FLEXIBILIZATION STUDY OF MATERIAL AND ENERGY FLOWS IN MINING

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AGENDA

- Motivation
- Object of investigation and system boundaries
- Data analysis and modelling
- Validation
- Simulation experiments and results
- Summary and future work

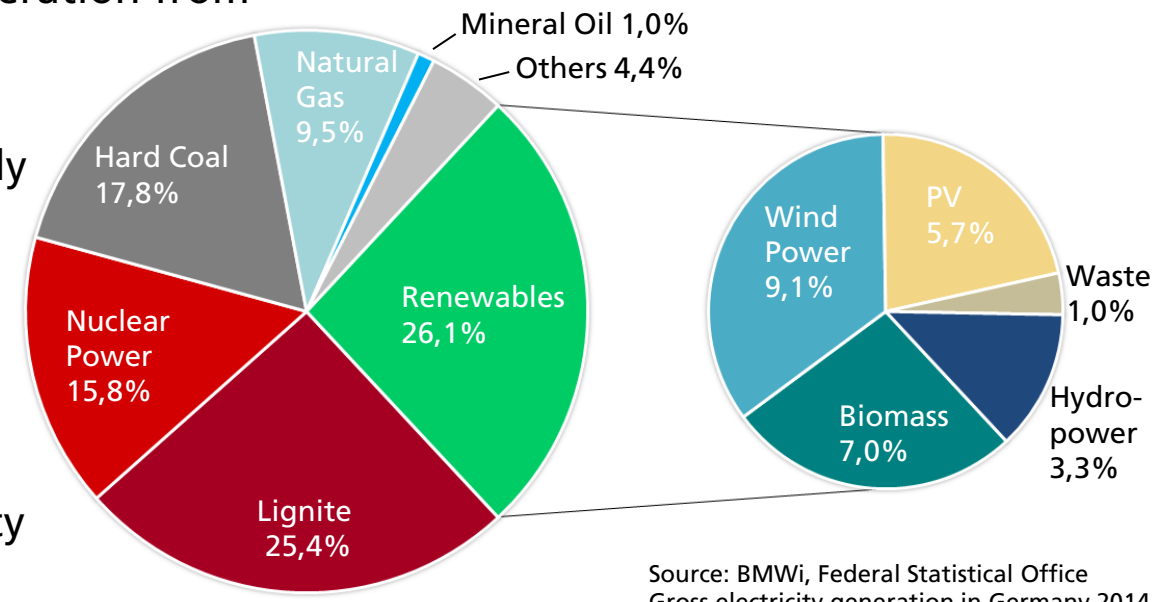
Motivation
Relevance of lignite

- Share of renewable energy sources (RES) is steadily rising

  → RES becomes a dominant factor in the market

- Large share of Europe's electricity is still generated in lignite-fired power plants (LFPP)

- Conventional power generation from lignite ensures:
  - Reliable energy supply in times with little RES availability
  - Necessary flexibility to the integration of RES into the electricity grid at high feed



Source: BMWi, Federal Statistical Office
Gross electricity generation in Germany 2014

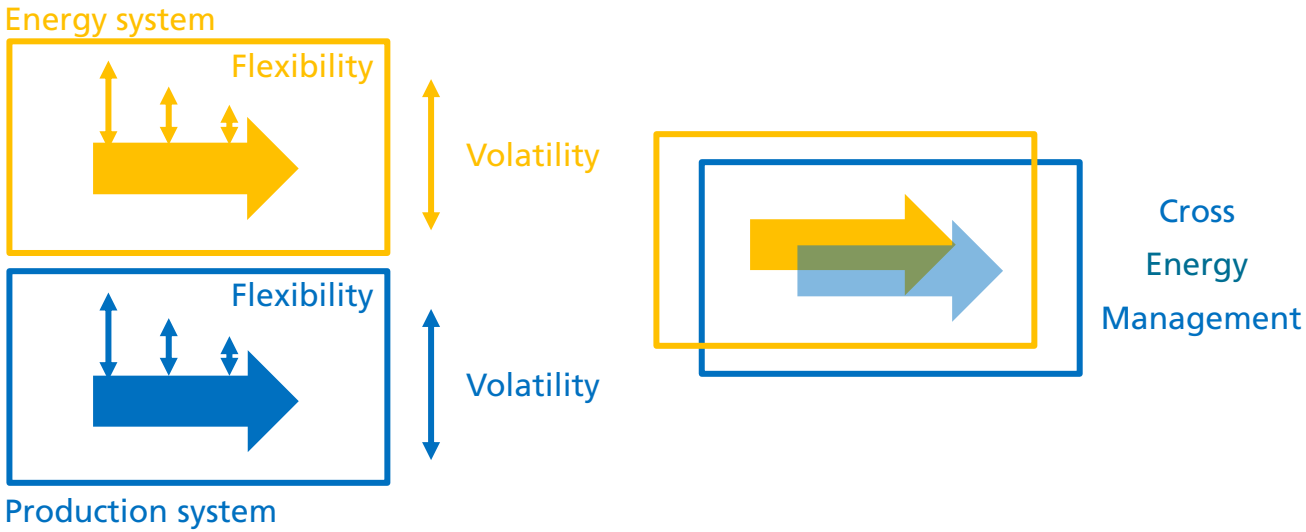
Motivation

From energy efficiency to systemic energy efficiency

- Efficiency potentials in LFPP and open-pit mining (OPM) are nearly exhausted

  → Interaction of individual elements in the LFPP-OPM system as starting point

Problem: Energy efficiency of a subsystem depends on the energetic situation of the overall energy system



Solution: Integration of flexibilities from production and energy system for situational overall optimization

