# Research on social benefits resulting from NEDO projects

## — Study of the top 70 NEDO Inside Products —

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"NEDO Inside Products" are defined as products or processes using core technologies resulting from NEDO's research and development projects. In this study, we analyzed and estimated the creation, and $CO_2$ emission reduction. Our analysis revealed that NEDO Inside Products sales in 2010 amounted to 4.08 trillion yen while projected sales from 2011 to 2020 are estimated to increase to 69.1 trillion yen. Job creation estimates between 2011 and 2020 range from 109 to 185 thousand people per year, and $CO_2$ emission can be reduced by 53 million tons per year. Furthermore, in-depth and systematic analysis showed that many NEDO Inside Products developed after 1999, including components and manufacturing technologies, are being utilized in the latest household electric appliances, computers, and automotive products. Lastly, we found that NEDO projects have significantly contributed to the establishment of various types of recycling systems: Another example of the extensive benefit to the society brought about by NEDO's research and development projects.

*Keywords* : Follow-up monitoring, national project, development result, impact evaluation, gross social benefit

## 1 Introduction

There has been a number of research conducted on the economic evaluation of government-funded R&D projects in Japan, but they tend to be limited to estimates and sensitivity analyses under limited conditions: It is not simple to identify the factors necessary for the evaluation of cost-effectiveness of R&D projects (i.e., the contribution rate of project outcomes, basic production unit, etc.). Shiotani *et al.* carried out a return on investment analysis of nuclear power generation, taking the following effects into account: generation costs reduction, environmental load reduction, risk to life reduction, energy security improvement, resource depletion control, and fuel import reduction.[1] Yanagisawa *et al.* estimated the cost-effectiveness of the products utilizing radiation on various grounds, considering the factors including device costs, radiation dosage, and the contribution rate to added product value.[2] Kimura *et al.* qualitatively evaluated the impact of energy-saving effects of thermal energy related projects as an economic evaluation of national projects.[3] Besides, there are several accounts on different types of economic evaluation and benefit of public policies;[4]-[10] however, all these reports lack details on parameter settings and variables related to the influence of market conditions as well as the contribution rate of project outcomes to practical applications, selling price, and changes in sales volume. Nonetheless, they seem to simply focus on identifying certain trends. In contrast, G. B. Jordan *et al.* of the US Department of Energy compiled a detailed guideline of benefit-cost analysis comprising economic benefits, energy benefits, environmental benefits, energy security benefits, and knowledge benefits for the development of renewable energy and energy saving technologies through US public R&D projects. They introduced a series of case studies to demonstrate the analyses using time adjustment factors and sensitivity analysis.[11]

Since the projects conducted by New Energy and Industrial Technology Development Organization (NEDO) are funded by taxes, they must be accountable to taxpayers by showing how effectively the investment in development are being returned to the public. To meet such demand, NEDO initiated the selection of "NEDO Inside Products" – the products or the processes in which any NEDO project outcome is being used as their core technology (i.e., innovative technologies that are essential to practical applications and cannot be emulated by others; including those enabling the emergence of new functionality, newly integrated technologies, innovative manufacturing and processing technologies, highly reliable characterization technologies) in FY 2009. Assuming the contribution rate of the project outcomes against the products' sales being 100 %, these products' economic impacts such as net sales have been estimated.[12]-[18]

In this research, we conducted survey, and made evaluations and analyses to identify the social impact of "Top 70 NEDO Inside Products": The net sales, induced economic effects, technological ripple effects, and gross social benefit (e.g., $CO_2$ reduction, energy saving, and job creation) of the project outcomes that have been remarkable success and eventually generated strong sales through the fundamental and core projects as well as the projects aimed at practical application

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(Fig. 1). Note that we are well aware that the companies require over ten times the amount NEDO invest in an R&D project for the practical application and commercialization of the project outcome; we were unable to take this into account because the information regarding the companies' actual expense is not always available. Yet, the method for comprehensive impact we present in this research will help clarify the direction of future R&Ds by giving ballpark figures of the R&D project outcomes in which NEDO invested, and we believe that this study should be of great significance to academic, socioeconomic, and public policy research.

## 2 Selection of NEDO Inside Product candidates

NEDO's R&D projects started in FY 1980; 100~200 projects or more are conducted each year, and over 3 trillion yen of development fund have been invested so far. At first, it was exceptionally painstaking to find out how many of NEDO project outcomes had actually been put to practical use and directly contributing to the products' sales. Hence, we decided to extract the products and the processes that were considered to be the products of NEDO project outcomes from NEDO's 20-year, and 30-year achievement reports. The preliminary selection of candidate products was subsequently made by perusing past press releases, corporate web-sites, journal articles, NEDO accomplishment reports, and follow-up surveys. For the secondary selection, questionnaire surveys and interviews to the participants and others involved in the projects were carried out. A group of external experts examined the degree of contribution to practical application and the sales status of the project outcomes, and finally, prospective "NEDO Inside Product" candidates were selected. The selection criteria are explained below.

### *2.1 Selection method for "NEDO Inside Product" candidates*

In selecting "NEDO Inside Product" candidates, the products with most recent sales figures being substantial, and those with marginal sales figures but bringing about extensive gross social benefit are extracted referring to the publications including industrial reports, NEDO achievement reports,

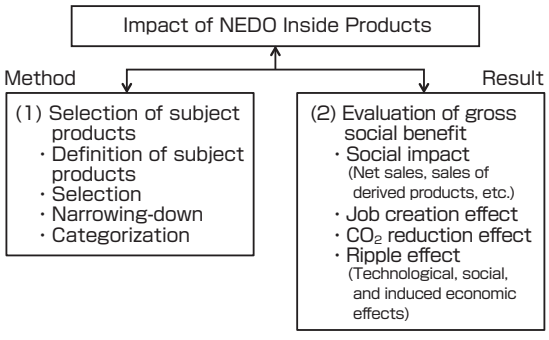



**Fig. 1 Structure of the selection method and gross social benefits of the NEDO Inside Products**

and corporate reports; which is followed by questionnaire surveys (on current and future sales and gross social benefit) and interviews to the companies participated in NEDO projects at the time of development. The sales figures and gross social benefit listed in the corporate survey are carefully reviewed through the interviews to industrial associations or at a committee of experts. In cases where the answer to questionnaire does not provide sufficient amount of information, we perform supplementary calculations using the data published by industrial associations and private research institutions. These results are adopted after consulting with the participating companies and industrial associations. This specific survey method and the selection method of 70 products are explained as follows.

### *2.2 Scope of NEDO Inside Products*

NEDO projects are generally designed to commercialize basic research findings from universities or public research institutes which have been major academic impact. In an effort to tackle complex social issues which cannot be resolved by a single group or company for their risky nature, particularly in case of emergency, NEDO also manages technology development projects in collaboration with industry and academia with practical application in mind. For these reasons, many of NEDO Inside Products are the products of core technologies evolved from NEDO projects, having achieved remarkably high development targets and utilized their realization/commercialization know-how. The core technologies developed in NEDO projects can be defined as the technologies developed via industry-academia-government collaboration, and innovative technologies essential for practical applications. Specifically, they include the technologies which enable high conversion efficiency, high-speed separation, high-speed reaction, ultra-long life span, ultra-lightweight, high durability, surface control, energy savings, high-efficiency combustion control, high-reliability evaluation, and the emergence of reciprocal functions. The reason for setting the contribution rate of the project outcomes 100 % is that almost all the eligible products: (1) were developed through multiple mid-to long term projects; (2) addressed topics the companies would seldom consider and had difficulty obtaining funding for the purpose; (3) were in need for support from external experts, which was difficult to obtain in corporate research, (4) would never be put to practical application if it were not for the NEDO project outcome; (5) must be realized as corporate obligation owing to the funding support from the tax during the critical phase of development; (6) may differ in contribution rate and the companies are unable to grasp; and (7) were realized following the completion of the project and their subsequent commercialization was more likely due to the know-how and the companies' manufacturing effort rather than the funded research opportunity. As all the products share at least two of the points above, the calculations are performed with 100 % contribution rate on

the assumption that practical applications could not have been achieved without NEDO projects. Nevertheless, the sales information regarding the products of NEDO projects is only a fragment even at this point. Having selected the products, NEDO Inside Products are first categorized as follows: (i) New products which led to the establishment of new business divisions within the participating companies with most recent annual sales of 100 billion yen or above; (ii) new products with most recent sales between 10 billion and 100 billion yen; and (iii) the products with meager sales but with great potential for gross social benefit. The specific procedures of categorization are explained below.

### *2.3 Definition of NEDO Inside Products*

The candidates of NEDO Inside Products are defined as follows:

1) The products are included if their core technologies were developed in the course of NEDO project and contributed greatly to realization and commercialization of the products, even if the companies participated in other R&D project(s) before or after the NEDO project.
2) The products are considered if the technologies developed by the participating universities and public research institutes were transferred to their co-participants for realization and commercialization.
3) The products are NOT considered if they were the outcomes of NEDO's funding aid or grant projects and, "International Demonstrations/Joint Projects" whose purpose is to introduce and disseminate the products.
4) The products are NOT considered if they were the outcomes of research-only projects.

### *2.4 Points of corporate questionnaires*

The following is the list of questions to the companies that participated in NEDO projects: (1) Product name; (2) project name, project period, and allocated budget; (3) the outline of project outcome(s) and in which part of the NEDO Inside Product the project outcome is used; (4) the names of the co-participants in charge of sales; (5) the product's cumulative sales figures for the past five years for each participating company, or the sales data of the overall industry;[19]-[23] (6) most recent sales figures as of 2010, and the sales forecasts for 2011-2020; (7) the evidence used for estimating items (5) and (6) (e.g., published data and journal articles); (8) gross social benefit (e.g., the amount of $CO_2$ reduced, energy efficiency, and job creation); and (9) patents and journal articles, know-how, the potential ripple effect to other products, awards, and other notable information. In cases where sufficient information could be obtained from the questionnaire, the following data are utilized: (10) Data published by industrial associations; and (11) data published by public bodies and private research companies. (12) In addition, any other missing data are complemented by our calculations based on different sales figures and gross social benefit, and we use these data after obtaining approval from the participants.[12]-[16]

### *2.5 Narrowing down the NEDO Inside Product candidates*

The narrowing-down of NEDO Inside Products involved a four-step process as shown in Fig. 2: Data collection/extraction, preliminary narrowing-down, secondary narrowing-down, and verification. The following five means were taken in data collection and extraction: (1) Follow-up questionnaires, interviews, etc.; (2) patent specifications, literature, industry journals, NEDO related documents, etc.; (3) press releases, investor relations data, press reports, etc.; (4) reports from project participants; and (5) product reviews from key persons of the industry. All these means had both advantages and disadvantages, and it was practically impossible for NEDO Inside Products to form a population based on a single information source.[24] For (1) to (4), while it was more likely that we find the details on practical application, the current market trends remained unclear in most cases. It was often the case that available information could only be traced back to the time of market release: The longer the time after the development and the more the market being niche, the slimmer the chance of obtaining the figures. On the other hand, (5) was an efficient way to collect the information on the products' market release, but the information on their relevance to specific NEDO projects at the time of development were not available in many cases. As far as the relevance to NEDO projects are concerned, the information could be verified referring to NEDO database and other sources. However, sufficient amount of information was not available for many of the projects dating back to the 1980s. As a consequence, NEDO Inside Product candidates were selected by combining the information from (1) to (5).[12]-[16] After conducting the preliminary narrowing-down of candidates using (1) to (3), the secondary narrowing-down was carried out using the questionnaires and the interviews ((4) and (5)), and the information was confirmed by a committee of external experts. This was how we selected Top 70 NEDO Inside Products.

