行政院原子能委員會

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各部門提升能源使用效率之節能減碳效益評估

Reduction of energy consumption and carbon emission achieved by efficiency improvement in respective sectors

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Abstract

No technology that is already feasible to date can solve the resource shortage and security problem alone. Therefore, collective implementation of energy saving measures is needed to make a significant change towards a sustainable future. Technology roadmapping is known as an effective approach that can be taken to enhance the communication, support consensus building, and lead to an agreed and collective implementation of technologies. In this project, a framework for construction of Taiwanese roadmap for energy technology domain is prototyped. The visions on where the roadmap should direct to, will be taken from the national energy target.

First, the technologies in Photoelectronics (i.e., LED, Photovoltaics, LCD), Electricity, Petrochemical (i.e., fuels, others), Steel, Domestic, and Transportation sectors are screened from the viewpoint of its feasibility and effectiveness. This is performed through i) interviews, ii) literature review, iii) major contribution analysis, iv) theoretical limit analysis, and v) market projection. The screened technologies are further analyzed from its component technology, cost, materials required, environmental impact, and social acceptability. The technologies without sufficient data were eliminated from the analysis in this report, but review was made so that further study on scenario development is facilitated.

Technology assessment results are integrated to draw a holistic and scientifically supported and broken-down vision and roadmap of energy systems in the short-middle term (2020). In doing so, projections of population, market, resource price, etc. are made.

The constructed framework is demonstrated for analysis on scenario for Electric Vehicles, considering its potential load balancing capability. It is shown that greenhouse gas emission reduction effect of EVs is contributed by which factors, canceled by which factors, and what kind of assumption needs to be made to derive such a conclusion.

Keywords: Roadmapping, Carbon emission, Energy saving technologies

摘要

目前科技沒有可行的技術可以單獨解決資源短缺和安全問題。因此節能措施的集體執行需作重大改變以因應未來永續發展之目標。為達成此目的，技術發展藍圖被視作為一有效之方法，不僅可加強溝通，建立支持共識，並可使技術執行達到共同一致性。本研究將以台灣節能技術發展藍圖作為雛型架構進行研究分析，而此藍圖之願景將作為國家能源發展的目標。

首先，根據其技術發展之可行性與有效性，篩選出、光學(如LED、太陽能、LCD)、電力、石化(如燃料或其他)、鋼鐵、住商與運輸等各部門，並藉由 i)調查訪問、ii)文獻回顧、iii)重大效益分析、iv)理論限制分析、v)市場預測等研究方法，進一步分析其組件技術、成本、材料需求、環境衝擊以及社會接納度。而對於缺少重要資料之技術僅進行簡略之相關文獻參考回顧，以利後續研究之情境發展。

本研究將未來人口、市場與資源價格預測等外在因子納入考量，整合技術評估結果，完整且具科學論證性地指出詳細的能源願景，並描繪出短期(2020)能源系統發展藍圖。此外，本研究所建立之系統架構，考慮電動汽車其潛在之負載平衡能力，模擬各種情境分析。藉由分析過程可得知影響電動汽車溫室氣體排放減量效益之因素為

何、及何種條件需被假設，進而得到不同之情境分析結論。

關鍵詞：技術發展藍圖，節能減碳效益，節能技術

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Executive Summary of Project Checkpoints

In this project 1) Technology assessment, 2) Review of targeting and benchmarking methods, 3) Review of promotion policies, 4) Construction of Visions, and 5) Analysis of Bottleneck, risk, and uncertainty were the checkpoint items. Here we summarize our achievement on these 5 items.

✓ **Technology assessment**

- Photoelectric sector
- Electric parts
- Electricity
- Petrochemical – Fuel production
- Petrochemical – Others
- Steel
- Domestic Transportation

In this report, we have screened technologies that are relatively higher impact, with higher potential, and have sufficient data for evaluation from abovementioned sectors.

Electricity generation and utilization (PV system, Wind power), and **Transportation** (EV and hybrid vehicles), were chosen as the technologies to elaborate on, while **Domestic** (fuel cell systems, air conditioners, heat pump boiler) and utility for **industries in general** (fuel cell cogeneration of heat and power, air conditioners, heat pump boiler) were reviewed. Through the review, the data in need to complete building them into the technology roadmap were clarified.

Efficiency improvement technologies in **Steel industry** are already implemented, and have less potential for further improvement in Taiwan. Further reduction should be explored in a cross-sectoral approach: carbon emission from steel industry may increase but the improved product quality may reduce much more emissions in other sectors. The remaining challenge will be in reuse of low temperature heat waste.
According to the report on October 1, 2012 [1], china steel has already implemented high temperature heat recovery process, which help them earn more than 10 billion NTD of electricity fee. They recover 3,697 Tcal (35%) and the other 65% of the heat waste is not utilized. Among the recovered waste heat, over 650℃ comprises 42.3%, 250-650℃ comprises 57.7%, and below 250℃ portion is not recovered at all. For example, China Steel is conducting a pilot-scale test for utilization of waste heat for producing algae, which can be used to produce renewable biodiesel. This process simultaneously fixes carbon from the flue gas emitted from the process. Another potential will be to utilize physical or chemical heat pump to upgrade the temperature of the heat.

Both Japan and Taiwan, industrial sectors use half of the energy in the nation. In Japan, **Petrochemical** industry emits ~30% of the carbon emission, and 40% of which are by distillation. Therefore, 6% of the national emission is contributed from distillation in general. There are technologies that can improve energy efficiencies of various types of distillation columns. For example, ***hybrid use of distillation and membrane separation*** might be able to cut down the energy consumption by half – therefore 3% of energy consumption can be reduced. For Taiwan also, petrochemical industry is a major energy consumer, and energy saving at a similar magnitude is expected. However, we do not yet have information on how this technology will change the inventories in the petrochemical industries. Since this technology has a high potential, it is recommended to evaluate it in detail and consider investment on such membrane materials.

- ✓ **Targeting and Benchmarking methods**

In Taiwan, there are targets for GHG emission reduction, introduction of renewable energy, and energy intensity. These methods all look at the sustainability aspect of energy from different perspectives.

GHG emission reduction: Sustainable energy policy framework (永續能源政策綱領)[2] sets the target at GHG emission should come back to the level of 2008 during 2016-2020. At 2025, the emission should be at the same level as in 2000.

Renewables: Renewable Energy Development Act (再生能源發展條例:第六條) [3] sets the target to enhance the capacity of electricity supply from renewables by 6,500-10,000MW.

Energy intensity: The Framework on Energy Development (能源發展綱領)[4] says that the energy intensity should improve by 2% annually.

- **Promotion Policies**

Examples of promotion policies[5, 6] for energy efficiency enhancement include:

- **Feed-in-tariff (FIT):**

  The energy generated by PV systems, wind power, etc. can be sold to the power grid with a fixed rate at a better price. The selling price of the electricity will decline every year to encourage earlier installation. For example, application for PV systems installation is currently on application basis. The project will be evaluated, with check points such as its expected generation, whether the roof is legally constructed, etc. There is an annual quota for the projects allowed to feed in, in order to ensure the program do not go bankrupt because of the "excessively" accelerated installation.

- **Mandates for implementation of energy saving equipment for new constructions:**

  As mentioned in the interview record shown in appendix 1, Taipei municipal government has mandated for all the newly constructed swimming pools for schools to use energy saving facilities. This kind of mandate for public projects can be helpful in promoting installations.

- **Preferential loaning system for financing:**

  For investment on energy saving technologies or renewable energy facilities, financing can be a bottleneck. Several banks in

Taiwan, including Cathay United Bank (國泰世華銀行) has financing program for PV systems. These programs will apply lower interests, or apply the installed system itself as collateral for the financing. This kind of loaning system is combined with the ESCO model introduced below.

- **Energy saving rewards**

For consumer of low voltage power, the government encourages energy saving by giving out rewards. The rewards are calculated based on how much electric energy consumption was saved compared to the same month in the previous year.

For high voltage consumers, no such energy saving reward is available. (If the consumer improve the power factor of the factory, the electricity fee will be cheaper. The power factor can be improved by for example using active compensation equipment. This is because factories with low power factor will require more current than it is supposed to, and more current is not used at the factory, which means the burden of the infrastructure becomes higher. However, this is not related with energy saving itself.)

- **Business models**

For PV systems, there are a business model of **roof rental**. The energy company will install the PV systems on a roof rent by the owner of the building. The PV systems belong to the energy company, and so does the benefit from selling the power. With this business model, the owner of the roof can make small profit from lending the roof, no additional investment is needed for the owner. In addition, the owner can benefit from protection of the roof from direct irradiation (thereby reduce loading on air conditioning in some case), and also improvement of the image due to the PV panels if they are visible. The bottleneck of this model is that in Taiwan, illegal construction is seen on almost all of the buildings for residential purposes, which makes the building disqualified for PV systems installation with FIT promotion.

For energy saving project in general, "**Energy Service Company (ESCO)**" is an emerging industry that can promote energy efficiency improvement. This type of company will install the system (heat pump, PV system, etc.) and paid back for the cost (including profit of the ESCO) by the benefit generated by energy saving. After it is paid back, the benefit from energy saving is totally on the owner. This business model can reduce the investment of the owner. Because the banks consider this kind of project is relatively stable and good one, several banks offer better deal for the loan.

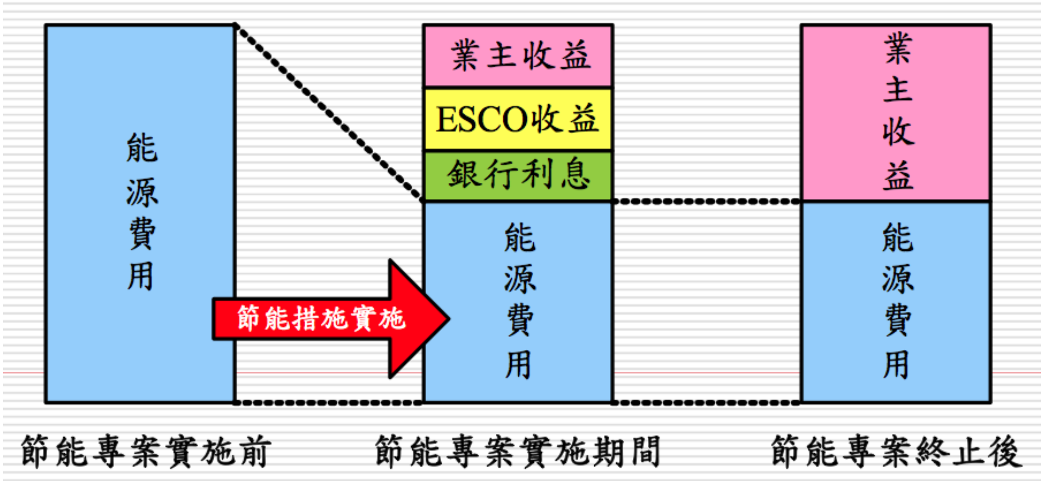


Figure Explanation of ESCO business model introduced by 陳輝俊台灣 ESCO 產業發展協會理事長 in 2008[7]

✓ Construction of Visions

In this project, visions for future vehicle use were prototyped. It is made clear that more detailed information on the demand of transportation is needed to draw a more agreeable vision, rather than just making mostly a projection of the current trends.

It was also clarified that if nuclear power is going to be reduced according to the schedule, it is impossible to supply growing power needs at the year 2020, if the power demand was to grow as illustrated by Taipower in their report[8]. Because many of the technologies need more time for implementation, accelerated replacement of refrigerators and air conditioners, and encouragement and enforcement and energy saving measures is needed. Taiwan industries also need to prepare for expanding risk of electricity shortage in the near future.

In Taiwan, 2020-2030 is a period when it peaks its population. Therefore, it must be kept in mind that we should not make a reasonable investment not just for supply the electric power during this period but with consideration of after the decline in power demand. Otherwise, the next generation will need to bear the cost when they do not really need that many facilities. For example, if more thorough energy saving actions during 2020-30 can reduce the number of nuclear reactors that needs to start operating, it becomes worthy to invest on such an energy saving actions, education, infrastructure and investment. In this research, we have shown this through preliminary calculation for 2050. Using the technology assessment framework presented in this report, a more active discussion based on quantitative figures and integrated scenarios should be initiated as soon as possible.

- ✓ **Analysis of bottleneck, risk, and uncertainty**

Bottleneck identified is the cost of the high efficiency devices. For example, it is mentioned in the report that heat pump boilers and fuel cell cogeneration systems have good potentials, however, in Taiwan, commercialized systems are not available in package. Key parts such as compressor are mostly produced in Japan. Such a situation can keep the price of the systems high, and thus become a bottleneck for the introduction of these technologies.

The **risk** identified in this study is material supply for PV, motors for generators and batteries for EVs. To reduce such risks, development of recycling technologies for the materials used in these device, and development of alternative materials that can diversify the risk. Another emerging risk is the supply chain risk. For example the flooding in Thailand (influencing manufacturing of personal computers), or Earthquake in Japan (influencing global production of cars) has revealed that the supply chain is actually quite globalized, and in some cases, quite concentrated for the sake of lowering the cost and management of knowledge. Under such situation, some simple defect in the supply chain can bring a critical damage in some particular industry.

There are lots of **uncertainties** identified; for example in evaluation of EV, the following were the major uncertainties;

- future strategies for nuclear power plant
- future smart grid infrastructure

For such uncertainties, we utilize scenario analysis approach. This is demonstrated using the example of evaluation of EV promotion. The premise of scenario analysis is that we do not try to make a prediction (or forecast) that is accurate. In scenario analysis, the objective is to be prepared for lots of future situations that are all possible to emerge.

Chapter 1 Introduction

1.1 Use of roadmapping for making important, society-wide decisions

Some decisions on technology management are so important that could influence the future of the entire society. For example, investment for future energy systems, strategies to tackle major societal threats (ex. adaptation to aging society) are among those important decisions.

Such decisions must 1) be made based on scientifically consistent and/or unbiased facts, 2) be agreeable among the stakeholders, and 3) be a responsible and just one for other parties. The other parties here include other countries in the global society, and future generations.

It is widely understood, that the decisions related to energy systems are important because it is closely linked with environmental impacts that is related to public health, resource that must be shared globally and amongst the current and future generations, well-being of the energy users, and production activities that bring the prosperity to the people.

Many energy-saving technologies are entering the market recently, for example: heat pumps (incl. refrigerators, air conditioning, and boiler), solar photovoltaic systems (PV), fuel cell cogeneration systems, hybrid electric vehicles, etc. Since none of these technologies alone can solve the entire energy-related problems, it is important to construct an attractive future vision and roadmap to induce a collective implementation that links the current situation and the vision. The roadmap needs to be drawn with feasible technologies with reasonable future projections (not the maximum potential, not too conservative estimates). The roadmap is usually updated frequently reflecting the progresses and breakthroughs made in the technology development.

1.2 Objective

The objective of this study is to construct energy technology roadmapping tools for Taiwan. The tools will allow its users to construct the energy roadmap that could match the national energy targets, so that it could trigger wide discussions, enhance understanding, promote agreement, direct efficient investment and bring international competitiveness and thereby increased well-being and sustainability to Taiwanese society.

Roadmapping approach is used at a countries' level, as well as in a business to build an agreed future vision and the pathways towards the vision. Perhaps the most famous roadmap is the one issued from ITRS (International Technology Roadmap for Semiconductors), which is established by semiconductor companies aiming at meeting the target set by the famous "Moore's Law".

Among the energy technology roadmap, a Japanese group have recently completed a project "Future Energy Systems Designed by Feasible Technologies" financed by the Ministry of Environment of Japan. Figure 1-1 shows the boundary definition and structure of the energy roadmap taken from their project report[9]. **Fuel generation (in brown)**, **energy conversion (in green)**, and **energy usage (in blue)** are the primary categories. Energy saving technologies we focus in this project could be a part of any of these three categories.

Energy usage is further categorized into **Domestic and Office (in dark blue)**, **Industry (in red),** and **Transportation (in teal blue)**. Technologies in these subcategories can determine the demand for fuels and electricity. According to market mechanisms and incentives added by policies, the way fuels and electricity are supplied is determined.

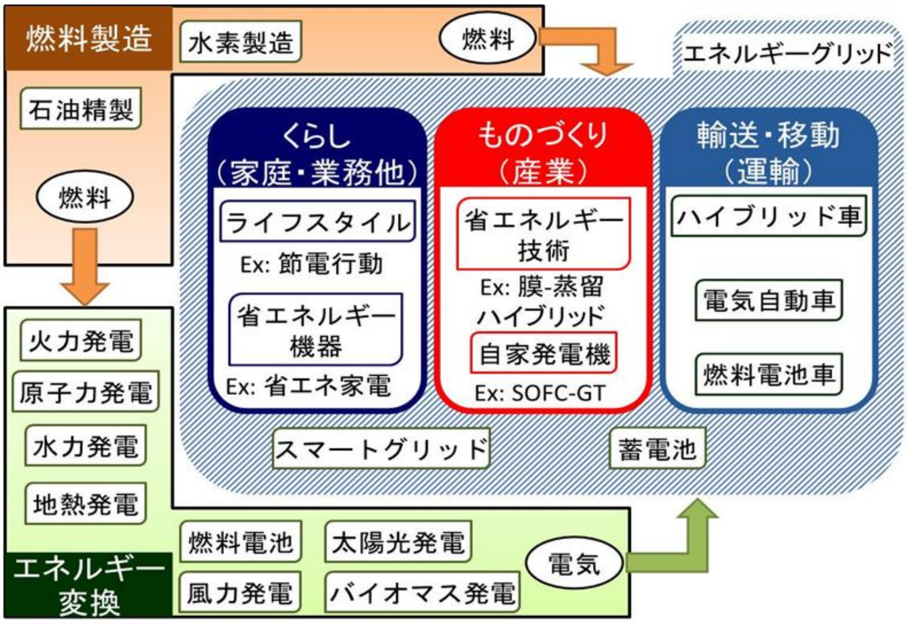


Figure 1-1 Structure and boundary definition of energy technology roadmap from Japanese study[9]

Chapter 2 Methodology

The framework of the methodology used in this study is summarized in Figure 2-1. This framework basically inherits the structure and boundary definition presented in Figure 1-1 by the Japanese group. The difference we have made is in the two models used for simulating consequential changes in the greenhouse gas emissions induced by changes in electric power and fuel demand: POM, COM-Petro, and PDPM.

In the project conducted by the Japanese group, they also use a model that is equivalent with the power mix optimization model (POM) presented in green hexagon. In this way, it becomes possible to simulate changes in emission from power plants reflecting how the power use changes as a result of the evaluated scenarios (Figure 2-2).

For fuel production, they have just multiplied a value, emission inventory (ex. kg-CO_2 L^{-1} of reductions in fuel consumption) for the differences made in fuel consumption. However, just like in the electricity sector, the way we use petrochemical products could influence the emissions in various ways. To consider this effect, we have developed a consequential material flow model for petrochemical industries (COM-Petro) shown in the red hexagon (Figure 2-3).

Finally for energy consumption, an important technology is emerging. It is electric vehicles (EVs), which are equipped with batteries. The batteries are energy storage, and by utilizing the batteries on EVs to balance the loading of the power grid, it can contribute in reducing the emissions from the power plants. An imaginary pattern of an individual EV contributing in load balancing is illustrated in Figure 2-4. The car charges its battery over the night, and uses it for commuting to (8:00-9:00) and from (17:00-18:00) the workplace. During the parking at the workplace, the EV controlled by a smart charge-discharge facility can discharge part of its stored power to the grid to shave the peaks in the power loading on the grid (13:00-17:00). Still, there is enough power left in the battery on this EV to commute with some redundancy (here approx. 60% of the full state of charge) to make the EV work stably and for some irregular uses outside of the routine use. We have prototyped a power demand projection model (PDPM) that can estimate the maximum potential of load balancing achieved by EVs, while satisfying the transportation needs. The Japanese group, have considered the contribution of EVs but in a much optimistic manner without consideration of user's behavior patterns. The PDPM is subject to enhancement so that it can consider introduction of other technologies and changes in lifestyle.

In the following sections, the elements (models and scenarios) presented in the Figure 2-1 are elaborated on. To construct technology scenarios and a roadmap, feasible technologies must be identified and assessed. This is done by i) interviews (Please see Appendix 1, 2), ii) literature review, iii) major contribution analysis, iv) theoretical limit analysis, and v) market projection. Once identified feasible, the technologies are further assessed from its component technology, cost, materials required, environmental impact, and social acceptability. The scenarios listed in Figure 2-1, however, is not the only set of scenarios that should be evaluated. Other kinds of scenarios might need to be added on to this list, and for the scenario categories that are already listed, a more sophisticated scenario should be constructed for a thorough analysis. Here this study just demonstrates the framework and tools developed to enable consideration of various sub-scenarios in an integrated manner.

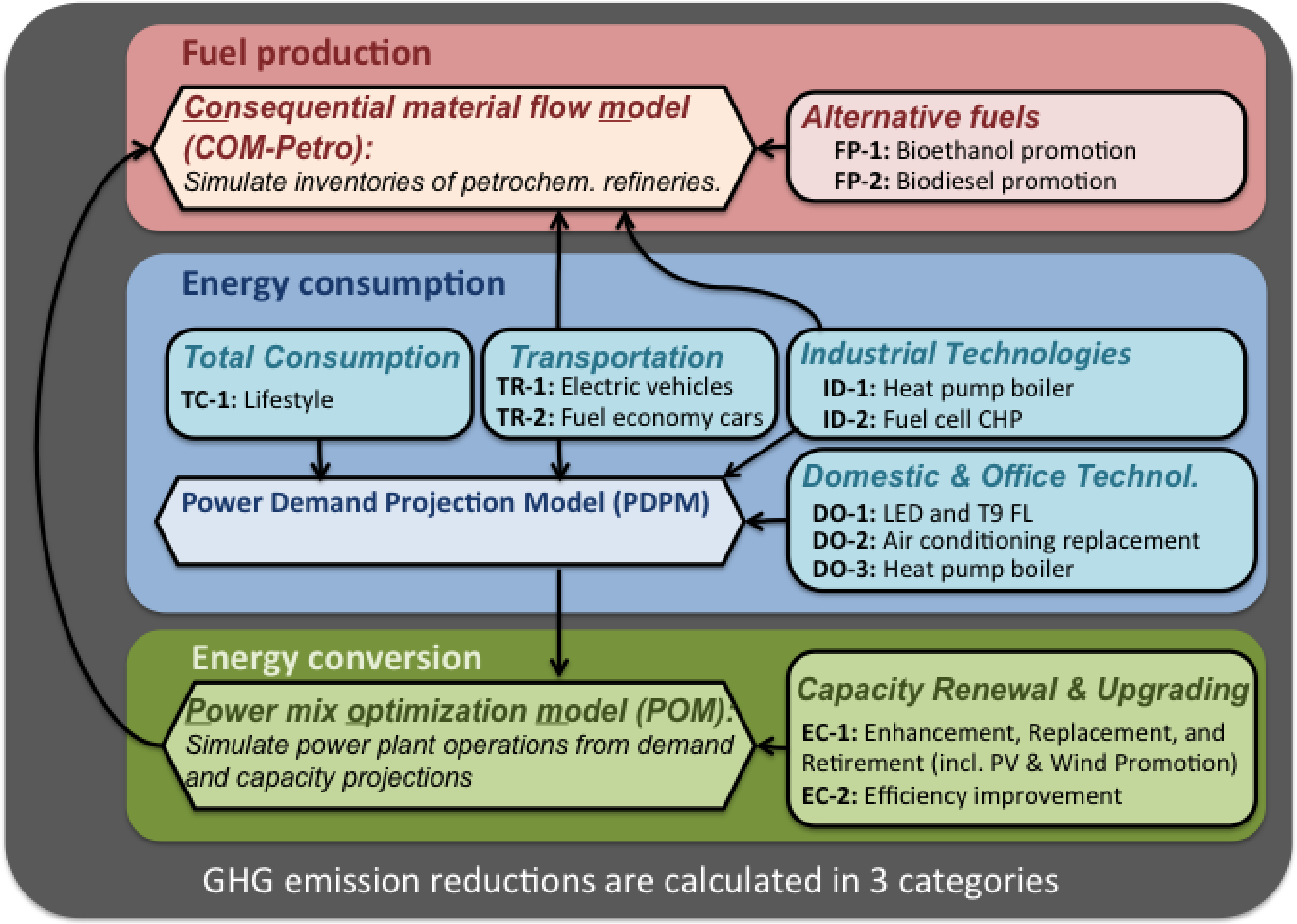


Figure 2-1 Scope of the technologies (in oval), and the constructed tools (in hexagon) and relationship among them

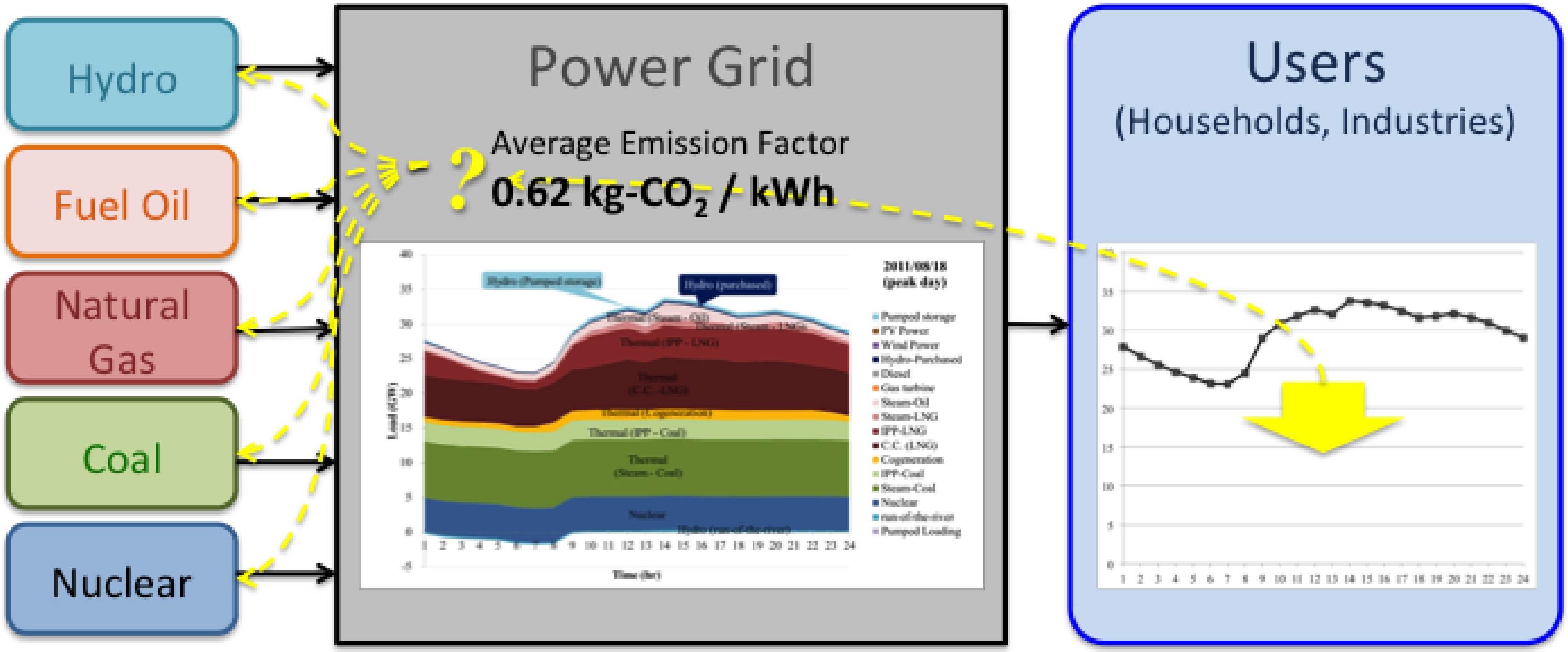


Figure 2-2 Electricity saving caused by energy efficiency improvement does not reduce the average greenhouse gases calculated for current power supply. POM simulates power mix from the load curves after implementing the energy efficiency improvement.

