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The National Programs for Development of Energy Technologies

Osamu Kimura*

Central Research Institute of Electric Power Industry

Abstract:

Japan has promoted development of new energy and energy conservation technologies through the major national programs. In this paper we analyze the effectiveness of the programs.

* Corresponding author. [o-kimura@criepi.denken.or.jp]

1. Introduction

To prevent climate change, what’s needed is drastic reduction of emission for a long time, not a few percent reduction in a short time. Hence it is very important to figure out how to promote the development of technologies to achieve it.

More than thirty years ago Japanese government had already launched major national programs to promote development of new energy and energy conservation technologies. In this paper we analyze three main programs after the oil crises, i.e. the Sunshine Program, the Moonlight Program, and the New Sunshine Program.

As a matter of fact, the Japanese national programs have been frequently assessed by Ministry of Economy, Trade and Industry (METI; former Ministry of International Trade and Industry(MITI)) and New Energy and Industrial Technology Development Organization (NEDO) since 1997. Each project has been closely examined for the validity of goal settings and management of research and development, and the results.

So, using the reports of those assessments as well as the results of our own literature researches and interviews, we are summing up the national programs. In this paper we explore the answers for the following two questions.

(1) What is the achievement of the national programs continued for nearly 20 years?
(2) How should we organize the national programs in the future?

To answer the questions, at first we introduce overview of the national programs and thereafter examine them by means of cost-effectiveness analyses and case analyses.

2. Overview of the Japanese national programs

In 1974 in the wake of the first oil crisis, Japan launched the Sunshine Program led by Agency of Industrial Science and Technology in MITI.

The principal goal of the program was to find alternative energy to oil and under close cooperation of industry, government, and academic organizations technology development was promoted in four areas, i.e. solar energy, geothermal energy, hydrogen energy and coal, through the initiatives of the government.

In 1978 another national program called the Moonlight Program was launched to develop new energy conservation technologies.

The program was focused on research and development of large-scale energy conservation technologies including highly efficient power generation technologies such as highly efficient gas turbine and MHD power generation, heat utilization technology, and power storage technology (Figure 1).

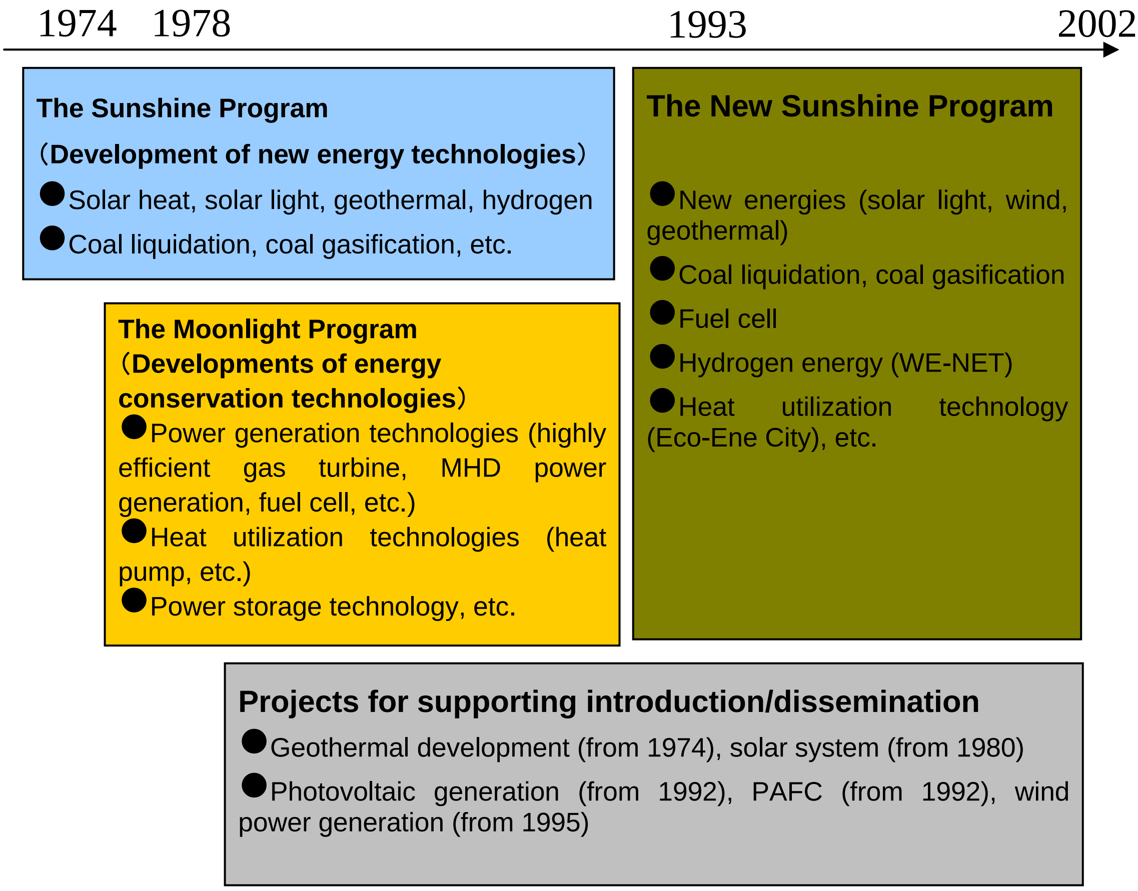


Fig. 1 National programs for development of energy conservation and new energy technologies

The two programs were unified into a new program called the New Sunshine Program in 1993 and in 2002 the program was terminated owing to the restructuring of government ministries and agencies, and then a new system of research and development programs was established.

In this paper we follow up and examine the path until the New Sunshine Program was terminated in 2002.

●**Policy for supporting introduction/dissemination**

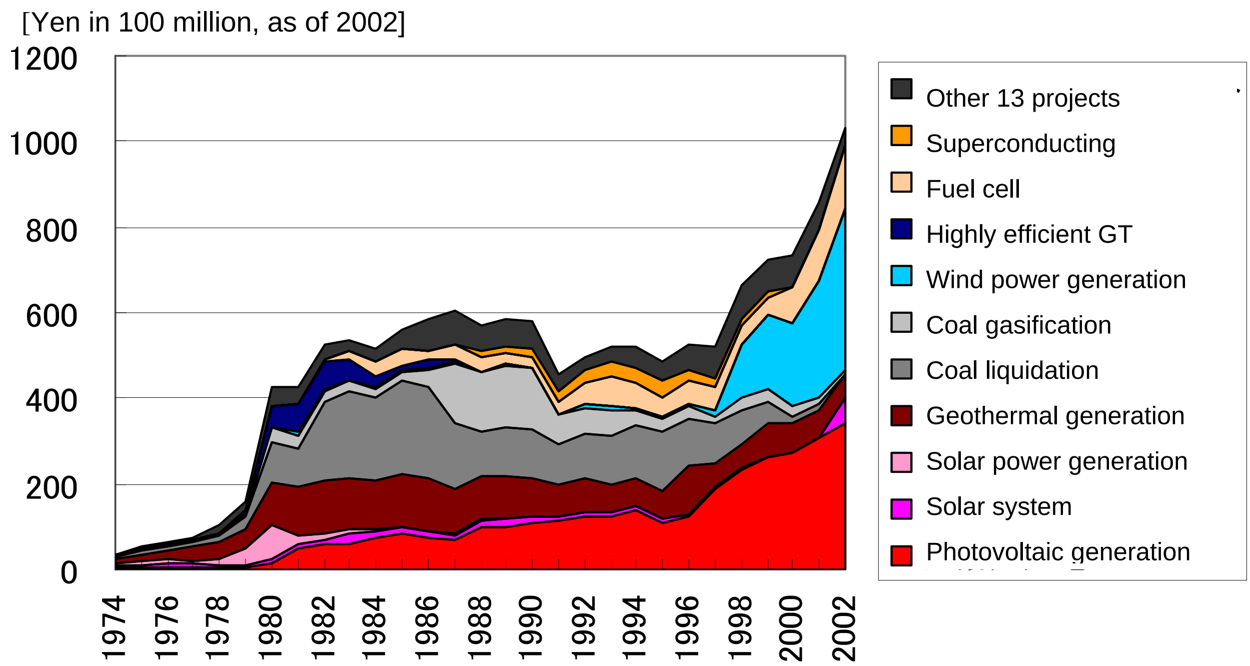
While promoting the research and development programs, as for the near practical technologies, the government has promoted the measures for introduction/dissemination of them.

