Measuring multiple benefits for energy efficiency in the industrial sector

Wolfgang Eichhammer
Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Str. 48
DE-76139 Karlsruhe
Germany
and Utrecht University
Heidelberglaan 2
NL-3584 CS Utrecht
The Netherlands
wolfgang.eichhammer@isi.fraunhofer.de
w.a.eichhammer@uu.nl

Matthias Reuter
Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Str. 48
DE-76139 Karlsruhe
Germany
matthias.reuter@isi.fraunhofer.de

Rainer Walz
Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Str. 48
DE-76139 Karlsruhe
Germany
rainer.walz@isi.fraunhofer.de

Martin Patel
University of Geneva
Institute for Environmental Sciences
Bd Carl Vogt 66
CH-1205 Geneva
Switzerland
Martin.Patel@unige.ch

Keywords

multiple benefits, energy efficiency policy, energy efficiency indicator, top-down evaluation methods, bottom-up analysis

Abstract

In previous work we developed a comprehensive indicator set for measuring multiple benefits of energy efficiency (MB-EE). The aim is to complement the harmonised approach to energy efficiency indicators and policies which is realised through the ODYSSEE-MURE project (www.odyssee-mure.eu) with an indicator set measuring Multiple Benefits.

We focus in this paper on indicators to characterise MB which are relevant for the energy efficiency industry at the macro-level and, hence, also the whole economy:

- MB indicators describing innovation and competitiveness triggered by EE (e.g. impacts related to innovative EE technologies and foreign trade with EE technologies)
- Turnover achieved through energy savings, which makes relevant contributions to the economic development of a country.
- Macro-economic impacts from EE, in particular impacts on economic growth and employment

We discuss the methodological approach to the indicator set, the underlying data sources and limitations. This indicator set is applied for EU28 countries or a subset of countries. Knowledge made available in new tools and projects, such as the ODYSSEE-MURE facility on multiple benefits should therefore be made easily accessible for the policy level and be used by policy makers when evaluating the impacts of energy efficiency policies.

Introduction

Energy Efficiency (EE) measures are frequently economic on their own, however, partly with long payback periods which is an obstacle in the industrial sector, in particular. Next to energy savings themselves, and the money saved, other benefits might be important in the formulation of savings policy: new employment, reduced import dependence, less health problems, etc. The EC and national governments are increasingly taking multiple benefits in EU policy on EE into consideration (COM (2014) 520). In addition, national governments are already looking into multiple benefits, such as the employment effects in the recent National Energy Outlook NEO for the Netherlands or in the Monitoring Report of the German "Energiewende" (transformation of the energy system). We use the word "multiple benefits" to characterise those additional impacts. However, various terms have been developed and used to describe the concept over the years: co-benefits, ancillary benefits, non-energy benefits (NEBs), multiple benefits (MBs) or impacts.

In previous work we developed a comprehensive indicator set for measuring multiple benefits of energy efficiency (MB-EE) (Reuter et al. 2017). The indicator set chosen was departing from IEA (2014) and enhancing the set with additional indicators, e.g. indicators describing innovation and competitiveness in the economy through energy efficiency technologies. The aim is to complement the harmonised approach to energy efficiency indicators and policies, which is realised through the ODYSSEE-MURE project (www.odyssee-mure.eu), with an indicator set measuring MB-EE. An indicator approach to MB-EE has advantages and disadvantages:

- Advantages are that the benefits can be characterised on a regular basis, possibly annually. This is important for regular reporting and monitoring procedures, which is increasingly a need at the policy level. Another advantage is that such indicators can be established quite rapidly and do not need continuously running of complex energy system or macro-economic models.

- Disadvantage is that the precision of such indicators may be limited, given that the methodology is simpler than detailed modelling of impacts. However, with time such indicator sets can be improved, as they can be "gauged" with detailed case studies based on modelling or other methodologies.

In the indicator approach developed, the MB-EEs were classified into three groups: environmental, economic, and social-related MBs (Table 1). The first group contains most relevant and direct aspects of energy efficiency such as energy savings and reduced GHG emissions. The second group comprises, among others, positive macro-economic impacts on economic growth, for innovation and competitiveness as well as import dependency. The third group of impacts covers aspects such as health benefits, poverty alleviation and employment. A main characteristic of those indicators is that they are – as far as possible – derived from energy savings. Such energy savings can be derived either from a top-down perspective, i.e. related to statistical EE indicators such as those developed under the ODYSSEE-MURE project, or the bottom-up perspective, i.e. related to savings established for individual energy efficiency measures. The main difference is that the first includes also autonomous energy savings while the latter only comprises policy related energy savings.

We focus in this paper on MB-EE indicators from Table 1 relevant for the energy efficiency industry and, hence, also the whole economy. In fact, MBs can be characterised both at the level of individual companies (micro-level) and at the level of the whole sector (macro-level). In the following sections, we discuss the main MB indicators with relevance for the macro-level, selected from Table 1, as there are:

- MB indicators describing innovation and competitiveness triggered by EE (e.g. impacts related to innovative EE technologies and foreign trade with EE technologies).
- Turnover achieved through energy savings, which makes relevant contributions to the economic development of a country.
- Macro-economic impacts from EE, in particular impacts on economic growth and employment.

Given the fact that the methodologies presented for such an MB indicator set are still under development, we further discuss the present limitation to the methodologies.

Further MB indicators with relevance for the industry sector (mainly relevant for the micro-level) are not discussed due to space limitations, e.g.:

- Micro-economic impacts from EE in industry (e.g. impacts on industrial productivity, asset value).
- Global and Local Pollutants avoided through EE in the industrial sector.
- MBs from Energy and Resource Management in the industrial sector.

Methodology and Results for Selected Industrial MB Indicators

INNOVATION AND COMPETITIVENESS TRIGGERED BY EE

Innovative low-carbon technologies contribute to enhancing the competitiveness of industrial companies and of economies. Anchoring the idea of sustainability in the economic development process as early as possible is gaining enormous significance. Such technologies may give an advantage to those who develop first these technologies (although it is not excluded that late-comers may have good strategies in the catch-up process). In order to realise such first mover advantages, domestic suppliers must demonstrate long-lasting competitive advantages in the corresponding technologies. Here the conditions for establishing so-called lead markets play an important role. Establishing not easily transferable industrial clusters which consist in combining technological capability with demand that is open to innovations and favours early learning effects and their integration in differentiated production structures, are decisive pre-conditions for the success of a national innovation system.

Innovation capability and competitiveness are constructs which is are not directly measurable. It is therefore necessary to find indicators which at least come close to describing it. A widely accepted system to do so adapts indicators from various sub-fields of the innovation process such as patents as R&D output, which are presumed to describe the direct result of the R&D process. At the same time, 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.

