International Master's Program in International Studies
National Chengchi University
國立政治大學國際研究英語碩士學位學程

Reliability Analysis of Taiwan's Power System: A Cross-Country Comparison

台灣供電系統可靠度分析：跨國比較

Eric Alexander Strom 史愛理
Advisor: Dr. Ssu-li Chang 張四立教授

July, 2016

Reliability Analysis of Taiwan's Power System: A Cross-Country Comparison

台灣供電系統可靠度分析：跨國比較

by

ERIC ALEXANDER STROM

史愛理

APPROVED BY

Committee Member

Committee Member

Committee Member

Thesis Advisor

Program Director

International Master's Program in International Studies

NATIONAL CHENGCHI UNIVERSITY

July, 2016

Acknowledgements

I would like to thank my advisor, Professor Ssu-li Chang 張四立 of the Institute of Natural Resources Management at National Taipei Universes, who sparked my initial interest in this topic. Dr. Chang spent an enormous amount of time and effort to shepherd me through this process.

I would also like to thank Dr. Hei-Chu “Ruby” Liao 廖惠珠 of the Department of Economics at Tamkang University and Dr. Bai-ku Wei 魏百谷 of the Graduate Institute of Russian Studies at National Chengchi University for their assistance in revising my thesis, as well as for agreeing to join my committee.

Special thanks Dr. Yeh-Chung Lu 盧葉中 of the Department of Diplomacy at National Chengchi University, Director of the International Master’s Program in International Studies, who moved heaven and earth to make my graduation possible.

Additional thanks to Ms. Hsueh Mei-Ying 薛美英 of Taipower’s electrical dispatch office for helping me acquire the data needed for this study.

Abstract

This thesis examines reliability and long term planning in Taiwan's power system by developing new metrics to evaluate existing systems, and then comparing them with comparable data from North America. The study involved series of spreadsheets retrieved from Taipower's Power Dispatch Office to determine historical reliability for all generation in Taiwan, deriving a new metric to analyze that data, and then comparing it to North America Generating Availability Data System figures. The study then uses those figures to evaluate existing long term electrical usage projections from different Taiwanese government bodies. The study concludes that while Taiwan's existing power systems have comparably high reliability, excessive politicization of electricity and lack of political autonomy in energy administration hinder Taiwan's long term electrical prospects. Additionally, existing evaluations of long-term needs are overly optimistic and do not account for political changes.

Keywords: Taipower Co., Power System, Cross-country Analysis, reliability

Abstract (Chinese):

本論文範圍為台灣供電系統可靠分析而審查長期電力消費發展，發展新供電可靠指標，而拿新指標來跟北美洲供電系統做比較。本論文以現有的台電公司電力調度處建立新分析架構來做跨國分析。然而本分析用新架構來審查現有的台灣各政府單位預期電力消費發展計劃。

關鍵詞：台電，供電系統，跨國分析，可靠指標

Table of Contents

Acknowledgements i
Abstract ii
Table of Contents iii
Figures and Tables iv
Chapter 1: Background and Purpose of Study 1
1.1: Purpose 1
1.2: Why Taiwan? - Special case 2
Taiwan’s Energy Security 5
Taiwan’s electrical system by the numbers 6
1.3 Supply balance 6
Capacity Factors: Difference between installed capacity and actual production 14
Different types of reserves 16
1.4 The Limits of Renewables: The Case of Germany’s *Energiewende* 18
Chapter 2: Literature Review 22
2.1: The Link between GDP and Electricity consumption 22
2.2: Policies of Taiwan’s Major Political Parties 23
2.2.1 KMT Policies 23
2.2.2 DPP Policies 23
What would 10% actually look like? 26
Chapter 3: Methodology 27
3.1 Analysis 29
3.2 Data sources 29
3.3 Model Construction and Preliminary Analysis 30
3.4 Preliminary Results 34
3.5 Capacity Factor Vs Availability Factor 36
3.6 Discussion 37
3.7 Problems with Taipower’s Numbers 37
Chapter 4: Results 42
4.1 Initial Observations 42
4.2 International Comparison 42
4.3 Early Conclusions 45
4.4 Limitations of the AIA/AIG Model 46
4.5 Projections 47
4.6 How Much Operating reserve would Taiwan need? 51

4.7 Further Study 52
4.8 Qualitative analysis: 53
4.9 Taipower's Double Edged Sword 53
4.10 Resolving political deadlock: 56
Chapter 5: Conclusions 59
Research Questions: 59
Final Remarks 61
Bibliography 62
Appendices 71
Appendix 1 June Preliminary Analysis 71
Appendix 2 Combined AIA/AIG Results from all sources 72
Appendix 3 Source Raw Data and Individual AIA/AIG Calculations 73
3.1 Taipower Thermal Generators 73
3.2 Taipower Nuclear Generators 75
3.3 Taipower Hydro Generators 76
3.4 IPP and Cogeneration Extrapolations 78
3.5 Taipower Solar 79
3.6 IPP Solar 80
3.7 IPP Wind 81
3.8 Taipower Wind 82
Appendix 4 Projections 85
4.1 Taipower Projections 85
4.2 Taipower Projections - 100% Nuclear Availability Scenario 87
4.3 MOEA Projections 89
4.4 MOEA Projections - 100% Nuclear Availability Scenario 92

Figures and Tables

Figure 1.3.1: Spinning reserve illustration, Taipower. Illustrates load curve during July 15th 2013 10
Deceptive Numbers: Co-Gen distortions in statistics 11
Figure 1.3.2: Taiwan Installed Generating Capacity by Fuel Type 2015 (Source MOEA BOE Energy Statistics Handbook 2015) 12
Figure 1.3.3: Taiwan Net Renewable Installed capacity by source in MW - 2015 (MOEA) .. 13
Figure 1.3.4: From 15-06-2016 at 5AM. Most units under environmental or transmission restraints 13
Figure 1.3.5: Taiwan Total Electricity Generation by fuel, 2015. Data from MOEA BOE Energy Statistics handbook 15

Figure 1.3.6: Taiwan Net Renewable Generation Breakdown by Source, 2015. Data from MOEA BOE Energy Statistics handbook 15
Figure 1.4.1: Electricity production in Germany in week 26, 2011 (Fraunhofer Institute for Solar Energy Systems ISE) 19
Figure 1.4.2: Electricity production in Germany in week 26, 2016 (Fraunhofer Institute for Solar Energy Systems ISE) 19
Figure 1.4.3 Electricity Import and Export of Germany in week 26, 2011, positive numbers indicate imports (Fraunhofer Institute for Solar Energy Systems ISE)........ 20
Figure 1.4.4 Electricity Import and Export of Germany in week 26, 2016, positive numbers indicate imports (Fraunhofer Institute for Solar Energy Systems ISE)........ 20
Figure 2.2.2: GDP and Electricity Consumption Growth Rates Compared (MOEA 2014).... 25
Preliminary Quantitative Analysis: 31
Equation 3.3.1 31
Equation 3.3.2 31
Equation 3.3.3: Effective Availability Factor 32
Equation 3.3.4 Average individual generation was calculated as follows: 33
.... 39
Figure 3.7.1: Taiwan Capacity factors by source, 2015. Data sourced from Taipower, Data.gov.tw, and MOEA Energy Statistics handbook 2015 39
Figure 3.7.2. Taiwan Average availability by source (In KW) - 2015. Note that this uses Average Individual Generation instead of average individual availability for wind and solar sources. 40
Figure 3.7.3; Taiwan Average Availability (KW) by source, using AIG for wind, solar, and cogen 41
Table 4.2.1: Taiwan Availability Factors compared to US NERC GADS data. 44
Table 4.2.1: Taiwan 2015 Capacity Factors compared to NERC GADS Net Capacity Factors. 44
Table 4.2.3: Taiwan 2015 figures compared to seasonal GADS availability 45
Figure 4.5.1: Comparison of MOEA 2014 and Taipower 2016 long term development reports 48
Figure 4.5.2: Taiwan 2015 Average Availability Assuming 100% Nuclear Availability 49
Figure 4.5.3: Projection Scenarios Assuming 100% Nuclear Availability........ 51

Chapter 1: Background and Purpose of Study

1.1: Purpose

This thesis seeks to explore the underlying cause of Taiwanese energy insecurity first by examining the current situation using established indicators, domestic policies, and comparing those with international standards. Then the author will examine Taiwan's governance structures and interest groups. From there, the author will make policy recommendations for different scenarios.

This thesis will rely on existing energy security and energy indicators as data sources, but the primary analysis will be descriptive - exploring policy issues in a qualitative way. For example, as a marginalized island nation, Taiwan is unable to import electricity and must rely entirely on domestic power production. This kind of constraint is not easily articulated in a quantitative analysis.

The goal is to weave together political and technical realities to find the most effective path forward. It is this author's observation that energy governance in Taiwan is increasingly politicized, and the discussions in the political and technical spheres are disconnected. News articles discuss energy imports and the electricity supply without any context or background. Op-eds appear in influential newspapers citing inaccurate figures, sometimes even being unable to distinguish between different units of energy. The DPP's own energy policy is based on political aspiration rather than technical requirements. We need a meaningful analysis that examines not just technical issues, but how Taiwanese civil society and government shapes energy policy. Though energy in most countries does have a political dimension, Taiwan's top-heavy policy making structure and the absence of a centralized, independent energy policy body that is both technically literate and politically savvy mean that a more robust analysis is needed.

Because of Taiwan's geographic isolation, the problems with energy policy, and electricity policy in particular, are much more pressing than they would be otherwise. When

Germany, the United States, or any other large or land-linked economy has a problem, they can use fixed infrastructure to import from their neighbors. Cross border pipelines, transmission lines, scalable land shipping - all of these are backup plans not available to a small island nation. Even Japan has multiple independent power grids with interties. Their relative size allows them to pool risk in a way that is beyond Taiwan's capacity. Taiwan's single grid is efficient and effective, but needs more flexibility than an interconnected grid because risk cannot be shared by multiple independent actors.

In many such interconnected countries, there is a tendency to view power in "net" terms. For example, Germany continues to enjoy large profits from its electricity exports - and has a huge export heavy balance, but still relies on imports to meet demand during evening hours when solar plants don't produce. Though this is an effective strategy for an integrated European economy, or any large grid, this cannot work in an isolated grid. In an isolated island grid, physics will trump accounting. We can print more money, but not more energy. If electrical load exceeds generation and there are no imports available, load shedding is required.

1.2: Why Taiwan? - Special case

Taiwan provides a unique opportunity to explore energy security issues because of its geographical and political isolation, coupled with its high tech, energy intensive economy. In most other countries there is substantially more flexibility in energy policy because of the proximity of neighbors or indigenous energy supplies. Taiwan has neither.

For example: Germany can close its nuclear and coal burning plants - originally its key sources of baseload electricity production - and still import baseload power from the extensive French nuclear infrastructure through the European grid. Though this "outsourcing" of electrical production could, under some indicator schemes, threaten German energy security, the profound difference is that this is a feasible policy option to begin with.

Germany's proximity to Russia also gives it import prospects for natural gas for indigenous power production. Germany also has substantial domestic coal resources.

Powerful diplomatic allies and integration into the European union add further cushion to German energy policy.

Taiwan, conversely, has a completely isolated power grid, no land neighbors, and virtually non-existent indigenous energy resources. There are no direct energy links to neighbors, nor are there any credible plans to build them. Taiwan's non-indigenous energy supplies must be imported through conventional shipping.

This lack of local resources is made even more complex by its lack of diplomatic capital. Taiwan's government - the Republic of China - was the losing side of the Chinese civil war. When the communists took power on the mainland, the nationalists retreated to Taiwan and took the ROC government with them. The ROC has been largely unrecognized since the 70's when the PRC replaced them as "China" on the UN security council. To the chagrin of the locals, PRC claims the self-governed democracy as part of its territory, and refuses to have relations with any country formally recognizes the ROC on Taiwan. As a result, most countries have formal relations with the PRC and unofficial relations with Taiwan. This political reality means that Taiwan is dramatically constrained on the international scene. The PRC works very hard to exclude Taiwan from most international organizations, as well as causing routine political crises.

The political situation makes Taiwan's energy situation even more dire because it cannot rely on diplomatic allies or the international community for energy assistance. Additionally, it must strike a careful balance between cooperation with mainland China and protecting its de-facto independent status.

There periodic discussion in local news about Taiwan's impending energy crisis, but there has been surprisingly little analysis, nor have there been substantial figures presented. This section will outline Taiwan's energy mix and it's geopolitical and geostrategic implications.

There are conflicting reports about exactly how much of Taiwan's energy supply is imported. The US EIA figures for 2010 seem to indicate that Taiwan imports somewhere between 85 and 90% of its energy. However, the Bureau of Energy within Taiwan's Ministry of Economic Affairs reports 97.49% "imported energy dependence." The discrepancy may arise from the EIA's consideration of nuclear power as a domestic resource, regardless of fuel origin, as well as the re-exportation of coal products (US EIA) coupled small domestic oil and natural gas. Regardless of the exact degree, Taiwan imports the overwhelming majority of its energy.

Thus far, Taiwan has been very careful to avoid direct energy links with the PRC. 100% of coal has imported since domestic production stopped in 2001 (US IEA Country Profile). Coal imports primarily from Australia and Indonesia, with less than 4% imported from mainland China as of 2011 (IFRI report). This is a downward trend, falling from 6.5% the year before, even as total imports increased. Even so, over the course of 15 years, Taiwan's electricity consumption has more than doubled, from 102 to 218 billion kilowatt hours (US EIA Country Statistics), and electricity consumption continues to rise.

Taiwan's nuclear power program operates with the US as its exclusive supplier of nuclear fuel, but the government has announced that it intends to slowly reduce its "dependence on nuclear power" - potentially exacerbating Taiwan's existing baseload power shortfall.

For oil, Taiwan relies heavily both on imported crude oil for domestic refinement as well as imports of finished petroleum products. Most of Taiwan's domestic crude has been exhausted, though the US EIA reports that Taiwan continues to produce around seventy-three thousand barrels per year - negligible compared to the nearly 400 million barrels per year it consumes.

What remains in the energy mix consists of miniscule amounts of domestic renewables and hydroelectric, consisting of less than two percent of the energy mix. Ironically, the smallest contributor to Taiwan's energy mix is the only one immune from external price shocks and resource crises. The government has announced plans to increase energy from renewables to 16% by 2025, but it is unclear if this is a feasible goal.

(Liao, Jhou 2013)

Taiwan's Energy Security

Taiwan is highly energy insecure. The 21st century Energy security risk index ranks Taiwan as a Quartile IV (Highest Risk), chiefly because of its heavy reliance on imports. (Institute for 21st Century Energy., 2012) A significant portion of this assessment stems from an indicator referred to as "import exposure." The report classifies these by source - oil, coal, and natural gas - as well as adding a fourth field "total import exposure" to reflect imports in addition to these three. Since Taiwan relies so heavily on the traditional three imports, plus complete imports of nuclear fuel, scores in this range suffer considerably. Since the results are based on the percentage of national supply based on imports, having no substantial domestic supply of any of them substantially increases Taiwan's risk.

The other source of Taiwan's energy insecurity is the economy's dependence on energy, commonly referred to as energy intensity. The risk index indicates that as Taiwan's economy continues to expand into more high-tech industry, that the economic dependence on energy prices dramatically. Should imports be disrupted, Taiwan's economy would suffer serious damage.

Chief among imports is coal (ROC Bureau of Energy, EIA Country Profile). Coal makes up a majority of Taiwan's electricity production, and is almost completely imported. Electricity usage in Taiwan has more than doubled in the last 15 years (EIA Country statistics), causing serious environmental degradation and, as much of Taiwan's electricity is based on traditional thermal/coal plants, further aggravating Taiwan's energy insecurity.

While energy insecurity is important, this thesis will focus on Taiwan's electricity supply system. However, the role of electricity as only a single facet of energy security cannot be understated. If primary sources of energy like coal, petroleum products, nuclear, or other fuels are unavailable due to supply shortage or political/military disputes, this analysis becomes moot. It is, however, the author's opinion that dealing first with electricity is a more immediate and solvable problem than dealing with energy security directly. Moreover, energy security is such a broad topic as to dramatically exceed the scope of a master's thesis. It is my hope to address these issues in future PhD research.

Taiwan's electrical system by the numbers

1.3 Supply balance

A power supply must always be balanced. Supply must always equal demand. With some exceptions, electricity cannot be stored. Therefore, electricity must be consumed at the precise moment it is generated. If not enough power is supplied, system frequency drops. There may be blackouts or brownouts, and if the shortage is severe enough, the system must shed load, meaning that it must cut some consumers. In Taiwan, this is done by region in accordance with the load shedding procedures currently in place (台灣電力股份有限公司, 2016), first by forcing the largest consumers to "sequester" themselves, then timing blackouts by region with increasing frequency as the shortages get worse. There is a priority, with national defense taking precedence, then medical facilities and public transportation etc.…

Conversely, if power generation is too high, equipment may be damaged. Power lines could overheat, catch fire, or simply melt. Damage to consumer and business equipment could be enormous.

The best analogy would be to think of a power system much like a water system - except that electricity travels at approximately the speed of light, and so changes in load or generation (demand and supply) are promulgated through the system virtually instantly. Electricity travels near the speed of light, depending on the transmission medium (Banks, 2007). It is then useful to think of generators as electricity pumps, and the power grid as a system of pipes on a massive scale.

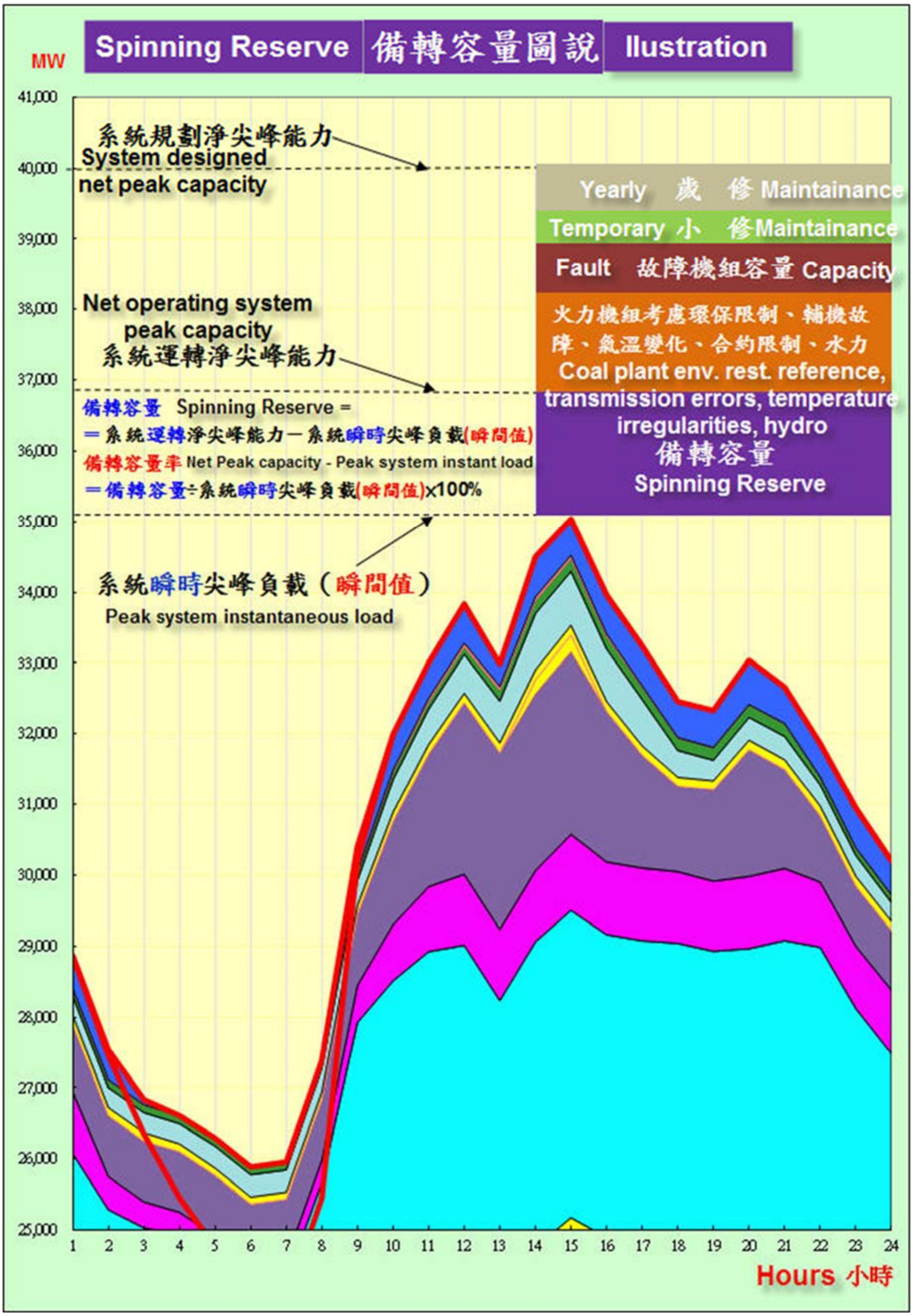
Power usage changes throughout the day. The highest spike is referred to as peak load. Generally speaking, power generation is divided into two types - baseload generation and peak load generation. The logic is that baseload power should have high reliability and high uptime, with a low cost per kilowatt hour. Coal and most forms of nuclear power are examples of this type of power source. Peak power, conversely, is only used when electricity usage is at its highest. In Taiwan, this tends to be in the early afternoon. The most important characteristic of peaking power sources is dispatch ability: the ability to change output rapidly in response to changes in load that occur beyond the range of operating reserves. These kinds of energy sources can usually be dispatched within 5 minutes of any event, and are typically load following. Common examples include natural gas and hydro-electric.

Renewables - specifically solar and wind - present unique problems because they are not always available. Sometimes, the wind doesn't blow or the sun doesn't shine - and when they do, they do not always do so at the time, place, or amount anticipated. This means that renewables must be pooled either on a massive scale to minimize risks (extremely costly) - or backed up by near-instant dispatchable power supplies. The US National Renewable Energy Laboratory describes this capacity as a new form of reserve - called ramping reserves. NREL points out that this form of reserve has not been widely studied. (*Impacts of Solar Power on Operating Reserve Requirements (Fact Sheet)*, 2012) The prime examples of renewable power development - namely in Europe, and specifically Germany - have intertied power grids with neighboring countries which mitigates some of the uncertainty when dealing with these kinds of renewable energy sources, so they have not had to explore ramping reserves.

Germany in particular relies heavily on pumped storage facilities. However, conventional sources still make up more than 70% of the German power supply. Approx. 16% of Germany's total power comes from nuclear, 44% from coal, and 14% from gas. The remaining ~26% comes from mixed renewables. Although Germany's power import/export balance is positive, they still rely on imports to balance their load in the evening. See **section 1.4 The Limits of Renewables: The Case of Germany's Energiewende.**

To understand the difference between base and peak load, Taipower has provided a reference schematic. It should be noted that Taipower's records are surprisingly complete.

While searching for materials for this thesis, it should be noted that US power companies do not provide nearly as much information as is provided by Taipower. In interviews with staff from Bonneville Power in the US, this was attributed to national security issues and concerns about giving private actors an economic advantage.



Spinning Reserve 備轉容量圖說 Ilustration
MW
41,000
40,000
39,000
38,000
37,000
36,000
35,000
34,000
33,000
32,000
31,000
30,000
29,000
28,000
27,000
26,000
25,000
系統規劃淨尖峰能力
System designed
net peak capacity
Net operating system
peak capacity
系統運轉淨尖峰能力
備轉容量 Spinning Reserve =
＝系統運轉淨尖峰能力－系統瞬時尖峰負載(瞬間值)
備轉容量率 Net Peak capacity - Peak system instant load
＝備轉容量÷系統瞬時尖峰負載(瞬間值)×100%
系統瞬時尖峰負載（瞬間值）
Peak system instantaneous load
Yearly 歲 修 Maintainance
Temporary 小 修Maintainance
Fault 故障機組容量 Capacity
火力機組考慮環保限制、輔機故障、氣溫變化、合約限制、水力
Coal plant env. rest. reference, transmission errors, temperature irregularities, hydro
備轉容量
Spinning Reserve
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours 小時

Figure 1.3.1: Spinning reserve illustration, Taipower. Illustrates load curve during July 15th 2013

Figure X depicts the second highest recorded load on Taipower's system - from July 15th 2013. The peak load from this time was 35,097MW. While the largest load in Taiwanese history was 35,385MW on July 2 2014 (Taipower), Taipower continues to use the 2013 metric for its publications to describe its policies on spinning reserves. In general, power usage tends to peak on weekdays during the early to midafternoon during the summer.

The figure lists the highest planned grid output is listed as 40GW, with nearly a gigawatt allocated for maintenance, 500MW for fault capacity, and approximately 1.5GW for the combined category of "thermal environmental restrictions reference point, transmission errors, temperature variations, and hydropower." This last category may be someone of a misnomer because these four things don't necessarily have anything in common.

Environmental regulations on high polluting or high emission power sources make sense - Taiwan is extremely dependent on coal and fuel oil for much of its capacity. Transmission errors could conceivably be equipment failures. By temperature variations, it is likely referring to temperature variations in transmission lines. As discussed above, as load on lines increases, they begin to heat up. With too much load, lines heat to the point where they begin to sag. Since high voltage transmission lines are rarely insulated, it is essential that they not touch other structures, for risk of electrocution and starting fires - to say nothing of electrical service interruption.

The last describes hydrological events or other issues in hydro power generation. Some seasons yield less water than others. For Taiwan's pumped storage systems, they are typically charged at night with excess capacity and discharged during peak hours. This cannot always occur. Droughts or other technical difficulties can also plague conventional pumped hydro storage alike.

Unfortunately, these events are not correlated. Lumping them into one category risks the events coinciding and adding to each other. Even these seemingly generous margins for error are not sufficient to ensure an uninterrupted supply of power.

Deceptive Numbers: Co-Gen distortions in statistics

Some critics argue that the Ministry of Economics Energy Handbook for 2015 reports that more than 48GW of generating capacity, (Fang， Jay, 2016) and that this should be more than enough to meet Taiwan's maximum recorded demand of 35.3GW, but these numbers do not tell the full story. More than 8GW of this number comes what are called "co-gen" plants in Taiwan. These facilities are mainly coal-fired boilers that generate steam for manufacturing purposes, which is sometimes available for power generation if surpluses are available. However, there is no guarantee of this. It is therefore essential that any analysis of Taiwan's power grid treat cogen sources as having extremely low-capacity factors for the purposes of public power generation. Taipower's own real time data system records the installed capacity of Co-gen facilities as being only 622.1MW, a far cry from the 8GW listed in the Bureau of Energy Statistics Handbook. This is because the BOEA handbook lists all possible installed capacity, not just generating capacity available to the public power grid. As a result, this installed capacity figure is somewhat inflated.

It should be noted that the Co-gen facilities often output more power to the grid than their recorded capacity. The following was taken on July 4th 2016 at 4PM

Figure X: Co-Gen power output taken from Taipower's real-time information system. The columns are Power source, installed capacity, and output capacity

⊟ 汽電共生(Co-Gen)

汽電共生	622.1	1551.3	-
小計	622.1(1.5%)	1551.3(4.6%)	

Taiwan's installed capacity is as follows: Coal:34.53 (16,815.7MW) Oil:7.59 (3,697.0) LNG: 33.11 (16,125.9) Nuclear:10.56 (5,144.0) Conventional Hydro: 4.29 (2,089.4) Wind:

1.33 (646.7) Solar PV: 1.33 (842.0) Biomass: 0.23 (111.3) Waste: 1.29 (629.1) with an additional 5.34 (2,602.0) from pumped storage.

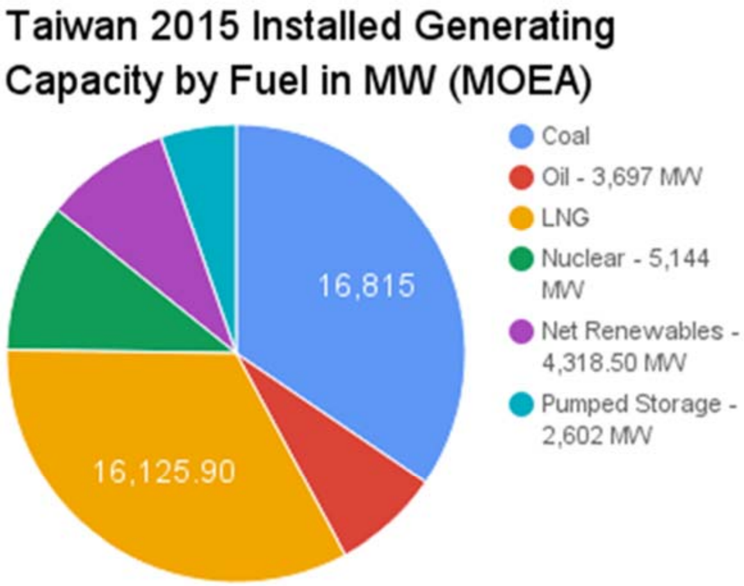


Figure 1.3.2: Taiwan Installed Generating Capacity by Fuel Type 2015 (Source MOEA BOE Energy Statistics Handbook 2015)

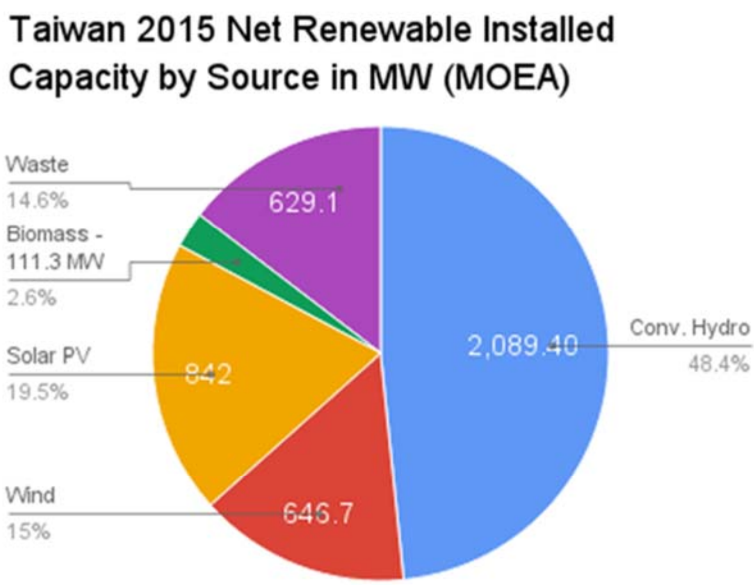


Figure 1.3.3: Taiwan Net Renewable Installed capacity by source in MW - 2015 (MOEA)

The chart makes clear that well over 40% of Taiwan's installed generation capacity comes from coal and oil burning plants. These facilities are subject to strict environmental regulations that prevent them from operating at the maximum capacities. In fact, these plants often operate at only 30% of their generating capacity, while still counting as installed generating capacity.