In particular the subsidies for the development of geothermal energy, and the subsidies or low-interest loans for installation of solar systems, photovoltaic generations, phosphoric acid fuel cells and wind power generations were introduced.

Although these measures were not included in the Sunshine Program and the other national programs, they were recognized as the follow-up measures of the national programs covering the areas from research and development to verification test and were practically implemented as part of them. So this study takes account of them as one of the subjects.

●**Consistent devotion of the huge amounts of budgets**

Figure 2 shows the trend of government budgets for the national programs to promote new energy and energy conservation technologies and the projects for supporting the introduction of them. We classified the national projects for promoting new energy and energy conservation technologies included in the Sunshine Program, the Moonlight Program, and the New Sunshine Program into twenty-three groups. This figure shows the ten major groups individually and the other thirteen groups in a lump as “Other 13 projects.”



(Source: NEDO reports and others. For details, refer to reference 1.)

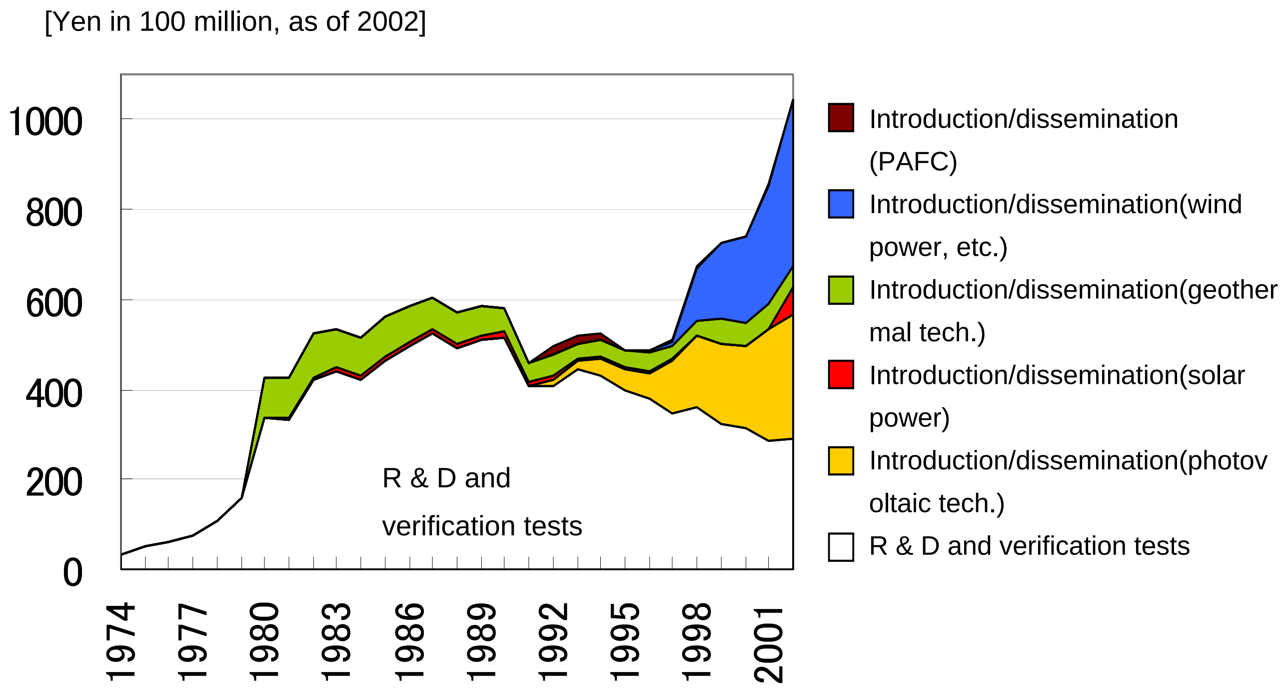
Government budgets from 1974 to 2002 totaled about 1.3 trillion yen (as of 2002).

(Subsidies for the introduction/dissemination of technologies are included.)

Fig.2 National programs for development of energy conservation and new energy technologies ― Budget trends of each project

This figure shows the process of consistently devoting the budget of around 50 billion yen every year from 1980s to 1990s. The sum of the budgets from 1974 when the Sunshine Program was launched to 2002 amounts to 1.3 trillion yen. In particular, photovoltaic generation, geothermal power generation, coal liquidation, coal gasification, fuel cell and wind power generation projects were provided with larger amounts of budgets than those for others.

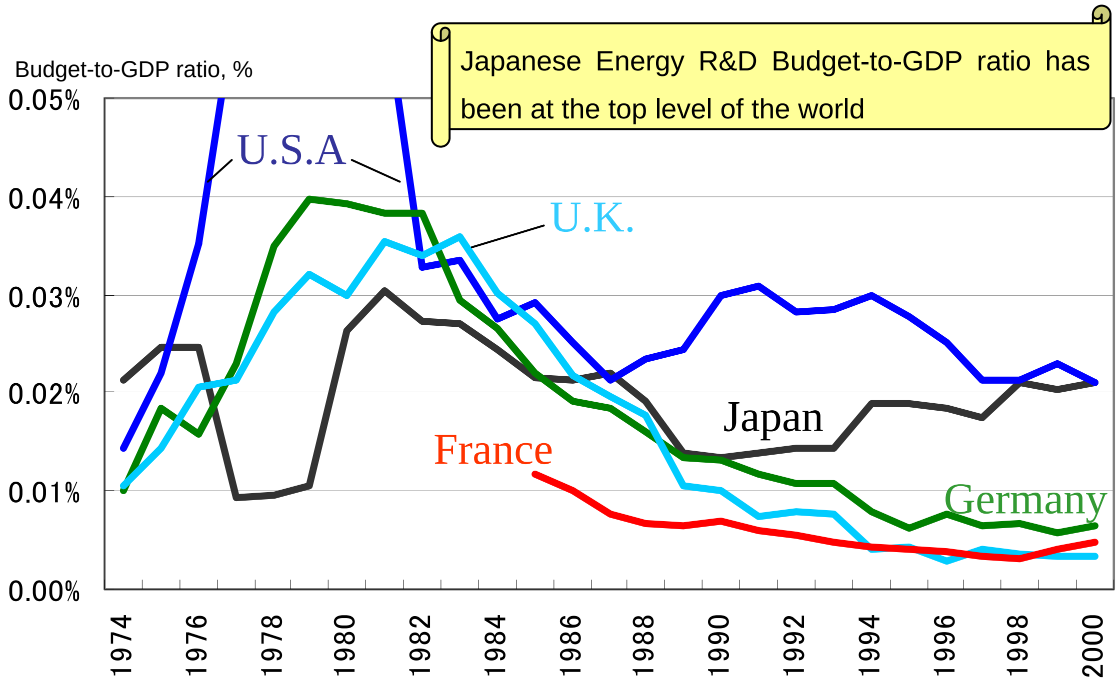
Soaring of the budgets from the second half of 1990s was due to substantial increase of subsidies for supporting the introduction. Figure 3 shows the same government budgets as those in Figure 2 broken down to R & D and verification budgets and the budgets for the introduction/dissemination. While R & D and verification budgets hovered around 40 billion yen since 1980s, subsidizing budgets increased to 50 billion yen in the second half of 1990s. This was due to accelerated the introduction of photovoltaic generation and wind power generation resulting in the expansion of their budgets. Although the subsidies for introducing photovoltaic generation was reduced rapidly after this period and the subsidiary projects for residential systems were terminated in 2006, the total budget for introduction/dissemination still maintain the same level as that of R & D budgets.



