Model-based Controls and Systems Engineering for Building and Aircraft Systems

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OUTLINE

- UTC, UTRC, and UTRC Ireland
- UTRC Ireland Building Energy Research & selected projects
  - COOPERATE (EU co-funded FP7)
  - ELSA (EU co-funded H2020)
  - Energy in Time (EU co-funded FP7)
- UTRC Ireland Aerospace Research & selected project
  - MISSION (EU co-funded CS2)

United Technologies

Business units

Otis

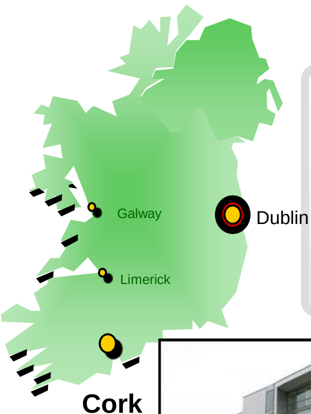
Pratt & Whitney

UTC Climate, Controls & Security

UTC Aerospace Systems

UTRC IRELAND

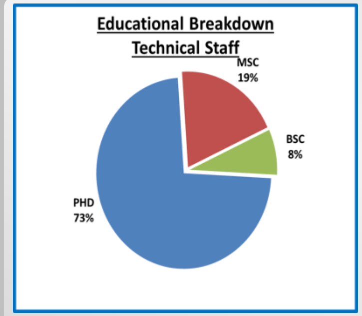
Est. 2010 in Cork

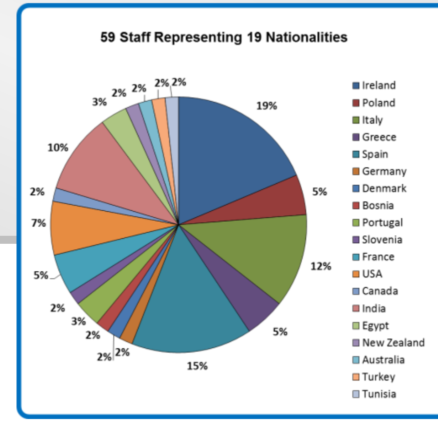


Objectives…

- Hub for European interactions
- Leverage existing investments in ICT
- Testbed for energy and security technologies
- Support aerospace BUs

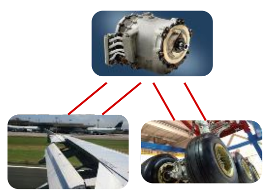
Highly skilled and diverse workforce



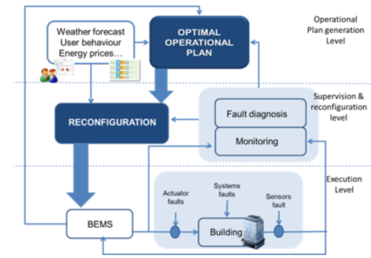


Technical capabilities and Groups

Power Electronics & System Modeling



Controls & Decision Support



Networks & Embedded Systems

Leveraging national and EU network of innovation

Insight – Centre for Data Analytics

SFI – Research Centres

Lero – Software Engineering Research Centre

Connect – Communication Networks Research Centre

IDA Ireland

Seventh Framework Programme

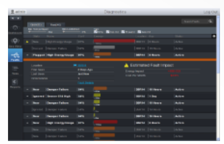
Horizon 2020

Clean Sky 2

UTRC IRELAND TECHNICAL CAPABILITIES

Controls & Decision support

- Thermal system modeling
- Model-based control design
- Model-predictive control
- Optimization-based control
- Fault detection and impact analysis
- Data analytics for alarm management
- Data- and physics-based diagnostics
- Video analytics

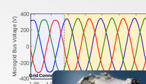


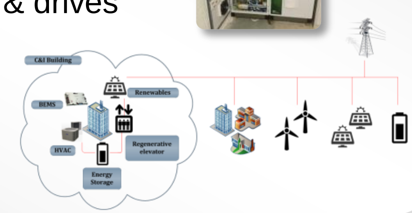
Networks & Embedded Systems

- Sensor networks
- Communications protocols
- Model-based design
- Formal methods
- Embedded systems
- Software engineering
- Constraint programming

