# Energy efficiency in industrial manufacturing using simulation-based optimization

Part of the EXPLAIN project


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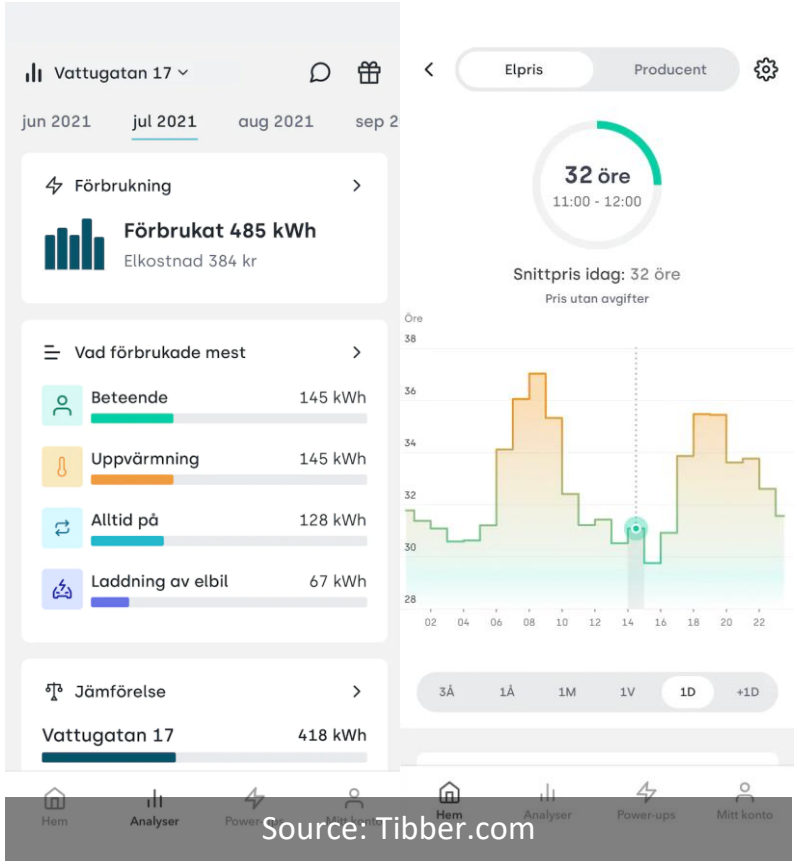
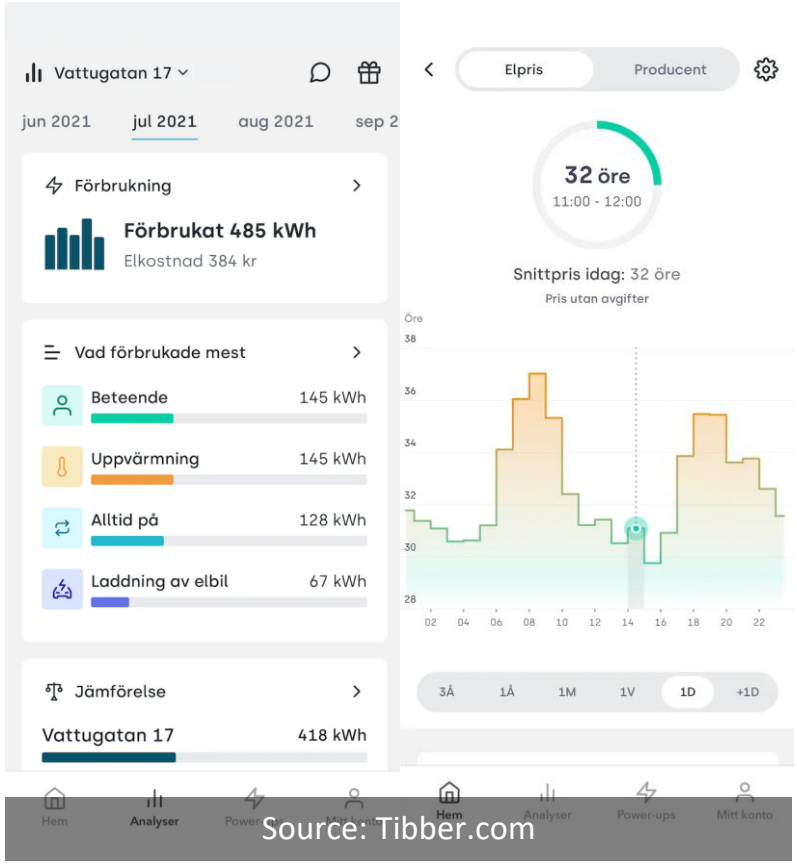
Anders Svensson, QFX, Scania

# Residential sector




Source: Tibber.com

## Residential sector




Source: Tibber.com

## Industrial manufacturing

# Content of the presentation

Relevance & Background

Approach

Use case example

Conclusion

# Relevance

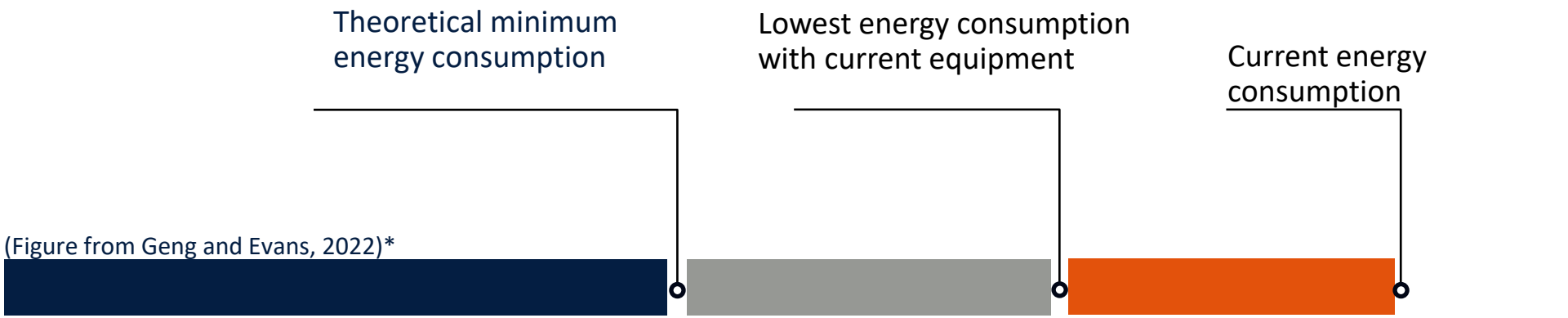
Energy costs rising

85% of GHG emissions within Industrial Operations by 2030

Science Based Targets
- 25% energy use by 2025

20-40 % of energy used in production is wasted

# Background: Energy waste in production




Production development

Today approximately **20-40% of energy used is wasted** (Estimated by QFX energy experts)



