BIOFUEL CONTRIBUTION IN MEETING RENEWABLE ENERGY AND CLIMATE POLICY TARGETS IN LATVIA

Gaidis Klavs, Ivars Kudrenickis, Janis Rekis
Institute of Physical Energetics
energy@edi.lv, janis.rekis@gmail.com

Abstract. The ambitious EU climate-energy policy sets to the Member States non-Emission Trading Scheme sectors challenging targets requiring to implement those RES utilisation policies and measures which contribution to greenhouse gas (GHG) emissions reduction is the greatest and at the same time have a good economic performance. GHG emissions balance of full cycle of bio fuel production and utilisation in Latvia should be evaluated, taking into account the feedstock production and processing emissions. To construct and analyse the scenarios of Latvian energy supply system development, including utilisation of the 1st generation bio fuels and evaluation of their contribution to meet Latvia's GHG emissions targets, the optimisation planning MARKAL-Latvia model was applied. Comparison of bio fuels pathways shows that biodiesel pathway requires less energy and land compared with ethanol pathway, while involving slightly higher N_2O emissions. The implementation of RES in the transport sector target 10 % by 2020 with the use of bio fuels reduces the total GHG emissions of the Latvian energy sector compared with the base scenario by 2 % (176 Gg). The key macro-economic indicators (bio fuels scenario additional costs in terms of GDP of 0.09 %, costs of emissions reduction 379 EUR·t^{-1} CO_2) are assessed compared to the base scenario. The modelling results indicate, in the overall context, the use of the 1st generation bio fuels is one of the most expensive measures in the energy sector.

Keywords: bio fuels, climate change, GHG abatement, bottom-up energy models, scenarios.

Introduction

The EU's 2020 climate and energy package [1] is a set of binding legislation with the aim to ensure that the EU meets its climate and energy targets for 2020. Under the Effort Sharing Decision [2], Latvia has taken binding annual targets to limit its greenhouse gas (GHG) emissions from the sectors not covered by the EU Emission Trading Scheme (ETS), such as housing, agriculture, waste and transport (excluding aviation), by 17 % above the 2005 level. The Renewable Energy Directive [3] sets a target for Latvia of meeting at least 40 % renewable energy sources (RES) in gross final energy consumption by 2020, including at least 10 % of transport fuels provided by RES. The Directive sets sustainability criteria for all bio fuels produced or consumed to ensure that they are produced in a sustainable and environmentally friendly manner.

In 2014, the EU leaders agreed on the domestic 2030 GHG emissions reduction target of at least 40 % compared to 1990; the sectors covered by the EU ETS would have to reduce their emissions by 43 % compared to 2005 and emissions from the sectors outside the EU ETS would need to be cut by 30 % below the 2005 level at the EU scale, and this will need to be translated into binding Member State (MS) targets. The 2030 policy framework [4] also sets an objective of increasing the share of renewable energy to at least 27 % of the EU's energy consumption by 2030, however this RES objective would not be translated into the MSs targets through the EU legislation allowing the MSs flexible transformation of their energy systems.

Methods: bio fuel pathways analysis

To analyse the full cycle of bio fuel production and utilisation, we used an improved MARKAL model of the energy-environmental system which we have been developing since 1995 by creating the MARKAL-Latvia model and applying it for the national level research [5-7]. Fishbone and Abilock [8] and Loulou et.al.[9] see MARKAL as a demand driven model, integrating the supply and end-use sectors of economy, and lay emphasis on the description of energy related sub-sectors and on the minimization of the long term discounted cost of all the modelled energy-environmental system. The model holds descriptions of different energy sources, energy transformation and distribution, and energy end-use processes in all economic sectors, including a set of technological and energy efficiency options. The system's cost includes investment and operation and maintenance costs for all technologies, plus the procurement costs for all fuels, minus the revenue from exported fuels, minus the salvage value of all residual technologies at the end of the horizon. The model covers 11 periods of 5 years each, so that the modelled horizon covers 1998 to 2052, inclusive. In the years 2000, 2005 and

2010, the actual installed capacities and activity levels of all technologies are imposed, thus providing that MARKAL exactly represents the real system being modelled. MARKAL determines future investments and activity of technologies at each time period, while ensuring demands, emission caps, and sets of other different constraints. In addition, the model chooses to adjust the demand levels endogenously, due to corresponding own price elasticities [10]. E.g., when the RES target is introduced, prices for some services increase and alongside with fuel and technology switching there is an option to reduce some demand levels according to the demand curve.

