Reducing Energy Consumption by Behavioural Change

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Abstract On global as well as national levels, top-down approaches to reduce climate-related energy consumption have not been successful and effective at all until now. Thus, a bottom-up approach is recommended: citizens role should change from consumers to prosumers, to (co-)decision-makers regarding energy-related behaviour, and to co-investors in the new energy infrastrucure. However behavioural change is difficult to realize in face of the 'knowledge-behaviour gap', 'value-action gap', or 'attitude-behaviour gap'. Thus, the CODALoop project collected data with its platform Energanz and developed the socio-cognitive model for energy-related behaviour. In the new planned IF4E project that model becomes an integrated module of a process model for energy-related behavioural change with real-time feedback loops, real-time energy consumption data, and a user's Personal Energy Profile (PEP) which is updated continuously. The challenges and risks in investigating and implementing the proposed process model in real settings for changing climate-related energy consumption behaviour are discussed. This position paper aims receiving feedback of experts regarding the planned project before its realization.

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1 Introduction

In Europe, Japan and elsewhere, facing climate change[1] and environmental hazards with respect to greenhouse gases, pollution, radiation etc. – and the fundamental role of energy consumption – long reaching programs have been created. For example, recently, the programs *European Green Deal*[2] and the Japanese *Society 5.0*[3] clearly name and describe the problems and challenges that have to be tackled. However, since many years, technical, economical, and other measures have been discussed at different levels and scopes without reaching actual and substantial impact[4]. For instance, on the global level, regular conferences on climate change have been held for about 30 years[5] – and even the recent global agreement (Paris, 2015) is questioned after a few years again (e.g., withdraw of the USA[6]), although public pressure becomes stronger (e.g., the *Fridays for Future* movement[7]). On national levels, for example, even new nuclear power plants[8] (esp. in China and India[9]) and coal mines (esp. in Australia[10]) are planned. On the other hand, plans for positive national measures are seldom but existent, like the decision of the German Government[11] to stop the production of electric energy by nuclear power plants until 2022[12] and by coal-fired power stations until 2038[13] – called 'energy turnover' or 'Energiewende' in German.

In other words, at the global and the national levels, effective decisions and measures happen seldom; therefore, in general, such top-down approaches have not been successful and effective at all up to now.

Thus, this paper presents two related bottom-up approaches: The recently finished CODALoop project will be mentioned briefly, because it is the starting point and an

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[1] United Nations Environment Programme (UNEP) (2019). The Emissions Gap Report 2019. A UN Environment Synthesis Report. Series: The Emissions Gap Report, 10th Edition, 26th November 2019
https://www.unenvironment.org/resources/emissions-gap-report-2019; Executive summary (in Japanese): https://www.iges.or.jp/jp/publication_documents/pub/policyreport/jp/10436/UN_Emissions+Gap+Report_2019_J.pdf

[2] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en; https://ec.europa.eu/commission/presscorner/detail/en/IP_19_5534

[3] https://www8.cao.go.jp/cstp/english/basic/5thbasicplan.pdf – https://www8.cao.go.jp/cstp/english/basic/5thbasicplan_outline.pdf

[4] http://www.caneurope.org/docman/climate-energy-targets/3357-off-target-ranking-of-eu-countries-ambition-and-progress-in-fighting-climate-change/file

[5] https://en.wikipedia.org/wiki/United_Nations_Climate_Change_conference

[6] https://en.wikipedia.org/wiki/United_States_withdrawal_from_the_Paris_Agreement

[7] https://en.wikipedia.org/wiki/School_strike_for_the_climate

[8] https://data.oecd.org/energy/nuclear-power-plants.htm

[9] https://www.world-nuclear.org/information-library/country-profiles/countries-g-n/india.aspx

[10] https://www.ga.gov.au/scientific-topics/energy/basics

[11] European Commission (2018) Mission-oriented R&I policies: Case Study Report Energiewende (DE). Available at: http://europa.eu/!md89DM

[12] https://www.world-nuclear.org/information-library/country-profiles/countries-g-n/germany.aspx

[13] https://www.euronews.com/2020/01/16/germany-reaches-agreement-to-phase-out-coal-by-2038

integrated module of our newly planned IF4E project. IF4E proposes an integrated process model for energy-related behavioural change with real-time feedback loops and real-time energy consumption data. IF4E is described in more detail in order to stimulate and to receive feedback from the participants of the ABC 2020 conference before realizing this project.

