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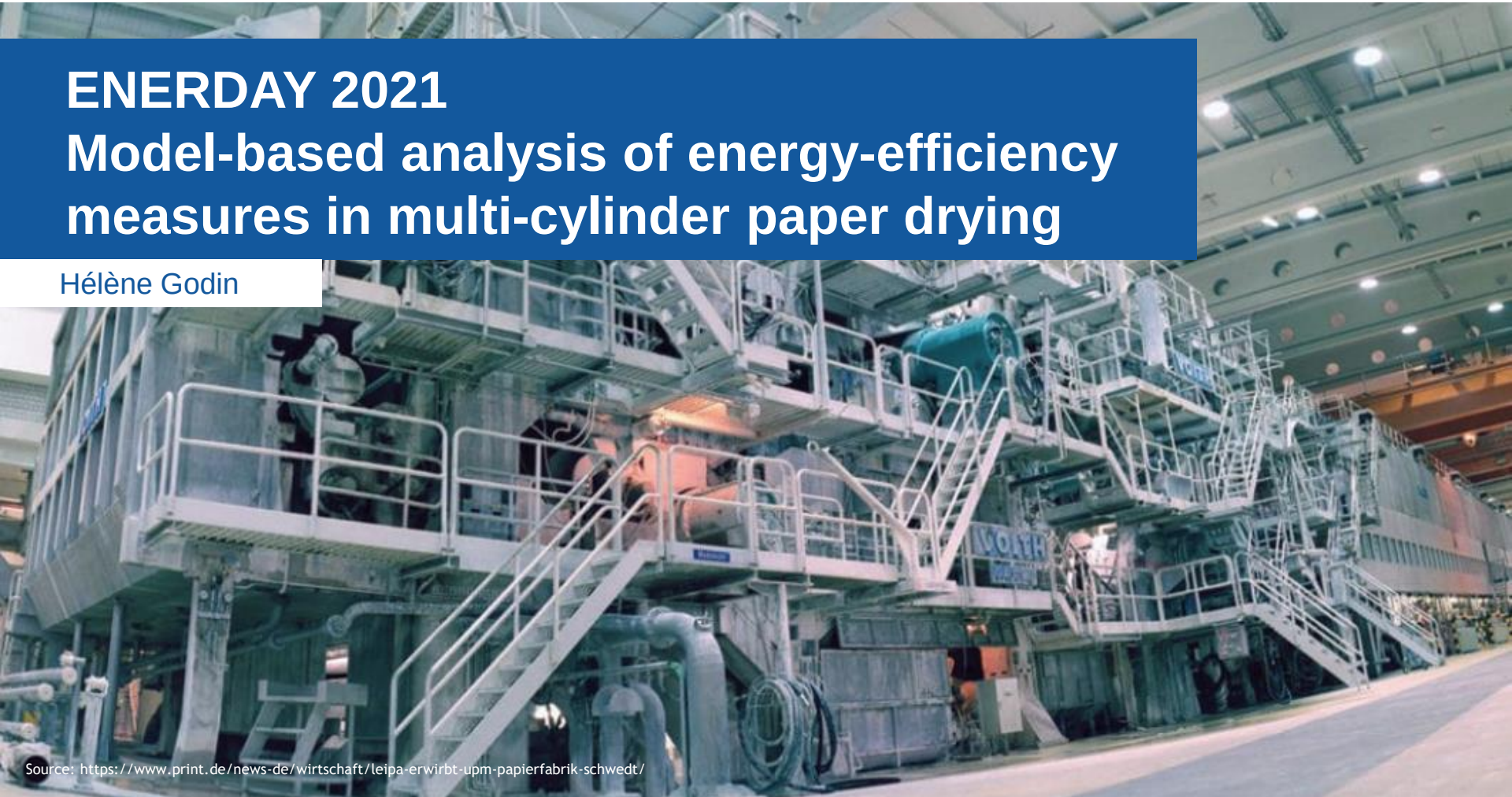
Rationelle Energieanwendung (IER)

GREES
Graduierten- und Forschungsschule
Effiziente Energienutzung Stuttgart

# ENERDAY 2021
# Model-based analysis of energy-efficiency measures in multi-cylinder paper drying

Hélène Godin

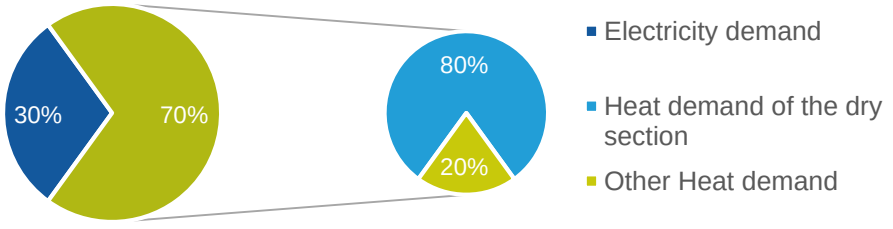


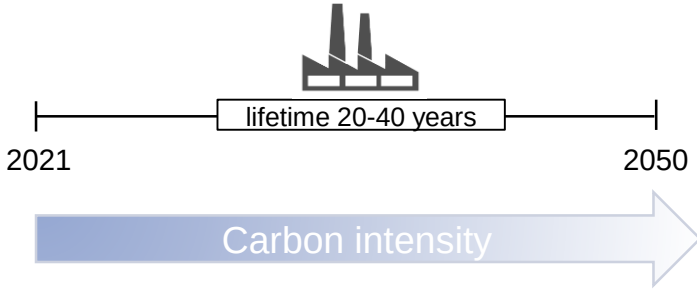
Source: https://www.print.de/news-de/wirtschaft/leipa-erwirbt-upm-papierfabrik-schwedt/

# Motivation and Objectives

- The **Pulp & Paper** branch is the **4th biggest industrial energy consumer** (IEA 2020).

