United Technologies Research Center

Model-Based Comparative Evaluation of Control-Oriented Retrofit Scenarios

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OptEEmAL OPTIMISED ENERGY EFFICIENT DESIGN PLATFORM FOR REFURBISHMENT AT DISTRICT LEVEL

June 29th, 2017

SUSTAINABLE PLACES 2017 June 28 – 30, 2017 MIDDLESBROUGH, UK

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AGENDA

- OptEEmAL Project Objective
- OptEEmAL Project Approach
- Active & Control ECMs Catalogue
- Retrofit Scenario Generation and Evaluation Process
- HVAC and Control ECMs Implementation
- Conclusions

OPTEEMAL OBJECTIVE

Develop and demonstrate a wed-based platform for retrofits at district level

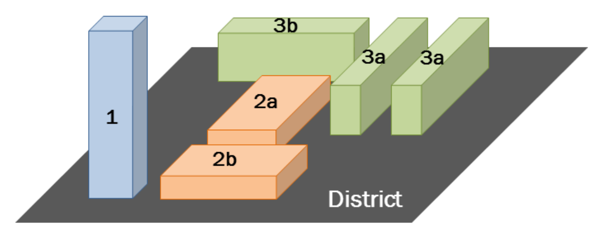
Web-based platform for district **energy-efficient retrofitting design** to:

- Support integrated design methodologies (IPD methods)
- Systemic delivery of optimised designs
- Reduce uncertainties and time of the design process
- Provide improved solutions compared to Business-as-usual

Through a **3-steps process**:

- Diagnosis (using input data) and formulation of scenarios
- Evaluation and optimisation
- Best scenario selection and data exportation to stakeholders

Consortium as a whole:
13 partners, 8 countries
Coordinator: Fundación CARTIF, Spain



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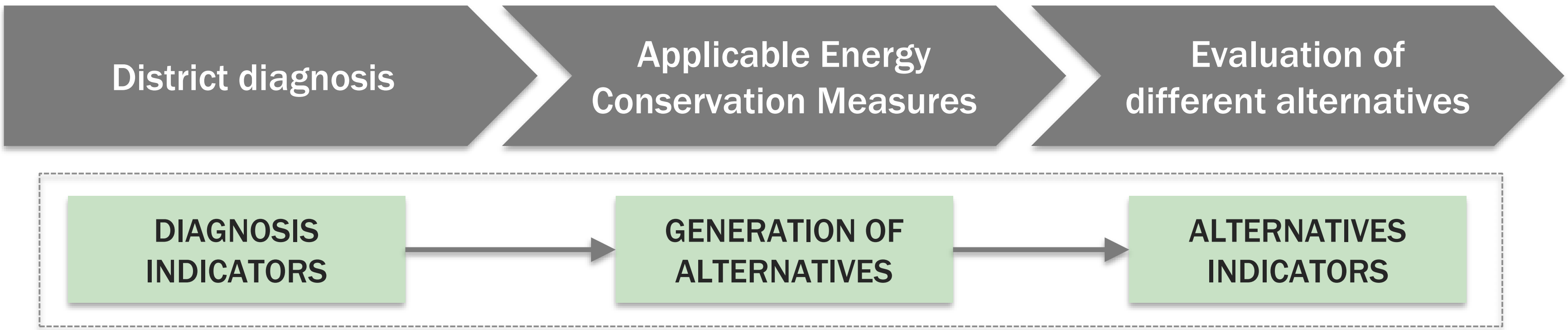
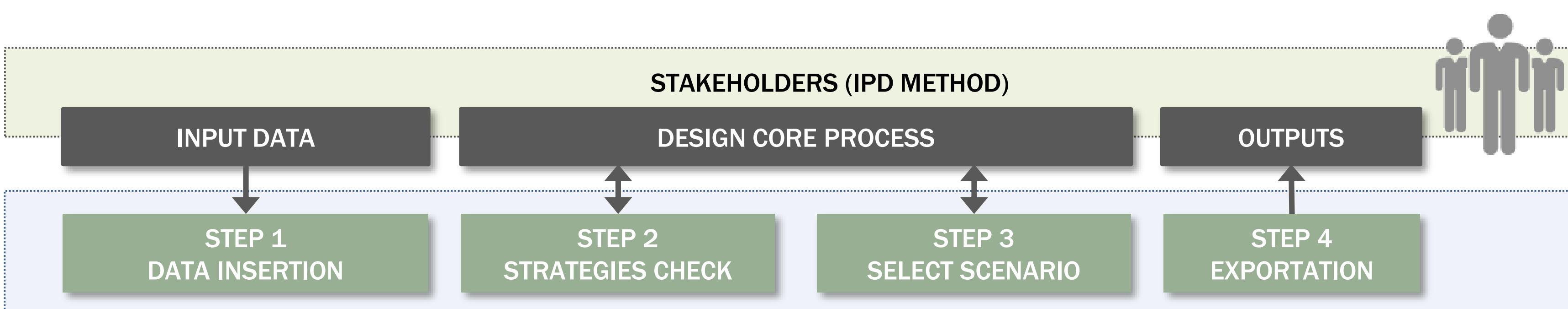
OPTEEMAL OBJECTIVE