*Geng, D., & Evans, S. (2022). A literature review of energy waste in the manufacturing industry. *Computers and Industrial Engineering*, *173*. https://doi.org/10.1016/j.cie.2022.108713

# Background: Energy waste in production


Value-adding activities (processing)
5–20%

Necessary, but non-value-adding activities (e.g., safety and work environment)
40–70%

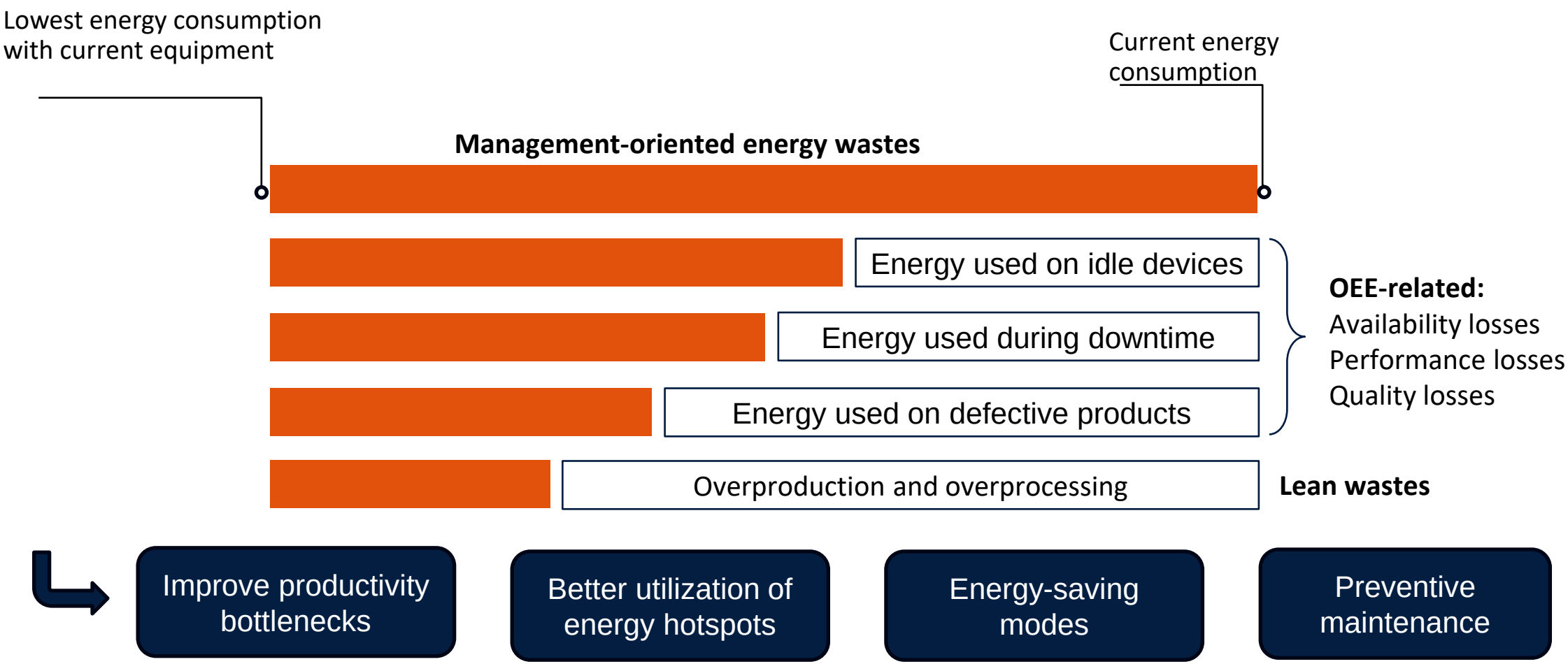
Non-value-adding activities (e.g., idling, downtime)
20–40%

i) Value-adding energy shall be *optimized*

ii) Necessary, but non-value adding energy shall be *minimized*

iii) Non-value adding energy shall be *eliminated*

# Background: Energy waste in production



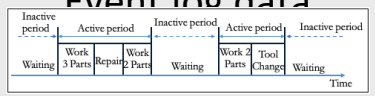



Geng, D., Evans, S., Kishita Y. (2023). The identification and classification of energy waste for efficient energy supervision in manufacturing factories. *Renewable and Sustainable Energy Reviews*, *173*. https://doi.org/10.1016/j.rser.2023.113409

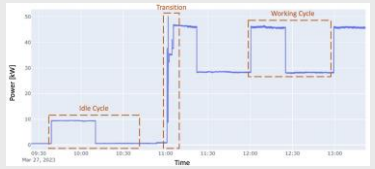
# Approach: Simulation-based optimization

