Open-Source Modelling and Simulation of Innovative Power Generation Systems Using OpenModelica: The Case of the FlexiCaL Project

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OpenModelica

Outline

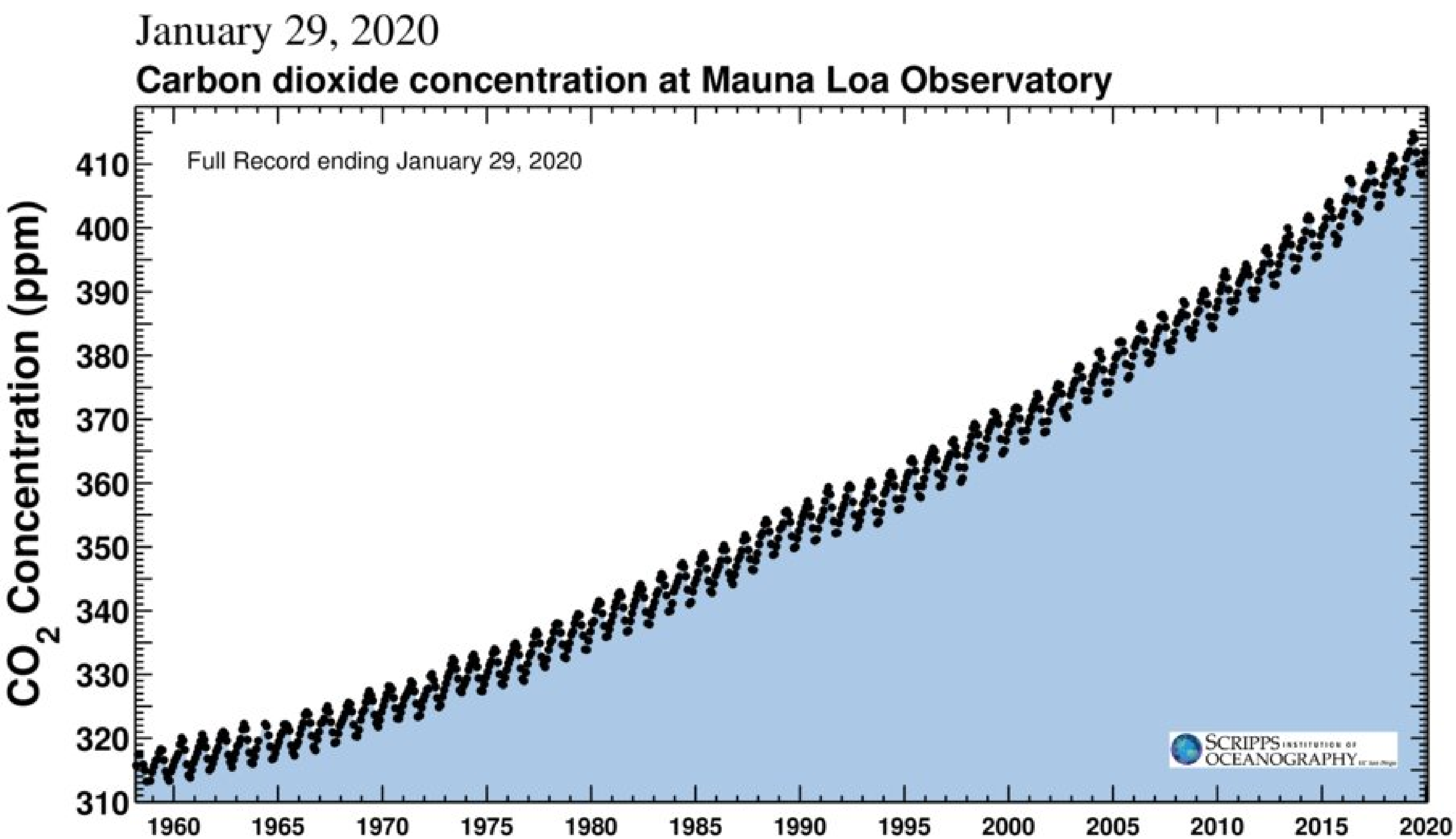
- The issue of climate change
- The FlexiCaL project

- Objectives of the modelling activity
- What are the Modelica models used for
- Relevance for the OSMC and the scientific community
- Presentation of the model

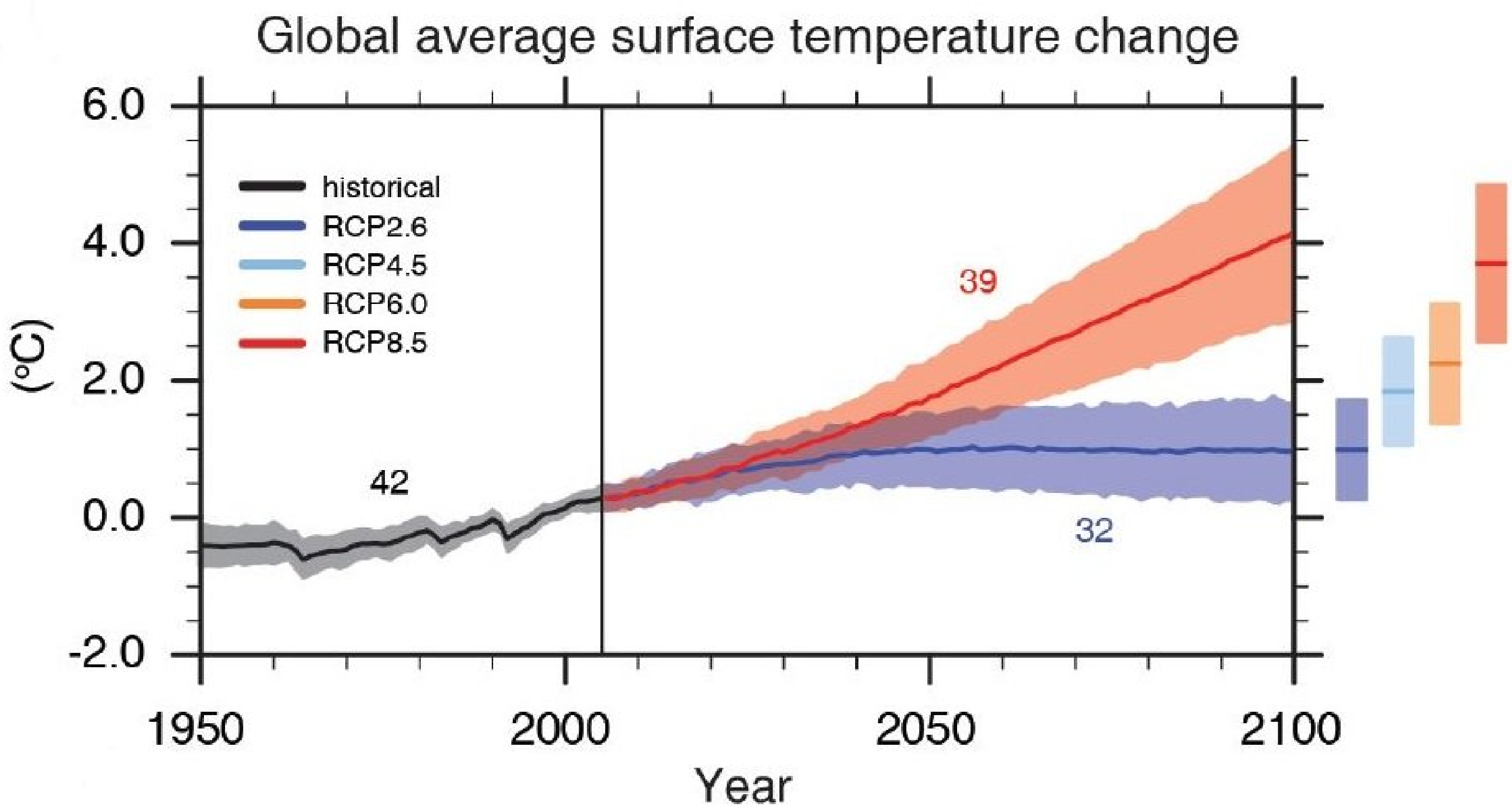
- Current status of OMC support
- Outlook and future work

