



INTRODUCTION OF THE DRYING TOOLBOX: THEORETICAL POTENTIAL FOR ENERGY SAVINGS IN DRYING PROCESSES

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OVERVIEW IEA HPT ANNEX 59 “HEAT PUMPS FOR DRYING”

- Objective: evaluate potentials on energy savings in drying processes
- Scope: Heat pumps in dryers integrated in industrial, commercial and household applications (white goods)
- Duration 2022 - 2025
- Participants: AT, CH, CN, DE, NO, SE, US

Key message:

**“heat pumps are
relevant for
drying”**

OVERVIEW ANNEX 59

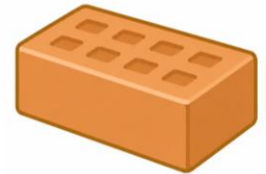
„HEAT PUMPS FOR DRYING“

Tasks

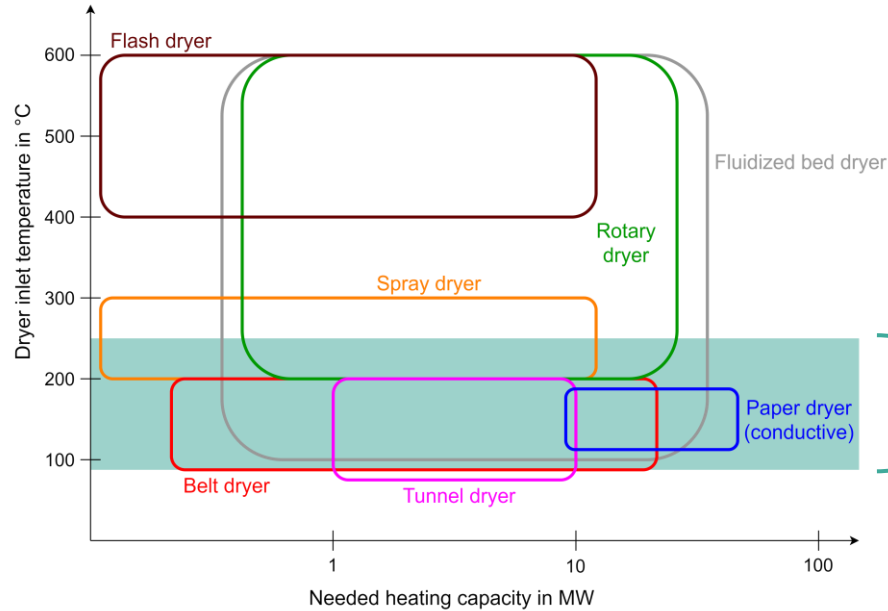
- Task 1: **Overview** on **drying processes** (temperature, capacity, relevance for energy system, suitability for heat pumps)
- Task 2: Assessment of **theoretical optimum** for important/relevant drying processes (KPIs, references for labelling)
- Task 3: **Monitoring** of different dryers with integrated heat pumps
- Task 4: **Overview** on the **market** for
 - household, (e.g. white goods, tumble dryers)
 - commercial (e.g. finisher) and
 - industrial dryers (e.g flow stream dryer)
- Task 5: **Dissemination** of results

WHY USING HEAT PUMPS FOR DRYING ?

- Drying is energy intensive
- Needed temperature range often 100-200°C
- Moist exhaust air as a source
- Different industries:
 - Food
 - Animal feed
 - Ceramics
 - Paper
 - Chemicals



