The Abdus Salam International Centre for Theoretical Physics

2490-7

Joint ICTP-IAEA Advancing Modelling of Climate, Land-use, Energy and Water (CLEW) Interactions

7 - 11 October 2013

Modelling of energy sector development with broader use of RES

A. Galinis
Lithuanian Energy Institute
Kaunas

Strada Costiera, 11 - 34151 - Trieste - Italy • Tel. +39 0402240111 • Fax. +39 040224163 • sci_info@ictp.it • www.ictp.it
ICTP is governed by UNESCO, IAEA, and Italy, and it is a UNESCO Category 1 Institute

Modelling of energy sector development with broader use of RES

A.Galinis

Lithuanian Energy Institute

Plan of presentation

Overview of the current situation;

Methodological approach for assessment of possible reaction of the Lithuanian energy sector to the changed situation and energy policy initiatives for broader utilisation of RES;

Overview of separate parts of the mathematical model representing processes of the CLEW approach:

land use,
growing of agricultural products,
irrigation,
forestry,
use of agricultural products for energy purposes,

Some results

Overview of the current situation

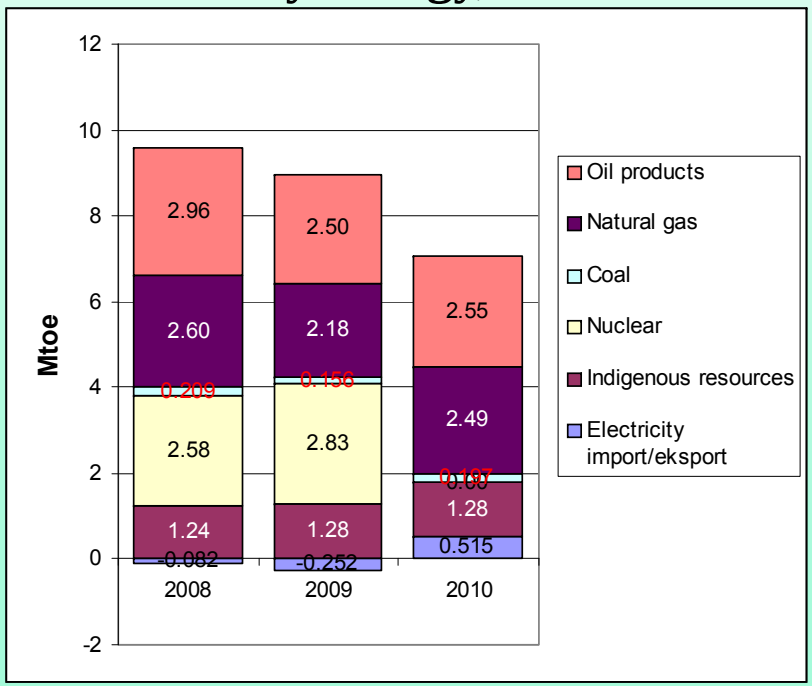

Lithuania
Sverige
Sweden
Suomi
Finland
Gulf of
Bothnia
Norge
Norway
Bergen
Oslo
Uppsala
Helsinki
Sankt-Peterburg
Stockholm
Tallinn
Baltic Sea
Eesti
Estonia
Göteborg
North Sea
Danmark
Denmark
Malmö
Lietuva
Lithuania
Gdańsk
Vilnius
Minsk
Kiel
Hamburg
Lübeck
Szczecin
Berlin
Bydgoszcz
Беларусь
Belarus
Nederland
Netherlands
Bremen
Polska
Poland
Dresden
Deutschland
Germany
België
Belgique
Belgium
Kraków
Česká Rep
Czech Rep
Ostrava
Frankfurt
am Main
Paris
Slovensko
Slovakia
München
Wien
Freiburg im
Breisgau
Österreich
Austria
Magyarország
Hungary
Zürich
Vaduz
France
Zagreb
Lyon
Milano
Torino
Bologna
Hrvatska
Croatia
Beograd
România
Romania
Genova
Toulouse
Marseille
Nice
Italia
Italy
Sarajevo
Србија
Serbia
Prishtinë
България
Bulgaria
Black Sea
Georgia
Moskva
Nizhniy
Novgorod
Mahilyow
Gomel
Kyiv
Kharkiv
Україна
Ukraine
Dnipropetrovs'k
Donets'k
Zaporozhye
Moldova
Chişinău
Odessa
București

General characteristic

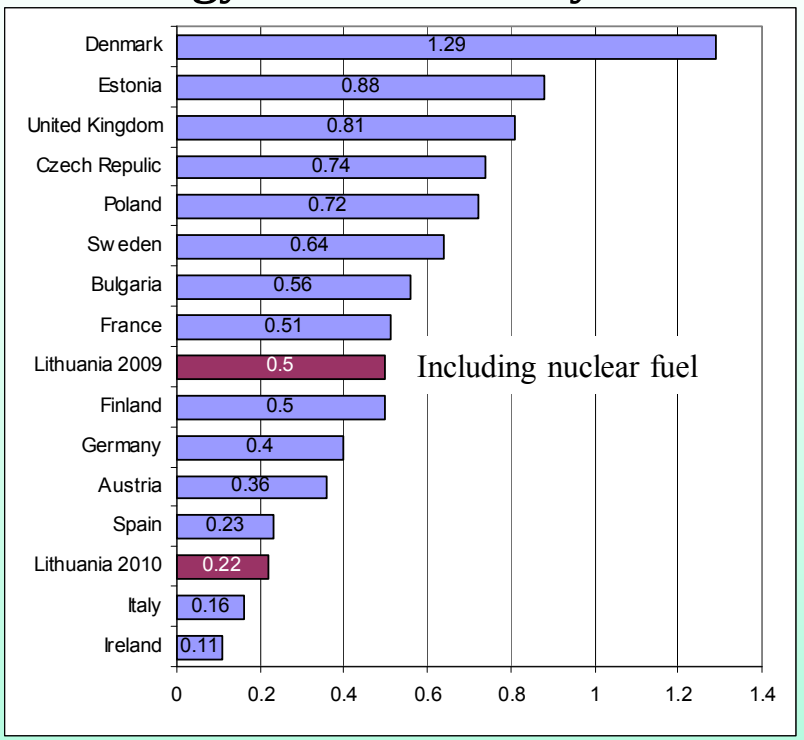
Growth indexes, %

	2000-2008	2009	2010
GDP	7,4	-14,7	1,3
Primary energy requirement	3,3	-6,8	-18,9
Final energy	3,4	-6,4	3,7
Final electricity	4,8	-7,4	-0,5

Primary energy, Mtoe

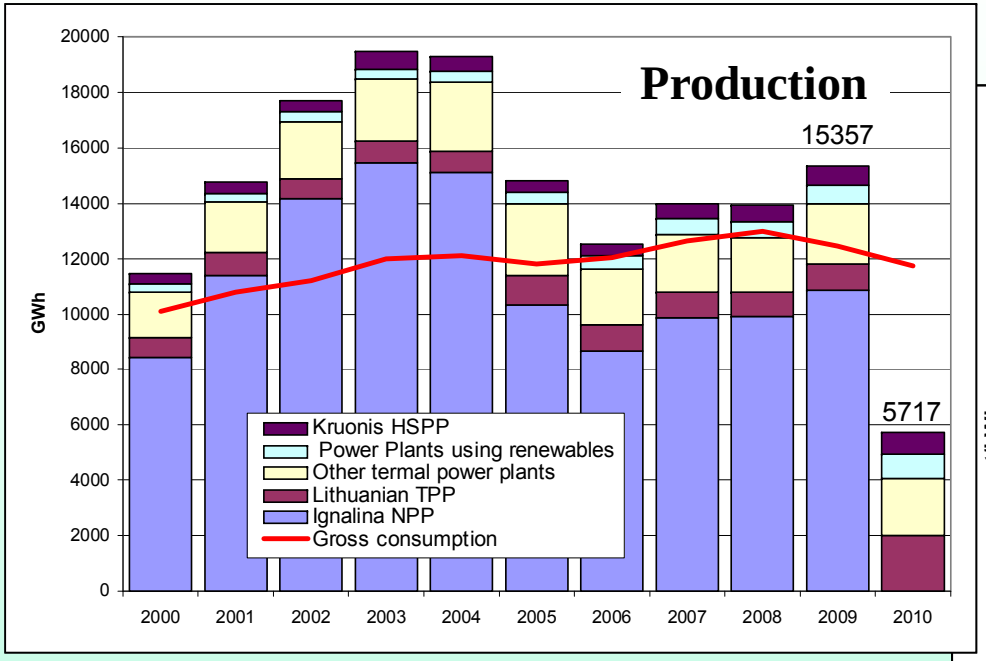


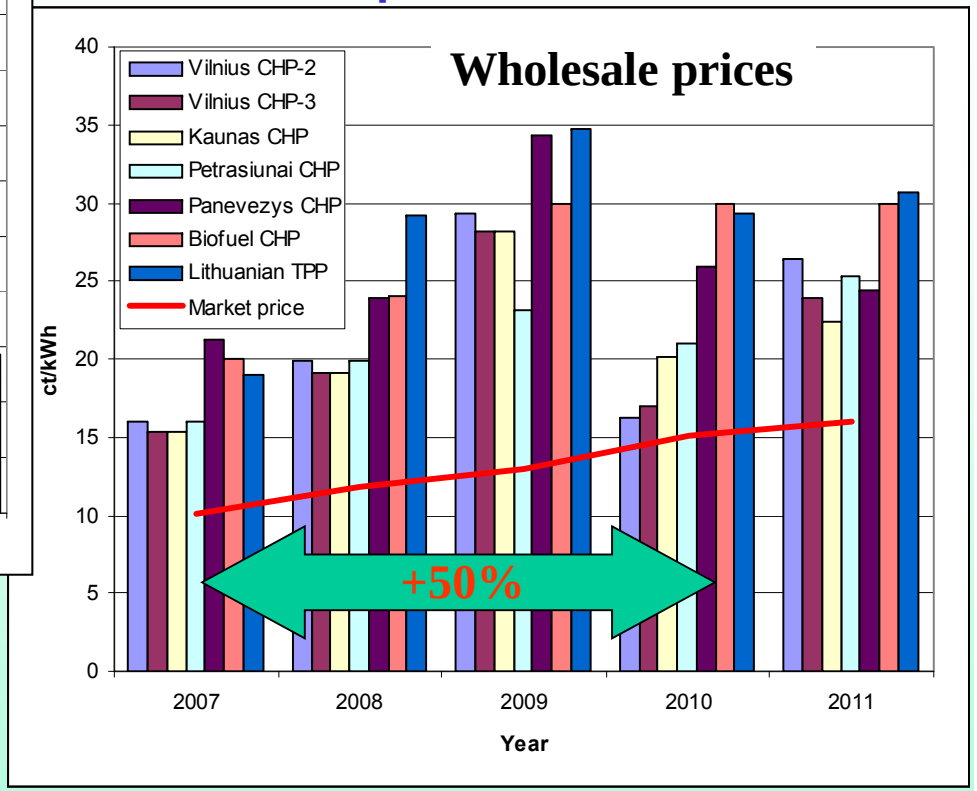
Energy self-sufficiency in 2009

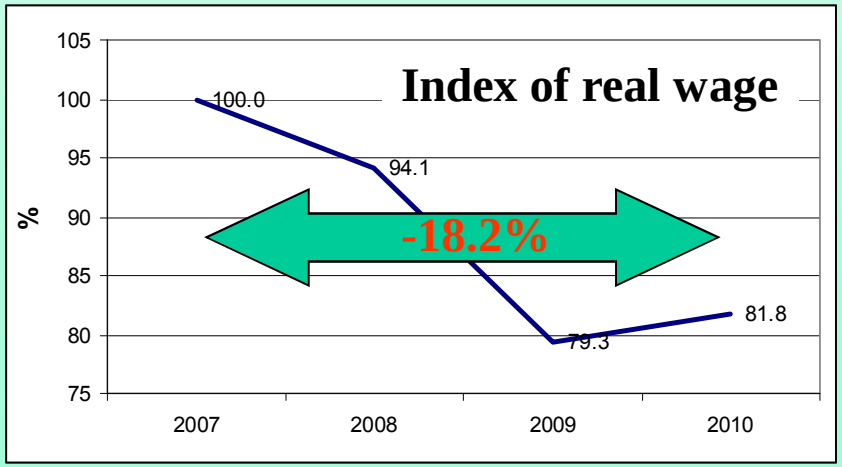


Electricity sector

Export in 2003 was 7,5 TWh but in 2010 import reached 6 TWh



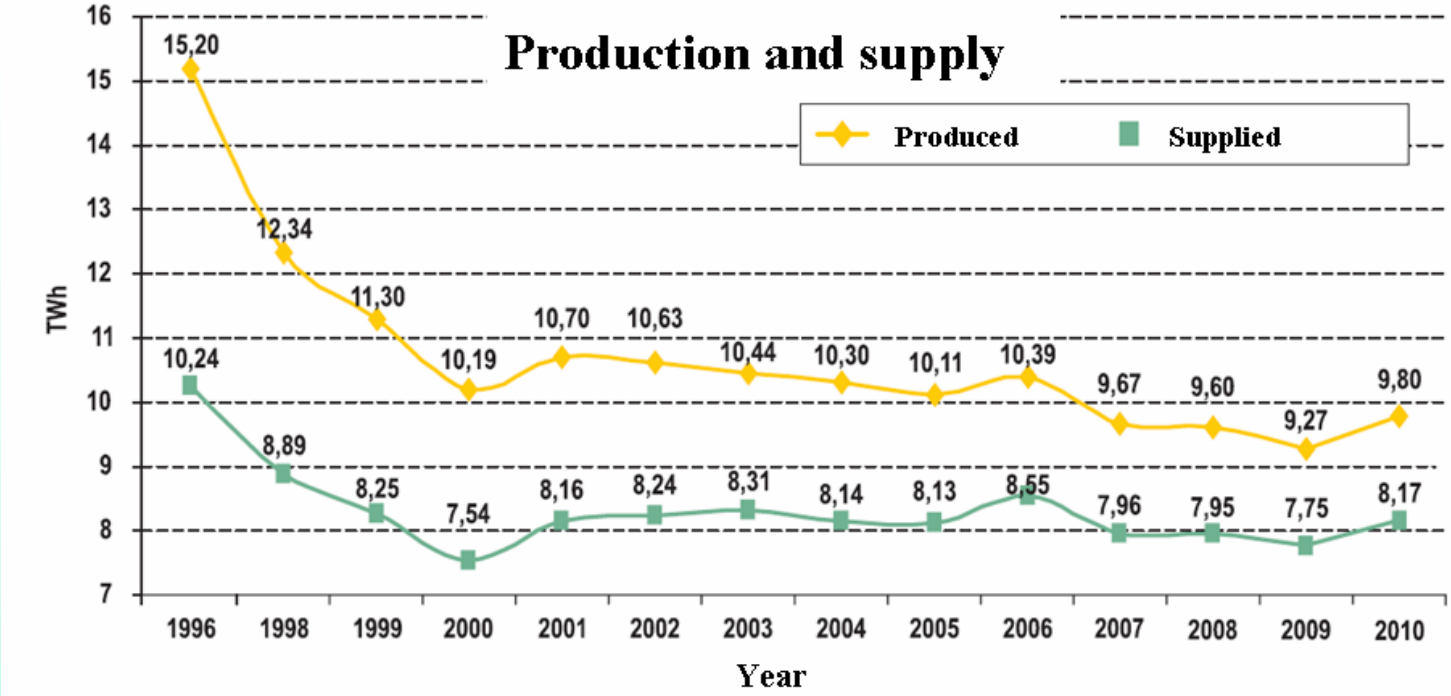


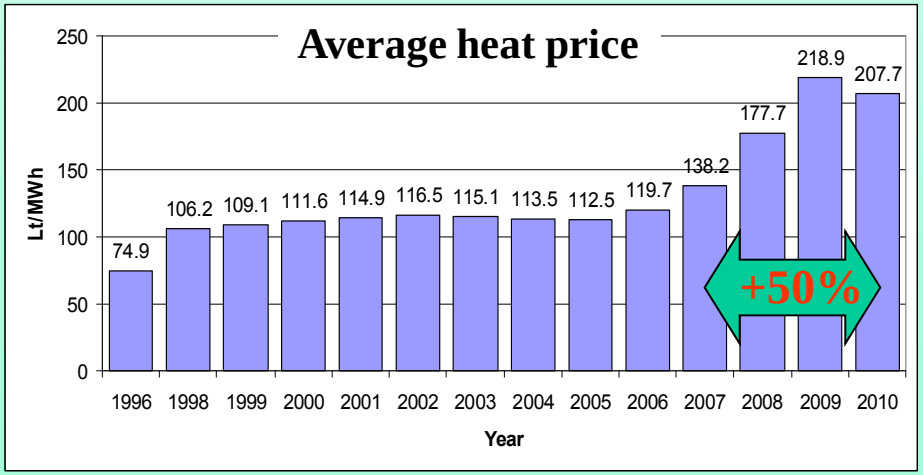


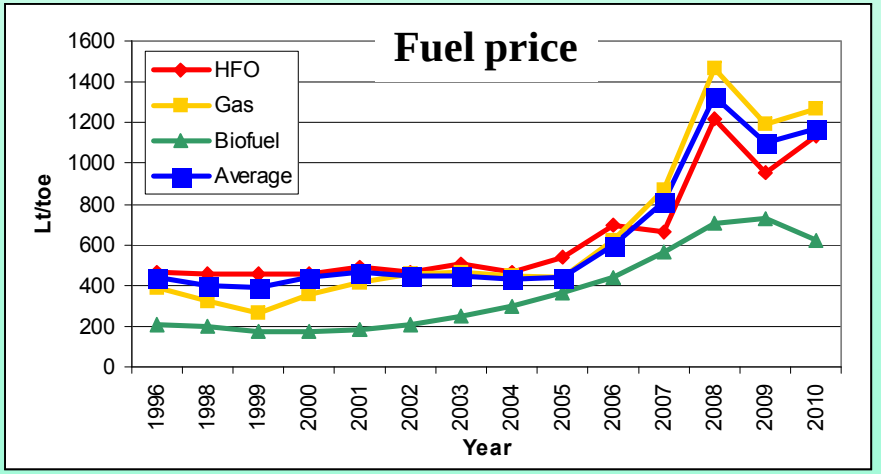
	2007	2008	2009	2010	2011
Vilnius CHP-2	16.00	19.88	29.34	16.25	26.39
Vilnius CHP-3	15.36	19.09	28.18	16.98	23.88
Kaunas CHP	15.36	19.09	28.18	20.16	22.45
Petrasiunai CHP	16.00	19.88	23.14	21.00	25.27
Panevezys CHP	21.28	23.85	34.33	25.96	24.38
Biofuel CHP	20.00	24.00	30.00	30.00	30.00
Lithuanian TPP	19.00	29.18	34.68	29.31	30.75
Average market price	10.01	11.82	12.96	15.07	15.99*

