# Project details

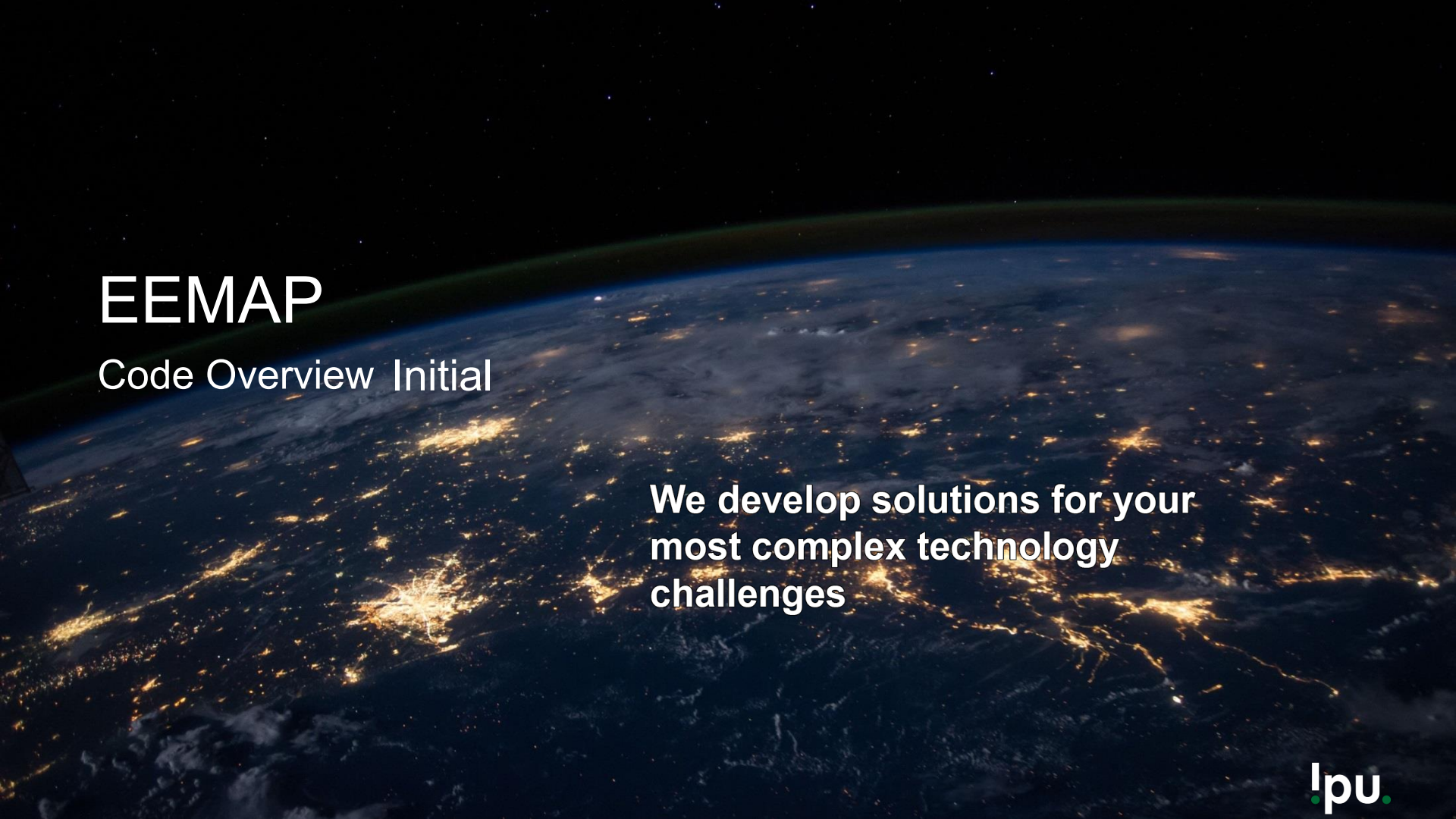
| | |
|---|---|
| **Project title** | Efficient Energy Mapping and Analysis for Optimization and Green Transition of Industrial Processes (EEMAP) |
| **File no.** | 64022-1073 |
| **Name of the funding scheme** | EUDP 2022-I |
| **Project managing company / institution** | Viegand Maagøe |
| **CVR number** (central business register) | 29688834 |
| **Project partners** | Viegand Maagøe, Danmarks Tekniske Universitet, IPU. |
| **Submission date** | 01 November 2024 |

# 8. Appendices

1. Code Doc_initial.pdf
2. Code Overview_2024-03-07.pdf
3. Defining the components_2023-10-23.pdf
4. Development Status 2_2022-01-10.pdf
5. Development Status 3_2024-03-07.pdf
6. Development status and evaluation of Tespy_2022-01-10.pdf
7. Documentation on calculations.pdf
8. ECOS conference_poster
9. ECOS paper - EEMAP methodology.pdf
10. Feedback session exercise 2 and 3_2024-02-29.pdf
11. Mapping state-of-the-art.pdf
12. Project status to EUDP_2024-03.pdf
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14. Project status with companies_2024-04-18.pdf
15. Screeninglist_idea catelogue.pdf
16. Screeningliste - idekatalog 00c fmh evaluated workshop.pdf
17. Simplifying the component structure_.pdf
18. Sneak Peek Party_General Presentation.pdf
19. Sneak Peek Party_Technical Presentation_2024-06-18_v2.pdf
20. Software Architecture Considerations_2023-02-28.pdf
21. User Guide to the tool_august2024.pdf

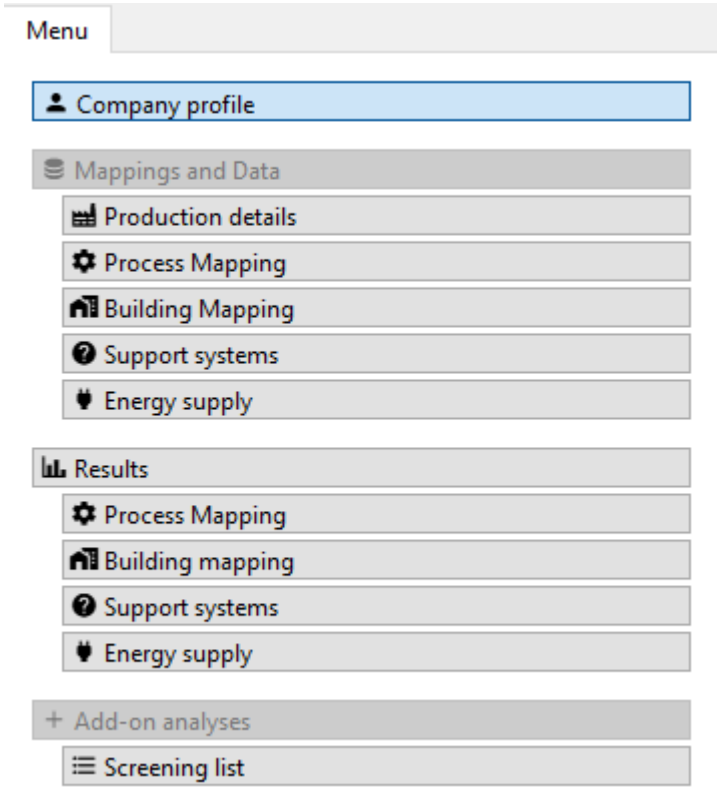
**Workshop presentations:**

22. Workshop 1 @FFSkagen_2022-10-10.pdf
23. Workshop 2 @Ovodan_2023-02-28.pdf
24. Workshop 3 @Avista_2023-08-29.pdf
25. Workshop 3_DTU @Avista_2023_08_29
26. Workshop 3_Live demo of the tool_2023-08-29.pdf
27. Workshop 4 @Skjern Paper_2024-05-22.pdf
28. Workshop 4_DTU @Skjern Paper_2024_05_22


EEMAP
Code Overview Initial
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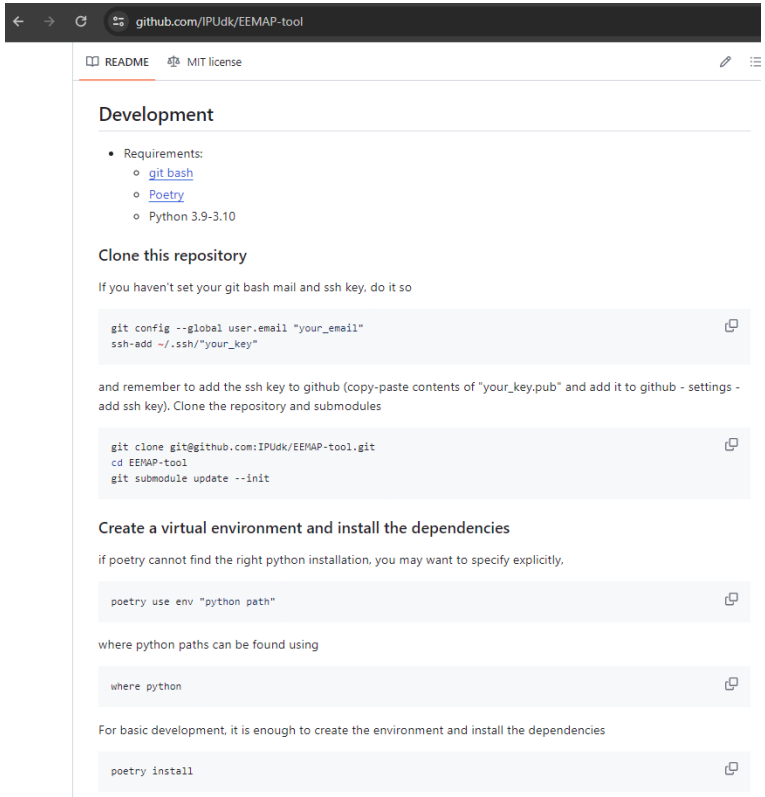
# Outline

- Local development setup
- Main files
  - Company profile
  - Production details
  - Mappings
  - Results
    - Export nodes from nodegraph (json format)
    - Export tespy networks and simulate in parallel
    - Export tespy results (csv format)
- Link between nodes and tespy models



# How to setup local development

Everything explained @
https://github.com/IPUdk/EEMAP-tool



# Main Window

- Path: *src/eemap/ui/MainWindow.py*
- Create and connect the side menu with the different pages.

```python
@Slot(bool)
def on_actionMenu010CompanyProfile_triggered(self, checked):
    if not checked:
        return
    self._checkParentAction(self.sender())
    self.ui.stackedWidget.setCurrentWidget(self.frameMainCompanyProfile)
```

- Connect the data of different pages with signals and slots.
- Define loading and saving of projects.
  - *_load_project()* and *_save_project()*
- Define Undo/Redo stack.

# Production Details

- Production Details tables:
- Path: *src/eemap/ui/FrameMainProductionDetails.py*
- Define data type of each column:

```
@dataclass
class MediaSpecificationTableModelEntry(TableModelEntry):
    mediaName: str = ""
    amount: UnitValueEntry = UnitValueEntry()
    mediaComponents: FloatTableOptions = FloatTableOptions()
    sectionTag: str = ""
    referencePerson: str = ""
    comment: str = ""
```

- Define table model, view, and initialize table:

```
self.table_model_EnergyCarrier = EnergyCarrierTableModel(EnergyCarrierTableModelEntry, self.undo_stack, self.ui._15_groupBoxEnergyCarrier)
self.table_view_EnergyCarrier = TableView()
cur_layout = self.ui._15_groupBoxEnergyCarrier.layout()
cur_dummy = self.ui.widgetTableEnergyCarrierDummy
cur_model = self.table_model_EnergyCarrier
cur_view  = self.table_view_EnergyCarrier
cur_name  = "EnergyCarrierTable"
self.table_init(cur_layout, cur_dummy, cur_model, cur_view, cur_name)
```

# Mappings

- Creating new nodes:
  - Path: *src/eemap/ui/nodes/**
  - Add node to *__init__.py* to include it in the respective mapping
  - Ex:

```python
class Source(BaseComponent):
    """
    A node class representing a Source.
    """
    NODE_NAME = "Source"

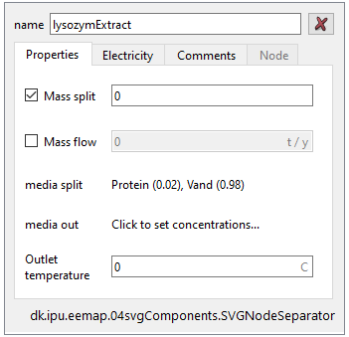
    def __init__(self, qgraphics_item=None):
        super().__init__(qgraphics_item)
        self.add_output("out1")

        # put pressure first, so that it can be set to None, if State is gas
        self.create_component_property("pout", NumPropertyEdit, level=self.Level.NoLevelFixedPar, connection_name='out1', tespy_name='p', value = [1,1.0,""], unit = "p_unit")

        self.create_component_property("m", NumPropertyEdit, connection_name='out1', display_name="Mass flow", unit = "m_unit")
        self.create_component_property("T", NumPropertyEditWithState, connection_name='out1', display_name="Temperature", unit = "T_unit")
        self.create_component_property("media", FloatTablePropertyEdit, connection_name='out1', tespy_name="fluid", display_name="Media")
```

# Mappings

- Property widgets:
  - Path: *src/eemap/ui/widgets/properties_widgets.py*
  - Define the property's widget in the property bin




  - Methods:
    - *load_property()* → Turn the property value into Tespy's format
    - *from_tespy()* → Update the property value from Tespy's results
    - *media_update()* → Update property with data from the Media Definition table
    - *consumption_update()* → Update property with data from the Media Consumption table
    - *assignable_energy_carrier()* → Update property with data from the Energy Carrier table

# Results

- Path: *src/ui/Results.py* and *src/ui/ResultsMapping.py*
- Results come from the mapping's signal *results_ready*, ex:

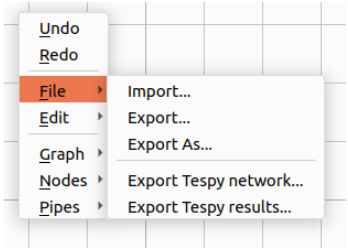
```
self.frameProcessMapping.results_ready.connect(self.resultsTables._on_process_mapping_results_ready)
self.frameProcessMapping.results_ready.connect(self.resultsProcessMappingResults._on_process_mapping_results_ready)
```

  - The signal returns a dictionary with Tespy's results and a list with the mapping's nodes
    - Tespy's results is a series of Pandas DataFrames with the calculation results
    - The nodes contain their input and calculated property values

```
# All node properties
node.properties()['custom']
# Get a specific property
node.get_property('Q')
```

# Results

- Exporting results:
  - After running the calculation on the process mapping, you can export the results as csv files.



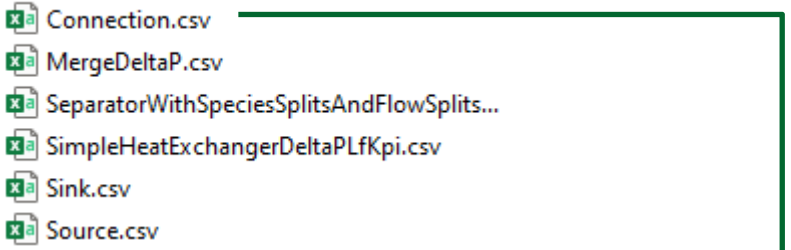

  - You can also export the generated Tespy network and run it in a python script (outside the software)
    - Path: *design\run-exported-design.py*

```
from tespy.networks import load_network
import logging
logging.basicConfig(level=logging.DEBUG)

nw = load_network("design/design")
nw.solve("design")

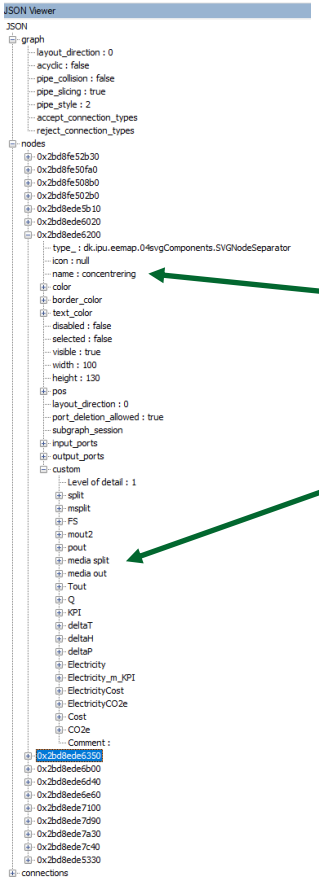
nw.print_results()
print(nw.results['Connection'])
```

# Results (csv format)




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | m | m_unit | v | v_unit | p | p_unit | h | h_unit | T | T_unit | Td_bp | Td_bp_un | vol | vol_unit | x | x_unit | s | s_unit | FoodProte | Water |
| 2 | Source-TankCooler | 6755 | t / y | 0.000209 | m3 / s | 1 | bar | 55.02123 | kJ / kg | 15 | C | -84.6059 | C | 0.000974 | m3 / kg | 0 | - | 195.9198 | J / kgK | 0.11 | 0.89 |
| 3 | TankCooler-heater | 6755 | t / y | 0.000208 | m3 / s | 1 | bar | 36.19713 | kJ / kg | 10.23793 | C | -89.368 | C | 0.000973 | m3 / kg | 0 | - | 130.0464 | J / kgK | 0.11 | 0.89 |
| 4 | heater-Lysosym | 6755 | t / y | 0.000209 | m3 / s | 1 | bar | 114.2222 | kJ / kg | 30 | C | -69.6059 | C | 0.000978 | m3 / kg | 0 | - | 396.204 | J / kgK | 0.11 | 0.89 |
| 5 | Lysosym-ferment | 6721.225 | t / y | 0.000208 | m3 / s | 1 | bar | 114.1745 | kJ / kg | 30 | C | -69.6059 | C | 0.000977 | m3 / kg | 0 | - | 396.0374 | J / kgK | 0.110452 | 0.889548 |
| 6 | Lysosym-lysosymEx | 33.775 | t / y | 1.07E-06 | m3 / s | 1 | bar | 123.7124 | kJ / kg | 30 | C | -69.6059 | C | 0.000999 | m3 / kg | 0 | - | 429.3581 | J / kgK | 0.02 | 0.98 |
| 7 | ferment-concentrering | 6721.225 | t / y | 0.000209 | m3 / s | 1 | bar | 141.7818 | kJ / kg | 37 | C | -62.6059 | C | 0.00098 | m3 / kg | 0 | - | 486.0701 | J / kgK | 0.110452 | 0.889548 |
| 8 | concentrering-cooling | 3093.227 | t / y | 9.30E-05 | m3 / s | 1 | bar | 126.188 | kJ / kg | 37 | C | -62.6059 | C | 0.000948 | m3 / kg | 0 | - | 432.0417 | J / kgK | 0.24 | 0.76 |
| 9 | concentrering-concentreringEx | 3627.998 | t / y | 0.000116 | m3 / s | 1 | bar | 155.0772 | kJ / kg | 37 | C | -62.6059 | C | 0.001007 | m3 / kg | -1 | - | 532.1346 | J / kgK | 0 | 1 |
| 10 | cooling-Drier | 3093.227 | t / y | 9.23E-05 | m3 / s | 1 | bar | -2.27831 | kJ / kg | 2 | C | -97.6059 | C | 0.000941 | m3 / kg | 0 | - | -7.47477 | J / kgK | 0.24 | 0.76 |
| 11 | Drier-driedVapor | 2303.467 | t / y | 0.878475 | m3 / s | 0.123519 | bar | 2591.289 | kJ / kg | 50 | C | 0 | C | 12.02691 | m3 / kg | 1 | - | 8074.835 | J / kgK | 0 | 1 |
| 12 | Drier-Mixer | 789.7601 | t / y | 1.96E-05 | m3 / s | 1 | bar | 70.34029 | kJ / kg | 50 | C | -49.6059 | C | 0.000782 | m3 / kg | 0 | - | 229.8432 | J / kgK | 0.94 | 0.06 |
| 13 | Source 1-Mixer | 100 | t / y | 2.48E-06 | m3 / s | 1 | bar | 70.34029 | kJ / kg | 50 | C | -49.6059 | C | 0.000782 | m3 / kg | 0 | - | 229.8432 | J / kgK | 0.94 | 0.06 |
| 14 | Mixer-pasteur | 889.7601 | t / y | 2.21E-05 | m3 / s | 1 | bar | 70.34029 | kJ / kg | 50 | C | -49.6059 | C | 0.000782 | m3 / kg | 0 | - | 229.8432 | J / kgK | 0.94 | 0.06 |
| 15 | pasteur-cooling 1 | 889.7601 | t / y | 2.24E-05 | m3 / s | 1 | bar | 152.1479 | kJ / kg | 87 | C | -12.6059 | C | 0.000794 | m3 / kg | 0 | - | 469.4898 | J / kgK | 0.94 | 0.06 |
| 16 | cooling 1-product | 889.7601 | t / y | 2.18E-05 | m3 / s | 1 | bar | 5.039528 | kJ / kg | 20 | C | -79.6059 | C | 0.000772 | m3 / kg | 0 | - | 17.78816 | J / kgK | 0.94 | 0.06 |
| 17 | | | | | | | | | | | | | | | | | | | | | |

# Results (json format)




- Graph, nodes, connections are saved..
  - Node name correspond to exact names of components used
  - Nodes have custom parameters will all node variables and values

# Node classes (and link to tespy class)

- Check out the nodes here:
  - *src\eemap\ui\nodes\component_nodes.py*
    - *src\eemap\ui\nodes\component_svg_nodes.py*
      (contains graphics and tespy model name):

```
class SVGNodeGenericHeatExchanger(SimpleHeatExchangerModel):
    __identifier__ = "dk.ipu.eemap.04svgComponents"
    tespy_type = "SimpleHeatExchangerDeltaPLfKpi"
    NODE_NAME = 'GenericHeatExchanger'
```

tespy model name

  - *src\eemap\ui\nodes\building_nodes.py*
  - *src\eemap\ui\nodes\support_nodes.py*
  - *src\eemap\ui\nodes\energy_nodes.py*

```
class MappingDegreeEnergyNode(BaseBuildingSupportEnergyNode):
    type = "Consumption"
    NODE_NAME = "MappingDegree"
    tespy_type = "SinkEnergy"
```

tespy model name

# Tespy classes

Everything located here:

- *externals\tespy\src\tespy\components\newComponents.py*
- *externals\tespy\src\tespy\components\newAdvancedComponents.py*
- *externals\tespy\src\tespy\components\EnergySupplyComponents.py*

Also check the test models here:

- *externals\tespy\incompressiblesTests**

*Example of energy balances using Q or KPI*

*Browse the class hierarchy to see all equations*
*docstrings are available for tespy base classes only.*

```
class SimpleHeatExchangerDeltaPLfKpi(SimpleHeatExchangerDeltaP):

    def energy_balance_func(self):

        return self.inl[0].m.val_SI * (self.outl[0].h.val_SI -
               self.inl[0].h.val_SI)*(1+self.LF.val) - self.Q.val

    def KPI_func(self):
        return self.inl[0].m.val_SI * (self.outl[0].h.val_SI -
               self.inl[0].h.val_SI)*(1+self.LF.val) - self.KPI.val *
               self.inl[0].m.val_SI
```

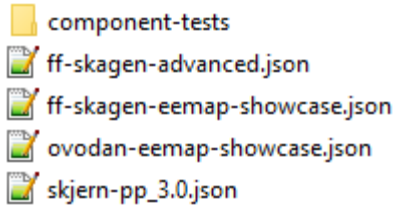
# Load sample files

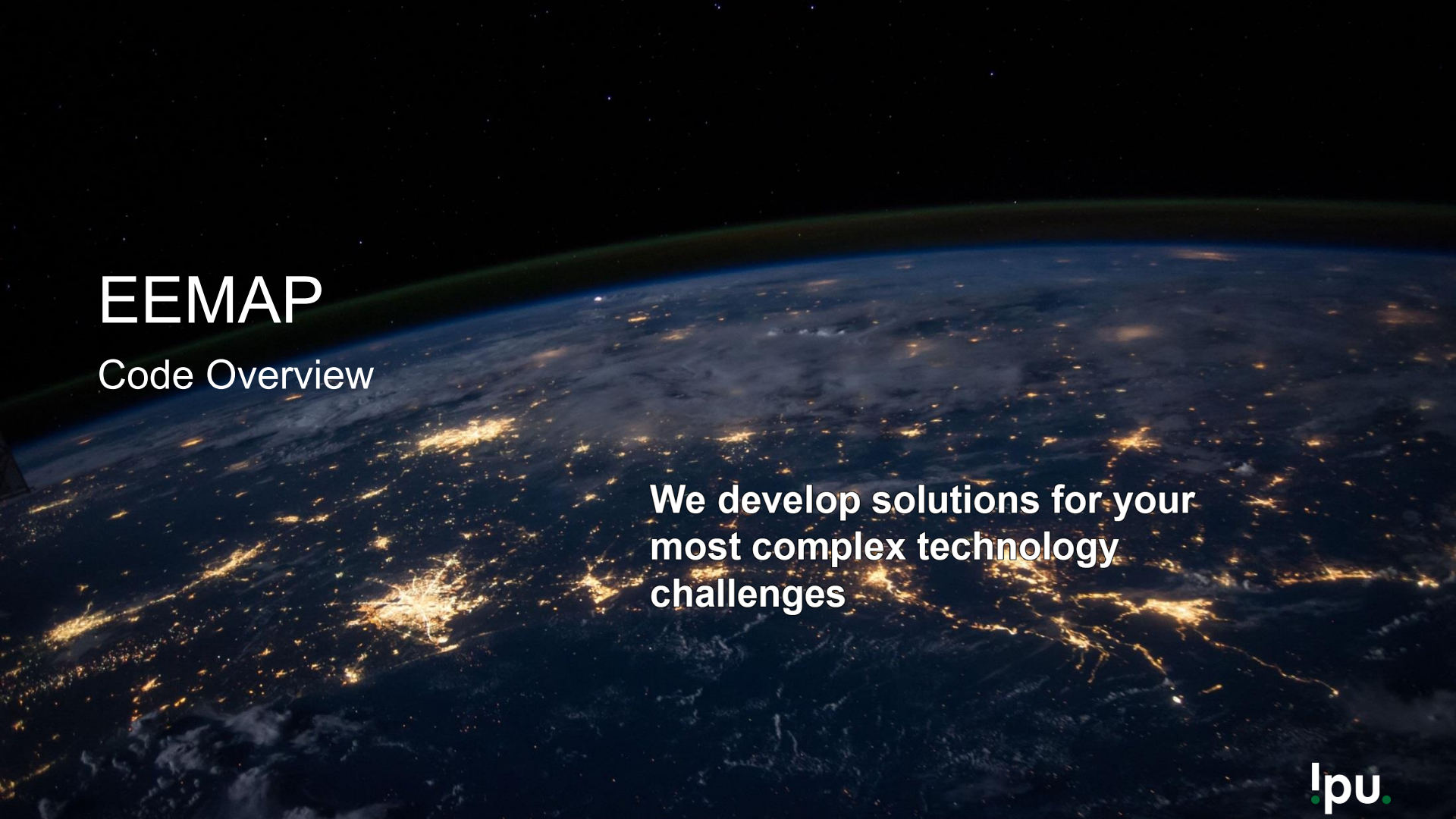
## Installer “path”

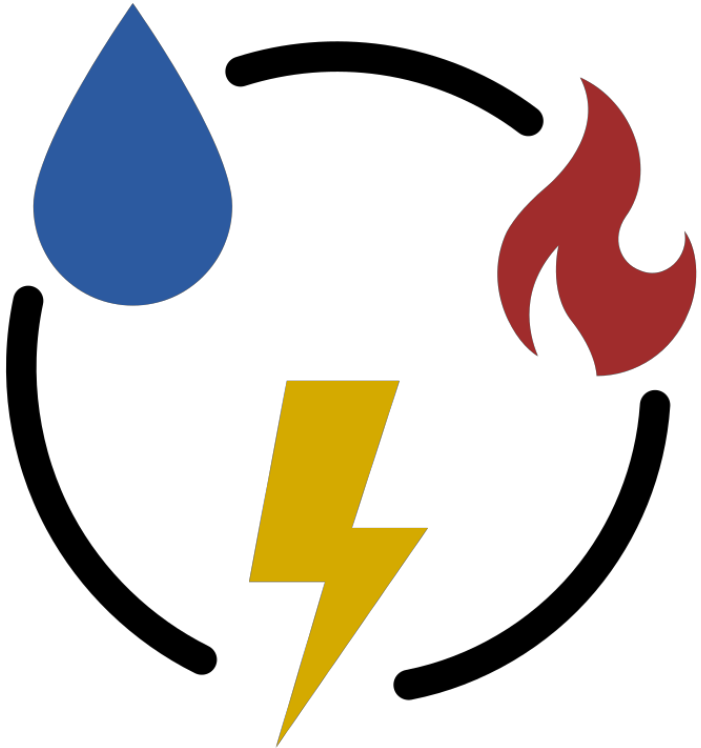
- *C:\Users\”user”\AppData\Roaming\IPU\EEMAP\eemap\json*

## Development “path”

- *src\json*

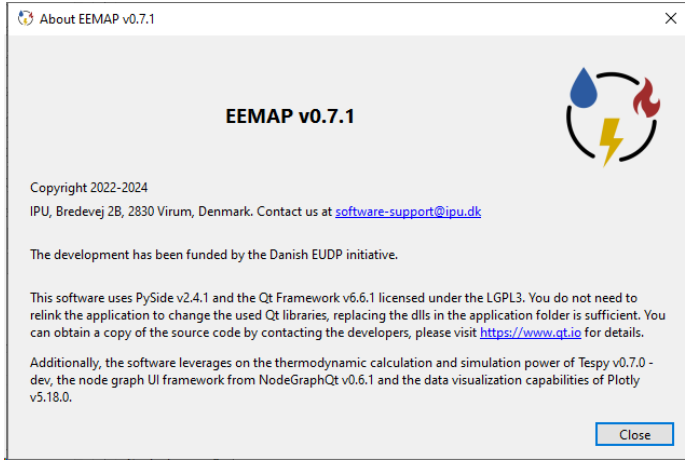



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# Software tool developed with Qt for python

- QT for python
- NodegraphQt
- Tespy
- Plotly
- Coolprop



# Software architecture

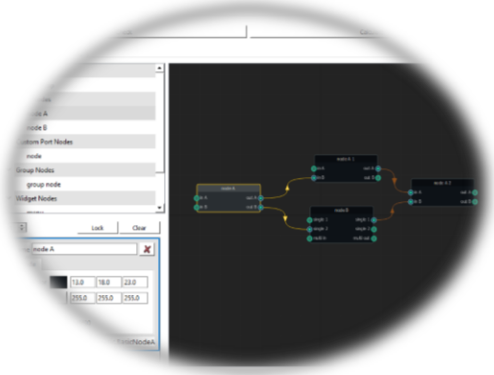
PySide6

## Calculator (backend)

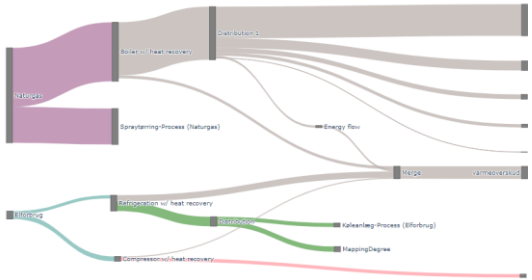
tespy ['tɛs.paɪ]

Coolprop

## NodeGraphQt



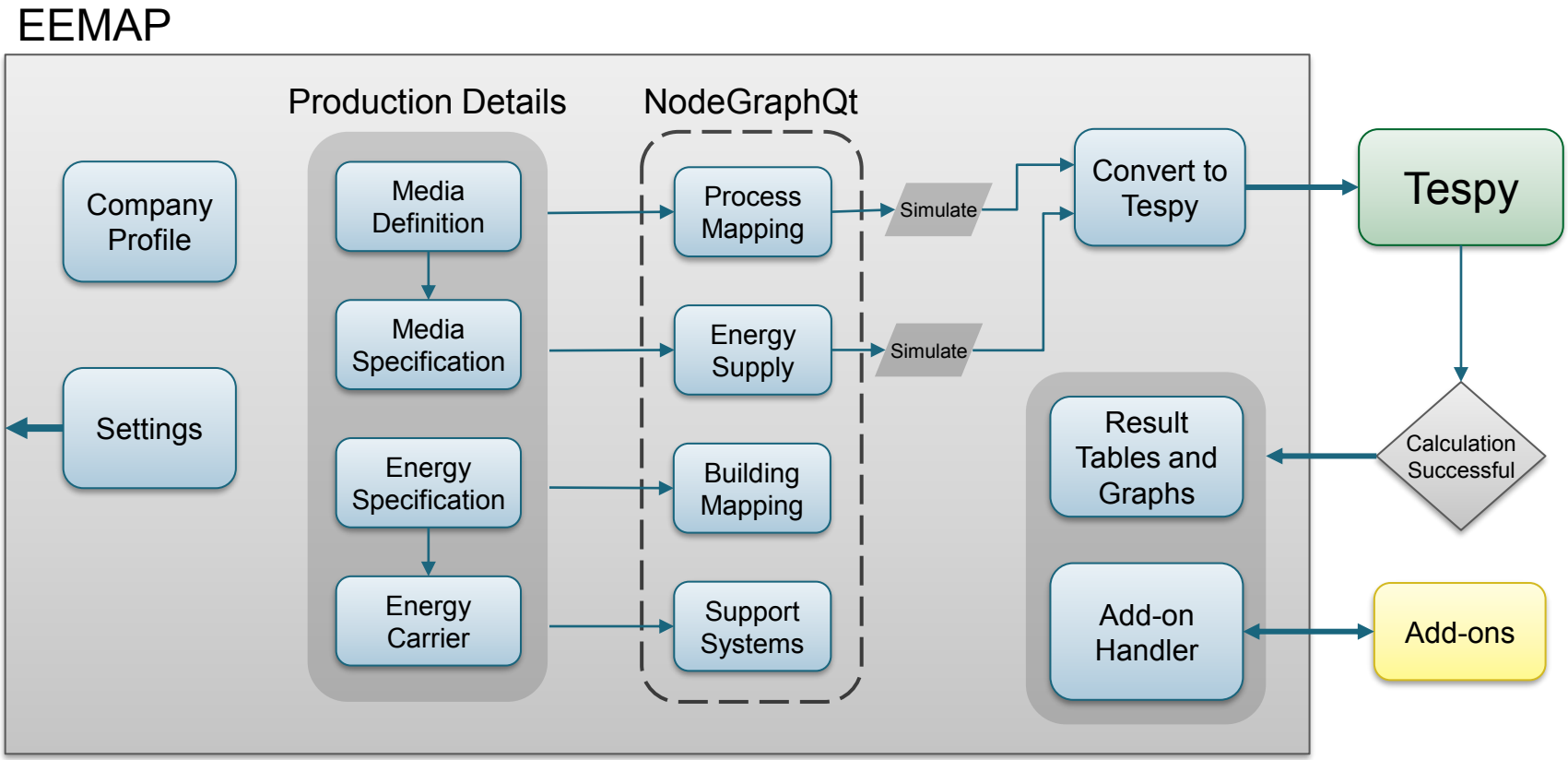
## Plotly



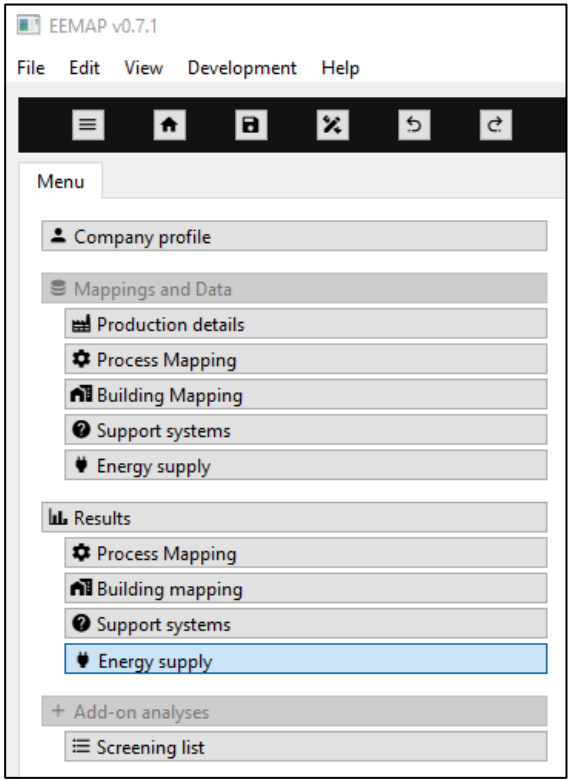
Translation

Visualization

# Software architecture



# Overview

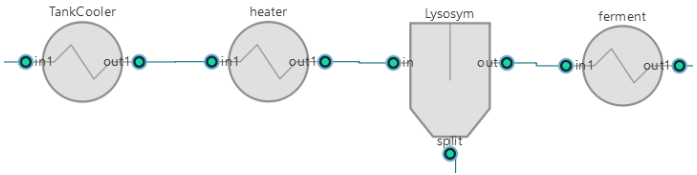



## Company info

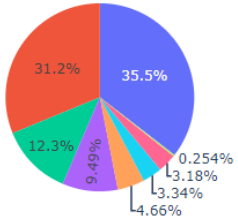
Company References

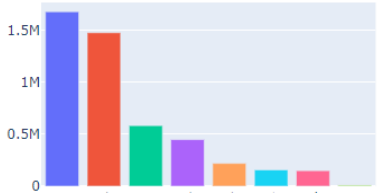
| title | person | date |
|---|---|---|
| Søren | jensen | 2024-03-07 12:18 |
| Peter | nielsen | 2024-01-25 07:36 |
| Torven | Caluse | 2024-01-25 07:36 |

## Mapping detail and calculations




## Results

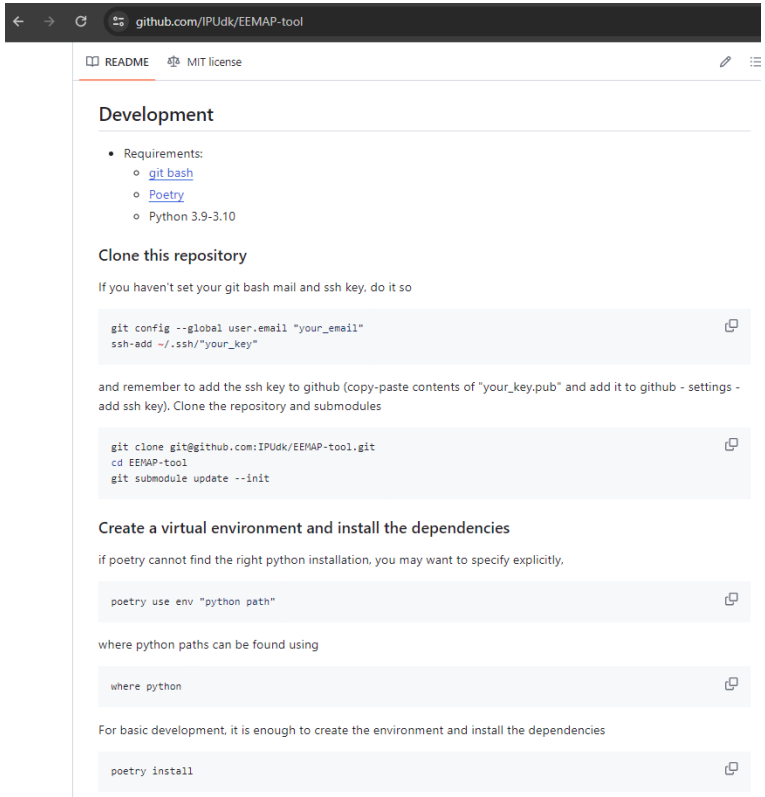



## Addon analysis

# How to setup local development

Everything explained @
https://github.com/IPUdk/EEMAP-tool



# Main Window

- Path: *src/eemap/ui/MainWindow.py*
- Create the application pages.

```
# Add the company profile
self.frameMainCompanyProfile = FrameMainCompanyProfile(self.undo_stack, self)
self.ui.stackedWidget.addWidget(self.frameMainCompanyProfile)
self.frame_2_buttons[self.frameMainCompanyProfile] = self.ui.actionMenu010CompanyProfile
```

- Connect the side menu to open different pages.

```
@Slot(bool)
def on_actionMenu010CompanyProfile_triggered(self, checked):
    if not checked:
        return
    self._checkParentAction(self.sender())
    self.ui.stackedWidget.setCurrentWidget(self.frameMainCompanyProfile)
```

- Connect the data of different pages with signals and slots.

```
# slot trigger change of nodes
self.settingsChanged.connect(self.frameProcessMapping.on_settings_changed)
self.settingsChanged.connect(self.frameEnergySupply.on_settings_changed)
```

- Define *_save_project* and *_load_project* functions.

# Production Details

- Production Details tables:
- Path: *src/eemap/ui/FrameMainProductionDetails.py*
- Define the table's model entry.
  - Data type of each column:

```python
@dataclass
class MediaSpecificationTableModelEntry(TableModelEntry):
    mediaName: str = ""
    amount: UnitValueEntry = UnitValueEntry()
    mediaComponents: FloatTableOptions = FloatTableOptions()
    sectionTag: str = ""
    referencePerson: str = ""
    comment: str = ""
```

- Define table model, view, and initialize table:

```python
self.table_model_EnergyCarrier = EnergyCarrierTableModel(EnergyCarrierTableModelEntry, self.undo_stack, self.ui._15_groupBoxEnergyCarrier)
self.table_view_EnergyCarrier = TableView()
cur_layout = self.ui._15_groupBoxEnergyCarrier.layout()
cur_dummy = self.ui.widgetTableEnergyCarrierDummy
cur_model = self.table_model_EnergyCarrier
cur_view  = self.table_view_EnergyCarrier
cur_name  = "EnergyCarrierTable"
self.table_init(cur_layout, cur_dummy, cur_model, cur_view, cur_name)
```

# Production Details

- Every table model has a *“modelName”Changed* signal.
  - Gets the table data when some has changed.

```
prod_details.table_model_MediaDefinition.mediaDefinitionChanged.connect(self.on_mediaDefinitionChanged)
prod_details.table_model_MediaSpecificationConsumption.mediaSpecificationChanged.connect(self.on_mediaConsumptionChanged)
prod_details.table_model_EnergyCarrier.energyCarrierChanged.connect(self.on_energyCarrierChanged)
```

  - Gives a list of model entries, where every entry is the values of a row. Ex:




```
[MediaSpecificationTableModelEntry(mediaName='Consumption0', amount=UnitValueEntry(value=15.0, unit='t / y'), mediaComponents=FloatTableOptions([FloatTableEntry(id=2809345597568,
label='Water, all states', coolpropName='HEOS::Water', value=0.8), FloatTableEntry(id=2809345594640, label='Protein', coolpropName='INCOMP::FoodProtein', value=0.2)]), sectionTag=
'', referencePerson='', comment='', _unique_id=2809327806896)]
```

# Settings

- Path: *src/eemap/ui/HelpDlgSettings.py*
- Get settings with the signal *settingsChanged* in the MainWindow.
- It gives a dictionary with the settings.
  - It contains guess values for Tespy's calculation, units, and the costs.
  - The unit names in the settings are used by the tables and the nodeGraph to display the unit of each parameter.


```
{'global_guess_values': {'m0': [0, 0.0], 'p0': 1.0, 'h0': 100.0}, 'network_params': {'m_unit': 'kg / y', 'SF_unit': 'kg / y', 'Q_unit': 'kWh / y', 'Q_loss_unit': 'kWh / y', 'Q_
total_unit': 'kWh / y', 'KPI_unit': 'kWh / kg', 'KPIQ_unit': 'kWh / kWh', 'kA_unit': 'kW / K', 'T_unit': '°C', 'p_unit': 'bar', 'h_unit': 'kJ / kg'}, 'eemap_params': {'Duration
_unit': 'y', 'Mass_unit': 'kg', 'Energy_unit': 'kWh', 'RH_unit': '%', 'x_unit': 'kg/kg', 'no_unit': '-'}, 'energy_prices': {'Energy_to_kWh_conversion_factor': 1.0, 'Energy_to_M
ass_conversion_factor': 0.001, 'currency': 'kr', 'electricity_co2': 0.53, 'electricity_cost': 1.0, 'gas_co2': 0.201, 'gas_cost': 1.0, 'liquid_fuel_co2': 0.279, 'liquid_fuel_cos
t': 1.0, 'solid_fuel_co2': 0.395, 'solid_fuel_cost': 1.0}}
```

# Mappings

- Creating new nodes:
  - Path: *src/eemap/ui/nodes/**
  - Add node to *__init__.py* to include it in the respective mapping
  - Example of a node:

```python
class Source(BaseComponent):
    """
    A node class representing a Source.
    """
    NODE_NAME = "Source"

    def __init__(self, qgraphics_item=None):
        super().__init__(qgraphics_item)
        self.add_output("out1")

        # put pressure first, so that it can be set to None, if State is gas
        self.create_component_property("pout", NumPropertyEdit, level=self.Level.NoLevelFixedPar, connection_name='out1', tespy_name='p', value = [1,1.0,""], unit = "p_unit")

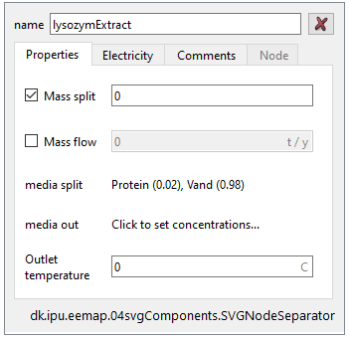
        self.create_component_property("m", NumPropertyEdit, connection_name='out1', display_name="Mass flow", unit = "m_unit")
        self.create_component_property("T", NumPropertyEditWithState, connection_name='out1', display_name="Temperature", unit = "T_unit")
        self.create_component_property("media", FloatTablePropertyEdit, connection_name='out1', tespy_name="fluid", display_name="Media")
```

# Mappings

- Defining a property with *create_component_property()*:
  - name → Property name.
  - widget_type → Type of widget shown in the property bin.
  - value (optional) → Initialize wit a set value.
    - If not defined, use property DEFAULT
  - level (optional) → One of the BaseNode.Level types.
  - tespy_name (optional) → The property's name in Tespy
  - connection_name (optional) → Define if it's a connection property.
    - "out1", "out2", ...
  - display_name (optional) → Property name to be displayed in the UI.
  - MassBalanceValue (optional) → Define mass balance value.
    - Used when level is in Level.MassBalance
  - unit (optional) → Define the unit type of the property.
    - T_unit, h_unit, ...
  - node_widget (optional) → widget type to be displayed in the node block.
  - node_widget_display_name (optional) → Property name to be displayed in the node_widget.
  - tab (optional) → which tab of the property bin to show the property.

# Mappings

- Property widgets:
  - Path: *src/eemap/ui/widgets/properties_widgets.py*
  - Define the property's widget in the property bin




  - Methods:
    - *load_property()* → Turn the property value into Tespy's format
    - *from_tespy()* → Update the property value from Tespy's results
    - *media_update()* → Update property with data from the Media Definition table
    - *consumption_update()* → Update property with data from the Media Consumption table
    - *assignable_energy_carrier()* → Update property with data from the Energy Carrier table

# Node classes (and link to tespy class)

- Check out the nodes here:
  - *src\eemap\ui\nodes\component_nodes.py*
    - *src\eemap\ui\nodes\component_svg_nodes.py*
      (contains graphics and tespy model name):

```
class SVGNodeGenericHeatExchanger(SimpleHeatExchangerModel):
    __identifier__ = "dk.ipu.eemap.04svgComponents"
    tespy_type = "SimpleHeatExchangerDeltaPLfKpi"
    NODE_NAME = 'GenericHeatExchanger'
```

tespy model name

  - *src\eemap\ui\nodes\building_nodes.py*
  - *src\eemap\ui\nodes\support_nodes.py*
  - *src\eemap\ui\nodes\energy_nodes.py*

```
class MappingDegreeEnergyNode(BaseBuildingSupportEnergyNode):
    type = "Consumption"
    NODE_NAME = "MappingDegree"
    tespy_type = "SinkEnergy"
```

tespy model name

# Tespy classes

Everything located here:

- *externals\tespy\src\tespy\components\newComponents.py*
- *externals\tespy\src\tespy\components\newAdvancedComponents.py*
- *externals\tespy\src\tespy\components\EnergySupplyComponents.py*

Also check the test models here:

- *externals\tespy\incompressiblesTests**

*Example of energy balances using Q or KPI*

*Browse the class hierarchy to see all equations*
*docstrings are available for tespy base classes only.*

```
class SimpleHeatExchangerDeltaPLfKpi(SimpleHeatExchangerDeltaP):

    def energy_balance_func(self):

        return self.inl[0].m.val_SI * (self.outl[0].h.val_SI -
               self.inl[0].h.val_SI)*(1+self.LF.val) - self.Q.val

    def KPI_func(self):
        return self.inl[0].m.val_SI * (self.outl[0].h.val_SI -
               self.inl[0].h.val_SI)*(1+self.LF.val) - self.KPI.val *
               self.inl[0].m.val_SI
```

# NodeGraph to Tespy Conversion

- Path: *src/eemap/threads/TespyRunnable.py*
- Automatically load the parameters to the Tespy format using the *load_property()* function of every property of the node.
  - Automatically load it as a connection property (ghostsensor) or a node property depending on the property creation definition.

```
# load params
node_params: dict = eemap_node.load_2_tespy(node.get("custom", {}))
# Load ghost sensor
self.ghost_sensors_dict[node_id] = eemap_node.load_ghostsensors_2_tespy(
    node.get("custom", {})
)

# in case we use other names for than the exact tespy_name (e.g. for svg components)
if hasattr(eemap_node, "tespy_type"):  # TODO: make it default
    node_type = eemap_node.tespy_type

# Save component parameters
tespy_component = getattr(tespy.components, node_type)
self.node_2_tespy[node_id] = tespy_component(
    node["name"], **node_params
)
```

# NodeGraph to Tespy Conversion

- Path: *src/eemap/threads/TespyRunnable.py*
- Int the *_create_connection()* function use the connections of the NodeGraph to connect the Tespy components.
  - Handle Sensors and other “non-tespy” nodes in the connections.
  - Set attributes of the connection, given the “ghost sensor” properties.

```
# Define label
conn_label = "-".join(
    [
        self.node_2_tespy[from_node_id].label,
        self.node_2_tespy[to_node_id].label,
    ]
)
if sensor:
    sensor.set_connection_name(conn_label)

# Create the connection
c = Connection(
    self.node_2_tespy[from_node_id],
    from_port,
    self.node_2_tespy[to_node_id],
    to_port,
    label=conn_label,
    **self.global_guess_vals,
)

# Apply Ghost_sensor
for k, v in self.ghost_sensors_dict[from_node_id].items():
    if k == from_port:
        c.set_attr(**self.ghost_sensors_dict[from_node_id][k])

return c
```

# Results

- Path: *src/ui/Results.py* and *src/ui/ResultsMapping.py*
- Results come from the mapping's signal *results_ready*, ex:

```
self.frameProcessMapping.results_ready.connect(self.resultsTables._on_process_mapping_results_ready)
self.frameProcessMapping.results_ready.connect(self.resultsProcessMappingResults._on_process_mapping_results_ready)
```

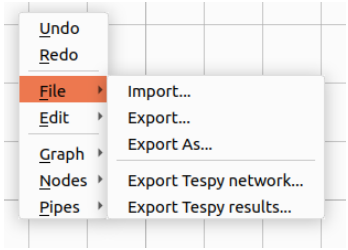
  - The signal returns a dictionary with Tespy's results and a list with the mapping's nodes
    - Tespy's results is a series of Pandas DataFrames with the calculation results
      - See an example of the connection DataFrame as csv in the CSV results slide.
    - The nodes contain their input and calculated property values

```
# All node properties
node.properties()['custom']
# Get a specific property
node.get_property('Q')
```

```
print(node.properties()['custom'])
{'Level of detail': 0, 'pout': [1, 1.0, 'bar'], 'media liquid': [[2614970076080, 'Water', 'HEOS::Water', False, 0.8614444444444445], [2614920130816, 'Protein', 'INCOMP::FoodProtein', True, 0.129], [2394786739824, 'Fat', 'INCOMP::FoodFat', False, 0.009555555555555558]], 'Tout': [1, 40.0, 'C'], 'xout': [0, -1.0, 'kg/kg'], 'Q': [0, -0.0, 'J / s'], 'KPI': [0, -0.0, 'J / kg'], 'kA': [0, -0.0, 'W / K'], 'deltaT': [1, None, 'C'], 'deltaH': [1, None, 'kJ / kg'], 'deltaP': [1, None, 'bar'], 'dTo': [1, None, 'C'], 'Energy carrier': [{-999: {'cost_conversion_factor': -999, 'co2_conversion_factor': -999, 'energy_source': '', 'label': ''}, 2602736405856: {}, 2602736405952: {}, 2602736405664: {}}, '', -1], 'Electricity': [0, 0.0, 'J / s'], 'Electricity_m_KPI': [0, 0.0, 'J / kg'], 'Electricity_Q_KPI': [1, 0.03, 'kWh / kWh'], 'ElectricityCost': [0, 0.0, 'kr'], 'ElectricityCO2e': [0, 0.0, 'kg'], 'Cost': [0, 0.0, 'kr'], 'CO2e': [0, 0.0, 'kg'], 'Comment': ''}
```

# Results

- Exporting results:
  - After running the calculation on the process mapping, you can export the results as csv files.



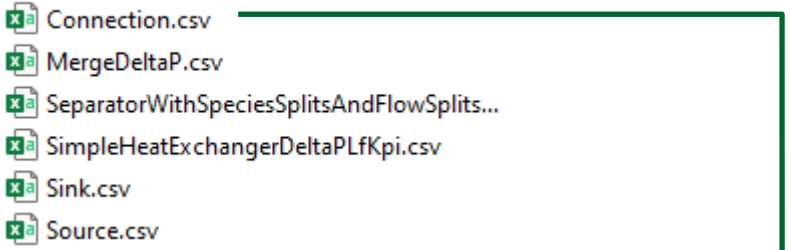

  - You can also export the generated Tespy network and run it in a python script (outside the software)
    - Path: *design\run-exported-design.py*

```
from tespy.networks import load_network
import logging
logging.basicConfig(level=logging.DEBUG)

nw = load_network("design/design")
nw.solve("design")

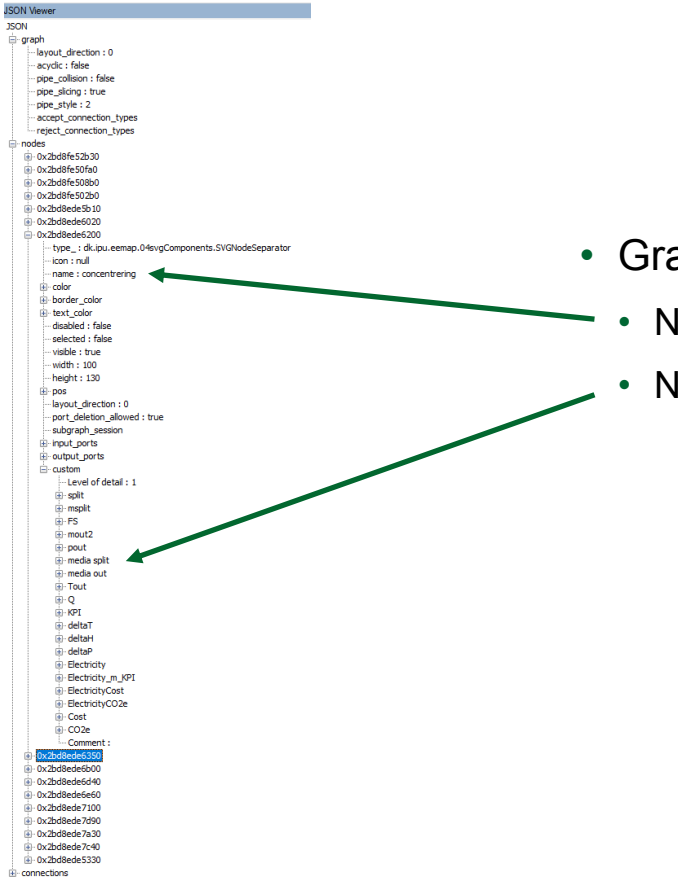
nw.print_results()
print(nw.results['Connection'])
```

# Results (csv format)




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | m | m_unit | v | v_unit | p | p_unit | h | h_unit | T | T_unit | Td_bp | Td_bp_un | vol | vol_unit | x | x_unit | s | s_unit | FoodProte | Water |
| 2 | Source-TankCooler | 6755 | t / y | 0.000209 | m3 / s | 1 | bar | 55.02123 | kJ / kg | 15 | C | -84.6059 | C | 0.000974 | m3 / kg | 0 | - | 195.9198 | J / kgK | 0.11 | 0.89 |
| 3 | TankCooler-heater | 6755 | t / y | 0.000208 | m3 / s | 1 | bar | 36.19713 | kJ / kg | 10.23793 | C | -89.368 | C | 0.000973 | m3 / kg | 0 | - | 130.0464 | J / kgK | 0.11 | 0.89 |
| 4 | heater-Lysosym | 6755 | t / y | 0.000209 | m3 / s | 1 | bar | 114.2222 | kJ / kg | 30 | C | -69.6059 | C | 0.000978 | m3 / kg | 0 | - | 396.204 | J / kgK | 0.11 | 0.89 |
| 5 | Lysosym-ferment | 6721.225 | t / y | 0.000208 | m3 / s | 1 | bar | 114.1745 | kJ / kg | 30 | C | -69.6059 | C | 0.000977 | m3 / kg | 0 | - | 396.0374 | J / kgK | 0.110452 | 0.889548 |
| 6 | Lysosym-lysosymEx | 33.775 | t / y | 1.07E-06 | m3 / s | 1 | bar | 123.7124 | kJ / kg | 30 | C | -69.6059 | C | 0.000999 | m3 / kg | 0 | - | 429.3581 | J / kgK | 0.02 | 0.98 |
| 7 | ferment-concentrering | 6721.225 | t / y | 0.000209 | m3 / s | 1 | bar | 141.7818 | kJ / kg | 37 | C | -62.6059 | C | 0.00098 | m3 / kg | 0 | - | 486.0701 | J / kgK | 0.110452 | 0.889548 |
| 8 | concentrering-cooling | 3093.227 | t / y | 9.30E-05 | m3 / s | 1 | bar | 126.188 | kJ / kg | 37 | C | -62.6059 | C | 0.000948 | m3 / kg | 0 | - | 432.0417 | J / kgK | 0.24 | 0.76 |
| 9 | concentrering-concentreringEx | 3627.998 | t / y | 0.000116 | m3 / s | 1 | bar | 155.0772 | kJ / kg | 37 | C | -62.6059 | C | 0.001007 | m3 / kg | -1 | - | 532.1346 | J / kgK | 0 | 1 |
| 10 | cooling-Drier | 3093.227 | t / y | 9.23E-05 | m3 / s | 1 | bar | -2.27831 | kJ / kg | 2 | C | -97.6059 | C | 0.000941 | m3 / kg | 0 | - | -7.47477 | J / kgK | 0.24 | 0.76 |
| 11 | Drier-driedVapor | 2303.467 | t / y | 0.878475 | m3 / s | 0.123519 | bar | 2591.289 | kJ / kg | 50 | C | 0 | C | 12.02691 | m3 / kg | 1 | - | 8074.835 | J / kgK | 0 | 1 |
| 12 | Drier-Mixer | 789.7601 | t / y | 1.96E-05 | m3 / s | 1 | bar | 70.34029 | kJ / kg | 50 | C | -49.6059 | C | 0.000782 | m3 / kg | 0 | - | 229.8432 | J / kgK | 0.94 | 0.06 |
| 13 | Source 1-Mixer | 100 | t / y | 2.48E-06 | m3 / s | 1 | bar | 70.34029 | kJ / kg | 50 | C | -49.6059 | C | 0.000782 | m3 / kg | 0 | - | 229.8432 | J / kgK | 0.94 | 0.06 |
| 14 | Mixer-pasteur | 889.7601 | t / y | 2.21E-05 | m3 / s | 1 | bar | 70.34029 | kJ / kg | 50 | C | -49.6059 | C | 0.000782 | m3 / kg | 0 | - | 229.8432 | J / kgK | 0.94 | 0.06 |
| 15 | pasteur-cooling 1 | 889.7601 | t / y | 2.24E-05 | m3 / s | 1 | bar | 152.1479 | kJ / kg | 87 | C | -12.6059 | C | 0.000794 | m3 / kg | 0 | - | 469.4898 | J / kgK | 0.94 | 0.06 |
| 16 | cooling 1-product | 889.7601 | t / y | 2.18E-05 | m3 / s | 1 | bar | 5.039528 | kJ / kg | 20 | C | -79.6059 | C | 0.000772 | m3 / kg | 0 | - | 17.78816 | J / kgK | 0.94 | 0.06 |
| 17 | | | | | | | | | | | | | | | | | | | | | |

# Results (json format)




- Graph, nodes, connections are saved..
  - Node name correspond to exact names of components used
  - Nodes have custom parameters will all node variables and values

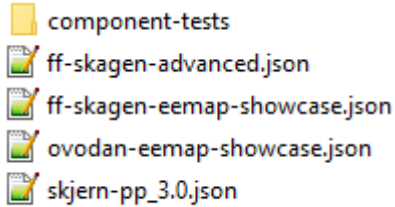
# Load sample files

## Installer “path”

- *C:\Users\”user”\AppData\Roaming\IPU\EEMAP\eemap\json*

## Development “path”

- *src\json*



# Add-ons

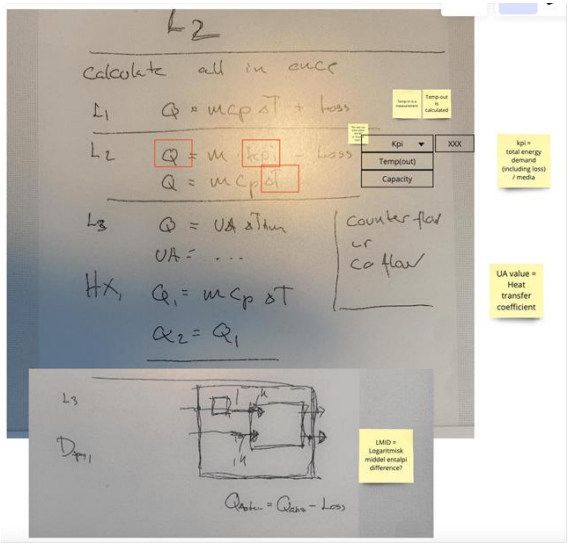
- Add-ons to make custom analyses on the results:
  - Add the python file to the folder: *src/ui/add_ons/*
  - Define your add-on in the json file: *src/ui/add_ons/add_ons.json*
    - Path, Widget (class), and functions. Ex:

```
{
    "Example_Addon": {
        "module_path": "eemap.ui.add_ons.example_addon",
        "widget": "ExampleAddOn",
        "functions": {
            "settings": "on_settings_changed",
            "process": "on_process_mapping_results_ready",
            "building": "on_building_mapping_results_ready",
            "support": "on_support_systems_results_ready",
            "energy": "on_energy_supply_results_ready"
        }
    }
}
```

    - You only need to define the functions that you want the results from.
- Look into the example add-on: *src/ui/add_ons/example_addon.py*

# EEMAP
# Energikortlægningsværktøj

- **Defining the components**



# Component structure

## Different elements in the process mapping structure

Step one:

- Mass balance

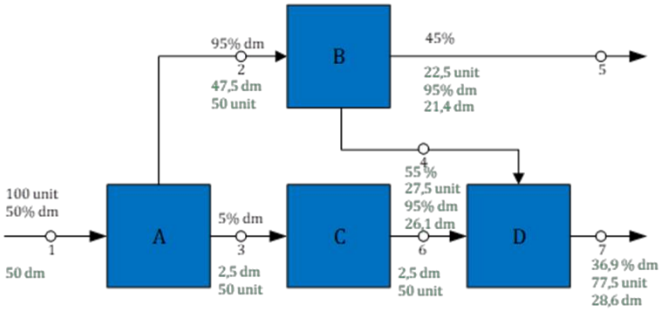
Step two

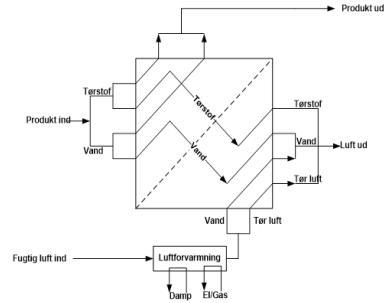
- Global

or

- Specific

**We can on be in one of the steps at the time**



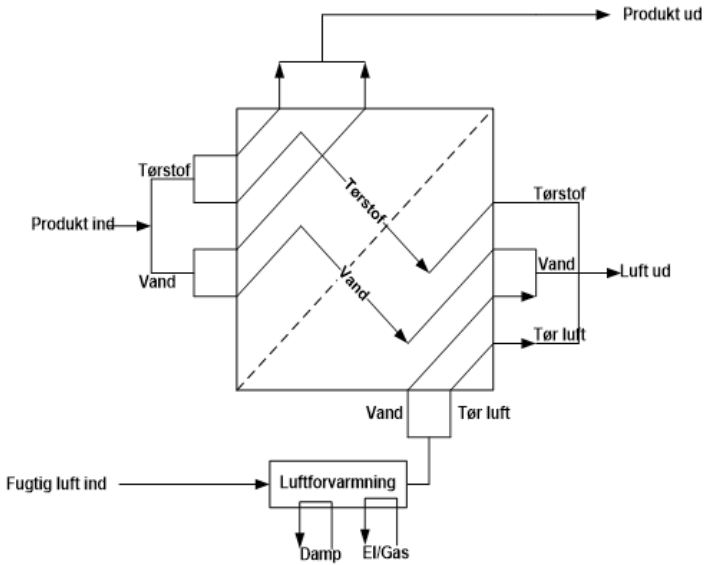
# Step one - Mass balance

## Different elements in the process mapping structure

The mass balance is the first step in the process mapping process.

The mass balance account for all the elements in the mass flows e.g. water, dry matter, fat, protein etc.

Challenges: How do we deal with the mass contribution from a combustion process that is determined by the energy balance ?



# Step two energy mapping

## Different elements in the process mapping structure

Step two in the energy mapping is where you decide how to map the energy consumption, based on the information available.

There will be two approaches a global approach that can be used for all components and there will be a specific approach that can be used for all components

All the components will be based on the six basis component blocks.

Basic component blocks

- Splitter
- Connector
- Direct heat and mass transfers
- Indirect heat transfers
- Electrical treatment
- Exothermal and endothermal

Challenges:
- Do we need one that handles combustion?
- We need to track the secondary side of the heat consumer, in the case that this is used in another component afterwards.

# Step two energy mapping

## Different elements in the process mapping structure

Global

When using the global, we can work with three inputs:

$$\boldsymbol{Q} = \dot{m} \times \Delta h \times \alpha$$

$$\alpha \; is \; a \; loss \; factor$$

$$\Delta h = f(P_{in}, P_{out}, T_{in}, \boldsymbol{T_{out}}, c_{in}, c_{out})$$

$$\boldsymbol{kpi} = \frac{Q}{\dot{m}}$$

$T_{in}$ is always given

We can use Q, $T_{out}$ , kpi as input and then the two others will be output

Challenges

- P is constant

- $T_{out}$ does not always make sense to define as an output

- Is the Kpi always defined as a function of the main product coming in to the unit?

# Step two energy mapping

## Different elements in the process mapping structure

Global

When using the global, we can work with three inputs:

$$\boldsymbol{Q} = \dot{m} \times \Delta h \times \alpha$$

$$\alpha \; is \; a \; loss \; factor$$

$$\Delta h = f(P_{in}, P_{out}, T_{in}, \boldsymbol{T_{out}}, c_{in}, c_{out})$$

$$\boldsymbol{kpi} = \frac{Q}{\dot{m}}$$

$T_{in}$ is always given

We can use Q, $T_{out}$ , kpi as input and then the two others will be output

Challenges

- P is constant

- $T_{out}$ does not always make sense to define as an output

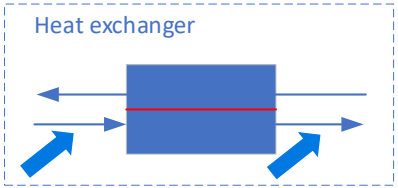
- Is the Kpi always defined as a function of the main product coming in to the unit?

- Q can be steam, electricity, .. Or any other energy source

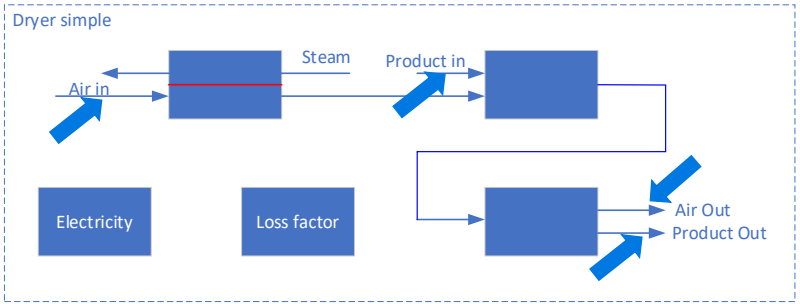
# Step two energy mapping

## Different elements in the process mapping structure

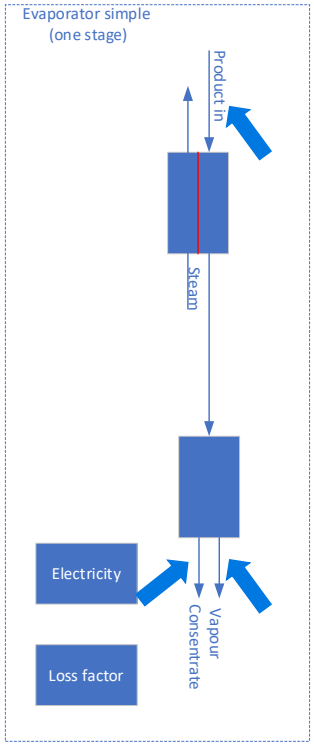
Example of indirect (heat exchanger and evaporator) and direct heat exchange (dryer )




One component




Three component




Two component

# Step two energy mapping

## Different elements in the process mapping structure

Specific:

When using the specific option, we need to add additional information to the component. The specific function splits up the component to some extend in subcomponents

Heat exchanger

- Type of heat exchanger

<u>Heat exchanger Inputs:</u>

- UA value
- Pinch temperature
- Efficiency

Dryer

- Type of dryer – there can be variations on the dryer configuration

<u>Spray dryer input</u>

- Temperature of the heating media going out of the heater

Evaporator

- Type of evaporator – there can be variations on the evaporator configuration

<u>Thermal evaporator input</u>

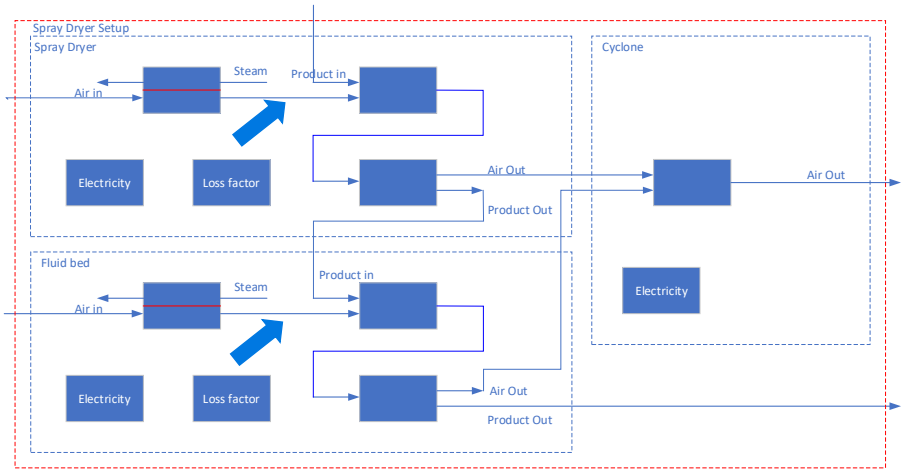
-number of stages

- pressure of each step

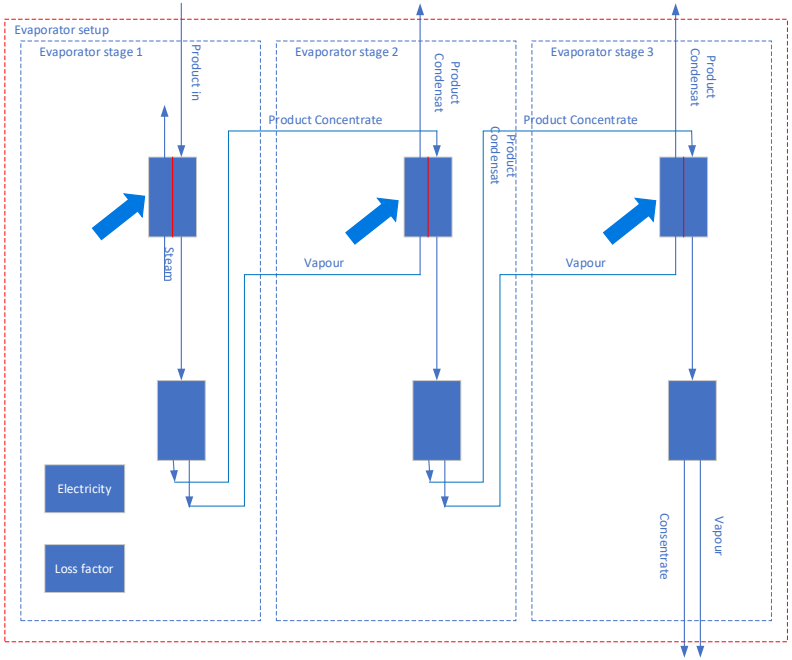
# Step two energy mapping

## Different elements in the process mapping structure

Example of indirect (heat exchanger and evaporator) and direct heat exchange (dryer )




Example of a dryer section




Example of an evaporator section

# Step two energy mapping

## Different elements in the process mapping structure

Electricity

Electricity is treated in three ways:

$$P = \boldsymbol{measurred}$$

$$\boldsymbol{kpi} = \frac{P}{\dot{m}}$$

$$\mathrm{P} = \boldsymbol{p} \times \boldsymbol{h} \times \boldsymbol{\varepsilon} \times \boldsymbol{\theta}$$

$p = effect, h = hours, \varepsilon = load, \theta =$ control

Challenges

- Is electricity linked to the thermal process

- relation to masse flow e.g. consumption related to pumps

- Should this be a separate “box” or should it be a part of the thermal “box”

# Other

## Followup

Royal Unibrew – Energy mapping

Status mail to companies

Involvement of companies

Start up the three other mappings

# Kontakt



**Fridolin Müller Holm**

**Chef for industri**

**Viegand Maagøe A/S**

**Tlf. +45 31 75 17 14**

**E-mail: fmh@viegandmaagoe.dk**

**WWW.VIEGANDMAAGOE.DK**



# EEMAP Status 2022/01/10

## Status and evaluation of tespy

**Development Status 1 and evaluation of Tespy**

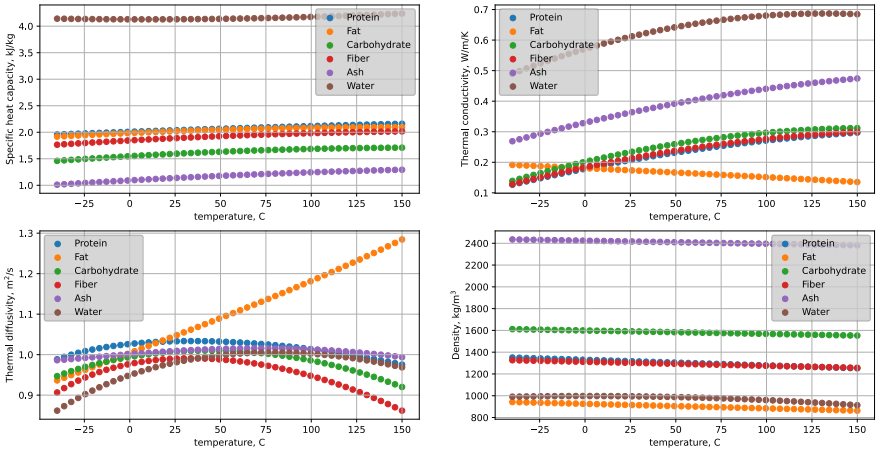
**We develop solutions for your most complex technology challenges**

!pu.

# Food properties

# **Food properties** – intermediate implementation in CoolProp

- ASHRAE Handbook – Refrigeration, Ch 9, Thermal properties of foods
  - Contains polynomials for water, protein, fat, carbohydrate, fiber, ash
  - Huge table with constituents in many foods
  - Freezing points and equations for frozen food etc.
- So far only unfrozen properties are implemented…




9.4 2006 ASHRAE Handbook—Refrigeration (SI)

Table 3 Unfrozen Composition Data, Initial Freezing Point, and Specific Heats of Foods* (*Continued*)

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# tespy

# Modeling concept



- Component based design and part load simulator
  - Steady state operation
  - Generic topology based on standard components
  - Part load behaviour through lookup tables or custom equations
  - Thermodynamic engine: CoolProp

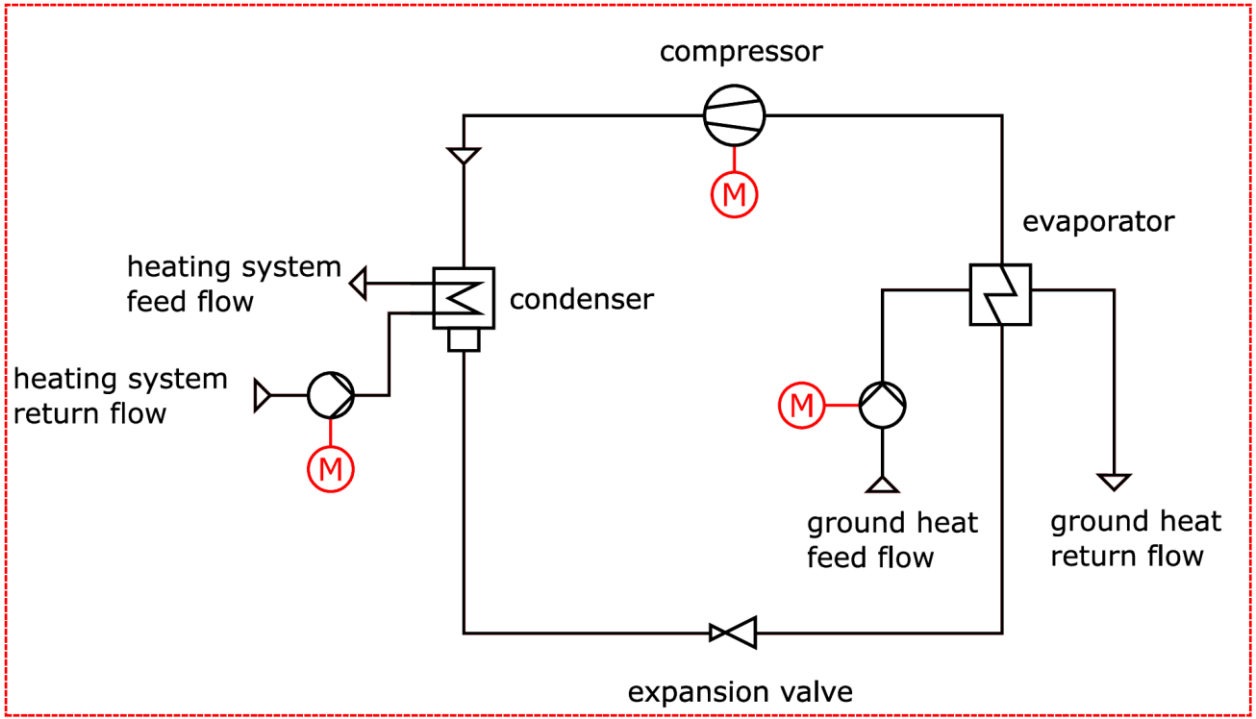
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slide contents @ Francesco Witte

# Software architecture



- **Components**
  - Power and heat transfer
  - Pressure change
  - Efficiency
- **Connections**
  - Mass flow
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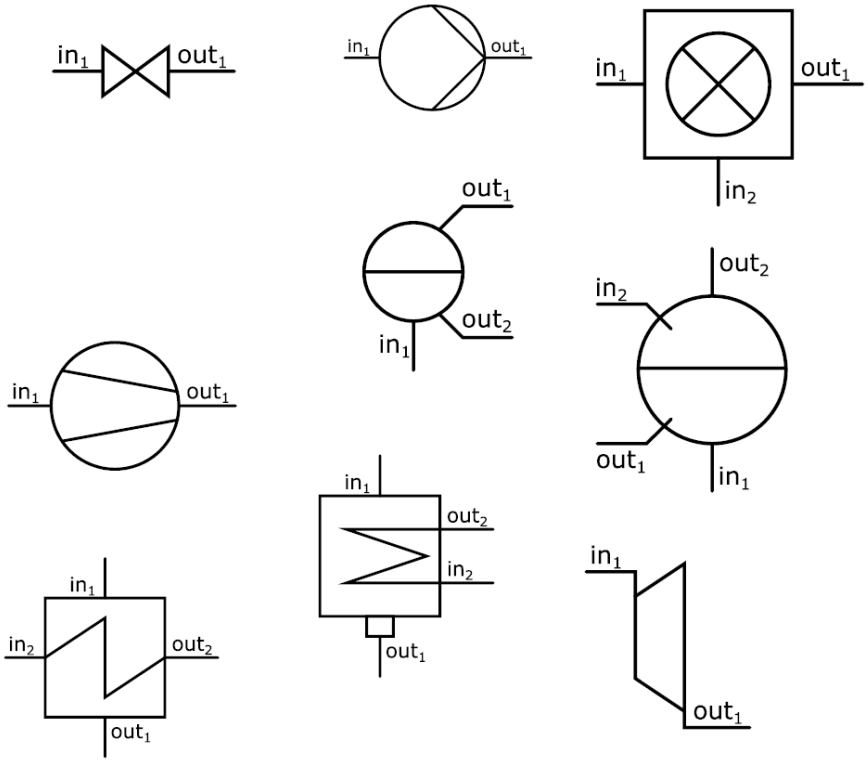



slide contents @ Francesco Witte

# Components



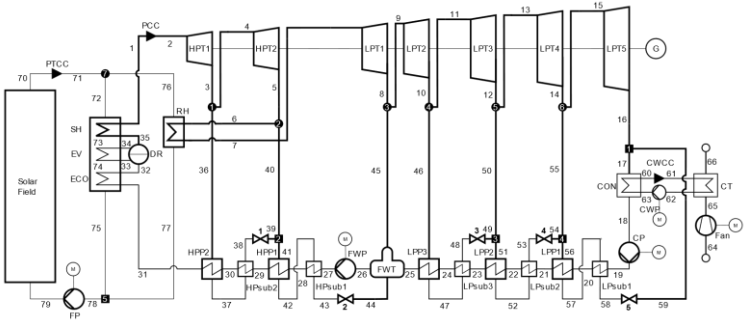
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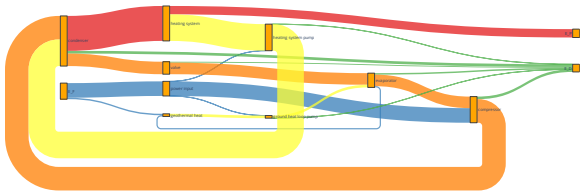

slide contents @ Francesco Witte

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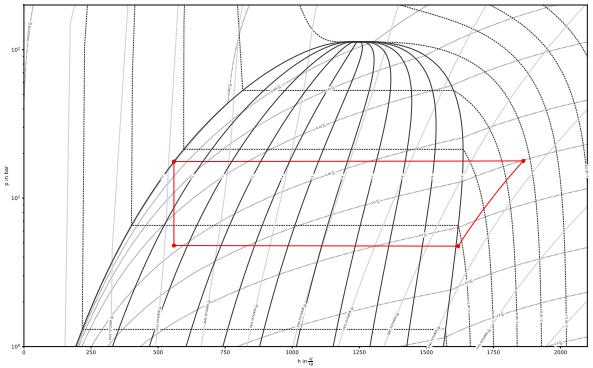
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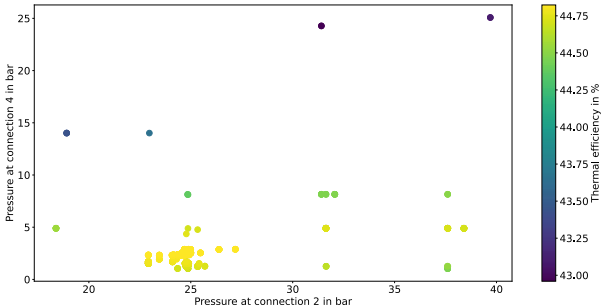

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fluprodia



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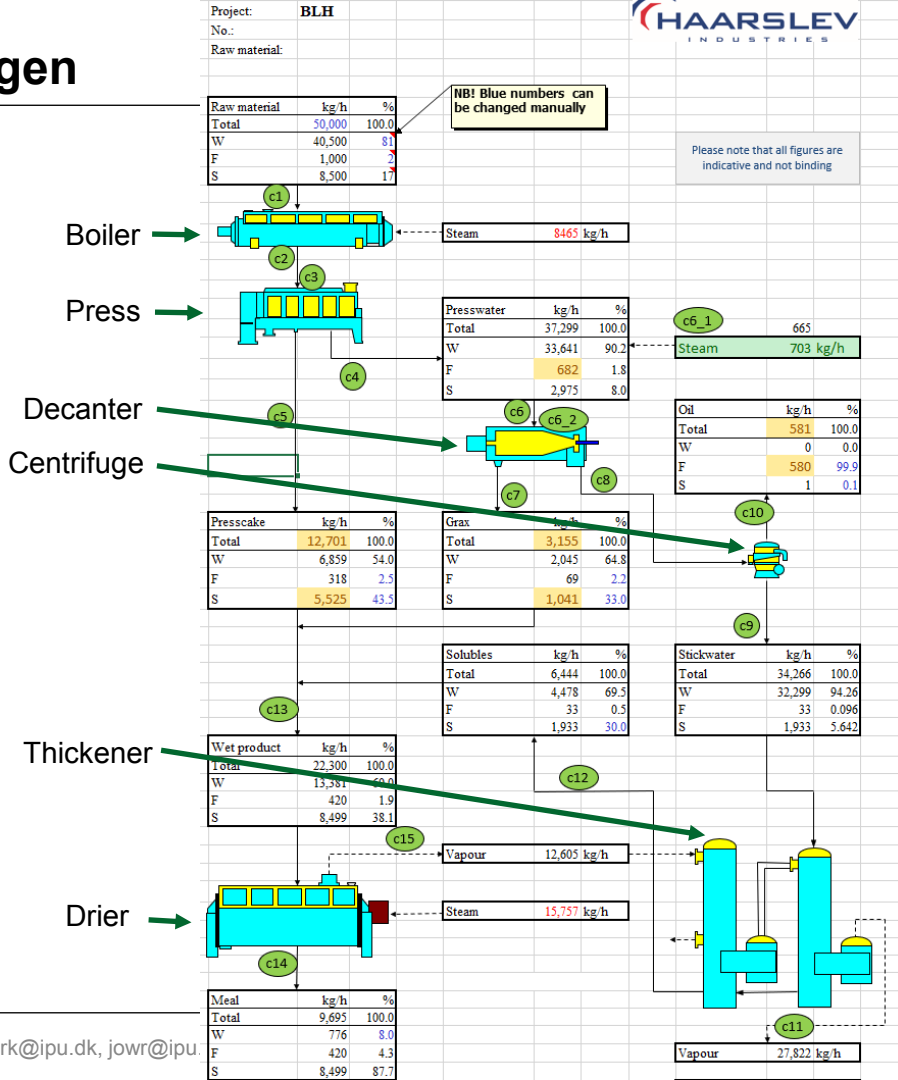



slide contents @ Francesco Witte

# Test plant Skagen

Need
to define
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TS/TF splits
hacked




**Raw material:**
Specific heat 0.90 kcal/kg°C
Heat of evaporation 503 kcal/kg

RM. Temp. 0 °C
Cooking temp. 95 °C ← Boiler

**Presswater:**
T1 90 °C
T2 100 °C ← Press
Specific heat 0.95 kcal/kg°C

**Fish oil:**
Recovery 85 % ← Decanter+centrifuge
related to F in presswater

**Presscake:**
TS-split 65 % ← Press
related to S in raw material

**Grax:**
TS-split 35 % ← Decanter
related to S in presswater

**Cooker:**
Steam pressure 6.0 bar 4
SCR 250 kg/m² 196
Heating surface 200.0 m² 255.1

**Press:**
RPM screws 2.0 rpm
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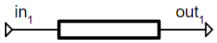
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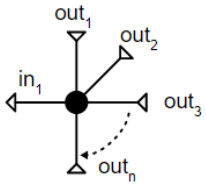
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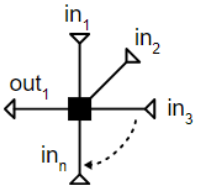
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Merge




tespy: Merge

- Missing features
  - Unfixing equal outlet pressures



# EEMAP Status 2022/01/10

## Status and evaluation of tespy

**Development Status 2**

**We develop solutions for your most complex technology challenges**

!pu.

# Status

- Setup git repository and dependencies on CoolProp and tespy
- Shared preliminary state of EEMAP UI v0.0.1
- Added intermediate food properties in CoolProp and ideal liquid mixtures in tespy
- Evaluated the use of tespy package
- Modelled and simulated “skagen plant” with some hacks “successfully”
  - Fishmealprocess_Conventional Standard BLH (002).xlsx
- Studied documentation of tespy

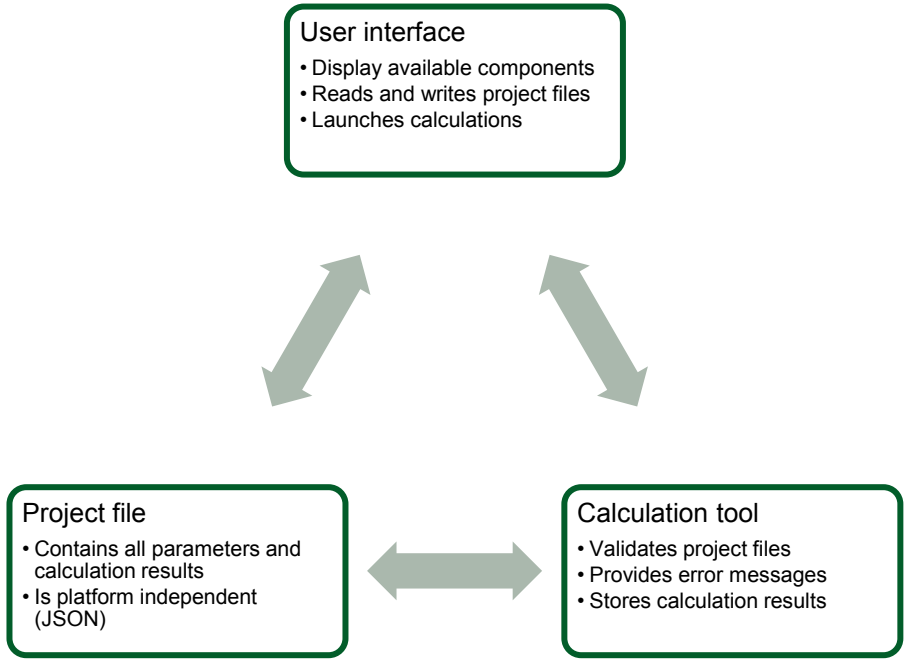
# EEMAP UI

# Draft software specification

- An installable desktop software that supports at least the Windows platform v10 and v11.
- A UI that enables the user to map a process involving flows of energy and material.
- The laws of physics should be enforced as much as possible. This includes mass and energy balances.
- Material and energy flows should be traceable throughout the process. An automatic generation of distribution diagrams is desirable.
- Process operations and flows should be accessible on a flow chart as well as in a tabulated form.
- Changing parameters and values in one place should modify the data model and thus impact all views of the same data set.
- Custom KPIs should be created. This could be implemented as a table that assigns names to variables and conducts simple calculations.
- Unit operations should have multiple possible configuration options. A default value can be overwritten with user input.

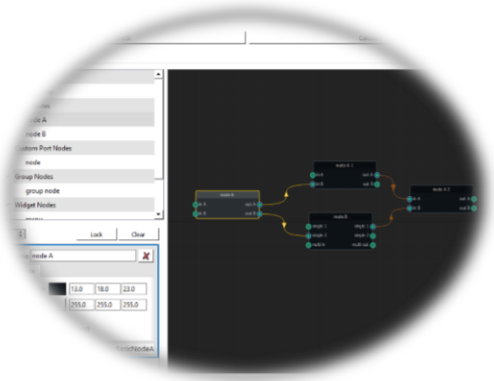
# Software architecture considerations

- The UI and the calculation tool should be two independent pieces of software for the following reasons:
  - Batch processing of several mapping projects and parameter sweeps do not need a UI.
  - The person collecting information for a mapping does not necessarily have to calculate.
- However, using Python for both tasks makes it easy to integrate the UI with the calculation core.
- The project files contain all inputs and may contain outputs as well.



# Software architecture considerations

## NodeGraphQt



## Translation

## tespy

tespy
['tɛs.paɪ]

# Food properties

# **Food properties** – intermediate implementation in CoolProp

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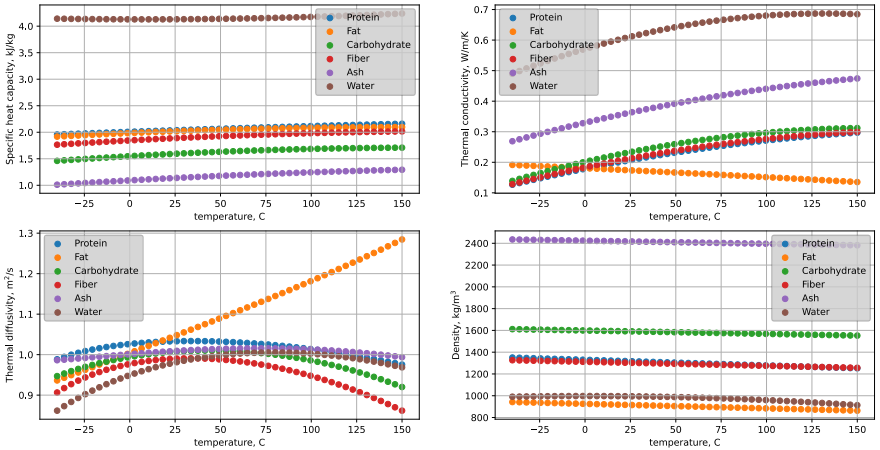





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# tespy

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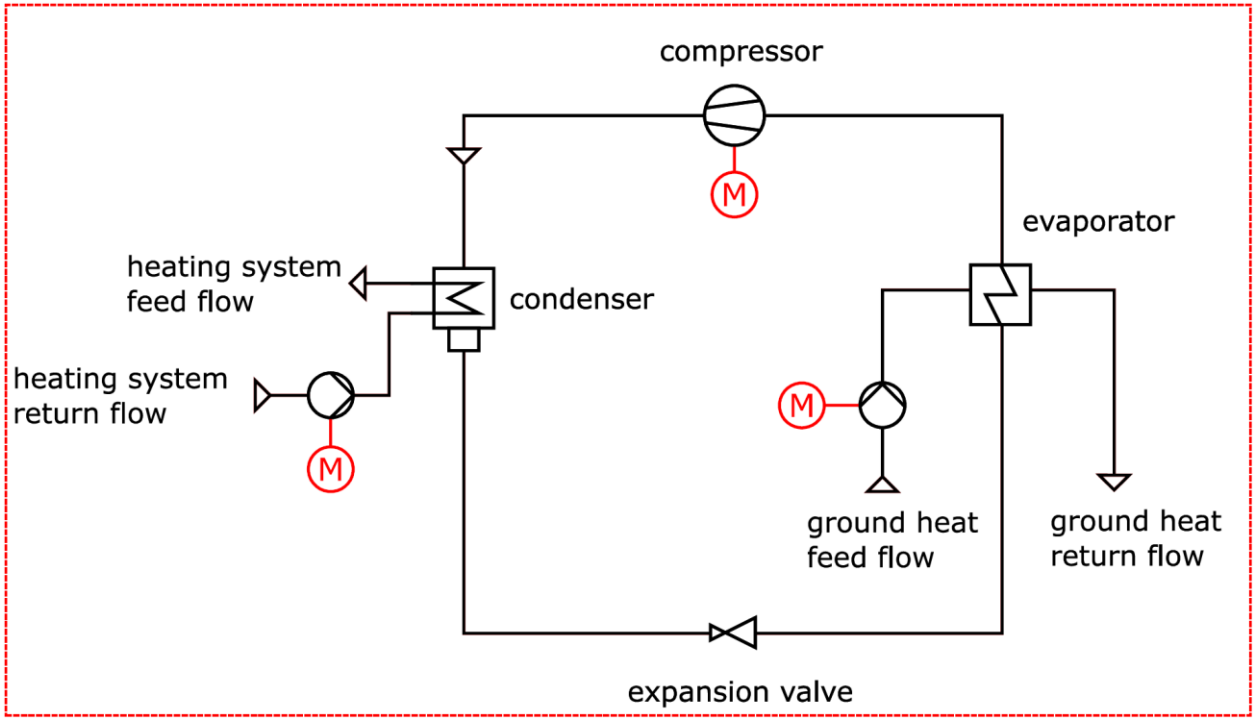
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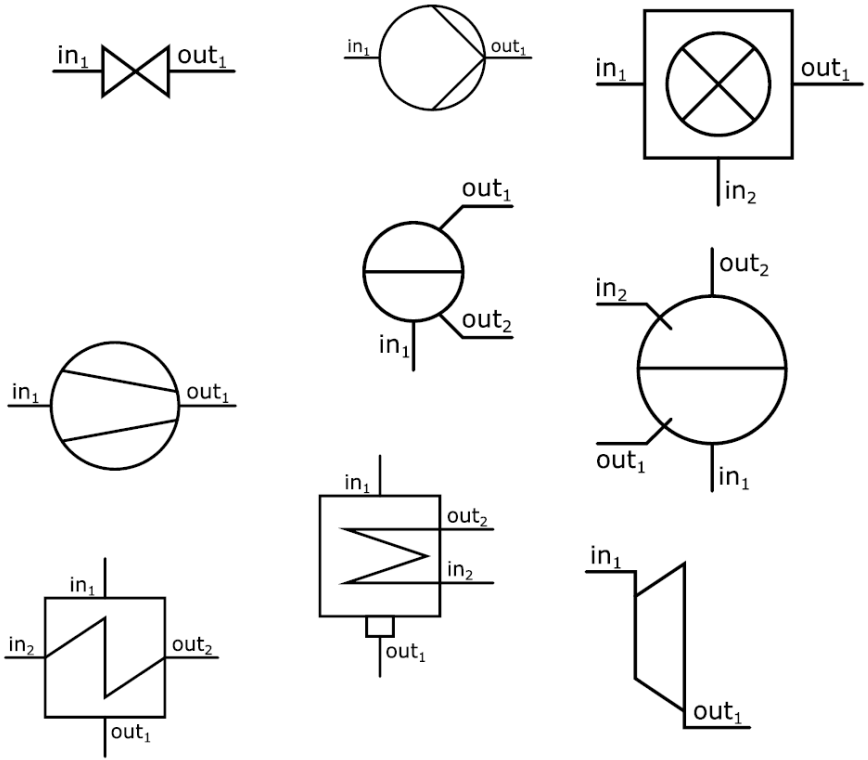



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# Components



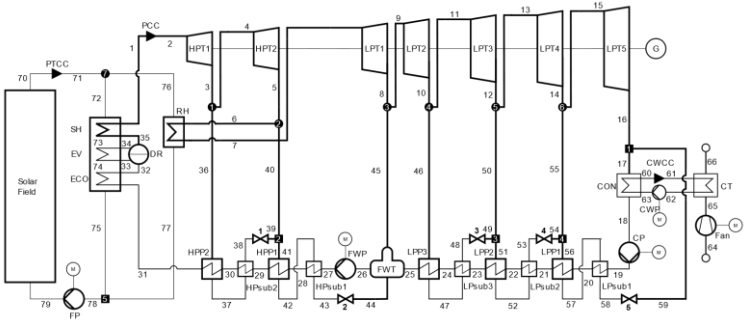
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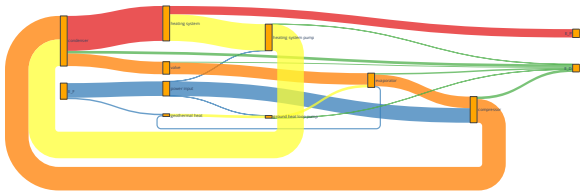

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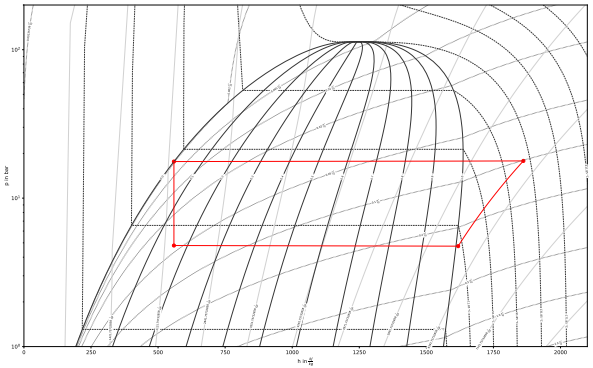
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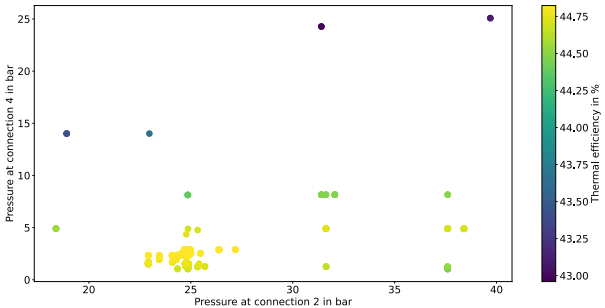

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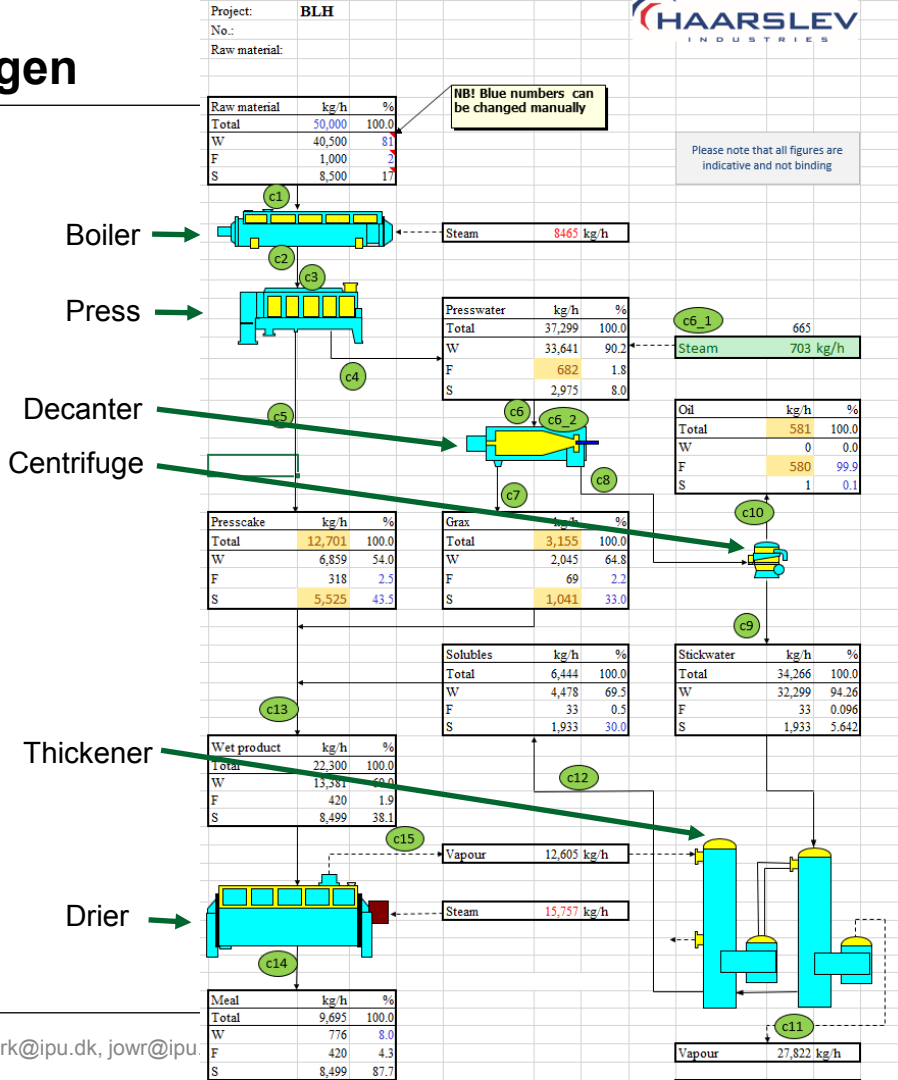



slide contents @ Francesco Witte

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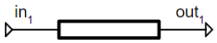
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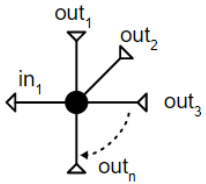
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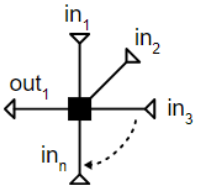
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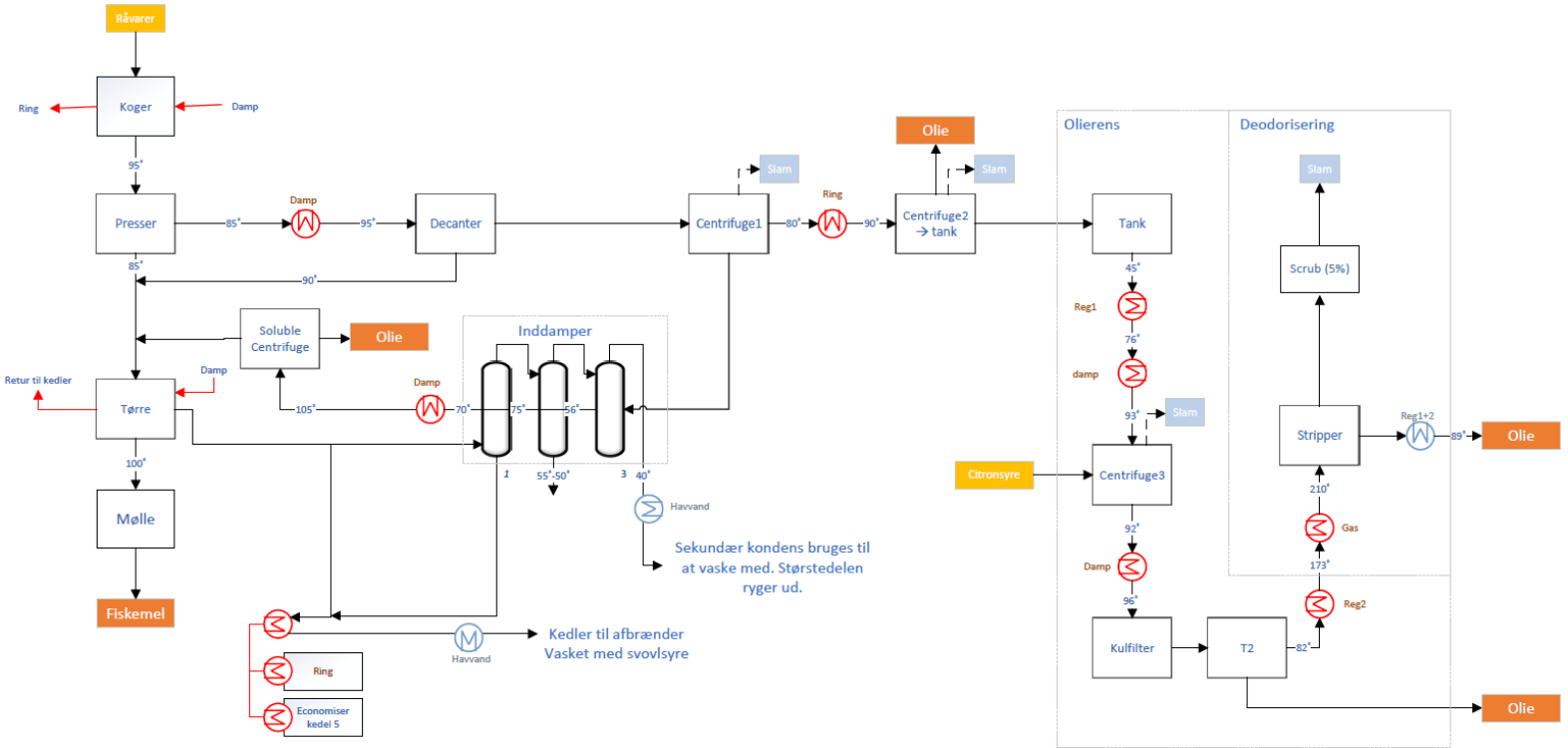



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# Test plant Skagen

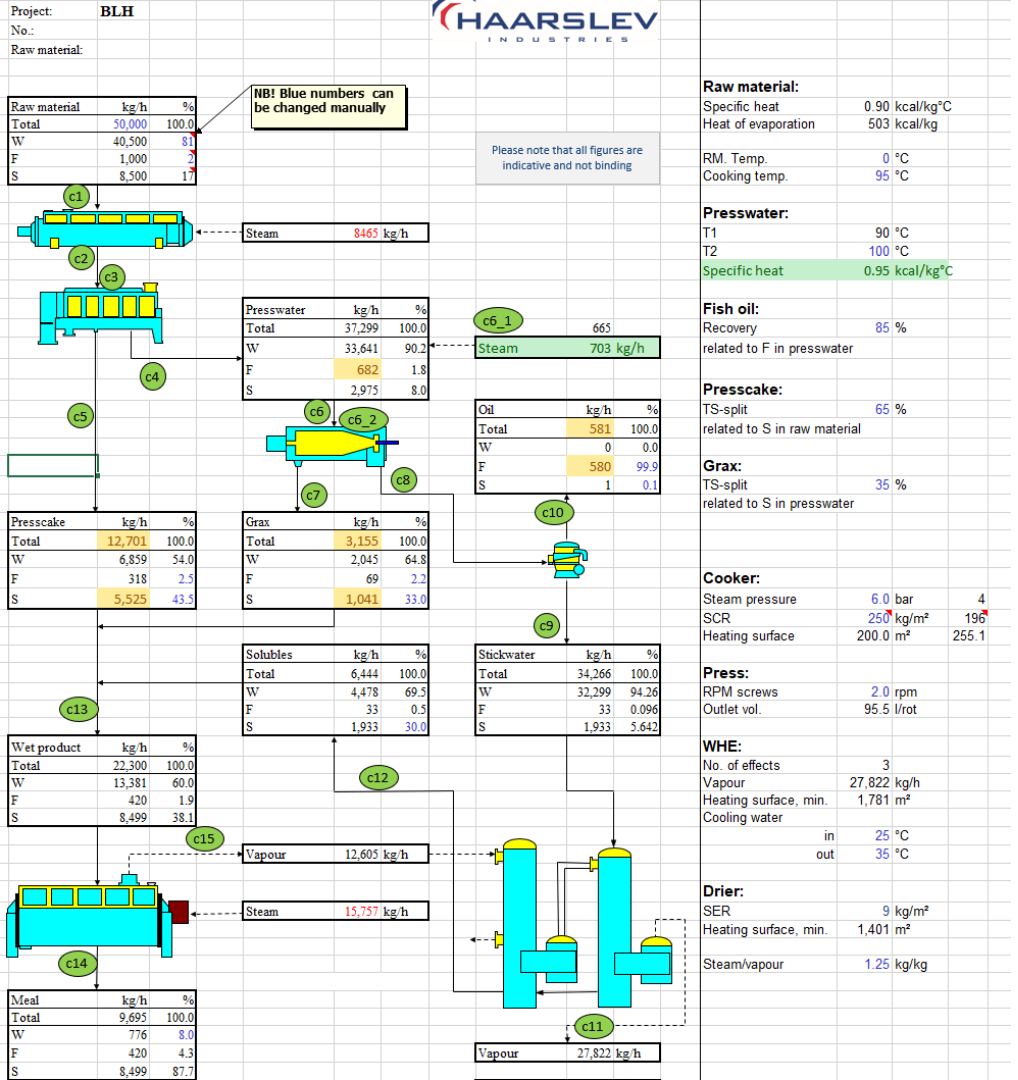
- Need to define necessary components, detail level and inputs



# Skagen plant

- tespy results

| | m | p | h | T | FoodFat | FoodProtein | FoodWater |
|---|---|---|---|---|---|---|---|
| **c1** | 50000 | 1 | -74.6 | 0.0 | 0.020 | 0.170 | 0.810 |
| **c2** | 50000 | 1 | 281.3 | 95.0 | 0.020 | 0.170 | 0.810 |
| **c3** | 50000 | 1 | 262.4 | 90.0 | 0.020 | 0.170 | 0.810 |
| **c4** | 12701 | 1 | 223.2 | 90.0 | 0.025 | 0.435 | 0.540 |
| **c5** | 37299 | 1 | 275.7 | 90.0 | 0.018 | 0.080 | 0.902 |
| **c6** | 37299 | 1 | 315.4 | 100.0 | 0.018 | 0.080 | 0.902 |
| **c6_1** | 703 | 1 | 331.7 | 100.0 | 0.000 | 0.000 | 1.000 |
| **c6_2** | 38002 | 1 | 315.7 | 100.0 | 0.018 | 0.078 | 0.904 |
| **c7** | 3155 | 1 | 273.3 | 100.0 | 0.022 | 0.330 | 0.648 |
| **c7o** | 3155 | 1 | 273.3 | 100.0 | 0.022 | 0.330 | 0.648 |
| **c8** | 34847 | 1 | 319.5 | 100.0 | 0.018 | 0.055 | 0.927 |
| **c9** | 34266 | 1 | 322.2 | 100.0 | 0.001 | 0.056 | 0.943 |
| **c10** | 581 | 1 | 164.2 | 100.0 | 0.999 | 0.001 | 0.000 |
| **c11** | 27822 | 1 | 331.7 | 100.0 | 0.000 | 0.000 | 1.000 |
| **c12** | 6444 | 1 | 281.1 | 100.0 | 0.005 | 0.300 | 0.695 |
| **c12o** | 6444 | 1 | 281.1 | 100.0 | 0.005 | 0.300 | 0.695 |
| **c13** | 22300 | 1 | 247.0 | 94.5 | 0.019 | 0.381 | 0.600 |
| **c14** | 9695 | 1 | 166.7 | 94.5 | 0.043 | 0.877 | 0.080 |
| **c15** | 12605 | 1 | 308.8 | 94.5 | 0.000 | 0.000 | 1.000 |



# IPU recommends

- Use **NodeGraphQt**
  - Basic graphics already in place
  - Need adaption to components and conditions (inputs as required by backend)

- Use **tespy**
  - For short-cutting model development
  - Models need some elaboration but the framework is in place
  - Translation between other backends is also possible, but keeping everything in python is wanted

- Preparation of component specifications for the tool @Viegand Maagøe @DTU




# WIP: Software requirements specification

# Introduction and purpose

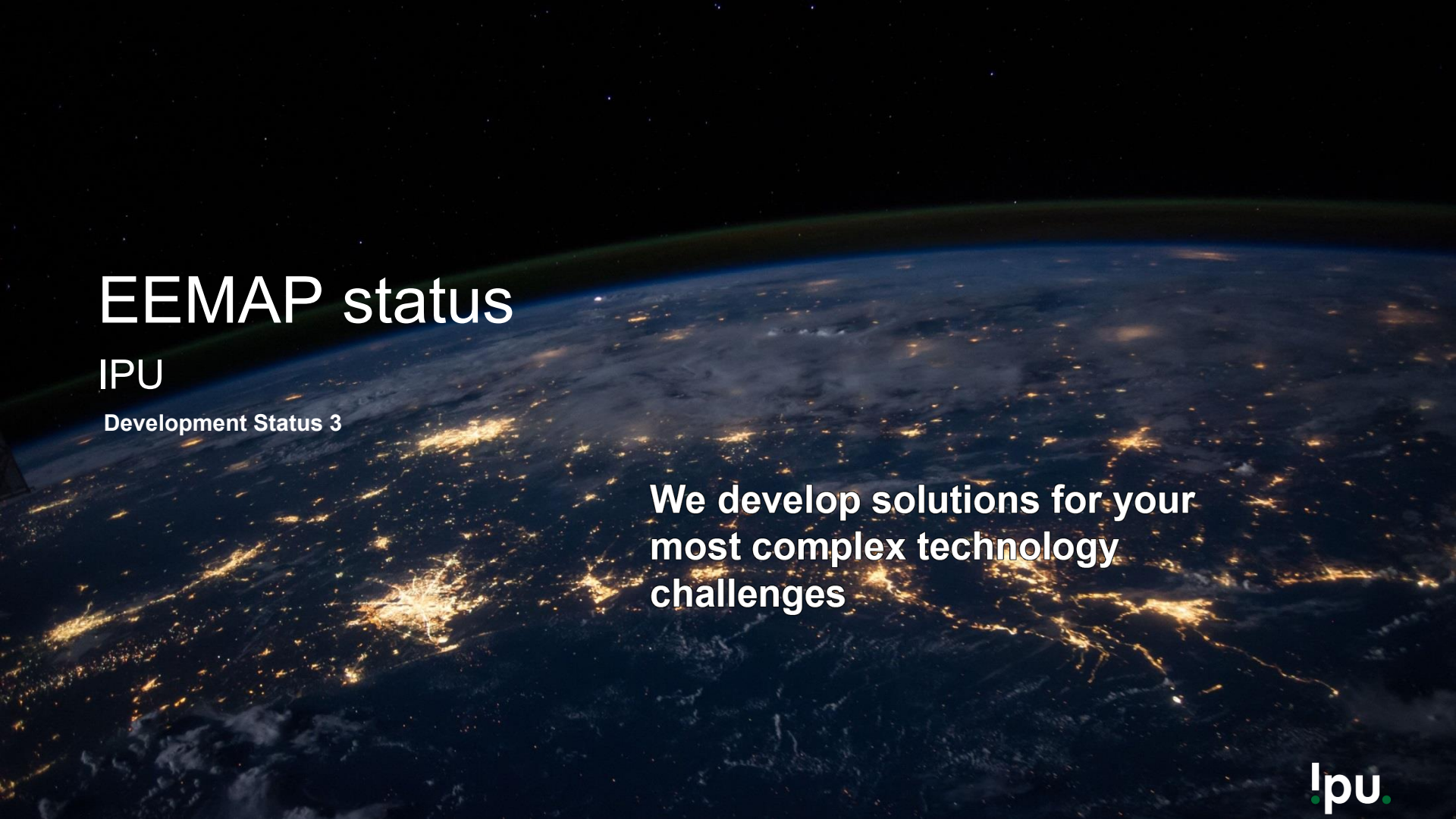
- Intended audience
  - The specification is primarily intended to be used in the core project group.
  - For documentation purposes, parts of the specification may be shared with 3rd parties.
- Intended use
  - We use this document to communicate our intentions and to agree on the details of the development.
  - This document shall also be used as a description of what is NOT going to be created.
- Software scope
  - The software shall help with energy mappings.
- Nomenclature

# Description

- User needs
- Assumptions
- Dependencies

# Features and requirements

- Functional requirements
- External interfaces
- System features
- Non-functional requirements



# EEMAP status

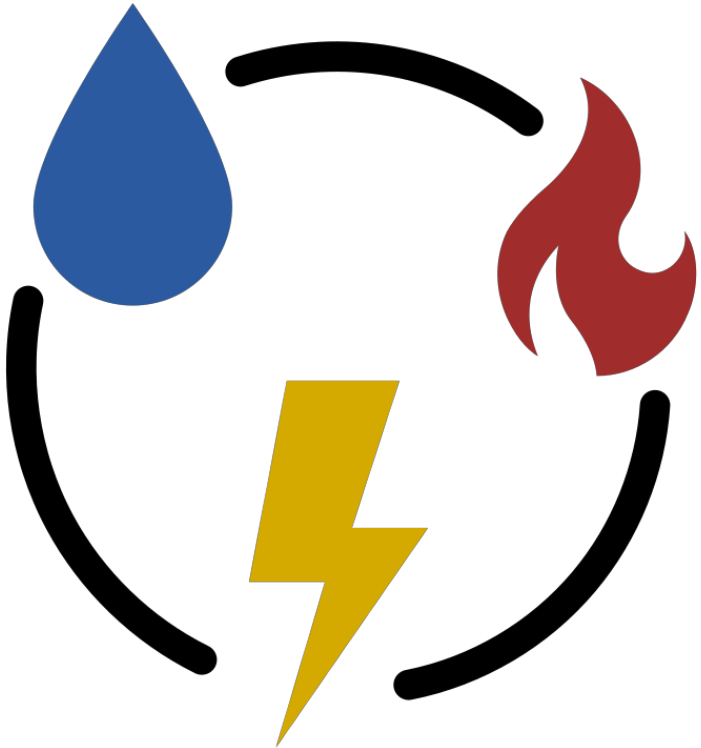
## IPU

**Development Status 3**

**We develop solutions for your most complex technology challenges**

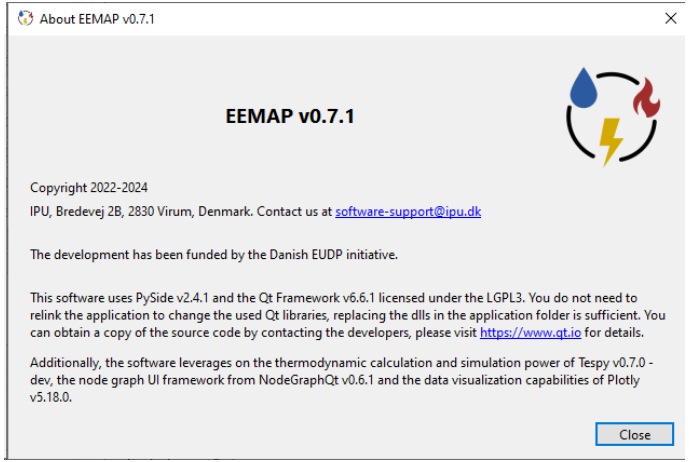
!pu.

