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ECHOES Report

Proposal for SSH oriented indicators to support policy-making for clean energy transition in EU

Report

Proposal for SSH oriented indicators to support policy-making for clean energy transition in EU

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AUTHOR(S)
Suvisanna Correia, Lassi Similä, Hanne Siikavirta, Tiina Koljonen

INTERNAL REVIEWER(S)
Christian A. Klöckner, Izaskun Jimenez Iturriza, Elena Dimitrova, Milena Tasheva-Petrova, Angel Burov, Irina Mutafchiyska

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ABSTRACT
This report proposes indicators related to individual and collective energy choices for supporting the implementation of the Energy Union and SET-plan. The report discusses the use of indicators in general, describes indicators in the Energy Union framework including the SET-Plan, and provides a review of SSH-relevant indicators in the scientific and public literature. Based on systematic screening of literature, 87 indicators particularly relevant to the ECHOES targets were shortlisted. These indicators cover relevant technological foci, social dimensions and energy transition aspects, allowing tracking and analysis of development of decision-making on personal and collective levels. The indicators proposal of this report is based on selected indicators from the shortlist, with indicator suggestions by SET Plan Action 3.1 on energy consumers and Energy Union framework. The final proposal, fine-tuned with the feedback from the ECHOES consortium, consists of 27 indicators. The quality of indicators in the proposal is classified in three levels according to data availability, update resolution and the need for further definition work. Importantly, indicators ready for database implementation are suggested in each of the relevant areas, and indicators based on ECHOES main survey data are suggested, showcasing the added value of the project in recommendations for future data collections.

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1 Introduction

The overarching objective[1] of ECHOES (Energy CHOices supporting the Energy union and the Set-plan) is to unlock the policy potential of an integrated social science perspective bounded by central socio-cultural, socio-economic, socio-political, and gender issues that influence individual and collective energy choices and social acceptance of the energy transition in Europe. ECHOES will therefore foster the implementation of the European Strategic Energy Technology Plan (SET-Plan)[2] and advance the Energy Transition, in addition to the decarbonization of the EU's future energy system.

As a part of tackling the high-level objectives of the ECHOES above, the goal of the Work Package 2, *"Formulation of SSH database and SSH indicators"* has a target of collecting, synthesizing, and curating relevant data, in addition to formulating indicators related to individual and collective energy choices and behaviour. Earlier related work of WP2 has dealt with scanning of external databases and data on SSH dimension (Similä, Koljonen, 2017), as well as with design of the open access database to be implemented as key ECHOES result (Correia, Similä, Piira, Kannari, Koljonen, 2018). This third and final deliverable of WP2, "*Proposal for SSH oriented indicators to support policy-making for clean energy transition in EU",* especially focuses on the *indicator* dimension.

The work on indicators in ECHOES has the specific aim to support the EU in the definition of a monitoring system, which could be used for assessing the progress of the Energy Union. The approach of this report is based on the one hand, on a wide literature review in the scientific literature on SSH indicators, as well as relevant EU and other public documents. On the other hand, the approach has synergies with design and implementation of the ECHOES database that has been developed in co-operation with several ECHOES researchers studying the different levels of decision-making with various methods. Hence, at best, the developed indicators would efficiently utilize and present the ECHOES data in the database to support the Energy Union monitoring system in considering the SSH dimension.

Central to all research activities in ECHOES are its technological foci of a) smart energy technology, b) electric mobility, and c) buildings. ECHOES addresses the challenges in these areas by employing the innovative theoretical concept of "energy collectives" which covers determinants of energy choices from the perspective of (1) individual decision-making as part of collectives (micro), (2) collectives constituting energy cultures and life-styles (meso), and (3) formal social units (macro).

It is necessary to further define what was studied in the technological foci of the ECHOES project for indicator development work in this report:

> *Smart energy technologies* as referred to in the SET Plan documentation[2] include distributed, small-scale renewable energy production technologies (typically rooftop photovoltaic (PV), solar thermal and micro wind, heat pumps and bioenergy), in addition to a range of technologies for the traditional "demand side" management (e.g. in-home displays, home automation, smart home appliances, etc.) and energy storage. The transformations with the deployment of smart meters, smart controls, smart appliances, and their integration in home networks, are of key importance for the energy system transition.

[1] The objectives and definitions reviewed in this section are mentioned in several ECHOES documents and deliverables, e.g. ECHOES Grant Agreement (ECHOES 2016), Similä & Koljonen (2017).

[2] see http://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan

The SET-Plan identifies *electric mobility* as one of the core technologies to be implemented and further developed to enhance road transport efficiency. Both passenger and goods transportation account for a substantial amount of the environmental impact of the member states of the EU.

The last technology focus is *buildings* - which includes construction activities, insulation, energy efficiency upgrading, heating, cooling, illuminating, and energy use behaviour in buildings.

To summarize the objectives for ECHOES indicator work, which are referred to in several instances of the Grant Agreement[3] (ECHOES 2016), WP2 creates a set of indicators to support research performed in ECHOES. The objective is also to formulate relevant indicators, which will help understanding the possible barriers and carriers for a change and support comparison of energy lifestyles. Formulation of the indicators aims also to support the EU in the formulation of a monitoring system, which could be used for assessing the progress of the Energy Union, especially related to solidarity, security, and confidence.

Indicators for energy transition built for the ECHOES project aim at informing energy and climate policies in order to reduce carbon-based and other emissions from energy production and consumption in the European Union. To advance climate change mitigation and adaptation, the indicators developed should address the three technological foci of the ECHOES project, that are central pieces in new ways of using energy in daily lives of European citizens. In addition, the report especially addresses *energy poverty*, as it is one of the major barriers for acceptance for a significant part of European populations in adapting to low carbon and energy efficient modes of daily behaviour. Also, it is especially mentioned to be considered in the European Union climate and energy policies (see Chapter 1.1), and as one measure of solidarity belongs to a theme especially targeted by the ECHOES indicators. The presence of energy poverty in Europe calls for protection of vulnerable groups (Clancy, Daskalova, Feenstra, Franceschelli, & Sanz Blomeyer, 2017). Furthermore, for low income groups, whose energy consumption does not even meet the adequate living standard, the means to influence personal and household emissions are limited. ((eds.) Csiba, K; Bajomi, A; Gosztonyi, A, 2016).

Building on the aforementioned targets, this report - Deliverable 2.3 of the ECHOES project - aims at formulating indicators related to individual and collective energy choices with a view to support the implementation of the Energy union and SET-plan. Deliverable 2.3 is closely linked to the development of the open access ECHOES database. The development of the indicators builds also on findings in the ECHOES project – in particular the policy potential analysis in Work Package 3.

1.1 EU climate and energy policy

1.1.1 Energy Union

The EU has committed itself to a clean energy transition, which will contribute to fulfilling the goals of the Paris Agreement on climate change and provide clean energy to all. EU has put in place the legislative framework for climate and energy policy with legally binding targets covering all sectors of the economy to achieve at least 40% greenhouse gas emissions reductions by 2030. Targets are also set for the share of the renewable energy and energy efficiency. Discussions on the climate-neutrality goal for EU by 2050 are ongoing. Several EU Member States have set their own climate or carbon-neutrality targets.

To ensure that the EU targets are met, a system of energy and climate governance has been agreed as a part of the legislative framework. The aim is that the Union and its Member States plan together and deliver collectively on 2030 targets and on a socially fair and cost-effective transition to a climate neutral economy by 2050. According to the Commission's analysis of the draft national energy and climate plans (NECP) submitted by EU Member States there is a need to step up the ambition level.

[3] ECHOES 2016. Grant Agreement number: 727470 — ECHOES — H2020-LCE-2016-2017/H2020-LCE-2016-RES-CCS-RIA.

Furthermore, it is stated that for the success of the EU's energy and climate plans, the social dimension must be integrated from the outset. This will help to ensure a socially fair, just transition and, eventually, social acceptance and public support for reform.

To this end the Commission encourages the Member States in their final NECPs (due 31 December 2019)[4] to *"fully tackle the issue of ensuring a socially just and fair transition. This encompasses notably employment aspects, including training, upskilling and reskilling, as well as adequate social protection for people concerned by the energy transition. Properly addressing the energy poverty dimension is also needed, including by assessing the number of households in energy poverty and where necessary defining an indicative objective to reduce energy poverty. Finally, those Member States concerned should consider the impact of the transition on the populations living in coal or carbon-intensive regions and make the link with existing, planned or necessary actions in this regard."*

1.1.2 SET-Plan

As part of the Energy Union Strategy and in particular its dimension for research, innovation and competitiveness, the European Strategic Energy Technology Plan (SET Plan) and the Communication on Accelerating Clean Energy Innovation[5] have identified the strategic research and innovation priorities and actions needed at EU level to accelerate energy system transformation in a cost-effective way. Concrete actions have been proposed and agreed in the Implementation Plans.[6]

1.2 Policy potential analysis in the ECHOES project

The ECHOES report D3.3 Policy Potential Analysis (Klöckner, Rodrigues, Chebaeva, Dimitrova, Frieden, Koksvik, Koljonen, Löfström, Qiu & Røyrvik, Tzanev, & Velte, 2018) presents the results of the analyses of more than 100 policy documents of the level of the EU, the Member States, and regions in Europe.

According to the analysis the EU-level low-carbon energy strategies and related impact assessments have previously mainly focused on technological portfolios, viability and pathways while the social changes and acceptance, political feasibility and institutional aspects have largely been missing. The vision is that citizens/consumers take ownership of the energy transition, benefit from new technologies to reduce their bills, participate actively in the market, and vulnerable consumers are protected.

The general conclusion presented in the report is that although the citizen/consumer has made her/his way from the periphery into the centre of the policy documents, the concept of consumer decisions is in most cases oversimplified.

> *"The main overarching assumption reflected in most analysed policy documents is that (a) consumers are important actors, (b) they lack information and given they are provided with the right information they will act accordingly, and (c) consumer behaviour is based on economic considerations, which calls for monetary incentives, subsidies and price regulations. Whereas the first conclusion is shared by the authors of this report – we consider consumers indeed a central category of the Energy Transition – the second and third assumption are – based on our knowledge and the work conducted in the ECHOES project – far too restricted to assume that they will be enough to motivate consumers and citizens to engage.*

[4] Communication..."United in delivering the Energy Union and Climate Action - Setting the foundations for a successful clean energy transition" COM(2019) 285 final, 18 June 2019. https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union/national-energy-climate-plans

[5] https://ec.europa.eu/energy/sites/ener/files/documents/1_en_act_part1_v6_0.pdf

[6] https://setis.ec.europa.eu/actions-towards-implementing-integrated-set-plan/implementation-plans

The information provision assumption is based on an information deficit hypothesis, which states that consumers are inactive or engage in unwanted behaviour because they do not know better. Whereas information and knowledge about impacts of behaviours and alternatives as well as technologies are necessary to be able to act, they have been shown to not be sufficient to initiate action. Consumers receive a vast amount of information every day, every minute and information alone is not a strong enough trigger for change in behaviours or practices. Similarly, although consumer behaviour is embedded in an economic framework and the choice of actions and implementation of technology is to a certain degree determined by its economic payoff, human decision-making is very seldom rational in an economic sense, but rather coloured by cultures, social impacts, believes, values, attitudes, behaviour of other people, the historic development of energy lifestyles and practices and the like."

The ECHOES Deliverable 3.3 (Klöckner, Rodrigues, Chebaeva, Dimitrova, Frieden, Koksvik, Koljonen, Löfström, Qiu & Røyrvik, Tzanev, Velte, 2018) describes barriers – in addition to the oversimplified understanding of human behaviour – for better integration of rich social science knowledge in policy-making such as:

- *"The policy system in the energy sector is built in a way that general EU policy is implemented in national law and then into local measures. Therefore, the initial policy documents remain rather unspecific. However, in the implementation the general character of the documents and vagueness with respect to consumers is often translated down to the next level and thus perpetuated where it should be more specific.*
- *Policies analysed had a tendency to be general and not having mechanisms built in that allow for targeting to different regions, cultures, value orientations and lifestyles. Taking this diversity into account requires an extra loop of 'diagnosing' the consumer / social group that is targeted.*
- *Policies are not good enough in acknowledging different levels of social units and tend to treat decision-makers on an individual level, ignoring their social connectedness both horizontally and vertically. New ways of policy-making need to be developed to reach more targeted measures.*
- *Social scientists tend to avoid giving clear advice on policy measures, especially in complex situations outlined above."*

1.3 Purpose and scope of this document

The purpose of this document is to describe the *ECHOES indicator development process* and discuss a proposal for new indicators and related future data collection based on the results of the ECHOES project. The ECHOES project's technological foci (smart energy technologies, electric mobility and buildings) in addition to decision-making constitute the central elements of the ECHOES indicator framework. In addition, all energy decision-making should consider social impacts, which is also increasingly recognised by the EC. As an example, gender and energy poverty are important factors, that need to be both monitored (e.g. ex-post evaluation) and considered (e.g. ex-ante analysis) in all energy related decision-making, and therefore also reside in the ECHOES decision-making levels. Their recognition is critical for the success of a clean energy transition in Europe.

