WP5: Self-Correcting Intelligent Building Energy Management System (SCI-BEMS)

Dimosthenis Tsagkrasoulis (WVT)

Heat4COOL project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 723925

Work Package Objectives

- Design the control system architecture
- Design and develop user profiling models for comfort and health preservation
- Design, configure and develop the SCI-BEMS
- Test and validate the SCI-BEMS

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Work Package Tasks and Deliverables

- T5.1: User requirements, specifications and architecture design of the SCI-BEMS - *M4-M7 Completed*
  - D5.1 M7 Report - Submitted

- T5.2: SCI-BEMS communication architecture & middleware design - *M8-M18 Completed*
  - D5.2 M18 Demonstrator - Submitted

- T5.3: Definition of optimal human-centric control strategies & SCI-BEMS development - *M8-M18 (M20) Completed*
  - *D5.3 M18 (M20) Report - Submitted*

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Work Package Tasks and Deliverables

- T5.4 System integration and Testing of the SCI-BEMS - *M11-M36 (M54) Completed*
  - D5.4 M20 (M25) Demonstrator - Submitted
  - D5.5 M29 (M35) Demonstrator - Submitted
  - D5.6 M36 (M54) Demonstrator - Submitted

- Milestone MS6: First Prototype of the SCI-BEMS M20 (M25)

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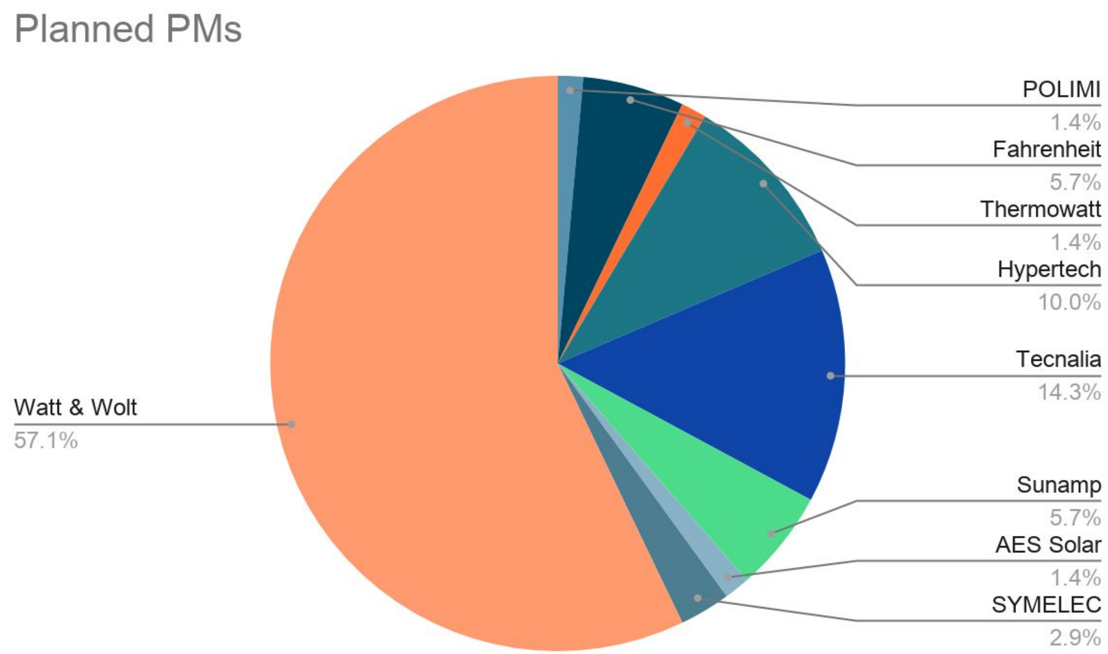
Planned use of PMs

WP5	
POLIMI	1
Fahrenheit	4
Thermowatt	1
Hypertech	7
Tecnalia	10
Sunamp	4
AES Solar	1
SYMELEC	2
Watt & Wolt	40
Total	**70**



Associated Key Exploitable Result (KER):

Self Correcting Intelligent - Building Energy Management System (SCI-BEMS)

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Work Package Results

- Task 5.1 User requirements, specifications and architecture design of the SCI-BEMS (M4-M7)

