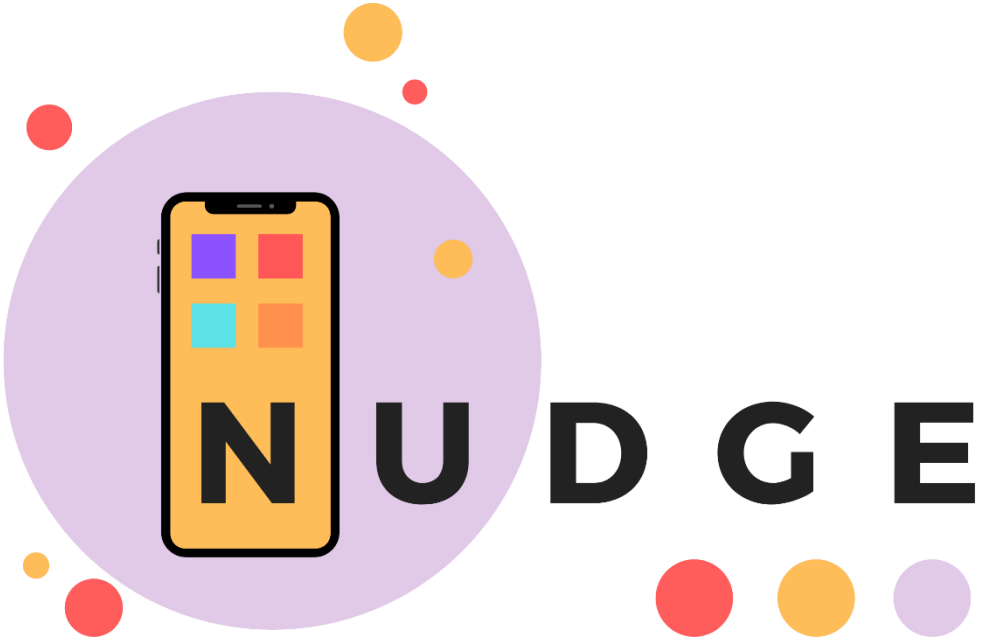

Nudging consumers towards energy efficiency through behavioural science

Deliverable 6.4

Scientific booklet

Deliverable Information

Nature: Public

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Author: Marine Faber Perrio, IEECP

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Nudging consumers towards energy efficiency through behavioural science

Project information

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Project Acronym	NUDGE
Project Number	927012
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Rev.	Written by	Date	Checked by	Date
1	Marine Faber Perrio, IEECP	13.11.23	Marta Gabriel, INEGI Merkouris Karaliopoulos, AUEB Peter Conradie, imec-UGent	15.11.23

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NUDGE

Nudging consumers towards energy efficiency through behavioural science

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

beegy the energy manager

imec

Οικονομικό Πανεπιστήμιο Αθηνών — Athens University of Economics and Business

inegi driving science & innovation

Fraunhofer ISI

Zelena Energetska Zadruga

domx IoT Technologies

Spring-Stof

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Introduction

To demonstrate the NUDGE project research findings and raise awareness in the scientific community, publications in technical literature and dedicated journals were foreseen by academic and technological partners through publications in peer-reviewed journals. In addition, papers were presented at conferences and other events.

NUDGE partners, when responsible for a publication, ensured it followed the open access standards (through self-archiving (green open access) or open access publishing (gold open access)), i.e., without costs for the readers.

All publications, when becoming open access, were added to the NUDGE website, both in the Knowledge Hub area, and with a news item per publication with either a simplified summary or the full abstract, authors, and link to the publisher (or direct pdf).

13 publications and proceedings were reported by the NUGE research team, with 7 that became open access during the project lifetime while 6 more were submitted to two publishers and to the BEHAVE conference, happening as the project ends in November 2023. They should become open access in the coming months, and the NUDGE project communication partner, IEECP, will ensure they are shared publicly on the website when available.

PROCESS AND GUIDELINES FOR SCIENTIFIC PUBLICATIONS

NUDGE was a highly scientific project, which included the evaluation of behavioural interventions, modelling, field trials, leading to many potential research publications. The results though came late in the project, as most interventions lasted for the whole project, having as impact that almost half of the publications are not yet available / published. We therefore chose to include them in this document, as submitted.

The process

To demonstrate the NUDGE project research findings and raise awareness in the scientific community, publications in technical literature and dedicated journals were foreseen through publications in peer-reviewed journals and magazines and through papers presented at conferences and other events.

The following guidelines were shared with partners upon starting the project 3 years ago:

"To demonstrate the research findings and raise awareness in the scientific community, publications in technical literature and dedicated journals could be foreseen by academic and technological partners through publications in peer-reviewed journals and magazines and through papers presented at conferences and other events. The partner responsible for a publication will ensure the papers follow the open access standards (through self-archiving (green open access) or open access publishing (gold open access)), i.e., without costs for the readers. It is to be noted that Article Processing Charges (APCs) for Open-Access-Publications are eligible costs for project accounting.

Depending on the selected journal or other type of publication, project partners will have to use one of the three different possibilities for open access, namely:

- **Open access publishing** (without author processing charges): partners may opt for publishing directly in OA journals, i.e., journals which provide open access immediately, by default, without any charges,
- **'Gold' OA publishing:** partners may also decide to publish in journals that sell subscriptions, offering the possibility of making individual articles openly accessible (hybrid journals). In such a case, authors will pay the fee to publish the material for open access, whereby most high- level journals offer this option.
- **Self-archiving ('green' OA):** alternatively, beneficiaries may deposit the final peer-reviewed article or manuscript in an online disciplinary, institutional or public repository of their choice, ensuring open access to the publication within a maximum of six months. When relevant, beneficiaries will moreover deposit at the same time the

research data needed to validate the results presented in the deposited scientific publication into a data repository.

Another opportunity arose in 2020, a new way to disseminate the papers: Open Research Europe provides all Horizon 2020 and Horizon Europe beneficiaries and their researchers with an easy, high quality peer-reviewed venue to publish their results in open access, at no cost to them, and in full compliance with open access policies."

All publications, when becoming open access, were added to the NUDGE website, both in the Knowledge Hub area, and with a news item per publication with either a simplified summary or the full abstract, authors, and link to the publisher (or direct pdf).

