NUDGE

Nudging consumers towards energy efficiency through behavioural science

Deliverable D4.1 / D4.3

Report on pilot results: interim report

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NUDGE
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About

Efforts to induce energy-friendly behaviour from end-users through behavioural interventions are characterized by a lack of customer personalization ("one-size-fits-all interventions"), a partial understanding about how different interventions interact with each other, and contrasting evidence about their effectiveness, as a result of poor testing under real-world conditions.

NUDGE has been conceived to unleash the potential of behavioural interventions for long-lasting energy efficiency behaviour changes, paving the way to the generalized use of such interventions as a worthy addition to the policy-making toolbox. We take a mixed approach to the consumer analysis and intervention design with tasks combining surveys and field trials. Firmly rooted in behavioural science methods, we will study individual psychological and contextual variables underlying consumers' behaviour to tailor the design of behavioural interventions for them, with a clear bias towards interventions of the nudging type.

The designed interventions are compared against traditional ones in field trials (pilots) in five different EU states, exhibiting striking diversity in terms of innovative energy usage scenarios (e.g., PV production for EV charging, DR for natural gas), demographic and socio-economic variables of the involved populations, mediation platforms for operationalizing the intervention (smart mobile apps, dashboards, web portals, educational material and intergenerational learning practices).

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957012.

Project partners

IEECP – Institute for European Energy and Climate Policy
domX
Spring-Stof
imec
ZEZ – Zelena Energetska Zadruga
beegy – the energy manager
Active Citizenship Network – Cittadinanzattiva
Fraunhofer ISI
inegi – driving science & innovation
Athens University of Economics and Business

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About this Deliverable

This report documents the first batch of datasets obtained from the events and activities held by the five pilots throughout the first 22 months of the NUDGE project. It comprises an overview of the data sets generated from the activities conducted under the framework of Work Package 4 "Implementing energy interventions through field trials" in particular for the pre-intervention phase, that has been concluded for all the pilots, except for the Croatian Pilot).

The aspects addressed in this document include reporting on the characteristics of the households selected per pilot, data collected from the execution of the works conducted in the different countries and the quality assurance and control (QA/QC) related to the results that are reported. In particular, data collected per pilot includes geographical and climate/meteorological data, survey and technical relevant data on the characteristics of the participant households, interaction of the users with the digital user interfaces (apps and webportal), and data on Energy use that has been collected in the NUDGE Central Platform).

The present report covers as well the deliverable D4.3 (*Report on pilot results: interim report – with confidential data*), considering the absense of confidential data to include.

This is an interim report that will serve as basis to produce a subsequent and more comprehensive deliverable on the NUDGE pilot results, expected to be released in M36 (D4.2 Report on pilot results: final report). In addition, data collected in the pilots will be extensively processed, studied and reported in Deliverables D1.3 (M36), and D2.3 (M36).

1. Introduction

The NUDGE project includes a comprehensive applied methodology focusing on testing the potential of behavioural-science inspired energy efficiency interventions with real users and quantify the respective energy-efficient behaviour change by the implementation of 5 pilot trials in different European countries:

- *Efficient control of heating and DHW preparation for Natural Gas consuming boilers in Greece (GR);*
- *Interdisciplinary project-based education on home energy consumption for children in Belgium (BE);*
- *Optimization of EV charging with self-produced PV power in Germany (DE);*
- *Healthy homes for long-lasting energy efficiency behaviour in Portugal (PT);*
- *Promoting distributed self-production for local Energy communities in Croatia (HR).*

The five pilots offer high heterogeneity and differentiate with each other with respect to contextual factors of the pilot participants (e.g., country, age groups, income), energy use scenario (e.g., household heating, EV charging, PV production), technology/platform used as mediator for operationalizing the interventions (e.g., mobile app, web portal) and to the means of measuring and communicating (e.g., human interaction, short notifications by a feedback system). At the same time the pilots share the use of energy monitoring and management tools (energy consumption and production where applicable) and of digital user interfaces (enabling the interaction with end consumers and the operationalization of the planned interventions), suited to the pilot-specific needs. In addition, the execution of all five pilots in NUDGE follows an identical three-phase time plan that includes pre-intervention (baseline data), intervention (testing of the planned interventions) and post-intervention phases (long-lasting behavioural change analysis). The intervention phase consists of the implementation of 3 sequential interventions ($1^{st}/2^{nd}/3^{rd}$ intervention phases, called also of NUDGE 1, NUDGE2 and NUDGE 3) that are delivered to the users through the pilot-specific interface tools (apps, webportal).

This report is part of the NUDGE Work Package (WP) 4 "Implementing energy interventions through field trials". In particular, this document aims at compiling information on the data sets architecture and preliminary data resulting from the implementation of the 5 pilots by M22 (Jun '22).

At the time of this interim report, the pilots have concluded the pre-intervention phase, or are at the final stage of this baseline phase (Croatian Pilot), and two pilots (Greek and German ones) had also completed their first intervention phase (NUDGE 1). During the first stages of the implementation of the pilot, some efforts have been made in order to ensure as uniform as possible collection and reporting of data.

The collected data that are relevant to the pilots, comprise:

- *Geographical and climate/meteorological data*
    - *Maps with the location of the participant households*
    - *Meteorological data from public databases (Copernicus data for the period of study from the beginning of the pre-intervention phase)*
- *Relevant characteristics of the participant households*

- *Survey data*
- *Technical data*

- *Data on the interaction of the users with the digital user interfaces*
- *Data on Energy use (energy meters data collected in the NUDGE Central Platform)*

The following chapters describe the data collection strategy per pilot and the respective datasets that are available by M22.

2. Data on the recruited Households

The strategy for participant recruitment in NUDGE was initiated by the defined eligibility criteria properly adjusted to the pilot-specific characteristics. The type and number of participants recruited by M22 (Jun '22) per pilot, and for which data has been already collected are presented in Table 1.

Table 1. Participants recruited with energy data flowing to NUDGE central platform at M22, originally planned versus actual participation per pilot

Country	Institute	Eligible participant description	Number of participants planned on GA	Number of participants at M22
Greece (GR)	DOMX	Residential clients of DOMX and their families with natural gas boilers for space heating	100	61
Belgium (BE)	SPRING-STOF	School children and their families having energy meters installed in their house	50	22*
Germany (DE)	Beegy	Residential clients of MVV and their families having a PV-system connected to the beegy gateway including those with EVCS	100	111
Portugal (PT)	INEGI	Families with children younger than 12 years-old	100	101
Croatia (HR)	ZEZ	Households with PV financed by a national initiative and supported by ZEZ Energy Cooperative	100	47

GA, Grant Agreement; PV, Photovoltaics; EVCS, Electric vehicle charging system
* 1st cohort: 36 students attended the lessons but only 22 have an energy digital meter (+ 28 control group not exposed to nudging treatment). 2nd cohort study planned during the academic year 2022-2023.

In accordance with the Grant Agreement, in each pilot country, the target number of households to include in the trial is 100, except for the case of Belgium, for which the target was established to 50 (25 per cohort attending lessons in the academic years 2021/2022 and 2022/2023). However, at the time of writing, recruitment is on-going for some of the pilots (GR, BE, and HR).

This section includes information on the geographical location of households per pilot country and respective meteorological data (outdoor temperatures- ERA5 data from the Copernicus project, https://doi.org/10.24381/cds.adbb2d47) along with information on relevant technical characteristics of the participant households, e.g., types of boilers existing in the participant homes, building age, energy class, house size and gas tariff.

2.1. The Greek (GR) pilot

The Greek pilot aims to efficiently tune the operation of legacy natural gas boilers for heating and Domestic Hot Water (DHW) preparation, by exposing previously unused control capabilities, such as modulation control, weather compensation, scheduling, and others. To this end, the DOMX retrofitting equipment will be installed as 100 legacy boilers of households spread across different cities in Greece, to provide both fine-grained heating control as well as natural gas consumption evaluation. Among the recruited pilot households, users will sequentially receive updated application versions implementing the different nudging interventions. However, as it is up to the end users to decide on using the app or the wall thermostat, the size of the intervention and control groups will vary in each nudging phase.

Briefly, the user engagement process was split into 3 main phases. First, DOMX mailed and contacted a pool of their existing customers to inform them about the NUDGE pilot activities. Second, the research teams of collaborating energy suppliers were contacted, in order to approach users from their portfolios. And lastly, three HVAC installation maintenance companies were contacted, in order to promote the DOMX device and services, by explaining the benefits of joining the NUDGE pilot activities.

2.1.1. Geographic Distribution of the participant households

By M22, a total of 61 households were equipped with the DOMX heating controller in the GR pilot. The GR pilot includes participant households in 4 different cities: Thessaloniki (n=46), Volos (n=10), Athens (n=4) and Kalampaka (n=1). The approximate location of the participant households is presented in Figure 1.

Figure 1. Location of households for the Greek pilot in the North and centre region of Greece.

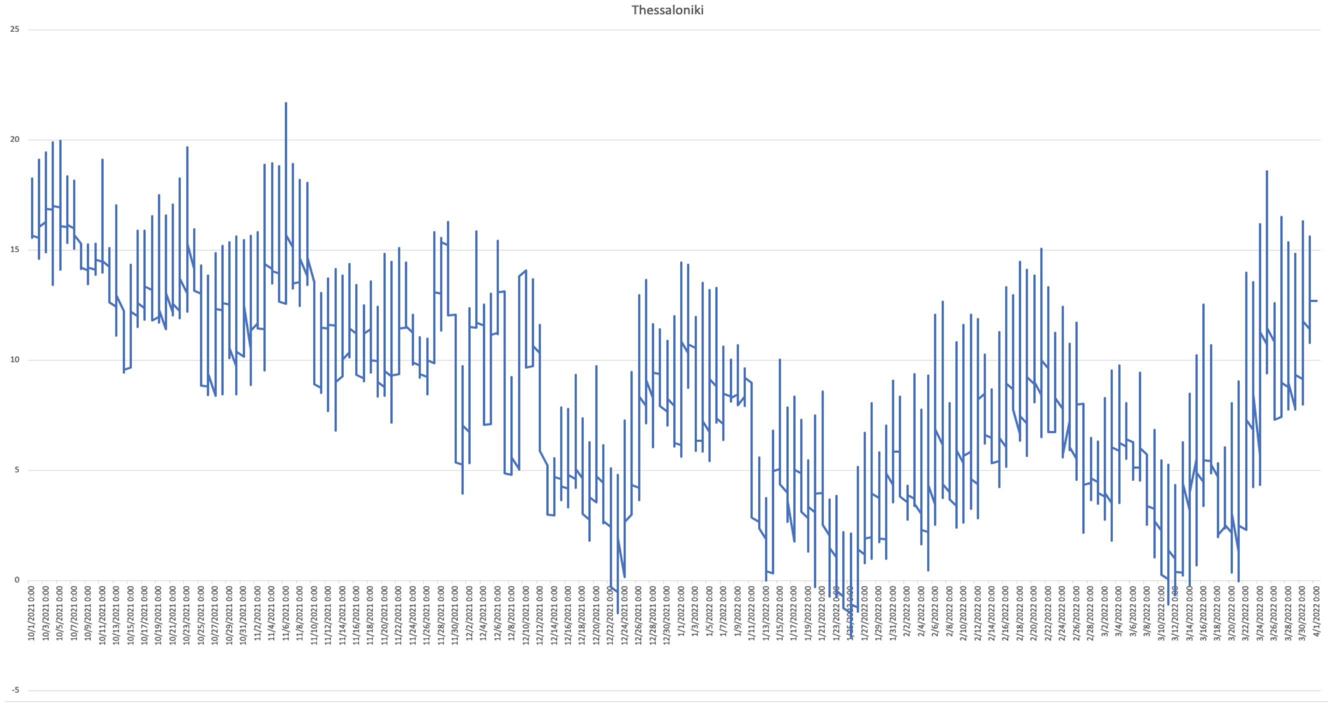
2.1.2. Climate and Meteorological data

The climate in Greece is predominantly Mediterranean. However, due to the country's geography, Greece has a wide range of micro-climates and local variations. The Greek mainland is extremely mountainous, making Greece one of the most mountainous countries in Europe. The cities of Volos and Kalampaka are located in central Greece, while Athens is located in the southern part. To the west, the climate is generally wetter and has some maritime features. To the east, it is generally drier and windier in summer. The northern areas of Greece (Thessaloniki) have a transitional climate between the continental and the Mediterranean climate. Finally, the southern areas have a predominantly Mediterranean climate.

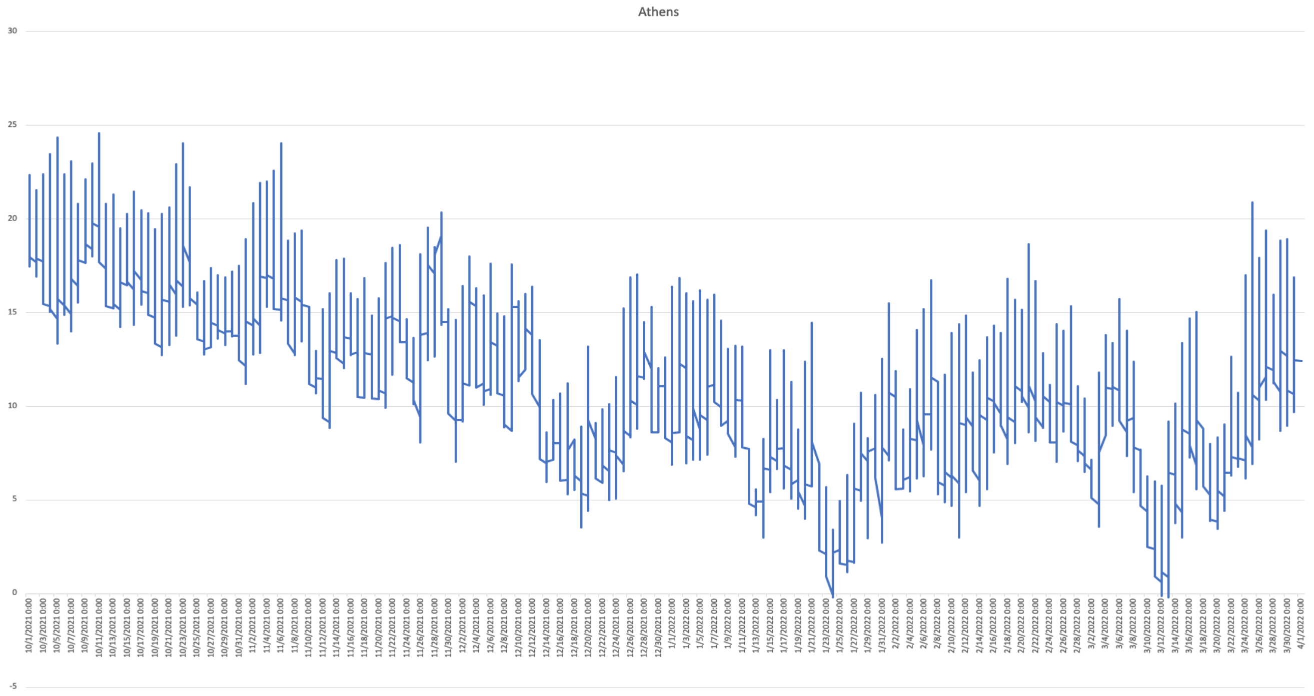
The **pre-intervention phase of the GR pilot** for collection of baseline data had a duration of **3 months (from Oct '21 to Dec '21)**, **NUDGE 1** period had a duration **of 3 months (from Jan '22 to Mar '22)**. In Table 2 is presented some basic metrics for the local outdoor temperature registered during baseline and Nudge 1 periods. Meteorological data acquired from Copernicus is presented below in Figure 2 for the 3 cities with the largest number of pilot users.

Table 2. Outdoor temperature evolution for the 3 cities of the GR pilot

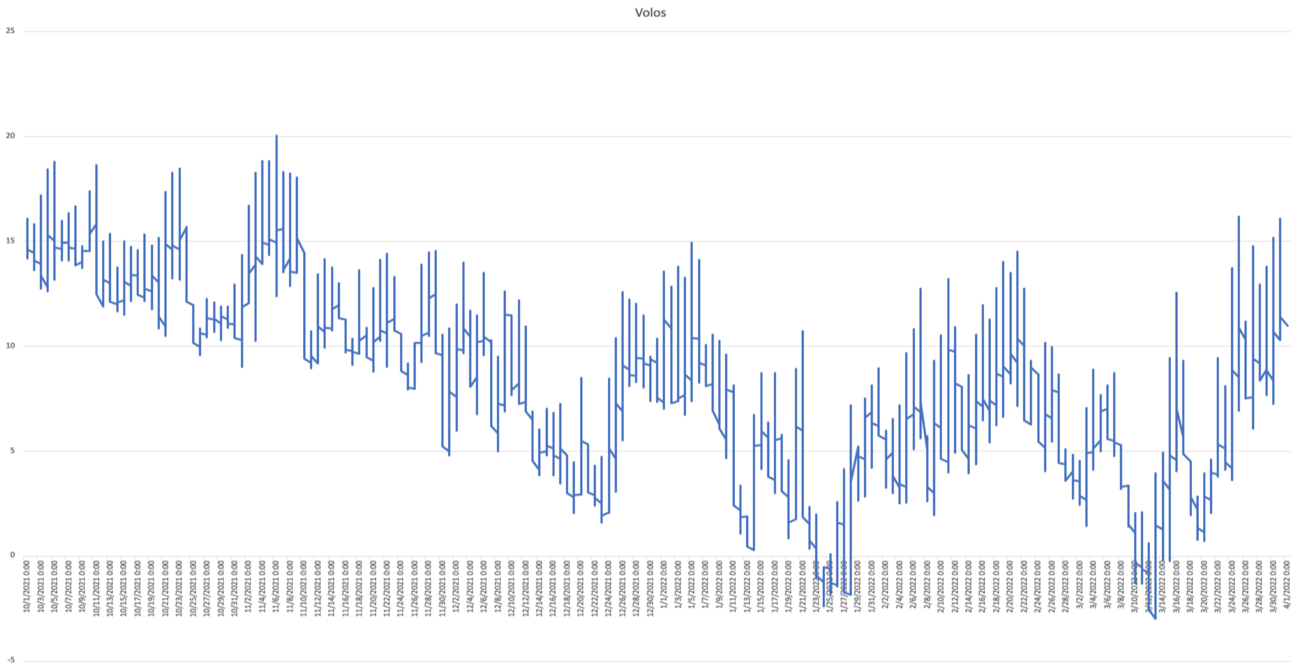
City	Baseline period Mean (Min – Max)	Nudge 1 period Mean (Min – Max)
Thessaloniki	11.4°C (-1.4°C - 21.7°C)	6.6°C (-2.5°C - 18.6°C)
Athens	14.3°C (3.5°C - 24.6°C)	9.1°C (-0.2°C - 20.8°C)
Volos	11.1°C (1.6°C - 20.0°C)	6.1°C (-2.9°C - 16.1°C)



(a) Thessaloniki



(b) Athens



(c) Volos

Figure 2. Ambient air Temperature in Thessaloniki, Athens and Volos from October '21 until March '22 (data from the Copernicus project)

2.1.3. Relevant characteristics of the recruited households

Surveys were developed in order to capture data about the characteristics of the households, such as the period of construction, energy class, house size, boiler type and gas tariff. Regarding the Greek pilot, by M22, 40 participants provided information on their household characteristics, as presented in Table 3.

Table 3. Summary of the results collected through surveys on the characteristics of the households participating in the GR pilot

Household characteristics	*n* (%)	Mean (Min – Max)
Period of construction	--	
1946 - 1960	1 (2.6)	
1961 - 1980	11 (28.9)	
1981 - 1990	10 (26.3)	
1991 - 2000	8 (21.1)	
2001 - 2010	7 (18.4)	
2011 - 2015	1 (2.6)	
Energy class	--	
A	1 (4.5)	

B+	3 (13.6)	
C	5 (22.7)	
D	10 (45.5)	
E	3 (13.6)	
House size (m²)	--	80.0 (40.0 – 130.0)
40 - 59	6 (14.6)	
60 - 79	11 (26.8)	
80 - 99	15 (36.6)	
100 - 119	6 (14.6)	
120 - 139	3 (7.3)	
Boiler type	--	
OpenTherm	49 (80.3)	
ONOFF	12 (19.7)	
Gas Tariff	--	
Fixed	19 (63.3)	
Dynamic	11 (36.7)	

According to data presented in the table:

- More than a half of the participants (55.2%) live in buildings constructed between 1961 and 1990, whereas 42.1% live in buildings completed after 1991, and only 21% live in more recent dwellings (built after 2001).
- As for the households' energy classes, there are 9 energy rating categories (A+, A, B+, B, C, D, E, F, G, A+ being the highest and most efficient) which are determined by a range of values based on the estimated total primary energy consumption of the building. Most of the households (68.2%) have C or D energy classes, and only 18.1% have B+ or A classes.
- Most of the residences (63.4%) present areas between 60 and 99 m^2 and 21.9% are larger than 100 m^2.
- The great majority of the participant households (80.3%) have OpenTherm boilers, whereas only 19.7% of the boilers existing in the participant homes are of the type "ONOFF".
- Most of the GR users (63.3%) have a fixed gas tariff and the remaining have the dynamic one.

2.2. The Belgian (BE) pilot

The aim of this pilot was to study the behaviour of students and their families about energy consumption through energy lessons and intergenerational learning. Specific nudges were integrated in the lessons in combination with the use of visualisations of the energy consumption by EnergyID, an openly accessible platform that is made available by a Belgian social co-operative to families, organisations, and cities. Schools and children to be included in the intervention group were selected from Sep until Dec '21. Eight schools demonstrated interest in organising the series of 5 lessons in their school. However, a high number of children did not have any digital meter to assess energy consumption at home. Thus, the 3 schools with children having digital meters were selected to organise the lessons. A fourth class was composed at SPRING-STOF with individual children coming from 8 different schools. In this way, **36 children (22 with a digital meter and 14 with an analogue meter) were selected to attend the series of 5 lessons**. The meters of participant households were connected to EnergyID. Only the participants with a digital meter were able to send data to the central Nudge platform.Geographic Distribution of the participant households

The participant schools were selected in Leuven, in the centre of Belgium. The homes of the selected participant children are situated in and around Leuven as well, as shown in Figure 3. Almost all participants live in the province Flemish-Brabant, except for one participant who is living in the province Walloon-Brabant, in the south of Flemish-Brabant (35 km from Leuven) and another living in Limburg, in the east of Flemish-Brabant (50 km from Leuven).

Figure 3. Location of households of families with children engaged for the Belgian pilot in the region of Leuven (Central Region of Belgium, Northwestern Europe).

2.2.1. Climate and Meteorological data

The climate in Belgium is a mild maritime climate characterised by moderate temperatures. The average Belgian temperature is 10.2°C. July is the warmest month with an average temperature of 18.1°C, while January is the coldest month with an average temperature of 3°C. The average annual precipitation for Belgium is 910 mm/year. On average, the most precipitation falls during winter and the least during spring.

Most precipitation falls in December (average 100 mm) while April is the driest month (average 50 mm) (www.meteo.be/nl/klimaat). The climate is similar for the locations where the participants live (in the centre of the country).

The pre-intervention phase of the Belgian pilot for the collection of **baseline data** had a duration of approximately **3 months (from Nov '21 to Jan '22)**. **For the 1st cohort** conducted in the academic year 2021/2022, the **lessons with the nudges started in Feb '22 and lasted until Jun '22**. Meteorological data acquired from Copernicus for the period until Mar '22 is presented below for the city of Leuven where most of the pilot participants live.

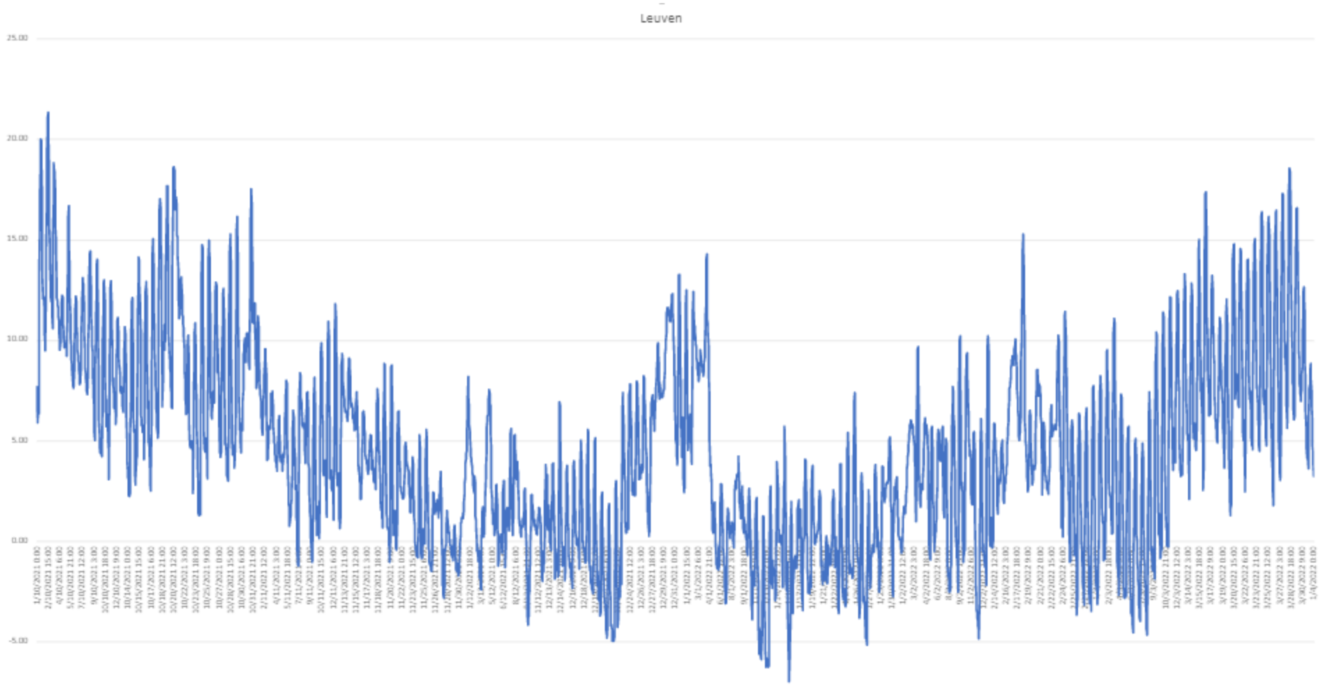


Figure 4. Ambient air Temperature in Leuven from October '21 until March '22 (data from Copernicus project)

As observed in Figure 4, the outdoor temperature in the region of Leuven during the period from 1.11.2021 until 28.2.2022 mostly ranges between -5°C and 10°C, with a mean temperature of 2.7°C and only few days going below -5°C or above 10°C. The lowest temperature was -7°C on January 16th 2022 and the highest temperature 15.3°C on February 18th 2022. Starting from Mar '22, temperature raised with a mean temperature of 6.6°C and larger variations between –4.7°C and 18.6°C.