The current study develops further and significantly upgrades the approaches and methods presented by Klāvs and Reķis [7], which has been the first attempt to model the impact of bio fuels in Latvia. In this study, the 1st generation bio fuels – ethanol and biodiesel – pathways are evaluated and presented in the chart to produce 1 PJ of bio fuel (see Fig. 1). In the model, ethanol is produced by traditional fermentation methods from wheat, while biodiesel is produced from raw oil extracted from rapeseeds and then transesterificated by using ethanol – fatty acid ethyl ester (FAEE). For the processes auxiliary energy is required and several co-products are produced – straw, distiller's dried grain with solubles (DDGS) in the case of ethanol, and straw, rapeseed cake and glycerine in the case of biodiesel. Co-products later are not used for energy purposes except some fraction of straw. The GHG emissions calculation model for locally produced bio fuels was designed in accordance with the methodology of the Renewable Energy Directive [3] and explained in detail in the Biograce Project [11].

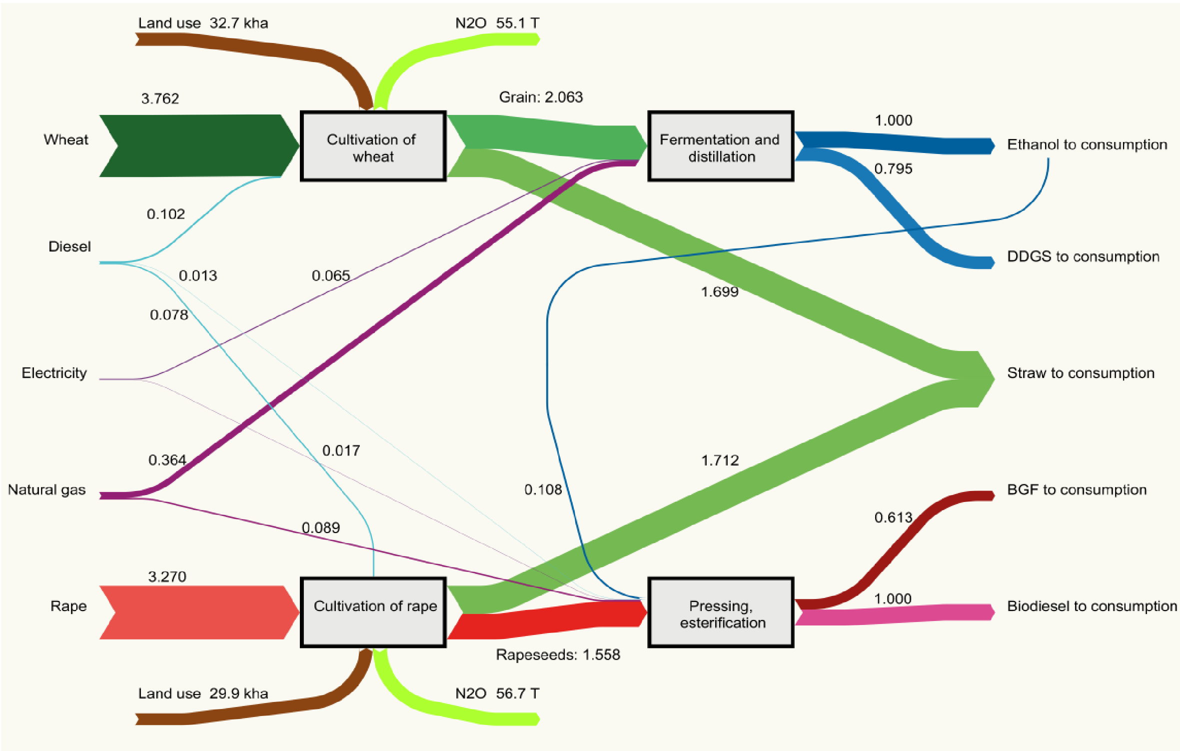

Fig. 1. **Ethanol and biodiesel production pathways: energy balance, land use and N_2O emissions from land use for production of 1 PJ bio fuel** (figures in PJ, unless otherwise stated)