OPTEEMAL design process based on IPD approach



- Catalogue of Energy Conservation Measures
- Selection of indicators to evaluate the current conditions and alternatives
- Selection of tools to calculate the indicators
- Ensure that data is interoperable among different sources for the needed tools



PROJECT APPROACH

OptEEmAL platform integrates 5 main pillars to deliver services

1 BIM approach

1. COLLABORATION among stakeholders

2. CONTINUOUS UPDATE (parameterisable elements)

3. CHANGE REDUCTION

4. COST REDUCTION

2 IPD approach

1. COMMUNICATION among stakeholders

2. KNOWLEDGE SHARE among stakeholders

3. OBJECTIVES SETTING (reach consensus)

3 ECMs catalogue

1. DISTRICT AND BUILDING LEVEL measures

2. PASSIVE, ACTIVE AND CONTROL measures to tackle all possible types of intervention

4 MCDA deployment

1. SIMULATION using external tools

2. EVALUATION BASED ON DPIs

ENE ECO ENV

COM SOC URB

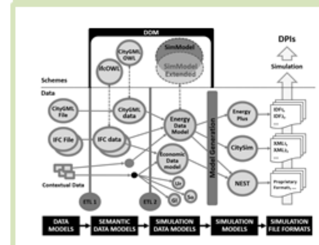
3. OPTIMISATION based on calculation results