Power Electronics

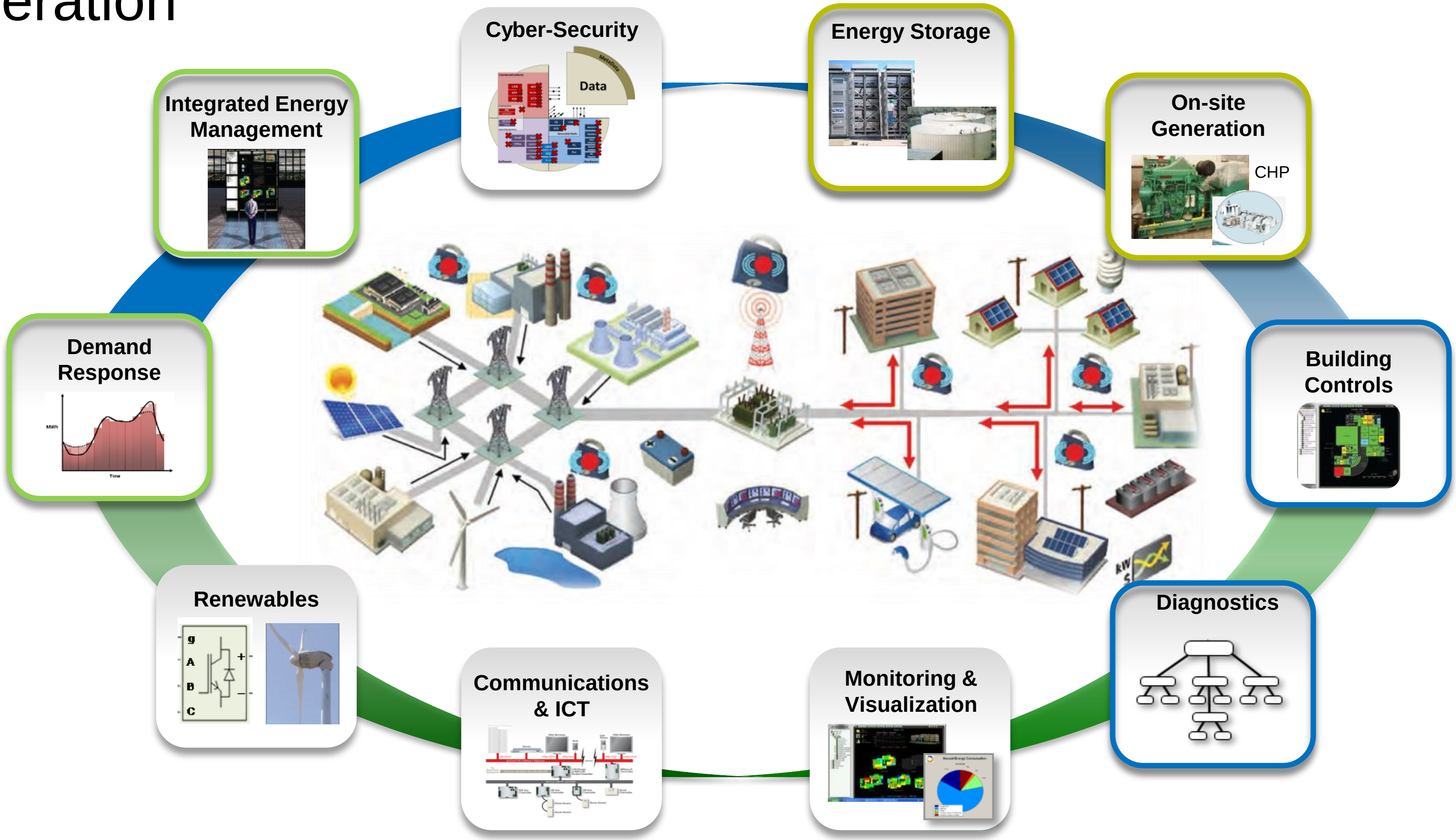
- Hierarchical system modeling and controls
- Model-based power converter design
- Electric motor optimization
- Digital control of converters & drives
- Power quality analysis
- Grid estimation & emulation
- HiL / rapid prototyping





UTRC IRELAND ENERGY RESEARCH

Innovative solutions for system integration, monitoring and operation



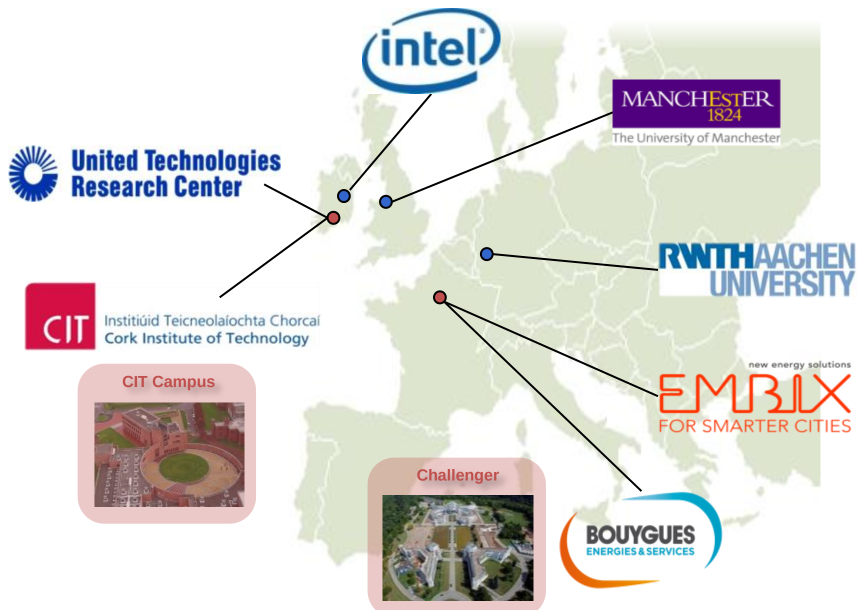
Developing key technology enablers for the **new generation** of **energy services and products**

