Modelling of storage processes in TIMES-PanEU

Julia Welsch, PD Dr. Markus Blesl

Institute for Energy Economics and the Rational Use of Energy
University of Stuttgart
Germany

Copenhagen, 18.11.2014

Structure

Structure

Motivation and objective

Motivation:

- Political included expansion of electricity generation from renewable energies in Germany
- In consequence increasingly fluctuating feeding of electricity from wind- and photovoltaic systems

➔ Thus there will be occur to an increasing degree negative and fluctuating residual loads in the future

➔ Storage of excess electricity or curtailment

➔ Versatile possibilities for using excess electricity

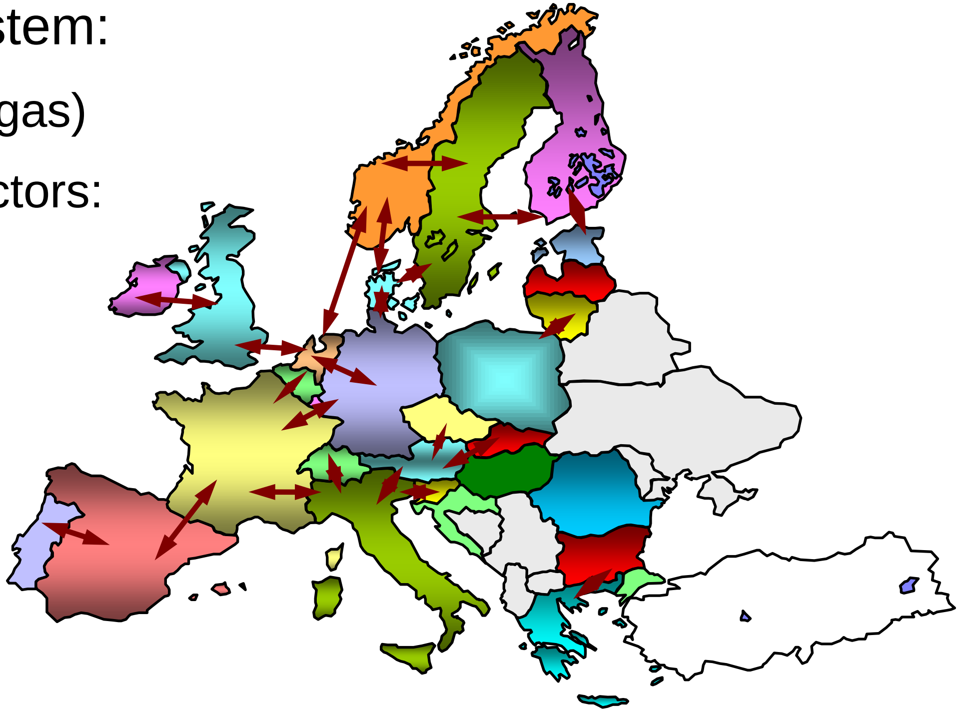
Objective:

- Determination of optimal configuration of storage- and Power-to-X-technologies (for Germany) under minimization of total system costs
- Analysis of interactions between energy supply and energy demand with use of Power-to-X

