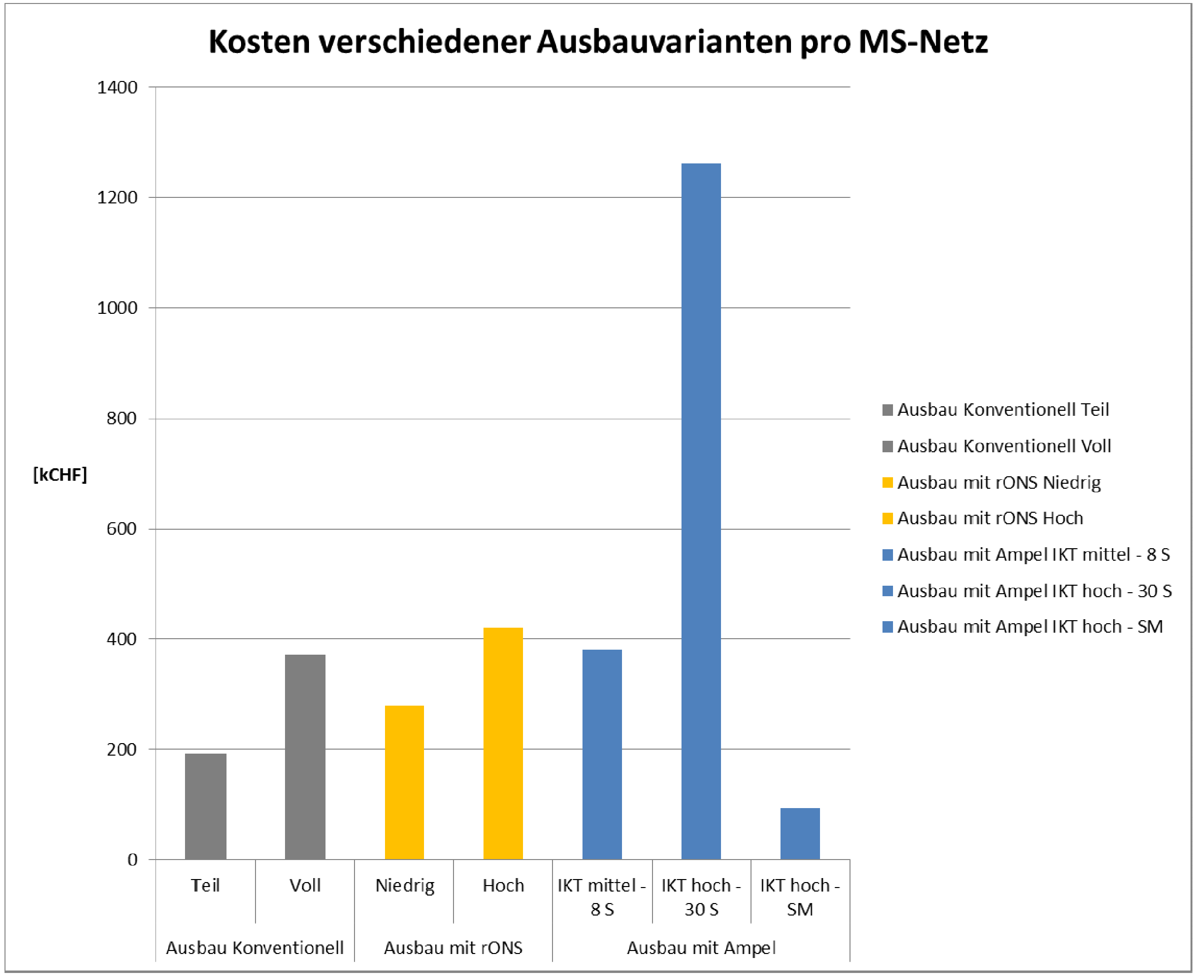
- Figures show results of evaluating steps 1a with the following definitions
  - Green: during 8760 h of simulation just green states of grid
  - Yellow: several yellow phases (and a few red) come up in simulation
  - Red: overwhelming red phases come up in simulation
- Only configuration with yellow state: urban networks in 2035





