Filling the gap:

QUANTIFYING THE ACTUAL CARBON AND FLEXIBILITY PERFORMANCE OF BUILDINGS

Report on smartEn demonstration trials

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smartEn Smart Energy Europe

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Introduction

The European Union is at a historical turning point. The high energy dependency on fossil fuels, exposed by the war in Ukraine, has revealed alarming implications on both energy prices paid by European consumers and the EU's energy security. Several solutions are currently being deliberated by EU policy-makers, through the REPowerEU plan, to urgently overcome the stalemate.

Despite these efforts, however, some of these solutions, in particular those in the short-term, are not fully aligned with the climate neutrality trajectory. The proposed solutions should not abandon the objectives of the EU Green Deal. The energy transition will only be cost-effective, efficient and resilient if the EU bases its energy system on clean electricity and relies on the active contribution of all energy end-use sectors, including buildings.

Here, the European building stock can provide a significant contribution but must be refurbished – hence the need for a rapid implementation of the Renovation Wave strategy. Buildings in the EU currently account for 40% of the European energy demand, although their consumption is 75% inefficient and is responsible for 36% of CO2 emissions[1].

It is therefore crucial to improve their energy optimisation and stimulate their integration in the local energy system, whether it be through flexible consumption of clean electricity produced on-site and/or from the grid they are connected to. In this way, the development of zero-emission buildings would bring benefits to both occupants and the energy system[2].

[1] European Commission, "New rules for greener and smarter buildings will increase quality of life for all Europeans", 2019, *https://tinyurl.com/2p8fu5de*
[2] For more information, please have a look at smartEn Q&A publication "Presenting the value of flexible buildings", 2021, *https://tinyurl.com/2s4dcejv*

The value of actual performance measurements in buildings

The carbon footprint and the demand-side flexibility of buildings are rarely quantified with actual performance values.

Today, theoretical values on a building's energy performance are normally provided by the Energy Performance Certificate, which is calculated in different ways across Europe and often not evidence-based[3].

The voluntary Smart Readiness Indicator for buildings also provides qualitative information on buildings but is still not deployed, although a European methodology for its calculation was set up[4].

smartEn believes in the value of actual, operational and quantitative measurements for both the carbon and flexibility performance of each building. This is crucial as it allows for:

- Increased awareness for building owners, developers, architects, and energy managers;
- Valuable (individual and/or aggregated) information to relevant stakeholders i.e., system operators and service providers on a distributed resource that could be activated;
- Accurate tracking of progress in building renovations;
- Linking of financial incentives with increased actual performance.

In 2020 smartEn published a position paper that set the general principles for the quantification of demand-side flexibility in buildings, while throughout 2021 smartEn members engaged in internal reflections and demonstration trials to identify suitable metrics in order to test them in both residential and commercial buildings.

The present publication aims to outline the results of this effort and inspire the ongoing negotiations of the so-called 'Fit for 55' package, in particular the revision of the Energy Performance of Buildings Directive (EPBD).

[3] For more information, see the project X-tendo from Building Performance Institute Europe (2020), X-TENDO-REPORT_FINAL_200519_pages.pdf (bpie.eu)
[4] Smart Readiness Indicator Implementing Act, 2020, *https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R2156&from=EN*
Smart Readiness Indicator Delegated Act, 2020, *https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R2155&qid=1648745047777&from=EN*

Proposal for actual performance metrics

smartEn recommends the use of the following three metrics to measure the carbon and the demand-side flexibility performance of each building:

$kgCO2/time/m^2$

Zero-emission buildings are the end goal and the metric of $kgCO2/time/m^2$ should provide figures on the carbon footprint of a building in a specific timeframe (which could vary from real-time to annual). This metric alone does not, however, necessarily imply the activation of the flexibility potential of a building and its active integration in the grid (e.g., the self-consumption of an islanded building with rooftop PVs would be equal to zero). For this reason, as a stand-alone metric, it does not necessarily provide valuable information on the dynamic contribution of a building to the time-dependent flexible integration of more variable clean energy in a building and should be complemented by 2 other metrics.

