INNOVATIVE CONCEPTS AND APPLICATION FOR LARGE SCALE AND MULTIMODE SYSTEMS : AN INDUSTRIAL USE CASE STUDY OF HEAT NETWORKS

Valentin Gavan[1], Patrick Chombart[2],
Charlie Duprat[2], Jérémie Fricker[3], Benoît Radet[4], Kevin Maquin[4]

[1] ***ENGIE Lab CRIGEN***, *4 rue Joséphine Baker, 93240 Stains, France*
[2] ***Dassault Systèmes SE***, *10 rue Marcel Dassault, CS 40501 78946 Vélizy-Villacoublay Cedex , France*
[3] ***ENGIE Lab Cylergie***, *18 Avenue Tony Garnier, 69007 Lyon*
[4] ***Digital Product Simulation***, *108, Avenue Jean Moulin, 78170 La Celle Saint-Cloud, France*

Summary

1

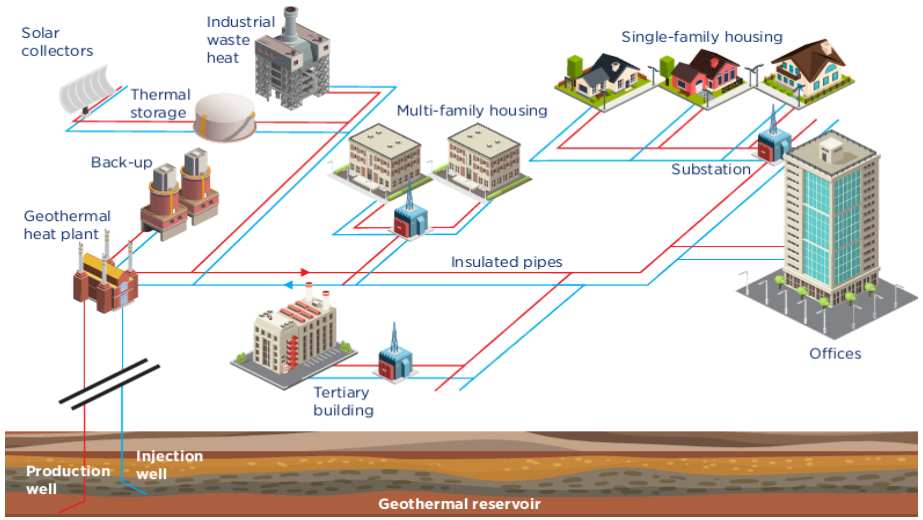
MODELISCALE project short presentation

Rationales

“[…] the summer that ended indifference”* ?

- An **unprecedented summer** in Europe with a beluga swimming in the Seine river, heatwaves at a level unseen before, wildfires across the country, a deadly storm in Corsica, and an energy crisis looming above Europe → **similar events as in 2018 when our research began**
- **All these situations call on us :**
  - To be more inventive
  - And accelerate the reduction of human pressure on the climate
  - By decarbonizing our activities by promoting alternatives to existing fossil powered systems
  - **And considering district thermal energy networks as a solid alternative to decarbonize thermal energy usages**

Source : Le Monde, August 22, 2022



Source : IRENA

Le Monde, August 22, 2022

A French consortia for the creation and simulation of digital twins of Energy Systems

MODELISCALE – Create innovative technological bricks to better analyze large, diverse and complex scenarios for large scale decentralized multi physics energy systems

- **8 major players in digital engineering, industry and research**
- Facts & figures :
  - Leader : Dassault Systemes
  - Dates : [Jan 2018, Jul 2021]
  - Efforts : 50+ ManxYears
  - Budget : 5.4 M€
  - https://www.3ds.com/modeliscale

ModeliScale

EDF Inria · Dassault Systèmes · CEA INES · ENGIE eurobios · DPS Digital Product Simulation Inc. · PHIMECA Solutions for robust engineering