Research papers, journal publications and event proceedings

- Research paper – Self-consumption rises due to energy crises? An evaluation of prosumers' consumption behavior in 2022 (July 2023)
- Peer-reviewed paper: Why do people turn down the heat? Applying behavioural theories to assess reductions in space heating and energy consumption in Europe (April 2023)
- Open access article: Opportunities for Promoting Healthy Homes and Long-Lasting Energy-Efficient Behaviour among Families with Children in Portugal (February 2023)
- Beyond clustering: rethinking the segmentation of energy consumers when nudging them towards energy-saving behavior (December 2022)
- Peer-reviewed paper – Intervening me softly – Modeling nudging interventions to change EV user preferences (June 2022)
- SDGs and the engagement of EU citizens: The role of behavioral science in the energy transition (March 2021)

Figure 1. NUDGE publications on the project website

ALL NUDGE PUBLICATIONS AT A GLIMPSE

To ease the readers' journey, we gather here below, in a table, all publications – published or soon-to-be and the links currently available. The full abstracts are added in the below chapters, while the full papers available are linked on the NUDGE project website, under the Knowledge Hub.

Table 1. NUDGE publications

Title	Quotation / authors	Link on NUDGE or publisher websites	Status
Intervening me Softly - Modelling Nudging Interventions to Change Electric Vehicle User Preferences	Jonas Burkhardt1, Sabine Pelka1, 2, Dr. Matthias Kühnbach1 1Fraunhofer Institute for Systems & Innovation Research ISI, 2 Delft University of Technology ECEEE Conference, 6-10/06/2022	https://www.nudgeproject.eu/peer-reviewed-paper-intervening-me-softly-modeling-nudging-interventions-to-change-ev-user-preferences-2022/	Published – Accepted conference paper
Beyond clustering: rethinking the segmentation of energy consumers when nudging them towards energy-saving behavior	Merkourios Karaliopoulos (Athens University of Economics and Business); Leonidas Tsolas (Athens University of Economics and Business); Maria Halkidi (University of Piraeus); Iordanis Koutsopoulos (Athens University of Economics and Business); Stephanie Van Hove (Ghent University); and Peter Conradie (Ghent University)	https://www.nudgeproject.eu/peer-reviewed-paper-beyond-clustering-rethinking-the-segmentation-of-energy-consumers-when-nudging-them-towards-energy-saving-behavior-2022/	Published – Journal paper
Opportunities for Promoting Healthy Homes and Long-Lasting Energy-Efficient Behaviour among Families with Children in Portugal	Gabriel, M.F.; Cardoso, J.P.; Felgueiras, F.; Azeredo, J.; Filipe, D.; Conradie, P.; Van Hove, S.; Mourão, Z.; Anagnostopoulos, F.; Azevedo, I. Opportunities for Promoting Healthy Homes and Long-Lasting Energy-Efficient Behaviour among Families with Children in Portugal. Energies 2023, 16, 1872. https://doi.org/10.3390/en16041872	https://www.nudgeproject.eu/open-access-article-opportunities-for-promoting-healthy-homes-and-long-lasting-energy-efficient-behaviour-among-families-with-children-in-portugal/	Published – Journal paper
SDGs and the engagement of EU citizens: The role of behavioural science in the energy transition	Amadori, M., & Votta, M. (2021). SDGs and the engagement of EU citizens: The role of behavioural science in the energy transition. Resources and Environmental Economics, 3(1), 239-244. https://doi.org/10.25082/REE.2021.01.003	https://www.syncsci.com/journal/REE/article/view/536	Published – Open access peer-reviewed commentary
Why do people turn down the heat? Applying behavioural theories to assess reductions in space heating and	Peter Conradie, Stephanie Van Hove, Sabine Pelka, Merkouris Karaliopoulos, Filippos Anagnostopoulos, Heike Brugger, Koen Ponnet,	https://www.nudgeproject.eu/peer-reviewed-paper-why-do-people-turn-down-the-heat-applying-behavioural-theories-to-assess-reductions-in-space-heating-	Published – Journal paper

energy consumption in Europe	Why do people turn down the heat? Applying behavioural theories to assess reductions in space heating and energy consumption in Europe, Energy Research & Social Science, Volume 100, 2023, 103059, ISSN 2214-6296, https://doi.org/10.1016/j.erss.2023.103059.	and-energy-consumption-in-europe-2023/	
Self-consumption rises due to energy crises? An evaluation of prosumers' consumption behavior in 2022	S. Pelka et al., "Self-consumption rises due to energy crises? An evaluation of prosumers' consumption behavior in 2022," 2023 19th International Conference on the European Energy Market (EEM), Lappeenranta, Finland, 2023, pp. 1-6, doi: 10.1109/EEM58374.2023.10161968.	https://www.nudgeproject.eu/peer-reviewed-paper-self-consumption-rises-due-to-energy-crises-an-evaluation-of-prosumers-consumption-behavior-in-2022/	Published – Accepted conference paper
Promoting healthy homes and long-lasting energy efficient behaviour among families with children in Portugal: Preliminary data from NUDGE project	Marta F. Gabriel 1, João Pedro Cardoso01, Fátima Felgueiras1,2, Joana Azeredo01, David Filipe1, Peter Conradie3, Filippos Anagnostopoulos4, Isabel Azevedo1 1 LAETA – INEGI, 2 EPIUnit, Institute of Public Health, University of Porto, Portugal & Laboratory for Integrative and Translational Research in Population Health (ITR) 3 imec-mict-UGent 4 IEECP	Extended abstract accepted for oral communication for the CEES 2023 | 2nd International Conference on Construction, Energy, Environment & Sustainability - 27-30 June 2023, Funchal – Portugal. https://www.nudgeproject.eu/open-access-article-opportunities-for-promoting-healthy-homes-and-long-lasting-energy-efficient-behaviour-among-families-with-children-in-portugal/	Accepted conference paper
Can nudging optimize self-consumption? Evidence from a field experiment with prosumers in Germany	Sabine Pelka 1,2,*, Anne Kesselring 2, Sabine Preuß 2, Emile Chappin 1, Laurens de Vries 1 1 = Energy and Industry Group, Faculty of Technology Policy and Management, Delft University of Technology 2 = Fraunhofer Institute for Systems and Innovation Research ISI	Submitted to the Smart Energy Magazine in August 2023	Submitted
Slashing the surplus – how prosumers with smart metering respond to regulatory restrictions on self-consumption in Croatia	Anne Kesselring1 *, Sabine Pelka1,2, Erica Svetec3, Lucija Nad3 , Sebastian Seebauer4 , Sara Skardelly4 , and Sabine Preuß1 1: Fraunhofer ISI 2: Energy and Industry Group, Faculty of Technology Policy and Management, Delft University of Technology	Submitted to the BEHAVE conference, presented on November 28, 2023	Accepted conference paper