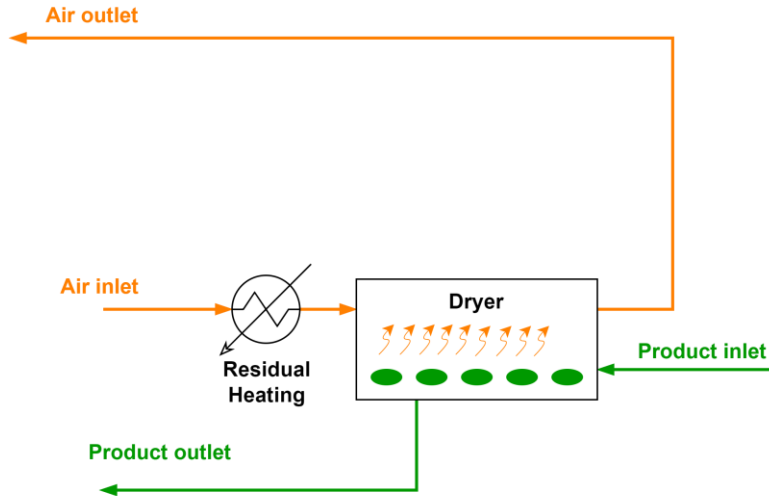
DRYER TECHNOLOGIES



Temperature range suitable for market available heat pumps

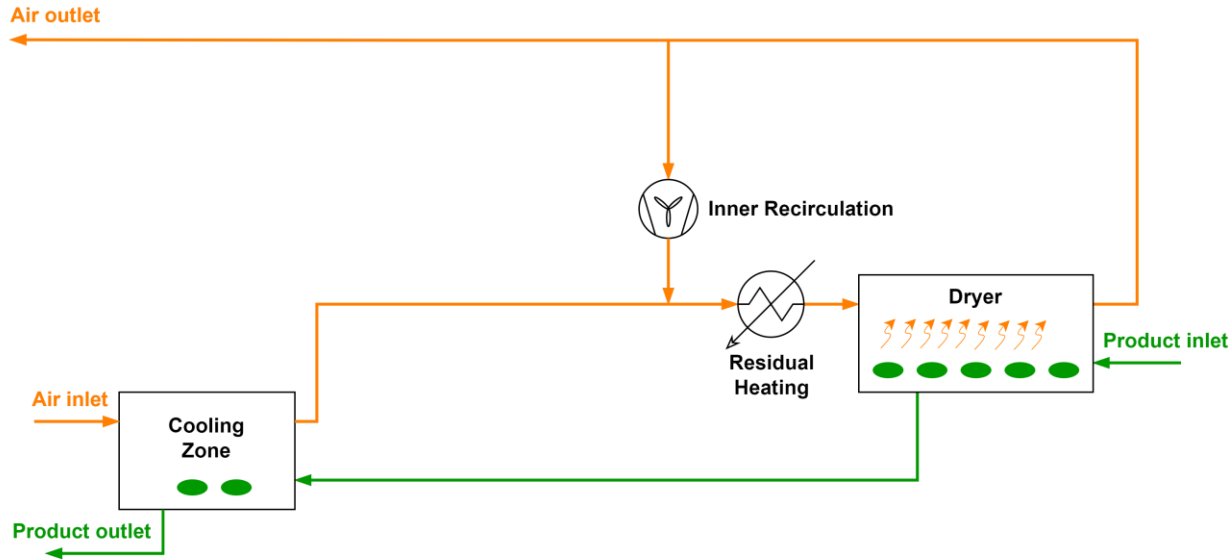
Higher residence time - lower drying temperature - beneficial for heat pumps

