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

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at the 2nd International Scientific Conference on "*Energy and Climate Change*" of the PROMITHEAS network,
Location: the National and Kapodistrian University of Athens,
8th and 9th of October, 2009

# Reflecting to 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)**

- In this paper the **green quota scenario** is simulating the role of the power producing technology mix in rising the share of renewables for electricity production up to 30% by 2050
- The **double dividend** of CO2 taxation relates to the improvement in environmental quality (**the first dividend**), and to the ways of using the additional tax revenues for a revenue-neutral cut of existing taxes (**the second dividend**). The additional carbon tax revenues can be allocated in three different ways:

1. reduction in the labor tax
2. cut in the consumption tax
3. lump-sum refund to the low income part of the households

# Methodology -TD-BU-E3 DGEM

For assessing the long term (till 2060) effects of policies and quantify their 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)

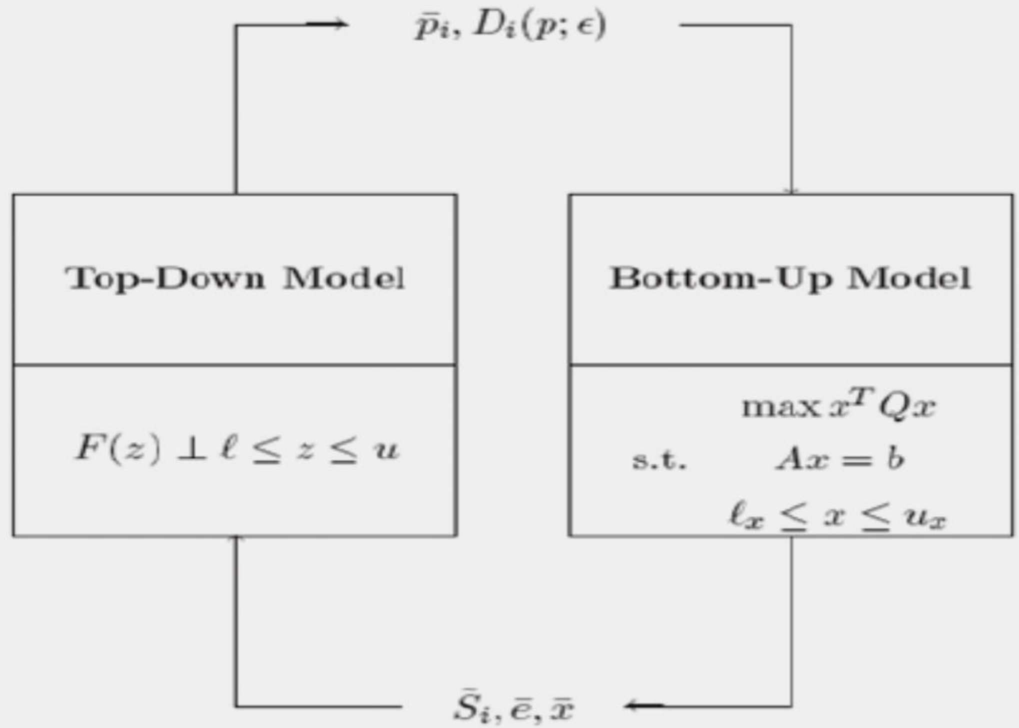
# The TD-BU-E3 DGEM

Our effort was inspired by the pivotal work by Prof. Pantelis Capros and his team on the **THE GEM-E3 MODEL - A GENERAL EQUILIBRIUM MODEL FOR 27 EUROPEAN COUNTRIES**

In developing our model we benefited from formulated as mixed complementarity problems (MCP) market equilibrium by Christoph Böhringer and Thomas F. Rutherford in their publication **Combining Top-Down and Bottom-up in Energy Policy Analysis: A Decomposition Approach.**

**Some recent utilities implemented by** Thomas F. Rutherford like GAMS/MPSGE, macro functions, PATHS solver, etc., made the programming easy and flexible

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; epsilon). These demand curves and relative* prices parameterize the bottom-up model which may either be integrated in the MCP framework or be solved iteratively as a quadratic programming problem.