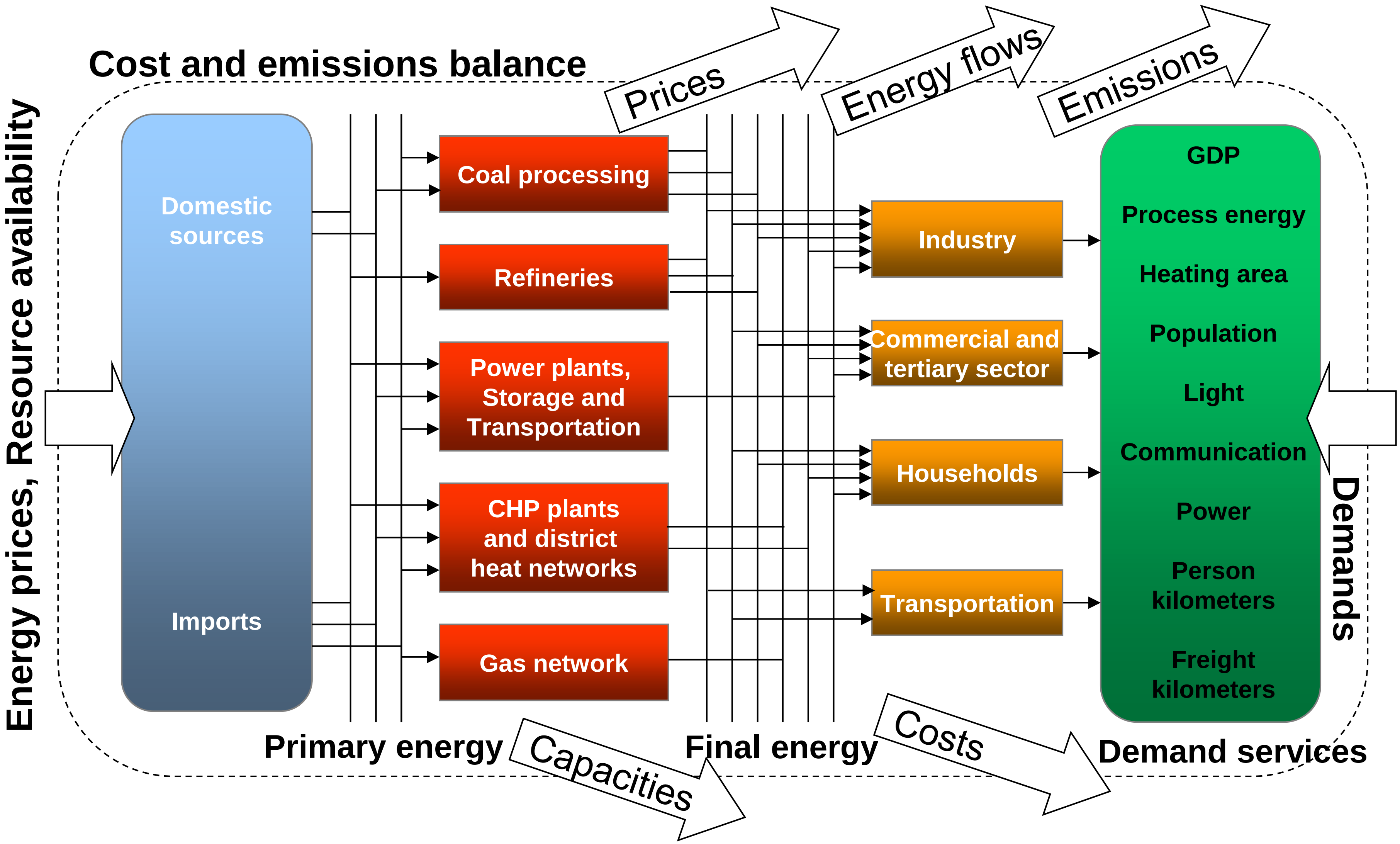
Structure

The TIMES-PanEU energy system model

- Linear optimization model
- 30 regions (EU-28 + Norway, Switzerland)
- Time horizon: 2010 – 2050
- Mapping of the whole energy system:
  i. Energy supply (electricity, heat, gas)
  ii. Energy demand, divided into sectors:
    1. Residential sector
    2. Commercial sector
    3. Agriculture
    4. Industry
    5. Transport



