



## WP1.2 MPC

WP Leader: Lieve Helsen, presented by Filip Jorissen

Expert Meeting Aachen  
April 3-4, 2019

## WP1.2 Goals and Work Plan

# THE GOALS

Using Modelica,  
an equation-based object-oriented modelling language

1. To develop a **framework** to test and assess MPC performance
2. To develop an open-source **Library for MPC**
3. To compare and **benchmark** different **MPC formulations**

# THE WORK PLAN

## WP1.2 Model Predictive Control (MPC)

### Task 1.2.1:

Develop a framework to test and assess MPC performance

### Task 1.2.2:

Compare and benchmark MPC algorithms

### Task 1.2.3:

Develop a Modelica library for MPC

# ACTION PLAN DEFINED IN PARIS

## Focus points defined for the period between Paris and Aachen Meeting

1. Emulator models: development, documentation and review, including checklist for review process
2. BOP-TEST: prototype testing
3. MPC description template: finalization
4. Key performance indicators: quantification, including definition of scenarios to vary boundary conditions
5. Modelica library for MPC: overview of models already available

## WP1.2 Contributors

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Affiliation	Team members
KU Leuven (WP Leader)	Lieve Helsen, Filip Jorissen, Damien Picard, Iago Cupeiro, Jan Drgona, Javier Arroyo (now at LBNL)
LBNL	David Blum, Michael Wetter, Antoine Gautier
PNNL	Draguna Vrabie, Sen Huang, Yan Chen
NREL	Kyle Benne, Yanfei Li
SDU	Krzysztof Arendt
ENGIE Lab	Valentin Gavan
ENGIE-Axima	Lisa Rivalin (now at LBNL)
3E	Roel De Coninck
IK4	Jesus Febres, Susana Lopez

# WP1.2 Status work



# STATUS WORK

## Coordination Meetings since Paris Meeting

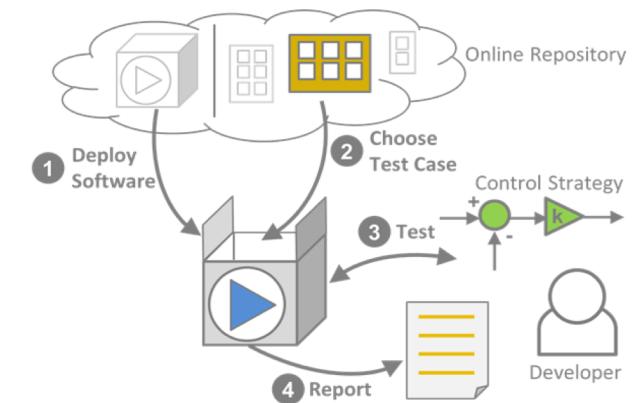
- January 19, 2019:  
Update and discussion on Emulators, BOPTEST, KPIs, MPC description template, Modelica library for MPC, joint papers, Championship Japan, Mission Innovation
- February 19, 2019:  
Update and discussion on Emulators, BOPTEST, KPIs, MPC description template, Modelica library for MPC, joint papers, points for Aachen meeting, IEA-EBC Annex ‘Smart data-driven solutions for high-performance buildings’.
- March 21, 2019:  
Introduction Tea Zakula (Zagreb University), Planning Break-out sessions Aachen meeting, Update and discussion on Emulators, BOPTEST, KPIs, MPC description template, Modelica library for MPC, joint papers