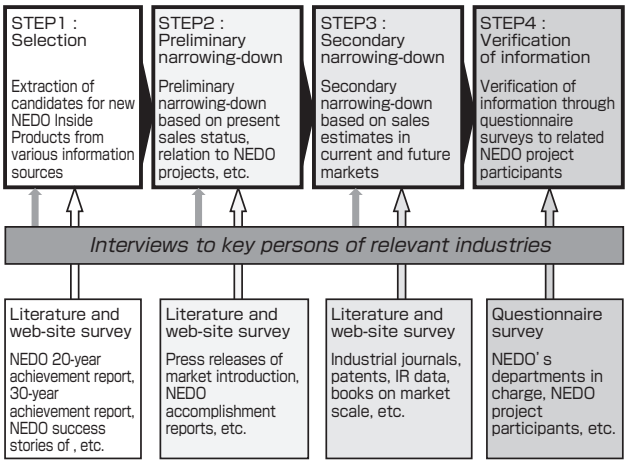



**Fig. 2 Selection scheme of NEDO Inside Products**

**Table 1. Categorization of Top 70 NEDO Inside Products**

| Index | Aim | Outline | Effect | Specific NEDO Inside Products (in order of products and parts) |
|---|---|---|---|---|
| 1. 【Pioneers of new market】 | Take lead in creating new markets! | Create new markets and provide mid-to long-term support for innovative R&D that is too risky to be undertaken by a single private company. | · Market creation<br>· Sales<br>· Employment | [12 products] Solar power generation, Blu-ray Disc related technology, residential heat pump hot water supply systems, wind power generation, residential fuel cells, robots (industrial, motion assistant, etc.), clean diesel vehicles, natural gas vehicles, superconducting wire rods, mobile batteries, high-output secondary batteries |
| 2. 【Boosters of Japanese industry's international competitiveness】 | Take advantage in industrial competitiveness through world-leading technologies! | Strengthen Japan's industrial competitiveness by accelerating the technological development in highly competitive areas. | · International strategies<br>· Sales<br>· Presence | [15 products] High-performance stoker furnaces, excimer laser semiconductor devices, large catalytic chemical vapor deposition (CAT-CVD) machines, turbo refrigerators, semiconductor evaluation technology devices, energy sharing technology of plant community by pinch technology, high-performance LED materials, hard disk drives, nonvolatile semiconductor memories, stacked dynamic random access memories (DRAM), power semiconductor materials, storage batteries for space use, non-stage transmission for automobiles, polarizing film for liquid crystal displays (LCD), electric double-layer capacitors, electronic chip laminated films |
| 3. 【Technological stimuli to a wide range of fields】 | Support innovation in wide-ranging fields of technology through core technology development! | Promote technological innovations in the development of materials and core technologies that may cost too much time and money for private companies to undertake. | · Industrial infrastructure<br>· Social infrastructure<br>· Academic ripple effects | [8 products] Industrial medium-scale power generators, casting simulation, high-function high-reliability servers, adhesive for resin parts, metal glass, photocatalysts, fine ceramics, micro electro mechanical systems (MEMS) |
| 4. 【Contributor to solving environment and energy issues】 | Contribute to solving environment and energy issues through highly reliable technologies! | Contribute to creating an environment-conscious society through new technological development addressing serious environmental and energy issues (energy efficiency, new energy, reduction of hazardous substances, etc.) | · Regulatory compliance<br>· Global environment<br>· Energy efficiency<br>· Comfortable and convenient | [16 products] Geothermal power generation, waste power generation, high-performance industrial furnace, low-emission hybrid diesel car, energy-saving construction machines, industrial heat pump, standby power digital copier, thermal storage transportation, next-generation adsorption refrigerator, cold heat storage system, submerged combustion method for chlorofluorocarbon decomposition, low fuel consumption tire, waste solid fuel, sulfur-free light oil, eco-cement, high-performance high-function vacuum insulating materials |
| 5. 【Agent for realizing safe, secure, and comfortable living】 | Realize safe, secure, and comfortable lives through diverse technological repertoires. | Support safe, secure, and comfortable living of the people in Japan and the rest of the world by developing new technologies and making best of them. | · Safe and secure<br>· Social contribution<br>· Comfort and convenience | [19 products] Nano-ion products, 4D radiographic computed tomography (CT) diagnostic systems, microscopes for biological research, confocal laser microscopes, cryoelectron microscopes, short-leg braces, energy-saving large displays, gasoline vapor recovery devices, non volatile organic compounds (VOC) coating systems, rapid sensitive analyzing systems for oligosaccharides, body fat scales, twin-arm construction machines, membrane bioreactor (MBR) units, high-efficiency anaerobic biological treatment [such as up-flow anaerobic sludge blanket (UASB)], exhaust gas post-treatment systems, bio-remediation, insulating materials for electronic materials, cleaning gas for semiconductor manufacturing, asbestos substitute gaskets |

Having examined the latest sales figures and noticed some similar products (robots and power semiconductors) of Top 50 NEDO Inside Products listed in our previous paper being integrated,[24] 50 products were reorganized into 47 products. Hence, we added 23 new products to the previous list for this research. To select new candidates, the involvement of NEDO projects was once again examined with documents such as project accomplishment reports or NEDO database.[25] Regarding the products' current market status, we collected the articles reporting the product deployment by searching press releases of the companies involved and the journals of relevant fields. We compared the products' cumulative sales for the past five years, most recent sales figures, future sales forecasts, and potential benefits to the society, and 154 products were extracted in the preliminary narrowing-down. In the secondary narrowing-down, the number of products was reduced to 72 after quantitative evaluations, interviews, and the discussion with the committee of external experts. Ultimately, 70 best-selling products were selected.

### *2.6 Categorization of NEDO Inside Products*

The products were initially categorized in accordance with the project's basic plan and characteristics: That is, whether the product (1) is a pioneer of new market; (2) is competitive in international markets; (3) pushes the boundaries of the technology, and (4) addresses any social issue.[12]-[16] Half of these products fell under Category (4), in line with NEDO's mission. After in-depth analyses and discussions, however, we found out that the products (4) should be best categorized under social demands or everyday life issues. As it made the characteristics of products more evident, the products under (4) were re-grouped into "resources/energy solutions" and "safety/security/comfort providers." Consequently, NEDO Inside Products were re-categorized into following five categories: (1) pioneers of new market: 12 products; (2) boosters of Japanese industry's international competitiveness: 15 products; (3) technological stimuli to a wide range of fields: 8 products; (4) solutions to resources and energy issues: 16 products; and (5) providers of safety, security, and comfort: 19 products (Table 1). As can be seen from this categorization, many of the technologies in these products and processes were developed with intent to address social issues (e.g., $CO_2$ reduction, energy saving, new energy, environment, reduction of hazardous substances, exhaust gas, quality of living, waste, and medical care). Despite their sales figures being insignificant, it can be said that a considerable portion of NEDO Inside Products make substantial contribution to the society by offering such technologies that deals with changes in regulations, and environmental problems, and support medical diagnosis, and medical/nursing-care.

### *2.7 Sales forecast of NEDO Inside Products*

The sales figures of NEDO Inside Products fluctuate depending on years after market launch. In most cases, the product sales remains subtle for several years, shows a gradual increase, and becomes saturated after reaching a level of maturity. It eventually declines after a period of

time. Figure 3(A) shows the life-cycle curve of the sales of a NEDO Inside Product. NEDO Inside Products are diverse in lifespan: From a solar power generation device with almost 30-year lifespan to electronic components that only last for few years. Therefore, it was crucial to adopt an optimal life-cycle curve by exploring a suitable timescale to define the characteristics of the product from different perspectives. To evaluate the sales impact of NEDO Inside Products, three types of figures, i.e., cumulative sales for the past five years, most recent sales, and sales forecasts, were estimated.

The sales figures could shift depending on the product as shown in (B), (C), and (D) of Fig. 3. Figure 3(B) demonstrates the products whose sales growth rate would continue to surpass the previous figures for a given period of time. This is based on the sales growth rate up to 2011 assuming that it should continue until 2020. In Figure 3(C), the curve denotes the products the industry and the government expect a certain level of growth each year. As for the products whose future sales forecasts were provided by the companies in reply to the questionnaire, we performed the calculation assuming that the sales would grow until 2020 at the growth rate from 2011 to a given time in future. Represented in Figure 3(D) are the products with short lifespan, or whose future sales are somewhat unpredictable. These figures are projected on the condition that there would be no growth after 2011 and therefore the figures should remain the same.[13]-[18][24] The products showing the curves (E), (X), and (Z) are those that are discontinued, have had negligible sales volumes if any, and had sales record in the past but currently almost none being sold respectively: We excluded these products or processes from the list of NEDO Inside Products candidates.

### *2.8 Success factors of NEDO Inside Products*

Listed below are the major factors we identified from the questionnaires and the interviews, which led NEDO Inside Products to success: (1) The participants gained significantly larger amount of data, compared to their usual research situation; (2) the companies made use of a mechanism which brought about improved reliability and problem-solving strategies, and development, modification, and extension(scale-up) of research policies through joint research opportunity with universities; (3) the participants were reasonably confident with the technology from the start for its practical feasibility and commercial viability; (4) the participants kept the idea for long until the project launch; (5) the participants had already had unrivaled know-how and capabilities, which saw further improvement and were exploited in the course of the project; (6) the participants were skeptical about the market information and proactive in exchanging information within the team; and (7) the participants carried out prototype demonstrations and repeatedly verified and modified the technology to the point where it was elaborate enough to ensure its proximity to commercialization. We presume that there should be some other factor(s) involved, which need follow-up surveys to be clarified.