Max kW of shiftable capacity at different times of the day per season

This metric highlights the maximum power capacity that could be available from the participating assets in a building for both price- and incentive-driven flexibility schemes under certain conditions (e.g., for a given time period during the day, depending on the season, 50kW of shiftable capacity in a commercial building for 2hrs in wintertime). This maximum shiftable capacity should ensure that the comfort and well-being of occupants are not impacted negatively. It must be noted that the resulting figure from the application of this metric does not necessarily mean that this flexible capacity is activated.

kWh of activated volume of energy per season

This metric provides a figure on the amount of energy that is dispatched from the building as a result of both implicit and explicit flexibility schemes. For this reason, this metric is dependent on the specific market conditions and the available price signals in the geographical context where a building is located. The seasonal parameter is needed to stress that weather conditions impact the activated flexibility volume of some assets behind the meter.

Altogether, these indicators provide an accurate overview on:

- the carbon emissions of a building
- the capacity of flexible assets behind the meter
- the flexibility volume activated by a building

Demonstration Trials: testing metrics to quantify the actual performance of buildings

Six companies, members of smartEn, applied the identified metrics in different types of buildings, both residential and commercial, in different parts of Europe.

Dcbel

Dcbel, a Canadian company active in Europe sitting at the nexus of residential solar power, electric vehicle charging, smart home and customer-centric utilities, carried out a project in a retrofitted house with a size of 220m^2 in a suburb of Paris, France.

A wide range of assets were active in the demonstration trial which took place between January and November 2021, namely, smart gas heating, smart pellet stoves, ventilation, water heating (spa), 2 EV charging points, smart appliances (washing machine, dryer), smart lighting system and solar PV installation.

By scheduling the occupant's electricity consumption on the day ahead, as well as automating the consumption via a real-time price response, Dcbel was able to shift the occupant's electricity load at a cheaper period of time, where the electricity was more abundant and often renewable-based. This implicit flexibility scheme time was conducted using Barry Dynamic tariffs indexed on French Spot prices.

The following data was collected:

- Dcbel calculated the real-time CO_2 emissions of the building, with the support of the Electricity Map software, before and after renovation. Notably, the carbon footprint reduced from 10t/m^2 before renovation, to 4t/m^2/year after renovation;
- From all participating assets, 11 kW up and down respectively was the maximum shiftable capacity in the 11 months covered by the demonstration trial;
- Dcbel was able to provide granular information on the activated volume from all participating assets behind-the-meter:

- ventilation: 700 kWh/11 months x 2 (up & down)
- water heating: 1708 kWh/11 months x 2 (up & down)
- EV charging: 3308 kWh/11 months x 2 (up & down)
- washing machine: 30,8 kWh/6 months (only from June)

Geo

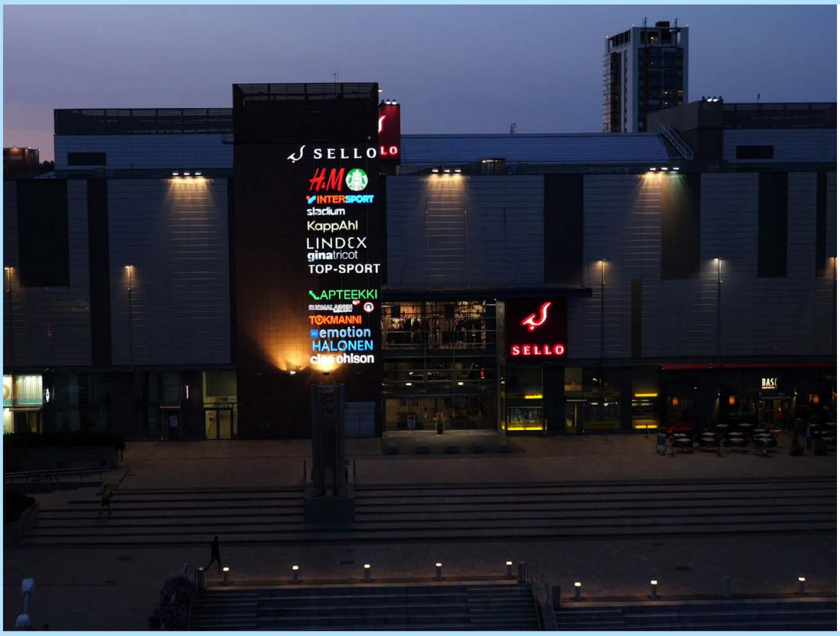
Geo, a British leading provider of in-home displays, mobile, and on-line services for UK and international domestic energy markets, carried out an independent project involving a pool of 20 homes across the United Kingdom (Brighton, Cambridge, London, Sunderland, York) to demonstrate market and household acceptance, and engagement in domestic flexible programmes. To achieve this, Geo connected Home Energy Management Systems (HEMS) to smart meters and aggregator platforms.