# STATUS WORK

Task 1.2.1: Development of a framework to test and assess MPC performance

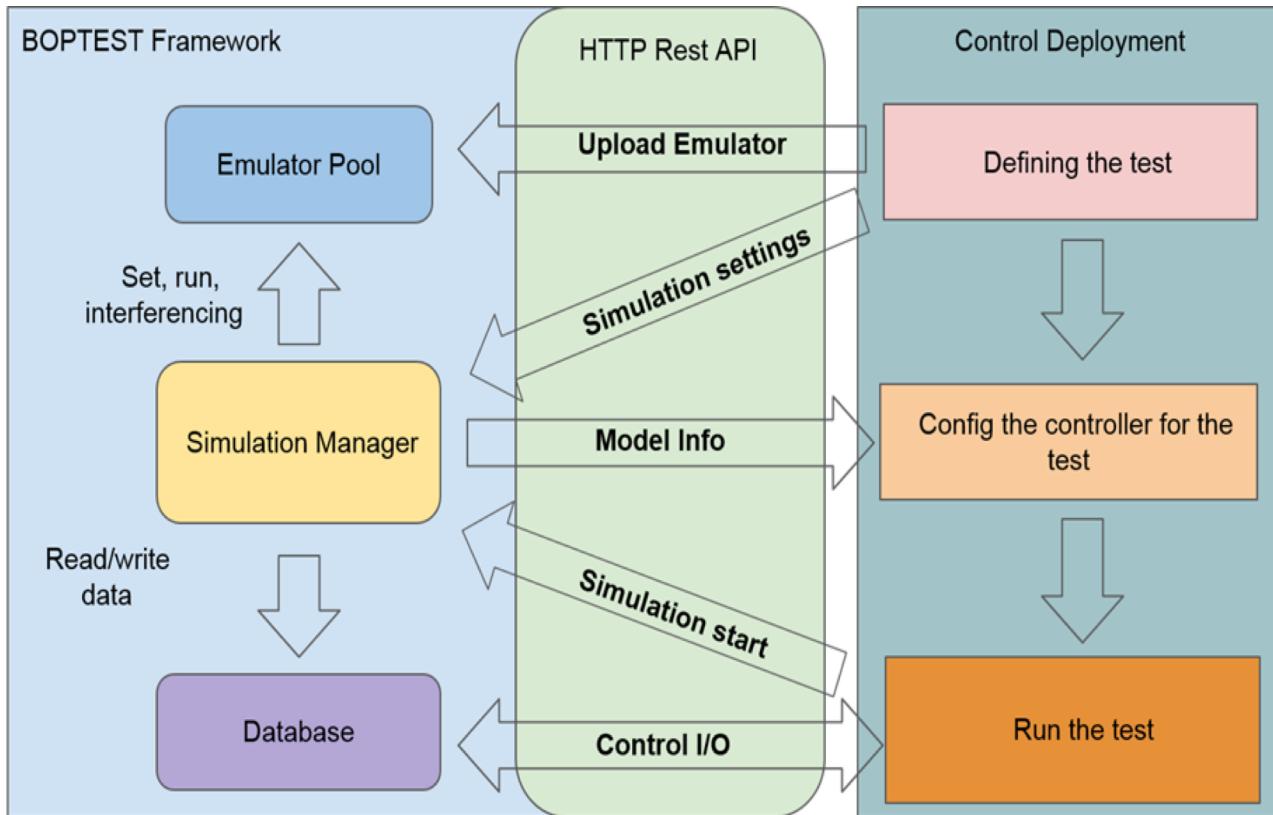
**Virtual test bed - Architecture which allows control by MPC**

- ✓ Workflow for use cases: ready
- ✓ Prototype: ready and being tested in different environments
- ✓ Documentation of development requirements and guide: reviewed and finalized
- ✓ List of use cases we would like to support in BOPTEST: ongoing, decision to be taken in BS 2-2

