Database for monitoring and evaluating government energy efficiency programs: a Japanese case

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Abstract

To monitor the governmental support for energy efficiency and assess its progress, it is vital to keep track of basic aspects of energy efficiency programs, such as expenditures, targeted sectors, supported technologies and energy savings achieved. However, because energy efficiency programs are so diverse and are sometimes managed by various departments of a government, it is often difficult even to make a comprehensive list of the programs and to identify the total amount of public funding for them, not to mention their energy savings. In this paper, the author makes a case study of Japanese energy efficiency programs using a unique database called "Governmental Program Review Sheets" (GPRS). GPRS covers all of the programs funded by the Japanese government, of which number amounts to around 5,000, and contains basic information such as objectives, outlines, expenditures, and outcomes of each program in a standardized format. GPRS was firstly published in 2010 by the government as an administrative reform activity, and since has been being amended annually. GPRS can be a powerful database for monitoring and evaluating energy efficiency programs. By using GPRS, the paper provides comprehensive quantification of public funding to support energy efficiency in Japan, as well as their cost per saved energy, and makes some policy recommendations. The paper also tries a comparative analysis between Japan, US and Europe concerning similarities and differences of public funding for energy efficiency based on related data from literature in other two regions. The paper concludes by discussing the usefulness of program database like GPRS for making and evaluating energy efficiency programs.

Introduction

As a mean to mitigate climate change, improve energy security and increase industrial competitiveness, many countries adopt various energy efficiency policies, ranging from regulatory, informative, economic, and voluntary instruments. Among them, government funding for energy efficiency, such as subsidies for energy efficient investments, is one of the most important policy instruments. Lack of capital and high discount rates in consumers' decision are considered to be major market barriers to cost-effective energy efficiency investments (DeCanio 1993, Jaffe & Stavins 1994). Removing them requires for example, among other options, investment subsidies or low interest rate loans by the government. Insufficient information on efficient energy use is also a major market barrier, which can be removed by an energy audit program, energy management program, educational campaigns, and behavioural programs supported by the government (Anderson & Newell 2004, Gillingham & Palmer 2014). Such subsidies and support programs all require public budgets. Thus, public funding for energy efficiency programs is a vital issue in making effective energy efficiency policy.

So, how much money is spent for energy efficiency programs? Which sectors and which measures are supported? Furthermore, how much energy is saved by those programs? These are very basic questions for effective policy-making, but are often difficult to answer. It is because a proper statistics on governmental spending is lacking in some cases, and in other

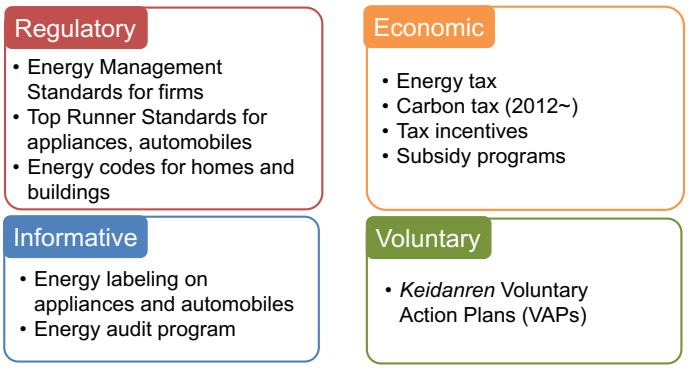

Figure 1. Major policy instruments for energy efficiency in Japan.

cases related data is fragmented, making a holistic analysis almost impossible.

This paper provides a comprehensive quantification of public funding to support energy efficiency in Japan, using unique database called "Governmental Program Review Sheets" (GPRS). GPRS covers all of the programs funded by the Japanese government, of which number amounts to around 5,000, and contains basic information such as objectives, outlines, expenditures, and outcomes of each program in a standardized format. GPRS was firstly published in 2010 by the government as an administrative reform activity, and since has been being amended annually. GPRS can be a powerful database for monitoring and evaluating energy efficiency programs. This paper analyses not only public expenditure for energy efficiency programs, but also their evaluation result, i.e. cost-effectiveness of programs.

In Japan, a range of policy instruments for energy efficiency have been implemented since 1980's (Figure 1). Some instruments, such as energy taxes, minimum efficiency performance standards for energy-consuming equipment, building codes, and energy audit programs, are more or less similar to those implemented in other developed countries. Major characteristics of Japanese policy when compared to other countries' include:

- Since 1979, Japan has a mandatory regulation to install energy management systems for middle- to large- companies in industrial and commercial sectors (Kimura & Noda 2014);
- Since 1997, the major instrument for energy-intensive industry is the *Keidanren* Voluntary Action Plan (Wakabayashi 2013, Thollander et al. 2015);
- While Japan does not have an energy efficiency obligation scheme for energy companies, subsidy programs by the government is a major instrument in the country's energy efficiency policy framework, spending almost EUR 4 billion per year, as is shown in this paper.

In spite of such importance, governmental spending for energy efficiency so far has received little interest in the literature. This paper is the first to give a holistic analysis on the total costs, portfolio, and energy savings of the Japanese energy efficiency programs.

The rest of the paper is structured as follows. Section 2 explains GPRS database which we used for the analysis. By using the database, section 3 analyses public spending for energy efficiency programs in Japan, followed by analyse of evaluation data in GPRS (Section 4). Based on analyses in Section 3 and 4, Section 5 makes a critical assessment of Japanese energy efficiency programs. Section 6 tries a comparison between Japan, US and Europe.