General structure of TIMES-PanEU



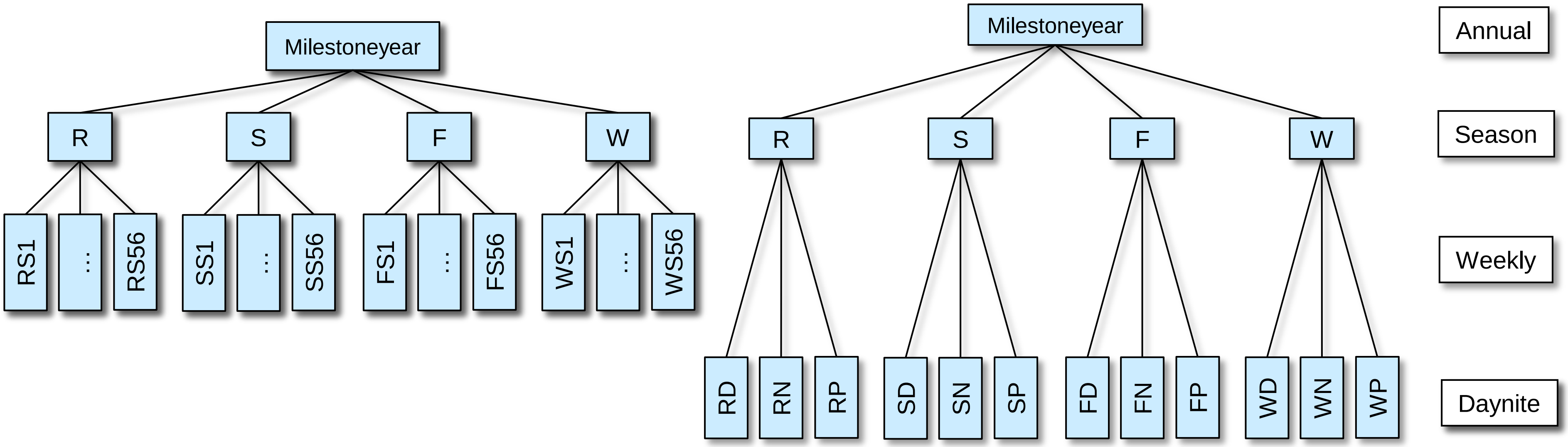
Temporal resolution

Germany

- 224 time segments (One week per season, three-hourly)
- Continuous temporal resolution for mapping storage processes

Rest of Europe

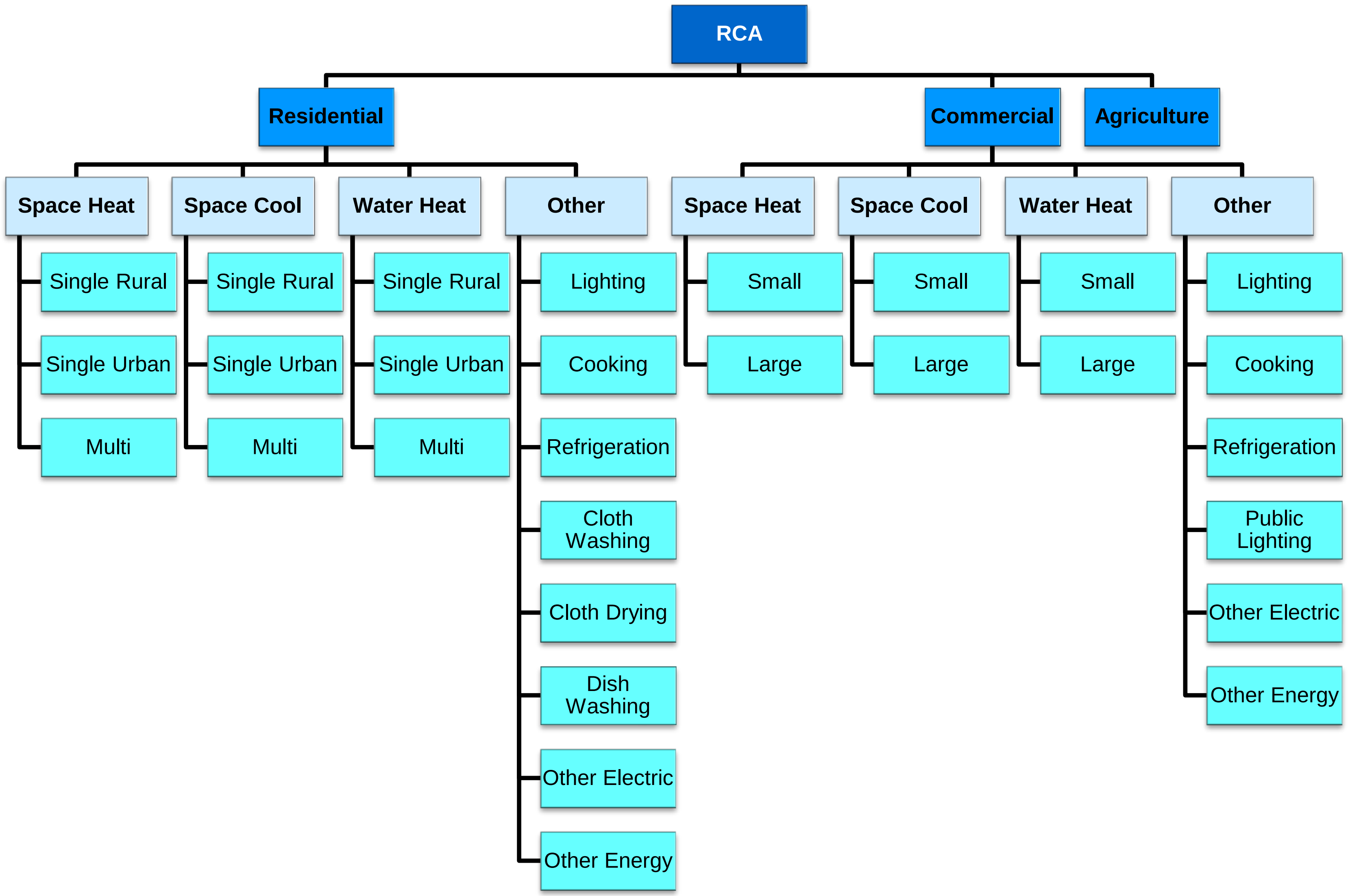
- 12 time segments
- Discontinuous temporal resolution