The calculation is performed sequentially in steps starting with the calculation of wheat and rape cultivation emissions, taking into account the crop harvest and seed material characteristics, fuel consumption, N-containing fertiliser application to the soil as well as N_2O emissions from the soil indirectly induced by agricultural activities, and finishing with the grain and rapeseed processing and bio fuel production emissions. Wheat and rape cultivation emissions are calculated on the basis of the parameters characterizing Latvian local conditions such as average yield, the use of fertilisers and fuel consumption; for the feedstock processing characterization the information provided in the Well-to-Tank Report [12] was used. As a result, GHG emissions savings from bio fuels utilisation, taking into account N_2O emissions related to bio fuels feedstock material cultivation, were calculated. Fig. 1

shows that biodiesel pathway requires less energy and land compared with ethanol production, while involving slightly higher N_2O emissions.

According to the GHG inventory Guidelines [13], the noted above N_2O emissions from fertilizer application and soils are included in the *4.Agriculture* category, while the GHG emissions from other bio fuel cycle stages – in the *1.Energy* category. Specific N_2O emissions are affected by the interaction of several factors – the sown area and yield, which in turn depends on the amount of the used fertilisers as well as the amount of straw left on the field. The trend of sown area and yield for both crops, according the data of the Central Statistical Bureau of Latvia [14], is increasing as shown in Fig. 2. Consequently, there is the compensation of the specific factors affecting N_2O emissions, namely, one of the factors increases the emissions while the other – reduces.

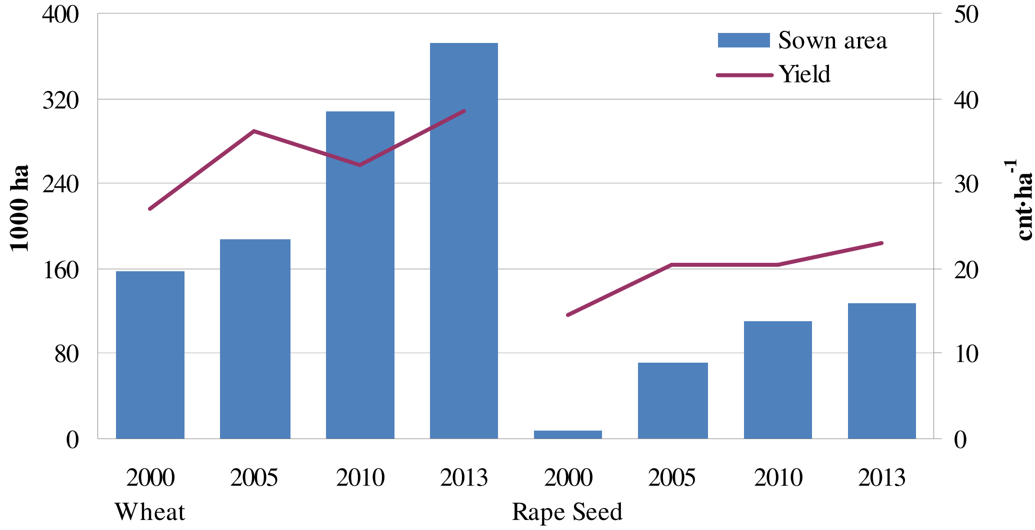

Fig. 2. **Wheat and rape seed sown area and yield in Latvia, 2000-2013**

Results and discussion: GHG emissions from the first generation bio fuels

In the study three scenarios were analysed: (1) "E-BASE" – BASE scenario with the existing policies and measures in 2014; (2) "E-R40-F10" – BASE scenario with defined overall RES target 40 % and RES in the transport sector (RES-F) target 10 %; and (3) "E-F10" – BASE scenario with defined RES-F target 10 %. In the context of bio fuel the analysis of the difference between the "E-BASE" and "E-F10" scenarios is important. The "E-R40-F10" scenario, in its turn, shows the total GHG emission reductions to be achieved by meeting the RES target set in the Renewable Energy Directive [3].