(Source: NEDO report and others. For details, refer to reference 1)

Fig. 3 National programs for the development of energy conservation and new energy technologies — Trends of R & D budget and introduction/dissemination subsidies

Figure 4 shows comparison of Japanese government budgets for developing energy technologies with those of the other major countries in the world. Each dot represents the ratio of R & D budgets for energy technologies excluding nuclear power technology to GDP of the country. (Note that the subsidies for enlarging employment of technologies are excluded from the budgets.)



Source: Prepared based on IEA "Energy R&D Database"

Japan had consistently spent large amounts of budget still after 1990s.

Fig. 4 Government budgets of major countries for development of energy technologies (excluding nuclear-related budgets)

The United States experienced violent up and down after the second oil crisis, but thereafter have maintained the world's highest levels of investments to energy technology R & D. Japan also stands at the world's highest levels along with the United States. Meanwhile, in Germany and other European major countries the government investments to energy technology R & D have declined since mid-1980s. This can be accounted for by energy price stagnation and progress in liberalization. The high levels of government investments consistently kept in Japan are distinguished from them of European countries and can be considered as one of the main features of Japanese investments to energy technology R & D.

Figure 5 summarizes the foregoing observations. The Japanese government has steadily sustained large amounts of investments for a long time to R & D of new energy and energy conservation technologies. The budgets for the Sunshine Program and the other national programs and the measures of the introduction/dissemination from 1974 to 2002 totaled approximately 1.3 trillion yen. This is in contrast to decreasing trend of the other developed countries' energy R & D budgets and can be considered as one of the main features of the Japanese national programs. And the budgets for the measures of the introduction/dissemination, which has been increased significantly since mid-1990s, are also a distinguishable feature of the Japanese government investments.

◆Massive and steady investments rarely seen in the other developed countries

- The total amount of the budgets (from 1974 to 2002, including the budgets for introduction/dissemination) was about 1.3 trillion yen (as of 2002).
- Steadily successive investments are different from them of the other developed countries.

◆Priority areas had been expanded to the measures for introduction/dissemination since mid-1990s

- It was considered necessary to review and examine both of the two aspects of R & D and introduction/dissemination

Fig. 5 Features of the Japanese national programs

3. Costs and effects of the Japanese national programs

This paper analyzes cost-effectiveness of the Japanese national programs shown in Figures 1 to 3.

The analysis was conducted on the basis of the method employed in the National Research Council assessment “Energy Research at DOE: Was It Worth It?” in 2001.

This means that the government budgets for R & D and enlarging employment are regarded as cost, and energy conservation and emission reduction accomplished by enlarging employment of realized technologies through the national programs are regarded as effects.

Using such simple factors makes it possible to analyze a range of 23 areas of projects included in the Sunshine Program and the other national programs from a common viewpoint. The other effects which cannot be identified by the method are supplemented later through case analyses.

● **Procedure of cost-effectiveness analysis**

Figure 6 shows the procedure of the cost-effectiveness analysis.

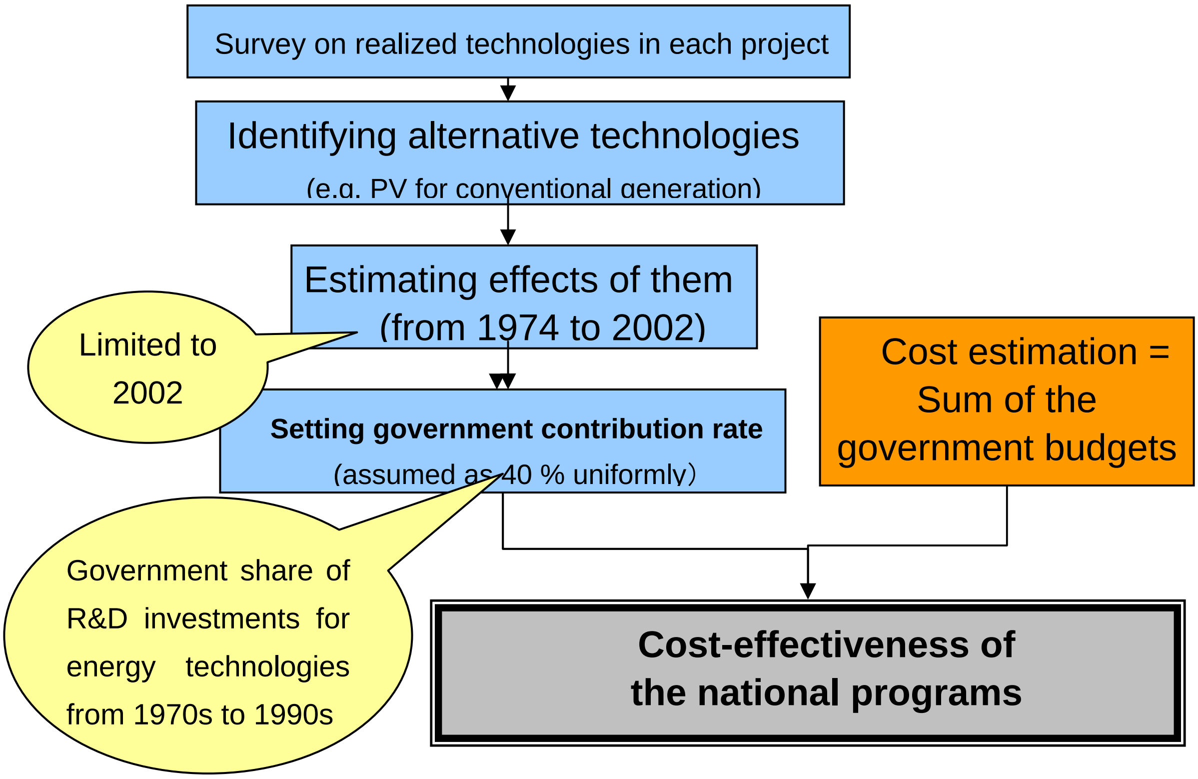


Fig. 6 Procedure of the cost-effectiveness analysis

At first we determined about each project whether its results were realized or not. As described later, in nine of all projects classified in twenty-three areas, realizations of the results were identified.

Then we identified the technologies which can be deemed to have been alternative as the result of their practical application. For example, if photovoltaic generation technology is applied in practical use and the electric power produced by photovoltaic panels are actually consumed by users or sold to power distribution network, the energy can be deemed to alternate transmitted power by just that much. Thus we identified them as alternative technologies.

As for each of the technologies, we estimated its effects of energy conservation and CO2 emission reduction compared with conventional technologies. The estimation covered the period from 1974 to 2002.

However, all the effects resulted from the above estimation were not only caused by the national programs and the governmental measures of enlarging employment. Private companies and energy users also bore a portion of development and installation costs and, first of all, practical applications of the technologies could be advanced to some extent without any governmental initiatives.

Hence we introduced the concept of government contribution rate. This represents the ratio of government contributions to practical application and dissemination of the technologies.

Note that we assumed that the rate was 40 percent as a whole, because we could not examine the rate about each project.

The figure – 40 percent – is at the same level as the government share of R & D investments for energy technologies excluding nuclear power technology and therefore, at least from a macroscopic aspect, can be considered as an appropriate assumption. So we estimated the cost-effectiveness of the national programs using this figure.

