Climate Effects of Electrifying the Transport Sector: Principles and the Case of Sweden

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1. Introduction

Transportation relies to a considerable extent on fossil fuels. In the EU approximately 90 percent of the energy use in the transportation sector originates from fossil sources, rendering the sector accountable for about 20 percent EU-15's greenhouse-gas (GHG) emissions (EEA, 2011). This share varies amongst the member states due to variations in *e.g.* transport volumes and modal splits as well as energy mixes in power and heat production. The demand for transportation is expected to continue to grow rapidly. In particular this is so for air travelling and freight transports on roads. Cost-effective fulfillment of the EU's objective of reducing its aggregate GHG emissions by 20 percent to the year 2020 is therefore likely to require substantial adjustments within the transport sector. Politicians seem particularly interested in projects that curb the GHG emissions from transportation without restricting transportation *per se*. One suggested such project is to electrify (parts of) the transportation system, *e.g.*, promoting electric vehicles on roads or facilitating shifts from road to (electrified) transport modes such as railways.

This paper discusses principles for identifying and appraising the impact on GHG emissions from electrifying transportation. We are primarily interested in the road-to-rail case, but the principles apply to other cases as well, both inside and outside the transportation sector. The underlying motive for the paper is an ongoing debate regarding how and to what extent investments in rail infrastructure influences GHG emissions and how to adequately consider the effects in cost-benefit analyses (CBAs) of such investments. Various approaches have been proposed. For instance, some argue that one must use the average GHG-emission factor of electricity production, *i.e.* total emissions from the power sector divided by total production in terms of kWh. Other argues that it is the marginal emission factor that is of interest, *i.e.* emissions per electricity unit for the power plant lastly employed. It has also been argued that if the railway operator only buys electricity based on renewable fuels, the investment would produce no GHG emissions. And, some note that if power producers are included in a cap-and-trade system, any increment in the electricity demand would not affect aggregate emissions, only permit prices. At the other end of the spectrum some advocates the use of so-called life-cycle analysis (LCA) of electricity production as well as of the transport investment. There is no simple and universal answer on how to deal with the impact on GHG emissions of electrifying transportation. Instead, the answer is highly context dependent. Our objective is to provide a structured discussion that sheds light on the problem of where and when various approaches are valid.

Our discussion is mainly of principal nature. However, references are occasionally made to the Swedish case, which may be of particular interest since the power production there is essentially carbon free and since Sweden has a rather long history of non-mandatory green electricity contracts as well as a mandatory system of so-called green power certificates. To fix ideas, we consider a railway investment that would transfer a certain amount of transportation from road to rail. However, we only address a small part of the effects of such a shift. Shifting goods freight from road to rail may decrease (increase) congestion on roads (rail) and influence costs, transport time as well as energy use in several ways. We focus here on two sub-questions, namely the consequences of the increment in the electricity demand that follows our investment project and how any changes in GHG emissions should be dealt with in an otherwise complete and adequate cost-benefit analysis of our railway project.

The analytical approach adopted here is to start (in Section 2) with a seemingly simple context where there is no climate or energy policies. We then sequentially add circumstances that make the analytical context more realistic. In Section 3 a mandatory system of green electricity certificates is introduced. Thereafter, in Section 4 we add climate policy instruments, *e.g.* international climate agreement, tradable emission permits and carbon taxes. The context thereby becomes increasingly complex during the presentation. However, one of the main messages of the paper is that the adequate approach of identifying and appraising the relevant GHG effects of our rail way investment at the same time becomes less complicated, not to say simple. Section 5 sums up and concludes.

2. No Policies

We begin by discussing the short-term impact on GHG emissions of an increased electricity demand in a context where no climate or energy policies are present. By short term we mean the time period during which the electricity production capacity is fixed. Throughout the analysis we assume that market prices reflect the value of all resources but GHG emissions. Three questions are central for our discussion. First, should one use the *MEF* or *AEF* of electricity production to assess the effect a railway investment has on GHG emissions? Second, does the existence of any voluntary contractual arrangement specifying that the railway operator only purchases green electricity matter? Third, how should we value the quantified GHG effect?

