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Integration of Energy from Intermittent Renewable Power Plants with Pumped Storage Hydropower Plants in the Case of Nepal

by

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "Integration of Energy from Intermittent Renewable Power Plants with Pumped Storage Hydropower Plants in the Case of Nepal" was submitted by Pradip Man Shrestha in partial fulfillment of the requirements for the degree of Master in Energy System Planning and Management.

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ABSTRACT

Nepal's demand for energy is in increasing trend and the demand for a modern form of energy is no exception, electrical energy demand in the country is also increasing trend. In the case of Nepal, the electrical energy production sector is mainly based on hydroelectric power. This condition of power production creates a deficit in the power supply, and in the current context, demand is managed by the additional imported power supply.

To realize the concept of energy security, if the country does not import power to manage power demand, then it has to manage its available energy. To fulfill this motive the power produced by the solar power plant is stored in pumped power plants during the daytime and regenerate power during peak.

In 2030, installed hydropower is forecasted nearly 7000MW, and about 700 MW of solar will be connected to the grid; during the wet season there is enough power generation to fulfill energy demand, whereas, during the dry season, power demand during peak can be managed by energy stored in pumped power plants which are charged by power generated by solar power plants and the hydropower combined. In case of a low growth rate of the economy, months with a shortage of energy can be managed by total installed hydro and solar combined with storage (PHSP). In the case of policy intervention due to energy transition, there seems to be a huge gap in supply so there is a high scope of energy storage (PHSP) combined with additional installation of Solar PV.

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Pradip Man Shrestha

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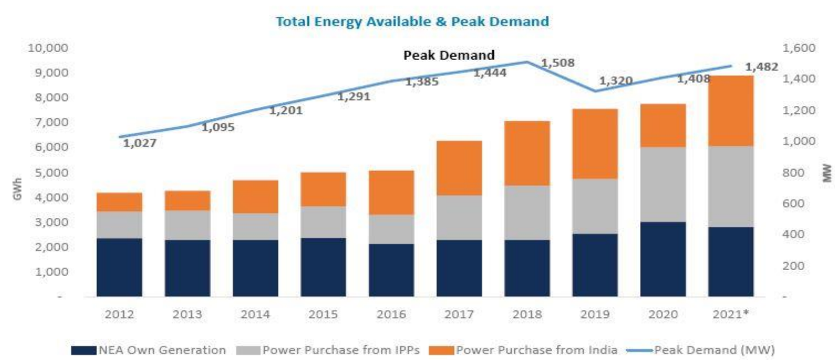
LIST OF ABBREVIATION

AC	Alternating Current
BAU	Business As Usual
CSP	Concentrated Solar Power
GHG	Green House Gas
GWhr	Gigawatts Hour
JICA	Japan International Cooperation Agency
ICIMOD	International Center for Integrated Mountain Development
KW	Kilo Watt
LDC	Load Duration Curve
MAED	Model for Analysis of Energy Demand
MW	Mega Watt
NEA	Nepal Electricity Authority
PHSP	Pumped Hydro Storage Plant
PV	Photo Voltaic
P-N	Positive-Negative
TWh	Terra Watt Hour
W	Watt
WECS	Water and Energy Commission Secretariat

CHAPTER 1: INTRODUCTION

1.1 Background

Energy is one of the basic needs to sustain society's development. In today's world, electricity is the backbone of all industrialized countries (World, 2013). In the case of Nepal, the number of electricity consumers of NEA has been increasing gradually over the years, the number of consumers increased by 7.37 % in the year 2021 by from 4.22 million to 5.08 million (NEA, 2020). According to NEA report 2077-78 as shown in figure no 1, we can say Energy and power demand are increasing each year, and there is still a gap in energy and power as well. Till 2016 there was a huge power gap between demand and supply, but during that year this gap was minimized near to zero by the energy imported from India. The energy exchange market was quite a price competitive and the price was nearly equal to the domestic market, but due to world politics, the price was increased by nearly 5 folds. The main reason for the increment is the rise in the price of coal and the Indian electricity grid system base load is coal thermal.



Particulars	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021*
Availability (GWh)										
NEA Own Generation	2,359	2,292	2,298	2,368	2,133	2,305	2,308	2,548	3,021	2,811
Power Purchase from IPPs	1,074	1,176	1,070	1,269	1,166	1,778	2,168	2,190	2,991	3,241
Power Purchase from India	746	790	1,319	1,370	1,778	2,175	2,582	2,813	1,729	2,826
Total Availability (GWh)	4,179	4,258	4,687	5,007	5,077	6,258	7,058	7,551	7,741	8,878
Peak Demand (MW)	1,027	1,095	1,201	1,291	1,385	1,444	1,508	1,320	1,408	1,482
* Provisional Figures (Subject to audit)										
Peak Demad MW	102,665	109,462	120,098	129,110	138,530	144,410	150,816	132,028	140,794	148,200

Figure 1Total Energy Available & Peak Demand (NEA report 2077-78)

Nepal's national electrical system base load is based on the run-off river, there is only one storage power plant and few are peaking run-off river-type power plants there is limited storage capacity for peaking during the daily high demand period. Also, there is an occurrence of the dry season, during this period there is less discharge in the river thus resulting in less production of power. Therefore, there are gaps in demand and supply due to the nature of resources and the existing production system. This can be mitigated by increasing capacity either by increasing the production capacity or by storing energy during excess and producing power from stored energy during high-demand periods.

Apart from the base load of hydroelectric power new alternative renewable resources are also being introduced into the electric system, solar photovoltaic power plants are most used and studies are going on the adaptation of wind electricity. Power from this type of power plant is intermittent that is it is available in the occurrence of its source only; in the case of solar Photovoltaic power is available only during the sunshine time. If we see the power consumption pattern of Nepal's daily peak load starts in the evening and ends at around 9’O clock at night, but power is not available when it is needed most. If the power produced from solar photovoltaic power systems could be stored in another form of energy and consumed when it is required. For this purpose of storing energy from these intermittent power plants, a mature technology of pumped hydropower plant could be a viable option for Nepal

1.2 Problem Statement

Nepal is trying to increase the capacity and quality of its various energy sources including electrical energy, it has a target of 10,000 MW installed capacity just only in hydropower resources(ADB, 2017).

Most of the hydropower, which will be developed, is of runoff river type, which has limited ability to generate power in a peaking period during dry seasons. The country’s most of the river hydrology has less flow during the dry season so due to this, during those dry periods power generation capacity is around 30% only. Thus, in the dry season, there is limited power generation and is insufficient during a peak period of a given daytime.

Also, there is one provision in the Nepal Electricity Authority only grid operator in Nepal to allow around 10 % of Solar and other renewable power sources in the base load of a system. Solar PV has also limited power generation time, that is only in the daytime when power demand is not at peak condition.

So, in both conditions, there is always a gap between the generation time and consumption time creating a deficit in the supply. This can be mitigated by storing the surplus power in the form of energy storage and consumption during the peak period, given natural resources and economic conditions in the case of Nepal Pumped Hydro Storage Electricity might be one viable solution.

1.3 Research Objective

The objective of this research are as follows:

Main Objective

- To Study the scope of the Integration of energy from a solar photovoltaic power plant with a pumped hydropower plant

Specific Objective

- To develop the hourly load curve for year 2030
- To evaluate energy deficit in 2030
- To analyze the possibility of PHSP and solar PV integration in the load management of electric power system in Nepal.

1.4 Assumption and Limitation

The assumption and limitation of this research are as follows:

1. Complete energy system of Nepal is not in scope of this study, only electric energy system is considered for this study.
2. This study assumes condition of not importing electrical energy at all; it emphasizes the concept of energy security.
3. The study only covers the scenario of A.D 2030, seven years from study time
4. The intermittent renewable energy taken for the study is Solar only, no other resources are considered for this research
5. Dry season is from December to May and Wet season is from June to November
6. Optimization of power generation is not adopted.

CHAPTER 2: LITERATURE REVIEW

2.1 Conventional Hydropower Plants

Power is generated by the potential energy in the water conserved in a reservoir created by head difference is converted into kinetic energy by flow of water through water conduit. By the usage of turbines this kinetic energy is further converted into electricity, amount of energy that is extracted from the water in a reservoir depends on the size of the reservoir, the flow of water, turbine efficiency, resistances in pipes and the head level. The head is the vertical distance between the inlet of water and the turbine (Andrews, 2007).

The reservoir, or the water flowing in the river are normally referred to as upstream, while the river/stream below the outlet of the power plant is referred to as downstream. At the inflow of the penstock is a control gate where water flow is regulated according to preferred production. The turbine and generator are located in the powerhouse, and this is the setup where energy is converted to electricity and further transformed by a transformer to higher voltage and transported to the power network (Løvvold, September 2020).

2.2 Pumped Storage Hydro Power

The pumped storage power plant consists of upper pond (or upper reservoir), lower pond (or lower reservoir), waterway and powerhouse. In this system, electricity is generated with the water stored in the upper pond in response to the peak demand in the daytime or evening. Contrarily, during the night time when the power demand drops, the water is pumped up from the lower pond to the upper pond using the excess energy generated by the other plants typical PHSP plant is composed of two reservoirs of equal volume situated to maximize their height difference, known as the head (Japan International Cooperation Agency, 2011). These reservoirs are connected by a system of waterways along which a pumping-generating station is located. Under favorable geological conditions, the station will be located underground otherwise it will be situated on the lower reservoir (Hosseini, 2013)

2.2.1 Classification based on flow source

Pumped storage power generation is classified into the "pure pumped storage type" and "pumped and natural flow storage type". (Japan International Cooperation Agency, 2011)

1) Pure pumped storage type

Electricity of the pure pumped storage type is generated by utilizing the head and circulating water stored in the lower and upper ponds. This type is not affected by river flow because the power plant does not use natural water but uses only circulating water. Therefore, the output can be set freely by determining the head and maximum plant discharge.

2) Pumped and natural flow storage type

Electricity of the pumped and natural flow storage is generated by utilizing the circulating water stored in the lower and upper ponds and natural flow into the upper pond. This type has a merit to be able to reduce pumping energy by using natural flow into the upper pond.

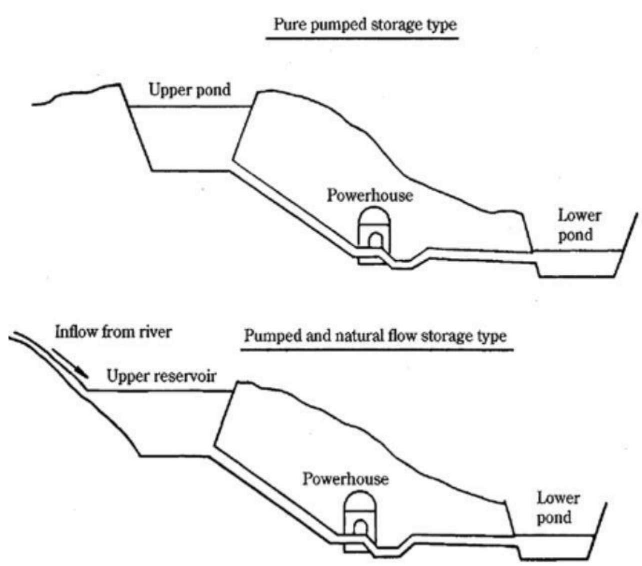


Figure 2 PHSP type based on flow-Source JICA PHSP guideline

2.2.2 Classification Based on the Nature of the Lower Reservoir

Based on the nature of reservoirs involved, pumped hydro plants typically come in two types namely open-loop PHSP systems and closed-loop PHSP systems (Hosseini, 2013)

Open-loop PHSP plants are those type which rely entirely on water that is pumped to an upper reservoir from a lower reservoir, with a source connection to a natural body of water, as illustrated in Fig. 3. The energy capacity of this PHSP is only limited by the size of the upper basin. These PHSP have the advantage that it can use the existing lake, river or ocean as the lower reservoir, thus reducing the cost of construction and the PHSP have no significant negative impact on the water body (Deane & Gallachóir, 2015)

In a Pump-back or "closed-loop" PHSP scheme, there is no water inflow in any reservoir and so the artificial construction of reservoirs, the lower or the upper one or sometimes both of them is required (Fig. 3). This make PHSP scheme suitable for locations with no naturally available lake, river, or ocean to be utilized as the lower reservoir. If this particular scheme has the advantage to have a limited environmental impact, it has the drawback to usually involve huge capital investment and to be often used for small to medium scale PHSP (Deane & Gallachóir, 2015). The energy capacity of this PHSP is limited by the size of the lower reservoir as well as the upper reservoir and also a make-up water is always required for the replenishment of seepage losses or evaporation.

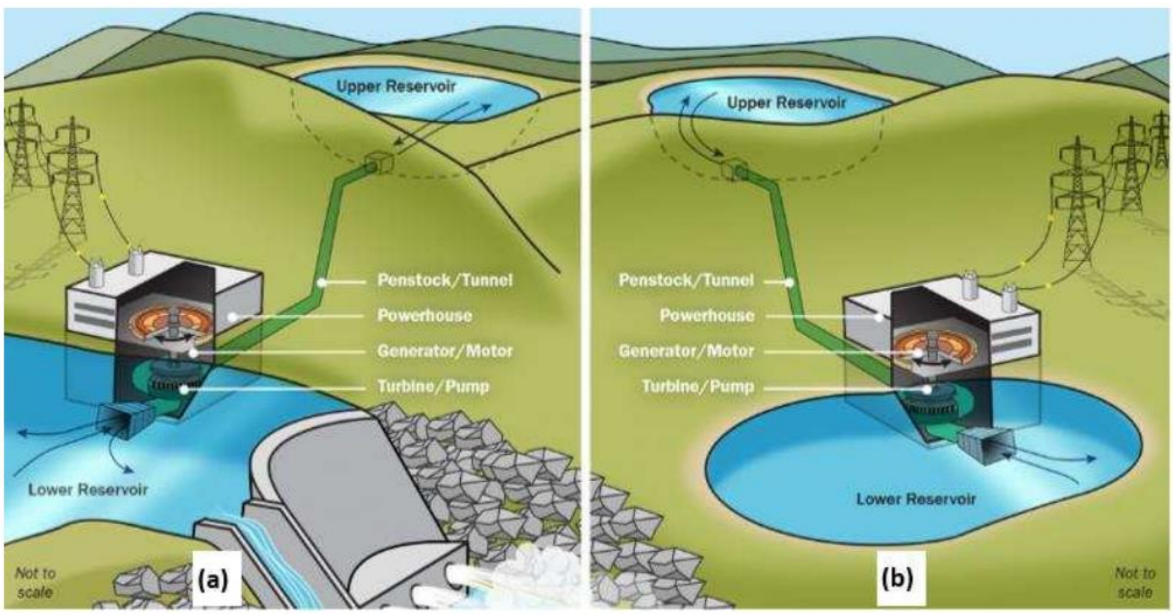


Figure 3 Models of open-loop (a) and closed-loop (b) pumped energy storage plants.-Deane & Gallachoir

2.2.3 Classification Based on the Location of the Plant

This classification of PHSP plants considers indoor or buildings PHSP and outdoor schemes.

Almost existing PHSP across the globe are constructed in open spaces and/or below the ground surface and therefore considered as outdoor PHSP (Blakers et al., 2021). However, the literature reports some PHSP experimental plants sized to fit a building (Rehman et al., 2015) According to Oliveira and Hendrick (de Oliveira e Silva & Hendrick, 2016) the economies of scale that render large PHSP installations competitive are not present in such small installations but they point that their costs could be significantly lowered if synergies with existing reservoirs could be found. Such coming PHSP are classified as indoor.

2.3 Solar PV-PHSP Hybrid Systems

Pumped-hydro storage has been utilized to control the erratic and intermittent nature of solar energy before integrating into grid, thus managing the fluctuation and intermittency.

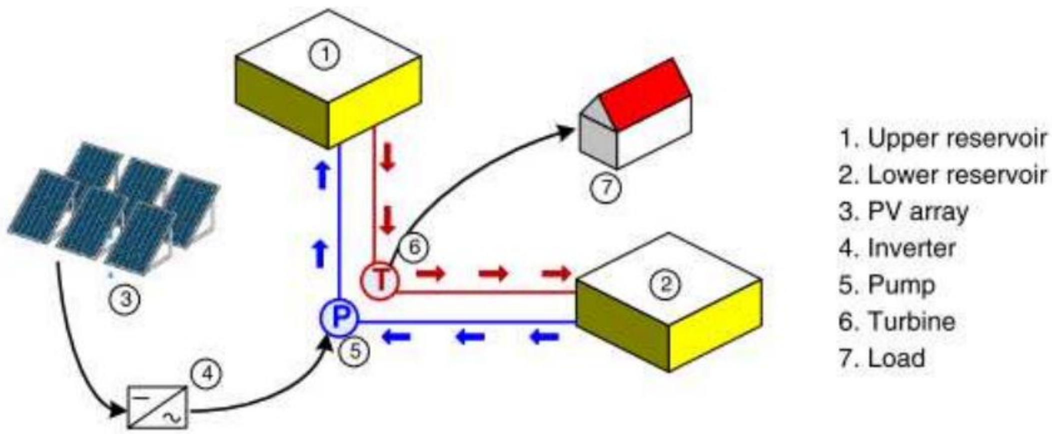


Figure 4 Solar PV-powered PHSP system schematic

2.4 Solar Power

Solar energy is the origin of all type of energy form found in Earth, and it is one of the abundant energy source. Energy travels in Earth as a radiation or considers it as photons, which is absorbed and converted to heat, and the uneven distribution gives rise to pressure differences, both horizontally and vertically. This in turn, along with Earth's rotation and tilt, results in weather, fluid dynamics in the atmosphere and ocean. In addition to being abundant, solar energy is a clean, renewable energy source, it is environmentally friendly, pollution free, and is more or less available all around the world, even though some locations have a varying income throughout the year. Earth receives 1.8 x 1011 MW power from the sun, which is several thousand times greater than our total current power consumption (Solanki, 2016). Current solar energy conversion technology is mainly two types, one is the thermal solar energy conversion and another is solar photovoltaic conversion technology. For this thesis purpose only photovoltaic electricity generation technologies will be included.

2.4.1 Energy from the Sun

The solar constant, S = 1367 W/m2, an average figure, describes the quantity of solar energy that reaches the top of Earth's atmosphere, or extraterrestrial solar irradiation. It varies with variations in solar emission strength as well as seasonally due to variations in the sun-Earth distance. Not all of this irradiation reaches the Earth's surface because to atmospheric absorption and scattering. There are four probable effects when the sun's extraterrestrial radiation enters the Earth's atmosphere. It can be either reflected back into space (6%), pass through the atmosphere and be absorbed (16%), radiate straight to Earth, or be dispersed, which causes radiation to be randomly redistributed in all directions.

Nepal is located at a latitude of 26–30° north latitude, with the sun shining for >300 days per year. It has relatively high insolation of an average of ~17 megajoules per m2 per day (1.7 TWh per km2 per year) and national average sunshine hours of 6.8 per day. This makes Nepal a country with moderately high solar potential. All parts of the country are reasonably favorable for solar energy (Lohani & Blakers, 2021).

2.4.2 PV - Solar Photovoltaics

There are numerous technologies for absorbing the energy from the sun in form of electricity generation. It can be done either by concentrated solar power (CSP) or by photovoltaics (PV), PV. For this study, only PV will be considered here, and amongst different technologies, the crystalline silicon solar cells are the most common one.

Since semiconductors are used to build solar Photovoltaic cells, the photovoltaic effect can be used by igniting electrons at a P-N junction. This results in a voltage difference across the junction, and the natural state seeks an electron relaxation, or a recombination of electron-hole pairs. The most straightforward way to do this is for the electron to move through an external circuit. As a result, the circuit generates a current that can be used to generate electricity. The

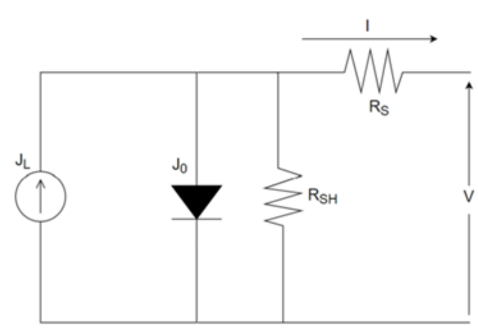


Figure 5 Equivalent Circuit of a P-N junction cell

design of the photovoltaic device and the quantity of losses that take place determine the voltage and current that can be obtained.

2.4.3 Solar Power Plants

PV systems come in a variety of sizes and can be off-grid, grid-connected, or a component of a hybrid system. Solar power plants, PV power plants, solar parks, and solar farms are all terms used to describe utility size installations.

All PV systems that want to output AC power needs an inverter, and there are several different types of inverters with varying efficiencies. The average lifetime of PV power plants is estimated to be about 30 years, and their end-of life management seems promising for recycling of materials. The degradation of PV panels is only time dependent, and not affected by the amount of production.

2.4.4 Calculation of Solar Power from Photovoltaics

PV output calculations formula is adopted from (www.photovoltaic-software.com/PV-solar-*energy-calculation.php)*

P = A.r.H.PR

Where,

P = power (Watts)

A = Total solar panel area (m2)

r = solar panel efficiency (%)

H = irradiance (watt/m2)

PR = performance ratio for losses (range between 0.5 and 0.9 – 0.9)

PR value is dependent on site, technology and sizing of system. Inverter losses, temperature losses, DC and AC cable losses, shading, losses due to weak radiation, losses due to dust, snow etc.