# EEMAP Status



# Software tool developed with Qt for python

- QT for python
- NodegraphQt
- Tespy
- Plotly
- Coolprop



# Software architecture

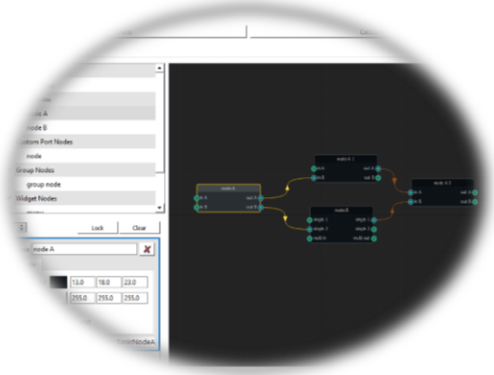
PySide6 (frontend)

## Calculator (backend)

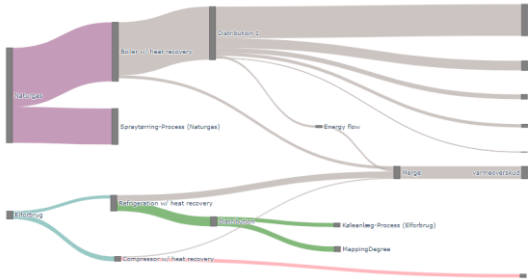
tespy ['tɛs.paɪ]

Coolprop

## NodeGraphQt



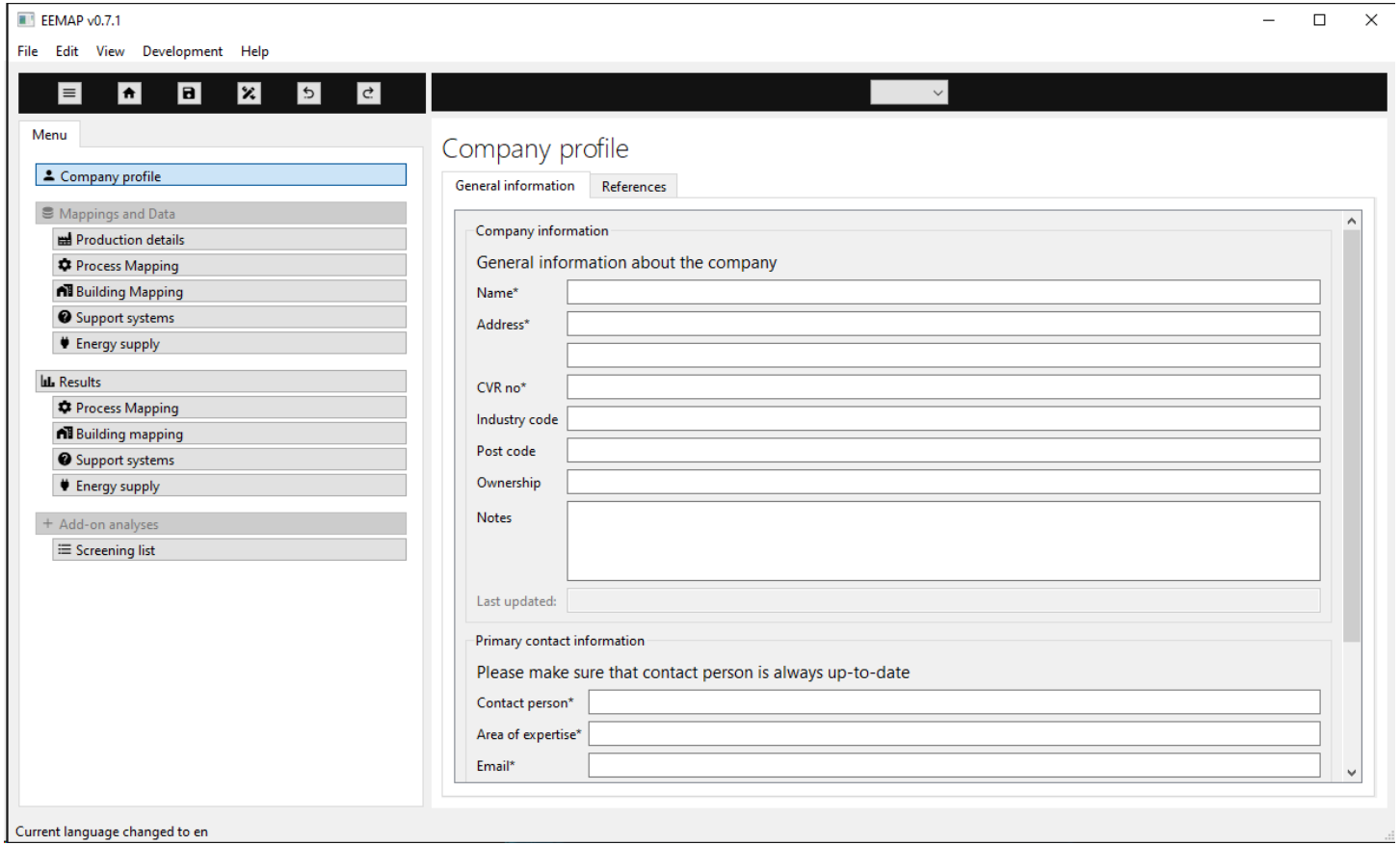
## Plotly



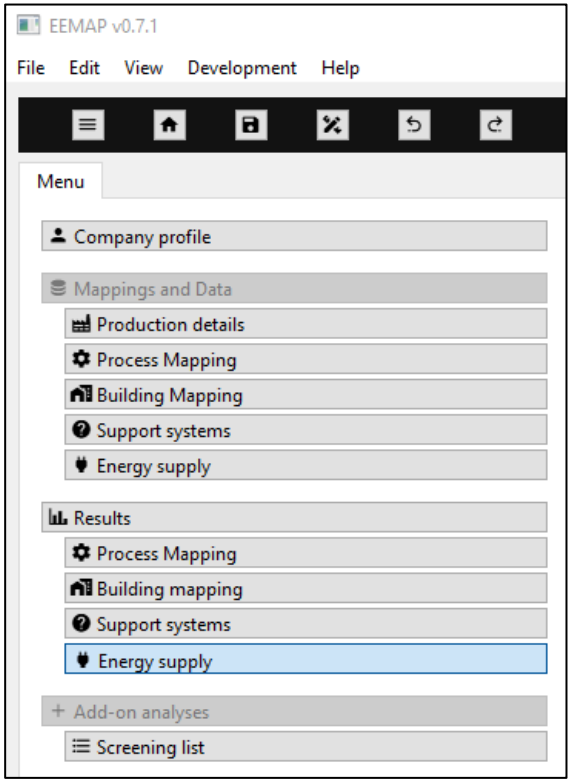
Translation

Visualization

# Overview


EEMAP v0.7.1
File
Edit
View
Development
Help
Menu
Company profile
Mappings and Data
Production details
Process Mapping
Building Mapping
Support systems
Energy supply
Results
Process Mapping
Building mapping
Support systems
Energy supply
Add-on analyses
Screening list
Company profile
General information
References
Company information
General information about the company
Name*
Address*
CVR no*
Industry code
Post code
Ownership
Notes
Last updated:
Primary contact information
Please make sure that contact person is always up-to-date
Contact person*
Area of expertise*
Email*
Current language changed to en

# Overview

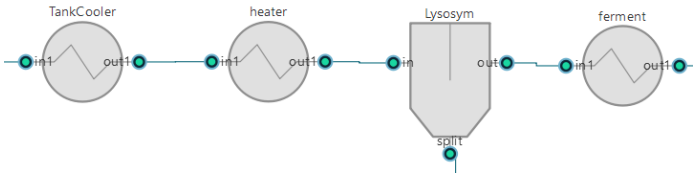



## Company info

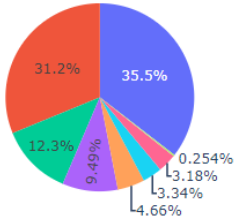
Company References

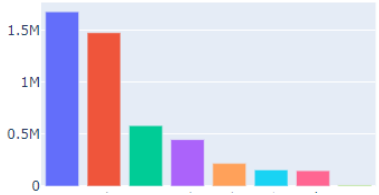
| title | person | date |
|---|---|---|
| Søren | jensen | 2024-03-07 12:18 |
| Peter | nielsen | 2024-01-25 07:36 |
| Torven | Caluse | 2024-01-25 07:36 |

## Mapping detail and calculations




## Results




## Addon analysis



# backup




# tespy

# tespy

- Component based design and part load simulator
  - Steady state
  - Generic architecture
  - Added 6 models
    - Separator with
      - Heat loss
      - S-split
      - F-split
      - Heat bus
      - …

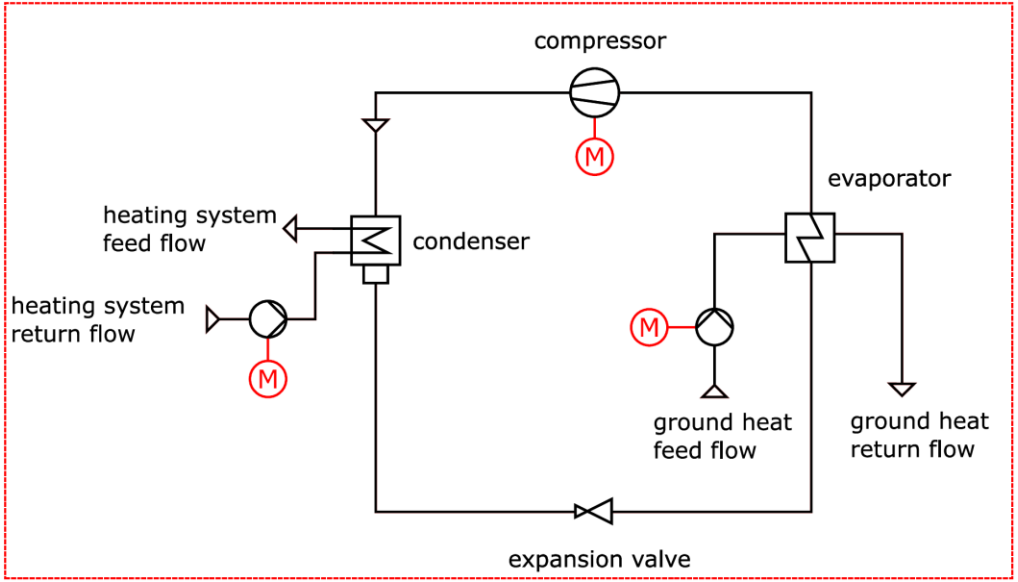
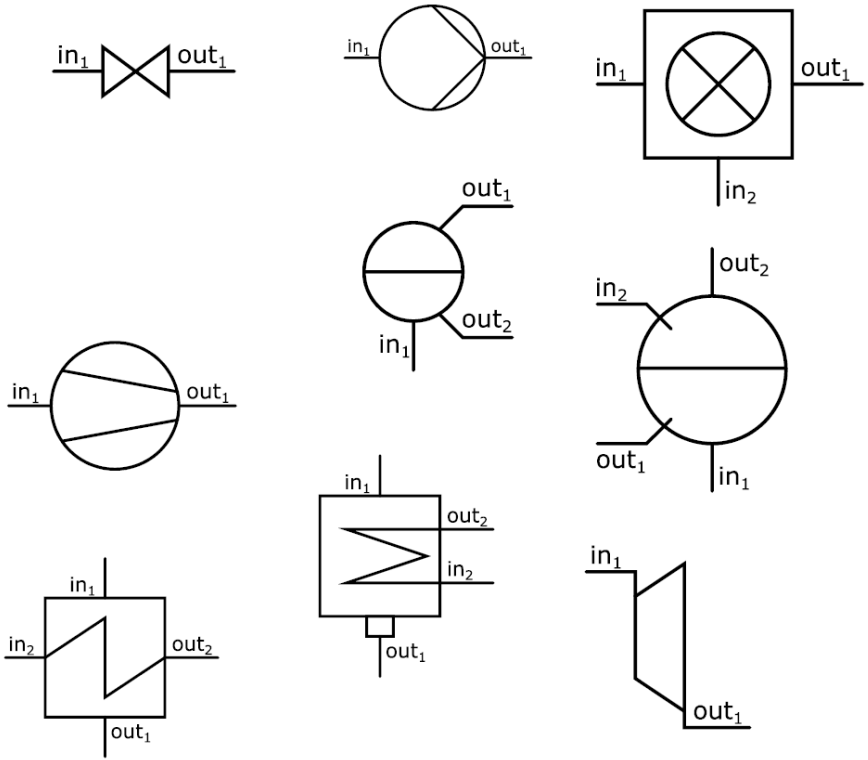



figure by Francesco Witte

# tespy components



- **Basics**
  - Cycle closer
  - Sink
  - Source
  - Subsystem interface
- **Combustion**
  - Combustion chamber
  - Diabatic combustion chamber
  - Combustion engine
- **Heat exchangers**
  - Simplified heat exchanger
  - Solar collector
  - Parabolic trough
  - Heat exchanger
  - Condenser
  - Desuperheater
- **Nodes**
  - Droplet separator
  - Drum
  - Merge
  - Separator
  - Splitter
- **Piping**
  - Pipe
  - Valve
- **Reactors**
  - Fuel cell
  - Water electrolyzer
- **Turbomachinery**
  - Compressor
  - Pump
  - Turbine




slide contents @ Francesco Witte

# Food properties

# Food properties

- ASHRAE Handbook – Refrigeration, Ch 9, Thermal properties of foods



Table 3 Unfrozen Composition Data, Initial Freezing Point, and Specific Heats of Foods* (*Continued*)

| Food Item | Moisture Content, % $x_{wo}$ | Protein, % $x_p$ | Fat, % $x_f$ | Carbohydrate Total, % $x_c$ | Carbohydrate Fiber, % $x_{fb}$ | Ash, % $x_a$ | Initial Freezing Point, °C | Specific Heat Above Freezing, kJ/(kg·K) | Specific Heat Below Freezing kJ/(kg·K) | Latent Heat of Fusion, kJ/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| **Whole Fish** | | | | | | | | | | |
| Cod | 81.22 | 17.81 | 0.67 | 0.0 | 0.0 | 1.16 | –2.2 | 3.78 | 2.14 | 271 |
| Haddock | 79.92 | 18.91 | 0.72 | 0.0 | 0.0 | 1.21 | –2.2 | 3.75 | 2.14 | 267 |
| Halibut | 77.92 | 20.81 | 2.29 | 0.0 | 0.0 | 1.36 | –2.2 | 3.74 | 2.18 | 260 |
| Herring, kippered | 59.70 | 24.58 | 12.37 | 0.0 | 0.0 | 1.94 | –2.2 | 3.26 | 2.27 | 199 |
| Mackerel, Atlantic | 63.55 | 18.60 | 13.89 | 0.0 | 0.0 | 1.35 | –2.2 | 3.33 | 2.23 | 212 |
| Perch | 78.70 | 18.62 | 1.63 | 0.0 | 0.0 | 1.20 | –2.2 | 3.71 | 2.15 | 263 |
| Pollock, Atlantic | 78.18 | 19.44 | 0.98 | 0.0 | 0.0 | 1.41 | –2.2 | 3.70 | 2.15 | 261 |
| Salmon, pink | 76.35 | 19.94 | 3.45 | 0.0 | 0.0 | 1.22 | –2.2 | 3.68 | 2.17 | 255 |
| Tuna, bluefin | 68.09 | 23.33 | 4.90 | 0.0 | 0.0 | 1.18 | –2.2 | 3.43 | 2.19 | 227 |
| Whiting | 80.27 | 18.31 | 1.31 | 0.0 | 0.0 | 1.30 | –2.2 | 3.77 | 2.15 | 268 |
| **Shellfish** | | | | | | | | | | |
| Clams | 81.82 | 12.77 | 0.97 | 2.57 | 0.0 | 1.87 | –2.2 | 3.76 | 2.13 | 273 |
| Lobster, American | 76.76 | 18.80 | 0.90 | 0.50 | 0.0 | 2.20 | –2.2 | 3.64 | 2.15 | 256 |
| Oysters | 85.16 | 7.05 | 2.46 | 3.91 | 0.0 | 1.42 | –2.2 | 3.83 | 2.12 | 284 |
| Scallop, meat | 78.57 | 16.78 | 0.76 | 2.36 | 0.0 | 1.53 | –2.2 | 3.71 | 2.15 | 262 |
| Shrimp | 75.86 | 20.31 | 1.73 | 0.91 | 0.0 | 1.20 | –2.2 | 3.65 | 2.16 | 253 |

# EEMAP Documentation

**Projekt:**

**Emne:**

**Dato:** **01-07-2024**

**Til:**

**Kopi til:**

**Fra:**

## 1 Introduction

The following catalogue will contain a description of a list of different components available in EEMAP to represent the process industry. The catalogue is not an exhaustive list of all existing process equipment but will cover the necessary unit operations needed for mapping the energy consumption of the main consumers. The tool was developed based on mapping production companies in general but was tested and developed in close relation to 6 different production companies. Furthermore, the catalogue will also cover energy consumption resulting from other energy consumers in the company. The energy consuming components have been divided into 4 categories:

- Process
- Building
- Support systems
- Energy supply

Each component in the catalogue will be shortly described and their use and integration in EEMAP is documented. The general principles of calculating the energy and mass balance over each component is described. This catalogue should be seen as a detailed documentation of the components available in EEMAP for mapping purposes, how they can be used and what inputs they have.

# 2 Components overview

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# 3 EEMAP components

EEMAP works on a component level. Each component can represent a subdivision of a unit operation or an entire section of machinery, depending on the detail level of the model. Just as the detail level of the model is adjustable so are the detail level of the data in each component. This can either be a static electricity or thermal energy consumption, a KPI for energy per kg of product flowing through the component or a temperature of the product exiting the component.

The final results will only be as accurate as the data provided to the program. The nature of the program working through robust thermodynamic calculations means that further uncertainty is not introduced.

# 4 Mass balance

Mass balance is not described in general terms as it is individual for each component how this is defined. For all components a simple conservation of mass is always present, and all waste streams are quantified and present in the program. This is ensured as all waste streams must go to a sink component.

# 5 Thermal energy balance

To determine the thermal energy balance different approaches are considered. For a component an outlet temperature might be known, a set KPI of energy usage per product through the component or a set heat flow into the component. For each of these the resulting state of the product or resulting heat flow of the product is determined.

First the approach with a fixed outlet temperature is considered. For this a simple example of a generic heat exchanger is used where a stream of product, $\dot{m}$, is heated from its initial temperature, $T_{in}$, to its outlet temperature, $T_{out}$. For the system to be properly defined the inlet temperature of this component must be defined, either in the previous process component or in the source this heat exchanger is connected to. Furthermore, the mass flow is defined from the mass balance that is defined before any thermal energy balance can be run in EEMAP.
With this the thermal energy balance of the component is expressed as follows:

$$\dot{Q} = \dot{m} \cdot c_p \cdot (T_{out} - T_{in})$$

From this thermal energy balance the KPI of the components, here considered to be in units of energy pr. Mass, can be determined:

$$KPI = \frac{\dot{Q}}{\dot{m}}$$

Next approach is the set KPI of the component, $KPI$, here considered to be in units of energy pr. Mass. As previously stated, the mass flow and initial temperature of the product are both known. As such the following sets of equations allows the heat flow to the component and temperature of the product out of the component to be determined:

$$\dot{Q} = \dot{m} \cdot KPI$$
$$T_{out} = \frac{\dot{Q}}{\dot{m} \cdot c_p} + T_{in}$$

Finally, the approach with a fixed heat flow into the component is considered. With this approach the KPI and temperature out of the component can both be determined directly:

$$KPI = \frac{\dot{Q}}{\dot{m}}$$
$$T_{out} = \frac{\dot{Q}}{\dot{m} \cdot c_p} + T_{in}$$

For the individual components these thermal energy balances are employed, for components with multiple streams the principles are the same but applied to each individual stream.

# 6 Electrical consumption

Process components have the electrical consumption determined through the following variables:

1. **Fixed:** A fixed electricity consumption, set as energy over time in the preselected units of energy and time. For example, kWh/y.
2. **Mass flow KPI:** A KPI set for the electricity consumption based off the mass flow through the component. Defined as energy per mass flow with the preselected units of energy, mass and time. For example, kWh/t.
3. **Energy flow KPI:** A KPI set for the electricity consumption based off the thermal energy flow in the component. For example, kWh/kWh.

Not all components have all three variables for defining electricity consumption. Since the electricity consumption is handled the same for all components across the different mappings the individual components will not have documentation relating to defining the electrical consumption.

# 7 Process

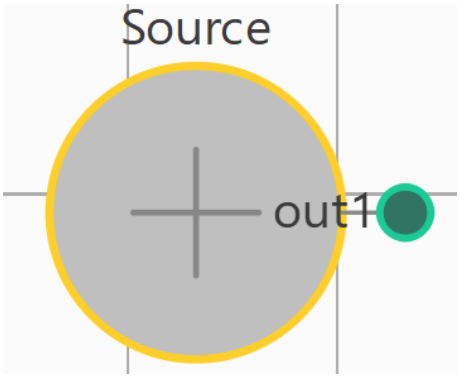
The components used in the process mapping are described individually. The section is ordered the same as in EEMAPs component menu. Only components with a connection to the product flow is included.

## 7.1 Source

The source component is necessary to model in EEMAP and at least one must be present in all process mappings. The source component creates a stream which exits the component through the “out1” outlet. The component has the following variables:

1. **Mass flow:** Mass flow of the media exiting the source
2. **Temperature:** Temperature of the media exiting the source
3. **Media:** Concentrations of the media exiting the source

The media must be fully defined by having several media fractions adding up to 1. The temperature cannot be set to 0 or an error will occur.

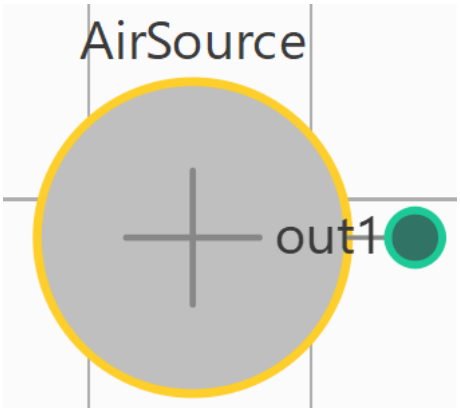



## 7.2 Air source

The air source is used to introduce a moist air stream. Only the two-stream drier considers moist air properties in terms of evaporation. The component has a single outlet. The component has the following variables:

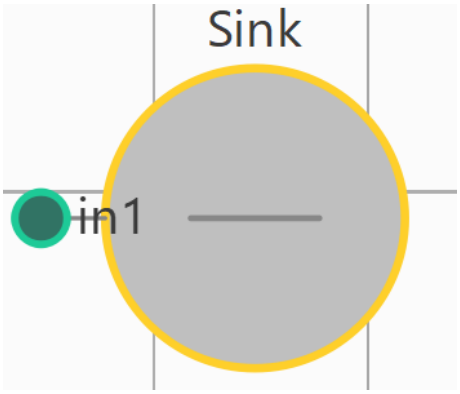
1. **Mass flow:** The mass flow of the moist air

2. **Temperature:** The temperature of the moist air
3. **Relative humidity:** The relative humidity of the moist air, the value is a decimal number where 1 is 100%




## 7.3 Sink

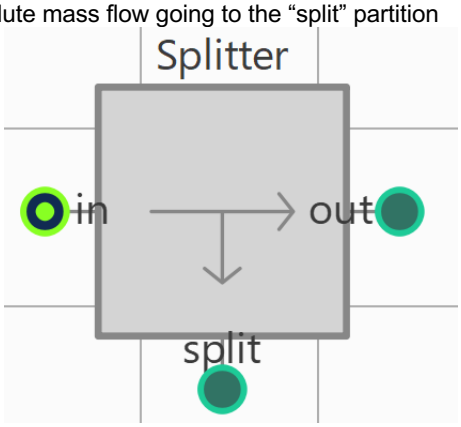
The sink component is necessary to model in EEMAP and at least one must be present in all process mappings. The sink has one inlet, and it collects the stream going into the component. It is used as an end of a product line or an exit of the process for waste product. The component in theory allows for the media concentration to be manipulated and defined, however this is not advised.




## 7.4 Splitter

The splitter component splits a stream into an “out” partition and a “split” partition. The component has the following variables:

1. **Mass split**: The fraction of the mass flow into the component going to the “split” partition
2. **Mass flow**: The absolute mass flow going to the “split” partition



### 7.4.1 Mass balance

One of the two variables must be defined in the component to solve the mass balance. The splitter is a relatively simple component so only one input is required.

### 7.4.2 Thermal energy balance

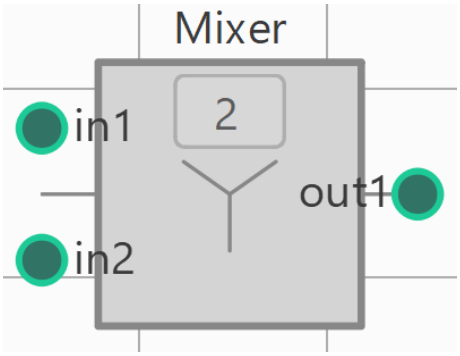
A splitter contains no thermal energy balance beyond the thermal energy balance achieved from the mass balance found over the component.

## 7.5 Mixer

The mixer component mixes the streams going into the component to one stream going out of the component. The component has the following variable:

1. **num_in**: Number of streams to be mixed in the component

It should be noted that the variable is defined on the graphic of the component and not available in the component menu to the left.




### 7.5.1 Mass balance

The number of streams going into the component must be defined, it is set to 2 by default. By connecting streams to all inputs, the component will be defined.

### 7.5.2 Thermal energy balance

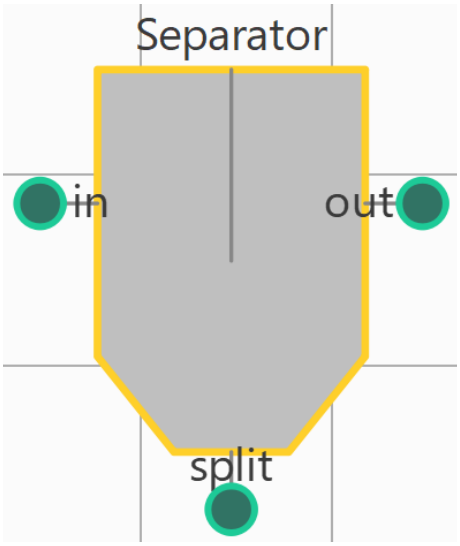
A mixer contains no thermal energy balance beyond the thermal energy balance achieved from the mass balance found over the component.

## 7.6 Separator

The separator component splits a stream into an “out” partition and a “split” partition. The component has the following variables:

1. **Mass split**: The fraction of the mass flow into the component going to the “split” partition
2. **Mass flow**: The absolute mass flow going to the “split” partition
3. **Media split**: The media concentrations for the “split” partition
4. **Media out**: The media concentrations for the "out” partition
5. **Outlet temperature**: The temperature out of the component for both “out” and "split" partitions

To define the flow out of the component either the mass split or mass flow variables must be defined, only one or the other can be defined.
For a media consisting of only one media-component (e.g. water, food protein, etc.) the separator cannot be used. Instead, a splitter component should be utilized.




### 7.6.1 Mass balance

For the separator component to be defined the mass flow equations must have enough inputs to solve. If the mass flow or mass split is known this should be one of the inputs. Beyond this media concentrations must be defined.

The concentrations of either the “out” or “split” partition must be fully defined, meaning that a value is specified for the concentration of all media-components in one of the streams.

One additional input is required, and either the mass split or flow can be supplied to determine the mass flow. Alternatively, one concentration can be supplied to the partition that has not yet been fully defined. Defining only concentrations is possible with the separator, but this can lead to non-converging systems.

### 7.6.2 Thermal energy balance

To determine the thermal energy balance of the separator the outlet temperature is given for the component. This temperature is the same for both the “split” and “out”.

## 7.7 Press

The press component splits a stream into a “liquid” partition and a “cake” partition. The component has the following variables:

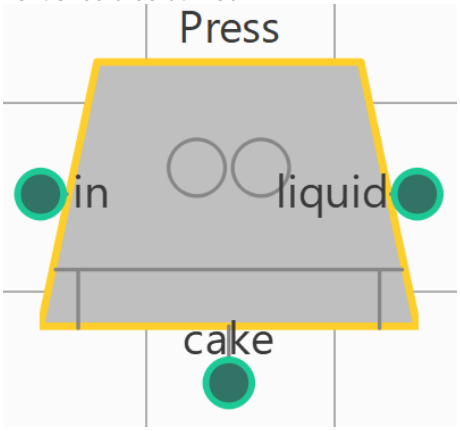
1. Media split:
    a. **Value**: The mass flow of the media-component chosen below going to the “cake” partition expressed as a fraction of the total mass flow into the component.
    It is important to note that this is not the total mass flow to the “cake” partition, this is discussed further in the mass balance section of the component.
    b. **Media**: The media-component for which a mass flow is defined

2. Mass flow:
    a. **Value**: The absolute mass flow of the media-component defined below going to the “cake” partition.
    It is important to note that this is not the total mass flow to the “cake” partition, this is discussed further in the mass balance section of the component.
    b. **Media**: The concentrations of the media going to the “cake” partition

3. **Media cake**: The media concentrations for the “cake” partition

4. **Outlet temperature**: Temperature out of the component for both “liquid” and “cake” partitions

To define the flow out of the component either the mass split or mass flow variables must be defined, only one or the other can be defined.
For a media consisting of only one media-component (e.g. water, food protein, etc.) the press cannot be used. Instead, a splitter component should be utilized.




### 7.7.1 Mass balance

For the press component to be defined the mass flow equations must have enough inputs to solve.
To determine the overall mass flow distribution between the “liquid” and “cake” partitions, along with the media concentrations, either the mass flow variables or the mass split variables must be defined. Only one of the two sets of variables can be defined at a time.

Both sets of variables will define the mass flow of a single media-component to the “cake” partition, along with the media concentrations for the cake the total mass flow can be determined. The remaining mass flow is then directed to the “liquid” partition with the resulting media concentrations as an output.

For the mass split variables, it is important to remember that the mass flow being defined is dependent on the total mass flow into the component, but only defines the mass flow of a specific media-component to the “cake” partition.
The same is true for the mass value variables, however, here a fixed value for the mass flow of a specific media-component is given instead.

The “Media” variable defines the media-component, for which a mass flow is defined, is chosen.

### 7.7.2 Thermal energy balance

To determine the thermal energy balance of the press the outlet temperature is given for the component. This temperature is the same for both the “cake” and “liquid”.

## 7.8 Decanter

The decanter component splits a stream into a “liquid” partition and a “grax” partition. The component has the following variables:

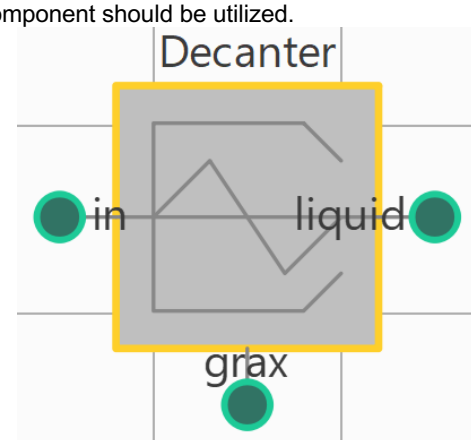
1. Media split:
    a. **Value**: The mass flow of the media-component chosen below going to the “grax” partition expressed as a fraction of the total mass flow into the component.
    It is important to note that this is not the total mass flow to the “grax” partition, this is discussed further in the mass balance section of the component.

b. **Media**: The media-component for which a mass flow is defined

2. Mass flow:
    a. **Value**: The absolute mass flow of the media-component defined below going to the "grax" partition.
    It is important to note that this is not the total mass flow to the "grax" partition, this is discussed further in the mass balance section of the component.
    b. **Media**: The concentrations of the media going to the "grax" partition

3. **Media grax**: The media concentrations for the "grax" partition
4. **Outlet temperature**: Temperature out of the component for both "liquid" and "grax" partitions

To define the flow out of the component either the mass split or mass flow variables must be defined, only one or the other can be defined.
For a media consisting of only one media-component (e.g. water, food protein, etc.) the decanter cannot be used. Instead, a splitter component should be utilized.




### 7.8.1 Mass balance

For the decanter component to be defined the mass flow equations must have enough inputs to solve. To determine the overall mass flow distribution between the "liquid" and "grax" partitions, along with the media concentrations, either the mass flow variables or the mass split variables must be defined. Only one of the two sets of variables can be defined at a time.

Both sets of variables will define the mass flow of a single media-component to the "grax" partition, along with the media concentrations for the grax the total mass flow can be determined. The remaining mass flow is then directed to the "liquid" partition with the resulting media concentrations as an output.

For the mass split variables, it is important to remember that the mass flow being defined is dependent on the total mass flow into the component, but only defines the mass flow of a specific media-component to the "grax" partition.
The same is true for the mass value variables, however, here a fixed value for the mass flow of a specific media-component is given instead.

The "Media" variable defines the media-component, for which a mass flow is defined, is chosen.

### 7.8.2 Thermal energy balance

To determine the thermal energy balance of the decanter the outlet temperature is given for the component. This temperature is the same for both the "grax" and "liquid".

## 7.9 Centrifuge

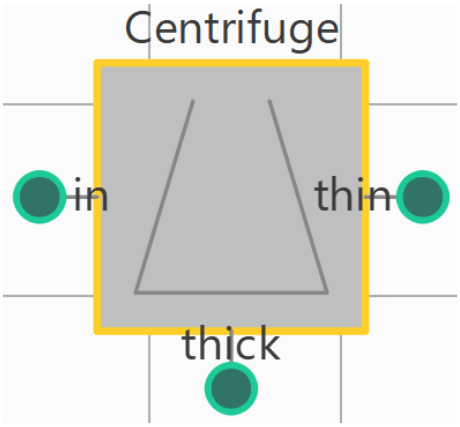
The centrifuge component splits a stream into a “thin” partition and a “thick” partition. The component has the following variables:

1. Media split:
    a. **Value:** The mass flow of the media-component chosen below going to the “thick” partition expressed as a fraction of the total mass flow into the component.
    It is important to note that this is not the total mass flow to the “thick” partition, this is discussed further in the mass balance section of the component.
    b. **Media:** The media-component for which a mass flow is defined

2. Mass flow:
    a. **Value:** The absolute mass flow of the media-component defined below going to the “thick” partition.
    It is important to note that this is not the total mass flow to the “thick” partition, this is discussed further in the mass balance section of the component.
    b. **Media:** The concentrations of the media going to the “thick” partition

3. **Media thick:** The media concentrations for the “thick” partition
4. **Outlet temperature:** Temperature out of the component for both “thin” and “thick” partitions

To define the flow out of the component either the mass split or mass flow variables must be defined, only one or the other can be defined.
For a media consisting of only one media-component (water, food protein, etc.) the centrifuge cannot be used. Instead, a splitter component should be utilized.




### 7.9.1 Mass balance

For the centrifuge component to be defined the mass flow equations must have enough inputs to solve. To determine the overall mass flow distribution between the “thin” and “thick” partitions, along with the media concentrations, either the mass flow variables or the mass split variables must be defined. Only one of the two sets of variables can be defined at a time.

Both sets of variables will define the mass flow of a single media-component to the “thick” partition, along with the media concentrations for the thick the total mass flow can be determined. The remaining mass flow is then directed to the “thin” partition with the resulting media concentrations as an output.

For the mass split variables, it is important to remember that the mass flow being defined is dependent on the total mass flow into the component, but only defines the mass flow of a specific media-component to the “thick” partition.
The same is true for the mass value variables, however, here a fixed value for the mass flow of a specific media-component is given instead.

The “Media” variable defines the media-component, for which a mass flow is defined, is chosen.

### 7.9.2 Thermal energy balance

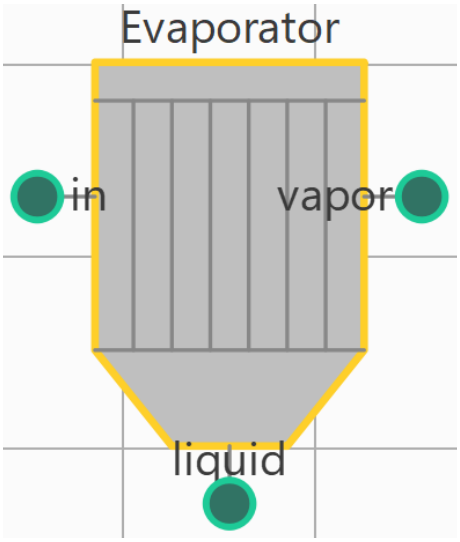
To determine the thermal energy balance of the centrifuge the outlet temperature is given for the component. This temperature is the same for both the “thick” and “thin”.

## 7.10 Evaporator

The evaporator component splits a stream into a “vapor” partition and a “liquid” partition. The component has the following variables:

1. **Media liquid:** The media concentrations for the “liquid” partition
2. **Outlet temperature:** The temperature out of the component for both partitions
3. **Vaporized media:** The media that will evaporate and exit the component through the “vapor” partition

Vaporized media must always be defined.




### 7.10.1 Mass balance

To define the mass flow out of the component the variable “media liquid” must be set. However, as the media-components of the “vapor” partition is always set to be exclusively the vaporized media only one of the media-components can be defined. As only the vaporized media is removed the ratio between the other potential media-components will be constant, and as such defining one of the media components the rest will naturally follow. With all media-components apart from water defined it will simply be the residual.

### 7.10.2 Thermal energy balance

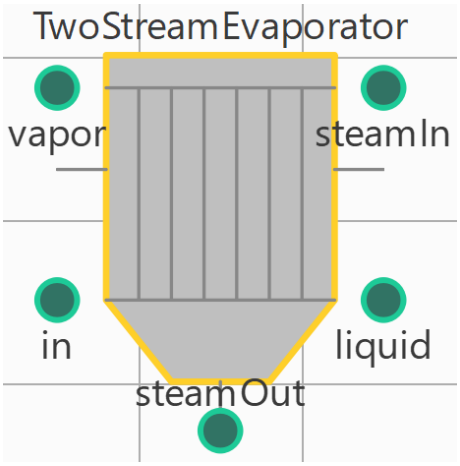
The thermal energy balance of the evaporator is determined by the outlet temperature provided. From this it is possible to determine the amount of energy required to heat the “liquid” partition to this temperature. Likewise, the amount of energy required to evaporate the “vapor” partition and having that stream exit at the same temperature.

## 7.11 Two Stream Evaporator

The two-stream evaporator has two inlet streams being “in” and “steamIn”, respectively for the product going into the component and the steam supplied to the component. The component has the mass flow of “steamIn” go to “steamOut”, this stream provides the thermal energy for the component. The component splits the “in”-stream into a “liquid” partition and a “vapor” partition. The component has the following variables:

1. **Media liquid:** The media concentrations for the “liquid” partition
2. **Evap. Temp.:** The temperature the evaporation in the component
3. **Steam quality:** Steam quality of the “steamOut“ partition
4. **Heat flow rate:** The absolute heat flow of the component
5. **Kpi (m_water):** The energy required to evaporate a given mass of water
6. **UA-value:** The UA-value, denoting the heat transfer pr. Degree of temperature difference
7. **Vaporized media:** The media that will evaporate and exit the component through the “vapor” partition

Vaporized media must always be defined.




### 7.11.1 Mass balance

To define the mass flow out of the component the variable “media liquid” must be set. However, as the media-components of the “vapor” partition is always set to be exclusively the vaporized media only one of the media-components can be defined. As only the vaporized media is removed the ratio between the other potential media-components will be constant, and as such defining one of the media components the rest will naturally follow. With all media-components apart from water defined it will simply be the re-sidual.

### 7.11.2 Thermal energy balance

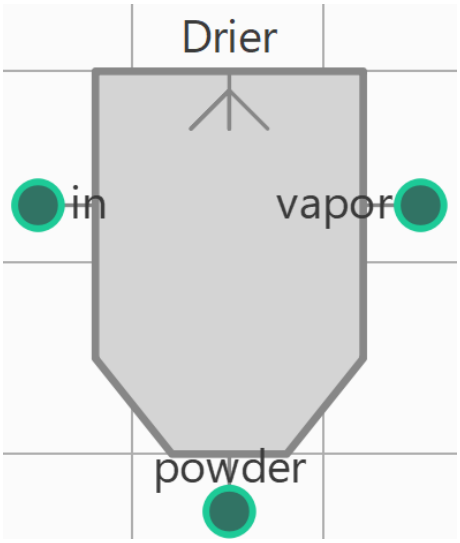
The thermal energy balance of the two-stream evaporator is determined by one of the variables 2-6 provided. When solving for the energy balance it is also possible to have the mass balance result from any combination of two of the variables 1-6.

## 7.12 Drier

The drier component splits a stream into a “vapor” partition and a “powder” partition. The component has the following variables:

1. **Media powder:** The media concentrations for the “powder” partition
2. **Outlet temperature:** The temperature out of the component for both partitions
3. **Vaporized media:** The media that will evaporate and exit the component through the “vapor” partition

Vaporized media must always be defined.




### 7.12.1 Mass balance

To define the mass flow out of the component the variable “media powder” must be set. However, as the media-components of the “vapor” partition is always set to be exclusively the vaporized media only one of the media-components can be defined. As only the vaporized media is removed the ratio between the other potential media-components will be constant, and as such defining one of the media components the rest will naturally follow. With all media-components apart from water defined it will simply be the residual.

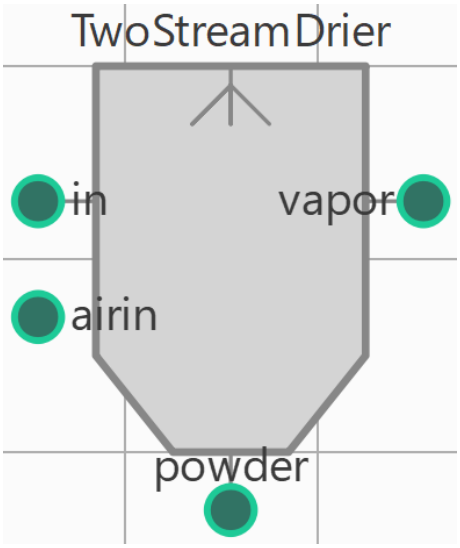
### 7.12.2 Thermal energy balance

The thermal energy balance of the drier is determined by the outlet temperature provided. From this it is possible to determine the amount of energy required to heat the “powder” partition to this temperature. Likewise, the amount of energy required to evaporate the “vapor” partition and having that stream exit at the same temperature.

## 7.13 Two Stream Drier

The two-stream drier has two inlet streams being “airIn” and “in”. The component splits the two inlet streams into a “vapor” partition and a “powder” partition. The “airIn” stream all ends up in the “vapor” partition and the “in” stream is distributed between the “vapor” and “powder” partitions. The component has the following variables:

1. **Media vapor:** The media concentrations for the “vapor” partition
2. **Media powder:** The media concentrations for the “powder” partition
3. **Air temp. out:** The temperature of the “vapor” partition
4. **Heat flow rate:** The absolute heat flow of the component
5. **Kpi (m_water):** The energy required to evaporate a given mass of water
6. **UA-value:** The UA-value, denoting the heat transfer pr. Degree of temperature difference
7. **Wetbulb eff.:** The wet bulb efficiency of the drying, denoting the degree to which the theoretical maximum evaporation to the air occurs




### 7.13.1 Mass balance

The mass balance is defined through fully defining the “media vapor” partition or the “media powder” partition.

### 7.13.2 Thermal energy balance

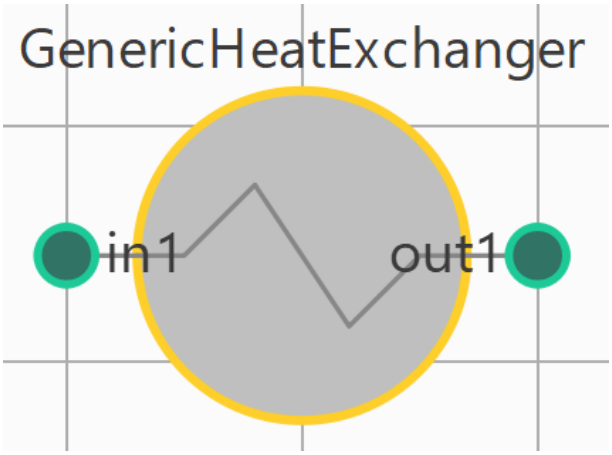
The thermal energy balance arises directly from the mass balance. This is the case as the distribution of the mass from the “in” stream into the two partitions defines how much will be evaporated. This in turn defines the thermal energy balance of the component.

For the thermal energy balance the component can also be defined using variables 3-7. It should be noted that invalid combinations of the variables and media compositions can easily occur as the drier component works with moist air calculations. Therefore, this component must be defined very carefully as to not violate physical properties of moist air.

## 7.14 Generic Heat Exchanger

The generic heat exchanger has a single input and output. The component has the following variables:

1. **Heat flow rate:** The absolute heat flow of the component
2. **Kpi:** A thermal energy KPI determining the energy flow on a basis of mass flow through the component
3. **Outlet temperature:** The temperature out of the component. The stream out of the heat exchanger can be defined to be in liquid or vapor phase.




### 7.14.1 Mass balance

As the component only has one inlet and one outlet the mass balance is trivial, and nothing must be defined for the component.

### 7.14.2 Thermal energy balance

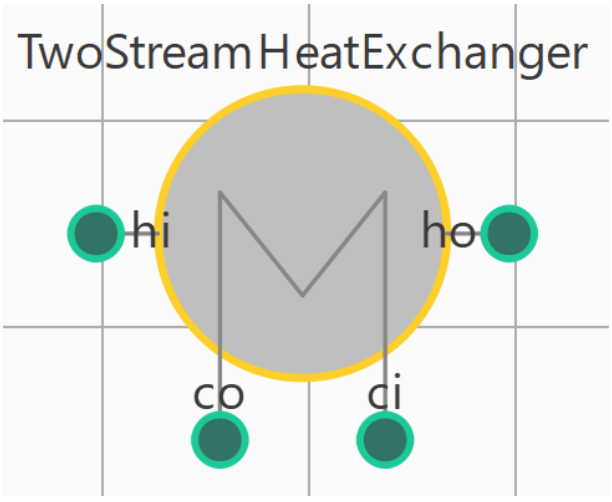
The thermal energy balance is defined by one of the three variables. Only one can be chosen at a time.

## 7.15 Two Stream Heat Exchanger

The two stream heat exchanger has two inlets, “hi” and “ci”, and two outlets, “ho” and “co”. The component has the following variables:

1. **Heat flow rate:** The absolute heat flow of the component
2. **Minimum pinch temperature:** The minimal temperature difference that occurs between the two streams exchanging heat
3. **Overall UA-value:** The UA-value, denoting the heat transfer pr. Degree of temperature difference
4. **Temperature out1:** The temperature out of the component’s “ho” outlet.
5. **Temperature out2:** The temperature out of the components “co” outlet.

The ”hi” and ”ho” is the inlet and outlet of the hot stream from which heat flows to the cold stream with inlet “ci” and outlet “co”.



### 7.15.1 Mass balance

As the cold and hot streams only exchange heat and doesn't mix the mass balance is trivial, and nothing must be defined for the component.

### 7.15.2 Thermal energy balance

The thermal energy balance is defined by one of the five variables. Only one can be chosen at a time.

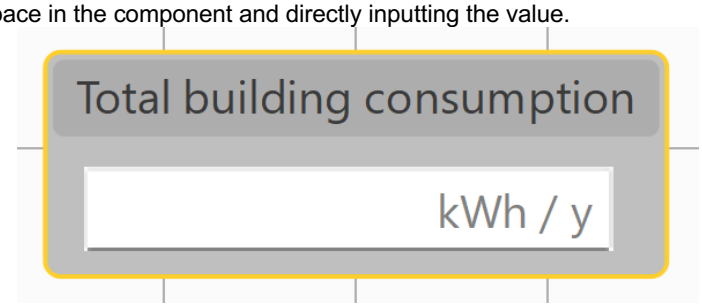
# 8 Building mapping

The building mapping is based on the "Total building consumption" node which is the total heat consumption of all buildings. It is in how the consumption is distributed on the buildings the building mapping is built. Each component in the building mapping is described individually.

For the building mapping it is possible to import a background photo and remove it again using the two buttons next to the calculation button. This allows a more visually recognizable mapping through a sketch made in another program or by hand, or an overview photo of the site.

## 8.1 Total building consumption

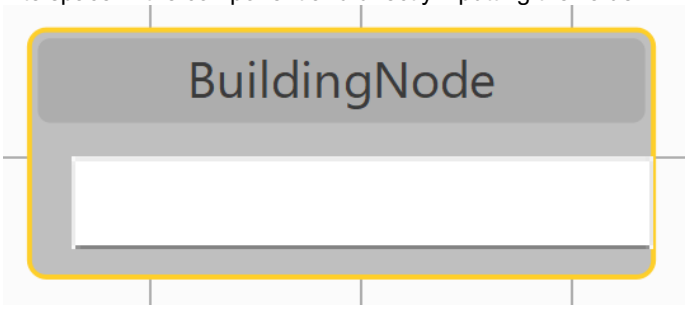
The Total building consumption component is defined through its one variable called "Total energy". This can either be defined by double clicking the component and entering the value as usual or by clicking the empty white space in the component and directly inputting the value.




It is important to note that exactly one Total building consumption component must be defined in the building mapping.

## 8.2 Building Node

The building node is used to represent one building each and is defined through its one variable "Energy ratio". This can either be defined by double clicking the component and entering the value as usual or by clicking the empty white space in the component and directly inputting the value.

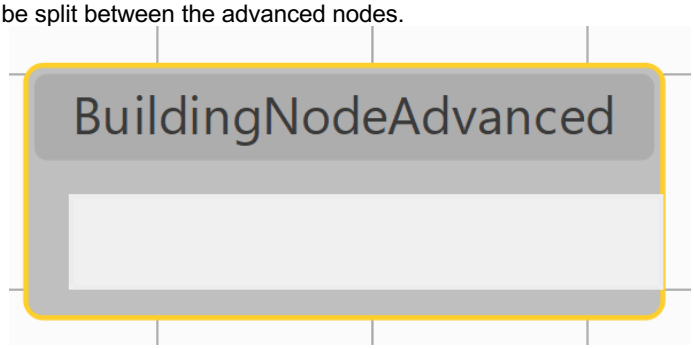



Energy ratio is given as a decimal number and the sum of the energy ratios of all the Building Nodes present must add up to 1.

## 8.3 Building Node Advanced

The advanced building node uses several inputs to weigh the energy consumption between the building nodes in the mapping. This occurs with any combination of advanced and simple building nodes. It is

important to note that the advanced building nodes will be distributing the total building consumption not accounted for. This means that if simple nodes account for 20% of the total building consumption the remaining 80% will be split between the advanced nodes.

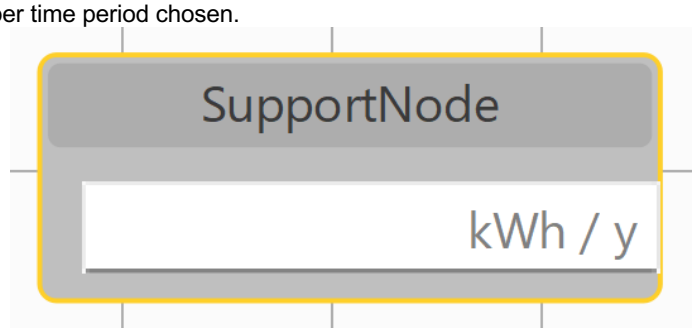



The component is defined by the following variables:

1. **Building age:** Building age as defined by span of years
2. **Building condition:** The general building condition as a subjective factor
3. **Building area:** The area of the building
4. **Building temperature:** The average temperature the building is heated to

# 9 Support mapping

The support mapping only contains one component, the Support node. This component is simply defined by the variable “Support consumption”. This is the energy consumption of each support system. It is given in energy per time period chosen.




Any number of support nodes can be added, each with separate energy carriers if needed. This allows for a very flexible mapping of the support systems as multiple can be lumped into one support node or a more detailed approach can be taken.

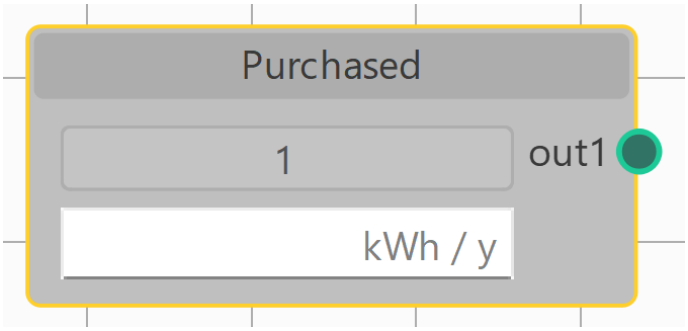
# 10 Energy supply

The energy supply is mapped through several components, each will be described individually. Only nodes directly relating to the mapping will be described. Some components can be directly loaded from different mappings and data entries using the update button next to the calculations button.

To update already existing components they must be deleted, the update button can be pressed, and the updated components can be reconnected to the model.

## 10.1 Purchased

This component represents the purchased primary energy located at the left side of the energy supply mapping. It has any number of outlets. This component is automatically added for each value and energy type defined in “Energy specifications” under “Production details”. If more are required, they can be added by manually adding more components when doing the energy supply mapping.

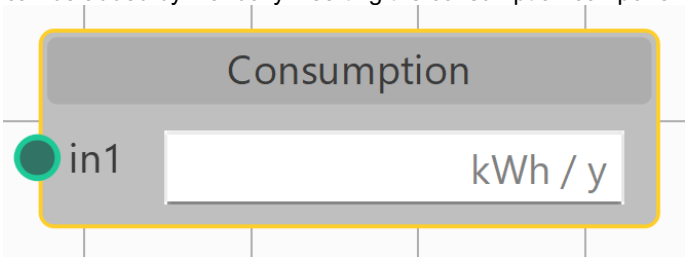



The component has the following variables:

1. **Energy:** The total energy purchased and going into the system
2. **Number of outlets:** The number of outlets of the component. The variable can only be defined by double clicking the grey number on the component and changing the value
3. **Energy array:** The energy flow out of each outlet of the component, can be set individually or be left as variable

## 10.2 Consumption

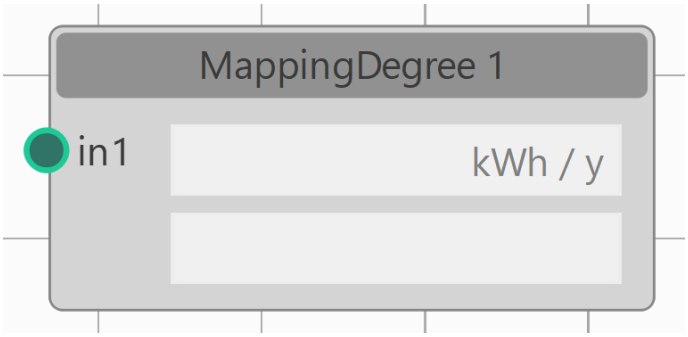
The consumption component is the consumption of energy by the final users. It has a single inlet. This can be loaded from the other mappings as results by using the update button. If further consumptions are necessary, they can be added by manually inserting the consumption component.




The consumption component only has the variable “Energy” which is the total energy consumption by the component.

## 10.3 Mapping degree

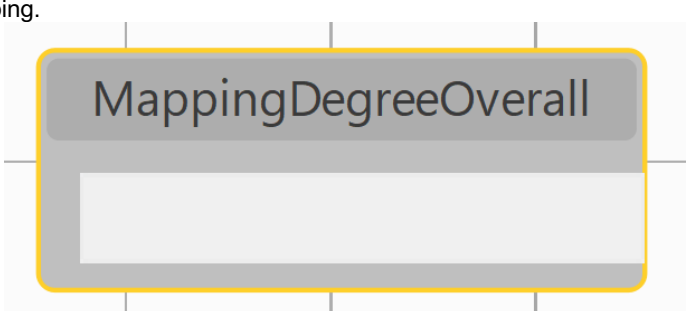
The mapping degree component is used to calculate the difference between the total energy consumption from a distribution component and the energy going into the distribution component. It has a single inlet. It is added as an extra consumption would be, but it requires no variables as it returns on the absolute and percentagewise difference between the energy coming in and going out of the distribution component.




This makes the mapping degree a check of how well the calculated energy consumption and the supplied energy input into the concrete supply system matches.

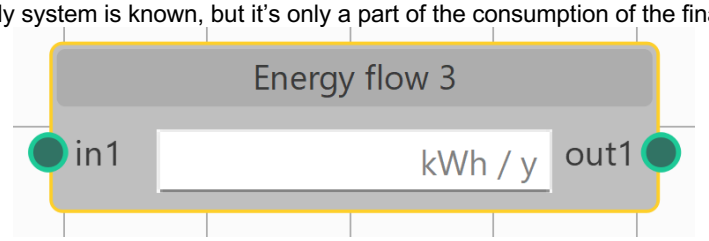
## 10.4 Mapping degree overall

The overall mapping degree determines how much thermal energy goes into the system and how much is being used. Electrical energy is neglected due to technical limitations. This gives an overview of the accuracy of the thermal mapping of the process and supply system. No variables can be defined for the component which is placed anywhere in the mapping with no inlets or outlets. Only one should be defined for each mapping.




## 10.5 Energy flow

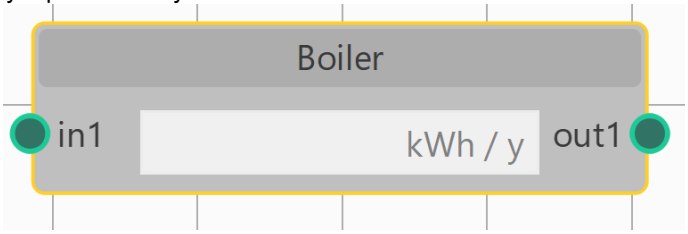
The energy flow component is used for determining the energy flow in a splitting of energy that is not otherwise defined. It has a single inlet and outlet. This could occur when data on energy flow in a subset of the energy supply system is known, but it's only a part of the consumption of the final users.




The component is defined through its one variable "Energy" which defines the energy flow through the component.

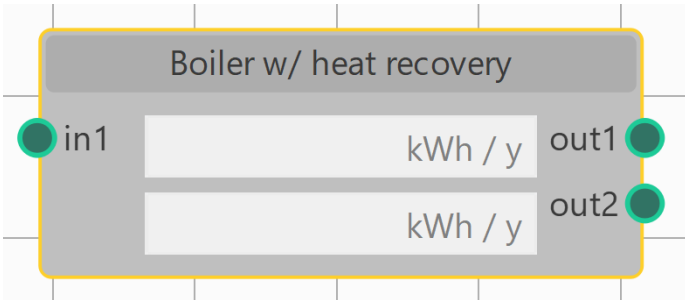
## 10.6 Boiler

The boiler component is a simple boiler defined only by its efficiency in converting primary energy to thermal energy. This could be any primary energy type like gas, woodchips or electricity. It has a single inlet and outlet. The efficiency is defined through the components only variable "Boiler efficiency" which is the boiler efficiency represented by a decimal number where 1 is 100%.




## 10.7 Boiler w/ heat recovery

The boiler with heat recovery component converts primary energy to thermal energy. It has one inlet and two outlets, "out1" and "out2". The "out1" outlet is the thermal energy directly converted in the boiler and the "out2" outlet is the heat recovered from waste heat. The boiler with heat recovery allows a percentage of the waste heat from boiler with thermal efficiencies less than 100% to be utilized.

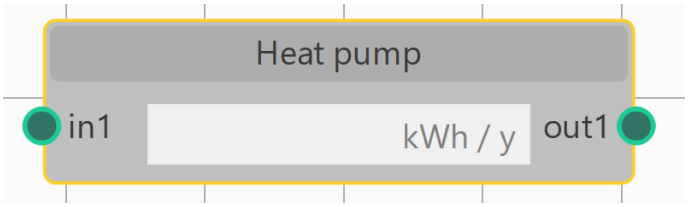



The component has the following variables:

1. **Boiler efficiency:** The thermal efficiency of the boiler given as a decimal number where 1 is 100%
2. **Useful heating ratio:** The ratio of the waste heat that is turned into useful heat given as a decimal number where 1 is 100%

## 10.8 Heat pump

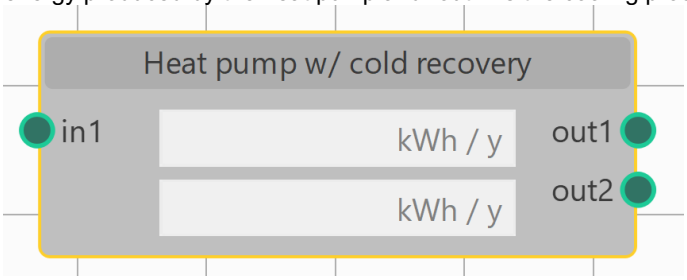
The heat pump component uses an energy input to produce thermal energy at high efficiency. The component has a single inlet and outlet.




The component has a single variable “COP” which is the coefficient of performance for the heat pump. This is the efficiency of the heat pump converting the energy supplied into thermal energy. It’s given as a ratio and as such a COP of 3 means 3 units of energy in produces 3 units of thermal energy out, or an efficiency of 300%.

## 10.9 Heat pump w/ cold recovery

The heat pump with cold recovery converts primary energy to thermal energy and allows the cooling produced by the process to be utilized as well. It has one inlet and two outlets, “out1” and “out2”. The “out1” outlet is the thermal energy produced by the heat pump and “out2” is the cooling produced.

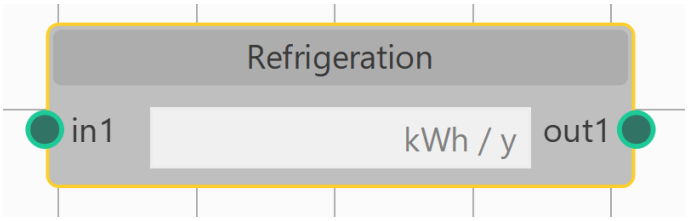



The component has the following variables:

1. **COP:** The coefficient of performance for the heat pump, given as a decimal number where 1 is 100%
2. **Useful cooling ratio:** The ratio of the cooling produced by the heat pump that is utilized, given as a decimal number where 1 is 100%

## 10.10 Refrigeration

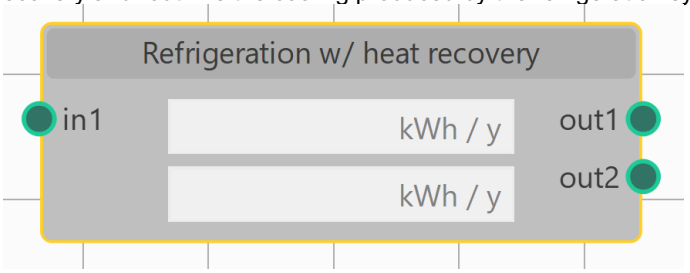
The refrigeration component uses an energy input to produce cooling at high efficiency. The component has a single inlet and outlet.




The component has a single variable “COP” which is the coefficient of performance for the refrigeration system. This Is the efficiency of the refrigeration component converting the energy supplied into cooling. It is given as a ratio where 1 is 100%.

## 10.11 Refrigeration w/ heat recovery

The component refrigeration with heat recovery allows the heat produced by the cooling process to be utilized. It has a single inlet and two outlets, “out1” and “out2”. The “out1” outlet is the heat that can be obtained from heat recovery and “out2” is the cooling produced by the refrigeration system.

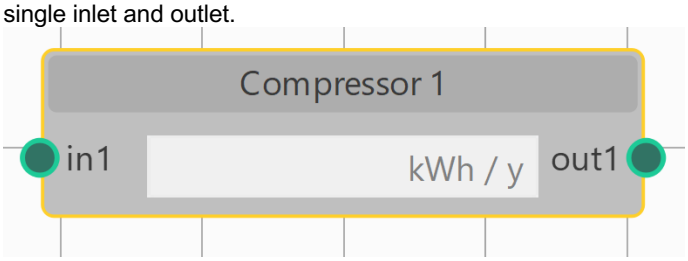



The component has the following variables:

1. **COP:** The coefficient of performance for the refrigeration system, given as a decimal number where 1 is 100%
2. **Useful heating ratio:** The ratio of the heat produced by the refrigeration system that is utilized, given as a decimal number where 1 is 100%

## 10.12 Compressor

The compressor component allows energy usage for compressed air production to be taken into account specifically. It has a single inlet and outlet.



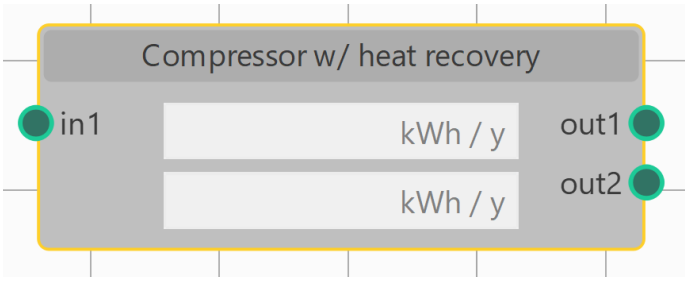

It is defined through its one variable “Compressor efficiency” which determines the efficiency of the compressor as a ratio where 1 is 100%.

## 10.13 Compressor w/ heat recovery

The compressor with heat recovery allows energy consumption for production of compressed air and the resulting heat from the process to be mapped. The component has one inlet and two outlets “out1” and “out2”. The outlet “out1” is the product of the compressor and “out2” is the heat recovered.

The component has the following variables:

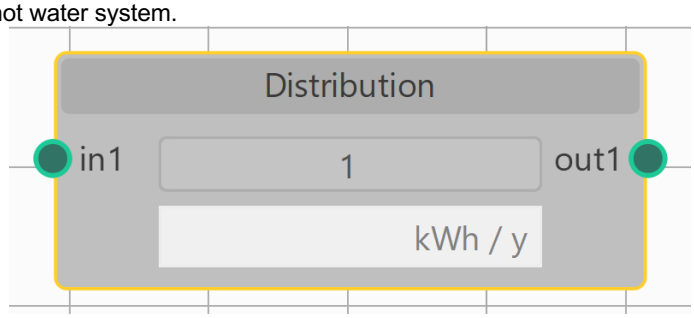
1. **Compressor efficiency:** The electric efficiency of the compressor, given as a decimal number where 1 is 100%
2. **Useful heating ratio:** The ratio of the energy going into the compressor that is utilized as heat, given as a decimal number where 1 is 100%




It should be noted that a compressor can have more energy out of the component than into the component. This is as the product of the compressor is often defined as the total electrical consumption of the compressor. The electricity is used for compression of air and ultimately all energy put into the compressor goes into the change of pressure and heat. A high electrical efficiency combined with a high degree of the energy recovered as heat will result in a flow of more energy out of the compressor than into it. This is purely as the product out of the compressor shouldn't be seen as energy flowing out of the compressor.

## 10.14 Distribution

The distribution component allows energy going to different end users to be distributed. It has one inlet and a number of outlets. For a system where multiple end users, for example like a CIP system and the hot water demand for buildings both are supplied by a hot water system, both end users should be supplied by the same hot water system.

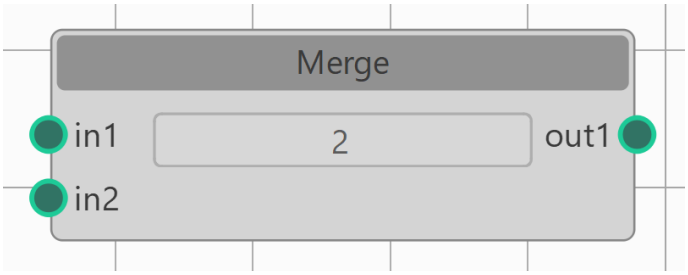



The component has the following variables:

1. **Loss ratio:** How much energy is lost in the distribution of the energy, given as a decimal number where 1 is 100%
2. **Number of outlets:** The number of outlets of the component. The variable can only be defined by double clicking the grey number on the component and changing the value

## 10.15 Merge

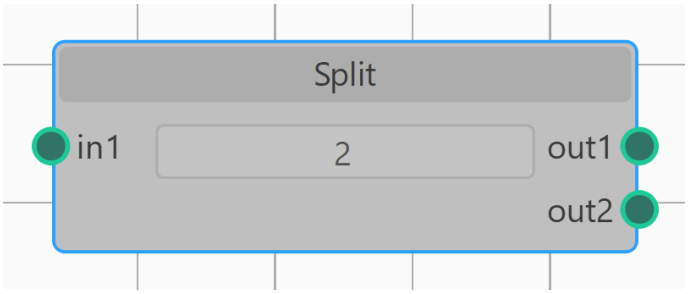
The merge component will collect the energy going into the component into one outlet. It has a number of inlets and one outlet.




The merge component only has one variable, the number of inlets. The variable can only be defined by double clicking the grey number on the component and changing the value.

## 10.16 Split

The split component splits a single inlet into a number of outlets.




The split component only has one variable, the number of outlets. The variable can only be defined by double clicking the grey number on the component and changing the value.

# 11 Visual components

Some components are used throughout EEMAP for better visualization of the process and a clearer model. Each is described in general terms as they can often be used for varying purposes.

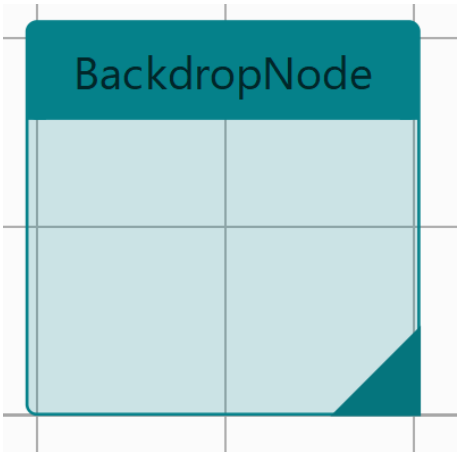
## 11.1 Text

The text component allows simple text to be added in one line.




## 11.2 Backdrop Node

The backdrop node can be formed into any rectangular shape. It has a minimum size, but in theory it has no upper limit. The node can contain text in its title space and in the opaque box that the node makes. To adjust the size of the node the bottom right corner is pulled, this is indicated by the triangle in the same corner.



# Efficient energy mapping for supporting green transition in industries – EEMAP

Nasrin Arjomand Kermani[a*], Martin Ryhl Kærn[b], Rikke Hovedskov Andersen[c], Jorrit Wronski[b], Fridolin Müller Holm[c], Brian Elmegaard[a]

[a] Technical University of Denmark , [b]IPU A/S, [c]Viegand & Maagøe A/S

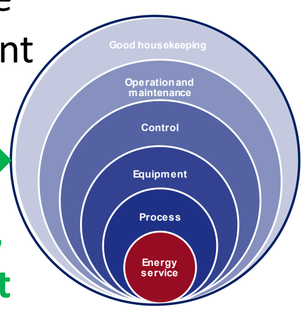
## Introduction



Green transition in industry

Identifying the correct "baseline" leads to much more cost-efficient solution

**To identify the right ”baseline”, energy mapping is an important tool**



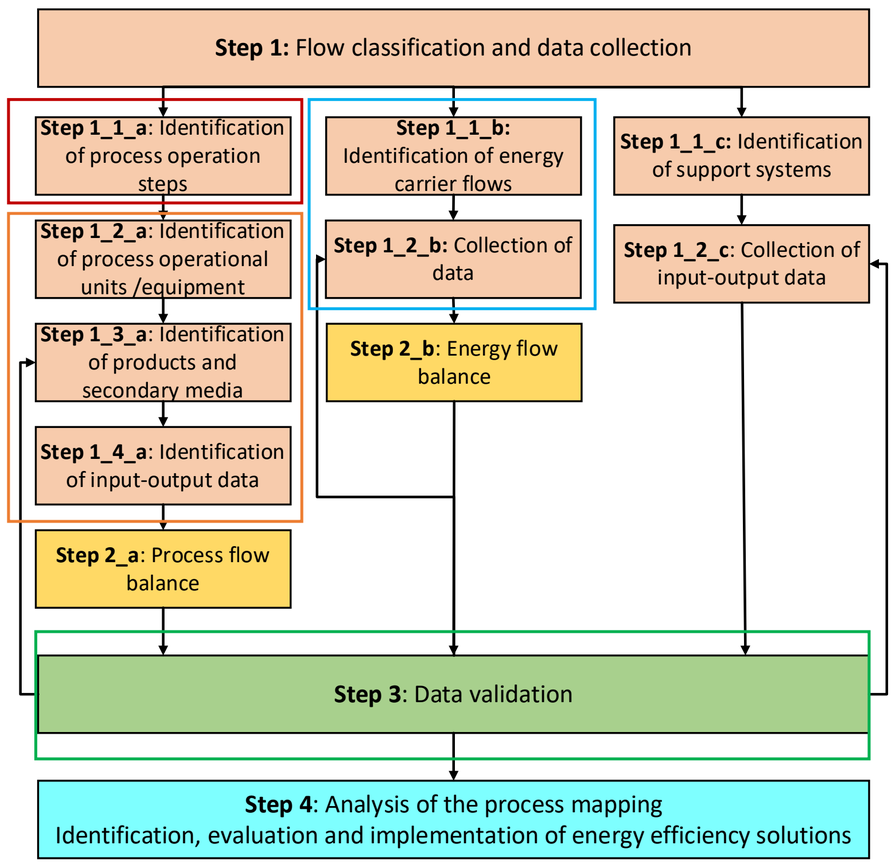

Energy optimization approach

Current Energy mapping is expensive and time-consuming

The proposed process mapping methodology is to effectively obtain production and energy data from industrial plants in a short time.

## Proposed methodology

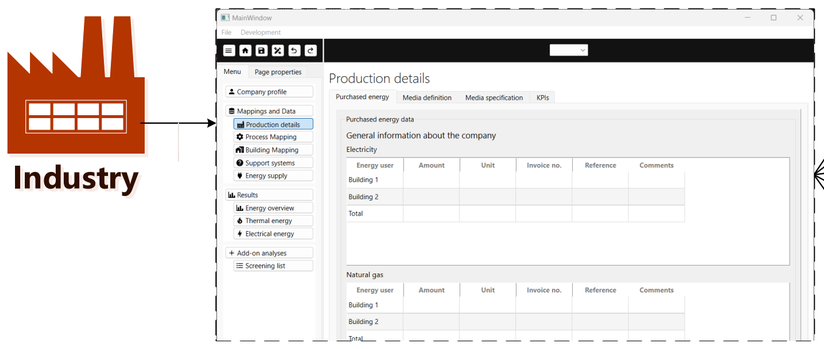
A generic, holistic, and flexible model, a step to creating a software



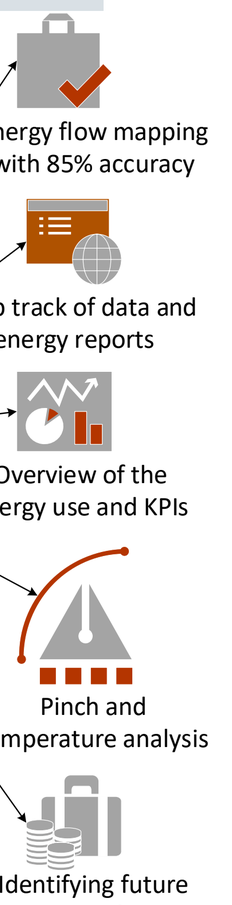

## EEMAP - TOOL

**Transition towards a greener process industry**

### EEMAP Software




- Creation of energy flow mappings in a cost-effective and efficient manner, using only a few days on-site
- Continuous generation of energy savings, turning a single-shot approach to energy mapping into an ongoing cyclic process
- Providing insights into how production activities function within an industrial facility and how energy and production are interconnected

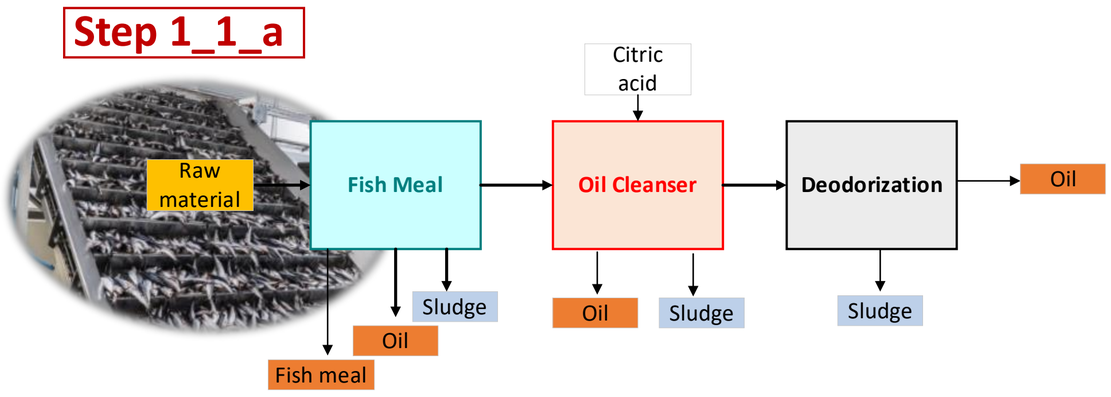



## Case Study

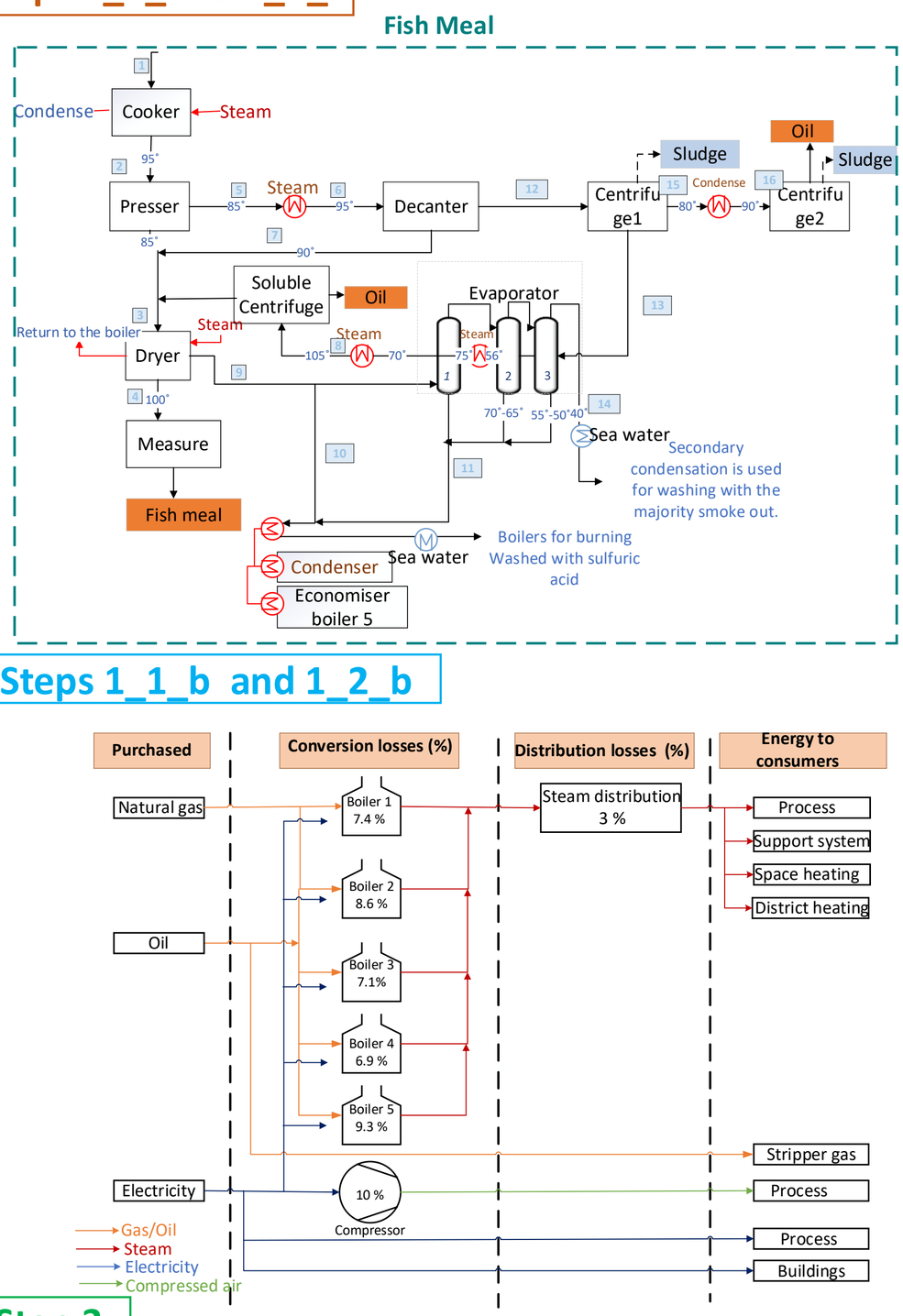
The production site specializes in the manufacturing of fish meal and fish oil, operating 24/7. The plant processes fish by-products, such as the remains of fish that are not used for human consumption, to create high-quality protein and oil products.




### Step 1_1_a




### Steps 1_2_a to 1_4_a




### Steps 1_1_b and 1_2_b




### Step 3

✓ **88% of the energy use is mapped**

## Acknowledgments

The work was funded by the EUDP Program; Project number 64022-1073, and project title “Efficient Energy Mapping and Analysis for Optimization and Green Transition of Industrial Processes”.

## Contacts



Nasrin Arjomand Kermani
DTU Construct, Section of Thermal Energy
nasker@dtu.dk

# Efficient energy mapping for supporting green transition in industries

***Nasrin Arjomand Kermani[a*], Martin Ryhl Kærn[b], Rikke Hovedskov Andersen[c], Jorrit Wronski[b], Fridolin Müller Holm[c], Brian Elmegaard[a]***

*[a] Department of Civil and Mechanical Engineering, Technical University of Denmark, Lyngby, Denmark, nasker@mek.dtu.dk, CA, brel@dtu.dk*
*[b]IPU, Virum, Denmark, mrk@ipu.dk, jowr@ipu.dk*
*[c]Viegand & Maagøe A/S, Copenhagen, Denmark, ran@viegandmaagoe.dk, fmh@viegandmaagoe.dk*

**Abstract:**
The process industry is facing the green transition from conventional to renewable energy sources. Executing it in a cost-effective manner will require increased energy efficiency, electrification, and a clear overall strategy from the beginning. A prerequisite for a strong strategy is an energy mapping that describes the energy use within an industrial facility. However, creating such a mapping can be expensive and time-consuming.

The primary goal of the proposed process mapping methodology is to effectively obtain production and energy data from industrial plants in a short time. This can be analyzed to provide a generic, holistic, and flexible model. The model is a step towards creating a software tool that generates energy flow mappings for industrial end-users to make energy optimization decisions. In addition to documenting energy flows, the tool supports the continuous improvement of the energy mapping itself and the actual energy use.

The required data is collected by reviewing existing specifications of production facilities, complemented with interviews with personnel working on the production lines, as well as other on-site investigations. The information is then entered into the developed model, which produces energy flow mapping as output. The model' s output can then be used to gain an overview of the primary energy used and identify future opportunities for energy optimization, electrification, and decarbonization of industrial sites. An industry use case has successfully illustrated the performance of the model reaching 88% accuracy.

**Keywords:**
Energy mapping, Generic model, Support tool, Green transition, Decarbonization of industry

## 1. Introduction

The global challenge of achieving emission reductions and climate neutrality necessitates the prioritization of resources across various industries and sectors worldwide. In many countries, including Denmark, the manufacturing industry significantly contributes to energy use and greenhouse gas emissions. In Denmark specifically, the manufacturing industry accounts for 160 PJ or 21% of final energy use [1]. Consequently, optimizing energy use becomes crucial when it comes to industrial processes. However, energy mapping can be costly, as it requires a detailed understanding of the process at hand.

Recent studies indicate that the current trends and implementation of existing policies aimed at reducing primary energy use in Europe will not achieve a 20% improvement in energy efficiency [2]. Various barriers hinder the adoption of energy-efficient technologies and practices, as categorized by Sorrell et al. [3] ] in a taxonomy that compiles important contributions from literature. These barriers are divided into economic, organizational, and behavioral aspects, with fifteen different barriers identified as significant in literature. The study highlights the high cost associated with gathering, analyzing, and applying information, as well as the lack of information leading to missed opportunities for cost-effective energy efficiency. Additionally, the

perceived cost of energy conservation has been recognized as a barrier to industrial energy efficiency investments in Greece [4].

Furthermore, Bunse et al. [5] conducted a review of methodologies for incorporating energy efficiency performance into production management and found that most industrial companies still lack effective methods to comprehensively and practically address energy efficiency. The authors attribute the gap between industrial needs and scientific literature to several reasons, including the complexity of production sites, which often operate multiple production processes to meet business needs, variability in energy intensity factors across different products, and isolated analysis of specific energy use without considering production operations. Consequently, there is potential for misleading conclusions when attempting to account for all variables associated with energy efficiency. Additionally, the authors note that analyzing thermal energy usage is more challenging in practice compared to analyzing electrical usage.

Currently, existing software designed for energy mapping focuses on the entire process operation, requiring a high level of detail and many input parameters. In many cases, these parameters are unknown, resulting in unnecessary efforts on details that may have little importance for actual energy optimization. Alternatively, using Excel software as a tool for energy mapping is challenged by the complexity of systems, causing the program to become too slow for practical use. Additionally, achieving accurate results with Excel requires decent experience in energy mapping and the calculation tool.

Energy mapping is currently mandated under the European Union's Energy Efficiency Directive (EED) [6]. It is the first step in performing mandatory energy audits every four years, to develop projects that increase energy efficiency. Complying with the DS/EN ISO 50001 "Energy Management Systems" also requires companies to perform an "Energy Review" with the same core ideas, establishing key performance indicators (KPIs) and identifying significant energy users (SEUs).

The primary goal of the project presented in this study is to develop a generic, holistic, and flexible process mapping methodology that efficiently obtains production and energy data from industrial plants within a short time frame. The aim is to describe at least 85% of thermal energy used at any industrial facility, using only a few days on-site with qualified staff and an additional day for preparations and fine-tuning. This approach enables the creation of energy mappings in a cost-effective and efficient manner, contributing significantly to the transition towards a greener process industry. By making energy audits cheaper and faster, the number of energy mappings created each year is expected to increase, thereby reducing energy use and quantifying optimization potential [7]. Moreover, studies [8,9] have demonstrated that energy efficiency measures can have a broader impact beyond energy savings, such as process, facility, and organizational levels. These measures can also lead to non-energy benefits, such as increased productivity, improved product quality, reduced costs of environmental compliance, decreased carbon and emission footprint, and lower waste disposal expenses, among others. Worrell et al. [10] have compiled a comprehensive list of non-energy benefits associated with energy efficiency technologies.

In addition, the model presented in this study is a step towards creating a software tool that generates energy flow mappings for industrial end-users, enabling decision-making with energy optimization in mind. The tool supports the continuous improvement of the energy mapping itself and actual energy use. It also serves as the foundation for continuous generation of energy savings, turning a single-shot approach to energy mapping into an ongoing cyclic process, aligning well with the current trend towards increasing energy efficiency targets.

Such a tool can provide sufficient data from numerous manufacturers required to train machine algorithms designed for energy management in different types of processing activities, introducing the digital twin concept for industrial energy systems, intelligent recommendations, and demand-side management in the future.

# 2. Method

## 2.1. Generic process mapping approach

The primary goal of the proposed process mapping methodology is to effectively obtain production and energy data from industrial plants in a short time. This data can then be analyzed to provide a generic, holistic, and adaptable model that covers the following perspectives.

- The model should be generic in nature, making it applicable to diverse production plants, ranging from small and medium-sized companies (which typically face obstacles towards energy-efficiency measures) to large-sized companies.
- It should pursue a holistic perspective on the relationship between manufacturing processes and energy usage, encompassing all relevant processes and energy flows.

- The model should be adaptable to changes in the production environment, such as equipment relocation or process improvement.
- It should provide a data set for multi-dimensional evaluation, including energy savings, electrification, and carbon neutrality strategies in all relevant fields of action. Additionally, it should support the continuous improvement of energy mapping.

The methodology consists of four main steps and several sub-steps, as illustrated in Figure 1, and described in the following text. These steps are generally applied to all production lines and can be scaled up and/or aggregated to the factory level. The outcome of the calculations and data validation also serves as the basis for iteratively improving the quality of the energy mapping. By gradually adding more sensor data and reducing uncertainties one node at a time, the user can maintain an overview of the overall plant operation while working with individual components.

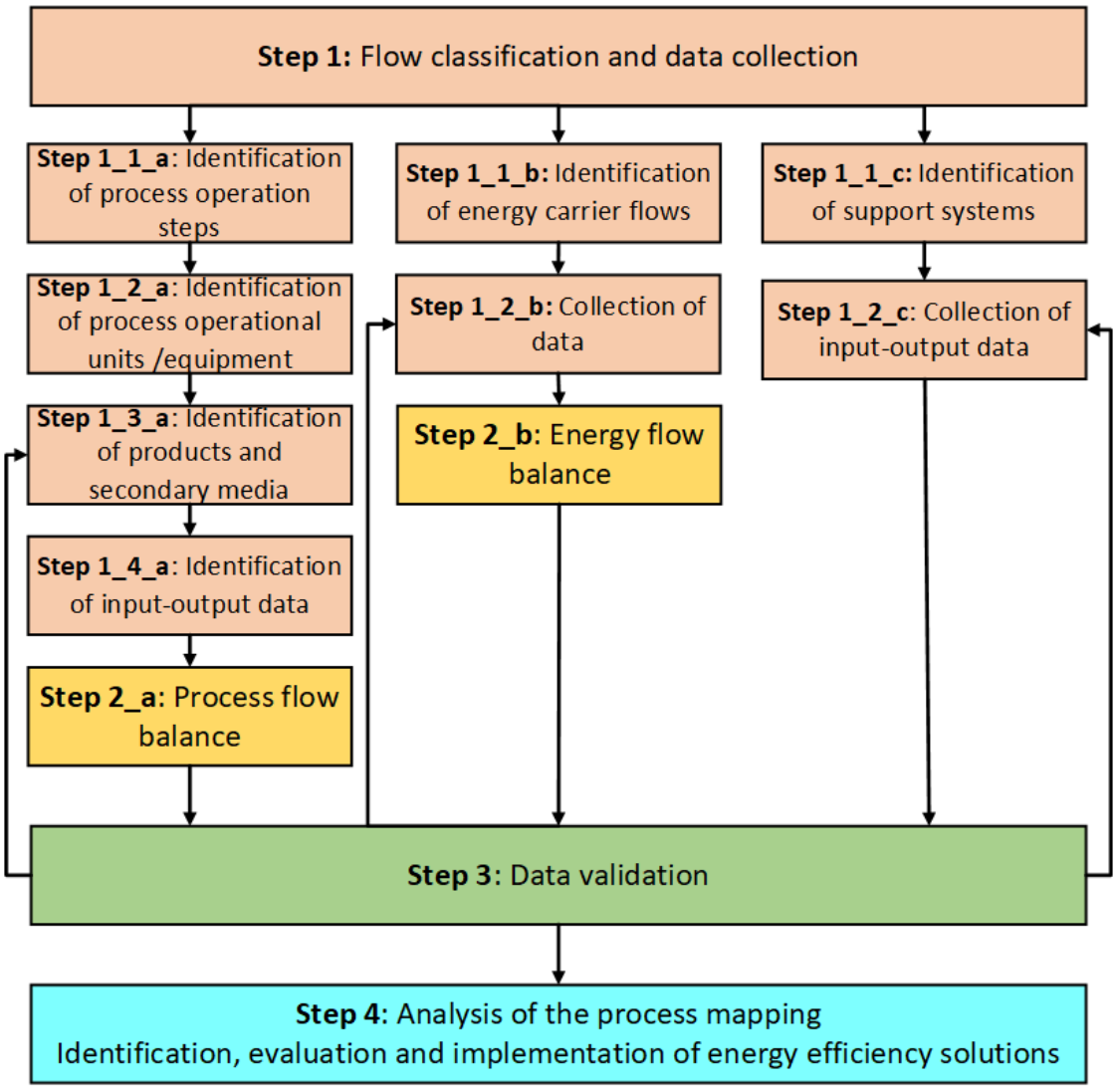



**Figure. 1**. The proposed methodology consists of 4 main steps and several sub-steps

**Step 1: Flow classifications and data collection**

Effective flow classifications and data collection are essential for developing a comprehensive understanding of energy use within production plants. This understanding will lead to the identification of areas of energy inefficiency and waste, facilitating the development of strategies for overall energy efficiency improvement in the future. Flow classifications involve categorizing energy usage based on its source, form, and utilization within a production process. This includes identifying the various inputs and outputs of energy within the facility, as well as how energy is transformed and used by different machines, equipment, and production lines. Data collection is the process of gathering and analyzing information on energy usage in a production environment, which can be done in various ways.

To further understand the amount of energy use in production plants, it is crucial to map out the flow of energy within an industrial facility, categorize energy usage, and analyze its correlation with production processes and outputs. Raw materials are consumed in production processes, which convert them into products, along with potential by-products that may or may not be desirable. These processes often require a significant amount of energy, which is partially utilized for value-added activities contributing to the final form and composition of products. However, the remaining energy is wasted in the form of heat losses and emissions. It is important to understand not only the operation of the equipment but also the actual energy requirement from the process. This is achieved by establishing a process flow balance, which involves tracing the flow of the product through process operations (POs) from start to finish and accounting for the mass and energy balance of each PO, as explained briefly in step 2. Energy mapping utilizes streams to track the conversion paths of different forms of primary inputs, such as chemical energy, electrical energy, and thermal energy.

The concept of flows allows for the design of a structure that can serve as the foundation for a software application. The data structure should be designed with various processes in mind and be tested with a variety of applications and industries. By applying these steps to a production environment, the relationship between process, equipment, and energy usage is highlighted, providing insights into how production activities function within an industrial facility and how energy and production are interconnected.

**Production flow (sub-steps: 1_1_a -1_4_a)**

**Step 1_1_a: Identification of the process operational steps**

The entire production line can be further divided into different process operational steps. Each process step can be defined and labeled according to production specifications or internal factory documents. Understanding the current production system and breaking it down into appropriate steps will provide a solid foundation for the energy mapping and future assessments. This involves identifying the individual process steps, their sequence, and the inputs and outputs for each step.

**Step 1_2_a: Identification of the process operational units/equipment**

Once an industrial process has been selected, the next step is to describe the existing process steps and their corresponding unit operations and equipment. This can be achieved by assuming that the product flow passes through several blocks, which can be arranged in parallel, series, or loops. Each block represents a unit operation with significant energy demand, such as pasteurization, boiling, evaporation, drying, and distillation, along with their respective subprocesses, if applicable. The equipment used for each process is then identified, along with the quantity of equipment per step. While a real production plant may consist of many process operation units and components, the focus should be on those with the highest energy demand. Table 1 presents list of process operational units and equipment that can be included in this part.

It is important to note that there may be many interconnections between the process step and process equipment, as well as primary and secondary production flows, but simplification is necessary to illustrate that each product will only follow one main path through the process.

To ensure consistency throughout the energy mapping process, the basic operational blocks developed in the previous step should be reused. This necessitates testing the proposed blocks and interconnections in various production plants and refining them to establish a robust foundation for future implementation in the software tool.

**Table 1.** List of process operational units and equipment that can be included

| **Process operational units and equipment** | | | | |
|---|---|---|---|---|
| **Mechanical** | **Thermal (indirect)** | **Thermal (direct)** | **Electric** | **Heat transfer** |
| - Collector<br>- Mixing, stirring, suspension, sedimentation, wetting, absorption<br>- Splitters<br>- Separation of flows, filtration, extraction, centrifuge, decanters, press | - Evaporator<br>- indirect drying<br>- Boiling<br>- Baking<br>- Distillation<br>- Reactor | - Drying<br>- Stripping | - Compressor<br>- Induction cooker | - Warm up<br>- Cooling<br>- Pasteurization<br>- fermentation |

**Step 1_3_a: Identification of the products and secondary media**

The amount and type of raw materials used in the production process, as well as the flow of products through the process, should be recorded annually and updated regularly. This information can be used to track changes in the amount and type of raw materials used in the production process, as well as changes in the flow of products through the process.

Apart from the main production flow, it is important to identify the secondary media used in each operational unit to heat up, cool down, pasteurize, or wash the main product flow. These secondary media could be anything used to transfer heat to or from the product flow, such as air, water, or steam, etc.

For example, in a drying operation, hot air might be blown into the dryer to heat up the product. In a pasteurization or washing operation, hot water might be sprayed into the unit to pasteurize the main product or to wash the equipment used in the production line. In some cases, steam might be injected directly into the product flow to increase the temperature of the product flow or change its consistency. In all these cases, the secondary media requires energy, which should be accounted for in the energy use of the operational unit process.

Additionally, this information can also be used to evaluate the effectiveness of different energy-saving strategies, such as optimizing the use of secondary media or using alternative methods to heat up, cool down, or pasteurize the product flow in the future**.**

**Step 1_4_a: Collection of input-output data**

In this step, all inlet and outlet data of the product and secondary flows in production lines are collected, along with their respective state conditions, such as temperature, pressure, mass flow rates, specific heat, and other relevant parameters.

If energy meters are installed at this step, the information can be gathered from the energy monitoring system. Otherwise, the required data is collected by reviewing existing production specifications complemented with interviews with personnel, such as production associates, supervisors, and managers, as well as other on-site investigations, information from control rooms, and manual calculation of the remaining required information.

**Step 1_1_b: Identification of energy carrier flows through the facility**

The main objective of this step is to identify the main energy supply systems, including electricity, heating and cooling utilities, and their corresponding purchasing, conversion, and transmission processes.

Energy carrier flows are the sources of energy that supply electricity, steam, or other forms of energy required for powering equipment, heating, and cooling in an industrial plant. These sources can either be purchased from outside (i.e., electricity from the grid or heat from district heating network) or generated on-site by converting primary energy sources, such as natural gas, oil, coal, biomass, or renewable sources, such as solar, wind, or geothermal energy.

To convert primary energy sources into usable energy, various types of equipment, such as boilers, cooling systems, heat pumps, turbines, generators, and motors, are used. These systems can transform energy from one form to another. Heating utility refers to systems or equipment that provide heat energy to a process or facility. The source of heat energy can be steam, hot water, thermal oil, or combustion gases from a furnace, boiler, or heat pump. On the other hand, cooling utility removes heat energy from a process or facility by consuming a certain amount of electricity, depending on the system's coefficient of performance (COP). Cooling utilities can be supplied through cooling towers, chillers, or refrigeration systems, and the source of cooling energy can be air, water, or other fluids. These heating and cooling utilities are commonly used in various industrial processes, such as chemical reactions, food processing, and manufacturing, where temperature control is critical. The temperature and flow rate of the heating and cooling utilities are usually monitored and controlled to ensure that process conditions are maintained within the desired range.

Energy transmission refers to the distribution of energy from the source to the end-use consumers, which can involve various transmission systems, such as pipelines for transporting natural gas or liquids, electrical grids for transmitting electricity, and piping systems for delivering steam, hot water or cooled fluid. The end-use consumers can be divided into different categories of production processes, support systems, space heating, or even direct delivery to a district heating network.

In addition to supplying energy, industrial plants can also implement various energy recovery and conservation measures to improve efficiency and reduce costs. Heat recovery systems can capture waste heat from one process and reuse it in another, reducing the need for additional energy input. Compressed air systems can

be optimized to reduce energy consumption, and motors and pumps can be upgraded to more energy-efficient models.

**Step 1_2_b: Collection of data**
Data collection for electricity consumption, heating, and cooling utilities in an industrial plant typically involves gathering information on various aspects, such as:

- Electricity consumption: This typically involves identifying the equipment with the highest electricity consumption, such as motors, pumps, fans, compressors, and conveyors. The common methods of collecting electricity consumption data can be smart meters, manual meters, and billing data.

- Heating and cooling utilities: This includes the amount of heat generated by the heating equipment (e.g., boilers, furnaces, heat exchangers), the type of fuel used (e.g., natural gas, oil, biomass), and the efficiency of the heating systems. It also includes the amount of cooling generated by the cooling equipment (e.g., chillers, cooling towers, heat exchangers), the type of refrigerant or cooling medium used (e.g., water, glycol), and the efficiency of the cooling system.

Excess heat recovery: Any excess heat that is recovered from process equipment or buildings and reused for other applications. This includes information on the heat recovery equipment (e.g., heat exchangers) and the amount of heat recovered.

The required data for the last parts can be collected through various means, such as using sensors and meters installed on the heating and cooling equipment and piping network to monitor temperature, pressure, flow rate, and energy use. Data can also be collected manually by taking measurements at specific intervals or by reviewing equipment logs and maintenance records or interviewing personnel.

**Step 1_1_c: Identification of support systems**
In an industrial plant, support systems are crucial for the efficient and safe operation of the facility. One important support system is cleaning in place (CIP), which allows for the cleaning of process equipment and piping without disassembly. Additionally, industrial plants may have other support systems in place, such as:

- Water treatment systems: Since industrial processes often require large amounts of water, water treatment systems may be necessary to ensure that the water is safe for use and meets the required quality standards.
- Waste treatment systems: Industrial processes can generate waste products that must be treated or disposed of properly to prevent environmental contamination.

**Step 1_2_c: Collection of input-output data**
To collect energy data for support systems in industrial plants, it is typically necessary to gather information on equipment specifications and energy requirements for running the systems that support the main production process. Energy meters can be installed on the equipment to measure usage, while energy bills and consumption records can be reviewed to track energy use. Here are some examples of energy data that may be collected for support systems:

- Electrical power consumption: Monitoring the power consumption of motors, pumps, and other electrical equipment used to support the manufacturing process can help determine the energy usage of support systems.
- Steam consumption: Measuring the amount of steam used to support the manufacturing process can help determine the energy usage of the steam system.
- Water consumption: Measuring the amount of water used to support the production process can help determine the energy usage of the water supply and treatment systems.

**Step 2_a: Process flow balances**
This step involves conducting energy and mass balances for each unit operation that comprises the industrial processes. Inlet and outlet process streams, along with their respective state conditions (such as temperature, pressure, mass flow, specific heat, etc.), which are collected in previous steps, are used to determine the energy and mass balances of the production throughout the facility based on the first law of thermodynamics.

By conducting the process flow balance, we can understand the energy requirements of the process. Each cooling and heating demand yields a specific energy demand that can be calculated. These demands will vary depending on the amount of product input into the model. All these individual demands are then summed up

to establish the process energy requirement, both in terms of heating and cooling. These energy demands can be reduced and optimized.

**Step 2_b: Energy flow balance**

An energy flow balance is carried out in addition to the process flow balance, to describe the energy flow through and the efficiency of the utility systems at the process site. It involves four overall sub-steps: “Purchase”, “Conversion”, “Distribution”, and “Energy Use”. The starting point of this balance “Purchase” is the energy bill, based on energy consumed as purchased fuels.

To illustrate, consider the example of a natural gas boiler producing steam for a process. In the “Purchase” sub-step, the purchased energy is examined from the company's bookkeeping to determine the gas input for the boilers. In the “Conversion” sub-step, all conversion losses related to producing steam from natural gas in the boiler are accounted for, including flue gas loss, radiation loss, blowdown, and deaerator. Additionally, conversion gains can be estimated, such as the introduction of valuable heat from waste heat through a heat pump.

The “Distribution” sub-step involves accounting for all distribution losses related to distributing the steam on the process facility, mainly consisting of heat loss from piping and condensate losses. Subtracting all losses from the known purchased amount yields the amount of steam consumed on site. Finally, the “Energy Use” step is the output of the energy flow balance. Figure 2 provides an example of energy supply and energy use and their interconnection, corresponding to four sub-steps of step 2_b.

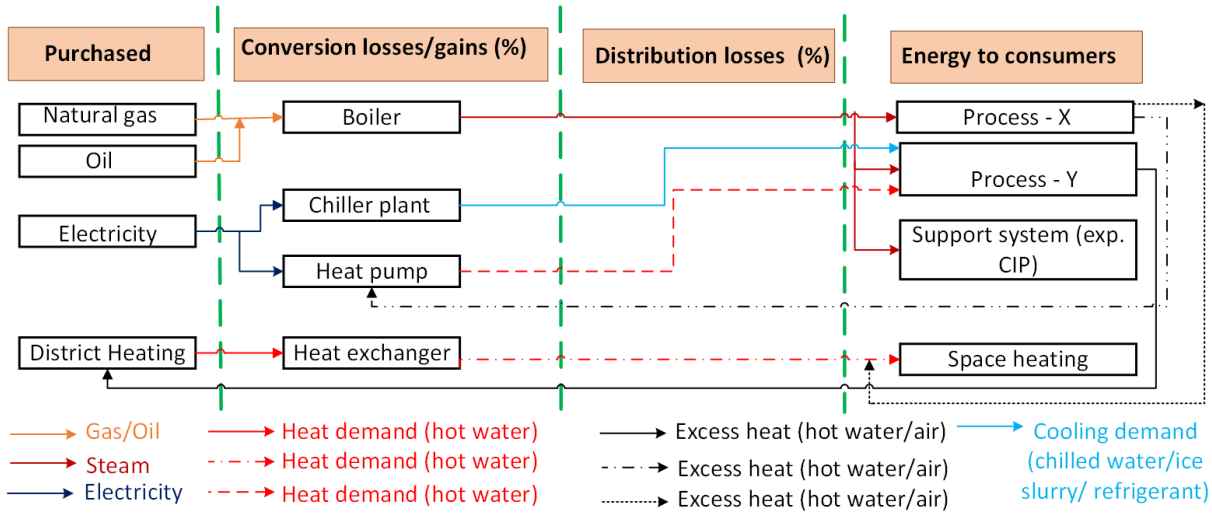



**Figure. 2**. An example of energy supply and energy use and their interconnection, corresponding to the four sub-steps of step 2_b. Different arrows of the same color correspond to different temperature levels of similar media

**Step 3: Data validation**

In an ideal energy mapping scenario, the energy flow balance output (i.e., “Energy use” calculated in step 2-b) should equal the energy requirement calculated from the process flow balance (calculated in step 2-a). However, due to measurement uncertainties, poor data quality, and generalizations of complex processes, some deviation from this ideal situation can be expected. The accuracy of the energy mapping can then be determined as follows.

$$Accuracy = \frac{(Process\ energy\ requierment + Conversion\ losses + Conversion\ gains + Distribution\ losses)}{(Purchased\ energy + Conversion\ gains)} \quad (1)$$

**Step 4: Analysis of the process map (including evaluation of energy efficiency solutions and implementation)**

Once all the necessary data has been collected, the energy mapping analysis can be completed, and the outputs can be generated. The immediate outputs of a thorough energy mapping exercise include:

- Simple energy overview: This involves identifying trends, patterns, and areas of high energy demand within the production line. Such an analysis can help identify significant energy users (SEUs), equipment KPIs, and efficiencies that can be easily developed and maintained to comply with ISO certifications.
- Pinch analysis: This involves analyzing the energy use in the process in relation to the temperature requirements. The analysis determines the minimum possible demands for heating and cooling utilities. This information can be used for further process integration studies, the integration of heat pumps into the process, and the optimal selection of utilities.