HOW TO INCREASE ENERGY EFFICIENCY REFERENCE



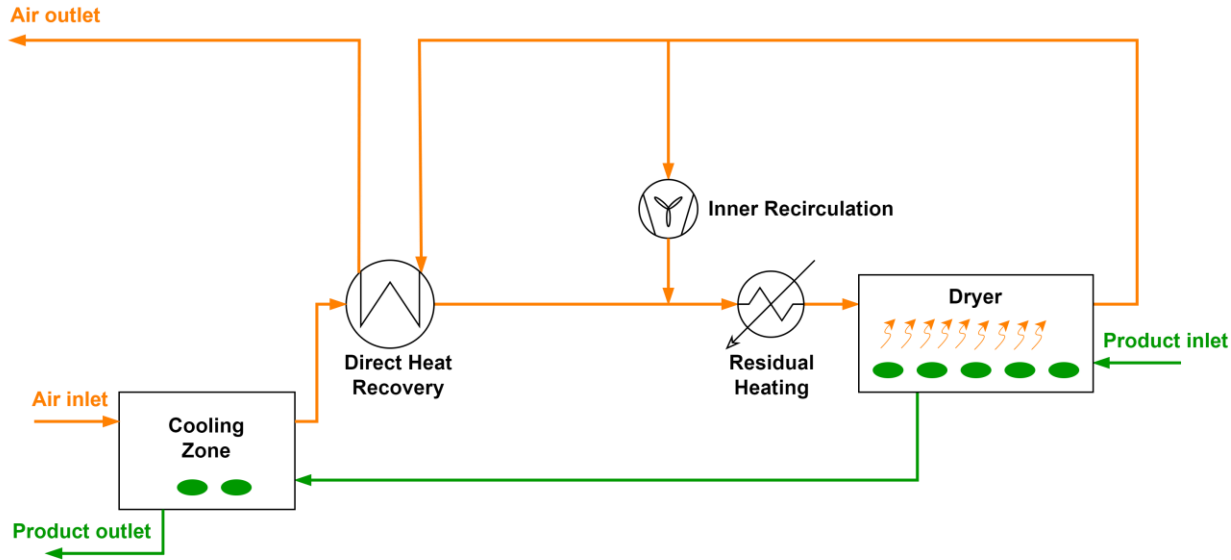
- Basic drying process
- No heat recovery measures
- Residual heating using natural gas or electricity
- Air as a drying agent most common

HOW TO INCREASE ENERGY EFFICIENCY PRODUCT COOLER AND RECIRCULATION



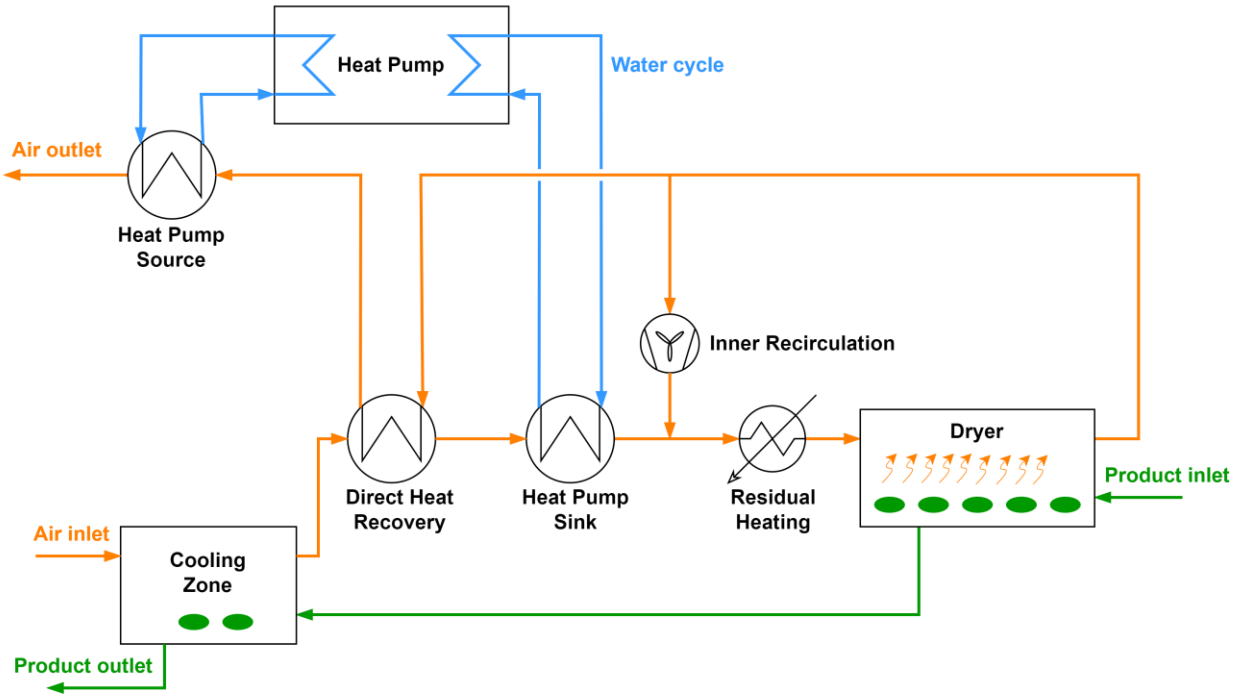
- Recirculation of drying agent
- Increase of moisture content of exhaust
- Decrease of fresh air mass flow
- Recover sensible heat of the product