Fig.3 compares the MARKAL-Latvia model results of energy consumption by different fuels for the transport sector in Latvia up to 2035 in the "E-BASE" and "E-F10" scenarios. The use of bio fuel in the "E-F10" scenario with meeting the RES target in the transport sector in 2020 increases more than three times compared with 2010, and it is more than twice than in the "E-BASE" scenario.

In Latvia, according to the National Inventory Report 2014, the total GHG emissions from *4.Agriculture* sector in 2012 were 2420 Gg, where GHG emissions from *4D.Agricultural land* contributed 1513 Gg [15].

The study estimated that GHG emissions from the soil resulting from the cultivation of the 1st generation bio fuel crops – wheat and rape – in 2030, depending on the scenario, form 1.3-3.3 % of the total *4. Agriculture sector* GHG emissions in Latvia in 2010. Although in the scenario with the defined RES-F target 10 % in the transport sector bio fuel crops cultivation emissions are more than twice higher than in the BASE scenario, they account for only 5.3 % of GHG emissions from *4D. Agriculture land* in 2010 (Fig. 4, left graph). One can see that on the same arable land area (as in 2013) by 2020 the cultivation of bio fuel crops will account for 11.1-27.7 % of the total wheat and rape area, and compared to 2013 would increase by 10.2-29.9 %, depending on the scenario. In 2030, in its turn, the required area of arable land, necessary for the production of the required quantity of bio fuel feedstock, depending on the scenario forms 10.8-27.3 % of the total wheat and rape area in 2013

(Fig. 4, right graph). Replacing fossil fuels with bio fuels, CO_2 emissions are reduced because CO_2 emissions from combustion of bio fuels are not taken into account. According to the GHG inventory Guidelines, this reduction manifests in assessing *1.Energy* sector emissions, which includes also emissions from fuel combustion in the transport sector. Fig. 5 shows the GHG emissions reductions in the Latvian energy sector as modelling results when using bio fuels in different scenarios. As it can be seen, the implementation of the RES-F target by 2020 with the use of bio fuels ("E-F10" scenario) reduces the GHG emissions compared with the BASE scenario by 2 % (176 Gg), while achieving the overall RES target ("E-R40-F10"scenario) reduces GHG emissions against the BASE scenario by 17.5 % (1578 Gg).

