

Plug-and-Play solutions for energy-efficiency deep renovation of European building stock



Dr. Rizal Sebastian

Anna Gralka MSc., Dr. Marco Arnesano, Prof. Gian Marco Revel, Prof. Timo Hartmann

1. Problem statement

Main barriers for deep renovation at European scale

2. Hypothesis

Plug-and-Play (PnP) renovation with simple, affordable and fast implementation

3. Theoretical review

Adaptation and adoption of PnP concept from IT to construction

4. Research methodology

Applied research in the P2ENDURE collaborative project

5. R&D achievement

Prototype solutions and real pilot projects

6. Conclusion and discussion

Innovative aspects and scientific contribution

1. Problem statement

- **Almost 90% of the existing building stock in the EU is older than 30 years, but the rate of renovation is only 1-2% each year, and within this only 5% of the renovated buildings achieve >60% energy saving**
(source: European Parliament, 2016, Boosting Building Renovation: What potential and value for Europe?)
- This fact is hard to accept since:
 - Advanced renovation solutions (products and services) are available
 - Sustainability policies and financial benefits encourage energy-efficient buildings
 - Research in deep renovation have achieved a high Technology Readiness Level (TRL)
- So, the research questions are:
 - What are the barriers for large-scale deep renovation in Europe?
 - How to break these barriers?

1. Problem statement

- **Barriers for large-scale deep renovation in Europe**

(source: European Parliament, 2016, Boosting Building Renovation: What potential and value for Europe?)

- Financial barriers : renovation cost, access to finance, [temporarily] low energy price
- Technical barriers : lack of affordable technical solutions and knowhow of professionals
- Process barriers : fragmentation in supply-chain and high complexity for owners/occupants
- Regulatory barriers : varying performance requirements and definition of (deep) renovation
- Awareness barriers : insufficient insights in renovation benefits and increased user comfort

2. Hypothesis

- **Plug-and-Play (PnP) concept is key to large-scale deep renovation**
 - PnP deep renovation goes beyond ‘modular building units’
 - Plug-and-Play (PnP) solutions can break through the current renovation barriers
 - Scan-to-BIM-to-BEM is essential for PnP product and process integration
 - Upgrading building’s smartness through deep renovation can be facilitated PnP updates

3. Theoretical review

- The origin of PnP technologies from IT hardware and software domains, and the practical adoption and adaptation of the PnP concepts and principles for building deep renovation

- PnP common understanding:
Connecting an external device to a computer / electronic system without the need for manual installation of driver software or intervention



- PnP building components:

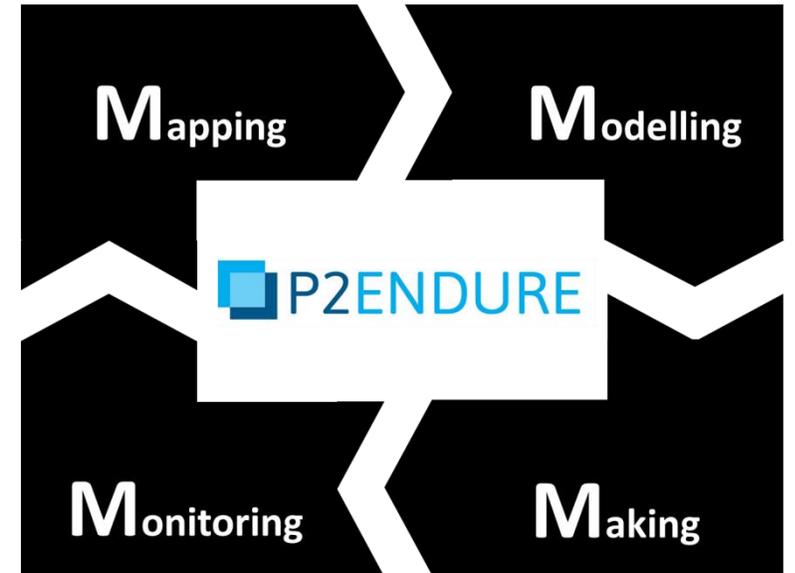


- PnP building automation:



4. Research methodology

- **Scan-to-BIM-to-BEM**
digital upgrade of building and energy information
- **Plug-and-Play renovation**
upgrade of building components, potential of smart control systems
- **On-site 3D printing**
robotics for façade retrofitting, potential of smart materials
- **IEQ monitoring system**
upgrade of Indoor Environment Quality, potential of IoT smart sensing



5. R&D achievement

■ Scan-to-BIM

Digital reconstruction of the existing building in As-Built BIM

- Exterior and interior laser and thermal scans
- No fully automated procedures / tools are yet available