As a pilot implementation of the **TD-BU-E3 DGEM**, we have formulated a stylized dynamic pilot model with one representative agent (+ government for redistribution) and three non-energy goods(*agriculture, energy intensive good and others) and a set* of four energy goods (*OIL, GAS, COL (coal), and ELE (electricity)).*

The existing and prospective renewable technologies are:

•Existing and new types of wind engines,

•Fuel Wood and advanced use of biomass/liquefaction 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

In the MCP framework, the algebraic representation of the pilot model begins from the dual cost minimization problems of the individual producers. For sectors *i (agriculture, energy intensive good and others) we have cost-minimizing unit energy costs given* by:

$$
\begin{aligned}
p_i^E \;=\; & \left(\frac{p_{\mathrm{ELE}}}{\theta_i^{\mathrm{ELE}}}\right)^{\theta_i^{\mathrm{ELE}}} \Bigg\{ \delta_i \left(\frac{p_{\mathrm{COL}}}{\delta_i}\right)^{(1-\sigma_i^E)} \\
& + (1-\delta_i)\left[\left(\frac{p_{\mathrm{OIL}}}{(1-\delta_i)\theta_i^{\mathrm{OIL}}}\right)^{\theta_i^{\mathrm{OIL}}} \left(\frac{p_{\mathrm{GAS}}}{(1-\delta_i)(1-\theta_i^{\mathrm{OIL}})}\right)^{(1-\theta_i^{\mathrm{OIL}})}\right]^{(1-\sigma_i^E)} \Bigg\}^{1/(1-\sigma_i^E)}
\end{aligned}
$$

Unit profit functions for $x$ and $y$ are in turn given by:

$$
\begin{aligned}
\Pi_i \;=\; & p_i - \frac{1}{\phi_i}\Bigg[\gamma_i \left(\frac{p_i^E}{\gamma_i}\right)^{(1-\sigma_i)} \\
& + (1-\gamma_i)\left(\frac{r_i}{\theta_i(1-\gamma_i)}\right)^{\theta_i(1-\sigma_i)} \left(\frac{w}{(1-\theta_i)(1-\gamma_i)}\right)^{(1-\theta_i)(1-\sigma_i)}\Bigg]^{1/(1-\sigma_i)}
\end{aligned}
$$

The unit cost of energy inputs to final demand are given by:

$$
p_c^E = \left(\sum_i \beta_i \left(\frac{p_i^E}{\beta_i}\right)^{1-\sigma^{EC}}\right)^{1/(1-\sigma^{EC})}
$$

and the resulting cost of a unit of final consumption is:

$$p^c = \left[ \alpha \left( \frac{p_c^E}{\alpha} \right)^{1-\sigma^C} + (1-\alpha) \left( \left( \frac{p_x}{\theta^C(1-\alpha)} \right)^{\theta^C} \left( \frac{p_y}{(1-\theta^C)(1-\alpha)} \right)^{(1-\theta^C)} \right)^{1-\sigma^C} \right]^{1/(1-\sigma^C)}$$

Finally, the unit profit associated with technology $t$ for energy good $i = \{col, \ oil, \ gas, \ ele\}$ is:

$$\Pi_{it}^E = p_i^E - p_x a_{it}^x - p_y a_{it}^y - \sum_{i'} p_i^E b_{i'it} - \mu_{it}$$

Given the underlying functional forms, we observe that the complementarity conditions only will apply for the energy sector technologies and the shadow prices on the associated capacity constraints; all of the macro economic prices and quantities will be non-zero.

We can then write the equilibrium as the following mixed complementarity problem:

- Zero-profit conditions:

$$\bar{z}_{it} \geq z_{it} \perp \mu_{it} \geq 0$$

$$-\Pi_{it}^{E} \geq 0 \perp z_{it} \geq 0$$

$$\Pi_x = 0$$

$$\Pi_y = 0$$

- Market clearence conditions:

$$x = \sum_{it} a^x_{it} z_{it} + c\frac{\partial \Pi_c}{\partial p_x}$$

$$y = \sum_{it} a^y_{it} z_{it} + c\frac{\partial \Pi_c}{\partial p_y}$$

$$\bar{L} = x\frac{\partial \Pi_x}{\partial w} + y\frac{\partial \Pi_y}{\partial w}$$

