Report

Horizon 2020 project "*Advancing Sustainable Circular Bioeconomy in Central and Eastern European Countries (BIOEASTsUP)*" grant agreement No 862699

Bioeconomy: policy simulation tool

Developed by

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Task description

This task corresponds to work package 1 (WP1) Task 1.3. **Developing a CEE Virtual Toolbox** Step **2 Demonstrate a tool**: and is developed by RTU.

The task main aim is to provide virtual toolbox for bioeconomy strategy development.

CEE virtual toolbox provides guidance to use existing analytical and policy tools to better understand the bioeconomy potentials (i.e. biomass availability, regional stakeholders, innovative value-chains). The overall objective of WP1 is to support BIOEAST countries in the development of national bioeconomy strategies. CEE toolbox for supporting the process, analyse the capacities of and relationships between the actors. The overall objective of the task is to develop a Virtual Toolbox (VRT) to be used by BIOEAST countries in the development of their national bioeconomy strategies.

Step 2: Demonstrate a tool: perform simulation assessment of the level of support for bioeconomy strategy development and the impact on the national economy in the BIOEAST countries. An existing system dynamic model (that is "white box" causal-descriptive modelling tool) that has been created for Latvia will be used to simulate assessment in Poland. The efficiency and sustainability of policy instruments will be assessed together with the activities promoting bioeconomy development with respect to the related value chains in the BIOEAST countries.

Abstract

Main topic: Interactive tool

Document/search engine: Bioeconomy: policy simulation tool

Framework project: EEA grant project "Development of bioeconomical model for sustainable use of biological resources in order to reduce climate changes and improve adaptation capacity (BIO-CLIMATE)"

Within Horizon 2020 project "Advancing Sustainbale circular Bioeconomy in Central and Eastern European Countries (BIOEASTsUP)" model was upgraded, data renewed and tool made accessible to policy makers based on system dynamic model.

Short name of the project: BIO-CLIMATE, BIOEASTsUP

Website link: https://exchange.iseesystems.com/public/testlearntestsagain/bioekonomika/index.html#page1

Short description: Inspection tool for bioeconomy policy makers. Allows to look at and manage employment, financial and greenhouse gas emission data related to cultivation of crops, forests, and production of added value products from certain raw materials. Interconnects macro, meso and micro scale of bioeconomy. Main measures represented are turnover of bioeconomy, added value and employment, investments, GHG emissions and land use. In addition, location quotient, bioeconomy labour productivity and added value to turnover parameters also are shown as output. There are several changeable parameters available for modelling: Added value products, product price, unit production costs, other costs, discount rate, specific investment in technology, organic land fraction, value chain selection (on/off) and subsidies.

Countries/regions described/represented: Latvia

Year: 2015 – 2016

1. Background of the bioeconomy policy simulation tool: Inside of the model

System dynamic modelling is “white –box” causal descriptive modelling tool. This tool was created in order to facilitate bioeconomy policy design. General framework includes bioeconomy sectors, their land use, production and consumption of raw material, research and development, investments in and utilization of labour, finances (value creation, capital and operating costs and profit) [1].

Jay W. Forrester’s *The System Dynamic National Model* is a frontrunner of the field focusing on interlinks between national macro and microeconomics policy decisions [2][3]. Bernardo and D’Alessandro in 2016 used system dynamic approach to asses’ impact of low carbon investments on long term provisions [3] and fallowing work with tool for national sustainable development planning in China [4]. The research carried out by *Musango, Brent and Bassi* focussed on exploring the contribution of technology policies to the transfer to a green economy model of South Africa via integrated, system dynamics approach [5]. There are numerous academics that have analyse macroeconomics via system dynamics in reference to green and sustainable economics [3]. It is acknowledged that system dynamics approach for sustainable development policy is feedback rich and thoroughly integrated helping identify policies that would benefit sustainable development goals (SDGs) and trade-offs [6]. Toward a flexible integration of modelling tools to support informed policy making and regular monitoring in order to connect indicators from micro, meso and macro scales they should be dynamically interconnected and linked with SDG for bioeconomy by using system dynamic modelling (software such as *Vensim*, *Stella* or *AnyLogic*) [7].

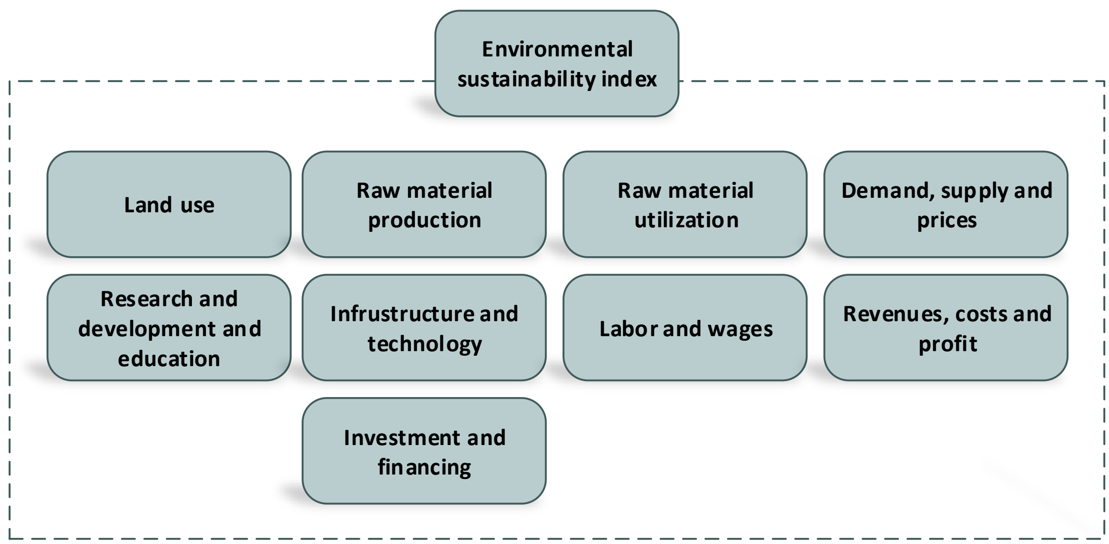

Fig. 1.1. Structure of bioeconomy model [1]

Generic structure of the developed bio economy model, see Fig.1., consists of 10 interrelated modules. Land and raw materials production is first and most important in bio economy, current land use is determined by the yield of production of different bio products by land and price of commodity. Yield shows the productivity how much of commodity may be produced by hectare of land. Raw material utilization and the production of derivatives, where they can be sold with minor or no processing (e.g. apples or firewood), however there is possibility after processing sold more goods with higher added value (e.g. apple cider or plywood). It will also add the demand for labour and capital investments. Revenues are determined by volume sold and price obtained. The revenues must justify costs allocated with production costs, that consists of capital costs. Products are assumed to be sold at fixed price that corresponds to market prices. The costs of labour reflect the level of education to be held by workforce. This is determined by technology-level characterizing the physical capital employed. Research and development is important for new product and production line creation as well as improved productivity of existing value chains or capital efficiency through technology improvements. Environmental sustainability is calculated as emergy expenditures [1]. Environmental sustainability index (ESI) is viewed inside the model, at the level of individual production output, if ESI > 1 then an emergy tax is applied to the product. ESI is not included in the interactive tool, because the impact is very low and it will not give a substantial information for decision makers in this case.

This model adds the possibility to explore feedbacks that link value added by production of derivatives calculated per unit of land or raw materials by allocating land use and the production of such materials to the allocation of materials for different production chains [1].