●Definition of "practical applications"

In this analysis "the practical applications from the national programs" were broadly interpreted and not confined to target technologies of the national programs. For example, reheat gas turbine, the target technology of the highly efficient gas turbine project, had not become practically applicable.

But the project was closely connected with development of gas turbine combined-cycle power generation system by a participant manufacturer and could be considered to contribute to a certain extent to development of an alternative technology. So we recognized a utilization of the technology was accomplished in the project owing to the national programs.

Meanwhile, Eco-Ene City project in the bottom line of Figure 7 was excluded from estimation of effects because a part of the target technology has practically become applicable. But it had not yet definitely commercialized in 2002.

Project	**Realized technologies**	**Baselines for estimation (Replaced technologies)**
PV generation	**Home and Industrial PV systems**	**Transmitted power**
Solar system	**Solar water heater, solar system**	**LPG, oil-fired and utility gas boilers**
Geothermal generation	**Geothermal generation**	**Transmitted power**
Wind power generation	**Wind power generation system**	**Transmitted power**

Fuel cell generation	**PAFC generation system**	**Transmitted power and utility gas boiler**
Highly efficient GT	**GT combined-cycle power generation system**	**LNG steam power generation**
Waste heat utilization	**Industrial heat pump**	**Heavy oil boiler**
Super heat pump	**Highly efficient industrial heat pump (Ultra-High Eff)**	**Conventional screw chiller**
Eco-Ene City	**Heat storage air conditioning by use of hydrate slurry**	--

Fig. 7 Assumption of technologies realized and replaced by national programs

●Estimation of cost-effectiveness

Figure 8 shows the results of estimation on the effects of energy conservation and CO2 emission reduction as for the projects in which some realization of the technologies were recognized.

	Total budgets (yen in 100 million, as of 2002)	Energy conservation (kL in 10 thousands)	CO2 emission reduction (t-CO2 in 10 thousands)
PV	3,153	20	44
Geothermal	2,220	187	402
Fuel cell	1,035	14	37
Wind power	720	18	39
Solar system	344	703	1,746
Highly efficient GT	312	1,287	2,461
Super heat pump	109	0.2	0.3
Eco-Ene City	91	n.a.	n.a.
Waste heat recovery	42	285	974
Total	13,413 *)	2,514	5,703

*) Total amount of the budgets for all the projects including ones in which no practical application was achieved.

(Source: Estimation by Central Research Institute of Electric Power Industry. For details, refer to reference 1)

Fig. 8 Government's budgets of national programs and results on estimating their effects

From this figure it can be seen that most of the effects on reduction was caused by only four projects – highly efficient gas turbine, solar system, waste heat recovery and geothermal generation projects – of all the twenty-three projects.

And those projects were basically focused on improvement of conventional technologies and support of their introductions while the new technology development projects including photovoltaic generation and fuel cell projects were generously invested but had not achieved so large effects of energy conservation and emission reduction until 2002. We discuss those two aspects in detail later.

Figure 9 shows the projects whose technologies have not yet come to applicable stages and the total amounts of their government budgets. It can be seen that in fact there are many national projects which had not yet come to applicable stages and large amounts of investments were devoted to coal liquidation and coal gasification projects.

	Total government budgets （yen in 100 million, as of 2002）
Coal liquidation	2,689
Coal gasification	1,181
Superconducting power application technology	288
Solar power generation	222
Dispersed-type battery energy storage	184
Ceramic gas turbine	169
WE-NET	162
General-purpose stirling engine	80
High-performance separating membrane combined methane gas production	77
Ultralow loss power element technology	61
Hydrogen production technology	53
MHD generation	45
Deep-seated hot water supply system	25

Fig.9 National programs without prospect of practical application at the present time

Those projects have not yet led to practical application but it is not appropriate to assume that they were failed.

Coal gasification project is now in validation phase and leaves open the possibility of being put to practical application. And superconducting and MHD generation projects made effects in various ways for the related areas. Those effects need to be closely examined on a case-by-case basis.

Figure 10 shows the summarized result of cost-effectiveness analysis of the national programs.

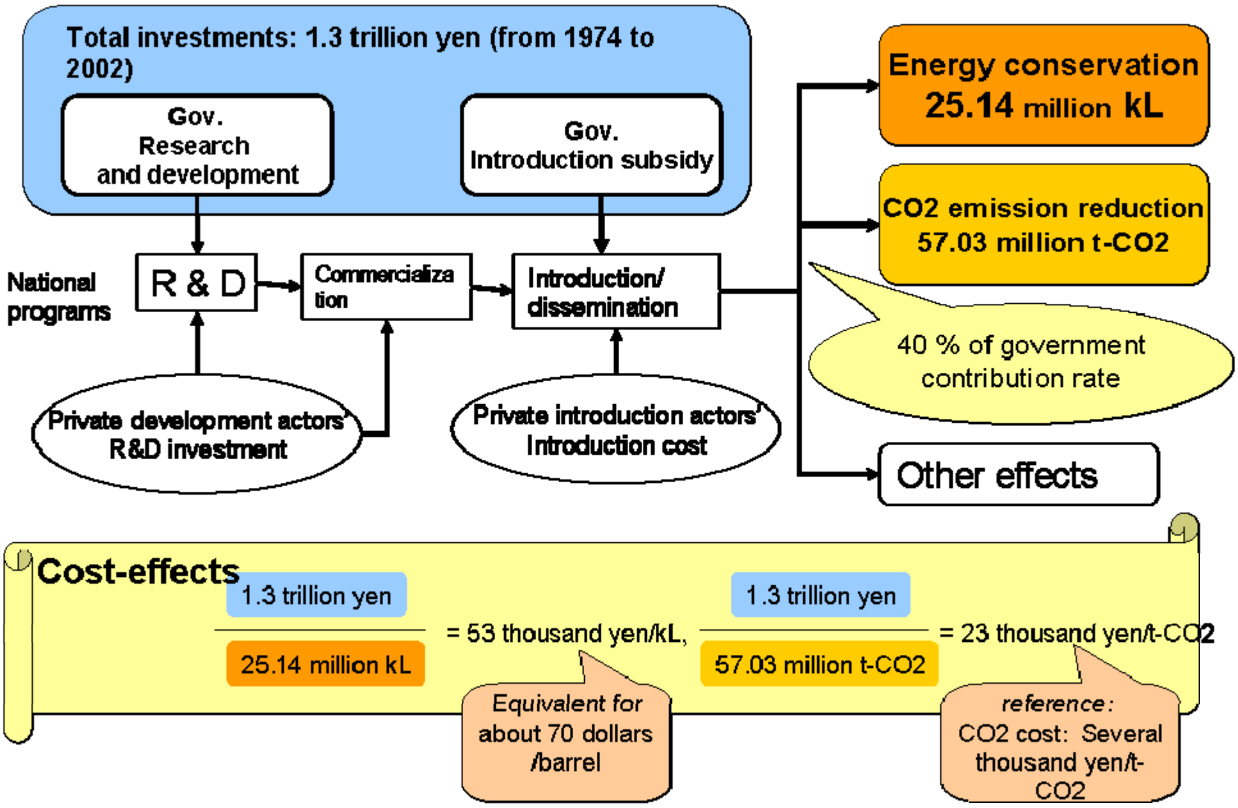


Fig. 10 Cost-effectiveness of national programs

For the period from 1974 to 2002 the accumulated effects of energy conservation and emission reduction were estimated respectively as 25.14 million kl and 57.03 million t-CO_2.

Then the total amount of government investments was divided by the figures to determine the cost-effects. The results were approximately 50 thousands yen/kl (Assumed 120 yen/dollar results in about 70 dollar/barrel.) for energy conservation and approximately 20 thousands yen/t-CO_2 for CO_2 emission reduction.

