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New Buildings Energy Renovation Business Models incorporating dual energy services

NOVICE

Grant Agreement No: 745594

Collaborative Project

D5.3 Description of scenarios and simulation results

D5.4 Report on revenue flows and feasibility studies

Deliverable No.	D5.3 Description of scenarios and simulation results D5.4 Report on revenue flows and feasibility studies (incl. risk analysis) per country from scenario results per building type and country
Work package	WP5: Revenue Streams Quantification and Monetisation
Task	Task 5.2 Modelling of the test cases and baseline determination Task 5.3 Scenarios determination for dual services Task 5.4 Revenue Streams Quantification from Energy Savings and Demand Response Task 5.5 Monetisation, Feasibility Study and Risk Analysis
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<tr><th></th><th colspan="5">Deliverable administration</th></tr>
<tr><td>No & name</td><td colspan="5">D5.3 Description of scenarios and simulation results
D5.4 Report on revenue flows and feasibility studies (incl. risk analysis) per country from scenario results per building type and country</td></tr>
<tr><td>Status</td><td>Final</td><td>**Due**</td><td>M19</td><td>**Date**</td><td>31/05/2020</td></tr>
<tr><td>Author(s)</td><td colspan="5">Christof Amann (e7), Jo Southernwood (IERC), Jesus Igancio Torrens Galdiz (Tecnalia)</td></tr>
<tr><td>Description of the related task and the deliverable in the DoA</td><td colspan="5">**Task 5.2: Modelling of the test cases and baseline determination**
For all buildings, selected modelling will be set up and executed. As DR services will affect several technical parameters that are directly or indirectly related to comfort parameters (temperature, humidity, CO2, etc.), modelling should include these parameters. One critical requirement will be that all simulations are able to deal with DR data from the scenarios that will be developed in T5.3. For the calculation of additional revenue streams at least three scenarios have to be considered: (i) baseline scenario: what would have happened without a renovation; (ii) BaU scenario: where the energy and economic performance is evaluated under the business as usual interventions conventionally undertaken; (iii) dual energy service scenarios: energy and economic effects by NOVICE suggested interventions under defined scenarios of dual energy services provision. The task will be carried out in close and frequent exchange with the partners providing scenarios (T5.3) and calculating revenue streams (T5.4).

Task 5.3: Scenarios determination for dual services
Regulatory and market framework conditions for DR services vary to a large extent from country to country. Based on WP3 (regulatory framework), WP2 (technologies) and T5.1, scenarios have to be developed for each open European market. Those scenarios should be inclusive of the difference market structures and conditions (e.g. consumer participation at the wholesale, day ahead or intraday market), building operational profiles, aggregation conditions, climate, state incentives, etc. In order to reduce the number of total scenarios and to exchange experiences between partners and countries, scenarios are developed in a scenario-workshop that will take place in M13 (coinciding with third project meeting). Scenario parameters will be directly used for simulations (T5.2).

Task 5.4: Revenue Stream Quantification from energy savings and demand response
For all scenarios revenue streams that either come from EE or DR services will be quantified. This will be done for each scenario and each building type for each country. The resolution of revenue data for the calculation of the revenue streams must be appropriate and has to be justified. In competitive markets (e.g. where revenues depend on capacity and energy prize of competitors) revenues have to be calculated for real case, but also for best (good) and worst (bad) case conditions. For comparability of results, templates and common calculation tools will be used. The revenue streams will not only include the market income by the services but also state incentives (i.e. Renewable Heat Incentive or Feed In Tariffs).

Task 5.5: Monetisation and feasibility study and risk analysis (e7, Months 16-21)
Feasibility studies and risk analysis will be prepared in this task where not only revenues but also additional costs for equipment, running costs for maintenance and support and transaction costs (e.g. for participation in DR markets, or for Aggregators) will be considered. Feasibility studies will be conducted for all building types and all countries for real, but also for best (good) and worst (bad) case conditions. Development status of DR services market shows quite a big variety in Europe, thus, risk analysis will be necessary. This risk analysis will take into account that DR market is quite different from “normal” energy market that framework conditions are in an ongoing change in some countries, and that only a few real world experiences in applying DR services in buildings exist. All feasibility studies will follow a similar structure (template).</td></tr>
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<tr><td>V</td><td colspan="2">Authors</td><td colspan="3">Description</td></tr>
<tr><td>0.1</td><td colspan="2">Christof Amann</td><td colspan="3">Table of contents</td></tr>
<tr><td>0.2</td><td colspan="2">Christof Amann</td><td colspan="3">First Draft</td></tr>
<tr><td>0.3</td><td colspan="2">Christof Amann, Jo Southernwood, Ignacio Torrens</td><td colspan="3">Contributions to Chapter 3 and 4</td></tr>
<tr><td>0.4</td><td colspan="2">Christof Amann, Jo Southernwood, Ignacio Torrens</td><td colspan="3">Review</td></tr>
<tr><td>1.0</td><td colspan="2">Christof Amann, Jo Southernwood, Ignacio Torrens</td><td colspan="3">Final Report</td></tr>
</table>

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TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

The aim of this report is to estimate and analyse revenue streams for the NOVICE dual services business model from demand response and from energy efficiency improvements. This is done for 3 different building archetypes and for 3 markets in Europe.

Modelling has considered different scenarios that best represent the types of building that are most suited to the NOVICE business model, the varying climatic conditions around Europe, the different levels of maturity of DR markets in Europe and the different types of DR programmes that are available. The following building typologies were selected as most suited to the NOVICE business model:

- Large Offices
- Hotels
- Hospitals

For each of the building archetypes in each of the selected countries, three energy scenarios have been modelled: 1) the baseline scenario; 2) the business as usual scenario, i.e. energy efficiency measures only; 3) the NOVICE proposed solution i.e. energy efficiency plus demand response measures implemented. The energy modelling has focussed only on turn down events (chillers).

Revenue streams are generated from two sources in NOVICE dual service projects, (1) from energy cost savings resulting from the implementation of energy efficiency measures, and (2) from offering flexibility services to the corresponding markets. Results from the revenue flow calculation for the selected archetypes show that for the case of simply use chillers as switchable load, revenues from demand response reach a significant amount only in hospitals in Spain and Austria and in office buildings in Spain and are more or less insignificant in all other cases. However, modelling and scenarios were set up as a kind of “worst case” that is quite straightforward, but commonly applied. For the NOVICE dual services model, additional efforts could draw a quite different picture:

- Experienced aggregators will include air handling units, pumps, fans, onsite generators, CHP, PV, storage etc. This will increase potential revenues.
- Implementation of demand response will need tailor made solutions, i.e. select appropriate assets for particular demand response products and implement the optimal demand response strategy.
- It is crucial for the NOVICE dual service model to select the appropriate buildings with the necessary energy consumption and available assets for demand response corresponding to market conditions.

Demand for flexibility will increase in the future and regulatory framework conditions will be adapted for further implementation of demand response. In several European markets, aggregators are successfully offering demand response products. Only market participants that can provide tailor-made solutions for their clients will succeed. The NOVICE dual service model will have its place in this process.

2 INTRODUCTION AND BACKGROUND

The aim of the NOVICE project is the development and demonstration of an innovative business model for Energy Service Companies (ESCOs) that will provide energy savings to buildings and demand response (DR) services to the grid after renovating buildings or blocks of buildings. A dual revenue stream shall thus be enabled that can reduce payback period for investments in buildings renovations and accelerate the much-needed market uptake of the Energy Performance Contracting (EPC) based financing model (www.novice-project.eu).

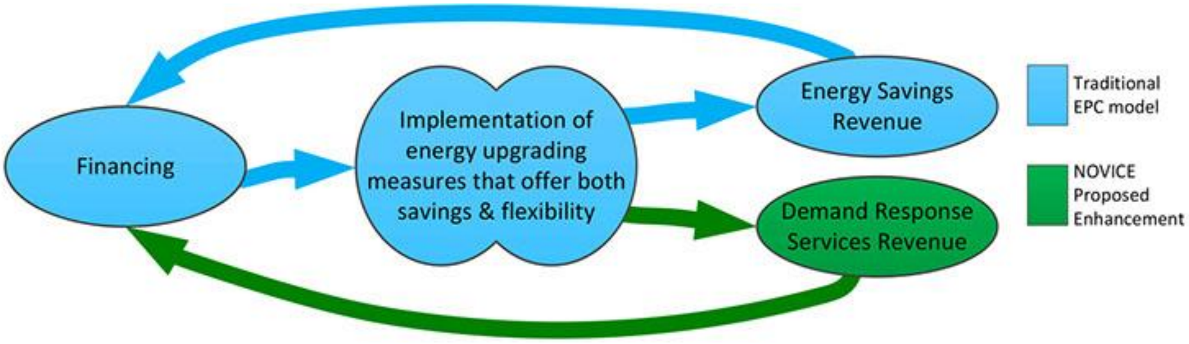


Figure 1: NOVICE Dual Services Model

The aim of this report is to estimate and analyse revenue streams for the NOVICE dual services business model from demand response and from energy efficiency improvements. This is done for 3 different building archetypes and for 3 markets in Europe. Feasibility will be assessed as well as risks for clients implementing the NOVICE dual services.

The initial idea behind the approach applied here is, that only buildings with a large energy consumption are suitable for EPC projects where energy efficiency improvements are used to recover initial investments. For the selection of the building types (archetypes) and for the scenarios developed, one major assumption is that flexibility is related to energy consumption. In order to get comparable results among different markets, a straightforward, however realistic and commonly applied, approach was used for the selection of the switchable loads in buildings, i.e. the turn-down of chillers as the only asset for demand response. This simplification, on the other hand, limits significance of the resulting conclusions from the modelling and revenue calculation. Market conditions are still quite different between countries and this should be considered in the definition of the most appropriate demand response strategy as well as in the selection of the most suitable assets and loads in buildings selected for NOVICE dual services.

3 DESCRIPTION OF SCENARIOS

The energy and financial modelling has considered different scenarios that best represent the types of building that are most suited to the NOVICE business model, the varying climatic conditions around Europe, the different levels of maturity of DR markets in Europe and the different types of DR programmes that are available for revenue generation. Considering all of these aspects could have resulted in the generation of thousands of different scenarios, so where possible, simplifications were made to select the scenarios that best reflect real world cases. This ensures that the outputs from the model are as useful as possible to ESCOs, Aggregators, Building Owners and other stakeholders that are considering a dual services approach to building renovations. This chapter describes in more detail the basis upon which the scenarios were selected.

3.1 SELECTION OF BUILDING ARCHETYPES

In Deliverable 5.1 (D5.1), “Report on typology of buildings suitable for dual energy services”, the NOVICE project team analysed the different non-domestic building typologies found around Europe (offices, educational buildings, health care facilities, hotels and restaurants, sports facilities, wholesale and retail trade service buildings) in terms of:

- Energy consumption per square meter
- Floor area coverage
- Energy consumption per building
- Building size distribution
- Energy efficiency potential
- Demand response potential
- The status of operational constraints (e.g. regulations on air change rates in the health sector)
- Building age distribution

For each building typology, the parameters above were scored (low, medium or high) to establish the most suitable building types in which to deploy the proposed NOVICE business model. As a result of this analysis, the NOVICE team selected the following building typologies as most suited to the NOVICE business model:

- **Offices** account for around 30% of commercial building floor area, the highest of any of the building classes examined. Energy consumption in offices constitutes about 20% of the overall non-residential demand and in general, offices have high potential for both energy efficiency improvements and participation in demand response programmes with few regulatory or operational constraints preventing participation in a NOVICE-style approach to energy management. In many countries, EPC has been embraced by public sector organisations as a way of improving energy efficiency in the long term without the need for an initial capital outlay. NOVICE could provide a means of driving uptake of EPCs in the private sector by reducing contract duration if it can be shown that a dual energy services approach can be beneficial for office buildings.

- **Hotels and restaurants** occupy around 15% of the European non-residential building stock by floor area and can have significant energy demand, particularly in Southern latitudes that have large cooling requirements in the summer. The need to keep guests comfortable at all times can lead to high energy consumption in this sector and therefore, a high potential for energy efficiency improvements and participation in demand response programmes is expected.

Many larger hotels include additional facilities such as swimming pools, spas, restaurants and conferencing facilities, which can significantly drive up energy consumption while at the same time provide a large opportunity for energy saving and demand response actions. Operational constraints and the need for quick return on investment sometimes prevents hotel owners from undertaking refurbishment works because of the level of disruption and potential loss of income during the refurbishment. However, larger hotel chains are often competing for the same business and run at very tight margins, so reducing the operating cost could result in an increase in profits more easily than increasing the occupancy rates.

- **Health Care Facilities** such as hospitals tend to be located in large buildings and often have high energy consumption per square meter, as they are occupied at all times, must maintain comfortable indoor conditions for building occupants and are filled with a large quantity of energy intensive equipment. Hospitals are present in every European city and have high potential for energy efficiency due to the large amount of energy consuming equipment on site and the need to continuously regulate the temperature, humidity and air quality for the comfort of building users. Critically there is significant potential for demand response participation as many hospitals have on-site generators or combined heat and power plants (not considered in this report) that can be used to export electricity to the grid when required. The main obstacle in health care facilities is overcoming operational constraints, as conserving energy is often not a priority in health care environments, particularly hospitals. However, pressure to reduce costs has boosted uptake of EPCs in this category of buildings, making hospitals particularly suitable for dual energy services approach.

As a result of this analysis, the energy and financial modelling undertaken in this work package has focussed on **Large Offices, Large Hotels and Hospitals**, as these represent the best opportunities for the NOVICE project. The US Department of Energy (DOE) reference building models for each of these building types has been used as a starting point for the EnergyPlus modelling that will be undertaken in this work package, assuming post-1980 construction. The EnergyPlus model input files are freely available for others to use for further analysis.

3.2 DR MARKET SELECTION

Climatic conditions can have an impact on the energy saving potential of the energy efficiency measures that can be implemented in each of the building archetypes selected above. For example, buildings in southern latitudes are likely to have lower heating loads in winter and higher cooling loads in summer compared to buildings in northern latitudes. In addition, the level of maturity for demand response markets differs across Europe due to the wide variation of regulatory conditions that exist and differing requirements for flexibility in each of the Member States. To ensure that the energy and financial modelling considers these climatic differences, as well as the differences in market conditions each of the three building archetypes will be modelled in the following three countries:

- **Ireland** represents a north-western European country with a temperate humid climate. The winter months can be cold, resulting in a large heating load but temperatures do not tend to fall to the extreme lows that are common in northern Europe. Summers are mild, but not uncomfortably hot so cooling loads tend to be smaller compared to central and southern European countries. Ireland also represents a demand response market with **high maturity** as several programmes are open for participation and there are several demand response aggregators operating successfully in the country.

- **Austria** represents a central European country within a temperate climatic zone with cold winters yet warm summers. As a result, there are opportunities for energy efficiency in terms of both heating and cooling loads. Austria also represents a demand response market of **medium maturity** where some demand response markets are open but regulatory barriers prevent widespread participation especially for aggregated loads.

- **Spain** represents a Mediterranean European country with a climate characterised by hot dry summers and mild winters. As a result, the main opportunities for energy efficiency relate to reduction of summer cooling loads. Spain also represents a demand response market with **low maturity**. Aggregation of loads is not legal in Spain and this has restricted participation to implicit demand response only.

3.3 ENERGY SCENARIOS

For each of the building archetypes in each of the selected countries, three energy scenarios have been modelled: 1) the baseline scenario; 2) the business as usual scenario, i.e. energy efficiency measures only; 3) the NOVICE proposed solution i.e. energy efficiency plus demand response measures implemented. These three scenarios are described in more detail below.

3.3.1 The baseline scenario

The baseline scenario simply takes the DOE reference building energy model for a large office, a large hotel and a hospital and assumes that the original buildings being considered were constructed between 1980 and 2004. This corresponds to the widely held view that buildings that are around 20 years old are most suitable for an energy efficiency upgrade. The insulation values, lighting levels, and HVAC equipment types and efficiencies in the reference model meet the minimum requirements of Standard 90.1-1989 (ASHRAE 1989). The typical climatic conditions in each of the three chosen countries (Ireland, Austria and Spain) were then added to these models to determine the baseline energy consumption of these buildings.

3.3.2 The 'business as usual' scenario

The 'business as usual' scenario models the impact of implementing the most cost-effective energy efficiency measures on building energy consumption in each of the three building archetypes for each of the selected countries. In each case, it has been assumed that the installed energy efficiency measures result in a building that meets the minimum requirements of the building standards that were applicable in 2010 in terms of insulation values, lighting levels, HVAC equipment types and efficiencies in each of the selected countries. This has been cross referenced with the energy efficiency technologies that were identified as most suitable for NOVICE in Deliverable 2.1 "Lifecycle Performance of Building Energy Upgrades" and the package of 'technology kits' that were deemed appropriate for different buildings depending on their HVAC system. Typically, this has resulted in an improvement in HVAC equipment efficiencies of approximately 10% and a reduction in lighting energy consumption of around 40% based on the most common and cost-effective energy efficiency interventions. Based on the experience within the NOVICE consortium, these savings can be considered typical in building refurbishments. However, further savings would be possible with deep retrofitting but this is not subject to typical EPC projects.