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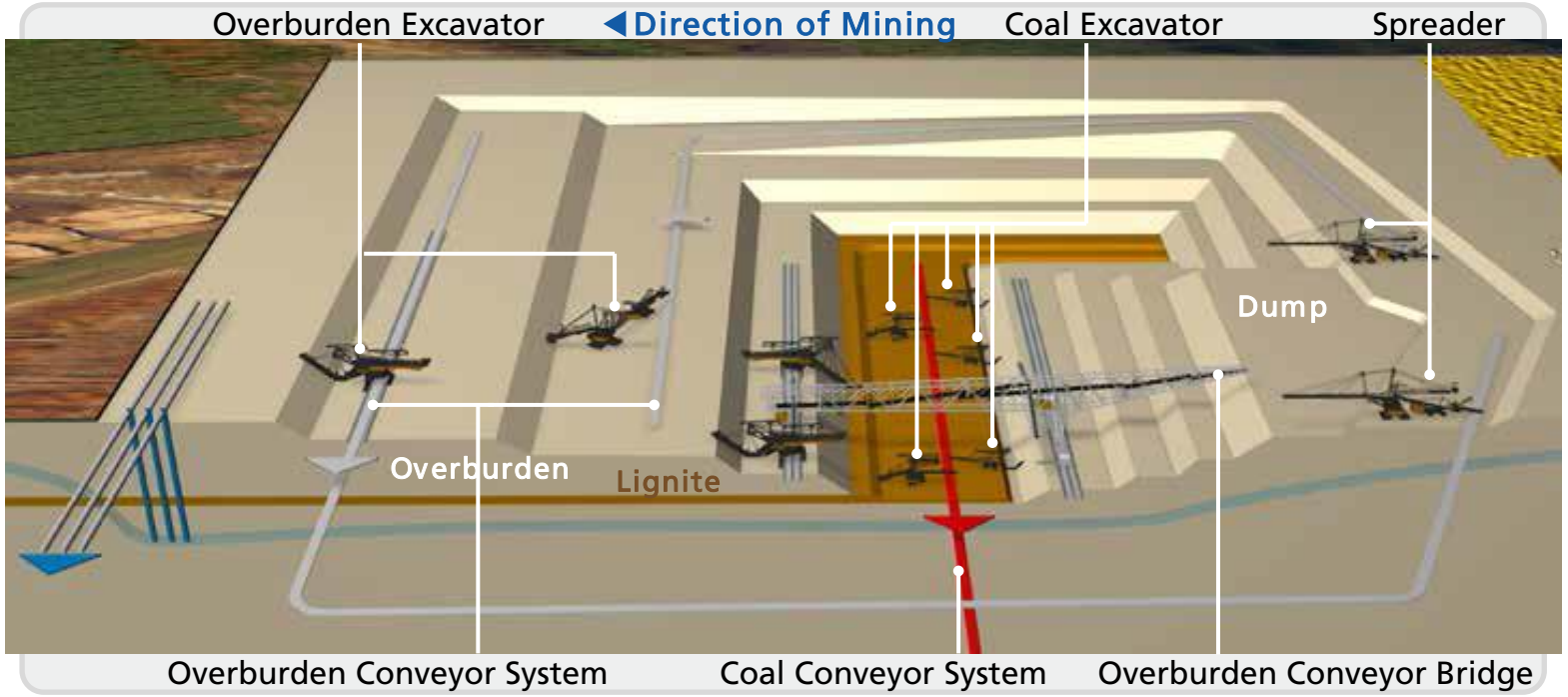
Object of investigation and system boundaries
The OPM Welzow-Süd

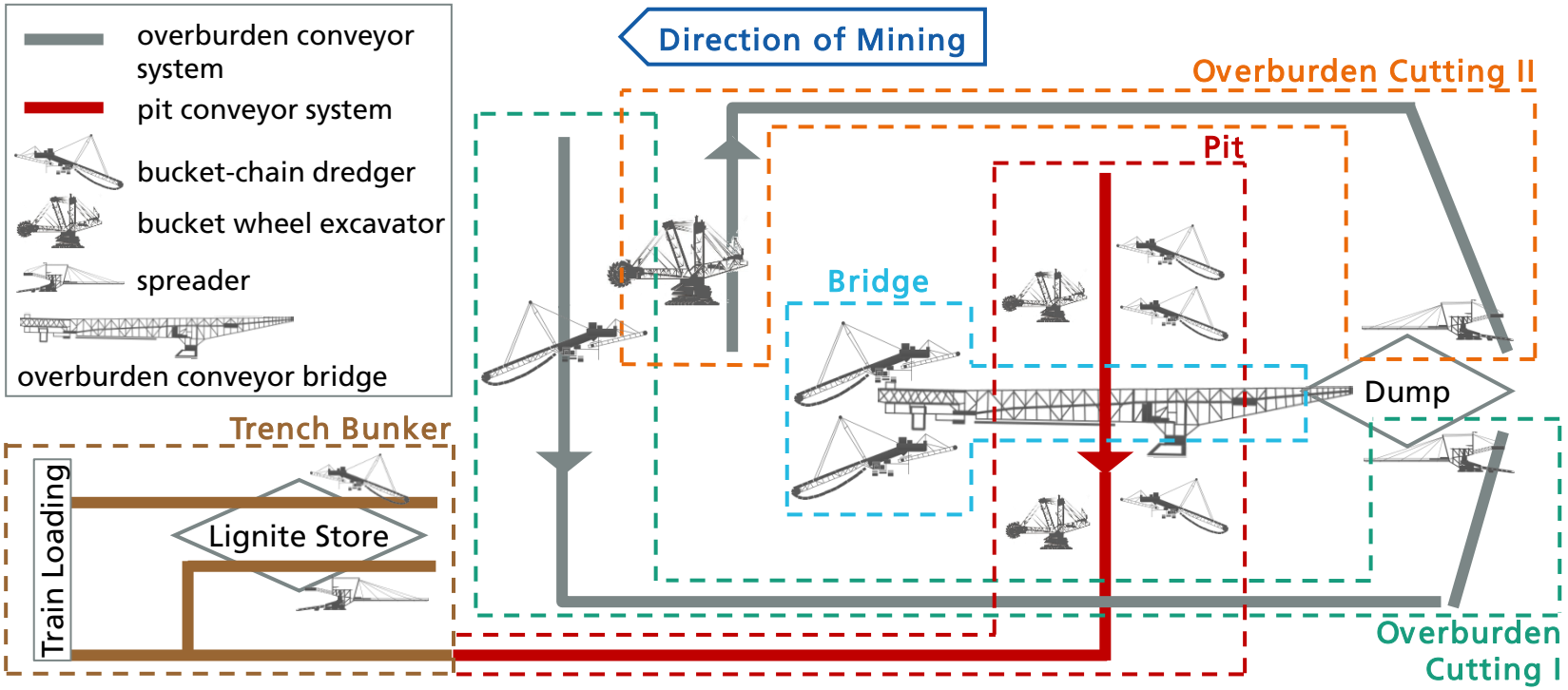
- Continuous equipment technology and direct dump system
- Annual conveying capacity of 110 Mm³ overburden and 20Mt lignite
- Yearly energy consumption between 300 to 350 GWh