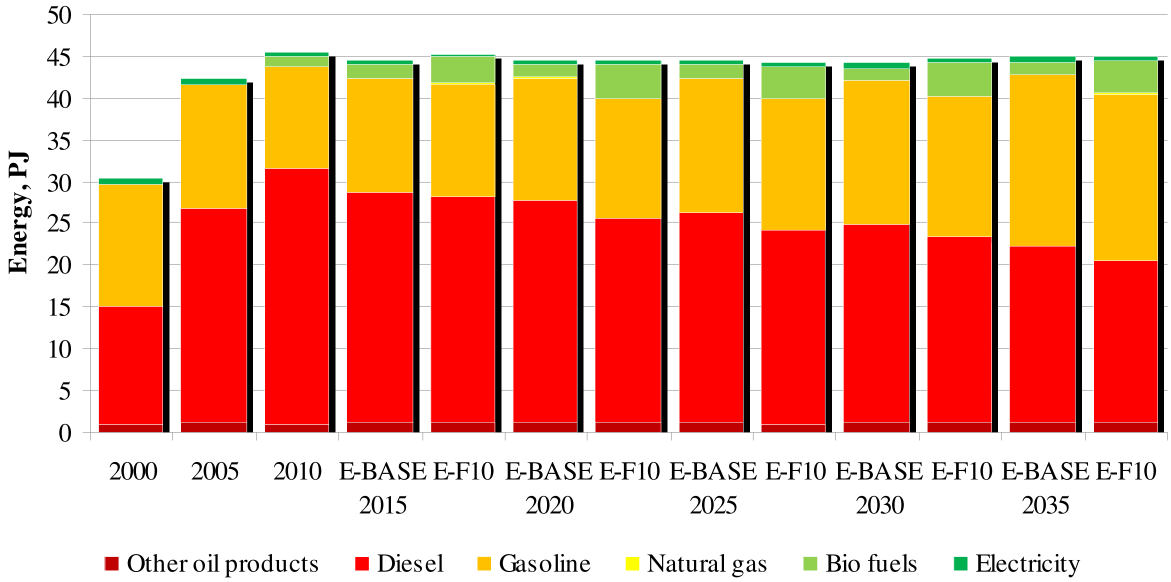

Fig. 3. **Energy consumption in the Latvian transport sector: history and modelling results**

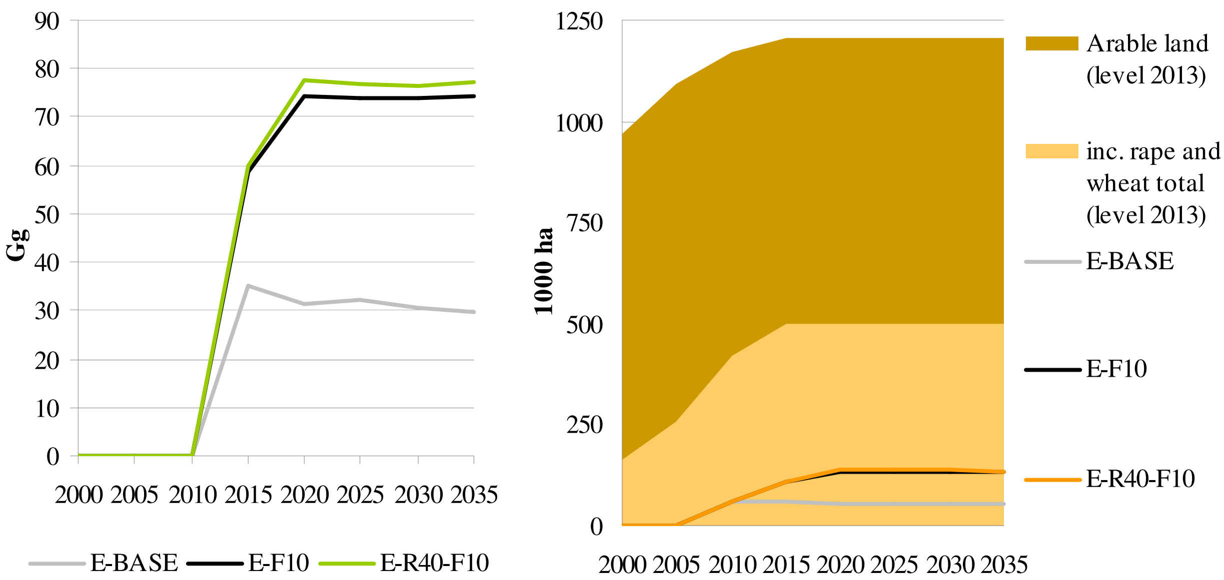

Fig. 4. **GHG emissions from soil in bio fuel feedstock production (left) and the necessary arable land area (right) in Latvia: modelling results**

Assessing the impact of the use of bio fuels on the total GHG emissions reductions, as indicated above, it is important to take into account the GHG emissions resulting from the cultivation of bio fuel crops and the bio fuel production process. The modelling results show that in the case of Latvia, replacing fossil fuels with bio fuels, the GHG emissions savings amounted to approximately 75 %, taking into account the feedstock production emissions. As seen in Fig. 5 and Fig. 6, achieving the overall RES target affects to a great extent the total GHG emissions level in Latvia. However, the impact of bio fuel use on the GHG emissions reduction in the energy sector is low and it becomes minimal in the context of the total GHG emissions reduction up to 2020. After 2020, the 1st generation bio fuel production and utilisation, as an overall RES target meeting measure, may even contribute to the increase of the total GHG emissions.