  - Lead Partner: HYP, Participants: FAR, THW, TEC, SUN, SYM

  - Objectives:
    - Definition of user requirements for the SCI-BEMS
    - Definition of functionalities for the sub-systems
    - Extraction of functional and non-functional specifications
    - Definition of the end-to-end system architecture

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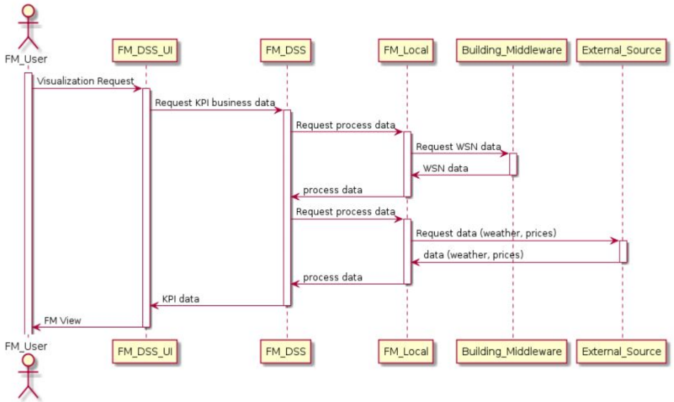
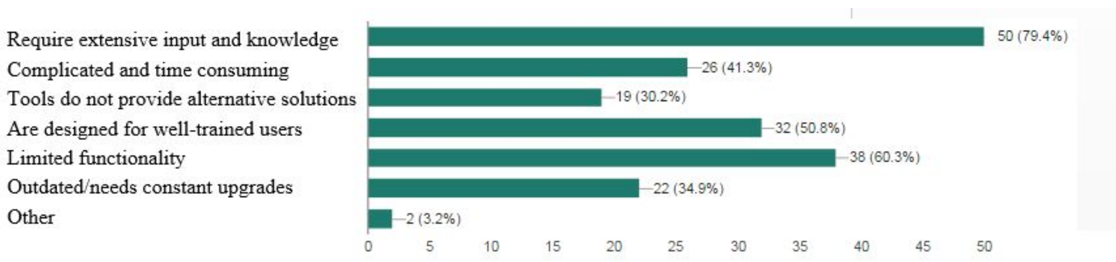
Work Package Results

❖ Task 5.1 User requirements, specifications and architecture design of the SCI-BEMS (M4-M7)

- ➢ Definition of business scenarios and identification of stakeholders
- ➢ Circulation of questionnaires for gathering user requirements
- ➢ Extraction of functional and non-functional requirements
- ➢ System architecture for SCI-BEMS and its components
- ➢ Definition of SCI-BEMS data model





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Work Package Results

- Task 5.2 SCI-BEMS communication architecture & middleware design (M8-M18)

  - Lead Partner: TEC, Participants: FAR, HYP, SUN, AES

  - Objectives:
    - Evaluate and select the communication architecture for wireless sensor networks and buses, protocols and systems for building automation
    - Design the middleware layer that integrates wireless communications, bus communications and building automation systems enabling a real-time response by the SCI-BEMS

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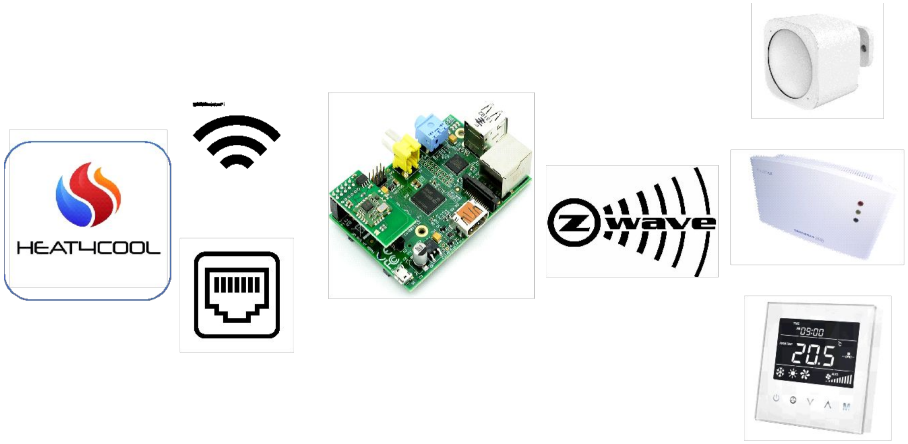
Work Package Results