Some policy issues that can be addressed by use of this model:

- How should the land be allocated across alternative forms of primary resources (raw materials) production in order to reach higher added value per unit of land[1] . ***In the interactive tool the prices and costs of products can be changed, therefore the amount of land allocated to cultivation will change.***
- How should the raw material be allocated across alternative forms of production of derivatives, taking into account total value added per unit of raw material[1]
- How should investments in research, development, capital and labour be made, considering resulting total value added per unit of investment[1] Jā var apskatīties slēdzot ON OFF ķēdes un mainot pārdošanas cenas vai izmaksas. ***In the interactive tool it can be viewed by switching the ON/OFF value chains and changing the selling price or cost.***
- How may subsidies contribute to redirect the land use, flows of material, investments in research, development, capital and labour in the direction of high value added production lines [1]. ***In the interactive tool by reducing the total cost, profits increases, and the distribution of land depends on total production. Therefore, increasing subsidies increases profits and increases the area under which a particular raw material is grown.***

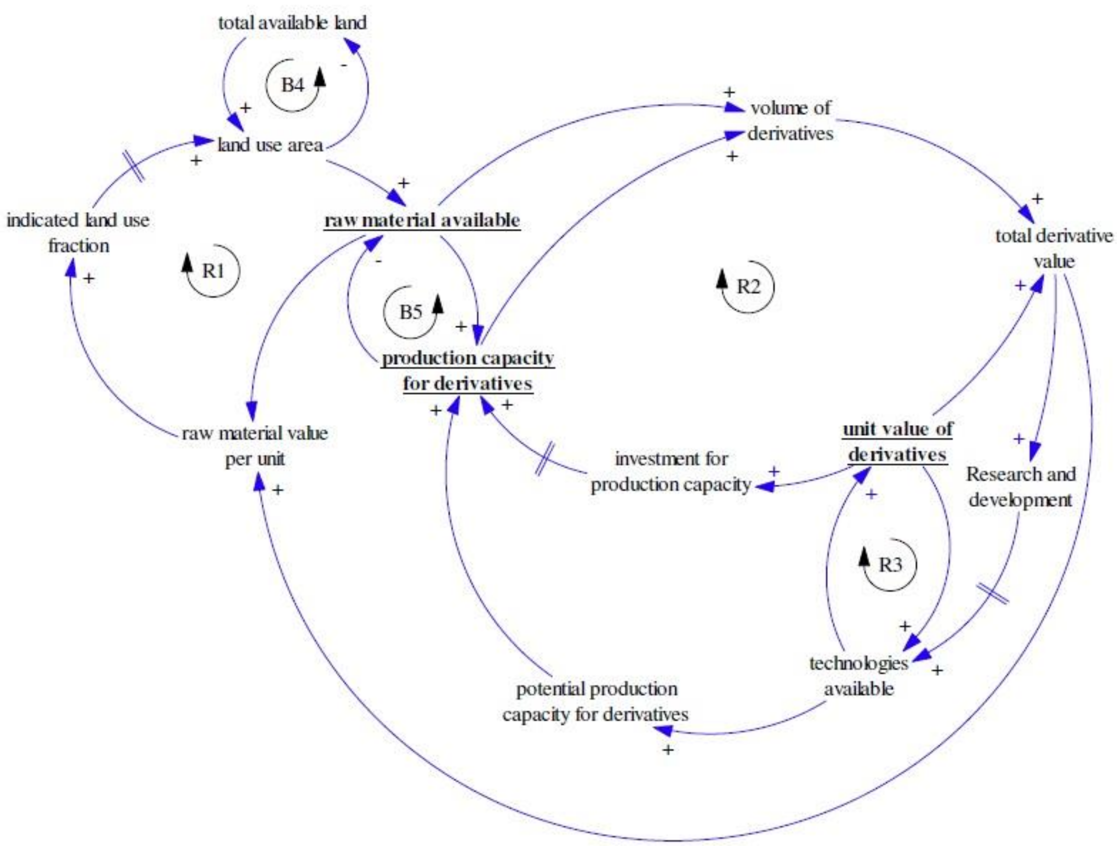

Fig. 1.2. Causal loop diagram illustrating structure of the model [1]

Main stock and flow causal loop diagram is seen in fig.1.2. with four reinforcing and one balancing loop. This illustrates feedback structure of the system [1]. Second balancing loop is seen in fig. 1.3.

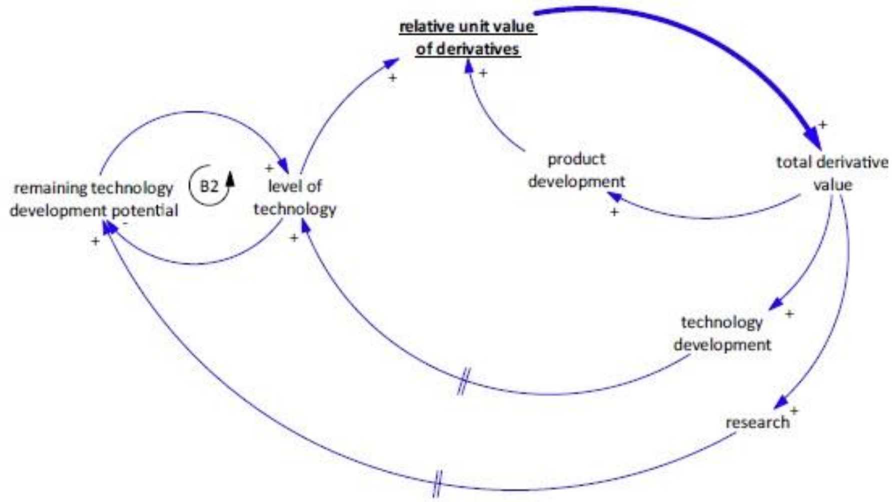

Fig.1.3. Causal loop diagram illustrating the main structural components of the model: the three processes that may modify the relative unit value of derivatives [1]

The main question for policy design is about instruments to be used for higher added value creation from the national bio resources while maintaining sustainable development. To increase availability of raw materials several political instruments can be used: support for production of certain raw materials, diverting raw material export to the production of higher added value within country, by supporting research, development and education that could lead to higher efficiency. Support for investment (e.g. subsidies) can positively reflect to production capacities [1].

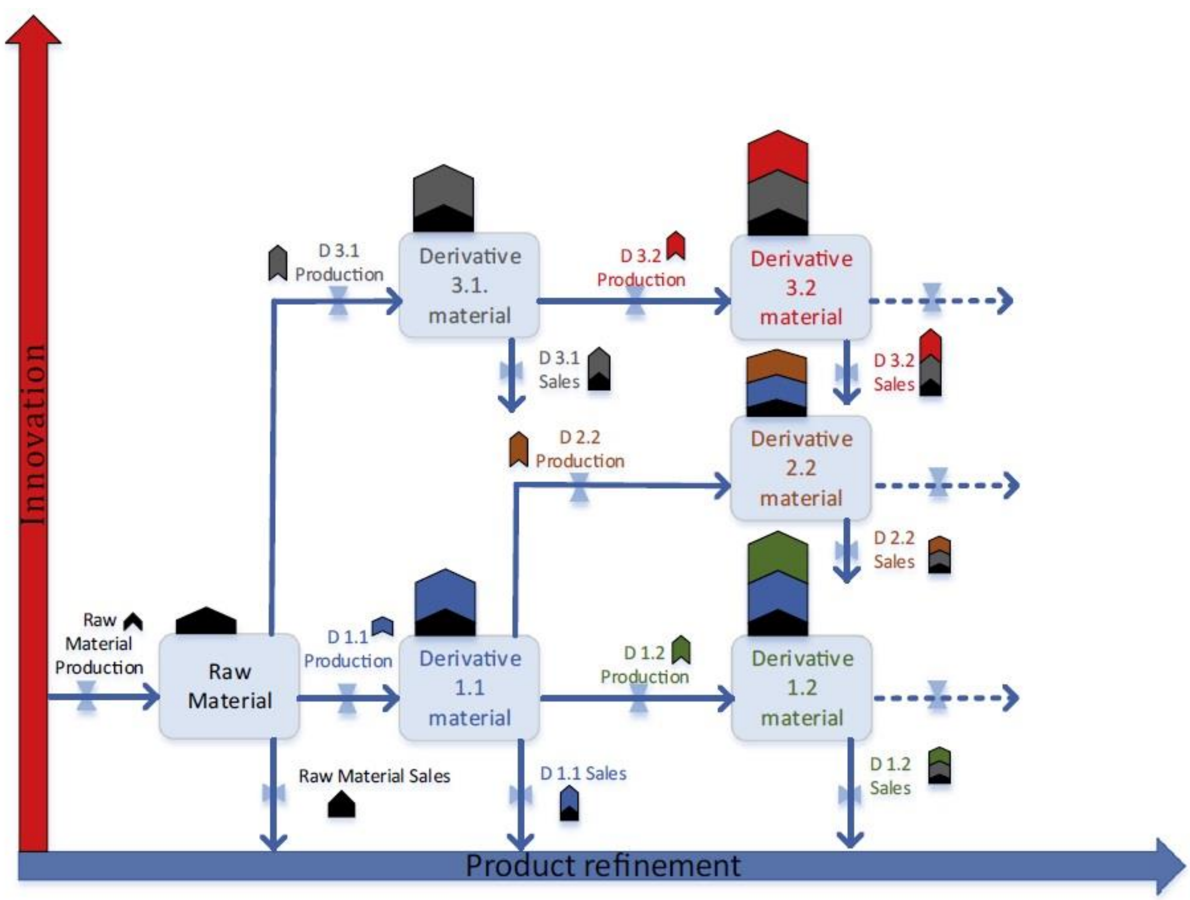

Fig. 1.4. Added value chains for product lines created from raw material [1]

