REflex

Analysis of the
European energy system

Information Brief

Broadening the awareness and communicating long term strategies towards sustainability - some insights from the REFLEX project

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CO_2	Carbon dioxide	LCC	Life cycle costing
GHG	Greenhouse gas	LCSA	Life cycle sustainability assessment
ICoS	Integrative Concept of Sustainability	e-LCA	Environmental life cycle assessment
NIMBY	Not in my backyard	SA	Sustainability assessment
SDGs	Sustainable Development Goals	SDG1	No poverty
SDG2	Zero Hunger	SDG3	Good health and well-being
SDG4	Lifelong learning opportunities	SDG5	Gender equality
SDG6	Clean water and sanitation	SDG7	Affordable and clean energy
SDG8	Decent work and economic growth	SDG9	Industry, innovation and infrastructure
SDG10	Reduced inequalities	SDG11	Sustainable cities and communities
SDG12	Responsible consumption and production	SDG13	Climate action
SDG14	Life below water	SDG15	Life on land
SDG16	Peace, justice and strong institutions	SDG17	Partnerships for the goals
s-LCA	Social life cycle assessment		

1 Introduction

Sustainability remains an ongoing challenge regarding the understanding of its primordial approach. One key reason indicates that the overall conditions to reach a so-called “sustainable system” are frequently questionable, inconsistent or even neglected. These conditions are generally related to the environment and the relationship of human being impact in a long and undetermined term. Impacts on environment and society (e.g. disturbance of ecosystem services or stressors of society, job, and affordability) create dilemmas that are seldom taken into account along the economic, engineering or even political processes. Therefore, those dilemmas are part of the transition towards the principles of sustainability.

The scientific community brings up all the envisioned dilemmas into a methodological approach to assist mainly decision-makers and policy-makers, the sustainability assessment. Even though there is divergence among the conceptual methodological approach as explicitly defined by Sala et al. (2015):

- Life cycle sustainability assessment (LCSA): an assessment structured according to different variants of the standardized method life cycle assessment (LCA) - environment (e-LCA), social (s-LCA) and economic (LCC). Since it is established on a single conceptual scope, a set of indicators derived from the variants of LCA integrates the pillars of sustainability in a weighting method.
- Sustainability assessment (SA): an assessment focused on normative plans, as an optimal resolution among sustainability science and strategic actions. SA does not follow any specific method. SA is driven by a guiding vision supplemented by indicators, surveys or models/tools to determine the distance-to-target, for example.

The REFLEX project has taken the challenge to offer guidance, principles and measurement towards sustainability as a layout for the future European energy systems. Under this approach, LCSA does not fully fulfill the desired goal. In compliance with Sala et al. (2015), the triple-bottom-line approach does not give specific paths to determine policy-based demarcation lines. The methodology also does not provide any flexibility to include indicators out of the scope of each variant[1]. The Integrative Concept of Sustainability (ICoS) of the Helmholtz Association (Kopfmüller J. et al. 2001) represents, in the context of sustainability assessment, a direction through vision and goals to discuss the overall conditions which might occur along the transition to reach the proposed European energy systems in the REFLEX project.

This information brief brings first a discussion on how sustainability is being dealt with the transition process for low-carbon European energy systems. Secondly, the structure of the ICoS is adapted to the context of the REFLEX project. The primary objective is to add a vision that has not been taken for low-carbon European energy systems yet. Thus, there is the chance to build up a discussion whether new developments and technological breakthroughs for the future European energy system shall pursue a contribution to climate mitigation and simultaneously “meet the needs of the present generation without compromise the future

[1] Most of the variants of LCA have pre-determined indicators as outputs.

generation," the roots of sustainability (WCED 1987). It additionally proposes a qualitative nexus approach to interlink sustainability into the global action plan – Sustainable Development Goals (UNFCCC, 2015). This document closes with the commitment to bring the first insights on how to merge energy system modelling results of the REFLEX consortium into the sustainability context. It should be noted this information brief is part of an ongoing work-package of the REFLEX project.