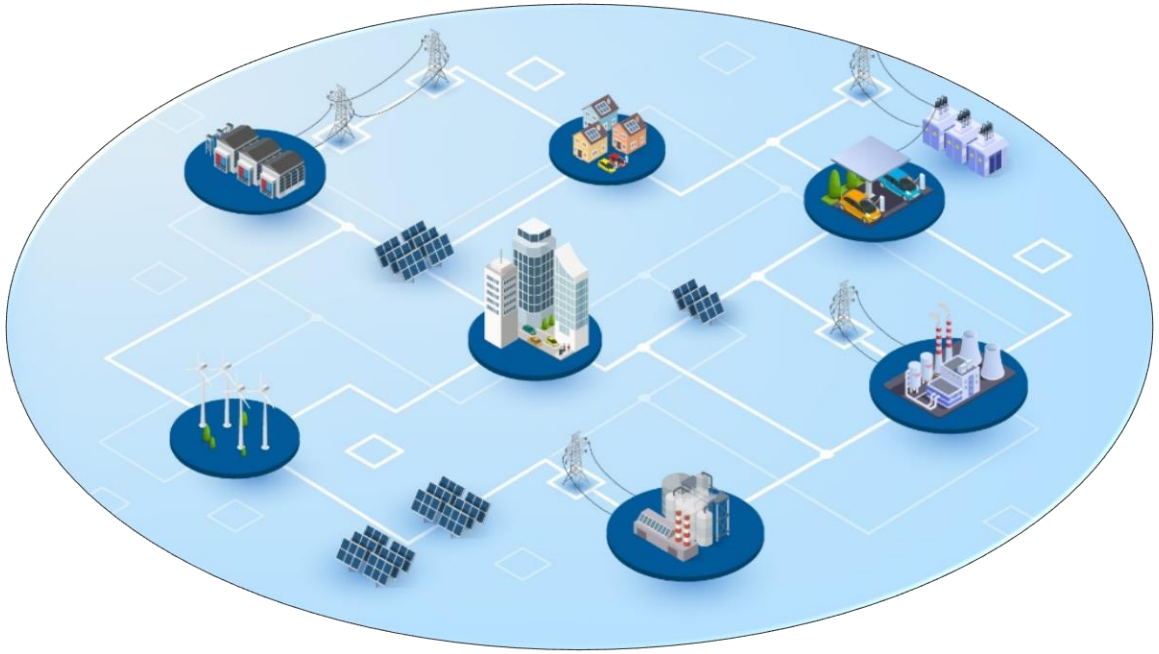
French state financial support

Systematic Paris Region Systems & ICT Cluster · bpifrance · DGE Direction Générale des Entreprises · tenerrdis · FUI

Addressing multiple modeling challenges

Leveraging on Modelica to Model and Simulate large models of energy systems, in a multi-mode context

- **Ambitions :**
  - to develop new scientific concepts for the **analysis and solving in multi mode, initialization** and **enlarge scaling**
  - to prototype technological solutions based on the Modelica and FMI open standards in apps & **Modelica library prototypes**
  - and to **validate them on industrial demonstrators in several French cities** (**Rillieux-la-Pape,** Vélizy, Chambéry) with Dymola & 3DEXPERIENCE