From the measured buildings, a 120m^2 home with 4 rooms in Cambridge was involved in the demonstration trial. During the period of January to February 2021, stationary battery, hot water inverter, solar and an EV were analysed.

The following data was collected:

- Geo calculated the monthly carbon footprint of the house before and after renovation, with the installation of a battery. The carbon footprint was of 20,45 gCO2/day/m^2 before the installation, and of 18,9 gCO2/day/m^2 after;
- 2 kW was the maximum shiftable capacity for 30min throughout January and February 2021 in order to avoid that the comfort of occupants was impacted;
- 1,05 kWh (down) and 1,11 kWh (up) were activated each day throughout January and February 2021.

Siemens



SIEMENS
Ingenuity for life

Siemens, a multinational company offering building automation systems for all types of buildings, carried out its project in Espoo, Finland, in a shopping mall of 182 000m², of which 92 000m² were commercial shops. This took place during the month of June 2021.

The building was participating in the FCR-N reserve market and was open to demand-side resources at per hour slots as set by the Finnish TSO.

Assets included electricity heating, air conditioning, ventilation, backup power generation, solar panels, lithium-ion battery system, EV charging systems, and other electricity consumption units.

The following data was collected:

- 1800 kW up and down respectively for the battery system and 600 kW for the HVAC systems was the maximum shiftable capacity that bid in June 2021 to the FCR-N market;
- The building is carbon neutral (0 kgCO2/year/m^2) because it self-consumes renewable energy from the installed on-site PVs. It also purchases renewable energy and compensates the remaining carbon.

tiko Energy Solutions

Tiko Energy Solutions, a Swiss company that develops flexible and modular solutions providing fast frequency response using residential prosumers' devices, conducted the demonstration trials in a residential house of 127m², over a period of 24 hours in December 2020, in Laufenburg, Switzerland. The only asset participating was a 300-litre water boiler.

This house is part of a pool of buildings reaching a cumulative power of 5MW – the minimum size to bid on the markets in Switzerland, managed by tiko Energy Solutions.

The following data was collected:

- 4 kW was the maximum shiftable capacity for 2 hours in a day in December 2020, based on the only flexible asset participating in this demonstration trial;
- 4,33 kWh was activated on a specific day in December 2020;
- Tiko calculated the CO2 metric with the Electricity Map software, based on the energy savings that their system provides to building's occupant. Tiko's system allows the consumer to save around 10% of energy annually. Before Tiko's installation, the carbon footprint of the house was of 2470 gCO2/kWh/day, while 2217 gCO2/kWh/day after installation.

Voltalis

Voltalis, a French aggregator specialised in residential buildings, conducted the demonstration trial in Ravens Craig, Scotland, in a residential block of flats from September 2020 to February 2021 when demand for power is the highest during the cold winter months. The total area of the participating apartments in the building block is 2077m² and the building is equipped with electric heater devices, namely, electric heating and water boilers.

To harness the flexibility potential, Voltalis provided occupants with their own connected devices to adjust consumption in real time and sell it to the power markets. Flexibility was activated through periods of 5-10min of interruption, with an oscillation that can be counted in tenths of degree, which did not have any impact on the occupants.

The following data was collected:

- 99,6 kW was the maximum shiftable capacity during the months of September 2020 and February 2021, based on the electric heater devices utilised by Voltalis;
- From that available flexible capacity, 3631 kWh was the monthly potential that could be offered to electricity markets and 106 kWh was the maximum daily activation for the 2020/2021 winter;
- Voltalis decided to differentiate from other participating companies and provided a figure on the CO_2 emission savings resulting from the activation of the flexibility of the installed assets: 2,7t CO_2 of emissions were saved for the 2020/2021 winter period.

