Assessment of Measuring Energy Efficiency Performance in Industry: Case Study of the Iron and Steel Industry

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ABSTRACT

Energy efficiency improvement is a basic yet significant way of addressing both energy security and environment concerns. Various attempts to measure energy efficiency performance exist and produce indices which can be used to guide policy. This paper explores possible indices in industry: absolute energy consumption, energy intensity, diffusion of specific energy saving technology and thermal efficiency. It considers in particular issues such as boundary definitions, country comparison and benchmarking, in light of possible implications for policy choices. The limitations of both energy intensity and technology diffusion indicators are also discussed. A case study on Japan's iron and steel industry illustrates the critical role of proper boundary definitions for a meaningful assessment of energy efficiency in industry. Depending on the boundaries set for the analysis, the energy consumption per ton of crude steel ranges from 16 to 21 GJ, which points to the care with which international comparisons should be drawn. This paper stresses the importance of a proper understanding of various methods to assess energy efficiency, and the linkage with policy objectives and frameworks.

Introduction

The profile of energy efficiency has risen recently due to increased concerns about the local and global environmental impacts of energy use, as well as energy security. The measurement of energy efficiency is therefore becoming more policy-relevant than it may have been in the recent past. In industry, this issue is especially complex, due to various kinds of processes and end-use types. It is difficult to demonstrate consistent and comparable indices, a condition for proper policy analysis.

Energy efficiency performance (EEP) has been measured in different ways for different purposes, and in many cases, has been demonstrated via widely publicized indicators. An inappropriate use of indicators has the potential to compromise policy decisions.

How Have Measures of Energy Efficiency Performance Been Used?

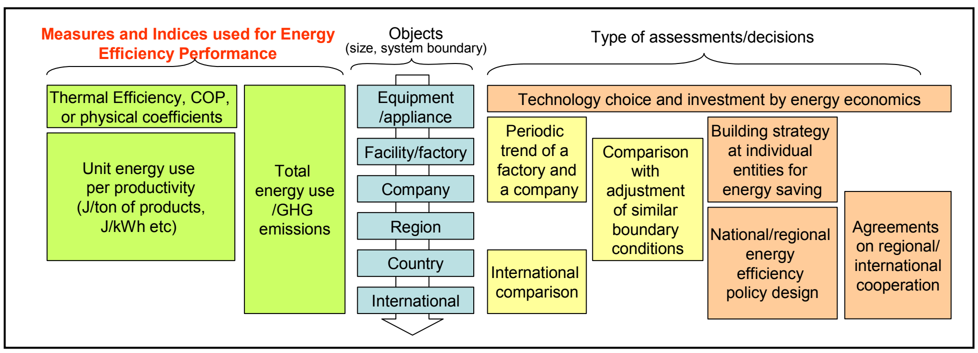
The measure or index that should be used for EEP depends almost entirely on the purpose sought. For example, in order to compare the EEP of equipment when an industrial facility operator wants to use energy economically the most appropriate approach may be thermal efficiency, the total output of useable energy divided by energy input (see Figure 1). If the company wants to see the trend of energy use in different factories and compare the productivity of energy use, it may adopt the energy input divided by production output for each facility. For climate change policy purposes, total GHG emissions have been used as an inclusive indicator expressing a country's overall contribution. Inappropriate use of those numbers may mislead political direction or decision.

Once numbers are published, they are sometimes taken as "truth" without consideration for: how they were measured; what assumptions and data were used; the background data ranges and uncertainty due to difficulties in data collection; and whether they are appropriate with respect to the original analytical purpose and for broader and longer term application. Accordingly, it is important that, before offering "numbers" using defined methodologies, the potential methodologies that could be used for their production should be comprehensively assessed.

The general approach of assessing how much energy is consumed to produce the same products needs to be carefully considered, mainly because it can be difficult to justifiably make the "same products" assumption. In the case of thermal efficiency, this is easy as the "product" is "energy". But in case looking at industrial materials such as steel, cement, chemical products, pulp and paper, a wide range of products is available for each. Moreover, energy intensity will be influenced by boundary definitions of each object.

The objectives of this paper are to indicate possible indices to express EEP in industry and to clarify the characteristics of each index, noting advantages and disadvantages, political implications, and their linkage with policy framework. The importance of setting assessment boundary definitions is also discussed, in a concrete manner using the case of the Japanese iron and steel industry.