Typical final energy use distribution in paper making

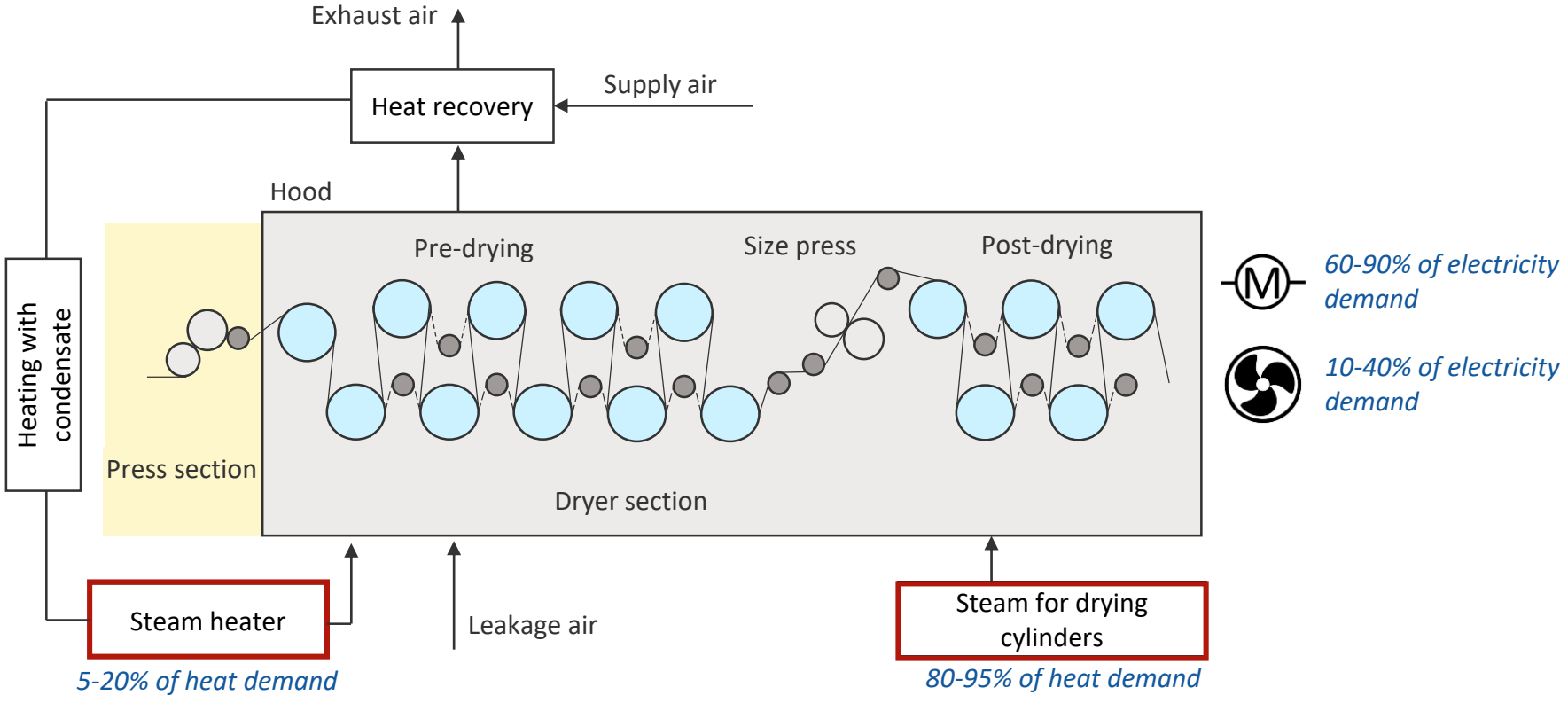



- Energy efficiency along with material efficiency and fuel switch constitue the main levers for decarbonizing paper making.
- Development of a **framework for the energy assessment of a combination of structural energy-efficiency improvements in multi-cylinder paper drying.**