●Generally reasonable cost-effectiveness of the national programs

Those figures must be deemed as only rough estimates because they were based on much simplified assumptions, as mentioned above, but may be regarded as somewhat high values in consideration of the oil prices and emission credits in recent years.

However, those figures must be more carefully evaluated considering the following conservative aspects of this estimation.

(1) The evaluation period was limited to 2002 to express the results as actual figures but for some technologies the period was not enough to evaluate energy conservation and CO_2 emission reduction effects which can be reasonably thought to take some time to be realized.

(2) As for the projects whose technologies have not yet been utilized, it remains possible that some technologies will be utilized and produce some effects in the future.

(3) The national programs have more effects, such as stimulation of investments of private companies and institutes, cultivation of human resources, and building-up knowledge base, than practical application of the technologies. But those effects are not factored into the estimation.

Considering those aspects, the above results of estimation can be deemed not bad and the cost-effectiveness of the national programs can be thought to be generally reasonable.

●Interpretation of differences in cost-effectiveness of the projects

Finally we should briefly discuss the differences in cost-effectiveness of the projects. 98 percent of emission reduction effects of the national programs were produced by only four projects – highly efficient gas turbine project, solar system project, waste heat recovery project, and geothermal generation project. These projects were all focused on improvements of the existing technologies and support for their introductions. On the other hand new technology development projects, including photovoltaic generation project and fuel cell project, were evaluated as less effective.

But can you declare the R & D investments to those new technologies were not effective? We don’t have the stance. Those projects have the possibilities to become widely utilized and yield large effects depending on the future development. And, as mentioned below, photovoltaic generation project has created an industry. Although all new technology projects might not be applicable to such a case, we think ambitious investments to various new technology developments are also significant as a part of the portfolio of the national programs.

4. Case analyses of the national programs

Now we review each of the projects to see the reality of the national programs which cannot be observed by such a quantitative analysis as shown in the previous section and get some lessons for the future.

The projects to be reviewed in this section are shown in Figure 11.

Project name	Summary
Highly efficient GT	Development of highly efficient GT system and elemental technologies including high-temperature metal and ceramic materials
Waste heat recovery	Research and development of heat recovery and transmission technologies and industrial heat pump
Geothermal generation	Survey of geothermal resources, verification and study of geothermal survey technology, survey of deep-seated geothermal resources, development of binary cycle power plant, development of hot dry rock power generation technology, debt guarantee for development fund, and subsidizing installation of power generating facilities
PV generation	Development of production technologies of solar cells (thin film polycrystalline solar cell, thin film solar cell, super high-efficiency solar cell) and their systems, verification test of the systems, supporting for introduction/promotion of the technologies
Wind power generation	Development of large scale wind power generation system, development of wind power generation system for isolated islands, subsidizing survey of wind characteristics and installation
Super heat pump	Development of high-performance compression-type heat pump and chemical heat storage device, development of 1000 kW class pilot system
Coal liquidation	Study of bituminous coal and brown coal liquidation, building a pilot plant and testing
Fuel cell (MCFC)	Development of large capacity stack of molten carbonate fuel cell (MCFC), study of operations and supports

Fig. 11 National programs for case analysis

The following reviews analyze the roles of the national programs in the process of developing technologies and the factors which influenced advancement or success and failure of technology development and derive some lessons for the future.

The reviews are based on literature researches of existing case studies, technology assessment reports, and technical reports by the national program participants and interviews with the officers involved in the national programs, NEDO, manufacturers, electric power companies, research institutes, and so on.

●Highly efficient gas turbine project

This project was launched to develop highly efficient gas turbine with a total efficiency of 55 percent or more in 1970s when gas turbine combined-cycle power generation had not yet been introduced as a major power generation technology as is today.

The chosen goal of the project was reheat gas turbine technology which has not yet been utilized in Japan. So the choice and project design are criticized as inappropriate. But it is also a fact that the national programs contributed to improvement of gas turbine combined-cycle power generation technology of the participant manufacturers. Especially Mitsubishi Heavy Industries, Ltd., a company which played a central role in the project, has grown up to hold the third largest share after General Electric and Siemens in the world (Figure 12).

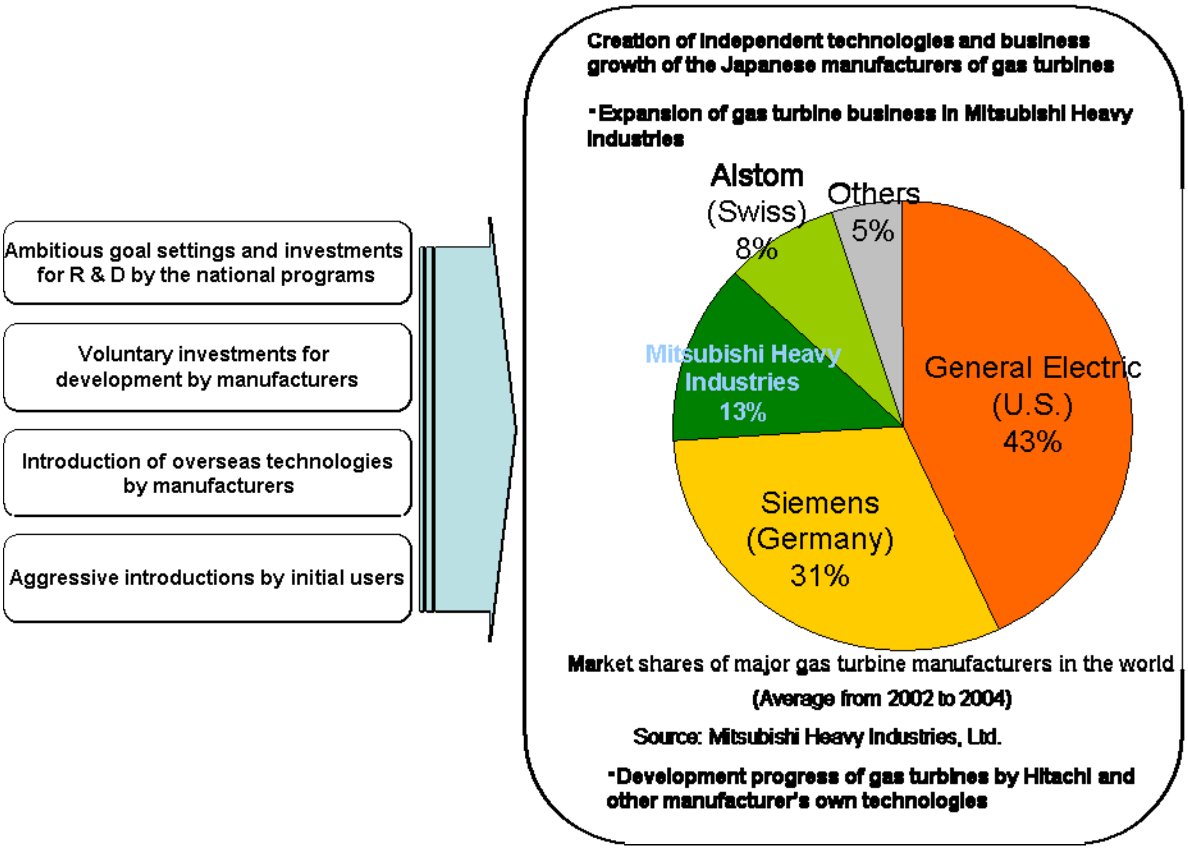


Fig. 12 The national programs made opportunities for creating gas turbine industry

Of course, establishment of such an internationally competitive company was not only due to the national programs. Manufacturer's self-motivating development on the basis of the technologies introduced from the United States played a dominant role. And electric power companies including Tohoku-Electric Power Co., Inc. actively introduced the generation technology and created the market in 1980s when gas turbine combined-cycle power generation technology had not yet existed in Japan. This fact is also conceived to have significantly influenced the technology development.