$$\bar{K}_x = x\frac{\partial \Pi_x}{\partial r_x}$$

$$\bar{K}_y = y\frac{\partial \Pi_y}{\partial r_y}$$

$$\sum_{t} z_{it} - \sum_{i't} b_{ii't} z_{i't} = c\frac{\partial \Pi_c}{\partial p^E_i} + x\frac{\partial \Pi_x}{\partial p^E_i} + y\frac{\partial \Pi_y}{\partial p^E_i}$$

$$c = \frac{M}{p_c}$$

- Income balance:

$$M = r_x\bar{K}_x + r_y\bar{K}_y + w\bar{L} + \sum_{it} \mu_{it}\bar{z}_{it}$$

The bottom-up model can be represented as a quadratic programming problem in which the sum of producer and consumer surplus is maximized subject to supply-demand balances for energy and resource bounds on technologies:

$$\max \sum_i \tilde{p}_i^E \left(1 + \frac{2\tilde{S}_i - S_i}{2\epsilon_i \tilde{S}_i}\right) - \tilde{p}_x x_E - \tilde{p}_y y_E$$

subject to

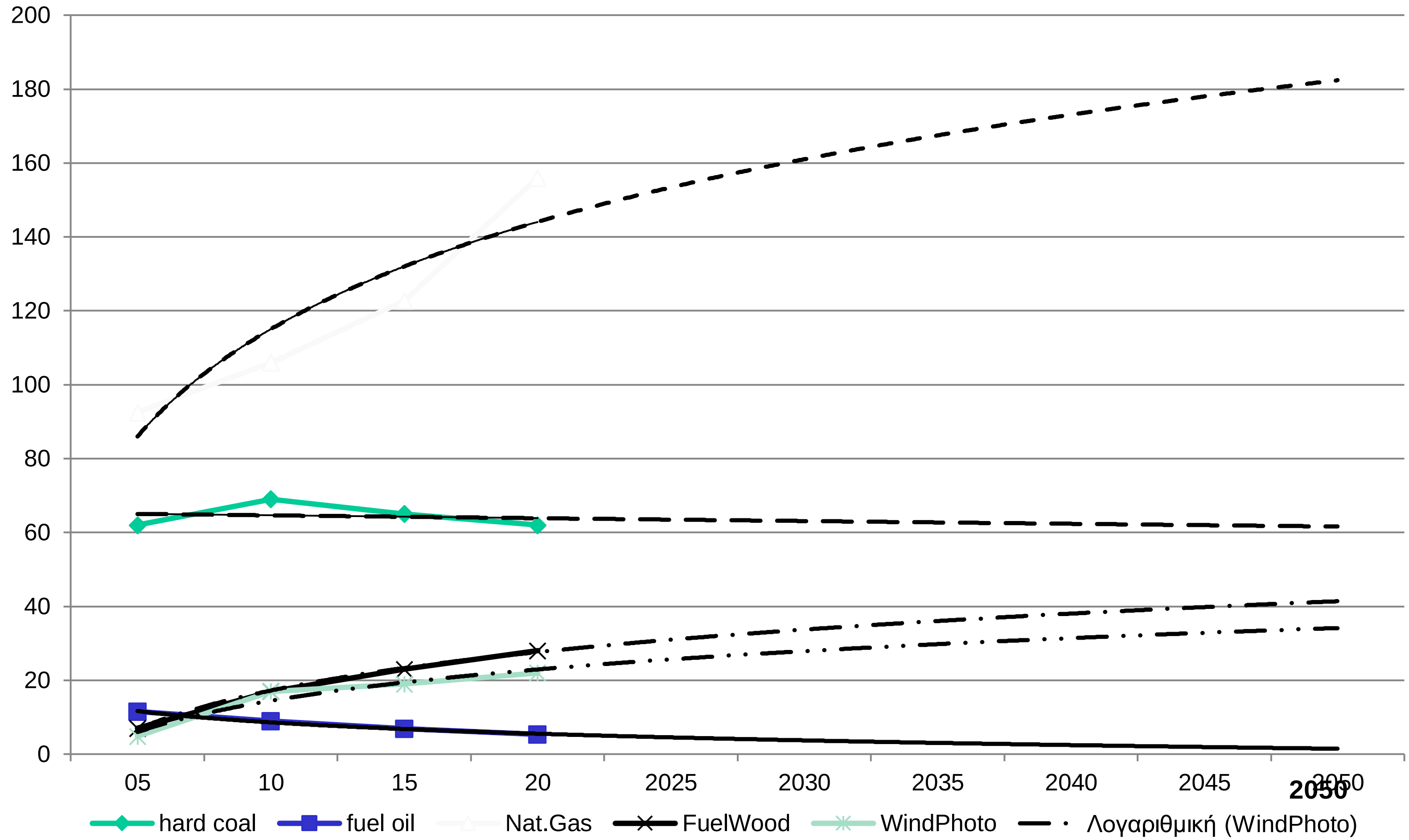
$$S_i = \sum_t z_{it} - \sum_{i't} b_{ii't} z_{i't}$$