### 2.2. Case study

The methodology was implemented for a case study to provide a preliminary assessment of its quality. The case study involved a production plant for fishmeal and fish oil. The site descriptions and outcomes of the implementation are detailed below. It should be noted that the proposed method was evaluated up to the end of step 3, while step 4 will be continued in future work.

The production site specializes in the manufacturing of fishmeal and fish oil, operating 24/7. The plant processes fish by-products, such as the remains of fish that are not used for human consumption, to create high-quality protein and oil products. The process begins with the delivery of raw materials to the plant, where they are sorted. The fish is then cooked and pressed to extract the liquid portion, which is separated into fish oil and water. The solid portion is dried and ground into fishmeal. The resulting products are packaged and shipped to customers worldwide. Fishmeal is a valuable source of protein and other nutrients used in animal feed, while fish oil is a rich source of omega-3 fatty acids, which are essential for human health and used in dietary supplements, pharmaceuticals, and other industrial applications.

## 3. Results

The first three steps of the proposed methodology have been implemented in a production line, and the required data has been collected and evaluated. The results provide a visual representation of the process and energy relationship for the presented production line and are briefly summarized below.

### 3.1. Case study

Figure 3 and 4 show the general overview of the process steps and process units (sub-step 1_1_a and 1_2_a of the proposed methodology). The process steps identified for the plants are the main production line to produce fish meal, oil cleanser, and deodorization. The identified process steps related to the main production line include process operational units, such as the cooker, presser, dryer, decanter, evaporator, and centrifuge. The oil cleanser and deodorization include process operational units, such as the centrifuge, filter, stripper, and scrub.

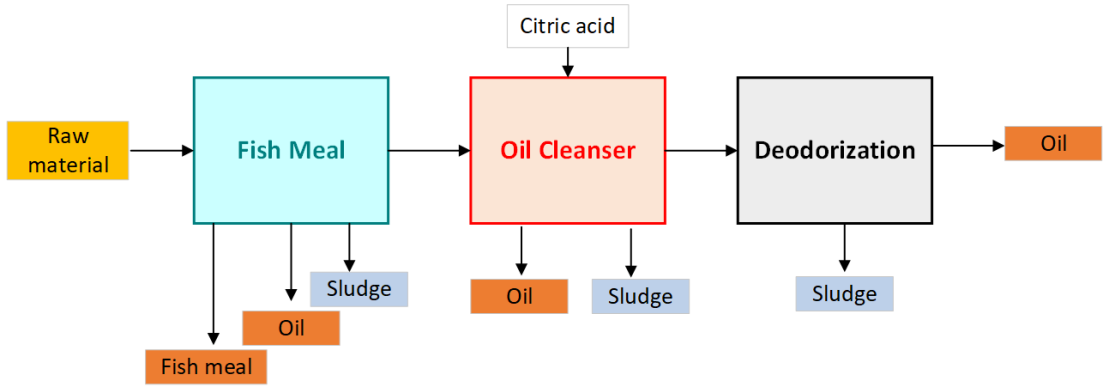



**Figure. 3.** The process operational steps for the presented case study, corresponding to step 1_1_a of the proposed methodology

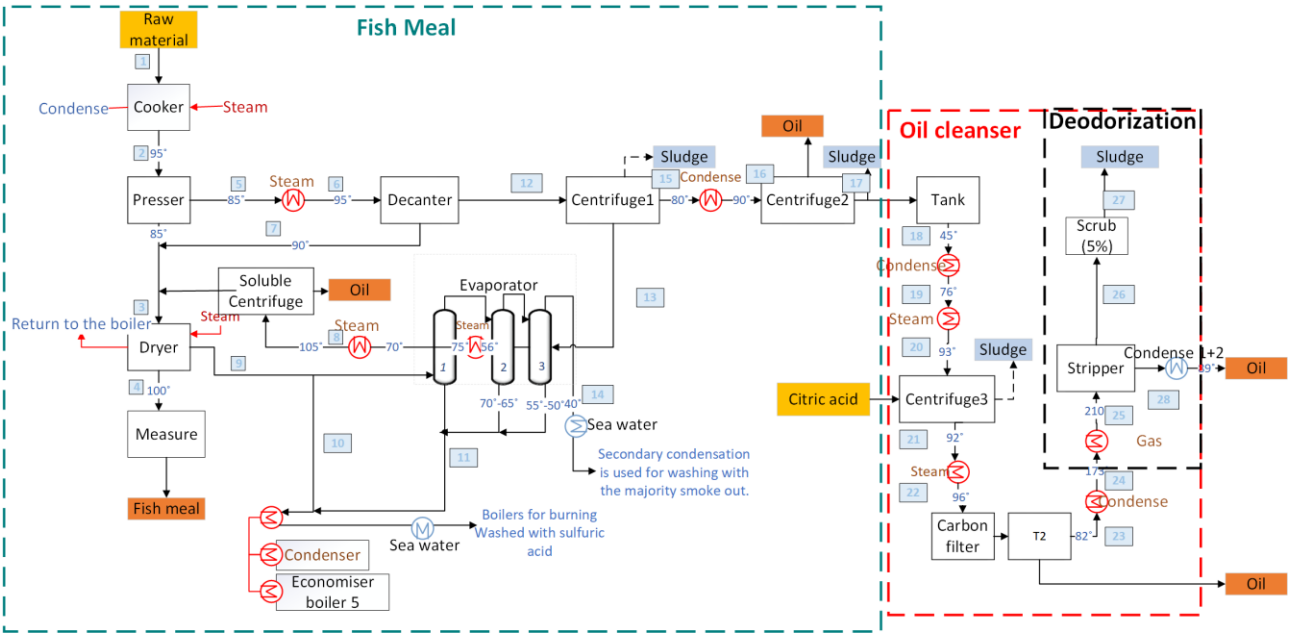



**Figure. 4.** The process operational units for the case study, corresponding to step 1_2_a of the proposed methodology.

Figure 5 presents the process flow balance (sub-step 2-a), considering the process step related to the main production line to produce fish meal and process operational units that influence the mass balances or final energy use. The required data, including temperature, mass flows, and recipes (fraction of water, fat, and solid), are introduced as input and output data of the main production flow.

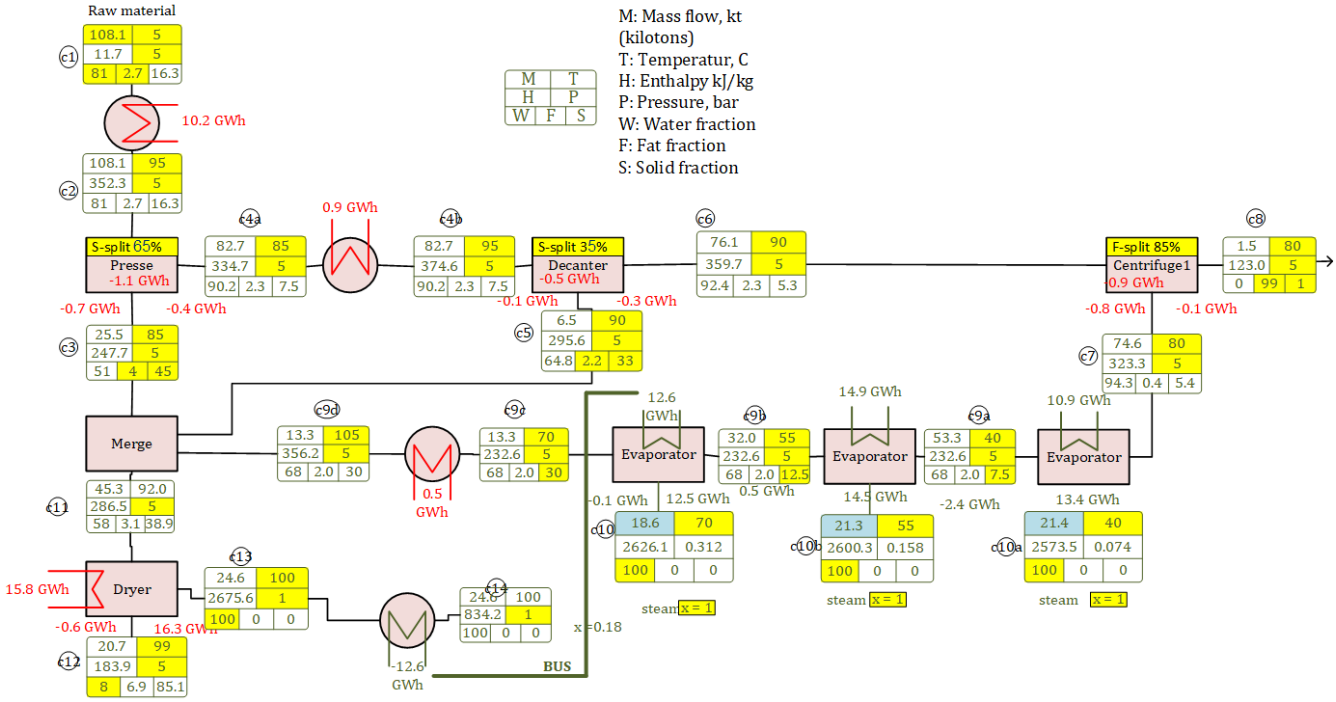



**Figure. 5.** The mass and energy balance for the case study, corresponding to step 2_a of the proposed methodology.

It should be mentioned that the mass and energy balance presented in Figure 5 belongs only to one type of material. However, in practice, the company has handled three different types of raw materials, equal to 108143, 919221, and 70293 tons/year, which requires a total of 73242561 kWh heating demand.

Figure 6 presents steps 1_1_b, 1_2_b, and 2_b including the identification of energy flows, data collection, and energy flow balances for the presented case study. The steam is generated by five steam boilers mainly

run on oil and natural gas. Table 2 presents the amount of energy calculated in the four sub-steps of step 2_b. It should be mentioned that since the production plant does not have a significant user of a support system such as CIP, steps 1_1_c and 1_2_c have been neglected.

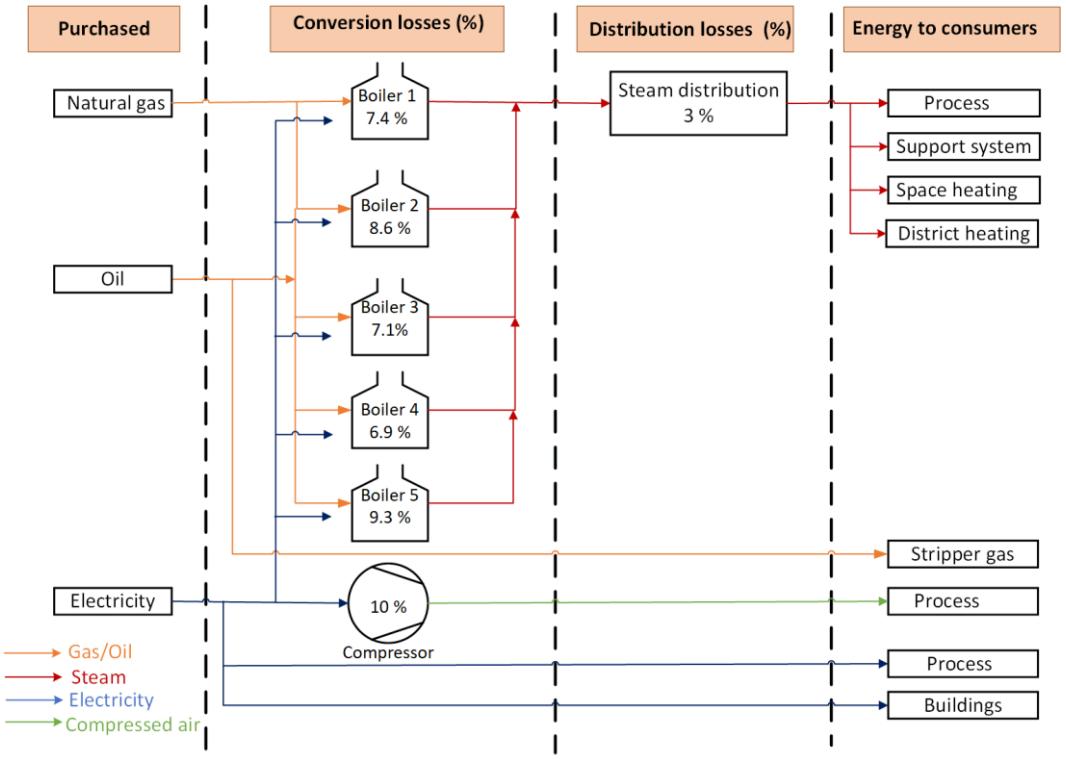



**Figure. 6.** The energy flows, data collection, and energy flow balances for the presented case study, corresponding to steps 1_1_b, 1_2_b, and 2_b of the proposed methodology

**Table 2.** The required amount of energy in *four overall sub-steps: "Purchase", "Conversion", "Distribution", and "Energy Use",*

| | Heating utility | | | | |
|---|---|---|---|---|---|
| | | **Purchase fuel** | **Conversion losses** | **Distribution losses** | **Energy (steam) to end-use consumers** |
| **Equipment** | 5 steam boilers Using natural gas and oil, with 0.92 - 0.94 % efficiency slightly differ for different boilers | Natural gas: 115184432 kWh<br><br>Oil: 7619 kWh<br><br>Total steam produced: 22993535 kWh | 6-9 %<br><br>≃1701522 kWh for each boiler depending on efficiency<br><br>Total steam: 105954221 kWh | 3 %<br><br>3178626 kWh<br><br>Total steam: 102775585 kWh | Production flow: 73.242.562 kWh (obtained from step 2_a)<br><br>Space heating: 6.277.252 kWh<br><br>Delivery to district heating 13.026.300 kWh |

Finally, from step 3, Eq.1, an 88 % accuracy of the mapping can be obtained.

## 4. Discussion

The proposed methodology acknowledges the challenges that may arise when verifying step 3, particularly in diverse and complex production plants. It is crucial to ensure that the interconnections between production flow, secondary media, and utilities are accurately represented to obtain correct values for the process and

energy flow balance. To address this, further verification and validation of the methodology should be conducted across a range of production plants with varying complexities. This will help establish the methodology's robustness and reliability, allowing for adjustments and improvements as necessary.

A comprehensive guideline should also be developed to assist users, especially those in the manufacturing industry who may not be well-versed in energy mapping techniques. The guideline should provide clear instructions and explanations, enabling users to effectively follow and utilize the software developed based on the proposed methodology. To ensure the usability and practicality of the software, it is essential to involve a diverse group of participants in case studies representing different industries. This will enable real-world testing and feedback from consultants, engineers, and production managers who possess domain-specific knowledge and experience. Their involvement will help identify potential challenges, provide valuable insights, and ensure that the software meets the requirements and expectations of various industries. By conducting extensive testing and gathering feedback, the methodology and accompanying software can be refined and optimized to maximize their effectiveness and usability in different production environments.

Figure 7 illustrates a screenshot of the software that is currently under development. The software aims to represent the steps outlined in the methodology and provide a user-friendly interface for conducting energy mapping in production plants. Before the software is officially launched, it is essential to thoroughly test and evaluate its performance and functionality. This testing phase should involve different groups, as mentioned above. By involving these diverse groups, their valuable insights and feedback can be gathered to identify any potential issues, improve usability, and ensure that the software meets the specific needs and requirements of different production environments.

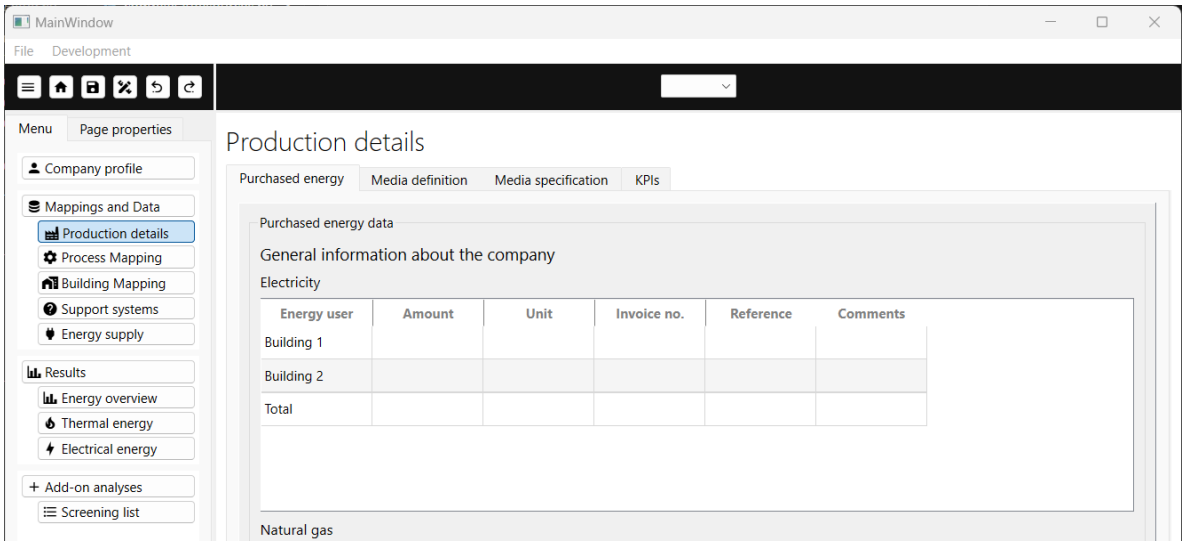



**Figure. 7.** Screen shot of the current software in the development phase

# Conclusion

The paper presented a generic methodology to accelerate the energy mapping of production lines. The performance of individual process steps is modeled with a few inputs following the steps presented in the following methodology. Process operational units representing different operational steps are identified. A few readily available data are collected, while the rest are defined by exploiting engineering judgment, such as the experience of the involved industrial partners visiting the plant, and estimated default values. Being able to bypass blind spots with regards to sensor data allows us to continue the work without costly and time-consuming measurement campaigns. The procedures developed in the proposed methodology thus enable the user to complete an energy mapping that may have been much more difficult to carry out otherwise.

The methodology was implemented in a case study as an examples of Danish food industry. By implementing the methodology in a case study, it was demonstrated that the necessary data can be collected and evaluated effectively, representing 88% accuracy.

The results of the case study showcased the potential of the methodology in visualizing the process and energy relationships within production lines. This enables the identification of significant energy users, equipment key performance indicators (KPIs), and opportunities for improving energy efficiency.

## Acknowledgments

The work was financially supported by EUDP, the research and development fund of the Danish Energy Association, under the project (64022-1073) “Efficient Energy Mapping and Analysis for Optimization and Green Transition of Industrial Processes”. The authors thanks FF Skagen A/S for their participation as a case study in the project.

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Viegand Maagøe

# Øvelses ark 3

Torsdag d. 29. februar 2024

Buildings, Support Systems & Results

# Formål

Med den seneste opdatering følger nye funktionaliteter under menu punkterne: **Buildings, Support Systems** og **Results.**

Som en fortsættelse af den tidligere feedbacksession ser vi frem til at opretholde det gode samarbejde og teste disse nye funktioner.

På de kommende sider vil der være øvelser, der guider jer gennem de funktioner, vi gerne vil have feedback på.

Viegand Maagøe

# Download EEMAP og Json-filer

- Download EEMAP v.0.7.0 her: https://drive.google.com/file/d/1z76lRgw0TAzEhB7S3T94AwJDAR6dt9GP/view?usp=sharing

- Åben filen Skjern-pp_3.0* ved at følge følgende sti:
  - File (oppe i menubaren) > Open > eemap > json > Skjern-pp_3.0

*Ikke fuld kortlægning, kun delprocessen er kortlagt.

Viegand Maagøe

# Øvelse 1 - Buildings

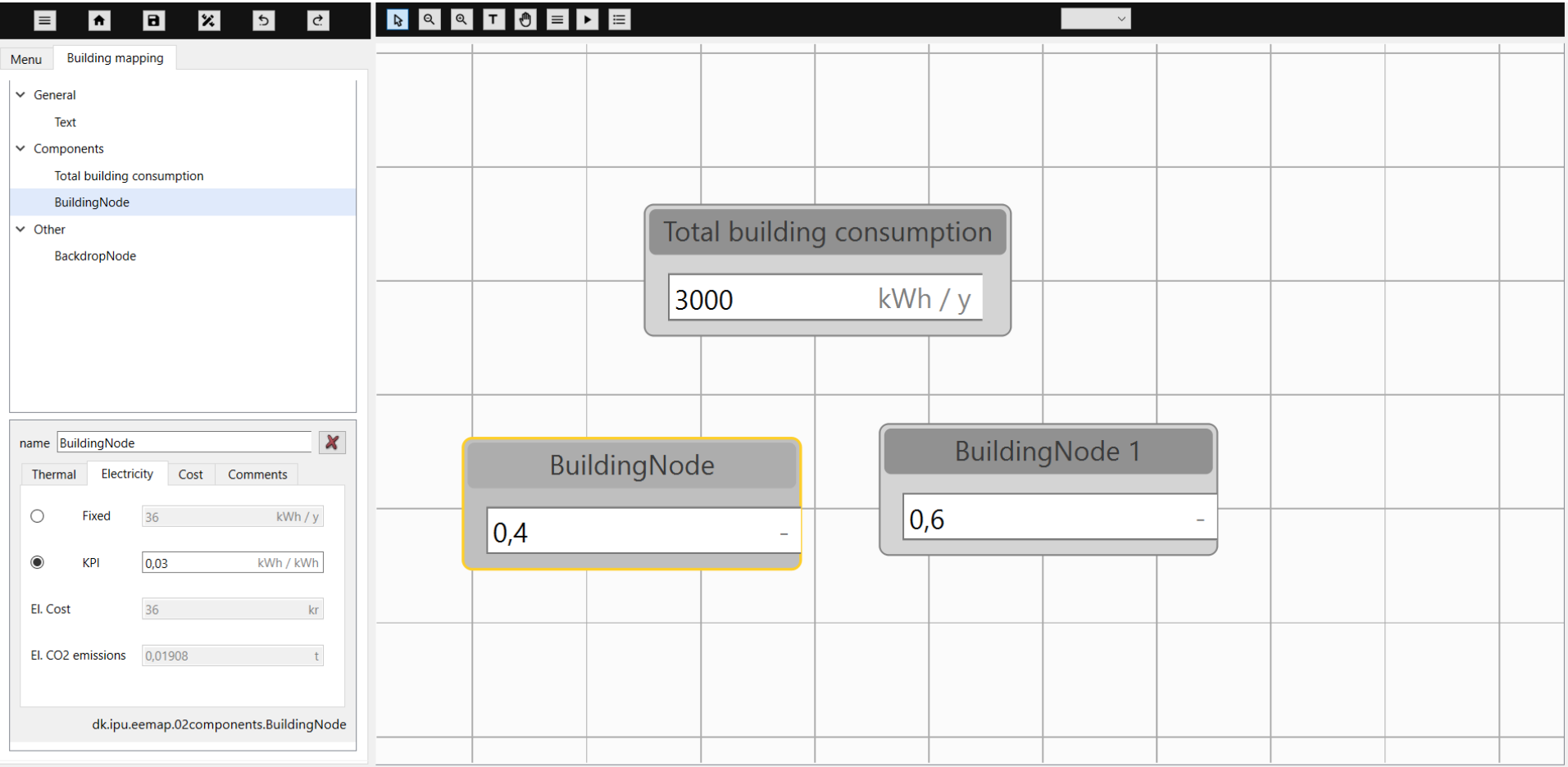
1. Indsæt komponenten ”total building consumption” og giv den en værdi
2. Indsæt *minimum to* ”building nodes” og giv den en termisk og elektrisk værdi
3. Tryk på *play*-knappen oppe i menu baren
4. Undersøg de værdier, som bliver udregnet i de forskellige ”building nodes”

**Overvej gerne følgende:**

1. Giver de forskellige funktionaliteter mening?
2. Hvad forstår du ved ”Energy ratio”

# Øvelse 1 - Buildings

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# Øvelse 2 – Support systems

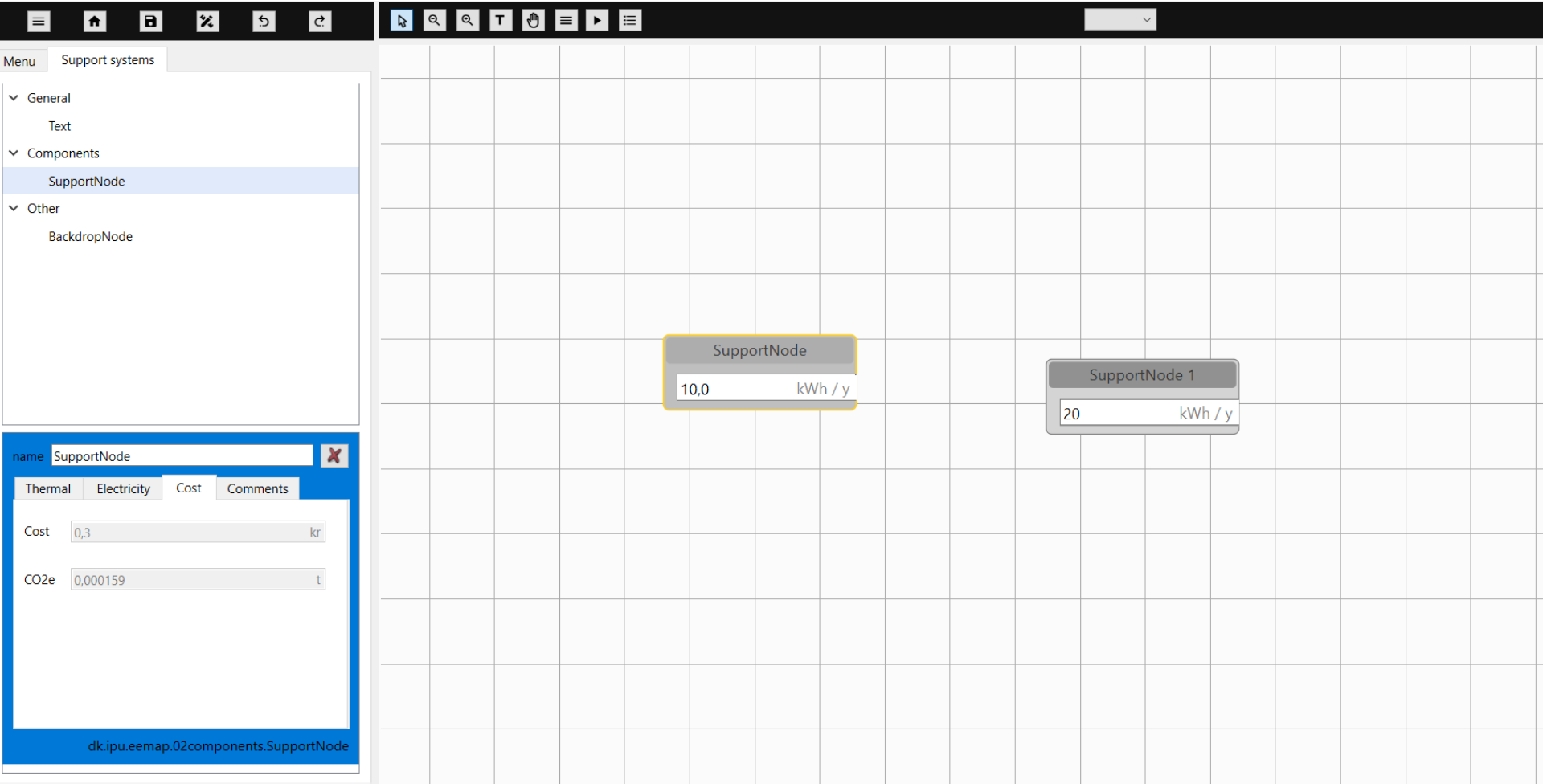
1. Indsæt minimum to komponenter ”support node” fra komponent biblioteket navn ” og giv den/dem en værdi
2. Tryk på *play*-knappen oppe i menu baren
3. Tryk ind på Results > Support systems og undersøg resultaterne – giver de mening?

**Overvej gerne følgende:**

1. Giver de forskellige funktionaliteter mening?
2. Forstår du hvad der bliver udregnet når du trykker på ”play”?

# Øvelse 2 – Support Systems

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# Øvelse 2 – Results > Support Systems

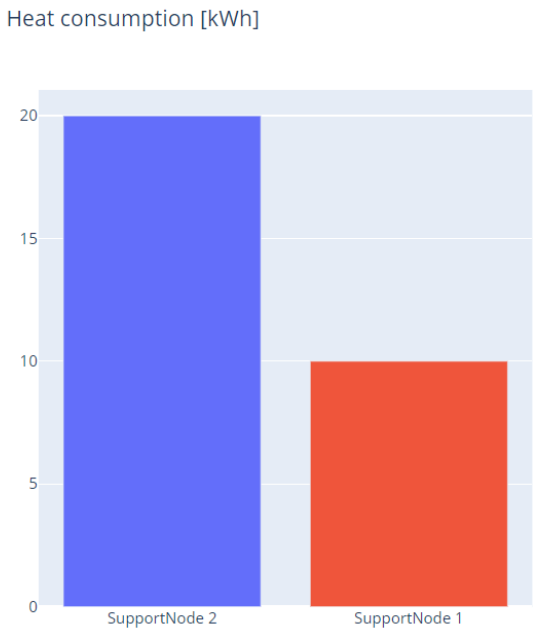
Viegand Maagøe

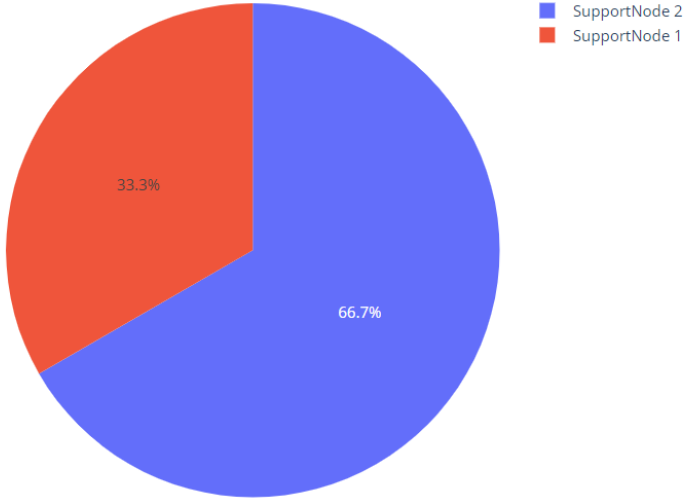
Menu

- Company profile
- Mappings and Data
  - Production details
  - Process Mapping
  - Building Mapping
  - Support systems
  - Energy supply
- Results
  - Process Mapping
  - Building mapping
  - Support systems
  - Energy supply
- Add-on analyses
  - Screening list

## Energy overview

Energy consumption | Heat Energy | Heat Cost | Heat CO2e | Cool Energy | Cool Cost | Cool CO2e



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# Øvelse 3 – Results

Udfyld information selv – prøv at lave en simple kortlægning

1. Gå ind på Process mapping siden og tryk på *play*-knappen
2. Gå dernæst ind på Process Mapping under Results
3. Undersøg de forskellige faner under resultatsiden. Reflekter over visningen af resultaterne – giver det mening?

# Øvelse 3– Results

Viegand Maagøe

Menu

- Company profile
- Mappings and Data
  - Production details
  - Process Mapping
  - Building Mapping
  - Support systems
  - Energy supply
- Results
  - Process Mapping
  - Building mapping
  - Support systems
  - Energy supply
- Add-on analyses
  - Screening list

## Energy overview

Energy consumption | Sankey Mass | Heat Energy | Heat Cost | Heat CO2e | Cool Energy | Cool Cost | Cool CO2e

### Heating Consumption

| Name | Energy carrier | Source energy | Type | Heat [kWh / y] | KPI [kWh / t] | Heat loss [kWh / y] | Electricity [kWh / y] | Cost [kr] | CO2e [t] | Heat share [-] | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|

### Cooling Consumption

| Name | Energy carrier | Source energy | Type | Heat [kWh / y] | KPI [kWh / t] | Heat loss [kWh / y] | Electricity [kWh / y] | Cost [kr] | CO2e [t] | Heat share [-] | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|

### Process equipment

| Name | Energy carrier | Source energy | Type | Heat [kWh / y] | KPI [kWh / t] | Heat loss [kWh / y] | Electricity [kWh / y] | Cost [kr] | CO2e [t] | Heat share [-] | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| airsplit 1 | | | cold loss | | | 0,0 | 15.056,5 | 15.056,5 | 7,97995 | | |
| Valse | | | cold loss | | | 0,0 | 16.893 | 16.893 | 8,9533 | | |
| TurboForm | | | cold loss | | | 0,0 | 42.477,6 | 42.477,6 | 22,5131 | | |
| Turbo | | | cold loss | | | 0,0 | 48.210,6 | 48.210,6 | 25,5516 | | |
| Spalting | | | cold loss | | | 0,0 | 106.216 | 106.216 | 56,2946 | | |
| Separator | | | cold loss | | | 0,0 | 17.455,8 | 17.455,8 | 9,25159 | | |
| Refiner1to3 | | | heatless | | | | 61.955 | 61.955 | 32,8362 | | |
| PulperWaste | | | cold loss | | | 0,0 | 48.285,6 | 48.285,6 | 25,5914 | | |
| Pulper | | | heatless | | | | 48.285,6 | 48.285,6 | 25,5914 | | |
| Press 1 | | | cold loss | | | 0,0 | 14.493,7 | 14.493,7 | 7,68167 | | |
| Press | | | cold loss | | | 0,0 | 16.890 | 16.890 | 8,95171 | | |
| Kar2 | | | heatless | | | | 106.239 | 106.239 | 56,3065 | | |

Mapping state-of-the-art
Component mapping in Energy Mappings

| FF Skagen | Mapping method | Variables used | Ovodan | Mapping method | Variables used | Skjern Paper | Mapping Method | Variables used |
|---|---|---|---|---|---|---|---|---|
| Cooker | 3 | m_dot, Δtemp, Cp | Heater | 3 | m_dot, Δtemp, Cp | Primærlinje 5 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Dryer | 3 | m_dot, Δtemp, Cp, ΔvH | Fermenting | 3 | m_dot, Δtemp, Cp | Sekundærlinje 5,1 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Vaporizer | 3 | m_dot, Δtemp, Cp | Spray dryer (direct heat) | 3 | m_dot, Δtemp, Cp | Primærlinje 4 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Decanter (direct heat) | 3 | m_dot, Δtemp, Cp | Spray dryer | 1 | | Primærlinje 3 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Centrifuge 2 (direct heat) | 3 | m_dot, Δtemp, Cp | Pasteurizer | 3 | m_dot, Δtemp, Cp | Primærlinje 2 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Centrifuge 2 (direct heat) | 3 | m_dot, Δtemp, Cp | Heat room | 1 | | Primærlinje 1 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Centrifuge 3 (direct heat) | 3 | m_dot, Δtemp, Cp | Dissolving (direct heat) | 3 | m_dot, Δtemp, Cp | | | |
| Kulfilter (direct heat) | 3 | m_dot, Δtemp, Cp | Buildings | 1 | | | | |
| Stripper (direct heat) | 3 | m_dot, Δtemp, Cp | Hot water | 1 | | | | |
| Vaporizer (water cooling) | 3 | m_dot, Δtemp, Cp | CIP Tank | 3 | m_dot, Δtemp, Cp | | | |
| Space heating | 1 | | CIP RO | 3 | m_dot, Δtemp, Cp | | | |
| Steam boiler | 1 | | CIP Centrifuge | 3 | m_dot, Δtemp, Cp | | | |
| Compressed air | 1 | | | | | | | |

Comment:
Some components are mapped with electricity consumption
For FF Skagen this is done by readings of electricity meters

| | List of mapping methods | | | |
|---|---|---|---|---|
| **Level** | Process | Building | Support systems | Energy supply |
| **1** | Percentage / measurement | Percentage / measurement | Percentage / measurement | Measurement + effeciency |
| **2** | KPI * flow | Energimærke*area*dT | Total flow * dT * Cp of mix | Detailed effciency |
| **3** | Thermodynamic eq. | Heat loss equation | Thermodynamic dynamic eq. | TBD |

# EEMAP
# Energikortlægningsværktøj

Et projekt støtte af EUDP

**Project status: EUDP 2024_03**

March 2024

# Oversigt

1) Introduktion af deltagerne
2) Status på projektet og arbejdsprocesserne
3) Præsentation af kortlægningsværktøjet
4) Oplæg til det videre forløb, herunder tidsplan
5) Økonomi
6) Drøftelser af det videre liv for EEMAP
7) Evt.

# Introduktion af deltagere

Bordet rundt:

- EUDP
- Viegand Maagøe
- DTU
- IPU

# Status på projektet og arbejdsprocesserne

Project management (WP1)

Scoping (WP2)

Mapping state of the art (WP3)

Field Mapping (WP4)

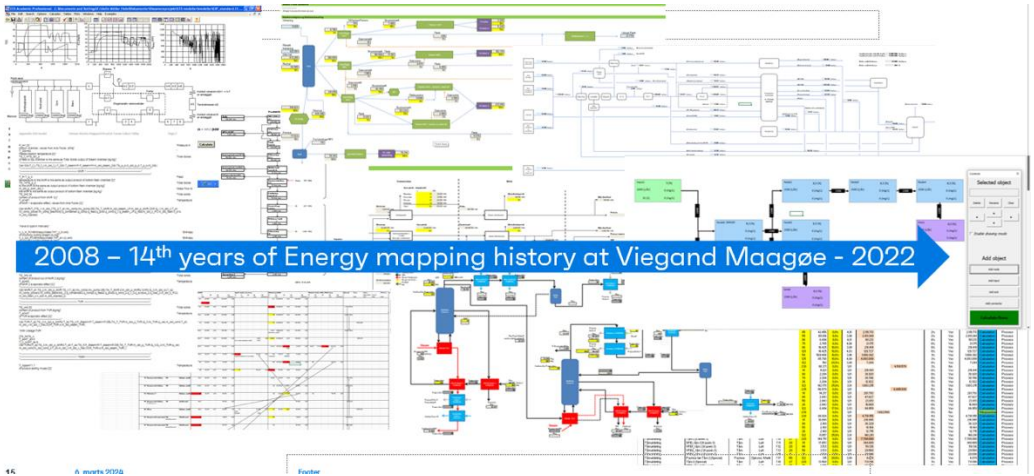
Programming (WP5)

Add-on analyses (WP6)

Field test (WP7)

Maturing and Analysis Expansion (WP8)

Communication (WP9)



# Status på projektet og arbejdsprocesserne

## Project management

Overordnet projektledelse

- Møder
- Rapportering
- Økonomi

Arbejdspakke specifik projektledelse

Arbejdes- og ledelsesmøder (DTU, IPU og VMAS)

Workshops: FF-Skagen, Ovodan, Avista Green





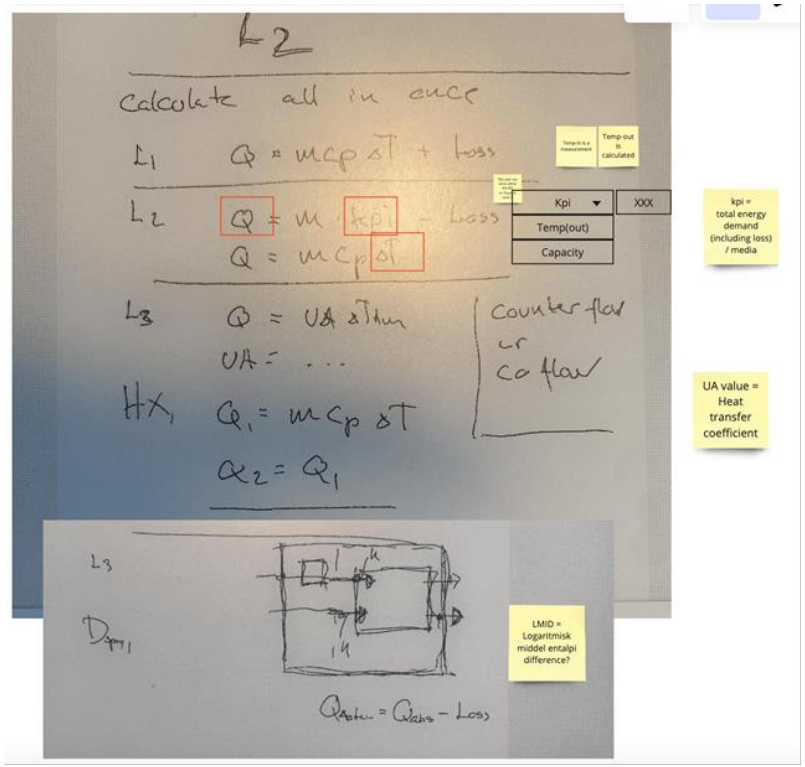


# Status på projektet og arbejdsprocesserne

## Scoping

Workshops (DTU, IPU og VMAS)

- Form
- Omfang
- Detaljeringsniveau
- Brugervenlighed
- …



# Status på projektet og arbejdsprocesserne

## Mapping state of the art

- Masse balancer
- Energibalancer

- Process
- Bygning
- Supporting
- Energiforsyning

*Table 1 levels of mapping*

| Level | List of mapping methods<br>Process | Building | Support systems | Energy supply |
|---|---|---|---|---|
| 1 | Percentage / measurement | Percentage / measurement | Percentage / measurement | Percentage / measurement |
| 2 | KPI * flow | Energi-mærke*area*dT | Total flow * KPI | Efficiency |
| 3 | Thermodynamic eq. | Heat loss equation | Thermodynamic dynamic eq. + correction factor (losses and heating of equipment) | Detailed efficiency |
| Mapping principals | Mass and Energy balance | Energy balance | Mass and Energy balance | Energy balance |

### 7.5 Decanter

The decanter component splits a stream into a "liquid" partition and a "prax" partition. The component has the following variables:

1. Media split:
   a. **Value**: The mass flow of the media-component chosen below going to the "prax" partition expressed as a fraction of the total mass flow into the component.
   It is important to note that this is not the total mass flow to the "prax" partition, this is discussed further in the mass balance section of the component.
   b. **Media**: The media-component for which a mass flow is defined

2. Mass flow:
   a. **Value**: The absolute mass flow of the media-component defined below going to the "prax" partition.
   It is important to note that this is not the total mass flow to the "prax" partition, this is discussed further in the mass balance section of the component.
   b. **Media**: The concentrations of the media going to the "prax" partition

3. **Media prax**: The media concentrations for the "prax" partition
4. **Outlet temperature**: Temperature out of the component for both "liquid" and "prax" partitions

To define the flow out of the component either the mass split or mass flow variables must be defined, only one or the other can be defined.
For a media consisting of only one media-component (eg. Water, Foodprotein etc.) the decanter cannot be used. Instead a splitter component should be utilized.

#### 7.5.1 Mass balance

For the decanter component to be defined the mass flow equations must have enough inputs to solve. To determine the overall mass flow distribution between the "liquid" and "prax" partitions, along with the media concentrations, either the mass flow variables or the mass split variables must be defined. Only one of the two sets of variables can be defined at a time.

Both sets of variables will define the mass flow of a single media-component to the "prax" partition, along with the media concentrations for the prax the total mass flow can be determined. The remaining mass flow is then directed to the "liquid" partition with the resulting media concentrations as an output.

For the mass split variables it is important to remember that the mass flow being defined is dependent on the total mass flow into the component, but only defines the mass flow of a specific media-component to the "prax" partition.
The same is true for the mass value variables, however, here a fixed value for the mass flow of a specific media-component is given instead.

The "Media" variable defines the media-component, for which a mass flow is defined, is chosen.

#### 7.5.2 Thermal energy balance

To determine the thermal energy balance of the decanter the outlet temperature is given for the component. This temperature is the same for both the "prax" and "liquid". With this it is possible to determine the thermal energy balance with the temperature approach, described in section ... equations xx to yy

### 2 Components overview

| Category | Process | Building | Support systems | Energy Supply |
|---|---|---|---|---|
| Description | The process components are components, which energy consumption are directly related to the operation of the process and the corresponding mass flow. | Building components entail energy contributions related to the operation of buildings for both process, storage and administration. | Support system components are equipment used in or for the process operation that are not directly linked to the process mass flow. | Energy supply components are the energy converting components that convert the purchased energy form into the energy bearing media. |
| List | 1. Cooker<br>2. Dryer<br>3. Vaporizer<br>4. Evaporator<br>5. Decanter<br>6. Centrifuge<br>7. Membranes (ult. filter)<br>8. Stripper<br>9. Heating<br>10. Fermenting<br>11. Spray dryer<br>12. Pasteurizer<br>13. Heat exch<br>14. Agitation (Conc. (acing)<br>15. Mixer<br>16. Distillation<br>17. Indirect dryer<br>18. Compressor<br>19. Microwave<br>20. Pressure treatment<br>21. Ultraviolet<br>22. Infrared<br>23. Cooling<br>24. Baking<br>25. Press<br>26. Desorption<br>27. Extraction<br>28. Suspension<br>29. Sedimentation<br>30. Humidification | 1. Space heating<br>2. Space cooling<br>3. Electricity<br>a. Light<br>b. Kitchen<br>c. IT-equip. | 1. CIP<br>2. Water<br>3. Effluent<br>4. Waste water treatment | 1. Gas/oil boiler<br>2. Electrical boiler<br>3. Biomass boiler<br>4. Heat pump<br>5. Refrigeration / Cooling system<br>6. Combined heating and cooling production<br>7. Compressed air<br>8. Vacuum<br>9. Solar panels<br>10. Solar heating |

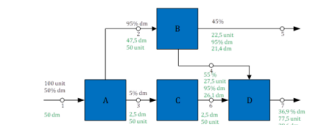
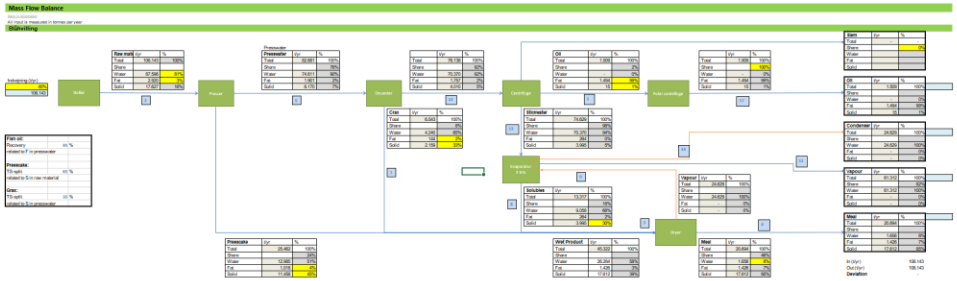



*Figure 2 example of a mass balance using dry matter fractions for defining flows.*

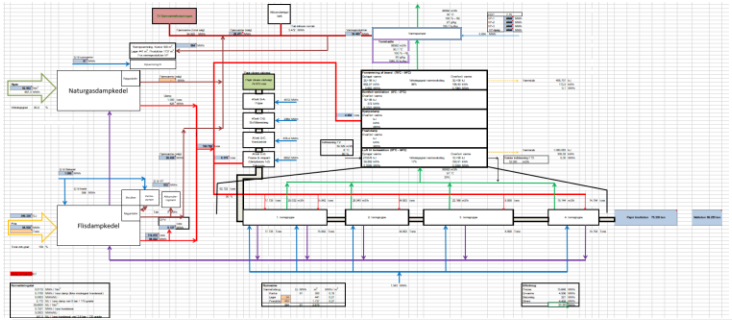
# Status på projektet og arbejdsprocesserne

## Field Mapping

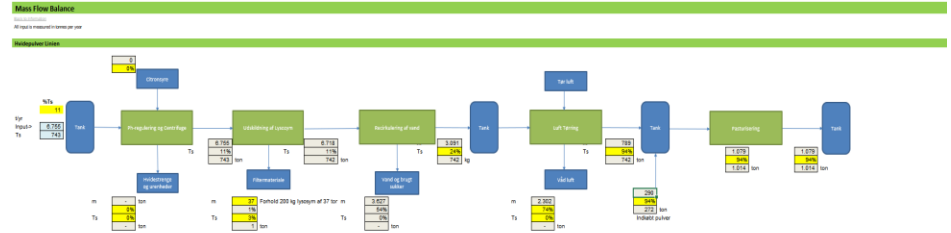
FF-Skagen




Skjern Paper (Master student)




Ovodan



# Status på projektet og arbejdsprocesserne

## Programming

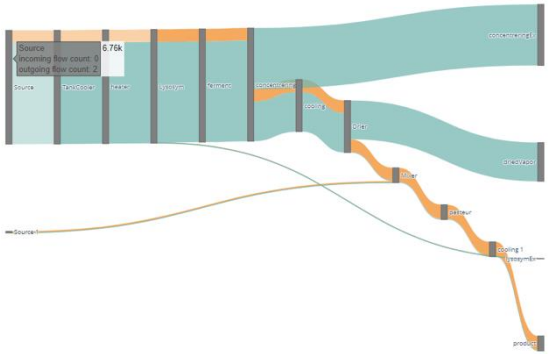
Beskrives under præsentation af værktøjet

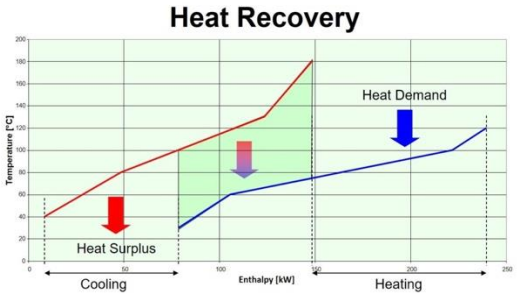
# Status på projektet og arbejdsprocesserne

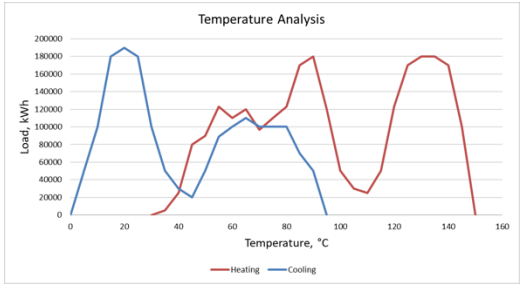
## Add-on analyses

- Sankey (mass, energy, CO2 og økonomi)
- Screening (300 punkter)
- Temperatur analyse
- Pinch analyse
- Ny udvikling af metoder er planlagt til sommeren, men forventes ikke integreret.
  - Identifikation af sensors
  - Identifikation af uvæsentlige strømme
  - Identifikaiton af elektrificerings teknologier



# Status på projektet og arbejdsprocesserne

## Field test

**Udviklingsvirksomheder**

FF-Skagen : 95 % færdige

Skjern Paper: 75 % færdige

Ovodan: 90 % færdige

**Testvirksomheder**

Avista Green: forventes gennemført I uge 13

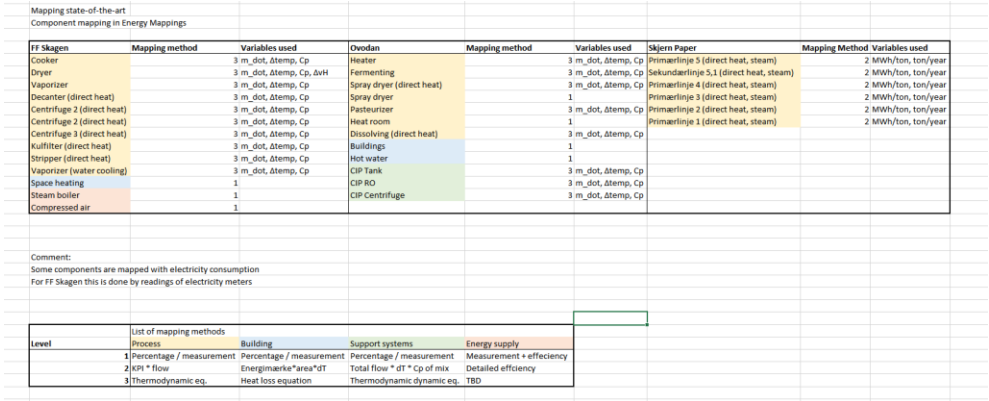
PPG: gennemføres I uge 10 og 11

Royal Unibrew (Batchelor Student) færdiggøres i uge 13

# Status på projektet og arbejdsprocesserne

## Maturing and Analysis Expansion

Flere interne workshops har været afholdt, med fokus på at udvikle værktøjet i et omfang, der rækker uden for den specifikke efterspørgsel fra de seks involverede virksomheder.



Mapping state-of-the-art
Component mapping in Energy Mappings

| FF Skagen | Mapping method | Variables used | Ovodan | Mapping method | Variables used | Skjern Paper | Mapping Method | Variables used |
|---|---|---|---|---|---|---|---|---|
| Cooker | | 3 m_dot, Δtemp, Cp | Heater | | 3 m_dot, Δtemp, Cp | Primærlinje 5 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Dryer | | 3 m_dot, Δtemp, Cp, ΔvH | Fermenting | | 3 m_dot, Δtemp, Cp | Sekundærlinje 5,1 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Vaporizer | | 3 m_dot, Δtemp, Cp | Spray dryer (direct heat) | | 3 m_dot, Δtemp, Cp | Primærlinje 4 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Decanter (direct heat) | | 3 m_dot, Δtemp, Cp | Spray dryer | | 1 | Primærlinje 3 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Centrifuge 2 (direct heat) | | 3 m_dot, Δtemp, Cp | Pasteurizer | | 3 m_dot, Δtemp, Cp | Primærlinje 2 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Centrifuge 2 (direct heat) | | 3 m_dot, Δtemp, Cp | Heat room | | 1 | Primærlinje 1 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Centrifuge 3 (direct heat) | | 3 m_dot, Δtemp, Cp | Dissolving (direct heat) | | 3 m_dot, Δtemp, Cp | | | |
| Kulfilter (direct heat) | | 3 m_dot, Δtemp, Cp | Buildings | | 1 | | | |
| Stripper (direct heat) | | 3 m_dot, Δtemp, Cp | Hot water | | 1 | | | |
| Vaporizer (water cooling) | | 3 m_dot, Δtemp, Cp | CIP Tank | | 3 m_dot, Δtemp, Cp | | | |
| Space heating | | 1 | CIP RO | | 3 m_dot, Δtemp, Cp | | | |
| Steam boiler | | 1 | CIP Centrifuge | | 3 m_dot, Δtemp, Cp | | | |
| Compressed air | | 1 | | | | | | |

Comment:
Some components are mapped with electricity consumption
For FF Skagen this is done by readings of electricity meters

| | List of mapping methods | | | |
|---|---|---|---|---|
| Level | Process | Building | Support systems | Energy supply |
| 1 | Percentage / measurement | Percentage / measurement | Percentage / measurement | Measurement + effeciency |
| 2 | KPI * flow | Energimærke*area*dT | Total flow * dT * Cp of mix | Detailed effciency |
| 3 | Thermodynamic eq. | Heat loss equation | Thermodynamic dynamic eq. | TBD |

### Basic component blocks

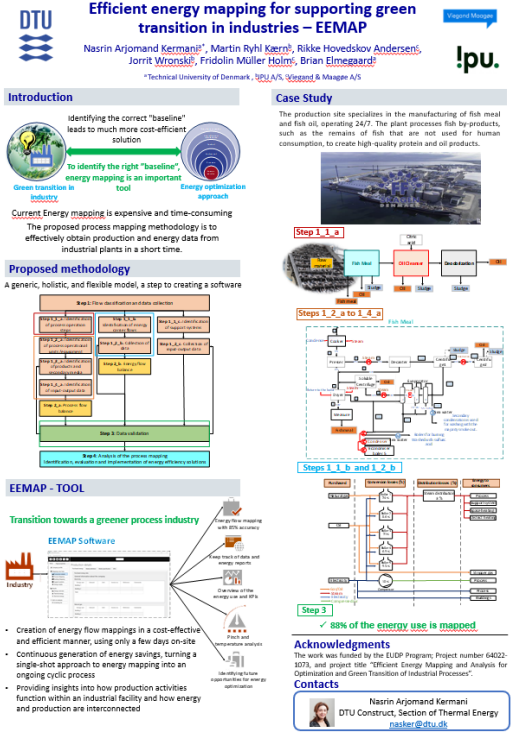
- Splitter
- Connector
- Direct heat and mass transfers
- Indirect heat transfers
- Electrical treatment
- Exothermal and endothermal

Clean up og debugging er i gang.

# Status på projektet og arbejdsprocesserne

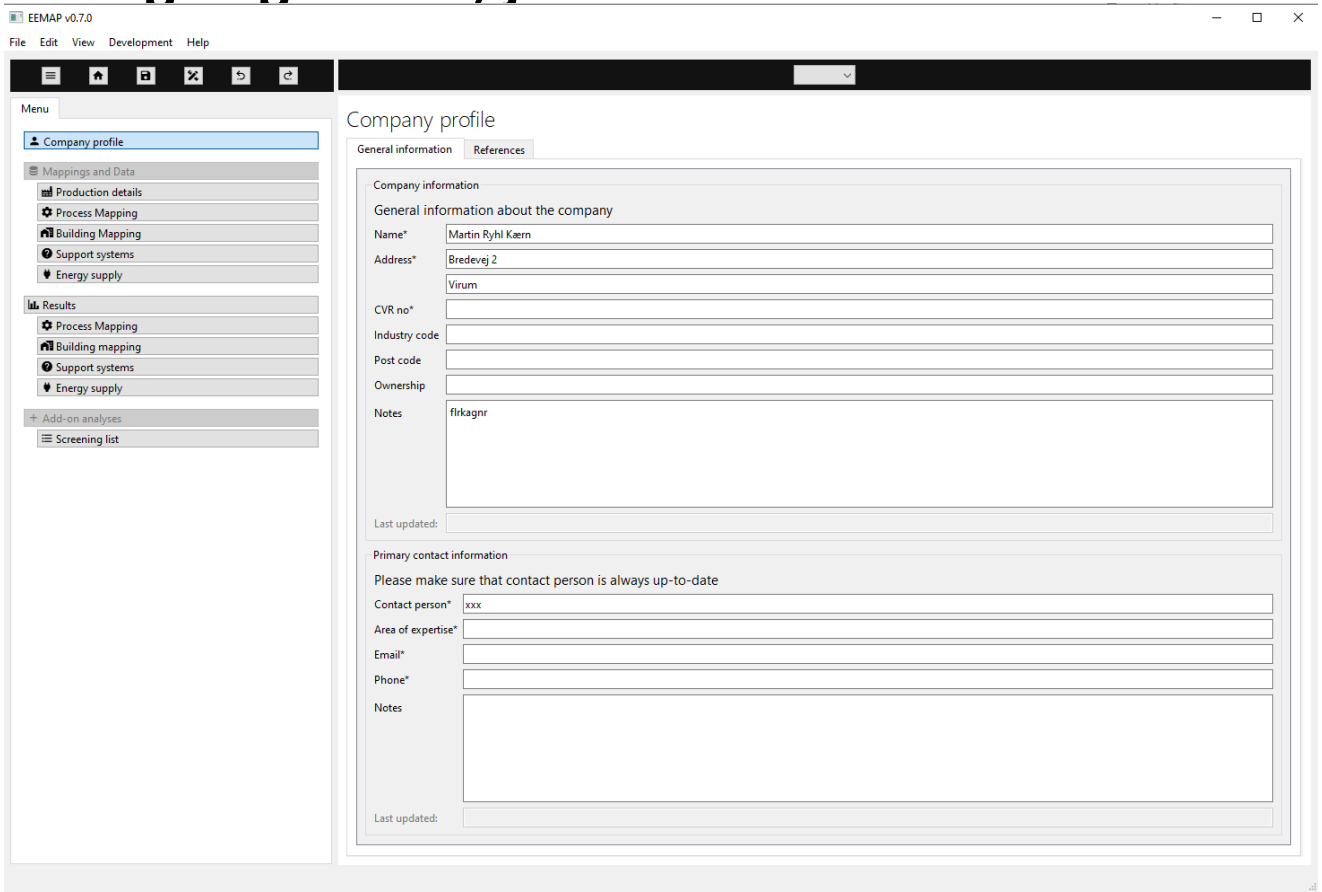
## Communication

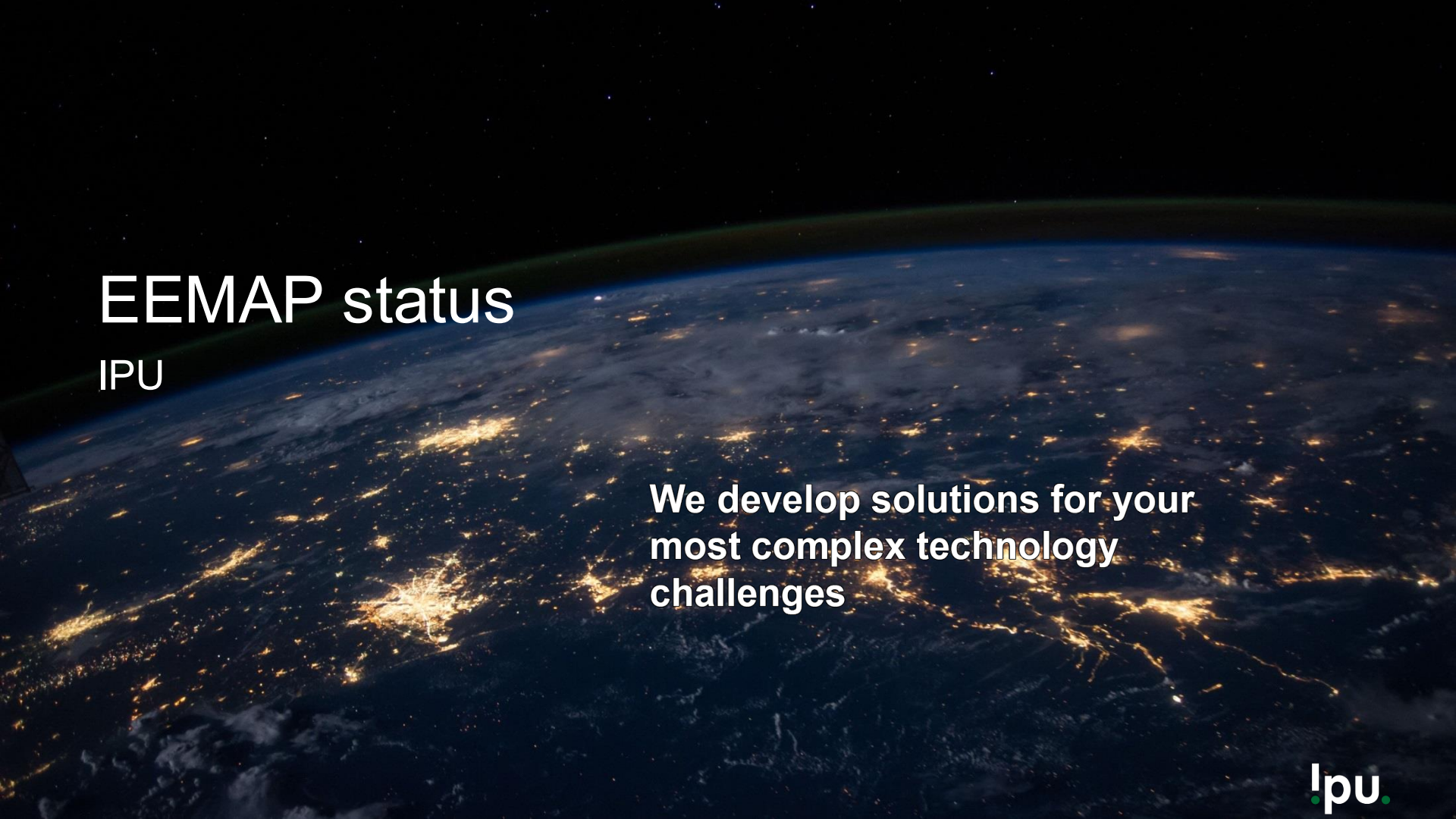
- The methodology behind EEMAP has been published and presented in a conference paper at ECOS 2023 Ecos 2023 Las Palmas de Gran Canaria Spain – Ecos 2023 Conference Las Palmas de Gran Canaria Spain
- Industry Decarbonisation knowledge exchange, Ambassade du Danemark en France – The Danish Embassy in France, November 2022.
- Decarbonisation of the Danish Industry - Projects and research activities", Knowledge sharing TES-DTU and California Energy Commission (group of 7 people including: Commissioner: Andrew McAlliste, Advisor to Commissioner: David Johnson, Director of the Efficiency Division: Mike Sokol, Deputy Director of the Energy Research and Development Division: Angie Gould, Danish energy agency advisor: Fabian Buhler, Energy advisor form innovation center Denmark: Claus Krog Ekman ) organized by Danish Energy Agency, September 2023.
- Danida fellowship center course (DFC), entitled: "Energy Efficiency and Energy Management in Buildings and Industry ", to 20 participants from developing countries (partners in Danida financed development cooperation projects and programs), DTU, August 2023.
- Abstract and presentation of energy mapping and EEMAP at the IEA conference in Goteborg in 2023.
- LinkedIn, Podcast, Videoer



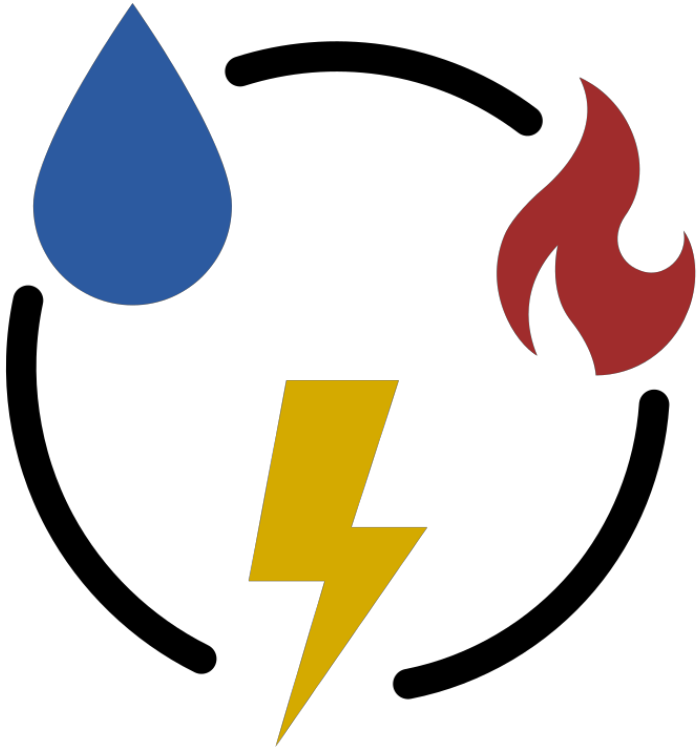
# Præsentation af kortlægningsværktøjet

- Introduktion til værktøjerne bag EEMAP
- Introduktion til opbygningen af værktøjet
- Introduktion til strukturen og funktionaliteten
- Introduktion til resultaterne
- Eksempel på brugen af værktøjet



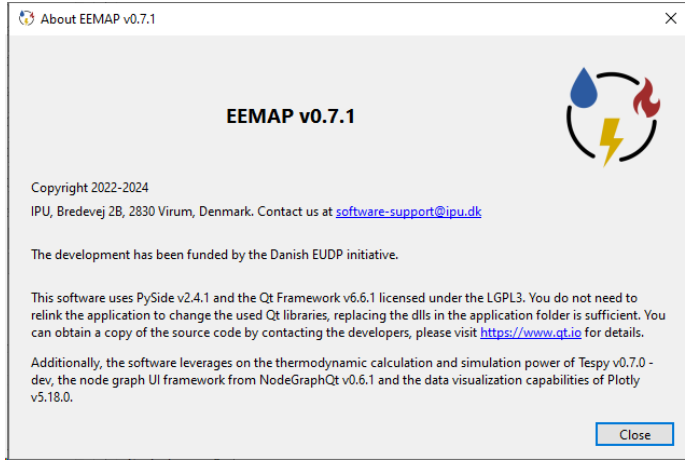

EEMAP status
IPU
We develop solutions for your most complex technology challenges
!pu.

# EEMAP Status



# Software tool developed with Qt for python

- QT for python
- NodegraphQt
- Tespy
- Plotly




- Coolprop

# Software architecture

PySide6 (frontend)

## Calculator (backend)

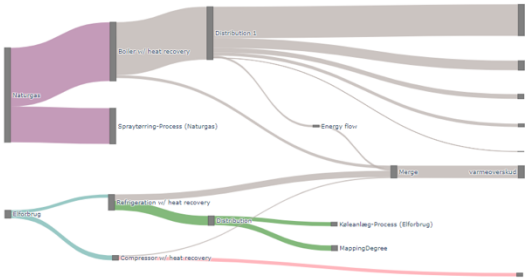
tespy ['tɛs.paɪ]

Coolprop

## NodeGraphQt



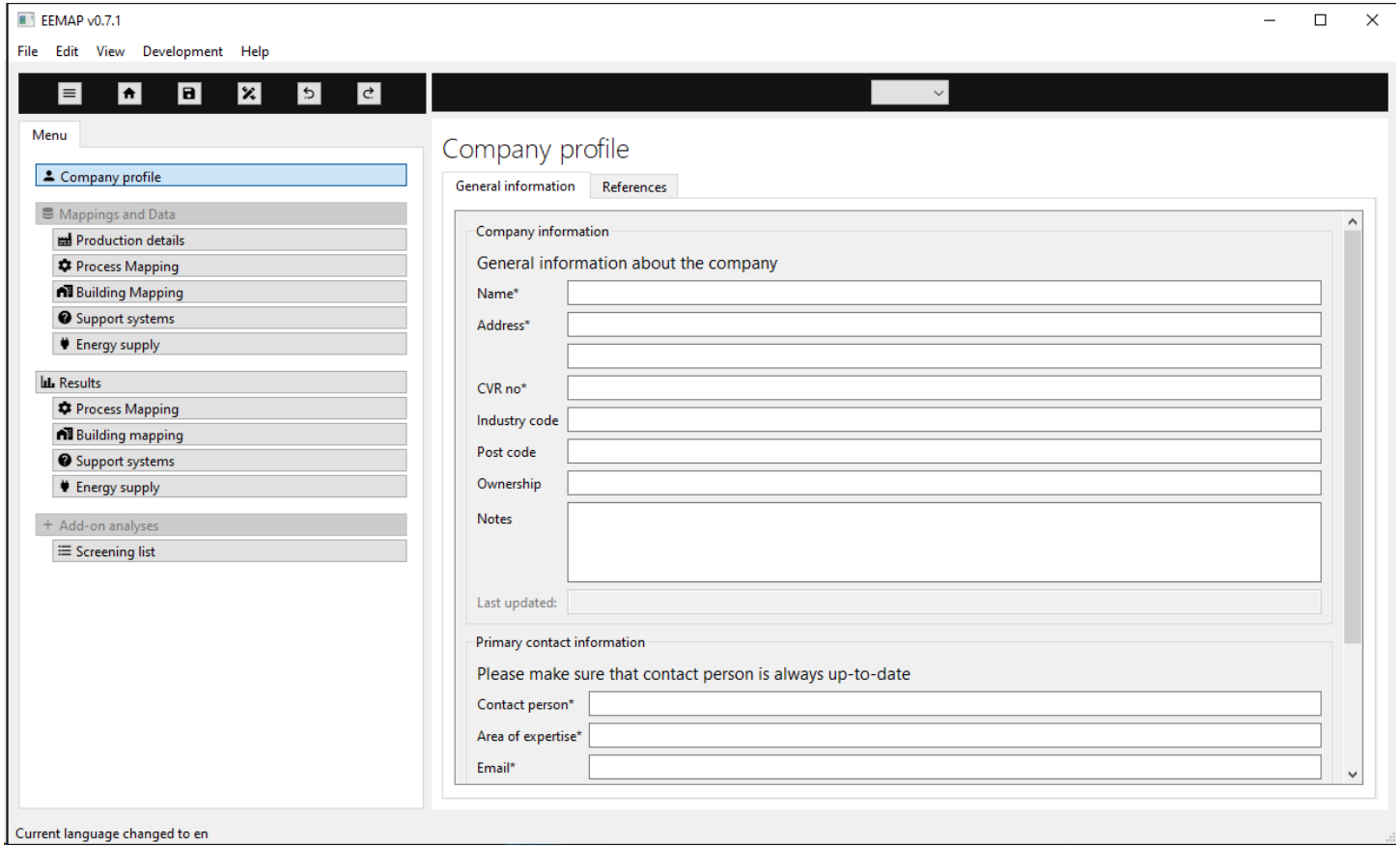
## Plotly



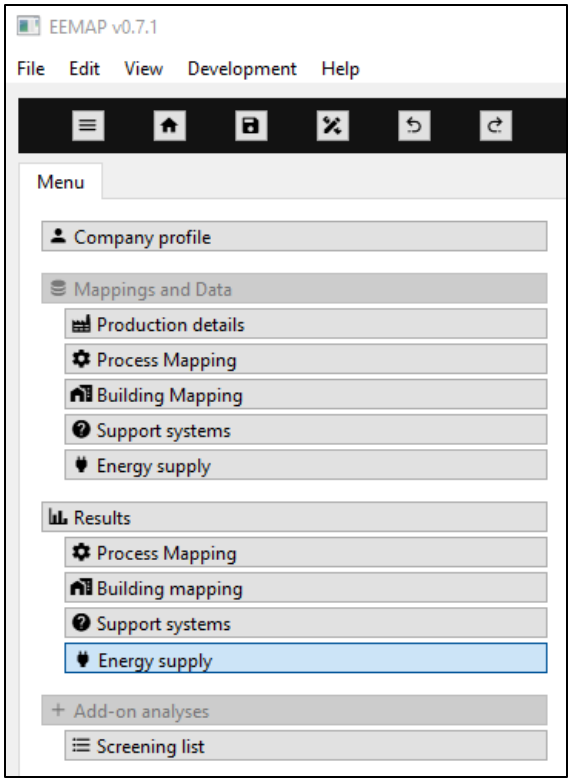
Translation

Visualization

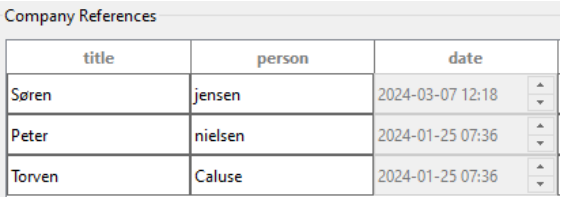
# Overview


EEMAP v0.7.1
File
Edit
View
Development
Help
Menu
Company profile
Mappings and Data
Production details
Process Mapping
Building Mapping
Support systems
Energy supply
Results
Process Mapping
Building mapping
Support systems
Energy supply
Add-on analyses
Screening list
Company profile
General information
References
Company information
General information about the company
Name*
Address*
CVR no*
Industry code
Post code
Ownership
Notes
Last updated:
Primary contact information
Please make sure that contact person is always up-to-date
Contact person*
Area of expertise*
Email*
Current language changed to en

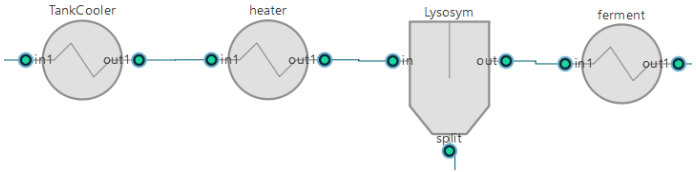
# Overview



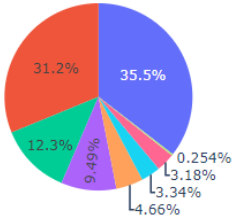

## Company info

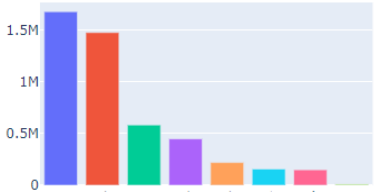



## Mapping detail and calculations




## Results




## Addon analysis



# Oplæg til det videre forløb, herunder tidsplan

## Tidsplan

The project is scheduled to last for 2 years in total –starting effectively with the decision from EUDP in June

**Gantt diagram**

EUDP

Det Energiteknologiske Udviklings- og Demonstrationsprogram

**Project title: Efficient Energy Mapping and Analysis for Optimization and Green Transition of Industrial Processes (EEMAP)**

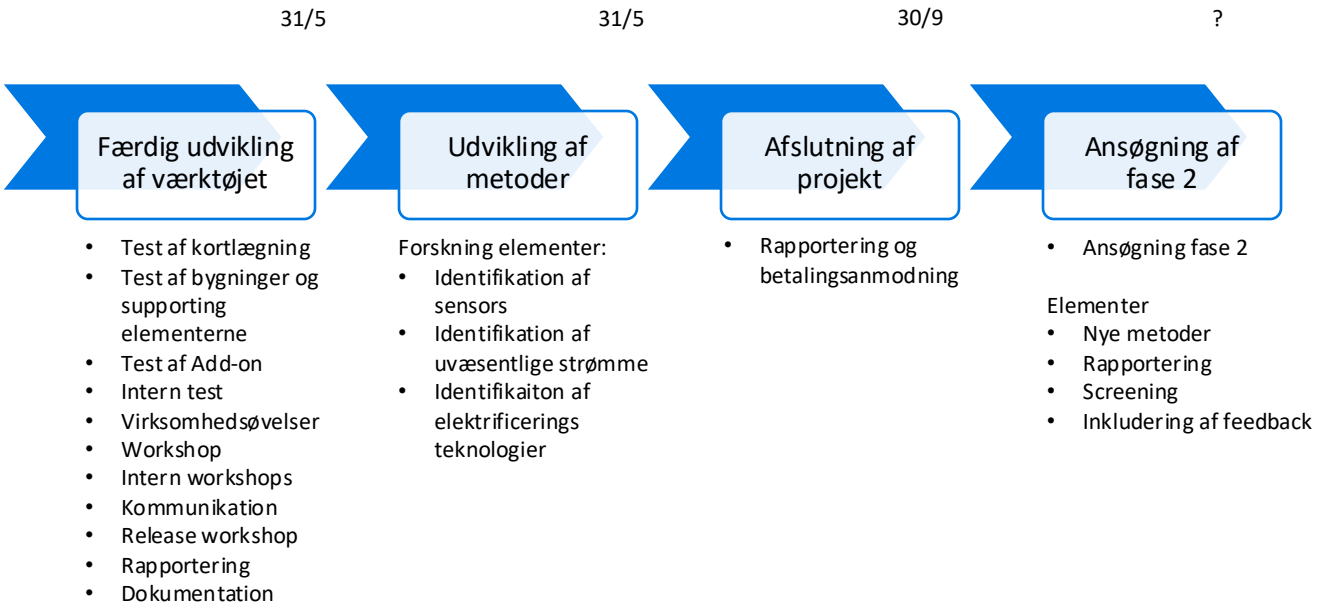
**Project start: June 2022**

**Project end: June 2024**

| Year/År | 2022 | | | | | | | | | | | | 2023 | | | | | | | | | | | | 2024 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work packages/Projektets arbejdspakker:** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| **WP1 - Project Management** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP2 - Scoping** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP3 - Mapping state-of-the-art** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP4 - Field Mapping (Without Tool)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP5 - Programming** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP6 - Add-on Analyses** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP7 - Field Test (With Tool)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP8 - Maturing and Analyses Expansion** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP9 - Communication** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Milestones/Milepæle** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M1 - Design Specifciation Completed | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| M2 - Techonology Parameter Table Completed | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | |
| M3 - First version ready for field testing | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | | | | | |
| M4 - Finalized Tool | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | |
| M5 - Presentation at ECOS Conference 2023 | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | |
| **Commercial milestones/Kommerc. milepæle** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CM1 - Project Finalization | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | |
| CM2 - Mapping of potential add-ons and their commercial potential | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | |
| CM3 - Model proof of concept in operational environment | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | |

# Oplæg til det videre forløb, herunder tidsplan

Bud på det videre forløb, hvilket også omfatter et udsættelse af project afslutning frem til 30/9 2024



# Økonomi

## Status og ønsker

- DTU: 65%
- VMAS: 70%
- IPU: 100%
- Udviklingsvirksomheder: 50%
- Testvirksomheder: 20 %
- En betalingsanmodning sommeren 2023
- Flytning af 200 timer sommeren
- Ønskes om flytning af beløb svarende til 200 timer
- Om allokering fra udgifter til timer
- Om allokering fra virksomheder til IPU

| | Viegand Maagøe | IPU | DTU | FF Skagen | Company X | Skjern Papir | AVISTA Green | Royal Unibrew | PPG Coatings Denmark A/S |
|---|---|---|---|---|---|---|---|---|---|
| **Project Management** | *300 hours* | | | | | | | | |
| | | | | | | | | | |
| **Administration** | *200 hours* | | | | | | | | |
| | | | | | | | | | |
| **Technical Competences** | | | | | | | | | |
| Scoping | *200 hours* | *100 hours* | *300 hours* | *150 hours* | *150 hours* | *150 hours* | | | |
| Technology Review | *100 hours* | | *300 hours* | | | | | | |
| Programming and Debugging | *125 hours* | *1200 hours* | *125 hours* | | | | | | |
| Analysess | *150 hours* | *300 hours* | *500 hours* | | | | | | |
| | | | | | | | | | |
| **Commercial Competences** | | | | | | | | | |
| Mapping | *600 hours* | *50 hours* | | *150 hours* | *150 hours* | *150 hours* | *150 hours* | *150 hours* | *150 hours* |
| | | | | | | | | | |
| **Communication** | *250 hours* | *100 hours* | *500 hours* | | | | | | |
| | | | | | | | | | |
| **Hours in total** | ***1975 hours*** | ***1750 hours*** | ***1725 hours*** | ***300 hours*** | ***300 hours*** | ***300 hours*** | ***150 hours*** | ***150 hours*** | ***150 hours*** |

# Drøftelser af det videre liv for EEMAP

Ansøgning fase 2

Økonomi

Ejerskab

Udvikling

# Kontakt




Fridolin Müller Holm

Chef for industri

Viegand Maagøe A/S

Tlf. +45 31 75 17 14

E-mail: fmh@viegandmaagoe.dk

WWW.VIEGANDMAAGOE.DK





Sneaster Asrat

Design Ingeniør

Viegand Maagøe A/S

Tlf. +45 42 21 49 00

E-mail: sas@viegandmaagoe.dk

WWW.VIEGANDMAAGOE.DK





Brian Elmegaard

Professor

DTU

Tlf. +45 25 41 69

E-mail: be@mek.dtu.dk

WWW.TES.MEK.DTU.DK





Jorrit Wronski

Specialist Engineer

IPU

Tlf. +45 45 16 04 26

E-mail: jowr@ipu.dk

WWW.IPU.DK

# backup

# tespy

- Component based design and part load simulator
  - Steady state
  - Generic architecture
  - Added 6 models
    - Separator with
      - Heat loss
      - S-split
      - F-split
      - Heat bus
      - …

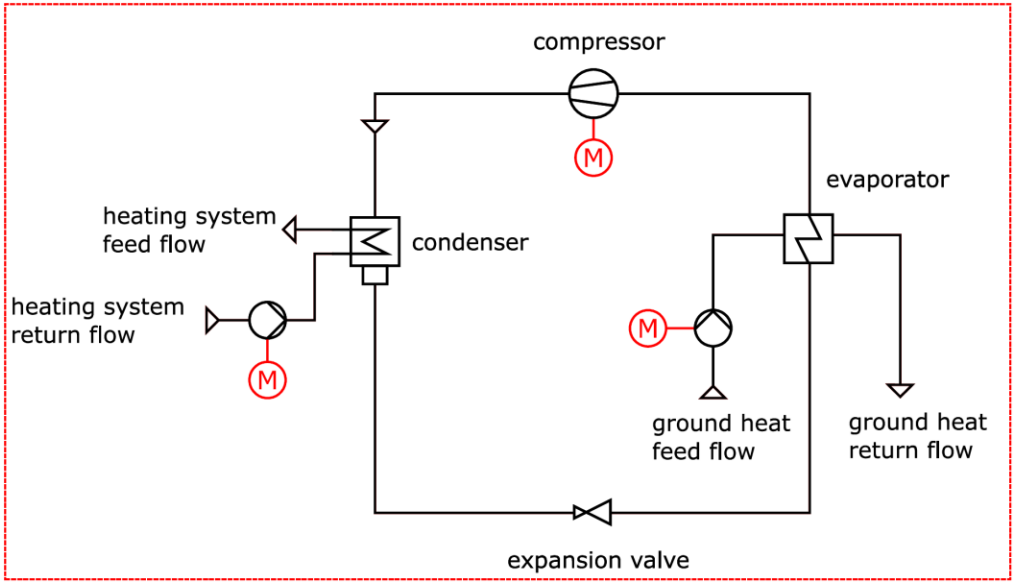
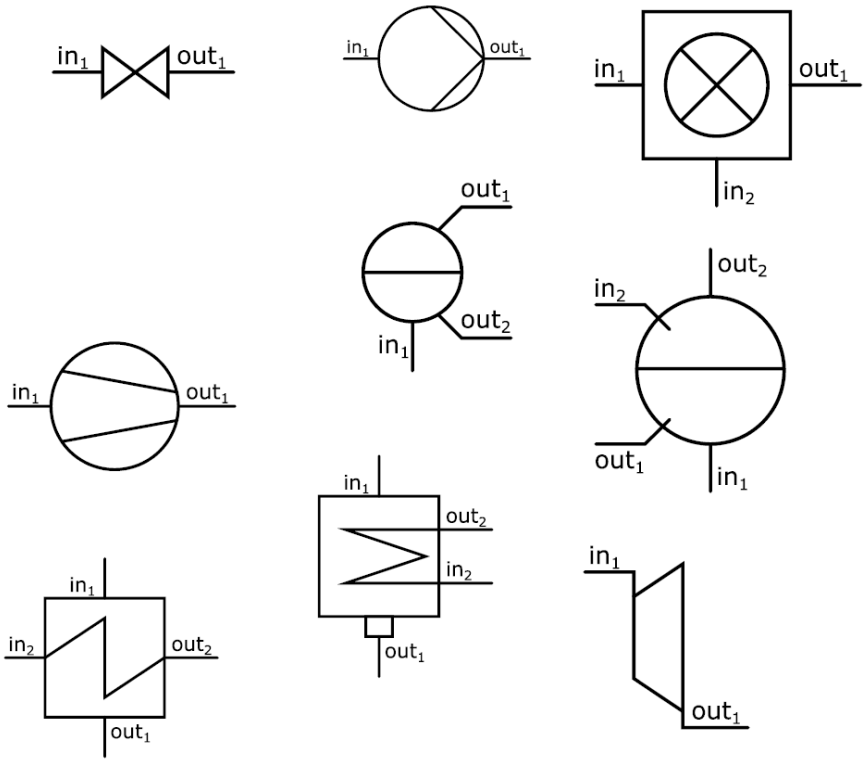



figure by Francesco Witte

# tespy components



- **Basics**
  - Cycle closer
  - Sink
  - Source
  - Subsystem interface
- **Combustion**
  - Combustion chamber
  - Diabatic combustion chamber
  - Combustion engine
- **Heat exchangers**
  - Simplified heat exchanger
  - Solar collector
  - Parabolic trough
  - Heat exchanger
  - Condenser
  - Desuperheater
- **Nodes**
  - Droplet separator
  - Drum
  - Merge
  - Separator
  - Splitter
- **Piping**
  - Pipe
  - Valve
- **Reactors**
  - Fuel cell
  - Water electrolyzer
- **Turbomachinery**
  - Compressor
  - Pump
  - Turbine




slide contents @ Francesco Witte

# Food properties

# EEMAP
# Energikortlægningsværktøj

Et projekt støtte af EUDP

**Project status: EUDP_2024-08**

August 2024

# Oversigt

1) Introduktion af deltagerne
2) Status på projektet og arbejdsprocesserne
3) Præsentation af kortlægningsværktøjet
4) Oplæg til det videre forløb, herunder tidsplan
5) Økonomi
6) Drøftelser af det videre liv for EEMAP
7) Evt.

# Introduktion af deltagere

Bordet rundt:

- EUDP
- Viegand Maagøe
- DTU
- IPU

# Status på projektet og arbejdsprocesserne

Project management (WP1)

Scoping (WP2)

Mapping state of the art (WP3)

Field Mapping (WP4)

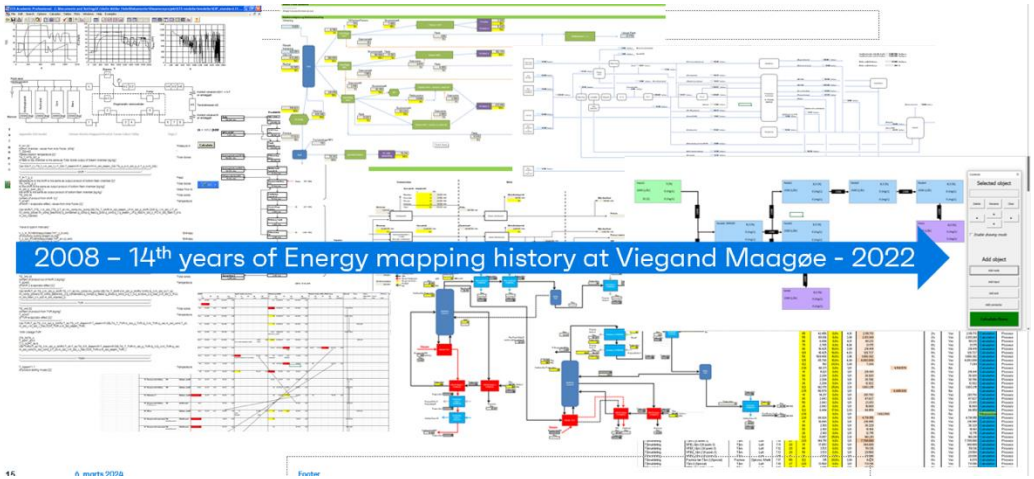
Programming (WP5)

Add-on analyses (WP6)

Field test (WP7)

Maturing and Analysis Expansion (WP8)

Communication (WP9)



# Status på projektet og arbejdsprocesserne

## Project management

Overordnet projektledelse

- Møder
- Rapportering
- Økonomi

Arbejdspakke specifik projektledelse

Arbejdes- og ledelsesmøder (DTU, IPU og VMAS)

Workshops: FF-Skagen, Ovodan, Avista Green





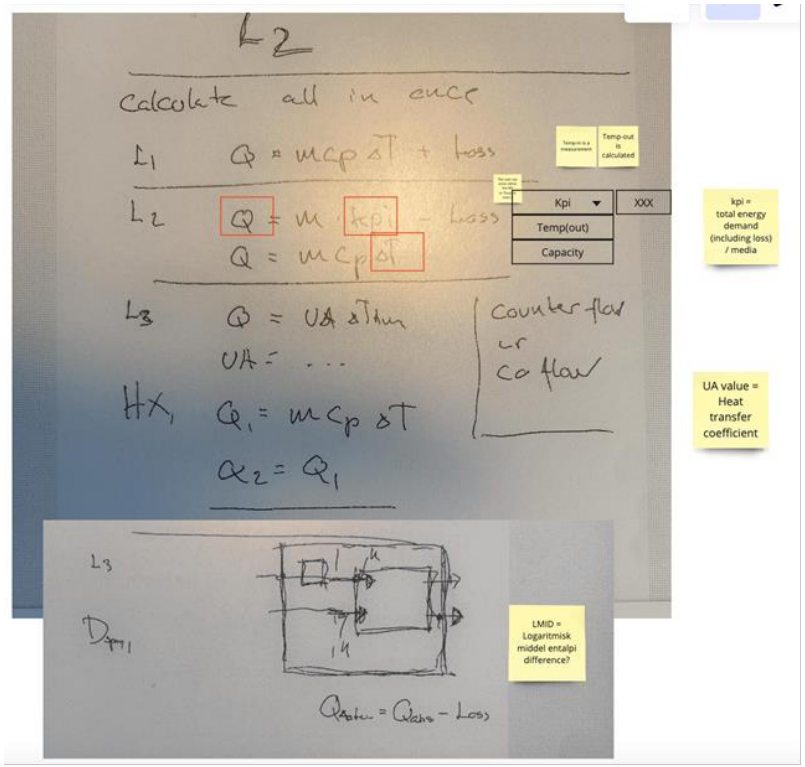


# Status på projektet og arbejdsprocesserne

## Scoping

Workshops (DTU, IPU og VMAS)

- Form
- Omfang
- Detaljeringsniveau
- Brugervenlighed
- …



# Status på projektet og arbejdsprocesserne

## Mapping state of the art

- Masse balancer
- Energibalancer

- Process
- Bygning
- Supporting
- Energiforsyning

*Table 1 levels of mapping*

| Level | List of mapping methods<br>Process | Building | Support systems | Energy supply |
|---|---|---|---|---|
| 1 | Percentage / measurement | Percentage / measurement | Percentage / measurement | Percentage / measurement |
| 2 | KPI * flow | Energi-mærke*area*dT | Total flow * KPI | Efficiency |
| 3 | Thermodynamic eq. | Heat loss equation | Thermodynamic dynamic eq. + correction factor (losses and heating of equipment) | Detailed efficiency |
| Mapping principals | Mass and Energy balance | Energy balance | Mass and Energy balance | Energy balance |

### 7.5 Decanter

The decanter component splits a stream into a "liquid" partition and a "prax" partition. The component has the following variables:

1. Media split:
   a. **Value**: The mass flow of the media-component chosen below going to the "prax" partition expressed as a fraction of the total mass flow into the component.
   It is important to note that this is not the total mass flow to the "prax" partition, this is discussed further in the mass balance section of the component.
   b. **Media**: The media-component for which a mass flow is defined

2. Mass flow:
   a. **Value**: The absolute mass flow of the media-component defined below going to the "prax" partition.
   It is important to note that this is not the total mass flow to the "prax" partition, this is discussed further in the mass balance section of the component.
   b. **Media**: The concentrations of the media going to the "prax" partition

3. **Media prax**: The media concentrations for the "prax" partition
4. **Outlet temperature**: Temperature out of the component for both "liquid" and "prax" partitions

To define the flow out of the component either the mass split or mass flow variables must be defined, only one or the other can be defined.
For a media consisting of only one media-component (eg. Water, Foodprotein etc.) the decanter cannot be used. Instead a splitter component should be utilized.

#### 7.5.1 Mass balance

For the decanter component to be defined the mass flow equations must have enough inputs to solve. To determine the overall mass flow distribution between the "liquid" and "prax" partitions, along with the media concentrations, either the mass flow variables or the mass split variables must be defined. Only one of the two sets of variables can be defined at a time.

Both sets of variables will define the mass flow of a single media-component to the "prax" partition, along with the media concentrations for the prax the total mass flow can be determined. The remaining mass flow is then directed to the "liquid" partition with the resulting media concentrations as an output.

For the mass split variables it is important to remember that the mass flow being defined is dependent on the total mass flow into the component, but only defines the mass flow of a specific media-component to the "prax" partition.
The same is true for the mass value variables, however, here a fixed value for the mass flow of a specific media-component is given instead.

The "Media" variable defines the media-component, for which a mass flow is defined, is chosen.

#### 7.5.2 Thermal energy balance

To determine the thermal energy balance of the decanter the outlet temperature is given for the component. This temperature is the same for both the "prax" and "liquid". With this it is possible to determine the thermal energy balance with the temperature approach, described in section ... equations xx to yy

### 2 Components overview

| Category | Process | Building | Support systems | Energy Supply |
|---|---|---|---|---|
| Description | The process components are components, which energy consumption are directly related to the operation of the process and the corresponding mass flow. | Building components entail energy contributions related to the operation of buildings for both process, storage and administration. | Support system components are equipment used in or for the process operation that are not directly linked to the process mass flow. | Energy supply components are the energy converting components that convert the purchased energy form into the energy bearing media. |
| List | 1. Cooker<br>2. Dryer<br>3. Vaporizer<br>4. Evaporator<br>5. Decanter<br>6. Centrifuge<br>7. Membranes (ult. filter)<br>8. Stripper<br>9. Heating<br>10. Fermenting<br>11. Spray dryer<br>12. Pasteurizer<br>13. Heat exch<br>14. Agitation (Conc. (acing)<br>15. Mixer<br>16. Distillation<br>17. Indirect dryer<br>18. Compressor<br>19. Microwave<br>20. Pressure treatment<br>21. Ultraviolet<br>22. Infrared<br>23. Cooling<br>24. Baking<br>25. Press<br>26. Desorption<br>27. Extraction<br>28. Suspension<br>29. Sedimentation<br>30. Humidification | 1. Space heating<br>2. Space cooling<br>3. Electricity<br>a. Light<br>b. Kitchen<br>c. IT-equip. | 1. CIP<br>2. Water<br>3. Effluent<br>4. Waste water treatment | 1. Gas/oil boiler<br>2. Electrical boiler<br>3. Biomass boiler<br>4. Heat pump<br>5. Refrigeration / Cooling system<br>6. Combined heating and cooling production<br>7. Compressed air<br>8. Vacuum<br>9. Solar panels<br>10. Solar heating |

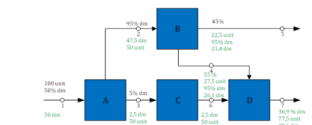
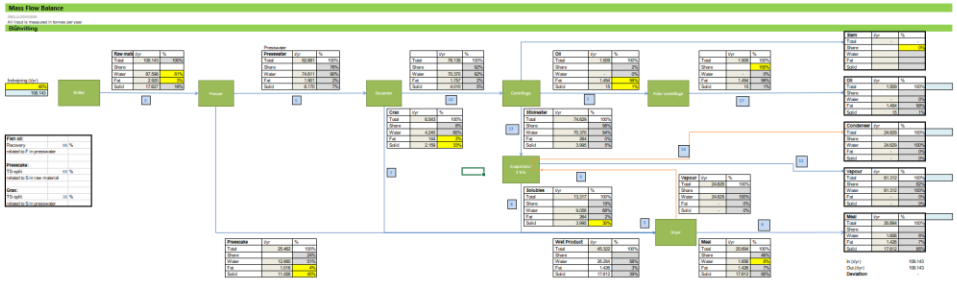



*Figure 2 example of a mass balance using dry matter fractions for defining flows.*

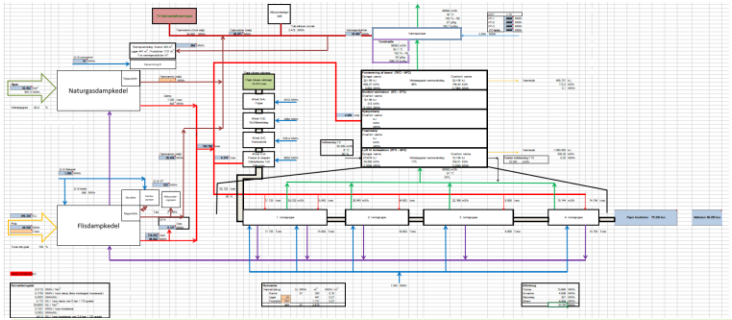
# Status på projektet og arbejdsprocesserne

## Field Mapping

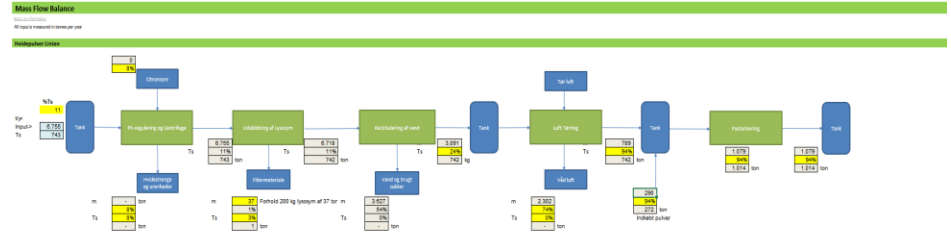
FF-Skagen




Skjern Paper (Master student)




Ovodan



# Status på projektet og arbejdsprocesserne

## Programming

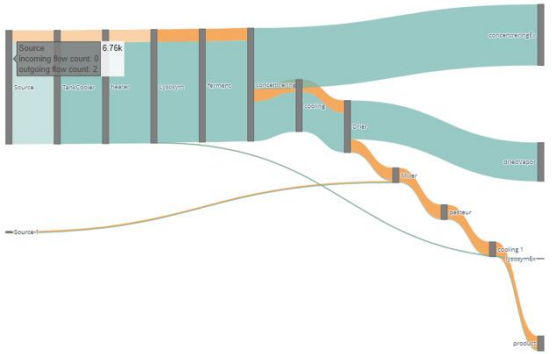
Beskrives under præsentation af værktøjet

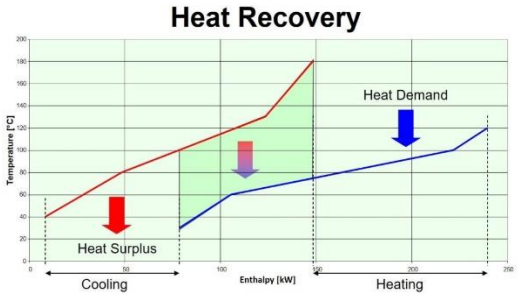
# Status på projektet og arbejdsprocesserne

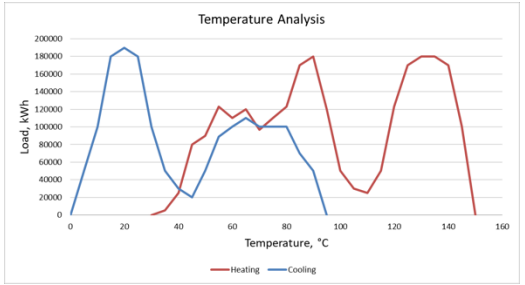
## Add-on analyses

- Sankey (mass, energy, CO2 og økonomi)
- Screening (300 punkter)
- Temperatur analyse
- Pinch analyse
- Ny udvikling af metoder er planlagt til sommeren, men forventes ikke integreret.
  - Identifikation af sensors
  - Identifikation af uvæsentlige strømme
  - Identifikaiton af elektrificerings teknologier



# Status på projektet og arbejdsprocesserne

## Field test

**Udviklingsvirksomheder**

FF-Skagen : 95 % færdige

Skjern Paper: 75 % færdige

Ovodan: 90 % færdige

**Testvirksomheder**

Avista Green: forventes gennemført I uge 13

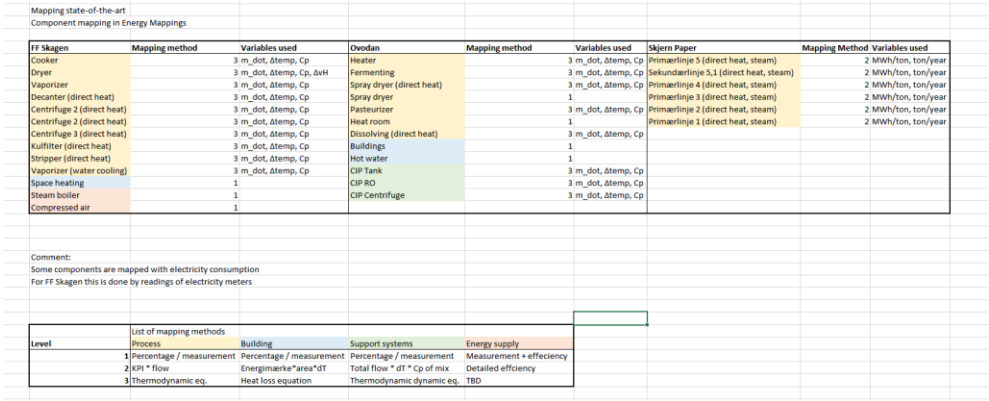
PPG: gennemføres I uge 10 og 11

Royal Unibrew (Batchelor Student) færdiggøres i uge 13

# Status på projektet og arbejdsprocesserne

## Maturing and Analysis Expansion

Flere interne workshops har været afholdt, med fokus på at udvikle værktøjet i et omfang, der rækker uden for den specifikke efterspørgsel fra de seks involverede virksomheder.



Mapping state-of-the-art
Component mapping in Energy Mappings

| FF Skagen | Mapping method | Variables used | Ovodan | Mapping method | Variables used | Skjern Paper | Mapping Method | Variables used |
|---|---|---|---|---|---|---|---|---|
| Cooker | | 3 m_dot, Δtemp, Cp | Heater | | 3 m_dot, Δtemp, Cp | Primærlinje 5 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Dryer | | 3 m_dot, Δtemp, Cp, ΔvH | Fermenting | | 3 m_dot, Δtemp, Cp | Sekundærlinje 5,1 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Vaporizer | | 3 m_dot, Δtemp, Cp | Spray dryer (direct heat) | | 3 m_dot, Δtemp, Cp | Primærlinje 4 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Decanter (direct heat) | | 3 m_dot, Δtemp, Cp | Spray dryer | | 1 | Primærlinje 3 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Centrifuge 2 (direct heat) | | 3 m_dot, Δtemp, Cp | Pasteurizer | | 3 m_dot, Δtemp, Cp | Primærlinje 2 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Centrifuge 2 (direct heat) | | 3 m_dot, Δtemp, Cp | Heat room | | 1 | Primærlinje 1 (direct heat, steam) | 2 | MWh/ton, ton/year |
| Centrifuge 3 (direct heat) | | 3 m_dot, Δtemp, Cp | Dissolving (direct heat) | | 3 m_dot, Δtemp, Cp | | | |
| Kulfilter (direct heat) | | 3 m_dot, Δtemp, Cp | Buildings | | 1 | | | |
| Stripper (direct heat) | | 3 m_dot, Δtemp, Cp | Hot water | | 1 | | | |
| Vaporizer (water cooling) | | 3 m_dot, Δtemp, Cp | CIP Tank | | 3 m_dot, Δtemp, Cp | | | |
| Space heating | | 1 | CIP RO | | 3 m_dot, Δtemp, Cp | | | |
| Steam boiler | | 1 | CIP Centrifuge | | 3 m_dot, Δtemp, Cp | | | |
| Compressed air | | 1 | | | | | | |

Comment:
Some components are mapped with electricity consumption
For FF Skagen this is done by readings of electricity meters

| | List of mapping methods | | | |
|---|---|---|---|---|
| Level | Process | Building | Support systems | Energy supply |
| 1 | Percentage / measurement | Percentage / measurement | Percentage / measurement | Measurement + effeciency |
| 2 | KPI * flow | Energimærke*area*dT | Total flow * dT * Cp of mix | Detailed effciency |
| 3 | Thermodynamic eq. | Heat loss equation | Thermodynamic dynamic eq. | TBD |

### Basic component blocks

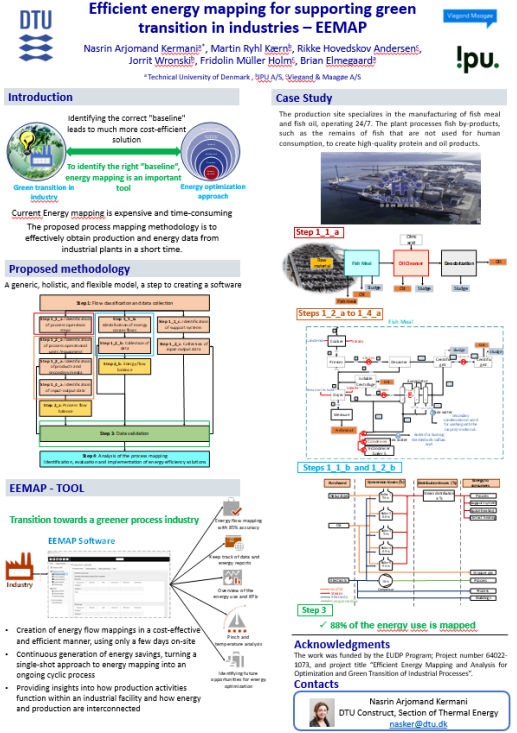
- Splitter
- Connector
- Direct heat and mass transfers
- Indirect heat transfers
- Electrical treatment
- Exothermal and endothermal

Clean up og debugging er i gang.

# Status på projektet og arbejdsprocesserne

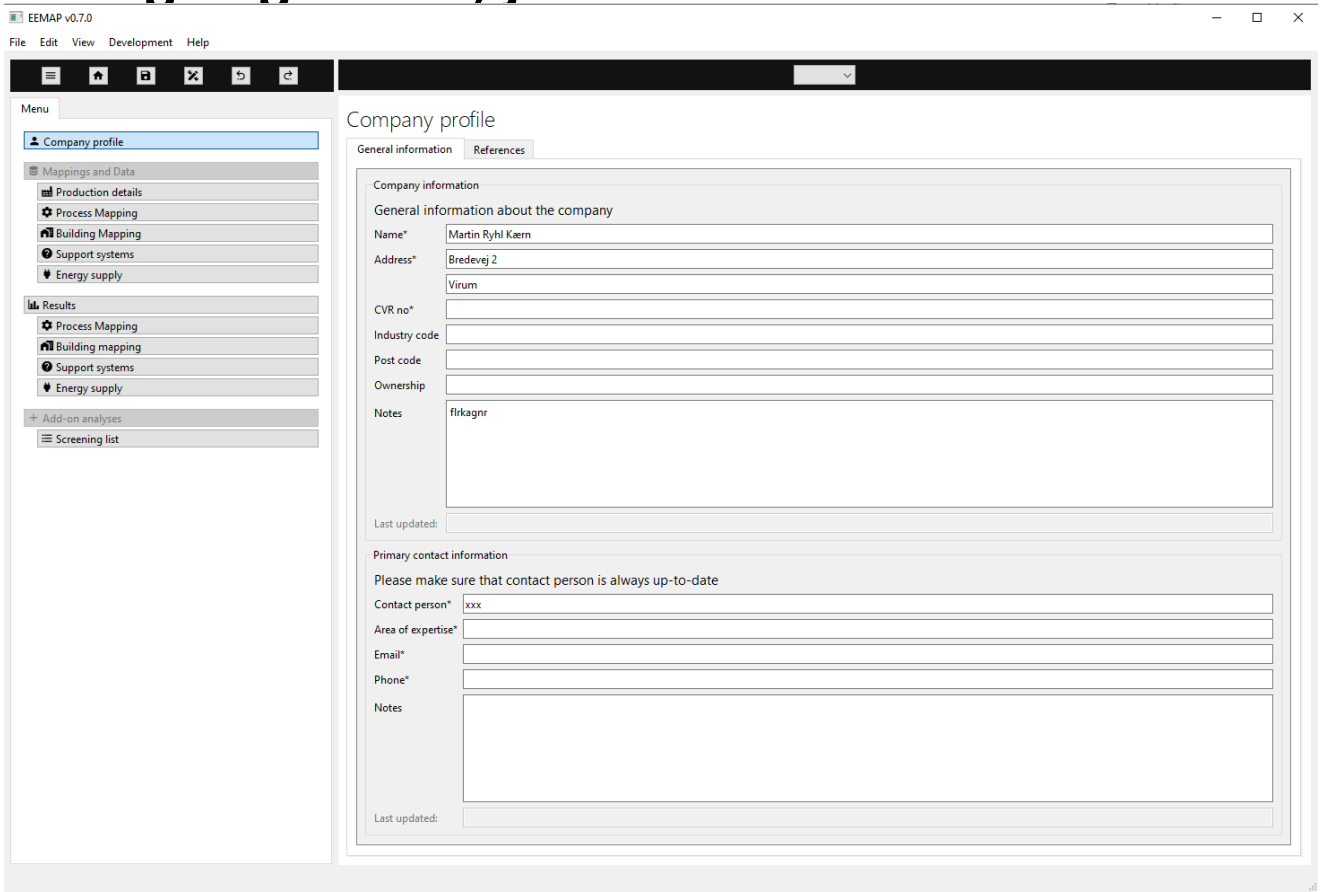
## Communication

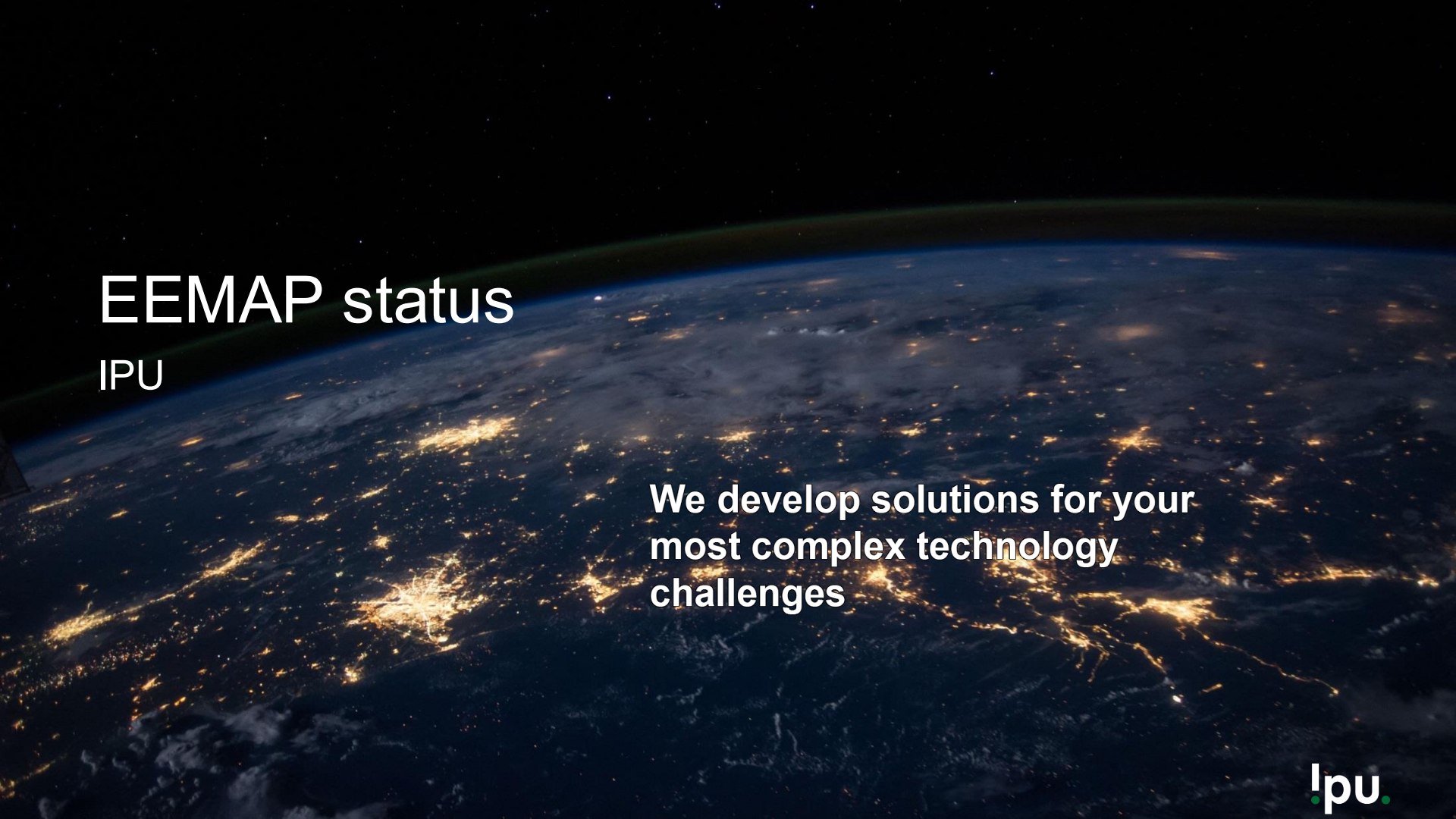
- The methodology behind EEMAP has been published and presented in a conference paper at ECOS 2023 Ecos 2023 Las Palmas de Gran Canaria Spain – Ecos 2023 Conference Las Palmas de Gran Canaria Spain
- Industry Decarbonisation knowledge exchange, Ambassade du Danemark en France – The Danish Embassy in France, November 2022.
- Decarbonisation of the Danish Industry - Projects and research activities", Knowledge sharing TES-DTU and California Energy Commission (group of 7 people including: Commissioner: Andrew McAlliste, Advisor to Commissioner: David Johnson, Director of the Efficiency Division: Mike Sokol, Deputy Director of the Energy Research and Development Division: Angie Gould, Danish energy agency advisor: Fabian Buhler, Energy advisor form innovation center Denmark: Claus Krog Ekman ) organized by Danish Energy Agency, September 2023.
- Danida fellowship center course (DFC), entitled: "Energy Efficiency and Energy Management in Buildings and Industry ", to 20 participants from developing countries (partners in Danida financed development cooperation projects and programs), DTU, August 2023.
- Abstract and presentation of energy mapping and EEMAP at the IEA conference in Goteborg in 2023.
- LinkedIn, Podcast, Videoer



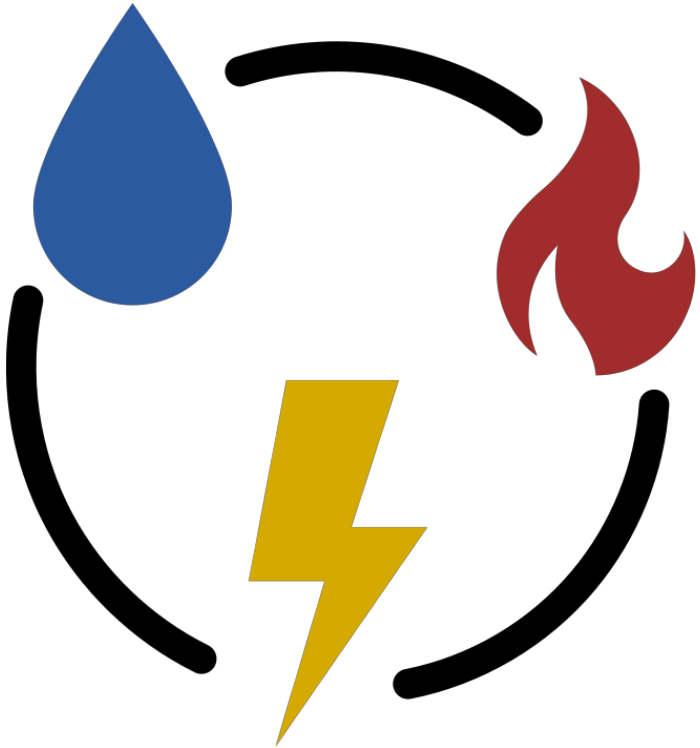
# Præsentation af kortlægningsværktøjet

- Introduktion til værktøjerne bag EEMAP
- Introduktion til opbygningen af værktøjet
- Introduktion til strukturen og funktionaliteten
- Introduktion til resultaterne
- Eksempel på brugen af værktøjet



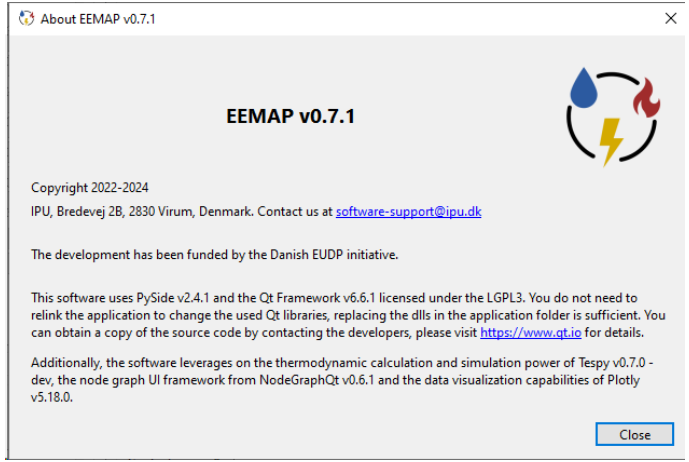

EEMAP status
IPU
We develop solutions for your most complex technology challenges
!pu.