❖ Task 5.2 SCI-BEMS communication architecture & middleware design (M8-M18)

- ➢ Evaluation and selection of hardware components
- ➢ Implementation of communication software based on Openhab and ZWave protocols



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Work Package Results

- Task 5.3 Definition of optimal human-centric control strategies & SCI-BEMS development (M8-M23)

  - Lead Partner: HYP, Participants: POL, FAR, TEC, SUN

  - Objectives:
    - Design the behavioural profiling framework to enable the preservation of comfort and health aspects
    - Exploration and definition of control strategies that balance user comfort, energy efficiency and services to the grid
    - Establishment of optimal control for Heat4Cool devices given detailed models of the utilized devices

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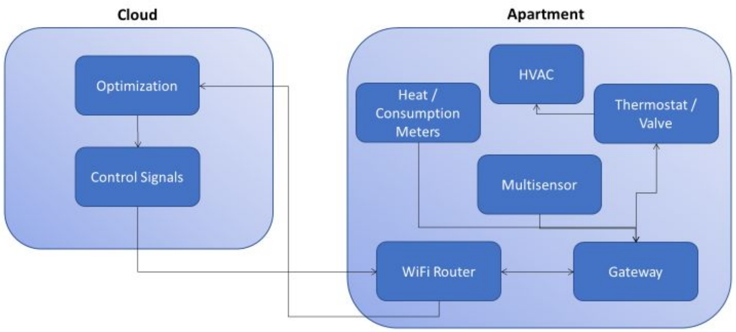
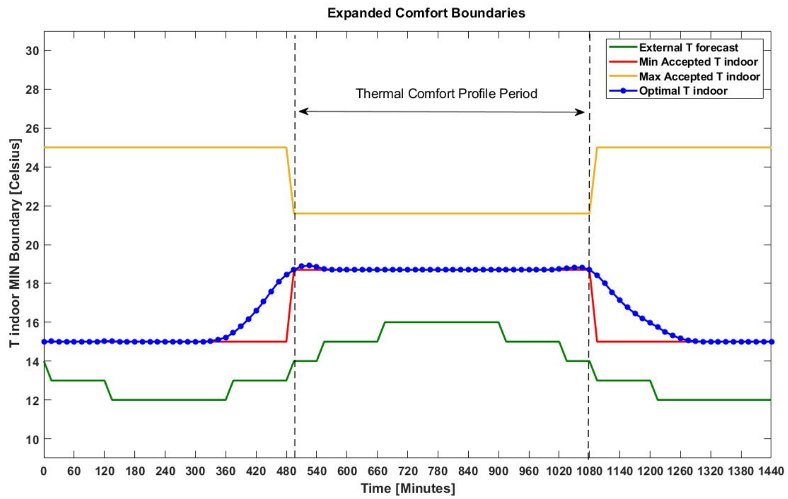
Work Package Results

❖ Task 5.3 Definition of optimal human-centric control strategies & SCI-BEMS development (M8-M23)

- ➢ Definition of comfort and energy optimization profiling framework. Development of relevant subcomponents
- ➢ Exploration of control strategies for Heat4Cool devices
- ➢ Automated identification, refinement and forecasting of personal comfort preferences.





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Work Package Results

- Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)

  - Lead Partner: HYP, Participants: FAR, TEC, SUN, SYM

  - Objectives:
    - Overall integration of software components and subsystems
    - Interfacing with the energy sub-systems
    - Validation of the system at the KUBIK building
    - Deployment deployment strategies and plans for the pilot buildings

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Work Package Results

- Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)

  - Work Done prior to M37:
    - System Integration and communication with the middleware
    - Deployment and user manuals in conjunction with WP6
    - Evaluation of first SCI-BEMS prototype at Hypertech's premises