⊟ **燃油(Oil)**

協和#1	500.0	156.3	31.3%	環保限制
協和#2	500.0	155.6	31.1%	
協和#3	500.0	150.7	30.1%	
協和#4	500.0	148.0	29.6%	運轉限制
大林#3	375.0	0.0	0.0%	環保限制
大林#4	375.0	0.0	0.0%	環保限制
小計	2750.0(6.7%)	610.6(2.8%)		

Figure 1.3.4: From 15-06-2016 at 5AM. Most units under environmental or transmission restraints

Even if we accept coal as a dominant source and restrict environmental concerns to oil, we still face substantial supply problems. In the figure above we see that more than 2GWs of capacity are lost because of these restrictions. That already exceeds the margins provided for environmental and transmission problems, ignoring all other forms of power. In the event of other problems, like thermal anomalies on the lines or other issues with transmission or hydroelectric, this dramatically increases the risk of a power shortage and rationing. Clearly this measure is not a reliable assessment of contingencies.

Beyond these problems with, we have the two reactors undergoing yearly maintenance both Unit 1's at the first and second nuclear power plants - a total of 1,621mw. LNG XingDa#4 and Nanbu#3 operating at 50% capacity due to overhauls - 591.2MW. An unknown malfunction at the IPP LNG Guoguang plant - 480MW. Overhauls at hydros

QingShan#3 92 Tianlun#5(though this is outputting) (105), along with hydrology issues at both Zhuolan facilities 80MW and Zengwen 50. Finally, yearly maintenance at pumping Station Daguan 2 unit 2 250MW. Now we are short 3,019.2 MW. This would be within the normal range for the maintenance and misc. problems calculation, but when combined with the environmental constraints, we have more than 5GWs currently out of service due maintenance, transmission constraints, or environmental constraints.

Then one must consider the role of the investor-owned power plants. With 3097.1MW of IPP-Coal and another 4610.0 of IPP LNG, which amounts to 7707.1MW, or 15.8% of the overall installed capacity. Many of these plants are much more expensive to run than Taipower's own facilities, depending on the facility and the price of the contract. IPP thermal plants cost from NT$2.05 for coal to NT$3.29/KWh for LNG, compared with NT$1.22 for Taipower Coal or $2.68 for Taipower LNG. (台灣電力股份有限公司, 2012)

Capacity Factors: Difference between installed capacity and actual production

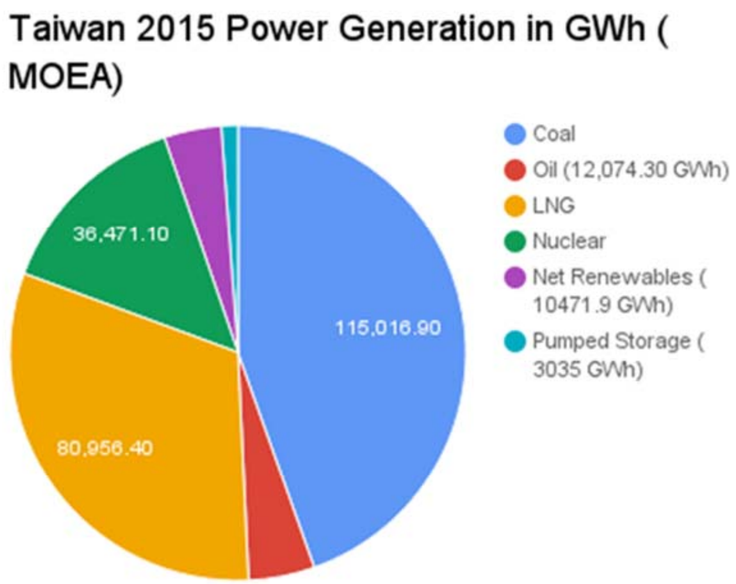


Figure 1.3.5: Taiwan Total Electricity Generation by fuel, 2015. Data from MOEA BOE Energy Statistics handbook

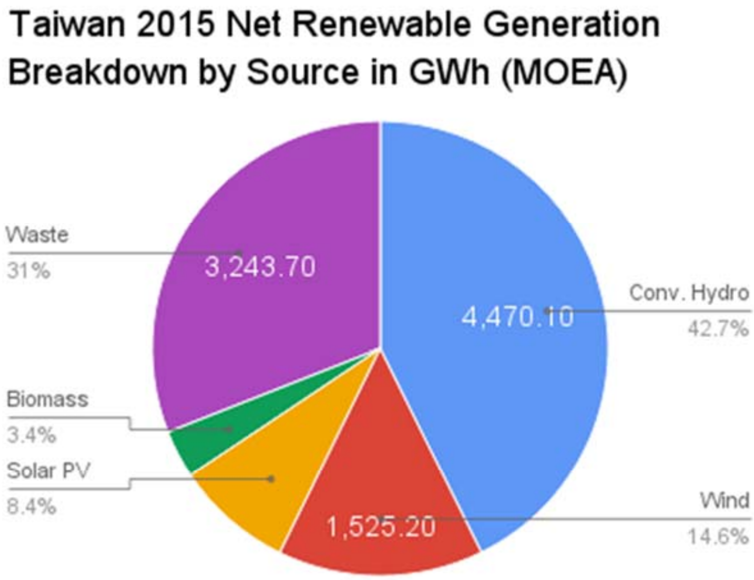


Figure 1.3.6: Taiwan Net Renewable Generation Breakdown by Source, 2015. Data from MOEA BOE Energy Statistics handbook

These figures are quite stunning compared to **Figure 1.3.2**: Installed capacity because we see some substantial disparities between installed capacity and actual generation. Coal and nuclear make up 34.5% and 10.6% of the installed capacity, respectively, but generate 44.6% and 14.6% of the actual power used over the course of the year. If we to look at previous years, both would go up substantially due to their relatively higher share of the baseload. Since coal and nuclear are among the most cost effective/kwh and have extremely high uptimes and capacity factors, it makes sense that they make up proportionally higher amounts of actual generation.

Different types of reserves

Explain Spinning reserves, ramping reserves, regulating reserves, and following reserves as described by NREL

Taipower uses only two descriptors in its public data for reserves. The first is “備用容量率” - which describes the yearly maximum operating reserve that the public power system is required by law to handle. Though it is currently fixed by law at 15%, in 2015 it had fallen to 11.5%. (Taipower, Historical figures, 2016). The second type “備轉容量率” or “spinning reserve” is a daily value, which is recalculated each day based on expected load. (Taipower Figures, 2016)

There are several different measures of reliability in a power system. The US National Renewable Energy Laboratory has several definitions of reserves for dealing with different events. NREL mentions Spinning reserve (which NREL refers to as contingency reserves) - but does not directly address operating reserves. It also addresses regulating reserves, which are usually governed by automatic systems to correct small sudden changes such as spike or drop in frequency. They also recognize following reserve and a new type of reserve, ramping reserve. Following reserves are manual reserves that are directed by system operators to follow changes in load. Taipower does not appear to employ them directly beyond the usual scheduling, and relies at least in part of pumped storage to deal with peak storage. Finally, ramping reserves are a new form of reserve that are designed to deal with events relating specifically to renewables - changes in weather conditions that might affect renewable output.

Green Gambit

There are movements to transition to green power in Taiwan - but most “green “energy sources, like wind and solar - require “backups.” There are times when capacity is needed and the wind simply doesn’t blow, the sun doesn’t shine. Given Taiwan’s minimal pumped storage capabilities, backup power supplies are necessary. In most economies -

like in Germany - these take two forms: importing power from neighbors, and domestic generation that can be mustered immediately (such as natural gas).

Taiwan's electricity consumption is continuing to grow as there is further electrification of the transit infrastructure. The High Speed Rail, MRT systems, and most conventional rail are run entirely on electricity. Additionally, there is a push toward electrification with electric scooters, notably Gogoro. These scooters are also heavily subsidized. (經濟部工業局, 2008)

Shifting transportation in particular away from primary energy sources toward electrification is a laudable goal. If only because of their scale, fossil-fueled power plants at scale are more efficient than individual vehicle motors. Even so, this strategy will only be effective at reducing greenhouse gas emissions and other pollutants if the power system is transitioned away from its heavy dependence on fossil fuels. Additionally, it should be noted that while electrification may reduce overall energy consumption (net oil imports and the like) - it will surely not decrease electricity consumption, especially in the short term. According to the BOEA energy statistics handbook, 11.90% of total energy was spent in transportation, while 28.8% was spent on electricity. Although serious challenges prevent major replacement of fuels in aviation in the near future, we can safely assume that electrification of ground consumer transport will shift much of this energy cost to be delivered through electrification, either through rail - which is already largely electrified - or consumer land vehicles, such as the Gogoro scooters or perhaps even electric cars. Given the relatively low cost per kilometer driven of such vehicles, we can expect them to see as much or more use compared with conventional petroleum-primary vehicles. Although the electrification of personal transit will likely reduce the overall energy costs of transportation, shifting personal vehicles away from fossil fuels and to the electrical grid may increase demand for electricity by creating a new category of consumption vehicles, even if the impact of these new transportation systems causes a net reduction in energy usage.

Due to obvious limits of electrification technology, we should not expect to see trucking electrified in the near future. At best, we will see biofuels replacing conventional fuels - as already occurs in the US. It is likely that these fuels will still have to be imported, as biofuel development in Taiwan has been stunted by lack of adequate governance mechanisms for food-waste products, and by low prices for conventional petroleum, preventing the growth of indigenous ethanol. (Hsu, 2014)

1.4 The Limits of Renewables: The Case of Germany's *Energiewende*

Many advocates of wind and photovoltaics hold up Germany's *Energiewende* as a model for the world to follow, and particularly Taiwan. However, many proponents of German energy policy in the context of Taiwan often fail to mention that, while Germany's net renewable generation and exports are impressive, even after several years of development, Germany still relies on imports in the evening when solar facilities are not available, and so while Germany can offer substantial exports of surplus solar power during the day, resulting in a net export of energy, on the daily peak cycle, they are still import dependent. Connection to the European grid and neighbors provides Germany with a kind of insurance policy that Taiwan does not have. That means that even if Taiwan were prepared to make massive investments in solar and wind generation, in addition to a power grid that could support distributed and variable generation, comparable investments in conventional sources would need to continue to ensure stable supply during the transition.

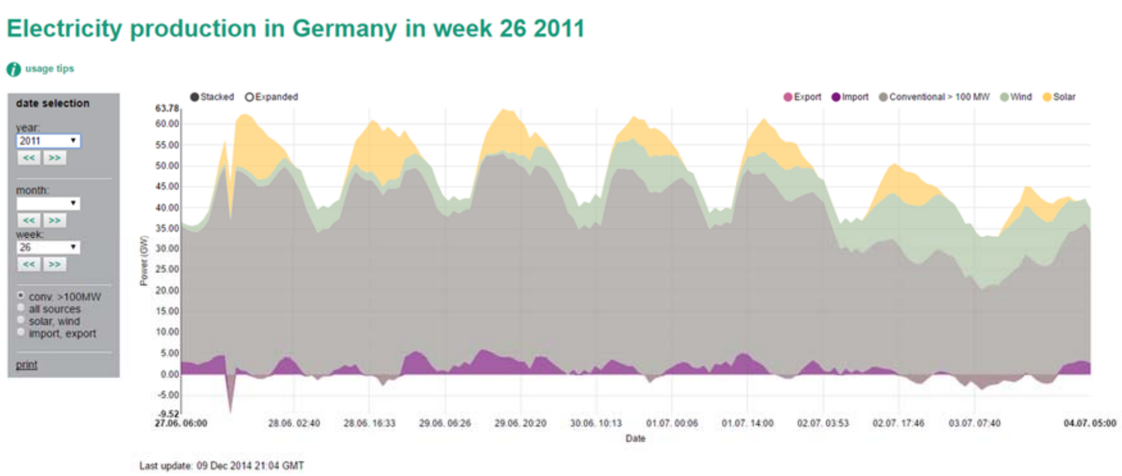


Figure 1.4.1: Electricity production in Germany in week 26, 2011 (Fraunhofer Institute for Solar Energy Systems ISE)

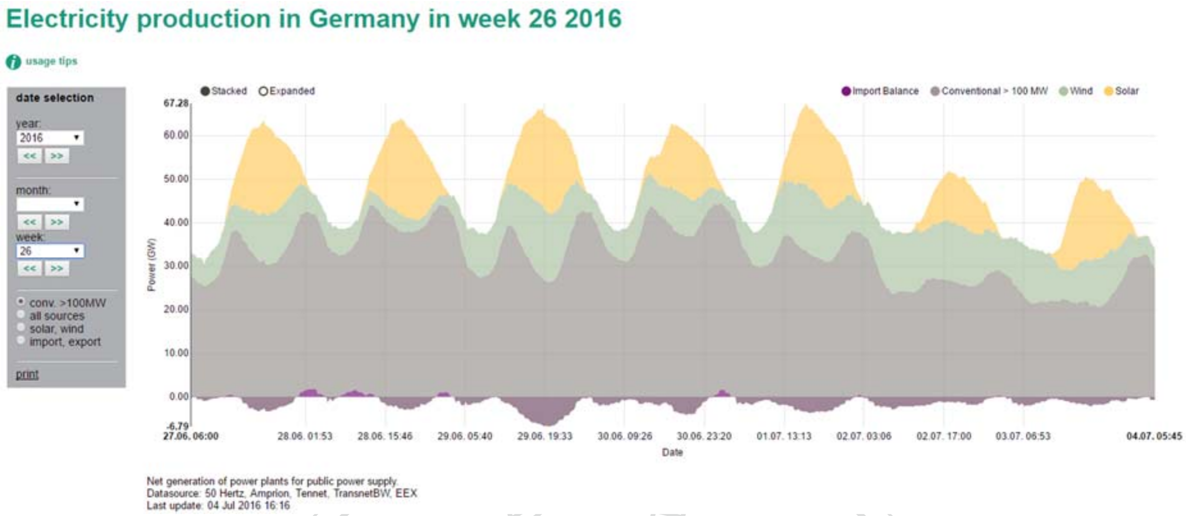


Figure 1.4.2: Electricity production in Germany in week 26, 2016 (Fraunhofer Institute for Solar Energy Systems ISE)

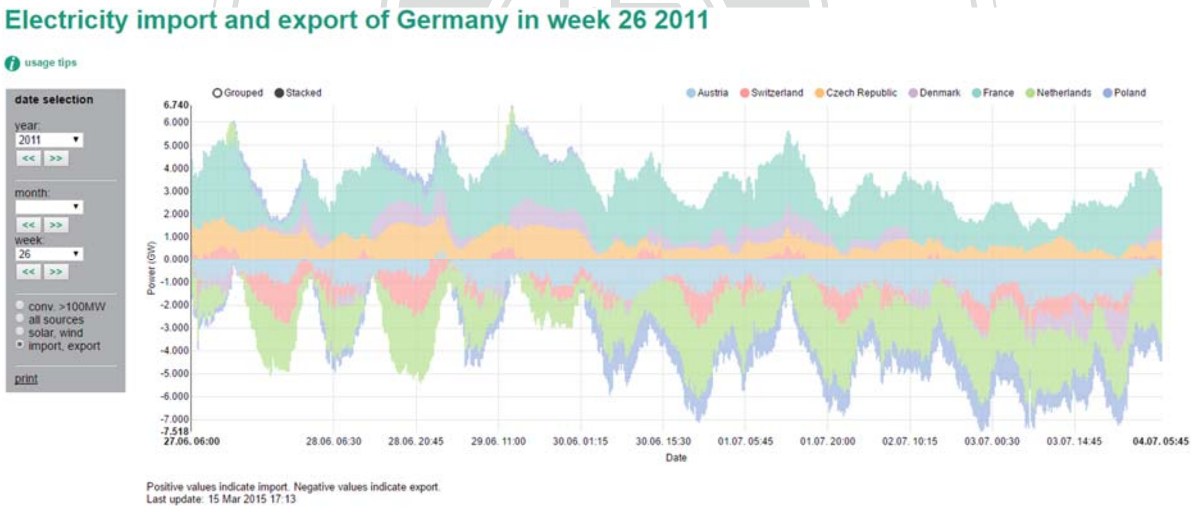


Figure 1.4.3 Electricity Import and Export of Germany in week 26, 2011, positive numbers indicate imports (Fraunhofer Institute for Solar Energy Systems ISE)

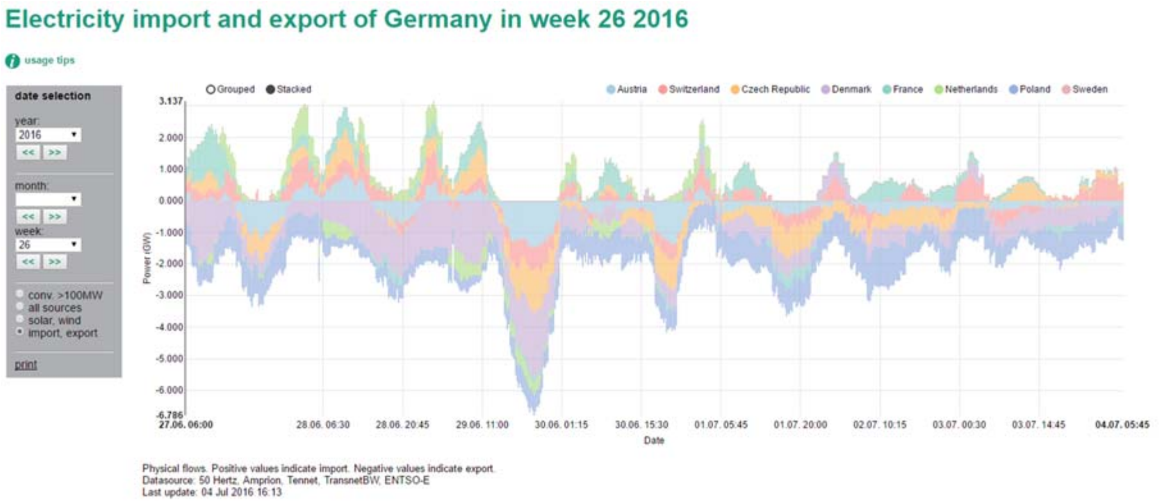


Figure 1.4.4 Electricity Import and Export of Germany in week 26, 2016, positive numbers indicate imports (Fraunhofer Institute for Solar Energy Systems ISE)

Data and charts retrieved from Fraunhaufer ISE https://www.energy-charts.de/power.htm

As we can see from **Figures 1.4.1-1.4.4**, over the course of five years, in spite of an increase in peak electricity consumption for the same week from 63.78 in week 26 of 2011 to 68.28 in 2016, imports have gone down and exports have increased. Yet in spite of these incredible gains, Germany still relies on imports in the evening. During more severe months, or if we look to earlier years, the import numbers go up substantially. Moreover, more than 75% of Germany's electrical production still comes from nonrenewable sources, like coal, natural gas, and nuclear (which is scheduled for a phase-out). Currently, fossil fuel and nuclear generation make up just over 74% of German generation. (Federal Ministry for Economic Affairs and Energy, Germany, 2014)

This analysis is specifically intended to highly a single point: Germany's renewables require backup. Though zero-price wholesale prices or even negative wholesale prices can account for the massive power exports, it is important that we highlight that, even after five years of this policy, Germany still relies on imports to cover its evening demand when it's renewable sources are not available.

As an island nation, Taiwan cannot rely on its neighbors for electricity, and as an export oriented economy whose economic base is manufacturing, its GDP growth is coupled with its electricity consumption (see section **2.1: The Link between GDP Electricity consumption**)

Chapter 2: Literature Review

2.1: The Link between GDP and Electricity consumption

In their article, “Electricity shortages and firm productivity: Evidence from China's industrial firms,” Fisher-Vanden, Mansur, and Wang discuss a core argument that is central to this paper. Their analysis of the PRC’s development suggests that electricity shortages do not prompt private generation, as is commonly believed. Instead, it often prompts either the outsourcing of the most energy intense processes or, more concerning, a storage of materials. The accumulation of material is inventory that is an effective drain on capital. One major distinction between the PRC and Taiwan is that the PRC does not have a unified power grid. It has many resources, particularly in new renewables, that are unutilized or underutilized even as there are other shortages Given Taiwan’s export oriented economy and its impending power supply issues, this serves as a crucial theoretical link which establishes the potential risks to Taiwan’s economy in the event of large scale power rationing.

Allcott, Collard-Wexler, and O'Connell “How Do Electricity Shortages Affect Industry? Evidence from India.” They conclude that electricity shortages do indeed lead to a lag in economic growth. Investment in private generation is not as efficient as large public pools of electricity, and electricity shortages disproportionately affect smaller producers because they are not large enough to benefit from economies of scale in backup generation. This results in economic lag as funds that could be spent on other production or investment. Although not directly related to this study, it might be worthwhile to explore the role and reasons for the development of cogeneration, and if that phenomenon might be linked to shortages of supply in Taiwan’s energy system

An often cited problem by energy researchers in Taiwan is the connection or “linkage” between Taiwan’s GDP growth rates and electricity consumption rates, as well as the energy intensity of the Taiwanese economy. This has been noted in the MOEA Energy Statistics handbooks over the years (See **Figure X**).

2.2: Policies of Taiwan's Major Political Parties

Both Taiwan's major political parties - the Chinese Nationalist Party (KMT) and the Democratic Progressive Party (DPP) - have published energy policies of varying degrees of thoroughness.

2.2.1 KMT Policies

The KMT has not published a substantive policy white paper on energy, even though its own website says it supports a "pluralistic energy policy, to ensure energy security, and under the premise of a reasonable electricity price, with complimentary both boosts and savings pragmatically develop clean energy, and strive towards a sustainable homeland." ("政策綱領 - 中國國民黨全球資訊網 KMT Official Webstie," [sic] n.d.)

This is little more than a political slogan, but essentially means an "all of the above" energy policy, without setting targets or deadlines. It is well known that they have been staunch supporters of nuclear power in the past. Perhaps a better view of KMT energy policy is Hong Xiuzhu's endorsement of a niche, pro-nuclear blogger Chen Licheng. ("台灣能源," n.d.) Since the KMT currently lacks any governing mandate, even if they had a fully-fledged energy plan, it would not be possible to implement.

2.2.2 DPP Policies

The New DPP government has not articulated a meaningful energy policy since march of 2014. The DPP's website says only that it will set Taiwan's Reserve Generating capacity to 10% （民進黨新境界文教基金會）- substantially lower than even the lowest reserve ratio in the US. (US EIA 2012) Even the lowest US ratio - in Texas - is five percentage points higher than the DPP proposal for Taiwan - and heat waves in Texas have previously caused supply problems (US EIA 2012) requiring Texas to import power from neighboring states. Moreover, this is particularly jarring when you consider that the DPP is not only proposing stripping Taiwan of its backup generating capacity, but also that unlike the power grids in the US and Europe, as an isolated island, Taiwan cannot import electricity from its neighbors.

It is not clear to this author how the DPP plans to accomplish this change. Given President Tsai's promise to phase out all nuclear plants, this would require only replacing these facilities, but bolstering existing capacity to reach 10% from other sources.

The current listing for the system-wide maximum output is 36,882M, according to Taipower's estimates for March 24, 2016, and yet the energy policies are based on the Bureau of Energy Reports (MOEA 2015), the last of which suggested Taiwan had an installed capacity of more than 48 GW. As mentioned in previous sections Taiwan has already had multiple electricity shortages (吳象元, News lense, 2015) due to periodic malfunctions and maintenance.

It should be noted that the DPP's expanded energy policy contains a number of errors concerning the installed generating capacity of Taipower's system, along with the long term growth expectations. However, the DPP's citations of older MOEA Long Term Electricity Planning documents do not account for early failures and maintenance of nuclear power plants, nor do they account for any reliability issues in Taiwan's power supply。

Though Taiwan can import liquefied natural gas and other petroleum products, without the installed capacity to convert it into electricity, a sudden crisis - such as a generation facility being damaged, as often happens with both coal and nuclear plants in Taiwan - having the fuel on hand does not translate into usable electricity. Thus, further reducing Taiwan's reserve ratio could make the supply problem more serious.

Additionally, Taiwan's GDP growth is tied to its manufacturing, which is in turn tied to electricity consumption, as Taiwan's GDP/kwh is still tightly coupled, unlike other advanced economies. See figure 2.2.2 (MOEA 2014).

Figure 2.2.2: GDP and Electricity Consumption Growth Rates Compared (MOEA 2014)

It is unwise, therefore, to further risk Taiwan's electrical and economic stability for a proposal that has not been well thought out. The DPP and President Tsai's proposal essentially assumes an unrealistic level of reliability - as there have been several occasions within the last two years.

While Taiwan does have a massive oil stockpile- approximately 90 days' worth, depending on source (Yao, 2001) - and substantial refining capability to convert raw crude into whatever industrial petroleum or fuel it might need. However, the availability of fuel4 does not translate into reliable electrical power, and it is electrical power to which Taiwan's GDP output is tied.

What would 10% actually look like?

Right now, Taipower projected spinning reserve is just over 5% - already well below the 10% mark. Based on the current calculations last year's operating reserve was 11.4% (Taipower historical data) Current generation capacity is insufficient, certainly. All it would take would be the shutdown of a few plants, and that reserve ratio would be gone, as we saw on July 1st, 2015 - when several power facilities experienced malfunctions. At current levels of power consumption, that's just about 3.5 GWs of power. The quantitative analysis component of this thesis is designed to evaluate the relationship between operating reserve and real-world availability.

In most power systems, reserve ratios are configured to be the size of the largest generator plus some fraction of the peak load. This is needed because if the single largest facility were to be somehow disabled, the power system would have to make up not only the cost of the lost generator, but may have other problems as well. Drops in frequency or voltage could cause other reliability issues within the system.

Perhaps most importantly: having reserves does not mean they have to be used. Taipower primary expenses (beyond the massive capital loss of Gongliao/Longmen) are fuel, not personnel. Maintaining, say, extra natural gas plants, and alternating between them to ensure all staff and equipment were functioning normally, would not represent a meaningful environmental impact - since net usage is not likely to go up purely because of availability alone.

Chapter 3: Methodology

This thesis will follow a relatively simple methodology: first quantitative. The author will evaluate historical data for Taiwan's power system during the summer months. As the data is only available for two years, the year with the highest completeness will be selected. If the author is unable to obtain data about the reliability of the generation facilities in question (i.e., number of hours/days undergoing maintenance) then the author will rely on average daily output of each facility and spinning reserve ratio to try to establish an underlying capacity factor, or at least some measure of reliability. Once those figures are attained, I will evaluate them based on various measures of Taiwan's projected energy needs. Those projected needs can be done several ways. The ROC Bureau of Energy and Ministry of economic affairs both have reports detailing long term projections of electricity consumption. However, it is my own instinct that these reports are overly optimistic, particularly considering the role that co-generation plays in Taiwan's energy mix. The trend found in other countries has been that co-gen is an exception, not a norm, and that private generation for private consumption is usually less common than factories halting production and accumulating inventory of input materials. While these are preliminary studies and require further evaluation, it strengthens the case that co-gen power is not economically sustainable, and that Taiwan's continuing power shortages place a potential (if unknown) downward drag on the Taiwanese economy, as demonstrated from the earlier discussion of energy intensity, and strengthens the case for enlarging public power pools.

If number of down days can be retrieved from Taipower, a simple statistical model could be built to provide a mathematical base for a recommended energy reserve. The current model is based on a heuristic or "rule of thumb" established by Taiwan's legislature, and as has been demonstrated in previous sections, this figure is overly optimistic for the purposes of determining reliability. The objective of this section will be to answer the following question:

Given available historical data on Taiwan's generating reliability, what operating reserve would be required to maintain reliability for a feasible, worst-case scenario?

Though the question seems vast, and there are many possible ways to calculate this, this thesis will answer, if possible, with simple probabilities, rather than more exotic calculations used in some power grids.

Once that figure has been determined, simple projections based on anticipated economic growth could be made to determine what generating requirements will be in the coming years. Those requirements can be compared to existing policies, and can include different scenarios concerning the political fate of nuclear power. (Activation or mothballing of Lungmen facility, extension or non-extension of life for existing plants, and probability of success on other renewable goals)

Once reliability indicators have been derived and compared with different projections, if there is a discrepancy, the author will evaluate the political or governance causes. The hypothesis here is that Taiwan's energy shortfall is not caused by unusual technical difficulties, but rather by governance issues. This leads us to our second research question:

Based on current stakeholders in Taiwan's electricity policy, what policy changes would be needed to implement a policy to guarantee supply?