The Issue of Climate Change

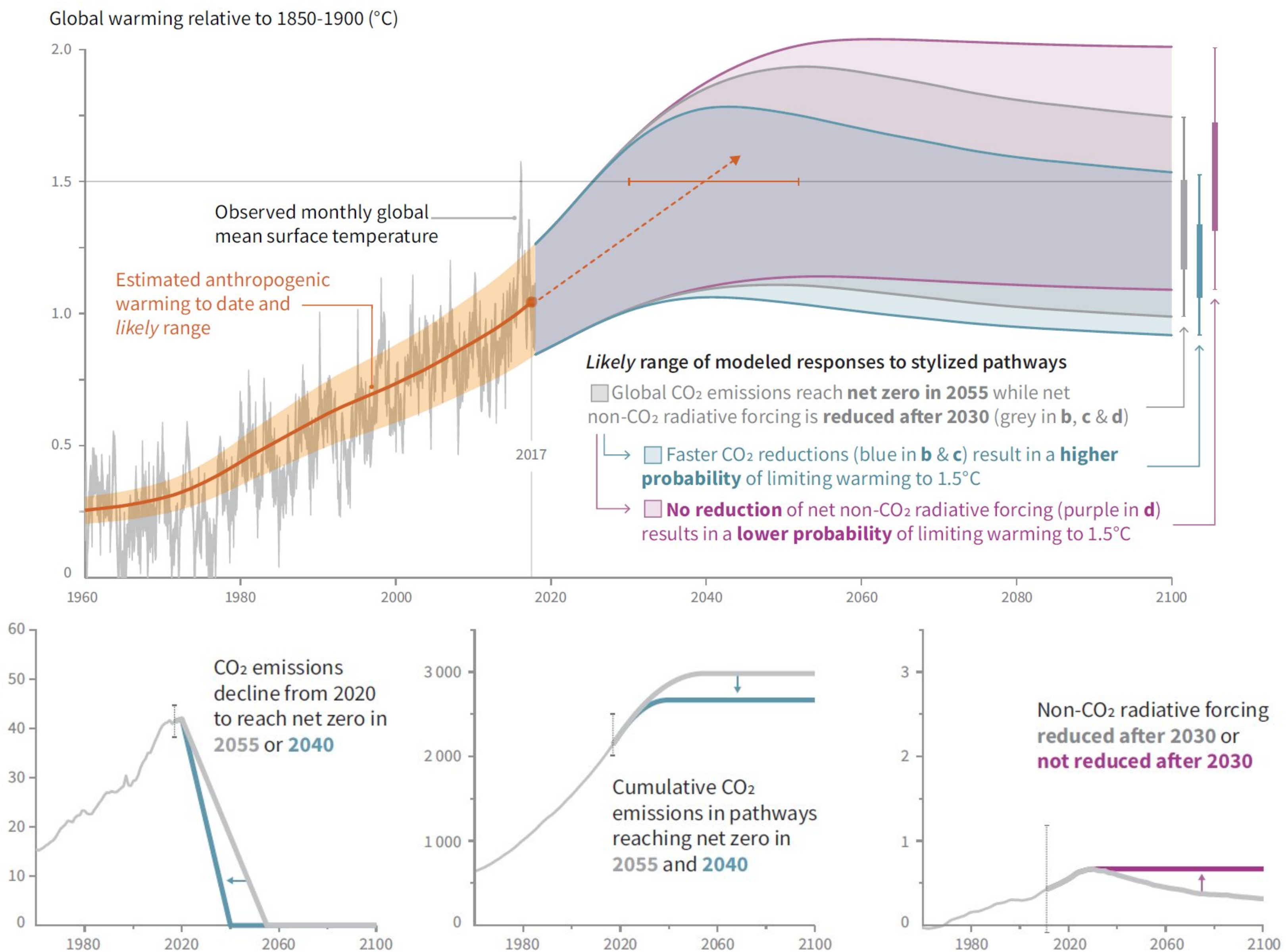
The Keeling Curve



Global Temperature Rise Scenarios (IPCC 2013)



The 1.5 °C Scenario (IPCC 2018)