Equipment Description	*Unit Price*
Raspberry Pi 3 Model B+	33.04 €
Raspberry 9098138 -Case Raspberry Official PI 3	5.77 €
Official 5V 2.5A Power Adapter for the Raspberry Pi 3	9.93 €
Z-WAVE.ME RaZberry2 Transceiver	48.71 €
microSDHC Memory Card	9.83 €
Z-Wave Plus Aeotec Clamp Power Meter - Three Clamps (60A)	97.84 €
Aeon Labs MultiSensor 6 - Z-Wave Plus (Temperature - Humidity - Light Sensor - Presence)	40.50 €
IntesisBox WMP	180.00 €

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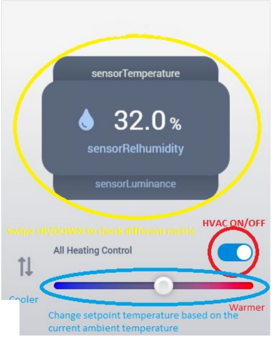
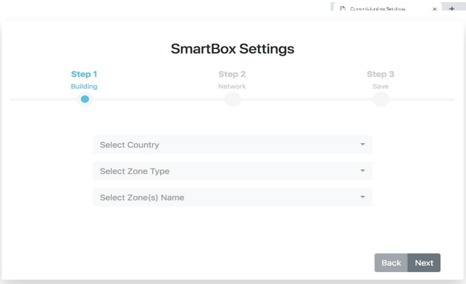
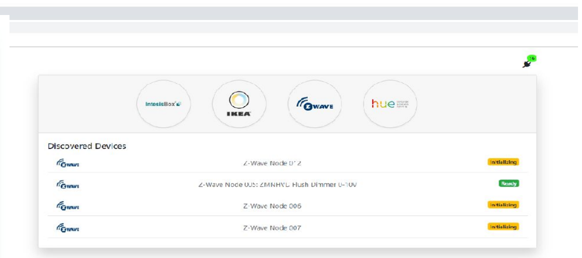
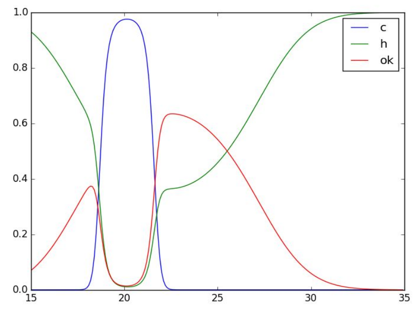
Work Package Results

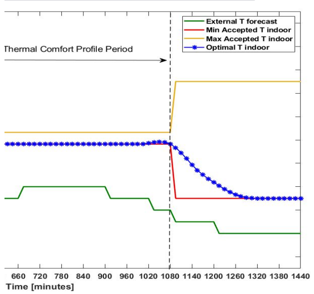
- Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)
  - Work Done prior to M37:
    - UI development for commissioning and for the end user with remote monitoring and control capabilities
    - Web Services available through REST APIs
      - Comfort Profile
      - Thermal Model Parameter Estimation
      - Thermal Optimization
      - Data Retrieval











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Work Package Results

❖ Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)

➢ Work Done prior to M37:

■ Evaluation of second SCI-BEMS prototype at Kubik

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Work Package Results

- Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)

  - Work Done during M37-M54:
    - Commissioning, operation and evaluation in Valencia pilot.
    - Control Strategy:
      - Heating and cooling setpoints were identified in a weekly basis and were sent remotely to the fan coil thermostats. The occupants reserved full control of the status of the fan coil, and could override the setpoint selections manually.

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Work Package Results

- Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)

  - Work Done during M37-M54:
    - Evaluation results from Valencia between January and March 2021.
    - The automation service was activated between 19-31 of January and 01-31 of March.
    - The baseline period was the month of February
    - Average Daily Heat Production with SCI-BEMS:
      - inactive: 278838.71 Wh
      - active: 232857.143 Wh

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Work Package Results

- Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)

  - Work Done during M37-M54:
    - Relative reduction in heat produced by the heat pumps: 16,49%
    - Two-sided t-test with the null hypothesis that the expected (average) daily heat production is the same with or without SCI-BEMS was performed:
      - p-value before controlling for the effect of external temperature: 0.0346
      - p-value after controlling for the effect of external temperature: 0.00017