HOW TO INCREASE ENERGY EFFICIENCY DIRECT HEAT RECOVERY (DHR)



- Preheating of fresh air via heat exchange with exhaust air
- Recover sensible heat of exhaust air
- Large potential for drying processes, which require high exhaust temperatures

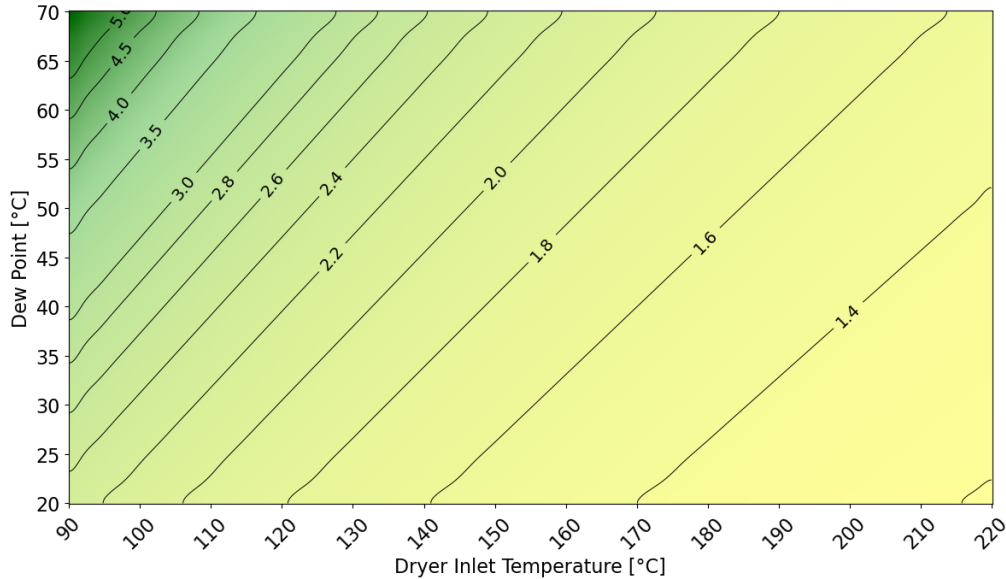
HOW TO INCREASE ENERGY EFFICIENCY HEAT PUMP



- Mostly condensation of moisture in exhaust air needed for sufficient energy supply at source side
- Dew point decisive for source temperature
- COP improved by higher moisture of exhaust

HEAT PUMPS IN DRYING PROCESSES

ATTAINABLE COP



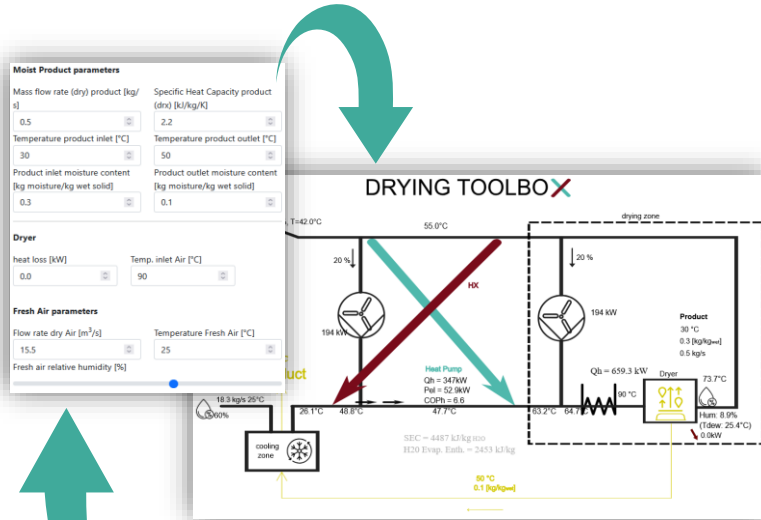
$$COP_{Carnot} = \frac{T_H}{T_H - T_C}$$