2 The European energy systems and commitments to sustainability

After years of discussion about sustainability, Paris Agreement and the launched 17 Sustainable Development Goals (SDGs) has the approach to determine crucial areas to be the focus of many nations (UNFCCC, 2015). In recent years, European Commission has thoroughly dealt with the systemic challenge posed by both productivity and consumption of non-renewable primary and final energy with respect to the global climate change. As part of the next step for a sustainable European future (European Commission, 2016), energy systems became a priority for the strategic plan. The European Commission assumes within the strategic plan (European Commission, 2016):

- Europe is highly dependent on importation. Despite that, the challenge regarding access to energy systems was not a Union mainstream issue anymore. A shift to low-carbon energy systems brings controversies when social and environmental costs for fragmented energy markets. Under these circumstances, the Union has the objective to ensure secure and affordable energy systems for business and households, the purposes of the SDG7 - affordable and clean energy for all.
- A shift to low-carbon energy systems required the establishment of the ambitious domestic target to reduce at least 40% of the sectoral greenhouse gas (GHG) emissions for 2030 (European Commission, 2016). This commitment already puts the Union in front of the sustainable goal to climate change actions (SDG13).

Nevertheless, the further influence of the future energy systems beyond affordability and climate change could no longer be down-played or even ignored. The largest part of the 17 SDGs can be said to address an issue where the energy systems might be directly or indirectly connected, such as SDG3 on Health, SDG4 on Education, SDG8 on decent work and economic growth and so forth. The grand-challenge forward is how to bring the related issues of socio-economic sectors, such as the energy system for example, without overlook or underestimate the direct and indirect impacts on another sustainable development goal.

3 Integrative Concept of Sustainability (ICoS) - the sustainability framework for the REFLEX project

REFLEX project addresses a broad system covering all types of energy used in society, in terms of power and heat generation as well as mobility, for a vast geographical area being EU28+Norway and Switzerland. Next to the environmental, social and economic impacts that might arise simultaneously regarding the future energy system, there are principles to be taken for an integrative sustainability assessment. ICoS underlines three main guiding visions (Kopfmüller J. et al. 2001; Grunwald, A. 2012):

- justice: a pre-requisite for well-being in society with rights, obligations and opportunities;
- global orientation: a perspective regarding the limits of growth from local to global and vice-versa.
- anthropocentric orientation: duties of the human-being in service of natural cycles.

The constitutive elements of ICoS disclose the most significant considerations that could potentially jeopardize sustainable development at all. In the same streamline and according to the REFLEX scenarios description (Poganietz W-R. et al. 2017), some implications are foreseen that could put at risk the goals of the European Climate Policies (COM, 2011/0112):

- The need for a vast technological development;
- A shift of dependencies from fossil-based resources to metal and bio-based resources not available locally to (1) meet first the target and (2) keep the system functioning for an undetermined time slot;
- Interdependences regarding the socio-environment impacts occurring on the global supply market;
- A local society, which needs to absorb the changes, re-adapt and act on behalf of it.

Under the constitutive elements, ICoS discloses three fundamental goals and preconditions to follow the guiding visions: (1) securing human existence; (2) maintaining society's productive potential and (3) preserving society's options for development and action. For each goal, a set of rules pre-defined in the conceptual framework (Kopfmüller J. et al. 2001) guarantees a guideline to merge the scope of the REFLEX project. The rules provide an orientation for an action plan to be materialized by suitable indicators. Politically, it is crucial to structure the entire framework with the SDGs to assist further discussions relevant for the strategic plan - sustainable European future (European Commission, 2016).

3.1 Securing human existence

Climate-friendly energy systems do not secure a system free of human health impacts or promotion of well-being. Humans are increasingly exposed to climatic effects (e.g., abrupt weather changes) and susceptible to fine particles pollution often not visible (e.g., particulate matter 2.5[2]). Such effects are influencing the life conditions as well as increasing the vulnerability for health problems.

Another fact related to humans is linked to the affordability of the needs and health impacts. Life conditions and standards have changed drastically in the last decade's affecting society in different ways, and not always positively due to economic development. For example, qualified job opportunities and wage growth are usually indicators to express economic development linked to the quality of life. Therefore, individuals who are less educated and nearing retirement age need to deal with financial stressors living within the same society. Nevertheless, it is evident that local society has to experience a socio-economic transition regarding the affordability of all types of energy such as power, heat and mobility when a new system is aimed for.

Under these circumstances, the goal securing human existence brings five rules focused to:

- protect the human-health of present and future generation from different type of stressors;
- protect local society from conducting their own life autonomously.

Table 1 shows the results of merging the context of ICoS with the scope of the REFLEX project and the SDGs.

