CONTROL OPTIMIZATION OF HYDRONIC LOW-EXERGY HEATING AND COOLING SYSTEMS

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Mini-Workshop on optimal control of thermal systems in buildings using Modelica

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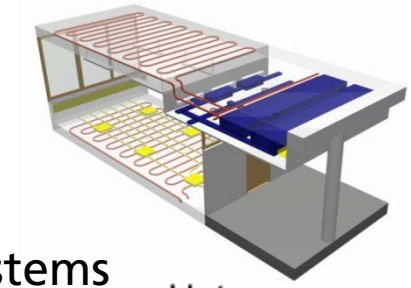
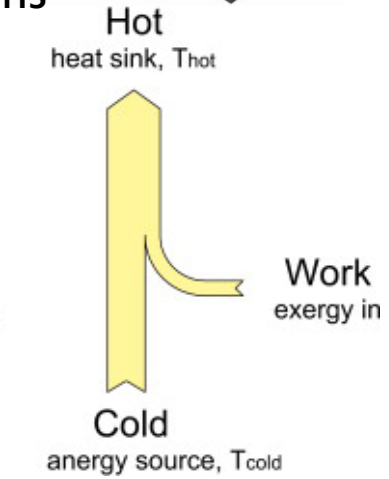
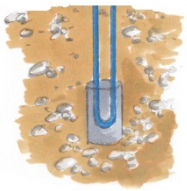
Introduction – Low-Exergy Systems

- Utilizing low exergy heat sources and sinks (e.g. borehole heat exchanger)
- Heat distribution with radiant heating and cooling systems (e.g. thermally activated building systems, TABS)
- Active Heating: Heat transformation in heat pump
- Passive Cooling: Direct re-cooling to borehole







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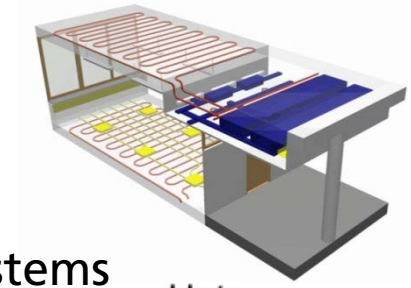
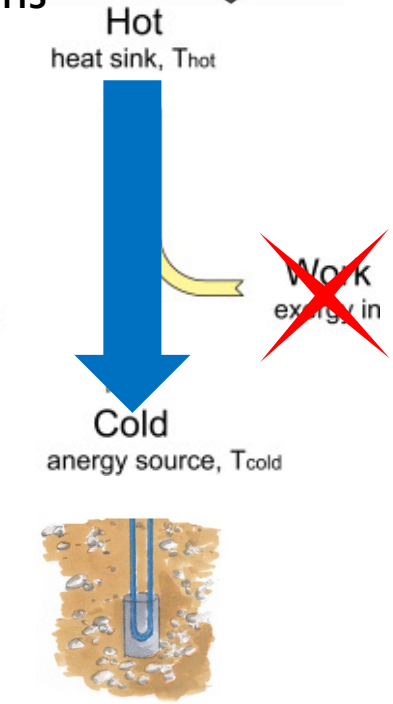
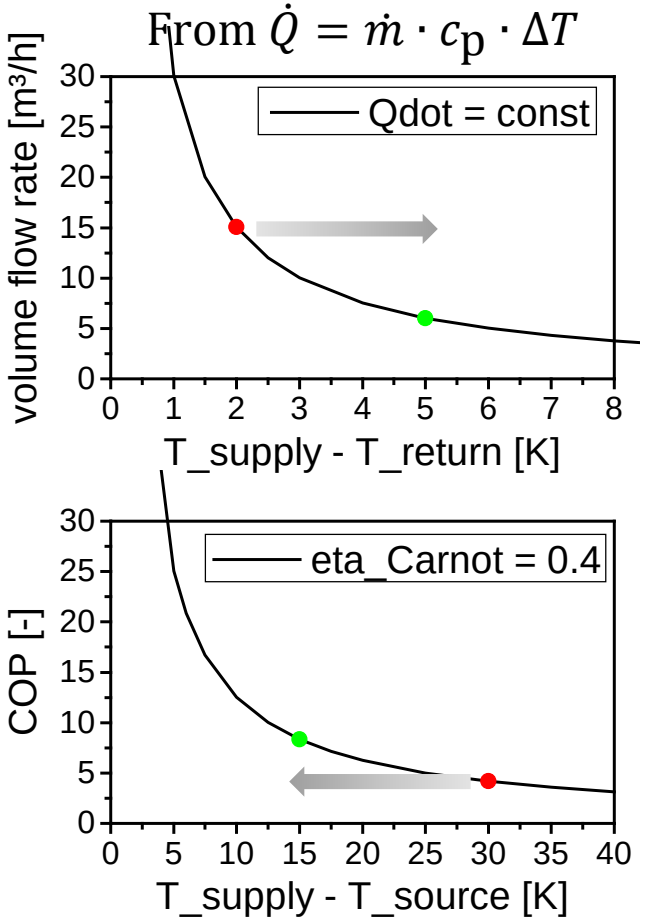