FP7 COOPERATE

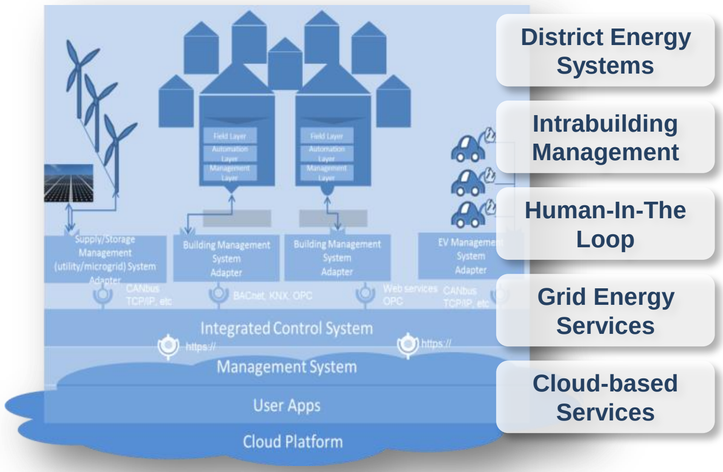
Control and optimization of energy positive neighbourhoods

Project Objectives

- Develop an open, scalable neighborhood energy management platform
- Services-oriented architecture for developing neighborhood energy services
- District-level energy optimization and decision support algorithms



COOPERATE neighbourhood services and management platform



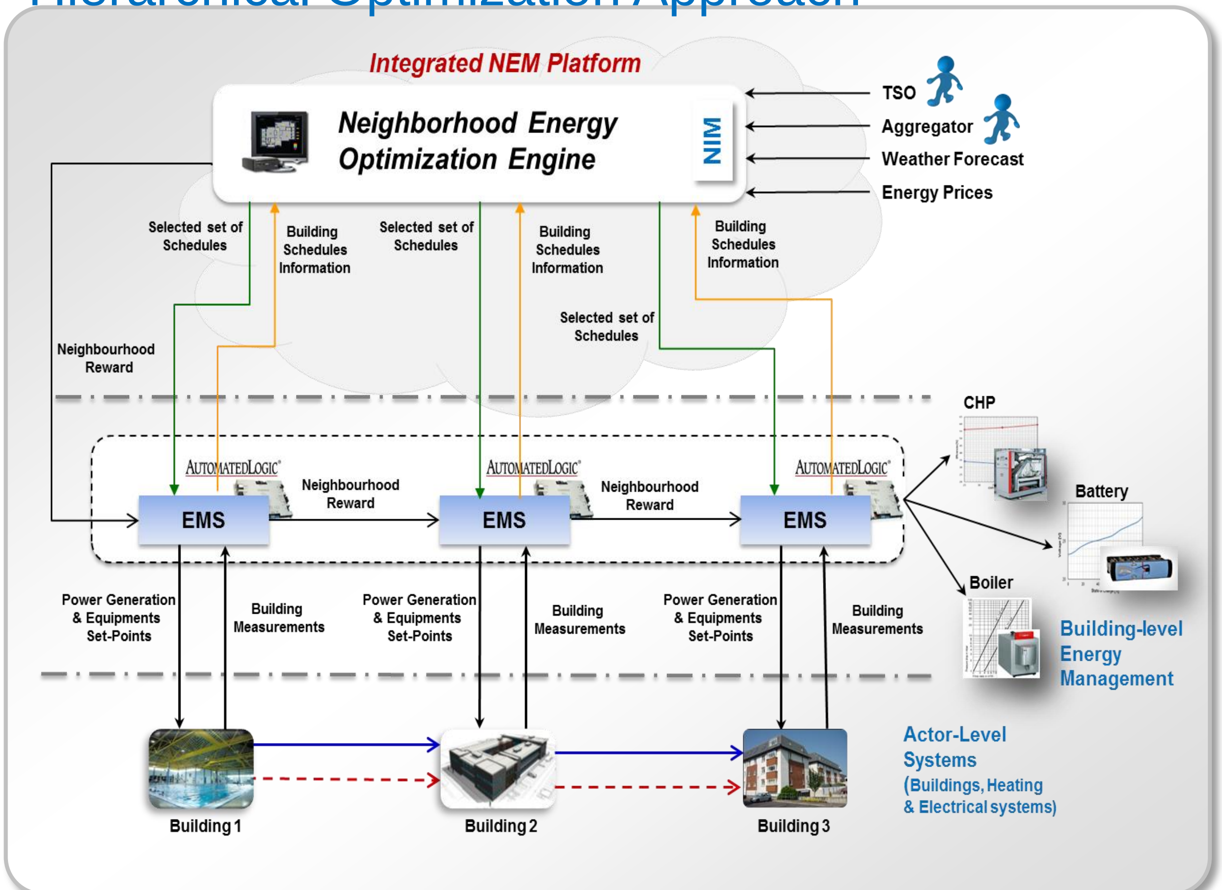
Key challenges:

- Distributed heterogeneous multi-energy systems and loads
- Integration of heterogeneous thermal and electrical systems
- Integration of loads, embedded generation and storage
- *Requires a System-Of-Systems (SoS) approach*

FP7 COOPERATE

Hierarchical approach to neighbourhood energy optimization developed

Hierarchical Optimization Approach



Objective:

- ✓ Reduce neighbourhood cost/emissions
- ✓ Multi-site supply, demand and storage optimization
- ✓ Coordinate generation and demand from different buildings

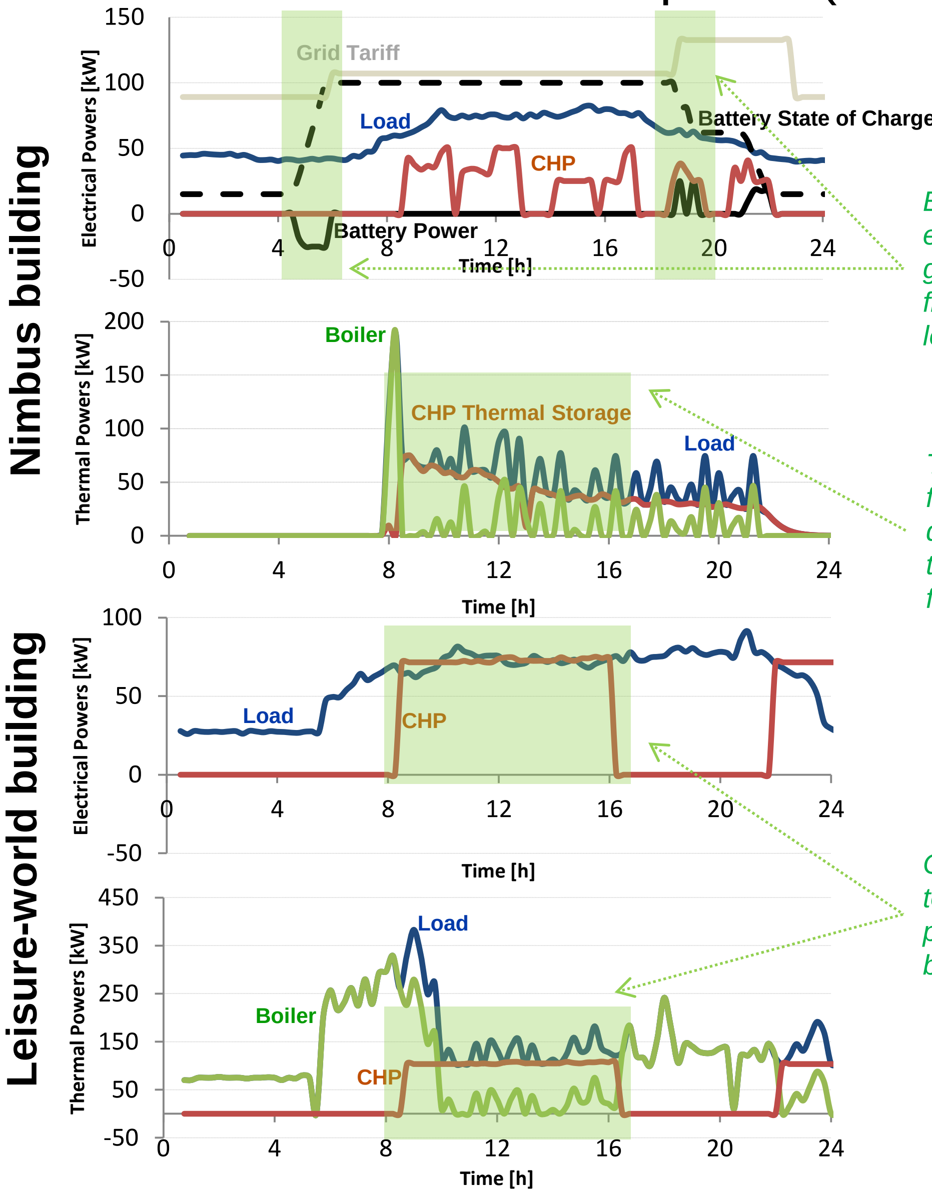
Challenges:

- ✓ Balance building and neighbourhood objectives (cost, emissions)
- ✓ Limited data available or disclosed in multi-owner districts
- ✓ Variable or real-time energy prices

Exploit flexibility at building equipment and loads to reduce overall neighbourhood cost and maximize RES and storage use

BISHOPSTOWN CAMPUS DEMO

In-field demonstration completed (February 15th-17th, 2015)

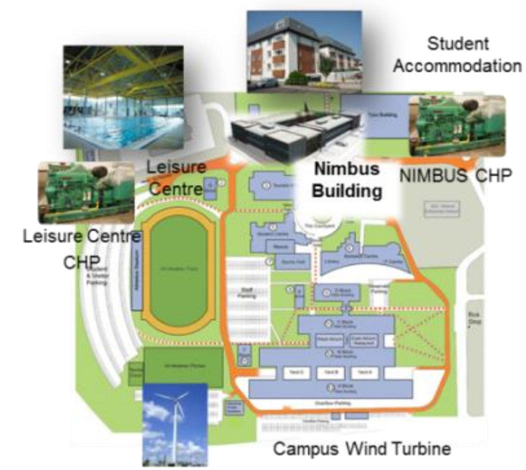


Battery flexibility enables to shift grid purchase from high tariff to low tariff time