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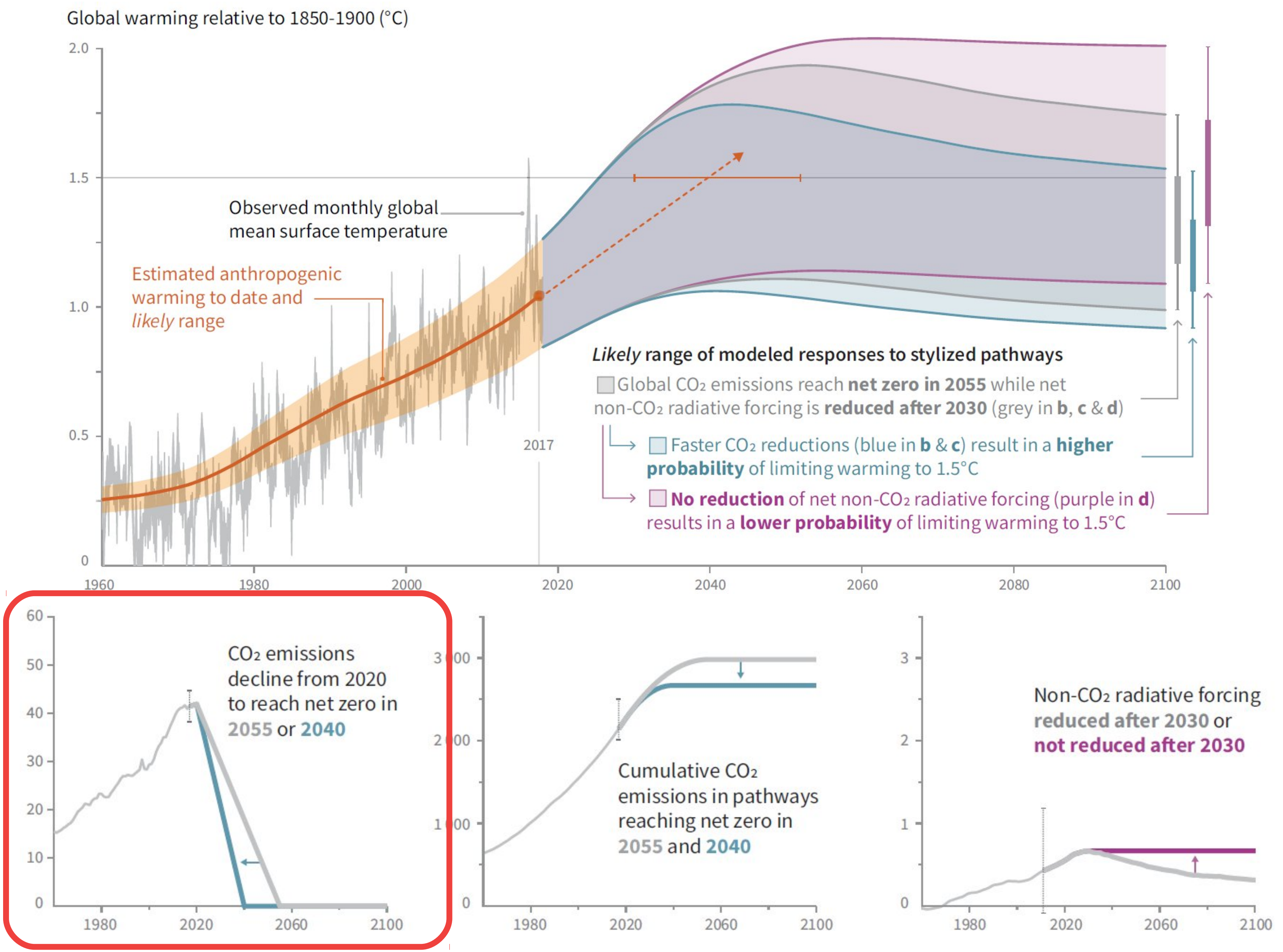
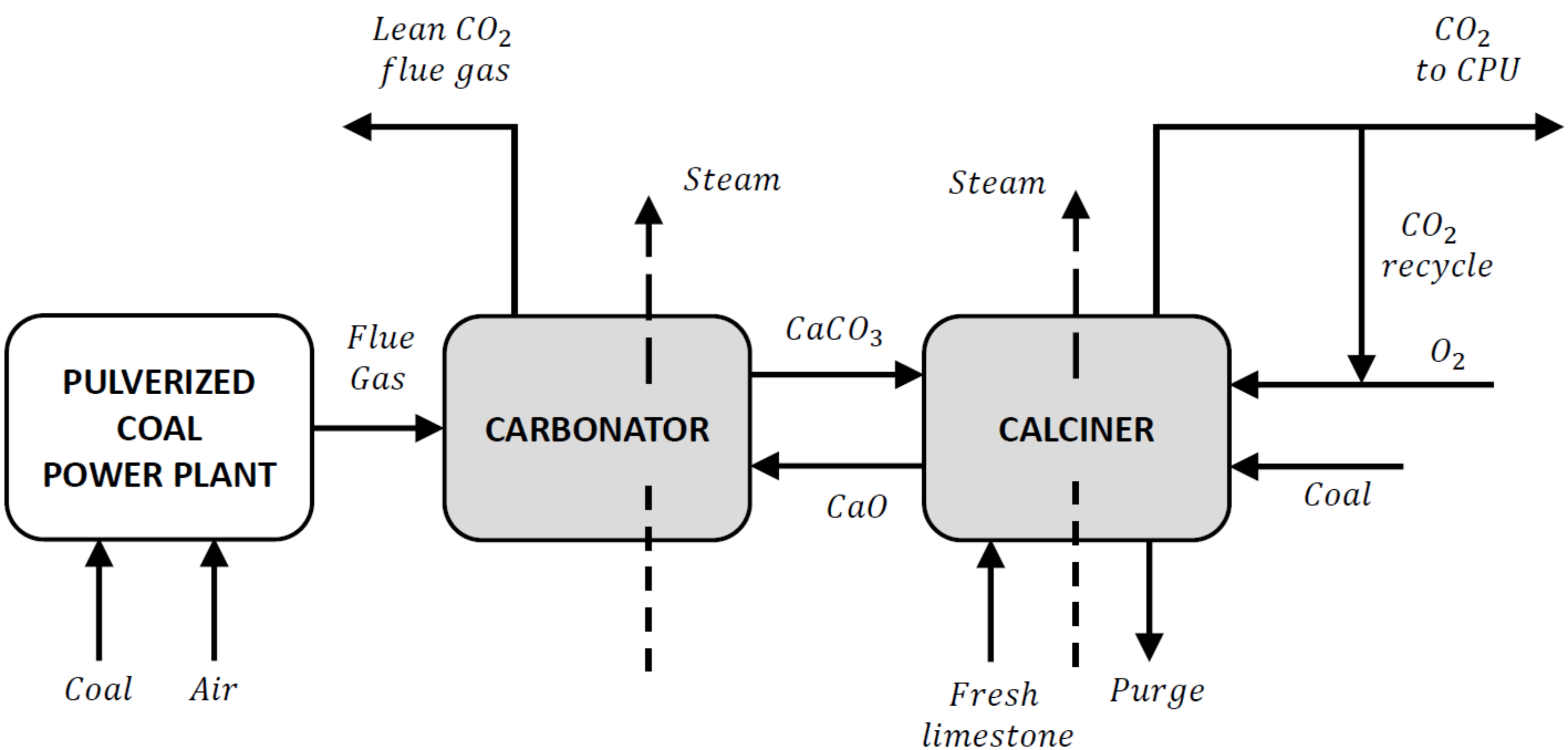


The FlexiCaL Project

Calcium Looping Technology (CaL)

- First proposed by Shimizu et al, 1999
- Currently demonstrated at lab and pilot scale (< 1.5 MW)