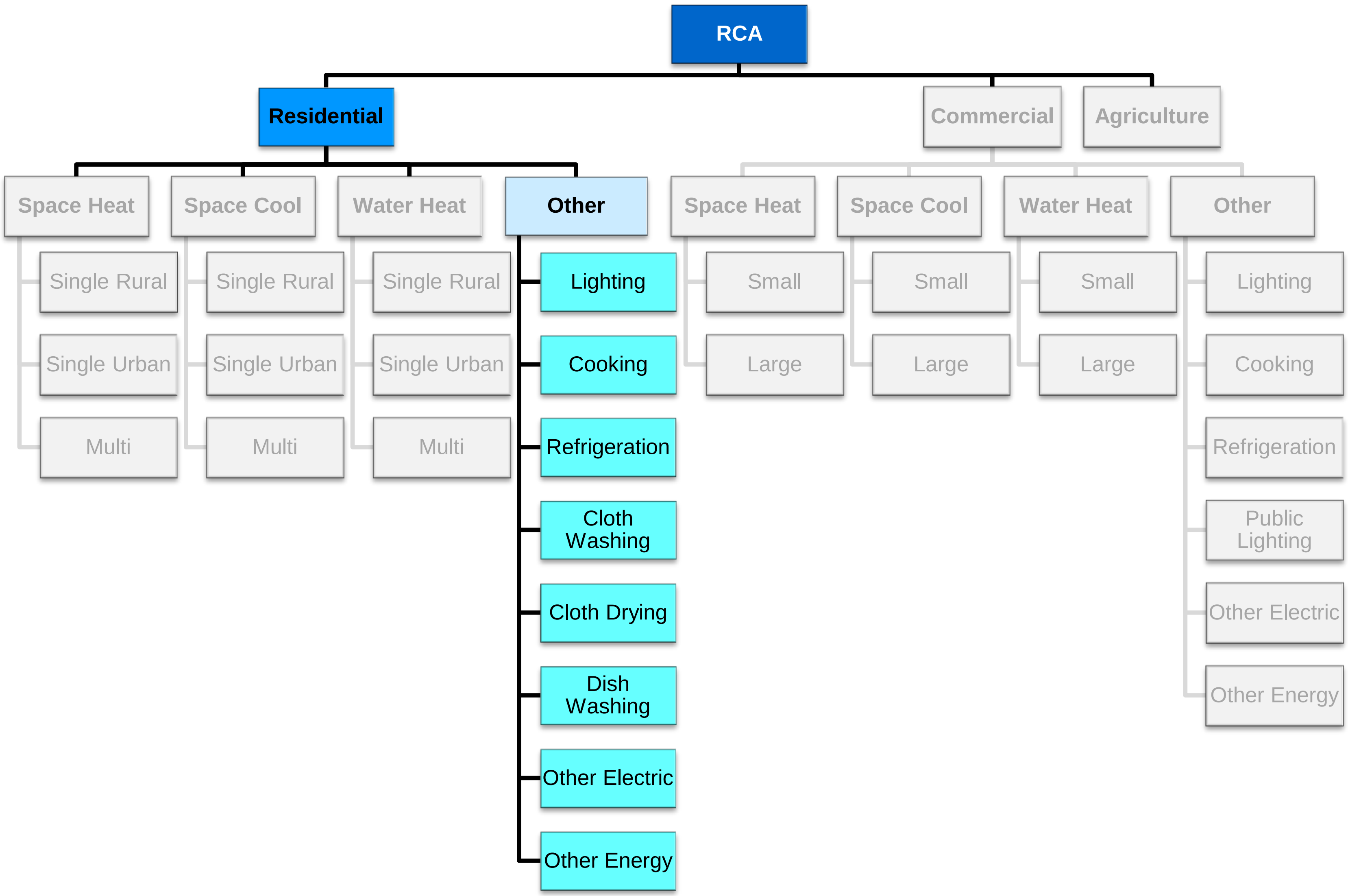
➔ Coupling of timeslice trees for modelling trade processes with parameter IRE_TSCVT

