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Industrial energy efficiency and competitiveness

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WORKING PAPER 05/2011

Industrial energy efficiency and competitiveness

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1 Introduction

Energy efficiency in industry is strongly linked in various ways with competitiveness in newly industrialized countries (NICs), transition countries, developing and developed nations. These different links exist on a micro, company-based level, but also on a more aggregated level for industries and economies: energy efficiency contributes toward reducing overall company expenses, increases productivity, has effects on competitiveness and the trade balance on an economy-wide level, and, by creating a home market for energy efficient technologies, supports the development of successful technology supply industry in that field. The principal driver for an energy efficient development of industry is the need in all countries to rapidly achieve cleaner production modes and to decrease costs. This will lead to a rapidly growing market in which developing countries may also more readily find an opportunity to develop their industries.

This chapter aims to analyse the links between energy efficiency and industrial competitiveness. This empirical research is performed for a set of 35 countries, combining developed, newly industrialized, transition and developing countries. The first part of this chapter analyses the relevance of energy consumption and energy efficiency in the industrial sector of the group of countries; the second part investigates to what extent countries are presently prepared to absorb energy efficiency technologies and even to develop industries which are capable of producing energy efficiency products and processes for the market.

The empirical research concept in this chapter is based on a systematic innovation approach. This approach highlights the various actors and their communication pattern. In addition to traditional R&D policies, the factors influencing the demand for energy efficient technologies are also an important driver for future innovations. Policy coordination between the different regulatory regimes consequently becomes a major challenge for policy making.

A country's preparedness to absorb such technological development for the benefit of the respective country differs greatly. We identify five groups for the absorption capacities with quite different characteristics. This implies that suitable strategies have to be developed by the different countries, taking into account the major barriers to such a development in their respective group. The production and diffusion of new solutions crucially depend on the interplay of the different actors in the innovation process. In the framework of this heuristic, soft context, factors (e. g. situative conditions for policy design and impacts) and aspects of a demand-oriented innovation policy can be analysed, barriers identified and suitable measures introduced to remove such barriers.

2 Energy efficiency and industrial competitiveness

Energy efficiency in industry is strongly linked with competitiveness in NICs, transition countries, developing and developed nations in various ways. These different links exist on a micro, company-based level, but also on a more aggregated level for industries and economies:

- Companies have to pay for the energy they use. There is ample evidence that companies do not utilize all cost-efficient technologies available to them. The IPCC has estimated that 10-30 % of the energy consumption could be reduced without additional net costs (no-regret potential). **Thus, an increase in energy efficiency could contribute to reduce overall company costs.**
- Most energy efficiency technologies belong to so-called integrated environmental technologies. In contrast to end-of-pipe technologies, they have the potential to influence the productivity of the production process. Analysis of the most important industrial energy efficiency technologies has shown that a **productivity increase** can be expected if energy efficient process technologies are introduced (Walz 1999). This effect is, however, generally much smaller for auxiliary energy efficient technologies (i.e. technologies which do not concern the central production process such as, for example, compressed air, pumps, ventilation, etc.).
- On the economy-wide level, **competitiveness will be enhanced** when industry consumes less energy. There are also **effects on the trade balance**, not only when the energy is imported, but also when it stems from the country's own resources, because the energy carrier could be exported and achieve high prices on the international markets.
- **By creating a home market for energy efficient technologies, the development of successful technology supply industry in that field is supported**. If such an industry exists, the dependence on technology imports is reduced, or may even open up the potential to become a technology provider for other countries. Thus, the demand for energy efficiency technologies can also act as a demand-led innovation policy.

To sum up the argument: The principal driver for an energy efficient development of industry is the need in all countries to achieve rapidly cleaner production modes and to decrease costs. Developing countries should take that into account early on in order to avoid costly adjustment processes later. **This will provide a rapidly growing market in which even developing countries can more readily have opportunities to develop their industries**.

The discussion on energy efficiency and industrial competitiveness must also be regarded in terms of the debate on technological catch-up and leapfrogging, which can be traced back some time. It gained prominence among scholars developing an evolutionary theory of trade. Technological cooperation focuses on the knowledge base required by the technologies and on enabling competences in the countries. Since the end of the 1980's, the concepts of "Social or Absorptive Capacity" and "Technological Capabilities" are widespread. The results of various empirical studies on economic development processes in NICs have underscored the importance of absorptive capacity and competence building. Clearly the countries need absorptive capacity if they want to push energy efficiency within their industry.

Furthermore, there is increasing debate about the changing nature of prerequisites for learning and knowledge acquisition. One aspect to consider is the trend toward the development of technological and production capabilities are increasingly becoming separated. Another aspect relates to the effect of globalization on the mechanisms for knowledge dissemination. Archibugi and Pietrobelli (2003) stress the point that importing technology, per se, has little impact on learning, and call for policies to upgrade cooperation strategies towards technological partnering. Nelson (2007) highlights the changing legal environment and the fact that the scientific and technical communities have been moving much closer together. All these factors lead to the conclusion that **domestic competences in energy-related science and technology fields are increasingly a prerequisite for the successful absorption of energy technologies** in Newly Industrialised Countries (NICs) and developing countries.

At the beginning of this section, we have outlined the economic rationale for pushing energy efficiency. In addition to reducing costs and energy consumption, it is also linked to building a domestic supply industry of energy efficiency technologies and realizing export potential in this field. The economic rationale for pushing green innovations in order to realize export potential is linked to the concepts of first mover advantages and lead markets. A first mover advantage requires that competition is driven not so much by cost differentials and the resulting attractiveness of international production location alone, but also by quality aspects. The following factors have to be taken into account when assessing the potential of countries to become a leading supplier in a specific energy technology (Beise and Rennings 2005; Walz/Schleich 2009):

- The importance of the demand side is an important part of the analysis, not only to achieve economies of scale and to ensure a market for the suppliers, but also to incorporate the knowledge of the users into further development (user-producer interaction).
- The development of the domestic supply industry must also be supported by innovation-friendly regulation. This holds especially for technologies which are used in highly regulated

sectors or which depend on environmental externalities being internalized into the market. However, there is a lot of additional research necessary to develop a clear methodology on how to operationalize the innovation friendliness of regulation.

- It is widely held that innovation and economic success also depend on how a specific technology is embedded into other relevant industry clusters. Learning effects, expectations of the users of the technology and knowledge spillover are more easily realized if the flow of this (tacit) knowledge is facilitated by proximity and a common knowledge of language and institutions.
- It has become increasingly accepted that international trade performance of technologies also depends on technological capabilities. Despite all the problems and caveats associated with measuring technological capabilities, indicators on R&D expenditures and patent indicators, such as share of patents or the relative patent advantage, are among the most widely used indicators. The empirical importance of these indicators for trade patterns is also supported by recent empirical research (e.g. Sanyal 2004, Andersson and Ejermo 2008 and Madsen 2008).

Altogether, it is more and more acknowledged that the absorption of existing technologies and the development of abilities to further advance these technologies and their international marketing are closely interwoven (Nelson 2007). For both strategies – absorption of knowledge from traditional industrialized countries and establishing export-oriented market success – it is necessary to develop substantial capabilities for energy technologies within the countries.

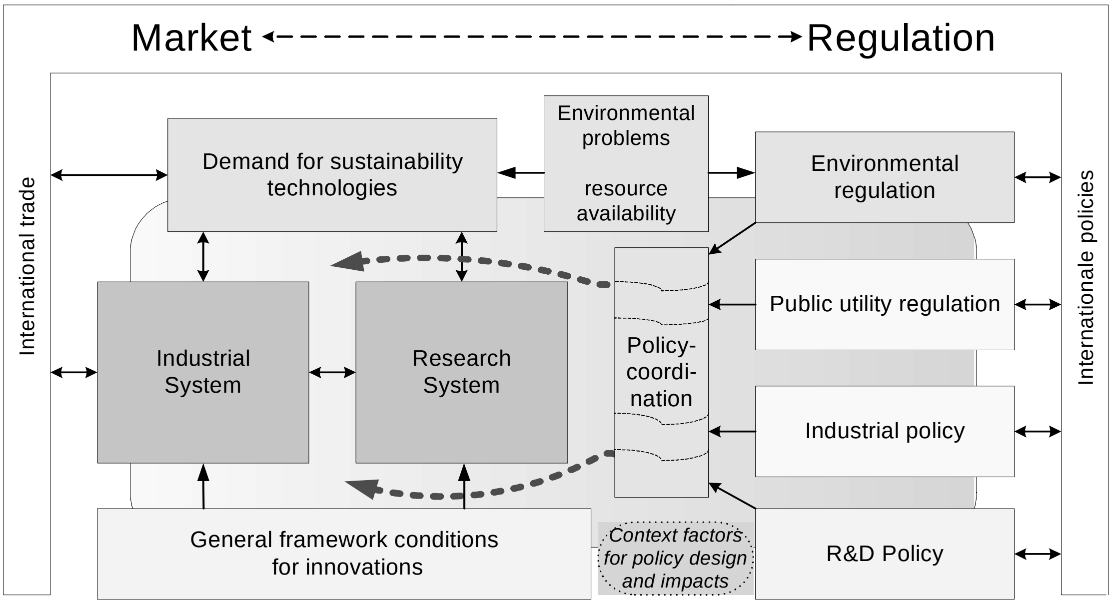
This chapter aims to analyse the links between energy efficiency and industrial competitiveness. This empirical research is performed for a set of 35 countries[1] combining developed, newly industrialized, transition and developing countries. The first part of this chapter analyses the relevance of energy consumption and energy efficiency in the industrial sector for the group of countries; the second part investigates to what extent countries are currently prepared to develop industries capable of producing energy efficiency products and processes for the market.