## Input data

Event log data

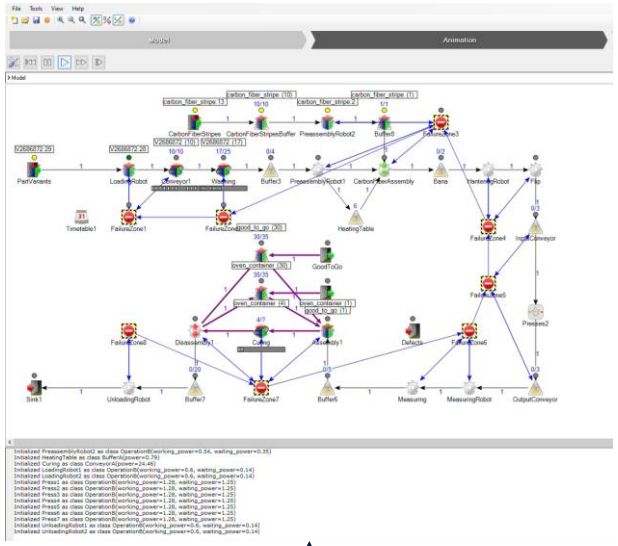



Energy consumption



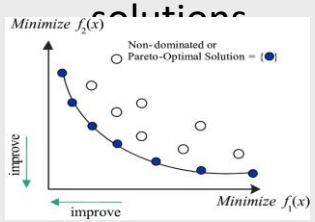

Process understanding

## Discrete-event simulation model

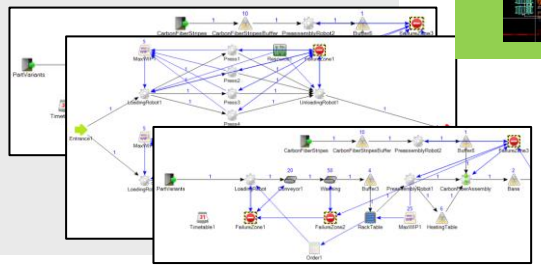


## Output data

Pareto optimal solutions




Creating proposals



## Production decision

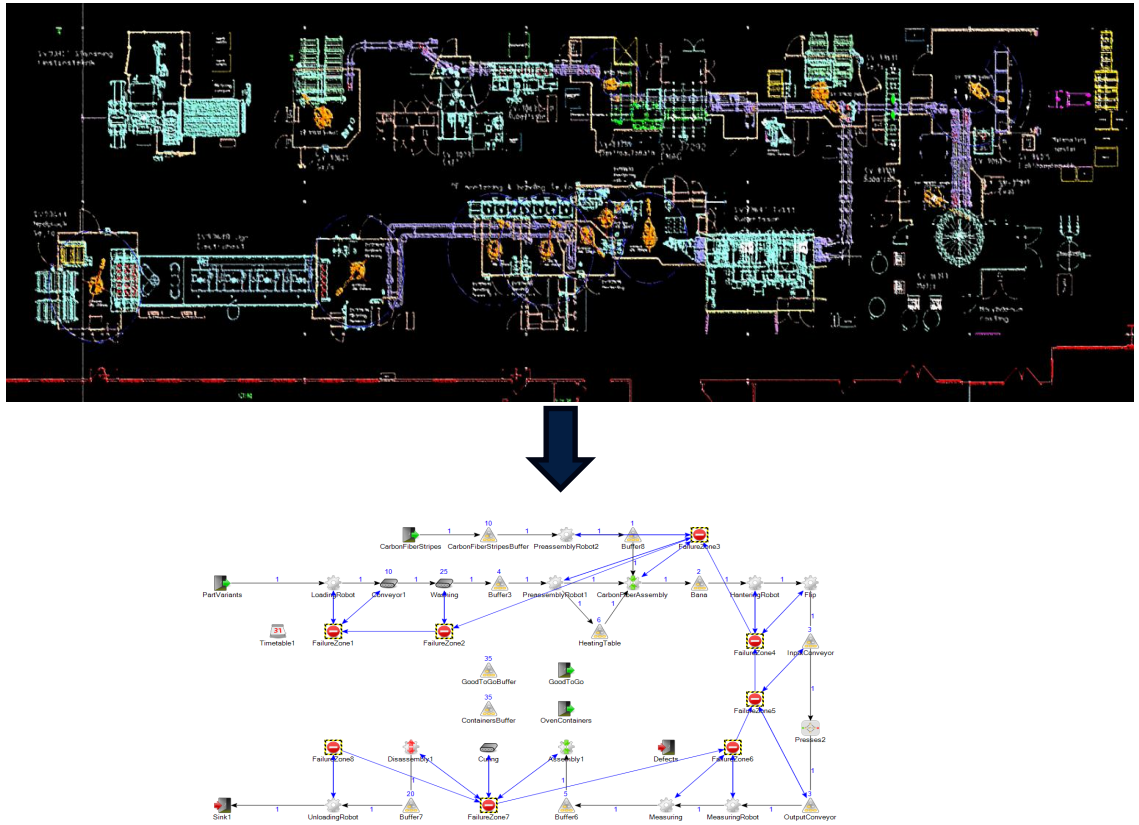
Digital support for production development for energy efficiency through

- Simulation-driven Optimization
- Data modelling

# Use case example

# 1. Use case

- **Process:** Automated line, new equipment, good data availability. Electricity as main energy carrier.
- **Goal:** The goal of the project is studying how to make the line more energy efficient while ensuring system productivity is not compromised.
- **Hypothesis**: We can model the production line in terms of its productivity and energy consumption to simulate different scenarios and to find the optimal configuration of the line.