1 2 3 4 5

5 Use of ontologies

1. COMMON DATA MODEL (DDM)

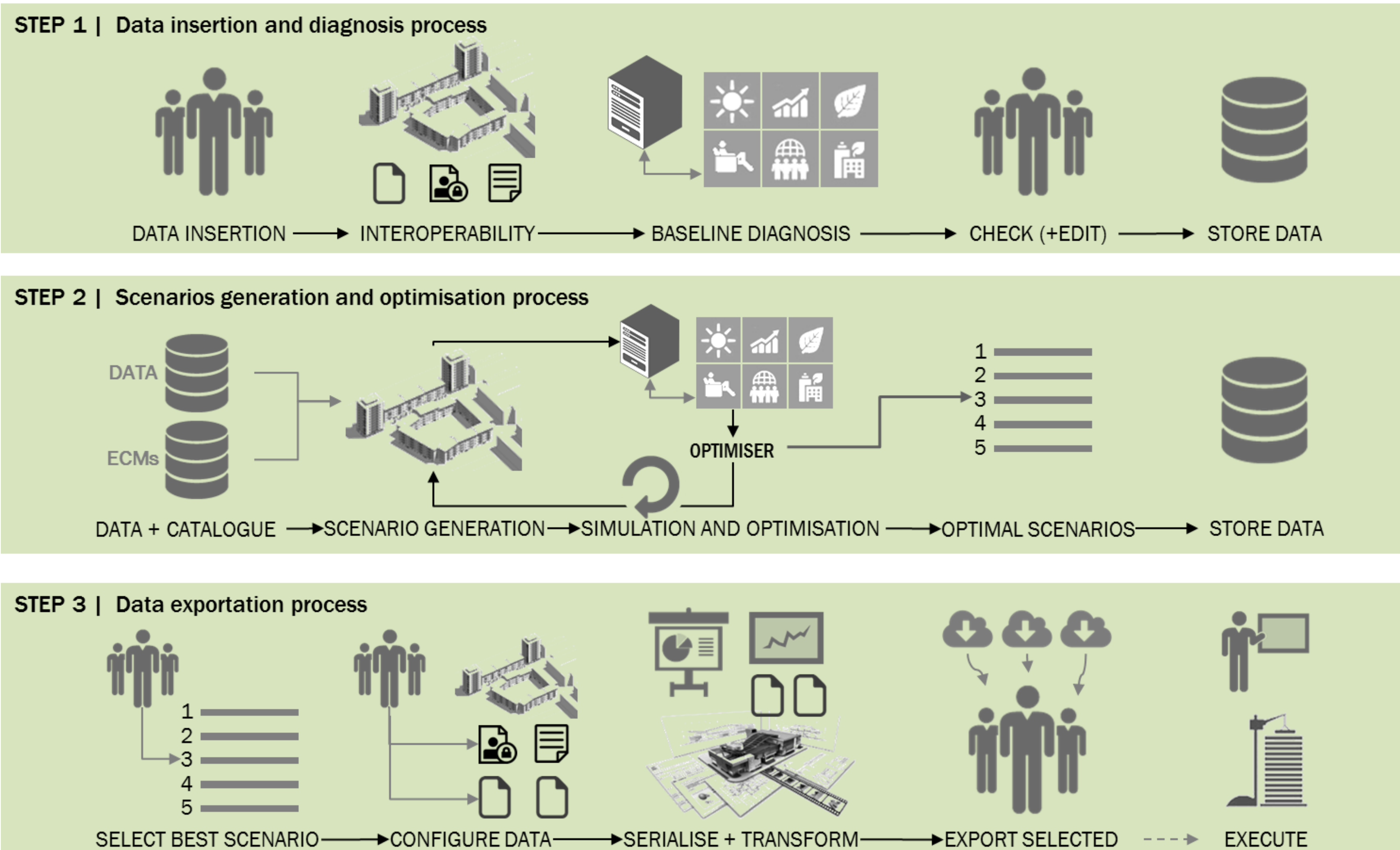
2. TRANSFORMATION OF INPUT DATA to comply with the established data model



