Universität Stuttgart
Institut für Energiewirtschaft und
Rationelle Energieanwendung (IER)

INTEGRATED ASSESSMENT OF ENERGY EFFICIENCY MEASURES IN AN INDUSTRIAL ENERGY SUPPLY SYSTEM
-
A CASE STUDY OF THE GERMAN PLASTIC PROCESSING INDUSTRY

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IER

Introduction and Objective

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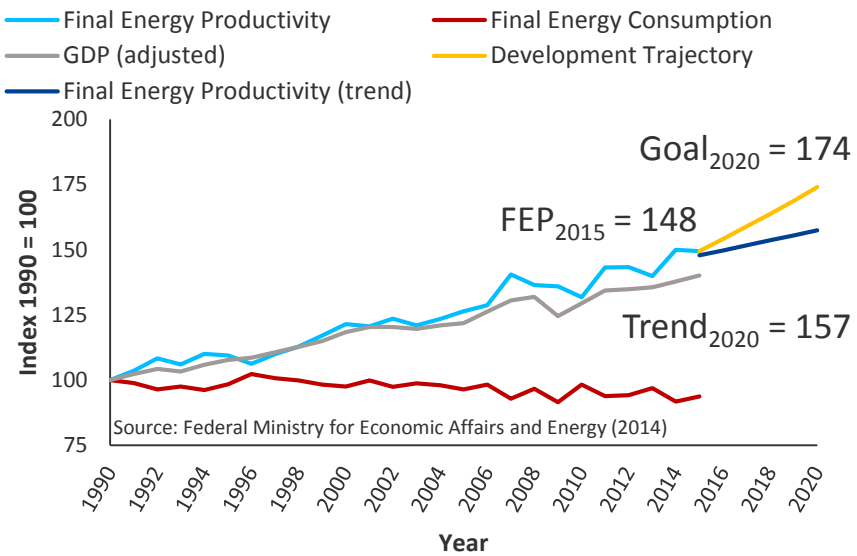
The German industry had a share of 29 % of final energy consumption in 2015.

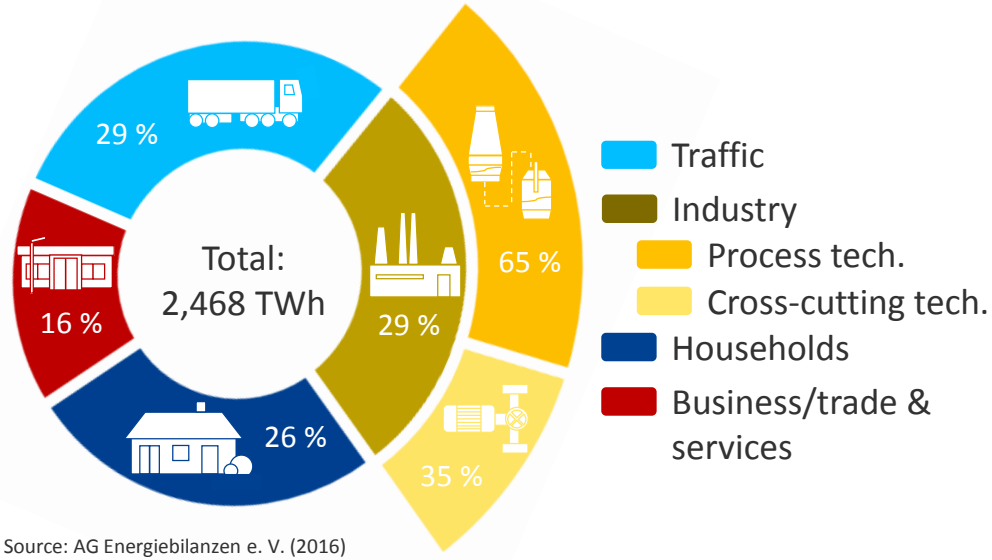
INCREASING FINAL ENERGY PRODUCTIVITY…

- … by 2.1 %/a from 2008 until 2050



FINAL ENERGY CONSUMPTION IN 2015

- Industry: 716 TWh (29 %)



Source: AG Energiebilanzen e. V. (2016)

The **German industry** is of **particular importance** when trying to reach the proclaimed energy efficiency goals.

Introduction and Objective

Industrial decision-makers depend on detailed information about energy efficiency measures.

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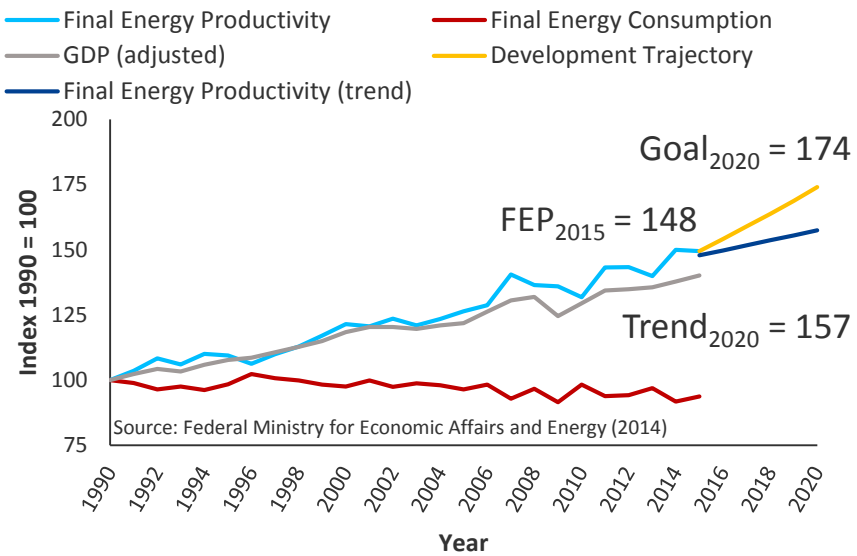