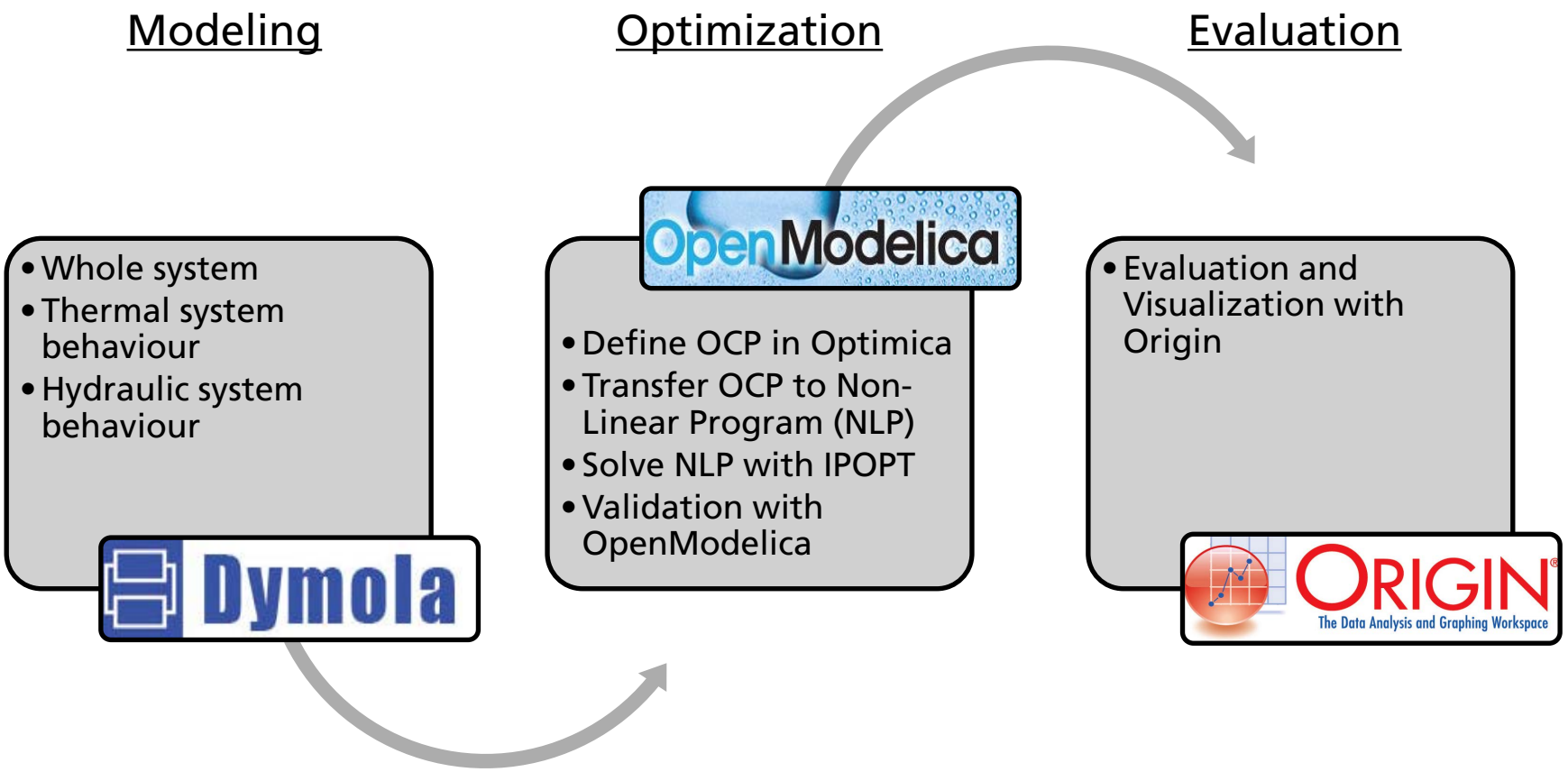
Optimal Control Problem (OCP)

- Objective:
  „Minimal energy demand
  with regard to thermal comfort“
- Conflict of objectives:
  - Reduce volume flow rates
  - Reduce supply water temperature
- → Thermo-hydraulic optimization

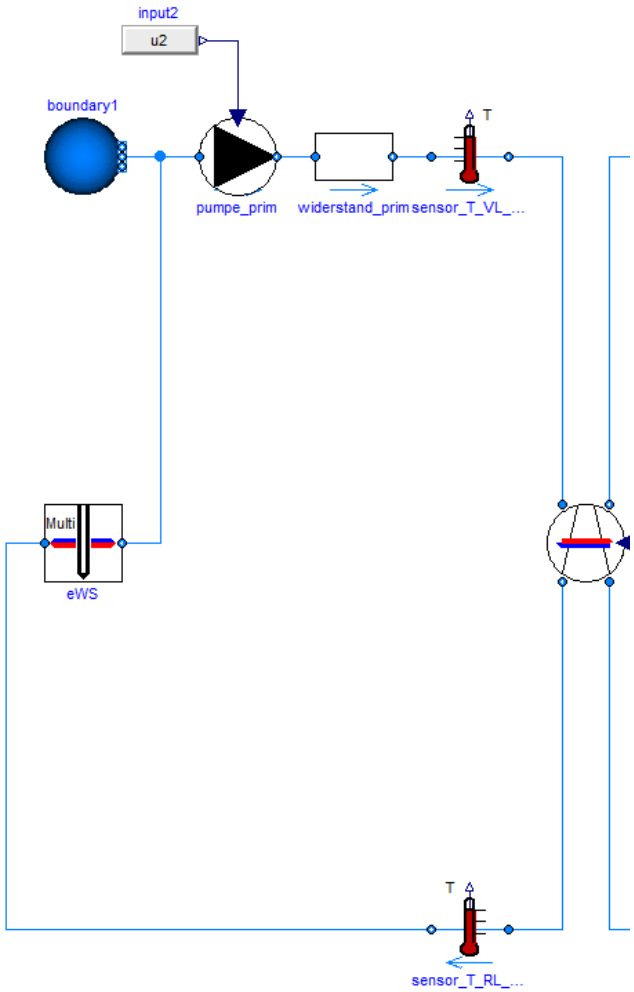
From $\dot{Q} = \dot{m} \cdot c_p \cdot \Delta T$