# EEMAP Status



# Software tool developed with Qt for python

- QT for python
- NodegraphQt
- Tespy
- Plotly




- Coolprop

# Software architecture

PySide6 (frontend)

## Calculator (backend)

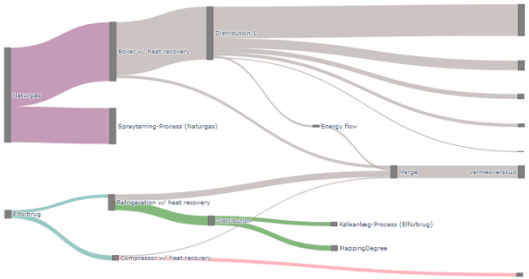
tespy ['tɛs.paɪ]

Coolprop

## NodeGraphQt



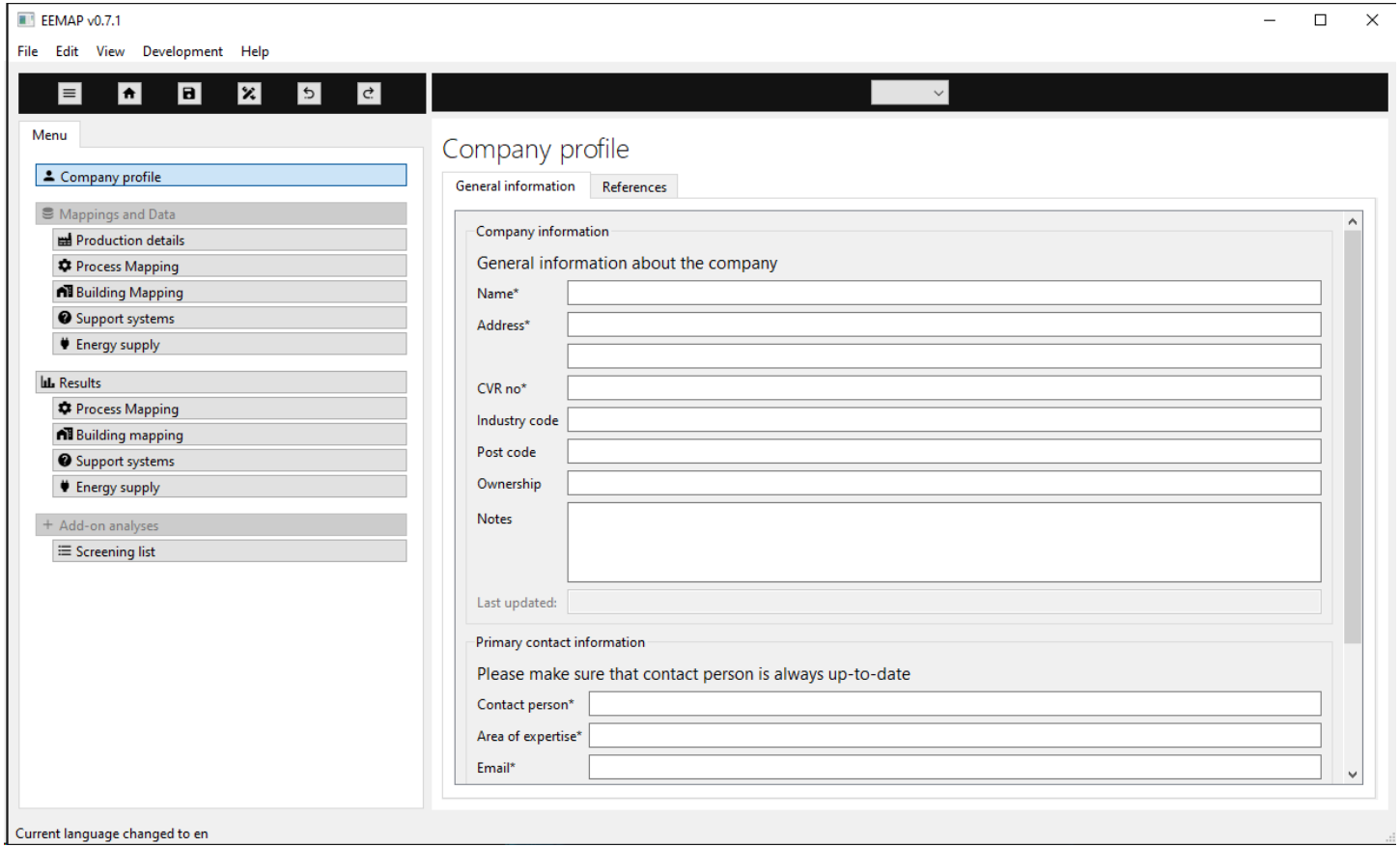
## Plotly



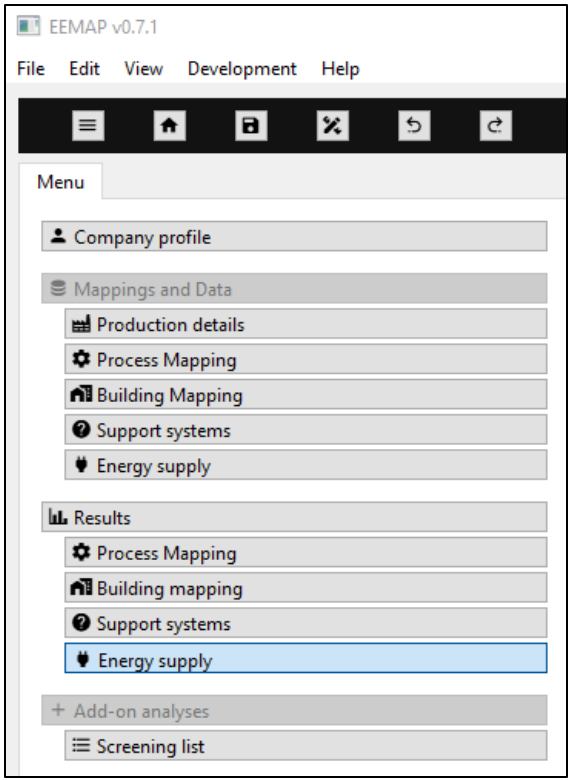
Translation

Visualization

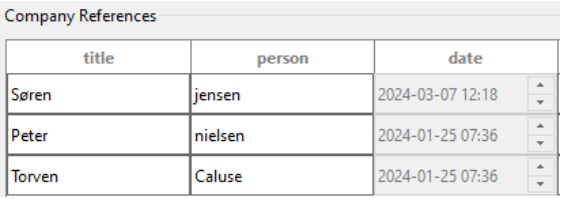
# Overview


EEMAP v0.7.1
File
Edit
View
Development
Help
Menu
Company profile
Mappings and Data
Production details
Process Mapping
Building Mapping
Support systems
Energy supply
Results
Process Mapping
Building mapping
Support systems
Energy supply
Add-on analyses
Screening list
Company profile
General information
References
Company information
General information about the company
Name*
Address*
CVR no*
Industry code
Post code
Ownership
Notes
Last updated:
Primary contact information
Please make sure that contact person is always up-to-date
Contact person*
Area of expertise*
Email*
Current language changed to en

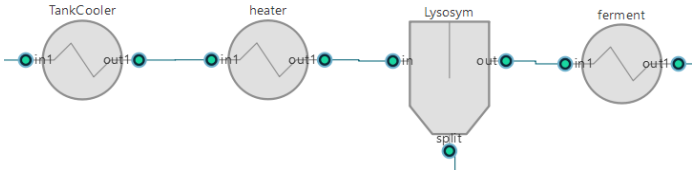
# Overview



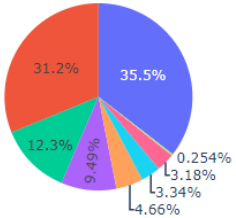

## Company info

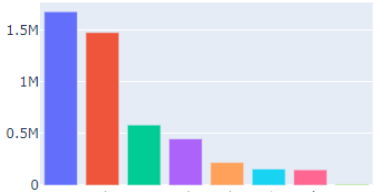



## Mapping detail and calculations




## Results




## Addon analysis



# Oplæg til det videre forløb, herunder tidsplan

## Tidsplan

The project is scheduled to last for 2 years in total –starting effectively with the decision from EUDP in June

**Gantt diagram**

EUDP

Det Energiteknologiske Udviklings- og Demonstrationsprogram

**Project title: Efficient Energy Mapping and Analysis for Optimization and Green Transition of Industrial Processes (EEMAP)**

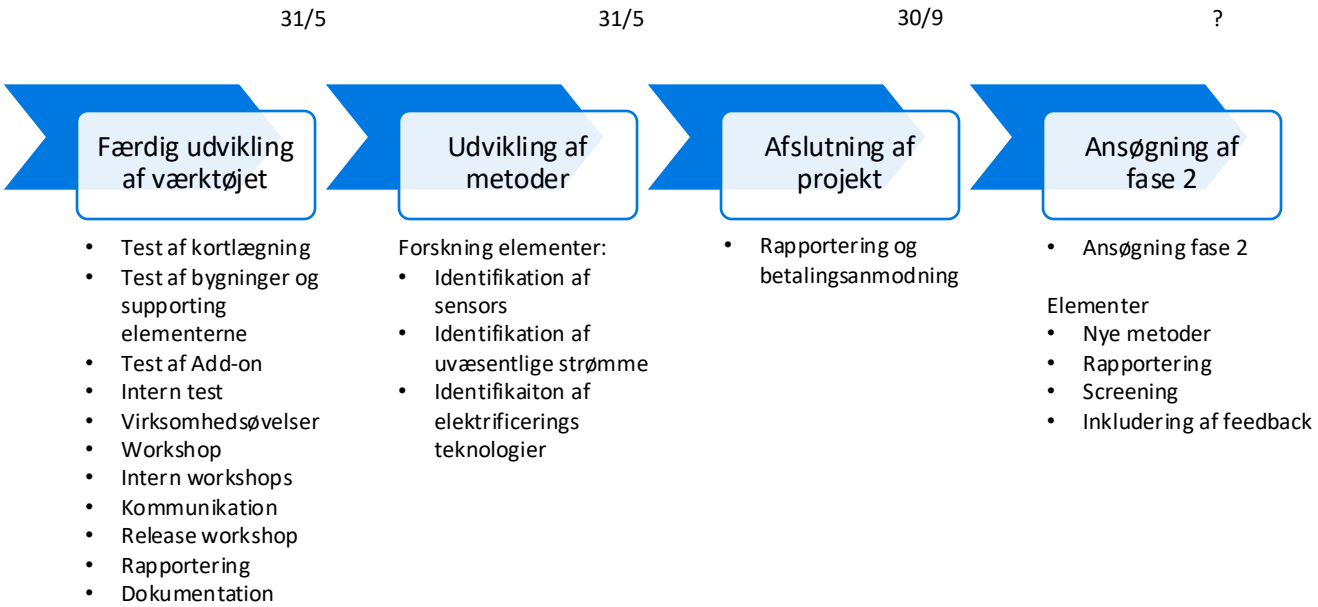
**Project start: June 2022**

**Project end: June 2024**

| Year/År | 2022 | | | | | | | | | | | | 2023 | | | | | | | | | | | | 2024 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work packages/Projektets arbejdspakker:** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| **WP1 - Project Management** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP2 - Scoping** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP3 - Mapping state-of-the-art** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP4 - Field Mapping (Without Tool)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP5 - Programming** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP6 - Add-on Analyses** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP7 - Field Test (With Tool)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP8 - Maturing and Analyses Expansion** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **WP9 - Communication** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Milestones/Milepæle** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M1 - Design Specifciation Completed | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| M2 - Techonology Parameter Table Completed | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | |
| M3 - First version ready for field testing | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | | | | | |
| M4 - Finalized Tool | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | |
| M5 - Presentation at ECOS Conference 2023 | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | |
| **Commercial milestones/Kommerc. milepæle** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CM1 - Project Finalization | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | |
| CM2 - Mapping of potential add-ons and their commercial potential | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | |
| CM3 - Model proof of concept in operational environment | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | |

# Oplæg til det videre forløb, herunder tidsplan

Bud på det videre forløb, hvilket også omfatter et udsættelse af project afslutning frem til 30/9 2024



# Økonomi

## Status og ønsker

- DTU: 65%
- VMAS: 70%
- IPU: 100%
- Udviklingsvirksomheder: 50%
- Testvirksomheder: 20 %
- En betalingsanmodning sommeren 2023
- Flytning af 200 timer sommeren
- Ønskes om flytning af beløb svarende til 200 timer
- Om allokering fra udgifter til timer
- Om allokering fra virksomheder til IPU

| | Viegand Maagøe | IPU | DTU | FF Skagen | Company X | Skjern Papir | AVISTA Green | Royal Unibrew | PPG Coatings Denmark A/S |
|---|---|---|---|---|---|---|---|---|---|
| **Project Management** | *300 hours* | | | | | | | | |
| | | | | | | | | | |
| **Administration** | *200 hours* | | | | | | | | |
| | | | | | | | | | |
| **Technical Competences** | | | | | | | | | |
| Scoping | *200 hours* | *100 hours* | *300 hours* | *150 hours* | *150 hours* | *150 hours* | | | |
| Technology Review | *100 hours* | | *300 hours* | | | | | | |
| Programming and Debugging | *125 hours* | *1200 hours* | *125 hours* | | | | | | |
| Analysess | *150 hours* | *300 hours* | *500 hours* | | | | | | |
| | | | | | | | | | |
| **Commercial Competences** | | | | | | | | | |
| Mapping | *600 hours* | *50 hours* | | *150 hours* | *150 hours* | *150 hours* | *150 hours* | *150 hours* | *150 hours* |
| | | | | | | | | | |
| **Communication** | *250 hours* | *100 hours* | *500 hours* | | | | | | |
| | | | | | | | | | |
| **Hours in total** | ***1975 hours*** | ***1750 hours*** | ***1725 hours*** | ***300 hours*** | ***300 hours*** | ***300 hours*** | ***150 hours*** | ***150 hours*** | ***150 hours*** |

# Drøftelser af det videre liv for EEMAP

Ansøgning fase 2

Økonomi

Ejerskab

Udvikling

# Evt.

…

# Kontakt




Fridolin Müller Holm

Chef for industri

Viegand Maagøe A/S

Tlf. +45 31 75 17 14

E-mail: fmh@viegandmaagoe.dk

WWW.VIEGANDMAAGOE.DK





Sneaster Asrat

Design Ingeniør

Viegand Maagøe A/S

Tlf. +45 42 21 49 00

E-mail: sas@viegandmaagoe.dk

WWW.VIEGANDMAAGOE.DK





Brian Elmegaard

Professor

DTU

Tlf. +45 25 41 69

E-mail: be@mek.dtu.dk

WWW.TES.MEK.DTU.DK





Jorrit Wronski

Specialist Engineer

IPU

Tlf. +45 45 16 04 26

E-mail: jowr@ipu.dk

WWW.IPU.DK

# backup




# tespy

# tespy

- Component based design and part load simulator
  - Steady state
  - Generic architecture
  - Added 6 models
    - Separator with
      - Heat loss
      - S-split
      - F-split
      - Heat bus
      - …

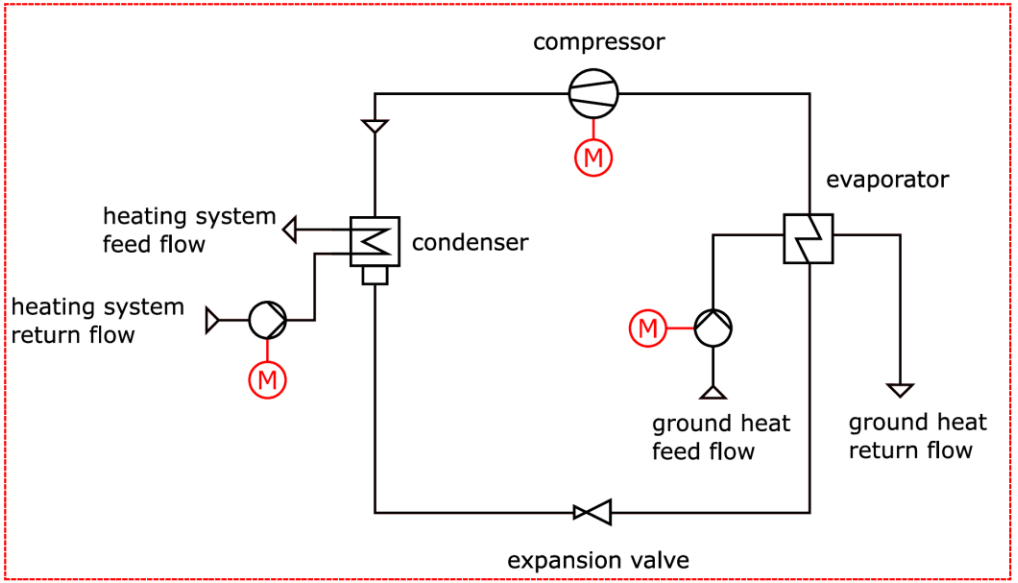
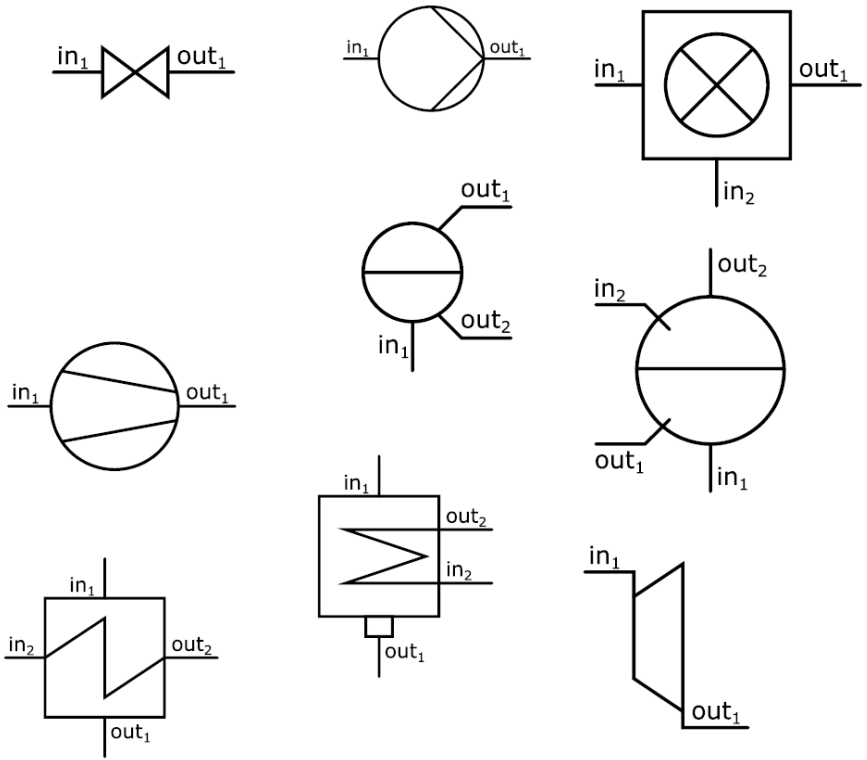



figure by Francesco Witte

# tespy components



- **Basics**
  - Cycle closer
  - Sink
  - Source
  - Subsystem interface
- **Combustion**
  - Combustion chamber
  - Diabatic combustion chamber
  - Combustion engine
- **Heat exchangers**
  - Simplified heat exchanger
  - Solar collector
  - Parabolic trough
  - Heat exchanger
  - Condenser
  - Desuperheater
- **Nodes**
  - Droplet separator
  - Drum
  - Merge
  - Separator
  - Splitter
- **Piping**
  - Pipe
  - Valve
- **Reactors**
  - Fuel cell
  - Water electrolyzer
- **Turbomachinery**
  - Compressor
  - Pump
  - Turbine




slide contents @ Francesco Witte

# Food properties

# Food properties

- ASHRAE Handbook – Refrigeration, Ch 9, Thermal properties of foods



Table 3 Unfrozen Composition Data, Initial Freezing Point, and Specific Heats of Foods* (*Continued*)

| Food Item | Moisture Content, % $x_{wo}$ | Protein, % $x_p$ | Fat, % $x_f$ | Carbohydrate Total, % $x_c$ | Carbohydrate Fiber, % $x_{fb}$ | Ash, % $x_a$ | Initial Freezing Point, °C | Specific Heat Above Freezing, kJ/(kg·K) | Specific Heat Below Freezing kJ/(kg·K) | Latent Heat of Fusion, kJ/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| **Whole Fish** | | | | | | | | | | |
| Cod | 81.22 | 17.81 | 0.67 | 0.0 | 0.0 | 1.16 | –2.2 | 3.78 | 2.14 | 271 |
| Haddock | 79.92 | 18.91 | 0.72 | 0.0 | 0.0 | 1.21 | –2.2 | 3.75 | 2.14 | 267 |
| Halibut | 77.92 | 20.81 | 2.29 | 0.0 | 0.0 | 1.36 | –2.2 | 3.74 | 2.18 | 260 |
| Herring, kippered | 59.70 | 24.58 | 12.37 | 0.0 | 0.0 | 1.94 | –2.2 | 3.26 | 2.27 | 199 |
| Mackerel, Atlantic | 63.55 | 18.60 | 13.89 | 0.0 | 0.0 | 1.35 | –2.2 | 3.33 | 2.23 | 212 |
| Perch | 78.70 | 18.62 | 1.63 | 0.0 | 0.0 | 1.20 | –2.2 | 3.71 | 2.15 | 263 |
| Pollock, Atlantic | 78.18 | 19.44 | 0.98 | 0.0 | 0.0 | 1.41 | –2.2 | 3.70 | 2.15 | 261 |
| Salmon, pink | 76.35 | 19.94 | 3.45 | 0.0 | 0.0 | 1.22 | –2.2 | 3.68 | 2.17 | 255 |
| Tuna, bluefin | 68.09 | 23.33 | 4.90 | 0.0 | 0.0 | 1.18 | –2.2 | 3.43 | 2.19 | 227 |
| Whiting | 80.27 | 18.31 | 1.31 | 0.0 | 0.0 | 1.30 | –2.2 | 3.77 | 2.15 | 268 |
| **Shellfish** | | | | | | | | | | |
| Clams | 81.82 | 12.77 | 0.97 | 2.57 | 0.0 | 1.87 | –2.2 | 3.76 | 2.13 | 273 |
| Lobster, American | 76.76 | 18.80 | 0.90 | 0.50 | 0.0 | 2.20 | –2.2 | 3.64 | 2.15 | 256 |
| Oysters | 85.16 | 7.05 | 2.46 | 3.91 | 0.0 | 1.42 | –2.2 | 3.83 | 2.12 | 284 |
| Scallop, meat | 78.57 | 16.78 | 0.76 | 2.36 | 0.0 | 1.53 | –2.2 | 3.71 | 2.15 | 262 |
| Shrimp | 75.86 | 20.31 | 1.73 | 0.91 | 0.0 | 1.20 | –2.2 | 3.65 | 2.16 | 253 |

# Food properties

- ASHRAE Handbook – Refrigeration, Ch 9, Thermal properties of foods



Table 3 Unfrozen Composition Data, Initial Freezing Point, and Specific Heats of Foods* (*Continued*)

| Food Item | Moisture Content, % $x_{wo}$ | Protein, % $x_p$ | Fat, % $x_f$ | Carbohydrate Total, % $x_c$ | Carbohydrate Fiber, % $x_{fb}$ | Ash, % $x_a$ | Initial Freezing Point, °C | Specific Heat Above Freezing, kJ/(kg·K) | Specific Heat Below Freezing kJ/(kg·K) | Latent Heat of Fusion, kJ/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| **Whole Fish** | | | | | | | | | | |
| Cod | 81.22 | 17.81 | 0.67 | 0.0 | 0.0 | 1.16 | –2.2 | 3.78 | 2.14 | 271 |
| Haddock | 79.92 | 18.91 | 0.72 | 0.0 | 0.0 | 1.21 | –2.2 | 3.75 | 2.14 | 267 |
| Halibut | 77.92 | 20.81 | 2.29 | 0.0 | 0.0 | 1.36 | –2.2 | 3.74 | 2.18 | 260 |
| Herring, kippered | 59.70 | 24.58 | 12.37 | 0.0 | 0.0 | 1.94 | –2.2 | 3.26 | 2.27 | 199 |
| Mackerel, Atlantic | 63.55 | 18.60 | 13.89 | 0.0 | 0.0 | 1.35 | –2.2 | 3.33 | 2.23 | 212 |
| Perch | 78.70 | 18.62 | 1.63 | 0.0 | 0.0 | 1.20 | –2.2 | 3.71 | 2.15 | 263 |
| Pollock, Atlantic | 78.18 | 19.44 | 0.98 | 0.0 | 0.0 | 1.41 | –2.2 | 3.70 | 2.15 | 261 |
| Salmon, pink | 76.35 | 19.94 | 3.45 | 0.0 | 0.0 | 1.22 | –2.2 | 3.68 | 2.17 | 255 |
| Tuna, bluefin | 68.09 | 23.33 | 4.90 | 0.0 | 0.0 | 1.18 | –2.2 | 3.43 | 2.19 | 227 |
| Whiting | 80.27 | 18.31 | 1.31 | 0.0 | 0.0 | 1.30 | –2.2 | 3.77 | 2.15 | 268 |
| **Shellfish** | | | | | | | | | | |
| Clams | 81.82 | 12.77 | 0.97 | 2.57 | 0.0 | 1.87 | –2.2 | 3.76 | 2.13 | 273 |
| Lobster, American | 76.76 | 18.80 | 0.90 | 0.50 | 0.0 | 2.20 | –2.2 | 3.64 | 2.15 | 256 |
| Oysters | 85.16 | 7.05 | 2.46 | 3.91 | 0.0 | 1.42 | –2.2 | 3.83 | 2.12 | 284 |
| Scallop, meat | 78.57 | 16.78 | 0.76 | 2.36 | 0.0 | 1.53 | –2.2 | 3.71 | 2.15 | 262 |
| Shrimp | 75.86 | 20.31 | 1.73 | 0.91 | 0.0 | 1.20 | –2.2 | 3.65 | 2.16 | 253 |

# Idea catalogue

| ID. | Mapping area | System type | Sub-system | Area | Title | Description |
|---|---|---|---|---|---|---|
| B1 | Building | Ventilation | | Heat recovery | Rotary heat exchar | Proper heat recovery efficiency is vital. Use rotary heat exchanger if air streams can be mixed. This will result in a high heat recovery effeciency close to ~80% recovery. |
| B2 | Building | Ventilation | | Heat recovery | Cross flow heat exh | Use heat pipes / cross flow heat exhchangers if mixing air streams is not an option. Will result in ~60-70% recovery. |
| B3 | Building | Ventilation | | Heat recovery | Water loops | Use water loops to transport heat recovery when the intake and outlet are not in close proximity. Will yield approximately 50-60% recovery. |
| B4 | Building | Ventilation | | Heat recovery | Ventilation KPI | Displaying heat recovery efficiency on screen or having it as a KPI will support operating personnel in catching malfunctions. |
| B5 | Building | Ventilation | | VSD & Control | Air exchange rate | Air change should fit the application. Design ventilation systems to meet the specific needs of the building, avoiding over- or under-ventilation, which can lead to increased energy |
| B6 | Building | Ventilation | | VSD & Control | Demand driven | Shut down ventilation / reduce air change in off hours. |
| B7 | Building | Ventilation | | VSD & Control | Demand driven | Control the system by demand using sensors and VSD. Separating buildings into different zones, can allow system to be shut off using dampers. |
| B8 | Building | Ventilation | | Insulation | Thermal insulaion | Insulation of ducts: Insulate ducts to reduce heat loss and improve energy efficiency. |
| B9 | Building | Ventilation | | Ventilator | Motor efficiency | Use IE3/IE4 motors for new applications |
| B10 | Building | Ventilation | | Ventilator | Convertion to dire | Avoid belt driven machines. |
| B11 | Building | Ventilation | | Ventilator | Proper duct sizing | Proper duct sizing: Ensure that ducts are properly sized to minimize air leakage and reduce the energy required to move air through the system. |
| B12 | Building | Ventilation | | Ventilator | Ventilation KPI | SEL-value can be used as a KPI, (SEL-value =(P_air_in+P_air_out/q_v)) for systems with heat recovery. |
| B13 | Building | Ventilation | | Ventilator | Pressure loss reduc | Reduction of pressure loss, ducts, filters, … |
| B14 | Building | Ventilation | | Filters | Monitor filter state | Make sure pressure sensors are installed to monitor filter state in order to change it timely. Use efficient air filters to improve air quality and reduce energy consumption by reducing the load on fans and heating/cooling systems. |
| B15 | Building | Ventilation | | VSD & Control | Volume flow | Reduction of volume flow to the actual demand |
| B16 | Building | Ventilation | | Installation | Avoid short circuit | Make sure that inlet and outlet is not short cutted - propper location |
| B17 | Building | Ventilation | | Design | Mapping ventilatic | Mapping ventilation system - actual and needed air exchange rate and ducts layout |
| B18 | Building | Building | | Cooling - air conditioning | | Reduce running time |
| B19 | Building | Building | | Cooling - air conditioning | | Reduce condensation temperature |
| B20 | Building | Building | | Cooling - air conditioning | | Increase flow temperature |
| B21 | Building | Building | | Cooling - air conditioning | | Implement control dependant on demand |
| B22 | Building | Building | | Cooling - air conditioning | | Upgrade cooling utility |
| B23 | Building | Building | | Cooling - air conditioning | | Maintenance of cooling utility |
| B24 | Building | Building | | Lighting | Best practice | Implement motion sensors in relevant rooms. Only in areas with a lot of traffic, lights should be turned on 24/7. |

| | | | | | |
|---|---|---|---|---|---|
| B25 | Building | Building | Lighting | Best practice | Use efficint lighting sources - e.g. LED lights. |
| B26 | Building | Building | Lighting | Best practice | Light intensity controlled by daylight and light intensity should not be higher than the norm for the area (e.g. 200 lumens for work areas). |
| B27 | Building | Building | Lighting | Best practice | Daylight controlled LED lights in the cold storage, and lights are automatically put out in areas with no movement. |
| B28 | Building | Building | Lighting | Best practice | The light data should be at least: Efficiency "tube 100lm/w" "High bay 91 lm/w" // Light colour: temp. 4000K and quality RA >80 // Lifetime: tube > 50000 h. High bay 75000 h // |
| B29 | Building | Building | Lighting | | Reduce of running time |
| B30 | Building | Building | Lighting | | Section division of lighting utility |
| B31 | Building | Building | Lighting | | Maintanence of lighting utility |
| B32 | Building | Building | Heating | | Reduction of room temperature |
| B33 | Building | Building | Heating | | Implement radiator thermostat valve |
| B34 | Building | Building | Heating | | Establish outdoor temperature compensation |
| B35 | Building | Building | Heating | | Establish night mode / reduce heating during the night |
| B36 | Building | Building | Heating | | Exhange older gas boiler to condensation gas boiler |
| B37 | Building | Building | Heating | | Exhange older gas- or oil boiler to district heating or heat pump |
| B38 | Building | Building | Heating | | Exhange or insulation of hot water tank, heat exchanger, valvs and piping |
| B39 | Building | Building | Heating | | Insulation of piping for central heating and hot service water |
| B40 | Building | Building | Heating | | Exchange circulation pump for central heating |
| B41 | Building | Building | Heating | | Maintenance of heating utility |
| B42 | Building | Building | Climate screen | | Insulation of roof and ceiling |
| B43 | Building | Building | Climate screen | | Insulation of exterior wall |
| B44 | Building | Building | Climate screen | | Insulation of floor seperation / floors |
| B45 | Building | Building | Climate screen | | Exchange windows and doors for more energy efficient ones |
| B46 | Building | Building | Climate screen | | Install fast opening and closing ports |
| B47 | Building | Building | IT equipment | | Reduce operation time |
| B48 | Building | Building | IT equipment | | Reduce idle operation time |
| B49 | Building | Building | IT equipment | | Replace older computer equipment, e.g. monitors, printers or copy printer |
| B50 | Building | Building | IT equipment | | Replace older servers with more energy efficient ones. |
| B51 | Building | Building | Kitchen equipment | | Reduce operation time |
| B52 | Building | Building | Kitchen equipment | | Reduce idle operation time |
| B53 | Building | Building | Kitchen equipment | | Replace older kitchen equipment, e.g. stoves, ovens or dishwashers |
| ES1 | Energy supply | Compressed air | Heat recovery | Heat recovery | Are the installations equipped with heat recovery? If not is there a suitable use for the heat? |

| | | | | | |
|---|---|---|---|---|---|
| ES2 | Energy supply | Compressed air | Leakage | Leak Detection | Regular Leak Detection can be useful in larger systems. Conduct regular leak detection and repair to prevent the loss of compressed air, which can significantly reduce energy efficiency - annual survey yields 10% total savings. Well maintained plants have 5-10% air leak. |
| ES3 | Energy supply | Compressed air | Leakage | System seperation | For large systems: Use zone shutoff during downtime of sub production lines. |
| ES4 | Energy supply | Compressed air | Dimensioning | Air compressor sizi | Proper sizing of air compressors: Ensure that air compressors are properly sized to meet the demand of the system, avoiding over- or under-capacity. |
| ES5 | Energy supply | Compressed air | Working pressure | Pressur optimisatic | Is it possible to lower operating pressure? Dimensions should be according to most demanding consumer. |
| ES6 | Energy supply | Compressed air | Part load handling | Multiple Compress | Introducing multiple compressors that can be turned on and off according to demand will keep all compressors but 1 at full load. Efficiency of the compressors is reduced at part load. Running any compressor at part load should be kept to a minimum. |
| ES7 | Energy supply | Compressed air | Part load handling | Compressed air bu | Installing at buffer system to reduce part load and incure stable conditions for the compressed air. |
| ES8 | Energy supply | Compressed air | Part load handling | Variable Speed Dri | VSD can be installed on the last compressor to meet varying load demands. VSD effective if compressor load is continously executed below 75%. Will have negative effect above due to VSD loss. |
| ES9 | Energy supply | Compressed air | Dryer system | Removing moistur | Ensure system installation for removing moisture from the air. |
| ES10 | Energy supply | Compressed air | Dryer system | Refrigerated driers | Best practice is absorbtion dessicant driers WITH heating of regeneration air |
| ES11 | Energy supply | Compressed air | Dryer system | Regeneration cont | Implement regeneration control of drier system. |
| ES12 | Energy supply | Compressed air | Intake | Air cleaning | Intake should be as dry / clean / cold as possible. Rule of thumb is that 3˚C decrease equals in 1% energy saving. |
| ES13 | Energy supply | Compressed air | Inappropriate use | Replacement of act | Use electric actuators over compressed air. Is compressed air needed? |
| ES14 | Energy supply | Compressed air | Maintenance | Air compressor ma | Maintenance and upgrades: Regular maintenance and upgrades to air compressors, such as replacing worn-out components or upgrading to more efficient models, can improve energy efficiency. |
| ES15 | Energy supply | Compressed air | Piping | Pipe sizing | Proper pipe sizing to reduce pressure losses |
| ES16 | Energy supply | Compressed air | Filters | Air filtration optim | Air filtration optimization: Optimize air filtration systems to reduce the load on air compressors, improve air quality, and increase energy efficiency. |
| ES17 | Energy supply | Compressed air | Control valves | Flow regulation | Proper use of control valves: Properly use control valves to regulate the flow of compressed air, reducing energy consumption and improving overall system efficiency. |
| ES18 | Energy supply | Compressed air | Control | Compressed air KPI | Generating at KPI to monitor the efficinecy of compressed air system. E.g. kWh/kg air |
| ES19 | Energy supply | Compressed air | Mapping | Compresed air syst | Mapping compressed air system - pressure demand and system layout (incl sizing). |
| ES20 | Energy supply | Vacuum system | | | Use of high-efficiency vacuum pumps: Consider upgrading to more energy-efficient vacuum pumps, such as rotary vane pumps or dry screw pumps, to improve energy efficiency. |
| ES21 | Energy supply | Vacuum system | | | Vacuum pump control optimization: Optimize the control system of vacuum pumps to match the vacuum level required by the process, reducing energy consumption. Implement VSDs to adjust the speed of the vacuum pump motor based on the process demand, reducing energy consumption. |
| ES22 | Energy supply | Vacuum system | | | Minimize leaks: Regularly inspect and repair any leaks in the vacuum system to prevent air infiltration, reducing the load on the vacuum pump and improving energy efficiency. |
| ES23 | Energy supply | Vacuum system | | | Regularly maintain and service vacuum pumps and associated equipment to ensure efficient operation and minimize energy losses. |
| ES24 | Energy supply | Gas boiler | Condensate Return | | Implement a condensate recovery system to capture and reuse waste heat, reducing energy consumption. |
| ES25 | Energy supply | Gas boiler | Condensate Return | | Conduct regular maintenance on steam boilers to ensure proper operation and minimize energy consumption. Steam traps should be regularly surveyed or they will begin to leak. |
| ES26 | Energy supply | Gas boiler | Deaerator | | Air vent and steam supply should be properly tuned for highest energy efficiency |

| | | | | | |
|---|---|---|---|---|---|
| ES27 | Energy supply | Gas boiler | Deaerator | Best practice | Install pressurised air dearators and pre-heat the feed water is pre-heated with waste heat. |
| ES28 | Energy supply | Gas boiler | Deaerator | | Reduce the steam coming out of the deaerator through venting pipes to a minimum and reuse the waste heat from the steam. |
| ES29 | Energy supply | Gas boiler | Flue gas | | Install economicers to reduce the losses from the flue gas. The economicers can be used to preheat feed water, makeup water or combustion air |
| ES30 | Energy supply | Gas boiler | Flue gas | | Heat Recovery: Flue gas outlet temperature should be kept as low as possible, although with sulfuric acid condensation in mind. |
| ES31 | Energy supply | Gas boiler | Flue gas | | O2 & CO monitors can detect infiltration air leaks as well as incomplete combustion. 1% infiltration air will give 20% increase in O2. |
| ES32 | Energy supply | Gas boiler | Insulation | | Improve insulation of boilers and piping to reduce heat loss and improve energy efficiency. Ceramic Fiber insulation + improved heater circuit controls can yield savings of 6-26% |
| ES33 | Energy supply | Gas boiler | Insulation | | Standby Boilers will lose 1-3% in heat losses, operational patterns should be investigated to minmise standby. |
| ES34 | Energy supply | Gas boiler | Maintenance | | Burners + Condensate return can yield losses of 30% without proper maintenance |
| ES35 | Energy supply | Gas boiler | Maintenance | | Fouling on the flue gas side + scaling on the water side will also significantly reduced boiler performance. |
| ES36 | Energy supply | Gas boiler | Monitoring and control | | Optimize control systems to ensure proper operation of steam boilers, reducing energy consumption. Efficiency and energy measurements of various boiler parts for KPIs & error detection |
| ES37 | Energy supply | Gas boiler | Dimensioning | | Proper boiler sizing: Ensure that steam boilers are properly sized to meet the demand of the system, avoiding over- or under-capacity. By looking at the heat load and peak in process areas, it can be possible to reduce the demand for boilers in operation at the same time. |
| ES38 | Energy supply | Gas boiler | Monitoring and control | | Control blow down by conductivity instead of time |
| ES39 | Energy supply | Gas boiler | Blowdown Water Recovery | | Use a flash tank first to separate usable steam from blow-down water, recover heat of liquid phase afterwards. Reduce blowdown rate or the amount of water that is periodically discharged from the boilers, to minimize energy consumption. |
| ES40 | Energy supply | Gas boiler | Air Intake | | Improve combustion efficiency by controlling the amount of excess air, fuel-to-air ratio, and combustion temperature to minimize energy consumption. Inlet temperature of the air can be increased if the intake can be moved from the floor to the ceiling of the boiler room. |
| ES41 | Energy supply | Gas boiler | Air Intake | | Move air intak from a cold location to a hot loocation (below the ceiling) |
| ES42 | Energy supply | Gas boiler | System design | | Challenge pressure level - is steam needed? Could differangated systems be introduced. |
| ES43 | Energy supply | Gas boiler | Maintenance | | Maintaining steam traps |
| ES44 | Energy supply | Refrigeration | Cooling water loops | | Ensure proper microbio control to minimise bacteria film and heat transfer reductions. |
| ES45 | Energy supply | Refrigeration | Cooling water loops | | Cooling loops should be seggregated into various temperature levels. |
| ES46 | Energy supply | Refrigeration | Cooling water loops | | Should be optimised in temperature to the limiting consumer. Also this limiting consumer temperature can be challenged or improved with a better heat exchanger etc. |
| ES47 | Energy supply | Refrigeration | Ice water loops | | Implement dynamic pressure control on the suction pressure to the ice water heat exchangers, so the suction pressure is fitted accordingly. |
| ES48 | Energy supply | Refrigeration | Ice water loops | | Implement variable speed regulation of circulation pumps for heat exchangers, ice water to process and ammonia circulation pumps. |
| ES49 | Energy supply | Refrigeration | Ice water loops | | Ice build up control: implement variable suction pressure of ice water coil, depending on the ice thickness at the coil or ice water flow, and frequency regulated air agitation. |
| ES50 | Energy supply | Refrigeration | Storage rooms | | Control room temperature according to the specifications of the stored goods. If there are more rooms on the same cooling system, the control system should be designed to shift set point, depending on the cooling demand from the different rooms. |

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| ES51 | Energy supply | Refrigeration | | Storage rooms | Minimise heat sources and heat infiltration, tight door sealing + regular inspection. Air locks can be installed for reduced moisture and air infiltration if operation allows. |
| ES52 | Energy supply | Refrigeration | | Storage rooms | Evaporator Fans should be cycled (run in intervals) to minimise energy usage, with careful monitoring of storage room temperature stratification. |
| ES53 | Energy supply | Refrigeration | | Condenser | Use excess heat for heat recovery directly or through heat pump. |
| ES54 | Energy supply | Refrigeration | | Condenser | Variable condenser pressure according to ambient temperature. |
| ES55 | Energy supply | Refrigeration | | Condenser | By reducing the load on the condenser fans by 20 %, it is possible to save 50 % power. |
| ES56 | Energy supply | Refrigeration | | Condenser | Implement VSD and an intelligent control system to ensure an optimal balance in power usage between the compressor and the condenser. |
| ES57 | Energy supply | Refrigeration | | Condenser | Fouling: For each increase in condenser fouling factor of 0.0001, there is a corresponding increase of 1.1% in absorbed compressor power. Energy requirement can be increased as much as 25% by fouling of chiller condenser. |
| ES58 | Energy supply | Refrigeration | | Thermal Cooling Storage | Cooling storage can either be used to take advantage of low electricity prices or to run the cooling plant at optimal efficiency constantly. |
| ES59 | Energy supply | Refrigeration | | Screw Compressor | Divide compressor plant into different suction pressures according to plant specification. |
| ES60 | Energy supply | Refrigeration | | Screw Compressor | Minimise the part load running of screw compressors by changing plant control sequences or by having variable speed drives or variable volume ratios (VI). |
| ES61 | Energy supply | Refrigeration | | Refrigerant Maintanence | Equip cooling/ice water plant with automatic water, air and oil purgers and do regular maintanence checks and services. |
| ES62 | Energy supply | Heat pump | | Condenser | Fouling: For each increase in condenser fouling factor of 0.0001, there is a corresponding increase of 1.1% in absorbed compressor power. Energy requirement can be increased as much as 25% by fouling of chiller condenser. |
| ES63 | Energy supply | Heat pump | | Heat exchanger | Ensure proper microbio control to minimise bacteria film and heat transfer reductions. |
| ES64 | Energy supply | Heat pump | | Refrigerant Maintanence | Equip plant with automatic water, air and oil purgers and do regular maintanence checks and services. |
| ES65 | Energy supply | Heat pump | | Control | Optimize heat pump control: Implement advanced control strategies to optimize the operation of the heat pump system, such as modulating compressor speed and optimizing defrost cycles. |
| ES66 | Energy supply | Heat pump | | Insulation | Insulation and sealing: Insulate pipes, ducts, and the building envelope to minimize heat loss or gain and improve overall system efficiency. |
| ES67 | Energy supply | Heat pump | | Heat recovery | Utilize waste heat recovery: Implement heat recovery systems to capture and utilize waste heat generated by the heat pump system for other heating or hot water needs. |
| ES68 | Energy supply | Heat pump | | Control | Optimized setpoints and scheduling: Optimize temperature setpoints and implement scheduling controls to match heating or cooling needs with occupancy or process requirements, reducing unnecessary energy consumption. |
| ES69 | Energy supply | Heat pump | | Monitoring and control | Monitoring and data analysis: Monitor and analyze energy consumption data to identify opportunities for further optimization and efficiency improvements. |
| ES70 | Energy supply | Electrical installations | | Design | Mapping main cabel routing to avoid overload and heat losses |
| ES71 | Energy supply | Electrical installations | | Maintenance | Thermography of switchboards two to detect bad connections and associated energy losses |
| ES72 | Energy supply | Energy production | | Solar panels | Installation of solar system |
| ES73 | Energy supply | Energy production | | Solar heating | Installation of solar heating system |
| P1 | Process | Pasteuriser | UHT | Heat recovery | Implement heat recovery systems to capture and reuse waste heat, reducing energy consumption. E.g. use product end cooling to preheat new UHT water. |
| P2 | Process | Pasteuriser | UHT | Standby Method | Investigate production patterns to estimate which is better:<br>- Hibernation: Reduced water circulation (~50% of normal) with recovery -> good with short breaks<br>- full stop with need for CIP before startup -> good with long breaks |
| P3 | Process | Pasteuriser | UHT | Maximise Product | For non-ESL (Extended Shelf Life) products there is no need to cool below 35 C. |
| P4 | Process | Pasteuriser | UHT | Turbidity sensor | Can be used to minimise purge water consumption during CIP / UHT |

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| P5 | Process | Pasteuriser | UHT | Longer production | Longer production runs |
| P6 | Process | Pasteuriser | UHT | Insulation | Improved insulation: Improve insulation of pipes and vessels to reduce heat loss and improve energy efficiency. |
| P7 | Process | Pasteuriser | UHT | Heating methods | Consider using energy-efficient heating methods, such as direct steam injection, to reduce energy consumption. |
| P8 | Process | Pasteuriser | | Regeneration effici | Good efficiency is in the interval 93-95%. Live monitoring could be beneficial for fault detection and KPI usage. |
| P9 | Process | Pasteuriser | | Operation pattern | Avoid idle running + standard operating procedure in place for when to start before pasteurisation and when to stop after CIP |
| P10 | Process | Pasteuriser | | Dynamic Ice water | Reduce evaporation pressure of compressor. When ice water return temperature increases. This alleviates freezing risks aswell as adjusting the optimal operation of the chiller. |
| P11 | Process | Pasteuriser | | End cooling heat re | The last amount of heat during pasteurisation cannot preheat product but can be recovered for next batch or alternative use. |
| P12 | Process | Pasteuriser | | Holding tubes | Reduce the holding time to the minimum necessary to meet process requirements, reducing energy consumption. Holding tubes should be insulated to minimize heat loss. |
| P13 | Process | Pasteuriser | | Insulation | Improve insulation of pipes and vessels to reduce heat loss and improve energy efficiency. |
| P14 | Process | Seperator | | Insulation | Improve insulation of pipes and vessels to reduce heat loss and improve energy efficiency. |
| P15 | Process | Seperator | Membrane | RO, NF, MF | Implement energy recovery devices: Install energy recovery devices, such as pressure exchangers or energy transfer systems, to recover energy from the concentrate stream and reduce energy consumption. |
| P16 | Process | Seperator | Membrane | RO, NF, MF | Optimize pre-treatment processes: Implement effective pre-treatment processes, such as filtration or softening, to minimize fouling and scaling on RO membranes, improving energy efficiency. |
| P17 | Process | Seperator | Membrane | RO, NF, MF | Regularly monitor the performance of membranes and implement effective cleaning and maintenance procedures to minimize fouling and maintain high efficiency. Adjust the frequency and intensity of membrane cleaning cycles to minimize energy and chemical consumption while ensuring optimal membrane performance. |
| P18 | Process | Seperator | Membrane | RO, NF, MF | Water recovery and reuse: Implement water recovery and reuse systems to minimize overall water consumption and reduce energy requirements for water treatment. |
| P19 | Process | Seperator | Membrane | RO, NF, MF | Minimize system backwashing: Optimize the frequency and duration of backwashing cycles to minimize water and energy consumption while maintaining membrane cleanliness. |
| P20 | Process | Seperator | Operation pattern | Idle running | Reduce idle running time and have SOP for startup. |
| P21 | Process | Seperator | Drives | Motors | Power consumption monitoring will aid in good operating procedures and possibility to set KPI. |
| P22 | Process | Seperator | Drives | Motors | Changing motors to IE3/IE4 and VSD will reduce energy consumption |
| P23 | Process | Seperator | Decanter | | Optimize decanter speed: Adjust the rotational speed of the decanter to the optimum level based on the specific separation requirements, reducing energy consumption. |
| P24 | Process | Seperator | Decanter | | Improve solids removal efficiency: Optimize the configuration and design of the decanter's discharge system to enhance the separation efficiency, reducing the need for reprocessing and improving energy efficiency. |
| P25 | Process | Seperator | Decanter | | Use of advanced separation technologies: Consider upgrading to decanters with advanced separation technologies, such as enhanced flow control systems or optimized bowl geometry, to improve separation efficiency and reduce energy consumption. |
| P26 | Process | Seperator | | | Process optimization: Optimize the upstream and downstream processes that feed into and receive the decanter's output to minimize energy requirements and maximize overall process efficiency. |
| P27 | Process | Seperator | Centrifuge | | Optimize centrifuge speed: Adjust the rotational speed of the centrifuge to the optimum level based on the specific separation requirements, reducing energy consumption. |

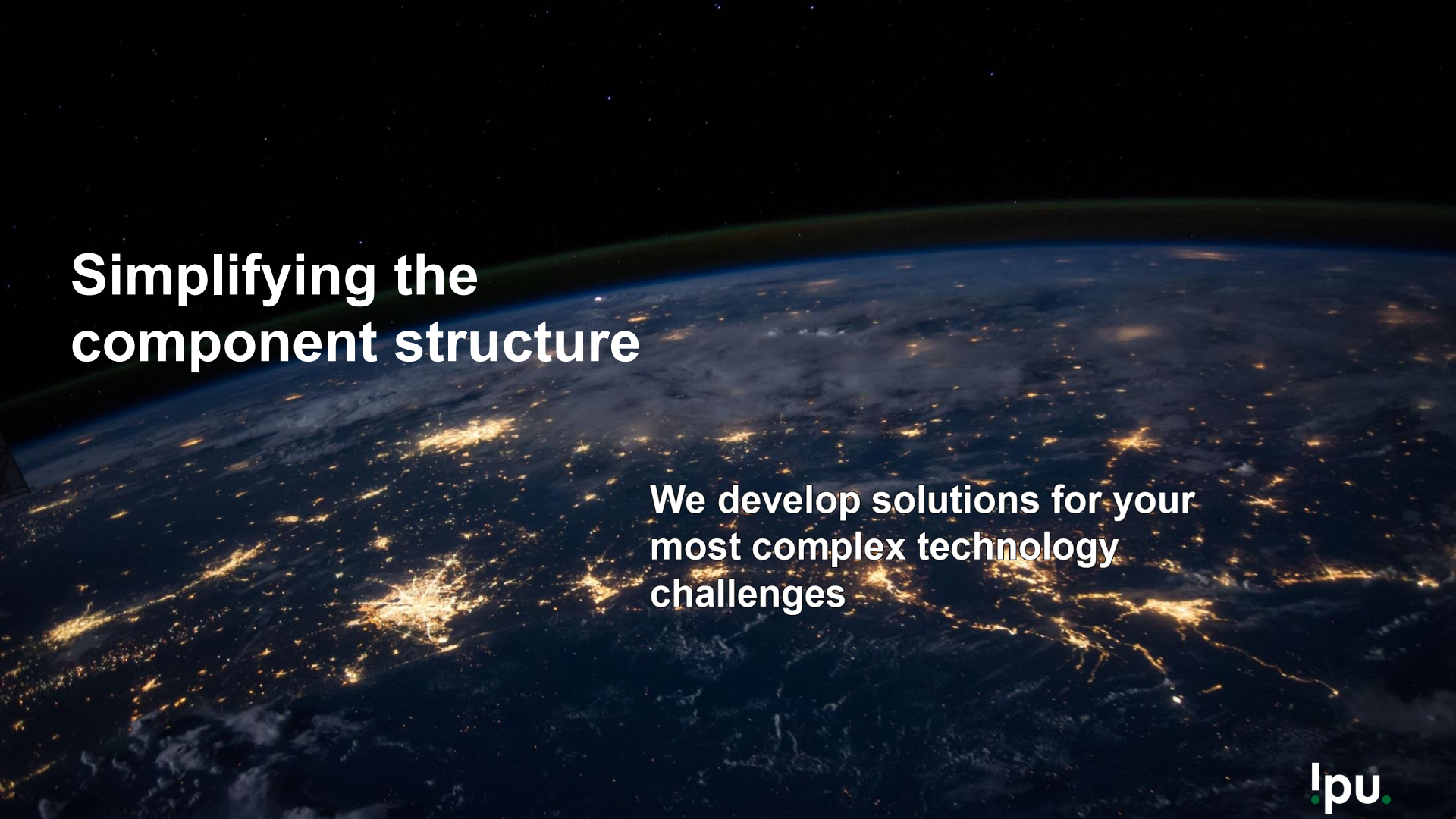
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| P28 | Process | Seperator | Centrifuge | | | Improve solids separation efficiency: Optimize the configuration and design of the centrifuge's bowl and discharge system to enhance the separation efficiency, reducing the need for reprocessing and improving energy efficiency. |
| P29 | Process | Seperator | Centrifuge | | | Use of advanced separation technologies: Consider upgrading to centrifuges with advanced separation technologies, such as enhanced flow control systems or optimized bowl geometry, to improve separation efficiency and reduce energy consumption. |
| P30 | Process | Seperator | Press | | | Optimize pressing force: Adjust the pressing force of the press to the minimum necessary to achieve the desired result, reducing energy consumption. |
| P31 | Process | Seperator | Press | | | Improve material handling: Optimize the material handling processes, such as feeding and discharge mechanisms, to minimize energy requirements and improve overall efficiency. |
| P32 | Process | Seperator | Press | | | Use of energy-efficient components: Choose energy-efficient components, such as hydraulic systems or pneumatic actuators, to reduce energy consumption. |
| P33 | Process | Seperator | Sift | | | Choose energy-efficient components, such as low-friction bearings or lightweight sieve materials, to reduce energy consumption. |
| P34 | Process | Seperator | Sift | | | Optimize the entire process that involves the sifter, including upstream and downstream operations, to minimize energy requirements and maximize overall process efficiency. |
| P35 | Process | Mixer | | Drives | Motors | Changing motors to IE3/IE4 and VSD will reduce energy consumption |
| P36 | Process | Mixer | | Drives | Motors | Optimised belts for mixer piston pump. |
| P37 | Process | Mixer | | Drives | Motors | Power consumption monitoring will aid in good operating procedures and possibility to set KPI. |
| P38 | Process | Mixer | Homogeniser | | Variable Flow / pre | Variable flow rate and pressure according to prescription of product |
| P39 | Process | Mixer | Homogeniser | | Two stage homoge | Can in some cases reduce energy use without interfering with quality of the product. Ratio should be P1/P2 = 0.2 |
| P40 | Process | Mixer | Homogeniser | | Cooling | Separate Piston & Oil cooling + Closed Water loop to save water |
| P41 | Process | Mixer | Homogeniser | | Control | Hydraulically actuated valves should be pressure-regultated according to the necessity of the product. |
| P42 | Process | Mixer | Homogeniser | | Pressure | Homogenise with lowest possible pressure so that homogenization of the product is not below target NIZO values. |
| P43 | Process | Mixer | | | Idle running | Reduce idle running time and have SOP for startup. |
| P44 | Process | Mixer | | | Insulation | Improve insulation of pipes and vessels to reduce heat loss and improve energy efficiency. |
| P45 | Process | Mixer | | | Running time | Reduce the mixing time to the minimum necessary to meet process requirements, reducing energy consumption. |
| P46 | Process | Mixer | | | Mixing type | Consider using energy-efficient mixing methods, such as high-shear mixing, to reduce energy consumption. |
| P47 | Process | Evaporation | | MVR / Extra stages | | Mechanical Vapour recompression can reduce energy consumption with 50-80% compared with traditional evaporation |
| P48 | Process | Evaporation | | MVR / Extra stages | | Extra evaporation effects/steps will reduce steam consumption |
| P49 | Process | Evaporation | | MVR / Extra stages | | If the exit steam from the evaporator can be utilized elsewhere, there is no value in improving energy efficiency |
| P50 | Process | Evaporation | | MVR / Extra stages | | Adding thermocompressors can improve efficiency |
| P51 | Process | Evaporation | | Leakage | | Check for leakages. Leakage air will impact vacuum evaporator efficiency negatively. |
| P52 | Process | Evaporation | | Ejector Replacement | | Replace Ejector with vacuum pumps for increased energy efficiency. |
| P53 | Process | Evaporation | | Heat recovery | | Utilise clean condensate latent heat from each evaporation step for other processes. |
| P54 | Process | Evaporation | | Heat recovery | | Reuse heat from condenser if applicable consumer can be identified and connected. |
| P55 | Process | Evaporation | | Seal water | | Seal water is often sent directly to drain. This should be reused in a closed loop. |
| P56 | Process | Evaporation | | Seal water | | Often not adjusted correctly. |
| P57 | Process | Evaporation | | Insulation | | Improve insulation of pipes and vessels to reduce heat loss and improve energy efficiency. |
| P58 | Process | Evaporation | | | | Pre-treatment of concentrate from evaporators to reduce viscosity. |
| P59 | Process | Drying | | Thermal | Drying exhaust | Heat recovery from dryer exhausts should be carried out if particle levels allow it. |

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| P60 | Process | Drying | | Thermal | Investigate if the inlet air can be preheated using waste heat sources from utility equipment. |
| P61 | Process | Drying | | Thermal | Remove moisture in preheat air with dehumidifer, and if possible use waste heat to regenerate it. |
| P62 | Process | Drying | Spray drying | Thermal | Optimize spray drying parameters, such as atomization pressure and air flow, to reduce energy consumption. |
| P63 | Process | Drying | | Thermal | Improve insulation of pipes and vessels to reduce heat loss and improve energy efficiency. Proper air heater & duct insulation is vital. |
| P64 | Process | Drying | | Control | Optimize control systems to ensure proper operation of the dryer, reducing energy consumption. Use VSD on fans over throttle valves to minimise energy consumption. |
| P65 | Process | Drying | | Control | Reduce the drying time to the minimum necessary to meet process requirements. Automatically shut down air heater during idle time between batches. |
| P66 | Process | Drying | | Insulation | Improve insulation of the dryer and its components to reduce heat loss and improve energy efficiency. |
| P67 | Process | Drying | | Control | Use sensors and control systems to monitor and control the moisture content of the product, optimizing the drying process and reducing energy usage. |
| P68 | Process | Drying | Disc dryer | | Process optimization: Optimize the overall drying process, including loading and unloading times, to minimize downtime and maximize energy efficiency. |
| P69 | Process | Drying | | | Optimize the airflow pattern within the dryer to ensure even distribution and efficient drying. |
| P70 | Process | Drying | Tumble dryer | | Optimize the load capacity of the tumble dryer to match the production requirements, avoiding overloading or underloading, which can lead to energy inefficiencies. |
| P71 | Process | Drying | Tumble dryer | | Consider using heat pump tumble dryers that use refrigerant-based heat exchange systems, providing higher energy efficiency compared to conventional dryers. |
| P72 | Process | Transport systems | Conveyor belt | | Choose conveyor belts with low rolling resistance and appropriate tension to reduce energy consumption. |
| P73 | Process | Transport systems | Conveyor belt | | Ensure proper belt tension to minimize friction and energy losses during material transport. |
| P74 | Process | Transport systems | Conveyor belt | | Utilize energy-efficient motors for driving the conveyor belt to reduce power consumption. |
| P75 | Process | Transport systems | Conveyor belt | | Adjust the conveyor belt speed based on material flow requirements to avoid unnecessary energy usage. Install VFDs on the conveyor belt motor to adjust the speed based on material flow requirements, reducing energy consumption during periods of lower demand. |
| P76 | Process | Transport systems | Conveyor belt | | Optimize the conveyor layout to minimize the number of turns and bends, reducing energy consumption and wear on the system. |
| P77 | Process | Transport systems | Conveyor belt | | Ensure proper loading and distribution of material on the conveyor to avoid imbalanced loads that can lead to increased energy usage. |
| P78 | Process | Transport systems | Conveyor belt | | Implement measures to minimize material spillage from the conveyor, as it can lead to unnecessary energy waste and increased maintenance. |
| P79 | Process | Transport systems | Conveyor belt | | Choose a conveyor chain with low friction and high efficiency to minimize energy consumption during material transport. |
| P80 | Process | Transport systems | Auger | | Use augers with optimized flight designs to minimize resistance and friction during material transport, reducing energy consumption. |
| P81 | Process | Cooling | | | Consider using energy-efficient chillers with high Coefficient of Performance (COP) or Energy Efficiency Ratio (EER) to reduce energy consumption. |
| P82 | Process | Cooling | | | Implement advanced control strategies and automation systems to optimize chiller operation based on process demand, reducing energy consumption. |
| P83 | Process | Cooling | | | Optimize cooling water flow rates and temperature setpoints to match the process cooling needs and minimize energy usage. |

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| P84 | Process | Cooling | Implement heat recovery systems to capture and reuse waste heat generated during the cooling process for other heating requirements, reducing energy consumption. |
| P85 | Process | Cooling | Utilize VSDs on pumps and fans to adjust the flow rate and speed based on process cooling demands, saving energy during periods of lower demand. |
| P86 | Process | Cooling | Improve insulation around cooling pipes and vessels to reduce heat gain and improve energy efficiency. |
| P87 | Process | Cooling | Perform regular maintenance on cooling equipment, including cleaning condenser coils and filters, to ensure efficient operation and minimize energy losses. |
| P88 | Process | Cooling | Optimize cooling tower operation and maintenance to ensure efficient heat rejection and water evaporation, reducing energy usage. |
| P89 | Process | Cooling | Consider using advanced cooling technologies, such as adiabatic coolers or free cooling, to reduce energy consumption during favorable weather conditions. |
| P90 | Process | Cooling | Optimize the overall cooling process, including temperature setpoints and control strategies, to minimize energy requirements. |
| P91 | Process | Packaging /bottling | Utilize energy-efficient motors and drives in the packaging or bottling machinery to reduce power consumption. |
| P92 | Process | Packaging /bottling | Implement advanced control systems and automation to optimize machine operation, reducing energy waste during idle periods. Install VSDs on conveyor belts and other moving parts to adjust speed based on production demand, saving energy during periods of lower throughput. |
| P93 | Process | Packaging /bottling | Optimize the operation of air compressors used in pneumatic systems, reducing air leaks and unnecessary energy consumption. |
| P94 | Process | Packaging /bottling | Optimize the overall packaging or bottling process, including material handling and production flow, to minimize energy requirements. |
| P95 | Process | Cooker | Consider using energy-efficient heating sources, such as natural gas, steam, or electricity, based on availability and cost-effectiveness. |
| P96 | Process | Cooker | Improve insulation around the cooker and its components to reduce heat loss and improve energy efficiency. |
| P97 | Process | Cooker | Implement heat recovery systems to capture and reuse waste heat generated during the cooking process for other heating requirements, reducing energy consumption. |
| P98 | Process | Cooker | Adjust the cooking temperature and time based on the specific product and process requirements, reducing energy usage. Evaluate the feasibility of using continuous cooking processes to reduce startup and shutdown energy losses, compared to batch cooking methods. |
| P99 | Process | Cooker | Use advanced control systems and automation to optimize the cooking process, ensuring precise temperature control and reducing energy waste. |
| P100 | Process | Cooker | Regularly inspect and maintain the industrial cooker, including cleaning burners or heat exchangers, to ensure efficient operation and minimize energy losses. |
| P101 | Process | Cooker | Consider using pressure cooking methods to reduce cooking time and energy consumption. |
| P102 | Process | Cooker | Optimize the overall cooking process, including upstream pre-heating, downstream heat recovery, product loading and unloading times to minimize downtime. |
| P103 | Process | Milling | Utilize energy-efficient motors and drives in milling machines to reduce power consumption. |
| P104 | Process | Milling | Adjust milling speed based on material characteristics and desired particle size, reducing energy usage. |
| P105 | Process | Milling | Optimize milling machine operation schedules to reduce idle time and energy waste. |
| P106 | Process | Milling | Perform regular maintenance and inspections to ensure milling equipment is in optimal condition and minimize energy losses. Ensure proper and regular lubrication of milling equipment to reduce friction and improve energy efficiency. |

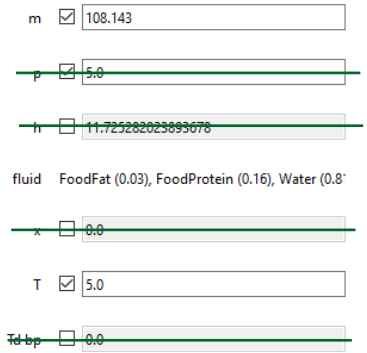
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| P107 | Process | Milling | | | | Implement heat recovery systems to capture and reuse waste heat generated during the milling process for other heating requirements. |
| P108 | Process | Milling | | | | Implement advanced control systems and automation to optimize milling processes, reducing energy waste and ensuring precise control. |
| P109 | Process | Tanks & Silos | | Agitation | | Minimize product agitation, and use only energy efficient agitators. Adjust agitation to specific demand. |
| P110 | Process | Tanks & Silos | | Insulation | | Improve insulation of tanks and silos to reduce heat loss and improve energy efficiency. Essential for outdoor installations. |
| P111 | Process | Tanks & Silos | | Ventilation | | Ensure proper ventilation of tanks and silos to reduce energy consumption. |
| P112 | Process | Pumps & valves | | Pumps | | New motors should be high efficiency standard IE3 / IE4 |
| P113 | Process | Pumps & valves | | Pumps | | VSD is essential in variable speed positions. Implement VFDs to adjust the speed of the pump motor, reducing energy consumption. |
| P114 | Process | Pumps & valves | | Valves | | Check seat flush on valves and reduce volume to a minimum. |
| P115 | Process | Pumps & valves | | Pressure | | Reduce system pressure to the minimum necessary to meet process requirements, reducing energy consumption. Implement pressure reducing valves to regulate pressure and reduce energy consumption. |
| P116 | Process | Pumps & valves | | Design | | Minimize pipeline friction by optimizing pipeline design, reducing energy consumption. |
| P117 | Process | Pumps & valves | | Maintenance | | Regular maintenance of pumps, including lubrication and replacement of worn parts, to improve energy efficiency. |
| P118 | Process | Agitation | | Design | | Making sure that the agitators are designed for the specific job. E.g. vertical/horisontal agitation, several agitators, agitation speed. |
| SS1 | Support system | Fresh water & Efluent plants | | Water treatment | Water recovery | Implement a technical water system, if possible, including enough tank capacity to reuse most of polisher water from RO- and microfiltration plants. |
| SS2 | Support system | Fresh water & Efluent plants | | Water treatment | Water recovery | Collect rain water and use it for "technical water", e.g. for cooling towers. |
| SS3 | Support system | Fresh water & Efluent plants | | Water treatment | Water recovery | Use e.g. polisher or rain water, for outside cleaning of distribution trucks. |
| SS4 | Support system | Fresh water & Efluent plants | | Water treatment | Water recovery | Reuse water for all CIP flushes possible except for final flush. |
| SS5 | Support system | Fresh water & Efluent plants | Effluent | Energy recovery | Biogas production | Biogas production from wastewater should be utilised in steam production. |
| SS6 | Support system | Fresh water & Efluent plants | Effluent | | | Blowers should have high efficiency motors and variable speed drives to adjust pump speed based on demand, reducing energy consumption. |
| SS7 | Support system | Fresh water & Efluent plants | Effluent | | | Aeration controlled according to the measured oxygen levels. |
| SS8 | Support system | Fresh water & Efluent plants | Effluent | | | Pre-treating: Implement a system for pre-treating waste water by using a flocculation/flotation system before the effluent plant, if relevant. The system removes more than 75 % of fat and protein. |
| SS9 | Support system | Fresh water & Efluent plants | Effluent | | | Sort all mix phases between product and water by e.g. turbidity and re-use it. It is also possible to collect product waste from CIP plants by using clean water for pre-rinse or first flush. |
| SS10 | Support system | Fresh water & Efluent plants | | Leakage | | Leak detection and repair: Conduct regular leak detection and repair to minimize water loss and reduce energy consumption. |
| SS11 | Support system | Fresh water & Efluent plants | | Design | | Proper piping design: Design piping systems to minimize friction loss and reduce energy consumption. |
| SS12 | Support system | Fresh water & Efluent plants | | Filters | | Use of efficient filters: Use efficient filters, such as self-cleaning or backwash filters, to reduce energy consumption. |
| SS13 | Support system | Fresh water & Efluent plants | Salt treatment | | | Consider upgrading to more energy-efficient equipment, such as pumps and filters, to improve energy efficiency. Implement VSDs to adjust the speed of pumps and motors based on the process demand, reducing energy consumption. |
| SS14 | Support system | Fresh water & Efluent plants | Salt treatment | | | Minimize backwashing frequency: Optimize the frequency and duration of backwashing cycles to reduce water and energy consumption. |
| SS15 | Support system | Fresh water & Efluent plants | | Energy recovery | | Energy recovery systems: Implement energy recovery systems, such as vortex systems or turbine systems, to recover energy from wastewater and reduce energy consumption. |

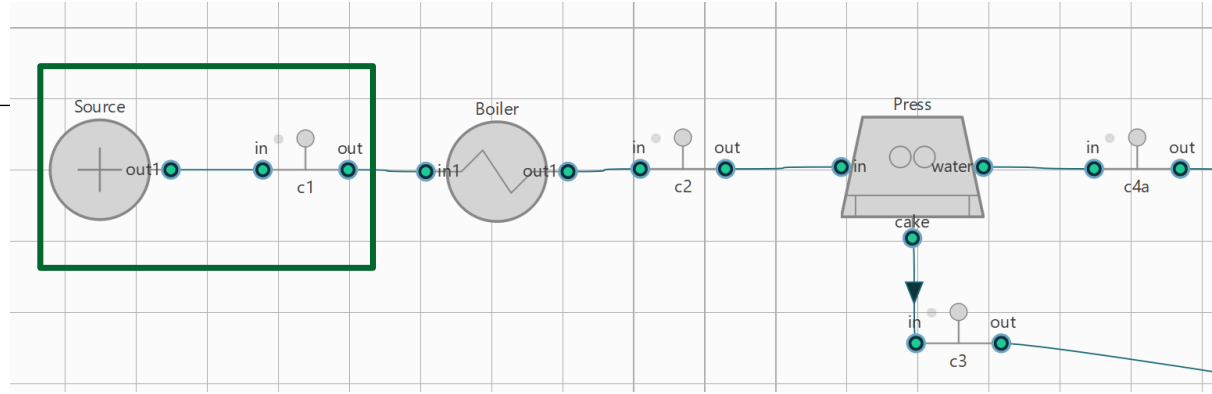
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| SS16 | Support system | Membranes | Water treatment | Consider using energy-efficient pumps, such as variable frequency drives (VFDs) or high-efficiency pumps, to reduce energy consumption. |
| SS17 | Support system | Membranes | Water treatment | Implement advanced control systems and automation to optimize pump operation based on water demand, reducing energy waste. |
| SS18 | Support system | Membranes | Water treatment | Evaluate and optimize the water treatment processes, such as coagulation, flocculation, sedimentation, and filtration, to improve overall efficiency and reduce energy usage. |
| SS19 | Support system | Membranes | Water treatment | Install energy recovery devices, such as pressure exchangers or energy transfer systems, to recover energy from the treatment process and reduce energy consumption. Implement heat recovery systems to capture and reuse waste heat generated during water treatment processes for other heating requirements. |
| SS20 | Support system | Membranes | Water treatment | Adjust the dosage and timing of chemicals used in water treatment to minimize waste and energy requirements. |
| SS21 | Support system | Membranes | Water treatment | Consider using advanced membrane technologies, such as reverse osmosis or nanofiltration, to improve water treatment efficiency and reduce energy consumption. |
| SS22 | Support system | Membranes | Water treatment | Perform regular maintenance and inspections to ensure water treatment equipment is in optimal condition and minimize energy losses. |
| SS23 | Support system | Membranes | Water treatment | Optimize the overall water treatment process, including flow rates, dosing rates, and system layouts, to minimize energy requirements. |
| SS24 | Support system | CIP | Heat recovery | Preheating of flush water to heat up equipment will lower necessary maximum temperature of lye & Acid. |
| SS25 | Support system | CIP | Heat recovery | Regeneration to next CIP cycle of waste phases. |
| SS26 | Support system | CIP | Re-using Chemical | High concentration phases as well as clear water phases should be reused. |
| SS27 | Support system | CIP | CIP monitoring | Electrical and heating power meters. Furthermore to minimise CIP Purge and for general monitoring: Flow, pH, temperature and turbidity. |
| SS28 | Support system | CIP | Heat recovery | Use of heat recovery: Implement heat recovery systems to capture and reuse waste heat, reducing energy consumption. In many applications steam can be replaced by reusing hot water CIP. |
| SS29 | Support system | CIP | CIP Heating | Avoid 24/7 standby heating of CIP Lye & Acid tanks -> use on & off control or a heat exchanger at CIP stream going out |
| SS30 | Support system | CIP | CIP Heating | Improved insulation: Improve insulation of pipes and vessels to reduce heat loss and improve energy efficiency. |
| SS31 | Support system | CIP | Longer production runs | Minimize the frequency of cleaning to reduce energy consumption. |
| SS32 | Support system | CIP | Temperature | Reduce the rinse water temperature to the minimum necessary to meet sanitary requirements, reducing energy consumption. |
| SS33 | Support system | CIP | VSD & Control | Implement variable speed drives to adjust the speed of pumps and agitators based on demand, reducing energy consumption. |
| SS34 | Support system | CIP | Cleaning agents | Consider using low-energy cleaning agents, such as citric acid or sodium hydroxide, to reduce energy consumption. |


Simplifying the component structure
We develop solutions for your most complex technology challenges
!pu.

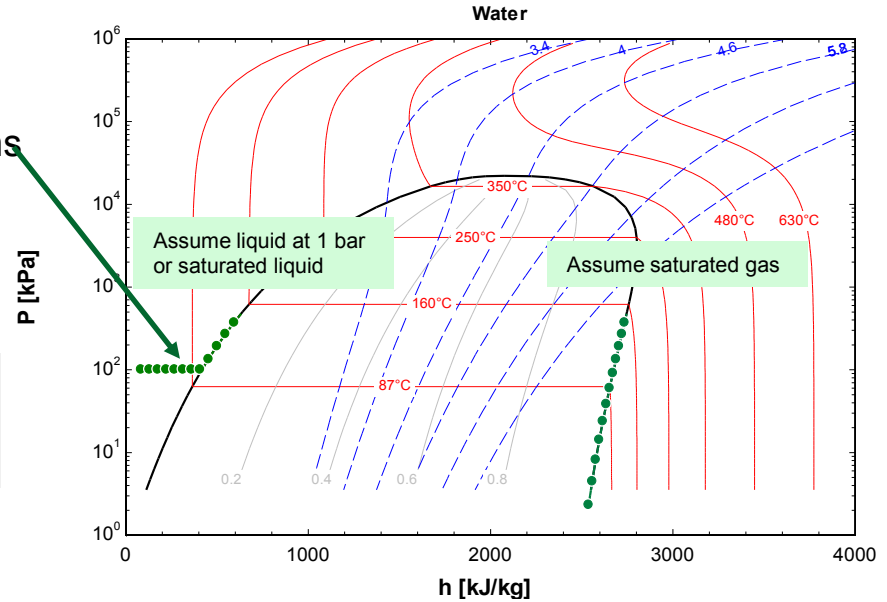
# Source

- Source becomes a single component with

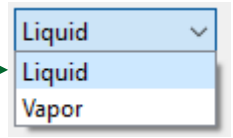


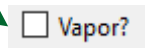




property assumptions




- Questions:
  - dropdown with (liquid/vapor)
  - check with “vapor check“
  - Separate gas-source model?

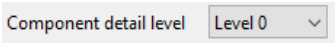
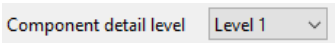
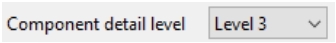


# Understanding levels

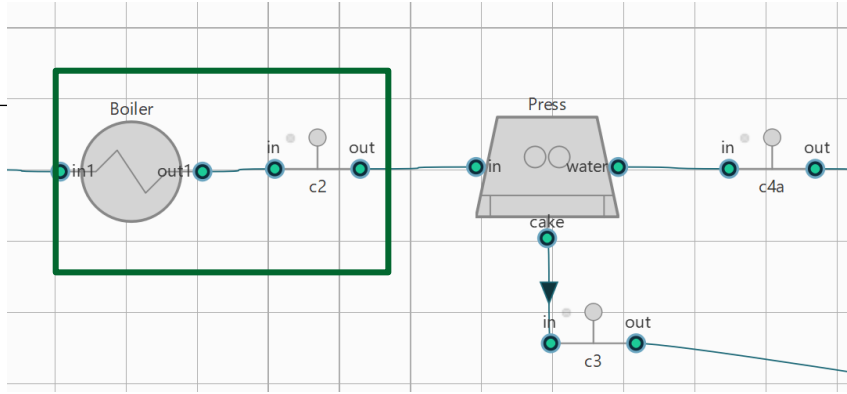
EB for level 1,2,3 ☺

**We plan to deal with the different component detail levels at the component level:**

| UI /frontend | Backend (now tespy, what happens behind the scene) |
|---|---|
|  | • Calculates mass and species flow balances<br>• Propagate h,p or T,p (no need for pressure drop or energy balance)<br>• One-to-one (inlet-outlets) are trivial propagations of mass and species flow<br>• One-to-two (inlet-outlets) involve media concentration specification, splits, etc.<br>• Two(+)-to-one (inlet-outlets) (mixing) require nothing |
|  | • With capacity (Q) specified, we calculate $T_{out}$ or $h_{out}$ using energy balance<br>e.g. $T_{out} = T_{in} + Q/cp/m$ |
|  | • With Kpi specified, capacity is specified by (Kpi*m), we calculate $T_{out}$ or $h_{out}$ using energy balance<br>e.g. $T_{out} = T_{in} + (m*Kpi)/cp/m$ |
|  | • With $T_{out}$ specified we calculate capacity using energy balance<br>e.g. $Q = m*dh$ |

# Heat exchanger

EB for level 1,2,3 ☺




Component detail level: Level 0 → $h_{out} = h_{in}$, $p_{out} = p_{in}$

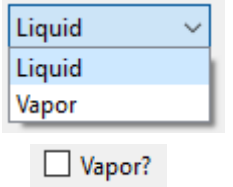
Component detail level: Level 1
Q ☑
→ $T_{out} = T_{in} + Q/cp/m$
$p_{out} = p_{in}$

Component detail level: Level 2
Kpi ☑
→ $T_{out} = T_{in} + (m*Kpi)/cp/m$
$p_{out} = p_{in}$

Component detail level: Level 3
T ☑
→ $T_{out} = T$ , $p_{out} = p_{in}$

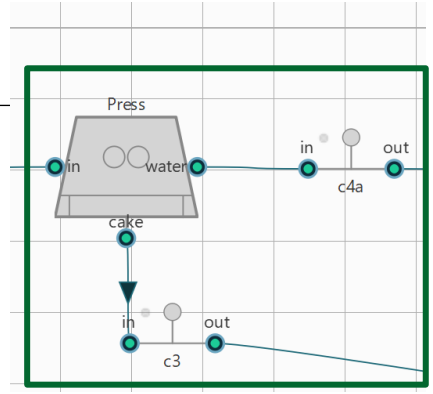
Q = m*dh (post calculation)

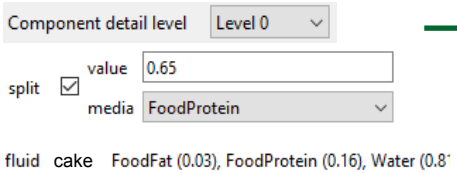
- Questions:
  - dropdown or check box ?
  - Or assume indifferent phase
    - Liquid-to-liquid
    - Gas-to-gas
    - ?



# Press (do we need level 1,2,3)

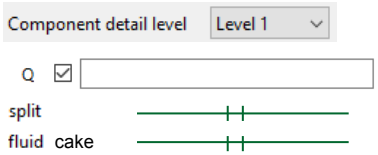
EB for level 1,2,3 ☺



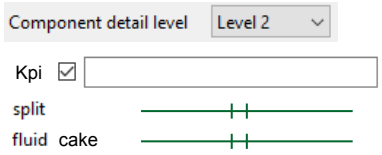

→ $T_{out,i} = T_{in}$, $p_{out,i} = p_{in}$ $\quad i \in 1,2$

Q is calculated heat loss/gain
h is allowed to vary in order to separate fluid



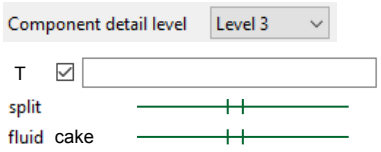

→ $h_{out} = h_{in} + Q/m$, $T_{out,1} = T_{out,2}$
$p_{out,i} = p_{in}$ $\quad i \in 1,2$

NB: Q is loss/gain




→ $h_{out} = h_{in} + (Kpi*m)/m$, $T_{out,1} = T_{out,2}$
$p_{out,i} = p_{in}$ $\quad i \in 1,2$

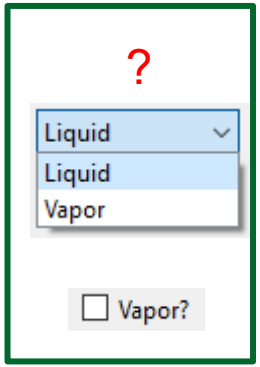
NB: Q is loss/gain




→ $T_{out,i} = T$ , $p_{out,i} = p_{in}$ $\quad i \in 1,2$

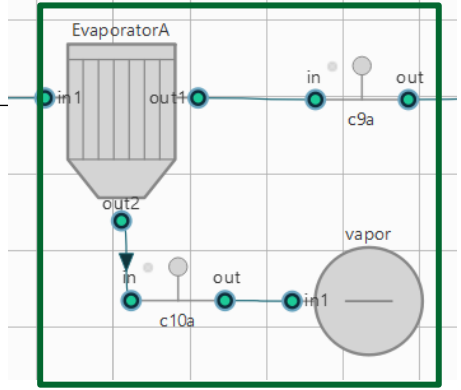
Q = m*dh (postcalculation)

NB: Q is loss/gain



# Evaporator (leaving out p=p equations)

EB for level 1,2,3 ☺




Component detail level: Level 0

$m_{evap}$ or part of main water flow

NB: $T_{evap}$ could also be specified here to avoid using $T_{in}$

→ Out,2 = saturated gas i.e. $h_{out,2} = h(x=1, T=T_{evap})$

$T_{evap} = T_{in}$

$T_{out,i} = T_{evap}$ $\quad i \in 1,2$

Component detail level: Level 1

Q ☑

$T_{evap}$

→ Out,2 = saturated gas i.e. $h_{out,2} = h(x=1, T=T_{evap})$

$T_{out,i} = T_{evap}$ $\quad i \in 1,2$

Component detail level: Level 2

Kpi ☑

$T_{evap}$

→ Out,2 = saturated gas i.e. $h_{out,2} = h(x=1, T=T_{evap})$

→ $Q = Kpi * m$

$T_{out,i} = T_{evap}$ $\quad i \in 1,2$

Component detail level: Level 3

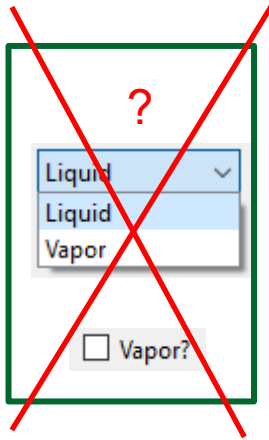
$T_{evap}$

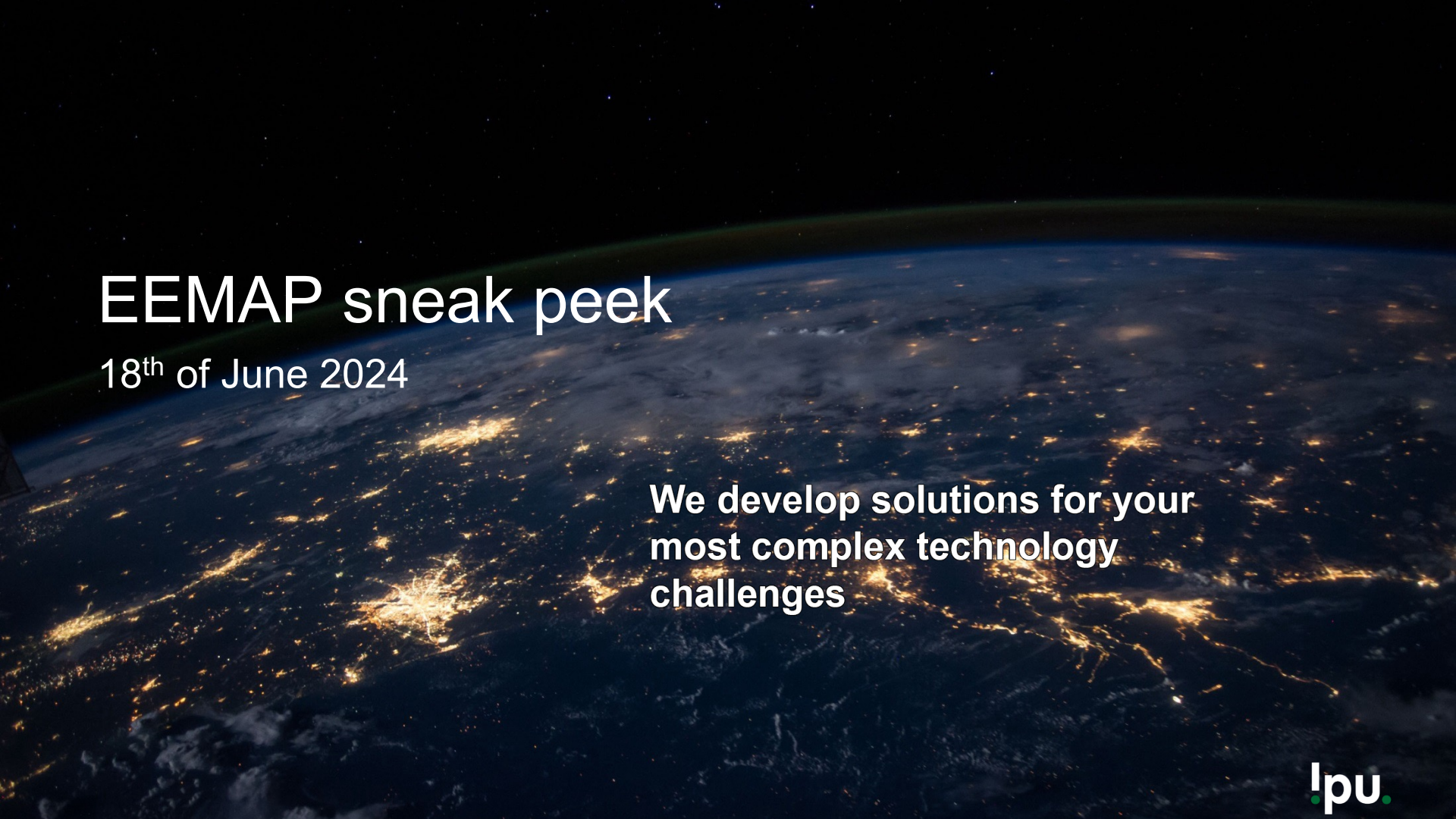
Thick fluid concentration

→ Out,2 = saturated gas i.e. $h_{out,2} = h(x=1, T=T_{evap})$

$T_{out,i} = T_{evap}$ $\quad i \in 1,2$

Automatically place sink on open outlets?





# EEMAP sneak peek

18th of June 2024

**We develop solutions for your most complex technology challenges**

!pu.

# Our heritage of results and unbiased advisory



# We are committed to making a significant difference




Therefore, our approach builds on…

- *Fast failure forward*
- *Risk & Value prioritization*
- *Inspiration from other domains and applications*
- *Understand, model & test iterations*
- *”T-profiled” team members*
- *High customer involvement*

# First in implementing sustainability in R&D



# Where would it make sense to discuss mutual opportunities?

| | Identify | Qualify | Develop | Implement |
|---|---|---|---|---|
| **Technology Development** | novo nordisk, VELUX | MAKEEN ENERGY, SEMCO maritime | KRONES, Coloplast | COMPANY VESTERGAARD, MAERSK LINE |
| **Sustainability & Decarbonization** | Coloplast, RGSNORDIC | FOSS, amager ressource center | AMGEN, HEATEN | ROCKWOOL, Coloplast |
| **Thermodynamics & EnergyTech** | DANTHERMGROUP | embraco | HEATEN | COPELAND |

# Cases for inspiration…

| | Identify | Qualify | Develop | Implement |
|---|---|---|---|---|
| **Technology Development** | novo nordisk, VELUX | MAKEEN ENERGY, semco maritime | KRONES, Coloplast | COMPANY VESTERGAARD, MAERSK LINE |
| **Sustainability & Decarbonization** | Coloplast, RGSNORDIC | FOSS, amager ressource center | AMGEN, HEATEN | ROCKWOOL, Coloplast |
| **Thermodynamics & EnergyTech** | DANTHERMGROUP, MAERSK LINE | embraco, MAN Energy Solutions Future in the making | HEATEN, Danfoss | COPELAND, NILAN OUTSTANDING INDOOR CLIMATE |

# Welcome and enjoy the presentations

IPU Thermodynamics and Energy Technology
Bredevej 2B, DK-2830 Virum, Denmark



# EEMAP



# Agenda

| | | |
|---|---|---|
| 12.30 - 12.40 | Coffee | All |
| 12:40 – 12:45 | Welcome to IPU | IPU |
| 12:45 - 13:15 | Introduction to the project: Energy Efficiency Mapping (EEMAP) | Viegand M. |
| 13:15 - 13:30 | The need for Energy Mapping | FF-Skagen |
| 13:30 - 14:00 | Introduction to the tool | IPU |
| 14:00 - 14:30 | Panel discussion – How do companies plan to use the tool? | All |
| 14:30 - 14:45 | Coffee break | All |
| 14:45 - 15:00 | Future needs to document energy efficiency | IPU |
| 15:00- 15:30 | Examples of building a calculation scenario | IPU |
| 15:30 - 15:45 | How to use the results in an add-on analysis | VMAS/DTU |
| 15:45 - 16:00 | Next steps in EEMAP | VMAS/DTU |
| 16:00 - 17:30 | Snacks and beverages | All |

# Welcome

Monday 24 June 2024



# Thank you!



**Fridolin Müller Holm**

fmh@viegandmaagoe.dk



**Sneaster Asrat**

sas@viegandmaagoe.dk



**Albert Bruun-Guassora**

abr@viegandmaagoe.dk



**Rikke H. Andersen**

ran@viegandmaagoe.dk



**Johan D. Hollederer**

idh@viegandmaagoe.dk



**Martin R. Kærn**

mrk@ipu.dk



**Jorrit Wronski**

jowr@ipu.dk



**Victor Lyra**

vily@ipu.dk



**Brian Elmegaard**

brel@dtu.dk



**Nasrin A. Kermani**

nasker@dtu.dk



**Roger P. Solé**

rpiso@dtu.dk

# Thank you – to the companies

| FF Skagen | Skjern Paper | Ovodan | Royal Unibrew | PPG | Avista Green |
|---|---|---|---|---|---|
| Thorkild Olesen | Søren Skærbæk | Henrik Mørk | Kasper Vad Gundestrup | Mark Palm | Peter Jonsson |

# Introduction to the project: **Energy Efficiency Mapping (EEMAP)**

By Viegand Maagøe

Monday 24 June 2024



# What is EEMAP?

- The development of a software tool that can reduce time and costs associated with making an energy map
- Tool that create an easy overview, that create desiccations for where to focus in terms of mapping and project development
- Uses the results from the mapping as an information basis for the optimization of the processes.

# What do we get out of EEMAP?

- Expanded use of energy mapping in industry supports the sector's green transition
- Digitizing the process industry's analog energy systems by determining the right needs for sensor investments and data collection
- Supports decision-making processes in connection with the implementation of corporate strategies, as well as reporting requirements to the authorities

# Project organisationen

## Viegand Maagøe

Project managers

Engineering consulting company

Experience with energy mapping and great interest in digitizing performance work

## IPU

Software developers with expertise in thermal processes

## DTU

The Technical University of Denmark

Researchers within thermal processes in industry

Conveys industrial learning and supports tool development through experience with process ıg.

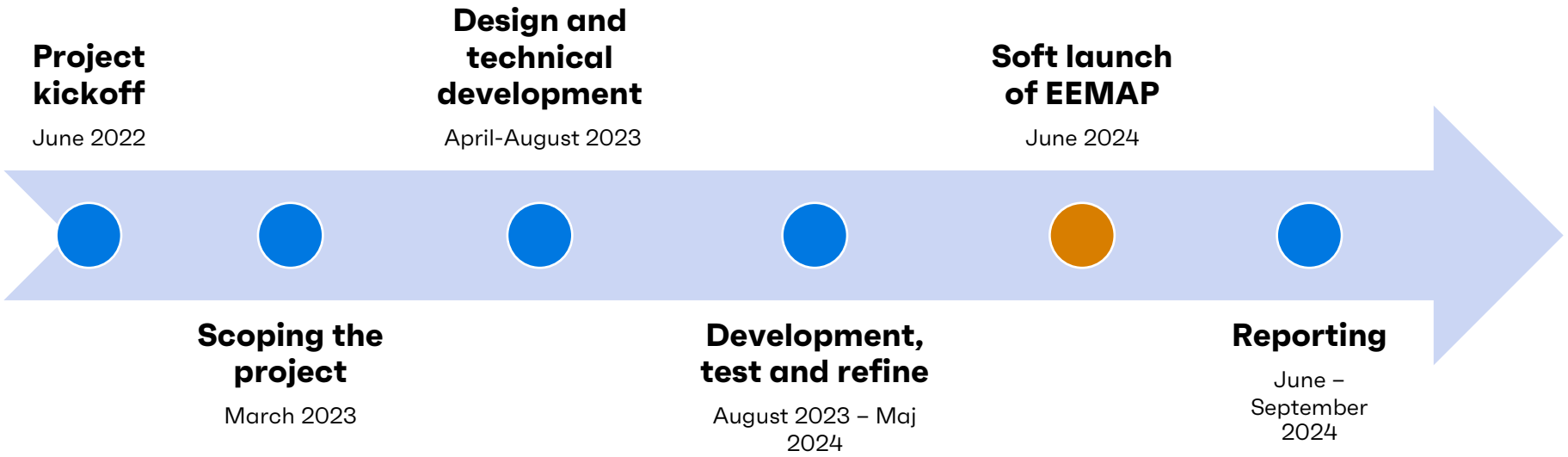
## Virksomhederne

The development and testing companies

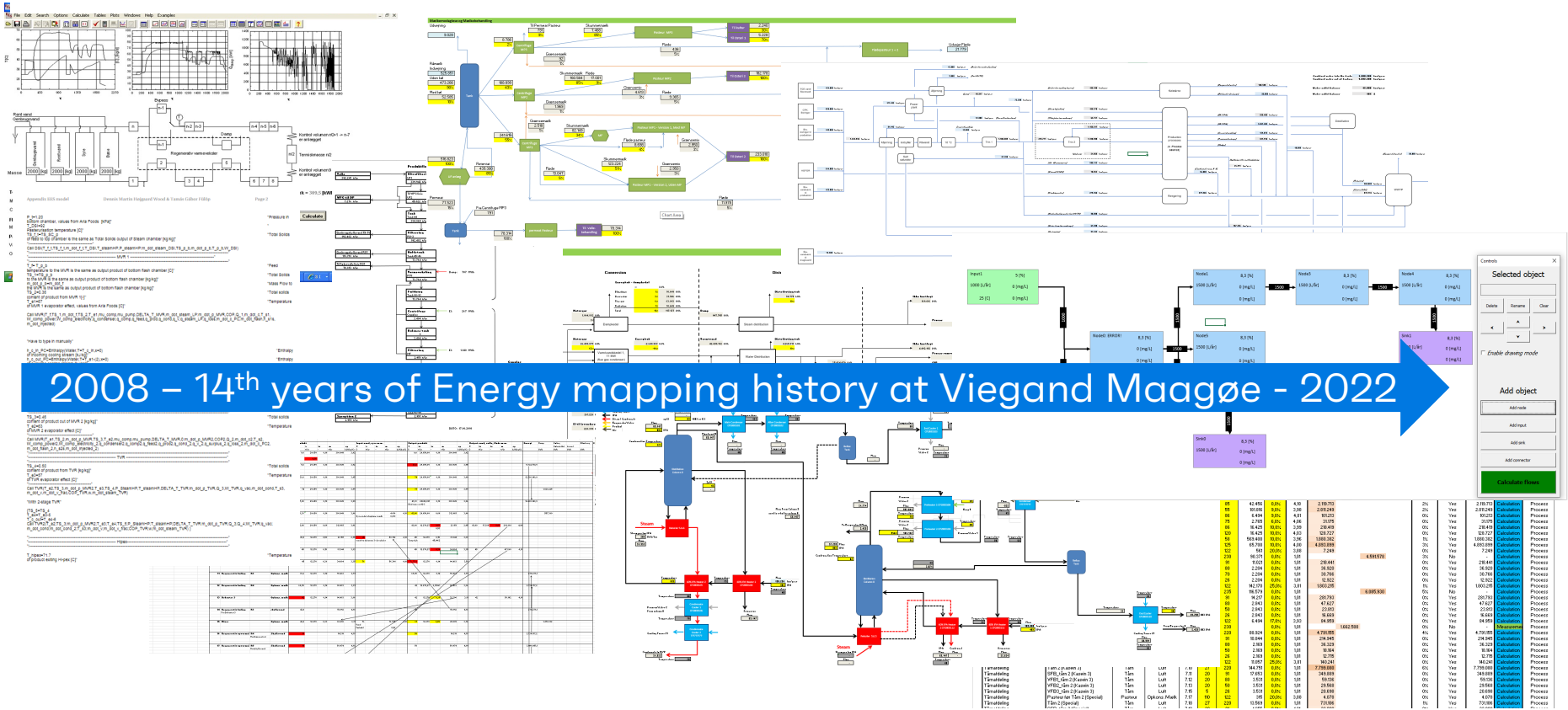
FF-Skagen
Skjern Paper
Ovodan

PPG
Royal Unibrew
Avista Green

# Project progress

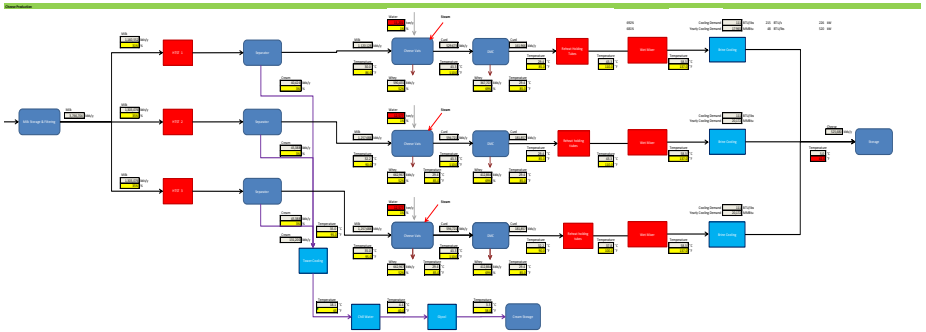


# Energy mapping history



# Mapping process

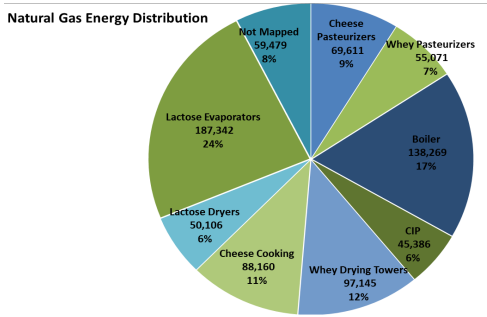
## 1. Flow sheeting



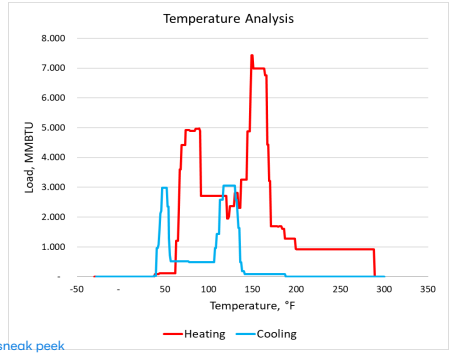
## 2. Energy balance

| Section | Line | Equipment | Medium | Heat Transfer Code Or Equipment number | Temp. In | Temp. Out | E-KPI | Mass flow | Dry matter | Cp | Steam |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | °F | °F | MmbtuKlbs | klbs/yr | % | btu/lbs | MMBtu |
| Cheese Pasteurizers | Cheese HTST 1 | Steam Preheating | Water | | 93.4 | 110.0 | | 537,123 | 0.0% | 1.00 | 8,916 |
| Cheese Pasteurizers | Cheese HTST 1 | Pasteurizer Steam | Raw Milk | | 152.5 | 164.2 | | 1,160,552 | 15.0% | 0.96 | 13,681 |
| Cheese Pasteurizers | Cheese HTST 2 | Steam Preheating | Water | | 93.4 | 110.0 | | 605,778 | 0.0% | 1.00 | 10,056 |
| Cheese Pasteurizers | Cheese HTST 2 | Pasteurizer Steam | Raw Milk | | 153.7 | 164.5 | | 1,323,076 | 15.0% | 0.96 | 13,561 |
| Cheese Pasteurizers | Cheese HTST 3 | Steam Preheating | Water | | 93.4 | 110.0 | | 575,489 | 0.0% | 1.00 | 9,553 |
| Cheese Pasteurizers | Cheese HTST 3 | Pasteurizer Steam | Raw Milk | | 153.9 | 165.4 | | 1,303,076 | 15.0% | 0.96 | 14,444 |
| Cheese Cooking | Line 1 | Reheat Tubes | Milk | | 85.0 | 110.0 | | 161,966 | 50.0% | 0.80 | 3,222 |
| Cheese Cooking | Line 1 | Wet Mixer | Milk | | 110.0 | 137.0 | | 161,966 | 50.0% | 0.83 | 3,633 |
| Cheese Cooking | Line 2 | Reheat Tubes | Milk | | 85.0 | 110.0 | | 181,857 | 50.0% | 0.80 | 3,617 |
| Cheese Cooking | Line 2 | Wet Mixer | Milk | | 110.0 | 137.0 | | 181,857 | 50.0% | 0.83 | 4,079 |
| Cheese Cooking | Line 3 | Reheat Tubes | Milk | | 90.0 | 100.0 | | 161,857 | 50.0% | 0.79 | 1,441 |
| Cheese Cooking | Line 3 | Wet Mixer | Milk | | 100.0 | 137.0 | | 181,857 | 50.0% | 0.82 | 5,544 |
| Whey Pasteurizers | Whey HTST 1 | Pasteurizer Steam | Whey | | 152.8 | 174.0 | | 979,808 | 7.0% | 0.98 | 20,456 |
| Whey Pasteurizers | Whey HTST 2 | Pasteurizer Steam | Whey | | 151.7 | 170.4 | | 1,183,342 | 7.0% | 0.98 | 21,761 |
| Whey Pasteurizers | Whey HTST 3 | Pasteurizer Steam | Whey | | | | | - | 7.0% | 0.95 | - |
| Whey Pasteurizers | Whey HTST 4 | Pasteurizer Steam | Whey | | 157.0 | 170.8 | | 946,674 | 7.0% | 0.98 | 12,854 |
| Whey Drying Towers | MSD Dryer | Burner Main Air | Air | | 65.0 | 512.0 | | 842,318 | 0.0% | 0.24 | 90,562 |
| Whey Drying Towers | MSD Dryer | SFB Steam Heat | Air | | 65.0 | 207.0 | | 149,272 | 0.0% | 0.24 | 5,098 |
| Whey Drying Towers | MSD Dryer | VF Steam Heat 1 | Air | | 65.0 | 142.0 | | 42,648 | 0.0% | 0.24 | 790 |
| Whey Drying Towers | MSD Dryer | VF Steam Heat 2 | Air | | 39.0 | 94.0 | | 53,311 | 0.0% | 0.24 | 705 |
| Lactose Evaporators | Evaporator A | Total Steam | | | 334.0 | 335.0 | 0.0797 | 783,727 | 0.0% | 1.00 | 62,447 |
| Lactose Evaporators | Evaporator B | Total Steam | | | 334.0 | 335.0 | 0.0797 | 783,727 | 0.0% | 1.00 | 62,447 |
| Lactose Evaporators | Evaporator C | Total Steam | | | 334.0 | 335.0 | 0.0797 | 783,727 | 0.0% | 1.00 | 62,447 |
| Lactose Dryers | Dryer Line 1 - Primary Dyer | Main Air Steam Heat | Air | | 147.3 | 299.0 | | 483,163 | 0.0% | 0.24 | 16,578 |
| Lactose Dryers | Dryer Line 1 - Secondary Dryer | Steam Heating 1 | Air | | 65.0 | 245.0 | | 144,949 | 0.0% | 0.24 | 6,275 |
| Lactose Dryers | Dryer Line 1 - Secondary Dryer | Steam Heating 2 | Air | | 40.0 | 53.8 | | 161,054 | 0.0% | 0.24 | 535 |
| Lactose Dryers | Dryer Line 2 - Primary Dyer | Main Air Steam Heat | Air | | 128.7 | 300.0 | | 483,163 | 0.0% | 0.24 | 19,909 |
| Lactose Dryers | Dryer Line 2 - Secondary Dryer | Steam Heating 1 | Air | | 65.0 | 245.0 | | 144,949 | 0.0% | 0.24 | 6,275 |
| Lactose Dryers | Dryer Line 2 - Secondary Dryer | Steam Heating 2 | Air | | 40.0 | 53.8 | | 161,054 | 0.0% | 0.24 | 535 |
| Cheese Cooking | Line 1 | Steam Heating | Milk | | 86.0 | 110.0 | | 1,120,128 | 15.0% | 0.94 | 25,240 |
| Cheese Cooking | Line 1 | Steam Heating | Milk | | 90.0 | 110.0 | | 1,257,688 | 15.0% | 0.94 | 23,637 |
| Cheese Cooking | Line 1 | Steam Heating | Milk | | 86.0 | 110.0 | | 1,257,688 | 15.0% | 0.94 | 17,747 |
| CIP Cow Water Preheat | CIP | Steam Heating | Water | | | | | | | 1.00 | - |
| | | | | | | | | | | 1.00 | - |
| | TOTAL | | | | | | | | | | 547,434 |

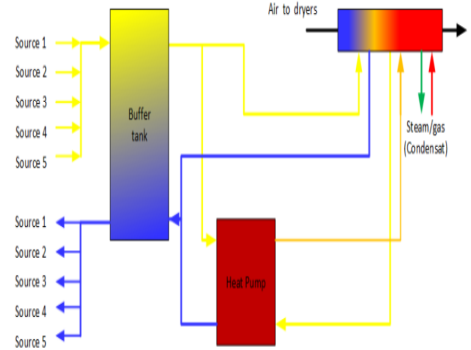
## 3. Finance




## 4. Understanding energy needs

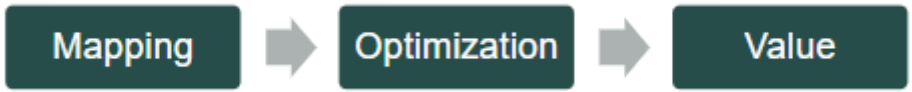



## 5. Projects



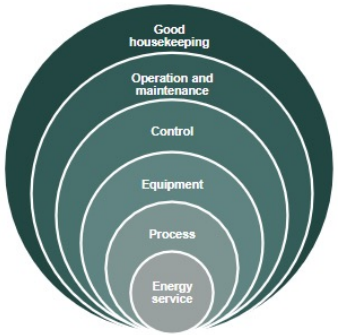
# Project background

In the project *Efficient Energy Mapping and Analysis for Optimization and Green Transition of Industrial Processes* (EEMAP) the partners will develop a software tool that can drastically reduce the time and cost related to producing an energy mapping. The goal is to be able to map a production facility in just a couple of days on site, compared to 2-4 weeks today. This will facilitate extended use of mapping in industry and hereby support the green transition of the sector. In addition, the project will facilitate digitalization of the highly analogue energy systems of the process industry, by determining the right needs for sensor investment and data collection.



# Project background

The aim of this project is to develop and test a new software tool capable of mapping and analysing energy use at industrial manufacturing sites efficiently and rapidly - as a complete substitute to excel. The goal is to be able to describe, in detail, at least 85% of the thermal energy use at any industrial facility using a maximum of only a few days on site with qualified staff and one additional day for preparations and fine tuning. The project will verify that the goal has been achieved by testing the tool on three sites in three different types of manufacturing industry. A potential expansion to such a tool is that it can provide enough data from a considerable number of manufacturers, which is required to train machine algorithms designed for energy management in different types of processing activities and introducing the digital twin concept for industrial energy systems.



# Project work packages (WP)

## WP 1+2: Project management and Scoping

### WP1: Project management

### WP2: Scoping

- The initial project phase will be focused on the WP2 (scoping). During the course of the software development three workshops will be held including the group 1 company partners. This is vital to carry out before initiating the other work packages.
- After a month of initial scoping WP3 (Mapping SoA), WP4 (Field Mapping), WP5 (Programming) and WP6 (Add-on Analyses) will be initiated almost simultaneously.
- The WP workload is distributed evenly among the project partners to ensure simultaneous progress.