3.3.3 The NOVICE scenario

The NOVICE scenario models the impact of implementing energy efficiency AND demand response (DR) measures in each of the three building archetypes for each of the selected countries. The range of possible options when considering DR events is vast, so to narrow down the options into a scenario that is manageable yet realistic, it was necessary to make some assumptions and simplifications about the type of DR events to be modelled. The assumptions and simplifications are listed below:

- The energy modelling has focussed only on turn down events i.e. which equipment can be turned off or turned down via the BMS during a DR event (e.g. chillers and HVAC equipment). This simplifies the scenario as it removes the scope for generators of any kind exporting electricity to the grid. In the context of NOVICE, this is an appropriate simplification as this type of equipment could be added to any suitable building and the outputs controlled according to grid requirements assuming there is a suitable demand response programme available regardless of any energy efficiency measures that have been implemented. NOVICE is primarily concerned with the interaction between energy efficiency and demand response, so limiting the modelling to turn-down events is entirely in keeping with this objective.

- As a direct consequence of the above simplification, frequency response, battery storage, and renewable energy generation are outside the scope of the energy and financial modelling. Whilst this is might be considered an over-simplification (since most aggregators will use the available flexibility from building assets across a range of different demand response programmes to generate more revenue), it does demonstrate a kind of “worst case” in terms of revenues generated.

- DR events can have a different impact on the building depending on when they occur. A DR event has been modelled on a typical day in summer, winter and during a shoulder season to allow simplification of the modelling of load profiles and the impact of the DR events whilst still considering the impact of seasonal differences. For simplicity, all events have been assumed to take place at the same times during the day, i.e. at 4.00, 8.00 a.m. and 12.00, 4.00, and 8.00 p.m.

- Turndown events can have different durations depending on the requirements of the grid and the DR programme in which the assets are enrolled. The impact of DR events lasting 15, 60, and 120 minutes has been tested to determine the impact on energy consumption and thermal comfort of building occupants. An additional analysis was carried out to determine the maximum length of a DR event that the building could endure without exceeding acceptable thermal comfort limits. This gives useful information to aggregators to help build their portfolio and to persuade network operators to change their requirements to allow greater participation.

- The modelling will consider rebound effects i.e. how long does it take and how much additional energy is required to bring the building back to its original state after a DR event. To do this the impact of the DR event on internal temperature, air quality and therefore the thermal comfort of occupants will be examined using the EnergyPlus model. This will determine how often these events can be offered without negative effects on the building operation and comfort of building users.

- Standard temperature, humidity and air quality ranges for each archetype will be used to set the acceptable parameters in the model. The middle of the range will be used for the BAU interventions. Parameters will be allowed to drift to the minimum or maximum values in the range for the NOVICE interventions. Rebound effects will be assessed by calculating the additional energy required to return the building to the middle of the acceptable operating range after a DR event.

- Implicit DR has not been modelled for this work as it is considered that this load shifting away from peak times should be done routinely where possible as part of the energy efficiency or cost optimisation of the building.

- Triad avoidance (i.e. the significantly higher charges for energy consumption on the 3 days of the year with the highest peak consumption), can yield significant savings for high energy users that are able to respond to these events by turning down consumption. However, this scenario is quite specific to the UK case and requires accurate forecasting of when triads are likely to occur. For this reason, triads have been excluded from the modelling.

4 MODELLING OF ARCHETYPES

4.1 DESCRIPTION OF ENERGYPLUS MODEL

A preliminary analysis of the existing commercial building stock and its suitability for adopting a dual-services (energy efficiency and demand response) business model was presented in Deliverable 5.1: “Report on typology of buildings suitable for dual energy services”. Based on this preliminary analysis, a sub-set of building archetypes that shows the highest potential were selected for a more detailed assessment.

These selected buildings archetypes (Figure 2) are:

- Large Hotel
- Large Office Building
- Hospital

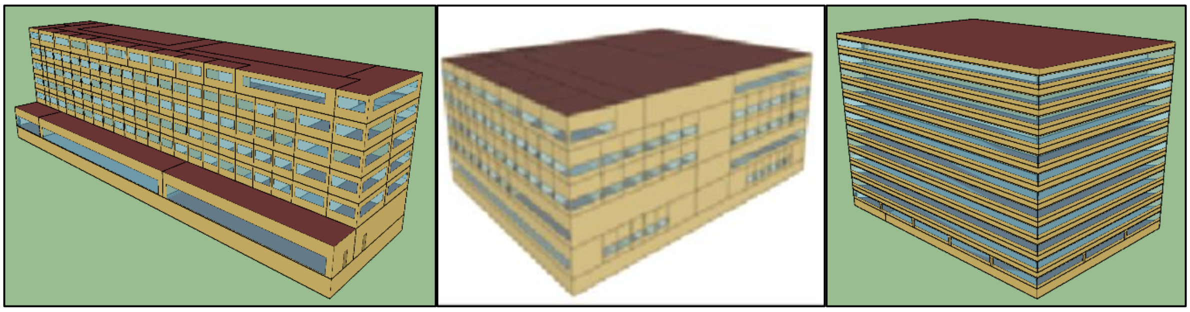


Figure 2: Building Archetypes (Source: DOE)

Dynamic energy models, based on the DOE reference commercial building energy models, representing the most common characteristics and designs of these building archetypes are developed to assess several scenarios to quantify the benefits and identify the risks of dual-services contracts in non-residential buildings.

A complete description of the models representing these building archetypes and their characteristics are presented in section 3 of Deliverable 5.2: “Reports on technical and economic characteristics for selected buildings”. Furthermore, assumptions on operation schedules, HVAC characteristics and details about building zones and their use is described in the appendix of that document.

4.2 MODELLING RESULTS

The results from the scenarios simulated are presented in three different stages:

- The first stage represents a situation taken as baseline, this being the building archetype in operation before any upgrade is applied to it.
- The second stage represents the initial building after an upgrade process where (typical) energy efficiency measures are applied to the building archetype.
- The third stage includes the scenario where explicit demand response strategies applied to a plant element (i.e. chillers) are enabled.

The savings from these energy measures and their implications on occupant comfort are discussed in this section.

4.2.1 Operation assumptions

All the architectural and operation characteristics of the selected building archetypes are described in detail in Deliverable 5.2. The tables below are extracted from it and summarize HVAC operation and occupancy control for every building type.

Large Hotel:

HVAC Control	
Thermostat Set point	Guest Rooms: 24° C cooling, 21° C heating Public Area: 24° C cooling, 21° C heating
Thermostat Setback	Setback is based on codes and standards
Supply air temperature	For the **VAV system**, the supply air temperature is set at 12.8° C. Temperature reset may be required by codes and standards. For the **DOAS**, the supply air temperature is reset according to the outdoor air temperature: • T_{supply} = 15.5° C when T_{oa} < 15.5° C; • T_{supply} = 12.8° C when T_{oa} > 21° C; Interpolation when T_{oa} is between 15.5° and 21° C.

Table 4-1: HVAC Control of Large Hotel

Hospital:

HVAC Control	
Thermostat Set point	24° C cooling, 21° C heating
Thermostat Setback	No setback
Supply air temperature	Maximum 40° C, Minimum 11° C
Chilled water supply temperatures	6.7° C
Hot water supply temperatures	82° C

Table 4-2: HVAC Control of Hospital

Large Office:

HVAC Control	
Thermostat Set point	24°C cooling, 21°C heating
Thermostat Setback	No setback
Supply air temperature	Maximum 40° C, Minimum 11° C
Chilled water supply temperatures	6.7° C

Hot water supply temperatures	82° C

Table 4-3: HVAC Control of Large Office

4.2.2 Baseline

The annual results of the simulations for the three chosen locations are shown by building type and represented by:

- Annual Energy Use Intensity (E.U.I.) of the building, that gives a comparable metric representing the energy consumption of a building.
- Annual E.U.I. by end use, that shows the weight the different end-uses have on the overall consumption of the building.