$$\eta_{Carnot} = \frac{COP}{COP_{Carnot}} = 0.5$$

T_H is 5K higher than dryer inlet temperature

T_C is 5K lower than dew point

POTENTIAL ESTIMATION – DRYING TOOLBOX



- Online tool for analyzing heat recovery options
 - Quantification of potential energy savings
 - Sankey diagram
- Underlying base model in Dymola/Modelica
 - Material and energy balances
 - Dryer itself must be known
 - No kinetics
- Input panel and graphic interface

Give it a try!

<https://drying-toolbox.ait.ac.at/>



DRYING TOOLBOX - INPUT

Moist Product parameters

Mass flow rate (dry) product
[kg/s]

Specific Heat Capacity
product (d_{rx}) [kJ/kg/K]

Temperature product inlet
[°C]

Temperature product outlet
[°C]

Product inlet moisture
content [kg moisture/kg wet
solid]

Product outlet moisture
content [kg moisture/kg wet
solid]

Dryer

heat loss [kW]

Temp. inlet Air [°C]

Fresh Air parameters

Flow rate dry Air [m³/s]

Temperature Fresh Air [°C]

Inlet air humidity 0%

Assumptions made for this example

- 2nd law efficiency of heat pump: 0.5
- ΔT for direct heat recovery: 20°C
- Product cooler: Product cooled to 35°
- Fresh air 25°C, completely dry
- No thermal losses