The empirical research concept in this chapter is based on a systematic innovation approach. This approach highlights the various actors and their communication pattern. In addition to tra-

1 The countries examined are: Algeria, Argentina, Austria, Brazil, Chile, China, Egypt, Finland, Germany, India, Indonesia, Iran, Japan, Kazakhstan, Kenya, Malaysia, Mexico, Morocco, Nigeria, Pakistan, Philippines, Poland, Russia, Singapore, South Africa, South Korea, Taiwan, Thailand, Tunisia, Turkey, Ukraine, United Arab Emirates, USA, Venezuela, Vietnam. The figures and information given in this section generally refer to this set of countries.

ditional R&D policies, the factors influencing the demand for technologies are also an important driver for future innovations. However, energy technologies differ from "normal" innovations in manufacturing in this respect. The formation of demand depends strongly on the specific role of regulations: environmental regulation acts as an important driver for the demand of technologies in this field. Furthermore, economic sector regulation, which is necessary to deal with monopolistic bottlenecks quite common in network-based industries, also influences the incentives of actors in technology decisions. This also leads to the conclusion that policy coordination between the different regulatory regimes becomes a major challenge for policy making.

Figure 1 Diagram of a system of sustainability innovations



Source: Walz et al. 2008

The concept of a system of sustainability innovation (Figure 1) can also be used to explain the manifold aspects which must be addressed by empirical research. In the remaining chapter, empirical results for the following three aspects are presented:

1. Environmental problems and energy consumption are strongly interrelated and also influence the demand for energy efficiency technologies. However, the energy consumption of industry depends on both the composition of the economy (structural effect) and the technical efficiency. This is analysed in Section 3 of this chapter.
2. The technological capabilities of the countries with regard to industrial energy efficiency are associated with the industrial and research system. The technological capa-

bilities in this specific technological field are analysed in Section 4 with technology-specific innovation indicators.

3. Increasing the capabilities in energy efficiency technologies also depend on the general framework conditions for innovations. The weaker they are, the more difficult it is for specific energy technology measures to be successful. To contrast the technological capabilities in energy efficiency technologies with the general framework conditions, survey data from the World Economic Forum WEF (2008) is used. Thus, the results depend on the analytical framework of these approaches and must be cautiously interpreted. These results are also presented in Section 4 of this chapter.

However, it is important to point out that not all relevant links between energy efficiency and industrial competitiveness could be analysed. The demand for energy efficient technologies is also influenced by specific regulatory measures, which go beyond the scope of this chapter. Furthermore, it was not possible to look at the interaction between the actors in the innovation system or the networks they form. Clearly the analysis presented in the following sections can only provide a first snapshot of the relation between energy efficiency and industrial competitiveness and constitutes merely a first step towards a more thorough analysis of the underlying mechanisms and the function of the innovation system.

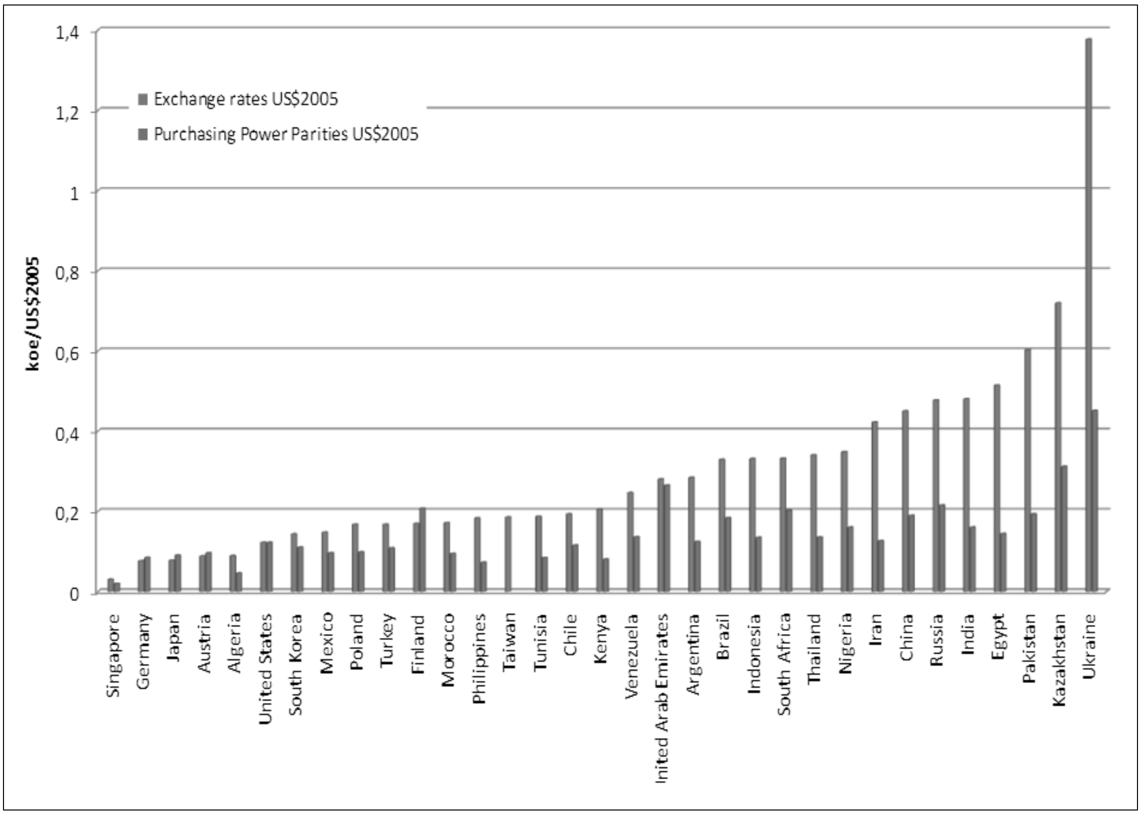
3 Industrial energy consumption and competitiveness

In developing and NICs, the immediate impact of industrial energy efficiency on the competitiveness of the country is much greater than for developed countries:

- Examining the period from 2000-2008, the share of the industrial sector in final energy consumption has been increasing in NICs, developing in transition countries from 34 to nearly 40 % (with highest shares close to 50 % in countries like China), while its share has decreased from 25 % to 23 % in the same period in developed countries (ENERDATA 2010). **This implies that the weight of industrial sector in energy terms is nearly twice as high in those countries than in the more developed countries**.
- At the same time, there is a **large gap in the level of energy efficiency between the lowest and the highest industrial energy intensities of the selected country group**. If energy efficiency is measured with industrial energy intensity (energy consumed per unit of industrial value added), there is a spread of 46 in Figure 2, from lowest to highest, with an average distance between developing and developed countries at a factor of

4. Even if this distance shrinks to a factor of 1.6, if purchasing power parities are used which take the different living standards into account, this does not consider that exchange rates are most relevant for imported energy, as energy imports are paid in US$. Factors such as the industrial structure explain some of these high values. Nevertheless, the conclusion that the industrial sectors in developing countries are, on average, 2-4 times less energy efficient certainly remains valid.

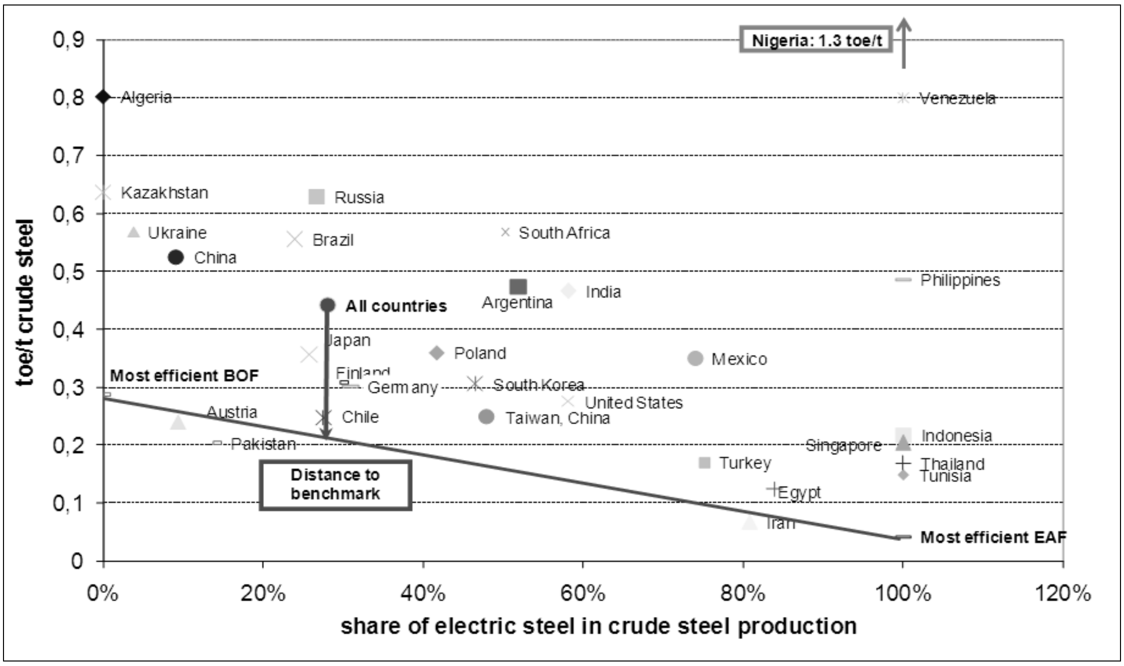
Figure 2 Spread in industrial energy intensities