This report is based on the ECHOES results in several ways; for example, the analysis of policy documents conducted in ECHOES D3.3 reveals shortcomings in inclusion of social changes and acceptance, political feasibility and institutional aspects. These, in turn, could justify the development of an ECHOES indicator framework and SSH indicators to better consider these dimensions in policy measures. Furthermore, the ECHOES results, such as the multi-national survey, provide data for relevant indicators as such or indirectly, e.g. through application of relevant aggregation methods.

The deliverable D2.3 aims at answering the following questions:

(1) What is an indicator and what are indicators used for?
(2) Which indicators are included in the Energy Union framework and in the SET-Plan? Which are relevant from the perspective of energy related SSH and ECHOES?

(3) Which indicators are proposed in the scientific and public literature that are relevant from the perspective of energy related SSH and ECHOES?
(4) What should the ECHOES indicator framework consist of and how would the proposed SSH-indicators support the Energy Union and SET-Plan? How should the three technology foci of ECHOES, i.e. buildings, electric mobility, and smart energy technology, be considered in formulating the ECHOES indicator framework?
(5) What data would be needed for the ECHOES indicator framework and how should the indicators be integrated in the open-access ECHOES database? Are there future needs for data collection?

This report is structured as follows:

Chapter 2 discusses the indicators and their use in general. Chapter 3 describes indicators in the Energy Union framework including the SET-Plan. Chapter 4 provides a review of SSH-relevant indicators in the scientific and public literature. Building on the previous chapters, Chapter 5 describes the ECHOES indicator framework. Chapter 6 discusses the integration of indicators into the ECHOES database, and Chapter 7 provides conclusions, including a proposal for ECHOES indicators, discussion, and suggestion for next steps.

2 Indicators and their use

The definition of an indicator and the use of indicators vary in different domains and contexts. Gallopín (1996) discusses environmental and sustainability indicators and suggests that indicators can be defined as “variables that summarize or otherwise simplify relevant information, make visible or perceptible phenomena of interest, and quantify, measure, and communicate relevant information” (Gallopín, 1996).

The term indicator is regularly used at the interface between science and policy (Heink & Kowarik, 2010). The development of sustainability indicators is a process of both scientific "knowledge production" and of political "norm creation", and both components need to be properly acknowledged. Rametsteiner et al. found that the political norm creation dimension is not fully and explicitly recognized in science-led processes (Rametsteiner, Pülzl, Alkan-Olsson, & Frederiksen, 2011).

Peer-reviewed literature on developing high-quality indicators for various aspects of a clean energy transition is a developing area of research. Most of the work so far focuses on technological aspects and high level of aggregation, while indicators pertaining to SSH aspects of the energy transition are emerging but so far only few in peer-reviewed scientific literature. As of writing this report see for example Hakala and Bjelic (2016), Rösch, Bräutigam, Kopfmüller, Stelzer, and Fricke (2018), Rösch, Bräutigam, Kopfmüller, Stelzer, and Lichtner (2017) or Szulecki (2018).

Peer-reviewed literature on sustainable development indicators discussing for example the types of indicators, their use and influence (e.g. Huovila, Bosch, & Airaksinen, 2019; King, 2016; Lehtonen, Sébastien, & Bauler, 2016; Magee & Scerri, 2012; Rinne, Lyytimäki, & Kautto, 2013; Scerri, 2010; Sébastien & Bauler, 2013; Waas et al., 2014) can provide some useful insights into the development of framework for the ECHOES indicators. A thorough review of the peer-reviewed literature on sustainability indicators was, however, beyond the scope of this report.

Rinne et al (2013) use a conceptual model with three types of indicators (instrumental, conceptual and political). Instrumental indicators inform policy-making by communicating if the development is on right track or if adaptations or changes are required to fulfil decided objectives or reaching targets. In the conceptual role, an indicator might help framing a policy problem, and in a political role, indicators would be selected or used in a strategic way to support or to legitimize e.g. a specific decision. Rinne at al. suggest that conceptual use of indicators is the key for enhanced indicator influence in the long term (Rinne et al., 2013).

King (2016) introduces a functional classification of sustainability indicators (see Table 1) stating that in seeking to develop indicators with maximized impact, there should be recognition that the function of the selected indicators should be a major determining factor. The classification utilizes performance measurement literature referring to consistent top-level support, knowledge increase, and organizational capacity as three drivers of effective measurement systems. A leadership/political function is related to setting work programs and focus, the knowledge increase function can lead to enlightening (often referred also as a conceptual use of indicator), and the capacity assessment function is required to understand improvements or failures to maintain organizational systems (instrumental use of indicators). Intrinsic dimension refers to the importance of indicators to the internal interests of governance groups and extrinsic dimension to the public needs and wants (King, 2016).

Table 1. Functional classification of sustainability indicators (King 2016).

	Leadership/Political functions	Knowledge increase functions	Capacity assessment functions
Intrinsic (leaders/organizations)	Political & operational	Problem recognition and awareness	Justificatory
Extrinsic (general public)	Normative guidance	Communication & opinion forming	Monitoring, control & reporting

Lehtonen et al. (2016) discuss the intended use and unanticipated influence of sustainability indicators. Indicators are classified into three broad categories – descriptive (pure data without a specific intended use), performance (allow judging progress towards a norm), and composite (big picture in a manner that is accessible to diverse audiences e.g. ecological footprint). It is suggested that the pathways between indicator design processes, indicators, indicator use, and indicator influence are complex and largely unpredictable. The instrumental role of indicators entails the use of indicators as direct input to specific decisions typically involving "single-loop learning". Conceptual use of indicators (either the process of indicator construction or indicators themselves) may help to shape the conceptual frameworks and mental models of actors by providing background information, and by creating shared understanding through more complex types of "double and triple-loop" social learning. In their political role, indicators can serve as "ammunition" to influence agenda-setting and problem-definition, highlight neglected issues or (de)stabilise and (de)legitimize prevailing frameworks of thought and actors (Lehtonen et al., 2016).

Sebastien and Bauler (2013) discuss the use and influence of composite indicators for sustainable development through three types of factors: indicator factors (e.g. quality attributes), policy factors (institutional context) and user factors (beliefs and representations of policy actors) based on qualitative empirical analysis at an individual, interpersonal and collective level. Composite indicators are not systematically used directly, but they can be used as "framework indicators", enhancing the conceptual and symbolic influence of data. Sebastien and Bauler suggest that major gaps remain between indicator creators and users, leading to misunderstandings between actors. Further, they suggest that new types of governance processes could be taking place, led by "middle actors" (e.g. NGO's, think tanks, scientists). These actors propose "middle-up" and "middle-down" indicators to decisions makers as well as to citizens (Sébastien & Bauler, 2013).

Gudmundsson and Sorensen (2013) studied the use and influence of indicators in strategic policy-making within the sustainable transport agenda at the national (Sweden) and EU level. They concluded that in both cases, several indicators were used in policy processes and they seemed to play a very limited direct instrumental role. In both cases, the indicators were used together with other forms of input information (e.g. together with models and scenarios to produce ex-ante assessment of alternative policy measures). The influence of indicators in policy development was unclear and subject to interpretation. A variety of indicator, user, and policy factors can contribute to explain the use and influence of indicators. Gudmundsson and Sorensen suggest that the influence may increase when indicators are linked to quantitative policy objectives, when policy makers are involved in the design and development of indicators and indicator systems and when indicators are connected to a system of Management-by-Objectives (MBO where the overall annual budget appropriation and reporting is one of the key processes to manage policy performance) (Gudmundsson & Sørensen, 2013).

Huovila et al. (2019) discuss indicators for target setting, performance assessment, monitoring, management and decision-making purposes for city managers related to smart, sustainable cities. They have developed a taxonomy to evaluate indicators against five conceptual urban focuses (types of urban sustainability and smartness), ten sectoral application domains (energy, transport, ICT, etc.) and five indicator types (input, process, output, outcome, impact) in order to provide information on typological factors in indicators differentiating their usefulness for a given purpose. The focus areas of sustainability are provided by the triple bottom line of sustainability (People, Planet and Prosperity). Focus areas for smartness are hard smartness (physical infrastructure) and soft smartness (intangible assets and people). The input-process-output-outcome-impact typology is used by several UN bodies

to measure the performance of their international programs, strategies and projects.[7] Huovila et al suggest that the use of a similar typology helps to capture progress at different time scales and also better specifities in cities' local perspectives (Huovila et al., 2019).

Waas et al. (2014) assert that sustainable development must be considered as a decision-making strategy. In this context, sustainability assessment and sustainability indicators can be powerful decision-supporting tools that foster sustainable development by addressing three sustainability decision-making challenges: interpretation, information-structuring, and influence (Waas et al., 2014). Further, sustainability indicator development needs to reconcile on the role of top-down and bottom-up methods. Scerri (2010) has demonstrated the importance and usefulness of mixing qualitative and quantitative approaches in participatory residential sustainability policy and practice. Recognizing as foundational the need to negotiate the terms, on which the task of achieving sustainability is implemented, the approach links "natural" with "social" scientific endeavour in a policy-oriented and practical approach of binding together quantitative with qualitative "indicators" of sustainability (Scerri, 2010). Further, the establishment of defensible issues and indicators to use tend to be a principal difficulty. Magee & Scerri presented a structured approach for transitioning from initial community consultation designed to elicit issues to the downstream definition, composition and measurement of those issues via indicators (Magee & Scerri, 2012).

To summarize the theoretical discussions above, a general indicator framework is presented in Fig.1. The framework can be used for positioning the proposed indicators based on their purpose, type and subsequent steps from development to use and impact.

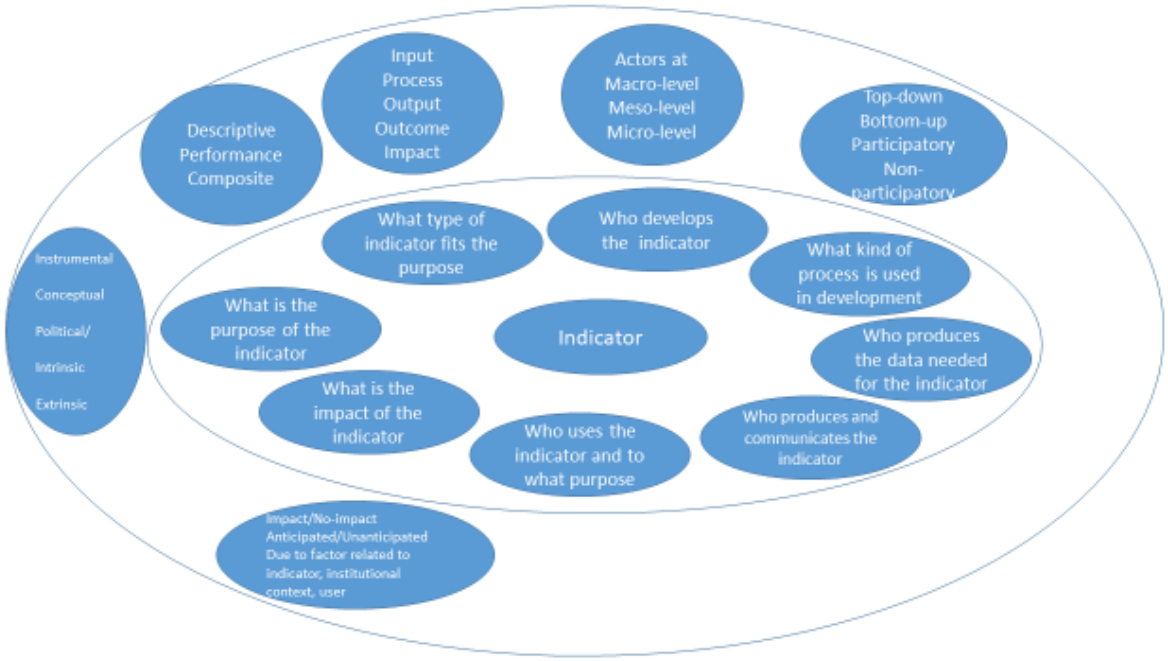

Figure 1. Generic sustainability Indicator framework.

[7] United Nations Office for Disaster Risk reduction UNISDR (2015). Monitoring and evaluation framework. https://www.unisdr.org/we/inform/publications/49324

3 Energy Union Strategy and Indicators

The aim of this chapter is to review the relevant regulatory framework of the Energy Union as well as Implementation Plans of the SET-Plan for their indicator relevant parts and discuss them vis-à-vis the development of the ECHOES indicator framework.

3.1 Governance of the Energy Union Regulation

Governance of the Energy Union regulation aims at integrating and streamlining most of the current energy and climate planning and reporting requirements of EU countries as well as the Commission's monitoring obligations.

The aim of the governance mechanism is to ensure i.e. effective opportunities for the public to participate in the preparation of national plans and the long-term strategies. Member States' integrated national energy and climate progress reports should mirror the elements in the integrated national energy and climate plans. The details of the progress report will be specified in the implementing act. The aim of the progress reports is to ensure transparency towards the Union, other Member States, regional and local authorities, market actors including consumers, any other relevant stakeholders, and the general public.

Governance regulation includes definitions for indicators and key indicators as well as obligations for MS to assess the number of households in energy poverty taking into account *indicative Commission guidance on relevant indicators.* Indicators and key indicators are defined as follows:

'Indicator' means a quantitative or qualitative factor or variable that contributes to better understanding the progress made in implementing.

