Sustainable Energy Development

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***Abstract*—Energy production and consumption is closely related with all global economic, social and environmental development issues. In order to sustain and in turn to ensure sustainable society development the energy sector development should be sustainable by itself. Therefore the main goal of sustainable energy development is to ensure production and use of energy resources in ways that promote—or at least are compatible with—long-term human well-being and ecological balance. The competitiveness of countries is directly related to the progress achieved in implementing sustainable energy development as the energy sector has great significance for the future development of the country. The energy sector is crucial for economic growth and has a major impact on the environment. Sustainable energy development permits the decoupling of economic growth from energy consumption and the decoupling of energy consumption from atmospheric pollution.**

***Index Terms*—Energy strategy; sustainable energy; sustainable energy indicators.**

I. Introduction

The directives targeting energy efficiency, renewables and climate change mitigation indicates the EU energy policy priorities: reduction of energy impact on environment, improvements in energy generation and energy use efficiencies, increase in reliability and security of energy supply, promotion of renewables use and climate change mitigation. All these directives have specific targets which can be addressed by quantitative indicators. As targets set by specific directives are related the use of interlinked indicators framework to address these targets can be useful tool for energy policy analysis and monitoring. Such tool applied by EU member states can help to harmonize EU energy policies and enhance its implementation on country level.

The aim of the paper is to analyze sustainable energy targets and their interrelations by applying interlinked indicators framework.

The main objectives to achieve this aim are listed below: to analyze sustainable energy development concept; to analyze sustainable energy development targets based on analysis of EU energy policy documents; to apply indicators framework for analysis of interlinkages between sustainable energy development targets.

Energy production and consumption is directly linked to all global economic, social and environmental issues. Energy is the main driving force of economic development. In order to achieve sustainable development the energy sector development should be sustainable by itself. The main goal of sustainable energy development is to ensure production and use of energy resources in ways that promote—or at least are compatible with-long-term human well-being and ecological balance [1]-[3].

EU has ambitious targets in terms of sustainable energy development. The main energy policy agenda is linked to sustainable energy development. There are several important EU policy documents and directives which are directly linked to sustainable energy development. These directives promote energy efficiency and utilization of renewable energy sources, climate change mitigation and atmospheric pollution reduction policies. Promotion of renewable energy sources and energy efficiency improvements are among priorities of EU energy policy. The increase in energy efficiency and utilization of renewable energy sources can allow achieving other important targets of sustainable energy development: climate change mitigation, security of energy supply and energy affordability [4].

The main EU sustainable energy development aims are: to ensure secure, affordable and clean energy for EU citizens and businesses by allowing a free flow of energy across national borders within the EU, and bringing new technologies and renewed infrastructure to cut household bills, create jobs and boost growth To pursue these goals the EU has formulated targets for 2020, 2030, and 2050.

The 2020 Energy Strategy defines the EU's energy priorities between 2010 and 2020. It aims to: reduce greenhouse gases by at least 20%; to increase the share of renewable energy in the EU's energy mix to at least 20% of consumption and to improve energy efficiency by at least 20%. In addition EU Member States agreed on following targets to be met by 2030: a binding EU target of at least a 40% reduction in greenhouse gas emissions by 2030, compared to 1990; a binding target of at least 27% of renewable energy in the EU; an energy efficiency increase of at least 27%, to be reviewed by 2020 with the potential to raise the target to 30% by 2030; the completion of the internal energy market by reaching an electricity interconnection target of 15% between EU countries by 2030, and pushing forward important infrastructure projects. Together, these goals provide the EU with a stable policy framework on greenhouse gas emissions, renewables and energy efficiency, which gives investors more certainty and confirms the EU's lead in these fields on a global scale.

The EU also aims to achieve an 80% to 95% reduction in greenhouse gases compared to 1990 levels by 2050. Its Energy Roadmap 2050 analyses a series of scenarios on how to meet this target.

II. Sustainable Energy Development

There are more than 70 definitions of sustainable development that can be found in economic literature, including different aspects of sustainable development. The most appropriate definition of sustainable development is

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formulated in the communication of Brundtland commission [5]. This definition defines sustainable development as development which satisfies demands of the current time and at the same time do not makes dangers for future generations to satisfy their needs. Usually sustainable development concept covers economic, ecological and social development issues or economic, environmental and social dimensions of sustainability [6].