# Project work packages (WP)

## WP 3+4: Mapping – state of the art and Field mapping

**WP3: Mapping - state of the art.**

- WP3 will identify a catalogue of inputs from best available technology to emerging technologies. Upon completion the catalogue will be input in the software tool.

**WP4: Field mapping.**

- WP4 will initially focus on developing the framework for the tool. The generic structures that have been established during the first months of scoping. Specific output and analysis setup will be reserved for when WP4 data is available

# Project work packages (WP)

## WP 5+6+7: Programming, Add on analysis and Field test

**WP5: Programming.**

- When WP4 is concluded it will serve as vital input data to WP5.

**WP6: Add on analysis**

- WP6 will work to build upon the tool framework and specify the analyses output.

**WP7: Field test.**

- When WP5 concludes the tool will be field tested at the partner companies in WP7.
- Each site will be asked to provide a set of data prior to the actual mapping. The experts will use a couple of days on site with production specialists. **The mapping will be finished after the visit and a screening list will be developed for each company partner.** The screening list will target the value propositions Energy Efficiency, Electrification and Excess Heat to District Heating

# Project work packages (WP)

## WP 8+9: Maturing and analyzing expansion and Communication

**WP8: Maturing and analyzing expansion.**

- During the final step of the project WP8 will correct any errors encountered during the field test as well as implement new relevant outputs and learnings identified.

**WP9: Communication**

- WP9 relates to the production of articles related to the research articles as well as concluding on the results produced by the tool itself.

# The need for Energy Mapping

by Thorkil Olesen, FF Skagen



# The need for Energy Mapping

Thorkil Olesen

Energy- and Environmental Manager

FF SKAGEN DENMARK

# FF Skagen




## Certified quality …

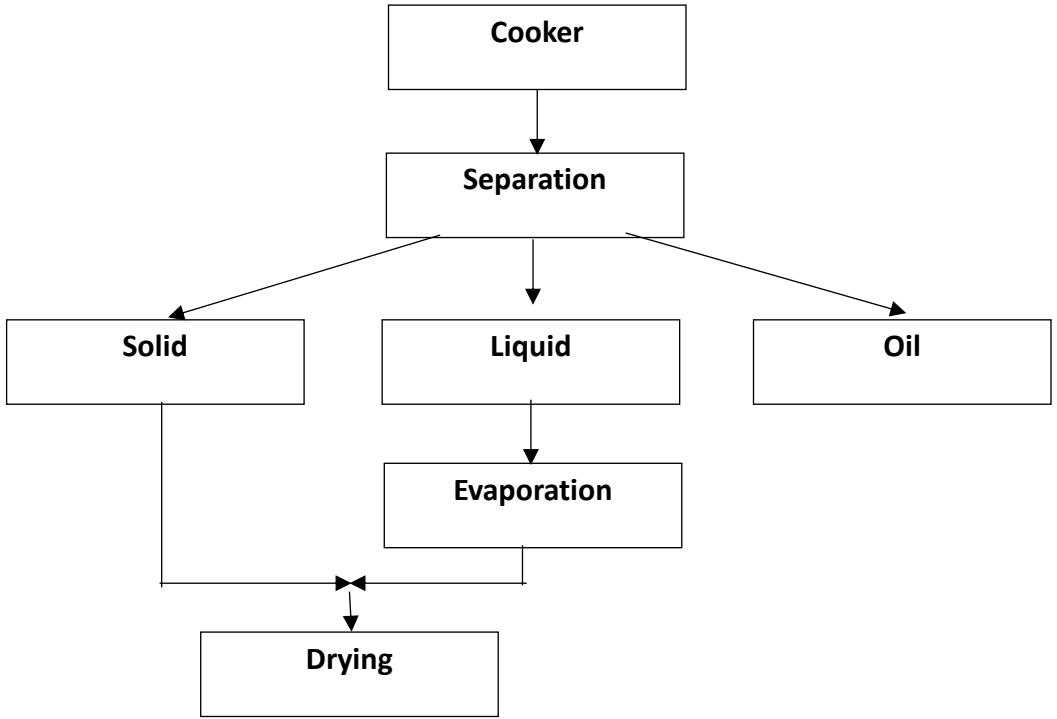
- One of the leading producers og fish meal and fish oil in the world.
- Developing, production and distribution of healthy products as protein supply for aquaculture, agriculture og petfood industry.
- Owned by fishermen and fish industry.
- Advanced production facilities on Skagen Harbour with the sea as nearest neighbour.
- More than 100 employees.
- 450.000 tonnes of raw material received yearly.
- 120.000 tonnes of fish meal and fish oil produced yearly.
- Export to more that 60 different countries worldwide.
- Certified on quality, environment, sustainably fisheries and feed security.

# The need for Energy Mapping

- Legal demand: EU directive 2012/27
- Overview of energy consumption and energy losses
- Less need for measurements
- Test for change in raw material or operating conditions
- Test for change of process and machinery

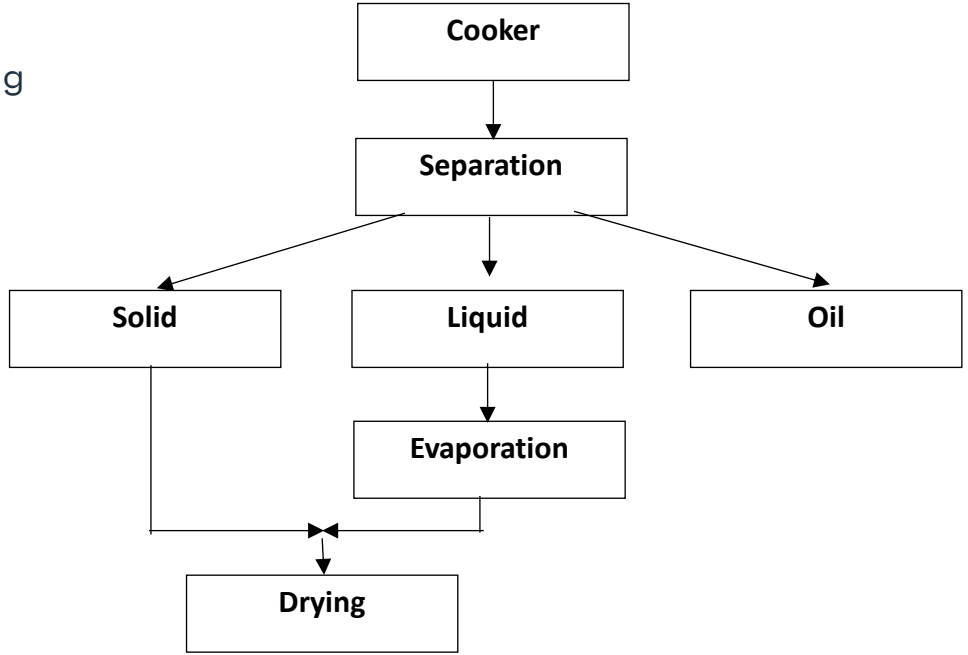
# Change in operating conditions

- Drying is very expensive
- Evaporation on waste heat
- Water content in solids
- Water content in concentrate from evaporator
- Water content in dried fish meal



# Change of process or machinery

- New technology for cooking
- New use for waste heat e.g. pre-cooking
- New technology for drying
- Use of heat pumps or vapour recompression



# Introduction to the tool, EEMAP

by Martin Ryhl Kærn, IPU



# Panel discussion – using EEMAP in practice

Thorkil Olesen (FF Skagen) and Kasper Vad Gundestrup, (Royal Unibrew)



# OVODAN FOODS A/S

- OVODAN is a privately owned Thornico Company headquartered in Denmark.
- Since 1942, we have supported customers with cutting-edge egg-based solutions.
- In Odense, we produce white, plum and whole egg powder for the food industry. From both liquid egg whites and various other egg powder types.



OVODAN
RELIABLE EGG SOLUTIONS

# Pioneers in egg-based solutions

**Our products can be found in:**

- Bakeries and patisseries
- Fine dinning
- Fish and meat products
- Pasta & Noodles
- Soups
- Enhancers
- Lysozyme (for preservation)

**Certifications**

- Kosher, Halal, BRC 3rd party



OVODAN
RELIABLE EGG SOLUTIONS

# Sonoco Skjern

The sustainable paper factory of the future




SONOCO

# Paper and cardboard produced from 100% recycled fibres for all of Europe

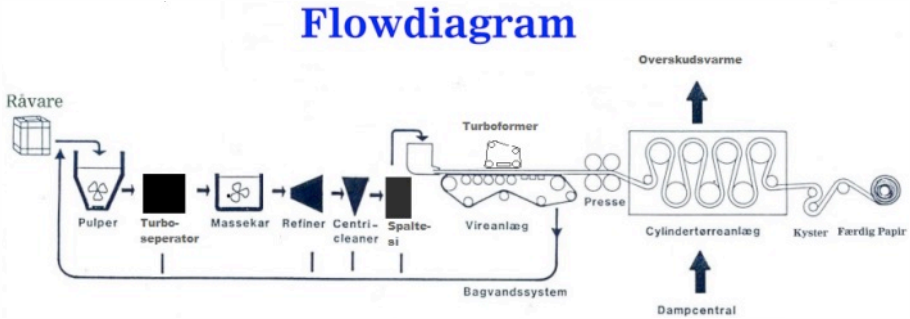


- The paper factory is from 1965
- 80 employees. 5 teams and 3 shifts.
- Yearly production of 75.000 ton paper

**Yearly energy usage:**

- Electricity from solar panels 27,000 MWh, wood chips verified sustainable 35,000 tons
- ISO standards 14001, 50001 and 9001 – certified
- FSC®, PEFC, BFR, Nordic Swan ecolabel, EU toy directive and VEII regulation compliance



# Coffee break



# Agenda

| | | |
|---|---|---|
| 12.30 - 12.40 | Coffee | All |
| 12:40 – 12:45 | Welcome to IPU | IPU |
| 12:45 - 13:15 | Introduction to the project: Energy Efficiency Mapping (EEMAP) | Viegand M. |
| 13:15 - 13:30 | The need for Energy Mapping | FF-Skagen |
| 13:30 - 14:00 | Introduction to the tool | IPU |
| 14:00 - 14:30 | Panel discussion – How do companies plan to use the tool? | All |
| 14:30 - 14:45 | Coffee break | All |
| 14:45 - 15:00 | Future needs to document energy efficiency | IPU |
| 15:00- 15:30 | Examples of building a calculation scenario | IPU |
| 15:30 - 15:45 | How to use the results in an add-on analysis | VMAS/DTU |
| 15:45 - 16:00 | Next steps in EEMAP | VMAS/DTU |
| 16:00 - 17:30 | Snacks and beverages | All |

# Future needs to document energy efficiency

by Ulf Gilberg, IPU



# Future needs to document energy effeciency

Ulf Gilberg: ug@ipu.dk +45 20649349

June, 2024
www.ipu.dk

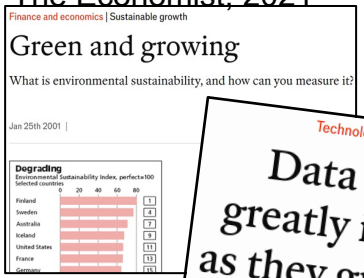


# Illustration of the green transition pressure on data

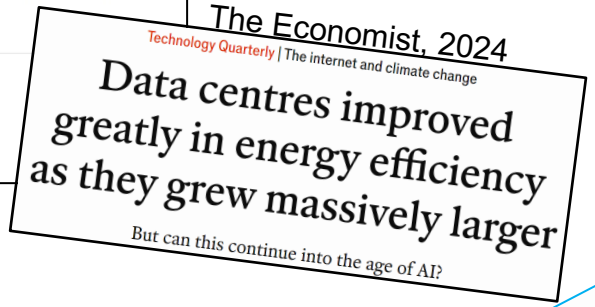
Børsen today




The Economist, 2021




The Economist, 2024




Access to funding based on data




IEA, World Energy Investment, 2024

**The world now invests almost twice as much in clean energy as it does in fossil fuels…**

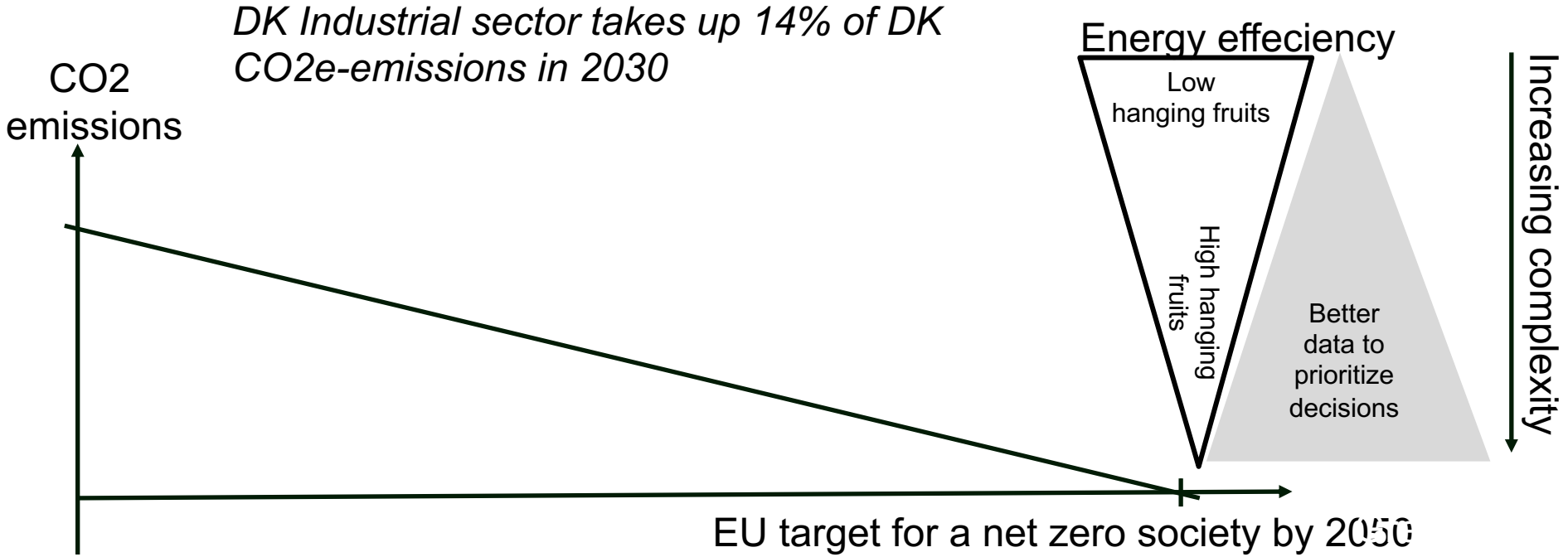
**Much greater efforts are needed to get on track to meet energy & climate goals, including those agreed at COP28**

https://www.iea.org/reports/world-energy-investment-2024/overview-and-key-findings




Barslays

# Illustration of the green transition pressure on data



# Driving data driven energy efficiency decisions is costfull for SMEs

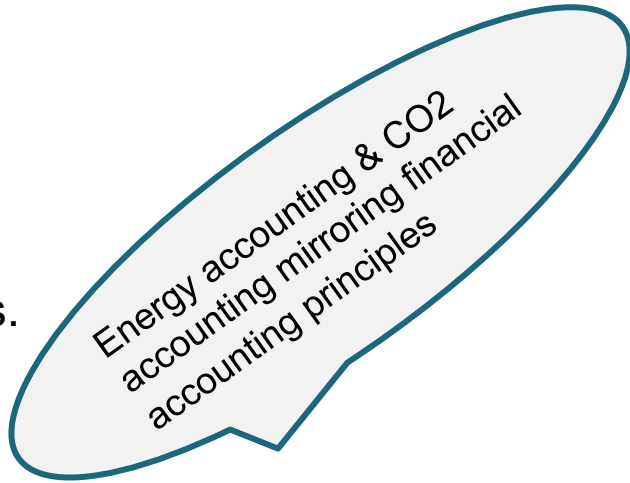
- Baseline overview of energy consumption and costs
- Identifying hotspots for where to invest in savings
- Estimating return of investment
- Establish documentation of results to sponsor, bank, investor.

Large Enterprises have access to a host of software solutions and consultants to help a data driven process.

Denmark, is a country of SMEs.

Googling for simplified, easy, low-cost, data driven decision support for energy efficiency investments. Gives few results.

=> Hence the need for initiatives like EEMAP



# How to create a mapping in EEMAP

by Martin Ryhl Kærn, IPU



# Using the results for an analysis

by Viegand Maagøe and DTU



# How to make use of the results?

(DTU/VM)

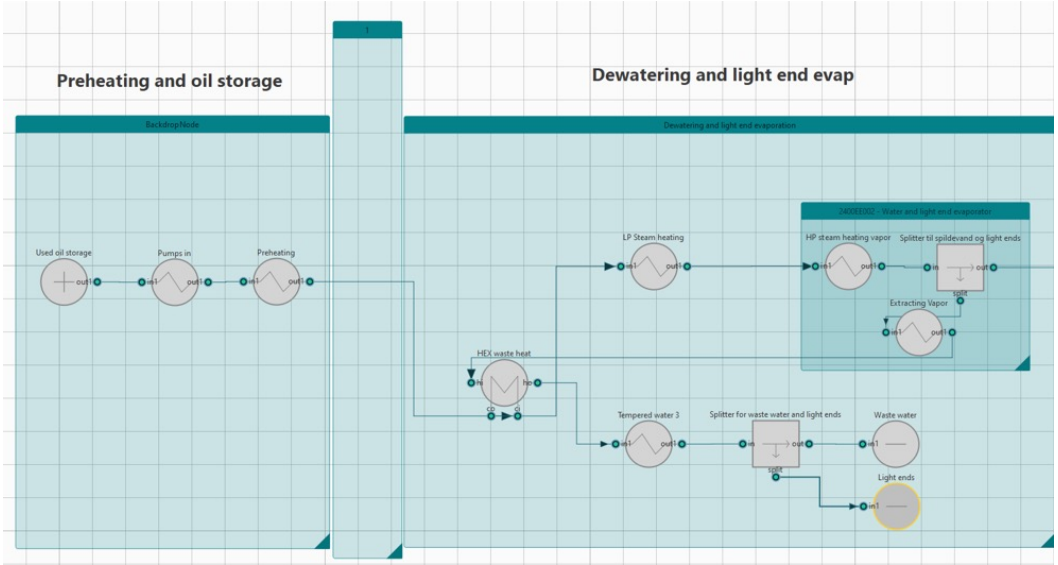
- Process and supply overview
- Mapping degree as a measure of overall overview
- Scalable model as a simulation tool
- KPIs on subsystems
- Proportional energy consumption on components
- Pinch analysis, HEX network and Temperature analysis
- Collection of energy data as a basis for reporting
- Screening list
- Investigation of project possibilities
- Energy management and energy monitoring

# How to make use of the results?

(DTU/VM)

Overview of:

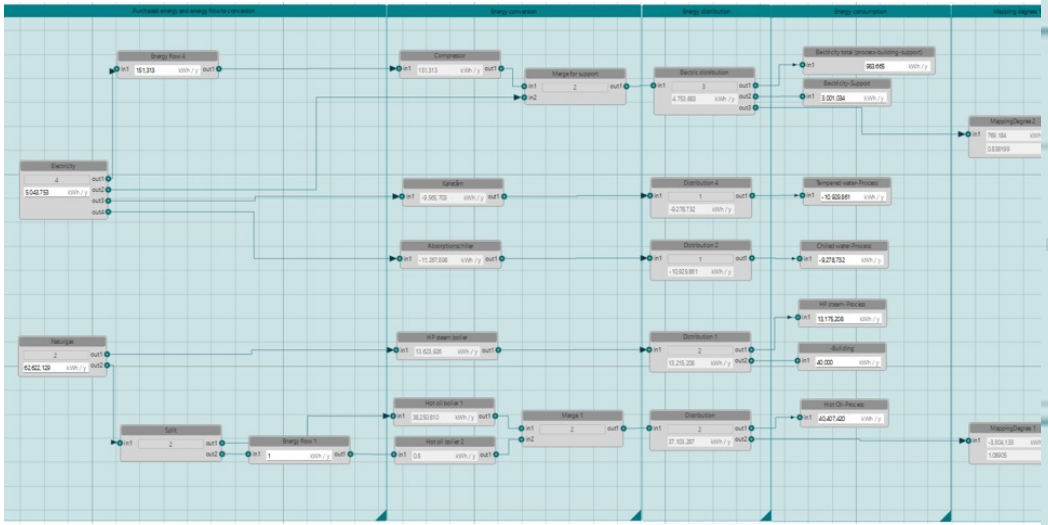
- Processes
- Utility system
- Sub-systems
- Space heating system

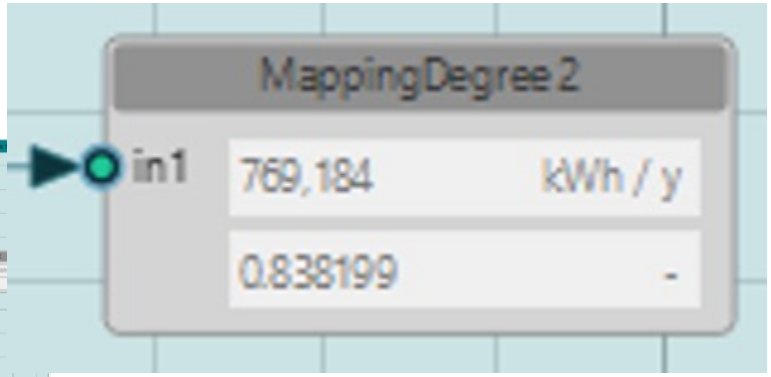


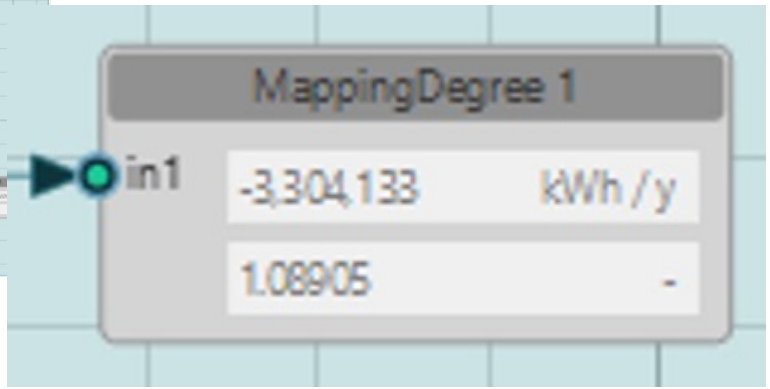
# How to make use of the results?

(DTU/VM)

- Mapping degree as a measure of overall overview





# How to make use of the results?

(DTU/VM)

Scalable model as a simulation tool

- Changes in process
- Other inputs
- Modeling of specific units
- OPEX Budget for production changes

KPIs on subsystems

- Can be found for all components
- Production key figures
- Goals for others

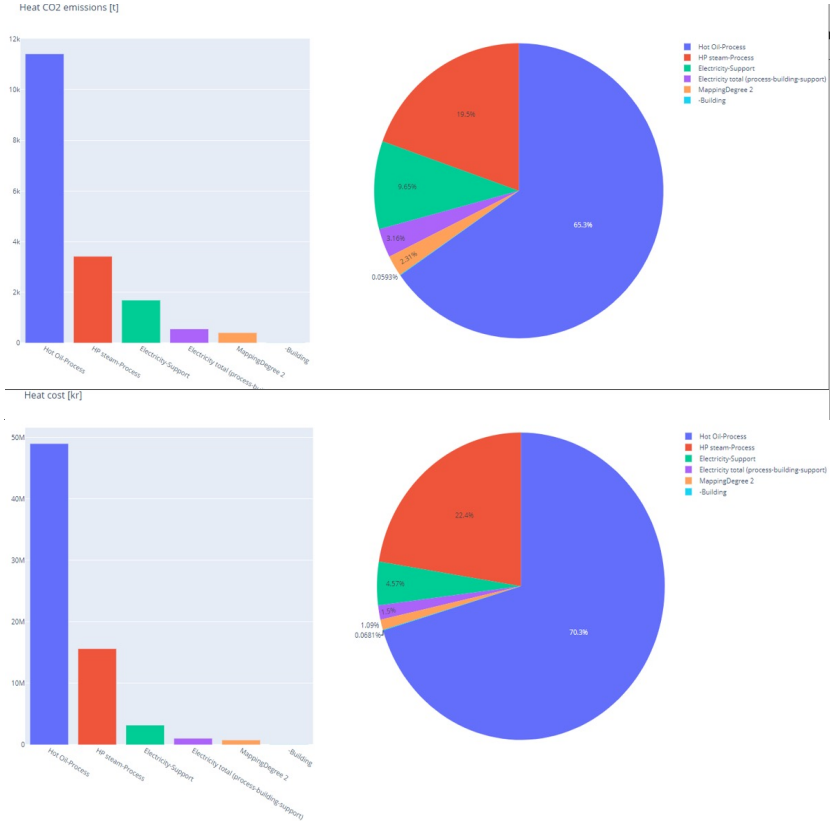
**Idea catalogue**

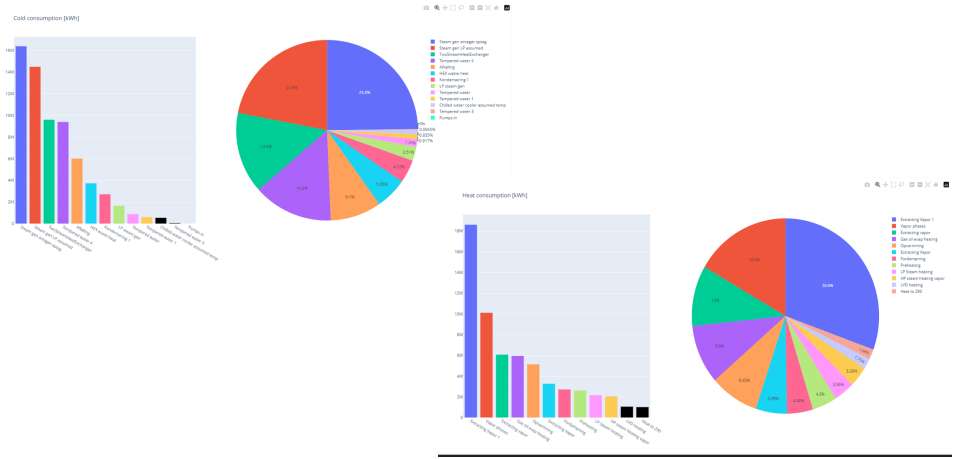
| ID. | Mapping area | System type | Sub-syste | Area | Title | Description |
|---|---|---|---|---|---|---|
| B1 | Building | Ventilation | | Heat recovery | Rotary heat exch | Proper heat recovery efficiency is vital. Use rotary heat exchanger if air streams can be mixed. This will result in a high heat recovery effeciency close to ~80% |
| B2 | Building | Ventilation | | Heat recovery | Cross flow heat | Use heat pipes / cross flow heat exhchangers if mixing air streams is not an option. Will result in ~60-70% recovery. |
| B3 | Building | Ventilation | | Heat recovery | Water loops | Use water loops to transport heat recovery when the intake and outlet are not in close proximity. Will yield approximately 50-60% recovery. |
| B4 | Building | Ventilation | | Heat recovery | Ventilation KPI | Displaying heat recovery efficiency on screen or having it as a KPI will support operating personnel in catching malfunctions. |
| B5 | Building | Ventilation | | VSD & Control | Air exchange rat | Air change should fit the application. Design ventilation systems to meet the specific needs of the building, avoiding over- or under-ventilation, which can |
| B6 | Building | Ventilation | | VSD & Control | Demand driven | Shut down ventilation / reduce air change in off hours. |
| B7 | Building | Ventilation | | VSD & Control | Demand driven | Control the system by demand using sensors and VSD. Separating buildings into different zones, can allow system to be shut off using dampers. |
| B8 | Building | Ventilation | | Insulation | Thermal insulaic | Insulation of ducts: Insulate ducts to reduce heat loss and improve energy efficiency. |
| B9 | Building | Ventilation | | Ventilator | Motor efficiency | Use IE3/IE4 motors for new applications |
| B10 | Building | Ventilation | | Ventilator | Convertion to di | Avoid belt driven machines. |
| B11 | Building | Ventilation | | Ventilator | Proper duct sizir | Proper duct sizing: Ensure that ducts are properly sized to minimize air leakage and reduce the energy required to move air through the system. |
| B12 | Building | Ventilation | | Ventilator | Ventilation KPI | SEL-value can be used as a KPI, (SEL-value =(P_air_in+P_air_out/q_v)) for systems with heat recovery. |
| B13 | Building | Ventilation | | Ventilator | Pressure loss re | Reduction of pressure loss, ducts, filters, ... |
| B14 | Building | Ventilation | | Filters | Monitor filter st | Make sure pressure sensors are installed to monitor filter state in order to change it timely. Use efficient air filters to improve air quality and reduce energy consumption by reducing the load on fans and heating/cooling systems. |
| B15 | Building | Ventilation | | VSD & Control | Volume flow | Reduction of volume flow to the actual demand |
| B16 | Building | Ventilation | | Installation | Avoid short circ | Make sure that inlet and outlet is not short cutted - propper location |
| B17 | Building | Ventilation | | Design | Mapping ventila | Mapping ventilation system - actual and needed air exchange rate and ducts layout |

# How to make use of the results?

(DTU/VM)

- Proportional energy consumption on components
  - Process
  - Energy supply
  - Energy/Cost/CO2

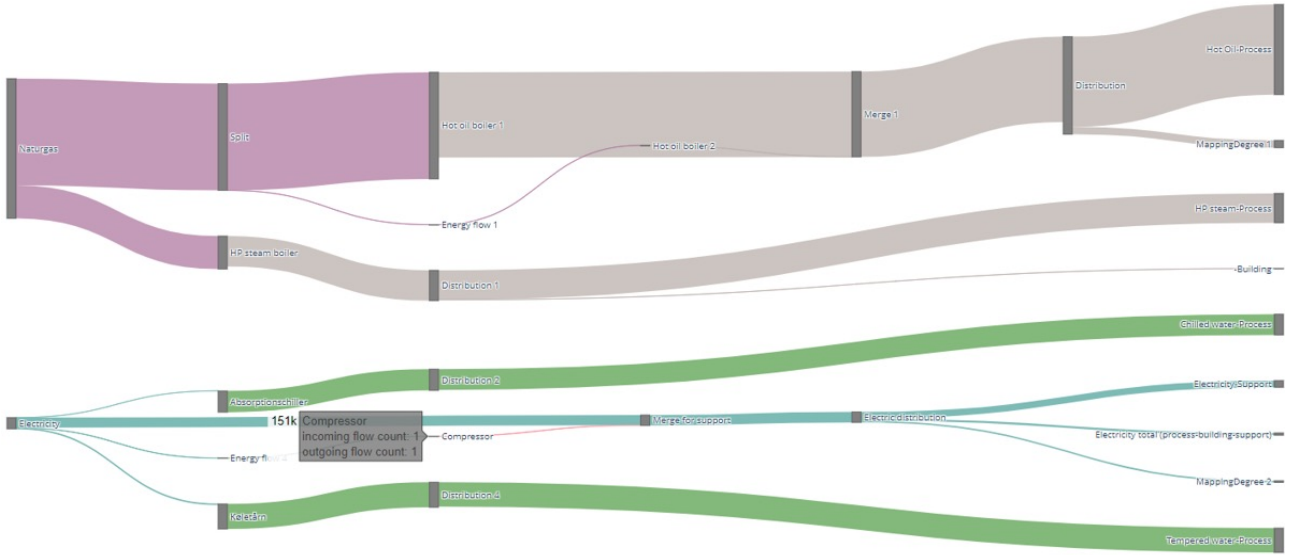


# How to make use of the results?

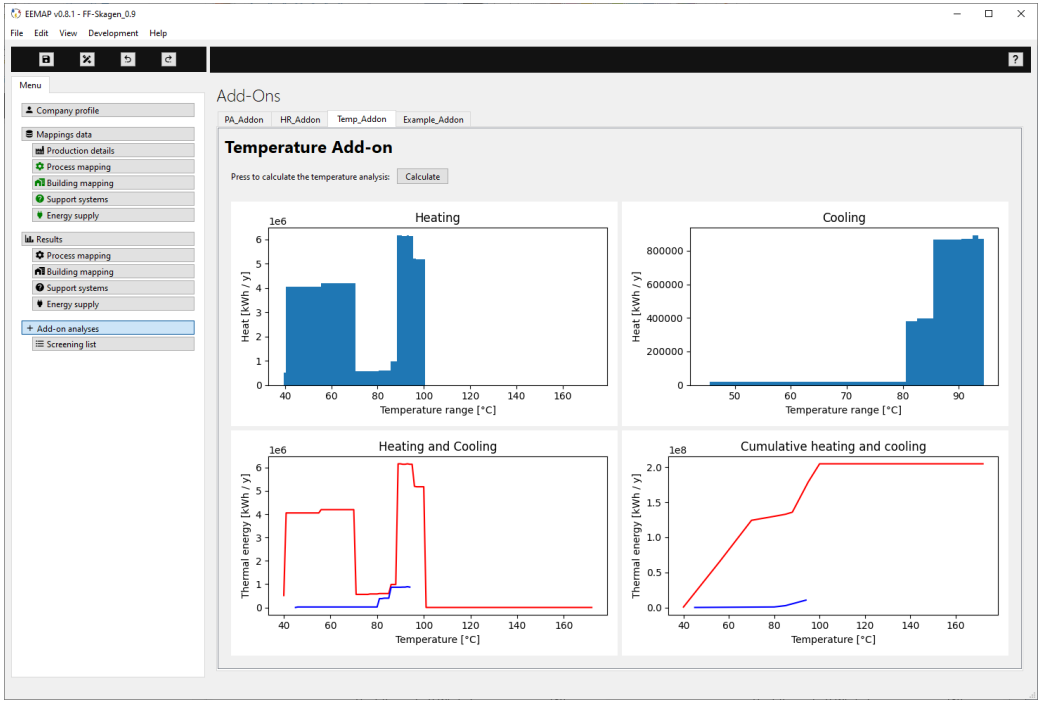
(DTU/VM)

- Proportional energy consumption on components
  - Visual overview
  - Relationship between electrical and thermal
  - Mapping degree
  - Supply systems
  - Loss



# How to make use of the results?

**Temperature analysis**, Pinch analysis, heat exchanger network, electrification

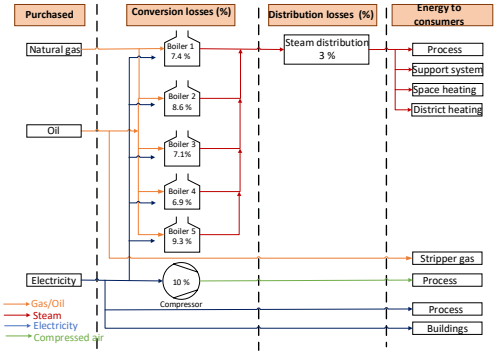


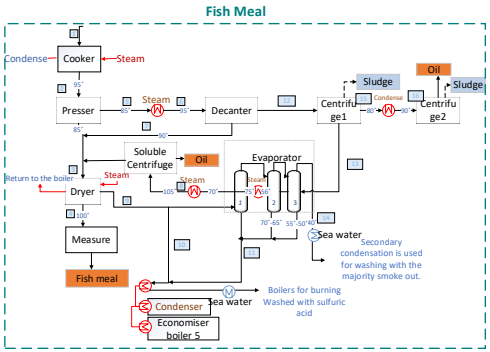
# Energy flow mapping - FF Skagen

**88% of the energy use is mapped (Degree of mapping)**



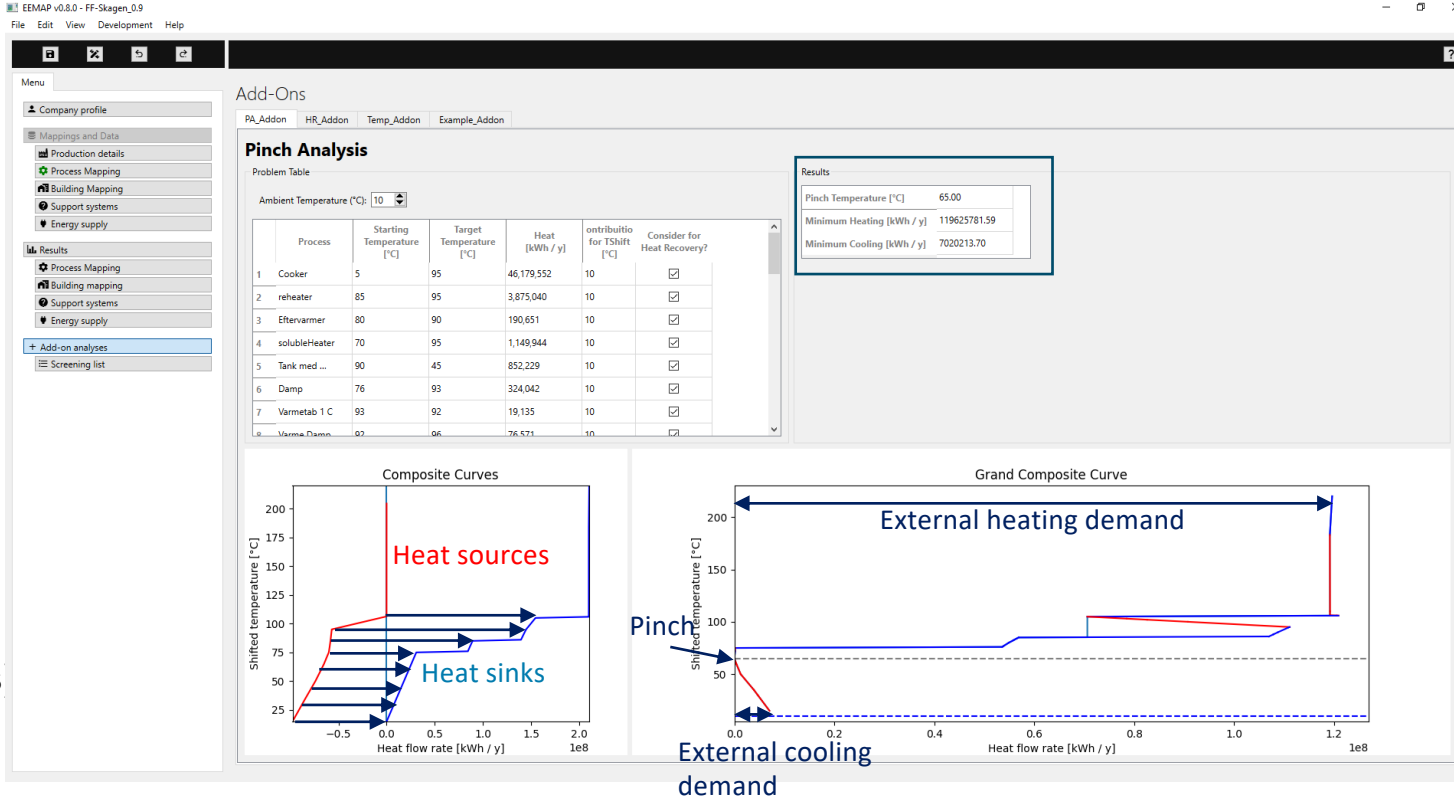


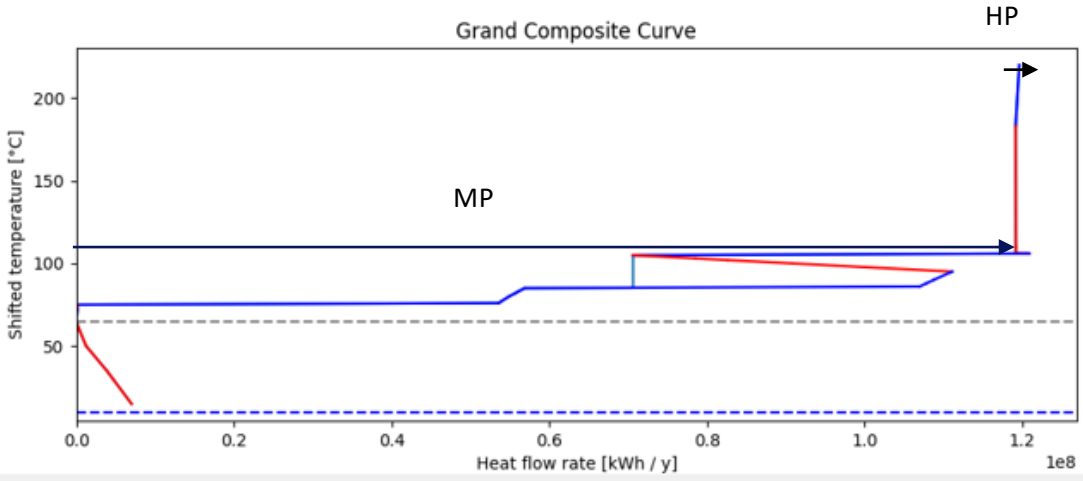


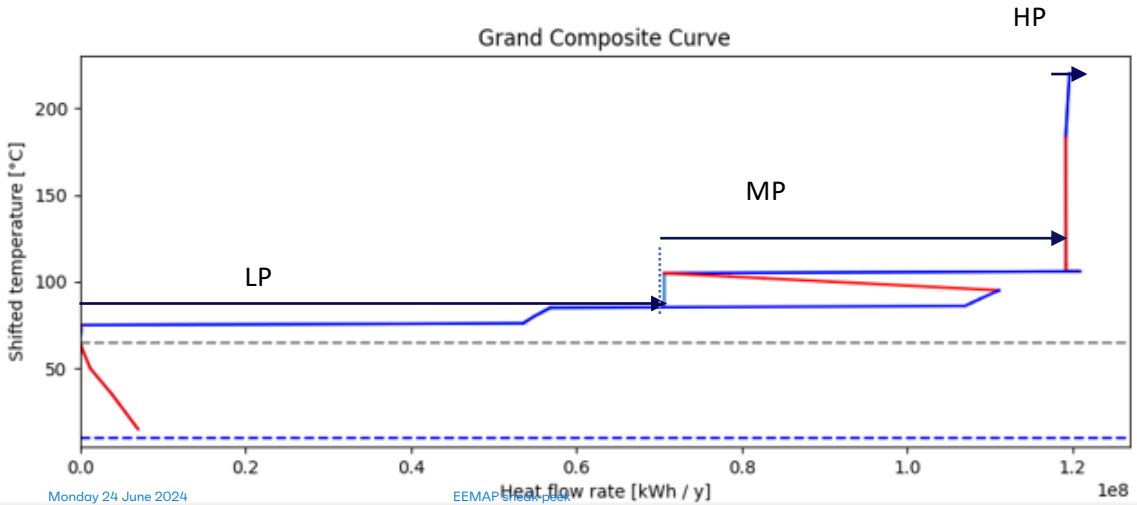



# Add on - Pinch Analysis

- Table and graphical illustration of possibilities
- Energy targeting (minimum external heating and cooling demand)
- Energy targeting (minimum external heating and cooling demand for the selected processes



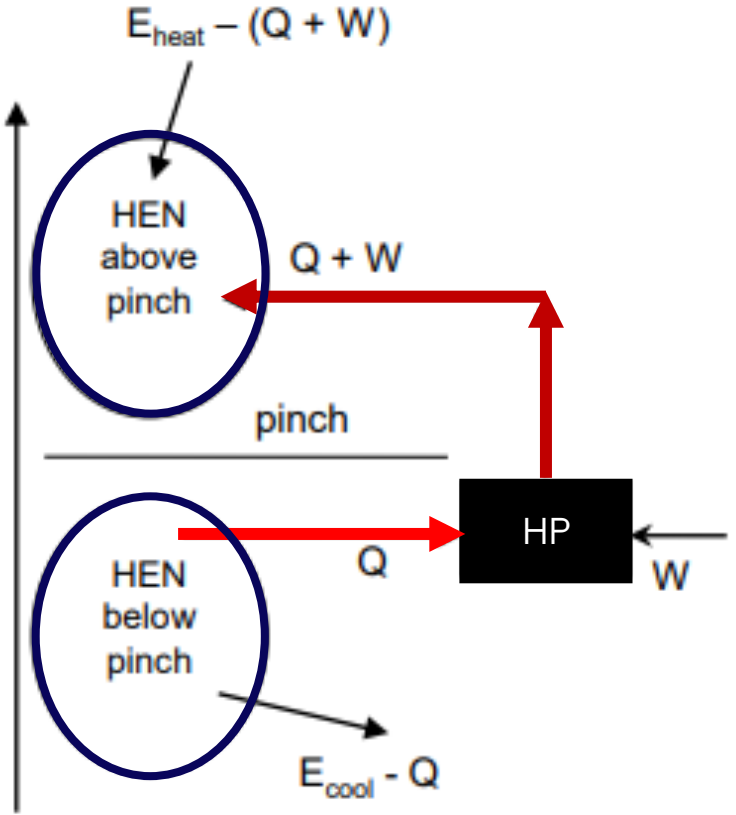



# Add on – Pinch Analysis **Multiple utility targeting**

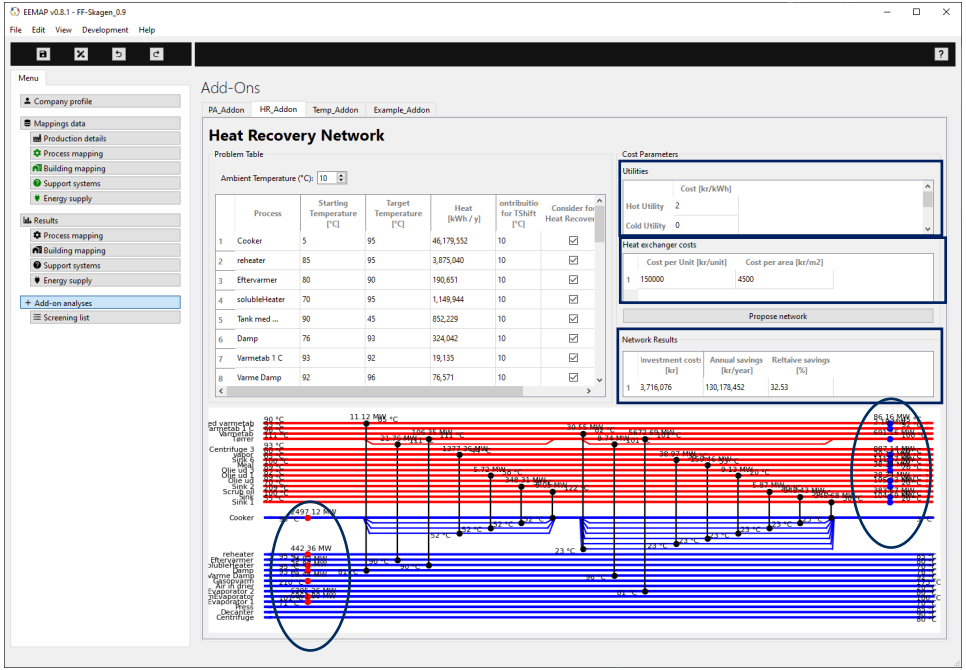
# Add on - Pinch Analysis  Electrification(future work)

- Minimum work target in the case of fully electrified
- Enhance process integration - Basis for integration of heat pumps and MVRs and right choices



# Add on – Pinch Analysis **Heat exchange network design**

- Basis for heat exchanger network design and direct heat recovery (economic heat exchanger network design)
- Improved exiting heat exchanger network



# Next steps

by Viegand Maagøe and DTU



# Next step

(DTU/VM)

- Test and give feedback (link)
- Download presentation
- Until September
  - Individualize the solutions for each company for further dialogue
  - Evaluate the effect of degree of mapping on pinch analysis
    - The use of methods previously developed by DTU for process optimization under uncertainty and further improvement of EEMAP software
    - Minimizing the requirements for measured data to ensure the effective utilization of the mapping tool
    - Indication for extra sensor installation for essential data that is missing.
- Next phase
  - EEMAP V.2.0
    - Extension of functionalities, analysis and improved user experience
    - ”Sponsor”

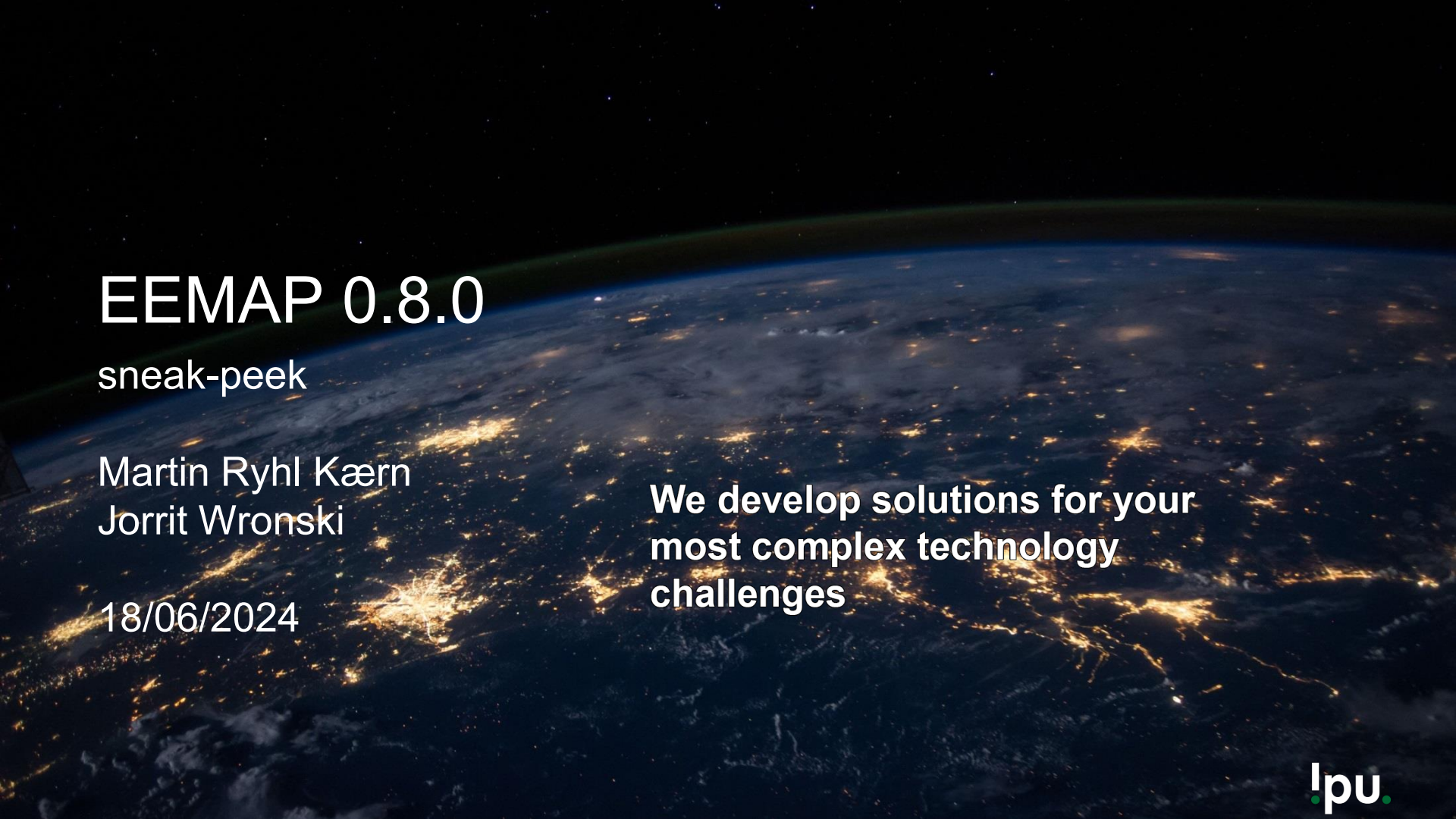
# Thank you

Monday 24 June 2024



# Snacks and beverage





# EEMAP 0.8.0

sneak-peek

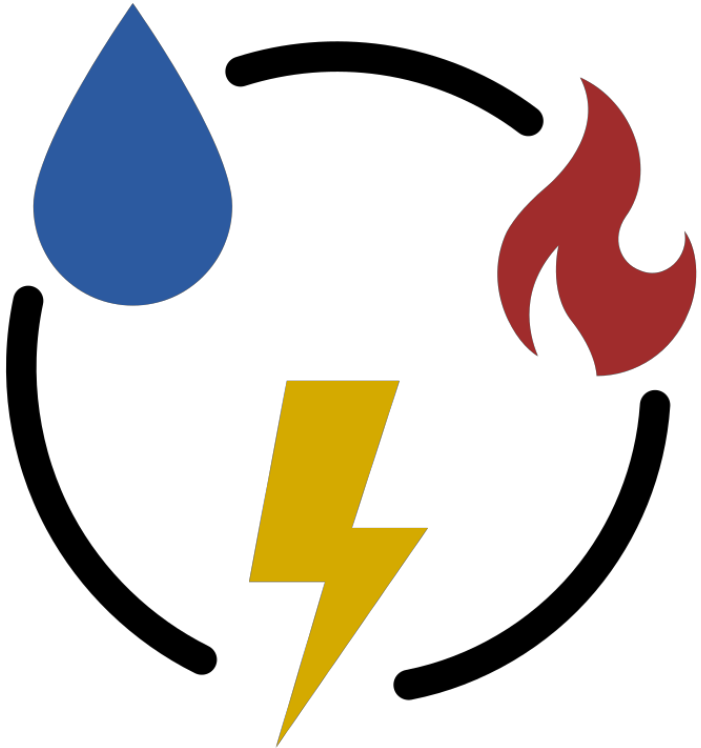
Martin Ryhl Kærn
Jorrit Wronski

18/06/2024

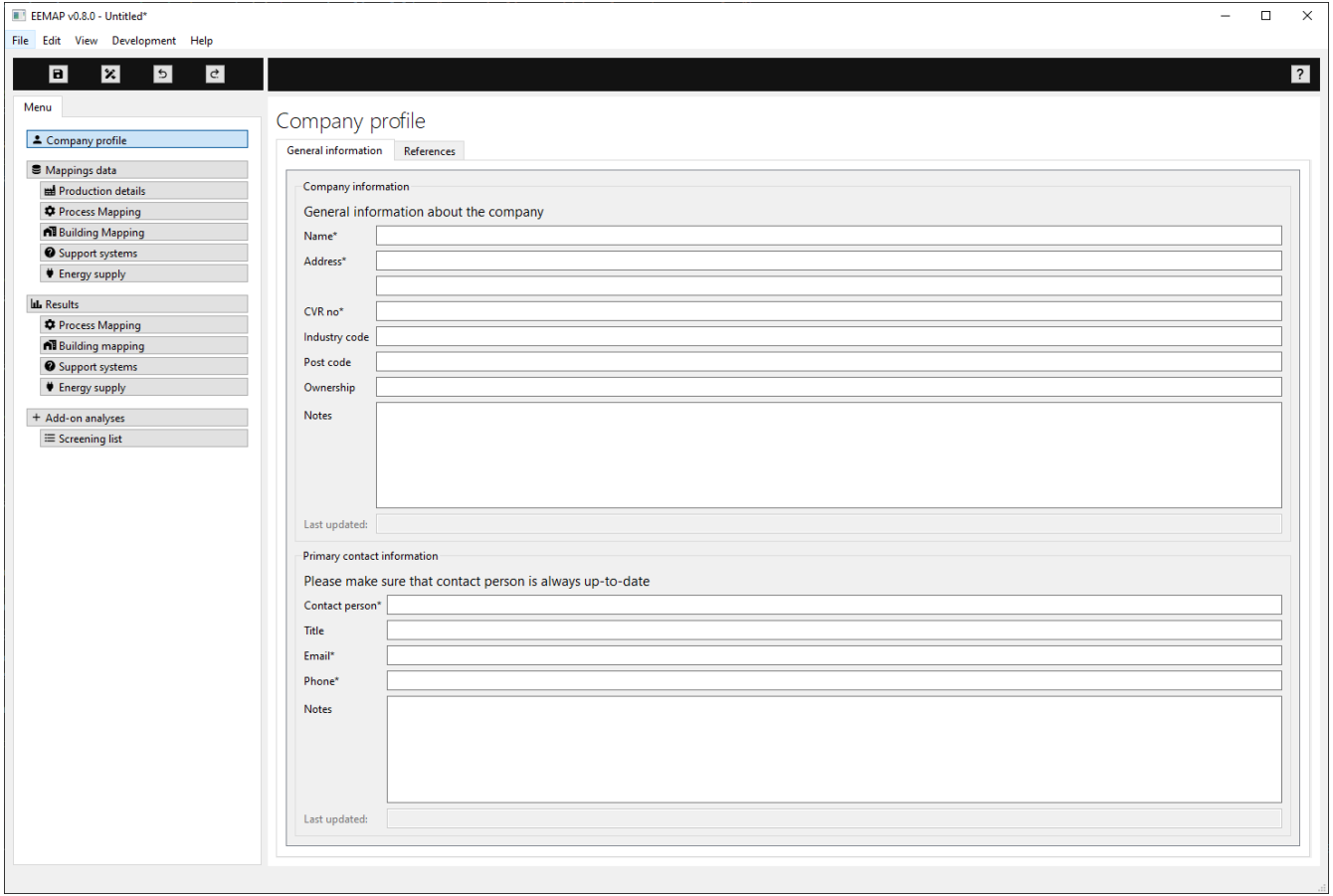
**We develop solutions for your most complex technology challenges**

!pu.

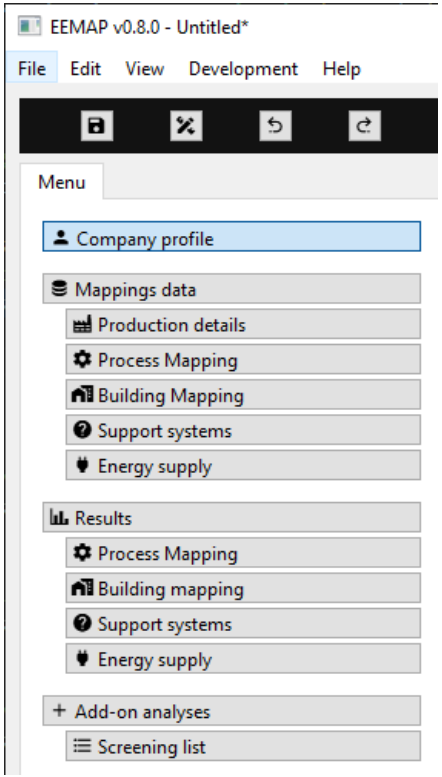
# EEMAP Logo



# Main window


EEMAP v0.8.0 - Untitled*
File
Edit
View
Development
Help
Menu
Company profile
Mappings data
Production details
Process Mapping
Building Mapping
Support systems
Energy supply
Results
Process Mapping
Building mapping
Support systems
Energy supply
Add-on analyses
Screening list
Company profile
General information
References
Company information
General information about the company
Name*
Address*
CVR no*
Industry code
Post code
Ownership
Notes
Last updated:
Primary contact information
Please make sure that contact person is always up-to-date
Contact person*
Title
Email*
Phone*
Notes
Last updated:

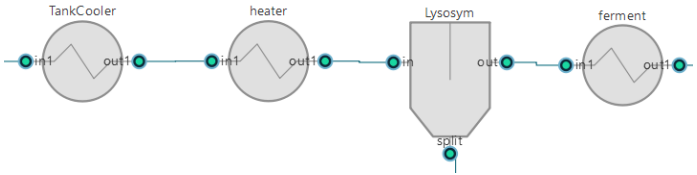
# Left navigation panel



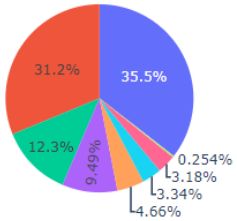

## Company profile

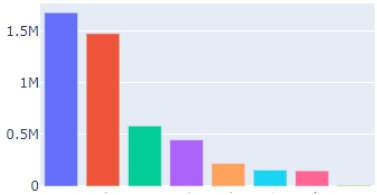



## Mapping data

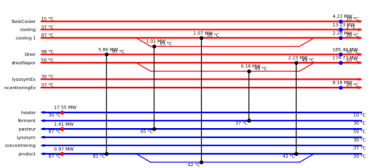


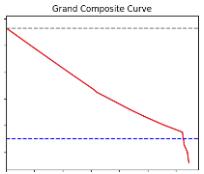

## Results



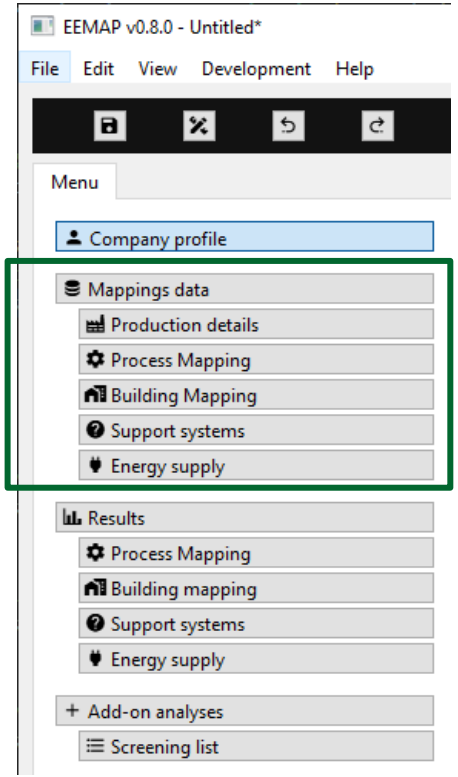




## Addon analysis

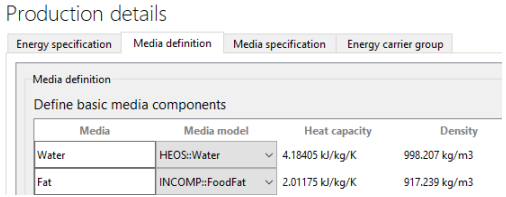




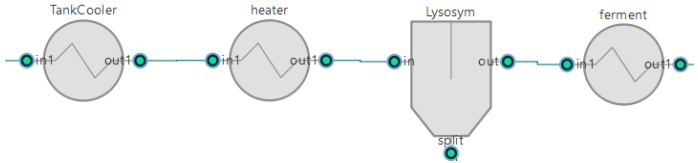
# Zooming in on “Mapping data”




**Production details**



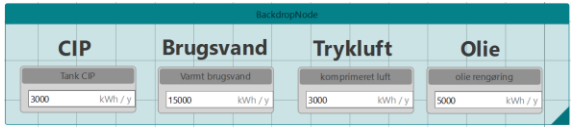

**Process mapping**



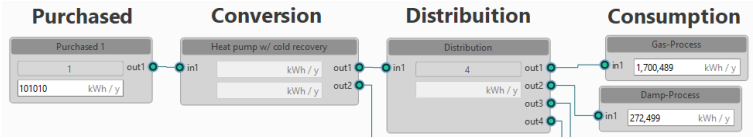

**Building mapping**




**Support systems**




**Energy supply**



# Software dependencies

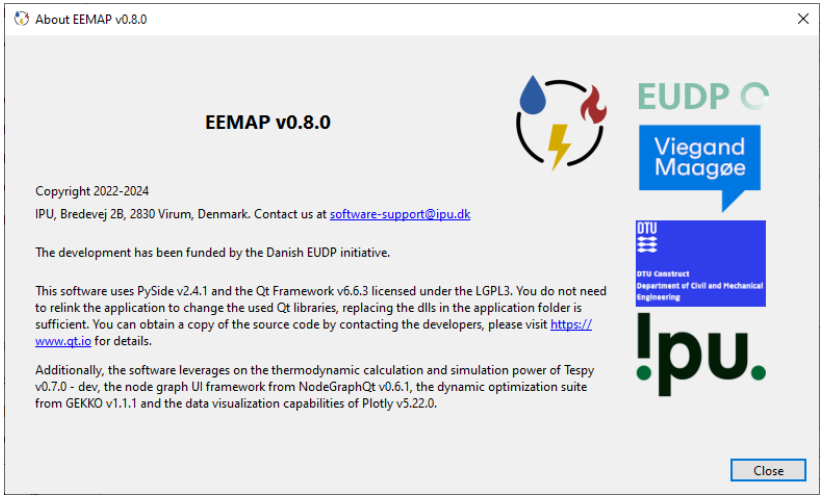
Qt for python

NodegraphQt

Tespy

Plotly

GEKKO




CoolProp

# Software architecture

Backend

tespy ['tɛs.paɪ]

CoolProp

Translation

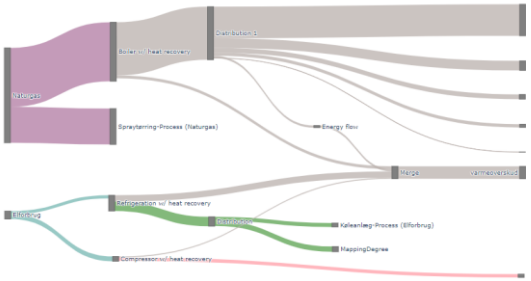
PySide6

NodeGraph Qt

Frontend

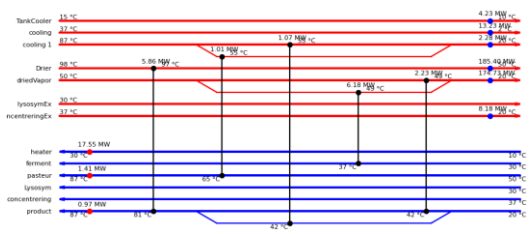
Visualization

plotly



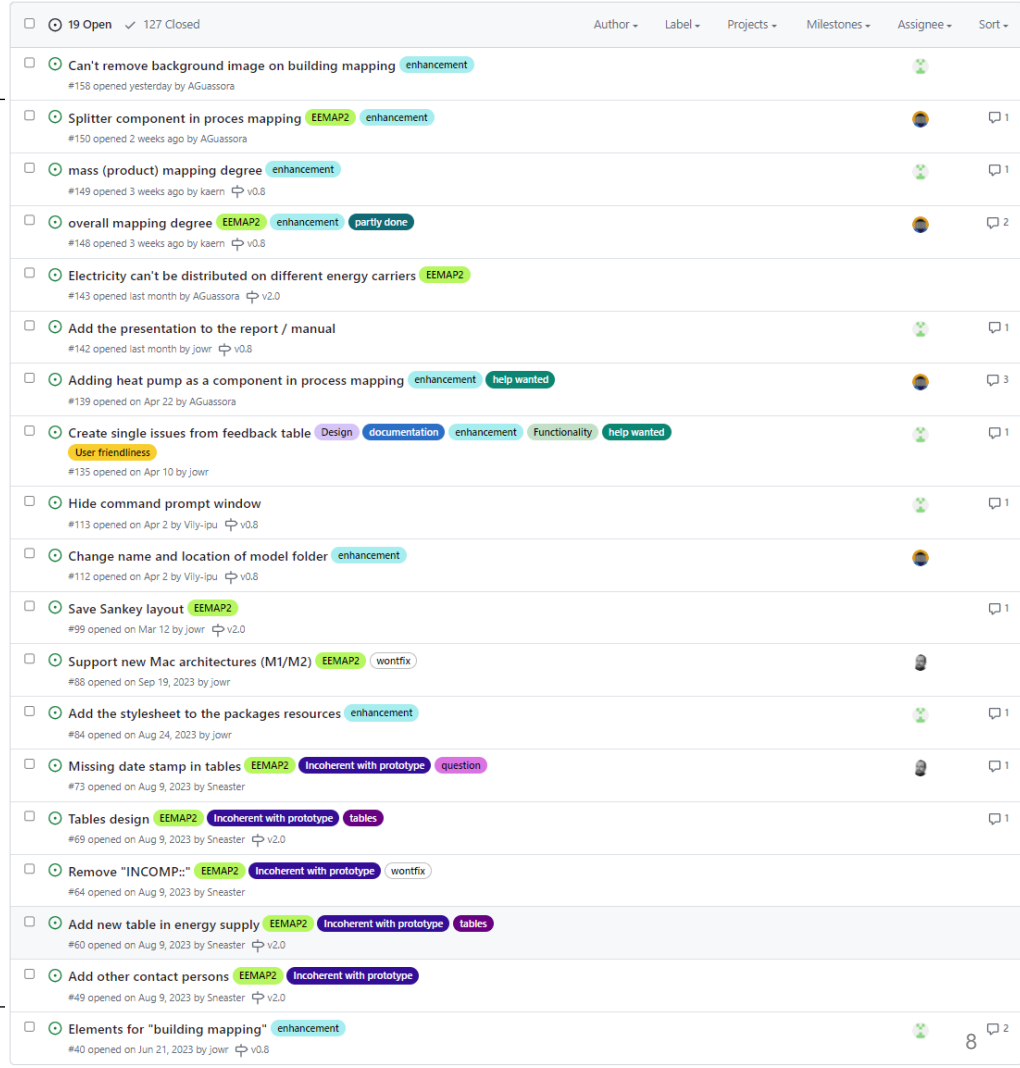
Optimization

GEKKO DYNAMIC OPTIMIZATION

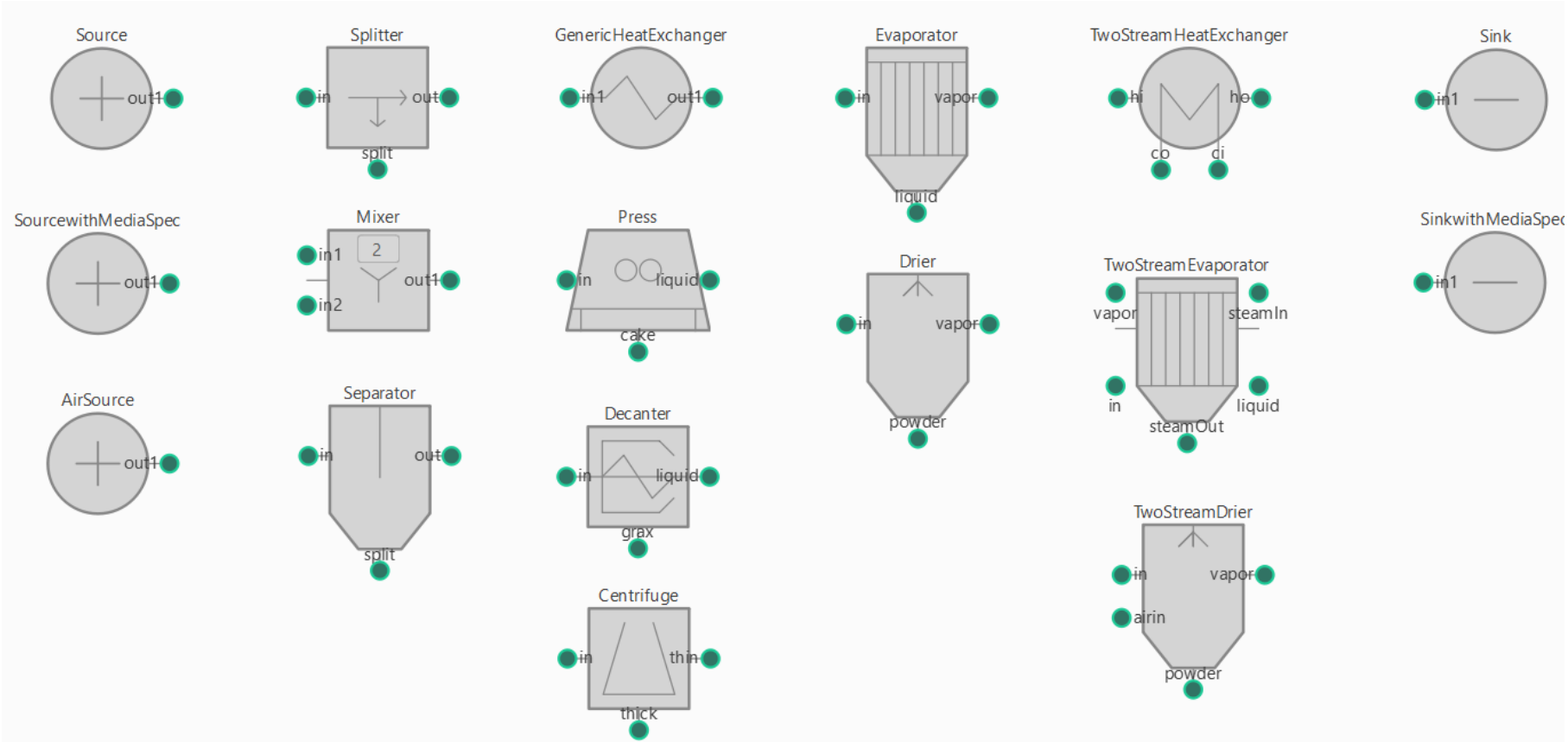


# GitHub issues

- Be done
- Maybe done
- EEMAP 2.0
- Partly done



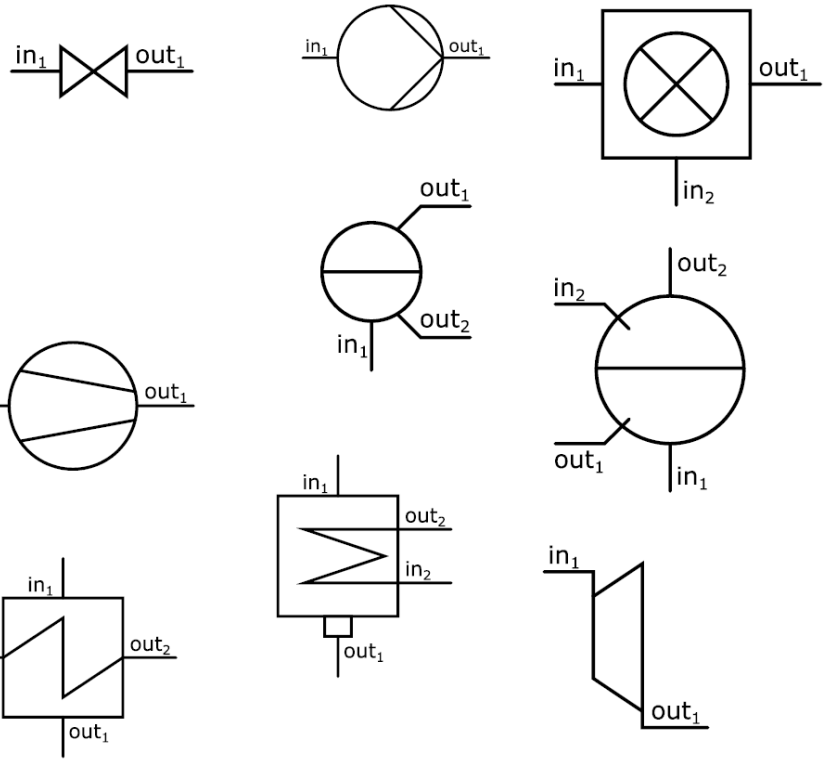
# Zooming in on “process mapping” components



# tespy components



- **Basics**
  - Cycle closer
  - Sink
  - Source
  - Subsystem interface
- **Combustion**
  - Combustion chamber
  - Diabatic combustion chamber
  - Combustion engine
- **Heat exchangers**
  - Simplified heat exchanger
  - Solar collector
  - Parabolic trough
  - Heat exchanger
  - Condenser
  - Desuperheater
- **Nodes**
  - Droplet separator
  - Drum
  - Merge
  - Separator
  - Splitter
- **Piping**
  - Pipe
  - Valve
- **Reactors**
  - Fuel cell
  - Water electrolyzer
- **Turbomachinery**
  - Compressor
  - Pump
  - Turbine




slide contents @ Francesco Witte

# Media

## CoolProp standard fluids

- Water
- Propylene glycol
- Ethylene glycol
- Ethanol
- Acetone
- Hexane
- Air

*… easily extendable with many other coolprop fluids*

## CoolProp food constituents

- Fat
- Protein
- Sugar/carbohydrate
- Fiber
- Ash

*… virtually defines thousands of foods by their composition and water content, see*

**FoodData Central (USDA)**
https://fdc.nal.usda.gov/fdc-app.html

## Custom fluids

- Petroleum
- Linseed oil
- Kerosene
- Turpentine

*… simple polynomial fluids based on*

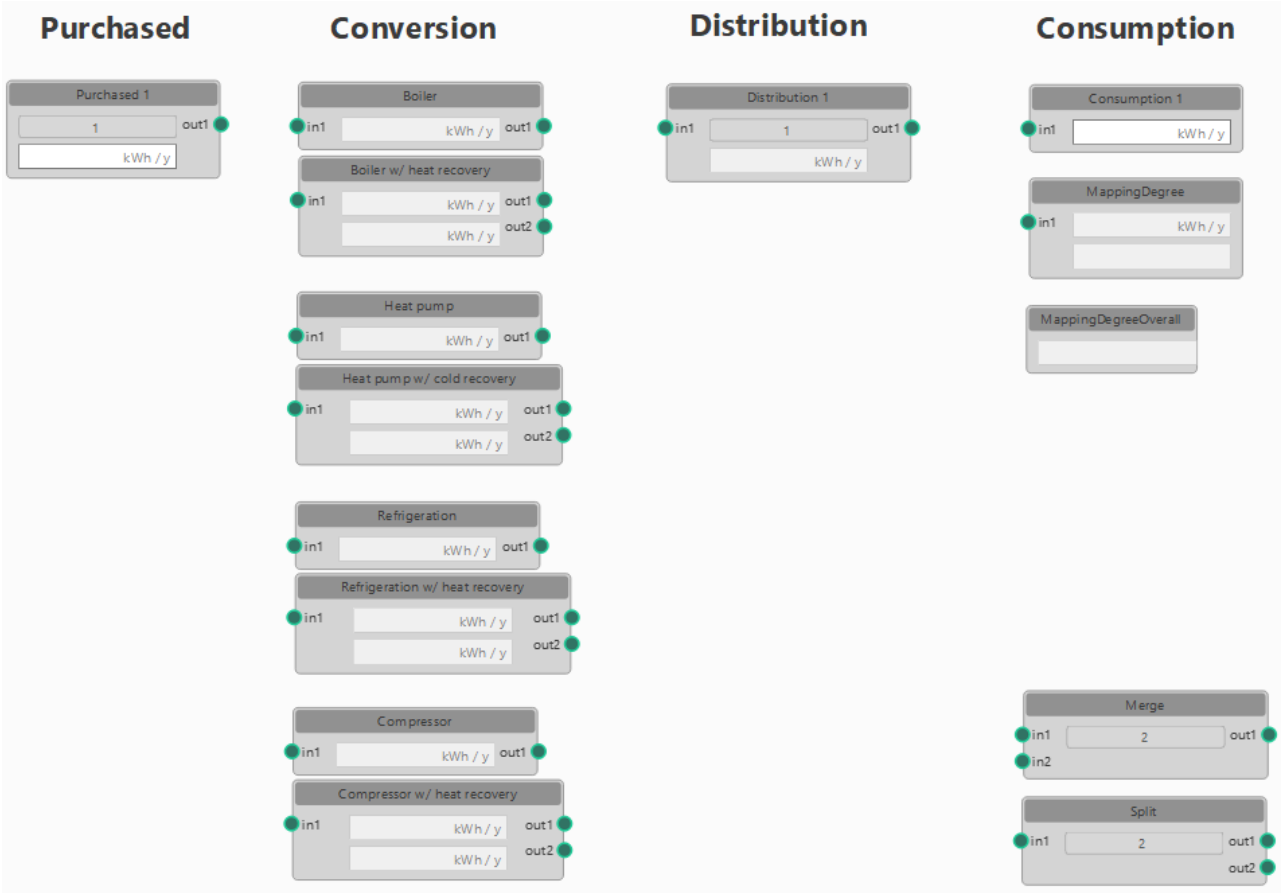
- *Specific heat capacity*
- *Density*
- *Latent heat*

# Media (foods)

- ASHRAE Handbook – Refrigeration, Ch 9, Thermal properties of foods

| Food Item | Moisture Content, % $x_{wo}$ | Protein, % $x_p$ | Fat, % $x_f$ | Carbohydrate | | Ash, % $x_a$ |
|---|---|---|---|---|---|---|
| | | | | Total, % $x_c$ | Fiber, % $x_{fb}$ | |
| **Whole Fish** | | | | | | |
| Cod | 81.22 | 17.81 | 0.67 | 0.0 | 0.0 | 1.16 |
| Haddock | 79.92 | 18.91 | 0.72 | 0.0 | 0.0 | 1.21 |
| Halibut | 77.92 | 20.81 | 2.29 | 0.0 | 0.0 | 1.36 |
| Herring, kippered | 59.70 | 24.58 | 12.37 | 0.0 | 0.0 | 1.94 |
| Mackerel, Atlantic | 63.55 | 18.60 | 13.89 | 0.0 | 0.0 | 1.35 |
| Perch | 78.70 | 18.62 | 1.63 | 0.0 | 0.0 | 1.20 |
| Pollock, Atlantic | 78.18 | 19.44 | 0.98 | 0.0 | 0.0 | 1.41 |
| Salmon, pink | 76.35 | 19.94 | 3.45 | 0.0 | 0.0 | 1.22 |
| Tuna, bluefin | 68.09 | 23.33 | 4.90 | 0.0 | 0.0 | 1.18 |
| Whiting | 80.27 | 18.31 | 1.31 | 0.0 | 0.0 | 1.30 |
| **Shellfish** | | | | | | |
| Clams | 81.82 | 12.77 | 0.97 | 2.57 | 0.0 | 1.87 |
| Lobster, American | 76.76 | 18.80 | 0.90 | 0.50 | 0.0 | 2.20 |
| Oysters | 85.16 | 7.05 | 2.46 | 3.91 | 0.0 | 1.42 |
| Scallop, meat | 78.57 | 16.78 | 0.76 | 2.36 | 0.0 | 1.53 |
| Shrimp | 75.86 | 20.31 | 1.73 | 0.91 | 0.0 | 1.20 |

# Zooming in on “energy supply” components

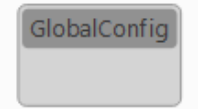


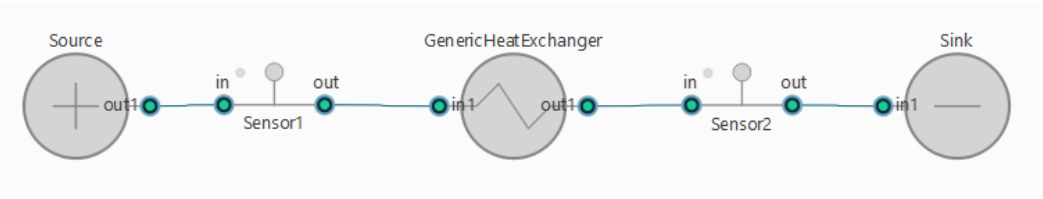
# A walk down memory lane

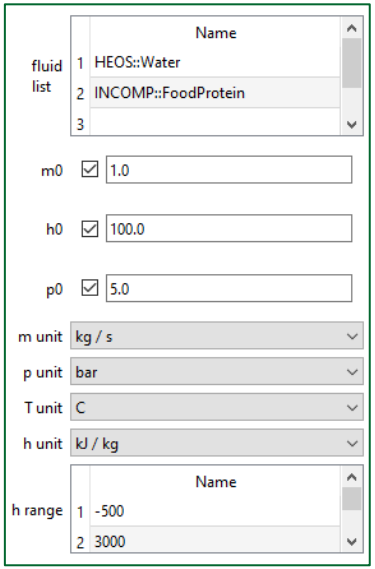
*… before the sneak peek*

# A walk down memory lane

## Global config node

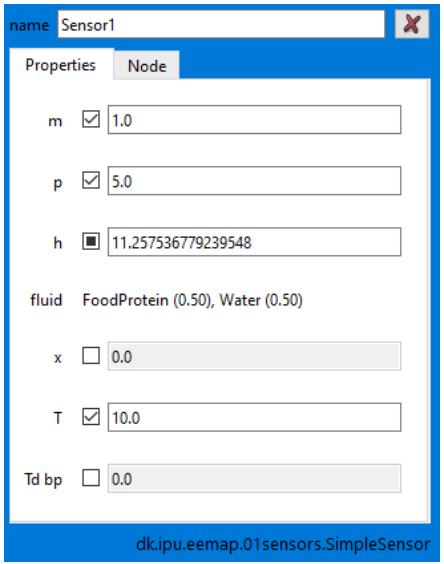


# A walk down memory lane

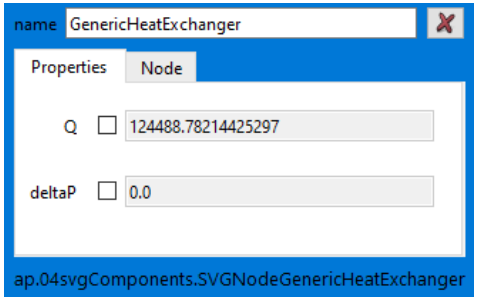
## Sensor node

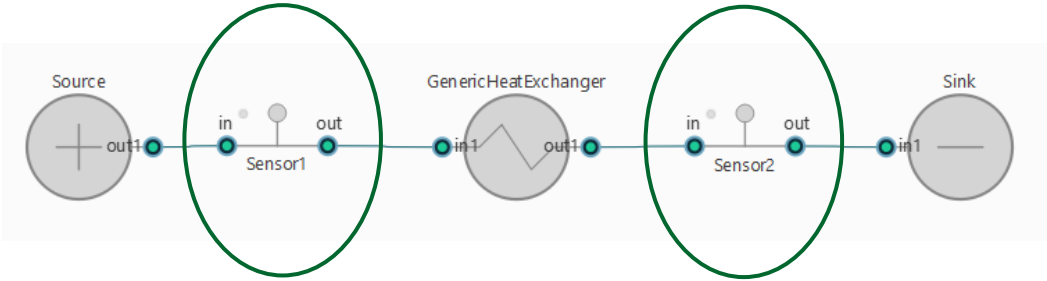



## Tri-state checkbox

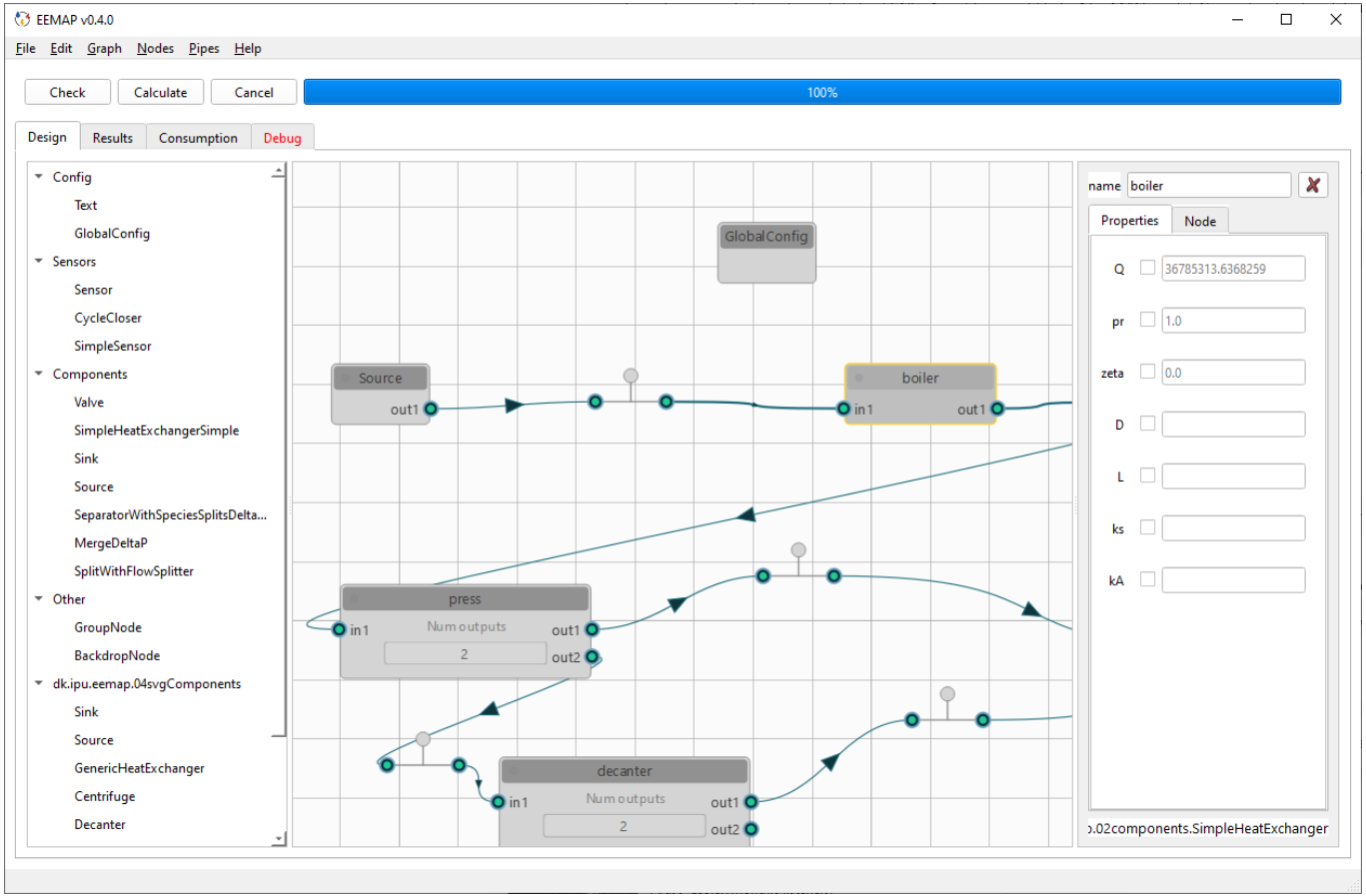
- Not set
- Override global guess
- Set parameter

## Pressure drop



# A walk down memory lane



# Sneak-peek

# Thank you

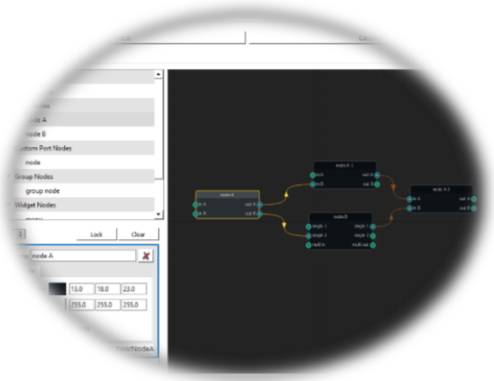


IPU Thermodynamics and Energy Technology
Bredevej 2B, DK-2830 Virum, Denmark
mrk@ipu.dk / www.ipu.dk
Dir. +45 45 16 04 36

| | PA | HA | TP | sankey M | sankey E | pies | Mappings deg |
|---|---|---|---|---|---|---|---|
| avista | 4 | 4 (3) | 5 | 0 | 2 | 5 | 5 |
| skagen | 4 | 50/50 % stuck | 2 | 0 | 1 | 4 | 2 |
| ovodan | 5 | 5 (1) | 1 | 4 | 4 | 4 | 1 |
| PPG | 5 | 5 | 3 | 10 | 10 | 5 | |
| unibrew | | | | | | | |
| skjern | | | | | | | |

# Software architecture considerations

## NodeGraphQt



## Translation

## tespy

tespy
['tɛs.paɪ]

# Food properties

# Food properties

- ASHRAE Handbook – Refrigeration, Ch 9, Thermal properties of foods



Table 3 Unfrozen Composition Data, Initial Freezing Point, and Specific Heats of Foods* (*Continued*)

| Food Item | Moisture Content, % $x_{wo}$ | Protein, % $x_p$ | Fat, % $x_f$ | Carbohydrate Total, % $x_c$ | Carbohydrate Fiber, % $x_{fb}$ | Ash, % $x_a$ | Initial Freezing Point, °C | Specific Heat Above Freezing, kJ/(kg·K) | Specific Heat Below Freezing kJ/(kg·K) | Latent Heat of Fusion, kJ/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| **Whole Fish** | | | | | | | | | | |
| Cod | 81.22 | 17.81 | 0.67 | 0.0 | 0.0 | 1.16 | –2.2 | 3.78 | 2.14 | 271 |
| Haddock | 79.92 | 18.91 | 0.72 | 0.0 | 0.0 | 1.21 | –2.2 | 3.75 | 2.14 | 267 |
| Halibut | 77.92 | 20.81 | 2.29 | 0.0 | 0.0 | 1.36 | –2.2 | 3.74 | 2.18 | 260 |
| Herring, kippered | 59.70 | 24.58 | 12.37 | 0.0 | 0.0 | 1.94 | –2.2 | 3.26 | 2.27 | 199 |
| Mackerel, Atlantic | 63.55 | 18.60 | 13.89 | 0.0 | 0.0 | 1.35 | –2.2 | 3.33 | 2.23 | 212 |
| Perch | 78.70 | 18.62 | 1.63 | 0.0 | 0.0 | 1.20 | –2.2 | 3.71 | 2.15 | 263 |
| Pollock, Atlantic | 78.18 | 19.44 | 0.98 | 0.0 | 0.0 | 1.41 | –2.2 | 3.70 | 2.15 | 261 |
| Salmon, pink | 76.35 | 19.94 | 3.45 | 0.0 | 0.0 | 1.22 | –2.2 | 3.68 | 2.17 | 255 |
| Tuna, bluefin | 68.09 | 23.33 | 4.90 | 0.0 | 0.0 | 1.18 | –2.2 | 3.43 | 2.19 | 227 |
| Whiting | 80.27 | 18.31 | 1.31 | 0.0 | 0.0 | 1.30 | –2.2 | 3.77 | 2.15 | 268 |
| **Shellfish** | | | | | | | | | | |
| Clams | 81.82 | 12.77 | 0.97 | 2.57 | 0.0 | 1.87 | –2.2 | 3.76 | 2.13 | 273 |
| Lobster, American | 76.76 | 18.80 | 0.90 | 0.50 | 0.0 | 2.20 | –2.2 | 3.64 | 2.15 | 256 |
| Oysters | 85.16 | 7.05 | 2.46 | 3.91 | 0.0 | 1.42 | –2.2 | 3.83 | 2.12 | 284 |
| Scallop, meat | 78.57 | 16.78 | 0.76 | 2.36 | 0.0 | 1.53 | –2.2 | 3.71 | 2.15 | 262 |
| Shrimp | 75.86 | 20.31 | 1.73 | 0.91 | 0.0 | 1.20 | –2.2 | 3.65 | 2.16 | 253 |




# tespy

# tespy

- Component based design and part load simulator
  - Steady state
  - Generic architecture
  - Added 6 models
    - Separator with
      - Heat loss
      - S-split
      - F-split
      - Heat bus
      - …

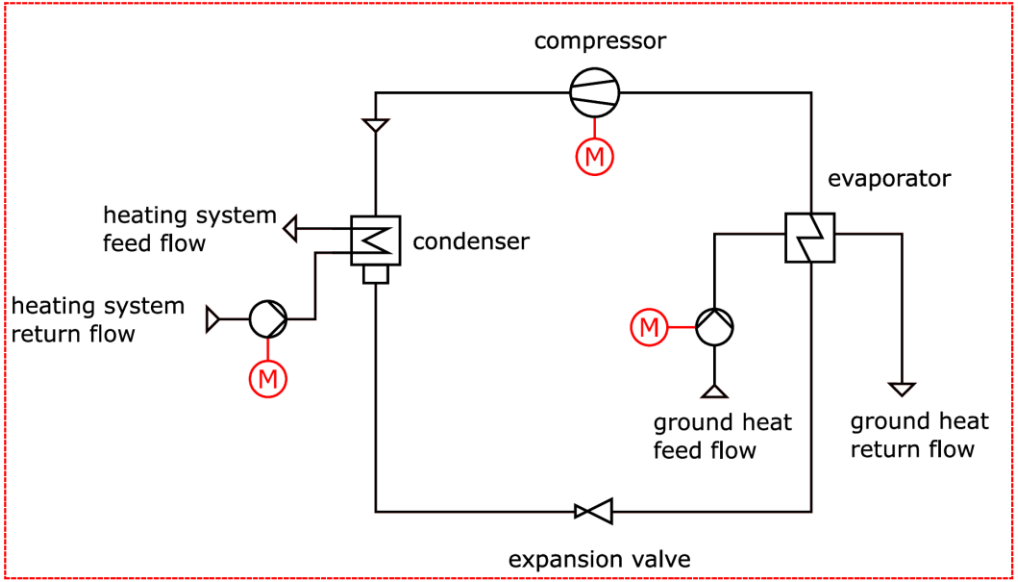
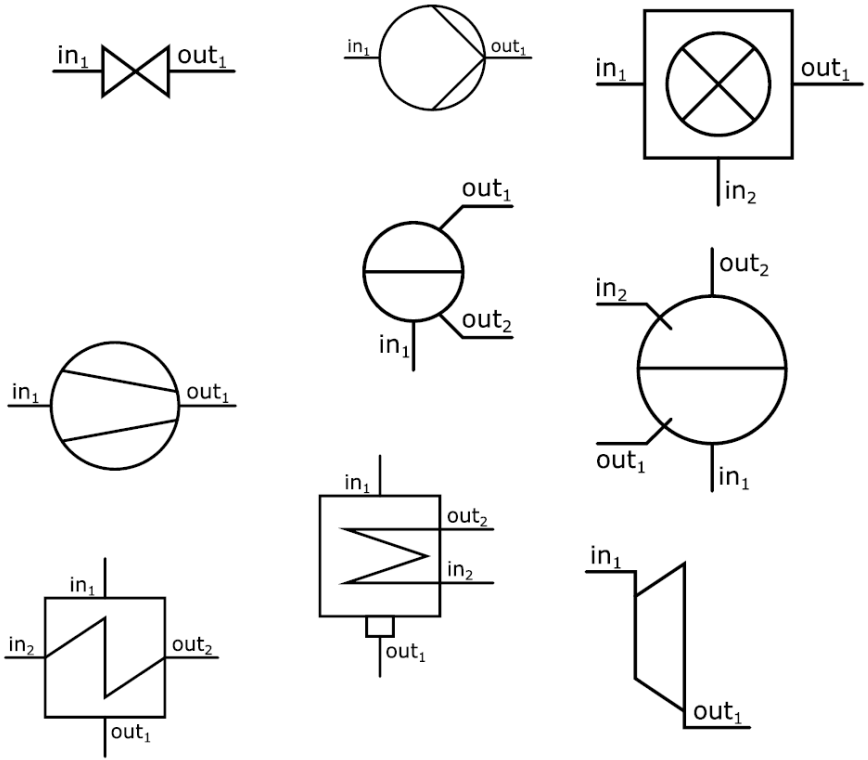



figure by Francesco Witte

# tespy components



- **Basics**
  - Cycle closer
  - Sink
  - Source
  - Subsystem interface
- **Combustion**
  - Combustion chamber
  - Diabatic combustion chamber
  - Combustion engine
- **Heat exchangers**
  - Simplified heat exchanger
  - Solar collector
  - Parabolic trough
  - Heat exchanger
  - Condenser
  - Desuperheater
- **Nodes**
  - Droplet separator
  - Drum
  - Merge
  - Separator
  - Splitter
- **Piping**
  - Pipe
  - Valve
- **Reactors**
  - Fuel cell
  - Water electrolyzer
- **Turbomachinery**
  - Compressor
  - Pump
  - Turbine



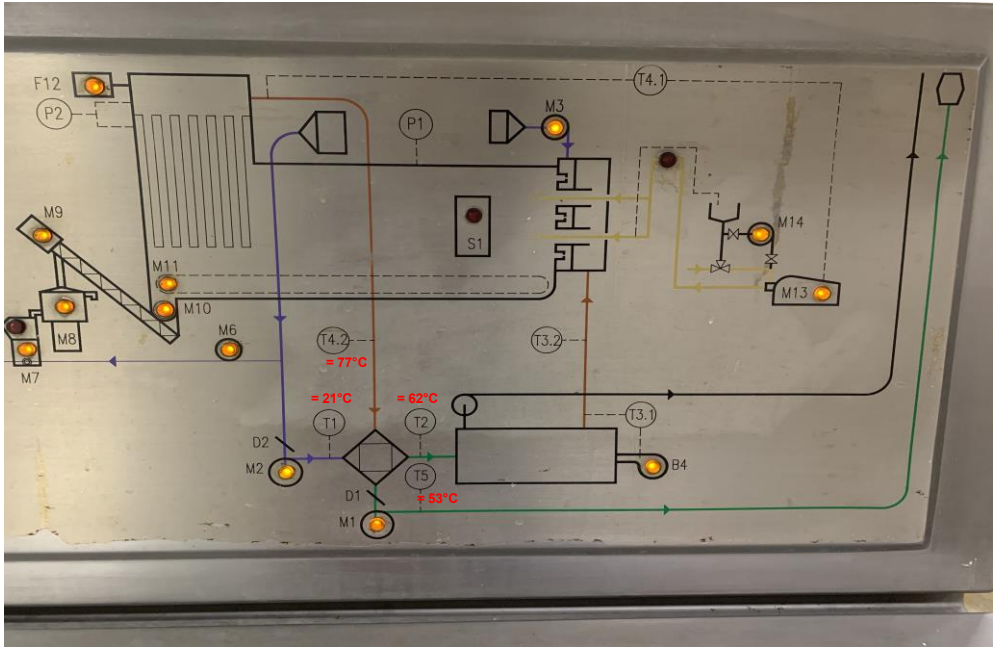

slide contents @ Francesco Witte

# Ovodan

# Case plant Ovodan




*Figur 8 Produktionsflow*



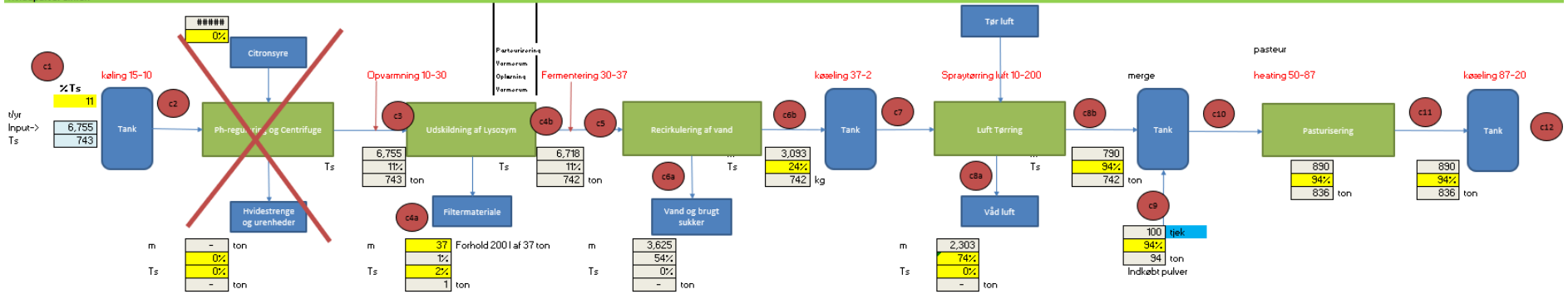
# Viegand Maagøe map

## Mass Flow Balance

Back to Information

All input is measured in tonnes per year

### Hvidepulver Linien




## Heating & cooling consumption

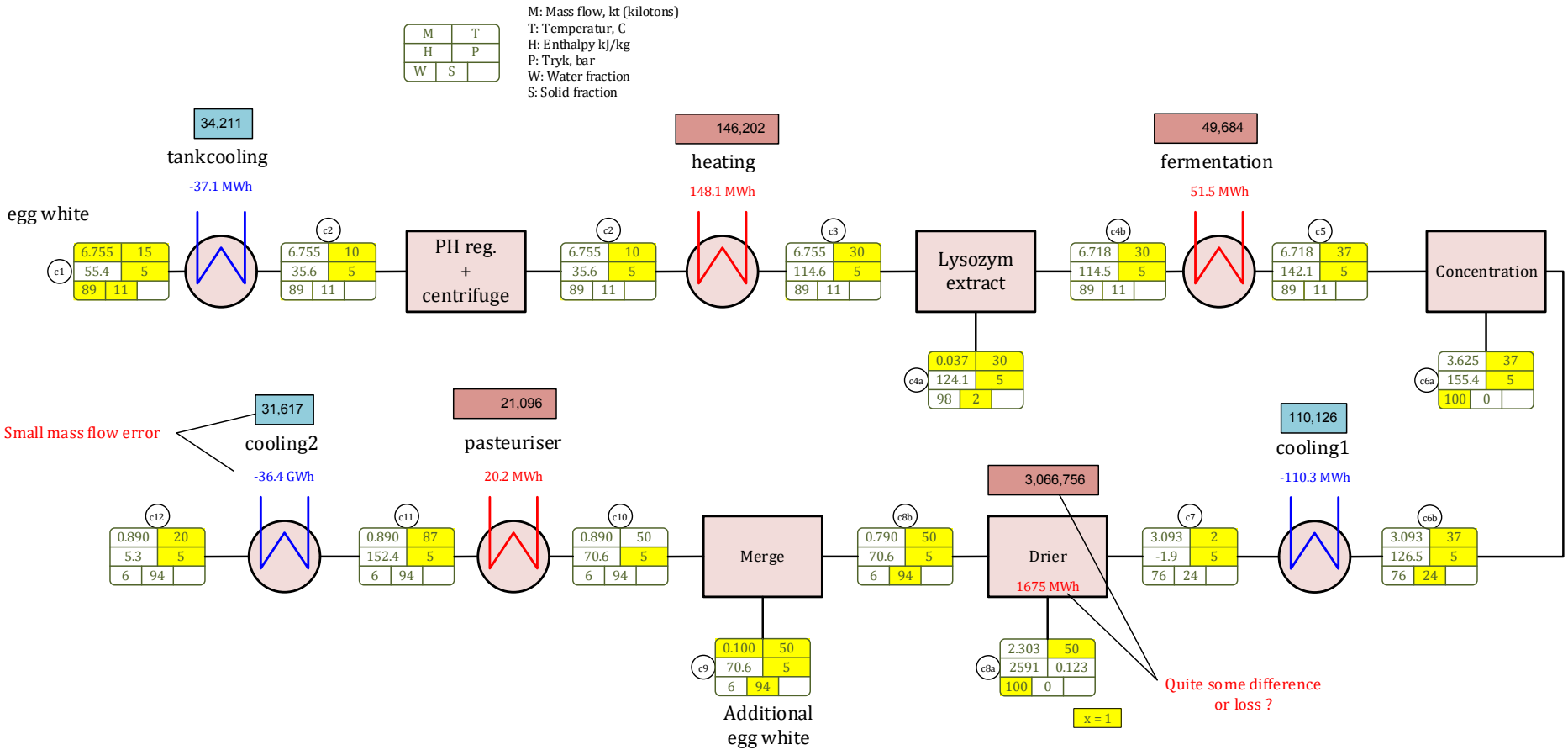
Back to Information

### Heating consumption

| Section | Line | Equipment | Medium | Stream no | Temp. In °C | Temp. Out °C | Mass flow t/yr | Dry matter % | Cp kJ/KgK | Steam kWh | Gas kWh | Energy water kWh | Share of total | Incl. in temperature analysis? | Incl. in temperature analysis? | Energy consumption is based on | Type | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Opvarmning | Hvidepulver | | Æggehvide | | 10 | 30 | 6,755 | 11.0% | 3.90 | 146,202 | | | 3% | yes | 146,202 | Calculation | Process | |
| Fermentering | Hvidepulver | | Æggehvidepulver | | 30 | 37 | 6,718 | 15.5% | 3.80 | 49,684 | | | 1% | Yes | 49,684 | Calculation | Process | |
| Spraytørring | Hvidepulver | | Luft | | 10 | 200 | | 0.0% | | | 3,066,756 | | 0% | Yes | 3,066,756 | Measurements | Process | |
| Pasteurisering | Hvidepulver | | Æggehvidepulver | | 50 | 87 | 890 | 92.0% | 2.31 | 21,096 | | | 0% | Yes | 21,096 | Calculation | Process | |
| | TOTAL | | | | | | | | | 216,982 | 3,066,756 | - | 5% | 3,283,738 | | | | |

### Cooling consumption

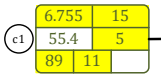
| Section | Line | Equipment | Medium | Stream no | Temp. In °C | Temp. Out °C | Mass flow t/yr | Dry matter % | Cp kJ/KgK | Ice water kWh | Raw water kWh | Energy water kWh | Share of total | Incl. in temperature analysis? | Incl. in temperature analysis? | Energy consumption is based on | Type | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Køling | Hvidepulver | | Egg white powder | | 15 | 10 | 6,755 | 20.0% | 3.65 | 34,211 | | | #DIV/0! | Yes | 34,211 | Calculation | Process | |
| Køling | Hvidepulver | | Egg white powder | | 37 | 2 | 3,093 | 20.0% | 3.66 | 110,126 | | | | Yes | 110,126 | Calculation | | |
| Køling | Hvidepulver | | Egg white powder | | 87 | 20 | 790 | 92.0% | 2.15 | 31,617 | | | #DIV/0! | Yes | 31,617 | Calculation | Process | |
| | | | | | | | | | 4.18 | | | | #DIV/0! | | - | | Process | |
| | TOTAL | | | | | | | | | 175,954 | - | - | #DIV/0! | | 175,954 | | | |


M: Mass flow, kt (kilotons)
T: Temperatur, C
H: Enthalpy kJ/kg
P: Tryk, bar
W: Water fraction
S: Solid fraction
M T H P W S
egg white
c1 6.755 15 55.4 5 89 11
34,211
tankcooling
-37.1 MWh
c2 6.755 10 35.6 5 89 11
PH reg. + centrifuge
c2 6.755 10 35.6 5 89 11
146,202
heating
148.1 MWh
c3 6.755 30 114.6 5 89 11
Lysozym extract
c4a 0.037 30 124.1 5 98 2
c4b 6.718 30 114.5 5 89 11
49,684
fermentation
51.5 MWh
c5 6.718 37 142.1 5 89 11
Concentration
c6a 3.625 37 155.4 5 100 0
Small mass flow error
31,617
cooling2
-36.4 GWh
c12 0.890 20 5.3 5 6 94
c11 0.890 87 152.4 5 6 94
21,096
pasteuriser
20.2 MWh
c10 0.890 50 70.6 5 6 94
Merge
c9 0.100 50 70.6 5 6 94
Additional egg white
c8b 0.790 50 70.6 5 6 94
3,066,756
Drier
1675 MWh
c8a 2.303 50 2591 0.123 100 0
x = 1
c7 3.093 2 -1.9 5 76 24
110,126
cooling1
-110.3 MWh
c6b 3.093 37 126.5 5 76 24
Quite some difference or loss ?