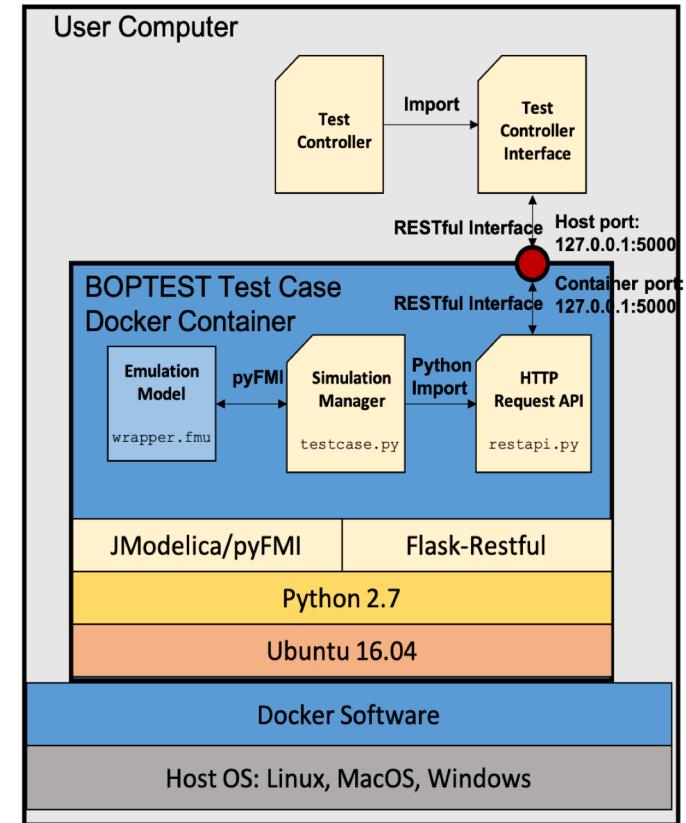


Framework concept

# STATUS WORK



Software platform architecture



Prototype of BOPTEST software platform

# STATUS WORK

Task 1.2.1: Development of a framework to test and assess MPC performance  
BOP-TEST

## Virtual test bed - Detailed emulator models

- ✓ Modelica template/guidelines for standardizing towards KPIs and inputs/outputs communication: integrated in ‘Requirements and guides document BOPTEST’
- ✓ Emulators: development, documentation and review: ongoing
- ✓ Peer review process (checklists and unit tests):
  - ✓ first version checklist is ready and sent to external reviewers, example in BS 1-1
  - ✓ unit tests in BOPTEST repository (using the whole BOPTEST toolchain)

Emulator	Developer	Developed	Documented	Reviewed by	BOP-TEST ready
BESTEST hydronic (1z)	Filip	In IDEAS	Being finalized	Dave: yes	Overwrite blocks
BESTEST air-based (1z)	Dave	In BUILDINGS	Not yet	Filip	
8z residential hydronic heating	Valentin	ready	1 <sup>st</sup> version	Krzysztof: ongoing	
8z residential hydronic heating + air cooling	Valentin	ready	1 <sup>st</sup> version	Krzysztof: ongoing	
Air-based commercial (1z)	Dave	Almost ready	1 <sup>st</sup> version	Jesus	
Hydronic commercial (1z)	Krzysztof	ready	ongoing	Valentin	
5z air-based commercial	Dave	In BUILDINGS	1 <sup>st</sup> version	Yanfea (Filip)	
mz hybrid office (simple)	Iago	In IDEAS	Validation ongoing	Valentin	
mz hybrid office (complex)	Filip	In progress	Not yet	PNNL?	
mz air-based prototype (complex)	Sen Huang	ready	1 <sup>st</sup> version	Iago	

# STATUS WORK

## Task 1.2.2: Comparison and benchmarking MPC algorithms

Virtual test bed developed in Task 1.2.1 is used to **test MPC formulations and solvers** on common emulators, which allows benchmarking the MPC algorithms using selected performance indicators

- ✓ MPC description template (control engineering versus physical notation): reviewed and finalized
- ✓ Core KPIs quantification: calculation module (with input/output requirements) ready flexibility indicator through scenario
- ✓ List of scenarios to vary boundary conditions (e.g. weather, price profile energy vectors (consistent with emission factors), uncertainty on forecast ...)  
Robustness towards forecast errors to be discussed in BS 2-2

# THE WORK PLAN

## Task 1.2.3: Development of a Modelica library for MPC

**Library of models** that can be used to efficiently solve optimal control problems for building and district energy systems (& that can be combined with parameter and state estimation algorithms)

- ✓ All physical equations need to be at least twice continuously differentiable with bounded derivatives on compact sets
- ✓ Separate Library that implements the IBPSA Library
- ✓ Compliant with JModelica → no integer problems
- ✓ Overview of available models: ready
- ✓ Merge and start building experience and gaining insights

# STATUS WORK



## Focus points defined for the period between Paris and Aachen

- ✓ Emulator models: development, documentation and review, including checklist for review process **ONGOING**
- ✓ BOP-TEST: prototype testing **ONGOING**
- ✓ MPC description template: finalization **READY**
- ✓ Key performance indicators: quantification **READY**  
definition of scenarios to vary boundary conditions **ONGOING**
- ✓ Modelica library for MPC: overview of models already available **ONGOING**

# STATUS WORK

## Publications

- Paper BS2019 accepted (minor changes)