Object of investigation and system boundaries

Premisses

- Consideration of system elements, which are directly related to the material flows of lignite and overburden as well as the flow of electricity
- Indirect areas of the OPM were disregarded
- Train loading marks the system boundary



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Object of investigation and system boundaries
Energy demand

- Energy consumption of the system elements depends on
  - Geological profile: removed material (soil or lignite type, spec. density, humidity)
  - OPM progress: conveyor systems (length, gradient, currently transported mass)
  - Operating situation: operating states (production plan, breakdowns)

Elements (selection)	∅-electricity consumption [MWh per hour]
Bucket wheel excavator (OC II)	3,7
Overburden conveyor (OC II)	13,77
Spreader (OC II)	2,71
Bucket-chain dredger (Bridge)	4,31
Overburden conveyor bride	8,04
Bucket wheel excavator (pit)	0,9

Average hourly consumptions for actively producing equipment

Data analysis and modelling
Emphases of the data analysis

- Representation of the geological profile

  How many units of volume (soil or lignite type) are removed and in what order?

- Identifying the operating states

  Which energy-related load cases has the considered system element?

- Determination of the power consumption per operating state

  How much electrical energy is required in the corresponding operating state?

- Determination of the operating and shift times

  Which energy operating state is assumed at what time?

- Relation between output and energy demand

  Exists an correlation and how the relation can be described?

Data analysis and modelling
Geological profile

- High resolution modelling was determined to require inexpedient effort

  → Abstraction of the geological profile as a time series of multiple types of volume units

- Generation of volume or tons units from measured values for output and electricity consumption

  → Result: series of removed material for each excavator including:

soil type | specific volume | specific energy demand | associated operation time

Model path	Name	Volume	PowerDemand	OperationTime
.Tagebau.Stoffströme.B1	Sand	735	4908	5
.Tagebau.Stoffströme.B1	Sand	805	4812	5
.Tagebau.Stoffströme.B1	Sand	520	3804	4
.Tagebau.Stoffströme.B3	SKT > 50%	300	2076	3
.Tagebau.Stoffströme.B3	SKT > 50%	805	4476	5
.Tagebau.Stoffströme.B3	SKT > 50%	845	4728	5

Extract from the series of removed material of the bridge group

Data analysis and modelling
Operating states

Coal Excavators

- Off
- Breakdown
- Overburden
- Normal Mode

Conveyor Systems and Spreaders

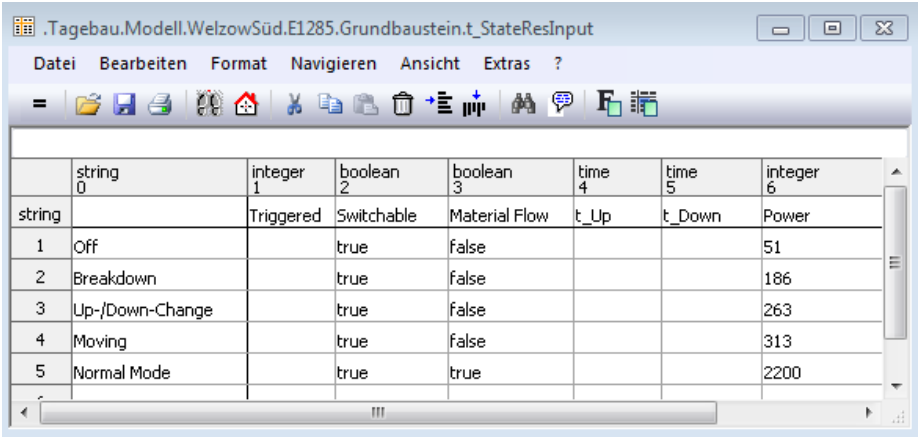
- Off
- Breakdown
- Start up
- Normal Mode