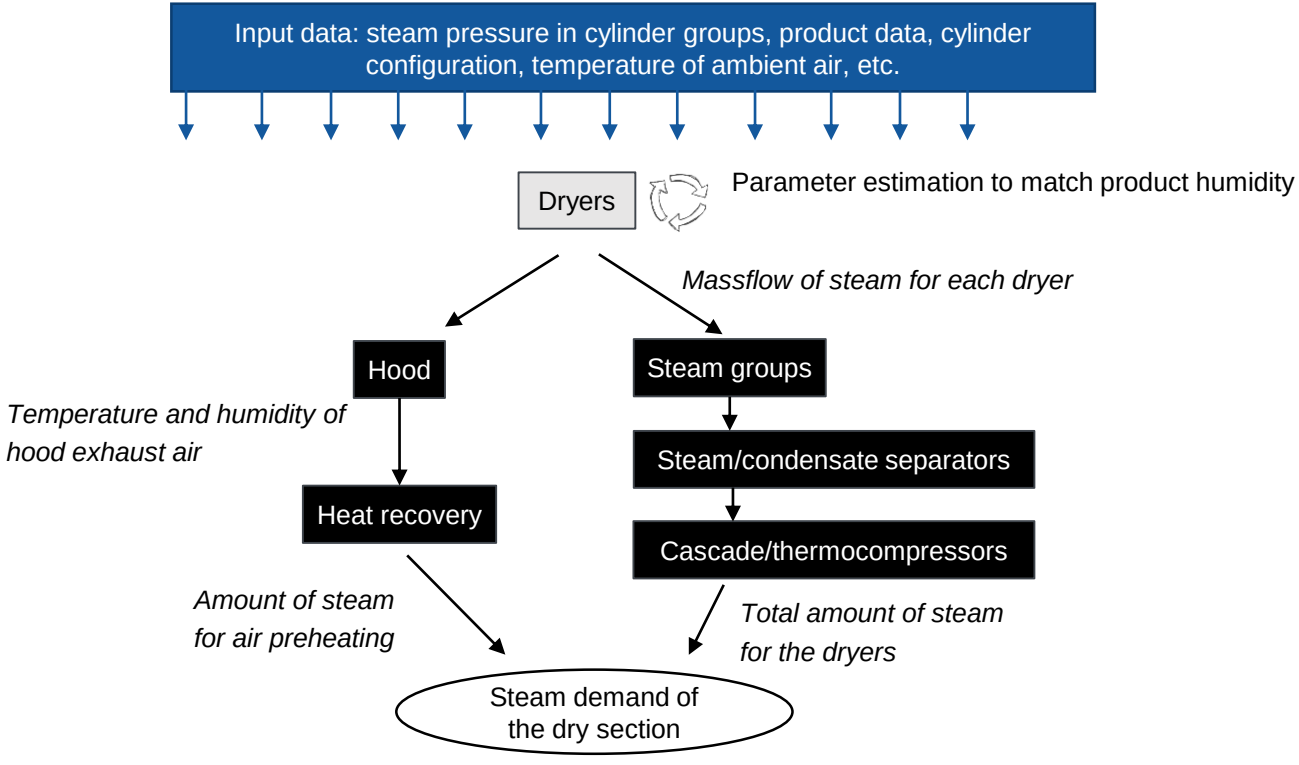
[1] estimations baed on Suhr et al (2015), Bajpai (2016) and Laurijssen (2010)

# Model


Exhaust air
Heat recovery
Supply air
Hood
Heating with condensate
Pre-drying
Size press
Post-drying
Press section
Dryer section
Steam heater
Leakage air
Steam for drying cylinders
5-20% of heat demand
80-95% of heat demand
60-90% of electricity demand
10-40% of electricity demand

