A DYNAMIC GENERAL EQUILIBRIUM ANALYSIS FOR AUSTRIA: THE ROLE OF THE GREEN QUOTA AND REVENUE RECYCLING SCHEMES IN THE CLIMATE CHANGE OPTIONS

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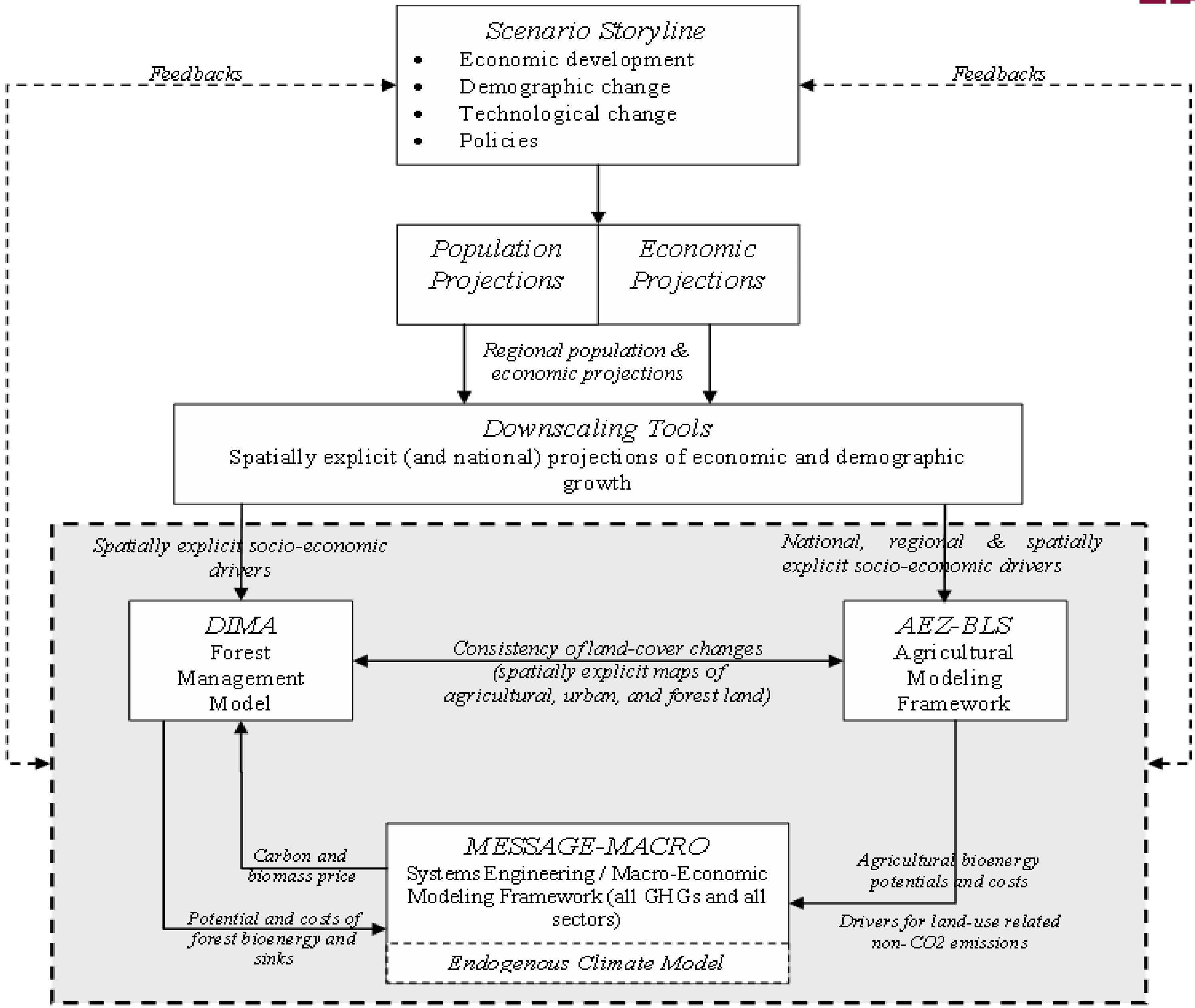
Methodology -TD-BU-E3 DGEM

To assess the long term (till 2060) effects of energy and environmental policies and quantify their macro economic and sectoral impacts we have developed **Top/Down** (macroeconomic part) - **Bottom-Up** (technological part), **E3** (energy, environment, economy) dynamic general equilibrium model allowing for systematic trade-off analysis of environmental quality, economic performance and welfare (consumption)

IIASA Integrated Assessment Modelling Framework



Hybrid modeling

- Hybrid modeling is the direct combination of bottom-up and top-down in a complementarity format.
- Complementarity is a feature of economic equilibrium and this feature can then be exploited to formulate an economic equilibrium as a mixed complementarity problem (**MCP**).
- The complementarity format facilitates weak inequalities and logical connections between **prices** and **market conditions** exemplified by the following equations:

$price \geq 0$ - the price of excess goods can't be negative

$$supply - demand \geq 0$$

$$price * (supply - demand) = 0$$

The declaration of the model as an MCP:

The **decision Variables** can be classified into:

Y a nonnegative m-vector of activity levels,

P a nonnegative n-vector of Prices,

M a nonnegative h-vector of Households (one Household, one Government agent)

An Equilibrium is achieved if the following conditions are satisfied:

1. No Activity makes a positive profit *(**Zero Profit condition**)*:

$$-\pi_j(p) \geq 0$$

$$\pi_j(p) = r_j - c_j$$

where $\pi_j(p)$ is the unit profit function of activity j (revenue r_j minus cost c_j)

2. Market clearance conditions and

3. Income balances

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2. An example for market clearing for the sectoral output is depicted bellow.