# 2. Data inputs for energy simulation[1]

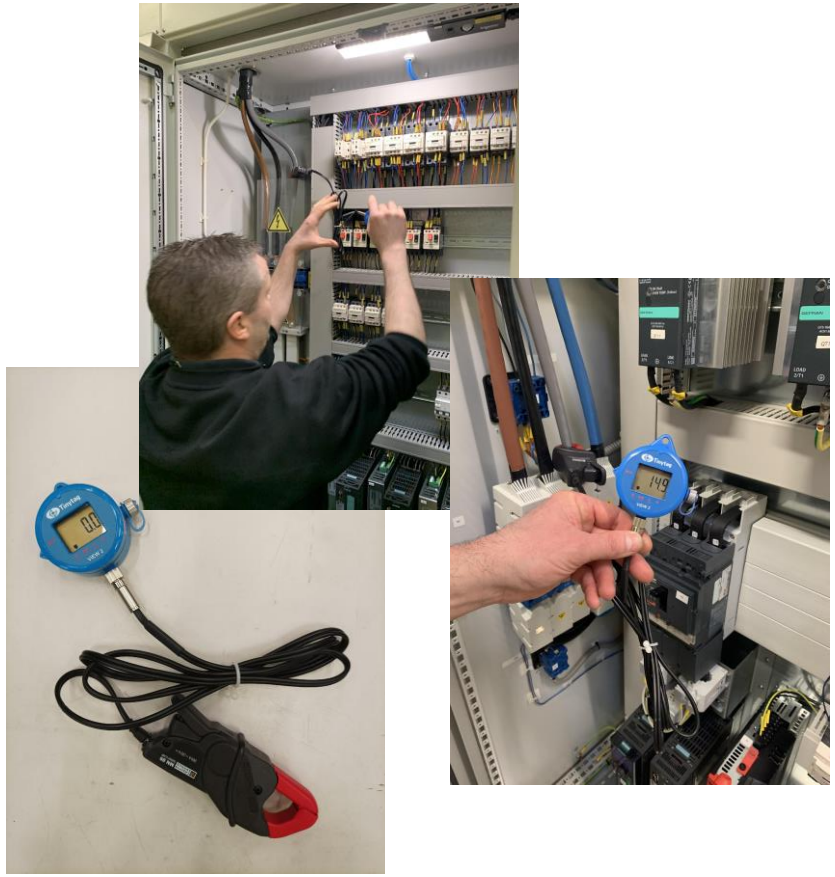
Energy data

Average consumption per shift / machine / operating state

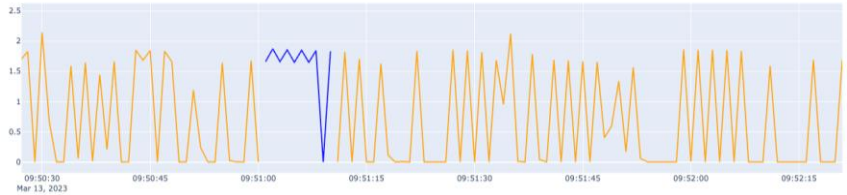
Energy costs

Energy input data

Manual data collection



Energy profile per machine




[1] VDI 3633 - Simulation of systems in materials handling, logistics and production - Terms and definitions

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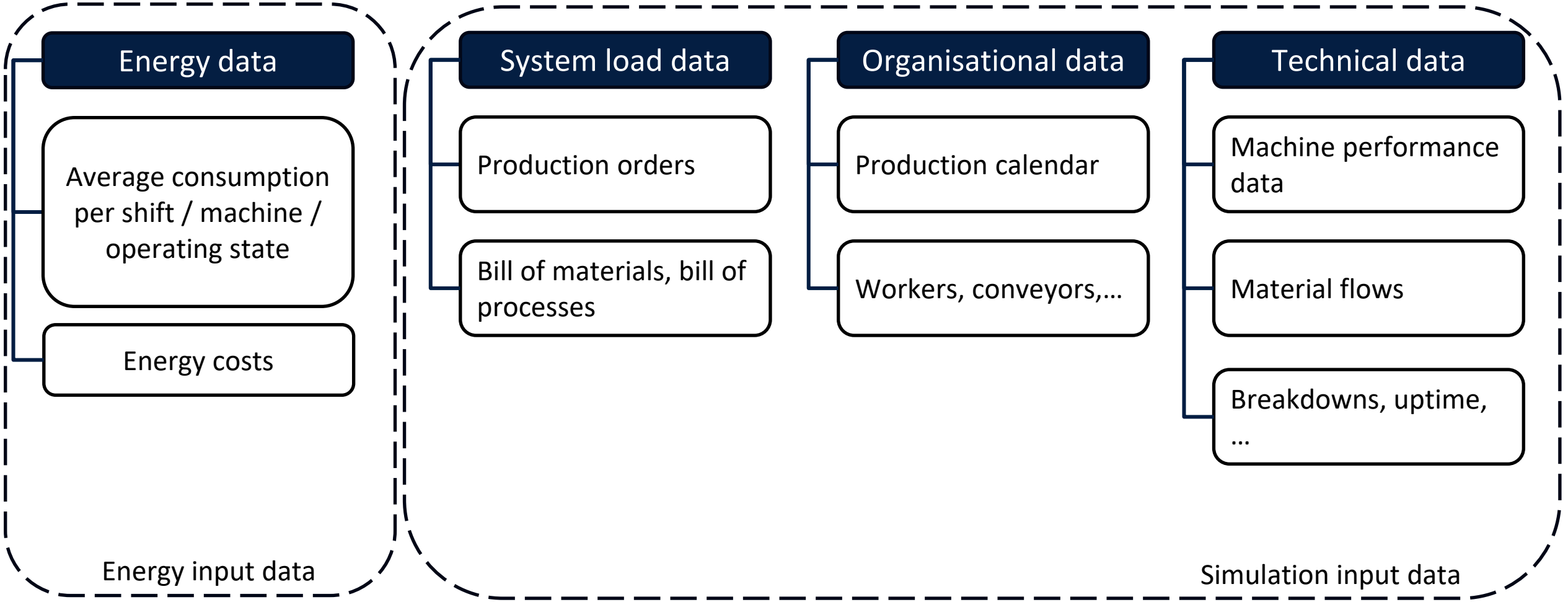
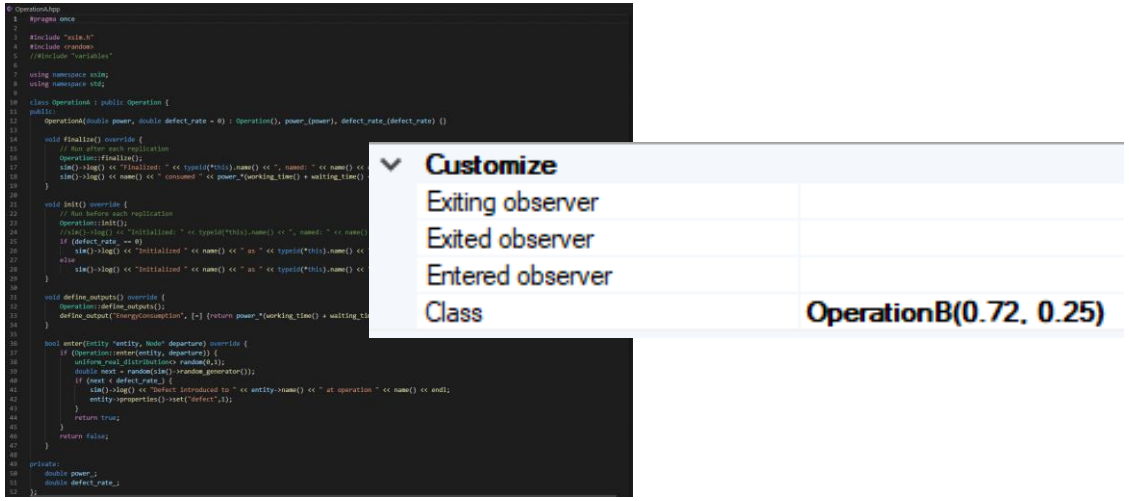