'Key indicators' mean the indicators for the progress made with regard to the five dimensions of the Energy Union as proposed by the Commission, that are 1) energy security; 2) the internal energy market; 3) energy efficiency; 4) decarbonisation of the economy; and 5) research, innovation and competitiveness.

The governance regulation refers to indicators also in the provisions related to national energy and climate plans:

Regarding energy efficiency, it is required that there needs to be *"indicative milestones of the long-term strategy for the renovation of the national stock of residential and non-residential buildings, both public and private, the* ***roadmap with domestically established measurable progress indicators****, an evidence-based estimate of expected energy savings and wider benefits, and the contributions to the Union's energy efficiency targets…"*

Regarding the internal electricity markets and the level of electricity interconnectivity, MS need to include objectives, targets, and contributions in their national plans *"…taking into account the 2020 interconnection target of 10% and the* ***indicators of the urgency of action*** *based on price differential in the wholesale market, nominal transmission capacity of interconnectors in relation to peak load and to installed renewable generation capacity… Each new interconnector shall be subject to a socioeconomic and environmental cost-benefit analysis and implemented only if the potential benefits outweigh the costs."*

The governance regulation includes also requirements to report indicators as part of analytical basis of national plans and as GHG inventory information. Indicators are also mentioned as one source of information in the assessment of progress carried out by the Commission.

3.2 Energy Efficiency Directive and Energy Performance of Buildings Directive

Energy efficiency directive (2012/27/EU)[8] includes requirements to report indicators (e.g. disposable income of households) as part of the annual report. The revised energy efficiency directive does not include any provisions for indicators. The reporting requirements, including possible indicators, for the period 2021-2030 will be decided later. The revised energy efficiency directive includes provisions for energy poverty and clearer rights for consumers (especially those in multi-apartment buildings) with collective heating systems to receive more frequent and more useful information on their energy consumption, also enabling them to better understand and control their heating bill.

The revised Energy Performance of Buildings Directive[9] includes (in addition to the domestically established measurable progress indicators for the renovation roadmap) provision for a delegated act *"establishing an optional common Union scheme for rating the smart readiness of buildings. The rating shall be based on an assessment of the capabilities of a building or building unit to adapt its operation to the needs of the occupant and the grid and to improve its energy efficiency and overall performance."* The delegated act – to be adopted by 31 December 2019 – includes establishing the definition of the ***smart readiness indicator*** and a methodology by which it is to be calculated. Common general framework for rating the smart readiness of buildings is provided in the Annex to the Directive.

3.3 Recast Renewable Energy Directive

The Revised Renewable Energy Directive does not include any provisions related to indicators. One of the objectives of the revised directive is to put the consumer at the centre of the energy transition. Thus, there is potentially need for SSH-relevant indicators that would support setting up and monitoring policies that aim at this objective.

The Directive includes definitions for "renewables self-consumer", "jointly acting renewables self-consumers", and "renewable energy community". The aim is to create an *"enabling framework"* for consumers and communities to promote renewable energy. The aim is also to increase local participation and acceptance of renewable energy as well as helping to fight energy poverty.

Member States are required to include a summary of the policies and measures under the enabling framework and assess their implementation in their integrated national energy and climate plans and progress reports.

3.4 Directive on common rules for the internal market for electricity

The Directive for Internal Market for Electricity[10] does not include provisions for indicators that would be relevant for the ECHOES perspective. There are, however, several provisions for consumer empowerment and protection e.g. related to active customers, citizen energy communities, smart metering systems, data management, demand response through aggregators, vulnerable customers and energy poverty that are potentially relevant for development of SSH-indicators.

Member States are, for example, required to define the concept of vulnerable customers "*which may refer to energy poverty and, inter alia, to the prohibition of disconnection of electricity to such customers in critical times. The concept of vulnerable customers may include income levels, the share of energy expenditure of disposable income, the energy efficiency of homes, critical dependence on electrical equipment for health reasons, age or other criteria."*

[8] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:315:0001:0056:en:PDF
[9] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32010L0031
[10] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019L0944

When assessing the number of households in energy poverty, Member States are required to *"establish and publish a set of criteria, which may include low income, high expenditure of disposable income on energy and poor energy efficiency."*

3.5 SET Plan

The Implementation Plans of the SET Plan[11] were reviewed for references to indicators and consumers/citizens. Some of the Implementation Plans can be regarded as non-relevant for the ECHOES-project (e.g. Continue efforts to make EU industry less energy intensive and more competitive and the CCS and CCU Implementation Plan). Some Implementation Plans refer to SSH-relevant issues without suggesting indicators. For example, the Implementation Plan for the Initiative for global leadership in deep geothermal mentions annual gathering of information regarding the perception of local communities in regards to near-by geothermal plants (built or under construction). The Implementation Plan for the Initiative for global leadership in ocean energy mentions the development of the assessment of the socio-economics components (e.g. jobs, turnover, share of GDP) to establish the best techniques to benefit developers, communities and the EU.

Task 4 in the Implementation Plan 3.1 Smart Solutions for Energy Consumers is to develop key performance indicators for consumer benefits and engagement. The Annex to the Implementation Plan includes KPIs for measuring consumer benefits (Table 2) developed by Joint Programme e3s of the European Energy Research Alliance (EERA) and KIC Innoenergy.

[11] https://setis.ec.europa.eu/actions-towards-implementing-integrated-set-plan/implementation-plans

Table 2. SET Plan Action 3.1. Indicator proposal.

Area	Indicator	Data availability
Involvement of citizens in energy production: Self-production of energy	Household PV production (% of total PV production in MS)	Household PV production: regional reference data (Baviera)
	Nº of bioenergy villages per MS	Nº of bioenergy villages per MS (studies on best practice for Austria, Croatia and Germany)
	% of consumers, which are member of energy cooperatives	Members of energy cooperatives: available from Cooperatives Europe and RES Coop: 1,250 cooperative enterprises, 300,000 members
Consumer behaviour / preferences - smart appliances-	Nº of smart meters with feedback function for customer per MS	Smart meters: ACER / JRC – feedback function needs greater observation
	Nº energy savings apps per capita and MS	Energy saving apps: inventory of THE4BEES project – 69 apps nº of downloads – industry data required
	Customer satisfaction with smart thermostats	Customer satisfaction smart thermostats – market reports available, industry data preferable
Participation in demand response	Degree of market opening to demand response	Market opening: observed by SEDC and JRC
	Nº of households and SMEs participating in DR	Households and SMEs: reference data in leading demand response markets?
	Nº of V2G (vehicle to grid) participating in DR	V2G – could eventually be delivered by EAFO (European Alternative Fuels Observatory)
Market participation	% of customers switching suppliers to 100% RES?	Switching rates: available from ACER (electricity and gas)
	Nº of aggregators operating in each MS	Aggregators: not yet available, only the numbers of retailers active in each country (ACER)
Impact on household energy bills	Development of final household energy demand	Household energy demand: EUROSTAT
	Development of final household electricity demand	Household electricity demand: EUROSTAT
	Development of energy poverty rates in MS	Energy poverty rates: Energy Poverty Observatory and BPIE
Societal Readiness Level	Increase in households' annual energy investment Acceleration of energy conservation and efficiency actions and impacts	Observatory of energy conservation and energy efficient behaviours, actions and impacts (to be created)

TABLE 1. KPIS SUMMARY

Monitoring and Evaluation activities in the Implementation Plan "Europe to become a global role model in integrated, innovative solutions for the planning, deployment, and replication of Positive Energy Districts (PED)" can also potentially provide relevant information related to the SSH-indicators.

4 Indicators in scientific and public literature

4.1 Review of Indicator Literature for ECHOES indicator development

This short review looks at research literature on use of indicators in energy transition research. The details of the searches conducted are available from the authors of this report. This review presents literature on indicator studies on the individual and cultural level (micro-meso) and then moves to studies, which handle more aggregated levels – organizations, municipalities, businesses, national, and finally international. In addition, some literature on developing robust indicators has been discussed above in Chapter 2. As will be discussed below, peer-reviewed literature finds a few, but not extensive numbers of SSH dimensions in indicators for clean and zero carbon energy transition. The review shows that social sciences and humanities seem to be an emerging dimension of energy transition research, with a handful of most topical papers recently published in 2018, while earlier work focuses on techno-economic aspects and recognizes the need for socio-economic and socio-technological indicators for sustainability and resilience of clean energy transitions. There is a notable distinction between literature on climate change mitigation and adaption: literature on mitigation has traditionally focused on quantitative indicators and techno-economic topics, while indicators on adaption are newer and tend to bring in more qualitative indicators, see e.g. (van Vuuren et al., 2012). This likely reflects an expansion in the professions involved in activities and tasks related to climate change, with adaptation activities rising in importance and urgency. This division is also found in sustainability indicators in general, e.g. Reed, Fraser, and Dougill (2006).

4.1.1 Energy transition indicators with individual and collective dimensions

O'Brien et al. explored low carbon strivings – personal goals to reduce carbon footprint in the household – and found that they can predict a wide range of diverse behaviours to reduce greenhouse gas emissions. They propose a Low Carbon Readiness Index (LCRI), an easy-to-use indicator of the general public's readiness to transition to a fully low carbon lifestyle. The LCRI is a validated measures with four studies and predicts reduction in actual energy use, arguably an aggregate measure of actual low carbon behaviours, LCRI can be used to develop low carbon policies and monitor their implementation (O'Brien et al., 2018).

Koehrsen explored the role of religion in local energy transitions and identified three potential functions: (1) campaigning and intermediation in the public sphere; (2) 'materialization' of transitions by creating participation in tangible projects; (3) spreading of values and worldviews that advance environmental attitudes and action. Although religion attended each of these functions in the region studied, actors from other social subsystems appeared to take over these functions in a more efficient way (Koehrsen, 2015).

Araujó et al. studied electric vehicles and solar photovoltaic technology diffusion in the State of New York, US, to shed light on the attributes of early adopters of clean energy. Using geospatial, regression, and cluster analyses of zip code level and county indicators, they analysed trends with locational, political and socio-demographic profiles to identify adoption patterns. In line with the literature, they confirmed the importance of income and median home value for electric vehicle and solar photovoltaic technology adoption. Political orientation and age tendencies are more nuanced and less predictive (Araújo, Boucher, & Aphale, 2019).

4.1.2 Energy transition indicators at local level

Tan et al. (2017) propose a new holistic indicator framework for low-carbon cities, including the perspectives of Economic, Energy patterns, Social and Living, Carbon and Environment, Urban mobility, Solid waste, and Water. The framework was applied to ten global cities to rank their low-carbon performance. The indicator system serves as a guideline for the standardization of LCC and further identifies the key aspects of low-carbon management for different cities (Tan et al., 2017). In similar vein, Urrutia-Azcona et al. embarked from the concept of Smart Zero Carbon City (SZCC) to develop a set of indicators named the SZCC Readiness Level. This method analyses key aspects of cities: Characteristics of the city; City plans and strategies; Energy; Mobility; Infrastructures and ICT

services; as well as Citizen Engagement. It was implemented in five Basque cities, which represent different urban typologies (Urrutia-Azcona, Fontán-Agorreta, Díez-Trinidad, Rodríguez-Pérez-Curiel, & Vicente-Gómez, 2018).

Aste et al. (2014) presented a monitoring methodology for efficiency in domestic heating in Italy for local energy planning, taking advantage of the use of indicators to compare efficiency indicators across multiple criteria. Their systems accounts for different perspectives, including those of the society and the end-user (Aste, Buzzetti, Caputo, & Manfren, 2014). Facchinetti et al. (2016) look at local energy management in Switzerland and new business models arising from distributed generation. They collected energy business managers' perceptions to support innovation and give insights into policy challenges and opportunities in local energy management (Facchinetti, Eid, Bollinger, & Sulzer, 2016). Nielsen and Jørgensen (2015) studied Danish island Samsø that aims to energy independence and carbon neutrality. To help steering the energy transition process, they developed a sustainability analysis framework that accounts for infrastructure, transfers, inputs and outputs, and consumption in terms of exergy. These inform sustainability indicators that can monitor the efficacy of the measures taken (Nielsen & Jørgensen, 2015).

Vergerio et al. (2018) tackle the urgent requirement to develop local energy policies able to speed uptaking of energy efficiency measures, lowering some barriers to the interventions. They developed a methodology as support to the decision-making process in defining local energy policies and applied it in city of Torino. This methodology takes advantage of Key Performance Indexes, quadrant-charts, Reference Buildings etc. and evaluation approaches: cost-optimal analysis, cost-benefits analysis to support, local energy planning policies on public buildings (Vergerio et al., 2018).

4.1.3 Indicators for national energy transitions – barriers and resilience

Binder et al. (2017) analysed resilience for energy systems in transition with regard to both social and technical aspects. Their indicator system builds upon research on social-ecological systems with core attributes of diversity and connectivity (Binder, Mühlemeier, & Wyss, 2017). Mühlemeier et al. (2017) then used the indicator set for diversity and connectivity to study the resilience of the energy transition process in Bavaria. The connectivity indicators showed that the transition could stagnate, while the diversity indicators pointed to a resilient transition process. They advocate the importance of interdisciplinary analysis for resilience of energy transitions (Mühlemeier, Binder, & Wyss, 2017).