Table 1. Rules for securing human existence

Rule	Explanation	SDGs
Protection of human health	Early evidence and transparency of human health impacts across the sectoral energy system need to be assured. Present and future generation need to find out new procedures (e.g., medical and infrastructural) for protecting themselves.	SDG3 - Good health and well-being
Ensuring the needs	With high investment costs for technology development (e.g., new wind or solar parks, low carbon public transport), energy services such as power, heat and mobility need to be adaptable to average expenditure of local society.	SDG7 - Affordable energy
Securing an autonomous existence	Technological development and service implementation for a centralized or decentralized system need to build resilient infrastructure linked to labor market conditions for alternative (also innovative) job creation covering different ages and educational profiles.	SDG9 - Industry innovation and infrastructure SDG10 - Reduced inequalities
Fair sharing in the use of services	Access to climate friendly energy system is limited to power and heat generation linked to weather conditions (e.g., sunlight, wind speed) and urban sprawl (e.g., the road expansion). Utilization of energy services must be given by the principle of fairness and preferences for joint activities (e.g., avoid excessive power use and car sharing respectively).	SDG11 - Sustainable cities and communities SDG12 - Responsible consumption and production

[2] Particulate matter represents a human health impact enhancing diseases on the respiratory system. This impact occurs due to many human activities, which release organic and inorganic substances with a small diameter of around 2.5 μm on the air.

Balancing extreme inequalities in income and wealth	Performing a centralized or decentralized system requires not only technology research & developers, but also technicians and an entire staff community. Balancing in income and wealth promotes cooperation, collaboration and stimulate labor satisfaction.	SDG8 - Decent work and economic growth SDG10 - Reduced inequalities SDG17 - Partnership for the goals

3.2 Maintaining society's productive potential

While the goal to secure human existence is focused on individual level, the goal "maintaining society's productive potential" brings the consensus that we are living in a system with different society's characteristics under local, regional and global constraints.

Centralized or decentralized energy systems will comprise the deployment of highly sophisticated renewable technologies to fulfill the greenhouse gas emission reduction goals. Some of the examples are related to the deployment of wind and solar energy. These are promising energy carriers and their respective technologies are still technological improvements. Wind turbines with more power capacity are the optimal ones for offshore wind farms for instance, but the search for lightweight components and power equipment to minimize losses are troublesome for engineers. Despite the fact, Europe has shown successes in research & innovation there is a risk for upcoming impacts, which are ignored (or not relevant) at low market shares but becoming relevant at large penetrations. Superconductors, permanent magnet and solar thin-film cells are just some examples of emerging technologies demanding irreplaceable resources presented on the list of raw materials critical to Europe's economy (European Commission, 2018). In regards to the resource availability, the production line of those technologies is also a concern in the global market nowadays. We recognize an increasing pressure on global supply market of critical resources and the limitations mostly related to geological availability and the socio-environmental impacts.

A climate-friendly energy system extends not only to new and innovative technologies but also to the possibility to bring alternatives for existing infrastructure through substitution of their consumables, such us combustion systems for electricity and heat as well as fuel for mobility. Bioenergy from plant-derived materials will prevail as the most common alternative due to short natural cycle and origin. Therefore, as part of the bio-economy, plant-derived materials (biomass) is limited due to multiple demands within the energy sectors and beyond them. Especially the transport sector, the transformation for a bio-based system still depends on specific primary biomasses due to their chemical characteristics. Biodiesel and biokerosene are samples of fuels produced by esterification process of high oil compounding plants that cultivation reliant on land and weather conditions (e.g., tropical climate) that are not usually met in European countries.

The establishment of such an energy system (centralized or decentralized) requires a set of challenges as the examples mentioned above. For those reasons, loading speed of human actions and the environment and ecosystem responses must be balanced. This calls for environmental measures to disclose the emissions behind the clean energy systems – especially the impacts due to manufacturing and end-of-life – and implication of undesirable emissions for carbon control and sequestration technologies.

The conditions for centralized and decentralized energy systems are not dependent singly of ecosystem services, but also investments in the qualified workforce. Investments in qualified workforce shall likewise correspond to grow the knowledge (an intangible asset) and maintain the competencies of employees (economically known as knowledge capital[3]).

Under the framework of ICoS, five interim rules emphasize important conditions to discuss a conscious development for safeguarding society and its continuous capacity for expansion. Table 2 discloses the in-depth approaches which scenarios of the REFLEX project. These principles attempt to the use of resources linked to the international efforts for affordable and clean energy (SDG7), the climate actions (SDG13) and preservation of life below water (SDG14) and on land (SDG15).