Overburden Conveyor Bridge and Trench Bunker Equipment

- Off
- Breakdown
- Normal Mode

Excavators of Overburden Cutting I + II and Bridge Group

- Off
- Breakdown
- Up-/Down-Change or Layer-Change
- Moving
- Normal Mode



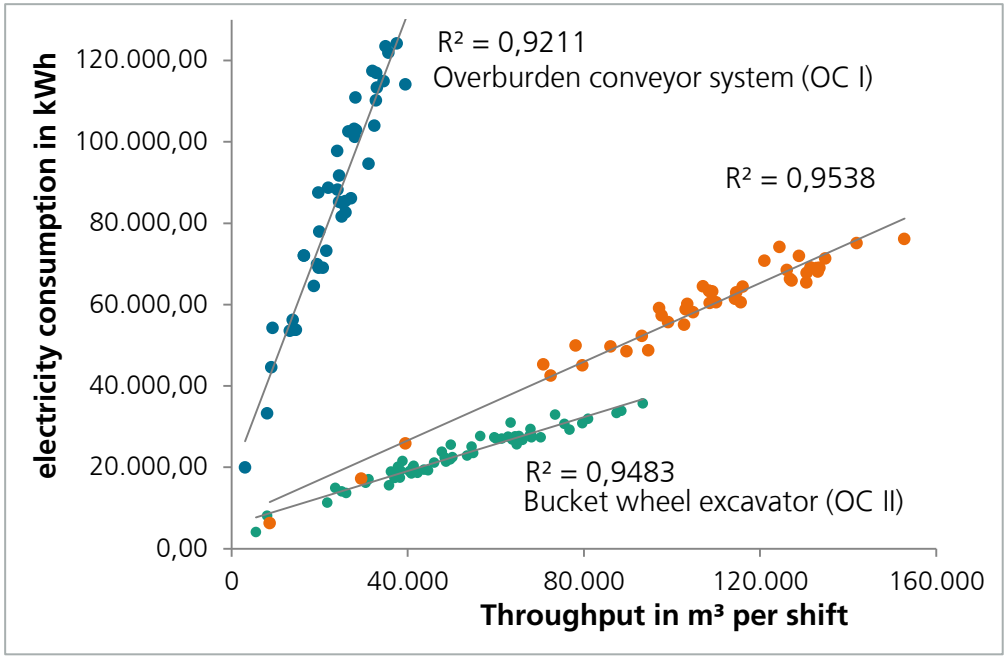
	string 0	integer 1	boolean 2	boolean 3	time 4	time 5	integer 6
string		Triggered	Switchable	Material Flow	t_Up	t_Down	Power
1	Off		true	false			51
2	Breakdown		true	false			186
3	Up-/Down-Change		true	false			263
4	Moving		true	false			313
5	Normal Mode		true	true			2200

Resource input table of the bucket-chain dredger of OC I

Data analysis and modelling

Power consumption and output of conveyor systems

- Dependencies are detectable in the data (see figure)
- For the excavators the correlation is described in the geological profile
- Problem: current throughput over time for conveyor systems are unknown



→ To analyse the relationship, more detailed data had to be generated
→ Fine grained (minutely) conveyor content was simulated using detailed input data for excavators (geological profile) and equipment operating states
→ Conveyor content data was then used to find linear regression functions for power consumption

- I.e.: Combination of real and simulation data to create the regression functions

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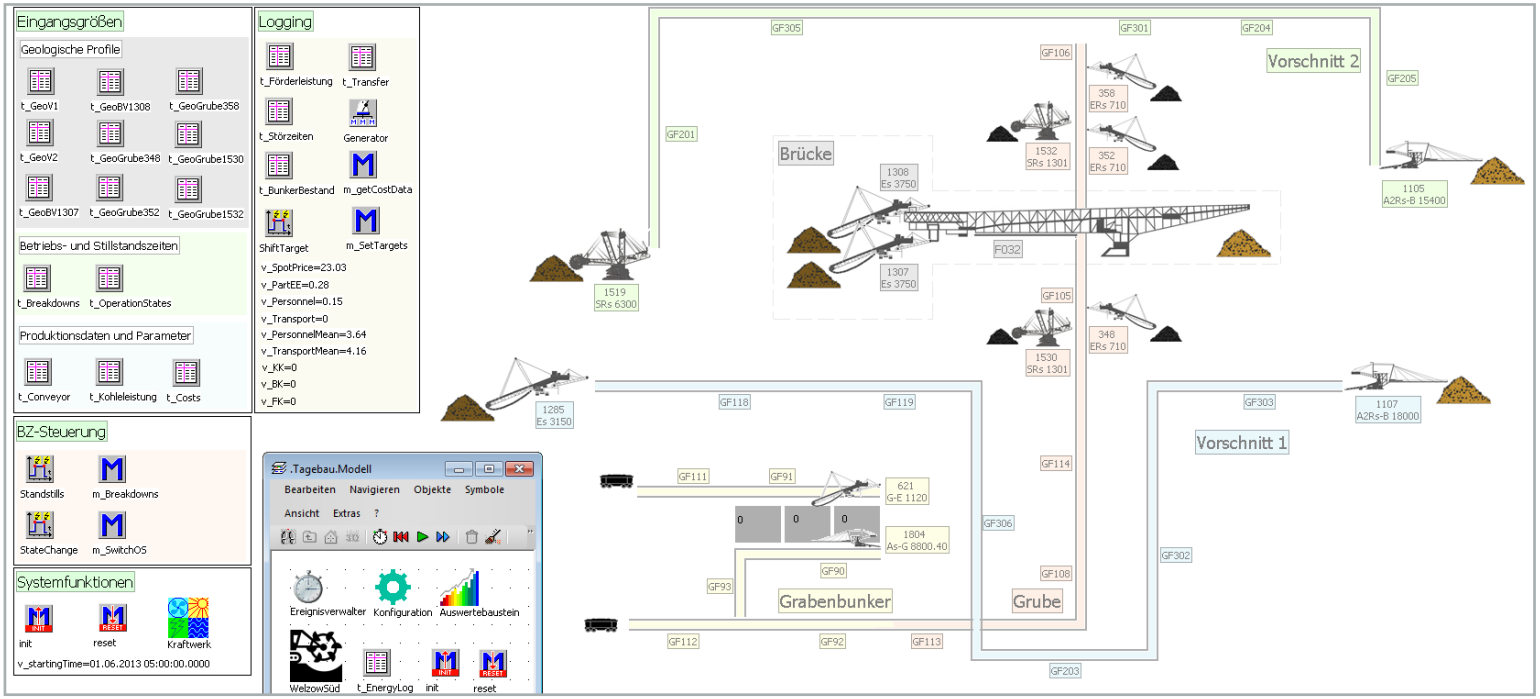
Data analysis and modelling
Simulation model