Answering the first question is rather straight-forward. The *MEF*-approach is the relevant one. The reason behind this lies in the merit order of power producing facilities on a competitive power market. Typically, production facilities are employed in a cost-increasing order. Power plants producing at a low short-run variable cost (*SRVC*) are used before plants with higher costs. Those with highest costs are started only when needed to meet occasionally demand spikes. Given the uncertainty surrounding future demand for electricity (*D*) and future fuel prices and the considerably time it takes to create new production capacity, there will usually exists substantial reserve capacity on the market. This situation is illustrated in Figure 1, where D_0 denotes the expected demand schedule in the absence of our railway project and the graph *S* illustrates the supply curve (the merit order of existing production plants).[1] Our railway project consumes *A* units of electricity and therefore shifts the demand to D_1. More costly plants than plant *x* must then be employed, something that raises the electricity price. This fosters the electricity demand somewhat. After this demand adjustment, the produced and consumed amount of electricity has gone up with q_1-q_0. As long as electricity demand is not totally inelastic the increment in power production will be smaller than the railway project's direct consumption of electricity. The GHG effect of this incremental production equals $\Delta GHG = a_x \Delta kWh_x + a_y \Delta kWh_y$, where a_i denotes plant *i*'s specific emission factor (*i.e.*, GHG emission per kWh production). This is the (true) *MEF*-approach.

1 At the Nordic/Scandinavian electricity market, producers submit to the market maker (Nordpool) their individual supply schedules (*i.e.* how much they are willingly to produce at different price levels). Given profit interested firms and a competitive environment this procedure yield a market supply curve close to a merit ordering based on SRVC (**ref's to theoretical and experimental studies**).

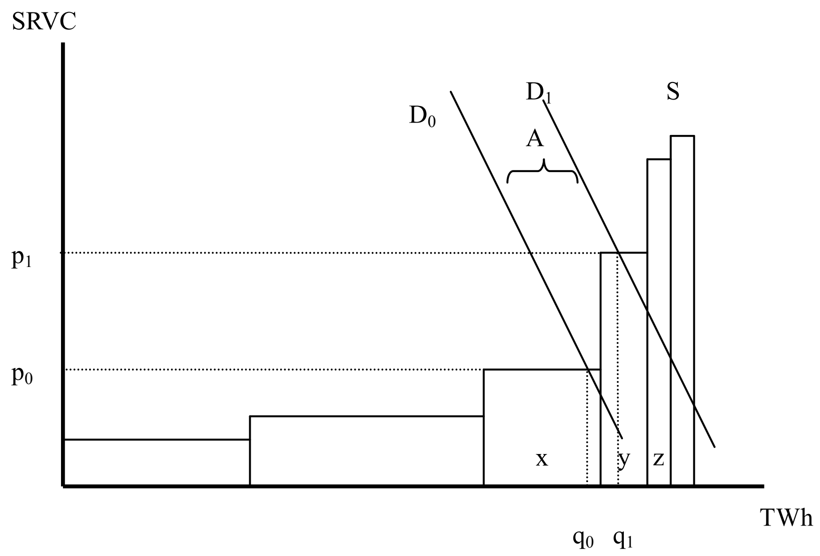

Figure 1. Illustration of the power market

Consider now the *AEF*-approach, where the incremental production is multiplied with the emission factor a (= total emissions from power production/total production). Then, the assessed GHG-effect becomes $a(\Delta kWh_x + \Delta kWh_y)$. If y where the only carbon emitting plant, the *AEF*-approach would hold our railway investment accountable for less carbon emissions than actually created, *i.e.*, $a(\Delta kWh_x + \Delta kWh_y) < a_y\Delta kWh_y$. If, on the other hand all plants but x and y are emitting, the opposite could apply. The size of the error depends crucially on how heterogeneous power plants are regarding their specific emission factors for carbon dioxide (CO_2). The size of the error may be substantial as the following example show.

Assume that our railway investment increases power production with 50 GWh per year. If this production were coal based (for which $a_i = 886.8$ *g*CO_2 *per kWh)*[2] *the yearly carbon dioxide emissions would increase with 0.44 Mton. If only plant y is emitting and*

[2] See Hondo (2002).

aggregate production amounts to 135 TWh, then AEF-approach would hold our project accountable for only .0003 Mton CO_2.