Taiwan's lack of an independent energy authority coupled with Taipower being directly answerable to the legislature means that technical requirements are deprioritized over political requirements. That means that when demand grows, the only responsible authorities do not necessarily take action because legislators fear being electorally punished if they take remedial actions. Raising the price of electricity, expanding nuclear or coal power, or mass land seizures for solar deployments would all result in electoral punishment. Additionally, due to prioritization in load shedding, a majority of the voting population will be isolated from the direct effects of shortages, since residential users receive highest priority after essential services. (限電種類,台灣電力股份有限公司, 2016). However, without understanding the exact nature of Taiwan's power issues, we cannot assess the potential political impacts in realistic terms.

3.1 Analysis

If we assume as true the premise that Taiwan's current economic growth is directly linked to electricity consumption, we can predict electricity consumption changes by tracking economic growth. Although it is likely that Taiwan's economy will hopefully one day uncouple from energy and electricity in particular, that is unlikely in the near term. To do this Taiwan would need to shift away from manufacturing toward services. That kind of economic restructuring will likely take more time than Taiwan's medium term electricity production problems. Projections of power availability suggest that Taiwan will face periodic shortages for at least the next five years, and that they will continue to worsen. We know that power limitations, technical or political, cause a serious economic drag, either by acquiring inventories, or by limiting the profitability of largest firms due to replacement generating capacity or by pushing out the smaller firms that cannot support the economies of scale required to make private generation effective.

3.2 Data sources

The Generating Availability Data System (GADS) is maintained by the North American Electric Reliability Corporation (NERC). It is a statistical database of all of the different grid-conceited generators in the United States and Canada. GADS reporting is mandatory for all generators larger than 20 MW, and covers 71% of all generators. It is important to emphasize that the North American electricity market is profoundly different from Taiwan. Each region within the US has a different configuration from that of Taiwan. Some regions have entirely privatized, market based electrical supplies. Others, like the Tennessee Valley Authority are fully federally owned. In Washington State, there is publically owned transmission, mixed generation, and separate ownership of distribution. The most unique aspect of the North American grid compared to Taiwan is its size and that all grids are interconnected. When there is a shortage in one grid, they can buy power from neighbors through interties. Policies such as operating reserve and grid composition are set by each region and utility in accordance with local laws. In spite of these differences, GADS provides a rich data source that we can use as a basis for comparison.

Taipower's Power Dispatching Department keeps figures on historical availability of all Taipower sources for many years. Those these data sets are not public; they are available on request. Some of this data can be used to do a comparison with GADS.

These reliability indicators can be compared with regional indicators from the US. The North American Electric Reliability Corporation maintains extensive records on the reliability of US generation through the Generating Availability Data System (GADS) - a data source which is available to the public. The author can then compare the

3.3 Model Construction and Preliminary Analysis

Taiwan's long term power projections may be misleading. Although the MOEA 2014 report on long term electricity growth suggests that installed capacity will continue to grow, most of the growth the report documents will be in renewables with extremely low capacity factors. Taipower's Long Term Growth report also suggests a similar, if more serious power shortfall. The full data sources for these reports are not available.

Preliminary Quantitative Analysis:

To answer the question, “how much reserve does Taiwan need?” I have developed a prototype metric - Average Individual Availability - derived statistic for evaluating reliability of individual generation systems. Its formula is simple:

Equation 3.3.1

$$\text{Average Individual Availability} = Installed\ Capacity \times \frac{Availability}{100\%}$$

This metric tells us, on average, how much capacity is *available* according to Taipower’s metrics of availability. Those metrics often drastically exceed capacity factors - especially for wind power - so we can conclude that availability refers to maintenance, hydrology, transmission and operational limits, and faults. It may also include environmental restrictions. Taipower’s availability statistic is calculated as follows:

Equation 3.3.2

可用率＝〔１－（影響供電量／參考容量／全期時數）〕Ｘ 100 ％

$$Availability\ Rate = (1 - (IGC/NMC)/PH) \times 100\%$$

Where: IGC=Impact to Generating Capacity, NMC=Net Maximum Capacity, PH=Period Hours

This metric has a number of serious flaws, but it still enhances our understanding of Taiwan’s electrical supply reliability by providing us with a baseline probability of when power is available from traditional sources. In phone interviews with the Taipower Electrical Dispatch section, their officers confirmed Taipower’s Availability Factor is impacted by situations like maintenance, thermal variations, hydrology problems (for hydro), breakdowns, transmission problems, fuel problems, or other technical issues that could influence supply availability. They did not explain exactly how this was calculated for each source, and this will remain a major weakness of this study.

NERC uses a collection of statistics, but the most important for the purposes of this study is the Effective availability factor. Although it has a different calculation procedure which is much more transparent than Taipower's number, it still provides an availability percentage which accounts for both planned and unplanned outages:

Equation 3.3.3: Effective Availability Factor

$$EAF = \frac{(AH - EPDH - EFDH - EMDH - ESEDH)}{PH} \times 100\%$$

EAF: Effective Availability Factor
AH: Available Hours
EPDH: Equivalent Planned Derated Hours
EFDH: Equivalent Forced Derated Hours
EMDH: Equivalent Maintenance Derated Hours
ESEDH: Equivalent Seasonal Derated Hours
Source: GADS Data Reporting Instructions, Jan 2015, NERC

These are all derived from GADS data. While it is unclear how exactly Taipower's numbers are calculated, they are assumed equivalent to the GADS data for the purposes of this study. This assumption will require further study if this technique is to be widely implemented as a comparative model. This assumption only affects this study where direct comparisons are made between NERC GADS data and Taiwan's data, and does not affect the evaluation of Taiwan's long term forecasts.

Capacity factors alone are an insufficient means of assessing reliability of high uptime sources and dispatchable sources because they never exceed demand, nor do they unambiguously tell us about the underlying reasons for lack of production. In my proposal, I provided evidence of days when Taipower had serious losses of capacity due to maintenance and other unforeseen issues. This metric quantifies those events and provides general probabilities of failures based on historical data from Taiwan's own experience.

This metric has a number of weaknesses: It is extremely to apply to intermittent sources like wind and solar. For wind, this metric only evaluates that wind turbines are not malfunctioning and able to harness any wind resources available. It does not allow us to know when the wind blows to generate power. For solar, Taipower does not keep availability statistics, and this metric cannot be calculated at all. Even so, solar suffers the same problems that wind does: the availability of the power plant does not mean the availability of intermittent and uncontrollable resources. This metric also distorts pumped storage. Pumped storage facilities need to be charged, and the availability metric provided by Taipower only indicates that the facilities are operational, not when they are charged. For these sources, capacity factors will remain indispensable for power system planning. Though the initial analysis assumed 100% availability factors, but upon further consideration, using capacity factors may be more accurate. In the datasets, I call this **average individual generation**, and it is used when availability is thought to be unrepresentative.

Equation 3.3.4 Average individual generation was calculated as follows:

$$Installed\ Capacity \times \frac{Capacity\ Factor}{100\%}$$

A further problem comes from IPP facilities and Cogeneration. Taipower does not keep facility level statistics on private power plants. For the purposes of this study, I assumed that the reliability of these private thermal plants was comparable to those of Taipower facilities using the same source, and extrapolated the values based on the combined average individual availability for all Taipower thermal plants on all co-gen and IPP plants. This will no doubt distort the result, but due to limited time, assuming these facilities to have similar repair records still provide a useful analysis.

3.4 Preliminary Results

Based on the author's June 2015 analysis, Taiwan had an average availability of 37,960.8 MW. That means that at any given time, we could assume that just under 38GW of generating facilities would be "available" - that is, not broken, under maintenance, or suffering other technical problems. This is overly optimistic because solar and wind sources have artificially inflated numbers. Capacity factors would be better analyses for these sources. Without wind and solar, the amount is 36,958.0 MW.

This means that, barring other factors such as political ones, Taiwan should have a consistent source of power up to this peak level. It may be possible to reach higher outputs, but based on this historical period, it is not likely, nor could it be relied upon. I think of it as a maximum theoretical reliable supply.

Availability data of any kind of IPP and Cogeneration is not available to this author's knowledge. In places where it is necessary, Availability rates for these sources are assumed to be comparable to Taipower's availability for the same sources. This is both highly generous, as Taipower's availability rates are unusually high, and therefore also potentially inaccurate, skewing the IPP availability on the higher side. This is particularly true in the case of cogeneration, as the cogen system is not really firm power and produces only a small fraction of its reported installed capacity.

For IPP capacity factors, they are calculated only using yearly averages, since monthly data is unavailable. The total IPP generation and capacity factors were derived in several steps. First, the total IPP generation and total LNG generation were retrieved from the MOEA Handbook, then Taipower's total LNG generation was subtracted from the LNG total. The remaining LNG figure represents IPP LNG generation for the year. From there, that is subtracted from the total IPP value. The remaining IPP value should contain coal and IPP solar. IPP solar values - acquired from data.gov.tw - are then subtracted, leaving us with the IPP coal value. The MOEA Energy Statistics Handbook value for coal is not used because Co-Gen might also be counted, and co-gen installed capacity is extremely difficult to nail down.

Using a similar process, we can derive IPP solar and wind installed capacity and, with data.gov.tw availability can derive their capacity factors.

The true measures of reliability for Cogeneration have proven to be extremely difficult. Cogeneration refers to boilers for industrial use - usually coal fired - which sell their surplus steam as wholesale electricity to Taipower. The total generation is listed by Taipower and data.gov.tw, but installed capacity is hard to know. Not all of these facilities are designed for power generation, and installed capacity, availability, and capacity are unclear from easily accessible data. The MOEA handbook implies that there may be more than 7GW of installed available, while Taipower's real time data system lists less than 0.6GW - but by this measurement they had capacity factors of more than 100% during 2015. In the quantitative analysis, this thesis calculates all cogen capacity factors twice - once with the MOEA installed capacity, and once with Taipower's installed capacity. The difference in capacity factors is startling. Using the higher MOEA installed capacity results in average Cogen capacity factors around 12%, while the Taipower installed capacity ranges from 120%-190+%. Since the generated capacity is likely accurate, and GADS has no comparable data, we will have to settle for incomplete data in this regard. GADS does record co-generation capacity and availability data, but it is unclear how much installed capacity there may be, as GADS records a number of retirements for cogeneration, and no new installations as of 2014.

For the availability factor, since Co-gen is primarily coal-based, Taipower's coal availability factors were used in the initial analysis, however, this proved to be unrepresentative. Therefore, for this calculation this thesis has opted to use the same Average Individual Generation - based on capacity factor and installed capacity - similar to the metric for renewable source. However, without more information on how cogeneration is implemented, there is no way to tell which would be more appropriate. Further studies and data about cogeneration will be needed for a more thorough analysis. This method is, in the author's opinion, the single greatest flaw in this analysis. However, without more accurate data about exactly how much installed capacity there is, and what kind of grid availability to expect, there is no way to make a more precise analysis.

Finally, there is no availability data for solar - IPP or Taipower. Availability data therefore uses solar capacity factors instead. Since solar-PV panels themselves have no moving parts, they are unlikely to be damaged easily. No data was found on whether these systems have sun-tracking capabilities, which could conceivably require more maintenance. Capacity factor may be a more appropriate measure for wind and solar, since, unlike conventional sources, their output cannot be controlled. Additionally, it is reasonable to assume that renewable sources will be used whenever they are available, since they have no fuel cost.

Taipower's wind systems do provide availability factors. However, those figures are not representative of available capacity. This analysis will therefore use capacity factors for both wind and solar. Using availability factor for wind does increase numbers somewhat, but this author feels that since that does not represent actual generating availability, this measurement is not useful in a power system with limited storage.

3.5 Capacity Factor Vs Availability Factor

Capacity factors demonstrate different things for different sources. For dispatchable sources - those sources whose generation can be controlled (conventional sources, usually) - it demonstrates usage. A coal plant that is available 80% of the time, with a capacity factor of 40% tells us that this facility is able to produce more if needed - up to its nameplate capacity 80% of the time (or perhaps some other combination of time and capacity, depending on regulation and maintenance). However, for wind and solar, capacity factors generally represent their total availability. In most cases, power from these sources is used whenever it is available, since they have no fuel cost. In Taiwan's case, its wind farms have availability factors well in excess of 80%, but very low capacity factors. These likely either reflect the low quality of wind resources, or the inability of the grid to accept them. Due to the flexibility demonstrated by Taiwan's LNG-fired plants, this author is inclined toward the former - low quality resources.

3.6 Discussion

From here, calculate all figures for summer months. Do an evaluation of spinning reserve and operating reserve? Compare this data to an EPRI region in the United State using GADS. Evaluate Taiwanese future demand and supply growth using these figures to counter balance traditional operating reserve. Devise minimum safe operating reserve based on this metric, along with a recommended reserve. Evaluate how Taiwan could develop renewables given this metric. Evaluate DPP, Taipower, and MOEA projects based on these figures.

3.7 Problems with Taipower's Numbers

Taipower's data has several errors. The first is that in all cases where percentages are totaled, either for availability or capacity factors, they are done by a simple average (total percentage points/number of generators) and are not weighted based on the nameplate capacity of the facility. This substantially changes the numbers. All calculations introduced in this paper have corrected for this error, and whenever percentages are used that represent multiple generators in aggregate, they will be weighted based on the installed or nameplate capacity of the generators involved.

Second, Taipower does not explain specifically how it's reliability and capacity factors are calculated. NERC and GADS distinguish between net generation - the power that is put into the grid - and gross generation - the power that comes out of the generator. This difference may not be apparent immediately. To clarify, many power plants consume some of their own generated electricity to use for instrumentation, control systems, or any other number of needs. Therefore, net generation is generation after any usage internal to the plant, while gross generation includes both grid transmitted power AND power that was consumed inside the facility. The reason this is useful is to understand maintenance and efficiency procedures inside plants. Taipower, being essentially a monopoly, is responsible for all consumption and most generation on its network, and so it may not be efficient or effective to track this data. Further study may be warranted, but this is well outside the realm of the paper.

Third: There were a number of cases where data was either corrupted, or data was input in an incorrect form. Specifically, in several sources many of the numbers included white spaces, which cause spreadsheet programs to treat the cell as text, rather than as numbers. Although this study corrected for that, it is possible that other studies would have been unable to do so.

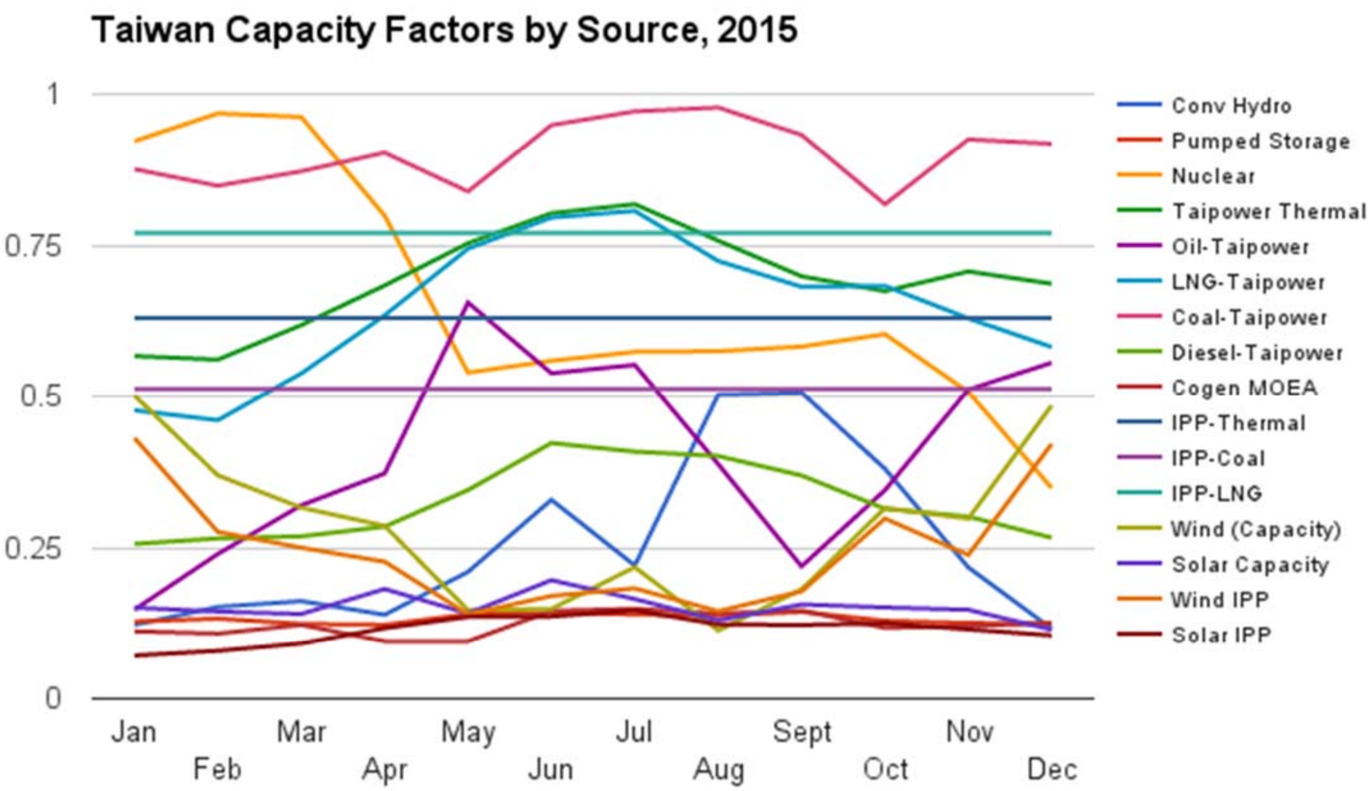


Figure 3.7.1: Taiwan Capacity factors by source, 2015. Data sourced from Taipower, Data.gov.tw, and MOEA Energy Statistics handbook 2015

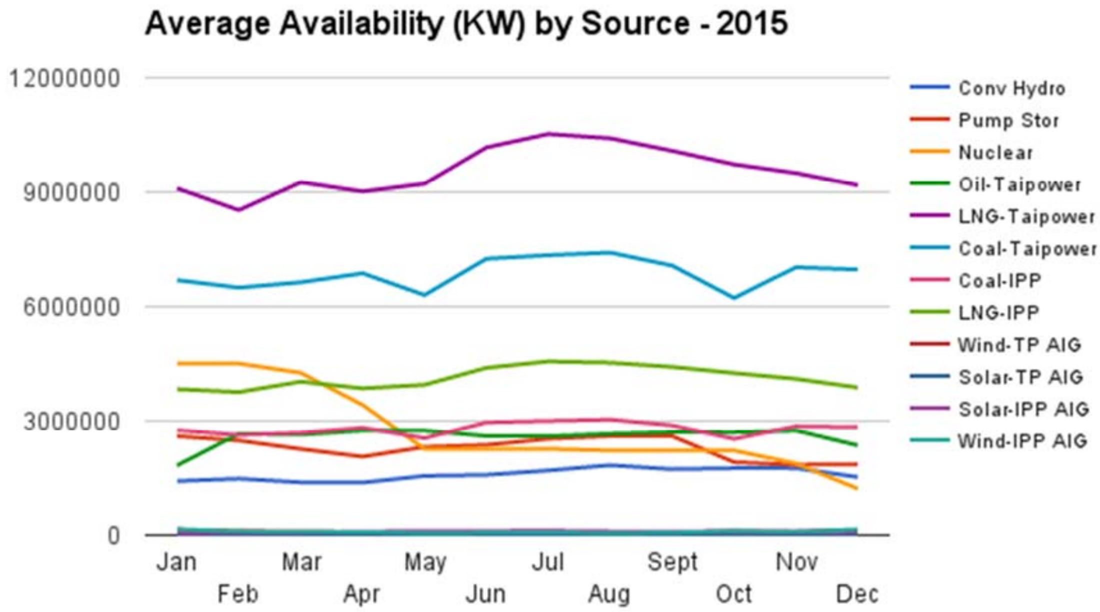


Figure 3.7.2. Taiwan Average availability by source (In KW) - 2015. Note that this uses Average Individual Generation instead of average individual availability for wind and solar sources.

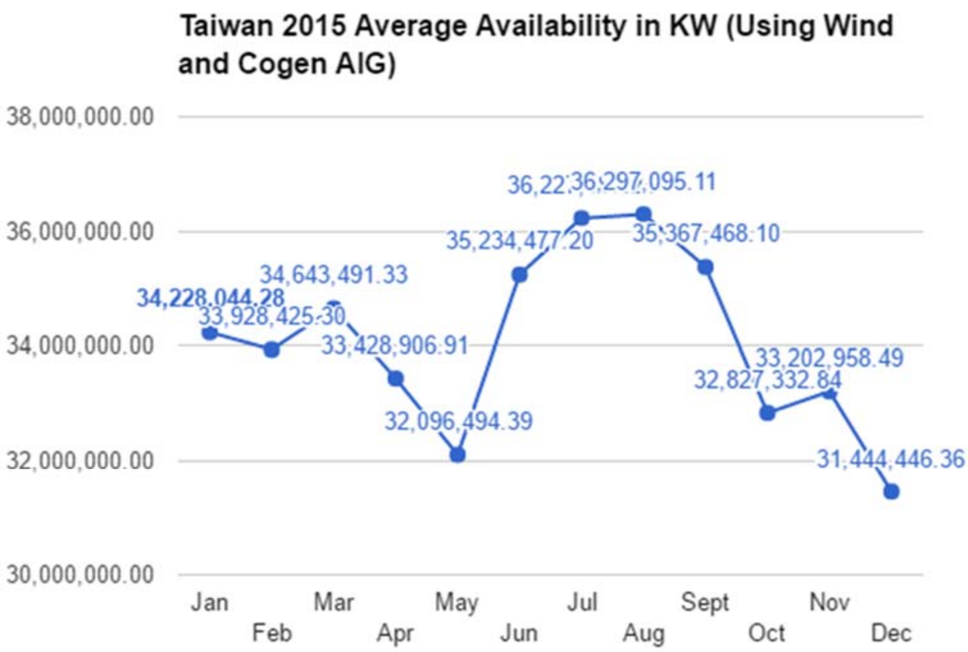


Figure 3.7.3; Taiwan Average Availability (KW) by source, using AIG for wind, solar, and cogen

Chapter 4: Results

4.1 Initial Observations

The first notable observation is that availability is generally higher during the summer. Much higher. We can speculate that Taipower shifts it maintenance to winter months when demand is lower. Not surprisingly, capacity factors also peak during the summer months.

During 2015, much of Taiwan's nuclear capacity was impacted due to maintenance problems. Taiwan lost an average of nearly 3 GW of generating availability due to nuclear outages. Nuclear Plant 1 Reactor One has been out of commission since December 2014 due to a minor malfunction - a loose handle on a fuel cask. The legislature has so far refused to accept the atomic energy council's report on the incident that would allow the plant to resume operation. (Chen, Wei-han, 2016) What is perhaps most shocking is that during July and August, even though availability spikes slightly, likely due to maintenance planning, to 36,220 MW, peak demand during this time was 35,385 MW. That small difference of less than 1GW represents two large generators or one nuclear power plant.

This 3GW of nuclear outage represents the entirety of Taipower's reserve for outages of all causes. Any additional failures would result in power shortages at peak hours.

4.2 International Comparison

When compared with aggregate GADS data from the US, Taiwan's power system reveals two major observations. The first is that Taiwan's power system has, on the whole, a higher level of availability than similar systems in the US. The only exception was diesel generation, which was slightly lower than US generation availability. However, this may not be viable. Diesel generation in Taiwan only occurs as backup, on-site supply for large plants (which does not feed into the grid) or as generation for outlying islands. In the US, only companies operate grid connected diesel generators, and the sample size may be so small as to not be useful comparison. See Table X. Note that the most recent GADS data is 2014. However, US electricity consumption has remained relatively stable for some time as the US economy's energy intensity

The capacity factors are somewhat more interesting. When compared to US figures we see that, with the exception of nuclear, ALL Taiwanese capacity factors are much higher than those of the US. Even considering the availability problems with Taiwan's nuclear installations, they still contribute an impressive share to Taiwan's capacity factors. Overhauls have allowed them to generate in slight excess of their original nameplate capacities.

In every field, Taiwan dramatically out produces the NERC facilities. In the case of Taipower's coal facilities, they had a 90.25% capacity factor, and a 90.31% availability. That means that Taipower's coal facilities were running at nearly maximum capacity for the entire time they were functional. Nuclear availability was only 54%, but generated at 66% capacity because of overhauls. The coal IPP facilities also run at extremely high capacity above 70%. Taipower LNG runs at well above 60%, compared to the US 10%. IPP LNG runs over 51%. This ordering suggests a clear cost of generation for Taipower, which is played out in Taipower's 2015 generating cost breakdown - NTD1.15/KWh for nuclear, 1.22 for Taipower coal, 2.05 for IPP coal, 2.68 for Taipower LNG, and 3.29 (on average) for IPP LNG. Cogeneration was also quite cheap at 2.21/KWh, but without a better understanding of how much potential generating capacity Taiwan's cogen facilities have, and how much is installed, it will be difficult to compare those to US figures. (台灣電力股份有限公司, 2012)

	Taiwan 2015 Availability Factors	2014 NERC AF	2014 NERC EAF
Hydro (Conventional)	83.79%	80.69%	80.13%
Hydro (Pumped Storage)	87.93%	82.33%	82.10%
Nuclear	53.89%	91.89%	90.38%
Thermal (All sources)	90.63%	83.87%	81.75%
Oil-Taipower	93.23%	84.84%	83.97%
LNG-Taipower	89.65%	80.57%	79.50%
Coal-Taipower	90.31%	84.92%	82.53%
Diesel-Taipower	90.60%	93.79%	92.63%

Table 4.2.1: Taiwan Availability Factors compared to US NERC GADS data.

	Taiwan 2015 CF	NERC 2014 NCF
Hydro (Conv)	25.47%	37.62%
Hydro (Pumped Storage)	13.26%	8.03%
Nuclear	66.15%	91.14%
Thermal-Taipower	69.37%	49.27%
Oil-Taipower	40.35%	9.25%
LNG-Taipower	64.61%	10.31%
Coal-Taipower	90.25%	61.12%
Diesel-Taipower	32.51%	12.90%
Thermal-IPP	62.95%	49.27%
IPP-LNG	51.16%	10.31%
IPP-Coal	77.03%	61.12%

Table 4.2.1: Taiwan 2015 Capacity Factors compared to NERC GADS Net Capacity Factors.

	Jan-Feb + Dec 2015	Dec2011 - Feb 2012	Jun 2015 - Aug 2015	Jun 2011 - Aug 2011
	Taiwan Winter	NERC Winter	Taiwan Summer	NERC Summer
CF	49.49%	49.37%	57.18%	52.90%
AF	68.95%	88.67%	74.60%	90.57%

Table 4.2.3: Taiwan 2015 figures compared to seasonal GADS availability

4.3 Early Conclusions

It can be said with certainty that, compared to NERC, Taiwan is much more dependent on its existing generation, leaving much less room for failure. In 2014, the peak demand for power was 35.38 GW, and the corresponding availability was only 36.22 G. This suggests that the current generating availability in Taiwan may be too low. Losing any two large generators during this period would have resulted in power rationing. Additionally, the spread of the availability data suggests that, unlike the US data (which is seasonally flat) that this situation is unusual. Indeed, the shifting of maintenance schedules to off seasons may be a cost saving strategy in a region which does not rely on winter heating, but shifting or deferring maintenance may not be the best way to ensure long term reliability. As mentioned in the background section, the operating reserve margin approach that Taiwan currently takes to reliability does not adequately account for availability at peak times or availability and capacity differences between diverse sources. The current model sets aside approximately 3 GW of reserve for availability related problems, but we see from this data that, even accounting for the seasonal maintenance shifts, consumes nearly 5GW, consuming not only the contingency reserve but also most of the spinning reserve. This leaves less than 1 GW of effective reserve - the size of two large generators or one nuclear power plant. A failure could easily lead to power rationing, and these numbers show that any given power system type has at least a 1% rate of failure, even with the shifting of maintenance off season. If this cycle cannot be sustained, the risks go up dramatically.

Policy makers should carefully consider the risks of using a source-blind operating reserve margin to plan power system availability. Operating reserve is calculated exclusively using peak consumption divided by installed capacity, and does not distinguish between different generating sources. The current configuration leaves no room for consumption growth and very little room for error. Due to the energy intense configuration of Taiwan's economy, economic growth in the short and medium term will require additional generation. Additionally, recently announced ambitions for investments in wind and solar will require more than a simple operating reserve calculation due the low capacity factors and minimum dispatch ability of these sources.

This model demonstrates that Taiwan has enough generating capacity to meet its current demand - but it does so by managing failure rates in its generation, and it leads credence to Taipower's statements that "we cannot gamble forever". A single extra failure on a peak day could force power rationing. Between 2015 and 2016, the peak demand climbed from 35.38 GW to 35.56 GW, and the average consumption in 2016 has been higher than the same time in 2015, with multiple days having demand above 35 GW. Without substantial investments in generation or dramatic cuts in consumption, this trend will not be sustainable.

4.4 Limitations of the AIA/AIG Model

This model has a number of serious limitations and requires further study in several areas. The first issues are the lack of data regard cogeneration installed capacity. This has already been highlighted extensively.

Second, the AIA figures calculated so far are based on a single year of data. Taipower has vast riches of data about availability factors going back more than 10 years. Time was not sufficient to evaluate all of them. As these data sets are gradually opened up, a more expansive data set should be developed that takes into account historical maintenance as well as age of equipment. This data would have substantially altered the availability data of nuclear facilities, which is covered in more detail in the next section.