The FlexiCaL project

- Funded by the EU Research Fund for Coal and Steel (RFCS)
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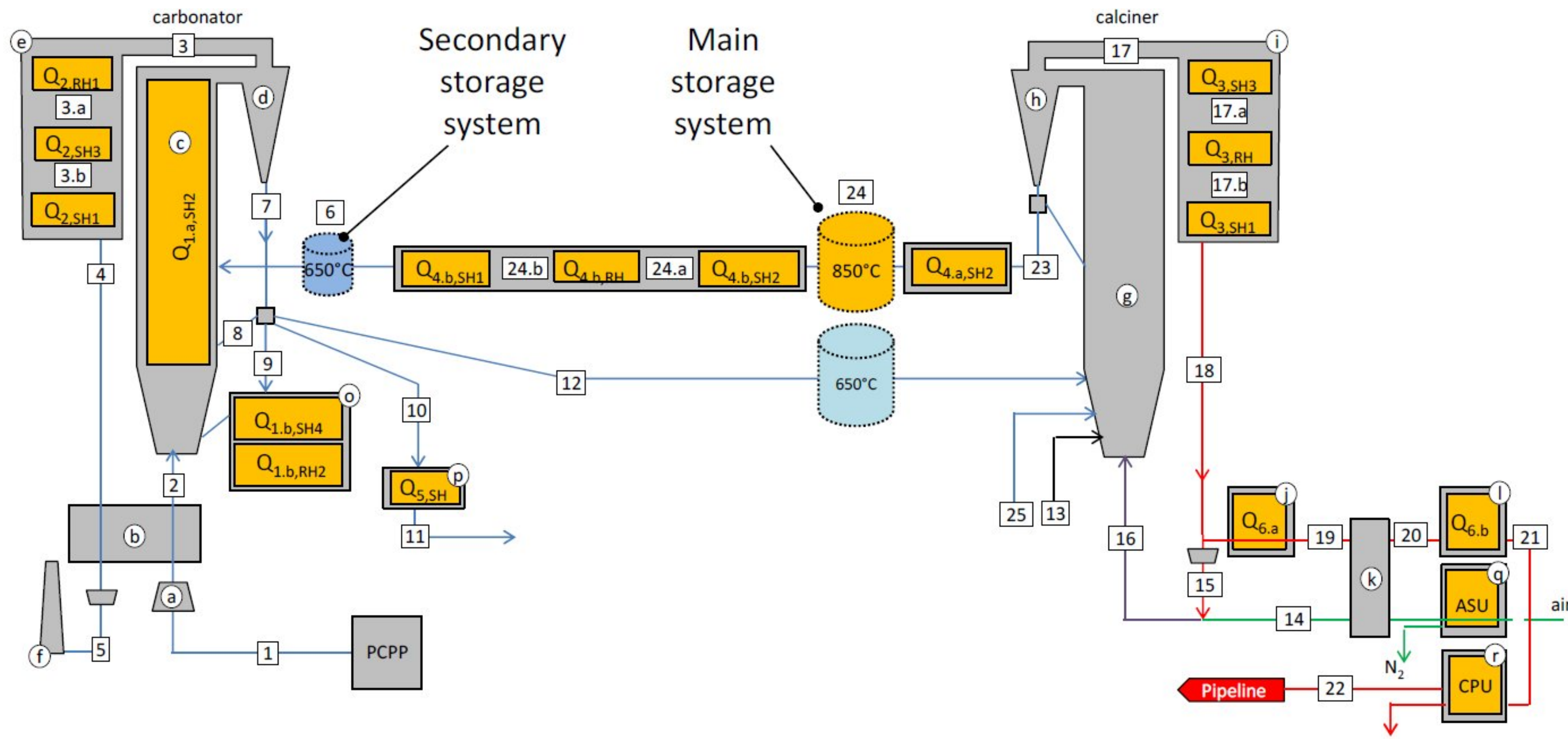
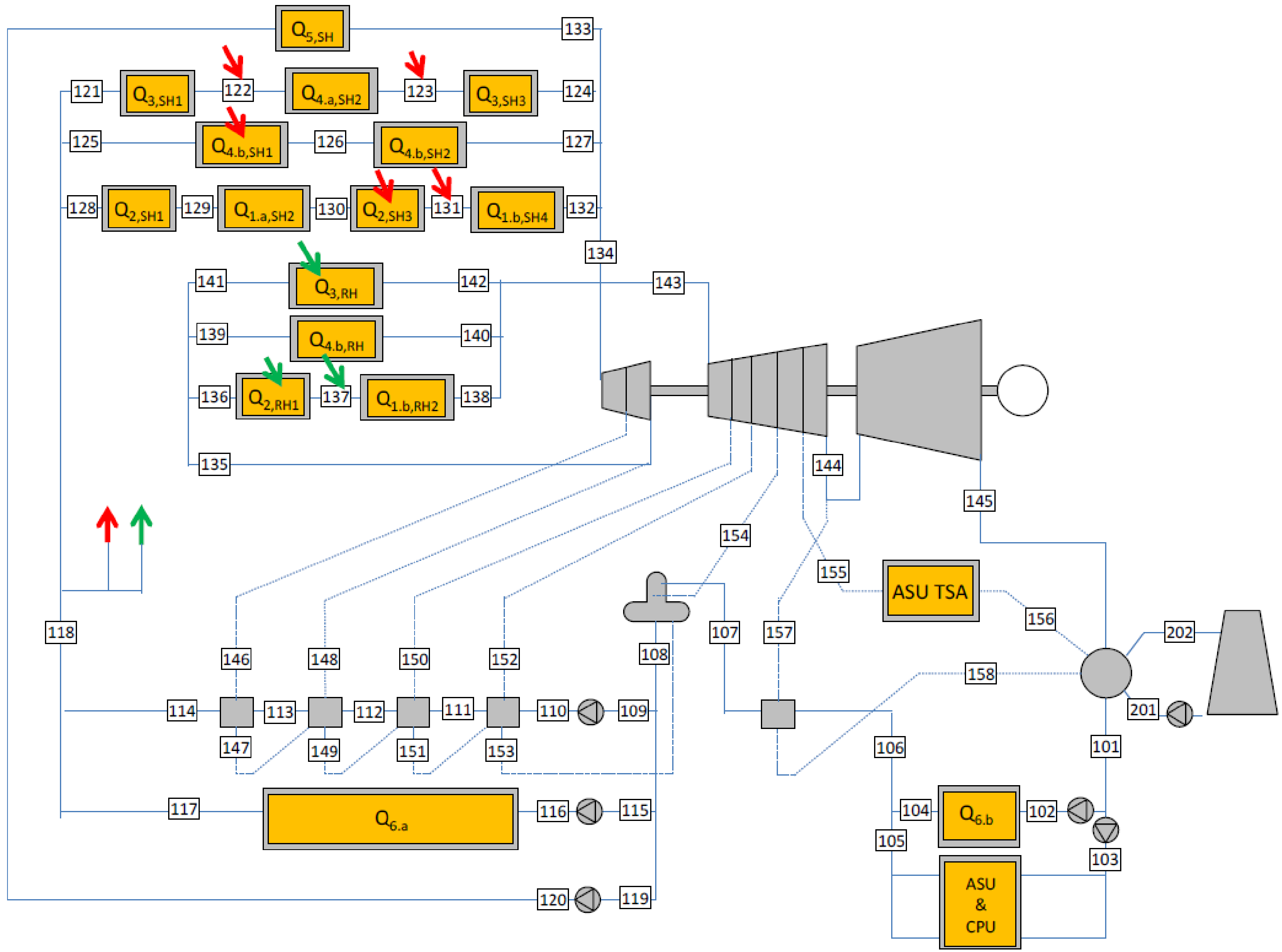
- Design a full-scale plant capable of flexible performance
  - Off design operation
  - Transient operation

The FlexiCaL plant – CaL side



The FlexiCaL plant – Steam side



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- Assess the dynamic behaviour and controllability

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- Assess the dynamic behaviour and controllability
- Design a suitable plant-wide control strategy
- Assess the ability of the controlled FlexiCal plant to follow ramp load changes of the PCPP and to provide extra power for ancillary services

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- Use Modelica and re-use existing libraries as much as possible (ThermoPower and IndustrialControlSystems)

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- Simulation of closed loop transients
    - PCPP load ramp rate
    - CaO heat exchanger boost
    - Turbine bleed valve throttling

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Perform all the modelling activities with OMC

Publish the model on github.com

Make the model usable with 100% OS toolchain

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- Showcase of the OpenModelica tool capabilities
  - Demonstration of tool performance on real-life industrial case
  - All stakeholders can download and check with their eyes, no restrictions
  - Double-edged sword!