We now turn to the second question, namely the effects of voluntary green electricity contracts (*i.e.*, contracts specifying that the electricity purchased should come from carbon free power plants). The selling idea of such contracts is to alter the merit order at the power market in a “climate friendly” direction. However, it is not evident that they actually accomplish this. A contract giving the owner of plant *z* a unit remuneration of at least p_z would make him/her willingly to offer its capacity for production at price below the variable costs of plant *x*. Plant *z* would thereby exclude plant *y* from the market and we would have plant *x* at the price setting margin also after our railway project. In this case, our railway operator would pay more for electricity but not create any direct GHG emissions. Nor would our project affect the market price of electricity and there would thereby be no fostering of the demand for electricity. However, it is not likely that such a situation would arise. Instead, we would expect that our operator, when entering a green contract, excludes some other agent(s) from engaging in a similar contract and thereby forcing him/her to buy conventional power. Thus, whether or not our operator engage in a green contract is irrelevant for our railway project’s effects on the GHG emissions from power production.

So far we have considered only direct GHG emissions of power production (essentially carbon emissions from fuel combustion).[3] GHG emissions arise also when fuels are extracted, processed and transported. This is so for both fossil fuels and biomass based fuels, see e.g. Searchinger et al. (2008). To consider such indirect emissions (IE) a LCA must be conducted of the incremental electricity production as well as the reduced fuel use for road transportation. Studies indicate that these indirect emissions may be substantial. Our railway investment’s net-effect on global emissions then becomes.

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[3] Also combustion of biomass releases carbon. Usually it is assumed that the direct emissions from bio-fuel combustion equal the amount of carbon assimilated by the bio mass during its growing phase, an assumption we here maintain.

(1) $\Delta GHG = \Sigma a_i \Delta kWh_i + \Sigma \Delta IE_i + (\Delta GHG_{Road} + \Delta IE_{Road})$

The two first terms of the right-hand side captures the effects associated with the incremental electricity production and the last two terms the change in emissions due to less road traffic.

Electricity is traded across borders, a trade expected to grow in Europe as new transmission cables materialize between countries and regulatory hinders are erased. Only considering domestic power production capacity is potentially misleading. For instance, the Swedish MEF is close to zero. But Sweden is an integrated part of North European electricity market for which the marginal power plants are coal fired, implying a MEF close to 900 gCO_2 per kWh. For a railway project that increases the electricity production with 50 GWh this means direct emissions to nearly 500 tons CO_2 per year.

In the longer run new power plants will built. However, this generally takes considerable time, *e.g.*, due to technical complexity, juridical procedures and bureaucracy. For instance, in Sweden the average time from applying for building approval for a new wind mill to when construction begins is 48 months. One explanation for this is that there are currently 27 different instances that have to approve the construction plans.[4] Consequently, there is a non-negligible mid-term to consider. During this time, an (unexpected) shift in electricity demand will not influence the characteristics of the power generating capital, but some electricity may be produced in new plants. However, these plants have not been directly motivated by the demand shift, *i.e.*, they are planned but not constructed at the time of the demand shift. Thus, in the mid-term, the same principles as in the short term apply, although the relevant *MEF* may be substantially different since new plants are taken into consideration.

In the long run, our railway-project may influence the composition of the power production. It is then the characteristics of these new plants that will determine how much

4 Source; http://www.goldwind.nu/vindkraft.php (110620).

GHG emissions that our project causes. In the absence of energy and climate policies, new capacity is likely to be coal based. However, voluntary green contracts might render "green" power plants to be built in which case $a_x = 0$. Our railway operator would then pay more for electricity in order to avoid (direct) GHG emissions. It should also be noted that in the long run the LCA of power production also includes emissions from construction of the plants and land use changes, which may be substantial (se e.g., Hondo, 2002, and Wibe 2010).

We now turn to the third question, namely how to value GHG emissions accruing to our railway investment. In this simple context with no international climate treaty or other climate and energy policy instruments, higher GHG emissions from the power sector imply essentially the same increment in global emissions. The risk for climate change is a global public bad. A globally benevolent social planner would therefore attach a value v_G to emission reductions that equals the sum of all individuals' valuation of the additional risk. However, in the absence of an international/global treaty coordinating nations' behavior, it is sub-optimal for a single country to unilaterally abate up to the point where the cost for further abatements equal v_G. Instead, a government (interested in maximizing its citizens' welfare) would only consider the unilateral, domestic valuation of this additional risk (v_S) which by definition lies below v_G, and by circumstances substantially so (IPCC, **200x**). This is not a policy recommendation, just a conclusion consistent with the assumed context. It should be noted that, irrespectively of which approach one takes, it is by no means a simple task to arrive at precise estimates of v_G or v_S. In both cases the task involves calculating the sum of many future generations valuation of the climate effects incurred.