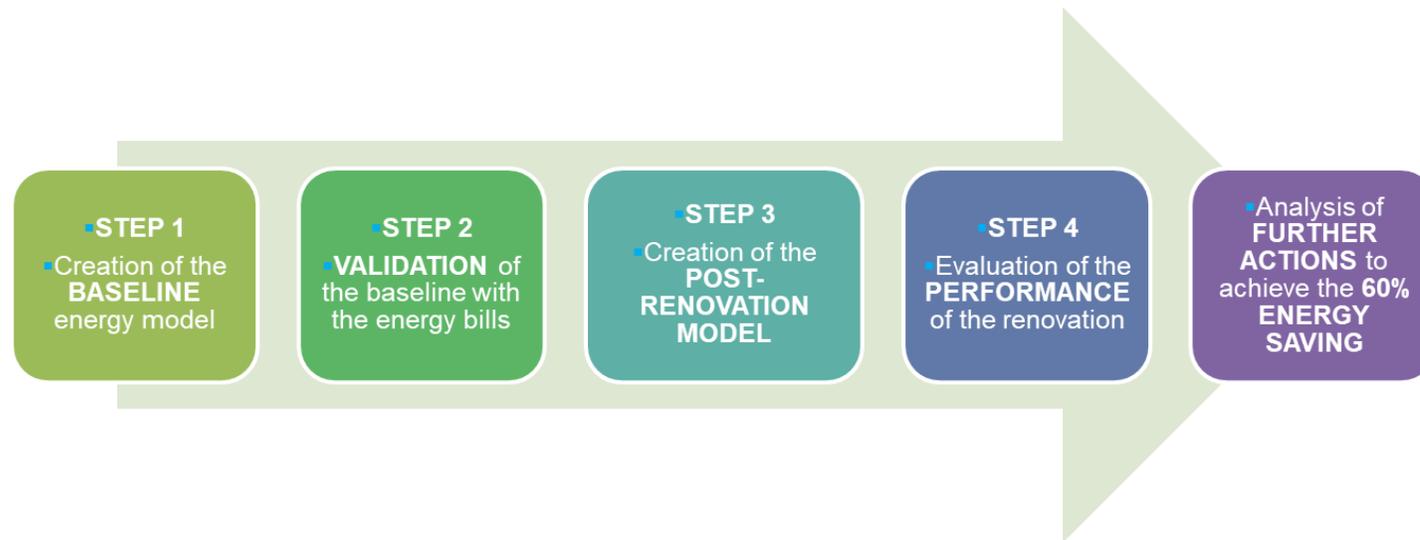


5. R&D achievement

■ BIM-to-BEM

Experiments with 2 different methods and toolsets:

- Revit – IFC – CYPETHERM
- Revit – SketchUp with Legacy OpenStudio plugin – EnergyPlus [using open source tools]



5. R&D achievement

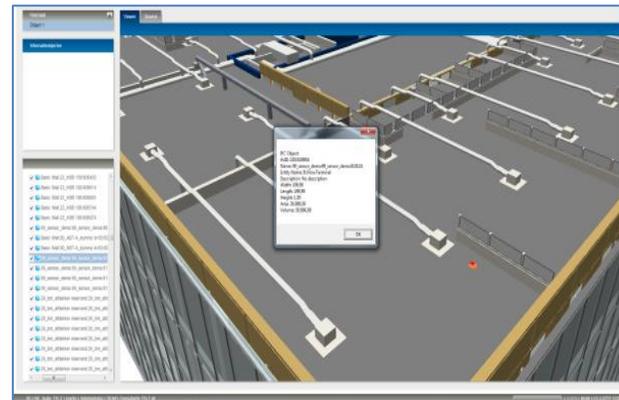
■ BIM-to-BEM

Existing technical bottlenecks:

- Only relatively simple BIM models can be facilitated
- Difficulties in making simulation of several design variants containing geometric changes
- Needed extra time to redefine BIM properties besides geometry when these can not be imported by the current BEM tools
- Issues with BEM system parameters depending on obtained data of the existing energy system, especially regarding old energy systems (e.g. old fashioned boilers)
- Issues with BEM material parameters depending on the materials properties and stratigraphy data
- Limited flexibility in choosing the simulation and output preferences in the current BEM tools