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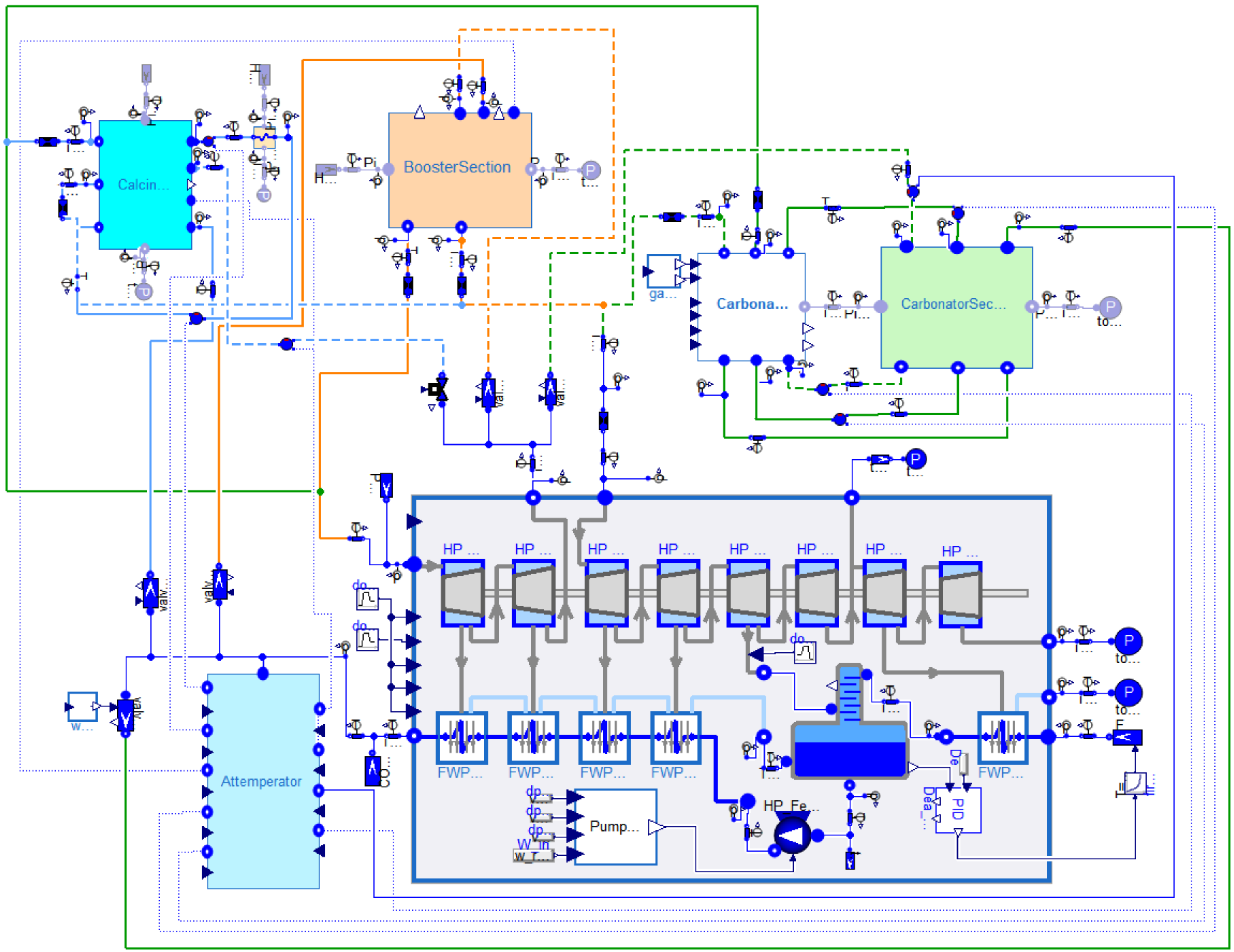
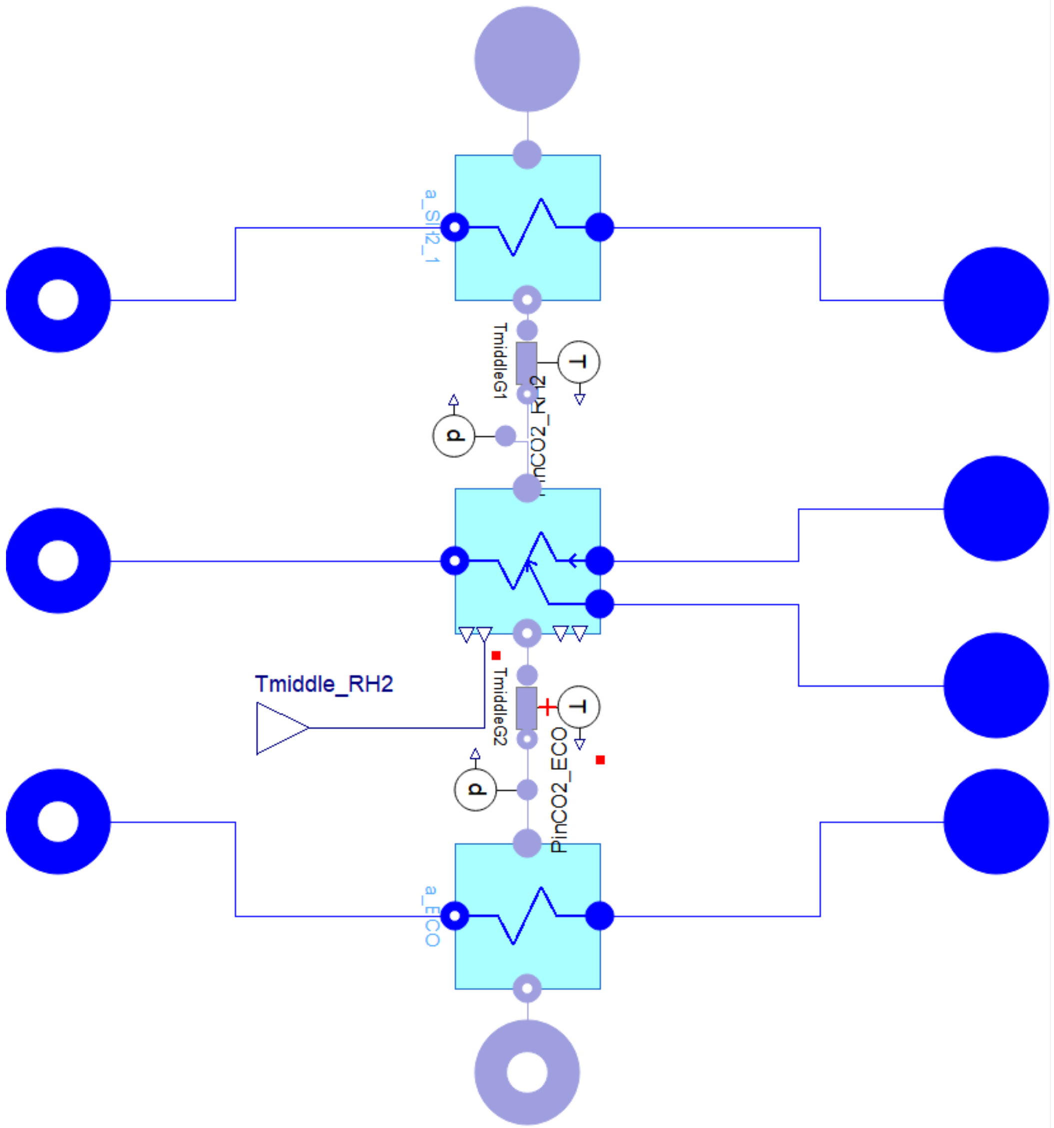
- Allows other people to reuse the model for further research
- Provides engineers and researchers with a fully developed example
  - How to organize a complex power plant model in Modelica
  - How to carry out different activities in an efficient way without code duplication
  - Significant tutorial value

