Indirect and unintended influence of energy policy instruments on energy efficiency investment – an analysis for the pulp and paper industry

Ali Aydemir
Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Straße 48
D-76139 Karlsruhe
Germany
ali.aydemir@isi.fraunhofer.de

Nele Friedrichsen
Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Straße 48
D-76139 Karlsruhe
Germany
nele.friedrichsen@isi.fraunhofer.de

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Abstract
Paper production is an energy-intensive process. It accounted for roughly 12.7 % of the industrial final energy demand in Germany in 2010. With regard to electricity utilization, it accounted for about 9.5 % of the industrial electricity demand in Germany in 2010. However, significant potentials to increase energy efficiency via new technologies do exist. Yet realization of these potentials is slow, with lack of profitability being one of the most important barriers to the adoption of energy-efficient technologies in the industry.

The profitability of efficiency investments largely depends on electricity prices with lower prices increasing the pay back time of efficiency investments and vice-versa. Electricity prices include politically driven levies that vary within the EU. Typically, certain exemptions from paying the full levies apply to industrial electricity consumption. Our paper deals with the question of how strongly these levies and privileges that reduce levies for industrial electricity consumption influence the profitability of energy efficiency investment in Germany, France, the Netherlands and the UK. As different economic and technical boundary conditions underlie different sectors, we analyse a stylized case in the pulp and paper sector.

First, we define a sample paper mill. Important characteristics are the annual electricity consumption (determined by annual production and specific electricity consumption) and the capacity and voltage at which the plant is connected to the electricity grid. Second, we derive the electricity price including levies for the paper mill. Third, we calculate the internal rate of return (IRR) of an investment in a high-efficiency paper refiner. Finally, we vary the politically driven components of the electricity price to investigate their influence on profitability and compare results across countries. A sensitivity analysis is also conducted for varying efficiency gains.

The results give insight into a) how strong privileges with regard to policy-driven power price components for industrial electricity consumption affect profitability of energy-efficient investment and b) how this influence differs between the compared member states. Further analysis is needed for energy efficiency technologies with other characteristics and in other sectors.

Introduction
Paper producers within the EU have faced several new competitive challenges in recent years. One challenge is the changing demand situation causing structural problems. Demand for graphical paper is declining, and expected to decrease further over the next few years, due to the trend towards electronic publishing and communication compared to paper-based products.[1] For example, in Germany, the Federal Parliament (Bundestag) decided to circulate parliamentary materials, such as legislative proposals, reports etc., electronically with the aim of reducing its paper consumption (EUWID 2013a). Competition in the face of overcapacities creates enormous pressures on prices, in particular for mass products. In recent years several paper plants have closed down or reduced their capacity (e.g. Frohnleiten in Austria in 2012, Hamburger GmbH; Mantova

1. For sanitary papers, the situation looks brighter as demand is growing. The outlook for specialty papers and packaging papers is also better.

in Italy in 2013, Burgo; Hyltebruk & Kvarnsveden in Sweden in 2013, Stora Enso), while others have been bought by big international companies (e.g. Kinnevik by Korsnäs, 2012 in Sweden). Further market consolidation is expected in the future. Uronen (2010) analysed standardized interviews with 36 senior managers within the pulp and paper industry cluster, where 90 % "of the respondents predicted either modest or significant consolidation to take place in the next 5 years, with the clear majority anticipating a fairly modest increase" (Uronen 2010, p. 124).

Furthermore, investment activity might not take place in Europe. Large paper producers are often global players within the paper market (e.g. Stora Enso, UPM Kymmene and Norske Skog). Their assets and infrastructure allow them to set up new facilities at locations where production conditions are more favourable. The reinvestment ratios from PWC (2012, p. 11) indicate that in recent years large production capacities have been mainly set up in Latin America and Asia. While raw material availability, lower energy prices and cheap labour are all likely factors contributing to the desire to open paper mills in these regions, the main driver is said to be the expectation of growing markets and proximity to demand since these are important success factors for paper mills.

In particular, in the sector of mass paper products competition is likely to be dominated by price rather than by quality. This competition drives profits down and makes it difficult for companies to achieve price increases in the face of rising input costs. Analysing financial data of the 100 largest forests, paper and packaging companies in the world, PWC (2012) reports that the Eurozone's strong sales increase from 2010 to 2011 (10.3 %) "did not translate into net earnings increases as price increases were offset by input cost increases". For some types of paper the situation might even be worse. As mentioned above, overcapacity and declining demand have been seen in the markets for graphical papers. In Germany and the UK experts note that even in the face of increasing costs, companies have been unable to achieve price increases. Therefore, profits have been declining.