Figure 1. Variety of Measures and Indices Used for Energy Efficiency Performances



Energy efficiency comparisons and the importance of boundary definitions. What is achieved by use of measured energy efficiency? It is most likely to be used to examine the trend of energy consumption of the "object" (see Figure 1). It is an effective analytical tool whenever they are structurally identical over the observation period (e.g. similar boundaries). We should be careful about what energy efficiency conclusions can be drawn when objects cannot be compared clearly.

For example, objects A and B are assumed, which are defined with a certain boundary (e.g. a country, an enterprise or a mill). The question is whether the measured energy efficiency of A, which is inferior to B, should be brought close to the efficiency of B, or whether both A and B's values should be improved to aim for a benchmark target. If the components of B differ greatly from A, one may doubt the validity of comparing these objects' efficiencies. Generally speaking, the difference of components grows in significance with the breadth of the system boundary. Relatively speaking, efficiencies at the equipment level are easier to compare, though its efficiency is widely affected by other factors, sometimes unique to entities. These include operating ratios and maintenance methods.

In which cases does performance information, measured within boundary definitions with different components, become meaningful? The answer is, when seeking improvement through a component change within the existing configurations. However, in many industrial processes, there are many physical, technical, and economical considerations to be taken into account when making a decision on the component. As a result, the substitution of other components may not always be possible.

Assessing Measures of Energy Efficiency Performance (MEEPs)

There are several MEEPs for industry, for example: *absolute amount of energy consumption* – heat value; *thermal energy efficiency of equipment* – heat value divided by heat value; *energy consumption intensity*– heat value divided by material value.

The latter two are likely to be discussed as "energy efficiency". Thermal efficiency or equipment energy intensity is used for the expression of end-use technology efficiency. Energy intensity is used slightly more in larger assessment boundary, in terms of process, company or factory, and sometimes country level, compared to thermal efficiency. This paper deals with matters of "boundary definitions" in a more concrete manner with a case study using iron and steel. The absolute amount of energy consumption is sometimes adopted as another possible MEEP, although it becomes meaningless without an indication of production volumes.

Another possible MEEP is *diffusion ratios of energy efficient facilities/ types of equipment*. This indicates the quantitative deployment of a specific energy efficient technology. When looking at energy efficient technologies alone, it should be remembered that they are common worldwide, and they have similar individual performances everywhere. How much those technologies were and will be installed could be a useful index – assuming that installation implies actual use of the equipment. The above-mentioned MEEPs ought to be considered against the following dimensions: required data and data availability; assumptions, and size of systems covered, which is related to their credibility.

Policy Application of MEEPs

Some policies and measures would ideally require the use of MEEP indices, primarily to evaluate their performance. In industry, examples include the energy efficiency of electric motors such as output divided by input power, used in the USA Energy Policy Act and EU energy labels. Cap and trade systems such as EU emission trading scheme (EU ETS) set absolute targets as implicit indices, albeit with some flexibility to achieve targets with the help of the CO_2 market – this obviously drives a wedge between the measurement of an industry's performance on, say, energy efficiency, and its compliance with emission objectives.[1] The Dutch benchmark covenant uses energy intensity targets. The UK Emission Trading System, the UK Climate Change Agreement and Japan's Keidanren (Japan Business Federation) voluntary action plan adopt both intensity and absolute amounts of energy and CO_2 as MEEPs. While not all such policy instruments sought primarily to improve energy efficiency, they have often relied on MEEPs to set performance.

[1] Indeed, what may seem like a significant improvement from an energy efficiency performance standpoint may not be economical in light of the cost of CO_2 allowances that offer a valid alternative for compliance under a cap-and-trade system.

Criteria for assessment of MEEPs for policy and measures. Competing methodologies exist, each best suited for various analytical and policy purposes. The following criteria help identify which index is best suited to a particular policy purpose.