2.5 Power Demand and Supply

The demand for electricity varies depending on the season and the time of day. The load is the amount of power required by the power supplier. The load curve is the curve that displays the state of load fluctuation over time. The term "daily load curve" refers to a load fluctuation curve that is typically constructed for a single day (24 hours). The yearly load curve is the curve that represents the variation in load over a single year.

The characteristics of daily load fluctuation vary depending on the composition of the power demand. Generally, the load increases in the daytime due to the operation of factories and offices, or in the evening when electricity is consumed for lighting. It drops off through the night to the early morning and again during the noon-time period. In the load curve, peak load may include those areas before and after reaching its peak. The heavy load time of day is termed on-peak load times (peak time) while the light load time of day late at night and early in the morning is termed the off-peak load time (off-peak time) (Guideline and Manual for Hydropower Development Vol. 1 Conventional Hydropower and, March 2011).

2.6 Load Curve

The load on a power station is never constant; it varies in each time of day or varies with change of season and weather condition. In case of load variations during the whole day (i.e., 24 hours) load are recorded half-hourly or hourly and are plotted against time on the graph. The curve thus obtained is known as daily load curve as it shows the variations of load with respect to time during the day. In a typical daily load curve of a power station, load is never constant and thus load on the power station is varying. There is certain time where load is maximum and other most of time there is a minimum load. It may be seen that load curve indicates at a glance the general character of the load that is being imposed on the plant. The monthly load curve can be obtained from the daily load curves of that month. For this purpose, average values of power over a month at different times of the day are calculated and then plotted on the graph. The monthly load curve is generally used to fix the rates of energy. The yearly load curve is obtained by considering the monthly load curves of that particular year. The yearly load curve is generally used to determine the annual load factor.

2.7 Load Duration Curve

Load Duration Curve provides information on the amount of power utilized during a given period. LDC is usually represented in a graph between the load on power plants and the produced energy in kilowatts. Area under the curve in LDC provides an indication of the amount of energy demanded. Furthermore, loads in LDC are usually arranged in sliding order of their magnitude. LDC chart is essential since it provides a view on the efficiency of energy grid. The figure 6 below shows an example of a LDC.

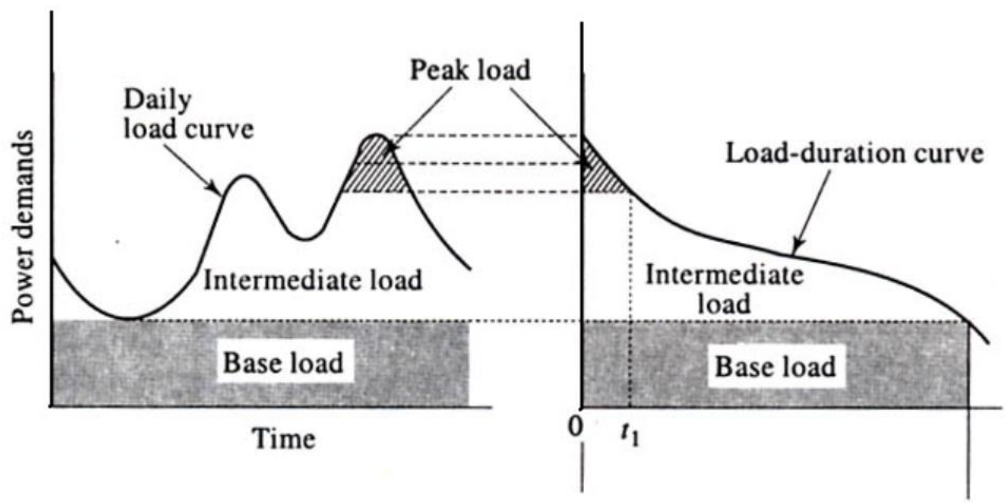


Figure 6 Load duration curve and its relation to generation (source: pua.edu.eg)

2.8 Load forecasting

"Electric load /demand forecasting is a vital process in the planning of the electricity industry and plays a crucial role in the operation of electric power systems. The electric power load forecast is highly related to the economy's development, and it is also related to national security and the daily operation of society. Therefore, the accuracy of electric load forecasting has great importance for energy generating capacity scheduling and power system management, as these accurate forecasts lead to substantial savings in operating and maintenance costs, and correct decisions for future development. Furthermore, electric power load forecasting represents the initial step in developing future generation, transmission, and distribution facilities. However, the accuracy of electric load forecasting cannot often fulfill our desired result because it is influenced by various uncertain and uncontrollable factors such as economic development, human social activities, country policies, and climate change .”(Hammad et al., 2020)

2.9 Previous Study

Abid et al, 2021 reports that Solar PV with PHS remains the optimal system configuration for both rural and urban cases even when the construction costs where the capital cost of PV remains to be the most dominating factor (Abid et al., 2021).

The need for storage in electricity systems with intermittent generation capacity, and pumped hydro continues to be much cheaper for large-scale energy storage. The all-in cost of fully balanced 100% solar and wind electricity systems is below the cost of an equivalent fossil fuel system for most of the world (Blakers et al., 2021).

(Sah et al., 2014) states that Nepal’s power system should have sufficient natural storage and forced storage power plants to improve the system’s reliability and daily peak electrical demand could also be adequately covered by demand-side management, using a pumped-storage hydropower plant. Furthermore, study recommends to connect solar and wind power plants in tandem with pumped-storage plants.

This study states that Nepal will be able to achieve energy self-sufficiency during the twenty-first century. Nepal has good solar and moderate hydroelectric potential but has negligible wind- and fossil-energy resources. The solar potential is about 100 times larger than that required to support a 100% solar-energy system in which all Nepalese citizens enjoy a similar per-person energy consumption to developed countries, without the use of fossil fuels and without the environmental degradation resulting from damming Nepal’s Himalayan rivers. Nepal has vast low-cost off-river pumped hydro-energy-storage potential, thus eliminating the need for on-river hydro storage and moderating the need for large-scale batteries. Solar, with support from hydro and battery storage, is likely to be the primary route for renewable electrification and rapid growth of the Nepalese energy system.(Lohani & Blakers, 2021)

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Research Framework

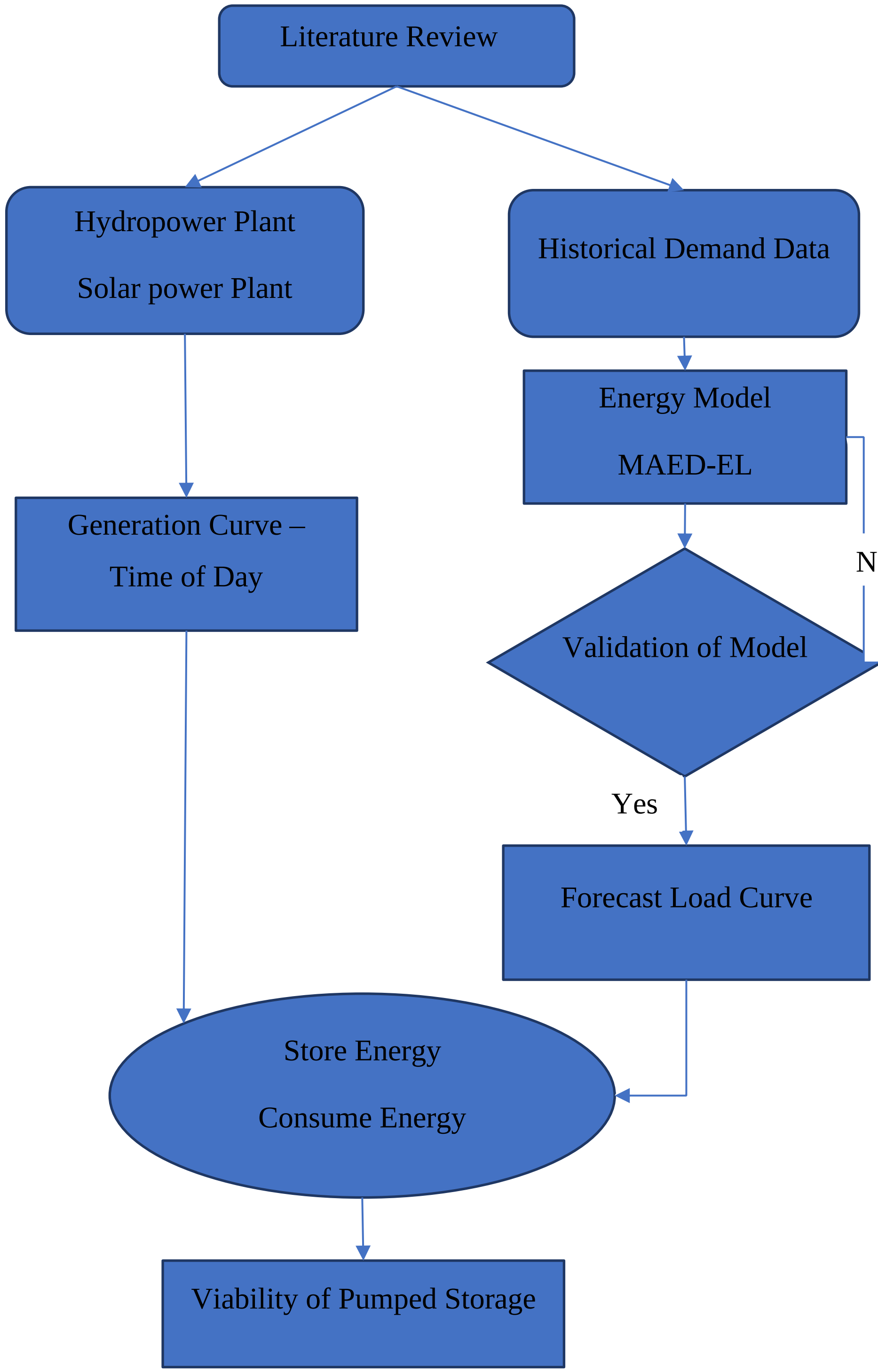


Figure 7 Methodology for Research Work

Initial work for this research was literature review, which gave overview and idea to conceptualize whole study. Past research and the theory related with solar power, pumped hydro storage in foreign country as well as need in Nepal, energy modeling using various tools mainly MAED was considered for this study.

3.2 Historical Demand Data and other data

The main source of data is from the Nepal Electricity Authority through the annual reports and various Directorate of NEA, important data were collected and mainly historical load data was collected. Load data of one year is considered as base year for study, hourly load data of each day that is 24-hour load for each day and in total 365 days of a year is taken. Beside load data, expected future power production and energy from hydropower is taken from NEA. Solar data is obtained from website of energydata.info; other necessary data is referenced from the research paper. For different load according to different scenarios, a paper from WECS was referred; it has an analysis of future in Business as usual, normal growth rate and intervention scenario.

3.3 Spread Sheet

Spread sheet was used for data representation and graphical representation and many other required is carried out. The main purpose of the spreadsheet will be to prepare data, which is required to input in MAED-el, all data is sorted and calculated beforehand and was used for post calculation.

3.4 Energy Model MAED-EL

MAED evaluates future energy demands based on medium to long-term scenarios of socioeconomic, technological and demographic development. Energy demand is disaggregated into a large number of end-use categories corresponding to different goods and services. The influences of social, economic and technological driving factors from a given scenario are estimated. These are combined to give an overall picture of future energy demand growth.

Historical data of daily hourly load data is used to create an energy model as stated earlier daily data of one-hour interval and for one year in total 8760 load data is required for this software. This complete set of data is then fed into the excel sheet, this preprocessing of data is an important step as this calculates seasonal coefficient, daily coefficient and hourly coefficient. Then all the calculated coefficients are punched into MAED-el, thus a result obtained is an hourly electrical energy model. This model was verified by comparing with past patterns of power usage, Energy model was modified until it resembled past patterns. A verified model, which was obtained after many trials, is used to forecast daily load curve of future, a projected energy demand in GWh is necessary for forecasting hourly load demand and coefficient calculated earlier.

All coefficients used to create energy model of base year 2022 is used to forecast power demand data of future year 2030, here power data is taken from the NEA's simulation of energy forecast.

3.5 Generation and Demand

Generation from two types of power plants are considered in this study, one is hydro power plant with forecasted generation capacity and another is solar power plant with forecasted generation capacity. Power generation from solar power plants for each month is calculated from past irradiance data, that is from Monthly Average Irradiance data. In case of hydropower generation, a constant national generation is taken for each month, which is forecasted by NEA. Expected hydropower, which will be connected to grid in future was considered for study; only domestic hydro generation is considered imported power was excluded for this study.

For calculation of energy from solar plant solar irradiance data is used, process is described as follows.

3.6 Solar Irradiance

Solar irradiance data of Nepal various is collected from the website energydata.info, below is an example of irradiance-time of day that occurred at Lumle, derived from the detail data provided in website. To estimate the average solar electricity generation from the solar power plant Monthly average Irradiance time of day is utilized for study.

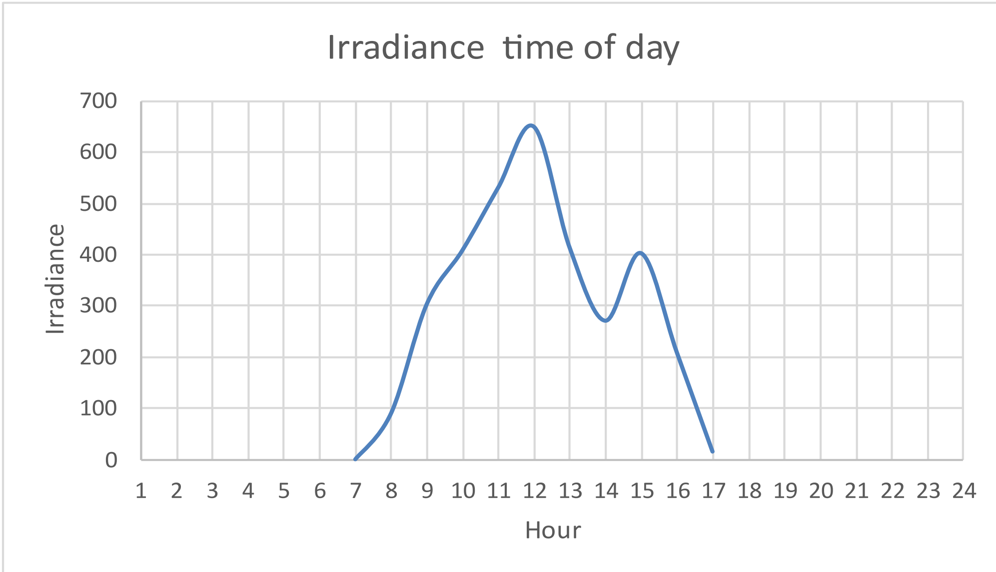


Figure 8 Irradiance-time of day, Lumle-January 1st, 2020

For calculating the power and energy from the solar power of installed 700 MW, solar irradiance data is taken. Irradiance data and installed capacity is equated to obtain the average monthly generation curve. Monthly average daily irradiation data is used instead of daily irradiance data so that the irradiance can be approximate for a day of a month.

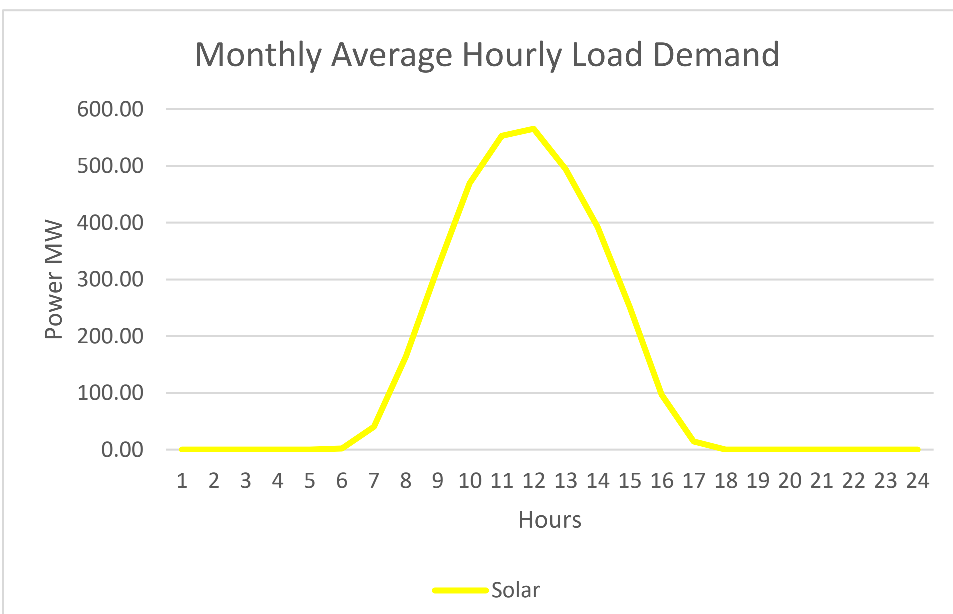


Figure 9 Power Production of 700MW solar plant -Time of day-by average monthly daily irradiance of January

Demand of power and energy is taken reference from two sources one is NEA and another is WECS, NEA forecasts the installed capacity of powerhouses on basis of the powerhouse under construction and which are in pipeline of construction, power generation and available energy is also forecasted on the basis of past generation data and data of upcoming powerhouses. In context of Demand, WECS forecasted it on basis of past electrical demand and projected economic growth.

For the Energy Demand Analysis, three different scenarios of WECS were prepared considering GDP growth rates of 4.5%, 7.2 % and 9.2%. These are Business as Usual; reference and high growth rates are assumed analyzing the past growth rates and the targets set out by the government through various plan documents (WECS, 2017). In case of high growth rate of 7.3% and 9.2% a policy intervention is done by introduction of electric cooking, water heating and electric transportation.

Various scenario analysis were analyzed to see the condition in various input, five-scenario analysis is described as follows.

Business as Usual

In this scenario of Business as Usual Monthly average hourly load Demand data is forecasted for each month of a year, hydro power generation is taken from the NEA forecast data for each month that is average monthly power generation. Finally, power production from the 700 MW solar power production is considered, a monthly average power production is calculated from the monthly average irradiance data. Growth rate in this scenario is 4.5 % and annual total energy demand considered is 20073 GWhr.

Reference Scenario

Reference scenario case is a scenario in which the growth rate is assumed to be 7.2 % and total annual energy demand is forecasted to be 24956 GWhr by WECS. Average hourly load demand data is forecasted for each month of a year for analysis, hydropower generation is taken from the NEA forecast data for each month that is average monthly power generation. Finally, power production from the 700 MW solar power production is considered, a monthly average power production is calculated from the monthly average irradiance data.

High Scenario

In this scenario High Scenario Monthly average hourly load Demand data is forecasted for each month of a year, hydropower generation is taken from the NEA forecast data for each month that is average monthly power generation hydropower generation installed capacity is 6983.1 MW. Finally, power production from the 700 MW solar power production is considered, and monthly average power production is calculated from the monthly average irradiance data. The growth rate in this scenario is 9.2 % and the annual total energy demand considered is 29864 GWhr.

Policy Intervention Scenario 7.2%

WECS has considered the scenario in which there is policy intervention by government, there shall be 100% of the cooking with electricity and 75% of water heating with electricity in urban areas by 2020, metro in cities by 2025, (WECS, 2017). Growth rate in this scenario is 7.2 % and annual total energy demand considered is 35335 GWhr. In this scenario of Policy Intervention, Monthly average hourly load Demand data is forecasted for each month of a year, hydropower generation is taken from the NEA forecast data for each month that is average monthly power generation hydropower generation installed capacity is 6983.1 MW. Power production from the 700 MW solar power production is considered, a monthly average power production is calculated from the monthly average irradiance data.

Policy intervention Scenario 9.2%

This scenario is similar as Policy intervention scenario with 7.2%, difference is growth rate of 9.2% and the energy demand is considered is 41264 GWhr.

3.7 Store Energy/Consume Energy

To calculate the overall energy and power balance all the data respectively generation curve and load curve was fit into one graph. From the historical data of irradiance and projected solar power plant capacity, the average monthly power time of day available from solar is created; the curve obtained is available energy on that day. The solar energy curve and Load demand curve are matched, if there is high demand then that energy is consumed at that time but if the demand is fulfilled by the hydro generation energy from solar is surplus, this surplus energy will be used to pump water to higher reservoirs. Also, any surplus energy from the hydropower can be utilize to charge pumped hydro storage power plant, then according to the load demand curve what quantity of energy will be available to store and what time will be it regenerated for consumption is calculated.

The procedure or the methodology of the thesis is summarized in the steps below.

- The total installed capacity of hydropower plants in Nepal were collected from the Nepal Electricity Authority.
- Data of Solar Photo Voltaic power plants which will be installed in coming 5-10 years, was collected.
- Solar power generation curve was developed from the sunshine data of Nepal.
- Finding data for total power generation, the energy available during the dry season, the wet season, and the energy balance.
- Collected and analyzed the historical load duration curve and then the electric load demand curve and electric load duration curve was forecasted.