In this paper, governmental spending is expressed in nominal terms, and Japanese Yen (JPY) is converted to Euro (EUR) by an exchange rate of 130 JPY/Euro, unless otherwise stated. The spending (program cost) in this paper does not mean the budgeted figure but the actual spending, and includes all the spending by a program, i.e. not only subsidies but also various administration costs are included[1].

Data

GPRS DATABASE

Governmental Program Review was started in 2009 by the former Democratic Party (DP) government, who took the administration from the Liberal Democratic Party (LDP) in 2009, as a regulatory reform activity that dealt with all public policies (not only energy efficiency or climate policies). While the review originally targeted about 500 programs that LDP started and that DP wanted to turn down, it was expanded in 2010 to include all the programs administered by the government, whose number amounts to about 5,000. Even after LDP took over the administration again in 2012, it was decided to continue with some modifications (Council for Regulatory Reform 2013).

In each of the review, programs implemented a year earlier are reviewed. The major material used in the review is Government Program Review Sheets (GPRS), a set of summary sheets made for each program containing basic information of the program, such as the title, purpose, outline of activity, quantitative targets and results achieved, personnel and division of the ministry in charge, self-evaluation by the division, recommendations from the evaluation division, budget, actual spending, money flow, major contractors, and so on. Each set of GPRS is normally about three to 10 pages long. GPRS is prepared by a division which administers the program, and is checked and reviewed by an evaluation division of the ministry.

The subject of this paper is all the programs that were implemented from 2009 to 2014 and reviewed a year after i.e. from 2010 to 2015. Programs included in the analysis were confined to those administered by three ministries, namely Ministry of Economics, Trade and Industry (METI), Ministry of Environment (MoE), and Ministry of Land, Infrastructure, Transport and Tourism (MLIT), because they are the major ministries that administer programs related to climate and energy. The three ministries filled out 9,055 sheets of GPRS during the six years. By combining the sheets for the same, continued programs, 3,082 unique programs were identified. Among them, 600 programs were considered to be related to climate change mitigation. Those programs were identified firstly by searching keywords, such as climate change, carbon emission reduction, energy efficiency, energy conservation, renewable energy, cleaner coal, biomass, smart community, etc. in their title, pur-

1. Note that the labour cost of employees of each ministry is not included in the spending reported in GPRS, because it is allocated as a general expenditure by each ministry so is not tied to a specific program.

pose and outline descriptions. The programs containing such keywords were then checked one by one by the author if their major purpose was climate change mitigation or more specific technology development and/or deployment for that purpose. Programs related to nuclear energy, forest sink, and earth observation were excluded. The purpose of scoping climate related programs from a broader perspective is to understand the relative importance of energy efficiency in the public spending for climate change mitigation. The total cost for climate change mitigation programs was EUR 5,9 billion over 6 years.

It should be noted that, while GPRS includes all of the governmental programs that have budget expenditures, i.e. all subsidy programs, it does not include any tax incentive program, because tax incentives are "off-budget" in Japan, i.e. it is a reduction of tax revenue and does not involve spending of the government. In Japan there are fairly large tax incentive programs going on for energy efficiency investments, such as Tax Reduction Program for Green Investments and Eco-car Tax Reduction Program. Actual reductions of tax revenue by these incentive programs are only partially known[2], and are estimated to be more than EUR 6 billion in 2013, which is about 6 times larger than the annual public spending for the energy & climate programs (EUR 5,9 billion over 6 years) (MoF 2016). It should also be noted that financial support for renewable energy adoption by Feed-in Tariff Law (FIT), which in 2015 exceeded EUR 11 billion and is expected to increase, is not included in GPRS. The fact that GPRS does not include such large implicit subsidies is a big limitation of the database and of this paper. In addition, funding by regional and local governments are not included in GPRS either, though their funding might not be so large compared to that of the central government.

CLASSIFICATION OF PROGRAMS

600 programs for climate change mitigation during 2009 to 2014 are classified by two perspectives as shown below. The categorizations are based on existing ones such as IEA (2016) and MoE (2015a), as well as the actual prominence of particular groups of programs in the portfolio. In case a program can fit into several categories, it was classified as such, and its budget were divided equally to all the categories it belongs[3].

1. By technology: A program was classified according to the technology it supports, either as energy efficiency, renewable energy, cleaner coal, smart community, battery technology, cross-cutting program, and others. Programs for Energy efficiency were further classified by sub-categories; residential sector, commercial sector, industrial sector, transport sector, power sector, distributed generation, material/cross-cutting technologies, and others.
2. By type of support: A program was classified according to the type of governmental support, either as R&D subsidy, technology demonstration subsidy, investment subsidy, energy audit and management support, education and awareness, purchase of carbon credits, and others.

Spending for energy efficiency programs in Japan

In this section spending for energy efficiency programs is quantified by using GPRS database. Figure 2 shows the trend of the total costs of 600 programs related to climate change mitigation from 2009 to 2014. The costs are shown by technology supported, while the costs of several programs with the largest budgets are shown separately for easier understanding of the base trend. It clearly shows a large fluctuation due to giant programs, such as "Eco-Car" and two "Eco-Point Programs", which were all started as a response to the financial crisis after 2008. "Eco-Car Subsidy Program"[4] is so far the biggest investment subsidy program for energy efficiency in Japan. In the program purchasers of automobiles and trucks that exceed the national fuel economy standards could receive fixed subsidies, e.g. a EUR 770 subsidy for an automobile. The total cost of the program from 2009 to 2014 was EUR 7.4 billion. "Eco-Point Program for Appliances" provided investment subsidies to households when purchasing air-conditioners, refrigerators, and TVs, while "Eco-Point Program for Houses" provided subsidies for new construction or renovation of residential houses. Total costs of the appliance program was EUR 3.7 billion from 2009 to 2010, while costs of the house program was EUR 2.9 billion from 2009 to 2011. The total costs of the three "Eco" programs amount to EUR 14 billion, a 75 % of the total costs for climate change mitigation programs in the six years. Spending for renewable energy and electricity-saving related programs that were appropriated as Reconstruction programs after the Great East Japan Earth Quake and Tsunami in 2011 is also noticeable. The remaining spending is basically constant at about EUR 3 billion per year, about 50 % and 30 % of which is spent for energy efficiency and renewable energy, respectively.

