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Multicriteria analysis of climate change mitigation scenarios for Lithuania

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Abstract— **The aim of the paper is assess climate change mitigation measures in energy sector based on sustainable energy sector development targets. The main tasks to achieve this aim are: to develop indicators framework for sustainability assessment of climate change mitigation measures in energy sector; to apply this framework for sustainability assessment of climate change mitigation policies in Lithuanian energy sector. This methodological approach allows to achieve harmonization of climate change and energy policies and to enhance synergies between them. The main results presented in the paper. The system of indicators was developed based on EU energy policy targets. The assessment and ranking of market based climate change mitigation tools was performed by applying energy sector optimization model Message. The multi-criteria analysis of market based climate change mitigation tools was performed for Lithuania and the package of the best climate change mitigation tools in terms of achieving sustainable energy development targets in Lithuania was selected.**

Keywords: climate change mitigation, multi criteria analysis.

I. INTRODUCTION

Climate change and its mitigation policy are priority problems of the entire world, the European Union and individual countries. Since greenhouse gas emissions arising from the combustion of organic fuels (70 % of all greenhouse gas in Lithuania), is the most easily controlled, many climate change mitigation tools are implemented in the energy sector. At the same time energy is a major driving force of economic and social development. Thus, it is important that climate change mitigation policy would not contradict long-term social and economic sustainable development objectives.

There is currently applied a number of different market instruments for the implementing climate change policy and for the implementation of the closely related environmental policy measures in energy for the other priority objectives of energy policy (increase of renewable energy and energy efficiency, energy feed security and so forth.). However, the effects of these measures are not clear, and countries, implementing climate change mitigation policy, select the specific policy measures, regardless of their ability to implement other priority objectives of environmental and energy policy, i.e. there is lack of a comprehensive methodologies, the best climate change mitigation measures, and their choice of packages, which would ensure the implementation of all main energy and environmental policy objectives with the lowest costs and would guarantee policy measures synergetic effect.

II. SUSTAINABLE ENERGY DEVELOPMENT INDICATORS SYSTEM FOR THE ANALYSIS OF MARKET BASED CLIMATE CHANGE MITIGATION TOOLS IMPLEMENTATION IN THE ENERGY

For assessment of climate change mitigation tools the indicators system presenting EU energy and environmental policy targets will be developed. Selected indicators are grouped into four priority groups established under the EU's energy policy: increasing energy efficiency, renewable energy sources consumption, and greenhouse gas emission reduction. [1]. Sustainable energy development indicators extensions are formed to reflect the EU's national policy documents.

The selection of market based climate change mitigation tools or their combinations can be performed using energy optimization models. By applying the energy system optimization model "MESSAGE" [2] we can assess climate change mitigation tools impact on greenhouse gas emissions reduction and other impacts, such as impact on energy efficiency, renewable energy sources promotion, and other atmospheric pollutants emissions reduction, because climate change mitigation tools have an impact on these objectives. The proposed assessment methodology of climate change mitigation tools impact in energy sector is based on the assessment of climate change mitigation tools impact on the main sustainable energy development objectives.

TABLE I. CLIMATE CHANGE MITIGATION SCENARIOS

Variant	Trade in emission allowances or CO_2 tax from 2005, EUR / t	Fixed electricity purchase price or green certificates rate from 2005, EUR / kWh
Base variant "With tools"	10	0,06
A1 variant	0	0,06
A2 variant	13,5	0,06
A3 variant	10	0,2
A4 variant	10	0
A5 variant "With the new tools"	13,5	0,2
A6 variant "Without tools"	0	0

Table I introduces main parameters of the scenarios. Negotiable emissions allowance price is set according to the average price of emission allowances, established in 2005-2007 in the market - 10 EUR / t. CO_2 tax is set to 13.5 EUR /

ton, based on previous studies data [3]. The average price of green certificates - 0.2 € / kWh - is modeled on the basis of experience from other countries, where are applied green certificates [4].

Further is analyzed the impact of six climate change scenarios on the main Lithuanian sustainable energy development objectives. In particular, it is appropriate to examine what impact on the primary energy intensity had separate implemented market based climate change mitigation (MBCCM) tools and their packages. The summarized data of the scenarios and their impact on sustainable energy development goals are set in Table II.