2.2.2. Relevant characteristics of the recruited households

Regarding the Belgian pilot, 32 out of the 36 participants of the intervention group provided information on a number of household's characteristics, as presented in Table 4. From these 32 participants, 17 participants with a digital meter are included. The data is relative to the participant house that works as primary residence.

Table 4. Household characteristics of the participants of the intervention group based on data in EnergyID.

Household characteristics of 32 participants	*n* (%)
Central heating system	32 (100)
Natural gas	26 (72)
Heating oil	4 (13)
Electricity	2 (6)
Additional Heating	32 (100)
None	24 (75)
Electricity	6 (19)
Firewood	1 (3)
Pellets	1 (3)
Warm water	32 (100)
Natural gas	25 (78)
Heating oil	4 (13)
Electricity	3 (9)
Cooking	32 (100)
Electricity	25 (78)
Natural gas	6 (19)
Propane	1 (3)

n (%) refers to the total number of respondent families and respective percentage in the valid cases

Most BE pilot participants (72%) use natural gas in a central heating system and 78% are heating warm water with natural gas as well. Most of the participants don't have an additional heating system. In case they have an additional heating system, this is most often electrical heating. Most households are cooking with an electric hob.

The characteristics of the 36 children from the intervention group who attended the lessons are presented in Table 5. The gender and age are based on the questionnaire that the children completed. The class group and number of lessons attended are registered by the teachers.

Table 5. Characteristics of the children of the intervention group attending the lessons

Child characteristics	n (%)	Mean (Min – Max)
Sex	36 (100)	
Male	27 (75)	
Female	9 (25)	
Age	36 (100)	12 (9 – 15)

Class group	36 (100)	
Class group 1	13 (36)	
Class group 2	10 (28)	
Class group 3	6 (17)	
Class group 4	7 (19)	
Number of lessons attended	36 (100)	4.8 (3 – 5)
Frequency of consulting EnergyID-dashboard by the child		
Min. 1x/week	4 (11)	
3x/month	3 (8)	
2x/month	7 (19)	
1x/month	7 (19)	
once	14 (39)	
never	1 (3)	

n (%) refers to the total number of respondent families and respective percentage in the valid cases
Max, maximum; Min, minimum

After attending the lessons, the children estimated how many times they consulted EnergyID themselves. The frequency varied, as shown in Table 5 and Figure 5.

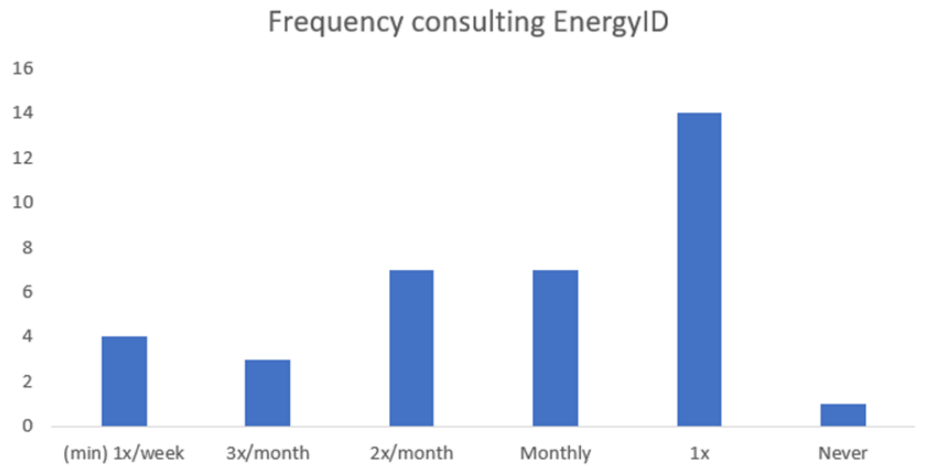


Figure 5. Frequency of consulting the graphs in EnergyID reported by the children of the intervention group in the questionnaire (posttest)

2.2.3. Additional data

Additional data about the houses of the participants were gathered through the EnergyID platform, as presented in Figure 6. These questions were not mandatory for the participants to complete. Therefore, although the data is not fully representative, the percentages can provide an impression of the distribution of the prevalence of some characteristics in the intervention group.

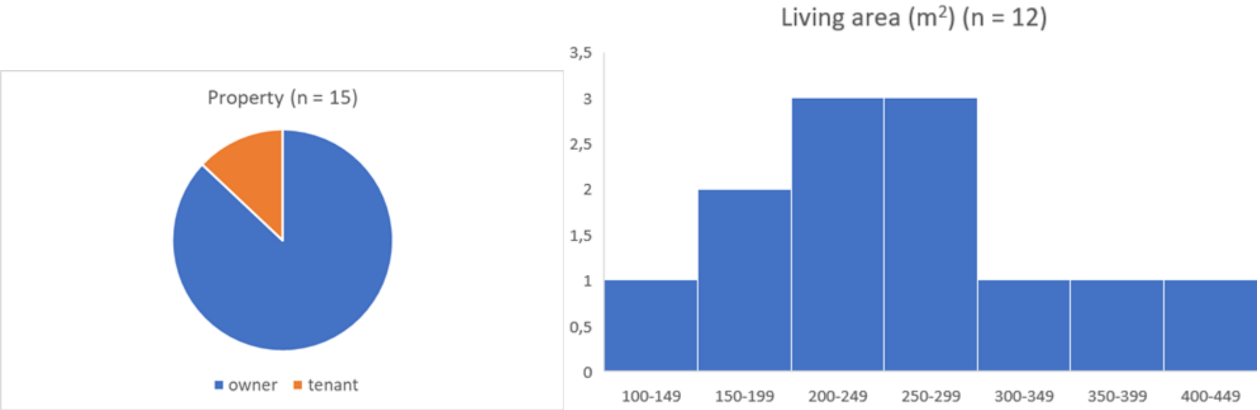


Figure 6. Left: Pie chart of percentage owners in comparison with tenants for the participants of the intervention group; Right: Histogram of the living area of the participants of the intervention group based on EnergyID

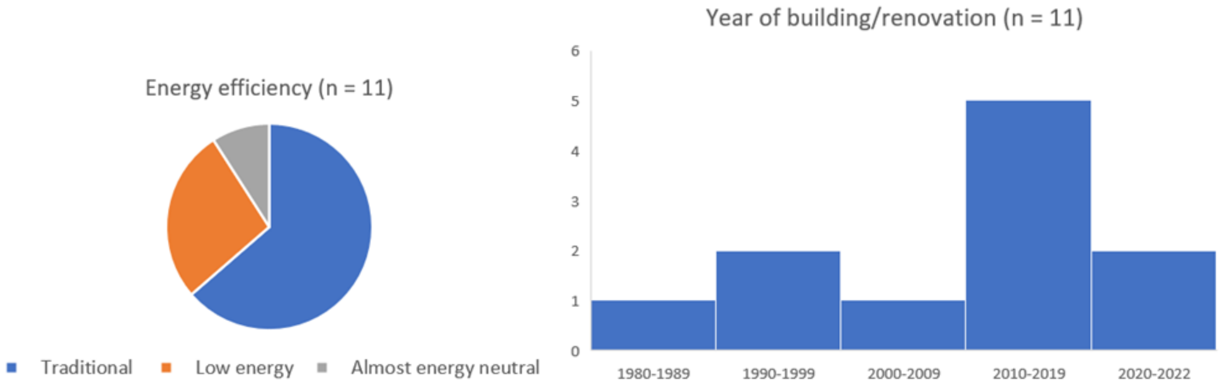


Figure 7. Left: Pie chart of the energy efficiency of the house of the participants of the intervention group based on EnergyID; Right: Histogram of the year of building or renovation (if applicable) for the house of the participants of the intervention group based on EnergyID

2.3. The German (DE) pilot

The German pilot aims to reduce the overall power consumption and increase the use of self-produced solar energy, overall and specifically when charging an electric vehicle (EV) at home. For that purpose, the DE pilot sought 100 residential households from the existing customer base of MVV Energie AG in the Rhine-

Neckar metropolitan area. As a prerequisite, all participating households needed to have a PV-system, enabling them to produce their own solar energy, with or without a battery. In addition, at least 50 participants should have an EV charging station (EVCS) at home that is able to be connected and controlled remotely by beegy. More than 400 customers of MVV were contacted in five recruiting waves.

The established target was to have a total of 100 participating households, equally allocated to the EV-group (50 participants) and the PV-group (50 participants). The pilot reached this target by M18 (Oct '21) with a total of 102 pilot households, equally split into 51 EV and 51 PV households. Participants in the EV group were entitled to receive our EV charging app. During the following provisioning process of the app, it was discovered that not all 51 EV households did fulfil all technical prerequisites. Several EVs did not provide 3-phase charging and further PV-installations had more than one inverter. Therefore, 22 EV-households had to be transferred to the PV group.

Further recruitment activities were initiated, to add additional households to the EV-group. As a result, **on M22 (Jun '22), we have a total of 111 pilot households, split into 39 EV and 72 PV participant groups.**

2.3.1. Geographic Distribution of the participant households

The pilot households were recruited mainly in the city of Mannheim and its neighbouring area. As of M22, 103 participants are located within a 50 km radius around the city centre of Mannheim. The other 8 participants are located further away, with the biggest distance being 250 km.

The approximate location of participating households is presented in Figure 8.

Figure 8. Location of households engaged for the German pilot in the region of Mannheim (South Western part of Germany).

2.3.2. Climate and Meteorological data

The climate in the region of the city of Mannheim is rather warm and sunny. Located in the warmest summer region in Germany, the "Rhine shift", temperatures rise up and above 35 °C in summer.
Climate in this area has mild differences between highs and lows, and there is adequate rainfall year-round. Due to the Rhine River, humidity in summer is high. In winter, snow is rare, even in the coldest months. The Köppen Climate Classification subtype for this climate is "Cfb" (Marine West Coast Climate/Oceanic climate).

Meteorological data is not stored for pilot households. Instead, meteorological data was taken from Copernicus project and is presented below in Figure 9.

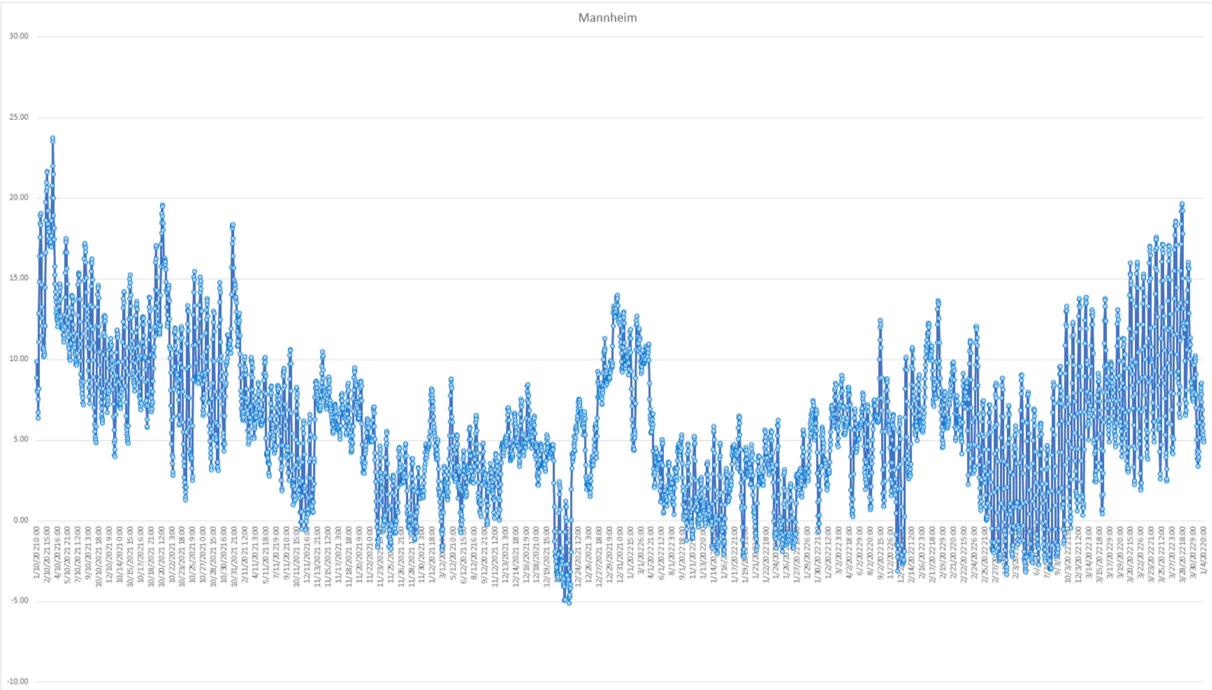


Figure 9. Ambient air Temperature in Mannheim from October '21 until March '22 (data from Copernicus project)

As observed in the Figure for the 6-months period Oct '21 – Mar '22, the outdoor temperature in the Mannheim region during Winter (1.12.2021 - 20.3.2022) mostly ranges between 0°C and 5°C, with only few days going below 0°C. The lowest temperature was -5°C on December 23rd 2021.

2.3.3. Relevant characteristics of the recruited households

The most relevant characteristics of the 111 participating households in the German pilot are the components of their decentralised energy system. All of them have a PV-system installed. Two have actually even two PV-systems, which are measured by two separate meters. The PV-systems have a total capacity/maximum output of 906 kWp. The average capacity per system is 8.16 kWp. Only 13 PV-systems go beyond 10kWp, which is the typical threshold for residential PV systems. The largest installation has a max. output of 19.47 kWp.

98 households have installed a battery storage together with their PV-system. This is a penetration of 88% of installed PV-systems. The installed batteries have a total capacity of 610 kWh. The average capacity per battery is 6.84 kWh. The two largest batteries have a capacity of 12.8 kWh.

66 pilot households have installed an EV charging station (EVCS), which can be connected to the beegy Gateway and thus may be actively controlled. These EVCS are of the following types: 48 Keba P30-c, 6 Keba x-series and 12 Webasto Next. The EV charging app can only support the charging of EVs on 3 phases.

Another prerequisite is that the PV-system shall only have one inverter. Therefore, only 39 of these 66 households were enabled for smart EV charging.

Further, 10 participating households also have an EVCS. However, these are not connected to the beegy Gateway, because they either do not provide a technical interface or because the type of EVCS has not been integrated into the Energy Management Platform. Therefore, the penetration of EVCS (and thus EVs) already reaches 68 % in the participating households (66+10=76/111). We assume that this will further increase.

Heat pumps are currently not individually connected to the beegy Energy Management System, and, therefore, are not visualised separately in the Web Portal. They may however contribute to the total energy consumption, if they are not separately connected to the grid and thus measured separately.
19 participating households reported having a heat pump installed.

In line with the intervention plan, the pilot households are grouped into four sub-groups.

- *EV1 and EV2 have a PV system, with or without a battery and an EVCS which is connected and which enables smart charging of an EV.*
- *PV1 and PV2 have a PV system, with or without battery – but no connected EVCS.*

The technical installations of these four sub-groups are described in the table below:

Table 6. Summary of Installed components in the 4 sub-groups of the German pilot

		EV1	EV2	PV1	PV2	Total
Participating households		18	21	36	36	
Components						
	PV system	18	21	36	36	111
	Battery	17	19	28	34	98
	EVCS					
	- connected	18	21	16	11	66
	- others	0	0	2	8	10
	Heat pump	3	3	6	7	19

2.4. The Portuguese (PT) pilot

The pilot study organised in Portugal aims to promote long-term energy savings in building energy use while providing healthy and comfortable homes for families with young children. Nudging interventions are being delivered to end users through an application that was specifically developed for the pilot, by presenting informative data and/or recommending different actions to optimise energy use, also taking into consideration indoor environmental quality (IEQ). Energy consumption and IEQ sensor data, along with data gathered through the smartphone app (e.g., user interactions/visualisations, feedback, acceptance of recommendations) will constitute the datasets employed for evaluating the efficiency and IEQ improvement and behaviour change of participating consumers.

During the engagement activities conducted in Portugal, more than 150 people demonstrated interest in participating in the study. A phone call campaign was organised to ensure that interested individuals fulfil all the eligibility criteria (e.g., children younger than 12 years old living in the same household, Wi-fi coverage in the location of the main electric switchboard of the house, etc.). Eligible participants shared their home addresses and provided consent to receiving the visit of the INEGI team in the next few days. Trained personnel from INEGI visited each home to conduct a walkthrough inspection and building survey, install equipment for continuous monitoring of electricity consumption (Shelly 3 EM), and collect any relevant complementary information. **By M22 (Jun '22), a total of 101 families with children younger than 12 years old were engaged in the PT pilot**. The **visits for installations in the 101 houses were conducted from Jul '21 to Apr '22**.

2.4.1. Geographic distribution of the participant households

All participant **households are located within a 40 km radius from Porto** (the second-largest city in Portugal). The PT pilot includes participant households **distributed by 12 municipalities** Porto (n=36), Matosinhos (n=18), Maia (n=15), Vila Nova de Gaia (n=13), Gondomar (n=10), Valongo (n=2), Vila do Conde (n=1), Póvoa de Varzim (n=1), Paços de Ferreira (n=1), Santa Maria da Feira (n=1), Ovar (n=1), Vila Nova de Famalicão (n=1), and Penafiel (n=1).
The approximate location of the dwellings of the participant families is presented in Figure 10.

Figure 10. Location of households of families with children engaged for the PT pilot in the region of Porto (Northern Region, Portugal, Southern Europe).

2.4.2. Climate and Meteorological data

The climate in Porto is temperate oceanic, with mild, rainy winters and pleasantly warm, dry sunny summers. The pre-intervention phase of the PT pilot for collection of baseline data had a duration of 5 months (from the 1st of Jan '22 till the 3rd of Jun '22). Although ambient air temperature data for the whole baseline period is not yet available for download from Copernicus, temperature data for the first 3 months of the baseline is presented in the figure below.

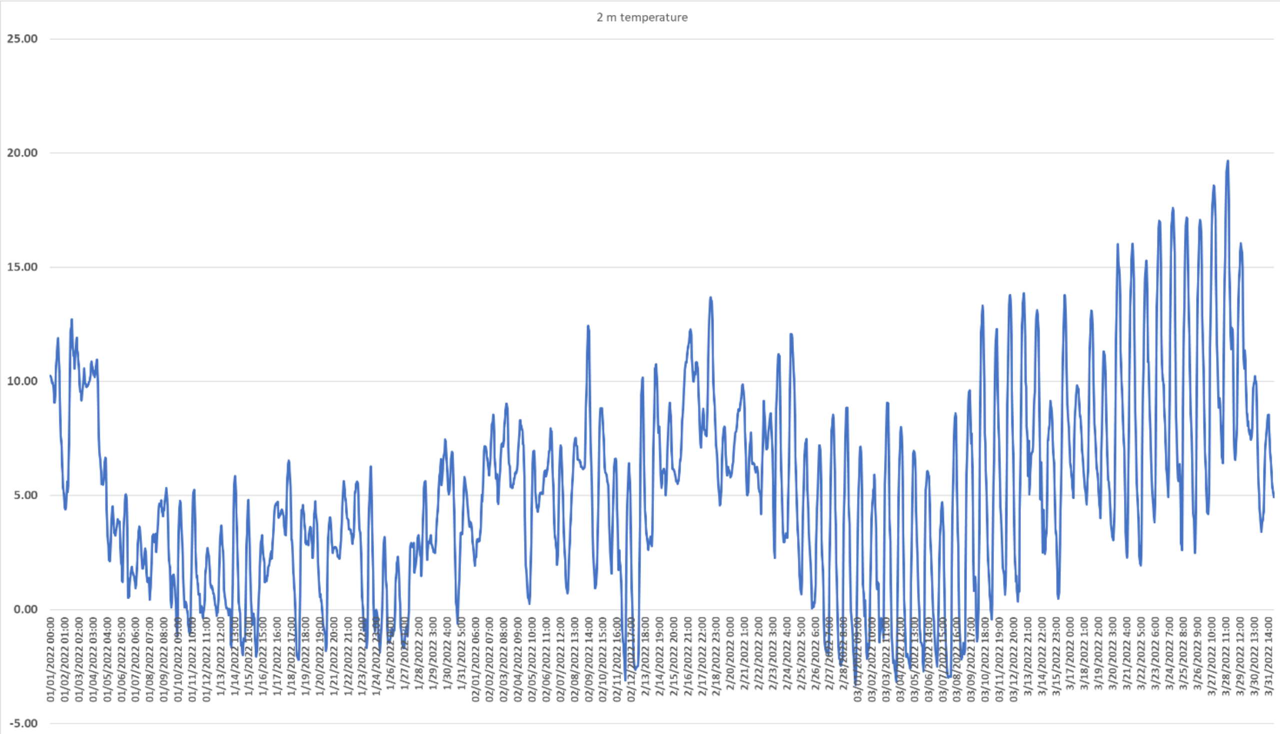


Figure 11. Ambient air Temperature in Porto from October '21 until March '22 (data from Copernicus project)

As observed in the Figure, for the first 3 months baseline, relative to heating season (Jan – Mar '22), the outdoor temperature has highly varied, ranging from -3.30ºC (03/01/2022 6:00) to 19.65 ºC (03/28/2022 15:00).

2.4.3. Relevant characteristics of the recruited households

A geographical study of the area in which the houses were located was conducted based on the Google Maps view in order to collect information on the characteristics of the surrounding outdoor environment. This is particularly relevant to collect data on putative outdoor sources of air pollution in the proximity of the participant's homes. A user-friendly electronic checklist was developed to assist in the standardised collection of data on the characteristics of the buildings, occupants, indoor spaces, energy use, pollution sources and surrounding outdoor environment. All participants (n=101) agreed to provide information for completing the checklist. Data were collected by a trained interviewer during the visits to the participant households for energy-meter installations.

Main data obtained from the checklist were presented through frequencies and valid percentages and/or, if applicable (for numeric data), mean and absolute minimum and maximum values in Table 7.