3. TRANSFORMATION OF OUTPUT DATA to comply with users' requirements

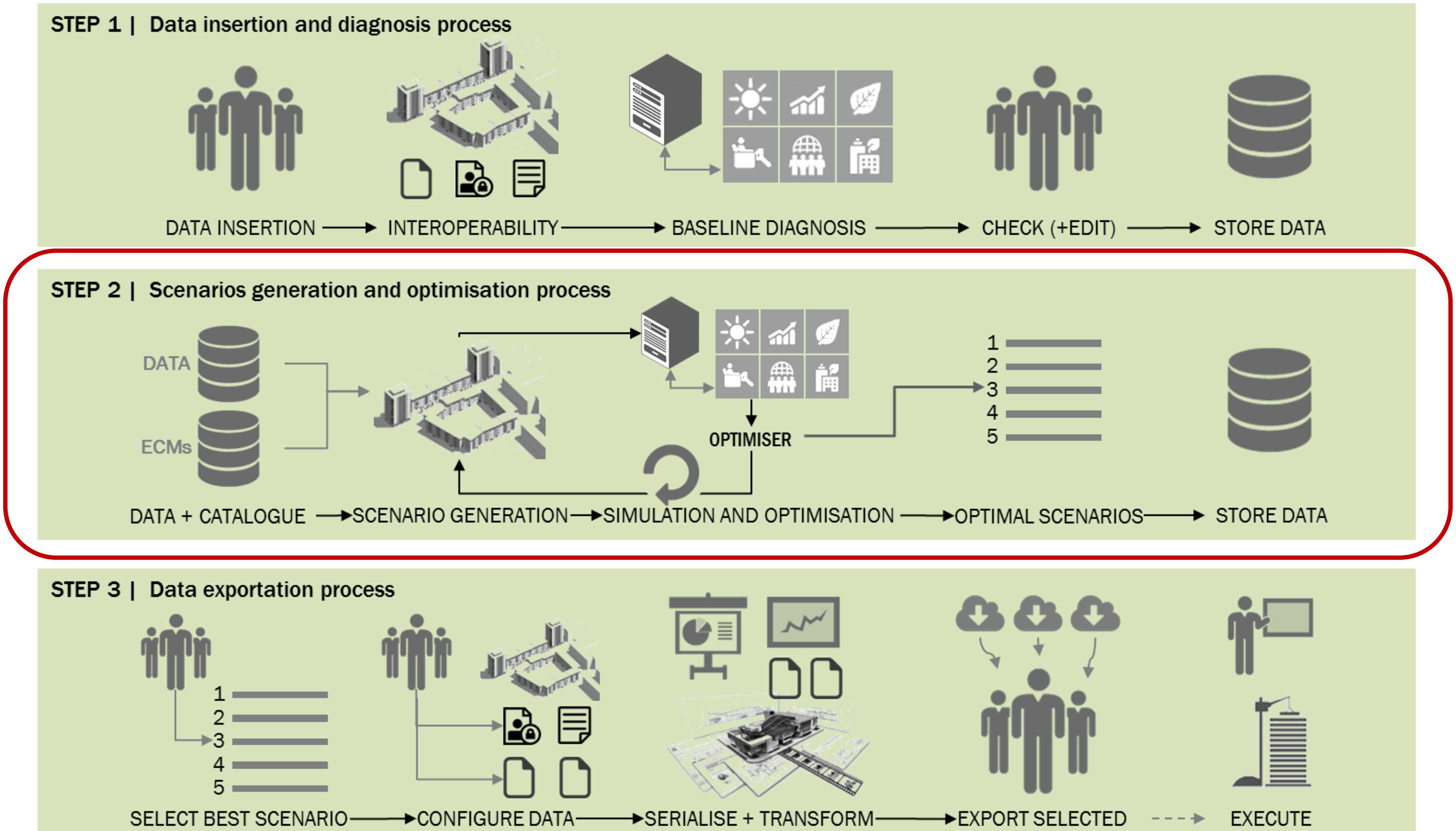
PROJECT APPROACH

Three main processes supported by the platform



PROJECT APPROACH

Three main processes supported by the platform

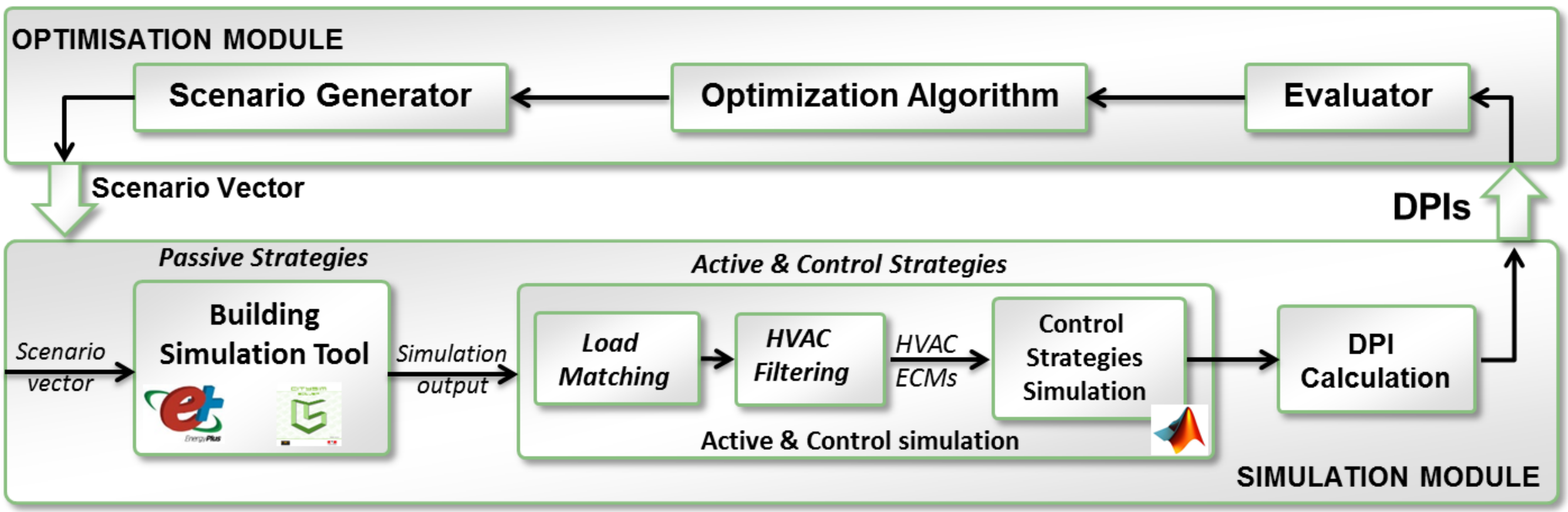


ACTIVE & CONTROL ECMs CATALOGUE

L1	L2	L3	L4	L5		Script
Active ECM	default	Boiler	Condensing diesel boiler	26	58	Replace
				35	73	
				44		
			Natural gas boiler	15	143	
				38	239	
				53	384	
			Condensing natural gas boiler	18	97	
				34	208	
				49	369	
			Biomass boiler	20	300	
				40	550	
				60		
		CombinedHeatPower Unit	Combined Heat Power with natural gas fuel type	50	400	Replace
				100	500	
				205		
		Chiller	Electric reciprocating chiller	38.4	85.8	Replace
				49.9	220	
				63.9	450	
		WaterToAirHeatPump	Default	42	92	Replace
				53	137	
				69		
Control	default	Thermostat	System Scheduling (Therm 1)	Heating	Cooling	Install
			Optimal StartUp and ShutDown (Therm 2)	Heating	Cooling	
		Plant Control	Weather Compensation	Heating	Heating / cooling	