Fig.1.4. shows application example of added value chains for product lines where raw material sales are with lowest added value, but with increasing production the added value also increases [1]. Unit value of derivatives may increase if demand for raw materials used for production exceeds supply or value is added by more knowledge. Unit value also can be increased by more efficient use of resources for production, which is also promoted by "technologies available" [1].

2. Platform of the bioeconomy policy simulation tool: outside of the model

This tool is based on existing system dynamic model that is developed in project BIO-CLIMATE. In BIOEASTsUP project SD model has been updated with data, also it is transferred from interface in *Powersim Studio* to more superior interface – *Stella Architect*, that provided an opportunity to make an interactive tool platform for stakeholders and decision makers.

Main purpose of building this interactive tool is to transfer existing complex bioeconomy model available for stakeholders and policy makers in more easy to understand way with main parameters as output and changeable parameters for opportunity to see the impact on them. There are limitations on parameters that can be easily perceptible in one page, therefore interface is made in several pages, trying to cover different stages of the model (from national point of view to sector analysis to value chain analysis).

Therefore, main characteristics were chosen according to European Union updated bioeconomy strategy bioeconomy main measures – turnover of bioeconomy, created value added and employment (referring as jobs)[8] and in addition investments, GHG emissions and land use. Also includes location quotient, bioeconomy labour productivity and added value to turnover.

System dynamic model is unique for each country, it can be adapted to other countries and in this project adaptation for Poland case is under development by IUNG with close collaboration with RTU. However, this is first attempt for transforming bioeconomy system dynamic model to an interactive platform for stakeholders and policy makers and provides a good knowledge base on how the results and modelling possibilities can support policy makers for bioeconomy strategy development.

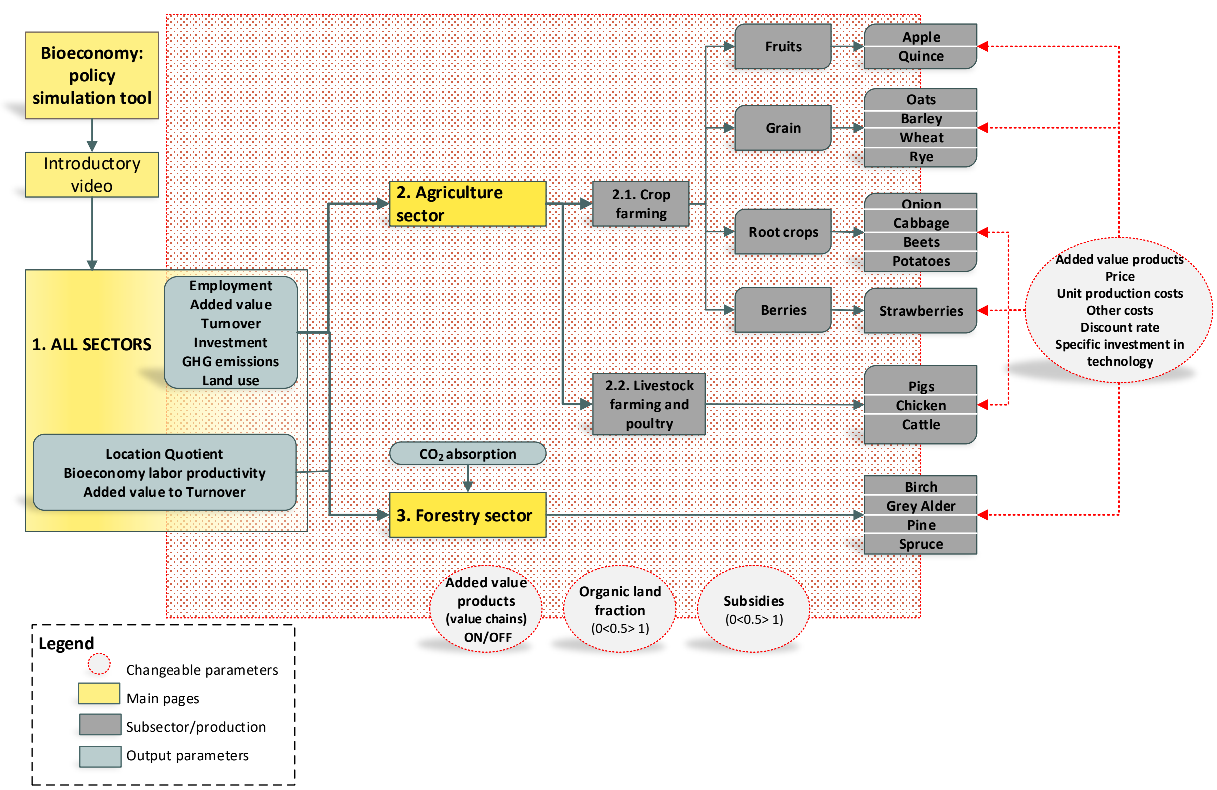

Fig. 2.1. Main structure of bioeconomy: policy simulation tool

Main structure of bioeconomy policy simulation tool starts with introductory part and introduction video that shows in brief how to use the tool, see fig.2.1. for main structure of interface. Four main pages identified is all sectors page, agriculture sector page, forestry sector page and bioeconomy complex indicator page. Furthermore, there are subpages for agriculture that divides into crop farming and livestock farming and main production groups – fruits, grains, root crops and berries. As for forestry sector it is birch, grey alder, pine and spruce. Each of the page is further described into details.

Table 1. Production value distribution

Production value	Intermediate consumption	Raw materials
		Materials
		Services
		Energy
	Added value	Labour force
		Depreciation
		Interest payments
		Taxes on production
		Profit

Employment is measured in full time equivalent (FTE), annual added value is measured as EUR /year in calculation added value includes labour costs, depreciation, interest payments, taxes on production and profit, see table 1. Accumulated added value is measured in EUR, Annual investments EUR/yr and accumulated investments EUR. Annual CO_2 emission equivalent, t/year and accumulated CO_2 emission equivalent, t. Land use in hectares.

Page "Introduction"

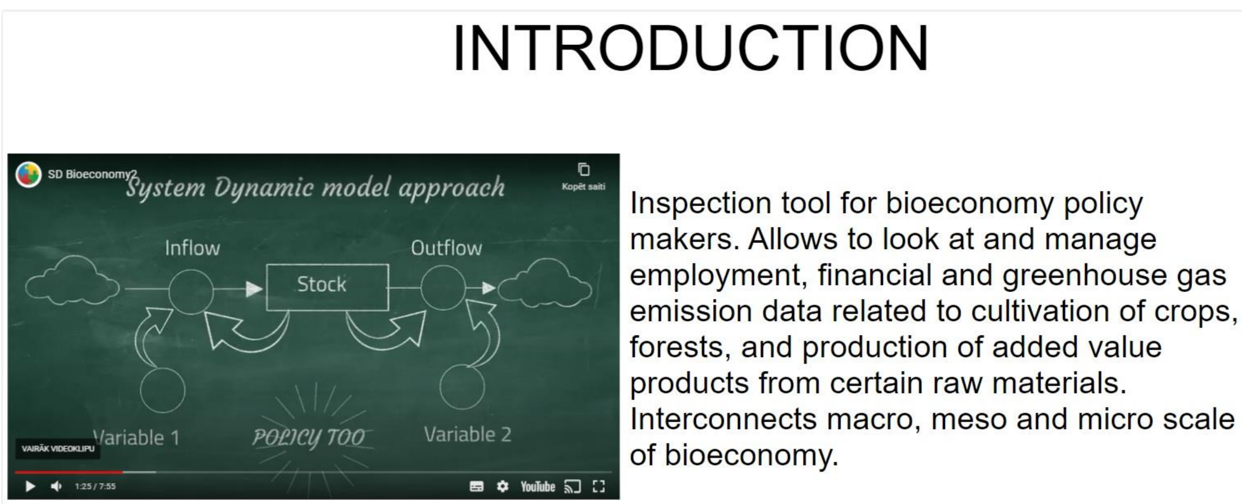

Fig. 2.2. Introduction of bioeconomy inspection tool

In introduction page you can find short description of tool and introductory video, see figure 2.2., that consists of two main parts – first part describes overall perspective on bioeconomy policy tool use and aim, and second part instructs on how to use the tool.