Main indicators measuring the **competitiveness of a country** for a given technology, hence also for energy efficiency technologies, are the following two:

- **World Market Shares (WHA):** share of exports (a) for a given technology j and a country i related to the sum of all exports across all countries ($\Sigma_i a_{ij}$) for that given technology.

World trade for technology j

$$WHA_{ij} = 100 * (a_{ij} / \sum_i a_{ij}) \quad (1)$$

- Specialisation indicators established in a **Revealed Competitive Advantage RCA Analysis**: comparison of the export (a) / import (e) ratio of technology j (a_{ij}/e_{ij}) with the general export/import ratio of the country i when summing exports/imports up across all technologies ($\Sigma_j a_{ij}/\Sigma_j e_{ij}$). Then, the RCA is compared across the countries.

Export/Import performance of the country for all technologies

Export/Import performance for technology j

$$RCA_{ij} = 100 * \tanh \ \ln \left[(a_{ij}/e_{ij}) / \left(\sum_j a_{ij} / \sum_j e_{ij} \right) \right] \quad (2)$$

This indicator is normalised so that it varies from -100 (extremely unfavourable specialisation or export/ import performance for a given technology compared to the average

Table 1. Set of indicators for the quantification of multiple benefits of energy efficiency (EE). In yellow: main industrial (macro-level) MB-EE indicators selected for the analysis. In bold: further MB-EE indicators relevant for the industrial sector (mainly at the micro-level).

Category	Sub-category	Indicator
	Energy and Resource Management	
Environmental	Energy savings	Annual energy savings
Environmental	**Saving of fossil fuels**	Saving on fossil fuels; extension of range of fossil fuels
Environmental	Impacts on RES targets	Lowering of RES target; replacement of RES capacity; reduced need for interconnectors
	Global and Local Pollutants	
Environmental	**GHG savings**	Annual CO_2 savings linked to energy savings
Environmental	**Local air pollution**	Emission factors for avoided local pollutants (incl. electricity)
	Energy poverty	
Social	Alleviation of energy poverty	Impact of savings on energy cost shares in household income
	Living comfort	
Social	Health and well-being	Externalities linked to health impacts
Social	Disposable household income	Shares of energy costs in household income
	Innovation and Competitiveness	
Economic	**Innovation impacts**	Patent indicators
Economic	**Competitiveness**	Indicators on foreign trade with EE products
Economic	**Turnover of EE goods**	Production statistics
	Economy (Macro)	
Economic	**Impact on GDP**	Impact of energy savings on GDP growth
Economic	**Employment effects**	Input-Output (I/O) analysis
Economic	Impact on energy prices	Price elasticities
Economic	Public budgets	State income from employment based on energy savings
	Economy (Micro)	
Economic	**Industrial productivity**	Semi-quantitative classification of impacts
Economic	**Asset value**	Valuation of buildings and companies for different end-uses according to energy efficiency benefits
	Energy Security and Energy Delivery	
Economic	Energy security (A)	Import dependency (conversion to primary energy necessary)
Economic	Energy security (B)	Impact on supplier diversity (Herfindahl-Hirschman-Index)
Economic	Impact on integration of renewables	Demand-response potentials by country

Source: Reuter et al. 2017.

for all technologies) to +100 (extremely high specialisation). The value 0 corresponds to an average specialisation. With these specialisation indicators the activities of the different countries can be compared independent from size effects.

Main indicators measuring the **innovative behaviour** (i.e. its ability to conquer future market shares) of a country for a given technology, hence also for energy efficiency technologies, are the following two:

- **Share in world patents for a given technology:** The simplest indicator for innovative behaviour is the world patent share (PA) for a given technology j and a given country i. That is the ratio of the patents (p) held by a given country i for a given technology j (p_{ij}) compared to the sum of all patents for that technology across all countries ($\Sigma_i p_{ij}$). These shares can then be compared for different countries but also for different technologies. For each country i and each technology, technology group or technology area j patent shares (PA) are calculated as follows:

Patent volume for technology j

$$PA_{ij} = 100 * (p_{ij} / \sum_i p_{ij}) \qquad (3)$$

- **Relative Patent Share (RPA):** compares the patent share for a technology j in a country i ($p_{ij}/\Sigma_i p_{ij}$) with the performance of all technologies in a country, i.e. summing further on j ($\Sigma_j p_{ij}/\Sigma_{ij} p_{ij}$). This measures how innovative a country is for a given technology compared to all other technologies in the country.

Patent performance for technology j

Patent performance of the country for all technologies

$$RPA_{ij} = 100 * \tanh \ \ln[(p_{ij} / \sum_i p_{ij}) / (\sum_j p_{ij} / \sum_{ij} p_{ij})] \qquad (4)$$

The same remarks on normalisation as for RCA hold for RPA, i.e more innovative countries present positive RPAs.

Unfortunately, there is no direct link between such type of innovation and competitiveness indicators for MB and energy savings, though one could hypothesize that countries with a strong energy efficiency policy (and corresponding large energy savings) and an appropriate industrial strategy may appear as strong in such type of indicators. However, more factors of influence are relevant for such type of indicators: for example the general industrial policy and business environment is probably as relevant as energy efficiency policy. Hence, it is not straightforward to establish such a relationship directly but a multi-policy analysis is required.

Two main databases are used for the analysis of competitiveness and innovation:

- The database UN COMTRADE is referred to for foreign trade figures (comtrade.un.org).
- The patent searches primarily draw on patent applications at the World Intellectual Property Organization WIPO and thus international patents (http://www.wipo.int).

The technologies investigated in the field of EE were hierarchized into areas, technology groups and technologies (Table 2). The technologies were then associated with the corresponding classifications within the UN Comtrade and WIPO patent statistics. Transport technologies were not included in this group.

We present and discuss below a few selected results. The annex provides tables that are more detailed.

- The EU28 have a high but decreasing share of about 42 % in world trade for the whole Area of Energy Efficiency Technologies (WHA, Figure 1) as defined in Table 2. The highest shares in Europe are seen with Germany (15 %), Italy (8 %), France (4 %) and the UK (3 %). On a worldwide level, most notable is the rapid penetration of China in the trade for energy efficiency technologies approaching 20 %.
- The Revealed Competitive Advantage RCA Analysis (Figure 2) which measures the export specialisation, shows nevertheless that the export specialisation for the whole Area of Energy Efficiency Technologies remains positive for a number of European countries (i.e. energy efficiency technologies are performing better in the export/import ratio as defined above than the average of the technologies in a country. This implies that energy efficiency technologies make a positive contribution to the economic development of those countries. However, in China, the RCA for Energy Efficient Technologies has moved rapidly from a negative value to a strongly positive RCA value of 60, i.e. energy efficient technologies contribute over-proportional to the development of the Chinese economy.
- The development of patent shares (PA, Figure 3) in the Technology Group of "Energy efficient processes in industry" shows that globally the EU28 have a high share worldwide but which is slowly eroding since 2009 at the expense of Japan, Korea and China. The same holds for the US where the erosion is even stronger. Germany, as the strongest EU economy, holds the largest share in patents in that field.
- Finally, the Relative Patent Shares (RPA) for the Technology Group of "Energy efficient processes in industry" (Figure 4) is still positive for the EU28 with a value around 20, while Japan approaches 35. China and the US still present negative values for the RPA, indicating that the innovation efforts for this Technology Group are still at a high level compared to competitors but advantages compared to China could be shrinking, as the number of patents is rising in that country quite rapidly.