Generation curve and electric load duration curve were fitted to find the possibility of storing electric power with help of the pumped storage hydroelectric technology

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Load data of national demand by NEA

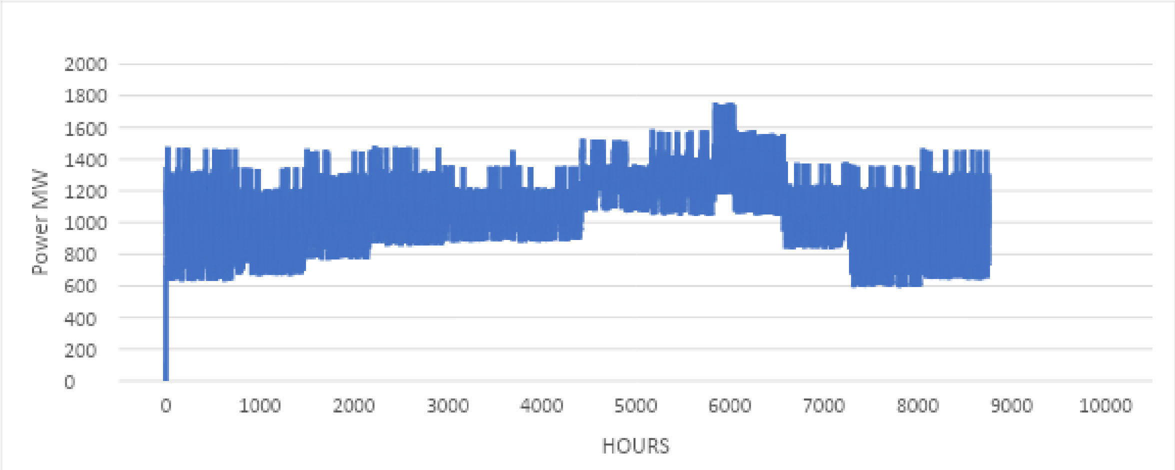


Figure 10 Hourly Load of year 2022

This figure 10 is the graphical representation of the hourly load demand data of one year of Nepal, which is managed by the NEA. It contains daily hourly load data, in a day 24 hour load data is taken and daily hourly data of all the months are included starting from January to December. Each month peak of day load is described in table 1 below.

Table 1 Monthly Power demand of year 2022

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Load(MW)	1714	1599	1599	1717	1884	1954	1527	1586	1759	1511	1549	1702

In twelve months, maximum demand of year is 1954 MW at 20:00 hours, which is in month of Ashad (June). In a day, there are varying quantity of load from 0:00 hours to 24:00 hours, but here only peak load of a day is represented usually peak in demand is seen two times a day this pattern of demand is seen in each month.

4.2 Energy model in MAED-EL

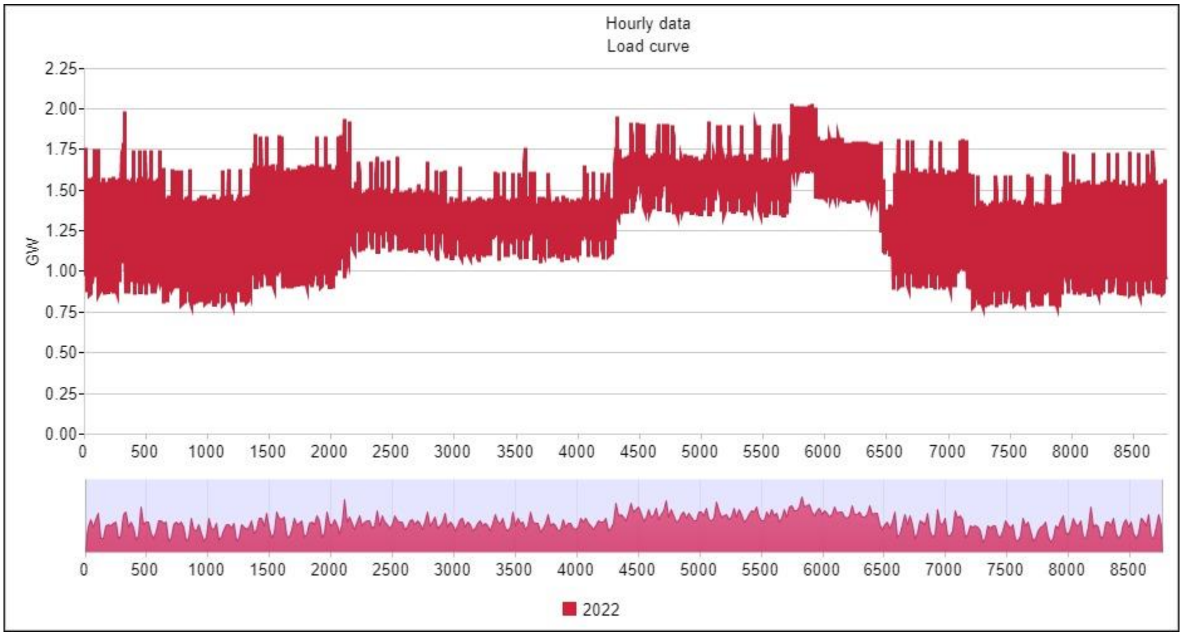


Figure 11 Hourly Load Curve 2022 from MAED- EL

This simulated data is of one year that is of 2022, there are in total 8760 hours consisting of 24 hours of one day. Maximum load demand is 2033MW in month of Ashad, considering the load demand pattern there is quite resemblance and even the maximum load is not that different from actual load. So this model is considered as a usable model to forecast the load hour of medium term forecasting.

4.3 Hourly load curve of 2030

From the model 2022 created hourly load curve of 2030 is calculated, for each scenarios individual forecast are calculated, forecast is based on the power demand pattern of 2022 and the energy forecast done by NEA. In the figure 12 below load curve of 2030 and 2022 combined is shown, this load curve of 2030 is case of High Case scenario with GDP growth of 9.2%, energy demand 2964GWh. Forecasted peak power is 6197 MW

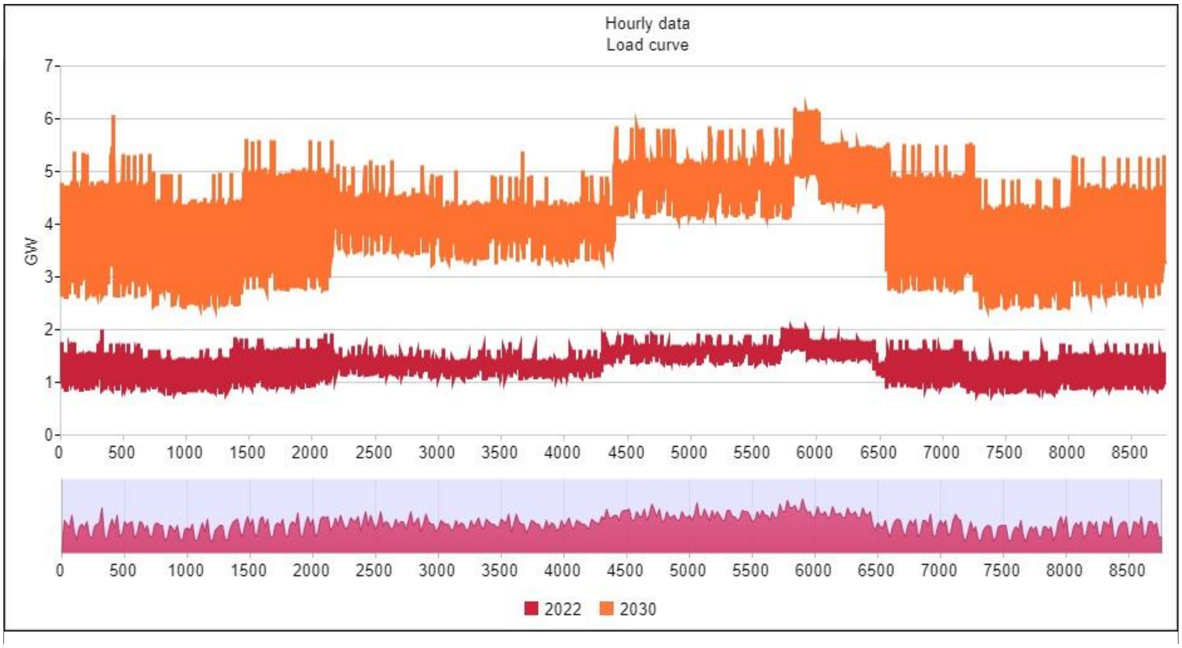


Figure 12 Hourly Load Curve of 2022 and 2030 from MAED-EL

By using the energy model obtained from software hourly load data of 2030 are obtained, one year of hourly load data is forecasted. As for examples, figure 13 is a Monthly average hourly load curve, it of January 2030 BAU it shows the demand of electricity in 24 hour, in this load curve peak demand is of 4112 MW at 19:00 hours of day.

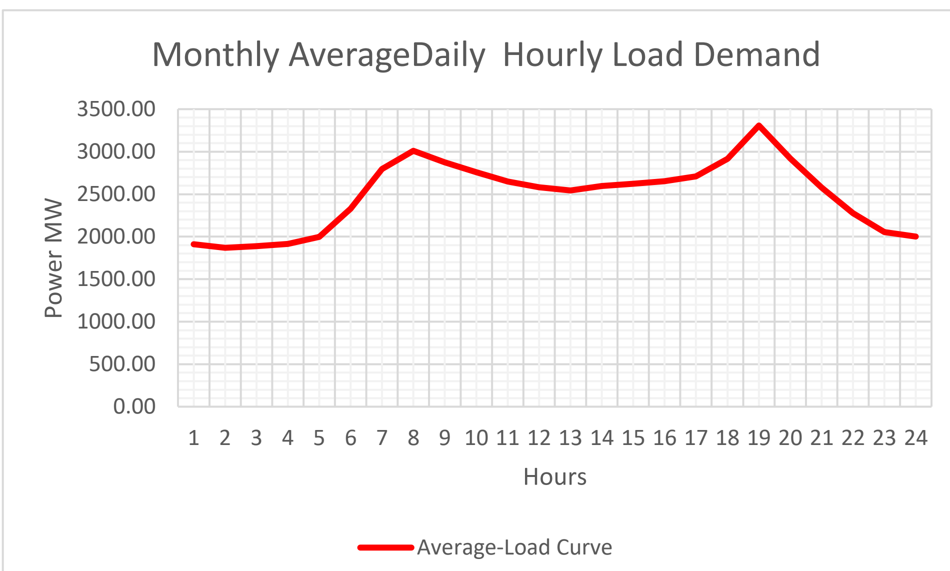


Figure 13 Monthly average - Hourly Load curve of 2030, January

4.4 Monthly Average Hourly Load Curve of 2030

Year 2030 scenarios are represented in this chapter.

There are five numbers of scenarios for analysis, first is Business as Usual, Reference Scenario, High Scenario, Policy Intervention with growth rate 7.2% and finally Policy Intervention with Growth rate 9.2%. All scenarios are summarized in tabular from as in table no 2 below.

Table 2 Scenarios with respected energy demand

Year/GWh	BAU 4.5%	Reference scenario 7.2%	High Scenario 9.2%	Policy intervention 7.2%	Policy intervention 9,2%
2030	20073	24956	29864	35335	41264

4.4.1 Business as Usual Scenario

Data obtained from the given condition of Business as Usual Scenario with 4.5% growth is as follows. There were total twelve Monthly average hourly load demand forecasted; only months with deficit in power supply is represented and discussed.

January, 2030

Figure no 14 below shows the forecasted average monthly demand curve of January, 2030, hydro generation and energy available from solar.

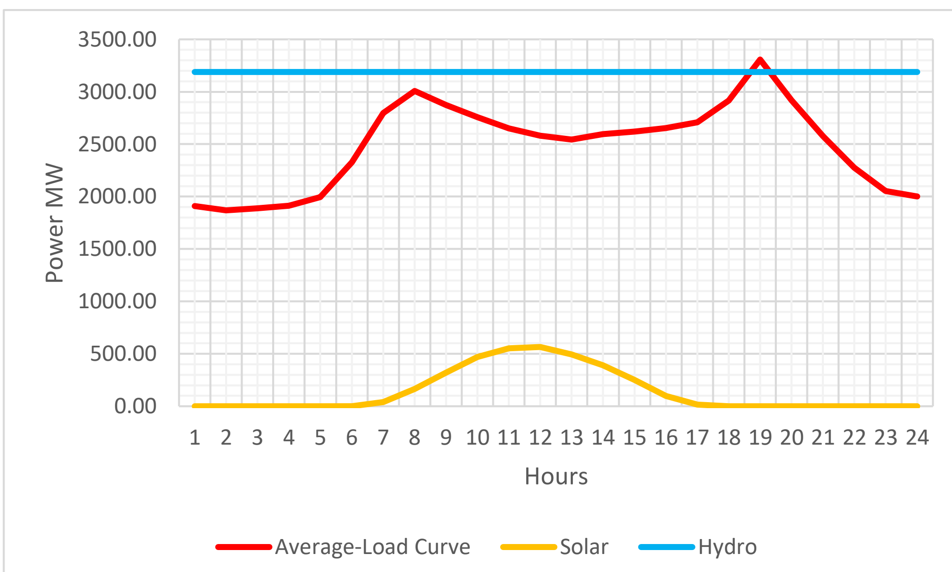


Figure 14 BAU scenario of January 2030

In this month the hydro generation is not able fulfill to national load demand, for the time 18:30 to 19:30 hours, at this time period there is nearly 0.5 MWhr energy gap and power deficit of 118 MW. Solar power is produced from the time 7:00 hours to nearly 16:30 hours, from this irradiance there is production of 3.3 GWhr of energy which is monthly average daily production from solar power of 700MW installed capacity. Energy deficit can be fulfilled by PHSP operation from solar energy alone.

February 2030

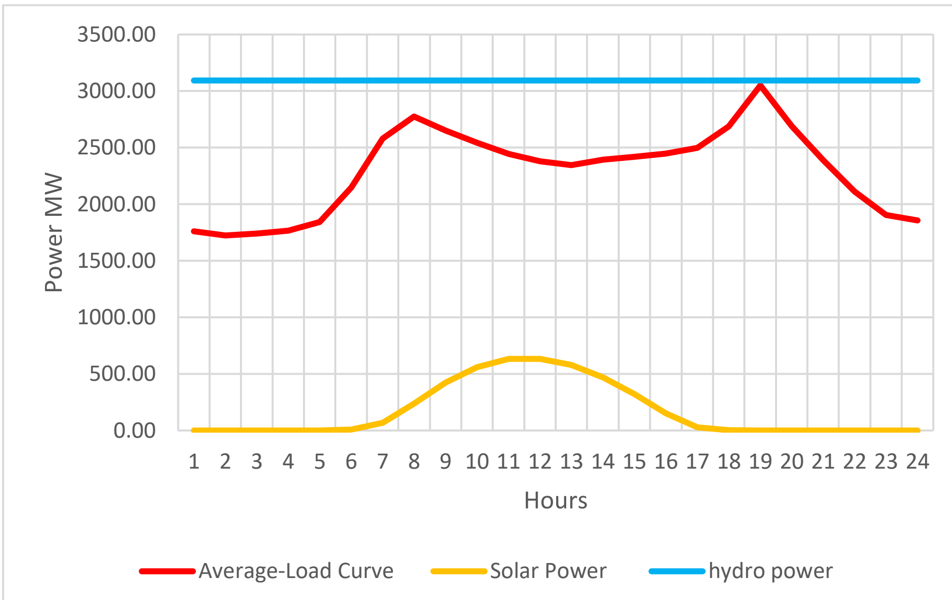


Figure 15 BAU scenario of February 2030

In this month of February as shown in figure 15, the power production from the hydropower is enough to fulfill the forecasted monthly average power demand for that month. Monthly average solar energy in a single day is about 4.117 GWhr with power production of 3093MW, monthly average electricity demand forecasted for a single day is about 53.33 GWhr with peak power demand of 3049 MW and monthly average daily energy from hydropower is 71.11 GWhr.

March 2030

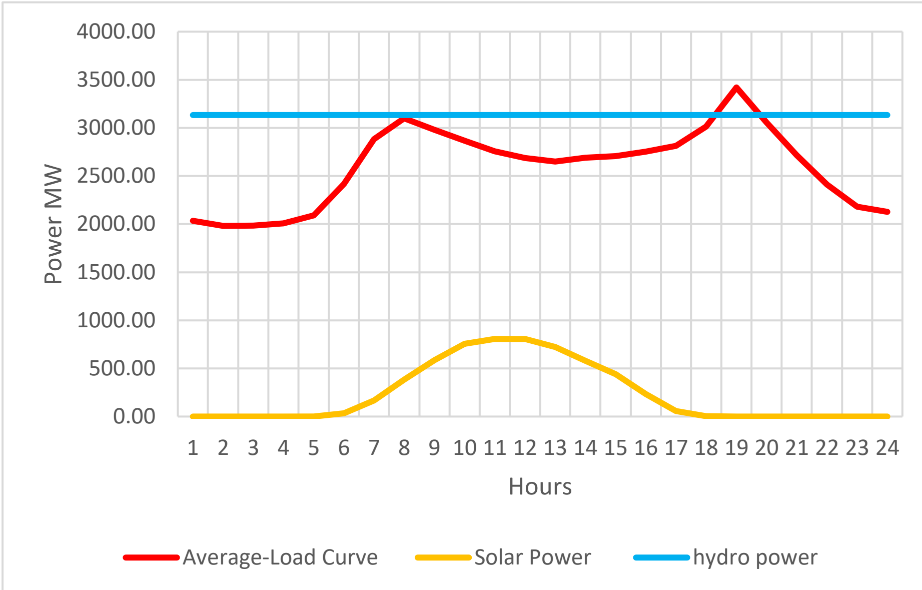


Figure 16 BAU scenario of March 2030

Monthly average load demand of March in figure number 16 is nearly 60.24 GWhr per day, available energy from hydropower which is monthly average production of a day, is 72.07 GWhr and solar power generation is 5.57 GWhr. But during the peak time from 18:30 hours to 19:30 hours there is deficit in power supply only by the hydro power production capacity for that period of time lagging, about 280 MW of power is lagging at peak and total 0.19 GWhr of energy is deficit at that period. Combine Energy from solar and surplus energy from hydro, total 14.94 GWhr can be produced after storing. Thus, the energy available from the solar power generation can be utilize to fulfill that gap in the deficit period, if solar energy is stored and power is reproduced during that time of need.

Energy balance of three months described above are summarized in the table 3 below. All three months are from dry season**.**

Table 3 Summary of Business-as-Usual Scenario

Month	**Power Deficit**	**Energy-Deficit**	**Energy Available from PHSP**	**Final Deficit after PHSP**
January	118 MW	0.5 GWhr	16.08 GWhr	0
February	0	0		0
March	286 MW	0.19 GWhr	14.94 GWhr	0

In this Business As Usual scenario in total there are in total two namely January and March that are deficit months, so for these two months, energy storage and regeneration seem necessary. Load management can be done by 700 MW of solar connected to PHSP, for power management power of 286 MW is required.

4.4.2 Reference Scenario

In this condition of Reference Scenario Data obtained with 7.2% growth is as follows. Twelve Monthly average hourly load demand were analyzed, only months with deficit in power supply is represented and discussed.

January, 2030

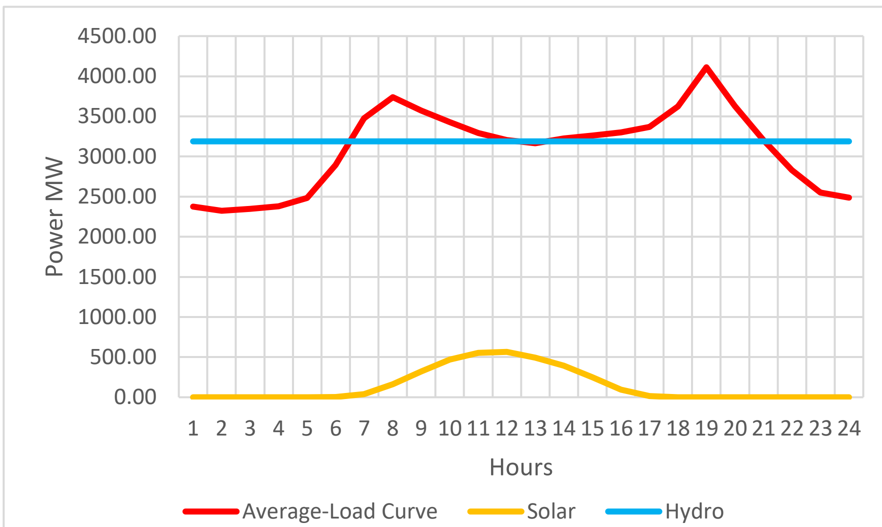


Figure 17 Reference scenario of January 2030

Reference scenario January 2030 (figure 17), in this month the monthly solar energy production is about 3.36 GWhr, total energy demand is 71.84 GWhr and total hydro power generation available is 73.342 GWhr with maximum of 3188 MW of power generation whereas maximum power demand is of 3995 MW at peak time. As it is seen in figure 18 above from 6:30 hours to 11:30 hours, there is deficit of around 1.43 GWhr of energy with peak demand of 3604.85 MW at that time. Also, from time 13:30 to 21:00 hours there is deficit of about 2.19 GWhr of energy in total and there is peak demand up to 3995 MW also, deficit in power at peak period is about 923 MW. While utilizing the stored energy in PSHP from solar and surplus from hydro total available energy is 7.21 GWhr of energy, so energy from both solar power and hydropower plant is also stored in PHSP then all the peak demand can be fulfilled.