Where

mcm is the micro consistent Social Accounting Matrix

and

**mPYcompC - ** sectoral products consumption composite

macro

$$Y(i) * mcm(i,i) \geq -mcm(i,\text{"hh"}) * C \left(\frac{PC}{mPYcompC}\right)^{\sigma_y} \left(\frac{mPYcompC}{PY(i)}\right)^{\sigma_c^y} - mcm(i,\text{"ele"}) DELE - mcm(i,\text{"govt"}) G + i0(i)$$

Bottom-Up integration:

We consider the energy sector mathematical programming problem which seeks to find the least-cost schedule for meeting an exogenous set of energy demands using a given set of energy technologies, t:

$$\min \sum_t \bar{c}_t y_t$$

Subject to:

$$\sum_t a_{jt} y_t = \bar{d}_j \quad \forall j \epsilon \{Energy\ Goods\}$$

$$\sum_t b_{kt} y_t = K_k \quad \forall k \epsilon \{Energy\ Resources\}$$

y_t is the activity level of energy technology t

a_{jt} denotes the netput (input or output) of energy good j by technology t

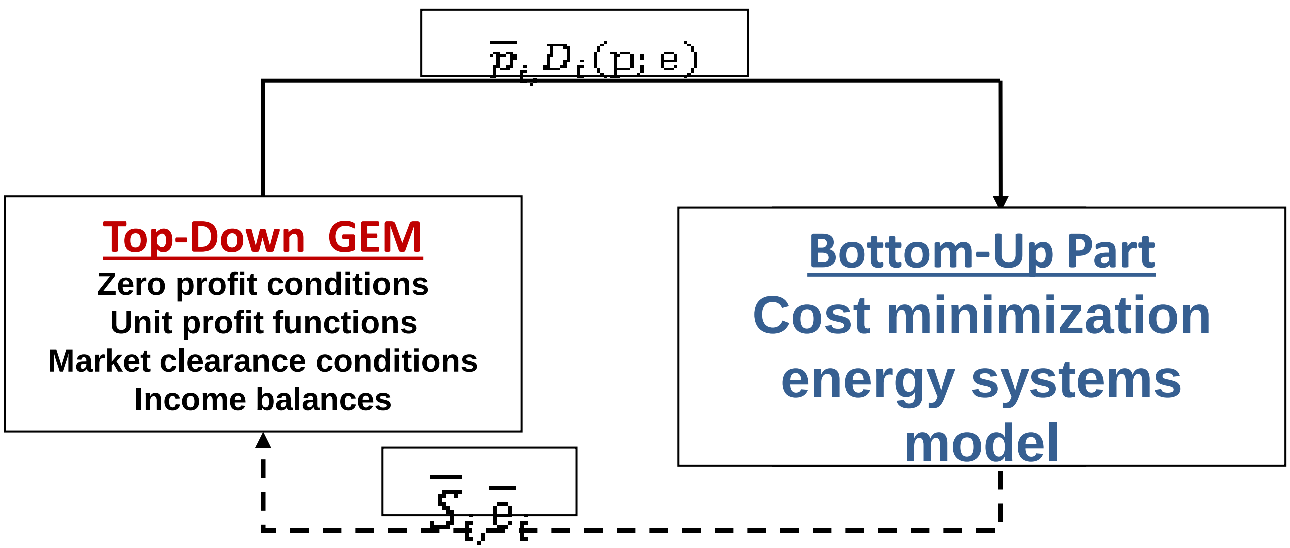
$\bar{c}_t$ is the exogenous marginal cost of technology t

$\bar{d}_j$ represents market demand for energy good j

b_{kt} Is the unit demand for energy resource k by technology t

K_k is the aggregate supply of energy resource, k

The basic steps involved in the iterative model solution are: The top-down model is solved as a complementarity problem, taking net energy supplies (e_i) *and energy* sector inputs (x) *as given. The computed equilibrium determines prices* (p_i) *and a set of* linear demand curves for energy sector outputs - D_i (p; ϵ). *These demand curves and relative* prices parameterize the bottom-up model which may be either integrated in the MCP framework or be solved iteratively as a quadratic programming problem.



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The Dynamic set up

We want to solve the model in sequence of **60** periods with one equilibrium per Period.

For that each variable will be extended to be a time dependent vector

The linking of the Periods is done via the **Capital stock** und **Investments** - new variables for the new equations :

$$K_{t+1} = (1 - \partial)K_t + I_t \quad (mkt)$$

$$p_t^K = r_t^K + (1 - \partial)p_{t+1}^K \quad (zprf)$$

To avoid the end of the period problems the **Capital stock** for it is exogenously determined;

Then the PATH Solver is computing the equilibrium path for all periods.