Figure 3 shows spending for energy efficiency programs by type of governmental support. The costs for giant programs, all of which are investment subsidies, are shown separately again. A dominant portion of the total spending is for investment subsidies; it is 85 % when Eco-Car and Eco-Point programs are included, and is 60 % even when those programs are excluded. On the other hand, R&D and demonstration programs receive about EUR 500 million per year constantly. Major R&D and demonstration programs include "Program for innovative energy efficiency technologies", which supports various kinds of innovative energy efficiency technologies, and "International demonstration program for energy efficient technologies and systems", which supports demonstration projects in other countries concerning pre-market energy efficient technologies and systems developed by Japanese manufactures.

Figure 4 shows the same program costs by targeted sector. Again, due to the large shares of Eco-Car and Eco-Point programs, the portfolio of energy efficiency program spending

2. Unlike some western countries, such as US, Japan do not have a comprehensive report on the revenue reductions by tax incentives. In 2011 Ministry of Finance started an annual survey on the actual implementation of tax incentive measures, but it covers corporate tax only (MoF 2016).

3. When a program of EUR 10 million supports energy efficient technology as well as renewable energy technology, then the program was classified as both of the categories. As for the budget a half of it, EUR 5 million, was considered to be for energy efficient technology, while another EUR 5 million was for renewable energy technology.

4. This is a different program from Eco-car Tax Reduction Program mentioned in the previous section.

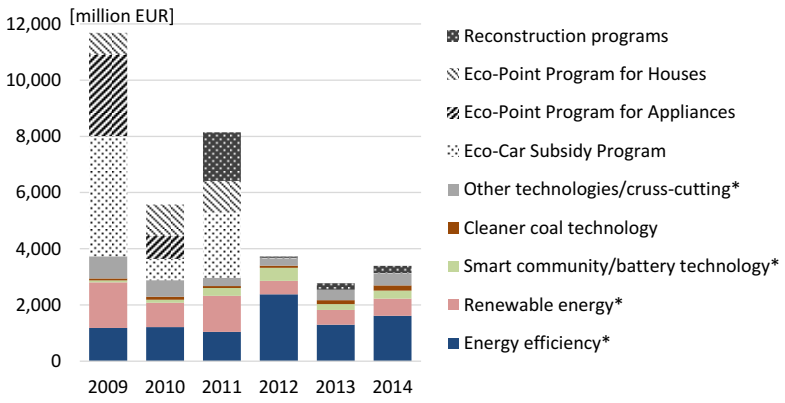

*Figure 2. Program spending related to climate change mitigation in Japan, 2009 2014. Source: author's estimation based on GPRS database. * Excluding spending for the programs presented separately in the figure.*

is skewed toward residential and transport sectors. Shares of spending for residential and transport programs are 33 % and 41 % respectively, leaving only 12 % for commercial and industry programs. On the other hand, when the three programs were excluded, the sectoral shares become more evenly and all range from 10 % to 20 %.

In Figure 4, a large increase of spending for transport sector in 2012 is indicated, which also relates to the increase of energy efficiency spending in 2012 (see Figures 2 and 3). This is because of the Program for building infrastructure for powering next-generation vehicles, which supported building battery-charging stations for EVs and PHEVs. It was started as an emergency economic policy in 2012 with the budget of EUR 773 billion.

Evaluating the cost-effectiveness of programs

GPRS contains data concerning the outcome of the program, i.e. quantitative target and actual achievement. By using the data, this section analyses how properly outcome of the programs, especially energy and CO_2 emission savings, is evaluated. For some programs that have data on energy and/or CO_2 emission savings achieved, their cost-effectiveness is also estimated. The analysis is focused on programs categorized as investment subsidies, because they usually have direct energy and CO_2 emission savings that should be reported in GPRS database. In addition, due to the resource constraints, the subject of the analysis was limited to 80 programs that had the largest budgets. The 80 programs cover 99 % of the 176 investment subsidy programs in terms of program costs (EUR 4,309 out of 4,356 million per year), so would reflect the total trend.

HOW PROGRAMS ARE EVALUATED (OR NOT)

Concerning the 80 investment subsidy programs, type of evaluation data reported in GPRS was checked and summarized in Table 1. Seven programs had no information on program results. Another 22, including the biggest "Eco-Car Subsidy Program", had the number of installations or projects supported by them, but no data by which one can analyse energy or CO_2 emission saved were reported. On the other hand, 34 programs had estimates of savings achieved. Of the 40 energy efficiency programs, 15 had data on energy and/or CO_2 emission saved, and the others had only number of installations or market share of the supported technology. Among them, as for the effectiveness of "Eco-Point Programs" for appliances and houses, CO_2 emission saving data, such as "approximately 980,000 tCO_2 per year (for Appliances Program in FY2009) and "approximately 200,000 tCO_2 per year" (for Houses Program in FY2010), are reported, although their estimation source or method were not shown.