- **Reliability:** data credibility and assurance; robustness of the methodology (i.e. flexibility when it is used in different contexts.) Existing statistics can be used for the absolute amount of energy consumption of industry and energy intensity, but they were often originally developed for different purposes. When looking at a sub-categorized sector, the boundary of each category and item should be carefully checked. Another frequent problem lies in consistency within existing statistics. For example, data on energy consumption and production of the paper and pulp industry differ in current FAO data and IEA data. (IEEJ, 2006) Some countries show no energy consumption in the pulp and paper sector due to IEA data but some amount of pulp/paper were produced under FAO. As for diffusion ratios, we note that current data is in most cases inadequate and cannot support a proper assessment of a policy aiming at diffusing specific energy efficient technologies in a sector. In fact, such policies should be accompanied by proper reporting and a monitoring mechanism.

- **Feasibility:** transaction costs; stakeholders' acceptance. New data collection is usually costly. The use of existing data causes concerns stated in the "reliability" section. Once an agreement exists on the need to collect energy data, further discussion is necessary to define common boundary setting among stakeholders – an effort that cannot be overestimated. Another data barrier, e.g. when considering a measure based on technology diffusion ratios, is the confidentiality of the information. What may seem like an effective policy measure may be unfeasible if companies are not prepared to disclose information on their practice.

- **Verifiability:** or monitoring; whether energy savings–between current and targeted values– are traceable, and economic or dynamic assessment is possible after the policy is implemented.

The assessment using these criteria will show that there is no ideal MEEP in any case. It is not aimed at deciding the "best" one, but selecting an appropriate one for the individual policy and measures. This is more concretely illustrated below.

Concerns for Application of Indices for Policy Framework

Country, company or global level. When multinational industrial companies are becoming more common, why is comparison of different countries' energy efficiency performance necessary? The answer is simple. Policy is basically decided at the national level, where its effects can be observed and assessed; further, national circumstances also matter, among which energy price levels are an overriding consideration in energy efficiency. Rather than making comparison a purpose in and of itself, it should be targeted to make useful indices for country policy with provision of a method whereby regional and national differences can be clearly considered.

Necessary approaches for the use of "energy intensity". There are several conceivable ways to achieve more accurate estimated values using the MEEP for "energy intensity", especially when those values are used for comparison: (1)preparing a detailed energy input/output database; (2)consensus in setting fundamental process (components) within boundaries and matching boundary definitions of objects to be compared; (3)focusing on some critical elements within the system boundary.

Even then, problems remain. As in the chemical and petrochemical industries, there are cases in which many processes are integrated by the combination of supply of various products, with the entire process operated to minimize the energy cost. In such integrated systems, assuming that the detailed data are gathered, energy intensity data on a product or process product basis is of limited value. In addition, such detailed energy reporting may reveal strategic information about the cost structure of a company to its competitors.

In industries with multiple combinations of processes, appropriate indices for energy efficiency should be linked with each basic process. They are, in the case of the chemical and petrochemical industries: distillation, heat exchange, chemical reaction, steam generation and the use of electric power. Possible indices are not particularly useful in "energy intensity". Thermal/yield loss ratios at each reaction site, the boiler, pump and motor efficiency are more relevant to the basic processes carried out in energy technology.

In addition, there is a problem with respect to the Antitrust Law in implementing collections of detailed energy data by process. If the law is interpreted very strictly, two points can be argued, which may be related to price manipulation by enterprises. Some sharing of the energy data only by industrial body, without third party, is connected to sharing cost information. In addition, bringing energy efficiency close to a certain target that industry may set for itself may correspond to the specific arrangement which also relates to cost.

Benchmarking. The term “benchmarking”, in the context of energy efficiency, is employed in the context of converting energy efficiency performance with a certain standardized common format, setting particular numbers from best performance data or average of some percentages of top efficiency as targeted efficiency. Benchmarking could possibly be used for policy related to energy efficiency.

The benchmark covenant in the Netherlands is used to identify energy intensity of every process, and use this value to direct their eventual evolution within the top 10% worldwide. A recent benchmarking study in the iron and steel industry in Canada (NRCAN/CSPA 2007) compares national steelmaking plants of four integrated steelmaking plants and eight electric arc furnaces with the Ecotech model plant, as defined by the International Iron and Steel Institute (IISI, 1998). In recent discussions, benchmark(ing), sometimes includes establishing indices which is a pre-action to benchmarking. In such cases, indexation and benchmarking are united. The terms need to be used with caution.