For the pilot implementation of **TD-BU-E3 DGEM**, our stylized dynamic pilot model contains:

- **Households** as a representative agent (+ **government** for redistribution)

three non-energy sectors:

X1 - Agriculture,

X2 - Energy intensive goods,

X3 - Other goods

Three conventional primary energy sources:

Oil, Gas, Coal (COL)

The renewable energy forms are represented by

(1) Hydro power; (2) **Solar Energy**, (3) **Biomass for space heating and power production**, and (4) **Wind energy**

and by the respective **electricity (ELE)** producing technologies

The renewable technologies represented in the model are:

- Wind engines: existing and new types
- Fuel Wood for space heating and power production
- Advanced technologies for biomass use, e.g. liquefaction
- Advanced photovoltaic devices

The relative prices per unit of electricity produced have been ranked from the cheapest, hydro power, to the most expensive, new solar photovoltaic - assumed to be 2.2 more expensive

Reflecting on to the integrated energy and climate change policy guidelines, as adopted by the EU in 2008

we aim to assess quantitatively the macroeconomic and sectoral impacts of two alternative policy instruments :

- **quota obligation systems and**
- **carbon taxation (double dividend)**

The **green quota scenario** is simulating the structural change in power producing technology mix needed to achieve a 30% share of renewables (without hydro) in the electricity production by 2050

The **double dividend** of CO2 taxation is:

1st dividend: the **improvement in environmental quality**, and

2nd dividend: alternative ways of recycling the additional tax revenues for a revenue-neutral cut of existing taxes. The additional carbon tax revenues can be allocated in three different ways: 1. labor tax reduction; 2. cut in the consumption tax; 3. lump-sum refund to the low income part of the households

In defining our energy scenarios we considered the

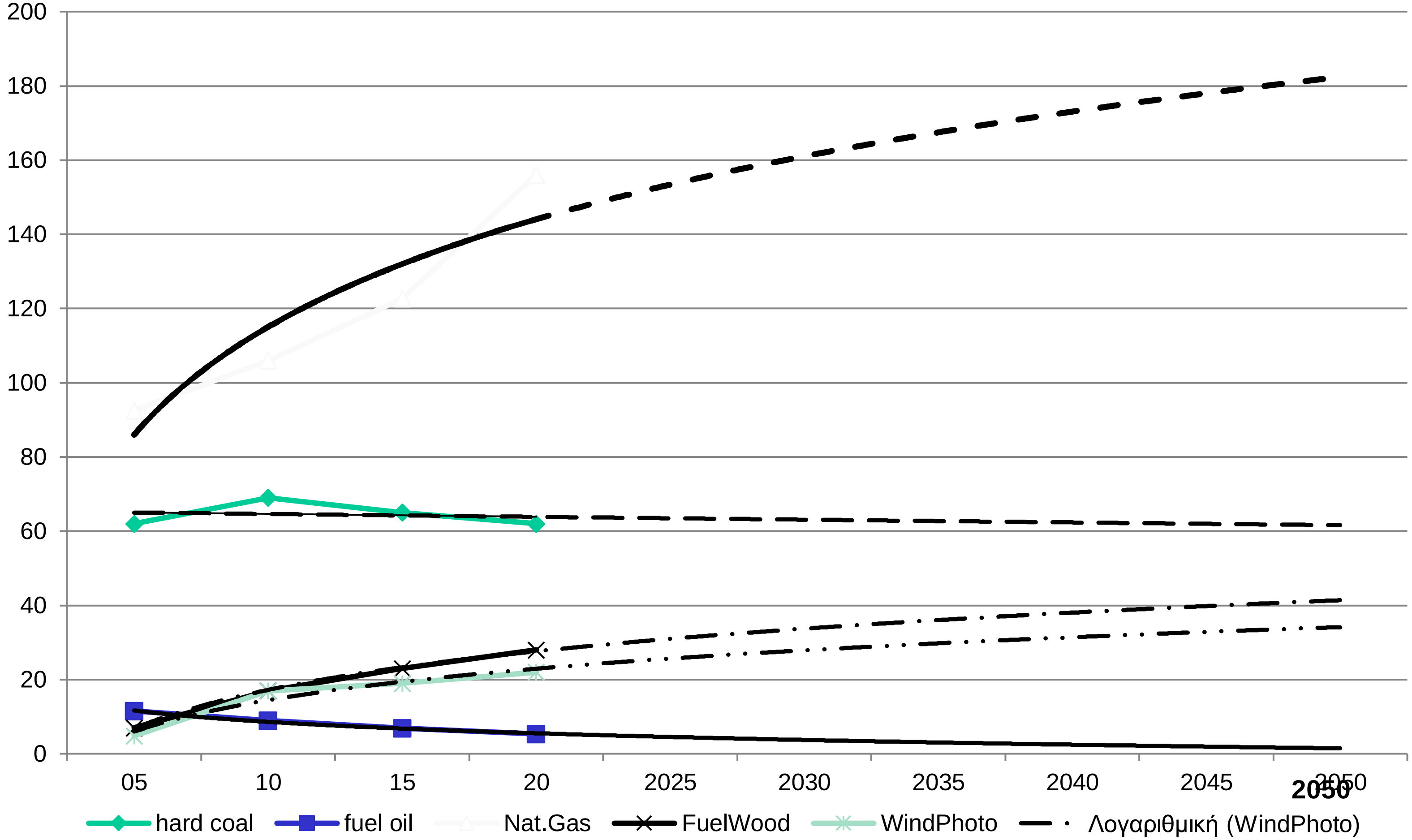
Ranking of EU countries according to the kg CO_2 emission per 1 EURO