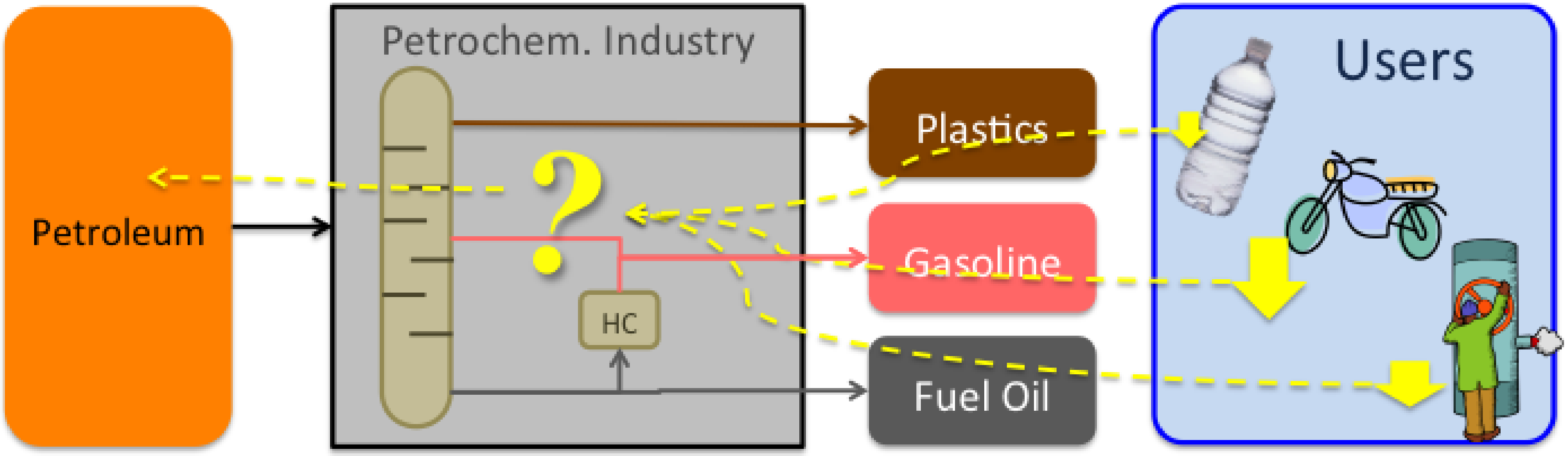


Figure 2-3 Reduction in consumption of petrochemical products do not reduce the greenhouse gases emission allocated based on the current production. This is because the proportion of the products is different from the original as a result of applying adjustment processes, consuming energy. Hydrocracking (HC) is an example of such process, producing part of gasoline from fuel (heavy) oil. Reduction in gasoline consumption can result in less use of HC, thus increase in energy efficiency of the entire process, thus reducing the emission inventories of all the petrochemical products.

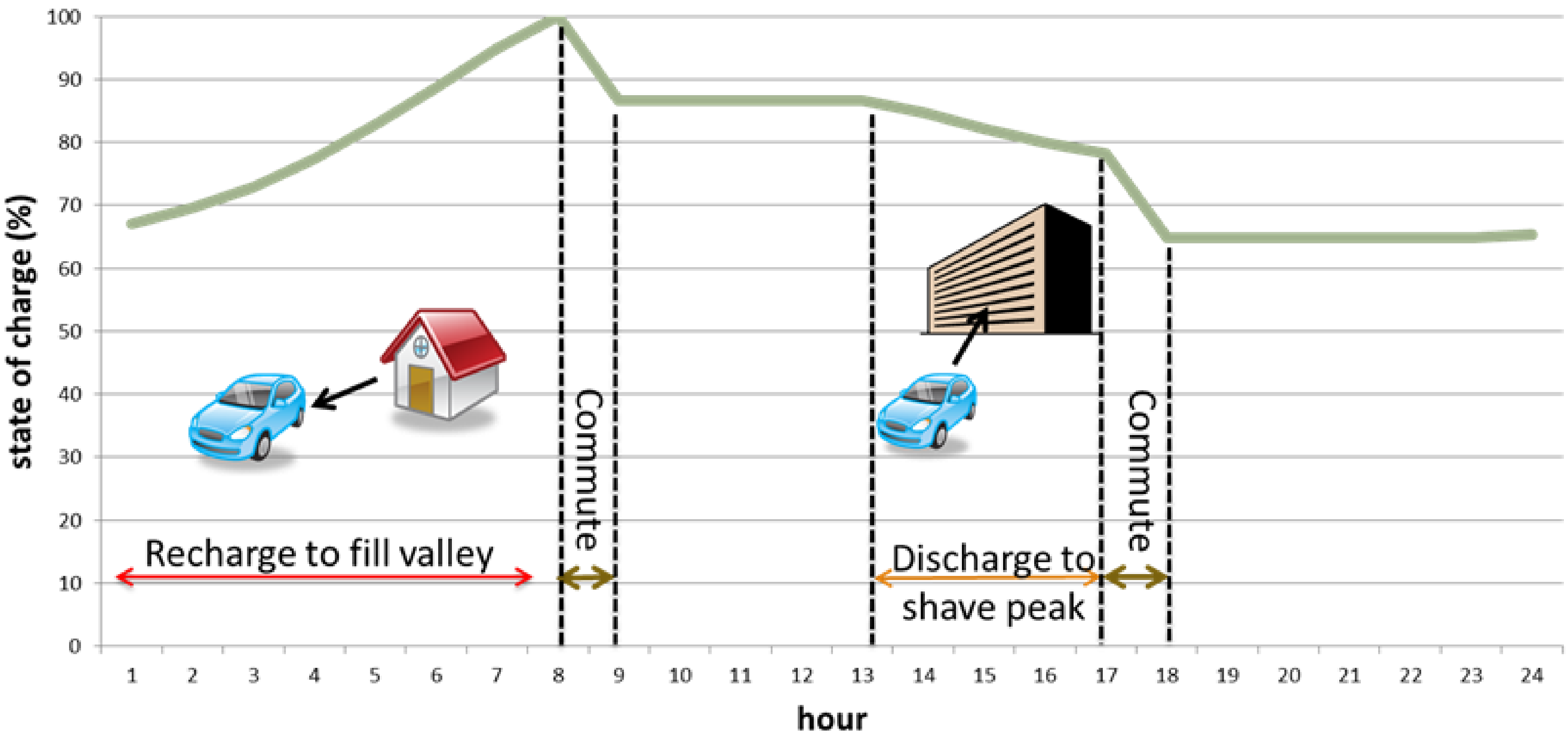


Figure 2-4 Patterns of state of charge of EV over 24 hours (Image)

2.1 Scenarios in fuel production sectors

Primary categories of scenarios that could influence the GHG emission from fuel production will be replacement of old refineries, construction of new plants, and changing type and amount of traded fuels. In addition, promotion of alternative fuels, such as ethanol and biodiesel to replace gasoline and diesel can influence the GHG emissions.

2.1.1 Production facilities and trade strategies

The efficiency and capability of production of various kinds of fuels from the imported petroleum highly depend on the facilities. Usually, it is not possible to supply all the needs in petrochemical products by only importing petroleum. A country would either export the surplus or import insufficient chemical products to meet the domestic demand. When the domestic demand change due to the improvement in energy efficiency, lifestyle change, population change, and promotion of alternative fuels, the operation of existing processes would need to accommodate the changes in the demand. Some of the adjustment can be made even with the existing facilities, but some may not be possible.

In this report, we use the current facilities and trading strategies for the petrochemical products in Taiwan. To create such a scenario, first the following assumptions are made.

1) Benzene, Toluene, Xylene, Ethylene, Propylene and Butadiene can be traded when there is a surplus or shortage in domestic production.

2) Changes in demand of gasoline, diesel, fuel oil, and kerosene are solely met by the domestic production from petroleum. (In reality, the changes are adjusted also by exports and imports, or changing operating conditions.)
3) The refineries can change the way they produce the products in the proportion of the demand, by adjusting the production routes.

Based on these assumptions, the following baseline scenario is made for this study.

Baseline Scenario for production facilities and trade strategies

- Capacities of the constituent processes in the refineries are kept constant.
- There is no change in efficiency in the individual constituent processes.

2.1.2 Alternative fuels scenario

Introduction of biofuels will reduce the demand of gasoline and diesel oil from the petrochemical refineries. In this report, we use only the baseline scenarios as described in the following subsections. Table 2-1 summarizes the alternative fuels scenario assessed in this study.

Table 2-1 Summary of alternative fuel scenarios

	Gasoline demand reduced by bioethanol promotion	Diesel demand reduced by biodiesel promotion
Baseline	150,000	0
Conservative	0	0

Note: values are in kL and shown on the basis of 2011

FP-1 Bioethanol promotion

For bioethanol the following roadmap (Figure 2-5) is presented by the Taiwan's government.

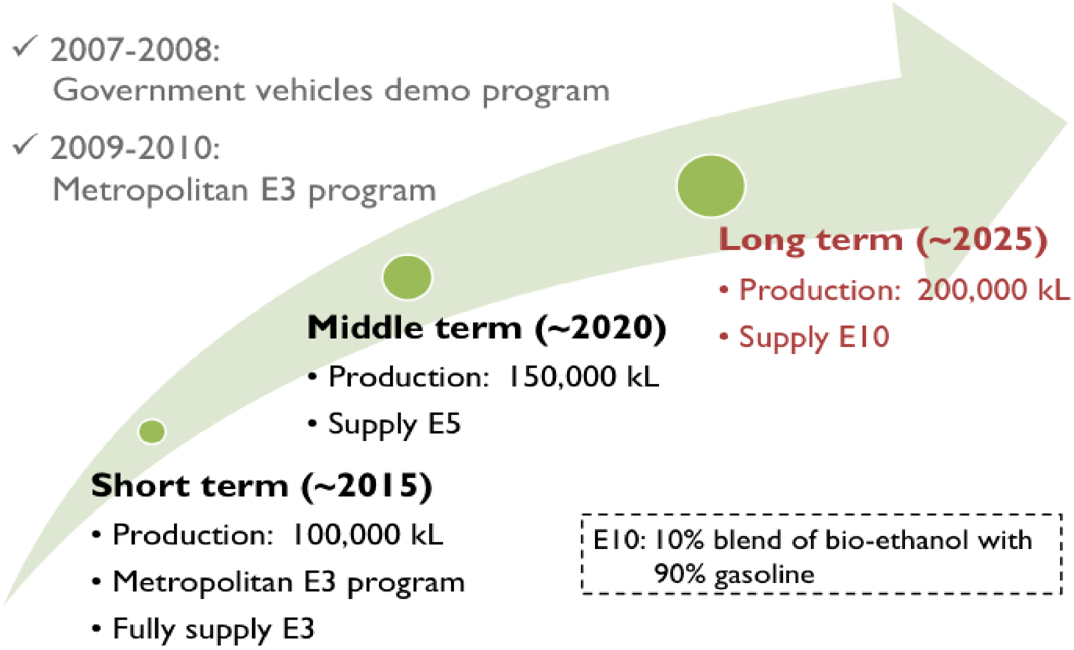


Figure 2-5 Taiwan's Roadmap for bioethanol introduction [10]

FP-2 Biodiesel promotion

Since 2010, biodiesel is mixed in diesel fuel sold at gas stations at 2% by volume (B2). Here, we assume that this status is maintained, and biodiesel is not further promoted as a fuel for vehicles.

2.2 Scenarios in energy consumption sectors

Scenarios are developed to calculate i) changes in power demand throughout a year, and the ii) changes in annual fuels demand.

The baseline scenarios are primarily developed based on plans and acts. For some categories, more scenarios are prepared.

2.2.1 Transportation scenarios

In Taiwan, transportation is one of the major GHG emitting energy consumption sectors. Here, two transportation-related technologies are investigated. First is penetration of Electric Vehicles (T-1) and the second is Fuel Economy Cars (T-2).

TR-1 Electric Vehicles (EVs)

Electric vehicles (EVs) industry is one of the "green energy industries" that are promoted by the Taiwan's national policy. However, there are also concerns such as those on pollutions and GHG emission, and energy efficiency.

EVs consume electricity instead of fuels. As power plants are known as major source of pollutants, including CO_2, there is a concern on whether promotion of EVs in Taiwan (or EVs made in Taiwan in any other country) could increase the air pollutants. Another concern is GHG emission. EVs will shift the GHG emission from the tail of cars to the power plants, but not necessarily reduce them. In terms of energy efficiency, since energy conversion at the power plants lose around

60-70% of the energy content of the fuels, one would naturally question whether it is better to use electricity as energy media, or just use direct conversion into power from fuels.

To answer part of these questions, the Electric Vehicles' Developing Strategy and Act (智慧電動車發展策略與行動方案)[11], presents a well-to-wheel study on energy efficiency as illustrated in Figure 2-6. According to this calculation, EVs look slightly more efficient than the internal combustion vehicles. However, by the time EVs are entering the market at a significant number, the efficiencies used in this calculation might be already outdated. To discuss such aspect, using the numbers presented in Figure 2-6, a sensitivity analysis is conducted as shown in Figure 2-7. We can see how ICE vehicles development (ex. by wider introduction of hybrid vehicles), and upgrading of energy conversion efficiency at the power plants are related to each other. Furthermore, the threshold lines are drawn for a variety of efficiency of refineries (black numbers) and battery charging/discharging (red numbers).

However, even with this useful figure, the hourly aspect of GHG emission from the power generation is not considered. Therefore, it is not possible to answer how EVs introduced in the future will add loading on the power grid, and emit how much more GHGs. On the other hand, it is said that EVs can be used for load balancing, thus reduce GHG emissions from the grid. Again the potential in doing so is controversial. As a result of load balancing, the base load or middle base power generators can be used more. In Taiwan, these are Nuclear, Coal, and LNG combined cycles. Nuclear is already operated at the maximum possible capacity factor, so it will not be influenced by EVs introduction. Based on current energy conversion efficiency, if combined cycles can be increased as a result of load balancing, GHG emission can be reduced. However, if coal is increased, GHG emission will increase.

To provide an answer to such controversy, we need a quantitative scenario for EV use patterns. The use patterns are influenced by the volume of the EVs and the way each of the EVs are used. Neither of these is considered in the previously introduced well-to-wheel analysis.

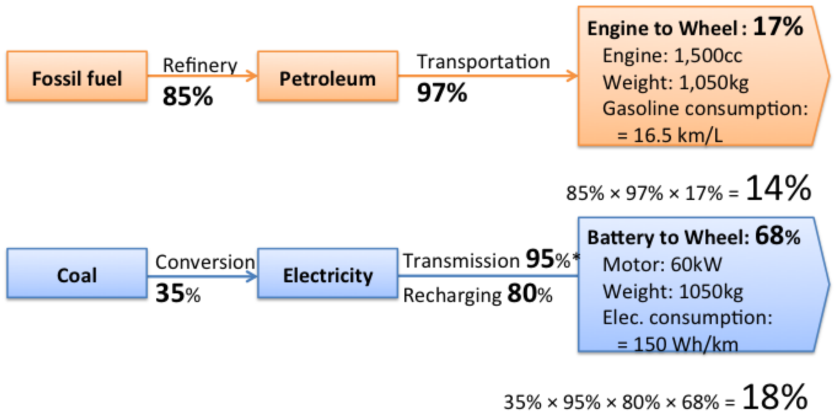


Figure 2-6 A well-to-wheel energy efficiency of EVs[11]

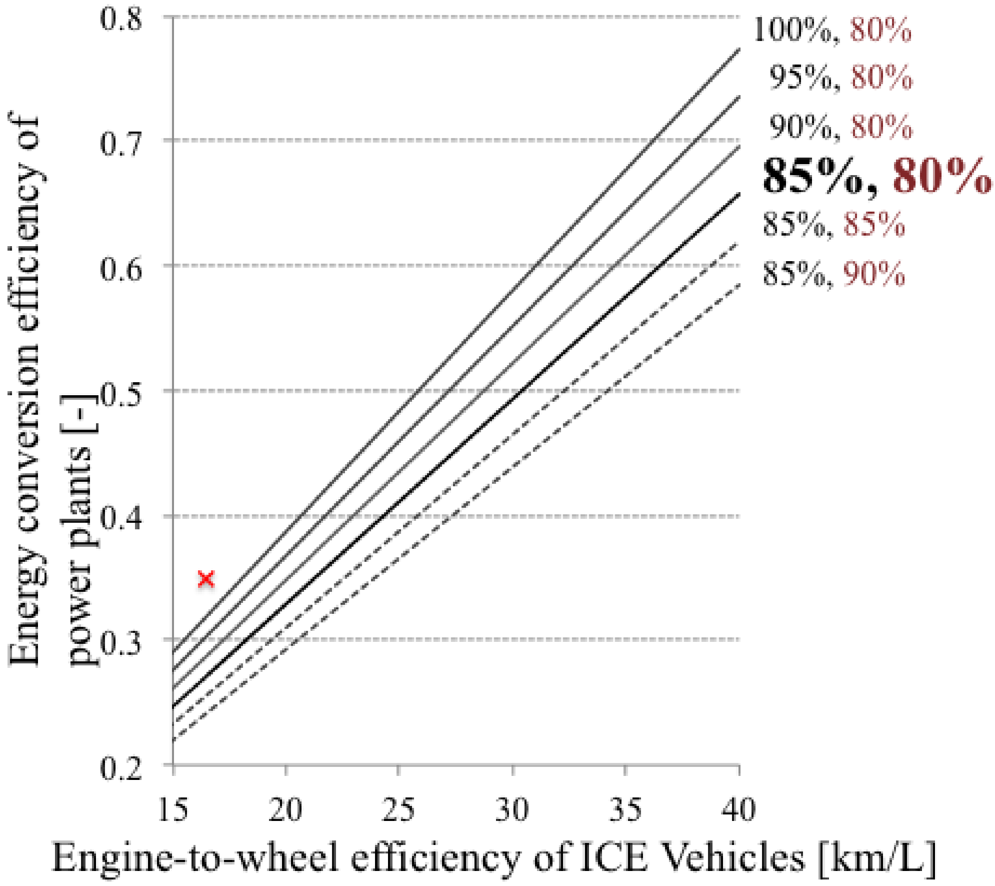


Figure 2-7 Criteria of EVs being more energy efficient compared to ICEV.

To consider the volume of EVs introduced in the future, a roadmap for introduction of the EVs was used (**Figure 2-8**). We will still need to examine the feasibility of this scenario and other possible scenarios. In this report, we have accepted this plan as the baseline scenario.

From this information we need to figure out how many EVs will be used in the market at the time of assessment. Here, we assume a lifetime of 7 years for EVs, and calculated the number of EVs used in the market as shown in Table 2-2. As seen in Figure 2-9, in 2020, it reaches approximately half of the saturation, which is supposed to reach already at around 2025.

We have found that there is another interpretation of this roadmap. This various interpretation comes from the ambiguity of language expression in the roadmap. In Figure 2-9, the red curve shows this interpretation, much more conservative than the one we adopt as a baseline. The values in Figure 2-9 is calculated as shown in Table 2-3.

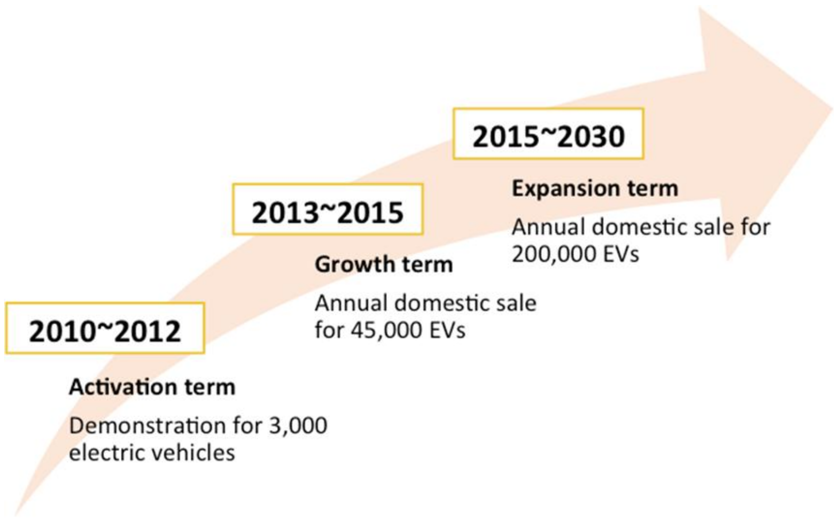


Figure 2-8 Roadmap for electric vehicles introduction by Taiwan's government[11]

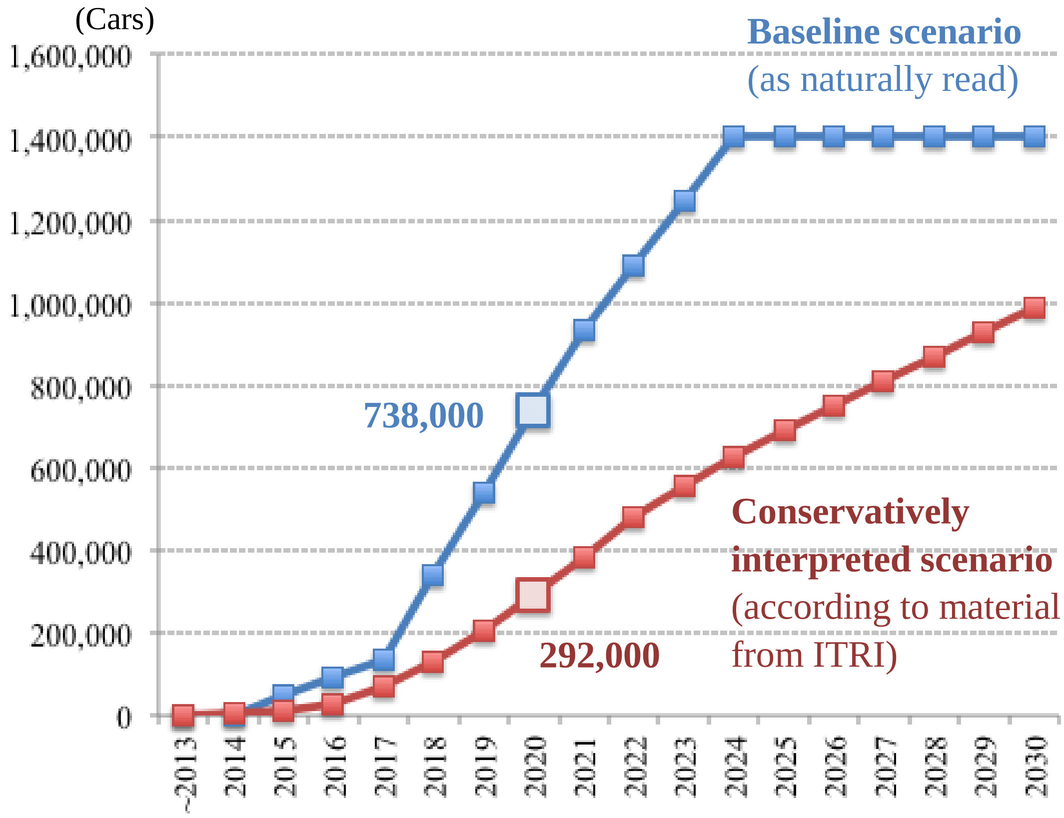


Figure 2-9 Number of EVs' used calculated according to the government roadmap (assuming average lifetime of EVs = 7 years)

Table 2-2 Number of EVs in baseline scenario

Year	**Total**	**New**	**Discarded**
-2013	0	3,000	0
2014	3,000	45,000	0
2015	48,000	45,000	0
2016	93,000	45,000	0
2017	138,000	200,000	0
2018	338,000	200,000	0
2019	538,000	200,000	3,000
2020	**738,000**	200,000	45,000
2021	935,000	200,000	45,000
2022	1,090,000	200,000	45,000
2023	1,245,000	200,000	200,000
2024	1,400,000	200,000	200,000
2025	1,400,000	200,000	200,000

Table 2-3 Number of EVs in conservatively interpreted scenario

Year	**Total**	**New**	**Discarded**
-2013	0	3,250	0
2014	3,250	7,000	0
2015	10,250	15,000	0
2016	25,250	45,000	0
2017	70,250	60,000	0
2018	130,250	75,000	0
2019	205,250	90,000	3,250
2020	**292,000**	100,000	7,000
2021	385,000	110,000	15,000
2022	480,000	120,000	45,000
2023	555,000	130,000	60,000
2024	625,000	140,000	75,000
2025	690,000	150,000	90,000
2026	750,000	160,000	100,000
2027	810,000	170,000	110,000
2028	870,000	180,000	120,000
2029	930,000	190,000	130,000
2030	990,000	200,000	140,000

In addition to the number of EVs that are used in Taiwan, we need to know how they are used; namely when it will be charged, and when will it be able to discharge the extra power stored in the battery to balance the load on the grid. As a prototype of model to simulate the way EVs are used, we have created a use scenario of number of EVs in various locations during daytime as shown in Table 2-4. Please note that the data are fictitious here. It is recommended to conduct more detailed analyses on how people use personal cars on an hourly basis during different period of a year.

Finally, to consider the load balancing potential, the situation of infrastructure construction has to be assumed. Here, we have four stations for EVs: home, company, mall, and roadside. We assume that all the homes have both charging and discharging (feed-in) equipment. For other locations, we calculated varied cases, ex. no discharging infrastructure at mall, etc. Charging and discharging equipment are considered separately: therefore, there are 4 patterns for each location outside of home which makes a combination of $4^3 = 64$ patterns of scenarios.

Table 2-4 Number of EVs in various locations in each season

8 Patterns		EV in location *i* during daytime (N_i)		
		N_1 (company)	N_2 (mall)	N_3 (road side)
Chinese new year		0 (0%)	258,000 (40%)	387,000 (60%)
Peak day		322,500 (50%)	161,250 (25%)	161,250 (25%)
Weekday	Summer Middle Winter	322,500 (50%)	161,250 (25%)	161,250 (25%)
Weekend	Summer Middle Winter	161,250 (25%)	161,250 (25%)	322,500 (50%)

TR-2 Fuel economy cars

Here, we develop a scenario model for estimation of number of respective kinds of personal cars in use, newly sold, and discarded. The number of cars is estimated using the following equation 1:

$$E(t) = p(t)C(t) \qquad \text{eq. 1}$$

Where,

$p(t)$ = estimated population at year t

$C(t)$ = number of car/people at year t

The number of car/people function is defined in equation 2 [12]:

$$C(t) = \frac{1}{C_{\min} - (C_{\max} - C_{\min})\exp[-\alpha(t - t_o)]} \qquad \text{eq. 2}$$

Where,

C_{min} = 3

(From statistics, the number of people/car stabilises at 2-3. U.S., U.K., France, Germany, Japan are around 2 [13].)

C_{max} = 3.9

(based on the current ratio of population and number of cars)

α = 0.12145

t_0 = 2011

Substituting equation 2 to equation 1 and with the existing population estimation in Taiwan, the curve shown in Figure 2-10 is obtained for the number of cars used during 2011 to 2030.

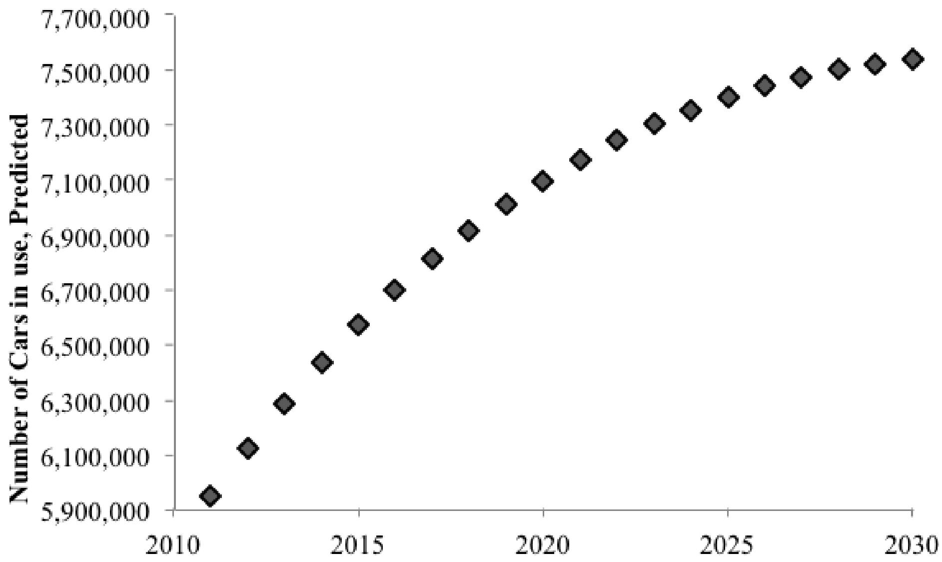


Figure 2-10 Predicted number of cars in use, 2010-2030

To predict for the number of new demand cars, equation 3 is used.

$$N = E_t - E_{t-1} + D_{t-1} \qquad \text{eq. 3}$$

Where,

N = demand for new cars at year t

$E_t - E_{t-1}$ = annual increase in the number of cars

D_{t-1} = number of discarded cars

The number of discarded cars is calculated using the Weibull Distribution function, shown in equation 4. In this kind of model, use of Weibul distribution is a common practice. The parameters were determined according to a literature [14]. In this literature, the author used the simulated result on discarded number of cars and modified the shape parameter to fit with past data on registered discarded number of cars.

$$W(Y) = 1 - \exp\left[-\left(\frac{y}{Y_t}\right)^b \Gamma\left(1 + \frac{1}{b}\right)^b \right] \qquad \text{eq. 4}$$

Where,

$W(Y)$ = accumulated disposal ratio

Y_t = car life (assumed to be 10 years)

b = shape parameter (which is equal to 4 in this study)

Γ = gamma function

To obtain the number of disposed cars in a given current year, the disposal ratio ([$W(Y) - W(Y\text{-}1)$] is multiplied to the number of actual new cars until the year before the given present year, and used the data to predict for the future discarded number of cars. Figure 2-11 shows the result of the prediction.