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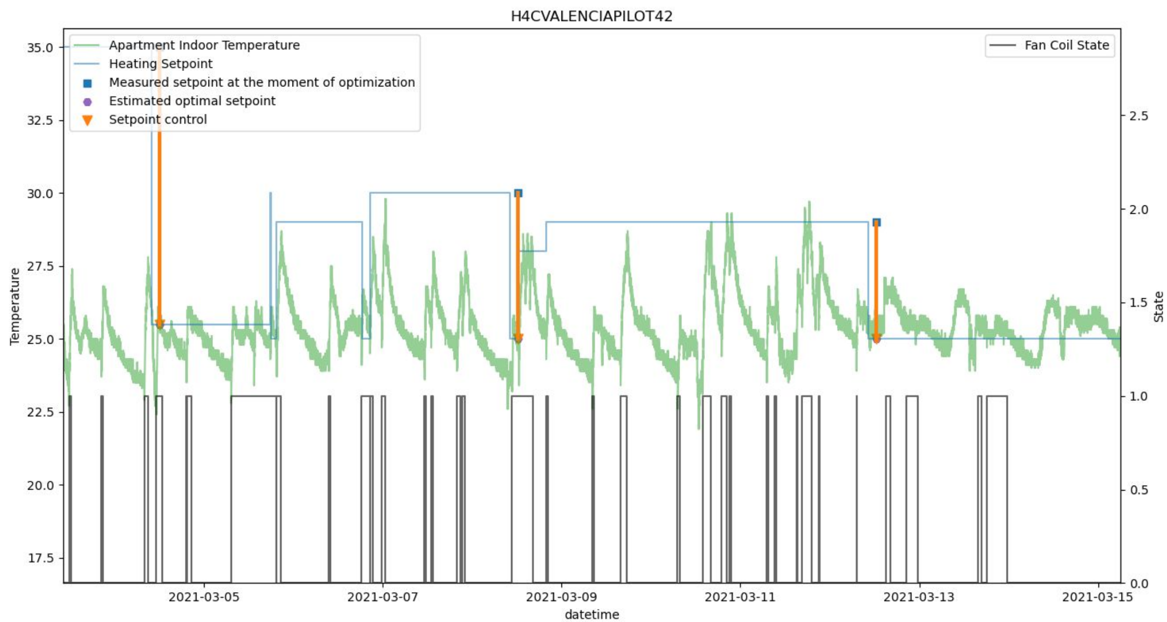
Work Package Results

❖ Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)

➢ Work Done during M37-M54:

■ SCI-BEMS automation service - Apartment 4-2, March 2021



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Work Package Results

- Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)

  - Work Done during M37-M54:
    - Commissioning, operation and evaluation in Chorzow pilot.
    - Control Strategy:
      - Thermal model identification followed by numerical optimization to establish the ideal setpoint for the Fibaro thermostatic heads.

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Work Package Results

- Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)

  - Work Done during M37-M54:
    - Evaluation results from zone: living room of apartment 10A
      - Baseline period: 16-23/10/2020
      - Remote setpoint control between 24-30/10/2020.
      - Thermal model and ideal setpoint identified during baseline period.
    - Thermostatic valve setpoints set by the users could not be attained by the system
    - During baseline, temperature raises and dips significantly and multiple times, which suggests inefficient use of the system

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Work Package Results

❖ Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)

➢ Work Done during M37-M54:

- Setpoints for the two valves in the zone were set to 20 and 18 degrees Celsius by the SCI-BEMS for the last week of October.
- The indoor temperature evolution becomes significantly smoother during that period.
- Heat consumption during the baseline period was 140.555 kWh
- Heat consumption during the control period was 17.222 kWh, a relative reduction of approximately 87.7%.