Hence, from this case, we can learn that the national programs sometimes lead to creation of a new industry and the significant roles in the course of it are fulfilled by manufacturer's self-motivating investments and existence of users who introduce the technologies initially.

●Waste heat recovery project

In this project development of heat pump and heat transmission technologies for utilizing the waste heat generated from industrial sector was promoted. When the project was launched, heat pump for consumer use had already been commercialized, but industrial heat pump for high temperature heat supply had not yet been put to practical use. Its practical use was a major achievement of the project. The participant manufacturers commercialized their industrial heat pumps one after another and by mid-1990s about 500 models had been placed on the domestic market (Figure 13).

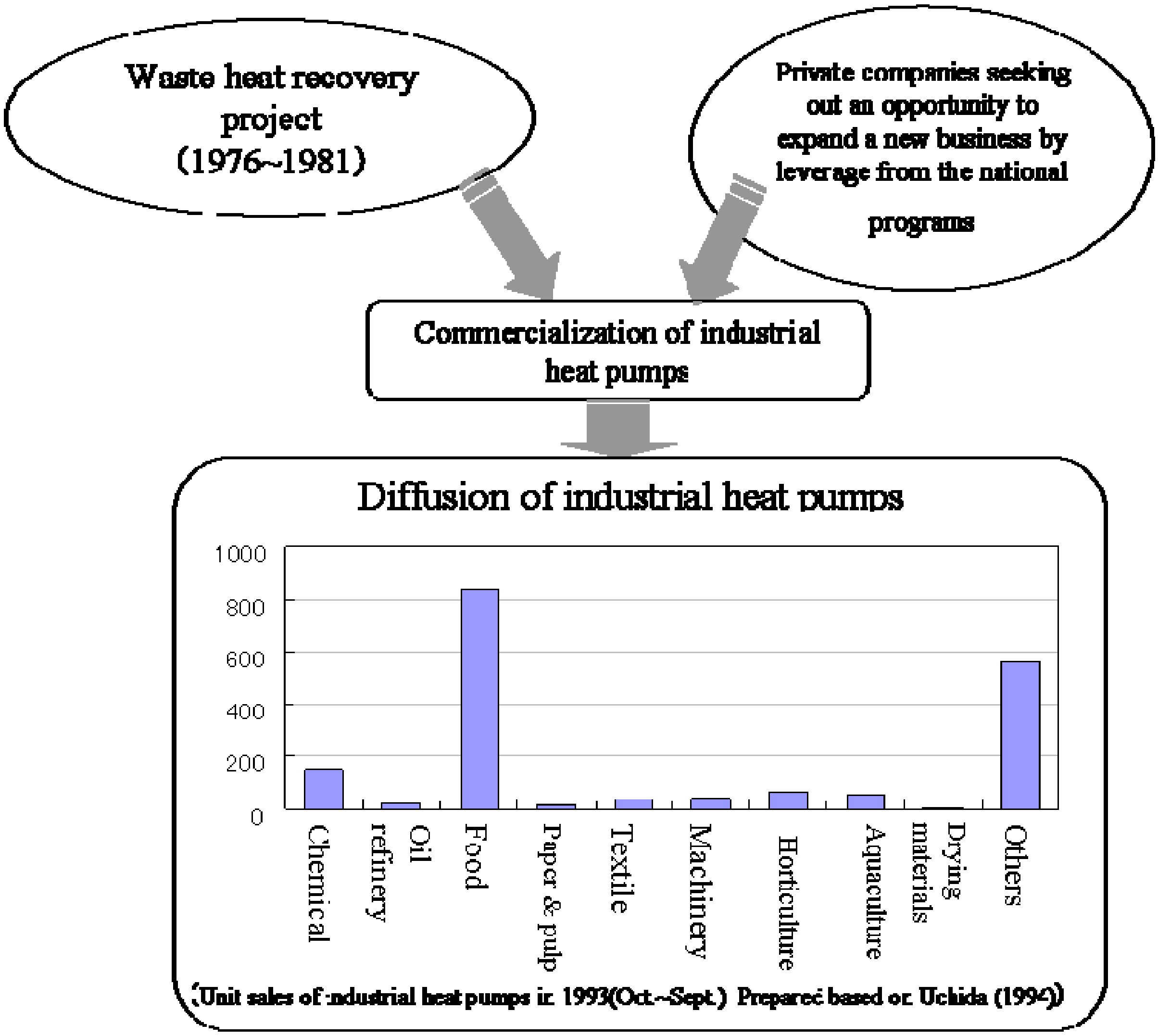


Fig. 13 The national programs made opportunities for the practical application and diffusion of industrial heat pumps

One of the manufacturers which launched their heat pump businesses at the opportunity of the national program and has enlarged it told in the interview that they would like to more highly appreciate the government's selection of industrial heat pump as an goal than the commissions of the national programs.

Thus it can be said that the government's setting of an appropriate direction for each national program and participant manufacturers to leverage the program are vital for success of the national programs.

●Geothermal generation project

In the area of geothermal development a large amount of subsidies had been spent for surveys of geothermal resources and development of them since the Sunshine Program was launched. Those subsidizing measures are said to contribute a great deal to growth of geothermal generation capacity in early 1990s after 20 year's lead time.

But, as for those subsidizing programs in which huge numbers of exploratory wells were drilled, it is criticized that there were many budget-wasting programs. A large amount of expenses for subsidies has continued still after 1990s, but there are no symptoms indicating increase of geothermal generations. From the fact we can observe that in some cases subsidies may work so well in new energy development, but that does not always hold true because of such inefficient case.

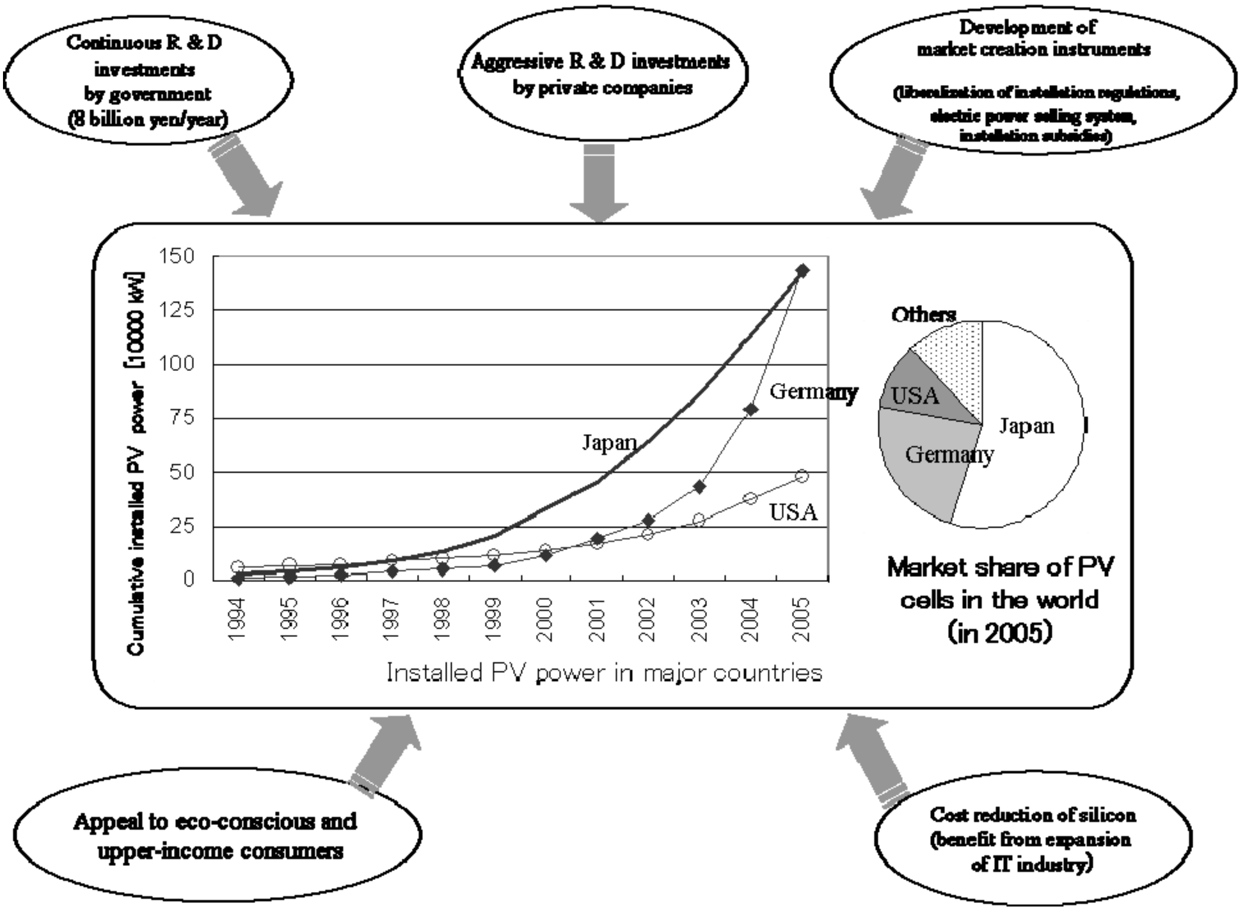
The development of new technologies including binary generation and hot dry rock power generation are also promoted. But they have not been put to practical use. The technologies themselves were developed in the course of the national programs but further development toward practical use had not been made because developing efforts in private sector had stopped after the national program was terminated.