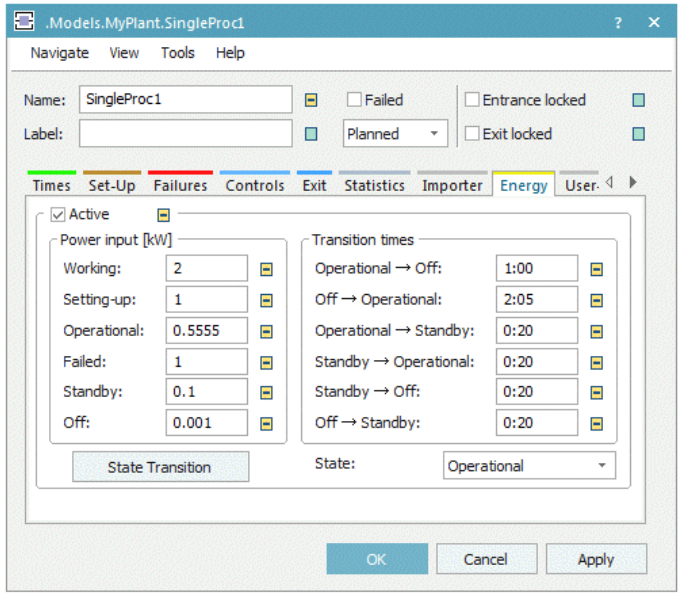

[1] VDI 3633 - Simulation of systems in materials handling, logistics and production - Terms and definitions

# Example: Energy data inputs in simulation software

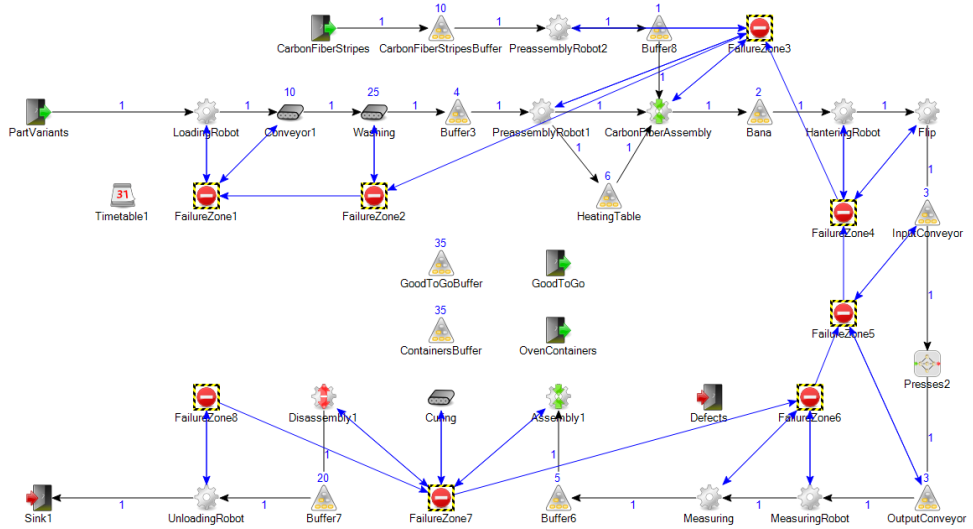
**FACTS Analyzer**: Define class in code editor