* Average for I and II quarter

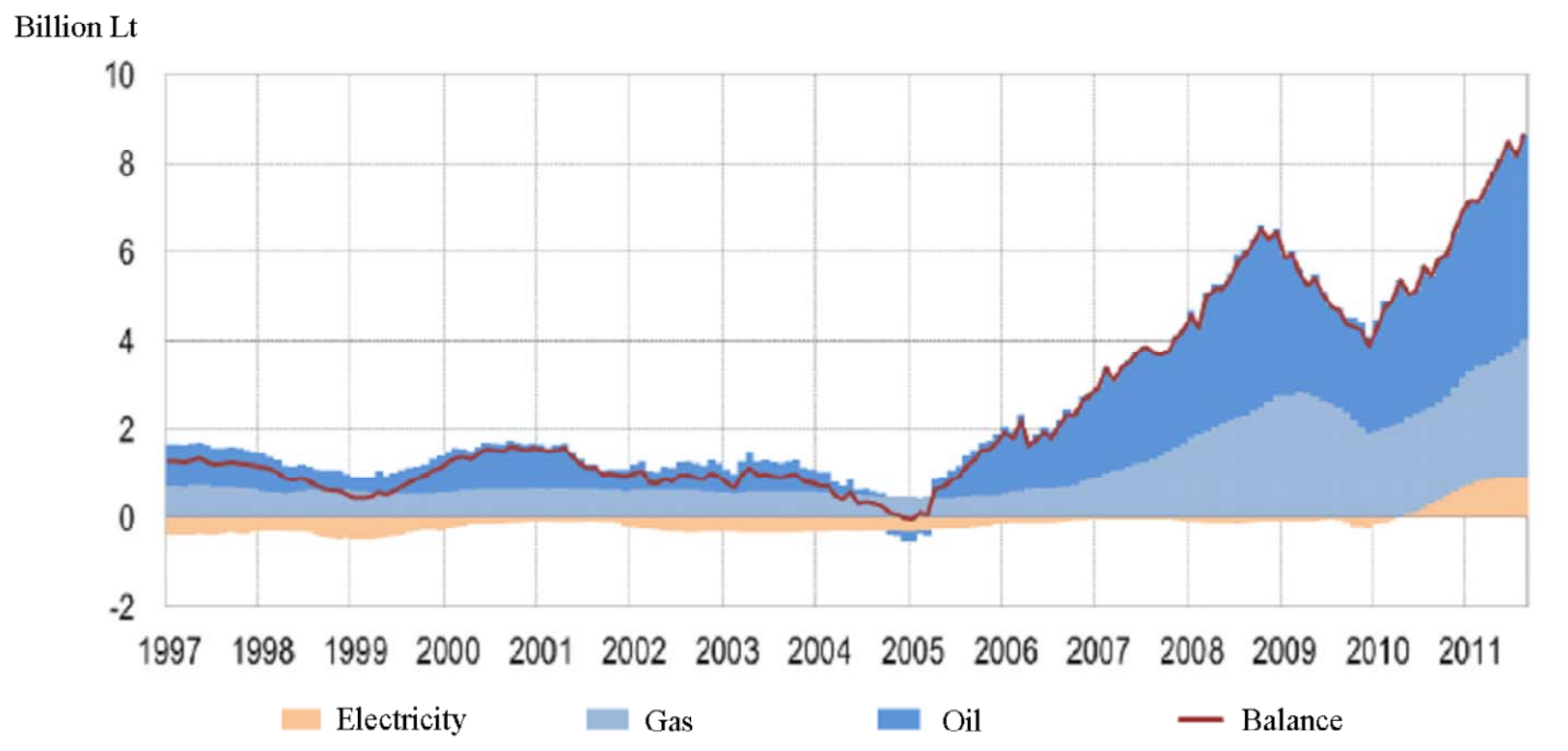
District heating







Payments for energy sources



Source: Nordea

Energy policy stipulating higher utilisation of RES

Directive 2009/28/EC 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 (*LT 23% of RES gross final energy demand in 2020 and 10% in transport*),

Directive 2010/75/EC of the European parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control),

Directive 2009/29/EC of the European parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community,

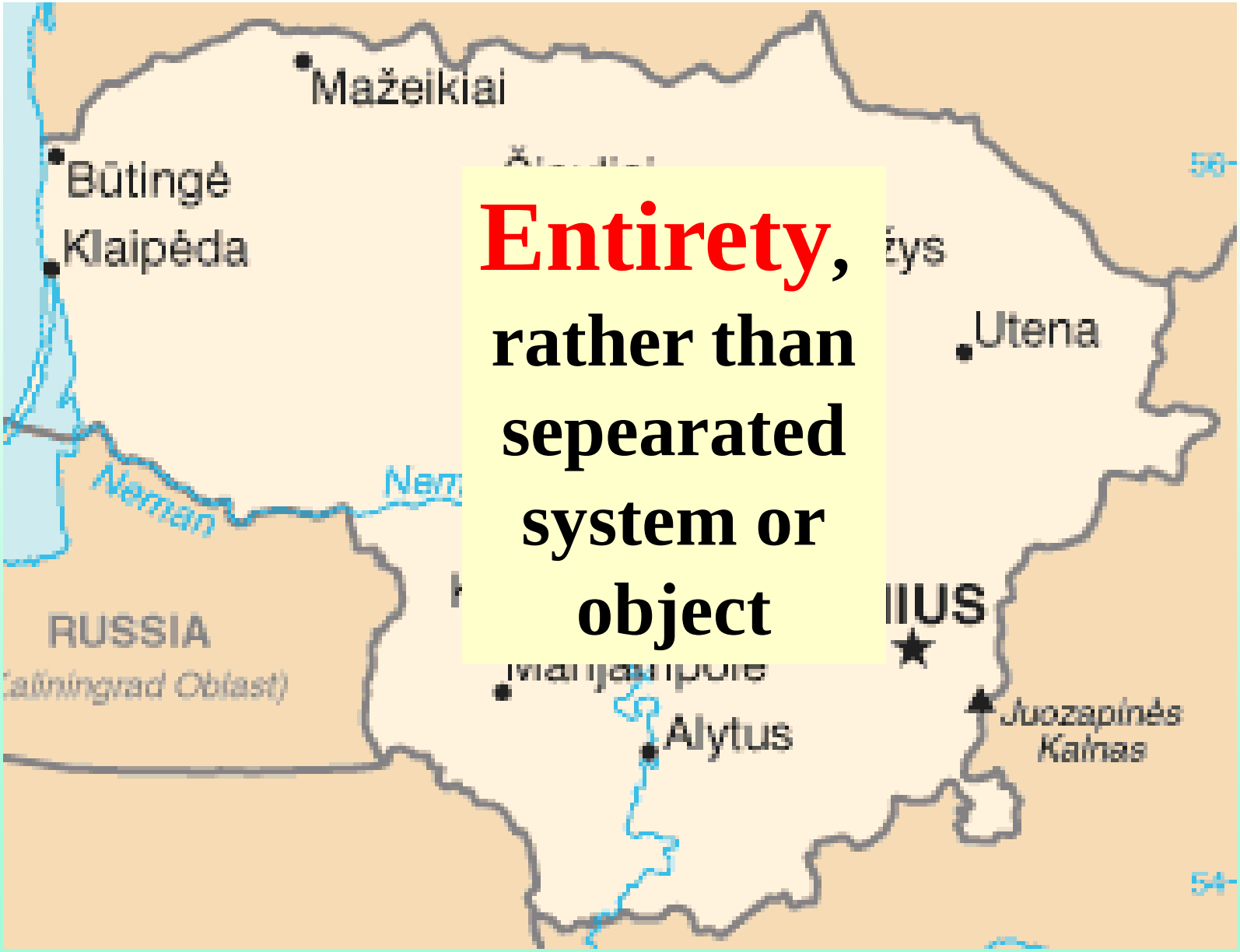
Security of energy supply,

Improvement of trade balance,

Others

Methodological approach for assessment of possible reaction of the Lithuanian energy sector to the changed situation and energy policy initiatives for broader utilisation of RES

The main attention paid



Entirety, rather than sepearated system or object

Main attitudes for analysis

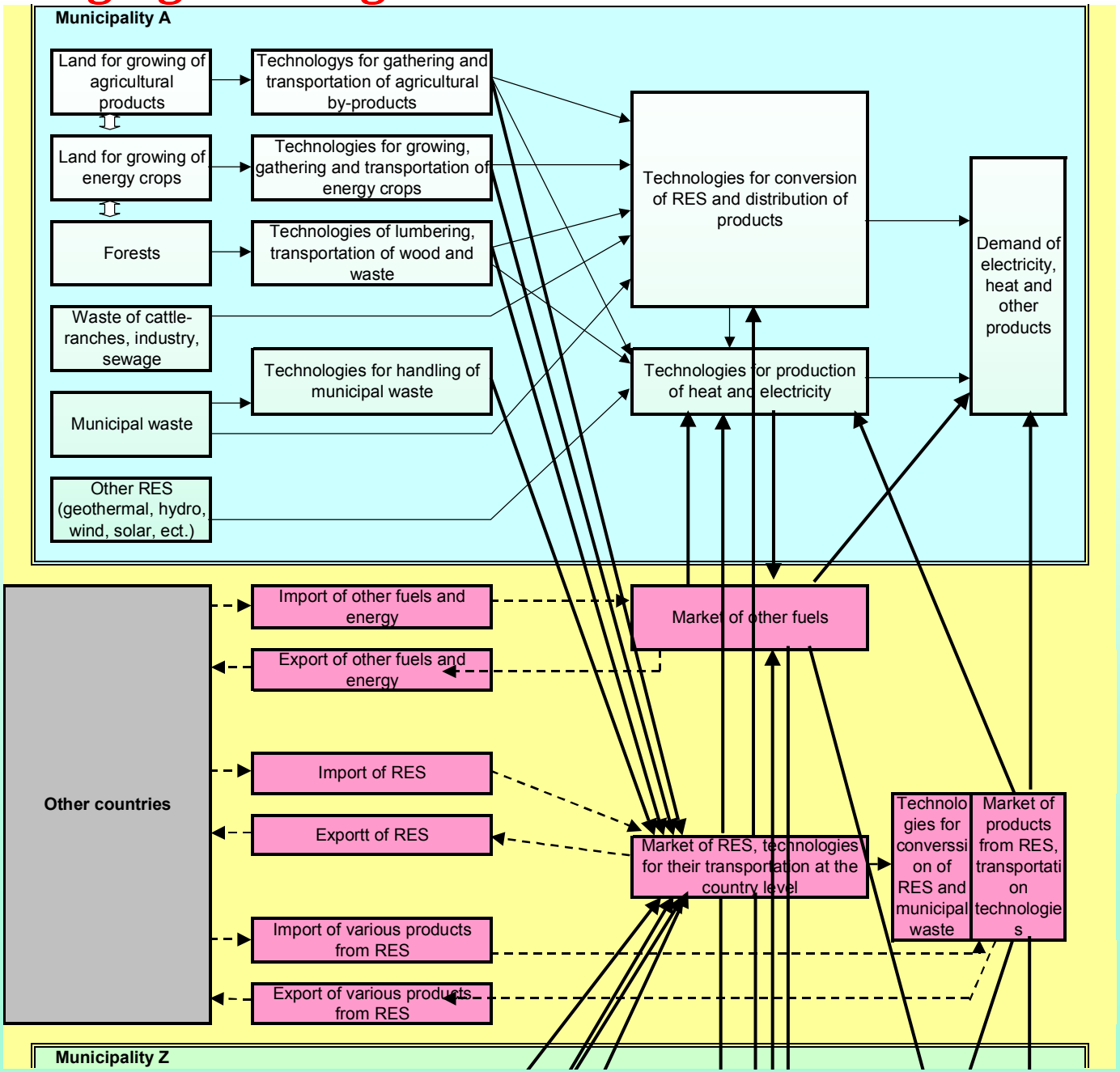
Effectiveness of utilisation of each type of RES is analysed in parallel with possible utilisation options of other energy sources,

Level of RES utilisation should meet requirements of EU Directive 2009/28/EC, should be in correspondence with the rational objective of the country for energy security and commitments of the country in the field of environment protection, etc.,

Broader utilisation of RES has to be reached on the least cost basis,

Analysis has to take into account regional (municipality or other) pecularities.

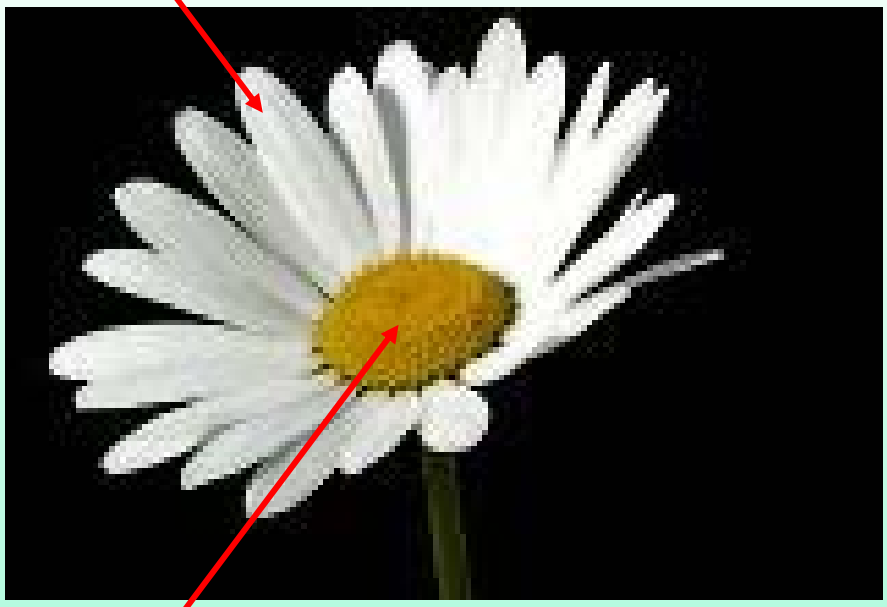
Agregated diagram of the mathematical model



Municipalities in Lithuania

Characteristic of the mathematical model for analysis of Land-Energy-Water interactions at municipality level