Paper production is energy-intensive and hence energy costs make up a significant portion of production costs. The main cost factors in paper production are raw material costs, labour, and energy costs. Raw material costs account for approximately one third of turnover, labour for approximately 14 %. Energy costs account for roughly 12 % of turnover with 50 % of the energy costs being electricity costs. If electricity price increases are asymmetric across countries this decreases paper producers' competitiveness in countries with increasing prices (all else being equal).

In many EU countries a considerable portion of the electricity price is driven by policy instruments, most notably energy taxes and renewable energy support policies. Several countries are charging private and industrial electricity consumers additional levies to finance the support of renewable power generation. One popular instrument under the German Renewable Energy Act is the feed-in tariff. The feed-in tariff grants a fixed remuneration for each kilowatt hour generated from renewable sources and fed into the public grid. It thereby supports investments in renewable power generation. The resulting costs are passed onto final consumers via the renewable energy surcharge. Importantly though, industrial electricity consumers receive significant discounts from the surcharge. Similarly, exemptions and reductions from the burdens of other policy instruments (such as electricity taxes) exist in Germany and other countries to prevent excessive burdens on energy-intensive companies. Typically, the pulp and paper industry falls within the group of privileged industries.

Importantly, absolute energy costs depend on energy demand and not just on the specific price per unit of electricity. Hence, energy efficiency improvements may be an important measure to secure competitiveness in a paper sector oriented towards sustainability. Notably, the profitability of the efficiency investment depends on the energy price. With higher prices, profitability of efficiency improvements increases and vice versa. Hence, political measures that reduce the electricity price for industrial consumers may have a negative impact on the incentives to invest in energy efficiency. We are interested in understanding the degree to which these policy driven differences in power prices across Germany, the Netherlands, France and the UK have an impact on investment profitability. We analyse Germany, France, the Netherlands, and the UK based on their international relevance within the paper sector. They all have a leading position in the world export share in the paper sector: Germany 11–12 %, France roughly 4 %, and the Netherlands and the UK roughly 3 %.[2]

We find for our stylized case study that politically driven burdens on industrial electricity consumption deviate among the compared member states. Thus, the profitability of the assessed energy investment opportunity deviates among the compared member states. More specifically, the internal rate of return (IRR) deviates by up to 3.7 % points for the same investment opportunity due to different levels of policy-driven burdens among Germany, Netherlands, the UK and France. We have also investigated the effect of the policy-driven privileges (i.e. preferential treatments on levies) for industrial electricity consumption on the profitability of the evaluated energy efficiency investment within each country. We find a deviating impact on the IRR. For the Netherlands, the IRR decreases by 1.5 % due to existing exemptions that ease the electricity cost burdens for industry. For the UK, the IRR decreases by only 1.2 % as a result of the privileged power prices and for France by 2.3 %. The highest difference has been found in Germany, where the IRR is 13.8 % lower due to exemption rules.

However, it is not sufficient to investigate the relative effect of the price reductions since absolute prices crucially influence the profitability of energy efficiency investments. The absolute policy-driven burden is highest in Germany, even though also the reduction of burdens due to exemption rules is highest in Germany. The EU is currently investigating exemptions on "green charges" for German industry. This creates uncertainty on the continuation of privileges, increases the risk of misjudging an investment opportunity and works to the detriment of investment. Therefore, we also investigate the potential price increase resulting from a discontinuation of the privileges.

The rest of the paper is structured as follows: We first present politically driven electricity price differences between Germany, the Netherlands, France and the UK and briefly mention the main underlying policy instruments. We then conduct a profit-

2. Other European countries to include would be Sweden, Finland and Italy, which also have high world export shares ranging from 5–6 % for Sweden down to roughly 3 % for Italy. First priority, however, would be the addition of competitors from outside Europe such as the US, China, or Russia.

ability analysis for our sample paper mill evaluating one energy efficiency investment opportunity based on the derived electricity prices. Finally, we discuss the sensitivity of the results.