2 The CODALoop - Project

Because of that, bottom-up approaches are currently under discussion. With regards to energy consumption, the role of citizens as users and customers of energy services is asked to undergo conceptual changes: the role of citizens should change from consumers to prosumers, to (co-)decision-makers on his/her energy-related behaviour, and to co-investors in the new infrastructures which is mandatory for a successful transformation of energy system.

However, it is a well-known fact that even motivated persons with appropriate knowledge often do not decide and behave according to his/her attitudes, values, emotions and cognitive insights [3] which is called 'knowledge-behaviour gap', 'value-action gap', or 'attitude-behaviour gap' - and may cause 'cognitive dissonance'.

Thus, understanding the underlying cognitive and affective dimensions of energy consumption of individuals – such as motivation, cognitions, attitudes, potentials and barriers – is a necessity to successfully create and apply psychological and digital means for supporting people in reducing their energy consumption.

In the recently finished CODALoop project[14] (see [8]), a diverse set of cognitive models on behavioural change (Social Cognitive Theory, Health-Belief Model, Theory of Reasoned Action, Theory of Planned Behaviour, Protection Motivation Theory, Health Action Process Approach, Transtheoretical Model, Precaution Adoption Process Model) has been explored and investigated by Michael Bedek and Dietrich Albert [2]. The variables and dimensions have been analyzed and selected, based on their potential of predicting energy-consumption related behavioural changes, and finally used for empirically investigating their 'predictive' power. Behaviour is conceptualized as energy consumption on a household-level (in kWh): energy consumption in the fields of dwelling, mobility, and leisure activities is assessed via questionnaires (the so-called energy matrix) which has been developed in the context of the CODALoop project.

The main aim of the cognitive model we have been looking for is to predict energy consumption by a small set of relevant variables. In addition to that, it aims to facilitate the understanding of how these variables interact with each other. Based on existing literature, items or questions have been identified and selected that assess these variables. This operationalization resulted in a first version of a questionnaire, which has been filled out by around 120 end-users in Austria, The Netherlands and Turkey.

[14] https://jpi-urbaneurope.eu/project/codaloop/

The questions have been presented with the platform *Energanz*[15] and the responses could be given by manipulating sliders (see Fig. 1) which have been considered as easier to understand by several users, compared to a purely numerical Likert-scale. The items in Fig. 1 refer to energy consumption at the household and state ‘I am confident reduce my dwellings’ energy consumption even if it is hard for me‘ (with the poles ‚completely disagree‘ vs. ‚completely agree‘), ‘The decision to reduce my dwellings’ energy consumption is beyond my control‘, and ‘Reducing my dwellings’ energy consumption within the next 2 months would be. . . ‘ (with the poles ‚very useless‘ vs. ‚very useful‘ and ‚very unpleasant‘ vs. ‚very pleasant‘, respectively). The final questionnaire as well as the set of underlying variables can be found in [2].