Methodology (1)
Toolchain / Optimization Approach



Methodology (2)
Modelling in Dymola/Modelica



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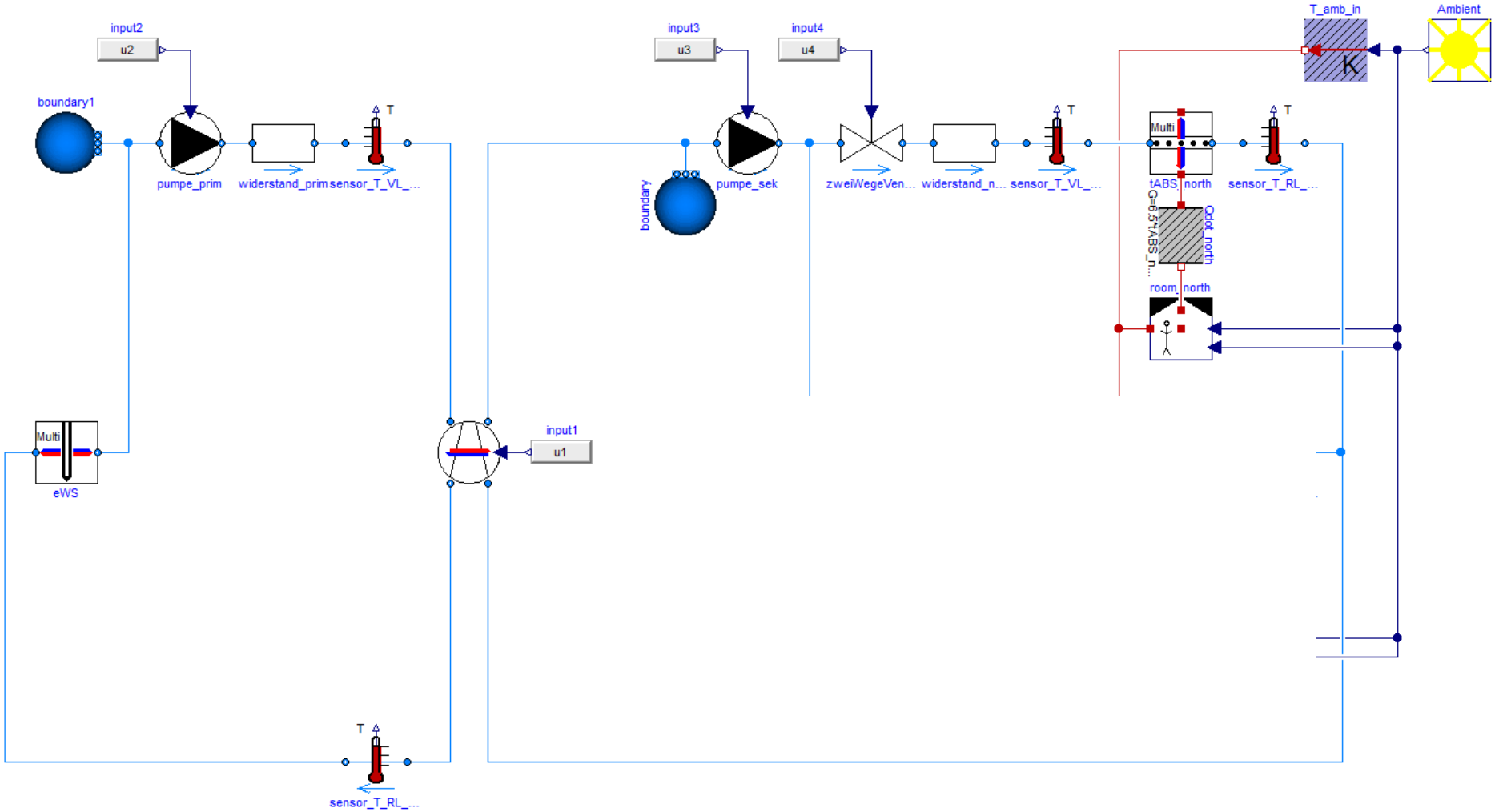

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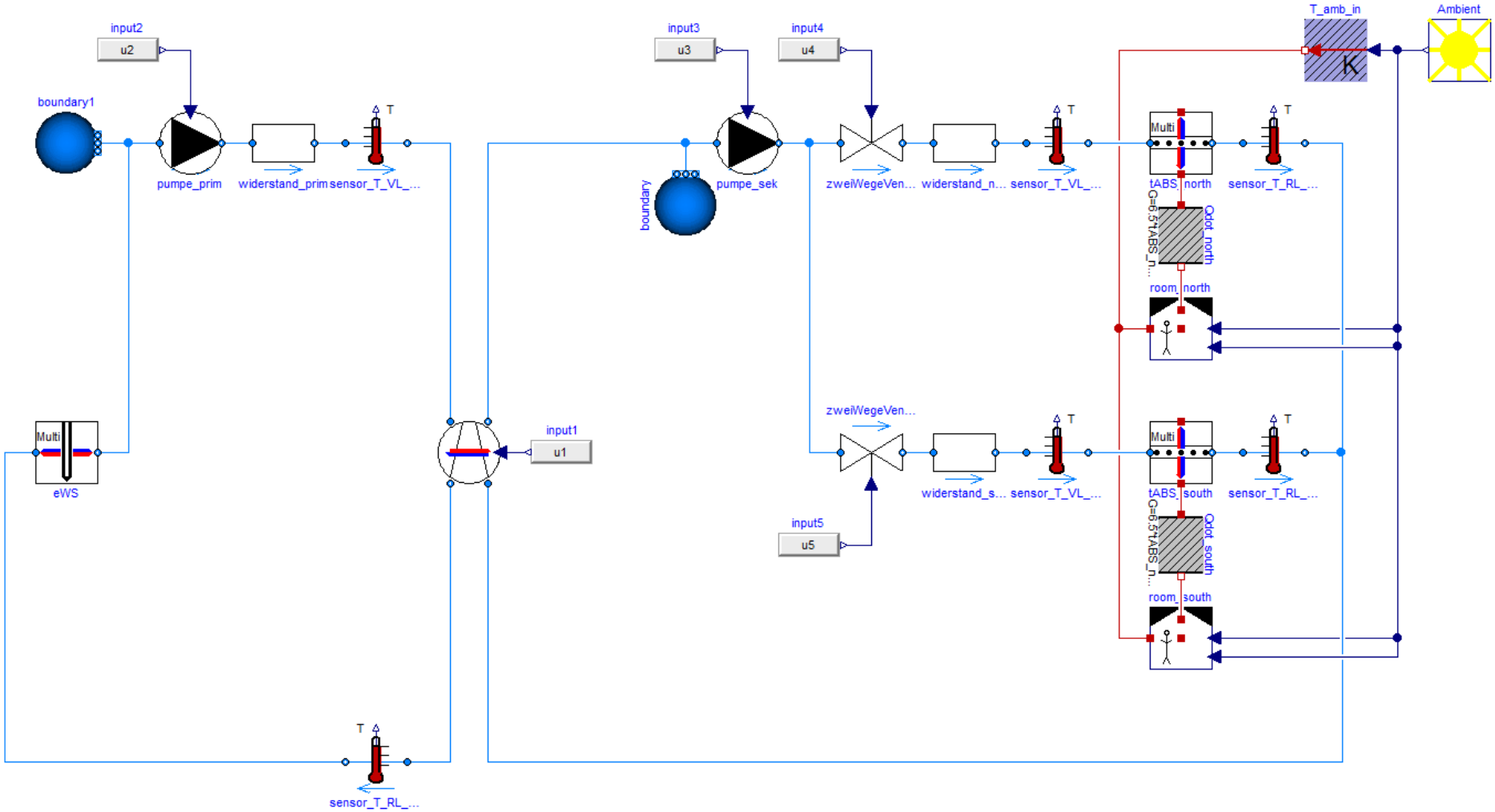