As policy-makers are considering the revision of the EU ETS for 2013 onward, benchmarking has been proposed as one option to help allocate efforts to various installations within any given industrial activity (Vanderborght 2006). The option would rest on a CO_2 performance standard that establishes a benchmark for similar activities. If CO_2 emissions are higher than the benchmark level, emissions must be reduced – or allowances be purchased to cover emissions above benchmark – and if lower, emission allowances are generated, and can be sold. Such an approach would provide a more direct incentive to improve the CO_2 intensity of production, especially to those that are under-performing, as their cost would be affected immediately. However, careful consideration should be given to the design of the benchmark, to ensure that it encourages a broad improvement in the CO_2 intensity of production, inside and outside the strict perimeter of the installation. Such an approach should not lead, in particular, to the relocation of certain CO_2-intensive processes outside the plant. In the spirit of linking the EU ETS with other systems, it is also important that similar approaches are taken so that one system does not create a more favorable treatment than the other, at the expense of the environment. Whether benchmarking will eventually be used in the next phase of the ETS is by no means certain, but the expertise around it is certainly useful as governments seek to deliver the right economic signal to covered industrial sources.

Possibility and limitation of the use of diffusion ratios. For example, energy efficiency improvement potentials can be estimated by the use of diffusion ratios in the equation below.

$$P_{EET} = \Sigma \ P_{EEt} = \Sigma \ (DR_{Tt} - DR_{Ct}) \times EEI_t$$

P_{EET}: total energy efficiency improvement potentials; P_{EEt}: energy efficiency improvement potentials of each energy efficient technology (equipment/facility, etc); DR_{Tt}: target diffusion ratio of technology; DR_{Ct}: current diffusion ratio of technology; EEI_t: energy efficiency improvement by technology which is the difference between the processes with and without the technology.

The DR_{Tt} varies due to market, economic, and social factors such as actual priorities for introduction and energy cost. The EEI_t could be clearly defined because it is focused on a specific technology and a specific process, though it needs careful consideration of assumptions about existing technology it is replaced.

The author made an estimate of CO_2 emission reduction potentials of iron and steel industry in 2030 in past research, based on a survey of DR_{Ct} based on a survey of the relevant literature, interview with experts, and questionnaires, with assumption of 100% of DR_{Tt} (Tanaka *et al.* 2006). Although it requires further concrete surveys of DR_{Ct} and improvement of DR_{Tt} with considerations of factors stated above, it was one of the styles of assessing CO_2 reduction potentials which focused technology. Figure 2 shows results from the research.

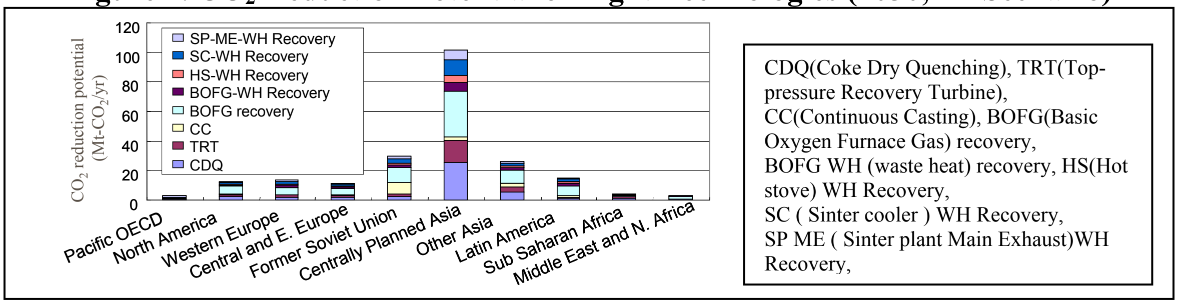
By application of the diffusion ratios as indices, there are advantages to making policy relevant discussion possible without the difficulties of boundary definitions, for example, the policy/framework which regulates action related to technology such as international co-operation for technology development and promoting application. Under the actual worldwide scheme, the Steel Task Force at the Asia-Pacific Partnership on Clean Development and Climate (AP6), the survey of technology installation in iron and steel industry investigated only on/off status of each technology. An initial survey was completed at the end of September 2006.[2] (AP6 2006)

As further work, for example, setting numerical targets for technology transfer using these diffusion ratio indices might be proposed. The strictness of the targets should be entrusted to political judgment, but it can be said that whether they are strict or not depends on the characteristics of the indices. In addition, those target settings should be carefully monitored in the context that the discussion connects to the proposition directly linked with individual technology. Originally, investments are focused to allow prioritized introduction of economically efficient technologies. The set of technology used in the market is influenced by national conditions and existing policy and framework of the respective country.