Presentation of the Model

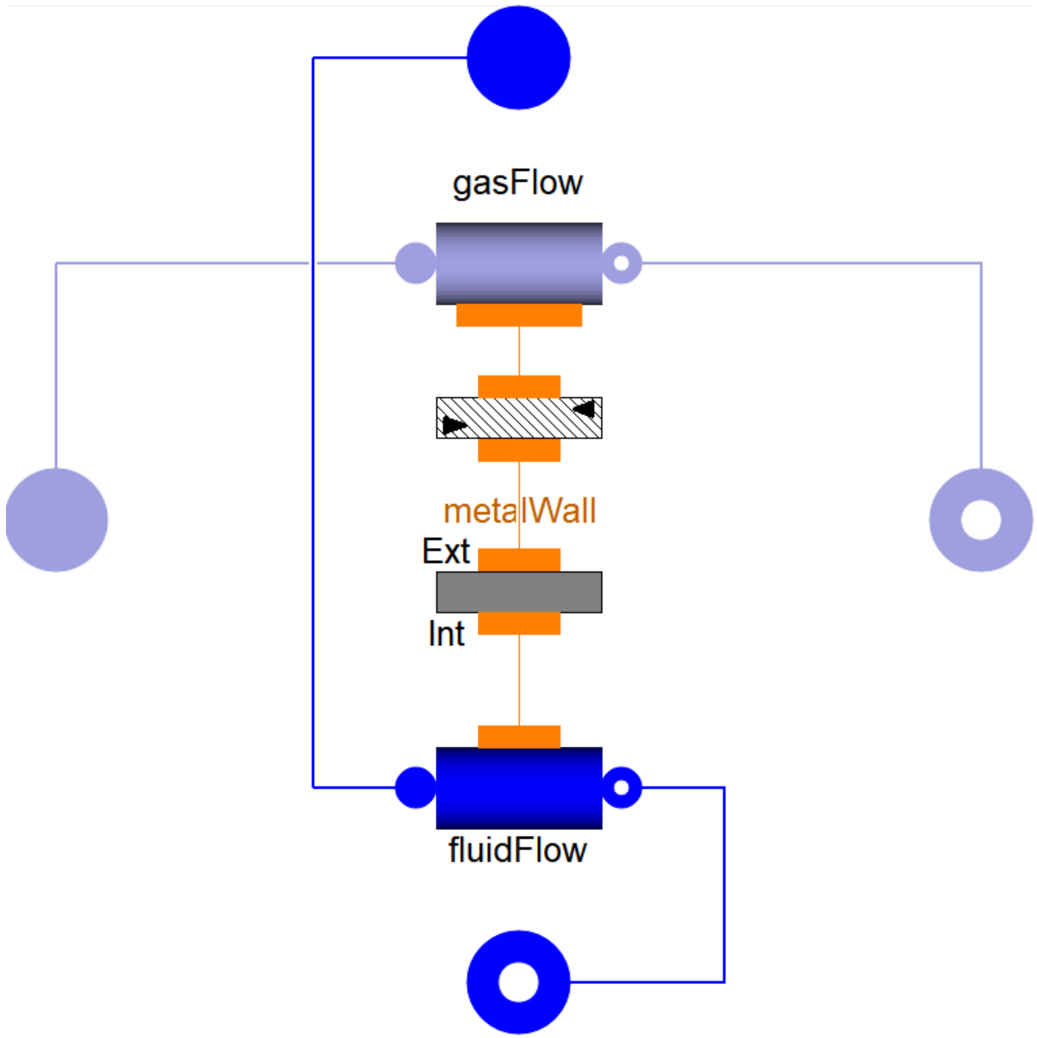
Top-level view of the plant model



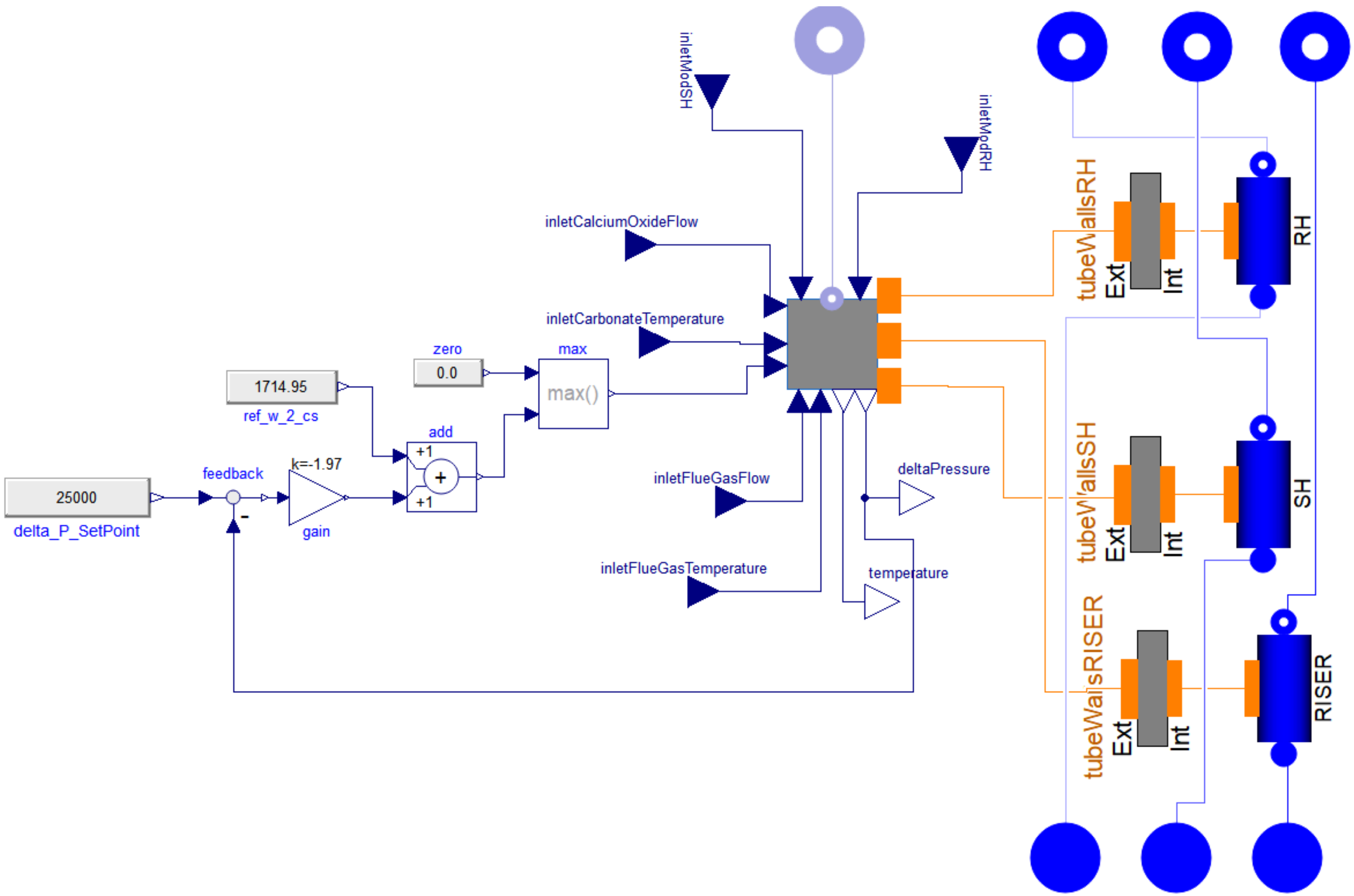
Calciner exhaust section



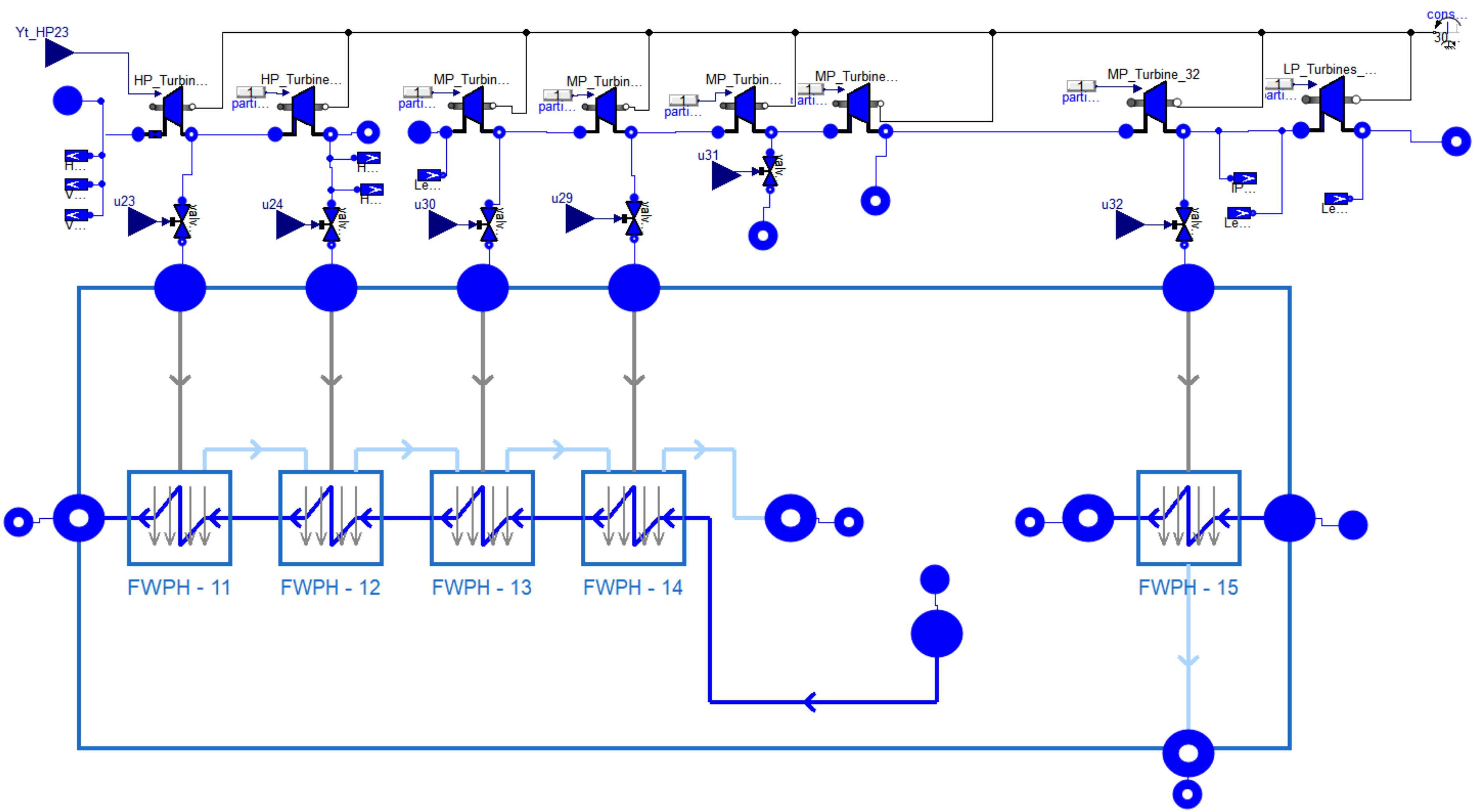
Individual steam – fluidized CaO heat exchanger