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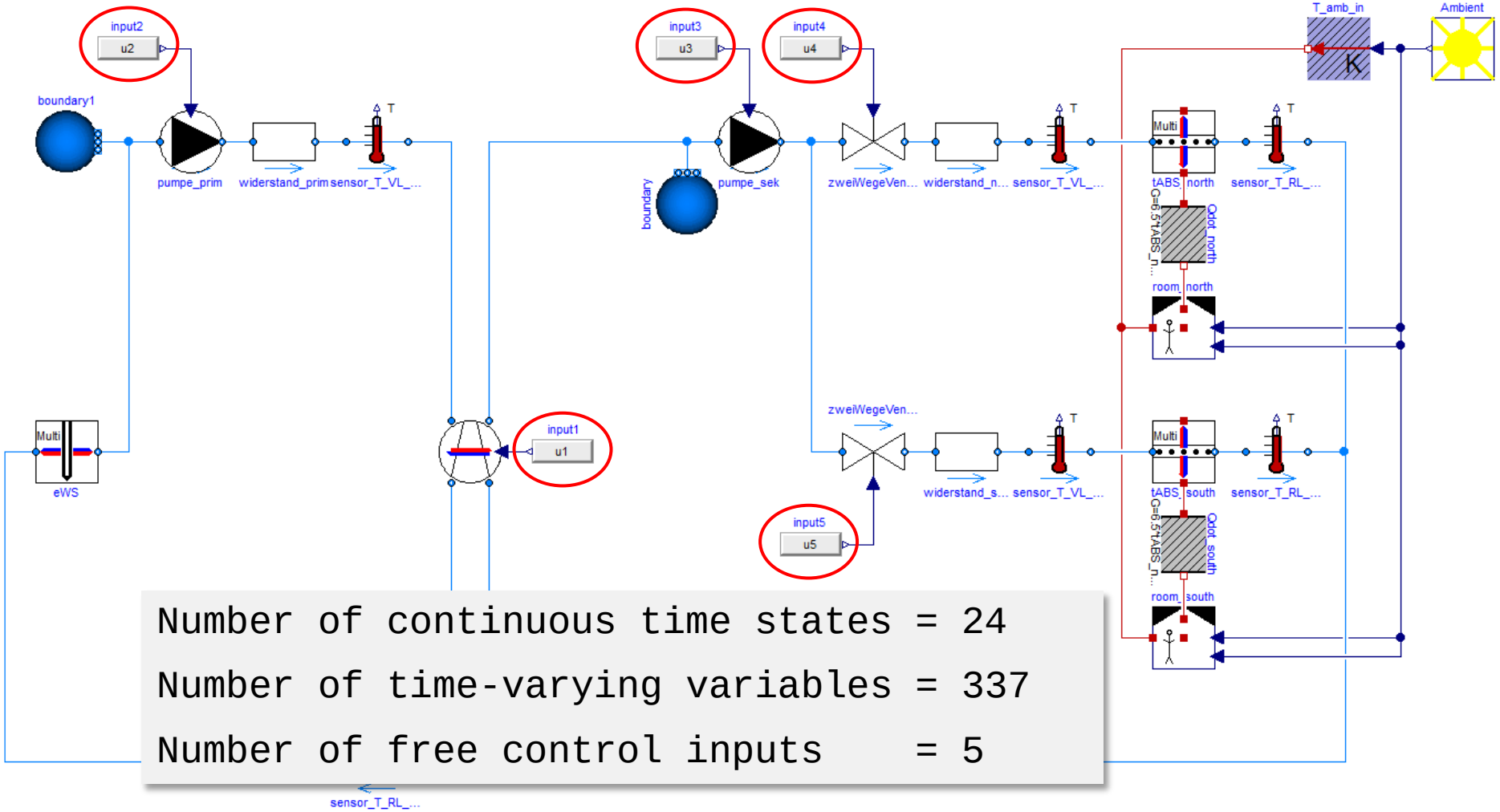



```
Number of continuous time states = 24
Number of time-varying variables = 337
Number of free control inputs    = 5
```

Methodology (3)
Optimization Framework in OpenModelica (Ruge et al. 2014)

