Choosing between technological options in climate policy: pitfalls in assessing their efficiency[1]

Sonntag Axel
Vienna University of Economics and Business
Institute for Labour Economics
axel.sonntag@wu.ac.at

Schubert Uwe
Vienna University of Economics and Business
Institute for Regional Development and Environment
uwe.schubert@wu.ac.at

1. Global energy issues and the need for urgent policy action

Considering the total dependence on fossil energy carriers - in 2008 81% of the world's total primary energy supply (TPES) was provided by coal, oil and gas (IEA, 2010) - this dependence hence, is not easy to overcome. As climate change is a global problem all countries have to share the burden, but especially the OECD countries are required to reduce their consumption levels as they are the biggest energy consumers in per capita as well as in absolute terms. In 2009 the OECD countries were responsible for 5.170 Mtoe which equals a share of 44.2% of the global TPES (IEA, 2010). Furthermore, many OECD countries are currently on the way to fail to achieve their Kyoto target. Austria's present emissions for example surpass the internationally binding goal by 26% (Federal Enrionment Agency, 2010). Therefore and due to a lack of time, respectively, it becomes even more important to put policy measures into action urgently in order to comply. Otherwise painfully high penalties could be charged which would considerably burden the national budgets. Moreover, another important argument has been made. It was Nicholas Stern, who unveiled crucial evidence that acting now in order to prevent further uprising environmental costs caused by climate change will cost about 1% of the current GDP. If nothing would be done the effort only to cope with the most dangerous and life-threatening consequences of climate change would rise to yearly expenditures of 5% to 20% of the GDP (Stern, 2008). Additionally, oil prices as one of the most important indicators concerning overall energy costs have risen dramatically recently. Due to diplomatic and geopolitical tensions, supply uncertainty and the widely discussed peak-oil problems are recurrent issues and play a fundamental role in the energy discussion as well.

This contribution deals with some policy aspects regarding the challenges mentioned. A very widely acknowledged strategy to overcome the difficulties is to rely on technology and energy policy to reduce GHG emissions. In these considerations, however, sometimes important arguments are neglected. This paper constitutes an attempt to point out some of the common pitfalls, making use of data from official Austrian statistics and a modified and expanded input-output modell to assess the quantitative implications of neglecting some basic theoretical ideas. This paper deals only with technological options and does not consider any "soft" approaches to reducing emissions. This is not done because the authors don't believe in their effectiveness, but to point out that a purely technology based policy has its drawbacks and exclusive reliance on it is not warranted.

[1] This paper includes results of the project 'Monetary Energy Footprint Analysis' funded by the Austrian National Bank (Jubiläumsfonds der Österreichischen Nationalbank) and was conducted in cooperation with the World Wide Fund for Nature Austria.

The contribution is structured in the following fashion: Following an introduction in chapter 1, chapter 2 is dedicated to a description of the commonly used method of marginal CO_2 abatement cost curves. Structural weaknesses of this widespread approach are unveiled. The following chapter 3 introduces the SEPE Model, which allows for taking into account inter-industrial effects of technology change and energy policy measures as well. Chapter 4 shows some empirical estimates, also of the mistakes likely to occur. Data for Austria are used in this endeavor to put some flesh on the theoretical model bones. In chapter 5 some conclusions are presented.

2. Beauty and pitfalls in using marginal cost curves of CO_2 emissions' reduction

As already mentioned in the introduction, policy makers are well advised to introduce policies which aim at reducing the consumption of fossil fuels. To do so, several technological measures with promising reduction capabilities are available. Due to budget restrictions and the goal to keep the total costs to the economy low, only highly efficient instruments should be considered.

A common method to compare different technical policy measures with regard to their efficiency is to calculate their CO_2 abatement costs [Euro per ton CO_2] and the additional costs of increasing reductions (marginal costs).

Given the simple structure in Figure 1, the CO_2 abatement costs could be calculated by comparing a newly available technology (the introduction of it is considered to be a (technological) 'policy measure') with the currently applied technological solution (status quo).