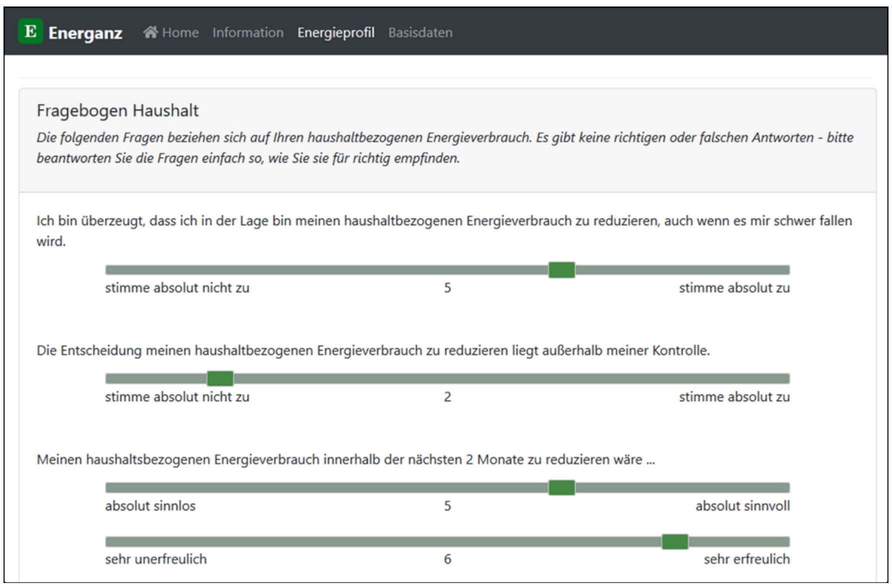

Fig. 1 The items of the questionnaire can be answered using sliders

Analyzing the empirical response patterns using methods of psychological classical test-theory, the variables and items with the highest predictive validity have been selected for the final socio-psychological-cognitive model (Fig. 2). This final model consists of 7 predictor variables and the questionnaire of 15 items. The predictor variables are: *self-efficacy*, *volition*, *past behaviour*, *behavioural intention*, *perceived behavioural control*, *social norms* and *attitudes*. They are the same for all countries (Austria, Turkey, and The Netherlands) and different energy domains (such as dwelling, mobility, and leisure activities). The relationship between the variables in Fig. 2 are correlative rather than causal, and thus, no arrows are shown. However, structural equation models from other authors, e.g. on the Theory of Reasoned Action, suggest some causal-like relationships, e.g. between ’Attitudes’ on ’Behavioural Intention’.

[15] http://energanz.cognitive-science.at/

As mentioned already, in Fig. 2, the connecting lines between variables represent correlative relationships rather than causal relationships; except for c1 (Beliefs about consequences) and c2 (Evaluation of these consequences) on the one side and C (Attitudes) on the other side – in these cases the lines should be read as "c1 x c2 constitutes C" (i.e. an indirect measurement for the construct 'attitudes'). There are three pairs of items for "c1 x c2", i.e. six items for the indirect measurement of Attitudes as well as two items for their direct measurement. There is one item for Perceived Behavioural Control, Action Self-efficacy, Volition, Behavioural Intention, and Past Behaviour, respectively. And finally, two items have been selected for the direct measurement of Subjective Norms. This results in 15 items – compared to 44 items of the initial questionnaire.

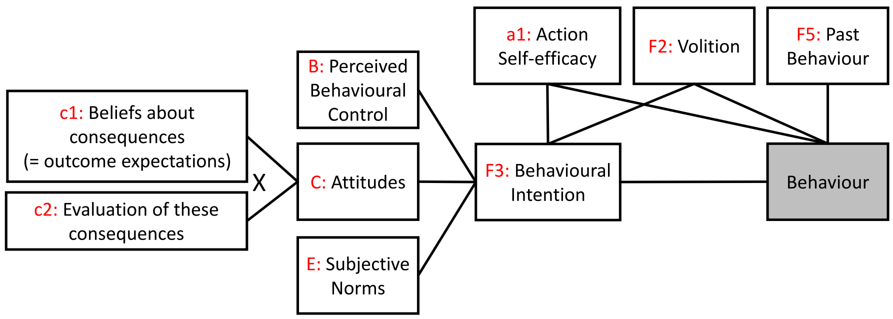

Fig. 2 Final socio-psychological-cognitive model (from [2])

The empirically validated different cognitive models are not exactly identical, because the correlations and weights between different variables and between variables and their items, differ for the three countries and the three above mentioned energy domains. Furthermore, and more important, the so far empirically validated socio-psychological-cognitive model represents primarily correlational dependencies, no causal-like relationships. Nevertheless, the model allows to derive hypothesis and recommendations regarding the effects of concrete interventions on energy-related behaviour and behavioural change; however, these predictions have to be empirically validated. Regarding empirical validation, the data collection in CODALoop with questionnaires has been not perfectly comfortable for the users – although the platform *Energanz* has been used. The reason is that too many questions have to be answered from the users' point of view. For instance, even the amount of energy consumption had to be entered manually to the platform (for current legal and technical reasons) by the users.