Source: ENERDATA Global Energy & CO_2 Data 2010

- The gap in energy efficiency is also confirmed when looking at specific products, such as steel, cement or paper production, using physical activity indicators. In Figure 3, the position of the countries is partly influenced by the share of electric steel production, which uses less energy than the blast furnace route. The vertical distance from the red line which represents a mix of the most efficient blast furnace process (BOF, based mainly on iron ore) and electric arc process (EAF, based on scrap) shows the distance of a given country with the same process mix to the benchmark set by the most efficient processes. With a comparable process share, a factor of 2-4 with respect to the benchmark can also be observed here. However, moving from the left-hand-side of the diagram to the larger share of EAF steel may also present an improvement in energy efficiency, but this is more difficult to realize in some countries. Developing countries tend to have a stronger focus on electric steel processes, because they represent smaller units which can be more easily managed and financed. On the other hand, scrap, which is a necessary ingredient for EAF steelmaking, is less readily available. Differences between countries may be explained by a lack in investments, such as in Algeria, or by the introduction of modern energy efficient processes, such as the MIDREX process in Iran, which is mainly based on natural gas[2]; hence the low energy consumption of the country in Figure 3 (see also the case study in Section 4.4).

Figure 3 Unit consumption per tonne of steel as a function of the share of electric arc furnace (EAF) steel in total crude steel production (2007)

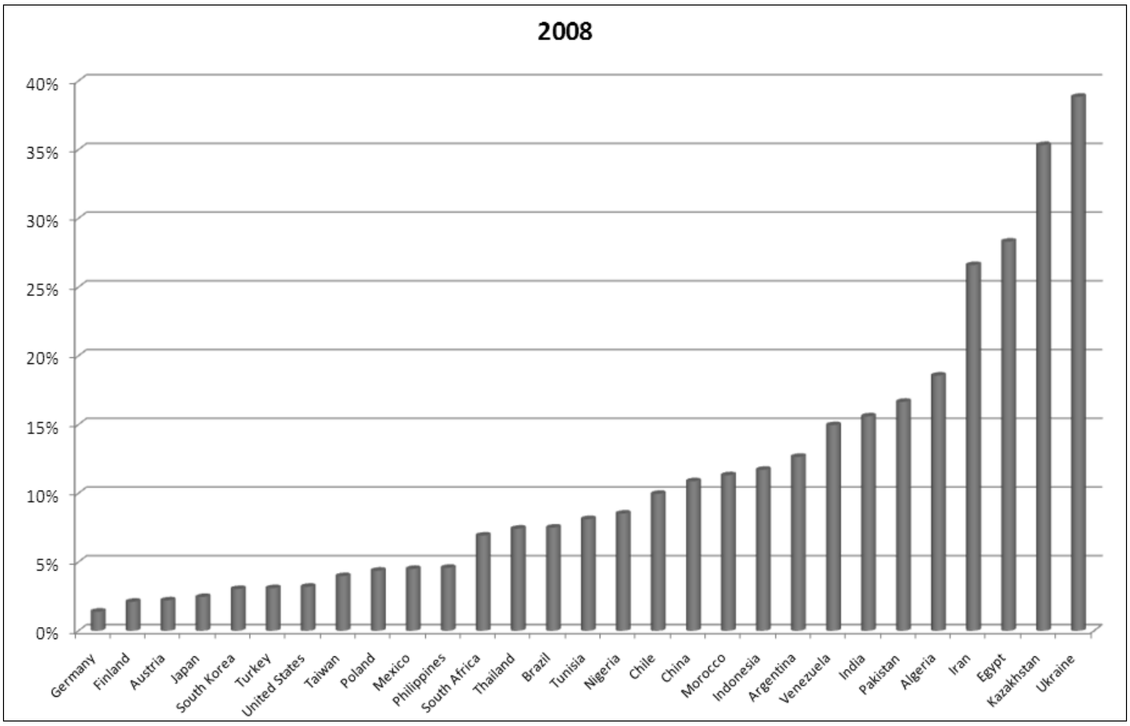


Source: ENERDATA Global Energy & CO_2 Data 2010; Worldsteel 2010

The consequence of this gap is that the more wastefully a country uses energy in its own industry, the higher the portion of manufacturing-added value added which has to be spent on energy is. This is illustrated by Figure 4: While the countries on the left-hand side only spend 1-2 % of manufacturing-added value added on energy, countries on the right side de facto spend - if implicit and explicit subsidies are not considered - nearly 40 %. If the oil price rises to levels beyond that of 2008 (around 95 US$/barrel, on average), the share further increases.

2 http://steelmaking.wordpress.com/2010/01/28/iran-steel-industry-overview/

Figure 4 Cost share of industrial energy consumption in value added by the manufacturing industry (2008)

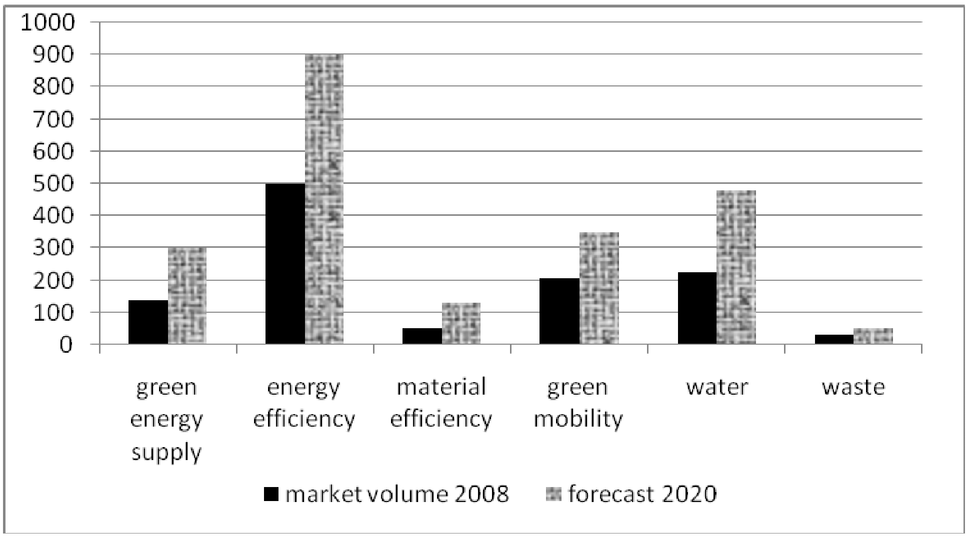


Note: The energy carriers consumed were evaluated for this graph with world market prices, including energy exporting countries which tend to have much lower energy prices for their own industries. This is justified by the lost opportunity to sell more of the energy at market prices. The value added by manufacturing excludes the value added of energy industries which in energy exporting countries bias the picture.

4 Development of industries for energy efficiency products and processes

The market for energy efficiency appears to be the most important among future markets for environmental goods and processes. Forecasts predict a market volume of EUR 900 billion by 2020 for the energy efficient technology market, which already today represents EUR 450 billion worldwide (Figure 5). Especially developing countries, as shown in the previous section, will need to install energy efficiency technologies to enable further growth in markets with increasingly scarce and expensive energy resources. Efficient industrial products and processes will have a substantial share in those countries, given the large weight of industrial energy consumption in their overall consumption. The extent to which they will benefit from the transformation of their economy to move toward more efficient production modes will strongly depend on whether they are able and prepared to absorb these technologies and develop their own industries for efficient processes and products.

Figure 5 **Growth of market volumes in the lead markets for environmental goods and processes (in billion EUR)**



Source: Data from DIW/ISI/Berger 2007, Roland Berger 2008, ECORYS et al. 2009

4.1 Methodology to analyse the technological capability for industrial energy efficiency technologies

To assess the preparedness of developed, newly industrialized and developing countries, **the technological capability** of the set of 35 countries named above is examined within the scope of industrial energy efficiency with the help of patent and foreign trade indicators. Technological capability addresses a construct which is not directly measurable. It is therefore necessary to find indicators which, at the very least, come close to describing it. Measuring technological capabilities can draw on experience with innovation indicators made over the last two decades (see Smith 2005; Freeman and Soete 2009). However, in each case a cautious interpretation is necessary, because each indicator is associated with caveats.