			Sequencing	Heating	Cooling	
			Load Following	Heating CT1	Heating CT3	
				Heating CT2	Heating CT4	

SCENARIO GENERATION AND EVALUATION

HVAC and controls simulation decoupled from the passive ECM simulation



Process for generation of applicable configurations

Generate scenario binary strings from **(0 0 0 … 0)** to **(1 1 1 … 1)**

↓

Multiply the scenario binary row arrays by the column array of sizes

↓

Filter out the results which guarantee total supply greater than size

List of applicable configurations

Max Load = 200 kW	0	0	0	0	0	69.6	90	90
	0	0	0	0	69.6	0	90	90
	0	0	0	0	69.6	69.6	0	90
	0	0	0	0	69.6	69.6	90	0
	0	0	0	45	0	0	90	90
	0	0	0	45	0	69.6	0	90
	0	0	0	45	0	69.6	90	0
	0	0	0	45	69.6	0	0	90
	0	0	0	45	69.6	0	90	0
	0	0	45	0	0	0	90	90
	0	0	45	0	0	69.6	0	90
	0	0	45	0	0	69.6	90	0
	0	0	45	0	69.6	0	0	90
	0	0	45	0	69.6	0	90	0
	0	34.8	0	0	0	0	90	90
	34.8	0	0	0	0	0	90	90
300 kW	0	0	0	0	69.6	69.6	90	90

Example of Catalogue

Boiler	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4
Size	34.8	34.8	45	45	69.6	69.6	90	90