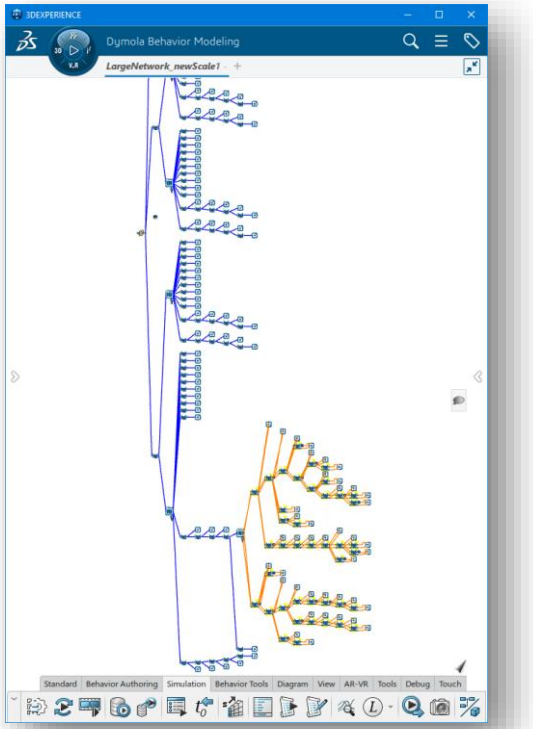
2

Modelica based developments

ModeliScale Software developments

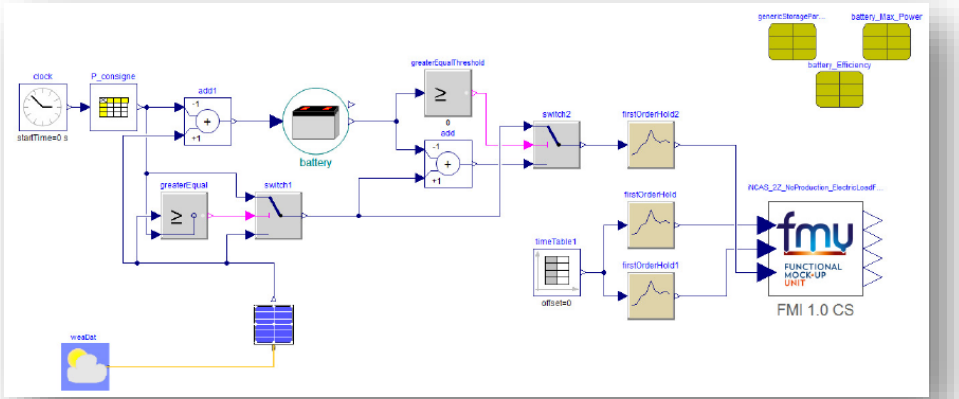
Several improvements to analyze, compile, install and execute large models

- **IsamDAE prototype**
  - Multi mode analysis of systems
- **CATIA and Dymola applications**
  - Increased performances
    - Handling of nonlinear algebraic loop , Sparse solvers for static models
    - Parallelism for multi-rate models, Translation and compilation time
  - New approach for model initialization (data assimilation)
  - Interface with IsamDAE to test multi modes on Modelica models
- **DACCOSIM application :** Improved FMI based distributed Large Scale Co simulation
- **FMI standard enhancements** (2 proposals included in FMI standard V3.0)
- **New multiphysics libraries prototypes :**
  - electrical components ElectricGrid (DPS),
  - heat network components ThermoGrid (DPS)
  - Thermal components (Eurobios),
  - electrical components PowerSysPro (EDF, open)