Thermal Storage flexibility used to decouple thermal demand from generation

CHP flexibility to reduce grid purchase and boiler utilisation

CIT Campus Demosite

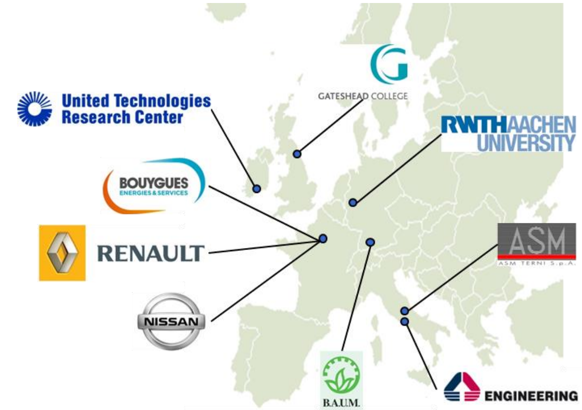


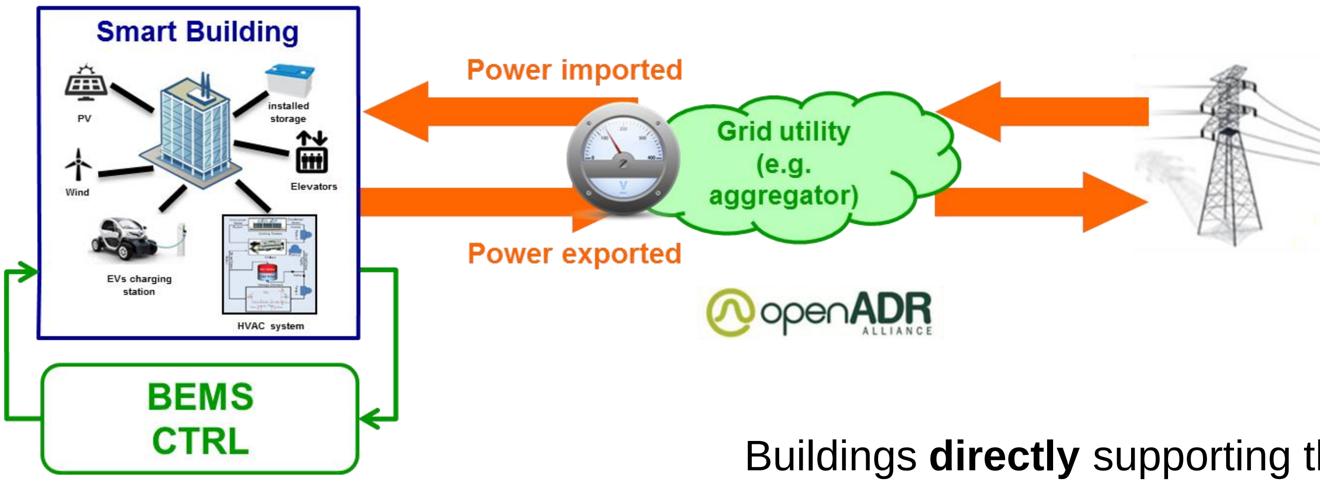
- ✓ Coordinate electrical, thermal storage and local generation to minimize total energy cost (electricity + natural gas)
- ✓ 11% total energy consumption reduction by using battery and CHP flexibility
- ✓ Optimal battery operation: charge at low tariff and discharge at high tariff
- ✓ Additional savings from local CHP generation (exploit low gas vs grid tariffs)

H2020 ELSA

Energy Local Storage Advanced system

- Bring electricity storage system based on electric vehicle used batteries (2nd life batteries) and Building Energy Management System (BEMS) to an industrial level
- Pilot technology at 6 demo sites (France, UK, Spain, Italy and Germany)