COST-EFFECTIVENESS OF SELECTED PROGRAMS

By using the data of the 34 programs identified in Table 1, cost per ton of CO_2 saved for each program was estimated by the following method: program costs incurred at the government side divided by lifetime savings of CO_2 emission [EUR/tCO_2]. This was the dominant method when cost-effectiveness of a program is estimated in GPRS. When there was data on energy and/or CO_2 emission savings on annual basis but no cost-effectiveness figure using the above method, then it was estimated by the same method, assuming lifetime of the measure as 10 to 15 years, depending on the measure. This is what the evaluation literature in US calls "the program administrator cost", and not "the total resource cost", which also takes the participants' cost and the avoided cost into consideration (Friedrich et al. 2009, Billingsley et al. 2014)[5]. A program cost here was consisted mainly of subsidies to participants, but also of all the other administration costs incurred at the government side but excluding the labour costs of government officers.

The result is presented in Figure 5. It contains not only energy efficiency programs (shown by grey bars) but also other climate related programs (white bars) for comparison. Some programs shows high cost-effectiveness, being less than EUR 50/tCO_2. The lowest cost program is "Low-interest loans" program, which is highly efficient from the government point of view because it only provides interest subsidy, i.e. the difference between the low-interest rate and the market rate. Some

5. In the literature, a popular metric for analysing cost-effectiveness of energy efficiency programs is the levelized cost of lifetime energy savings. which is the cost of acquiring energy savings that accrue over the lifetime of the actions taken through a program, amortised over the lifetime of the actions (Billingsley et al. 2014). None of the estimations of savings reported in GPRS, however, used this annualized approach, and instead they simply used the program cost and divided it by lifetime savings. This paper applied the same method.

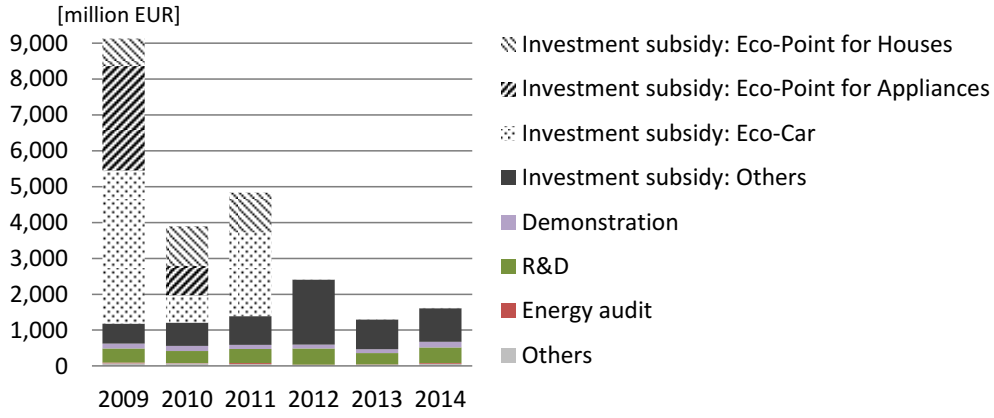

Figure 3. Program spending for energy efficiency in Japan by type of support. Source: author's estimation based on GPRS database. Note: the figure only includes spending of energy efficiency programs, a part of the spending for climate change mitigation programs as presented in Figure 2.

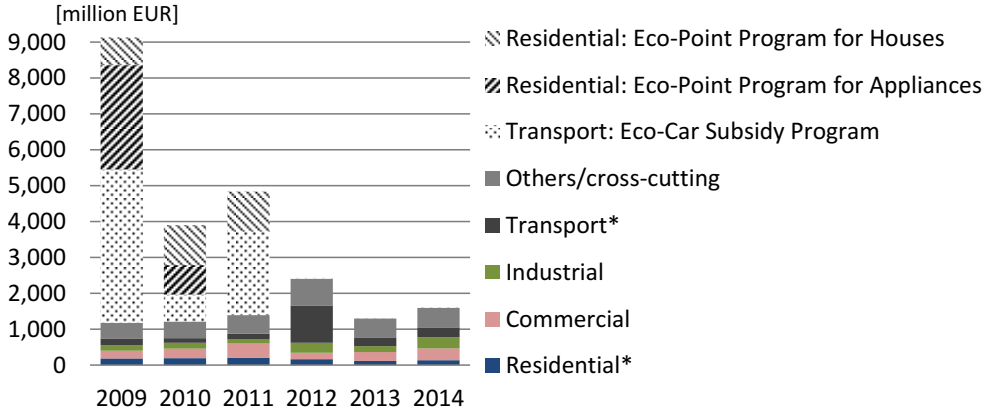

*Figure 4. Program spending for energy efficiency in Japan by target sector. Source: author's estimation based on GPRS database. * Excluding spending for the three programs presented separately in the figure.*

Table 1. How the 80 investment subsidy programs are evaluated in GPRS database.

Type of evaluation data reported in GPRS	No. of programs	(%)
Energy/CO_2 emission saved or energy produced (by renewables) e.g. Energy saved [kLcoe], CO_2 emission saved [tCO_2], Cost per CO_2 emission saved [EUR/tCO_2], biomass energy produced [kL]	34	(43 %)
Capacity installed e.g. Renewable power generation capacity [kW]	12	(15 %)
Number of installations/projects	22	(28 %)
Others e.g. Market share of the supported technology	5	(6 %)
No data reported (i.e. blank)	7	(9 %)
Total	80	(100 %)

of the other programs with the lowest cost per saved CO_2 include energy efficiency programs that targeted cost-effective potentials, such as "Subsidy for energy efficient investments in commercial and industrial sectors". On the other hand, other programs are estimated to be very expensive, being more than EUR 1,000/tCO_2. These are even higher than the social cost of carbon estimated in the literature, which typically rages between USD 10 to 200 (e.g. US Interagency Working Group on Social Cost of Carbon 2015).