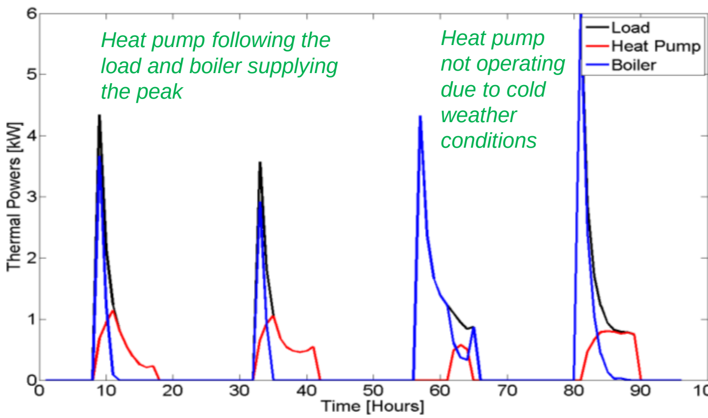
HVAC & CONTROL ECMs IMPLEMENTATION

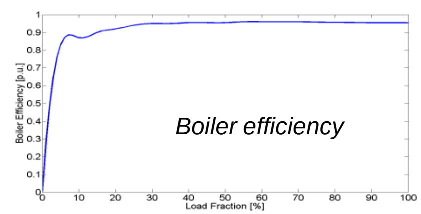
Heating: Load following control applied to boiler and heat pump – Case 195

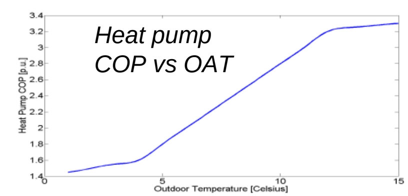
Single building supplied by a boiler and heat pump

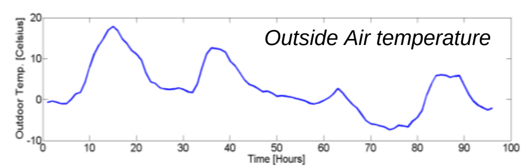
- Thermal load profile taken from EnergyPlus simulation
- Control ECM decides the thermal power delivered by heat pump and boiler
- Boiler of 6 kW and heat pump of 4 kW with variable efficiency

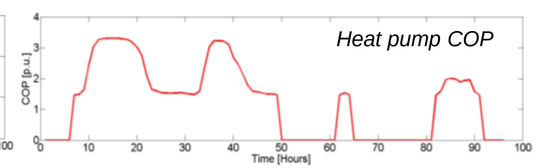
Simulation Results over a period of four days











Energy and Economic DPI Calculation

Energy DPI: ENE02 Final energy consumption

$$\sum_t \left[\frac{P_{bo}(t)}{\eta_{bo}} \Delta t + \frac{P_{hp}(t)}{COP} \Delta t \right] = 50\ kWh$$

Economic DPI: ECO01 Operational energy cost

$$\sum_t \left[C_{gas} \frac{P_{bo}(t)}{\eta_{bo}} \Delta t + C_{grid}(t) \frac{P_{hp}(t)}{COP} \Delta t \right] = 2.52\ €$$

DPI calculation based on C_{gas} = 0.05 €/kWh and C_{grid} = 0.08 €/kWh

HVAC & CONTROL ECMs IMPLEMENTATION

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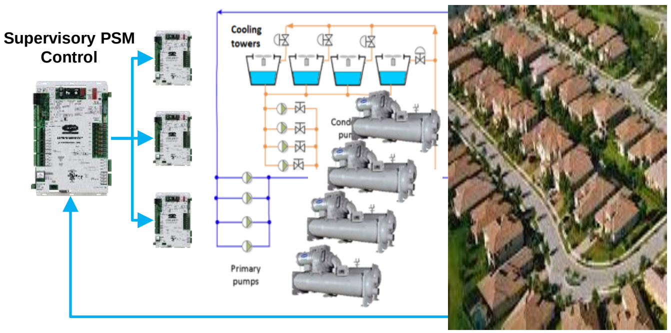
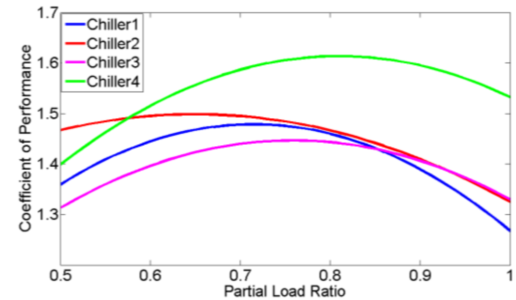
Cooling: Optimized Sequencing Control applied to chiller plant