Table 2. Rules for maintaining society's productive potential

Rule	Explanation	SDGs
Use of renewable resources	The actual supply of renewable resources is limited by the increase competition or by the production conditions in case of land-use-change and weather conditions (e.g., biomass). The latter is also influenced by legal regulation and acceptance in the case of solar and wind parks. For this reasons, efficient and conscientious use is necessary.	SDG7 - Affordable energy
Use of non-renewable resources	A system free of non-renewable resources is not possible, although substitution of fossil-based resources is aimed. It is therefore recognized the need for an upstanding consumption and effective strategies linked to technological progress towards recycling.	SDG7 - Affordable energy
Use of the environment as a sink for waste and emissions	The absorption and recovery time for environment and ecosystems must be respected. An increase in greenhouse gases affects the absorption capacity of the environment and an excess of nitrogen could higher the acidification and eutrophication of ecosystems, for instance.	SDG13 - Climate action SDG14 - Life below water SDG15 - Life on land
Avoiding unacceptable technical risks	Upgrading of conventional technologies to a mitigated system can play a role for centralized and decentralized systems in many European countries. Air quality due to the solvent for CO_2 mitigation and proper waste treatment has to be controlled to avoid particulate emissions, eutrophication, and acidification respectively. Technical risks linked to solvent losses and hazardous waste from carbon-capturing technologies must be avoided.	SDG3 - Good health and well-being SDG13 - Climate action SDG14 - Life below water SDG15 - Life on land
Development of man-made, human and knowledge capital	In principle, a circular-flow economy should ensure positive value creation. A negative value added could be accepted for individual sectors if there are overriding reasons for supporting the circular-flow economy. However, this would require other sectors and private households to be able to generate sufficient tax revenues to support the respective sector.	SDG8 - Decent work and economic growth

[3] BMWA: *Wissensbilanz - Made in Germany.* 2004, S. 11.

3.3 Preserving society's options for development and action

Behind the European Climate Policy based on a combination of political targets and industrial engagement, there is a strong and heritage culture found in the society of partners countries. Integration of socio-cultural aspects in this climate policy is crucial for its implementation and for ensuring, it has public support. The multi-cultural aspects of EU28+Norway and Switzerland countries are strongly associated with various cultural behavior and aesthetic experiences. These socio-cultural characteristics call for joint-alternative solutions to act in favor and, at the same time, preserve the root values independently of any energy system development. Within this goal, independent of the establishment of either a centralized or decentralized energy system, societal participation is crucial. Five rules of ICoS (s. Table 3) are interpreted and bring additional observations regarding the continuation of the transformation process contributing to the international efforts for affordable and clean energy (SDG7). It requires a general EU28+2 partnership to uphold past and present socio-cultural organization of society. This precept includes the learning process to deal with the transformation phase interconnected to the economic and cultural functions.

Table 3. Rules for preserving society's options for development and action

Rule	Observation	SDGs
Equal access for all to information, education and occupation	The transformation process requires an intensive communication and information strategy. All members of society in EU 28+2 must be aware of political targets and local decisions.	SDG4 - Lifelong learning opportunities SDG17 - Partnership for the goals
Participation in societal decision-making processes	The technologies being studied for a centralized and decentralized system will influence local living conditions either directly (by investing in appropriate sites) or indirectly (via upstream and downstream chains). The concepts discussed will affect the living conditions in the regions concerned and possible reactions, comparable to the not in my backyard (NIMBY), needs to be considered. Those reactions can inflame organizations constituted for defending the interests enhancing negative impressions.	SDG16 - Building inclusive societies at all levels SDG17 - Partnership for the goals
Preservation of the cultural function of nature	Although wind and solar parks will dominate a centralized and decentralized electricity market or even new road systems will be needed, interventions to nature lead to demand of land and reduction of biodiversity.	SDG15 - Life on land
Conservation of social resources	Centralized or decentralized systems will boost different opinions in society. Due to that,inclusive societies must be enhanced to avoid conflicts and ensure social cohesion.	SDG16 - Building inclusive societies at all levels
Conservation of cultural heritage and diversity	Several cultural facilities in EU28+2 need to adapt to a new power and heat system. Local decisions need to be analysed to safeguard the cultural heritage and meet the demand.	SDG17 - Partnership for the goals

4 Determining the linkage between REFLEX modelling exercise and the sustainability assessment

It has to be emphasized that the REFLEX consortium brings expertise on the research fields of techno-economic learning, fundamental energy system modelling and environmental and social life cycle assessment as a feed-in aiming at ensuring the comprehensiveness of the built scenarios. The ICoS requires an additional participatory method to identify the most appropriate indicators to fulfil all the rules. For the REFLEX project the reductionistic approach will be applied. The objective therefore is to identify and assign relevant indicators derived from the model results for rules with compatible context. The primary purpose is to bring a consistent and quantitative sustainability assessment model even that some rules potentially will be excluded. Table 4 shows examples of indicators extracted from the modelling pool of the REFLEX project.