4.2.2.1 Large Hotel archetype model

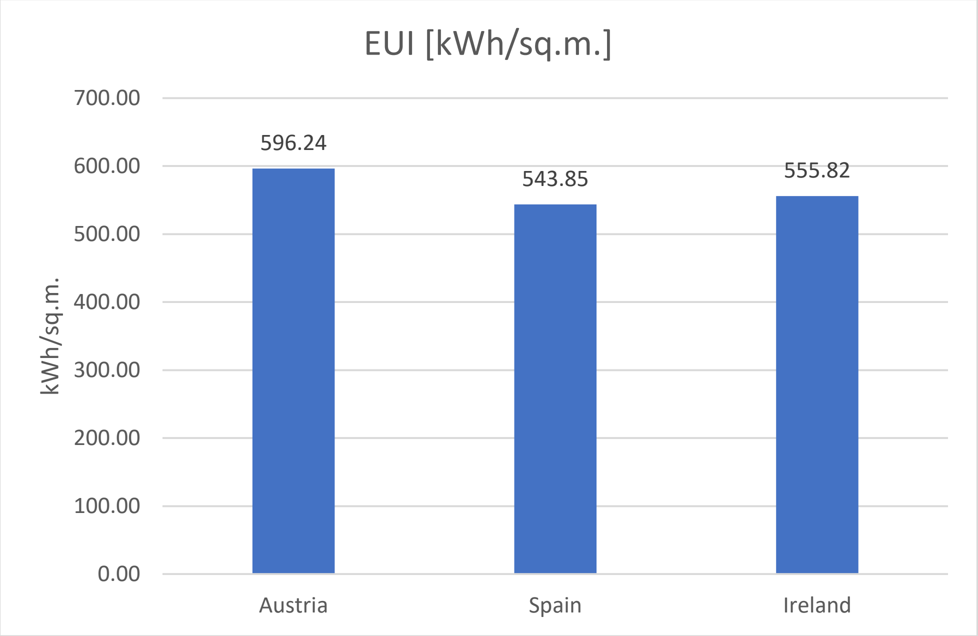


Figure 3: Annual Energy Use Intensity of Large Hotel

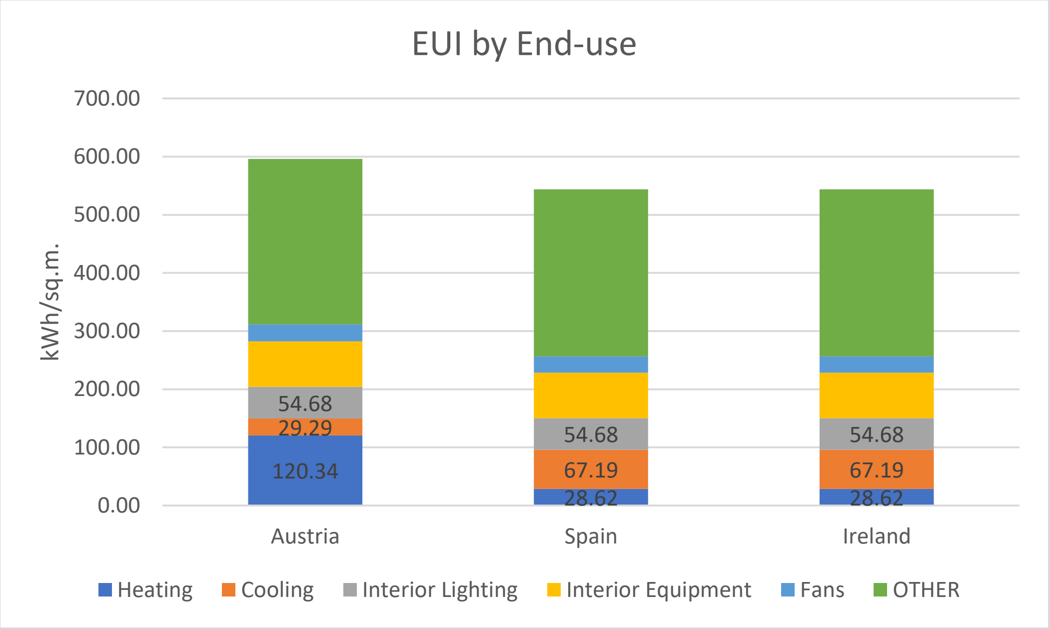


Figure 4: EUI of Large Hotel by End-Use

4.2.2.2 Hospital archetype model

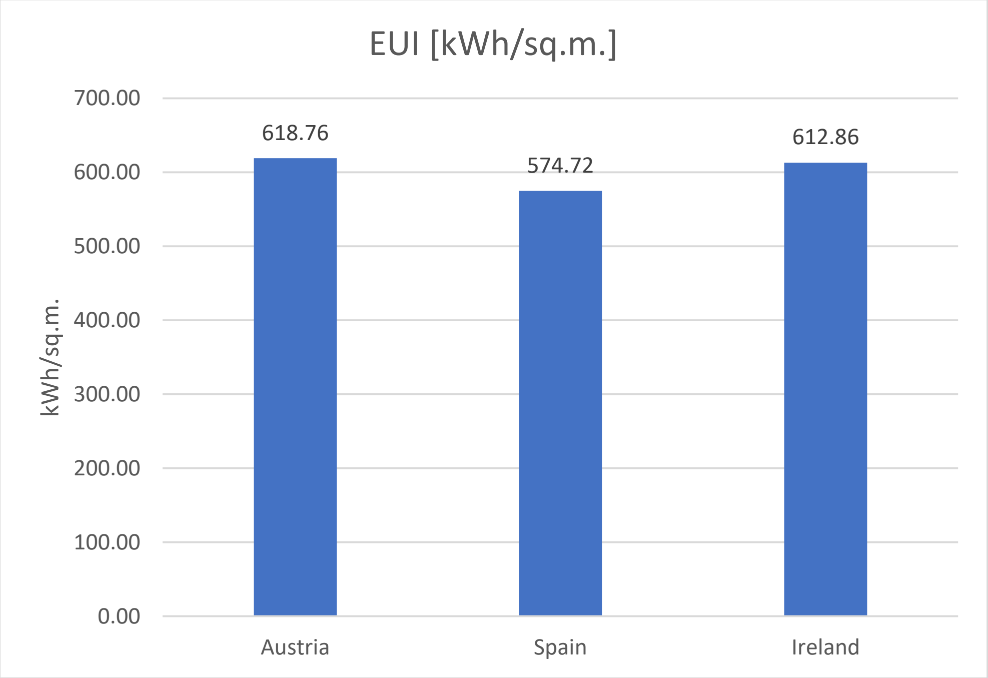


Figure 5: Annual Energy Use Intensity of Hospital

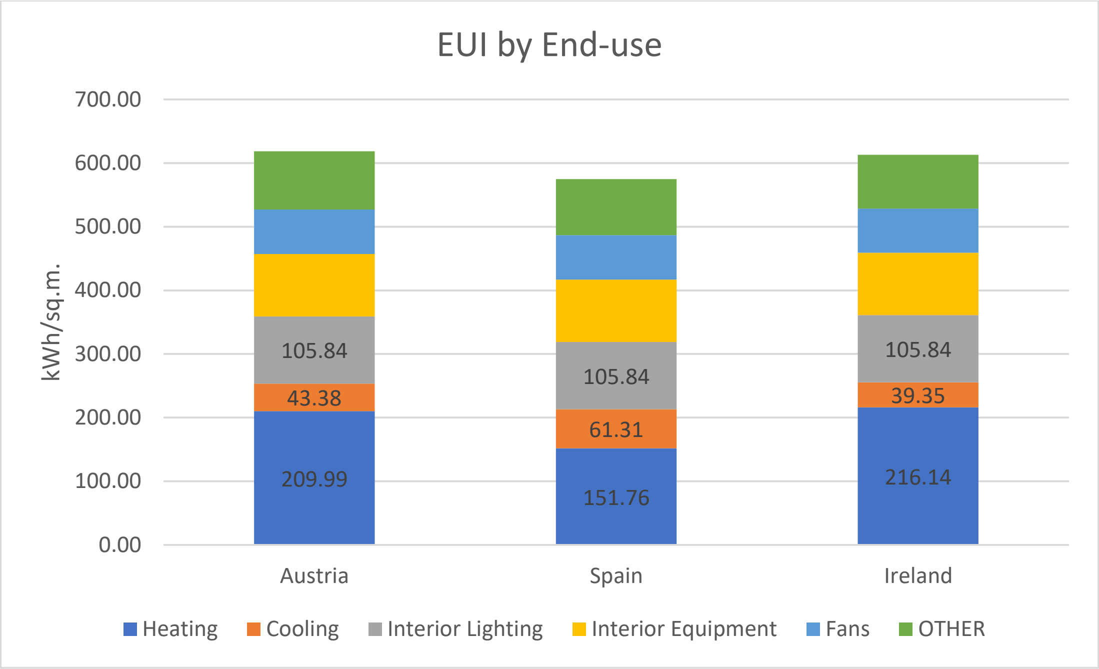


Figure 6: EUI of Hospital by End-Use

4.2.2.3 Large Office archetype model

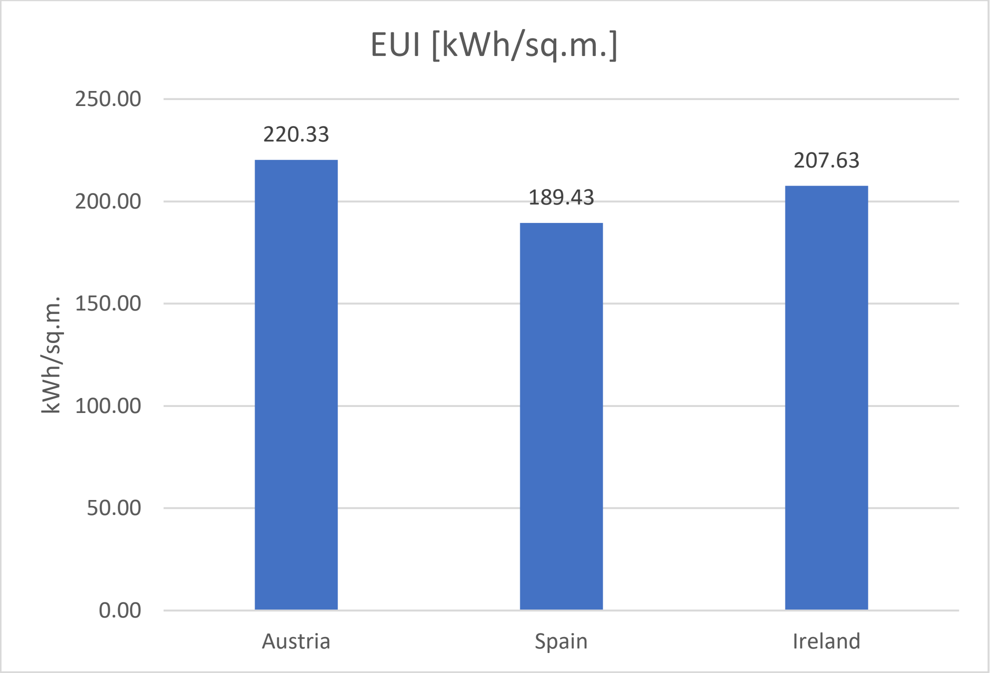


Figure 7: Annual Energy Use Intensity of Large Office

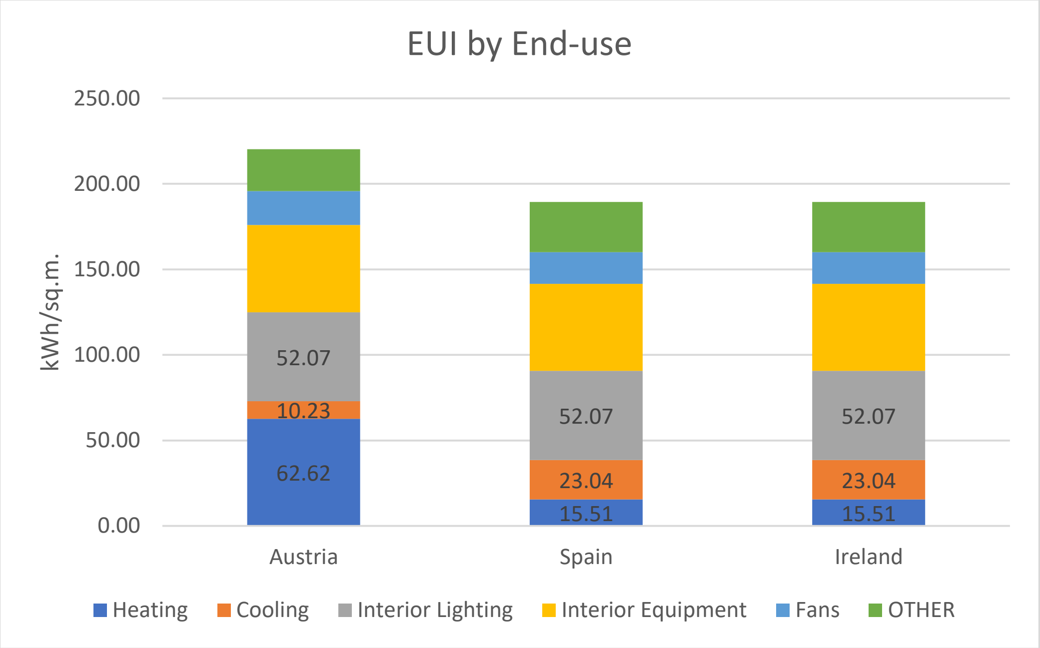


Figure 8: EUI of Large Office by End-Use

4.2.3 BAU

The Business-as-usual case represents a typical retrofit in a commercial building, including high return of investment energy measures such as upgrading lighting and plant equipment and their control. In this case, the buildings were upgraded with higher efficiency chillers, expert commissioning is performed on central boilers assuming a gain of 5% in energy efficiency and lighting was upgraded to LED technology.

Overall annual E.U.I. and E.U.I. by end-use as well as consumption reduction of the energy measures applied are shown to represent the improvement of the retrofit performed on the baseline case (vs. BAU case). These results are also shown for the three different chosen climates.

4.2.3.1 Large Hotel archetype model

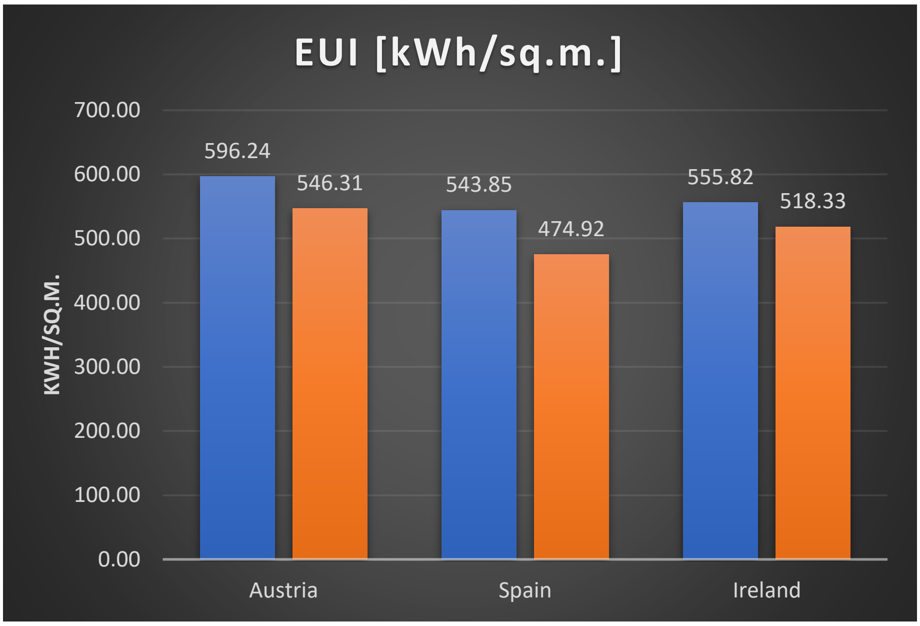


Figure 9: EUI before and after Implementation of Energy Efficiency Measures (Large Hotels)

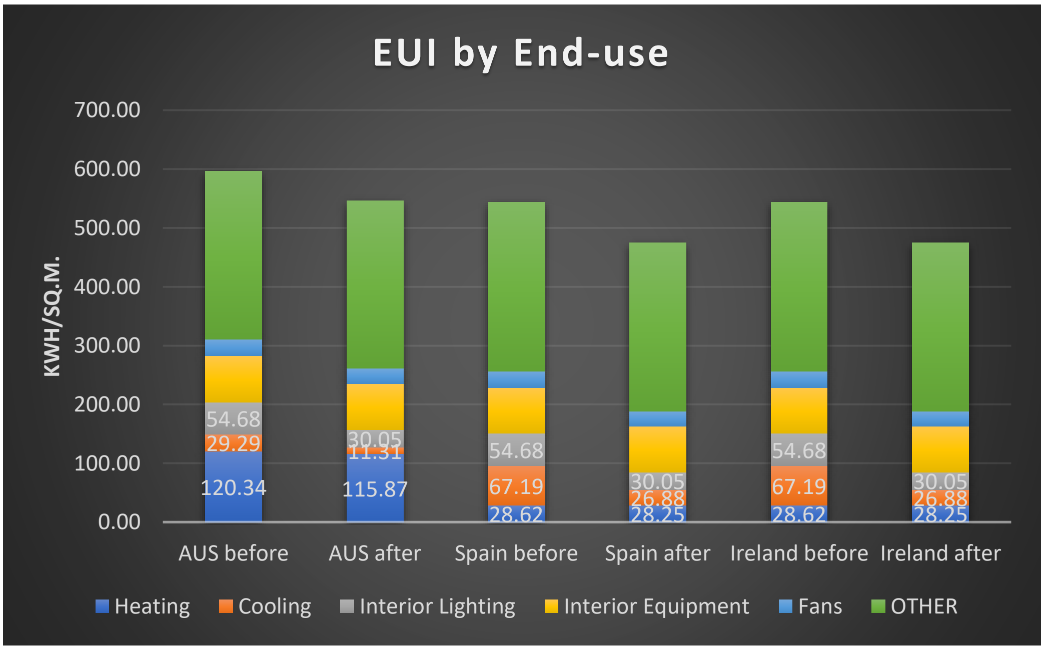


Figure 10: EUI by End-use before and after Implementation of Energy Efficiency Measures (Large Hotels)

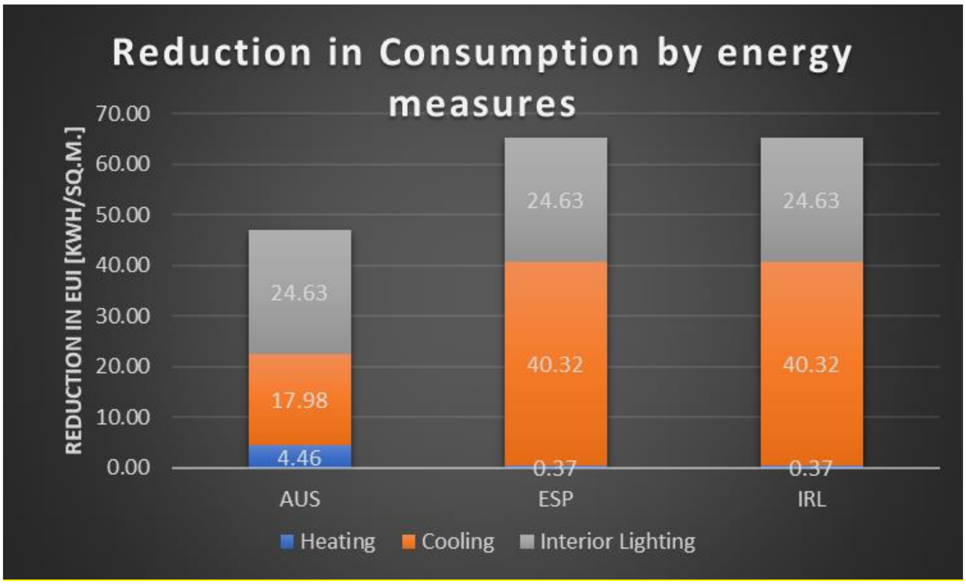


Figure 11: Reduction in Energy Consumption (Large Hotels)

4.2.3.2 Hospital archetype model

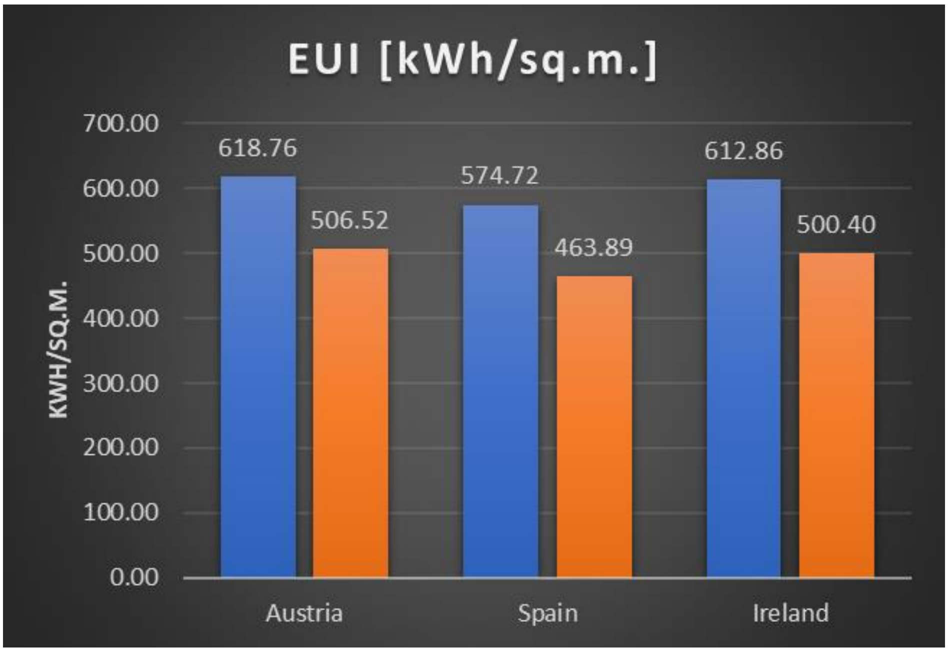


Figure 12: EUI before and after Implementation of Energy Efficiency Measures (Hospitals)

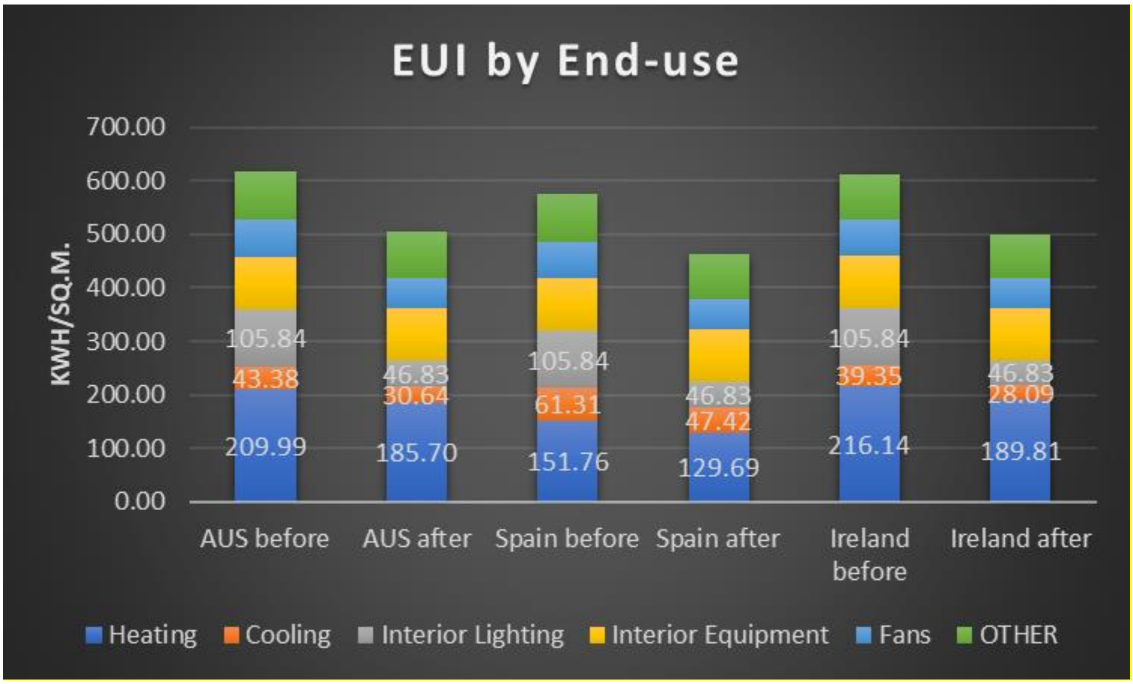


Figure 13: EUI by End-use before and after Implementation of Energy Efficiency Measures (Hospitals)