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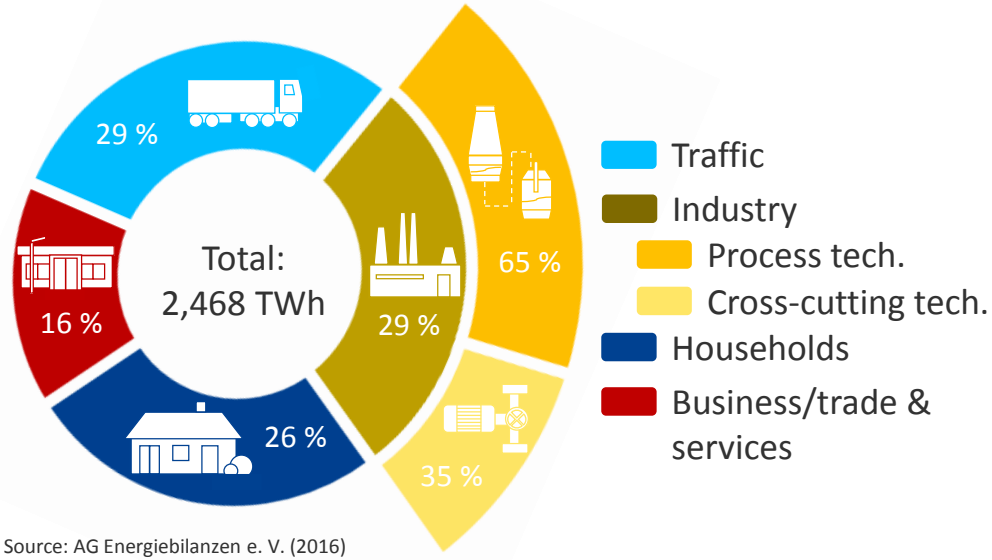

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- The **German industry** is of **particular importance** when trying to reach the proclaimed energy efficiency goals.
- At this point, there is no method for the holistic assessment of energy efficiency measures considering the dynamic system behavior as well as the interactions between energy efficiency measures.

Introduction and Objective

Interactions between EEM are often neglected when evaluating energy saving potentials.

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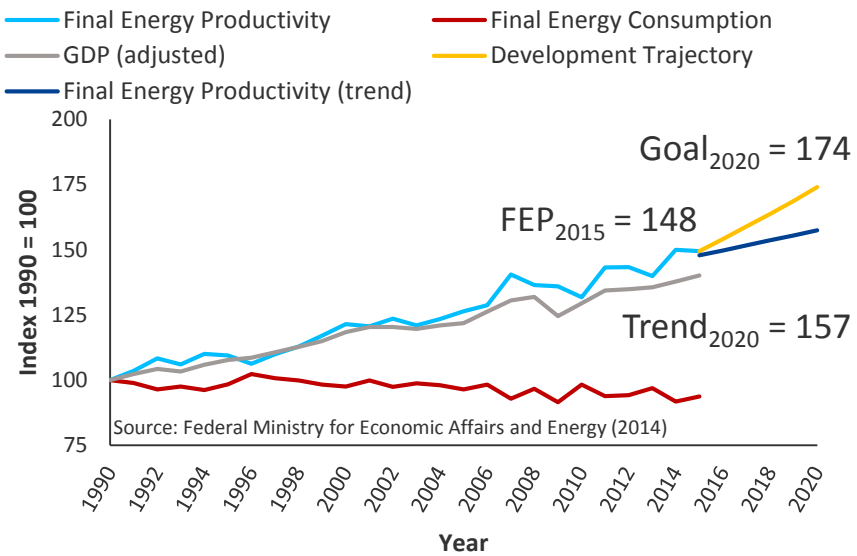

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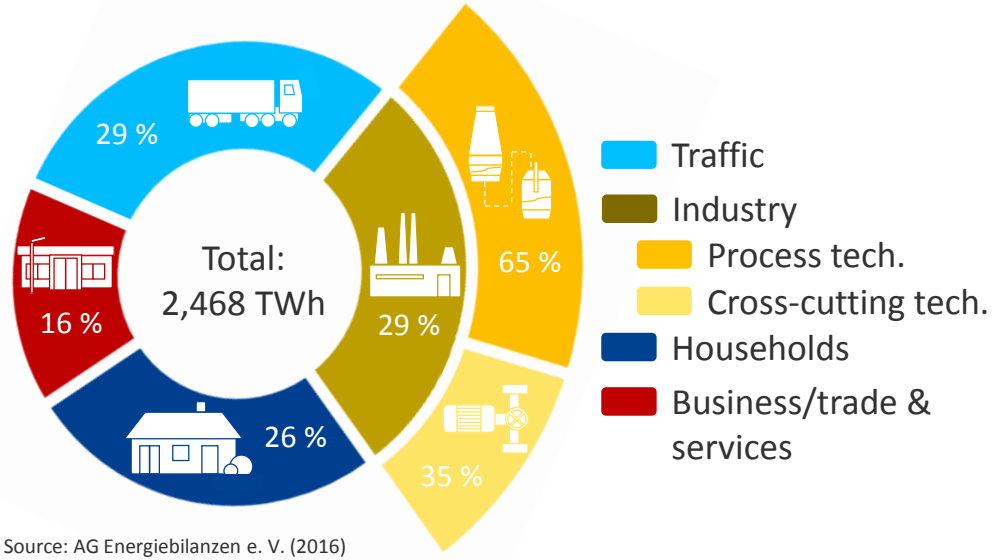

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- The **German industry** is of **particular importance** when trying to reach the proclaimed energy efficiency goals.
- At this point, there is no method for the holistic assessment of energy efficiency measures considering the dynamic system behavior as well as the interactions between energy efficiency measures.
- The main objective of this study is to **evaluate the impact of the dynamic system behavior** as well as Interactions between energy efficiency measures on the economic energy efficiency potential.

Method

Method

This holistic approach facilitated the consideration of dynamic system behavior & interactions.