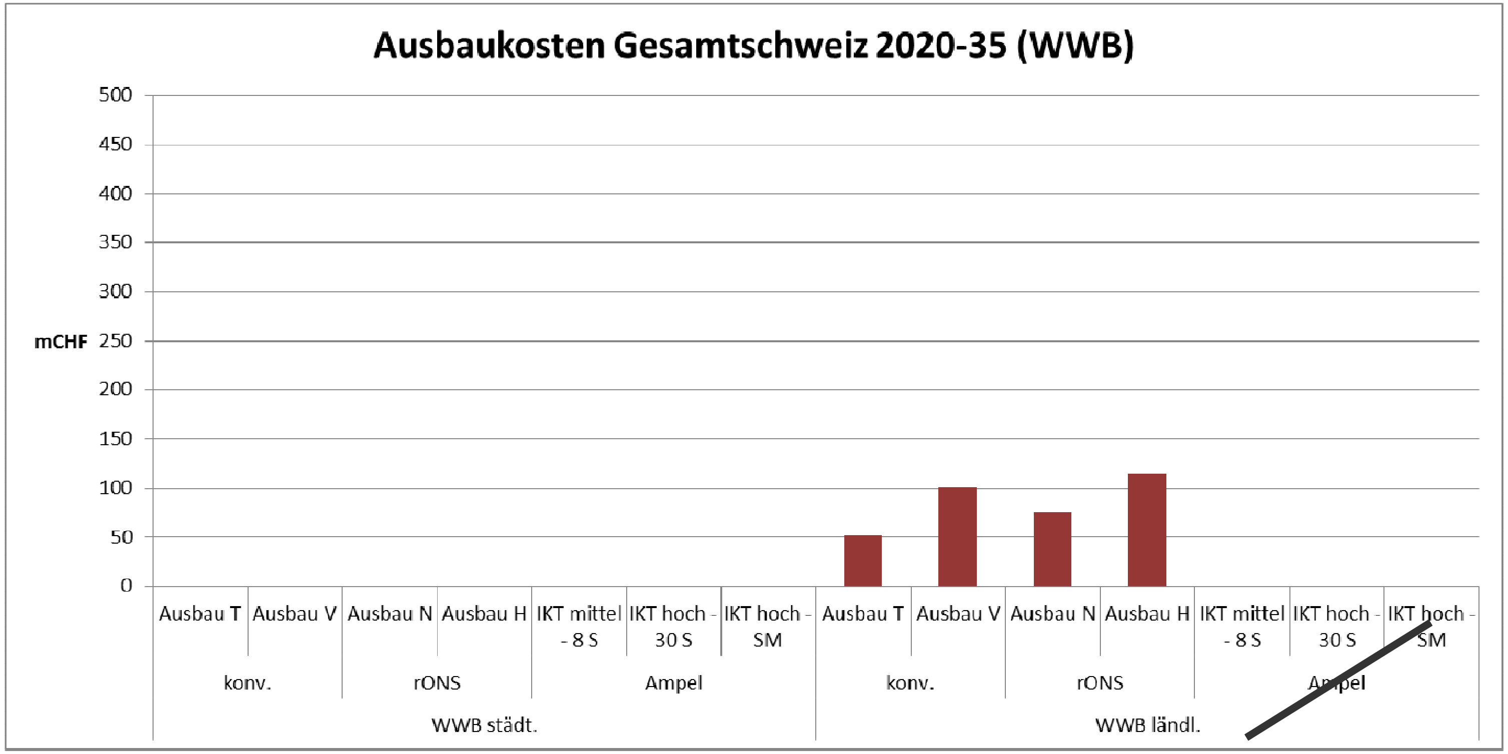
Results – investment costs in MV-network

- We compare three solutions based on grid for shortages
  - Conventional grid expansion (where necessary / all LV strands of MV-Grid)
  - Usage of variable secondary substation within LV- Grids (where necessary , as new- or replacement investment)
  - Ampelmodell (*three different technical implementations)*
- Figures shows CAPEX for different solution approaches within Distribution grid.