This section refers to **patents as** intermediary indicators on the one hand. They are assumed to be an **early indicator for future technological development**. On the other hand, **foreign trade indicators** are constructed, which belong to the class of output indicators. They focus more on the **application and diffusion of technologies in R&D-intensive product markets**:

- Patents are among the most used indicators in innovation research. They belong to the intermediate output indicators of knowledge development, and are directly related to technological capabilities. The analysis draws on patent applications at the World Intellectual Property Organization WIPO and, thus, transnational patents (for the concept, see Frietsch and

Schmoch, 2009). This approach uses a method of mapping international patents which does not target individual markets, but is much more transnational in character. The patents identified this way reveal those segments in which patent applicants are already taking a broader international perspective. The latest year available is 2007, the years 2003 - 2007 were chosen as the period of study so that a statistically more reliable evaluation is achieved in which stochastic fluctuations in individual years are evened out.

- International trade figures indicate the degree to which a country is able to compete internationally. As argued above, the competitiveness with regard to technology-intensive goods is influenced by the technological capabilities of the countries. Sustainability innovations mostly fall into the category of sectors which are classified as medium-high-technology industries. Thus, trade figures for these technologies also indicate the degree of technological capabilities. For trade figures, the database UN-COMTRADE[3] is used. The classification of the technologies uses the Harmonized System (HS) 2002. This foreign trade classification allows more disaggregation and therefore a better targeting of the sustainability technologies compared with the older classifications common in international comparisons (Standard International Trade Classification SITC). The latest year available for the analysis was 2007.

This is a methodology which is well-established in reporting technological performance. It has also been employed for the analysis of the broader field of sustainability-relevant technologies, including NICs (Walz et al. 2008). Here it is applied with a focus on technologies relevant to efficient industrial products and processes, including for developed countries and economies outside the OECD.

In the remainder of this section, empirical results for the following aspects are presented:
For patents and world trade, the share of the countries in the world total was calculated (patent share, world export share). Patent shares and foreign trade shares are influenced by the size of the country and its general state of development. The larger a country, the larger is, on average, the number of patents it publishes, or the larger its foreign trade share. To account for country size effects, it is therefore common to calculate "specialization" indicators. Specialization indicators show the position of a given technology in relation to the average performance of all technologies in the country. Positive specialization indicators show that the competence of the country in a given technology is over-proportional compared to all technologies. Negative spe-

3 http://comtrade.un.org/

cialization indicators show that the country is performing under-proportionally for the technology. Thus, a positive specialization also indicates the areas in which a country has been particularly successful in international competition. The specialization indicators (relative patent advantage RPA and revealed comparative advantage RCA[4]) were calculated to analyse whether or not the NICs specialize on energy efficient processes and products.

The analysis of a specialization profile is not feasible if the number of patents is too low. In this case, the low overall number indicates not much knowledge development on the international technological front is occurring.

Energy efficiency technologies are neither a patent class nor a classification in the HS-2002 classification of the trade data from the UN-COMTRADE databank which can be easily identified. Thus, it was necessary to categorize key technological concepts and segments in the classification. They were transformed into specific search concepts for patent data and trade data. This required substantial engineering skills.

Furthermore, there is a dual use problem with the identified segments. The data only indicates there is a technological capability and not necessarily that these technologies are already implemented in a way that the environmental burden is reduced. Thus, there can be differences between the resulting energy efficiency in industry, which is analysed in Chapter 3, and the technological capability, which is analysed in this chapter.

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4 For every country i and every technology field j, the Relative Patent Activity RPA is calculated according to: $RPA_{ij} = 100 * \tanh \ln[(p_{ij} / \sum_i p_{ij}) / (\sum_j p_{ij} / \sum_{ij} p_{ij})]$; the RCA was calculated according to: $RCA_{ij} = 100 * \tanh \ln[(x_{ij}/m_{ij}) / (\sum_j x_{ij} / \sum_j m_{ij})]$. All specialization indicators are normalized between +100 and –100 (see Grupp, 1998).

This chapter focuses on two large groups of industrial technologies: energy efficient industrial processes and auxiliary equipment (see table below):

Area	Technology Group	Technologies
Energy efficiency technologies in industry	Energy efficient processes in industry (IP)	Equipment for iron/steel production, cement production, paper production, etc.
	Energy efficient industrial auxiliary equipment (IAE)	Heat exchangers, efficient electric motors, pumps, ventilators, etc., efficient industrial furnaces and driers

The absorption of technologies, their adaptation to domestic need and the further development of technologies depend on favourable general innovation conditions. Various composite innovation indicators have been developed which indicate the general innovation capability of countries. Archibugi (2009) highlights that none are without caveats and that they must interpreted with caution. Among the most quoted composite innovation indices are the "innovation and sophistication factors", which form a pillar of the well-known Global Competitiveness Index of the World Economic Forum (WEF). They are based on an expert panel's judgement and the numbers clearly reflect a subjective nature. Furthermore, methodological issues, such as a possible selection bias among the experts, must always be kept in mind. However, the index of the World Economic Forum has been refined over the years; it is available for many countries and frequently updated. Thus, we also refer to this approach und use the data from WEF (2008) to measure general innovation conditions in the countries.

4.2 Indicators for the absorption capability for industrial energy efficient production and products

Based on the analysis of foreign trade and innovation capacity, the preparedness of the countries named for the absorption of energy efficient industrial processes and products (auxiliary equipment) is examined in this section. The results for the selected countries are summarized in Tables 1a and 1b.

Table 1a Evaluation of results for energy efficient process technologies

Country	Patent share	Export share	Comments on specialization	WEF-index on innovation
US	Very high	Very high	Negative patent, pos. trade spec.	Very high
JP	Very high	Very high	Slight positive spec.	Very high
DE	Very high	Very high	Positive patent and trade spec.	Very high
FI	High	Very High	Very pos. patent and trade spec.	Very high
AT	High	High	Very Pos. patent and trade spec.	High
KR	High	High	Negative patent spec.	High
CN	High	Very high	Neg. patents and trade spec.	Low-medium
BR	High	High	Pos. patent, neg. trade spec.	Low-medium
UA	medium	High	Very pos. patent and trade spec.	Lower
SG	medium	medium	Negative patent and trade spec.	High
IN	Medium	Medium	Negative spec.	Low-medium
ZA	Medium	Medium	Negative spec.	Low-medium
PL	Medium	Medium	Pos. patent, neg. trade spec.	Lower
MX	Medium	Low	Very pos. patent, neg. trade spec.	Lower
RU	Medium	Low	pos. patent, very neg. trade spec.	Lower
TW	Low		Very neg. spec.	High
MY	Low	Low	Negative spec.	Medium-high
CL	Low	Low	Patent spec. N/A, very neg. trade	Low-medium
ID	Low	Low	Patent spec. N/A, very neg. trade	Lower
TH	Low	Low	Patent spec. N/A, very neg. trade	Lower
TR	Low	Medium	Patent spec. N/A, very neg. trade	Lower
PH	Very low	Low	Patent spec. N/A, very neg. trade	Lower
IR	Low	Low	Patent spec. N/A, very neg. trade	Lower
AR	Low	Low	Patent spec. N/A, very neg. trade	Low
TN	Very low	Very Low	Patent spec. N/A, very neg. trade	Low-medium
VN	Very low	Very Low	Patent spec. N/A, very neg. trade	Lower
EG	Very low	Very Low	Patent spec. N/A, very neg. trade	Lower
KZ	Very low	Low	Patent spec. N/A, very neg. trade	Lower
VE	Very low	Very Low	Patent spec. N/A, very neg. trade	Low
KE	Very low	Very low	Patent spec. N/A, very neg. trade	Lower
NG	Very low	Very low	Patent spec. N/A, very neg. trade	Lower
MA	Very low	Very low	Patent spec. N/A, very neg. trade	Lower
PK	Very low	Very low	Patent spec. N/A, very neg. trade	Low
DZ	Very low	Very low	Patent spec. N/A, very neg. trade	Low