Input

Representative companies

- German plastic processing industry
- Production process
- Production capacity/utilization
- Shift model

Energy efficiency measures

- Application potential
- Costs and lifetime

Model

Model structure

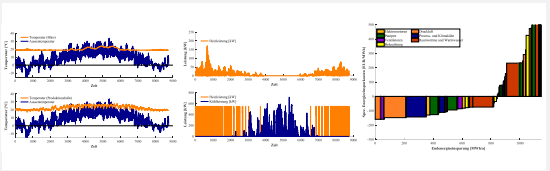
- Technology-oriented bottom-up energy demand model
- Modular hierarchy structure

Mathematical model description

- Deterministic
- Non-linear programming
- Heuristic optimisation approach

Results

- Final energy demand
- Technology specific (economic and technical) energy saving potentials
- Optimised investment schedule



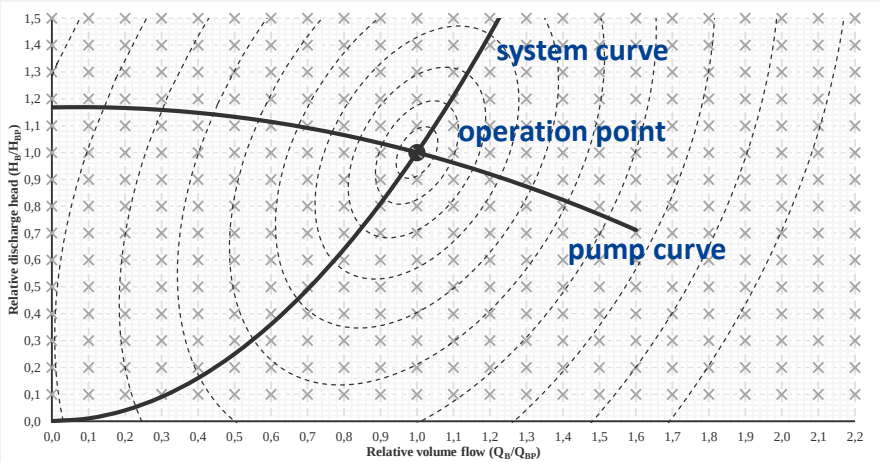
Modeling of an industrial energy supply system

Implemented cross-cutting technologies

- Production: electric motors, pumps, ventilation, compressed air, process-cooling
- Infrastructure: lighting, air conditioning and space heating

Evaluation of final energy consumption

- Endogenous calculation of product specific synthetic load profiles for useful energy.
- Technology specific time resolution considering partial as well as full load operation.
- Generic efficiency diagrams for cross-cutting technologies.
- Different control concepts (e. g. for a pump: throttle control, bypass control, on-off control, speed control)



Case-study for the German plastic processing industry

Case-study for the German plastic processing industry

The German plastic processing industry is strongly shaped by medium-sized companies …

INDUSTRY STRUCTURE

- NACE 22.2 Manufacturing of plastic products
  - Companies: 2,845
  - Employees: 301,834
  - Turnover: 56,121 mio. EUR
  - Export share: 35,3 %
- About **92 %** of the companies have **less than 250 employees** (Ø 106 employees per company).

Source: Dispan (2013)

Case-study for the German plastic processing industry

… and four characteristic production processes used for different product characteristics.

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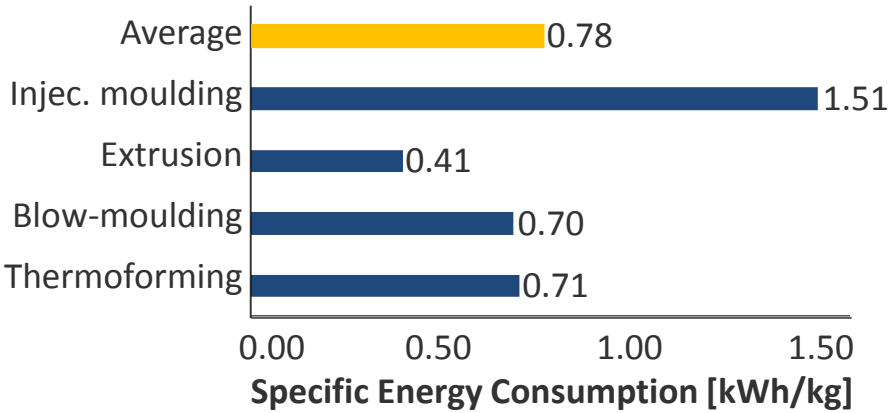
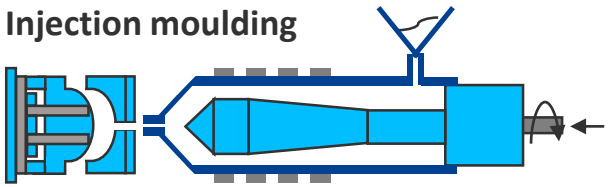
RELEVANT PRODUCTION PROCESSES

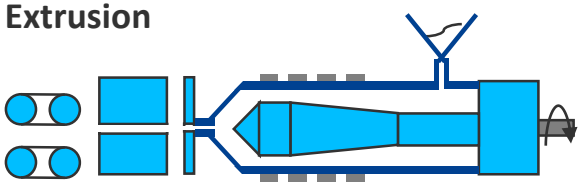


Source: Own calculations based on Consultic (2015), German Federal Statistical Office (2013), Urbanek, Saal (2011), EUROMAP (2011)