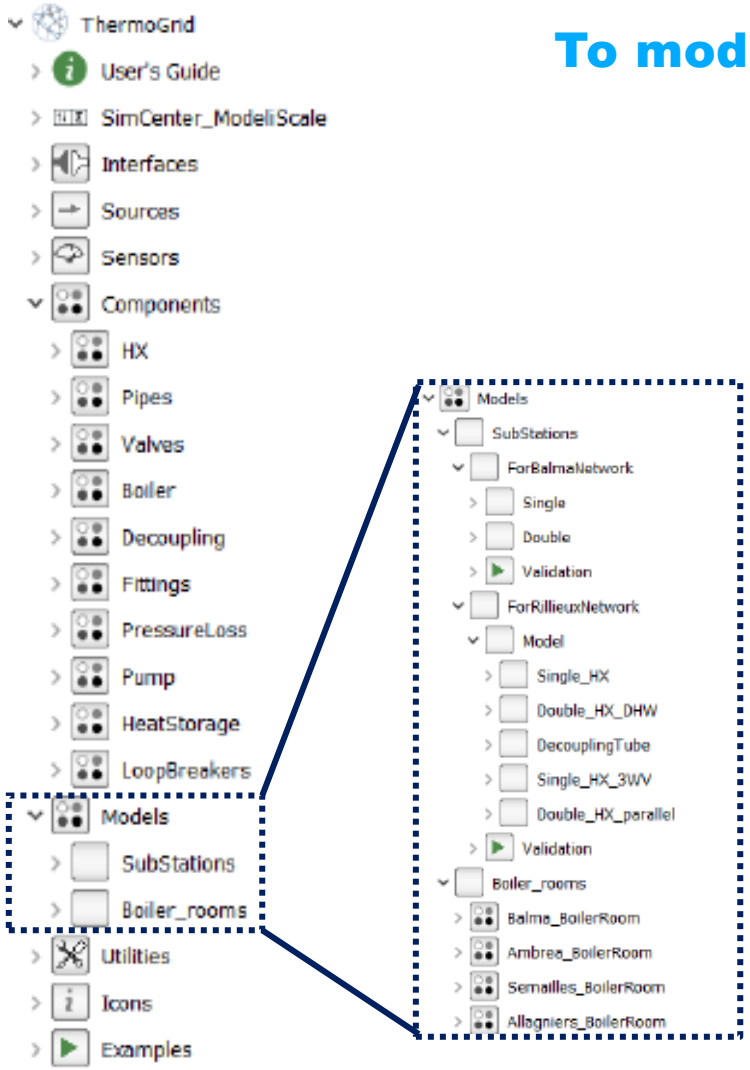


*Modelling a large electrical network in CATIA **3D**EXPERIENCE*

Modelling with battery storage



Dedicated Modelica library for ENGIE needs



To model and simulate district thermal energy networks

- **From operational specifications and 'from the field' requirements**
- **Library breakdown overview**
  - Interfaces
  - Sources
  - Sensors
  - **Components**: individual components with their validation models
  - **Models**: substations and boiler rooms models
  - Utilities
  - **Examples**: complete models of district heating networks
- **Developed by DPS**