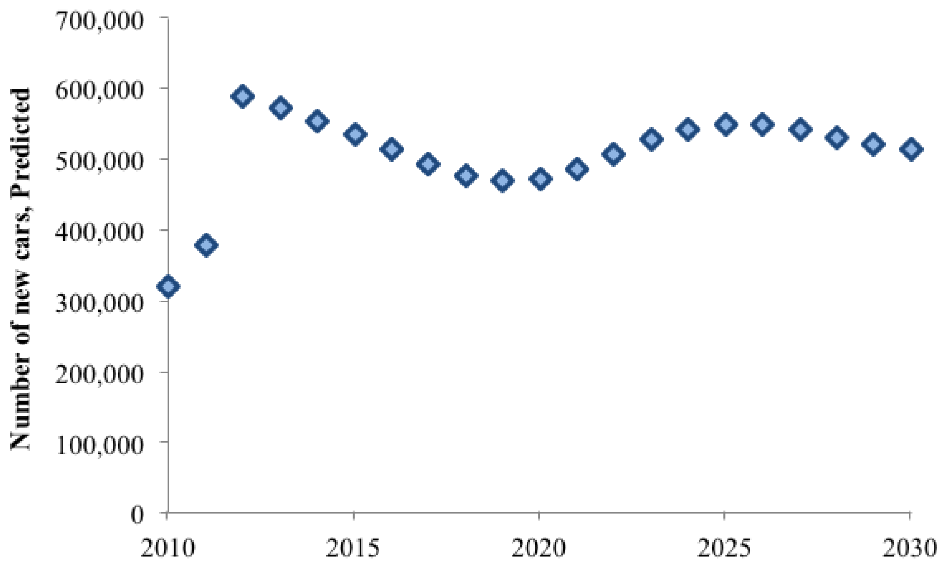


Figure 2-11 Predicted number of new cars, 2010-2030

Based on Taiwan government's roadmap of EV implementation and the actual sales of EVs in year 2010, scenario on the new sales of fuel economy cars in Taiwan in the next 20 years were constructed. Table 2-5 shows the fraction of Battery EV (BEV), Plug-in Hybrid Electric Vehicles (PHEV), Hybrid Electric Vehicles (HEV) and Internal Combustion Engine Vehicles (ICEV) in year 2010, 2020, and 2030; while Figure 2-12 shows how the trend of sales are throughout these years. Figure 2-13 then summarizes how the proportion of different kinds of personal vehicles changes over years. In this study, heavy loaded freight vehicles are not considered, as it is considered it does not belong to the market of EVs.

It is expected for the BEV to continuously rising until 2030, and at this year, it will surpass the number of HEV sales. PHEV sales will be growing as well, but as this type of car is just an expensive version of HEV (containing more batteries for a longer range driving but still has a combustion engine), it would not be as popular as BEVs. The HEV sales are projected to peak at year 2025 and will decline from thereon as people continue to embrace the emission-free cars such as BEVs.

Table 2-5 A scenario on fraction of vehicles in 2010, 2020 and 2030. Values on BEV row are based on the government EV roadmap, conservatively interpreted, introduced in Table 2-4. Values on 2010 are based on recorded values. Values in bold italic are the scenario parameters.

	2010	2020	2030
BEV	0.00078	0.21	0.39
PHEV	0.00031	***0.1***	***0.2***
HEV	0.002	***0.4***	***0.35***
ICEV	0.9969	***0.29***	***0.06***

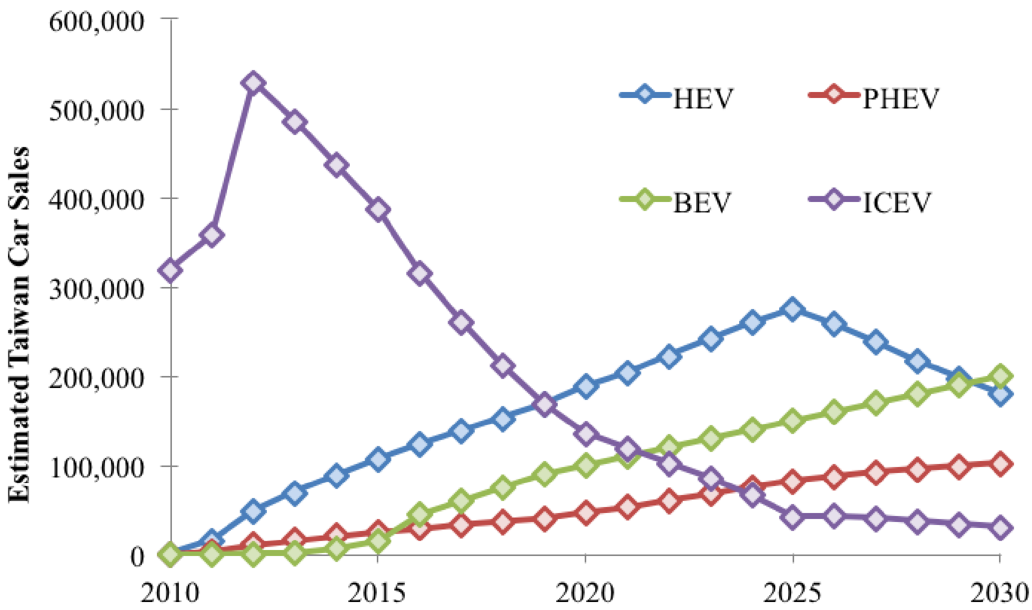


Figure 2-12 Predicted number of new cars sold during 2010-2030

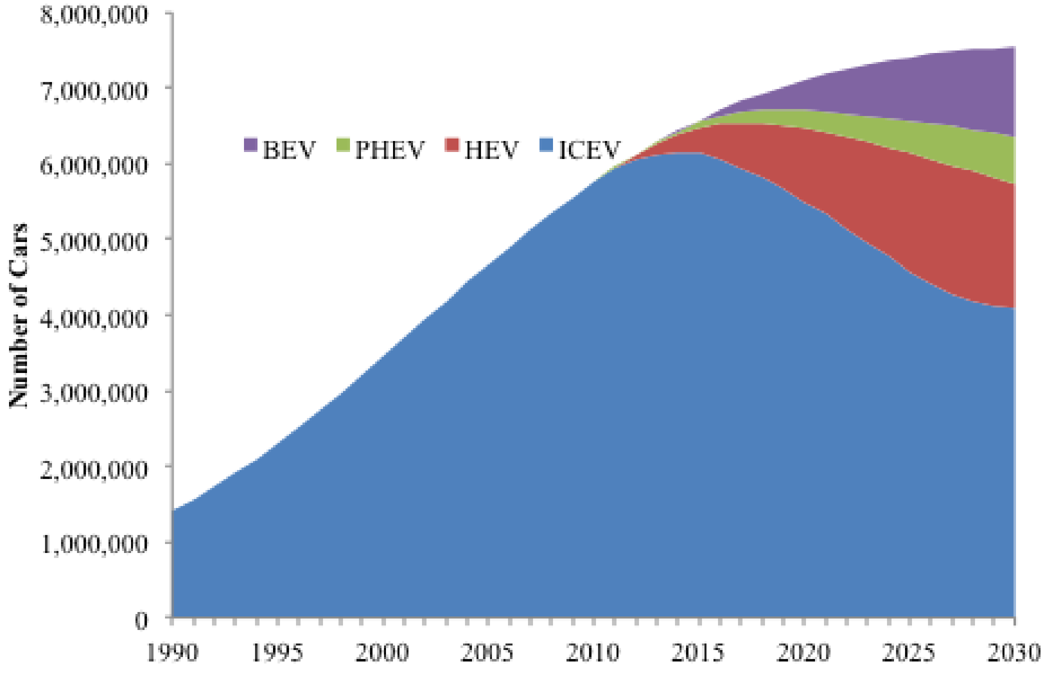


Figure 2-13 Breakdown of simulated number of cars, 1990-2030

2.2.2 Total consumption scenarios

It is eventually needed to explore how much change in the total needs of service is necessary to achieve targets such as GHG emission, or other particular visions. Once we know the limit of the role of technologies, the gap between the GHG emission reduction targets needs to be filled relying on changing the consumption patterns.

TC-1: Lifestyle

Here in this study, we do not assume any significant change in the life style, which is beyond what is included in the power supply projection made by Bureau of Energy (100 年長期負載預測與電源開發規劃摘要報告)[8], as shown in Table 2-6.

Table 2-6 Loading projection down to 2030

民國100～119年台電系統長期電力負載預測									
Year		供電量		平均負載		尖峰負載		負載率	線路損失率
民國	西元	億度	成長率(%)	萬瓩	成長率(%)	萬瓩	成長率(%)	成長率(%)	成長率(%)
100	2011	2,095.4	—	2,392.0	—	3,378.7	—	70.8	4.84
101	2012	2,144.9	2.4	2,448.5	2.4	3,443.8	1.9	71.1	4.71
102	2013	2,222.7	3.6	2,537.3	3.6	3,569.0	3.6	71.1	4.69
103	2014	2,307.8	3.8	2,634.5	3.8	3,702.7	3.7	71.2	4.66
104	2015	2,399.5	4	2,739.1	4	3,844.5	3.8	71.2	4.64
105	2016	2,482.2	3.4	2,833.5	3.4	3,975.9	3.4	71.3	4.62
106	2017	2,560.6	3.2	2,923.1	3.2	4,101.2	3.2	71.3	4.6
107	2018	2,635.4	2.9	3,008.4	2.9	4,220.5	2.9	71.3	4.58
108	2019	2,706.6	2.7	3,089.7	2.7	4,334.1	2.7	71.3	4.56
109	**2020**	**2,774.3**	**2.5**	**3,167.0**	**2.5**	**4,442.1**	**2.5**	**71.3**	**4.54**
110	2021	2,837.8	2.3	3,239.4	2.3	4,541.7	2.2	71.3	4.53
111	2022	2,897.6	2.1	3,307.8	2.1	4,636.2	2.1	71.3	4.51
112	2023	2,954.7	2	3,372.9	2	4,725.7	1.9	71.4	4.5
113	2024	3,008.3	1.8	3,434.2	1.8	4,810.4	1.8	71.4	4.48
114	2025	3,062.8	1.8	3,496.4	1.8	4,895.9	1.8	71.4	4.47
115	2026	3,117.3	1.8	3,558.5	1.8	4,982.0	1.8	71.4	4.45
116	2027	3,170.1	1.7	3,618.9	1.7	5,065.2	1.7	71.4	4.44
117	2028	3,223.2	1.7	3,679.4	1.7	5,148.6	1.6	71.5	4.42
118	2029	3,276.5	1.7	3,740.3	1.7	5,232.2	1.6	71.5	4.41
119	**2030**	**3,329.10**	**1.6**	**3,800.4**	**1.6**	**5,314.7**	**1.6**	**71.5**	**4.4**
100-119平均成長率(%)		2.48		2.48		2.41			

註：民國100年為實績值。

Using projection on average and peak loading information shown in red in Table 2-6, we have created future load curves preserving the shape of the daily loading curves. The method we have used is summarized in Figure 2-14.

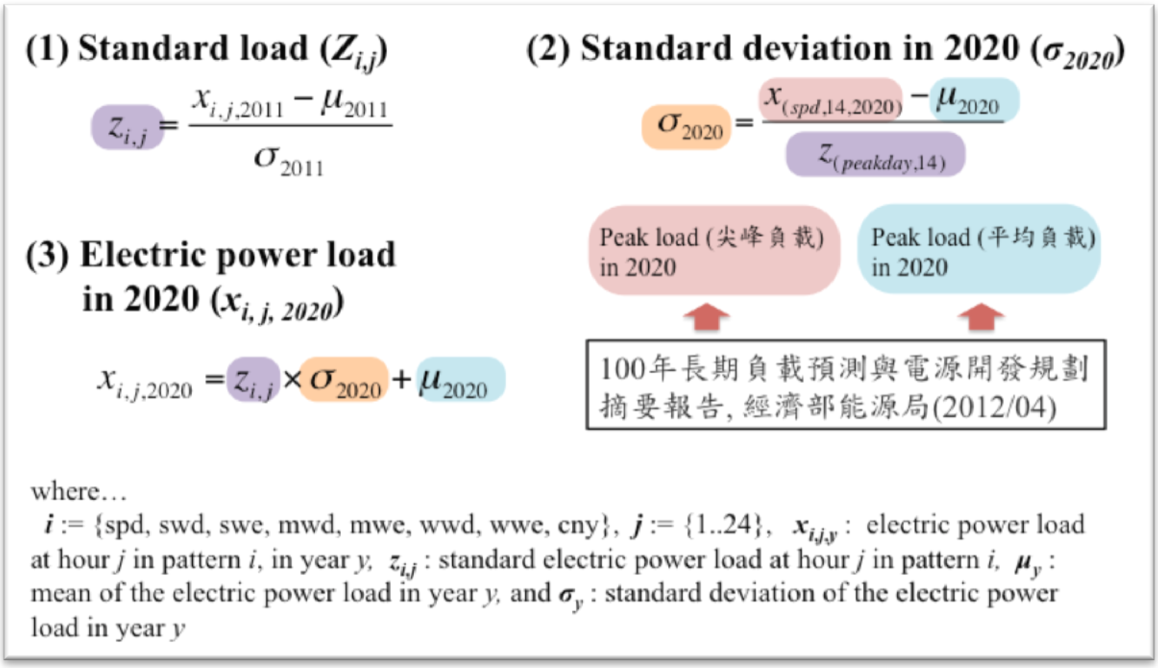
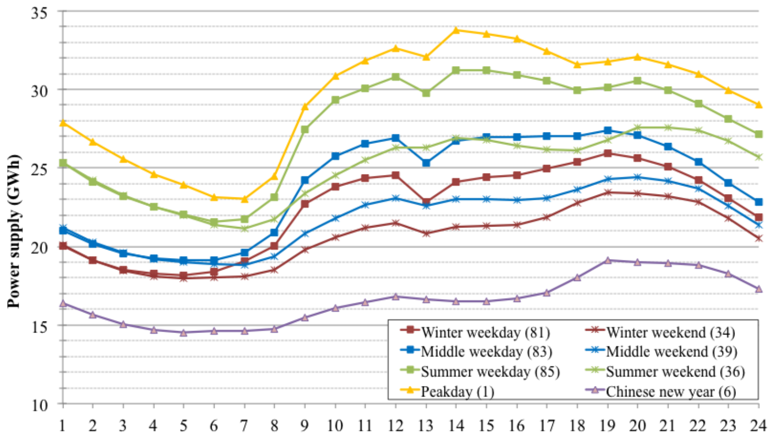
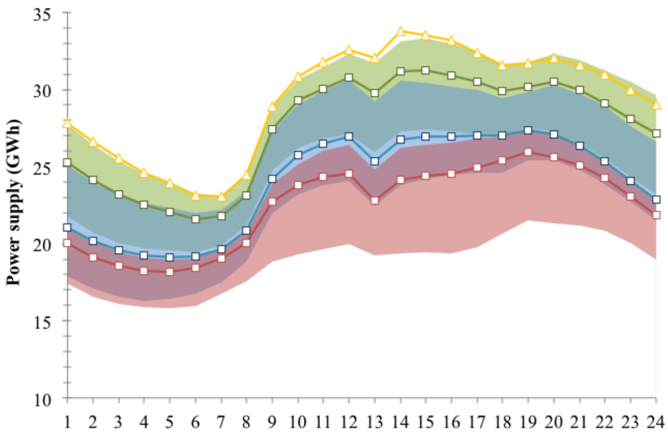


Figure 2-14 A symmetric projection of future hourly load curve in a year, using example of projection of 2020 from the data of 2011.

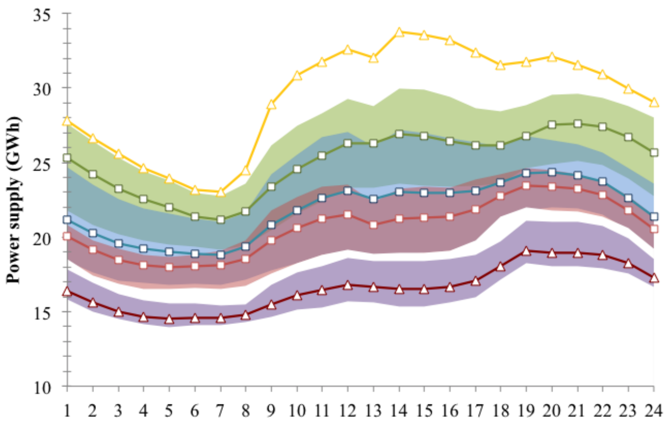
The hourly power consumption in 2011 was obtained from Taipower through personal communication[15], and analyzed. As a result eight characteristic hourly patterns were identified, as shown in Figure 2-15a. Figures 2-15b and 15c shows the range of the actual demands that are represented by the respected curves. There are overlaps, but we will find that the representativeness of these curves is actually quite good. Using these seasonal curves, the curves in 2020 and 2030 are developed as shown in Figure 2-16.



(a)



(b)



(c)

Figure 2-15 8 characteristic hourly patterns of power load in Taiwan (a), and its coverage range for (b) [peak day, weekdays] and (c) [weekends, chinese new year].

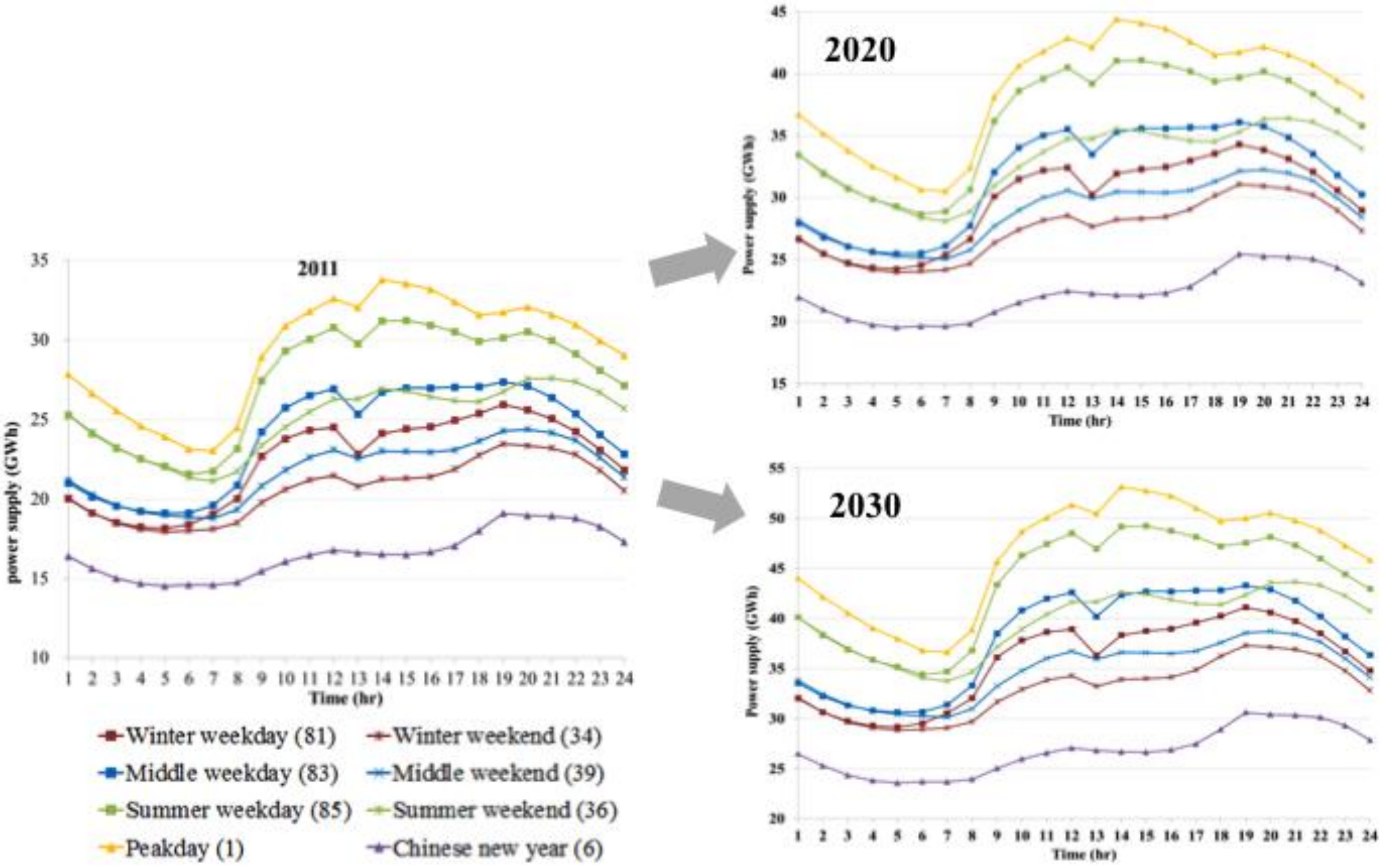


Figure 2-16 Hourly load curves from 2011 and the simulated curves in 2020 and 2030.

2.2.3 Industrial technologies

We have screened out that heat pump and fuel cell boilers are example of the two feasible and deployable technologies in 2020. Both of these scenarios will influence power and fuel demand. In this section we review the situation of the development of these technologies and its potential.

In this report, however, we assumed that these technologies will not enter our market by 2020, i.e., no contribution of these technologies are taken into account.

ID-1 Heat pump boiler

In industries where hot water is needed, application of heat pump boiler can be an attractive option. Heat pump boiler can boil water with much lower energy consumption compared to use of fuels. If we cook water based on combustion, the energy that can be transformed into heat is at most as much as the heat content of the fuel. However, the heat pump boiler can use the electricity for transporting heat; therefore, it is not bound to the heat content. Usually, this kind of boiler would transport more than 3-4 times of the electricity consumed. Even considering the energy loss at power generation, it is most likely able to save energy in total. This technology is particularly advantageous in Taiwan's condition, as it has a warm ambient temperature throughout the year. Food industry will have particularly large potential to utilize this technology.

Threat of this kind of technology is the supply of the systems. Currently, the systems for high-end compressors used in heat pump boiler systems are mostly produced in Japan. These systems utilize CO_2 as working fluid to transport heat. Since Japan is protecting this technology, there can be a price barrier for Taiwan's industry to introduce heat pump boiler system. There are a number of companies providing heat pump system in Taiwan. We have conducted interview to the heat pump system vendors (Appendix 1, 2).

In Japan, the heat pump boilers are called "Eco-Cute" system. Major home appliance producers as well as more specialized producers sell these kinds of boiling systems, both for household and for industry. This names come from the sound of "hot water supply" in Japanese (給湯 [kyu-to → cute]).

ID-2 Fuel cell boiler

Fuel cells in general utilize reverse chemical reaction of electrolysis of water to generate electric power from H_2 and O_2. For industry, Molten Carbonate Fuel Cells (MCFC), Polymer Electrolyte Membrane Fuel Cells (PEMFC), Phosphoric Acid Fuel Cells (PAFC) and Solid Oxide Fuel Cells (SOFC) are available and used.

The commercial fuel cell systems utilize natural gas for fuel. First, the fuel gas is desulfurized, and then reformed to produce hydrogen. For high temperature fuel cells such as MCFC and SOFC, the reforming can be performed at the cells without the reformer. In case of commercial

PAFC sold from Fuji Electric Co., 42% of energy can be converted into electric energy, around 10% higher than typical gas engines. Moreover, the heat can be utilized to prepare hot water. Usually, fuel cells are expensive system, therefore operated at high capacity factor used for supplying base load of the facility.

Sites typically most suited for installation of fuel cell systems are hospitals, data center with lots of computer servers, and places where large scale water treatment using digestion (ex. wastewater treatment plant, beer company, etc.). In general places with fuel generation and ample heat demand are more suited. In addition, by realizing power generation on site of demand, installation of fuel cell systems can increase the redundancy of power and heat supply thereby increase tolerance to disasters such as earthquakes. Another interesting application is in the data center. In addition to increase security of power supply, fuel cell systems can be used to remove oxygen from inside of the data center. This can simplify the fire preventing equipment needed for the data center. Such an application can be useful in some of the production lines in high-tech industries in Taiwan. The PAFC unit, including installation cost is around 30,000,000 NTD, which is very expensive. However, in case of some municipalities such as in Tokyo, up to around 2/3 of this cost can be subsidized to ensure the safety of hospital under various events.

In Japan, fuel cell boilers are sold for households and commercial use with a nickname “ene-farm (エネファーム)”. At first, PEMFC was used for this purpose, but the efficiency was lower and so was the controllability of ratio between hot water and electricity. Since October 2011, SOFC based ene-farm started to sell in the market. This type of fuel cell boiler has higher efficiency with higher output controllability, therefore being expected to be the mainstream system in the future.

Despite its currently high cost, fuel cell systems has high potential of enhancing energy efficiency, and fuel diversification especially if it can be combined with needs in heat, oxygen removal, biogas utilization (or treatment), and redundancy in power supply. If Taiwan were to grow this industry, the government should promote this industry using systems made in Taiwan, and cultivate domestic market, until it reaches to the level where domestic industry has a competence in global market.

2.2.4 Domestic & Office Technologies

As can be seen in Table 2-7, the top 3 domestic consumers of electricity are 1) Air conditioner, 2) Boiler, and 3) Refrigerators, followed by hot water pot, personal computers, TV, and then illumination. Here we review air conditioner and boiler in this report.

However, as the breakdown of energy consumption in these items are not available, in the results, introduction of these technologies are not reflected. We suggest two remedies to this situation: 1) to conduct survey on consumer behaviors on the use of electric appliances, and 2) to conduct back-casting study (ex. how much domestic & office technologies should contribute in energy saving to achieve some specific target)

Table 2-7 Contribution of electric home appliances in the household energy consumption [16].

類別	電器名稱	耗電(W)	每年估計使用時間(時)	年用電量(度)*	使用說明
1.空調類	冷氣機	2,200	4時×30日×5月= 600	1.320.0	2,000kCal/hr，每天開機8小時，但實際啟動4小時
	吹風機	800	1/6時×15日×12月= 30	24.0	
	電暖器	1,250	6時×10日×2月= 120	150.0	寒流報到，才開機
	除溼機	200	4時×30日×6月= 720	144.0	濕度大，才開機
	電風扇	55	3時×30日×8月= 720	47.5	16吋，季節性使用
	抽風機	30	4時×10日×12月= 480	14.4	
2.照明類	白熾燈泡	180	3時×30日×12月= 1,080	194.4	餐廳用(60W*3只)
	日光燈	96	4時×30日×12月= 1,440	138.2	書房(24W*4型日光燈具耗電96W)
	省電燈泡	135	6時×30日×12月= 2,160	291.6	客廳27W*5型燈具耗電135W，發光效率與60W白熾燈泡相同
	神龕燈	10	24時×30日×12月= 8,640	86.4	全年每天24小時點燈
3.廚房類	微波爐	1,200	1/4時×30日×12月= 90	108.0	每天5次、3分，共1/4小時
	電磁爐	1,200	2時/月×12月= 24	28.8	
	開飲機	800	2時×30日×12月= 720	576.0	加熱750W，保溫50W
	電鍋	800	1/2時×30日×12月= 180	144.0	10人份電鍋
	電烤箱	800	2時/月×12月= 24	19.2	
	抽油煙機	350	1/3時×30日×12月= 120	42.0	
	果菜榨汁機	210	1時/月×12月= 12	2.5	
	烘碗機	200	1/2時×30日×12月= 180	36.0	
	電冰箱	200	12時×30日×12月= 4,320	864.0	420公升，每天運轉12小時
	電子鍋	1,000	1/2時×30日×12月= 180	180.0	每天煮飯1次，每次0.5小時
	烤麵包機	800	1/3時×15日×12月= 60	48.0	
4.衛浴類	電熱水器	8,800	1/3時×30日×12月= 120	1.056.0	淋浴每人5分，4人共1/3小時
	洗衣機	500	1/2時×30日×12月= 180	90.0	
	乾衣機	1,200	1/3時×10日×10月= 33	39.6	夏季較少使用
	電熨斗	800	3時/月×12月= 36	18.0	
	吸塵器	1,100	3時/月×12月= 36	39.6	
5.視聽類	電視機	200	4時×30日×12月= 1,440	288.0	29“映像管或32“液晶
	音響組合	200	1時×30日×12月= 360	72.0	
	個人電腦	300	6時×30日×12月= 2,160	648.0	每天使用6小時，休眠忽略不計
	小型音響	30	1時×30日×12月= 360	10.8	
	DVD光碟機	30	2時×15日×12月= 360	10.8	

註：1.*年用電度數(kWh) = 耗電(W) × 使用時間(h) ÷ 1000 (W/kW)。

2.表列各種電器的耗電量，會因廠牌、型號等不同，而有所差異。

3.表列每年使用時間為估計值，用戶可依電器實際功率及使用時間，自行估算年耗電量。

DO-1 Air conditioning replacement

Energy saving in air conditioning can be achieved by improving its performance (Coefficient Of Performance, COP), and by replacing old machines by the newer ones. Another method is to encourage users to set the temperature at higher indoor temperature setting. Figure 2-17 shows the theoretical COP values for various outdoor and indoor temperatures. As differences in outdoor temperature and indoor temperature become closer, the COP value is higher (i.e., more energy-saving).