**Siemens plant simulation:** Offers in-built function



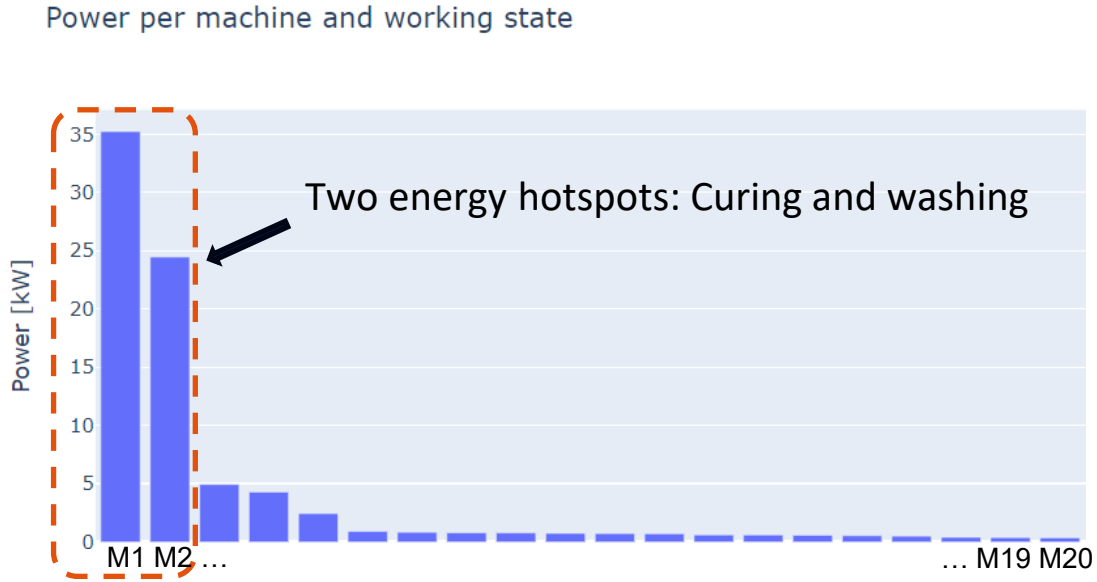
# 3. Model verification and validation



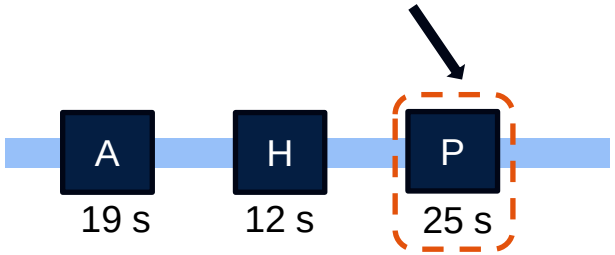

| System | TH [jph] | Relative error [%] |
|---|---|---|
| Real production line | 80,6 | - |
| DES Model (3 variants) | 84,57 | 4,96 |
| DES Model (4 variants) | 84,43 | 4,78 |

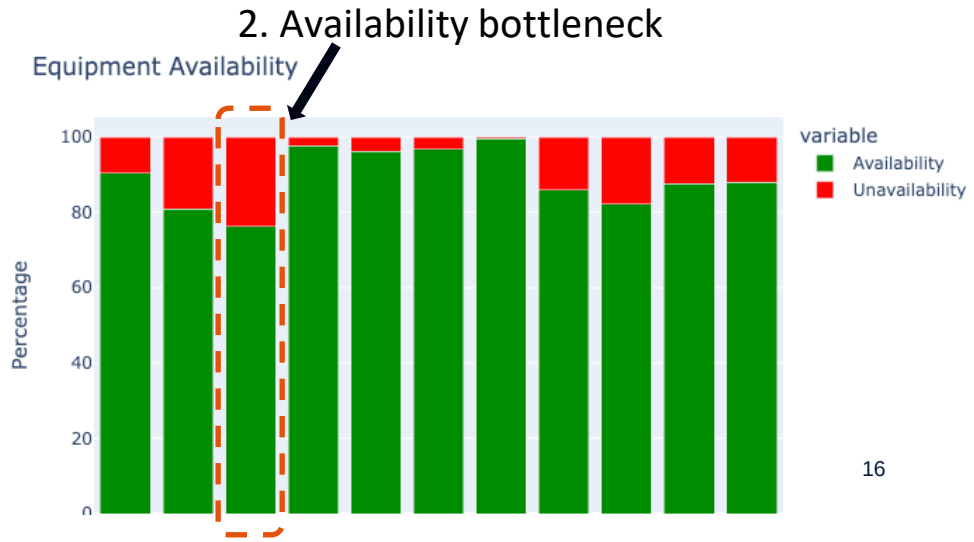
# 4. Define studies: Identify energy hotspots and bottlenecks

Energy hotspots:




Productivity bottlenecks:



# 4. Define studies

$$Consumed\ Energy\ per\ Part = \frac{Total\ Energy\ Consumption}{Produced\ Parts}$$

- 2 productivity bottlenecks
  - Study 1: Presses (cycle time bottleneck)
  - Study 2: Preassembly cell (availability bottleneck)
- 2 energy hotspots
  - Study 3: Washing machine
  - Study 4: Oven