3

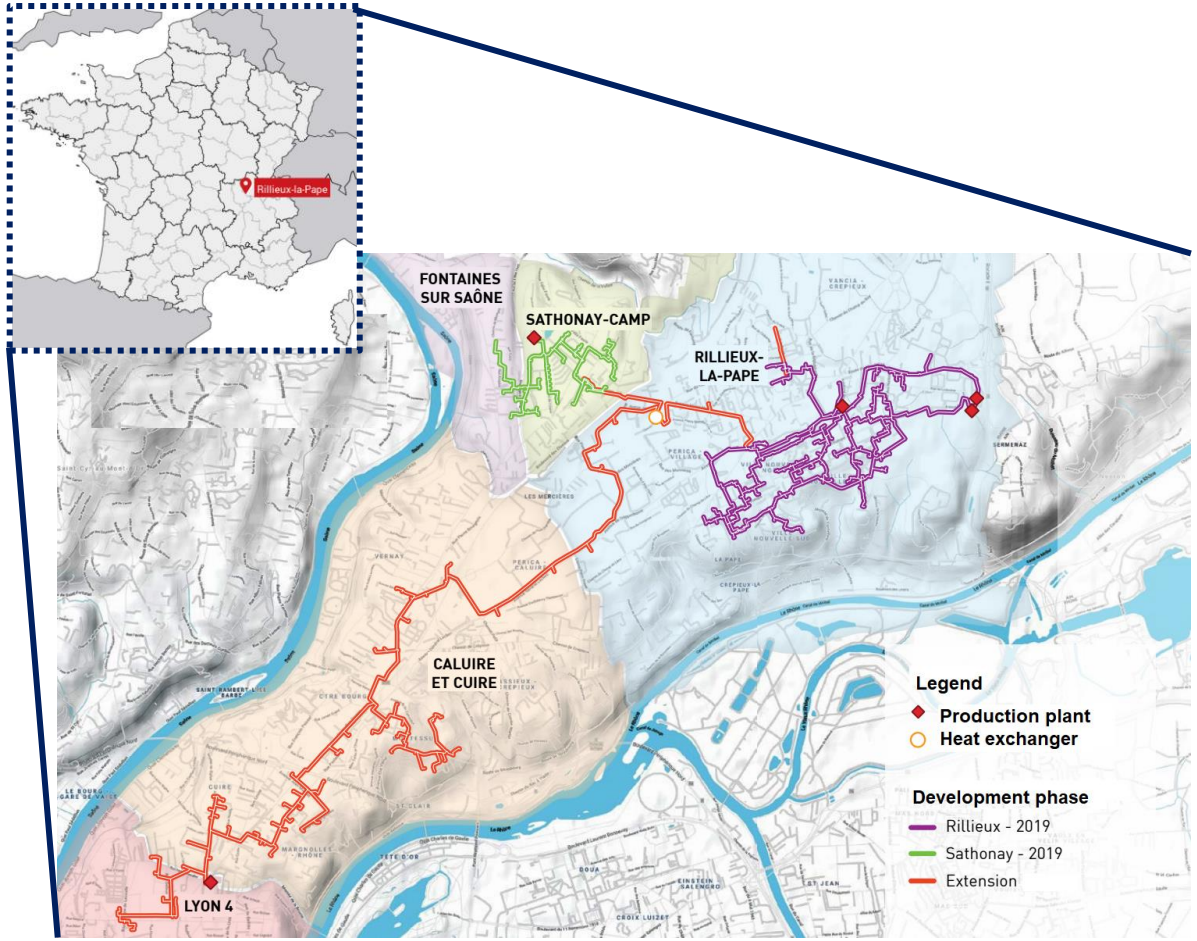
Use cases and application

Modeling and simulation of district thermal energy networks

Integrating operational specifications and ‘from the field’ requirements

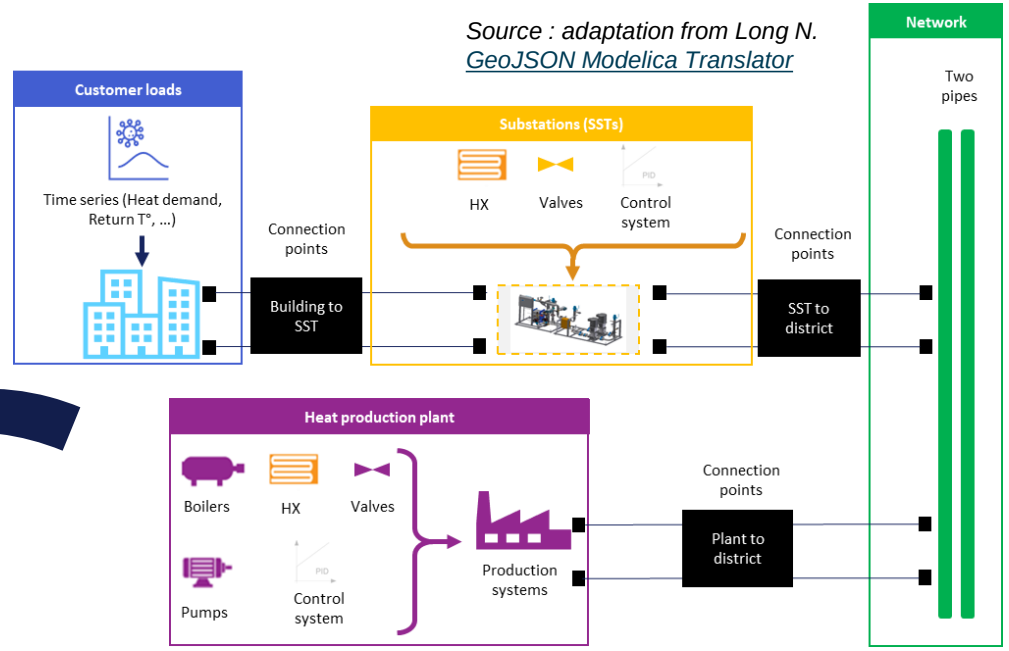
Provided by ENGIE

- **Thermal energy network** :
  - Rillieux-la-Pape, France (Lyon region)
  - Commissioned in 1970
  - Hot water district heating network (9 300 equivalent dwelling units) of **20 km long with 78 substations**, serving residential, municipality and commercial buildings
  - Several extensions planned in nearby cities of additional 45 km (22 000 equivalent dwelling units in 2040)
  - Energy mix : biomass boiler, gas boilers, waste heat from a nearby incineration plant