To sum up, the CODALoop-project produced interesting results on the one hand, especially the socio-psychological cognitive model, but on the other hand also insights to a number of challenges for future research and development.

Therefore, in the next phase, the model becomes an integrated module of a proposed integrated process model for energy-related behavioural change with **real-time** feedback loops and **real-time** energy consumption data.

3 Instant Feedback for Energy (IF4E) – A Planned Project

A proposed integrated process model is the basis for the currently planned project "Instant Feedback for Energy" (IF4E), which will transfer the results and findings to a first implementation phase until 2022: the automated and updatable provision of real-time energy consumption data, combined with the socio-psychological cognitive model and 'instant feedback loops' represent an innovative integrated solution for a *Personal Energy Profile* (PEP; see Fig. 3).

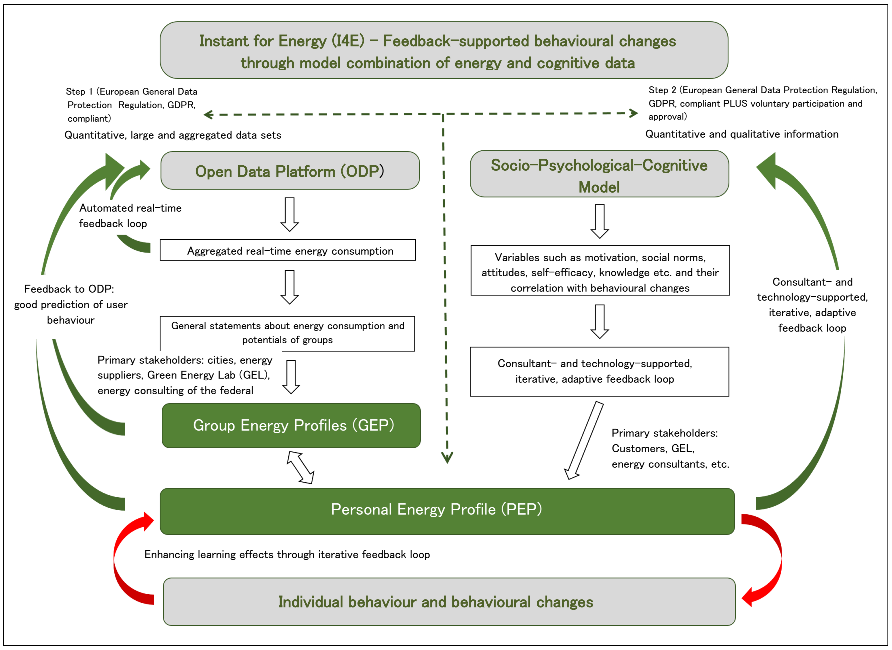

Fig. 3 The schematic "Instant Feedback for Energy" (IF4E) model for data- and feedback-supported behavioural change

Real-time energy consumption data in aggregated form (Step 1), or on an individual basis in the case of voluntary participation (Step 2), will be included to the PEP. An interim goal is defined as the provision of a pilot application that clearly exceeds the current state of the art. The project aims to significantly increase the involvement and active participation of citizens through data-based feedback and learning. This participation takes place on three levels as (i) individual users, (ii) as a group, community or resident of a district and (iii) as a multiplier such as a city, utility company or media company. Thus, IF4E would be ideally suited for campaigns and participation processes to activate citizens as (co-)decision makers of behavioural transformation and as (co-)investors for the innovative energy systems. Recruiting active citizens for participation is carried out by experienced and locally bounded authorities (like community servants, district leaders, various local societies, clubs and associations etc.), interested in regional environmental protection.