$$x_E = \sum_{it} a_{it}^x z_{it}$$

$$y_E = \sum_{it} a_{it}^y z_{it}$$

$$0 \le z_{it} \le \bar{z}_{it}$$

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



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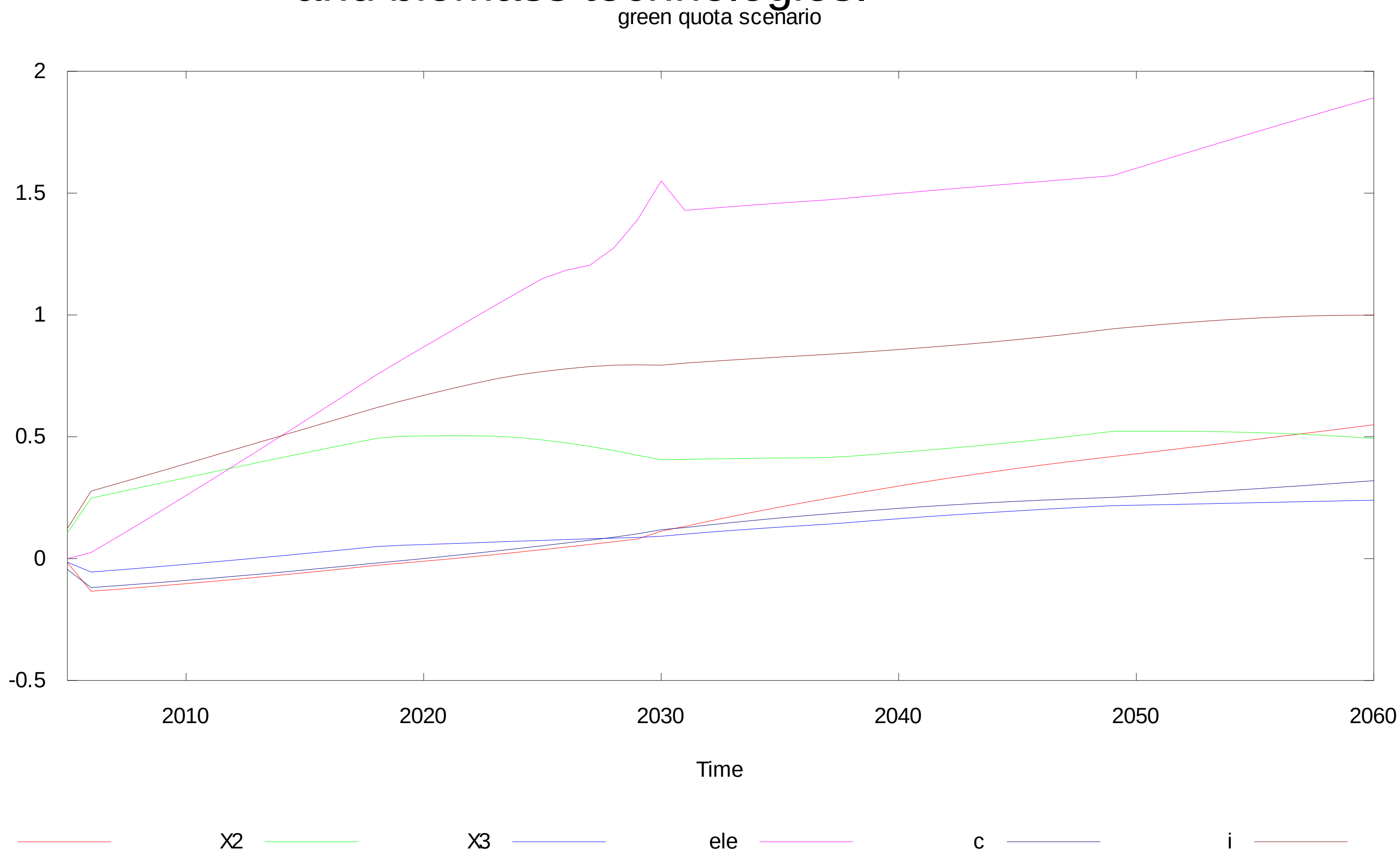
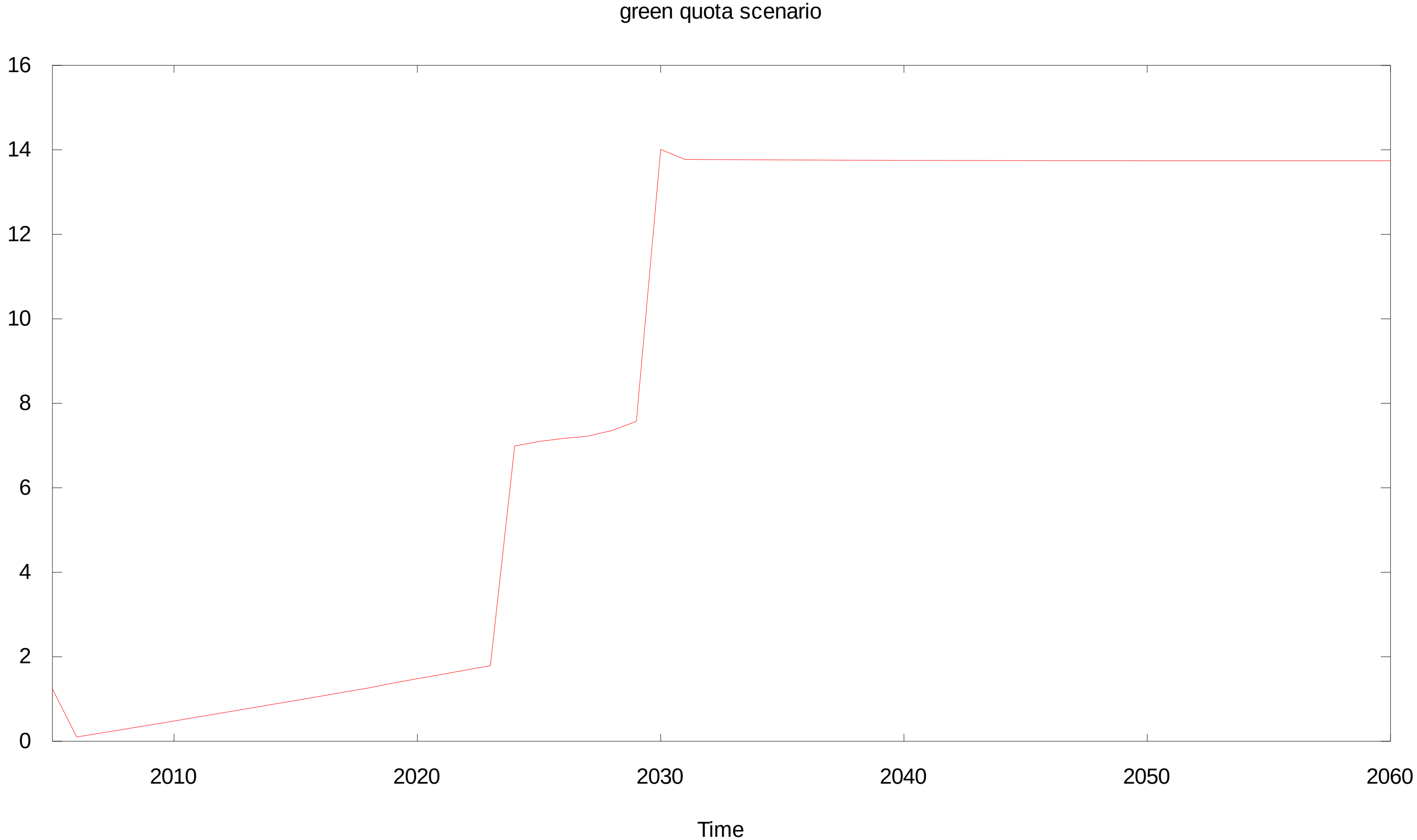
# The growth of the power production indexed with 1.66 is following quite closely the **green quota scenario assumption** and around 2030 there is a small bump. This is result of the exhaustion of the conventional hydro and bio-wind resources and the slum is due to the significant subsidies needed for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