[2] The Steel Task Force will also review energy intensity by mid 2007 data to enable comparison after solving the problem of boundaries.

In addition to policy and regulation, various background conditions in the respective country affect technology diffusion – amount, quality and prices of natural resource and energy, market requirement and company strategy, for example. Installation of technologies has been optimized given the particular circumstances, such as energy price and availability, especially in industrialized countries.

Figure 2. CO_2 Reduction Potential of Eight Technologies (2030, B2 Scenario)



Source: Tanaka *et al*., 2006

One good example is coke dry quenching technology (CDQ). CDQ has been broadly recognized to be superior to conventional wet type quenching from an energy efficiency point of view, but, no consensus exists, even among members of the International Iron and Steel Institute (IISI, 2007) about the improvement of efficiency if CDQ were to replace conventional wet quenching in every region in the world. CDQ has been heavily employed in countries and regions with cold climate and/or high energy prices such as the former Soviet Union and Japan. The latest plants in China and Korea have installed state-of-art technologies including CDQ. Moreover, for China, there is a more practical and serious reason behind the choice, because it suffers from water scarcity. However, Europe has not introduced CDQ. There may be several reasons: (1) under certain plant-wide heat balances, it is believed that necessary skills to attain the target quality of coke have already been achieved without CDQ; (2) the new closed type of wet quenching is superior to CDQ. This is preferred under European environment regulations because it eliminates dust emissions; (3) there is less incentive for onsite heat application in cases such as power generation using byproducts gas and energy from waste heat recovery.

Taking the above into account, it can be seen that uniform target diffusion rates are difficult to set. It is the process of setting which is important, especially if it is to play an important role in future framework issues.

Influences of Boundary Definitions in the Assessment Using Energy Intensities

Energy consumption and energy intensity are often estimated based on different definitions of an industry's boundaries, which invalidates comparison. This section adopts several boundary definitions and illustrates the resulting differences in energy intensity measurements. We rely on actual energy data from the Japanese iron and steel industry.

Basic processes within a boundary shown in Figure 3 are: blast furnace and basic oxygen furnace for integrated plants or electric arc furnace; casting; and hot/cold rolling. In addition, I also show the coke oven, sintering plant, pelletising plant, recycling system, and oxygen plant which supply materials used in those basic processes. When boundary definitions are discussed, the accounting of these upstream processes becomes critical. Major upstream structure in each country differs. For instance, in the US oxygen is outsourced in most cases, but not in Japanese plants, where a chemical plant for oxygen exists.

It is difficult to set common boundaries, based on the possible combination of these components. Even in similar enterprises, plants will differ on the exact elements necessary for the process. Carrying out a comparative assessment in such circumstances is like weighing and comparing two baskets: one with apples and bananas, and another with apples and grapes.