Third, GADS does have some serious limitations. The GADS tables make it somewhat difficult to find historical availability and capacity, and data only goes back to 2011 currently. Additionally, power composition of North America is quite different from Taiwan, with much heavier reliance on hydroelectric resources not available in Taiwan.

4.5 Projections

Taipower and the Ministry of Economic Affairs have both developed long term projections about electrical supply and demand. The MOEA "National long-term load forecasting and Power Development Plan Summary Report" was last updated in 2014. The Taipower "2016 Long Term Power Development Report" was just released in May 2016. This section will evaluate these projections in terms of Average Individual Availability and Average Individual Generation (for solar and wind). Initial cogeneration numbers are based on capacity factors, while the projections take MOEA's assumptions. MOEA's assumptions about capacity for waste, biomass, and geothermal are also accepted, since there isn't other information available.

The baseline for the Taipower and MOEA projections are substantially different. While it is true that the MOEA report was compiled in 2014, and the Taipower report in 2016 it is unclear what underlying calculations caused them to have such significant variations. Even the installed capacity figures vary substantially. The only obvious difference is that the MOEA report includes cogeneration, biomass, and waste in their long term plans. The Taipower information from 2015 does include these sources in its previous generation, as well as IPP sources, which are not normally found in Taipower reports.

The MOEA report explores two scenarios: Scenario 1 where Taiwan's Nuclear facilities have their lifetimes extended. Scenario 2 where the plants are mothballed on schedule. Both scenarios assume that the fourth facility, the Lungmen Nuclear Power Plant, will be sealed for the foreseeable future. Given the current political climate and the promise of the current administration to close nuclear plants as soon as possible, only the second scenario was followed.

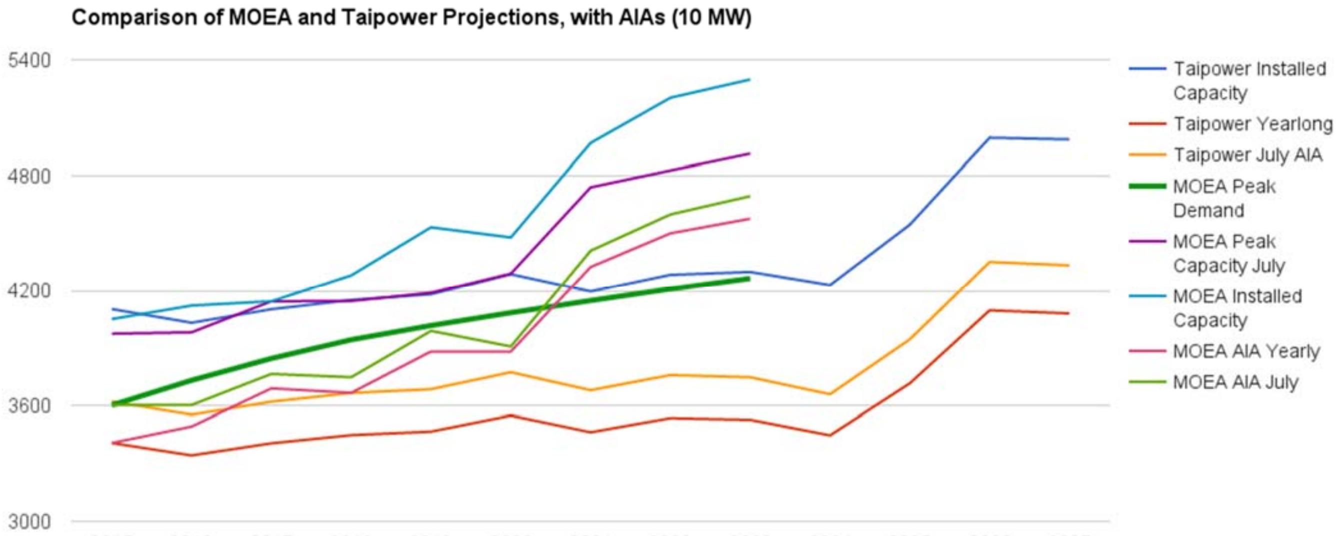


Figure 4.5.1: Comparison of MOEA 2014 and Taipower 2016 long term development reports

The Average Individual Availability was calculated based on the same 2015 numbers derived in the previous section. As mentioned before, these numbers have an unusual skew due to political stonewalling of the restart of the Jinshan Nuclear Power Plant Unit 1, which while offline is still listed as installed capacity, and therefore drags numbers down.

The data suggests that MOEA's projections may be extremely optimistic. To begin with, the MOEA report anticipates both a higher installed capacity and a much higher load than the actual figures from this year. As noted in previous sections, the MOEA long term report from 2013 also had similar flaws. It is possible that these reports did not anticipate the sluggishness of Taiwan's economy, which in turn would lead to less electrical consumption.

It is also possible that they did not anticipate the political firestorm surrounding the future of Taiwan’s nuclear power systems. Nuclear power in Taiwan has the highest ratio of capacity to availability of any source of power, and any distortion or disruption in nuclear generation has a much stronger impact on generating capacity than other sources.

Given the strong impact of nuclear power on total generation and availability, an alternative scenario has been plotted assuming that all nuclear facilities operate at 100% availability for the remainder of their established lifetimes. Though it is unlikely that they would have such a high uptime - needing to at a minimum refueling every 2 years - and it is politically

unlikely the Jinshan Nuclear Power Plant unit to resume operation without substantial political changes.

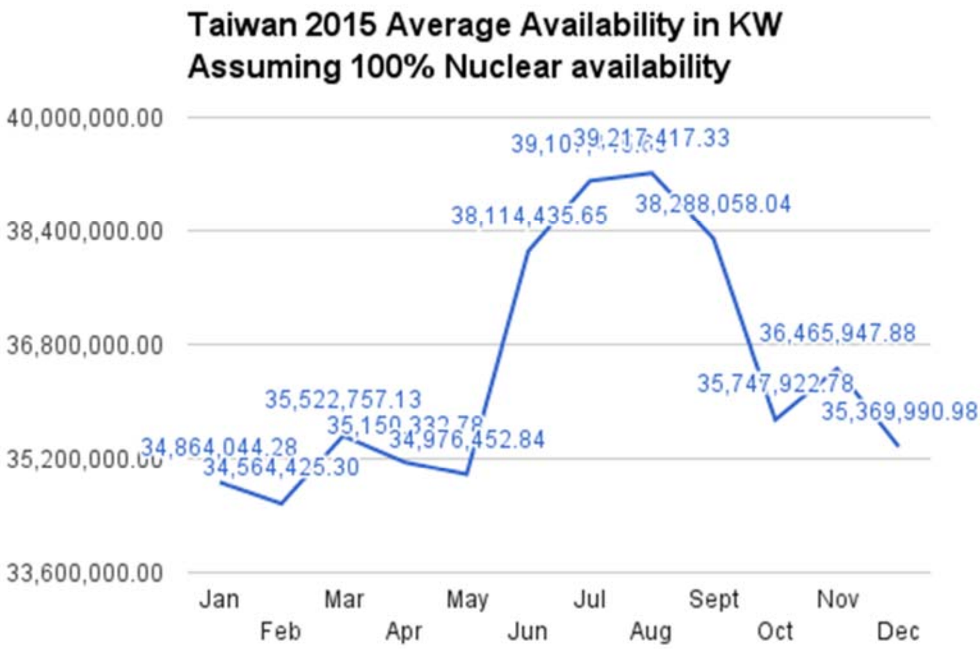


Figure 4.5.2: Taiwan 2015 Average Availability Assuming 100% Nuclear Availability

It is clear that both the MOEA and Taipower figures are relying on higher reliability figures for Taiwan’s existing nuclear plants than the political climate would allow. Only with all nuclear plants operating at full availability do their analyses make any sense. Even so, the

MOEA's projections remain extremely optimistic, and Taipower's are to a lesser extent. Using these figures, we can clearly see Taiwan has a generating deficit due to the nuclear shortage.

Part of the differences in the MOEA and Taipower figures could be explained by cogeneration. The MOEA report does make note of planned guaranteed peak power supplies from cogenerators. The second possible explanation is that MOEA's report uses the earliest possible start date for new Taipower generation, while the Taipower report provides a multiyear range. Taipower is planning to install more than 11 GW of new thermal generation over the next ten years - but the initialization dates for those sources are given as a long range of years, while the MOEA report seems to take the earliest possible start date at face value.

Additionally, many of the MOEA figures for renewables are overly optimistic compared with historical data. These factors alone still do not explain the higher MOEA numbers, but begin to explain the differences. Other possibilities include the unexpected slow economic growth, which would in turn lead to reduced consumption.

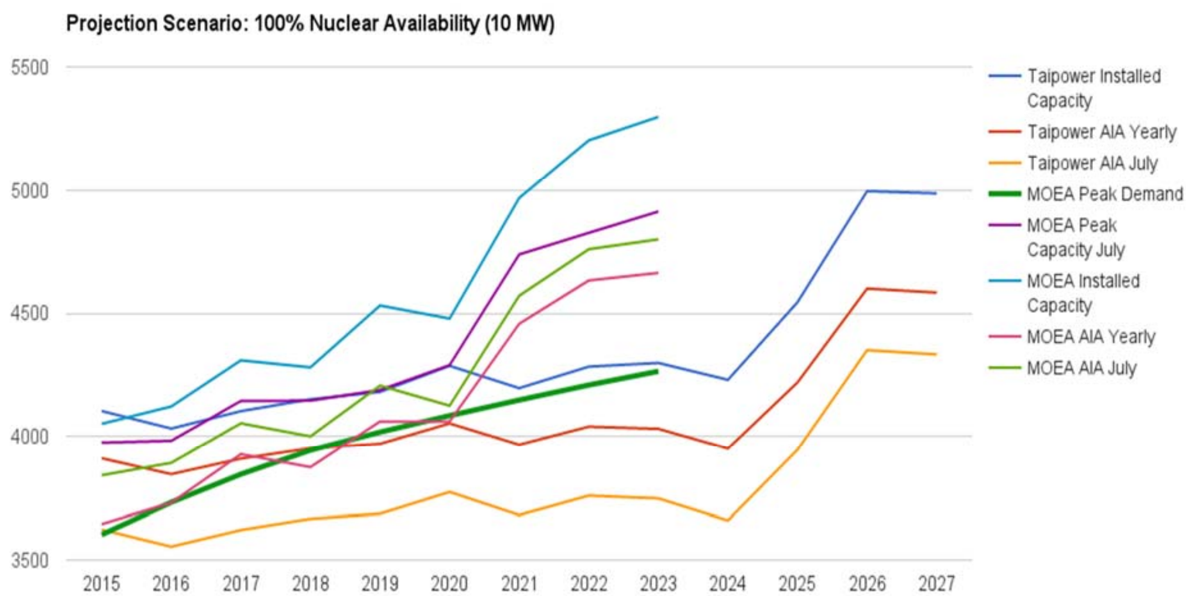


Figure 4.5.3: Projection Scenarios Assuming 100% Nuclear Availability

4.6 How Much Operating reserve would Taiwan need?

The amount of operating reserve needed to ensure a stable and reliable power system is highly dependent on the composition of generation. Availability factors and capacity factors vary wildly among sources, as the data in this section shows. A power supply that is based around highly dispatchable conventional sources or sources with very high availability and capacity factors will need less operating reserve to remain stable. More installed capacity with low capacity factors will necessitate a much higher operating reserve ratio to maintain current availability.

The major concern with the existing system is that, even though there is a 15% legally imposed operating reserve, it does not appear to have altered planning for the long term. 11.5% that existed in 2015 was barely sufficient, and led Taiwan to borderline power rationing due to maintenance failures which are largely predictable, as the model above demonstrates. It would therefore be more useful to build a new requirement based on minimum generating availability instead. The operating reserve margin is more like a "rule of thumb" than it is a true measure of reliability. This rule has been imposed by political means to political purpose.

Given Taiwan's current electricity mix, 15% would be more than sufficient. However, that energy mix is changing. Nuclear plants will be decommissioned by 2025, and the new government's push for solar-PV will, if successful, have a strong effect on how much reserve margin is needed due to solar PV's extremely low capacity factor in Taiwan, coupled with lack of storage.

For example: The new government has promised a full 20 GW of solar PV capacity by 2025. (Cai, Minchun, 2016) Even if we accept that the government will be able to provide this extremely large quantity, existing solar-PV installations in Taiwan have an average yearly capacity factor of 15.2%, according to this data. If that is true, then the average generation impact will be about 3 GW of available generation. However, since solar power only produces during the day, we may see a massive glut of power during the day, with no generation at night. Taiwan’s extremely limited energy storage facilities ensure that much of this power will be wasted.

Additionally, solar PV will mean that conventional sources to generate at night will become much more expensive as their capacity factors are reduced. Currently, Taiwan’s thermal plants are comparatively cheap to operate because they have such high capacity factors. If they go unused, however, their price per kwh could rise substantially as their capital costs become harder to defer through continuous generation.

4.7 Further Study

There are a number of ways this technique could be improved upon. First and foremost, it relies on only a single year of Taiwan's availability data. Though compensating for unusual nuclear dropouts can alleviate some of this disparity, Taipower has data going back many years. Those should be explored to get a more robust analysis.

Additionally, these calculations have relied on simple probability. A more advanced study could rely on frequentist statistics to better describe day-to-day availability and the likelihood of losing capacity. When combined with historical data, this would give a much more holistic projection.

Additional research is also needed to better understand Taiwan’s cogeneration system. Its installed capacity cannot be derived from any conventional source. The MOEA and bureau of energy data conflict, particularly about 2014-2015 years, as do the Taipower reports. It is clear from the capacity factors at least that Cogeneration in NERC regions and cogeneration in Taiwan operate very differently.

4.8 Qualitative analysis:

Taiwan Power Company Report

The report emphasizes the dangers of reckless reforms, and raises concerns about Taipower's rights and its ability to provide services to every citizen. The report highlighted that given the extreme levels of uncertainty caused by the current political situation, it is extremely difficult for the company to make long term plans and investments.

The report suggests that the population does not seem to understand the difference between total installed capacity and available capacity. The way that co-gen is being reported makes it appear as though it is a reliable source of power that can be mustered on demand, rather than the reality of surplus wholesale available at inconsistent times. This is evident by examining the civil society discourse (Fang, Jay, 2016), and that even reputable newspapers are unable to make the distinction suggests that electricity statistics need to be written more clearly. Even this researcher was originally stumped by this conundrum. The only recent official document where this issue has been clarified seems to be in Taipower's own report (Taiwan Power Company, 2016), and is not addressed in the Bureau of Energy's Handbook or long term power outlook. Inquisitive citizens do not have an easy means to check this themselves, and combined with current incentives, are not irrational in suspecting Taipower of bad faith. When combined with the lack of credibility that the KMT brings - Taipower's most vocal political supporter - it sheds further concern.

4.9 Taipower's Double Edged Sword

Taipower was created in 1946 by the ROC government, and then operated continuously during the martial law period. Though there have been incremental changes in the Investor-Owned-Power plant regulations and co-gen availability, Taipower is fundamentally governed the same way it always has been.

This is one area where Taiwan's democracy works against it. Taiwan has democratized, and its citizens are eager to find "social enemies" to protest against. The current ruling party - the DPP - was born as a protest party, and won the last election in a landslide. Taipower's configuration as a state-owned industry under the direct control of the legislature, then makes it extremely politically vulnerable. It does not have the power to set prices in attempts to curb demand generally, nor does it have any means of setting off-peak pricing to level the demand curve encourage shifting of consumption to times when power is cheaper to produce.

What has made Taipower so effective over the years under martial law, or post-democratization with a sympathetic legislature, has now made it intensely vulnerable to the DPP-controlled legislature. Civil society groups who are extremely suspicious of monopolies, and value the noble ideas of conservation, may vote against what is ultimately their own interests, and the DPP will let them. It takes years, even decades to change the composition of a country's energy and electrical systems. The fourth nuclear power plant was originally proposed in 1978 (Lassen, 2000) Construction did not begin until the late 90's, and were it not for the mothballed project, only the first reactor would be operational today - 38 years after the initial proposal. These cycles are much longer than the careers of many politicians, let alone an electoral cycle.

DPP politicians will continue to embrace potentially unfeasible renewable energy initiatives at the hands of their constituents because they will be electorally rewarded, and though potential losses will be economically devastating, it is unlikely that today's politicians will have to pay the political or economic price.

Moreover, the current system for rationing electricity prioritizes both essential public services and residential users. As mentioned in the background section, an overwhelming majority of Taiwan's electricity usage is industrial, and while this does indeed support much of Taiwan's economy, it is unlikely that a majority of the voting public would immediately notice a change. In the event of sudden, large scale cutbacks, factories would close or reduce production - but voters would be unlikely to notice and immediate change in their quality of life. Their air conditioners would still work, electrified public transit such as the Metro (MRT), Taiwan Rail Administration (TRA), and High Speed Rail (HSR)would still function. Smartphones would charge. The consumer side of life in Taiwan would continue unabated, initially. Environmental groups would say “Look at all of this scaremongering! The KMT and the large corporations want to put us under martial law, destroy our beautiful island with belching smokestacks, and harm our health with vile nuclear waste for their own profit!” This line of reasoning is compelling and well circulated. Populism is brewing all over the world, and Taiwan’s version of it is a strange form of eco-populism tied into to modern Taiwanese identity.

And so even as the Taiwanese electrical crisis worsened, even as its export oriented economy is undermined, the voters would continue to doubt the voices of restraint.

Taipower is constrained by the legislature, the legislature is constrained by voters. Voters do not have a direct, immediate stake in the system. Taiwan’s democracy, in this case, is working against itself because the institutions governing energy are still configured for a country under martial law. A dictatorship in a developed or semi-developed has an incentive to ensure steady supply of electricity over the long term if it wants to avoid a coup, and by nature cannot be punished electorally. It is therefore free to make long term investments in infrastructure. This has long been a strategy followed by the Communist Party of China.

To deal with this problem, the United States and other democracies have relied on politically independent energy agencies to manage and recommend policies, along with liberalized electricity markets to provide incentives to guarantee many participants in the electricity sector. The United States does this by having separate regional actors. Different regions have different policies. Some are completely privatized electrical markets, while others are public-private partnerships, and the Tennessee Valley Authority is a Federal monopoly. In the Northwest, a federally-owned power transmission company which owns some generating capacity is required to provide transmission to anyone who wants it at a reasonable fee, and they then resell it to municipalities or rural electric corporations, who are responsible for distribution. Thus, policy, generation, transmission, and distribution are all managed separately by politically independent actors, some of whom are regulated private companies, or even entirely private. This has the advantage of ensuring that so many actors are more difficult to be targeted for pure political opportunism. Though the American model has many disadvantages, as Banks notes on numerous occasions in his critiques about the dangers of privatization (Banks, 2007), it has the unintended side effect of making the power industry as a whole more politically robust.

However, partial or complete liberalism are not the only solution to this problem. The Tennessee Valley Authority in the US is entirely publicly owned, and most of its generating capacity is also public. While it is publically owned and the subject of periodic political upheaval, it is shielded from direct operational interference from the political sphere, with the ability to control prices.

Taipower is a serious victim of the horns effect. The Horns Effect, referencing the appearance of a western demon, is a well-documented cognitive bias that causes one's judgement to seriously impaired by a first impression. All subsequent judgements of a subject, being colored by an initial first impression that creates a snowball effect. Thus, it becomes easier and easier to scapegoat a single subject.

4.10 Resolving political deadlock:

Due to the massive amount of misinformation and misunderstanding surrounding Taiwan's power system, it is imperative that Taiwan create a credible, politically independent energy body to advise on energy policy and educate the public. Much of the political deadlock that does exist is there because of lack of information, which is exacerbated by the tense political climate. The KMT's continued defense of Taipower is harming Taipower's own interests, as Taipower is being contaminated by the KMT's perceived political illegitimacy. There is nothing inherently wrong with a state owned monopoly on power generation, transmission, and distribution - although liberalization could potentially provide a means of depoliticization, it is not the only means.

For the time being, there is a feedback effect going on in Taiwan's social institutions. The energy intensity of the Taiwanese economy means that energy, and electricity in particular, drive Taiwan's economy as long as it remains dependent on exports. The economy is part of what drives political action. President Tsai In-wen's inauguration speech was most about economic issues, and even as she hopes to bolster Taiwan's economy, her party continues to pursue a potentially unstable destabilizing energy agenda. Because neither the legislature, and more importantly, their constituents, have access to good information about electrical policy from trusted, independent authorities, their meddling makes the problem worse.

When Taipower protests, they are rebuked. (Liu, Lier, 2016) The DPP appointed representative to Japan has claimed that Taipower uses numbers to perpetuate lies at public expense, and this sentiment is echoed in Taiwan's civil society. Yet this thesis's analysis clearly shows that Taipower's and the MOEA long term projections may actually be too optimistic.

To resolve this feedback loop, Taiwan must improve the quality of information, and that requires a degree of political autonomy that is not currently possible. Liberalizing and privatizing Taipower will not solve this underlying problem, and this is the only way to start to solve the problems.

Taipower, and its defenders the KMT, have repeatedly failed to educate the public on their policies or on power system management. This author's own experience with Taipower's nuclear facilities showed a staff that was so desperate to cover its political futures that it failed to provide useful information. In most American children's textbooks, nuclear reactors are diagrammed beginning in the third grade, when children are eight years old. Activists informally interviewed in Taiwan's anti-nuclear movement don't even understand the difference between LNG and Coal plants, believing that thermal power plants (火力 in Chinese) are powered by some form of fire that is not tied to fossil fuels, let alone high carbon sources. Given this level of ignorance, it is no surprise the population is so vehemently opposed to nuclear power.

The World Nuclear Association provides overwhelming evidence that nuclear power is the safest source of power per kwh among all conventional sources, and that the primary dangers lie not in the technology, but in the institutions and practices that manage it. ("Safety of Nuclear Reactors - World Nuclear Association," May 2016). And yet even though a gas explosion killed dozens and injured hundreds, Taiwan continues to pin its energy future on a fossil fuel based power source. This problem is fundamentally a political one, which would be solved by effective and trustworthy information, which neither Taipower nor the KMT have been willing or able to provide. Until an autonomous energy agency is formed, the excessive politicization of energy will continue to stunt development of an effective electricity policy in Taiwan.

Chapter 5: Conclusions

Research Questions:

Given available historical data on Taiwan's generating reliability, what operating reserve would be required to maintain reliability for a feasible, worst-case scenario?

We have established that, during 2015, the less than 12% reserve ratio was barely enough. During July, the loss of a single plant or two large generators would have caused power rationing. This must be treated with several caveats.

The first caveat is the nuclear issue. With some of Taiwan's nuclear fleet out of commission during that year, largely due to political issues, the reserve ratio could be considered artificially inflated. These offline facilities still contribute to Taiwan's "Installed Generating Capacity" figures, but since they don't generate, they are essentially dead weight. Even so, Nuclear Power Plant 1 Unit 1, with a capacity of 636 MW, was the only facility out all year, with the second reactor going down during December only. Those two facilities combined contribute less than 2% to the operating reserve.

The second caveat is that the concept of operating reserve is tied to only two variables - peak demand and installed capacity. That means that low capacity factor sources like solar and wind could dramatically skew the operating reserve calculation as a measure of reliability. The current legal mandate of 15% operating reserve is only useful in so far as the energy mix is mostly high capacity factor sources.

The third is that, even with high capacity factor sources, this may not adequately account for economic growth. We have established that Taiwan's GDP growth and growth in electricity consumption are linked, and are likely to remain so for the foreseeable future. With 12% operating reserve, or effectively 11% due to political constraints on the first nuclear power plant, Taiwan was on the edge of an electrical shortage in July. The legal limit of 15% would *probably* be sufficient for the time being if the energy mix were mainly high capacity sources, but it leaves neither room for growth nor room for investment in lower capacity sources.

In summary, operating reserve is essentially a “rule of thumb” that will have to be adjusted relative the capacity and availability of different sources in an electricity mix. A fixed number may not be appropriate because operating reserve is based on installed capacity, not on the ability to deliver power. Calculating a specific operating reserve figure to use as a baseline would require foreknowledge of the composition of the energy mix, and the approximate capacity factors needed. If the government continues to invest in renewables, particular on a large scale, the use of operating reserve as a means of power system planning must be reevaluated, and a new metric should be used. Though Average Individual Generation and Average Individual availability are good candidates, it is not clear that they are sufficient on their own for long term planning, and more studies should be conducted.

Based on current stakeholders in Taiwan’s electricity policy, what policy changes would be need to be implemented to guarantee supply?

As outlined in the analysis, it is the opinion of this author that the single most important change is institutional. Taiwan currently lacks a politically autonomous energy authority, and given the direct control of the legislature over Taipower coupled with the relatively short tenure of elected officials, there is nothing to stop the electrical system from being used as a political football. This setup is not conducive to long term planning and investment. Full scale liberalization will not solve this problem entirely, as market economics do not apply in the traditional sense to power infrastructure. While some liberalization may correct some of the incentive problems, the lack of a coordinated government body for energy policy is a critical flaw in a system that is otherwise so centralized.

From the analysis, Taipower generally outperforms US and Canadian power companies in all areas except nuclear - where they faced unusual political constraints in the year analyzed. Privatizing or dismantling Taipower seems unlikely to increase reliability or reduce costs in terms of generation, as much of the NERC data comes from semi-private generators. However, this study did not evaluate transmission or distribution, which would need to be evaluated in any serious discussion of liberalization of the Taiwanese electrical market.

Final Remarks

This thesis has demonstrated Taiwan does indeed have an electricity shortage, though it is not immediately catastrophic. Taiwan's electricity generation reliability compares favorably with North American sources. This thesis has established that the existing models for projecting generation availability and up-time are too optimistic, and has highlighted the dangers that unrealistic projections may have on long term planning. Most importantly, it highlights the consequences of overly politicized decision making in the context of an electrical system. It is indeed possible to have a stable electrical grid while also reducing carbon footprint of electricity generation, but it will require either heavy investment in nuclear power (which is politically unfeasible) or a substantial overhaul of Taiwan's electricity industry and power system. Currently, Taipower is a helpless member part of a feedback loop that may lead to poor decision making due to a lack of independent analysis of available generation. The current energy institutions in Taiwan were designed to function under martial law or with a friendly government. Without independent policy advising and studies, Taiwan's electricity system becomes a pawn of politics, which prevents investment in long term solutions. While liberalization and marketization may solve some of these problems, it will ultimately require an energy agency with higher degree of political independence and legitimacy.

Bibliography

1% GDP growth in Taiwan “unlikely.” (n.d.). Retrieved July 4, 2016, from http://www.chinapost.com.tw/taiwan/business/2016/05/02/464933/1-GDP.htm

2.16.886.101.20003. (2015, January 23). New electricity pricing formula to promote industry’s sustainable growth [text/html]. Retrieved June 16, 2016, from http://www.ey.gov.tw/en/News_Content.aspx?n=1C6028CA080A27B3&s=A76600DB893AD52E

Allcott, H., Collard-Wexler, A., & O’Connell, S. D. (2014). *How Do Electricity Shortages Affect Industry? Evidence from India* (Working Paper No. 19977). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w19977

Banks, F. E. (2007). *The political economy of world energy : an introductory textbook*. Singapore; Hackensack, N.J.: World Scientific.

Cai, Minchun. (2016, June 22). 台政府公布再生能源目標，太陽能定調 20GW_集邦光伏網. Retrieved June 28, 2016, from http://pv.energytrend.com.tw/news/20160622-14063.html

Chen, Wei-han. (2016, June 14). Reactor restart chance “virtually zero” - Taipei Times. *Taipei Times*. Retrieved from http://www.taipeitimes.com/News/taiwan/archives/2016/06/14/2003648582

Ela, E., Milligan, M. R., & Kirby, B. (2011). *Operating Reserves and Variable Generation: A comprehensive review of current strategies, studies, and fundamental research on the impact that increased penetration of variable renewable generation has on power system operating reserves*. National Renewable Energy Laboratory.

Electricity consumption per capita - Country Comparison - TOP 100. (n.d.). Retrieved July 25, 2016, from http://www.indexmundi.com/g/r.aspx?t=100&v=81000&l=en

Electricity rates cut by 9.56% from April 1: MOEA. (n.d.). Retrieved June 16, 2016, from http://www.chinapost.com.tw/taiwan/business/2016/03/16/460907/Electricity-rates.htm

Energy Statistics Handbook 2015. (n.d.). Bureau of Energy, Ministry of Economic Affairs.

Europe's dirty secret the unwelcome renaissance. (2013). *Economist Economist (United Kingdom)*, *406*(8817). Retrieved from http://www.economist.com/news/briefing/21569039-europes-energy-policy-delivers-worst-all-possible-worlds-unwelcome-renaissance

Fang, Jay. (2016, June 10). Taipower's "power shortage" myth - Taipei Times. *Taipei Times*. Taipei. Retrieved from http://www.taipeitimes.com/News/editorials/archives/2016/06/10/2003648267

Federal Ministry for Economic Affairs and Energy, Germany. (2014, June 27). Infografik: Aufwind für Strom aus Erneuerbaren. Retrieved July 4, 2016, from http://www.bmwi-energiewende.de/EWD/Redaktion/Newsletter/2014/20/Meldung/infografik-aufwind-fuer-strom-aus-erneuerbaren.html

Ferry, T. (2015, September 15). Taiwan's Energy Dilemma: Emission Reductions vs. Dwindling Supply. Retrieved July 4, 2016, from http://topics.amcham.com.tw/2015/09/carbon-abatement-and-energy-supply/

Ferry, T. (n.d.). Is Renewable Energy the Way Forward for Taiwan? - Taiwan Business TOPICS. Retrieved June 16, 2016, from http://topics.amcham.com.tw/2015/09/is-renewable-energy-the-way-forward-for-taiwan/

Fisher-Vanden, K., Mansur, E. T., & Wang, Q. (Juliana). (2015). Electricity shortages and firm productivity: Evidence from China's industrial firms. *Journal of Development Economics*, *114*, 172–188. http://doi.org/10.1016/j.jdeveco.2015.01.002

Fraunhofer Institute for Solar Energy Systems ISE. (n.d.). Electricity production in Germany | Energy Charts. Retrieved June 16, 2016, from https://www.energy-charts.de/power.htm

GADS Data Reporting Instructions – January 2015. (2015).