February 2030

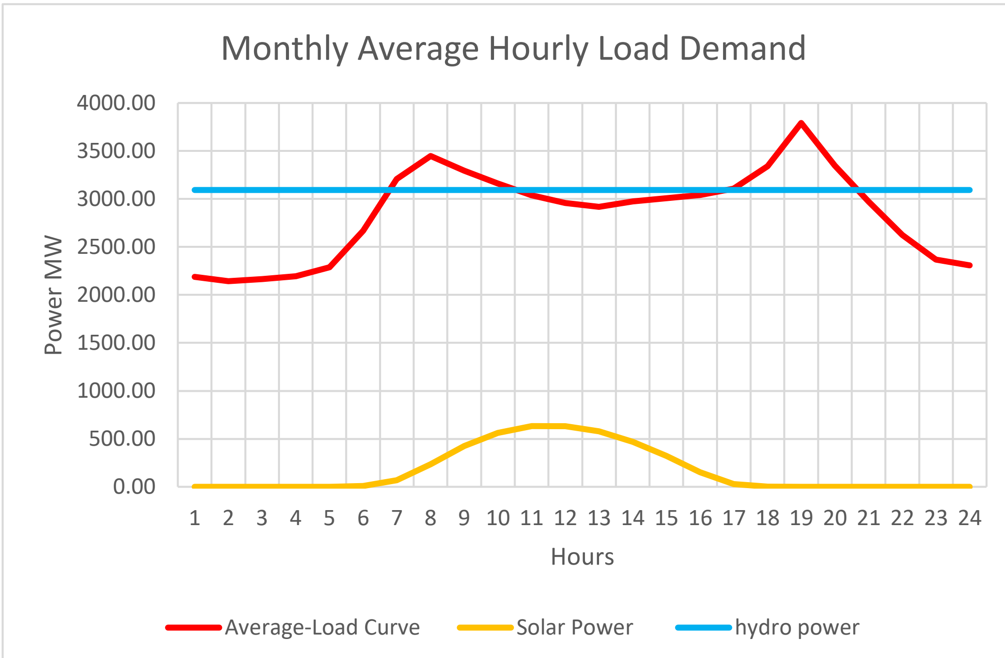


Figure 18 Reference scenario of February 2030

Here average monthly daily power production of February from hydro is 3093 MW and energy from hydropower is 71.15 GWhr per day, total energy from solar power is 4.11 GWhr that is average monthly daily production, with efficiency of pumped hydro power plant considered total available energy for a day is 3.49 GWhr. In figure 18, from 7:00 hours to 10:00 hours there is deficit of 0.65GWhr and from 17:00 hours to 20:00 hours deficit is 1.14 GWhr, during the peak period there is demand of 3372 MW of power in initial peak hour and 3570 MW of peak power demand in later peak hour and there is nearly 700MW power deficit during peak. So here, the energy from the solar that is stored in pumped hydro storage is enough to fulfill the deficit demand in both peak hour's periods in a given day.

March 2030

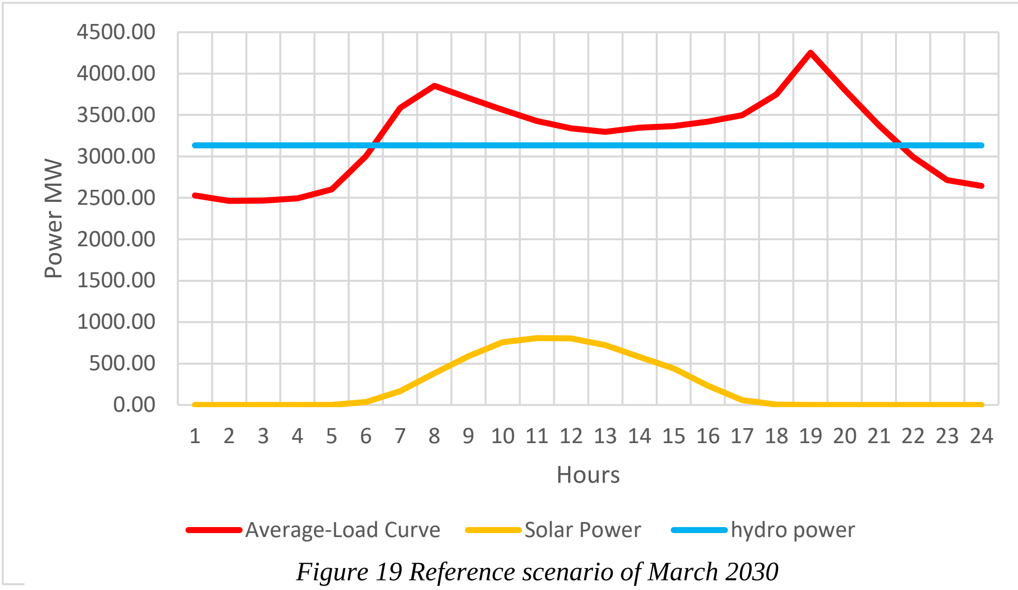


Figure 19 Reference scenario of March 2030

Reference scenario March, 2030, figure 19, in this month the monthly solar energy production is about 5.57 GWhr and total energy demand is 74.90 GWhr whereas total hydro power generation available is 72.07 GWhr with maximum of 3133 MW of power generation whereas maximum power demand is of 4252.3 MW at peak time. As it is seen in figure 20 above from 6:30 hours to 21:30 hours there is deficit of around 6.44 GWhr of energy with peak demand of 3779 MW at morning peak time, and there is peak demand up to 3995 MW in the evening with deficit of power 1100 MW. While utilizing the stored energy in PSHP total available energy is 4.73 GWhr of energy, so energy alone from solar is not enough to fulfill the peak demand if the power from hydropower plant which is 3.6 GWhr excess at various periods in a day is also stored in PHSP then all the peak demand can be fulfilled.

Energy balance of three months described above in this scenario are summarized in the table below. All three months are also from the dry season.

Table 4 Summary of Reference Scenario

Month	**Power Deficit**	**Energy-Deficit**	**Energy Available from PHSP**	**Final Deficit after PHSP**
January	923 MW	3.62 GWhr	7.12 GWhr	0
February	698 MW	1.79 GWhr	9.14 GWhr	0
March	1100 MW	6.44 GWhr	7.80 GWhr	0

In this Reference scenario in total there are in total three months January, February, and March that are deficit in energy, so for these months' energy storage and regeneration seem necessary. In all these months, there is enough energy from storage that can be used to manage the energy deficit, for power management 1100MW with 14.94GWhr of energy storage capacity is required to mitigate the energy shortage.

4.4.3 High Scenario

High Scenario case analysis data is presented as follows, as in above case only the months with energy deficit is described.

January, 2030

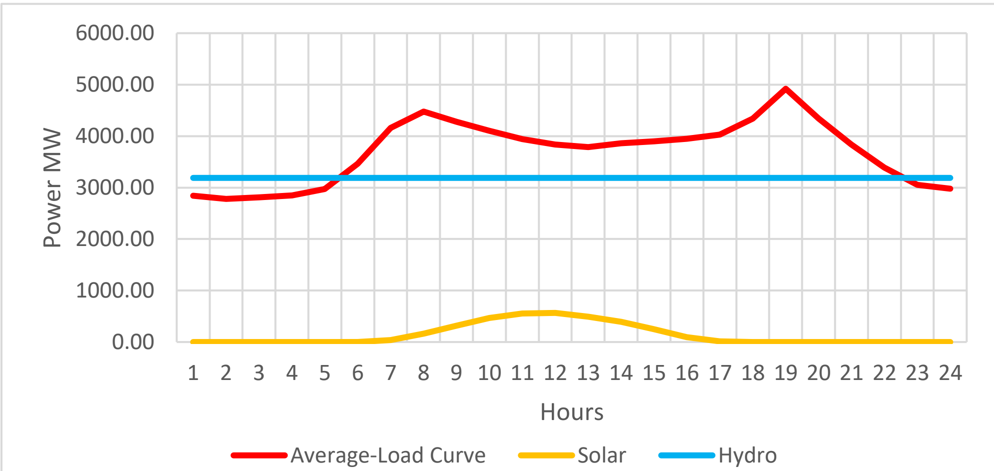


Figure 20 High scenario of January 2030

In this month of January, figure 20, the power from the hydro is forecasted to be 3188 MW on average, and solar power energy is about 3.36 GWhr. Demand for total energy per day is 85.79 GWhr and power demand at peak is 4920 MW, here the power supply deficit starts from 5:30 hrs and end at 22:30 hrs energy deficit is about 14.22 GWhr. Excess energy from the hydro can be stored in PHSP; about 1.58 GWhr is available from hydro after pumping available enrgy is 1.34 GWhr. From solar and hydro combined during deficit hours about 4.7 GWhr can be supplied and power deficit at peak is 1700 MW, but still there is deficit of 9.5 GWhr per day.

February, 2030

Forecasted Demand for the energy per day in this month is 79.35 GWhr with peak power demand of about 4537 MW, energy from solar is about 4.11 GWhr and energy from hydro is about 71.15 GWhr. As seen in figure 21, here from time 5:30 hrs. to time 22:00 hrs there is deficit of 10.6 GWhr and peak demand for power is about 4537MW. Energy available from PHSP, combined of both solar and hydro is about 5.57 GWhr and deficit in power at peak is 1445 MW and deficit in energy is 3.5 GWhr.

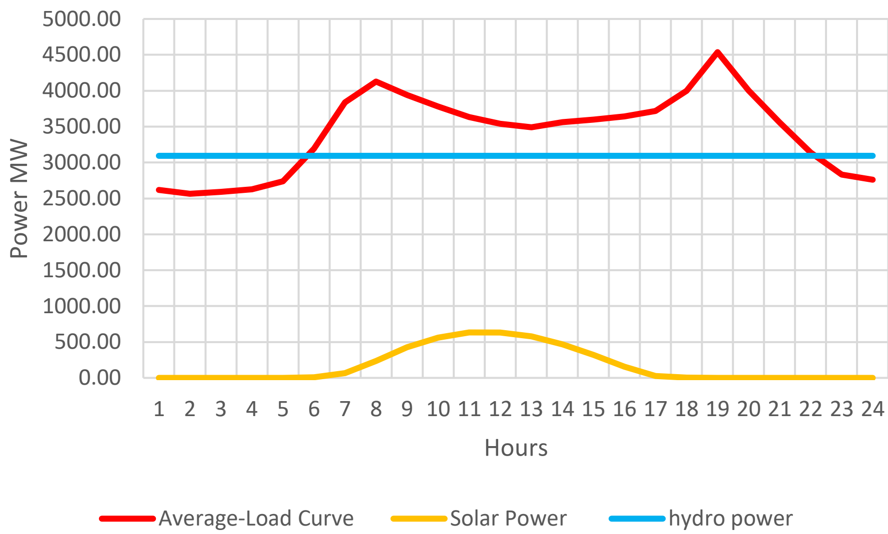


Figure 21 High scenario of February 2030

March 2030

In this month of March, shown in figure 22, forecasted Demand for the energy per day is 89.67GWhr with peak power demand of about 4088 MW, energy from solar is about 5.57 GWhr and energy from hydro is about 72.05 GWhr. Here from time 5:00 hrs to time 23:00 hrs there is deficit of 18.14 GWhr and peak demand for power is about 4537MW. Energy available from PHSP, combined of both solar and hydro is about 5.22 GWhr, deficit in power at peak is 1945MW, and deficit in energy is 12.95 GWhr.

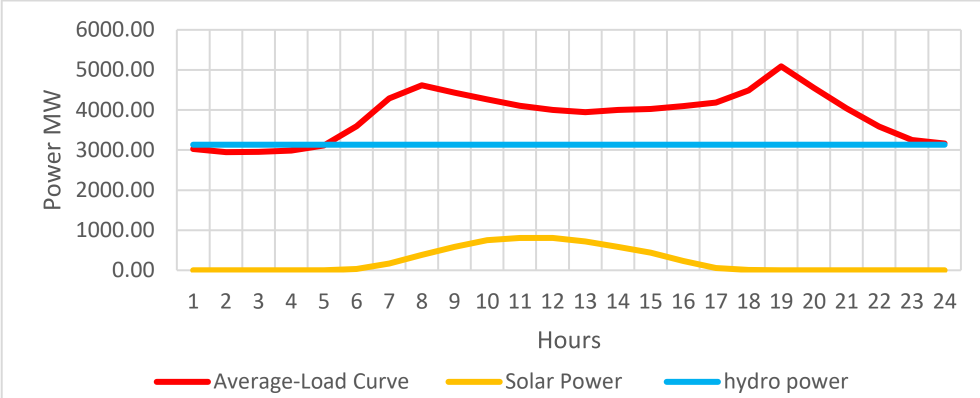


Figure 22 High scenario of March 2030

April, 2030

This month energy available from solar is about 5.29 GWhr, energy from hydro is 95.24

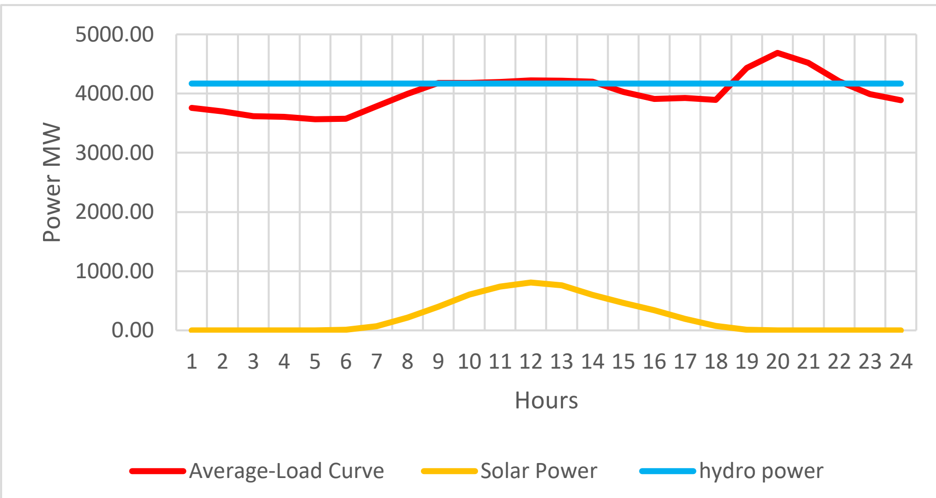


Figure 23 High scenario of April 2030

GWhr, and power production from hydro is 4165 MW, forecasted demand for the energy per day in this month is 92.45 GWhr with peak power demand of about 4687 MW. Here from time 8:30 hrs to time 15:30hrs and from 18:00 hrs to 22:00 hrs there is deficit of 11.6 GWhr and peak demand for power is about 4687MW as of in figure 23. Energy available from PHSP, combined of both solar and hydro is about 8.41 GWhr, deficit in power at peak is 518 MW, and deficit in energy is 7.23 GWhr.

Energy scenario of Four months described above in this scenario case is summarized in the table 5 below. All three months are also from the dry season.

Table 5 Summary of High Scenario

Month	Power Deficit	Energy-Deficit	Energy Available from PHSP	Final Deficit after PHSP
January	1731 MW	14.22 GWhr	4.20 GWhr	10.01 GWhr
February	1444 MW	10.64 GWhr	5.57 GWhr	5.06 GWhr
March	1955 MW	18.14 GWhr	5.22 GWhr	12.91 GWhr
April	518 MW	1.17 GWhr	8.41 GWhr	0.00 GWhr

In this scenario in a year there are in total four months January, February, March and April that are deficit in energy, so for these months' energy storage and regeneration is necessary. In these deficit months energy from PHSP with energy stored from 700MW solar power plant is only partially enough to manage energy deficit.

For complete management of energy and power 18.77 GWhr energy capacity 2000MW PHSP connected with 2700MW of solar power plant.

4.4.4 Policy Intervention 7.2%

Policy Intervention scenario with growth rate 7.2% shows different situation than other normal growth condition described above. Here also only deficit scenarios are described.

January, 2030

Energy available from solar in this month January (refer figure 24) is about 3.36 GWhr, energy from hydro is 73.3 GWhr, and power production from hydro is 3188 MW. Forecasted Demand for the energy per day in this month is 101.72 GWhr with peak power demand of about 5822 MW, Here from time 5:00 hrs to time 24:00hrs there is deficit of 28.38 GWhr and peak demand for power is about 5822MW. Energy available from PHSP, combined of both solar and hydro about 2.861 GWhr is available from storage and deficit in power at peak is 2633.3 MW.

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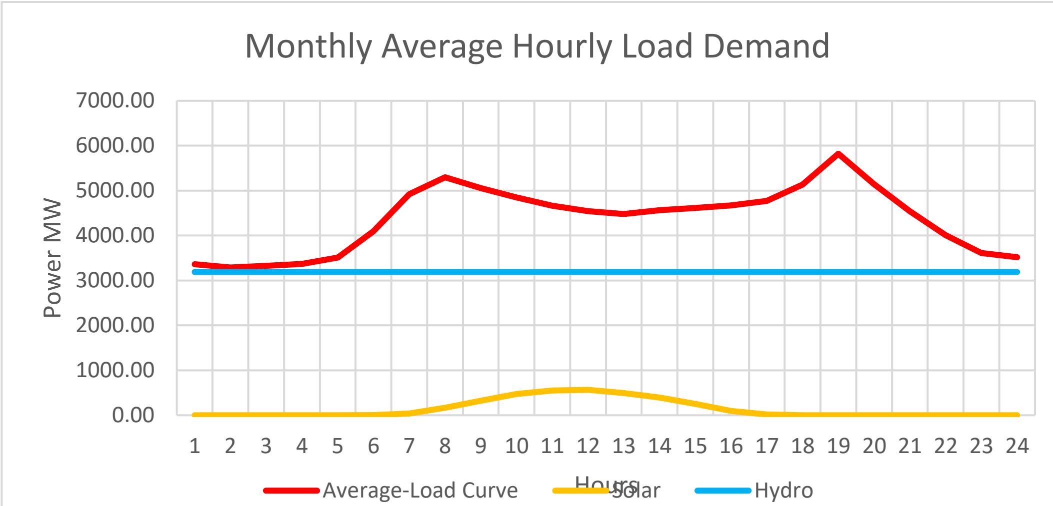

Figure 24 Policy Intervention 7.2% scenario of January 2030

February 2030

This month energy available from solar is about 4.11 GWhr, energy from hydro is 71.15 GWhr, and power production from hydro is 3093 MW. Forecasted Demand for the energy per day in this month is 93.88 GWhr with peak power demand of about 5386 MW, Here from time 5:00 hrs to time 24:00 hrs there is energy deficit of 22.81 GWhr. Energy available from PHSP, combined of both solar and hydro is about 3.56 GWhr and deficit in power at peak is 2275 MW and deficit in energy is 19.24 GWhr.

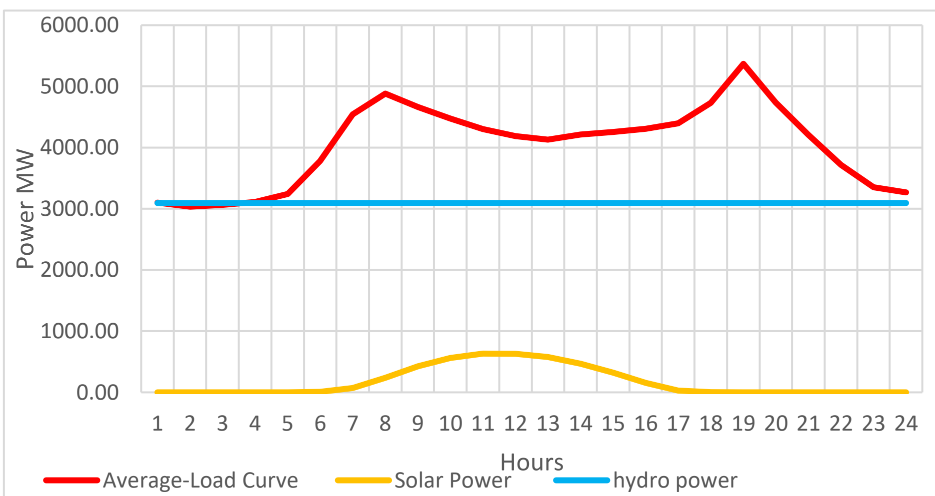

Figure 25 Policy Intervention scenario 7.2% of February 2030

March 2030

Forecasted Demand for the energy per day in this month March (figure 29) is 106.05 GWhr with peak power demand of about 6020 MW, energy from solar is about 5.57 GWhr and

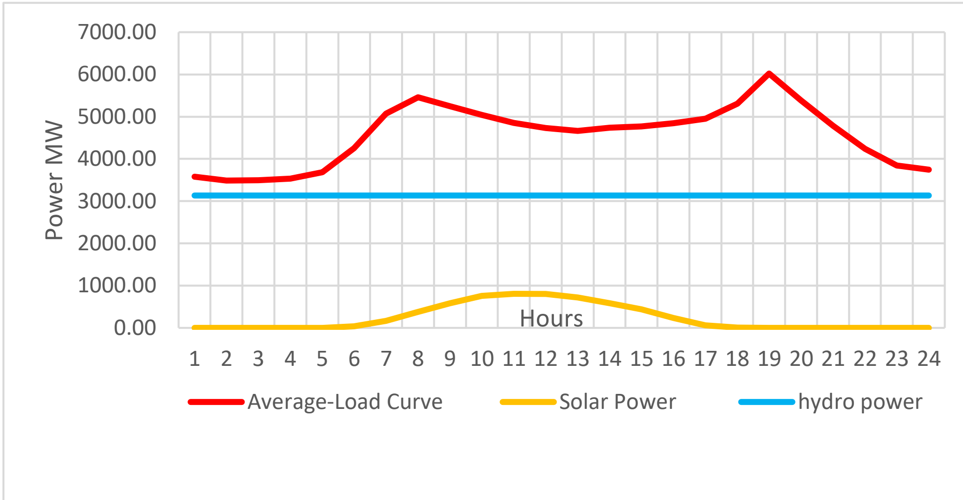

Figure 26 Policy Intervention scenario 7.2% of March 2030

energy from hydro is about 72.07 GWhr with power production of   3133 MW. Here from throughout the 24 hours there is deficit of 33.98 GWhr and peak demand for power is about 5268MW. Energy available from PHSP, combined of both solar and hydro is about 3.56 GWhr and deficit in power at peak is 2887 MW and deficit of energy is 29.25 GWhr.