Concerning the cost-effectiveness of energy efficiency programs, EUR 50, 100, and 500/tCO_2 could be roughly converted to 2.5, 5 and 25 cent EUR/kWh, respectively, by assuming all of the savings come from electricity and using the average fuel mix in Japan (0,5 kg CO_2/kWh). Furthermore, assuming that the participant cost is approximately twice as high as the program administrator cost, EUR 2.5 cent/kWh of the program administrator cost of would correspond to the total resource cost of EUR 7.5 cent/kWh. This converted numbers and Figure 5 indicate that many energy efficiency programs in Figure 5 have similar costs per kWh saved compared to the avoided cost, which is about EUR 10 cent/kWh in Japan, while other programs costs too much to justify on the basis of direct energy savings.

It should be noted that the cost-effectiveness shown in Figure 5 is solely based on the data reported in GPRS database, and the method to estimate energy and/or CO_2 emission savings was not described in detail in GPRS database. There are some cases where estimations of savings seemed to draw on detailed ex-post evaluation reports published elsewhere by these ministries, such as MoE (2015b), but in most cases they were based on simple engineering estimations. Therefore the accuracy of estimations of savings varies a lot among programs. Taking an example of "Eco-Point Program for Appliances", the cost-effectiveness estimation (EUR 244/tCO_2) is based on the estimation of annual savings of 2.7 million tCO_2, which appears in GPRS and is based on the ministries' estimate (MoE, METI and MIC 2011). However, their estimation is strongly criticised by Board of Audit of Japan as overestimation due to an inappropriate baseline setting (Board of Audit 2012). Board of Audit made a re-evaluation and estimated the annual savings as 0.2 million tCO_2, a 1/10 of the original estimate[6].

It should also be noted that there are uncertainties concerning lifetime of saving measures. In addition, none of the saving estimations considered free-rider effects, as will be discussed in detail in the next section. Because of those limitations and uncertainties in estimations, Figure 5 should be viewed as an illustration of the magnitude and variety of the program costs.

Critical assessment of Japanese energy efficiency programs

While some of the public programs for energy and climate in Japan have made a great contribution in reducing energy consumption and carbon emission, there are a number of concerns with regard to the portfolio, evaluation method, and cost-effectiveness.

GIANT PROGRAMS WITHOUT EVALUATION

Only a handful of programs consume a huge portion of the total spending for energy efficiency (see Figure 3 and 4). Nonetheless, they received no detailed evaluation on their outcome. "Eco-Car Subsidy Program" is a good example. It is so far the biggest subsidy program in this field in Japan, but has reported only the number of subsidized vehicles in GPRS. Nor is there any other evaluation conducted for this program so far, to the author's knowledge. Reported savings of "Eco-Point Program for Appliances" was criticised as overestimation, as described in the former section (Board of Audit 2012), which also raises doubt to the reported savings of "Eco-Point Program for Houses", especially because there is no source or method of the estimation described or no other evaluation report made public[7]. Considering their large budgets, these giant programs should receive more detailed evaluation on their achieved savings.

It might be true that the primary objective of these programs is economic stimulation rather than energy conservation, so that they should not be evaluated solely on the basis of the direct saving of energy or CO_2 emission. However, even if they were economic programs rather than efficiency programs, they should be designed carefully to give proper incentives for consumers to save energy and CO_2 emission, and should be evaluated from that perspective. Otherwise, such subsidy programs, even when they accelerate adoption of energy efficient technologies, can increase energy consumption due to rebound effects (Davis et al. 2014, Alberini et al. 2016). Because the budget of economic programs tends to be larger than typical energy efficiency programs, the impact would also be considerable when rebound effects become salient. Thus, evaluation is very important even for those programs whose primary objective is other than energy efficiency.

BIAS FOR TECHNOLOGICAL SOLUTIONS

The current portfolio of energy efficiency programs are clearly focused toward investment subsidies, as shown by Figure 4. On the other hand, non-technological measures, such as energy audit, energy management, and behavioural change, have received very limited amount of budgets so far, being less than 1 % of the total budgets. Improving energy efficiency requires not only innovative technologies but also management of them. Removing various market barriers involve organizational and human factors. Thus, there is a room to consider increased funding toward non-technological solutions.

6. Eco-Point Program for Appliances provided subsidies to householfs who replaced old air-conditioners, refrigerators, or televisions with new models with high efficiency grades. To estimate the energy savings by this program, MoE, METI and MIC (2011) considered the energy consumed by old appliances that are replaced by the program could be the baseline, whereas Board of Audit (2012) considered the average energy consumption of appliances that would have been purchased without the program should be, which is much smaller than that of old, replaced ones. It should also be noted that the baseline used in the estimation by MoE, METI and MIC (2011) was not made public until the investigation by Board of Audit (2012).

7. This is not always the case. Indeed, some programs did receive fairly detailed ex-post evaluations. Such examples include MoE (2015b) and Sustainable open Innovation Initiative (SII 2015). However, the three gitant programs did not.