	3: Green Energy Cooperative / Zelena Energetska Zadruga (ZEZ) 4: Joanneum Research Forschungsgesellschaft		
Exploring Determinants of Reducing Heating-Related Energy Consumption: Evidence from Five European Countries	Emma Martens1*, Peter Conradie1 Stephanie Van Hove1, Sabine Pelka, Sabine Preuss, Merkouris Karaliopoulos3, Andreas Chitos4, Marta Gabriel5, Koen Ponnet1 1: imec-mict-UGent 2: Fraunhofer Institute for Systems and Innovation Research 3: Department of Informatics, Athens University of Economics and Business 4: University of Piraeus, Department of Digital Systems 5: INEGI, Institute of Science and Innovation in Mechanical and Industrial Engineering	Submitted to the BEHAVE conference, presented on November 28, 2023	Accepted conference paper
Nudging households for energy savings via smartphone apps: an empirical study	Andreas Chitos1,2*, Merkouris Karaliopoulos1 , Sabine Pelka3,4, Maria Halkidi2 and Iordanis Koutsopoulos1 1Department of Informatics, Athens University of Economics and Business 2Department of Digital Systems, University of Piraeus 3Energy and Industry Group, Faculty of Technology Policy and Management, Delft University of Technology 4Fraunhofer ISI	Submitted to the BEHAVE conference, presented on November 28, 2023	Accepted conference paper
Behavioural Science for Energy Efficiency: Insights and Policy Recommendations from the NUDGE Project	Filippos Anagnostopoulos, IEECP; Marta Fonseca Gabriel , INEGI; Merkouris Karaliopoulos, AUEB; Sabine Pelka, Fraunhofer ISI	Submitted to the BEHAVE conference, presented on November 28, 2023	Accepted conference abstract
Implementation of an IoT architecture for promoting healthy air quality in 84 homes of families with children	Marta Fonseca Gabriel1, Gonçalo Marques2, David Filipe1, Fátima Felgueiras1, João Pedro Cardoso1, Joana Azeredo1, Giannis Kazdaridis3, Polychronis Symeonidis3, Stratos Keranidis3, Peter Conradie4, Isabel Azevedo1, Filippos Anagnostopoulos5 1 INEGI, Institute of Science and Innovation in Mechanical and Industrial Engineering, Campus da FEUP, Rua Dr. Roberto Frias 400, 4200-465, Porto, Portugal.	To be submitted in an indexed journal	In finalization - Submitted

	2 Polytechnic Institute of Coimbra, Technology and Management School of Oliveira do Hospital, Rua General Santos Costa, 3400-124 Oliveira do Hospital, Portugal. 3 domx home-IoT Technologies, Str. Sarafi 48E, 55132, Thessaloniki, Greece. 4 imec-mict-UGent, Ghent University, De Krook, Miriam Makebaplein 1, 9000, Ghent, Belgium. 5 IEECP, Institute for European Energy and Climate Policy, Amsterdam Sloterdijk Teleport Towers, Kingsfordweg 151, 1043GR Amsterdam, The Netherlands.		

PUBLISHED PAPERS AND PROCEEDINGS

This section gathers the published papers and includes the abstracts and all links available to the publications. We decided not to share the full pdfs to keep this report digestible, yet they are all available in one click.

1.1. Intervening me Softly - Modelling Nudging Interventions to change Electric Vehicle User Preferences

Authors

Jonas Burkhardt[1], Sabine Pelka[1, 2] (sabine.pelka@isi.fraunhofer.de), Dr. Matthias Kühnbach[1]
[1]Fraunhofer Institute for Systems & Innovation Research ISI, [2] Delft University of Technology
ECEEE Conference, 6-10/06/2022

Abstract

The charging of an increasing number of electric vehicles (EVs) leads to load peaks in the distribution grid. Controlled charging can reduce these peaks, but could also impair the mobility needs of the EV owners. Financial incentives are a frequently discussed measure to stimulate grid-friendly consumption, but they are limited in their attractiveness for the consumers.
A more intuitive approach is the so-called nudging interventions, which influence the decision-making of consumers through a change in their environment.
The design of nudging interventions, such as social comparison and normative feedback, is investigated in the literature but – so far – not simulated.
A translation of nudging interventions, into a modelling environment would, however, capture effects beyond a theoretical setting. We address this research gap - for the case of EV charging - by setting up an agent-based simulation that models the decision-making of and interaction between EV users. Our model displays the effect of nudging interventions on the preferred EV battery state of charge (SoC) for each agent.
Based on social networks, we model how interventions spread within the agent population. The selected interventions, social comparison, and normative feedback aim to minimize the preferred SoC.
The model captures different sensitivities of agents towards the interventions, different sizes, and structures of the networks, frequency of interventions, as well as the boomerang effect.
Our results show an overall reduction of the SoC for all interventions. The strongest impact can be allocated to the normative feedback.

Our findings thus indicate that nudging interventions cause agents to accept a lower SoC. Correspondingly, a larger share of the flexibility potential provided by EVs would be made accessible for controlled charging.

While our model is theoretical, it can be substantiated with empirical data on consumer preferences and combined with the modelling of controlled charging on the household, grid, and electricity system levels.

Links

- Fraunhofer website: https://publica.fraunhofer.de/entities/publication/a0bd1d63-2806-4168-8e84-620f4d139510/details
- Conference proceedings: https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2022/6-energy-efficient-and-low-carbon-mobility-for-all/intervening-me-softly-modeling-nudging-interventions-to-change-ev-user-preferences/
- NUDGE website: https://www.nudgeproject.eu/peer-reviewed-paper-intervening-me-softly-modeling-nudging-interventions-to-change-ev-user-preferences-2022/
- The NUDGE webpage includes both the pdf of the paper and the PPT of the presentation.