Page 1 "All sectors"

In page "All sectors" bioeconomy primary sectors are shown (forestry and agriculture), fisheries model in Latvia is under construction and is not included in this tool. Parameters that are shown to characterise all sectors are employment, added value, turnover, investments, GHG emissions and land use. Some parameters are shown also as accumulated values (like turnover, added value, investment and CO_2 equivalent) There is also a button where stakeholders can change "organic land fraction" changes from 0 to 0.5 to 1, for modelling and see the impact. The impact from organic land fraction changes can be seen for GHG emissions. Button subsidies allows to see changes if subsidies are introduced for different sectors.

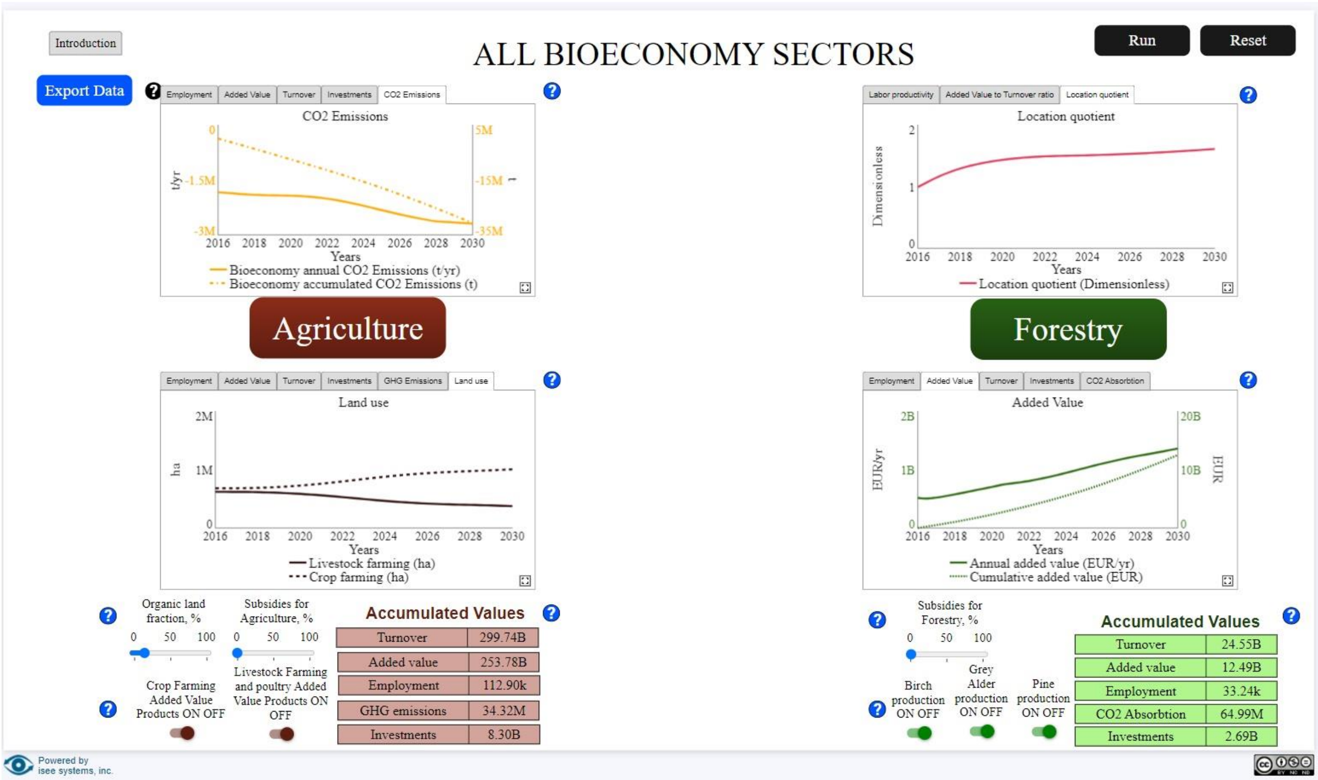

Fig.2.3. Main structure of the overall country level assessment of primary sectors

Main structure that is seen in model, see fig.2.3., is based on two main primary bioeconomy sectors –forestry and agriculture. Countries that have substantial part of aquacultures, should include also this sector. For Latvia fisheries aquacultures covers small part of bioeconomy therefore in model this part is still under development. However, for development of bioeconomy it has great potential in Latvia, therefore it will be modelled in future.

Use run button to activate simulation after changes has been made or reset simulation if you want to undo the changes and return to starting point of parameters. In this page it is also an option for selection of production in sectors, buttons "on and off"– for whole value chain selections: for agriculture it is for crop farming added value products and livestock farming added value products (on/off) and for forestry: birch production, pine production and grey alder production (on/off).

You can also export data (left upper corner).

If there are any questions about graphs or variables, press help button ? next to it.

Page 2 "Agriculture sector"

Agriculture sector divides in two main categories: crop farming and livestock farming, see fig.2.4. Results shown in crop farming employment, crop farming added value, turnover, Investment in crop farming technologies and crop farming GHG emissions, and land use. The same parameters can be seen for livestock farming. In agriculture sector page there are crop farming and livestock farming with possibility to select *"***on"** or "**off"** fruits added value production, root crop added value production, grain added value production, berries added value production that corresponds to crop farming and cattle added value production, pigs added value production and chicken added value production that corresponds to livestock farming.