Table 1b Evaluation of results for energy efficient auxiliary technologies

Country	Patent share	Export share	Comments on specialization	WEF-index on innovation
US	Very high	Very high	Negative patent spec.	Very high
JP	Very high	Very high	Positive patent and trade spec.	Very high
DE	Very high	Very high	Positive patent and trade spec.	Very high
FI	High	High	Positive trade spec.	Very high
AT	High	High	Positive patent and trade spec.	High
KR	High	High	Negative trade spec.	High
CN	High	Very high	Average spec. trade and patents	Low-medium
BR	High	High	Very positive patent spec.	Low-medium
MX	High	High	Very positive patent spec.	Lower
TW	High		Average spec.	High
SG	High	High	Negative spec.	High
MY	Medium	Medium	Negative trade spec.	Medium-high
IN	Medium	Medium	Negative spec.	Low-medium
ZA	Medium	Medium	Very pos. patent, neg. trade spec.	Low-medium
PL	Medium	Medium	Very pos. patent, neg. trade spec.	Lower
TR	Medium	Medium	Very pos. patent, neg. trade spec.	Lower
UA	Medium	Medium	Very pos. patent spec.	Lower
RU	Medium	Medium	pos. patent, very neg. trade spec.	Lower
TN	Very Low	Low	Patent spec. N/A, very neg. trade	Low-medium
CL	Low	Low	Patent spec. N/A, very neg. trade	Low-medium
ID	Very Low	Medium	Patent spec. N/A, very neg. trade	Lower
TH	Low	Medium	Patent spec. N/A, very neg. trade	Lower
PH	Very low	Low	Patent spec. N/A, very neg. trade	Lower
IR	Low	Low	Patent spec. N/A, very neg. trade	Lower
VN	Very low	Medium	Patent spec. N/A, very neg. trade	Lower
EG	Very low		Patent spec. N/A, very neg. trade	Lower
KZ	Very low	Low	Patent spec. N/A, very neg. trade	Lower
AR	Low	Medium	Patent spec. N/A, very neg. trade	Low
VE	Very low	Low	Patent spec. N/A, very neg. trade	Low
KE	Very low	Very low	Patent spec. N/A, very neg. trade	Lower
NG	Very low	Very low	Patent spec. N/A, very neg. trade	Lower
MA	Very low	Very low	Patent spec. N/A, very neg. trade	Lower
PK	Very low	Very low	Patent spec. N/A, very neg. trade	Low
DZ	Very low	Very low	Patent spec. N/A, very neg. trade	Low

Based on these data, plus the information available from bottom-up energy research in the countries, 5 country clusters were formed. The goal was to build a categorization of the absorption capability for the countries in the group for energy efficient industrial auxiliary equipment and processes based on the assessment of indicators. Five country categories were defined to characterize the absorption capability of energy efficient industrial technologies:

1: Very good absorption conditions; technology provider from traditional OECD countries

2: Strong development of absorption conditions among NICs, plus already substantial technology exports to other countries; technology provider from NICs

3: Absorption capacity already available to a certain degree with the potential to further enhance the role of a technology provider

4: Some absorption capacity available, but need to increase capabilities to improve conditions for application of technologies

5: Low absorption capacity, need to develop absorption capability

The countries are grouped in these five categories by combining the different indicators presented in Table 1a and Table 1b into a global overview. Although this may be somewhat ambiguous, it presents a rough proxy for the above-mentioned absorption capability.

Figure 6 and Figure 7 provide an overview about the capability cluster for the two technology groups “industrial process” and “industrial auxiliary technologies”. The countries were grouped in the respective energy efficiency capability cluster on the horizontal axis and ordered according to their general innovation capability score obtained from the WEF on the vertical axis (2008). The figures demonstrate that energy efficiency capabilities rise, by and large, with a higher general innovation capability. However, the picture is not as clear-cut as that. There are also countries with similar general innovation scores allocated throughout very different energy efficiency capability clusters. Clearly the differing industry structure plays a role here. Countries with an extensive process industry are much more likely to develop process know-how than countries without such an industry. This explains, for example, why the Ukraine can be found in the second-highest cluster. For auxiliary energy efficiency technologies, however, the effect of different industry structures is less pronounced.

From our point of view, these results support the hypothesis that the general innovation capability also plays a role in energy efficiency improvements. However, there are also specific factors which influence the absorption capacity for energy efficient technologies in industry beyond the general innovation frame and industry structure and the resulting energy consumption in industry. Thus, there clearly seems to be potential to target energy efficiency improvements with specifically designed policies and measures, which need, however, be well-adapted to the specific capability group.

Figure 6 Absorption capacity and capability for energy efficient process technologies in the general WEF innovation frame

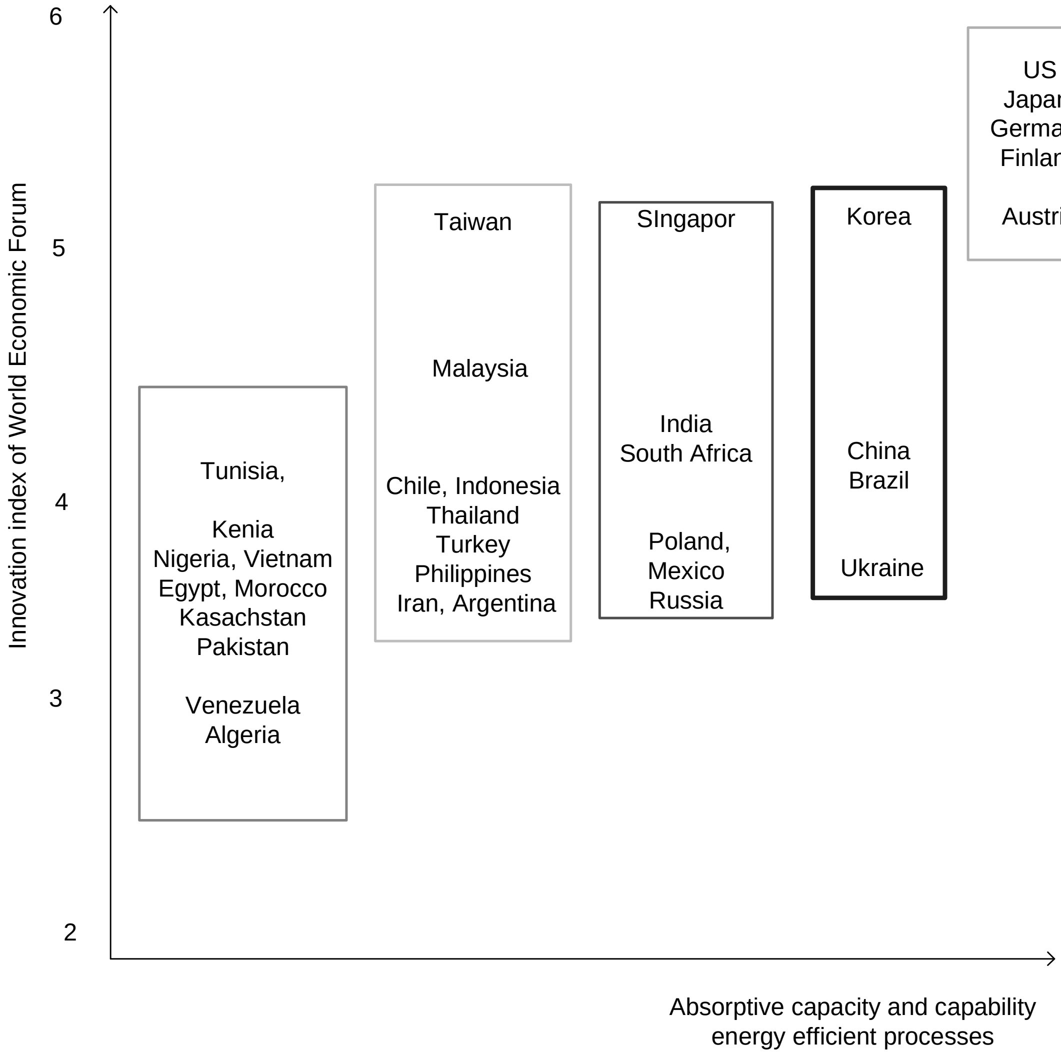
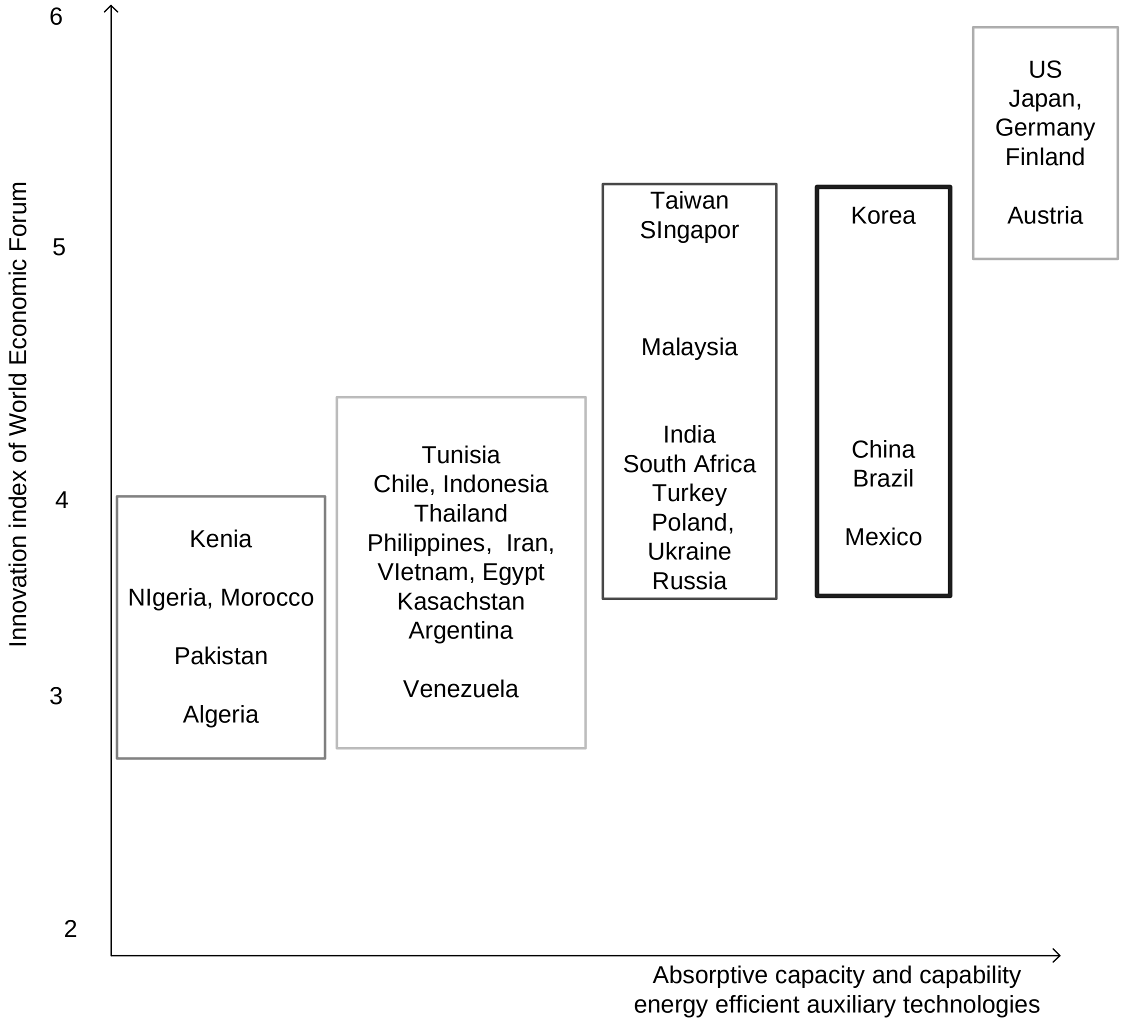