Methodological limitations linked to this MB indicator are in particular:

- The identification of technologies and technology groups in foreign trade and patent statistics. Progress has been made by developing own statistical categories for sustainable technologies, in particular in the field of patents but defining properly categories for energy efficient technologies is a challenge.
- System innovations (e.g. an energy efficient factory as a system) are very important aspects in a sustainable energy system but are not directly reflected in patent or foreign trade statistics. Effort needs therefore to be made to approximate such system innovations.
- The interpretation of patent indicators could be hampered by the fact that the patent behaviour may vary from country to country or from sector to sector.

A condensed way of comparing innovativeness and competitiveness are specialisation profiles for energy efficient technologies (Figure 5). A country in the upper right quadrant is strong

Table 2. Definition of EE Technologies.

Area	Technology Group	Technologies
Energy Efficiency Technologies	**EE building technology**	Efficient building components like insulation materials, insulation glassing, controlled air conditioning and ventilation, efficient conventional heating systems and heat pumps, building automation technologies. More difficult are system aspects in buildings such as low energy houses/passive houses
	EE electric technologies in buildings	Energy efficient lighting and energy efficient appliances
	EE processes in industry	Iron/steel production, paper production etc.
	EE industrial cross-cutting technologies	Heat exchangers, efficient electric motors, pumps, ventilators etc., efficient industrial furnaces and driers

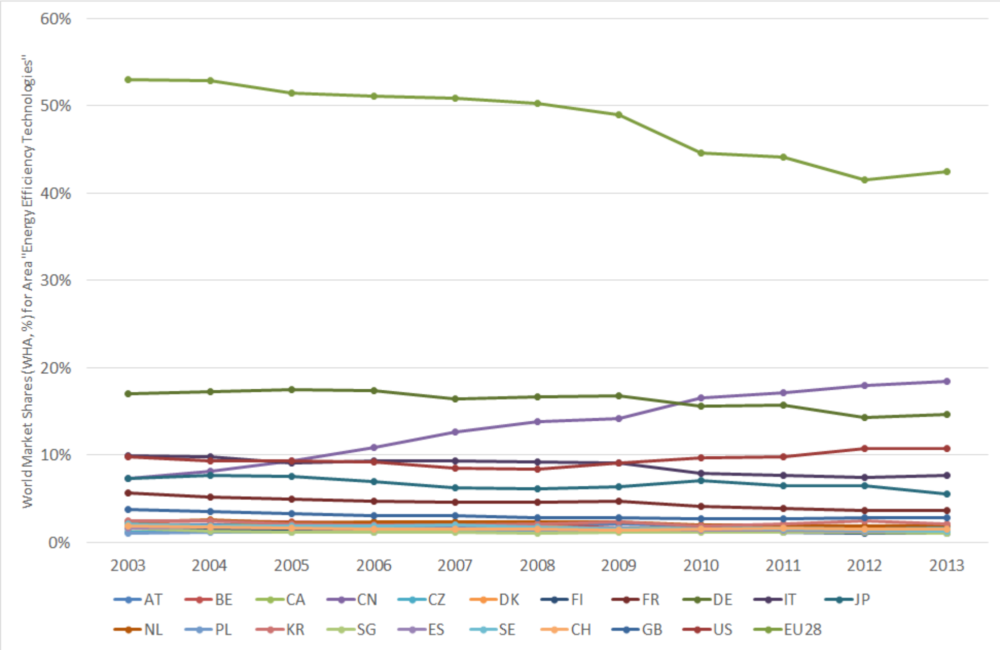

Figure 1. World Market Shares (WHA, %) for the Area "Energy Efficiency Technologies" as a whole. Calculated according to formula (1). Country codes: see Annex. Source: Fraunhofer ISI based on UN Comtrade.

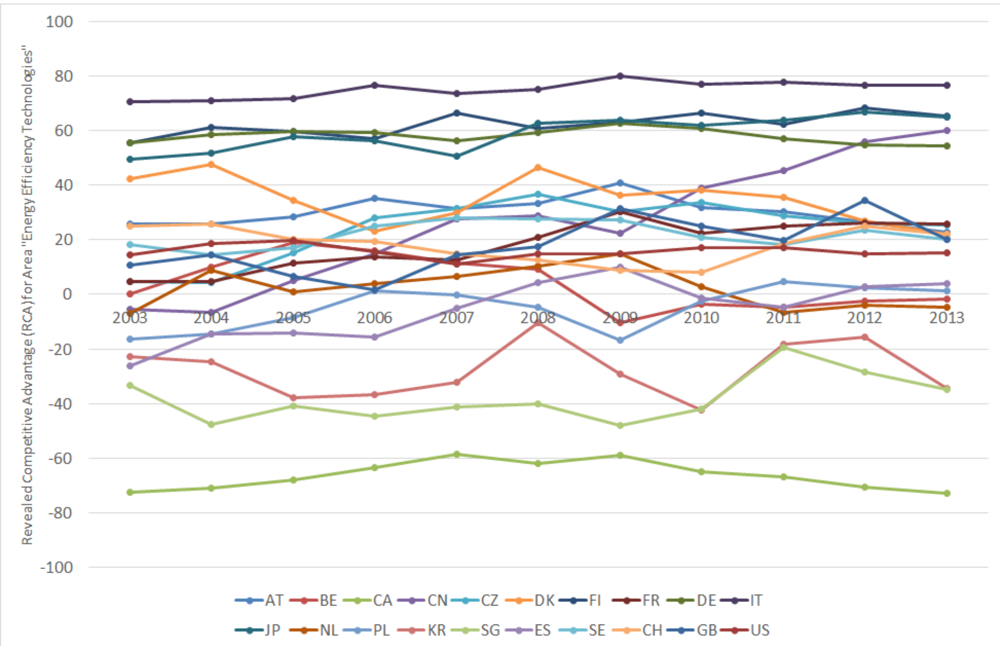

Figure 2. Revealed Competitive Advantage (RCA, relative number) for the Area "Energy Efficiency Technologies" as a whole. Calculated according to formula (2). Country codes: see Annex. Source: Fraunhofer ISI based on UN Comtrade.

in both innovation and competitiveness for EE technologies (e.g. Germany, Japan, Finland and Luxembourg). These countries are well performing now in energy efficient technologies and prepare well future markets through a strong innovation activity. Countries in the upper left quadrant are weak in innovation but strong in competitiveness (e.g. USA; however, the RCA is not very large); this could indicate weaker performance in future. Countries in the lower right part are weak in competition at present but strong in innovation; hence, they could conquer more market shares in future (e.g. Korea). Countries in the lower left quadrant are neither good in competitiveness nor innovation for EE technologies (e.g. India).