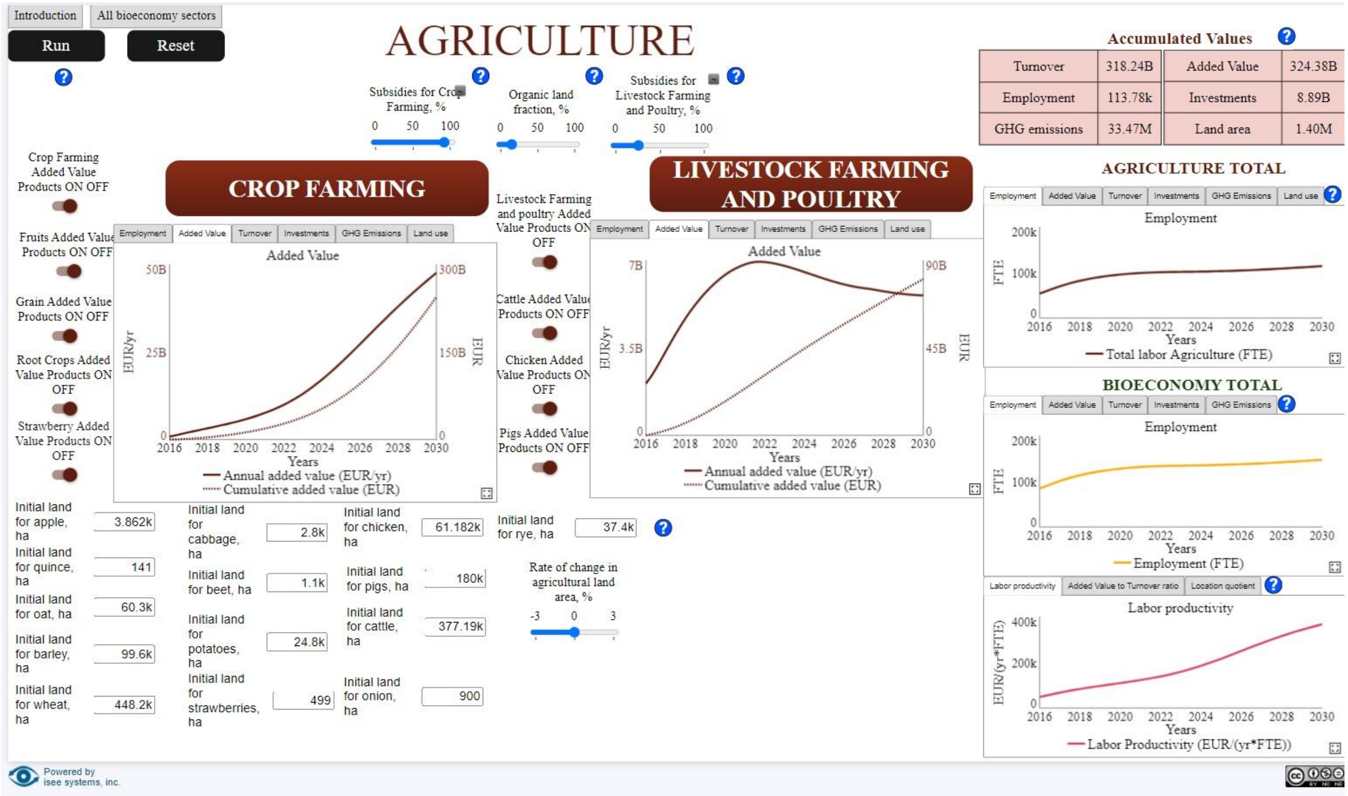

Fig. 2.4. Structure of the agriculture sector assessment

Also active buttons are “crop farming” and “livestock farming” that moves to the pages with more detailed analysis of each sub-sector. Livestock farming also includes poultry. There is active button for modelling organic land fraction for agriculture and subsidies for crop farming or livestock farming and poultry. Here is possible to change input data according to land that is accessible in country.

Page 2.1. “Crop farming”

All sub-sectors have the overall descriptive values seen in right upper corner, that shows accumulated added value, employment, turnover, investments, GHG emissions and land necessary for selected value chains and production, these values also change in corresponding changes made in value chains.

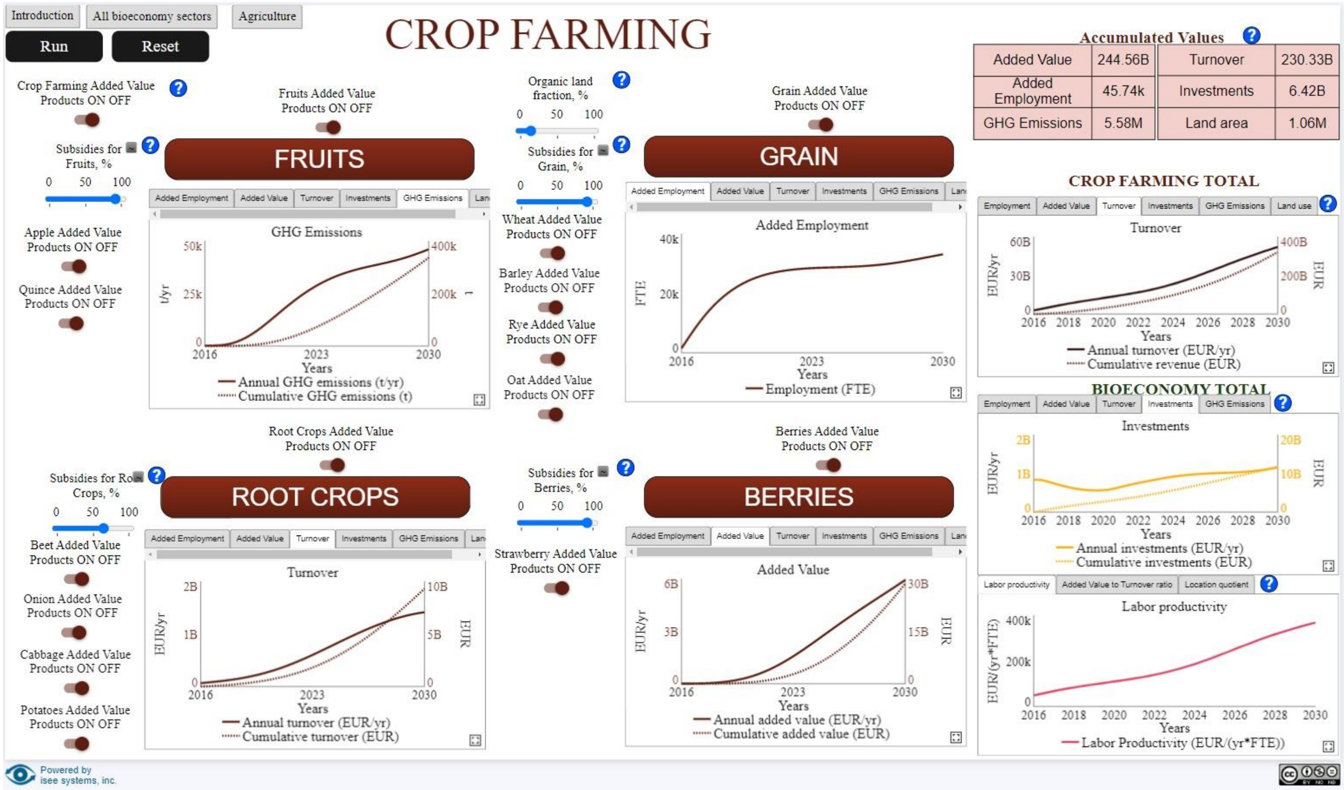

Fig. 2.5. Assessment of the crop farming

Crop farming division seen in fig. 2.5., are fallowing fruits, that includes basic production and value added product production: apple added value products (possible to select on/off production), quince added value products, grain, that includes wheat added value products, rye added value products, barley and oat added value products. Root crops includes beet, onion, cabbage, and potatoes added value products and berries contains strawberries added value products. There is an option to go into detail in each of the proposed crops – button “fruits” will lead to next page with value chains of different fruits presented, the same with buttons “root crops”, “grain” and “berries”.