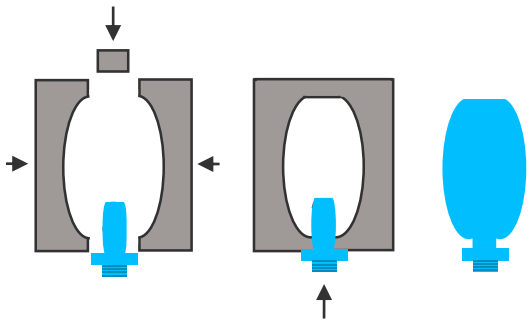
Injection moulding



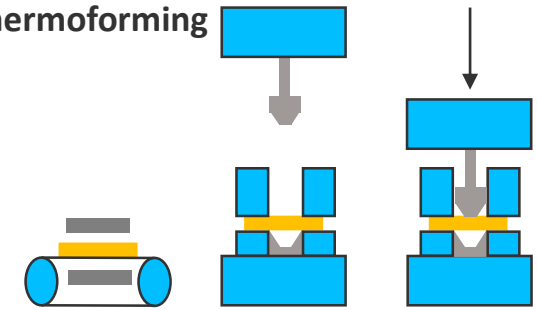
Extrusion



Blow moulding



Thermoforming



Case-study for the German plastic processing industry

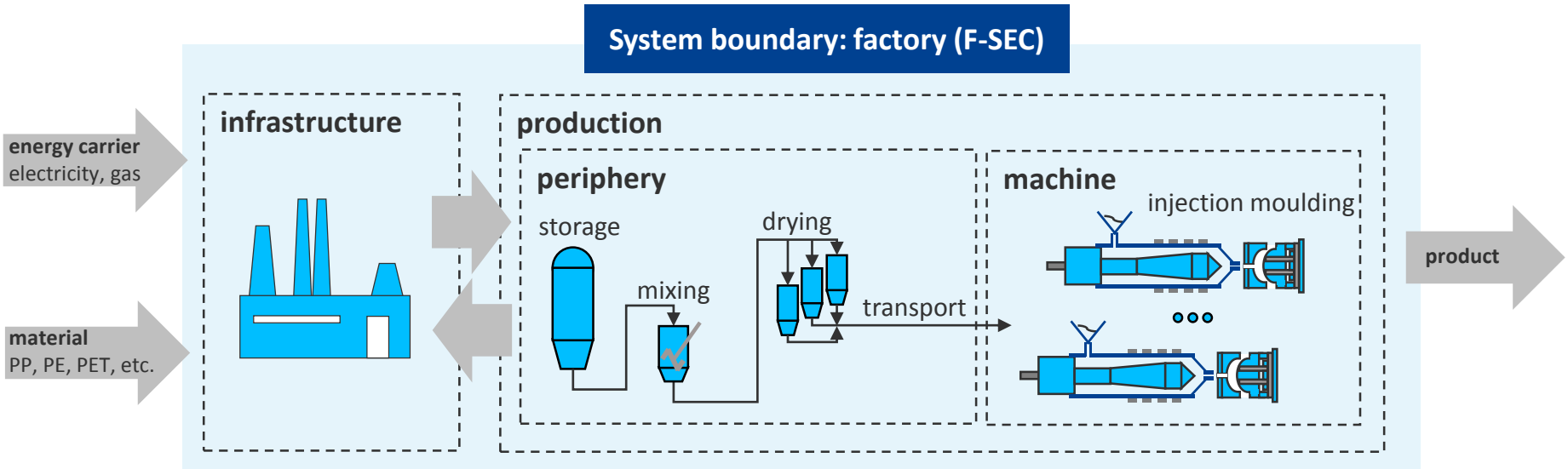
The generic injection moulding manufacturer produces small components (weight = 0.12 kg).

KEY INFORMATION

- The overall **final energy consumption** of an average injection moulding manufacturer is **8,026 MWh/a** (specific energy consumption: F-SEC: 4.35 kWh/kg).
- Production of **15.57 mio. parts per year** (average component weight: 0.12 kg).

BASE SCENARIO

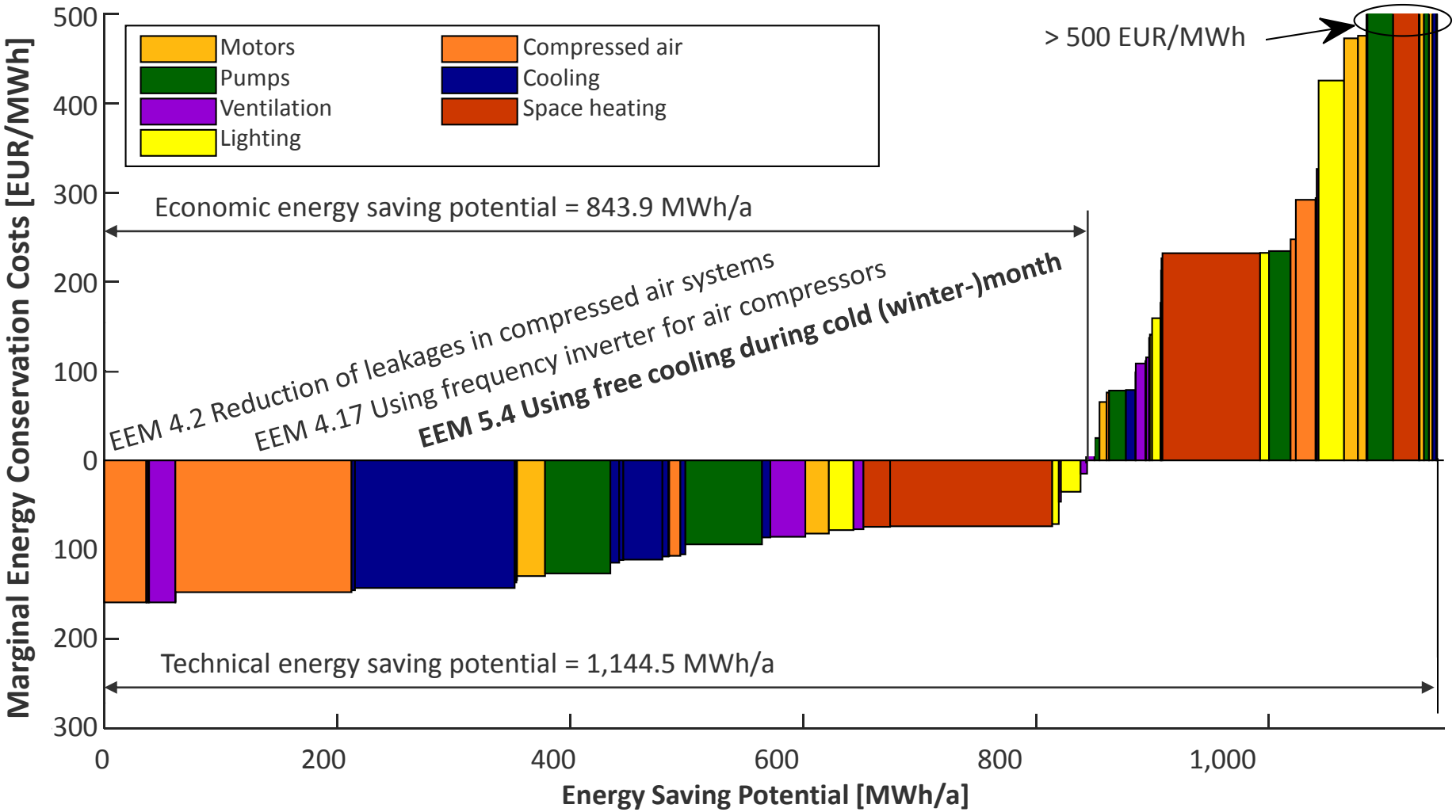
- Electricity price: 15.02 EUR/MWh_{el}
- Gas price: 3.37 EUR/MWh_{th}
- Increase of energy carrier prices: 1.0 %/a
- Interest rate: 15 %