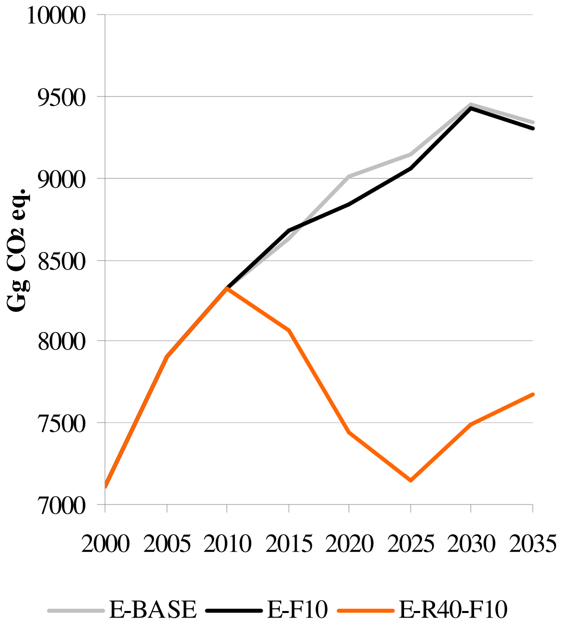

Fig. 5. **GHG emissions in Latvian energy sector: history and modelling results**

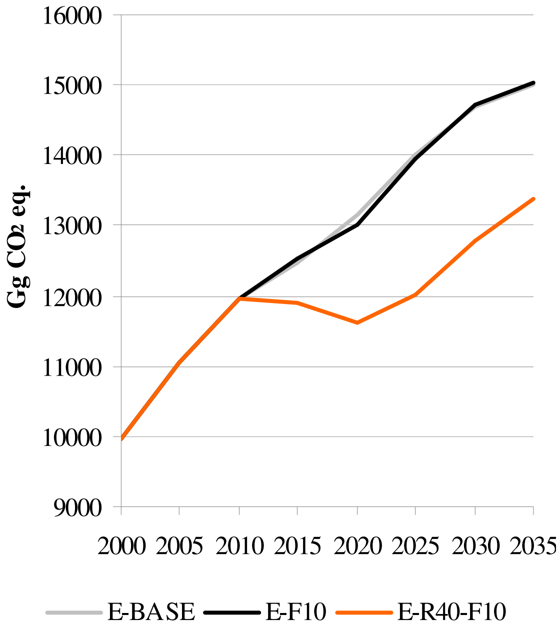

Fig. 6. **Total GHG emissions in Latvia: history and modelling results**

An important part of the presented study is the evaluation of the economic performance indicators of the scenarios "E-F10" and "E-R40-F10" compared with the "E-BASE" scenario (see Table 1). These indicators are evaluated annually average for 3 different time periods: (i) short-term, 2015-2020, (ii) long-term, 2015-2030, and (iii) a 50-year period, covering 2000-2050. The additional cost assessment approach is based on an alternative scenario modelling and comparing the obtained results with those of the BASE scenario. For further comparing of the costs the time-line segment of 2015-2030 is selected as it shows the impact of investments on costs more accurately.

Table 1

Economic performance indicators, compared with "E-BASE" scenario

Scenarios	**2015-2020**	**2015-2030**	**2000-2050**
Additional costs from GDP, %			
E-F10	0.09	0.09	0.06
E-R40-F10	0.35	0.39	0.21
GHG emissions reductions average costs, EUR(2010)·t^{-1} $CO_{2eq.}$			
E-F10	410	379	303
E-R40-F10	82	77	89
RES unit increase average costs, EUR(2010)·MWh^{-1}			
E-F10	52.6	43.2	46.5
E-R40-F10	21.2	22.4	27.6

The analysis of the modelling results reveals that the use of the 1st generation bio fuels in achieving the RES target and the GHG emissions reduction is one of the most expensive measures. The increase of one RES unit (MWh) when using bio fuels would cost nearly twice as much than the average cost of meeting the same target with other technologies used in the energy sector. Assessing the costs by using bio fuels for the GHG emissions reduction it may be noted that they are more than 4.5 times higher than the average available RES technology costs in the energy sector.