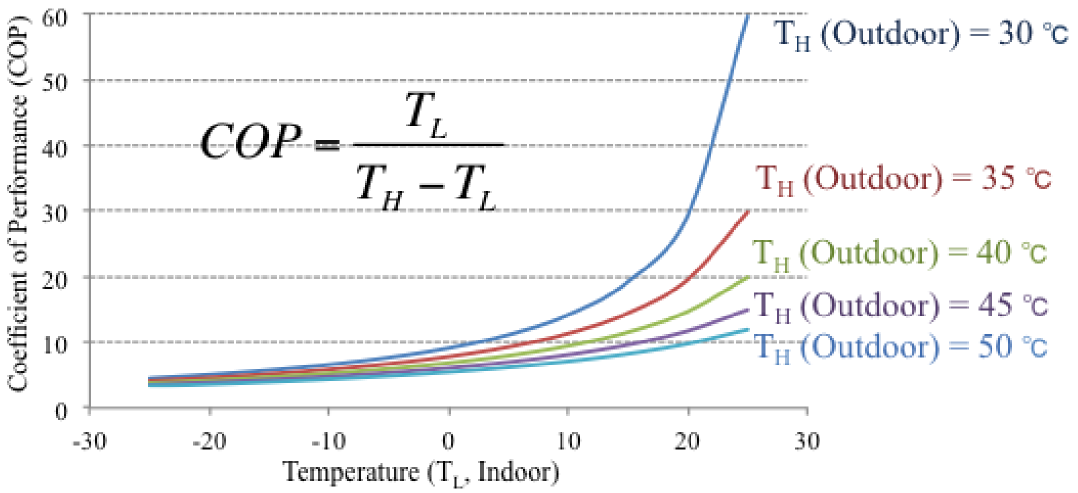


Figure 2-17 Heat pump Coefficient Of Performance (COP) for various indoor and outdoor temperatures.

Considering various loss of energy in the air conditioning units, the theoretical limit of domestic and commercial air conditioning systems were calculates as shown in Table 2-8. Here we can see that if relying on air conditioners with current structure, the systems currently sold are already close to its limit in efficiency. Therefore, reduction of air conditioning loading have to rely on development of new type of air conditioners (ex. separate dehumidizer and cooler system using absorbents), or on acceleration of replacement of old and inefficient air conditioners.

Figure 2-18 shows the lifetime distribution of air conditioners in Taiwan (Hsueh and Fukushima, 2010)[17]. Using this distribution obtained by fitting of past sales records, breakdown of age of air conditioners in use can be predicted by using the procedures summarized in Figure 2-19. Figure 2-20 shows the obtained distributions of air conditioners in use. The red row in the figure is for the year 2006, where the height of the bars represents the number of air conditioners still used in Taiwan, which was produced in respective years on “sold/imported” year axis. By using this approach, breakdown of air conditioners in 2030 can be predicted as shown in Figure 2-21. By developing scenarios for development of COP values in Taiwan over the period shown in this figure, we can predict how much energy will be used by air conditioners in 2030.

Table 2-8 The air conditioning systems are already close to the theoretical limit of its efficiency.

	Limit	2010
Domestic (2.2 kW)	7.0	6.76
Domestic (4.0 kW)	6.3	5.29
Commercial (4.5 kW)	6.2	4.71
Commercial (7.1 kW)	5.1	4.46

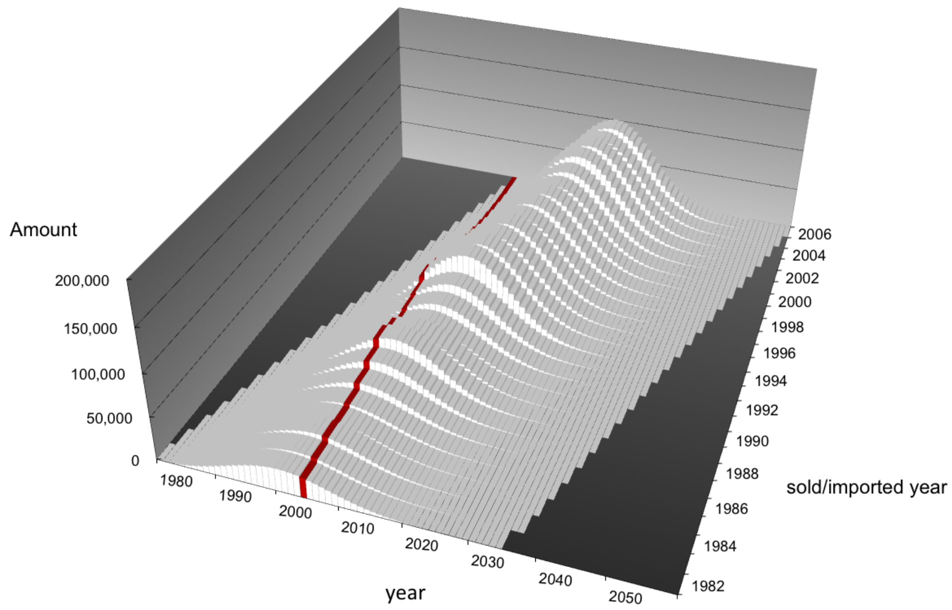


Figure 2-18 Lifetime distribution of air conditioners in Taiwan.

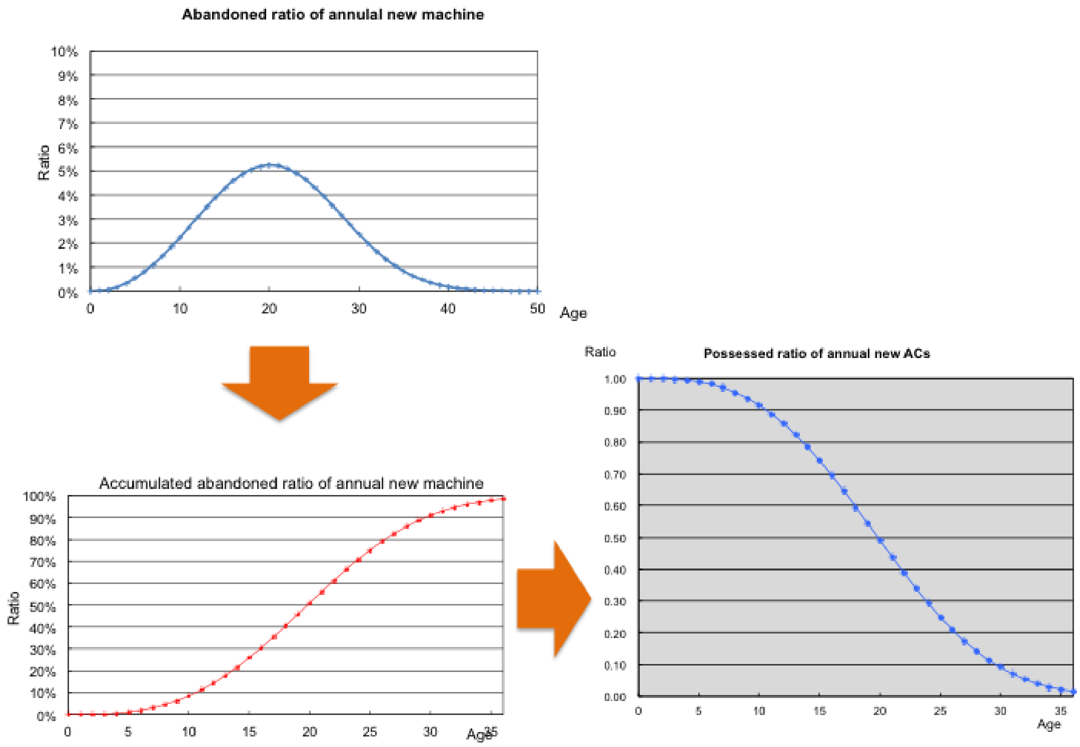


Figure 2-19 Calculation procedure of air conditioners in use which is sold in a certain year.

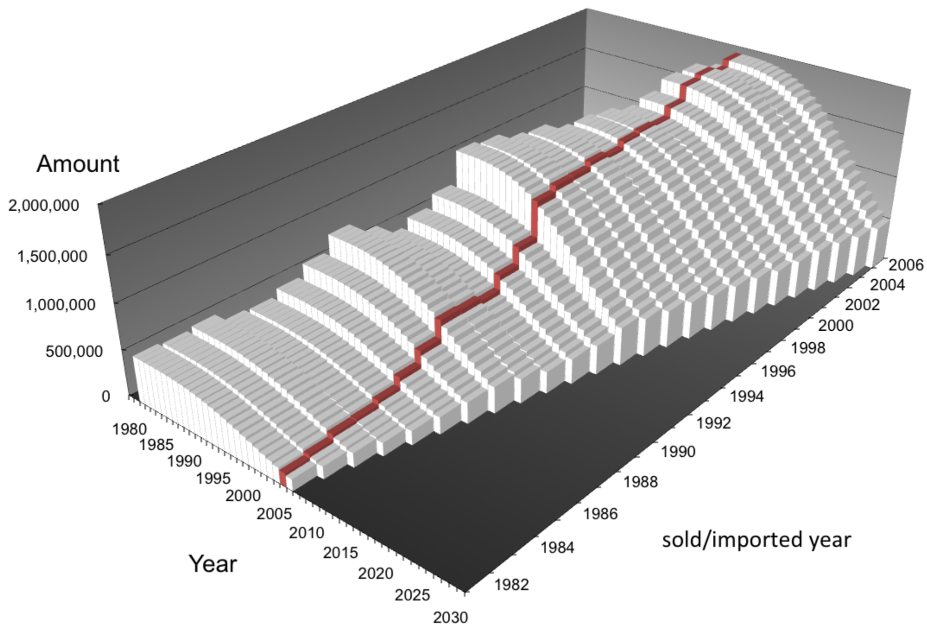


Figure 2-20 Air conditioners in use in 2006

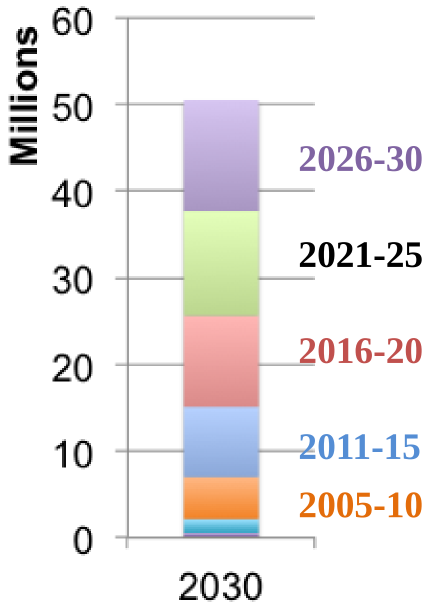


Figure 2-21 Simulated number of air conditioners in use in 2030

DO-2 Heat pump boiler

Heat pump boilers were already reviewed in the industrial technology section. The additional information worthwhile adding here is that in Japan, packaged system equipped with high performance hot water tank and intelligent control system is available.

Because hot water use patterns are diverse by households, and because heat pump boilers require more time compared with gas boilers, control system considering tank capacity and hot water usage is critical in satisfying daily needs without losing convenience in the households.

2.3 Scenarios in energy conversion sector

In this project, introduction of large-scale solar photovoltaic (PV) systems will be assessed. Considering the solar irradiation patterns in the southern part of Taiwan in the different seasons, the power generated by PC systems will be incorporated in the POM as a part of input data.

2.3.1 Capacity renewal & Upgrading

By stop using the old, deteriorated power plants and constructing new power plants, the efficiency of energy conversion will be improved, and will be able to save fuel costs. Enhancement of renewable energy such as PV systems and Wind power systems will also contribute in saving fuel requirement.

EC-1 Enhancement, replacement, and retirement

Here, the capacity enhancement plans presented by Taipower[8] is utilized as a baseline scenario (Figures 2-22, 2-23).

This plan includes promotion of PV and Wind power, as well as other IPPs. These power generators require special attention because their operation is not determined by minimizing the cost of power supplier.

Table 2-9 shows the monthly capacity factor of PV cells installed in Taiwan in 2011[18]. Using the hourly power generation pattern at the summer peak day, and the seasonal capacity factor calculated from the Table 2-9, we have obtained pattern of PV power generation in summer, middle, and winter seasons as shown in Figure 2-24, by multiplying the ratio of capacity factors.

Table 2-10 shows the monthly capacity factor of wind power generations systems installed in Taiwan[18]. This data is created from the record in 2011. To obtain the seasonal power generation patterns for wind power, we have utilized the difference in monthly capacity factors, but in a different way from predictions made for PV systems. For PV systems, the ratios of capacity factors across the seasons were multiplied to the generation pattern on the summer peak day. However for wind systems, the generation curves were shifted as shown in Figure 2-25.

Similarly, for IPPs, the monthly capacity factors were first calculated (Figure 2-26), and then, the daily power generation patterns were estimated (Figure 2-27).

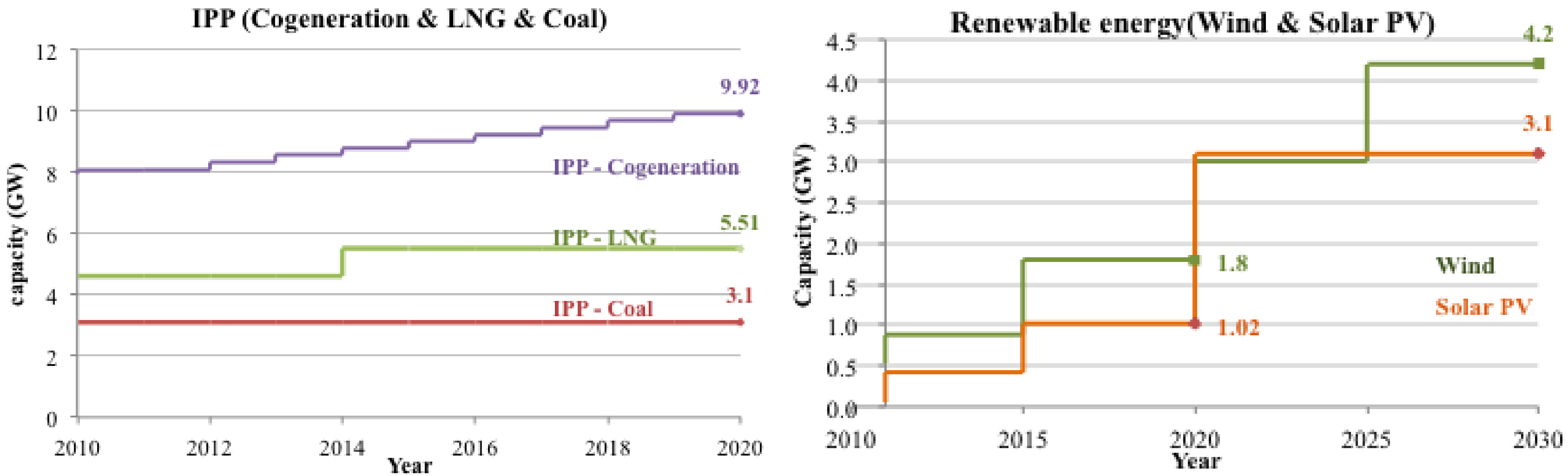


Figure 2-22 Capacity change scenario for IPP generators (left) and Wind and PV systems (right) 2010-2020.

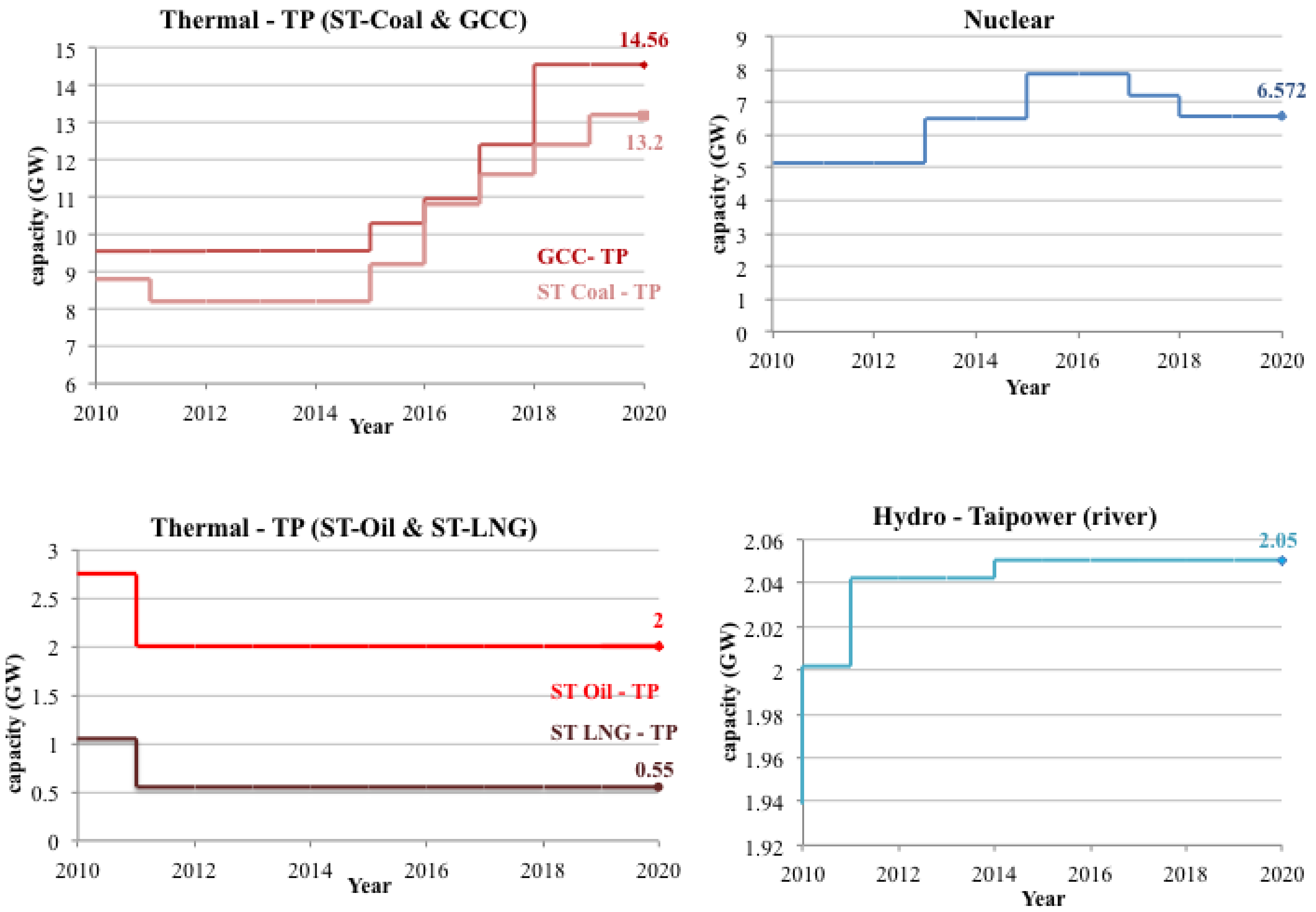


Figure 2-23 Capacity change scenario for Taipower generators, 2010-2020.

Table 2-9 The monthly capacity factors of PV systems in Taiwan (based on 2011)

		1	2	3	4	5	6	7	8	9	10	11	12
Capacity (MW)	(1)	22.9	23.3	24	25	25.6	26.3	28.3	35.1	36.3	37.6	39.9	41.1
Generation (MWh $month^{-1}$)	(2)	2470	2567	2663	2854	3371	3617	3887	4041	4076	4088	4010	4145
Number of days	(3)	31	28	31	30	31	30	31	31	30	31	30	31
Capacity factor (%)	(2) / ((1)*(3)*24))*100	14.50	16.40	14.91	15.86	17.70	19.10	18.46	15.48	15.59	14.61	13.96	13.55

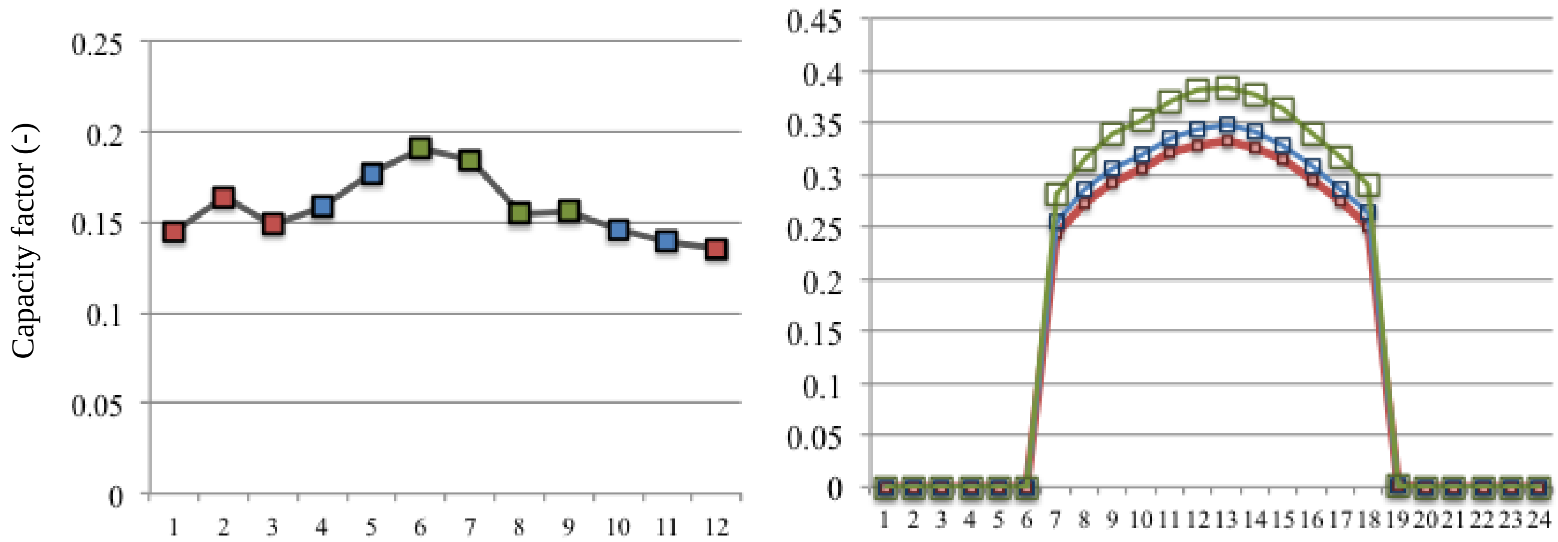


Figure 2-24 Monthly capacity factor (left) and seasonal power generation pattern of PV systems in Taiwan.

Table 2-10 The monthly capacity factors of Wind power systems in Taiwan (based on 2011)

		1	2	3	4	5	6	7	8	9	10	11	12
Capacity (MW)	(1)	477.6	477.6	506.6	506.6	506.6	506.6	519.5	517.5	524.4	524.4	524.4	524.4
Generation (GWh $month^{-1}$)	(2)	250.5	158.1	176.8	82.6	56.7	57.8	38.5	40.7	82.5	165.1	141.1	242.7
Number of days	(3)	31	28	31	30	31	30	31	31	30	31	30	31
Capacity factor (%)	((2)*1000) /((1)*(3)*24))*100	70.50	49.26	46.91	22.64	15.05	15.85	9.96	10.56	21.85	42.32	37.38	62.21

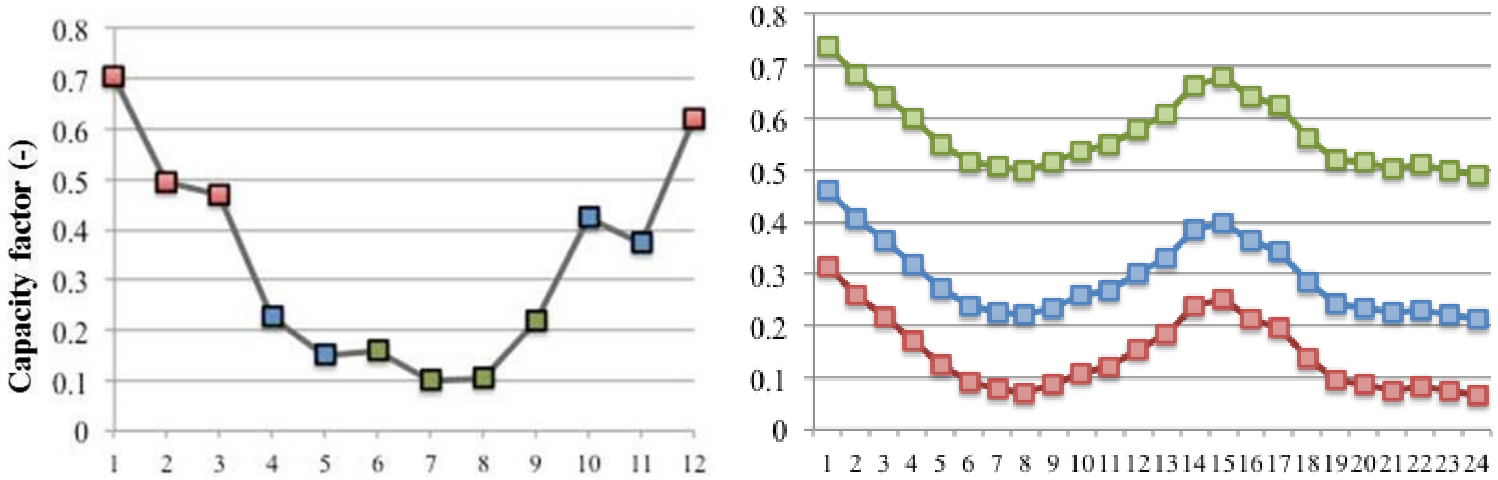


Figure 2-25 Monthly capacity factor (left) and seasonal power generation pattern of Wind power systems in Taiwan.

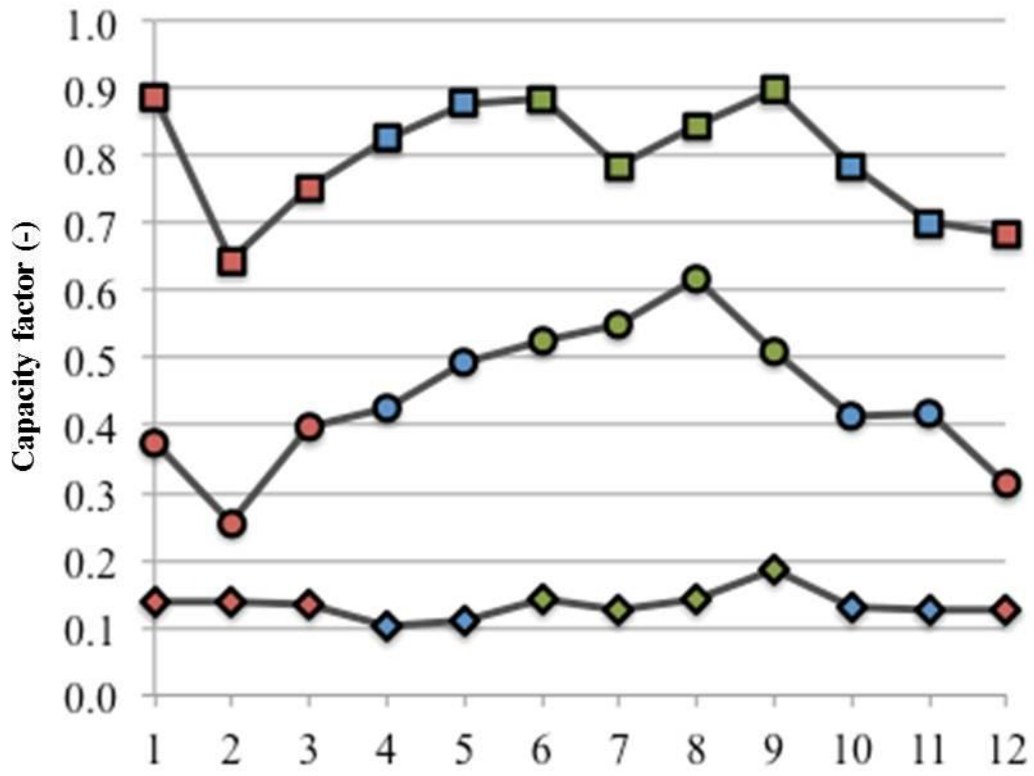


Figure 2-26 Monthly capacity factor of Independent Power Producers in Taiwan (Coal, LNG, and Cogeneration from the top).