Land-Energy-Water systems
of 60 municipalities



State market of fuels
and energies

Time period under analysis:
until year 2045,

5 time steps within a year,

60 types of fuels and energies,

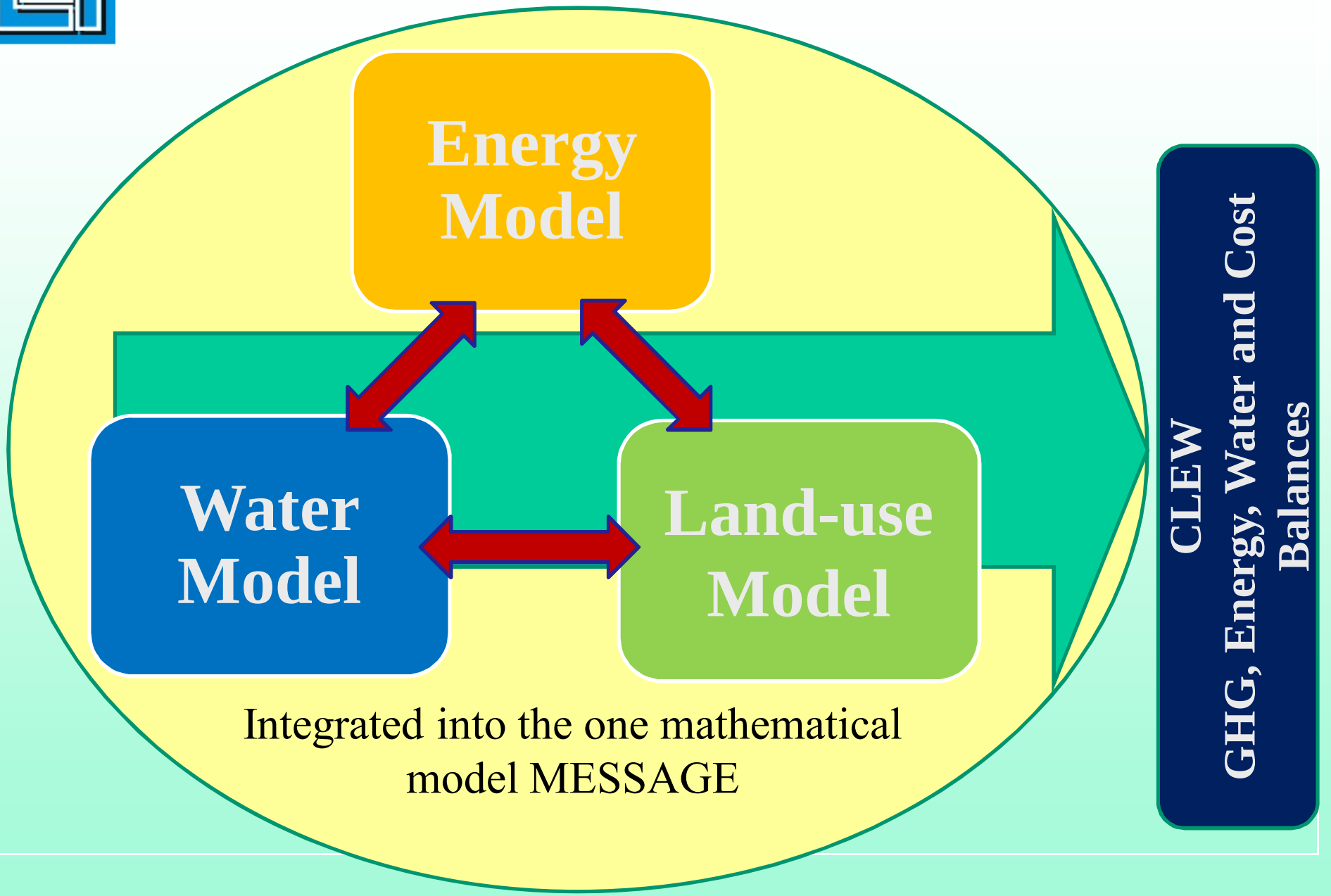
12 types of agricultural products,

~ 8 thousand technologies and processes,

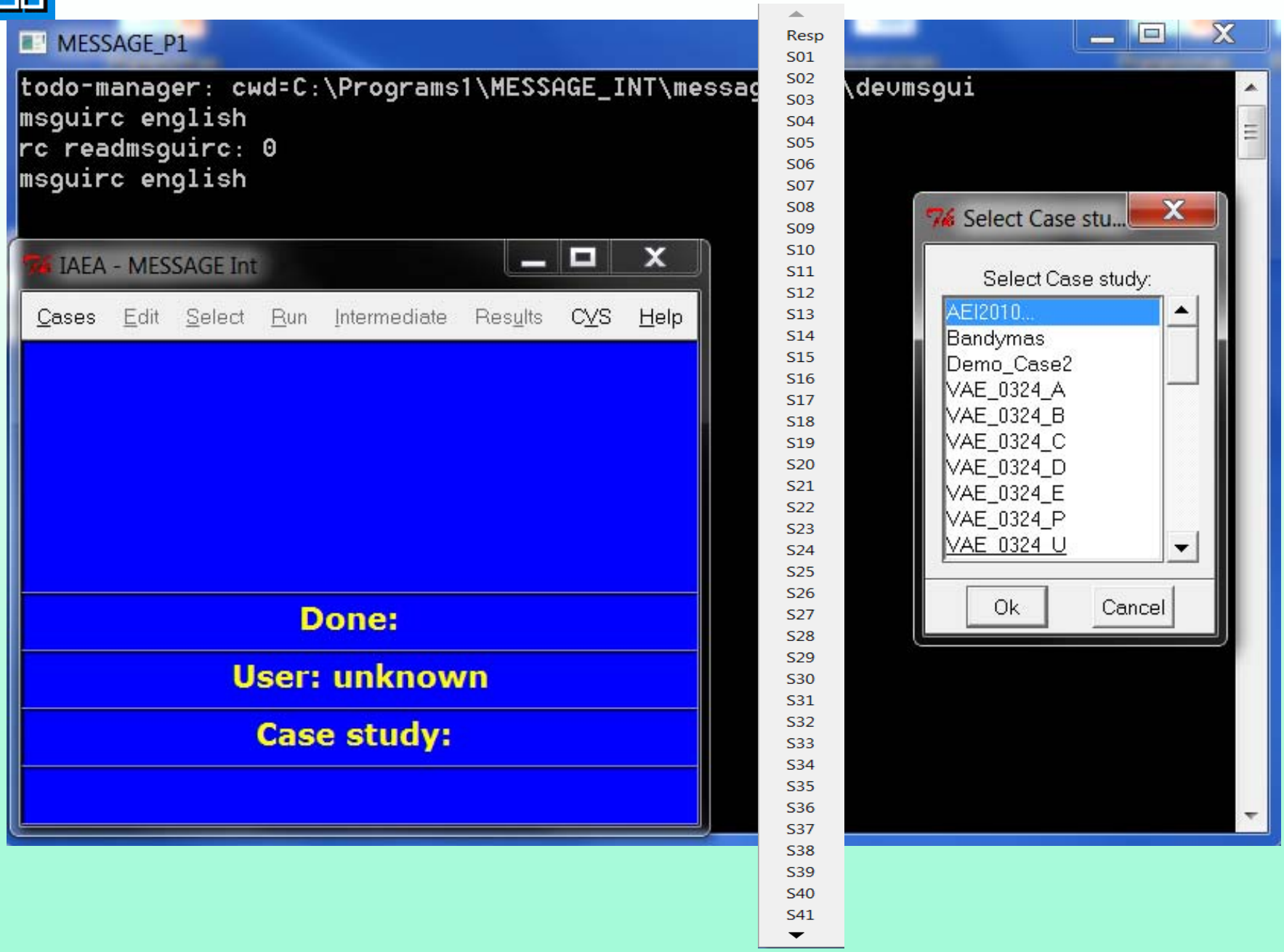
~2 milions variables,

Few milions equations.

Links with CLEW methodology

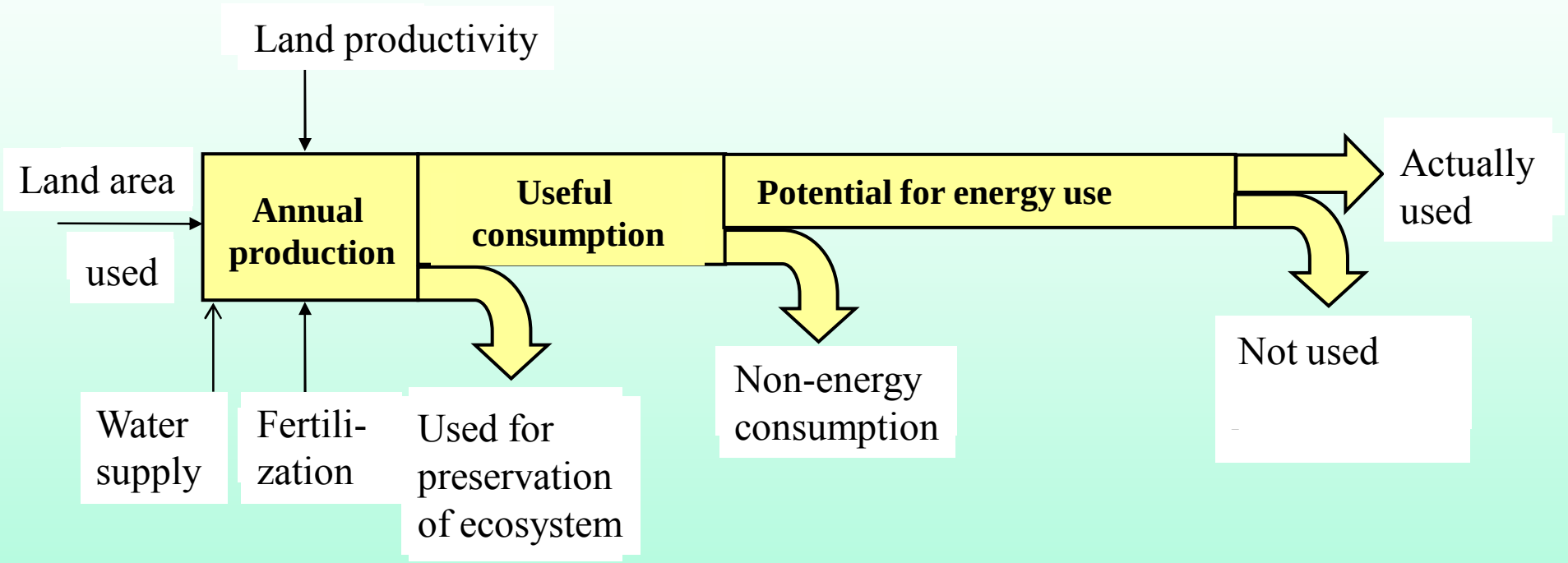


MESSAGE


MESSAGE_P1
todo-manager: cwd=C:\Programs1\MESSAGE_INT\messag
\devmsgui
msguirc english
rc readmsguirc: 0
msguirc english
IAEA - MESSAGE Int
Cases Edit Select Run Intermediate Results CVS Help
Done:
User: unknown
Case study:
Resp
S01
S02
S03
S04
S05
S06
S07
S08
S09
S10
S11
S12
S13
S14
S15
S16
S17
S18
S19
S20
S21
S22
S23
S24
S25
S26
S27
S28
S29
S30
S31
S32
S33
S34
S35
S36
S37
S38
S39
S40
S41
Select Case stu...
Select Case study:
AEI2010...
Bandymas
Demo_Case2
VAE_0324_A
VAE_0324_B
VAE_0324_C
VAE_0324_D
VAE_0324_E
VAE_0324_P
VAE_0324_U
Ok
Cancel

Overview of separate parts of the mathematical model representing processes of the CLEW approach

Potential of cultivated RES



Land use

Land (fixed amount)**:**

Used for roads,

Used by urban areas,

Occupied by forest,

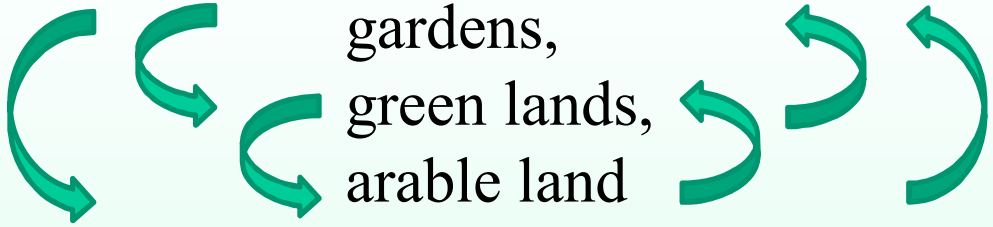
Used for agricultural purposes,

Used for other things,

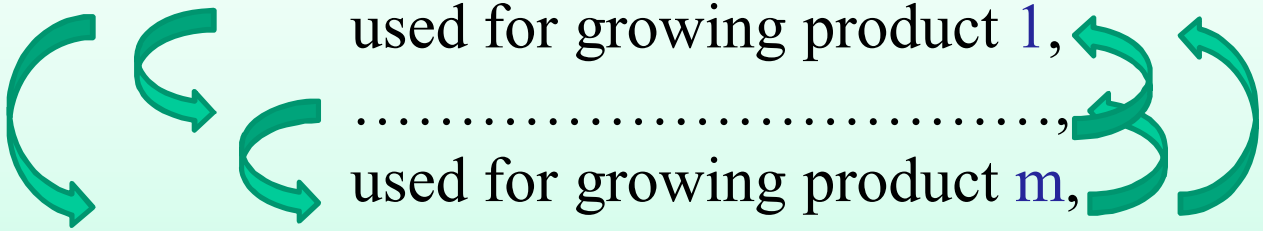
Not used.

Land used for agricultural purposes

Soil type 1



gardens,
green lands,
arable land



used for growing product 1,
……,
used for growing product m,

……

Soil type n

gardens,
green lands,
arable land

used for growing product 1,
……,
used for growing product k,

Land “Not used”

Damaged,

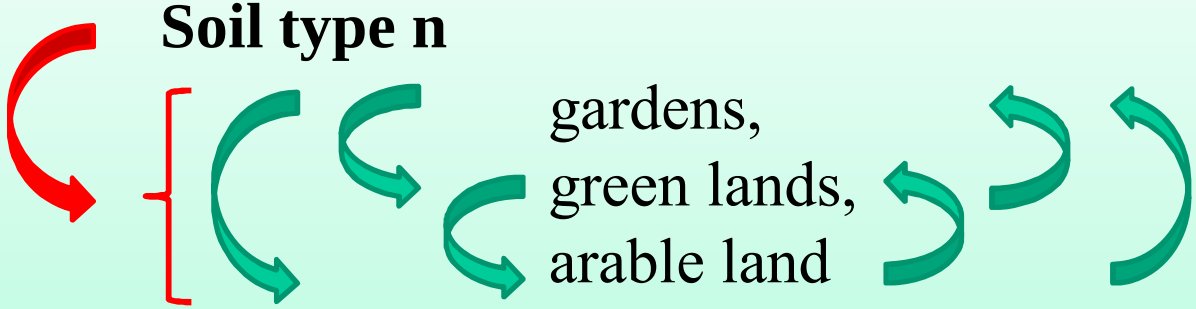
Not used because of excess:

Soil type 1,

Soil type 2,

……..

Soil type n



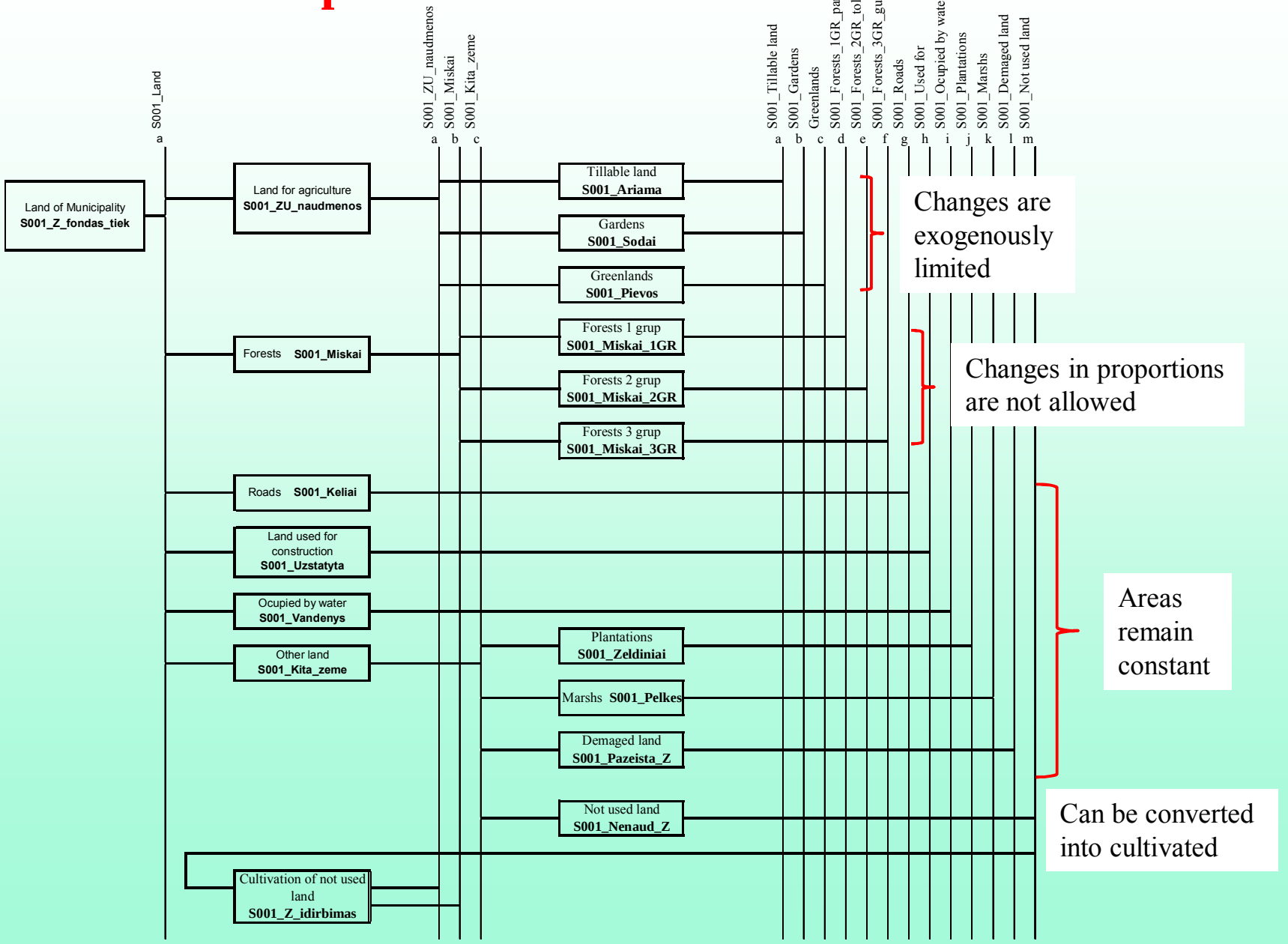
gardens,
green lands,
arable land

used for growing product 1,

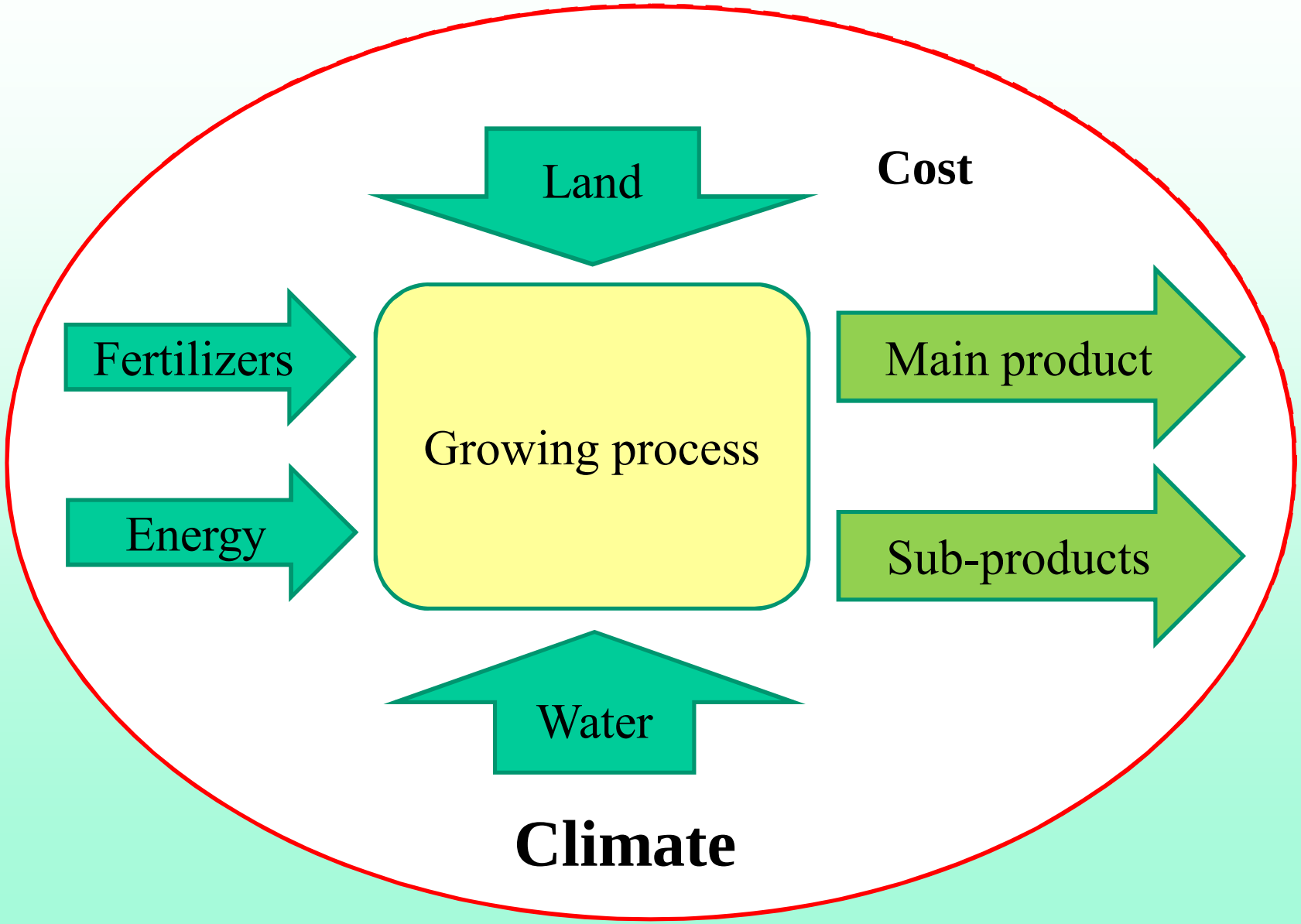
…….,

used for growing product m,

Fragment of the mathematical model. Simplified land balance



Growing of agricultural product



Data sources. Agricultural data (1)

- Database of indicators of Statistics Lithuania
  - Data series of yields, areas etc.
- Results of the agricultural census 2010 (published in July 2012):
  - Farms, land and land use
  - Agricultural crop area
  - Farm animals
  - Agricultural machinery and farm buildings
  - Agricultural production methods
  - Farm workers

Data sources. Agricultural data (2)

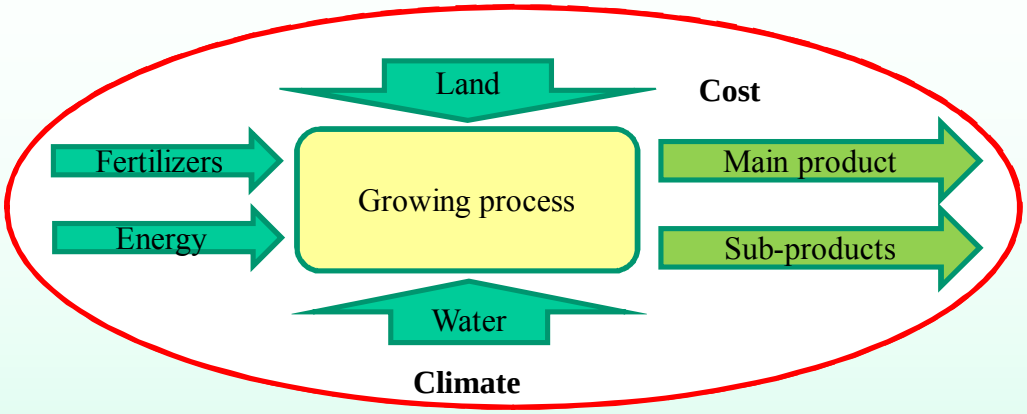
- Results of farm accountancy data network (FADN) survey
  - Performance data of family farms and agricultural companies (fixed, variable cost by type of farm, labor inputs, etc.)
- Valuation of mechanized agricultural services:
  - Detailed cost structure of particular activities in agriculture, e.g. ploughing, harrowing etc.
- Activity forecast of Lithuanian agricultural sector (2011):
  - Cost of agricultural commodities
- Other data sources...