DRYING TOOLBOX - OUTPUT

Energy consumption

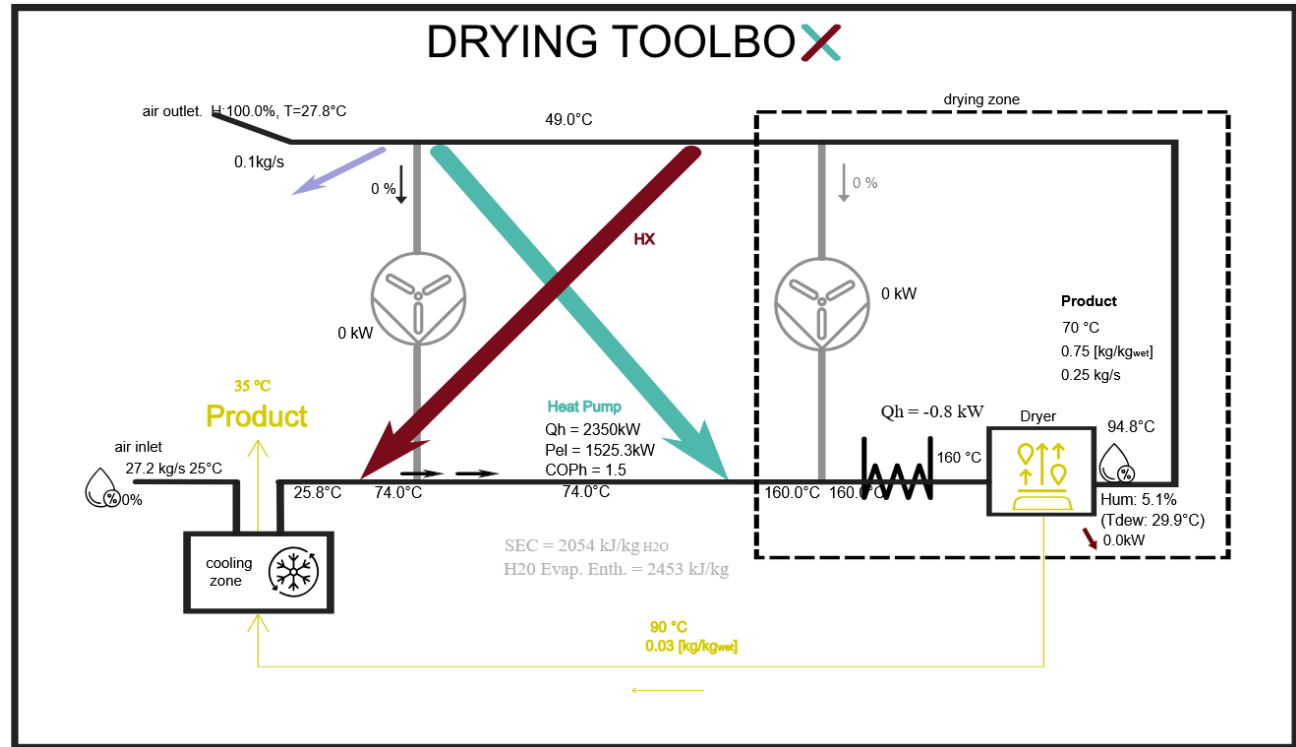
- SEC
- Residual heating
- Fans

Exhaust air

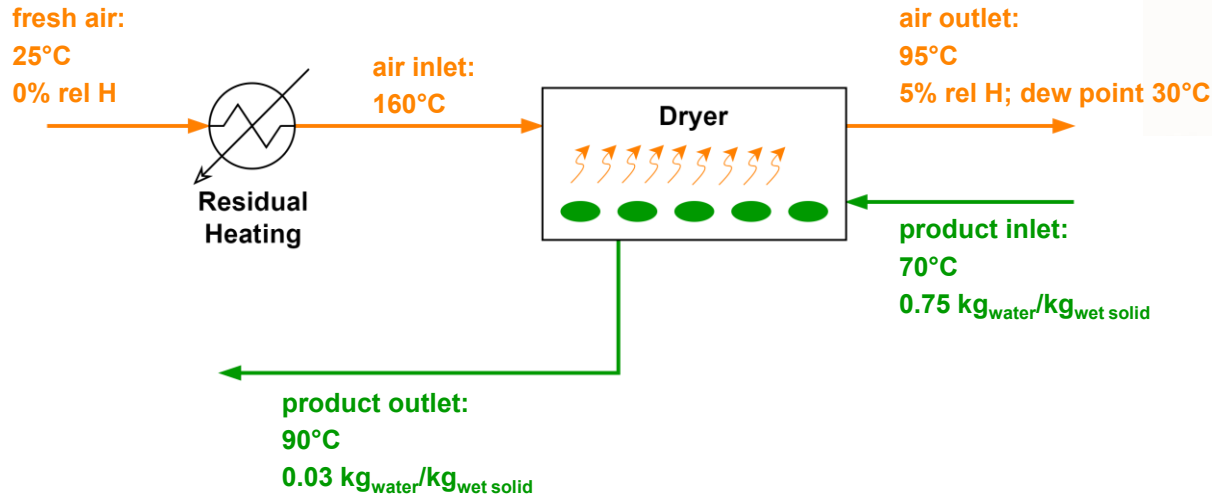
- Temperature
- Humidity

Heat pump

- Heating capacity
- Electricity consumption