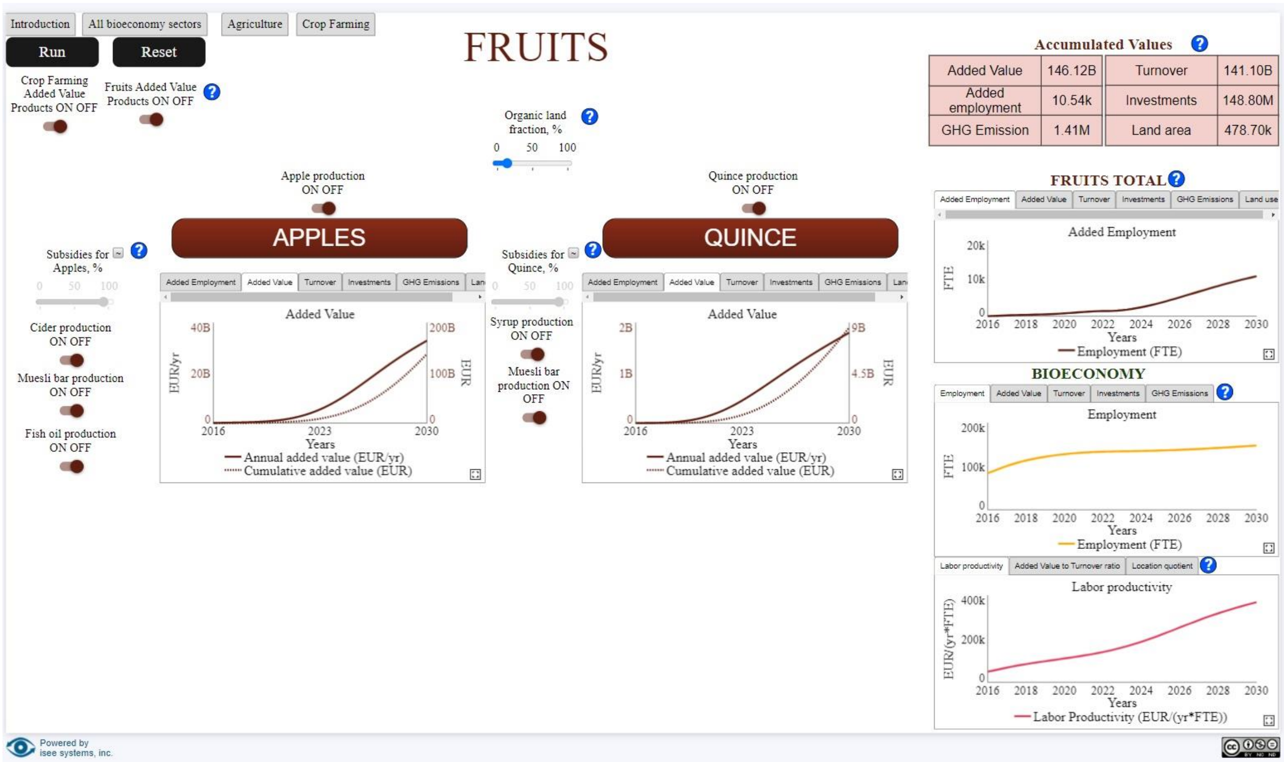

Fig. 2.6. Assessment of fruits production

In fruits(fig.2.6.) production section there are two main fruits – apple and quince. It is possible to select or unselect some product production and see the impact on overall performance.

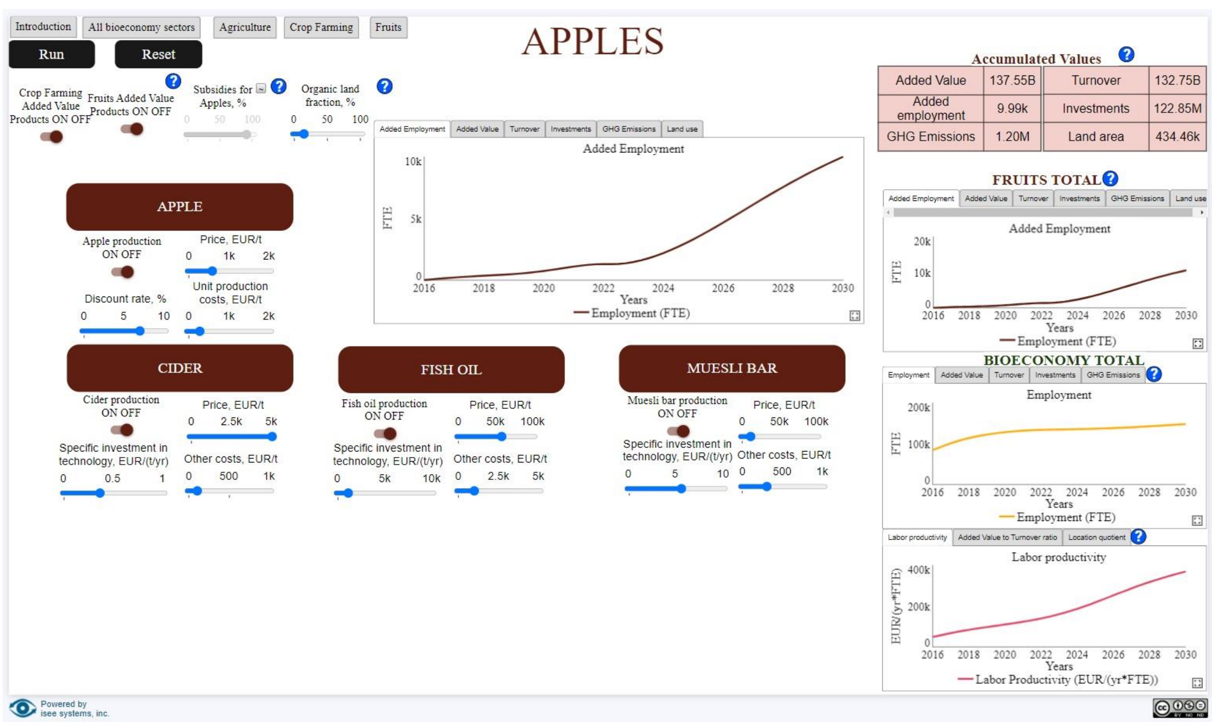

Fig. 2.7. Assessment of apples production

There are also detailed production variables: product price. Unit production costs, discount rate and specific investment in technology for each of the product chains.

Production chains (existing and new) for fruits are apple production, cider production, apple muesli bar production, fish oil production, quince production, quince syrup production and quince muesli bar production.

Grains taken into account are oat, barley, wheat and rye. Production chains for oat are colloidal oatmeal production, *Beta glucan* (oat) production, oat straw extract production. For barley it is beer production, leftover cookies production, Beta *glucan* (barley) production and barley straw extract production. For wheat – wheat production, starch and gluten production, gliadin and glutamine production, *ferulic acid* production, wheat germ oil production and ethanol (wheat) production. And for rye: rye production, kvass production, *arabinoxylan* production and ethanol (rye) production.

Root crops included in the model are onions, cabbages, beets and potatoes. Production chains (existing and new) for onions are quercetin powder production and biogas(onion) production. For cabbages it is cabbage extract powder production and cabbage powder production. For beets beetroot powder production and biogas(beet) production. For potatoes starch production, biogas (potatoes) production and *solanesol* production.

Page 2.2. “Livestock farming and poultry”

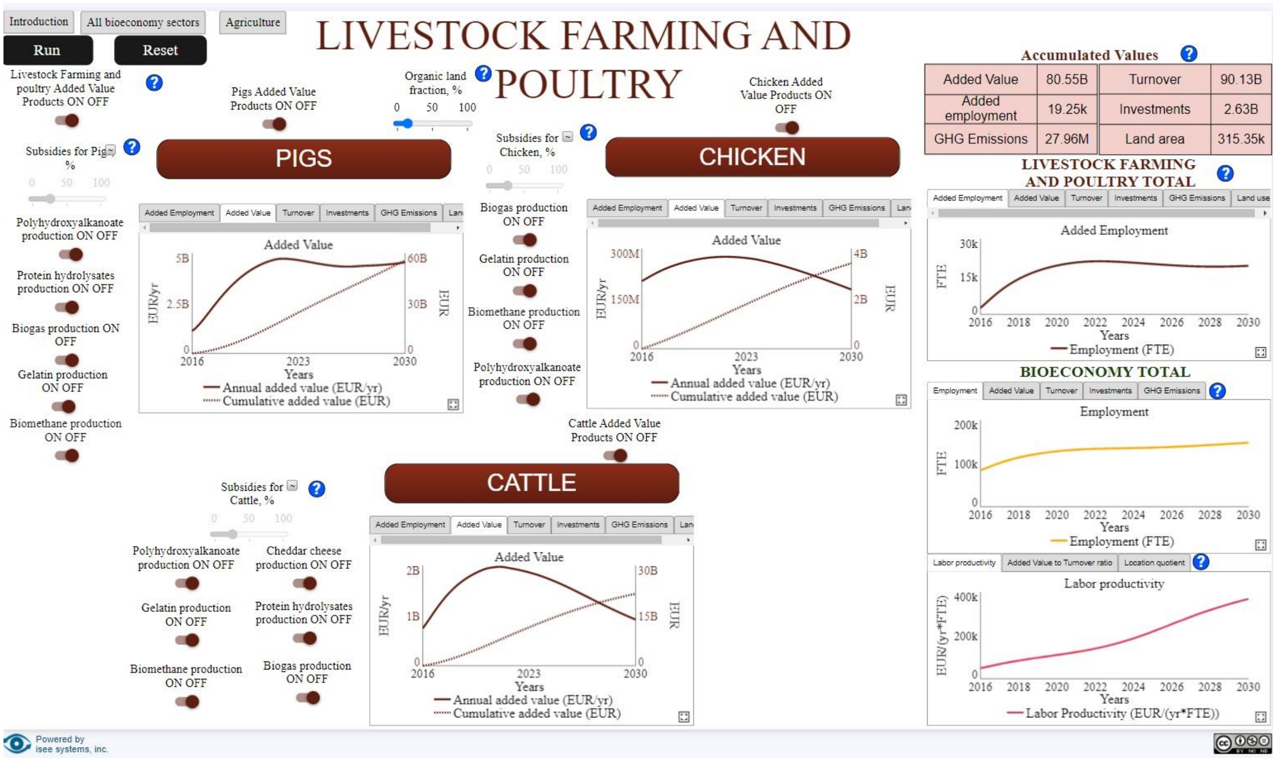

Fig.2.8. Structure of the agriculture sub-sector assessment: livestock and poultry

Livestock farming (fig.2.8.) looks at main breeding types in Latvia – cattle and pig breeding. Poultry looks at chicken farming (both meat production and egg production). For pigs’ production chains included in model are pork meat production, *polyhydroxyalkanoate*, protein hydrolysate, biogas and gelatine production.