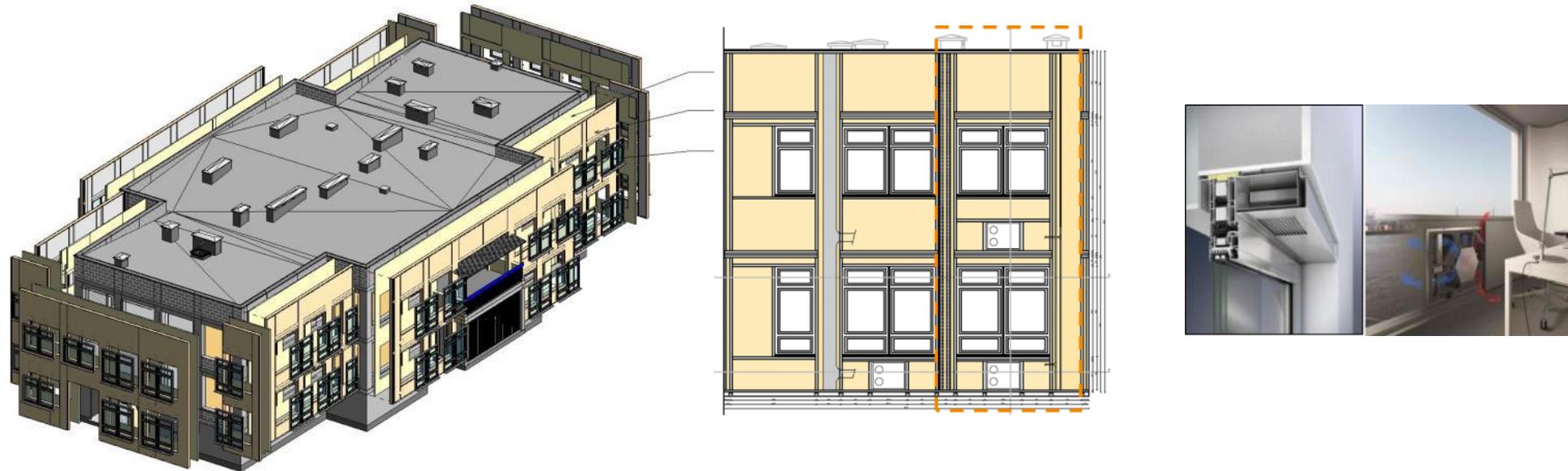
5. R&D achievement

- **(Potential) use of BIM and BEM to upgrade the building's smartness**
 - As-Built BIM as input for P2Endure Parametric Modeller to configure renovation options
 - Location and properties of the sensors installed in renovated building can be included in BIM
 - Based on sensor data, performance levels of different rooms / storeys can be visualized in 3D



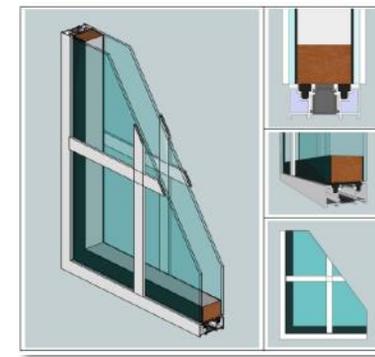
5. R&D achievement

- **Plug-and-Play renovation solutions**
 - Multifunctional panel with possible integration of climate regulation system
 - Potential PnP integration of smart control systems in adaptive building envelope



5. R&D achievement

- **Plug-and-Play renovation solutions**
 - Reversible window with advanced climate and energy properties
 - Potential PnP integration of smart sensors and control systems for an active window



5. R&D achievement

- **On-site 3D printing**
 - Collaborative robot for façade retrofitting by on-site 3D rendering and milling
 - Potential integration of advanced robotics and smart materials in on-site 3D printing



5. R&D achievement

- **IEQ monitoring system**
 - Comfort Eye (patented): affordable monitoring system of indoor temperature, air quality (CO2)
 - Potential integration of IoT smart sensing and actuators: IEQ monitoring system connected with BMS (Building Management System), real time data to BIM

IEQ Performance Assessment



The image illustrates the integration of IoT sensors, BIM software, and an IEQ performance assessment dashboard. The dashboard displays various metrics and charts, including:

- Standards compliance:** A line graph showing 'Variability' and 'Design Performance' over time.
- Sensitivity Analysis:** A pie chart showing the 'Impact of relevant parameters' on 'Indoor Air Quality'.
- Building Performance Category:** A bar chart showing 'KPIs' over time.
- Retrofit Solution XY:** A list of retrofit measures such as 'Foundation: Hollow-core Slab', 'Radiant Heating', and 'Double-glass window'.

The IoT sensor (Comfort Eye) is shown in a close-up view, and the BIM software interface is also visible. The sensor is installed in a room, and the room is shown in a photograph.

6. Conclusion and discussion

- **Plug-and-Play is a way to upgrade building's smartness through deep renovation**

PnP technologies and principles derived from IT hardware and software domains have potential for adaptation and practical adoption to upscale building deep renovation

- **The biggest challenge for PnP deep renovation is the interoperability and integration**

Integration is needed regarding both hardware (inter-connected renovation components, flexible joints) and software (BIM, modelling and simulation tools)

- **Just like in ICT domain, upgrading building's smartness goes through gradual updates**

Building deep renovation should be 'future proof' in terms of technology, economy and society. So, keep the PnP renovation systems open for continuous updates



Dr. Rizal Sebastian (Project Coordinator)



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