Growing cost and prices of selected agricultural commodities in Lithuania in 2009

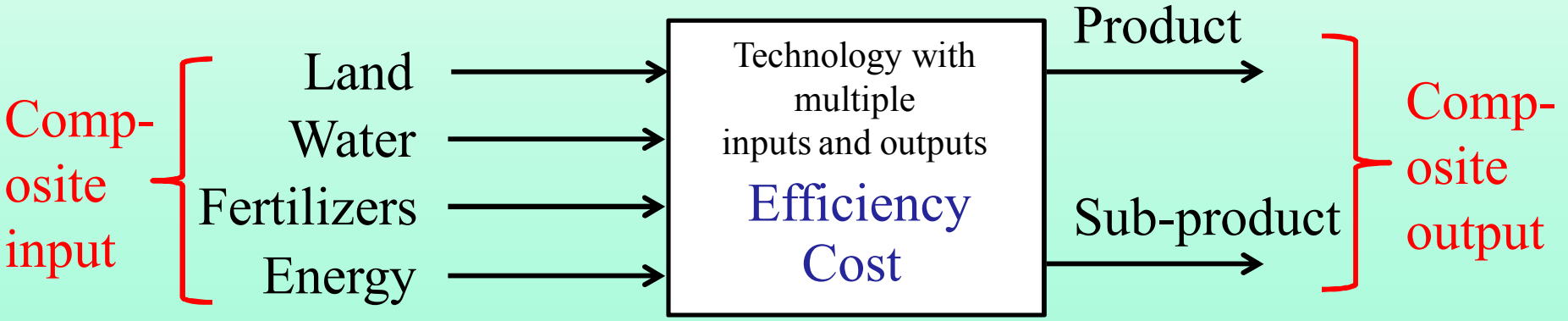
	Growing cost, EUR/ha	Average Yield, t/ha	Growing cost, EUR/t	Average price, EUR/t	Profit, EUR/t
Wheat	430.7	4.2	102.5	114.7	12.2
Rye	323.2	2.5	127.8	71.8	-56.0
Barley	328.7	3.0	108.6	91.8	-16.8
Rape	356.2	2.2	164.4	242.1	77.7

Source: own calculations based on the data from Statistics Lithuania and Kriščiukaitienė, I.; Tamošaitienė, A. et al. (2011). Lietuvos agrarinio sektoriaus veiklos rezultatų prognozės. Vilnius: LAEI.

Modeling of growing agricultural product



Representation as technology in the mathematical model

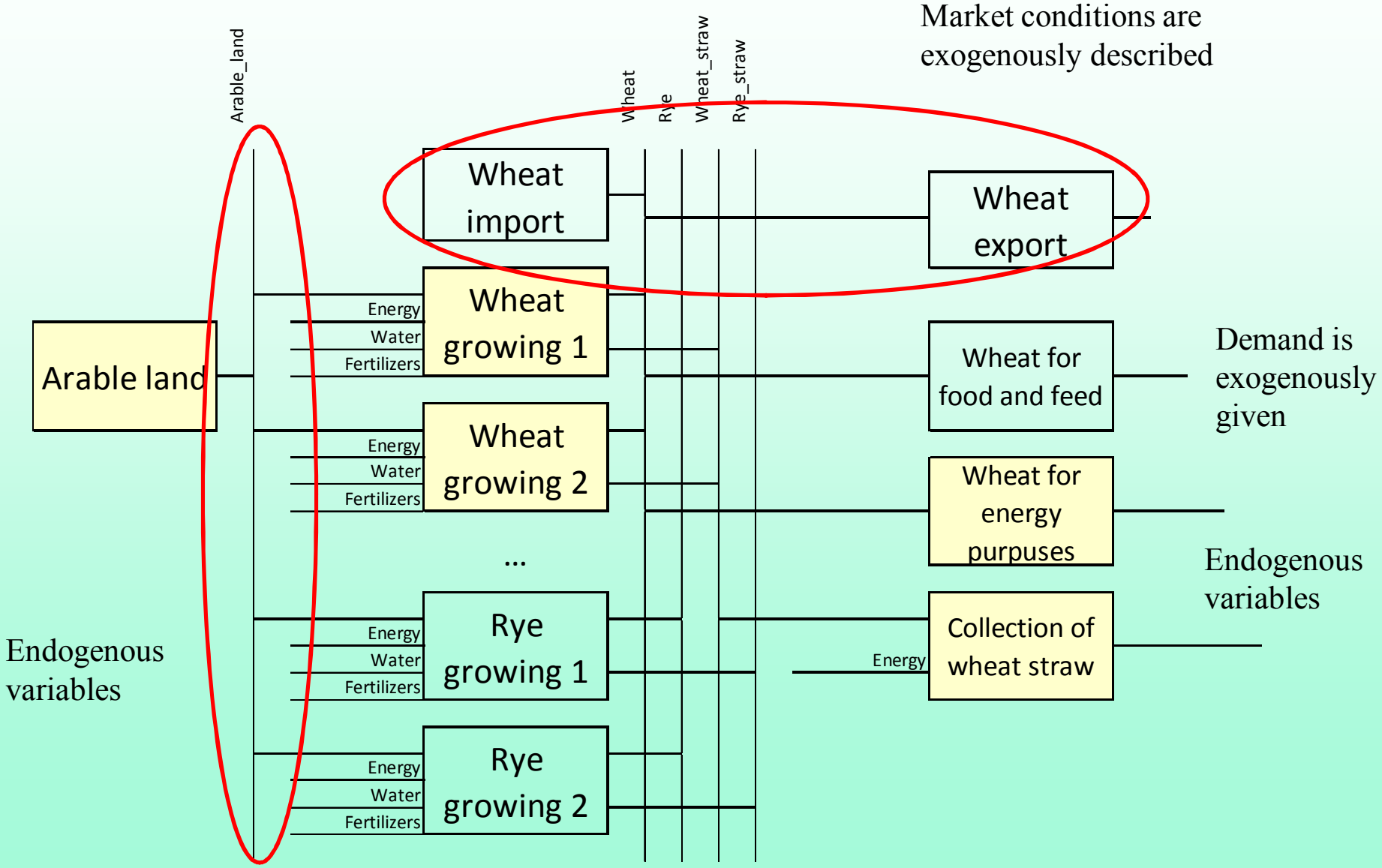


$$\text{Efficiency} = \frac{\text{Main product}}{\text{Land}}$$

Depend on climate

$$\text{Cost} = \frac{\text{Growing cost}}{\text{Main product}}$$

Fragment of the mathematical model. Growing of agricultural products



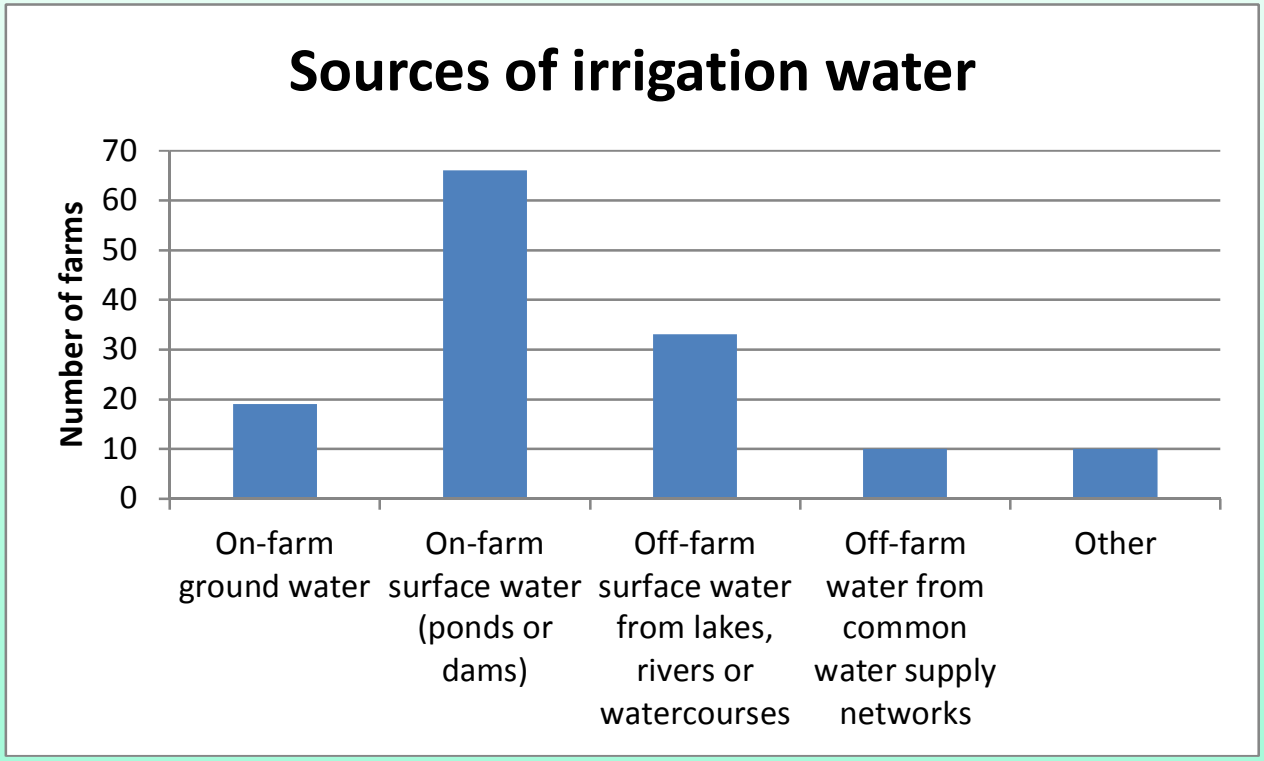
Straw utilisation for energy purposes (example)

- Assumptions:
  - Yield **4 t/ha**, weight of a roll 275 kg, 10 rolls in a trailer, destination 4 km
- Cost of pressing into rolls **35.6 EUR/ha**:
  - Fuel consumption 6.67 l/ha (Element of composite input)
  - Operation and maintenance cost 20.5 EUR/ha **(5.1 EUR/t)**
  - Time 0.68 hour/ha
  - Investment: tractor 41.7 thous. EUR, agricultural machine 26.4 thous. EUR
- Cost of transportation **12.6 EUR/ha**
  - Fuel consumption 3.10 l/ha (Element of composite input)
  - Operation and maintenance cost 7.3 EUR/ha **(1.8 EUR/t)**
  - Time 0.59 hour/ha
  - Investment: tractor 41.7 thous. EUR, agricultural machine (trailer) 9.8 thous. EUR

Source: own calculations based on Lietuvos agrarinės ekonomikos institutas (2011). Mechanizuotų žemės ūkio paslaugų įkainiai. III dalis. Derliaus nuėmimo darbai.

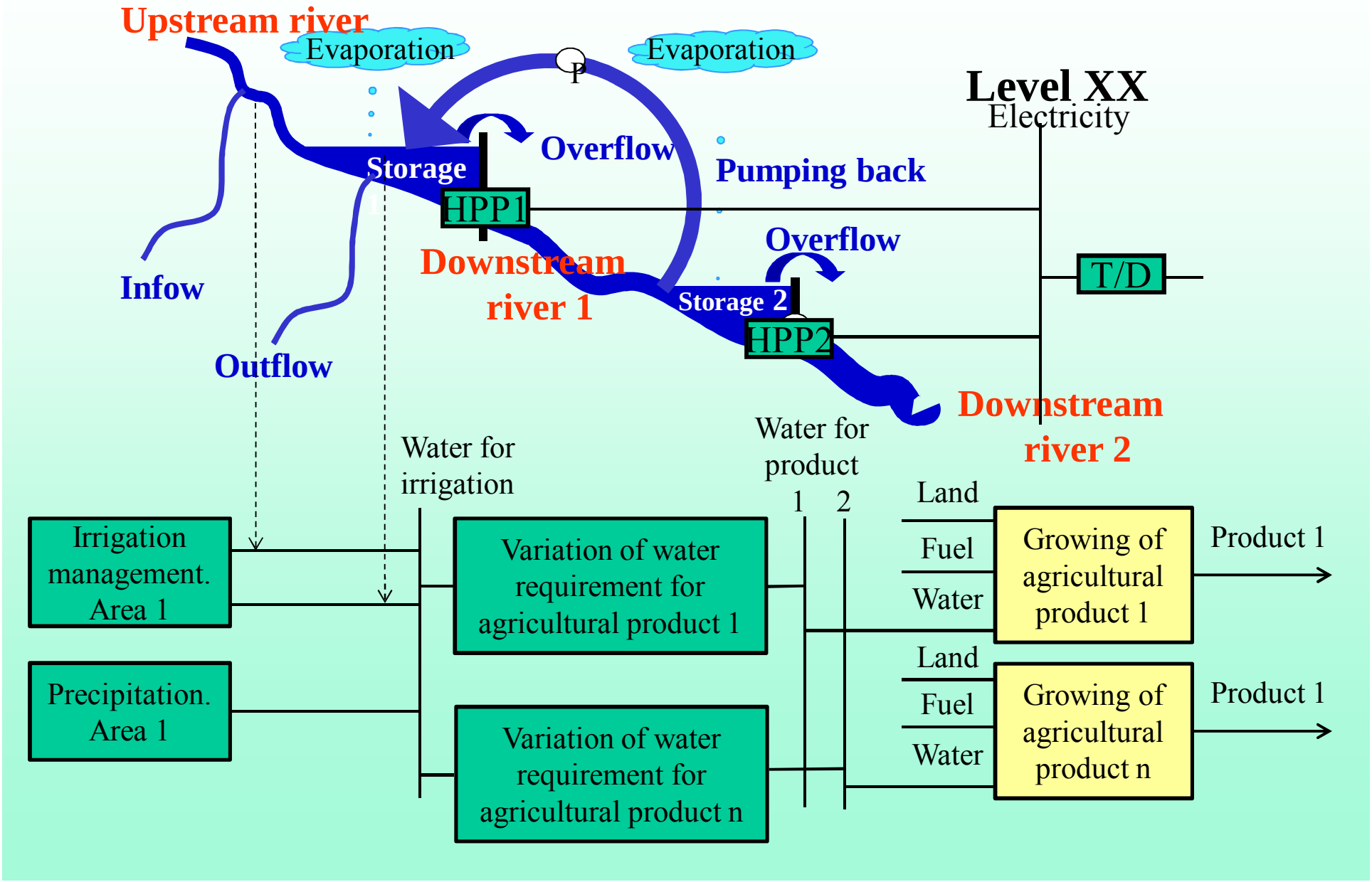
Irigation in Lithuania in 2010

- Irrigated land area: 1532 ha (0.05% of the utilised land on all farms)
- Volume of water used for irrigation: 455.760 thous. m3

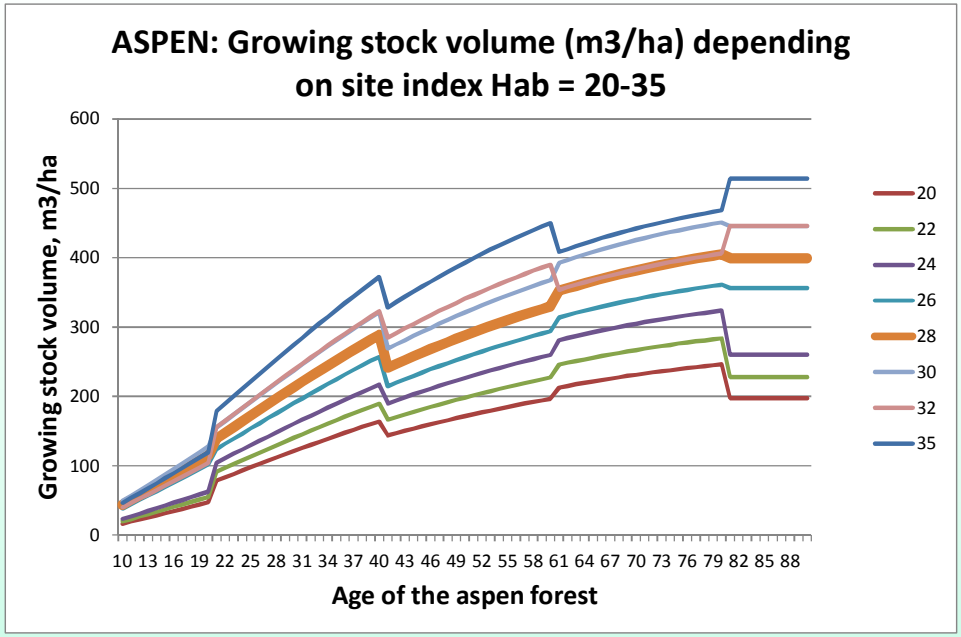


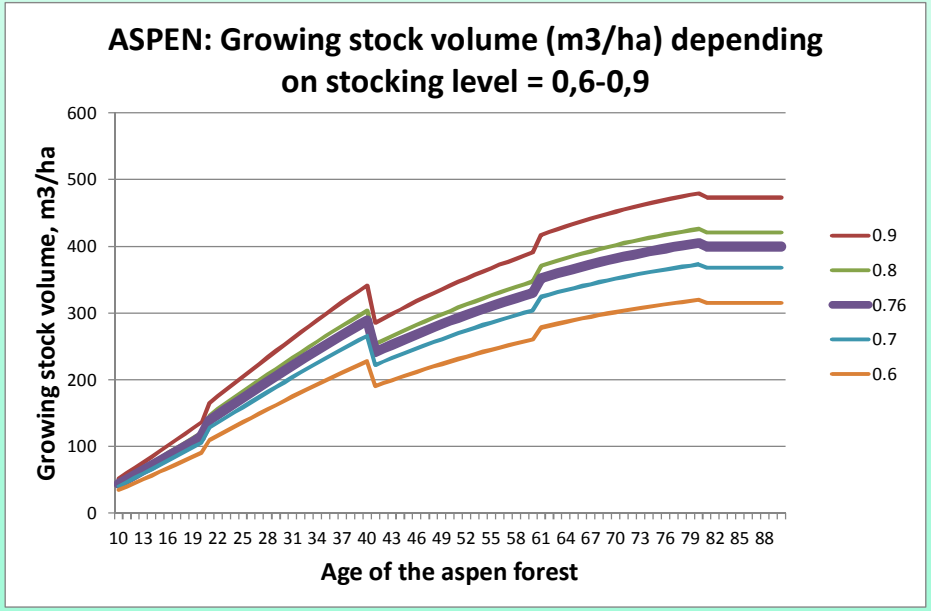
Data source: Results of the agricultural census 2010