Figure 3. Simplified Steel Making Scheme

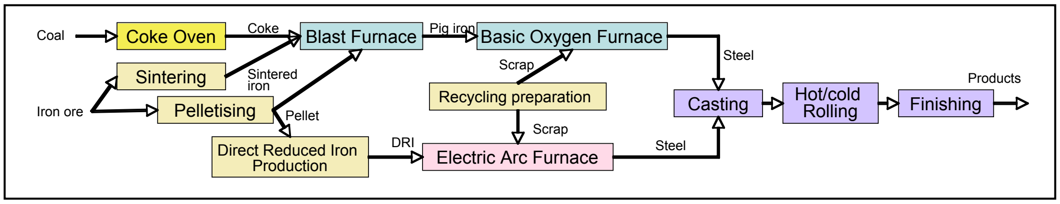
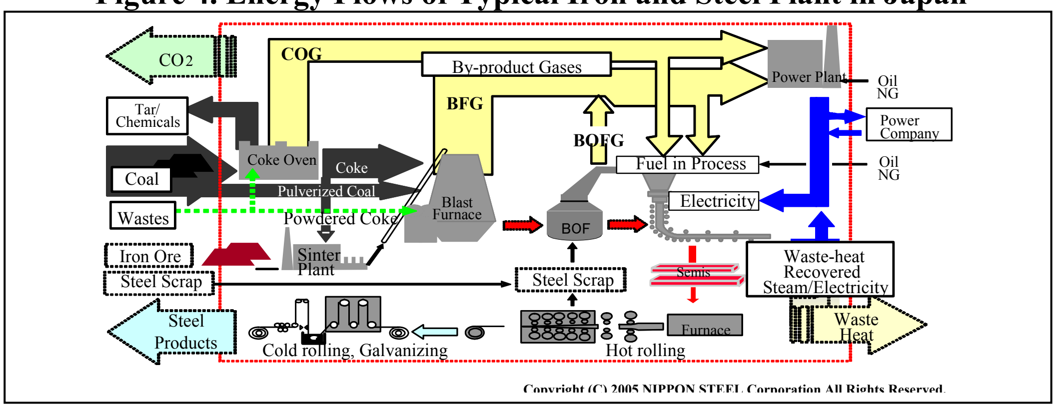


Figure 4. Energy Flows of Typical Iron and Steel Plant in Japan



Source: Nippon Steel, 2007

Moreover, as shown in Figure 4, heat and material are effectively exchanged and used in some cases between processes and/or beyond the mill. This of course depends on how broad the boundary is. Even with identical components, if a particular process is focused as a "small boundary", the means of how heat and material are transferred to the outside should be assessed.

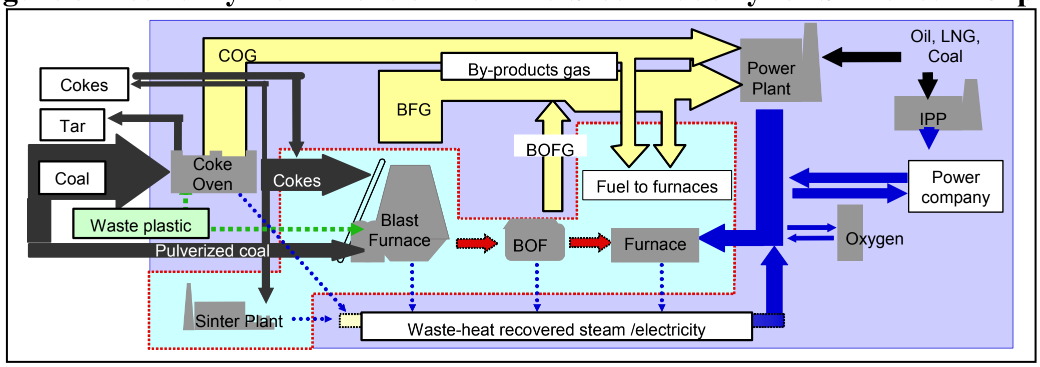
In most Japanese iron and steel plants, blast furnace gas (BFG) is collected and used to generate electricity, with the generation facility included in the plant's boundary. Some plants collect the unused waste heat and utilize it as much as possible in generation of electricity and other process. Each plant or company makes its own decisions about these operations. Heat application is optimized from whole plant level view in its specific environment. Where only the blast furnace is an assessment object, simply regarding energy consumed by the blast furnace as energy consumption causes misunderstanding. Input energy to blast furnace is not necessarily operated at minimum when the BFG is positively and usefully used in other processes. The energy passed to such other processes should be taken into account as deduction from energy consumption.

There are a few cases which supply products such as cast steel without hot and/or cold rolling processes. Almost 80% of total energy is consumed from coke ovens to casting, just before the hot rolling processes, and 90% is consumed before the cold rolling processes. Most mills have hot rolling processes. In addition, cold rolling deploys a wide range of processes depending on a variety of products. Evaluation boundary up to hot rolling process would be suitable.

Varieties of "Energy Efficiency" in Different Boundary Settings

Depending on policies, required formats of reporting are different. Here, we provide some energy statistics (Japan and IEA) that show the importance of a proper definition of boundaries, when measuring energy consumption in a given sector.