April 2030

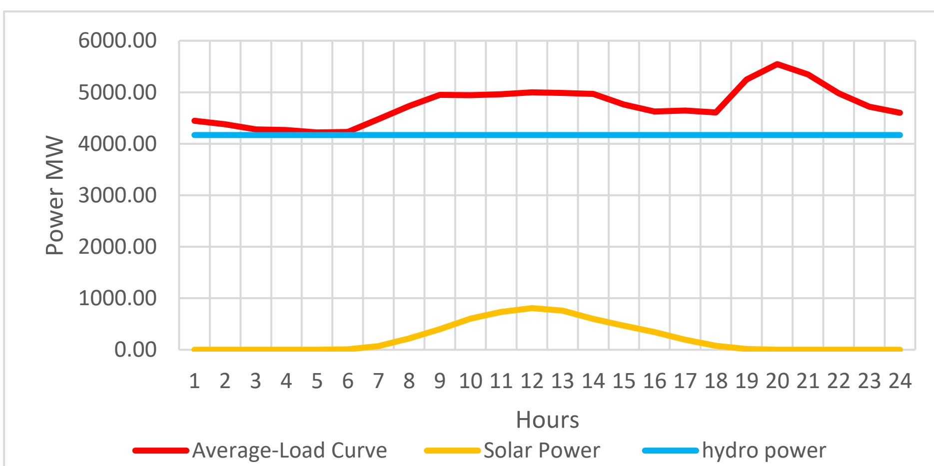

Figure 27 Policy Intervention scenario 7.2% of April 2030

Forecasted Demand for the energy per day in this month of April (refer figure 27) is 109.39 GWhr with peak power demand of about 5545 MW, energy from solar is about 35.294 GWhr and energy from hydro is about 95.88 GWhr with power production of 4168 MW. As in figure 27 here along 24 hrs there is deficit of 13.51 GWhr. Energy available from PHSP, combined of both solar and hydro is about 4.49 GWhr and deficit in power at peak is 1377MW and energy deficit is 9.01GWhr.

Energy scenario of Four months described above in this scenario is summarized in the table 6 below. All four months are also from the dry season.

Table 6 Summary of Policy Intervention-7.2% Scenario

Month	**Power Deficit**	**Energy-Deficit**	**Energy Available from PHSP**	**Final Deficit after PHSP**
January	2633 MW	28.38 GWhr	2.86 GWhr	25.52 GWhr
February	2275 MW	22.81 GWhr	3.56 GWhr	19.24 GWhr
March	2887 MW	33.98 GWhr	4.37 GWhr	29.25 GWhr
April	1377 MW	13.51GWhr	4.49 GWhr	9.01 GWhr

In this scenario in a year there are in total four months January, February, March and April that are deficit in energy, so for these months' energy storage and regeneration is necessary. In all four months, energy storage from PHSP is only partially enough to manage energy deficit, here energy requirement is nearly tenfold higher than storage capacity at maximum deficit condition.

For managing, the power demand there must be 2900MW of PHSP installed with capacity of 33.98GWhr, and for managing energy by PHSP there must be 2700MW solar PV installed.

4.4.5 Policy Intervention 9.2%

January 2030

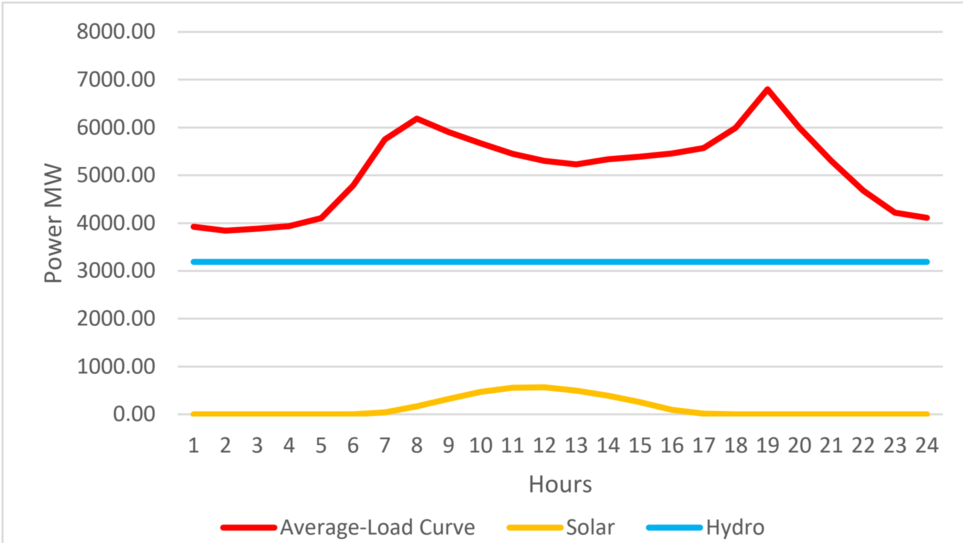

Figure 28 Policy Intervention scenario 9.2% of January 2030

Forecasted Demand for the energy per day in this month of January is 118.79 GWhr with peak power demand of about 6606 MW, available energy from solar is about 3.3 GWhr and energy from hydro is about 73.34 GWhr with power production of 3188 MW. As in figure 28 here along 24 hrs, there is deficit of 45.45 GWhr. Energy available from PHSP, only from solar and hydro is about 2.86 GWhr and deficit in power at peak is 3610 MW and energy is 42.59 GWhr.

February 2030

Forecasted Demand for the energy per day in this month of February is 109.64 GWhr with peak power demand of about 6269 MW, available energy from solar is about 4.11 GWhr and total energy from hydro is about 71.15 GWhr with power production of 3093 MW. Here in figure 33, along 24 hrs there is deficit of 38.49 GWhr. Energy available from PHSP, only from solar and hydro is about 3.49 GWhr and deficit in power at peak is 3176 MW and energy is 34.99 GWhr. integration of all the average monthly demand curve, hydro power and energy and power from solar is shown in figure 29.

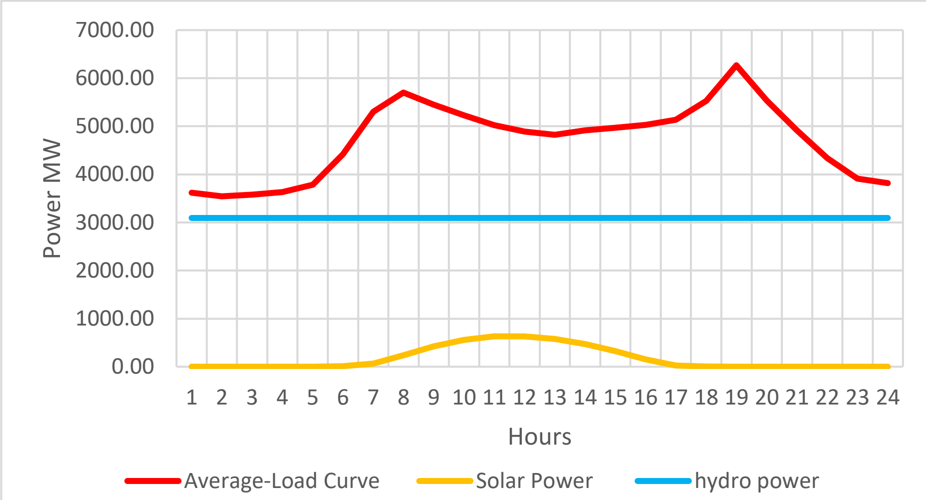

Figure 29 Policy Intervention scenario 9.2% of February 2030

March 2030

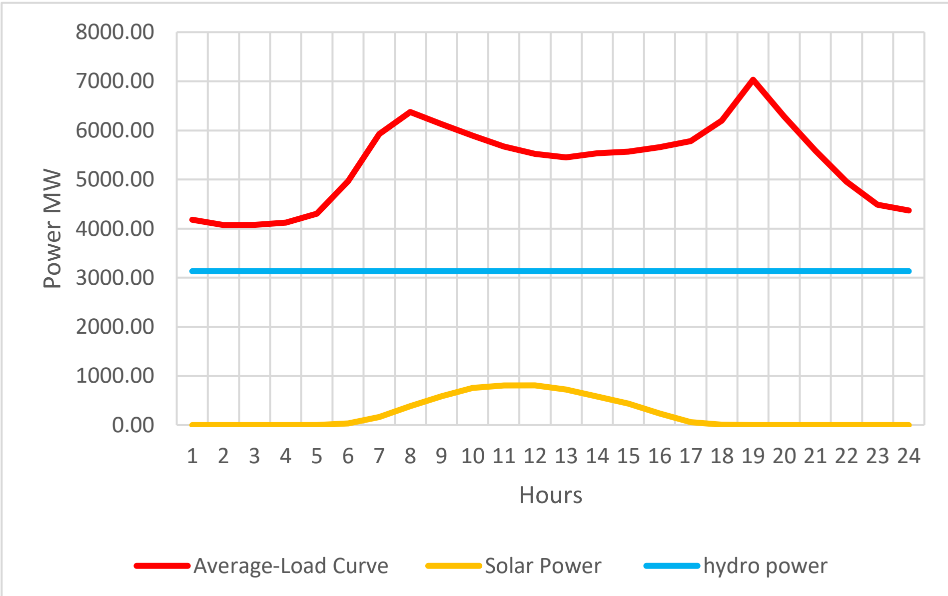

Figure 30 Policy Intervention scenario 9.2% of March 2030

March 2030 as shown in figure 30, forecasted Demand for the energy per day in this month is 123.85 GWhr with peak power demand of about 7031 MW, available energy from solar is about 4.73 GWhr and total energy from hydro is about 72.07 GWhr with power production from hydro of 3133 MW. Here along 24 hrs there is deficit of 51.78 GWhr. Energy available from PHSP, only from solar is about 3.89 GWhr and deficit in power at peak is 3897 MW and energy is 47.05 GWhr.

April 2030

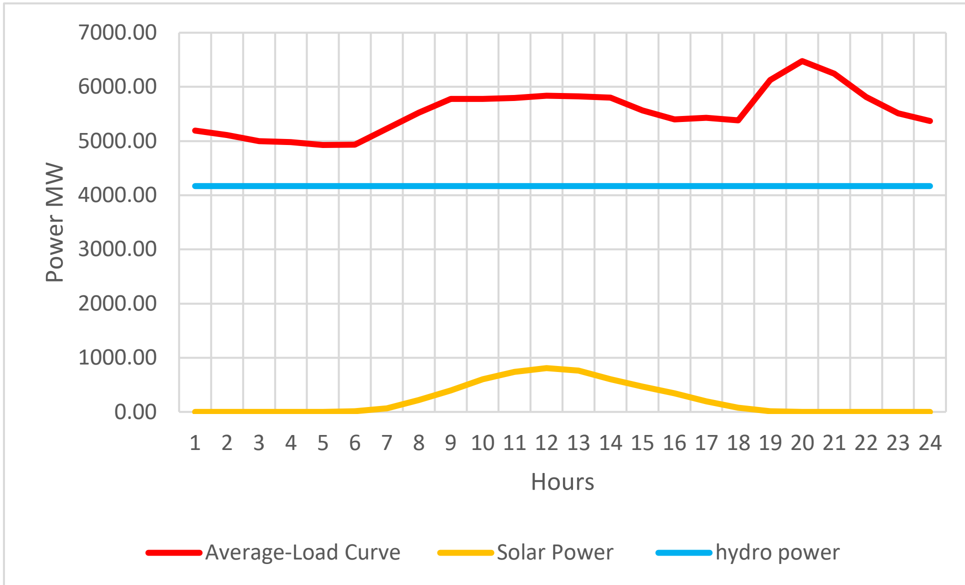

Figure 31 Policy Intervention scenario 9.2% of April 2030

Demand for the energy per day in this month April as in figure 31 is 127.75 GWhr with peak power demand of about 6476 MW, available energy from solar is about 5.29 GWhr, and energy from hydro is about 95.88 GWhr with power production of 4168 MW. Here along 24 hrs there is deficit of 31.87 GWhr. Energy available from PHSP, only from solar is about 4.49 GWhr so deficit in power at peak is 2307 MW and energy is 27.37 GWhr.

August 2030

Energy Demand per day in this month August is 151.24 GWhr with peak power demand of about 7511 MW, available energy from solar is about 4.85 GWhr, and energy from hydro is about 157.57 GWhr with power production of 6851 MW. Here along 24 hrs there is deficit of 1.61 GWhr. Energy available from PHSP, only from solar is about 4.12 GWhr and power deficit at peak is 660MW, all the demand and production is shown in figure 32.

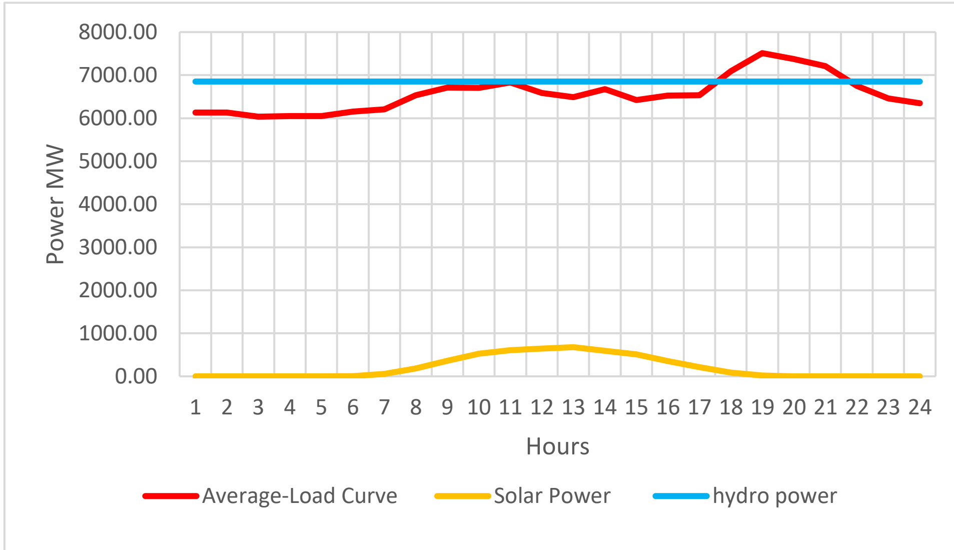

Figure 32 Policy Intervention scenario 9.2% of August 2030

September 2030

Here in September (refer figure 33) daily power production from hydro is 6850 MW and energy from hydropower is 157.55 GWhr per day, total energy from solar power is 4.45 GWhr that is monthly average daily production, with an efficiency of pumped hydropower plant considered total available energy for a day is 3.78 GWhr. From 8:30 hours to 12:00

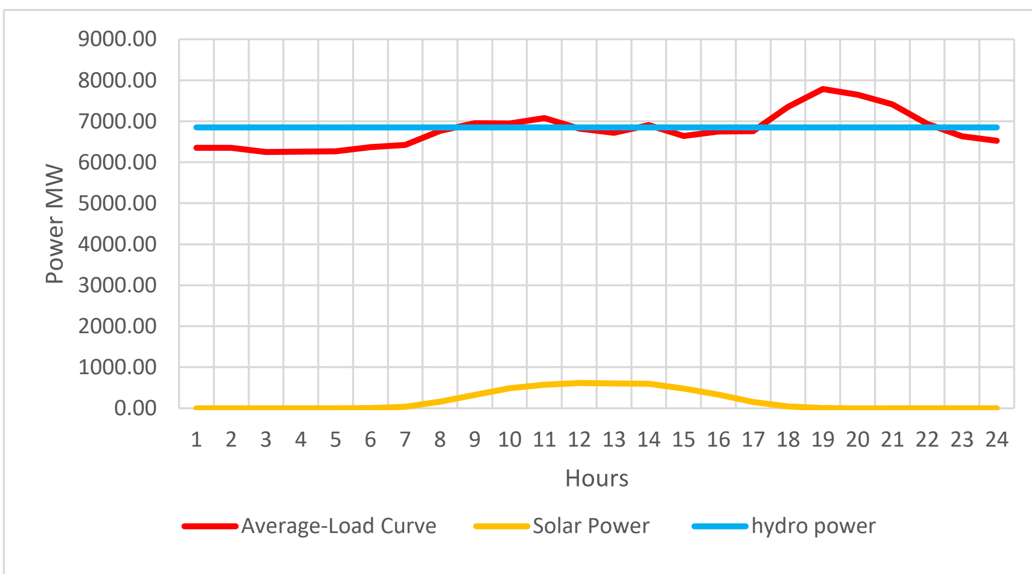

Figure 33 Policy Intervention scenario 9.2% of September 2030

hours there is deficit of 0.36 GWhr and from 17:00 hours to 20:00 hours deficit is 2.79 GWhr and at peak power deficit is 936 MW, during the peak period, there is a demand of 7011 MW of power in initial peak hour and 7786 MW of peak power demand in later peak hour. So here, the energy from the solar that is stored in pumped hydro storage alone is enough to fulfill the deficit demand in both peak hour periods in a given day.

October 2030

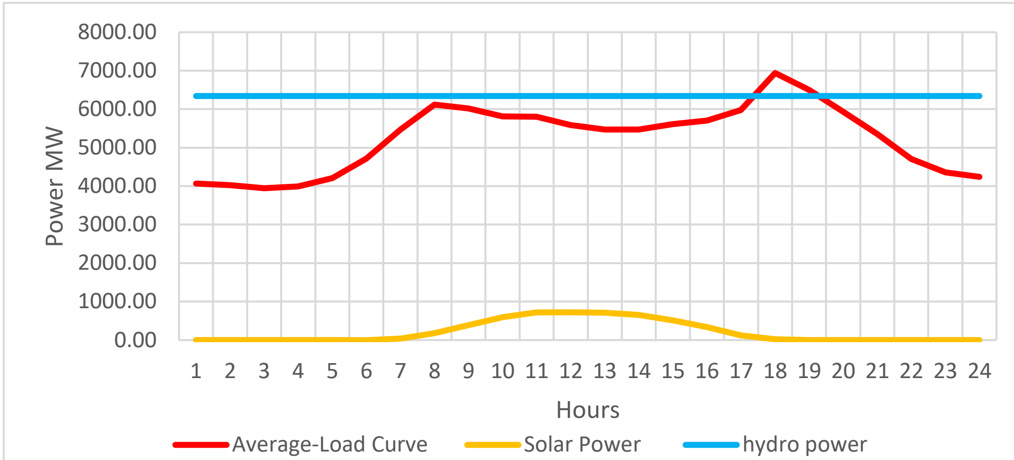

Figure 34 Policy Intervention scenario 9.2% of October 2030

Here monthly average daily power production hydro is 6341 MW and the energy from hydropower is 145.85 GWhr per day, total energy from solar power is 4.99 GWhr which is monthly average daily production, total available energy for a day is 4.24 GWhr. As in Figure 34 from 17:00 hours to 20:00 hours there is a deficit of 0.49 GWhr, during the peak period there is a demand of 6939 MW of power. So here, the energy from the solar, which is stored in pumped hydro storage alone, is enough to fulfill the deficit of 0.49 GWhr demand in both peak hour periods in a given day.

November 2030

In November (refer to figure 25), daily power production from hydro is 4554 MW and energy from hydropower is 104.76 GWhr per day, total energy from solar power is 4.13 GWhr which is monthly average daily production, total available energy through solar and from PHSP for a day is 3.51 GWhr. From 7:00 hours to 12:00 hours, there is peak formation of 5387 MW and from 15:00 hours to 21:00 hours, there is peak power demand of 6106MW, and the total deficit from 7:00 hours to 21:00 hours is 8.74 GWhr. The total energy from the solar and surplus hydro energy is 8.7 GWhr, which is stored in pumped hydro storage is nearly enough to fulfill the deficit demand in both peak hours periods.