TABLE II. CLIMATE CHANGE MITIGATION SCENARIO RANKING ACCORDING TO THE IMPACT ON SUSTAINABLE ENERGY DEVELOPMENT GOALS

Base	A1	A2	A3	A4	A5	A6	Task
Energy efficiency (EE)							
2	3	1	2	2	1	3	To reduce primary energy intensity by 50% compared with 2002.
3	5	1	2	4	1	5	To save 20 % of primary energy compared with 2005.
3	1	2	2	2	2	1	CHP share in electricity generation structure 13 % (2010)
4	1	2	2	2	3	1	CHP share in electricity generation structure 35 % (2025)
The consumption of renewable energy sources (RES)							
2	3	1	2	2	1	3	RES share in primary energy 12 % (2010)
2	3	1	2	2	1	3	RES share in primary energy 20 % (2025)
2	3	1	2	2	1	3	RES share in electricity generation 7 % (2010)
2	3	1	2	2	1	3	RES share in electricity generation 20 % (2025)
2	3	1	2	2	1	3	RES share in final energy 23 % (2020)
Greenhouse gas emissions reduction (GHG)							
2	3	1	2	2	1	3	To reduce CO_2 emissions by 8 %, compared with 1990 (2012)
2	3	1	2	2	1	3	To reduce CO_2 emissions by 20 %, compared with 1990 (2020)
Other pollutant emissions to the atmosphere							
2	3	2	1	2	1	2	To reduce SO_2 emissions by 35 %, compared with 1990 (2010)
2	3	6	4	5	1	3	To reduce SO_2 emissions by 82 %, compared with 2000 (2020)
3	7	2	5	4	1	6	To reduce NO_x emissions by 30 %, compared with 1990 (2010)
3	1	2	4	4	1	1	To reduce NO_x emissions by 60 %, compared with 2000 (2020)
Total system costs							
5	6	1	3	4	2	7	

As can be seen from the results given in Table III, A5 and A2 scenarios, which include additional MBCCM tools, allow achieving the greatest reduction in greenhouse gas (GHG) emissions and ensure the best results for the increase of renewable energy sources consumption and energy efficiency goals; however, it leads to the biggest system cost and reduces competitive ability of energy sector.

After evaluating the impact of individual climate change mitigation tools on GHG emissions reduction, there was found that the fixed prices of electricity purchase from RES can reduce GHG emissions only by 0.002 Mt in 2012. The impact in 2020 on GHG emissions reduction for the fixed purchase prices is not set. Meanwhile, the trade in emissions allowances can reduce GHG emissions by 0, 45 Mt till 2012, and 1.9 Mt till 2020. So, the trade in emissions allowances outweighs the fixed purchase prices impact. It was found that the most important MBCCM tool in various combinations of climate change mitigation packages is the GHG emission trading or carbon tax.

In order to perform multi-criteria analysis and select the best climate change mitigation tool or combination of them, there is a need to evaluate importance or weight of each of the criteria. Thus, on the basis of mathematical modeling results, there is formed a conjoint choice experiment, which will evaluate the Lithuanian population preferences and identify the main criteria (their weights), selecting MBCCM tools.

III. EXPERIMENT OF THE SELECTION OF THE MARKET BASED CLIMATE CHANGE MITIGATION TOOLS, IN ORDER TO ESTABLISH PUBLIC PREFERENCES

After determining the impact of MBCCM tools on sustainable energy development indicators in numerical terms, it is necessary to perform multi-criteria analysis and evaluate public preferences, that is, to determine what indicators of sustainable energy development society consider as the most important, selecting MBCCM tools. Then, after the conjoint experiment, it can be chosen the weights for individual indicators (criteria) of sustainable energy development and selected the best MBCCM tool or their combination for Lithuania [6]. By applying the conjoint choice analysis, it is possible to determine, which of evaluated MBCCM tools (the trade in emission allowances, in green, etc.) is the best in specific country population view according to their ability to meet the underlying criteria, selected by using energy and environmental policy

objectives. Thus, tools selection during choice experiment will depend on which tool is best, according to numerous criteria, reflecting the EU's policy priorities, which in some cases conflict with each other: impact on energy saving, renewable energy development, greenhouse gas emissions reduction, total system costs, etc..

Criterion level was determined using mathematical models. While modeling, there were formed individual climate change mitigation scenarios, which modeled the impact of individual MBCCM tools on the main sustainable development indicators.

As can be seen from Table 3, showing the climate change mitigation scenario ranking, under the impact on individual sustainable energy development goals, different MBCCM tools packages do not always show the best results, evaluating the impact on different sustainable development indicators.

The largest reduction in greenhouse gas emissions in most cases gives a tool or set of them, which maximizes the average electricity price. In addition, such tool has an impact on the dependence on import growth because high electricity prices encourage electricity import. Primary energy saving also guarantees the reduction of import dependence, while the saving is mainly driven by increased electricity prices. So, all selected criteria are closely linked and mutually influence each other, and both the energy sector modelling to assess the impact of individual policy instruments on determined indicators, and during the choice experiment determined preferences of population are very important steps, selecting climate change mitigation policy tools.