Results - Cost Scenario WWB (continue like before)

- For the time between 2010-2020 is no need for expansion, therefore no cost .
- For 2020-2035: Need for rural grids to avoid shortages, but no need for urban grids.



Concerning the assumptions about SM- and variable secondary substation -Rollout, RES goals and ML-Grids volume of WWB, results from step 1 & cost for each MV-Grid

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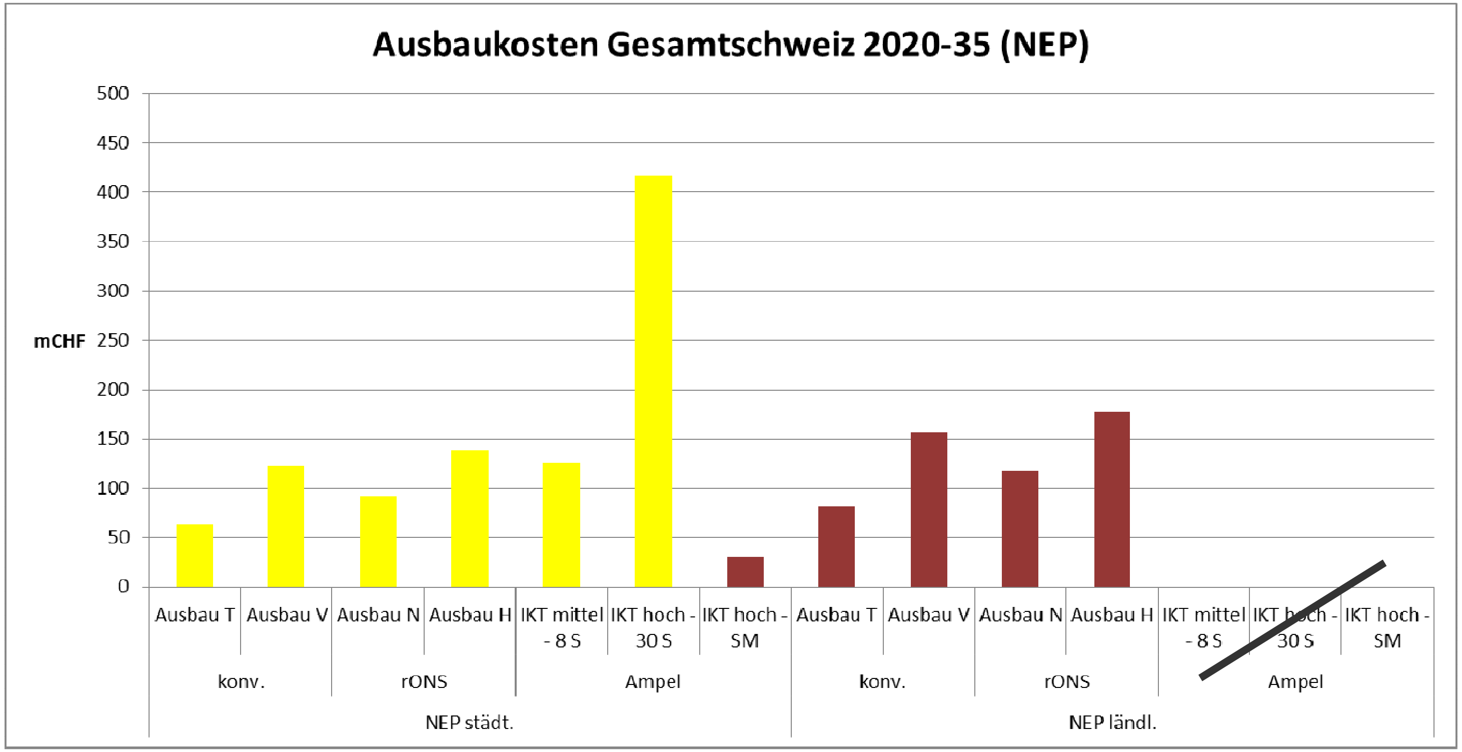
Results - Cost Scenario NEP