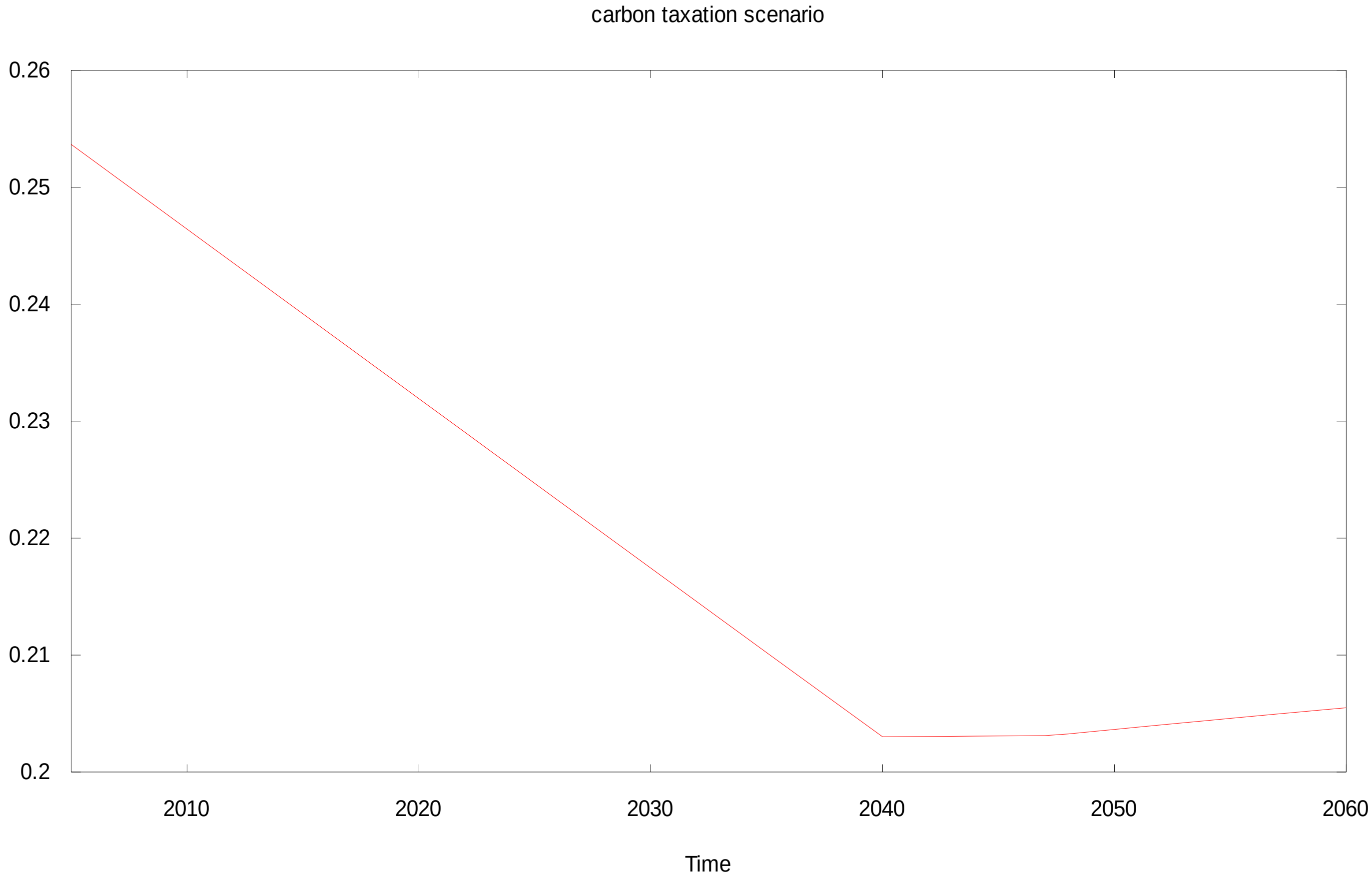
- The **greenhouse gases** are measured in megatons of Carbon dioxide equivalency ($MCO_2eq$) and there are a number of alternative tax instruments for reducing its emissions
- Over the last decade, several EU Member States have levied some type of carbon tax in order to reduce greenhouse gas emissions 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.