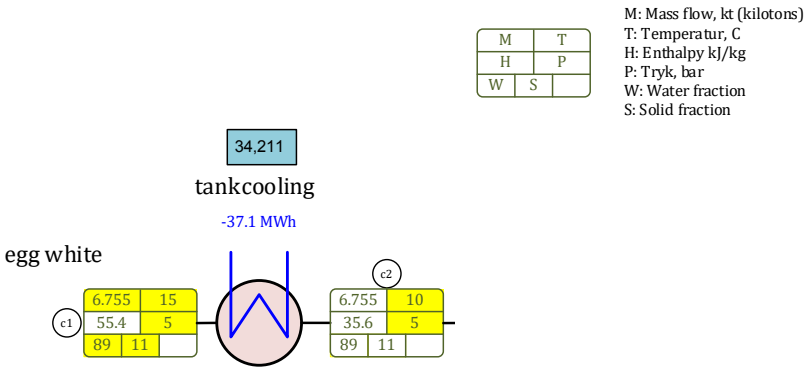



M: Mass flow, kt (kilotons)
T: Temperatur, C
H: Enthalpy kJ/kg
P: Tryk, bar
W: Water fraction
S: Solid fraction

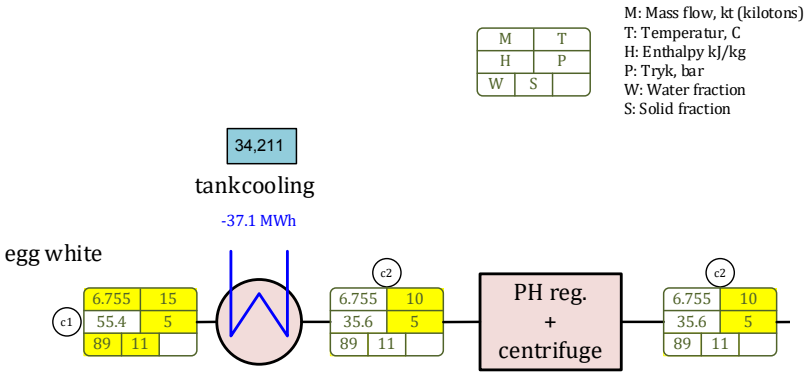
egg white



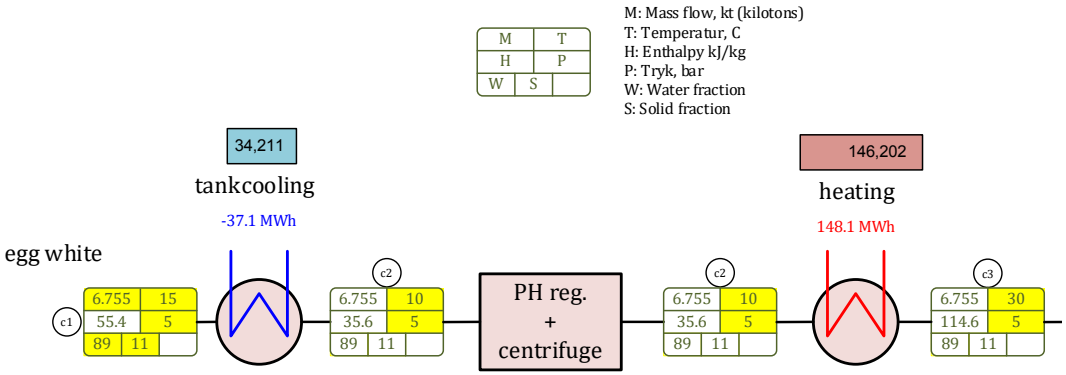

# Source condition must be defined



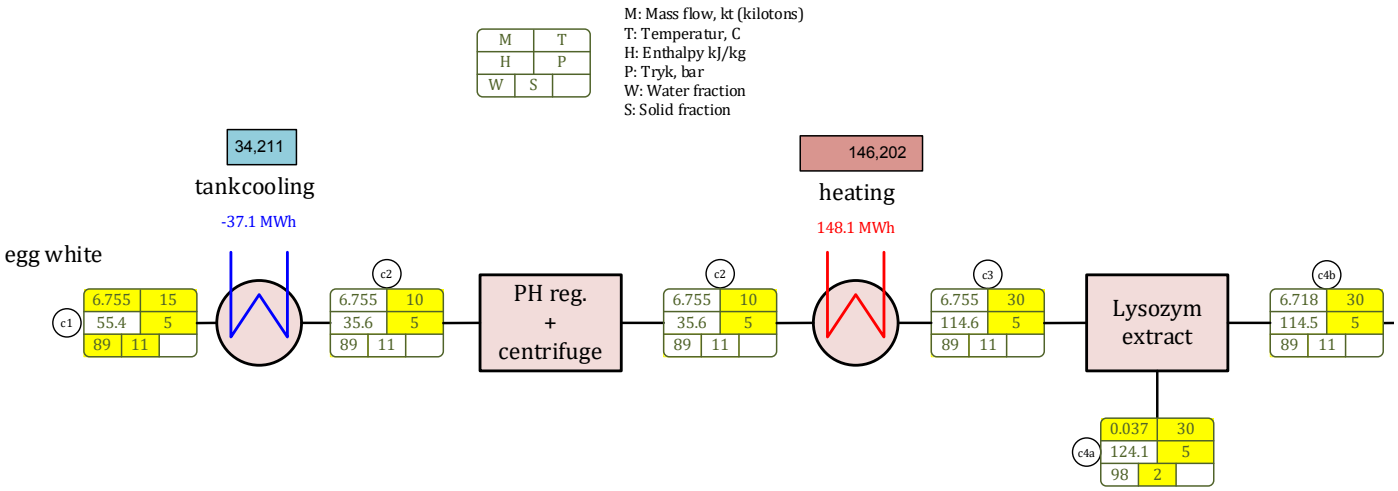

Heater/cooler is the same component, specify the exit temperature/pressure




Nothing important happened in this component… (not modelled)

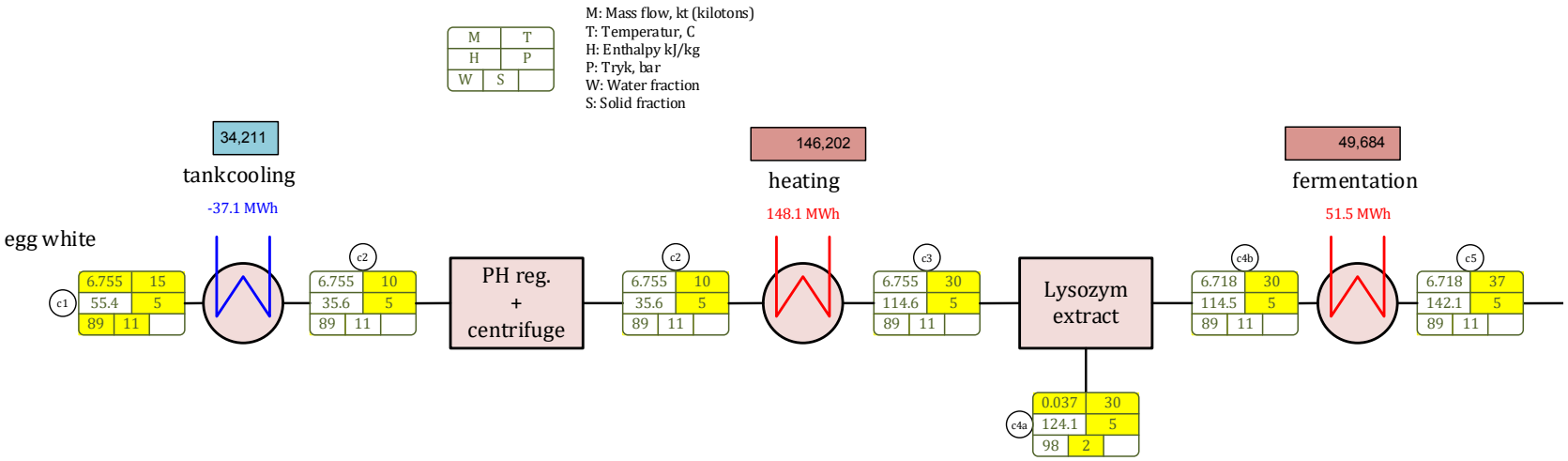



Heater/cooler is the same component, specify the exit temperature/pressure

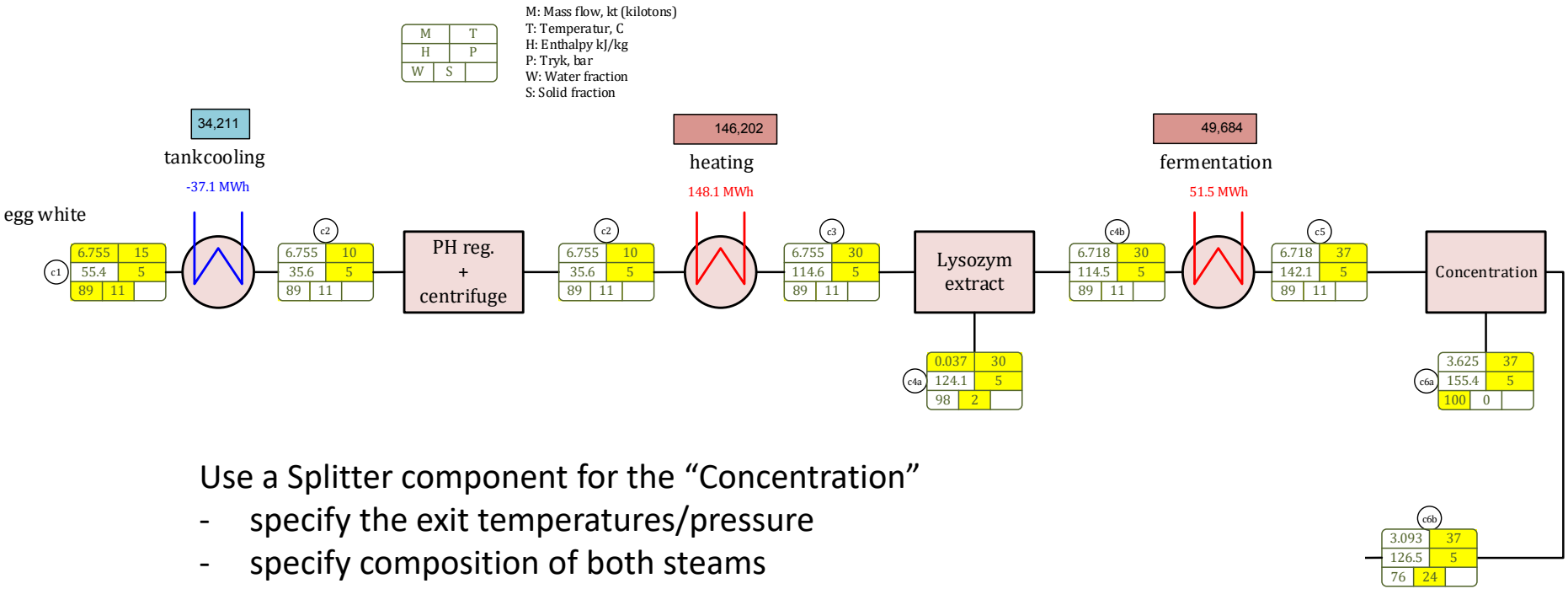



Use a Splitter component for the “Lysozym extraction”

- specify the exit temperatures/pressures
- specify mass flow and composition of extraction

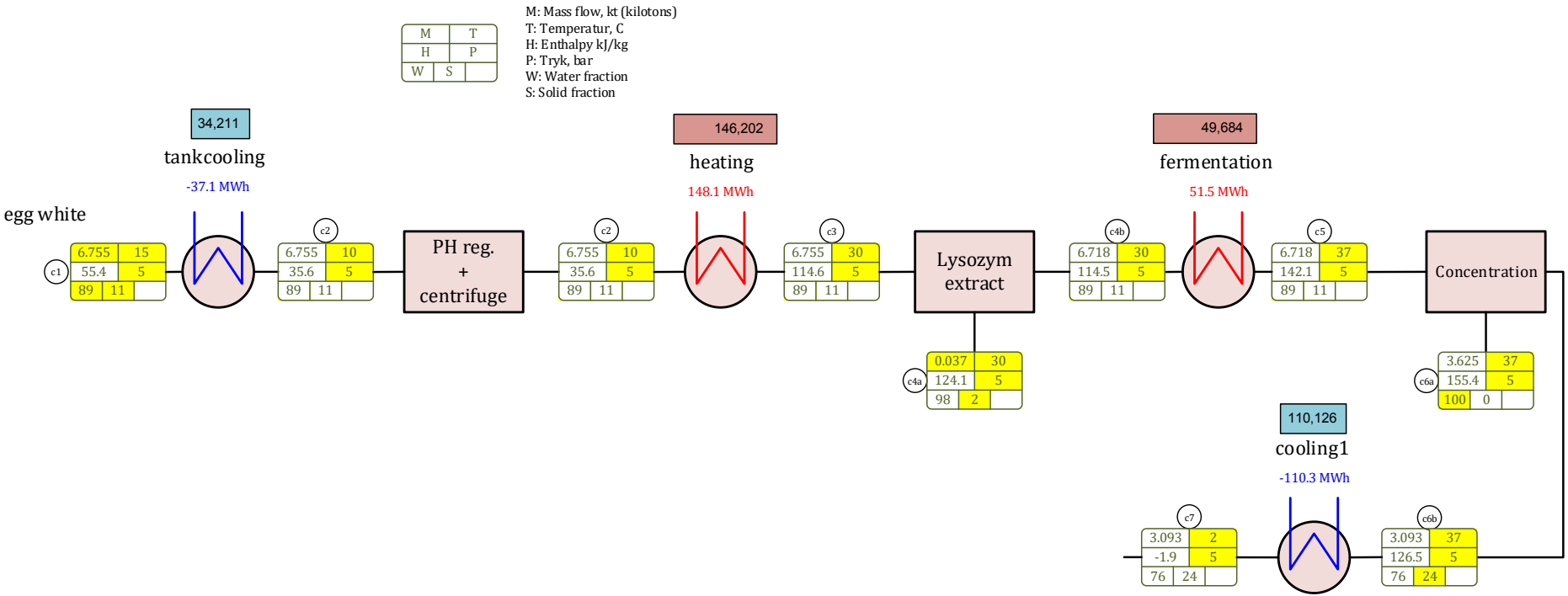



Heater/cooler is the same component, specify the exit temperature/pressure

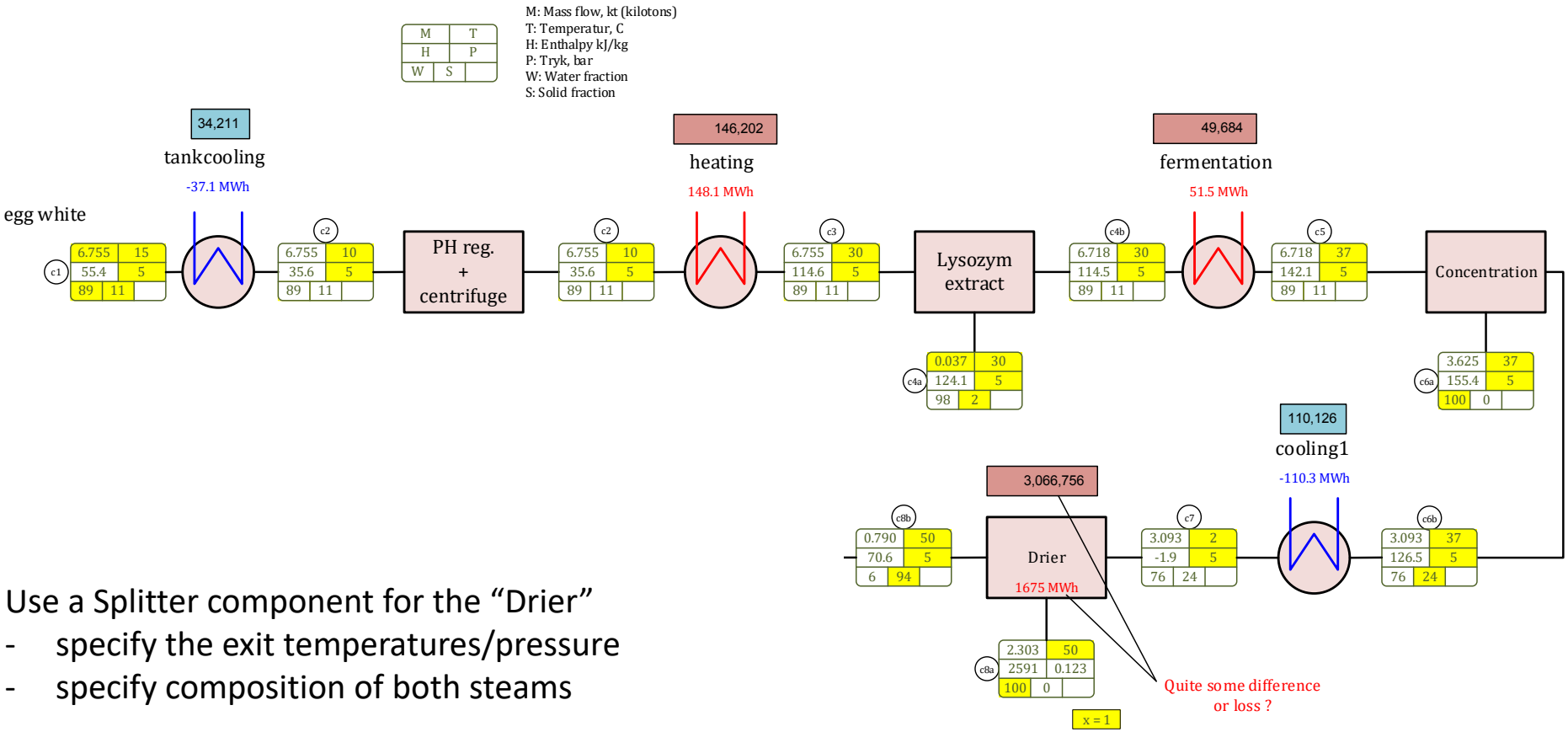



Use a Splitter component for the “Concentration”

- specify the exit temperatures/pressure
- specify composition of both steams

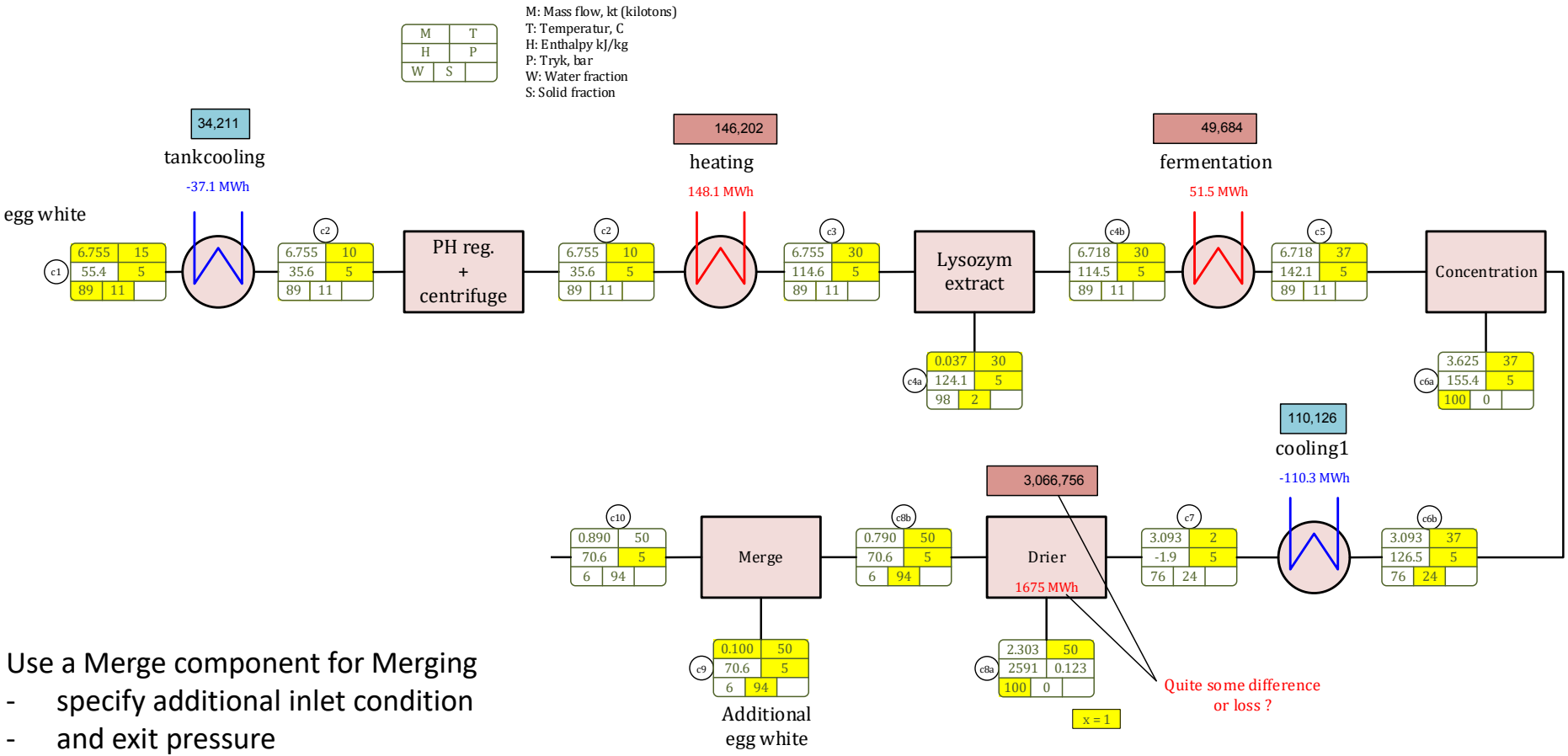



Heater/cooler is the same component, specify the exit temperature/pressure



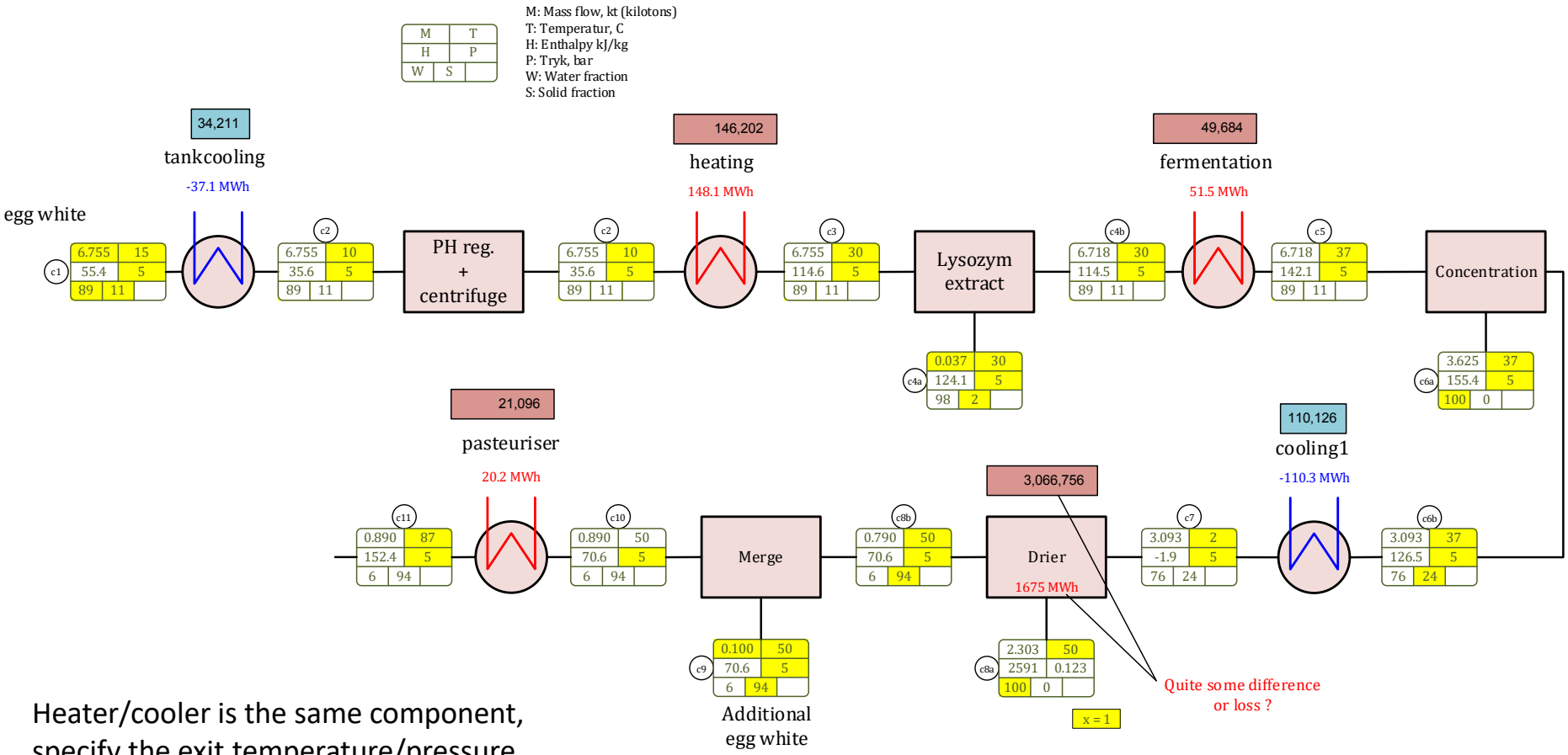

Use a Splitter component for the “Drier”

- specify the exit temperatures/pressure
- specify composition of both steams

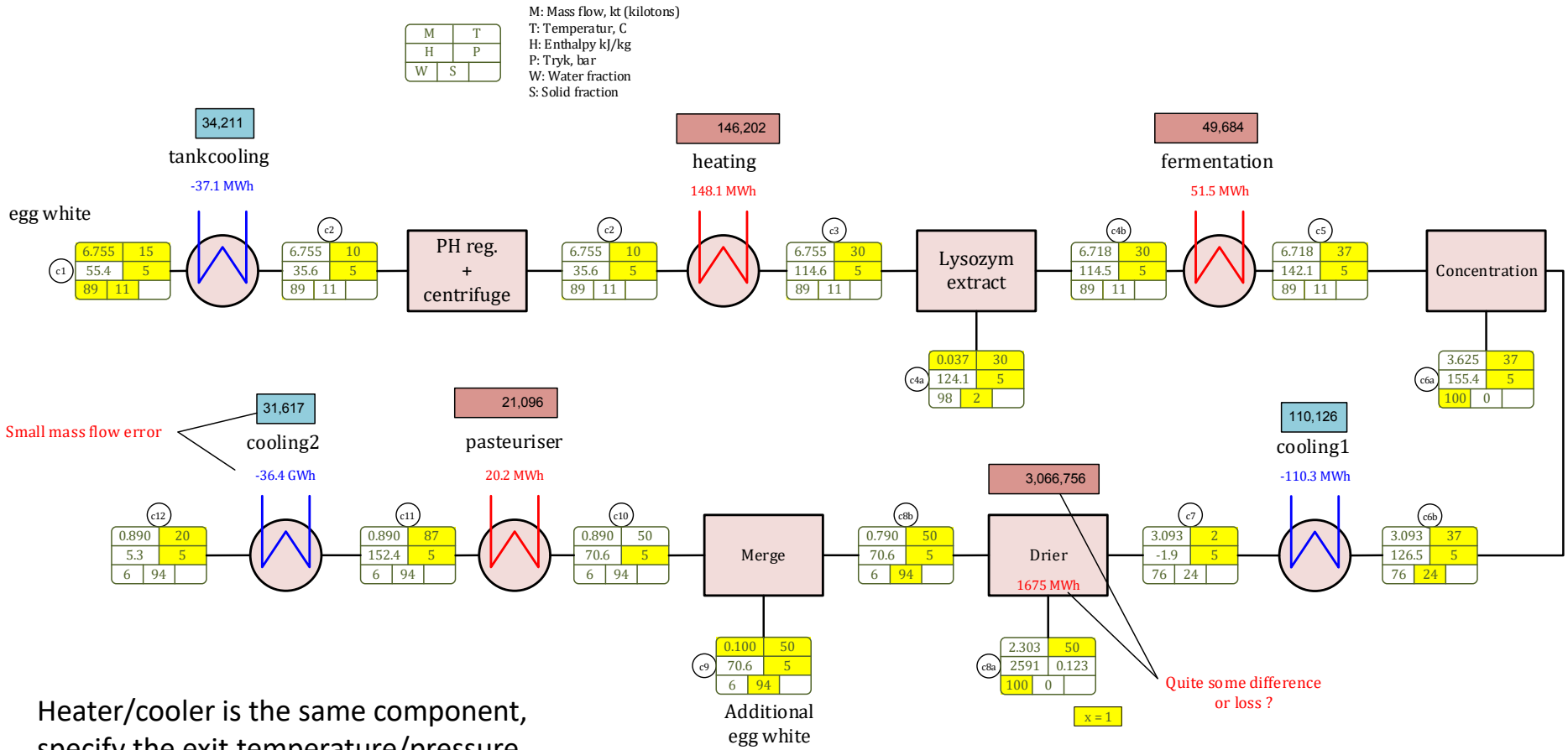


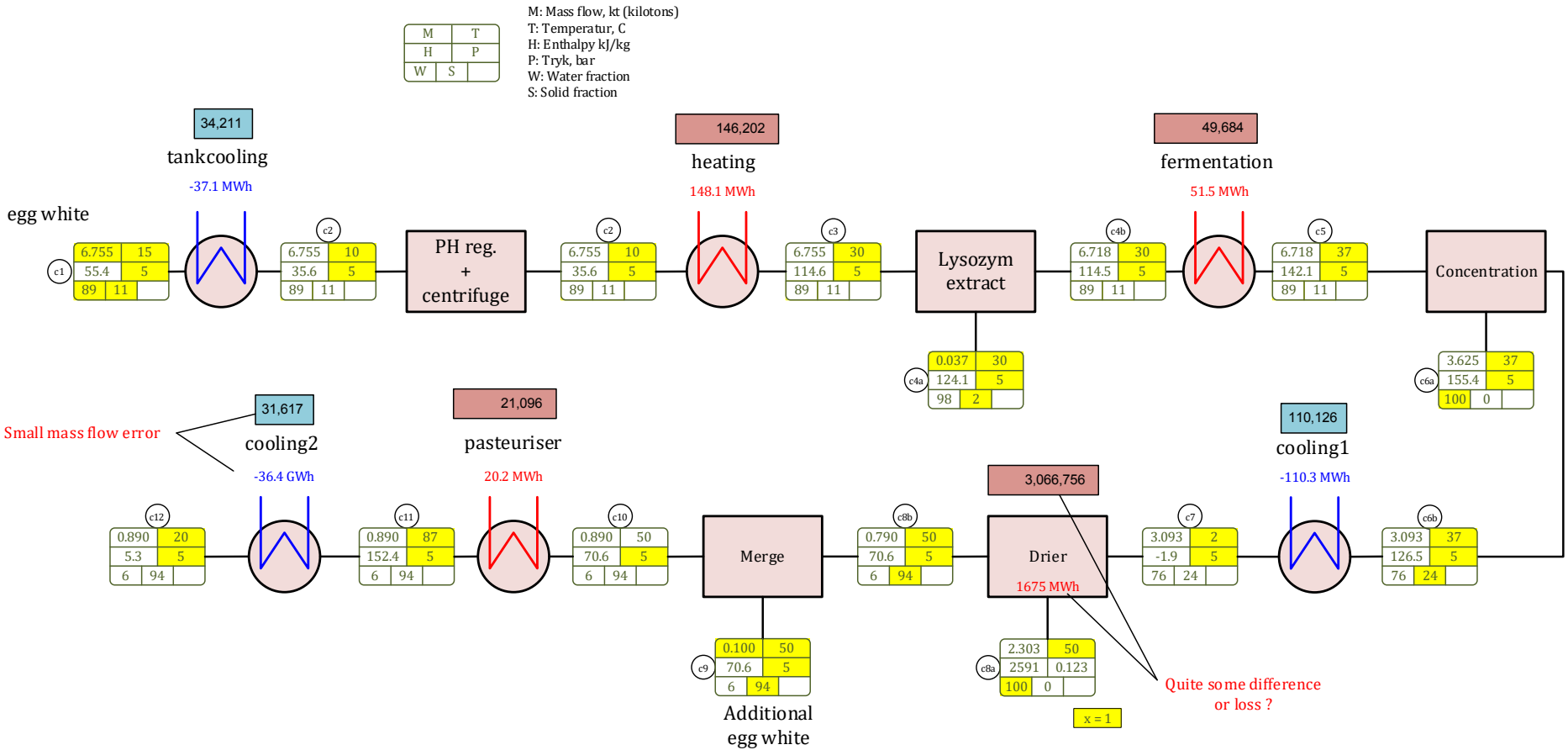

Use a Merge component for Merging

- specify additional inlet condition
- and exit pressure



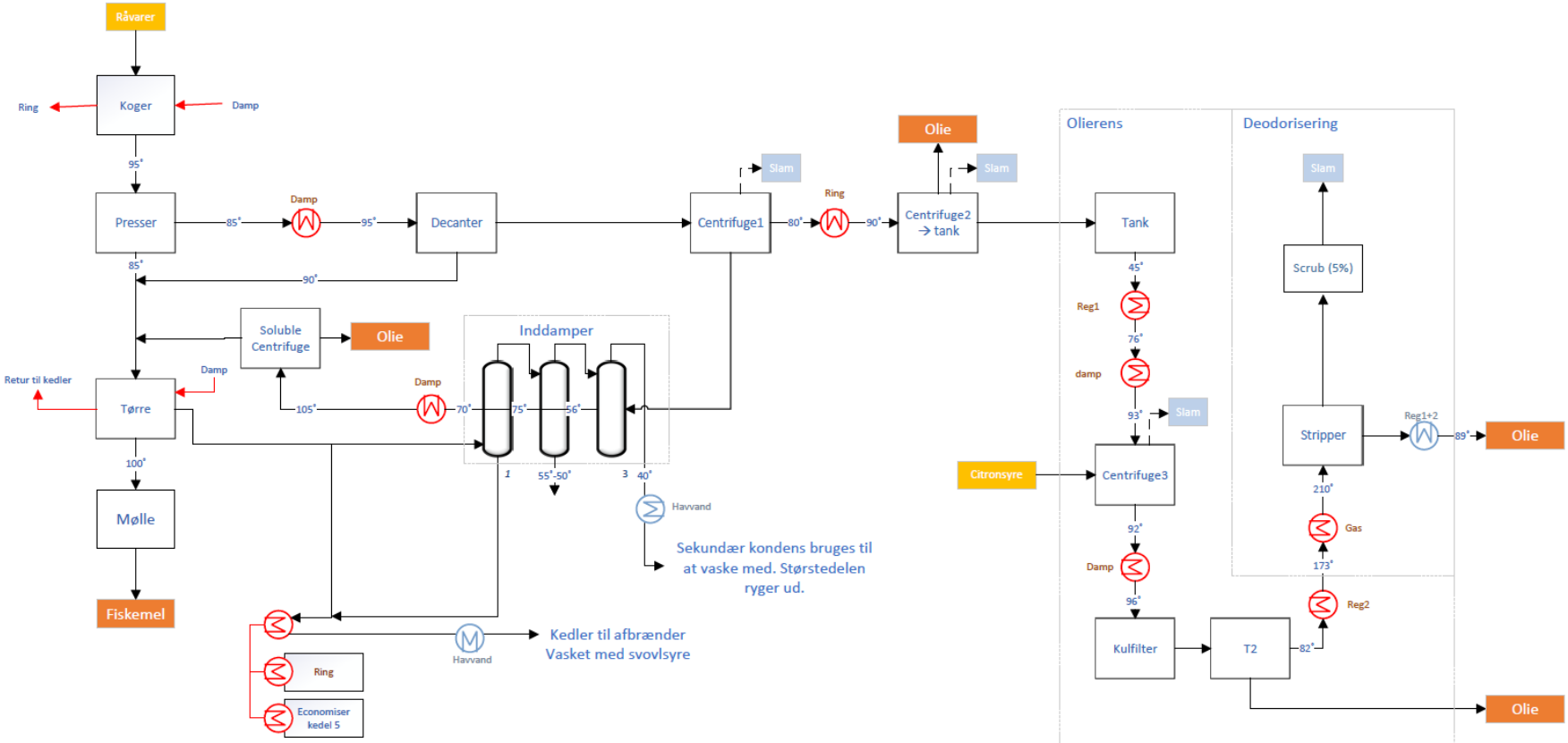

Heater/cooler is the same component,
specify the exit temperature/pressure


M: Mass flow, kt (kilotons)
T: Temperatur, C
H: Enthalpy kJ/kg
P: Tryk, bar
W: Water fraction
S: Solid fraction
M T H P W S
34,211
tankcooling
-37.1 MWh
egg white
146,202
heating
148.1 MWh
49,684
fermentation
51.5 MWh
PH reg. + centrifuge
Lysozym extract
Concentration
Small mass flow error
31,617
cooling2
-36.4 GWh
21,096
pasteuriser
20.2 MWh
110,126
cooling1
-110.3 MWh
3,066,756
Drier
1675 MWh
Merge
Additional egg white
x = 1
Quite some difference or loss ?
Heater/cooler is the same component, specify the exit temperature/pressure


M: Mass flow, kt (kilotons)
T: Temperatur, C
H: Enthalpy kJ/kg
P: Tryk, bar
W: Water fraction
S: Solid fraction
M T H P W S
egg white
c1 6.755 15 55.4 5 89 11
34,211
tankcooling
-37.1 MWh
c2 6.755 10 35.6 5 89 11
PH reg. + centrifuge
c2 6.755 10 35.6 5 89 11
146,202
heating
148.1 MWh
c3 6.755 30 114.6 5 89 11
Lysozym extract
c4a 0.037 30 124.1 5 98 2
c4b 6.718 30 114.5 5 89 11
49,684
fermentation
51.5 MWh
c5 6.718 37 142.1 5 89 11
Concentration
c6a 3.625 37 155.4 5 100 0
Small mass flow error
31,617
cooling2
-36.4 GWh
c12 0.890 20 5.3 5 6 94
c11 0.890 87 152.4 5 6 94
21,096
pasteuriser
20.2 MWh
c10 0.890 50 70.6 5 6 94
Merge
c9 0.100 50 70.6 5 6 94
Additional egg white
c8b 0.790 50 70.6 5 6 94
3,066,756
Drier
1675 MWh
c8a 2.303 50 2591 0.123 100 0
x = 1
c7 3.093 2 -1.9 5 76 24
110,126
cooling1
-110.3 MWh
c6b 3.093 37 126.5 5 76 24
Quite some difference or loss ?

# Skagen ff

# Case plant Skagen ff



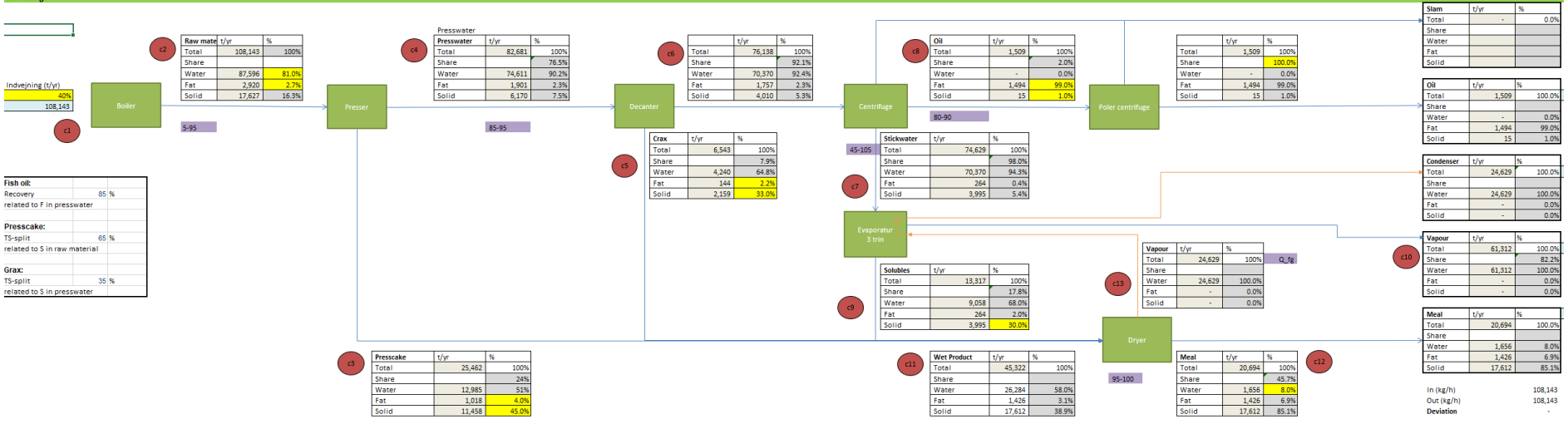
# Viegand Maagøe map

## Mass Flow Balance

Back to Information

All input is measured in tonnes per year

**Blåhvilling**



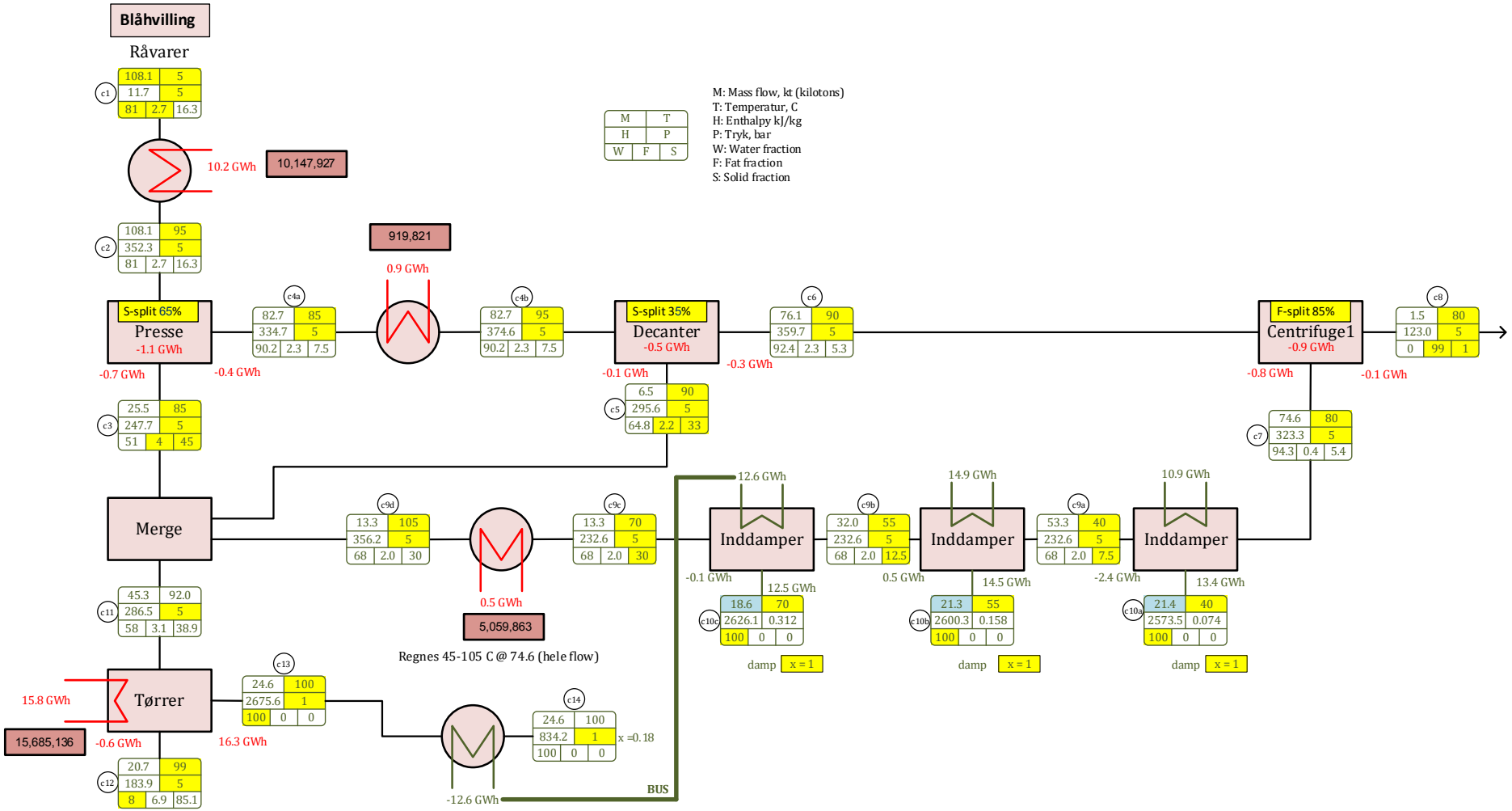

## Heating & cooling consumption

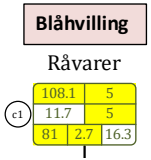
Back to Information

1.08E+08 3753.515 1.01E+07

**Heating consumption**

| Section | Raw material type | Equipment | Medium | Stream no | Temp. In °C | Temp. Out °C | Mass flow t/yr | Dry matter % | Cp kJ/KgK | Steam kWh | Vapour kWh | Reg kWh | Gas kWh | Ring kWh | Share of total | Incl. in temperature analysis? | Incl. in temperature analysis? | Energy consumption is based on | Type | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Koger | Råvarer 1 | | Råvarer 1 | | 5 | 95 | 108,143 | 19% | 3.75 | 10,147,927 | | | | | 9% | Yes | 10,147,927 | Calculation | Process | |
| Koger | Råvarer 2 | | Råvarer 2 | | 5 | 95 | 91,922 | 26% | 3.61 | 8,290,447 | | | | | 7% | Yes | 8,290,447 | Calculation | Process | |
| Koger | Råvarer 3 | | Råvarer 3 | | 5 | 95 | 70,293 | 23% | 3.66 | 6,438,368 | | | | | 6% | Yes | 6,438,368 | Calculation | Process | |
| Tørrer | Råvarer 1 | | Vådt produkt | | 95 | 100 | 45,322 | 42.0% | 3.46 | 15,685,136 | | | | | 14% | Yes | 15,685,136 | Calculation | Process | |
| Tørrer | Råvarer 2 | | Vådt produkt | | 95 | 100 | 35,719 | 45.1% | 3.41 | 11,609,914 | | | | | 10% | Yes | 11,609,914 | Calculation | Process | |
| Tørrer | Råvarer 3 | | Vådt produkt | | 95 | 100 | 26,084 | 44.5% | 3.42 | 8,576,477 | | | | | 7% | Yes | 8,576,477 | Calculation | Process | |
| Inddamper | Råvarer 1 | | Limvand | | 45 | 105 | 74,629 | 5.7% | 4.07 | | 5,059,863 | | | | 4% | Yes | #REF! | Calculation | Process | |
| Inddamper | Råvarer 2 | | Limvand | | 45 | 105 | 59,215 | 7.4% | 4.03 | | 3,981,827 | | | | 3% | Yes | #REF! | Calculation | Process | |
| Inddamper | Råvarer 3 | | Limvand | | 45 | 105 | 47,234 | 6.5% | 4.05 | | 3,190,272 | | | | 3% | Yes | #REF! | Calculation | Process | |
| Decanter | Råvarer 1 | | Pressevand | | 85 | 95 | 82,681 | 9.8% | 4.00 | 919,821 | | | | | 1% | Yes | 919,821 | Calculation | Process | |
| Decanter | Råvarer 2 | | Pressevand | | 85 | 95 | 71,740 | 18.9% | 3.84 | 765,479 | | | | | 1% | Yes | 765,479 | Calculation | Process | |
| Decanter | Råvarer 3 | | Pressevand | | 85 | 95 | 55,571 | 16.1% | 3.89 | 600,638 | | | | | 1% | Yes | 600,638 | Calculation | Process | |

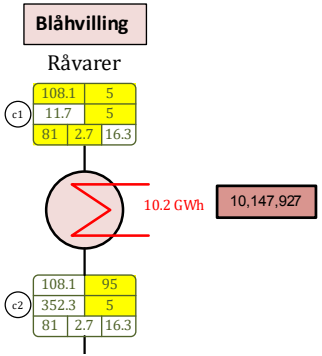

Blåhvilling
Råvarer
c1
108.1 5
11.7 5
81 2.7 16.3
10.2 GWh
10,147,927
M T
H P
W F S
M: Mass flow, kt (kilotons)
T: Temperatur, C
H: Enthalpy kJ/kg
P: Tryk, bar
W: Water fraction
F: Fat fraction
S: Solid fraction
c2
108.1 95
352.3 5
81 2.7 16.3
919,821
0.9 GWh
S-split 65%
Presse
-1.1 GWh
c4a
82.7 85
334.7 5
90.2 2.3 7.5
c4b
82.7 95
374.6 5
90.2 2.3 7.5
S-split 35%
Decanter
-0.5 GWh
c6
76.1 90
359.7 5
92.4 2.3 5.3
F-split 85%
Centrifuge1
-0.9 GWh
c8
1.5 80
123.0 5
0 99 1
-0.7 GWh
-0.4 GWh
-0.1 GWh
-0.3 GWh
-0.8 GWh
-0.1 GWh
c3
25.5 85
247.7 5
51 4 45
c5
6.5 90
295.6 5
64.8 2.2 33
c7
74.6 80
323.3 5
94.3 0.4 5.4
Merge
c9d
13.3 105
356.2 5
68 2.0 30
c9c
13.3 70
232.6 5
68 2.0 30
0.5 GWh
5,059,863
Regnes 45-105 C @ 74.6 (hele flow)
12.6 GWh
Inddamper
-0.1 GWh
c9b
32.0 55
232.6 5
68 2.0 12.5
14.9 GWh
Inddamper
0.5 GWh
c9a
53.3 40
232.6 5
68 2.0 7.5
10.9 GWh
Inddamper
-2.4 GWh
12.5 GWh
c10c
18.6 70
2626.1 0.312
100 0 0
damp
x = 1
14.5 GWh
c10b
21.3 55
2600.3 0.158
100 0 0
damp
x = 1
13.4 GWh
c10a
21.4 40
2573.5 0.074
100 0 0
damp
x = 1
c11
45.3 92.0
286.5 5
58 3.1 38.9
15.8 GWh
Tørrer
15,685,136
-0.6 GWh
c13
24.6 100
2675.6 1
100 0 0
16.3 GWh
c14
24.6 100
834.2 1
100 0 0
x =0.18
c12
20.7 99
183.9 5
8 6.9 85.1
-12.6 GWh
BUS




| | |
|---|---|
| M | T |
| H | P |
| W | F | S |

M: Mass flow, kt (kilotons)
T: Temperatur, C
H: Enthalpy kJ/kg
P: Tryk, bar
W: Water fraction
F: Fat fraction
S: Solid fraction

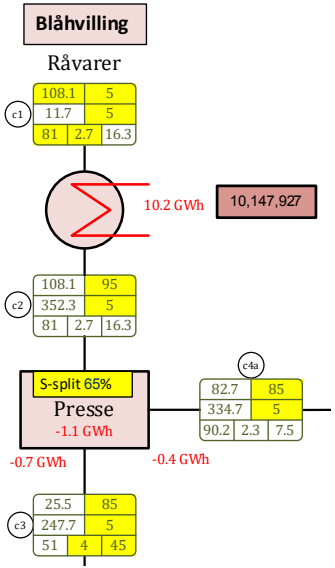
Source condition must be defined




| M | T |
|---|---|
| H | P |
| W | F | S |

M: Mass flow, kt (kilotons)
T: Temperatur, C
H: Enthalpy kJ/kg
P: Tryk, bar
W: Water fraction
F: Fat fraction
S: Solid fraction

Heater/cooler is the same component, specify the exit temperature, pressure

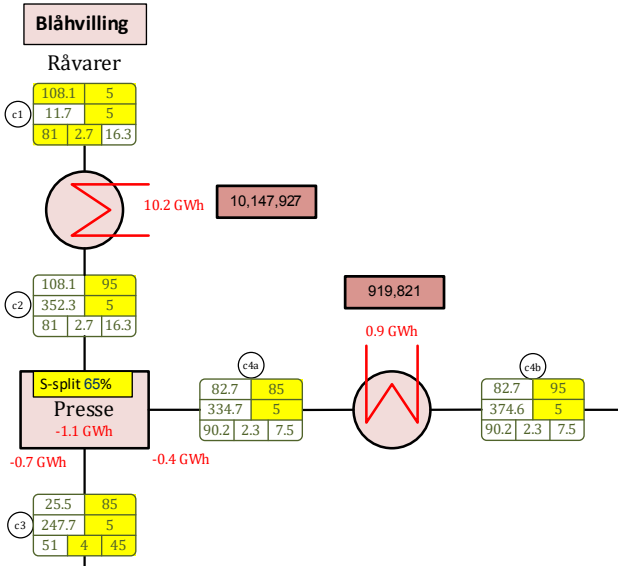



| | |
|---|---|
| M | T |
| H | P |
| W | F | S |

M: Mass flow, kt (kilotons)
T: Temperatur, C
H: Enthalpy kJ/kg
P: Tryk, bar
W: Water fraction
F: Fat fraction
S: Solid fraction

Use a Splitter component for the “Press”

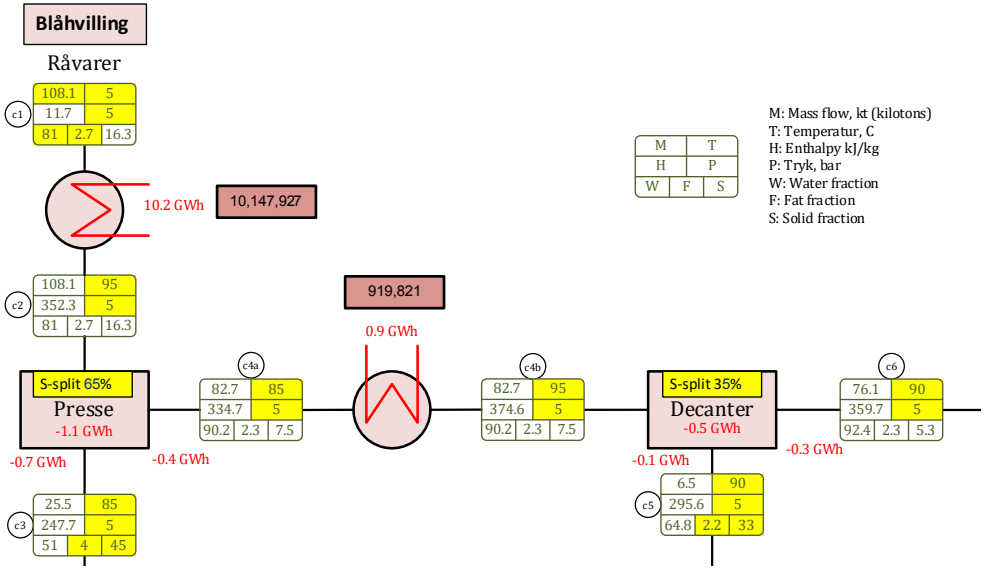
- specify the exit temperatures, pressures
- specify composition of “presscake” as well as “S-split”




| M | T |
|---|---|
| H | P |
| W | F | S |

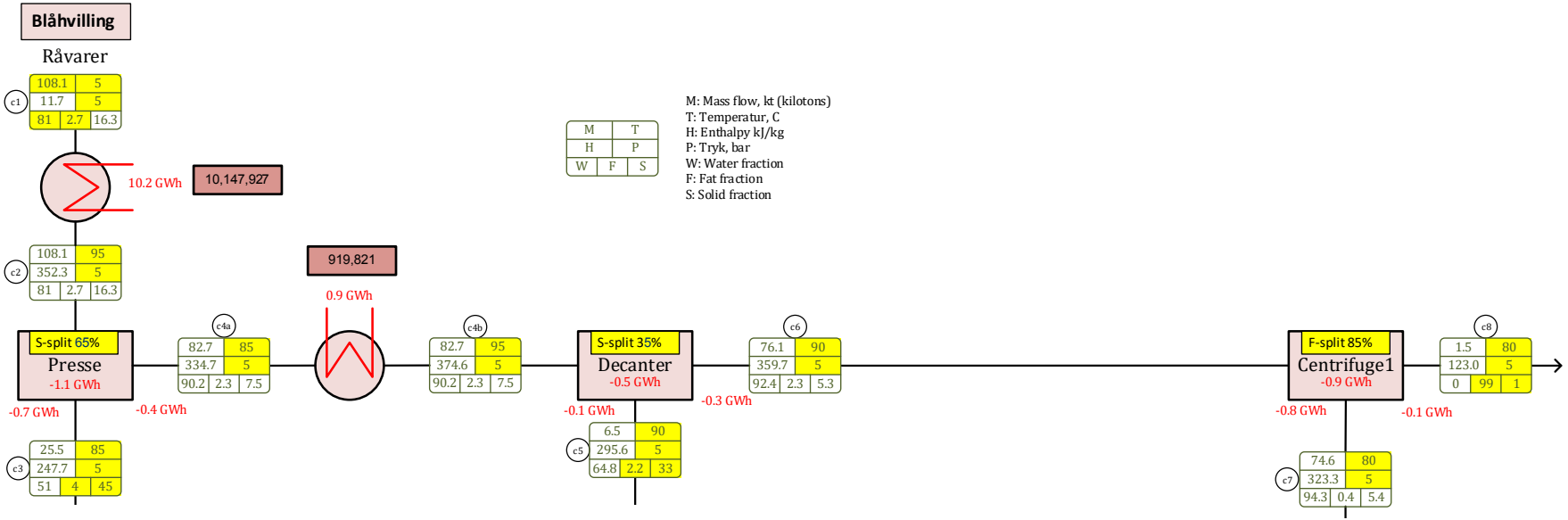
M: Mass flow, kt (kilotons)
T: Temperatur, C
H: Enthalpy kJ/kg
P: Tryk, bar
W: Water fraction
F: Fat fraction
S: Solid fraction

Heater/cooler is the same component, specify the exit temperature/pressure



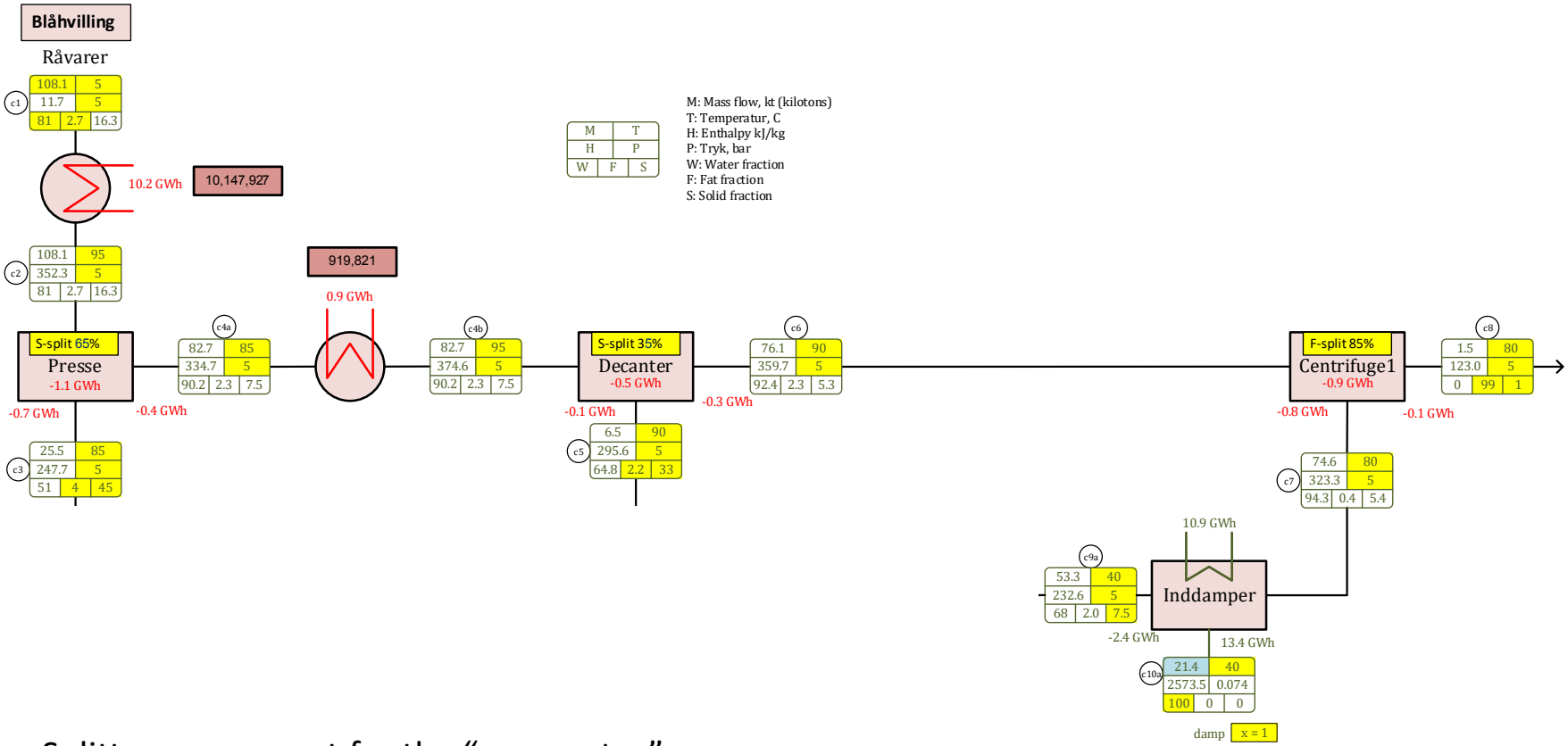

Use a Splitter component for the “Decanter”

- specify the exit temperatures/pressures
- specify composition of “Grax” as well as “S-split”



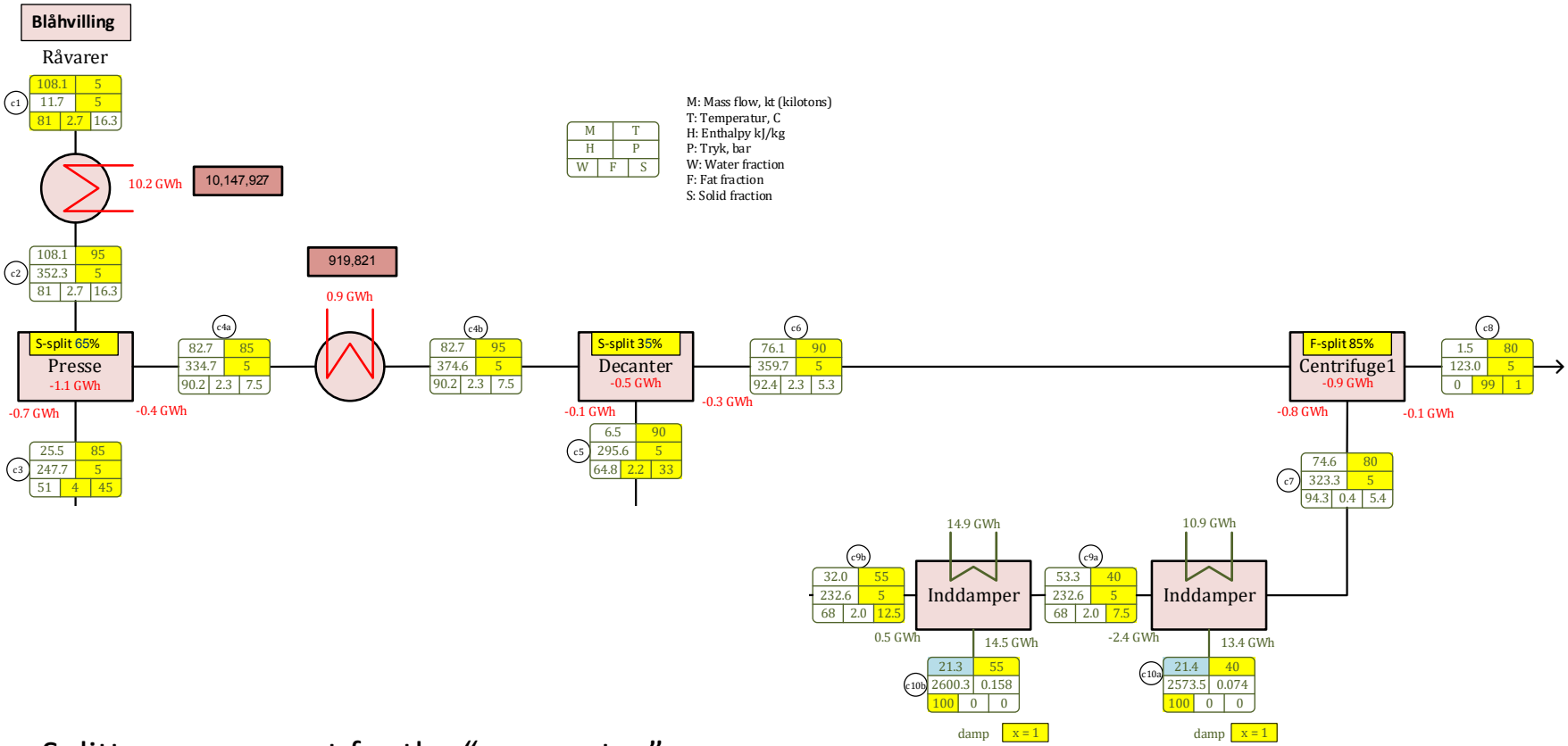

Use a Splitter component for the “Centrifuge”

- specify the exit temperatures/pressures
- specify composition of “Oil” as well as “F-split”



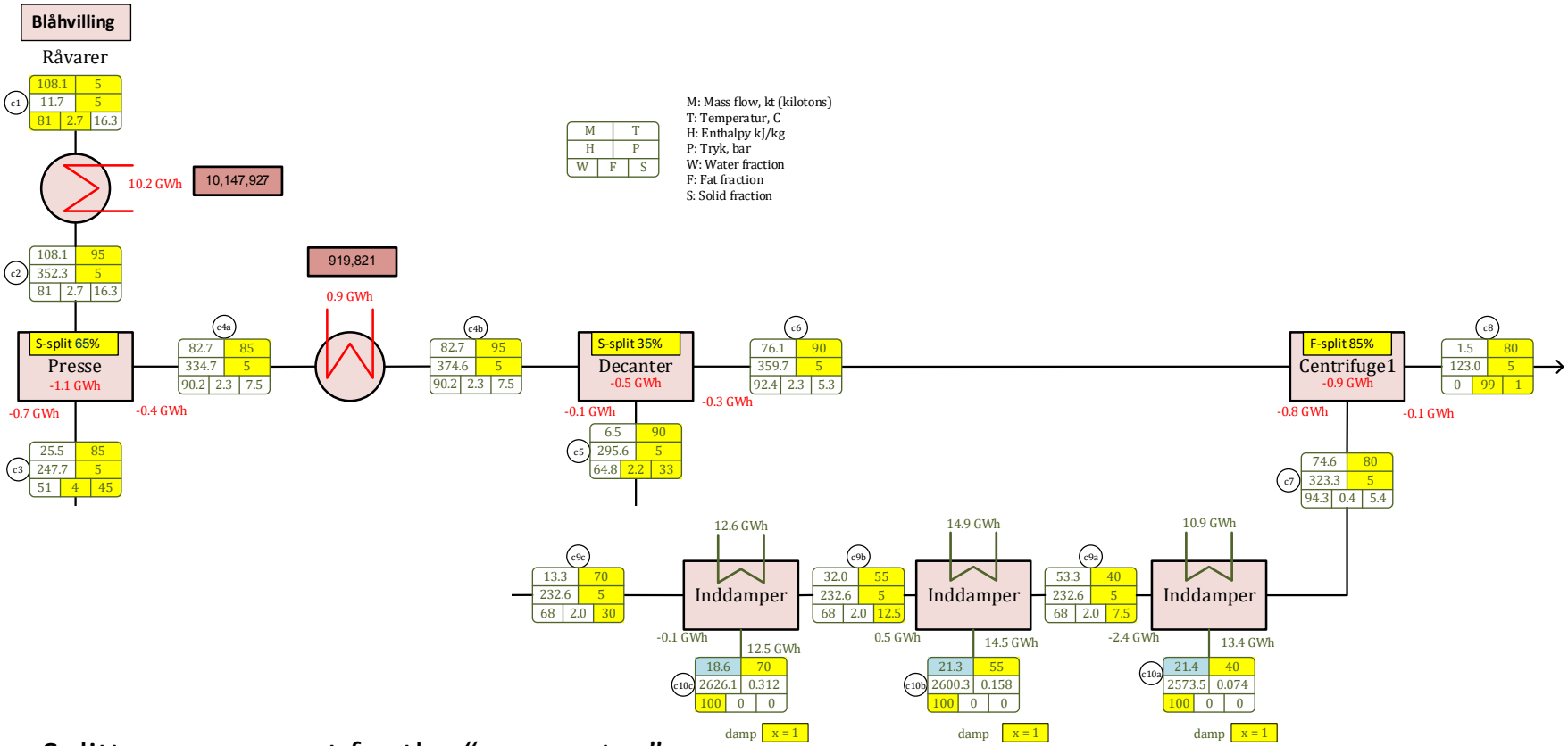

Use a Splitter component for the “evaporator”

- specify the exit temperatures (evaporation) and pressures (except x=1 for steam)
- specify solid composition of product



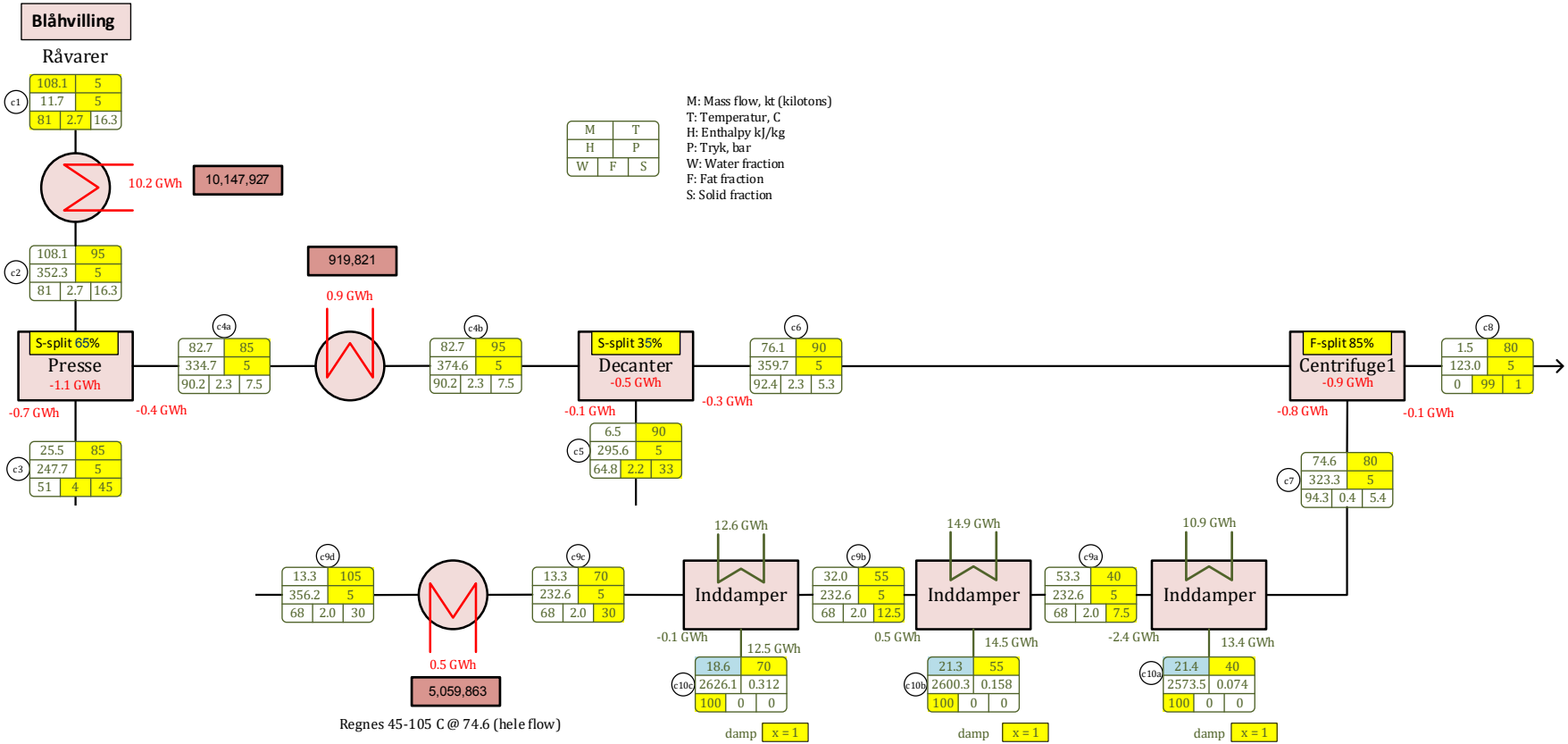

Use a Splitter component for the “evaporator”

- specify the exit temperatures (evaporation) and pressures (except x=1 for steam)
- specify solid composition of product

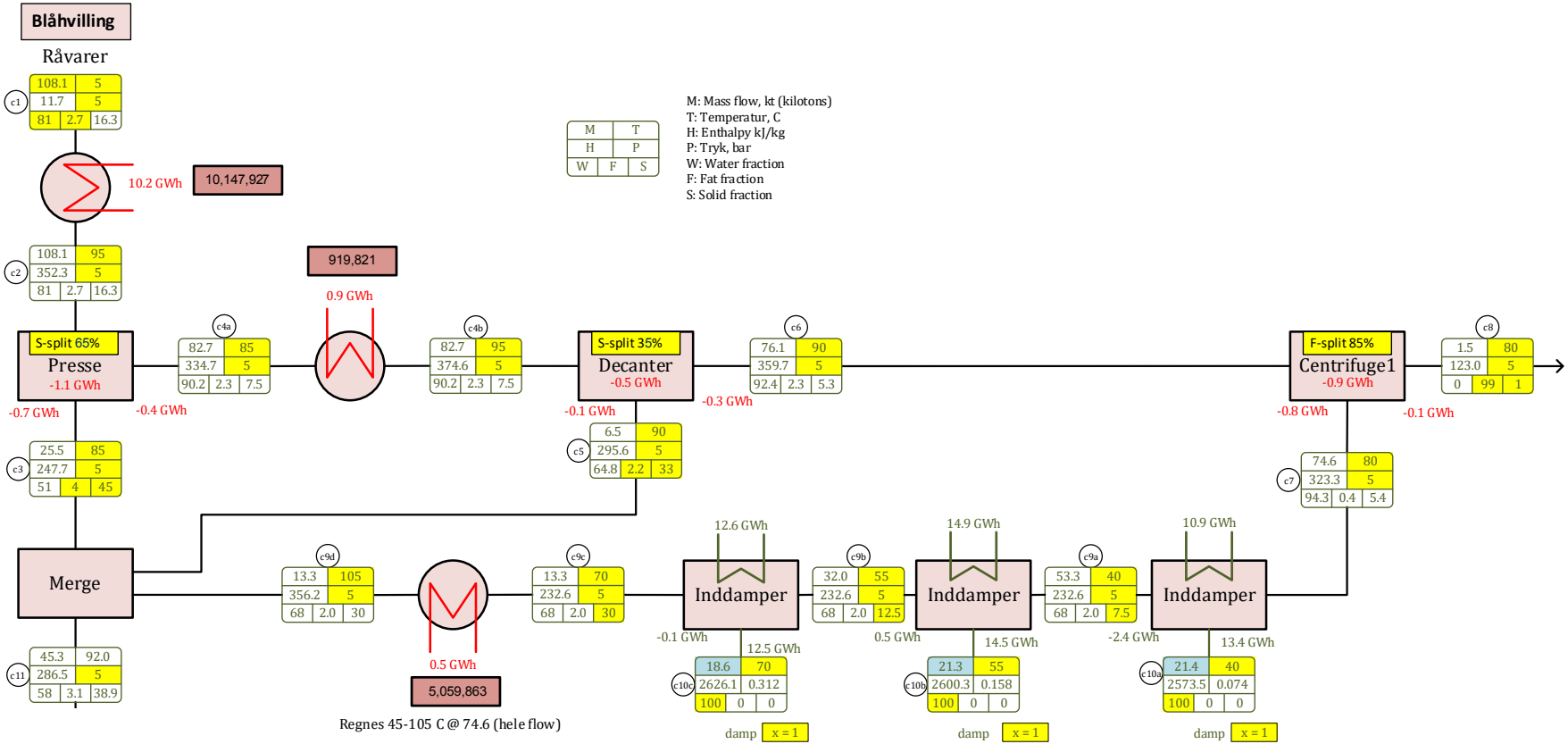



Use a Splitter component for the “evaporator”

- specify the exit temperatures (evaporation) and pressures (except x=1 for steam)
- specify solid composition of product

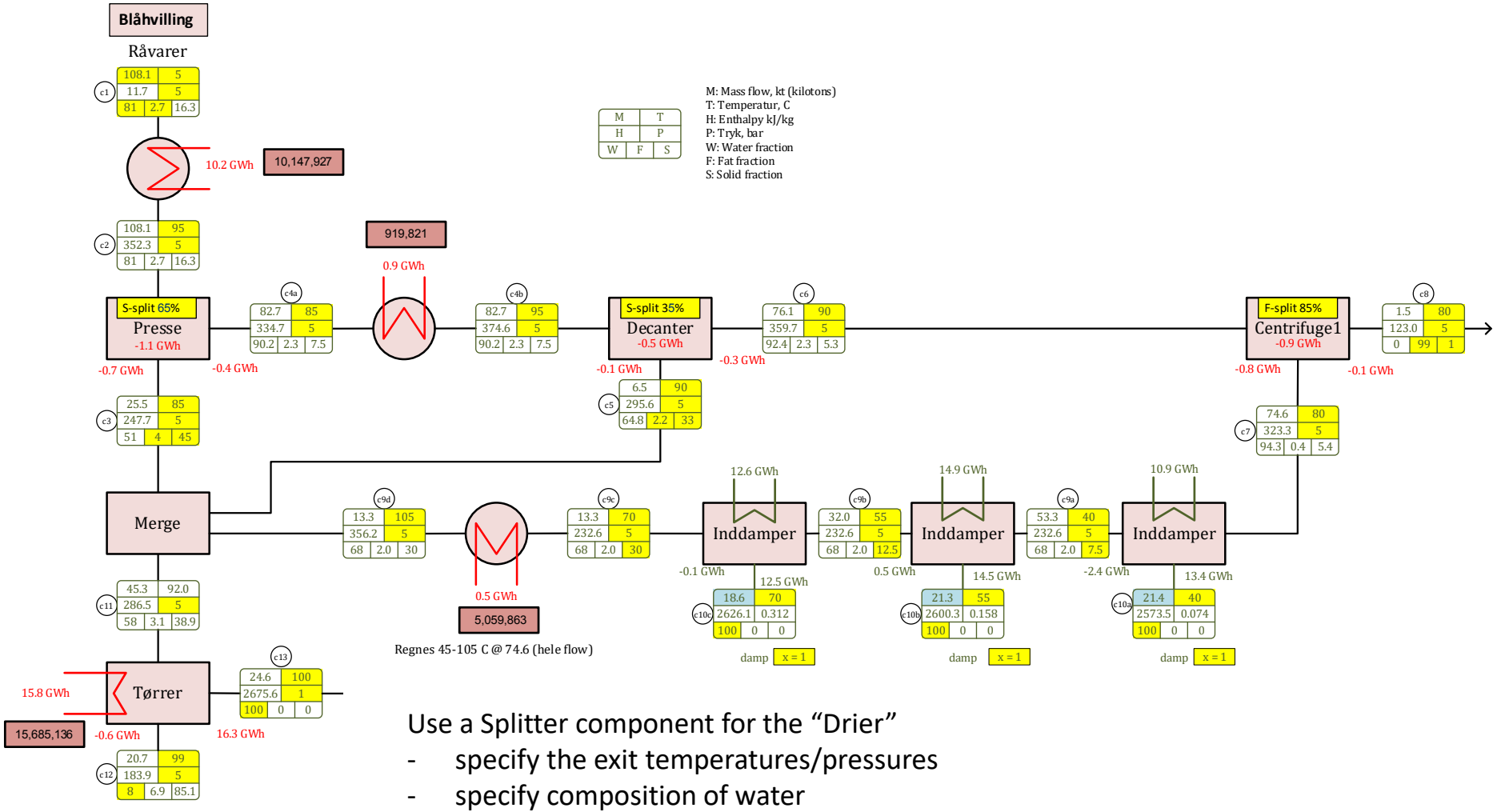



Heater/cooler is the same component, specify the exit temperature/pressure



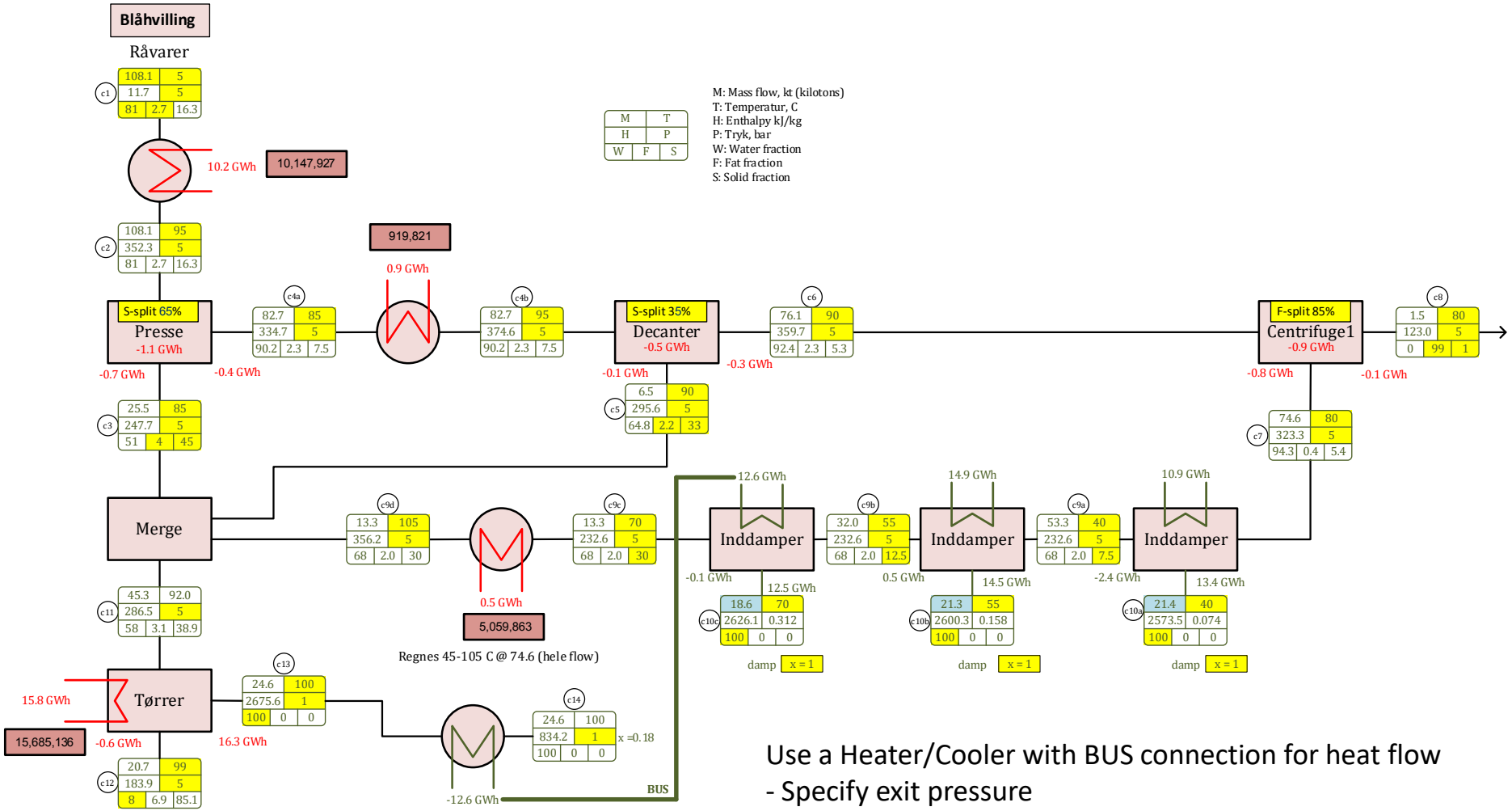

Use a Merge component for Merging

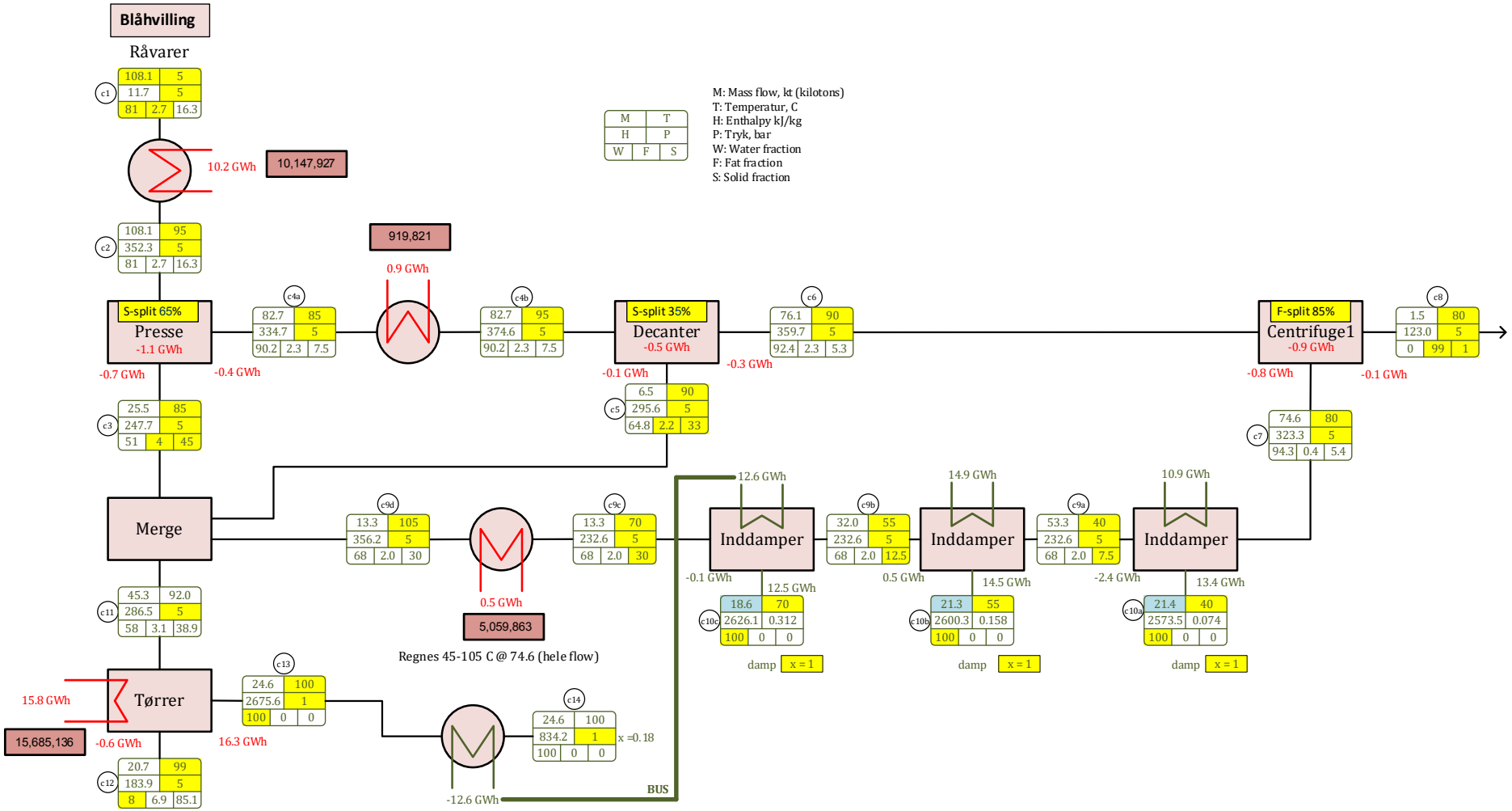
- specify exit pressure




Use a Splitter component for the “Drier”

- specify the exit temperatures/pressures
- specify composition of water


Blåhvilling
Råvarer
c1
108.1 5
11.7 5
81 2.7 16.3
10.2 GWh
10,147,927
c2
108.1 95
352.3 5
81 2.7 16.3
919,821
0.9 GWh
S-split 65%
Presse
-1.1 GWh
-0.7 GWh
-0.4 GWh
c4a
82.7 85
334.7 5
90.2 2.3 7.5
c4b
82.7 95
374.6 5
90.2 2.3 7.5
S-split 35%
Decanter
-0.5 GWh
-0.1 GWh
-0.3 GWh
c6
76.1 90
359.7 5
92.4 2.3 5.3
c5
6.5 90
295.6 5
64.8 2.2 33
F-split 85%
Centrifuge1
-0.9 GWh
-0.8 GWh
-0.1 GWh
c8
1.5 80
123.0 5
0 99 1
c7
74.6 80
323.3 5
94.3 0.4 5.4
c3
25.5 85
247.7 5
51 4 45
Merge
c9d
13.3 105
356.2 5
68 2.0 30
c9c
13.3 70
232.6 5
68 2.0 30
0.5 GWh
5,059,863
Regnes 45-105 C @ 74.6 (hele flow)
12.6 GWh
Inddamper
-0.1 GWh
12.5 GWh
c9b
32.0 55
232.6 5
68 2.0 12.5
14.9 GWh
Inddamper
0.5 GWh
14.5 GWh
c9a
53.3 40
232.6 5
68 2.0 7.5
10.9 GWh
Inddamper
-2.4 GWh
13.4 GWh
c10c
18.6 70
2626.1 0.312
100 0 0
damp
x = 1
c10b
21.3 55
2600.3 0.158
100 0 0
damp
x = 1
c10a
21.4 40
2573.5 0.074
100 0 0
damp
x = 1
c11
45.3 92.0
286.5 5
58 3.1 38.9
15.8 GWh
Tørrer
15,685,136
-0.6 GWh
16.3 GWh
c13
24.6 100
2675.6 1
100 0 0
c14
24.6 100
834.2 1
100 0 0
x =0.18
-12.6 GWh
BUS
c12
20.7 99
183.9 5
8 6.9 85.1
M T
H P
W F S
M: Mass flow, kt (kilotons)
T: Temperatur, C
H: Enthalpy kJ/kg
P: Tryk, bar
W: Water fraction
F: Fat fraction
S: Solid fraction
Use a Heater/Cooler with BUS connection for heat flow
- Specify exit pressure


Blåhvilling
Råvarer
c1
108.1 5
11.7 5
81 2.7 16.3
10.2 GWh
10,147,927
M T
H P
W F S
M: Mass flow, kt (kilotons)
T: Temperatur, C
H: Enthalpy kJ/kg
P: Tryk, bar
W: Water fraction
F: Fat fraction
S: Solid fraction
c2
108.1 95
352.3 5
81 2.7 16.3
919,821
0.9 GWh
S-split 65%
Presse
-1.1 GWh
c4a
82.7 85
334.7 5
90.2 2.3 7.5
c4b
82.7 95
374.6 5
90.2 2.3 7.5
S-split 35%
Decanter
-0.5 GWh
c6
76.1 90
359.7 5
92.4 2.3 5.3
F-split 85%
Centrifuge1
-0.9 GWh
c8
1.5 80
123.0 5
0 99 1
-0.7 GWh
-0.4 GWh
-0.1 GWh
-0.3 GWh
-0.8 GWh
-0.1 GWh
c3
25.5 85
247.7 5
51 4 45
c5
6.5 90
295.6 5
64.8 2.2 33
c7
74.6 80
323.3 5
94.3 0.4 5.4
Merge
c9d
13.3 105
356.2 5
68 2.0 30
c9c
13.3 70
232.6 5
68 2.0 30
0.5 GWh
5,059,863
Regnes 45-105 C @ 74.6 (hele flow)
12.6 GWh
Inddamper
-0.1 GWh
c9b
32.0 55
232.6 5
68 2.0 12.5
14.9 GWh
Inddamper
0.5 GWh
c9a
53.3 40
232.6 5
68 2.0 7.5
10.9 GWh
Inddamper
-2.4 GWh
12.5 GWh
c10c
18.6 70
2626.1 0.312
100 0 0
damp
x = 1
14.5 GWh
c10b
21.3 55
2600.3 0.158
100 0 0
damp
x = 1
13.4 GWh
c10a
21.4 40
2573.5 0.074
100 0 0
damp
x = 1
c11
45.3 92.0
286.5 5
58 3.1 38.9
15.8 GWh
Tørrer
15,685,136
-0.6 GWh
c13
24.6 100
2675.6 1
100 0 0
16.3 GWh
c14
24.6 100
834.2 1
100 0 0
x =0.18
c12
20.7 99
183.9 5
8 6.9 85.1
-12.6 GWh
BUS

# User manual to EEMAP

| | |
|---|---|
| **Projekt:** | **EEMAP** |
| **Recent update:** | **08.07.2024** |

**Disclaimer:** This is a manual for the tool, which should be used as a reference guide. It is still under development and is not yet comprehensive.

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# 1 Introduction

EEMAP is a tool designed to enhance two critical aspects: speed and quality assurance when conducting an energy mapping. The tool enables the user to effortlessly assemble and simulate process and energy flow balances by using predefined building blocks.

EEMAP is designed to be operated by an energy expert or consultant while conducting a real-time energy mapping at the production facility. The tool can also be used by an industrial employee with energy-related knowledge to edit and update the mappings as changes occur in the facility.

The purpose of this guide is to enable the user to build a model that will correctly represent the production site in the most efficient way, while minimizing the chance of errors. This is facilitated by the design of the program where the site is automatically broken down to the relevant subsystems one at a time. This guide will not contain concrete documentation on how individual components should be used and how to add custom media models. Instead, an overview of the program is available along with a step-by-step guide to building a working and stable model.

The tool is developed by the companies IPU, DTU and Viegand Maagøe with funding from the Danish Energy Agency through the Energy Technology Development and Demonstration Program (EUDP).

## 1.1 Instalment

EEMAP v0.7.7 can be found here and is available as an offline desktop app for PC users.

Download the file and install it directly on your computer.

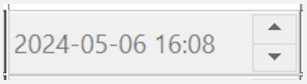
### 1.1.1 Typical errors

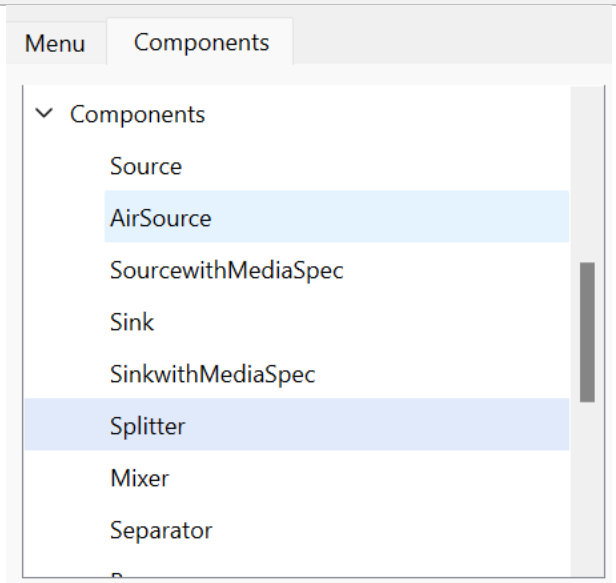
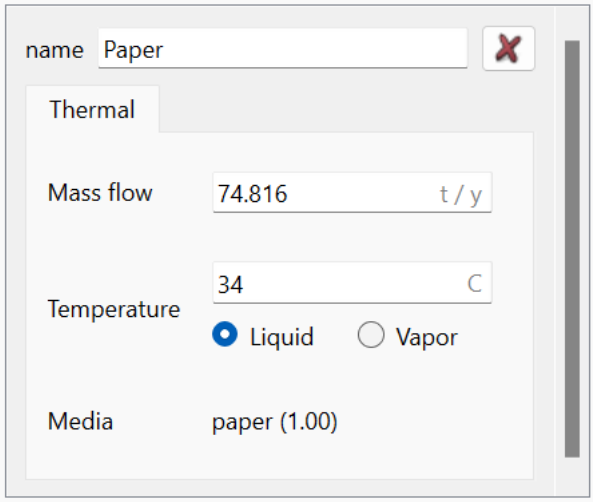
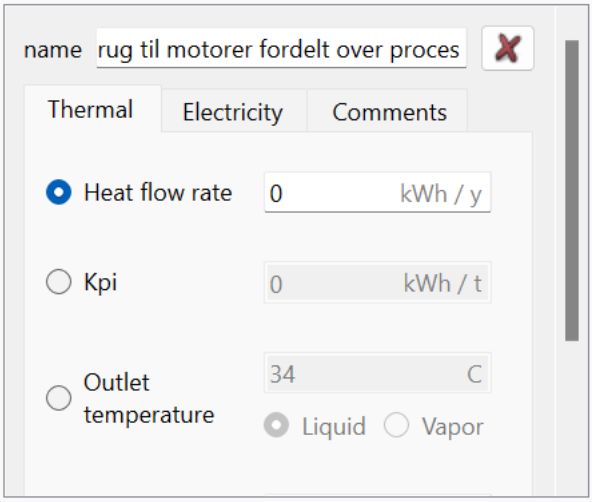
The tool has not been tested by enough users to compile a list of typical errors. However, below are a few hints for troubleshooting installation problems.

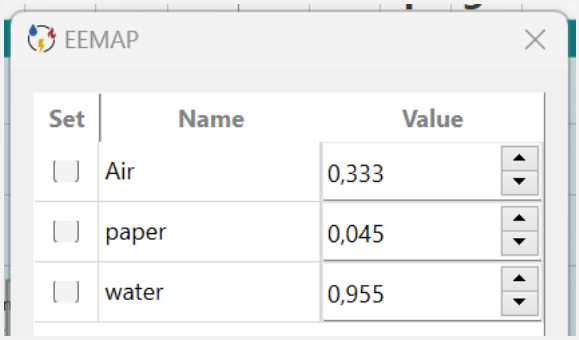
- When copying and pasting the license key, make sure to delete any trailing spaces. The key will not work if there are spaces at the end.
- EEMAP is currently only available for PC users.
- Check your security settings if you experience any trouble with downloading the programme.
- Try to restart your computer.

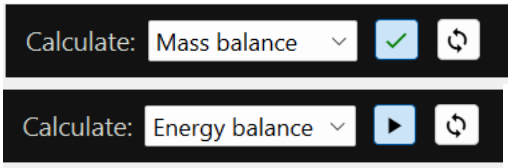
## 1.2 Symbol explanation

Below are the different symbols/features used throughout the tool, along with an image and an explanation of what each item/icon means. The explanations are categorised in tables explaining tables, menu icons, component specifications, etc.

| 1. Tables | | |
|---|---|---|
| **Item** | **Image** | **Explanation** |
| **Table arrows** |   | Press the top or bottom arrow to add or decrease the number. |
| **No cell boundary and grey text content** |   | The field is not editable and most likely a cell that is calculated based on other entries in the table. |
| | | |

| 2. Calculate Mass or Energy Balance | | |
|---|---|---|
| **Item** | **Image** | **Explanation** |
| **Insert a component** |  | The menu items in the 'Mappings and Data' have a tab called 'Component'.<br><br>Use the component library to set up your mappings by using predefined components. |
| **Add data to calculate** |  | Add the properties relevant to the component in the left menu.<br><br>Media properties are defined in the menu 'Production details' > 'Media specification' and 'Media definition'. |
| **Add data to calculate the energy balance** |  | Switch between the property tabs to add thermal and electrical properties to the component.<br><br>This is only possible based on the component specifications. |

| | | |
|---|---|---|
| **Media split and media out** |  | Define media flows out of the component if the component specifies this. It's typically for components where the stream in is split into two like a press where you have liquid and cake.<br><br>Enter the value of the media fraction if it is known and set a check mark. If not, then leave the row and make EEMAP calculate it for you (requires the proper circumstances).<br><br>Enter the media fraction in the cell value. |
| **Update connector guess values** |  | Press on the update button to update the connector 'guess values', meaning the solving process will start with the result found as first input. This leads to the model solving quicker. |

| **2. Menu** | | |
|---|---|---|
| **Item** | **Image** | **Explanation** |
| **'Play' button** |  | Switch between calculating the mass balance and the energy balance.<br><br>Check if the mapping is solved by pressing 'play'. |
| **Black menu icon** |  | The mapping has not been calculated. Go to the page and press on the play button to start the calculation. |

| | | |
|---|---|---|
| **Green menu icon** | Process mapping | The mapping has been calculated and is reflected in the results section. |
| **Red menu icon** | | There are some errors in the calculations. Check the error messages that appear and try to solve the mass or energy balance. |

## 1.3 System structure

The tool has been designed to follow the energy mapping approach used by the energy consultants at Viegand Maagøe. This approach is reflected in the left menu, where it is recommended to approach it from top to bottom as the information placed in the previous main sections feed into the following section. E.g. results can only show once information has been filled in the section Mappings and Data.

## 1.4 'Company Profile'

Type in the information about the company and the primary contact information of the company. A company can also use it to fill out the information of the consultant hired to conduct the energy mapping. In general, is this tab mainly relevant to differentiate between the different mappings and people involved.

## 1.5 'Mappings and data'

'Mapping and data' is not clickable but contains of several subcategories. This is where the mapping starts.

### 1.5.1 Production details

Fill in the production details of the company. This section is divided in 5 tabs all referring to the different aspects of the production details.

#### 1.5.1.1 Energy specification

Add the company's yearly purchased energy. Note the division between electricity, natural gas, liquid fuel, and solid fuel. The purchased energy information points are usually tracked in the accountant department via the invoice.

| Table item | Description |
|---|---|
| Energy user | Specify the energy user connected to the invoice. This information can create more transparency when looking at the energy supply later in the process. |
| Amount | Amount of energy used. |
| Kr/kWh* | Price for one unit of energy |
| Cost | Calculated based on the amount and kr/kWh |
| CO2e kg/kWh* | Calculated based on standard emission factor divided with the kWh. This field is editable. |
| CO2e | Calculated based on standard emission factor. This field is editable. |
| Invoice no. | For future reference. |
| Reference person | Input the source of information with name and last name. This aids future reference and task delegation, especially for those unfamiliar with the project. |
| Comments | Add a comment for future relevance. |

*The valuta and energy unit reflects what has been chosen in the tool settings (view the toolbox icon).

#### 1.5.1.2 Media definition

Here the media models are defined, these supply the thermodynamic properties to be used in calculations. Specifically heat capacity and density is shown, but these are not the only properties defined by the media models.

| Table item | Description |
|---|---|
| Media | Name the basic media components. E.g. protein. A standard name is given with the media model, but this can be changed. |
| Media model | Dropdown list with predefined media models based on XX database and custom-made media models to handle temperature limitations. |
| Heat capacity | Predefined value based on the media model. Possible to change if it does not align with actual circumstances. |
| Density | Predefined value based on the media model. Possible to change if it does not align with actual circumstances. |
| Reference person | Input the source of information with name and last name. This aids future reference and task delegation, especially for those unfamiliar with the project. |
| Comments | Add a comment for future relevance. |

#### 1.5.1.3 Media specification

The media specification outlines both the media consumed and produced. This section is closely connected with the media definition as the various media used here are derived from the media components defined within the media definition.

| Table item | Description |
|---|---|
| Media | Name the basic media components. E.g. protein |
| Amount | Dropdown list with predefined media models based on CoolProp databases[1] and custom made media models in order to handle … |
| Media components | Predefined based on the media model. Possible to change if it does not align with the reality |
| Section tag | Predefined based on the media model. Possible to change if it does not align with the reality. |
| Reference person | Input the source of information with name and last name. This aids future reference and task delegation, especially for those unfamiliar with the project. |
| Comments | Add a comment for future relevance. |

[1] The documentation can be found here: https://tespy.readthedocs.io/en/main/modules/fluid_properties.html#fluid-properties. Specifically the HEOS and INCOMP backends are used

# 2 Building the model – 'Best practice'

## 2.1 Production details

Before modelling the process, it's recommended to define the media in the process and the energy carrier groups. If the data for total energy usage is available this should also be defined before modelling starts.

### 2.1.1 Defining medias

In EEMAP medias are the components that make up a product. Milk is used as an example: a detailed model might represent it as part water, protein, and fat. A simpler model could represent milk as purely water. Both are approximations but the approximations are made from media models available in EEMAP. In defining medias these base medias are added to the model and named appropriately.

Medias in the process should be defined before mapping starts. However, this step should be taken to prepare for smooth modelling, not as a stop to the modelling process. If there's uncertainty around how a product should be defined, or which base medias should be used it is suggested to agree on a simple approximation. Once the modelling progresses new medias can easily be added, and compositions of product streams can be changed in the process mapping.

It is possible to define custom equations or constant values as media models. This is discussed separately. It's important to not have the same media model occur twice under different names as this will result in errors and the models will fail to converge.

### 2.1.2 Energy carrier groups

Energy carrier groups are meant to group the energy use of several components running off of the same energy distribution system. This could be everything driven by the steam boilers, a hot oil distribution system or cooling water.

It's again recommended to define the necessary energy carrier groups before mapping, however additional groups can be added as the need arises.

## 2.2 Process mapping

For the process mapping it is recommended to first build a simple representation of the entire production, or the entire subdivision of the production that is to be mapped. For this simple representation it's recommended to only solve for mass balance. This ensures the fewest possible inputs and will translate the process to a simple EEMAP model.

Once the simple model is solved for mass and energy balance it is recommended to enhance the parts of the model that needs immediate refinement. This should result in a more advanced model, but a better representation of the site being mapped.

In general, it is strongly recommended to be consistent with already established names and denominations in the company so the mapping will be easily recognizable for the end users.

### 2.2.1 Simple model

For the simple model it's beneficial to think in terms of mass and energy whether a step is relevant to include in the process. Examples of process steps that could be omitted initially include electrical consumption caused by transport of product from one process step to another, rearranging the product to be ready for next process with no mass split or significant energy use or a split of the product line to multiple smaller lines that will join together before the next process step.

These might all be omitted to achieve a simple model, however, should these be important to the company's understanding of the process, or important to recognize the sites layout, this process step can be included.

For the simple model it is strongly recommended that no advanced components are used, this would be heating exchangers for heat transport between two streams in the process mapping (TwoStreamHeatExchanger), driers driven by a stream in the process mapping (TwoStreamDrier) and an evaporator driven by a stream in the process mapping (TwoStreamEvaporator).

The next step is to solve for an energy balance, as this requires more inputs on almost all components. It's strongly recommended to initially disable all but the first component of the model and then step through the model one component at a time, adding the extra input and checking it's solving correctly.

This approach ensures that all components are fully defined, the alternative is to try and give all inputs to all components at once, which has a much greater chance of human error. Finally, this second pass through all components ensures that the first pass can be less thorough, which means a simple mass balance model can be achieved quicker.

Typically, data for mass flow and energy use can be well educated guesses or approximations known to the company in the simple model. It's recommended to add a comment to the components with unverified data to ensure it can be improved in the advanced model.

### 2.2.2 Advanced model

Updating the simple model to an advanced model should mostly concern inserting verified data into all components, expanding on simplified processes by splitting them into the appropriate steps and adding more complex components like heat exchangers for internal heat recovery.

The simple model should allow for identifying potential improvements to the model's accuracy and where detail is missing. The areas that need expanding should be prioritized based on the understanding of the process by the company and the impact of the components on the energy mapping.

Refining the simple model to the advanced is not described in further detail as this work will depend highly on the process being mapped. It's recommended that this is done in close collaboration with the company.

## 2.3 Building mapping

The building mapping is based around a known amount of energy consumption. This is assumed since it's required for companies to disclose their heat demand for space heating as it's taxed at a higher rate than energy going to process needs.

This known energy consumption for space heating is then divided onto buildings by supplying a percentage in each building node added. It's recommended that backdrop nodes are used to roughly sketch the layout of the site being mapped, this makes it easier to identify which building is which.

## 2.4 Support mapping

For the support mapping a node is added for each support system being mapped. In this node a constant energy usage is supplied. As the system is very simple it's only recommended to ensure that the nodes are placed within the initial view of the program so they're easy to see when switching to support mapping and that the nodes are organized in a fashion that makes them easy to read.

## 2.5 Energy supply mapping

The energy supply mapping essentially aims to pair the primary energy purchased with the energy consumption mapped in the software. As the consumptions are only found when the previous mappings

are done it's recommended to only start the mapping of the energy supply system once at least simple models of the process, buildings and support systems are done.

It is possible to start the mapping process before the other models are done, in this case the model cannot be solved but the components can be added to the conversion and distribution networks. Importing the consumptions allows the model to solve the energy balance and through the mapping degree components a resulting mapping degree can be found.

It's important to note that adding specific flows of energy could be necessary through the "energy flow" component. This allows systems with splits of energy to be distributed between e.g. multiple boilers all delivering energy to the same energy distribution system.

# 3 Results

Different results can be found for the mappings done, fundamentally they all contain data on a component level on thermal and electrical consumption. This data can be used for detailed analysis of components, documentation of the system or for other purposes. The data is available on all mappings through the "Results" menu item. Each mapping has different visualizations and a list view of the energy data for its components in the corresponding menu items. Each will be described in turn in the coming sections.

## 3.1 Process mapping (results)

The process mapping results contains data on a component level for each component in the process mapping. It also has a mass-sankey diagram which can be manipulated to produce a graphic representation of the mass flow in the process mapping. Diagrams showing the heating and cooling energy of each component through bar- and pie charts. This makes it easy to identify components with high impact on heating and cooling consumption.

## 3.2 Building mapping (results)

The building mapping results are available on a component basis as well as in diagrams. The building mapping shows both heating and cooling in diagrams, however the building mapping is only for the heat consumption of the buildings. The electrical data can be found on a component basis.

## 3.3 Support mapping (results)

The support mapping considers all energy as heating energy, and as such any consumption added in support mapping shows in the heating section. Both the thermal and electrical consumptions can be found on a component basis.

## 3.4 Energy supply (results)

For the energy supply mapping the results are also available on a component basis. Apart from the energy diagrams the cost and CO2 emissions are also represented in diagrams for both heating and cooling.

# 4 Add-on analysis

To use EEMAP add-ons, the process mapping must have been completed and energy balance must have been calculated.

OBS: Working with the add-ons requires a higher screen resolution to display all elements on the page. Switch to a larger screen if you are using a small laptop screen.

## 4.1 Pinch Analysis

### 4.1.1 Introduction to Pinch Analysis

Pinch analysis is a methodology used in process engineering for optimizing the energy efficiency of industrial processes, particularly in the context of heat exchanger networks.

Pinch Analysis is used to obtain “energy targets”, that is, the minimum heating and cooling utility consumption. These targets are absolute thermodynamic limits, showing what the process can achieve if the heat recovery, heating and cooling systems are correctly designed. Pinch Analysis can also help guide the design process of the heat recovery system, achieving a network design that meets these targets.

### 4.1.2 Composite Curves

Composite Curves (CC) are graphical tools used in pinch analysis. They represent the cumulative heat capacity of all hot and cold streams within a process, plotted on a temperature-enthalpy diagram. The hot composite curve shows the total heat available from hot streams, while the cold composite curve shows the total heat required by cold streams. These curves indicate at what temperatures energy demands are found and what temperatures contain available heat for heat recovery.

### 4.1.3 Grand Composite Curve

The Grand Composite Curve is derived by adding the hot and cold composite curves, plotting net heat flow (enthalpy) against temperature. The GCC highlights the pinch point, where the net heat flow is zero, and differentiates between heat surplus (above the pinch point) and heat deficit (below the pinch point). This graphical representation helps identify the minimum external heating (on the top of the curve) and cooling (on the bottom of the curve) requirements, showcasing opportunities for heat recovery and optimal heat exchanger network design.

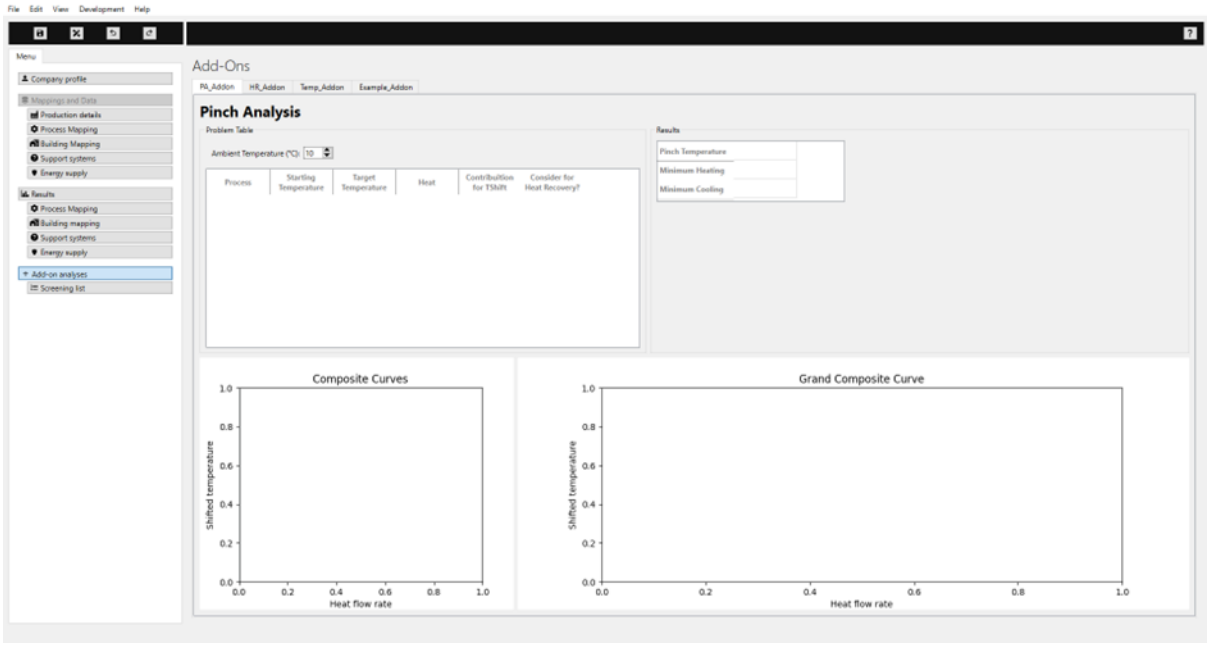
### 4.1.4 Pinch Point

The pinch point in pinch analysis is the temperature at which the closest approach between the hot and cold streams occurs, characterized by the minimum allowable temperature difference. It represents the optimal balance where the heat transferred from hot to cold streams is maximized, without violating thermodynamic constraints. It is found by plotting the Grand Composite curve and corresponds to the minimum energy point. By identifying the Pinch Point temperature, engineers can follow the “rules of Pinch analysis” to design a heat exchanger network that meets the energy targets:

- Heating should only take place above Pinch Point temperature.
- Cooling should only take place below Pinch Point temperature.
- Heat recovery across Pinch Point temperature should be avoided.

## 4.2 Pinch Analysis in EEMAP

To access the Pinch Analysis add-on page, you must press the “Add-on analyses” page on the left menu. The first tab corresponds to the basic Pinch Analysis tool of EEMAP. It looks as follows:




### 4.2.1 Problem Table

The input values to perform pinch analysis and find the energy targets of the process are represented in the problem table on the top-left of the page. In this table, the temperatures and heat requirements (first three columns) are derived from the results of the process mapping calculations. The “Ambient Temperature” is used to calculate the excess heat available in the “Sinks” specified during process mapping. Here, it is considered that these sinks are available from their initial temperature to this ambient temperature. Additionally, the components included in the analysis are the evaporators, driers, and heat exchangers. A process with a starting temperature lower than its target temperature will be considered a heat requirement, while a process with a starting temperature higher than its target temperature will be considered a cooling requirement/excess heat.

Next, the column “Contribution to TShift” represents the minimum approach temperature for heat exchange in each process. By default, processes including “Air” as the fluid will have a Contribution to TShift of 10 K, and other streams will have a contribution of 5 K. These values can be modified, usually depending on the heat transfer coefficient of the fluid involved. If the process does not require a large driving temperature difference, that is, in fluids with a high heat transfer coefficient, this value can be lowered.

The last column, “Consider for Heat Recovery,” indicates if the process should be considered in the analysis. If heat recovery in a given process is not possible, it can be ignored during the analysis.

### 4.2.2 Results

EEMAP performs Pinch Analysis automatically, and the main results are shown in the table on the top-right. The results include the Pinch Temperature, Minimum Heating, and Minimum Cooling (energy targets).

Designing the heat recovery network according to Pinch Analysis principles allows for reduction of heating and cooling utilities from their current state (refer to 'Process Mapping Results') to these targets. Heat recovery across the pinch temperature is prohibited, with heating and cooling limited to above and below this temperature, respectively. Pinch-violating processes, where these rules are not respected, can be identified to target energy efficiency measures.

Additionally, the Composite Curves and the Grand Composite Curve are displayed on the bottom-left and bottom-right of the page, respectively. The Composite Curves indicate the temperatures at which total energy requirements (heating and cooling) occur, while the Grand Composite Curve specifies not only the Pinch Temperature but also the energy targets (minimum heating and cooling).

## 4.3 Heat recovery network

While the algorithm for the design of energy efficient energy networks starting from the GCC are well defined and effective, the energy efficient designs are often complex and expensive. Another approach taken for the design of heat exchanger networks is considering the estimated investment costs of the elements of the network, that is, the heat exchangers to minimize the overall cost of the network though mathematical programming. These methods do not always provide the most energy efficient heat recovery system, but the most cost-efficient.

The TransHEN program presented by Hall et al. is included in the second add-on analysis in EEMAP. This method is based on GEKKO for the non-integer linear programming model and has effectively been used to design cost-effective heat recovery networks. The networks presented in the second add-on also consider the mapped heat streams, similarly to the PA, to propose a heat recovery network.

First, the unit costs of the heat exchangers as well as the heating and cooling utility are used as inputs before generating the network.

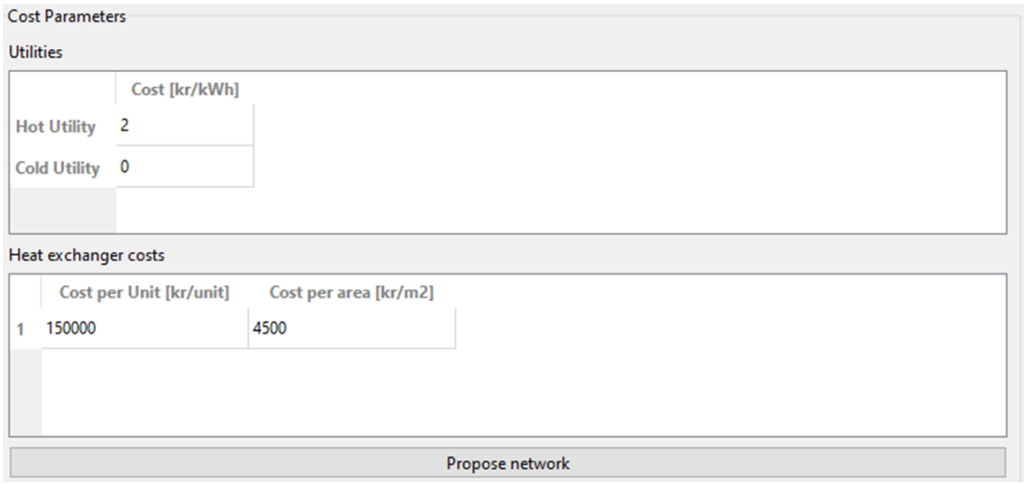



Figure 1: Cost inputs for heat exchanger network generation in EEMAP through TransHEN

Next, the heat exchanger network is generated, minimizing utility and investment costs.