		kg CO_2 emission per 1 EURO
1	Sweden	0,162
2	France	0,253
3	Denmark	0,284
4	UK	0,305
5	Austria	0,315
6	Ireland	0,317
7	Italy	0,378
8	Germany	0,399
9	Luxemburg	0,409
10	Belgium	0,4011
11	Holland	0,4112
12	Finland	0,4313
13	Portugal	0,4514
14	Spain	0,4715
15	Greece	0,5815
16	Latvia	0,5817
17	Slovenia	0,5918
18	Cyprus	0,6219
19	Malta	0,63
	EU average	*0,74*
20	Lithuania	0,7421
21	Hungary	0,8722
22	Slovakia	1,1823
23	Poland	1,3524
24	Czech Republic	1,5825
24	Romania	1,6426
26	Estonia	1,8727
27	Bulgaria	2,73

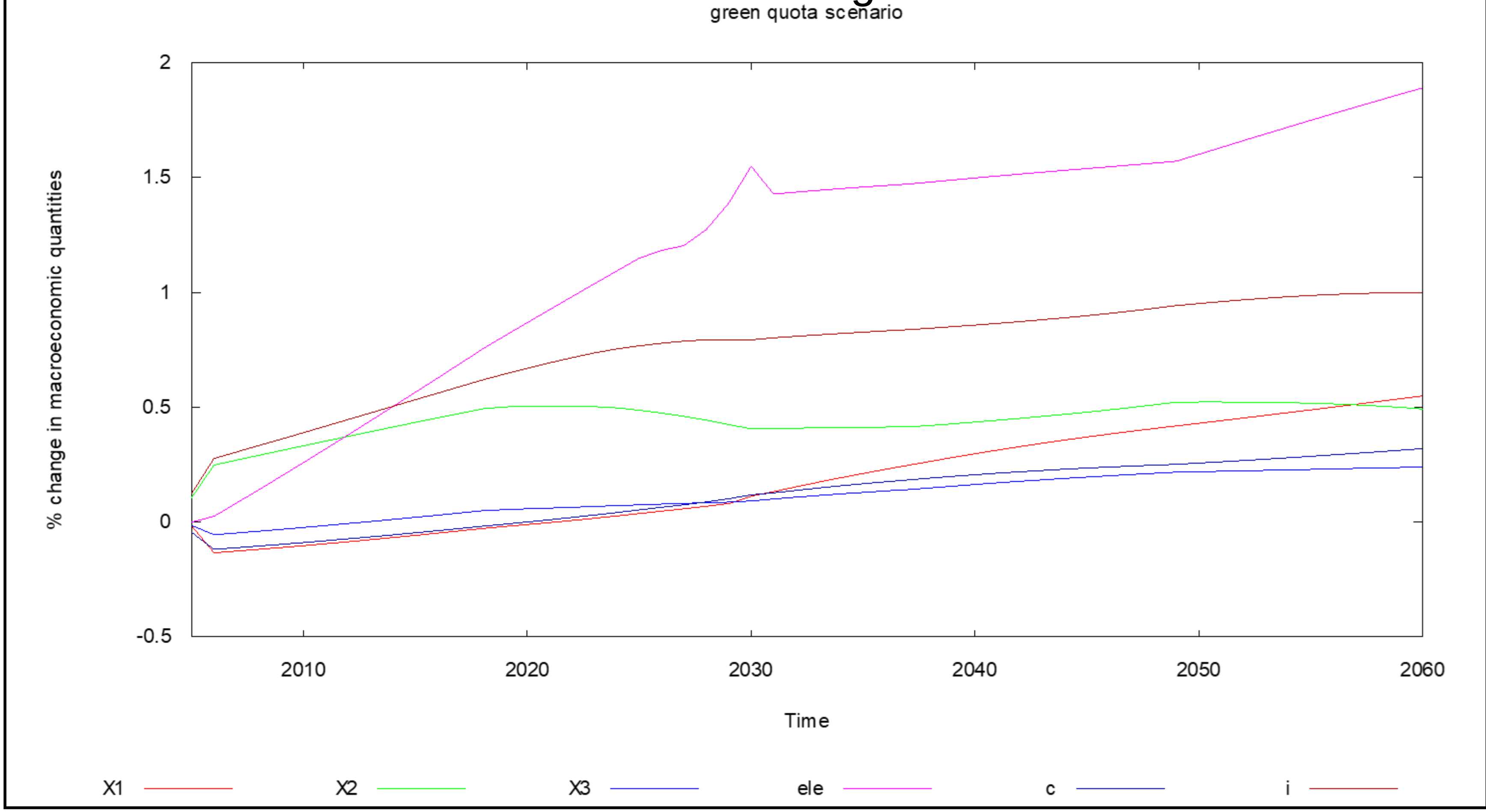
*- WEU (19) average – 0.4

As a guiding framework we used the “E50 - Energiestrategie Österreich” and the greenhouse gas emission scenarios for Western Europe (**WEU)** that were created under the IIASA Integrated Assessment Modeling Framework