District supplied by chiller plant

- Chillers 1&2 : 450 kW max, 225 kW min
- Chiller 3&4 : 1000 kW max, 500 kW min
- Thermal load profile taken as input
- Control ECM decides chiller sequencing and power set-points for each chiller

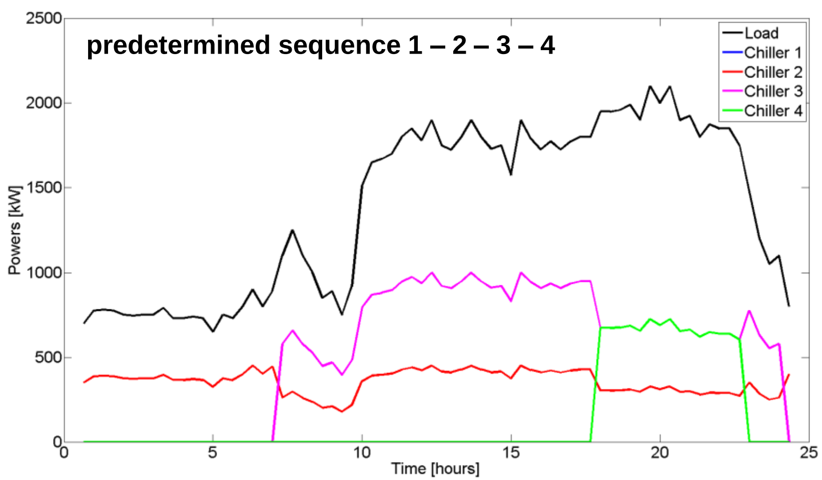


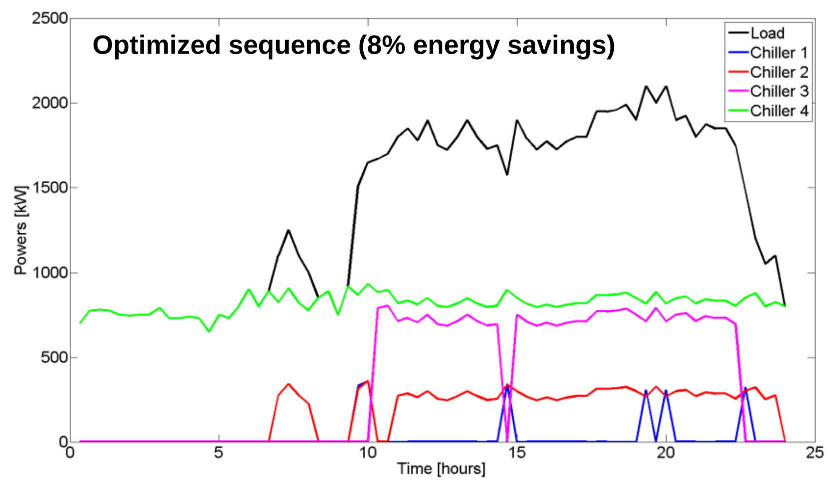
Baseline state – before retrofit

- Pre-determinate ON/OFF chiller sequence
- Total load shared proportionally to each Chiller size.
- COPs not used to determine Chillers set-points

Optimized sequence – post retrofit

- Combinatorial optimization to determine possible combinations of Chillers which meet the load
- Nonlinear optimization to optimize each possible scenario accounting for chiller COPs





CONCLUSIONS

- ✓ OptEEmAL is developing an innovative wed-based platform for retrofits at district level
- ✓ OptEEmAL platform integrates BIM, IPD, ECMs catalogue, MCDA and DDM to deliver optimal retrofit design
- ✓ In addition to the classical passive and active ECMs, OptEEmAL introduced control ECMs and integrated a process to determine their impact
- ✓ Two control ECMs have been implemented showing significant improvements in system operation
- ✓ The proposed simulation framework will enable system designers to easily generate, evaluate and compare multiple refurbishment configurations – including existing and future controls
- ✓ The model based approach and ECMs catalogue can be integrated and fully automated to generate and analyze retrofit scenarios using relevant district performance indicators