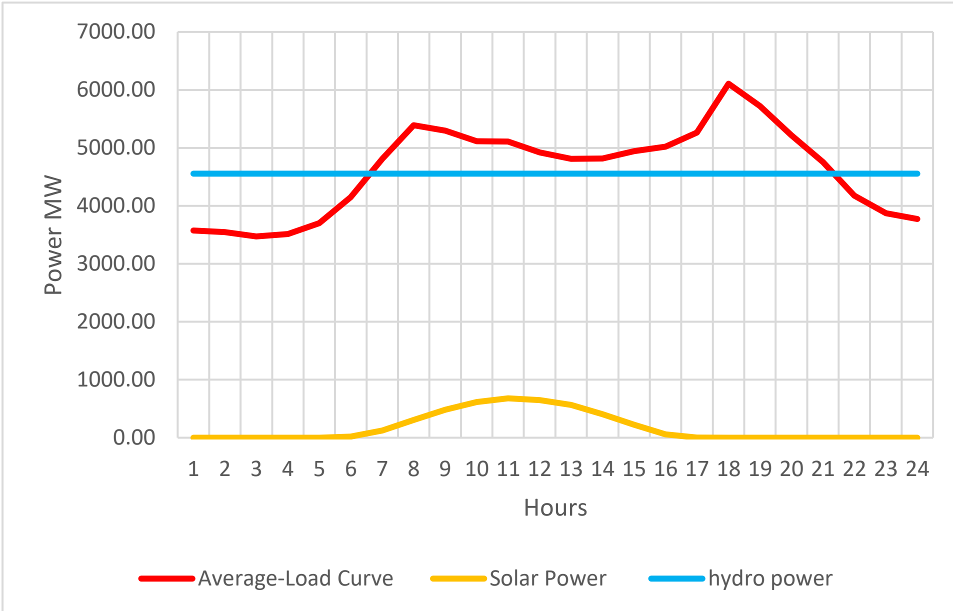

Figure 35 Policy Intervention scenario 9.2% of November 2030

December 2030

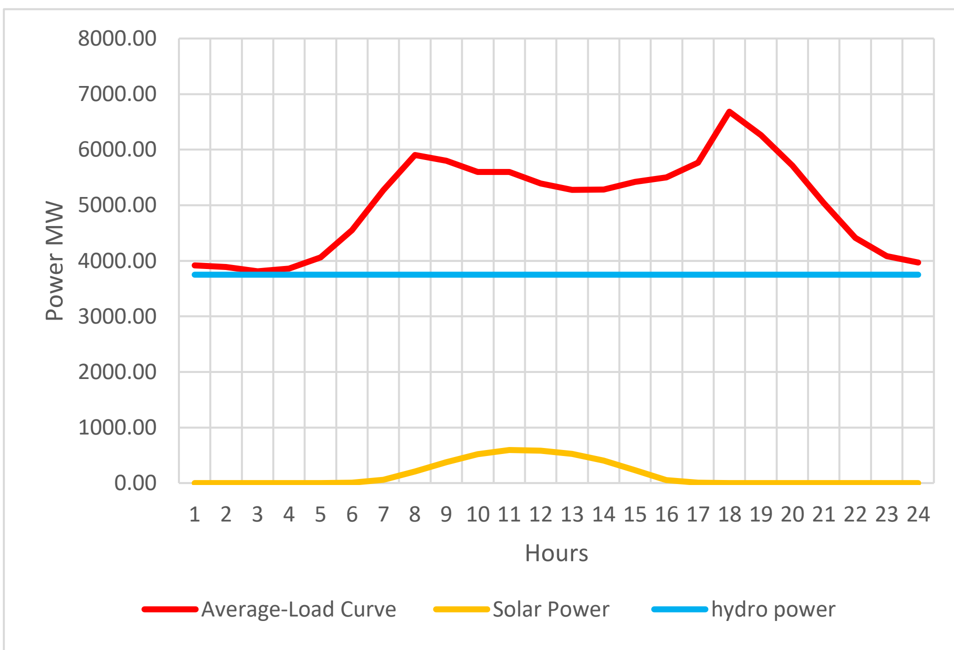

Figure 36 Policy Intervention scenario 9.2% of December 2030

Daily power production from hydro is 3750 MW and energy from hydropower is 117.12 GWhr per day, total monthly average daily energy from solar power is 3.57 GWhr, from PHSP available energy for a day is 3.51 GWhr. There are peak at 8:00 of 5901 MW and at 18:00 hours peak of6683 MW, as shown in figure 36 total deficit from 7:00 hours to 22:00 hours is 30.87 GWhr. Energy stored in PHSP from the solar and surplus hydro is 3.04 GWhr, so here there is energy deficit of 27.8 GWhr and power deficit is about 3040MW.

Energy scenario of all deficit months described above in this scenario are summarized in the table 7 below. Here months are also from the dry season as well as wet season.

Table 7 Summary Policy Intervention-9.2% Scenario

Month	**Power Deficit**	**Energy-Deficit**	**Stored Energy Available**	**Final Deficit**
January	3610 MW	45.45 GWhr	2.86 GWhr	42.59 GWhr
February	3176 MW	38.49 GWhr	3.49 GWhr	34.99 GWhr
March	3897 MW	51.78 GWhr	4.73 GWhr	47.04 GWhr
April	2307 MW	31.87 GWhr	4.49 GWhr	27.37 GWhr
August	660 MW	1.61 GWhr	10.87 GWhr	-
September	936 MW	3.16 GWhr	7.39 GWhr	-
October	598 MW	0.49 GWhr	25.03 GWhr	-
November	1551 MW	8.70 GWhr	8.7 GWhr	0.03 GWhr
December	2933 MW	30.87 GWhr	3.04 GWhr	27.83 GWhr

In this policy, intervention is 9.2%, in a year there are in total Nine months January to April, and August to December, so for these months' energy storage and regeneration are necessary. August, September, and October months are in the wet season, energy deficiency can be managed by installed solar power plants, in the rest of the months which are in the dry season, energy storage from solar power plants and hydro plant stored PHSP is only partially enough to manage energy deficit.

To manage the power, there must be about additional 4000MW power production through the PHSP, which that implies to manage the power load it must have an installation of PHSP of that capacity with 51.78GWhr energy storage. For managing, that energy there must be a 7700MW solar power plant installed.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

From the forecast and analysis of energy, power, and power demand in the overall scenario there in most scenarios there is an energy and power deficit in the dry season. In the first case of the Business as Usual Case Scenario with anticipated hydropower, plant in the future, and load demand in the future, there is need for PHSP with 286MW-installed capacity to manage power and energy shortage. Second case of the Reference Scenario, for the forecasted load and the hydropower plant there is a need for energy management, and PHSP capacity of 1100MW connected with 700MW of the solar power plant is enough to manage the deficit.

In the third case of the High Scenario, four months of the dry season need to be managed, with the condition of load and solar installed there is only partial management of energy. For complete management of energy and power 18.77 GWhr energy capacity 2000MW PHSP connected with 2700MW of the solar power plant.

In the case of policy intervention scenario, both cases of growth rate provided the condition of 7000MW of hydropower installed capacity and 700MW of the solar power plant is only partially enough to manage the deficit. For the first case of the intervention scenario, there is a requirement of 2900MW of PHSP with an energy of 33.98GWhr and a total installation of 2700MW of the solar plant, likewise in the second case of the intervention scenario 7000MW of the solar power plant and 4000MW of PHSP with an energy capacity of 52GWhr.

So analyzing the results, we can summarize that in case there is no policy intervention, and there is no energy transition in normal growth there is a need for PHSP with minimum installed capacity or an energy storage system. Whereas if growth is high then in this case there is the scope of PHSP and need for increment of Solar PV installment and connection in the national grid. In case of policy intervention then for load and energy balance, the national grid requires significant energy storage through PHSP and installation of Solar PV.

This study does not consider the optimized ratio of the energy mix of hydropower, solar power, and pumped hydro storage plant, so a study on an appropriate mix of all these power system is needed concerning various scenarios in the future. There are several months and a time period when there shall be no consumption of generation and storage capacity, so for utilization of those periods, the feasibility of power trade needs to be explored.

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APPENDIX

January 2030- Business as Usual

Hours	Average-Load Curve	Hours	Peak load day Power MW	Solar Irradiance	Power MW	hydro Power
1	1909.377185	1	1830.149222	0	0	3188.8
2	1868.953835	2	1777.997617	0	0	3188.8
3	1887.945876	3	1780.170013	0	0	3188.8
4	1914.305435	4	1798.864564	0	0	3188.8
5	1996.329344	5	1885.231352	0	0	3188.8
6	2327.946591	6	2217.277656	1.832608696	1.92423913	3188.8
7	2796.976306	7	2686.593614	38.64388824	40.57608265	3188.8
8	3008.422857	8	2899.511386	156.7314516	164.5680242	3188.8
9	2873.700468	9	2767.910267	305.8364516	321.1282742	3188.8
10	2756.850693	10	2650.354603	447.2054032	469.5656734	3188.8
11	2649.565231	11	2543.224292	526.7646237	553.1028548	3188.8
12	2579.434236	12	2472.466512	538.6118817	565.5424758	3188.8
13	2544.192119	13	2434.837359	471.0522312	494.6048427	3188.8
14	2594.581452	14	2476.961784	373.4374731	392.1093468	3188.8
15	2621.36151	15	2489.696159	239.8137097	251.8043952	3188.8
16	2653.60065	16	2535.361149	92.22472335	96.83595951	3188.8
17	2709.616811	17	2603.085933	13.72815269	14.41456033	3188.8
18	2915.659559	18	2818.129287	0	0	3188.8
19	3307.500842	19	3213.724693	0	0	3188.8
20	2919.269813	20	2831.210003	0	0	3188.8
21	2579.092906	21	2500.914275	0	0	3188.8
22	2276.121995	22	2202.422	0	0	3188.8
23	2052.78609	23	1980.703574	0	0	3188.8
24	2000.892054	24	1928.670203	0	0	3188.8
	59744.48386					

Hours	Energy Solar	Average energy Demand	energy	excess/deficit		
1	0	1889.16551	3188.8	1299.63449	1	1684.5686
2	0	1878.449856	3188.8	1310.350144	2	1853.2744
3	0	1901.125656	3188.8	1287.674344	3	2008.5174
4	0	1955.31739	3188.8	1233.48261	4	2150.2976
5	0.962119565	2162.137968	3188.8	1026.662032	5	2278.615
6	21.25016089	2562.461448	3188.8	626.3385515	6	2393.4696
7	102.5720534	2902.699582	3188.8	286.1004185	7	2494.8614
8	242.8481492	2941.061663	3188.8	247.7383373	8	2582.7904
9	395.3469738	2815.275581	3188.8	373.5244195	9	2657.2566
10	511.3342641	2703.207962	3188.8	485.5920382	10	2718.26

11	559.3226653	2614.499733	3188.8	574.3002668	11	2765.8006
12	530.0736593	2561.813178	3188.8	626.9868225	12	2799.8784
13	443.3570948	2569.386785	3188.8	619.4132145	13	2820.4934
14	321.956871	2607.971481	3188.8	580.8285193	14	2827.6456
15	174.3201773	2637.48108	3188.8	551.3189201	15	2821.335
16	55.62525992	2681.60873	3188.8	507.1912695	16	2801.5616
17	7.207280164	2812.638185	3188.8	376.1618153	17	2768.3254
18	0	3111.5802	3188.8	77.21979974	18	2721.6264
19	0	3113.385328	3188.8	75.41467245	19	2661.4646
20	0	2749.18136	3188.8	439.6186403	20	2587.84
21	0	2427.60745	3188.8	761.1925497	21	2500.7526
22	0	2164.454042	3188.8	1024.345958	22	2400.2024
23	0	2026.839072	3188.8	1161.960928	23	2286.1894
24	0			0	24	2158.7136
Total	3366.176729	57789.34924	73342.4	0	deficit	
				15553.05076	surlpus	
0.85	2861.250219			13220.09315	after PHSP	
	16081.34337	Total energy from PHSP				
	118.7008418	power deficit at peak				

March 2030- Business as Usual

			Peak load day	Solar		hydro
Hours	**Average-Load Curve**	**Hours**	**Power MW**	**Irradiance**	**Power MW**	**Power**
1	2034.314151	1	1925.264428	0	0	3133.5
2	1981.306955	2	1870.402437	0	0	3133.5
3	1984.335889	3	1872.687736	0	0	3133.5
4	2006.546791	4	1892.353867	0	0	3133.5
5	2092.450194	5	1983.209248	0.84	0.882	3133.5
6	2416.629393	6	2332.512425	32.68911696	34.32357281	3133.5
7	2883.046261	7	2826.219336	158.3377151	166.2546008	3133.5
8	3099.967921	8	3050.202719	364.0567742	382.2596129	3133.5
9	2979.697088	9	2911.76212	557.4272581	585.298621	3133.5
10	2865.171111	10	2788.096937	719.1738441	755.1325363	3133.5
11	2757.77386	11	2675.398926	768.1766935	806.5855282	3133.5
12	2687.042993	12	2600.963774	766.9171505	805.2630081	3133.5
13	2650.937237	13	2561.378985	687.681129	722.0651855	3133.5
14	2690.843839	14	2605.692671	552.4137634	580.0344516	3133.5
15	2707.223245	15	2619.088868	418.4702957	439.3938105	3133.5
16	2751.739191	16	2667.127126	222.6606633	233.7936964	3133.5
17	2814.083422	17	2738.371654	54.50868132	57.23411538	3133.5
18	3014.377952	18	2964.591087	5.225121951	5.486378049	3133.5
19	3420.278021	19	3380.746095	0	0	3133.5

20	3057.04676	20	2978.351625	0	0	3133.5
21	2716.461359	21	2630.890004	0	0	3133.5
22	2409.699813	22	2316.884702	0	0	3133.5
23	2182.405342	23	2083.643284	0	0	3133.5
24	2126.540717	24	2028.905672	0	0	3133.5

Hours	**Energy Solar**	**Average energy Demand**	**energy**	**excess/deficit**
1	0	2007.810553	3133.5	1125.689447
2	0	1982.821422	3133.5	1150.678578
3	0	1995.44134	3133.5	1138.05866
4	0.441	2049.498492	3133.5	1084.001508
5	17.60278641	2254.539793	3133.5	878.9602067
6	100.2890868	2649.837827	3133.5	483.6621731
7	274.2571069	2991.507091	3133.5	141.9929092
8	483.7791169	3039.832504	3133.5	93.66749581
9	670.2155786	2922.434099	3133.5	211.0659007
10	780.8590323	2811.472486	3133.5	322.0275145
11	805.9242681	2722.408426	3133.5	411.0915737
12	763.6640968	2668.990115	3133.5	464.509885
13	651.0498185	2670.890538	3133.5	462.6094617
14	509.714131	2699.033542	3133.5	434.4664576
15	336.5937534	2729.481218	3133.5	404.0187819
16	145.5139059	2782.911307	3133.5	350.5886934
17	31.36024672	2914.230687	3133.5	219.2693125
18	2.743189024	3217.327987	3133.5	-83.82798693
19	0	3238.662391	3133.5	-105.1623906
20	0	2886.754059	3133.5	246.7459405
21	0	2563.080586	3133.5	570.4194139
22	0	2296.052578	3133.5	837.4474223
23	0	2154.47303	3133.5	979.0269702
24	0			0

Total	5574.007117	60249.49207	72070.5	-188.9903775	deficit
				12009.9983	surlpus
0.85	4737.90605			10208.49856	after PHSP
	14946.40461	Total energy from PHSP			
	286.7780214	power deficit at peak			

January 2030- Reference Scenario

			Peak load day	Solar		hydro
Hours	Average-Load Curve	Hours	Power MW	Irradiance	Power MW	Power
1	2373.856276	1	2879.364183	0	0	3188.8
2	2323.599458	2	2797.314336	0	0	3188.8
3	2347.211542	3	2800.732156	0	0	3188.8
4	2379.983383	4	2830.144196	0	0	3188.8
5	2481.960599	5	2966.024611	0	0	3188.8
6	2894.247752	6	3488.431322	1.8326087	1.92423913	3188.8
7	3477.374617	7	4226.803659	38.6438882	40.5760827	3188.8
8	3740.258099	8	4561.786075	156.731452	164.568024	3188.8
9	3572.762859	9	4354.738723	305.836452	321.128274	3188.8
10	3427.487964	10	4169.789013	447.205403	469.565673	3188.8
11	3294.104015	11	4001.241456	526.764624	553.102855	3188.8
12	3206.912808	12	3889.918612	538.611882	565.542476	3188.8
13	3163.09762	13	3830.716862	471.052231	494.604843	3188.8
14	3225.744767	14	3896.991	373.437473	392.109347	3188.8
15	3259.039398	15	3917.025925	239.81371	251.804395	3188.8
16	3299.121099	16	3988.870414	92.2247233	96.8359595	3188.8
17	3368.763868	17	4095.421463	13.7281527	14.4145603	3188.8
18	3624.929006	18	4433.748044	0	0	3188.8
19	4112.09042	19	5056.136225	0	0	3188.8
20	3629.417499	20	4454.327867	0	0	3188.8
21	3206.488445	21	3934.675328	0	0	3188.8
22	2829.816196	22	3465.058996	0	0	3188.8
23	2552.151132	23	3116.230557	0	0	3188.8
24	2487.633244	24	3034.366727	0	0	3188.8

Hours	Energy Solar	Avge energy Demand	energy	excess/deficit
1	0	2348.72787	3188.8	840.072133
2	0	2335.4055	3188.8	853.3945
3	0	2363.59746	3188.8	825.202537
4	0	2430.97199	3188.8	757.828009
5	0.962119565	2688.10418	3188.8	500.695824
6	21.25016089	3185.81118	3188.8	2.98881544
7	102.5720534	3608.81636	3188.8	-420.01636
8	242.8481492	3656.51048	3188.8	-467.71048
9	395.3469738	3500.12541	3188.8	-311.32541
10	511.3342641	3360.79599	3188.8	-171.99599

11	559.3226653	3250.50841	3188.8	-61.708411	-1432.7567
12	530.0736593	3185.00521	3188.8	3.79478615	
13	443.3570948	3194.42119	3188.8	-5.6211936	
14	321.956871	3242.39208	3188.8	-53.592082	
15	174.3201773	3279.08025	3188.8	-90.280249	
16	55.62525992	3333.94248	3188.8	-145.14248	
17	7.207280164	3496.84644	3188.8	-308.04644	
18	0	3868.50971	3188.8	-679.70971	
19	0	3870.75396	3188.8	-681.95396	
20	0	3417.95297	3188.8	-229.15297	-2193.4991
21	0	3018.15232	3188.8	170.647679	
22	0	2690.98366	3188.8	497.816336	
23	0	2519.89219	3188.8	668.907812	
24	0			0	
Total	3366.176729	71847.3073	73342.4	-3626.2557	deficit
				5121.34843	surlpus
0.85	2861.250219			4353.14617	after PHSP
	7214.396387	Total energy from PHSP			
power deficit at peak	923.2904204			energy deficit	3588.14065

February 2030- Reference Scenario

			Peak load day	**Solar**		**hydro**
Hours	**Average-Load Curve**	**Hours**	**Power MW**	**Irradiance**	**Power MW**	**Power**
1	2188.805749	1	2125.431897	0	0	3093.5
2	2143.199087	2	2064.865969	0	0	3093.5
3	2165.32933	3	2067.388868	0	0	3093.5
4	2195.504095	4	2089.099664	0	0	3093.5
5	2289.096097	5	2189.401171	0	0	3093.5
6	2669.622341	6	2575.020987	8.31227496	8.72788871	3093.5
7	3207.29672	7	3120.058022	64.8247698	68.0660083	3093.5
8	3449.30946	8	3367.328693	224.891033	236.135585	3093.5
9	3294.65107	9	3214.494588	404.809766	425.050254	3093.5
10	3160.827039	10	3077.972082	533.561257	560.23932	3093.5
11	3037.830947	11	2953.556992	602.798889	632.938833	3093.5
12	2957.298016	12	2871.382905	601.875146	631.968904	3093.5
13	2916.916584	13	2827.682533	551.651082	579.233636	3093.5
14	2974.956704	14	2876.60346	446.212456	468.523079	3093.5
15	3006.26863	15	2891.392443	306.689094	322.023548	3093.5
16	3042.611116	16	2944.425182	145.989678	153.289162	3093.5
17	3106.547765	17	3023.07692	27.0037265	28.3539128	3093.5

18	3342.40088	18	3272.81612	2.4	2.52	3093.5
19	3791.833014	19	3732.238273	0	0	3093.5
20	3346.376025	20	3288.007325	0	0	3093.5
21	2971.598961	21	2904.42053	0	0	3093.5
22	2623.670841	22	2557.768467	0	0	3093.5
23	2367.654038	23	2300.277215	0	0	3093.5
24	2308.291392	24	2239.848598	0	0	3093.5

Hours	**Energy Solar**	**Avg energy Demand**	**energy**	**excess/deficit**	
1	0	2166.00242	3093.5	927.497582	
2	0	2154.26421	3093.5	939.235792	
3	0	2180.41671	3093.5	913.083287	
4	0	2242.3001	3093.5	851.199904	
5	4.363944354	2479.35922	3093.5	614.140781	
6	38.39694851	2938.45953	3093.5	155.04047	
7	152.1007966	3328.30309	3093.5	-234.80309	
8	330.5929197	3371.98026	3093.5	-278.48026	
9	492.6447873	3227.73905	3093.5	-134.23905	
10	596.5890768	3099.32899	3093.5	-5.8289933	-653.3514
11	632.4538684	2997.56448	3093.5	95.9355184	
12	605.6012697	2937.1073	3093.5	156.3927	
13	523.8783575	2945.93664	3093.5	147.563356	
14	395.2733136	2990.61267	3093.5	102.887333	
15	237.6563553	3024.43987	3093.5	69.0601271	
16	90.82153754	3074.57944	3093.5	18.9205594	
17	15.4369564	3224.47432	3093.5	-130.97432	
18	1.26	3567.11695	3093.5	-473.61695	
19	0	3569.10452	3093.5	-475.60452	
20	0	3158.98749	3093.5	-65.487493	-1145.6833
21	0	2797.6349	3093.5	295.865099	
22	0	2495.66244	3093.5	597.83756	
23	0	2337.97271	3093.5	755.527285	
24	0			0	
Total	4117.070132	66309.3473	71150.5	-1799.0347	deficit
				6640.18735	surplus
0.85	3499.509612			5644.15925	after PHSP
	9143.668862	Total energy from PHSP			
power deficit at peak	698.3330142				