Rösch et al. (2018) found that in the Federal indicator system for monitoring Germany's energy transitions neglects such aspects as affordability, participation, and acceptance. Building on the Integrative Concept of Sustainable Development, they developed a new indicator system that includes indicators related to the socio-technical interface of the energy system, in addition to indicators related to techno-economic and environmental aspects (Rösch et al., 2017). The authors then applied the Sustainability Indicator System (SIS) consisting of 45 indicators to assess policy measures implemented so far by the German Federal Government. They examined the appropriateness, sufficiency and the capability to achieve the energy policy and sustainability targets defined for the German energy system. One quarter of the sustainability indicators proposed in the paper are not yet monitored and remain without results (Rösch et al., 2018).

Hakala and Bjelic (2016) studied potential for Serbia to leapfrog the energy transition. They identified barriers and sustainable energy potential in the country. In particular, they discuss energy transition in its historical context with societal implications and effects. They call for energy policy emphasizing leapfrogging potential, based on the difference between EU-28 average indicators (Hakala & Bjelic, 2016). McLellan et al. also looked at the potential and limitations of transition to decentralized energy. Based on transitions theory, they examined the progress for decentralized energy in Japan after the Fukushima accident in 2011. Variation across different and differently affected areas was surprisingly small, implying that moving to more radical transition paths may call for supporting actions (McLellan, Chapman, & Aoki, 2016).

4.1.4 European Union and international indicators

Shivakumar et al. (2018) studied methods to develop indicators to measure progress in smart solutions for energy consumers, Action 3.1. in the EU SET plan framework. They reviewed both existing indicators that are able to monitor the levels of deployment of smart technologies, and estimates of demand response potential in Europe in regard to goals on energy efficiency, cost savings, and renewable energy (Shivakumar et al., 2018).

Pan and Ning (2015) developed a socio-technical framework to facilitate sharing and comparing zero-carbon building (ZCB) policies across different countries. They observed that human behaviours are poorly addresses in the ZCB policies, leading to a significant gap between policy goals and actual practices (Pan & Ning, 2015). Karimi et al. (2016) carried out a socio-cultural analysis of risk perception regarding CCS in the EU. They aggregated individual technology opinions with cross-cultural data and showed that nation-specific cultural issues approximate public reactions to CCS, providing a frame of analysis for tackling why and how societies and societal actors challenge and contest technologies and energy regimes (Karimi, Toikka, & Hukkinen, 2016).

Energy efficient HVAC-systems, buildings, and other energy consuming products help reducing CO_2-emissions in cities. Strasser et al. (2018) summarize the results of the Annex 63 − Implementation of Energy Strategies in Communities − within the Energy in Buildings and Communities Program (EBC) of the International Energy Agency (IEA). The paper includes procedures and best-practice examples to implement optimized energy strategies in communities. The implementation strategies deal with visions and targets, renewable energy strategies, legal frameworks, design of urban competition processes, tools supporting the decision-making process, monitoring, stakeholder engagement, socio-economic criteria, and organization structures (Strasser et al., 2018).

Vogt-Schilb and Hallegette (2017) reviewed the literature on how policy-makers can design climate policies and their nationally determined contributions in a socially and politically acceptable manner. To get the ambition right, policymakers can use sectoral roadmaps with targets and indicators that track progress toward zero emissions. They assert that monitoring economy-wide emission-reductions alone would not ensure that short-term action contributes meaningfully to the long-term decarbonization goal. To get the political economy right, climate policies can be designed so that they contribute to non-climate objectives and create broad coalitions of supporters (Vogt-Schilb & Hallegatte, 2017).

4.2 Public literature on energy transition indicators

Public indicators or ones belonging to so-called public or grey literature that are related to energy transition include actors and organizations of many types and many levels. Respectively, there are numerous indicator sets on the topic of energy transition.

Search terms “energy transition indicator” and “energy transition indicators” produced a surprisingly low number of relevant results that would contain actual indicator sets, while search engines naturally produce millions of responses. To expand the search, similar searches were conducted in Spanish, German, Finnish, and Swedish, in addition to English. This brought results on some nationally produced indicator sets and barometers. The indicators that were found, centred mostly on technological aspects of the energy transition, such as technologies adapted and amounts of energy produced with particular technology. The results will be introduced below in the shortlisted indicators, grouped by topic together with indicators found in the reviewed literature. Only climate barometers and other surveys produced results on individual or cultural-collective levels.

Searches for public literature covered large international organizations whose work touches energy, national level indicators, and on European level, European Union DGs and related units, think tanks, climate barometers, repeated studies and research projects. Results that are relevant to the European energy transition are reflected in more detail in the indicators shortlist in Chapter 5.2.

The following global organizations were investigated individually: International Energy Agency, United Nations, World Bank, World Energy Council, and World Economic Forum. As expected, these organizations produced high level, aggregated indicators or indices that focus on techno-economic aspects, global outlook and national comparisons. The World Economic Forum (WEF) and the World Energy Council (WEC) propose energy transition indices of national scales, while the United Nations (UN) and the World Bank focus primarily on the Sustainable Energy for All theme in developing countries.

Within the European Union, energy transition links to the themes of Energy Union indicators. The European Energy Poverty Observatory collects energy poverty indicators, while the think tank INSIGHT_E offers a wider set of energy transition indicators. The Eurobarometer tracks European climate change perceptions across the EU, and many European countries run their annual energy and climate barometers, however typically in national languages. Therefore, only the ones available in languages mentioned above were discovered. In addition, public literature searches found national level energy transition indicators for Germany, Switzerland and Spain, by a consultation agency, environmental NGO group and independent research institute, respectively. This goes on to show the varied nature of instances that are interested in monitoring the progress of a clean energy transition.

To summarize the findings in energy transition indicators found in scientific and public sources, the literature is still sparse, technology-oriented and top-down. There is a clear need for more knowledge about citizen's and communities participation in clean energy transition. This will be examined in more detail in Chapter 5, where shortlisted indicators from literature are presented.

5 ECHOES Indicator Framework

In this chapter, a *shortlist*, consisting of candidate indicators for relevant ECHOES targets as described above, is formed as a basis of developing the ECHOES indicators. The shortlist is based on a review of 51 most closely relevant documents, consisting of both scientific and public documents that resulted in so-called longlist of over 600 indicators. In the next phase, a set of criteria was applied, based on the CIVITAS framework (van Rooyen and Nesterova, 2013) and the CITYkeys project (Bosch P, Jongeneel S, Rovers V, Neumann H-M, Airaksinen M, Huovila A, 2017) to narrow down the list to present more relevant indicator candidates. The shortlist achieved as a result consists of 87 indicators. The shortlisted indicators provide with a justified list of indicators with good potential for being part of the ECHOES indicator proposal. The implementation of ECHOES indicators in relation to the ECHOES database, ECHOES results, and SET Plan Action 3.1 is discussed in chapters 6 and 7. Finally, we present a proposal for ECHOES indicators, including a number of indicators straightforwardly implementable in the ECHOES database in chapter 7. The process is depicted in Fig. 2.

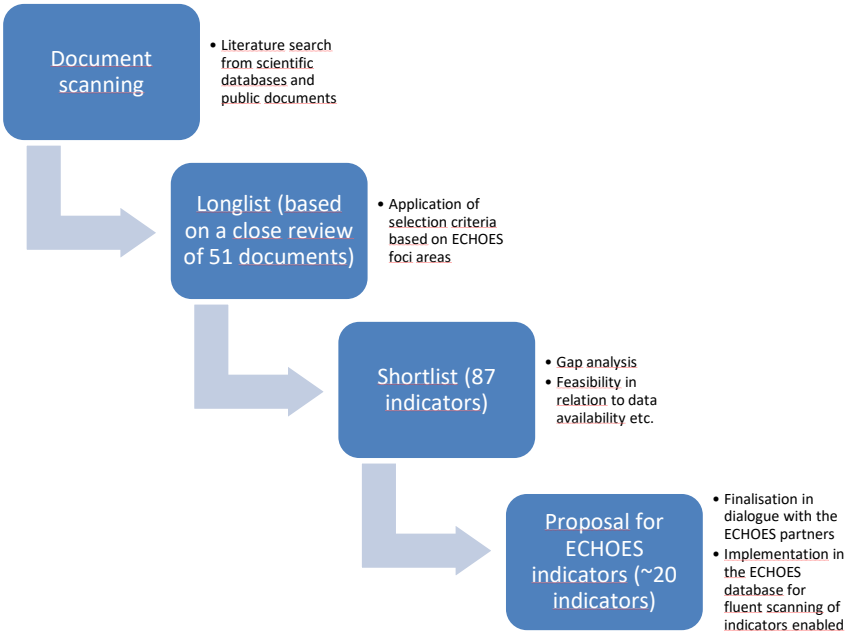

Figure 2. Process of developing the proposal for ECHOES indicators.

5.1 Indicator development and criteria for indicators

In general, indicators and in particular KPI's should express as precisely as possible the progress toward or the achievement of a goal. There may be more than one possible indicator to assess the progression towards a certain goal, in particular in complex issues such as e.g. energy poverty. Further, it is inherently challenging to set precise objectives for SSH topics that are in the centre of ECHOES project. Scanning the existing indicators sets that are relevant for the themes of the ECHOES project resulted in long lists of potential indicators, while specifically relevant indicators were available fairly little. To arrive at a shortlist of indicators for discussion with partners, a set of criteria was used, based on the CIVITAS framework (van Rooijen, T.; Nesterova, 2013) and the CITYkeys project (Bosch P, Jongeneel S, Rovers V, Neumann H-M, Airaksinen M, Huovila A, 2017). The criteria are shown in Table 3.

Table 3: Criteria applied to proposed ECHOES indicators / KPIs.

Indicator criteria	Purpose
RELEVANCE	Each indicator should have a significant importance for the evaluation process. That means that the indicators should have a strong link to the subthemes of the framework.
COMPLETENESS	The set of indicators should consider all aspects of the ECHOES project and as comprehensively as possibly, the implementation of SET Plan Action 3.1. on the Smart Energy Consumer.
AVAILABILITY	Data for the indicators should be easily available. As the inventory for gathering the data for the indicators should be kept limited in time and effort, the indicators should be based on data that ideally can be easily compiled from public sources. Indicators that require, for instance, interviews of users or dwellers are not suited as the large amounts of data needed are too expensive to gather. The same holds for indicators that require extensive recalculations and additional data, such as footprint indicators, and some financial indicators. However, data availability is not always feasible when establishing forward-looking indicators that at times aim at tracking technologies that are not fully in place, yet. Therefore, for a few indicators that score very high on relevance on the political agenda, new data collection is proposed. The European survey also produced high quality data that would fit indicator purposes with repeated data collection available from an open access database e.g. Eurostat, Energy poverty observatory, or SETIS.
MEASURABILITY	The identified indicators should be capable of being measured, preferably as objectively as possible.
RELIABILITY	The definitions of the indicators should be clear and not open for different interpretations. This holds for the definition itself and for the calculation methods behind the indicator.
FAMILIARITY	The indicators should be easy to understand by the users. In ECHOES, for a large number of indicators we have relied on indicators from existing indicator sets that generally comply with this requirement. For new indicators a definition has been developed that has a meaning in the context of existing policy goals.
NON-REDUNDANCY	Indicators within a system/framework should not measure the same aspect of a subtheme.
INDEPENDENCE	Small changes in the measurements of an indicator should not impact preferences assigned to other indicators in the evaluation.

The shortlisted indicators presented below have been assessed by their relevance, which is the first evaluation criteria. Longlisted indicators derived from existing research and public source on these criteria are available from the authors of this report.

5.2 Potential indicators for ECHOES: shortlist

This chapter introduces the research and other indicator systems that contain indicators with potential relevance for ECHOES approach and themes.

The presented list of potential indicators is based on broader longlist of indicators, to which selection criteria to identify the ECHOES relevant indicators are applied. As a result, 87 potential indicators with particular relevance to ECHOES were found, covering relevant technological foci, social dimensions, energy transition aspects, and availability allowing tracking of development on personal and collective level. The presented shortlist is based on a wide literature search, and thorough analysis of the candidate indicators in relation to ECHOES indicator targets (see Fig.2 earlier in this chapter). Thus, the majority of indicators found in the literature were rejected due to low relevance.

The relevant indicators on the shortlist are presented in the following sections. They have been organized under sub-themes as follows: **energy poverty, readiness for energy transition, smart cities and energy transition, buildings and mobility**. The first shortlist for energy transition indicators presented is based on the relevance criteria (Table 3) in 5.1.

5.2.1 Energy poverty

The European Energy Poverty Observatory (EPOV) focuses in producing information about energy poverty in Europe. Energy poverty is a multi-dimensional concept and therefore EPOV approaches measuring energy poverty by using a suite of indicators, which should be used in combination. Each indicator signals a slightly different aspect of the phenomenon.[12]

EPOV provides four different primary indicators for energy poverty, which are based on Eurostat data. The two self-reported experiences of limited access to energy services are recorded in EU-SILC database[13] *(Statistics on Income and Living Conditions*) and the other two are calculated using household income and/or energy expenditure data, based on Household Budget Survey. EPOV gathers also data on a number of secondary indicators that are relevant in the context of energy poverty, but not directly indicators of energy poverty itself. Included in secondary indicators so far are adequate cooling and damages in the dwelling.