Figure 5. Boundary Definitions of Iron and Steel Industry for Statistics in Japan



Source: Nippon Steel, 2007. Note: blue colored part is the boundary definition for the final use of iron and steel in General Energy Statistics, and elements in violet colored part are sorted in energy conversion sectors.

The General Energy Statistics (GES). GES is a basic energy database with synthesized-statistics from various original economical official statistics sources, published by government (ANRE, 2005) It shows how different kinds of energy sources imported to or produced in Japan are converted and consumed and in which forms, to which sectors, and under what purposes. The energy conversion sector was detailed in specific rows in order that these statistics focus on final energy consumptions. In the iron and steel industry, each mill reports every month to the statistics bureau at METI, which aggregates for the database. Iron and steel industry includes on-site oxygen plant and energy conversion sectors inside, such as coke oven, onsite power plant, waste-heat recovery, and independent power producer (IPP). Energy consumption for producing oxygen from outside the iron and steel boundary is not counted. The energy from/to those energy conversion facilities/processes are separately summarized in the statistics. In order to get a clear picture of total energy consumption, waste plastic is also accounted as energy. Energy consumption by waste-heat recovered electricity use is calculated with 9.0MJ/kWh, while 3.6MJ/kWh is used for the final electricity consumption. Figure 5 shows schematic view of boundary definitions for GES.

Table 1. Total Energy Consumption of Iron and Steel Industry in Japan FY 2003

Energy consumption at energy conversion sectors which related to iron and steel industry				Final energy consumption
	On-site electricity	On-site steam	Coke production	
Energy consumption (PJ)	204	7	215	1750

Source: ANRE 2005 Note: The number for coke production is a summation of coking related data for iron and steel in the statistics: coking production; coking production at steel-chemical plant; and own use at coking process. .

Coke oven gas (COG) and BFG are byproduct gases regarded as fuel generated from processes and are deducted from the energy consumption amount. However, there are cases in which waste heat is used for power generation as well. When electricity use as final energy consumption amount is added up to total, the power generated by waste heat is also counted – in other words, this is *double counting*. Here the total energy consumptions related to iron and steel sector, which are reported at the latest GES (ANRE, 2005), are shown in Table 1. Numbers of on-site electricity and steam includes the amount of using waste-energy, 66PJ and 69PJ respectively, which has once been accounted as the energy used at prior processes, in its aggregation. Secondary energy use by waste heat recovery should be deducted from total value.

Report to Nippon Keidanren Voluntary Action Plan. There is a Voluntary Action Plan by the Japan Business Federation (Nippon Keidanren) in which iron and steel industry declares amounts of CO_2 emission reductions achieved by energy efficiency improvement (Keindanren, 1997). All energy input/output related to iron and steel making in the plant is taken into account within the boundary, including energy conversion sectors in the same fashion as GES, except for IPP. Energy consumption related to electricity use from grid power is calculated with 10.26MJ/kWh which is based on the value of the year 1990, in order to separate out the energy efficiency improvement in power generation from the energy efficiency efforts in the iron and steel sectors. Consequently, primary energy consumption from grid electricity is accounted by use of the coefficient. Energy consumption for oxygen from outside is also accounted, unlike in the case of GES.. Data was reported to Japan Iron and Steel Federation (JISF) from each company and JISF prepares a summary to submit to Keidanren as information for following up. Because of this different method for data collection from GES, the double counting of electricity produced by waste-heat recovery did not occur in the number of total energy consumption. Basically this boundary is defined as to clarify the challenges of iron and steel industry. Individual efforts by company/entity are not identified in the total value.