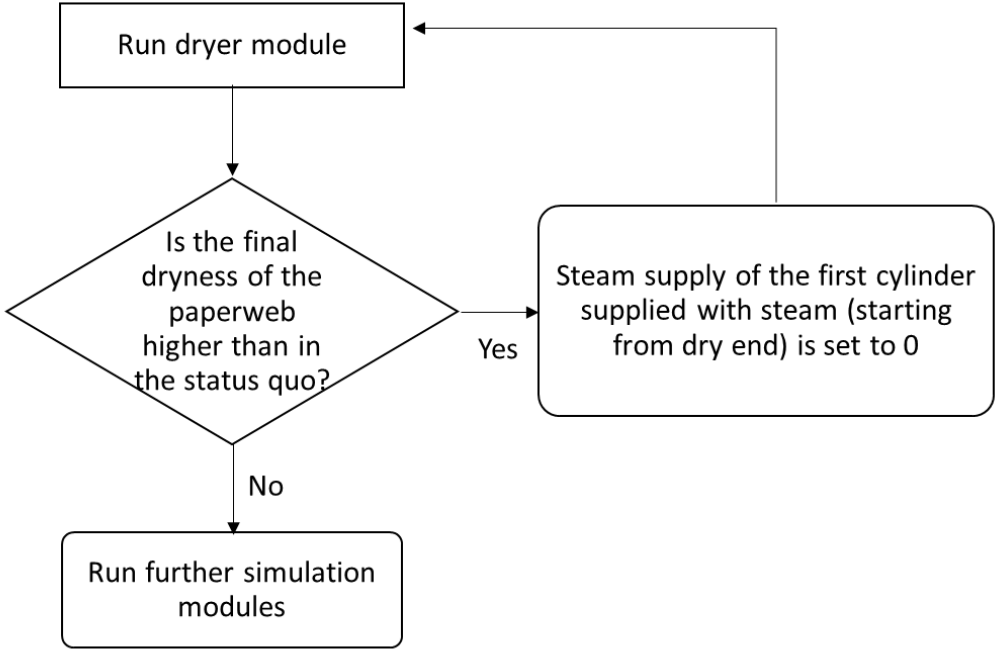
# Model

## Overview



# Model

## Measure evaluation: calculation procedure

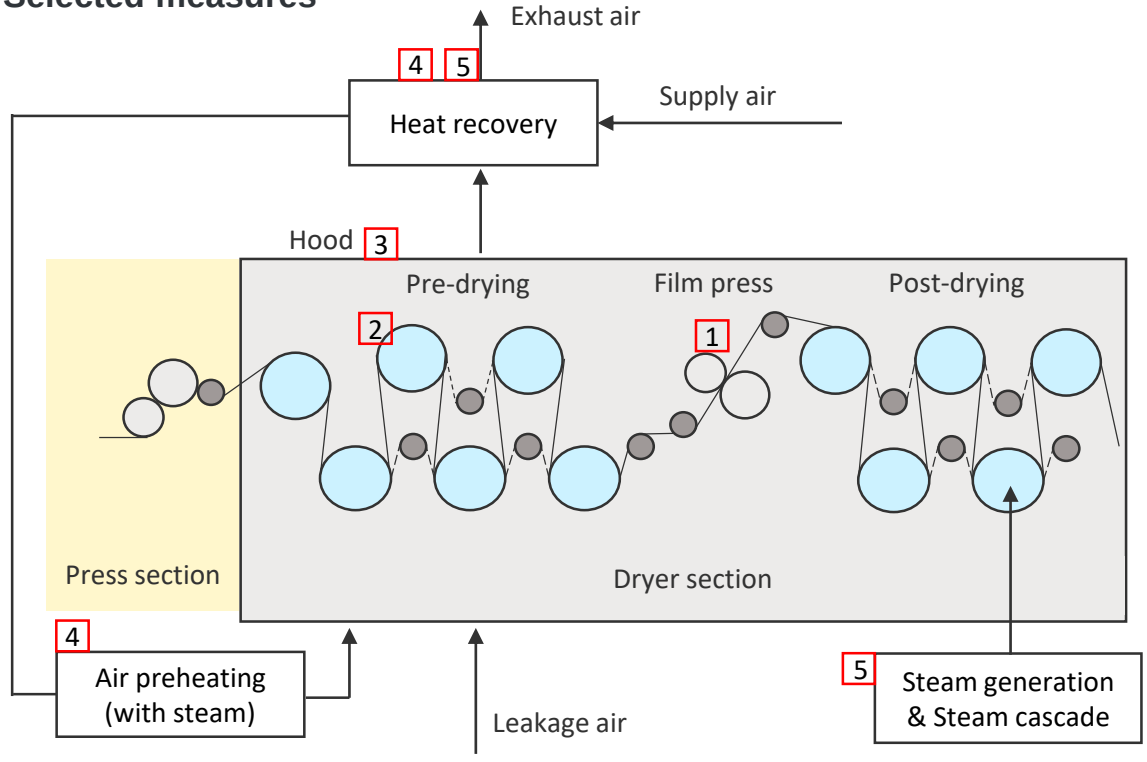


# Case Study

- The developed framework was applied to the dry section of a paper mill producing corrugated board in the North of Germany.
- The current steam consumption is equal to 1,4 t steam/t paper (39 MWth)
- The current hood is very inefficient (open, low dew point, high leakage air ratio)