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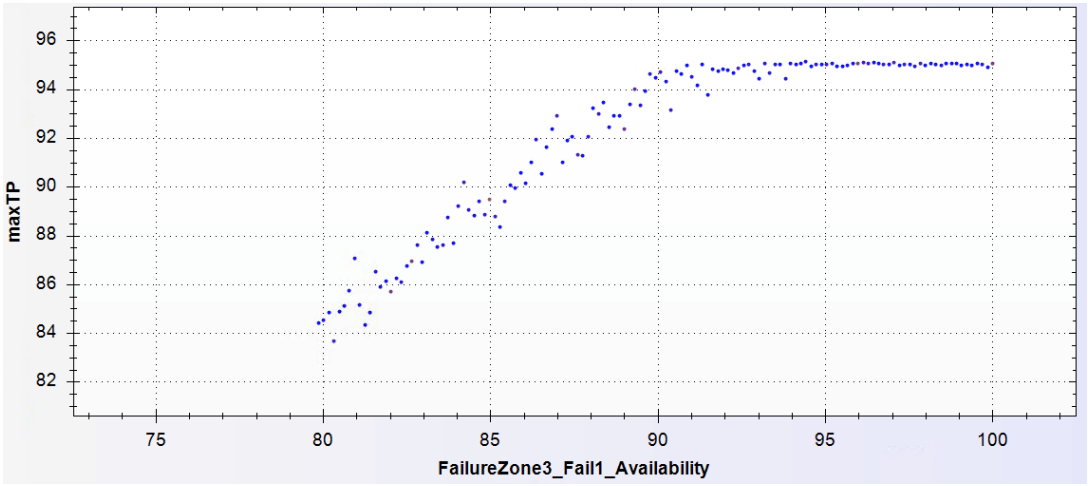
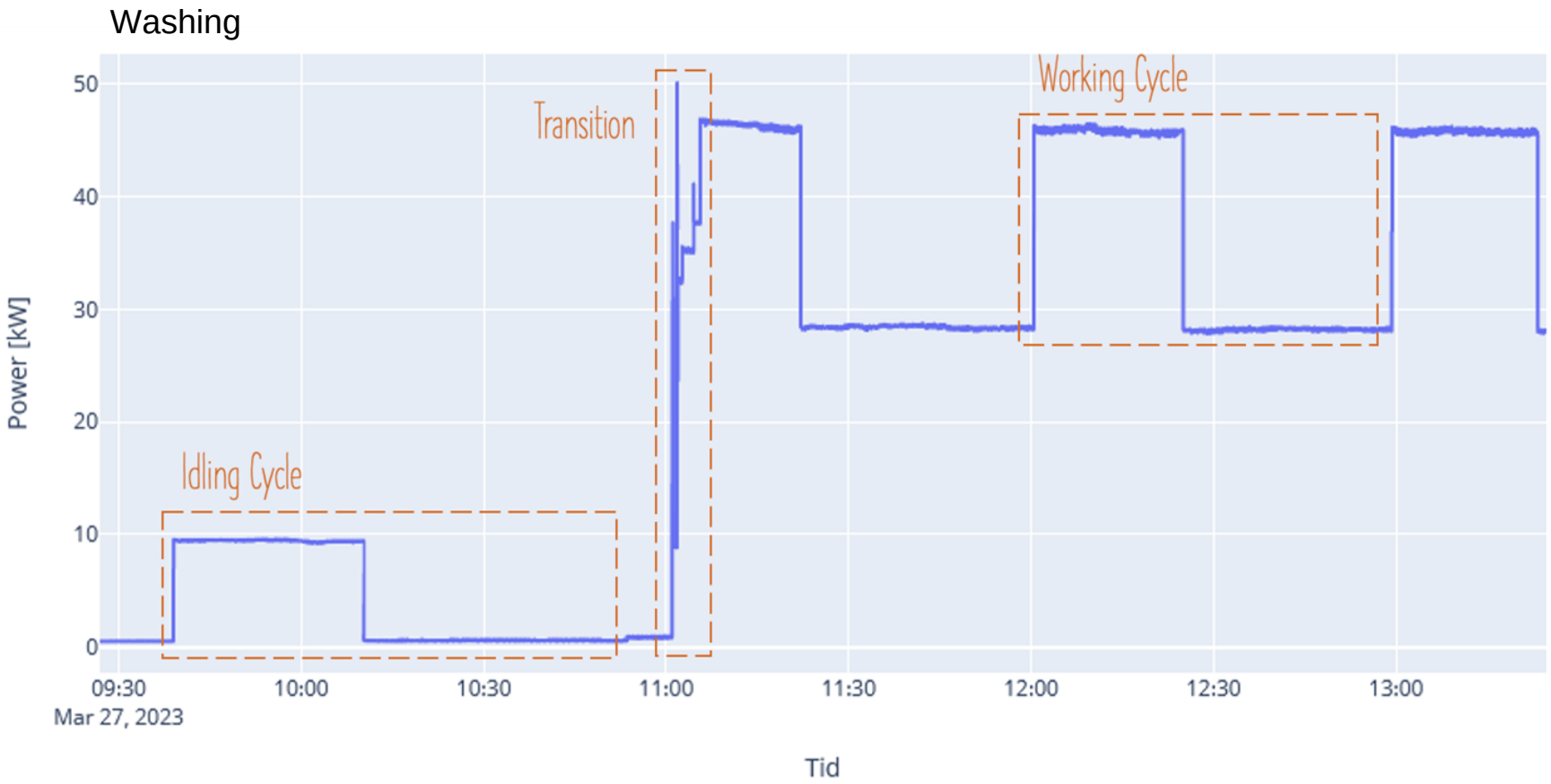
# Availability bottleneck: Line stops in pre-assembly cell