Expansion of the use of RES, including bio fuels, helps reduce the dependence on imported fossil energy resources. On the one hand, a wider use of RES requires additional investment in new technologies, but, on the other hand, it reduces the cost of imported energy resources. As shown in Fig.7, both the use of bio fuels in the scenario "E-F10" and the use of RES in the scenario "E-R40-F10" provide the benefits against the baseline, respectively 31 MEUR un 122 MEUR on average per year.

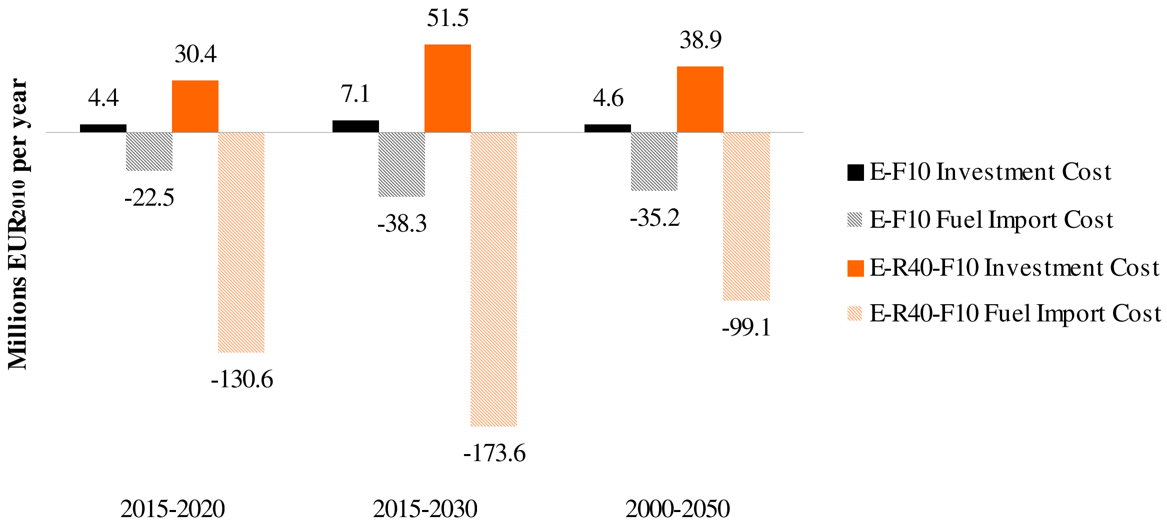

Fig. 7. **Undiscounted cost of annualized new investment and net fuel import vs E-BASE scenario**

Conclusions

1. The improved MARKAL-Latvia model with the 1st generation bio fuel pathways module provides an opportunity to assess the specific impact of RES technologies not only on GHG emissions in the energy sector, but also on the total national emissions.
2. The estimated 1st generation bio fuel GHG emissions reduction efficiency in Latvia's conditions is about 75 %. This means that from the use of bio fuel each unit of the reduced GHG emissions in the transport sector generates 0.25 units of GHG emissions in the agricultural sector.
3. On the basis of an alternative scenario modelling results it can be concluded that the use of the 1st generation bio fuels can help reduce the costs of imported energy resources, but it is one of the most expensive RES target achieving measures as the GHG emissions reduction costs are significantly higher than those of other policies and measures.
4. Consequently, the use of the 1st generation bio fuel technology for meeting the EU 2030 framework for climate and energy policy targets at the current stage of development is questionable and attention should rather be paid to the development of the 2nd generation bio fuels and other GHG reduction options.