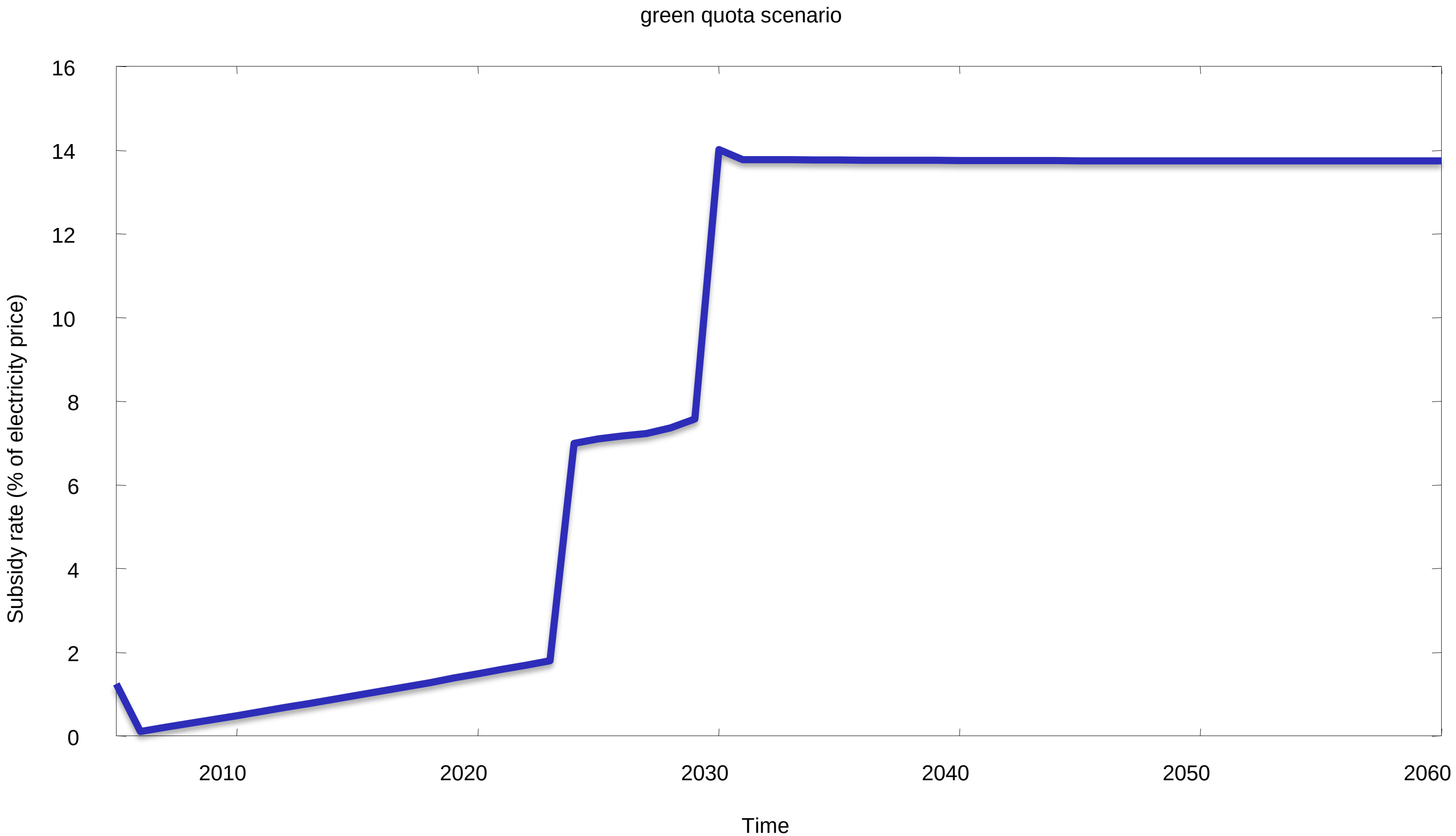
Scenario assumptions for the main technologies till 2050 (in PJ)



The growth of the power production indexed with 1.66 is following quite closely the **green quota scenario assumption** and around 2030 there is a small bump. This is result of the exhaustion of the conventional hydro and bio-wind resources and the slum is due to the significant subsidies needed for the start up of the new wind and biomass technologies.



The subsidy rates for the green technologies: The up of new and expensive technologies result in a jump of the subsidy rate for green technologies, first in 2025 at the level of 8% from the electricity production cost. When new Vintage wind reaches its potential, in 2030 there is another jump in subsidy rates reaching to 14%, so that new biomass technologies could start producing electricity.



Carbon Taxation (double dividend) Scenario

- The **greenhouse gases** are measured in megatons of Carbon dioxide equivalency (MCO_2eq) and there are a number of alternative tax instruments for reducing its emissions
- Over the last decade, several EU Member States have levied some type of carbon tax in order to reduce greenhouse gas emissions from fossil fuel combustion contributing to anthropogenic global warming (OECD 2001).
- In this context, the debate on the **double dividend** hypothesis has addressed the question of whether the usual trade-off between environmental benefits and gross economic costs (i.e. the costs disregarding environmental benefits) of emission taxes prevails in economies where distortionary taxes finance public spending.