Table 4. An exemplary set of indicators derived from model results for REFLEX sustainability assessment

Securing human existence			
Rules	**Model**	**Indicator**	**Observation**
Protection of human health	e-LCA and πESA	Particulate matter	The indicator is estimated according to the emissions released by different technologies (e.g., CCS, district heating) as an input for regional hotspots assessment.
Ensuring the needs	ASTRA	Average expenditure per person for mobility	The indicator is estimated on the basis of the evolution over time of passenger transport demand by mode and evolution of costs.
Balancing extreme inequalities in income and wealth	s-LCA	Unfair salaries	The indicator is estimated on the living wages, minimum wages and sectoral wages for such a service or class of service. For instance, the production of photovoltaic cells.

Under the scope of securing human existence (see 3.1), the set of indicators will be materialized in three perspectives to certify the human conditions (individual) exposure in front of centralized and decentralized systems (s. Table 4). One is the potential change in technologies (capitals) and fuels (consumables) employed in the energy sector and their respective impacts on the environment and human health simultaneously, for example. The second is potentially the consequences of the new structures linked to the energy sector. The third is the social impacts resulting from a global market production line of technologies.

All transitioning technological layout might be retrieved from the Energy Systems Modelling conducted within the REFLEX project. Further, any expected change of process technology with substantial implication for the impacts (e.g. steel producing industry using hydrogen instead of coal) and/or expected shifts in resource use for these processes of considerable importance (e.g., new feedstocks for biofuels as presented in a scientific paper from Ekener et al. 2018) might be considered in the LCA modelling. However, it is expected that the modelling interfaces will merge the two viewpoints for the sustainability assessment to derive the indicators as an additional contribution to academia.

5 Conclusion

According to the European Commission's political aim, energy systems are implicitly part of the cross-sector policy approach to ensure sustainable development. Therefore, there is a rising concern whether the targets are adequate or even the technological signs of progress are reliable to the roots of sustainability. This information brief achieved two main lessons learned:

- For future low-carbon energy systems, an additional amendment to the European Climate Policy is needed to maintain the Union focused on sustainability issues. The European Climate Policy is focused on affordability of modern systems and climate change, two action areas of Sustainable Development Goals (SDGs). Therefore, if energy systems could be taken as a hub for a substantial role in the Agenda 2030 the commitment to sustainability issues could be enlarged.
- The primary conditions to reach so-called "sustainable energy systems" based on the scope of the REFLEX project are based on the three goals of the Integrative Concept of Sustainability (Kopfmüller J. et al. 2001). The goals are concentrating to the ability of humans to protect themselves (including future generations) from anthropogenic actions, local and global societies need to maintain their productive capacity and cultural identities should not be lost.

However, from 17 SDGs, 12 of them could have a direct or indirect influence according to the qualitative nexus approach demonstrated in this information brief for the REFLEX project (Table 5).

Table 5. Influences of the REFLEX energy scenarios in the SDGs

Influence	SDGs
Direct – the rules of ICoS under the context of energy systems perform a bridging function to show progress or not on the acting area of the SDGs	Good health and well-being (3); Decent work and economic growth (8); Climate action (13); Life below water (14); Life on land (15)
Indirect - the rules of ICoS under the context of energy systems perform a bridging function. Therefore, there is no clear spectrum of progress or not on acting are of the SDGs	Lifelong learning opportunities (4); Sustainable cities and communities (11); Responsible Consumption and production (12); Peace, justice and strong institutions (16); Partnerships for the goals (17)

The sustainability framework for the REFLEX project is still ongoing. This exercise became fundamental to provide joint-knowledge for an audience with a different background and scientific disciplines having the SDGs as the well-known action orientation to assist the introduction of ICoS.

The guiding principles presented in this information brief can be useful in the continuous work for assessing the sustainability of the future energy scenarios within the REFLEX project and beyond. In this project, the task is substantially more extensive, as it does not only encompass the demand energy sector as such in addition to the supply. Moreover, all countries in EU 28+Norway and Switzerland are included. This will need to be more overarching in the details of each sector, employing the structures and data included in the databases intended to be used in the assessment in the REFLEX project. Yet, examples of indicators are presented in this document. It should be emphasized that the reductionistic approach is aimed to keep the framework congruent and straightforward. The entire indicator pool and their respective assessment will compose the final version of the sustainability framework at the end of the project. All indicators must give arguments to support policy recommendations regarding the performance of a particular sector and/or to provide the best available knowledge to enlighten communication in society.

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