We propose the inclusion of the four primary indicators by EPOV in the ECHOES indicators. In addition, we propose an indicator recording sufficient cooling to include in the ECHOES indicators, with questions that directly relate to affording the appropriate energy service, cooling. Adequate cooling is an indicator that is rising in importance with increasing frequency of heatwaves across Europe in summer time. As sixth energy poverty indicator, we propose damages in building, which is a secondary indicator in EPOV listing. Building damages indicate inability to maintain dwelling, which in turn signals low energy efficiency, the main cause to insufficient dwelling temperature in Europe ((eds.) Csiba, K; Bajomi, A; Gosztonyi, A, 2016). Further, damaged dwelling is gender-disaggregated data. We also propose that data for all energy poverty indicators be released in gender-disaggregated format.

Table 4: Energy poverty indicators from European Energy poverty institute

Primary indicators	Explanation	Data
1. Arrears on utility bills	Share of (sub-) population having arrears on utility bills.	Eurostat
2. Low share of energy expenditure in income (M/2)	The share of households whose absolute energy expenditure is below half the national median, or in other words abnormally low. Unless be due to high energy efficiency, it may indicate households dangerously under-consuming energy.	Eurostat, EPOV?
3. High share of energy expenditure in income (2M)	The proportion of households whose share of energy expenditure in income is more than twice the national median share.	Eurostat, EPOV
4. Inability to keep home adequately warm	Share of (sub-) population not able to keep their home adequately warm, based on question "Can your household afford to keep its home adequately warm?"	Eurostat
5. Inability to keep home sufficiently cool *Proposed for new collection!*	Share of (sub-) population not able to keep their home sufficiently cool, based on question "Can	Eurostat

[12] https://www.energypoverty.eu/indicators-data
[13] Statistics on income and living conditions https://ec.europa.eu/eurostat/web/income-and-living-conditions/data/database

	your household afford to keep its home sufficiently cool?"	
6. Presence of leak, damp, rot	Share of population with leak, damp or rot in their dwelling, based on question "Do you have any of the following problems with your dwelling / accommodation? - a leaking roof - damp walls/floors/foundation - rot in window frames or floor	Eurostat

5.2.2 Readiness for energy transition

Climate barometers and studies with similar topics produce information about climate change and energy transition attitudes, including readiness to take action.

Kashima et al. (2014) showed that environmental strivings, personal goals to improve the natural environment can predict a wide range of pro-environmental behaviours (Kashima, Paladino, & Margetts, 2014). O'Brien et al. (2018) propose a Low Carbon Readiness Index (LCRI), a short, three-item measure of the general public's readiness to transition to a fully low carbon lifestyle. It measures personal motivation to transition to low carbon living (O'Brien et al., 2018). In particular, responses to risk perception and readiness to take personal action indicate "transition readiness" according to the study. The LCRI items were developed by modifying Kashima et al.'s (2014) environmental strivings measure.

Table 5. Low carbon readiness indicators (O'Brien et al. 2018)

Indicators
(1) I work hard to reduce my greenhouse gas emissions whenever possible;
(2) I feel very good when I am successful in reducing my greenhouse gases;
(3) I would feel very bad if I did not reduce my greenhouse gas emissions
Scale: Strongly disagree; Disagree; Neither agree nor disagree; Agree; Strongly agree.

Climate barometers produce information about individual perceptions of climate change and measures to tackle it. Climate barometers in European countries are published by various types of organizations. The Eurobarometer survey on climate change, covering all MSs, has been out carried out multiple times since 2008, lastly in 2017. The Eurobarometer in climate change is effective particularly in recording transition readiness among European population. Special Eurobarometer 459[14] reported that in 2017, around three-quarters of European Union (EU) citizens (74%) considered climate change to be a very serious problem and more than nine in ten (92%) saw it as a serious problem.

In addition to Eurobarometer, national climate attitude studies have been carried out widely across Europe in national languages, in one-time or repeated studies. For example in Spain, the respective survey has been carried out by Centro de Investigaciones Sociologicas[15]. In Finland, the national climate barometer, Ilmastobarometri[16], is currently carried out annually and commenced by the governmental climate communications steering group. In Denmark, a national climate barometer is carried out by a local Green party think tank. Other institutions carry out regular or special investigations of climate attitudes in Europe as well, e.g. the European Social survey.

[14] https://ec.europa.eu/clima/sites/clima/files/support/docs/report_2017_en.pdf
[15] http://www.cis.es/cis/export/sites/default/-Archivos/Marginales/3220_3239/3231/es3231mar.html
[16] https://www.ym.fi/en-US/Climate_Barometer_2019_Finns_wish_to_hav(49671)

Furthermore, climate change perceptions have been explored in the ECHOES project, both in depth and widely in all the EU countries and three associate countries.

5.2.2.1 European climate barometer

The latest report of the Eurobarometer survey of 2017 on climate change[17] covers four main areas:

- Perceptions and seriousness of climate change;
- Action on climate change: responsibility for addressing the problem, and personal steps taken;
- Attitudes to fighting climate change and reducing fossil fuel imports;
- Looking to the future: support for national governments' targets for renewable energy and energy efficiency

Table 6: Questions on perceptions of climate change in the Eurobarometer survey 2017.

Seriousness of climate change	Scale
1. And how serious a problem do you think climate change is at this moment?	Scale 1-10, '1' meaning "not at all a serious problem" and '10' meaning "an extremely serious problem".
2. In your opinion, who within the EU is responsible for tackling climate change?	National governments 1, / The European Union 2, / Regional and local authorities 3, / Business and industry 4, / You personally 5, / Environmental groups 6, / Other 7, / All of them 8, / None 9, / Decline 10

Table 7: Questions on personal low carbon actions taken in the Eurobarometer survey 2017.

Which of the following actions, if any, apply to you? (Yes/No for each item)
1. You try to reduce your waste and you regularly separate it for recycling
2. You try to cut down on your consumption of disposable items whenever possible, e.g. plastic bags from the supermarket, excessive packaging
3. You buy locally produced and seasonal food whenever possible
4. When buying a new household appliance e.g. washing machine, fridge or TV, lower energy consumption is an important factor in your choice
5. You regularly use environmentally-friendly alternatives to your private car such as walking, cycling, taking public transport or car-sharing
6. You have insulated your home better to reduce your energy consumption
7. You avoid taking short-haul flights whenever possible
8. You have bought a new car and its low fuel consumption was an important factor in your choice
9. You have installed equipment in your home to control and reduce your energy consumption (e.g. smart meter)
10. You have switched to an energy supplier which offers a greater share of energy from renewable sources than your previous one
11. You have installed solar panels in your home
12. You have bought a low-energy home
13. You have bought an electric car

[17] Special Eurobarometer 459 report data available at: http://data.europa.eu/euodp/data/dataset/S2140_87_1_459_ENG

5.2.2.2 Climate barometer in Finland 2019

The Climate barometer in Finland 2019 included a large group of questions about transition readiness and low carbon lifestyles.[18] Questions particularly relevant to lifestyle transition are presented below in table 8. The survey was conducted in Finnish language and translated into English below.

Table 8: Low carbon lifestyle questions in 2019 Climate barometer of Finland

Questions
1. I have shifted to use green or eco-labelled electricity.
2. During the next 5 years, I intend to shift to use green or eco-labelled electricity.
3. I have reduced my electricity or heat consumption.
4. I am ready to use less electricity at times when the demand is highest.
5. I have reduced the amount of animal based food in my diet.
6. During the next 5 years, I intend to reduce the use of animal based products in my diet.
7. I have reduced flying due to climate reasons.
8. During the next 5 years, I intend to reduce flying due to climate reasons.
9. I have compensated the climate emissions of my actions with voluntary payments.
10. During the next 5 years, I intend to compensate the climate emissions of my actions with voluntary payments.
11. I have reduced purchasing goods due to climate reasons.
12. I agree that actions for climate change mitigation will cost me a few percentages of my net income e.g. due to environmental protection tax:
13. I have altered the heating system in my home to one with lower emissions.
14. During the next 5 years, I intend to alter the heating system in my home to one with lower emissions.
15. I have actively advanced emission cuts, energy saving or energy efficiency in my housing company.
16. During the next 5 years, I intend to actively advance emission cuts, energy saving or energy efficiency in my housing company.
17. I intend to purchase a low-emission electric or gas vehicle for my next car.
18. During the next 5 years, I intend to give up owning a car and shift to using sustainable mobility services (public transportation, shared bicycle or carpool).
19. I have reduced driving a car and increase sustainable mobility like walking, biking or using public transportation.
20. During the next 5 years, I intend to reduce driving a car and increase sustainable mobility like walking, biking or using public transportation.

5.2.2.3 European Social survey

European Social survey published a rotating module on European attitudes to climate change and energy, (rotating module, D1-32), in 2018. Rotating module studies are carried out each time with a new topic. The study covered

[18] https://www.ym.fi/fi-FI/Ajankohtaista/Tiedotteet/Tiedotteet_2019/Ilmastobarometri_2019_Suomalaiset_haluav(49670)

23 countries and the questions handled mostly similar themes as the Eurobarometer: reducing energy consumption and emissions, in addition to perception and sense of responsibility to take action.[19]

Table 9: Climate change perception and low carbon lifestyle questions in European Social Survey.

Questions
1. If you were to buy a large electrical appliance for your home, how likely is it that you would buy one of the most energy efficient ones?
2. There are some things that can be done to reduce energy use, such as switching off appliances that are not being used, walking for short journeys, or only using the heating or air conditioning when really needed. In your daily life, how often do you do things to reduce your energy use?
3. Overall, how confident are you that you could use less energy than you do now?
4. To what extent do you feel a personal responsibility to try to reduce climate change?
5. How worried are you about climate change?
6. Now imagine that large numbers of people limited their energy use. How likely do you think it is that this would reduce climate change?
7. How likely do you think it is that limiting your own energy use would help reduce climate change?

5.2.3 Smart cities and energy transition

Energy efficiency and various aspects of smart mobility are present in smart city frameworks. Some examples include the CITYkeys project,[20] a system of spatial indicators of urban sustainability, developed by Bourdic et al. (Bourdic, Salat, & Nowacki, 2012), and the Smart Zero Carbon City Readiness Level: a system for city decarbonisation diagnosis, by Urrutia-Azcona et al (Urrutia-Azcona et al., 2018).

5.2.3.1 Smart city indicators

Bourdic et al. developed a system of spatial indicators of urban sustainability to encompass the intrinsic complexity of the city. The proposed multi-scale and cross-scale indicators assess urban sustainability regarding the energy efficiency, social and environmental consequences. These indicators can assist with the comparison of urban projects against 60 indicators and methods, which quantify the energy efficiency, social and environmental consequences of different urban forms. Mobility indicators from this system examine topics closely linked to the ECHOES project. However, their approach is different with spatial indicators (Bourdic et al., 2012)

Table 10: CITYkeys smart city indicators linking with ECHOES themes (Bosch P, Jongeneel S, Rovers V, Neumann H-M, Airaksinen M, Huovila A, 2017).

Indicator	Unit	Description
1. Fuel poverty	% of hh	The percentage of households unable to afford the most basic levels of energy
2. Access to public transport	% of people	Share of population with access to a public transport stop within 500 m
3. Access to vehicle sharing solutions for city travel	#/100.000	Nr of vehicles available for sharing per 100.000 inhabitants

[19] Climate change survey report:
https://www.europeansocialsurvey.org/docs/findings/ESS8_toplines_issue_9_climatechange.pdf
Full ESS8 questionnaire:
https://www.europeansocialsurvey.org/docs/round8/fieldwork/source/ESS8_source_questionnaires.pdf

[20] http://www.citykeys-project.eu/citykeys/home

4. Relative length of bike route network	% in km	% of bicycle paths and lanes in relation to the length of streets (excl. motorways)
5. Renewable energy generated	% of MWh	% of total energy derived from RE sources, as a share of the city's total energy consumption
6. Public transport use	#/cap/year	Annual trips of public transport per capita

Urrutia-Azcona et al. present the Smart Zero Carbon City (SZCC) concept, a flexible characterization method, which can be adapted to different kinds of cities to evaluate the main features of each city, thus suggesting suitable interventions. The key aspects of cities according to the SZCC concept are: Characteristics of the city; City plans and strategies; Energy; Mobility; Infrastructures and ICT services; and Citizen Engagement. This characterization identifies the cities' strengths and weaknesses toward decarbonization, in particular for small and medium-sized municipalities, common in the European context. SZCC Readiness Level assessment has been implemented in five Basque cities, which represent different urban typologies (Urrutia-Azcona et al., 2018).

Table 11: Mobility indicators in Smart Zero Carbon methods. (Urrutia-Azcona et al., 2018)

Indicators	Unit
1. Pedestrian	%
2. Bicycle	%
3. Public transportation	%
4. Private vehicles	%
5. Number of vehicles (per capita)	Per capita
6. Percentage of electric vehicles	%
7. Number of charging points for electric vehicles	Number
8. Number of public transportation trips	Per capita
9. Bicycle lanes and paths	Km/habitant
10. Renewable energy in public transport	%

INSIGHT_E[21] is a European, scientific and multidisciplinary think-tank for energy, which informs the European Commission and other energy stakeholders. It supports Energy policy at the European level by providing advice on policy options and assessing their potential impact. The indicators published by this unit are mostly techno-economic. The indicators with best fit to ECHOES project are share of energy in household expenditures for all households, for low-revenue households and private investment in renewable energy.