# Case Study

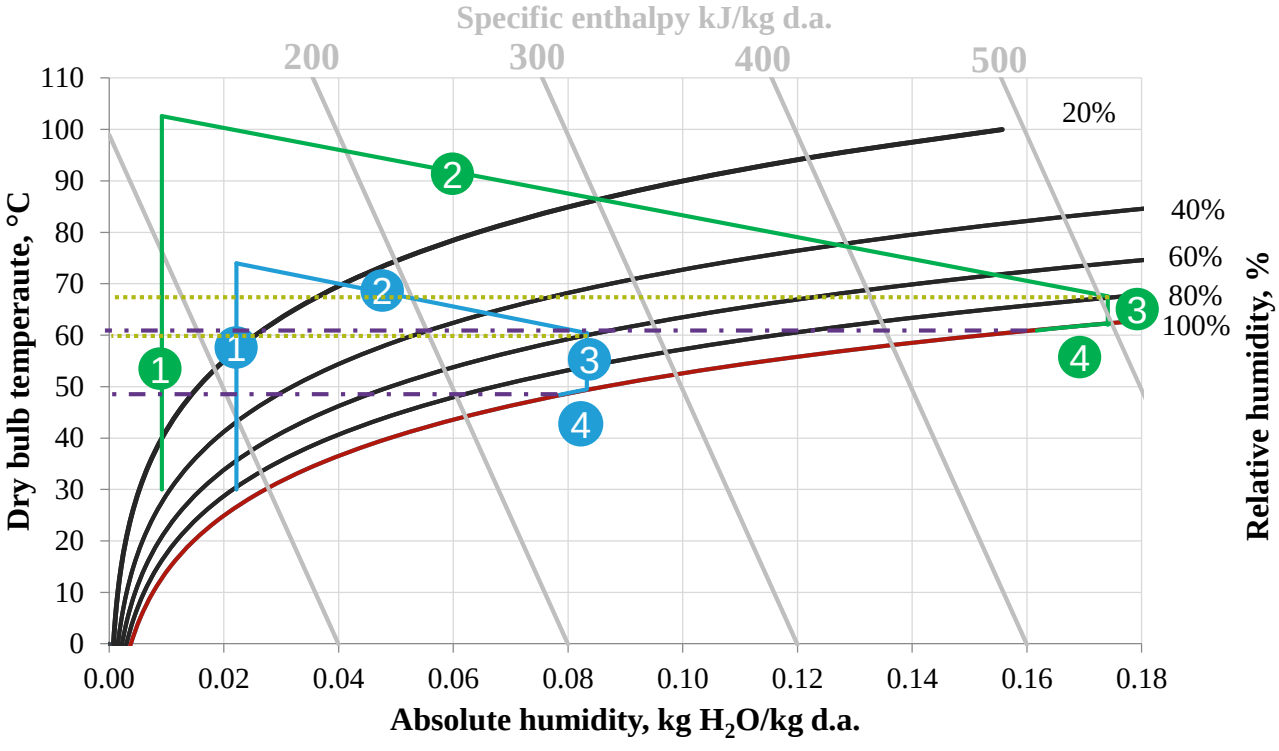
## Selected measures




| | Measure |
|---|---|
| 1 | Curtain Sizing |
| 2 | Replacement of cast iron cylinders with steel cylinders |
| 3 | Enclosed hood with higher dew point |
| 4 | Heat Pump to preheat air |
| 5 | Heat Pump to generate steam |