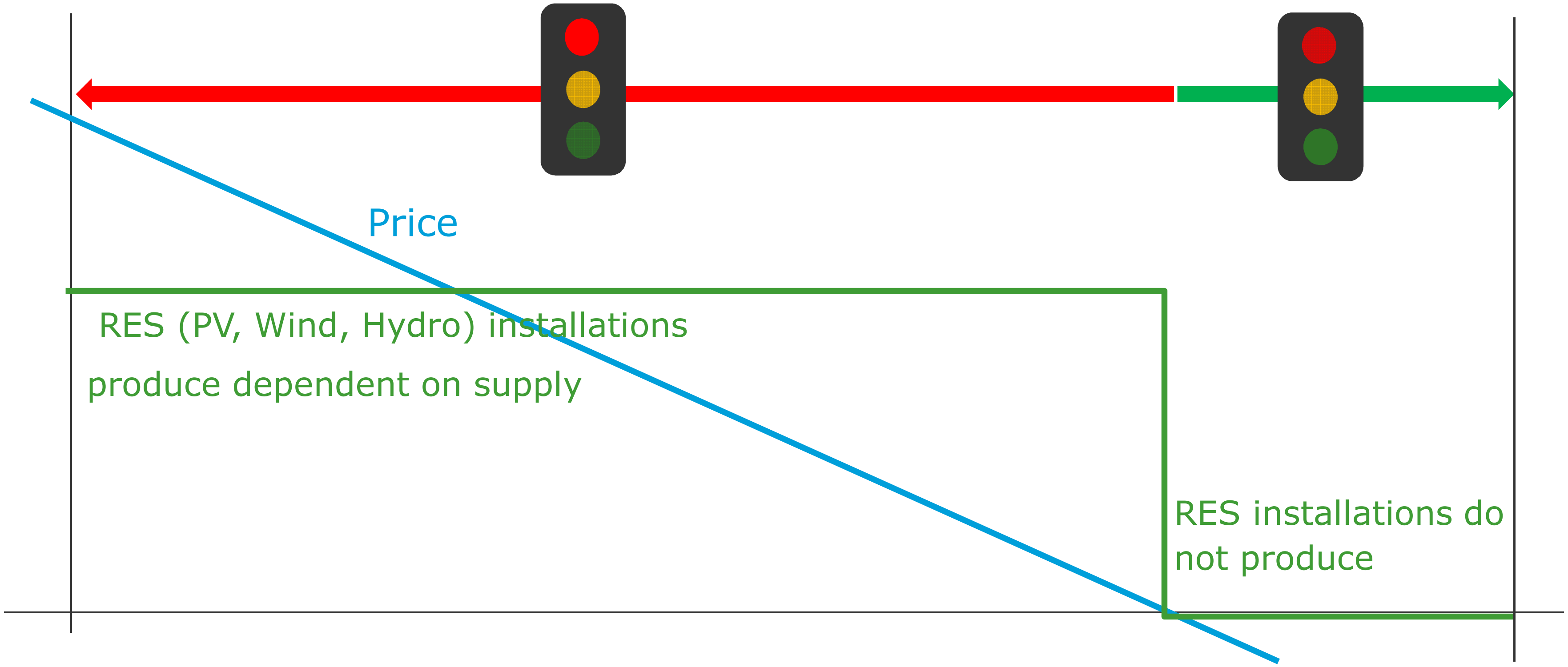
- For the time between 2010-2020 is no need for expansion, therefore no cost .
- For 2020-2035: Need for rural grids to avoid shortages, and space for a light solution for urban grids



Concerning the assumptions about SM- and variable secondary substation -Rollout, RES goals and ML-Grids volume of NEP, results from step 1 & cost for each MV-Grid