Table 7. Summary of the results on the characteristics of the households participating in the PT pilot

Household characteristics	*n* (%)	Mean (Min – Max)

Period of construction		
Before 1950	8 (8)	
1950-1980	9 (9)	
1980-2010	67 (66)	
After 2010	18 (18)	
Recent (last 6 months) refurbishing works	39 (39)	
Dimensions of the dwelling (approximate)		
Floor area (m^2)	--	171.0 (62.0 – 680.0)
Mean ceiling height (m)	--	2.6 (2.4 – 3.4)
House Typology		
Apartment	64 (63)	
Single-family house	37 (37)	
Number of floors		
1	60 (59)	
2	22 (22)	
3	16 (16)	
4	3 (3)	
Location of the dwelling within the building (floor)*		
Ground floor	7 (11)	
1	10 (15)	
2	18 (28)	
3	14 (22)	
4 or upper floors	16 (25)	
Number of occupants of the house per age groups		
Babies (0-4 years old)	65 (64)	1.0 (0.0 – 2.0)
Children/adolescents (5-17 years old)	62 (61)	1.0 (0.0 – 3.0)
Adults (18-65 years old)	101 (100)	2.1 (1.0 – 5.0)
Seniors (> 65 years old)	3 (3)	0.0 (0.0 – 2.0)
Period living in this dwelling		
< 2 years	19 (19)	
2 - 5 years	46 (46)	
6 - 10 years	17 (17)	
> 10 years	19 (19)	
Planning to move to a new home within the next 2 years	4 (4)	
Energy supply systems		
For home environment and water heating		
Electricity	77 (76)	
Natural gas	68 (67)	
Bottle gas (propane/butane)	17 (17)	
Solar Photovoltaic energy	4 (4)	
Solar Thermal Energy	18 (18)	
Wood (logs or chips)	32 (32)	
Pellets	6 (6)	
District Heating	0 (0)	
Other	2 (2)	
None	0 (0)	

For cooling	
Electricity	36 (36)
Solar photovoltaic energy	4 (4)
Other	0 (0)
None	65 (64)
For cooking	
Electricity	99 (98)
Natural gas	17 (17)
Bottle gas (propane/butane)	6 (6)
Solar Photovoltaic energy	4 (4)
Wood (logs or chips)	1 (1)
Pellets	0 (0)
Other	1 (1)
None	0 (0)
Electricity switchboard	
Single-phase	90 (89)
Three-phase	11 (11)
Electricity tariff	
Simple	88 (87)
Bi-hourly	12 (12)
Tri-hourly	1 (1)
Equipment and other appliances	
Heating, ventilation/acclimatisation devices	
Electric heating appliances	
Air conditioner(s)	26 (26)
Portable electric heater	32 (32)
Space Radiators	13 (13)
Central heating	41 (41)
Radiant/heated floor	4 (4)
Humidifiers	2 (2)
Dehumidifiers	25 (25)
Combustion devices	
Open Fireplace	7 (7)
Modern Fireplace (closed)	28 (28)
Heating stove	4 (4)
Portable gas heater	15 (15)
Fan heater	32 (32)
Fan	10 (10)
Air purifier(s)	2 (2)
Other	1 (1)
None	4 (4)
Water heating appliances:	
Gas water heater (boilers)	68 (67)
Heat pump	8 (8)
Electrical heaters	20 (20)
Solar water heaters	18 (18)

Other	5 (5)	
Cooking Devices		
Gas stove	22 (22)	
Electric stove	100 (99)	
Wood stove	1 (1)	
Other	3 (3)	
Home EV charging point	8 (8)	
Set points for temperature		
For domestic hot water		
Cold season (ºC)	38 (38)	54 (39 - 70)
Warm season (ºC)	37 (37)	51 (37 - 65)
For indoor environment		
Cold season (ºC)	28 (28)	21 (18 -25)
Warm season (ºC)	8 (8)	21 (17 - 24)
Consumer Products - Indoor use		
Air freshener and other fragranced products	74 (73)	
Manual	37 (37)	
Continuous/Automatic	30 (30)	
Incense	22 (22)	
Scented candles	22 (22)	
None	27 (27)	
Pesticides/Insecticides	32 (32)	
Manual insecticides	14 (14)	
Automatic aerosol insecticides	19 (19)	
Cockroach pesticide	0 (0)	
Rats control products	0 (0)	
Other	3 (3)	
None	69 (68)	
Cleaning products and procedures		
Bleach or detergent with bleach	89 (88)	
Spray	25 (25)	
Liquid	80 (79)	
Frequency (times per week)	--	1.8 (0.3 – 7.0)
Detergent with ammonia	28 (28)	
Spray	4 (4)	
Liquid	25 (25)	
Frequency (times per week)	--	1.5 (0.3 – 7.0)
Other detergent/cleaning products	99 (98)	
Spray	76 (75)	
Liquid	87 (86)	
Frequency (times per week)	--	1.8 (0.3 – 7.0)
Wax/Furniture polish	4 (4)	
Spray	1 (1)	
Liquid	3 (3)	
Frequency (times per week)	--	0.7 (0.5 – 1.0)
Indoors pets	50 (50)	

Dog	33 (33)	
Cat	20 (20)	
Other	7 (7)	
Plants inside the house	61 (60)	
Current practice to smoke indoors	6 (6)	
Cigar/cigarettes	3 (3)	
Electronic cigarettes	4 (4)	
Fenestration/Windows		
Window orientation		
North	51 (50)	3.6 (1.0 – 8.0)
West	54 (53)	3.6 (1.0 – 11.0)
South	62 (61)	3.3 (1.0 – 9.0)
East	58 (57)	3.4 (1.0 – 9.0)
Solar shading		
Both Internal and external	51 (50)	
Only Internal	34 (34)	
Only external	15 (15)	
None	1 (1)	
Opening windows		
Before 7 a.m.	0 (0)	
7 - 10 a.m.	73 (72)	
10 - 12 a.m.	56 (55)	
12 - 17 p.m.	57 (56)	
17 - 20 p.m.	36 (36)	
after 20 p.m.	0 (0)	
Opening windows during the cleaning procedures		
Always	73 (72)	
Often	21 (21)	
Sometimes	6 (6)	
Never	1 (1)	
Signs of indoor pathologies		
Physical	24 (24)	
Moisture-related	38 (38)	
Surrounding outdoor sources at distance up to 100 meters		
Traffic-related	62 (61)	
Busy road	44 (44)	
Highway	4 (4)	
Car parking	8 (8)	
Gas stations	7 (7)	
Other	34 (34)	
Industrial-related	4 (4)	
Agricultural-related	42 (42)	
Animal husbandry	14 (14)	
Cultivated fields	40 (40)	

Commercial	75 (74)
Laundry	12 (12)
Coffee bar/ Restaurant	64 (63)
Other commercial	45 (45)
Other outdoor sources	81 (80)
Landfill, waste disposal	0 (0)
Bus stop	42 (42)
Green/Forested area up to 100m	51 (50)
Other	3 (3)

n (%) refers to the total number of respondent families and respective percentage in the valid cases
* Only applicable to apartments
EV Electric vehicle; Max, maximum; Min, minimum

Main information from the table:

- Most (n = 67; 66%) of the participant families live in buildings constructed between 1980 and 2010, with about 17% living in buildings older than 1980 and 18% in buildings completed after 2010. A great portion of the residences consisted of apartments (n = 64; 63%), and the average area and ceiling height of the dwelling was 171.0 m^2 and 2.6 m, respectively.
- **4 families are planning to move to a new home within 2 years.** Thus, the PT pilot risks losing these participants during the execution of the project, but this is being closely monitored.
- 90 participants have a single-phase electric switchboard. For these participants, the 2 clamps available in the 3-phase electricity meter (shelly 3EM) were used to monitor the consumption of 2 specific equipment/devices for which the participants were more concerned about the consumption, in addition to the overall consumption of the home.
- 99% of the households use electrical devices for cooking and about **76% of the households surveyed use electricity as energy vector for indoor and/or water heating**. In addition, 36% use electricity for cooling purposes in the warm season.
- For those participants controlling indoor environment temperature through thermostats (only 28%), the reported set points defined for the heating season varied from 18 to 25 ºC. Moreover, 7 participants reported to define in their thermostats target temperature values higher that 21ºC.
- In the households with a PV system (4%) an extra energy meter was installed for measuring produced PV energy.
- Regarding the existence of **putative sources of pollution that can compromise the indoor air quality (IAQ)** of the homes (relevant data for the 2nd intervention to implement in the PT pilot in Sep '22):
    - about 6% of the families recognized the practice of smoking indoors;
    - 73% of the households used air fresheners and/or other fragranced products;
    - 32% of the households utilised manual (n = 14; 14%) and/or automatic aerosol insecticides (n = 19; 19%);
    - Only 72% of the participants report always opening the windows during the cleaning practices;

- Some of the dwellings present signals of physical (24%, noticeable cracks, fissures, altered staining or peeling) and moisture-related (38%, dampness and/or mould) damages in the dwelling's surfaces;
- A variety of outdoor sources of air pollution was identified in the surrounding environment of the households (mainly traffic and commercial-related sources).

2.4.4. Additional data: information from participants' electricity and gas invoices

During the visit to the participant homes, participants were invited to email both gas and electricity invoices on a monthly basis to the INEGI team. Since sending invoices was optional, the participation rate by M22 was relatively low as can be observed in Table 8. Nevertheless, data acquired from the invoices allowed us to produce a database and a rough estimation of the total energy consumed, and total energy costs (€/kWh) of both electricity and gas use in the participating households, which are presented in Figures 12 and 13.

Table 8. Number of households that provided invoices for collection of additional data (Electric Energy and Natural Gas).

	Electric Energy								Natural Gas							
	2021				2022				2021				2022			
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Number of households	14	22	31	43	46	37	41	28	11	15	21	27	28	22	25	17

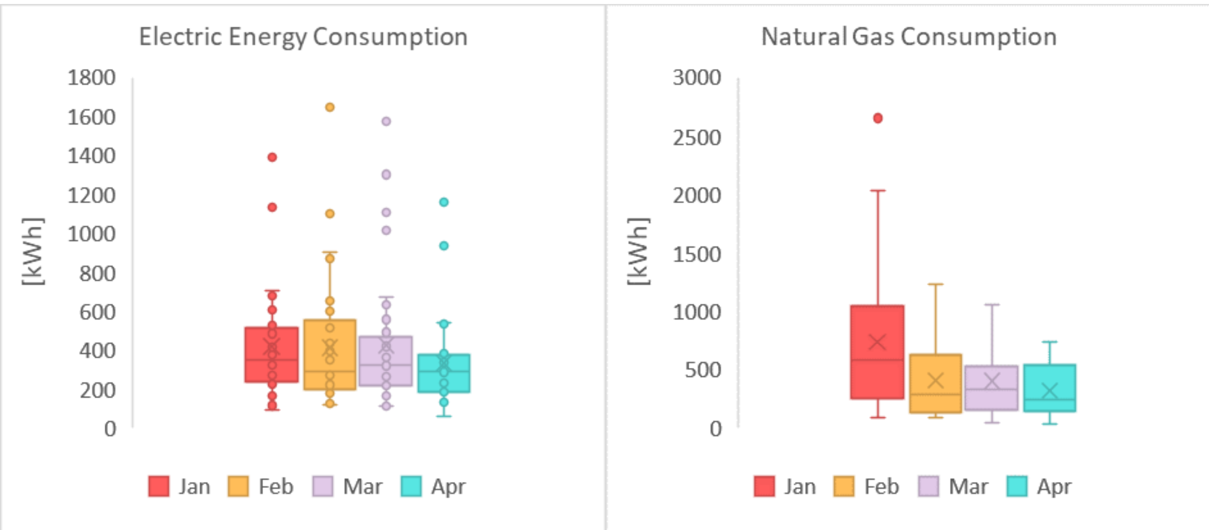


Figure 12. Monthly electricity and natural gas consumption (kWh) from January until April (2022) for some of the households engaged in the PT pilot.

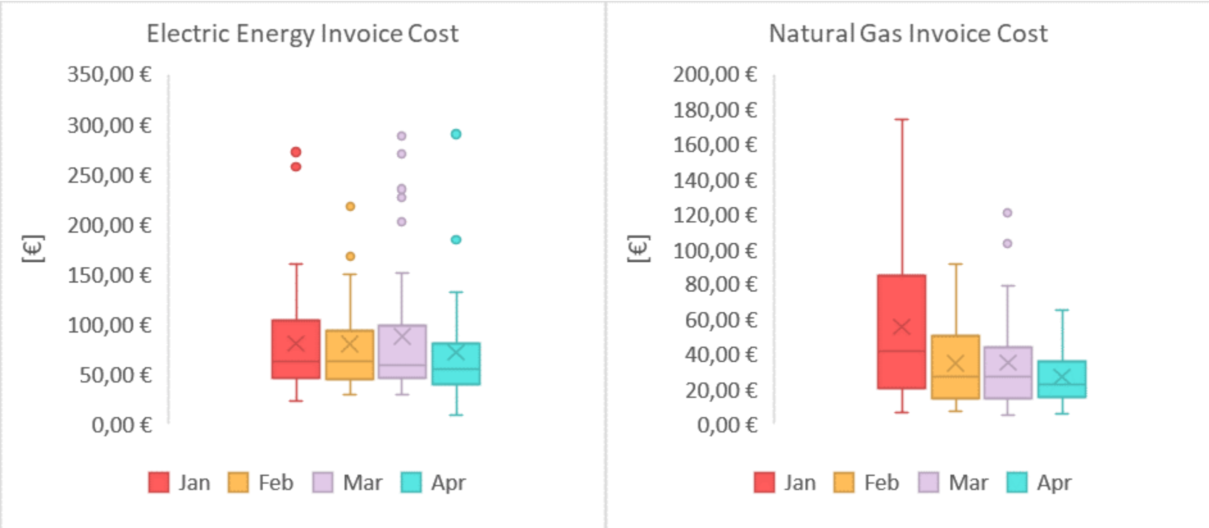


Figure 13. Monthly cost of the electric energy and natural gas from January until April (2022) for some of the households engaged in the PT pilot.

In analysing the energy consumption data taken from the 2022 invoices it was found that the total electricity consumption and respective costs seemed to be very similar for the first 3 months of the year. However, for natural gas consumption, a substantially higher consumption in January (average value of 735 kWh) was observed in comparison to the following months. The lowest consumption of both electric energy and natural gas (and respective costs) was registered in April. Although at the time of writing a low number of participants have provided their invoices ($n_{invoice\ electricity}$ = 28; $n_{invoice\ natural\ gas}$ = 17), this observation can be related to the beginning of the warm season (and consequent reduced need for using heating systems).

Because installations started in 2021, some of the first participants recruited shared invoices related to their electricity and gas consumption in the last months of 2021. Although the relevant data belong to 2022 (with the beginning of the pre-intervention phase), the invoices relative to 2021 were used to analyse the evolution of energy prices (€ per kWh) throughout the pilot execution as presented in the following figures.

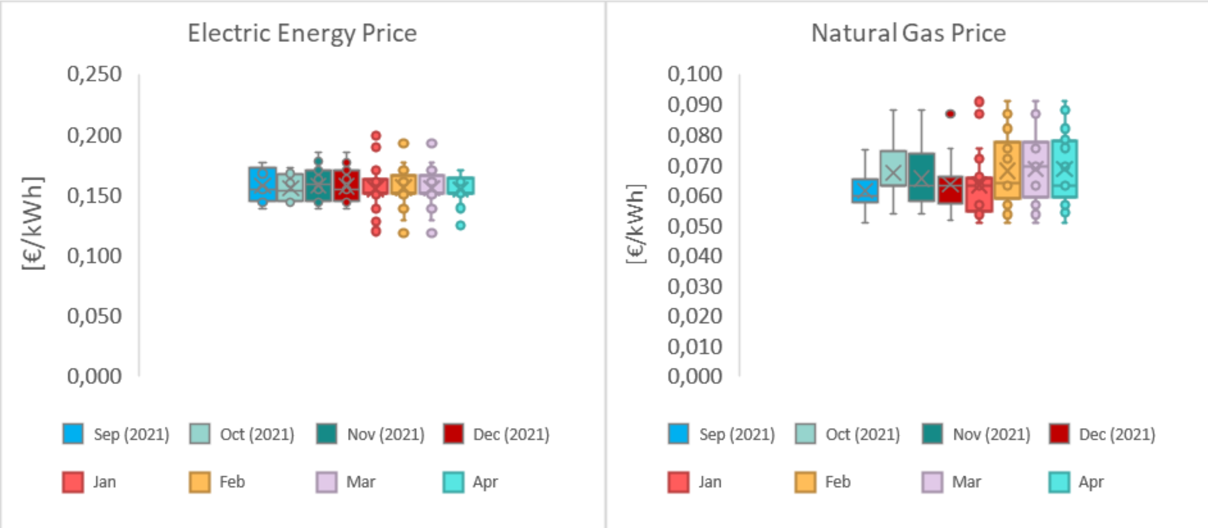


Figure 14. Evolution of energy prices of the electric energy and natural gas (€/kWh) from September 2021 until April 2022 for some of the households engaged in the PT pilot.

Regarding **the price of electricity (in €/kWh)**, there was an increase of 3.97% in the lowest quartile of the data between 2021 and 2022, but, in general, the average price **remained very constant (about 0.156 €/kWh)**. The **price of natural gas suffered only minor changes in 2022**, being, in this case, easier to observe through the respective graph: average of €0.064/kWh in 2021 and of €0.067/kWh in 2022. The months with a slightly higher gas price average were February, March and April, with a special focus on the last two months, which reached exactly the highest average value of all months, of 0.069 €/kWh. In fact, in Portugal some governmental actions have been conducted in order to mitigate the increasing energy prices, however, an increase is expected in the near future. INEGI will be continuing monitoring the evolution of the prices throughout the project execution. New contacts with participants will be established in order to encourage invoice sharing and gather reliable data.

2.5. The Croatian (HR) pilot

The Croatian pilot aims to optimise and increase the use of PV power systems in households, thus creating a more energy efficient home environment. This is supported by installing smart meter devices to monitor household's overall energy production and consumption.

Consumers (households-prosumers) will be able to monitor production and consumption from their PV system, and receive inputs to adapt their behaviour via different types of nudges in the form of push notifications, educational information and different features in the app. This way, consumers will be engaged through a simple smartphone application, encouraging them to undertake different actions to optimise their energy consumption and monitor the effect on their total energy consumption. Alongside the development of the app, a data collection platform is created to store the data from the smart meter devices and transfer it to the Nudge central platform and to the ZEZ's smartphone app (Sunči app).

During the engagement activities (which is still ongoing), a total of 308 people expressed an interest (M22) in joining the project. By means of an online Google form, people indicated whether they met the first requirement for participation in the Croatian pilot, I) having installed, ii) planning to install, or iii) do not have installed a PV system. This serves ZEZ as a preliminary selection whether potential users are acceptable to enter the Project.

The second prerequisite are technical conditions of electro installations in the households. From the total of 308 people who have expressed an interest in participation, 131 people indicated having installed a PV system or plan to install one in the near future (see Figure 15). These potential users are then entered in the second selection where ZEZ is assessing technical eligibility for the instalment of devices. That is, whether a household is having 1-phase or 3-phase meter, technical requirements usually consist of i) enough space in the fuse board and/or inverter board, and ii) good Wi-Fi connection, iii) long enough electrical wires for electrical pliers. When these requirements are met, and installation is successfully done, the participant has entered the project and can use the Sunči app to monitor the household's overall energy production and consumption.

By M22, 47 households have been engaged in the Croatian pilot. Whilst the 1st intervention will start once the minimum of 50 households have been reached (3rd checkpoint), which is planned for M24 (1st Aug 22).

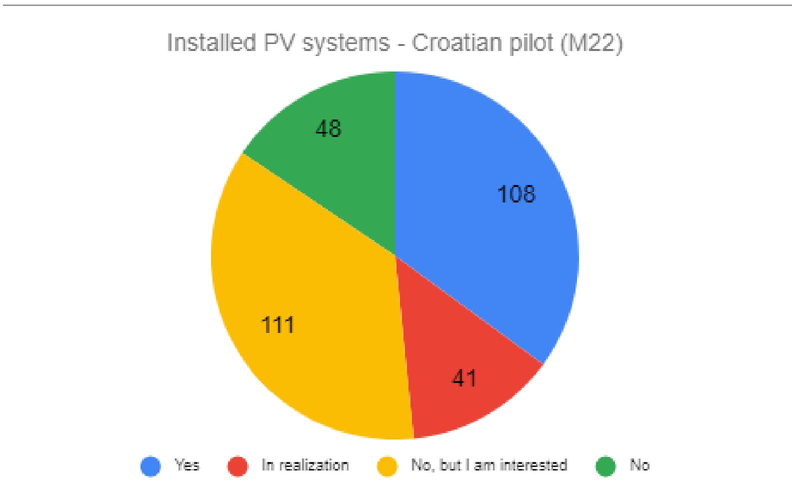


Figure 15. Overview of the express of interest for Croatian pilot (M22)

2.5.1. Geographic Distribution of the participant households

Initially, the geographic distribution of the participants and their households was supposed to be located in the city of Varaždin and its surrounding areas but due to unforeseen events (trying to find only 1-phase households to reduce the costs of installations and equipment), in agreement with the coordinator it was decided to expand the scope of the Croatian pilot to reach the targeted amount of 100 households.

Currently, the Croatian pilot focuses on the following areas: Varaždin and Zagreb County with its surrounding areas (in the Continental part of Croatia). However, due to the support and active collaboration the pilot has received from local installers, it has been decided to also include the eastern part of Croatia, also known as the Slavonia region (in particular, cities of Osijek, Vukovar, Slavonski Brod, and Vinkovci).

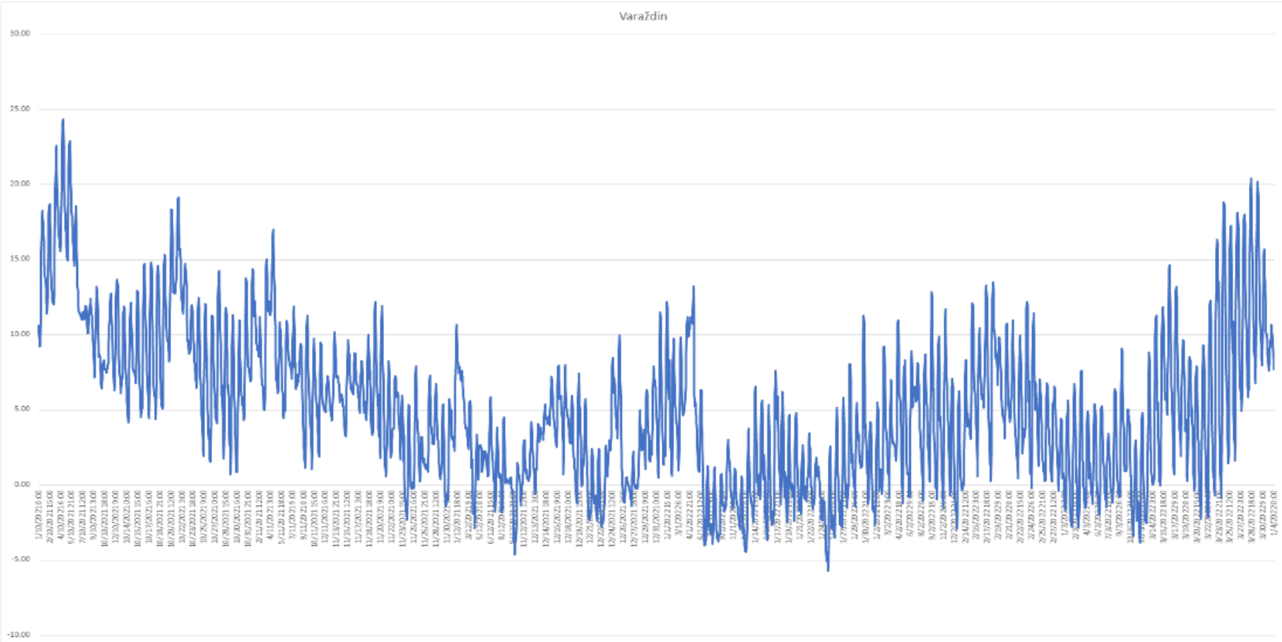
The locations of the 47 households in the Croatian pilot are presented in Figure 16 (the Continental part is on the left and the Slavonia region is on the right side of the attached map). The reason why this second region was chosen is because it has a similar demographic and geographical profile compared to the primary location of the Croatian pilot.

Figure 16. Location of households for the HR pilot in the north and north-east region of Croatia

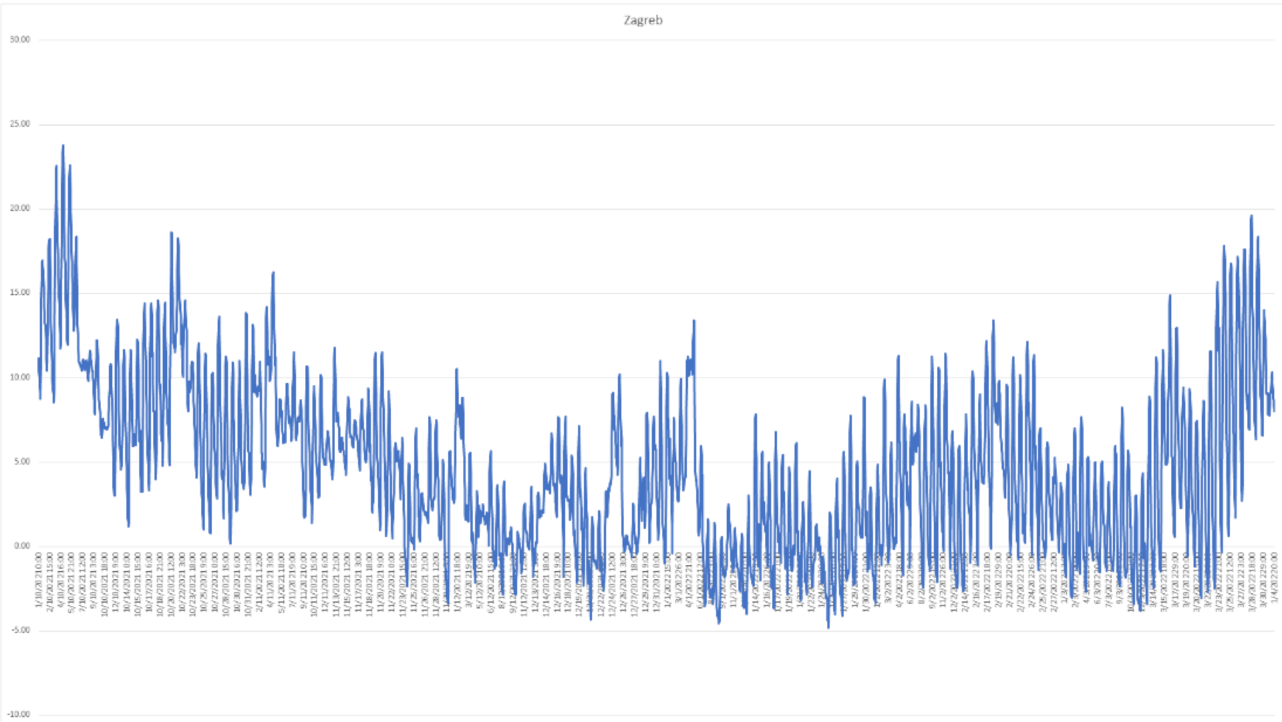
2.5.2. Climate and Meteorological data

All of the pilot participants are located in the north/north-east part of Croatia. The climate in those regions is similar - mild, and generally warm and temperate. The average annual temperature in Varaždin (N) is 11.3

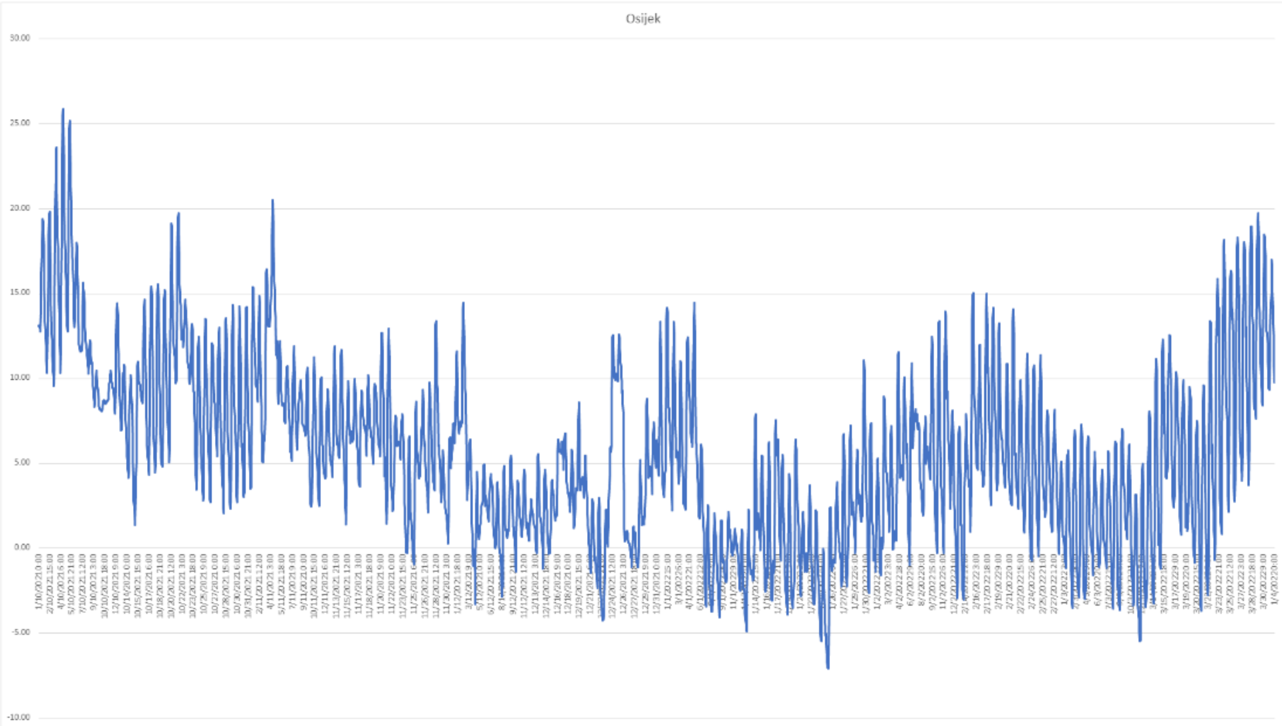
°C, and for Osijek (NE) is 12.5°C. For both Varaždin and Osijek July appears to be the warmest month of the year (*M* = 21-24°C) and January the coldest (*M* = 0.3-0.9°C).



a) Varaždin



b) Zagreb



c) Osijek

Figure 17. Ambient air Temperature in Varaždin (a), Zagreb (b) and Osijek (c) from October '21 until March '22 (data from Copernicus project)

Similar to the other pilots, data from Copernicus is being extracted for NUDGE data analytics purposes. In addition, The API on the openweathermap.org platform is being used to provide access to meteorological data acquired from user locations for the baseline period in the app. Thus, once a user becomes active in the app, the same data is collected and measured daily for each user (through phpMyAdmin). The data can be exported in any needed format and interpreted based on the requirements of each user individually, by location, or otherwise. In fact, when developing the Sunči app, a weather forecast was integrated into the app so that participants can plan their energy consumption and production based on weather conditions. The weather data is picked from the aforementioned platform based on the coordinates of the user and is gathering the following measurements: sunrise and sunset time, temperature, pressure, humidity, dew point, clouds, visibility, wind speed, weather, clouds, overcast clouds, and rain.