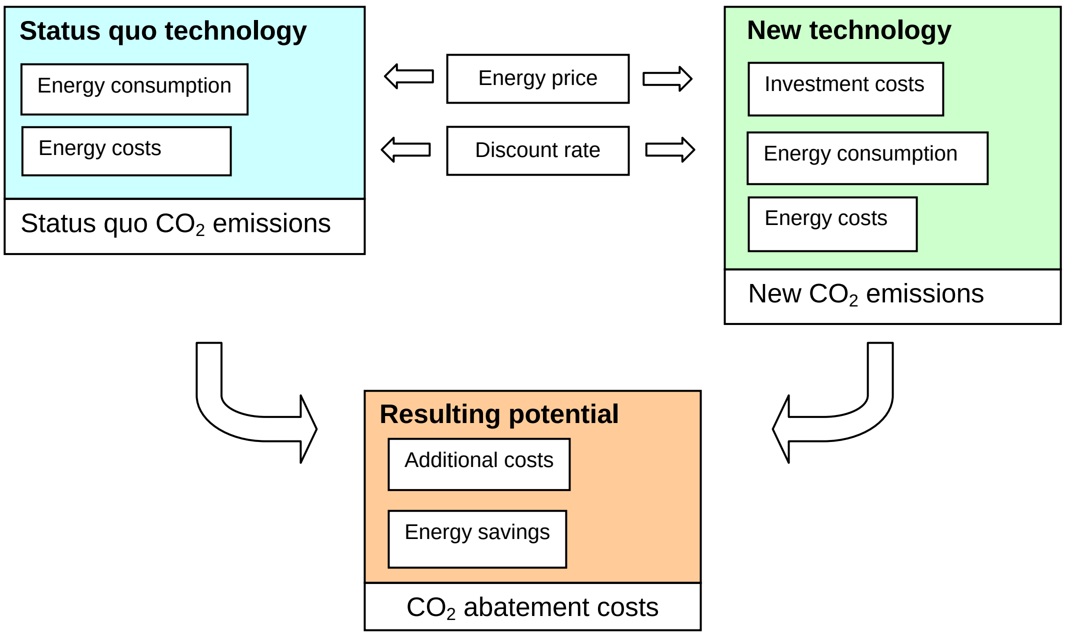

Figure 1: Deriving the CO_2 abatement costs

The “new technology” in our contribution is to be understood as the “Best Available new Technology” (BAT), existing blueprints that have not “matured” into a “tangible” product (no proto-type available) will not be considered in the following analysis.

Various studies have been conducted using the approach of CO_2 abatement costs because of its simple structure and the comparability of its results. (E.g. for the transport sector: Bates et al., 2001, ECMT, 2005).

One of the most important advantages of calculating Euros per ton of abated CO_2 emissions is motivated by this convenient comparability. Moreover, different abatement technologies can easily be checked against the actual prices of CO_2 permit certificates (e.g. EUAs in the EU Emissions Trading Scheme). Given a certain price level for CO_2 permits, the policy makers, both at the macro as well as the micro level, can then decide whether it is worth investing into some abatement technology or rather buy certificates in the market (note that this policy instrument does add some uncertainty to the decision process as not only current prices have to be known, but future developments need to be taken into account).