## 3 Impact evaluation of NEDO Inside Products

### *3.1 Characteristics of NEDO Inside Products*

Groups of top 70 NEDO Inside Products, including solar power generation, wind power generation, gas turbines, residential heat pump hot water supply system, micro-electro-mechanical systems (MEMS), and clean vehicles, have recently recorded above100 billion yen sales showing an upward trend. In contrast, some of the products with recent sales between 10 billion yen and 100 billion yen, waste power generation and residential fuel cells, for example, did not show significant sales growth as expected. This implies that they have already completed their introductory stage, or the production has been too costly. The sales of

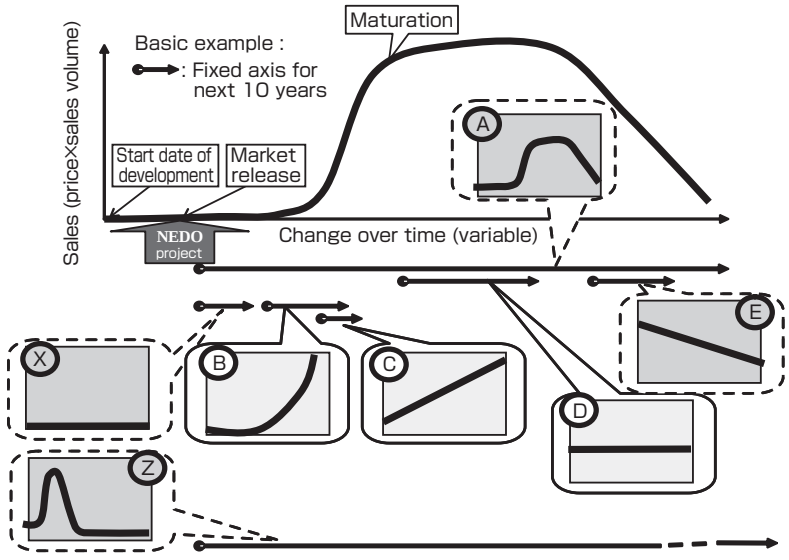



**Fig. 3 Life cycle of sales of NEDO Inside Products**

**Table 2. Sales performance of Top 70 NEDO Inside Products and their sales forecast**

| (Unit: 100 million yen) | NEDO budget outlay | | Sales performance | | Future sales forecast (cumulative for 2011~2020) |
|---|---|---|---|---|---|
| | Average R&D cost per fiscal year | Cumulative R&D cost | Most recent sales per year (2010) | Cumulative sales for past five years | |
| Solar power generation | 58 | 1,735 | 15,800 | 46,400 | 219,400 |
| Wind power generation | 4 | 85 | 2,600 | 7,300 | 41,100 |
| Gas turbines | 35 | 532 | 2,600 | 11,900 | 40,100 |
| Residential HP hot water supply systems | 12 | 154 | 3,400 | 16,000 | 38,500 |
| Residential fuel cells | 49 | 880 | 120 | 300 | 11,600 |
| Blue-ray products | 12 | 61 | 5,100 | 14,500 | 51,500 |
| Semiconductor products | 35 | 280 | 500 | 1,700 | 65,000 |
| MEMS | 18 | 250 | 400 | 1,200 | 6,700 |
| Fine ceramics | 5 | 123 | 100 | 110 | 10,500 |
| High-performance industrial furnaces | 11 | 80 | 20 | 400 | 1,100 |
| Waste power generation | 10 | 100 | 200 | 1,500 | 2,500 |
| Water treatment (membrane separation, etc.) | 19 | 118 | 400 | 1,300 | 6,000 |
| Bio microscopes | 20 | 98 | 100 | 90 | 1,200 |
| Others | — | 1,913 | 9,460 | 40,100 | 196,000 |
| Total | — | 6,409 | 40,800 | 142,800 | 691,200 |

Pioneers of new market | Boosters of Japanese industry's international competitiveness | Technological stimuli to a wide range of fields | Contributor to solving environment and energy issues | Agent for realizing safe, secure, and comfortable living

"Others" includes: Robots, large displays, waste power generation, vacuum insulators, chlorofluorocarbon decomposition, HD drives, semiconductor manufacturing technology, CNG vehicles, eco-cement, MEMS, body fat scales, semiconductor bonding technology, nano-ion products, x-ray CT diagnostic equipment, energy-saving construction machines, insulators for electronic materials, industrial heat pumps, standby power digital copiers , ice thermal storage systems, sulfur-free light oil, rapid sensitive analyzing systems for oligosaccharides, high-performance high-reliability servers, superconducting materials, stoker furnaces, photocatalysts, etc.

products intended for large-scale manufacturing facilities are particularly susceptible to general economic trends. Once these products are introduced, only the operational cost could be added to the sales figures; which is possibly a trend specific to the sector. In general, the products with large sales figures see a decline in unit price due to commoditization; however, their sales could be secured or even increased to certain degree by increasing sales volumes in/outside the country. We also find many of the products having marginal sales figures but contributed greatly to gross social benefit or industrial competitiveness (e.g., a significant $CO_2$ reduction and substantial international market share as a core product) under the categories addressing social issues (e.g., environmental issues, safety and security, and quality of living).

### *3.2 Evaluation of NEDO Inside Products' net sales*

Table 2 shows estimated NEDO's investment, cumulative sales for the past five years, most recent sales, and sales forecasts for the next ten years of Top 70 NEDO Inside Products. In respect to these products' cumulative R&D expense, 640.9 billion yen, the most recent sales can be estimated 4.08 trillion yen; the cumulative sales for the last five years 14.28 trillion yen; and the 2011-2020 sales forecast 69.1 trillion yen. Because it is often problematic to disclose a product's sales recorded by a single company, the figures were aggregated when several companies deal in the same NEDO Inside Product. The proprietary products are placed in "Others" category.[19]

Since NEDO projects are funded by taxes, we also estimated future tax revenue and potential job opportunities Top 70 NEDO Inside Products would offer. To this date, 640.9 billion yen was invested in the projects associated with Top 70 NEDO Inside Products. The total amount of investment over the next ten years is, in turn, expected to be 69.1 trillion yen, and according to Eq. (1) below, the expected tax revenue will be 1.291 trillion yen. It is now clear that the tax revenue from the products' sales for the next ten years is likely to exceed the amount invested in NEDO projects.

Cumulative national expenditure for Top 70 Inside Products: Approx. 640.9 billion yen

- Corporate income tax (approx. 69.1 trillion yen) × 3.66 % (pre-tax profit rate[Term 1]) × 40.69 % (effective corporate tax rate) = approx. 1.291 trillion yen … Eq.(1)

NEDO have invested approximately 3 trillion yen in R&D projects over the past 30 years, and from the results above, 640.9 billion yen has contributed to sales. Nonetheless, it is still unknown how the remaining 2.36 trillion yen investment has contributed to the sale although this certainly has brought about vocational training opportunities and technological ripple effects. At this point, we have concluded that the sales of 69.1 trillion yen could be expected in the next ten years from the 3 trillion yen investment. Further investigation is needed in order to see to what extent the investment of 2.36 trillion yen that seemingly has no effect on the sales might be related to other economic impacts and gross social benefit.

### *3.3 Job creation (for 2010, and cumulative total for 2011-2020)*

The impact of created job opportunities was calculated from the rate of labor cost against the product sales in domestic manufacturing sectors and the average income (FY 2004-2008 performance) based on the most recent sales and the

**Table 3. $CO_2$ reduction effect of NEDO Inside Products**

| Category | Specific NEDO Inside Products | $CO_2$ reduction effect[1] (ton-$CO_2$/year) |
|---|---|---|
| 1. Pioneers of new market | [8 products] Solar power generation, residential heat pump hot water supply systems, wind power generation, residential fuel cells, mobile batteries, gas turbines, high-output secondary batteries, clean diesel vehicles | 196,756,986 |
| 2. Boosters of Japanese industry's international competitiveness | [5 products] Power semiconductor materials, turbo refrigerators, non-stage transmission for automobiles (belt CVD), energy-sharing technology of plant community by pinch technology, high-performance LED materials | 37,443,907 |
| 3. Technological stimuli to wide range of fields | [1 product] Industrial medium-scale power generators | 231,250 |
| 4. Solutions to resources and energy issues | [14 products] Waste power generation, high-performance industrial furnaces, low-emission hybrid diesel vehicles, eco-cement, submerged combustion methods for chlorofluorocarbon decomposition, industrial heat pumps, high-performance high-function vacuum insulating materials, standby-power digital copiers, sulfur-free light oil, energy-saving construction machines, thermal storage transportation, geothermal power generation, waste solid fuel, low fuel consumption tires | 274,152,410 |
| 5. Providers of safety, security, and comfort | [2 products] Insulating materials for electronic materials, cleaning gas for semiconductor manufacturing | 20,968,776 |
| | Total (30 products) | 529,553,329 |

1) The amount of $CO_2$ reduced was calculated as the cumulative $CO_2$ reduction from the number of products expected to be introduced and the functions added in 2011～2020.

cumulative sales forecasts (2011-2020). This reveals that approximately 109,000 employment opportunities were created in 2010, and further 185,000 per year until 2020 [Eq. (2) and (3)]. In fact, the number of newly generated opportunities after 2011 had to be reduced to approximately 76,000 a year on the assumption that the same personnel remain employed [Eq.(4)].

- Approx. 4.08 trillion yen × 13.38 % (labor cost/product sales[Term 2]) ÷ 4,990,000 yen (average income) = approx. 109,000 jobs/year … Eq.(2)
- Approx. 69.1 trillion yen × 13.38 % (labor cost/product sales[Term 2]) ÷ 4,990,000 yen (average income) = approx. 1,850,000 jobs/10 years … Eq.(3)
- 1,850,000 jobs/10 years (the number of jobs increased since 2011) – 109,000 jobs/year (the number of people hired in 2010) = approx. 76,000 jobs/year … Eq.(4)

### *3.4 $CO_2$ reduction effect of 70 NEDO Inside Products*

30 out of 70 NEDO Inside Products have the potential to reduce one million ton of $CO_2$ per year; these include solar power generation, wind power generation, residential heat pumps, highly-efficient gas turbines, power semiconductors, LED materials, waste power generation, chlorofluorocarbon decomposition processes, refuse-derived fuel, semiconductor clean gas, and highly-efficient industrial furnaces. The $CO_2$ reduction effect of these products is—in such cases as the replacement of existing products or chlorofluorocarbon decomposition—often represented in global warming potential (GWP) and expressed in $CO_2$ unit: Based on the unit, these products are considered to make substantial contribution to greenhouse gas reduction. The companies, industrial associations, or NEDO provided the $CO_2$ units on the assumption that these NEDO Inside Products replaced existing products, which were subsequently reviewed by a committee of experts, and the amount of $CO_2$ reduced were estimated.[17][18] As the result, these products and processes are expected to reduce the $CO_2$ emission for the next ten years by approximately 530 million ton/10 years (Table 3). Since the amount of $CO_2$ emitted in Japan FY 2012 accounted for 1.343 billion ton, it can be said that these products and processes should achieve a 3.94 % reduction per year.