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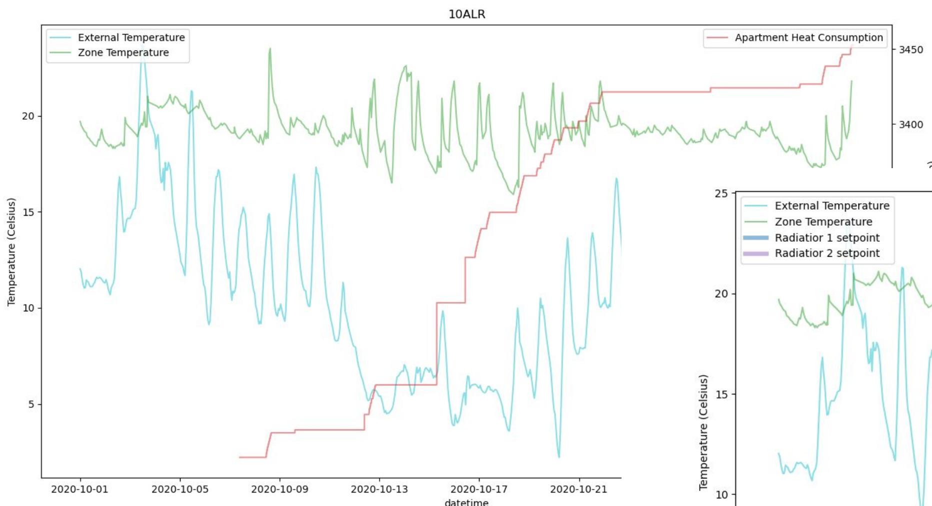
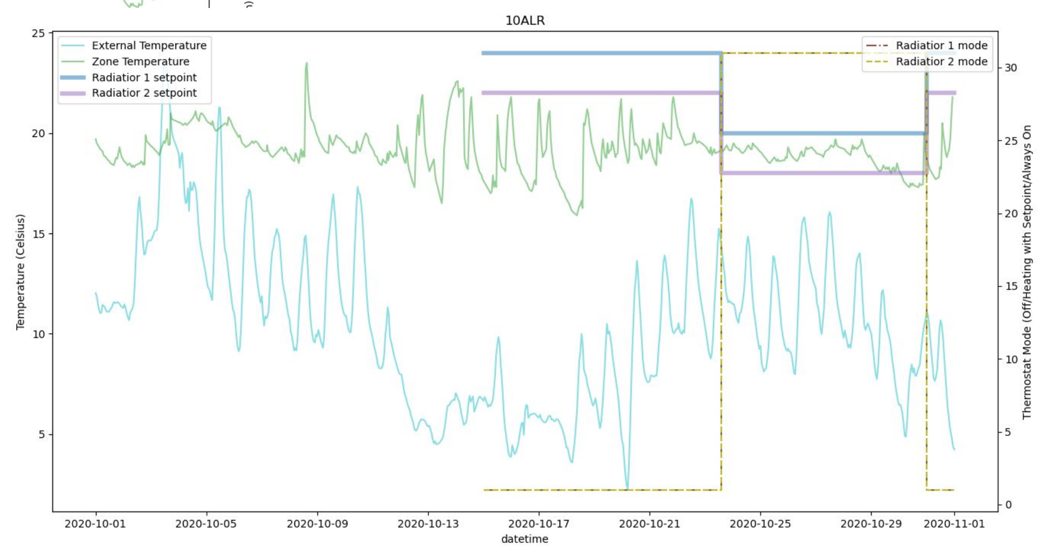
Work Package Results

- Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)

  - Work Done during M37-M54:





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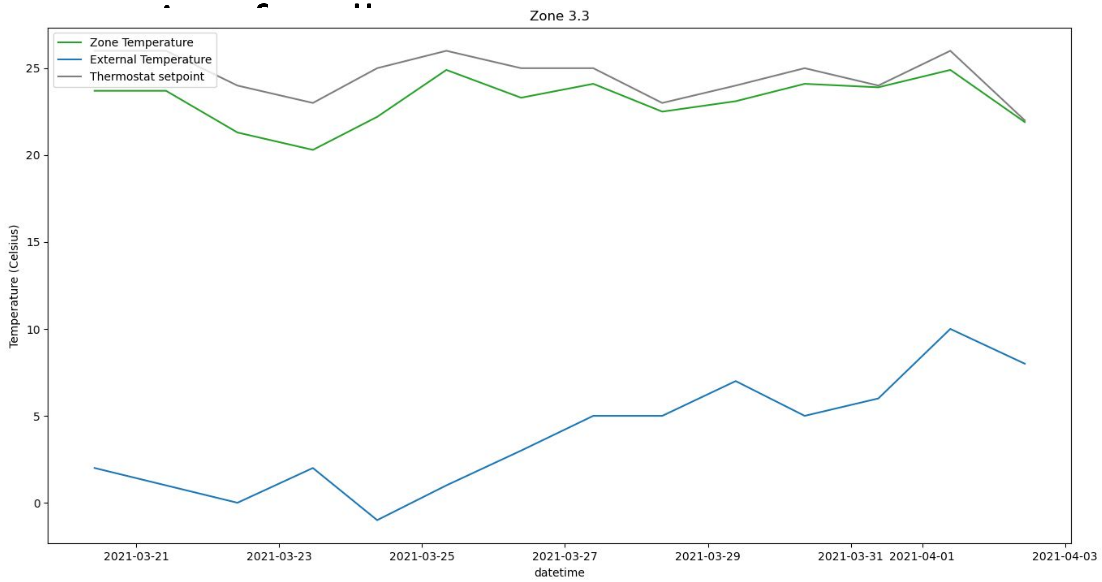
Work Package Results