Modeling of irrigation

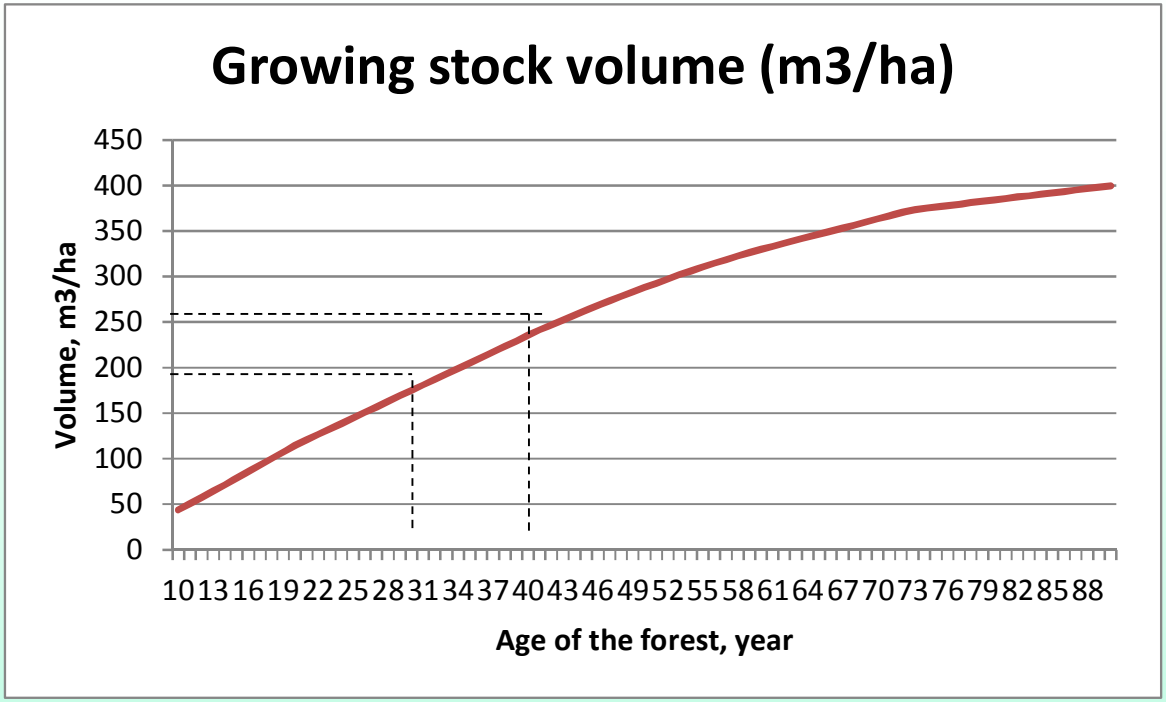


Forestry. Growing stock volume





Growing of forest in MESSAGE terms (1)



Cutting trees at age 30 years gives wood output equal to 175 m3/ha;

Cutting trees at age 40 years gives wood output equal to 235 m3/ha;

When to cut trees?;

What trees should be grown?;

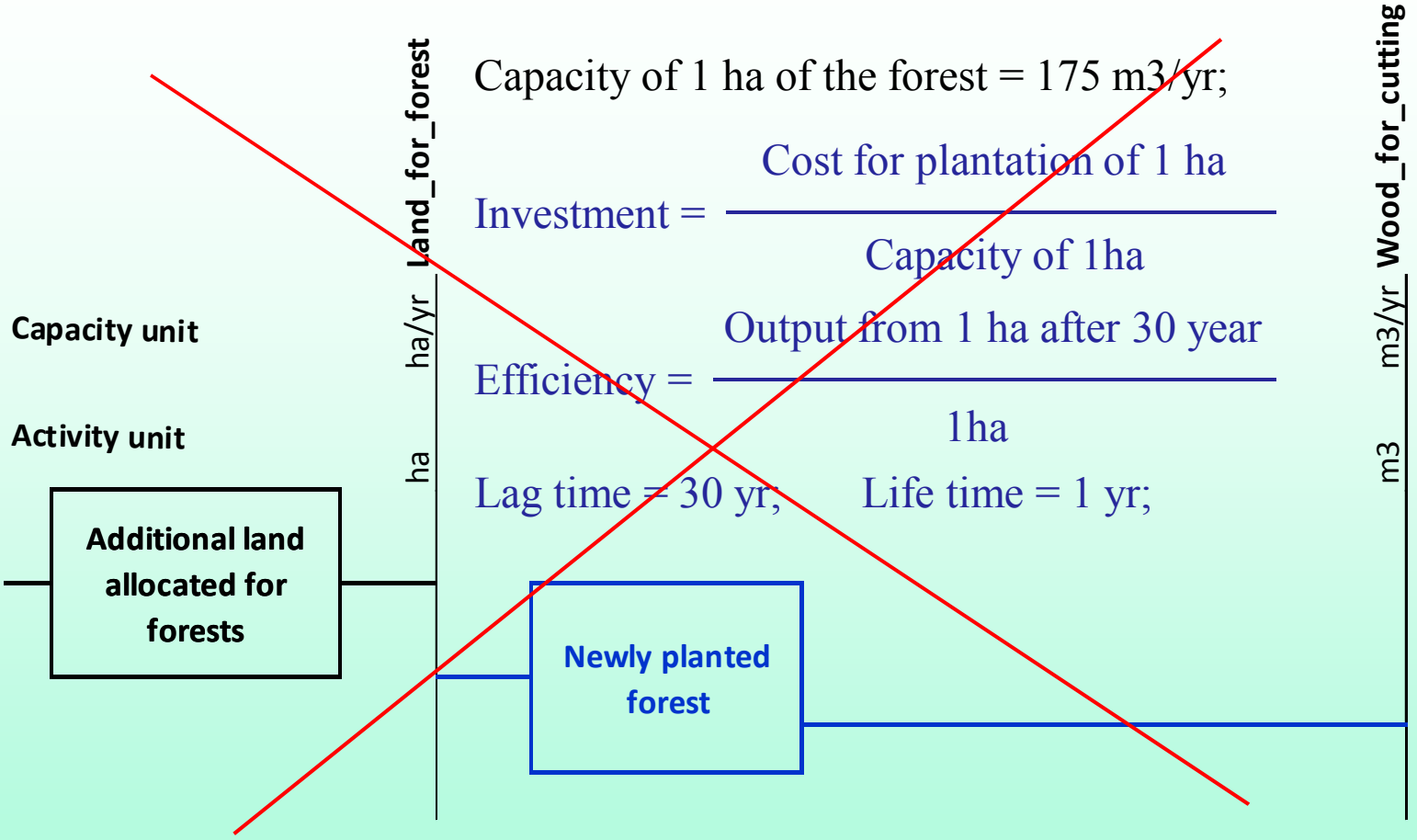
In capacity terms:

1 ha of forest after 30 years of growing trees has a the capacity of 175 m3 of wood/year (175 m3/yr).

1 ha of forest after 40 years of growing trees has a the capacity of 235 m3 of wood/year (235 m3/yr).

Output occurs ones after 30 or 40 years correspondingly.

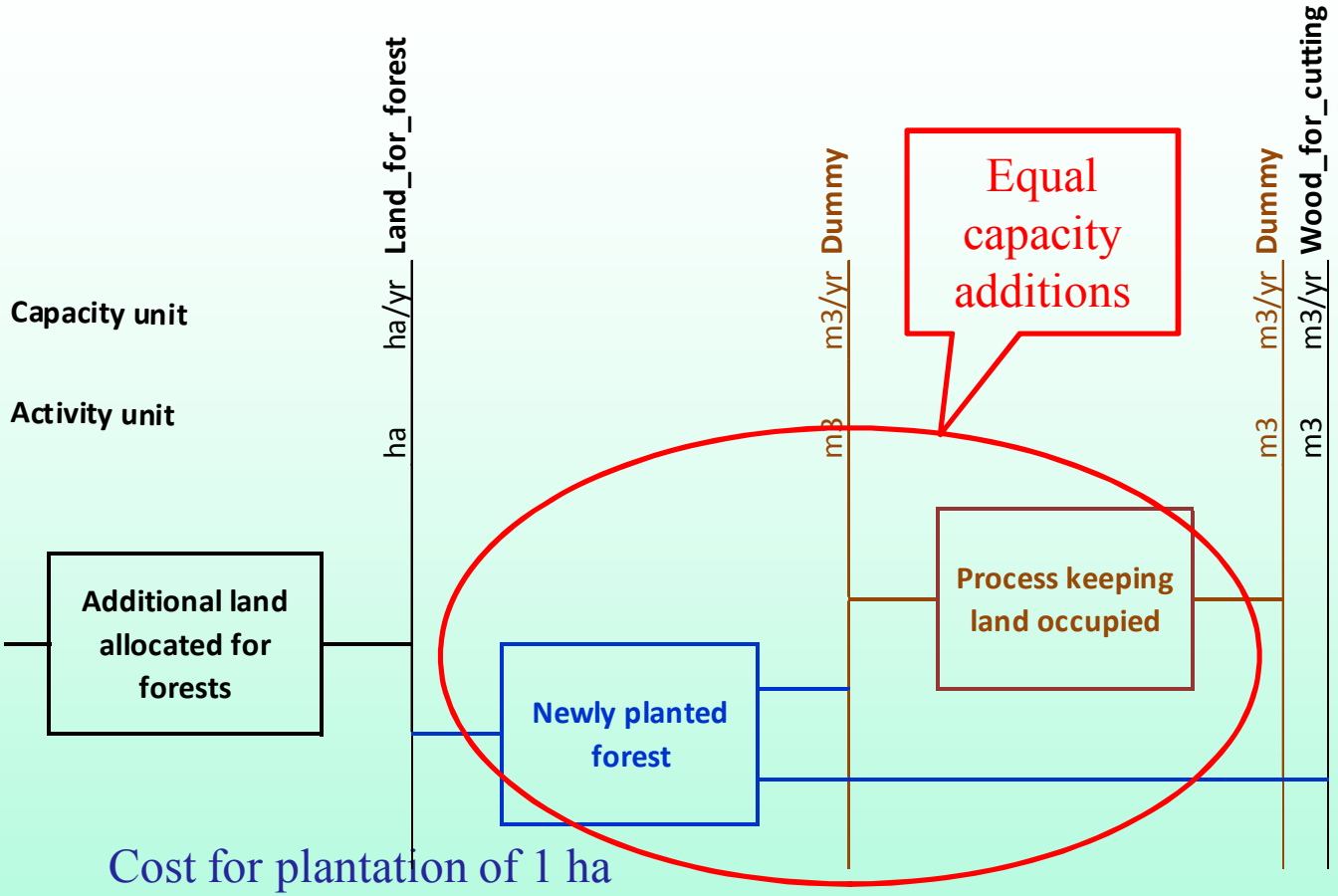
Growing of forest in MESSAGE terms (2)



Endogenous variables: **Capacity of annual plantations, Annual output after 30 years.**

Problem: Land occupied by the forest remain during 30 years

Growing of forest in MESSAGE terms (3)



$$\text{Investment} = \frac{\text{Cost for plantation of 1 ha}}{\text{Capacity of 1ha}}$$

$$\text{Efficiency} = \frac{\text{Output from 1 ha after 30 year}}{\text{1ha}}$$

~~Lag time = 30 yr;~~ Life time = 30 yr;

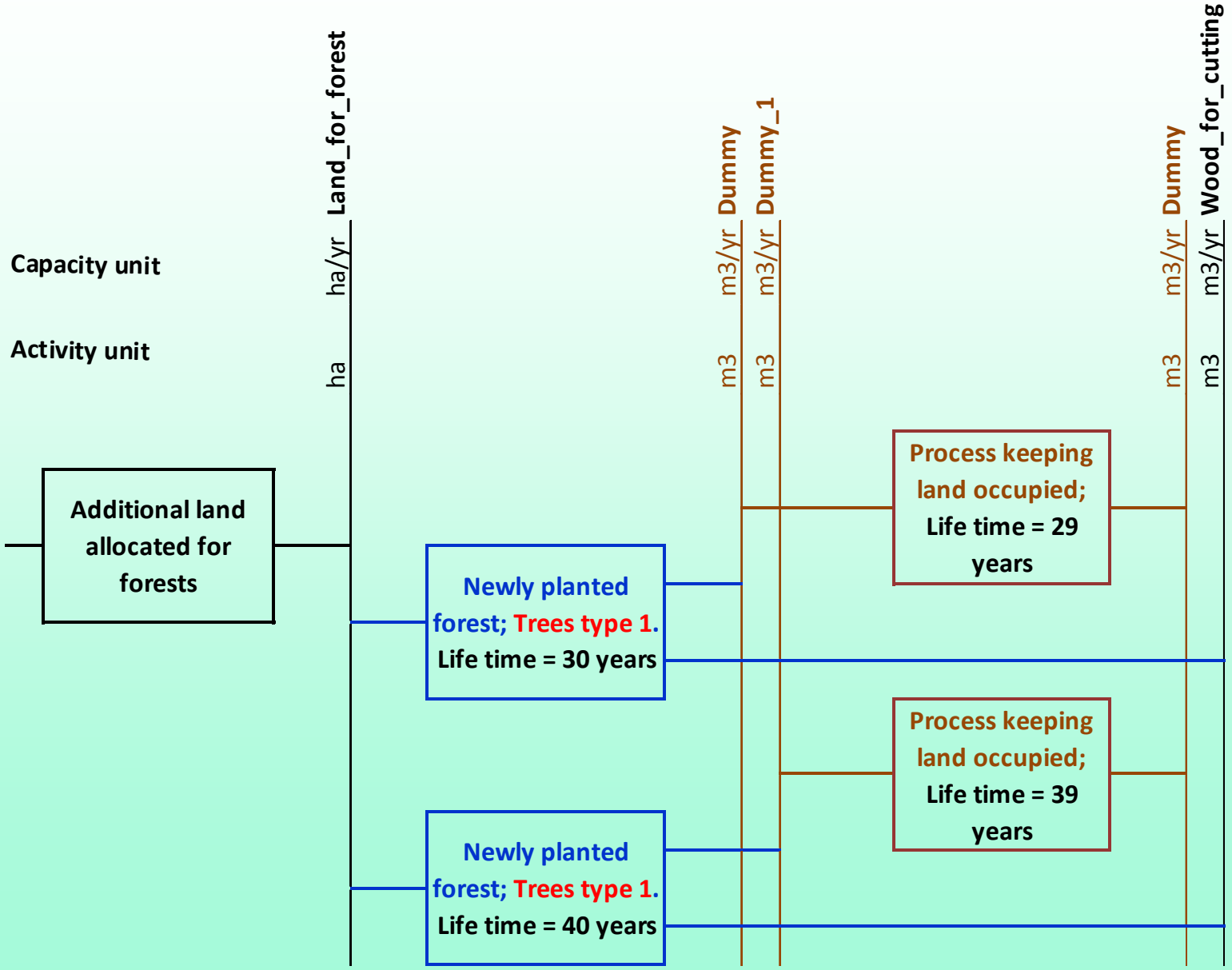
Investment = 0

$$\text{Efficiency} = \frac{\text{Output from 1 ha after 30 year}}{\text{1ha}}$$

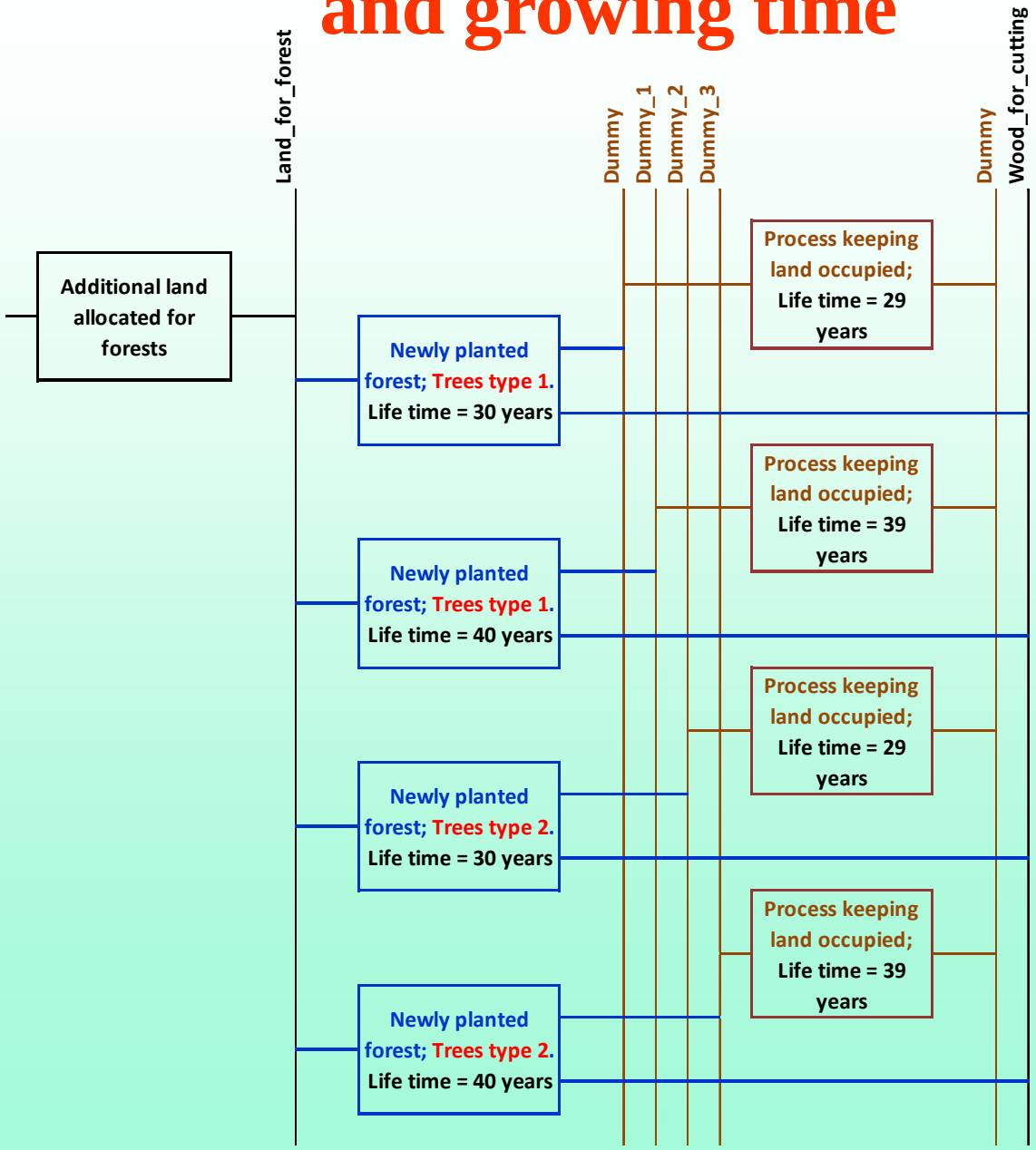
Util. factor = 1;