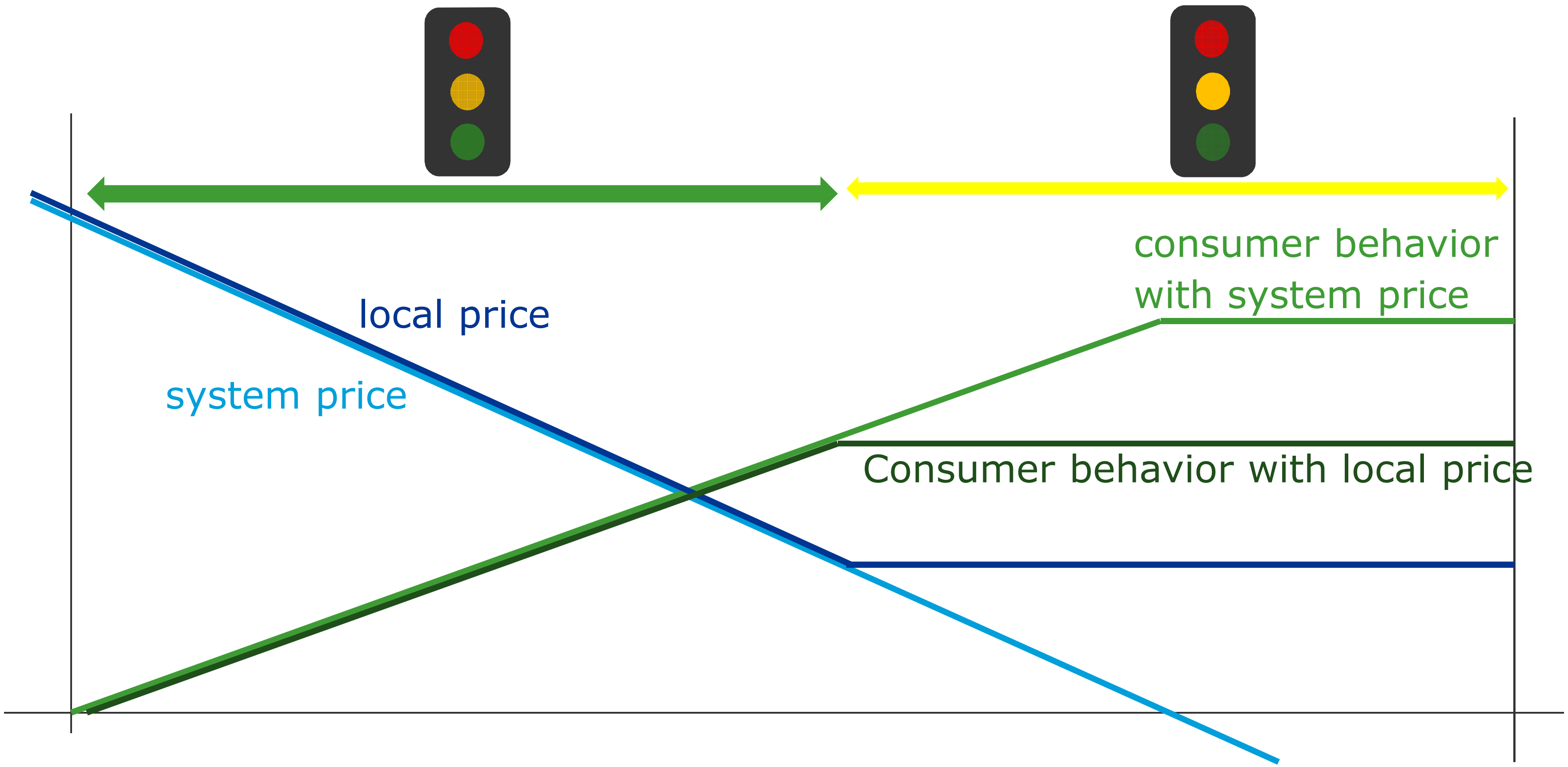
Stylized results – rural network

The production is depend on supply. If price is negative all RES-E will stop producing together. No fine tuning is possible. Typical situation in rural network.



Stylized results – urban network

DSM is more useful to control a light model, because the demand is price sensitive.
Urban networks include sufficient DSM to enable operation of flexibility market.