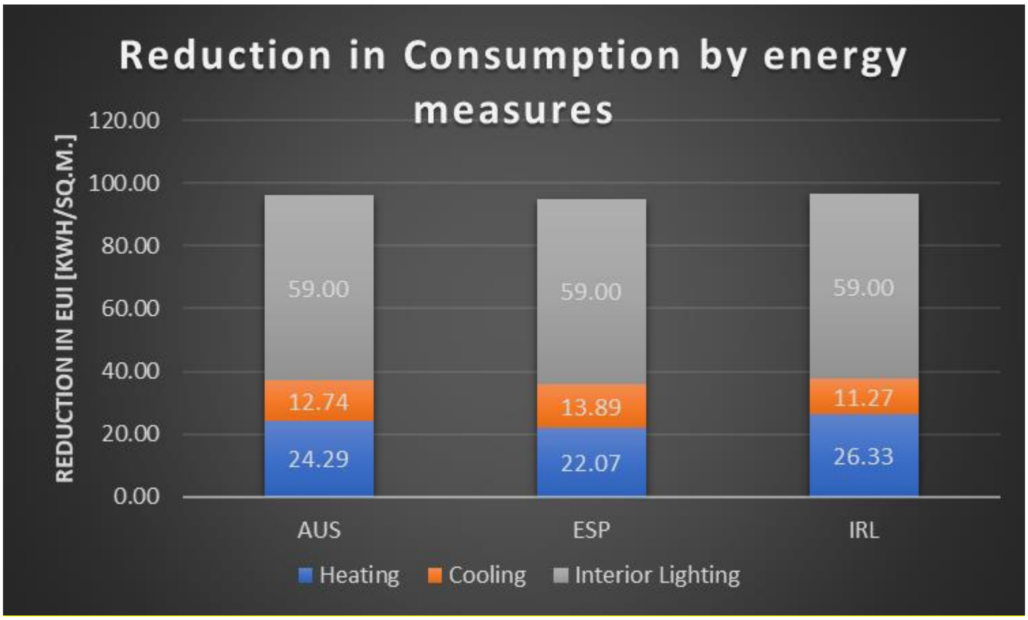


Figure 14: Reduction in Energy Consumption (Hospitals)

4.2.3.3 Large Office archetype model

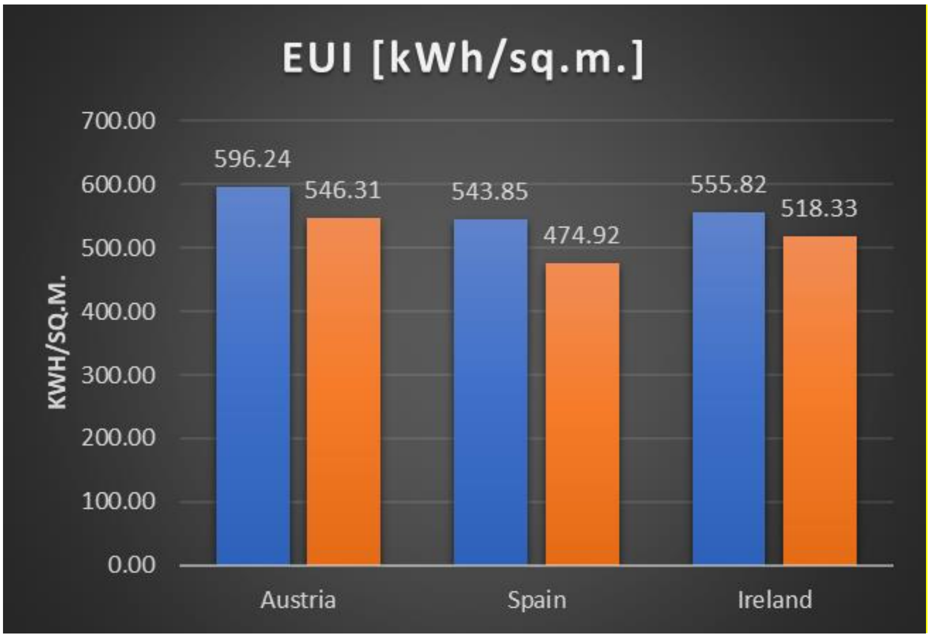


Figure 15: EUI before and after Implementation of Energy Efficiency Measures (Large Offices)

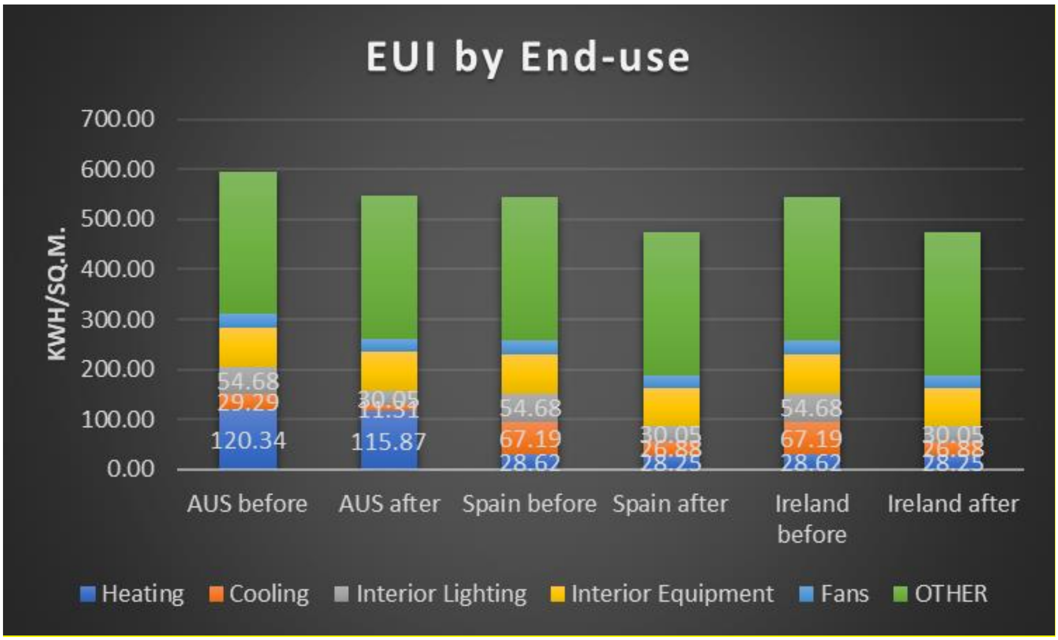


Figure 16: EUI by End-use before and after Implementation of Energy Efficiency Measures (Large Offices)

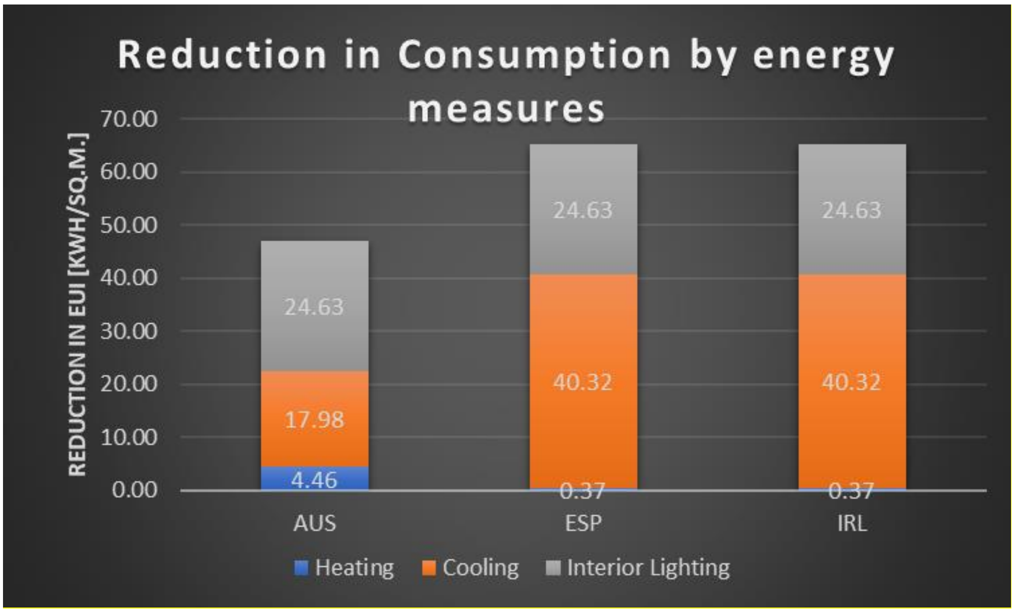


Figure 17: Reduction in Energy Consumption (Large Offices)

4.2.4 NOVICE Model

4.2.4.1 Thermal Comfort assessment under DR events

The NOVICE dual service model combines energy efficiency measures with demand response. Explicit demand response strategies such as turn-down events might reduce comfort conditions of the occupants. For this reason, an assessment of thermal comfort under the assumptions of the scenarios described in section 3 for the archetypes building is presented here.

The range of temperatures obtained in summer-day (worst-case) simulations for the three selected locations and for DR event durations of 15 minutes, 30 minutes, 1 hour and 2 hours are compared against the indoor set point temperature in hours of occupancy.

4.2.4.1.1 Hospital archetype

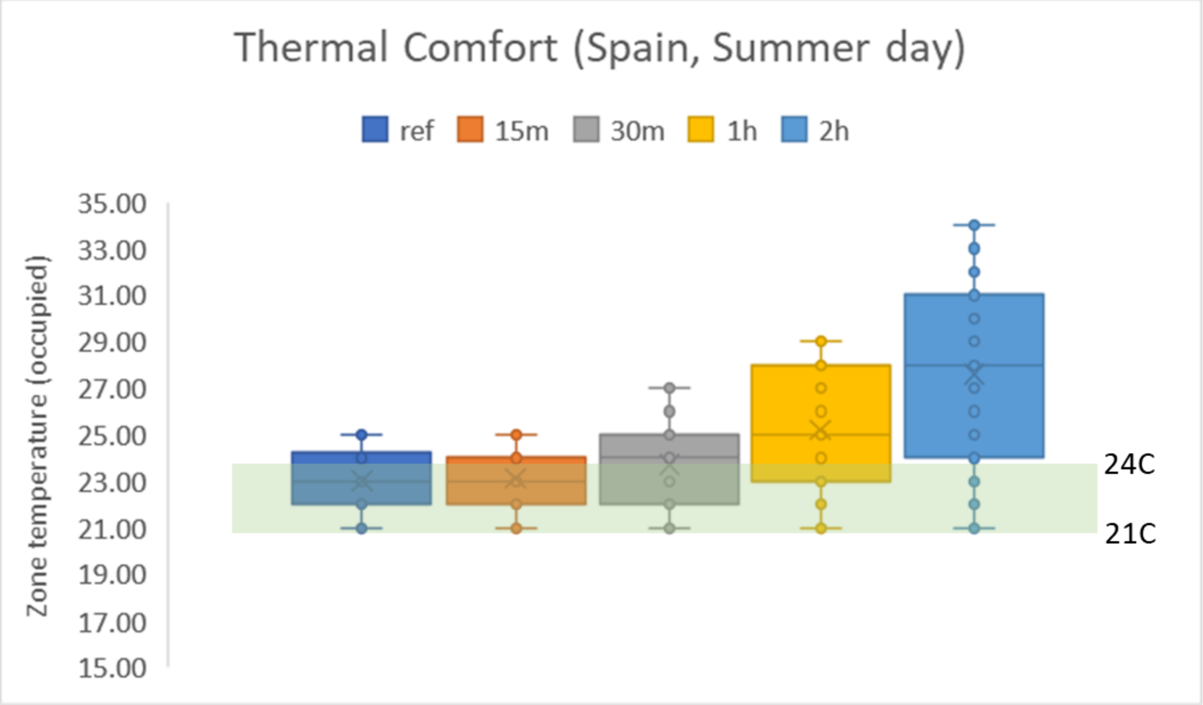


Figure 18: Thermal Comfort in Hospital (Spain, Summer Season)

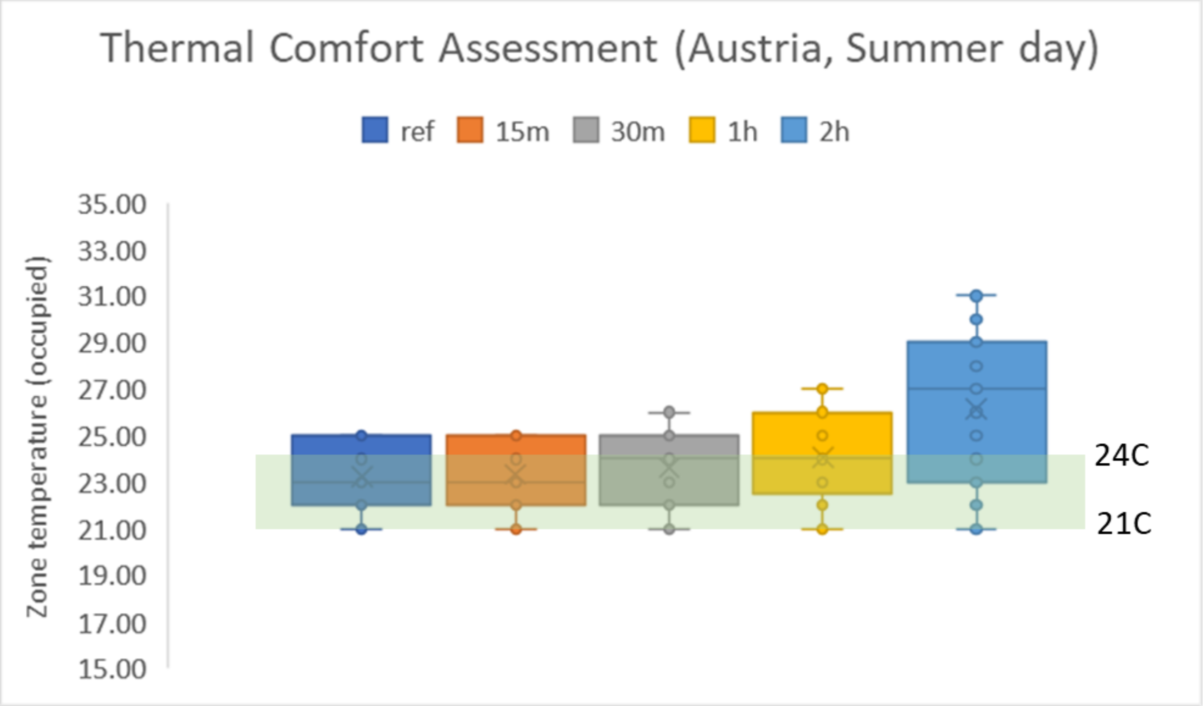


Figure 19: Thermal Comfort in Hospital (Austria, Summer Season)

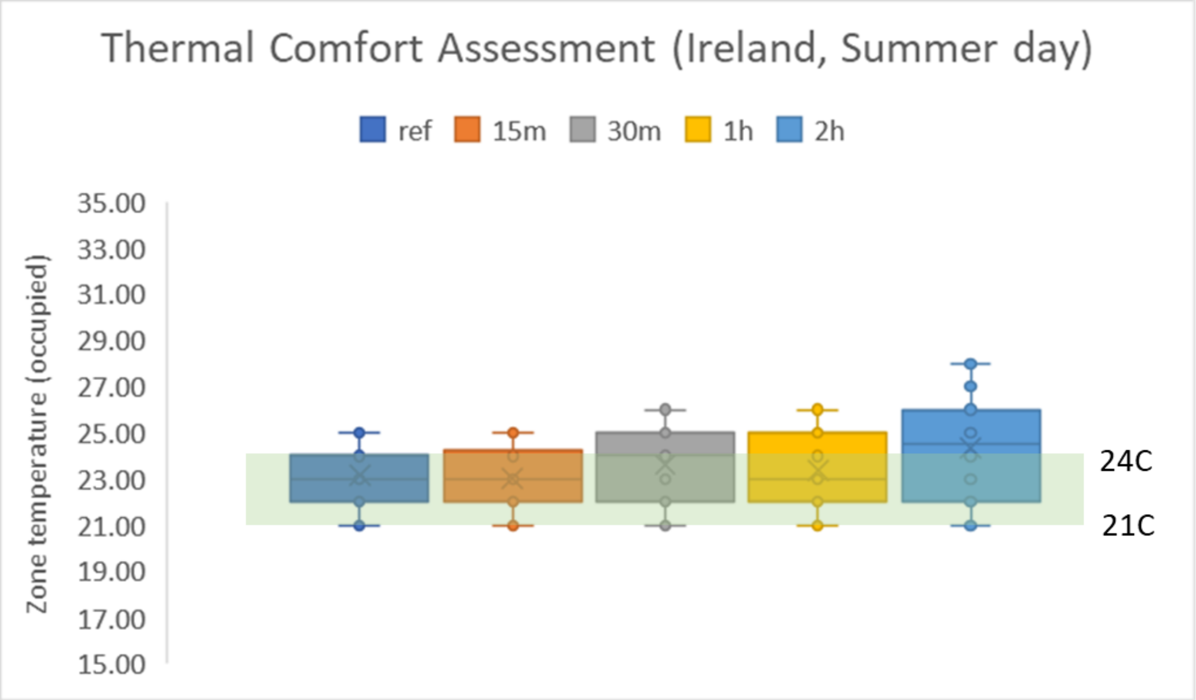


Figure 20: Thermal Comfort in Hospital (Ireland, Summer Season)

The results show that DR events of durations of 30 minutes or less are within thermal comfort boundaries. They also show that for the climatic conditions of Dublin (Ireland) an event of up to one hour would also be possible since indoor temperature can be maintained approximately 85% of the time within comfort boundaries (21 to 24° C). For both the Austria and the Spain cases DR events of one hour and longer would significantly impact comfort conditions of occupants.