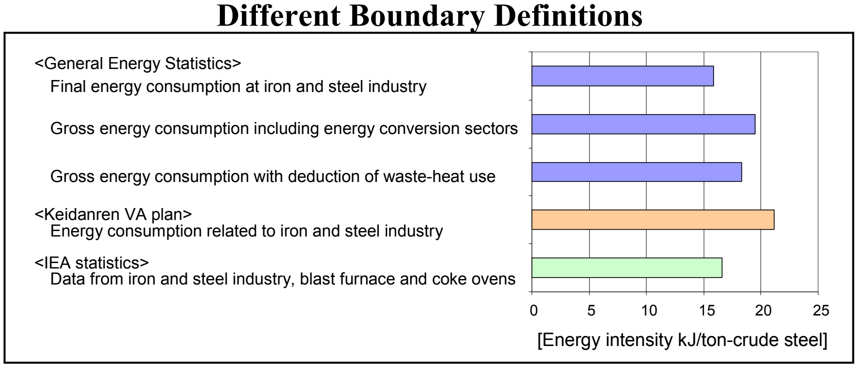
The periodical reports to the government concerning energy use at the factory level. Japanese iron and steel industry periodically reports to the METI based on the Law Concerning the Rational Use of Energy. The purpose of this report is to promote the energy conservation of the designated energy-using factory. The energy-saving results are measured using the energy intensity index. The aim of this report is not to have consistency with the former statistics which aim at grasping whole picture of energy balances in Japan. It is imposed to the plant/mill based on corporate definition, so that the report is not necessarily of the whole "iron and steel industry" and the covering range of boundary of each plan/mill differs greatly. For example, mill X might report a power plant within a boundary. On the other hand, mill Y might not report a power plant but a coke plant, though both mills have energy input *from or to* those plants. The energy intensity indices in this scheme are interesting to see the performance trend of each plan/mill, but hard to use for comparison among plants/mills.

Outside Japan: OECD/IEA energy statistics/balances. These are the statistics which have been used in various analyses because they represent a unique set of homogenous data for a wide range of countries. The energy balance is a presentation of the basic supply and demand data for all fuels in a common energy unit. These characteristics allow easy comparison between fuels. Here, electricity consumption is accounted for with its final, not primary energy equivalent, i.e. 3.6MJ/kWh.Japanese data is reported after rearrangement in the IEA format, based on data which was submitted for the General Energy Statistics (stated above). Coal and oil are reported in physical units, and gas is expressed in energy units. When converted to energy from physical unit, a set of conversion coefficients submitted by Japan is used for coal and crude oils: a common coefficient set by IEA is used for oil products. This results in some slight differences. As another issue, there is a possibility of double counting of waste heat energy for electricity using fuels which are not considered as fuel in the current IEA statistics. That will be a problem for such countries like Japan which utilizes waste heat as secondary energy, when electricity consumption in IEA statistics is added up with other fuel uses to get the total amount of energy consumption.

Comparison of results from boundary definitions. Figure 6 shows the results from five different boundary definitions for three data sources described above. The Keidanren boundary shows the highest value of energy consumption due to higher conversion coefficient of electricity and wider coverage in the boundary. On the other hand, consumption from IEA statistics seems low because items related to iron and steel are 'iron and steel industry, blast furnace and coke ovens' which are not as wide-ranging as the other two. When waste heat application is properly treated in the statistics, energy intensity becomes 1.2 kJ/ton-crude steel lower (differences between second and third blue lines in Figure 6), but it is relatively small compared to the differences in the coefficient. There will be more potentials of differences if waste heat increases from energy efficiency viewpoints in the near future.

The energy statistics published from these sources and, moreover, secondary indices derived from them– for example energy consumption per unit of output – are frequently used. In such a case, the evaluator would find that there are multiple values for energy consumption of iron and steel industry in Japan. Without a proper understanding of the background of these indices (such as boundary definitions), they would be confusing.

Figure 6. Energy Consumption Intensity of Iron and Steel Industry in Japan from Different Boundary Definitions



Source: JISF 2006, 2007; ANRE, 2005; IEA, 2007. Note: FY2003 for General Energy Statistics and Keidanren data. 2003 for IEA.

Conclusions

This paper focused on measuring industrial energy efficiency performance (MEEP), which takes various forms, purposes and applications. The beginning of the paper identified four kinds of MEEPs and clarifies the characteristics of each index, especially on energy intensity. The set of criteria for the influence of MEEPs in their application to policy framework were listed. For actual use of some MEEPs in future, the appropriateness of those measurements should be carefully considered against those criteria.

Boundary definition of a certain object is key for energy consumption measurement. The latter part of the paper, using the case of Japanese iron and steel industry, shows how boundary definitions influence the amount of energy consumption. There is more than a 25% difference between highest and lowest energy consumption as a result of differing boundary definitions. When energy consumption data is used for a political purpose, they are based on particular boundary setting needed for the policy. For any further assessment, the purpose behind the value should be considered.

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