Under the circumstances we can take references from Australia. In the country a venture business called Geodynamics has continued their development toward commercialization of hot dry rock power generation. Of course now it is unknown whether such an approach lead to commercialization and dissemination of hot dry rock power generation, but it can be said that such an independent development by private sector is necessary for commercialization of technology after the national program was terminated.

●Photovoltaic generation project

Photovoltaic (PV) generation is the typical technology which was utilized under the initiatives of the national programs. R & D in the area was launched in the Sunshine Program and its outcome had been commercialized since mid-1990s especially in home PV system market which has grown rapidly. One of the remarkable aspects is that Japanese manufacturers including Kyocera, Sharp and Sanyo has obtained a nearly half share in the world and formed a 400 billion industry in the domestic market.

The following five factors can be pointed out as the causes of the success (Figure 14). First of all the national programs have continuously invested generous R & D budgets. There was no other country which had invested such a large amount of budgets to the area successively.



Source：IEA-PVPS(2006)

Figure 14 Japan leads Photovoltaic generation technologies

Secondly introducing assistance measures such as relaxation of regulations about the connected distribution network, creation of technological guidelines and implementing installation subsidies, coupled with institutionalizing the surplus electricity purchasing system for the electric power companies, all encouraged the popularization of home PV systems. These market-creating measures can be pointed out as the second factor of the success.

The third factor was, as you can see, voluntary R & D investments by manufacturers. It is said that in 1980s no one expected such an enlargement of the PV market as is today. Under the uncertain circumstances manufacturers including Kyocera, Sanyo and Sharp had continued their R & D investments with positive intent to commercialize the technology.

And there is a fact that early purchasers of PV systems were highly eco-conscious upper-income earners. Carving out such a niche market was also an important factor of the success.

Finally reduction of silicon cost resulting from expansion of IT industry also contributed to reduction of PV cost and its popularization.

●Wind power generation project

The amount of wind power generation systems introduced has remarkably enlarged since mid-1990s and their generating capacity surpassed the one million kilowatt mark in 2006. The introduction subsidy for supporting the trend also enlarged and the total sum of it has run as high as about 100 billion yen in 2002.

However most of introduced systems have been made in Europe and the market share held by domestic manufacturers is only about 10 percent. The lag behind European manufacturers can be accounted for by the fact that through 1980s wind characteristics in Japan had been thought as not suitable for wind power generation and the government set low goals and allocated smaller amount of budgets than those for the other projects in the national programs. Therefore the future of wind power generation could not gather much hope and investments for development were not encouraged.

This showed poor prospect of forming a new market and less supports of the government does not encourage development of technologies.

On the other hand, Mitsubishi Heavy Industries holds a certain share in the world market as one of a few domestic manufacturers and increased their production mainly by entering the wind power generation market in the United States where the market had started to grow since 1980s.

This illustrates when an overseas market shows more promises than domestic market there is an option of developing technology to expand the business in the overseas market at first.

●Super heat pump project

This project has promoted development of high performance heat pump mainly intended for district heating and cooling. Although the technology satisfying the high goal was developed, installations of highly efficient heat pumps were extremely restricted because they needed too much cost and anyway the market of district heating and cooling remained sluggish.

But there was a product commercialized ten years after termination of the project. Called "Ultra High Eff Heat Pump;," the product was put to practical use by Chubu Electric Power Co., Inc. and Kobe Steel Ltd. which continued their developing efforts for commercialization after the project was terminated. This shows the importance of after-project investments by participant companies for commercializing the technologies of the national programs (Figure 15).

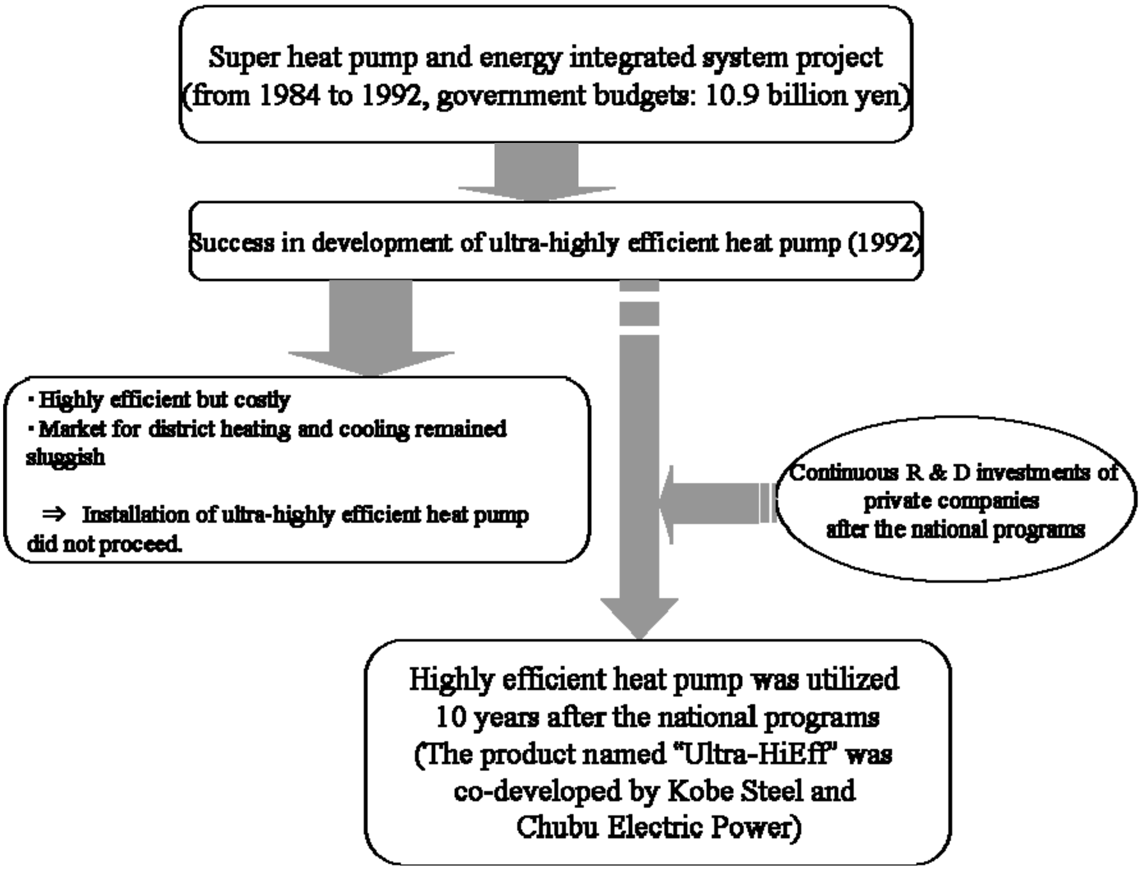


Figure 15 Continuous investments after the national programs by private companies yielded the practical application.