1.2. Beyond clustering: rethinking the segmentation of energy consumers when nudging them towards energy-saving behavior

Authors

Merkourios Karaliopoulos (Athens University of Economics and Business); Leonidas Tsolas (Athens University of Economics and Business); Maria Halkidi (University of Piraeus); Iordanis Koutsopoulos (Athens University of Economics and Business); Stephanie Van Hove (Ghent University); and Peter Conradie (Ghent University)

Abstract

Besides technological innovations in energy production and management technologies, the fight against climate change requires fundamental changes in our energy consumption behavior. Behavioral interventions are key to this process, especially when tailored to different energy consumer segments accounting for their socio-demographic profiles, socio- psychological characteristics and energy consumption practices.
In this work, we propose a novel approach to energy consumer segmentation that facilitates the choice of (nudging) interventions for each segment. We call it intervention-driven energy consumer profiling since it explicitly considers upfront the set of interventions that can be delivered to energy consumers and defines profiles that can be readily matched with them.

The profiles are specified as combinations of socio-psychological factors with implications for energy-saving behavior and are parameterized by thresholds that measure how strongly these factors are represented in each profile.
One profile represents ideal energy-savers, whereas each of the remaining five profiles shares one or two distinct features that serve as barriers towards energy-saving behavior and/or prescribe specific type of nudging interventions for strengthening such behavior.
We use the responses of users to a European-wide online survey to formulate and solve an optimization problem for these thresholds and then assign the survey respondents to the profiles.

Finally, we analyse them also in terms of socio-demographic variables and recommend appropriate nudging interventions for them.

Published in the ACM SIGENERGY Energy Informatics Review.

Links

- Publisher website: https://energy.acm.org/eir/beyond-clustering-rethinking-the-segmentation-of-energy-consumers-when-nudging-them-towards-energy-saving-behavior
- NUDGE website: https://www.nudgeproject.eu/peer-reviewed-paper-beyond-clustering-rethinking-the-segmentation-of-energy-consumers-when-nudging-them-towards-energy-saving-behavior-2022/

1.3. Opportunities for Promoting Healthy Homes and Long-Lasting Energy-Efficient Behaviour among Families with Children in Portugal

This article belongs to the MDPI Special Issue Integration of Energy, Health and Comfort: Towards a Sustainable Building Stock.

Authors / citation

Gabriel, M.F.; Cardoso, J.P.; Felgueiras, F.; Azeredo, J.; Filipe, D.; Conradie, P.; Van Hove, S.; Mourão, Z.; Anagnostopoulos, F.; Azevedo, I. Opportunities for Promoting Healthy Homes and Long-Lasting Energy-Efficient Behaviour among Families with Children in Portugal. Energies 2023, 16, 1872. https://doi.org/10.3390/en16041872

Abstract

Energy poverty vulnerability constitutes a significant concern in Portugal. Furthermore, there is evidence that a substantial number of children live in unhealthy homes. This study aims to comprehensively characterise a sample of 101 Portuguese families with children and their homes to identify opportunities for actions for promoting long-lasting energy efficiency and environment health-promoting behavioural changes. To accomplish this aim, two tools—a building survey checklist and a questionnaire to participants—were developed and implemented to collect harmonised data on building-specific characteristics and on participants' socioeconomic status and behaviour.
The results suggest that, for the population under study, the main opportunities for improvement include: replacing low energy-efficient technologies, with high emission rates, namely those used for heating purposes, with cleaner and more efficient alternatives;
providing citizens with detailed information about their home's energy use and indoor air quality and educating the population on the best-practices for reducing indoor air stuffiness, mitigating the risk of hazardous exposures, improving thermal comfort and saving energy.

Links

- Publisher website: https://www.mdpi.com/1996-1073/16/4/1872
- NUDGE website: https://www.nudgeproject.eu/open-access-article-opportunities-for-promoting-healthy-homes-and-long-lasting-energy-efficient-behaviour-among-families-with-children-in-portugal/
- Note that an extended abstract on the same research was also submitted and accepted for oral communication to CEES 2023, under the title "Promoting healthy homes and long-lasting energy efficient behaviour among families with children in Portugal: Preliminary data from NUDGE project". Available on the same page in the NUDGE site. See next page.

1.4. Promoting healthy homes and long-lasting energy efficient behaviour among families with children in Portugal: Preliminary data from NUDGE project

Accepted as oral communication to the **CEES 2023** | 2nd International Conference on Construction, Energy, Environment & Sustainability - 27-30 June 2023, Funchal – Portugal.

Authors

Marta F. Gabriel 1, João Pedro Cardoso1, Fátima Felgueiras1,2, Joana Azeredo1, David Filipe1, Peter Conradie3, Filippos Anagnostopoulos4, Isabel Azevedo1 - 1 LAETA – INEGI, Associated Laboratory for Energy and Aeronautics – Institute of Science and Innovation in Mechanical and Industrial Engineering; 2 EPIUnit, Institute of Public Health, University of Porto, Portugal & Laboratory for Integrative and Translational Research in Population Health (ITR); 3 imec-mict-UGent; 4 IEECP

Abstract

The NUDGE project focuses on testing the potential of behavioural-science inspired energy efficiency interventions with real users and quantifying the respective energy-efficient behaviour change by implementing 5 trials in different countries, with a striking diversity in terms of energy usage scenarios.
This work intends to present the preliminary data obtained from the pilot study that has been implemented in Portugal, which aims to promote long-term energy savings while providing healthy and comfortable homes for 101 families with children (<12 years old). In the preintervention phase, two tools – a building survey checklist and a questionnaire – were developed and implemented to collect harmonised data on building-specific characteristics and on participants' socioeconomic status and behaviour. Data from energy bills (January-June 2022) were also analysed for preliminarily assessing electricity and gas consumption and related costs. Briefly, findings allowed for deriving the following main hypotheses: i) strategies aiming at informing families about their overall and disaggregated (specific equipment) energy use motivate important energy-efficient behavioural changes; ii) the use of Internet of Things (IoT) systems for monitoring environmental parameters and triggering warnings to the occupants (e.g., when it is necessary to open windows due to high levels of CO_2) promote healthier behaviours; and iii) heating season, when significantly higher energy consumption and costs are observed, is a particularly opportune time for providing guidance to families to achieve energy-efficient and improved thermal comfort conditions.
Based on these results, the homes were equipped with energy meters (overall and disaggregated consumption) and indoor air quality (IAQ) sensors (temperature, relative humidity, CO_2, and particles).
Three sequential nudging interventions are being delivered to end users through a smartphone app by presenting informative data and/or recommending different actions to optimise energy use, also taking into consideration IAQ and comfort.