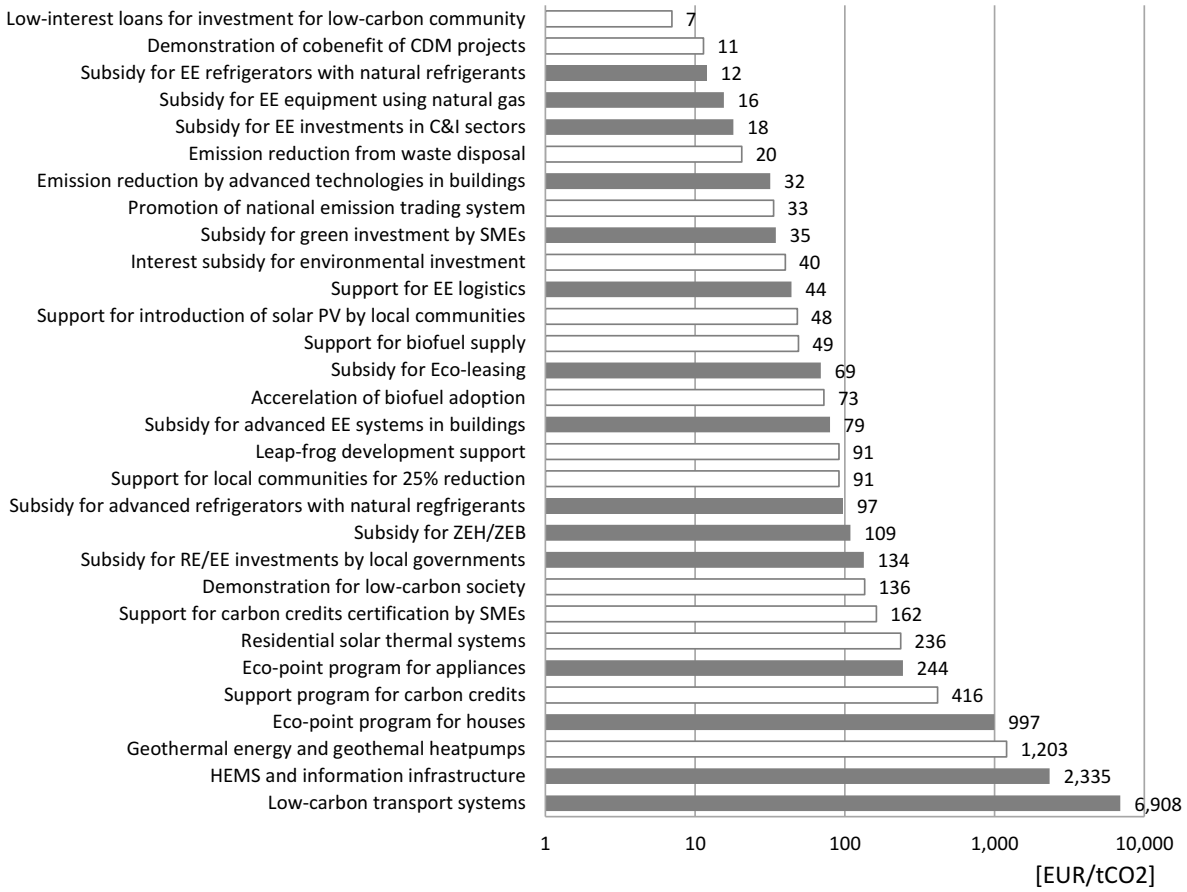

Figure 5. Program administrator cost per ton of saved CO_2 emission of selected subsidy programs in Japan. Notes: Log scale. Programs with gray bars are energy efficient programs, while those with white bars are other climate-related programs. Program names are author's tentative translation. Abbreviations: CDM (Clean Development Mechanism), EE (energy efficient), RE (renewable energy), C&I (commercial and industrial), SMEs (small- and medium-sized enterprises), ZEH (Zero-energy homes), ZEB (Zero energy buildings), HEMS (home energy management systems). Source: author's estimation based on GPRS database.

LACK OF EVALUATION OF ADDITIONALITY

As Figure 6 shows, energy and/or carbon savings are estimated for some of the energy efficiency programs. The government is also making increasing effort for policy evaluation through various channels, and Board of Audit (2012) is a good example of that. However, the methodology of energy efficiency program evaluation is not well established in Japan. Particularly, the lack of perspective of additionality, or free ridership, would be a problem. Free riders here mean consumers who received subsidies but would have done the same energy efficiency measures even without it. Existing estimates about investment subsidy programs for energy efficiency in Japan show, by using a survey, the rate of free ridership around 50 % (Kimura & Ofuji 2014). Free ridership which ranges from 40 to 85 % is also reported in Europe (Nauleau 2014). While it is impossible to eliminate free riders in subsidy programs, it is important to estimate free ridership (or additionality) ex-post in order to avoid overestimation of savings and to improve program design to minimize free riders.

LOW COST-EFFICIENCY OF SOME PROGRAMS

While it is true that many of the energy efficiency programs evaluated in Figure 5 have good cost-effectiveness, being less than EUR 100/tCO_2 (which approximates 5 cent EUR/kWh), several programs have fairly bad cost-effectiveness. When other programs that are not included in Figure 5 due to lack of data are evaluated, the number of programs with unfavourable cost-effectiveness would increase. Taking account of additionality would also worsen cost-effectiveness, because an additionality of 50 %, for example, would decrease the saving by half and double the cost per energy saved.

Comparable data in US and Europe

In this section data on public funding for energy efficiency programs in US and Europe that are comparable to Japanese data are presented. The three regions are more or less comparable in size of population, economic activity, and energy consumption[8]. Some implications from regional comparison are briefly discussed.

8. As for Japan, US, and EU-28, population is 127, 322, and 509 million (2015); GDP is 3,611, 13,677, and 14,635 billion EUR (2015 PPP); gross inland energy consumption is 455, 2,188, and 1,667 million toe, respectively (Eurostat 2016).