# Case Study

## Hood dew point & heat recovery



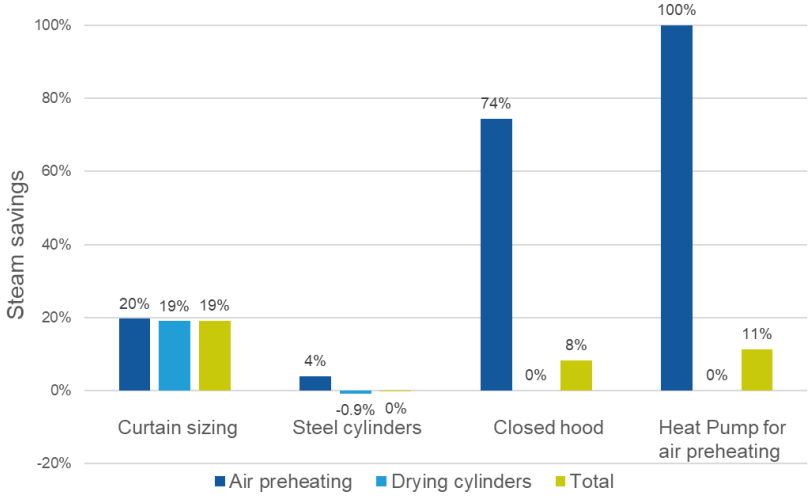

1. Air heating
2. Drying
3. Cooling until dew point (heat recovery)
4. Cooling along saturation curve (heat recovery)

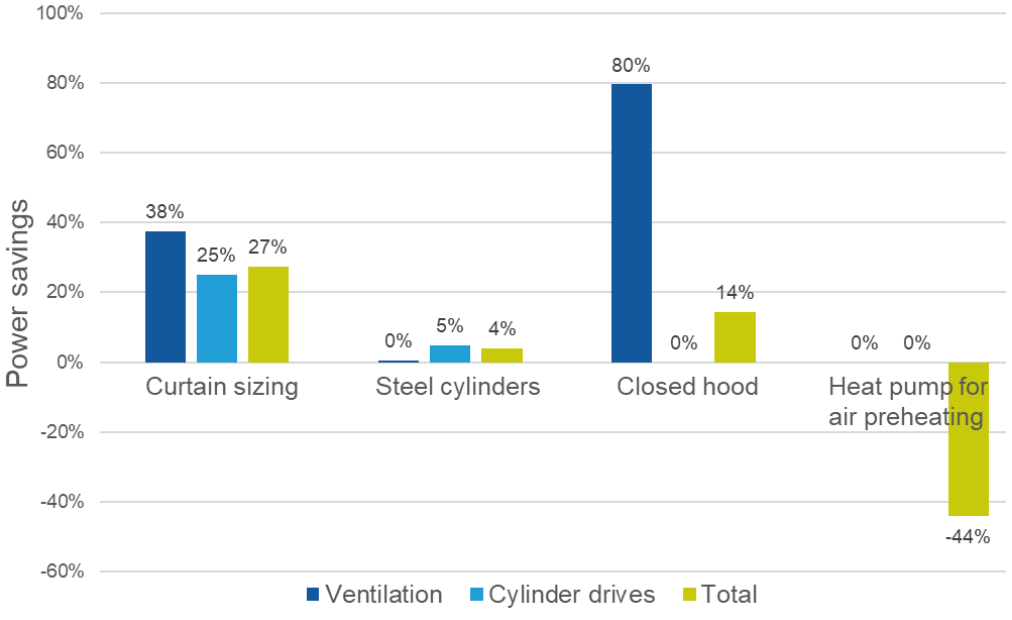
Open canopy hood with dew point 50°C

Closed hood with dew point 63°C

# Case Study

## Effect of individual measures on the steam and electricity demand of the dry section

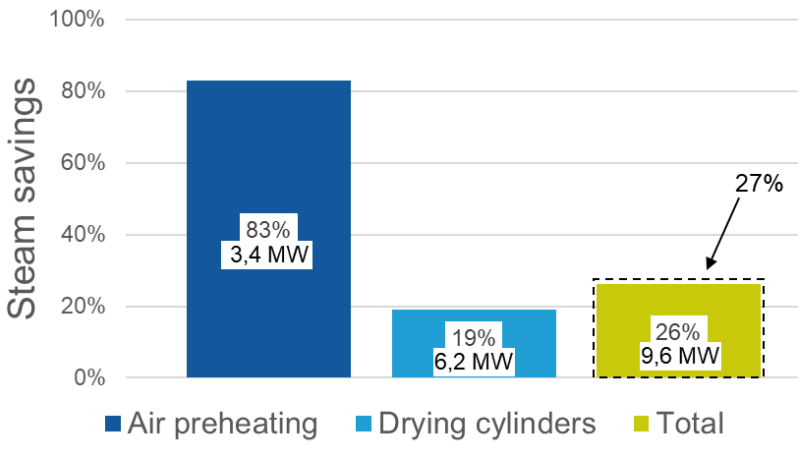


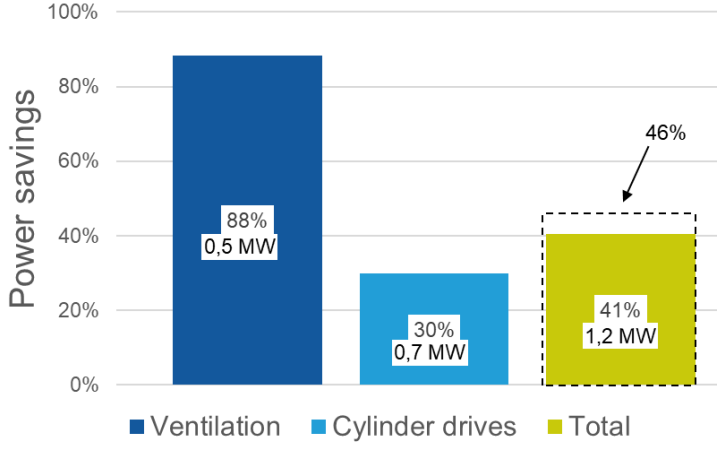



# Case Study

## Cumulated savings for all measures (without heat pump)

sum of the individual measure's effect



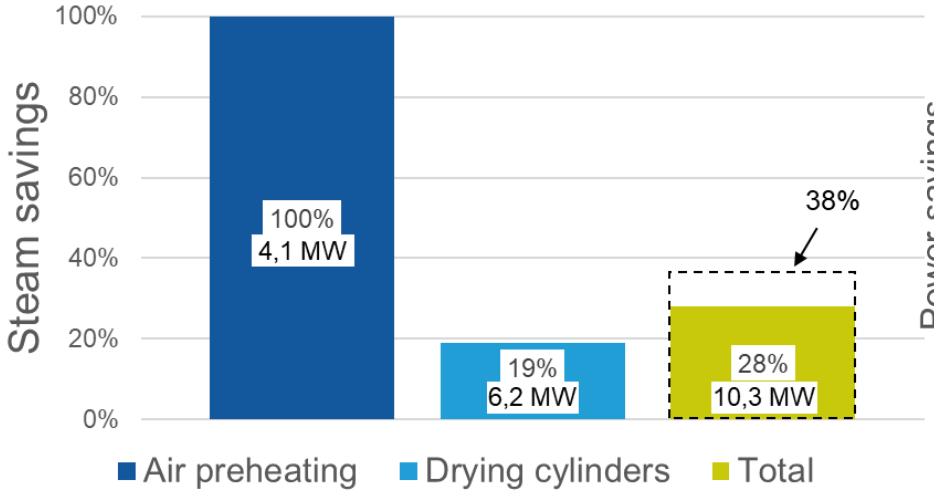



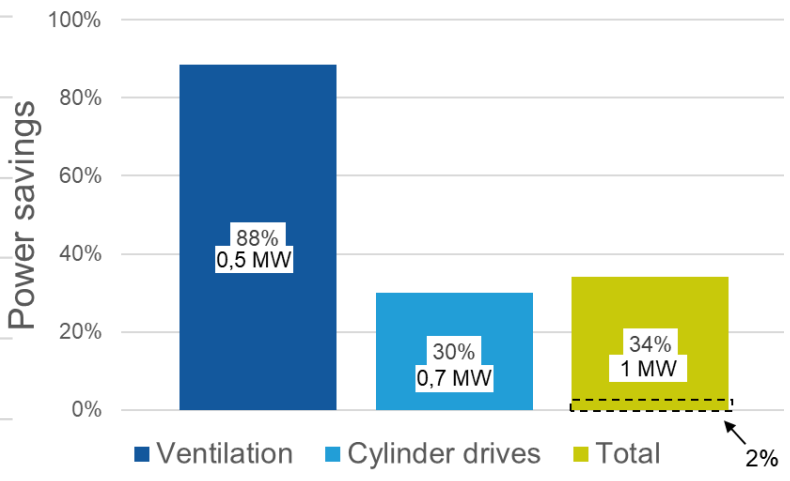

- The calculated savings differ from the sum of each individual measure's effect.
  → in particular because of interactions between the measures on the air massflows in the hood