Modelica/Optimica

Compilation of OCP in xml-format

Direct collocation

- Discretization of OCP
- Obtain Non-Linear Program

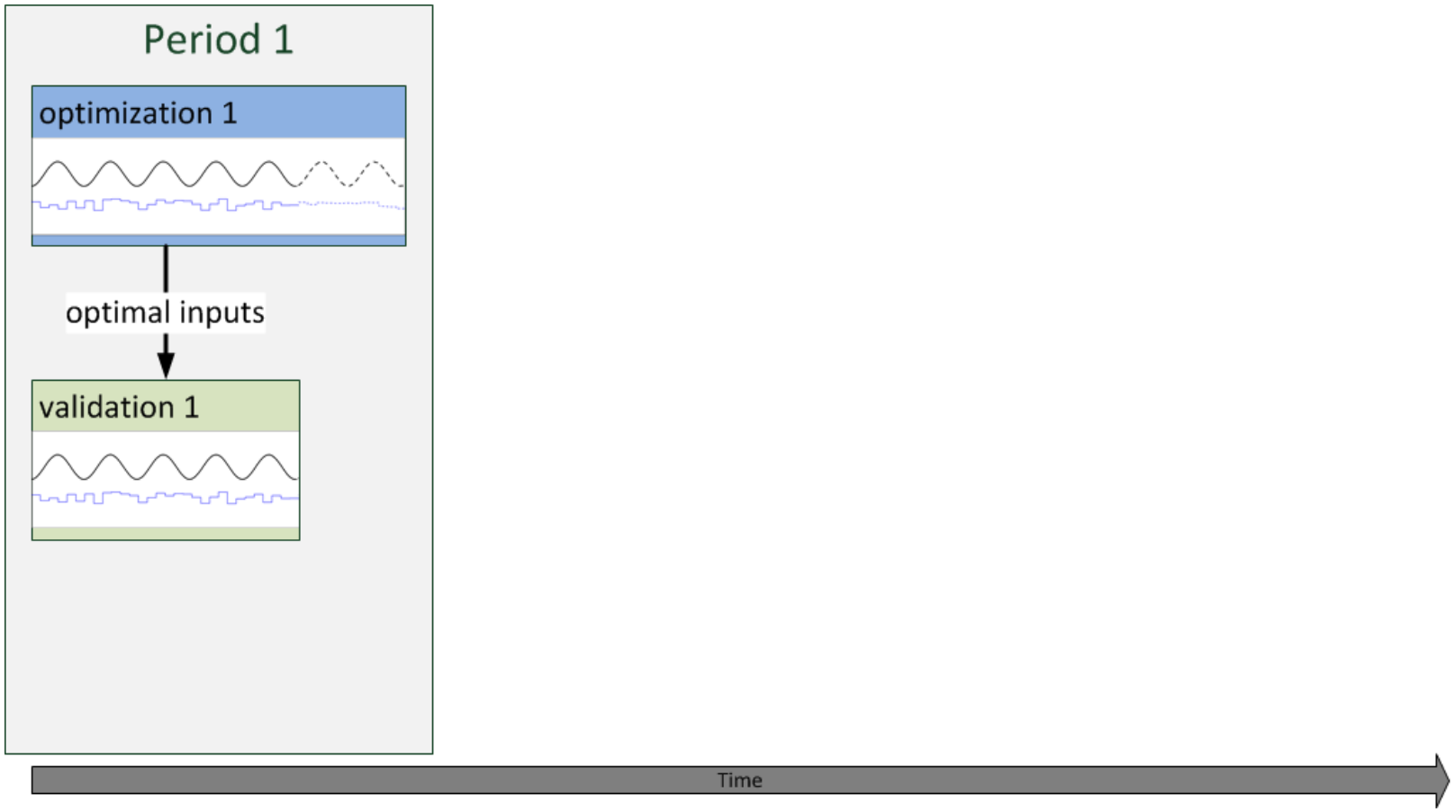
Solution of NLP with IPOPT

- Derivative information by ADOL-C

```
optimization opt (objective=energy+comfort)
   extends system_model;
equation
   energy       = W_HeatPump^2 + W_pumps^2;
   der(comfort) = max(T_set – T_room, 0)^2;
end opt;
```


Vitalij Ruge et al. (2014). Efficient implementation of collocation methods for optimization using OpenModelica and ADOL-C. Modelica Conference, Lund.