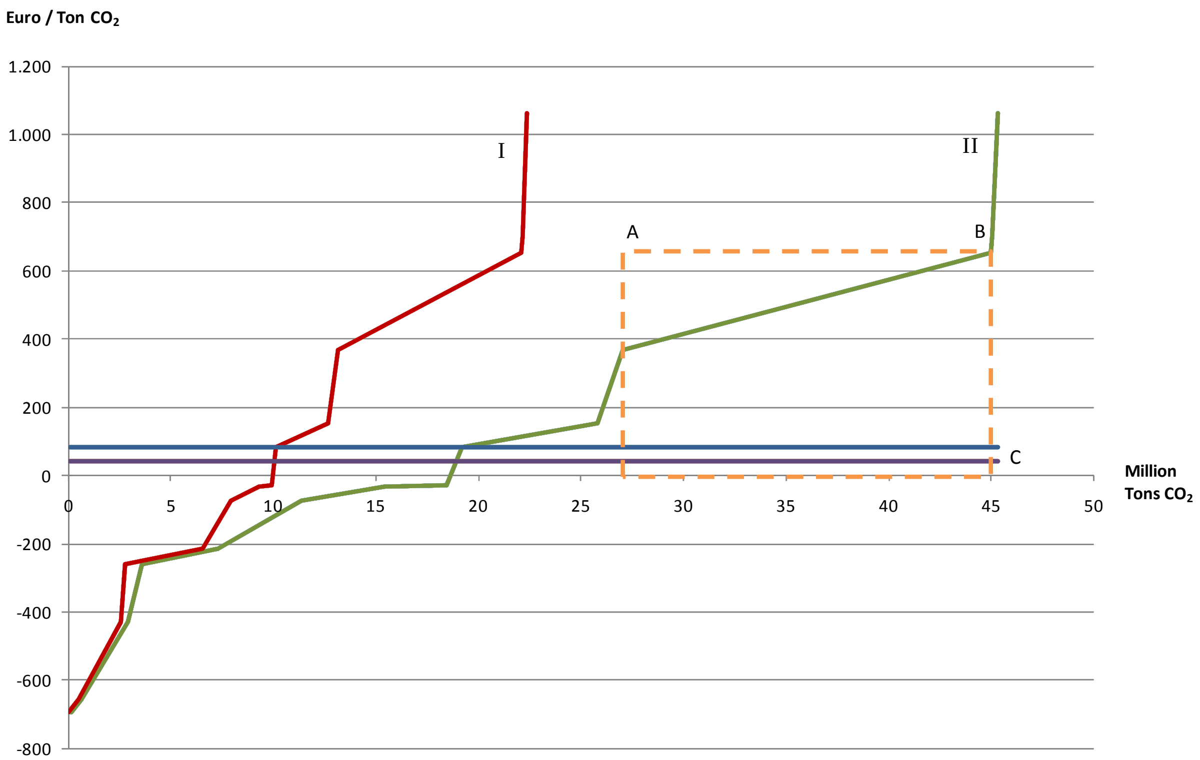

Figure 2: Marginal CO_2 abatement cost curve in the medium (I) and the long run (II), respectively

The calculation of CO_2 abatement costs, however, not only allows better comparability but also provides the chance to derive and draw marginal abatement cost curves as mentioned above. Figure 2 displays such a curve for the available technologies to reduce CO_2 emissions in Austria.

The ”box” (with dashed line) shown in the graph shows a step in the calculation of the marginal cost of reducing emissions by the introduction of a new technology. Whereas the upper border of the box (vertical distance B-C) displays the level of abatement costs per ton CO_2 (652 €/t), the horizontal length of the box stands for the potential amount of CO_2 that could be abated by this measure (distance A-B). In this case 17.9 Million tons could potentially be abated by implementing large scale photovoltaic electricity production. What can be easily seen is that the displayed technologies (each change in slope represents the border of a certain technology to another one) in Figure 2 differ widely both in abatement costs and emission abatement potential.

All technological measures under the zero line show negative CO_2 abatement costs which means that introducing these technologies would result in net savings in monetary as well as emission terms. Economically rational agents should therefore implement those measures anyway driven by their own interest (see Table 1: technologies 1-8). Other measures like the introduction of hybrid power trains for gasoline powered cars that come up with positive CO_2 abatement costs are not profitable at the status quo.[2] To overcome this situation, governmental subsidies could be used to reduce the investment costs of such abatement measures and thereby shift them under the zero line to create an economic incentive to invest in such technologies.

		Absolute CO_2 Potential	Cumulative CO_2 Potential	Life Cycle	Abatement Costs
		Tons	*Tons*	*Years*	*Euros / Ton*
1	Energy efficiency of office buildings	195,392.25	195,392.25	30.00	-694.13
2	Energy saving light bulbs	446,890.35	642,282.60	10.00	-657.78
3	Efficiency measures Trucks	2,271,096.80	2,913,379.40	11.00	-427.51
4	Thermal insulation of office buildings	690,056.50	3,603,435.90	30.00	-257.96
5	Efficiency measures cars	3,732,488.47	7,335,924.37	9.78	-215.69
6	Thermal insulation and fuel switch of multi dwelling buildings (households)	4,013,669.10	11,349,593.47	28.46	-72.35
7	Wind energy	4,057,690.00	15,407,283.47	30.00	-30.96
8	Small hydro power	3,051,230.00	18,458,513.47	50.00	-29.27
9	Biomass solid	722,995.00	19,181,508.47	30.00	83.03
10	Thermal insulation and fuel switch of single dwelling buildings (households)	6,628,315.67	25,809,824.14	26.49	154.22
11	Solarthermal energy	1,246,014.44	27,055,838.58	25.00	366.76
12	Photovoltaics	17,936,200.10	44,992,038.68	20.00	652.42
13	Efficient consumer electronics	66,472.94	45,058,511.63	10.00	702.50
14	Efficient household appliances	280,973.74	45,339,485.36	15.00	1,063.17

Table 1: Possible CO_2 abatement policy actions for the Austrian sectors “Transport, Households, Services and Energy”

[2] In order to avoid double counting difficulties in the transport sector it was necessary to combine several specific technologies to 2 integrated scenarios for cars and trucks, respectively. This is why single transport sector measures (e.g. hybrid vehicles) cannot be found up in Table 1 directly.

In order to illustrate the opportunity offered by this approach to directly assess the specific abatement costs and the amount of CO_2 which could be reduced by each ‘technology package’, consider the following examples:

The accumulated amount of CO_2 abated, as shown on the horizontal axis allows a direct reading of how much CO_2 could be abated if a certain amount of money would be spent for emissions reducing technologies or, the other way around, how much money must be invested in a new technology to achieve a certain level of CO_2 reduction.