## 4 Economic impact of NEDO Inside Products

The use of the inter-industry relations table enables us to figure out the (primary and secondary) induced economic effects of a NEDO Inside Product on the upstream and the downstream of its supply chain. However, the selection of the NEDO Inside Products viable for such estimation must be made with caution. The economic impacts presented in this research include "primary induced economic effect" by the products' "net sales" and the sales that are later derived from manufacturing, as well as "secondary induced economic effect" through payroll expenses. The terms above are defined as follows:

- Net sales: the sales figure of given product itself
- Primary induced economic effect: the sales effect of parts and materials that are necessary for manufacturing the product at the upstream of supply chain
- Secondary induced economic effect: the boost on employment and consumption resulted from the product's sales and primary induced effects

For the products with small sales figures and little statistical significance in the inter-industry relations tables, the estimation's margin of error possibly becomes larger;

which may represent an inaccurate overview of the project outcomes. Keeping this in mind, the products and the processes which meet the conditions below are subject to estimation.

### *4.1 Requirements of products that are subject to estimation of induced economic effects (primary and secondary)*

In the fields of semiconductor, automobile, or energy, a number of NEDO project outcomes are incorporated into a range of materials, parts, manufacturing machines, as well as end products. On the other hand, technology/know-how by itself has limited effects on net sales. Thus, it is necessary to define the status of the technology/know-how in the sectors involved (e.g., parts, manufacturing machines/devices, end products, alternative products, etc.) in order to avoid the overlaps in the estimates of net sales and induced economic effects. To perform a series of calculations, 20 out of Top 70 NEDO Inside Products which meet the conditions below, are subject to induced economic effect estimations (i.e., the ripple effects on sales in other sectors found in the inter-industry relations table: see Table 4).

- The product has recorded a certain sales volume (e.g., >10 billion yen per year)
- The product has been disseminated and gained a degree of recognition in the market, and its economic effect is likely to increase
- The product potentially creates new industries, or transforms into other innovative products/processes rather than simply add value to existing products/processes
- The product has been statistically significant in the category to which the products/processes belong

### *4.2 Estimation of induced economic effects*

There is a range of products and processes that utilize NEDO project outcomes, and the same sales estimation method is not always appropriate for all the products. Therefore, for each product and process, we discussed the induced economic effects of specific kind crucial for our purpose, having studied the characteristics of NEDO Inside Products. Note:

(1) The 2005 version of inter-industry relations tables (108 sectors across Japan) are used for the estimation with no adjustment to the figures provided.

(2) Difference between parts/materials and manufacturing machines;
In semiconductor production, NEDO project outcomes are, in many cases, being adopted as materials and parts. In contrast, the calculated economic effect of manufacturing machines (i.e., industrial machines) practically corresponds to their net sales at the time of market release. Hence, we only take the net sales into consideration for manufacturing machines, whereas both primary and secondary induced economic effects are estimated for the materials and parts since parts and materials take a significant portion in the figure.

(3) Overlaps in induced effect of parts/materials and end products;
In automobile industry, NEDO project outcomes are utilized in materials/parts, manufacturing machines, and end products (automobiles). In this paper, only the end products in which NEDO projects played major roles (i.e., low-emission hybrid diesel vehicles and clean diesel cars) are counted.

(4) Handling of the secondary induced effect by inter-industry relations analyses;
While the primary induced economic effect is an index that represents the economic impact on the upstream of a supply chain, the secondary induced economic effect is an index that represents the sales revenue (the net sales of the products and the processes utilizing NEDO project outcomes). The latter also includes payroll expenditures incurred by the primary induced economic effect. Instead of considering the secondary effect as an economic impact on a specific industry, it seems more appropriate to deem it as a social impact resulted from improved economic performance through increased employment opportunities.

(5) Handling of the economic effects in the energy field;
The products other than energy storage are the machines and devices that generate electricity: Some of those supply renewable energy while others improve the energy efficiency of conventional energy. Renewable energy-related devices in particular (solar/wind/geothermal power generation) are a group of products that are exploring new markets. Added to the increased sales revenue in the upstream market of supply chain, there has also been a variety of impacts including increased sales of electricity and job creation. It should be noted that renewable energy-related devices, gas turbines, and fuel cells are the energy-saving devices which contribute to reducing the use of fossil fuel at the same time.

### *4.3 Calculation of the primary and secondary induced economic effects by the inter-industry relations analysis*

In regard to the primary induced economic effect on the sectors involved in the manufacturing of NEDO Inside Products (the net sales associated with the production of NEDO Inside Products in the sectors shown in the inter-industry relationship), solar power generation for instance, the net sales we refer to only count the sales of solar panels with given technologies in domestic market. The demand price for each intermediate product during the panel production process was computed by the intermediate input coefficients of the inter-industry relations table. The result was subsequently multiplied by the end product's domestic self-sufficiency rate and inverse matrix coefficient to calculate the primary induced economic effect (the amount of

induced production).[26] Furthermore, the estimated "amount of increased employee income" resulted from the net sales and the primary induced economic effect was multiplied by consumption conversion rate to work out the "final demand of consumption demands." The amount of consumption demand of each industry was obtained by multiplying above mentioned "final demand of consumption demands and "private consumption expenditures by industry." The amount of consumption demand by industry was once again multiplied by the self-sufficiency rate and inverse matrix coefficient. Consequently, the secondary induced economic effect (the amount associated with the increased employment by the inter-industry relationship) was computed. The market size of the end product with given materials/parts was estimated using the information from the industrial relations chart by NEDO[27]-[30]and the statistics published by relevant bodies.[31]

### *4.4 Calculation of the primary and secondary induced economic effects of semiconductor products*

The semiconductor-related products among NEDO Inside Products include semiconductor parts and semiconductor devices. For the reason given in (2) of Subchapter 4.2, the amount of increased semiconductor parts production (for those likely to bring about both primary and secondary induced effects such as cell phones, smartphones, portable game consoles, PCs, hard disk drives, automobiles, etc.) turned out 53,470 (million yen per year). Provided that all the parts are supplied domestically, the net sales could be 53,470 (million yen per year). By multiplying the input coefficient (of parts (materials)) to this figure, the value of intermediate goods produced owing to the sales is worth 37,936 (million yen per year). Since some of these intermediate products are of foreign origin, 37,936 (million yen per year) was multiplied by the domestic self-sufficiency of each product for the amount of increased domestic demand (primary), 32,331 (million yen per year). Followed by the multiplication of the inverse matrix coefficient to the primary domestic demand, the estimated primary induced economic effect was 64,133 (million yen per year). Next, the amount induced by employee income (direct + primary) was calculated by adding the increased employee income, 9,822 (million yen

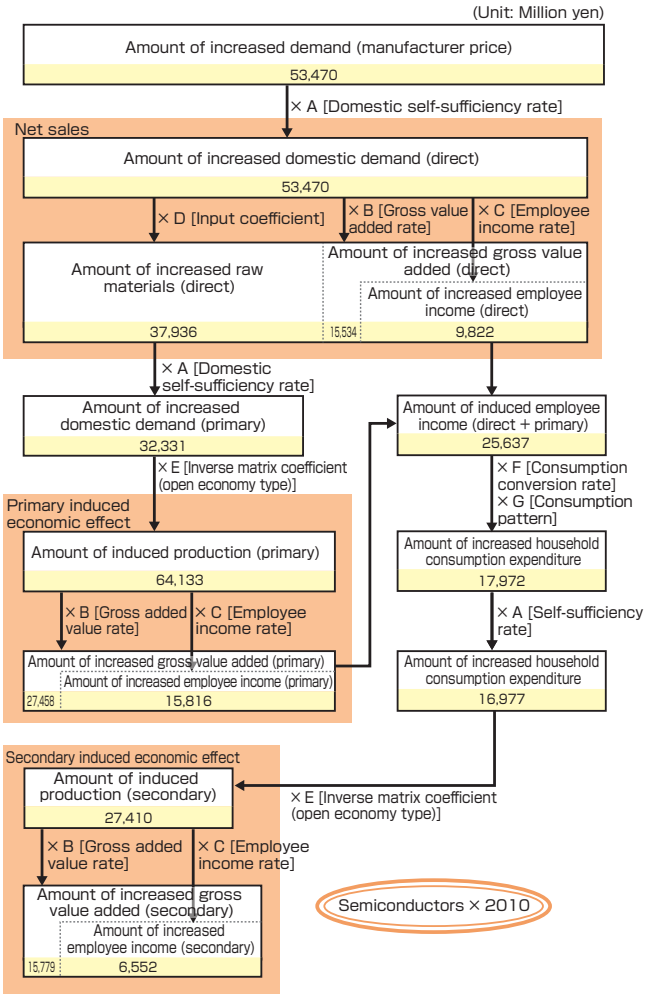



**Fig. 4-1 Economic ripple effect flow using the inter-industry relations table (semiconductor parts, 2010)**

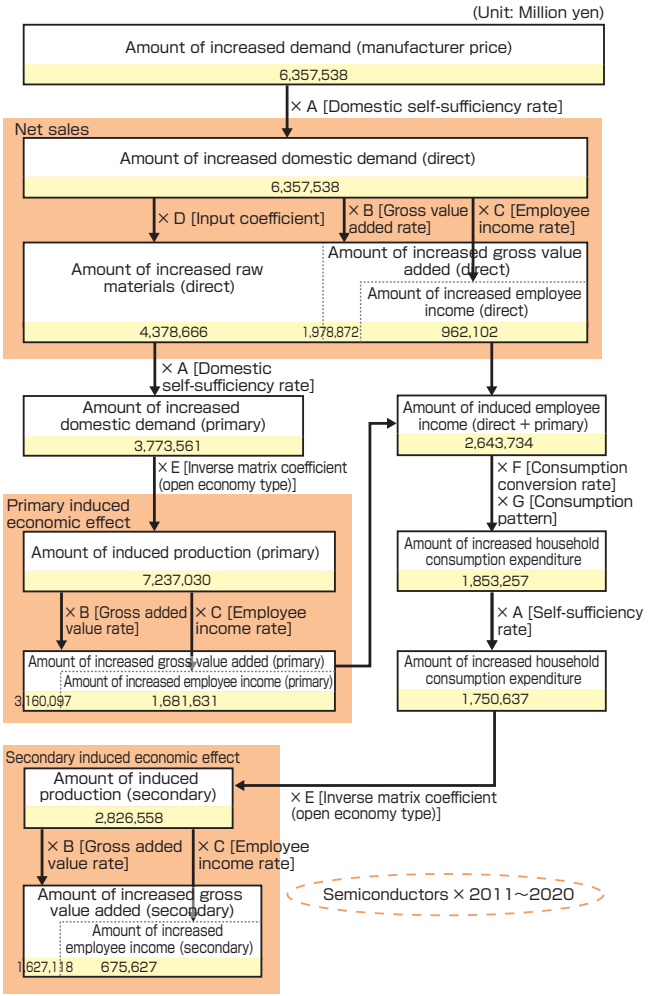



**Fig. 4-2 Economic ripple effect flow using the inter-industry relations table (semiconductor parts, 2011~2020)**

*The amount of increased demand (manufacturer price) was calculated from the single-year sales and future sales of the products that are expected to generate primary and secondary induced effects.