Acknowledgement

This paper has been supported by the Latvia National Research Programme 2014-2017 "The value and dynamic of Latvia's ecosystems under changing climate (EVIDEnT)".

References

1. The EU 2020 climate and energy package. [online][7.12.2014] Available at: http://ec.europa.eu /clima/policies/package/index_en.htm.
2. Effort sharing decision (Decision No406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020). Official Journal of the European Union, L140/136-148, 5.6.2009.
3. Directive 2009/28/EC (Renewable energy directive) of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and

amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Official Journal of the European Union, L140/16-60, 5.6.2009.
4. The EU 2030 framework for climate and energy policy. [online][7.12.2014] Available at: http://ec.europa.eu/clima/policies/package/index_en.htm.
5. Klāvs G., Reķis J. Latvijas enerģētikas attīstības scenāriju modelēšana (Modelling of Latvia's energy sector development scenarios). Research contracted by the Public Utilities Commission. Rīga: Institute of Physical Energetics, 2012, 35 p. [online][7.12.2014] Available at: www.sprk.gov.lv/uploads/doc/atskaiteregulators.pdf. (In Latvian).
6. Klāvs G., Reķis J. Latvijas enerģētikas attīstības scenāriju modelēšana laika posmā līdz 2030. gadam, ņemot vērā ekonomiskos, vides un politiskus aspektus (Modelling of Latvia's energy sector development scenarios up to 2020, taking into account economic, environmental and politics considerations). Research contracted by the Ministry of Economics Republic of Latvia. Rīga: Institute of Physical Energetics, 2012, 60 p. [online][7.12.2014] Available at: https://web.archive.org/web/20130806083405/http://em.gov.lv/em/2nd/?cat=30166 (in Latvian).
7. Klāvs G., Reķis J. Enerģētikas un vides rīcību politiku integrēta plānošana ilgtspējīgai attīstībai un labai pārvaldībai (Energy and environmental policies integrated planning for sustainable development and good governance). Research paper. Rīga: Soros Foundation-Latvia, 2012, 64 p. [online][7.12.2014] Available at: http://www.sfl.lv/public/30608.html. (In Latvian).
8. Fishbone, L.G., Abilock H. MARKAL, A Linear Programming Model for Energy Systems Analysis: Technical Description of the BNL Version. International Journal of Energy Research, Vol. 5, No. 4, 1981, pp. 353-375.
9. Loulou, R., Goldstein, G., Noble, K. Documentation for the MARKAL Family of Models. Energy Technology Systems Analysis Programme, 2004, 389 p. [online][7.12.2014] Available at: http://www.iea-etsap.org/web/MrklDoc-I_StdMARKAL.pdf.
10. Loulou, R., Lavigne, D. MARKAL Model with Elastic Demands: Application to GHG Emission Control", In: Operations Research and Environmental Engineering, Carraro, C. and Haurie, A. eds., Kluwer Academic Publishers, Dordrecht, Boston, London, 1996, pp. 201-220.
11. The EU Intelligent Energy Europe Programme: The Biograce ("Harmonised calculations of bioenergy greenhouse gas emissions in Europe") project. [online][7.12.2014] Available at: http://www.biograce.net.
12. Well-to-Tank Report: version 4.a. JEC – Joint Research Centre-EUCAR-CONCAWE collaboration, 2014. [online][7.12.2014]Available at: http://iet.jrc.ec.europa.eu/about-jec/downloads.
13. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. The Intergovernmental Panel on Climate Change. Available at: http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html.
14. Central Statistical Bureau of Latvia. Statistics databases (Agriculture, Forestry and Fishery): LAG004, LAG015, LAG016. [online][7.12.2014] Available at: http://data.csb.gov.lv/pxweb/en/lauks/lauks__ikgad__03Augk/?tablelist=true&rxid=a79839fe-11ba-4ecd-8cc3-4035692c5fc8.
15. Latvia national inventory submission under UN Framework Convention on Climate Change: Common Reporting Format (CRF), 2014. [online][7.12.2014] Available at: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php.