Results

Results

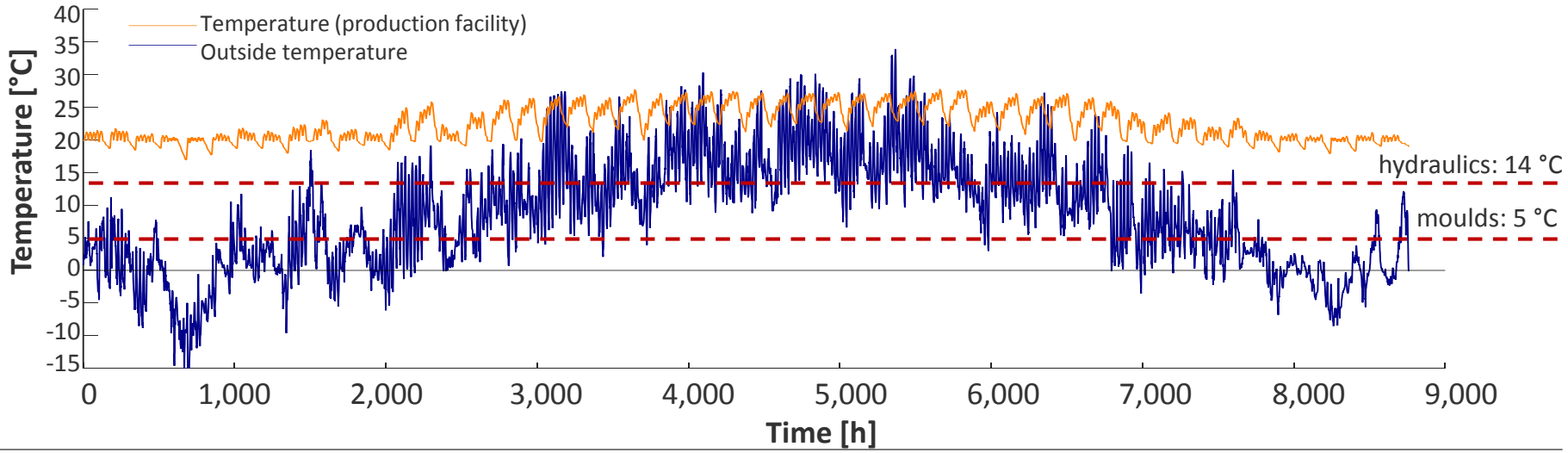
The economic energy saving potential equals 13.8 % of the total final energy consumption.



Results

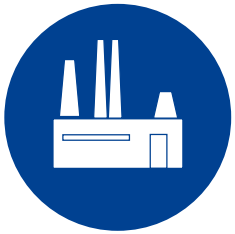
Using free cooling (EEM 5.4) saves 40.1 % of final energy consumption for process cooling.

- The demand for cooling the injection moulds as well as the hydraulics is nearly constant.
- The process cooling is supplied at an average energy efficient ratio (EER) of 1.4 using compression refrigeration machines.
- Average EER of free cooling is nearly eight times higher than the EER of the compression refrigeration machines. Thus 40.1 % of final energy consumption for process cooling can be saved using free cooling.
- This complies with estimations of manufacturers for refrigeration systems who indicate savings of up to 80 % (depending on the temperature).



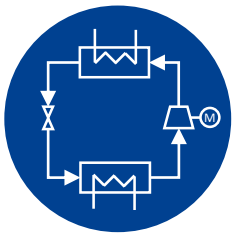
Results

Interactions between EEM significantly influence the (economic) energy saving potential.



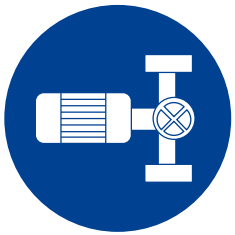
Interactions on a factory level

The economic energy saving potential of the **whole factory is reduced by 8.3 %** compared to the assumption, that all energy efficiency measures are mutually exclusive and there are no interactions between them.



Interactions on a technology-system level

When evaluating individual technology-systems the impact of interactions increases. For example, the economic energy saving potential for the **compressed air system is reduced by 17.1 %** due to interactions.