Deviating electricity cost for a sample paper mill in Europe

Assuming identical electricity power procurement prices, we calculate gross electricity prices for a sample paper mill in Germany, France, the Netherlands and the UK. Price determining characteristics are annual electricity consumption (determined by annual production and specific electricity consumption) and the capacity and voltage at which the plant is connected to the electricity grid. Furthermore, the share of electricity cost in gross value added and turnover is relevant for calculating levies in Germany. The paper production branch is affected by the Industrial Emissions Directive (IED). One of the basic IED principles is applying best available techniques. Thus, the environmental performance of paper production plants within the EU has to, at the very least, fulfil minimum environmental requirements set by Best Available Techniques (BATs). The Bavarian Paper Association (BayPapier 2012) states that 94 % of the electrical energy efficiency potential has already been reached in Germany compared to BAT values. In the EU's BREF document for the pulp and paper industry (2001) a BAT value of 1,200 kWh/t for the specific power consumption of a paper mill is given. We assume a value of 1,300 kWh/t, which is more or less in line with values stated in environmental reports for different paper mills (Stora Enso 2008, p. 12; Stora Enso 2012a, p. 9; Stora Enso 2012b, p. 2; Lang Papier 2010, p. 4; NorskeSkog 2012, p. 13). The share of electricity cost in gross value added and turnover has been derived from interviews with branch experts.[3] Finally we assume 6,000 full load hours per year. The assumptions for the sample paper mill are summarized in Table 1.

Friedrichsen et al. 2014 compare policy-driven components in electricity prices in accordance with current existing regulations in Germany, France, the Netherlands and the UK. They present gross electricity prices structured into the following categories: power procurement,[4] transmission and distribution, taxes (consumption tax), renewable energy support and value added tax. We use the results presented in Friedrichsen et al. 2014. The national price components/levies for the compared member states are listed in Table 2. Typically, industrial electricity consumption receives certain exemptions from renewable energy support or other preferential treatment such as reduced electricity taxes. These regulations are described in the following sections for each of the compared member states.

GERMANY

In Germany, companies may be able to benefit from reductions on network tariffs, the electricity tax (*Stromsteuer*), the concession levy (*Konzessionsabgabe*), the renewable energy surcharge (*EEG-Umlage*), the combined heat and power generation surcharge (*KWK-Umlage*), as well as the surcharge for compensating network operators for offshore grid connection liability[5] (*Offshorehaftungsumlage*) and the §19-levy on network tariffs *(§19 StromNEV-Umlage)*.[6]

Companies can benefit from a reduced renewable surcharge under the special exemption regulation (Besondere Ausgleichsregelung-BesAR).The qualification criteria for reduced payments are absolute electricity consumption, share of electricity costs in gross valued added and share of electricity costs in turnover.[7]

The exemptions for CHP surcharge, offshore grid connection liability surcharge, and §19-network-levy depend on electricity consumption as well as the ratio of electricity costs to turnover.

Reduced network tariffs may be granted upon request and are subject to approval by the regulator for companies with extensive network utilization which is indicated by a consumption of at least 10 GWh/a and more than 7,000 utilization hours per year (§19 StromNEV). The tariff reduction may not exceed 80 % in case of a minimum of 7,000 utilization hours, 90 % in case of a minimum of 7,500 h/a or up to 95 % for 8,000 h/a and more. Reduction from the concession levy depends on whether an organization is defined as a "special contract customer". "Special contract customers" that pay a price below a defined marginal price are not charged a levy.[8]

Tax reductions are granted for the entire manufacturing sector[9] and for certain activities and processes (other than paper production).[10] The remaining tax load may be further reduced under the so-called "surplus settlement" in special cases. The "surplus settlement" is available upon request for companies from the manufacturing sector. The calculation scheme for the

Table 1. Assumptions for the sample paper mill.

Production volume:	20,000 t/a
Electricity intensity:	1,300 kWh/t
Electricity demand:	26 GWh/a
Peak demand/ connection capacity:	3 MW
Full load hours:	6,000
Share of electricity cost in gross value added:	> 20 %
Share electricity cost in turnover:	> 5 %
Share of electricity cost on product cost:	< 50 %
Grid connection	> 250 kVA

3. The values refer to mills without self-generation of electricity. This is typical for small mills. Big mills often produce part of the power needed internally. This could decrease the share of power cost in gross value added turnover below the threshold for receiving privileges. Yet, the more important effect is that typically self-generation is not burdened with policy-driven levies at all. France is the exemption with the renewable surcharge which is charged for self-generation above 240 GWh/a.