➔ Integral optimization

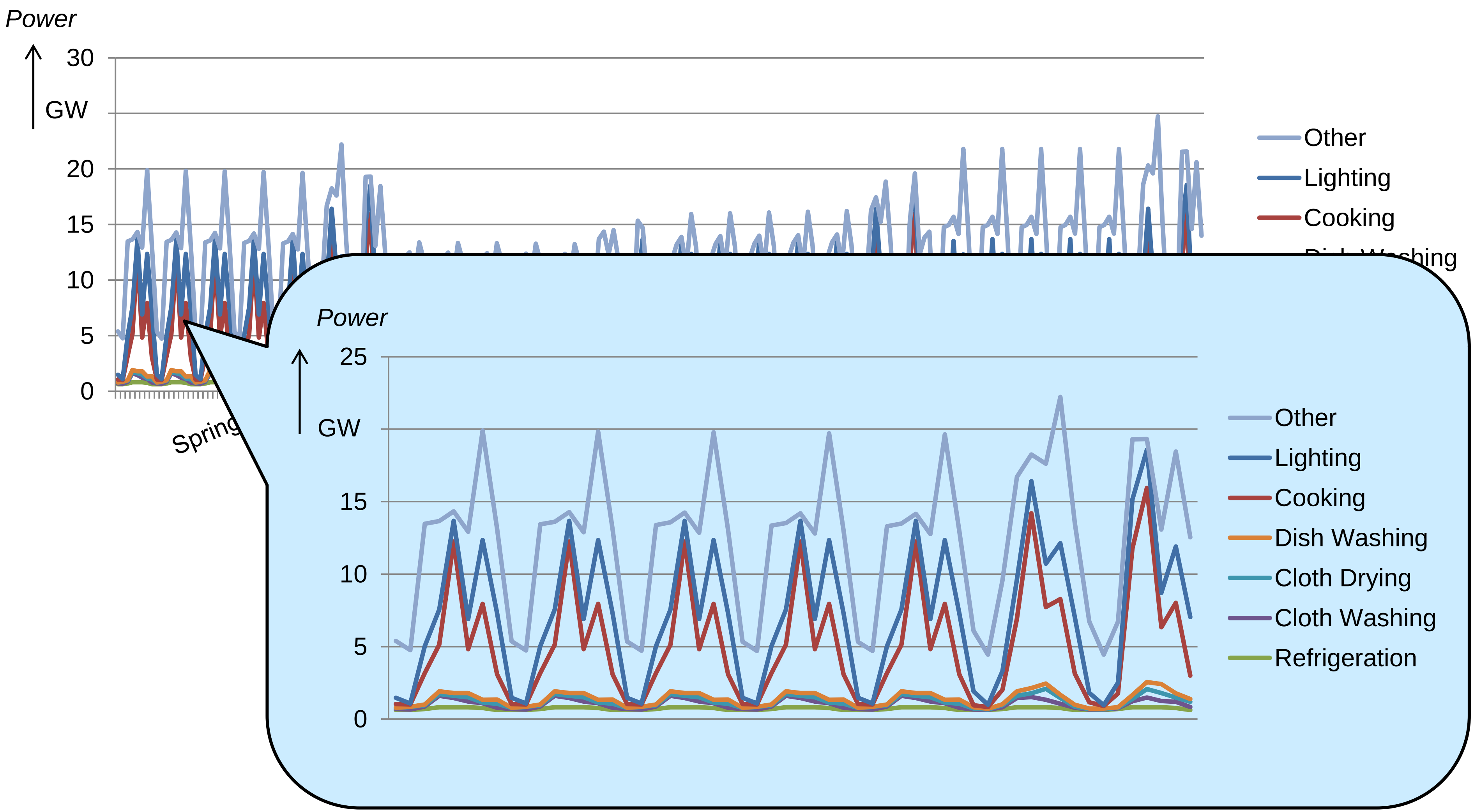
Examplary demand services



Residential Other



Residential Other



Structure

Modelling of storage processes in TIMES-PanEU

PRC_ACTUNT	PJ	PJ	PJ
PRC_CAPUNT	GW	PJ	GW
PRC_CAPACT	$\frac{8760\ GWh}{GW} = \frac{8760\ h \cdot 3600\ \frac{s}{h} \cdot 10^{-6}\ \frac{PW}{GW} \cdot GW}{GW} = 31{,}536\ \frac{PJ}{GW}$	$1\ \frac{PJ}{PJ}$	$31{,}536\ \frac{PJ}{GW}$