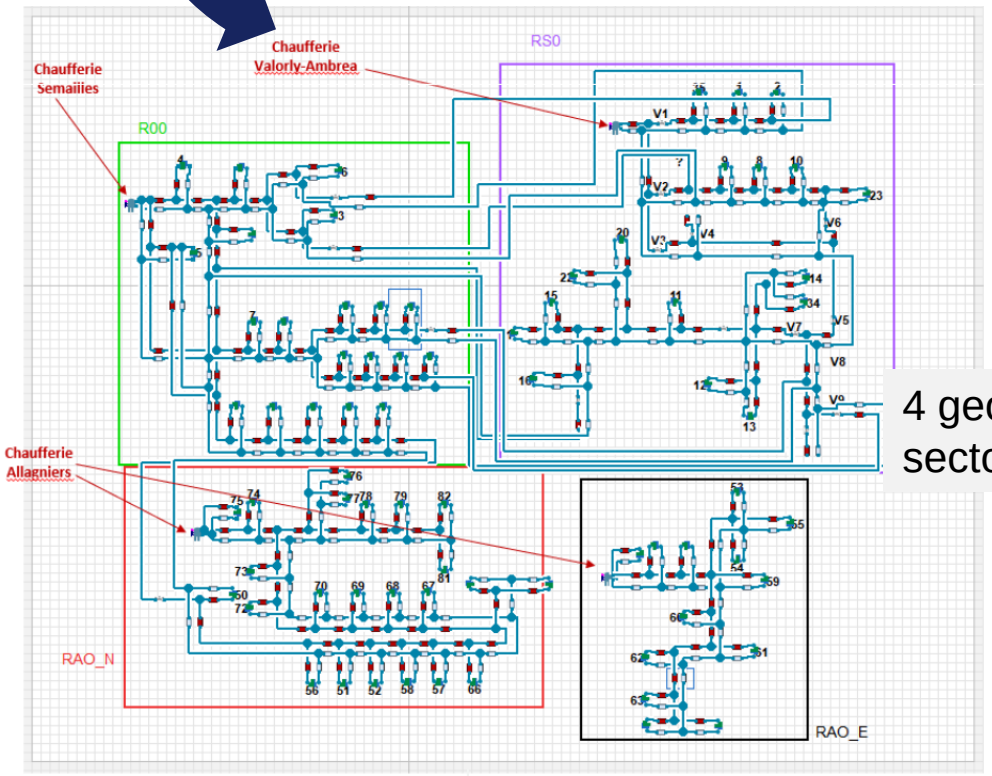
Bottom-up modeling approach used

Source : adaptation from Long N. [GeoJSON Modelica Translator]



Breakdown of the overall model into several parts to allow a good visualization and understanding of the network behavior

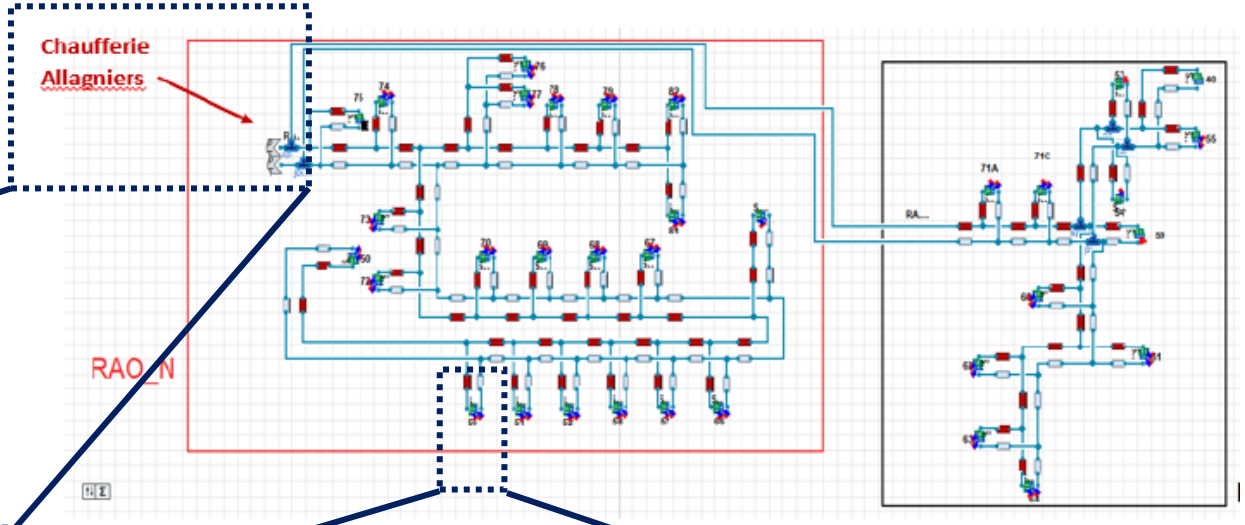
- **Customer loads & Substations :**
  - 15’ real-data time series from Jan. 2018 to Dec. 2019 with heat demand, T°, mass flow, valve opening, etc. for all the SSTs
  - HXs, valves, control system, etc. with their characteristics
- **Network :**
  - Pipes
  - 4 geographical sectors for future FMU based implementation
- **Heat production plant (x 3) :**
  - Gas boilers (5 MW, 2 x 12.75 MW)
  - Biomass boiler (5.6 MW), HX waste heat (20 MW)
  - Valves, pumps, hydraulic pressure breaker