Cattle production(fig.2.9.) includes cattle meet and milk production, also *polyhydroxyalkanoate,* protein hydrolysates, rennet production, cheddar cheese production, biogas and gelatine production.

For poultry (chicken) – chicken meat, egg production, *polyhydroxyalkanoate,* keratin production, biogas and galantine production.

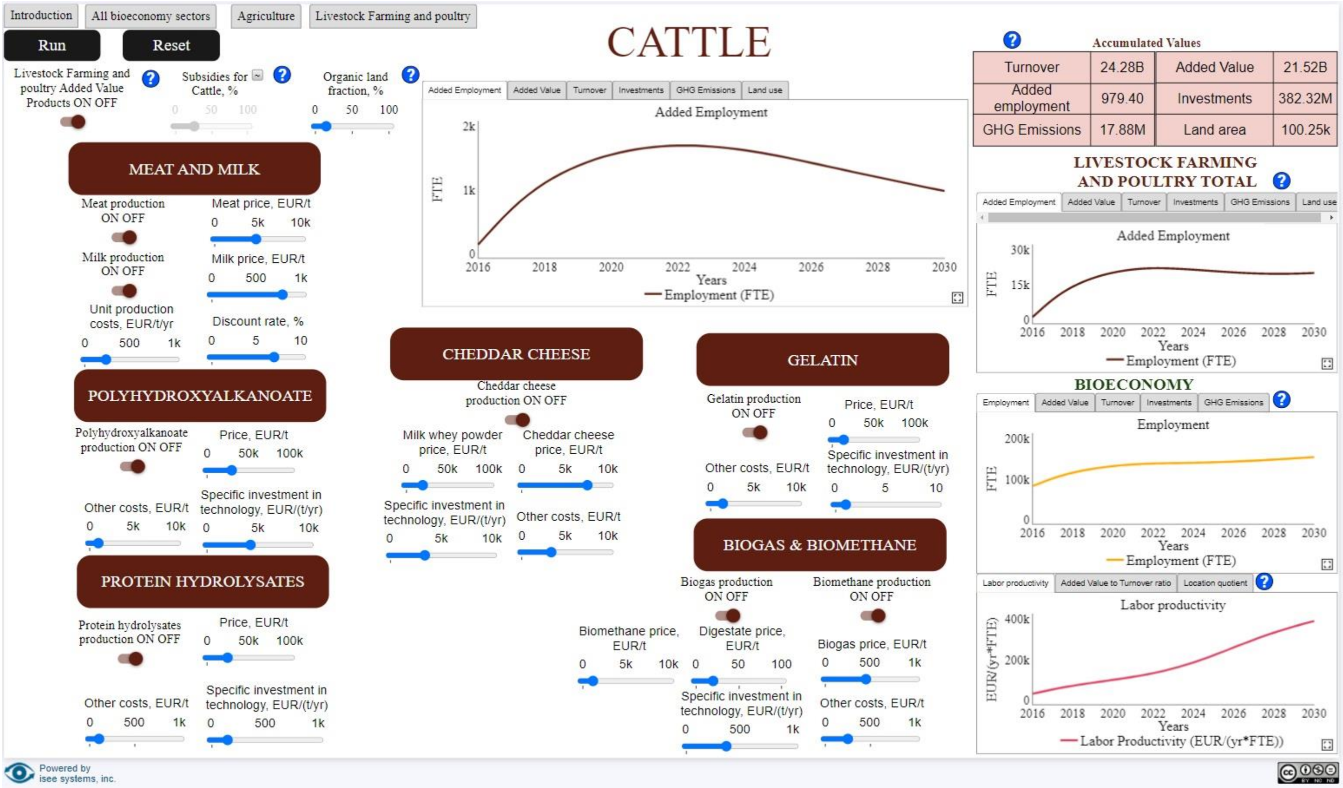

Fig. 2.9. Cattle production value chains assessment

Example of cattle value chains characteristics. For previously mentioned value chains (existing and new) included in cattle production it is possible to model by changeable parameters: selection of individual value chain (on/off), selection of product prices (values differs according of price ranges and existing prices), so the price ranges for simulation differs for different products, selection of discount rate, and selection of specific investments in technologies, as well as other costs. Same goes for chicken and pigs value chain characteristics in their pages.

Page 3 “Forestry sector”

Forestry sector compiles birch, grey alder and pine production, see fig. 2.10. The additional measure for forests are accumulated CO_2 absorption value. In forestry sector there are not subsectors as agriculture, there are seen the main tree species in Latvia and their value chains (existing and new).

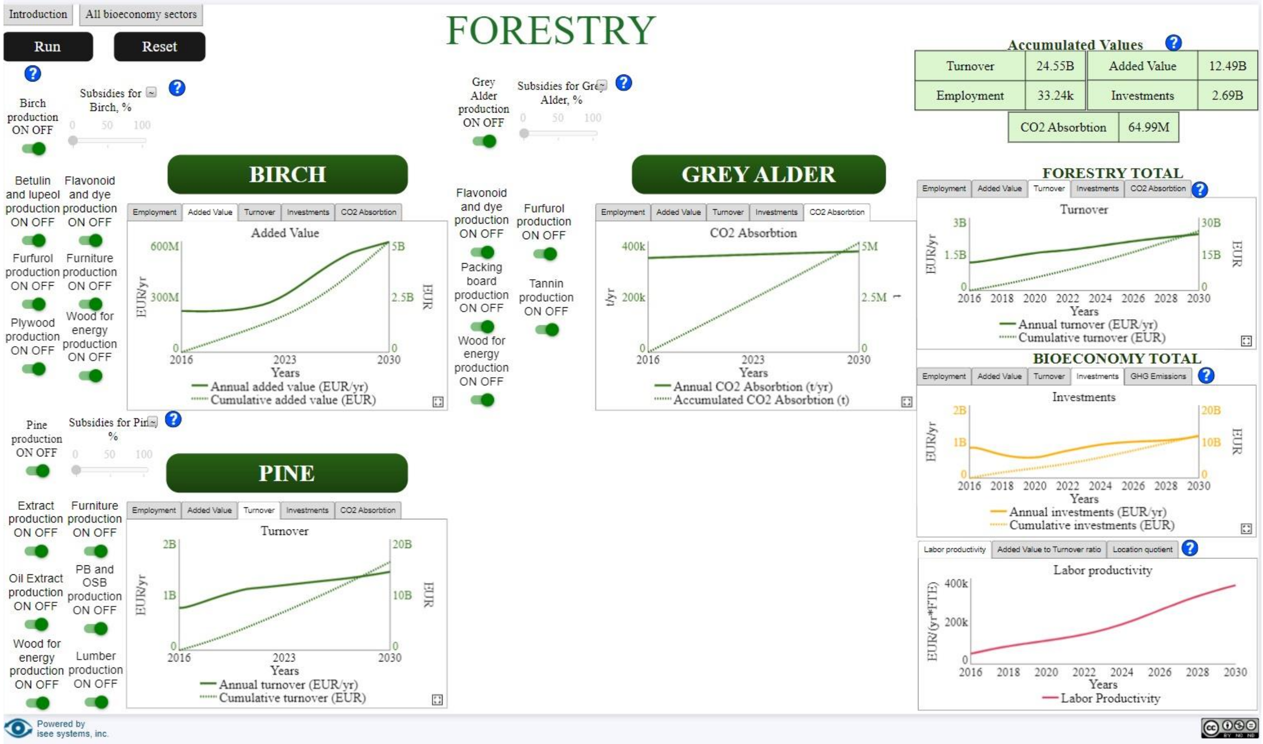

Fig. 2.10. Structure of the forestry sector assessment

Grey alder used for *furfurol*, bioethanol, *acetic acid*, lignin production, wood for energy, packaging board, tannin and *flavonoid* and dye extract production. Similar approach that was adapted for agriculture sector, also in forestry sector all three tree species are as active buttons to move in additional page and see value chains included in model with possibility to see the impact on overall performance in bioeconomy (total) and in selected sector.