[21] INSIGHT_E energy transition indicators http://www.insightenergy.org/

Table 12. Societal energy transition indicators from INSIGHT_E[19].

Indicator	Unit
1. Energy Poverty: Share of total population unable to warm home	% of population (Eurostat)
2. Share of energy in households housing expenditures	% for expenditures in all households, Eurostat
3. Energy poverty: Share of energy in low-revenue households housing expenditures	% for expenditures in all households, Eurostat
4. Private investment in renewable energies	€m nationally, Eurobserver

5.2.3.2 National studies and indicators

Only few national indicator sets would incorporate substantial number of SSH aspects of energy transition in European countries, with the notable exception of Germany. The German Energiewende has gathered substantial attention in terms of studies of its various aspects. Some of these studies' aspects include sustainability, social equality and resilience of transition. While successful in increasing investment in renewable energy, the German energy transition has experienced repercussions in increasing energy poverty, lacking transmission capacity, and efficient use of produced electricity.

Hakala and Bjelic (2016) examined whether economies in transition can leapfrog into a sustainable energy system. The list of eight indicators includes two that are effectively linked and relevant to an energy consumer at the individual or household level: energy poverty and energy price. (Hakala & Bjelic, 2016). The measure proposed is the share of total household income spent on energy, which has been used in the UK. Energy poverty measured this way needs to be limited to low income groups to be meaningful. There is a number of other important indicators for energy poverty in a household, which are suggested by theEnergy Poverty Observatory and discussed above. Respective indicators are proposed also in SET-Plan Action 3.1 on energy consumers.

Table 13: Transition economy indicators linking with ECHOES themes. (Hakala & Bjelic, 2016)

Objective	Condition	Indicator	Unit
Sustainable energy transition	Energy poverty	1. Share of total household income spent on energy	toe/US$2005
Leapfrogging	Competitiveness	2. Energy price	c€/kWh

The Swiss energy transition index[22], commissioned by Umweltallianz Schweiz, an alliance of several international environmental NGOs, includes 20 indicators, mostly focused on the national and not on the individual level. Relevant to the ECHOES themes and foci, three indicators repeat on general level the requirement to track progress of energy efficiency:

[22] Swiss energy transition index. Umweltallianz Schweiz (Greenpeace, Pro Natura, VCS und WWF)

Table 14. Energy efficiency indicators of Swiss energy transition index[23].

Indicator
1. Electricity use in households kWh/capita
2. Energy efficiency of private vehicles kWh/person-km
3. Energy efficiency in buildings kWh/capita

Rösch et al. (2017, 2018) developed an indicator-based sustainability assessment for the energy transition. They formulated specific sustainability goals, such as 'securing human existence', and ''maintaining society's productive potential'. Goals served to give a common nominator for each group of indicators. However, only the most relevant indicators are shown here. Some of the indicators are interesting for ECHOES indicator development, in particular the ones on energy poverty, gender, and acceptance of renewable energy sources. However, the list in Table 15. includes several aspirational indicators that have been proposed without data available in Germany. In Europe-wide context, data collection would be even more challenging for many other them, and in some cases we propose indicators from ECHOES European Survey instead, for the reason that it includes similar themes to this study. (Rösch et al., 2018, 2017).

Table 15.: Indicators for assessing sustainability of energy transition in Germany (Rösch et al. 2017, 2018)

Indicator	Data availability
1. Gender pay gap on the highest salary group in the energy sector	Destatis, Eurostat
2. Share of tourists who perceive energy power technologies as being disruptive in the vacation area	No data
3. Acceptance of renewable energies in the neighbourhood	AEE (Germany)
4. Acceptance of grid extension for achieving 100% renewable energy supply	No data
5. Share of households producing renewable energy	No data
6. Share of households buying renewable energy	No data
7. Number of energy cooperatives engaged in renewable energy plants	Involvement of citizens in energy production
8. Share of population living in regions with objective to shift to 100% renewable energy	No data

Heindl et al (2014) studied the German energy transition from the perspective of social justice by Heindl et al (2014. The point of departure in their work is that the transition of the German energy system towards renewable energy triggers considerable costs, which are passed to households by a surcharge per kilowatt-hour. This effectively leads to higher cost burden for poorer households relative to wealthier ones. From the perspective of social justice, the authors argue that costs are distributed in an unfair manner. They propose measures of fuel poverty and deprivation with respect to energy could serve as adequate ex-post indicators of non-affordability in Germany. Fuel poverty and energy deprivation are proposed also elsewhere as indicators of social justice in energy transitions (Heindl, Schüßler, & Löschel, 2014).

Binder, Mühlemeier and Wyss analysed resilience of energy systems in transition with regard to both social and technical aspects. Their indicator system builds upon research on social-ecological systems with core attributes of

[23] http://www.umweltallianz.ch/fileadmin/user_upload/ewx-information-lang-2017.pdf

diversity and connectivity (Binder et al., 2017). Their work belongs to a certain approach pertaining to resilience in ecological systems and are not designed for examining attitudes or actions of individuals or social groups. Therefore, their indicator system does not touch upon the ECHOES approach to energy transition.

5.2.4 Mobility

Energy transition indicators systems seem to typically focus in the electricity sector, while mobility or transportation was less often present. The European Union Transportation Scoreboard is an indicator service by DG Mobility and Transport. Among a wide range of transportation topics, the EU Transportation Scoreboard[24] contains the following indicators on electric mobility and personal vehicles.

Table 16: Electric mobility indicators of European Transportation Scoreboard

Indicator	Specification
1. Market share of electric passenger cars	Percentage of newly registered plug-in electric vehicles (PEV) per year. Includes Battery Electric Vehicles (BEV) and Plug-in hybrid electric vehicles (PHEV).
2. Number of Electric vehicle charging points	Number of electric vehicle charging points per 100'000 urban inhabitants.
3. Electrified railway lines	Percentage of electrified railway lines (out of total lines in use)

Transportation indicators were also found in the smart city context in the Smart Zero Carbon City (SZCC) system by Urrutia-Azcona and in CITYkeys indicator sets (see above).

5.2.5 Buildings

The EU is characterised by a rather old building stock, since most of it was built before the 1970s. Since 50% of the standing stock was built up to 1970s, most of the currently standing buildings are highly inefficient compared to modern requirements. A very important quality indicator leading to alleviating energy poverty is the level of insulation. Adequate insulation for walls, windows, floors and roofs allows the building to be heated or cooled with an efficient use of energy. Improved energy requirements translate to reduced energy costs, improved indoor air quality, higher comfort and to a reduction of energy poverty. These requirements vary widely across Europe, largely due to the climate of each region. ((eds.) Csiba, K; Bajomi, A; Gosztonyi, A, 2016)

Consequently, an adequately functioning building envelope that provides for sufficient thermal comport in all seasons, forms the basis for all energy saving and further energy efficiency measures. Energy efficiency retrofits are therefore of primary importance both in relieving energy poverty and reducing GHG emissions in residential buildings. However, according to BPIE energy poverty handbook of 2016, there are no adequate metrics to track renovation activities on the EU level, nor on the national level. Therefore, there is high uncertainty on the number of buildings or dwellings or on the floor area that is renovated annually. There is furthermore very little information on the level of energy efficiency improvements after renovations. ((eds.) Csiba, K; Bajomi, A; Gosztonyi, A, 2016)

Increased number of cooling demand days translates into to health concerns in European populations, affecting in particular, children, aging citizens and vulnerable groups. This makes sufficient cooling an indicator of increasing importance. Data and data collection protocol already exists at Eurostat. Regarding electricity infrastructure, heatwaves also have been observed to create a demand peak, which tends to increase emissions from peak capacity power plants. This peak demand can be managed through building thermal efficiency, efficient air

[24] https://ec.europa.eu/transport/facts-fundings/scoreboard_en

conditioning installations and demand response, as well as renewable, especially solar power generation during days with significant solar radiation and highest cooling need. However, there is a lack of data on European buildings and their energy consumption, exemplified clearly by the absence of renovation statistics (Csiba, K, Bajomi, A, & Gosztonyi, A, 2016).

Peer-reviewed literature found in context of buildings and energy transition indicators was thin. Aste et al. (2014) presented a monitoring methodology for efficiency in domestic heating in Italy for local energy planning, taking advantage of the use of indicators to compare efficiency indicators across multiple criteria. Their systems accounts for different perspectives, including those of the society and the end-user (Aste et al., 2014). Vergerio et al.(2018) Vergerio et al. tackle the urgent requirement to develop local energy policies able to speed up the adoption of energy efficiency measures in public sector buildings. They developed a methodology as support to the decision making process in defining local energy policies for transition toward post-carbon cities. The KPIs include total annual energy consumption, total annual CO_{2eq} emissions and total annual costs (Vergerio et al., 2018). The Echoes European survey addressed energy efficiency refurbishment. We propose to include the question "have there been energy efficiency refurbishments in your building" as an building focus indicator.

5.2.6 Global perspective

International organizations have various indices for tracking the state of energy systems and energy use, but they tend to focus on top level changes and less on energy transition. The Energy Transition Index of the World Economic Forum[25] is a composite index that focuses on tracking specific indicators to measure the energy system performance and transition readiness of 114 countries. At its core are two equally weighted sub-indexes: the system performance score and the transition readiness score.

The system performance score is calculated with 17 indicators, which are defined using the three imperatives of the energy system (energy triangle): economic development and growth, environmental sustainability, and security and access. The transition readiness score is calculated using 23 indicators, which define six enabling dimensions: capital and investment, regulation and political commitment, institutions and governance, infrastructure and innovative business environment, human capital and consumer participation, and energy system structure. Three transition readiness score indicators, similar to ones found in other scores, are jobs in low-carbon industries, share of electricity from renewable generation and energy consumption per capita. Overall, indicators on global focus on energy tend not to include SSH aspects of clean energy transition.

5.3 Gap analysis

The objective of ECHOES indicators is to foster the implementation of the SET-Plan Actions and advance the Energy Transition and the decarbonizing of EU's future energy system.The starting point for gap analysis is to observe the inclusion of ECHOES technological foci, decision-making levels, and inclusion of gender perspective in order to arrive to an indicator proposal for ECHOES project. The material collected about existing indicators shows, similarly as earlier reported in this project, that attitudes and acceptance of changes on personal and social levels has been largely overlooked until now, while they play a significant role in the daily decision-making of citizens. On the other hand, it is clear that when large scale changes in energy infrastructure are discussed, also technological indicators are important. Gaps in knowledge and data also link e.g. in gender, energy poverty and building stocks' energy efficiency or lack of thereof.

5.3.1 Gender

Gender aspects are neglected in nearly all indicator systems that were found for energy transition. The importance of gender equality in the energy transition has been recognized in the EU. Gender gaps exists at many levels in

[25] https://www.weforum.org/reports/fostering-effective-energy-transition-2019 (details: Fig. p. 28-30).

the energy sector, in education, occupation, decision-making, energy use in the private sphere, and energy poverty. There is also some evidence that women and men exhibit different attitudes toward energy transition and be motivated to act by different aspects: women, more than men tended to be motivated by environmental issues.

Further, gender is significant in all aspects of the energy transition. Women are in minority in energy policy-making and decision-making bodies at all levels in the European Union and its Member States, as well as in energy professions. Neither is the gender difference of energy consumption and demand recognised in energy services. The lack of gender-disaggregated data is a barrier to ensuring gender equality in the transition to sustainable energy (Clancy & Feenstra, 2019).

5.3.2 Energy poverty and vulnerable households

One of the critical aspects of gender inclusion is to recognise and address the gendered nature of energy poverty. Uninsulated homes, inefficient appliances (like for heating, cooking, hot water) and high energy prices are main reasons for energy poverty in the European Union. Due to their lower average income, women are at a greater risk of energy poverty than men. Women and men tend to have differing patterns of using energy services and they are unequally affected by energy poverty due to the gendered indicators such as income differences, housing conditions, care for dependent family members and age (Clancy & Feenstra, 2019).

The Energy Poverty Observatory identifies indicators to measure and monitor energy poverty in the EU. A distinction is made between primary indicators (e.g. arrears on energy bills and hidden energy poverty) and secondary indicators (e.g. poverty risks, energy expenses, equipped with heating or cooling). Although the indicators are chosen carefully based on the existing body of knowledge and research experience, none of the indicators consider gender inequalities nor are providing data disaggregated by gender. However, differing gender impact of energy poverty is well known both in Europe and developing countries. Single parent families (80% being women), single households and particularly older single households were particularly at risk of energy poverty ((eds.) Csiba, K; Bajomi, A; Gosztonyi, A, 2016). Eurostat collects data on housing conditions, disaggregated by gender, dependents, one-adult households and age. These data could be used to fill in the gap in gender relevant energy transition information.

5.3.3 Acceptance and attitudes

The motivation to pursue the clean energy transition in Europe is to cut GHG emissions and reduce to impacts of climate change. Responses to risk perception and readiness to take personal action indicate “transition readiness” according e.g. to O’Brien et al. (2018). Except this study, similar readiness indicators were not found in larger indicator sets. Climate barometers, European Social Survey and ECHOES project have, however, produced data about risk perception and readiness for transition.