The **double dividend** hypothesis

- Emission taxes raise public revenues which can be used to reduce existing tax distortions. Revenue recycling may then provide prospects for a double dividend from emission taxation (Goulder 1995):
- Apart from an improvement in environmental quality (the first dividend), the overall excess burden of the tax system may be reduced by using additional tax revenues for a revenue-neutral cut of existing distortionary taxes (the second dividend).
- If – at the margin – the excess burden of the environmental tax is smaller than that of the replaced (decreased) existing tax, public financing becomes more efficient and welfare gains will occur.

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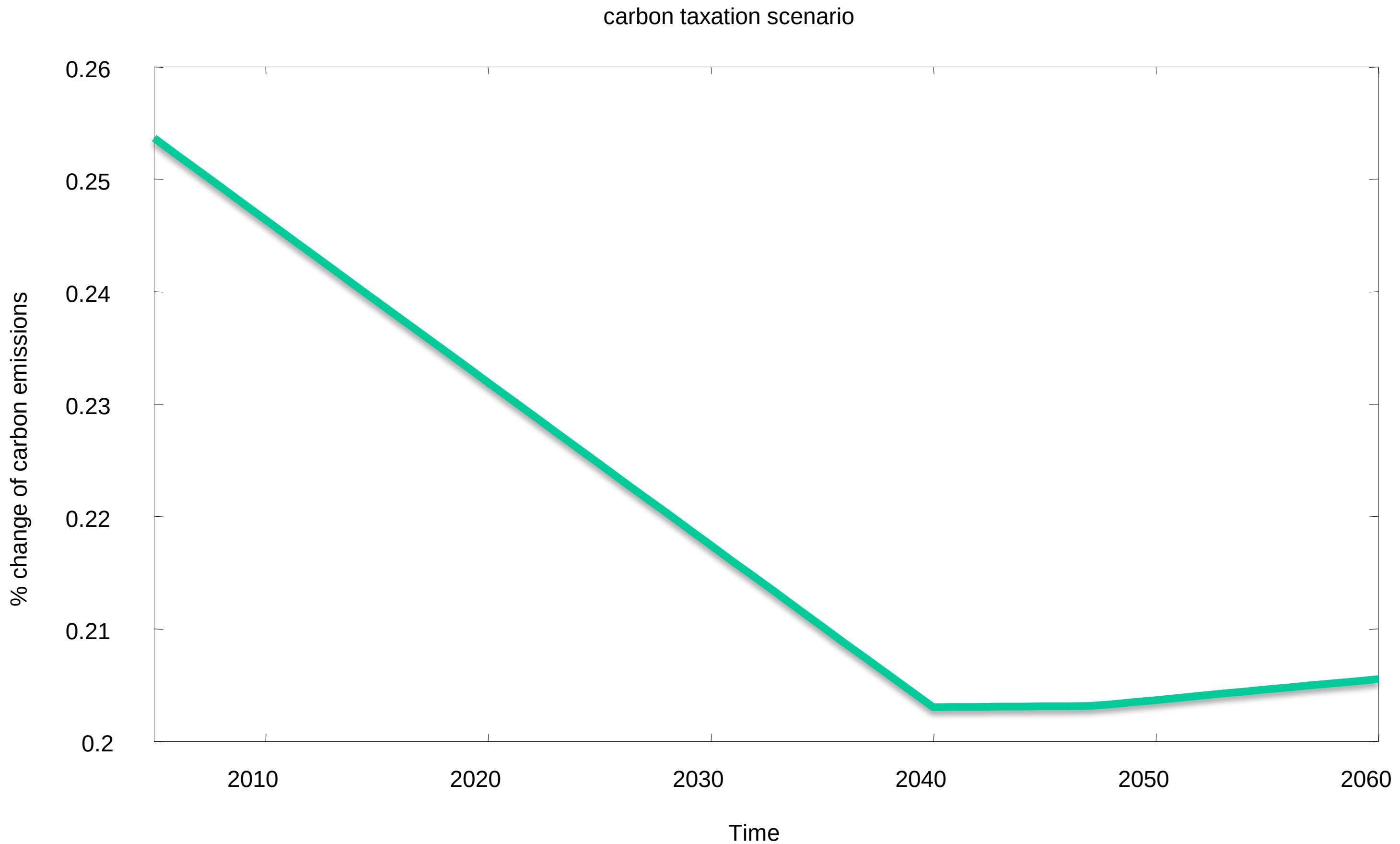
In our dynamic policy simulations, we investigate the economic effects of carbon taxes that are set sufficiently high to reduce carbon emissions by 20% compared to the base year emission level.