- Derivation of movable units (MUs) and assigning attributes for the various soil and coal types
- MU-instances were generated by a source for each excavator
- Discretisation of the material flows in 30-second units



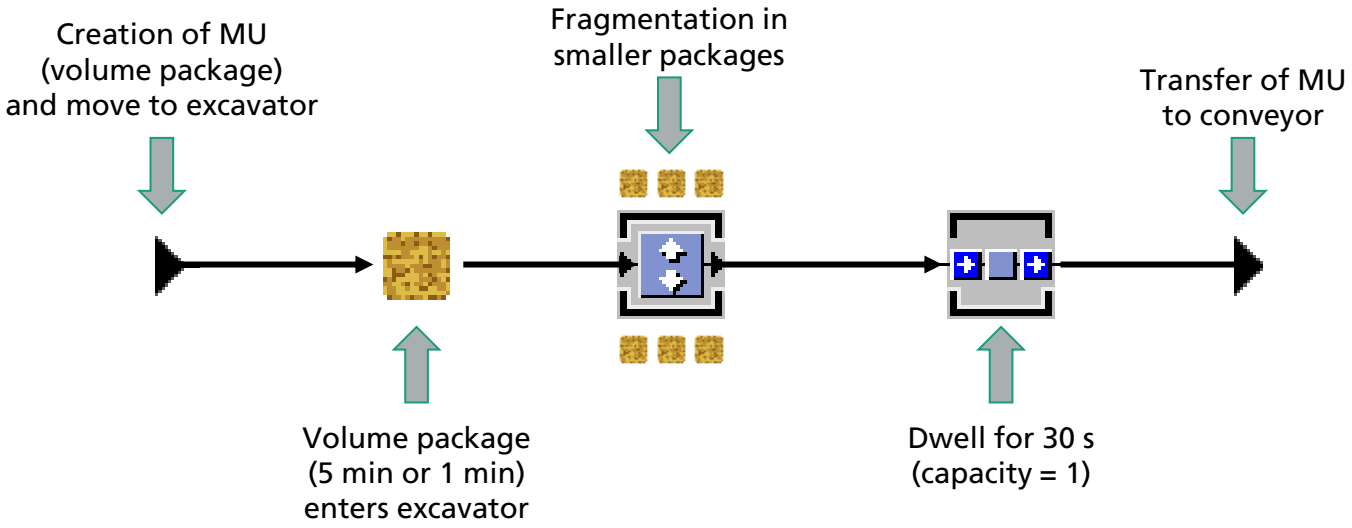
Data analysis and modelling
Discretisation of material flows (Excavator elements)

- Detailed data for geologic profile used for the creation of MUs

  → Volume and type of excavated material is logged every 5 min or 1 min along with equipment operating states during operation of the OPM

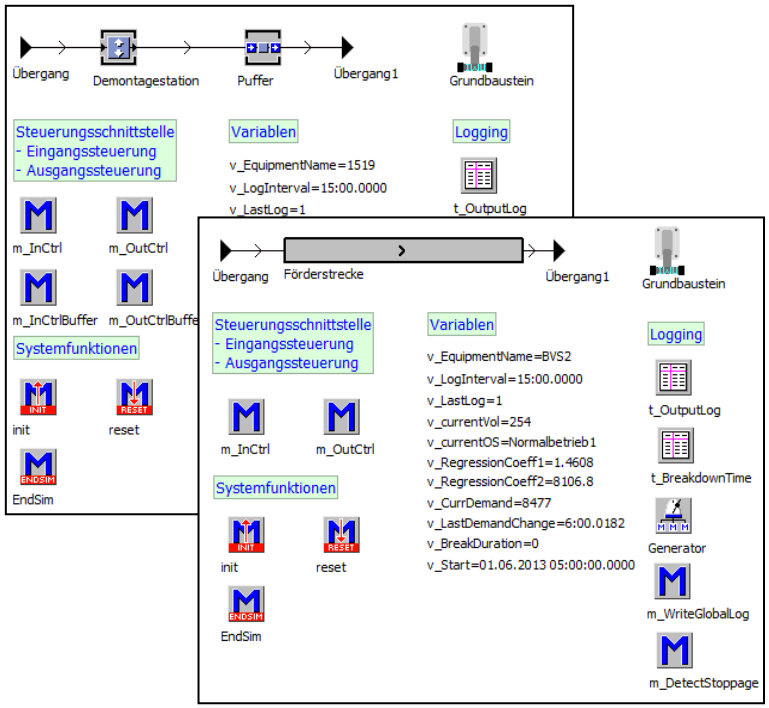
- Larger MUs are fragmented for higher resolution in following system elements