# Case Study

**Cumulated savings for all measures (heat pump for air preheating)**

sum of the individual measure's effect

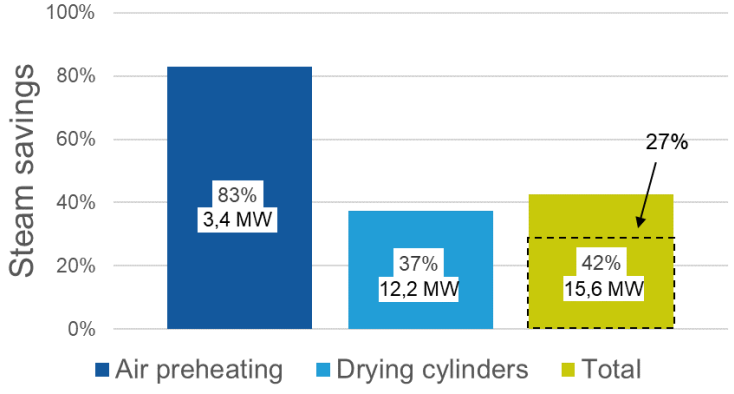


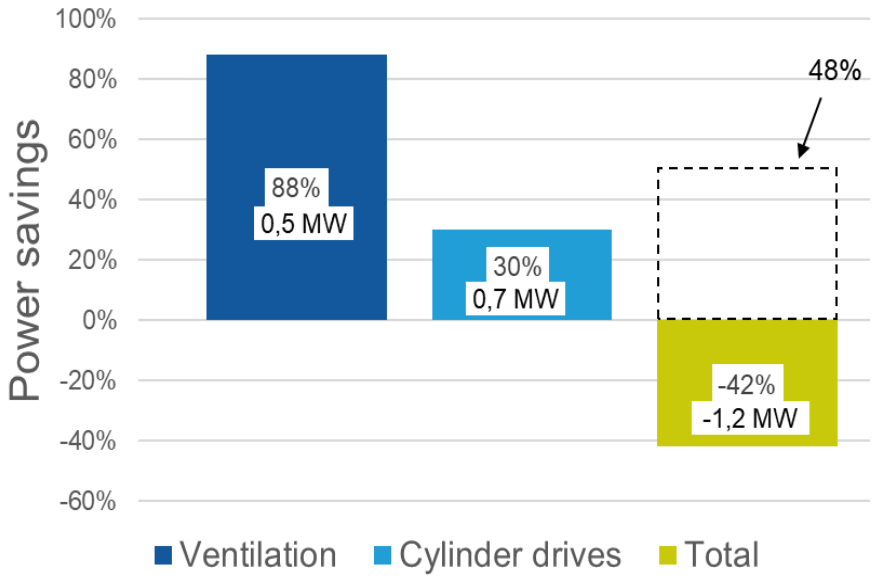



# Case Study

## Cumulated savings for all measures (heat pump for steam generation)

sum of the individual measure's effect



# Conclusion

- A framework for the assessment of energy-efficiency measures in multi-cylinder paper drying was developed and applied to a German paper mill producing corrugated paper.
- For the identified measures, the assessed steam and power savings are respectively:
  - 9,6 $MW_{th}$ (26%) and 1,2 $MW_{el}$ (41%) without heat pump
  - 10,3 $MW_{th}$ (28%) and 1 $MW_{el}$ (34%) when a heat pump is used for air preheating
  - 15,6 $MW_{th}$ (42%) and -1,2 $MW_{el}$ (-42%) when a heat pump is used for steam generation
- When assessing the effect of several measures their effect should be considered simultaneously to avoid high errors.

# Vielen Dank!

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# Literature


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# Literature review and Objectives