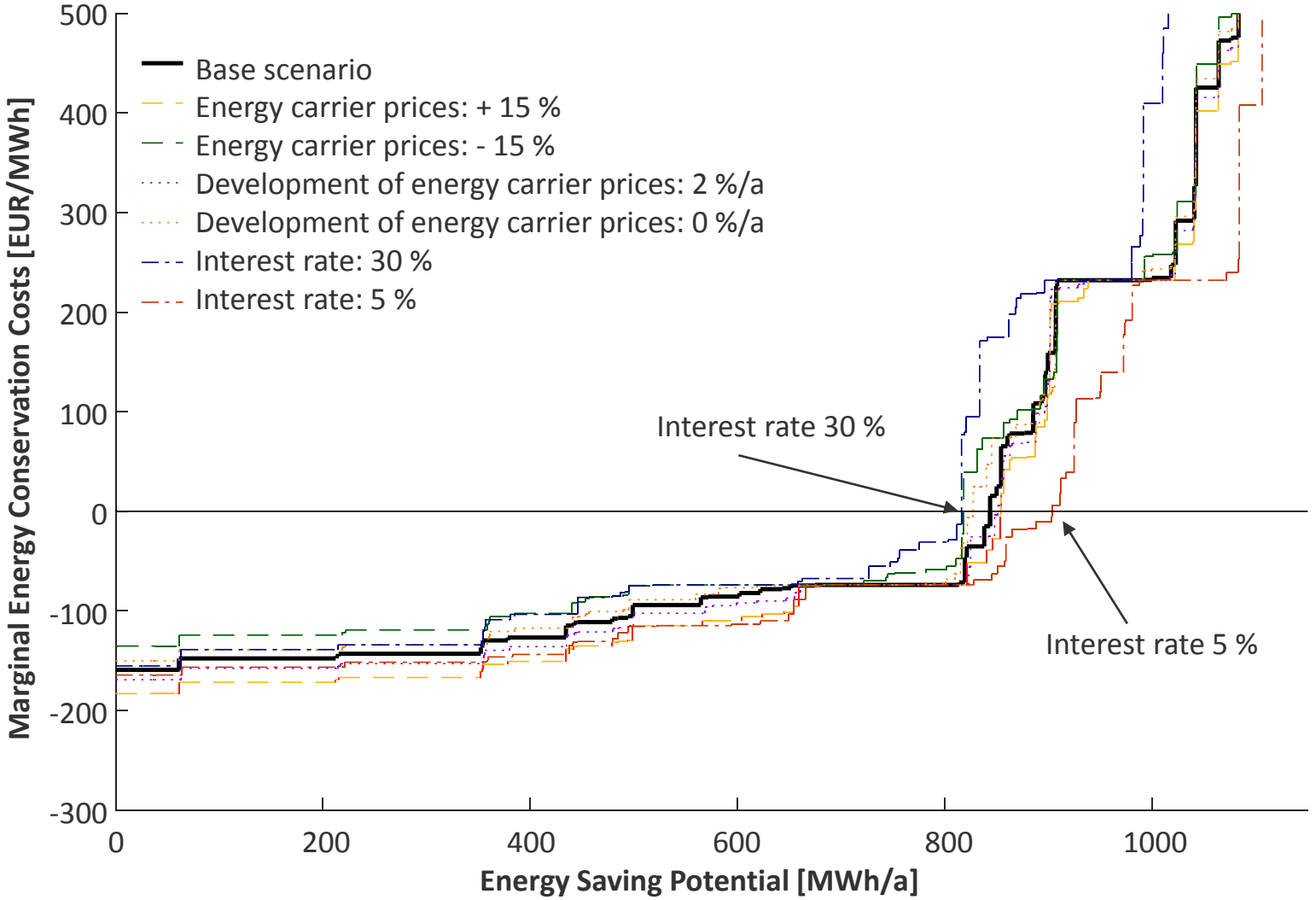
Interactions on a energy efficiency measure level

The impact of interactions is even larger when looking at individual EEM. For example the **energy saving potential of an IE4 motor** in the air-cooled condenser (liquefier) of the compression refrigeration unit **is reduced by 57.7 %.**

Neglecting interactions when evaluating EEM might lead to a **significant overestimation** of the energy saving potential and thereby can lead to **disappointments with energy saving investments.**