The figure below is showing the **rate of decarburization** of the **produced electricity**, namely the reduction of CO2 emissions per TWh of power production



While keeping consumption of public goods at the base-year level, the additional carbon tax revenues can be recycled in three different ways:

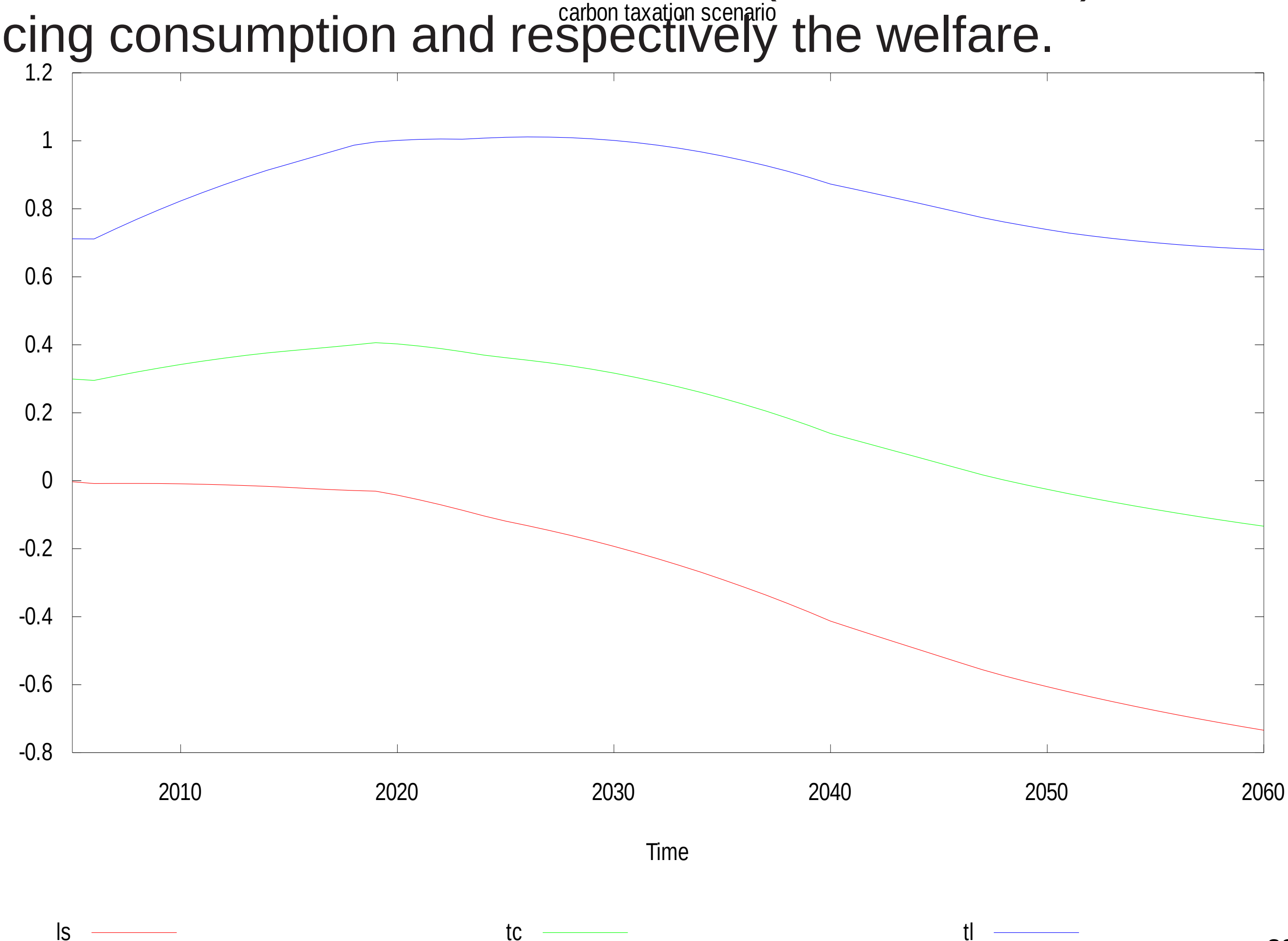
1. a reduction in the labor tax (labeled as “**TL**”)
2. a cut in the consumption tax (labeled as “**TC**”)
3. a lump-sum refund to the representative household (labeled in the Figure as “**LS**”)

As would be seen at the next slide the reduction of the distortionary consumption or labor taxes (TL) is superior in efficiency terms as compared to a lump-sum recycling of carbon tax revenues (LS).