March 2030- Reference Scenario

			Peak load day	Solar		hydro
Hours	Average-Load Curve	Hours	Power MW	Irradiance	Power MW	Power
1	2529.18567	1	2393.608284	0	0	3133.5
2	2463.283833	2	2325.40045	0	0	3133.5
3	2467.049592	3	2328.241675	0	0	3133.5
4	2494.663564	4	2352.691831	0	0	3133.5
5	2601.464008	5	2465.648881	0.84	0.882	3133.5
6	3004.503718	6	2899.924281	32.689117	34.3235728	3133.5
7	3584.382129	7	3513.731368	158.337715	166.254601	3133.5
8	3854.072607	8	3792.201418	364.056774	382.259613	3133.5
9	3704.544439	9	3620.083469	557.427258	585.298621	3133.5
10	3562.158633	10	3466.335235	719.173844	755.132536	3133.5
11	3428.635702	11	3326.22207	768.176694	806.585528	3133.5
12	3340.698696	12	3233.679666	766.917151	805.263008	3133.5
13	3295.809779	13	3184.465399	687.681129	722.065185	3133.5
14	3345.424144	14	3239.558925	552.413763	580.034452	3133.5
15	3365.788039	15	3256.213908	418.470296	439.39381	3133.5
16	3421.133027	16	3315.938053	222.660663	233.793696	3133.5
17	3498.643247	17	3404.513675	54.5086813	57.2341154	3133.5
18	3747.661843	18	3685.763721	5.22512195	5.48637805	3133.5
19	4252.302013	19	4203.153467	0	0	3133.5
20	3800.710354	20	3702.871676	0	0	3133.5
21	3377.273436	21	3270.885814	0	0	3133.5
22	2995.888434	22	2880.494925	0	0	3133.5
23	2713.301834	23	2590.514711	0	0	3133.5
24	2643.847464	24	2522.461512	0	0	3133.5

Hours	Energy Solar	Avg energy Demand	energy	excess/deficit
1	0	3728.70882	4168.8	440.091177
2	0	3659.02654	4168.8	509.773458
3	0	3612.2267	4168.8	556.5733
4	0	3586.32864	4168.8	582.471358
5	4.801591512	3569.13425	4168.8	599.665753
6	38.73984522	3678.82862	4168.8	489.971383
7	142.9777728	3891.50683	4168.8	277.29317
8	307.5858931	4089.04143	4168.8	79.7585738
9	500.3152657	4180.17637	4168.8	-11.376374
10	670.5991542	4187.10201	4168.8	-18.302007
11	773.051825	4208.77401	4168.8	-39.974006

12	784.3284021	4219.42534	4168.8	-50.625339	
13	680.215375	4207.56611	4168.8	-38.766111	-159.04384
14	533.4580271	4113.20434	4168.8	55.595661	
15	404.6340083	3967.77138	4168.8	201.02862	
16	268.8069344	3918.16789	4168.8	250.632111	
17	134.9590883	3911.738	4168.8	257.061999	
18	43.49620604	4165.57831	4168.8	3.22168879	
19	6.05953555	4561.42409	4168.8	-392.62409	
20	0	4602.71501	4168.8	-433.91501	
21	0	4363.07908	4168.8	-194.27908	-1020.8182
22	0	4099.1041	4168.8	69.6959039	
23	0	3938.17953	4168.8	230.620474	
24	0			0	

Total	5294.028924	92458.8074	95882.4	-1179.862	deficit
				4603.45463	surplus
	8412.861023	Total energy from PHSP			
power deficit at peak	518.4550701			7232.99901	

January 2030- High Scenario

			Peak load day	Solar		hydro
Hours	**Average-Load Curve**	**Hours**	**Power MW**	**Irradiance**	**Power MW**	**Power**
1	3757.391826	1	3687.343254	0	0	4168.8
2	3700.02582	2	3630.604513	0	0	4168.8
3	3618.027263	3	3543.428781	0	0	4168.8
4	3606.426136	4	3525.127289	0	0	4168.8
5	3566.231147	5	3480.100874	0	0	4168.8
6	3572.037346	6	3485.888013	9.145888594	9.603183024	4168.8
7	3785.619887	7	3695.894932	64.64429277	67.87650741	4168.8
8	3997.393773	8	3903.800895	207.694322	218.0790381	4168.8
9	4180.689079	9	4085.169009	378.1835696	397.0927481	4168.8
10	4179.663669	10	4084.709364	574.7978889	603.5377833	4168.8
11	4194.540344	11	4105.486352	702.5338333	737.660525	4168.8
12	4223.007668	12	4137.78467	769.9458333	808.443125	4168.8
13	4215.843011	13	4130.000506	724.0130278	760.2136792	4168.8
14	4199.289212	14	4114.603565	571.6353056	600.2170708	4168.8
15	4027.119466	15	3929.081387	444.4752222	466.6989833	4168.8
16	3908.423294	16	3804.319062	326.2562222	342.5690333	4168.8
17	3927.912484	17	3828.157868	185.7569862	195.0448355	4168.8
18	3895.563519	18	3806.611798	71.30794378	74.87334097	4168.8

19	4435.593103	19	4344.603878	11.54197248	12.1190711	4168.8
20	4687.25507	20	4595.542761	0	0	4168.8
21	4518.174949	21	4421.549757	0	0	4168.8
22	4207.983212	22	4103.15322	0	0	4168.8
23	3990.224981	23	3892.131709	0	0	4168.8
24	3886.134071	24	3790.224972	0	0	4168.8

Hours	**Energy Solar**	**Avg energy Demand**	**energy**	**excess/deficit**	
1	0	3728.708823	4168.8	440.0911769	
2	0	3659.026542	4168.8	509.7734583	
3	0	3612.2267	4168.8	556.5733004	
4	0	3586.328642	4168.8	582.4713584	
5	4.801591512	3569.134247	4168.8	599.6657533	
6	38.73984522	3678.828617	4168.8	489.9713832	
7	142.9777728	3891.50683	4168.8	277.2931697	
8	307.5858931	4089.041426	4168.8	79.75857376	
9	500.3152657	4180.176374	4168.8	-11.37637404	
10	670.5991542	4187.102007	4168.8	-18.30200661	
11	773.051825	4208.774006	4168.8	-39.97400599	
12	784.3284021	4219.425339	4168.8	-50.62533926	
13	680.215375	4207.566111	4168.8	-38.76611133	-159.0438372
14	533.4580271	4113.204339	4168.8	55.59566105	
15	404.6340083	3967.77138	4168.8	201.0286201	
16	268.8069344	3918.167889	4168.8	250.6321115	
17	134.9590883	3911.738001	4168.8	257.0619986	
18	43.49620604	4165.578311	4168.8	3.221688794	
19	6.05953555	4561.424087	4168.8	-392.6240866	
20	0	4602.71501	4168.8	-433.9150098	
21	0	4363.079081	4168.8	-194.2790806	-1020.818177
22	0	4099.104096	4168.8	69.69590388	
23	0	3938.179526	4168.8	230.6204745	
24	0			0	

Total	5294.028924	92458.80738	95882.4	-1179.862014	deficit
0.85	4499.924586			4603.454632	surplus
	8412.861023	total phsp		3912.936437	after PHSP
	518.4550701	power deficit at peak		7232.999009	Final deficit-energy

February 2030- High Scenario

			Peak load day	Solar		hydro
Hours	**Average-Load Curve**	**Hours**	**Power MW**	**Irradiance**	**Power MW**	**Power**
1	2619.26971	1	2543.432367	0	0	3093.5
2	2564.693762	2	2470.955173	0	0	3093.5
3	2591.176275	3	2473.974241	0	0	3093.5
4	2627.285394	4	2499.954815	0	0	3093.5
5	2739.283773	5	2619.982231	0	0	3093.5
6	3194.646642	6	3081.440405	8.312274959	8.727888707	3093.5
7	3838.063361	7	3733.667766	64.82476982	68.06600832	3093.5
8	4127.67181	8	4029.568203	224.8910333	236.1355849	3093.5
9	3942.597354	9	3846.676806	404.8097661	425.0502544	3093.5
10	3782.454668	10	3683.304947	533.5612573	560.2393202	3093.5
11	3635.26941	11	3534.421623	602.7988889	632.9388333	3093.5
12	3538.898379	12	3436.086676	601.8751462	631.9689035	3093.5
13	3490.575287	13	3383.79192	551.6510819	579.233636	3093.5
14	3560.029933	14	3442.333937	446.2124561	468.5230789	3093.5
15	3597.499854	15	3460.031413	306.6890936	322.0235482	3093.5
16	3640.989676	16	3523.493895	145.9896784	153.2891623	3093.5
17	3717.5005	17	3617.613766	27.00372647	28.35391279	3093.5
18	3999.737934	18	3916.468209	2.4	2.52	3093.5
19	4537.558148	19	4466.243139	0	0	3093.5
20	4004.494856	20	3934.647009	0	0	3093.5
21	3556.011835	21	3475.621682	0	0	3093.5
22	3139.658039	22	3060.794899	0	0	3093.5
23	2833.2914	23	2752.663838	0	0	3093.5
24	2762.254132	24	2680.350958	0	0	3093.5

Hours	Energy Solar	Avg energy Demand	energy	excess/deficit
1	0	2591.981736	3093.5	501.5182638
2	0	2577.935018	3093.5	515.5649815
3	0	2609.230835	3093.5	484.2691654
4	0	2683.284584	3093.5	410.2154161
5	4.363944354	2966.965208	3093.5	126.5347925
6	38.39694851	3516.355001	3093.5	-422.8550013
7	152.1007966	3982.867586	3093.5	-889.3675856
8	330.5929197	4035.134582	3093.5	-941.634582
9	492.6447873	3862.526011	3093.5	-769.026011

10	596.5890768	3708.862039	3093.5	-615.3620394	
11	632.4538684	3587.083895	3093.5	-493.5838948	
12	605.6012697	3514.736833	3093.5	-421.2368332	
13	523.8783575	3525.30261	3093.5	-431.8026103	
14	395.2733136	3578.764894	3093.5	-485.2648939	
15	237.6563553	3619.244765	3093.5	-525.7447653	
16	90.82153754	3679.245088	3093.5	-585.7450879	
17	15.4369564	3858.619217	3093.5	-765.1192166	
18	1.26	4268.648041	3093.5	-1175.148041	
19	0	4271.026502	3093.5	-1177.526502	
20	0	3780.253346	3093.5	-686.7533456	
21	0	3347.834937	3093.5	-254.334937	
22	0	2986.474719	3093.5	107.0252806	
23	0	2797.772766	3093.5	295.7272338	
24	0			0	
Total	4117.070132	79350.15021	71150.5	-10640.50535	deficit

0.85	3499.509612		2440.855134	surplus
	5574.236475	total phsp	2074.726864	after PHSP
	1444.058148	power deficit at peak	-5066.268871	final energy deficit

March 2030- High Scenario

			Peak load day	**Solar**		**hydro**

Hours	Average-Load Curve	Hours	Power MW	Irradiance	Power MW	Power
1	3026.59	1	2864.35	0.00	0.00	3133.5
ss	2947.73	2	2782.73	0.00	0.00	3133.5
3	2952.23	3	2786.13	0.00	0.00	3133.5
4	2985.28	4	2815.39	0.00	0.00	3133.5
5	3113.08	5	2950.56	0.84	0.88	3133.5
6	3595.39	6	3470.24	32.69	34.32	3133.5
7	4289.31	7	4204.76	158.34	166.25	3133.5
8	4612.04	8	4538.00	364.06	382.26	3133.5
9	4433.10	9	4332.03	557.43	585.30	3133.5
10	4262.71	10	4148.05	719.17	755.13	3133.5
11	4102.93	11	3980.38	768.18	806.59	3133.5
12	3997.70	12	3869.63	766.92	805.26	3133.5
13	3943.98	13	3810.74	687.68	722.07	3133.5
14	4003.36	14	3876.67	552.41	580.03	3133.5
15	4027.72	15	3896.60	418.47	439.39	3133.5
16	4093.95	16	3968.07	222.66	233.79	3133.5
17	4186.71	17	4074.07	54.51	57.23	3133.5
18	4484.70	18	4410.63	5.23	5.49	3133.5
19	5088.59	19	5029.77	0.00	0.00	3133.5
20	4548.18	20	4431.10	0.00	0.00	3133.5
21	4041.47	21	3914.16	0.00	0.00	3133.5
22	3585.08	22	3446.99	0.00	0.00	3133.5
23	3246.92	23	3099.98	0.00	0.00	3133.5
24	3163.80	24	3018.54	0.00	0.00	3133.5

Hours	Energy Solar	Avg energy Demand	energy	excess/deficit
1	0	2987.159586	3133.5	146.3404144
2	0	2949.981515	3133.5	183.5184846
3	0	2968.757046	3133.5	164.742954
4	0.441	3049.181636	3133.5	84.31836427
5	17.60278641	3354.235859	3133.5	-220.7358585
6	100.2890868	3942.348272	3133.5	-808.848272
7	274.2571069	4450.67343	3133.5	-1317.17343
8	483.7791169	4522.570513	3133.5	-1389.070513
9	670.2155786	4347.90873	3133.5	-1214.40873
10	780.8590323	4182.82341	3133.5	-1049.32341
11	805.9242681	4050.316607	3133.5	-916.8166066
12	763.6640968	3970.842465	3133.5	-837.3424648

13	651.0498185	3973.669857	3133.5	-840.1698568
14	509.714131	4015.540164	3133.5	-882.0401639
15	336.5937534	4060.839291	3133.5	-927.3392915
16	145.5139059	4140.330955	3133.5	-1006.830955
17	31.36024672	4335.703943	3133.5	-1202.203943
18	2.743189024	4786.642903	3133.5	-1653.142903
19	0	4818.383582	3133.5	-1684.883582
20	0	4294.82505	3133.5	-1161.32505
21	0	3813.273483	3133.5	-679.773483
22	0	3415.997319	3133.5	-282.4973188
23	0	3205.359566	3133.5	-71.85956562
24	0			0

Total	5,574.01	89,637.37	72,070.50	-18145.7854	deficit
0.85	4,737.91			578.9202173	surlpus
	5,229.99	total phsp		492.0821847	after PHSP
	1955.1	power deficit at peak		(12,915.80)	total deficit after PHSP

April 2030- High Scenario

		Load Data of Peak day		Solar		hydro
Hours	Average-Load Curve	Hours	Power MW	Irradiance	Power MW	power
1	3757.391826	1	3687.343254	0	0	4168.8
2	3700.02582	2	3630.604513	0	0	4168.8
3	3618.027263	3	3543.428781	0	0	4168.8
4	3606.426136	4	3525.127289	0	0	4168.8
5	3566.231147	5	3480.100874	0	0	4168.8
6	3572.037346	6	3485.888013	9.145888594	9.603183024	4168.8
7	3785.619887	7	3695.894932	64.64429277	67.87650741	4168.8
8	3997.393773	8	3903.800895	207.694322	218.0790381	4168.8
9	4180.689079	9	4085.169009	378.1835696	397.0927481	4168.8
10	4179.663669	10	4084.709364	574.7978889	603.5377833	4168.8
11	4194.540344	11	4105.486352	702.5338333	737.660525	4168.8
12	4223.007668	12	4137.78467	769.9458333	808.443125	4168.8
13	4215.843011	13	4130.000506	724.0130278	760.2136792	4168.8
14	4199.289212	14	4114.603565	571.6353056	600.2170708	4168.8

15	4027.119466	15	3929.081387	444.4752222	466.6989833	4168.8
16	3908.423294	16	3804.319062	326.2562222	342.5690333	4168.8
17	3927.912484	17	3828.157868	185.7569862	195.0448355	4168.8
18	3895.563519	18	3806.611798	71.30794378	74.87334097	4168.8
19	4435.593103	19	4344.603878	11.54197248	12.1190711	4168.8
20	4687.25507	20	4595.542761	0	0	4168.8
21	4518.174949	21	4421.549757	0	0	4168.8
22	4207.983212	22	4103.15322	0	0	4168.8
23	3990.224981	23	3892.131709	0	0	4168.8
24	3886.134071	24	3790.224972	0	0	4168.8

Hours	**Energy Solar (area)**	**Avg energy Demand**	**energy avilable**	**excess/deficit**	
1	0	3728.708823	4168.8	440.0911769	
2	0	3659.026542	4168.8	509.7734583	
3	0	3612.2267	4168.8	556.5733004	
4	0	3586.328642	4168.8	582.4713584	
5	4.801591512	3569.134247	4168.8	599.6657533	
6	38.73984522	3678.828617	4168.8	489.9713832	
7	142.9777728	3891.50683	4168.8	277.2931697	
8	307.5858931	4089.041426	4168.8	79.75857376	
9	500.3152657	4180.176374	4168.8	-11.37637404	
10	670.5991542	4187.102007	4168.8	-18.30200661	
11	773.051825	4208.774006	4168.8	-39.97400599	
12	784.3284021	4219.425339	4168.8	-50.62533926	
13	680.215375	4207.566111	4168.8	-38.76611133	-159.0438372
14	533.4580271	4113.204339	4168.8	55.59566105	
15	404.6340083	3967.77138	4168.8	201.0286201	
16	268.8069344	3918.167889	4168.8	250.6321115	
17	134.9590883	3911.738001	4168.8	257.0619986	
18	43.49620604	4165.578311	4168.8	3.221688794	
19	6.05953555	4561.424087	4168.8	-392.6240866	
20	0	4602.71501	4168.8	-433.9150098	
21	0	4363.079081	4168.8	-194.2790806	-1020.818177
22	0	4099.104096	4168.8	69.69590388	
23	0	3938.179526	4168.8	230.6204745	
24	0			0	

Total	5,294.03	92,458.81	95,882.40	-1179.862014	deficit
				4603.454632	surlpus
0.85	4,499.92			3912.936437	after PHSP
	8,412.86	total phsp			
	518.5	power deficit at peak		7,233.00	total deficit after PHSP

January 2030- Intervention 7.2%

			Peak load day	Solar		hydro
Hours	**Average-Load Curve**	**Hours**	**Power MW**	**Irradiance**	**Power MW**	**Power**
1	3361.124039	1	3221.657089	0	0	3188.8
2	3289.965813	2	3129.853325	0	0	3188.8
3	3323.397974	3	3133.677448	0	0	3188.8
4	3369.79936	4	3166.585931	0	0	3188.8
5	3514.188082	5	3318.61953	0	0	3188.8
6	4097.942151	6	3903.128879	1.832608696	1.92423913	3188.8
7	4923.586796	7	4729.277404	38.64388824	40.57608265	3188.8
8	5295.801408	8	5104.081843	156.7314516	164.5680242	3188.8
9	5058.646243	9	4872.421127	305.8364516	321.1282742	3188.8
10	4852.952685	10	4665.484975	447.2054032	469.5656734	3188.8
11	4664.095423	11	4476.90083	526.7646237	553.1028548	3188.8
12	4540.642093	12	4352.344154	538.6118817	565.5424758	3188.8
13	4478.60452	13	4286.104622	471.0522312	494.6048427	3188.8
14	4567.306113	14	4360.257293	373.4374731	392.1093468	3188.8
15	4614.447713	15	4382.673929	239.8137097	251.8043952	3188.8
16	4671.199072	16	4463.059144	92.22472335	96.83595951	3188.8
17	4769.80571	17	4582.276763	13.72815269	14.41456033	3188.8
18	5132.507872	18	4960.822914	0	0	3188.8
19	5822.275806	19	5657.199324	0	0	3188.8
20	5138.863092	20	4983.849223	0	0	3188.8
21	4540.041241	21	4402.421458	0	0	3188.8
22	4006.714028	22	3876.978099	0	0	3188.8
23	3613.570293	23	3486.681651	0	0	3188.8
24	3522.219934	24	3395.086017	0	0	3188.8

Hours	**Energy Solar (area)**	**Average energy**	**energy**	**excess/deficit**

		Demand (area)		
1	0	3325.544926	3188.8	-136.7449263
2	0	3306.681894	3188.8	-117.8818938
3	0	3346.598667	3188.8	-157.7986673
4	0	3441.993721	3188.8	-253.1937212
5	0.962119565	3806.065117	3188.8	-617.2651167
6	21.25016089	4510.764474	3188.8	-1321.964474
7	102.5720534	5109.694102	3188.8	-1920.894102
8	242.8481492	5177.223826	3188.8	-1988.423826
9	395.3469738	4955.799464	3188.8	-1766.999464
10	511.3342641	4758.524054	3188.8	-1569.724054
11	559.3226653	4602.368758	3188.8	-1413.568758
12	530.0736593	4509.623306	3188.8	-1320.823306
13	443.3570948	4522.955316	3188.8	-1334.155316
14	321.956871	4590.876913	3188.8	-1402.076913
15	174.3201773	4642.823393	3188.8	-1454.023393
16	55.62525992	4720.502391	3188.8	-1531.702391
17	7.207280164	4951.156791	3188.8	-1762.356791
18	0	5477.391839	3188.8	-2288.591839
19	0	5480.569449	3188.8	-2291.769449
20	0	4839.452167	3188.8	-1650.652167
21	0	4273.377635	3188.8	-1084.577635
22	0	3810.142161	3188.8	-621.3421606
23	0	3567.895114	3188.8	-379.0951139
24	0			0

Total	3,366.18	101,728.03	73,342.4	-28385.62547	deficit	
				0	surplus	
0.85	2,861.25			0	after PHSP	
	2,861.25	total phsp				
	2633.5	power deficit at peak		Energy deficit after PHSP		(25,524.38)

Februry 2030- Intervention 7.2%

			Peak load day	Solar		hydro
Hours	**Average-Load Curve**	**Hours**	**Power MW**	**Irradiance**	**Power MW**	**Power**
1	3099.11	1	3009.38	0	0.00	3093.5
2	3034.54	2	2923.63	0	0.00	3093.5
3	3065.87	3	2927.20	0	0.00	3093.5
4	3108.60	4	2957.94	0	0.00	3093.5