Life time = 29 yr;

Representation of different growing time



Representation of different trees and growing time



Forest. Other peculiarities

Fuel consumption for planting of the forest can be included into technology “Newly planted forest” and linked to capacity variable;

Fuel and water consumption, CO2 absorption, as well as growing cost (annual averages) can be included into technology “Process keeping land occupied”;

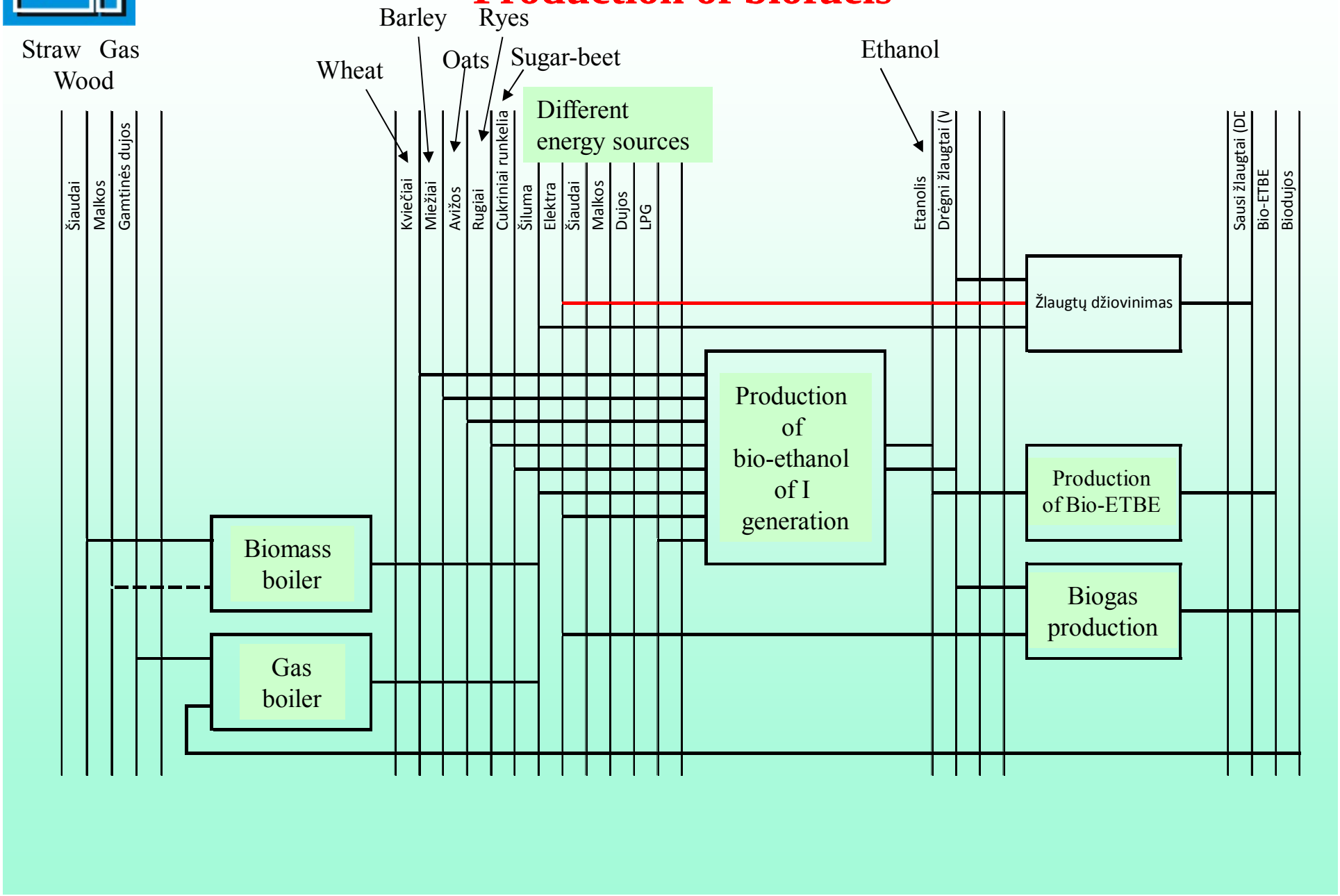
Cutting and transportation of trees can be represented as separate processes (technologies) having their own cost and fuel consumption;

Cutting trees gives two types of product: timber and branches. Their further processing is associated with different efficiency, cost, energy consumption. It might be necessary to represent them as separate commodity flows;

Cutting trees for industrial purposes involves production of sub-products (branches) that can be used for energy purposes;

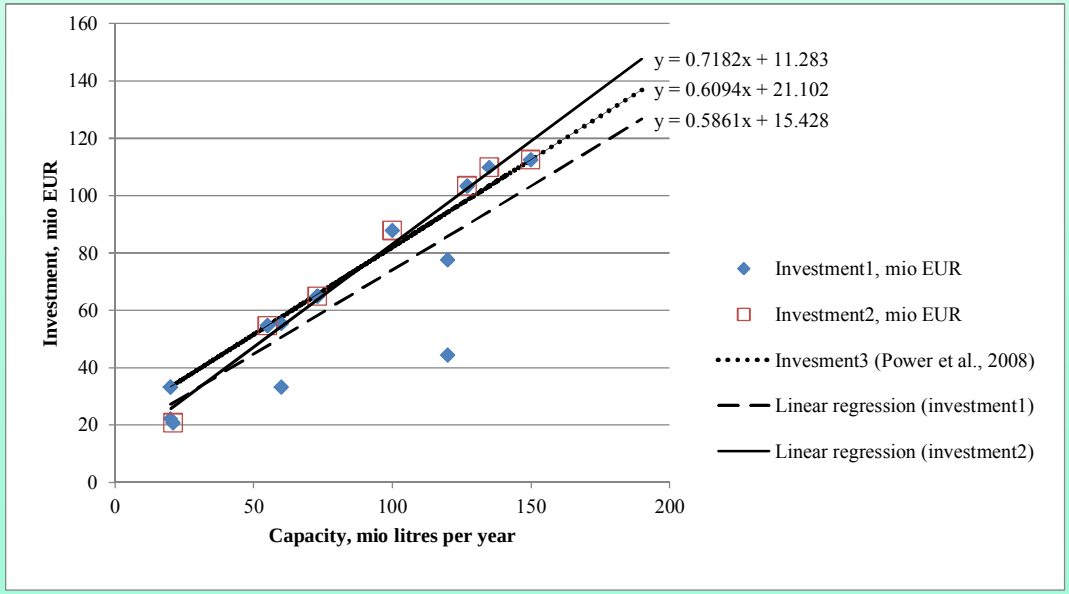
Part of wood has to remain in the forest;

Use of agricultural products for energy purposes. Production of biofuels

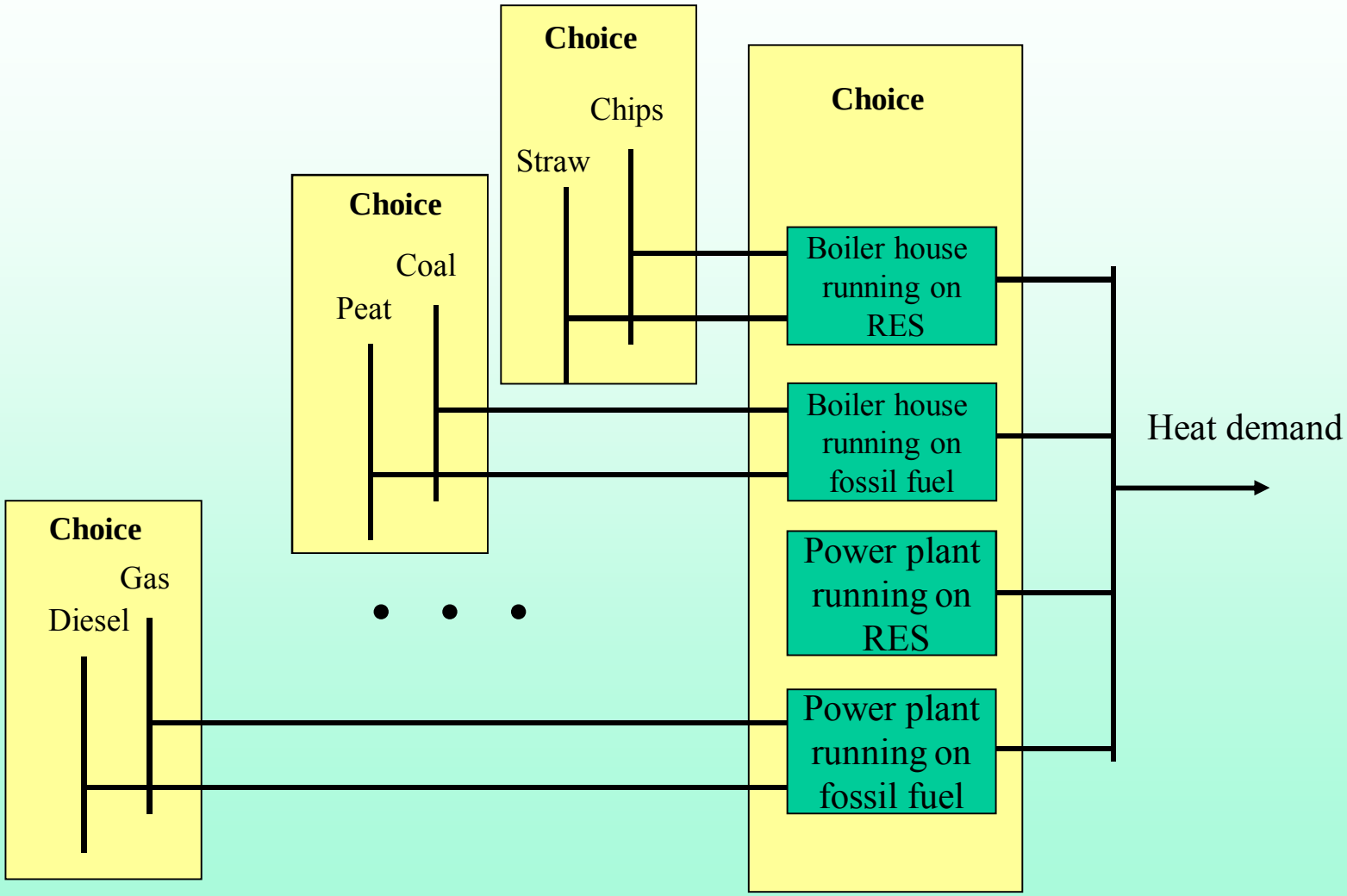


Production of bioethanol

- Efficiency: ~0.3 $t_{bioethanol}/t_{feedstock}$
- Variable cost 61.9 EUR/$t_{bioethanol}$
- Fixed cost 102.2 EUR/$t_{bioethanol}$/year
- Electricity consumption 192 kWh/$t_{bioethanol}$
- Heat consumption 1235kWh/$t_{bioethanol}$



Use of forestry and agricultural products for energy purposes (example)



Choices can not be made separatelly

Short summary of alternatives
and
some results

Alternatives analysed

Electricity sector:

a) Future operation of existing power plants and their refurbishment,
b) Construction of new power plants (Wind, solar, hydro, gas PP, RES PP, nuclear PP, etc.);

Sector of district heating:

a) Future operation of existing boiler houses and CHP, their modernisation, change of fuel types,
b) Construction of new boiler houses and CHP on fossil fuel, biofuel and municipal waste, use of heat pumps;

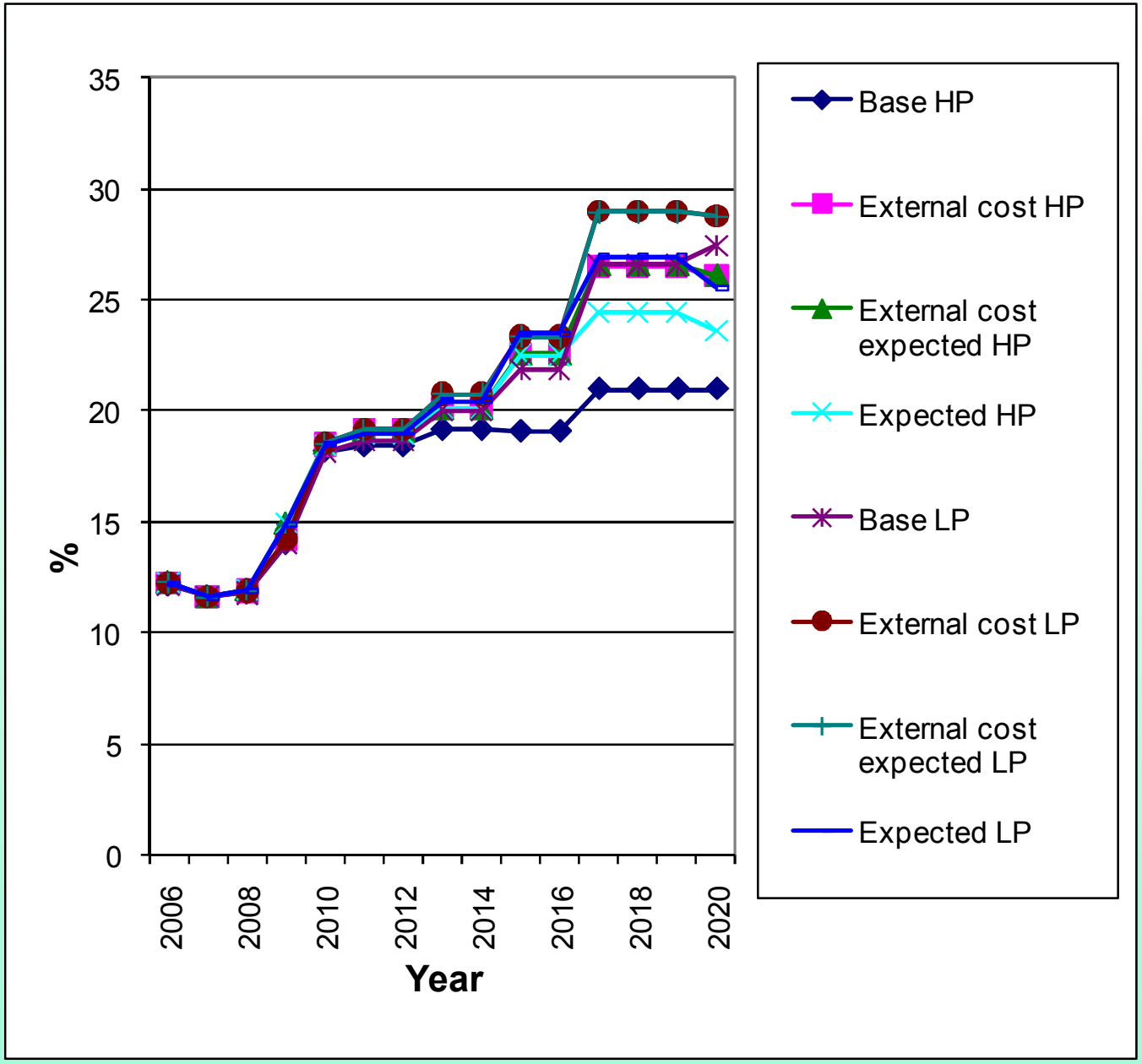
Sector of decentralized heat supply:

a) Future operation of existing equipments for space heating and hot water preparation,
b) Construction of new equipments for space heating and hot water preparation (bio fuel, fossil fuel, solar, geothermal, etc.);

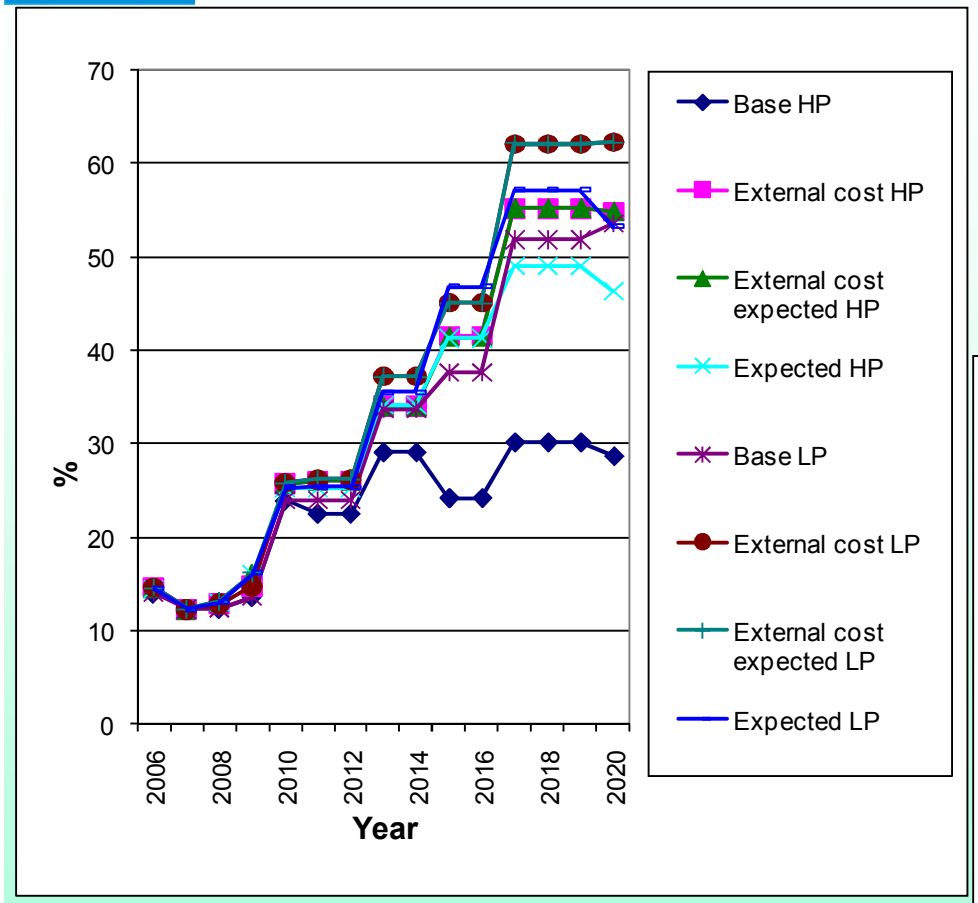
Sector for production of bio fuel:

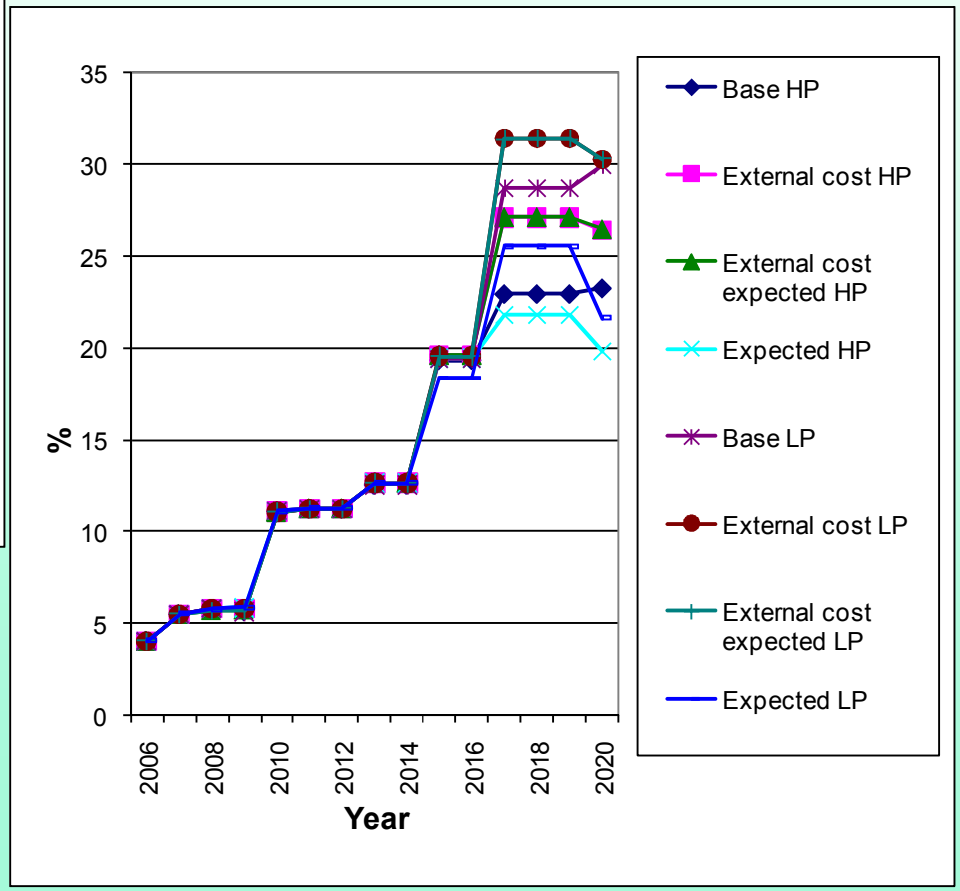
a) Production from agricultural products of bio components for blending with gasoline and diesel,
b) Production of hard bio fuels from wood, wood waste, forestry waste, agricultural products, etc.,
c) Production of biogas from stock-rising waste, industrial and municipal waste, agricultural products, residues from production of liquid bio fuels, etc.;

RES in gross final demand

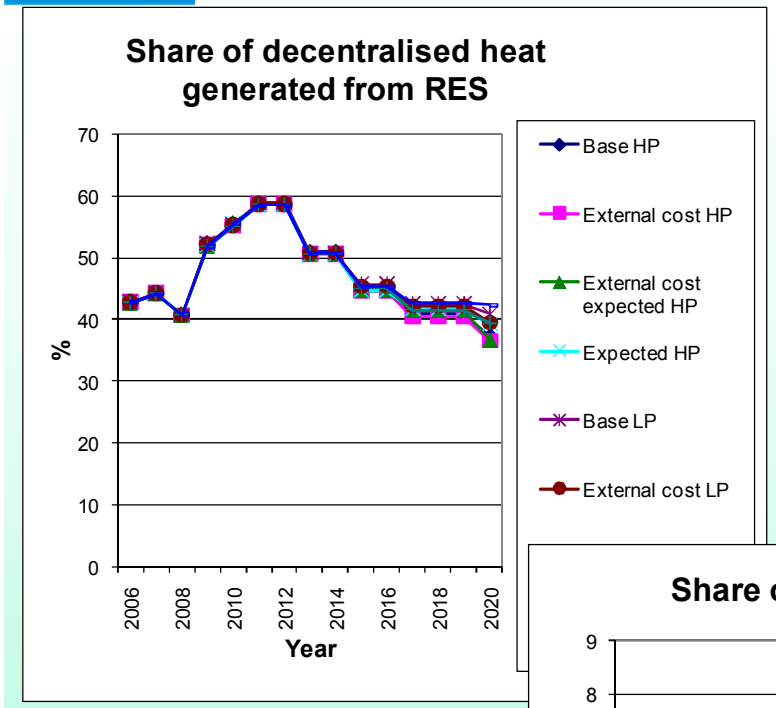


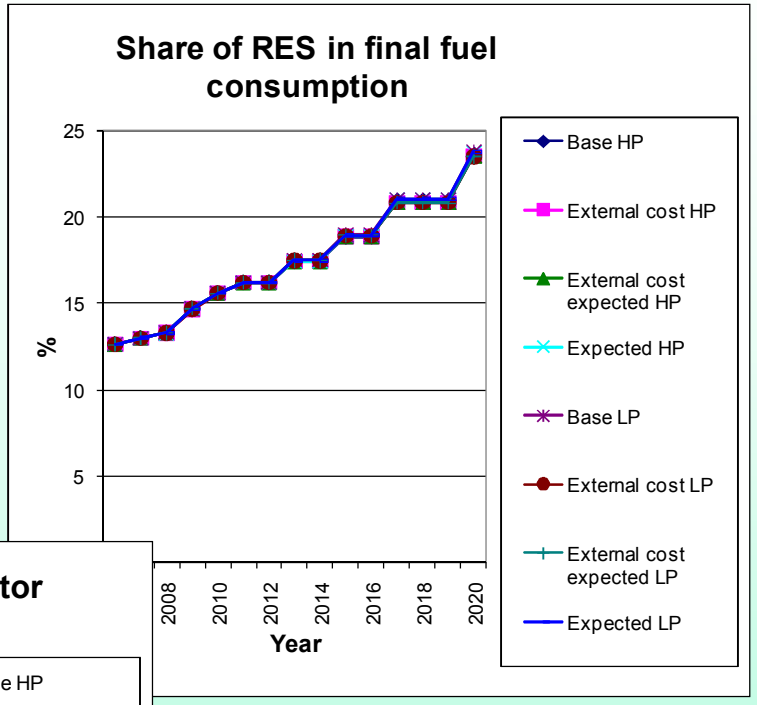
RES in district heating and electricity sectors

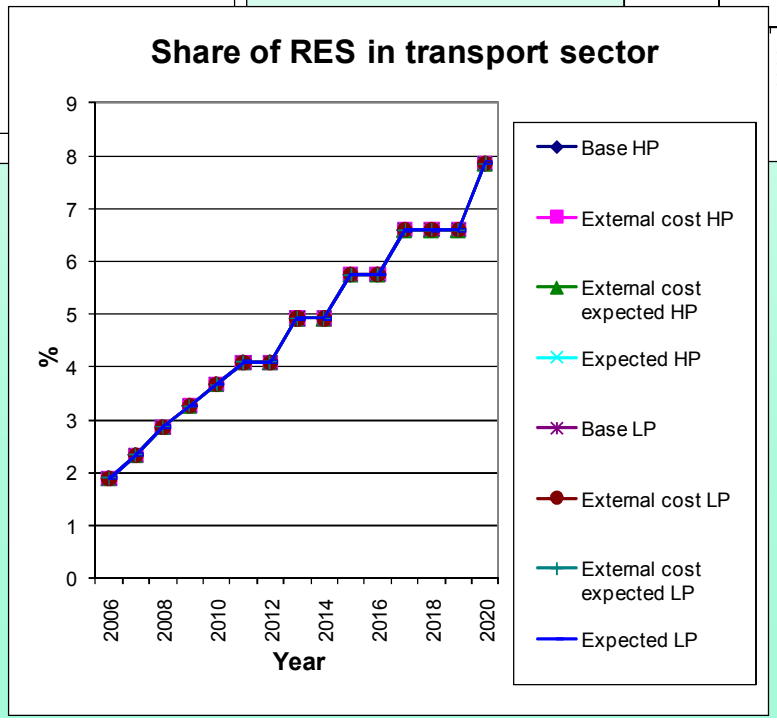




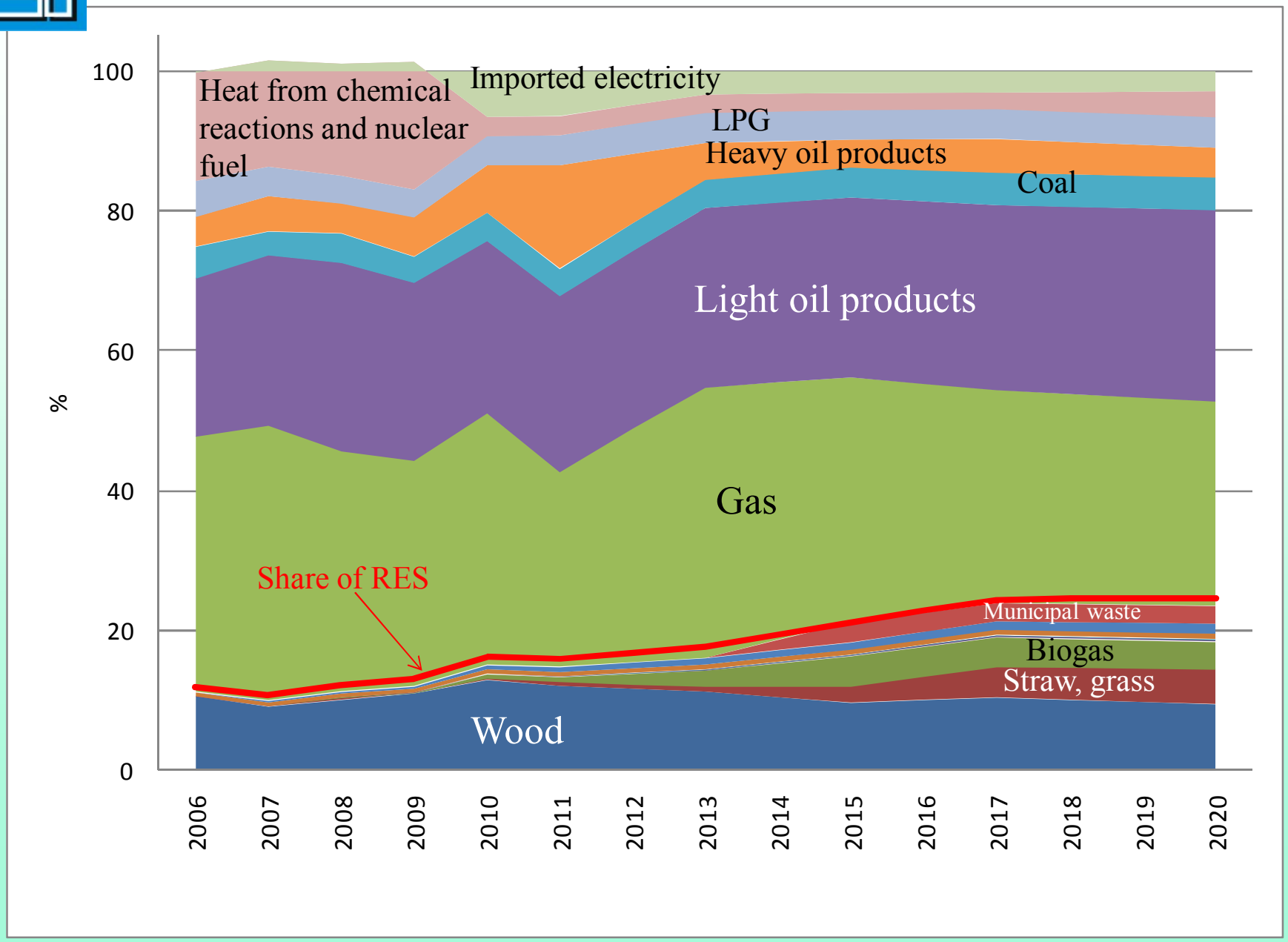
RES in other sectors



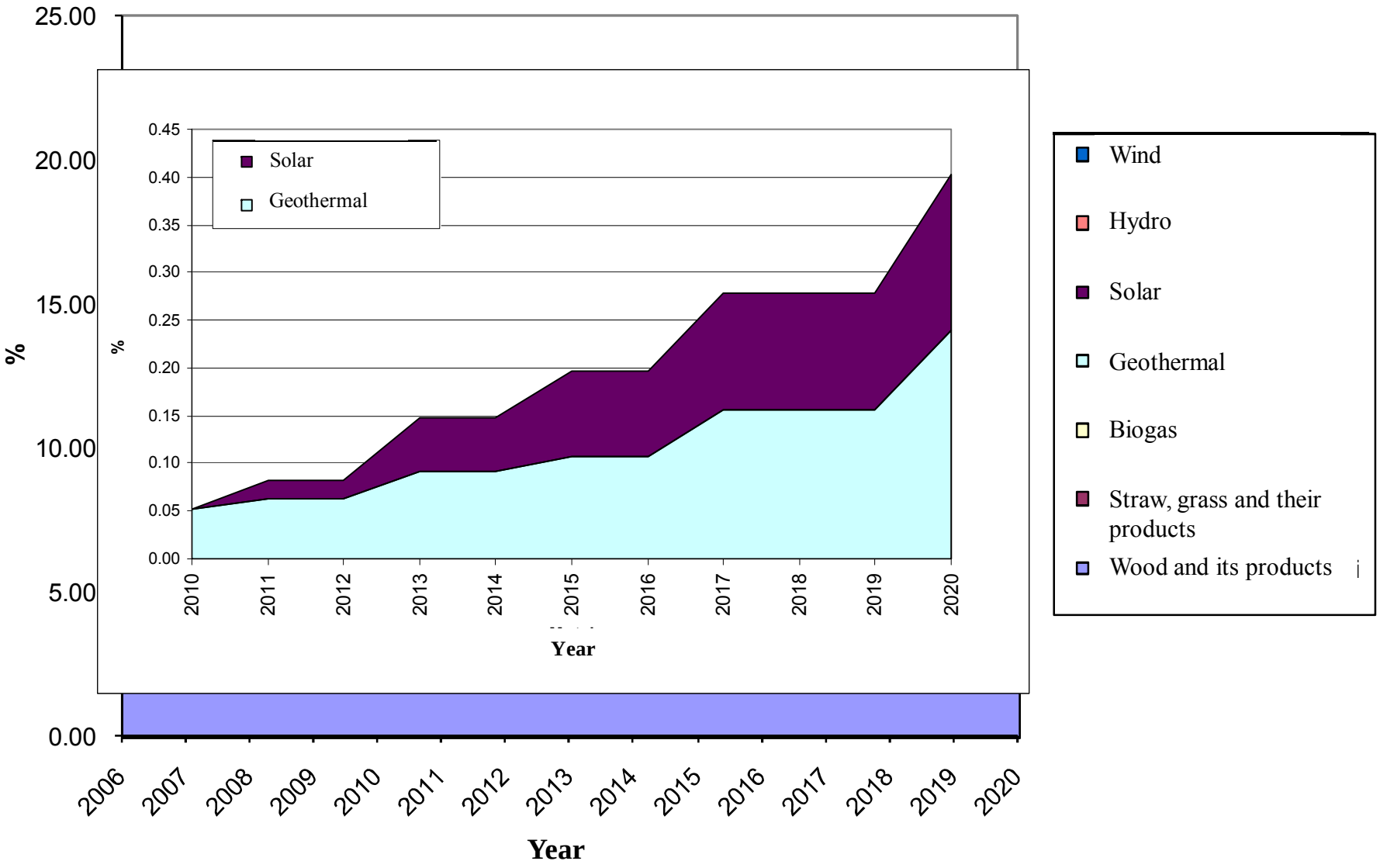




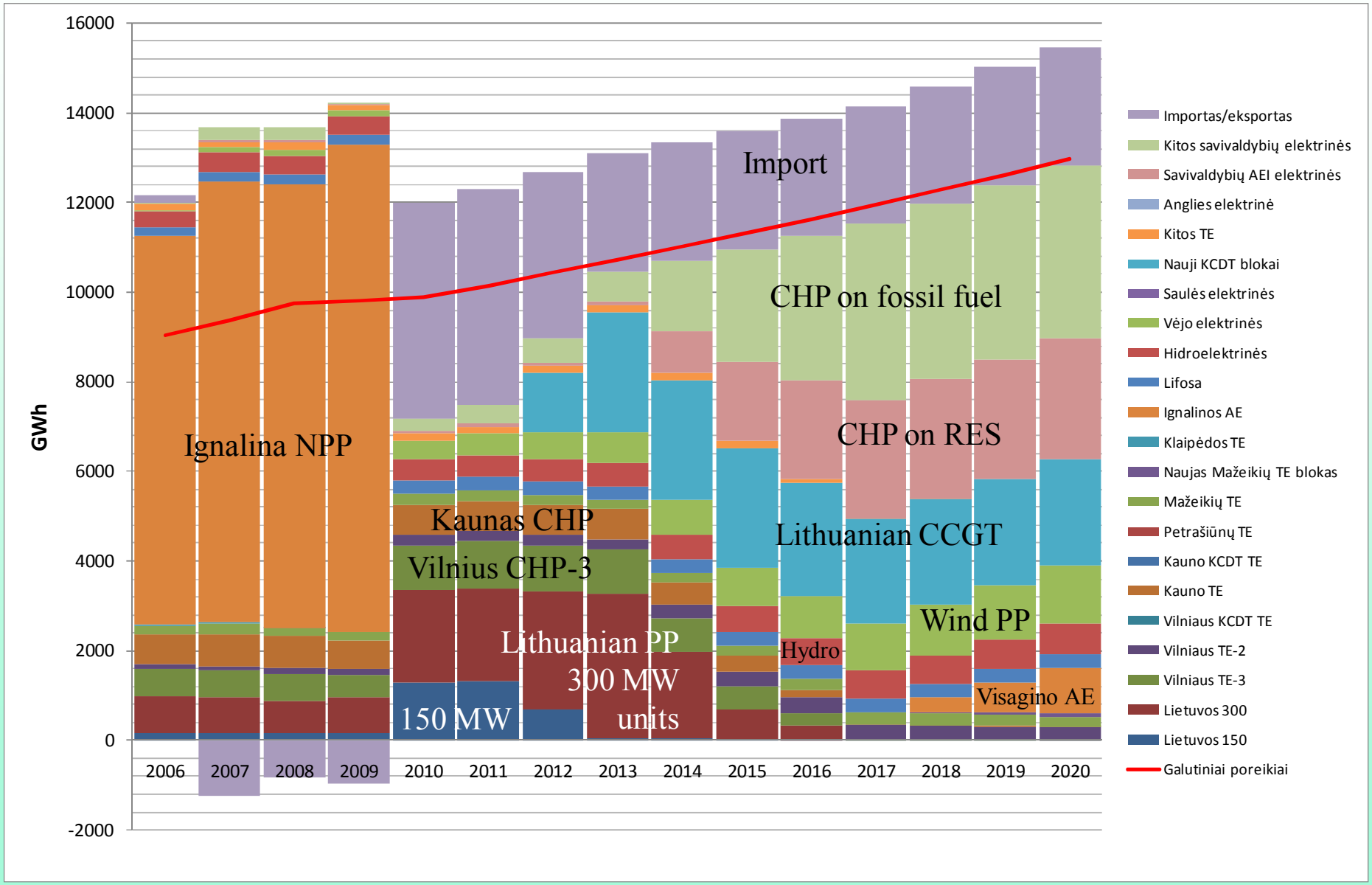
Structure of fuel and energy used in the country