5.3.4 Climate change impacts

Needs regarding anticipated future climate have so far not been recognised in energy transition indicators in the reviewed literature. This observation applies to both increase in cooling demand and vulnerability of energy infrastructure to extreme weather events, such as storm winds and floods. Resilience of energy infrastructure, including large, community scale and household systems, has not been discussed so far in context to European energy transition indicators.

Increased heat is already affecting European citizens, with increased health risks. In the warming climate, increasing cooling need is projected around Europe. Scenarios about the future of energy demand, including the heating and cooling demand, have been developed by many models. Jakubcionis and Carlsson simulated cooling need variations for EU-20 and estimated the impact of potential residential cooling demand on electricity generation and supply systems of EU. Hartner et al.(2017)[26] simulated the development of demand and supply for heating and

[26] https://www.eeg.tuwien.ac.at/conference/iaee2017/files/abstract/699_Hartner_abstract_2017-04-05_16-52.pdf

cooling in the European building sector, projecting a 28 % decrease in final energy demand for heating and cooling with current policy, and 38 % in ambitious policy scenario by 2050 in EU28, with a parallel 3-fold increase in final energy demand for space cooling. Fleiter et al. (2017) [27] developed baseline scenarios of the heating and cooling demand in buildings and industry in the 14 MSs until 2050, and the strong growth of space cooling has been foreseen by Kranzl and Braungardt (2018).[28]

Therefore, we propose establishing a new energy poverty indicator to track vulnerable groups' access to sufficient cooling. The indicator should record the share of (sub-) population not able to keep their home adequately cool, based on a questions "Is the cooling system efficient enough to keep the dwelling cool?" and/or "Is the dwelling sufficiently insulated against the warm?"

[27] https://heatroadmap.eu/wp-content/uploads/2018/11/HRE4_D3.3andD3.4.pdf#page=55&zoom=100,0,113

[28] JRC workshop 2018 p.13 http://s3platform.jrc.ec.europa.eu/documents/20182/244842/JRC113411_regional_s3p-workshop_report_181105_final.pdf/21de43eb-1891-46ea-b936-9fde5178c183

6 Integration of indicators to ECHOES database

The ECHOES database, the preliminary basic structure of which is presented in the ECHOES Deliverable 2.2 (Correia, Similä, Piira, Kannari, Koljonen, 2018), aims at presenting the relevant ECHOES result data in easily approachable format.

Summarized from the Grant Agreement[29] of the ECHOES project, the open access database of the ECHOES project should contain all data produced in ECHOES. Further, the ECHOES database, according to the Grant Agreement, will display how different national and EU governance frameworks affect decision-making processes and individual as well as collective choices. Regarding the data content, the Grant Agreement states that WP2 will combine SSH relevant data from existing databases to an appropriate extent but will especially focus on creating and collecting new quantitative and qualitative data (D2.2).

6.1 Example of exploration of indicators in the ECHOES database user interface

D2.2 introduces an interactive map of Europe as a key element of the user interface of the ECHOES database. According to guidelines of the database developed by the D2.2 release date (November 2018), an interactive map was envisaged to offer a selection of possibilities to explore quantitative results from ECHOES studies along with other selected variables. Relevantly for the indicator work documented in this report, the potential variables were suggested to contain a summary of available data for KPIs defined in the WP2, including selected KPIs from the SET Plan Actions (especially Action 3.1 related to energy consumers) and some key results from the ECHOES survey.

The development of the ECHOES database after the release of D2.2 (November 2018) until this report (August 2019) has been largely driven by ECHOES result. Especially, the development has been concentrated around finding the proper solutions for the main survey, and a lot of further functionalities and visual presentations have been implemented to the database based on feedback from the ECHOES partners.

Due to the fact that ECHOES indicators have not been defined or finally selected until this document and the database development work has focused on ECHOES data, the exact implementation of the indicators in the database has been scheduled to the last months of the ECHOES project. However, further integration of the indicator development work in parallel to the database development has been identified as a justified solution for two reasons. *First*, the ECHOES results, such as the multi-national survey, provide data for relevant indicators as such or indirectly, e.g. through application of relevant aggregation method. *Second*, the development of data tools, functionalities and user interface provide a structure for both ECHOES result data and SSH indicators. Hence, taking into account the database requirements in selection of the indicators and vice versa, is justifiable.

Fig. 3. presents a conceptual example of the exploration of ECHOES indicators based on preliminary implementation of the ECHOES database (phases “1”, “2” and “3” attached to the figure describe the sequence of choices a user could make). Elementarily, the user interface guides the user to explore the SSH indicators relevant for ECHOES topics.

[29] ECHOES 2016. Grant Agreement number: 727470 — ECHOES — H2020-LCE-2016-2017/H2020-LCE-2016-RES-CCS-RIA.

1. The user selects category "SSH indicators/ECHOES indicators" to explore the indicators implemented in the database

2. Based on a list the user interface produces, e.g. classified by foci areas, the user selects the areas for the "indicators" he/she is interested

3. The user selects the indicators he/she is interested in.

As a result, the user interface produces the of the database draws visualisation of the indicator, e.g. heat map

Figure 3. An example illustrating the exploration of ECHOES indicators through the user interface of the ECHOES database.

6.2 Database considerations for indicator characteristics

Whereas the shortlist for ECHOES indicators presented in chapter 5 and preliminary proposition of SET Plan Action 3.1 (Table 2) aim to fulfil the requirements for ECHOES indicators from a *substance* point of view, there are requirements of technical nature that have to be considered to accept them as eligible indicators.

Ideally, as using the database aims at easy exploration of SSH indicators related to individual and collective energy choices with a view to support the implementation of the Energy union and SET-plan, the data should be automatically — or at least with a reasonable workload — available for constant updates. The list below summarizes the identified preferred characteristics for the indicator data:

- All the EU countries (or even more) are covered in the data
- Data is annually updated (or at comparable resolution), preferably "automatically" by statistical authorities
- Data is available free of charge on open access basis, allowing reproducing
- Data can be classified as reliable, e.g. based on scientific or official statistical procedures
- Data is preferably produced by a neutral party (e.g. scientific organization or statistical official)

The ECHOES main survey explores many interesting SSH variables from ECHOES indicator requirement point of view and presents a natural starting point for the indicator development. Considering the requirements below, on one hand, the ECHOES main survey presents one-time effort and inconvenient for constant follow-up, repeatedly implemented surveys (e.g. Eurobarometer, European Social survey, Eurostat data) represent preferred options for indicator data from this viewpoint. On the other hand, the ECHOES results could efficiently fill many substance-based gaps in capturing the SSH dimension, and significant added value could be produced by the project if the questions identified most relevant could become a fixed part of one of the large repeated European surveys. Conclusively, in our final proposal for the indicators, the ECHOES main survey derived indicators are included, and in these cases, the proposal is complemented with a special recommendation is to collect the data regularly.

Regarding the user interface, the following guidelines are identified for the indicator implementation in the user interface:

- As there will be an abundance of ECHOES result data available in the ECHOES database, a guideline in indicator set implementation from the database point of view is keeping the number of indicators relatively small to allow the user to study them within reasonable time. As ECHOES has three technological foci and three levels of energy collectives in focus, a working number of 10-20 has been used in the proposal for the set of indicators.
- The navigation from the user interface to explore the developed indicators will be clearly separated from the vast number of other ECHOES result data in the user interface for convenient exploration. Hence, the user is properly guided to explore the indicators, e.g. in separate menu.
- Implementation of user-friendly data tools to explore the KPIs, such as studying correlations between the KPIs and ECHOES survey data, present targeted functionalities.

Whereas the exact modes of considering the requirements need to be studied in the software development process, the requirements identified in this section will be taken into account when the will be implemented in the user interface and back-end solution of the database.The requirements will also be used in assessing and formulation of the ECHOES indicator proposal.

The literature review used for compilation of the shortlist (chapters 4, 5) suggested that there are not too many ready indicators meeting all the requirements, especially in the publicly available sources that are constantly updated. Despite the first priority is to find such indicators, a secondary option is to define such indicators whose development can be tracked in further studies by repeating the surveys suggested. To fill some gaps, utilization of ECHOES data, despite its one-time nature, is an eligible option to showcase the added value of the project in recommendations for future data collections. As such, there will be a substantial amount of ECHOES data available for exploration in the ECHOES database, but the task is more to find the most relevant indicators filling the gaps identified from the data that is more deeply analysed in several ECHOES WPs.

In line of the characteristics discussed above, the indicator proposal list presented in next chapter consists of suggestions of various quality from several sources - e.g Eurostat, EPOV, ECHOES data, several external studies. Thus, the suggestions are classified from those only partially meeting the requirements to ones most eligible for database implementation. However, each suggestion is seen to add particular value in meeting the high-level targets of this report.

7 Conclusions

7.1 Proposed set of ECHOES indicators

The proposed set of ECHOES indicators consists of 27 indicators that have been selected keeping the ECHOES foci and respective barriers and carriers of energy transition in mind. Since several perspectives have been included, these indicators have potential to be employed for various purposes. However, the primary objective has been to support policy-making in clean energy transition and, especially, the SET-Plan implementation. In the selection process of the KPIs the focus has also been on ease of use. All selected indicators are based on one single measure, so that the information they carry would be easy to process. Therefore, the selected KPIs are useable for the decision-making by companies, communities, and other stakeholders. In the proposal, indicators with good temporal and geographical data availability from public sources have been preferred to guarantee them being calculable. It is also noteworthy that the ECHOES results have been utilised in three indicators suggested.

Some of the proposed ECHOES indicators are more directed to engagement of the consumers in energy transition. The indicators can be used, for example, in monitoring the progress in development of the enabling framework for smart energy systems, buildings and electric mobility. For policy makers at the EU and national levels these indicators are of instrumental type and provide information on the impacts of policies and possible needs for policy changes. In addition, more conceptual use of the same indicators may be possible e.g. in combination with other types of data provided in the ECHOES database or elsewhere.

In addition to the ECHOES foci, the proposed set of indicators puts some emphasis on energy poverty by introducing five indicators to track it. The indicators for energy poverty are justified because of the need to address the issue, which has also led to several provisions in the regulatory framework for the Energy Union (see Chapter 3). EU Member States are e.g. required to define vulnerable customers and establish and publish a set of criteria for assessing the number of households in energy poverty. Commission's analysis on the draft NECPs suggest that MS "should address energy poverty in a more structured way, starting with an assessment of the number of households in energy poverty as well as their main characteristics (composition, income levels, etc.) and their potential geographic concentration. Where the number is significant or where specific groups or regions are exposed to hardship, an indicative objective to reduce energy poverty coupled with relevant target groups, policies and measures as well as potential funding sources should be identified."

The suggestion by the Commission reflects barriers for better integration of social science in policy-making that was identified in the ECHOES project – namely general character and vagueness in lower level policies and measures and difficulties in taking into account the diversity of target groups. The suggested ECHOES indicators related to energy poverty aim at helping Commission and Member States in framing and monitoring energy poverty and measures for its reduction.

We also suggest other cross-cutting indicators with more conceptual nature, e.g. related to attitudes and gender that may provide additional insights into decision-making and progress in the clean energy transition. Gender is addressed in seven of the proposed indicators. Some of these address active engagement in energy transition. Some of them also address energy poverty, due to the gendered nature of energy poverty, and related vulnerable groups. As a new energy poverty indicator compared with those the Commission has already listed, and in bearing with the expectation that in the future Europe experiences increased cooling need, we propose an indicator to track access to sufficient cooling. Finally, attitude is included in three of the indicators, due to evidence that the perception of the seriousness of climate change encourages readiness to energy transition and low carbon actions. The indicator proposal is shown in Table 17. Importantly, all the foci areas identified in the indicator proposal indicate good data availability (green colour) for immediate calculation or follow-up of indicators.

Table 17: Proposal for ECHOES Energy Transition KPIs. Indicators calculable from existing data collected at least one time are highlighted with light green, whereas better data availability with constant updates available is highlighted with darker green. Yellow indicates the need for further definitions, method development and/or specific data collection effort. Primary ECHOES foci area relevance is seen in the left-hand-sided column.