### **Prototyping The BOPTEST Framework For Simulation-Based Testing Of Advanced Control Strategies In Buildings**

David Blum, Filip Jorissen, Sen Huang, Yan Chen, Javier Arroyo, Kyle Benne, Yanfei Li, Valentin Gavan, Lisa Rivalin, Lieve Helsen, Draguna Vrabie, Michael Wetter, Marina Sofos

# STATUS WORK

## Publications

- Paper SBE 2019 submitted

**IBPSA Project 1 : BIM/GIS and Modelica framework for building and community energy system design and operation ongoing developments, lessons learned and challenges**

Wetter, Michael; van Treeck, Christoph; Helsen, Lieve; Saelens, Dirk; Robinson, Darren; Maccarini, Alessandro; Schweiger, Gerald

# STATUS WORK

## Publications

- Paper Modelica Conference 2019 presented

**Integrated Modelica Model and Model Predictive Control of a Terraced House Using IDEAS**

Filip Jorissen, Lieve Helsen

# STATUS WORK

## Publications

- Journal paper: internal review phase

### **All you need to know about model predictive control for buildings**

Ján Drgoňa, Javier Arroyo, Iago Cupeiro Figueroa, Krzysztof Arendt, David Blum, Donghun Kim,  
Enric Perarnau Ollé, Juraj Oravec, Lieve Helsen

# STATUS WORK

## Publications

- Conference paper: in preparation

### **Scaling of different optimization tools**

Gerald Schweiger, Filip Jorissen, David Blum, Lieve Helsen

# STATUS WORK

## Other potential interesting initiatives

- 1<sup>st</sup> World Championship (June 2019) in Cybernetic Building Optimization (Japan)  
They built an emulator with a BACnet interface and a BMS front-end. Their goal is to measure the skills of building operators using a realistic emulator
- Mission Innovation Workshop Montréal
- IEA-EBC Annex ‘Smart Data-Driven Solutions for High Performance Buildings’
- IBO Boulder Workshop (August 2019)
- BS2021 organized by Flemish team (incl. Lieve & Dirk) – workshops!

## WP1.2: Plan for break out sessions

# THE PLAN FOR BREAK OUT SESSIONS – DAY 1

Content - title	Task 1.2	timing of session	room
<b>Topic 1.1 - EMULATORS</b> Example case: simple hydronic test case Emulator Development Updates Emulator Peer Review Guide and Checklist  Feedback from review process	BS 1-1  Damien Picard All  David Blum David Blum, Krzysztof Arendt, Valentin Gavan	day 1 - session 1  50 min	00.21
<b>Topic 1.2 - BOPTEST</b> Joint session with 1.1 and 1.2 about BOPTEST BOPTEST Prototype Development Updates and Documentation	BS 1-2  members WP1.1 can join  David Blum	day 1 - session 2  60 min	00.21/00.20

# THE PLAN FOR BREAK OUT SESSIONS – DAY 2

<b>Topic 2.1 - BOPTEST</b> Emulators fed into BOPTEST Large Office Building Testing Alfalfa / Boptest Integration Update, Presentation, and Demonstration	<b>BS 2-1</b>  Sen Huang, Draguna Vrabie  Kyle Benne	<b>day 2 - session 1</b>	70 min	00.21/00.20
<b>Topic 2.2 - USE CASES &amp; SCENARIOS</b> Demonstration of method for testing MPC robustness against erroneous forecasts Proposals/first list of use cases and scenarios (pricing scheme, yearly evaluation ...) Discussion on further steps	<b>BS 2-2</b>  Krzysztof Arendt  All All	<b>day 2 - session 2</b>	60 min	00.21
<b>Topic 2.3 - LIBRARY FOR MPC &amp; EXTENSION TO CLUSTERS</b> MPC description template - final version Modelica Library for MPC: overview of available models Modelica Library for MPC: approach and plan for action Optimal control for clusters of buildings: first thoughts	<b>BS 2-3</b>  Jan Drgona, Iago Cupeiro Filip Jorissen, David Blum All members WP3 can join	<b>day 2 - session 3</b>	70 min	00.21
<b>Topic 2.4 - ACTION PLAN</b> Prioritization of next steps, target timeline Action plan joint publications Dissemination of framework & results Keep open to discuss open issues	<b>BS 2-4</b>  Chair : Lieve Helsen	<b>day 2 - session 4</b>	60 min	00.21

# Acknowledgements

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