Methodology (4)
Moving-Horizon-Approach



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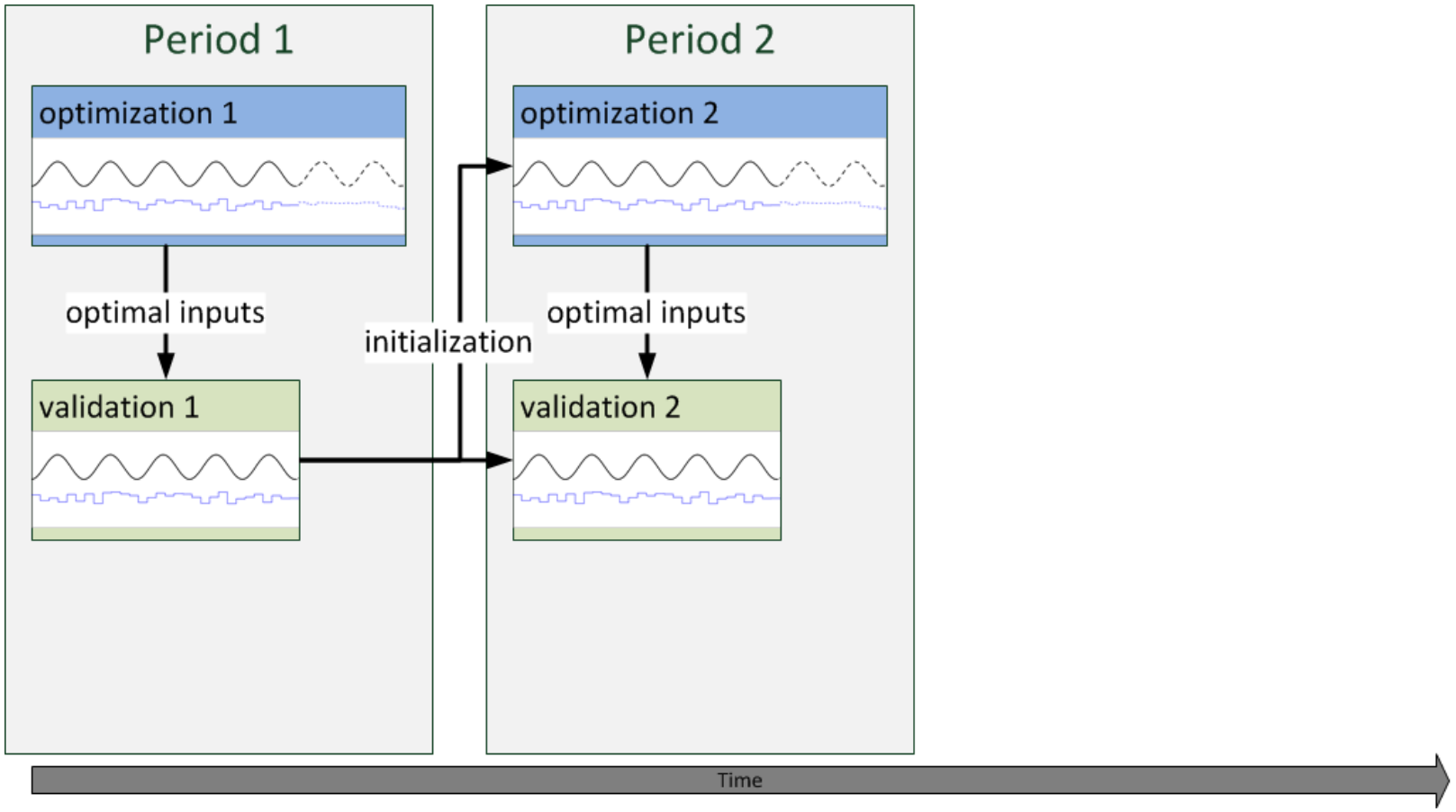

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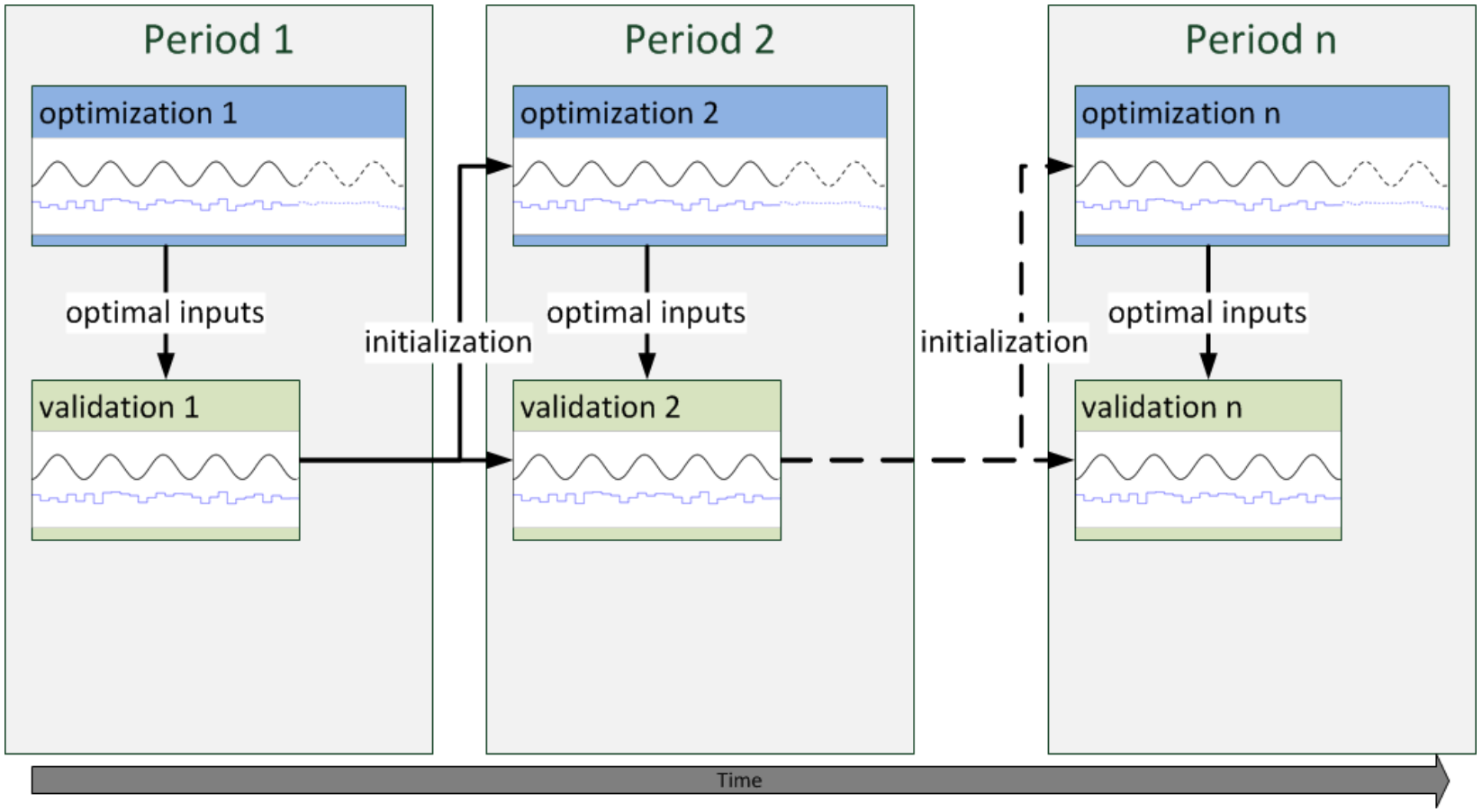