2.5.3. Relevant characteristics of the recruited households

At M22 (Jun '22), the Croatian pilot had 47 households (HH) with installed Shelly smart meter devices. From47 HH engaged users, 35 HH are having Shelly 3 EM devices which corresponds to the 3-phase households, whilst 12 HH are 1-phase meter and have been installed with Shelly EM, respectively. Based on the data collected via express of interest, Figure 18 presents the average PV plant size in the households engaged in the HR pilot. As it is shown, the majority of the households have either a 5 kW or 3 kW solar power plant. This correlates with the data given by the users, that on average, indicate that each household has between 3-5 residents. Smaller households typically have fewer occupants (2-4), which is reflected in the size of the PV plant (smaller HH, smaller PV plant).

Another interesting discovery when analysing data from the expression of interest was that some households with a lower number of occupants have a larger PV plant size due to the existence of electrical appliances that consume a high amount of energy (such as EVs), whilst households with smaller PV systems have heat pumps. Households who have >4 residents have PV plant size between 3 KW and 5 KW, which corresponds to the numbers of an average PV plant size presented in Figure 18. Finally, there are only a few households with PV plants bigger than 5 KW and this is usually correlated to a larger number of residents (>5) which are also having more than one large electrical appliance using a high amount of energy.

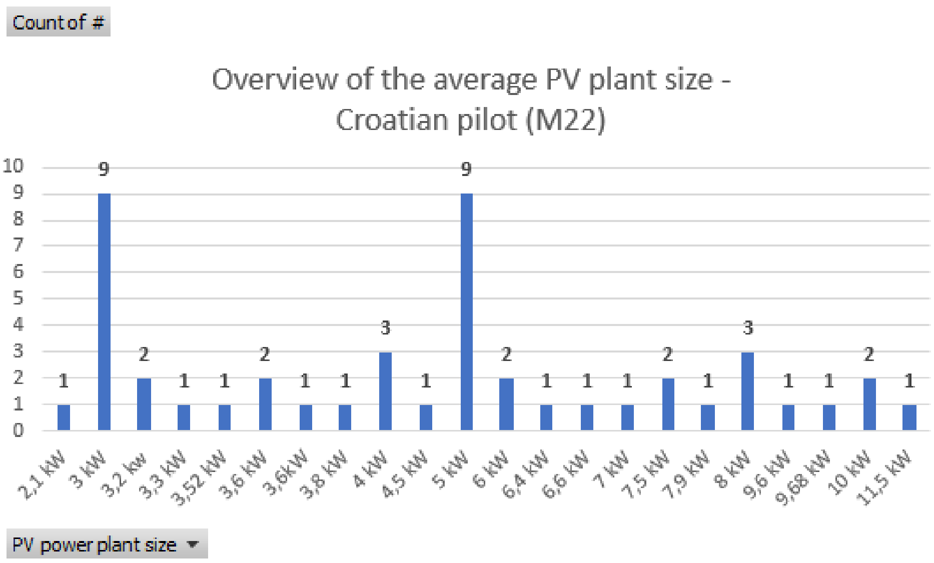


Figure 18. Overview of the average PV plant size with the installed smart meter devices for Croatian pilot (M22)

Information on other relevant household characteristics, namely those related to the existence of equipments that can have a substantial contribution to the households electricity consumption is presented in Figure 19. Only 6 households have EV, whilst others put more focus on other electrical devices. The reason why they have decided to buy an EV was mainly because of applying for the national subsidies within the Public call of the Energy Efficiency and Environmental Protection Fund (max. to 8.000 € or 40% of the total price). As EVs are still quite expensive, without government support Croatian citizens are not considering going into this investment standalone. Aside EVs, users are showing an interest in other electrical devices such as heat pumps (n=8), and PV collectors (n=11) and electrical boilers (n=15) both for hot water, which could help them in long-term planning to reduce electricity bills and have environmental impact in their local community.

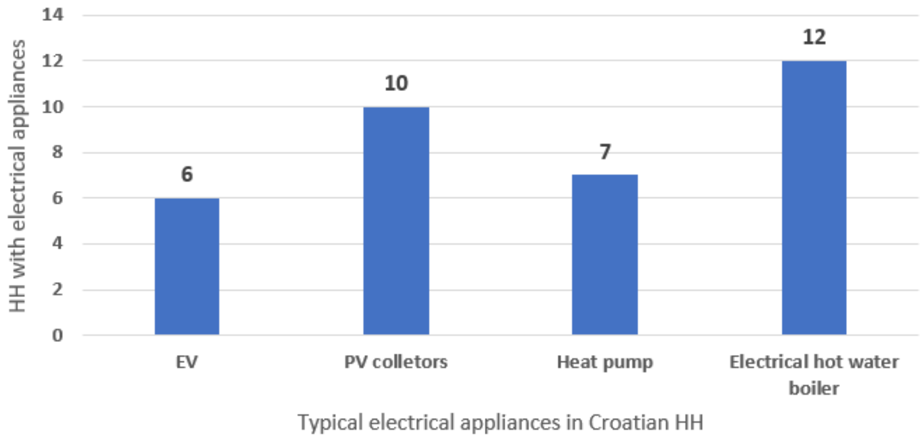


Figure 19. An overview of larger electrical devices in Croatian pilot households (households recruited by M22)

3. Sociodemographics of the pilots

Table 9 displays summary statistics for the five pilots, including sum data for all pilots. The following insights are based on the baseline pilot survey data and depend on the response rate per pilot. Actual pilot participation might be higher than the consequent response rates per pilot. With 105 respondents, the German pilot is the pilot with the highest response rate, while the Greek (n=40) and the Croatian pilot (n=41), have the fewest number of respondents on the baseline survey. Partly as a result, we have small group sizes for certain combinations of variables (e.g., only two respondents are women in the Croatian pilot). For instance, overall, our sample is overrepresented with men (72%), with the Croatian sample comprising 95% men. Portugal, by contrast, sees a more even spread with 49% women and 51% men.

We do find **statistically significant differences between the pilots with regards to age** (one way analysis of variance, $F(4,323) = 75.974$, $p=<0.001$). With a mean age of 56.34, the German pilot is the oldest cohort, while the 40 participants in Greece (M=34.05) are the youngest.

Table 9. Sociodemographic details of all five pilots

Pilot	DE	GR	BE	PT	HR	Total
Sample size	105	40	58	86	41	330
Age	56.34 (10.45)	34.05 (8.10)	42.67 (4.76)	39.89 (6.59)	47.80 (9.27)	45.9 (11.48)
Gender						
Female	13 (12%)	8 (20%)	27 (47%)	42 (49%)	2 (5%)	92 (28%)
Male	92 (88%)	32 (80%)	31 (53%)	44 (51%)	39 (95%)	238 (72%)
House type						
Single-family detached house	57 (54%)	5 (13%)	33 (57%)	13 (15%)	34 (83%)	142 (43%)
Semi-detached house (house with two separate entrances)	16 (15%)	0 (0%)	10 (17%)	8 (9%)	4 (10%)	38 (12%)
Terraced house (row house)	22 (21%)	0 (0%)	14 (24%)	10 (12%)	3 (7%)	49 (15%)
Apartment in a multi-family house	4 (4%)	35 (88%)	0 (0%)	53 (62%)	0 (0%)	92 (28%)
Other	6 (6%)	0 (0%)	1 (2%)	2 (2%)	0 (0%)	9 (3%)
House size	.	80.63 (22.70)	249.54 (82.68)	165.15 (107.08)	189.41 (65.17)	175.15 (99.86)

** When applicable either mean and standard deviation (between parentheses), or count and column % (between parentheses) are reported.*

Examining the household size, households of the Belgian pilot are the largest, with on average 4.61 people. In the Greek pilot, by contrast, the smallest households can be found with on average 2.51 people. One way analysis of variance shows that household size per pilot thus differs significantly (F=75.93, p<0.001), while post-hoc analysis indicates that the differences between the Croatian and Belgian pilots and the Portuguese and Croatian pilots are not statistically significant, raising just above the .05 significance level.

Table 10. Household composition

Number of members	**DE**	**GR**	**BE**	**PT**	**HR**
0	0	0	0	0	0
1	5	7	0	0	0
2	25	15	0	3	2
3	27	6	1	23	7
4	24	8	27	39	14
5	7	0	24	13	7
6	1	1	3	2	8
7	0	0	2	1	0
8	0	0	0	1	0
Invalid	16	3	1	4	3
Total	105	40	58	86	41

M (SD)	3.07 (SD =1.1)	2.51 (SD =1.19)	4.61 (SD =0.77)	3.94 (SD =1.00)	4.32 (SD =1.17)

** 27 people responded inconsistently to respectively the household type (e.g., single person, couple without children, etc.) and household count questions (i.e. number of people of household per age category), consequently these have been coded invalid for the respective analyses of these questions.*

4. Data collected through pilot-specific Platforms and Apps

4.1. The Greek (GR) pilot

Based on the collected energy data, we identified that out of the 61 households that were equipped with the DOMX heating controller by M22, only for 47 households valuable energy data were collected. Among the 47 households, 32 households actually used the application version that implements the 1st nudge during the heating season (68.1%). The rest 15 (31.9% households cannot be directly considered for evaluating the adoption of the first nudge as they actively used the thermostat as the main interface for controlling their natural gas boiler and not the app.

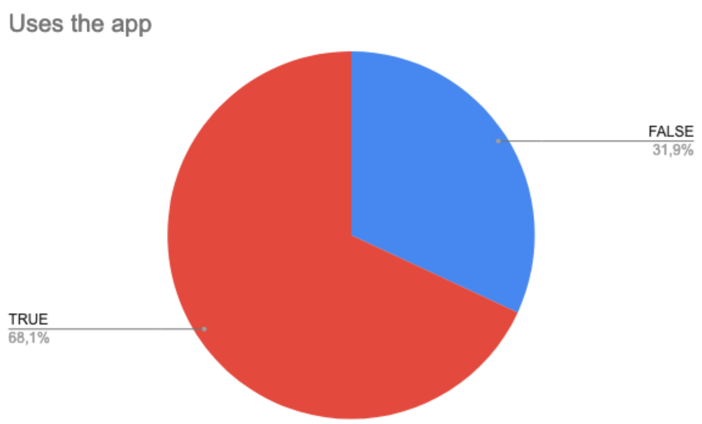


Figure 20. APP usage from the GR pilot participants

4.2. The Belgian (BE) pilot

EnergyID monitored when the participants of the Belgian pilot joined this platform (Figure 21). This depends on the moment of recruitment and the day that the meters were successfully connected to the platform.

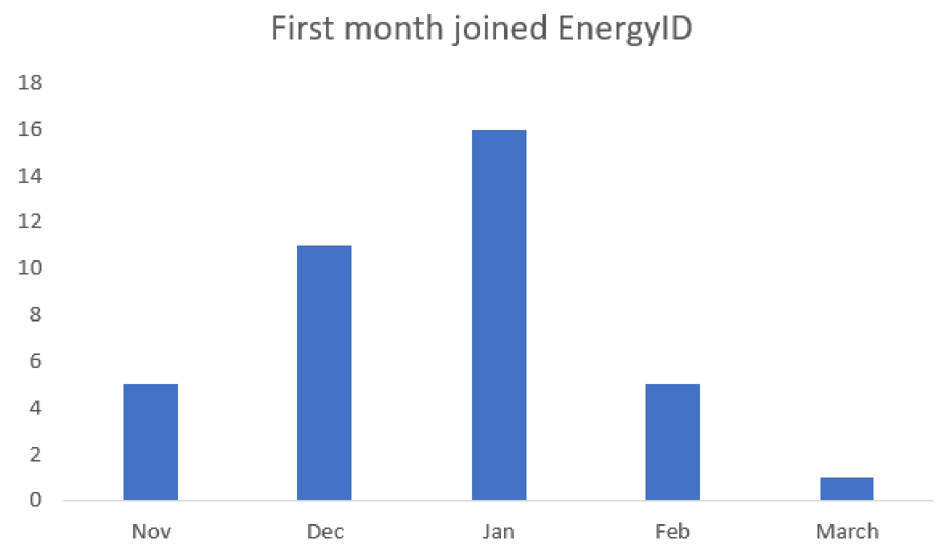


Figure 21. First month of joining EnergyID of the intervention group.

The month of the last activity was registered by EnergyID as well, as shown in Figure 22. This might be an activity by the child or by one of the parents. It must be mentioned that participants with an analogue meter automatically received an email on the first of the month to input their meter readings. People with a digital meter did not receive an email by EnergyID.

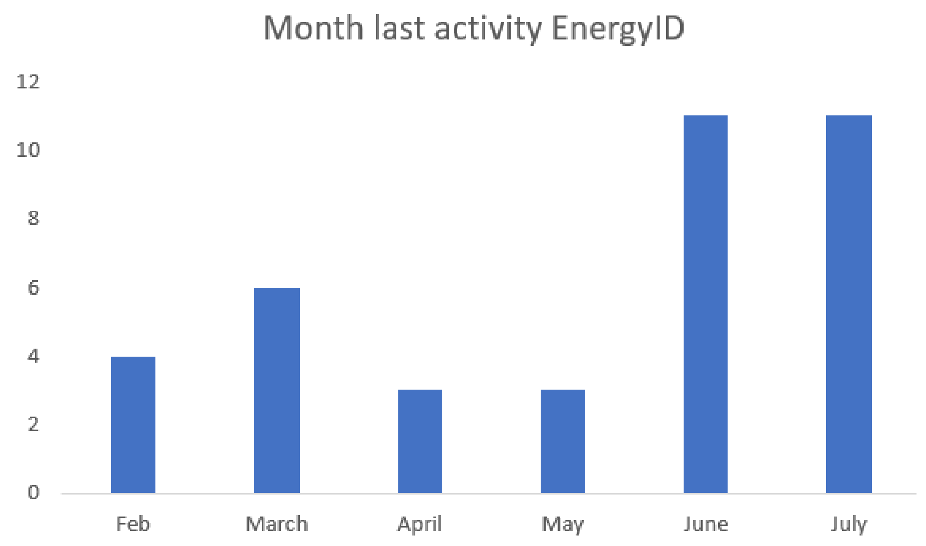


Figure 22. Month of last activity in EnergyID by the intervention group (status July '22).

4.3. The German (DE) pilot

The DE pilot did not collect data on the user interaction with the pilot interfaces (Charging App HERMINE and Webportal) till M22 (Jun '22). However, in order to monitor the use of the two Nudging platform tools, a tracking tool has been recently implemented, based on the software eTracker (https://www.etracker.com/). The tracking was first implemented on the Webportal, and became available with the start of the second intervention phase in M23 (July 2022). The tracking on the Charging App HERMINE became available in M25 (Sep '22).

The tracking will provide transparency on the following aspects

- Nb. of visitors
- Nb. of visits
- Nb. of clicks
- Duration of visits
- Pages viewed per visit

These figures will be available for every page on both tools and for every pilot customer, respectively for all four customer groups (PV1, PV2, EV1, EV2). It will document the number of visitors compared to the total number of pilot households, in total and differentiated by the four groups. This analysis can be done for each of the pages/ sites on the Webportal and Charging app and for each customer.

4.4. The Portuguese (PT) pilot

For the PT pilot, data on the interaction of the user with the Nudge.it App has been collected since the distribution of the App. In the basic version of the app that was specifically developed for this study (called "Nudge 0"), data on the date of login and on the number of instantaneous power data requests visualisations has been monitored.

Table 11. Descriptive statistics on the interaction of the users with the basic version of the App (from 21 March and 3 June)

User's interactions with the NUDGE	*n* (%)	Average	Median	(Min – Max)
Login*	86 (85)	2	1	(0 - 7)
Get Power**	86 (85)			
# data visualisations/requests		5	40	(0 – 972)
0	15 (15)			
1 - 10	16 (16)			
11 - 100	51 (50)			
101 - 500	16 (16)			
> 500	3 (3)			

n (%) refers to the total number of respondent families and respective percentage in the valid cases

* refers to the number of users who have introduces the provided credentials and successfully logged-in.
** relative to the number of users that have requested new data on the instantaneous power.

Since the distribution of the app till the beginning of the first nudging intervention (21th March to 3rd June), 85% of the participants have downloaded and successfully logged into the app, using the individual credentials provided. Fifteen participants have never logged in to the app and sixteen were very low participative, interacting with the app less than 10 times during the NUDGE 0 period. In turn, the remaining 70 participants have visualised the instantaneous power more than 10 times, with 19 having interacted intensively with the app (more than 100 times during NUDGE 0). The number of users that uses the app per day is also being monitored as presented in Figure 23.

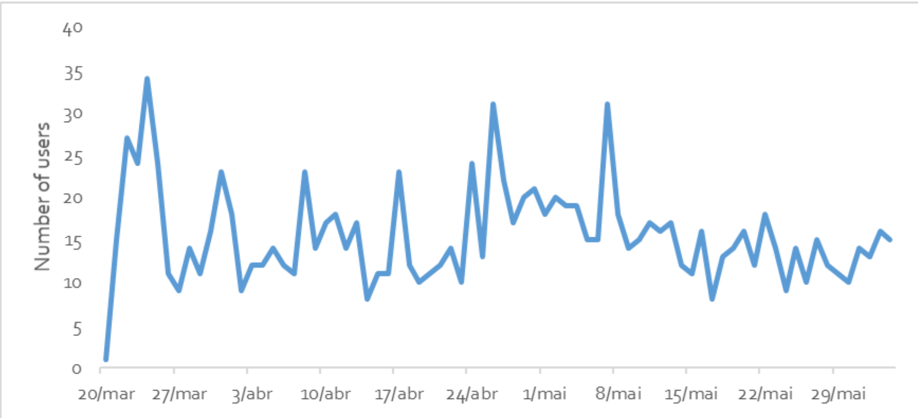


Figure 23. Number of PT users that requested new data on the instantaneous power per day during Nudge 0 period (from 21 March to 3 June).

4.5. The Croatian (HR) pilot

User interaction with the application is measured with Amplitude, a product analytics platform. It can provide different statistics, groupings and interactions with the app depending on the desired request. Examples are given in Figure 24 and Figure 25.

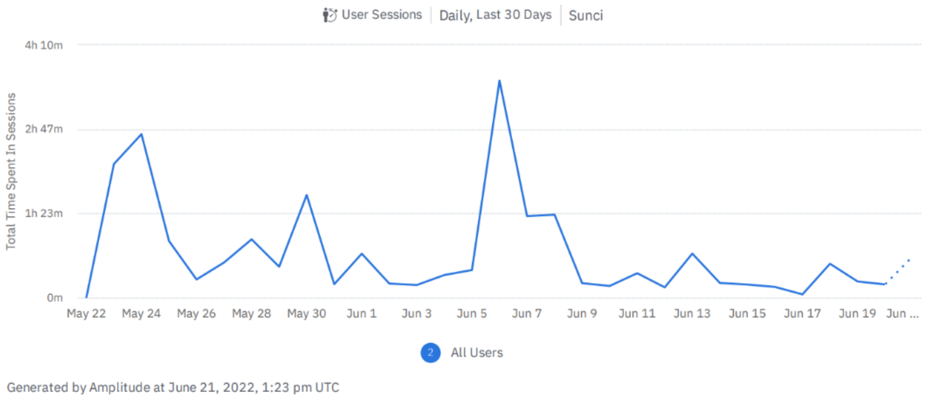


Figure 24. Data visualisation of total time spent in sessions for all users

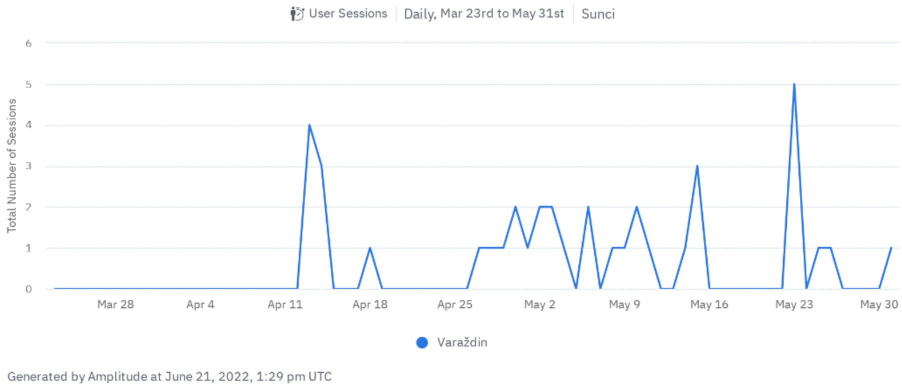


Figure 25. Data visualisation of total number of sessions based on the location grouping (in this example, Varaždin)

5. Energy data

This section summarizes the datasets that have become available so far from smart meters and other sensors used in the pilots. These data have been collected at the NUDGE central platform, where data from all pilot households are being delivered. Deliverable D3.1 provides details about the data collection system architecture in NUDGE. For each pilot, we report the following information:

- The number of households that provided data during the different stages of the pilot trials. By June 2022 (M22), three pilots have already completed the first intervention period (Belgian, German, Greek), for one (Portuguese) this is ongoing, and for one (the Croatian pilot) the first intervention phase is about to start on August 1st. All pilots have completed what is called the pre-intervention phase.

- Technical problems experienced in the collection process and what they meant in terms of missing data from the datasets.
- The time series collected for each pilot, namely the measures reported by each pilot and the frequency at which they are sent.
- Samples of those time series from random households together with basic information about the unit/granularity of measurement.

5.1. The Greek (GR) pilot

5.1.1. Number of households sending data

The number of households that had joined the Greek pilot by the time of the 1st intervention was 53. These households joined the pilot along a time period spanning the interval Nov '20-Feb '22. Six of those households quit the pilot almost immediately due to technical problems, leaving 47 households in the pilot.

5.1.1.1. Pre-intervention phase

The exact timeframe of the pre-intervention and 1st intervention phases for the Greek pilot are not known accurately. The duration of both varies for each household depending on when its resident(s) downloaded the mobile app and was/were exposed to the interventions. The nudge-enhanced version of the app was first released on January 17th; on March 4th it was announced that a new release of the app with new features was available. The last date is taken as a common reference for the launch of the 1st intervention, which lasted up to the end of Apr '22.

All 47 households sent energy data during the pre-intervention phase. For a given household, that is taken to last from the date that the household sent its first data to the data collection platform till March 4th. As seen in Figure 26, this phase varies substantially along households, reaching more than a year for households that joined the pilot early.