To this end, we propose an instrument that mobilizes resources for efficient climate adaptation beyond energy system transformation, driven by e.g. the recently founded Green Energy Lab[16], which is Austria's largest innovation laboratory for a sustainable energy future, or by the Energy-Community[17], which as an international organization that aims to create an integrated pan-European energy market.

Since the behavioural, decision-making, and investment potentials of citizens are estimated at approximately one third of the total potential of all measures for climate adaptation and energy system transformation, such a mobilization of citizens has the potential to become a decisive factor. Of course, this has to be demonstrated and investigated empirically in real settings.

4 Challenges for Real Settings and Pilots

In the following, challenges associated with the aims, objectives and principles for real settings and pilots of the IF4E project will be discussed. For a transformation to achieve a realistic goal, under current conditions, at least three components must be taken into account, designed and implemented: (i) energy consumption behaviour, (ii) socio-psychological cognitive predictor variables, and (iii) constraints in terms of acts, laws and regulations.

4.1 Energy consumption behaviour

To gain individual or aggregated energy consumption profiles (energy profiles), different data sources from the chosen energy domains (like electricity, heat and mobility) need to be continuously integrated. In doing so, it should be a general principle to ensure the highest possible privacy in collecting behavioural data for fostering behavioural change in energy consumption.

(a) The energy consumption data come from various sensors and energy providers. For example, *smart meters* provide continuously processed data for **electricity** consumption. Various competing energy suppliers provide consumption data, which have to be incorporated into the energy profile, e.g. via the Open Data Platform of the Green Energy Lab, or coming from regional, local energy communities[18] (in Austria e.g. the cities Steyr and Wörgl). Energy consumption data are also available on the market, e.g. by *meo*[19], the Smart Home Energy Corporation, Graz. This company

[16] https://greenenergylab.at/en/

[17] https://www.energy-community.org/

[18] https://energy-cities.eu/publication/how-cities-can-back-renewable-energy-communities/

[19] https://www.meo-energy.com/

makes transparent distributed, decentralized energy flows for electricity and **heat** on a time-based basis through its energy monitoring and energy management system.

(b) Regarding energy consumption related to human **mobility**, mobile phone tracking allows to continuously estimate and feed in mobility-related energy consumption; the estimation of energy consumption is done by algorithms that link real-time data of the individuals' course of movement via tracked geo-data. Such a service is provided by the Invenium Data Insights Corporation[20], the leading provider of movement analysis based on cellphone signals. Invenium is a Graz-based company of the Styrian Cluster Green Tech Valley[21], which is a global hotspot for innovative energy and environmental technologies. Of course, there are other companies and technologies that can provide human mobility data, e.g. based on navigation systems (e.g., for real-time traffic the company TomTom[22]). A technology that equips smartphones with low-cost Global Navigation Satellite System (GNSS) chipsets may be applied for future cross-border recording of mobility data [12]. The Mobilitydata.gv.at in Austria[23] – the national access point of Austria for mobility data – could serve as a platform. It is managed and hosted by AustriaTech Ltd. - however, its service would have to be further developed. At the European level, the Innovation and Networks Executive Agency (INEA)[24] can be involved. As part of the Horizon 2020 programme, it has defined the goal of implementing projects on smart, green and integrated transport as well as secure, clean and efficient energy. However, the availability and integration of mobility data is still very limited, which is why a reference model of an open platform for modular mobility services is proposed by Pflügler et al. [7]. Thus, we plan to start at the national level with an Austrian integrated project applying and testing our socio-psychological-cognitive model in the context of IF4E for reducing energy consumption.

4.2 Socio-psychological cognitive predictor variables

In order to capture and process the socio-psychological-cognitive predictor variables, the platform *Energanz* of the CODALoop project will be further developed. Of course, the principle of the highest possible privacy applies also to these data. Another goal is to keep the temporal and cognitive work load of the users as low as possible – without reducing the quality of the PEP.