On the other hand, the origin of Figure 2 could be shifted by taking into account the market price of tradable CO_2 allowances. As the two parallel lines above the horizontal axis represent CO_2 market prices of 40 and 85 €/t, it is quite obvious that more technology packages would become economically profitable if the market price of CO_2 allowances were going to rise.

Furthermore, Figure 2 provides information about the time horizon of implementing technological policy measures. Whereas some measures could be installed rather quickly (e.g. energy saving light bulbs), for other abatement options relatively long time periods have to be considered until their full potential can be realized (e.g. thermal insulation of multi dwelling buildings). The left curve in Figure 2 (labeled I) is constructed by the CO_2 abatement potential within the next ten years, whereas the right curve (label II) displays the long run potential, i.e. 40 years from now.

While thinking about the advantages of this methodology for calculating CO_2 abatement costs , providing useful information and therefore supporting rational decisions, the inherent structural weaknesses must also be considered, constituting potential pitfalls of this approach:

1. First of all, calculating a specific amount of money that should be invested to achieve a certain reduction potential does not consider difficulties in the penetration process in the ‘technology market’. It is quite obvious that such the **rate of innovation diffusion** plays an important role in the overall effectiveness of the implemented measure (despite the fact of being very important, this problem will not be discussed in detail in this contribution, but it will be assumed that already in the medium run fairly high penertration rates are achieved. Lower rates imply an attenuation of the potential as some of the old technologies which are more pollution intensive are still in operation).

2. Given a (theoretical) 100% penetration rate right after taking the decision for implementing some new technology, we would expect the CO_2 emissions level to decline exactly by the amount which engineers had predicted to derive the CO_2 abatement costs. Unfortunately this is not the case. It is usually not considered that the **production** of certain energy efficient gadgets itself **requires** (a significant amount of) **energy** and materials. The emissions induced by the production of the intermediate inputs (‘technologies’) also have to be considered when deciding on policy actions. As we will show in the 4th chapter, integrating these intermediate production cycles can have a significant effect on the overall emissions of an economy.

3. The third methodological flaw consists of disregarding the **change** of the **structure** of the **inter-industrial input-output relations** over time. (For our calculations reported in this contribution, this effect has been neglected due to the medium term perspective. The resulting error of

excluding such structural changes could be ignored in case of short to medium time horizons but would gain importance when providing estimates over longer periods, e.g. 30 to 50 years).

3. The SEPE-Model

How could we get a grip on the possible magnitude of the "production" effect mentioned as the second weakness above? Input-Output-Analysis (Leontief, 1941) has become a well known method for describing inter-industrial relations. As an I/O-table could be used for various purposes, calculating the effect of a changing final consumption on the gross production of an economy is still one of the most widely used options. In order to overcome the structural weakness of the information provided by marginal CO_2 abatement cost curves the authors developed a model for **S**tructural **E**nergy **P**olicy **E**valuation (short SEPE).

It is designed to integrate both the intended direct energy relevant consumption (investment) effects but also the indirect production effects including the production of the necessary intermediate inputs. Figure 3 provides an overview of the model.

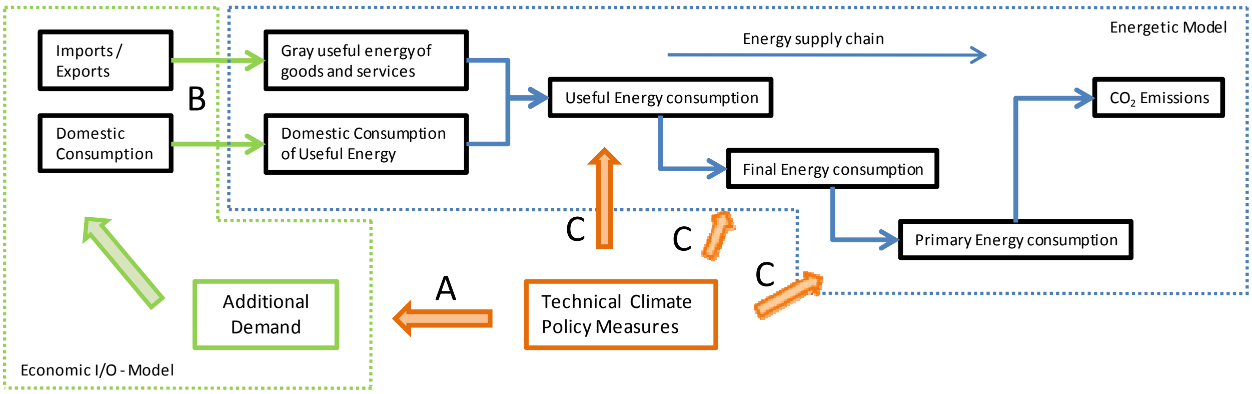

Figure 3: Structure of the SEPE Model

A technical climate policy measure is analyzed with respect to its effects on the final demand of the economy caused by investing into new technologies (relationship A in Figure 3). This analysis was conducted by manually inserting the monetary values of affected industrial sectors[3]. The new final consumption vector y is then multiplied by the Leontief inverse $(E\text{-}A)^{-1}$ to calculate the direct and indirect economic effects of this policy action on the gross production vector x.