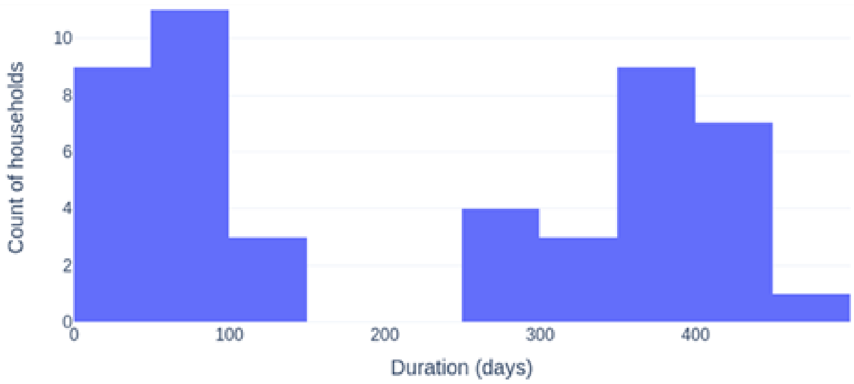


Figure 26. Duration of the intervention period for the 47 households in the Greek pilot

5.1.1.2. First intervention phase

All 47 households sent data to the NUDGE data collection platform within the intervention phase of the project.

5.1.2. Missing data

Seven households had to change their device during the pilot experimentation and another three experienced connectivity problems resulting in periods of no operation. These ten households are listed in Table 12

Table 12. Households that experienced provisional technical problems and days that no measurement data were reported from them for the period October 1, 2021 – March 4, 2022

Household id	Date of (first) device installation	Period(s) of silence	Period of silence duration (days)
HOME_1	March 9,2021	21-04-2021 / 27-04-2022	371
HOME_2	May 10, 2021	21-01-2022 / 24-03-2022	3
HOME_6	November 14, 2021	14-11-2021 / 03-01-2022	60
HOME_8	November 5, 2020	26-11-2021 / 20-12-2021 03-02-2022 / 04-03-2021	82
HOME_11	December 10, 2020	17-02-2022 / 04-03-2022	15
HOME_13	January 25, 2021	24-12-2021 / 25-12-2021	1
HOME_15	January 6, 2021	01-10-2021 / 17-10-2021 04-12-2021 / 04-02-2022	90
HOME_30	October 22, 2021	24-01-2022 / 04-03-2022	39
HOME_45	January 6, 2021	10-01-2022 / 04-03-2022	53
HOME_48	January 14, 2022	08-02-2022 / 04-03-2022	24

5.1.3. Collected measures : characteristics, sample time series and basic statistics

The parameters/metrics that are reported by the Greek pilot to the NUDGE platform are described in Deliverable 3.1. We reproduce relevant information from that deliverable in Table 13 for ease of reference.

There are 12 parameters that are monitored and reported to the NUDGE central platform. Nine of them concern the boiler operation and control by the domX device (operational settings, algorithmic choices, energy consumption) and three (Temperature, TempOutdoor, HumIndoor) are collected by sensors available on the domX device. We summarise basic information about the time series collected for each of those parameters in Table 14.

Table 13. Parameters that are reported by the Greek pilot households to the NUDGE central platform

Parameters	Description
Modulation	Current Boiler modulation Level (as percentage of max boiler output, with most common value being 24 kW)
BoilerT	Current Boiler Water temperature
BoilerHeat	Current Boiler Heat State - Shows whether the boiler circulator is active
BoilerWater	Current Boiler Water State - Shows whether the boiler DHW is active
TempOutdoor	Outdoor temperature - Input taken from the domX GW temperature Sensor (default) or by the Boiler temperature probe if it exists
Temperature	Current Room Temperature - Reported by the Thermostat or the domX indoor climate sensor
HumIndoor	Current Room Humidity - Reported by the domX indoor climate sensor
TempTarget	Desired Room Temperature Setting - Set by the Thermostat or the application
HeatingBalance	Weather compensation tradeoff that adapts the aggressiveness of the heating control algorithm (Controls the MAX boiler water temperature to be set)
OTCMaxT	Max Temperature that the weather compensation algorithm can output given the environmental conditions
EnergyIn	The energy consumption of the boiler for the past 5 minutes in kWh
PowerIn	The Instantaneous power consumption of the boiler in kW

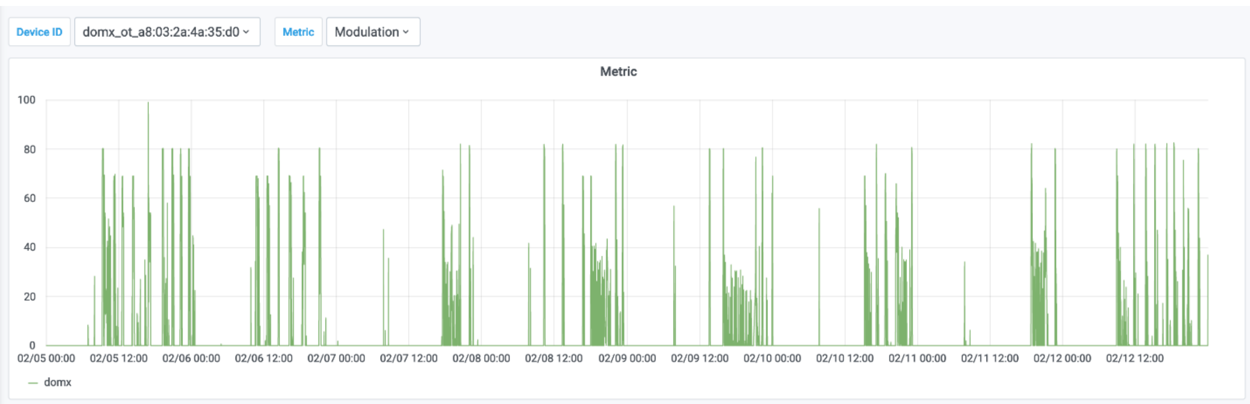
Table 14. Details on the readings for the parameters that are reported by households participating in the Greek pilot trial

Parameter	Value Type	Unit	Value range	Sampling frequency	Notes
Modulation	Integer	-	[0,100]	1 min	This metric is reported for Opentherm boilers only
BoilerT	Decimal	Celsius	{0,100}	1 min	This metric is reported for Opentherm boilers only
BoilerHeat	Binary	-	{0,1}	1 min	Shows whether the boiler circulator is active for Opentherm boilers and when

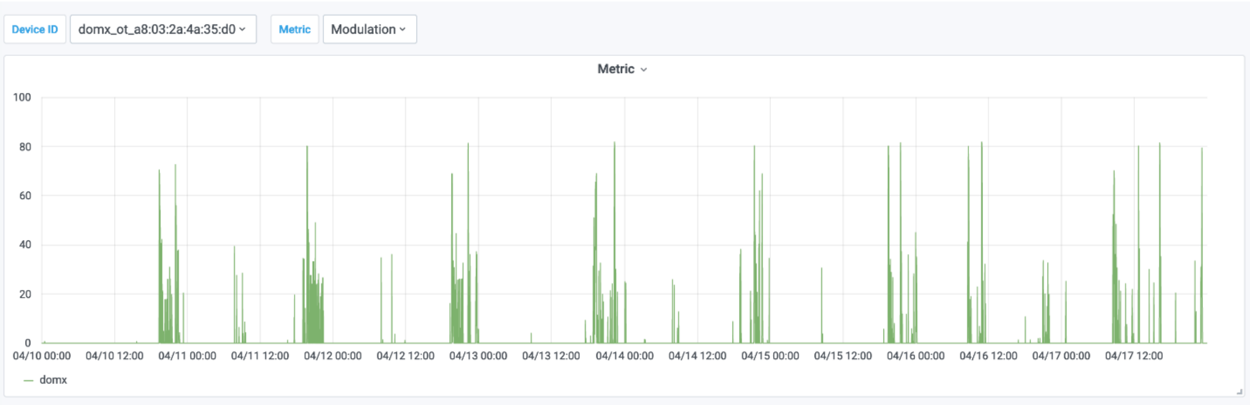
					there is heat request from the thermostat for the ONOFF ones.
BoilerWater	Binary	-	{0,1}	1 min	This metric is reported for Opentherm boilers only
TempOutdoor	Decimal	Celsius	-	1 min	
Temperature	Decimal	Celsius	-	1 min	
HumIndoor	Decimal	%	{0,100}	1 min	This metric is reported for homes with domX indoor climate sensor only
TempTarget	Decimal	Celsius	-	1 min	
Heating Balance	Decimal	Float	{1,10}	1 min	This metric is reported for both ONOFF and Opentherm boilers, but it is useful only for the Opentherm ones.
OTCMaxT	Decimal	Celsius	{0,100}	1 min	
EnergyIn	Decimal	Wh	-	5 min	
PowerIn	Decimal	kW	{1,24}	1 min	

Hereafter, we present an indicative time series for two one-week-long time intervals, one in February '22 and one in April '22, for a randomly chosen household (HOME_2).

Modulation



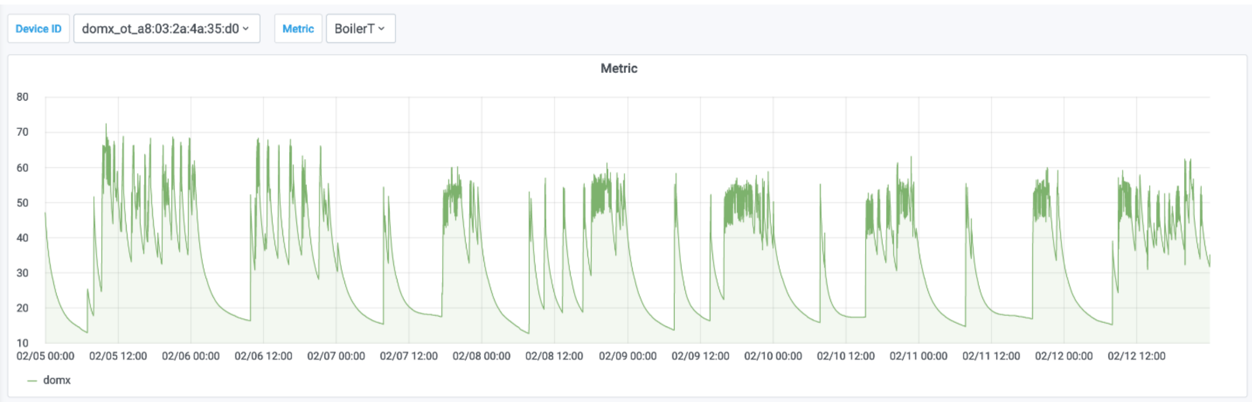
(a) *Week 05/02/22 - 12/02/22 with average outdoor temperature 10.1 °C.*



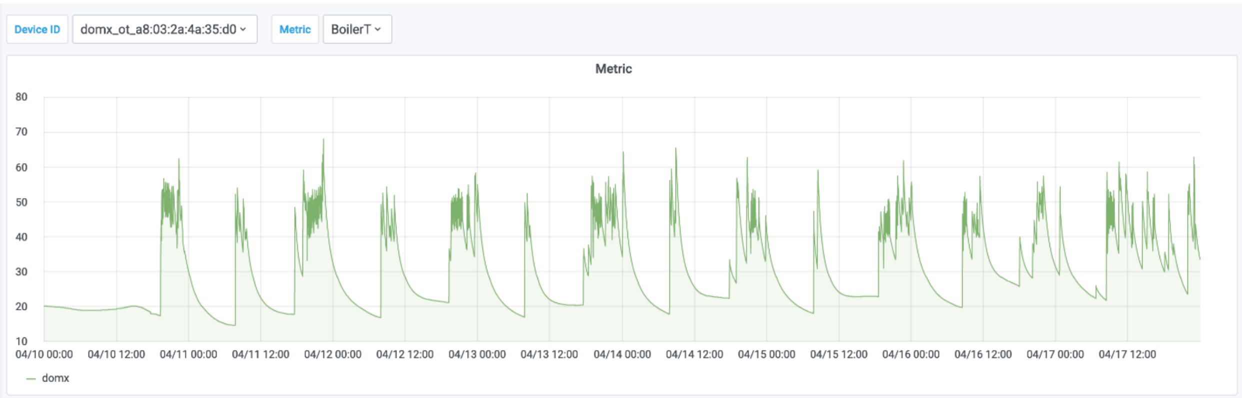
(b) *Week 10/04/22 - 17/04/22 with average outdoor temperature 15.2 °C.*

Figure 27. Modulation time-series for HOME_2 over two different one week-long periods.

BoilerT



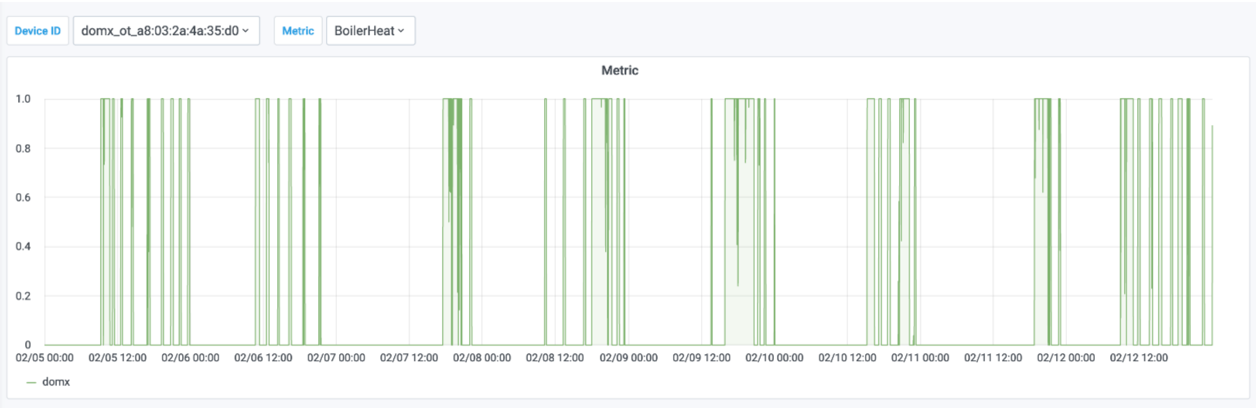
(a) *Week 05/02/22 - 12/02/22 with average outdoor temperature 10.1 °C.*



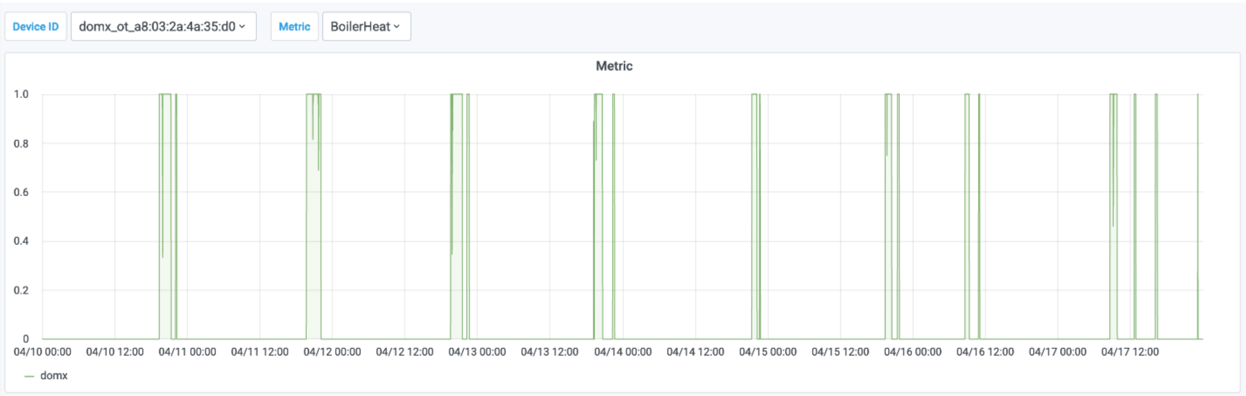
(b) Week 10/04/22 - 17/04/22 with average outdoor temperature 15.2 °C.

Figure 28. BoilerT time-series for HOME_2 over two different one week-long periods.

BoilerHeat



(a) *Week 05/02/22 - 12/02/22 with average outdoor temperature 10.1 °C.*

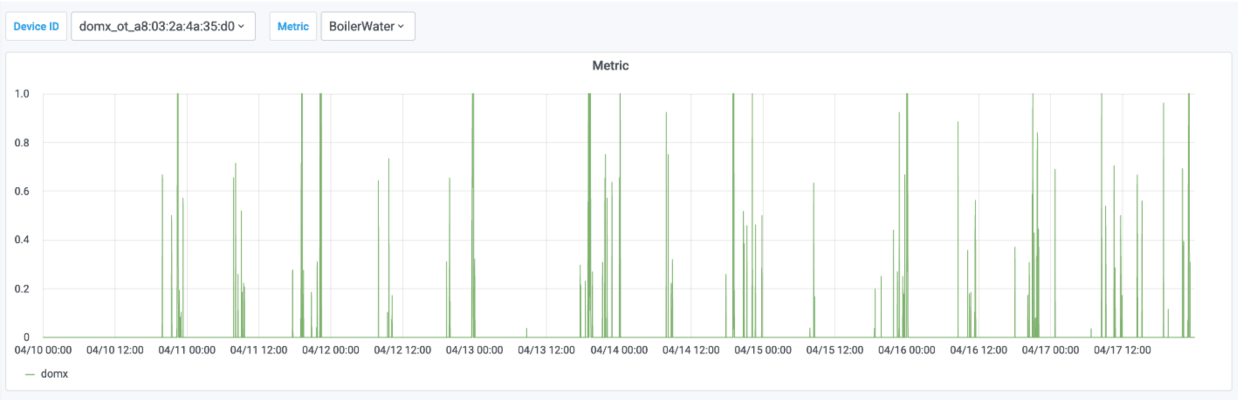


(b) Week 10/04/22 - 17/04/22 with average outdoor temperature 15.2 °C.

Figure 29 . BoilerHeat time-series for HOME_2 over two different one week-long periods.

BoilerWater

(a) *Week 05/02/22 - 12/02/22 with average outdoor temperature 10.1 °C.*



(b) Week 10/04/22 - 17/04/22 with average outdoor temperature 15.2 °C.

Figure 30. BoilerWater time-series for HOM _2 over two different one week-long periods.

TempOutdoor

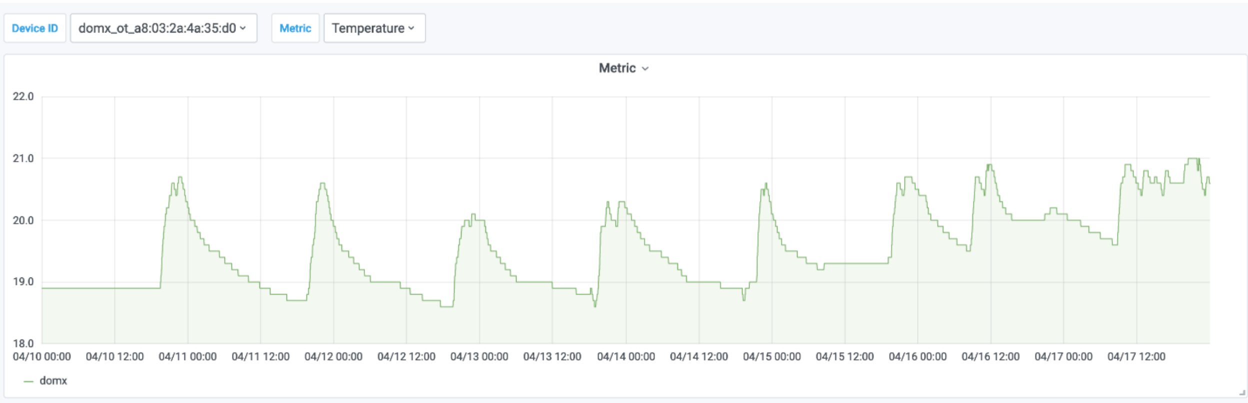
(a) *Week 05/02/22 - 12/02/22 with average outdoor temperature 10.1 °C.*

(b) Week 10/04/22 - 17/04/22 with average outdoor temperature 15.2 °C.

Figure 31. TempOutdoor time-series for HOME_2 over two different one week-long periods.

Temperature

(a) Week 05/02/22 - 12/02/22 with average outdoor temperature 10.1 °C.



(b) Week 10/04/22 - 17/04/22 with average outdoor temperature 15.2 °C.

Figure 32.Temperature time-series for HOME_2 over two different one week-long periods.

HumIndoor

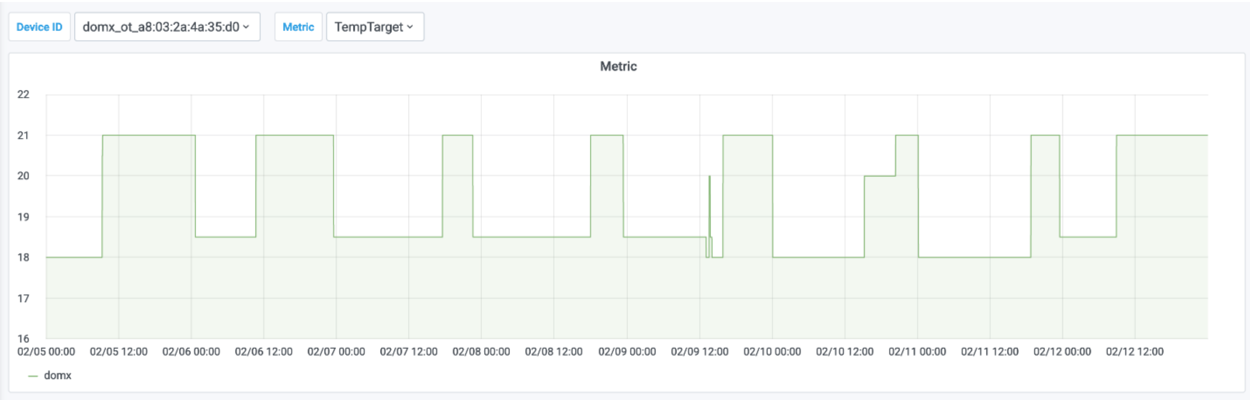
HOME_2 does not have domX indoor climate sensor, so we plot HumIndoor from another home nearby in Thessaloniki.

(a) Week 05/02/22 - 12/02/22 with average outdoor temperature 10.1 °C.

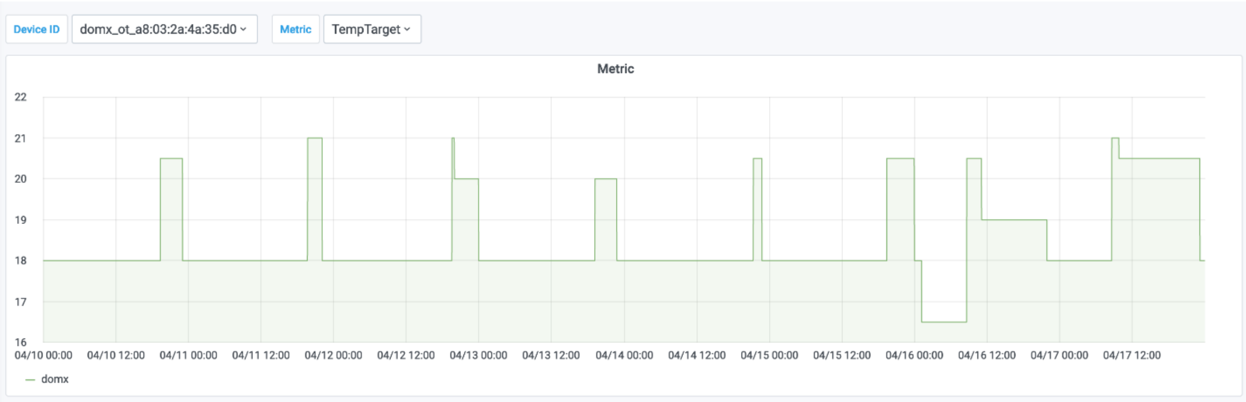
(b) Week 10/04/22 - 17/04/22 with average outdoor temperature 15.2 °C.

Figure 33. HumIndoor time-series for HOME_19 over two different one week-long periods.

TempTarget



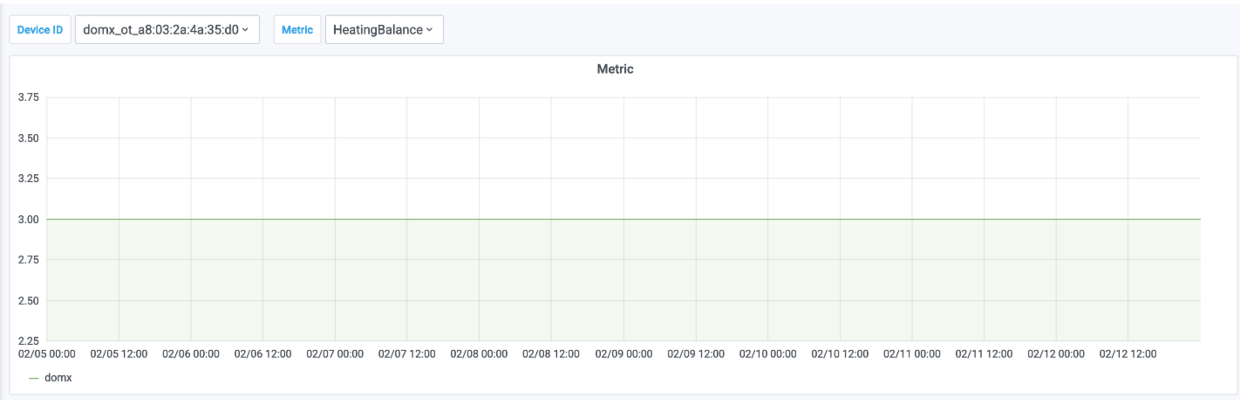
(a) Week 05/02/22 - 12/02/22 with average outdoor temperature 10.1 °C.