**Table 4. Ten-year sales forecast of NEDO Inside Products and their induced economic effects**

(Unit: 100 million yen)

| Field | Specific NEDO Inside Products[1)] | Induced economic effect (2011～2020) | | Net sales forecast[2)] (2011～2020) |
|---|---|---|---|---|
| | | Primary induced effect | Secondary induced effect | |
| Energy | Solar power generation, wind power generation, residential fuel cells, gas turbines, waste power generation, etc. | 360,539 | 154,440 | 319,811 |
| Semiconductors | Dye bond films, MEMS, non-volatile memories, DRAM, insulating materials for electronic materials, power semiconductor materials, etc. | 72,370 | 28,266 | 72,058 |
| Automobiles | Products: low-emission hybrid diesel vehicles, clean diesel vehicles<br>Parts: Desulfurization catalysts for sulfur-free light oil, sulfur-free light oil | 68,406 | 17,488 | 162,404 |
| Housing | Vacuum insulating materials, residential fuel cells, residential heat pumps, etc. | 119,670 | 47,358 | 103,358 |
| | Total | 620,985 | 247,552 | 657,632 |

1) Further induced effect is expected for 20 products among Top 70 NEDO Inside Products
2) Total amount for all the products within the fields in question was calculated regardless of the value of primary or secondary induced effect

per year) generated by the sales revenue and the increased employee income from primary induced economic effect of 15,816 (million yen per year). The result was multiplied by the consumption conversion rate and consumption pattern, and the increased household consumption expenditures, 17,972 (million yen per year) was obtained. As the household consumption includes imported products, each product was multiplied by the domestic self-sufficiency rate, then the inverse matrix coefficients; the estimated secondary induced economic effect was 27,410 (million yen per year). Additionally, the full extent of cumulative economic effects for 2011 - 2020 is provided in Figs. 4-1 and 4-2. For other industries, net sales and primary and secondary induced economic effects were calculated likewise.

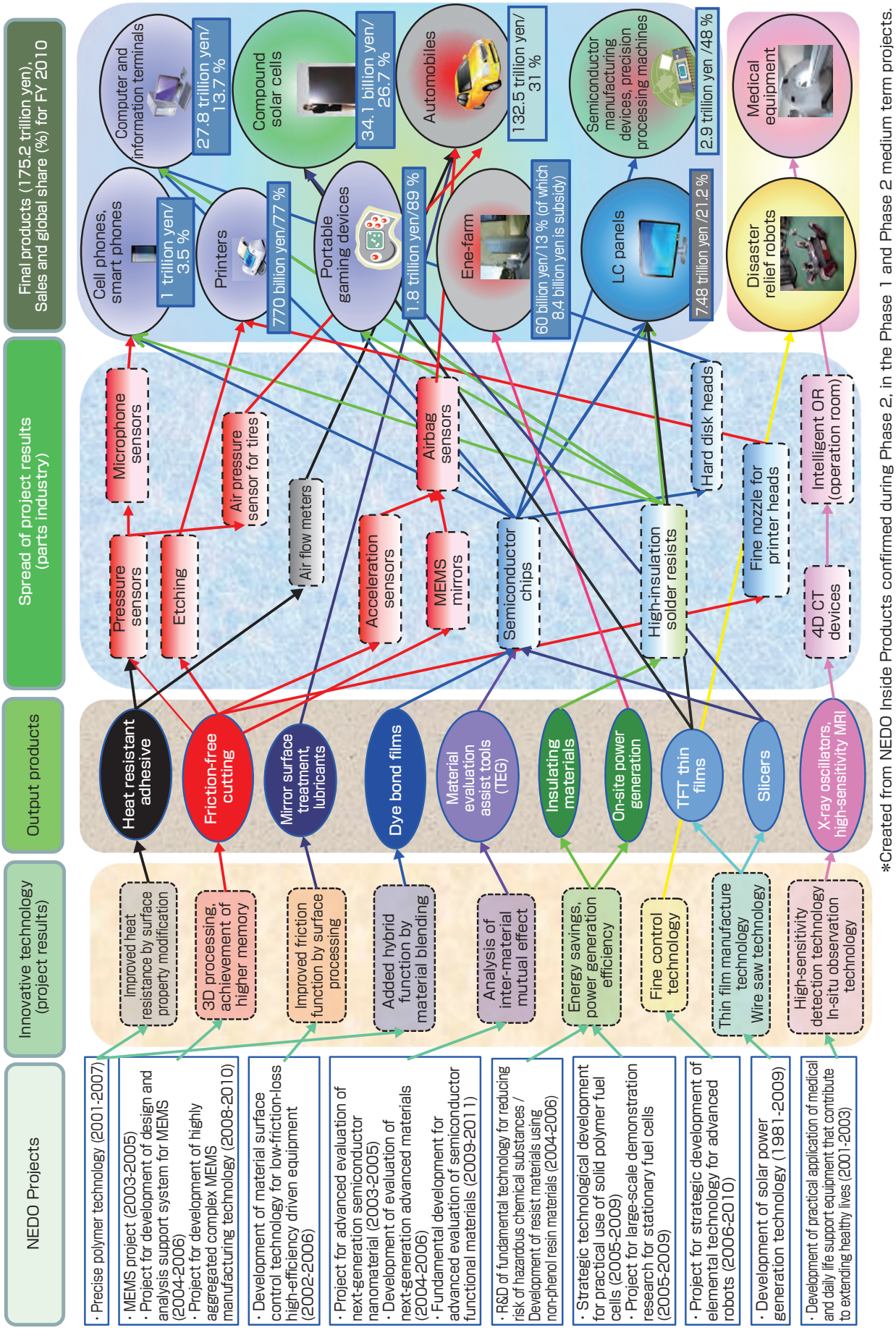
### *4.5 Calculation of the primary and secondary economic induced effects of NEDO Inside Products*

By utilizing the inter-industry relations table, we found out that 20 of NEDO Inside Products are viable for the calculation of the induced economic effects (primary and secondary) on upstream and downstream of their supply chains: the technological fields specific to these products are energy, semiconductors, automobiles, and housing. The summary of 2011-2020 forecasted net sales and economic effects consisting of net sales (65.76 trillion yen), primary induced economic effect (62.1 trillion yen), and secondary induced economic effect (24.76 trillion yen) are shown in Table 4. It is now evident that the best-selling energy-related products have also had significant induced economic effects. For the net sales forecast, the sales forecasts of all the products in the fields concerned were aggregated, regardless of the values of induced effects. It can be seen from the results in Table 4, the secondary induced economic effects (the effect on employment) of energy and housing-related products are larger than any other products. This is possibly attributed to the additional tasks besides manufacturing such as installation and transportation. There are in fact countless NEDO R&D projects that have potential to increase employment opportunities within manufacturing sectors; however, the results above suggest that it is important to envision further job opportunities which involve product installation and transportation, particularly when carrying out the project specifically aims at expanding job creation effect.

## 5 Technological ripple effect of NEDO Inside Products

### *5.1 NEDO Inside Products that have technological ripple effects as generic technologies*

NEDO Inside Products include parts/materials, processing technologies, and intermediate products which vastly contribute to the improvement of existing products despite their marginal net sales. Figure 5 shows the flow from the projects to the products (of high-functional parts and processes with far-reaching technological ripple effects, which are evolved from the NEDO projects after 2000), and their domestic sales and global market shares in FY 2010. Compared to the products and the processes which require long development period as in new energy and environmental products, the high-functional parts and the intermediate products with shorter product lifespan but highly versatile are rapidly spreading their technological ripple effects across the industries (e.g., automobiles, computer products, home appliances). In the interviews with the companies, we noticed their preference of the R&D of high-functional parts and intermediate products that can be carried out in a short period of time with lower development cost to the development of innovative large-scale machines or processes which are costly and time-consuming. The companies also seem to have positive outlook on the technological ripple effects of high-functional parts and intermediate products to other end products. Thus, we estimated that the sales effect on relevant products would reach approximately 175.2 trillion yen.[14][16][31] It is in fact relatively simply to calculate the sales of such end products as solar power generation, gas turbines, high-performance




*Created from NEDO Inside Products confirmed during Phase 2, in the Phase 1 and Phase 2 medium term projects.

**Fig. 5 Innovative technologies born from NEDO projects and midterm outcomes**

industrial furnaces, and residential fuel cells. However, the sales figures of parts/materials, processing technology, or intermediate products need to be inferred from the information given by the corporate researchers and the experts from industrial associations during the interviews, or from various other sources on how these products are incorporated into end products. For example, the core technologies developed in NEDO projects (e.g., MEMS, multilayered films, laser micro-processing, in-situ observation technology) benefit the production of functional intermediate products (e.g., pressure sensors, acceleration sensors, microphones); these technologies turned out to be incorporated into countless end products (e.g., automobiles, cell phones, game consoles) making a part of supply chains. It was also found out that a number of high-performance intermediate products among NEDO Inside Products have achieved more sophisticated functionality, lower cost, and energy efficiency by being combined with other NEDO Inside Products; which have been integrated into some major end products of the key industries in Japan.

### *5.2 NEDO Inside Products with significant gross social benefits*

There is a number of NEDO Inside Products which are enormously beneficial to the society despite the fact that their net sales are not significant. This applies to some environmental and energy-saving products, $CO_2$ reduction and recycling (resource cycling and landfill waste reduction), for instance. NEDO Inside Products with notable $CO_2$ reduction effect include the chlorofluorocarbon destruction processes. A process that detoxifies HFC-23 (trifluoromethane), a byproduct of chlorofluorocarbon coolant process for air conditioning which is high in GWP is typical of such products. There are 14 plants in Japan and eight or more overseas plants in operation adopting this process, and the domestic plants are known to reduce 7 million ton ($CO_2$ equivalent) per year. In 2010, it made a significant contribution to achieving the goal of COP3 (Kyoto Protocol; Third Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change).