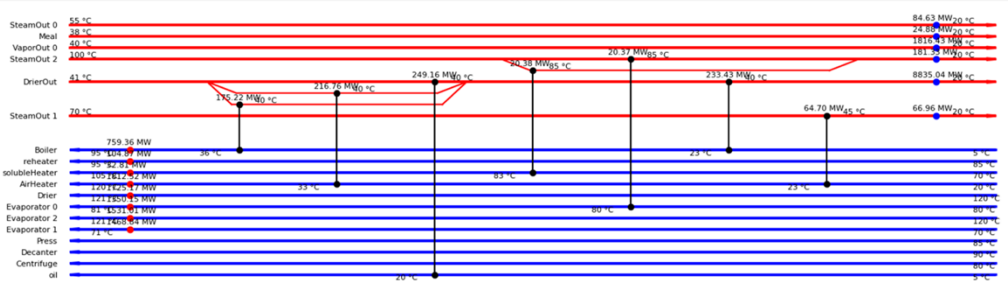



Figure 2: Example of a proposed heat exchanger network solution in EEMAP using TransHEN

The heat recovery heat exchangers (black) exchange heat from hot streams (blue) to cold streams (red). The investment costs are also shown together with the economic savings the relative energy savings.

Network Results

| | Investment costs [kr] | Annual savings [kr/year] | Reltaive savings [%] |
|---|---|---|---|
| 1 | 1,271,791 | 12,254,723 | 7.38 |

Figure 3: Economic and energy savings from the proposed heat recovery network.

The proposed networks can be used as preliminary starting points for the design of cost-effective heat exchanger networks that could improve the efficiency of the plant.

## 4.4 Temperature analysis

The temperature analysis feature in the EEMAP tool serves as an optional add-on that provides insights into the relationship between the temperature demands of various processes and energy consumption. This analysis visually illustrates energy usage both cumulatively and per degree Celsius, enabling users to understand and gain an overview of the temperature variations. By analyzing these temperature-dependent energy demands, companies can identify opportunities for optimization and more effectively manage their energy resources. The analysis output is visual graphs – an example can be seen in the figure below.

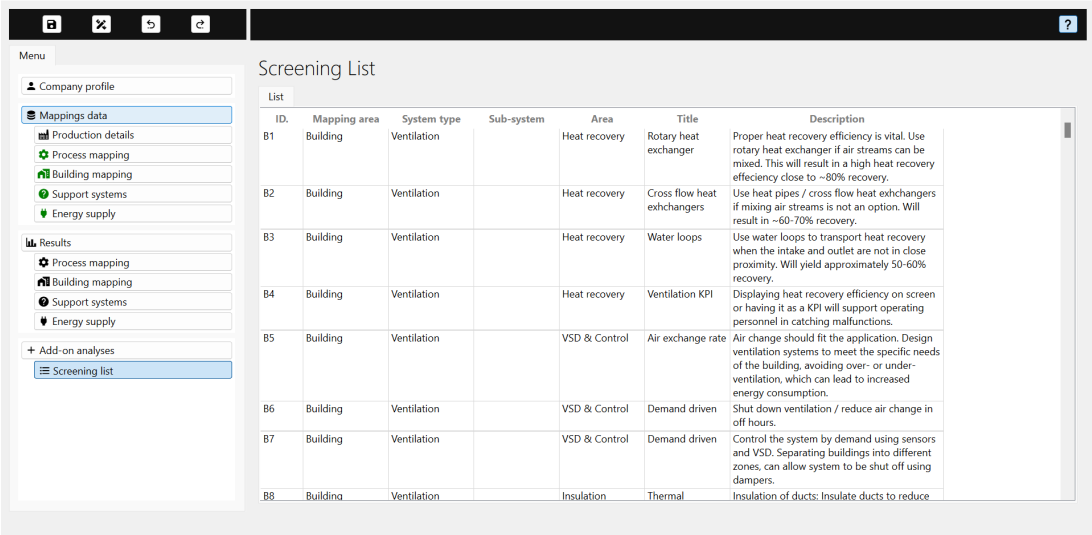



*Figure 4. An example of the Temperature analysis output*

## 4.5 Screening list

One of the most valuable outcomes of conducting an energy mapping of a company's processes is the generation of data-driven insights into potential energy efficiency projects. To capitalize on this advantage and embed it as a core feature, EEMAP includes a comprehensive "Screening List" of potential energy savings and efficiency projects.

This "Screening List" is organized within EEMAP and is accessible via the sub-tab "Screening list". It categorizes potential projects based on various criteria, such as the area of mapping (e.g., Process, Building, Support Systems, or Energy Supply) and system type (e.g., Ventilation, CIP, Pasteurizer), as well as by sub-system (e.g., UHT, Centrifuge). This structured approach not only provides users with a clear view of the different energy efficiency opportunities available but also facilitates easier decision-making regarding where to invest in energy-saving measures (see screen shot below).




By leveraging this organized and detailed screening list, users can quickly identify and prioritize projects based on their specific needs and potential impact. This feature turns EEMAP into a powerful tool for planning and executing energy efficiency strategies, thereby enhancing the overall value and effectiveness of energy management initiatives within any organization.

# EEMAP
# Energikortlægningsværktøj

1. Workshop d. 10. November 2022 ved FF Skagen




# Workshop 1 – In  FF Skagen , Sakgen, November 2022

# Formålet med mødet

- Få input til en produktspecifikation
- Få input til en beskrivelse af brugerkrav
- Prioritering af indsatsen/opgaverne
- Fælles billede af opgaven/projektet

# Agenda

26. september 2024

| | | |
|---|---|---|
| 1. | 10:00-10:30: | Status – hvor langt er vi? |
| 2. | 10:30-11:00: | Præsentation af kortlægning<br>• 1 Skjern Papir<br>• 2 Ovodan<br>• 3 FF-Skagen |
| 3. | 11:00-12:00: | Præsentation af FF Skagen – rundvisning |
| | 12:00-12:30: | Frokost |
| 4. | 12:30-13:00; | Præsentation af kortlægningsværktøjet |
| 5. | 13:00-14:00: | Drøftelser af problemstillinger, ønsker, detaljeringsgrad mm.<br>• Add-ons<br>• Outputs<br>• User interface |
| 6. | 14:00-14:15: | Plan for det videre forløb |
| 7. | 14:15-14:30: | Kommunikation |
| 8. | 14:30-14:45: | Samarbejdsaftale |
| 9. | 14:45-15:00: | Evt. |

# Status rundt om bordet

## Hvor langt er vi?

**To Do from MoM**

IPU:

- Develop simple component and make a first draft which will be presented at our next meeting

Viegand Maagøe:

- Give a first revision on the agreement. Using track changes and rewriting the standard template so it will fit on to our project setup.
- Share Excel spreadsheet with the mass balance drack and drop principals.
- Make a time schedule with more details
- Make a long list of Add-on and outputs.

DTU

- Will investigate if it will be possible to include master student in the project starting form 2024. Note the project must NOT relay on the outcome of the Master project. The projects can only contribute with additional analysis of component element. Nasrin will start looking for students

# Tidsplan

## Overblik

| Year/År | | | | | | | | 2023 | | | | | | | | | | | | 2024 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work packages/Projektets arbejdspakker:** | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 |
| **WP1 - Project Management** | | ■ | | | | | | | | | | | | ■ | | | | | | | |
| **WP2 - Scoping** | | ■ | | | | | | | | | | | | ■ | | | | | | | |
| **WP3 - Mapping state-of-the-art** | | ■ | | | | | | | | | | | | ■ | | | | | | | |
| **WP4 - Field Mapping (Without Tool)** | | ■ | | | | | | | | | | | | ■ | | | | | | | |
| **WP5 - Programming** | | ■ | | | | | | | | | | | | ■ | | | | | | | |
| **WP6 - Add-on Analyses** | | ■ | | | | | | | | | | | | ■ | | | | | | | |
| **WP7 - Field Test (With Tool)** | | ■ | | | | | | | | | | | | ■ | | | | | | | |
| **WP8 - Maturing and Analyses Expansion** | | ■ | | | | | | | | | | | | ■ | | | | | | | |
| **WP9 - Communication** | | ■ | | | | | | | | | | | | ■ | | | | | | | |
| **Milestones/Milepæle** | | | | | | | | | | | | | | | | | | | | | |
| M1 - Design Specifciation Completed | | | | | | | X | | | | | | | | | | | | | | |
| M2 - Techonology Parameter Table Completed | | | | | | | | | X | | | | | | | | | | | | |
| M3 - First version ready for field testing | | | | | | | | | | | | | X | | | | | | | | |
| M4 - Finalized Tool | | | | | | | | | | | | | | | | | | | | X | |
| M5 - Presentation at ECOS Conference 2023 | | | | | | | | | | | | | X | | | | | | | | |
| **Commercial milestones/Kommerc. milepæle** | | | | | | | | | | | | | | | | | | | | | |
| CM1 - Project Finalization | | | | | | | | | | | | | | | | | | | | X | |
| CM2 - Mapping of potential add-ons and their commercial potential | | | | | | | | | | | | | X | | | | | | | | |
| CM3 - Model proof of concept in operational environment | | | | | | | | | | | | | | | | X | | | | | |

WP 1-5 kick-off 2022

WP 6-9 kick-off 2023

# Work Packages (kick-off 2022)

## Deliverables and milestones overview

| | |
|---|---|
| **Name of work package** | Project Management |
| **Number of work package** | 1 |
| **Leader and partners of work package** | Lead: Viegand Maagøe<br>Partners: DTU and IPU |

**Deliverables/results of work package**

Quarterly project status meetings with the main project organization will be held and documented.

**Technical and commercial milestones**

CM1 Project Finalization

| | |
|---|---|
| **Name of work package** | Scoping |
| **Number of work package** | 2 |
| **Leader and partners of work package** | Lead: Viegand Maagøe<br>Partners: DTU, IPU, FF Skagen, Company X and Skjern Papir. |

**Deliverables/results of work package**

Minimum Viable Product specification, User journey description and user requirements, Software Design Specification Report.

**Technical and commercial milestones**

M1 Minimum viable product created, user journey established, and Design specification completed

Deliver EOY22

| | |
|---|---|
| **Name of work package** | Mapping state-of-the-art |
| **Number of work package** | 3 |
| **Leader and partners of work package** | Lead: DTU<br>Partners: Viegand Maagøe, IPU |

**Technical and commercial milestones**

M2 Documentation Report and Database Technology key parameter table

| | |
|---|---|
| **Name of work package** | Field Mapping |
| **Number of work package** | 4 |
| **Leader and partners of work package** | Lead: Viegand Maagøe<br>Partners: FF Skagen, Company X and Skjern Papir. |

**Deliverables/results of work package**

- 3x Energy Mapping in the existing Excel template.
- 3x Screening list for the partner companies.

Deliver EOY22

| | |
|---|---|
| **Name of work package** | Programming |
| **Number of work package** | 5 |
| **Leader and partners of work package** | Lead: IPU<br>Partners: Viegand Maagøe, DTU |

**Deliverables/results of work package**

- Minimum viable product
- Software Tool Version 1.
- User manual

**Technical and commercial milestones**

M3 First version ready for field testing.

# Work Packages (kick-off 2023)

## Deliverables and milestones overview

| | |
|---|---|
| **Name of work package** | Add-on Analyses |
| **Number of work package** | 6 |
| **Leader and partners of work package** | Lead: DTU<br>Partners: Viegand Maagøe, IPU |

**Deliverables/results of work package**

The three methods will provide additional results for the parts of an energy mapping and optimization related to the data collection phase, the analysis phase and the optimization phase. The methods will be analysed for the cases in the project. Based on the results of these assessments, they will be developed for implementation in the tool.

**Technical and commercial milestones**

CM2 Mapping of potential add-ons and their commercial potential

| | |
|---|---|
| **Name of work package** | Field Test |
| **Number of work package** | 7 |
| **Leader and partners of work package** | Lead: Viegand Maagøe<br>Partners: IPU, DTU, Avista Green, Royal Unibrew and PPG Coatings Danmark A/S. |

**Deliverables/results of work package**

5 Energy Mappings in the set timeframe of 3 days each.

**Technical and commercial milestones**

CM3 Model proof of concept in operational environment

| | |
|---|---|
| **Name of work package** | Maturing and Analyses Expansion |
| **Number of work package** | 8 |
| **Leader and partners of work package** | Lead: IPU<br>Partners: Viegand Maagøe, DTU |

**Deliverables/results of work package**

Finalized Software Tool.

**Technical and commercial milestones**

M4 Finalized Software Tool.

| | |
|---|---|
| **Name of work package** | Communication |
| **Number of work package** | 9 |
| **Leader and partners of work package** | Lead: Viegand Maagøe<br>Partners: DTU, IPU |

**Deliverables/results of work package**

- Three Case Descriptions
- Two (non-scientific) articles, published in relevant media
- One conference paper
- Two conference presentations
- One scientific journal article

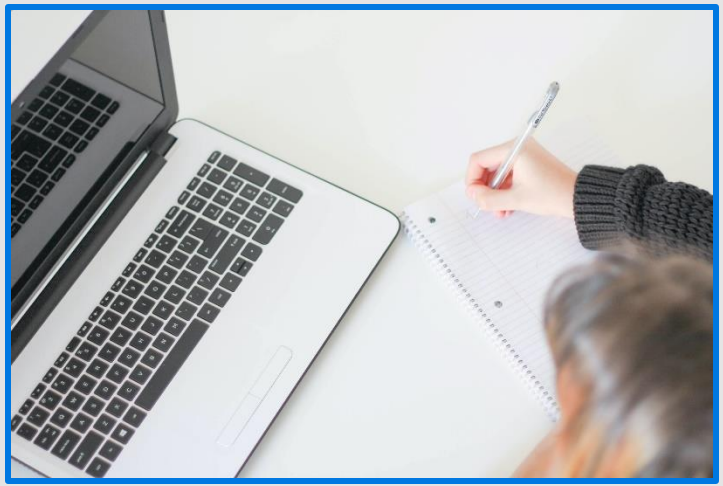
**Technical and commercial milestones**

M5 Presentation at ECOS Conference 2023

# EUDP Reporting Summary

All necessary templates can be found at

[eudp.dk/efter-tilskud](eudp.dk/efter-tilskud)



## Coorporation Agreement

6 months after funding commitment

## Payment Request

Biannually – no fixed deadline

## Change Request

During project period

## Annual Report

Annually 30/06

## Final Reporting

Technical reporting by end date

Financial reporting 2 months after end date

# Dissemination

- When disseminating via websites, press releases, etc. it must be clear that the project has been granted EUDP funding
- It should also be ensured in case of media coverage of the project
- Please notify EUDP when submitting press releases and similar



**Amanda Videbæk Laasholdt**
Communication, EUDP
amlt@ens.dk

Communication plan

Press releases

Short project film

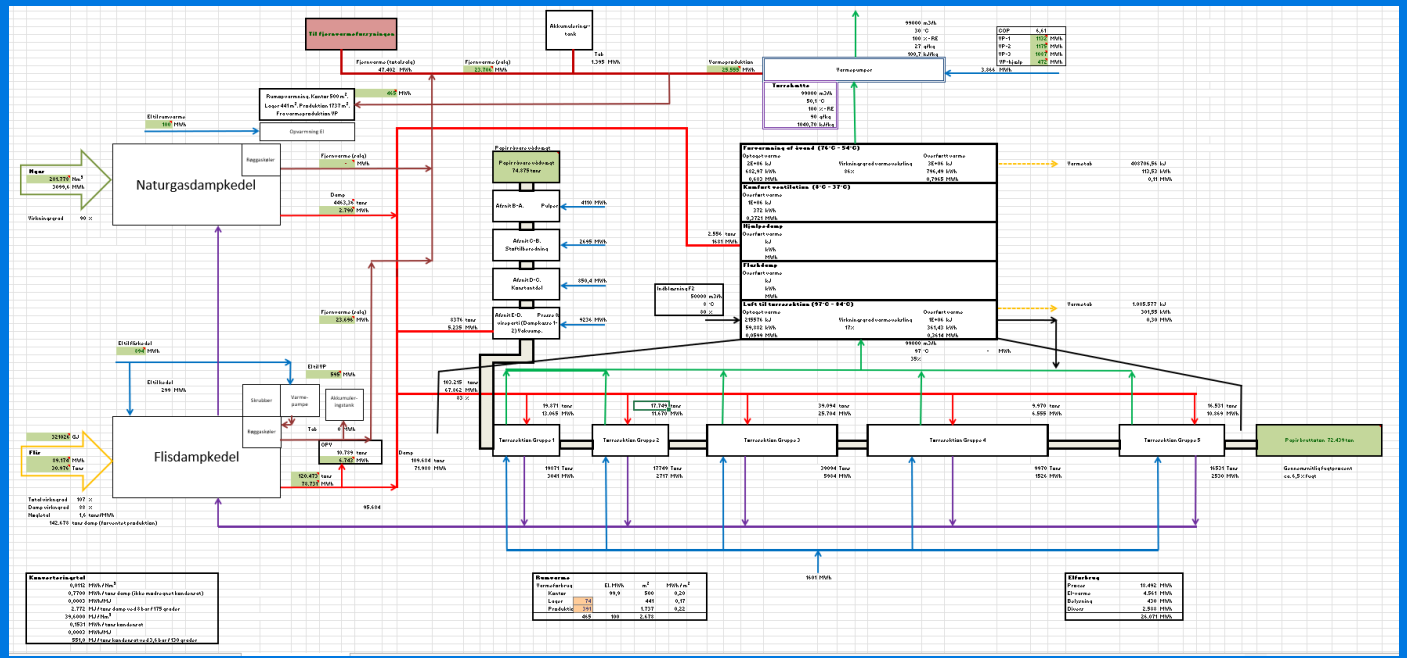
News for newsletters

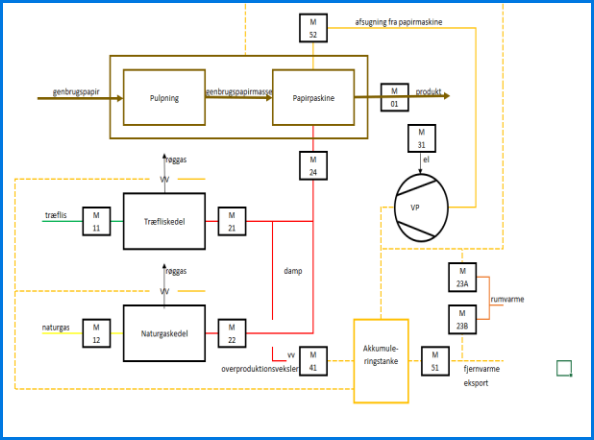
Events and network

# Kortlægninger

1. Skjern Papir
2. Ovodan
3. FF-Skagen

# Skjern Paper

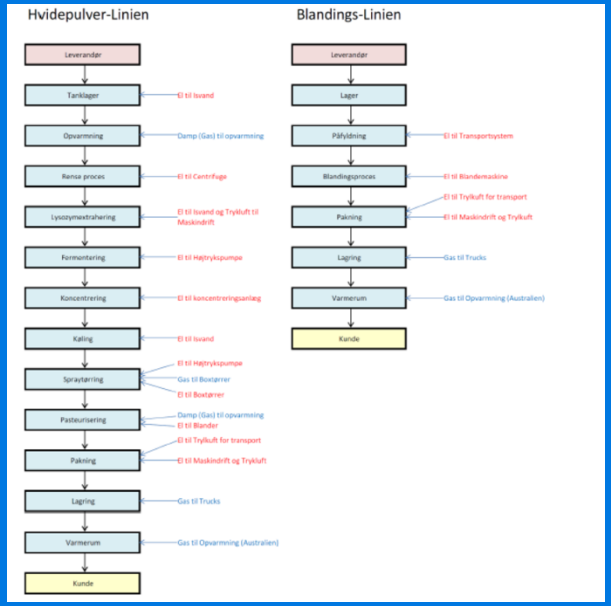





Status:

- Energikortlægning er på plads
- Første møde med Skjern Paper er afholdt

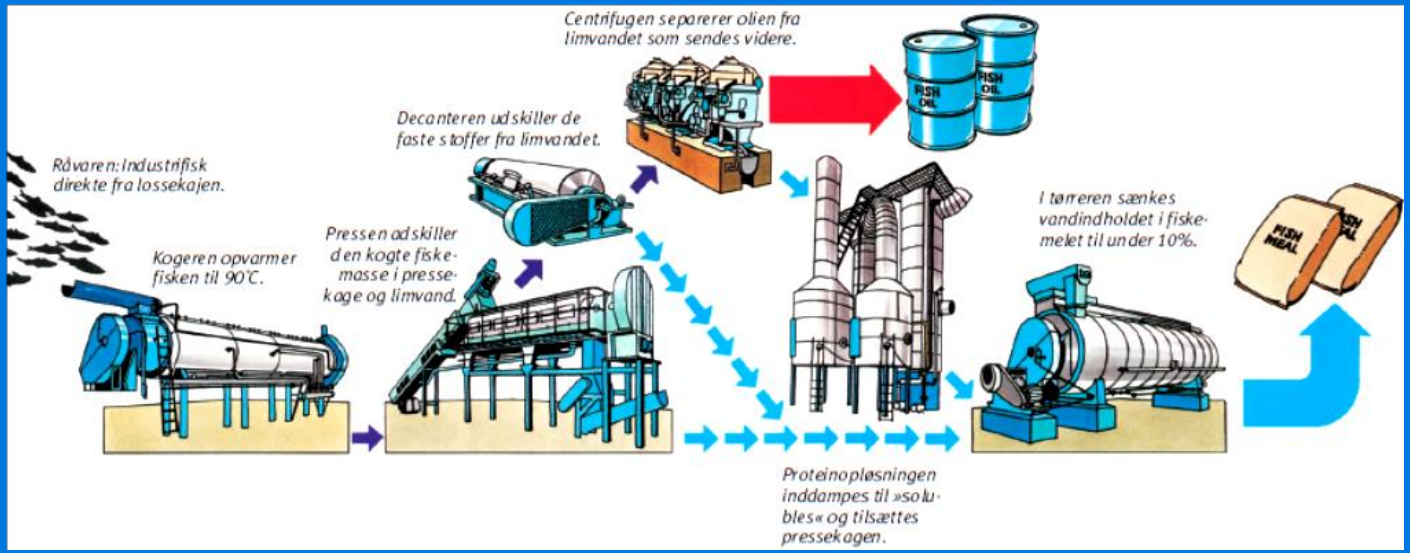
# Ovodan



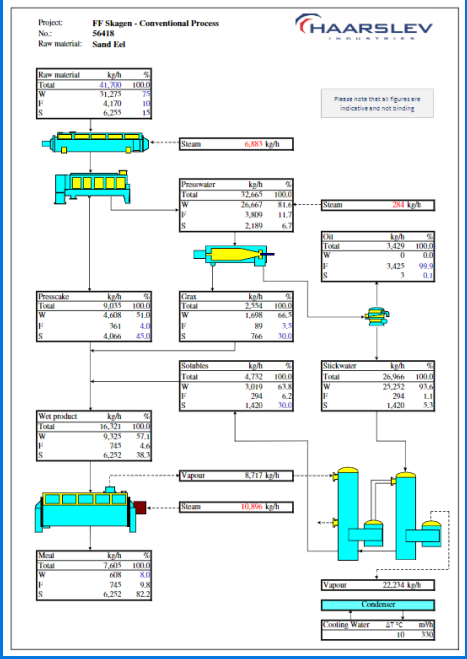

Status:

- Elkortlægning lavet
- Massebalance 90 % færdig
- Skabelon for energikortlægning udarbejdet
- Første gennemgang hos Ovodan afholt

# FF-Skagen


Centrifugen separerer olien fra limvandet som sendes videre.
Decanteren udskiller de faste stoffer fra limvandet.
Råvaren: Industrifisk direkte fra lossekajen.
Kogeren opvarmer fisken til 90°C.
Pressen adskiller den kogte fiskemasse i pressekage og limvand.
I tørreren sænkes vandindholdet i fiskemelet til under 10%.
Proteinopløsningen inddampes til »solubles« og tilsættes pressekagen.
FISH OIL
FISH MEAL

# FF-Skagen




Status:

- Materialer indsamlet
- Første arbejdsmøde afholdes den 11/11

# Præsentation og rundvisning

60 minutters tour of the premises

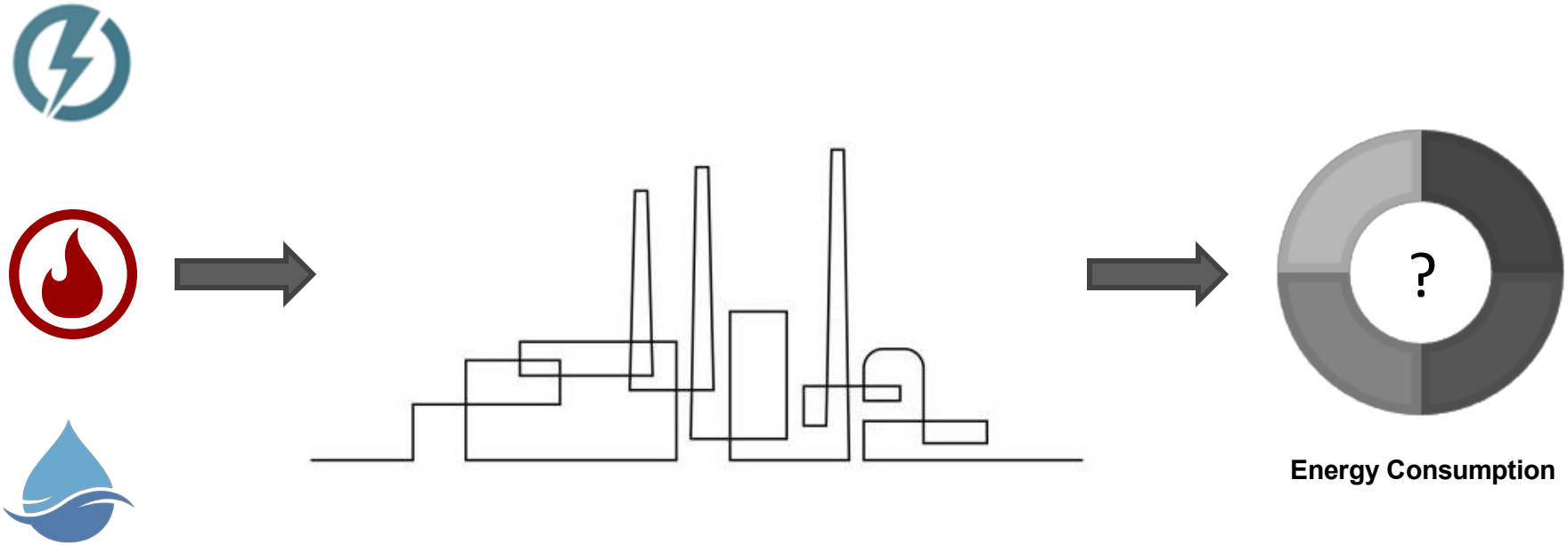
# Lunch break

# Præsentation af kortlægningsværktøjet

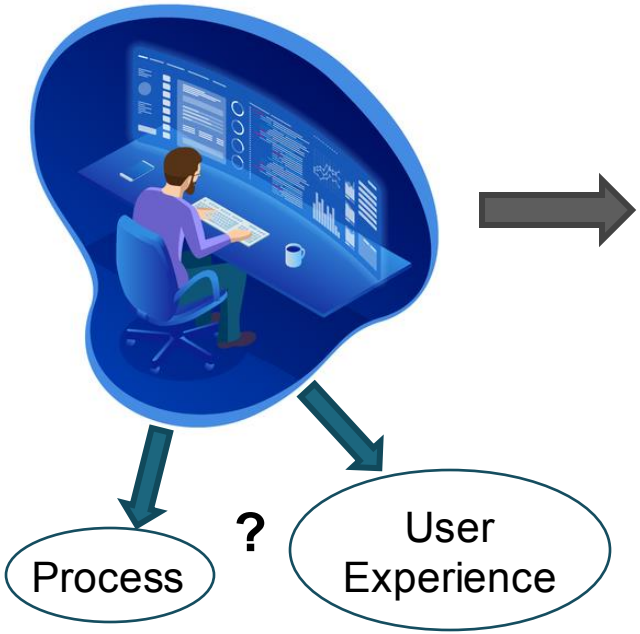
# EEMAP tool draft

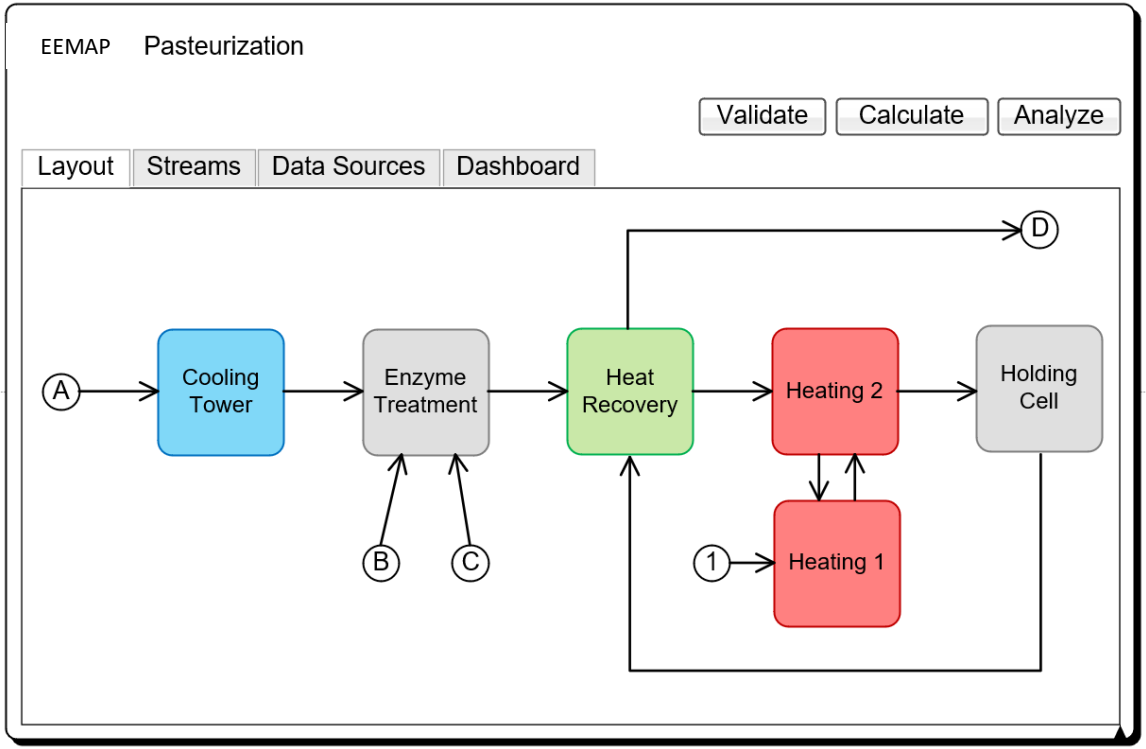
IPU

# The Challenge



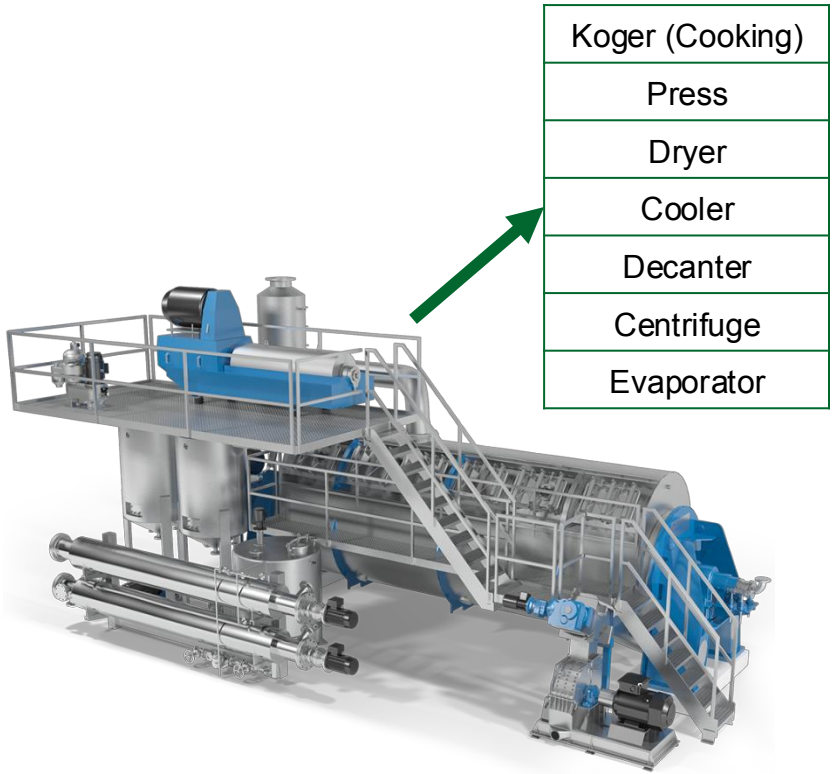
# The approach



# Understand the process

- **Processing equipment**



| Koger (Cooking) |
| --- |
| Press |
| Dryer |
| Cooler |
| Decanter |
| Centrifuge |
| Evaporator |

1. Physical process
   - Energy transfer
   - Fluid flow inside the process
2. Process configuration
   - Process connection
   - Drains
   - Heat recovery
3. Types of measurements
   - I/O measurements
   - Temperatures
   - Flowrates
4. Access to data and specifications

# User experience

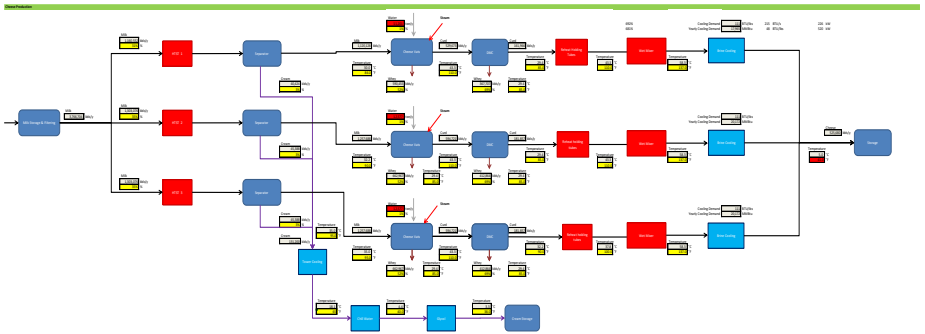
| EEMAP Characteristics |
| --- |
| Usefulness |
| Usability |
| Credibility |
| Visual appeal |
| Accessibility |
| Speed |
| Findable |

- Focus and priority
  - Usability
    - Intuitive
    - Navigation
    - Consistency
    - Error Prevention
  - Credibility
    - Calculation procedures
- Secondary
  - Visual Appeal
  - Speed

# Drøftelser af problemstillinger, ønsker, detaljeringsgrad mm.

# Kortlægningsprocessen

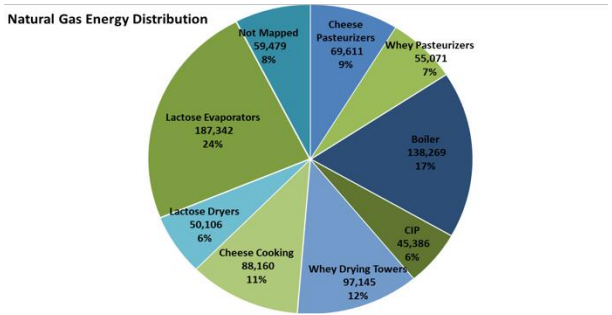
## 1. Flow sheeting



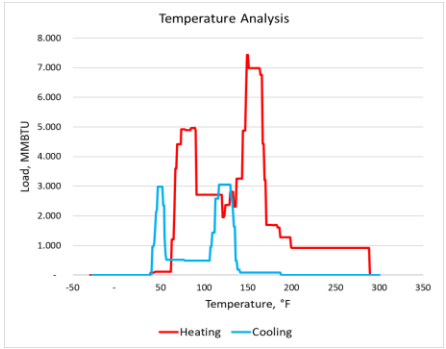
## 2. Energibalancer

| Section | Line | Equipment | Medium | Heat Transfer Code Or Equipment number | Temp. In °F | Temp. Out °F | E-KPI Mmbtu/klbs | Mass flow klbs/yr | Dry matter % | Cp btu/lbs | Steam MMBtu |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cheese Pasteurizers | Cheese HTST 1 | Steam Preheating | Water | | 93.4 | 110.0 | | 537,123 | 0.0% | 1.00 | 8,916 |
| Cheese Pasteurizers | Cheese HTST 1 | Pasteurizer Steam | Raw Milk | | 152.5 | 164.2 | | 1,160,552 | 15.0% | 0.96 | 13,581 |
| Cheese Pasteurizers | Cheese HTST 2 | Steam Preheating | Water | | 93.4 | 110.0 | | 606,778 | 0.0% | 1.00 | 10,056 |
| Cheese Pasteurizers | Cheese HTST 2 | Pasteurizer Steam | Raw Milk | | 153.7 | 164.5 | | 1,303,076 | 15.0% | 0.96 | 13,561 |
| Cheese Pasteurizers | Cheese HTST 3 | Steam Preheating | Water | | 93.4 | 110.0 | | 575,480 | 0.0% | 1.00 | 9,553 |
| Cheese Pasteurizers | Cheese HTST 3 | Pasteurizer Steam | Raw Milk | | 153.9 | 165.4 | | 1,303,076 | 15.0% | 0.96 | 14,444 |
| Cheese Cooking | Line 1 | Reheat Tubes | Milk | | 85.0 | 110.0 | | 161,966 | 50.0% | 0.80 | 3,222 |
| Cheese Cooking | Line 1 | Wet Mixer | Milk | | 110.0 | 137.0 | | 161,966 | 50.0% | 0.83 | 3,633 |
| Cheese Cooking | Line 2 | Reheat Tubes | Milk | | 85.0 | 110.0 | | 181,857 | 50.0% | 0.80 | 3,617 |
| Cheese Cooking | Line 2 | Wet Mixer | Milk | | 110.0 | 137.0 | | 181,857 | 50.0% | 0.83 | 4,079 |
| Cheese Cooking | Line 3 | Reheat Tubes | Milk | | 90.0 | 100.0 | | 181,857 | 50.0% | 0.79 | 1,441 |
| Cheese Cooking | Line 3 | Wet Mixer | Milk | | 100.0 | 137.0 | | 181,857 | 50.0% | 0.82 | 5,544 |
| Whey Pasteurizers | Whey HTST 1 | Pasteurizer Steam | Whey | | 152.8 | 174.0 | | 979,808 | 7.0% | 0.98 | 20,456 |
| Whey Pasteurizers | Whey HTST 2 | Pasteurizer Steam | Whey | | 151.7 | 170.4 | | 1,183,342 | 7.0% | 0.98 | 21,761 |
| Whey Pasteurizers | Whey HTST 3 | Pasteurizer Steam | Whey | | - | - | | - | 7.0% | 0.95 | - |
| Whey Pasteurizers | Whey HTST 4 | Pasteurizer Steam | Whey | | 157.0 | 170.8 | | 946,674 | 7.0% | 0.98 | 12,854 |
| Whey Drying Towers | MSD Dryer | Burner Main Air | Air | | 65.0 | 512.0 | | 842,318 | 0.0% | 0.24 | 90,562 |
| Whey Drying Towers | MSD Dryer | SFB Steam Heat | Air | | 65.0 | 207.0 | | 149,272 | 0.0% | 0.24 | 5,098 |
| Whey Drying Towers | MSD Dryer | VF Steam Heat 1 | Air | | 65.0 | 142.0 | | 42,640 | 0.0% | 0.24 | 750 |
| Whey Drying Towers | MSD Dryer | VF Steam Heat 2 | Air | | 39.0 | 94.0 | | 53,311 | 0.0% | 0.24 | 705 |
| Lactose Evaporators | Evaporator A | Total Steam | | | 334.0 | 335.0 | 0.079? | 783,727 | 0.0% | 1.00 | 62,447 |
| Lactose Evaporators | Evaporator B | Total Steam | | | 334.0 | 335.0 | 0.079? | 783,727 | 0.0% | 1.00 | 62,447 |
| Lactose Evaporators | Evaporator C | Total Steam | | | 334.0 | 335.0 | 0.079? | 783,727 | 0.0% | 1.00 | 62,447 |
| Lactose Dryers | Dryer Line 1 - Primary Dyer | Main Air Steam Heat | Air | | 147.3 | 299.0 | | 483,163 | 0.0% | 0.24 | 16,578 |
| Lactose Dryers | Dryer Line 1 - Secondary Dryer | Steam Heating 1 | Air | | 65.0 | 245.0 | | 144,949 | 0.0% | 0.24 | 6,275 |
| Lactose Dryers | Dryer Line 1 - Secondary Dyer | Steam Heating 2 | Air | | 40.0 | 53.8 | | 161,054 | 0.0% | 0.24 | 535 |
| Lactose Dryers | Dryer Line 2 - Primary Dyer | Main Air Steam Heat | Air | | 128.7 | 300.0 | | 483,163 | 0.0% | 0.24 | 19,909 |
| Lactose Dryers | Dryer Line 2 - Secondary Dryer | Steam Heating 1 | Air | | 65.0 | 245.0 | | 144,949 | 0.0% | 0.24 | 6,275 |
| Lactose Dryers | Dryer Line 2 - Secondary Dryer | Steam Heating 2 | Air | | 40.0 | 53.8 | | 161,054 | 0.0% | 0.24 | 535 |
| Cheese Cooking | Line 1 | Steam Heating | Milk | | 86.0 | 110.0 | | 1,120,128 | 15.0% | 0.94 | 25,240 |
| Cheese Cooking | Line 1 | Steam Heating | Milk | | 90.0 | 110.0 | | 1,257,688 | 15.0% | 0.94 | 23,637 |
| Cheese Cooking | Line 1 | Steam Heating | Milk | | 86.0 | 110.0 | | 1,257,688 | 15.0% | 0.94 | 17,747 |
| CIP Cow Water Preheat | CIP | Steam Heating | Water | | | | | | | 1.00 | - |
| | | | | | | | | | | 1.00 | - |
| | TOTAL | | | | | | | | | | 547,434 |

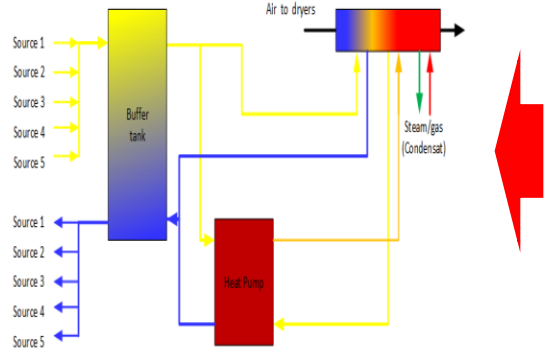
## 3. Økonomi




## 4. Forståelse af energibehov



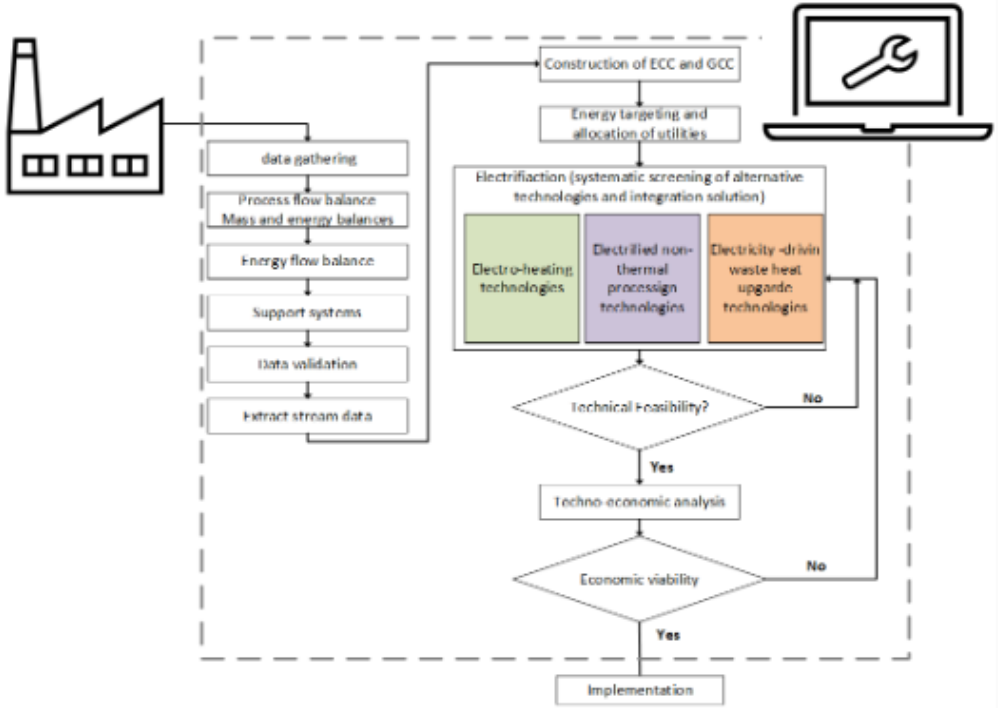

## 5. Projekter



# Kortlægningsværktøjet

## Emner

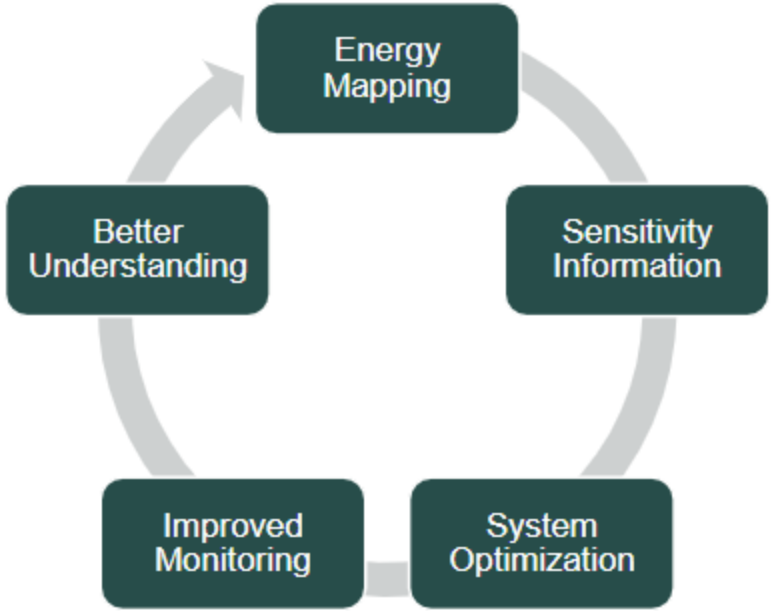
1. Grundlag for modellen
2. Detaljeringsgrad
3. Outputs
4. Add-on analyser
5. Andet



# Kortlægningsværktøjet

## Grundlag for modellen

1. Funktioner
2. Platform
3. Brugerflade(r)
4. …




The value propositions of the energy mapping are:

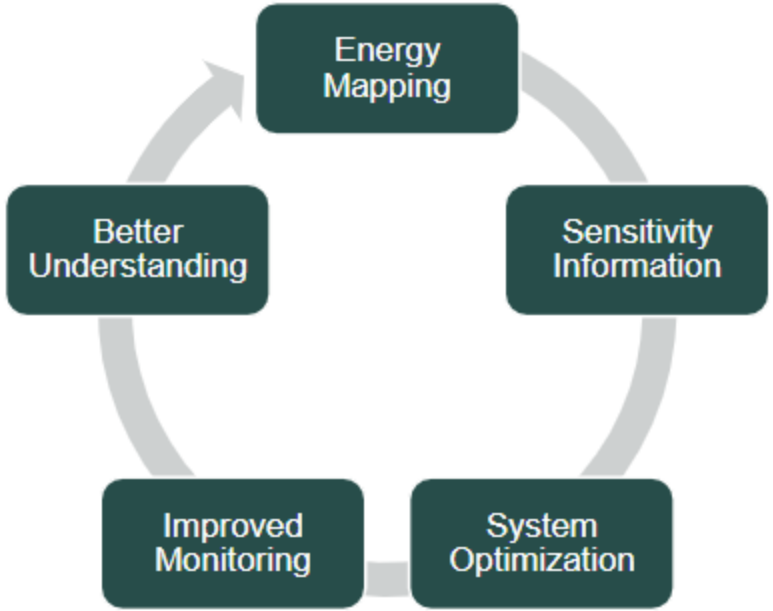
- Increased energy efficiency.
- Electrification of industrial processes.
- Utilizing excess heat to district heating projects.
- Developing company strategy for reaching zero $CO_2$ emissions (limited to scope 1 and scope 2 – as defined in [3])

# Kortlægningsværktøjet

## Grundlag for modellen

Elementer i kortlægningen

1. Termisk proceskortlægning
2. Elektrisk kortlægning
3. Kortlægninger af rumvarme.
    - Vand båret
    - Ventilation
4. Forsyning f.eks. køling, varme, trykluft
5. Andre elementer som ikke direkte kan henføres til processen f.eks. CIP.
6. Tidselementet (Statisk eller dynamisk) – valg af enheder



# Kortlægningsværktøjet

## Detaljeringsgrad

- Process (Graphical Programming)
  - Process Flow Balance: Product flow through the facility.
  - Energy Flow Balance: Energy carrier flow through the facility.
  - Support systems: Could be Cleaning in Place (CIP) or others not included in the above.

Denne vender vi tilbage til

Kortlægningsniveauer:

1. Hele virksomheden
2. Forsyning og de enkelte produktionslinjer
3. Enhedsoperationer
4. Elementerne i enhedsoperationerne
5. ….?

# Kortlægningsværktøjet

## Output

- Outputs (Tables, Diagrams, Plots, KPIs)
  - Process Energy Requirement and accuracy of model
  - Descriptive Energy Use and KPI's
  - Temperature and energy analysis (Pinch Analysis)
  - Energy targeting and optimal selection of utilities

I hvilken udstrækning ønsker vi stadig dette?

Hvad med ?

- CO2
- "datakvalitetsanalyse"

# Behov og tilgang til informationer

## Behov:

- Hvad skal kortlægningen understøtte?
- Hvordan skal kortlægningen bruges i det daglige
- Hvem skal ”eje” den?
- Hvad skal kortlægningen understøtte?

## Tilgængelige informationer:

- Hvad ved vi fra starten?
- Hvilket data kan gøres tilgængelige?
- Hvordan begrænser vi arbejdet for brugeren?
- Hvordan indarbejde vejledninger?

## Output:

- Hvilke output er vigtige?
- Hvordan skal de præsenteres?

## Analyser:

- Hvilke understøttende analyser vil hjælpe virksomhederne?
- Hvilke typer af screeninger ønskes

# Kortlægningsværktøjet

## Add-on analyser

- Energibesparelser
- Strategisk energi og CO2 planlægning
- Systematisk evaluering af elektrificeringsmuligheder
- Temperatur analyser
- Pinch analyse
- KPI analyse
- Sankey diagrammer
- Rapporteringer: ISO 50001, ISO 14001, Energisyn, dokumentation af energibesparelser
- Vand analyser

# Enhedsoperationer

## Forslag til enhedsoperationer

Mekanisk

- Samler
  - Blanding, omrøring, suspension, sedimentation, befugtning, absorption
- Splitter
  - Deling af strømme, filtrering, ekstraktion, centrifuge, dekanter, presse

Termisk (indirekte)

- Inddamper
- Kogning
- Bagning
- Destillation

Termisk (direkte)

- Tørring
- Stripping

Energioverførsel

- Opvarmning
- Køling
- Pasteurisering

# EEMAP tool discussion

Alle

# Videre forløb

1. Opgavefordeling + planlægning
2. EUPD Documentation demands:
    - Coorporation agreement (Samarbejdsaftale) 6 months after project kick-off
3. Deliverables EOF22
    - Minimum Viable Product specification,
    - User journey description and user requirements,
    - Software Design Specification Report.
    - 3x Energy mapping in the excel template
    - 3x Screening list for the partner companies

# Samarbejdsaftale / collaboration

1. Sendes ud start December til alle
2. Deadline hos EUDP (usikkert)
3. Underskrevet inden 31/12-2022

1. Finansieringsaftale ml. 6 virksomheder og VMAS på EUDP-støtte
2. Klar inden 31/12

1. Hovedparter
   - VMAS, DTU og IPU
2. Virksomhedsparter
   - Ovodan
   - FF Skagen
   - Skjern Papir
   - Royal Unibrew
   - Vista Green
   - PPG
3. Parter
   - Alle

# Evt.

# Kontakt




Fridolin Müller Holm

Chef for industri

Viegand Maagøe A/S

Tlf. +45 31 75 17 14

E-mail: fmh@viegandmaagoe.dk

WWW.VIEGANDMAAGOE.DK





Andreas Riis Christiansen

Projektleder

Viegand Maagøe A/S

Tlf. +45 31 75 17 44

E-mail: arc@viegandmaagoe.dk

WWW.VIEGANDMAAGOE.DK





Rikke Hovedskov Andersen

Projektmedarbejder

Viegand Maagøe A/S

Tlf. +45 60 29 78 29

E-mail: ran@viegandmaagoe.dk

WWW.VIEGANDMAAGOE.DK

# EEMAP
# Energikortlægningsværktøj

2. Workshop d. 28. Februar 2023 ved Ovodan



# Workshop 2 – In Ovodan , Odense, February 2023

# Formålet med mødet

- Give udviklingsvirksomhederne indblik i projektet
- Få input til brugeroplevelsen
- Fremvise af værktøjet
- Eksemplificering

# Agenda

26. september 2024

| | | |
|---|---|---|
| 1. | 10:00-10:15: | Præsentation af deltagere og dagsorden |
| 2. | 10:15-10.30: | Status<br>• Projektstatus<br>• Aftaler<br>• Rapporting |
| 3. | 10:30-11:00: | Gennemgang af de 3 kortlægninger<br>• 1 Skjern Papir<br>• 2 Ovodan<br>• 3 FF-Skagen |
| 4. | 11:00-11:30: | Rundvisning på Ovodan |
| 5. | 11:30-12:00: | Frokost |
| 6. | 12.00-12.30: | UX - Vis Regning af eksempel i værktøj (IPU) |
| 7. | 12.30-14.00: | UX – Brugerbehov og brugerrejse |
| 4. | 14:00-14:30: | Øvrige spørgsmål og feedback til værktøjet (I Figma og EEMAP) (mrk går 14.15) |
| 5. | 14:30-15:00: | Opsamling, videre foreløb og evt. |

# Status rundt om bordet

## Hvor langt er vi?

**Project status:**

IPU:

- Develop simple component and make a first draft of the tool

Viegand Maagøe:

- Make a time schedule with more details
- Showcase the 3 mappings and screening list
- Define user needs and propose functionality and user interface

**Agreements:**

- Collaboration agreement
- Financing agreement

**Reporting:**

- Payment request

# Tidsplan

## Overblik

| Year/År | | | | | | | | 2023 | | | | | | | | | | | | 2024 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Work packages/Projektets arbejdspakker:** | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 |
| | | | | | | | | | | | | | | | | | | | | | |
| **WP1 - Project Management** | | | | | | | | | | | | | | | | | | | | | |
| **WP2 - Scoping** | | | | | | | | | | | | | | | | | | | | | |
| **WP3 - Mapping state-of-the-art** | | | | | | | | | | | | | | | | | | | | | |
| **WP4 - Field Mapping (Without Tool)** | | | | | | | | | | | | | | | | | | | | | |
| **WP5 - Programming** | | | | | | | | | | | | | | | | | | | | | |
| **WP6 - Add-on Analyses** | | | | | | | | | | | | | | | | | | | | | |
| **WP7 - Field Test (With Tool)** | | | | | | | | | | | | | | | | | | | | | |
| **WP8 - Maturing and Analyses Expansion** | | | | | | | | | | | | | | | | | | | | | |
| **WP9 - Communication** | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| **Milestones/Milepæle** | | | | | | | | | | | | | | | | | | | | | |
| M1 - Design Specifciation Completed | | | | | | | X | | | | | | | | | | | | | | |
| M2 - Techonology Parameter Table Completed | | | | | | | | | X | | | | | | | | | | | | |
| M3 - First version ready for field testing | | | | | | | | | | | | | X | | | | | | | | |
| M4 - Finalized Tool | | | | | | | | | | | | | | | | | | | | X | |
| M5 - Presentation at ECOS Conference 2023 | | | | | | | | | | | | | X | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| **Commercial milestones/Kommerc. milepæle** | | | | | | | | | | | | | | | | | | | | | |
| CM1 - Project Finalization | | | | | | | | | | | | | | | | | | | | X | |
| CM2 - Mapping of potential add-ons and their commercial potential | | | | | | | | | | | | | X | | | | | | | | |
| CM3 - Model proof of concept in operational environment | | | | | | | | | | | | | | | | X | | | | | |

WP 1-5 kick-off 2022

WP 6-9 kick-off 2023

# Rapporteringer

## Tidsplan - kommentar

| | |
|---|---|
| **Name of work package** | Project Management |
| **Number of work package** | 1 |
| **Leader and partners of work package** | Lead: Viegand Maagøe<br>Partners: DTU and IPU |

| **Deliverables/results of work package** |
|---|
| Quarterly project status meetings with the main project organization will be held and documented. |
| **Technical and commercial milestones** |
| CM1 Project Finalization |

- Samarbejdsaftale
- Betalingsanmodning
- Statusmøder - løbende
- Workshops (3. næste 12 april i kbh.)

| | |
|---|---|
| **Name of work package** | Scoping |
| **Number of work package** | 2 |
| **Leader and partners of work package** | Lead: Viegand Maagøe<br>Partners: DTU, IPU, FF Skagen, Company X and Skjern Papir. |

| **Deliverables/results of work package** |
|---|
| Minimum Viable Product specification, User journey description and user requirements, Software Design Specification Report. |
| **Technical and commercial milestones** |
| M1 Minimum viable product created, user journey established, and Design specification completed |

- Software Design specification Report – (-3 mdr)
- User Journey description and user requirements – (-3 mdr)
- Minimum Viable Product specification – (-3 mdr)

Ovenstående færdiggøres på baggrund af input fra i dag.

# Rapporteringer

## Tidsplan - kommentar

| | |
|---|---|
| **Name of work package** | Mapping state-of-the-art |
| **Number of work package** | 3 |
| **Leader and partners of work package** | Lead: DTU<br>Partners: Viegand Maagøe, IPU |

| **Technical and commercial milestones** |
|---|
| M2 Documentation Report and Database Technology key parameter table |

- Documentation Report and Database Technology key parameter table – (-1 mdr.)
  - Dokumentation af den termodynamiske modellering for hver procesoperation.
  - Tilgængelige teknologier, begrænsninger, bedst tilgængelige teknologi og nye teknologier

| | |
|---|---|
| **Name of work package** | Field Mapping |
| **Number of work package** | 4 |
| **Leader and partners of work package** | Lead: Viegand Maagøe<br>Partners: FF Skagen, Company X and Skjern Papir. |

| **Deliverables/results of work package** |
|---|
| – 3x Energy Mapping in the existing Excel template.<br>– 3x Screening list for the partner companies. |

- Energikortlægninger – "færdig"
- Skjern Paper
- Rumvarme/CIP/El....

# Rapporteringer

## Tidsplan - kommentar

| | |
|---|---|
| **Name of work package** | Programming |
| **Number of work package** | 5 |
| **Leader and partners of work package** | Lead: IPU<br>Partners: Viegand Maagøe, DTU |

| **Deliverables/results of work package** |
|---|
| – Minimum viable product<br>– Software Tool Version 1.<br>– User manual |
| **Technical and commercial milestones** |
| M3 First version ready for field testing. |

| | |
|---|---|
| **Name of work package** | Add-on Analyses |
| **Number of work package** | 6 |
| **Leader and partners of work package** | Lead: DTU<br>Partners: Viegand Maagøe, IPU |

| **Deliverables/results of work package** |
|---|
| The three methods will provide additional results for the parts of an energy mapping and optimization related to the data collection phase, the analysis phase and the optimization phase. The methods will be analysed for the cases in the project. Based on the results of these assessments, they will be developed for implementation in the tool. |
| **Technical and commercial milestones** |
| CM2 Mapping of potential add-ons and their commercial potential |

- Efter planen
  - xxx

- Forslag - udarbejdet
- Prioritering – starter nu
- Input til værktøjet – starter nu

# Rapporteringer

## Tidsplan - kommentar

| | |
|---|---|
| **Number of work package** | 7 |
| **Leader and partners of work package** | Lead: Viegand Maagøe<br>Partners: IPU, DTU, Avista Green, Royal Unibrew and PPG Coatings Danmark A/S. |

| **Deliverables/results of work package** |
|---|
| 5 Energy Mappings in the set timeframe of 3 days each. |
| **Technical and commercial milestones** |
| CM3 Model proof of concept in operational environment |

- Starter inden sommer

| | |
|---|---|
| **Name of work package** | Maturing and Analyses Expansion |
| **Number of work package** | 8 |
| **Leader and partners of work package** | Lead: IPU<br>Partners: Viegand Maagøe, DTU |

| **Deliverables/results of work package** |
|---|
| Finalized Software Tool. |
| **Technical and commercial milestones** |
| M4 Finalized Software Tool. |

- Starter til efteråret

# Rapporteringer

## Tidsplan - kommentar

| | |
|---|---|
| **Name of work package** | Communication |
| **Number of work package** | 9 |
| **Leader and partners of work package** | Lead: Viegand Maagøe<br>Partners: DTU, IPU |

| **Deliverables/results of work package** |
|---|
| – Three Case Descriptions<br>– Two (non-scientific) articles, published in relevant media<br>– One conference paper<br>– Two conference presentations<br>– One scientific journal article |
| **Technical and commercial milestones** |
| M5 Presentation at ECOS Conference 2023 |

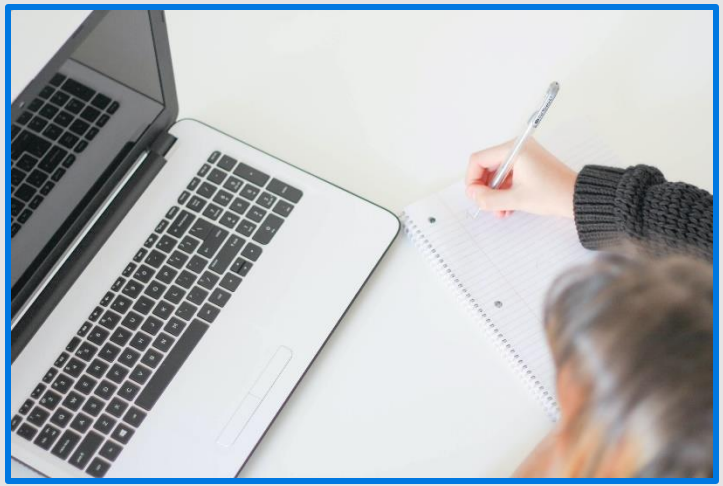
- Cases
  - Kortlægninger under udsrbejdelse sammen med EIA
- Artikler
  - En igang
- Konferance – ECOS
- Konferance præsentationer – ECOS + EIA
- Scientific jurnal – afventer

- Samlet set er vi lidt bagefter
-

# EUDP Reporting Summary

All necessary templates can be found at

[eudp.dk/efter-tilskud](eudp.dk/efter-tilskud)



## Coorporation Agreement

6 months after funding commitment

## Payment Request

Biannually – no fixed deadline

## Change Request

During project period

## Annual Report

Annually 30/06

## Final Reporting

Technical reporting by end date

Financial reporting 2 months after end date

# Rapporteringer

## Løbende timeregistrering

Sagsnummer EUDP

64022-1073

Titel

**Efficient Energy Mapping and Analysis for Optimization and Green Transition of Industrial Processes (EEMAP)**

Indsæt brugte timer fra hhv. administration og funktionærtimer og skriv en tilhørende note om aktivitet(er) til den pågældende måned. Tag med initialer hvem der har været aktiv på projektet i perioden og opdater løbende.

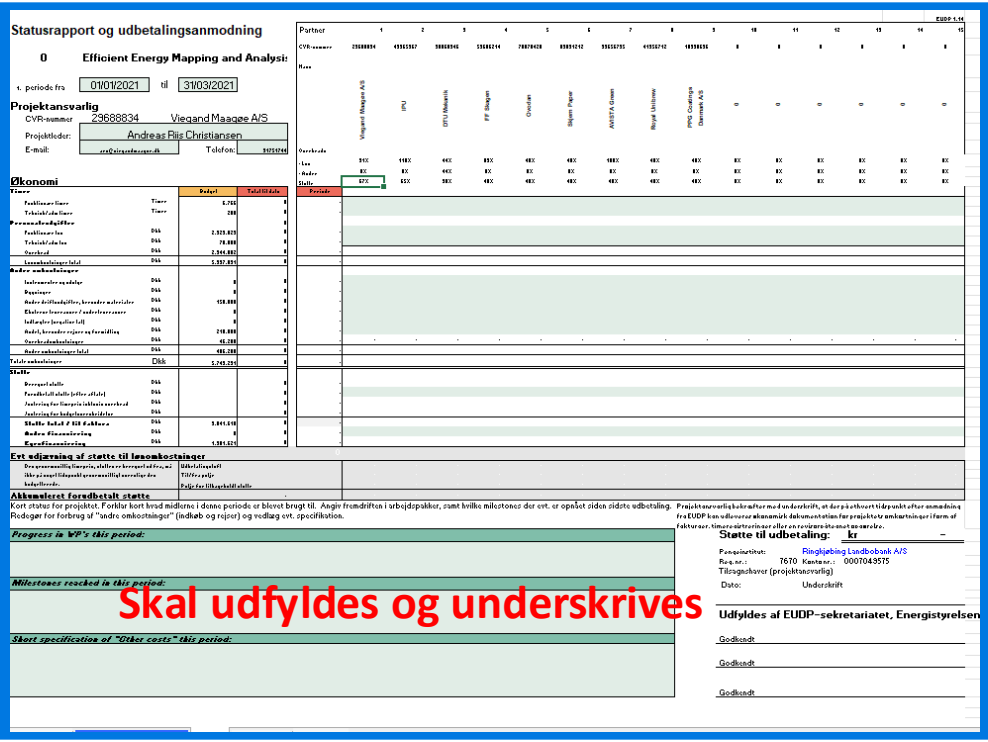
| | |
|---|---|
| Firma | **Viegand Maagøe A/S** |
| SE nummer | **29688834** |
| Navn | Fridolin Müller Holm |
| email | fmh@viegandmaagoe.dk |
| tlf.nr | 31751714 |

| | |
|---|---|
| Timebudget | 1975 |
| Kostpris | 425 |
| Funkt. | 1775 |
| Adm | 200 |

| Year | Month | Beskrivelse | Adm/tek timer | Funktionær timer | I alt | Forbrug % | |
|---|---|---|---|---|---|---|---|
| 2022 | 6 | | | | | 0% | |
| | 7 | | | | | 0% | |
| | 8 | opstartsmøde + koordinering | | | 14,75 | 1% | FMH, EAK, MIB, NIV, PKR, ARC |
| | 9 | kick-off, administration, intern sparring | | | 15,75 | 1% | FMH, ARC, LWI |
| | 10 | koordinering + field mapping (WP4) | | | 17,4 | 1% | FMH |
| | 11 | workshop, kortlægning, koordinering, projektledelse | | | 128,8 | 7% | FMH, RAN, JDH, LWI |
| | 12 | Kortlægning, screening lists, projektledelse | | | 61,75 | 3% | FMH, RAN, JDH |
| 2023 | 1 | Screening lists, projektledelde, ux-involvering | | | 57,5 | 3% | FMH, RAN, CCH |
| | 2 | | | | | 0% | |
| | 3 | | | | | 0% | |
| | 4 | | | | | 0% | |
| | 5 | | | | | 0% | |

# Rapporteringer

## Udbetalingsanmodning



Statusrapport og udbetalingsanmodning

0 Efficient Energy Mapping and Analysis

1. periode fra 01/01/2021 til 31/03/2021

Projektansvarlig

CVR-nummer 29688834 Viegand Maagøe A/S

Projektleder: Andreas Riis Christiansen

E-mail: Telefon:

Økonomi

Partner

Vingard Maagoe A/S | IPU | DTU Mekanik | FF Skagen | Orsted | Skjern Paper | ARGO'A Gruen | Royal Unibrew | PPG Coatings Denmark A/S

Et udtalelse af støtte til lønomkostninger

Akkumuleret forudbetalt støtte

Kort status for projektet. Forklar kort hvad milderne i denne periode er blevet brugt til. Angiv fremdriften i arbejdspakker, samt hvilke milestones der evt. er opnået siden sidste udbetaling. Projektansvarlig bekræfter med underskrift, at der på tidspunkt for udbetaling fra EUDP kan udleveres økonomisk dokumentation for projektets omkostninger i form af fakturaer, timeregistreringer eller anden revisionsmæssig dokumentation.

Redegør for forbrug af "andre omkostninger" (indkøb og rejser) og vedlæg evt. specifikation.

Progress in WP's this period:

Milestones reached in this period:

Short specification of "Other costs" this period:

Støtte til udbetaling: kr –

Pengeinstitut: Ringkjøbing Landbobank A/S

Reg.nr.: 7670 Kontonr.: 0007049575

Tilsagnshaver (projektansvarlig)

Dato: Underskrift

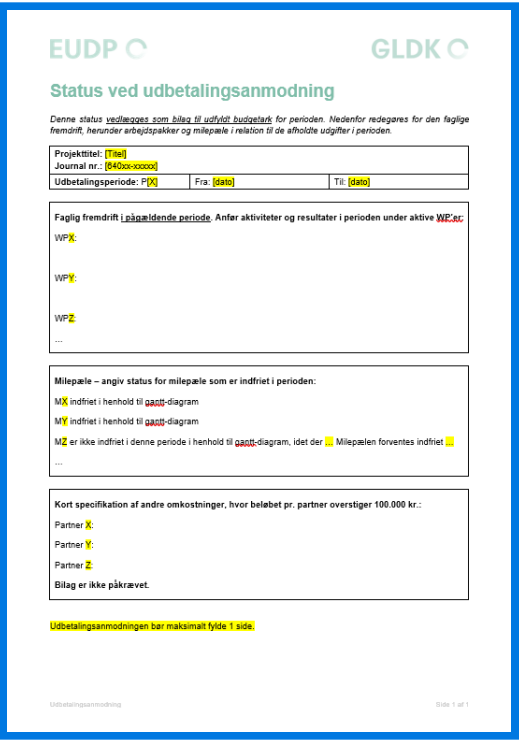
Udfyldes af EUDP-sekretariatet, Energistyrelsen

Godkendt

Godkendt

Godkendt

**Skal udfyldes og underskrives**



EUDP GLDK

Status ved udbetalingsanmodning

*Denne status vedlægges som bilag til udfyldt budgetark for perioden. Nedenfor redegøres for den faglige fremdrift, herunder arbejdspakker og milepæle i relation til de afholdte udgifter i perioden.*

Projekttitel: [Titel]
Journal nr.: [640xx-xxxxx]
Udbetalingsperiode: P[X] | Fra: [dato] | Til: [dato]

**Faglig fremdrift i pågældende periode. Anfør aktiviteter og resultater i perioden under aktive WP'er:**

WP X:

WP Y:

WP Z:

...

**Milepæle – angiv status for milepæle som er indfriet i perioden:**

MX indfriet i henhold til gantt-diagram

MY indfriet i henhold til gantt-diagram

MZ er ikke indfriet i denne periode i henhold til gantt-diagram, idet der ... Milepælen forventes indfriet ...

...

**Kort specifikation af andre omkostninger, hvor beløbet pr. partner overstiger 100.000 kr.:**

Partner X:

Partner Y:

Partner Z:

**Bilag er ikke påkrævet.**

Udbetalingsanmodningen bør maksimalt fylde 1 side.

# Rapporteringer

## Årsrapportering

1. Projektidentifikation
2. Projektgennemførsel
3. Projektets ressourceforbrug
4. Kommercialisering
5. Markedsmæssige og teknologisk risikovurdering
6. Øvrige oplysninger
7. Sammenfatning



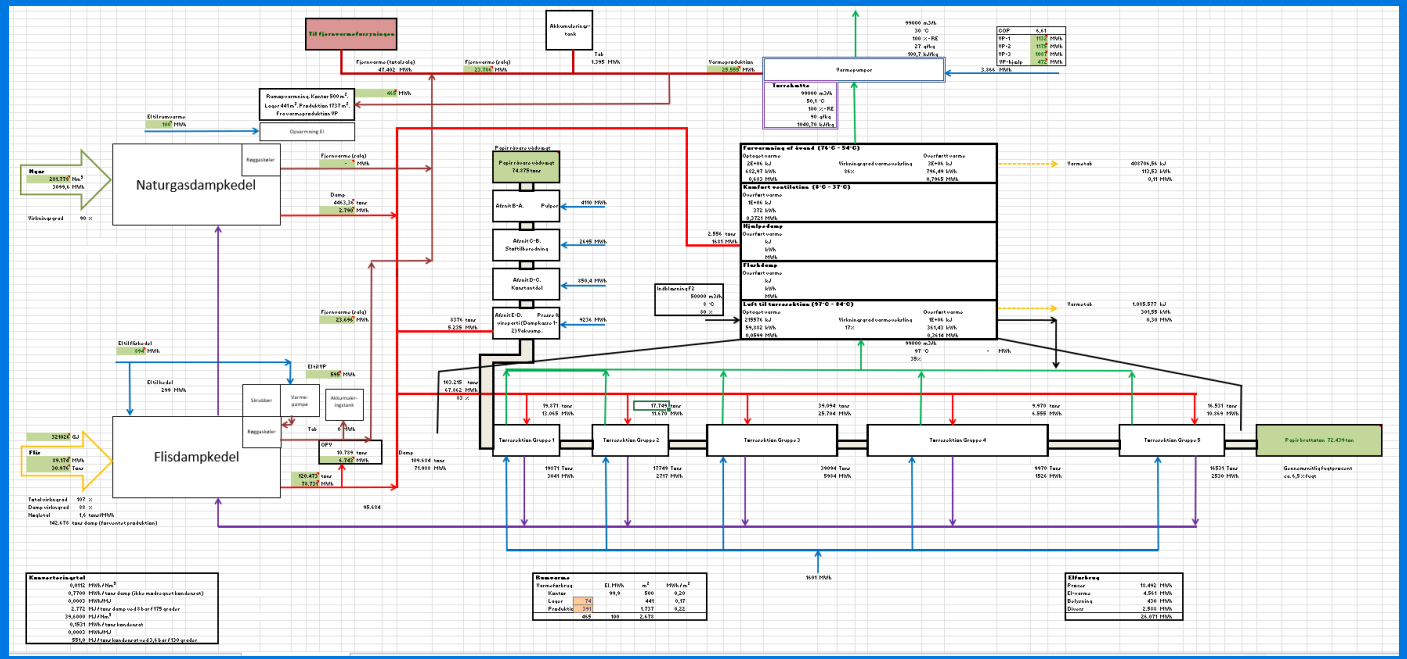
# Kortlægninger

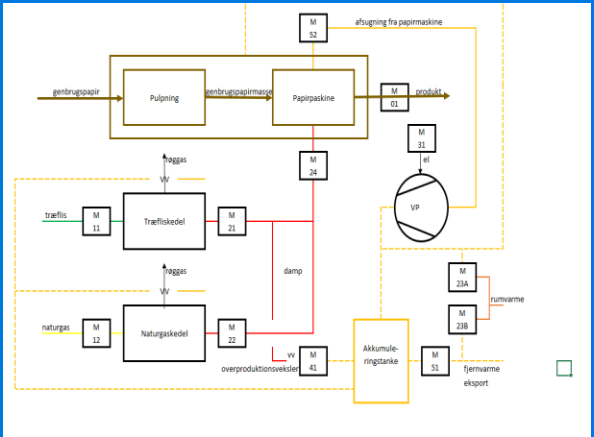
1. Skjern Papir
2. Ovodan
3. FF-Skagen

Formål med gennemgang af kortlægning

- Oplevelser / udfordringer?
- Datatilgængelighed?
- Hvordan har det været?
- Hvad bruger i kortlægningen til?

# Skjern Paper

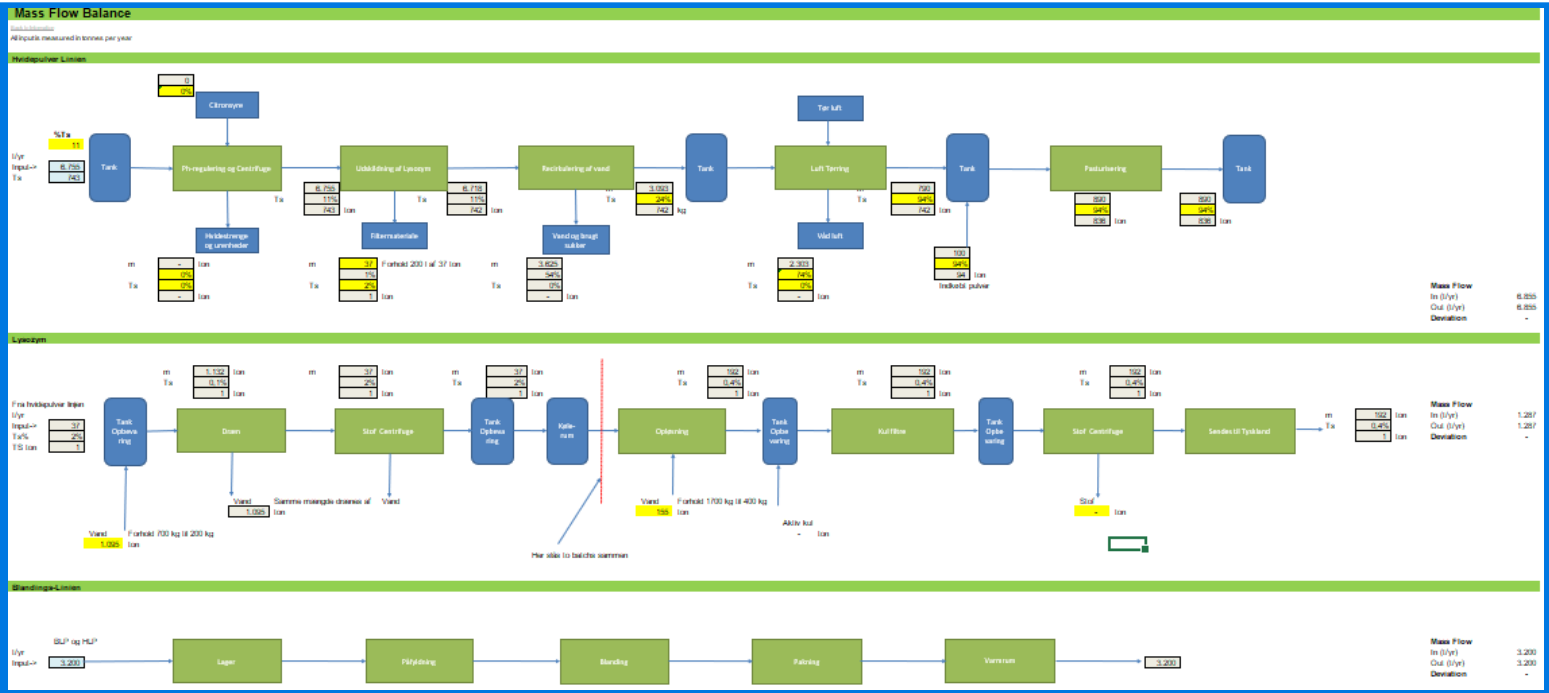


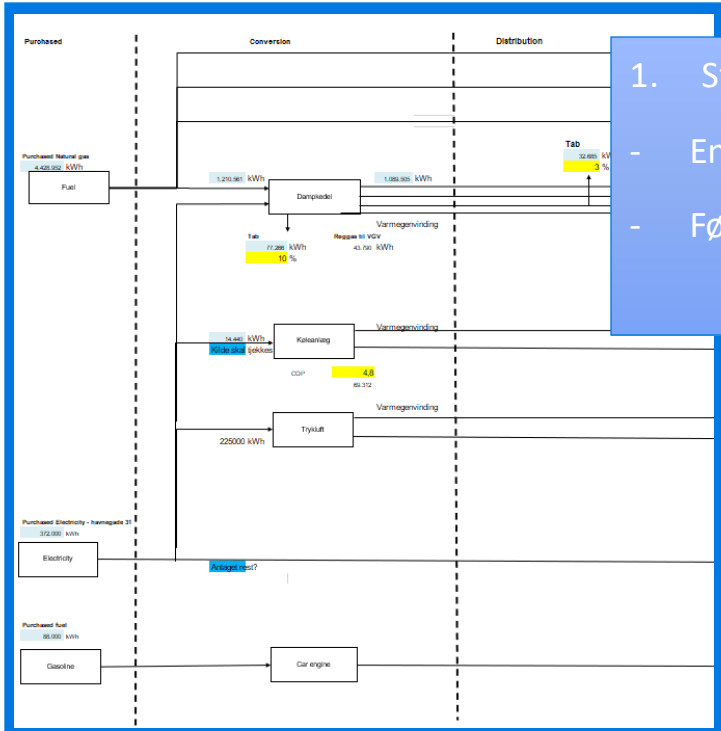



Status:

- Energikortlægning er på plads
- Første møde med Skjern Paper er afholdt

# Ovodan

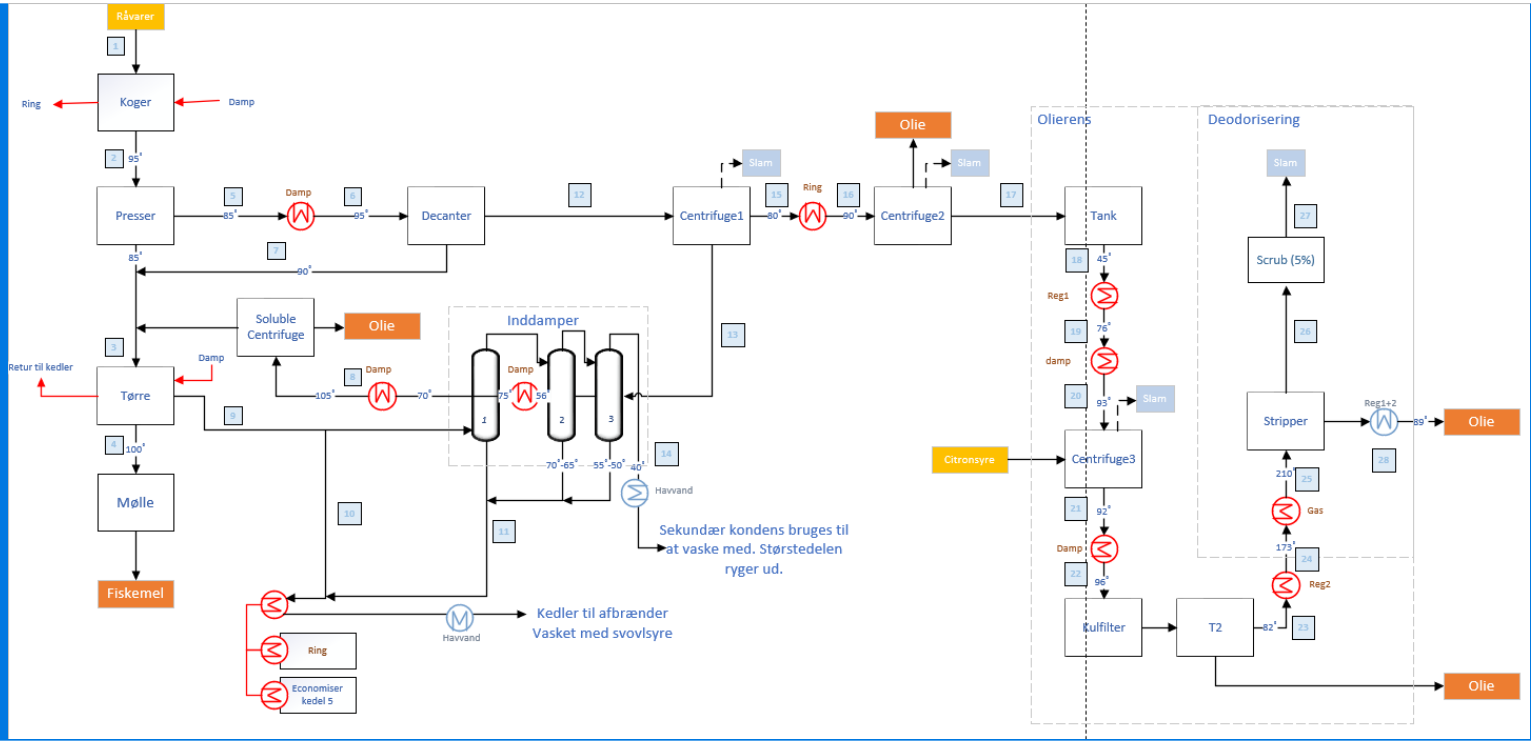

Mass Flow Balance
All inputs measured in tonnes per year
Hvidepulver Linien
Citronsyre
Tank
Ph-regulering og Centrifuge
Udskilning af Lysozym
Recirkulering af vand
Tank
Tør luft
Luft Tørring
Tank
Pasturisering
Tank
Hvidestrenge og urenheder
Filtermaterialle
Vand og brugt sulfat
Vådluft
Indkøbt pulver
Mass Flow
In (t/yr)
Out (t/yr)
Deviation
Lysozym
Fra hvidepulver linjen
Tank Opløsning
Dosen
Stof Centrifuge
Tank Opbevaring
Køle-rum
Opløsning
Tank Opbevaring
Kulfiltre
Tank Opbevaring
Stof Centrifuge
Sendes til Tyskland
Vand
Forhold 700 kg til 200 kg
Samme mængde drosses af
Her skal to batcher sammen
Forhold 1700 kg til 400 kg
Aktiv kul
Stof
Mass Flow
In (t/yr)
Out (t/yr)
Deviation
Blandinga-Linien
BLP og HLP
Lager
Pålydning
Blanding
Pakning
Varmrum
Mass Flow
In (t/yr)
Out (t/yr)
Deviation



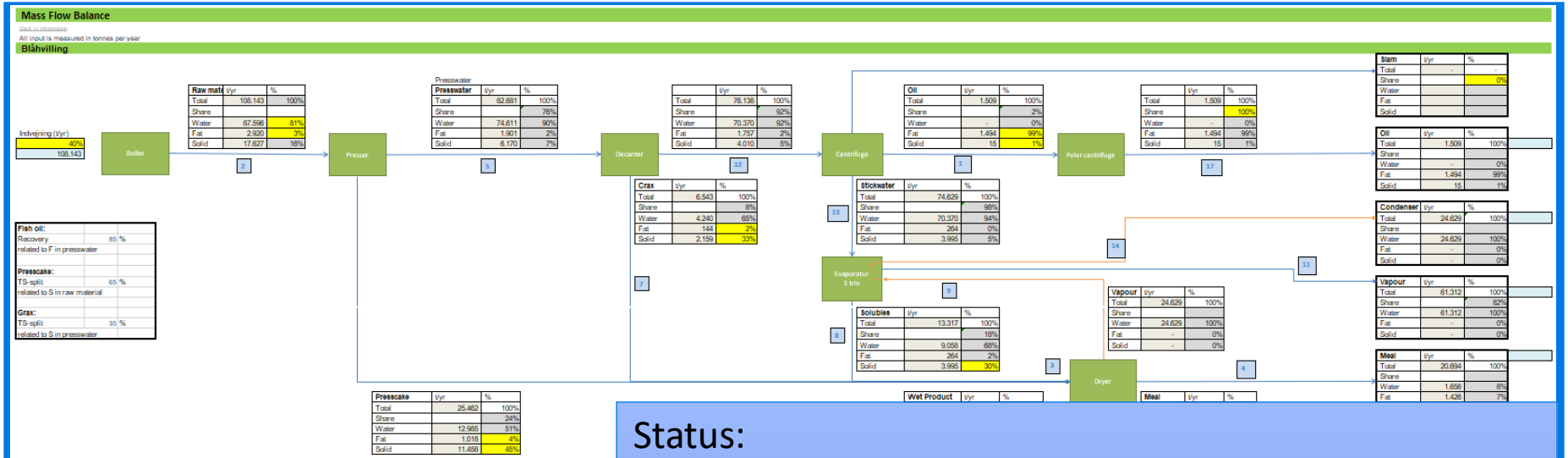

1. Status:

- Energikortlægning er lavet
- Første gennemgang med Ovodan afholdt

# FF-Skagen


Råvarer
Koger
Ring
Damp
Presser
Decanter
Centrifuge1
Centrifuge2
Olie
Slam
Ring
Damp
Soluble Centrifuge
Olie
Retur til kedler
Tørre
Damp
Inddamper
Mølle
Fiskemel
Havvand
Sekundær kondens bruges til at vaske med. Størstedelen ryger ud.
Kedler til afbrænder
Vasket med svovlsyre
Ring
Economiser kedel 5
Olierens
Deodorisering
Tank
Reg1
damp
Centrifuge3
Citronsyre
Sulfilter
T2
Scrub (5%)
Stripper
Reg1+2
Gas
Reg2
Olie
Olie

# FF-Skagen




Status:

- Energikortlægning lavet
- Brugt som eksempel til gennemregning i tool
- Første gennemgang lavet

# Rundvisning på Ovodan site

~30 min



# Frokost

# Eksempel på kortlægning i værktøj

# Brugerbehov og brugerrejse

!pu. DTU Viegand Maagøe

# Formålet med sessionen

- Review af brugeroplevelsen og oplæg til kernefunktioner
- Udpege udfordringer i brugerrejsen
- Få input til brugeroplevelsen

# Opsamling – fra seneste workshop

## Formål

- At gøre virksomhederne i stand til selv at udføre energikortlægning
- Drastisk minimere tiden, det tager, at udføre en energikortlægning

## Hvilke data skal EEMAP kunne opsamle?

- Virksomhedens produktionsprocesser og overordnede energiforbrug
- Historik over tid

## Ønsker til indhold

- Forklaringer, der hjælper brugeren
- Evt. en overordnet vejledning for kortlægningsprocessen

## Ønsker til output

- Energiforbrug fordelt på forskellige energiformer (el, isvand, damp etc.)
- Understøttende analyser (pinch, temperatur etc.)
- Relevante rapporter

# Ønsker til et kortlægningsværktøj

Hvad vil I forvente/ønske af et værktøj,
som I skal bruge til at lave energikortlægning med?

# Designprincipper

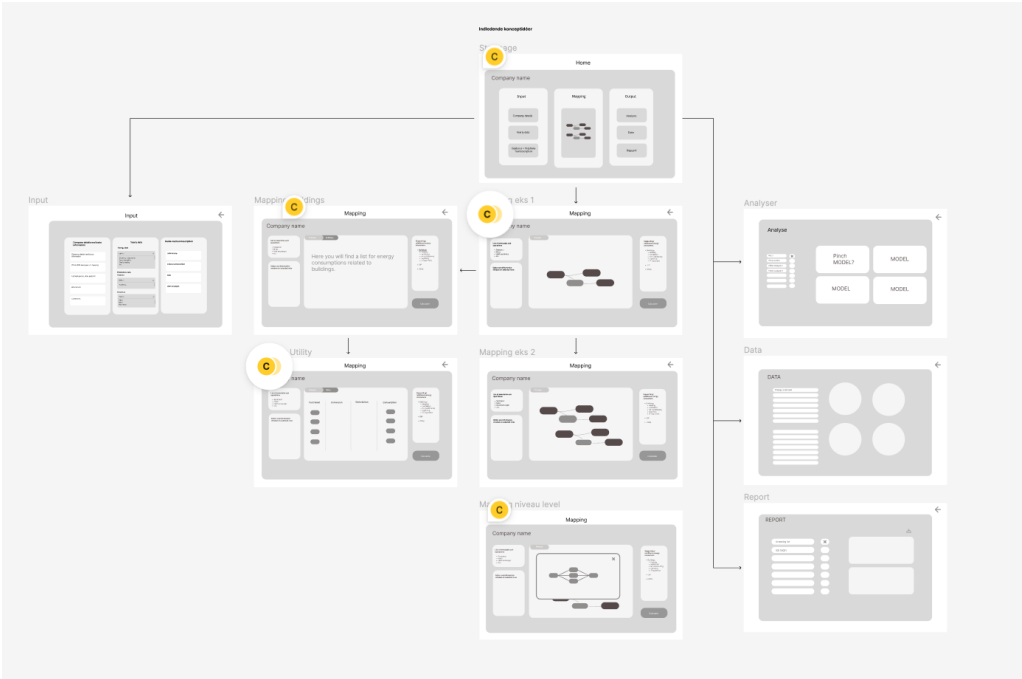
- Værktøjet/brugergrænsefladen skal være selvforklarende
- Værktøjets output skal lette jeres dagligdag/arbejde med energioptimering
- ?

# Brugerrejsen

## Hvordan ville I foretage en energikortlægning?

- Alene eller sammen med andre?
  - Hvad ville I forberede?
  - Computer, iPad, noter?
  - Hvilke udfordringer vil I have?
- Hvor trygge ville I være ved at foretage kortlægningen (i dag)?
  - Hvad ville gøre jer mere trygge?

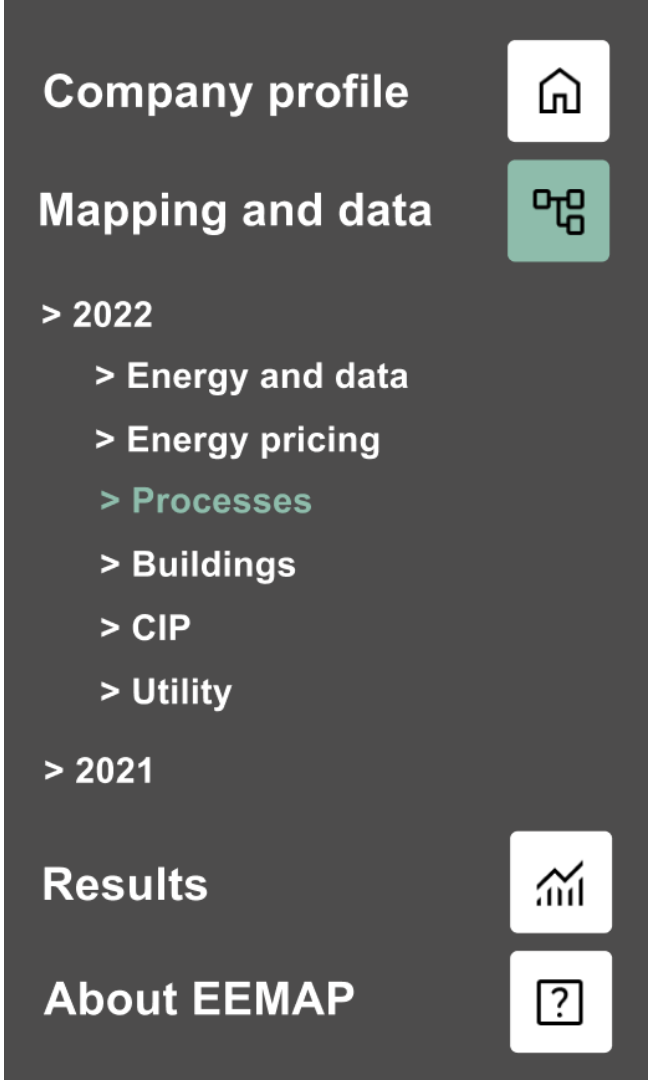
# Brugerflows – version 1



# Brugerflows – version 2

[Link til prototype]

Hvad forventer I, der gemmer sig bag menupunkterne?



# Resultater/output

## Analyser

- Energibesparelser
- Strategisk energi og CO2 planlægning
- Systematisk evaluering af elektrificeringsmuligheder
- Temperaturanalyser
- Pinch-analyse
- KPI-analyse
- Sankey diagrammer
- Rapporteringer: ISO 50001, ISO 14001, Energisyn, dokumentation af energibesparelser
- Vandanalyser

# Øvrige spørgsmål
# og feedback til værktøjet

# Evt.

# Kontakt




**Fridolin Müller Holm**

**Chef for industri**

**Viegand Maagøe A/S**

**Tlf. +45 31 75 17 14**

**E-mail: fmh@viegandmaagoe.dk**

**WWW.VIEGANDMAAGOE.DK**





**Pernille Yding Fredslund**

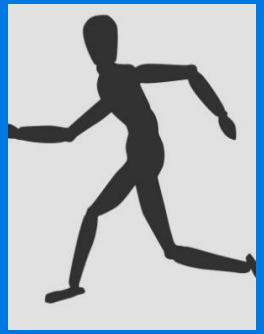
**Chef for Digital**

**Viegand Maagøe A/S**

**Tlf. +45 26 13 62 60**

**E-mail: pfe@viegandmaagoe.dk**

**WWW.VIEGANDMAAGOE.DK**


**Rikke Hovedskov Andersen**

**Projektmedarbejder**

**Viegand Maagøe A/S**

**Tlf. +45 60 29 78 29**

**E-mail: ran@viegandmaagoe.dk**

**WWW.VIEGANDMAAGOE.DK**

# EEMAP
# Energikortlægningsværktøj

Workshop 3

Tirsdag d. 29. august 2023, ved Avista.



# Workshop 3 – Avista Green in Kalundborg , August 2023

# Rundt om bordet –

Sæt nogle få ord på hvem I er og hvad I arbejder med.

# Agenda

| | |
|---|---|
| 10.00 – 10.10: | Introduktion til workshoppen (Fridolin) |
| 10.10 – 10.20: | Kort rundt om bordet (Alle) |
| 10.20 – 10.50: | Indblik i EEMAP-værktøjet og tankerne bag (Fridolin og Nasrin) |
| **10.50 – 11.00:** | **Pause** |
| 11.00 – 12.00: | Øvelse: Simpel energikortlægning i EEMAP (Aster) |
| **12.00 – 12.30:** | **Frokost** |
| 12.30 – 13.30: | Rundvisning på Avista (Peter) |
| 13.30 – 14.20: | Gennemgang af værktøjet: Fortolkning af resultaterne + diskussion i plenum (Fridolin og Aster) |
| **14.20 – 14.30:** | **Pause** |
| 14.30 – 15.00: | Afrunding og næste skridt (Fridolin og Aster) |

# Hvad er EEMAP-projektet?

- Udviklingen af et softwareværktøj, der kan reducerer tiden og omkostningerne forbundet med at lave en energikortlægning

- Anvender resultaterne fra kortlægningen, som et informationsgrundlag til optimeringen af processerne.

# Nytteværdi

- Udvidet brug af energikortlægning i industrien, understøtter sektorens grønne omstilling
- Digitalisering af processindustriens analoge energisystemer ved at fastlægge de rigtige behov for sensorinvesteringer og dataindsamling
- Understøtter beslutningsprocesser i forbindelse med implementering af virksomhedsstrategier, samt rapporteringskrav til myndighederne

# Projektorganisationen

## Viegand Maagøe

Projektansvarlige

Ingeniørrådgivnings-virksomhed

Erfaring med energikortlægninger og stor interesse i at digitalisere dette

## IPU

Softwareudviklere med ekspertise i termiske processer

## DTU

Forskere indenfor termiske processer i industrien

Formidler den industrielle læring og understøtter værktøjsudviklingen gennem erfaring med processmodellering.

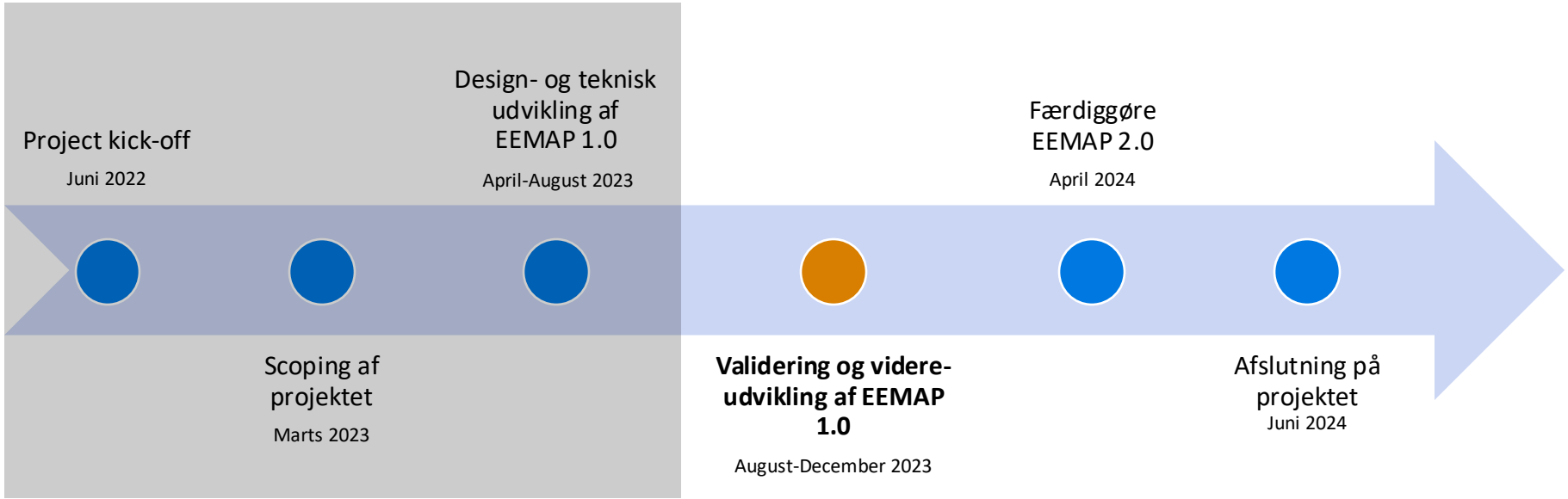
## Virksomhederne

Udvikling- og testvirksomhederne

FF-Skagen
Skjern Paper
Ovodan

PPG
Royal Unibrew
Avista Green

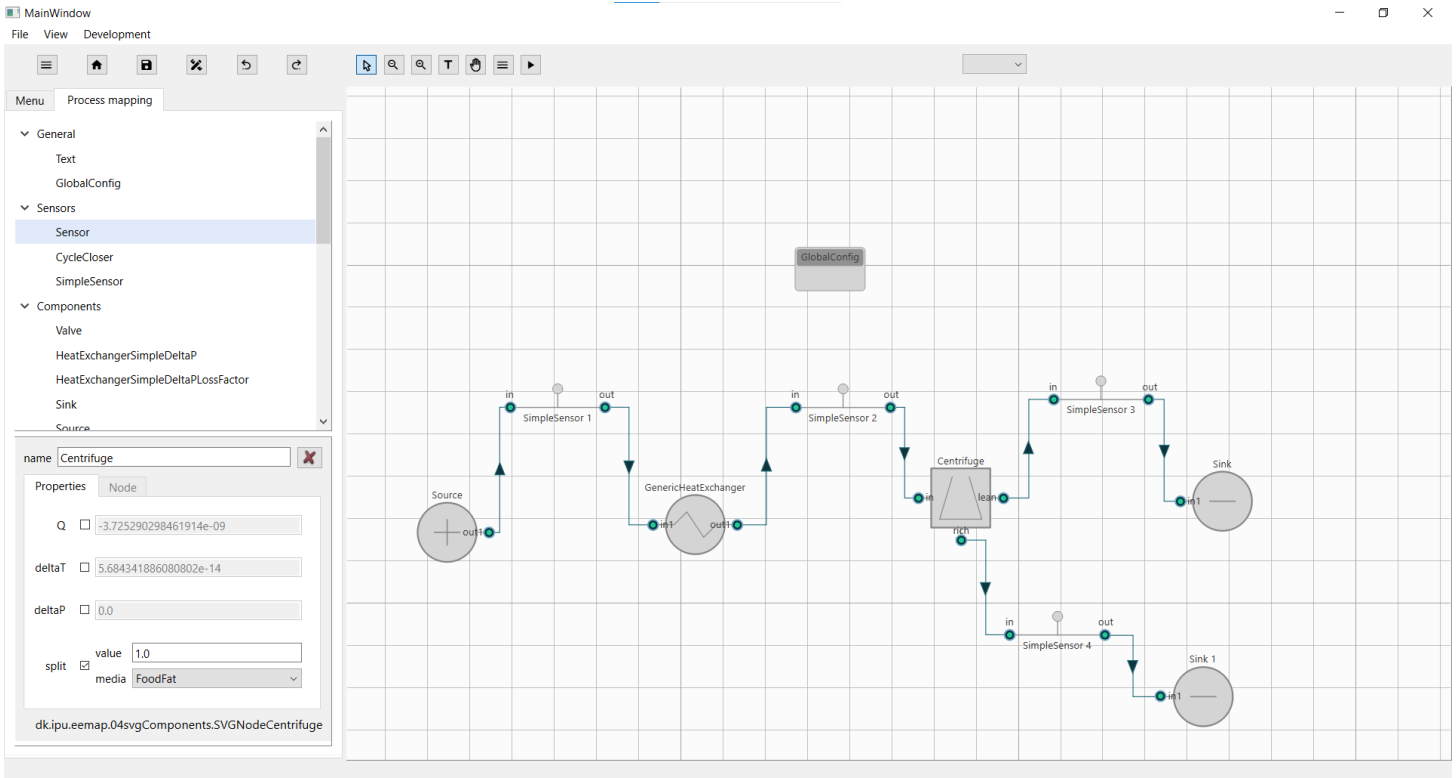
# Projektet i grove træk



# Formålet med workshoppen

- Give samarbejdsvirksomhederne et indblik i projektet
- Præsentere formålet og visionen med EEMAP-værktøjet
- Teste og få feedback på EEMAP-værktøjet. Virker det som intentionen?
- Give samarbejds- og udviklingsvirksomhederne et indblik i de næste skridt

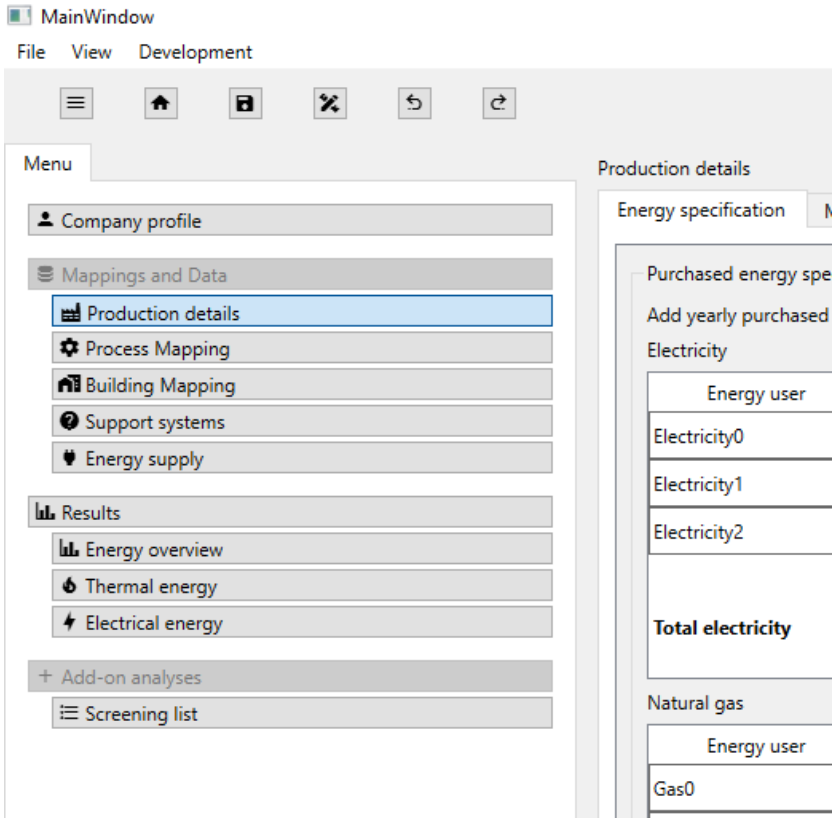
# Indblik i EEMAP-værktøjet og tankerne bag



# Workflow i værktøjet

Venstre menu, som viser arbejdsgangen i en kronologisk rækkefølge. Man kan dog springe frem og tilbage, som man har lyst

1. Indsæt generel virksomhedsinfo
2. Definere de overordnede inputs og outputs til produktionsvirksomheden fordelt som proces, bygninger, forsyning, mm.).
3. Se resultaterne
4. Lav analyser og optimer din proces



# 10 min pause …

# Øvelse 1

## Simpel energikortlægning i EEMAP

# Frokost pause

… Efterfulgt af rundvisning på Avista Oil

# Gennemgang af værktøjet

Menu Page properties

Company profile

Mapping and data
- Production details
- Process mapping
- Building mapping
- Support systems mapping
- Energy supply mapping

Results
- Energy overview
- Thermal usage
- KPI's

Add-on analysis
- Screening list
- Placeholder name
- Placeholder name

# Energy overview

**Get an overview of the consumed energy in your production**

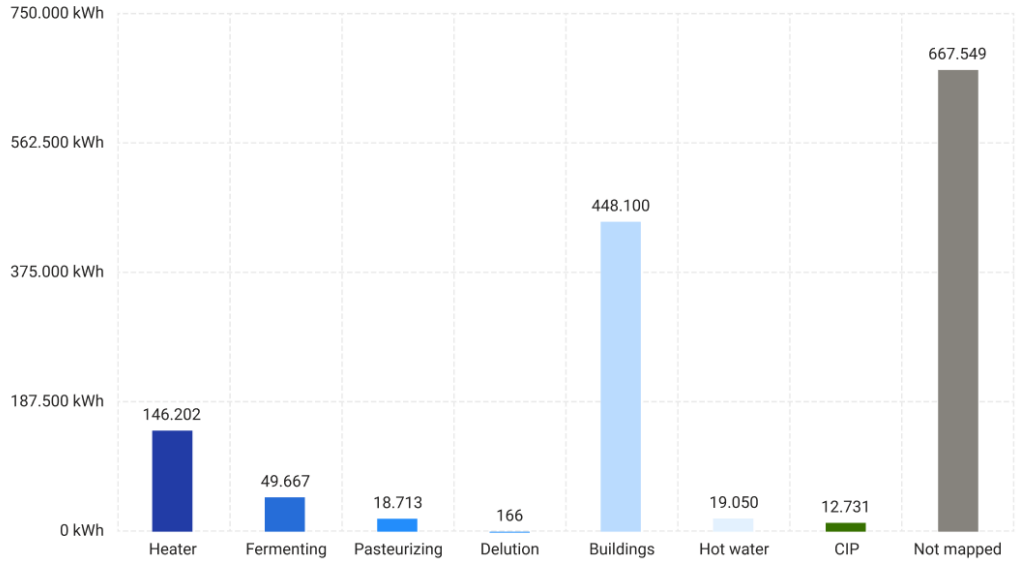
The following energy supplies have been registered in your mapping. Press the button for detailed view.

Steam | Gas | Water | Electricity

**Steam**

Registered energy 1.362.196 kWh

| | |
|---|---|
| Heater | 11 % |
| Fermenting | 4 % |
| Pasteurizing | 1 % |
| Delution | 0 % |
| Buildings | 33 % |
| Hot water | 1 % |
| CIP | 1 % |
| Not mapped/deviation | 49 % |



# Afrunding og næste skridt

# Fremadrettet arbejdsplan for virksomhederne

Afrunding og næste skridt

**Udviklingsvirksomhederne**

- Evaluering af version 2.0 (kortlægningsmetoder og resultater)
- Evaluering af version ...

**Workshops**

- Øvelser i nye kortlægningsfunktioner (November – hos?)
- Øvrige workshops

**Testvirksomhederne**

Forventninger til arbejdsprocessen

- Unibrew (find dato)
- PPG (find dato)
- Avista Green (find dato)

# Opsamling af workshoppens vigtigste pointer

# Til slut. Feedback på workshoppen

Hvad gik godt?

Hvad kan forbedres til næste gang?

Tak!