4.2.4.1.2 Office archetype

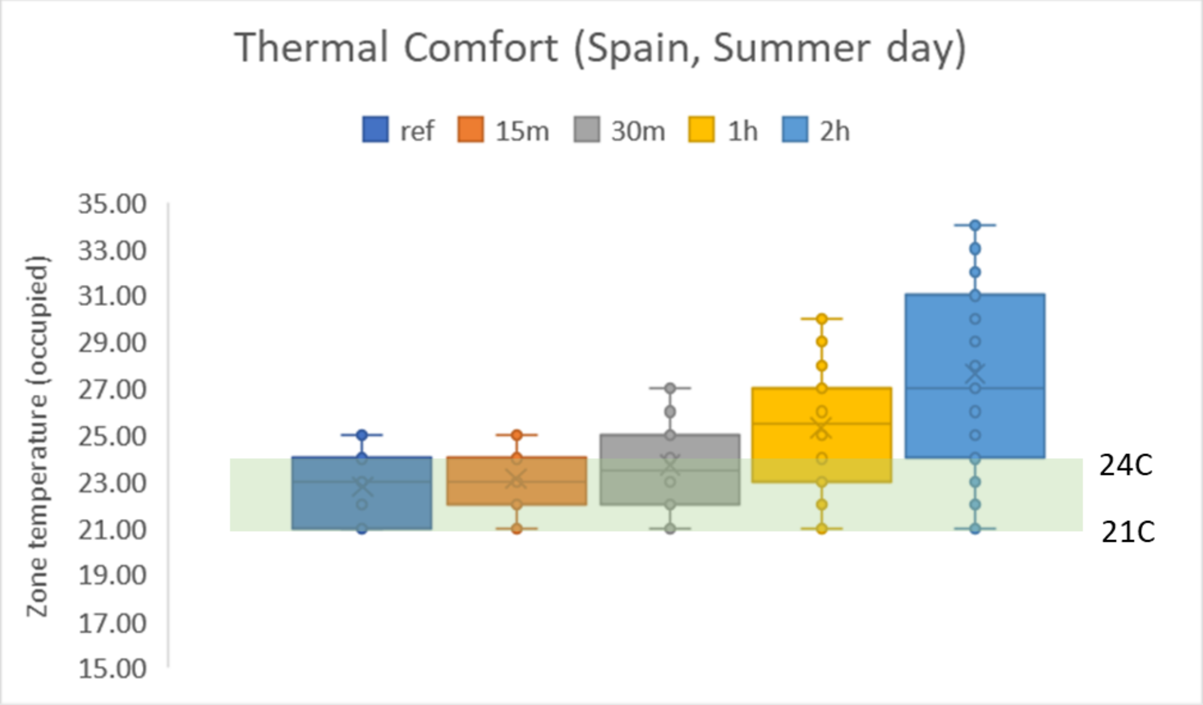


Figure 21: Thermal Comfort in Office (Spain, Summer Season)

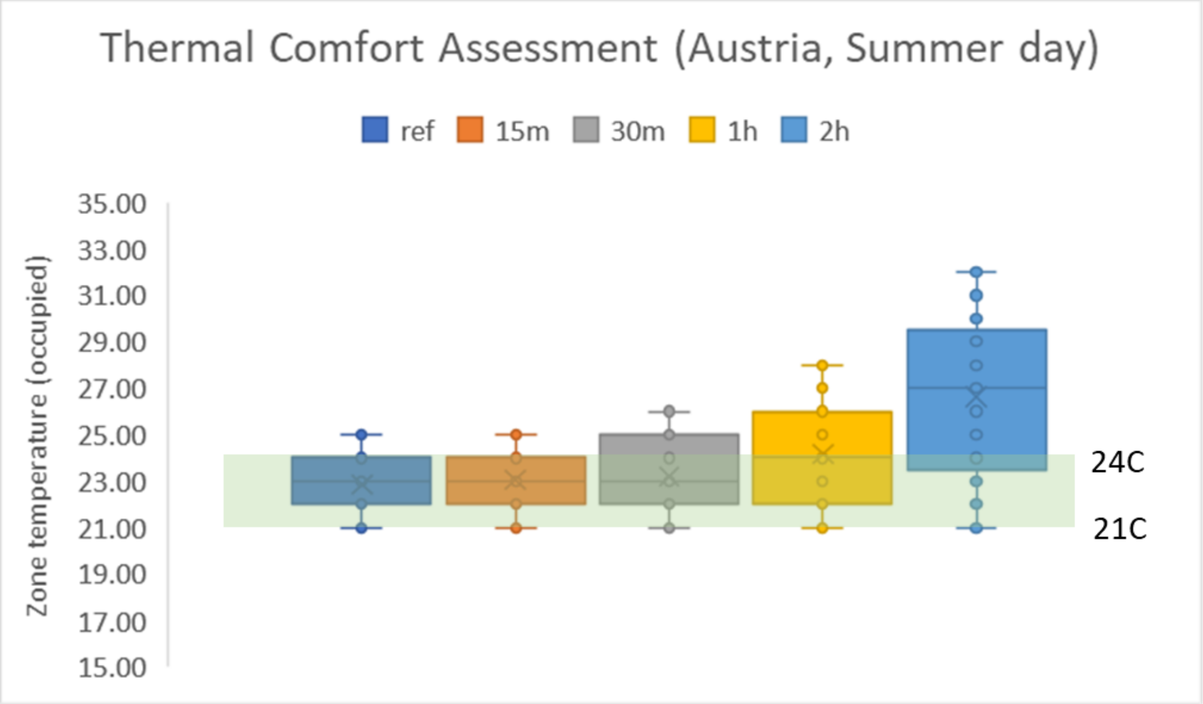


Figure 22: Thermal Comfort in Office (Austria, Summer Season)

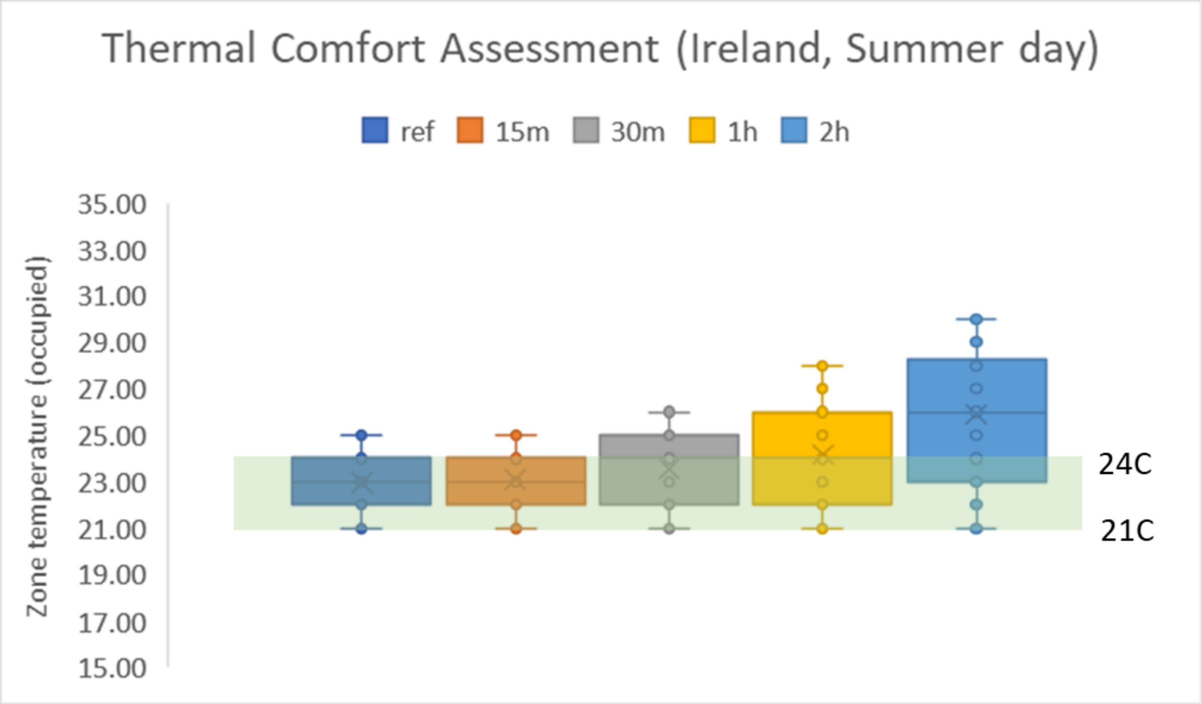


Figure 23: Thermal Comfort in Office (Ireland, Summer Season)

The results show that DR events of durations of 30 minutes or less are within thermal comfort boundaries, although this is not valid for meeting rooms where generally high internal loads are present.

4.2.4.1.3 Hotel archetype

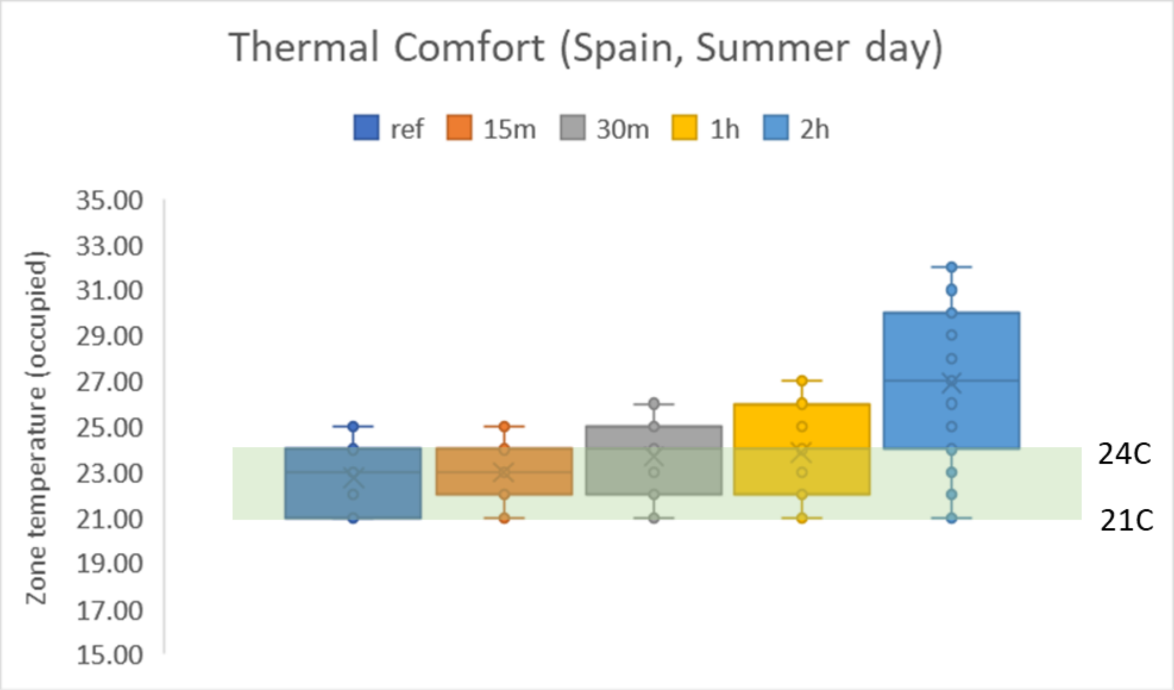


Figure 24: Thermal Comfort in Hotel (Spain, Summer Season)

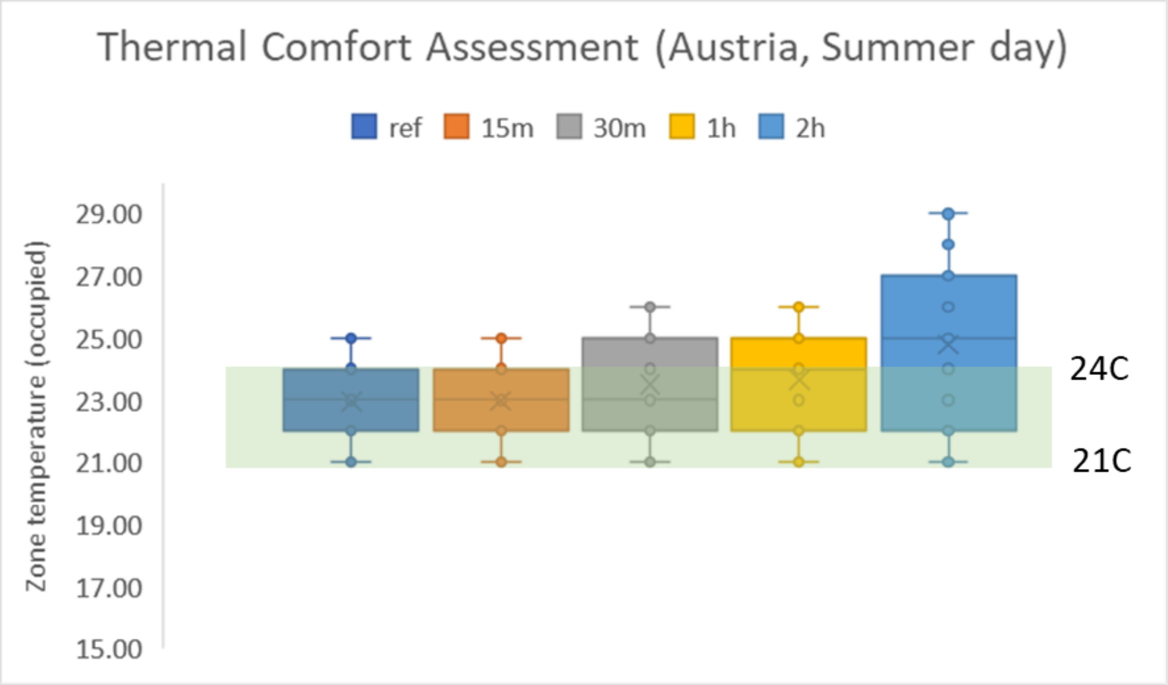


Figure 25: Thermal Comfort in Hotel (Austria, Summer Season)

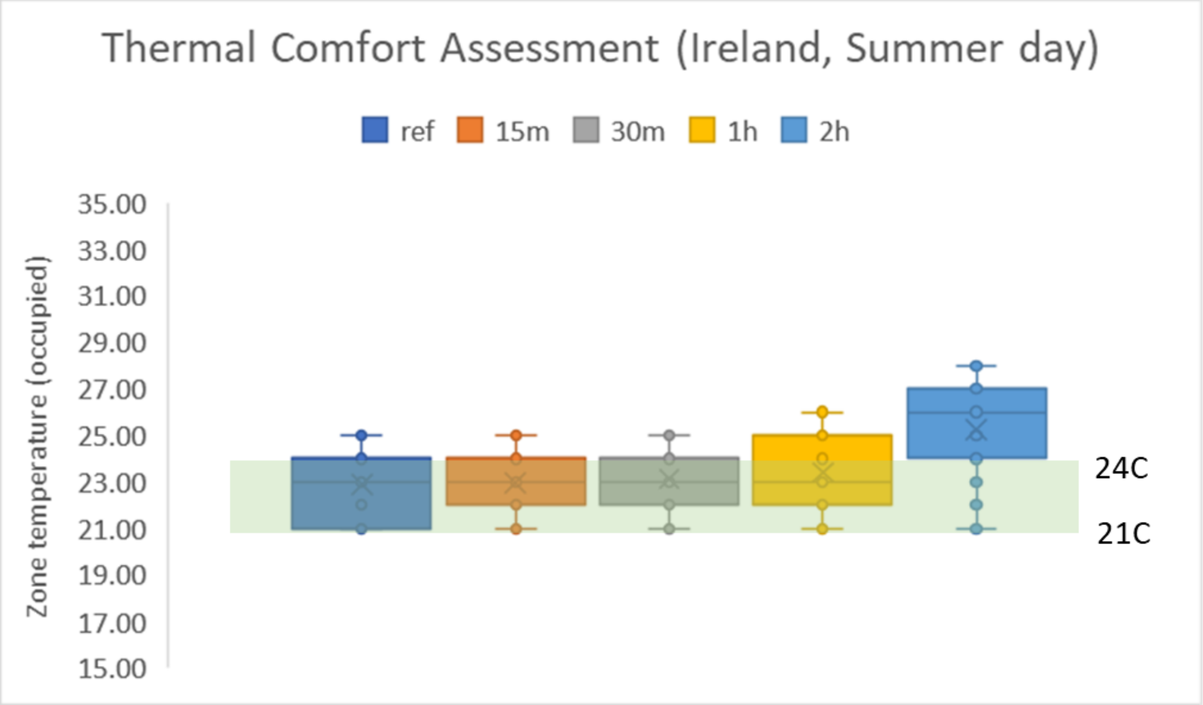


Figure 26: Thermal Comfort in Hotel (Ireland, Summer Season)

The results show that DR events of durations of 30 minutes or less are within thermal comfort boundaries. They also show that for the climatic conditions of Dublin (Ireland) and Vienna (Austria) events of up to one hour would also be possible since indoor temperature can be maintained approximately 85% of the time within comfort boundaries (21 to 24° Celsius). Here the occupancy profile of hotels, generally low in the hottest hours plays a role. DR events longer than one hour and 30 minutes for the case of Valencia (Spain) would significantly impact comfort conditions of the occupants.