Wattsdat

Wattsdat, an Italian Software-as-a-Service company that created the EoT (Energy of Things) multicloud platform, conducted its demonstration trial in the summer of 2021 in two shopping malls in Italy. The respective sizes of the malls were 2 205m^2 in Piacenza, and 10 254m^2 in Rome.

Wattsdat focused on the thermal inertia of the buildings to allow the flexible use of the electrical load of HVAC systems. Wattsdat assessed both implicit flexibility, shifting the HVAC load according to hourly prices, and explicit flexibility, assessing the maximum HVAC power reduction that could be offered to an aggregator.

Since the comfort of clients was a priority, both types of flexibility were assessed at different external temperatures and at different time slots, with a limit of less than 1°C change in internal temperatures in one hour.

The following data was collected:

- The maximum shift capacity during the summer period was from 40 up to 360 kW/hour. By processing data collected, Wattsdat was able to define the so-called "Flexibility Signature Matrix" of each building to identify the maximum power reduction at any given external temperature per time slots. However, as Wattsdat is not a Flexibility Service Provider, this is valuable information that could be provided to aggregators to activate the flexibility potential of a building;
- The carbon footprint reduction of the building using the flexibility potential, according to the "Flexibility Signature Matrix", is 0,6 up to 1,8 kgCO2/summer/m^2. This estimate is based on the average carbon intensity of the grid.

Lessons Learnt and Recommendations

The Demonstration trials applying the 3 metrics present the following takeaways:

- Data access and sharing is fundamental. Relevant data for the calculation of these metrics stem from both behind and in front of the meter. The lack of, or poor, granularity of data undermines the accuracy of the operational performance of a building;
- Participating companies mostly used data sourced from their own digital metering systems to collect data behind-the-meter;
- Participants had difficulties in measuring the carbon footprint in a harmonised way. This can mainly be attributed to the lack of transparent data in some countries on the grid's carbon and renewable content. Some participants opted to rely on commercial offers to get this real-time information, upon payment. It is therefore crucial that EU legislation requires system operators to disclose such real-time data to third parties at no cost;
- The application of the kgCO2/time/m^2 metric could represent either an overarching figure on the carbon performance of a building and/or a specific carbon reduction metric following the activation of the building's flexibility;
- Depending on the interoperability of behind the meter assets, metrics will focus on either some or all assets present in a building. Currently, appliances with the highest loads are mainly targeted for the application of the flexibility metrics;
- The discrepancy between high volumes of flexible capacity and low values for activated flexible capacity is the result of existing regulatory barriers, still present in different Member States due to a weak implementation of the EU Electricity Market Design[5]. Small scale flexibility assets, such as buildings, incur additional barriers compared to large industrial end-users;
- The 3 identified quantitative metrics can be further complemented by others if data is available. For instance, as the metric on the activated flexibility potential is dependent on the specific regulatory conditions in the geographical context where a building is located (see point above), this metric could be complemented by an additional figure on the potential kWh that could be activated if market conditions are ideal (upon clarification of the necessary improvements);
- The application of these 3 metrics could identify the baseline performance of a building. The comparison of data resulting from the application of these metrics, before and after a renovation, would quantify the maximisation of the value smart decentralised energy resources and services that could offer;
- Such ex-ante and ex-post comparisons should also be linked to financial incentives in order to drive smart building renovations and keep track of the contribution of buildings to increase the efficiency of the whole energy system.

[5] smartEn "The implementation of the Electricity Market Design for demand-side flexibility", 2nd edition, 22 March 2022.

Conclusions

The European Union is facing the crucial challenge of increasing its energy security while achieving the objectives of the Green Deal. Buildings can be part of the solution if they become clean, smart, and flexible energy assets. By doing so, they can provide important benefits to the consumer, the local grid, and the environment. For this to happen, buildings need to unleash their demand-side flexibility, a resource whose benefits are rarely quantified.

This report aims to correct this loophole by displaying quantifications of both the demand-side flexibility and the carbon footprint of a building. This was done by demonstration trials conducted by 6 companies, members of smartEn. Three metrics were tested in different types of buildings with variables such assize, location and markets.