(a) In the to be developed prototype for IF4E, the real-time energy consumption data for the domains electricity, heat and mobility (see above) will be combined with a socio-psychological cognitive model, its model-related behavioural data as well as the 'instant feedback loops'. This results in a PEP, which is updated more or

[20] https://invenium.io/en/

[21] https://www.greentech.at/en/

[22] https://developer.tomtom.com/products/traffic-api

[23] https://mobilitydata.gv.at/en/about-mobilitydatagvat

[24] https://ec.europa.eu/inea/en

less continuously by the energy consumption data, the socio-psychological cognitive behavioural data, and the feedback information (see Fig. 3). The PEP of an individual should be iteratively updated; it provides the basis for personal feedback, tailored counselling, behavioural changes and interventions. A problem is, that updating the personal socio-psychological cognitive model cannot take place without the user who is answering questions.

In the course of the CODALoop project, the so-called *Energanz* platform was developed (see above), a precursor necessary for basic research, which has to be further developed in IF4E. Using sliders as response mechanism for the users to answer the items of the socio-psychological-cognitive model will remain.

(b) Even with the energy consumption data coming from various sensors and energy providers, repeatedly answering of the entire questionnaire by the users in order to update the PEP as regularly as possible would be disproportionate and too much time-consuming. Therefore, IF4E will implement methods to reduce the temporal, cognitive, and working load of the users. The goal is to minimize the number of items without having to accept a too strong reduction of the measurement accuracy - compared to the availability of the whole questionnaire. One prominent method is based on the fact that, getting the actual answer to a particular question, the hypothetical answer to other questions can be concluded. This requires relationships between the questions/items in the form: "If the person answers item x with 'yes', he or she will (with a very high probability) also answer item y with 'yes'". Such a prerequisite relationship that is formulated here is a central concept of knowledge space theory ([4], [5], [1]). One possibility to identify this relation on the item set is the Inductive Item Tree Analysis (IITA; [9], [10], [11]). The IITA is a data-driven method that benefits from the largest possible samples; however, there are also theory-based approaches to determine the relationships between items (e.g., [6], [1]). The prerequisite relationships found are the basis for adaptive, personalized testing.

Other approaches to reduce the number of items to be processed could - at least as a default setting or as a temporary estimate - use the aggregated response patterns of the group on the basis of the similarity of a user with relevant others (in terms of group energy profiles), i.e. techniques of collaborative filtering and community building have to be applied. Also, the response intervals for trait items (i.e. 'personality' variables considered as stable over time) can be set longer than for state items (volatile variables) or the points of time can be selected adaptively, triggered by personal or environmental events. For larger data sets, diverse and more complex data mining and machine learning applications are also conceivable to figure out, how to use and to refine the structure derived from data, with the aim to reduce the mental workload of the users.

(c) Of course, also technological challenges must be overcome: to integrate the numerous, heterogeneous and distributed data to the PEP and to develop intelligent algorithms to perform simultaneously the calculations required for online feedback loops in real time for many households and people simultaneously The necessary technology and infrastructure (at least in urban regions) is available, and thus, these kinds of constraints are negligible or at least manageable. However, some other constraints have to be considered: acts, laws, and regulations.

4.3 Constraints in terms of acts, laws, and regulations

For collecting the data, performing the necessary computations and giving feedback, legal and regulative constrains have to be taken into consideration; some examples will be mentioned here.

(a) Above (Fig. 3) the European General Data Protection Regulation (GDPR)[25] has been mentioned: real-time energy consumption data allows for insights to the private life of individual citizens, which is protected by the GDPR; however, in case of voluntary participation and approval (Fig. 3, Step 2) individual data can be used for the PEP. For concrete guidance in data management, the current guidelines on fair data management[26] of the European Commission are helpful. These guidelines also consider aspects like open data, data interoperability, or data reuse. Another important aspect for developing IF4F is that all the involved stakeholders have to agree on common (open) standards for secure interfaces[27].