US

In the US, while the federal government bears costs for R&D and weatherization for low-income households, the majority of funding for energy efficiency programs is made by utility companies at the state level, which is in many cases required by state regulation called Energy Efficiency Resource Standards (EERS). Because the program spending by utility companies far exceeds the spending by the federal government, Figure 6 presents spending both at the federal and state levels. Total spending at the federal and state level amounts to EUR 6 to 7 billion in recent years. Direct Install and Rebates dominate a large share. When combined with Building/Home Performance and Weatherization, those technological subsidies make up about 60 % of the total energy efficiency spending. On the other hand, spending for organizational and behavioural support is small but have also noticeable shares in the portfolio. For example, Behaviour Change and Feedback programs in 2015 received EUR 116 million or 2 % of the total spending for energy efficiency programs. Furthermore, On-site Audit/ Assessment, Retro-Commissioning, and Energy Management Assistance together in 2015 received EUR 227 million, which is 4 % of the total.

EU

To the author's knowledge Janeiro et al. (2016) is the only report that compiled public funding for energy efficiency at the EU level with some details. Figure 7 presents identified public funding for energy efficiency in EU28. About 80 % of the total spending went to building sector. It also shows that loans are popular policy instrument in EU, of which more than half goes to the German KfW programs of low-interest loans for energy efficient construction and renovation. It should be noted, however, it is not clear in Janeiro et al. (2016) whether spending for "loans" represents the public cost, i.e. the subsidy to cover the difference between low-interest rates and the market rates, or the total amounts of the loans which would be refunded later. In addition, although they are categorized as soft loans due to data constrain, some part of it might be actually grants (Janeiro et al. 2016, p. 20).

It should also be noted that the data is subject to large uncertainties due to the difficulties in compiling multi-national data. The major data source of the study is 2014 National Energy Efficiency Action plans (NEEAPs) and 2015 Annual Reports in accordance with the requirement of the Energy Efficiency Directive, which do not necessarily provide a complete picture of public spending for energy efficiency in each member state. Moreover, it does not include public spending for energy efficiency RD&D activities. Nor does it include European funding, such as EU Structural Funds. Furthermore, unlike the US data above, which includes spending by energy utility companies when regulated by supplier obligations, the EU data does not include program spending by utility companies, although many member states adopt Energy Efficiency Obligations (EEOs). Because the total cost of EEO schemes in UK and Italy is estimated to be around EUR 700 million to 1 billion per year for each (ENSPOL 2015), combining the EEO costs would largely change the portfolio shown in Figure 7. Considering such incompleteness of the survey, Janeiro et al. (2016) stressed that the "results should be interpreted as the low-end estimations of public funding available." (Janeiro et al. 2016, p. 2)

DISCUSSION FROM COMPARISONS

Direct comparison of energy efficiency funding of the three regions is extremely difficult due to data constrain and the difference of methods each region adopted to compile data. It seems that US has the most comprehensive data, but each region's data is not perfect and should be refined so that a more meaningful comparison among nations could be done. Of particular importance would be to combine different

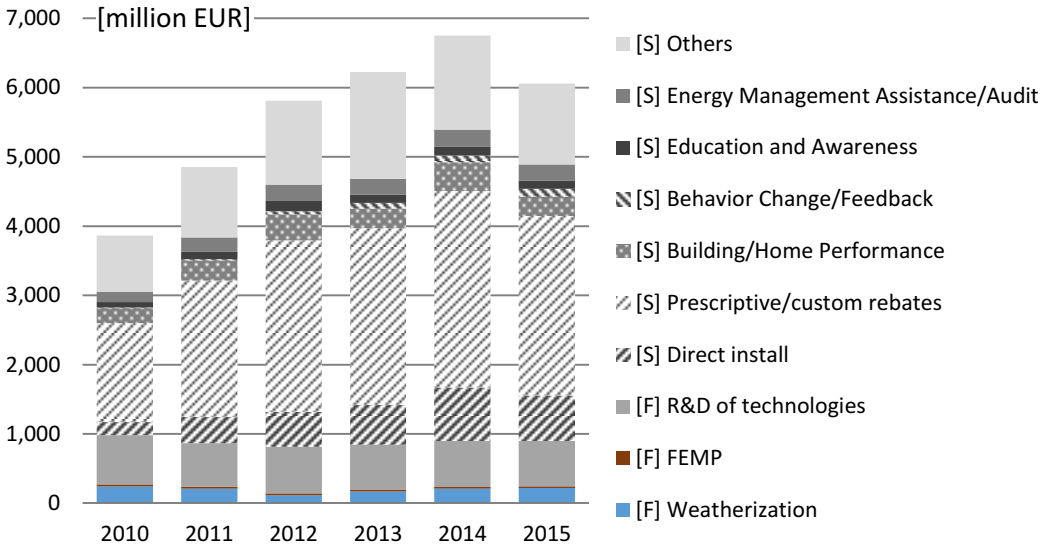

Figure 6. Energy efficiency program spending at the federal and state levels in the US, 2010–2015. [F] and [S] denote the federal government's and utilities' spending, respectively. Source: DOE (2011, 2012, 2013, 2014, 2015, 2016) and E Source (2016). USD is converted to EUR by an exchange rate of 0.9 EUR/USD.