4. They assume the same procurement price across all countries to concentrate on the effect of policy driven components.

5. Network operators pay compensation for delays or failures in network access to offshore wind generators. Part of these compensation costs can be socialized to consumers.

6. The §19-levy on network tariffs has been established by the government in order to pass on costs from reduced network tariffs for industrial sites. This levy has to be paid on top of general network tariffs.

7. In the application for exemption, the companies present data from the previous year to receive a reduction in the following year.

8. The marginal price is based on the average (net) revenue of all special contract customers. In 2010 this average revenue was 10.66 ct/kWh (destatis.de). Municipality and supplier may negotiate higher marginal prices.

9. The reduction has to exceed 250 euros/a.

10. Further exemptions exist. See electricity tax law (Stromsteuergesetz) for details.

redemption is based on the relation of electricity taxes and social security contributions. The "surplus settlement" enables a reduction of up to 90 % of the taxes paid. Since 2013 companies have been required to prove a certified energy management system to qualify for the "surplus settlement".

NETHERLANDS

In the Netherlands, industrial consumers with a consumption above 10 GWh/a benefit from reduced taxes.[11] They receive a tax waiver if they commit to taking measures to improve their energy efficiency. Furthermore, process-based tax exemption applies e.g. to electrolysis, metal production, or chemical reduction (Article 64 of the environmental taxes act).[12] Companies that signed a covenant and consume above 10 GWh per year are also exempt from paying the Dutch renewable energy surcharge SDE+.

UNITED KINGDOM

In the UK, companies can benefit from reduced rates of the *Climate Change Levy* (CCL) if they are part of a climate change agreement (CCA) and meet energy efficiency or carbon saving targets. The goals within the CCAs are based on figures for the overall sector benchmark. Industrial consumers also typically have to pay lower amounts for renewable energy support. We note that this is not a privilege in a strict sense, since suppliers have to pay for renewable obligations and pass the costs onto consumers.

FRANCE

In France, energy-intensive organisations with a connection capacity above 250 kVA pay a **general consumption tax** (*TICFE – taxe intérieure sur la consommation finale d'électricité)*. Companies receive exemptions from TICFE if their power costs account for 50 % or more of their product costs. Furthermore, the electricity demand of specific industrial processes such as electrolysis or metal production is exempt from TICFE.

Companies may also benefit from a reduction in CSPE (the public service charge that finances support for renewable generation and also contributes to subsidized power prices for disadvantaged people).[13] CSPE payments are limited to a maximum of 0.5% of the company`s gross value added for energy-intensive firms that use more than 7 GWh/a. Furthermore, annual CSPE payments per supply point are limited to a maximum amount of 559,350 euro (2012).

DEFINING THE CASES

In order to evaluate how strongly the above regulations for industrial electricity consumption affect profitability of energy-efficient investment and how this influence differs between the compared member states for the sample paper mill we calculated an electricity price with and without preferential treatment for industrial electricity consumption. The base case implies prices which are in line with the assumptions for the paper mill from Table 2 and incorporate the status quo of existing regulations as described above. Thus, the base case represents reference prices with existing preferential treatment of industrial electricity consumption. For comparison, we have calculated prices when some of these existing privileges would disappear. Thus, the following adoptions were made for the different member states:

- **UK:** For the UK, we tested the sensitivity to the reduction in the climate change levy. Reductions of the climate change levy depend on the conclusion of a climate change agreement linked to energy efficiency targets. The goals within the CCAs are based on figures for the overall sector benchmark. We consider it unrealistic that companies do not participate in the CCA since targets are typically manageable. Hence, the sensitivity is a hypothetical consideration of what would be if for any reason exemptions from the CCL were eliminated.
- **Netherlands:** In the Netherlands, preferential treatment is coupled with energy efficiency targets similar to the UK. For the non-privileged case we assume that preferential treatment by signing a covenant is not possible. That means full taxes and levies for renewable energy support have to be paid according to existing legislation.
- **France:** For France we assume for the non-privileged case that preferential treatment with regard to the renewable surcharge falls away. Thus, the full CSPE levies have to be paid. The taxes for the base case and the non-privileged case are the same as we assumed for the plant that electricity costs have a share of less than 50 % of product costs.
- **Germany:** In Germany, the main preferential treatment is the reduction of the renewable energy surcharge. The available reduction depends on the share of electricity cost in gross value added. If this share falls below 14 %, no reduction is granted. This can happen when the value of the produced goods is comparatively high. In the paper sector, this can be niche products or specialty papers. The share can also fall below 14 % when the plant has a high share of self-generation lowering costs for electricity purchases. For setting the non-privileged case we assume that no preferential treatment for levies from the category renewable energy support is granted. Furthermore, no tax reduction according to the "surplus settlement " is being applied.
- The construction of the cases is summarized in Table 2[14]. For the different member states the electricity price components for the non-privileged cases are presented in the Appendix (Table 7).