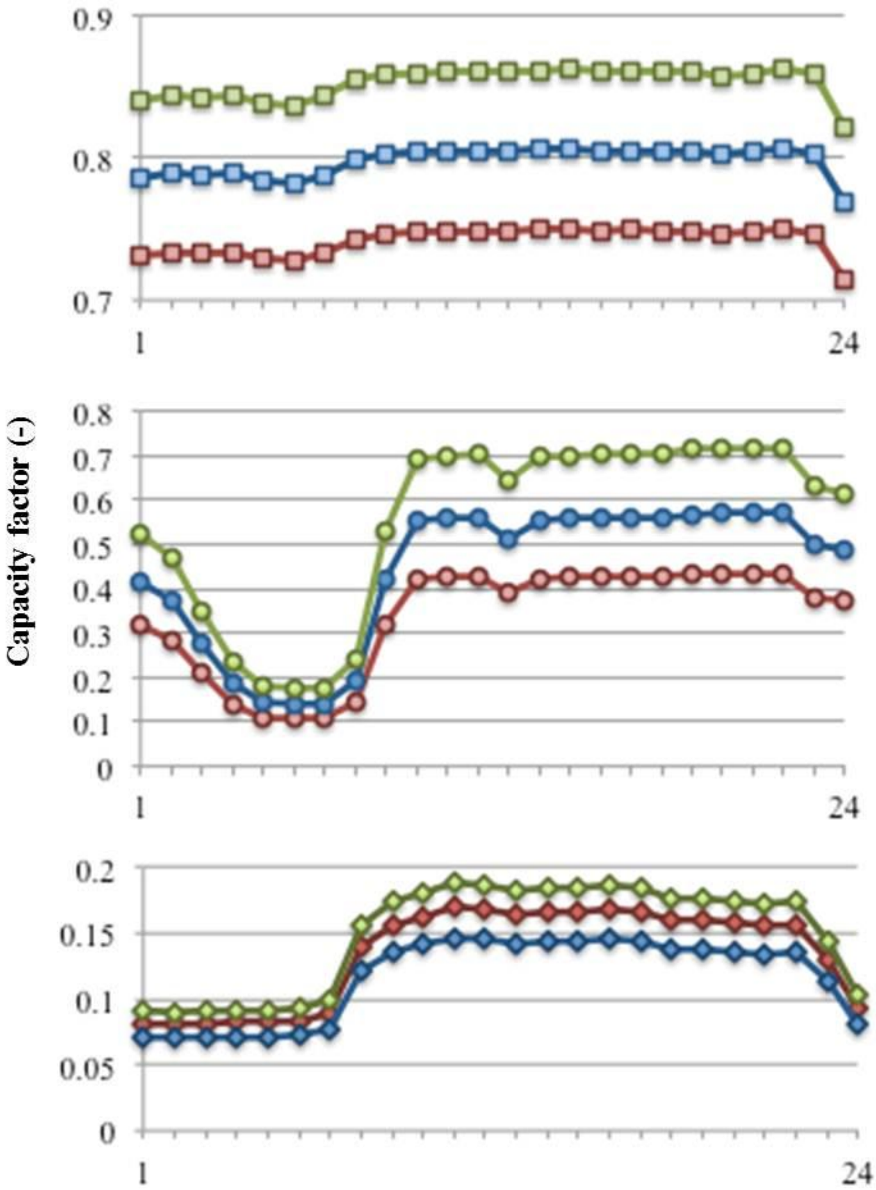


Figure 2-27 Seasonal power generation pattern of Independent Power Producers in Taiwan. Top: Coal, Middle: LNG, Bottom: Cogeneration.

EC-2 Efficiency improvement

As newer power plants are constructed, the efficiency of respective kind of power generation will improve. Therefore, basically energy conversion efficiency of power generation in the future is expected to improve. However in this report, we have utilized the current energy conversion efficiency as a baseline.

The authors strongly suggest examination of additional scenarios with energy efficiency improvement.

Energy efficiency will also depend on the operation patterns. If the power output is frequently adjusted, thermal power plants will lose energy, thus the efficiency declines. We will also suggest exploring possibility of modeling the efficiency variations in relation to capacity factors of respective types of power generators.

2.4 Models

2.4.1 Simulating future electric power supply structure

In this project, the **power mix optimization model (POM)** determines operation of various power plants to minimize the cost of operation by minimizing the operation cost. For installed capacity of power plants, various scenarios will be applied. Some of the scenarios will be generated by minimizing the total (= capital + operation) cost instead of operation cost only. To determine which kind of power plants will be constructed and operated, conversion efficiency, fuel type, future fuel price, and characteristics such as load following capability are needed as inputs to the model.

POM is already available as a model constructed on Excel with a commercial add-on package What's Best from LINDO systems, a rapid application development tool for programs with optimization. However, to assure flexibility and reusability, the model needs revision with a more descriptive and structured modeling tool such as General Algebraic Modeling System (GAMS) or A Mathematical Programming Language (AMPL). In this project, AMPL is chosen.

Figure 2-28 shows the output from the POM for peak load day in 2011, while Figure 2-29 shows the actual situation. There are still some discrepancies between the simulated and actual power mix, so a better calibration of the parameters in the model is required.[19, 20] The POM is capable of considering any number of seasons and power generation and storage technologies. Figure 2-30 shows the comparison between the simulated and actual electricity generation in each season. Although it is not exactly the same, we can see POM is simulating the situation quite well. For the data and model are described using AMPL.

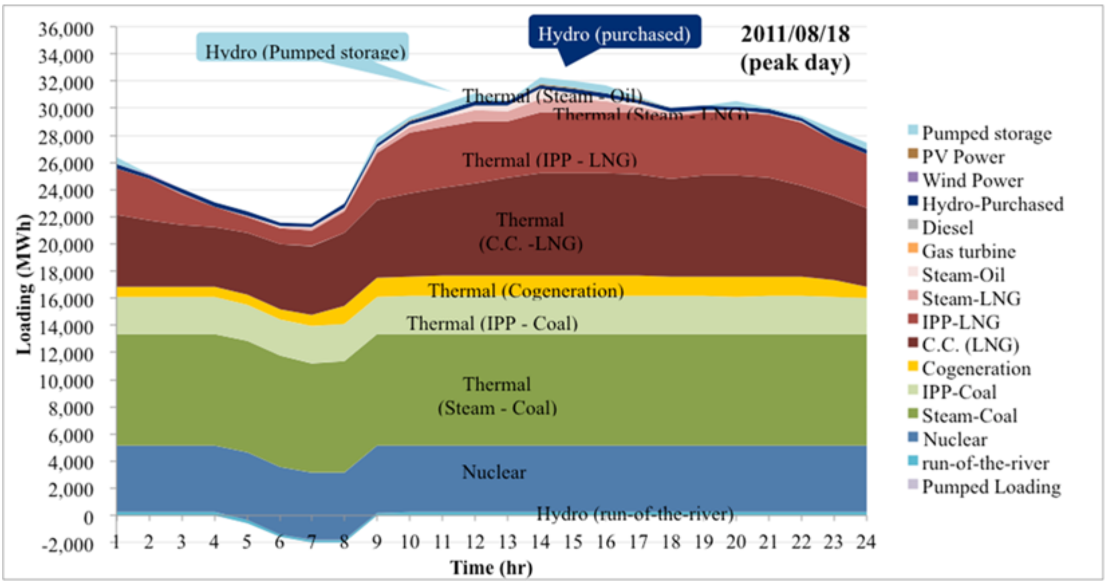


Figure 2-28 Simulated situation for peak day in 2011 (POM)

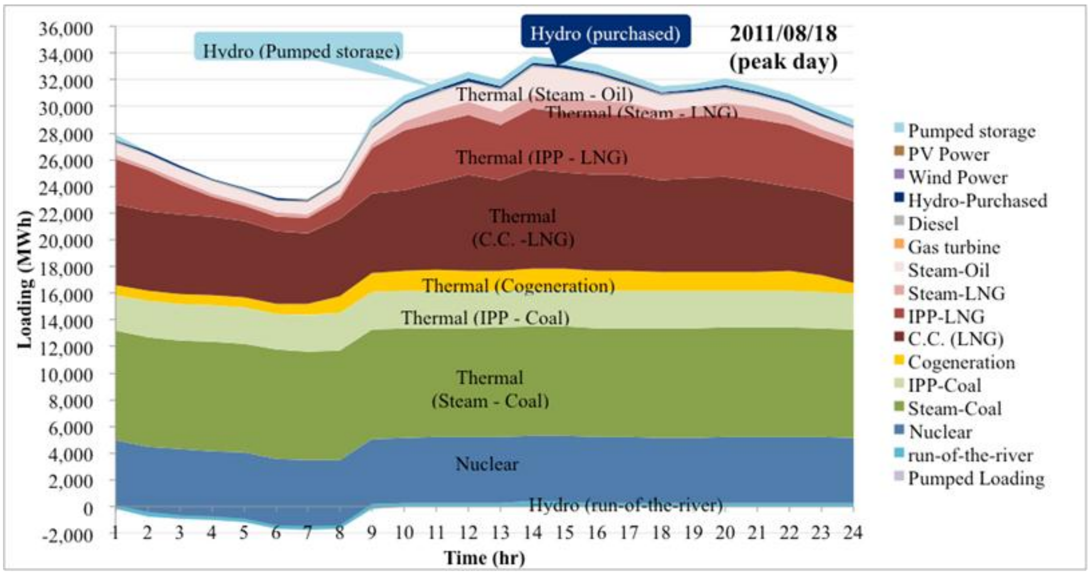


Figure 2-29 Actual situation for peak day in 2011

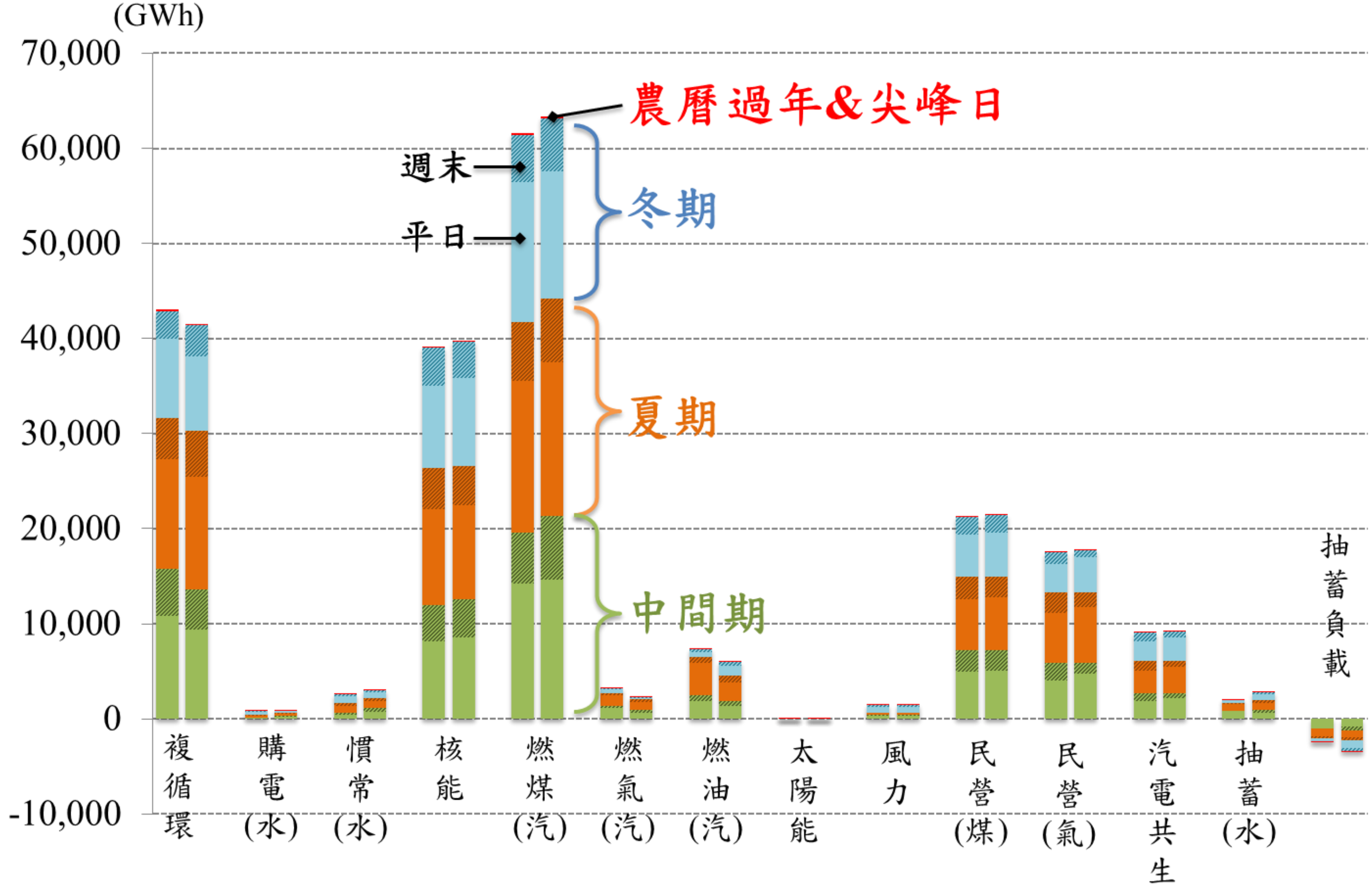


Figure 2-30 Simulated (left) and actual (right) electricity generation in 2011

2.4.2 Simulating future fuel supply structure

For example, by development of biofuels and penetration of EV and HEV technologies, it is expected that gasoline demand is declining in the future (Table 2-3). The implication of this demand structure change on carbon emission inventories of petrochemical industry should be determined considering the mechanisms of conversion of various raw materials into gasoline and the efficiencies of the processes. In this project, a **consequential material flow model for petrochemical industry (COM-Petro)** is developed, and utilized for evaluating the scenarios that affect demand structure of petrochemical products[21].

The operating situation of petroleum refineries in Taiwan in 2010 is used as an example to demonstrate the methodology and calculate environmental burdens reduction potential for different fossil fuel-saving technologies.

Table 2-11 Primary effect of fossil fuel-saving technology

Fossil fuel-saving technology	Primary effect
Alternative fuel	
bio-ethanol	Usage of gasoline decreased
bio-diesel	Usage of diesel decreased
Lighter material for car shell, Hybrid engine, Electric vehicle	Usage of gasoline and diesel decreased
Alternative material	
biodegradable plastic	Usage of propylene decreased

Petroleum refining is an extremely complicated, highly integrated process where the equipment and unit operation are tailored to specific feed properties. The level of complexity is increasing with time due to degrading quality of crude oil, i.e., heavier crude oils with higher sulfur content. Therefore, processes in petroleum refinery will be upgraded over time and could be different from the present form in the future. Figures 2-31 and 2-32 illustrate two typical petroleum refineries, which are mainly producing fuel (CPC Corporation, CPC) and petrochemicals (Formosa Petrochemical Corporation, FPCC).

As shown in Figure 2-33, in this study, first, a superset process model that covers all the processes and process linkages are prepared. Using the actual petrochemicals and fuels production data, yield (defined as the ratio between various coproducts from a chosen process) and efficiency (defined as the weight proportion between input and sum of output products) of respective processes is be calibrated by minimizing the difference between the simulated and actual production. This operation generates a model, which represent the country-specific petrochemical process. This is equivalent with determining the coefficients in a simultaneous equation system that describes a process system.

The calibrated model is then used to determine how much respective model is operated and how the products are processed in the given system, after a change in the product demand. This is equivalent with solving the simultaneous equation prepared in the previous step when demand is altered reflecting all the scenarios in energy-saving.

In this methodology, there are a number of assumptions involved. For example, it is assumed that the process inventories such as yield, efficiency, and emission factors are kept constant before and after the investigated change in product demand occurs. The change is realized only by how much respective processes are operated. For example, when gasoline demand decreases, cracking processes will be less used until the change is not any more absorbed without influencing the amount of other products produced. In reality, by changing the operation conditions, yield and efficiency can be adjusted to a limited extent.

If demand is changed in the future, petrochemical industry will adjust production capacities and functions by additional investment. This is not dealt with in the current version of the model.

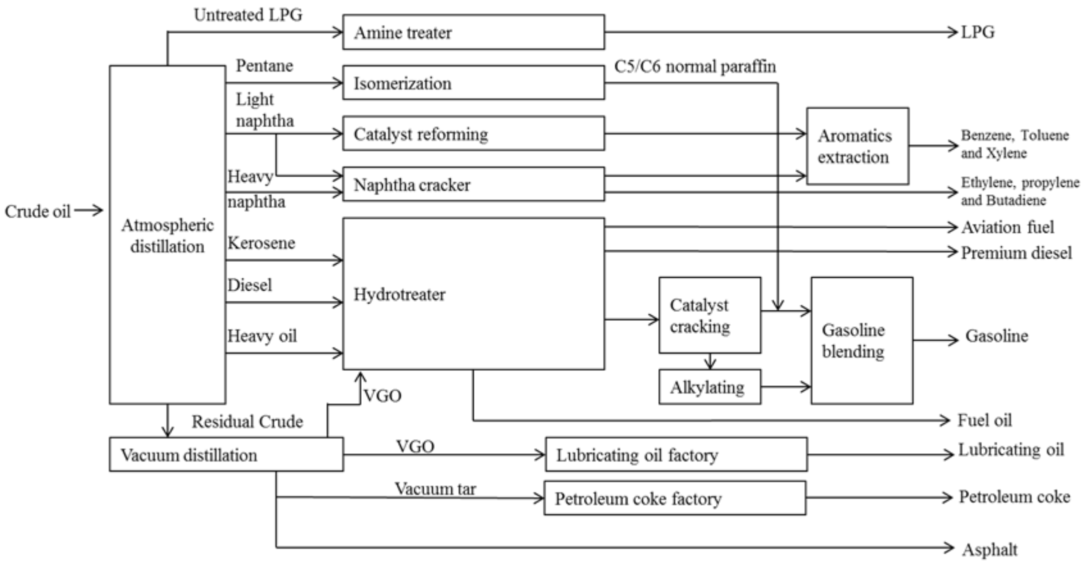


Figure 2-31 Typical petroleum refinery in CPC

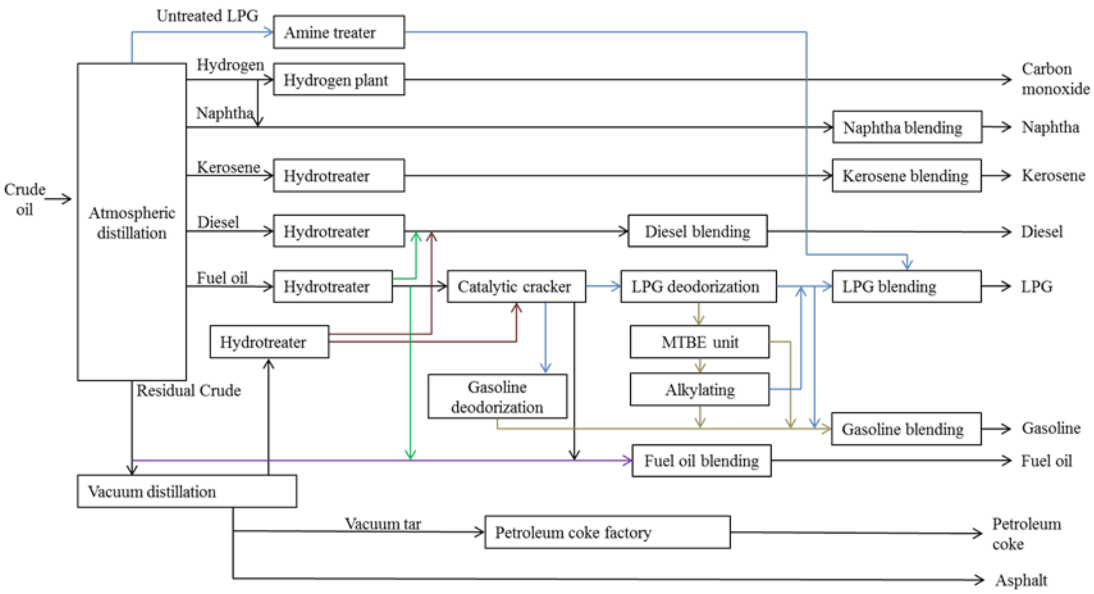


Figure 2-32 Typical petroleum refinery in FPCC

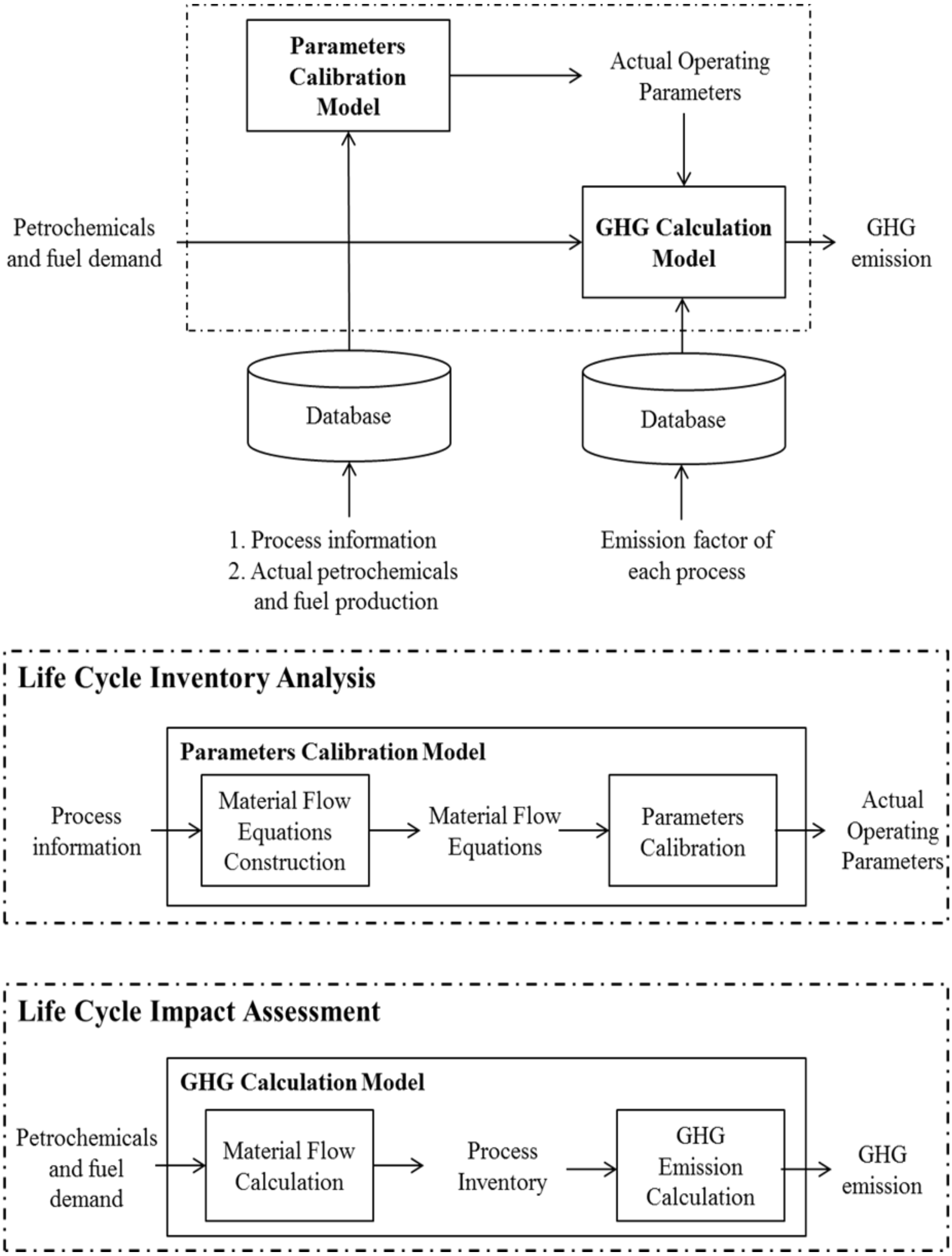


Figure 2-33 The structure of the consequential material flow model for petrochemical industry

Calibration

From Figure 2-34, we can see that petrochemical systems are quite different in yield and efficiency for different countries therefore it is important to use country-specific model.

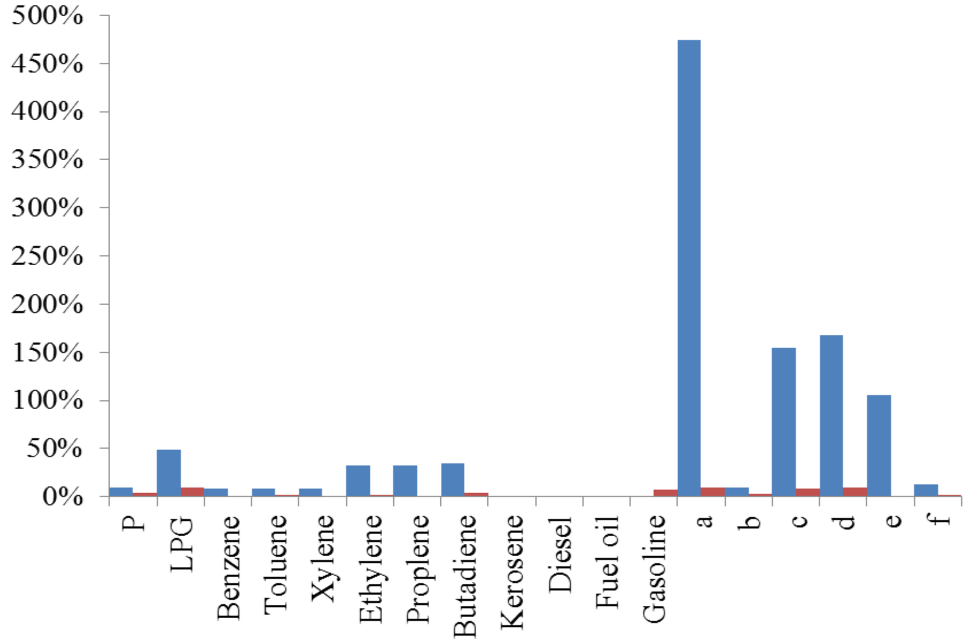


Figure 2-34 Errors of simulated productivity before (in blue) and after (in red) calibration. P: Petroleum, LPG: liquefied petroleum gas, *a*: benzene import, *b*: toluene import *c*: xylene import, *d*: ethylene import, *e*: propylene import, *f*: butadiene import

GHG calculation

Contribution of various fuel saving technologies are used as input information to the model, together with the changes in future power plant operations induced by various electricity-saving technologies. Figure 2-35 highlights the difference between the results from our model and the results when using emission inventories from LCA database. Not only that the heights of respective bars are different, but also there are maximum reduction limit. This is because actually refinery processes are not individual as modeled in LCA – the products are coproduced, and the fraction of coproducts are not entirely controllable. A balanced reduction in fuels, rather than a reduction strategy concentrated on a certain petroleum products will be favored in reality, and our model successfully simulates such situation.