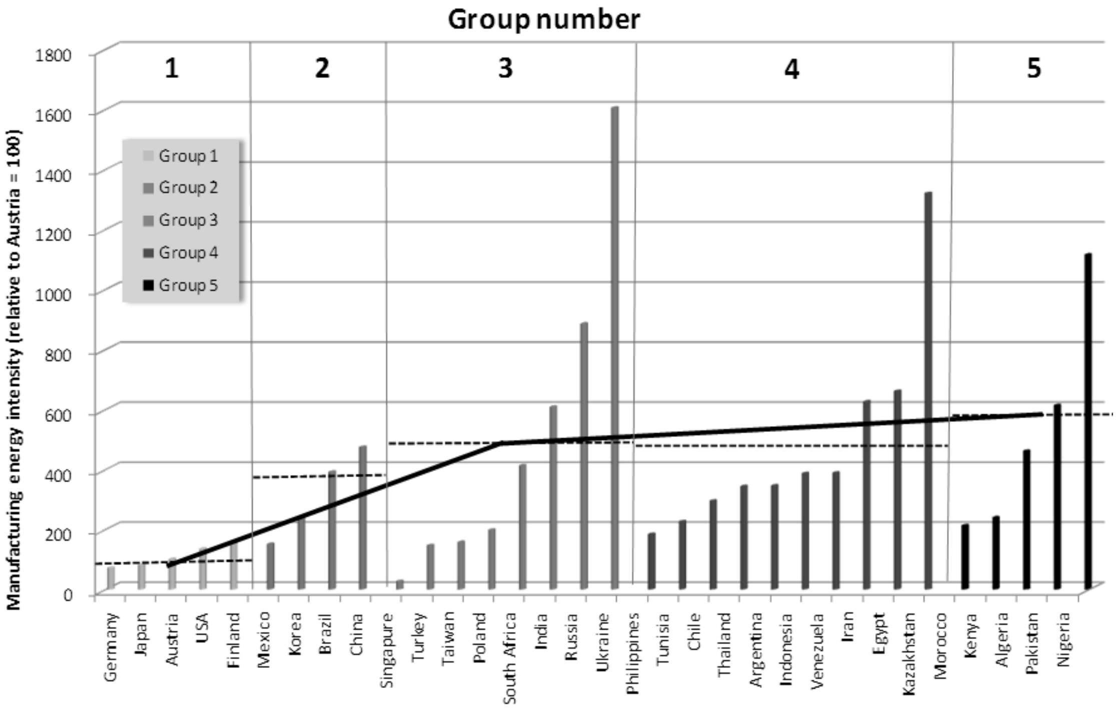
Figure 7 Absorption capacity and capability for energy efficient auxiliary technologies in the general WEF innovation frame



Furthermore, it is interesting to examine whether there is a link between the absorption capacity for energy efficient technologies and the present level of energy efficiency. One would expect that, with growing absorption capacity, industrial energy intensities may decrease. To evaluate this hypothesis, we ordered the energy intensities for manufacturing industries[5], normalised to the level of Austria (about the average of group 1), into five different clusters (see Figure 8).

5 We related the industrial energy consumption to the value added through manufacturing to remove the distorting effect of the large revenues from energy industries in oil and gas producing countries, such as Algeria, Kazakhstan, Nigeria, Russia, Venezuela. Those industries add little to energy consumption, but increase industrial value added many-fold. In other countries, the difference between manufacturing and industrial added value is much smaller.

Figure 8 **Industrial energy intensities (relative to Austria = 100) for the five different evaluation categories**



Source: ENERDATA Global Energy & CO_2 Data 2010
Note: The doted lines represent the weighted average manufacturing intensities of each group.

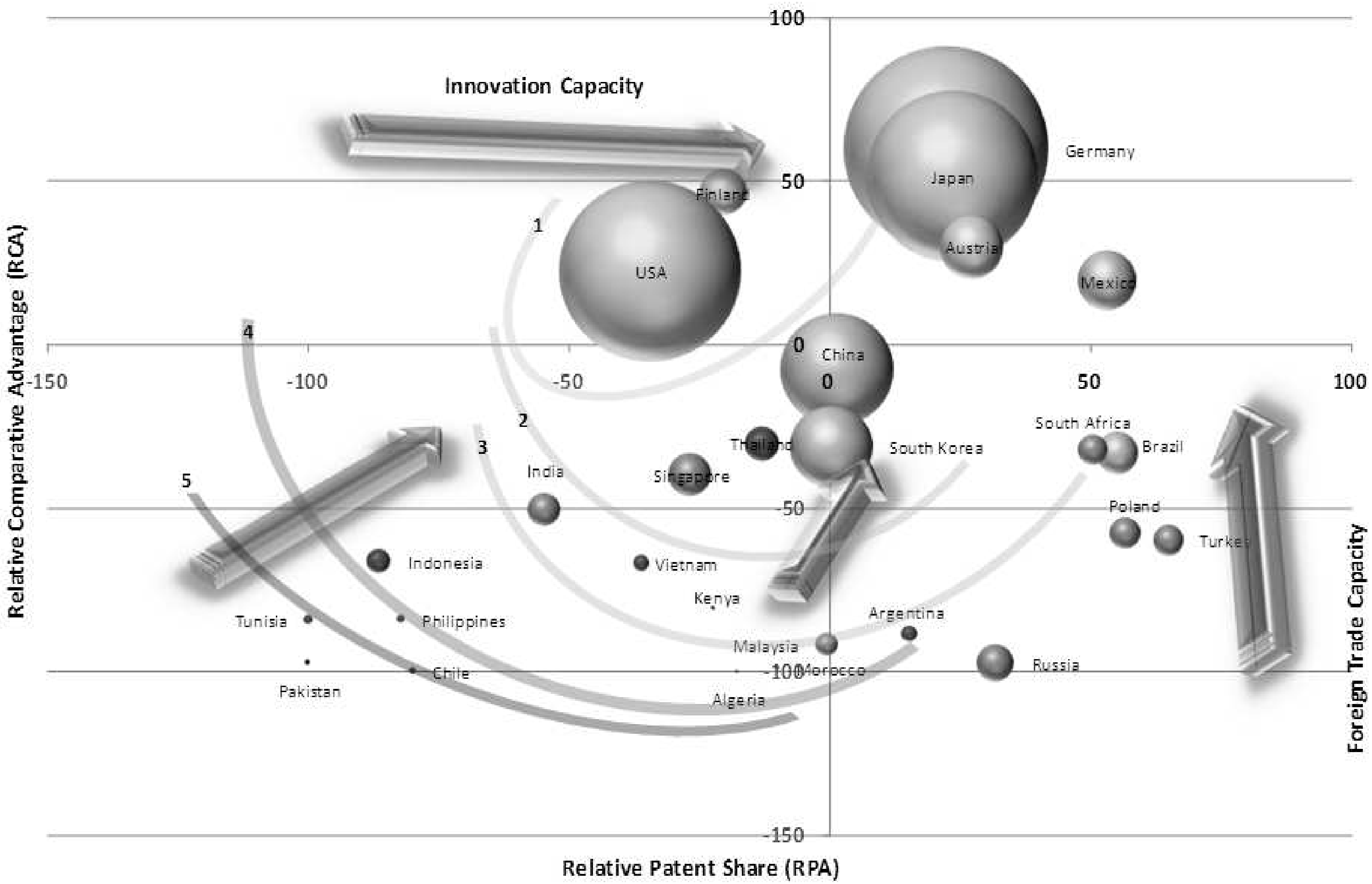
Generally, manufacturing energy intensity, as the most aggregate proxy for energy efficiency, increases beyond category 1-3 and remains roughly stable or increases slightly in the last category. Within each group there is considerable spread due to more or less industrialized structures[6], but also due to differences in energy efficiency. This effect can, however, only be illustrated by comparing manufacturing energy consumption of an average structure, which goes beyond the scope of this report. Why energy intensities saturate or only increase slightly beyond group 3 is probably related to earlier development phases, which implies less heavy industries.