1.5. SDGs and the engagement of EU citizens: The role of behavioural science in the energy transition // Open access peer reviewed commentary

Authors / citation

Amadori, M., & Votta, M. (2021). SDGs and the engagement of EU citizens: The role of behavioural science in the energy transition. Resources and Environmental Economics, 3(1), 239-244. https://doi.org/10.25082/REE.2021.01.003

Abstract

The EU's ambitious targets to increase energy efficiency and cope with the challenge of climate change have pushed several stakeholders, including public authorities and Distributed System Operators (DSOs), to actively invest in the energy transition and improve energy efficiency. Although a significant part of this investment concerns digital infrastructure (i.e., smart meters) allowing citizens to monitor and better manage their consumption of energy, it is pivotal to recognize the necessity for changes in the overall energy-related behaviour of consumers. Against this background, the NUDGE project seeks to first analyse the behaviour of European citizens with concern the energy consumption and to consequently design and test nudging interventions on different segments of the population, in the hope to derive recommendations tailored to each country and to design more general policies at European level. Hence, pilot projects will be carried out in households, energy communities, and schools in five different EU countries, while a general profiling survey will be disseminated online across the EU. Indeed, in order to profile users and assess the impact of an intervention, NUDGE takes a mixed approach which combines field experiments and randomized control trials with surveys, on-site observations, and reports. The latter provide additional insights to the psychological and contextual variables that result in the behaviours evidenced in the trials. Fundamental to this research is the collaboration of the consortium's partner Cittadinanzattiva-Active Citizenship Network with a number of civic and consumer organizations of different European countries that have shown their interest in the initiative and will collaborate in the dissemination of the online questionnaire in their country. Overall, this project is carried out with the ambition to of raising awareness of the projects' major outcomes among the European institutions, starting from the Inter-Institutional Group "SDG's for well-being and consumers' protection," which was launched at European level in February 2021 with the support of various Members of the European Parliament and the endorsement of 48 European and National Associations.

Links

- Publisher website: https://www.syncsci.com/journal/REE/article/view/536

1.6. Why do people turn down the heat? Applying behavioural theories to assess reductions in space heating and energy consumption in Europe

Authors / citation

Peter Conradie, Stephanie Van Hove, Sabine Pelka, Merkouris Karaliopoulos, Filippos Anagnostopoulos, Heike Brugger, Koen Ponnet; Why do people turn down the heat? Applying behavioural theories to assess reductions in space heating and energy consumption in Europe, Energy Research & Social Science, Volume 100, 2023, 103059, ISSN 2214-6296, https://doi.org/10.1016/j.erss.2023.103059
(https://www.sciencedirect.com/science/article/pii/S2214629623001196)

Abstract

Reducing heating-related energy consumption is vital in Europe, where it accounts for a significant portion of domestic energy usage. We studied the factors that influence reduced heating-related consumption by using three theoretical frameworks: the Theory of Planned Behaviour, the Value Belief Norm theory, and the Prototype Willingness Model. Our sample consisted of 3098 people from 29 European countries.
We conducted a confirmatory factor analysis to verify whether our observed variables measure our latent factors, followed by a structural equation model that incorporated these three behavioural models. We find that perceived behavioural control, subjective norms and attitudes (as part of the Theory of Planned Behaviour) are significant predictors of intent to reduce consumption. However, perceived behavioural control was not statistically significantly associated with behaviour.

Environmental concern had a more significant influence on attitudes towards energy reduction than bill consciousness. Attitude was additionally significantly associated with fear of losing comfort and energy knowledge. Moreover, personal moral norms (as part of Value Belief Norm Theory) and willingness (as part of the Prototype Willingness Model) contributed to explaining the intent to reduce consumption, while willingness was also associated with behaviour.

Links

- Publisher website: https://www.sciencedirect.com/science/article/pii/S2214629623001196?dgcid=coauthor
- NUDGE website: https://www.nudgeproject.eu/peer-reviewed-paper-why-do-people-turn-down-the-heat-applying-behavioural-theories-to-assess-reductions-in-space-heating-and-energy-consumption-in-europe-2023/

1.7. Self-consumption rises due to energy crises? An evaluation of prosumers' consumption behavior in 2022

Authors / citation

S. Pelka et al., "Self-consumption rises due to energy crises? An evaluation of prosumers' consumption behavior in 2022," 2023 19th International Conference on the European Energy Market (EEM), Lappeenranta, Finland, 2023, pp. 1-6, doi: 10.1109/EEM58374.2023.10161968.

Abstract

Prosumers with photovoltaic systems can reduce their electricity expenses by increasing their consumption of self-generated electricity. This makes them more resilient to price shocks, like the 2022 European energy crisis. We evaluate how prosumers adapt their consumption behavior in response to such political uncertainty and increasing electricity prices.

The collected survey and smart meter data allow us to evaluate the perceived self-reported and measured impact on self-consumption. Saving intentions due to the energy crisis are more clearly displayed by the survey than by the measured self-consumption. While solar radiation predominantly explains self-consumption changes, Google searches on electricity-related topics have limited explanatory power.

However, considering time lags and the interaction with solar radiation leads to more nuanced insights on the effect of Google searches. Depending on the level of solar radiation, the effect of Google searches ranges from decreasing the daily self-consumption by 26.45 Wh to increasing it by 69.45 Wh.

Links

- Publisher website: https://ieeexplore.ieee.org/document/10161968
- NUDGE website with pdf available: https://www.nudgeproject.eu/peer-reviewed-paper-self-consumption-rises-due-to-energy-crises-an-evaluation-of-prosumers-consumption-behavior-in-2022/

1.8. Slashing the surplus – how prosumers with smart metering respond to regulatory restrictions on self-consumption in Croatia

Presented on November 28, at the BEHAVE conference 2023.