TURNOVER OF ENERGY EFFICIENCY GOODS

The turnover with energy efficiency goods is another important indicator for the contribution of energy efficient technologies to economic growth. We focus in this section on the impact of energy savings on turnover of energy efficiency goods produced for the residential sector in particular the production of efficient boilers and insulation materials, which have different

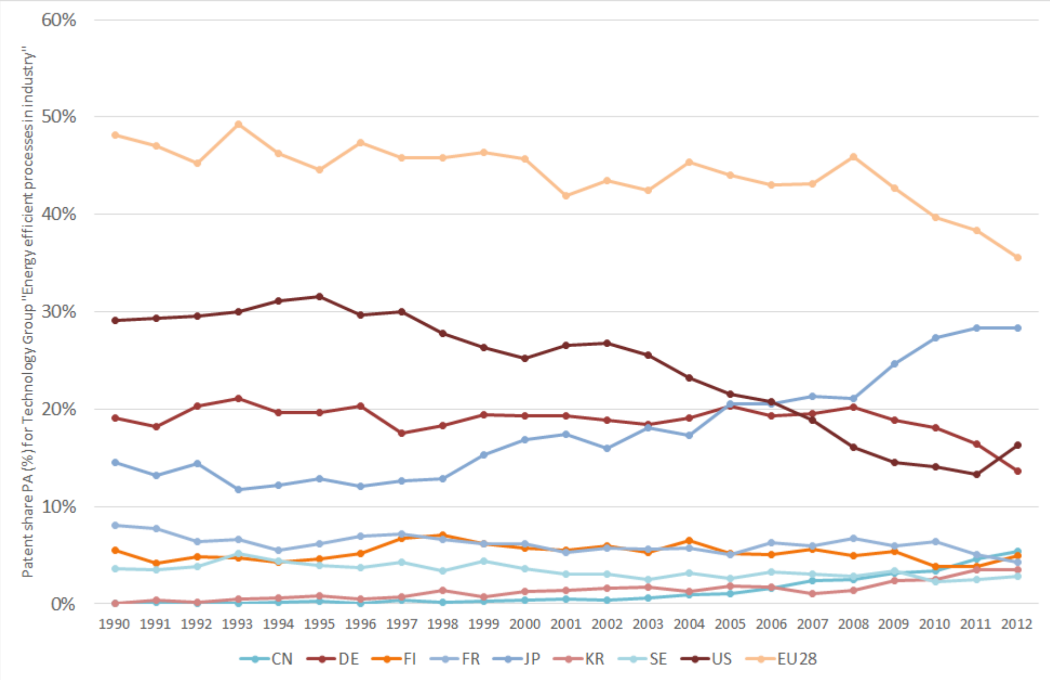

Figure 3. Patent shares (PA, %) for the Technology Group "Energy efficient processes in industry". Calculated according to formula (3). Country codes: see Annex. Source: Fraunhofer ISI based on World Intellectual Property Organization WIPO.

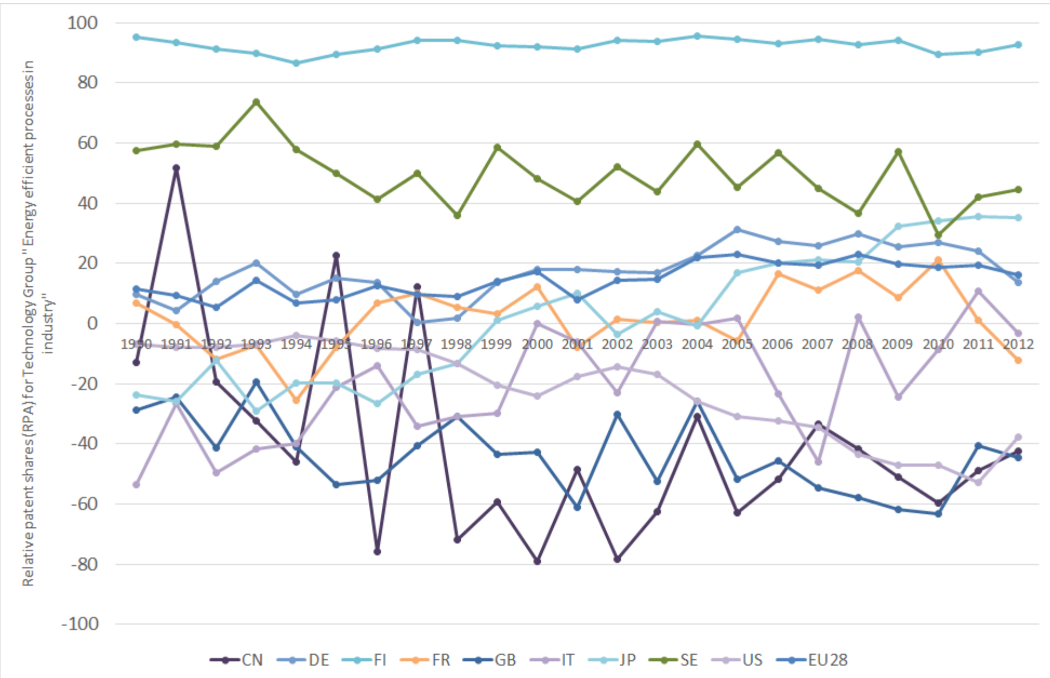

Figure 4. Relative patent shares (RPA, relative number) for Technology Group "Energy efficient processes in industry". Calculated according to formula (4). Country codes: see Annex. Source: Fraunhofer ISI based on World Intellectual Property Organization WIPO.

cost levels. This type of MB indicator can in principle be derived from energy savings, as frequently no direct statistics are available. To estimate the total turnover for energy efficiency technologies from energy savings, we calculate the weighted average of these investments per unit of energy savings where this is available. As an example, in the Netherlands these data are collected in an annual monitor on energy efficiency (Table 3). Based on these figures we see that the average investments in technologies for energy efficient existing buildings per GJ savings are in the range of 422–458 euro per GJ saved.