Generating Availability Data System (GADS). (n.d.). Retrieved June 29, 2016, from http://www.nerc.com/pa/RAPA/gads/Pages/default.aspx

Hsu, E. (2014, December 29). FEATURE: Taiwan regressing in biofuel, waste oil policy - Taipei Times. *Taipei Times*. Retrieved from http://www.taipeitimes.com/News/taiwan/archives/2014/12/29/2003607855/2

Hsu, Y.-Y., Lee, Y.-S., Jien, J.-D., Liang, C. C., Chen, K.-K., Lai, T.-S., & Lee, T.-E. (1990). Operating reserve and reliability analysis of the Taiwan power system. *IEE Proceedings C Generation, Transmission and Distribution*, *137*(5), 349. http://doi.org/10.1049/ip-c.1990.0048

Huang, Y., Bor, Y. J., & Peng, C.-Y. (2011). The long-term forecast of Taiwan's energy supply and demand: LEAP model application. *Energy Policy*, *39*(11), 6790–6803. http://doi.org/10.1016/j.enpol.2010.10.023

Impacts of Solar Power on Operating Reserve Requirements (Fact Sheet). (2012). Washington, D.C. : United States. Dept. of Energy. Office of Energy Efficiency and Renewable Energy ;

Installed power in Germany | Energy Charts. (n.d.). Retrieved June 16, 2016, from https://www.energy-charts.de/power_inst.htm

Institute for 21st Century Energy. (2012). International index of energy security risk : assessing risk in a global energy market. *International Index of Energy Security Risk : Assessing Risk in a Global Energy Market.*

Kuomintang News Network. (n.d.). Retrieved June 16, 2016, from http://www1.kmt.org.tw/english/page.aspx?type=article&mnum=112&anum=17837&kw=electricity

Lassen, J. (2000, September 10). Power play - Taipei Times. Retrieved July 17, 2016, from http://www.taipeitimes.com/News/feat/archives/2000/09/10/0000052791/1

Laws & Regulations Database and The Republic of China. (n.d.). Retrieved June 15, 2016, from http://law.moj.gov.tw/Eng/LawClass/LawAll.aspx?PCode=J0130002

Li, L. (n.d.). Taipower to cut electricity price 7.34% on average - Taipei Times. Retrieved June 16, 2016, from http://www.taipeitimes.com/News/biz/archives/2015/03/21/2003614014

Liao, H.-C., & Jhou, S. T. (n.d.). Taiwan's Severe Energy Security Challenges. Retrieved July 4, 2016, from http://www.brookings.edu/research/opinions/2013/09/12-taiwan-energy-security-liao

Liu, Lier. (2016, June 22). 【民報劉黎兒專欄】全民一起踢爆台灣最大的黑箱━電力黑箱 | 即時新聞 | 20160622. Retrieved July 28, 2016, from http://www.appledaily.com.tw/realtimenews/article/new/20160622/892006/

Maintaining natural-gas fired baseload plants. (n.d.). Retrieved June 16, 2016, from http://www.power-eng.com/articles/print/volume-117/issue-10/departments1/gas-generation/maintaining-natural-gas-fired-baseload-plants.html

Matthews, J. A. (n.d.). Concentrating Solar Power – China's New Solar Frontier —(CSP) | The Asia-Pacific Journal: Japan Focus. Retrieved July 5, 2016, from http://apjjf.org/-John_A_-Mathews/3946

Mei-Chih Hu. (n.d.). Renewable Energy vs. Nuclear Power: Taiwan's energy future in light of Chinese, German and Japanese experience since 3.11 —3.11 | The Asia-Pacific Journal: Japan Focus. Retrieved July 5, 2016, from http://apjjf.org/-John_A_-Mathews/3954

Ministry of Economic Affairs 經濟部能源局(Bureau of Energy. (2012, March 22). 2. 台電電廠現況 [文字]. Retrieved June 15, 2016, from http://web3.moeaboe.gov.tw/ecw/populace/content/Content.aspx?menu_id=997

NERC Short-Term Special Assessment Gas Electric_Final.pdf. (n.d.). Retrieved from http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC%20Short-Term%20Special%20Assessment%20Gas%20Electric_Final.pdf

North American Electric Reliability Corporation. (n.d.). *Generating Unit Statistical Brochure 1*.

Nunez, C. (2014, September 25). Switch to Natural Gas Won't Reduce Carbon Emissions Much, Study Finds. Retrieved June 16, 2016, from http://news.nationalgeographic.com/news/energy/2014/09/140924-natural-gas-impact-on-emissions/

Oil expected from Chad as Taiwan strives for energy self-sufficiency | Economics | FOCUS TAIWAN - CNA ENGLISH NEWS. (n.d.). Retrieved June 16, 2016, from http://focustaiwan.tw/news/aeco/201510250017.aspx

operating reserve management guideline - 20130718.pdf. (n.d.). Retrieved from http://www.nerc.com/comm/oc/reliability%20guideline%20dl/operating%20reserve%20management%20guideline%20-%2020130718.pdf

Operating_Reserve_Management_Guideline_20131018_Final.pdf. (n.d.). Retrieved from http://www.nerc.com/comm/OC/Reliability%20Guideline%20DL/Operating_Reserve_Management_Guideline_20131018_Final.pdf

Pao, H., & Lee, T. (2004). Forecasting the Consumption for Electricity in Taiwan. In *ICEB* (pp. 1143–1146). Retrieved from http://iceb.nccu.edu.tw/proceedings/2004/Paper/EN139-paper.pdf

PJM - Monthly Equivalent Forced Outage Rates. (n.d.). Retrieved July 5, 2016, from http://www.pjm.com/markets-and-operations/energy/real-time/historical-bid-data/eford.aspx

Planning Reserve Margin. (n.d.). Retrieved June 29, 2016, from http://www.nerc.com/pa/RAPA/ri/Pages/PlanningReserveMargin.aspx

Snapshot. (n.d.-a). Retrieved from http://www.taipeitimes.com/News/taiwan/archives/2014/12/29/2003607855/2

Snapshot. (n.d.-b). Retrieved from http://www.taipeitimes.com/News/feat/archives/2000/09/10/0000052791/1

Snapshot. (n.d.-c). Retrieved from
http://www.taipeitimes.com/News/taiwan/archives/2016/06/14/2003648582

Snapshot. (n.d.-d). Retrieved from
http://www.taipeitimes.com/News/editorials/archives/2016/06/10/2003648267/1

Snapshot. (n.d.-e). Retrieved from
http://www.taipeitimes.com/News/biz/archives/2015/03/21/2003614014

Taipower cautions that electricity supplies low due to recent heat wave. (n.d.). Retrieved June 28, 2016, from http://www.chinapost.com.tw/taiwan/national/national-news/2016/06/02/468058/Taipower-cautions.htm

Taiwan cancels biogas-from-food waste project due to lack of technology : Biofuels Digest. (n.d.). Retrieved from http://www.biofuelsdigest.com/bdigest/2014/09/22/taiwan-cancels-biogas-from-food-waste-project-due-to-lack-of-technology/

Taiwan electricity rates to fall almost 10% this year | Economics | FOCUS TAIWAN - CNA ENGLISH NEWS. (n.d.). Retrieved June 16, 2016, from
http://focustaiwan.tw/news/aeco/201509090011.aspx

Taiwan Power Company. (2016). *105 年長期電源開發方案*. Retrieved from
http://www.taipower.com.tw/content/new_info/images/105%E5%B9%B4%E6%96%B9%E6%A1%88%E5%A0%B1%E5%91%8A.pdf

Taiwan wastes electricity because it is cheap: minister. (n.d.). Retrieved June 16, 2016, from
http://www.chinapost.com.tw/taiwan/business/2013/08/31/387796/Taiwan-wastes.htm

Turton, M. (2013, September 2). The View from Taiwan: Electricity price woes continue. Retrieved from http://michaelturton.blogspot.com/2013/09/electricity-price-woes-continue.html

Turton, M. (n.d.). U.S. Exports to Taiwan of Fuel Ethanol (Thousand Barrels). Retrieved June 21, 2016, from https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=M_EPOOXE_EEX_NUS-NTW_MBBL&f=M

US Energy Information Administration. (n.d.). Taiwan Exports of Crude Oil and Petroleum Products by Destination. Retrieved June 21, 2016, from https://www.eia.gov/dnav/pet/pet_move_expc_dc_NUS-NTW_mbbl_a.htm

U.S. Energy Information Administration (EIA). (n.d.-a). Reserve electric generating capacity helps keep the lights on - Today in Energy -. Retrieved June 16, 2016, from http://www.eia.gov/todayinenergy/detail.cfm?id=6510

U.S. Energy Information Administration (EIA). (n.d.-b). South China Sea - International - Analysis -. Retrieved June 16, 2016, from https://www.eia.gov/beta/international/regions-topics.cfm?RegionTopicID=SCS

U.S. Energy Information Administration (EIA). (n.d.-c). World Oil Transit Chokepoints - International - Analysis - U.S. Energy Information Administration (EIA). Retrieved June 16, 2016, from https://www.eia.gov/beta/international/regions-topics.cfm?RegionTopicID=WOTC

World Nuclear Association. (2016, May). Safety of Nuclear Reactors. Retrieved July 17, 2016, from http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/safety-of-nuclear-power-reactors.aspx

World Nuclear Association. (n.d.). Nuclear Power in Germany. Retrieved June 15, 2016, from http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/germany.aspx

Yao, J.-H. (2001). *2-5_YaoJuiHsiang.pdf*. Bangkok. Retrieved from http://www.egcfe.ewg.apec.org/publications/proceedings/ESI/ESI_Bangkok_2001/2-5_YaoJuiHsiang.pdf

可靠度指標資訊系統. (n.d.). Retrieved June 18, 2016, from https://fmaw.itri.org.tw/PGSRAIS/4-3-1.html

台灣能源: 免費核能電子書及洪秀柱謝函. (n.d.). Retrieved from http://taiwanenergy.blogspot.com/2015/07/blog-post.html

台灣電力公司_太陽光電購電實績. (n.d.). Retrieved July 24, 2016, from http://data.gov.tw/node/32986

台灣電力公司_汽電共生購電實績. (n.d.). Retrieved July 24, 2016, from http://data.gov.tw/node/32985

台灣電力公司_風力購電實績. (n.d.). Retrieved July 24, 2016, from http://data.gov.tw/node/32987

台灣電力股份有限公司. (2012a, October 25). 台灣電力股份有限公司 [網頁]. Retrieved June 15, 2016, from http://www.taipower.com.tw/content/new_info/new_info_in.aspx?LinkID=27

台灣電力股份有限公司. (2012b, October 25). 各種發電方式之發電成本 [網頁]. Retrieved July 28, 2016, from http://www.taipower.com.tw/content/govern/govern05.aspx?YM1=10414&YM2=10506&YM3=10506

台灣電力股份有限公司. (2016, July 4). 限電的種類 [網頁]. Retrieved July 4, 2016, from http://www.taipower.com.tw/content/new_info/new_info-d23.aspx?LinkID=23

台灣電力股份有限公司. (n.d.-a). 備用容量之說明. Retrieved June 16, 2016, from http://www.taipower.com.tw/content/new_info/new_info-c33.aspx?LinkID=13

台灣電力股份有限公司. (n.d.-b). 台灣電力股份有限公司 Historical Operating Reserve. Retrieved June 21, 2016, from http://data.taipower.com.tw/opendata/apply/file/d003002/001.txt

台灣電力股份有限公司(first). (2012c, October 25). 台灣電力股份有限公司 [網頁]. Retrieved June 16, 2016, from http://www.taipower.com.tw/content/new_info/new_info_in.aspx?LinkID=27

吳象元. (n.d.). 和平電廠跳機 台電表示進入「限電警戒」 - The News Lens 關鍵評論網. Retrieved July 4, 2016, from http://www.thenewslens.com/article/19616

政策綱領 - 中國國民黨全球資訊網 KMT Official Webstie. (n.d.). Retrieved July 4, 2016, from http://www.kmt.org.tw/p/blog-page_3.html

經濟部工業局. (2008, May 19). 電動機車產業網--車輛維修資訊. Retrieved June 20, 2016, from http://www.lev.org.tw/subsidy/default.aspx

經濟部能源局(Bureau of Energy, M. of E. A. (2012a, January 18). 全國長期負載預測與電源開發規劃摘要報告 [文字]. Retrieved June 21, 2016, from http://web3.moeaboe.gov.tw/ECW/populace/content/Content.aspx?menu_id=65

經濟部能源局(Bureau of Energy, M. of E. A. (2012b, March 22). 2. 台電電廠現況 [文字]. Retrieved June 16, 2016, from http://web3.moeaboe.gov.tw/ecw/populace/content/Content.aspx?menu_id=997

財團法人新境界文教基金會. (2014). 民進黨的新能源政策. Retrieved from http://dppnff.tw/uploads/20140306011032_4976.pdf

資料資源 | 政府資料開放平臺. (n.d.). Retrieved June 21, 2016, from http://data.gov.tw/node/gov/resource/2522

Appendices:

Appendix 1 June Preliminary Analysis

	AVG Inv Avl	Installed Capacity				
IPP/Cogen	7,952,424.90	8,329,200		Yellow = Taipower Realtime data		
Thermal	20,545,807.51	21,519,240		PUrple: Extrapolation from Taipower Figures		
Wind	273,802.91	663,900		Red: Unknown, assume 100%		
Solar	729,000	729,000				
Nuclear	4,508,000	5,144,000		IPP-Coal	3097100	
Hydro	3,951,790.06	4,691,300		IPP LNG	4610000	
	37,960,825.38	41,076,640		Co-Gen	622100	
	Peak Load:				8329200	
	35,560,000			Pumped Storag	2,602,000	
				Conv hydro	2,089,300	
					4,691,300	

Appendix 2 Combined AIA/AIG Results from all sources

Monthly AIA (KW) - Calculated by Author															
	Installed Capacity (KW)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Yearend averag
Hydro (Conventional)	1,899,457.00	Conv Hydro	1,417,511.50	1,481,771.47	1,385,203.73	1,379,021.10	1,554,310.11	1,581,973.26	1,696,761.46	1,835,968.07	1,729,757.75	1,757,995.55	1,756,364.25	1,523,076.60	1,591,642.90
Hydro (Pumped Storage)	2,602,000.00	Pump Stor	2,602,000.00	2,485,000.60	2,262,786.20	2,061,672.10	2,316,577.00	2,369,816.80	2,529,482.80	2,602,000.00	2,602,000.00	1,915,808.50	1,845,723.50	1,861,908.80	2,287,898.03
Nuclear	5,144,000.00	Nuclear	4,508,000.00	4,508,000.00	4,264,734.20	3,422,574.13	2,264,041.55	2,264,041.55	2,264,041.55	2,223,677.78	2,223,410.06	2,223,410.06	1,881,010.61	1,218,455.38	2,772,116.41
OIL Net Availability	2,750,000.00	Oil-Taipower	1,828,462.50	2,661,850.00	2,638,587.50	2,749,800.00	2,747,200.00	2,604,300.00	2,599,350.00	2,662,400.00	2,708,250.00	2,702,900.00	2,747,600.00	2,357,787.50	2,584,040.63
GasNet Avail	10,634,950.00	LNG-Taipower	9,098,374.30	8,524,730.93	9,256,247.71	9,016,496.41	9,219,014.28	10,173,263.39	10,525,638.08	10,412,819.68	10,084,170.86	9,727,379.34	9,498,899.26	9,181,010.72	9,559,837.08
Coal Net Avail	7,600,000.00	Coal-Taipower	6,691,260.00	6,493,850.00	6,634,245.00	6,870,485.00	6,300,440.00	7,251,315.00	7,344,375.00	7,412,305.00	7,072,410.00	6,223,590.00	7,027,370.00	6,968,850.00	6,857,541.25
DIESEL Avil	254,290.00	Diesel-Taipower	224,805.76	240,047.35	231,979.61	215,959.98	221,606.52	236,929.12	246,428.03	248,204.73	242,632.16	238,842.68	233,446.76	226,414.36	233,941.42
Cogen MOEA	8,108,500.00	CoGen AIG	906,567.20	875,529.76	992,790.32	772,104.17	772,064.52	1,180,812.50	1,208,342.74	1,146,610.21	1,186,636.11	952,383.06	979,722.22	1,015,014.79	999,048.13
Coal-IPP	3,097,100.00	Coal-IPP	2,757,109.55	2,629,159.93	2,689,417.67	2,825,569.69	2,548,379.24	2,962,174.78	3,003,138.58	3,038,448.81	2,883,822.53	2,528,501.99	2,862,823.54	2,836,952.36	2,797,124.89
LNG-IPP	4,610,000.00	LNG-IPP	3,837,610.32	3,759,516.87	4,033,398.61	3,857,389.21	3,951,306.64	4,395,900.72	4,564,018.16	4,530,875.98	4,420,005.27	4,258,244.46	4,106,459.89	3,880,171.92	4,132,908.17
Wind-Taipower AIG	284,560.00	Wind-TP AIG	142,561.26	105,031.34	89,889.79	81,345.64	41,810.22	42,359.67	61,955.57	32,233.69	51,502.55	89,705.15	84,753.54	137,875.94	80,085.36
Solar-Taipower AIG	7,013.94	Solar-TP AIG	1,058.75	1,012.95	985.18	1,274.22	991.62	1,376.52	1,158.23	911.38	1,095.80	1,061.30	1,033.53	803.00	1,063.54
Solar-IPP AIG	796,000.00	Solar-IPP AIG	56,728.49	63,031.25	72,770.16	93,091.67	107,983.87	108,559.72	116,630.38	98,127.69	97,365.28	99,649.19	91,576.39	83,654.57	90,764.06
Wind-IPP AIG	362,140.00	Wind-IPP AIG	155,994.62	99,892.86	90,455.65	82,123.61	50,768.82	61,654.17	66,166.67	52,512.10	64,409.72	107,861.56	86,175.00	152,470.43	89,207.10
Total	48,150,010.94	Total (Wind CF)	34,228,044.28	33,928,425.30	34,643,491.33	33,428,906.91	32,096,494.39	35,234,477.20	36,227,487.24	36,297,095.11	35,367,468.10	32,827,332.84	33,202,958.49	31,444,446.36	34,077,218.96

Appendix 3 Source Raw Data and Individual AIA/AIG Calculations

3.1 Taipower Thermal Generators

電廠	機組		裝置容 (kW)	Jan 可用率 (%)		Feb 可用率 (%)		Mar 可用率 (%)		April 可用率 (%)		May 可用率 (%)		Jun 可用率 (%)		Jul 可用率 (%)		Aug 可用率 (%)		Sept 可用率 (%)		Oct 可用率 (%)		Nov 可用率 (%)		Dec 可用率 (%)	
		協 一	500,000	100	500000	100	500000	100	500000	100	500000	99.63	498150	81.35	406750	82.22	411100	100	500000	100	500000	98.75	493750	100	500000	80.73	403650
	汽	協 二	500,000	12.9	64500	82.45	412250	100	500000	100	500000	100	500000	89.8	449000	100	500000	100	500000	100	500000	100	500000	100	500000	100	500000
		協 三	500,000	100	500000	100	500000	100	500000	100	500000	100	500000	99.89	499450	88.19	440950	86.56	432800	97.53	487650	100	500000	99.63	498150	89.77	448850
	力	協 四	500,000	72.22	361100	99.92	499600	77.86	389300	99.96	499800	99.93	499650	99.82	499100	99.58	497900	95.92	479600	94.12	470600	99.93	499650	99.89	499450	99.86	499300
協和		協和合計	2,000,00	70.29	1405800	95.44	1908800	94.27	1885400	99.99	1999800	99.9	1998000	93.11	1862200	92.85	1857000	95.47	1909400	97.84	1956800	99.7	1994000	99.88	1997600	93	1860000
	汽	林 一	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	100	0		0		0
		林 二	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	100	0		0		0
林口	力	合 計	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	100	0		0		0
		大潭複一	742,700	99.63	739952.0	89.13	661968.5	99.42	738392.3	100	742700	100	742700	100	742700	100	742700	96.45	716334.1	75.15	558139.0	62.16	461662.3	96.73	718413.7	99.8	741214.6
	複	大潭複二	742,700	72.92	541576.8	0	0	78.39	582202.5	99.75	740843.2	99.77	740991.7	87.06	646594.6	97.79	726286.3	98.54	731856.5	100	742700	99.77	740991.7	100	742700	97.58	724726.6
	循	大潭複三	724,700	99.83	723468.0	89.47	648389.0	39.11	283430.1	3.93	28480.71	35.81	259515.0	85.2	617444.4	100	724700	100	724700	100	724700	100	724700	100	724700	100	724700
	環	大潭複四	724,700	83.42	604544.7	89.47	648389.0	98.51	713901.9	98.82	716148.5	98.88	716583.3	100	724700	100	724700	100	724700	96.45	698973.1	61.06	442501.8	75.78	549177.6	100	724700
		大潭複五	724,700	80.35	582296.4	89.47	648389.0	98.37	712887.3	84.96	615705.1	100	724700	100	724700	99.74	722815.7	99.84	723540.4	100	724700	100	724700	45.83	332130.0	0	0
		大潭複六	724,700	56.7	410904.9	69.72	505260.8	98.98	717308.0	100	724700	100	724700	100	724700	100	724700	100	724700	100	724700	100	724700	97.87	709263.8	100	724700
大潭		潭複合計	4,384,20	82.16	3602058.	71.06	3115412.	85.48	3747614.	81.35	3566546.	89.14	3908075.	95.37	4181211.	99.58	4365786.	99.13	4346057.	95.22	4174635.	87.13	3819953.	86.11	3775234.	82.99	3638447.
		通 複 一	258,500	92.03	237897.5	98.97	255837.4	99.69	257698.6	94.56	244437.6	99.58	257414.3	98.91	255682.3	99.43	257026.5	98.45	254493.2	96.04	248263.4	96.28	248883.8	99.84	258086.4	97.33	251598.0
	複	通 複 二	258,500	84.02	217191.7	100	258500	99.94	258344.9	91.19	235726.1	96.32	248987.2	97.9	253071.5	98.21	253872.8	94.58	244489.3	95.14	245936.9	99.4	256949	99.77	257905.4	98.76	255294.6
		通 複 三	246,800	81.68	201586.2	100	246800	100	246800	100	246800	98.67	243517.5	97.47	240555.9	98.07	242036.7	97.15	239766.2	91.27	225254.3	100	246800	89.01	219676.6	96.74	238754.3
	循	通 複 四	386,000	92.37	356548.2	95.5	368630	69.6	268656	91.27	352302.2	92.79	358169.4	100	386000	95.54	368784.4	99.49	384031.4	82.48	318372.8	99.52	384147.2	96.11	370984.6	100	386000
		通 複 五	386,000	99.36	383529.6	98.73	381097.8	100	386000	26.54	102444.4	0	0	80.87	312158.2	98.99	382101.4	96.51	372528.6	97.92	377971.2	89.57	345740.2	73.78	284790.8	83.98	324162.8
	環	通 複 六	321,200	99.48	319529.7	99.29	318919.4	99.8	320557.6	98.35	315900.2	72.41	232580.9	100	321200	99.21	318662.5	96.8	310921.6	100	321200	98.7	317024.4	99.29	318919.4	82.77	265857.2
通霄		通複合計	1,857,00	92.42	1716239.	98.53	1829702.	93.6	1738152	80.65	1497670.	72.19	1340568.	95.24	1768606.	98.14	1822459.	97.27	1806303.	93.54	1737037.	96.9	1799433	92.1	1710297	92.71	1721624.
		中 一	550,000	96.77	532235	99.44	546920	100	550000	100	550000	100	550000	100	550000	99.97	549835	100	550000	100	550000	85.03	467665	100	550000	100	550000
		中 二	550,000	100	550000	95.53	525415	100	550000	99.97	549835	100	550000	100	550000	97.95	538725	100	550000	100	550000	100	550000	20.85	114675	65.13	358215
	汽	中 三	550,000	100	550000	40.07	220385	0	0	55.03	302665	91.42	502810	99.63	547965	100	550000	100	550000	100	550000	100	550000	100	550000	100	550000
		中 四	550,000	93.89	516395	81.67	449185	100	550000	100	550000	100	550000	100	550000	100	550000	100	550000	99.98	549890	82.27	452485	100	550000	100	550000
		中 五	550,000	100	550000	100	550000	100	550000	100	550000	99.99	549945	99.91	549505	100	550000	100	550000	50.78	279290	0	0	91.08	500940	99.85	549175
		中 六	550,000	10.41	57255	70.86	389730	100	550000	100	550000	100	550000	100	550000	100	550000	100	550000	100	550000	100	550000	100	550000	99.9	549450
		中 七	550,000	99.88	549340	100	550000	100	550000	97.9	538450	100	550000	100	550000	100	550000	100	550000	97.79	537845	100	550000	100	550000	86.01	473055
		中 八	550,000	100	550000	100	550000	99.81	548955	100	550000	100	550000	76.91	423005	99.11	545105	98.8	543400	98.82	543510	100	550000	98.04	539220	100	550000
	力	中 九	550,000	96.98	533390	100	550000	100	550000	57.43	315865	0	0	80.05	440275	93.32	513260	100	550000	100	550000	95.3	524150	100	550000	100	550000
		中 十	550,000	81.45	447975	100	550000	100	550000	99.84	549120	94.35	518925	100	550000	100	550000	100	550000	100	550000	100	550000	100	550000	49.31	271205
		合 計	5,500,00	87.98	4838900	88.62	4874100	89.79	4938450	90.95	5002250	88.61	4873550	95.67	5261850	99.04	5447200	99.88	5493400	94.76	5211800	86.28	4745400	91.04	5007200	90.07	4953850
台中	氣渦輪	# 1~ #4	280,000	93.49	261772	89.69	251132	96.6	270480	99.24	277872	97.8	273840	100	280000	100	280000	100	280000	100	280000	100	280000	78.35	219380	93.81	262668
		興 一	500,000	51.24	256200	84.14	420700	84.07	420350	55.62	278100	81.88	409400	84.04	420200	83.76	418800	78.53	392650	84.14	420700	85.8	429000	85.53	427650	85.83	429150
		興 二	500,000	99.98	499900	100	500000	100	500000	99.38	496900	87.14	435700	99.1	495500	76.5	382500	88.1	440500	69.5	347500	6.69	33450	100	500000	98.16	490800
		興 三	550,000	99.93	549615	99.92	549560	99.95	549725	99.01	544555	6.15	33825	99.1	545050	99.95	549725	99.54	547470	98.95	544225	98.65	542575	99.07	544885	99.92	549560
		興 四	550,000	99.81	548955	25.81	141955	39.13	215215	99.09	544995	99.97	549835	96.33	529815	99.35	546425	97.87	538285	99.9	549450	86.23	474265	100	550000	99.68	548240
	汽力	合 計	2,100,00	88.33	1854930	76.75	1611750	80.24	1685040	88.8	1864800	68.02	1428420	94.79	1990590	90.37	1897770	91.38	1918980	88.67	1862070	70.47	1479870	96.32	2022720	96.09	2017890
		興 複 一	445,190	83.63	372312.3	91.6	407794.0	92.37	411222.0	100	445190	97.44	433793.1	100	445190	96.87	431255.5	99.33	442207.2	94.5	420704.5	92.04	409752.8	84.15	374627.3	98.29	437577.2
		興 複 二	445,190	88.26	392924.6	100	445190	100	445190	71.46	318132.7	71.99	320492.2	80.61	358867.6	100	445190	99.95	444967.4	100	445190	96.99	431789.7	100	445190	100	445190
		興 複 三	445,190	95.97	427248.8	98.11	436775.9	98.69	439358.0	99.43	442652.4	94.68	421505.8	97.69	434906.1	99.91	444789.3	100	445190	99.9	444744.8	100	445190	83.48	371644.6	71.07	316396.5
		興 複 四	445,190	0	0	29.09	129505.7	40.4	179856.7	88.61	394482.8	99.86	444566.7	99.01	440782.6	100	445190	99.94	444922.8	96.88	431300.0	93.49	416208.1	96.62	430142.5	100	445190
		興 複 五	445,190	97.32	433258.9	99.82	444388.6	92.57	412112.3	98.34	437799.8	100	445190	93.94	418211.4	94.36	420081.2	99.58	443320.2	98.32	437710.8	99.78	444210.5	100	445190	47.31	210619.3
興達	複循環	合 計	2,225,95	73.04	1625833.	83.72	1863565.	84.81	1887828.	91.57	2038302.	92.79	2065459.	94.25	2097957.	98.23	2186550.	99.76	2220607.	97.92	2179650.	96.46	2147151.	92.85	2066794.	83.33	1854884.
		南 複 一	288,800	100	288800	99.15	286345.2	90.28	260728.6	99.63	287731.4	99.78	288164.6	100	288800	98.93	285709.8	75.83	218997.0	79.98	230982.2	100	288800	96.25	277970	99.76	288106.8
		南 複 二	288,800	99.68	287875.8	100	288800	90.73	262028.2	99.53	287442.6	96.5	278692	99.87	288424.5	99.46	287240.4	79.97	230953.3	86.15	248801.2	100	288800	95.37	275428.5	100	288800
南部	複循環	南 複 三	288,800	100	288800	100	288800	100	288800	100	288800	100	288800	100	288800	100	288800	100	288800	84.14	242996.3	36.63	105787.4	36.63	105787.4	51.05	147432.4