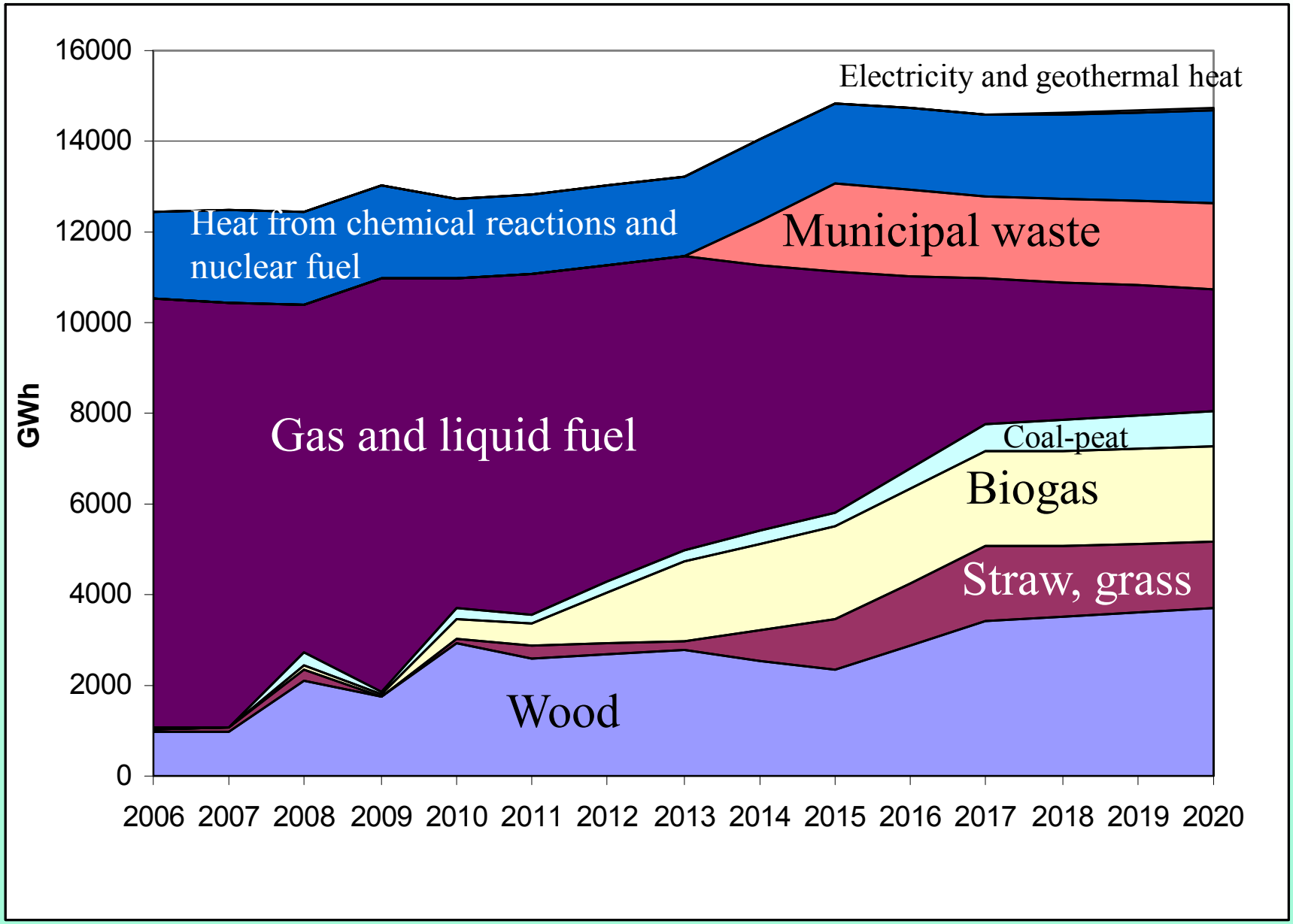
Structure of RES



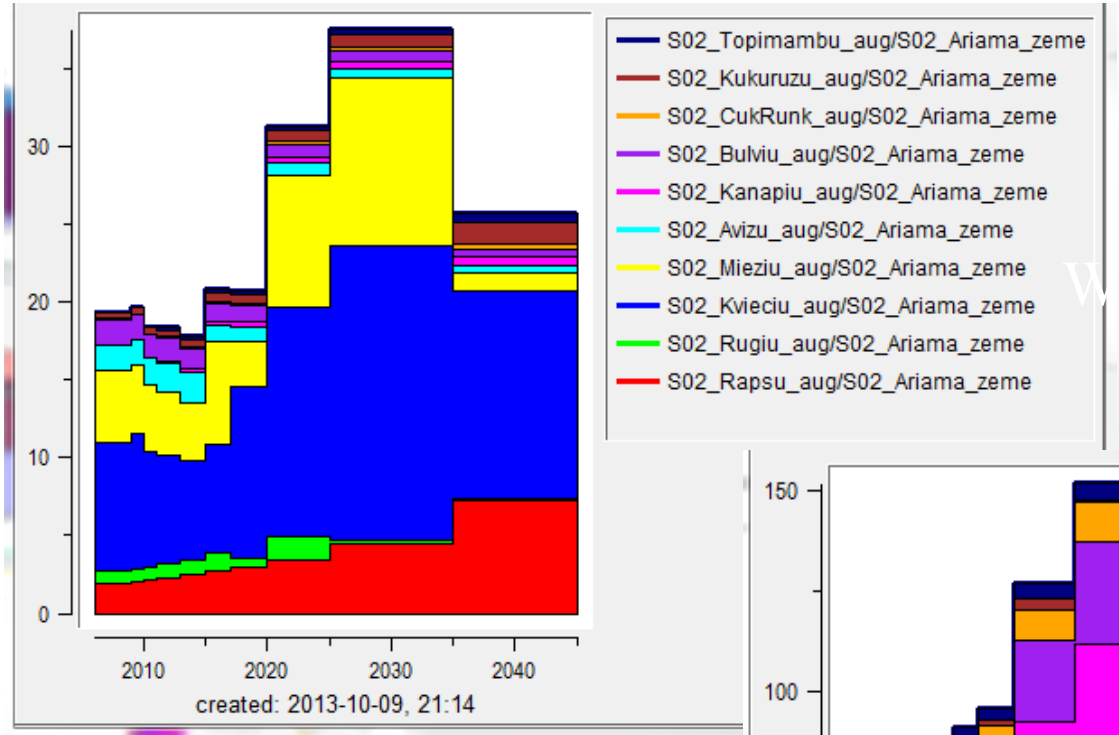
Production of electricity



Production of district heat according fuel types

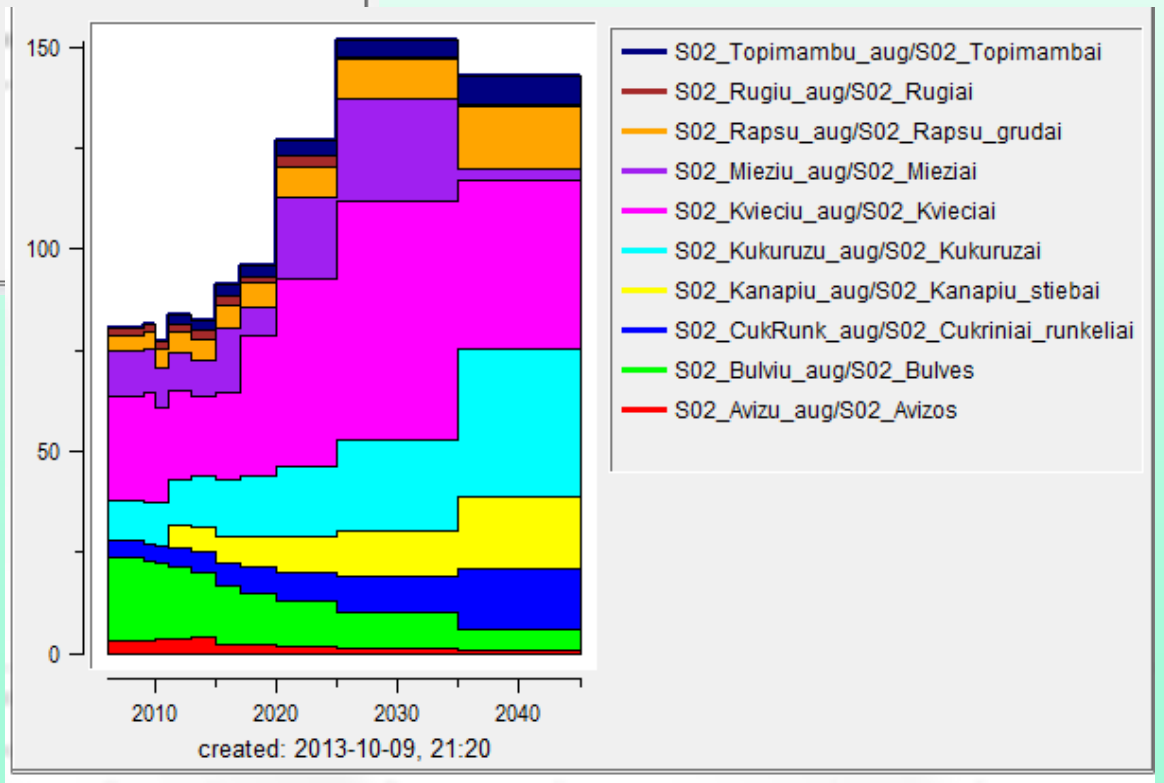


Land use for agricultural production and production in municipality S02

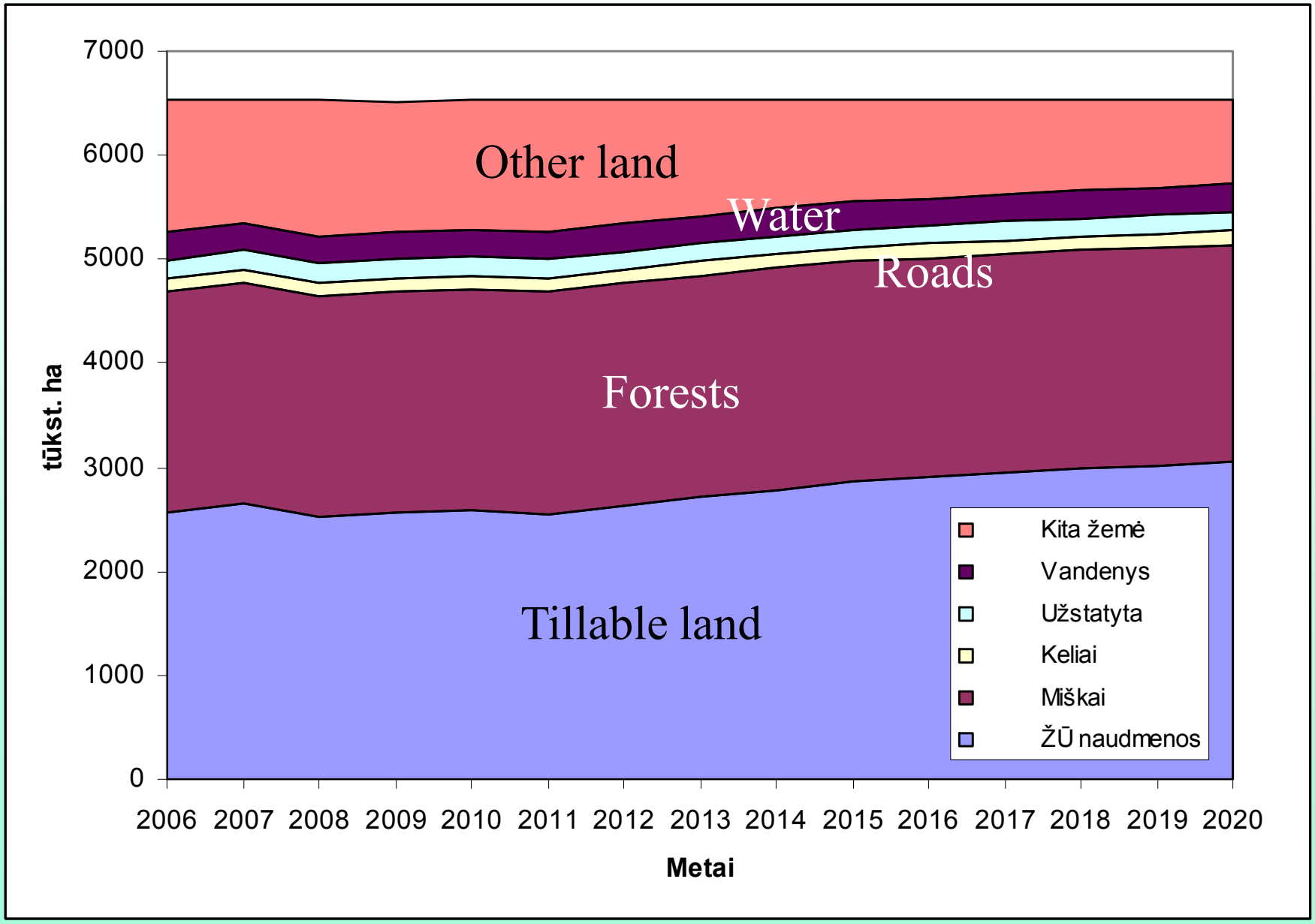


Water

Roads

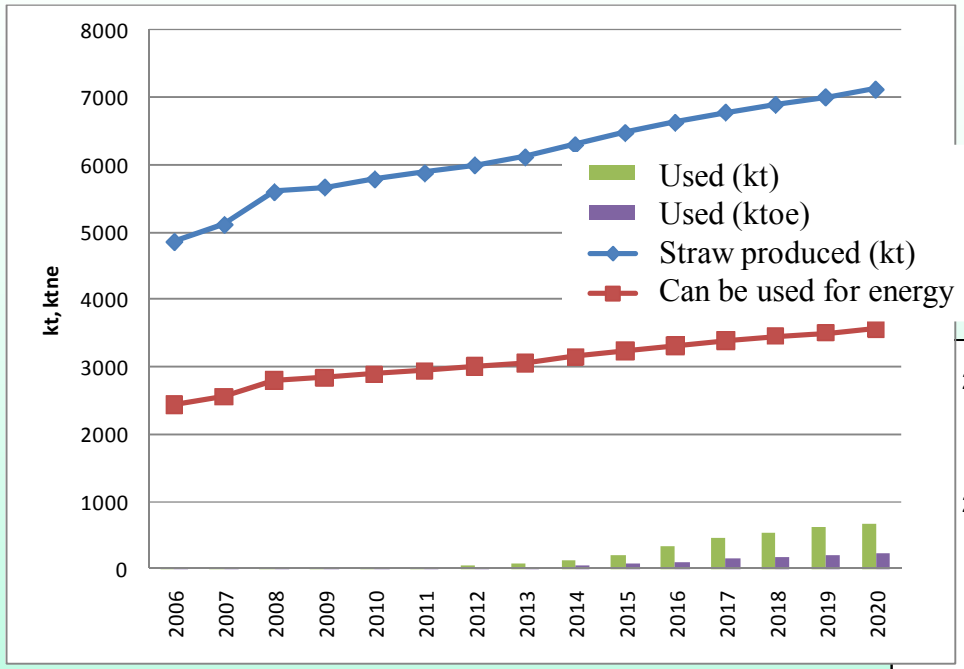


Land use

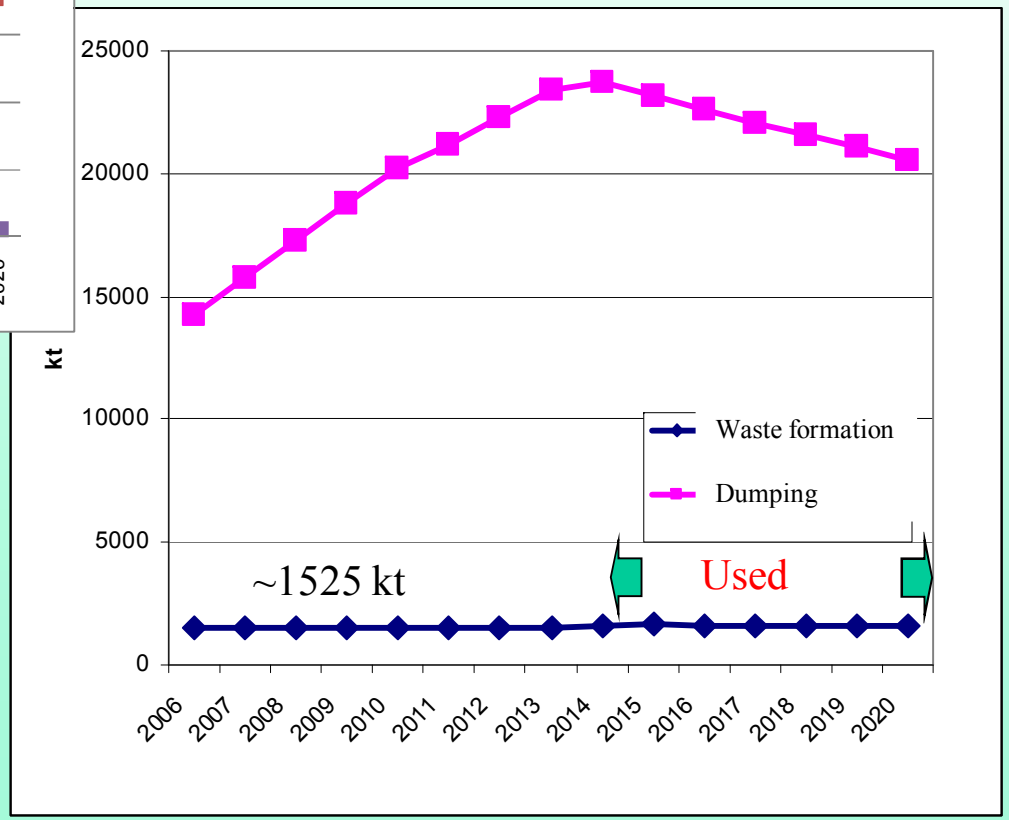

7000
6000
5000
4000
3000
2000
1000
0
tūkst. ha
Other land
Water
Roads
Forests
Tillable land
Kita žemė
Vandenys
Užstatyta
Keliai
Miškai
ŽŪ naudmenos
2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
Metai

Utilisation of straw and municipal waste

Straw



Municipal waste




Thank you for your attention.
Let’s hope for better future