Based on the ODYSSEE database we are able to calculate the total difference in climate-corrected unit consumption per dwelling over a certain period, which gives an indication on the energy savings per dwelling for each country of the EU28 and hence on the total savings by multiplying the decrease in energy use per dwelling with the number of dwellings in a country.

Based on the average cost of energy efficiency technologies the total turnover can be determined, in particular also in countries where investments are not directly available from statistics. Table 4 shows the estimated average annual turnover in the years 2011–2015 for a number of EU countries.

Methodological limitations linked to this MB indicator are in particular:

- Structural changes may be insufficiently separated from energy savings in statistics, leading to annual fluctuations.
- Lacking control data on investments into different types of energy efficient technologies.

MACRO-ECONOMIC IMPACTS (ECONOMIC GROWTH AND EMPLOYMENT) FROM EE

The investments into energy efficiency technologies discussed above lead to economic growth and employment. Figure 6 shows the benefit for (net) employment triggered in Germany based on energy efficiency programmes in the residential sector up to 2014. These impacts are calculated from the energy savings as provided for the different (bottom-up) programmes from the MURE database for different technologies. Total savings amount to 78 PJ. The impacts on gross value added and employment are then derived through European Input/Output (I/O) tables from Eurostat.

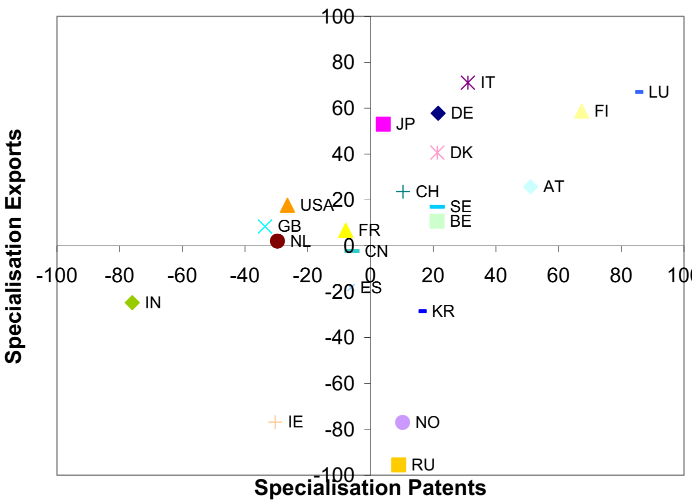

Figure 5. Specialization profiles for the Area "Energy Efficiency Technologies", averaged over a decade. RPA (in relative numbers) on the horizontal axis, RCA (in relative numbers) on the vertical axis. Source: Fraunhofer ISI based on World Intellectual Property Organization WIPO and UN Comtrade.

Table 3. Investments and energy savings of technologies for energy efficient existing buildings in the residential sector in the Netherlands.

	unit	2011	2012	2013	2014	2015
Investments insulation	million euro	2,041	1,965	1,858	2,150	2,302
Investment efficient boilers	million euro	865	877	865	865	866
Total investment EE technologies	million euro	2,906	2,842	2,723	3,015	3,168
Savings insulation	PJ	4.5	4.7	4.6	5.4	6.3
Savings efficient boilers	PJ	2.0	1.5	1.7	1.3	1.2
total savings	PJ	6.5	6.2	6.3	6.7	7.5
Euro per GJ savings insulation	euro/GJ	454	418	404	398	365
Euro per GJ savings efficient boilers	euro/GJ	432	585	509	666	722
Euro per GJ savings total	euro/GJ	447	458	432	450	422

Source: Dutch Annual Monitor on Energy Efficiency.

Table 4. Estimate of average turnover due to energy efficiency technologies produced for the residential sector 2011–2015 in European countries (million €/year).

Belgium	Croatia	Estonia	France	Italy	Latvia	Lithuania	Netherlands
323	311	119	3,910	2,428	89	154	2,538
Poland	Portugal	Romania	Slovakia	Slovenia	Spain	United Kingdom	
167	223	1,192	406	193	1,584	6,016	

Source: Estimate ECN based on Table 3 and energy savings from the ODYSSEE-MURE database.

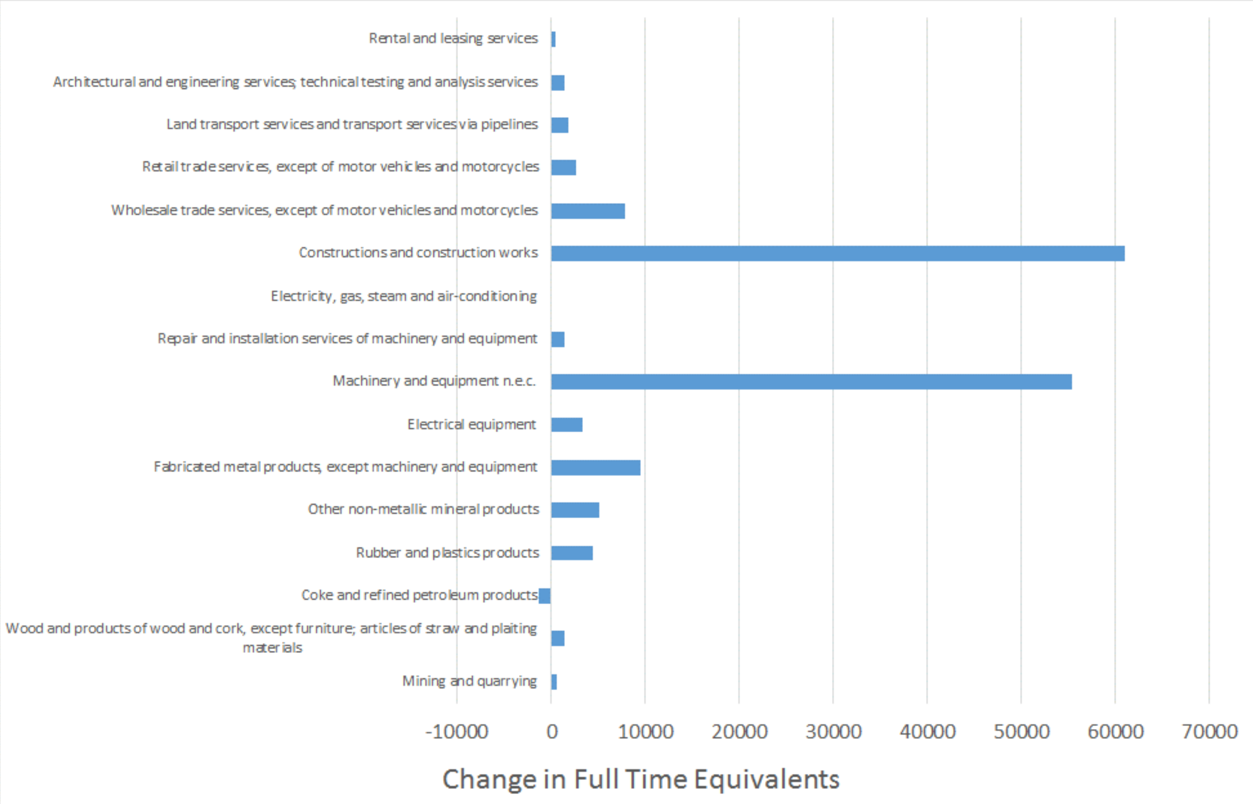

Figure 6. Change in full time employment equivalents due to energy efficiency programmes in Germany until 2014. Source: based on energy savings from the ODYSSEE-MURE database (by technology) and Input/Output tables from Eurostat.