		南 複 四	251,400	97.33	244687.6	100	251400	97.29	244587.0	0.09	226.26	0	0	85.28	214393.9	100	251400	100	251400	100	251400	100	251400	100	251400	100	251400		
		合 計	1,117,80	99.3	1109975.	99.78	1115340.	94.51	1056432.	76.56	855787.6	75.81	847404.1	96.54	1079124.	99.59	1113217.	88.69	991376.8	87.28	975615.8	83.79	936604.6	81.64	912571.9	87.42	977180.7		
		大 一			0		0		0		0		0		0		0		0		0		0		0		0		
		大 二			0		0		0		0		0		0		0		0		0		0		0		0		
		大 三	375,000	95.83	359362.5	100	375000	100	375000	100	375000	99.84	374400	100	375000	99.84	374400	100	375000	100	375000	100	375000	100	375000	43.97	164887.5		
		大 四	375,000	11.6	43500	100	375000	99.81	374287.5	100	375000	100	375000	100	375000	100	375000	100	375000	100	375000	89.2	334500	100	375000	90.96	341100		
		大 五	500,000	98.93	494650	10.71	53550	56.48	282400	99.57	497850	99.59	497950	99.45	497250	99.29	496450	100	500000	98.55	492750	96.56	482800	99.11	495550	99.84	499200		
		大 六	550,000	99.78	548790	100	550000	98.87	543785	100	550000	100	550000	99.66	548130	98.39	541145	100	550000	95.76	526680	98.88	543840	98.04	539220	88.98	489390		
大林	汽 力	合 計	1,800,00	80.61	1450980	75.08	1351440	87.46	1574280	99.88	1797840	99.85	1797300	99.74	1795320	99.27	1786860	100	1800000	98.28	1769040	96.47	1736460	99.14	1784520	83.17	1497060		
尖山			129,772	93.46	121284.9	98.03	127215.4	97.29	126255.1	91.06	118170.3	94.02	122011.6	98.45	127760.5	99.94	129694.1	99.9	129642.2	97.53	126566.6	100	129772	95.48	123906.3	91.08	118196.3		
塔山			90,992	83.98	76415.08	92.33	84012.91	91.21	82993.80	80.5	73248.56	85.03	77370.49	90.08	81965.59	97.93	89108.46	97.81	88999.27	94.48	85969.24	86.31	78535.19	87.18	79326.82	88.21	80264.04		
珠山			33,526	80.85	27105.77	85.96	28818.94	67.8	22730.62	73.2	24541.03	66.29	22224.38	81.14	27202.99	82.4	27625.42	88.18	29563.22	89.77	30096.29	91.08	30535.48	90.12	30213.63	83.38	27953.97		
	全火力合 計		21,519,2	84.07	18091225	84.35	18151478	88.36	19014400	88.8	19109085	87.16	18756169	95.53	20557329	97.64	21011385	97.68	21019993	94.76	20391631	89.15	19184402	91.65	19722383	88.3	19001488		
	油		2,750,00	65.73	1807575	96.69	2658975	95.82	2635050	99.99	2749725	99.91	2747525	95		94.8		96.72		98.43		98.3		99.91		85.98			
汽	煤		7,600,00	88.08	6694080	85.37	6488120	87.17	6624920	90.36	6867360	82.97	6305720	95.43		96.67		97.55		93.1		81.95		92.48		91.72			
力	天然氣		1,050,00	99.37	1043385	57.68	605640	78.78	827190	99.79	1047795	99.8	1047900	99.56		98.82		100		97.08		97.78		98.55		94.13			
	合 計		11,400,0	83.82	9555480	85.47	9743580	88.44	10082160	93.54	10663560	88.58	10098120	95.72		96.42		97.58		94.74		87.33		94.82		90.58			
	複循環合計		9,584,95	83.98	8049441.	82.65	7921961.	87.94	8429005.	83.05	7960300.	85.17	8163501.	95.22		98.99		97.72		94.62		90.83		88.34		85.47			
	氣渦輪合計		280,000	93.49	261772	89.69	251132	96.6	270480	99.24	277872	97.8	273840	100		100		100		100		100		78.35		93.81			
	柴油機合計		254,290	99.82	253832.2	100	254290	98.95	251619.9	100	254290	99.74	253628.8	90.08		100		87.12		100		83.66		84.44		100			
Net Avg Indiv Availability (KW)					18104674		18171610		19031539		19130613		18762100	Net Avg	20545807		20995791		21015729		20387463		19172712		19726696		18996730		19503455
Net EAF					0.841324		0.844435		0.884396		0.889000		0.871875		0.954764		0.975675		0.976601		0.947406		0.890956		0.916700		0.882778		0.906326
		OIL	2,750,00	OIL Net	1828462.		2661850		2638587.		2749800		2747200		2604300		2599350		2662400		2708250		2702900		2747600		2357787.		
				Oil AF	0.664895		0.967945		0.959486		0.999927		0.998981		0.947018		0.945218		0.968145		0.984818		0.982872		0.999127		0.857377		
		GAS	10,634,9	GasNet	9098374.		8524730.		9256247.		9016496.		9219014.		10173263		10525638		10412819		10084170		9727379.		9498899.		9181010.		
				Gas AF	0.855516		0.801576		0.870361		0.847817		0.866860		0.956587		0.989721		0.979113		0.948210		0.914661		0.893177		0.863286		
		COAL	7600000	Coal Net	6691260		6493850		6634245		6870485		6300440		7251315		7344375		7412305		7072410		6223590		7027370		6968850		
				Coal AF	0.880428		0.854453		0.872926		0.904011		0.829005		0.954120		0.966365		0.975303		0.930580		0.818893		0.924653		0.916953		
		DIESEL	254,290	DIESEL	224805.7		240047.3		231979.6		215959.9		221606.5		236929.1		246428.0		248204.7		242632.1		238842.6		233446.7		226414.3		
				Diesel A	0.884052		0.943990		0.912263		0.849266		0.871471		0.931728		0.969082		0.976069		0.954155		0.939253		0.918033		0.890378		

註：
1.可用率＝〔1－（影響供電量／參考容量／全期時數）〕X 100
2.林口氣渦輪機商轉日期為#3-1: 87.08.31，#3-2: 87.09.08，於100年11月除役。
3.台中氣渦輪機商轉日期分別為#1: 79.07.16，#2: 79.07.17，#3: 79.07.21，#4: 79.07.18。
4.尖山柴油機#1-12商轉日期分別為#1: 89.12.29，#2:89.11.17，#3: 89.11.25，#4: 90.02.27，#5: 91.05.09，#6: 91.06.5，
#7: 91.08.03，#8: 91.08.13，#9: 91.11.02，#10: 91.11.26，#11: 92.01.29，#12: 92.01.20。
5.深一~三號機於96.10.01除役.

Notes: This data has the serious flaw that all percentage totals of Availability Factorsare simple mathematical averages, not Weighted averages, and therefore provide no predictive power by relative facility size

eplaced "-" with 0s

3.2 Taipower Nuclear Generators

全年可用率統計表	年度：2015	Installed capacity (KW)	AF	AIA (KW)	AF	AIA (KW)	AF	AIA (KW)	AF	AIA (KW)	AF	AIA (KW)	AF	AIA (KW)	AF	AIA (KW)	AF	AIA (KW)	AF	AIA (KW)	AF	AIA (KW)	AF	AIA (KW)	AF	AIA (KW)
	月		01		02		03		04		05		06		07		08		09		10		11		12	
核一廠	一號機	636000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	二號機	636000	100	636000	100	636000	100	636000	100	636000	92.48	588172.8	100	588172.8	100	588172.8	95.16	559705.2365	100	559705.2365	100	559705.2365	96.8	541794.6689	0	0
核二廠	一號機	985000	100	985000	100	985000	100	985000	76.75	755987.5	3.4	25703.575	100	25703.575	100	25703.575	98.26	25256.3328	98.94	24988.61567	100	24988.61567	100	24988.61567	93.86	23454.31467
	二號機	985000	100	985000	100	985000	100	985000	100	985000	100	985000	100	985000	100	985000	100	985000	100	985000	100	985000	100	985000	100	985000
核三廠	一號機	951000	100	951000	100	951000	74.42	707734.2	31.29	221450.0312	100	221450.0312	100	221450.0312	100	221450.0312	94.83	210001.0646	100	210001.0646	100	210001.0646	100	210001.0646	100	210001.0646
	二號機	951000	100	951000	100	951000	100	951000	86.66	824136.6	53.84	443715.1454	100	443715.1454	100	443715.1454	100	443715.1454	100	443715.1454	100	443715.1454	26.87	119226.2596	0	0
		5144000		4508000		4508000		4264734.2		3422574.131		2264041.552		2264041.552		2264041.552		2223677.779		2223410.062		2223410.062		1881010.609		1218455.379
				0.8763608087		0.8763608087		0.8290696345		0.6653526694		0.4401324945		0.4401324945		0.4401324945		0.4322857269		0.4322336824		0.4322336824		0.3656708026		0.2368692417

Data provided by Taipower Electrical Dispatch Section, Availability

3.3 Taipower Hydro Generators

所在地	機組編號		Jan		Feb		March		April		May		June 2015		July		August		Sept		October		November		December	
Conventional		裝 置 容 量	可用率	AIA	可用率	AIA	可用率	AIA	可用率	AIA	可用率	AIA	可用率	AIA	可用率	AIA	可用率	AIA	可用率	AIA	可用率	AIA	可用率	AIA	可用率	AIA
Hydro		(kW)																								
			(%)		(%)		(%)		(%)		(%)		(%)		(%)		(%)		(%)		(%)		(%)		(%)	
新北市烏來區	1	11,250	100	11250	100	11250	100	11250	100	11250	79.3	8921.25	98.06	11031.75	100	11250	100	11250	100	11250	100	11250	100	11250	100	11250
	2	11,250	100	11250	100	11250	100	11250	100	11250	78.59	8841.375	95.21	10711.125	100	11250	100	11250	100	11250	100	11250	100	11250	100	11250
新北市新店區	1	6,500	100	6474.65	100	6500	77.53	5039.45	100	6500	100	6500	100	6500	100	6500	100	6500	100	6500	100	6500	100	6500	93.01	6045.65
	2	6,500	100	6474.65	100	6500	89.84	5839.6	100	6500	100	6500	100	6500	100	6500	100	6500	100	6500	100	6500	100	6500	92.94	6041.1
新北市新店區	3	5,000	100	5000	100	5000	100	5000	100	5000	100	5000	100	5000	100	5000	100	5000	100	5000	100	5000	72.89	3644.5	100	5000
新北市新店區	1	70,000	100	70000	100	70000	4.69	3283	4.44	3108	100	70000	100	70000	100	70000	100	70000	100	70000	100	70000	100	70000	100	70000
新竹縣竹東鎮	1	220	100	220	100	220	100	220	100	220	100	220	100	220	100	220	100	220	100	220	100	220	100	220	100	220
桃園縣復興鄉	1	40,000	0	0	0	0	0	0	0	0	0	0	14.11	5644	100	40000	100	40000	100	40000	86.27	34508	100	40000	100	40000
桃園縣龍潭鄉	1	45,000	0	0	0	0	0	0	0	0	0	0	0	0	4.29	1930.5	44.95	20227.5	57.25	25762.5	100	45000	85.42	38439	100	45000
	2	45,000	0	0	0	0	0	0	0	0	0	0	0	0	0.17	76.5	65.89	29650.5	18.82	8469	100	45000	86.28	38826	100	45000
苗栗縣卓蘭鎮	1	40,000	0	0	0	0	17.93	7172	100	40000	100	40000	100	40000	100	40000	100	40000	100	40000	77.04	30816	98.62	39448	100	40000
	2	40,000	100	40000	100	40000	100	40000	89.43	35772	100	40000	100	40000	100	40000	100	40000	100	40000	37.02	14808	0	0	0	0
台中市后里區	1	475	100	475	100	475	98.92	469.87	100	475	100	475	100	475	100	475	100	475	100	475	89.45	424.8875	100	475	100	475
	2	475	100	475	100	475	99.1	470.725	100	475	100	475	100	475	100	475	100	475	100	475	100	475	29.88	141.93	100	475
台中市和平區	1	78,000	100	78000	100	78000	100	78000	99.03	77243.4	100	78000	100	78000	100	78000	100	78000	100	78000	89.35	69693	100	78000	100	78000
	2	78,000	100	78000	100	78000	100	78000	98.89	77134.2	100	78000	100	78000	100	78000	100	78000	100	78000	100	78000	88.79	69256.2	100	78000
	3	78,000	100	78000	100	78000	100	78000	99.13	77321.4	100	78000	100	78000	100	78000	76.67	59802.6	100	78000	89.19	69568.2	100	78000	100	78000
台中市和平區	1	54,500	0	0	0	0	0	0	0	0	0	0	28.69	15636.05	100	54500	100	54500	96.09	52369.05	100	54500	68.56	37365.2		0
	2	54,500	0	0	0	0	0	0	0	0	100	54500	92.64	50488.8	100	54500	100	54500	96.82	52766.9	100	54500	93.03	50701.35		0
	3	54,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	54500	100	54500	100	54500	84.37	45981.65		0
	4	54,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	54500	0	0	67.4	36733	92.21	50254.45		0
台中市和平區	1	54,450	100	54450	100	54450	100	54450	99.29	54063.405	100	54450	100	54450	100	54450	100	54450	92.5	50366.25	100	54450	89.1	48514.95	100	54450
	2	54,450	100	54450	100	54450	100	54450	99.49	54172.305	100	54450	100	54450	100	54450	100	54450	92.5	50366.25	89.56	48765.42	100	54450	100	54450
	3	54,450	100	54450	100	54450	100	54450	99.19	54008.955	100	54450	100	54450	100	54450	100	54450	100	54450	100	54450	89.6	48787.2	100	54450
	4	54,450	100	54450	100	54450	100	54450	99.42	54134.19	100	54450	100	54450	100	54450	100	54450	100	54450	100	54450	89.66	48819.87	100	54450
台中市和平區	1	22,500	100	22500	100	22500	99.19	22317.75	100	22500	100	22500	100	22500	100	22500	89.59	20157.75	100	22500	100	22500	100	22500	100	22500
	2	22,500	100	22500	100	22500	99.28	22338	100	22500	100	22500	100	22500	100	22500	100	22500	100	22500	86.4	19440	100	22500	100	22500
	3	22,500	100	22500	100	22500	100	22500	100	22500	100	22500	100	22500	100	22500	100	22500	100	22500	100	22500	100	22500	100	22500
	4	22,500	100	22500	100	22500	99.14	22306.5	100	22500	100	22500	100	22500	100	22500	100	22500	100	22500	86.13	19379.25	100	22500	100	22500
	5	105,000	100	105000	100	105000	87.68	92064	100	105000	100	105000	100	105000	100	105000	100	105000	100	105000	100	105000	100	105000	99.42	104391
台中市和平區	1	66,735	100	66735	100	66735	87.41	58333.0635	100	66735	100	66735	83.13	55476.8055	100	66735	100	66735	100	66735	100	66735	100	66735	11.04	7367.54
	2	66,735	4	2822.8905	100	66735	100	66735	100	66735	100	66735	100	66735	100	66735	100	66735	86.74	57885.939	100	66735	100	66735	100	66735
台中市石岡區	1	945	100	945	100	945	98.92	934.794	100	945	100	945	89.79	848.5155	100	945	100	945	100	945	100	945	100	945	100	945
南投縣仁愛鄉	1	10,350	96	9904.95	100	10350	100	10350	100	10350	100	10350	100	10350	100	10350	100	10350	100	10350	92.47	9570.645	86.39	8941.365	100	10350
	2	10,350	100	10350	100	10350	100	10350	100	10350	100	10350	100	10350	100	10350	100	10350	100	10350	92.47	9570.645	86.39	8941.365	100	10350
	3	15,300	100	15300	100	15300	100	15300	100	15300	100	15300	100	15300	100	15300	100	15300	100	15300	100	15300	100	15300	100	15300
	4	19,700	100	19700	85.07	16758.79	100	19700	86.44	17028.68	100	19700	100	19700	100	19700	100	19700	100	19700	86.73	17085.81	99.72	19644.84	100	19700
	1	18,200	100	18200	100	18200	87.06	15844.92	100	18200	100	18200	100	18200	100	18200	100	18200	100	18200	100	18200	97.95	17826.9	90.32	16438.2
	2	2,700	100	2700	100	2700	89.57	2418.39	100	2700	100	2700	100	2700	100	2700	100	2700	100	2700	99.17	2677.59	98.1	2648.7	90.32	2438.64
南投縣水里鄉	1	22,000	99	21797.6	100	22000	95.74	21062.8	100	22000	100	22000	100	22000	100	22000	100	22000	100	22000	100	22000	98.03	21566.6	100	22000
	2	22,000	99	21793.2	100	22000	94.72	20838.4	97.72	21498.4	100	22000	100	22000	100	22000	100	22000	100	22000	100	22000	97.95	21549	100	22000
	3	22,000	99	21793.2	100	22000	100	22000	95.76	21067.2	100	22000	100	22000	100	22000	100	22000	100	22000	100	22000	98.98	21775.6	100	22000
	4	22,000	99	21782.2	99.88	21973.6	100	22000	95.69	21051.8	100	22000	98.56	21683.2	100	22000	100	22000	100	22000	100	22000	98.08	21577.6	100	22000
	5	22,000	99	21782.2	99.35	21857	100	22000	99.1	21802	100	22000	100	22000	100	22000	100	22000	100	22000	95.94	21106.8	98.86	21749.2	100	22000
南投縣水里鄉	1	12,800	14	1789.44	65.48	8381.44	100	12800	100	12800	100	12800	86.21	11034.88	95.54	12229.12	100	12800	100	12800	100	12800	100	12800	100	12800
南投縣水里鄉	1	21,750	100	21750	83.33	18124.275	0	0	0	0	0	0	98.56	21436.8	99.81	21708.675	100	21750	100	21750	100	21750	95.51	20773.425	100	21750
	2	21,750	100	21750	100	21750	100	21750	99.25	21586.875	100	21750	100	21750	96.27	20938.725	100	21750	100	21750	100	21750	89.38	19440.15	100	21750

雲林縣林內鄉	1	3,607	100	3607	100	3607	96.04	3464.1628	98.52	3553.6164	100	3607	98.99	3570.5693	100	3607	100	3607	51.76	1866.9832	0	0	0	0	89.25	3219.24
南投縣國姓鄉	1	4,320	100	4320	100	4320	90.27	3899.664	100	4320	99.76	4309.632	100	4320	100	4320	100	4320	100	4320	95.7	4134.24	100	4320	100	4320
台南市楠西區	1	50,000	100	50000	100	50000	97.96	48980	68.58	34290	100	50000	100	50000	100	50000	99.83	49915	100	50000	92.83	46415	100	50000		
高雄市六龜區	1	2,250	0	0	0	0	0	0	0	0	0	0	30	675	100	2250	100	2250	100	2250	100	2250	100	2250	100	2250
	2	2,250	0	0	0	0	0	0	0	0	0	0	41.67	937.575	100	2250	100	2250	100	2250	100	2250	100	2250	100	2250
高雄市美濃區	1	2,670	100	2670	100	2670	100	2670	100	2670	100	2670	100	2670	100	2670	100	2670	100	2670	92.29	2464.143	100	2670		
花蓮縣秀林鄉	1	16,000	100	16000	100	16000	100	16000	100	16000	100	16000	100	16000	100	16000	100	16000	92.95	14872	100	16000	100	16000		
	2	16,000	100	16000	100	16000	100	16000	55.94	8950.4	0	0	94.67	15147.2	100	16000	100	16000	100	16000	92.93	14868.8	100	16000		
花蓮縣秀林鄉	1	4,700	100	4700	100	4700	100	4700	100	4700	100	4700	92.88	4365.36	100	4700	100	4700	100	4700	100	4700	100	4700		
花蓮縣秀林鄉	1	48,600	100	48600	100	48600	100	48600	51.22	24892.92	78.87	38330.82	100	48600	100	48600	100	48600	100	48600	78.96	38374.56	100	48600	73.01	35482.8
	2	48,600	92	44624.52	100	48600	100	48600	100	48600	100	48600	100	48600	100	48600	100	48600	97.31	47292.66	100	48600	100	48600		
花蓮縣秀林鄉	1	9,500	100	9500	100	9500	100	9500	100	9500	100	9500	100	9500	100	9500	92.52	8789.4	99.86	9486.7	100	9500	100	9500		
花蓮縣秀林鄉	1	2,500	100	2500	100	2500	100	2500	95.6	2390	100	2500	100	2500	100	2500	100	2500	100	2500	72.73	1818.25	100	2500		
	2	2,500	100	2500	100	2500	100	2500	95.77	2394.25	100	2500	100	2500	100	2500	100	2500	100	2500	69.03	1725.75	100	2500		
	3	2,000	100	2000	100	2000	100	2000	100	2000	100	2000	100	2000	97.83	1956.6	100	2000	100	2000	82.84	1656.8	100	2000		
花蓮縣秀林鄉	1	4,200	100	4200	100	4200	100	4200	100	4200	100	4200	92.93	3903.06	100	4200	100	4200	100	4200	98.99	4157.58	100	4200		
花蓮縣秀林鄉	1	7,000	100	7000	100	7000	100	7000	100	7000	100	7000	100	7000	78.26	5478.2	100	7000	100	7000	52.29	3660.3	100	7000		
	2	7,000	100	7000	100	7000	100	7000	100	7000	100	7000	100	7000	96.74	6771.8	100	7000	59.35	4154.5	80.43	5630.1	100	7000		
	3	7,000	100	7000	100	7000	100	7000	100	7000	100	7000	100	7000	96.74	6771.8	100	7000	100	7000	57.25	4007.5	0	0		
花蓮縣秀林鄉	1	2,700	100	2700	100	2700	100	2700	100	2700	100	2700	100	2700	100	2700	100	2700	100	2700	92.5	2497.5	100	2700		
花蓮縣吉安鄉	1	2,000	100	2000	99.83	1996.6	100	2000	100	2000	100	2000	100	2000	100	2000	95.8	1916	100	2000	92.55	1851	92.7	1854		
花蓮縣壽豐鄉	1	2,700	100	2700	100	2700	100	2700	100	2700	95.67	2583.09	92.6	2500.2	100	2700	100	2700	100	2700	100	2700	100	2700		
花蓮縣秀林鄉	1	61,200	100	61200	91.78	56169.36	98.17	60080.04	100	61200	100	61200	100	61200	95.76	58605.12	98.91	60532.92	41.29	25269.48	49.72	30428.64	97.29	59541.48	43.11	26383.3
宜蘭縣三星鄉	1	9,000	0	0	0	0	0	0	1.10%	0.99	100	9000	100	9000	100	9000	100	9000	100	9000	100	9000	100	9000	100	9000
	2	9,000	100	9000	100	9000	100	9000	82.43%	74.187	81.98	7378.2	14.39	1295.1	100	9000	98.46	8861.4	100	9000	100	9000	100	9000	100	9000
宜蘭縣三星鄉	1	2,125	100	2125	100	2125	100	2125	27.25%	5.790625	88.1	1872.125	100	2125	100	2125	100	2125	100	2125	100	2125	100	2125	100	2125
	2	2,125	100	2125	100	2125	100	2125	82.51%	17.533375	100	2125	100	2125	100	2125	100	2125	100	2125	100	2125	100	2125	100	2125
	3	2,125	100	2125	100	2125	100	2125	82.49%	17.529125	35.13	746.5125	100	2125	100	2125	100	2125	100	2125	100	2125	100	2125	100	2125
	4	2,000	100	2000	100	2000	100	2000	82.36%	16.472	96.14	1922.8	100	2000	100	2000	100	2000	100	2000	100	2000	100	2000	100	2000
Total by Simple Aver		1,899,457	89		90.01		86.33		80.16		89		88.12		94.63		98.19		95.6		91.62		88.36		91.36	
Total by indv average				1417511.501		1481771.465		1385203.729		1379021.099		1554310.115		1581973.26		1696761.46		1835968.07		1729757.752		1757995.548		1756364.248		1523076
Total Net Availability Factor				0.7462719611		0.7801026636		0.7292630101		0.7260080636		0.8182918142		0.8328555268		0.8932876396		0.9665752212		0.9106590737		0.9255253199		0.9246664957		0.80184
Pumped Storage:																										
南投縣水里鄉	1	250,000	100	250000	100	250000	95.91	239775	100	250000	100	250000	100	250000	100	250000	100	250000	100	250000	65.77	164425	94.4	236000	100	250000
	2	250,000	100	250000	100	250000	95.96	239900	100	250000	100	250000	100	250000	100	250000	100	250000	100	250000	100	250000	51.29	128225	0	0
	3	250,000	100	250000	100	250000	66.92	167300	100	250000	100	250000	100	250000	100	250000	100	250000	100	250000	100	250000	100	250000	95.52	238800
	4	250,000	100	250000	100	250000	95.92	239800	100	250000	100	250000	100	250000	100	250000	100	250000	100	250000	100	250000	63.21	158025	100	250000
南投縣水里鄉	1	267,000	100	267000	100	267000	26.96	71983.2	54.51	145541.7	97.18	259470.6	100	267000	100	267000	100	267000	100	267000	100	267000	100	267000	88.29	235734.
	2	267,000	100	267000	100	267000	88.4	236028	3.75	10012.5	97.18	259470.6	100	267000	100	267000	100	267000	100	267000	37.12	99110.4	100	267000	100	267000
	3	267,000	100	267000	100	267000	100	267000	47.91	127919.7	86.2	230154	100	267000	100	267000	100	267000	100	267000	36.71	98015.7	67.57	180411.9	100	267000
	4	267,000	100	267000	100	267000	100	267000	100	267000	81.83	218486.1	41.76	111499.2	100	267000	100	267000	100	267000	1.22	3257.4	0	0	0	0
	5	267,000	100	267000	100	267000	100	267000	91.46	244198.2	30.71	81995.7	100	267000	100	267000	100	267000	100	267000	100	267000	100	267000	44.37	118467.
	6	267,000	100	267000	56.18	150000.6	100	267000	100	267000	100	267000	71.28	190317.6	72.84	194482.8	100	267000	100	267000	100	267000	34.48	92061.6	87.98	234906.
Total AIA		2,602,000		2602000		2485000.6		2262786.2		2061672.1		2316577		2369816.8		2529482.8		2602000		2602000		1915808.5		1845723.5		1861908
Weighted AF				1		0.9550348194		0.8696334358		0.7923413144		0.8903063028		0.9107674097		0.9721302075		1		1		0.7362830515		0.7093480015		0.71556
Indicates "----" converted to 0																										
Indicates Pumped Storage																										

3.4 IPP and Cogeneration Extrapolations

CAPACITY FACTORS													
Generation (GWh)	Installed Capacity (KW_	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
CoGen (Taipower RealTimeData)	622,100	674,486	588,356	738,636	555,915	574,416	850,185	899,007	853,078	854,378	708,573	705,400	755,171
Cogen (MOEA Cpaacity)	8,108,500.00	674,486	588,356	738,636	555,915	574,416	850,185	899,007	853,078	854,378	708,573	705,400	755,171
IPP-Thermal	7,681,100												
	Days per month:	31	28	31	30	31	30	31	31	30	31	30	31
IPP Breakdown													
Generated 2015 KWh	42,356,071,000.00												
KWh/Day	116044030.1												
IPP Generation (KWh)		3597364934	3249232844	3597364934	3481320904	3597364934	3481320904	3597364934	3597364934	3481320904	3597364934	3481320904	3597364934
IPP Capacity Factor		0.6294889954	0.6294889954	0.6294889954	0.6294889954	0.6294889954	0.6294889954	0.6294889954	0.6294889954	0.6294889954	0.6294889954	0.6294889954	0.6294889954
Cogen-TP CF		1.457269256	1.407377852	1.59586935	1.241125489	1.241061752	1.898107217	1.942360942	1.84312846	1.907468431	1.530916355	1.57486292	1.631594253
Cogen-MOEA CF		0.1118045513	0.1079767851	0.1224382219	0.09522157818	0.09521668818	0.1456265031	0.1490217355	0.1414084251	0.1463447137	0.117454901	0.1208265675	0.1251791065

Data extraced from Taipower cogen Purchase history and IPP MOEA data

IPP Data is a brute average, as monthly breakdowns are not available.