It is notable that there is a group of NEDO projects that have promoted the institutionalization of public services: The development of recycling technologies. The R&D projects on over 100 topics have been conducted[16]-[18] in response to recent changes in regulation, and the project outcomes offer invaluable solutions to such social issues as shortage of landfill sites in Japan, hazardous substance control, and resource conservation. Figure 6 epitomizes the technology architecture of recycling systems. In the past decades, there was no appropriate measure being taken other than recycling, recovery and reuse of glass bottles and newspapers. In the face of it, NEDO initiated basic and advanced R&D projects for materials and resource recycling technologies; which have successfully reduced the processing cost through the progress in technology and the improvement of process capacity. The technologies have been applied to a range of wastes and semifinishied goods (mixed materials), and in turn, led to increased recycling rate. Moreover, the progress in soft technologies, namely, life cycle assessment (LCA) and design for the environment (DfE) has enabled mutual improvement of soft and hard technologies, as can be seen from the development of the products that are easy to recycle. The recycling technologies that considerably benefit the society include “recycling plant of the four ‘white goods’ (televisions, air conditioners, washing machines, and refrigerators)” and “re-resourcing of waste plastics (blast furnace injection; liquefaction; and refuse paper and plastic fuel (RPF).” Unlike automobiles, recycling of white goods was made obligatory for the manufacturing companies in Japan, and at the time, the industry as a whole was in need for economical recycling systems. Several home appliance manufacturers had taken charge of the development these devices by bringing their own expertise together, and produced optimal processing devices in a short period of time overcoming different corporate interests. After a series of demonstrations and long-time continuous operation, a new system was established. From the interviews with the companies, we found out that there are currently 49 plants using this system in Japan recycling 931.000 ton per year. It should also be noted that the most important core technology in the development of this entire system was “sorting.” Before the current recycling system was introduced, waste processing had been managed by local governments, and the majority of solid waste had been simply cut into pieces and buried. The advanced sorting technologies developed through NEDO projects allow the most of useful parts to be recovered efficiently at low cost and the recycling rate to see a rapidly increase.

On the other hand, waste plastics had been buried in landfills until new technology was developed. It triggered a range of social problems including the shortage of landfill sites, soaring cost for processing, and dioxin emission during combustion. After LCA and careful economic evaluations, it was found that waste heat recovery (in some cases, electricity) in the form of thermal recycling would bring an enormous economic advantage. Following this, a safe combustion process (i.e., exhaust gas management) was introduced; which led to a > 90 % increase in recycling rate (power generation or thermal recycling accompanying combustion). As for the resource recovery of waste plastics (liquefaction, etc.), practical application as a system was viable only if the technology complied with the revised laws and met the demands (e.g., traceability of the resource, the volume of waste, the presence of recycling businesses).[16]-[18] Thus, the R&D projects would frequently face termination or suspension due to the lack of sufficient amount of waste, or prohibitive costs for labor and transportation, notwithstanding the technological excellence.

In the development of devices and processes in NEDO projects in the 1990s, the government and the industry conducted a

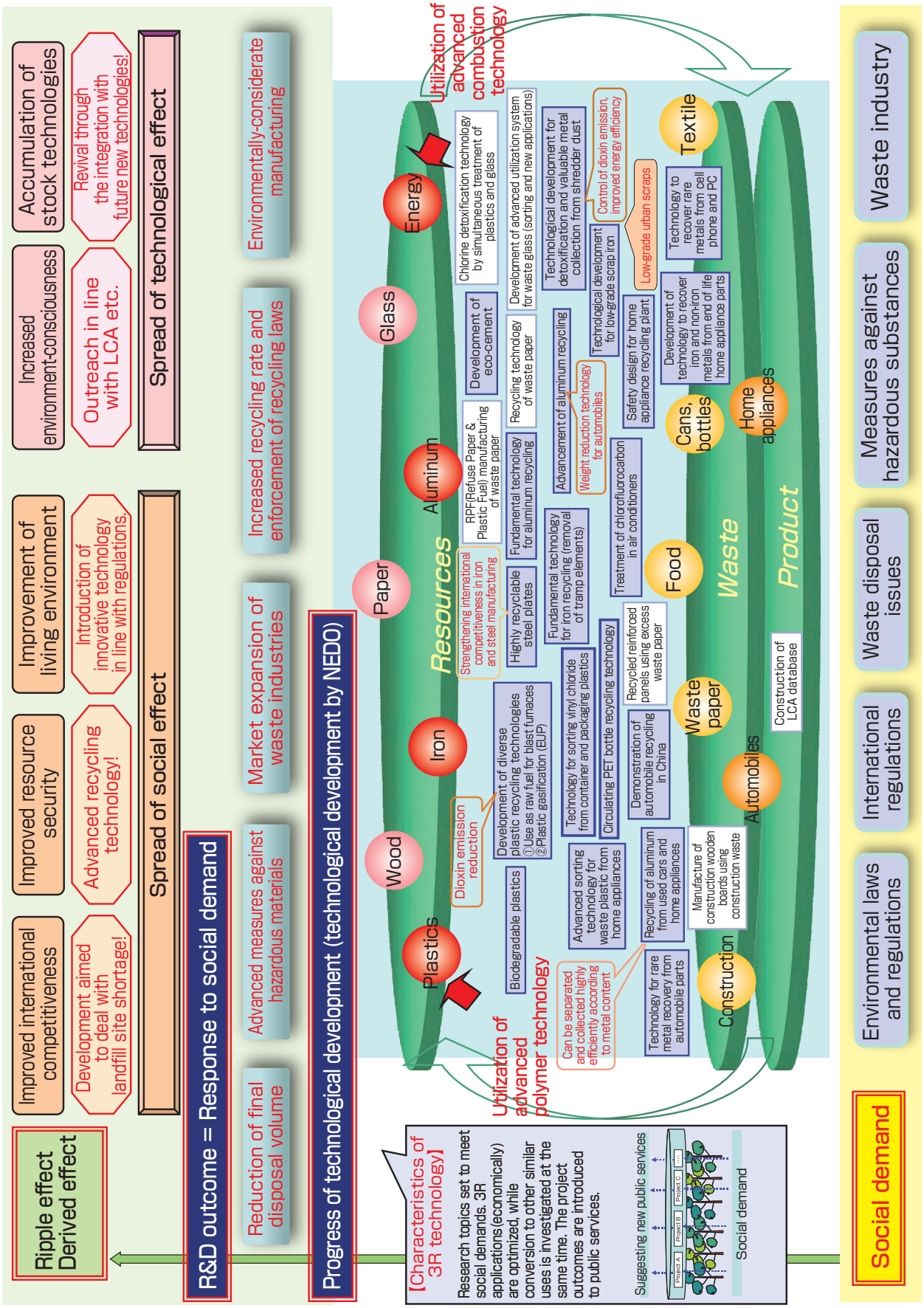



**Fig. 6 Relationship between the NEDO projects and recycling systems**

series of R&D projects aiming for instant practical application, while experiencing various failures. The major issue was the funding source: How to eke out the cost for recycling. Since the vast majority of the public saw no value in the spending on waste processing, it required awareness-raising as well as technological breakthroughs. Under such circumstances, NEDO collected a myriad of information, whereby they could develop the strategies for technology development. This provided hints for subsequent development plans and for other R&D projects.

As the result, the number of unsuccessful projects saw a sharp decline, and there were considerable benefits accrued to groups of developers and the parties directly involved (i.e., no redundancy in financial investment, schedule, and personnel). These are the findings from the corporate interviews.

## 6 Future challenges in expanding NEDO Inside Products

From the survey and the analyses of NEDO Inside Products, the following issues become evident, which need to be addressed for our future research to extend the scope of the products. Below is a summary of the discussions and possible solutions which we recognized in the course of this research.[17][18]

(1) Search for NEDO Inside Product candidates

It has been over 30 years since the establishment of NEDO. For their long list of projects, our research was not necessarily conducted in an efficient way: Listing promising products and processes which could be of past NEDO project outcomes, then referring to literature, reports, the interviews with participants, and other sources. Above all, it seems that the use of questionnaire survey to confirm the current market status of all the project outcomes is the most comprehensive and efficient way to explore NEDO Inside Products. NEDO, in fact, carry out six-year follow-up studies of the projects, and further five/ten/20-year follow-up surveys are also possible. Furthermore, it is crucial for the government to make efforts to help the public see NEDO project outcomes by the construction of a database for achievement reports and the additional interviews with retired employees of the participant companies for instance.

(2) Difficulty in gathering information on the old project outcomes

As a few of NEDO projects initiated back in the 1970s to 80s, it is extremely difficult to gather the information regarding the status of given project at the time, the process leading to the product's market release, and the overview of the technological progress. What we can do is to examine the current market's views on the R&D topics of three decades ago. Having said this, we once again emphasize the need for the interviews with the key in the field and the people in charge of these projects, as well as a database – an extensive record of "R&D heritages." These data will help us track where the current technologies stem from.[32]-[36]

(3) Rigidity in the evaluation of estimated sales

Based on the estimated market size and future outlook, the questionnaire surveys were conducted in order to verify and correct these figures. However, we noticed individual differences in the view on "the scope of NEDO Inside Products." If NEDO made the attempt to estimate the market scale themselves, for instance, they could possibly take advantage of the scope and methods of research. As in this research, the validity of the figures and findings must be ensured. It is thus recommended that the estimations and evaluations of benefits are made first of all, fair and square, and have external experts revise these figures and findings rather than the members actually managing given projects: Academics (e.g., project leaders or the chairs of academic societies) or the members of the industrial associations whose area of expertise is closely related to the projects may be best suited for such task.

(4) Problems associated with quantifying the effects other than sales

In this study, NEDO Inside Products were narrowed down according to the most recent sales figures and the sales forecasts. NEDO project outcomes offer a wide variety of benefits, and some of them deserve greater credit. For example, we made the evaluations in the light of contribution to improved quality of living and public satisfaction. Nevertheless, it is tricky to evaluate such benefit in the same way as the net sales since the opinions vary by individual, and it requires us to seek for a new method that allows these qualities to be comparable.[18] In effect, NEDO Inside Products that are not amenable for quantitative evaluation can be presented qualitatively. However, when the efforts made by different fields and other companies are all aligned, resulting set of efforts (NEDO projects) becomes all-inclusive and a specific impact (effect/benefit) may become hardly noticeable. We need to discuss how to shed light on these products by comparing with past products in the same field and category.