Impact on the gross value added amounts to a net growth of 11.4 billion Euro. Net employment increased by 154,000. Most of the sectors of the economy, in particular the construction sector and machinery and equipment, show positive impacts.

Conclusions on MB indicators aiming at economic benefits for companies and the economy

The present paper discussed an indicator approach to Multiple Benefits of Energy Efficiency, in particular indicators aiming at measuring economic benefits for companies and the economy. Such MB indicators include for example indicators for competitiveness and innovation, for turnover with energy efficient technologies, for impacts on economic growth and employment. They are relevant for enhancing monitoring and reporting procedures on the transformation of the energy system which usually focus on energy and greenhouse gas savings only.

The main policy implications from this analysis can be summarised as follows:

- While energy savings frequently are already beneficial for companies and the industrial sector as a whole, Multiple Benefits of Energy Efficiency enhance the value of energy savings.
- Today, however, the knowledge on MB-EE is scattered and not easily available for monitoring purposes and to feed policy instruments for energy efficiency. Knowledge made available in new tools and projects, such as the ODYSSEE-MURE facility on multiple benefits, should therefore be made easily accessible for the policy level and be used by policy makers when evaluating the impacts of energy efficiency policies.
- In particular, the economic MB indicators discussed in this paper enhance the quantitative knowledge on the relevance of energy savings for companies and the overall economy. Even in times of booming economies, it is important to be able to argue that EE policies contribute to strengthen the competitiveness of the economy and maintain employment, the more in times when economies are less growing.
- We suggest therefore that policy makers should systematically include such type of MB-EE when presenting the impacts of EE policies. Companies should develop, at the micro-level, similar type of indicators when evaluating EE measures.

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Acknowledgements

This paper has been developed based on work performed for the ODYSSEE-MURE project on energy efficiency indicators and policies (www.odyssee-mure.eu). We acknowledge the support from the European Commission (EASME) under the H2020 programme as well as from national governments for the project.

Annex: Detailed Tables on Indicators for Competitiveness and Innovation

Country codes: AT Austria, AU Australia, BE Belgium, CA Canada, CH Switzerland, CN China, CZ Czech Republic, DE Germany, ES Spain, FI Finland, FR France, GB United Kingdom, IT Italy, JP Japan, KR Korea, NL Netherlands, PL Poland, SE Sweden, US USA, EU28 European Union.

Table A1. World Market Shares (WHA, %) by country for the Area "Energy Efficiency Technologies" as a whole.

	AT	BE	CA	CN	CZ	DK	FI	FR	DE	IT	JP	NL	PL	KR	SG	ES	SE	CH	GB	US	EU28
2003	2,0%	2,3%	2,0%	7,3%	1,2%	1,8%	1,6%	5,6%	17,0%	9,9%	7,3%	2,3%	1,0%	2,5%	1,6%	1,7%	2,1%	1,8%	3,8%	9,9%	53,0%
2004	1,9%	2,5%	1,9%	8,1%	1,3%	1,7%	1,6%	5,2%	17,3%	9,8%	7,7%	2,6%	1,1%	2,5%	1,3%	1,8%	1,9%	1,8%	3,6%	9,4%	52,8%
2005	2,0%	2,4%	2,1%	9,4%	1,4%	1,6%	1,6%	4,9%	17,5%	9,1%	7,6%	2,3%	1,2%	2,1%	1,2%	1,7%	1,9%	1,6%	3,3%	9,3%	51,5%
2006	2,2%	2,2%	2,1%	10,8%	1,7%	1,5%	1,4%	4,7%	17,4%	9,4%	7,0%	2,3%	1,2%	2,0%	1,2%	1,5%	1,9%	1,6%	3,0%	9,2%	51,1%
2007	2,2%	2,3%	1,9%	12,7%	1,8%	1,6%	1,7%	4,6%	16,4%	9,4%	6,2%	2,4%	1,3%	2,0%	1,1%	1,6%	2,0%	1,5%	3,0%	8,6%	50,9%
2008	2,1%	2,1%	1,7%	13,8%	1,8%	1,9%	1,4%	4,6%	16,7%	9,2%	6,2%	2,4%	1,3%	2,1%	1,1%	1,6%	1,8%	1,5%	2,9%	8,4%	50,3%
2009	2,2%	1,6%	1,6%	14,1%	1,5%	1,5%	1,3%	4,7%	16,8%	9,1%	6,3%	2,4%	1,3%	2,4%	1,2%	1,7%	1,6%	1,5%	2,8%	9,1%	49,0%
2010	1,8%	1,6%	1,5%	16,5%	1,6%	1,4%	1,2%	4,1%	15,6%	7,9%	7,1%	2,0%	1,3%	1,9%	1,2%	1,4%	1,5%	1,6%	2,7%	9,7%	44,6%
2011	1,8%	1,5%	1,6%	17,2%	1,8%	1,3%	1,2%	3,9%	15,7%	7,7%	6,5%	2,0%	1,3%	2,1%	1,2%	1,4%	1,5%	1,6%	2,7%	9,9%	44,2%
2012	1,6%	1,4%	1,6%	18,0%	1,7%	1,3%	1,1%	3,6%	14,3%	7,4%	6,5%	1,9%	1,2%	2,4%	1,2%	1,3%	1,4%	1,5%	2,8%	10,7%	41,5%
2013	1,6%	1,5%	1,4%	18,5%	1,7%	1,2%	1,0%	3,7%	14,7%	7,7%	5,5%	2,0%	1,3%	2,2%	1,1%	1,4%	1,3%	1,5%	2,8%	10,8%	42,4%

Table A2. Revealed Competitive Advantage (RCA) for the Area "Energy Efficiency Technologies" as a whole.