❖ Task 5.4 System integration and Testing of the SCI-BEMS (M11-M54)

➢ Work Done during M37-M54:

- Partial commissioning in Sofia - Monitoring of indoor/outdoor temperatures and thermostat heating



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Issues During Demonstration and Lessons Learnt

- In Valencia
  - one gateway was installed per floor, serving three apartments.
    - Initially there were doubts about the communication. Tests performed verified that the infrastructure was stable and suitable.
  - multisensors could not be installed in the apartments.
    - Due to lack of occupancy information, it was decided that the automated setpoint control will be performed in a weekly basis.

- In Sofia the main issue was the lack of any demonstration time.

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Issues During Demonstration and Lessons Learnt

- In Chorzow:
  - Operational time of multisensors and thermostatic valves on a single charge was significantly shorter.
    - To partially address the issue, devices were parameterized to send data less frequently. It will now be advised to opt for plugged installations.
  - One thermostatic valve in each apartment was set to Always On position, to avoid a boiler failure mode due to different boiler/valve setpoint control.
  - Certain thermostatic valves are showcasing abnormal behaviour (limited manual control or limited data communication) without clear causes. Both cases are still being explored.

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Business Opportunities

- The SCI-BEMS, as a Key Exploitable Result concentrates on the needs of:
  - Energy service companies (ESCO) or aggregators
  - Facility Managers or dwelling occupants/end users

- The goal of the KER is to provide:
  - A lightweight and cost-effective system
  - An energy efficiency module that enables optimal handling of HVAC operation
  - A cost efficiency framework, which incorporates retail pricing information
  - A comfort preserving framework, which integrates building occupants comfort/discomfort boundaries

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Business Opportunities

❖ To achieve this goal, the SCI-BEMS was designed and developed according to the following principles:

- ➢ Use as basis open API communication standards and automation software
- ➢ Allow for flexible realization and customization of the system functionalities according to the infrastructure available
- ➢ Utilize off-the-self monitoring and control devices that are affordable and widely available
- ➢ Employ custom developed cloud services for data analysis and remote energy management.