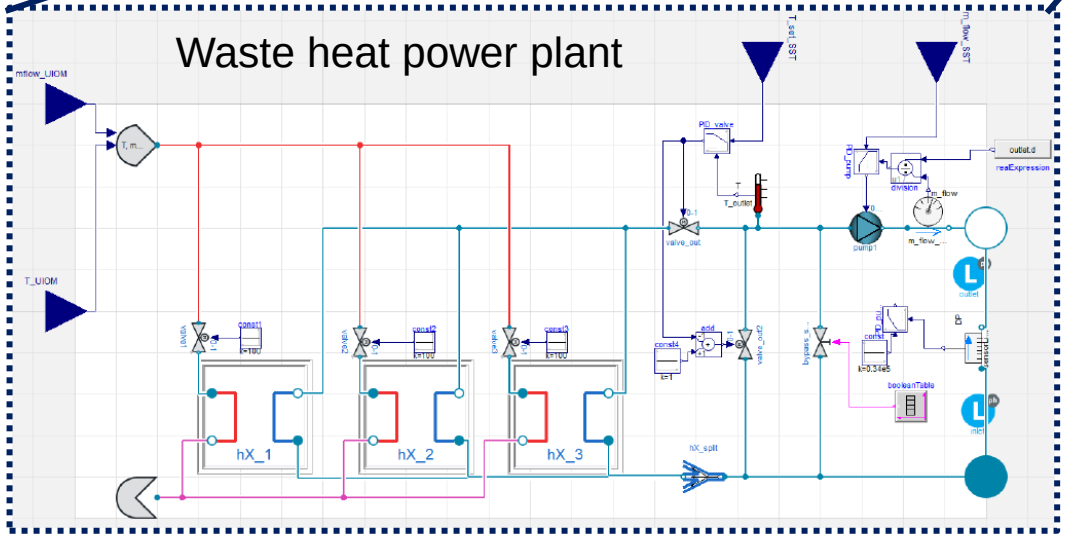


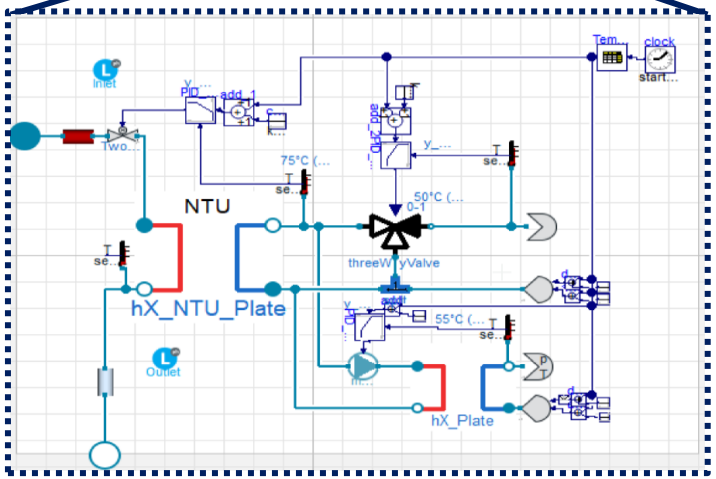
4 geographical sectors

Reproduce results as in the operating conditions

- Components tested with data from the field on one year simulation
- Good alignment of results with reality (in progress)
  - **≤ 1 K for temperatures**
  - **≤ 0.1 kg/s for mass flows**
  - **≤ 5 % for the energy consumption**