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 $CO_2$ 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:

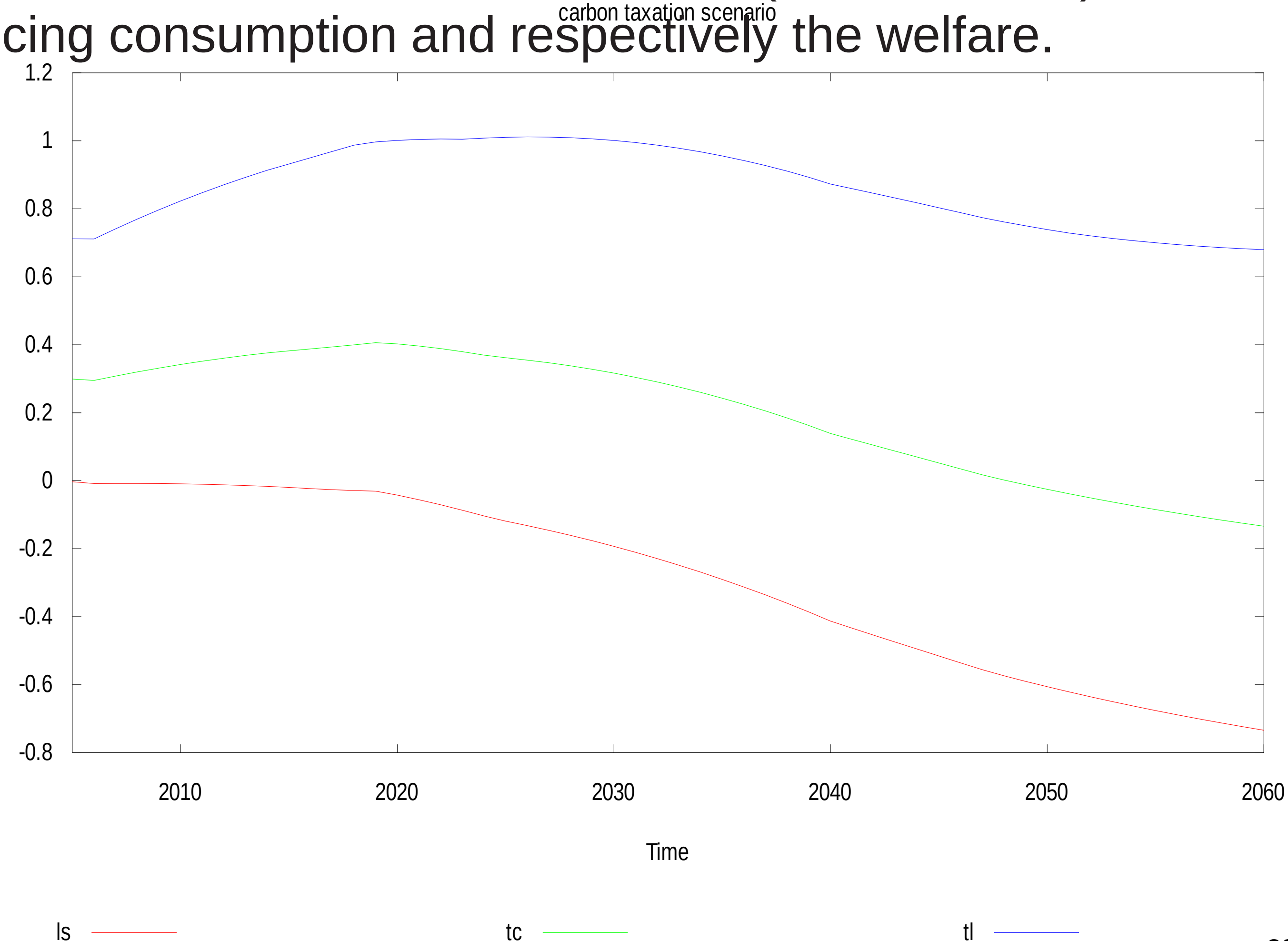
1. a reduction in the labor tax (labeled as “**TL**”)
2. a cut in the consumption tax (labeled as “**TC**”)
3. a lump-sum refund to the representative household (labeled in the Figure as “**LS**”)

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).