	AT	BE	CA	CN	CZ	DK	FI	FR	DE	IT	JP	NL	PL	KR	SG	ES	SE	CH	GB	US
2003	25,8	0,1	-72,5	-5,4	4,8	42,2	55,4	4,6	55,3	70,4	49,4	-7,0	-16,4	-22,6	-33,2	-26,0	18,4	25,2	10,7	14,6
2004	25,7	10,1	-70,9	-6,6	4,3	47,5	60,9	4,5	58,6	71,0	51,7	8,7	-14,5	-24,8	-47,5	-14,5	14,4	25,6	14,4	18,5
2005	28,5	19,2	-68,1	5,1	15,1	34,6	59,6	11,4	59,5	71,8	57,8	0,9	-8,4	-38,0	-40,9	-14,2	17,0	20,1	6,6	19,9
2006	35,1	16,2	-63,3	14,8	27,8	23,1	57,1	13,9	59,2	76,6	56,3	4,1	1,2	-36,8	-44,6	-15,6	25,2	19,4	1,8	15,7
2007	31,5	11,6	-58,7	27,5	31,4	30,1	66,4	12,7	56,1	73,6	50,4	6,7	-0,1	-32,2	-41,4	-5,2	27,8	15,0	14,4	10,9
2008	33,3	9,4	-62,0	28,8	36,6	46,4	60,6	20,9	59,3	75,2	62,7	10,4	-4,9	-10,3	-40,0	4,3	27,7	12,5	17,6	14,9
2009	40,9	-10,5	-58,9	22,4	30,1	36,1	62,9	30,2	62,7	80,1	63,7	15,0	-16,7	-29,1	-48,1	9,8	27,3	9,0	31,3	15,0
2010	31,8	-3,7	-65,1	39,0	33,6	38,2	66,6	22,3	60,7	77,1	61,8	2,8	-2,5	-42,5	-41,9	-1,2	20,7	7,9	25,0	17,0
2011	30,2	-4,6	-67,0	45,2	28,9	35,7	62,4	25,1	57,0	77,7	63,8	-6,7	4,7	-18,3	-19,3	-4,9	18,4	18,6	19,8	17,2
2012	26,5	-2,6	-70,5	55,7	26,2	27,0	68,4	26,1	54,6	76,7	66,7	-4,1	2,3	-15,8	-28,5	2,8	23,5	24,9	34,6	14,9
2013	22,7	-1,9	-72,9	60,0	25,4	21,9	65,3	25,7	54,3	76,6	64,8	-4,6	1,3	-34,6	-34,7	3,8	20,3	21,9	20,0	15,2

Table A3. Patent shares (PA, %) by country for the Technology Group "Energy efficient processes in industry".

	AT	AU	BE	CA	CH	CN	DE	DK	ES	FI	FR	GB	IT	JP	KR	NL	SE	US	EU28
1990	2,6%	1,3%	1,7%	1,8%	1,7%	0,1%	19,1%	0,7%	0,2%	5,5%	8,1%	5,1%	1,8%	14,5%	0,0%	1,5%	3,7%	29,1%	48,1%
1991	2,2%	0,9%	2,1%	2,4%	2,1%	0,1%	18,2%	0,9%	0,6%	4,2%	7,8%	5,0%	2,7%	13,2%	0,4%	1,5%	3,6%	29,3%	47,0%
1992	1,4%	1,5%	1,4%	3,1%	1,7%	0,1%	20,3%	1,2%	0,4%	4,8%	6,4%	4,1%	1,9%	14,4%	0,2%	0,9%	3,8%	29,5%	45,2%
1993	1,0%	0,9%	1,7%	1,2%	2,7%	0,1%	21,1%	0,9%	0,5%	4,8%	6,7%	5,1%	2,1%	11,7%	0,5%	0,8%	5,2%	30,0%	49,3%
1994	2,7%	0,9%	1,2%	2,3%	2,7%	0,1%	19,6%	2,1%	0,4%	4,3%	5,5%	4,0%	2,1%	12,2%	0,6%	1,5%	4,4%	31,1%	46,3%
1995	2,4%	1,2%	1,2%	2,1%	2,0%	0,2%	19,7%	1,0%	0,2%	4,6%	6,2%	3,2%	2,5%	12,9%	0,9%	1,4%	4,0%	31,5%	44,6%
1996	2,9%	0,8%	1,5%	2,1%	2,9%	0,1%	20,3%	0,8%	0,4%	5,2%	7,0%	3,2%	2,8%	12,1%	0,5%	1,5%	3,8%	29,7%	47,4%
1997	2,4%	0,7%	2,2%	1,9%	2,5%	0,3%	17,5%	0,5%	0,1%	6,8%	7,2%	3,5%	2,2%	12,7%	0,7%	1,7%	4,3%	30,0%	45,8%
1998	1,5%	0,8%	1,4%	2,4%	2,9%	0,1%	18,3%	1,0%	0,3%	7,1%	6,7%	4,0%	2,2%	12,9%	1,4%	1,9%	3,4%	27,7%	45,9%
1999	2,1%	1,0%	1,7%	2,0%	2,2%	0,3%	19,5%	1,0%	0,5%	6,2%	6,2%	3,5%	2,2%	15,3%	0,8%	1,6%	4,4%	26,3%	46,3%
2000	2,4%	1,1%	1,7%	2,1%	1,9%	0,4%	19,3%	0,6%	0,4%	5,7%	6,2%	3,4%	2,9%	16,9%	1,3%	1,7%	3,7%	25,2%	45,7%
2001	2,4%	1,0%	1,7%	1,8%	2,2%	0,5%	19,3%	0,6%	0,6%	5,5%	5,2%	2,6%	2,7%	17,4%	1,3%	1,4%	3,0%	26,5%	42,0%
2002	2,9%	0,9%	1,5%	1,7%	2,8%	0,4%	18,9%	0,6%	0,1%	6,0%	5,7%	3,7%	2,4%	16,0%	1,6%	1,5%	3,1%	26,8%	43,5%
2003	3,4%	1,3%	1,8%	1,8%	2,1%	0,6%	18,4%	0,4%	0,3%	5,3%	5,6%	2,6%	3,0%	18,1%	1,8%	1,8%	2,5%	25,5%	42,4%
2004	2,9%	1,5%	2,2%	1,3%	2,1%	1,0%	19,1%	0,4%	0,5%	6,5%	5,8%	3,4%	2,9%	17,3%	1,3%	1,8%	3,1%	23,2%	45,4%
2005	3,4%	1,2%	1,2%	1,8%	1,4%	1,1%	20,3%	0,2%	0,6%	5,2%	5,0%	2,3%	3,0%	20,6%	1,8%	2,0%	2,7%	21,5%	44,0%
2006	2,6%	1,1%	1,9%	1,6%	1,8%	1,6%	19,3%	0,2%	0,4%	5,1%	6,3%	2,6%	2,4%	20,5%	1,7%	1,5%	3,3%	20,7%	43,1%
2007	2,2%	1,4%	2,3%	2,7%	1,7%	2,4%	19,5%	0,4%	0,7%	5,6%	6,0%	2,2%	1,8%	21,3%	1,0%	2,3%	3,1%	18,9%	43,2%
2008	3,5%	1,3%	2,1%	2,0%	2,5%	2,5%	20,3%	0,9%	0,7%	5,0%	6,8%	2,1%	3,0%	21,1%	1,4%	1,9%	2,8%	16,0%	46,0%
2009	3,0%	1,0%	1,4%	1,9%	2,2%	3,2%	18,8%	0,4%	0,5%	5,4%	5,9%	1,9%	2,1%	24,7%	2,4%	1,7%	3,3%	14,5%	42,7%
2010	3,6%	0,7%	2,0%	1,4%	2,3%	3,4%	18,1%	0,9%	0,7%	3,9%	6,3%	1,8%	2,3%	27,4%	2,5%	1,4%	2,3%	14,1%	39,7%
2011	2,9%	0,8%	1,7%	2,1%	2,1%	4,6%	16,4%	0,6%	0,7%	3,9%	5,0%	2,3%	2,7%	28,3%	3,6%	2,2%	2,6%	13,3%	38,3%
2012	3,9%	0,6%	1,9%	1,4%	2,1%	5,4%	13,6%	0,5%	0,7%	5,0%	4,2%	2,0%	2,2%	28,4%	3,5%	1,5%	2,8%	16,3%	35,5%