Buildings **directly** supporting the grid: **active** role

Buildings communicating **flexibility**

openADR allows for automated demand response services

BEMS **coordinates** building operations **guaranteeing comfort**

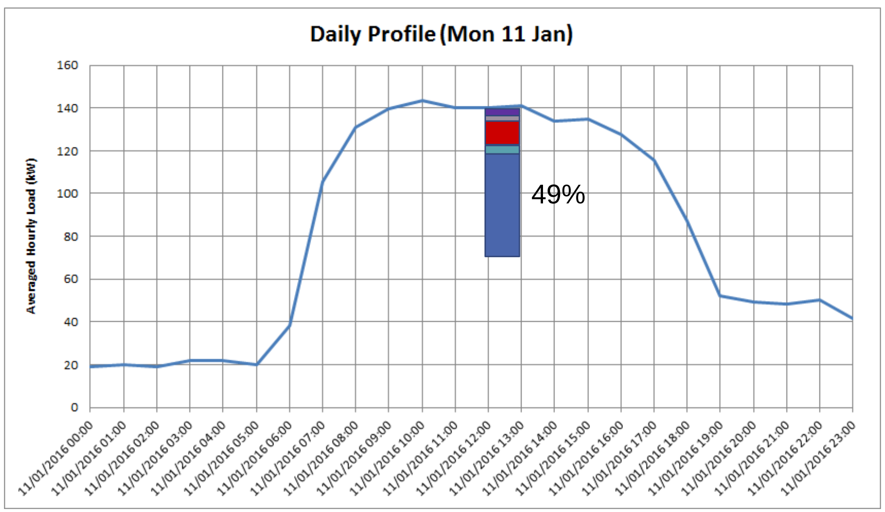
H2020 ELSA

Energy Local Storage Advanced system

SASMI building at Gateshead College (UK)

(Real electrical building consumption available, PV generation simulated using Dymola)

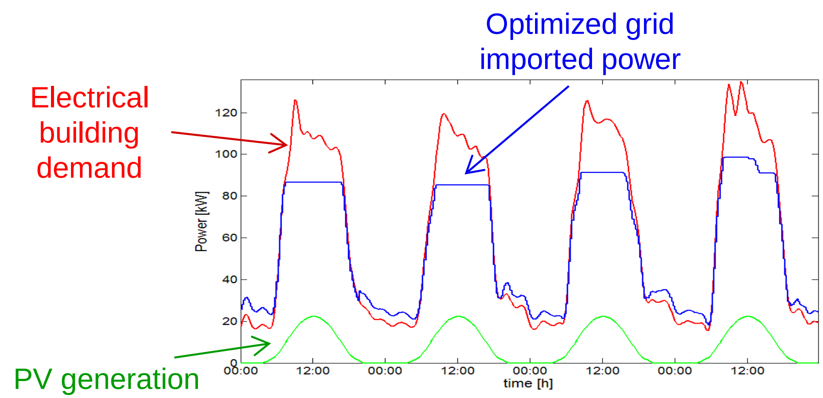
Use case 1: *demand response 1h flexibility*

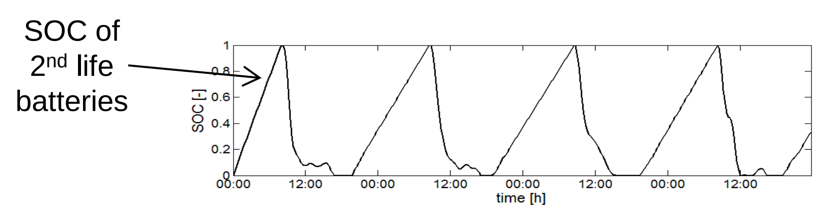


Battery, PV, 10% HVAC Reduction & Door Curtain

If grid requires, BEMS can coordinate batteries, PV and HVAC and can reduce the power consumption up to 49% for 1h event

Use case 2: *peak minimization*





BEMS can coordinate loads, batteries and PV to reduce the peak consumption up to 16%

H2020 ELSA

Energy Local Storage Advanced system

SASMI building (UK)

X 3

Storage system capacity

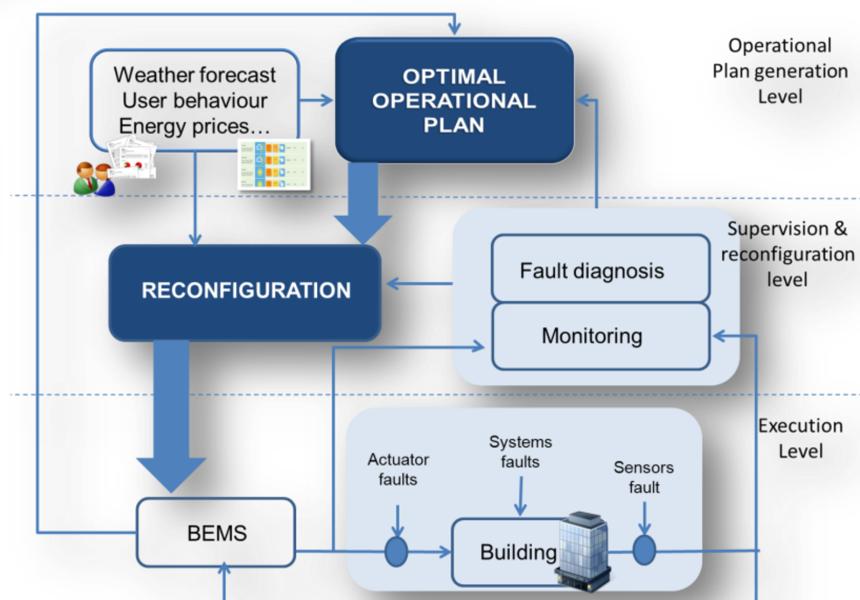
1st life batteries : 72 kWh
2nd life batteries: 48 kWh

ENERGY IN TIME

Resilient and Intelligent HVAC Diagnostics and Control

UTRC Role

- **HVAC Fault Detection and Diagnostics**
- **Efficient HVAC Commissioning**
- Advanced (MOD & FAC) Control
- Field demonstration in Carrier Montluel, France.