In practice the best definition of sustainable development is a capability to decouple economic development from resource utilization and environmental pollution. Than energy consumption increases more slowly than economic growth and environmental pollution is growing more slowly than consumption of energy resources we are facing sustainable development trends [7].

Energy production and consumption is closely related with all global economic, social and environmental development issues. In order to sustain and in turn to ensure sustainable society development the energy sector development should be sustainable by itself. Therefore the main goal of sustainable energy development is to ensure production and use of energy resources in ways that promote—or at least are compatible with—long-term human well-being and ecological balance [1]-[3].

The World Energy Council's definition of energy sustainability is based on three core dimensions – energy security, energy equity, and environmental sustainability. These core dimensions of sustainable energy creates a 'trilemma', and achieving high performance on all three dimensions includes complex interrelated links between governments and regulators, market agents, economic and social factors, national resources, environmental concerns, and individual behaviours [8].

The Energy Trilemma Index ranks countries' energy performance around the world and provides a framework to benchmark progress. The 2016 Energy Trilemma Index reveals signs of progress on three dimensions of the sustainable energy trilemma. Energy security dimension covers effective management of primary energy supply from domestic and external sources, reliability of energy infrastructure, and ability of energy providers to meet current and future energy demand. Energy equity covers energy accessibility and affordability across the population. Environmental sustainability dimension includes supply and demand side energy efficiencies and development of energy supply from renewable and other low carbon sources.

The Energy Trilemma Index quantifies the energy trilemma and comparatively ranks 125 countries in terms of their ability to provide a secure, affordable, and environmentally sustainable energy system. In addition, countries are awarded a balance score that highlights how well the country manages the trade-offs between the three energy trilemma dimensions and identifies top performing countries with a triple-A score.

The Index rankings are based on a range of data sets that capture both energy performance and the context of that energy performance. Energy performance indicators consider supply and demand, the affordability of and access to energy, and the environmental impact of a country's energy production and use. The contextual indicators consider the broader circumstances of energy performance including a country's ability to provide coherent, predictable and stable policy and regulatory frameworks, initiate research, development and demonstration (RD&D) and innovation, and attract investment.

Thirteen of the 125 countries achieved a triple-A score in progress of sustainable energy development. A more diversified and low-carbon energy mix will help to improve energy security and environmental sustainability but its positive effects may be compensated by rising energy consumption, which is predicted to increase significantly by 2060. Denmark, Switzerland and Sweden are ranked as the best countries according to the Energy Trilemma Index. In Latin America, Uruguay ranks the highest according Energy Trilemma Index, while in the Middle East, Israel outperforms its regional peers. In Sub-Saharan Africa, Mauritius performs best, and in Asia, New Zealand remains at the top level. Lithuania has 28th position.

Though Energy Trilemma Index is useful tool to compare countries in terms of achievements of sustainable energy development however energy trilemma approach does not allow to track impact of policies aiming to ensure sustainable energy development therefore more comprehensive indicators frameworks are necessary.

III. Indicators of Sustainable Energy Development

Achieving requirements of EU directives targeting sustainable energy development requires regular monitoring of impacts of selected policies and strategies to see if they are furthering sustainable energy development or if they should be adjusted. It is important to be able to measure a country's state of implementation of EU directives aiming at sustainable energy development and to monitor its progress or lack of progress towards achievement of the main targets set by these directives.

First of all it is necessary to know the country's current status concerning the established targets, what needs to be improved and how these improvements can be achieved [9] - [10].

Second, it is very important for policy makers to understand the implications of selected directives, energy, environmental and economic programmes, policies and plans and their impacts on achieving the main targets and goals set by the main directives. Therefore choosing energy fuels and associated technologies for the production, delivery and use of energy services, it is essential to take into account economic, social and environmental consequences. Therefore policy makers need simple methods for measuring and assessing sustainable energy development trends. For this purpose energy indicator establishing the most important targets of sustainable energy development can be used.