Table A4. Relative patent shares (RPA) for the Technology Group "Energy efficient processes in industry".

	AT	AU	BE	CA	CH	CN	DE	DK	ES	FI	FR	GB	IT	JP	KR	NL	SE	US	EU28
1990	71,27	13,40	53,74	36,53	-44,03	-12,99	9,59	-7,95	-76,12	95,00	6,95	-28,83	-53,53	-23,77	-	-42,91	57,34	-6,72	11,47
1991	62,51	-23,84	59,68	54,90	-21,98	51,65	4,15	20,80	1,37	93,29	-0,36	-24,31	-26,62	-25,85	29,55	-36,91	59,45	-7,82	9,20
1992	32,08	28,22	16,64	69,42	-44,84	-19,46	14,11	41,59	-21,75	91,06	-11,88	-41,49	-49,53	-12,10	-63,21	-73,87	59,02	-7,77	5,42
1993	0,51	-29,34	24,04	-14,92	4,25	-32,41	19,96	7,87	-17,66	89,66	-7,33	-19,42	-41,75	-29,12	-12,83	-76,98	73,67	-6,85	14,28
1994	73,62	-26,70	-2,79	45,40	0,94	-46,19	9,78	72,15	-48,09	86,64	-25,70	-40,84	-39,80	-19,63	1,42	-40,74	57,67	-3,94	6,76
1995	73,05	5,33	4,73	31,85	-19,39	22,68	14,97	18,35	-72,65	89,29	-7,82	-53,46	-21,30	-19,89	24,55	-46,98	50,04	-5,66	7,70
1996	80,39	-21,69	25,81	29,48	16,97	-75,95	13,58	0,66	-46,98	91,13	6,88	-52,02	-13,93	-26,47	-23,15	-43,97	41,41	-8,36	12,39
1997	68,88	-40,46	50,46	7,93	5,40	12,07	0,21	-33,30	-92,08	94,21	10,07	-40,46	-34,08	-17,00	-10,22	-31,26	49,89	-8,65	9,79
1998	40,09	-26,44	7,60	33,75	19,10	-71,93	1,62	16,22	-66,30	94,06	5,35	-31,01	-31,09	-13,47	28,93	-28,12	35,95	-13,34	8,97
1999	64,65	-21,50	32,40	8,85	-2,01	-59,15	13,67	20,25	-34,25	92,17	3,12	-43,57	-29,98	1,06	-46,20	-39,39	58,44	-20,60	14,12
2000	72,76	-11,91	41,30	14,69	-14,20	-79,03	17,88	-26,03	-59,03	91,95	12,07	-42,87	-0,18	5,62	-27,81	-36,52	48,25	-24,11	17,29
2001	70,18	-15,45	45,48	-6,32	-4,86	-48,58	17,86	-26,44	-28,28	91,20	-8,01	-61,24	-6,30	10,02	-38,44	-58,85	40,51	-17,74	7,98
2002	77,12	-25,12	26,51	-14,37	23,79	-78,52	17,36	-27,09	-94,79	94,22	1,40	-30,16	-23,19	-3,75	-44,54	-47,57	52,20	-14,29	14,17
2003	82,31	8,07	38,72	-5,92	-1,68	-62,56	16,95	-63,23	-74,24	93,82	0,28	-52,51	0,66	3,89	-52,48	-31,63	43,79	-16,77	14,55
2004	77,03	37,65	48,70	-33,51	-7,53	-30,97	22,68	-62,23	-62,12	95,39	0,88	-25,97	-0,46	-0,65	-76,43	-30,03	59,73	-25,94	21,89
2005	84,28	8,78	6,25	-11,80	-41,81	-62,77	31,18	-86,63	-49,17	94,34	-5,75	-51,60	1,59	16,89	-68,52	-11,97	45,38	-30,78	22,88
2006	69,43	2,36	46,26	-28,38	-17,46	-51,64	27,45	-82,32	-69,56	93,18	16,55	-45,58	-23,24	20,19	-75,04	-37,13	56,63	-32,27	20,17
2007	59,34	30,40	61,33	27,99	-25,92	-33,27	25,78	-69,92	-41,83	94,62	11,07	-54,80	-45,90	21,05	-90,05	6,97	44,93	-34,47	19,20
2008	82,06	23,04	49,77	4,38	10,15	-41,87	29,73	-4,86	-44,35	92,67	17,63	-57,81	1,95	20,48	-82,11	-22,30	36,69	-43,65	22,99
2009	75,39	3,28	22,97	-2,63	0,98	-50,90	25,34	-53,59	-71,61	94,19	8,66	-61,79	-24,31	32,42	-65,42	-23,09	57,25	-47,09	19,86
2010	81,68	-23,50	54,51	-33,04	6,73	-59,78	26,75	10,30	-55,40	89,37	21,20	-63,33	-8,57	34,09	-63,61	-19,64	29,44	-47,09	18,63
2011	75,82	-9,49	45,63	14,56	8,80	-48,73	23,88	-37,83	-49,26	90,31	0,90	-40,46	10,65	35,59	-40,78	19,66	42,08	-52,84	19,26
2012	86,39	-25,37	58,63	-23,08	6,14	-42,48	13,60	-37,92	-41,75	92,54	-12,29	-44,63	-3,42	35,06	-47,76	-20,19	44,61	-37,60	16,09