11. For private consumption above 10 GWh a rate of 1 ct/kWh applies.

12. For a full overview of regulations and exemptions see WET van 23 December 1994, houdende vaststelling van de Wet belastingen op milieugrondslag, Hoofdstuk VI. Energiebelasting.

13. CSPE also contributed to financing power supply in non-grid connected oversee areas.

14. "Transmission and distribution" in Table 2: Even though reduced tariffs for transmission and distribution might be seen as privileges for industry (e.g. in Germany) we do not consider these reductions in setting the cases. This is based on the fact that the pricing for network tariffs deviates significantly between the compared member states. In the U.K., for example the pricing is dependent on location whereas in Germany the load profile has significant influence on pricing the tariffs. Thus, setting comparison prices for the unprivileged cases might be unrealistic. As a consequence the prices for transmission and distribution are identical for the base and the unprivileged case.

Table 2. Cluster of electricity price components (see Table 3 for the resulting values of the base case).

Electricity price components	Base case	Non privileged case (e.g. case with reduced preferential treatment)
Transmission and distribution		
Network charges (D, UK, NL, F)	No privileges considered. Network charges assumed to be equal in base case and non-privileged case.	
Concession levy (D)		
Levy according to §19 of network tariff regulation (D)		
Taxes (consumption tax)		
Electricity tax (D)	Electricity tax is reduced down to 10% based on the "surplus settlement". (2), (3)	Electricity tax is being paid fully.
Electricity tax (TICFE) (F)	The taxes for both cases are the same. (2)	
Electricity tax (NL)	Tax reduction is applied according Covenant.	Regular tax is being paid fully.
Climate Change Levy (UK)	CCA is being applied for the sector. Thus the CCL levy is being reduced.	No CCA is being applied for the sector.
Renewable energy support		
Levy according to the renewable energy law (EEG-Umlage) (D)	Preferential treatment according to existing regulations is being applied. (1)	No preferential treatment is granted. All electricity price components are being paid fully.
Offshore grid connection liability levy (D)		
Combined heat and power generation levy (D)		
SDE+ (NL)	SDE+ levy reductions are applied according to Covenant.	SDE+ levy reductions are not applied.
CSPE (F)	CSPE reduction is being applied.	CSPE levy has to be paid fully.
Renewables Obligation (UK)	Renwables obligation is being paid fully in both cases as there is no reduction scheme.	

(1) The calculation scheme is presented in Friedrichsen et al. (2014).
(2) It is assumed that the technical processes within the paper mill are not exempt from electricity taxes in general.
(3) An energy management system is being applied by the company.

Critical review on defining the cases

The constructed cases give insights into preferential treatment for industrial electricity consumption on electricity taxes and levies for renewables. However, these cases do not take into account whether preferential treatment is also being applied on the level of electricity transmission and distribution cost.

Furthermore, price mechanisms for policy-driven electricity price components differ significantly in their structure. It is therefore debatable where to set the bottom line "non-privileged" for components. There might be additional mechanisms which have an indirect impact on electricity prices for industry. For example, for renewable energy support only one price component has been presented for the Netherlands, the UK and France, whereas three have been presented for Germany. However, this does not mean that there are no other schemes supporting renewables or energy-efficient technology among the compared countries. In the UK, for example, the smart meter program sets incentives to purchase smart meters in order to increase energy efficiency for private households. Renewable Obligations require suppliers to source a certain part of the electricity they supply from renewable sources. Anyhow, the management of passing on these costs is in the scope of the energy supplier with certain limitations. Typically, though industry pays a lower specific add-on than household consumers. Thus, it is not clear how these instruments affect industry and to which extent industry has to pay for such programs. Within our analysis, we do not consider these programs as politically driven preferential treatment.