And it is pointed out by many people that successive pursuit of heat utilization technology in more than one project was also important for development of heat pump technology. The series of the projects related with heat utilization from waste heat utilization project, super heat pump project to Eco-Ene City project made possible for research institutes and companies to successively secure budgets for developing the related technologies and in-house specialists and, as the result of it, led to the accumulation of the technologies.

It can be seen that the national programs played the role of providing stable circumstances for research and development.

●Coal liquidation project

Although total amount of budgets for this project was ranked second after that for photovoltaic generation neither liquidation technologies of brown coal nor bituminous coal have never been put to practical use. It is said that the technologies themselves have been almost completed, but the cost estimated at 44 to 60 dollars/barrel made them economically unfeasible. Hence there has been a lot of criticism that the project was a huge waste of money.

Specifically the following are pointed out as two of the causes. First, the government could not effectively respond to change in oil prices which came to hover at a low level. Second, many of the participant companies were concerned with taking back to utilize the elemental technologies in-house and there was no actor who challenged for real the commercialization of coal liquidation technology.

But surely soaring of oil prices in recent years has invited a new attitude to challenge commercialization. Shenhua Group, the largest coal company in China, has started to introduce coal liquidation technology from Europe and the United States. NEDO is providing their technical assistance for coal liquidation. And Kobe Steel is making use of the technologies of the national programs to launch a brown coal reforming business in Indonesia

Thus, as for the project, though many problems are pointed out, we must admit that it developed optional technologies which can be utilized depending on the circumstances.

●Molten carbonate fuel cell (MCFC) project

In this project molten carbonate fuel cell technology was developed as a next-generation fuel cell technology and a large scale demonstration system had been made successfully by 1999.

However, its commercialization is not yet in sight for several reasons. First, the project originally intended to develop an alternative technology to large scale thermal power generation and set a potential technology, namely external-reforming and high-pressure MCFC, as the goal to be accomplished, but the technology was difficult and the cost ran up high.

Besides, appearances of other highly efficient technologies including gas turbine combined-cycle power generation and slowing-down of the domestic power demand made the demands for replacing facility of thermal power stations uncertain.

Thus, because any distinctive market had never been created in 20 years after launching the project, the participant companies had withdrawn from the project one after another, and now there is no company which has a commercialization plan of external-reforming and high-pressure MCFC.

On the other hand, in the United States, a venture company called FCE launched sales of internal-reforming and atmospheric-pressure MCFC in 2002. FCE pursued early commercialization by focusing on cost reduction and selecting a technically and economically easier technology of internal-reforming and atmospheric pressure MCFC. Although they sold only several dozen units the accomplishment of commercialization may be highly appreciated anyway.

Judging by both cases in Japan and the United States, it can be said that private companies could not keep participating in development of a new technology without market creation as long as 20 years. And we can also learn from the cases that in such a case we could at first commercialize the technology and grow the market progressively while getting by on the sales.

●The roles played by the national programs

Figure 16 shows our findings made as a result of analysis of the roles played by the national programs about the eight cases.

- Provided opportunities for commercialization and creation of industries
  - The national programs provided important opportunities.
  - Case examples: PV, gas turbine, industrial heat pump

- Provided consistent frameworks for developing important technologies
  - Initiatives: Although commercialization might not be always achieved the national programs set important agenda and promoted continuous developments of research institutes and private companies by setting ambitious goals of introduction and implementing budgetary measures
  - Case examples: Heat pump for hot water, fuel cell, PV

- Other effects
  - Building up knowledge bases
  - Development of optional technologies which can be applied in practical use in the future, etc.
  - Case examples: Hot dry rock generation, coal liquidation, coal gasification

Figure 16 The roles played by the national programs

First, some of the national projects, such as PV project, gas turbine project, and industrial heat pump project, led to utilization of technologies and creation of industries. In each case, although self-motivating development of private companies played the major role, the national programs also made a certain contribution by making occasions for private developments.

And establishing consistent frameworks for developments of important technologies is also an important role fulfilled by the national programs. In heat pump project and fuel cell project the government took initiatives and, even if technologies could not always be put to practical use, they set important agendas for technologies and promoted development of research institutes and companies by setting high goals for introduction and budgetary measures.

Besides, there are more aspects we did not mention above. For example, some projects played important roles in building up knowledge base like surveys on geothermal resources, which helped to clarify geological structures, and R & D of coal, which made a significant contribution to chemistry. And coal liquidation technology has become one of the options which can be put to practical use depending on the circumstances in the future.

●What is important for managing the national programs in the future?

Figure 17 shows the points to keep in mind in managing the national programs in the future.

1. Is there a private company which will for real challenge commercialize?
   - Case examples: Gas turbine, super heat pump, hot dry rock generation, coal liquidation

2. Is there a step-by-step strategy for commercialization (niche market strategy)? Is there an initial user who introduces?
   - Case examples: PV, gas turbine, MCFC

3. Are policy measures for R & D and creating market coordinated?
   - Case examples: PV, wind power generation

Figure 17 Notes for designing the national programs in the future

First, because utilization of the national program technologies needs continuous investments after the programs, it is necessary to involve private companies which have serious intents to commercialize the technologies. For example, gas turbine and super heat pump technologies were made practical by the companies but in hot dry rock generation project and coal liquidation project there were not such an actor in the private sector.

Second, we think it is important whether we have a step-by-step strategy for utilization. For example, in the case of MCFC, we can find difficulty to keep private companies involved unless an initial introduction to the markets cannot be achieved in a short time. We need to set an intermediate goal of commercialization aimed at a niche market however small it is. By the same token, in PV project and gas turbine project we can see the importance to find users especially in an early stage.

Third, we can learn from PV project that it is important for commercialization of a new technology not only to research and develop it but also to steer policies adequately for creation of the market. It is expressed in English as both of "technology push" and "market pull" are necessary.

5. Conclusions

In closing Figure 18 summarizes the findings of our analysis.

Features of the Japanese national programs for development of energy technologies:

Massive and continuous investments without parallel in the world

In cost-effectiveness analysis…

- Budgets of the national programs for development of new energy and energy conservation technologies totaled about 1.3 trillion yen for the period from 1974 to 2002
- 10 out of 23 projects were commercialized
- Energy conservation effects: 25.14 million kL, CO_2 emission reduction effects: 57.03 million t-CO_2

In case analysis…

- Some projects led to commercialization and creation of industries
- Although commercialization might not be always achieved the national programs set important agenda and promoted continuous investments for development

↓

Returns of government's investments are generally reasonable.

Figure 18 Summary of this paper

The Japanese national programs are massive and long-term efforts without parallel in the world and have produced various important technologies. They include many fruitless projects but as a whole achieved acceptable results.

We position those efforts as unique contributions to the global community by Japan and think it is appropriate to take lessons from failures, improve and continue them.

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