(b) For balancing the interests and rights of the different stakeholders of the Austrian energy market (electricity and gas) the E-Control[28] has been founded and transformed into a public authority. The E-Controls' tasks are laid down in several Austrian acts. These acts also have to be considered in realizing the IF4E project.

(c) However, some aspects from our point of view are not yet sufficiently addressed in the energy sector - like transparency of algorithms, inclusion, pre-registration of investigation-plans. That means, IF4E will become a forerunner in the energy sector, discussing these aspects in detail. Furthermore, also aspects like controlling the process of data collection by the user, the possibility to withdraw voluntary participation, and the ownership of the data have to be discussed - especially if the focus is on research and innovation. For human-related research, also the best practice guidelines of the relevant scientific societies and regulations of the ethical boards of the participating universities have to be taken into account.

These aspects are also important for being able to reach our next goal beyond and after IF4E, and to make our **final vision** becoming real by using Artificial Intelligence (AI).

(d) In order to reduce users workload even more, finally instead of questionnaires, indirect measures might be used for updating the PEP by analyzing and interpreting 'natural energy-related' behavioural data, for getting indicator-variables for motivation, attitudes, intensions.

(e) These indicator-variables and methods have to be implemented in an intelligent system like *meo* box[29] in order to unburden the consumer even more. Finally, the AI-system controls and optimizes the entire individual energy balance the same way

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[25] https://ec.europa.eu/info/law/law-topic/data-protection_en

[26] https://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/oa_pilot/h2020-hi-oa-data-mgt_en.pdf

[27] https://www.dena.de/fileadmin/dena/Dokumente/Pdf/9240_Schnittstellen_und_Standards_fuer_die_Digitalisierung_der_Energiewende.pdf (in German)

[28] https://www.e-control.at/en/econtrol

[29] https://www.meo-energy.com/fuer-ihr-eigenheim-home-energy/

as the user him/her-self or even better, and leads to a drastic reduction in energy consumption.

However, even in these cases, behavioural changes are required and necessary: At the user's side: consent to use intelligent smart meters at home, to use energy sensors in the car, interest and investment in innovative technologies, like the *meo* box, acceptance of - and trust in the implemented algorithms. At the side of the energy supplier: to accept the right of consumers to contribute in decisions, making energy data available, accepting centralized platforms. And even the energy ministry and the parliament have to pass new acts and laws: ensuring that e.g. privacy is affected only to that extent that is absolutely necessary to reach the final goal.

The final goal is to balance the needs and interests of all the stakeholders and to create a win-win situation for all of them in reducing energy consumption and avoiding climate chance. For bridging the gap between the present and the future, IF4E is an important project going into that direction.

4.4 Outlook

As mentioned, the fundamental role of energy consumption for climate change is meanwhile accepted in Europe and Japan. The current European and Japanese high-level top-down measures have a time horizon of about 30 years until 2050. We are confident, that the proposed bottom-up approaches can be realized easier and earlier, because they are low-level and local. Thus, this kind of innovative cooperation between Europe and Japan may become a hot topic for Joint Research and Innovation Projects and of the next *EU-Japan Energy Dialog*[30] and of *Horizon Europe – the next research and innovation framework programme*[31] of the European Union[32] which will start on January 2021. Regarding the *implementation of the next research and innovation framework programme* "a portfolio of instruments to foster bottom up solutions"[33] is recommended and considered as important by 78% of survey participants[34]. The whole *Horizon Europe* programme will be mission-based, and one of them is: "Change begins at home" - that means in our case: Introducing behavioural changes among energy consumers by IF4E and thereby reducing energy consumption in a bottom-up fashion can have significant impact in global energy consumption reduction.

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[30] the last one: https://ec.europa.eu/energy/en/news/eu-japan-energy-dialogue-wide-ranging-partnership

[31] https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme_en

[32] https://europa.eu/european-union/index_en

[33] https://www.ffg.at/sites/default/files/downloads/page/mazzucato_report_2018.pdf, page 17

[34] https://ec.europa.eu/info/sites/info/files/research_and_innovation/mazzucato_report_missions_feedback.pdf

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