  → Smaller MUs leave excavator every 30 seconds, i.e. time-based volume MUs



Data analysis and modelling
Modelling the elements

- All system elements have an almost identical internal structure and functional principle
- Simulation of energy flows using eniBRIC
- Object class excavator: material flow is realised by disassembly station and buffer
- Overburden conveyor bridge, conveyor systems and spreaders were modelled identically as conveyor lines



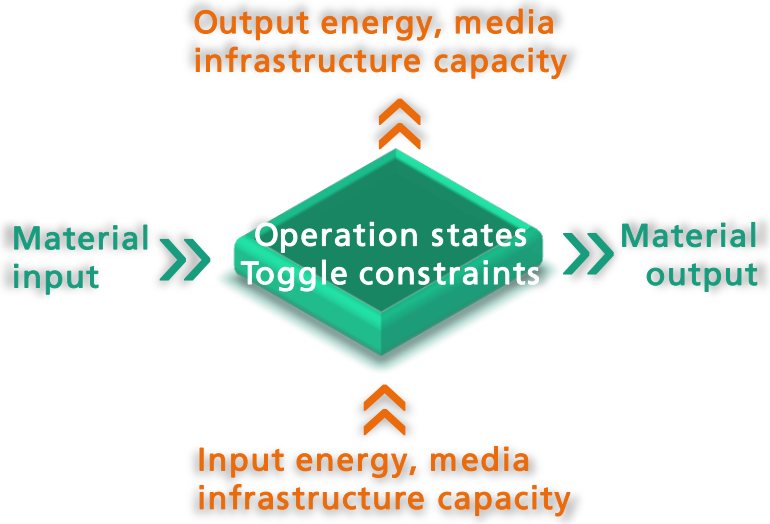
→ Calculation of volume-dependent energy consumption by means of regression curves

→ Load profile is updated through eniBRIC as soon as the content changes

Data analysis and modelling
Generic energy module „eniBRIC“

Why not use the EnergyAnalyzer? eniBRIC offers:

- Energy simulation for production facilities AND building / supply infrastructure
- Flexible parameterisation of an arbitrary number of “energy operating states” and energy carriers (e.g. electricity, cooling fluid, etc.)
- Allows for “energy operating state” controlled material flow
- Modular design, very fast, easy to integrate into planning workflows





free parameter setting



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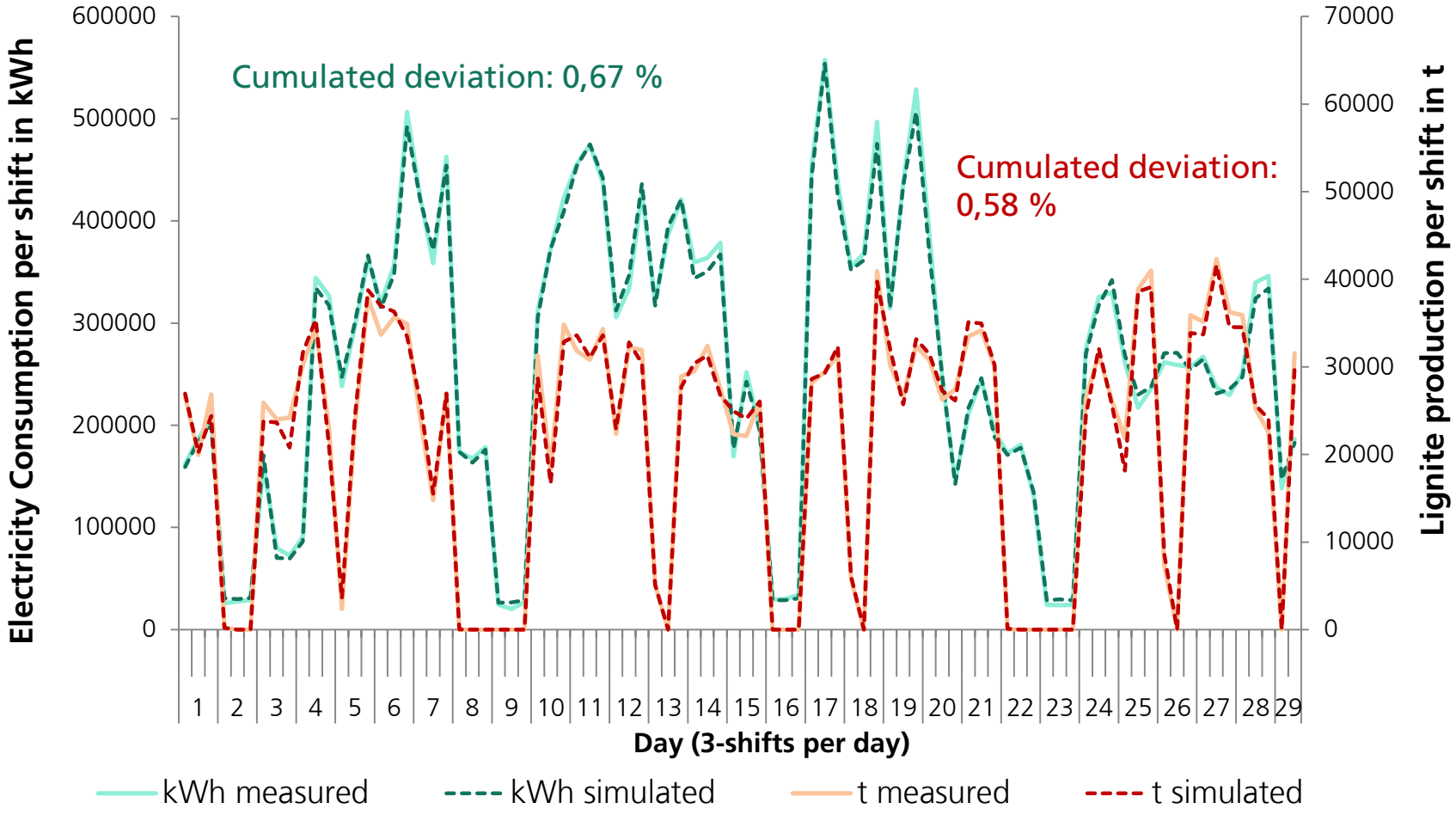
Validation