Benchmarking an energy efficiency opportunity for the sample paper mill

The profitability of an investment is typically benchmarked by the Net Present Value (NPV) and the Internal Rate of Return (IRR). Only Investments with a positive NPV are considered to be economically feasible expressing that the IRR is higher than the required rate of return. The required rate of return depends on:

- the opportunity cost (e.g. the return of an alternative investment) which the return of the proposed investment has to exceed, *or*
- the financing costs which have to be covered by the return of the proposed investment.

Several different approaches to derive the underlying required rate of return (i.e. the calculation interest) addressing these cir-

Table 3. Electricity prices for the sample paper mill.

	Germany		France		UK		Netherlands	
	with privileges	without privileges	with privileges	without privileges	with privileges	without privileges	with privileges	without privileges
Power procurement	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Transmission and distribution	1.70	1.70	0.98	0.98	1.69	1.69	0.59	0.59
Taxes (consumption tax)	0.16	2.05	0.05	0.05	0.06	0.64	0.00	0.47
Renewable energy support	0.47	5.65	0.05	1.05	0.47	0.47	0.00	0.14
Value added tax	1.39	2.74	1.20	1.39	1.44	1.56	1.17	1.30
Gross electricity price	8.72	17.15	7.28	8.47	8.66	9.35	6.76	7.50

Table 4. Assumptions for evaluated fictional energy efficiency investments (specific costs from Fleiter 2012, the other values are assumptions).

Technical Assumptions for the change of the refiner	
Saving potential [MWh/t]	0.0328
Annual increase of electricity price [%]	1.00
Minor overhaul (every year, % of total investment)	0.5
Major overhaul (after 10 years, % of total investment)	5
Financial Assumptions	
First year of operation	2015
Depreciation years	20
Application of funds (initial project costs)	
Specific project hardware cost [euro/t of capacity]	15.7
Project development cost (% of hardware cost)	5
Project implementation cost (% of hardware cost)	10
Origin of funds	
Shareholders' equity (equity ratio) [%]	100
Subsidies [%]	0
Borrowed funds[%]	0
Loan & Capital conditions	
Interest rate on loans [%]	3.0

cumstances are discussed in the literature (Rolfes 2003, p. 23). As a consequence the required rate of return used to evaluate investment opportunities might deviate between companies. Therefore, we refer mainly to the IRR which is independent from the required rate of return. Another important performance indicator of an investment is the pay back period. The risk of investment projects is usually evaluated lower with falling pay back periods. From the experience with industrial firms, it is known that energy efficiency investments with a pay back period longer than three years will often be unacceptable (Fleiter 2012, p. 99). This is especially the case for SMEs (Trianni 2012, p. 7-1).

Based on the derived electricity prices a fictional energy efficiency investment opportunity within the paper mill is benchmarked in the following section. The investment opportunity is changing the refiner to a more efficient one. To reduce the energy consumption at the refining process step an optimization of the refiner is also presented in the literature. This saving potential is primarily based on process optimization, i.e. reducing idle times during the refining process. Therefore, specific costs for such a measure are by far lower compared to changing the refiner into a more efficient one. The pay back time for such a measure is by far below three years. Thus, missing out on adopting such measures cannot be blamed on financial reasons, much less in unintended effects of policy-driven exemption rules for industrial electricity consumption. From a rational point of view only adaption barriers such as lacking knowledge etc. might dampen a diffusion of such a measure (Fleiter 2012, p. 41). As a consequence, to optimize the refiner is not investigated in the following.

Changing the refiner into a more efficient one offers an electricity saving potential of 2.5 % compared to the overall process efficiency. This is more or less in line with goals stated in environmental reports of existing paper mills (Stora Enso 2012a, p. 2). The assumed data to calculate IRR and the pay back period are listed in Table 4. Please note that the calculated pay back times are rather indicative of pay back times calculated within industry since, as mentioned above, the required rate of return is case and company specific. We calculate a static pay back period implying a required rate of return of 0 %.

The derived IRRs and pay back times to replace the old refiner with a more efficient one are listed in Table 5 for the compared countries. The pay back times for all cases are longer than three years. The IRRs range between 7.7 % and 11.4 % for the privileged and between 9.1 % and 25.2 % for the non-privileged case (i.e. as expected, the IRR increases with higher electricity prices). The deviation in IRRs between privileged and non-privileged cases strictly follows the deviation in electricity price differences between privileged and non-privileged cases, so that the deviation is highest in Germany followed by France, the Netherlands and the UK. Nevertheless, the IRRs are highest in Germany where gross electricity prices are highest for the sample paper mill.