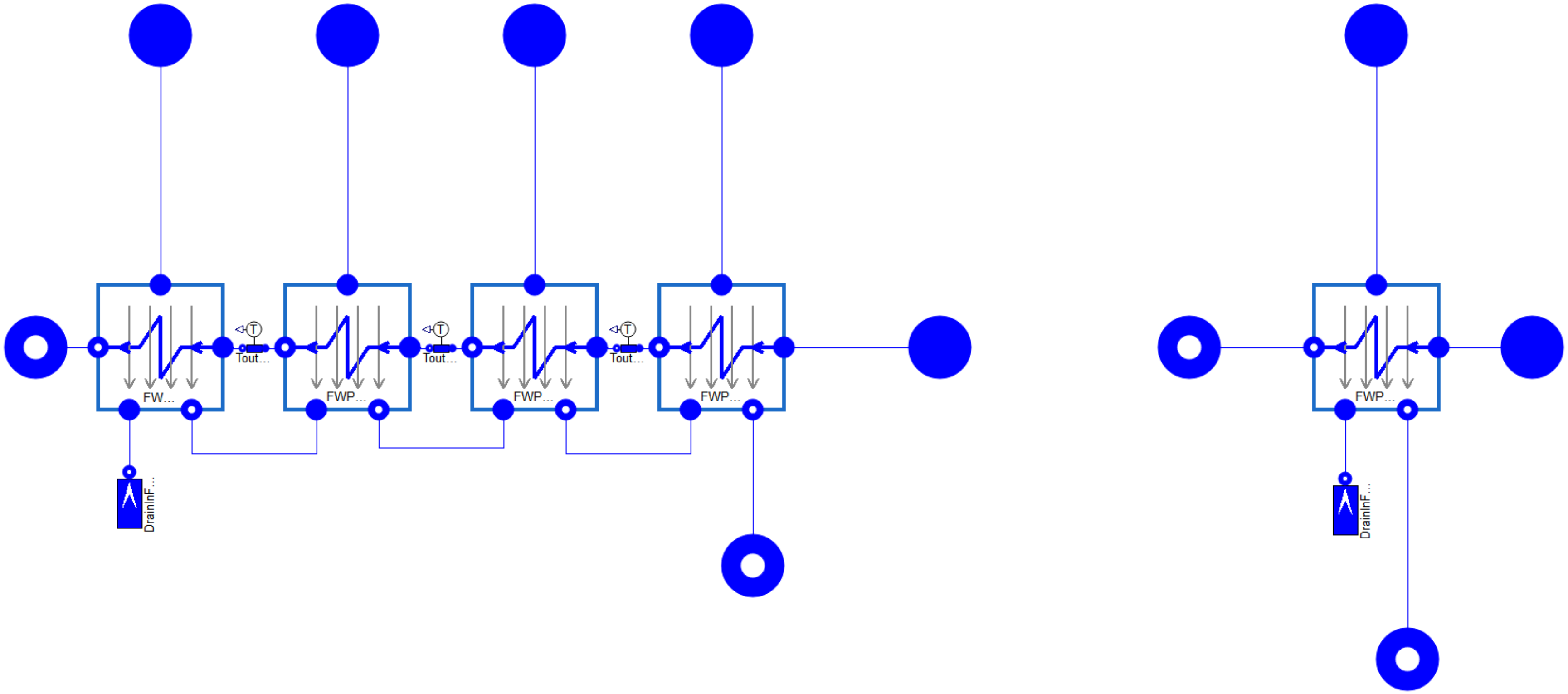
Carbonator model



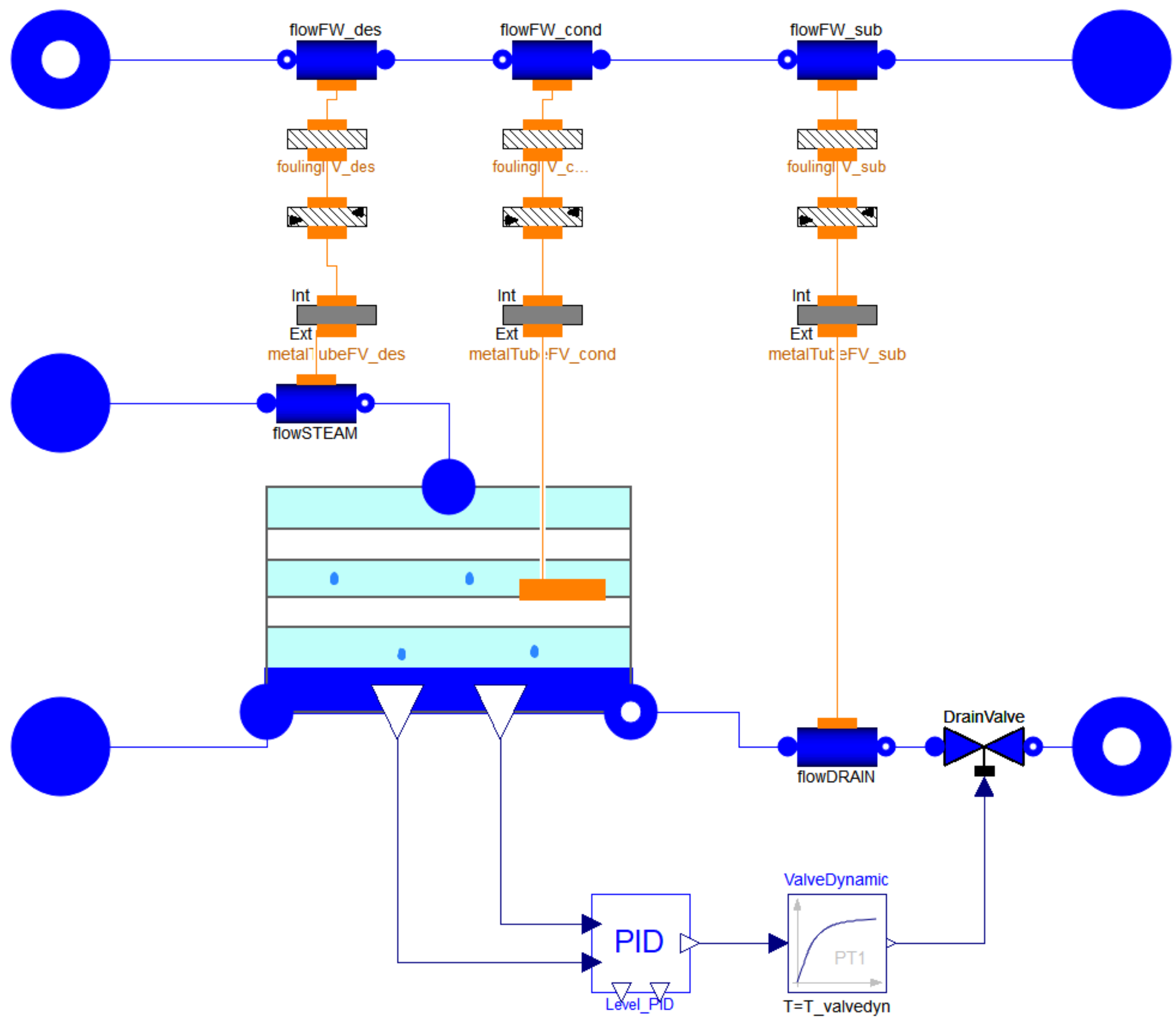
Turbine – Feedwater train model



Accurate feedwater train model



Accurate water preheater model



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- Closed-loop steady state
  - Control system is added, with given set points and load level
  - Suitable homotopy introduced on controllers to facilitate convergence

Current Status with OpenModelica 1.16.0-dev

Testing setup

- Lenovo Carbon X1
- CPU: Intel i7-8550, 1.8 Ghz, 8 virtual cores
- RAM: 16 GB
- SSD: 1 TB
- OS: Windows 10 Professional 64 bit
- OMC: 1.16.0-dev nighly build of 31 Jan 2020

GUI

- The diagrams are mostly displayed correctly
- Some glitches with extent
- Editing the models with few components is fine
- Parameter input is fine
- Replaceable Medium missing ($\rightarrow$ v. 1.15.0)
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Continue improvement of API used by OMEdit by using the faster new frontend

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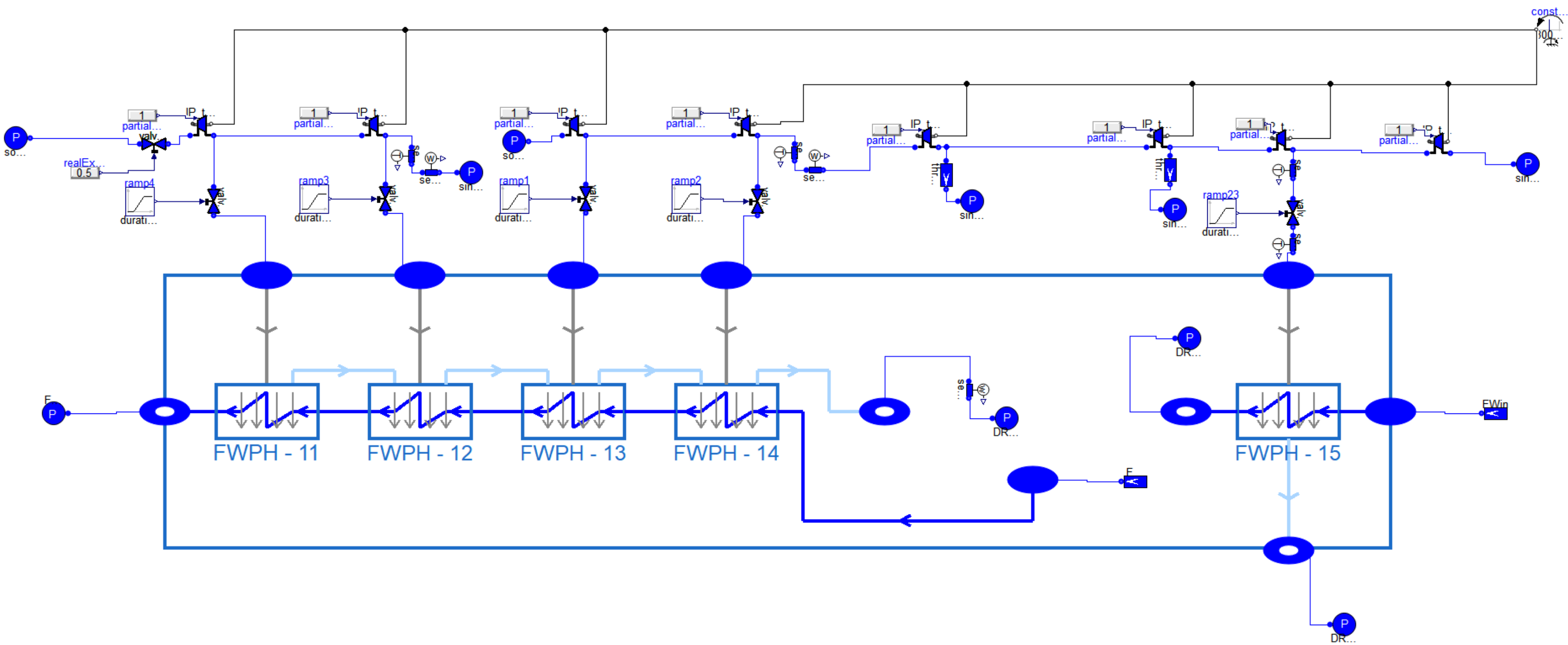
Room for improvement in code generation

- Faster selected back-end methods and templates
- Faster compilation (gcc → clang, factor 5)
- Resolve initial guess issues

Smaller case study: Feedwater/turbine unit test



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- C-code compilation (gcc): 1 m (Dymola: 6 s)
- Total compilation time: 1 m 40 s (Dymola: 18 s)
- Max memory usage: 3.7 GB
- Initialization time: 70 s (Dymola: 2.5 s)
- Simulation time: 6.5 s (Dymola: 4.2 s)

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Room for improvement at runtime:

- Performe CSE also during init (WiP)
- Improve optimization of Modelica.Media IF97 code

Outlook
&
Conclusions

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⇨ Opportunity to improve the quality of OpenModelica for industrial users

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- On going work
  - Streamlining OMEdit editor response for larger models (nfAPI)
  - Further speed-up of flattening
  - Optimization and speed-up of backend
  - Improve CSE handling in the runtime, part. at initialization

Thank you for your kind attention!