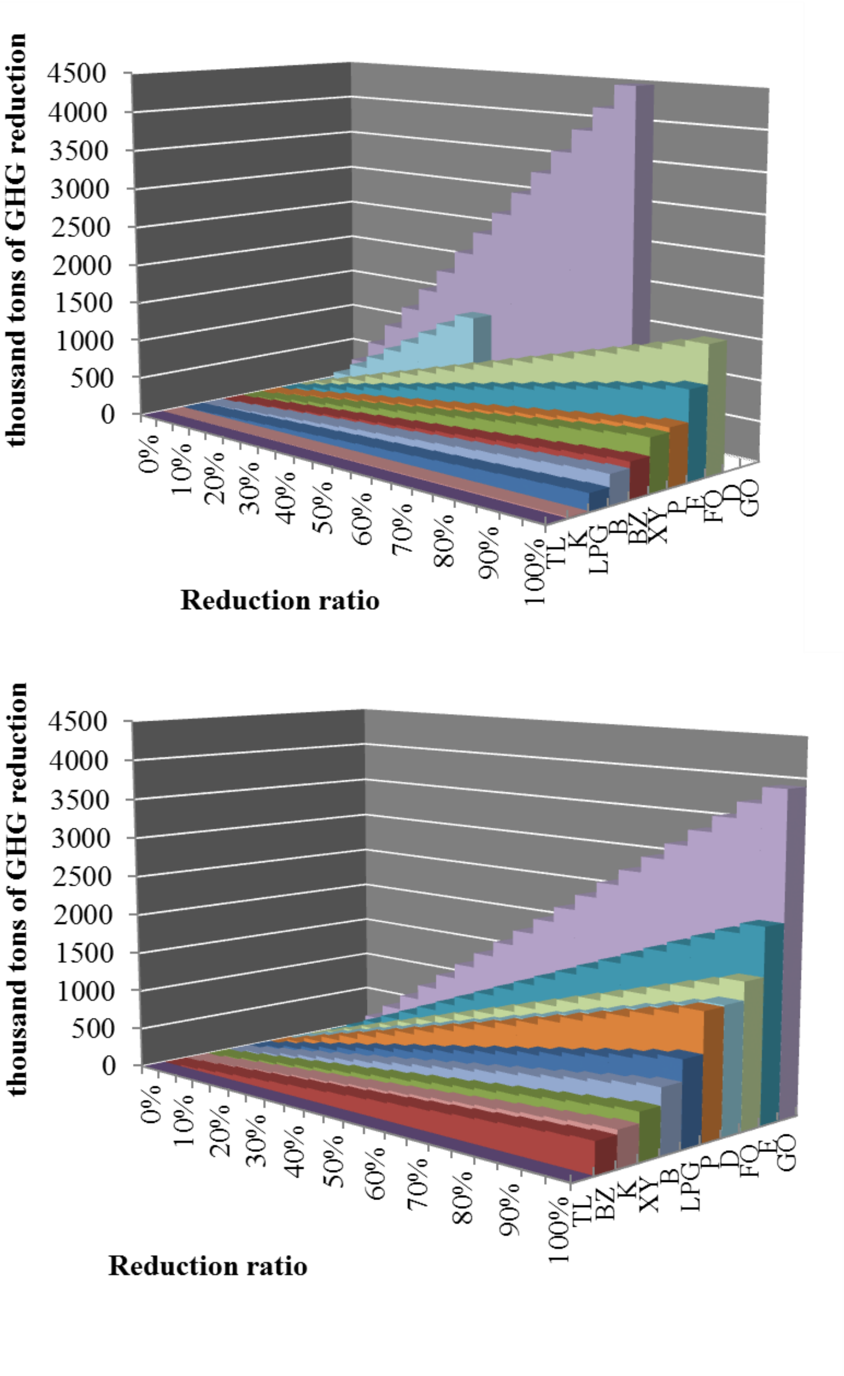


Figure 2-35 Comparison of GHG emission reduction estimation for reduction of production of individual petrochemical products. Our model (upper) and conventional LCA result (lower). TL: toluene, BZ: benzene, K: kerosene, XY: xylene, B: butadiene, LPG: liquefied petroleum gas, D: diesel oil, FO: fuel oil, E: Ethylene, GO: gasoline oil

2.4.3 Simulating future power demand from the scenarios

Creating raw future loading curves

First, the power loading based on current technologies, without any technologies introduced is created. In this report, the total consumption scenario serves this role. If there are more scenarios created in TC-1 for example by assuming effects by higher energy cost (elasticity scenario) or by education (energy saving lifestyle adoption scenario), these can be reflected in the raw future loading curves.

Consideration of energy consumption technology scenarios

Next, any technology that changes the electricity demand will be taken into account except for those that have load-balancing functions. In this study, although reviews are made, there is no information on hourly power consumption was obtained for the reviewed technologies. For example, such information shown in the Figure 2-36 is needed for each seasons defined in POM to assess improvement in air conditioners, refrigerators, etc. Up to date information on such items were not found for Taiwan. Therefore, all the baseline sub-scenarios for energy consumption technologies were set as one that do not influence future power demands.

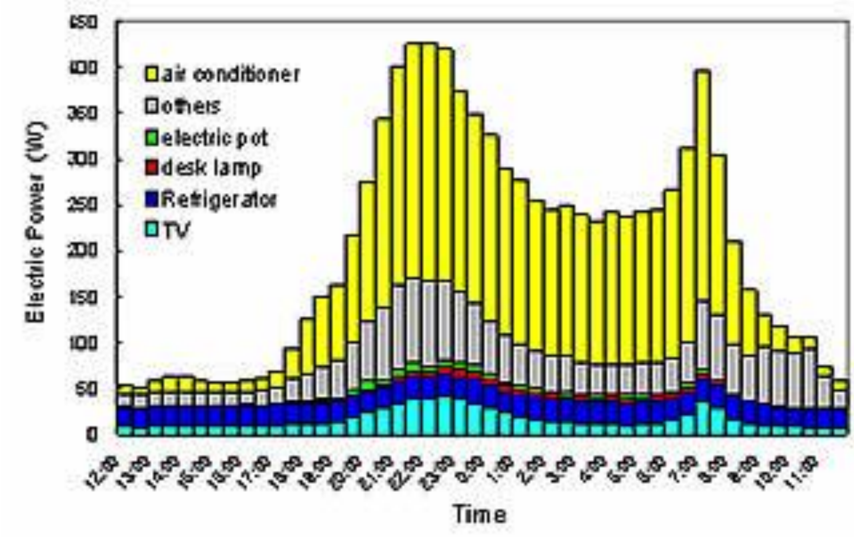


Figure 2-36 Power demand structure in a household. (Taken from http://www.energy.kyoto-u.ac.jp/english/professional/socio/energy_and_environment.html)[22]

Consideration of load balancing technology scenarios

Once the EV is introduced and managed, the electric energy charged in EV's battery could be discharged during the peak loading period. In this way, the curve is leveled and becomes more flat. This makes it possible to use only the newer, more efficient power plants at a higher capacity factor. Some expects electric vehicles to become a key element for its load balancing capabilities. Another key characteristic in the power grid is the demand response function, which influences the quality of power supply. If batteries can serve as energy storage method, hydro power plants may be used more for this purpose, thus works positive in maintaining the stability of voltage and frequency of power supply.

The smoothing and storage mechanism requires proper management of the electricity demand and supply. This could be achieved by the integration with smart grid[23]. Figure 2-37 shows the feature of smart grid. The figure illustrates use of renewable energy integrated with advanced metering infrastructure equipped in houses and buildings, which can simultaneously sense the fluctuation of power supplied to the grid and charge/discharge power.

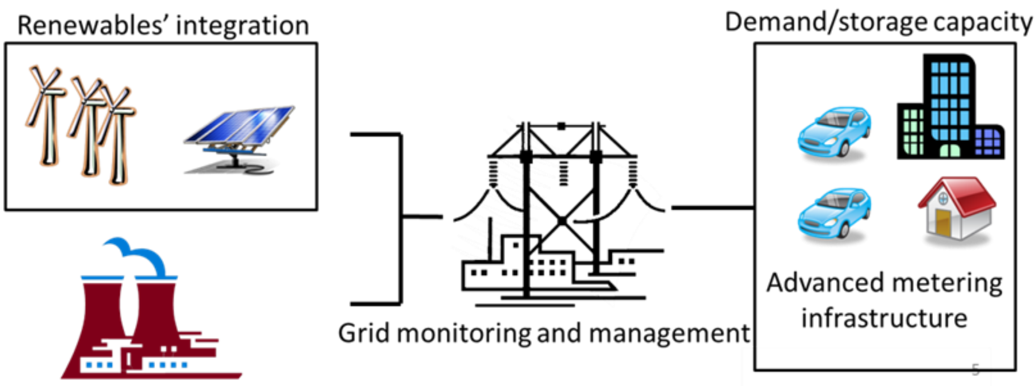


Figure 2-37 The integration of renewables, EVs and smart grid

Here, we present a simple design scheme for EVs use in the smart grid, to roughly estimate its contribution in load balancing. The design criteria are shown in Table 2-12. The data are taken or calculated from literatures[24] (Automotive Research and Testing Center).

As a realistic constraint in the operation of EVs in the smart grid, the tolerance level [25, 26] of the battery's state of charge (s.o.c.) is important. Batteries release energy more easily when their s.o.c. is above the tolerance level. In order to assure the stability of using EVs for transportation, the s.o.c. is set throughout the use in a day, not to fall below the tolerance level.

Table 2-12 Parameters used in the calculation of load balancing effect by EV [11, 27]

Characteristics of EVs	
Capacity	75000Wh
Tolerance level of charging	SOC=30%
Electricity consumption per kilometer	250Wh/km
Driving pattern	
Velocity	40km/h
Time to/off work	1 hour
Charge facility	
Destination	**Max(Wh)**
Company	17,600Wh
Mall	10,000Wh
Rode side	50,000Wh

In this design scheme, optimization technique is used to level the load curve. Objective function, design variables and constraints are described as follows:

Objective function: Minimize the variance of the grid loading

$$\min \sigma^2 = \sum_{i=1}^{24} (\bar{x} - x_i)^2 \qquad \text{eq. 5}$$

The electricity load after levelization $x_i = E_i + (y_i - y_{i-1})$ eq. 6

x_i = electricity load at i^{th} hour

E_i = original electricity load at i^{th} hour (is also set to be the electricity demand)

y_i = the electricity remained in the battery

Design variables: the electricity recharge/discharge per hour

$= y_i - y_{i-1}$ (+: recharge; -: discharge) eq. 7

Constraint:

1. The hourly dis- /re-charging may not exceed the capacity of the plugging equipment.

$$|y_i - y_{i-1}| \leqq \text{Kmax}_{dest} \qquad \text{eq. 8}$$

Destination (*dest*)	***Kmax*** $_{dest}$ **(Wh)**	**Description**
Company	17,600	220V × 80A
Mall	10,000	電動車充電對電力品質及電力供應影響之研究[28]
Road side	50,000	電動車充電商業模式與充電設備商機探討[29]

2. The state of charge (SOC) of battery during commuting would be kept above the tolerance level (= 30%).

$$\frac{y_c}{y_{\max}} \geq 0.3 \qquad \text{eq. 9}$$

c = 8, 17 (when destination is company)

c = 10, 19 (when destination is mall, roadside)

3. The total dis/recharging power in a day of the battery should be 0

$$\sum_{i=1}^{24}(y_i - y_{i-1}) = 0 \quad \text{(+: recharging; -: discharging)} \qquad \text{eq. 10}$$

4. EVs are leaving home with full SOC every day.

$$y_c = y_{\max}(= 75{,}000)$$

$$c = 8(company), 10(mall, roadside)$$

5. One commuting trip (one way) requires 10,000Wh

= (40 km/hr) × (250 Wh/km) × (1 hr)

No re- / dis-charging happens during commuting hour.

$$y_c - y_{c+1} = 10{,}000 \qquad \text{eq. 11}$$

$$c = 8{,}17(company)$$

$$c = 10{,}19(mall, roadside)$$

Using this kind of model, it becomes possible to illustrate how much the energy technologies influence the operation of the entire power supply system, and how the technology will be used in the society.

Chapter 3 Result and Discussion

The power and fuel demand was calculated consistently combining the sub-scenarios developed. To demonstrate the scenario analysis using this framework, an example of evaluation of EV technology in GHG emission reduction is shown as a result here.

3.1 Situation without EV promotion

3.1.1 Results from POM

Using the baseline sub-scenarios in energy consumption sector except for the TR-1 (Electric Vehicles), power demand projection was made by PDPM. Using the projection, together with baseline scenarios in EC-1 and EC-2, power mix was simulated for the year 2020 as illustrated in Figure 3-1.

Here, gasoline consumption, fuel oil consumption at the power plants and greenhouse gas emission from the vehicles and the power plants are estimated for the case when EV is absent. Gasoline consumption is calculated on the basis of ICEV (16 km L^{-1}) or on the basis of HEV (20 km L^{-1}).

3.1.2 Results from COM-Petro

The COM-Petro calibrated on the basis of Taiwanese Petrochemical Industry in 2011 calculated the baseline greenhouse gas emission under the current proportion of supply.

3.2 Situation with EV promotion

3.2.1 Results from PDPM

Figure 3-2 shows the use pattern of EVs for commuting to a company on summer weekday. Figure 3-3 shows the pattern on the summer weekend, for the EVs that go to mall for shopping. Patterns as shown in these two figures are created by PDPM, together with the power load curve after load balancing by EVs (baseline scenario), as shown in Figure 3-4. With the same number of EVs, depending on use patterns determined by completeness of the infrastructure, the load balancing achieved could be quite different.

3.2.2 Results from POM

Figures 3-5 and 3-6 show the results from POM using the outputs from PDPM. In Figure 3-5, the increase in coal and combined cycles are observed. This is reasonable as they are used as middle base. In Figure 3-6, a substantial decrease in hydro pump utilization is predicted. This is because the load balancing function provided by hydro pump is replaced by batteries on EV. The demand response capability of hydropower generators in general is very high. Therefore, EV may allow more room for hydro pump generators to work on stabilization of the power supply, which is a concern for future power supply system where more PV and Wind power systems are connected.

From the results, changes in fuel oil and gasoline demands are obtained in comparison with the results from 3.1.1.

3.2.3 Results from COM-Petro

Using the results from the previous section, greenhouse gas emissions in fuel production sector are calculated. In Figures 3-7 and 3-8, the simulated process flows in the model for the two scenarios in EV infrastructure is shown.

3.3 Discussions

The changes in GHG emissions from the three sectors, induced by the EV scenarios, are summarized in Figure 3-9. In energy conversion sector, because of increase in electricity generation for EVs, emission of GHGs have increased. The most of the increase occurred both in LNG combustion in Gas combined Cycles and then in coal combustion in Coal fired power plant.

In energy consumption sector, on the other hand, gasoline combustion is avoided. This results in reduction of GHG emissions, comparable but slightly more than the increase in energy conversion sector.

In fuel production sector, greenhouse gases emission reduction from simultaneous reduction in gasoline and heavy oil consumption is evaluated using COM-Petro.

By comparing the three, it becomes possible to say, that in cases where infrastructure for EVs to charge and discharge to contribute in load balancing is complete, if the vehicles replaced by the EVs were the ones with mileage at around 16 km L^{-1}, it will result in a slight reduction. However, the vehicles replaced by EVs were as good as 20 km L^{-1}, the emission reduction is not enough, therefore emission will increase in total. Although we can expect more reduction due to domestic surface transportation of fuels, emissions from ship to transport petroleum to Taiwan, and at mining, the GHG emission reduction is not apparent in the scenarios we have explored.

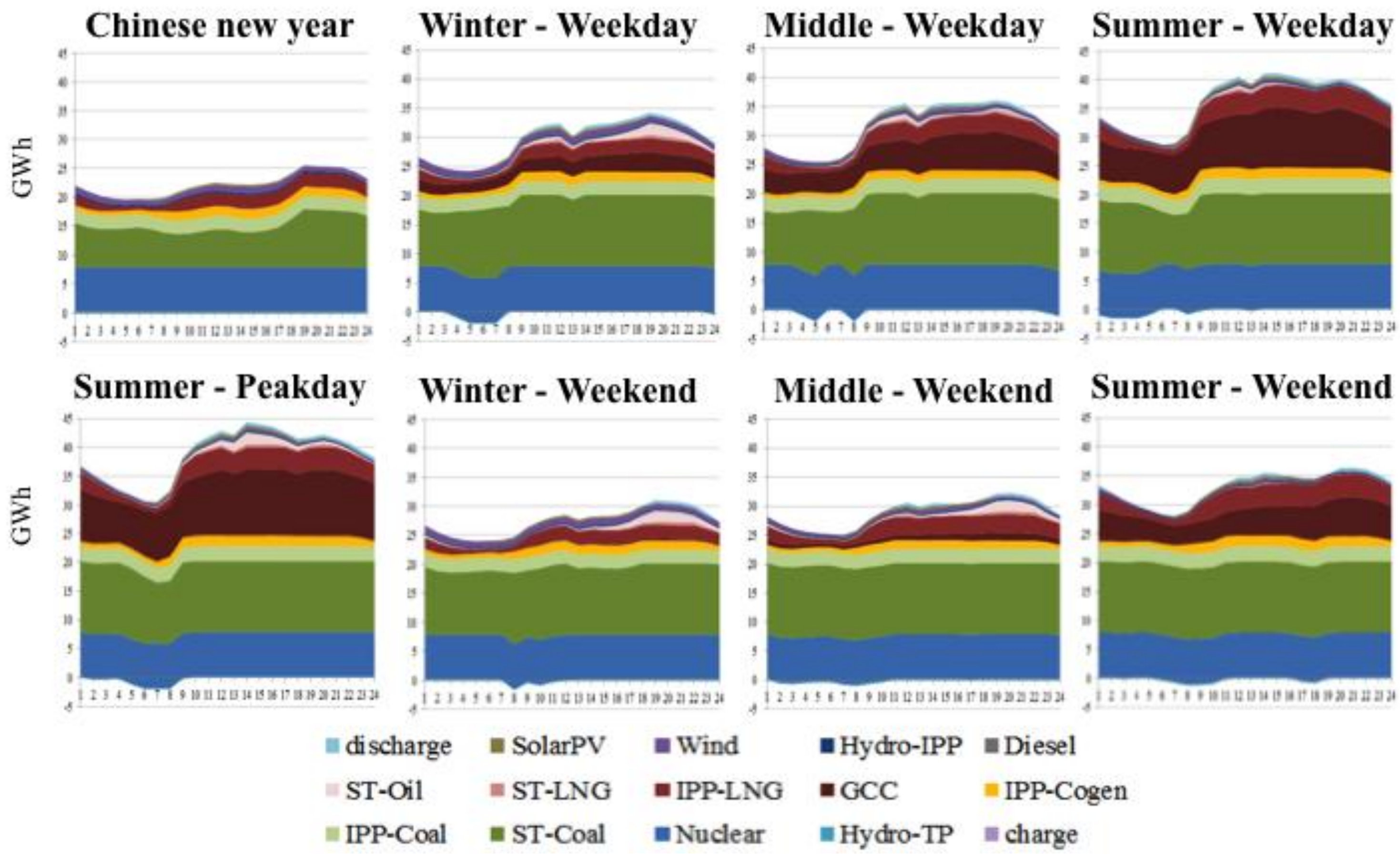


Figure 3-1 Simulated power generation structure in 2020

(without bioethanol promotion, with Wind and PV promotion)

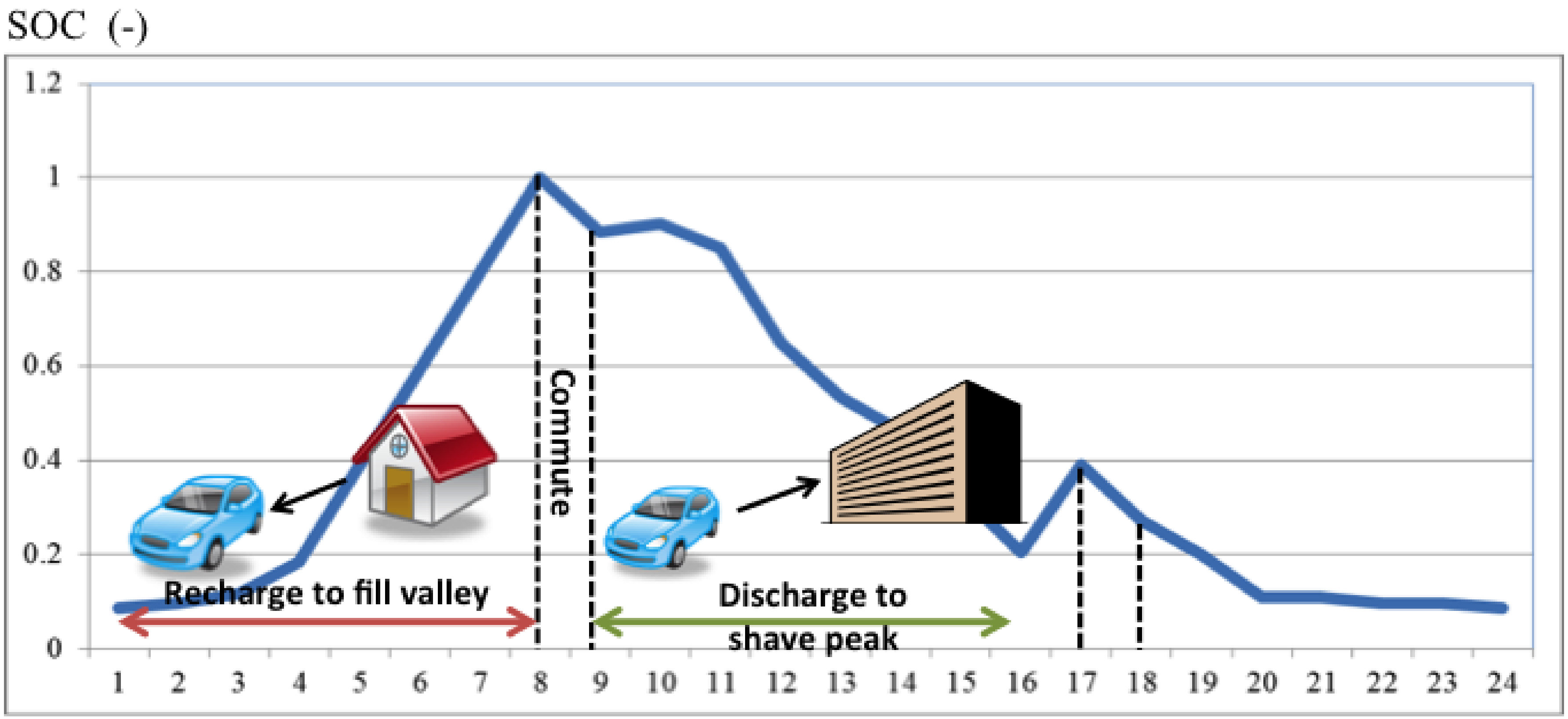


Figure 3-2 Hourly schedule of an electric vehicle on a summer weekday (Destination: Company)

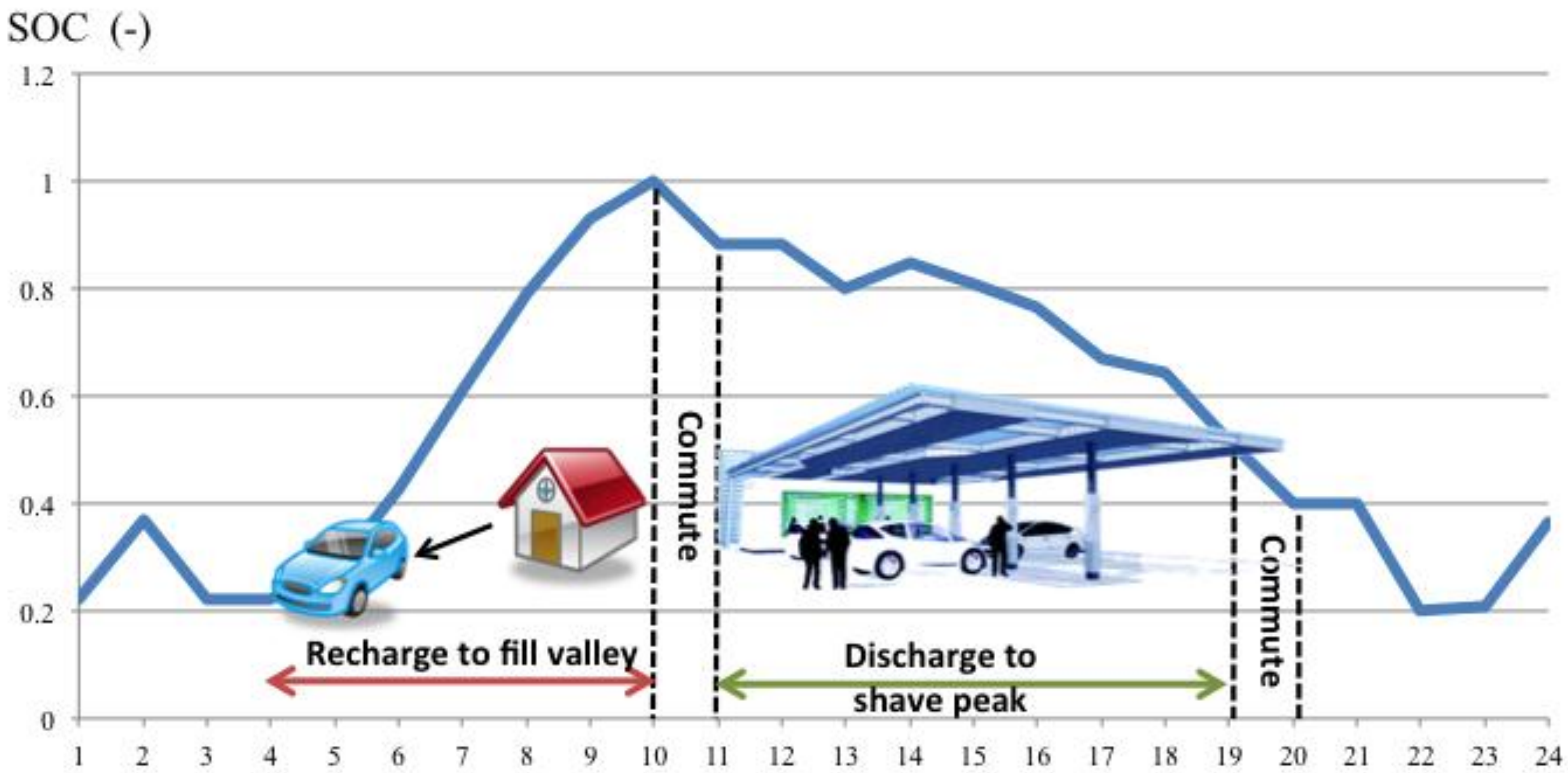


Figure 3-3 Hourly schedule of an electric vehicle on a summer weekend (Destination: mall)

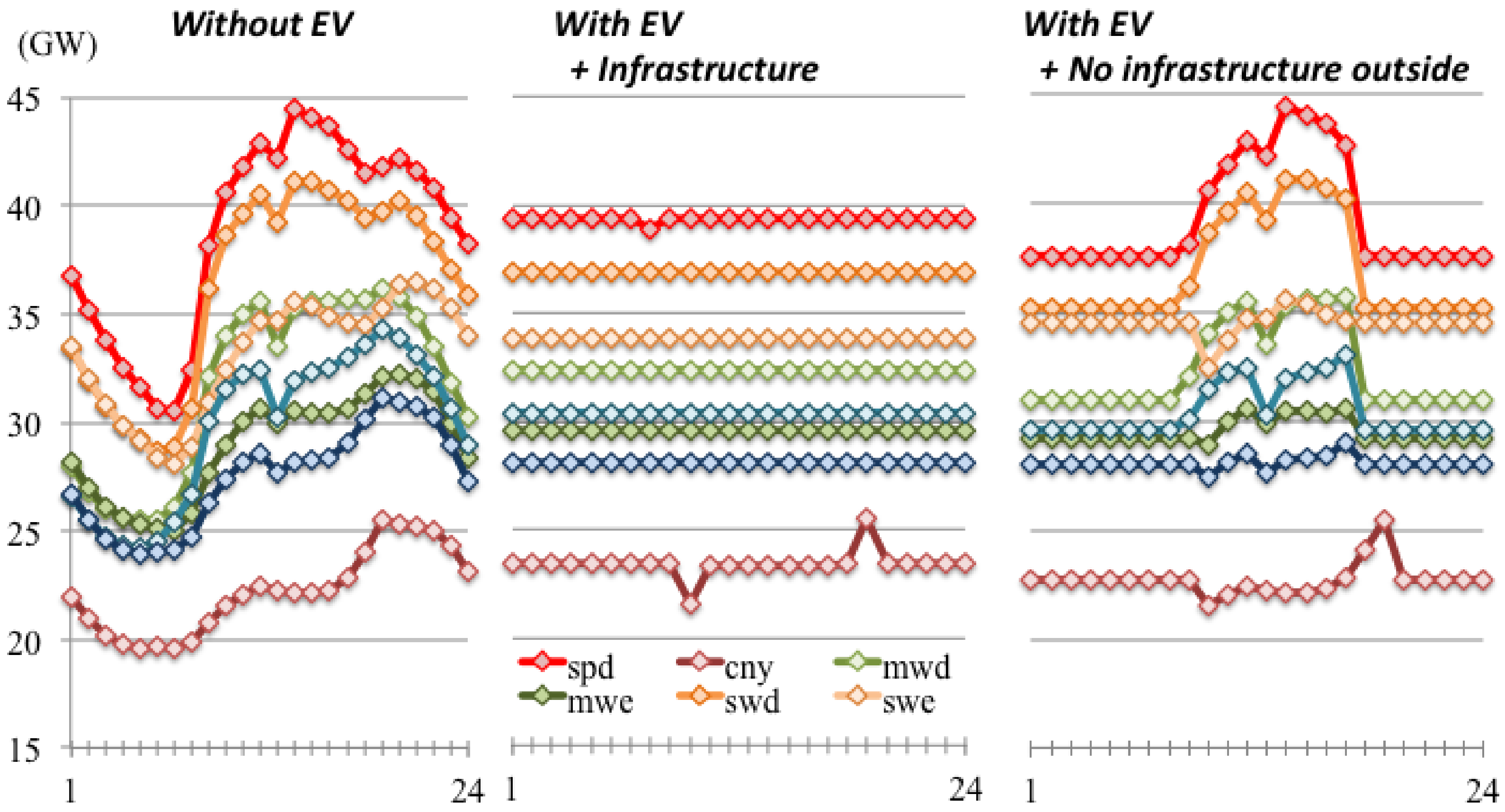


Figure 3-4 Hourly power load curves without load balancing by EVs (left), with load balancing achieved through infrastructures installed everywhere (center), and with load balancing only via discharging at home (right)

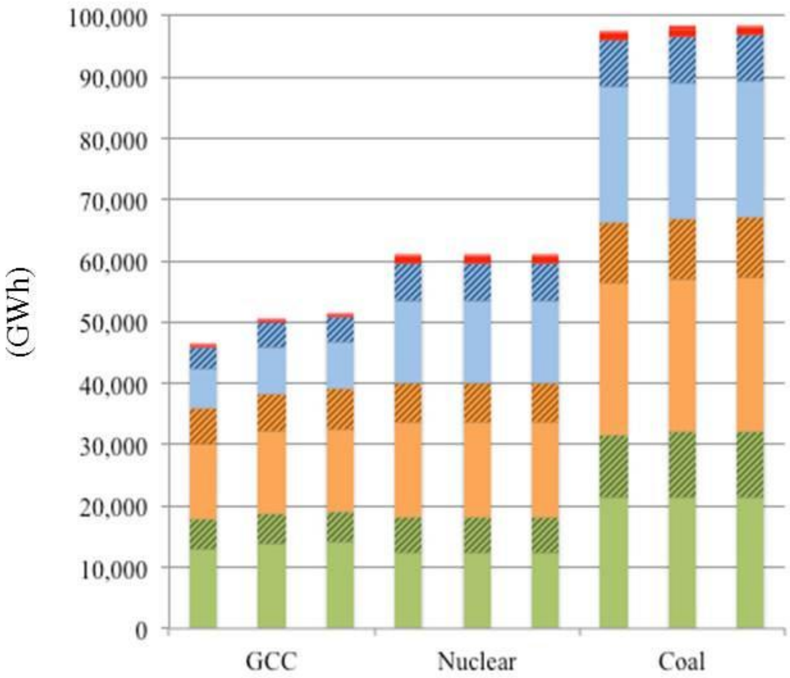


Figure 3-5 Power plant operation in the eight POM-seasons (green: middle, orange: summer, blue: winter) for GCC, Nuclear and Coal. Shadowed portion occurs in the weekend. The small red portion is the sum of chinese new year holidays and summer peak day. Operation of gas combined cycles and coal fired power plants have increased as a result of EVs introduction (middle and right bars for with and without complete infrastructure, respectively) compared to the control case (left most bar, without EV introduction).