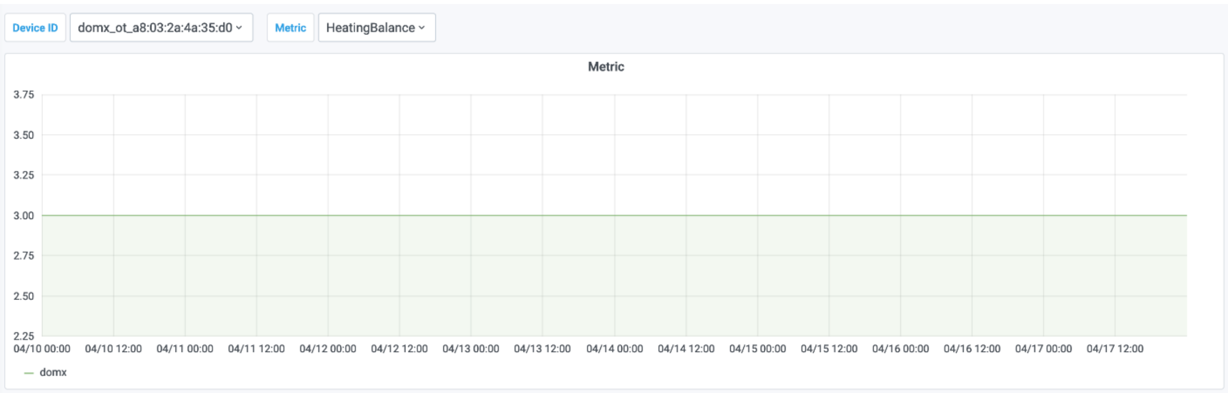
(b) Week 10/04/22 - 17/04/22 with average outdoor temperature 15.2 °C.

Figure 34. TempTarget time-series for HOME_2 over two different one week-long periods.

HeatingBalance



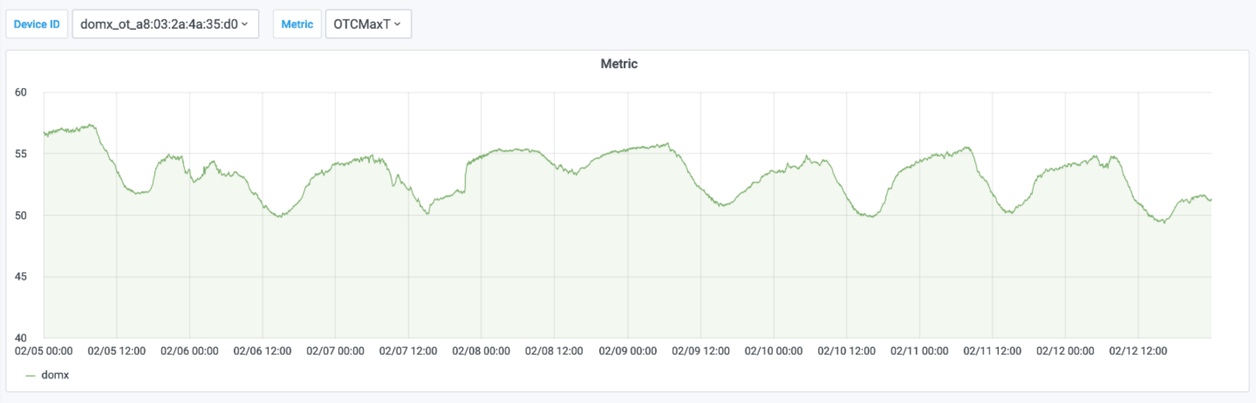
(a) Week 05/02/22 - 12/02/22 with average outdoor temperature 10.1 °C



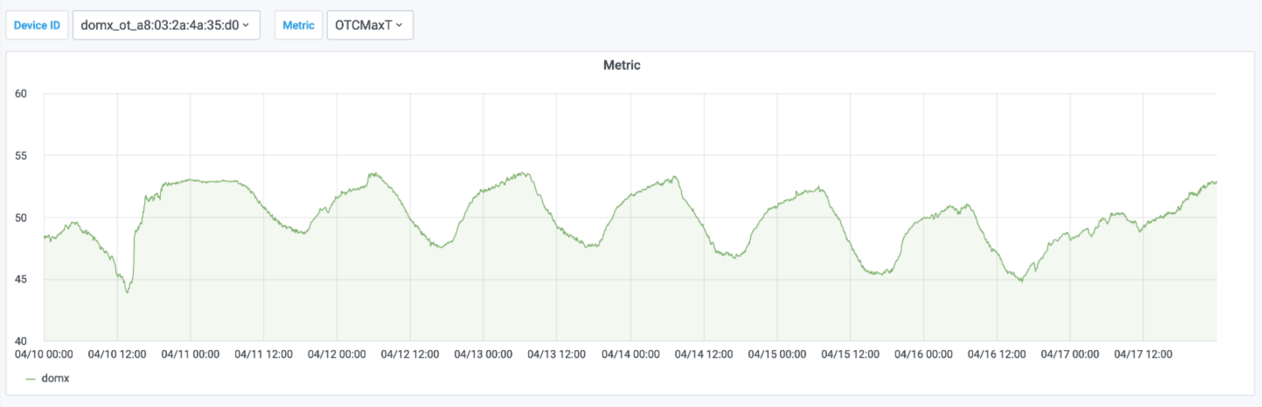
(b) Week 10/04/22 - 17/04/22 with average outdoor temperature 15.2 °C

Figure 35. HeatingBalance time series for HOME_2 over two different one week-long periods.

OTCMaxT



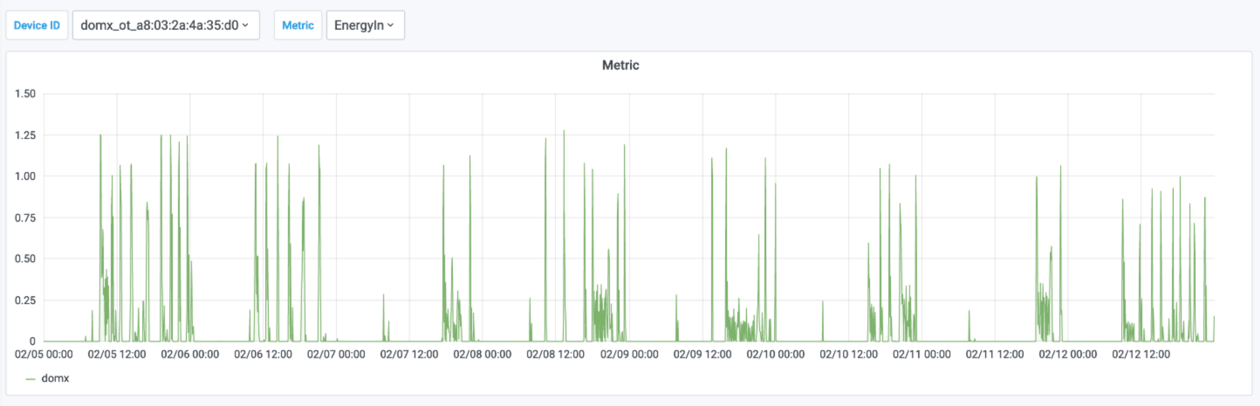
(a) Week 05/02/22 - 12/02/22 with average outdoor temperature 10.1 °C



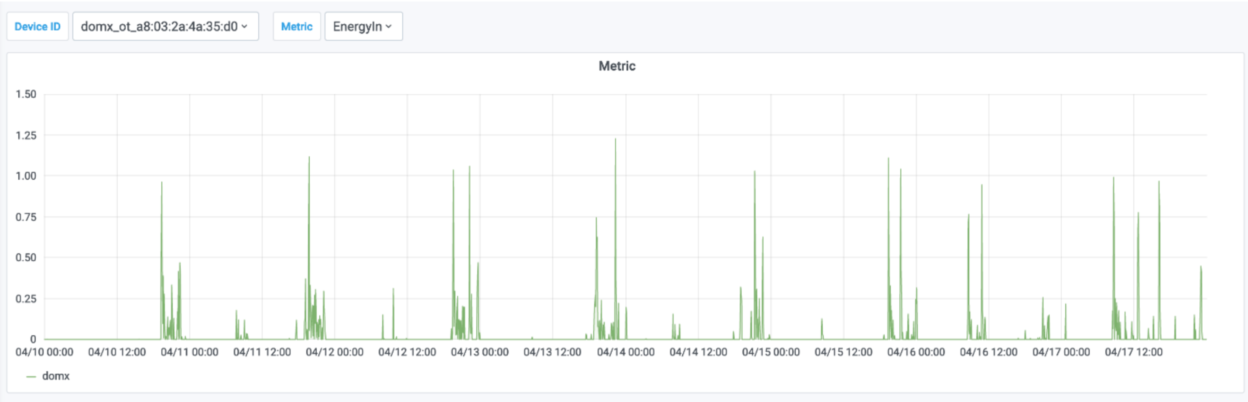
(b) Week 10/04/22 - 17/04/22 with average outdoor temperature 15.2 °C

Figure 36. OTCMaxT time-series for HOME_2 over two different one week-long periods.

EnergyIn



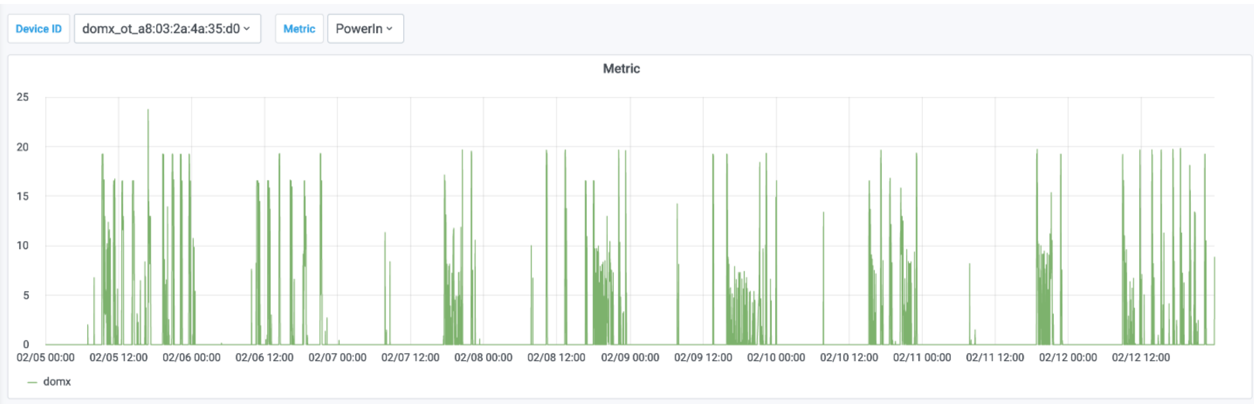
(a) Week 05/02/22 - 12/02/22 with average outdoor temperature 10.1 °C



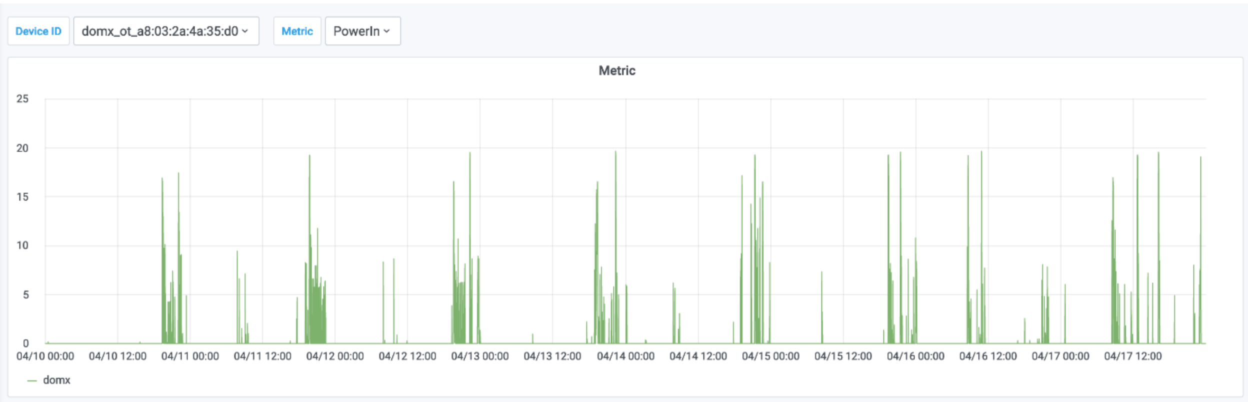
(b) Week 10/04/22 - 17/04/22 with average outdoor temperature 15.2 °C

Figure 37. EnergyIn time-series for HOME_2 over two different one week-long periods.

PowerIn



(a) Week 05/02/22 - 12/02/22 with average outdoor temperature 10.1 °C



(b) Week 10/04/22 - 17/04/22 with average outdoor temperature 15.2 °C

Figure 38. PowerIn time-series for HOME_2 over two different one week-long periods.

5.2. The Belgian (BE) pilot

5.2.1. Number of households sending data

The Belgian pilot consists of 64 households, of whom 22 are equipped with smart meters. Measurement data from households/families who are equipped with proper smart meters are sent to the EnergyID platform. Those 22 households could successfully connect to the EnergyID platform and provide sensor data to the Grafana platform. In the Belgian pilot, the dashboard from EnergyID is used during the lessons as a means to help children better understand their energy consumption. Hence, the related energy consumption data can be considered as a side product, which can help validate the hypothesized acquisition of expert knowledge and the increase of awareness about energy matters and consumption, as these are originally reported in the actual tests undertaken during the course.

All households, except for one, provide electricity consumption and/or production data (n = 22), of whom 14 provided data on their natural gas consumption. Two households provide data with regard to their electricity production of their PV installation. The tables of the respective parameters in section 5.2.3 also report these sample sizes.

5.2.2. Missing data

Only a minority of the Belgian sample, i.e., 36.5% of the total sample, is equipped with smart meters. Therefore, data from 40 households is lacking from the first cohort study.

With regard to the households equipped with smart meters, once data is logged all households stayed active and only appear to be silent for a couple of days. However, one household (i.e., BE033) stopped providing electricity consumption data since 24/03/2022 after only a period of 4.77 months, another household (i.e., BE015) stopped PV data provisioning since 23/02/2022 after only a period of 3.8 months (for comparison: $M_{duration}$ = 7.66, $SD_{duration}$ = 1.41).

5.2.3. Collected measures: characteristics, sample time series and basic statistics

In Deliverable D3.1, we have described the parameters/metrics that are reported by the Belgian pilot to the NUDGE platform. We reproduce relevant information from that deliverable in Table 15 for ease of reference.

Table 15. Parameters that are reported by the Belgian pilot households to the NUDGE central platform

Parameters	Description
ElectricityIn	The electricity consumption for the past 15 minutes in Wh (day and night rate)
ElectricityOut	The electricity injection for the past 15 minutes in Wh (day and night rate)
NaturalGas	The gas consumption for the past hour in Wh
SolarPanels	The electricity production by the PV installation per day in Wh

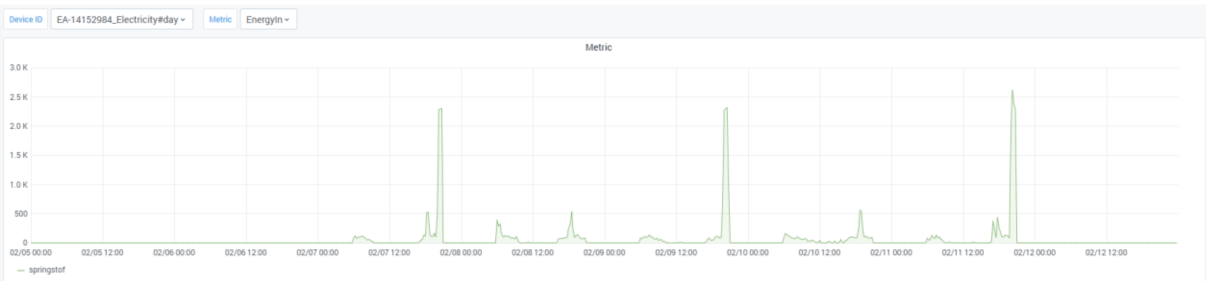
There are 4 parameters that are monitored by the EnergieID platform and reported to the NUDGE platform. The electricity consumption and production parameters are measured using daily and nightly rates at respectively peak and off-peak hours. We summarise basic information about the time series collected for each of those measures.

Table 16. Details on the readings for the parameters that are reported by households participating in the Belgian pilot trial

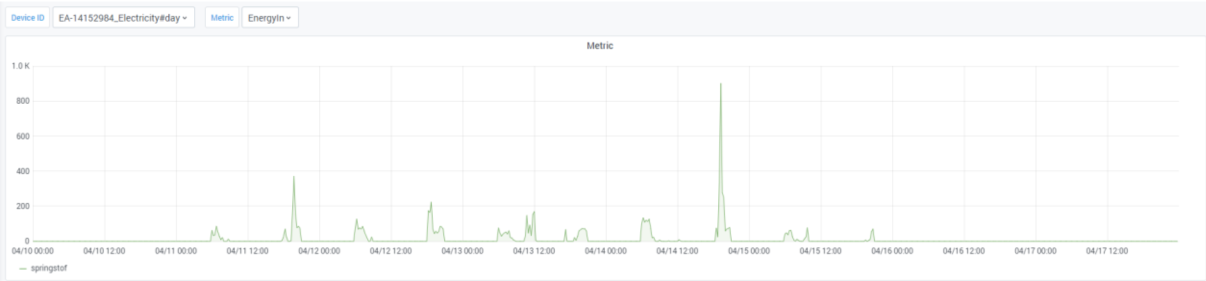
Parameter	Value Type	Unit	Sampling frequency	Notes	Sample (n)
ElectricityIn (day & night)	Integer	Wh	15 min	Day rate starts at 6:00 AM and ends at 20:45 PM. Night rate starts at 21:00 PM and ends at 5:45 AM, and during weekend days and legal holidays.	21
ElectricityOut (day & night)	Integer	Wh	15 min	Day rate starts at 6:00 AM and ends at 20:45 PM. Night rate starts at 21:00 PM and ends at 5:45 AM, and during weekend days and legal holidays.	9
NaturalGas	Integer	Wh	60 min	-	14
SolarPanels	Integer	Wh	Daily	-	2

ElectricityIn - day

In the plots below, electricity consumption can only be noticed on weekdays, i.e., 7/02-11/02 and 11/04-15/04, which are peak times and billed at day rate.



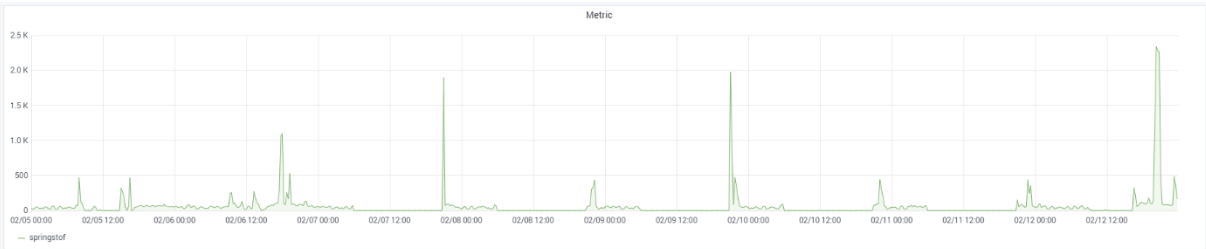
(a) Week 05/02/22 - 12/02/22



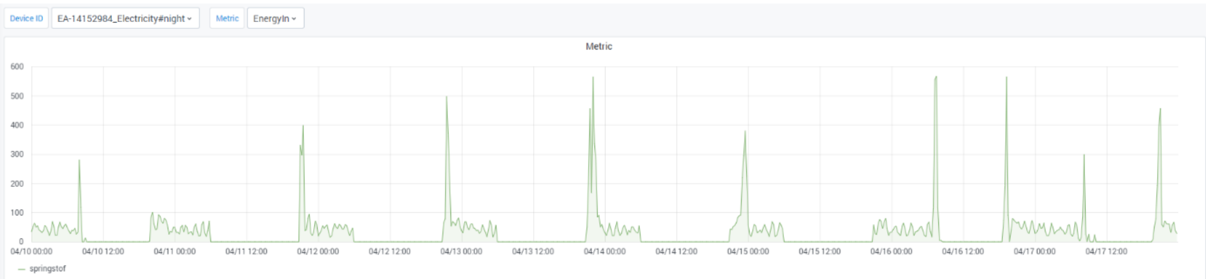
(b) Week 10/04/22 - 17/04/22

Figure 39. Electricity consumption for HOME _14 during the day over two different one week-long periods.

ElectricityIn - night



(a) Week 05/02/22 - 12/02/22

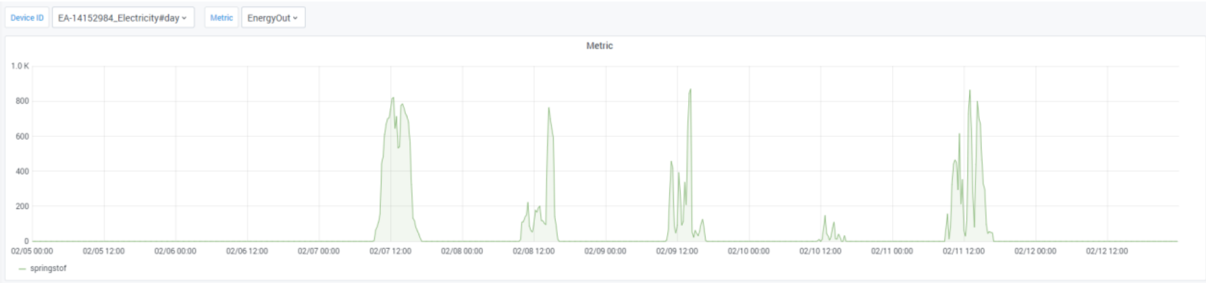


(b) Week 10/04/22 - 17/04/22

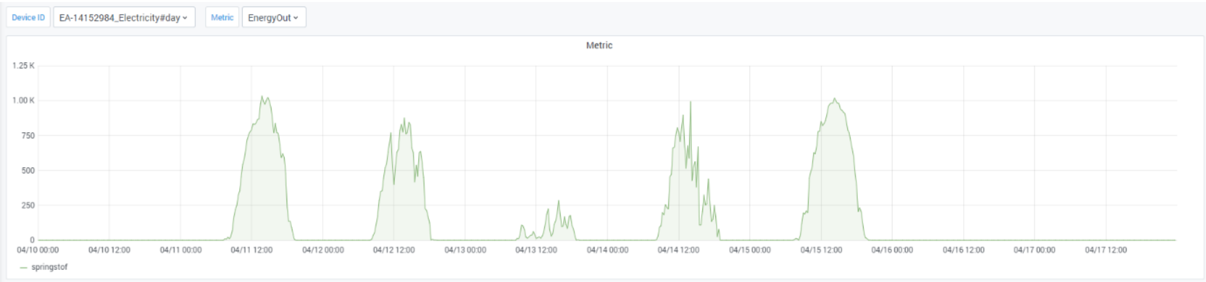
Figure 40. Electricity consumption for HOME _14 at night over two different one week-long periods.

ElectricityOut - day

In the plots below, electricity consumption can only be noticed on weekdays, i.e., 7/02-11/02 and 11/04-15/04, which are peak times and billed at day rate.



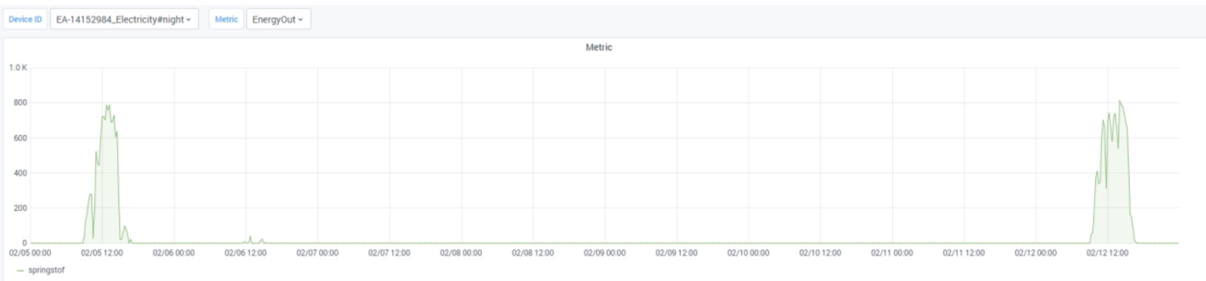
(a) Week 05/02/22 - 12/02/22



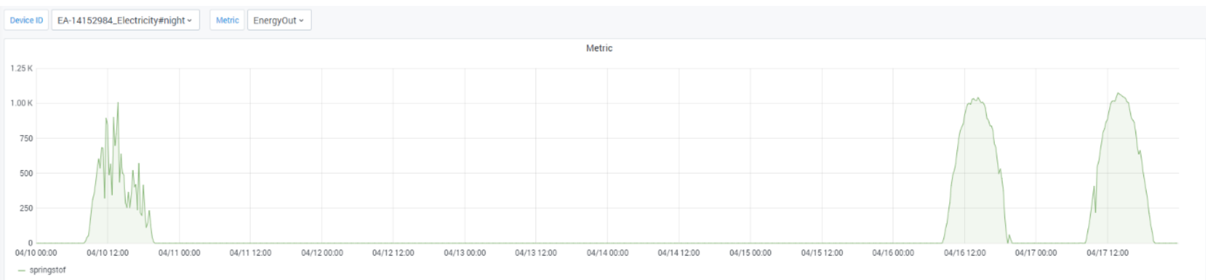
(b) Week 10/04/22 - 17/04/22

Figure 41. Electricity injection for HOME _14 during the day over two different one week-long periods.

ElectricityOut - night



(a) Week 05/02/22 - 12/02/22

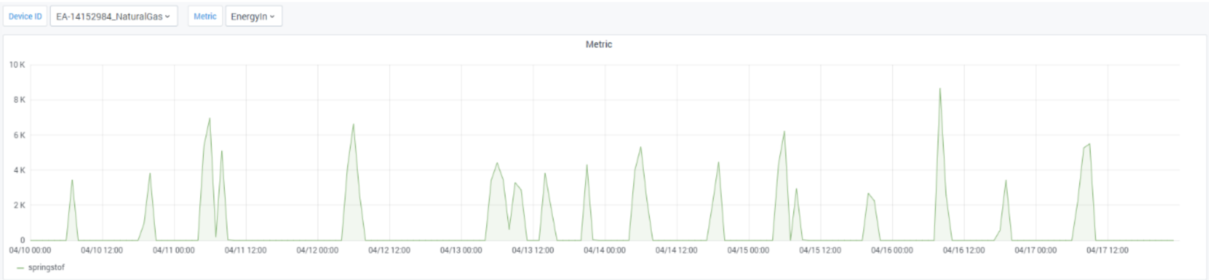


(b) Week 10/04/22 - 17/04/22

Figure 42. Electricity injection for HOME _14 at night over two different one week-long periods.