	Areas	Indicator	Source of indicator	Definition
Smart energy and self-production	Involvement of citizens in energy production: Self-production of energy	Share of households that have installed residential PV	Adapted from SET Plan Action 3.1. Indicator proposal Requires data collection	Share of households that have installed residential PV
	Collective actions Self-production of energy	Individual intention to commit in collective action together with other consumers or providers of energy	Adapted from SET Plan Action 3.1. Indicator proposal ECHOES European survey Proposed for repeated data collection	Measure to track would be the combined percentage of "Moderately agree" and "Highly agree" answers to question "I intend to commit in collective action together with other consumers or providers of energy (e.g. joining consumer initiatives, joining photovoltaic producer groups)."
	Consumer behaviour Smart energy	% of consumers with access to a smart electricity meter with a feedback function	SET Plan Action 3.1. Indicator proposal Smart meters: ACER/JRC Requires data collection	Requires definition of feedback function (type of access to consumption readings that qualifies as one)
	Participation in demand response Smart energy	Degree of market opening to demand response	SET Plan Action 3.1. Indicator proposal Smart Energy Demand Coalition (SEDC) Requires data collection	SEDC classifies European countries in four groups based on how well their regulatory framework enables Demand Response in electricity markets. In 2017, 18 European countries were examined.
	Market participation	% of customers that have switched suppliers to increased share of RES energy per year	Eurobarometer Proposed for repeated data collection	Based on response "You have switched to an energy supplier which offers a greater share of energy from renewable sources than your previous one " SET Plan Action 3.1. proposes to track switching to 100% RES
Buildings	Smart readiness in buildings: Smart energy, Buildings	Adoption of energy performance of buildings directives' SRI	New proposal Requires data collection and following directive's implementation in MSs	Preparation of the delegated act is ongoing

	Building energy efficiency refurbishments	Have energy efficiency renovations been made to your dwelling	ECHOES European Survey Proposed for repeated data collection	Based on question 'Have energy efficiency renovations been made to your dwelling'
	Development of final household heat demand in MS	Residential heat consumption	Eurostat Supply, transformation and consumption of heat - annual data [nrg_cb_h] residential	TJ/a in residential sector
	Development of final household electricity demand in MS	Residential electricity consumption	Eurostat Supply, transformation and consumption of electricity - annual data [nrg_cb_e], residential	MWh/a in residential sector
Mobility	Low carbon mobility	Public transport use	SZCC; CITYkeys; Eurostat Modal split of passenger transport - [tran_hv_psmod]	Annual trips of public transport per capita Public transport in the national, passenger transport modal split Share of public transport in the Functional Urban Areas' and Cities's journeys to work
	Electric mobility	Number of charging points for electric vehicles	EU Transport Scoreboard, based on Eurostat and European Alternative Fuels Observatory	Number per capita
	Low carbon mobility	Share of journeys to work by non-motorized means of transport	Eurostat Transport - cities and greater cities - [urb_ctran] Proposed for repeated data collection	Share of journeys to work by non-motorized mobility (walking, cycling) in the Functional Urban Areas and Cities
	Low carbon mobility	Access to vehicle sharing solutions for city travel	CITYkeys; Requires data collection	Nr of vehicles available for sharing per 100.000 inhabitants, differentiation between e-cars (incl. cargo) and light EVs (e-scooters and e-bikes)
Energy poverty	Development of energy poverty rates in MS	Arrears on utility bills	Energy poverty observatory / Eurostat	Share of (sub-) population having arrears on utility bills.
	Energy poverty	Low absolute energy expenditure (M/2)	Energy poverty observatory /Eurostat	Share of households whose absolute energy expenditure is below half the national median.
	Energy poverty	High share of energy expenditure in income (2M)	Energy poverty observatory /Eurostat	The 2M indicator presents the proportion of households whose share of energy expenditure in income is more than twice the national median share.

	Energy poverty Gender Vulnerable groups	Inability to keep home adequately warm	Energy poverty observatory /Eurostat EU-SILC) methodology - 2012 housing conditions: [ilc-hcm][HC060] Proposed for repeated data collection	Share of (sub-) population not able to keep their home adequately warm, based on concern "Is the heating system efficient enough to keep the dwelling warm?" and "Is the dwelling sufficiently insulated against the cold?"
	Energy poverty Gender Vulnerable groups Changing climate (adaptation)	Dwelling comfortably cool to keep home sufficiently cool	Energy poverty observatory /Eurostat EU-SILC) methodology - 2012 housing conditions: [ilc-hcm] [HC070] Proposed for repeated data collection	Share of (sub-) population not able to keep their home sufficiently cool during summer time by income quintile and degree of urbanisation [ilc_hcmp03] , based on concern "Is the cooling system efficient enough to keep the dwelling cool?" and/or "Is the dwelling sufficiently insulated against the warm?"
	Energy poverty Gender Vulnerable groups Buildings	Presence of leak, damp, rot in dwelling - indicating low energy efficiency in dwelling	Energy poverty observatory /Eurostat EU-SILC) methodology - 2012 housing conditions [sdg_01_60] Proposed for repeated data collection Gender-disaggregated and household data available!	Share of population with leak, damp or rot in their dwelling, based on question "Do you have any of the following problems with your dwelling / accommodation? - a leaking roof - damp walls / floors / foundation - rot in window frames or floor
Cross-cutting themes	Citizens' involvement; Gender	Gender of chairperson and board members of energy collectives	New proposal Requires data collection	Requires definition
	Gender	Gender pay gap on the highest salary group in the energy sector	Rösch et al. (2018) Eurostat Gender pay gap [earn_grgpg]	€/a Requires definition of highest income group (highest quintile common)
	Attitude Gender	Perception of seriousness of climate change in present	Eurobarometer Proposed for repeated data collection	Based on question "How serious a problem do you think climate change is at this moment?"
	Attitude Gender	Perception of seriousness of climate change in future	New proposal Requires data collection	How serious a problem do you think climate change will be in 10 years?

	Attitude Gender	Perception of responsibility of climate change mitigation	Eurobarometer Proposed for repeated data collection	Based on question "In your opinion, who within the EU is responsible for tackling climate change?" Distribution of multiple answers cover all ECHOES levels!
	Attitude	Acceptance of renewable energies in the neighbourhood	Rösch et al. (2018) Collected in Germany by AEE Requires data collection	% of the MS level population or some other definition Potentially split into wind, hydro, solar, geothermal, overhead transmission lines
	Attitude Identity	Perception of acting together to achieve energy transition	ECHOES European Survey Proposed for repeated data collection	'We as people in (country/municipality/EU) can act together to achieve the energy transition.'
	Governance	Local climate action plans and commitments	New proposal Requires data collection	% of municipalities with climate action plans or other documented climate action commitments

7.2 Discussion

7.2.1 Comparison between the ECHOES WP2 workshop suggestions regarding indicators and the results of this report

At an early stage of the ECHOES project, an expert WP2 workshop was organized in Brussels in October 2017 (Similä & Koljonen, 2017). The results of the workshop show relevant reference material for indicator development concentrated in this report. In this regard, especially, the following questions, around which the workshop was structured, are of interest:

- How to engage and activate decision-makers in energy transition? Consider the **decisive factors** that drive individual and collective energy choices in Europe on different levels.
- What kind of **SSH data and indicators** could describe the determinants of energy choices in different perspectives and foci areas?

For discussion, it is interesting to review the workshop results (where also contributors external to the project were present), and the indicator sets and frameworks considered in this document, in addition to the identified indicator opportunities produced by the ECHOES project. As such, in the workshop results, there are quite few indicators presented at a level of detail necessary to be eligible as ECHOES indicator (see Chapter 5). In addition, more of the suggestions from the workshop are interpreted as decisive factors. However, as the target of this report is formulate indicators related to individual and collective energy choices and behaviour, also the review of suggested decisive factors in energy choices is justified.

The most concrete suggestions for ECHOES indicators to track the development in different technological foci and levels of collectives (micro-meso-macro) presented in the workshop were summarized to show a large variety (Similä & Koljonen 2017). First, in the suggested indicators there are measurable ones, often to a high degree available in statistics (NOx content in cities, proportion of e-vehicles in new registrations, share of smart meters, etc.). Second, the suggestions included indicators that would call for specific study (e.g. satisfaction with mobility, heterogeneity of adopters) to be assessed. As a third group, there are ideas for high-level topics. On the topics, concrete suggestion for an indicator are lacking, and the indicators should be further developed by both methodology and/or input data. Examples for this group include high-level topics such as “Key Performance Indicators for heating” or “personal investment capacity”, or “health issues in zero energy buildings” (Similä & Koljonen 2017).

As can be seen from the proposal of this report (Table 17) and shortlist combined from various sources (Chapter 5), they include many of the themes already earlier suggested in the ECHOES workshop. This issue is discussed by the identified suggestion group in the following:

- The “physically measurable” indicators in the first group include e.g. several heating indicators, registration of e-vehicles, and share of smart meters that are also included in the proposal and accessible from international databases. Noteworthy, these indicators in the proposal passed the subsequent tests on data availability, reliability, and update resolution, and can therefore be presented as justified suggestions to a high degree.

- Regarding the second group, with “satisfaction of mobility” and “heterogeneity of adopters” as example, there are many identified surveys offering a range of data in these areas: the satisfaction theme is included e.g. in the European Union Transportation Scoreboard assessed as high-quality indicator source. The “heterogeneity of adopters” theme is also analysable from the data of the ECHOES main survey, however, with noted uncertainty of availability of constant updates.

- Regarding high-level themes suggested for indicators, health issues related to conditions of dwellings are present in one EPOV indicator ("presence of leak, damp, rot"), however, without the direct "zero energy buildings" connection. Heating and personal investment capacity are also included in both identified public sources, ECHOES results and in the ECHOES indicator proposal.

To summarize the indicator suggestions of the workshop in relation to the ECHOES indicator proposal, strikingly many of the concrete suggestions were classified as measurable techno-economic variables, whereas the indicator proposal derived in this report is more based on survey-based data. This potentially demonstrates the emphasis of ECHOES on SSH issues over typical measurable energy/economic variables.

Not only indicators – that tackle the issue directly – but also decisive factors on energy choices in different decision-making levels and technological foci were suggested in the expert workshop. Noteworthy, several ECHOES WPs have studied the issues much deeper, and the understanding on decisive factors has improved as the project has proceeded. Hence, the workshop suggestions are not used as a strict guideline but only for discussion.

Table 18: Suggested decisive factors in the ECHOES assessed in line with the ECHOES indicator proposal

Suggested decisive factors in the ECHOES workshop (10/2017), Similä & Koljonen (2017)	**Comment of a consideration of a factor in ECHOES indicator proposal: identified possibilities and barriers**
• **Economic factors including subsidies and costs**	• Typical macro data collected in national economy and energy statistics. • Economic data can be classified as SSH data (as economics belong to a group of social sciences), but perhaps the macro-level prices etc. as such are not the area where the ECHOES shows its greatest contribution. Therefore, the suggested indicators do not concentrate on this area. • Compiled ECHOES main survey includes some personal views on e.g. subsidies, allowing socio-demographic analysis (by gender, income level, etc.)
• **Regional differences**	• The ECHOES database tools are built for national comparisons. • The ECHOES main survey allows analysis of regional differences, e.g. ZIP code allows filtered by regions, as well as municipal/national/EU wide views presented in the questions.
• **Socio-demographic factors**	• Energy poverty raised as a key indicator in the proposal, data availability good • Gender issues identified as a key area in the indicator proposal and also highlighted in the workshop (and in the preceding report D2.1)

	• The ECHOES main survey data allows analysis by several socio-demographic variables, e.g. by gender, education and income levels.
• **Ease of a solution**	• This factor, reflected in e.g. the time demanded for implementing a choice, was listed as a factor especially present in buildings sector • In the studied material (shortlist), perhaps the least obvious indicator
• **Environmental and ecologic consciousness and lifestyles**	• Repeated surveys (Eurobarometer, European Social survey) include several technology-specific questions on lifestyles, as well as perceptions and seriousness of climate change as indicators potential for proposal • WP5 of the ECHOES, *Collective behavior driven by "energy cultures": European energy lifestyles,* especially touches these issues • The result data is to be available in the ECHOES database, allowing analysis of data
• **Awareness and level of knowledge**	• The share of "I don't know" answers in different surveys could be discussed as an indicator. However, people choose it for many reasons and it cannot be considered reliable.

Overall, based on Table 18 above, the suggested decisive factors of energy choices in the external ECHOES workshop can be said to be strongly covered by the identified external data sources or the ECHOES results, whereas the category "Easiness of a solution" shows the least obvious correspondence in the studied indicator set. Hence, the analysis on the effect of different socio-demographic groups, especially gender, that is repeatedly signalled in workshop and literature-based analysis, is seen as clearly value-adding functionality of the ECHOES indicator proposal. Furthermore, a possibility of filtering the ECHOES main survey results by gender in the database advances the possibility of inclusion of gender in different analyses.

7.2.2 Proposals for future work on SSH oriented indicators to support policy-making for clean energy transition

There is a clear need to continue the work on SSH oriented indicators for a clean energy transition as the implementation of the Energy Union and SET-Plan advances. The proposed ECHOES indicators aim at supporting the EU in the formulation of a monitoring system relevant for the technological foci of the ECHOES project. In addition to the ex-post analysis, KPIs could also support ex-ante analysis, which support formulating new policies. In the ECHOES Deliverable D2.1 (Similä & Koljonen 2017), it was discussed that the current impact assessments of energy and climate policies barely consider the SSH dimension, especially in the quantitative modelling of future energy systems. The biggest barriers lie both in lacking data and in lacking methods. Using KPIs could provide the first and more easy steps, but requires more research in model and data development.

Future work could also include evaluation of the fulfilment of the criteria, which was the basis of the selection of the indicators. Revisions to proposed set of criteria could be made based on the evaluation as well as possible changes to data availability in the future.

Fruitful area for future research on SSH-indicators for clean energy transition could also be the various purposes of indicators in and between various system levels (micro, meso and macro). Better integration of social sciences could benefit e.g. from conceptual use of indicators (the process of indicator construction or indicators themselves). This could help in shaping the conceptual frameworks and mental models of actors thus leading to improved understanding on the complexity of human behavior and the possibilities to incorporate this understanding into policy making.

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