Results

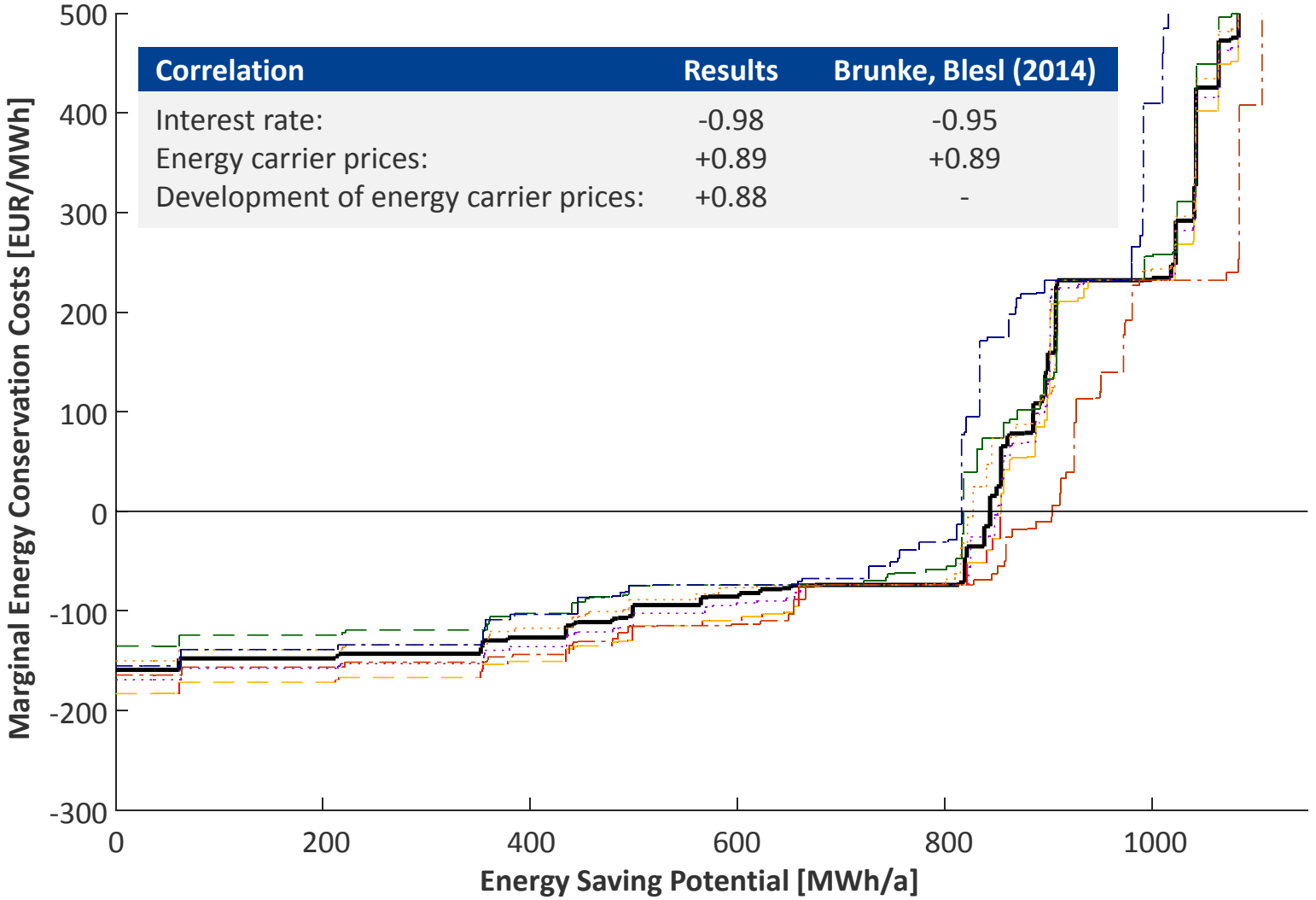
Changes in the interest rate have the highest impact on the economic energy saving potential.



Results

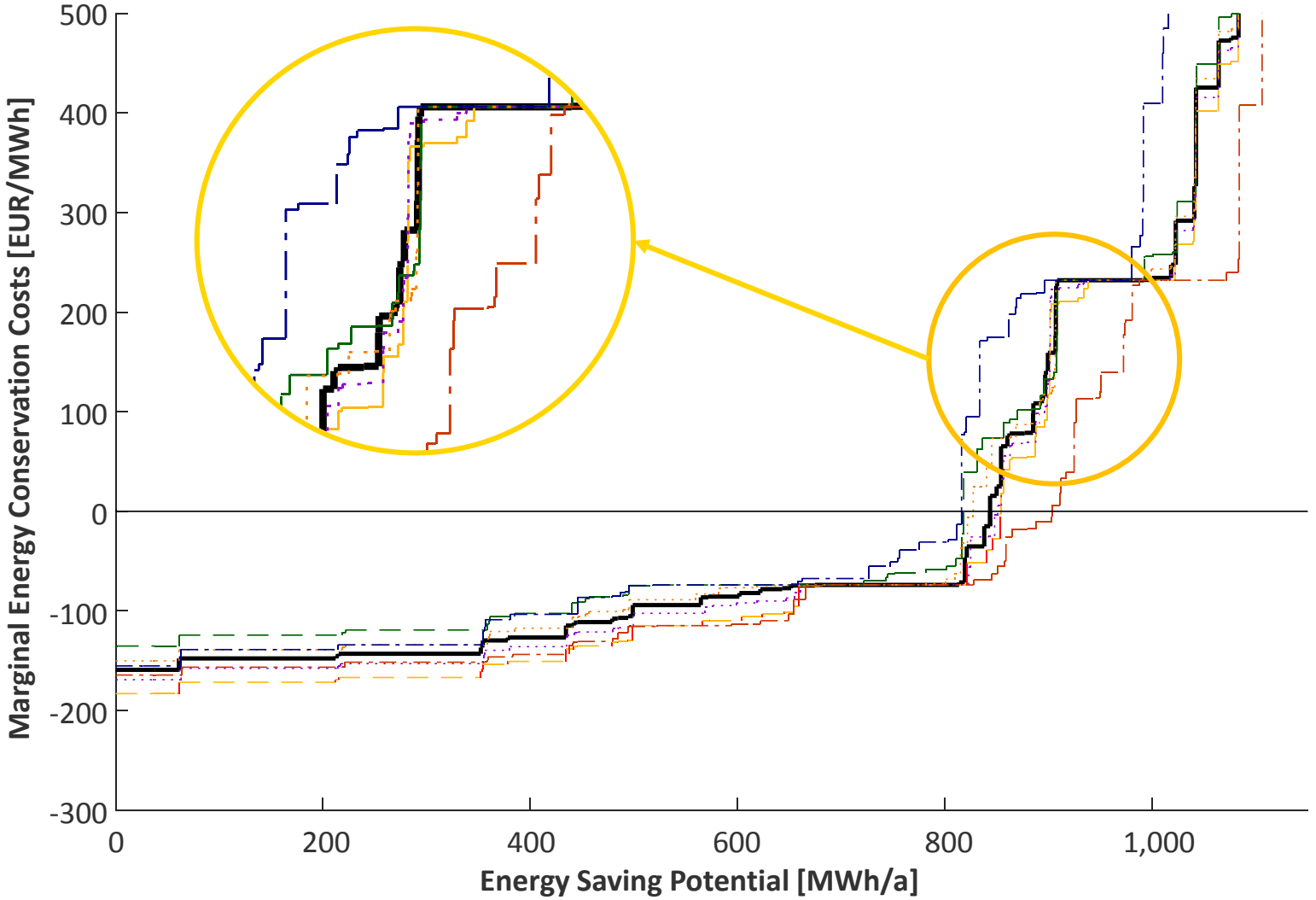
There is a strong correlation between the economic ESP an the changed parameters.