$$x = (E - A)^{-1} \cdot y$$

The corrected values of the gross production vector then affect the energy consumption which is also calculated on a sector specific basis (relationship B in Figure 3). To understand how the policy action affects the energetic structural consumption model (relations C in Figure 3) the latter will be described in

[3] As the measures investigated in this paper (e.g. thermal insulation of buildings) could be assigned to few clearly delineated I/O sectors, this approach can be judged as quite robust.

more detail in the subsequent section. The following parameters are used to calculate the overall effect on the CO_2 emissions:

The matrix EEC/Sec_{rel} displays the relative shares of, say, seven different effective energy categories (EEC) per Sector (Sec) and the vector EE equals the total effective energy consumption per sector (Statistik-Austria, 2000)[4]. This distribution of relative shares could be affected by implementing some technical policy measures, as discussed above. This would be the case, for instance, if a sector changes its energy consumption structure due to a reduced demand for space heating, as a consequence of investing into a new technique. This method is demonstrated in the following example:

$$EEC/Sec_{rel} = \begin{bmatrix} & Sec_1 & Sec_2 & .. & Sec_{44} \\ EEC_1 & 0,1 & 0,3 & .. & 0,15 \\ EEC_2 & 0,3 & 0,2 & .. & 0,4 \\ : & : & : & & : \\ EEC_7 & 0,2 & 0,25 & .. & 0,1 \end{bmatrix} \quad \text{and} \quad EE = \begin{bmatrix} Sec_1 & 300 \\ Sec_2 & 220 \\ : & : \\ Sec_{44} & 180 \end{bmatrix}$$

Summing up over all effective energy categories in absolute numbers delivers

$$EE = \sum_{i=1}^{7} EEC/Sec_{abs}^{i}$$

Combining those terms makes

$$EEC/Sec_{abs} = EEC/Sec_{rel} \cdot EE$$

One important aspect when dealing with the energy usage of an economy is the efficiency factor which is defined as the ratio between the amount of final energy (FE) serving as an input to provide a certain level of effective energy (EE) as output ready for consumption. Such factors are available for each EEC per sector. Thus, it is possible to translate the whole matrix EEC/Sec_{abs} into FE/Sec_{abs} by multiplying element-wise with the pertinent efficiency factor. These factors can also be changed by technology policy related, such as research and development expenditures e.g. used to increase the energetic efficiency of lighting systems (i.e. changing normal against energy saving light bulbs). FE/Sec_{abs} contains absolute values of the final energy consumption in the dimension 7 x 44 (7 effective energy categories for 44 economic sectors).
Statistical data are available providing the structural information which primary energy carriers are used to supply a specific level of final energy. Relative shares of how much the primary energy carriers are contributing to the supply of a certain effective energy category were calculated and could also be

[4] Thanks to the well documented Austrian energy statistics it was possible to use the existing intersectoral structure of the energy consumption to trace all changes induced by technical measures like the policy actions that will be discussed in a later part of this paper.

affected by external policy measures. A change in those relative numbers could be triggered e.g. by a fuel switch, which means, that a different primary energy carrier would then be used to provide the same level of effective energy for a certain category.

Combining the final energy consumption matrix FE with the relative distribution of the primary energy carriers (*PEC)* to supply the needed effective energy $PEC / EEC_{abs} = PEC / EEC_{rel} \cdot FE$ results in PEC / EEC_{abs} containing the absolute values of primary energy carriers (22 energy carriers) in terms of physical energy units necessary to provide effective energy for consumption (7 categories).
Summing up over all effective energy categories

$$PEC = \sum_{j=1}^{7} PEC / EEC_{abs}^{j}$$

yields the vector PE which contains the quantity of primary energy consumption for each primary energy carrier.
Multiplying this vector with the CO_2 emission factors element wise, creates a vector of CO_2 emissions by energy carrier, which summed up over all of them yields the desired final result of the SEPE model.