Comparison measured/simulated



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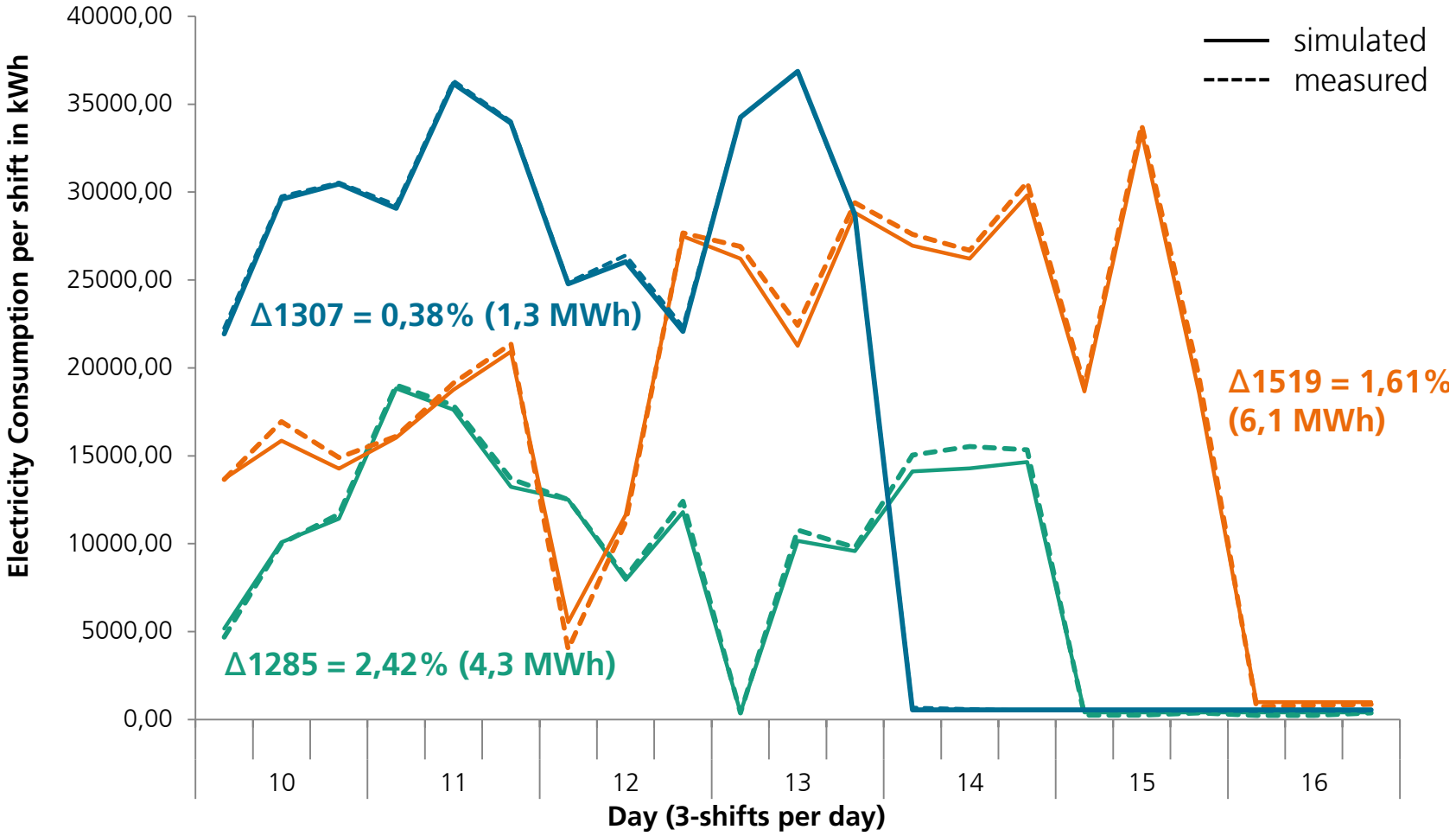