Correlation	Results	Brunke, Blesl (2014)
Interest rate:	-0.98	-0.95
Energy carrier prices:	+0.89	+0.89
Development of energy carrier prices:	+0.88	-



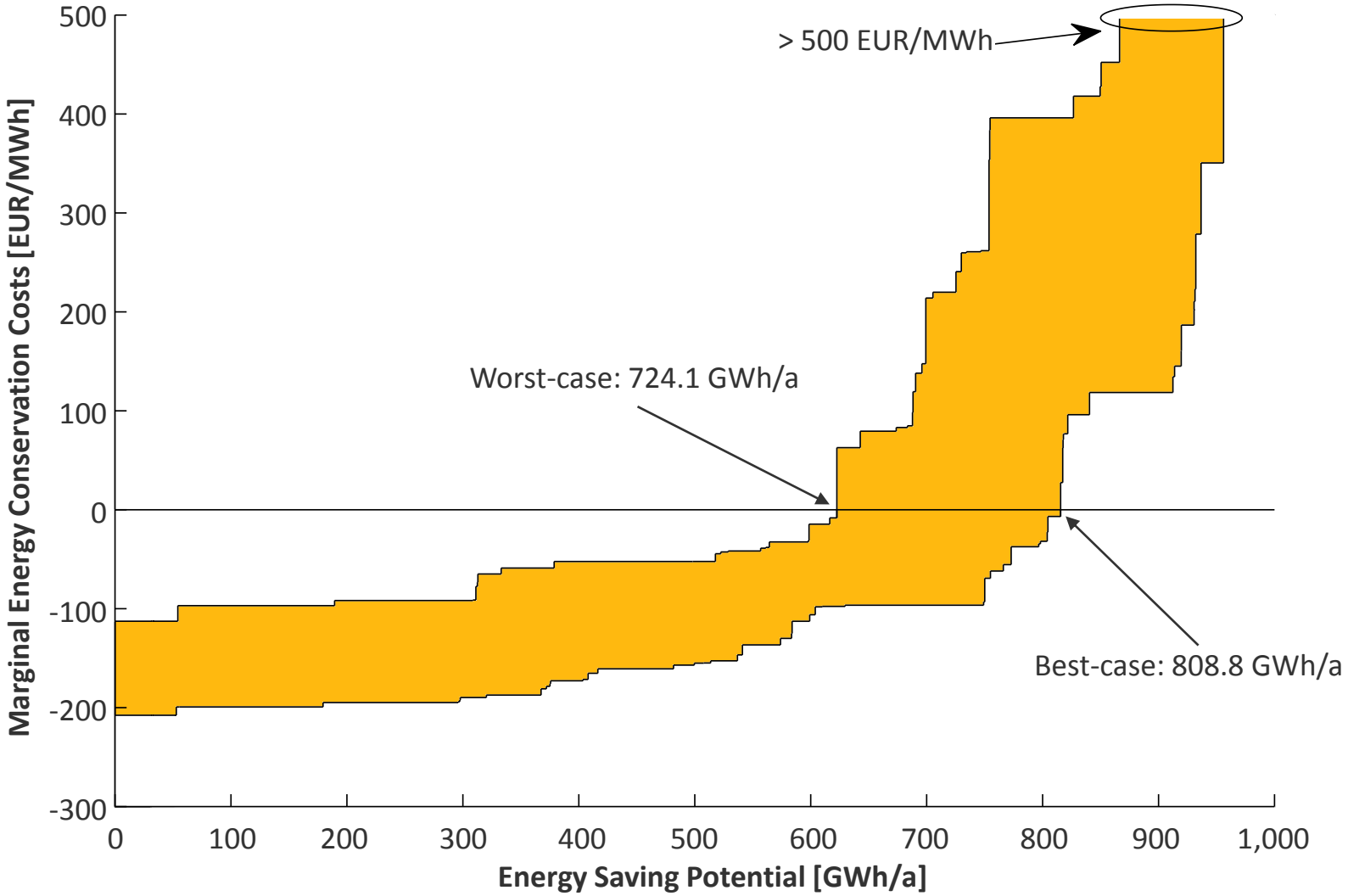
Results

A variation of the input parameters does not lead to a parallel shift of the MECC-Curve.



Results

Extrapolating the results onto the national level leads to an economic ESP of 11.9 to 15.4 %.



Conclusion

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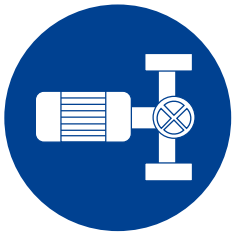
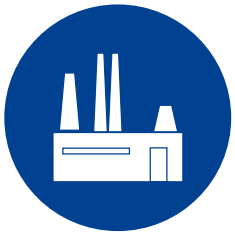


Impact of interactions between energy efficiency measures

The impact of interactions differs significantly when looking at a factory compared to an individual energy efficiency measure. When evaluating **individual energy efficiency measures** the changes of the energy saving potential due to interactions amounts for **up to 50 %**.



Energy efficiency potential in the German plastic processing industry

The results from the conducted case-study (injection moulding manufacturer producing small parts) show, that there is still a significant **economic energy saving potential of 11.9-15.4 %** for the evaluated cross-cutting technologies. Almost **74 %** of the identified technical energy saving **potential is cost-effective**.

Further research

With regard to the German plastic processing industry further research is necessary to evaluate the **impact of different product sizes** (→ different injection cycling times). Furthermore additional research is recommended to evaluate the economic energy saving potential for **other production processes** (extrusion, blow-moulding, thermoforming) in a similar way.

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