- COP

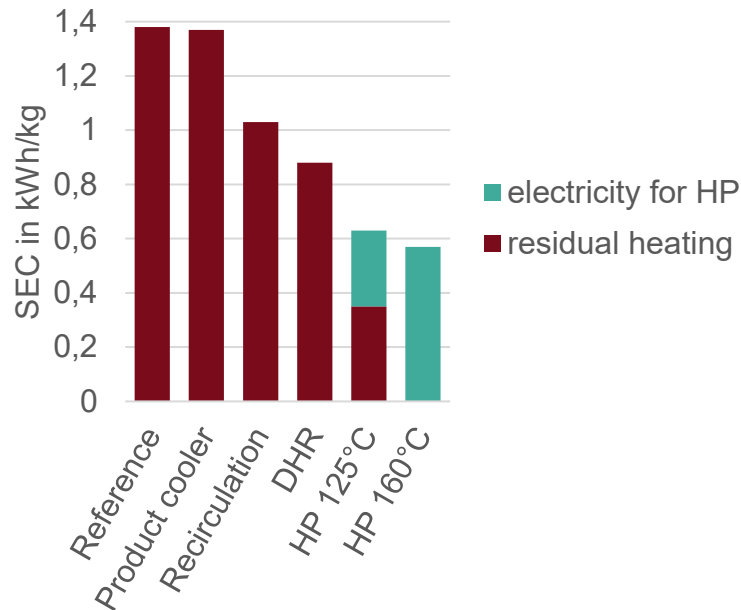


SPRAY DRYER FOR STARCH DERIVATE



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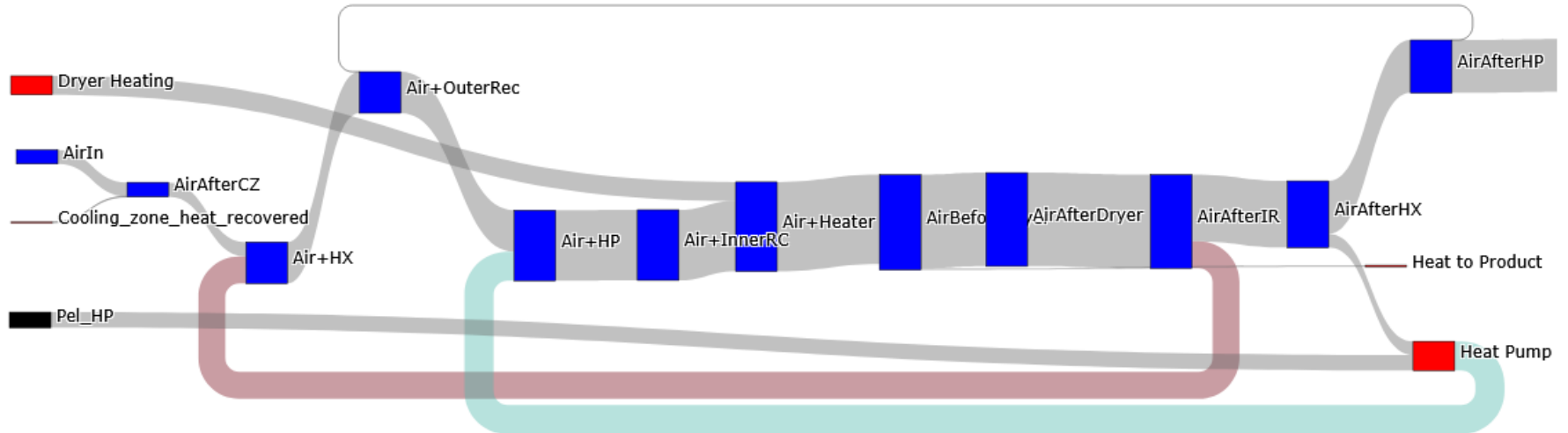
$$\text{SEC} = \frac{\text{energy demand}}{\text{mass of evaporated water}}$$