While the metrics suggested by smartEn provide accurate, operational and quantitative information on each building, the valorisation of the demand-side flexibility potential of all end-use sectors would not be possible without the elimination of existing barriers.

The impact of the revision of the EPBD and the other files under the Fit for 55 package would be hindered if the implementation of the European Electricity Market Design incurs further delays. This is the first step in enabling the activation of consumers' flexibility, including small energy assets from both residential and commercial buildings.

This publication is possible thanks to the support of The smarter E Europe

"Creating a new energy world" – that is the goal of The smarter E Europe, the continent's largest platform for the energy industry. In this new energy world, electricity and heat are generated decentrally from renewable energies. The share of volatile electricity continues to grow due to the new deployment of photovoltaic installations and wind power sites. How renewable energies can be better integrated into our distribution grids is therefore one of the most important questions of the energy transition, to which The smarter E Europe provides answers.

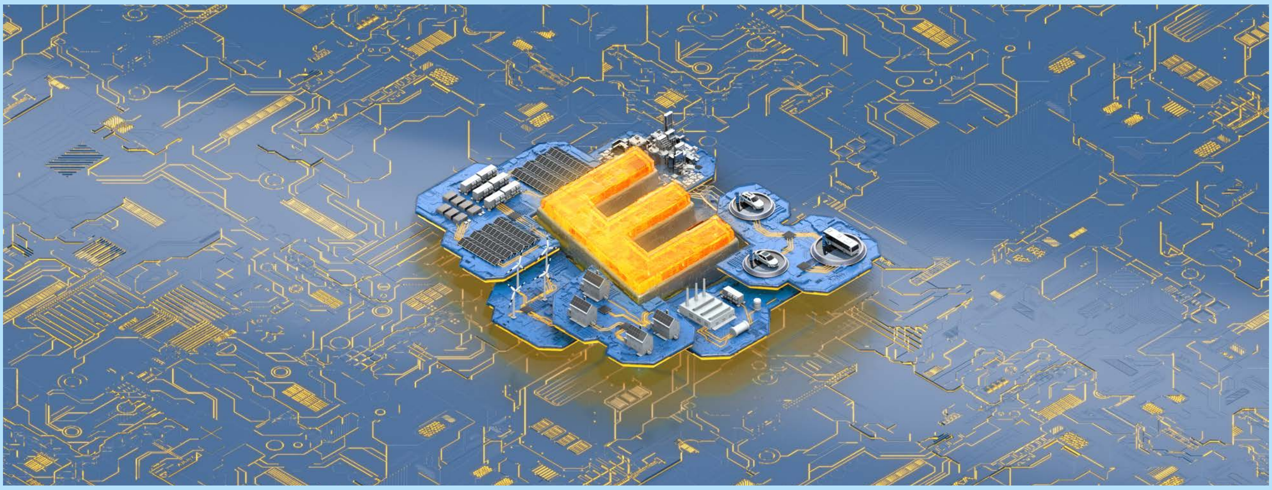
The focus is on cross-sector solutions linking electricity, heating and transportation for an intelligent and sustainable energy supply. The topics comprise all the core areas along the supply chain – from the generation, storage, distribution and usage of electricity and heat to sector coupling.

The smarter E Europe brings together four parallel exhibitions to give energy industry players from around the world a comprehensive overview of the latest innovations and trends. All events take place annually at Messe München:

- Intersolar Europe – The world's leading exhibition for the solar industry
- ees Europe – The continent's largest and most international exhibition for batteries and energy storage systems
- Power2Drive Europe – The international exhibition for charging infrastructure and e-mobility
- EM-Power Europe – The international exhibition for energy management and integrated energy solutions.

The smarter E Europe is organized by Solar Promotion GmbH and Freiburg Wirtschaft Touristik und Messe GmbH & Co. KG (FWTM).

More information: **www.TheSmarterE.de**



About smartEn - Smart Energy Europe

smartEn is the European business association integrating the consumer-driven solutions of the clean energy transition. We create opportunities for every company, building and car to support an increasingly renewable energy system. Our membership consists of the following companies:

The positions expressed in this document represent the views of smartEn as an association, but not necessarily the opinion of each specific smartEn member.

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