The WaterHub Modules: Material and Energy Flow Analysis of Domestic Hot Water Systems

Bruno Hadengue[1,2] Andreas Scheidegger[1] Eberhard Morgenroth[1,2] Tove A. Larsen[1]

[1]Eawag, Swiss Federal Institute of Aquatic Science and Technology, 8600 Dübendorf, Switzerland
bruno.hadengue@eawag.ch
[2]ETH Zurich, Institute of Environmental Engineering, 8093 Zürich, Switzerland

Domestic Hot Water (DHW) systems are large energy consumers. Mitigation measures involve more efficient hot water appliances and distribution systems, waste heat recovery systems, or changes in consumer habits. However, the implementation of these measures must be investigated carefully, as combinations may lead to unforeseen systemic interactions limiting their potential. Inter-level interactions, for instance, have been identified: a significant performance drop occurs when decentralized heat recovery appliances are implemented simultaneously to sewer-level energy recovery facilities. Similar intra-level interactions are hypothesized to occur in households. In addition to technological competition or synergies, water consumption patterns strongly influence systemic energy- and cost-efficiencies of DHW technologies.

The WaterHub Modules

We present modeling tools to identify and optimize household level interactions, in order to avoid competitive and promote synergetic combinations. The WaterHub modules were developed for Material and Energy Flow Analyses (MEFA) of DHW systems. Two modules are available: (i) the WaterHub Modelica library includes models for MEFA system definition, and (ii) The HydroGen Python module provides methods for the stochastic generation of appliance-specific hydrographs, used as input data for the simulation of the system energy and water flows.

The modules facilitate the workflow of DHW systems MEFAs and allow fast scripting of single simulations or Monte-Carlo processes. As an example, Figure 1 presents the water and energy flows in a DHW system containing a shower-level heat recovery device.

WaterHub Modelica Library

The WaterHub Modelica Library, inspired by the Modelica Standard Library (MSL) *Fluid* library, contains models for the construction of DHW systems:

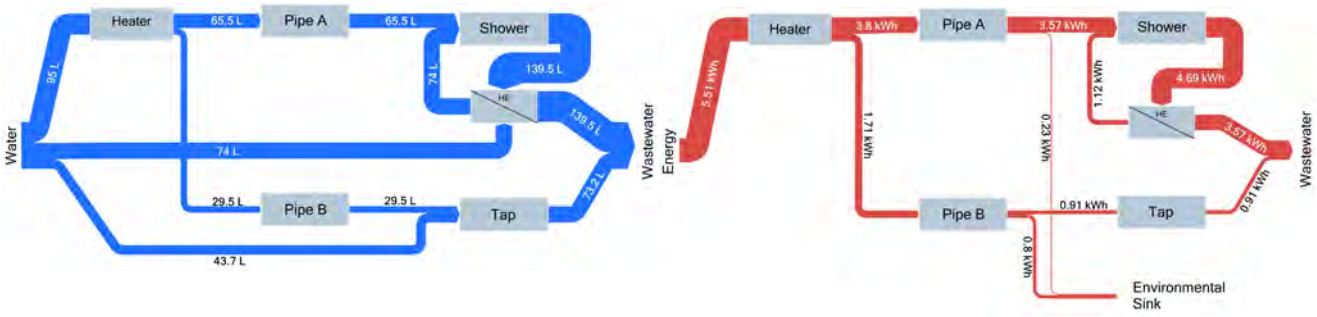
- *Appliances*: Technologies at the interface between the water consumer and the DHW system.
- *ImportExport*: Models for imported/exported water and energy flows.
- *Pipes and Carriers*: Water and energy carrier models.
- *DHW Systems*: Building blocks for DHW systems, e.g., boilers, reservoirs, water treatment units, etc.

HydroGen Python Module

The HydroGen Python module samples from distributions to generate appliance flows stochastically. *Events* are characterized by (i) a starting time, (ii) a flow rate, (iii) a temperature and (iv) a total event volume.

Conclusion

The WaterHub modules provide tools for the analysis of water and energy flows in households, facilitating (i) the identification of technological/behavioral interactions within DHW systems, (ii) consequent Life Cycle Assessment (LCA) or Multi Criteria Decision Analysis (MCDA).



(a) Water flows. (b) Energy flows.

Figure 1. Average daily water and energy flows in a didactical DHW system containing a shower-level heat recovery device (HE).