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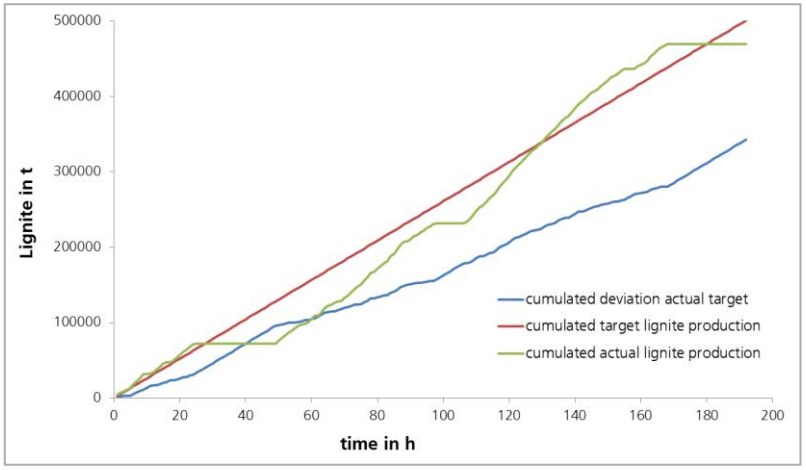
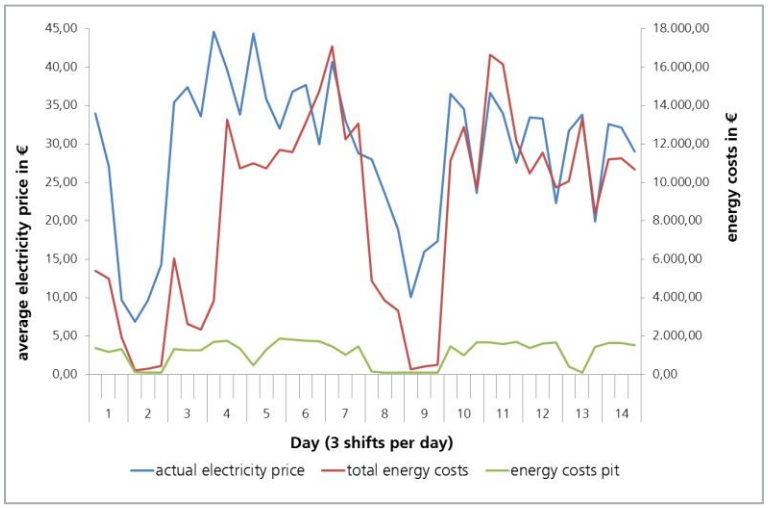
Simulation experiments and results
Indicators

- Simulation experiments were directed at the identification of flexibilities
- To assess the results various indicators were defined, for example:
  - Electricity price deviation from the average price
  - Primary energy factor for German electricity mix
  - Target/actual deviation of lignite output
  - Utilisation of capacity of lignite production
  - Cost variance for personnel and transportation
- In addition, the simulation can generate specific data for each volume package
  - Power consumption, production and lead time
  - Personnel, transport and energy costs
  - Contribution to overall system efficiency

Simulation experiments and results
Experiments and visualisation of results

- Several simulation experiments were performed to generate data, e.g.:
  - Reduction of lignite demand (high availability of RES)
  - An altered electricity price curve
  - Reduced frequency of breakdowns

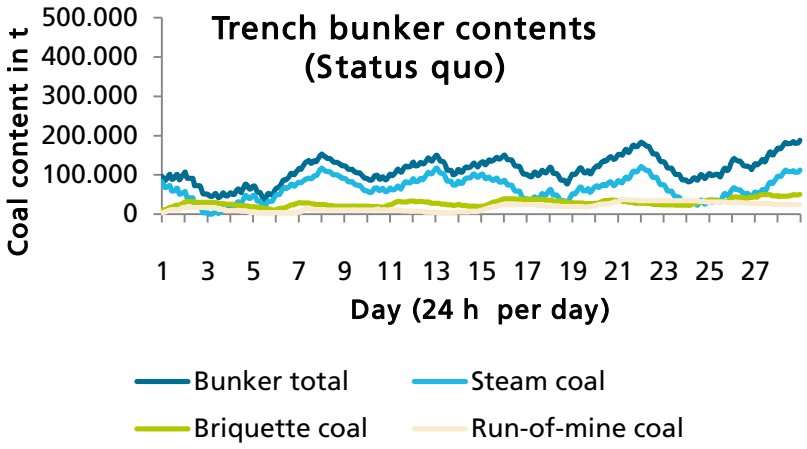


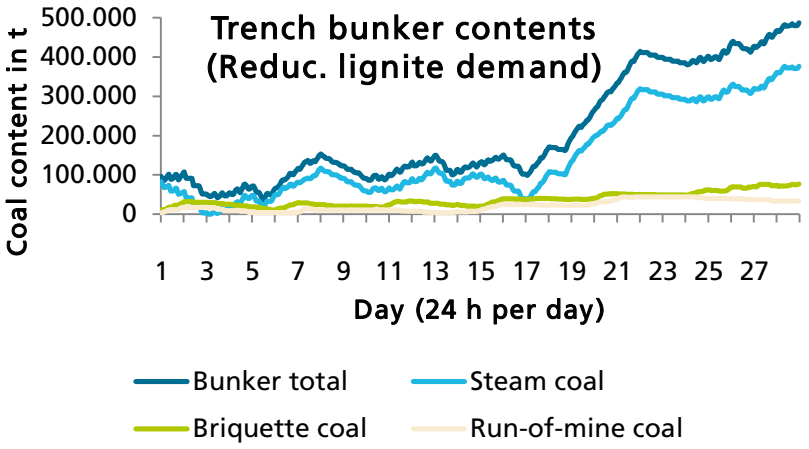


- First examinations regarding the indicators were carried out
- Results are currently being scrutinised by Vattenfall

Simulation experiments and results
Example: Reduction of lignite demand

- An increase in production of renewable energy sources diminishes the demand for output of LFPP and thus lignite
  - Trench bunker (outgoing buffer) starts to fill up if production continues unchanged
  - Course of action 1: Reduce production
    → Content threshold? OPM productivity?
  - Course of action 2: Shift production for higher energy efficiency
    → Price/content threshold?





Summary and future work

- Investigation and Modelling of an OPM as energy-intensive business with simultaneous supply function
- Using discrete event simulation as well as the eniBRIC module for modelling the energy flows
- Modelling of continuous processes by means of discretisation in Plant Simulation
- Utilisation of regression functions to calculate the volume-dependent energy consumption

  → Cumulated deviation about 0.5% within a month
- Preliminary experiments were performed and results are currently analysed by mining experts
- Enhancements of the database and additional experiments are planned

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- End of Presentation -

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