AUTOMATED FAULT DETECTION AND DIAGNOSTICS

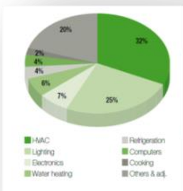
The Rationale

Building Diagnostics

Poorly Maintained, degraded and improperly controlled equipment wastes an estimated 15% to 30% of energy used in commercial buildings. Much of this waste can be prevented with wide spread adoption of automated condition based maintenance[1]

Equipment Diagnostics

Technologies such as automated FDD can save 20% of the energy consumed by HVAC, lighting, and refrigeration systems by eliminating operational faults[2]

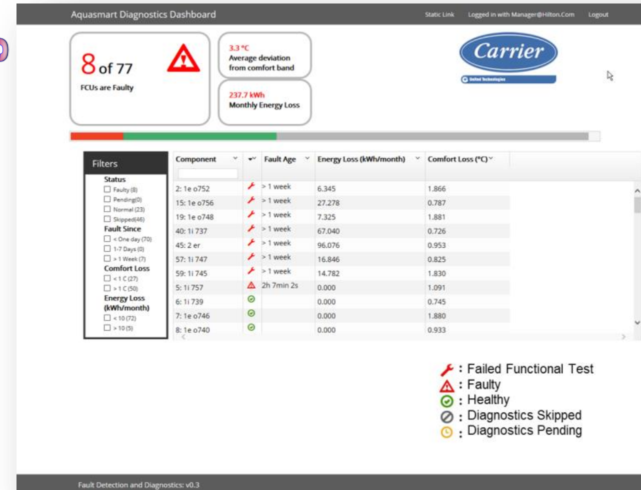


Energy Consumption in Commercial Buildings

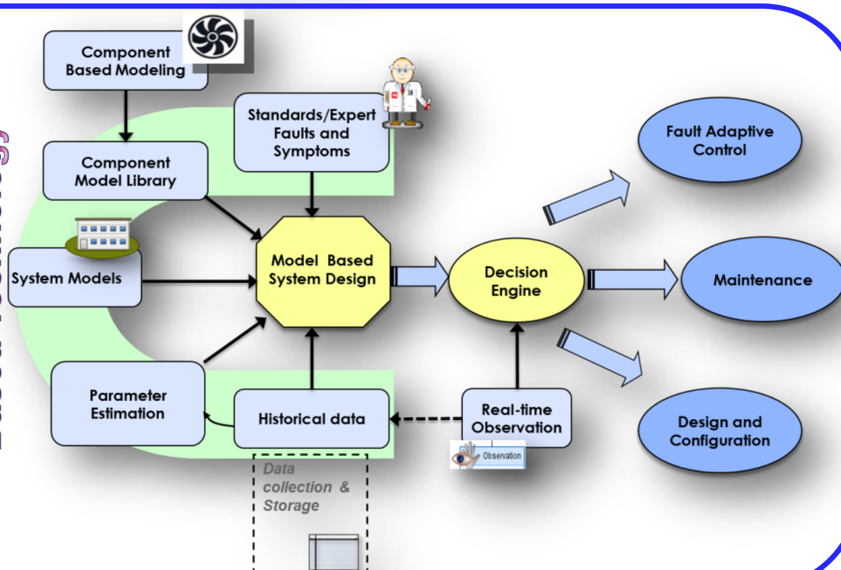
Energy performance of buildings is key to achieve the EU Climate & Energy objectives, namely the reduction of 20% of the Greenhouse gases emissions by 2020 and 20% energy savings by 2020[3]

[1] ***Methods for Fault Detection, Diagnostics and Prognostics for Building Systems – A Review, Part 1***. HVAC&R Research, Vol. 11, No. 1, Jan 2005.
[2] ***Energy Impact of Commercial Building Controls and Performance Diagnostics: Market Characterization***, Energy Impact of Building Faults and Energy Savings Potential, TIAX Report No D0180.
[3] **EU Energy Security and Solidarity Action Plan: 2nd Strategic Energy Review**, EU Commission Directorate General for Energy and Transport, 2008.