There are a several frameworks of indicators developed to assess the trends towards sustainable development [11]-[13], however the Energy Indicators for Sustainable Development (EISD) developed by International Atomic Energy Agency (IAEA) [14] is the most comprehensive and simple tool allowing to track progress achieved by countries in implementing interlinked sustainable energy development targets.

The EISD is an analytical tool which can help energy policy makers at all levels to incorporate the concept of sustainable development into energy policy. The EISD set is used to present energy and interlinked economic, environmental and social data for policy makers in a coherent

and consistent form, addressing the links between indicators. The EISD list allows to make comparisons, analyze trend and to make policy assessments.

Some indicators from EISD set can be selected for the analysis of the EU sustainable energy policies in EU Member States and for the assessing their success towards implementation of the main targets set by energy directives and other policies targeting sustainable energy development: energy efficiency improvements, use of renewables and greenhouse gas emission reduction. Indicators relevant to EU energy policies will be selected from the EISD list. EISD core set is organized following the conceptual framework used by United Nations Commission on Sustainable Development. There are 30 indicators, classified into three dimensions: social, economic and environmental. The scheme of core EISD is presented in Table I.

TABLE I: THE EISD FRAMEWORK

SOCIAL	
Eguity	**Health**
Accessibility SOC1 Affordability SOC2	Safety SOC4
ECONOMIC	
Use and production patterns	**Security**
Overall use ECO1 Overall production ECO2 Supply efficiency ECO3 Production ECO4 and ECO5	Imports ECO15 Strategic fuel stocks ECO16
ENVIRONMENTAL	
Air	**Water** / **Land**
Climate change ENV1 Air quality ENV2 and ENV3	Water quality ENV4 Soil quality ENV5 Forests ENV6

Trends in overall energy productivity, supply efficiency, end-use productivity, and fuel mix and energy security will be analyzed using economic dimension indicators. Climate change mitigation issues will be addressed by environmental dimension indicators. Energy affordability and accessibility are the main indicators of social dimension indicators.

The appropriate EISD were selected to address requirements of EU directives targeting security of supply (ECO 15), energy efficiency improvements (ECO2), promotion of renewable (ECO 11, ECO 13) and greenhouse gas (ENV1) and other atmospheric pollutants emissions (ENV2). The selected indicators were grouped by 4 priority areas established by EU energy policy: increase of energy efficiency, utilization of renewable energy sources, increase of security of energy supply and greenhouse gas and other atmospheric emission reduction.

TABLE II: INDICATORS SELECTED FOR EU ENERGY POLICY ANALYSIS

Indicators	Acronym	Directive	Target	Data
Energy efficiency (EE)				
Savings of primary energy supply	EE1	2020 Energy Strategy	20% from year 2002 level 27% from year 2002 level	2020 2030
Energy saved in buildings	EE2	Directive 2010/31/EC	22% of energy used in buildings	2020
The share of CHP in electricity production	EE3	Directive 2004/8/EC	35%	2025
Use of Renewables (RES)				
The share of renewables in primary energy supply	RES1	The White Paper on renewable sources	20%	2025
The share of renewables in electricity generation	RES2	Directive 2001/77/EC	20%	2020
The share of renewables in heat production	RES3	Lithuanian national energy strategy	25%	2020
The share of renewables in fuel used in transport	RES4	Directive 2003/30/EC	20% 15%	2020 2025
The share of renewables in final energy	RES5	2020 Energy Strategy	20% 27%	2020 2030
Security of Supply (SS)				
Energy independency	ES1	EU Green paper on European Strategy	50%	2030
Atmospheric Pollution Reduction				
Greenhouse gas emissions (CO_2 emissions)	GHG1	2020 Energy Strategy	Reduction by 20% of year 1990 level Reduction by 40% of year 1990 level Reduction by 85-90% of year 1990 level	2020 2030 2050
SO_2 emissions NO_xemissions VOC emissions NH_3emissions	ACD (1-5)	Gothenburg protocol NEC Directive 2001/81/EC	Reduction by 87%, by 50%, by 46%, by 41% compared to 2000 level	2020

The indicators framework for EU energy policy analysis and monitoring of targets by EU directives are presented in Table II.