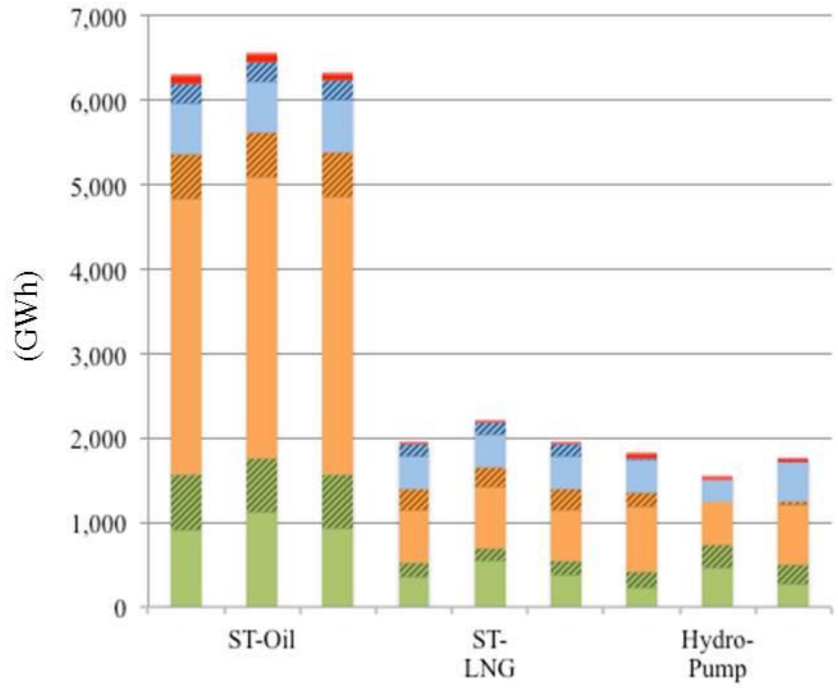


Figure 3-6 Power plant operation in the eight POM-seasons (green: middle, orange: summer, blue: winter) for Oil, LNG and Hydro-Pump. Shadowed portion occurs in the weekend. The small red portion is the sum of chinese new year holidays and summer peak day. Oil and LNG increases slightly, while use of hydro-pump is slightly decreased.

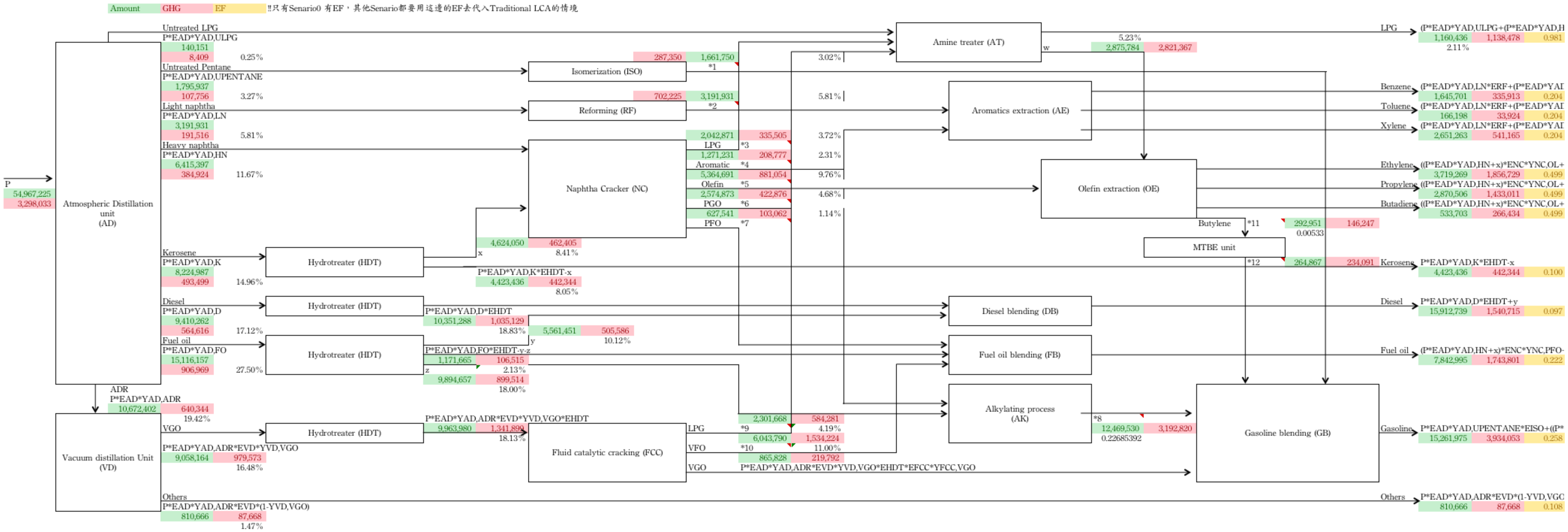


Figure 3-7 Outputs from COM-Petro: EV introduction with complete infrastructure

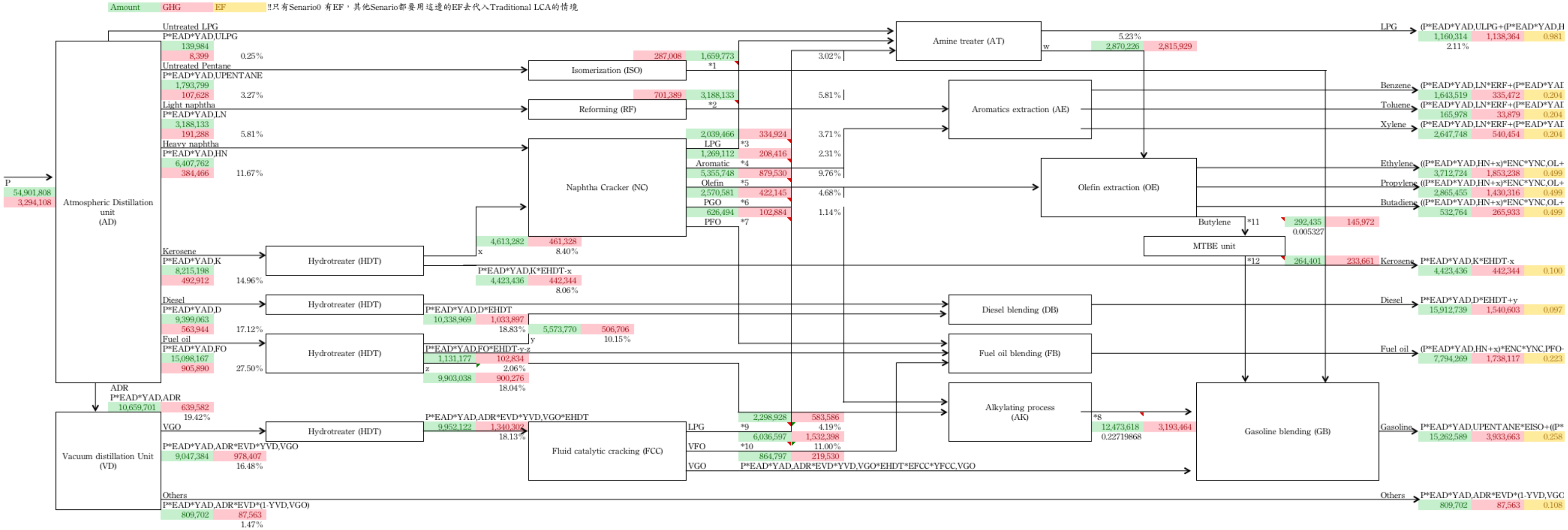


Figure 3-8 Outputs from COM-Petro: EV introduction without discharging infrastructure outside

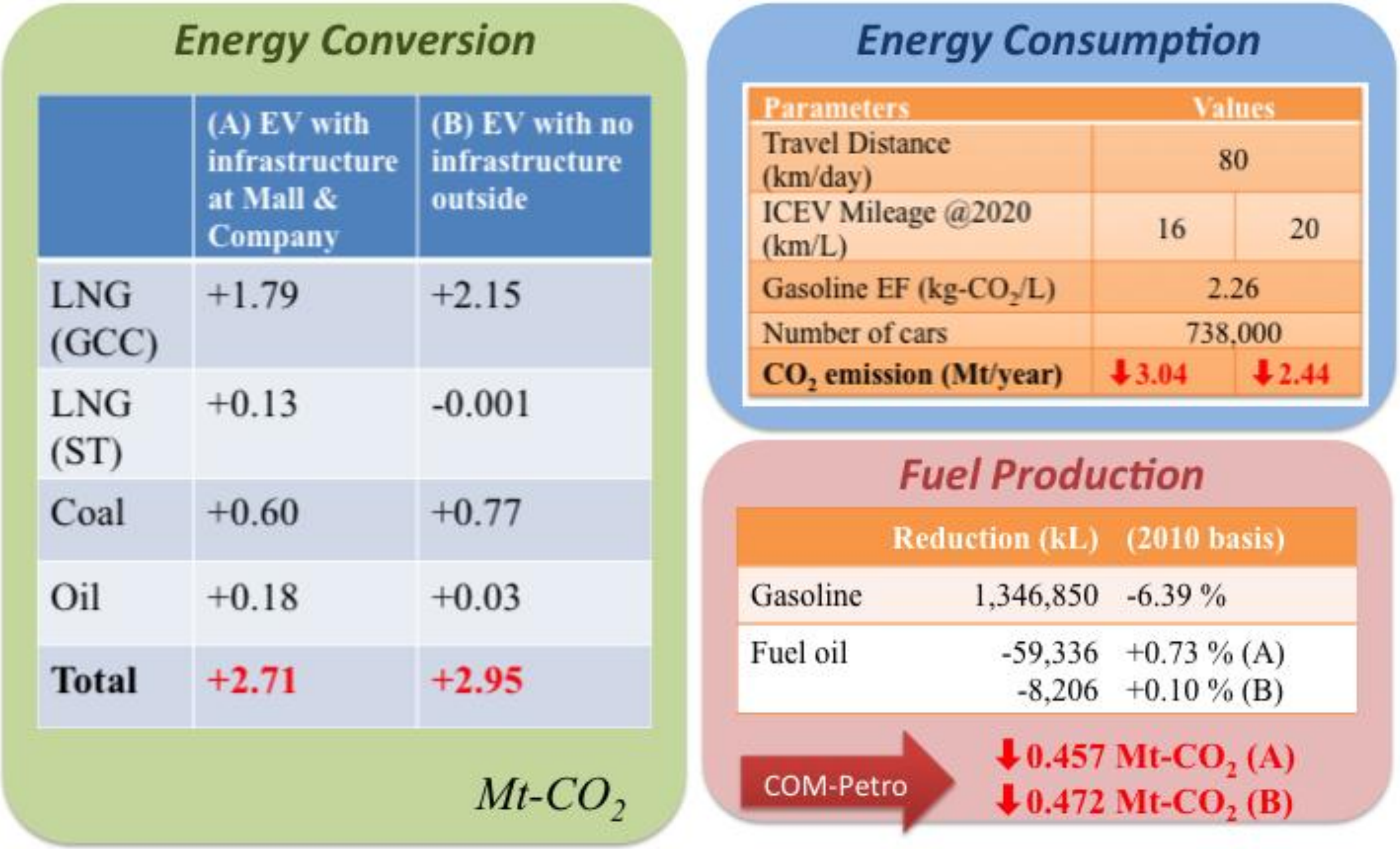


Figure 3-9 Summary of changes in GHG emission calculated using the proposed framework.

Chapter 4　Long-term visions

In the previous chapter, we have demonstrated use of a technology assessment framework that evaluates how energy saving technologies can contribute in GHG emission reduction. The proposed framework does consider the practical details of changes in GHG emission that occur in power generation sector, petrochemical sector, and energy consumption sectors.

To understand the role of technologies, in this chapter, we conduct a preliminary long-term energy supply/demand analysis using POM. By having a rough grasp of the trade-off between the growth in per-capita energy consumption and additional power generation capacity needed, we can understand how much role technology and lifestyle change have to take.

In doing so, first we accept the Taiwan's population trend (Figure 4-1) in the future as a basic assumption throughout the analysis. Next, in addition to the long term energy supply outlook by Taipower, we create alternative energy demand growth scenario (NCKUESEL) as shown in Figure 4-2, by assuming our scenario on development of per-capita energy demand shown in Figure 4-3. We can see that in Taipower and NCKUESEL scenarios, electric power demand hits the peak in 2044 and 2029, respectively. In both scenarios, 2050 is already beyond the peak of the electricity demand.

Next, we use PDPM to generate the hourly load curves for

POM-seasons in 2044 (Taipower scenario), 2029 (NCKUESEL scenario), and 2050 (Taipower scenario, NCKUESEL scenario). Then POM is used for the respective curves to see how much additional power generation capacity needs to be added from 2020. Here, the additional power generation capacity is assumed to be provided 50% by Coal-fired steam power plant and another 50% by Natural Gas-fired Combined Cycles.

Note that 2020-2025 is a critical time, because in our scenario for evaluation of EV, No.1 nuclear power plant is extended and still in use. It must be retired very soon, so we assumed it should retire during 2020-2025. According to current Taiwan policy, nuclear power plants should retire after 40 years of operation, and no more new nuclear power plants will be constructed. In this case, No. 2 and No. 3 power plants should also close during this period. In this calculation, we assumed that in 2020 all No.1-4 nuclear power plants are operating, but in 2029, 2044 and 2050, only No.4 nuclear power plant is operating.

The results are summarized in Table 4-1. The difference in additional power generation capacity needed is quite large.

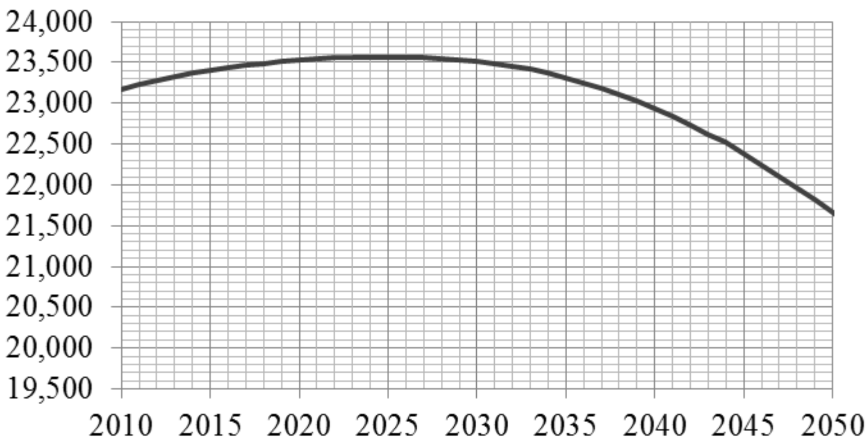


Figure 4-1 Population projection till 2050

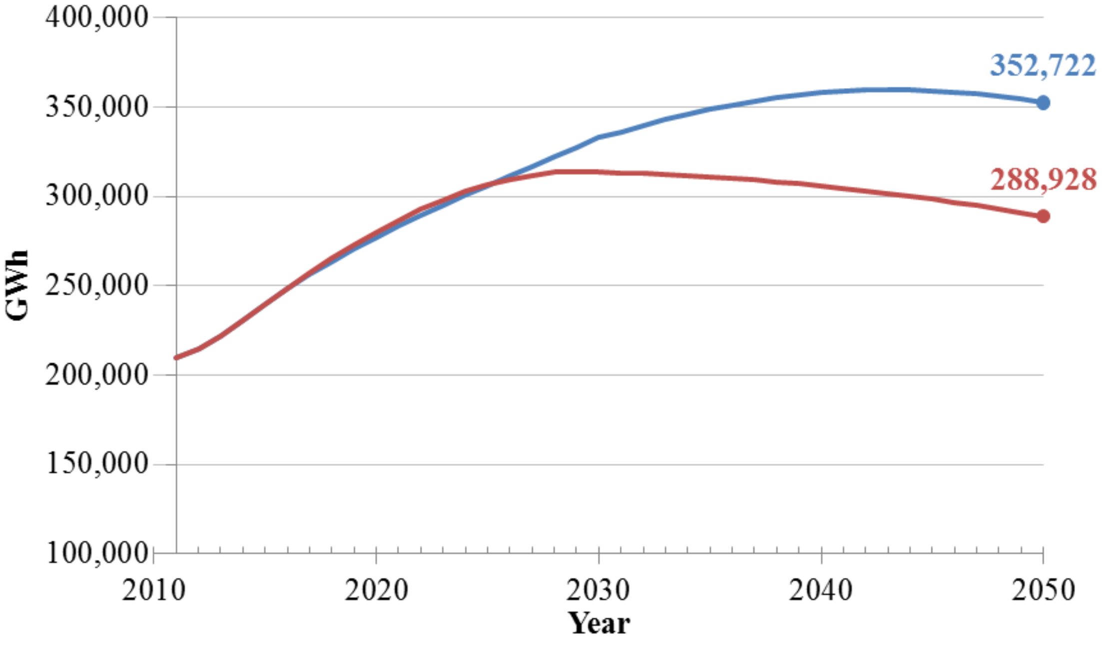


Figure 4-2 Projection of electric energy demand
(blue: Taipower scenario extrapolated to 2050, red: NCKUESEL)

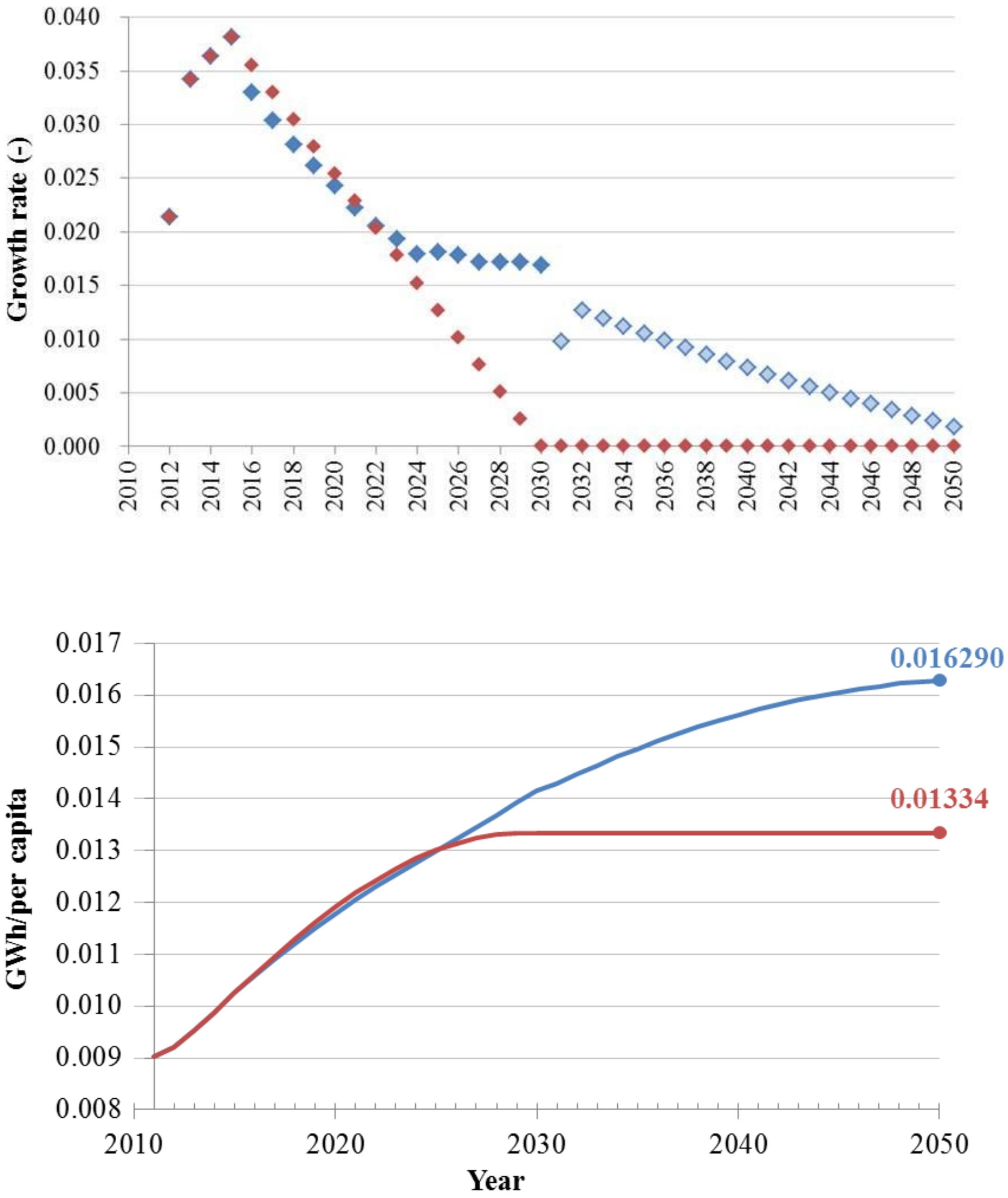


Figure 4-3 Projection of electric energy demand per capita (lower) and the growth rate of electric energy demand per capita (upper) (blue: Taipower scenario extrapolated to 2050, red: NCKUESEL)

Table 4-1 Comparison of the Taipower and ESELNCKU scenarios

	2020		Peak year (Nuclear=2.7 GW)		2050 (Nuclear =2.7GW)
			2029	**2044**	
Taipower	Nuclear	7.84	-	+19.6	+18.27
	Oil	2.00			
	Coal	13.20			
	LNG	0.55			
NCKU ESEL	GCC	14.56	+11.41	-	+6.95
	Diesel	0.22			
	Hydro (Taipower)	1.75			
	Hydro (IPP)	0.29			

Chapter 5　Conclusion

Here in this report, we have shown the overall framework of constructing the roadmaps for energy saving, low carbon technologies.

COM-Petro and POM is used to evaluate carbon emission reduction from power plant and petrochemical refineries. The two models are integrated to calculate greenhouse gases emission in a consistent manner.

Scenario development models for penetration in the market are needed. Some of such models are prototyped under this project. However, these models are more time consuming, and require large-scale surveys. Therefore, development of a decent model for scenario development is considered as a following study.

In the long term energy structure analysis, the importance of technology for energy saving together with lifestyle change is highlighted. It is suggested that a longer term scenarios on technology development should be constructed, thereby the contributions in GHG emission should be further separated into those from technology and from lifestyle. Another suggestion is to integrate the models we developed with studies on modification of industrial structures. Considering that the retirement of nuclear power plants are approaching quickly, these studies must be done with ample investment of funding, and conducted by a good network of researcher's.