Fleiter et al. (2012, p. 507) classify energy efficiency measures with respect to the expected adoption rate. They consider several factors such as internal rate of return, pay back time, transaction cost and the scope of modification. We categorize the investment opportunity "refiner replacement" according to the characteristics proposed by Fleiter et al. (2012, p. 507): IRRs are low (<10 %) for all base cases, except for Germany where the IRR (17 %) is classified as medium (10–30 %). The pay back time is very long (>8 years) or long (5–8 years) for all base cases. Finally, the type of modification is a technology replacement, which has system-wide effects and a medium lifetime (5–20 years). We conclude that a low adoption rate can be expected for the refiner exchange.

Thus, it is debatable whether energy policy instruments influence the benchmarking of the assessed investment opportunity significantly or not. Financial figures do not change much between the privileged and the non-privileged case in the UK and the Netherlands (NL). However, they do differ in France (F) and Germany (D) where the payback time decreases by nearly two (F) and nearly three years (D). Reviewing the figures qualitatively the IRR would still be low (<10 %) and the pay back time would still be long (5–8 years) in France. For Germany though, the IRR is 120 % higher without exemptions. In qualitative terms, pay back time and IRR would both be medium according to Fleiter et al. (2012) with 10–30 % and 3–5 years. Thus, the exemptions have a non-negligible effect on benchmarking the investment opportunity in Germany. Still, investigating the amount of exemptions is not sufficient to derive the influence of energy policy on the profitability of energy efficiency investments, since ultimately the profitability depends on the electricity price finally paid.

Assuming identical production values and identical electricity procurement prices (E in ct/kWh) for two fictional companies we calculate the amount of efficiency improvement necessary to level the highest and lowest deviation in policy-driven burdens among the compar d member states. For two companies with deviating specific burdens (B_1, B_2 in ct/kWh), to derive an identical electricity cost the relation in specific electricity consumption (I_2/I_1 in kWh/t) between the companies has to be as follows:

$$\frac{I_2}{I_1} = \left(\frac{B_1 + E}{B_2 + E}\right), \text{ with } B_1 < B_2.$$

We apply this calculation to the policy-driven difference in the electricity price of nearly 30 %. This would mean that the specific electricity consumption has to be nearly 23 % lower in the country with the highest burdens compared to the country with the lowest burdens to derive identical electricity costs (this case occurs by comparing the burdens for Germany and the Netherlands). To compare the smallest deviation in burdens, the specific electricity consumption has only to be reduced by 0.7 % (comparing the prices between the UK and Germany).

In order to evaluate how misjudgements in predictions surrounding the input factors affect the profitability of the refiner replacement a variation of crucial input factors has been carried out assuming an electricity price of 8 ct/kWh (which is the average (rounded) of the base case prices for the compared member states). The results are listed in Table 6. There is a proportional sensitivity to investment costs, assumed electricity price increases and predicted savings as expected. Another interesting aspect is the dependency of IRR on the origin of funds. Increasing the loan capital from 0 to 50 % reduces the IRR up to 5 %. Thus, the availability of equity capital or in reverse the interest rate on loans is significant for benchmarking energy-efficiency opportunities with comparable attributes for the assumed capital market conditions. However, this statement depends on the assumption of zero capital costs for equity capital when deriving the IRR.

Conclusion

One conclusion for our stylized case study is that policy-driven burdens for industrial electricity consumption have a deviating impact on benchmarking the profitability of energy investment opportunities among the compared member states. In our stylized case study this is the case for replacing a refiner with a more efficient one within a paper mill. This opportunity can be seen as a proxy for a "large" reinvestment within the pulp and paper industry due to the given attributes. Assuming identical electricity procurement prices the IRR deviates up to 3.7 % points for the same investment due to different levels of policy-driven components in the electricity price among Germany, Netherlands, France and the UK for the stylized base case. Consequently, the IRR is highest in Germany (11.4 %) followed by the UK and France. The lowest IRR of 7.7 % can be found in the Netherlands for the same investment.

We note that the extent to which exemption rules reduce power prices paid by industrial firms is not sufficient to derive the impact of energy policy on the profitability of energy efficiency investments since profitability depends on prices finally paid. These are highest in Germany even though reductions are also highest. Therefore, IRRs are also higher in Germany. Hence, when evaluating indirect and unintended influences of

Table 5. IRRs for changing the refiner into a more efficient one.