Authors

Anne Kesselring1 *, Sabine Pelka1,2, Erica Svetec3, Lucija Nad3 , Sebastian Seebauer4 , Sara Skardelly4 , and Sabine Preuß1; 1: Fraunhofer ISI (Institute for Systems and Innovation Research) 2: Energy and Industry Group, Faculty of Technology Policy and Management, Delft University of Technology; 3: Green Energy Cooperative / Zelena Energetska Zadruga (ZEZ); 4: Joanneum Research Forschungsgesellschaft

Abstract

Smart metering and home energy management systems (HEMS) support households with roof-top photovoltaic (PV) to optimize self-consumption.

These HEMS can convey subtle guidance for consumption shifts that address intuitive consumption routines. However, the efficacy of the guidance depends on the regulation of self-consumption.

This presentation provides experimental evidence on the interplay between both for the case of Croatia, where households that produce more electricity than they consume over the year are automatically re-classified as renewable traders and have additional administrative duties, as well as less favorable tax treatment.

This creates perverse incentives to reduce PV generation or increase energy consumption. We document strong behavioral reactions within a real-life field experiment, which was conducted as part of the larger Horizon 2020 project NUDGE.

The project collected both survey and smart meter data, which allows for a comprehensive picture of the behavioral reaction.

According to the survey wave before the end of the year, almost half of the participants considered curtailing their PV output. According to the smart meter data, a sizable share did indeed take action by shutting down production or by powering additional devices to reduce the surplus near the end of the calendar year.

In the final survey wave, prosumers provide ex-post insights on the specific measures taken to reduce surplus. Finally, we discuss insights from the experiment regarding the transparency and control offered by the HEMS, as well as how this can influence household behavior regarding the regulatory framework.
This paper will be presented at the following session, on November 28, 2023.

Session Details

Date & Time
Tuesday 28 November 2023, 15:25 - 16:40

Name
Applying behavioural insights to increase energy demand flexibility in high-emitting countries

Description
Peak demand reduction who is flexibility when and how? * **Philipp Grunewald**

Price signals when all things are not equal - an investigation of how price signals could affect different electricity user niches * **B. Stikvoort**

Exploring factors affecting electricity use during peak and off-peak times of day – results from Ireland's Behavioural Energy and Travel Tracker* **C. Lavin**

Slashing the surplus - how prosumers with smart metering respond to regulatory restrictions in self-consumption in Croatia * **A. Kesselink**

The role of consumers in automated response. Drivers, barriers and acceptance to participation. Lessons from a Swedish case study * **A. Nilsson**

Hosted by
Ondrej Kacha (The Behaviouralist) Otto Bernsen (RVO): moderator

Figure 2. BEHAVE session 1/4 details, November 28, 2023

1.9. Exploring Determinants of Reducing Heating-Related Energy Consumption: Evidence from Five European Countries

Presented on November 28, at the BEHAVE conference 2023.

Authors

Emma Martens1*, Peter Conradie1 Stephanie Van Hove1, Sabine Pelka, Sabine Preuss, Merkouris Karaliopoulos3, Andreas Chitos4, Marta Gabriel5, Koen Ponnet1; 1: imec-mict-Ugent; 2: Fraunhofer Institute for Systems and Innovation Research; 3: Department of Informatics, Athens University of Economics and Business; 4: University of Piraeus, Department of Digital Systems 5: INEGI, Institute of Science and Innovation in Mechanical and Industrial Engineering

Abstract

Efforts to reduce heating-related energy consumption have great potential for overall energy reduction, especially considering the significant contribution of heating to energy usage in Europe. This study examines the factors influencing people's intention to decrease energy usage.

The study involved 371 participants, with an average age of 44, of which 74% were men. These participants were part of a larger European project focused on promoting energy reduction. Based on a previous survey conducted in 29 countries with 3,098 participants, this article presents a smaller-scale model tested among individuals from Greece (n=40), Belgium (n=58), Croatia (n=82), Germany (n=105), and Portugal (n=86). We applied three robust theoretical frameworks: the Theory of Planned Behaviour, the Value Belief Norm theory, and the Prototype Willingness Model.
To ensure construct validity, we conducted a confirmatory factor analysis, followed by a structural equation model. Our findings provide support for all three behavioural theories. Specifically, we show that perceived behavioural control, subjective norms, and attitudes (part of Theory of Planned Behaviour) significantly predict the intent to reduce energy consumption, with perceived behavioural control being the strongest predictor.
Additionally, personal moral norms (from the Value Belief Norm Theory) and willingness (from the Prototype Willingness Model) play important roles in explaining the intention to reduce consumption.
Our results highlight the practical importance of individuals' perceived ability and their personal moral beliefs to reduce consumption, while positive role models can positively impact willingness (as part of the Prototype Willingness Model) to change one's consumption behaviour.

Links

- This paper is available in full format on the NUDGE website: https://www.nudgeproject.eu/22-11-23-meet-the-nudge-team-at-behave-28-29-11-23-in-maastricht/

Session Details

Date & Time
Tuesday 28 November 2023, 15:25 - 16:40

Name
Heating & cooling energy determinants

Description
The smart energy research lab - maximising the benefits of longitudinal data for empirical socio-technical research * **Simon Elam**

Shaping the energy and heat transition - insights for a transdisciplinary research project * **A. Zeitler**

Residential space cooling behaviour – results from a country-wide representative survey in Central Europe * **A. Gelesz**

Exploring determinants of reducing heating-related energy consumption. Evidence from 5 European countries * **Emma Martens**

Hosted by
Peter Conradie

Figure 3. BEHAVE session 2/4 details, November 28, 2023

1.10. Nudging households for energy savings via smartphone apps: an empirical study

Presented on November 28, at the BEHAVE conference 2023.

Authors

Andreas Chitos1,2*, Merkouris Karaliopoulos1 , Sabine Pelka3,4, Maria Halkidi2 and Iordanis Koutsopoulos1; 1Department of Informatics, Athens University of Economics and Business, Athens, Greece; 2Department of Digital Systems, University of Piraeus, Piraeus, Greece 3Energy and Industry Group, Faculty of Technology Policy and Management, Delft University of Technology, Delft, the Netherlands; 4Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, Germany

Abstract

Smartphone applications (apps) are a flexible and effective tool to nudge end users towards energy-efficient behavior. In the EU H2020 NUDGE project (www.nudgeproject.eu) smartphone apps are used in pilot experiments to realize nudging interventions targeting different energy efficiency goals: from the reduction of heating energy and electricity to the increase of consumption of self-generated electricity at energy prosumer households. In this paper, we study how effectively smartphone apps deliver nudges by analyzing recorded events from the interaction of pilot participants with the apps.