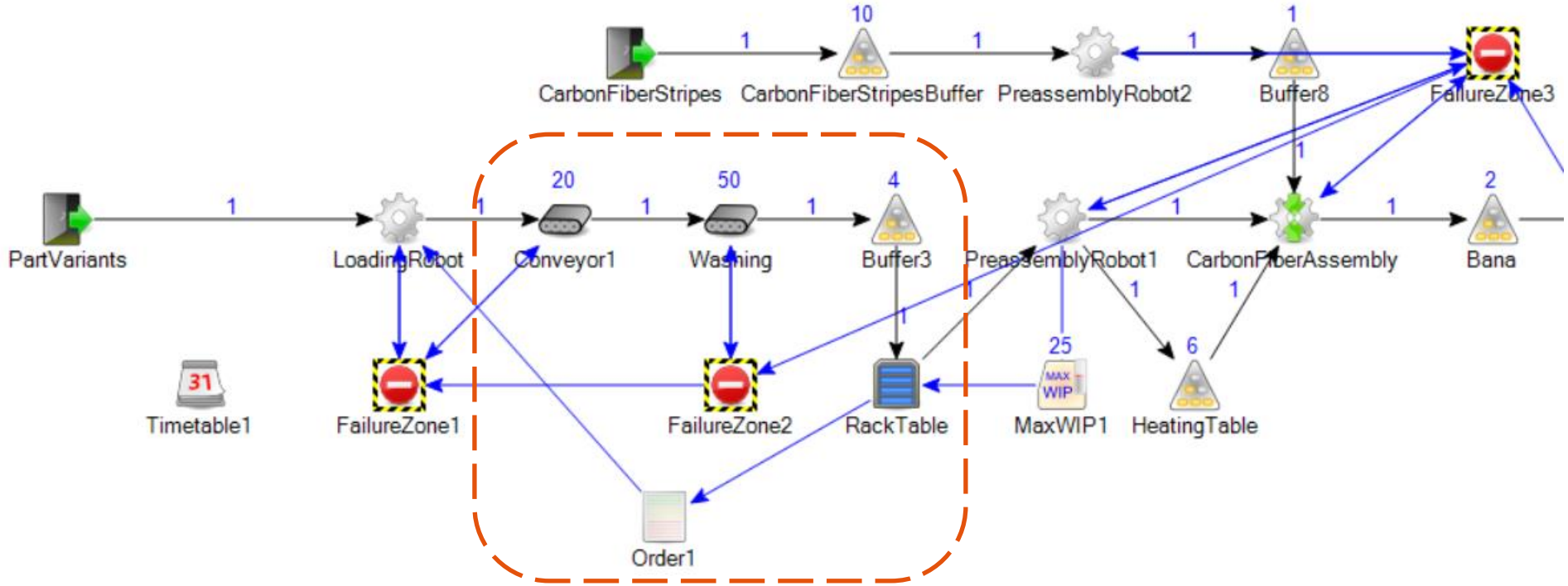



| Scenario | Availability [%] | TH [jph] | Produced parts [parts/week] | Total Energy Consumption [kWh/week] | Energy Consumption per part [kWh/part] | Energy Savings [SEK/week] |
|---|---|---|---|---|---|---|
| Current situation | 79,86 | 84,57 | 11840 | 12043,5 | 1,017 | - |
| Mitigate 50% of stops | 89,93 | 97,43 [+15.2%] | 13640,2 | 12070,7 | 0,885 [-12.98%] | 2026 |

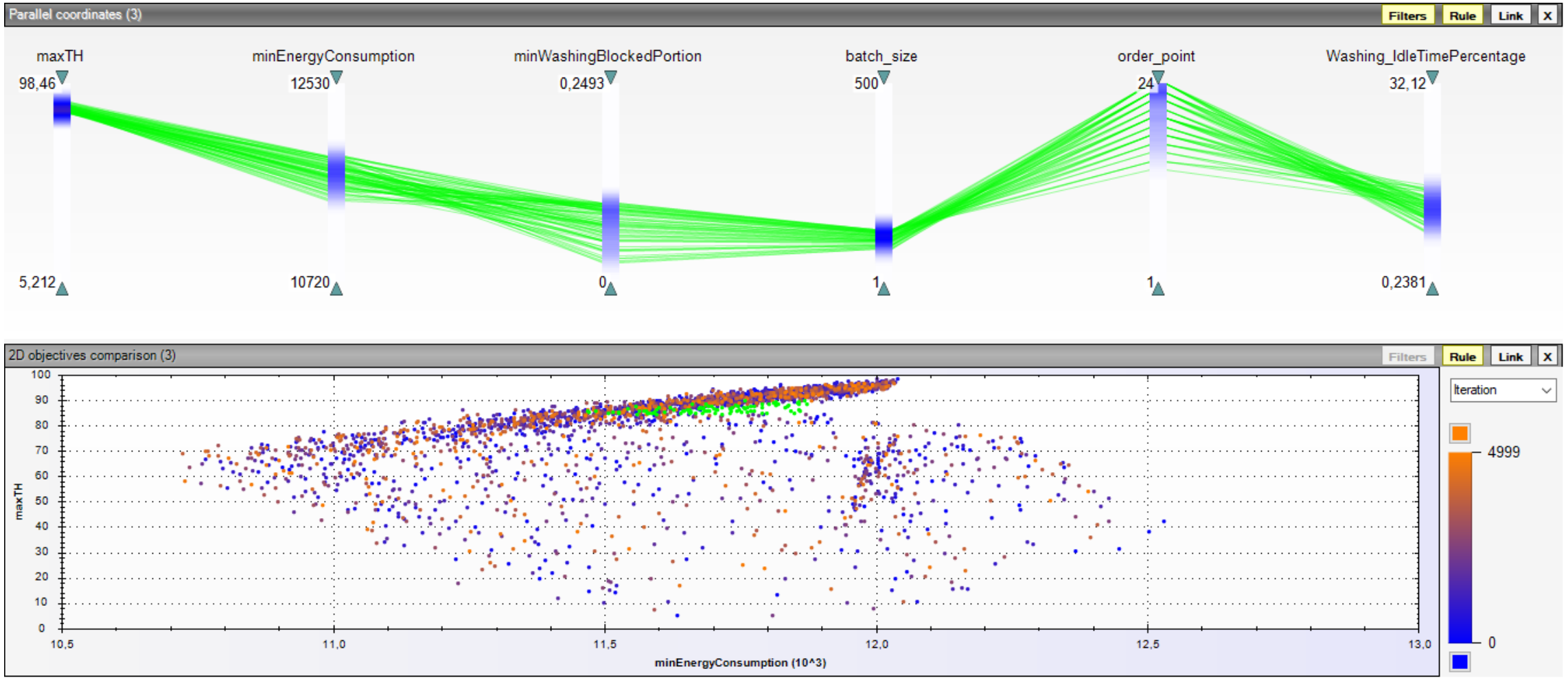
# Energy hotspot: Washing machine



# Energy hotspot: Batch processing in washing machine



# Energy hotspot: Optimizing utilization of washing machine



# Energy hotspot: Results of optimizing washing machine

| Scenario | TH [jph] | Produced parts [parts/week] | Total Energy Consumption [kWh/week] | Washing Blocked Portion [%] | Relative Idling Time [%] | Energy Consumption per part [kWh/part] | Energy Savings [SEK/week] |
|---|---|---|---|---|---|---|---|
| Current situation | 84,57 | 11840 | 12043,5 | 1,09 | 0,05 | **1,017** | - |
| Batch processing: batch_size=96, order_point=22 | 84,94 [+0.4%] | 11891,6 | 11641,2 | 4,4 | 13,97 | **0,979 [-3,74%]** | 508 |

# Learnings

- Method in modeling a production line in terms of production productivity and energy consumption

- Important to take holistic system's perspective
  - JIT may not be the best strategy when the goal is energy efficiency

- The relationship between OEE and energy waste, as well as other forms of energy waste not addressed by OEE

Outlook:

- Defining data requirements for energy optimization in production machines

- Continue to explore the use of SMO for energy efficiency

*Creating a demand-driven system design that supplies only the energy needed to fulfill customer requirements*

# Thank you!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