	Electricity price with privileges (base case)	Electricity price w/o privileges	IRR (base case)	Pay back time base [years]	IRR (w/o privileges)	Pay back time (w/o privileges) [years]	IRR delta due to privilege
UK	8.66	9.35	11.3 %	7.9	12.6 %	7.3	1.2 %
France	7.28	8.47	8.7 %	9.7	11.0 %	8.1	2.3 %
Netherlands	6.76	7.50	7.7 %	10.6	9.1 %	9.2	1.5 %
Germany	8.72	17.15	11.4 %	7.9	25.2 %	4.0	13.8 %

Table 6. Variation of input factors for the refiner exchange.

Variation of other factors with base price 8 ct/kWh, Exchange of refiner	IRR	Change to base [%]
Base case with 8 ct/kWh	10.1 %	0
Investment cost +10 %	8.7 %	-1.4 %
Investment cost -10 %	11.7 %	1.6 %
Electricity price increase 0,5 % per year	9.5 %	-0.6 %
Electricity price increase 1,5 % per year	10.7 %	0.6 %
Electricity savings +10 %	11.6 %	1.5 %
Electricity savings -10 %	8.6 %	-1.5 %
50 % loan	4.9 %	-5.2 %
100 % loan	1.1 %	-9.0 %

energy policy on the profitability of energy efficiency investments the absolute policy-driven burdens have to be also taken into account. This is even more relevant when affected firms are operating internationally. In these cases, higher costs for energy within an area do not inevitably cause higher investments in energy-efficient technologies within this area. Instead, one outcome of higher energy costs can be the consolidation among international competitors, especially where the disadvantage of higher energy costs cannot be levelled with higher energy efficiency.

For our sample paper mill the policy driven burdens are nearly twice as high in Germany than in the Netherlands in the realistic base case. In other words, the resulting gross electricity prices are nearly 30 % higher in Germany than in the Netherlands. We investigated to which degree improved energy efficiency could compensate for this price difference. Assuming identical production values and electricity procurement prices the specific electricity consumption of the production would have to be reduced by 23 % in order to level the deviation in specific electricity costs. This is unrealistic when considering existing efficiencies and BAT values (BREF document for the pulp and paper industry 2001).

Furthermore, we suggest that the uncertainty of exemptions is an adoption barrier or at least may cause investment backlogs for energy-efficient technologies for two reasons. On the one hand, the risk of misjudgement increases with uncertainty of the continuation of exemption rules – in particular when the exemption is very high. In other words, when an investment is being carried out on the assumption that specific exemptions will disappear in future, the investment might turn unprofitable if the exemptions continue. On the other hand, exemptions may be crucial for the competitiveness within a market in a specific area. This determines whether long-term investment decisions for a location are being undertaken or not. Potential investments at sites where preferential treatment on electricity prices is very high and the continuation of this treatment is uncertain might be assessed as risky. In order to avoid these risks, energy efficiency projects may be deferred as indicated in several interviews with branch experts.

Finally, the sensitivity analysis shows that the availability of equity capital or in reverse the interest rate on loans is significant for benchmarking energy efficiency opportunities for the assumed capital market conditions. Thus, further research is needed to find out to what extent capital providing funds can support the diffusion of energy-efficient technologies (e.g. Fleiter 2012 evaluates the "kfW-Förderprogramm").

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Appendix

Table 7. Electricity price components for the non privileged case.

All values in ct/kWh	Germany	Netherlands	France	UK
Electricity procurement	5	5	5	5
Transmission and distribution	**1.705**	**0.588**	**0.978**	**1.690**
Taxes (consumption tax)	**2.050**	**0.466**	**0.050**	**0.635**
Electricity Tax (D)	2.050	0.466	–	–
Electricity Tax (NL)	–	–	–	–
TICFE (F)	–	–	0.050	–
Climate Change Levy (UK)	–	–	–	0.635
Renewable energy support	**5.653**	**0.140**	**1.050**	**0.468**
EEG-Umlage (D)	5.277	–	–	–
Off-Shore-Haftungsumlage (D)	0.250	–	–	–
KWK-Umlage (D)	0.126	–	–	–
SDE+ (NL)	–	0.140	–	–
CSPE (F)	–	–	1.050	–
Renewables Obligation (UK)	–	–	–	0.468
Value added tax	**2.737**	**1.301**	**1.387**	**1.559**
SUM	17.145	7.496	8.466	9.352