Requirements for sustainable energy (energy efficiency improvements, the share of renewables, GHG emission reduction targets) are also presented in Table 1 based on review of the main EU energy policy documents. All these EU energy policy indicators can be connected to each other via the chain of mutual impacts seeking to develop comprehensive policy framework for monitoring implementation of EU directives and tracking various interacting policy measures targeting relevant indicators [14]. The last indicator in EU energy policy indicators framework is greenhouse gas emission indicator as all other EU policies (targeting energy efficiency improvements, promotion of renewable, and an increase in energy supply security) in the end have positive impact on greenhouse gas emission reduction [15] - [16].

Fig. 1 illustrates the linkages among the indicators selected for energy policy analysis in EU. Relevant policy actions based on analysis conducted in the previous sections are defined based on targeted indicators.

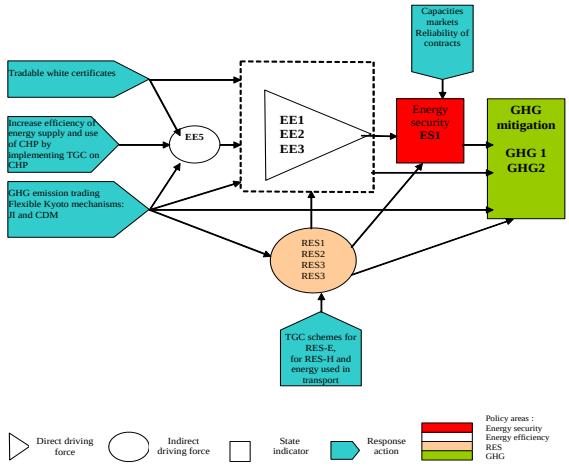

Fig. 1 Linkages between indicators and relevant policy actions based on the targeted indicators

The numbers in Figure 2 refer to the identification numbers of the indicators for monitoring of implementation of the main EU directives targeting sustainable energy development listed in Table 1.

As one can see from the framework of indicators presented in Figure 2 the response actions can be targeted on direct driving force, indirect driving indirect force and state indicators as well. In the end of chain of interconnected indicators we can GHG emission indicator. All other indicators presented in the chain of sustainable energy development indicators have impact on GHG emissions.

The similar sustainable development indicators frameworks and chains can be created in other sectors of economy as well however energy sector allows to most transparent track of the relationship between economic, social and environmental dimensions of sustainable development.

IV. Conclusion

1) Sustainable development is development which satisfies demands of the current time and at the same time do not makes dangers for future generations to satisfy their needs. Traditionally sustainable development concept involves economic, ecological and social development issues or economic, environmental and social dimensions of sustainability.
2) Energy produced and used in ways that support human development over the long term, in all its social, economic, and environmental dimensions is sustainable energy.
3) The World Energy Council's definition of energy sustainability is based on three core dimensions – energy security, energy equity, and environmental sustainability and taken together, they constitute a 'trilemma', and achieving high performance on all three entails complex links between public and private actors, governments and regulators, economic and social factors, national resources, environmental concerns, and individual behaviors'. The 2016 Energy Trilemma Index reveals signs of progress on all dimensions of the energy trilemma for 15 world countries.
4) Energy is an essential component of economic development, and energy sector decisions and practices will play a central role in determining the sustainability of development in every country, region and sector. At the same time, decisions and practices in other sectors have a very direct effect on energy supply and demand options. Energy sector policies and investments must be coordinated with those in the key energy end-use sectors: transportation, housing, construction and manufacturing. In each of these sectors, there are major opportunities for improving the efficiency of energy use and developing new technologies and energy supplies.
5) Sustainable energy indicators framework allows to define goals of sustainable energy development and to track progress achieved in implementing policies and measures targeting specific goals of sustainable energy development.
6) The sustainable energy development framework was created on the basis of EISD for monitoring sustainable energy development and addressing priorities of EU energy policies.
7) The linkages between indicators allow to implement harmonized policies and to track success of implemented policies via interlinked indicators of sustainable energy development.

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