Carrying out the choice experiment or a study of consumer preferences, it is necessary to limit the features or criteria, determined by the help of sustainable energy development indicators, number and the number of selected levels, since the number of formed survey scenarios depends on it. So, while experimenting, it was decided to limit by four key factors which are already selected, after analyzing the most important EU energy and environmental policy objectives [5]: (i) policy tool costs, expressed as total system costs, after tools implementation; (ii) impact of policy tools on primary energy savings or the intensity, (iii) impact of policy tools on renewable energy sources development, (iiii) the impact on greenhouse gas emissions.

There are selected three levels of criteria, which determine a number of comparisons of provided two scenarios for experiment, on the basis of mathematical modeling results under different scenarios. The criteria levels determined by mathematical modeling are given in the table III.

TABLE III. CLIMATE CHANGE MITIGATION SCENARIOS EVALUATION CRITERIA LEVELS

Criterion	1 level	2 level	3 level
Tool costs expressed as total system costs, billion EUR	5,397	5,521	6,600
Primary energy intensity 2020, GWh / mln. Lt	0,38	0,39	0,44
RES share in primary energy 2025, %	25	27	28
Greenhouse gas emissions 2020, Mt	4,7	4,9	6,8

Each of the hypothetical scenarios described in the questionnaire are presented in Table IV by a set of given features, where one of the criteria levels are different. All levels of criteria are determined, using mathematical modelling of the energy sector.

In each choice step, one scenario differs from other by two or more symptoms. Respondents are asked to choose between two scenarios for each pair of the scenarios, and later are asked to choose between the two scenarios and scenario A6, when is not implemented any policy tool.

Summarized the replies to the questionnaire on conjoint choice experiment, there can be drawn the following conclusions:

The most important criteria, selecting climate change mitigation scenarios, are the system costs, which determine the electricity price increase;

The second most important criterion is the greenhouse gas emissions into the atmosphere;

The primary energy savings is also an important factor;

RES consumption criterion is the last of importance;

After the assessment of population preferences and choosing among alternative climate change mitigation scenarios, the best scenarios of climate change mitigation in Lithuania would be A5 scenario, which includes the trade in emission allowances and the trade in green certificates, as 60% of respondents chose this scenario during a simple survey. However, according to the choice experiment results, the most important criterion is the total system costs, and the scenarios A2 and A5 have the highest system costs. Hence there is a need to do climate change mitigation scenarios multi-criteria analysis and apply the set order and weights of criteria importance during the conjoint choice experiment.

"Multi Cases Tool" multi-criteria decision-making model in Excel format is chosen in order to make a multi-criteria analysis of climate change mitigation scenarios. The results of multi-criteria decision-making model identified that the best scenarios in terms of achievement of sustainable energy development targets is A2 and A5 though they have the highest system cost however the other criteria overweigh the most important criteria in multi-criteria decision-making model.

IV. CONCLUSIONS

Indicators framework for climate change mitigation policies assessment was developed based on EU energy policy targets reflecting sustainable energy development targets. The main criteria for sustainability assessment of climate change mitigation tools are energy efficiency, use of renewable energy sources, GHG emission and other atmospheric pollutants emission reduction. These main criteria are expressed in terms of sustainable energy development indicators: energy intensity; the share of RES in final energy, the share of RES in electricity generation; CO2 emissions; SO_2 emissions; NO_x emissions etc.

By applying energy sector optimization model Message for Lithuania climate change mitigation scenarios were developed for Lithuania covering wide range of market

based climate change mitigation tools ranging for already implemented and foreseen climate change mitigation measures in Lithuania. Climate change mitigation measures were assessed based on results of climate change mitigation scenarios run and calculated indicators for sustainability assessment of climate change mitigation measures.

After evaluating the effect of individual climate change mitigation measure on GHG emissions reduction, there is found that the fixed electricity engross price from the RES allow to reduce GHG emissions only 0.002 Mt in 2012, and the engross price is not fixed for the impact of GHG emissions reduction in 2020. Meanwhile, the trade in emission allowances allows reducing GHG emissions 0.45 Mt to 2012 and 1.9 Mt to 2020. Thus, the trade in emission allowances outweigh the fixed engross price effect and the reduction of GHG emissions on the implemented climate change mitigation measures is caused by emissions trading.

After summarizing the results of conjoint choice analysis, the most important criteria was defined - the system costs, which cause electricity price increase. The second most important criterion is greenhouse gas emissions into the atmosphere. Also the important criterion is the primary energy savings. The use criterion of the renewable energy source according to the importance is the last.

The results of MCDA identified that the best scenarios in terms of achievement of sustainable energy development targets in Lithuania are A2 and A5 climate change mitigation scenarios representing a package of market based climate change mitigation tools: GHG emission trading and green certificate trading. Though these two scenarios have the highest system cost however the other criteria overweigh the most important criteria in multi-criteria decision-making model.

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