Generation/(Days*24hours*Installed Capacity)

Source Data in GW hrs

3.5 Taipower Solar

	裝置容量 (kWp)	一月 CF %	AIG (KW)	二月 CF %	AIG (KW)	三月 CF %	AIG (KW)	四月 CF %	AIG (KW)	五月 CF %	AIG (KW)	六月 CF %	AIG (KW)	七月 CF %	AIG (KW)	八月 CF %	AIG (KW)	九月 CF %	AIG (KW)	十月 CF %	AIG (KW)	十一月 CF %	AIG (KW)	十二月 CF %	AIG (KW)
金門	528	14.05	74.184	14.22	75.0816	11.54	60.9312	16.41	86.6448	11.9	62.832	16.13	85.1664	14.71	77.6688	15.62	82.4736	15.17	80.0976	15.27	80.6256	14.31	75.5568	9.22	48.6816
台中光電	2123.04	14.57	309.326928	13.5	286.6104	13.55	287.67192	18.17	385.756368	14	297.2256	19.76	419.512704	17.04	361.766016	12.65	268.56456	17.25	366.2244	15.95	338.62488	13.65	289.79496	11.66	247.546464
興達	1627.65	15.35	249.844275	16.88	274.74732	16.46	267.91119	20.6	335.2959	16.56	269.53884	19.95	324.716175	17.86	290.69829	13.95	227.05717	16.62	270.51543	16.81	273.60796	15.44	251.30916	15.16	246.75174
嘉義民雄	60	9.08	5.448	9.62	5.772	9.41	5.646	13.19	7.914	11.06	6.636	15.2	9.12	12.69	7.614	9.92	5.952	11.85	7.11	10.65	6.39	8.92	5.352	7.79	4.674
中部儲運	91.8	11.48	10.53864	11.7	10.7406	10.61	9.73998	16.17	14.84406	12.14	11.14452	18.92	17.36856	16.04	14.72472	12.99	11.92482	15.69	14.40342	13.25	12.1635	11.35	10.4193	8.97	8.23446
東勢新伯	115.8	11.66	13.50228	12.22	14.15076	11.02	12.76116	15.93	18.44694	11.6	13.4328	17.65	20.4387	14.49	16.77942	11.45	13.2591	13.54	15.67932	12.11	14.02338	11.94	13.82652	8.75	10.1325
永安	4636.8	15.71	728.44128	17.13	794.28384	17.33	803.55744	20.95	971.4096	17.21	797.99328	20.87	967.70016	17.44	808.65792	14.74	683.46432	17.78	824.42304	16.4	760.4352	16.15	748.8432	14.63	678.36384
路北	60.03	16.3	9.78489	17.67	10.607301	17.09	10.259127	20.55	12.336165	16.44	9.868932	20.77	12.468231	16.56	9.940968	14.15	8.494245	17.67	10.607301	16.73	10.043019	15.47	9.286641	15.09	9.058527
澎湖	70.61	12.33	8.706213	13.87	9.793607	11.91	8.409651	18.23	12.872203	15.76	11.128136	20.22	14.277342	18.12	12.794532	13.04	9.207544	17.87	12.618007	15.44	10.902184	14.49	10.231389	10.16	7.173976
中大	40.25	11.64	4.6851	9.76	3.9284	8.75	3.521875	13.9	5.59475	10.94	4.40335	18.24	7.3416	17.4	7.0035	13.77	5.542425	15.9	6.39975	13.28	5.3452	11.41	4.592525	7.05	2.837625
卓蘭	41.9	14.38	6.02522	13.78	5.77382	12.43	5.20817	16.83	7.05177	11.52	4.82688	17.06	7.14814	14.87	6.23053	12.34	5.17046	15.93	6.67467	14.47	6.06293	14.44	6.05036	10.69	4.47911
大潭	651.42	12.17	79.277814	10.59	68.985378	9.86	64.230012	14.92	97.191864	13.32	86.769144	20.12	131.065704	20.06	130.674852	16.3	106.18146	17.93	116.799606	13.94	90.807948	12.14	79.082388	6.9	44.94798
七美	154.56	9.96	15.394176	12.51	19.335456	8.94	13.817664	14.81	22.890336	12.79	19.768224	15.45	23.87952	13.91	21.499296	9.59	14.822304	14.43	22.303008	11.54	17.836224	10.36	16.012416	6.97	10.772832
核三	1458.24	16.12	235.068288	17.45	254.46288	16.32	237.98476	19.55	285.08592	15.73	229.381152	20.18	294.272832	16.78	244.692672	13.57	197.88316	16.09	234.630816	14.8	215.81952	16.82	245.27596	14.53	211.882272
后里	91.125	15.3	13.942125	14.95	13.623187	12.54	11.427075	18.9	17.222625	13.24	12.06495	18.68	17.02215	16.3	14.853375	13.57	12.365662	17.48	15.92865	15.54	14.160825	14.71	13.404487	11.74	10.698075
龍井光電	6485.94	15.18	984.565692	14.46	937.86692	14.25	924.24645	18.31	1187.575614	14.32	928.786608	19.91	1291.35065	16.66	1080.55760	12.78	828.90313	15.66	1015.698204	15.12	980.67412	14.77	957.97333	11.63	754.314822
Total In	7013.94		1058.74969		1012.9485		985.17765		1274.220414		991.618608		1376.51705		1158.22640		911.37673		1095.795804		1061.2997		1033.5301		802.996422
Weighted CF			0.15094935		0.1444193		0.1404599		0.181669705		0.14137825		0.19625446		0.16513206		0.1299379		0.156231134		0.1513129		0.1473537		0.11448578

3.6 IPP Solar

IPP	Days per month	31	28	31	30	31	30	31	31	30	31	30	31
KWH		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IPP Solar gnera	796000	42,206,000	42,357,000	54,141,000	67,026,000	80,340,000	78,163,000	86,773,000	73,007,000	70,103,000	74,139,000	65,935,000	62,239,000
IPP Solar Capa	796000	0.07126695304	0.07918498744	0.09141980062	0.11694933	0.1356581294	0.1363815606	0.1465205733	0.1232759902	0.1223181882	0.1251874291	0.1150457147	0.1050936808
IPP Solar AIG	796000	56728.49462	63031.25	72770.16129	93091.66667	107983.871	108559.7222	116630.3763	98127.68817	97365.27778	99649.19355	91576.38889	83654.56989
Actual generation retrieved form data.gov.tw													

3.7 IPP Wind

IPP Wind		31	28	31	30	31	30	31	31	30	31	30	31
IPP Wind	Installed Capaci	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IPP Wind Generat	362,140	116,060,000	67,128,000	67,299,000	59,129,000	37,772,000	44,391,000	49,228,000	39,069,000	46,375,000	80,249,000	62,046,000	113,438,000
IPP Wind Capacit	362,140	0.4307577833	0.2758404406	0.2497808725	0.2267731019	0.1401911338	0.1702495352	0.1827101857	0.1450049615	0.1778586244	0.2978449195	0.2379604573	0.4210262056
IPP Wind Average	362,140	155994.6237	99892.85714	90455.64516	82123.61111	50768.8172	61654.16667	66166.66667	52512.09677	64409.72222	107861.5591	86175	152470.4301
AIG = Installed Capacity * CF													

3.8 Taipower Wind

風站名稱	Installed Capacity KW	1月			2月			3月			4月			5月	
		容量因數	AIG (KW)	可用率	容量因數	AIG (KW)	可用率	容量因數	AIG (KW)	可用率	容量因數	AIG (KW)	可用率	容量因數	AIG (KW)
石門風力	3960	45.47	1800.612	98.45	26.3	1041.48	99.6	30.64	1213.344	97.35	21.7	859.32	98.6	12.98	514.008
林口風力	600	53.19	319.14	97.23	34.96	209.76	99.97	35.21	211.26	99.29	28.88	173.28	99.88	19.15	114.9
蘆竹風力	7200	47.38	3411.36	99.1	32.3	2325.6	99.94	34.51	2484.72	99.42	25.47	1833.84	99.39	15.97	1149.84
觀園風力	30000	58.25	17475	97.2	44.72	13416	98.86	42.31	12693	97.83	33.82	10146	97.9	25.39	7617
大潭風力	4500	52.98	2384.1	93.57	33.62	1512.9	97.3	35.65	1604.25	99.21	28.75	1293.75	99.37	27.07	1218.15
大潭二風力	4600	46.82	2153.72	98.81	27.76	1276.96	98.56	30.87	1420.02	99.74	24.05	1106.3	99.63	23.94	1101.24
大潭二之二風力	6000	58.03	3481.8	99.4	38.85	2331	99.11	39.9	2394	99.72	33.34	2000.4	99.94	30.87	1852.2
香山風力	12000	37.79	4534.8	95.89	23.6	2832	97.14	22.44	2692.8	97.84	21.79	2614.8	96.66	16.12	1934.4
中港風力	36000	35.47	12769.2	88.72	29.11	10479.6	93.99	24.99	8996.4	95.75	19.11	6879.6	89.27	9.93	3574.8
中火風力	6000	41.36	2481.6	98.01	29.55	1773	97.14	26.31	1578.6	98.37	22.22	1333.2	98.39	8.83	529.8
彰工風力	62000	53.96	33455.2	90.74	39.82	24688.4	88.3	33.78	20943.6	84.97	31.66	19629.2	94.01	13.88	8605.6
王功風力	23000	56.55	13006.5	99.18	41.99	9657.7	98.94	32.02	7364.6	99.65	32.26	7419.8	99.85	12.83	2950.9
麥寮風力	46000	46.2	21252	92	34.85	16031	94.07	23.39	10759.4	82.5	27.3	12558	96.9	9.47	4356.2
四湖風力	28000	46.02	12885.6	97.61	35.02	9805.6	96.55	29.27	8195.6	98.81	27.18	7610.4	99.45	11.3	3164
恆春風力	4500	58.75	2643.75	99.16	38.1	1714.5	99.15	33.3	1498.5	97.95	29.13	1310.85	99.37	25.94	1167.3
中屯風力	4800	63.45	3045.6	81.76	46.99	2255.52	85.27	47.59	2284.32	92.54	39.13	1878.24	95.98	13.12	629.76
湖西風力	5400	69.12	3732.48	99.83	48.28	2607.12	99.56	42.87	2314.98	96.16	33.99	1835.46	99.46	9.98	538.92
金門風力	4000	43.22	1728.8	99.95	26.83	1073.2	96.44	31.01	1240.4	97.31	21.58	863.2	99.99	19.78	791.2
Total	284560		142561.262			105031.34			89889.794			81345.64			41810.218
Capacity Factors			0.5009884102			0.3691008575			0.3158904765			0.2858646331			0.1469293576
	961024.366														
Yearly AIG (KW	80085.36383														
Yearly AIG Rat	0.2814357739														
Installed capacity from taipower realtime datasystem															

	6月			7月			8月			9月			10月			11月		
可用率	容量因數	AIG (KW)	可用率	容量因數	AIG (KW)	可用率	容量因數	AIG (KW)	可用率	容量因數	AIG (KW)	可用率	容量因數	AIG (KW)	可用率	容量因數	AIG (KW)	可用率
82.34	9.44	373.824	81.69	15.62	618.552	89.57	3.03	119.988	21.8	0	0	0	0	0	0	10.17	402.732	23.05
98.72	19.35	116.1	98.1	19.76	118.56	94.94	19.02	114.12	94.15	19.74	118.44	94.07	46.49	278.94	99.52	42.82	256.92	99.84
97.49	15.93	1146.96	99.15	16.62	1196.64	97.27	16.08	1157.76	98.53	19.87	1430.64	98.54	42.49	3059.28	98.73	37.84	2724.48	98.4
96.22	26.23	7869	90.39	26.39	7917	93.51	10.81	3243	50.73	23.68	7104	85.42	51.2	15360	94.4	44.81	13443	97.02
97.98	34.16	1537.2	98.29	28.58	1286.1	97.9	22.6	1017	89.02	24.47	1101.15	98.53	47.6	2142	96.91	27.76	1249.2	68.98
97.44	28.37	1305.02	96.38	21.63	994.98	95.55	22.21	1021.66	93.16	20.63	948.98	97.78	44.96	2068.16	99.9	34.75	1598.5	99.81
97.58	42.85	2571	98.64	34.18	2050.8	99.8	30.43	1825.8	97.95	27.49	1649.4	98.54	53.87	3232.2	96.43	42.98	2578.8	97.4
87.68	25.76	3091.2	75.74	23.06	2767.2	82.95	13.28	1593.6	60.86	13.07	1568.4	60.87	22.28	2673.6	63.61	17.78	2133.6	78.96
96.4	9.78	3520.8	97.83	15.12	5443.2	97	1.83	658.8	21.73	1.15	414	30.69	9.86	3549.6	47.7	13.6	4896	52.29
97.87	7.29	437.4	97.79	14	840	95.1	3.58	214.8	47.21	13.85	831	90.84	24.02	1441.2	96.48	22.39	1343.4	95.69
96.04	12.31	7632.2	98.77	23.3	14446	97.88	12.45	7719	94.55	22.04	13664.8	94.65	31.57	19573.4	90.16	32.98	20447.6	87.86
97.87	12.18	2801.4	99.21	21.98	5055.4	99.43	14.44	3321.2	95.49	25.24	5805.2	99.17	36.13	8309.9	99.27	34.22	7870.6	99.67
96.45	9.78	4498.8	96.94	19.53	8983.8	96.65	8.67	3988.2	79.88	17.1	7866	93.7	28.43	13077.8	94.04	27.4	12604	91.83
97.54	11.01	3082.8	99.37	21.74	6087.2	98.37	11.7	3276	92.69	16.13	4516.4	91.62	24.33	6812.4	92.84	24.79	6941.2	89.6
96.41	15.69	706.05	96.4	23.08	1038.6	93.14	17.62	792.9	87.21	21.2	954	95.99	38.39	1727.55	89.65	27.89	1255.05	75.25
90.06	8.73	419.04	95.96	22.71	1090.08	91.06	11.89	570.72	54.1	23.82	1143.36	76.65	38.89	1866.72	75.24	29.63	1422.24	78.16
97.47	7.52	406.08	99.22	19.19	1036.26	89.91	13.91	751.14	73.21	27.97	1510.38	94.58	52	2808	94.78	42.13	2275.02	84.81
98.81	21.12	844.8	99.76	24.63	985.2	99.7	21.2	848	99.17	21.91	876.4	99.96	43.11	1724.4	98.09	32.78	1311.2	99.94
		42359.674			61955.572			32233.688			51502.55			89705.15			84753.542	
		0.1488602544			0.2177241074			0.1132755412			0.1809901251			0.3152416011			0.2978406733	

12月		
容量因數	AIG (KW)	可用率
26.26	1039.896	47.11
48.38	290.28	98.01
55.02	3961.44	99.04
65.54	19662	98.26
38.3	1723.5	65.72
50.22	2310.12	99.88
61.72	3703.2	99.33
29.49	3538.8	76.72
21.84	7862.4	51.54
36.57	2194.2	92.56
53.43	33126.6	88.26
56.94	13096.2	99.6
49.22	22641.2	96.21
42.16	11804.8	90.07
51.7	2326.5	97.42
61.81	2966.88	83.07
70.28	3795.12	97.19
45.82	1832.8	99.94
	137875.936	
	0.4845232499	

Appendix 4 Projections

4.1 Taipower Projections

						July	0.9663651			0.9452181			0.9690826			0.9897214			0.4401324					
年（民國）						Yearlong	0.9023080			0.4035477			0.9199788			0.8989075			0.5389028			TOTAL		
						Renewable	Coal			Oil	Yearlong	July AIA	Diesel	Yearlong	July AIA	LNG	Yearlong	July AIA	Nukes	Yearlong	July AIA	Yearlong	JULY AIA	Taipower Net
104*2		Yearly CF	July CF	Yearly AI	July AIG	662.5	1069.7	Yearlong	July AIA	332.5	300.01742	321.31640		0	0	1524.5	1375.5686	1473.2236	514.4	464.14726	497.09822	3,407.72	3,622.75	4103.6
105							80	72.184644	77.309210	-75	-67.67310	-72.47738		0	0	-76.4	-68.93633	-73.83029		0	0	-64.42479	-68.99847	
								0	0		0	0		0	0		0	0		0	0	0	0	
								0	0		0	0		0	0		0	0		0	0	0	0	
																						-64.42479	-68.99847	
																						3343.2971	3553.7502	4032.2
106	Wind	0.2814357	0.2177241	0.4221536	0.3265861	1.5	80	72.184644	77.309210	-100	-90.23080	-96.63651		0	0	89.3	80.576109	86.296406		0	0	62.952102	67.295689	
								0	0		0	0		0	0		0	0		0	0	0	0	
								0	0		0	0		0	0		0	0		0	0	0	0	
																						62.952102	67.295689	
																						3406.2492	3621.0459	4103
107	Wind	0.2814357	0.2177241	0.5065843	0.3919033	1.8	160	144.36928	154.61842		0	0		0	0	-50	-45.11540	-48.31825	-63.6	-57.38679	-61.46082	42.373678	45.231245	
								0	0		0	0		0	0		0	0		0	0	0	0	
																						42.373678	45.231245	
																						3448.6228	3666.2771	4151.2
108	Solar	0.1516320	0.1651320	0.2729376	0.2972377	1.8	80	72.184644	77.309210		0	0	2.1	1.8948469	2.0293667		0	0	-63.6	-57.38679	-61.46082	16.965636	18.174992	
	Solar	0.1516320	0.1651320	1.4556676	1.5852678	9.6		0	0		0	0		0	0		0	0		0	0	1.4556676	1.5852678	
																						18.421304	19.760260	
																						3467.0441	3686.0374	4181.1
109	Wind	0.2814357	0.2177241	1.5478967	1.1974825	5.5		0	0		0	0	-14	-12.63231	-13.52911	178.5	161.06198	172.49617		0	0	149.97757	160.16454	
	Geotherma	0.5	0.5	0.1	0.1	0.2		0	0		0	0		0	0		0	0		0	0	0.1	0.1	
	Conv Hyrd	0.8379462	0.8932876	0.3351785	0.3573150	0.4		0	0		0	0		0	0	-77.2	-69.65818	-74.60338		0	0	-69.32300	-74.24607	
	Wind	0.2814357	0.2177241	0.5065843	0.3919033	1.8		0	0		0	0		0	0		0	0		0	0	0.5065843	0.3919033	
	Solar	0.1516320	0.1651320	1.6072997	1.7503999	10.6		0	0		0	0		0	0		0	0		0	0	1.6072997	1.7503999	
																						82.868452	88.160776	
																						3549.9126	3774.1982	4286.9
110	Wind	0.2814357	0.2177241	1.5478967	1.1974825	5.5		0	0		0	0		0	0		0	0	-98.5	-88.87734	-95.18696	-87.32944	-93.98948	
	Conv Hyrd	0.8379462	0.8932876	0.1675892	0.1786575	0.2		0	0		0	0		0	0		0	0		0	0	0.1675892	0.1786575	
	Wind	0.2814357	0.2177241	0.6473022	0.5007654	2.3		0	0		0	0		0	0		0	0		0	0	0.6473022	0.5007654	
																						-86.51455	-93.31005	
																						3463.3980	3680.8881	4196.4
111	Hydro	0.8379462	0.8932876	0.5865623	0.6253013	0.7		0	0		0	0		0	0	79.2	71.462798	76.536118		0	0	72.049360	77.161419	
	Wind	0.2814357	0.2177241	0.6473022	0.5007654	2.3		0	0		0	0		0	0		0	0		0	0	0.6473022	0.5007654	
	Solar	0.1516320	0.1651320	0.7581602	0.8256603	5		0	0		0	0		0	0		0	0		0	0	0.7581602	0.8256603	
																						73.454823	78.487845	
																						3536.8529	3759.3760	4283.6
112	Geotherma	0.5	0.5	0.5	0.5	1		0	0		0	0		0	0	79.2	71.462798	76.536118	-98.5	-88.87734	-95.18696	-16.91454	-18.15084	
	Wind	0.2814357	0.2177241	0.6473022	0.5007654	2.3		0	0		0	0		0	0		0	0		0	0	0.6473022	0.5007654	
	Solar	0.1516320	0.1651320	1.5163204	1.6513206	10		0	0		0	0		0	0		0	0		0	0	1.5163204	1.6513206	
	Wind	0.2814357	0.2177241	5.9101512	4.5722062	21		0	0		0	0		0	0		0	0		0	0	5.9101512	4.5722062	
																						-8.840771	-11.42655	
																						3528.0121	3747.9494	4298.6
113	Wind	0.2814357	0.2177241	0.5628715	0.4354482	2		0	0		0	0		0	0	79.2	71.462798	76.536118	-95.1	-85.80949	-91.90132	-13.78382	-14.92975	
	Geotherma	0.5	0.5	1	1	2		0	0		0	0		0	0	140	126.32312	135.29111		0	0	127.32312	136.29111	
	Solar	0.1516320	0.1651320	0.7581602	0.8256603	5		0	0		0	0		0	0	-222.6	-200.8537	-215.1128		0	0	-200.0956	-214.2872	

4.2 Taipower Projections - 100% Nuclear Availability Scenario

	Wind	0.2814357	0.2177241	5.9101512	4.5722062	21		0	0		0	0		0	0		0	0		0	0	5.9101512	4.5722062	
																						-80.64616	-88.35365	
																						3447.3659	3659.5958	4230.1
114	Geotherma	0.5	0.5	0.9	0.9	1.8	60	54.138483	57.981907		0	0	-14	-12.63231	-13.52911	79.2	71.462798	76.536118	-95.1	-85.80949	-91.90132	28.059472	29.987590	
	Wind	0.2814357	0.2177241	0.5628715	0.4354482	2		0	0		0	0		0	0	180	162.41545	173.94572		0	0	162.97832	174.38117	
	Wind	0.2814357	0.2177241	5.9101512	4.5722062	21		0	0		0	0		0	0		0	0		0	0	5.9101512	4.5722062	
								0	0		0	0		0	0	90	81.207725	86.972861		0	0	81.207725	86.972861	
								0	0		0	0		0	0	90	81.207725	86.972861		0	0	81.207725	86.972861	
								0	0		0	0		0	0		0	0		0	0	0	0	
								0	0	-100	-90.23080	-96.63651		0	0		0	0		0	0	-90.23080	-96.63651	
																						269.13259	286.25017	
																						3716.4985	3945.8459	4545
115	Wind	0.2814357	0.2177241	0.8443073	0.6531723	3	-100	-90.23080	-96.63651		0	0		0	0	90	81.207725	86.972861		0	0	-8.178773	-9.010478	
	Solar	0.1516320	0.1651320	0.7581602	0.8256603	5		0	0		0	0		0	0		0	0		0	0	0.7581602	0.8256603	
	Wind	0.2814357	0.2177241	3.9401008	3.0481375	14	60	54.138483	57.981907		0	0		0	0		0	0		0	0	58.078584	61.030045	
	Wind	0.2814357	0.2177241	5.1221310	3.9625787	18.2		0	0		0	0		0	0	180	162.41545	173.94572		0	0	167.53758	177.90830	
								0	0		0	0		0	0	180	162.41545	173.94572		0	0	162.41545	173.94572	
																						380.61100	404.69925	
																						4097.1095	4350.5452	4995.2
116	Solar	0.1516320	0.1651320	0.1516320	0.1651320	1	-110	-99.25388	-106.3001		0	0		0	0	90	81.207725	86.972861		0	0	-17.89452	-19.16217	
	Solar	0.1516320	0.1651320	1.5163204	1.6513206	10		0	0		0	0		0	0		0	0		0	0	1.5163204	1.6513206	
																						-16.37820	-17.51084	
																						4080.7313	4333.0343	4986.2
Net Increase (all sources)																								
5012.1						852	1379.7			57.5						2722.9			0					

						July	0.9663651316			0.9452181818			0.9690826474			0.9897214445			1					
年 (民國)						Yearlong	0.9023080592			0.4035477273			0.9199788506			0.8989075716			1			TOTAL		
						Renewables	煤			Oil	Yearlong AIA	July AIA	Diesel	Yearlong AIA	July AIA	氣	Yearlong AIA	July AIA	Nukes	Yearlong AIA	July AIA	Yearlong AIA	JULY AIA	
104*2		Yearly CF	July CF	Yearly AIG	July AIG	662.5	1069.7	Yearlong AIA	July AIA	332.5	300.0174297	321.3164063		0	0	1524.5	1375.568636	1473.223643	514.4	464.1472657	497.0982237	3,910.74	3,622.75	4103.6
105							80	72.18464474	77.30921053	-75	-67.67310444	-72.47738487		0	0	-76.4	-68.93633572	-73.83029605		0	0	-64.42479543	-68.9984704	
								0	0		0	0		0	0		0	0		0	0	0	0	
								0	0		0	0		0	0		0	0		0	0	0	0	
																						-64.42479543	-68.9984704	
																						3846.319774	3553.750254	4032.2
106	Wind	0.2814357739	0.2177241074	0.4221536609	0.3265861611	1.5	80	72.18464474	77.30921053	-100	-90.23080592	-96.63651316		0	0	89.3	80.57610969	86.29640625		0	0	62.95210216	67.29568978	
								0	0		0	0		0	0		0	0		0	0	0	0	
								0	0		0	0		0	0		0	0		0	0	0	0	
																						62.95210216	67.29568978	
																						3909.271876	3621.045943	4103
107	Wind	0.2814357739	0.2177241074	0.506584393	0.3919033933	1.8	160	144.3692895	154.6184211		0	0		0	0	-50	-45.11540296	-48.31825658	-63.6	-57.38679257	-61.46082237	42.37367834	45.2312455	
								0	0		0	0		0	0		0	0		0	0	0	0	
																						42.37367834	45.2312455	
																						3951.645554	3666.277189	4151.2
108	Solar	0.1516320495	0.1651320661	0.2729376891	0.297237719	1.8	80	72.18464474	77.30921053		0	0	2.1	1.894846924	2.029366776		0	0	-63.6	-57.38679257	-61.46082237	16.96563678	18.17499265	
	Solar	0.1516320495	0.1651320661	1.455667675	1.585267835	9.6		0	0		0	0		0	0		0	0		0	0	1.455667675	1.585267835	
																						18.42130446	19.76026049	
																						3970.066859	3686.037449	4181.1
109	Wind	0.2814357739	0.2177241074	1.547896756	1.197482591	5.5		0	0		0	0	-14	-12.63231283	-13.52911184	178.5	161.0619886	172.496176		0	0	149.9775725	160.1645467	
	Geothermal	0.5	0.5	0.1	0.1	0.2		0	0		0	0		0	0		0	0		0	0	0.1	0.1	
	Conv Hyrdro	0.8379462678	0.8932876396	0.3351785071	0.3573150558	0.4		0	0		0	0		0	0	-77.2	-69.65818217	-74.60338816		0	0	-69.32300366	-74.2460731	
	Wind	0.2814357739	0.2177241074	0.506584393	0.3919033933	1.8		0	0		0	0		0	0		0	0		0	0	0.506584393	0.3919033933	
	Solar	0.1516320495	0.1651320661	1.607299725	1.750399901	10.6		0	0		0	0		0	0		0	0		0	0	1.607299725	1.750399901	
																						82.86845295	88.16077693	
																						4052.935311	3774.198226	4286.9
110	Wind	0.2814357739	0.2177241074	1.547896756	1.197482591	5.5		0	0		0	0		0	0		0	0	-98.5	-88.87734383	-95.18696546	-87.32944707	-93.98948287	
	Conv Hyrdro	0.8379462678	0.8932876396	0.1675892536	0.1786575279	0.2		0	0		0	0		0	0		0	0		0	0	0.1675892536	0.1786575279	
	Wind	0.2814357739	0.2177241074	0.64730228	0.500765447	2.3		0	0		0	0		0	0		0	0		0	0	0.64730228	0.500765447	
																						-86.51455554	-93.3100599	
																						3966.420756	3680.888166	4196.4
111	Hydro	0.8379462678	0.8932876396	0.5865623875	0.6253013477	0.7		0	0		0	0		0	0	79.2	71.46279829	76.53611842		0	0	72.04936068	77.16141977	
	Wind	0.2814357739	0.2177241074	0.64730228	0.500765447	2.3		0	0		0	0		0	0		0	0		0	0	0.64730228	0.500765447	
	Solar	0.1516320495	0.1651320661	0.7581602475	0.8256603305	5		0	0		0	0		0	0		0	0		0	0	0.7581602475	0.8256603305	
																						73.4548232	78.48784555	
																						4039.875579	3759.376012	4283.6
112	Geothermal	0.5	0.5	0.5	0.5	1		0	0		0	0		0	0	79.2	71.46279829	76.53611842	-98.5	-88.87734383	-95.18696546	-16.91454554	-18.15084704	
	Wind	0.2814357739	0.2177241074	0.64730228	0.500765447	2.3		0	0		0	0		0	0		0	0		0	0	0.64730228	0.500765447	
	Solar	0.1516320495	0.1651320661	1.516320495	1.651320661	10		0	0		0	0		0	0		0	0		0	0	1.516320495	1.651320661	
	Wind	0.2814357739	0.2177241074	5.910151252	4.572206255	21		0	0		0	0		0	0		0	0		0	0	5.910151252	4.572206255	
																						-8.840771516	-11.42655468	
																						4031.034808	3747.949457	4298.6
113	Wind	0.2814357739	0.2177241074	0.5628715478	0.4354482148	2		0	0		0	0		0	0	79.2	71.46279829	76.53611842	-95.1	-85.80949643	-91.90132402	-13.78382659	-14.92975738	
	Geothermal	0.5	0.5	1	1	2		0	0		0	0		0	0	140	126.3231283	135.2911184		0	0	127.3231283	136.2911184	
	Solar	0.1516320495	0.1651320661	0.7581602475	0.8256603305	5		0	0		0	0		0	0	-222.6	-200.853774	-215.1128783		0	0	-200.0956137	-214.287218	
	Wind	0.2814357739	0.2177241074	5.910151252	4.572206255	21		0	0		0	0		0	0		0	0		0	0	5.910151252	4.572206255	
																						-80.64616078	-88.35365066	
																						3950.388647	3659.595807	4230.1
114	Geothermal	0.5	0.5	0.9	0.9	1.8	60	54.13848355	57.9819079		0	0	-14	-12.63231283	-13.52911184	79.2	71.46279829	76.53611842	-95.1	-85.80949643	-91.90132402	28.05947258	29.98759046	
	Wind	0.2814357739	0.2177241074	0.5628715478	0.4354482148	2		0	0		0	0		0	0	180	162.4154507	173.9457237		0	0	162.9783222	174.3811719	
	Wind	0.2814357739	0.2177241074	5.910151252	4.572206255	21		0	0		0	0		0	0		0	0		0	0	5.910151252	4.572206255	
								0	0		0	0		0	0	90	81.20772533	86.97286184		0	0	81.20772533	86.97286184	
								0	0		0	0		0	0	90	81.20772533	86.97286184		0	0	81.20772533	86.97286184	
								0	0		0	0		0	0		0	0		0	0	0	0	
								0	0	-100	-90.23080592	-96.63651316		0	0		0	0		0	0	-90.23080592	-96.63651316	