We, first, ask how much engaged are end users overall with the apps. More than three out of four users interact with the apps, albeit to different extent, so that they can be partitioned into three groups of low, medium and high app usage.
Their interaction with the app tends to last fractions of a minute and span a few app pages.

Turning to the actual users' exposure to the apps' nudging features, we find out that high percentages of users (up to 50% of the participants) exhibit zero or very occasional exposure to nudges during the intervention periods. Considering both the interaction with the app and the exposure to nudges, the app users are segmented into four distinct clusters.

Combining these data with the self-statements of participants in the surveys conducted prior to and following intervention periods, we characterize the socio-demographic characteristics of the four clusters and pinpoint possible differentiation in the intention and motivation self-statements of pilot participants across the identified cluster groups.

Session Details

Date & Time
Tuesday 28 November 2023, 13:55 - 15:10

Name
Energy Conservation tools

Description
Promoting household energy conservation through good setting and signposting in a Rasch-based recommendation system * **Alain D. Starke**

First steps towards a European algorithm to promote sustainable behavioural changes in citizens * **C. Sanz-Cuadrado**

Methods applied to optimise and personalise incentives to increase energy efficiency in the residential sector - review of the literature * **M. Nikoloski**

Nudging households for energy savings via smart phone apps - an empirical study * **A. Chitos**

Hosted by
Alain Starke

Figure 4. BEHAVE session 3/4 details, November 28, 2023

1.11. Behavioural Science for Energy Efficiency: Insights and Policy Recommendations from the NUDGE Project

Presented on November 28, at the BEHAVE conference 2023.

Authors

Filippos Anagnostopoulos, Marta Fonseca Gabriel, Merkouris Karaliopoulos, Sabine Pelka

Abstract

This session highlights the key findings and policy recommendations derived from the Horizon 2020 project NUDGE, which explores the potential of behavioural interventions in promoting energy efficiency choices. The project has conducted an extensive assessment of nudging interventions through a series of randomized controlled trials (RCTs) spanning households, energy communities, and schools across five EU Member States.

Adhering to fundamental principles of behavioural science, NUDGE has utilized a wide range of methodologies and tools to analyse participant behaviour. This comprehensive approach has resulted in the development of user profiles, suggested nudges, and a systematic evaluation of their effectiveness.

The project has relied on data gathered from user surveys and advanced sensors, including smart meters, apps, and indoor air quality sensors, during real-life field experiments. The accumulated research and experimentation have culminated in the formulation of policy recommendations for both public and private sectors.

NUDGE has played a vital role in assessing the potential inclusion of nudging interventions in the policy-making toolbox of EU and national policy makers and stakeholders, offering valuable insights into their efficacy and limitations.

In this session, we will discuss the lessons learned from the project, highlight important findings, identify areas for further research, and present key policy recommendations.

The session aims to foster dialogue and collaboration among researchers, policymakers, and stakeholders, enabling the translation of scientific insights into practical solutions for promoting energy efficiency.

Session Details

Date & Time
Tuesday 28 November 2023, 15:25 - 16:40

Name
How much energy do behavioural policy measures save?

Description
The importance of evaluation in the context of the EU Energy Efficiency Directive energy saving obligation and the ENSMOV plus project * **Samuel Thomas (Regulatory Assistance Project)**

Behavioural policy measures in the Energy Efficiency Directive Recast 2023 and RePowerEU energy savings plan * **Margot Pinault (European Commission)**

Significant electricity savings with info' nudging during the crisis winter in Finland * **Leila Timonen (Motiva)**

Evaluating Greece's public awareness campaign using the streamSAVE methodology * **Christos Tourkolias (CRES)**

Behavioural science for energy efficient insights and policy recommendations from the NUDGE project * **F. Anagnostopoulos (IEECP)**

Hosted by
Sam Thomas, Regulatory Assistance Project, for the ENSMOV plus EU LIFE-funded project.

Figure 5. BEHAVE session 4/4 details, November 28, 2023

SUBMITTED PAPERS

As more NUDGE results from the interventions became available, project partners authored more publications submitted to journals and conferences. Most should become available in the coming months and are listed/ detailed below.

1.1. Can nudging optimize self-consumption? Evidence from a field experiment with prosumers in Germany

Paper on nudging interventions / German data submitted to **Smart Energy** in Summer 2023.

Authors

Sabine Pelka 1,2,*, Anne Kesselring 2, Sabine Preuß 2, Emile Chappin 1, Laurens de Vries 1
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2 = Fraunhofer Institute for Systems and Innovation Research ISI, Breslauer Str. 48, 76139 Karlsruhe, Germany

Abstract

Aligning prosumers' electricity consumption to the availability of self-generated electricity decreases CO2 emissions and costs.

Nudges are proposed as one instrument to orchestrate such behavioral changes. At the same time, fragmented findings in the literature make it challenging to identify suitable nudges for specific households and contexts - specifically for optimizing self-consumption.

We test three sequentially applied nudges (feedback, social comparison, and default) delivered by digital tools in a field experiment with 111 German households with rooftop-photovoltaics.

The experiment design with a control-group, baseline measurements, and high-frequency smart-meter-data allows us to examine the causal effects of each nudge for increasing self-consumption. While feedback and social comparison deliver small self-consumption increases (3-4 percent), the smart changing default leads to a 16 percent increase for active participants.

In general, households with controllable electric vehicles show stronger effects than those without. Our results suggest that nudges are effective for developing new routines with such new, large consumption technologies.

For upscaling nudges for other prosumers, we recommend nudges that require little interaction and energy literacy since even the self-selected, motivated sample rarely interacted with the nudging tools.