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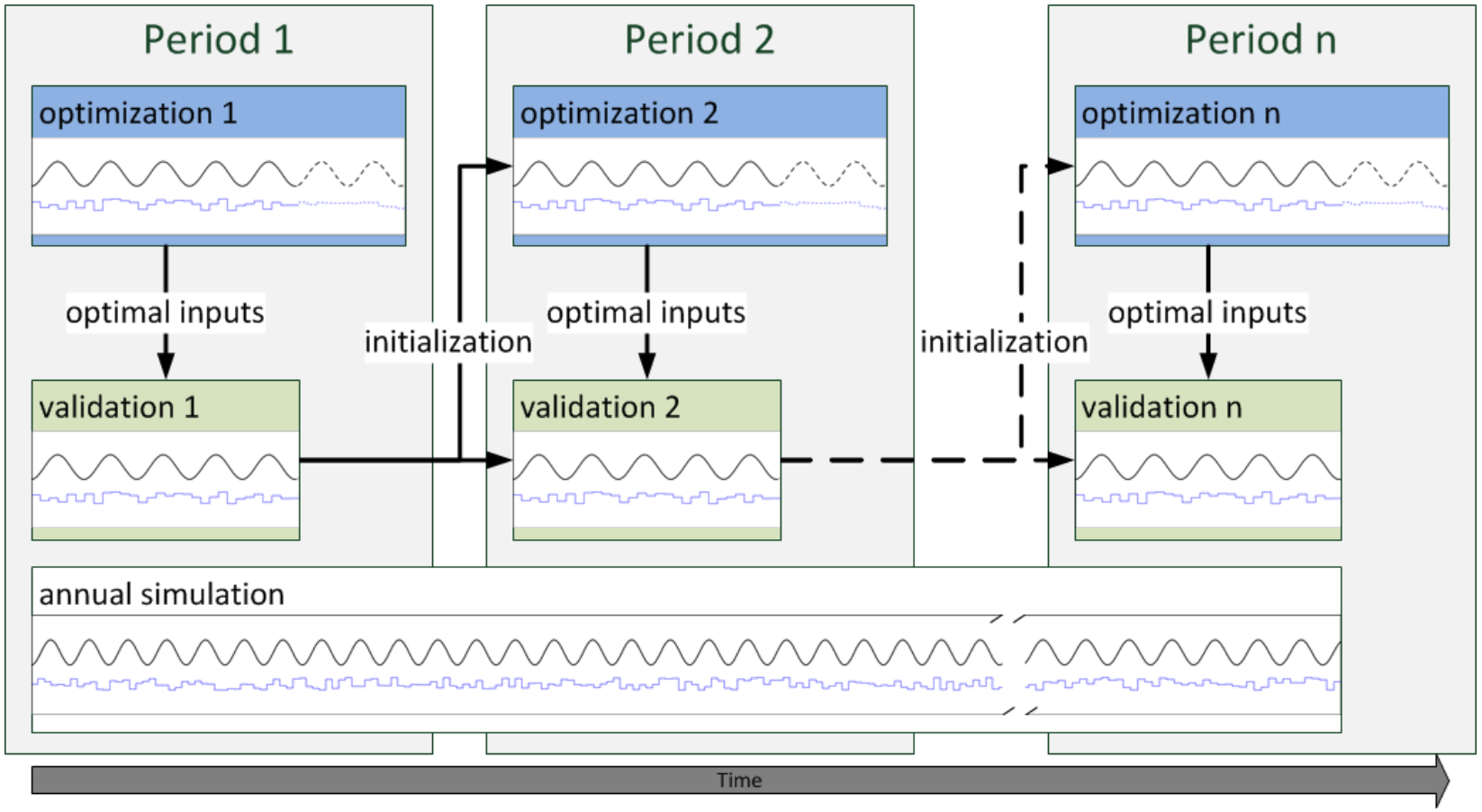