Results – cost-benefit-analysis over all scenarios

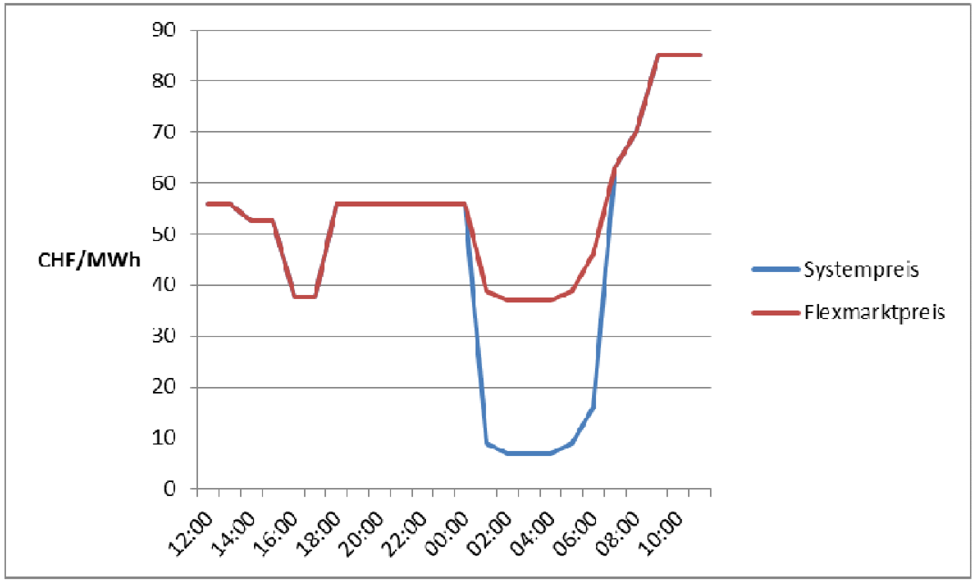
- Results for WWB and NEP
  - Ampelmodell does not generate benefits in a rural grid (both scenarios)
  - No need for expansion between 2010 and 2020, thus no direct benefit of the Ampelmodell (both scenarios)
  - Scenario WWB: no shortage in urban grids
- Evaluation focused of urban grids under NEP 2035
  - direct benefit of Ampelmodell :
    - Huge reduction of red states
    - Tackling situations with local shortages (yellow states)
      - Stabilize grid operation
  - Indirect Benefit of the light model
    - Incentives for local flexibilities (plus extra benefit in green phases, e.g. storages)
    - DSO gets detailed information from the ICT and also a better control
- REMARK: to reach a stable network it is also possible to use conventional grid expansions and variable secondary substation.

Results – changes in utility under flexibility market

Result for urban model grid (NEP 2035)

- Just a few yellow phases (11h for ICT high, 29h for ICT medium)
- By activating the market for flexibility the price is higher compared to the system price
- Difference in prices is highly significant (ratio 10:1)

Figure shows example for Price development in a Flex- and system market during a yellow phase



Profit 100kW DSM-plant p.a.	
ICT high	81 CHF
ICT medium	230 CHF

- Local flexibility (DSM) can benefit from the light model during few hours within the year
- **Indirect Benefit is small**

Conclusions & Recommendations

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ABSCHLUSSBERICHT

Kosten-Nutzen-Analyse einer Ampelmodelllösung für den Strommarkt der Schweiz

Studie im Auftrag des Bundesamt für Energie (BFE)

Dokumenten-Nr.: 9015-898-02
Datum: 02.06.2015
Datum der letzten Revision: 03.08.2015

- In general activating flexibilities by the DSO could be a good alternative to a grid expansion, if enough flexibilities exist to enable operation of flexibility market
- No need for Switzerland today and in foreseeable future, because local shortage caused by decentralised Energy production
- Ampelmodell is rather suitable for urban areas (load dominated) than for rural areas (feed-in dominated)
- Costs for flexibilities with Ampelmodell are high compared with other alternatives
- Coordination model based on bilateral agreements between Grid operator and supplier of flexibility is probably better suited for the purpose

Thank you for your attention!

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