5 REVENUE STREAMS AND COSTS OF THE NOVICE DUAL SERVICE

Revenue streams are generated from two sources in NOVICE dual service projects, (1) from energy cost savings resulting from the implementation of energy efficiency measures, and (2) from offering flexibility services to the corresponding markets. Both revenue flows are closely interrelated as there is a trade-off between flexibility and energy efficiency. In general, flexibility requires a technical unit combined with a storage (heat, cold, electricity, air, material stock etc.) with the ability to regulate the power consumption. Without a storage, any change in the power consumption would immediately lead to changes in comfort parameters or would directly affect production processes (in the case of industry). It is of utmost relevance that all storage processes have losses, without any exception. In theory, these losses have to be compensated by an increased energy consumption thus contradicting energy efficiency. This means that in the case that comfort parameters or process quality has to remain unchanged, flexibility leads to a reduction of energy efficiency. In other words: Optimal energy efficient buildings (or systems) cannot offer any flexibility without negatively affecting comfort or system parameters or without decreasing energy efficiency. However, in practice energy efficiency projects in EPC have some range of security concerning comfort or system parameters and energy efficiency level is related to the efforts from the ESCO. Hence, EPC projects result in energy efficient buildings and systems with a reliable economic performance that still have some room for further improvements or (short term) adjustments of comfort and system parameters that are in the range of guaranteed operation and where complaints from users or inhabitants do not exceed a certain - and accepted - level. In the modelling of the archetypes we rely on this range of tolerance.

5.1 REVENUE STREAMS FROM IMPROVED ENERGY EFFICIENCY

The first revenue stream stems from reduced energy costs resulting from the implementation of energy efficiency measures. One of the main challenges with revenue streams from energy savings is, that savings cannot be measured directly but rather have to be calculated against a predefined baseline. This baseline is crucial for a correct (i.e. accepted and agreed by both the client and the ESCO) calculation of energy savings revenue. For the calculation of the baseline and energy savings, international standards like IPMVP (International Performance Measurement and Verification Protocol, M&V; ISO 50 006 Energy Management - Measuring Energy Performance) are available and widely applied.

5.2 REVENUE STREAMS FOR FLEXIBILITY MARKETS

Flexibility can be defined as the ability to reduce (or increase) loads as a result of external signals (query, price etc.). There are different markets for flexibility in Europe, however, for the NOVICE dual services explicit demand response was selected as the most promising approach. More specifically, secondary control (aFRR) (including specific similar - but differently named - products on certain national markets) will be considered in the revenue stream modelling. It is not considered here that in some countries, flexibility can be offered to different markets simultaneously, this could further increase revenues but is limited to specific markets.

Revenues in control markets (ancillary services, reserve capacity market) typically consist of two main elements: (1) revenues from offered flexible power (availability) during a certain period of time and (2) revenues from actual load reduction (in the case of positive control energy; activation). Similar to energy savings calculations, it is necessary to define a baseline against which power reduction can be calculated. This is not only relevant for the correct calculation of revenues from control market but also compensation of the energy provider or the affected balancing responsible party. Methodology of M&V, however, has to be distinguished from energy efficiency savings calculations even though terms and approach are similar. The main question for M&V in flexibility is: What would have been the energy consumption in the case that no demand response event happened. This is important not only for financial compensation of the parties involved but also for avoiding counterbalancing by the balancing responsible party of the energy supplier.

5.3 MODELLING REVENUE STREAMS

5.3.1 Revenue streams from NOVICE dual service

Revenue stream from the NOVICE dual service (R_{NOV}) consist of revenue streams from energy efficiency (R_{EE}) and revenue streams from flexibility (R_{Flex}). As described above, these two revenue streams are not fully independent, flexibility events may lead to the so-called rebound effect that has to be considered as well. The rebound effect will be included in the calculation of the revenue streams from the flexibility.

$$R_{NOV} = R_{EE} + R_{Flex} \qquad [1]$$

Result of the calculation are the annual revenues in EURO.

5.3.2 Revenue stream from energy efficiency

Energy savings cannot be measured! According to international standards like IPMVP or ISO 50006, energy savings calculations require the definition of a baseline which has to be agreed between the ESCO and the client and against which the energy savings are calculated. For both, the energy costs of the agreed baseline ($EC_{Baseline}$) and the energy costs of the energy efficiency project (EC_{EE}) have to be calculated. Calculation of energy costs have to consider fixed parts (Fix) and variable parts (Var).

$$R_{EE} = EC_{Baseline} - EC_{EE} \qquad [2]$$

$$EC_{Baseline} = EC_{BaselineFix} + EC_{BaselineVar} \qquad [2\text{-}1]$$

$$EC_{EE} = EC_{EEFix} + EC_{EEVar} \qquad [2\text{-}2]$$

Result of the calculation are the annual revenues of the energy efficiency project in EURO without considering any flexibility. For the calculations in this report, we assume similar fixed energy costs for both baseline and energy efficiency project, only variable parts are considered for the revenue calculation.

5.3.3 Revenue stream from flexibility

For NOVICE, it was decided to focus on explicit demand response, i.e. directly rewarding availability and activation of electric loads. It was further decided to offer the flexibility on the ancillary service (control energy) market, particularly on the secondary control energy market. Products for these markets are available in most European countries, however, differing in tendering, detail product definition and market access. Revenues from these markets typically come from the availability of switchable loads (flexible power, R_{FlexP}) and from revenues for activation of the load (R_{FlexA}).

$$R_{Flex} = R_{FLexP} + R_{FlexA} \qquad [3]$$

Prices for availability (P_{FlexP}) as well as prices for activation of the power (P_{FlexA}) are results of the tendering process taking place daily, weekly, monthly or annually, depending on the respective country, market and product. Price is typically defined by the merit order resulting in large variations. However, for the calculation of the revenues average prices for certain products (time slices) for the winter, shoulder and summer season are applied here. Beside the variability in prices, revenues largely depend on success of offers and number of activations. In the NOVICE revenue calculation model this is implemented with two parameters:

(1) Probability of successful tenders which is mainly depending on the offered price for power availability (EUR per MW*h) in relation to the awarded price. Revenues are paid for the whole period (time slice) of the offered availability. For NOVICE, this holds true for the aggregator which offers (aggregated) flexibility to the market. Buildings represented by archetypes can offer only a part of the necessary flexibility (e.g. 1 hour instead of 4 hours). This has to be considered in the revenue calculation.

(2) Probability and duration of activation of flexibility, depending on the offered activation price (EUR per kWh) and requests resulting from grid balancing needs. Activation will only be requested for successful offers for the availability. In some markets, offers for price can be adjusted in short term previously to the activation period (time slice). From all successful tenders, only the ones with the best offer for activation will be requested by the tendering entity (TSO, transmission system operator; CAM, control area manager).

Revenues from the availability are calculated with the following formula:

$$R_{FlexP} = \sum[P_{FLexP,ts,s} * t_{FlexP,ts,s} * n_{FlexP,ts,s}) \qquad [3\text{-}1]$$

$$n_{FlexP,ts,s} = n_{OffersP,ts,s} * p_{SuccessP,ts,s} \qquad [3\text{-}2]$$

where:

$P_{FLexP,ts,s}$ ... (average successful) bid price for power availability per time slice (ts) and season (s) [EUR per MW*h]

$t_{FlexP,ts,s}$ ... availability period (e.g. 1 hour) per time slice (ts) and season (s)

$n_{FlexP,t,s}$ ... number of successful offers for power availability per time slice (ts) and season (s)

$n_{OffersP,t,s}$ ... number of offers for power availability per time slice (ts) and season (s)

$p_{SuccessP,t,s}$ ... probability for successful offers per time slice (ts) and season (s)

s ... season (winter, shoulder, summer)

Revenues from activation of flexible loads are calculated with the following formula:

$R_{FlexA} = \sum[P_{FLexA,ts,s} * t_{FlexA,ts,s} * n_{FlexA,ts,s})$ [3-3]

$n_{FlexA,ts,s} = n_{OffersP,ts,s} * p_{SuccessA,ts,s}$ [3-4]

where:

$P_{FLexA,ts,s}$ ... (average successful) bid price for activation of energy per time slice (ts) and season (s) [EUR per kWh]

$t_{FlexA,ts,s}$ ... (average) activation time (e.g. 0,5 hours) per time slice (ts) and season (s)

$n_{FlexA,ts,s}$ ... number of successful offers for activation per time slice (ts) and season (s)

$n_{OffersP,ts,s}$ ... number of offers for power availability (= numbers of offers for activation) per time slice (ts) and season (s)

$p_{SuccessA,ts,s}$ ... probability for activation per time slice (ts) and season (s)

with: $p_{SuccessA,ts,s} < p_{SuccessP,t,s}$

5.3.4 Rebound effect

Within the context of demand response, the rebound effect can be defined as an increase of the energy consumption, or peak load, due to the shift of energy from high price periods to low price periods. Increase of consumption may be a result of the behaviour of the building energy management system (BEMS) or could stem simply from losses in the storage system. For NOVICE rebound effect is estimated by comparing energy consumption profiles with and without DR events for a certain period after the demand response event. The economic value of the rebound effect is calculated with the energy supply tariff.

There are 3 different cases:

- DR event is a single event without any overshoots after termination, no rebound effect, additional energy savings;
- DR event leads to compensation after termination or at a later stage, no rebound effect, no energy savings;
- DR events leads to compensation with overshoots and/or covering of losses, rebound effect.

In all cases the supplier bills the baseline consumption, hence, there is no change of energy supply costs. Rebound effect has to be compensated by the DR aggregator.

Revenues from DR have to cover the rebound effect.

5.4 ENERGY TARIFFS AND MODELLING DATA

5.4.1 Electricity prices and DR Tariffs

Energy tariffs were taken from EUROSTAT reports. It was assumed that data represent the variable part of the tariffs. However, VAT and other recoverable taxes were excluded.

[EUR per kWh]	**Austria**	**Spain**	**Ireland**	**comment**
Hospital	0,1100	0,1000	0,1450	Band IB
Large Office	0,1100	0,1000	0,1450	Band IB
Hotel	0,1100	0,1000	0,1450	Band IB

Table 5-1: Energy tariffs for calculation of revenues (Source: EUROSTAT 2019)

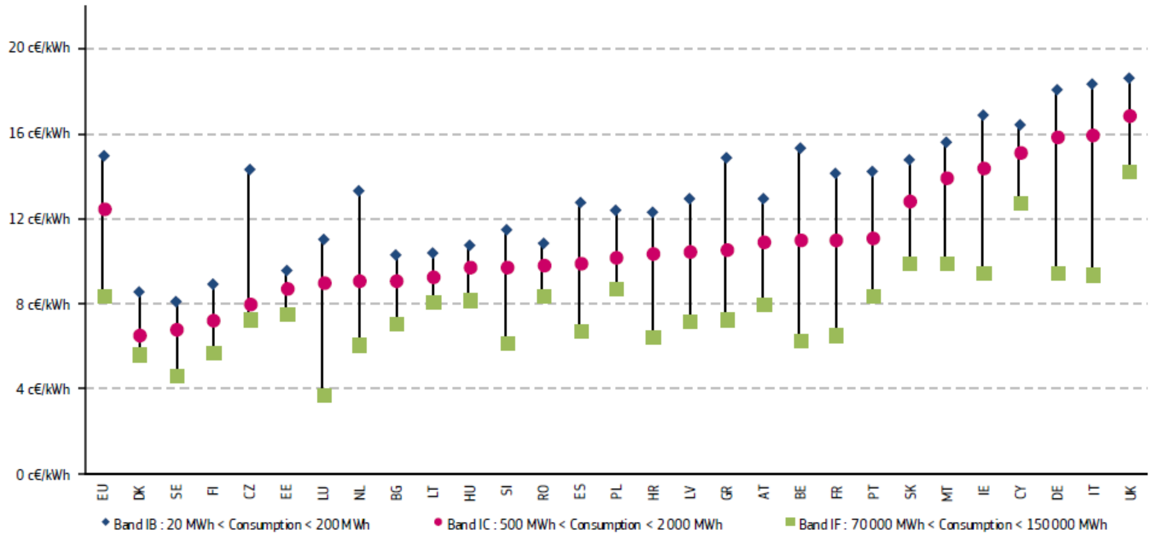


Figure 27: Electricity prices in Europe, September 2019, excluding VAT and recoverable taxes (Source: EUROSTAT 2019)

5.4.2 DR Market description (aFFR)

In this analysis, we selected the secondary control energy market (aFRR) for the modelling. This market typically has a significant share in terms of annual costs. Tertiary control energy market (mFRR, RR) has long been the main entrance market for demand response (DR), however, due to improvements in digitalisation and automation, the requirements of the secondary control market are no longer a barrier and is more appropriate for market entrance of demand response aggregation.

aFRR (secondary control energy market)	**Austria**	**Spain**	**Ireland**	
Price for offering capacity	0,00293	0,01275	0,00196	EUR per kW*h

Price for activation	0,12500	0,05750	-	EUR per kWh
	2018	2018	2018	

Table 5-2: Secondary control energy market prices

5.4.2.1 Spain

In Spain, secondary control energy is called “secondary regulation”. As an optional ancillary service, it is managed by competitive market mechanisms with the objective of maintaining the real-time generation-demand balance within the control block “Spain” [RED Electrica 2015] with a time horizon of 20 seconds to 15 minutes. Secondary regulation is provided by Regulation Areas (Control Zones). It is tendered daily for every hourly period of the next day, both upwards and downwards. Compensation is based on:

- Availability (secondary reserve)
- Usage/activation (secondary energy)

In 2018, secondary energy (upwards; shut down of loads) had a volume of 1.086 GWh and an average price of 57,5 EUR/MWh (maximum: 180,3 EUR/MWh).

An average of 616 MW of positive secondary reserve was requested in 2018 with an average price of 12,75 EUR/MW (maximum: 100 EUR/MW).

5.4.2.2 Austria

Control energy is tendered daily in Austria by Austrian Power Grid (APG). Prequalification and tender details vary between different types of control energy products (primary, secondary and tertiary control energy). For secondary control energy, 200 MW (either positive and negative) are required and tendered daily. Minimum offer for the first offer is 1 MW, following offers need a size of at least 5 MW. Offers do not have to be symmetrically, i.e. offers do not have to include switch-on and switch-off events simultaneously. All offers have to include a price for the power (EUR per MW per h) and a price for activation of the energy (EUR per MWh). Offers are selected along the price for power and rewarded on a pay-as-bid basis. Activation is based on the energy prices of the selected offers.

Austrian control area manager (Austrian Power Grid, APG) publishes summary data of control energy market regularly.

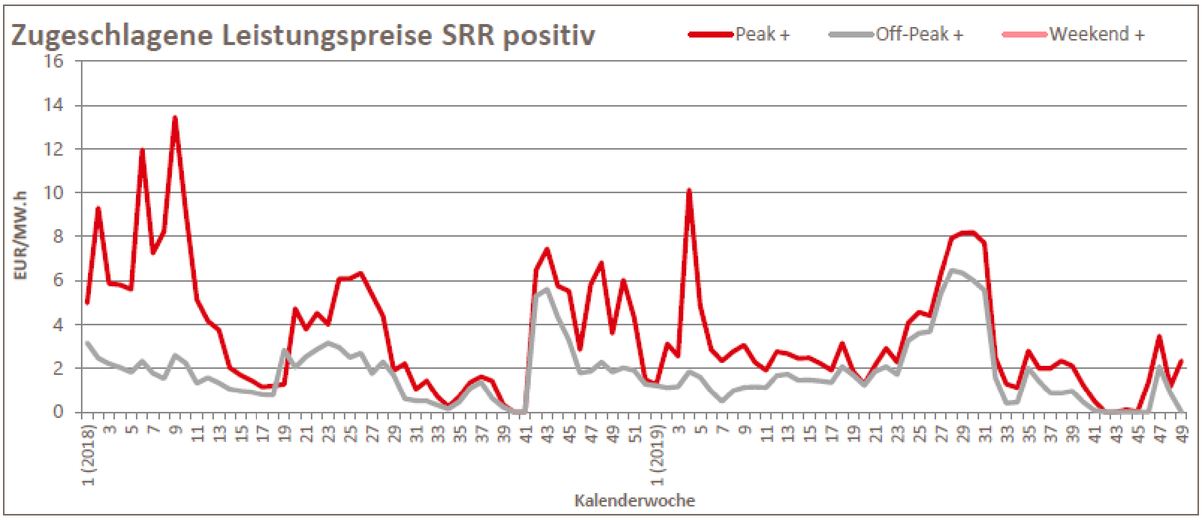
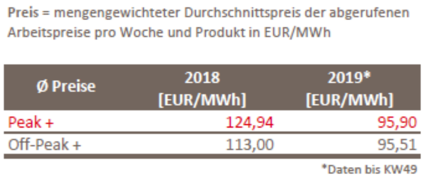


Figure 28: Accepted prices for power for positive secondary control reserves (Source: APG 2020)



Preis = mengengewichteter Durchschnittspreis der abgerufenen Arbeitspreise pro Woche und Produkt in EUR/MWh

Ø Preise	2018 [EUR/MWh]	2019* [EUR/MWh]
Peak +	124,94	95,90
Off-Peak +	113,00	95,51

*Daten bis KW49

Table 5-3: Weighted prices for activation of positive secondary control energy (Source: APG 2020)

The average weighted price for activated positive secondary control energy (= shutdown of loads) for peak times 2018 was 124,94 EUR per MWh (maximum: 450 EUR per MWh).