Natural gas

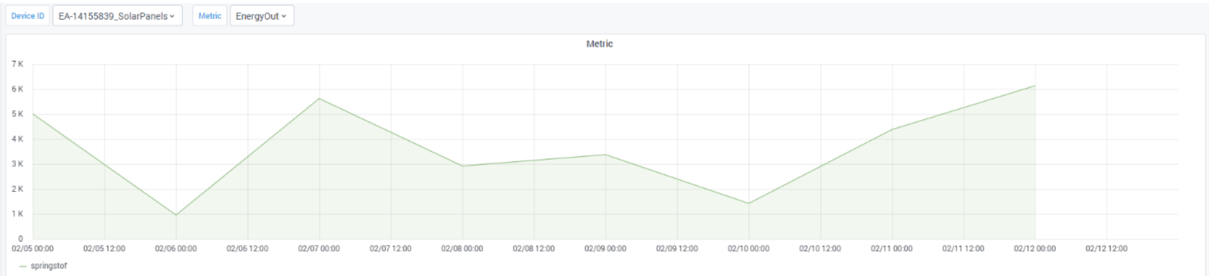
(a) Week 05/02/22 - 12/02/22



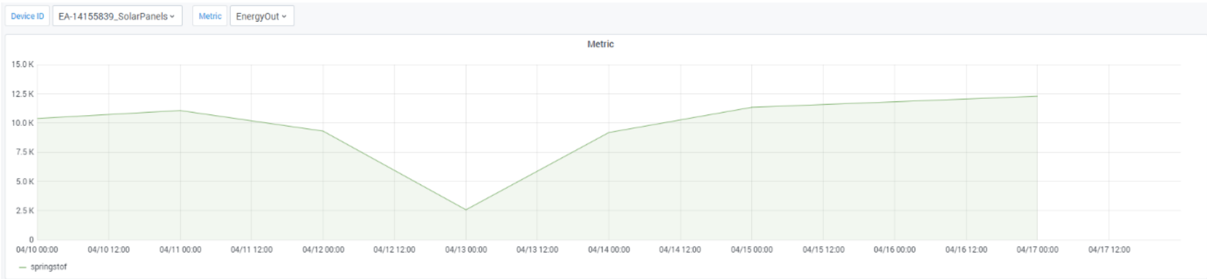
(b) Week 10/04/22 - 17/04/22

Figure 43. Natural gas consumption for HOME _14 over two different one week-long periods.

Solar panels



(a) Week 05/02/22 - 12/02/22



(b) Week 10/04/22 - 17/04/22

Figure 44. Electricity production for HOME _35 over two different one week-long periods.

5.3. The German (DE) pilot

5.3.1. Number of households sending data

As described above, the DE pilot reached a sample of 111 participants by M22 (Jun '22). For Figure 45, we consider the participants who joined till Jan' 2022 and no participants who joined later. This restriction leads to only 105 participants in Jan'22. 6 participants joined after Jan '22, which result in the total 111 participants in Jun' 22. 94 out of the 100 recruited participants were sending data to the central platform in October 2021 due to a delay in the connection. Due to some connection problems in Apr '22 and Jun '22, the number temporarily decreased.

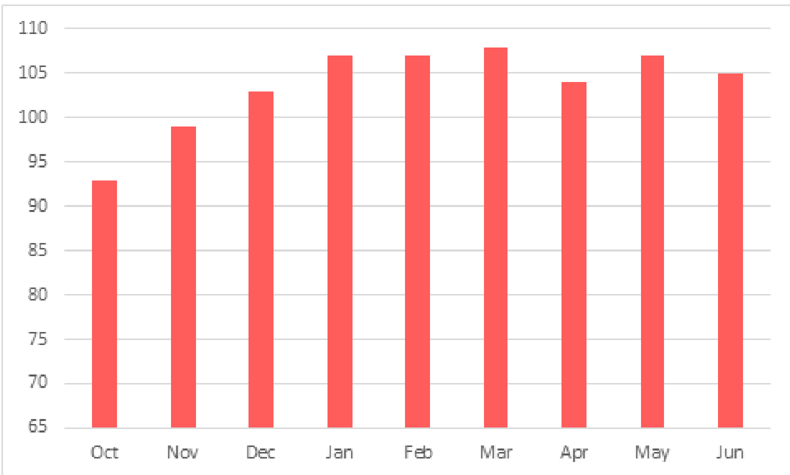


Figure 45. Number of households in the German pilot sending data to the central platform in the period Oct '21-Jun '22 (only participants who joined till Jan '22 are considered)

5.3.2. Missing data

The data points, which are collected every 20 seconds in a cumulative manner, are differentiated and aggregated into hourly profiles. Table 17 presents the number of hourly values prepared for the calculation of the relevant behaviour.

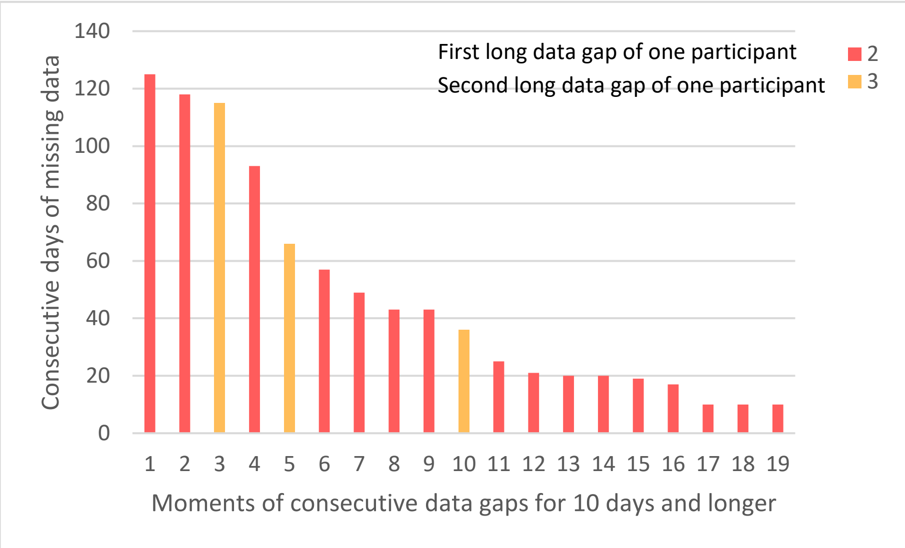


Figure 46. Consecutive data gaps for 10 days and longer

Small data gaps (up to one day) are interpolated. 16 participants with consecutive missing data of 10 to 125 days are identified. Three of them show recurrent periods of missing data. The three participants are excluded for this analysis. For the other 13 ones, only the periods of missing data is excluded. For future evaluations, approaches to fill the gaps with similar data points are considered. Depending on the approach, it will be decided which level of data gaps is acceptable to be considered for the analysis.

Ranging from 4.1 to 7.1 percent, the share of missing data points differs between the different kinds of meters.

Table 17. Share of missing data points w.r.t. the number of overall data points per meter/metric

	Grid meter - energy in	Grid meter - energy out	PV1 meter - energy out	PV2 meter - energy out
Data points	586,177	593,401	591,384	11,812
Missing	7.1%	7.0%	7.0%	4.1%

5.3.3. Collected measures: characteristics, sample time series and basic statistics

The sensor data of the DE pilot is collected by a maximum of six meters per household, which measure:

- the energy consumed and fed in the grid ("grid meter")
- the household consumption ("home meter")
- the charging process of the EV ("charging meter")
- the charging process of the battery ("battery meter")
- the electricity production of the PV system ("PV1 meter")
- the electricity production of a second set of PV panels ("PV2 meter"). Two participants expanded their PV rooftop system by installing a second set of panels.

To calculate the relevant KPIs (the increase of the autarky rate and reduction of overall consumption), the measured energy of the PV meter(s) and the grid meter are combined (such as described in D1.2).

The home and charging meters only measure consumed electricity (=energy in), the PV meters only measure produced electricity (=energy out) and the grid and battery meters measure both. The power is measured as well, but not further used for the calculations of the KPIs, nor the other measured metrics.

Table 18. Overview of metrics and meters for DE pilot

Metric	Grid meter	Home meter	Charging meter		Battery meter	PV 1 meter	PV 2 meter
Energy in / power in	x	x	x		x		
Energy out/ power out	x				x	x	x
Further metrics measured					Battery temperature		

In the following, we present the mean, minimum and maximum values of the measured energy per meter based on the raw data sent to the platform. The measurements are collected in a 20 second resolution in Wh. Some extreme values occur due to incorrect measurements during maintenance work. They are excluded in the process of data processing described in D1.2.

Table 19. Overview of measurements for DE pilot

Meter & metric	Value Type	Unit	Sampling frequency
Grid meter – energy in	Decimal	Wh	20 sec
Grid meter – energy out	Decimal	Wh	20 sec
Home meter – energy in	Decimal	Wh	20 sec

Charging meter – energy in	Decimal	Wh	20 sec
Battery meter – energy in	Decimal	Wh	20 sec
Battery meter – energy out	Decimal	Wh	20 sec
PV meter (1 & 2) – energy out	Decimal	Wh	20 sec

Grid meter – energy in

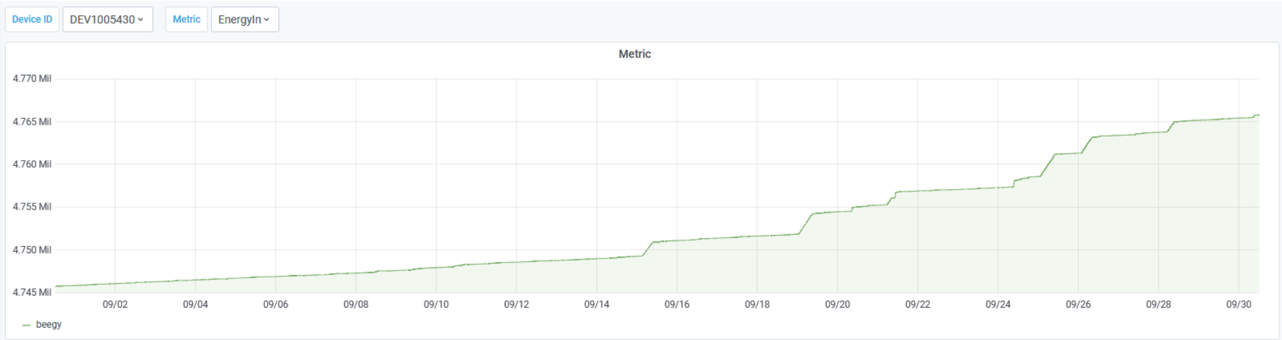


Figure 47. HOME 4 grid meter consumption plot for September 2022

Grid meter – energy out

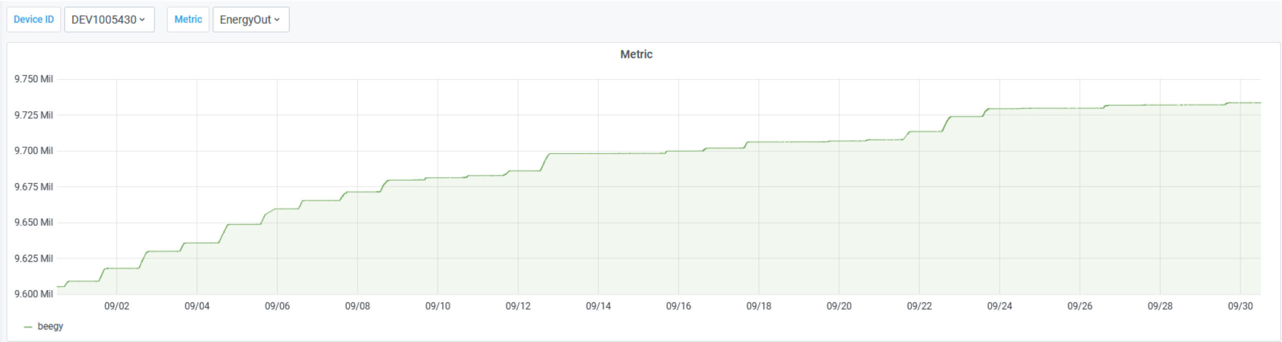


Figure 48. HOME 4 grid meter production plot for September 2022

Home meter – energy in

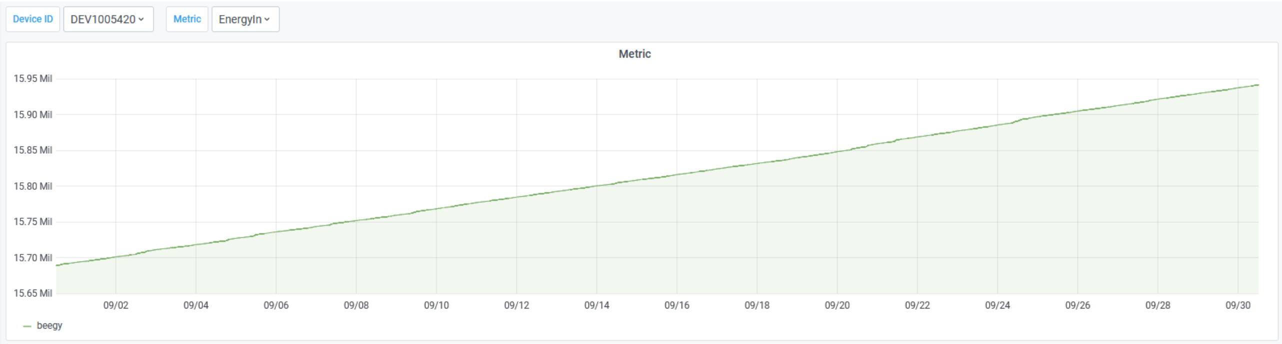


Figure 49. HOME 4 home meter consumption plot for September 2022

Charging meter – energy in

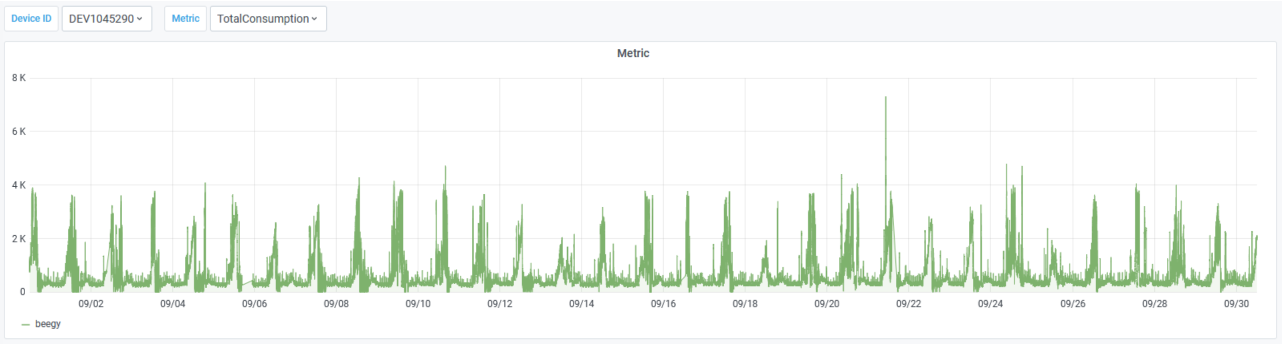


Figure 50. HOME 4 charging meter consumption plot for September 2022

Battery meter – energy in

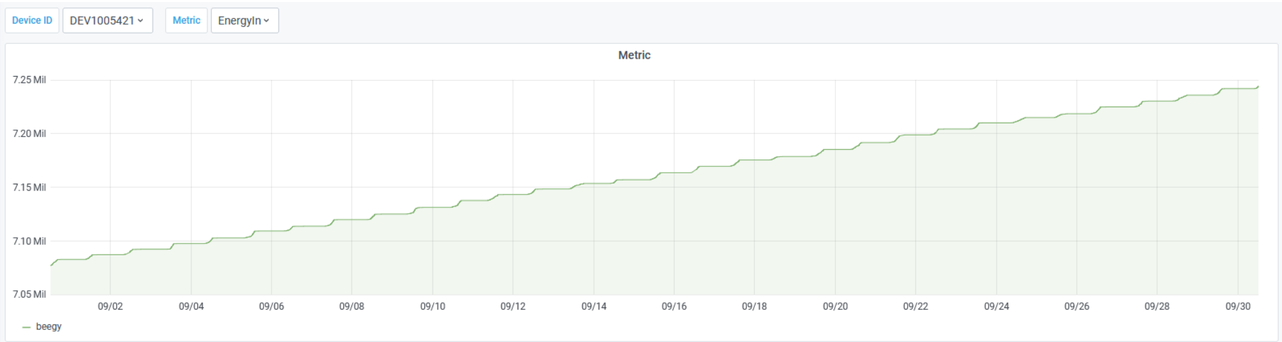


Figure 51. HOME 4 battery meter consumption plot for September 2022

Battery meter – energy out

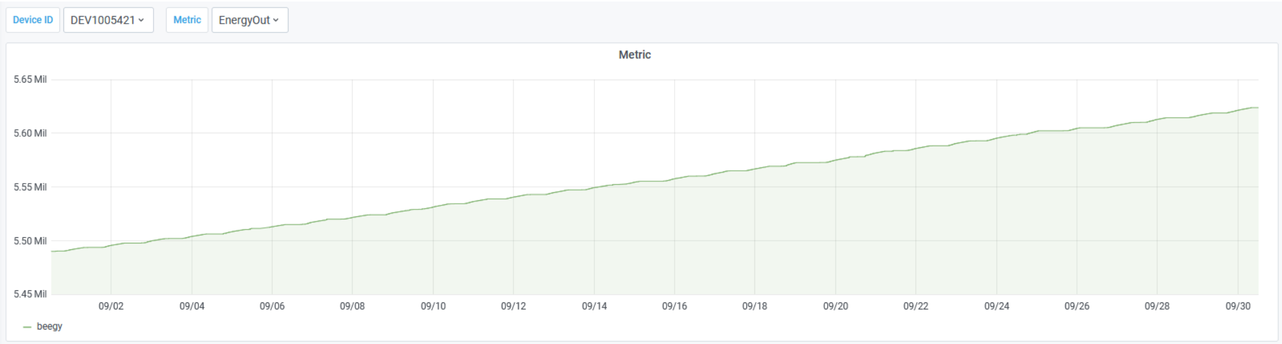


Figure 52. HOME 4 battery meter fed in electricity plot for September 2022

PV meter (1 & 2) – energy out

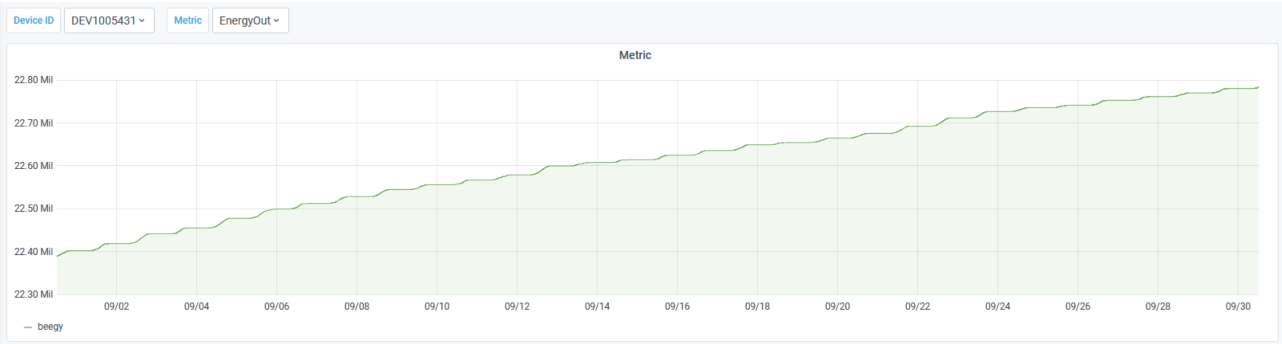


Figure 53. HOME 4 PV production plot for September 2022

5.4. The Portuguese (PT) pilot

5.3.4. Number of households sending data

On the basis of the date of the first submission of energy data to the NUDGE central platform, 101 households joined the PT pilot from July '21 to May '22. One household joined early, in July '21, 59 households joined between the interval September and December '21 and another 41 did so in the first five months of 2022. The highest number of entries was recorded in Nov '21 (n=23) and the second highest in Feb '22 (n = 21).

5.3.4.1. Pre-intervention phase

The 1st intervention nominally started for the Portuguese pilot on June 3rd, when the nudge-enhanced version of the mobile app became available. The actual duration of the pre-intervention period for each household depends on when its resident(s) actually downloaded the nudge-enhanced version of the mobile app.

In the case of the PT pilot, the mobile app first became available for download on March 21st 2022 and devices that were already part of the pilot could download it anytime afterwards up to June 3rd. Households that joined the pilot after March 21st got hold of the mobile app about two weeks after their entry to the pilot so that we could collect measurement data from them in the absence of the mobile app.

Hence, the overall pre-intervention period for each household can be split into two intervals. The first one lasts from the time the household joined the pilot till the moment its resident(s) downloaded and first used the mobile app with nudge 0, whereas the second interval starts from that time and finishes sometime after June 3rd, when the household resident(s) downloaded the nudge-enhanced version of the app and were actually exposed to it.

5.3.4.2. First intervention phase

The 1st intervention phase in the Portuguese pilot is split in two periods. In the first period, lasting from June 3rd to July 15th, 50 out of the total 101 households form the Intervention group and the remaining 51 comprise the Control group. The household roles are reversed in the second half, which lasts from Aug 1st till Sep 15th, a 2-week wash out period separating the two six-week long intervention periods. In what follows, we focus on the first half of the intervention period (June 3rd- July 15th), for which data was available by the time of writing.

47 out of the 50 households originally assigned to the intervention group were exposed to the nudge 0 features, before being exposed to a nudging intervention. Five of those 47 households did not download the nudge 1 release of the app, whereas 3 households originally assigned to the Intervention group downloaded neither the nudge 0 release nor the nudge 1 release. This means that overall, 8 households out of the 50 comprising the Intervention group did not download and interact with the nudging features of the mobile app at all throughout the duration of the intervention phase.

On the other hand, 39 out of the 51 households allocated to the Control group had interacted with the application and had been exposed to Nudge 0 by June 3rd and 5 more households did so in the interval June 3rd – July 15th . Seven households had not even downloaded the mobile app by that time.

5.3.5. Missing data

We try to identify silent days for each household, i.e., days during which no sensor data was reported throughout that day by the household. Figure 54 presents the number of households per day that experience a silent day.

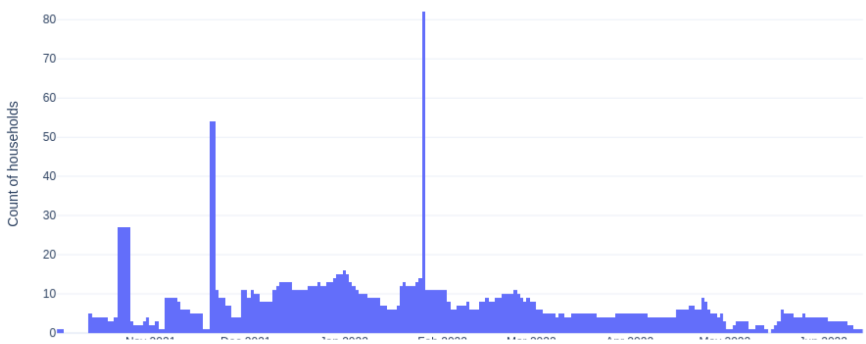


Figure 54. Number of Portuguese pilot participants that do not send any data during the day vs. time

5.3.6. Collected measures: characteristics, sample time series and basic statistics

In Deliverable D3.1, we have described the parameters/metrics that are reported by households participating in the Portuguese pilot to the NUDGE platform. Relevant information is reproduced from that deliverable in Table 20 for ease of reference.