4. Empirical results of the model calculations

Despite the fact that the theoretical model looks promising, empirical evidence is required to corroborate the assumed relations and test for their significance. To demonstrate the significance of considering the interindustrial multipliers (SEPE model based) when assessing the effects of different scenarios two extreme examples are shown.
Consider technical measures available to reduce CO_2 emissions of trucks. Including the full interindustry linkages in producing the goods required only has minor consequences (the reduction of CO_2 is attenuated in the estimates calculated by 3.7%). In Figure 4, this potential is shown closest to the origin of the two curves depicting the reduction possibilities without (dashed line) and with (full line) taking the input/output linkages into account.
There are other measures which lead to significant effects in the CO_2 reduction potential. A prominent example is the introduction of photovoltaics at the present level of cost and effectiveness. Without application of the SEPE model the potential was estimated at 7.9 million tons, which shrinks to 2.2 million tons when taking the production effects into account (-72%)[5].
In an extreme case, the induced production effect of a measure considered could even lead to an increase of emissions. This is the case e.g. for single family detached houses. Without the input/output effect the positive reduction potential was estimated at 4.7 million tons, deducting the production effect results in a *decrease* of the total potential of minus 3.7 tons (= negative potential!).

---

[5] Note: Although the two curves in figure 4 look very similar to those in Figure 2, they have a totally different meaning. Whereas in Figure 2, the attenuated potential has its reasons in a too short time horizon, the reduced potential in figure 4 is due to the additional CO2 emissions that are induced by producing the new techniques meant to reduce emission levels.

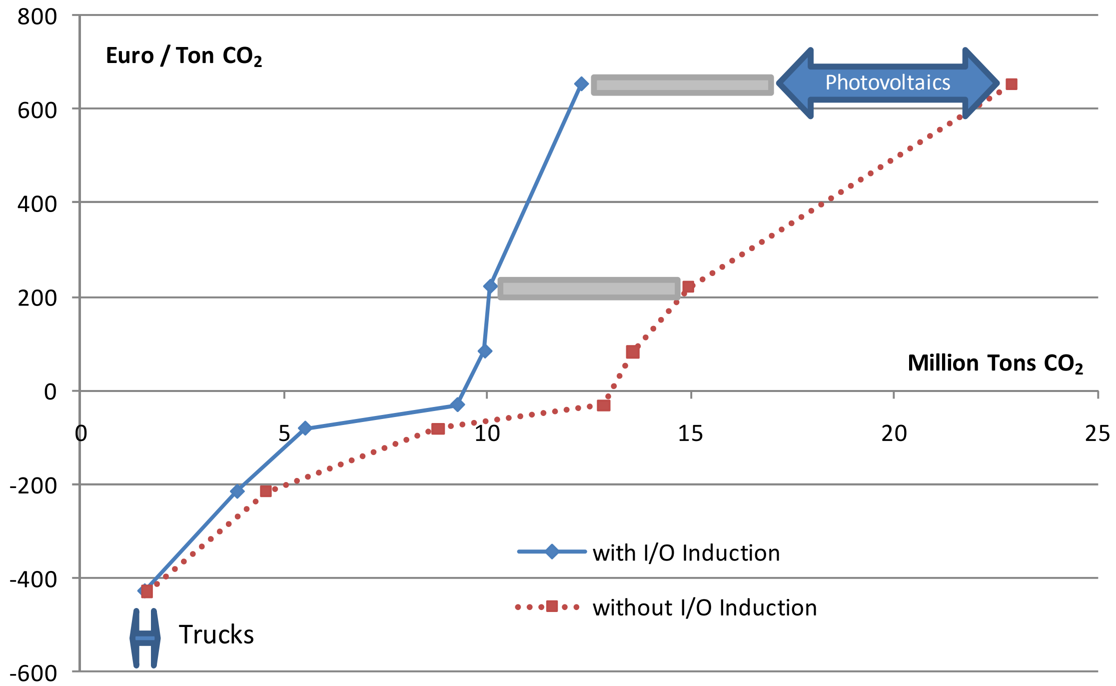

Figure 4 Reduction potentials including interindustrial effects of two technological measures

As an additional example consider e.g., that the government intends forcing all private car holders to switch to cars equipped with hybrid power drive trains within the next 8 years. Enforcing this policy action would consequently lead to an increased car production by 2.35 times within the next 8 years, higher than under a “business as usual scenario”. This calculation is based on the registration of over 319.000 new cars per year in Austria in 2009 (Statistics Austria, 2010).

As a consequence to this boost in production, the demand for goods of the sector ‘motorized vehicles and parts of motorized vehicles’ (NACE 34) as well as ‘trade with motorized vehicles and maintenance’ (NACE 50) increases by 75.6 million Euros and 5.08 billion Euros, respectively. On the other hand the final demand for ‘petroleum products’ (NACE 23) decreases by 122 million Euros caused by the reduced specific fuel consumption of the new fleet.