To sum up: In this context with no climate or energy policies an amount $v_S \Delta GHG$, should be added to the cost side of an otherwise complete and comprehensive CBA of our railway investment. ΔGHG is given by (1) and based on a MEF calculated for the relevant electricity market, which in the Swedish case amounts to the North European one. In the short run, voluntary green electricity contract will, in general, not influence the emissions from incremental power production. In the long run they may, however. Then, the railway operator will pay a higher electricity price in order to lower the projects climate cost. Whether this increases or lowers the cost-benefit ratio of the project depends on how large the markup on the green electricity is relative the value of emission reductions.

3. Green Electricity Certificates

We now add a mandatory system that mills in electricity based on renewable energy sources to the analytical context. The system we have in mind resembles the Swedish system of green electricity certificates. Such a system effectively divides power production into two groups; generation based on renewables vis-à-vis non-renewables. Each unit of electricity generated from renewables yields a certificate to the producer. This creates a supply of certificates. To create a demand, electricity consumers (or on their behalf electricity distributors) are obliged to hold a certain number of certificates per electricity unit consumed (sold). The producers of renewable energy may sell certificates to the electricity consumers, thus getting revenues for their production over and above the market price on electricity. The policy variable is the number of certificates the consumers are obliged to hold per consumed unit, α. Figure 2 illustrates such a certificate system. For simplicity we assume a totally inelastic electricity demand, located at q. The demand for certificates equals q_G (= αq). This is the amount of green electricity produced. The rest of the electricity demand is met by conventional power production, q_C.

As the Figure 2 is drawn there would be no green electricity without the system and the supply of electricity would be given by MC_1 and the competitive price would be p_1. By milling in q_G units of green electricity the system shifts the supply curve of conventional electricity to the right to MC_2. The market price then becomes p_2, and only q_C units of conventional electricity is produced. Thus, the system lowers the market price. This is so because it is the most costly conventional power plants that are substituted away in favor of green electricity. In order for q_G units to be produced the price on green electricity must at least be p_3, which given a market price of p_2 gives a competitive certificate price equal to p_G. Since green electricity is more costly than conventional aggregate cost of power production increases. This additional cost is distributed out over consumers by a certain fee on electricity consumption, so the consumers end up paying $p_2 + p_G q_G / q$ per electricity unit.[5]