Graphical abstract

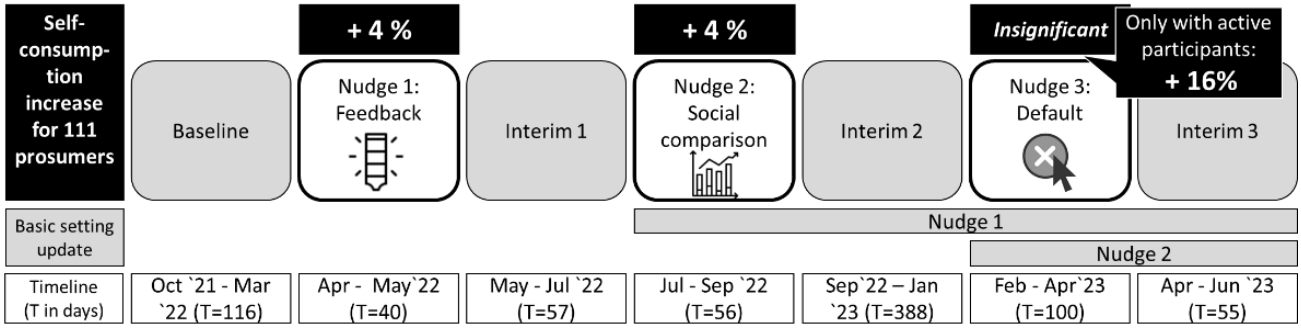

Figure 6. Graphical abstract

1.2. Implementation of an IoT architecture for promoting healthy air quality in 84 homes of families with children

Submitted to the Journal of Hazardous Materials on 12/10/2023, currently under review status.

Authors

Marta Fonseca Gabriel1, Gonçalo Marques2, David Filipe1, Fátima Felgueiras1, João Pedro Cardoso1, Joana Azeredo1, Giannis Kazdaridis3, Polychronis Symeonidis3, Stratos Keranidis3, Peter Conradie4, Isabel Azevedo1, Filippos Anagnostopoulos5

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5 IEECP, Institute for European Energy and Climate Policy, Amsterdam Sloterdijk Teleport

Abstract

This work aimed to assess the effectiveness of the implementation of an Internet of Things (IoT) system incorporating low-cost sensors (LCS) in encouraging behavioural changes to promote healthy indoor air quality (IAQ) in homes.

To accomplish this aim, we developed an IoT architecture to collect real-time data on carbon dioxide (CO_2), temperature, relative humidity and particulate matter ($PM_{2.5}$ and PM_{10}) in 84 homes of families with children, living in the region of Porto.

A randomised cross-over trial was carried out from 16th November 2022 to 24th January 2023, and the intervention under study consisted on providing access to real-time IAQ data and to alerts with recommendation when concentrations were high, through a smartphone app.

Results showed that from the comparison of IAQ data from control and intervention periods, a significant decrease in the CO_2 concentrations was achieved. In addition, a great percentage of participants recognized that data presented through the app motivated them to take useful actions to enhance IAQ.

Overall, this study constitutes a step forward to provide valuable field evidence on strengths and limitations of the use of IoT systems based on LCS in empowering citizens on the factors that may influence exposure to air pollution at home.

Graphical abstract

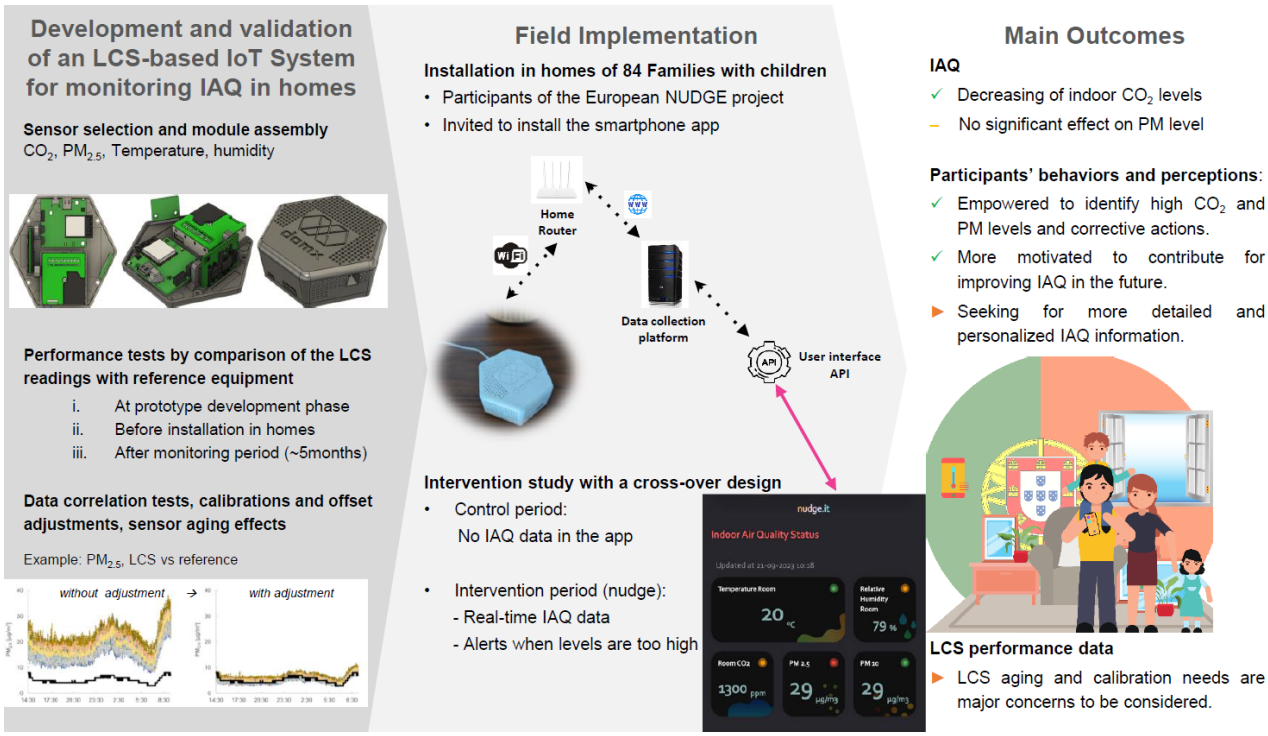

Figure 7. Paper graphical abstract

Conclusion

NUDGE research has already fed in a number of publications, addressed to researchers, in the shape of scientific journal papers, or as policy briefs addressing policymakers. The project legacy will continue through these important material, as open access documents to a wide community of people who can exploit them.

The scientific partners of the consortium will explore the possibility of building on the late outcomes of the project to prepare future publications.