PRC_ACTUNT: $Activity\ of\ a\ process$

PRC_CAPUNT: $Capacity\ of\ a\ process$

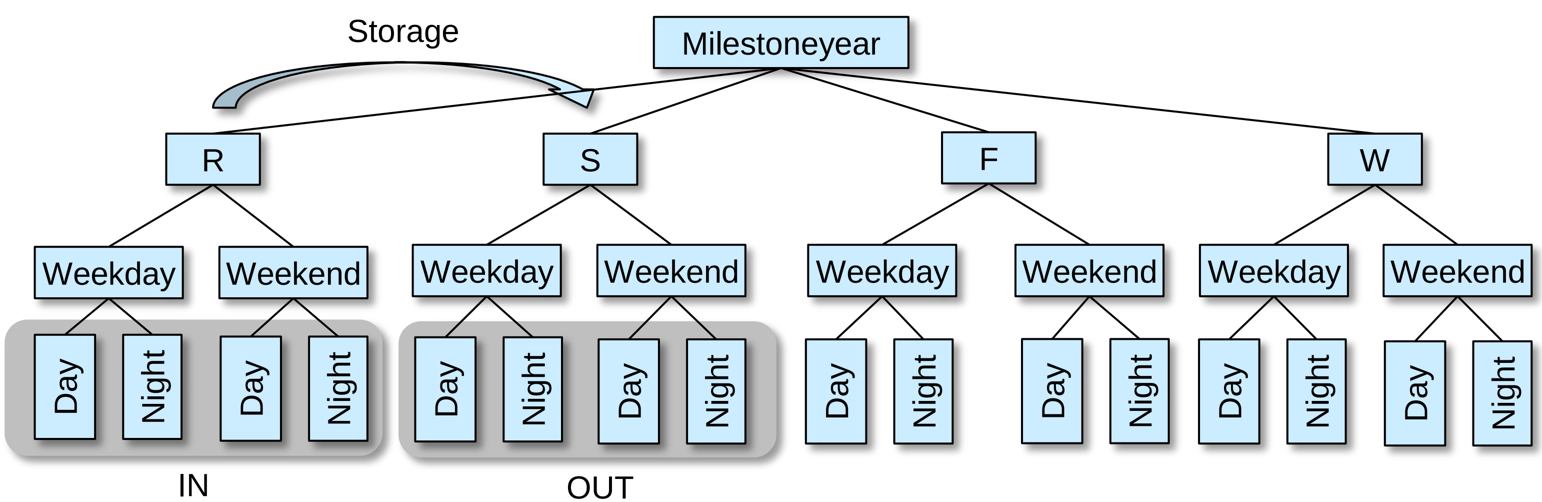
PRC_CAPACT: $Ratio\ from\ activity\ and\ capacity$

➔ Storage power and storage capacity are endogenous results of modeling

Modelling of storage processes in TIMES

Two different types of storage processes in TIMES:

- Inter-Period Storage: Storage between periods (Store in and store out with constant power over the whole period)
- Timeslice Storage: Storage between time segments within a period (in accordance with the definition of the storage level)
- Generalized timeslice storage: Combination of timeslice storages with different timeslice levels, STS or STK



Timeslice Storage

General simplified equations $(\forall\, r, v, t, p, c, ts)$:

1. Time overall equation EQ_STGTSS: $VAR\_ACT(r,v,t,p,ts) = VAR\_ACT(r,v,t,p,ts-1) + VAR\_SIN(r,v,t,p,c,ts-1) - VAR\_SOUT(r,v,t,p,c,ts-1)$
2. Whole storage capacity is available in every timeslice EQL_CAPACT:

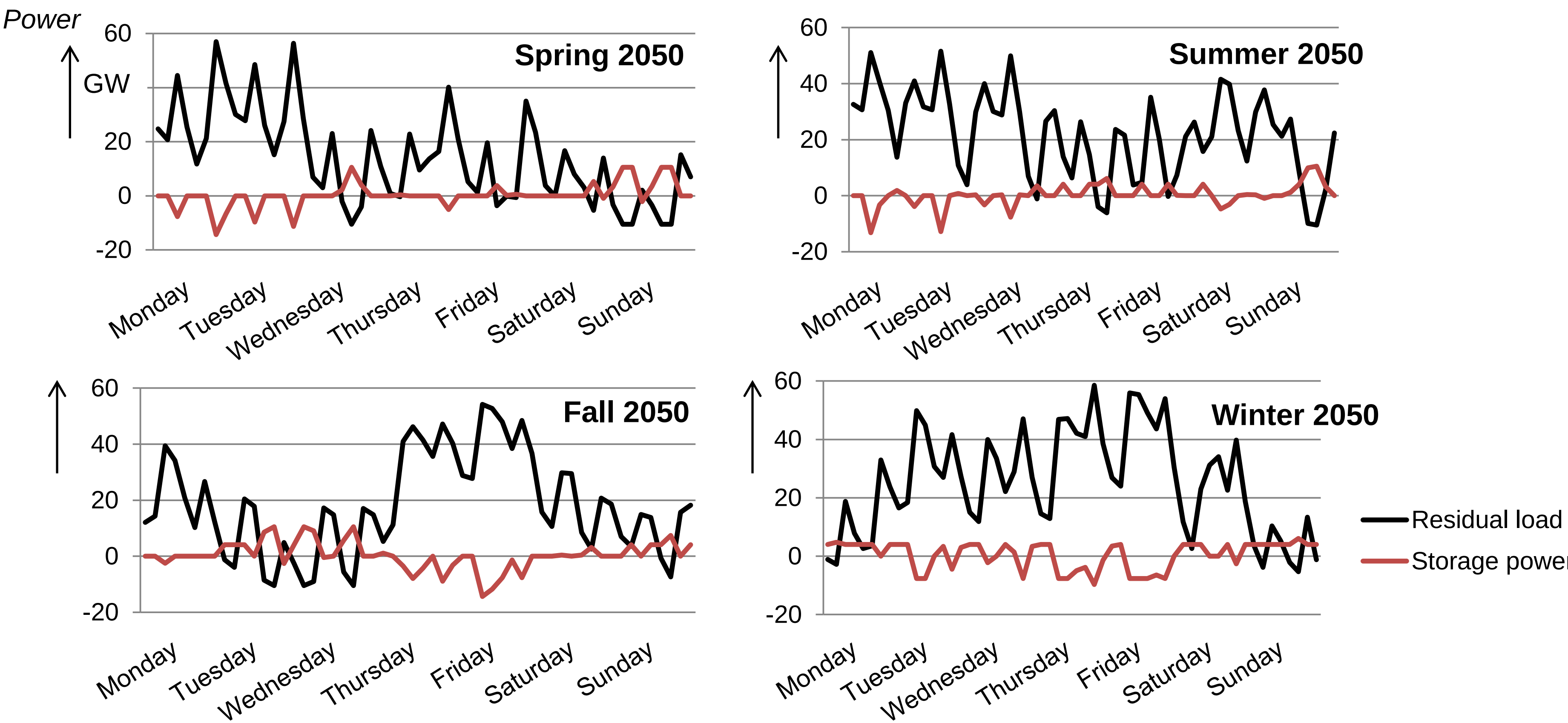
$$VAR\_ACT(r,v,t,p,ts) \cdot \frac{1}{RS\_STGPRD(r,ts)} \leq$$
$$\left(\sum_{v=Baseyear}^{t}(VAR\_NCAP(r,v,p)) + NCAP\_PASTI(r,v,p)\right) \cdot PRC\_CAPACT(r,p)$$

r: Region
v: Year of commissioning
t: Current period
p: Process
c: Commodity
ts: timeslices of storage level
VAR_ACT: Storage content at the beginning of ts
VAR_NCAP: New installed capacity
NCAP_PASTI: Stock
PRC_CAPACT = 1

Storage Level	Season/ Annual	Weekly	Daynite
$\boldsymbol{RS\_STGPRD(r,ts)}$	1	$\frac{8760}{24 \cdot 7} \cdot G\_YRFR(r,x)$ *(x is directly upstream, defined node of weekly)*	$365 \cdot G\_YRFR(r,x)$ *(x is directly upstream, defined node of daynite)*