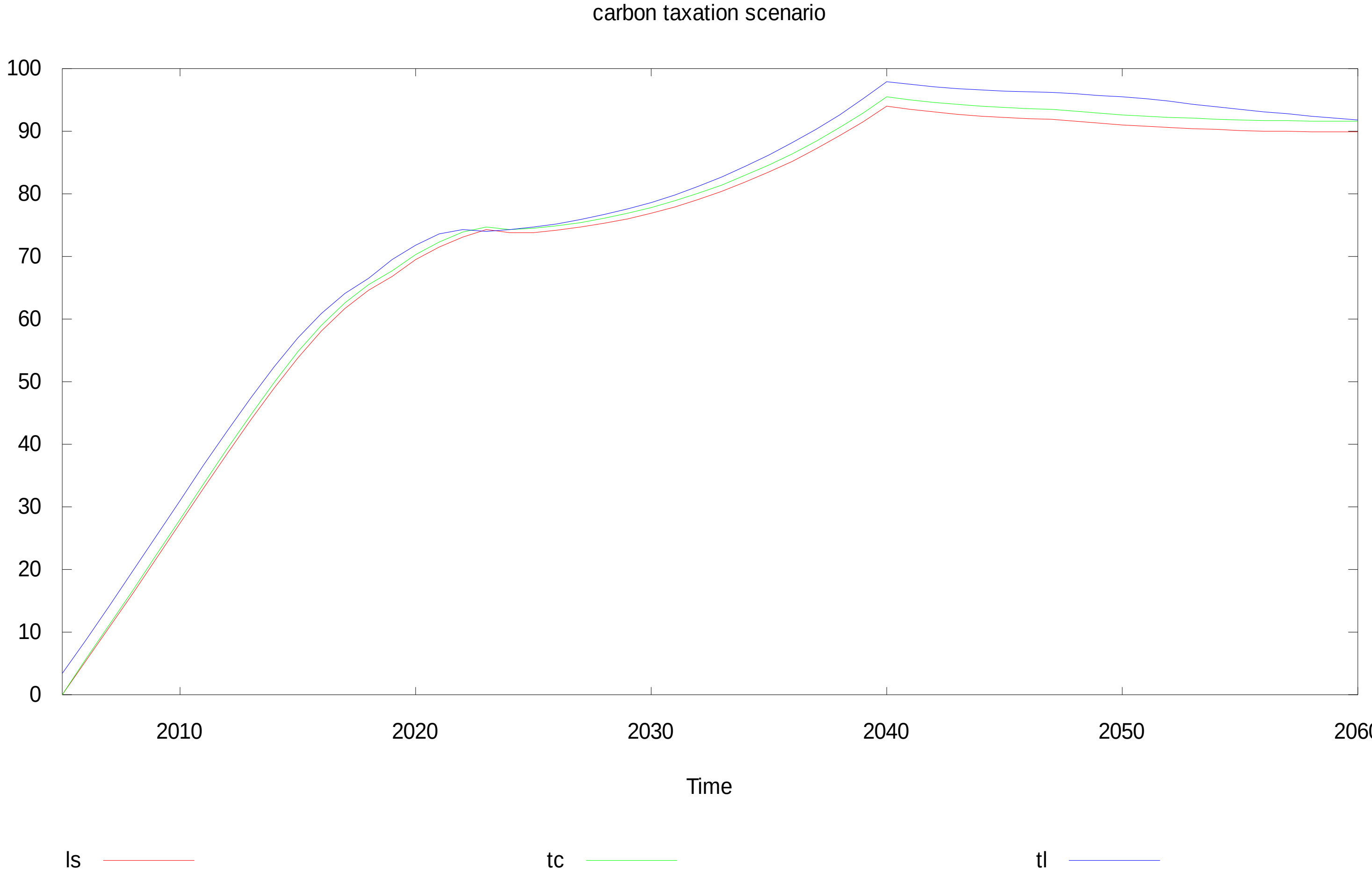
Reflecting the larger marginal excess burden of the initial labor tax vis a vis the initial consumption tax, labor tax recycling is distinctly more beneficial than consumption tax recycling.

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 $CO_2$.



# 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.

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**.