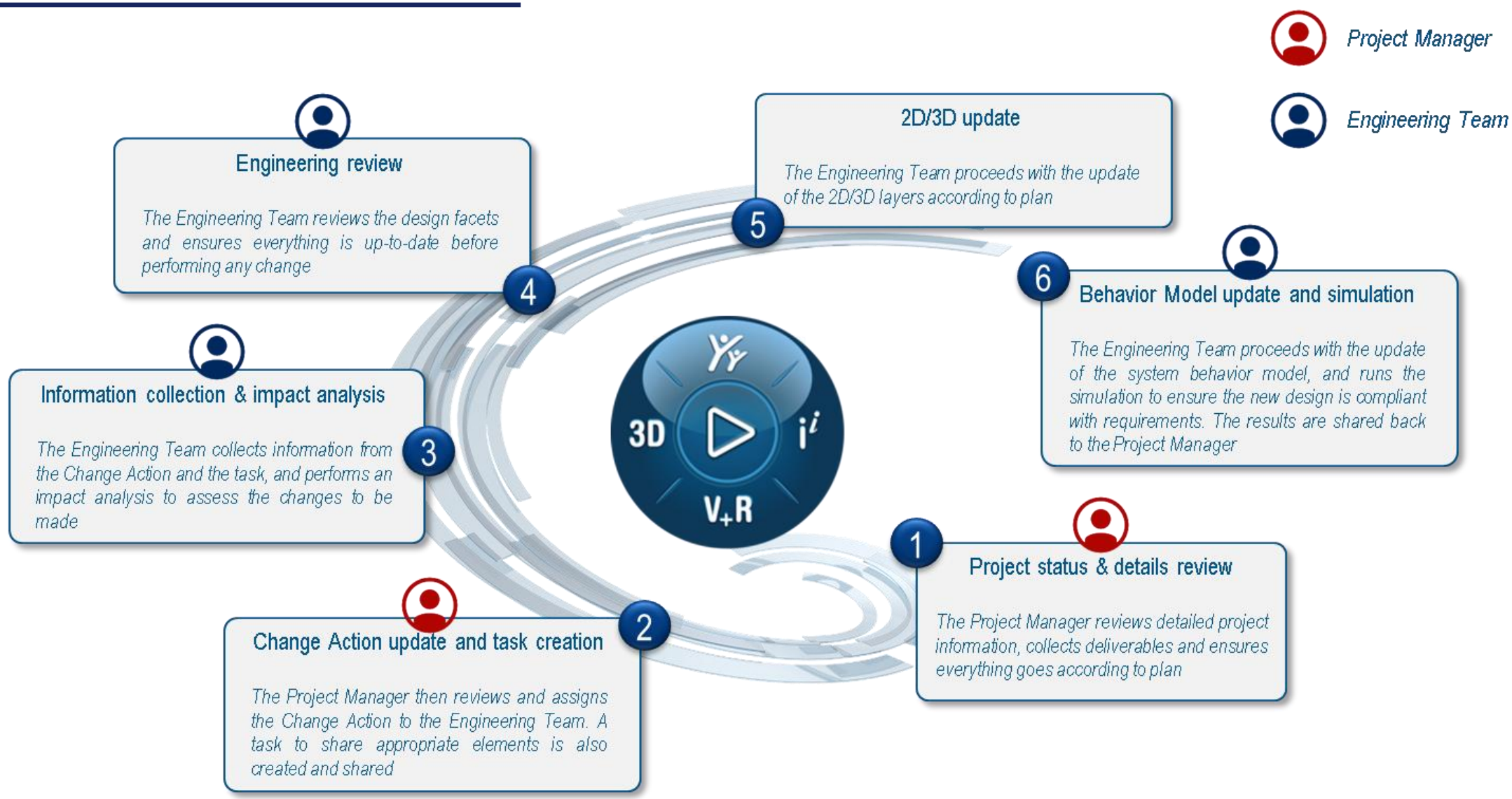




SST with DHW production on the secondary circuit

- Several difficulties especially during the simulation phase (CPU time)
- Significant progress has been done to better analyze, compile, install and execute large models

Demonstrator – network modification in 3DEXPERIENCE



Demonstrator – network modification in 3DEXPERIENCE

4

Conclusions

A meaningful opportunity for the involved partners on multiple accounts

Innovative concepts for large scale and multi mode systems

- **Modeling track** :
  - New technique for systems initialization
  - Significant improvements in Modelica domain (libraries, tools, FMI)
  - Enhanced ModSim of large-scale energy systems with accurate results
- **Industrial track :**
  - Support of design studies for a better answer to market needs
  - But still needed improvement for large scale and acceptable calculation time
  - Dymola improvement should also be beneficial for other industries (Aerospace, Mobility)
- **Collaborative opportunity** around a strategic topic for industrial players to converge on new business processes and needs
- **Tooling and language perspectives**
  - Pursue the Work initiated in ModeliScale for larger systems, and multi mode analysis, compilation, and simulation of Modelica models, mature the initialization approach

French state financial support

Acknowledgement : This work was funded and supported by BPIFrance and Region Ile de France through the French FUI ModeliScale research project

Annex

Breakdown of the overall model