## 7 Summary

We conducted a questionnaire survey and interviews with the NEDO project participants and the members of relevant industrial associations, in an attempt to select top 70 of NEDO Inside Products based on the significance of the product's economic impact (i.e., sales figures and induced economic

effects) and its contribution to the society. These NEDO Inside Products are subject to change in the order of few years as a consequence of a drop in retail price or fluctuations in sales volume. Thus, it requires consistent monitoring of their sales and ripple effects. All products are the results of further R&D activities and investments for practical application/ commercialization: The effort participant companies made after the completion of NEDO projects. For the realization and commercialization of R&D outcomes, the companies are known to make investment an order of magnitude larger than the funding awarded by NEDO; however, business investment against sales revenue was out of our scope since every single amount of business investment was hardly obtainable. It should be noted that it often takes over 10 or 20 years for the practical application and commercial production of an innovative technology.[24] This implies that it is a long-term research investment that can develop unique and unrivaled expertise, turn young researchers into leading figures, and lead to preemptive investment for future R&Ds.

By assuming the contribution rate of NEDO project outcomes to be 100 %, we could present maximized sales revenue and contribution estimates of the R&D outcomes . We could also grasp the general trend of project outcomes and the milestones towards practical application (the effectiveness of industry-government-academia collaboration, success factors in management (see Subchapter 2.8), adaptability to regulations, overcoming of failures, etc.). What is more, the study enabled us to roughly evaluate NEDO's development investment from their project outcomes in terms of overall impact to the society-induced economic effects and gross social benefit (e.g., $CO_2$ reduction, energy efficiency, and job creation), added to the products' sales.

30 years have passed since the first NEDO project, and approximately 3 trillion yen has been invested as development fund. To make above estimates, we chose only a portion of prospective products on grounds of sales performance. The ripple effects, the impact from the know-how, and gross social benefit of the rest of the products were excluded. Figure 7 illustrates NEDO Inside Products' impact on economy, technology, and the emergence of further functionalities. The industry would regard the economic effects including sales and job creation, while research communities may benefit from the technological effects through paper submissions, patent applications, and awards. On the other hand, consumers' perspective lies heavily on the products' gross social benefit such as the improvement in quality of living and safety and security measures. In sum, the purpose of our research was the evaluation of overall impact induced by NEDO Inside Products in the light of economic effects and gross social benefit. The economic effects could withstand quantitative evaluation to certain extent; the benefits such as $CO_2$ reduction or job creation could be expressed in figure although some others including quality of living and a sense of convenience are not fit for quantitative measurement. In future, it is necessary for us to elaborate the impact evaluation methods while extending our research on the products' emerging functionalities for the improvement in quality of living and public services; reduction in public investment; added convenience, safety and security; and health maintenance. Also, another research on the intellectual property of NEDO Inside Products is underway, and a paper is forthcoming.

## Acknowledgement

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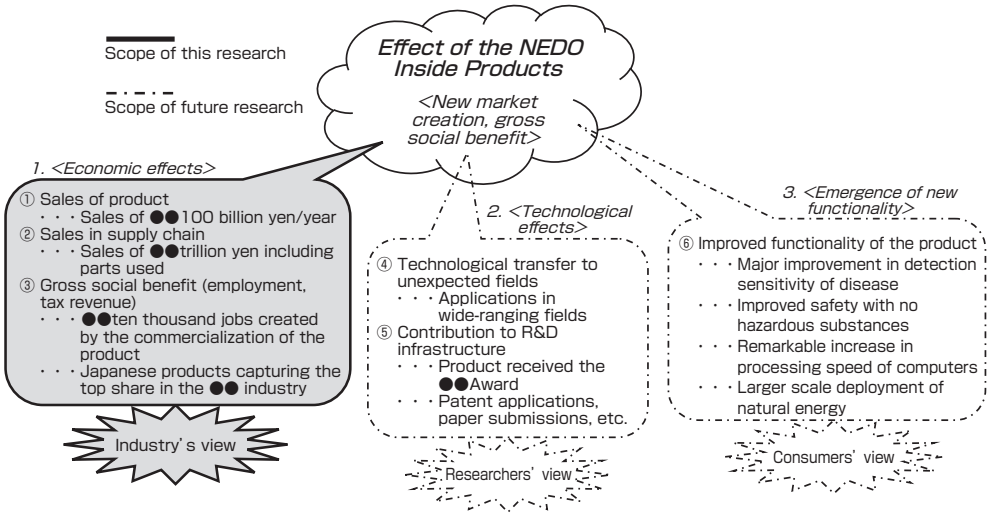


**Fig. 7 Ripple effect of NEDO Inside Products**

## Terminologies

Term 1. Pre-tax profit rate: Net profit divided by net sales prior to tax deduction (See *Financial Statements Statistics of Corporations by Industry*, Ministry of Finances[27] (average 2004-2008 performance value)). Tax revenues from the investment of development expenses (cumulative total for 2010-2020) were estimated using the pre-tax profit rate (average 2004-2008 performance value of domestic manufacturers).

Term 2. Personnel expense percentage: The percentage for manufacturing sectors. (See *Financial Statements Statistics of Corporations by Industry*, Ministry of Finances[27] (average 2004-2008 performance value)). Average income refers to the average income of manufacturing industry (sum of chemical, metal machining, textile, and others) based on *Private Sector Wage Fact-Finding Survey*, by National Tax Agency (average 2004 – 2008 performance value).

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## Discussions with Reviewers

### Overall

**Comment (Akira Kageyama, Research and Innovation Promotion Headquarters, AIST; Naoto Kobayashi, Center for Research Strategy, Waseda University)**

There is a social demand for the assessment and disclosure of the cost-effectiveness (effect of investment) of national-funded R&D projects. While the methodology has yet to be established, this is a valuable paper which has discussed the cost-effectiveness

of selected 70 products in NEDO projects which were successfully put into practical application and turned to commercial products recoding significant sales figures. As for the project outcomes in particular, the paper provides analyses and discussions not only of the sales effects of listed products, but also the gross social benefit such as induced economic effects, job creation, ripple effects to other technologies, and the reduction of $CO_2$ emissions. Furthermore, the paper extracts and presents the success factors of NEDO Inside Products, which are remarkably useful for the future R&D projects and innovation policies in Japan.

## 1 Positioning of the paper

**Comment (Ayu Washizu, Faculty of Social Sciences, Waseda University)**

While the public seek for the clarification of cost-effectiveness of science and technology budget, it is generally difficult to indicate how specific funding results in specific outcomes. However, this study demonstrates that based on the research findings which could only be possible by such agency as NEDO, and this can be a valuable academic achievement.

**Comment (Akira Kageyama)**

This is an invaluable piece of work that discusses the cost (investment) effectiveness by selecting 70 products from the themes NEDO's R&D projects tackled. In regard to the effects, not only does the paper discuss the sales effects of listed products, but also the gross social benefit such as induced economic effects, job creation, ripple effect to other technologies, and the reduction of $CO_2$ emissions; which makes characteristic of this research. It becomes even more complex as time lapses and the lines linking technological ripple effects increase. This will certainly make the survey and analysis more complex, but the effort (or perhaps, challenge) of changing what was conventionally deemed as tacit knowledge into explicit knowledge is essential for both NEDO and the industries. Since both parties are accountable for NEDO projects, I hope this step to be incorporated into the evaluation system with NEDO taking leadership. Moreover, you successfully extracted and presented the success factors of NEDO Inside Products after the discussions with reviewers; which carries considerable implications for R&D project management in future. I believe that this paper is also beneficial as a study on R&D methodology.

**Comment (Naoto Kobayashi)**

This paper successfully shows useful cases investigating the effectiveness of the national investment in R&D. In conducting NEDO projects, it is crucical that all the research promotion organizations prepare adequate research data accumulation methodologies in advance, which will be useful for future policies on R&D and innovation in Japan.

**Comment (Ayu Washizu)**

This research is also a summary of how individual science and technology developed in NEDO projects interrelate with each other and consequently comes to fruition as a commercial product, and the follow-up study of this whole process in detail. This tallies with *Synthesiology*'s objective.

**Answer (Masaru Yamashita)**

I have considered it crucial to show the project outcomes quantitatively as NEDO projects are run by national funding. Thus, we submitted this paper in the hope that this would be a chance to prove their benefit. I am grateful to the people involved for giving us this opportunity. When we had an oral presentation at the American Evaluation Association a few years ago, our work was fortunate enough to receive credit from the experts around the world. As a result, last year, we submitted a paper to *Research Evaluation*, a journal published by AEA. We later conducted additional research with new perspective, and submitted this highly original paper to *Synthesiology*. I presume that this article has become more elaborate by specifying the success factors of NEDO Inside Products with certain degree of precision, reflecting invaluable comments from the reviewers. To this date, the description of project achievement available for external viewers remained qualitative. We presented semi-quantitative evaluations and visualized invisible results, and the resulting paper turned out successful in enhancing the quality of research by alluding to challenging issues.

Such effort we made in this research must be carried on for a mid- to long-term. I notice the importance of follow-up surveys, and continuous revision of the figures and search for new directions must be done at the same time. Additionally, it is strongly recommended that NEDO establish a system that can measure the effectiveness of their project management with the help of our result. In the course of this research, we came across a number of new findings. It would be grateful if we attract a wider readership in research communities and businesses in Japan, so that we can continue to provide information as hints and implications for successful R&D projects by NEDO, companies, or universities.

## 2 Structure of the paper

**Comment (Naoto Kobayashi)**

The goal of this paper is the "evaluation of gross social benefit of NEDO Inside Products developed with national funding." Two major elements to achieve this are: (1) the selection of NEDO Inside Products, and (2) the evaluation of gross social benefit of NEDO Inside Products. The sub-factors of (1) include the methodologies such as the definition of NEDO Inside Products, and the selection procedure. The sub-factors of (2) include economic evaluations, job creation, $CO_2$ reduction, and the projection of ripple effects. I would recommend you to clarify the structure of this research you have in mind by showing that in a diagram at the end of chapter 1.

**Answer (Masaru Yamashita)**

Thank you for your valuable advice. We have added Fig. 1 at the end of chapter 1, so that our readers can see the outline of this paper.

## 3 Categorization and inter-industry relations analysis

**Question and Comment (Ayu Washizu)**

You defined new product categories since the existing ones had been insufficient. As categorization is the basis of analyses and therefore is of vital importance, it seems necessary to discuss more in detail (drawing upon previous research) why you decided on this categorization. In general, innovation can be divided into product innovation and process innovation. Perhaps the former can be further divided into the creation of an unprecedented product and the improvement of existing products. The latter may be the innovation of manufacturing machines and the development of materials to be incorporated into products. Such categorization should be relevant to the discussion on the characteristics of social effects that innovation may bring about. Thus, I suggest you expound more on your categorization.

The input-output analysis is used as the method to calculate the indirect effect against the direct effect. How you use the table in the paper is not an unusual one.