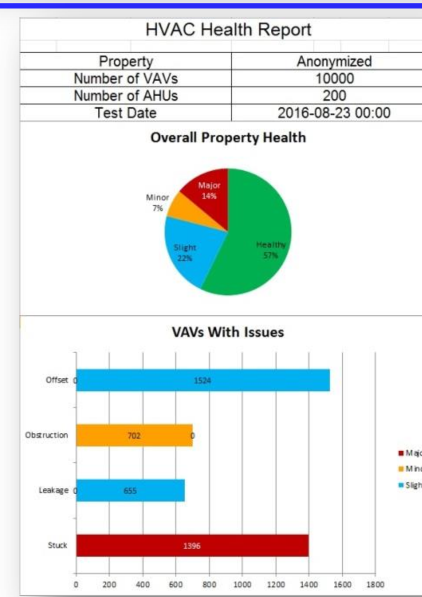
Real Time Health Monitoring



Hybrid Physics and Data Based Technology



Automated Commissioning & On Demand Building Health Analysis

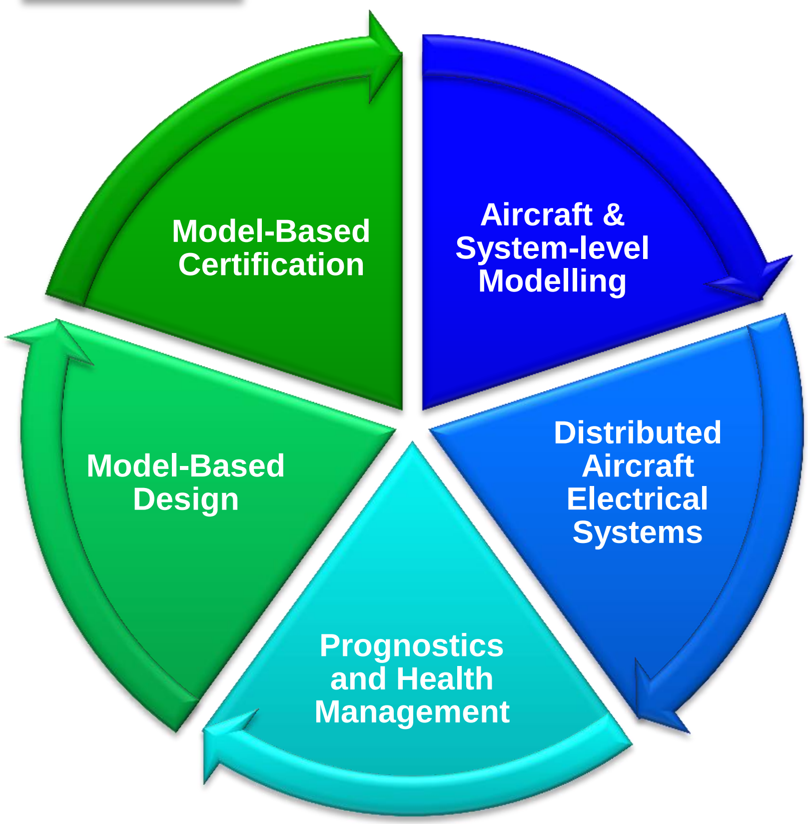


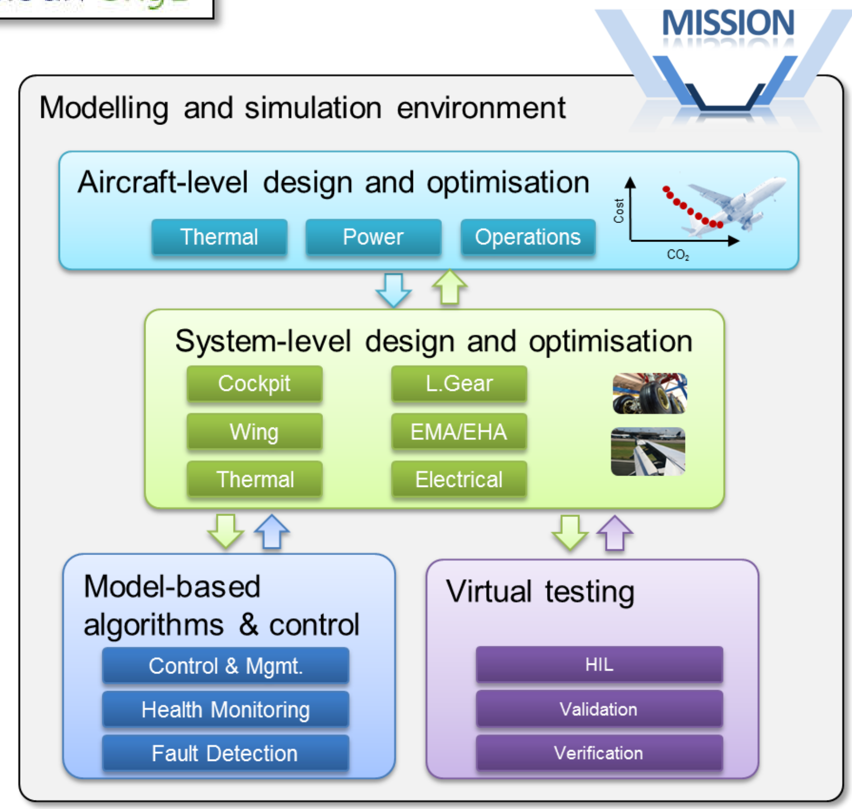
UTRC IRELAND – AEROSPACE PROGRAMS

Developing methods and tools for integration of complex aerospace systems

Centre of Excellence in Cyber-Physical Systems for Aerospace

Modelling and Simulation Tools for Systems Integration on Aircraft





UTRC Ireland & ALES Partnering with:

UTC Aerospace Systems

Supporting your vision

dSPACE