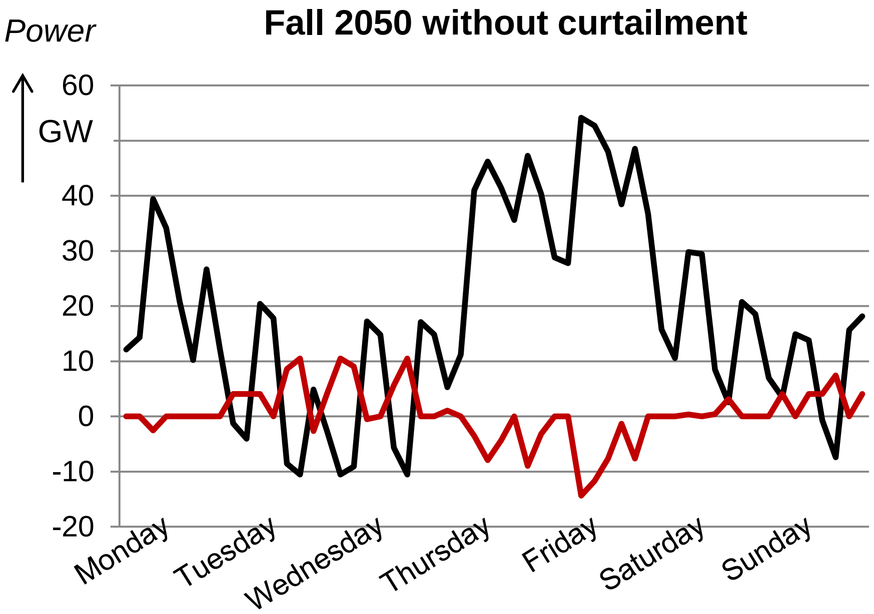
Structure

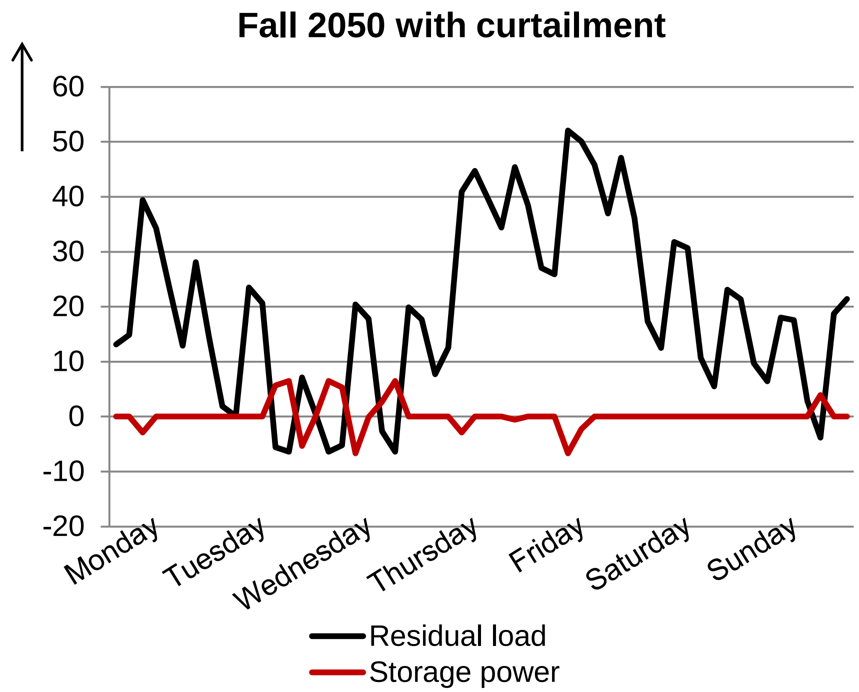
Operation of electricity storage in the year 2050 without Curtailment (only Germany)



- ➔ Store in times of low or negative residual load (electricity price low)
- ➔ Store out in times of high residual load (electricity price high)

Operation of electricity storage in the year 2050 with Curtailment (only Germany)





- ➔ Lower storage capacity than in scenario without curtailment
- ➔ Lower total system costs in scenario with curtailment

Structure

Conclusion and outlook

Conclusion:

- Need of more electricity storage with increasingly power input of fluctuating renewable energies
- Objective value difference ca. 35 Billions Euro

➔ Possibility of curtailment leads to a lower electricity storage capacity and lower total system costs

Outlook:

- Analysis of Power-to-Heat, Power-to-Gas and other electricity storages (compressed air, battery)
- Reserve power
- Differenet scenarios
- Sensitivity analysis

Thank you!

julia.welsch@ier.uni-stuttgart.de

Backup

Modeling of storage processes in TIMES-PanEU

Energy storage		Transformation processes
Electricity storage Pumped storage Compressed air storage Battery storage		
Heat storage Hot water storage	⟷	**Power-to-Heat** Heater
Gas storage Hydrogen storage Natural gas storage Natural gas grid	⟷	**Power-to-Gas** Elektrolysis Fuel cell Methanation