However, as the inventor Leontief notes, the input-output table is a method to analyze the effect of technology changes by treating the change in technology as the change of input coefficients. Recently, it has been applied to LCA in engineering field, and adopted to analyze environmental impact and the ripple effects of $CO_2$. It is preferable if you consider this way of using the table in future input-output analysis. It is difficult for the public

to obtain the information on how innovation can be reflected in the input coefficient, but such organization as NEDO should be capable of acquiring the data. As your future topic, and as a part of NEDO's product evaluation activity, the implementation of the new method of exploiting the table deserves further discussion. In addition, the selection criterion for the calculation method shown in Fig. 4 may need an explanation referring to past literature.

**Answer (Masaru Yamashita)**

I appreciate your corrective guidance. In this paper, we aimed to demonstrate the impact of NEDO Inside Products on society. NEDO's mission is to promote national projects in the areas of environment, energy, and industrial technologies. From this standpoint, each product falls under one of the following categories: The product "(1) is a pioneer of the market, (2) is competitive in international markets, (3) pushes the boundaries of the technology, and (4) addresses any social issue." Over half of the products belong to category (4) reflecting the primary objective of NEDO's establishment. After careful examination of these technologies, we found that it would make more sense if we divided (4) into social demands and everyday life issues. Having consulted with external experts, we re-categorized the item (4) as (4) solutions to resources and energy issues, and (5) providers of safety, security, and comfort. As a result, we have five categories. This process is explained in detail in subchapter 2.6.

For the inter-industry relations analysis, we eventually added the reference detailing relevant information in subchapter 4.3 due to the word count of this article. As you pointed out, it is a method frequently used in LCA and other analyses, but to calculate the effects NEDO Inside Products induced using the inter-industry relations table, we made investigation from different perspectives focusing on these two points: (1) Distinction must be made between the products amenable for the calculation of induced effects and those that are not, and (2) the threshold values need careful examination. As a result, B-to-B products were chosen subject to estimation as they have no problem calculating the induced effects using the inter-industry relations table, and for B-to-C products, calculations were performed on the assumption that there were hardly any induced effects among the industries and the only contribution being made was the sales revenue of NEDO Inside Products. In future, we are willing to utilize the inter-industry relations table to calculate the benefits and induced effects for environmental effects and $CO_2$ ripple effects analyses as well as sales figures.

## 4 Industry-academia-government collaboration and contribution rate to the NEDO projects

**Question and comment (Akira Kageyama, Naoto Kobayashi, and Ayu Washizu)**

On top of the funding awarded by a NEDO project, there must be an amount of expense given from participating enterprises. How did you handle this burden on participant companies when looking at investment efficiency? You posited the contribution rate of NEDO's R&D outcome to be 100 %, and your initial explanation for this was: 1) practical application would have been seriously delayed or could not have been achieved without given project outcome; 2) many of the products underwent development phases from basic/generic to demonstration, and 3) the project's contribution rate to practical application differs depending on the product and cannot be specified due to the difficulty associated with verification. As the Great East Japan Earthquake devastated a semiconductor plant and it affected the operation of automobile manufacturers around the world, the product's whole supply-chain goes dysfunctional however tiny the missing part may be. Assuming a 100 % contribution rate is a way to represent certain viewpoint. However, it is seemingly inevitable for you to face criticism for overestimating the rate.

In the theory of R&D management, there is a widespread saying: Surviving "Valley of Death" to confront "Darwinian Sea." The manufacturers, in particular, are aware that they will never arrive at a new product or business without crossing Darwinian Sea. Furthermore, "practical application would have been seriously delayed or could not have been achieved without given project outcome" holds true (necessary condition) and is critical. But, considering the additional investment[Note*] of substantial amount necessary to record sales from a new business or a new product (sufficient condition), it is essential to examine and account for the basis of the 100 % contribution rate.

Note*) (1) Reproducibility of the technology, (2) investigation on yield increase, (3) investigation on scalability and subsequent optimization, (4) marketing, (5) close cooperation including joint research with user companies, (6) establishment of quality-assurance system, and etc.

**Answer (Masaru Yamashita)**

Thank you for such pertinent advice. We have received the same question from a number of researchers regarding the point you mentioned. For the products taken up as NEDO Inside Products, their sales figures are presented after obtaining approval from the developers, relevant bodies, and the researchers involved. Moreover, the contribution rate was set at 100 % because two or more of the following conditions would apply to almost all the products:

> (1) were developed through multiple mid-to long term projects; (2) addressed topics the companies would seldom consider and had difficulty obtaining funding for the purpose; (3) were in need for support from external experts, which was difficult to obtain in corporate research, (4) would never be put to practical application if it were not for the NEDO project outcome; (5) must be realized as corporate obligation owing to the funding support from the tax during the critical phase of development; (6) may differ in contribution rate and the companies are unable to grasp; and (7) were realized following the completion of the project and their subsequent commercialization was more likely due to the know-how and the companies' manufacturing effort rather than the funded research opportunity.

The maximum (sales) effect was calculated accordingly. We have added the above text and revised the items for subchapter 2.2 "Scope of NEDO Inside Products." In chapter 7, we have also inserted, "For the realization and commercialization of R&D outcomes, the companies are known to make investment an order of magnitude larger than the funding awarded by NEDO".

## 5 Understanding of R&D expenditure for NEDO projects

**Question and Comment (Ayu Washizu)**

It is always an issue when considering R&D expenses how to evaluate the expenditure on failed R&D projects. Since the scope of this research is the development projects that were successful, it is most unlikely that you have included the R&D expenditure on failures. Nonetheless, even a failed development project may have technological ripple effects as shown in Fig. 5, and it could be valuable because it establishes the fact that "this doesn't work." This may eventually be a factor leading a project to success. Therefore, the expenses on failures have supposedly contributed to successful results. In the cost-effectiveness calculations, you figured out the maximum effect assuming a 100 % contribution rate. Taking those expenditures into account, you might have to consider slightly exaggerating the figures when conducting sensitivity analyses.

**Answer (Masaru Yamashita)**

I totally agree with your point. NEDO has invested approximately 3 trillion yen as R&D expenditure over 30 years. It is only 70 out of it which have come into our focus as NEDO Inside Products. As demonstrated in subchapter 3.2, the investment of some 640 billion yen has actually generated practical application and sales, and the remaining 2.34 trillion yen resulted in failure. The follow-up survey by NEDO indicates that nearly 20 % of the project participants has successfully managed practical application and market launch, but those actually record sales are even less. However, in the answers to the questionnaire, almost all the researchers who took part in unsuccessful projects commented that they gained a degree of success in the form of papers, patents, know-how, training, and networking. About 80-90 % of them in fact admitted that they were reasonably satisfied despite the hardship during the project. Nevertheless, it seemed more appropriate to present as much quantifiable data as possible instead of showcasing such positive responses, in order to avoid subjectivity and self-satisfaction in evaluation. We considered it crucial to focus on such data as employment, $CO_2$ reduction, secondary social effects, and gross social benefit (resource circulation by recycling, $CO_2$ reduction, environmental measures, etc.) which can be presented in figure.

## 6 Technological ripple effects

**Comment (Ayu Washizu)**

I found Figs. 5 and 6 interesting as it gives a picture of technological development. In my view, the ripple effects of technologies that are not apparent in particular need more attention. These must be clearly illustrated, and the description in chapter 5 needs to be more precise.

**Answer (Masaru Yamashita)**

Due to the word limit, we mention only the essence of technological ripple effects; however, we have changed the description in chapter 5 to a more specific expression to make it clearer. Particularly, not only did we discuss the technology but also the effects on the human resource and the environment in the last paragraph. As for the complexity of Fig.6, we have revised it and simplified the diagram.

## 7 Success factors and their evolvement in future project management

**Question and comment (Naoto Kobayashi and Akira Kageyama)**

In the classification and selection of NEDO Inside Products, you might have explored the effective measures the companies and NEDO take or the positive effects the market environment caused that create such 'stellar' products. It is worth including the points above in brief at, for example, the end of chapter 2.

I would also recommend you analyze the successes and the failures whereby you can develop a simple and useful evaluation method to measure the investment effects; which can be utilized in the management and evaluation of future R&D projects.

**Answer (Masaru Yamashita)**

For almost all the NEDO Inside Products under investigation, we conducted interviews as well as questionnaire surveys. The successful projects, by and large, manage to materialize the seeds of technology in the way that satisfy the needs and the market demand. At the same time, we recognized the major factors of success below:

(1) The participants gained significantly larger amount of data, compared to their usual research situation; (2) the companies explored a mechanism which brought about improved reliability and problem-solving strategies, and development, modification, and extension of research policies through joint research opportunity with universities; (3) the participants were reasonably confident with the technology from the start for its practical feasibility and commercial viability; (4) the participants kept the idea for long before the project launch; (5) the participants had already had unrivaled know-how and capabilities, which saw further improvement and were exploited in the course of the project; (6) the participants were skeptical about the market information and proactive in exchanging information within the team; and (7) the participants carried out prototype demonstrations and repeatedly verified and modified the technology to the point where it was elaborate enough to ensure its proximity to commercialization.

These were discussed in newly added subchapter 2.8 "Success factors of NEDO Inside Products."

We conduct interviews and questionnaire surveys on a project for up to five years after the completion, asking (almost all) the companies involved to participate. Using methods such as regression analysis, we work out the possible behavior patterns of successes and failures. As a result, we found out that unsuccessful projects and successful projects are somewhat different in the way they treat failures. The quality we have achieved in this paper is attributed to the discussion with the reviewers; which enabled us to extract and present the success factors of NEDO Inside Products. By sharing the results from these analyses, we hope to give NEDO's project management food for thought. An article specifically on these analyses will be submitted in due course.

## 8 Intellectual property of NEDO Inside Products

**Comment (Akira Kageyama)**

It is presumably due to the limitation of space, but you spared no effort to mention patents in this paper. Patents are incredibly important as the means to protect R&D achievements. If you managed to describe the level of patent protection the 70 themes of NEDO Inside Products are offered, that would illustrate a part of the technological effects and serve as an index of the international competitiveness of made-in-Japan technologies. A few lines of description should be sufficient enough to show that you are aware of the significance of intellectual property.

**Answer (Masaru Yamashita)**

As you pointed out, the patents represent remarkable achievement. There is a study underway confirming the patents' relevance to NEDO project outcomes, and so far, only around 30,000 are being investigated. A team of researchers will have opportunities to publish the findings in the form of oral presentation in an academic society meeting or a journal article. For this reason, I added a line "another research on the intellectual property of NEDO Inside Products is underway, and a paper is forthcoming." in chapter 7 "Summary."