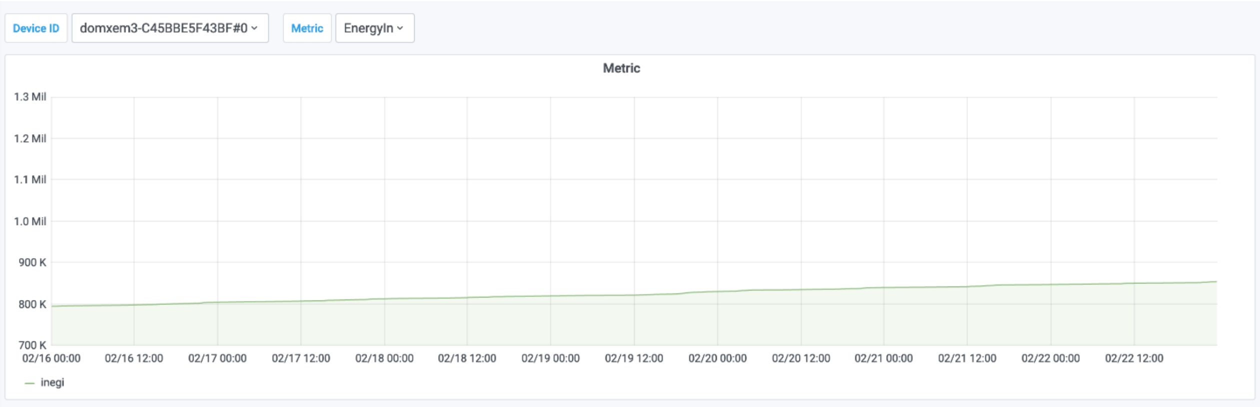
Table 20. The 9 parameters that are reported to the NUDGE central platform by households participating in the Portuguese pilot

Parameter	Value Type	Unit	Value range	Sampling frequency	Notes
EnergyIn	Decimal	Wh	-	30 sec	
EnergyOut	Decimal	Wh	-	30 sec	
PowerIn	Decimal	W	-	30 sec	
InstEnergyIn	Integer	Wmin	-	1 min	
InstEnergyOut	Integer	Wmin	-	1 min	
ReactivePower	Integer	W	-	30 sec	This metric is reported for 1-phase meters only
Voltage	Decimal	V	-	30 sec	
Current	Decimal	A	-	30 sec	This metric is reported for 3-phase meters only
Pf	Decimal	-	{0,1}	30 sec	

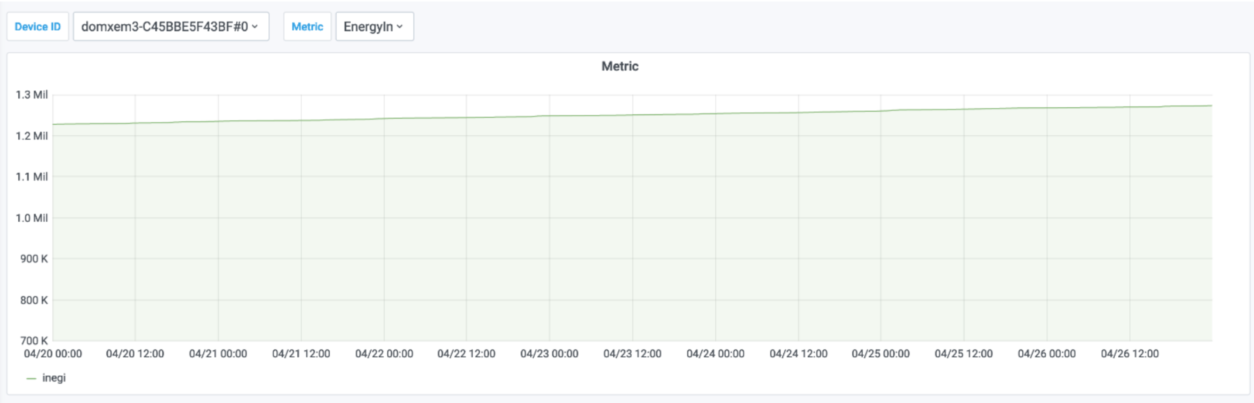
Hereafter, we present indicative time series for two one-week-long time intervals, one in Feb '22 during the pre-intervention phase and one in Apr '22 during the NUDGE0 period, for a household (HOME_16), that was chosen based on the criteria:

- To have a profile representative of the majority of the participants of the PT pilot (monophasic switchboard, No PV)
- To be one of the participants who have interacted substantially with the NUDGE0 version of the App.

EnergyIn



(a) Week in February, 16/02/22 - 22/02/22



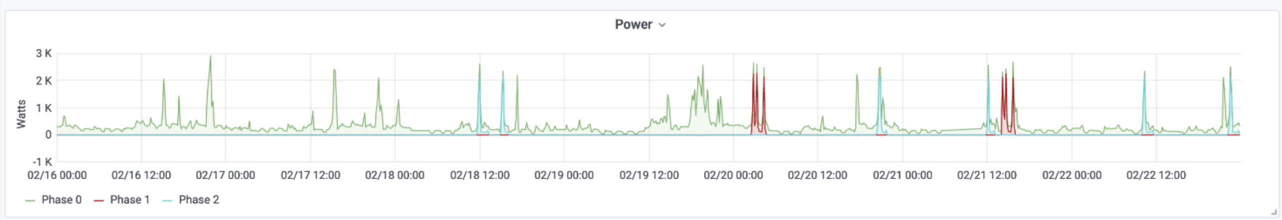
(b) Week in April 20/04/22 - 26/04/22

Figure 55. EnergyIn time-series for HOME_16 over two different one week-long periods.

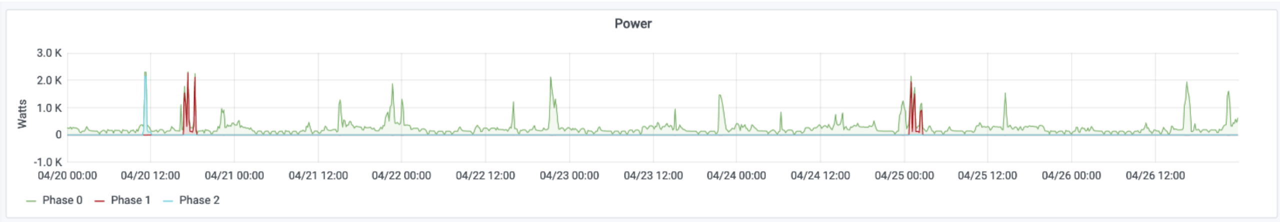
EnergyOut

No need to present a time-series for EnergyOut as there is no returned energy to the grid.

PowerIn



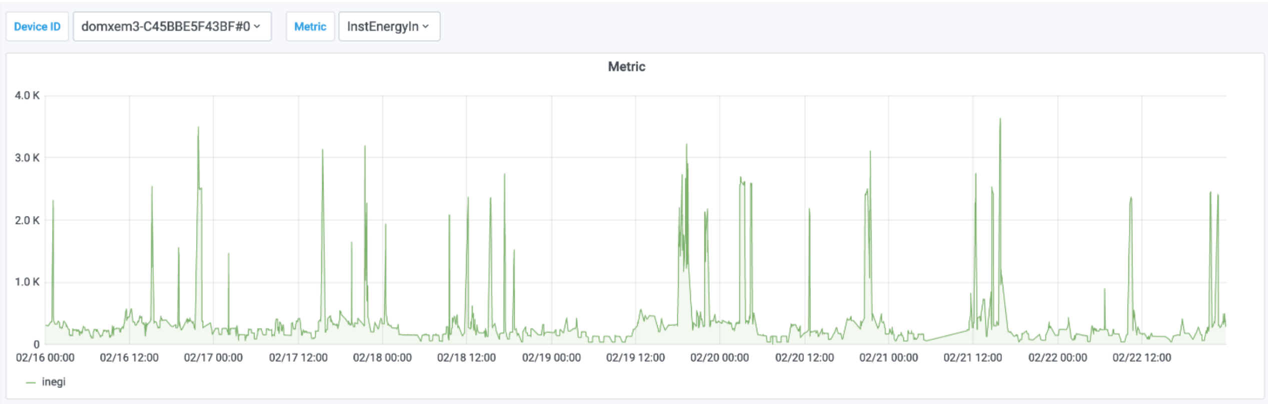
(a) Week in February, 16/02/22 - 22/02/22



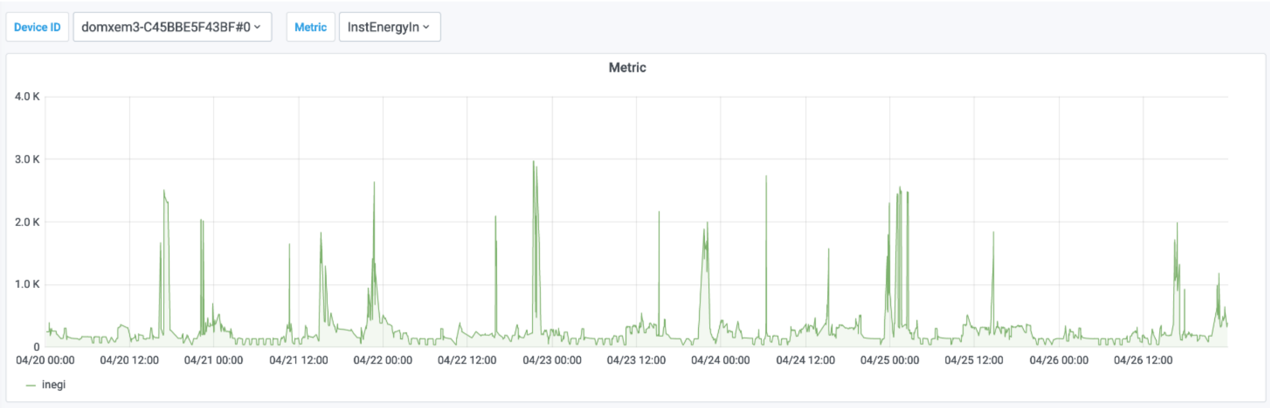
(b) Week in April 20/04/22 - 26/04/22

Figure 56. PowerIn time-series per phase for HOME_16 over two different one week-long periods.

InstEnergyIn



(a) Week in February, 16/02/22 - 22/02/22



(b) Week in April 20/04/22 - 26/04/22

Figure 57. InstEnergyIn time-series for HOME_16 over two different one week-long periods.

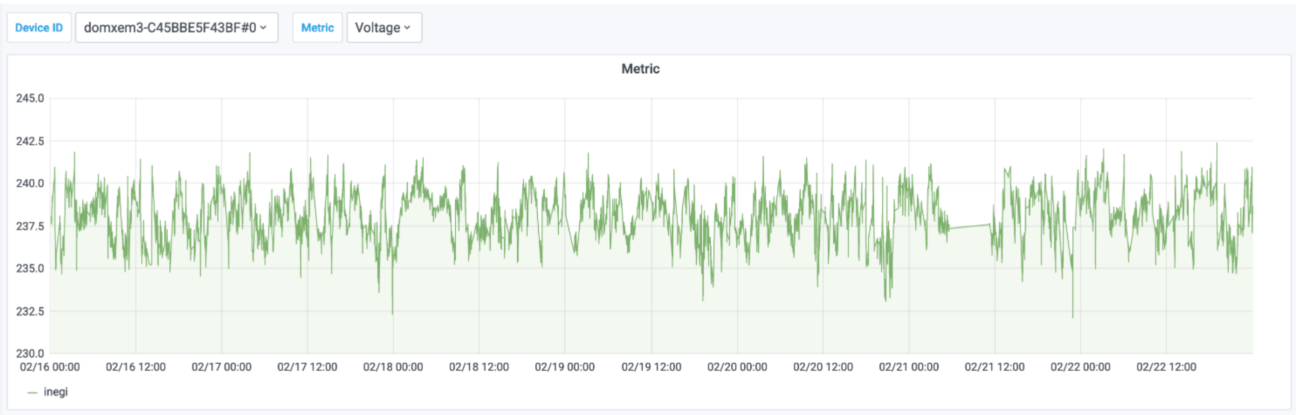
InstEnergyOut

No need to present time-series for InstEnergyOut as there is no returned energy to the grid.

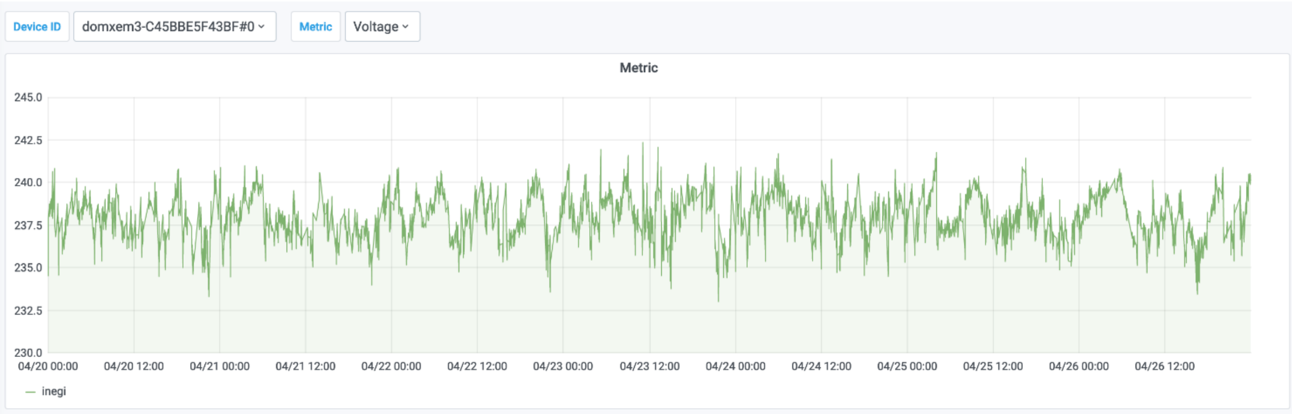
ReactivePower

The energy meter of HOME_16 is a 3-phase meter, so it does not report the ReactivePower metric.

Voltage



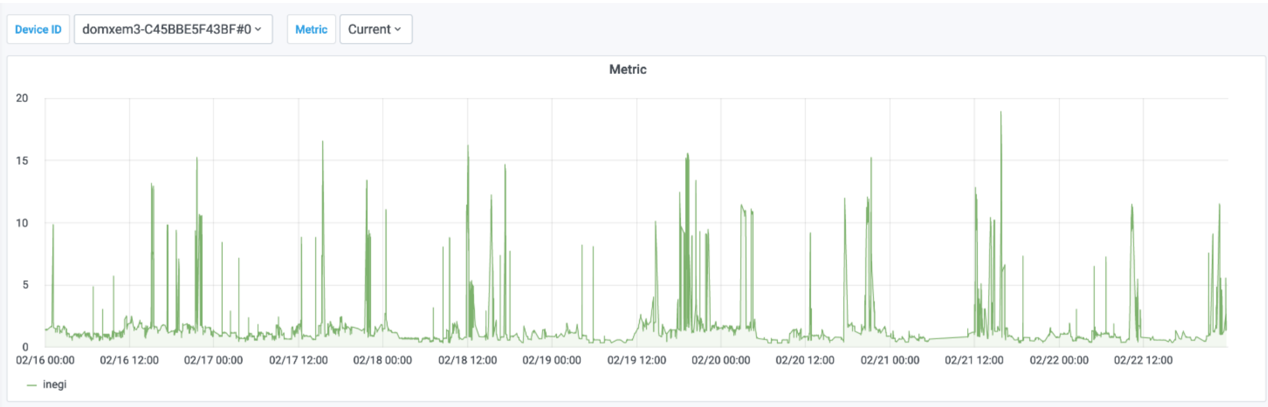
(a) Week in February, 16/02/22 - 22/02/22



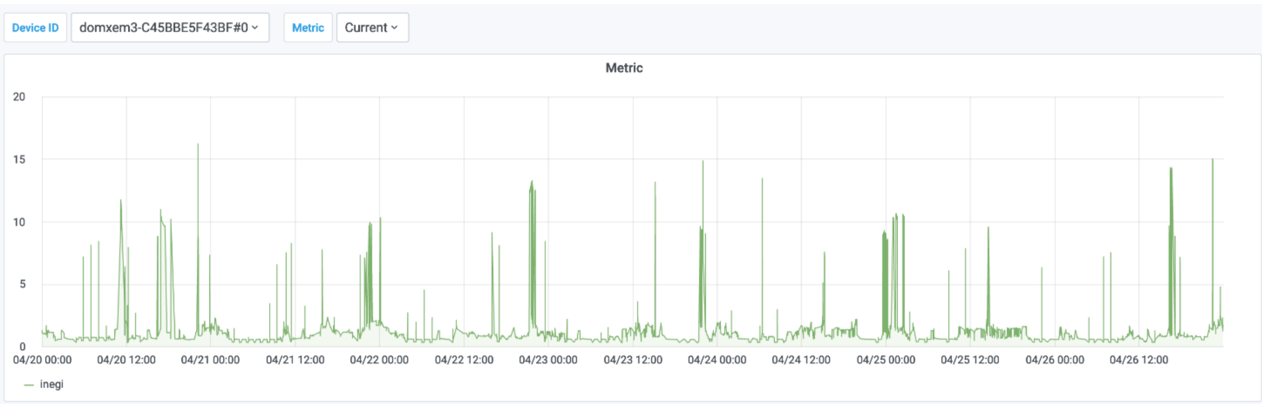
(b) Week in April 20/04/22 - 26/04/22

Figure 58. Voltage time-series for HOME_16 over two different one week-long periods.

Current



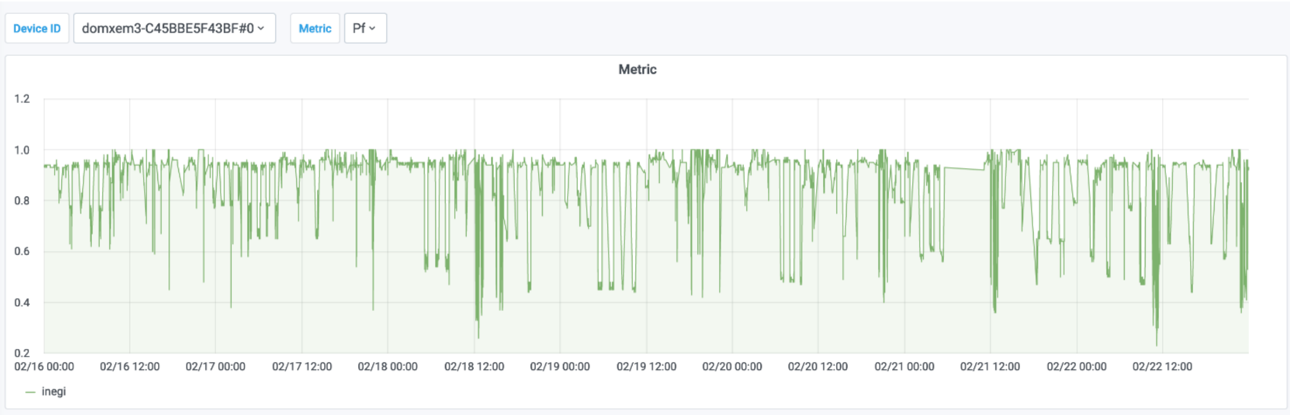
(a) Week in February, 16/02/22 - 22/02/22



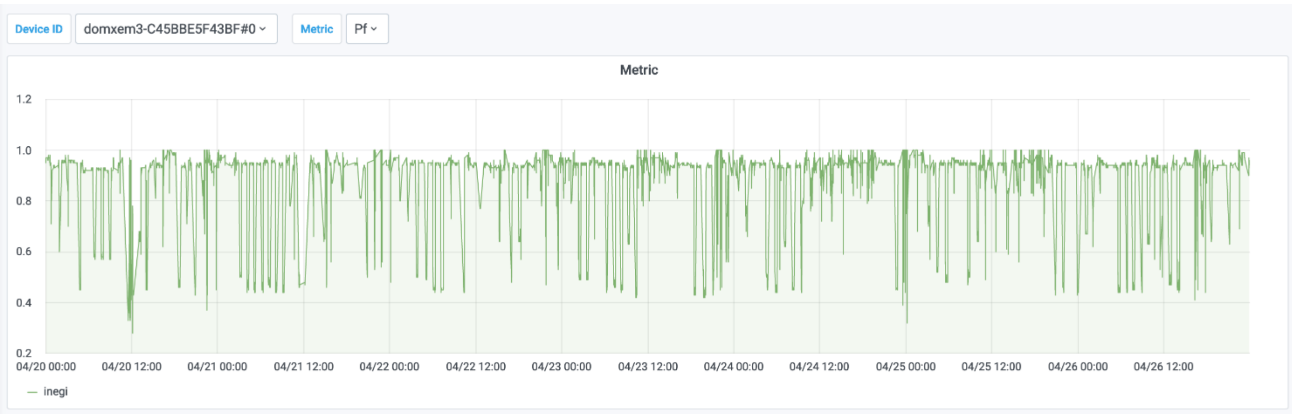
(b) Week in April 20/04/22 - 26/04/22

Figure 59. Current time-series for HOME_16 over two different one week-long periods.

Pf



(a) Week in February, 16/02/22 - 22/02/22



(b) Week in April 20/04/22 - 26/04/22

Figure 60. Pf time-series for HOME_16 over two different one week-long periods.

5.5. The Croatian (HR) pilot

5.5.1. Number of households sending data

The HR pilot reached a sample of 47 participants by M22 (Jun' 22). Data is sent by 46 households by that time due to a delay in the network connection of one household.

5.5.2. Missing data

Due to partly missing data categories, 8 participants are excluded from the following analysis (indexed as 0003, 0005, 0017, 0022, 0027, 0037, 0036 and 0046) and the sample is reduced to 38 participants in June and 35 participants in May. Additional information can be found in D1.2.

5.5.3. Collected measures: characteristics, sample time series and basic statistics

The sensor data of the HR pilot is collected by meters measuring the PV production and electricity consumption in one or three phases, depending on the kind of inverter in use. A three-phase inverter is used by two thirds of the participants. The values of the single phases need to be added to the overall amount of electricity for one metric, respectively for consumption and production. These metrics are then combined to calculate the overall consumption and the autarky rate.

For each meter, energy in and energy out metrics are collected. For the consumption meter energy in represents energy taken from the grid, and energy out represents energy fed into the grid. For the production meter sum of both values measure total production, where energy in has zero value (or low value due to the connection itself) and energy out represents produced energy.

Table 21. Overview of metrics for HR pilot

Parameter	Value Type	Unit	Value range	Sampling frequency	Notes
EnergyIn	Decimal	Wh	-	5min	
EnergyOut	Decimal	Wh	-	5min	
PowerIn	Decimal	W	-	5min	
ReactivePower	Integer	W	-	5min	This metric is reported for 1-phase meters only
Voltage	Decimal	V	-	5min	
Current	Decimal	A	-	5min	This metric is reported for 3-phase meters only
Pf	Decimal	-	{0,1}	5min	

Metric	Production meter	Consumption meter
Energy in / power in	x	x
Energy out/ power out	x	x

Table 22. Overview of relevant measurements for HR pilot

Metric	Value Type	Unit	Sampling frequency
Energy in	Decimal	Wh	15 min
Energy out	Decimal	Wh	15 min

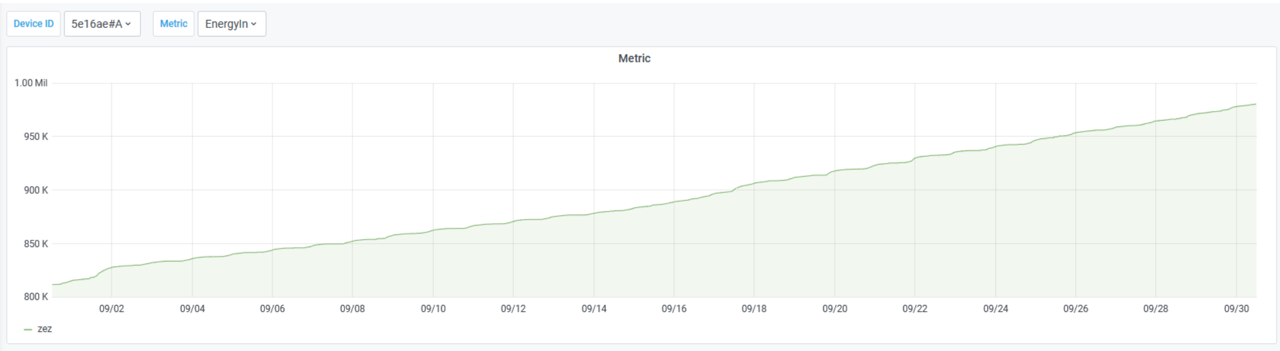


Figure 61. Energy consumption (Energy IN) of participant 5e16ae phase A

Energy out

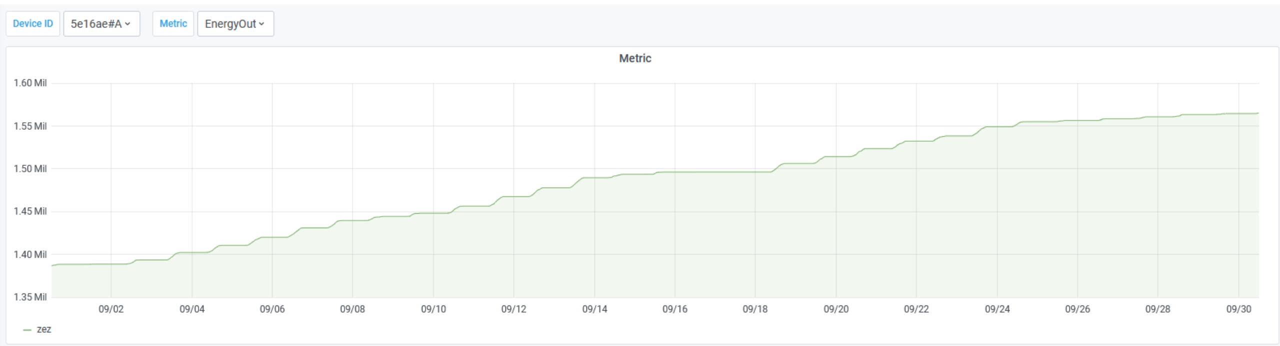


Figure 62. Energy production (Energy OUT) of participant 5e16ae phase A

Conclusion and Further Steps

A large amount of data have been collected in the light of NUDGE project targets, and especially for the WP4 objectives. The datasets that are being assembled during the first 22 months of execution of the 5 pilots of the project were reviewed and presented in this document. In particular, this report presented preliminary data (obtained by M22, Jun '22) on geographical and climate/meteorological information, survey and technical relevant data on the characteristics of the participant households, interaction of the users with the digital user interfaces (apps and webportal), and on data on Energy use that has been collected in the NUDGE Central Platform) per NUDGE pilot.

At the time of writing (M22), the recruitment of participants for some of the pilots (Greek, Croatian and Belgium (2nd cohort)) is on-going as well as data management and analytics activities. Thus, the present report is more focused on presenting the type of information and parameters that have been monitored and on disclosing the structure of the datasets that are being generated.

What comes next?

The pilots are expected to continue the progression in terms of recruitment of the final sample of participants, execution of the pilot-specific intervention plans and data management and analytics. A subsequent deliverable (D4.4 Report on pilot results: final report) will be released in the final stage of the project implementation (M36) to further comprehensively present the final outputs of the pilots.