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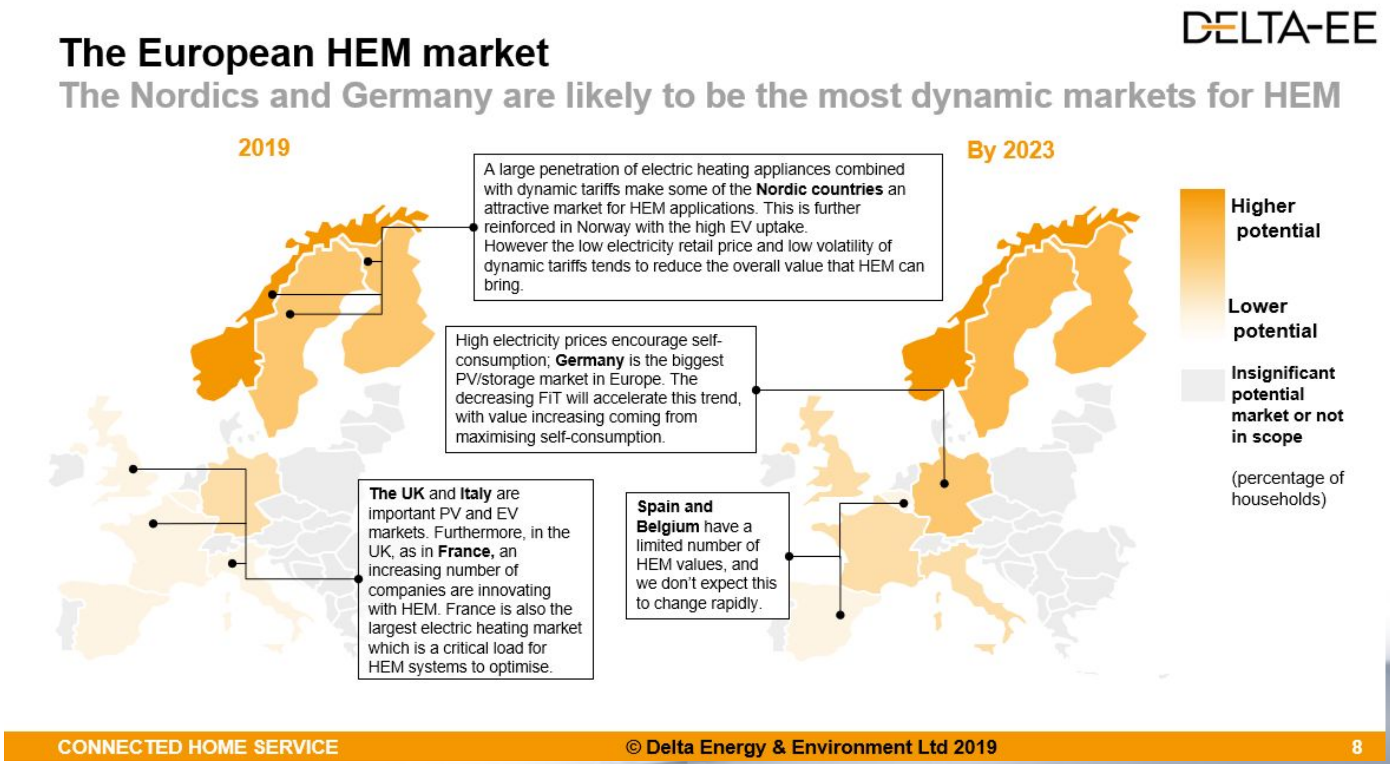
Business Opportunities

- By 2023, the Home Energy Management market is expected to reach 2.3 million units installed.
- The highest potential for growth has been located in the Nordic countries and in Germany, followed closely by France, UK and Italy.



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Potential Barriers

- Investment, installation, operational and maintenance expenses
  - The cost of investment must be justified by the appropriate revenue streams for all stakeholders.
- Lack of interoperable smart appliances on the market
  - Complexity can become high if communication and control is not standardized between subsystems involved.
- Increased threat to the privacy of the consumers
  - Any data connecting back to the users must be handled with strict care during the lifecycle of the analysis.
- Lack of understanding and/or interest of smart home technical aspects by end users
  - A product can only be successful if it captures the interest of the end users.

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Technical and economic viability

- SCI-BEMS reaches TRL 6 upon completion of the Heat4Cool project.

- 5-year financial plan:
  - The first 2 to 3 years are required for further research and development to create a market-ready product (TRL 9)
  - 3 years of commercial exploitation following that period.

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Technical and economic viability

- The revenue channel consists of annual license fees paid either directly by the consumer or indirectly by the ESCo/Aggregator The cost per individual dwelling will be 50 Euro. Furthermore an installation fee of 100 Euros will be charged.

- The target number of customers for the first year upon market entry is set to 500. In subsequent years, a 30% increase in this number is anticipated annually. With these assumptions at hand, the break even point is reached at the end of the fifth year.

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Technical and economic viability

	Year				
	2021	2022	2023	2024	2025
Cost (€)	121.000	100.000	44.500	44.500	44.500
Revenue (€)	0	0	75.000	122.500	184.250
Yearly Balance (€)	-121.000	-221.000	-190.500	-112.500	27.250

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Thank you

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