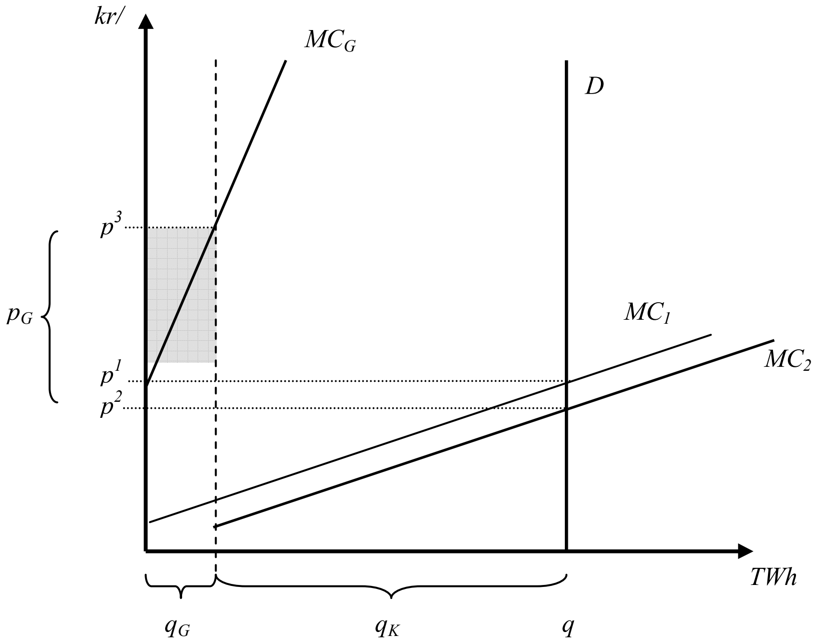

Figure 2. Green electricity certificates

The formula for our railway project's net-effect on global GHG emissions is still given by (1) and this effect is still to be valued by v_S. However, an increment in electricity consumption will now be met partly by green power plant and partly by conventional. So even if the price on the regional (Norh European) power market is set by coal fired plants, the relevant MEF contains green power plants. The green certificate system thereby lowers the direct GHG emissions from power production associated with our project. To what extent the system influences the indirect emissions of power production is an open question. As compared to the non-policy case the CBA of our project is affected in two ways: (i) *via* the change in net-emissions and (ii) *via* higher electricity expenditures.

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[5] In principle this consumer price may be below or above p_1. However, in practice it is likely to be above. For more about green electricity certificates, se Carlén, Carling and Mandell (2005).

It should be noted that a mandatory system for electricity certificates makes voluntary green contracts insignificant. Such contracts, when leading to investments in green production capacity, will reduce the price on certificates and thereby lead to less investment in green power capacities elsewhere.[6] For a discussion on this topic see *e.g.* Broberg and Brännlund (2010). So, in the presence of a mandatory green electricity certificate system additional voluntary green power contracts only increases our project's electricity expenditures.

4. Climate Policy Instruments

So far there has been some robustness in the formula constituting the "climate post" in an otherwise perfect CBA of our railway project. The reason behind this is that we so far only have considered second-best responses to the threat of rapid climate changes, *i.e.*, behaviour and/or policy measures indirectly affecting parts of GHG emissions, such as voluntary green power contracts and mandatory system for green electricity certificates. We now introduce climate-policy instruments to the analytical context. The instruments we consider steer *via* the price on GHG eissions and have the capability of attaining the first-best outcome.

First we introduce a cap-and-trade system for carbon emissions from electricity production and other energy intensive industries, *i.e.* a policy instrument akin to the European Emission Trading System (EU ETS). Thereafter we add an emission cap for other GHG emissions in the EU. We then have a context closely resembling the current climate-policy architecture in EU. Finally, we discuss the effects of our railway project in the presence of a comprehensive global climate treaty of the Kyoto Protocol type.

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[6] It should be noted that in some instances may the mandatory system's definition of green electricity differ from the consumers' opinion.

Cap-and-trade system covering power production (EU ETS)

A cap-and-trade system sets a cap for the system's aggregate emissions and allocates tradable emission permits to the participating firms. Given profit maximizing firms and compliant behavior, aggregate emissions will be held constant at the cap level irrespectively of how emissions/abatements are distributed amongst the firms. Competitive permit trade will allocate abatement efforts in a cost-effective way. The unit cost of further abatements will then equal the permit price, p_{ETS}.[7] An immediate implication of this system is that our railway project no longer influences aggregate (direct) emissions from power producers and other firms under the cap. Incremental power production now only leads to that someone else under the cap must undertake further abatements. The climate policy effect of our railroad investment now equals $p_{ETS}\Sigma a_i \Delta kWh_i + v_s[\Sigma\Delta IE_i + \Delta GHG_{Road} + \Delta IE_{Road}]$. The first term of this expression is included in the electricity price and will therefore appear as an increment of our project's expenditures on electricity. Thus, the climate policy post in an otherwise complete and adequate CBA of our railway project boils down to

(2) $v_s[\Sigma\Delta IE_i + (\Delta GHG_{Road} + \Delta IE_{Road})]$

We no longer have to worry about MEF of power production and how to value emissions from electricity production. However, we still need to quantify and value the project's effects on emissions outside the cap-and-trade system.[8] It should be noted that now neither voluntary green power contracts nor the mandatory system of electricity certificates has any effects on GHG emissions. They would now only serve to increase our projects electricity expenditures.

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[7] This has been known for long, see *e.g.*, Dales (1968) and Montgomery (1972).