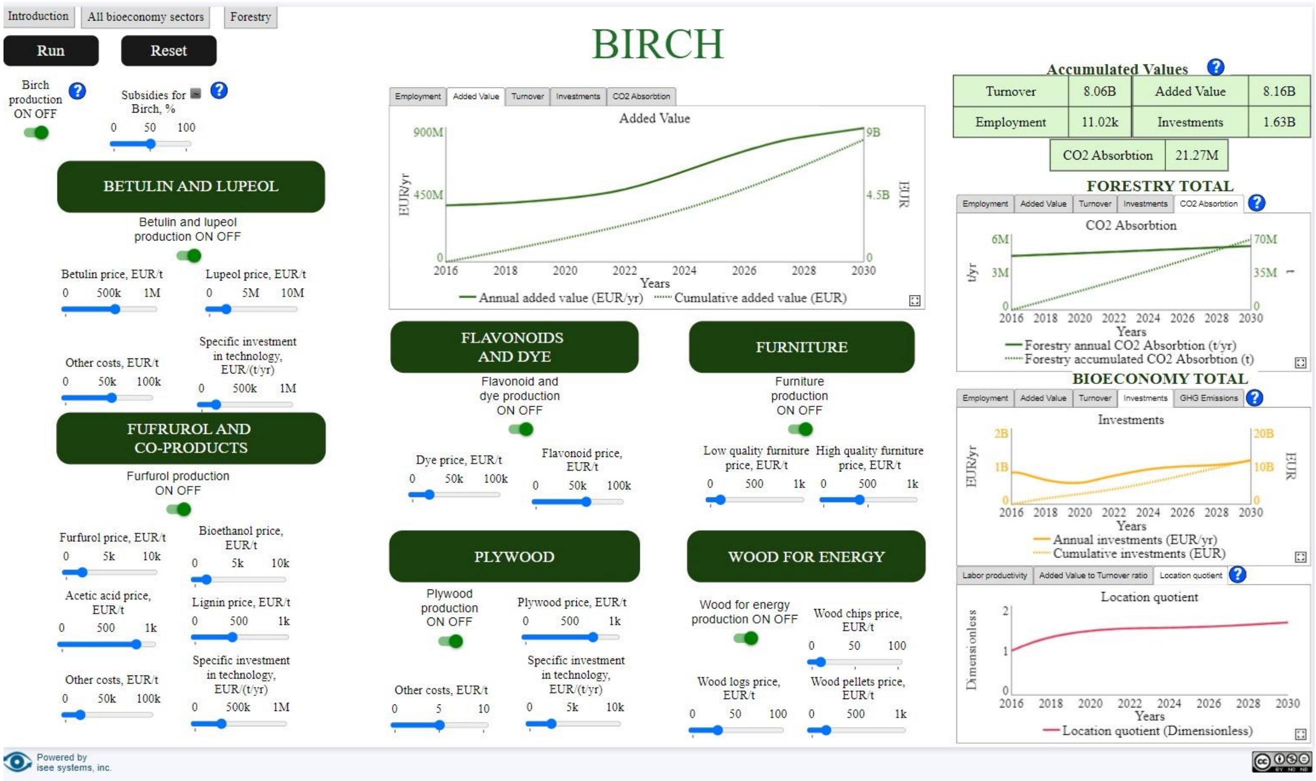

Fig. 2.11. Birch production value chains assessment

Example shown in fig. 2.11. is for birch production value chains included in model are flavonoid and dye extract production (with variables: *furfuol* price, bioethanol price, *acetic acid* price, lignin price, dye price Delivery Duty Unpaid (DDU), flavonoid price DDU), wood for energy production, *betulin* and *lupeol* production, plywood production and furniture production (low quality (LQ) furniture and high quality (HQ) furniture).

Pine wood used for lumber production, Particle board (PB) and Oriented Strand Board (OSB) production, oil extract production, wood for energy (logs, chips, pellets), bark extract and furniture production (low quality, high quality).

Grey alder value chains for selection are packaging board, furfural and co-products (such us lignin, bioethanol and acidic acid), tannins, flavonoids and dye and wood for energy (logs, pellets and wood chips).

Conclusions

1. The ability to make interactive tool from existing bioeconomy model provides available for policy makers and stakeholders as easily accessible model without necessity for knowledge on system dynamic model building and calculations.
2. Model created as generic framework model for bioeconomy sectors includes land use, production and consumption of raw materials, research and development, investments and utilization of production with their labour, finances and sustainability. Some of these characteristics are made as changeable parameters, some as output parameters and some are inside the model and works as link between parameters.
3. Subsectors shows not only generic structure of the system but also give insights in the structural details, explaining internal dynamics of the system.
4. This kind of tool can provide support for policy makers and with additional communication between academics and policy makers it is possible to make this tool for other countries. With existing country case model, it is easier to policy makers to decide on characteristics of the model: changeable and output parameters to include in their case and sectors to applied to, as well as what added value chains to include (only existing or also new and innovative value chains).
5. System dynamic model can be made in all three levels micro, meso and macro levels. It also gives opportunity to construct the model in different combinations to be applicable all three levels (meso, micro and macro). Therefore, providing framework of city, province, region, national development plans or urban symbiosis.

References

[1] A. Blumberga, G. Bazbauers, P. I. Davidsen, D. Blumberga, A. Gravelsins, and T. Prodanuks, “System dynamics model of a biotechonomy,” *J. Clean. Prod.*, vol. 172, pp. 4018–4032, 2018, doi: 10.1016/j.jclepro.2017.03.132.

[2] J. W. Forrester, “The System Dynamics National Model: Macrobehavior from Microstructure,” *Comput. Manag. Complex Syst.*, pp. 3–12, 1989, doi: 10.1007/978-3-642-74946-9_1.

[3] R. Azis, A. Blumberga, and G. Bazbauers, “The role of forest biotechonomy industry in the macroeconomic development model of the national economy of Latvia: A system dynamics approach,” *Energy Procedia*, vol. 128, pp. 32–37, 2017, doi: 10.1016/j.egypro.2017.09.011.

[4] W. Qu, W. Shi, J. Zhang, and T. Liu, “T21 China 2050: A Tool for National Sustainable Development Planning,” *Geogr. Sustain.*, vol. 1, no. 1, pp. 33–46, 2020, doi: 10.1016/j.geosus.2020.03.004.

[5] J. K. Musango, A. C. Brent, and A. M. Bassi, “Modelling the transition towards a green economy in South Africa,” *Technol. Forecast. Soc. Change*, vol. 87, pp. 257–273, 2014, doi: 10.1016/j.techfore.2013.12.022.

[6] M. Pedercini, S. Arquitt, and D. Chan, “Integrated simulation for the 2030 agenda,” *Syst. Dyn. Rev.*, vol. 36, no. 3, pp. 333–357, 2020, doi: 10.1002/sdr.1665.

[7] M. O’Brien, D. Wechsler, S. Bringezu, and R. Schaldach, “Toward a systemic monitoring of the European bioeconomy: Gaps, needs and the integration of sustainability indicators and targets for global land use,” *Land use policy*, vol. 66, no. December 2016, pp. 162–171, 2017, doi: 10.1016/j.landusepol.2017.04.047.

[8] European Commission, “The Bioeconomy Strategy. A sustainable bioeconomy for Europe: strengthening the connection between economy, society and the environment,” 2018. https://ec.europa.eu/knowledge4policy/node/33004_lv (accessed Feb. 11, 2020).