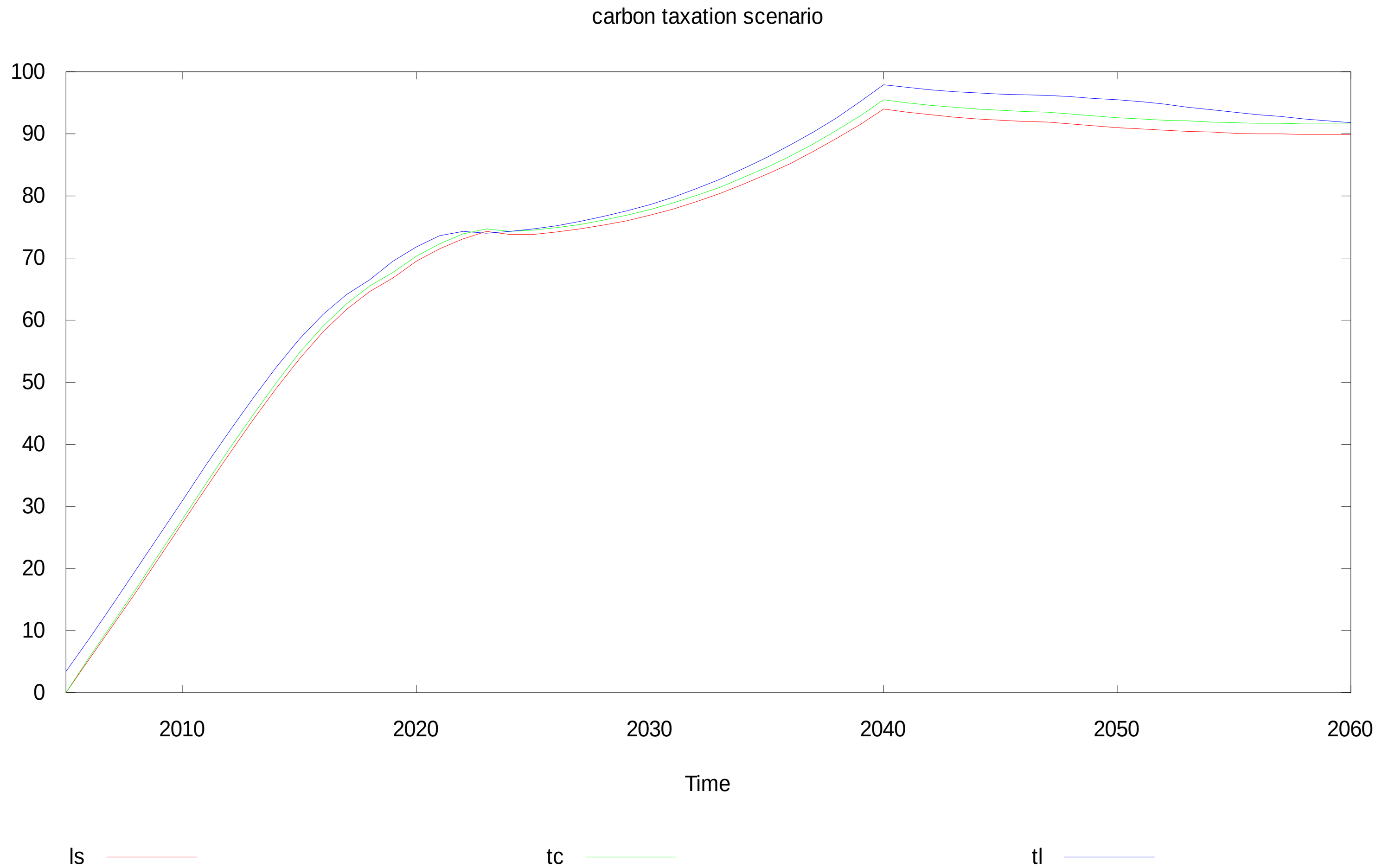
Reflecting the larger marginal excess burden of the initial labor tax vis a vis the initial consumption tax, labor tax recycling is distinctly more beneficial than consumption tax recycling.

Reducing the labor tax (blue line - **TL**) increases consumption levels over a long period of time and with 0.7 to 1 percent over the GDP growth.

With consumption tax (green line - TC) consumption increases from 0.3 to 0.4% over the GDP growth and the recycling through lump-sum refund to the households (red line - LS) tends to be reducing consumption and respectively the welfare.



The associated carbon tax rates, or the marginal abatement cost (MAC) needed to achieve the target emission reductions has been computed at below EUR 100 that correlates very well with other multi country studies for the EU region, e.g. MAC levels for Austria have been estimated by the EU´s "Impact Assessment of the EU's objectives on climate change and renewable energy for 2020" to be around € 90/t CO2.



CONCLUSIONS

By developing and extensively validating Top/Down -BU for Bottom-up E3 dynamic general equilibrium model (TD-BU-E3 DGEM) we assessed the long term impacts on the macroeconomic and sectoral structural components of two alternative policy instruments for responses to climate change and for promotion of renewable energy sources:

- Green quota, and
- Carbon Taxation (double dividend)

In our baseline Scenario, as a part of the adaptation strategy, we assumed de-coupling of electricity demand growth from the economic growth.

The runs for the **Green quota scenario** have shown that due to increasing demands of biomass the agriculture sector is growing while the output of heavy industries is slightly declining due the general trend in exporting/downsizing the energy intensive industries.

- due to the high capital intensity of the power sector the growth of investment is following closely the growth of the electricity output
- despite the significant investment demand the consumption is growing, albeit at a lower rate,.

To summarize: achieving the quota of close to 30% by 2050 is feasible and there are sufficient supplies of renewable resources available for electricity production.

- It also seems that the economic burden is bearable and the welfare is growing.

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The **double dividend** hypothesis is addressing the question on the trade-off between environmental benefits and gross economic costs (i.e. the costs disregarding environmental benefits) or how to make best use emission taxes in economies where distortionary taxes finance public spending.

- Emission taxes raise public revenues which can be used to reduce existing tax distortions.
- Revenue recycling may then provide prospects for a double dividend from emission taxation.

While keeping public good consumption at the base-year level, the additional carbon tax revenues can be recycled in three different ways:

- a reduction in the distortionary labor tax
- a cut in the distortionary consumption tax
- a lump-sum refund to the representative household

The results of the simulations have shown that:

- **the reduction** in the distortionary **labor tax is increasing consumption**
- consumption increases to a much lesser extend if the consumption tax is reduced .

From the other side lump-sum refund to representative household is reducing consumption and respectively the welfare.

Hence,

only for the case of labor tax recycling, we could assume the existence of a strong double dividend.