EU Burden Sharing Agreement

EU ETS is not the only emission cap within the EU. The so-called burden sharing agreement (EU, 1998) allots national quotas to the member states for their GHG emissions outside EU ETS during 2008-12. Moreover, a second agreement exists for the period 2013-20 (EU, 2009). Both these agreements define caps for the member states aggregate emissions from what we here denotes the other sector (OS).[9] Together these caps and the corresponding caps for the EU ETS constitute caps for EU's aggregate emissions for the periods 2008-12 and 2013-20.[10] Both agreements allows for trade with quota units. This is in particular so for the period 2013-20 for which the agreement defines a fully developed cap-and-trade systems with governments as the trading parties. This option for intergovernmental emissions trading implies that there exists an alternative cost for a country of emitting. Given well-functioning such quota unit trade there will be an EU-wide price on GHG emissions from the member states' OS.

Most European countries use domestic fuel taxes to control their GHG emissions. Some countries, such as Sweden, have an explicit CO_2 tax. The Swedish carbon tax currently amounts to 1.08 SEK per kg CO_2, which is substantially above p_{ETS} (approx. .20 SEK per kg CO_2) and most estimates of v_G and also v_S (Brännlund, 2009). However, at least in Sweden the carbon tax has dual objectives; to finance public expenditures and to control emissions. We can therefore not interpret its level as the marginal abatement costs in the

[8] It is possible that some of the emissions we have labeled indirect now materialize under the emission cap, in which case the term $\Sigma\Delta IE_i$ now is smaller. However, in practice this effect is likely to be small and is henceforth ignored.

[9] Usually, this sector, which broadly comprises transportation, light industry, business and services, is called the non-trading sector. However, as becoming obvious below this is a somewhat misleading terms whereby we instead uses the term OS.

[10] For the year 2020 the two caps sum to 80 percent of the emission level in 1990. The aggregated cap level may be adjusted by member states and/or firms under EU ETS engaging in trade emission quota units/permits with agents outside the EU.

Swedish OS. This poses a practical problem for CBAs of our railway project that we come back to below.

The shift from road to rail induced by our investment will now, in general, not result in a corresponding reduction of the aggregate GHG emissions from EU's OS or the global emissions. Instead, the government either adjusts the tax level so that the emissions in the Swedish OS is kept at a constant level or keep the tax level constant whereby some quota units are freed. In the latter case, the government may sell additional quota units to other governments or save them for future use.[11] In both cases revenues are created for Sweden. In the former case, abatement costs are avoided in the Swedish OS. In the latter case, revenues from geographical or inter-temporal emissions trading materialize. For the moment, assume that the values of these options are equal (*i.e.*, that the Swedish policy s cost-effective) and let t_{OS} denote this value. The climate policy relevant effect of our railway investment can then be stated as $p_{ETS}\Sigma a_i \Delta kWh_i + t_{OS}\Delta GHG_{Road} + v_s[\Sigma\Delta IE_i + \Delta IE_{Road}]$. The first two terms are internalized in market prices, the electricity price and the fuel prices respectively. Thus the adequate explicit climate post in our CBA has now been reduced to

(3) $$v_s[\Sigma\Delta IE_i + \Delta IE_{Road}]$$

We only have to quantify and value the indirect emissions associated with our railway project. As indicated above potentially these indirect emissions may be large and perhaps especially so for bio fuels. Nevertheless they are often ignored. It may seem strange that this effect on global emissions should be valued by the Swedish domestic valuation of reduced risk for rapid and large climate changes. However, as explained above, this is the consistent approach for emissions that is not subject to any international climate treaty.

The circumstance that less and less of our project's climate policy relevant effects are dealt with by an explicit climate post in the CBA should not be interpreted as the threat of

[11] Only if the government annuls quota units would a global emission reduction materialize. However, such a behavior is not in accordance with an efficiency oriented government (Hoel, 2009).

rapid climate changes being less prioritized. On the contrary, it is a consequence of effective climate policies being implemented. Market prices are now reflecting the value/cost of GHG emissions (as it has been defined by political negotiations) something that steer billions of decisions in a "climate friendly" direction.

It should be noted that our railway project may have a climate policy dividend even when not reducing the aggregate demand for emissions. This happens if t_{OS} is sufficiently above p_{ETS}. So if the cost-benefit ratio of our project is below one, when moving transport activities from the OS to EU ETS (thereby substituting high-cost abatements with low-cost abatements) it will contribute to a more cost-effective climate policy. As noted above, it is not straightforward to interpret the level of the Swedish carbon tax as the marginal abatement cost within the OS. To arrive at an adequate CBA of our project we need information about to what extent the tax level is motivated by fiscal considerations (i.e., how large the tax would be in the case there would be no climate threat) and which part of it that is climate motivated.