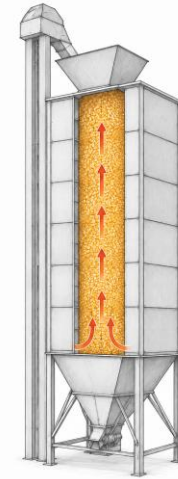
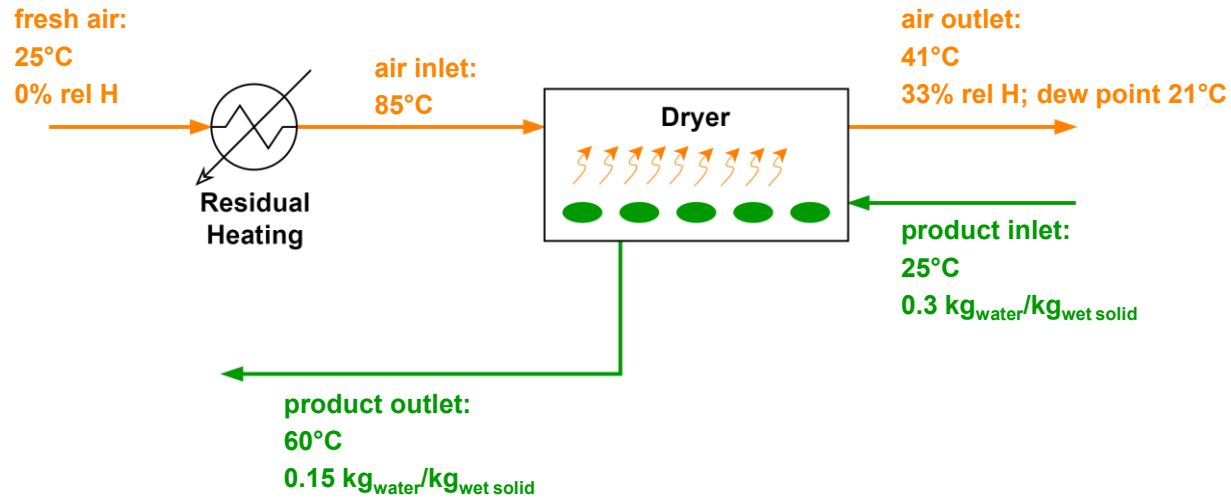
- Exhaust air with high temperature and low moisture
 - ➔ Potential for energy savings by recirculation or DHR
- Heat pump supplying 160°C
 - ➔ Fully electrified
 - ➔ Low COP (COP ~ 1.5)
- Heat pump supplying 125°C
 - ➔ Residual heating still needed
 - ➔ Better COP

SPRAY DRYER FOR STARCH DERIVATE

Case “Heat pump 125°C”

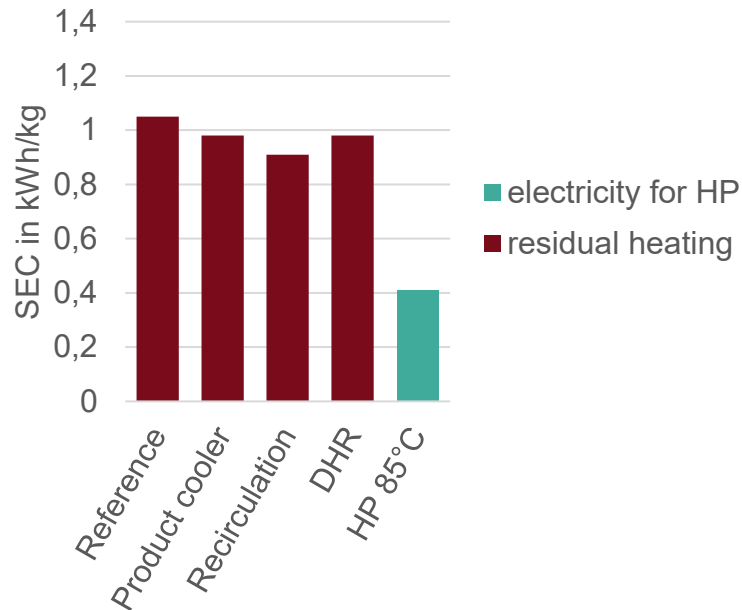


TOWER DRYER FOR CORN



TOWER DRYER FOR CORN

$$\text{SEC} = \frac{\text{energy demand}}{\text{mass of evaporated water}}$$



- DHR not feasible due to low exhaust air temperature
- Lower drying temperature beneficial for heat pump
→ COP ~ 2.4

CONCLUSION

- High potential for energy savings in drying processes
 - Product cooler, recirculation, direct heat recovery → low to middle improvement
 - Heat pump → savings up to 61%, inherent decarbonization via green electricity

Investigate your drying
process using the
Drying Toolbox

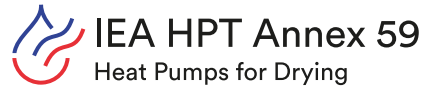


<https://drying-toolbox.ait.ac.at/>

Find more information
on the homepage
IEA HPT Project 59



<https://heatpumpingtechnologies.org/project59/>



THANK YOU!

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