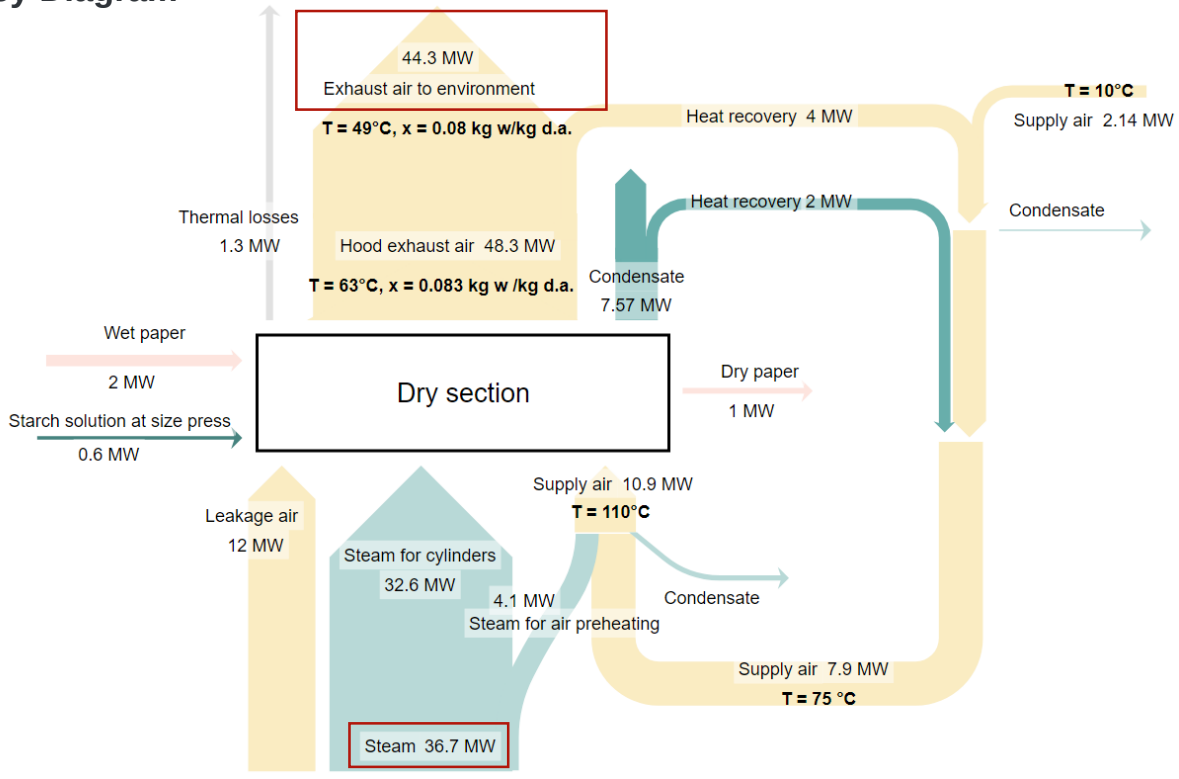
| Site-specific analysis of energy-efficiency measures in multi-cylinder paper drying | Measures | | | | | |
|---|---|---|---|---|---|---|
| | Object of measure(s) | | Type | | | |
| | Heat demand | Heat recovery | Operational | Structural | More than 1 measure? | Measure interactions |
| Yin et al 2016 | x | | | x | | |
| Schneeberger 2014 | x | x | x | x | x | |
| Ghodbanan et al 2016 | x | | x | | | |
| Kong et al. 2016 | x | x | x | | x | |
| Li et al. 2011 | x | | x | | | |
| Chen et al. 2016 | x | | x | | | |
| Sivill and Ahtila 2009 | | x | x | x | | |
| Treppe et al 2012 | | x | | x | x | |
| Lindell and Stenström 2006 | x | x | | x | | |

- Past studies focus on operational improvements, analyse the effect of only one measure and/or don't consider the combined effect of retrofit measures at different levels.

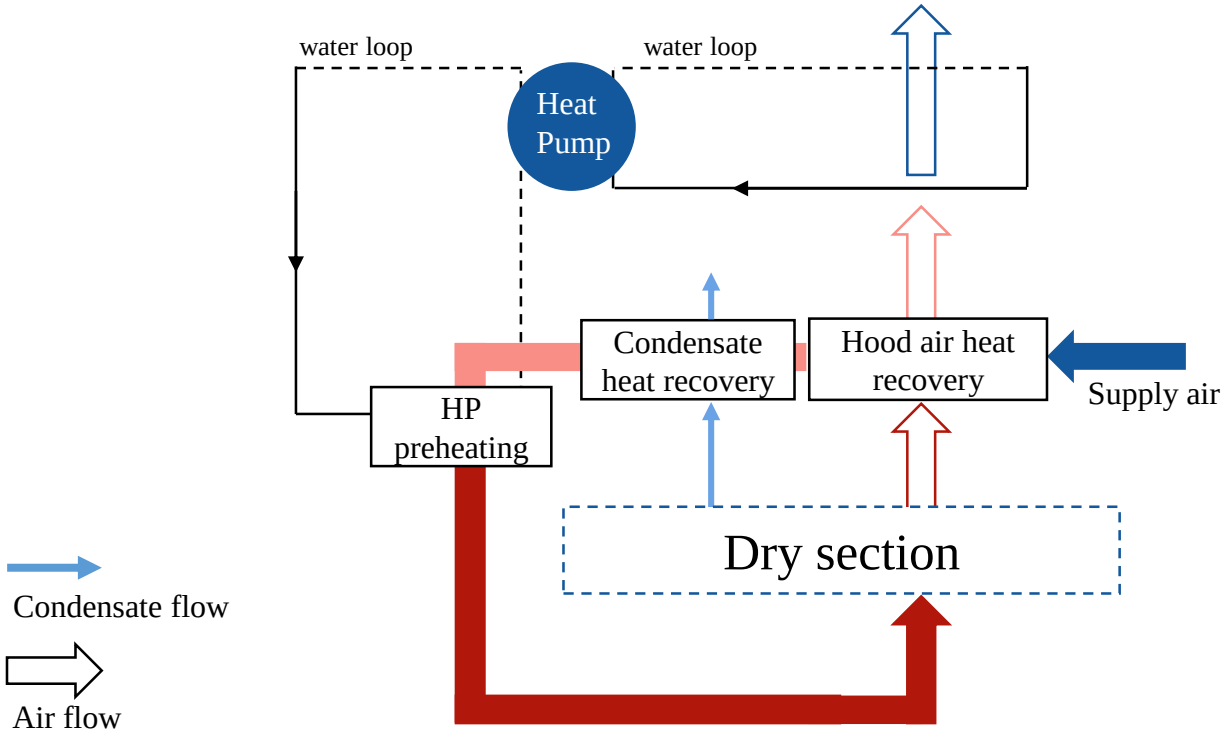
- Development of a **framework for the energy assessment of a combination of structural energy-efficiency improvements in multi-cylinder paper drying.**

# Case Study

## Status Quo – Sankey Diagram



# Heat pump for air preheating



# Heat pump for steam generation