A Global Climate Treaty of KP type.

The world is striving for a global climate treaty. Although some steps have been taken in this direction, most notably the negotiation of the Kyoto Protocol (UN, 1997), it is by no means a straightforward road towards such a treaty. Nevertheless, we here assume the existence of a global climate threaty of the Kyoto Protocol type and discuss what it implies for the CBA of our railway investment.

Now also the indirect emissions of our project will materialize under a cap and be priced. The aggregate global emissions will thus be unaffected. Our project now only imply that someone else has to undertake further or less abatements, and therefore leads to that costs are incurred or avoided elsewhere. These effects are reflected by the international quota unit price (p_W) under this climate treaty. The climate policy relevant effects of our projects can then be stated as $p_{ETS}\Sigma a_i\Delta kWh_i + t_{OS}\Delta GHG_{Road} + p_W(\Sigma\Delta IE_i + \Delta IE_{Road})$. Now also the last term internalized in market prices and will therefore appear in various places in a complete and adequate CBA of our railway project. For instance, the initial demand for road transports will be smaller under the current context than under the previously ones. There is therefore no need for a special treatment of GHG emissions in the CBA. Most notable, the planner doesn't have to assess the environmental cost of GHG emissions.

5. Concluding Remark

We have here discussed principles for assessments of the GHG effects of a railway project that shifts a certain amount of transports from road to rail. It has been shown that the adequate way of considering these effects in an otherwise complete CBA of the project depends on the climate and energy policy context under which the project is undertaken.

In a context with no climate or energy policies at all, the relevant climate post of our railway investment equal the country's unilateral valuation of the projects net-effect on global GHG emissions. The net-effect consists of both direct *and* indirect GHG emissions of power production and the change in emissions associated with road traffic. The direct emissions from power production should be assessed by the means of the marginal emmission factor of electricity production (MEF) derived for the relevant regional electricity market. For a Swedish railroad investment this is the North European market, at which the marginal power production is coal based.

Voluntary green electricity contracts between the railway operator and power producers may in the long run imply that the project is responsible for less GHG emissions than a traditional MEF-assessment would indicate. However, in the short run and when there exists a mandatory system of green electricity certificates, such contracts only serves to increase the project's expenditures on electricity. A system of green electricity certificates (of the Swedish type) has two implications in this otherwise non-policy context: (i) the relevant MEF will now consist of the weighted sum of the marginal plant on the North

European power market and the marginal green power plant in Sweden and (ii) the extra cost of green electricity is included in the consumer price on electricity.

At the other end of the policy-context spectrum we have a comprehensive global climate treaty inducing a uniform price on GHG emissions. In this case, market prices reflect all relevant climate policy effects and there would be no need for any specific and explicit treatment of these effects in the CBA of our railway investment. In fact any such treatment would run the risk of counting the same effect twice. This is not to say that our project of electrifying transportation cannot produce a climate policy dividend, only that such dividends automatically and correctly will be considered in the CBA of the project.

Such a comprehensive global climate treaty has yet to materialize although some steps have been taken. However, in the EU most emissions are capped. A railway investment electrifying (part of) the transport sector will therefore give rise to mainly pecuniary effects which existing market prices reflect. Even though the effect on global GHG emissions will be minor, reallocating abatements between the road transport sector and the EU ETS may contribute to a cost-effective fulfillment of the EU's climate policy targets. This would be the case if it is more costly to abate in the former than in the latter and the cost benefit ratio of our project is equal to or below one. Since the relevant effects are internalized in the electricity price and fuel prices any such dividends are automatically captured by a comprehensive CBA. An explicit treatment is only called for to the extent the project affects emissions outside EU's emission caps. Example of such emissions is some of the indirect emissions of power production and (bio and fossil) fuel consumptions. To adequately consider these effects a life-cycle-analysis are needed.

The circumstance that less and less of our project's climate policy relevant effects needs explicit consideration by the means of an separate climate post in the CBA should not be interpreted as the threat of rapid climate changes being less prioritized. On the contrary, it is a consequence of effective climate policies being implemented that internalize the value/cost of GHG emissions (as it has been defined by the political system) in market prices. Billions of every-day decisions are now steered in a "climate friendly" direction.

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