																						269.1325908	286.2501791	
																						4219.521238	3945.845986	4545
115	Wind	0.2814357739	0.2177241074	0.8443073217	0.6531723222	3	-100	-90.23080592	-96.63651316		0	0		0	0	90	81.20772533	86.97286184		0	0	-8.17877327	-9.010478994	
	Solar	0.1516320495	0.1651320661	0.7581602475	0.8256603305	5		0	0		0	0		0	0		0	0		0	0	0.7581602475	0.8256603305	
	Wind	0.2814357739	0.2177241074	3.940100835	3.048137504	14	60	54.13848355	57.9819079		0	0		0	0		0	0		0	0	58.07858439	61.0300454	
	Wind	0.2814357739	0.2177241074	5.122131085	3.962578755	18.2		0	0		0	0		0	0	180	162.4154507	173.9457237		0	0	167.5375817	177.9083024	
								0	0		0	0		0	0	180	162.4154507	173.9457237		0	0	162.4154507	173.9457237	
																						380.6110038	404.6992529	
																						4600.132241	4350.545239	4995.2
116	Solar	0.1516320495	0.1651320661	0.1516320495	0.1651320661	1	-110	-99.25388651	-106.3001645		0	0		0	0	90	81.20772533	86.97286184		0	0	-17.89452913	-19.16217057	
	Solar	0.1516320495	0.1651320661	1.516320495	1.651320661	10		0	0		0	0		0	0		0	0		0	0	1.516320495	1.651320661	
																						-16.37820864	-17.5108499	
																						4583.754033	4333.034389	4986.2
Net Total:	5012.1					852	1379.7			57.5						2722.9			0					

4.3 MOEA Projections

Original Spreadsheet taken from MOEA National long-term load forecasting and Power Development Plan Summary Report
AIA/AIG calculated by author
表 3-7　民國 102 ~ 112 年情境二長期電源開發方案
單位：萬瓩

年	尖峰負載	計畫名稱	商轉月 (月初)	能源類別	Specific Source	Yearly AF (CF f	July AF (CF)	裝置容量 增減	年底合計	淨尖峰能力 增減	七月初合計	YEARLY A Effect on ye	JULY Effect on July	AIA/AIG calcu	AIA/AIG (JULY) (10MW)	備用容量率 (%)
102	3,395.70								4,118.20		3,990.90					17.50%
103	3,482.10	外購太陽光電(民)	1~7	Renewable Ene	Solar IPP	0.1140251948	Solar IPP	8.5	4,092.20	1.7	3,995.10					14.70%
		台中#3 增加出力	1	Coal	Coal	0.9023080592	0.9663651316	0		1.29						
		苗栗通苑、竹威風力(民)	27	Renewable Ene	Wind IPP	0.2463331851	Wind IPP	1.84		0.11						
		通霄 CCGT#4 增加出力	6	LNG	LNG	0.8989075716	0.9897214445	2.8		2.74						
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		-1.32						
		(林口#1,#2 退休)	9	Coal	Coal	0.9023080592	0.9663651316	-60		-48.2						
		太陽光電一期(龍井 I 等)	12	Renewable Ene	Solar	0.1516320495	0.1651320661	0.5		0.1						
		再生能源規劃增量	12	Renewable Ene	Renewable Ene	Renewable Ene	Renewable Ener	13.1		1.27						
		再生能源規劃增量11	12	Renewable Ene	Renewable Ene	Renewable Ene	Renewable Ener	2.7		1.05						
104	3,602.60	陸域風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	10	4,051.40	0.6	3,975.00			3,407.72		10.30%
		離岸風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	1.5		0.09						
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	24		4.8						
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.2		0.1						
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.15		0.1						
		核二提升出力 3.6*10MW	1	Nuclear	Nuclear	0.5389028784	0.4401324945	0		3.6					3,622.75	
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		6.81			6.81			
		(台東蘭嶼#3~4 退休)	10	Diesel	Diesel	0.9199788506	0.9690826474	-0.1		-0.08			-0.10			
		(通霄 cc#1~#3 退休)	11	LNG	LNG	0.8989075716	0.9897214445	-76.38		-74.85			-75.59			
		(東引#4 退休)	12	Diesel	Diesel	0.9199788506	0.9690826474	-0.03		-0.01			-0.03			
		(南竿#5 退休)	12	Diesel	Diesel	0.9199788506	0.9690826474	-0.11		-0.06			-0.11			
													-69.02		3,553.73	
105	3,732.20	陸域風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	10	4,122.00	0.6	3,982.30	2.81	2.18			6.70%
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	24.8		4.96		3.76	4.10			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	0.3		0.15		0.15	0.15			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.2		0.1		0.10	0.10			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.2		0.13		0.13	0.13			
		林口新#1	1	Coal	Coal	0.9023080592	0.9663651316	80		75.2		72.18	77.31			
		青山復建容量調整	1	Renewable Ene	Hydro (Adjustm	0.8379462678	0.8379462678	0.8		36.8		0.67	0.67			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		8.61		8.61	8.61			
		(大林#3~4 退休)	7	Oil	Oil	0.4035477273	0.9452181818	-75		-71.12		-30.27	-70.89			
		(大林#5 退休)	7	LNG	LNG	0.8989075716	0.9897214445	-50		-48.3		-44.95	-49.49			
		大林新#1	7	Coal	Coal	0.9023080592	0.9663651316	80		75.2		72.18	77.31			
		東引#6 新增	12	Diesel	Diesel	0.9199788506	0.9690826474	0.15		0.13		0.14	0.15			
												85.53	50.32	3,493.25	3,604.05	
106	3,846.00	陸域風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	10	4,309.10	0.6	4,144.40	2.81	2.18			7.80%
		慣常水力增量	1	Renewable Ene	Conv Hydro	0.8379462678	0.8932876396	0.1		0.05		0.08	0.09			
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	25		5		3.79	4.13			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	0.4		0.2		0.20	0.20			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.25		0.13		0.13	0.13			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.2		0.13		0.13	0.13			
		林口新#2	1	Coal	Coal	0.9023080592	0.9663651316	80		75.2		72.18	77.31			
		東引#7 新增	6	Diesel	Diesel	0.9199788506	0.9690826474	0.15		0.13		0.14	0.15			
		台東蘭嶼#3~4 更新	6	Diesel	Diesel	0.9199788506	0.9690826474	0.3		0.26		0.28	0.29			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		5.02		5.02	5.02			
		大林新#2	7	Coal	Coal	0.9023080592	0.9663651316	80		75.2		72.18	77.31			
		(台東綠島#3~4 退休)	10	Diesel	Diesel	0.9199788506	0.9690826474	-0.1		-0.08		-0.09	-0.10			
		通霄新 cc#1	10	LNG	LNG	0.8989075716	0.9897214445	89.26		87.47		80.24	88.34			
		(協和#1~2 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-100		-97		-40.35	-94.52			
		(西莒#5 退休)	12	Diesel	Diesel	0.9199788506	0.9690826474	-0.05		-0.04		-0.05	-0.05			
		南竿珠山#5~6 新增	12	Oil	Oil	0.4035477273	0.9452181818	0.77		0.65		0.31	0.73			
												197.01	161.33	3,690.26	3,765.38	

11欲達 103 年再生能源目標，則當年度陸域風力需新增 100MW、太陽光電 210MW、地熱能發電 1MW、及生質物發電 1MW，由於台電 10302 無核四案無說明 7 月新增之再生能源規劃種類及容量，故本研究於僅於表中 103 年 12 月補足剩餘之裝置容量與淨尖峰能力。

表 3-7　民國 102 ~ 112 年情境二長期電源開發方案（續 1）
單位：萬瓩

年	尖峰負載	計畫名稱	商轉月(月初)	能源類別	能源類別	能源類別	能源類別	裝置容量		淨尖峰能力		#VALUE!				備用容量率(%)
								增減	年底合計	增減	七月初合計	#VALUE!				
107	3,943.50	陸域風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	8	4,280.70	0.48	4,145.70	2.25	1.74			5.10%
		慣常水力增量	1	Renewable Ene	0.2547097071	0.8379462678	0.2547097071	0.2		0.1		0.17	0.05			
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	25		5		3.79	4.13			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	1.5		0.75		0.75	0.75			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.25		0.13		0.13	0.13			
		廢棄物發電增量	1	Renewable Ene	Renewable Ene	Renewable Ene	Renewable Ener	0.2		0.13		0.13	0.13			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		3.7		3.70	3.70			
		(核一#1 退休)	12	Nuclear	Nuclear	0.5389028784	0.4401324945	-63.6		-61.89		-34.27	-27.99			
		(核一#1 全黑氣渦輪退休)	12	Diesel	Diesel	0.9199788506	0.9690826474	0		-3.82		0.00	0.00			
												-23.35	-17.36	3,666.91	3,748.02	
108	4,017.70	陸域風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	7	4,531.40	0.42	4,189.00	1.97	1.52			4.30%
		離岸風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	20.5		1.23		5.77	4.46			
		慣常水力增量	1	Renewable Ene	Conv Hydro	0.8379462678	0.8932876396	0.4		0.19		0.34	0.36			
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	26		5.2		3.94	4.29			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	1.3		0.65		0.65	0.65			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.25		0.13		0.13	0.13			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.2		0.13		0.13	0.13			
		通霄新 cc#2	4	LNG	LNG	0.8989075716	0.9897214445	89.26		87.47		80.24	88.34			
		台東綠島#3~4 更新	6	Diesel	Diesel	0.9199788506	0.9690826474	0.2		0.17		0.18	0.19			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		4.05		4.05	4.05			
		(核一#2 退休)	7	Nuclear	Nuclear	0.5389028784	0.4401324945	-63.6		-61.99		-34.27	-27.99			
		(核一#2 全黑氣渦輪退休)	7	Diesel	Diesel	0.9199788506	0.9690826474	0		-3.82		0.00	0.00			
		林口新#3	7	Coal	Coal	0.9023080592	0.9663651316	80		75.2		72.18	77.31			
		通霄新 cc#3	10	LNG	LNG	0.8989075716	0.9897214445	89.26		87.47		80.24	88.34			
												215.54	241.79	3,882.45	3,989.82	
109	4,084.80	陸域風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	3.6	4,478.50	0.22	4,289.70	1.01	0.78			5.00%
		離岸風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	10		0.6		2.81	2.18			
		慣常水力增量	1	Renewable Ene	Conv Hydro	0.8379462678	0.8932876396	0.4		0.19		0.34	0.36			
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	27		5.4		4.09	4.46			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	3		1.5		1.50	1.50			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.25		0.13		0.13	0.13			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.3		0.2		0.20	0.20			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		4.96		4.96	4.96			
		(尖山#1~3 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-3.13		-2.4		-1.26	-2.96			
		(塔山#1~4 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-3.16		-2.48		-1.28	-2.99			
		(台中氣渦輪#1,4 退休)	11	Diesel	Diesel	0.9199788506	0.9690826474	-14		-13.94		-12.88	-13.57			
		(通霄 cc#4~#5 退休)	11	LNG	LNG	0.8989075716	0.9897214445	-77.2		-75.65		-69.40	-76.41			
												-69.77	-81.35	3,882.45	3,908.46	
110	4,148.20	離岸風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	10	4,968.00	0.6	4,738.60	2.81	2.18			14.20%
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	35		7		5.31	5.78			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	1.4		0.7		0.70	0.70			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.31		0.16		0.16	0.16			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.3		0.2		0.20	0.20			
		新複循環機組#1~6(北*5+南*1)	1	LNG	LNG	0.8989075716	0.9897214445	540		529.2		485.41	534.45			
		塔山#9 新增	4	Oil	Oil	0.4035477273	0.9452181818	1		0.85		0.40	0.95			
		塔山#10 新增	7	Oil	Oil	0.4035477273	0.9452181818	1		0.85		0.40	0.95			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		3.83		3.83	3.83			
		(尖山#4 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-1.04		-0.8		-0.42	-0.98			
		(核二#1 退休)	12	Nuclear	Nuclear	0.5389028784	0.4401324945	-98.5		-98.84		-53.08	-43.35			
		(核二#1 全黑氣渦輪退休)	12	Diesel	Diesel	0.9199788506	0.9690826474	0		-3.92		-3.92	-3.92			
												441.81	500.93	4,324.26	4,409.39	

表 3-7　民國 102～112 年情境二長期電源開發方案（續 2）

單位：萬瓩

年	尖峰負載	計畫名稱	商轉月(月初)	能源類別	能源類別	能源類別	能源類別	裝置容量		淨尖峰能力		#VALUE!				備用容量率(%)
								增減	年底合計	增減	七月初合計	#VALUE!				
111	4,209.10	離岸風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	20	5,202.70	1.2	4,826.20	5.63	4.35			14.70%
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	37		7.4		5.61	6.11			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	1.6		0.8		0.80	0.80			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.31		0.16		0.16	0.16			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.4		0.26		0.26	0.26			
		新複循環機組#7~8(北*1+南*1)	1	LNG	LNG	0.8989075716	0.9897214445	180		176.4		161.80	178.15			

		塔山#11 新增	4	Oil	Oil	0.4035477273	0.9452181818	1		0.85		0.40	0.95			
		塔山#12 新增	7	Oil	Oil	0.4035477273	0.9452181818	1		0.85		0.40	0.95			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		3.22		3.22	3.22			
		(尖山#5~10 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-6.6		-5.92		-2.66	-6.24			
												175.63	188.71	4,499.88	4,598.10	
112	4,264.80	金門發電機組新增	1	Oil	Oil	0.4035477273	0.9452181818	4.9	5,297.60	4.17	4,912.60	1.98	4.63			15.20%
		離岸風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	30		1.8		8.44	6.53			
		慣常水力增量	1	Renewable Ene	Conv Hydro	0.8379462678	0.8932876396	0.1		0.05		0.08	0.09			
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	39		7.8		5.91	6.44			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	1.9		0.95		0.95	0.95			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.31		0.16		0.16	0.16			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.3		0.2		0.20	0.20			
		新複循環機組#9~10(北*2)	1	LNG	LNG	0.8989075716	0.9897214445	180		176.4		161.80	178.15			
		(核二#2 退休)	3	Nuclear	Nuclear	0.5389028784	0.4401324945	-98.5		-98.92		-53.08	-43.35			
		(核二#2 全黑氣渦輪退休)	3	Diesel	Diesel	0.9199788506	0.9690826474	0		-3.92		0.00	0.00			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		3.67		3.67	3.67			
		(尖山#5~10 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-2.2		-1.97		-0.89	-2.08			
		(塔山#5~8 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-3.3		-2.59		-1.33	-3.12			
		(南部 cc#1~2 退休)	11	LNG	LNG	0.8989075716	0.9897214445	-57.76		-54.6		-51.92	-57.17			
		東引#8 新增	12	Diesel	Diesel	0.9199788506	0.9690826474	0.15		0.13		0.14	0.15			
												76.12	95.25	4,576.00	4,693.35	

資料來源：台電公司電源開發處及本研究整理。

MOEA Projecitons - 100% Nuclear Availability Scenario

表 3-7　民國 102～112 年情境二長期電源開發方案

單位：萬瓩

年	尖峰負載	計畫名稱	商轉月 (月初)	能源類別	Specific Source	Yearly AF (CF)	July AF (CF)	裝置容量		淨尖峰能力		YEARLY A	JULY			備用容量率 (%)
								增減	年底合計	增減	七月初合計	Effect on ye	Effect on July	AIA/AIG calcu	AIA/AIG (JULY) (10MW)	
102	3,395.70								4,118.20		3,990.90					17.50%
103	3,482.10	外購太陽光電(民)	1~7	Renewable Ene	Solar IPP	0.1140251948	0.1465205733	8.5	4,092.20	1.7	3,995.10					14.70%
		台中#3 增加出力	1	Coal	Coal	0.9023080592	0.9663651316	0		1.29						
		苗栗通苑、竹威風力(民)	27	Renewable Ene	Wind IPP	0.2463331851	0.1827101857	1.84		0.11						
		通霄 CCGT#4 增加出力	6	LNG	LNG	0.8989075716	0.9897214445	2.8		2.74						
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		-1.32						
		(林口#1,#2 退休)	9	Coal	Coal	0.9023080592	0.9663651316	-60		-48.2						
		太陽光電一期(龍井 I 等)	12	Renewable Ene	Solar	0.1516320495	0.1651320661	0.5		0.1						
		再生能源規劃增量	12	Renewable Ene	Renewable Ene	Renewable Ene	Renewable Ene	13.1		1.27						
		再生能源規劃增量11	12	Renewable Ene	Renewable Ene	Renewable Ene	Renewable Ene	2.7		1.05						
104	3,602.60	陸域風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	10	4,051.40	0.6	3,975.00			3,407.72		10.30%
		離岸風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	1.5		0.09						
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	24		4.8						
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.2		0.1						
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.15		0.1						
		核二提升出力 3.6*10MW	1	Nuclear	Nuclear	0.5389028784	0.4401324945	0		3.6					3,622.75	
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		6.81			6.81			
		(台東蘭嶼#3~4 退休)	10	Diesel	Diesel	0.9199788506	0.9690826474	-0.1		-0.08			-0.10			
		(通霄 cc#1~#3 退休)	11	LNG	LNG	0.8989075716	0.9897214445	-76.38		-74.85			-75.59			
		(東引#4 退休)	12	Diesel	Diesel	0.9199788506	0.9690826474	-0.03		-0.01			-0.03			
		(南竿#5 退休)	12	Diesel	Diesel	0.9199788506	0.9690826474	-0.11		-0.06			-0.11			
													-69.02		3,553.73	
105	3,732.20	陸域風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	10	4,122.00	0.6	3,982.30	2.81	2.18			6.70%
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	24.8		4.96		3.76	4.10			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	0.3		0.15		0.15	0.15			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.2		0.1		0.10	0.10			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.2		0.13		0.13	0.13			
		林口新#1	1	Coal	Coal	0.9023080592	0.9663651316	80		75.2		72.18	77.31			
		青山復建容量調整	1	Renewable Ene	Hydro (Adjustm	0.8379462678	0.8379462678	0.8		36.8		0.67	0.67			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		8.61		8.61	8.61			
		(大林#3~4 退休)	7	Oil	Oil	0.4035477273	0.9452181818	-75		-71.12		-30.27	-70.89			
		(大林#5 退休)	7	LNG	LNG	0.8989075716	0.9897214445	-50		-48.3		-44.95	-49.49			
		大林新#1	7	Coal	Coal	0.9023080592	0.9663651316	80		75.2		72.18	77.31			
		東引#6 新增	12	Diesel	Diesel	0.9199788506	0.9690826474	0.15		0.13		0.14	0.15			
												85.53	50.32	3,493.25	3,604.05	
106	3,846.00	陸域風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	10	4,309.10	0.6	4,144.40	2.81	2.18			7.80%
		慣常水力增量	1	Renewable Ene	Conv Hydro	0.8379462678	0.8932876396	0.1		0.05		0.08	0.09			
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	25		5		3.79	4.13			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	0.4		0.2		0.20	0.20			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.25		0.13		0.13	0.13			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.2		0.13		0.13	0.13			
		林口新#2	1	Coal	Coal	0.9023080592	0.9663651316	80		75.2		72.18	77.31			
		東引#7 新增	6	Diesel	Diesel	0.9199788506	0.9690826474	0.15		0.13		0.14	0.15			
		台東蘭嶼#3~4 更新	6	Diesel	Diesel	0.9199788506	0.9690826474	0.3		0.26		0.28	0.29			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		5.02		5.02	5.02			
		大林新#2	7	Coal	Coal	0.9023080592	0.9663651316	80		75.2		72.18	77.31			
		(台東綠島#3~4 退休)	10	Diesel	Diesel	0.9199788506	0.9690826474	-0.1		-0.08		-0.09	-0.10			
		通霄新 cc#1	10	LNG	LNG	0.8989075716	0.9897214445	89.26		87.47		80.24	88.34			
		(協和#1~2 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-100		-97		-40.35	-94.52			
		(西莒#5 退休)	12	Diesel	Diesel	0.9199788506	0.9690826474	-0.05		-0.04		-0.05	-0.05			
		南竿珠山#5~6 新增	12	Oil	Oil	0.4035477273	0.9452181818	0.77		0.65		0.31	0.73			
												197.01	161.33	3,690.26	3,765.38	

11欲達 103 年再生能源目標，則當年度陸域風力需新增 100MW、太陽光電 210MW、地熱能發電 1MW、及生質物發電 1MW，由於台電 10302 無核四案無說明 7 月新增之再生能源規劃種類及容量，故本研究於僅於表中 103 年 12 月補足剩餘之裝置容量與淨尖峰能力。

表 3-7　民國 102～112 年情境二長期電源開發方案（續 1）

單位：萬瓩

年	尖峰負載	計畫名稱	商轉月 (月初)	能源類別	能源類別	能源類別	能源類別	裝置容量		淨尖峰能力		#VALUE!		備用容量率 (%)
								增減	年底合計	增減	七月初合計	#VALUE!		
107	3,943.50	陸域風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	8	4,280.70	0.48	4,145.70	2.25	1.74	5.10%
		慣常水力增量	1	Renewable Ene	0.2547097071	0.8379462678	0.2547097071	0.2		0.1		0.17	0.05	

		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	25		5		3.79	4.13			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	1.5		0.75		0.75	0.75			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.25		0.13		0.13	0.13			
		廢棄物發電增量	1	Renewable Ene	Renewable Ene	Renewable Ene	Renewable Ene	0.2		0.13		0.13	0.13			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		3.7		3.70	3.70			
		(核一#1 退休)	12	Nuclear	Nuclear	0.5389028784	0.4401324945	-63.6		-61.89		-34.27	-27.99			
		(核一#1 全黑氣渦輪退休)	12	Diesel	Diesel	0.9199788506	0.9690826474	0		-3.82		0.00	0.00			
												-23.35	-17.36	3,666.91	3,748.02	
108	4,017.70	陸域風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	7	4,531.40	0.42	4,189.00	1.97	1.52			4.30%
		離岸風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	20.5		1.23		5.77	4.46			
		慣常水力增量	1	Renewable Ene	Conv Hydro	0.8379462678	0.8932876396	0.4		0.19		0.34	0.36			
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	26		5.2		3.94	4.29			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	1.3		0.65		0.65	0.65			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.25		0.13		0.13	0.13			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.2		0.13		0.13	0.13			
		通霄新 cc#2	4	LNG	LNG	0.8989075716	0.9897214445	89.26		87.47		80.24	88.34			
		台東綠島#3~4 更新	6	Diesel	Diesel	0.9199788506	0.9690826474	0.2		0.17		0.18	0.19			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		4.05		4.05	4.05			
		(核一#2 退休)	7	Nuclear	Nuclear	0.5389028784	0.4401324945	-63.6		-61.99		-34.27	-27.99			
		(核一#2 全黑氣渦輪退休)	7	Diesel	Diesel	0.9199788506	0.9690826474	0		-3.82		0.00	0.00			
		林口新#3	7	Coal	Coal	0.9023080592	0.9663651316	80		75.2		72.18	77.31			
		通霄新 cc#3	10	LNG	LNG	0.8989075716	0.9897214445	89.26		87.47		80.24	88.34			
												215.54	241.79	3,882.45	3,989.82	
109	4,084.80	陸域風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	3.6	4,478.50	0.22	4,289.70	1.01	0.78			5.00%
		離岸風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	10		0.6		2.81	2.18			
		慣常水力增量	1	Renewable Ene	Conv Hydro	0.8379462678	0.8932876396	0.4		0.19		0.34	0.36			
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	27		5.4		4.09	4.46			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	3		1.5		1.50	1.50			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.25		0.13		0.13	0.13			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.3		0.2		0.20	0.20			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		4.96		4.96	4.96			
		(尖山#1~3 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-3.13		-2.4		-1.26	-2.96			
		(塔山#1~4 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-3.16		-2.48		-1.28	-2.99			
		(台中氣渦輪#1,4 退休)	11	Diesel	Diesel	0.9199788506	0.9690826474	-14		-13.94		-12.88	-13.57			
		(通霄 cc#4~#5 退休)	11	LNG	LNG	0.8989075716	0.9897214445	-77.2		-75.65		-69.40	-76.41			
												-69.77	-81.35	3,882.45	3,908.46	
110	4,148.20	離岸風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	10	4,968.00	0.6	4,738.60	2.81	2.18			14.20%
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	35		7		5.31	5.78			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	1.4		0.7		0.70	0.70			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.31		0.16		0.16	0.16			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.3		0.2		0.20	0.20			
		新複循環機組#1~6(北*5+南*1)	1	LNG	LNG	0.8989075716	0.9897214445	540		529.2		485.41	534.45			
		塔山#9 新增	4	Oil	Oil	0.4035477273	0.9452181818	1		0.85		0.40	0.95			
		塔山#10 新增	7	Oil	Oil	0.4035477273	0.9452181818	1		0.85		0.40	0.95			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		3.83		3.83	3.83			
		(尖山#4 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-1.04		-0.8		-0.42	-0.98			
		(核二#1 退休)	12	Nuclear	Nuclear	0.5389028784	0.4401324945	-98.5		-98.84		-53.08	-43.35			
		(核二#1 全黑氣渦輪退休)	12	Diesel	Diesel	0.9199788506	0.9690826474	0		-3.92		-3.92	-3.92			
												441.81	500.93	4,324.26	4,409.39	

表 3-7　民國 102～112 年情境二長期電源開發方案（續 2）

單位：萬瓩

年	尖峰負載	計畫名稱	商轉月 (月初)	能源類別	能源類別	能源類別	能源類別	裝置容量		淨尖峰能力		#VALUE!				備用容量率 (%)
								增減	年底合計	增減	七月初合計	#VALUE!				
111	4,209.10	離岸風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	20	5,202.70	1.2	4,826.20	5.63	4.35			14.70%
		太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	37		7.4		5.61	6.11			
		地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	1.6		0.8		0.80	0.80			
		生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.31		0.16		0.16	0.16			
		廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.4		0.26		0.26	0.26			
		新複循環機組#7~8(北*1+南*1)	1	LNG	LNG	0.8989075716	0.9897214445	180		176.4		161.80	178.15			
		塔山#11 新增	4	Oil	Oil	0.4035477273	0.9452181818	1		0.85		0.40	0.95			
		塔山#12 新增	7	Oil	Oil	0.4035477273	0.9452181818	1		0.85		0.40	0.95			
		汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		3.22		3.22	3.22			
		(尖山#5~10 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-6.6		-5.92		-2.66	-6.24			
												175.63	188.71	4,499.88	4,598.10	
112	4,264.80	金門發電機組新增	1	Oil	Oil	0.4035477273	0.9452181818	4.9	5,297.60	4.17	4,912.60	1.98	4.63			15.20%
		離岸風力增量	1	Renewable Ene	Wind	0.2814357739	0.2177241074	30		1.8		8.44	6.53			

慣常水力增量	1	Renewable Ene	Conv Hydro	0.8379462678	0.8932876396	0.1		0.05		0.08	0.09		
太陽光電增量	1	Renewable Ene	Solar	0.1516320495	0.1651320661	39		7.8		5.91	6.44		
地熱能增量	1	Renewable Ene	Geothermal	Geothermal	Geothermal	1.9		0.95		0.95	0.95		
生質物發電增量	1	Renewable Ene	Biomass	Biomass	Biomass	0.31		0.16		0.16	0.16		
廢棄物發電增量	1	Renewable Ene	Waste	Waste	Waste	0.3		0.2		0.20	0.20		
新複循環機組#9~10(北*2)	1	LNG	LNG	0.8989075716	0.9897214445	180		176.4		161.80	178.15		
(核二#2 退休)	3	Nuclear	Nuclear	0.5389028784	0.4401324945	-98.5		-98.92		-53.08	-43.35		
(核二#2 全黑氣渦輪退休)	3	Diesel	Diesel	0.9199788506	0.9690826474	0		-3.92		0.00	0.00		
汽電共生尖峰保證容量增量	7	Coal	Cogen	Cogen	Cogen	0		3.67		3.67	3.67		
(尖山#5~10 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-2.2		-1.97		-0.89	-2.08		
(塔山#5~8 退休)	11	Oil	Oil	0.4035477273	0.9452181818	-3.3		-2.59		-1.33	-3.12		
(南部 cc#1~2 退休)	11	LNG	LNG	0.8989075716	0.9897214445	-57.76		-54.6		-51.92	-57.17		
東引#8 新增	12	Diesel	Diesel	0.9199788506	0.9690826474	0.15		0.13		0.14	0.15		
										76.12	95.25	4,576.00	4,693.35

資料來源：台電公司電源開發處及本研究整理。

	2015	2016	2017	2018	2019	2020	2021	2022	2023
MOEA Peak De	3,602.60	3,732.20	3,846.00	3,943.50	4,017.70	4,084.80	4,148.20	4,209.10	4,264.80
MOEA Installed	4,051.40	4,122.00	4,309.10	4,280.70	4,531.40	4,478.50	4,968.00	5,202.70	5,297.60
AIA Yearly	3,407.72	3,493.25	3,690.26	3,666.91	3,882.45	3,882.45	4,324.26	4,499.88	4,576.00
AIA July	3,553.73	3,604.05	3,765.38	3,748.02	3,989.82	3,908.46	4,409.39	4,598.10	4,693.35
MOEA July Pea	3,975.00	3,982.30	4,144.40	4,145.70	4,189.00	4,289.70	4,738.60	4,826.20	4,912.60