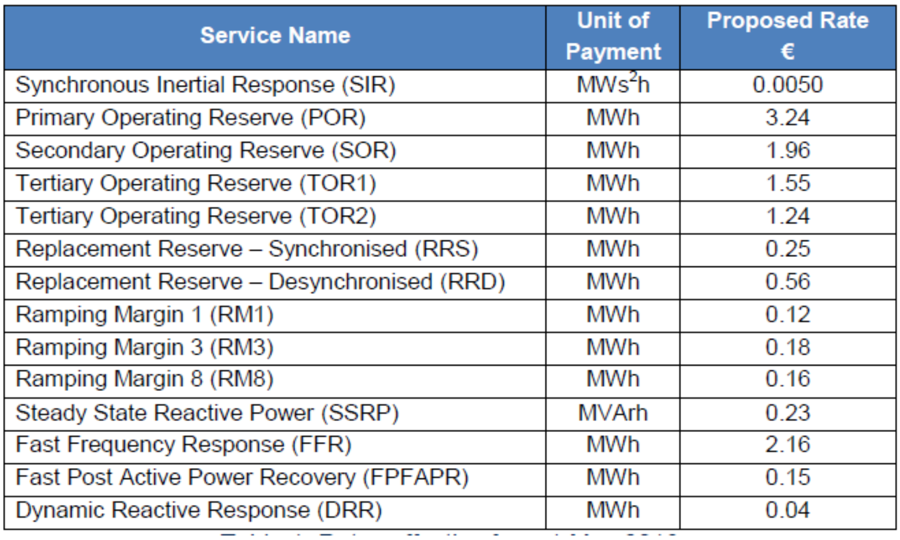
5.4.2.3 Ireland

In DS3 System Service Fixed Contract Agreement (2019) and the DS3 System Services Statement of Payments (applicable from 1 May 2018) Secondary Operating Reserve (SOR) is described in detail.

Payments for SOR are based on the available SOR volume (MW):

SOR Trading Period Payment [EUR] = SOR Available Volume [MW] x SOR Payment Rate [EUR/MWh] x SOR Scaling Factor [1] X Trading Period Duration [h]

Hence, in Ireland there is no payment for activation.



Service Name	Unit of Payment	Proposed Rate €
Synchronous Inertial Response (SIR)	MWs^2h	0.0050
Primary Operating Reserve (POR)	MWh	3.24
Secondary Operating Reserve (SOR)	MWh	1.96
Tertiary Operating Reserve (TOR1)	MWh	1.55
Tertiary Operating Reserve (TOR2)	MWh	1.24
Replacement Reserve – Synchronised (RRS)	MWh	0.25
Replacement Reserve – Desynchronised (RRD)	MWh	0.56
Ramping Margin 1 (RM1)	MWh	0.12
Ramping Margin 3 (RM3)	MWh	0.18
Ramping Margin 8 (RM8)	MWh	0.16
Steady State Reactive Power (SSRP)	MVArh	0.23
Fast Frequency Response (FFR)	MWh	2.16
Fast Post Active Power Recovery (FPFAPR)	MWh	0.15
Dynamic Reactive Response (DRR)	MWh	0.04

Table 5-4: Tariffs for ancillary services in Ireland (Source: EIRGRID plc 2019)

5.5 COST ESTIMATIONS FOR DR

According to Leutgöb et al. 2019 the following cost elements have to be considered for Demand Response:

- **Assessment of DR potential of the client.** Assessment of the DR potential is crucial for any ESCO/aggregator as it is the main metric to decide on the profitability of offering flexibility (additional to energy efficiency). Potential depends on the type of building, HVAC equipment but also on the market. Potential can be high in markets where a few DR events with a very short duration occur and - for the same facility - may be insignificant for DR products with other requirements, e.g. long durations. Assessments may be built on experience (low costs) but could also rely on energy audits (medium costs) or modelling (high costs).

- **Contracting cost (between ESCO and client).** For the NOVICE dual service approach, additional contracting costs are considered rather small, as templates exist and EPC preparation include DR as one further aspect. Without standardized contractual agreements and procedures, this cost item could also be prohibitive.
- **Hardware cost.** For the NOVICE dual service only additional investments are considered. Necessary installations for the energy efficiency improvement can also be used for Demand Response. Hardware costs for Demand Response are dominated by measurement and control technologies as well as equipment for communication (including software). In general, investment costs for Demand Response are rather small compared to energy efficiency investments.
- **Operation and maintenance (O&M) cost.** This cost item includes costs for communication and remote operation between ESCO/aggregator and client as well as costs for trouble-shooting and helpdesk activities.
- **Measurement and verification (M&V) cost.** Explicit Demand Response requires M&V towards the electricity market. This requires certain investments in measurement equipment and data exchange has to be secured between client and ESCO/aggregator.

Reliable cost estimations for demand response are hard to find, especially for the case of non-industrial applications. There is no research available that provides a “unified, comparable metric for determining the short-term average cost for flexibility”. [Eid et al. 2019]

In a case study for the Netherlands, [Eid et al. 2019] different technologies/options for offering flexibility were assessed from the perspective of an aggregator. Upfront investments ranged from 1.500 to 2.500 EUR per kW for most technologies (storages etc.) to 200 EUR per kW for demand management. Based on 10 kW of switchable power, net present value (NPV) of demand management was calculated to be 2.810 EUR, only including investments and other costs on the side of the aggregator. Under the assumption that investment costs do not directly depend on the load switched, this fits to the range published for industrial loads [Kreuder et al. 2013]. The majority of respondents of this survey had investments in the range of 4.000 to 6.000 EUR (communication box: 3.000 EUR) while annual personnel costs were 2.000 to 5.000 EUR (Figure 29). Hence, a range of 2.000 to 5.000 EUR for upfront costs may serve as a good guess for feasibility assessments, annual personnel costs should be insignificant for service buildings. This also is in line with internal data at e7.

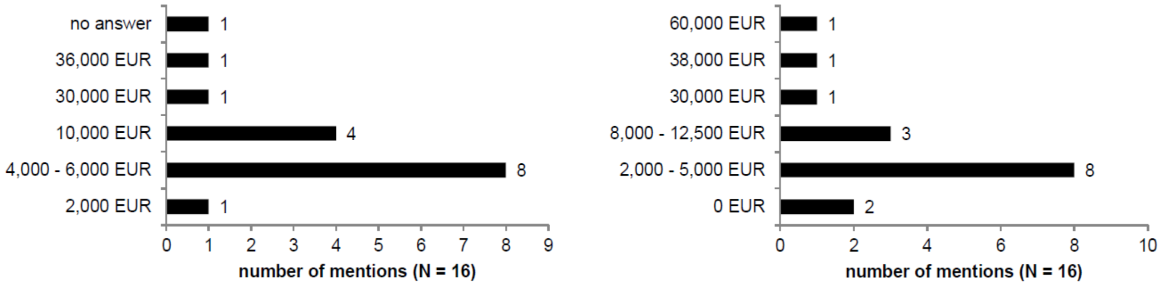


Figure 29: Investment costs and annual fixed costs (personnel costs) for industrial DR (Kreuder et al. 2013)

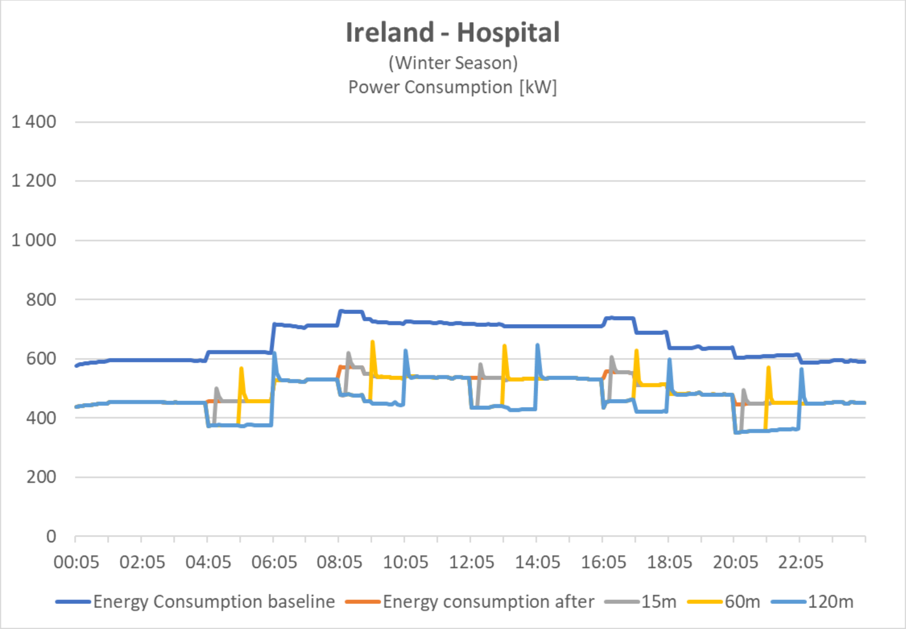
6 RESULTS FOR DIFFERENT DR MARKETS

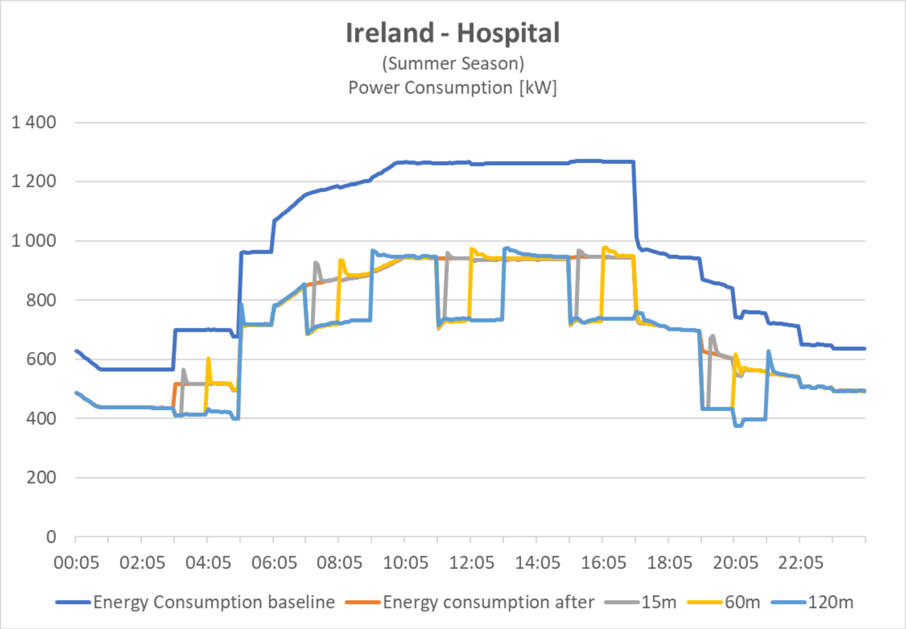
6.1 MAIN RESULTS

6.1.1 Energy Profiles and Switchable Loads

Energy profiles were modelled for all building types in different markets and climates. Only turn-down events (switch-off of chillers) were considered. This was done for 4, 8 and 12 a.m. as well as for 4 and 8 p.m. with a duration of 15 min, 1 hour and 2 hours. In order to consider different physical behaviour of the buildings during the year, modelling of Demand Response (DR) events was carried out for the winter, shoulder and summer season. Depending on the season and the duration of the DR event, switchable load was calculated. Additionally, rebound effect was estimated.

As an example, energy profiles of a hospital in Ireland are presented. Energy consumption is significantly larger in summer as are the switchable loads.





In the following tables average switchable loads are documented. It is obvious that loads depend on the type of building, season, climate (IRL, AUT, ESP), and time during the day. Except for hospitals, switchable loads (chillers) are only available during certain periods of time. E.g. hotels and offices have no or only limited potential for shut-down in winter and shoulder season.

6.1.1.1 Ireland

	Winter	Shoulder	Summer
Time	[kW]	[kW]	[kW]
04:00	81	100	99
08:00	92	100	148
12:00	100	99	204
16:00	94	100	210
20:00	92	103	175

Table 6-1: Switchable Loads in Hospital (IRL)

	Winter	Shoulder	Summer
Time	[kW]	[kW]	[kW]
04:00	0	12	0
08:00	0	12	19
12:00	0	12	*)
16:00	0	12	*)
20:00	0	0	18

*Table 6-2: Switchable Loads in Hotel (IRL, *) switch-off is overcompensated within switching period)*

	Winter	Shoulder	Summer
Time	[kW]	[kW]	[kW]
04:00	0	44	0
08:00	0	84	86
12:00	0	86	131
16:00	0	86	87
20:00	0	0	180

Table 6-3: Switchable Loads in Office (IRL): average switchable load (2 hours)

6.1.1.2 Spain

	Winter	Shoulder	Summer
Time	[kW]	[kW]	[kW]
04:00	80	97	189
08:00	79	95	235
12:00	104	125	312
16:00	104	112	313
20:00	101	110	246

Table 6-4: Switchable Loads in Hospital (ESP)

	Winter	Shoulder	Summer
Time	[kW]	[kW]	[kW]
04:00	0	0	16
08:00	0	4	8
12:00	18	3	109
16:00	18	*)	127
20:00	11	9	72

*Table 6-5: Switchable Loads in Hotel (ESP, *) switch-off is overcompensated)*

	Winter	Shoulder	Summer
Time	[kW]	[kW]	[kW]
04:00	0	2	*)
08:00	0	26	316
12:00	36	112	556
16:00	24	123	532
20:00	32	0	401

*Table 6-6: Switchable Loads in Office (ESP, *) switch-off is overcompensated)*

6.1.1.3 Austria

	Winter	Shoulder	Summer
Time	[kW]	[kW]	[kW]
04:00	65	74	117
08:00	74	76	183
12:00	84	90	258
16:00	82	96	244
20:00	77	91	175

Table 6-7: Switchable Loads in Hospital (AUT)

	Winter	Shoulder	Summer
Time	[kW]	[kW]	[kW]
04:00	0	0	25
08:00	0	0	*)
12:00	0	11	22
16:00	0	8	30
20:00	0	0	8

*Table 6-8: Switchable Loads in Hotel (AUT, *) switch-off is overcompensated)*

	Winter	Shoulder	Summer
Time	[kW]	[kW]	[kW]
04:00	0	0	*)
08:00	0	0	13
12:00	0	0	234
16:00	0	0	188
20:00	0	0	57

*Table 6-9: Switchable Loads in Office (AUT, *) switch-off is overcompensated)*

With a few exceptions, hotels do not have any significant loads (> 50 kW). Office buildings have a clear dependency on the climate and time during the day. Switchable loads are high between 8 a.m. and 8 p.m. (12 a.m. and 4 p.m.) in summer and - to a lower extent - in shoulder season and more or less insignificant in winter.

From a demand response perspective, only hospitals can offer a significant amount of switchable loads during the whole year with a range from approximately 70 to 300 kW.