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Appendix 1 - Interview Record (Heat Pump Boiler)

熱泵熱水器廠商訪談紀錄

訪談對象：承研能源科技股份有限公司

時間：2012 年 3 月 28 日 上午 9 時 30 分至 10 時 30 分

地點：承研能源科技股份有限公司(台北市內湖區瑞光路 258 巷 2 號 8 樓之 2)

出席人員：承研 黃文峰總經理、成大 莊碧珊

訪談內容：

一、前言

黃總經理：因公司較偏向商用，所以對於家用相關資訊的回答可能不那麼精準，只能提供個人想法。

二、ESCO 服務

Q1：能否簡略說明 ESCO 服務？

A1：ESCO，Energy Service Company，能源技術服務公司，主要就是對業主做節能保證。例如幫客戶安裝熱泵系統，工程設備需花費 500 萬元，但一年可幫客戶省下 200 萬元，客戶可從省下來的錢分 2.5 年分期支付。也就是說客戶完全不用投資初期的

設備成本(工程費用)，且這兩年半的期間的所有維護成本也計算在內，客戶完全不須付費，只要提供場地即可。

Q2：節省費用是依據什麼去做計算？

A2：依照國外 IPMVP 的一個量測驗證(M&V)方式，國內綠基會網站有一套標準的量測驗證模式。以熱泵系統為例，可能要去量測出水溫度、耗電狀況等。補充：International Performance Management & Verification Protocol(IPMVP)，國際節能量測量和驗證規程，是國際上開發和改進能校評估標準、工具和方法，從而幫助使用者量化和管理最終能源使用效率、可再生能源和水資源使用效率相關的風險和收益方法。

Q3：因有可能是節省燃料費用，是否為依照燃料時價去做計算，並隨時做調整？

A3：可以在簽約時決定使用浮動價格方式或固定價格方式做計算。例如使用浮動方式的話，可按照每個月當月的油平均單價或者是電的平均單價去做計算。但一般使用浮動方式較少，因為比較麻煩，所以大多都是以簽約當天的價格作為固定基準，使用固定方式會比較方便，可減少在會計上計算處理麻煩。

Q4：目前提供 ESCO 服務的公司數量為何？

A4：實際有提供服務的公司數量不太確定，但目前加入 ESCO 協會的會員大概有 100 多家廠商，包含中華電信也是會員之一，可至 ESCO 協會網站查詢。

Q5：在綠基會的節能手冊有提及某一 ESCO 服務案例，其全年節省能源費用達 80.16%，請問這樣的比例算高嗎？

A5：節省的比例有分兩種，一種是節省能源比例(節能率)，另一種為節省能源費用比例。節能率換算是以油當量為單位，節省費用則是以金錢為計算準則。若節能率為 50%~62%，其節省能源費用比例可能是 80%。以熱泵而言，節能率及節省能源費用比例最少都有 50%以上，要看它施工的狀況。

Q6：一般商業的 ESCO 服務工程，其 Pay-Back Time 大概是多久？

A6：若客戶採買斷的方式(施工設備自付)，其回收期限不能超過三年，客戶所能夠接受的回收期限約三至四年。若採不買斷，也就是採節能保證方式，以節省下來的錢支付，公司或客戶能接受的時間為五年。依照能耗的狀況，現在一般市場上能接受的大概有三年、五年、八年、十年，若熱水使用量越多，回收年限就會縮短。

Q7：是否有無法做到客戶與 ESCO 公司雙贏的案例？

A7：若是有這情況發生的話，大概就是因為它的回收期限太長，那麼就會建議不採 ESCO 方式進行。例如太陽光電發電系統，它的回收期限較長，就不會採用節能保證，須以買斷的方式。

Q8：能否說明貴公司 ESCO 能源技術服務經濟效益及工程實際節能減碳成效？

A8：一般來講，一個 ESCO 案例大概可以替客戶平均每年可省下約 300 萬元的費用。除以電的平均單價，再乘以電的碳排放係數，即可得知其減碳效果。若節省的能源為燃料的話，也是以此類似方式去做計算。

三、安裝環境限制及建議

Q1：安裝熱泵熱水器時，是否會受到空間或者是光線等的限制？可否說明熱泵熱水器安裝環境之建議？

A1：因熱泵熱水器並非像電加熱器那種即熱式熱水器，它需要時間及較大的儲存桶槽，讓水循環加熱，屬於蓄熱式熱水器，也因此需要額外的空間來放置儲水桶槽。一般商業用的熱泵系統，其安裝地點大多位於屋頂、1 樓地表或者是地下室。另外熱泵熱水器並沒有光線的限制，應是熱源的限制，因為熱泵熱水器大部分都是取大氣中的熱能，主機最好能安裝在熱源充足的地

方，如地下室、靠近機房的地方或者是大氣取熱方便的屋頂，但不能是密閉空間。由於密閉空間的熱源有限，空氣取熱循環會導致該空間溫度下降，取熱、製熱效果變差，且溫度下降導致環境過冷也會造成主機跳機。所以若在戶外的話，盡量選擇空曠地點；若為室內，盡量是靠近熱源的地方，且不能是密閉空間，須讓其有流通循環的管道取熱，以上為空氣對水主機的安裝環境建議。倘若是水對水主機，因為它是從冰水主機的回水取熱，因此其裝設位置並沒有任何限制。至於儲熱桶槽的安裝位置，雖然並沒有受熱源限制，但最好還是靠近主機較為洽當，否則管線設置會變長，除了施工成本增加，熱損失也會對加熱保溫效果有所折扣。

Q2：安裝商用熱泵熱水器時，較常遇到的問題有哪些？

A2：第一個是空間，剛已有提到。其次是載重，如儲熱槽放置於屋頂，其承載重量也是須考量的因素，要經過嚴密的結構計算，確認是否適合擺設。若無足夠空間可擺放儲熱槽，則必須變更設計：如縮小桶槽容量，增設主機以進行搭配。我們有專業的設計團隊會依照每個案例的情形量身訂做。第三是電源，假如以前是無需使用電的柴油鍋爐系統，經更改為熱泵系統，會有

電源供應的需求，因此必須在有電源提供的地方安裝且須重新拉線配電。

四、使用情形

Q1：空氣對水機型與水對水機型哪一種效能較好？

A1：依照使用同樣壓縮機及能量守恆原理，產生出來的熱能與效率是相同的。只是在運用上，因為空氣對水主機所排出的冷風，會排至大氣，可能沒辦法完全回收；而水對水主機則會直接排在冰水管裡，可以全部回收。因此如果系統允許的話，一般而言我們會建議盡量安裝水對水系統，可以有更完整的運用，但這跟效率是沒有關係的。

Q2：一般商用熱泵熱水器是否會與空調作結合應用？其節能減碳成效如何？

A2：這會因不同情形而有所限制。如學校宿舍，若每個房間的冷氣都屬於分離式冷氣或窗型冷氣就沒辦法與熱泵熱水器做結合，必須是使用中央冰水系統的才可以。醫院、飯店、工廠一定會與空調做結合，至於泳池就不一定了。若與空調做結合，從冰水系統回水溫度 12℃取熱，出水溫度 7℃，即可省下空調費用。在製造熱水同時提供冷氣，其節能成效計算：一個 50RT 的熱

泵主機大約可節省 60RT 的冷凍，熱與冷的比例大概是 80%，也就是說 50RT 的製熱可省下 60RT 的製冷。若以一個房間 4 坪的冷房能力是 1 噸，那大概就可省下 240 坪的冷氣費用，節能成效算是不錯。但假若熱水已達停止製熱之溫度，則冷氣就不再提供，因此現在有些複合機，當溫度到達不再製熱時，可利用一些散熱水箱散熱，以利再製熱並持續提供冷氣。會購買此類複合機的使用者多半只是想買一台主機可同時當熱水及冷氣使用，但其實這樣並不划算，不建議此種作法。

Q3：若遇取熱源熱能不足時(如冬季室外溫度低時)，是否會有其他輔助熱源？

A3：在設計階段，有些會以平均溫度做設計(全年平均溫度 25℃)來選用主機，但本公司是以冬天的平均溫度(13~15℃)做設計去選擇主機，因主機已加大容量，就不需要額外補助熱源。但如果要省設備費用，以全年平均溫度 25℃做設計，則必需額外加裝電熱器在桶槽裡，當熱源不足時就以電熱器加熱，但輔助時間不會太長，一年大概就大概 1 個月的時間。所以其實南部會比較適合裝設熱泵，幾乎不用輔助熱源。

Q4：使用不同的冷媒(ex. R-22/R134a..)，熱泵熱水器使用效能是否會

有所差異？

A4：現在 R-22 已不能使用，已改用環保冷媒 R134a。但它只是個媒介，理論上對熱泵熱水器的使用效能應該差異不大。冷媒會影響壓縮機的壓力，所以會影響的是熱泵熱水器的使用壽命，而不是其使用效能。使用 R134a 的主機壽命會比使用 R-22 還要來的好，因為它壓力比較低；有些混合冷媒的壓力會更低，系統壓力越低越好，但對系統製熱效能無多大影響。一般熱泵產品的使用年限大概都是 10 年以上,前提是要有正常保養程序。

五、市場狀況及技術發展狀況

Q1：貴公司產品自進口代理還是自產？

A1：都有。一些高溫熱泵(溫度可到 80~90℃)就是代理日本的產品(CO_2冷媒機種)，中溫熱泵產品就是我們自行生產製造的。

Q2：影響熱泵熱水器普及化的主要困難是價格太高，可否說明熱泵熱水器或系統成本評估及降低的可能性以及其訂價策略該如何訂定？

A2：熱泵熱水器成本最貴的部分就是壓縮機，壓縮機大部分都是進口的，其單價不太容易降價，除非購買量很大，但其實台灣的市場不是太大。未來有可能是進口大陸的壓縮機產品，價格才

可能會比較低，但相對的品質就會比較差。此外目前家用的普及率尚低，所以降價空間小，成本高(一台大概 6~7 萬元)，市場接受度有待考驗。除非能源單價一直提高，那麼它回收年限就會比較快。至於商用的話，因為使用量大，回收年限短，因此較划算。其實價格就是經濟學的供需理論，需求多，購買成本可以壓低，這跟經濟與市場有關係。

Q3：依您對熱泵產業的瞭解，目前國內有多少廠商投入熱泵熱水器的市場？您認為國內熱泵熱水器的市場規模有無擴張的空間？

A3：就我所知就有 40 家以上吧。本公司屬於製造兼銷售，但製造方面是指主機生產，其他像儲熱桶槽則是與其他供應商配合。台灣市場有限，若要擴張就必須創造更多的價值讓市場接受。家用的話，可能就必須降價；商用則是要提供更高的使用效率，這樣或許市場接受度會提高。

Q4：台灣是否適用使用 CO_2 冷媒(R744)的熱泵熱水器產品(如日本 ECO-Cute 產品)？在台灣，該類產品甚少，其原因為何？是否是因為製造技術上的困難亦或是成本太高？

A4：這類產品在台灣少的原因是技術與價格，因為壓縮機的技術是掌握在日本手中，台灣沒有生產這種壓縮機。至於為何沒辦法

生產，是因為它的系統壓力很大，可能是我們正常熱泵系統壓力的 10 倍。因壓力過大，目前國內壓縮機廠商沒有技術可生產製造。且日本也不會單賣壓縮機，會連同主機系統一起賣，畢竟單賣壓縮機獲利有限。如賣整台主機系統，一台家用在日本可賣 80 萬日幣，換算成台幣約 20~30 萬元，價格太高，因此這種產品在台灣較少被使用。ECO-Cute 產品是屬於高溫熱泵熱水器，製熱可至 95℃，另外冬天的溫度如在-15℃以上，仍可取熱製熱水，所以在日本會比較適用，且比較環保、效率高。

Q5：CO_2 冷媒熱泵熱水器是未來發展趨勢嗎？

A5：不認為。若以環保層面來看，它確實是未來使用趨勢；但若以價格層面來看，並不認為會是未來市場趨勢，因為單價太高，現今全世界也大概只有日本使用比較多而已。

Q6：可否說明熱泵熱水器技術發展之趨勢及產業未來發展方向。貴公司在熱泵熱水器的規劃及未來遠景為何？

A6：技術面已經是非常成熟。對於未來規畫，本公司未來規劃與目標不是偏向技術方面，而是提供管理面的服務，使熱泵系統使用效率提升。所謂的服務是指在裝設系統時，會加裝一個雲端能源管理平台(遠端控制)，依照不同的室外溫度(季節)與使用時

段去控制設定主機製熱溫度。因為熱泵是溫度設定越高，效率越差。若設定溫度在 55℃，其效率較比較低；設定在 42℃，相對效率就會比較高。依照不同季節氣溫變化去調整適當設定溫度，讓熱泵熱水器使用效能提升。另外使用時段的不同，例如用電的尖峰與離峰時段(電價不同，尖離峰單價大約差 3 倍)，盡量設定在離峰時段(晚上)去進行加熱，可節省更多的能源費用。此外設計也算是服務的一種，在設計時期會提供完善的規劃，如建議與空調結合或其他，這也是提升使用效率的方法。

Q7：貴公司有考慮要往家用方面業務進行拓展嗎？

A7：目前不會，因為家用業務會改變整個服務體系，可能需要隨傳隨到，因此需要較多的經銷服務地點，目前本公司還沒有足夠的經銷服務資源來滿足家用消費者的需求。

六、推廣成效與推廣、補助政策建議

Q1：為達到節能減碳之效果，各國逐漸推廣使用熱泵熱水器，就您的研究或瞭解，您認為國內在熱泵熱水器安裝的推廣成效如何？

A1：就商業的角度來看，已經推行得滿不錯的。像現在台北市政府在建立新的學校游泳池時，規定要使用節能設備，幾乎都是以

使用熱泵熱水系統為主。即使初次設備成本高，但因回收年限短，約二至三年即可回收，營運成本可以隨之降低。且協會與能源局每年都有四至五場的示範補助推廣，能源局對於節能案件都有補助工程費用(非針對熱泵熱水器產品補助)，例如成大醫院的熱泵熱水系統就有申請補助款，也辦過示範觀摩會。這些可至綠基會的網站找尋相關資料。所以就商業來講，我認為推廣的算是相當成功，醫院、學校宿舍及泳池幾乎 60% ~ 70% 都是使用熱泵熱水系統。至於家用的部分，因其單價太高，且使用量小，回收年限長，目前推行成效有限。補充：節能專案計畫補助金額以新台幣五百萬元為上限，且未超過該計畫執行經費三分之一為原則。

Q2：對於政府推廣熱泵熱水器政策制定之建議及看法(包含目標制定、推動方式等)。

A2：經濟部能源局已對商用部分有適當的能源補助推廣，若針對家用的話，政府可先訂定目標，如在 2015 年，家用熱泵熱水器安裝普及率可能要達到 20% ~ 30%之類的。當目標制定完成，再使用獎勵補助方式,如同太陽能熱水器的補助方式去進行推廣。也可透過電視媒體宣傳，畢竟現在仍有很多消費者並不清楚熱

泵熱水器此類產品。另外也可透過一些社區、住宅去進行示範宣傳的觀摩，或者也可鼓勵建商建造例如集合式住宅時，可安裝熱泵熱水器送給消費者，給予其獎勵補助。

Q3：各國在推廣熱泵熱水器時期，皆會運用相關補助優惠配套措施。您對政府補助熱泵熱水器的相關措施建立之建議與看法為何？

A3：商業的話就是之前所提及的補助節能專案，節能率達 15%以上最多可補助五百萬元，但不得超過工程總價(包含設備)的 1/3。每年設有補助總額限制，如一年一億五千萬元等，可至綠基會網站參閱。家用的話，可依使用期間的方式來進行補助：假如家用的熱泵可 8 年回收，而一般市場上可接受的回收年限大概是 5 年，因此政府可補助 3 年的價錢，這樣家用普及率可能會提升。

Appendix 2 - Interview Record (Heat Pump Boiler)-2

熱泵熱水器廠商訪談紀錄

訪談對象：善騰太陽能源股份有限公司

時間：2012 年 4 月 5 日上午 10 時 00 分至 11 時 30 分

地點：善騰太陽能源股份有限公司(台中市大甲鎮東二街 18 號)

出席人員：善騰 葉志忠總經理、成大 莊碧珊

訪談內容：

一、ESCO 服務

Q：貴公司有提供 ESCO 服務嗎？

A：做熱泵的每一家廠商都有提供 ESCO 服務，我們也有加入 ESCO 的會員，台灣有好多家銀行和租賃業者與都有 ESCO 業務。因為熱泵的金額高，所以這些租賃業者皆有此業務，只要是合法公司即可。台灣三百多家做熱泵的大概有 98%都可以做。

二、安裝情形與限制

Q1：以台灣住宅環境為例，哪些地方(或區域)建議安裝熱泵熱水器？哪些地方 (或區域)較不建議安裝熱泵熱水器？(ex. 公寓/透天厝 or 南部/北部…等等)

A1：熱泵熱水器基本上並沒有什麼限制，南北部、公寓或透天厝都可安裝、且安裝位置位於陽台、廚房、屋頂皆可，沒有安裝環境限制，只要空氣流通即可。地下室的話，則必須要有抽風機，讓空氣保持流通。目前全世界裝設率最好的就是日本與德國。他們一年之中有半年是下雪的，所以與光線是沒關係的。至於太陽能熱水器則會有光線限制，安裝在南部是比較建議，中北部較不建議安裝則是因為公寓大樓居多，不方便裝設。

Q2：除了空氣流通外，家用及商用熱泵熱水器是否會有空間大小的限制？例如是否需考量儲熱桶槽的大小？

A2：我們公司的家用熱泵熱水器屬於一體式。大陸產品就是主機與儲熱桶槽分開的，所以會比較占空間。雖然本公司一體式及分離式產品都有，但因為台灣土地、住宅空間小，考慮到方便、美觀、簡潔及其他住宅環境因素，我們主推一體式產品。至於兩者間的效能差異，工研院環工所已有在測試效能，可自行參閱。不管是循環加熱，還是間接加熱，或者是靜態加熱，每一種都有其不同的 CNS 測試方法。至於商用熱泵熱水器多少會受空間大小所限制，但會依現場環境與客戶需求去設計規劃，所以環境空間本來就是評估項目之一，不會特別點提出。任何限

制都會在現場勘查環境、設計規劃階段就已考量，包含空間大小、樓板乘載、建築結構計算都是在設計階段會考量的因素，倘若不行，就會另想辦法利用不同的機組組合變化來解決。

Q3：商業或住宅安裝熱泵熱水器時，較常遇到的問題有哪些？

A3：我們都有標準的安裝 SOP 程序。本公司是從研發、銷售、設計、安裝、服務都一手包辦，產品皆是在台灣製造(只有壓縮機不是，為日本進口)，從買鋼板進來生產製造，不像其他廠商是在大陸生產製造(與大陸廠家 OEM)。因為我們從研發、設計、製造到安裝都是我們自己來的，所以一些安裝限制都在設計時就已考慮進去，因此不會發生問題。

三、使用情形

Q1：一般商業用或家用熱泵熱水器是否會與空調作結合應用？其節能減碳成效如何？

A1：商用一般都會與空調結合。家用有室內外分離的雙效機(有室外機，以及室內機當冷氣)，其是以冷氣為主，而非熱水，所以成效不是太好，且故障率還滿高的。一般會做此種機型的並不是標準熱泵製造商，而是由冷氣業者轉為改造。一台冷氣成本可能只有一至兩萬元而已，因此單價也不會太貴。此種機種大陸

產品比較多，但品質會有差，推這種機型的品牌沒有一家撐過兩年。不過，這種應用也會是未來發展趨勢的主流之一，在台灣幾乎所有冷氣業者也都有在生產。雙效機與複合機不同，雙效機大多是由冷氣改製而成，它的效能是否良好，這牽扯到每一家的技術跟專業與參數，不能以一家去做評斷，因為目前工研院或台灣的電解中心、工業局也好，都還沒有任何相關報告。此機種的好壞應該在近兩年使用情形下就會有所評斷，但目前由於不同廠商的產品優劣性差異太大，較不好評斷。

Q2：若遇取熱源熱能不足時(如冬季室外溫度低時)，是否會有其他輔助熱源？

A2：台灣是海島型氣候的國家，濕度高，當冬天室外溫度 10℃，大陸產品就會結霜，而我們的產品在-10℃都還可以使用。空氣流通，為什麼會結霜？因為大陸產品是在廣東製造，並沒有考慮台灣特殊的氣候環境去做設計。以台灣的環境而言，還是會有熱源不足的時候，那多是以電熱加熱為輔助。但如果設備結霜，當需除霜的那段時間無須沒有加熱(沒有急迫性的話)，其實是不需使用到電熱器的。而整個工程規畫也會去考量怎麼讓設備(蒸發器)不結霜，這須依賴經驗與技術。

Q3：使用不同的冷媒(ex. R-22/R134a..)，熱泵熱水器使用效能是否會有所差異？

A3：冷媒不同，壓縮機不能互用。只有 R-22 與 R417 可以互用。熱泵熱水器並沒有強制限制不能使用 R-22，只有冷氣才有限制，但其實現在全世界是禁止使用 R-22 的。大陸產品是使用 R417(與 R-22 共用壓縮機)，但這種壓縮機消耗完之後已不會再製造。目前冷凍空調都是使用 R134a 環保冷媒，而我們則是使用 R410a。R410a 不僅是環保冷媒，高壓高效能，相對的技術也比較高。但並不是壓力越高，系統效能越好，而是壓縮機的效能可以提高 15%~30%，根據壓縮機的機型還有整個系統的規劃設計，包含電控、迴路都會對系統效能有所影響。

Q4：若以太陽光電發電系統提供電力給住家所有電器使用，包含熱泵熱水器，這樣的做法是否最有效率?

A4：如果以環保面來看的話，這樣做是最環保的，因為熱泵熱水器不是再生能源，它只是節能產品。不過這樣做應該是不可能的，就算住家屋頂全裝滿太陽集熱板，所提供的電力都不足以提供冷氣、照明使用，更何況還有熱泵熱水器及其他家電。且前置期的花費很貴，只有一些示範教育的綠能建築會這樣做，但自

家用的幾乎不會這樣做，建置成本大概要花 100~200 多萬元，投資報酬率大概要 15~20 年才能回本。

四、技術發展狀況及市場狀況

Q1：請問目前家用熱泵熱水器價錢為何？

A1：一台有 4~5 萬元，也有 6~7 萬元的。正常都在 5~8 萬最多。而太陽能熱水器大概在 4~7 萬元，4 萬以下的產品就可能需考量其品質是否良好。

Q2：影響熱泵熱水器普及化的主要困難是價格太高，可否說明熱泵熱水器或系統成本評估及降低的可能性?

A2：如果在台灣製造，成本要下降的可能性幾乎沒有。假若是台灣冷氣業者生產的熱泵熱水器產品，因是直接用冷氣機改造，與專業的熱水器廠相比，成本會便宜一點；但若與大陸的冷氣廠所製作的熱水器相比，台灣冷氣廠的熱水器產品還是貴了一點，因為大陸的冷氣成本本來就比台灣便宜。但整體而言，價格要下降須具備幾個因素：第一，要模組化，第二，要大量。模組化量產，才有可能把成本壓低。但因產品製作需使用很多金屬原料，這會受世界的金屬價格而有所變動。另外，使用自動化設備製造，亦可節省成本支出，不過本公司把節省的成本支出

拿來投入研發，因此成本方面降低的可能性低。

Q3：對於熱泵熱水器產品的訂價策略該如何訂定？

A3：不一定。目前其他廠商的家用熱泵熱水器產品，其末端售價沒有一家比我們高，並不是說價格便宜就好，他們沒有考慮到一個品牌的價值還有提供的售後服務。本公司每個縣市都設有專賣店，家用的經銷商拓展始於兩年前，產品皆是全球保固兩年(日本只保固一年)，終身免費安檢。全台灣只有本公司有提供如此服務，這需要投入相當多的人力資源及人員教育。

Q4：台灣是否適用使用 CO_2 冷媒(R744)的熱泵熱水器產品(如日本 ECO-Cute 產品)？在台灣，該類產品甚少，其原因為何？是否是因為製造技術上的困難亦或是成本太高？

A4：日本商用及家用全是使用 CO_2 熱泵熱水器，而本公司的 CO_2 熱泵熱水器產品是商用的。家用不推的緣故是一般非 CO_2 冷媒的熱泵熱水器賣 5~6 萬元，消費者就已覺得太貴，若是 CO_2 熱泵熱水器，如日本 Eco-cute 產品，換算成台幣，一台要價 20~26 萬元左右，價差約 4 至 5 倍。一般非 CO_2 冷媒的家用熱泵熱水器，回收年限大概 3~5 年就可回收，但家用 CO_2 熱泵熱水器需要 10~15 年以上才有可能回收。家用在台灣市場率低，價格太

貴是主要原因且回收年限長，以及台灣的使用環境並不需要用到 CO_2 冷媒機型，導致這產品於台灣推廣不易。商用 CO_2 熱泵熱水器，考量其使用量與使用溫度，回收年限很短，大約兩年內就可回收，所以在台灣才能被接受。本公司 CO_2 主機整機產品是進口，是與日本合作雙方生產，只有桶槽才在台灣組裝。不能單買壓縮機自行生產，光是專利就有很多限制。此類產品在台灣數量較少，主因還是價格太貴，以及生產技術的問題。目前工研院實驗室有研發，但沒量產，全世界只有德國與日本有量產。而技術不是只有壓縮機的問題，還包含電控或迴路，亦即是整個系統的技術。

Q5：您認為國內熱泵熱水器的市場規模有無擴張的空間？

A5：整個市場從去年開始擴張，估計大概今年與明年是最輝煌的時期。因為所有廠商與業者相繼投入，大約在投入的兩年後(經過兩個冬天的使用期)就可看出產品的優劣性，屆時很多產品就會被市場淘汰，這是許多產業的必經趨勢。中國大陸的許多品牌，為何現在只剩下幾家而已？就是因為環境因素的不同，大陸產品並沒有考慮台灣的氣候條件與水質問題，熱交換器設計太小，導致機器塞住無法使用，而因此被淘汰。預估在今年年底，全

亞洲99%的品牌都會進入台灣市場，經過今、明年兩個冬天的使用，大約有30%~40%的廠商將被淘汰。到後年，整個市場才會比較穩定健全。

Q6：在熱泵熱水器的發展中，應達到何種規模經濟較具有發展效益？

A6：去年經濟部工業局公告去年台灣的全部家電(含檯燈、電視、冰箱、冷氣、熱水器等等)總營業額為457億台幣，而熱泵才佔整體營業額不到30億台幣(家用與商用總和)。日本的CO_2熱泵熱水器(單一產品)，年產值是3000多億日幣，相當等於台幣1000多億左右。台灣與日本差異甚大，主要是因為日本政府對熱泵熱水器的重視程度。台灣如果要達到政府重視的規模，大概需做到 100 多億台幣以上(熱泵熱水器，商業與家用總和)。預估大概是最快明年或後年就可達到，今年應該有希望朝50億台幣邁進。

Q7：油電雙漲會影響熱泵熱水器產業嗎？

A7：因為油電漲價，相對的其他民生物資也會漲價，消費者荷包縮水。熱泵熱水器畢竟單價高，會導致消費者的消費行為趨於保守，所以對於熱泵熱水器裝設業績不一定會有利。

Q8：可否說明熱泵熱水器技術發展之趨勢及產業未來發展方向。而

貴公司在熱泵熱水器的規劃及未來遠景為何？

A8：每一家的策略都不一樣。台灣熱泵熱水器產業的發展趨勢，可能會朝 R410 環保冷媒的產品發展。台灣要發展 CO_2 熱泵熱水器比較不可能，因為壓縮機與其他電控設備的專利都被綁死。另外之前提到的雙效機是屬於冷凍空調的，這也是未來發展趨勢其中之一。而本公司的未來規劃，無論何種熱水器皆會發展，商用 CO_2 熱泵熱水器目前已進行推廣，但家用的還不一定，因為台灣市場不一定適合。服務方面，本公司產品終身皆免費安檢;另外考慮到消費者的裝修問題，假日亦會有值班的客服人員，盡量去達到消費者需求，努力提升服務品質。

五、推廣成效與補助制度建議

Q1：面對溫室氣體減量的壓力，您認為政府應否課徵碳稅或能源稅？是否會進而促使增進熱泵熱水器的裝設率？

A1：碳稅與能源稅是全世界未來必定會課徵的稅，我個人也是很支持徵稅的，而徵碳稅或能源稅對任何節能減碳產品的發展及推廣都是有幫助的。此外本公司亦開始針對所有熱泵產品計算產品碳足跡，因現在美國的四大賣場，只要沒有碳足跡的限定產品是禁止進入賣場販賣。

Q2：為達到節能減碳之效果，各國逐漸推廣使用熱泵熱水器，就您的瞭解，您認為國內在熱泵熱水器安裝的推廣成效如何？

A2：基本上還是有很多消費者都不知道。本公司是發展台灣家用熱泵歷史最悠久的公司，約快 13 年。在 98 年 12 月推出第一支熱泵產品電視廣告後，消費者才比較知道什麼是熱泵熱水器，在此之前客戶對象都以科技業、公教機關、環保團體居多，佔本公司的業績約七至八成，一般家用消費者都不太了解。然而這兩年來，家用熱泵熱水器的推廣成效並沒有比日本慢，日本每年大概有 30% ~50%的成長，而本公司連續兩年也都有超過 30%的成長。至於商用的話，這兩年也是成長許多，因為大陸客來台的關係，日月潭、花蓮、阿里山、墾丁相繼建蓋的飯店民宿非常多，相對的商用熱泵業績也有所成長。但去年商用最大宗是在於政府提倡節能減碳的關係，熱泵熱水器列於公家機關的台灣銀行共同採購契約中，幾乎所有的部隊(軍方)、學校、公家機關都已全部改用熱泵熱水器。另外在 99、100 年政府內政部或教育部以及愛台十大建設的校園節能減碳案件都有補助，屬於全額補助，但需要公開招標。政府對於節能案例也有補助，最高補助金額 500 萬，但目前並沒有針對熱泵熱水器產品提供

補助。全世界熱泵熱水器的節能效能都有甚多相關數據，對於政府在評估相關補助辦法時應該會有所幫助，因此希望政府能加快腳步，制定出更完善的補助措施。

Q3：在推廣熱泵熱水器的政策上，有哪些宣導措施可以刺激消費者購買使用？

A3：主要還是要看政府的政策。政府政策若採用限定產品的方式，這樣會導致其他熱水器產品的廠商抗議。雖然日本是全面限制只能使用熱泵、南非禁止使用電熱水器與瓦斯熱水器，但因為台灣過度民主、過度政治性鬥爭，強制性的策略比較不可能推行，在台灣採用補助的方式來發展推廣會較沒有爭議性。

Q4：對於政府推廣熱泵熱水器政策制定之建議及看法(包含目標制定、推動方式等)及對政府補助熱泵熱水器的相關措施建立之建議與看法為何？

A4：可以比照日本或歐洲國家的能源政策。像日本針對熱泵熱水器進行補助；北歐三國是全額補助，家家戶戶都裝熱泵；澳大利亞是補助 75%；南非也是全額補助。這要看政府對節能減碳是不是真的有心要做，當然還需看國家的財產預算。補助方面，可以類似冷氣的能源級數進行補助。能源一級以上的產品，可

以水的容量，或者是以其他容量來評判第一次安裝能補助多少錢，亦可以能源效率或是製熱能力等方式去計算補助金額。