Figure 9 and Figure 10 show so-called specialization patterns for the two groups of industrial auxiliary equipment and industrial processes. The horizontal position characterizes the innovation capability through the Relative Patent Analysis, while the vertical position characterizes the foreign trade capability through the revealed competitive advantage for these technology areas. The size of the sphere for each country is proportional to the shares of the country regarding

6 It must be noted that aside from energy efficiency, energy intensities are also influenced by differences in industrial structures, which may partly explain the large spread of intensities within one category.

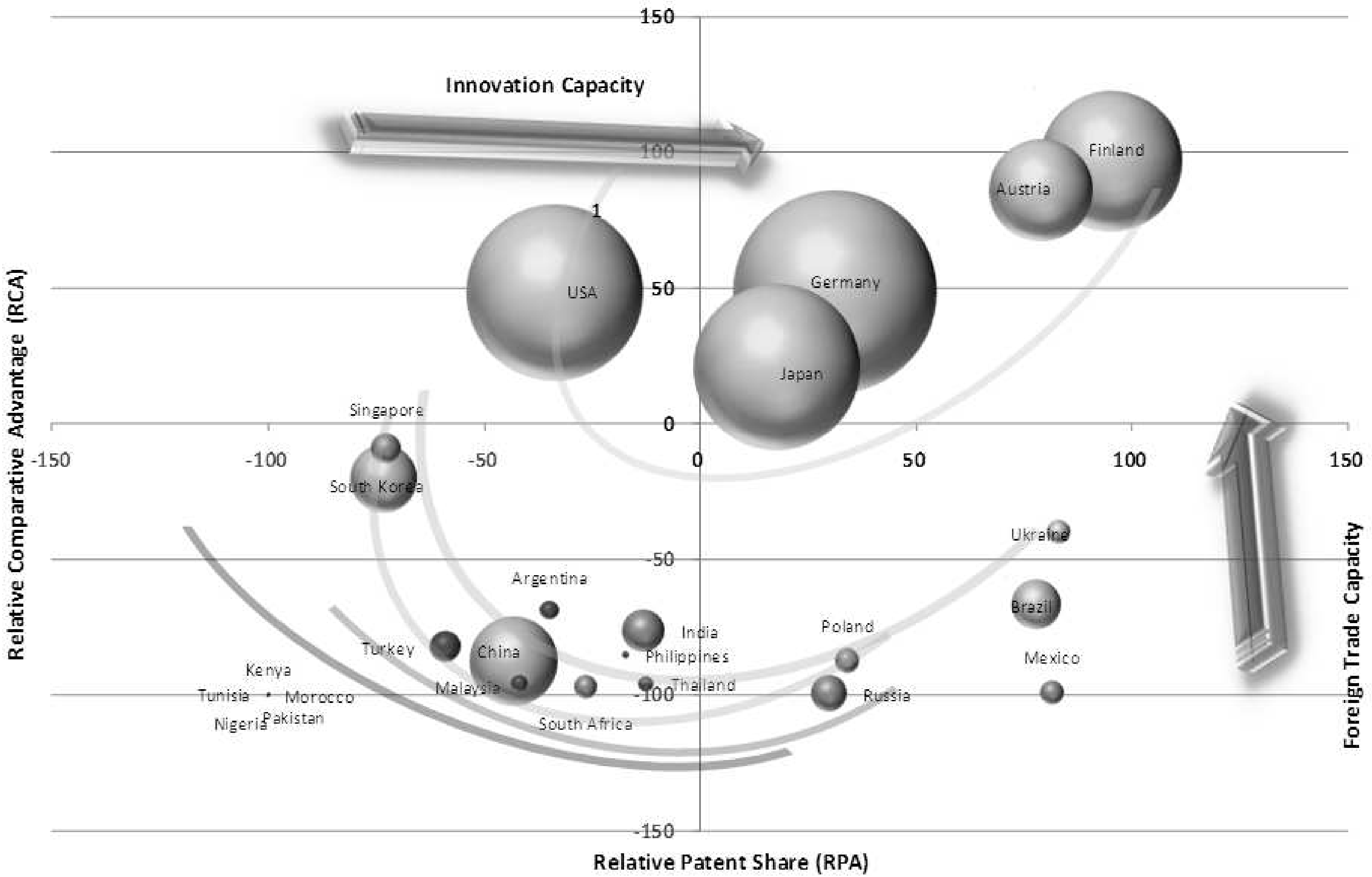
patents and trade. The more a country is in the upper right corner, the more it specializes in the technology. Generally, it can be observed that the five categories defined above spread roughly from the lower left corner to the upper right corner, as indicated by the coloured border lines in Figure 10. Although the trends are fairly similar between industrial auxiliary and process equipment, it can be observed that for efficient industrial processes the distance to the first category still appears somewhat larger, especially for the second and third group of countries that already implemented those technologies to some degree. The reason for this could be that industrial processes are generally more complex to develop than industrial auxiliary equipment. Furthermore, a second interpretation could be that for process technologies, market volumes are smaller and therefore higher market specialization prevails.

Figure 9 Evaluation of specialization patterns for efficient auxiliary industrial equipment



Note: The figure presents the specialization profiles for innovation capability and foreign trade performance in the area of industrial auxiliary equipment on the axes of the graph. World market and patent shares are expressed in the size of the sphere; the colour of the sphere represents the category of absorption capability.

Figure 10 Evaluation of specialization patterns for efficient industrial processes



Note: See previous figure for explanations

4.3 Preparedness of countries for the incorporation of energy efficient industrial processes and auxiliary equipment

This section discusses the implications of the analysis presented in the previous section. In the introduction it was argued that the rapidly growing market demand for energy efficient products and processes could open up opportunities for newly industrialized and developing countries to strengthen their economic growth. Supporting policies, particularly those directed at increasing demand for such technologies on the home market, may provide a suitable basis for economic development. Therefore, the countries of the five different categories defined in the previous section have an interest in actively pursuing the path from the lower left to the upper right corner in Figure 10, as indicated with the arrows[7]. The discussion about setting up lead markets has, until now, primarily concentrated on industrialized countries. In the recent past, however, increases in technological capabilities have also been identified in rapidly growing economies. Consequently, they are increasingly in a position to develop a lead market position on their own. In connection with the integration of sustainability innovations in the economic process of catching-up, Walz/Meyer-Krahmer (2003) propose the thesis that the rapidly growing economies could display a particularly high potential to establish lead markets, especially with sustainability innovations. The background for this includes a greater significance of regulation-dependent demand, as well as less path dependencies, as the structures have not yet become as rigid as in "old" industrialized countries or are still under development. Furthermore, these countries could have the advantage of adapting technologies faster to the specific needs of the growing markets in new and developing economies. With the prospect of lead markets for sustainability innovations emerging in those countries, the interest of these countries could change dramatically: sustainability technologies would not only become an element of technological modernization and establishment of a domestic infrastructure, but also object of a world market-oriented export strategy and would experience an enormous increase in importance within the catching-up strategy of the countries involved.

However, as shown above, the preparedness of the countries to absorb such technology development for their own benefit differs greatly. While countries in groups 2-3 may already be involved in the development of such processes, countries in the groups up to 5 have a longer way

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7 It is clear that not all countries will or can follow the path of the more performing countries in all technology fields; by definition some countries will export more than others if there is specialisation. However, there is a broad technology area involved with energy efficient technologies in industries, which allows for a variety of countries to find their specialty while impeding that the distance to the most performing countries gets large and leads to large volumes of imports for energy efficient technologies.

to go when setting up energy efficient industries developing products and processes for the world market. **This implies that suitable strategies must be developed by the different countries, taking the major barriers to such a development in their respective group into account.** The production and diffusion of new solutions crucially depend on the interplay of the different actors in the innovation process (see also Figure 1). Within the framework of these heuristic, soft context factors (e. g. situative conditions for policy design and impacts) and aspects of a demand-oriented innovation policy can be analysed, barriers identified and suitable measures introduced to remove such barriers.

Below, suitable steps relevant to the five groups defined above are briefly discussed, but more refined analysis is necessary to develop operational strategies:

Group 1: This group displays very good absorption conditions and thus far generally includes technology providers from OECD countries. To further advance these countries' needs for focussing on enhancing demand for the technology while facilitating the growth of industrial actors. R&D policy may insure developing future technologies, but is not the most important element in the strategy.

Group 2: This group has very good absorption conditions among Newly Industrialised Countries (NICs); they are potential technology providers among NICs. Frequently they are also characterized by large home markets which - if accompanied by successful demand policies - could largely influence the world market level and set the path for future cost digression of those technologies, opening up new markets.