6.1.2 Revenue Streams

Revenue streams for 2 hours shut down events were calculated based on the following assumptions:

Number of successful tenders:	**50%**
Share of activation (share of successful tenders with shut-down signal):	15%
Duration of activation (share of offered/max duration):	100%

Revenue Streams for Hospitals:

Hospital	**Austria**	**Spain**	**Ireland**	
Electricity consumption before upgrade	7 550 404	7 834 373	7 360 607	kWh
Electricity consumption after upgrade	5 662 270	5 932 155	5 493 872	kWh
Electricity savings	1 888 134	1 902 218	1 866 734	kWh
Revenues from electricity savings	**207 695**	**190 222**	**270 676**	**EUR**
Revenues from offering capacity	755	4 157	489	EUR
Revenues from activation	4 833	2 812	0	EUR
Costs for rebound effect	429	192	290	EUR
(Compensation costs)	(4 253)	(4 890)	(5 430)	EUR
Revenues from DR (excl. compensation costs)	**5 158**	**6 777**	**199**	**EUR**
Share of DR	2,5	3,6	0,1	%
Natural gas consumption before upgrade	6 252 989	4 946 500	6 391 039	kWh
Natural gas consumption after upgrade	5 707 983	4 451 406	5 800 342	kWh

Natural gas savings	545 006	495 094	590 697	kWh
Revenues from natural gas savings	**38 150**	**34 657**	**41 349**	**EUR**
Total revenues from energy savings	**245 845**	**224 879**	**312 025**	**EUR**

Table 6-10: Hospitals: Revenues from Energy Efficiency and Demand Response (2 hours shut down event)

Revenue Streams for Hotels:

Hotel	**Austria**	**Spain**	**Ireland**	
Electricity consumption before upgrade	2 030 227	2 451 220	1 844 609	kWh
Electricity consumption after upgrade	1 494 637	1 667 382	1 420 709	kWh
Electricity savings	535 589	783 838	423 900	kWh
Revenues from electricity savings	**58 915**	**78 384**	**61 465**	**EUR**
Revenues from offering capacity	37	530	19	EUR
Revenues from activation	235	359	0	EUR
Costs for rebound effect	225	240	91	EUR
(Compensation costs)	(207)	(624)	(212)	EUR
Revenues from DR (excl. compensation costs)	**47**	**649**	**-71**	**EUR**
Share of DR	0,1	0,8	n.a.	%
Natural gas consumption before upgrade	4 752 022	3 711 472	4 460 650	kWh
Natural gas consumption after upgrade	4 701 369	3 707 292	4 463 575	kWh
Natural gas savings	50 653	4 181	-2 925	kWh
Revenues from natural gas savings	**3 546**	**293**	**-205**	**EUR**
Total revenues from energy savings	**62 461**	**78 677**	**61 260**	**EUR**

Table 6-11: Hotels: Revenues from Energy Efficiency and Demand Response (2 hours shut down event)

Revenue Streams for Office Buildings:

Office Building	**Austria**	**Spain**	**Ireland**	
Electricity consumption before upgrade	6 747 153	7 300 170	6 394 797	kWh
Electricity consumption after upgrade	5 049 514	5 969 319	5 143 481	kWh
Electricity savings	1 697 638	1 330 851	1 251 315	kWh
Revenues from electricity savings	**186 740**	**133 085**	**181 441**	**EUR**

Revenues from offering capacity	274	4 395	225	EUR
Revenues from activation	1 750	2 973	0	EUR
Costs for rebound effect	2 394	840	637	EUR
(Compensation costs)	(1 540)	(5 171)	(2 494)	EUR
Revenues from DR (excl. compensation costs)	**-370**	**6 528**	**-412**	**EUR**
Share of DR	n.a.	4,9	n.a.	%
Natural gas consumption before upgrade	6 252 989	1 335 958	3 229 828	kWh
Natural gas consumption after upgrade	5 707 983	1 350 828	3 189 856	kWh
Natural gas savings	545 006	-14 869	39 972	kWh
Revenues from natural gas savings	**38 150**	**-1 041**	**2 798**	**EUR**
Total revenues from energy savings	**224 890**	**132 044**	**184 239**	**EUR**

Table 6-12: Large Offices: Revenues from Energy Efficiency and Demand Response (2 hours shut down event)

In the following tables, revenues from energy efficiency measures are compared to shut-down event of 15 minutes and 2 hours for all markets and building types.

Ireland	**Hospital**	**Hotel**	**Office building**	
total revenues from energy savings	312 025	61 260	184 239	EUR
Revenues from DR (15 min)	-*	-	-	EUR
Revenues from DR (2 hours)	199	-	-	EUR

* negative revenue (mainly due to rebound effect)

Table 6-13: Ireland: Comparison of Revenues from DR events

Spain	**Hospital**	**Hotel**	**Office building**	
total revenues from energy savings	224 879	78 677	132 044	EUR
Revenues from DR (15 min)	813	84	601	EUR
Revenues from DR (2 hours)	6 777	649	6 528	EUR

Table 6-14: Spain: Comparison of Revenues from DR events

Austria	**Hospital**	**Hotel**	**Office building**	
total revenues from energy savings	245 845	62 461	224 890	EUR
Revenues from DR (15 min)	587	14	-	EUR
Revenues from DR (2 hours)	5 158	47	-	EUR

Table 6-15: Austria: Comparison of Revenues from DR events

Results from the revenue flow calculation for the selected archetypes show that for the case of simply use chillers as switchable load revenues from demand response reach a significant amount only in hospitals in Spain and Austria and in office buildings in Spain and is more or less insignificant in all other cases. However, modelling and scenarios were set up as a kind of "worst case" that is quite straightforward, but commonly applied. For the NOVICE dual services model, additional efforts could draw a quite different picture:

- Selection of only one asset (chiller) for demand response is common and straightforward. However, experienced aggregators will search for additional opportunities in buildings, including air handling units, pumps, fans, onsite generators, CHP, PV, storage etc. This will increase complexity but also increase loads and potential revenues.
- Market conditions differ significantly in Europe. Implementation of demand response will therefore need tailor-made solutions, i.e. selection of appropriate assets for particular demand response products and implementation of the optimal demand response strategy. Quite different to energy efficiency, demand response does not allow for the application of standardized measures.
- It is crucial for the NOVICE dual service model to select the appropriate buildings with the necessary energy consumption and available assets for demand response corresponding to market conditions. This needs a lot of experience on the side of the ESCO closely cooperating with aggregators.

In addition, the following aspects must also be considered:

- Calculated revenues in this report do not include any compensation for reduced energy supply or imbalance costs for the energy providers or balance responsible party. If aggregators are obliged to compensate energy providers for the reduced energy consumption, revenues might be further reduced for all buildings in all markets. The new EU Directive on internal electricity market will have to clarify this task in the coming years.
- Reducing the duration of the shutdown event reduces revenues further. In order not to exceed comfort parameters, shut down events should be below 30 minutes. This means that demand response is not feasible at all for all archetypes modelled. This point is linked to available products and the specific market conditions.

6.2 FEASIBILITY STUDIES FOR ARCHETYPES AND RISK ANALYSIS

For all archetypes and markets, feasibility studies were carried out. Feasibility studies consider the revenue streams from energy efficiency (EE) and flexibility (DR), cost estimations for EE and DR and also include a risk analysis and presentation of risk mitigation strategies.

6.2.1 Risk Analysis

Offering flexibility via an aggregator is a new, highly complex and thus risky endeavour, both for building owners as well as for aggregators or ESCOs. For this brief analysis for the NOVICE dual service model we distinguish between qualitative and quantitative risks.

6.2.1.1 Qualitative Risk Analysis

In this risk analysis an overview on possible issues related with the NOVICE dual service is given.

One of the main prerequisites for the implementation of demand response in any service building is that it does not affect **comfort parameters** in a way that causes the defined and agreed operation parameters, (like indoor temperature, humidity or CO_2-content), to be exceeded. Building owners or companies responsible for the operation of buildings try to avoid **complaints** as far as possible. As can easily be seen, there is a clear trade-off between demand response and comfort/complaints. From the perspective of building owners, demand response is only acceptable, if comfort parameters are not affected beyond a certain level. On the other side, aggregators need a **guarantee to switch loads** from the building during a certain time period. Otherwise, redundancy level, i.e. to aggregate a large number of buildings in order to provide necessary loads, needs to be very high, increasing costs for the aggregator and reducing revenues per building.

Depending on the contracted aggregates to be used for demand response, technical issues may arise, too. Frequent switching is likely to **increase malfunctions** of aggregates and **higher maintenance costs**.

Due to already mentioned trade-off and interrelation between demand response, energy efficiency and operational parameters, the **complexity of NOVICE dual service contracts** is significantly higher than the already complex EPC agreements. This not only increases costs but also possibility of **flaws** or **errors**.

Different to energy tariffs, **development of prices for the secondary control market** is difficult to predict in the short term as well as in the long run. This means that revenues may not occur at all or to a small extent only. Furthermore, prices are directly affected by regulatory framework conditions, leading to more or less **unpredictable potential for revenues** from demand response.

Revenues do no only depend on prices but also on the **success rate for tenders**. As in any controlled energy market, only **well experienced market participants will be successful** in this highly competitive market, further reducing revenue potential.

Depending on the demand response approach, the type of building and technical units, **rebound effect** may have a significant impact on revenues.

6.2.1.2 Quantitative Risk Analysis

In this brief quantitative risk analysis major parameters affecting revenue streams from demand response will be varied. Revenues from demand response will be calculated and compared to the business-as-usual scenario (BAU). The following parameters have a direct impact on revenue flows:

- Price for offering capacity (plus 100% compared to assumed market price)
- Price for activation of load (plus 100% compared to assumed market price)
- Success rate for tenders (BAU: 50%; 100%, i.e. all tenders are successful)
- Share of activation of successful tenders (BAU: 15%; 50%, i.e. control energy is activated in 50% of successful tenders)
- Consideration of compensation (i.e. energy providers receive full compensation)

Due to different market rules and requirements, results will differ in different markets and for different building archetypes models.

	Spain		
2 hours DR event	**Hospital**	**Difference to BAU**	
Revenues from DR (BAU)	6 777	0	EUR

(1) Successful tenders: 100% (BAU: 50%)	13 554	+ 6 777	EUR
(2) Share of activation: 50% (BAU: 15%)	12 891	+ 6 114	EUR
(3) Price for offering capacity: + 100%	10 934	+ 4 833	EUR
(4) Price for activation: + 100%	9 589	+ 2 812	EUR
(5) Consideration of (full) compensation	1 887	- 4 890	EUR
(1) + (2) + (3) + (4)	52 842	+ 46 065	EUR
(1) + (2) + (3) + (4) + (5)	20 240	+ 13 463	EUR

Table 6-16: Risk Analysis Hospital Spain

	Austria		
2 hours DR event	**Hospital**	**Difference to BAU**	
Revenues from DR (BAU)	5 158	0	EUR
(1) Successful tenders: 100% (BAU: 50%)	10 317	+ 5 158	EUR
(2) Share of activation: 50% (BAU: 15%)	15 433	+ 10 275	EUR
(3) Price for offering capacity: + 100%	5 914	+ 756	EUR
(4) Price for activation: + 100%	9 991	+ 4 833	EUR
(5) Consideration of compensation	905	- 4 253	EUR
(1) + (2) + (3) + (4)	64 593	+ 59 435	EUR
(1) + (2) + (3) + (4) + (5)	36 241	+ 21 083	EUR

Table 6-17: Risk Analysis Hospital Austria

	Ireland		
2 hours DR event	**Hospital**	**Difference to BAU**	
Revenues from DR (BAU)	199	0	EUR
(1) Successful tenders: 100% (BAU: 50%)	399	+ 199	EUR
(2) Share of activation: 50% (BAU: 15%)	(199)	(0)	EUR
(3) Price for offering capacity: + 100%	689	+ 490	EUR
(4) Price for activation: + 100%	(199)	(0)	EUR
(5) Consideration of compensation	- 5 231	- 5 430	EUR
(1) + (2) + (3) + (4)	1 378	+ 1 179	EUR
(1) + (2) + (3) + (4) + (5)	- 36 176	- 36 375	EUR

Table 6-18: Risk Analysis Hospital Ireland

This analysis shows that revenues highly depend on market conditions and market success. However, for the case of Ireland, where revenues do not include a remuneration for activation, the selected demand response strategy presented in this analysis does not fit to the specific market conditions. It does not, for example, consider the possibility of offering site flexibility to different flexibility products simultaneously, leading to significantly higher revenues as presented in this modelling approach (see Deliverable D6.2). Finally, compensation for reduced energy supply or imbalance costs for the energy providers or balance responsible party might be a decisive factor. The new EU Directive on internal electricity market will have to clarify this task in the coming years, Member States are obliged to implement the Directive until End of 2020.

6.2.2 Risk Mitigation Strategies

It was already mentioned that this calculation of revenue streams covers a kind of “worst case”. Implementing the NOVICE dual service requires risk mitigation strategies that should encompass the following elements:

- A clear definition and agreement on acceptable comfort ranges should be stated in the EPC with the client. Ensuring the building parameters stay inside this range will avoid complaints in general but also during demand response events.
- Demand response strategies should be tailor made for the client’s needs, the type of the building and the particular market conditions. This includes the appropriate selection of assets and the participation in different demand response programmes, e.g. FFR, simultaneously where possible.
- Complexity can be reduced by the use of standardized contract templates, ESCO-aggregator working relationships and the NOVICE MoU.
- For aggregators, contract duration will be a critical issue in a highly dynamic and uncertain market. For clients, on the other side, short contract durations might include guaranteed revenues for the whole contract period.
- Finally, cooperation with well experienced ESCOs and aggregators will reduce risk for all parties further.

7 DISCUSSION OF RESULTS

For the calculation of revenues from the NOVICE dual service, combining energy efficiency with demand response in retrofitted buildings, a straightforward, however realistic and common, approach was assumed. In order to compare results for different buildings and different markets, the most cost-effective and broadly applied energy efficiency measures were selected (including HVAC, lighting, controls), supplemented by the selection of chillers as the only, but simple to handle, demand response asset. Furthermore, only secondary control energy market was considered for all countries included in the analysis. Altogether, presented results can be considered a kind of simplified “basic or worst case” scenario, a quite conservative assessment for the NOVICE dual service model.

Results of revenue calculations and risk analysis show that under the given assumptions, the NOVICE dual service model is highly dependent on the type and size of the building, the particular market conditions and, when it comes to demand response, a thorough selection of demand response products and appropriate assets in the buildings.

Revenues for participation in demand response markets as calculated for scenarios in this document, clearly show, that with this simplified approach, share of income from demand response is quite low, in some cases insignificant, compared to savings from energy efficiency measures. Hence, depending on the specific conditions, a more sophisticated - and tailor made - approach will be necessary to generate enough additional revenues to accelerate refurbishment activities in Europe within the framework of EPC projects. Regardless of the increasing need for flexibility in the electricity market and the clear political will of the European Commission to foster participation of consumers in all markets, demand response will play an increasing role for selected types of EPC projects. The reasons for this conclusion are manifold:

- Flexibility markets, with a particular focus on ancillary services market, operated by TSOs, were traditionally developed for a small number of large electricity producers with flexible units. There is a clear need for adapting this market towards new stakeholders and market participants, i.e. smaller loads.
- Flexibility demand will increase in the electricity system, however, complexity and volatility of flexibility markets are extraordinary, thus complicating reliable predictions of prices and success rates for tendering processes. Only a few very experienced and specialized market participants (e.g. aggregators) with appropriate portfolios will be successful on these markets.
- Upfront and transaction costs for the integration of small and medium sized loads (significantly lower than 1 MW) into the flexibility market can be seen as one major barrier.
- One major factor for the integration of demand response in the market is the relation of flexibility prices and compensation towards energy providers.

In D5.5 the technical specifications for the proposed retrofit projects were described for the two proposed demonstration sites: a leisure centre in Dublin, Ireland, and a youth hostel in London, UK. The leisure centre in Dublin had already implemented a number of energy efficiency measures as it was already under EPC with NOVICE project partner NLGES when the NOVICE project started. The NOVICE project team undertook a desktop energy audit of the youth hostel in London and identified a number of possible energy efficiency measures. As described in D5.5, the energy efficiency measures identified and implemented at both sites included lighting upgrades and HVAC system and control upgrades, which matches the modelling approach taken here in the ‘business as usual’ and NOVICE scenarios. In both demonstration cases the predicted savings were greater than the 10% improvement predicted in this modelling, but 10% represents the lower limit of achievable energy efficiency in most buildings and therefore represents a kind of “worst case” for energy efficiency, an approach that is consistent with the scenarios identified here that look at the worst case for the NOVICE model. In addition, as described in D5.5, the leisure centre’s participation in demand response events was limited to load shedding due to a combination of the type and size of assets available on site, the client’s requirement to avoid disruption to normal operation and the inability of the CHP to export to the grid. Again, this matches the NOVICE scenario modelled here which represents the worst case, most restricted implementation of the NOVICE model and as noted in D5.5, achievable revenues may have been higher if the site had been able to participate in fast frequency response programmes.

8 CONCLUSION

Results of this analysis show clearly, that the NOVICE dual service model is highly depending on appropriate framework conditions in order to accelerate refurbishment activities in the framework of EPC projects.

Demand for flexibility will increase in the future and regulatory framework conditions will be adapted for further implementation of demand response. In several European markets, aggregators are successfully offering demand response products. It is supposed that demand response market will further develop, at least at a slow pace, but this development will need individual solutions. Only market participants that will provide tailor-made solutions for their clients will succeed. The NOVICE dual service model will have its place in this process but implementation largely depends on specific conditions, be it the type of the building, technical equipment, market conditions or other relevant aspects.

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