Table 2 shows more details regarding a policy of promoting hybrid cars by additionally indicating the estimated effects by energy carrier (these estimates are based on data of the Austrian economy including structural data from the year 1998[6]). The numbers represent tons of CO_2 emitted by the consumption of energy services provided by 22 different energy carriers.

[6] 1998 is the latest year when the last full energy census was conducted and therefore serves as reference year.

		Forced Change to Hybrid Cars			Thermal Insulation of Residential Buildings		
Energy carrier	*Business as usual*	*Energy model only*	*full SEPE - model*	*Difference*	*Energy model only*	*full SEPE - model*	*Difference*
Hard coal	1.323.602,56	1.323.602,56	1.329.990,16	6.387,59	1.115.733,31	1.178.938,32	63.205,01
Brown coal	112.509,75	112.509,75	112.976,20	466,45	105.376,47	108.405,21	3.028,74
Briquettes	188.391,21	188.391,21	189.071,97	680,76	111.810,01	113.813,37	2.003,35
Coke	4.033.366,79	4.033.366,79	4.059.898,25	26.531,46	3.814.797,74	4.223.807,61	409.009,87
Peat	778,26	778,26	781,04	2,78	458,33	465,68	7,36
Gasoline	6.760.999,84	5.702.794,01	5.741.846,97	39.052,96	6.760.999,84	7.083.231,14	322.231,31
Petroleum	149.251,41	134.264,46	135.049,86	785,40	149.251,41	156.464,06	7.212,65
Diesel	11.235.249,37	9.556.535,22	9.620.743,68	64.208,46	11.235.249,37	11.772.274,67	537.025,30
Heating oil light	6.068.795,12	6.068.795,12	6.090.881,81	22.086,69	3.638.566,73	3.707.900,66	69.333,92
Heating oil heavy	2.422.971,78	2.422.971,78	2.434.045,02	11.073,24	2.106.212,26	2.203.107,80	96.895,54
Liquid gas	423.387,85	421.575,25	423.890,04	2.314,80	349.011,08	377.241,61	28.230,53
Other petroleum prod.	1.462,33	1.289,51	1.297,32	7,82	1.462,33	1.523,41	61,08
Natural gas	8.430.741,53	8.430.066,20	8.468.184,32	38.118,12	6.681.434,06	7.009.234,82	327.800,76
Converter gas	531.187,55	531.187,55	534.920,21	3.732,66	531.187,55	592.356,91	61.169,36
Coke oven gas	348.567,49	348.567,49	351.016,88	2.449,39	348.567,49	388.707,19	40.139,71
Flamable waste	352.004,25	352.004,25	353.514,46	1.510,21	325.590,11	336.623,76	11.033,64
Fuelwood	8.389.026,89	8.389.026,89	8.419.607,52	30.580,63	5.016.112,58	5.113.477,46	97.364,88
Biogenous fuels	2.555.585,16	2.555.585,16	2.565.882,82	10.297,66	2.370.429,29	2.430.119,55	59.690,27
Ambience heat	0,00	0,00	0,00	0,00	0,00	0,00	0,00
District heating	1.984.600,62	1.984.600,62	1.991.982,46	7.381,84	1.215.437,97	1.242.983,13	27.545,17
Hydro power	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Electric power	7.932.061,52	7.853.566,58	7.906.256,39	52.689,81	7.366.063,91	7.757.059,30	390.995,39
	63.244.541,27	60.411.478,65	60.731.837,38	320.358,72	53.243.751,84	55.797.735,68	2.553.983,84
		-4,48%	-3,97%	-11,31%	-15,81%	-11,77%	-25,54%

Table 2: Simulation results of two policy scenarios with and without the I/O part of the SEPE model

By introducing the command and control type policy to substitute old cars by new hybrid cars within 8 years we would have expected a decrease of 4.48% of the Austrian CO_2 emissions. This refers to a technological-energetic evaluation only and leaves out important economic implications. When additionally considering the intermediate inputs following the SEPE model, the reduction potential decreases to 3.97% which accounts for 320 thousand tons less abatement potential. This equals a decrease in the emission reduction potential by 11.31%, which certainly is a considerably high figure (see Table 2).