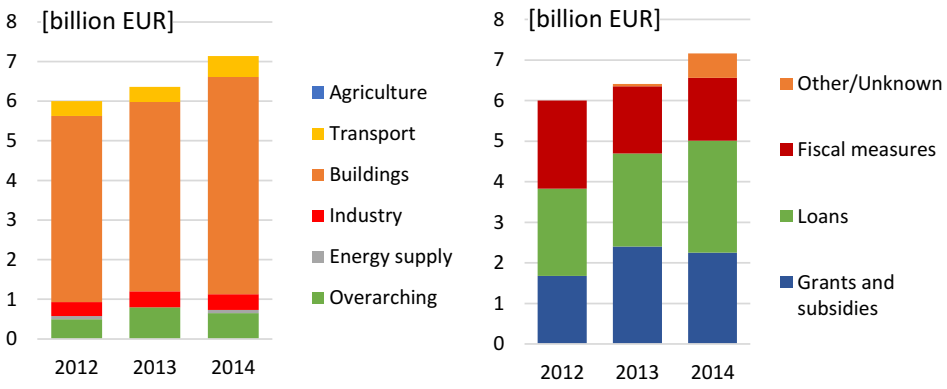

Figure 7. Public spending for energy efficiency by EU-28 by targeted sector (left) and by type of policy instrument applied (right), 2012 2014. Note: It is not clear whether "Loans" is the public cost, i.e. the subsidy to cover the difference between low-interest rates and the market rates, or the total amounts of the loans which would be refunded later. Source: Janeiro et al. (2016).

kinds of data sources, such as government budgets, fiscal incentives that are off-budget, and utility spending for energy efficiency spurred by EEO or EERS schemes. Otherwise one fails to get the full picture of the public spending for energy efficiency. In this regard GPRS of Japan has a serious limitation because it only includes governmental spending, although its comprehensiveness concerning governmental spending is a great strength.

From the comparison with the Japanese and US portfolio, a focus toward technological solutions in Japan became evident again. There is no behaviour change/feedback program for households in Japan. Nor is there a dedicated program that assist companies establish energy management systems, such as strategic energy management programs (SEM) in US (see e.g. CEE 2014). There are long-standing energy audit programs, but their budgets are much smaller (about EUR 8 million per year). This difference of focus might be partly because the energy prices in Japan are much higher than in US, and because Japan has a mandatory regulation to install energy management systems for middle to large companies in industrial and commercial sectors (Kimura & Noda 2014). Even if such factors might reduce the necessity for additional support programs, there seems to be a room to consider increased public funding for such behavioural/organizational programs, in addition to the existing energy management regulation[9].

While this paper compared funding for energy efficiency programs, it would be even more useful to compare the results of the programs, i.e. energy savings and cost per saved energy. However, a great care would be needed to compare such data, because methods, scope, and assumptions used to estimate energy savings and program costs may vary among regions. Although there is some data available, such as Friedrich et al. (2009) and Billingsley et al. (2014), this is beyond the scope of this paper and would be a topic for future research.

9. The combination of regulatory and supportive approaches is important because the Japanese experience shows that, only with regulation, many small- and medium-sized companies try to comply with the regulation only by paperworks, not by tangible energy management actions, due to lack of organizational capability, which might be overcome by a support program (Kimura & Noda 2014).

Concluding remarks

Since public funding for energy efficiency programs is an important policy instrument to remove market barriers and to spur private investments in energy efficiency, it is a very basic policy challenge to make a holistic assessment of the total spending, portfolio, and outcome of related programs. A comprehensive database of governmental programs, like GPRS in Japan, would enable such assessment and help identify areas that need to be improved, as this paper demonstrated using the case of Japanese programs. This process would be further facilitated when such data is compared internationally, because national comparisons shed light on strength and weakness of each nation's policy framework. Note that such comparison is, however, no easy task and requires very careful considerations as to how the data should be compared and interpreted. When comparing the program cost data, the scope is critically important. GPRS database in Japan does not contain implicit spending by tax incentive programs, whereas EU data collected by Janeiro et al. (2016) does, for example. On the other hand, the EU data does not include costs to meet supplier obligations, while the US data by E Source is dedicated for compiling such data. This indicates that a single database like GPRS is seldom sufficient for meaningful comparison, and thus combining several data sources would be needed to have a common ground for international comparison. Likewise, having the same methods for estimating energy and/or CO_2 emission savings is of critical importance when comparing programs, especially among different regions. In this respect GPRS database has a serious problem because it lacks detailed information on the methods employed to estimate program outcome. In addition issues such as free ridership and lifetime of measures are also major sources of uncertainties in estimating energy saving in the case of Japanese GPRS database.

In the case of Japan, GPRS database was developed not only for climate and energy efficiency, but for the regulatory reforms and policy evaluation in a much broader context. However, it would also be possible to develop a similar database for climate and energy programs in their specific context, because there are some occasions where related data is gathered for establishing a similar review process. For example, under the

Paris Agreement, nations submit commitments called Intended Nationally Determined Contributions (INDC) whose progress will be reviewed every five years. For this, many nations would establish a process within which it monitors the progress periodically. Another example in Europe would be the process to prepare and review the National Energy Efficiency Action Plans (NEEAPs) and annual reports. In those processes, various data on energy and climate programs such as spending, targets and outcomes are collected and compiled after all. If so, it would be efficient and feasible to establish a common framework and develop database on programs for energy and climate. GPRS in Japan could be a basic model for that. Taking an example of Japan, the government established "Plan for Global Warming Countermeasures" in May 2016 (MoE 2016) to achieve its INDC target to reduce greenhouse gas emissions by 26 % by 2030 compared to the 2013 level. Although the plan says that the progress is going to be monitored and reviewed every year, it is assumed that only the national or sectoral progress in terms of emissions or deployment status of measures will be monitored, and the impact or contribution of public programs compiled in the plan itself will not. Linking GPRS database with the monitoring process of the plan would be highly valuable because that would not only provide a reliable and useful source of program data but would also enable periodic evaluation of all the programs that are needed to achieve the national reduction target. Therefore, linking such a database as GPRS and a monitoring process of climate and energy plans would greatly enhance the understanding and improvement of energy and climate programs in each nation.

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