# Kontakt



**Fridolin Müller Holm**

Chef for industri

Viegand Maagøe A/S

Tlf. +45 31 75 17 14

fmh@viegandmaagoe.dk



**Rikke H. Andersen**

Junior Projektleder

Viegand Maagøe A/S

Tlf. +45 60 29 78 29

ran@viegandmaagoe.dk



**Sneaster Asrat**

Design ingeniør

Viegand Maagøe A/S

Tlf. +45 42 21 49 00

sas@viegandmaagoe.dk



**Johan D. Hollederer**

Studentermedhjælper

Viegand Maagøe A/S

Tlf. +45

jdh@viegandmaagoe.dk



**Martin Ryhl Kærn**

Specialist Ingeniør, Termodynamik og Energi Teknologi

IPU

Tlf. +45 45 16 04 36

mrk@ipu.dk

# Kontakt



**Jorrit Wronski**

Specialist Ingeniør, Termodynamik og Energi Teknologi

IPU

Tlf. +45 45 16 04 26

jowr@ipu.dk

**Victor Lyra**

Studentermedhjælper

IPU

vily@ipu.dk



**Brian Elmegaard**

Sektionsleder, Professor

DTU Construct, Institut for Byggeri og Mekanisk Teknologi

Tlf. +45 45 25 41 69

brel@dtu.dk



**Nasrin A. Kermani**

Forsker

DTU Construct, Institut for Byggeri og Mekanisk Teknologi

Tlf. +45 45 25 41 74

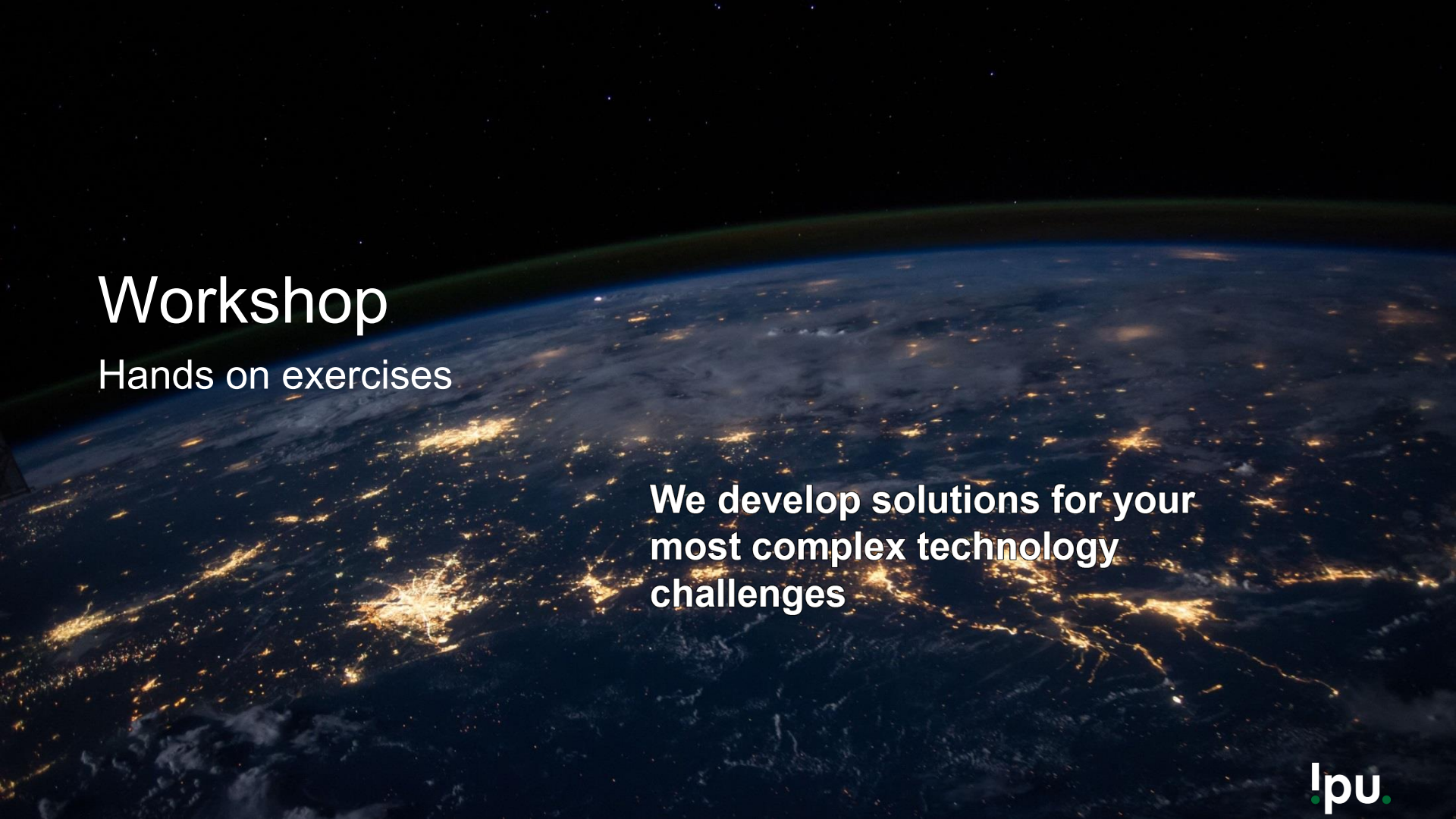
nasker@dtu.dk

# Hvad er EEMAP-projektet?

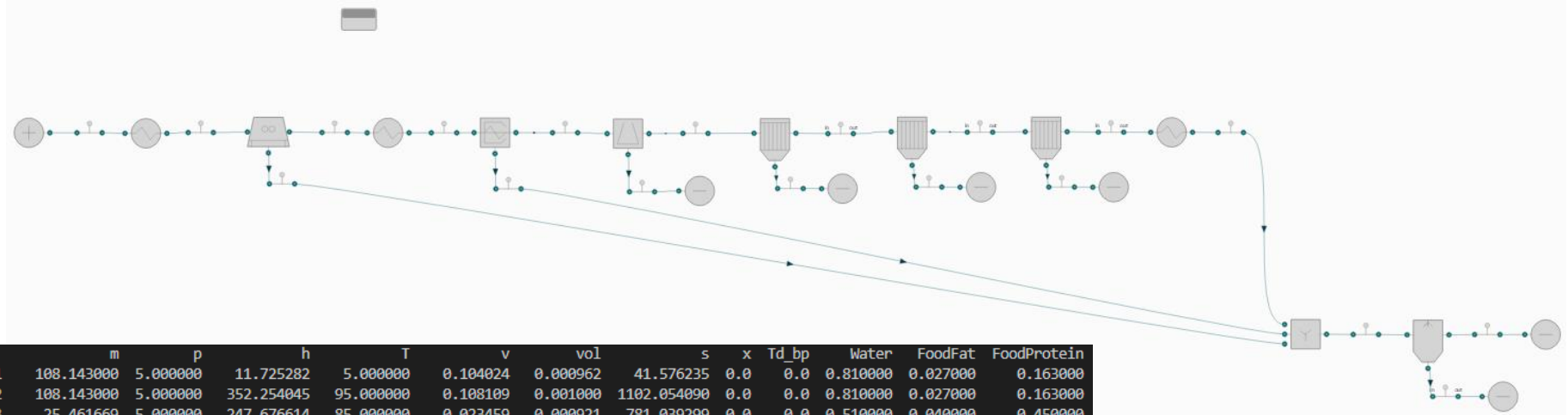
**Efficient Energy Mapping and Analysis for Optimization and Green Transition of Industrial Processes.*

- Udviklingen af et **softwareværktøj**, der kan **reducerer tiden** og **omkostningerne** forbundet med at lave en energikortlægning

- **Anvender resultaterne** fra kortlægningen, som et informationsgrundlag til **optimeringen** af processerne.

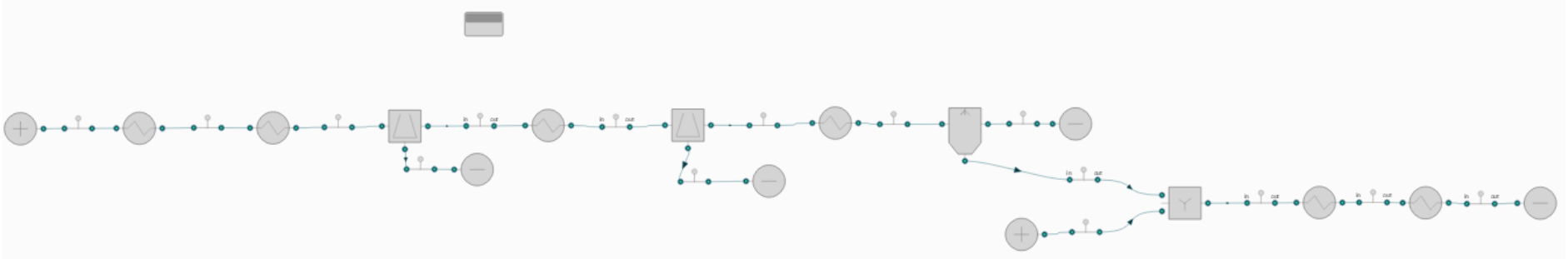

Workshop
Hands on exercises
We develop solutions for your most complex technology challenges
!pu.

# Skagen map with 3 evaporators :: Skagen9_svg_map_02.json



| | m | p | h | T | v | vol | s | x | Td_bp | Water | FoodFat | FoodProtein |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| c1 | 108.143000 | 5.000000 | 11.725282 | 5.000000 | 0.104024 | 0.000962 | 41.576235 | 0.0 | 0.0 | 0.810000 | 0.027000 | 0.163000 |
| c2 | 108.143000 | 5.000000 | 352.254045 | 95.000000 | 0.108109 | 0.001000 | 1102.054090 | 0.0 | 0.0 | 0.810000 | 0.027000 | 0.163000 |
| c3 | 25.461669 | 5.000000 | 247.676614 | 85.000000 | 0.023459 | 0.000921 | 781.039299 | 0.0 | 0.0 | 0.510000 | 0.040000 | 0.450000 |
| c4a | 82.681331 | 5.000000 | 334.691229 | 85.000000 | 0.083948 | 0.001015 | 1063.858945 | 0.0 | 0.0 | 0.902385 | 0.022997 | 0.074619 |
| c4b | 82.681331 | 5.000000 | 374.680613 | 95.000000 | 0.084515 | 0.001022 | 1173.983402 | 0.0 | 0.0 | 0.902385 | 0.022997 | 0.074619 |
| c5 | 6.543471 | 5.000000 | 295.608789 | 90.000000 | 0.006237 | 0.000953 | 928.566602 | 0.0 | 0.0 | 0.648000 | 0.022000 | 0.330000 |
| c6 | 76.137861 | 5.000000 | 359.750464 | 90.000000 | 0.077989 | 0.001024 | 1135.657420 | 0.0 | 0.0 | 0.924247 | 0.023082 | 0.052670 |
| c7 | 74.628949 | 5.000000 | 323.315839 | 80.000000 | 0.075796 | 0.001016 | 1035.829353 | 0.0 | 0.0 | 0.942934 | 0.003532 | 0.053533 |
| c8 | 1.508911 | 5.000000 | 123.048658 | 80.000000 | 0.001686 | 0.001117 | 380.343002 | 0.0 | 0.0 | 0.000000 | 0.990000 | 0.010000 |
| c9a | 53.268316 | 5.000000 | 157.827615 | 40.000000 | 0.052727 | 0.000990 | 537.226815 | 0.0 | 0.0 | 0.920051 | 0.004949 | 0.075000 |
| c9b | 31.960989 | 5.000000 | 209.920819 | 55.100000 | 0.031463 | 0.000984 | 697.456227 | 0.0 | 0.0 | 0.866752 | 0.008248 | 0.125000 |
| c9c | 13.317079 | 5.000000 | 232.606017 | 70.000000 | 0.012645 | 0.000950 | 753.085501 | 0.0 | 0.0 | 0.680205 | 0.019795 | 0.300000 |
| c9d | 13.317079 | 5.000000 | 356.195509 | 105.000000 | 0.012918 | 0.000970 | 1096.015054 | 0.0 | 0.0 | 0.680205 | 0.019795 | 0.300000 |
| c10a | 21.360634 | 0.073849 | 2573.510322 | 40.000000 | 416.855839 | 19.515144 | 8255.548109 | 1.0 | NaN | 1.000000 | 0.000000 | 0.000000 |
| c10b | 21.307326 | 0.158378 | 2600.269529 | 55.100000 | 202.874414 | 9.521345 | 7988.170110 | 1.0 | NaN | 1.000000 | 0.000000 | 0.000000 |
| c10c | 18.643911 | 0.312009 | 2626.096401 | 70.000000 | 93.956767 | 5.039542 | 7753.999489 | 1.0 | NaN | 1.000000 | 0.000000 | 0.000000 |
| c11 | 45.322218 | 5.000000 | 286.483132 | 92.013727 | 0.042605 | 0.000940 | 895.872398 | 0.0 | 0.0 | 0.579935 | 0.031464 | 0.388600 |
| c12 | 20.693759 | 5.000000 | 186.425736 | 100.000000 | 0.017121 | 0.000827 | 564.383151 | 0.0 | 0.0 | 0.080000 | 0.068912 | 0.851088 |
| c13 | 24.628459 | 1.014180 | 2675.569884 | 100.000000 | 41.173023 | 1.671766 | 7354.119146 | 1.0 | NaN | 1.000000 | 0.000000 | 0.000000 |

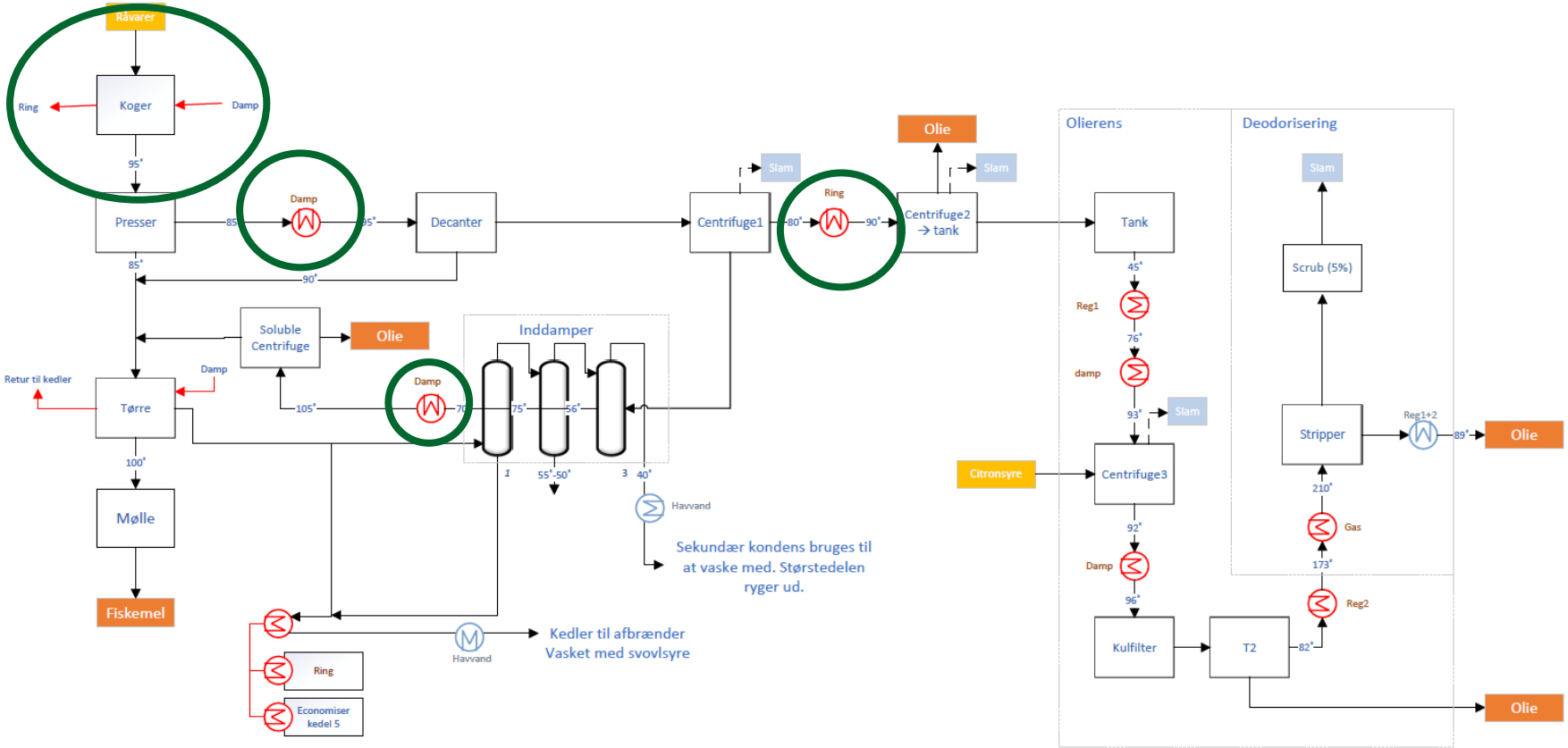
# Ovodan map :: ovodan_svg.json



| | m | p | h | T | v | vol | s | x | Td_bp | Water | FoodProtein |
|---|---|---|---|---|---|---|---|---|---|---|---|
| c1 | 6.755000 | 5.000000 | 55.391515 | 15.0 | 0.006578 | 0.000974 | 195.852833 | 0.0 | 0.0 | 0.890000 | 0.110000 |
| c2 | 6.755000 | 5.000000 | 35.632639 | 10.0 | 0.006574 | 0.000973 | 126.679306 | 0.0 | 0.0 | 0.890000 | 0.110000 |
| c3 | 6.755000 | 5.000000 | 114.576303 | 30.0 | 0.006602 | 0.000977 | 396.082263 | 0.0 | 0.0 | 0.890000 | 0.110000 |
| c4a | 0.037000 | 5.000000 | 124.075188 | 30.0 | 0.000037 | 0.000999 | 429.236209 | 0.0 | 0.0 | 0.980000 | 0.020000 |
| c4b | 6.718000 | 5.000000 | 114.523987 | 30.0 | 0.006566 | 0.000977 | 395.899665 | 0.0 | 0.0 | 0.889504 | 0.110496 |
| c5 | 6.718000 | 5.000000 | 142.124127 | 37.0 | 0.006581 | 0.000980 | 485.908901 | 0.0 | 0.0 | 0.889504 | 0.110496 |
| c6a | 3.625042 | 5.000000 | 155.434594 | 37.0 | 0.003649 | 0.001007 | 531.988785 | -1.0 | NaN | 1.000000 | 0.000000 |
| c6b | 3.092958 | 5.000000 | 126.523852 | 37.0 | 0.002932 | 0.000948 | 431.901869 | 0.0 | 0.0 | 0.760000 | 0.240000 |
| c7 | 3.092958 | 5.000000 | -1.907165 | 2.0 | 0.002909 | 0.000940 | -7.493258 | 0.0 | 0.0 | 0.760000 | 0.240000 |
| c8a | 2.303267 | 0.123519 | 2591.288888 | 50.0 | 27.701194 | 12.026915 | 8074.834856 | 1.0 | NaN | 1.000000 | 0.000000 |
| c8b | 0.789691 | 5.000000 | 70.612275 | 50.0 | 0.000617 | 0.000782 | 229.717409 | 0.0 | 0.0 | 0.060000 | 0.940000 |
| c9 | 0.100000 | 5.000000 | 70.612275 | 50.0 | 0.000078 | 0.000782 | 229.717409 | 0.0 | 0.0 | 0.060000 | 0.940000 |
| c10 | 0.889691 | 5.000000 | 70.612275 | 50.0 | 0.000695 | 0.000782 | 229.717409 | 0.0 | 0.0 | 0.060000 | 0.940000 |
| c11 | 0.889691 | 5.000000 | 152.416674 | 87.0 | 0.000706 | 0.000794 | 469.354751 | 0.0 | 0.0 | 0.060000 | 0.940000 |
| c12 | 0.889691 | 5.000000 | 5.314242 | 20.0 | 0.000687 | 0.000772 | 17.671231 | 0.0 | 0.0 | 0.060000 | 0.940000 |

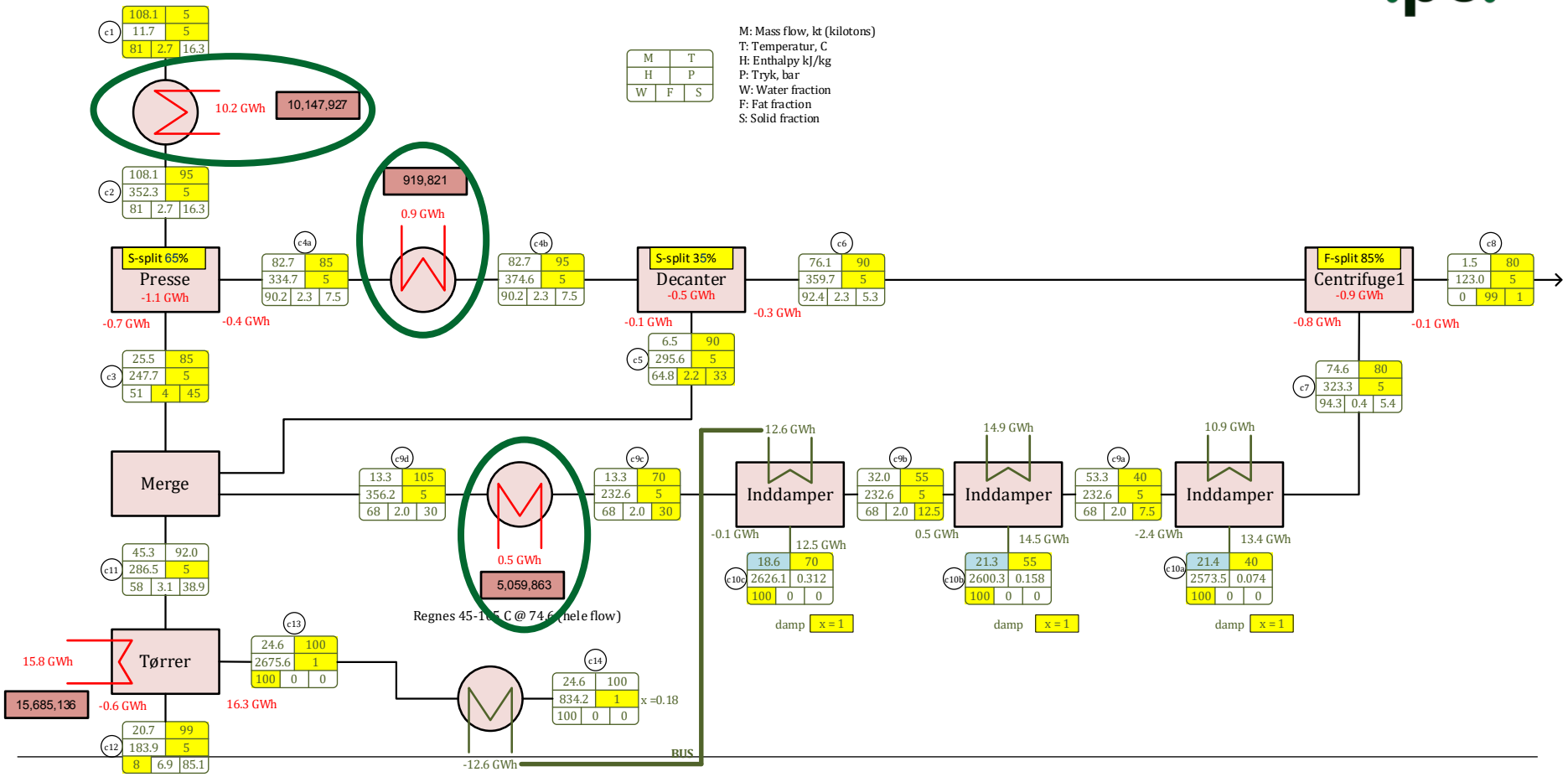
# Heat Exchangers

# Case plant Skagen ff



**Blåhvilling**

Råvarer




DTU

# EEMAP OUTCOME/ADD ON

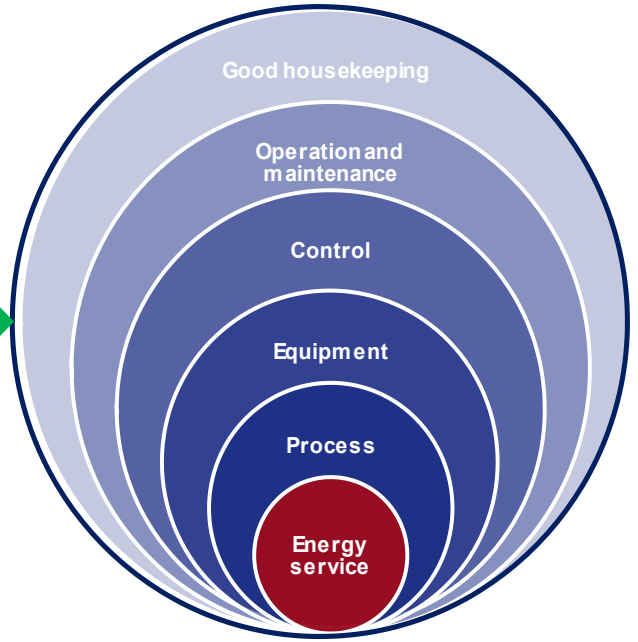
Nasrin Arjomand Kermani

# First step towards energy optimization

Identifying the correct "baseline" leads to much more cost-efficient solution



**To identify the right ”baseline”, energy mapping is an important tool**




**Green transition in industry**

**Energy optimization approach**


FF
SKAGEN
DENMARK


SKJERN PAPER


OVODAN
RELIABLE EGG SOLUTIONS

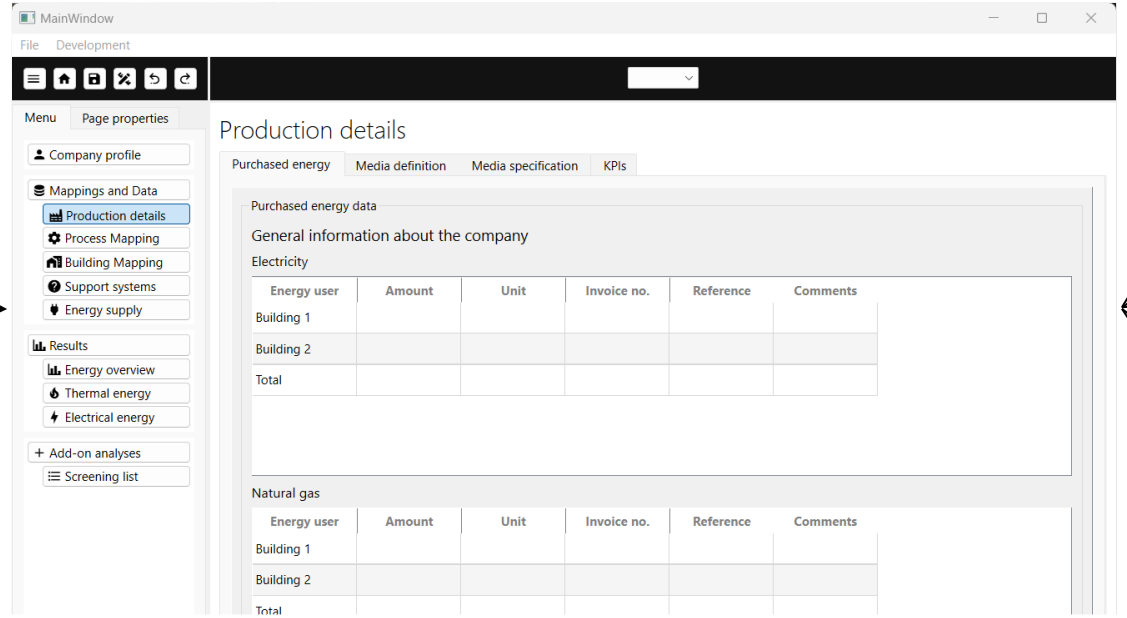

AVISTA OIL


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PPG Industries
Bringing innovation to the surface.™


ROYAL
UNIBREW

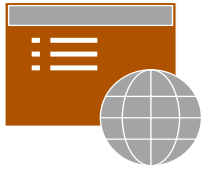
# EEMAP Outcome/ Add on



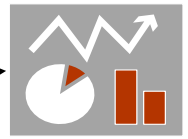





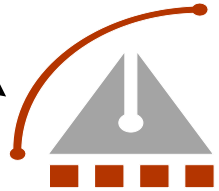

Energy flow mapping - 85% accuracy



Keep track of data and energy reports



Overview of the energy use and KPIS

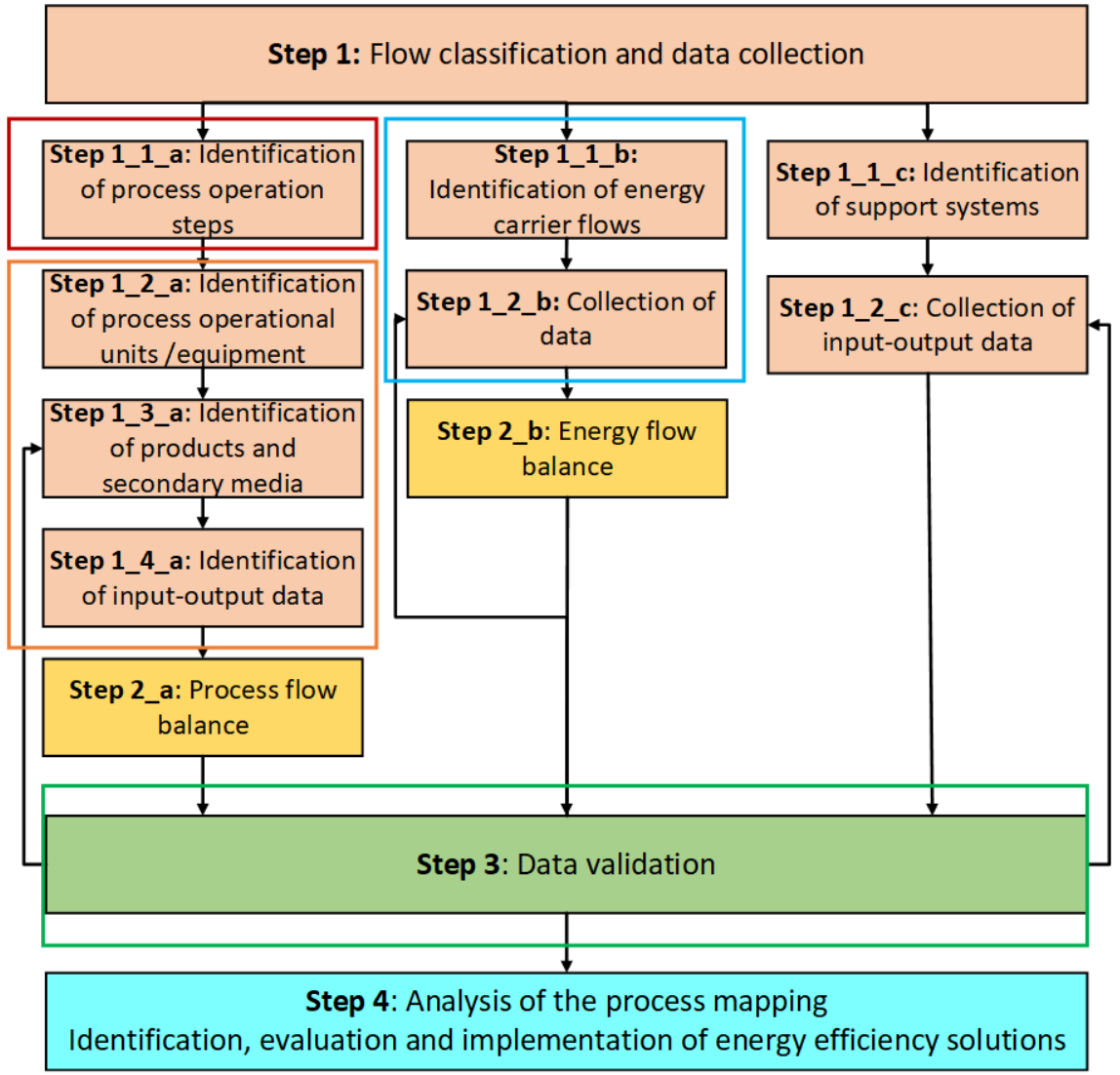


Temperature and Pinch analysis

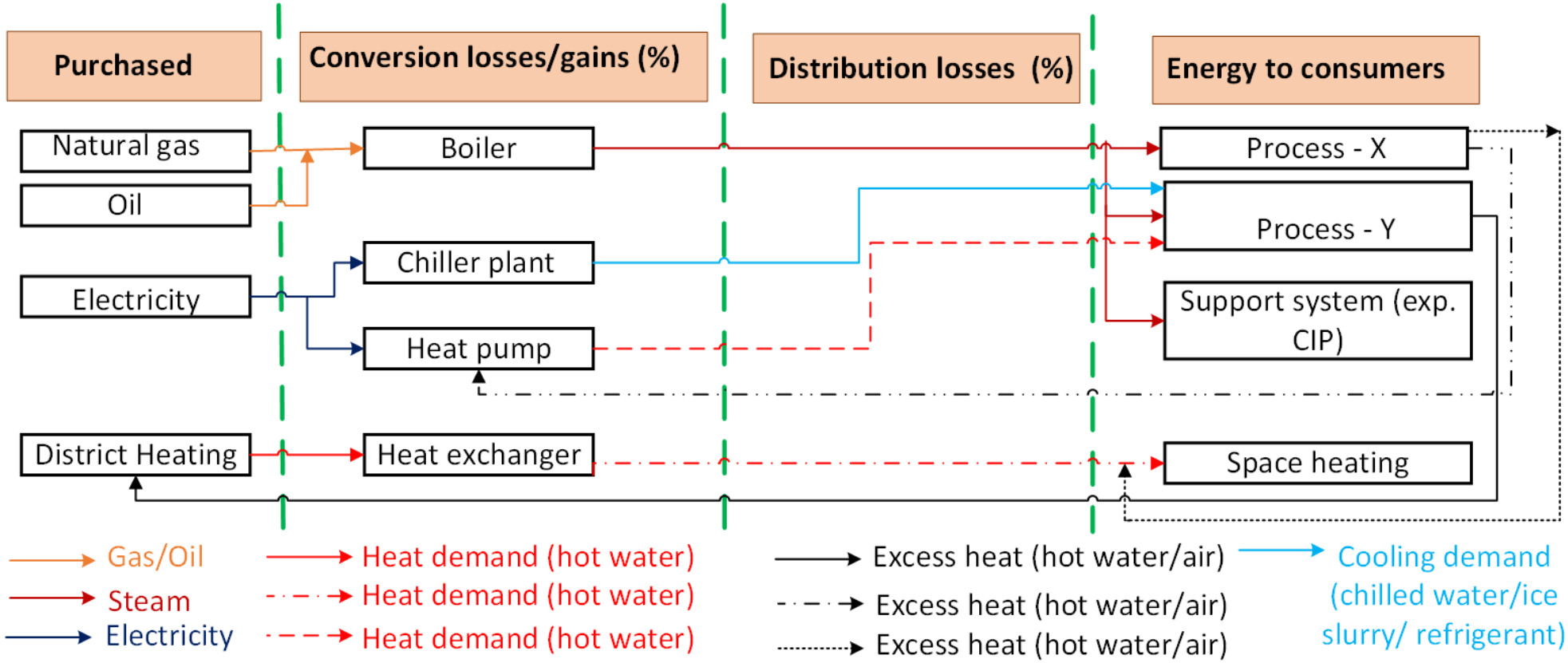


Identification of future opportunities for energy optimization

# Energy flow mapping - Methodology



# Energy flow mapping - Methodology



# Energy flow mapping - FF Skagen

**Step 1_1_a:** Identification of process operation steps

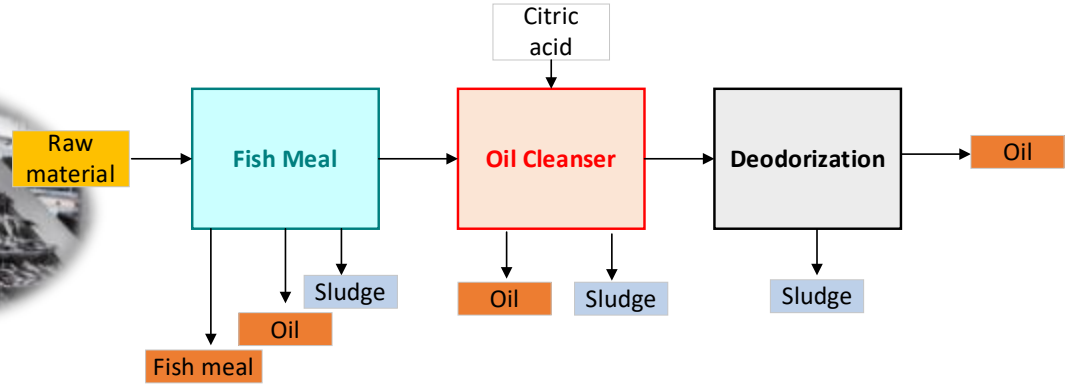
**Step 1_2_a:** Identification of process operational units /equipment

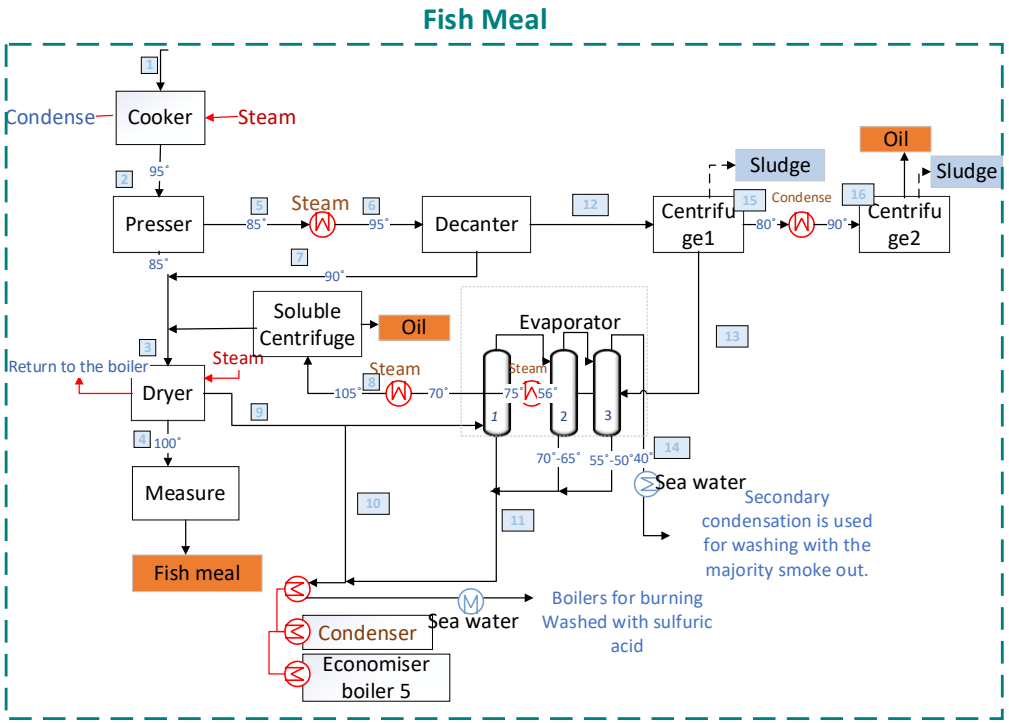
**Step 1_3_a:** Identification of products and secondary media

**Step 1_4_a:** Identification of input-output data

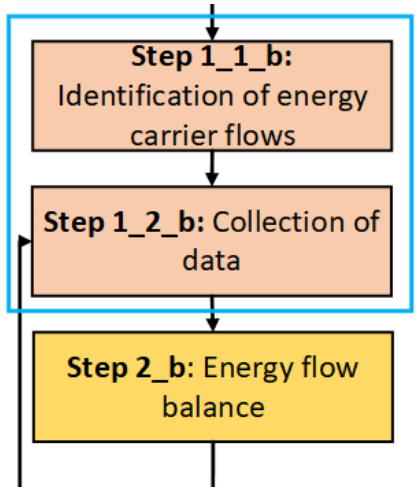
**Step 2_a:** Process flow balance

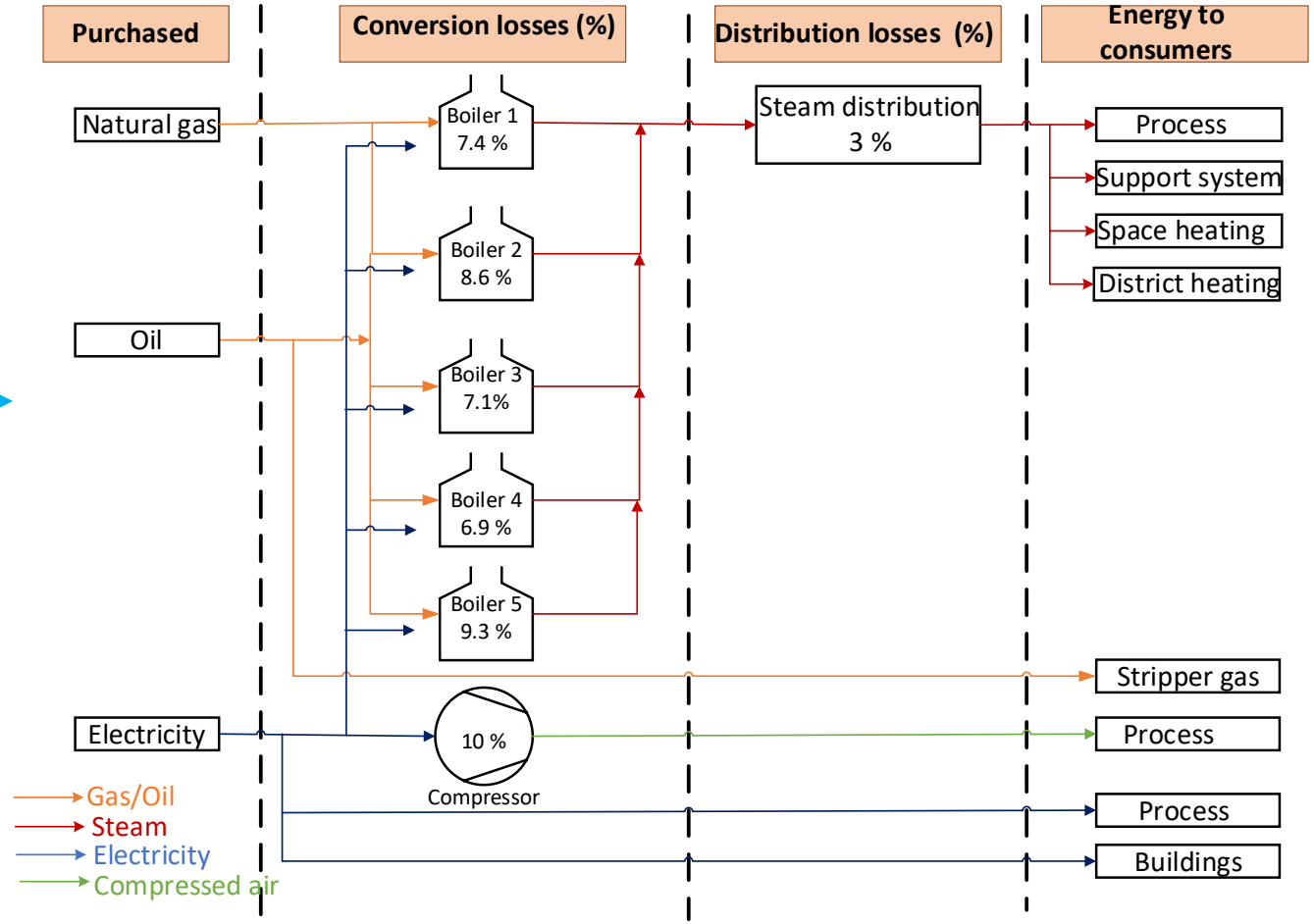




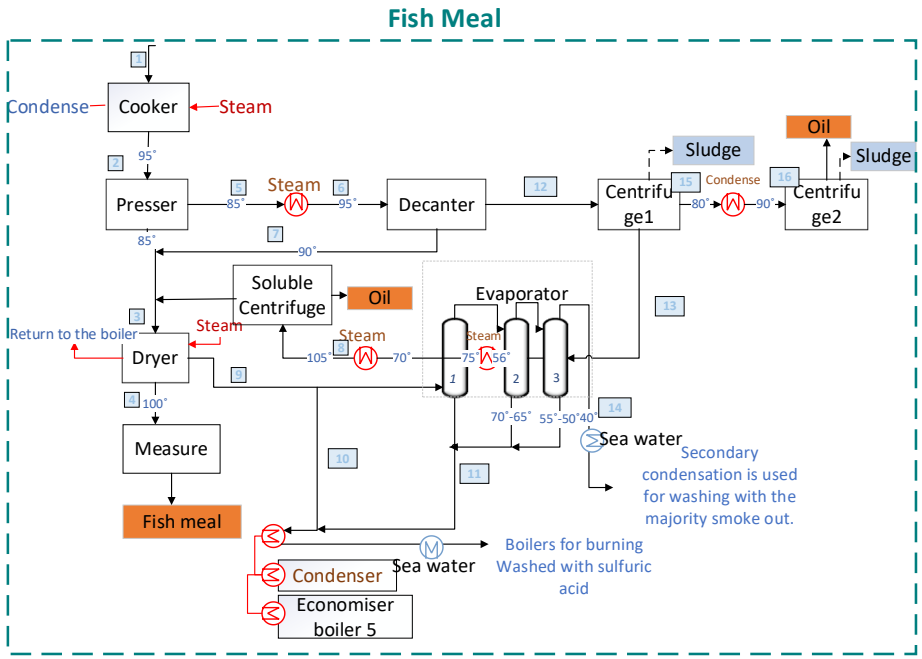



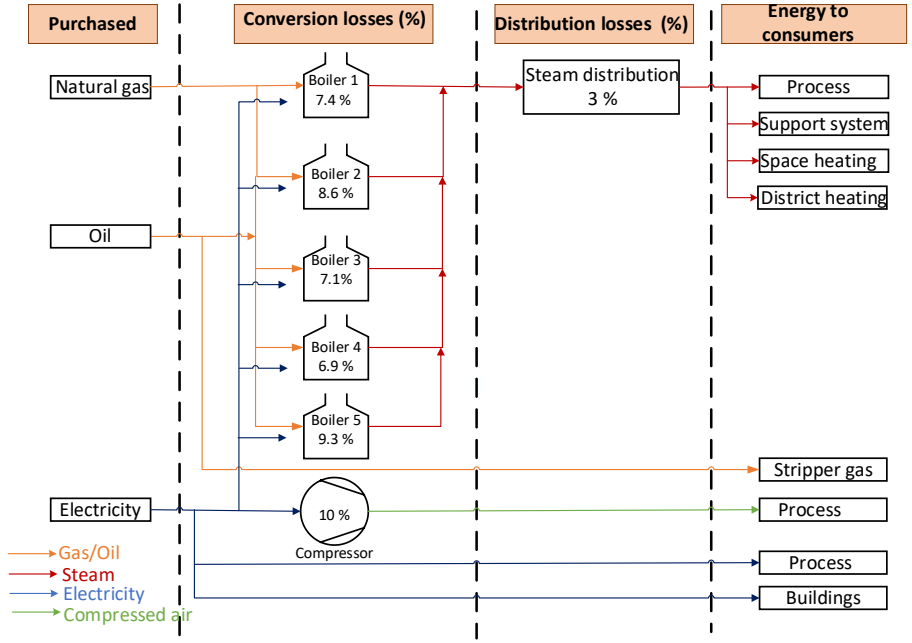
# Energy flow mapping - FF Skagen



# Energy flow mapping - FF Skagen



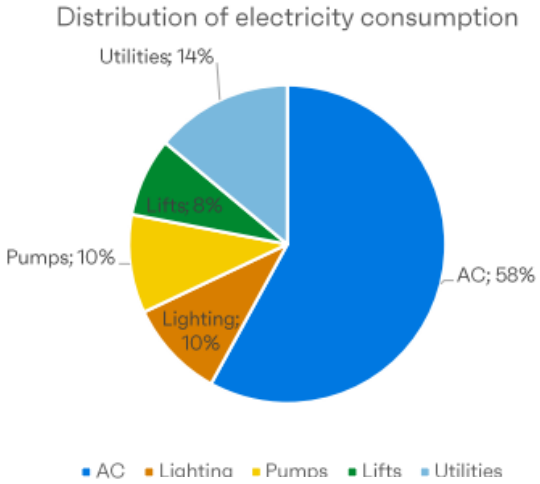



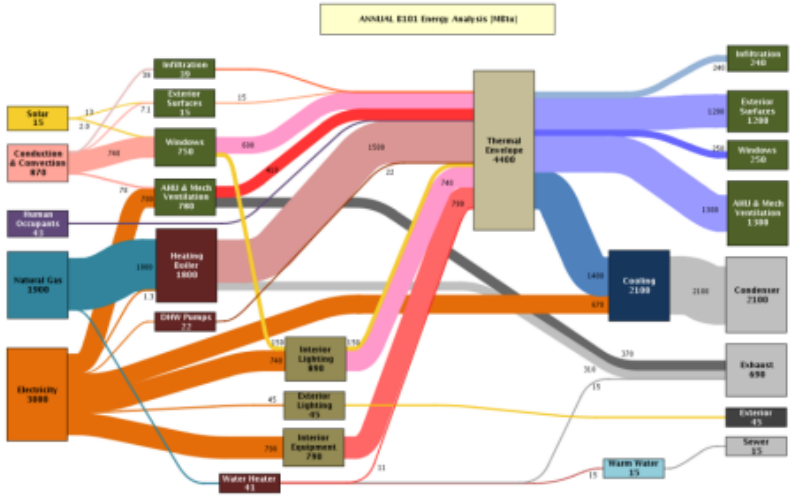

**Step 3**: Data validation

✓ **88% of the energy use is mapped**

# Overview of the energy use and KPIS

- Energy flow diagrams
- Identify significant energy users
- Create an overview and a mutual understanding of the site
- Energy saving charts



# Example of CP Kelco

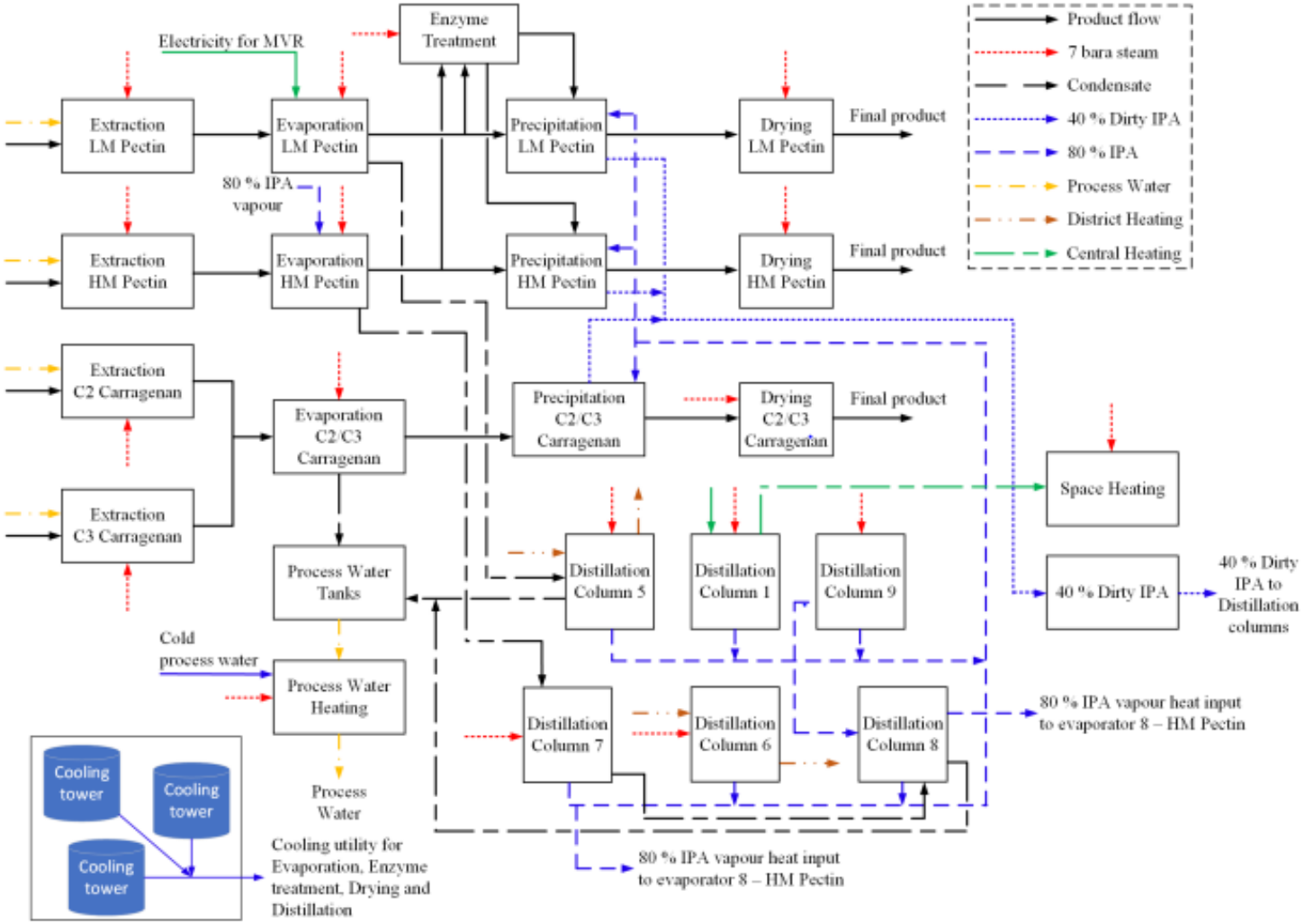


## Production processes

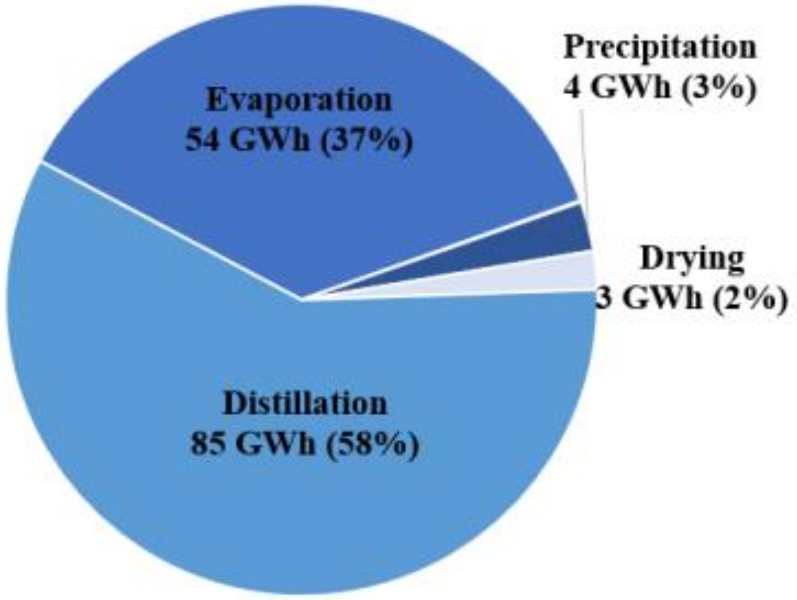
- Extraction
- Evaporation
- Precipitation/Separation
- Drying

## Production utilities

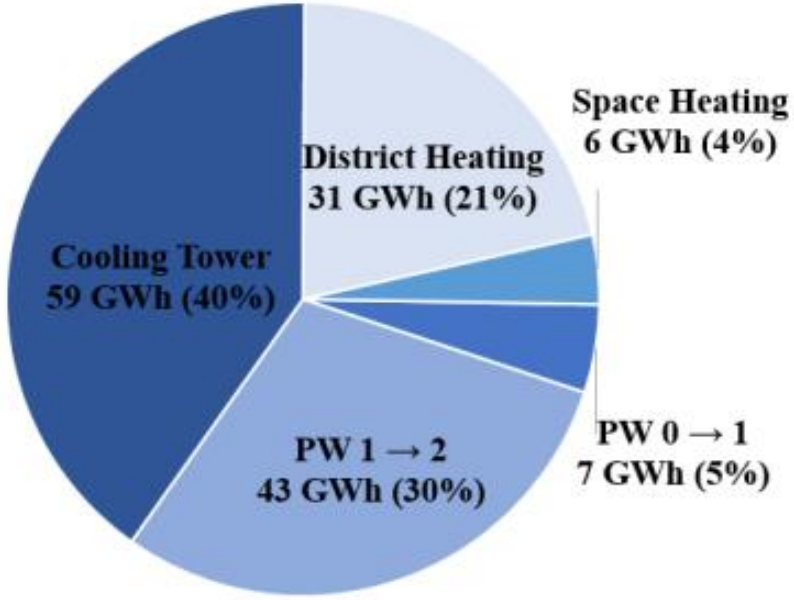
- Heating of processes
- Cooling of processes
- Service processes
- Distillation
- Central heating



# Overview of the energy use - CP Kelco




(a) Cooling of processes




(b) Cooling utilities

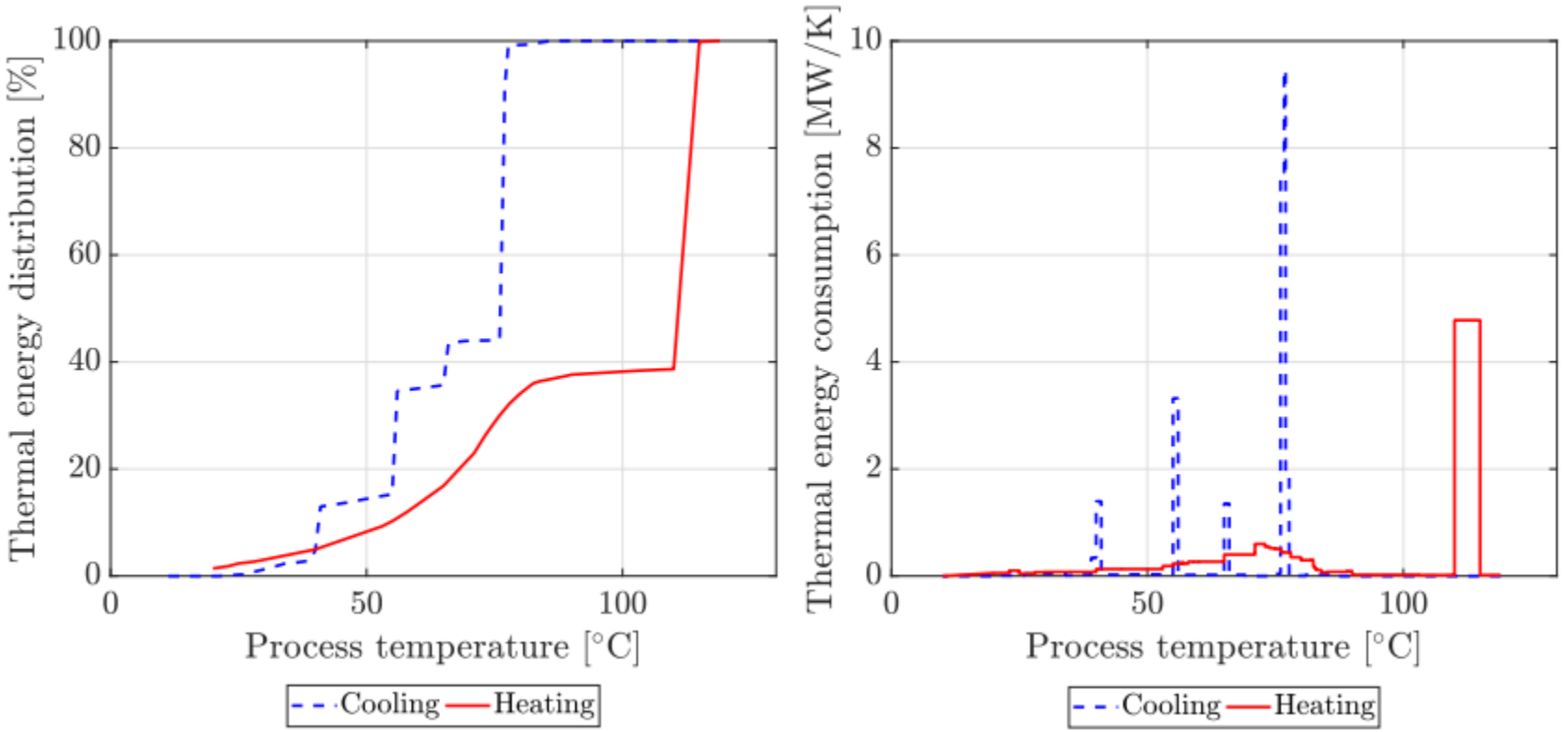
Distribution of cooling demand for processes and contribution ratio of cooling utilities at CP Kelco

# Temperature analysis

**Understanding of energy usage**

How energy is produced and how energy is used – Finding the gaps

# Temperature analysis - CP Kelco




Energy mapping of CP Kelco for process heating and cooling demand

# Pinch Analysis

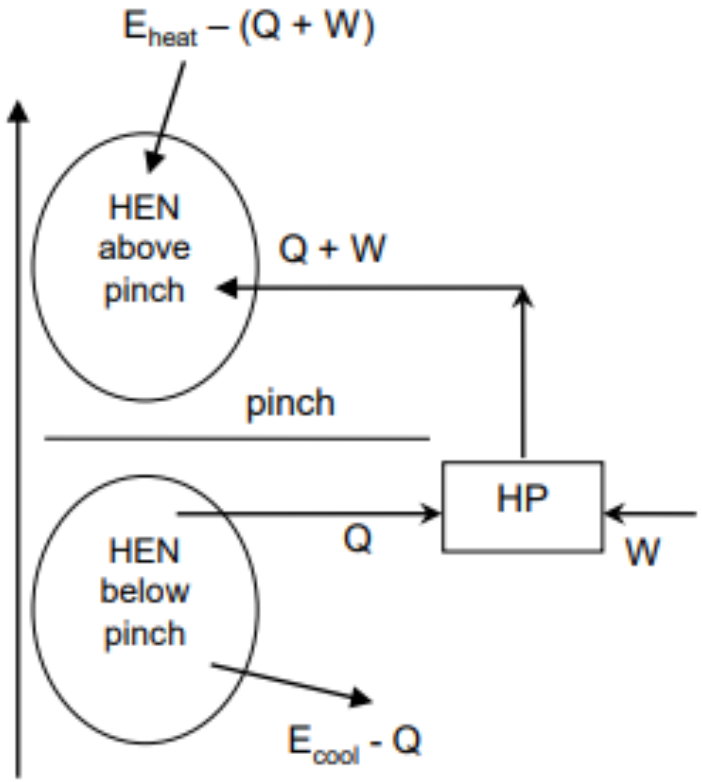
Pinch Analysis is a systematic methodology which focuses on minimizing energy use and maximizing heat integration by identifying temperature "pinch points" in a system

# Applications of Pinch Analysis



- Table and graphical illustration of possibilities
- Energy targeting
- Basis for heat exchanger network design and direct heat recovery
- Improved exiting heat exchanger network
- Enhance process integration - Basis for integration of heat pumps and

# Applications of Pinch Analysis

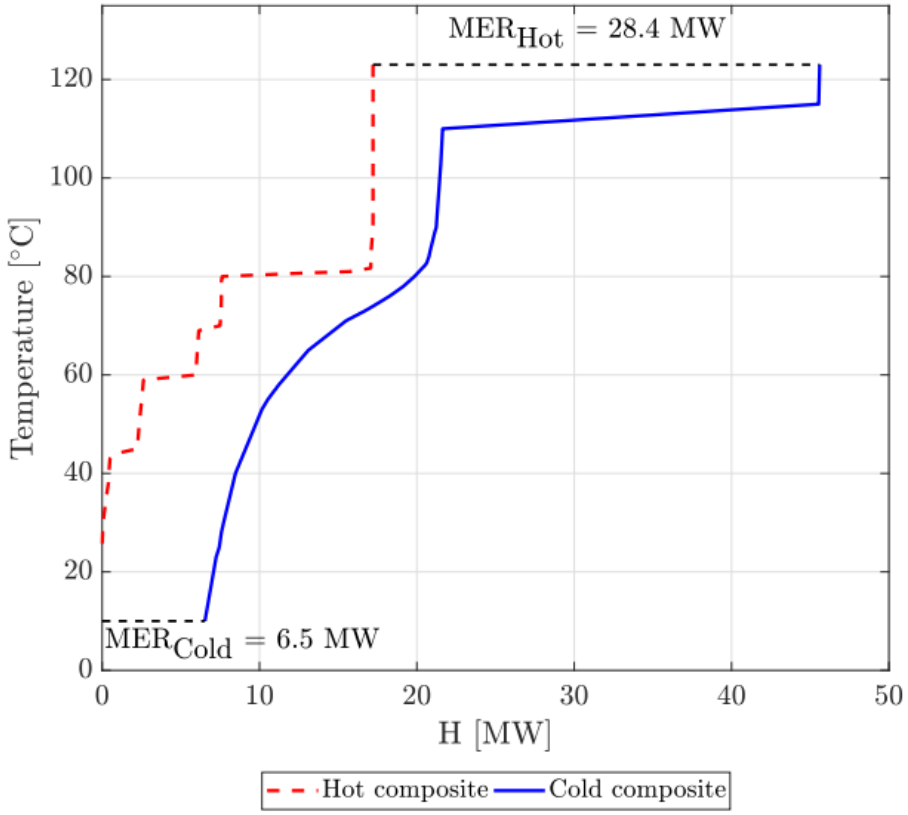



Appropriate placement of heat pump

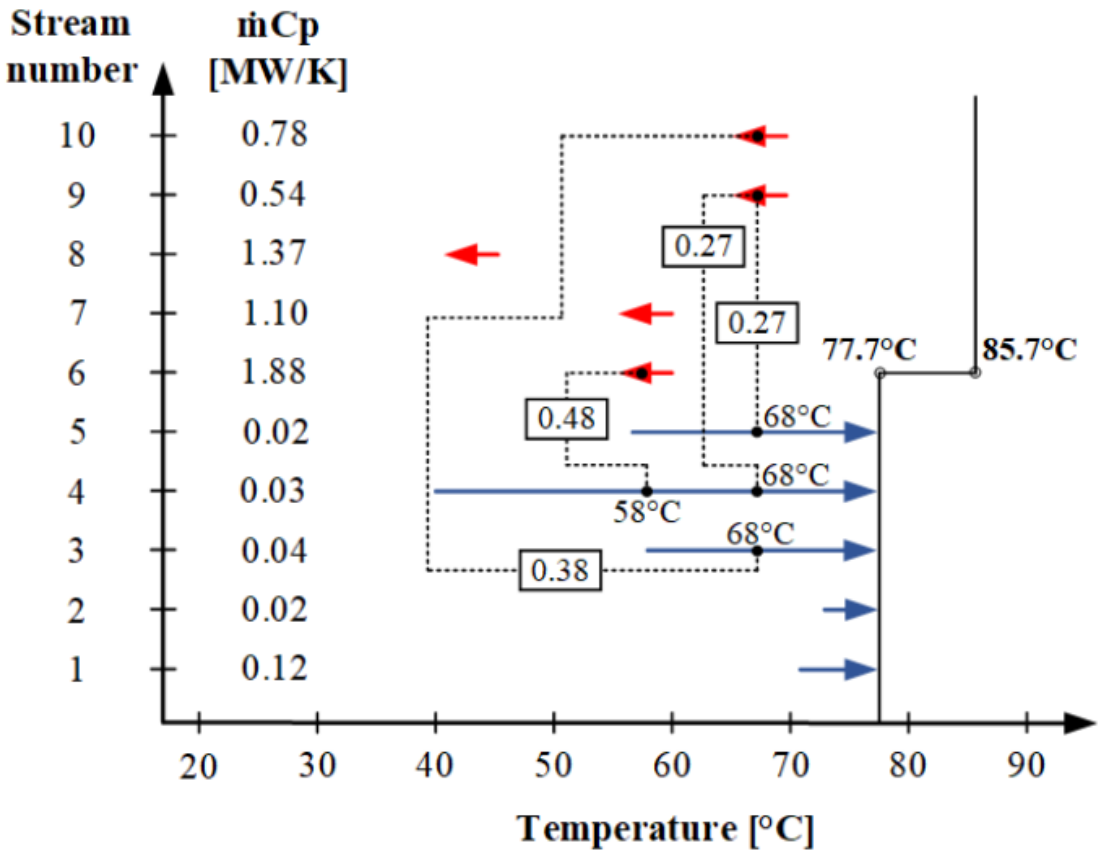
Across the Pinch

# Pinch Analysis - CP Kelco

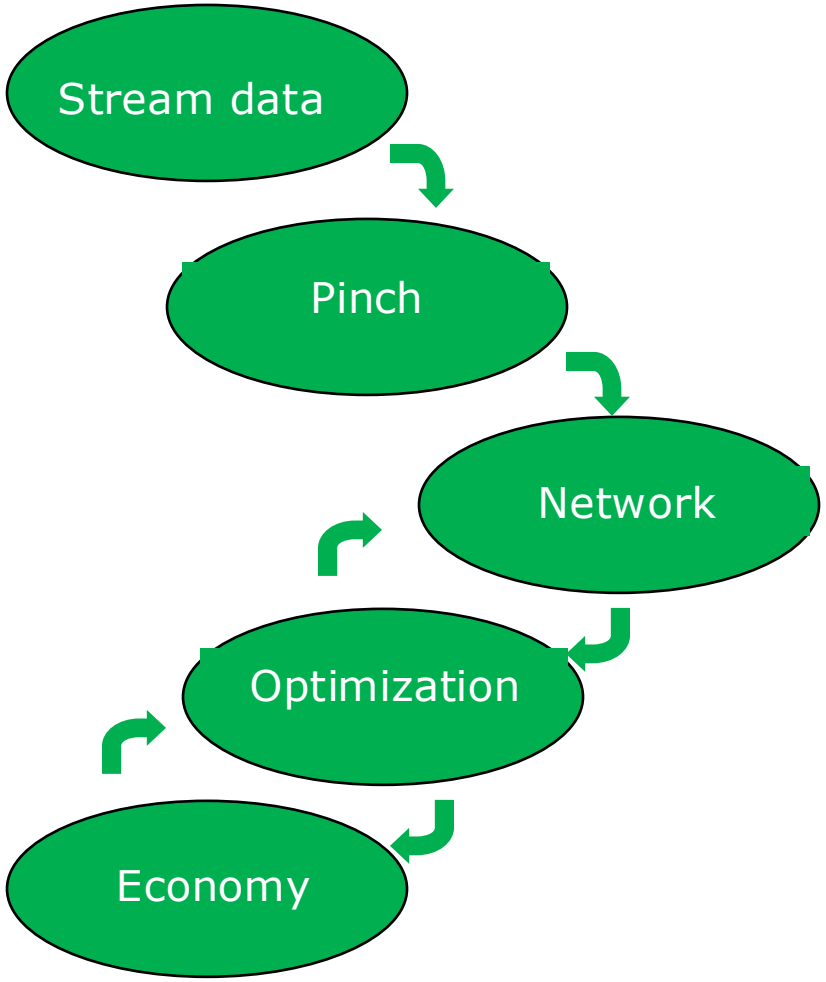




# Heat Exchanger Network - CP Kelco




HEN proposal for remaining streams



# Thank you

# EEMAP
# Afslutningsmøde

23. maj 2024





# Workshop 4 – in Skjern Paper, Skjern , May 2024

# Agenda

**10.00 – 10.45:** Feedback runde i plenum på de seneste ændringer, samt bruger guiden, hvor der indgår en 'best practice'* (VM)

**10.45 – 11.15:** Visning af værktøjets seneste opdateringer (IPU)

**11.15 – 11.25:** Evt. kort pause

**11.25 – 12.00:** Oplæg om hvordan man kan gøre brug af resultaterne (DTU/VM)

**12.00 – 12.30:** Frokost pause

**12.30 – 13.00:** Koordinering af 'Release Party' hos IPU d. 18. Juni

**13.00 – 14.00:** EEMAP 2.0 – hvad skal inkluderes i værktøjet? Interesse i at fortsætte samarbejdet?

**14.00 – 15.00:** Tur rundt på Skjern Papir

Viegand Maagøe

# Feedback i plenum /VM

- Nyeste version, seneste ændringer
- Brugermanual
- Udfyldning af elektricitetsdelen

Viegand Maagøe

# Visning af værktøjets seneste ændringer /IPU

Ændringer inkluderer:

- Mulighed for at definere sine egne medier også med faseskift
- Se hvilken fil man har åben
- Begrænsninger på zoom
- Gætværdier slettes når nye fluider vælges
- Total elektricitet kan ses i energy supply
- …

# Brug af resultaterne

/VM og DTU

# Oplæg om hvordan man kan gøre brug af resultaterne

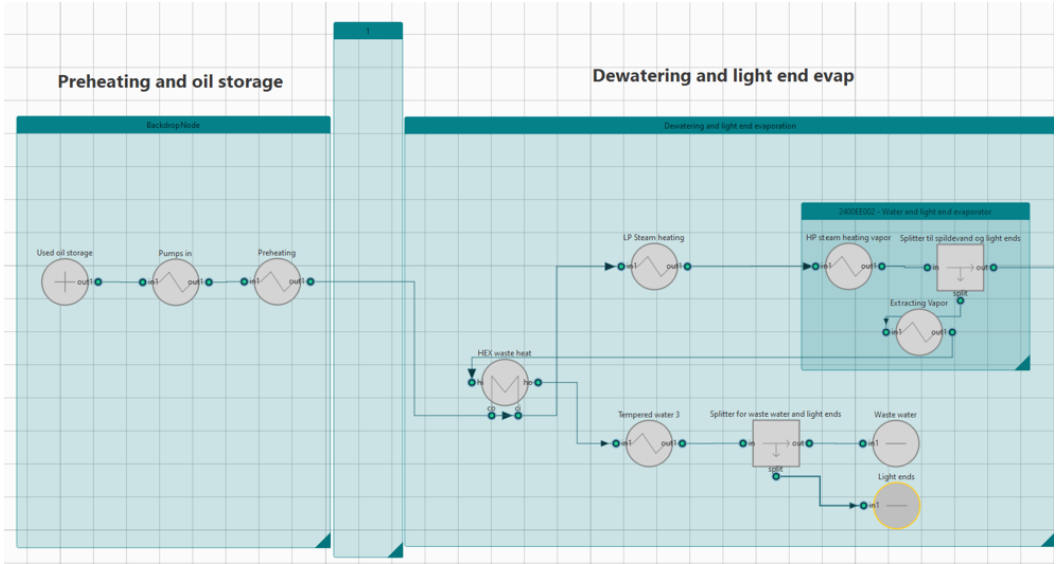
(DTU/VM)

- Proces og forsyningsoverblik
- Mapping degree som mål for samlet overblik
- Skalerbar model som simuleringsværktøj
- KPI'er på undersystemer
- Forholdsmæssige energiforbrug på komponenter
- Pinch-analyse, HEX-netværk og Temperaturanalyse
- Samling af energidata som basis for rapportering
- Screeningsliste
- Undersøgelse af projekt muligheder
- Energy management and energisyn

# Oplæg om hvordan man kan gøre brug af resultaterne

(DTU/VM)

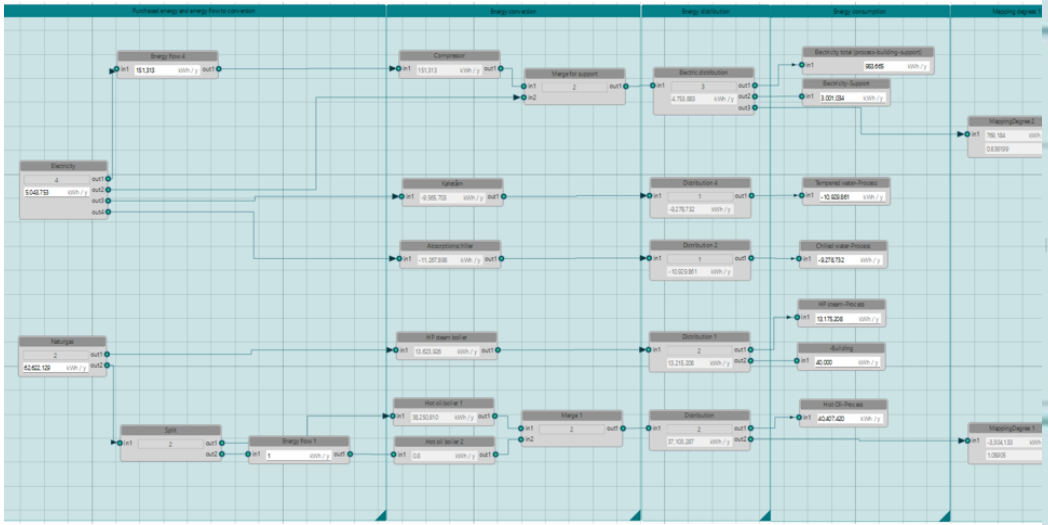
- Proces og forsyningsoverblik

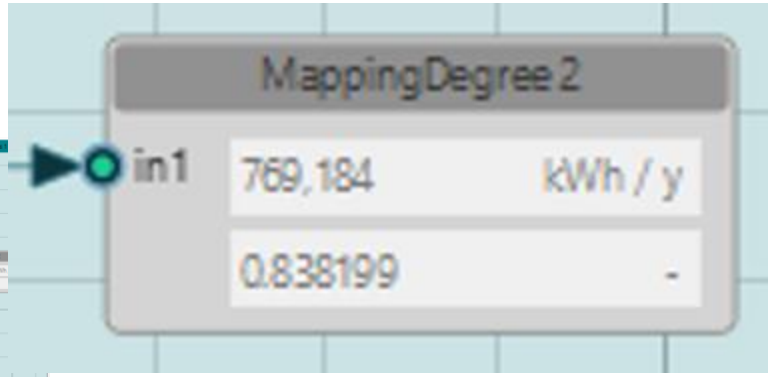


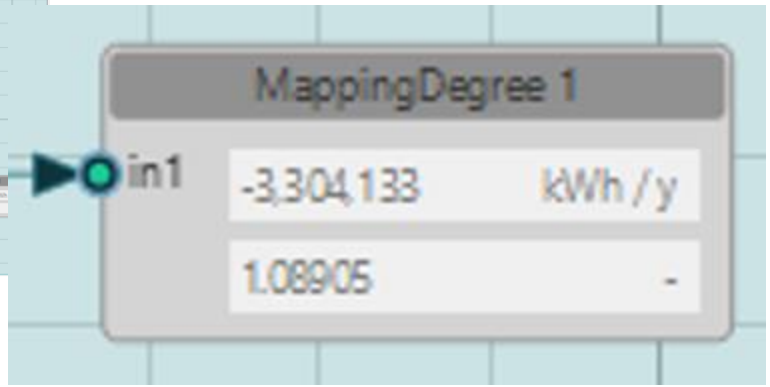
# Oplæg om hvordan man kan gøre brug af resultaterne

(DTU/VM)

- Mapping degree som mål for samlet overblik





# Oplæg om hvordan man kan gøre brug af resultaterne

(DTU/VM)

- Skalerbar model som simuleringsværktøj
  - Ændringer i proces
  - Andre inputs
  - OPEX Budget ved produktionsændringer

Viegand Maagøe

# Oplæg om hvordan man kan gøre brug af resultaterne

(DTU/VM)

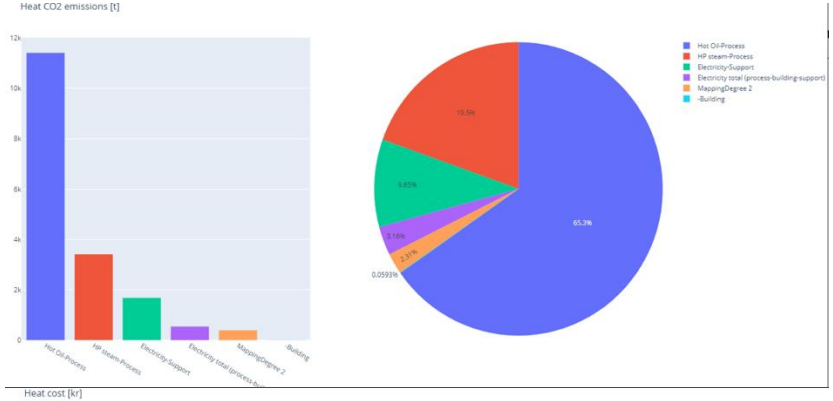
- KPI'er på undersystemer
  - Kan findes for samtlige komponenter
  - Produktionsnøgletal
  - Målsætninger for andre

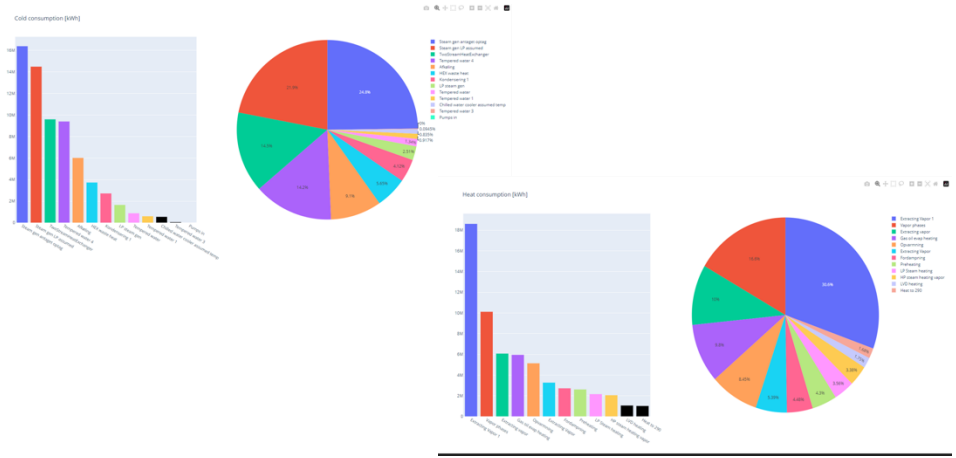
- Kunne visualisering af KPI'er være interessant?

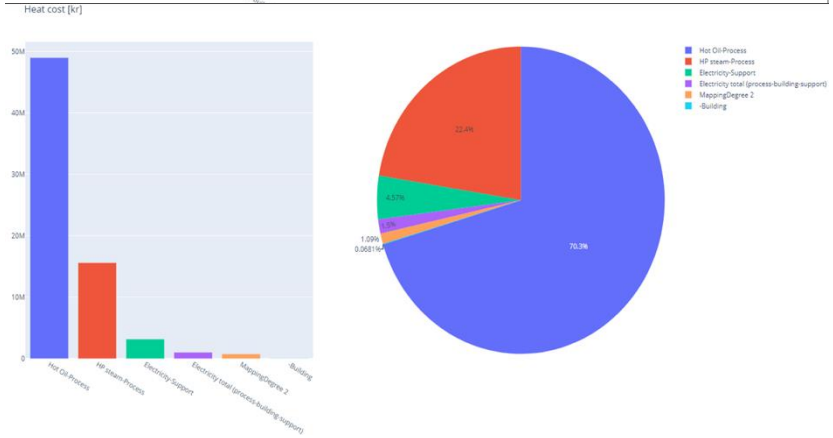
# Oplæg om hvordan man kan gøre brug af resultaterne

(DTU/VM)

- Forholdsmæssige energiforbrug på komponenter
  - Process
  - Energy supply
  - Energy/Cost/CO2



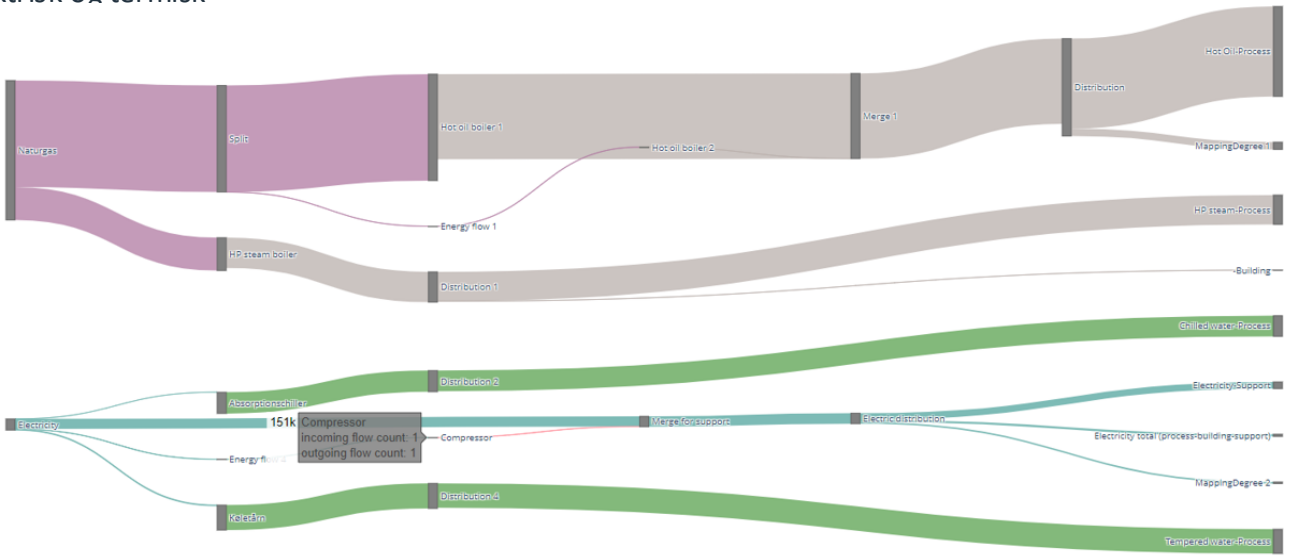



# Oplæg om hvordan man kan gøre brug af resultaterne

(DTU/VM)

- Forholdsmæssige energiforbrug på komponenter
  - Visuelt overblik
  - Sammenhæng mellem elektrisk og termisk
  - Mapping degree
  - Forsyningssystemer
  - Tab

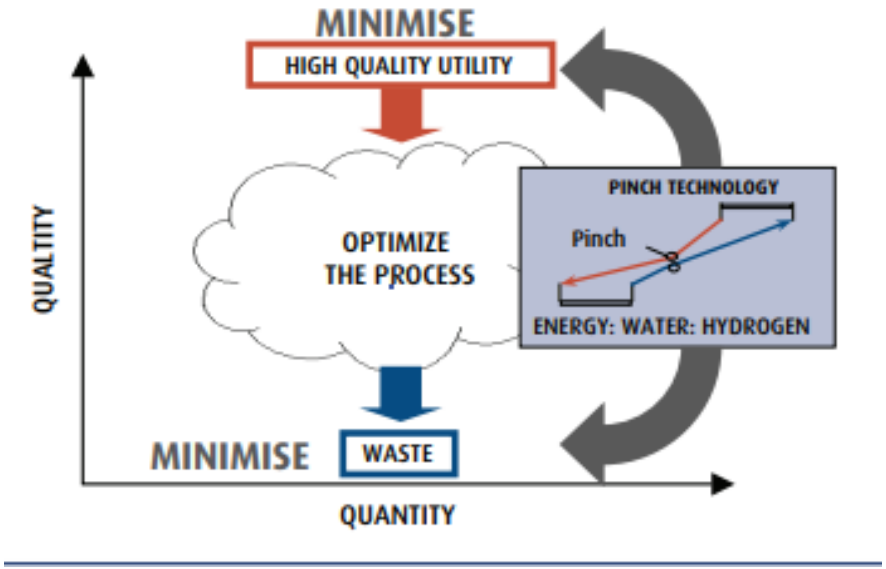


# Add on Analysis

23/ May/ 2024

# Add on - Pinch Analysis

Pinch Analysis is a systematic methodology which focuses on minimizing energy use and maximizing heat integration by identifying temperature "pinch points" in a system



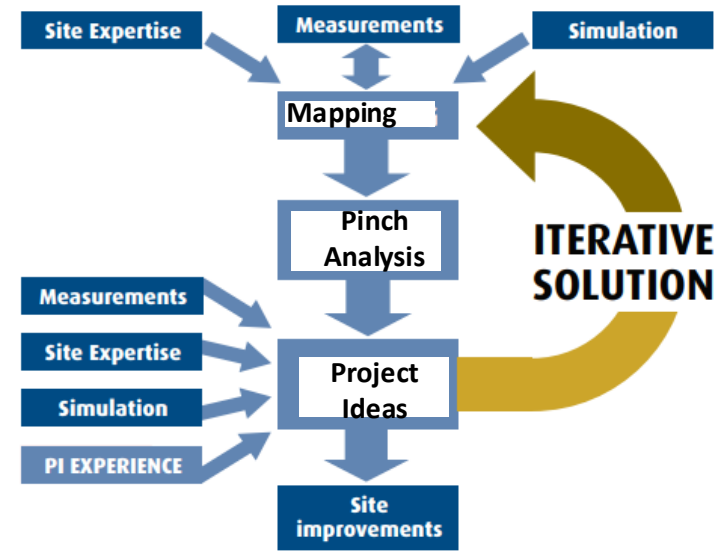
# Add on - Applications of Pinch Analysis

- Table and graphical illustration of possibilities

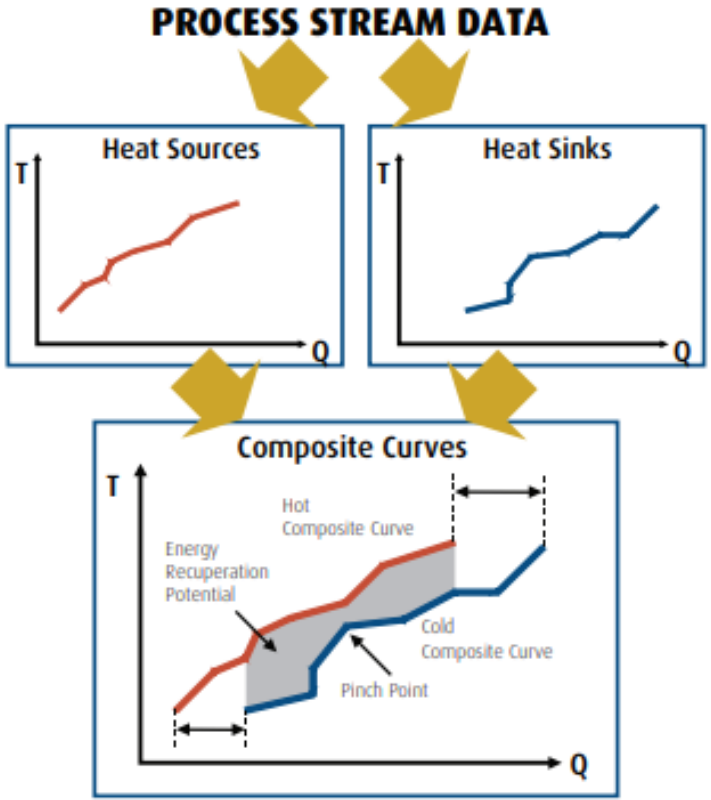
- Energy targeting (minimum external heating and cooling demand)
- Energy targeting (minimum external heating and cooling demand for each process)

- Basis for heat exchanger network design and direct heat recovery (economic heat exchanger network design)
- Improved exiting heat exchanger network

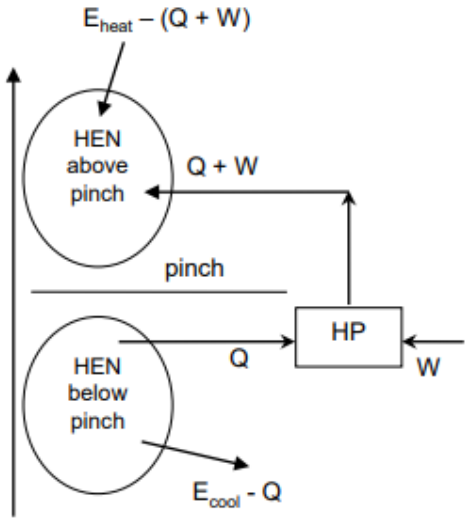
- Minimum work target in case of fully electrified
- Enhance process integration - Basis for integration of heat pumps and MVRs and right choices
- Multiple utility targeting



# Pinch Analysis – Energy targeting and direct heat



# Applications of Pinch Analysis



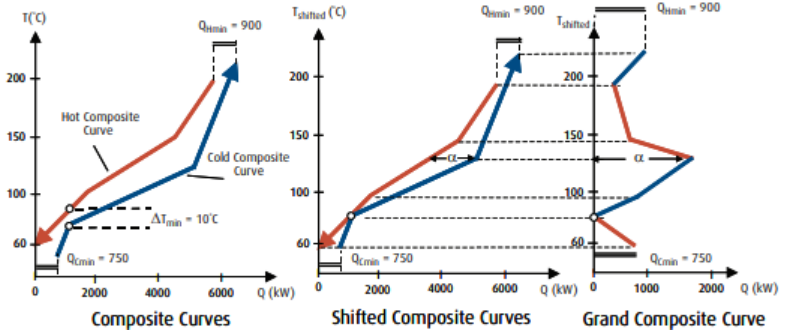

If the heat pump is not located in the right place, you still electrify and reduce CO2 emission but do not contributing to the reduction of external heating and cooling demand (minimum energy targeting)

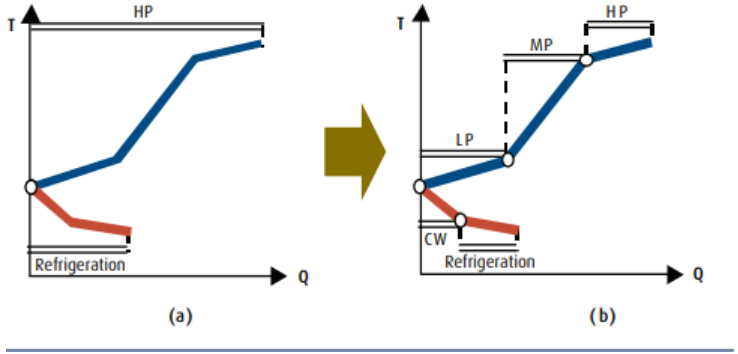
Appropriate placement of heat pump and MVR
Across the Pinch

# Pinch Analysis – Multiple utility targeting

Viegand Maagøe

- This requires linking the process (heating/cooling) with utility source
- Hot utility source can be hot air, hot water, LP, MP, HP steam
- Cold utility source can be ambient air, cold water, and refrigeration system



# Avista oil - Pinch Analysis – Energy targeting

Add-Ons

PA_Addon | HR_Addon | Example_Addon

## Pinch Analysis

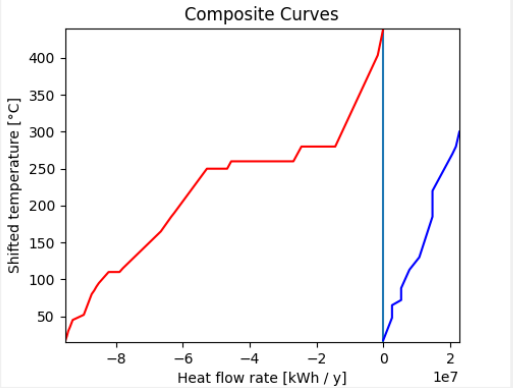
Problem Table

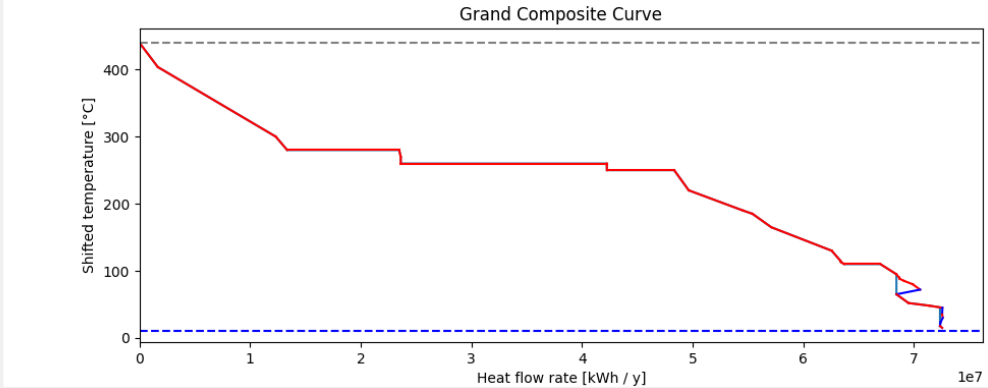
Ambient Temperature (°C): 10

| | Process | Starting Temperature [°C] | Target Temperature [°C] | Heat [kWh / y] | ontribuitio for TShift [°C] | Consider for Heat Recovery? |
|---|---|---|---|---|---|---|
| 1 | Pumps in | 8 | 8 | 0 | 10 | ☑ |
| 2 | Preheating | 8 | 38 | 2,619,921 | 10 | ☑ |
| 3 | LP Steam heating | 78 | 100 | 2,167,763 | 10 | ☑ |
| 4 | HP steam ... | 100 | 120 | 2,060,119 | 10 | ☑ |
| 5 | Extracting Vapor | 120 | 120 | 3,278,505 | 10 | ☑ |
| 6 | Tempered water 3 | 40 | 28 | 62,491 | 10 | ☑ |
| 7 | Gas oil evap ... | 210 | 260 | 5,963,943 | 10 | ☑ |

Results

| | |
|---|---|
| Pinch Temperature [°C] | 440.00 |
| Minimum Heating [kWh / y] | 0.00 |
| Minimum Cooling [kWh / y] | 72552391.78 |



# Avista oil - Pinch Analysis – Economical heat exchanger network solution

Viegand Maagøe

Add-Ons

PA_Addon | HR_Addon | Example_Addon

## Heat Recovery Network

Problem Table

Ambient Temperature (°C): 10

| | Process | Starting Temperature [°C] | Target Temperature [°C] | Heat [kWh / y] | ontribuitio for TShift [°C] | Consider for Heat Recovery? |
|---|---|---|---|---|---|---|
| 22 | Afkøling | 175 | 90 | 6,023,716 | 10 | ☐ |
| 23 | Opvarmning | 103 | 175 | 5,145,657 | 10 | ☐ |
| 24 | Raffinat | 90 | 20 | 2,010,810 | 5 | ☐ |
| 25 | Gas oil tank | 40 | 20 | 229,008 | 5 | ☐ |
| 26 | Waste water | 28 | 20 | 137,950 | 5 | ☐ |
| 27 | Asphalt | 195 | 20 | 1,978,248 | 5 | ☐ |
| 28 | Gas oil tank 1 | 40 | 20 | 13,232 | 5 | ☐ |
| 29 | NMP out | 55 | 20 | 14,203 | 5 | ☐ |
| 30 | Light ends | 28 | 20 | 23,269 | 5 | ☐ |

Cost Parameters

Utilities

| | Cost [kr/kWh] |
|---|---|
| Hot Utility | 2 |
| Cold Utility | 0 |

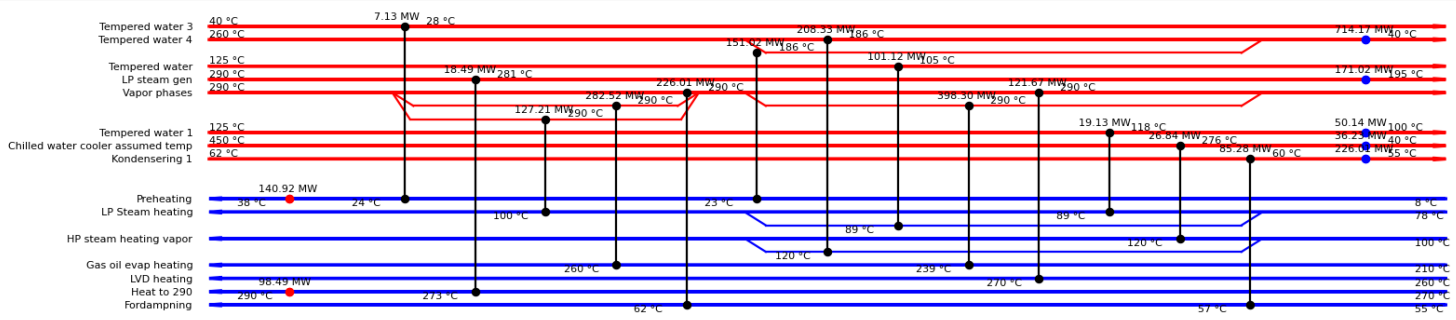
Heat exchanger costs

| | Cost per Unit [kr/unit] | Cost per area [kr/m2] |
|---|---|---|
| 1 | 150000 | 4500 |

Propose network

Network Results

| | Investment costs [kr] | Annual savings [kr/year] | Reltaive savings [%] |
|---|---|---|---|
| 1 | 2,200,701 | 31,063,818 | 88.10 |



# Current work going on

Viegand Maagøe

- Evaluate the effect of degree of mapping on pinch analysis
- Individualize the solutions for each compony for further dialogue
- Development of screening list for possible electro-technologies and energy saving options for each compony

**Research part of the project aims at**

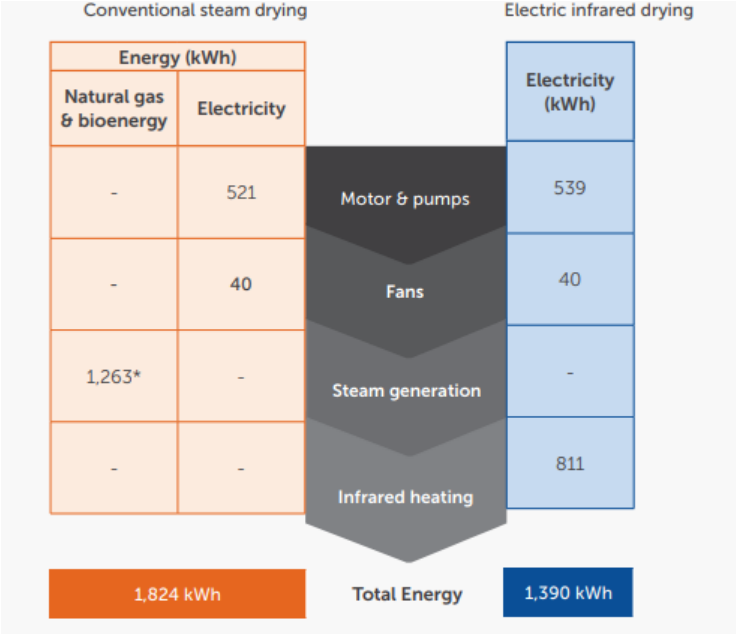
1) Verification of the optimal method (developed by DTU) for data collection and energy mapping in the industry.
2) Supporting the use of these methods for process optimization under uncertainty and further improvement of EEMAP software
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# Development of screening list - possible electro-technology solutions and energy saving

Viegand Maagøe

**Example: how to electrify recycled paper**

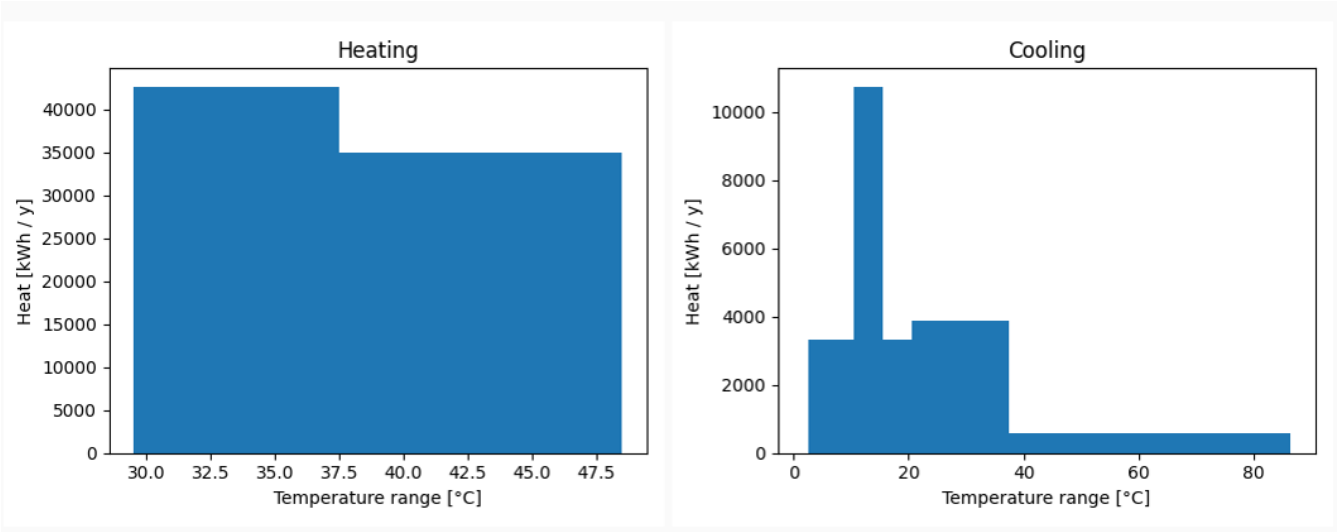
Comparison of energy uses in drying 1 tonne of paper



# Oplæg om hvordan man kan gøre brug af resultaterne

(DTU/VM)

- Pinch-analyse, HEX-netværk og Temperaturanalyse
  - Varmegenvinding direkte
  - Varmegenvinding indirekte via varmepumper



# Oplæg om hvordan man kan gøre brug af resultaterne

(DTU/VM)

- Screeningsliste
  - Inspiration i dens nuværende form
  - Mere direkte råd i fremtiden

# Oplæg om hvordan man kan gøre brug af resultaterne

(DTU/VM)

- Undersøgelse af projekt muligheder
  - Test af forskellige projekt ideer
  - Varierende detaljeringsgrader
  - F.eks.
    - Værdien af installation af exonomicer
    - Værdien af udvidelse af regenerativ
    - Værdien af varmegenvinding på tørre proces
    - OPEX i forbindelse med udvidelser

Op
(DTU

- E
  - A

!pu. DTU Viegand Maagøe

# Agenda

Click to add text

| | | |
|---|---|---|
| 12.30 - 12.45 | Welcome | All |
| 12:45 - 13:00 | Introduction to the project: Energy Efficiency Mapping (EEMAP) | VMAS |
| 13:00 - 13:15 | The need for Energy Mapping | FF-Skagen |
| 13:15 - 14:00 | Introduction to the tool EEMAP | IPU |
| 14:00 - 14:30 | Debate: | ALL companies |
| 14:30 - 14:45 | Coffee break | All |
| 14:45 - 15:00 | How to create a mapping in EEMAP | IPU |
| 15:00 - 15:15 | Mapping of a case company - experiences | Ovodan |
| 15:15 - 15:30 | How to use the results to add-on analysis | VMAS/DTU |
| 15:30 - 15:45 | Requests for future elements and functionalities | AVISTA |
| 15:45 - 16:00 | Next steps in EEMAP | VMAS/DTU |
| 16:00 - 17:30 | Snacks and drinks | All |

# Koordinering af 'Release Party'

**Release Party tirsdag d. 18. juni hos IPU (Virum).**

- Hvor mange kommer?
- Mod på at holde et kort oplæg om forløbet og (fremtidig) brug af EEMAP
- Har i nogle, som i gerne vil have inviteret med?

# Agenda

| Kl | tid | Emne |
|---|---|---|
| **12.30 - 12.45** | **15 min** | **Kaffe** |
| 12:45-13:00 | 15 min | Introduktion til projektet |
| 13:00-13:15 | 15 min | Behovet for kortlægning |
| 13:15-14:00 | 45 min | Introduktion til værktøjet |
| 14:00-14:30 | 30 min | Debate: the companies present themselves briefly and discuss how they plan to use the tool |
| **14:30-14:45** | **15 min** | **Kaffe + buffer** |
| 14:45-15:00 | 15 min | Eksempel på opbygning af case |
| 15:00-15:15 | 15 min | Eksempel på kortlægning |
| 15:15-15:30 | 15 min | Hvad kan man bruge resultaterne til / add-on analyser |
| 15:30-15:45 | 15 min | Ønsker til fremtidige elementer og funktionaliteter |
| 15:45-16:00 | 15 min | Fremtiden, herunder hvordan får man adgang, hvad hvis man vil være med I næste fase, hvad skal den indeholde, timing .... |
| **16:00 - XX:XX** | | **Snacks og drikkelse** |

# EEMAP 2.0

- Hvilke funktionaliteter mangler?
- Hvilke funktionaliteter er planlagte?
- Interesse i at fortsætte samarbejdet?



# Rundtur på Skjern Papir

Viegand Maagøe

# Tak for i dag

**Navn**
Tlf. 28 XX XX XX
abc@viegandmaagoe.dk




DTU

# Add on Analysis

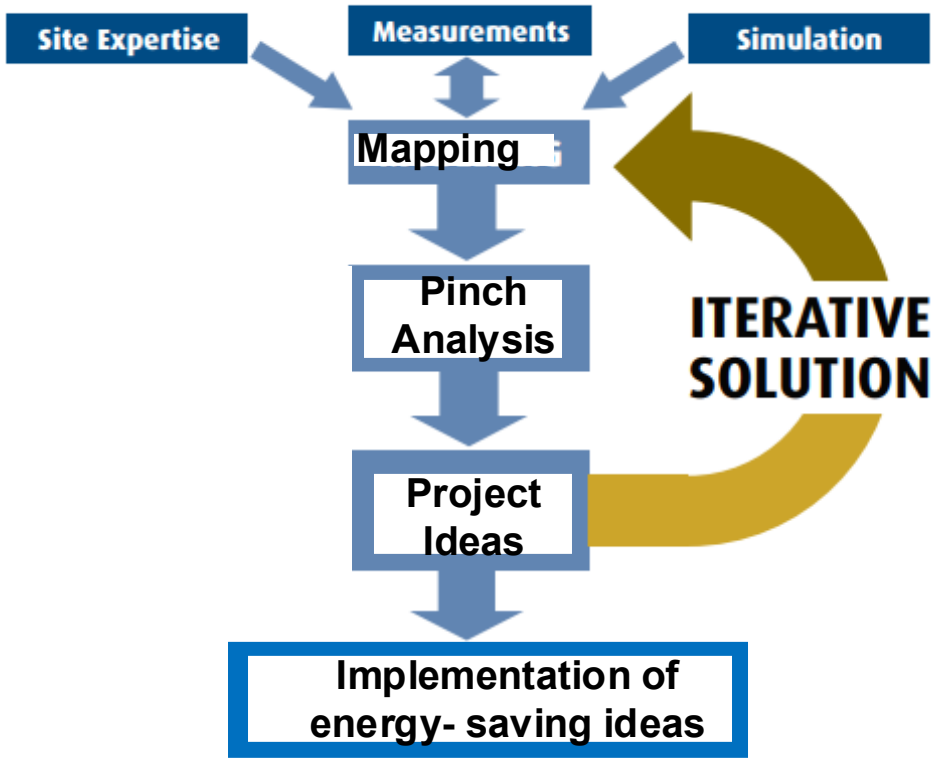
23/ May/ 2024

# Add on - Pinch Analysis

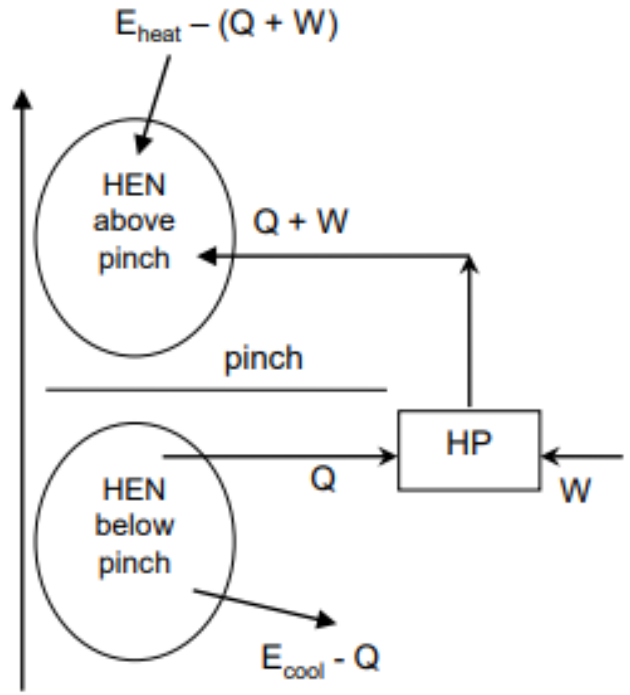
Pinch Analysis is a systematic methodology which focuses on minimizing energy use and maximizing heat integration by identifying temperature "pinch points" in a system

# Add on - Applications of Pinch Analysis

- Table and graphical illustration of possibilities
- Energy targeting (minimum external heating and cooling demand)
- Energy targeting (minimum external heating and cooling demand for each process)
- Basis for heat exchanger network design and direct heat recovery (economic heat exchanger network design)
- Improved exiting heat exchanger network
- Minimum work target in case of fully electrified
- Enhance process integration - Basis for integration of heat pumps and MVRs and right choices
- Multiple utility targeting



# Applications of Pinch Analysis




If the heat pump is not located in the right place, you still electrify and reduce CO2 emission but do not contributing to the reduction of external heating and cooling demand (minimum energy targeting)

Appropriate placement of heat pump and MVR

Across the Pinch

# Pinch Analysis – Multiple utility targeting

- This requires linking the process (heating/cooling) with utility source
- Hot utility source can be hot air, hot water, Low Pressure, Medium Pressure, High Pressure steam
- Cold utility source can be ambient air, cold water, and refrigeration system

# Avista oil - Pinch Analysis – Economical heat exchanger network solution

Add-Ons

PA_Addon | HR_Addon | Example_Addon

## Heat Recovery Network

Problem Table

Ambient Temperature (°C): 10

| | Process | Starting Temperature [°C] | Target Temperature [°C] | Heat [kWh / y] | ontribuitio for TShift [°C] | Consider for Heat Recovery? |
|---|---|---|---|---|---|---|
| 22 | Afkøling | 175 | 90 | 6,023,716 | 10 | ☐ |
| 23 | Opvarmning | 103 | 175 | 5,145,657 | 10 | ☐ |
| 24 | Raffinat | 90 | 20 | 2,010,810 | 5 | ☐ |
| 25 | Gas oil tank | 40 | 20 | 229,008 | 5 | ☐ |
| 26 | Waste water | 28 | 20 | 137,950 | 5 | ☐ |
| 27 | Asphalt | 195 | 20 | 1,978,248 | 5 | ☐ |
| 28 | Gas oil tank 1 | 40 | 20 | 13,232 | 5 | ☐ |
| 29 | NMP out | 55 | 20 | 14,203 | 5 | ☐ |
| 30 | Light ends | 28 | 20 | 23,269 | 5 | ☐ |

Cost Parameters

Utilities

| | Cost [kr/kWh] |
|---|---|
| Hot Utility | 2 |
| Cold Utility | 0 |

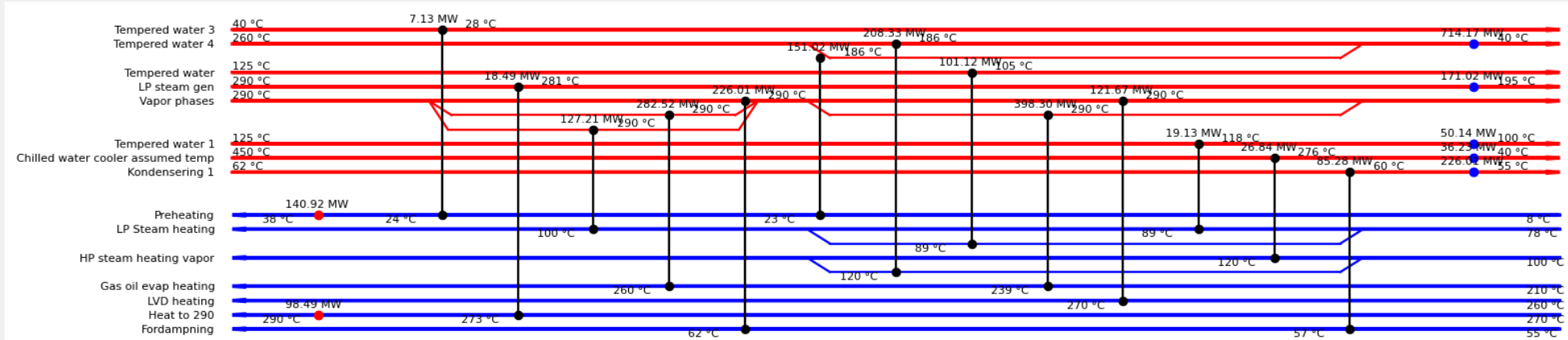
Heat exchanger costs

| | Cost per Unit [kr/unit] | Cost per area [kr/m2] |
|---|---|---|
| 1 | 150000 | 4500 |

Propose network

Network Results

| | Investment costs [kr] | Annual savings [kr/year] | Reltaive savings [%] |
|---|---|---|---|
| 1 | 2,200,701 | 31,063,818 | 88.10 |



# Current work going on

- Evaluate the effect of degree of mapping on pinch analysis
- Individualize the solutions for each compony for further dialogue
- Development of screening list for possible electro-technologies and energy saving options for each compony

**Research part of the project aims at**

1) Verification of the optimal method (developed by DTU) for data collection and energy mapping in the industry.
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