Applying the SEPE model to other sectors causes similar consequences. Almost all technical studies for reducing CO_2 emissions argue that thermal insulation of buildings is one of the most important measures to be taken because of its great reduction potential in absolute terms. This claim is also made in the case for Austria. Whereas insulating residential buildings could potentially reduce the overall Austrian CO_2 emissions by significant 15.81%, applying the SEPE model and therefore considering intermediate economic activities, shrinks this figure by one quarter to 11.77%. Consequently, the actual emission reduction potential of this measure is diminished by more than 2.55 million tons of CO_2 (pertinent figures can be found in the bottom right section of Table 2 and in the third line of Table 3). Whereas Table 2 gives an impression of the detailed energy carrier based calculation of the additional CO_2 emissions, Table 3 provides a more aggregated overview of several other technical policy measures and their decreased potential when the full feed-back mechanism of the SEPE model is taken into account.

These results are important for policy makers to take note of when designing a plan to meet specific targets, such as the Kyoto requirement.

	CO_2 potential without *I/O-induction*	cumulative potential	CO_2 potential with *I/O-induction*	cumulative potential	absolute difference	relative difference	cumulatively decreased potential
Measures	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*%*	*Tons*
Heavy duty trucks	1,632,577	1,632,577	1,572,530	1,572,530	-60,048	-3.68%	-60,048
Personal cars	2,923,376	4,555,954	2,270,269	3,842,798	-653,108	-22.34%	-713,155
Multi dwelling buildings	4,220,333	8,776,287	1,666,349	5,509,147	-2,553,984	-60.52%	-3,267,139
Wind power generation	4,069,148	12,845,434	3,735,645	9,244,792	-333,503	-8.20%	-3,600,642
Biomass power generation	725,784	13,571,218	673,620	9,918,412	-52,163	-7.19%	-3,652,805
Solarthermal production	1,362,350	14,933,568	133,494	10,051,907	-1,228,855	-90.20%	-4,881,661
Photovoltaics	7,932,062	22,865,629	2,232,548	12,284,455	-5,699,513	-71.85%	-10,581,174

Table 3 Technological measures and the effects of including production and inter-industrial linkage effects

5. Conclusions and Outlook

Most industrial countries are aware of their moral responsibility with respect to climate change, but they also fear penalties, e.g. for not achieving the binding Kyoto target emission levels. The governments are therefore increasingly under pressure and are looking for adequate policy measures they can implement in order to comply with the international CO_2 emission reduction aims.

Traditional policy selection criteria as presented in the CO_2 abatement costs are commonly used to support the policy makers in deciding about the most efficient actions to be taken. This paper introduces a new approach by combining a standard economic input-output model with structured energy statistics in order to assess the output stimulating effects of climate policy actions. This additional economic output, as it has been shown, partially diminishes the effect of CO_2 emissions' reduction. To save policy makers from unexpected consequences or even penalties, they are therefore strongly advised to rethink or rather intensify at least some of their climate policy actions in the light of the information provided in this paper, as the measures probably do not reach as far as they are expected to,.

Further research is needed to find innovative ways of considering the systematic incorporation of structural technological and economic effects that occur when setting energy policies, which is currently done 'manually' in model calculations instead of systematically. It is not only the effect of a policy measure on final demand that has to taken into account, but also the change in the input-output coefficients due to technological change introduced by the implementation of the policy program. This becomes even more important if longer time horizons are under consideration (see problem 3 mentioned in chapter 2 of this paper).

Literature

Bates, J., Brand, C., Davison, P. & Hill, N. (2001) Economic Evaluation of Sectoral Emission Reduction Objectives for Climate Change - Economic Evaluation of Emissions Reductions in the Transport Sector of the EU. EU Commission - DG Environment.

BMLFUW (2007) Anpassung der Klimastrategie Österreichs zur Erreichung des Kyoto-Ziels 2008-2012.

ECMT (2005) Making cars more fuel efficient. Technology for real improvements on the road. International Energy Agency.

Federal Enrionment Agency (2010), Umweltbundesamt. Emissionstrends 1990 - 2008. Federal Enrionment Agency (FEA), Vienna.

IEA (2010) Key World Energy Statistics 2010, International Energy Agency (IEA).

IPCC (2007) Fourth Assesment Report – Climate Change 2007 – Synthesis Report. Intergovernmental Panel on Climate Change.

Leontieff, W. W. (1941) <<The>> structure of American economy, 1919 - 1929, an empirical application of equilibrium analysis, Cambridge {u.a., Harvard Univ. Pr.

Statistics Austria (2000) Nutzenergie-Analyse 1998, Wien, Verlag Österreich.

Statistics Austria (2004) Input-Output-Table 2000. Vienna, Österreich Verlag.

Statistics Austria (2010) Registration of new vehicles 2009.

Stern, N. H. (2008) <<The>> economics of climate change - the Stern review, Cambridge u.a., Cambridge Univ. Press.