Group 3: The countries represented in this group have generally developed absorption conditions. Barriers may more likely reside in the fact that the opportunities of new technologies are perceived in their value to economic development. It is therefore important that key actors develop views on the technologies which allow adapting the innovation framework to favour their uptake.

Group 4: Countries in this group already have some absorption conditions available to a certain degree. In those countries in would be important to identify products/processes which suit the previous know-how of the industrial sector and local actors well and develop suitable strategies to promote technologies for a limited number of niche products. The aim should also be to broaden technical and organizational skills important for using energy efficient technologies in industry.

Group 5: Low absorption capacity, need to build absorption capability. The absorption of energy efficient industrial products and processes in this group is difficult to extremely difficult, given the general lack of competitiveness in those countries. Inadequate frameworks and barriers in the innovation system will not be easily overcome. In those countries, rapid steps toward competitive industry are difficult, but, especially through international development aid, individual examples of successful competitive companies could be developed that focus on technologies adapted for local markets, while aiming to improve the general development framework for energy efficiency[8].

4.4 Case studies of the successful implementation of production processes in newly industrialized and developing countries

This section presents two case studies on the implementation of energy efficient processes and products in newly industrialized and developing countries:

- Case study 1 shows the successful implementation of new steel making processes in Iran
- Case study 2 is on the implementation of the production of efficient electric motors in Brazil

In both cases the contribution to the country's competitiveness and the private sector could be important.

4.4.1 Implementation of efficient steel production processes in Iran[9]

The conventional method of manufacturing steel consists of sintering or pelletization plants, coke ovens, blast furnaces, and basic oxygen furnaces[10]. Such plants require high capital expenses and raw materials of stringent specifications. Coking coal is needed to make coke strong enough to support the load in the blast furnace. Integrated steel plants of less than one million

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8 An example of such activity is the development of micro-electricity grids/micro-financing structures by the German Technical Society GTZ that help small local manufacturers set up a business. Through the incentives built into the micro-grid development, the businesses must to evolve in an energy efficient way in line with the capacities of the micro-grid.

9 Motlagh, M.: Expansion of DRI--EAF based steel industry in Iran. Saturday, February 1, 2003. www.allbusiness.com/primary-metal-manufacturing/iron-steel-mills-ferroalloy/ 528303-1.html

10 This paragraph is cited from http://en.wikipedia.org/wiki/Direct_reduced_iron

tonnes annual capacity are generally not economically viable. The coke ovens and sintering plants in an integrated steel plant are polluting and expensive units. Direct reduction is an alternative route of iron making. It has been developed to overcome some of the difficulties of conventional blast furnaces. Direct-reduced iron or sponge iron is produced from the direct reduction of iron ore (in the form of lumps, pellets or fines) by a reducing gas (a mixture of hydrogen and carbon monoxide) produced from natural gas or coal. The specific investment and operating costs of direct reduction plants are low compared to integrated steel plants and are more suitable for many developing countries where supplies of coking coal are limited. The direct reduction process is intrinsically more energy efficient than the blast furnace because it operates at a lower temperature; there are several other factors which also make it economical. Among others, direct-reduced iron is richer in iron than pig iron, and an excellent feedstock for the electric furnaces used by mini mills, allowing them to use lower grades of scrap for the rest of the charge or to produce higher grades of steel. Hot Direct Reduced Iron is iron not cooled before discharge from the reduction furnace, immediately transported to a waiting electric arc furnace and charged, thereby saving energy. In most cases, the DRI plant is located near a natural gas source, as it is more cost effective to ship the ore than the gas. The Midrex process that requires pellets is still the most popular, representing two-thirds of world production. The COREX process uses fine ore.

There is little market for DRI in countries with efficient integrated steelworks and available scrap steel, such as Japan. However, in newly developing countries, there is a shortage of scrap and with high scrap freight costs to those regions there is an important margin available for DRI used in the electric arc furnace.

In Iran, the first Russian-built plants followed the conventional blast furnace route. Since the 1990s, Iran followed the Direct Reduced Iron / Electric Arc Furnace route to make best use of locally available ore and natural gas. Iran has limited reserves of coking coal, and in view of its large natural gas reserves, the expansion of the steel industry using gas-based DRI routes appeared attractive. In the 1990s Iran started to produce DRI by means of an Iranian developed and owned process known as `Zam Zam'. The capacity of the plant was 600kt/y and has been in use since 1998. Based on another Iranian developed DR Process known as `Ghaem', production increased further since 1996. Both Ghaem and Zam-Zam processes are of the in-situ catalytic reforming type, developed by joint research between university and industry in Iran. No gas reformer is required, since all reforming reactions take place inside the shaft furnace. As a result of this, in 2009, Iran was the world's 2nd largest DRI producer after India. Future expansion of crude steel production capacity is planned at 15 Mt/y, up from the present-day crude capacity of around 10 Mt/y. Up until now this was mainly motivated by the wish to cover the country's strongly growing demand. Iran is still a net importer of larger amounts of steel products and ranked second on the list of net importers of steel in 2007[11]. Nevertheless, in 2008 apparent steel use was covered up to 70 %, compared to 50 % in 2003. However, the country's goal is to expand steel exports. This could generate another source of revenue for Iran once oil and gas resources run short. Iranian steel has already penetrated the international market for flat products and special bar quality; larger scale operations are now underway for greater export of all finished products.

4.4.2 Implementation of the production of efficient electric motors in Brazil [12]

After the electricity shortage of 2001 in Brazil, the ''Energy Efficiency Act'' (Law 10,295 of 2001, Oct, 17) was launched as an instrument to establish MEPS (minimum energy performance standards) for equipment and appliances. The first equipment type that was regulated in Brazil was the squirrel cage three-phase induction electric motor, covered by Decree 4,508 of 2002, Dec, 11th. This equipment uses about 32% of Brazil's electricity. In fact, Decree 4,508 was a further step in a voluntary process of energy efficiency improvement pursued since 1993 through the Brazilian Labelling Program (PBE –Programa Brasileiro de Etiquetagem). Through the PBE, Brazilian motor manufacturers, CEPEL1 (responsible for motor testing) and INMETRO2 (PBE coordinator) defined, by consensus, a series of sequentially more stringent annual or biennial efficiency targets for both standard and high-efficiency classes on a voluntary basis.

The success of this process justified the adoption of mandatory MEPS for induction motors. In particular, Brazilian manufacturers reaped a benefit, since standard eliminated foreign competition from less efficient units which had been sold primarily as components. The voluntary process improved the Brazilian motor energy efficiency significantly. The last step alone—MEPS adoption—saved 1% of the electricity used by motors, which postponed a 250MW hydroelectric power station. The next step toward energy efficiency was the Inter-Ministerial Ordinance 553, which was launched in December 2005 (it come in force 4 years after approval). It specified a single set of MEPS level eliminating efficiency levels below those previously defined as 'high

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11 World Steel in Figures 2009. World Steel Association. www.worldsteel.org/pictures/publicationfiles/WSIF09.pdf

12 Pinto-Garcia et al. (2007)

efficiency'. This meant that only high efficiency motors would be manufactured after 2010 in Brazil (currently all manufacturers have a high efficiency motors line, but these represent only about 10% of production). This transition is expected to have – next to the environmental impact - deep repercussions in industrial processes and equipment prices for consumers.

Analysing the financial impacts motor-by-motor, Pinto-Garcia et al. (2007) conclude that the motor substitution is, in general, advantageous to the individual company. The cost effectiveness varies with patterns of use and electricity cost, rated power and polarity. Considering a sample of industrial motors, the average cost of the conserved energy by motor substitution, at a 12% of discount rate, usually adapted to the Brazilian electrical system expansion, is far below the winning bids in the auctions for the Brazilian electrical system expansion. Furthermore, it does not include the social and environmental benefits of saving electricity. With respect to the manufacturers, Pinto-Garcia et al. (2007) observe that the expansion of this market share of efficient motors up to 100% requires significant changes in the manufacturing process, including new equipment, tools and an operation schedule affecting all manufacturers, but especially the smaller ones. Therefore, Pinto-Garcia estimates that the economies of scale achieved with the production increase will be in great part offset by the need for new investments, which means it is reasonable assume that prices of high efficiency motors, about 40 % higher than standard ones, will not change significantly. The mass production of high efficiency motors requires a substantial increase in the use of some materials, particularly in ferro-silicon plates, for which there is only one supplier in the national market. In addition, the demand for steel has strongly increased in the global economy. Some action is therefore needed to assure adequate supply of this material to avoid even greater impacts on retail motor prices. An increase in the minimum efficiency of motors produced by Brazilian manufacturers and its impact on prices is likely to encourage further entry into the market by less expensive, foreign-made products, mainly motors as a component of equipment. The Energy Efficiency Law in Brazil requires the same performance for these motors, but the enforcement is more complicated and is still in its initial control stage.

This discussion by Pinto-Garcia shows that the implications of energy efficient industrial auxiliary technologies on local manufactures need to be investigated carefully to avoid that bottlenecks in the supply of components for more efficient technology could put local manufacturers at a disadvantage.

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