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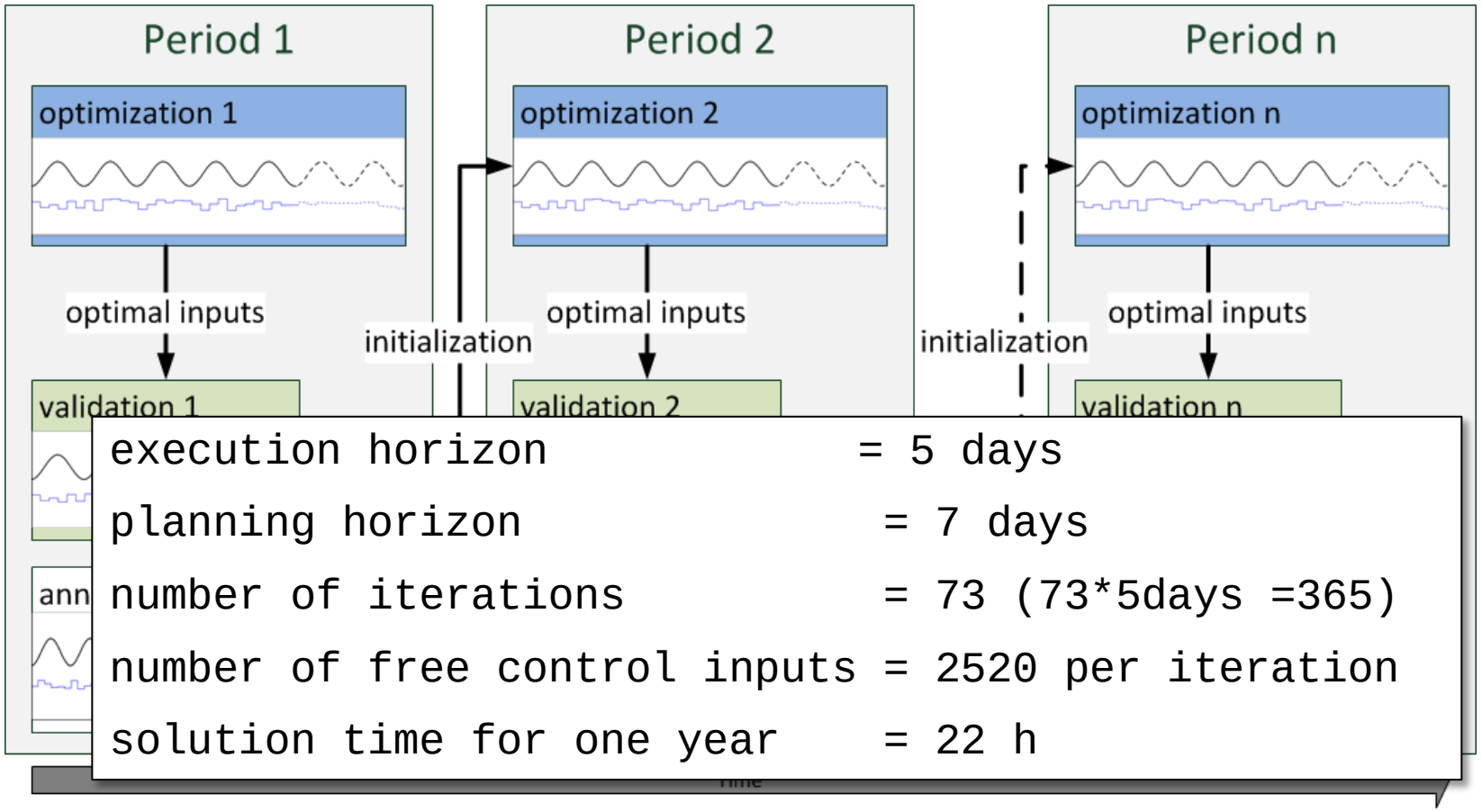
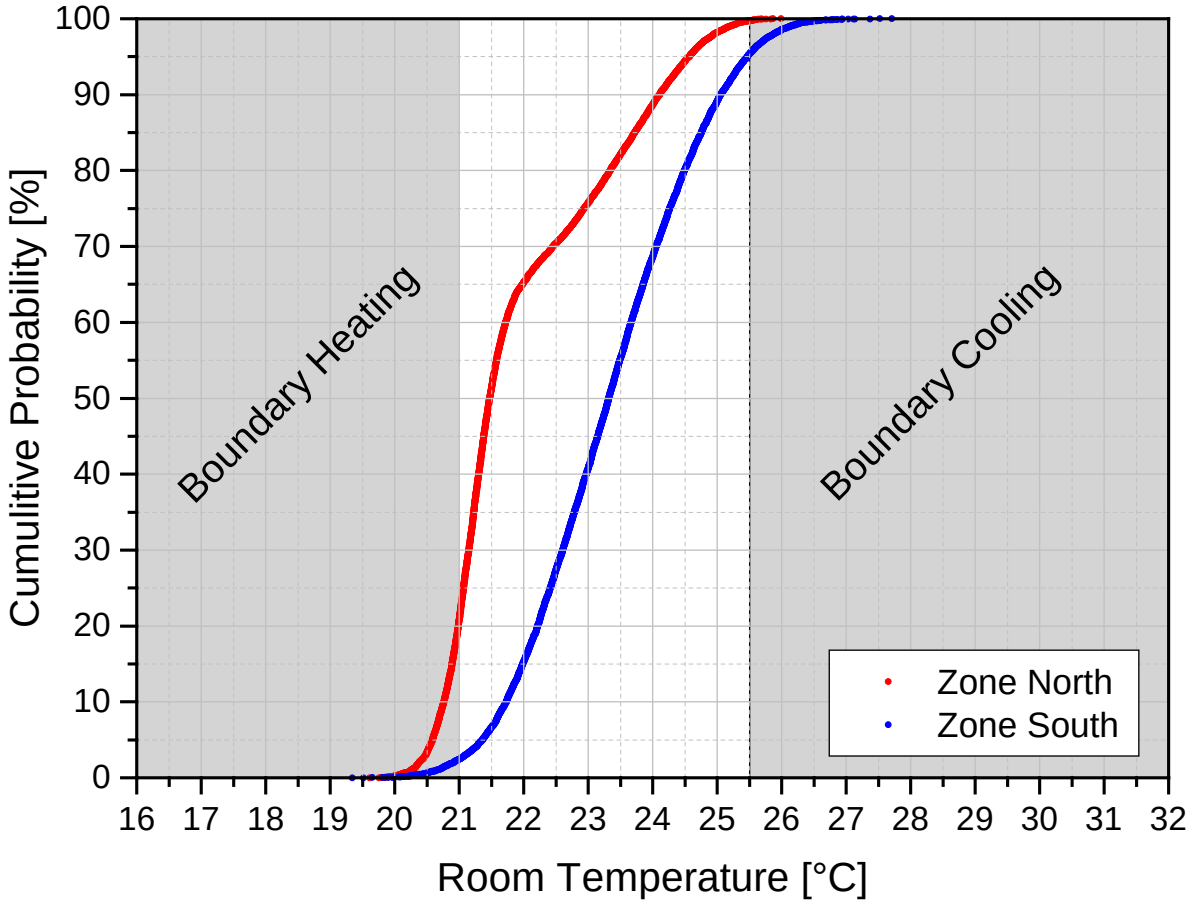


Exemplary Results

Room Temperatures – Annual Simulation/Optimization



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Conclusion and Outlook

Conclusion:

- Development of a “OpenModelica compatible” **model library** for derivative-based optimization
- Development of a **methodology for annual optimizations** with the optimization framework in OpenModelica
- Exemplary optimization runs with **whole low-exergy system models**

Outlook:

- On-going development of component models
- Improvement of optimization performance (e.g. by using CasADi)?!

Thank you for your attention!

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