5	3241.11	5	3099.96	0	0.00	3093.5
6	3779.90	6	3645.95	8.312274959	8.73	3093.5
7	4541.19	7	4417.67	64.82476982	68.07	3093.5
8	4883.85	8	4767.77	224.8910333	236.14	3093.5
9	4664.87	9	4551.38	404.8097661	425.05	3093.5
10	4475.39	10	4358.08	533.5612573	560.24	3093.5
11	4301.24	11	4181.92	602.7988889	632.94	3093.5
12	4187.21	12	4065.57	601.8751462	631.97	3093.5
13	4130.04	13	4003.69	551.6510819	579.23	3093.5
14	4212.22	14	4072.96	446.2124561	468.52	3093.5
15	4256.55	15	4093.90	306.6890936	322.02	3093.5
16	4308.01	16	4168.99	145.9896784	153.29	3093.5
17	4398.54	17	4280.35	27.00372647	28.35	3093.5
18	4732.48	18	4633.95	2.4	2.52	3093.5
19	5368.83	19	5284.45	0	0.00	3093.5
20	4738.11	20	4655.46	0	0.00	3093.5
21	4207.46	21	4112.35	0	0.00	3093.5
22	3714.83	22	3621.52	0	0.00	3093.5
23	3352.34	23	3256.94	0	0.00	3093.5
24	3268.29	24	3171.38	0	0.00	3093.5

	Energy Solar (area)	**Avg energy Demand**	**energy**	**excess/deficit**	
	0	3066.82543	3093.5	26.67456973	
	0	3050.205394	3093.5	43.29460625	
	0	3087.234514	3093.5	6.26548556	
	0	3174.8547	3093.5	-81.35470039	
	4.363944354	3510.504809	3093.5	-417.0048087	
	38.39694851	4160.541253	3093.5	-1067.041253	
	152.1007966	4712.517618	3093.5	-1619.017618	
	330.5929197	4774.35978	3093.5	-1680.85978	
	492.6447873	4570.129808	3093.5	-1476.629808	
	596.5890768	4388.315034	3093.5	-1294.815034	
	632.4538684	4244.227479	3093.5	-1150.727479	
	605.6012697	4158.626641	3093.5	-1065.126641	
	523.8783575	4171.128038	3093.5	-1077.628038	
	395.2733136	4234.38446	3093.5	-1140.88446	
	237.6563553	4282.280129	3093.5	-1188.780129	
	90.82153754	4353.272341	3093.5	-1259.772341	
	15.4369564	4565.5073	3093.5	-1472.0073	
	1.26	5050.652241	3093.5	-1957.152241	
	0	5053.466429	3093.5	-1959.966429	
	0	4472.785024	3093.5	-1379.285024	
	0	3961.148791	3093.5	-867.6487911	

	0	3533.588408	3093.5	-440.0884078	
	0	3310.316793	3093.5	-216.8167925	
	0			0	
Total	4,117.07	93,886.87	71,150.5	-22812.60708	deficit
				76.23466155	surlpus
0.85	3,499.51			64.79946231	after PHSP
	3,564.31	total phsp			
	2275.3	power deficit at peak		(19,248.30)	Energy deficit after PHSP

March 2030- Intervention 7.2%

			Peak load day	**Solar**		**hydro**
Hours	**Average-Load Curve**	**Hours**	**Power MW**	**Irradiance**	**Power MW**	**power**
1	3581.05368	1	3389.090748	0	0	3133.5
2	3487.743798	2	3292.515824	0	0	3133.5
3	3493.075706	3	3296.538691	0	0	3133.5
4	3532.174107	4	3331.15747	0	0	3133.5
5	3683.391999	5	3491.092452	0.84	0.882	3133.5
6	4254.052688	6	4105.979502	32.68911696	34.32357281	3133.5
7	5075.097874	7	4975.064028	158.3377151	166.2546008	3133.5
8	5456.950455	8	5369.347535	364.0567742	382.2596129	3133.5
9	5245.234723	9	5125.647113	557.4272581	585.298621	3133.5
10	5043.631804	10	4907.956224	719.1738441	755.1325363	3133.5
11	4854.577758	11	4709.571119	768.1766935	806.5855282	3133.5
12	4730.068457	12	4578.541073	766.9171505	805.2630081	3133.5
13	4666.5106	13	4508.858987	687.681129	722.0651855	3133.5
14	4736.759182	14	4586.865468	552.4137634	580.0344516	3133.5
15	4765.592257	15	4610.447125	418.4702957	439.3938105	3133.5
16	4843.95478	16	4695.010062	222.6606633	233.7936964	3133.5
17	4953.700878	17	4820.423574	54.50868132	57.23411538	3133.5
18	5306.28431	18	5218.643255	5.225121951	5.486378049	3133.5
19	6020.800273	19	5951.211242	0	0	3133.5
20	5381.39527	20	5242.866272	0	0	3133.5
21	4781.854338	21	4631.220958	0	0	3133.5
22	4241.854376	22	4078.469633	0	0	3133.5
23	3841.742279	23	3667.888977	0	0	3133.5
24	3743.402393	24	3571.533	0	0	3133.5

Hours	Energy Solar (area)	Average energy Demand (area)	energy avilable	excess/deficit	
1	0	3534.398739	3133.5	-400.8987395	
2	0	3490.409752	3133.5	-356.9097524	
3	0	3512.624907	3133.5	-379.1249069	
4	0.441	3607.783053	3133.5	-474.2830531	
5	17.60278641	3968.722343	3133.5	-835.2223433	
6	100.2890868	4664.575281	3133.5	-1531.075281	
7	274.2571069	5266.024164	3133.5	-2132.524164	
8	483.7791169	5351.092589	3133.5	-2217.592589	
9	670.2155786	5144.433264	3133.5	-2010.933264	
10	780.8590323	4949.104781	3133.5	-1815.604781	
11	805.9242681	4792.323108	3133.5	-1658.823108	
12	763.6640968	4698.289529	3133.5	-1564.789529	
13	651.0498185	4701.634891	3133.5	-1568.134891	
14	509.714131	4751.17572	3133.5	-1617.67572	
15	336.5937534	4804.773519	3133.5	-1671.273519	
16	145.5139059	4898.827829	3133.5	-1765.327829	
17	31.36024672	5129.992594	3133.5	-1996.492594	
18	2.743189024	5663.542292	3133.5	-2530.042292	
19	0	5701.097772	3133.5	-2567.597772	
20	0	5081.624804	3133.5	-1948.124804	
21	0	4511.854357	3133.5	-1378.354357	
22	0	4041.798328	3133.5	-908.2983277	
23	0	3792.572336	3133.5	-659.0723363	
24	0			0	
Total	5,574.01	106,058.68	72,070.5	-33988.17595	deficit
				0	surlpus
0.85	4,737.91			0	after PHSP
	4,737.91	total phsp			
	2887.3	power deficit at peak		(29,250.27)	Energy deficit after PHSP

April 2030- Intervention 7.2%

			Peak load day	Solar		hydro
Hours	Average-Load Curve	Hours	Power MW	Irradiance	Power MW	power
1	4445.735339	1	4362.854068	0	0	4168.8
2	4377.860044	2	4295.72095	0	0	4168.8
3	4280.839584	3	4192.574871	0	0	4168.8
4	4267.113163	4	4170.920599	0	0	4168.8
5	4219.554567	5	4117.645473	0	0	4168.8

6	4226.424445	6	4124.492798	9.145888594	9.603183024	4168.8
7	4479.134701	7	4372.972389	64.64429277	67.87650741	4168.8
8	4729.704962	8	4618.966134	207.694322	218.0790381	4168.8
9	4946.579447	9	4833.560372	378.1835696	397.0927481	4168.8
10	4945.366185	10	4833.016521	574.7978889	603.5377833	4168.8
11	4962.968225	11	4857.599793	702.5338333	737.660525	4168.8
12	4996.650681	12	4895.815072	769.9458333	808.443125	4168.8
13	4988.17348	13	4886.604872	724.0130278	760.2136792	4168.8
14	4968.587071	14	4868.387255	571.6353056	600.2170708	4168.8
15	4764.876317	15	4648.87794	444.4752222	466.6989833	4168.8
16	4624.435343	16	4501.259512	326.2562222	342.5690333	4168.8
17	4647.494897	17	4529.465519	185.7569862	195.0448355	4168.8
18	4609.219694	18	4503.97227	71.30794378	74.87334097	4168.8
19	5248.181165	19	5140.522972	11.54197248	12.1190711	4168.8
20	5545.946889	20	5437.433145	0	0	4168.8
21	5345.891771	21	5231.565117	0	0	4168.8
22	4978.873787	22	4854.839239	0	0	4168.8
23	4721.222867	23	4605.159186	0	0	4168.8
24	4598.062797	24	4484.583425	0	0	4168.8

Hours	**Energy Solar (area)**	**Average energy Demand (area)**	**energy avilable**	**excess/deficit**
1	0	4411.797692	4168.8	-242.9976917
2	0	4329.349814	4168.8	-160.5498142
3	0	4273.976374	4168.8	-105.1763739
4	0	4243.333865	4168.8	-74.53386529
5	4.801591512	4222.989506	4168.8	-54.18950602
6	38.73984522	4352.779573	4168.8	-183.9795732
7	142.9777728	4604.419832	4168.8	-435.6198316
8	307.5858931	4838.142205	4168.8	-669.3422045
9	500.3152657	4945.972816	4168.8	-777.172816
10	670.5991542	4954.167205	4168.8	-785.3672048
11	773.051825	4979.809453	4168.8	-811.0094529
12	784.3284021	4992.41208	4168.8	-823.6120802
13	680.215375	4978.380275	4168.8	-809.5802754
14	533.4580271	4866.731694	4168.8	-697.9316943
15	404.6340083	4694.65583	4168.8	-525.85583
16	268.8069344	4635.96512	4168.8	-467.1651199
17	134.9590883	4628.357296	4168.8	-459.5572957
18	43.49620604	4928.700429	4168.8	-759.9004295
19	6.05953555	5397.064027	4168.8	-1228.264027
20	0	5445.91933	4168.8	-1277.11933
21	0	5162.382779	4168.8	-993.582779

22	0	4850.048327	4168.8	-681.248327
23	0	4659.642832	4168.8	-490.842832
24	0			0

Total	5,294.03	109,397.00	95,882.4	-13514.59835	deficit
				0	surplus
0.85	4,499.92			0	after PHSP
	4,499.92	total phsp			
	1377.1	power deficit at peak		(9,014.67)	Energy deficit after PHSP

January 2030- Intervention 9.2% Scenario

			Peak load day	**Solar**		**Hydro**
Hours	**Average-Load Curve**	**Hours**	**Power MW**	**Irradiance**	**Power MW**	**Power**
1	3925.100392	1	3762.231728	0	0	3188.8
2	3842.002245	2	3655.023846	0	0	3188.8
3	3881.044121	3	3659.489634	0	0	3188.8
4	3935.23138	4	3697.919961	0	0	3188.8
5	4103.847658	5	3875.463883	0	0	3188.8
6	4785.552142	6	4558.050377	1.832608696	1.92423913	3188.8
7	5749.734981	7	5522.821645	38.64388824	40.5760827	3188.8
8	6184.404961	8	5960.516009	156.7314516	164.568024	3188.8
9	5907.456589	9	5689.984021	305.8364516	321.128274	3188.8
10	5667.248892	10	5448.32523	447.2054032	469.565673	3188.8
11	5446.702519	11	5228.097802	526.7646237	553.102855	3188.8
12	5302.534465	12	5082.641267	538.6118817	565.542476	3188.8
13	5230.087361	13	5005.287141	471.0522312	494.604843	3188.8
14	5333.672546	14	5091.882183	373.4374731	392.109347	3188.8
15	5388.724223	15	5118.060196	239.8137097	251.804395	3188.8
16	5454.998118	16	5211.933564	92.22472335	96.8359595	3188.8
17	5570.150355	17	5351.155181	13.72815269	14.4145603	3188.8
18	5993.711754	18	5793.219095	0	0	3188.8
19	6799.218589	19	6606.443269	0	0	3188.8
20	6001.133342	20	5820.10908	0	0	3188.8
21	5301.832794	21	5141.12124	0	0	3188.8
22	4679.016489	22	4527.511654	0	0	3188.8
23	4219.905606	23	4071.725815	0	0	3188.8
24	4113.227208	24	3964.760985	0	0	3188.8
	122816.5387					

Hours	Energy Solar	Avg Energy Demand	Energy	Excess/Deficit	
1	0	3883.551318	3188.8	-694.7513184	
2	0	3861.523183	3188.8	-672.7231828	
3	0	3908.13775	3188.8	-719.3377503	
4	0	4019.539519	3188.8	-830.7395192	
5	0.962119565	4444.6999	3188.8	-1255.8999	
6	21.25016089	5267.643561	3188.8	-2078.843561	
7	102.5720534	5967.069971	3188.8	-2778.269971	
8	242.8481492	6045.930775	3188.8	-2857.130775	
9	395.3469738	5787.35274	3188.8	-2598.55274	
10	511.3342641	5556.975706	3188.8	-2368.175706	
11	559.3226653	5374.618492	3188.8	-2185.818492	
12	530.0736593	5266.310913	3188.8	-2077.510913	
13	443.3570948	5281.879954	3188.8	-2093.079954	
14	321.956871	5361.198385	3188.8	-2172.398385	
15	174.3201773	5421.861171	3188.8	-2233.061171	
16	55.62525992	5512.574237	3188.8	-2323.774237	
17	7.207280164	5781.931054	3188.8	-2593.131054	
18	0	6396.465171	3188.8	-3207.665171	
19	0	6400.175966	3188.8	-3211.375966	
20	0	5651.483068	3188.8	-2462.683068	
21	0	4990.424642	3188.8	-1801.624642	
22	0	4449.461048	3188.8	-1260.661048	
23	0	4166.566407	3188.8	-977.7664067	
24	0			0	
Total	3,366.18	118,797.37	73,342.4	-45454.97493	Deficit
0.85	2,861.25			0	Surplus
	2,861.25	Total PHSP		0	after PHSP
	3610.4	Power Deficit at peak		(42,593.72)	Final Deficit

February 2030- Intervention 9.2% Scenario

			Peak load day	Solar		Hydro
Hours	Average-Load Curve	Hours	Power MW	Irradiance	Power MW	Power
1	**3619.12**	**1**	**3514.34**	**0**	**0.00**	**3093.5**
2	3543.72	2	3414.19	0	0.00	3093.5
3	3580.31	3	3418.37	0	0.00	3093.5
4	3630.20	4	3454.26	0	0.00	3093.5
5	3784.95	5	3620.11	0	0.00	3093.5
6	4414.14	6	4257.72	8.312274959	8.73	3093.5

7	5303.17	7	5158.92	64.82476982	68.07	3093.5
8	5703.33	8	5567.78	224.8910333	236.14	3093.5
9	5447.61	9	5315.07	404.8097661	425.05	3093.5
10	5226.33	10	5089.33	533.5612573	560.24	3093.5
11	5022.96	11	4883.62	602.7988889	632.94	3093.5
12	4889.80	12	4747.75	601.8751462	631.97	3093.5
13	4823.03	13	4675.49	551.6510819	579.23	3093.5
14	4919.00	14	4756.38	446.2124561	468.52	3093.5
15	4970.78	15	4780.83	306.6890936	322.02	3093.5
16	5030.87	16	4868.52	145.9896784	153.29	3093.5
17	5136.58	17	4998.57	27.00372647	28.35	3093.5
18	5526.56	18	5411.50	2.4	2.52	3093.5
19	6269.68	19	6171.14	0	0.00	3093.5
20	5533.13	20	5436.62	0	0.00	3093.5
21	4913.45	21	4802.37	0	0.00	3093.5
22	4338.16	22	4229.19	0	0.00	3093.5
23	3914.85	23	3803.44	0	0.00	3093.5
24	3816.69	24	3703.52	0	0.00	3093.5

Hours	**Energy Solar**	**Avg Energy Demand**	**Energy**	**Excess/Deficit**	
1	0	3581.420251	3093.5	-487.9202506	
2	0	3562.011472	3093.5	-468.5114721	
3	0	3605.253856	3093.5	-511.7538561	
4	0	3707.576181	3093.5	-614.076181	
5	4.363944354	4099.546354	3093.5	-1006.046354	
6	38.39694851	4858.654995	3093.5	-1765.154995	
7	152.1007966	5503.249667	3093.5	-2409.749667	
8	330.5929197	5575.468571	3093.5	-2481.968571	
9	492.6447873	5336.970042	3093.5	-2243.470042	
10	596.5890768	5124.647843	3093.5	-2031.147843	
11	632.4538684	4956.383265	3093.5	-1862.883265	
12	605.6012697	4856.419123	3093.5	-1762.919123	
13	523.8783575	4871.018179	3093.5	-1777.518179	
14	395.2733136	4944.888648	3093.5	-1851.388648	
15	237.6563553	5000.820921	3093.5	-1907.320921	
16	90.82153754	5083.725198	3093.5	-1990.225198	
17	15.4369564	5331.571904	3093.5	-2238.071904	
18	1.26	5898.121241	3093.5	-2804.621241	
19	0	5901.407634	3093.5	-2807.907634	
20	0	5223.291389	3093.5	-2129.791389	
21	0	4625.80568	3093.5	-1532.30568	
22	0	4126.503242	3093.5	-1033.003242	
23	0	3865.767996	3093.5	-772.2679957	

24	0			0	
Total	4,117.07	109,640.52	71,150.5	-38490.02365	Deficit
0.85	3,499.51			0	Surplus
	3,499.51	Total PHSP		0	after PHSP
	2275.325916	Power Deficit at peak		-19248.298	Final deficit (energy)

March 2030- Intervention 9.2% Scenario

			Peak load day	**Solar**		**Hydro**
Hours	**Average-Load Curve**	**Hours**	**Power MW**	**Irradiance**	**Power MW**	**Power**
1	4181.93	1	3957.76	0.00	0.00	3133.5
2	4072.97	2	3844.98	0.00	0.00	3133.5
3	4079.19	3	3849.68	0.00	0.00	3133.5
4	4124.85	4	3890.11	0.00	0.00	3133.5
5	4301.44	5	4076.88	0.84	0.88	3133.5
6	4967.86	6	4794.94	32.69	34.32	3133.5
7	5926.67	7	5809.85	158.34	166.25	3133.5
8	6372.59	8	6270.29	364.06	382.26	3133.5
9	6125.35	9	5985.70	557.43	585.30	3133.5
10	5889.92	10	5731.48	719.17	755.13	3133.5
11	5669.15	11	5499.81	768.18	806.59	3133.5
12	5523.75	12	5346.79	766.92	805.26	3133.5
13	5449.52	13	5265.42	687.68	722.07	3133.5
14	5531.56	14	5356.51	552.41	580.03	3133.5
15	5565.23	15	5384.05	418.47	439.39	3133.5
16	5656.74	16	5482.80	222.66	233.79	3133.5
17	5784.90	17	5629.26	54.51	57.23	3133.5
18	6196.65	18	6094.30	5.23	5.49	3133.5
19	7031.05	19	6949.79	0.00	0.00	3133.5
20	6284.36	20	6122.59	0.00	0.00	3133.5
21	5584.22	21	5408.31	0.00	0.00	3133.5
22	4953.61	22	4762.81	0.00	0.00	3133.5
23	4486.36	23	4283.34	0.00	0.00	3133.5
24	4371.52	24	4170.81	0.00	0.00	3133.5

Hours	**Energy Solar**	**Avg Energy Demand**	**Energy**	**Excess/Deficit**		
1	0	4127.449543	3133.5	-993.9495425		
2	0	4076.079469	3133.5	-942.5794686		
3	0	4102.022192	3133.5	-968.5221922		
4	0.441	4213.147302	3133.5	-1079.647302		
5	17.60278641	4634.650029	3133.5	-1501.150029		
6	100.2890868	5447.262895	3133.5	-2313.762895		

7	274.2571069	6149.631276	3133.5	-3016.131276		
8	483.7791169	6248.973669	3133.5	-3115.473669		
9	670.2155786	6007.638154	3133.5	-2874.138154		
10	780.8590323	5779.53473	3133.5	-2646.03473		
11	805.9242681	5596.446037	3133.5	-2462.946037		
12	763.6640968	5486.634191	3133.5	-2353.134191		
13	651.0498185	5490.540884	3133.5	-2357.040884		
14	509.714131	5548.394365	3133.5	-2414.894365		
15	336.5937534	5610.985552	3133.5	-2477.485552		
16	145.5139059	5720.821609	3133.5	-2587.321609		
17	31.36024672	5990.774428	3133.5	-2857.274428		
18	2.743189024	6613.850548	3133.5	-3480.350548		
19	0	6657.707611	3133.5	-3524.207611		
20	0	5934.290814	3133.5	-2800.790814		
21	0	5268.916321	3133.5	-2135.416321		
22	0	4719.987723	3133.5	-1586.487723		
23	0	4428.943113	3133.5	-1295.443113		
24	0			0		
Total	5,574.01	123,854.68	72,070.5	-51784.18245	Deficit	
0.85	4,737.91			0	Surplus	
	4,737.91	Total PHSP		0	after PHSP	
	3897.6	Power Deficit at peak		(47,046.28)	Final Deficit	

April 2030- Intervention 9.2% Scenario

			Peak load day	Solar		Hydro
Hours	**Average-Load Curve**	**Hours**	**Power MW**	**Irradiance**	**Power MW**	**Power**
1	5191.70293	1	5094.914681	0	0	4168.8
2	5112.43857	2	5016.517031	0	0	4168.8
3	4999.138662	3	4896.063662	0	0	4168.8
4	4983.10903	4	4870.775933	0	0	4168.8
5	4927.570388	5	4808.561562	0	0	4168.8
6	4935.59299	6	4816.557827	9.145888594	9.60318302	4168.8
7	5230.706504	7	5106.730795	64.64429277	67.8765074	4168.8
8	5523.320944	8	5394.000808	207.694322	218.079038	4168.8
9	5776.585661	9	5644.602666	378.1835696	397.092748	4168.8
10	5775.16882	10	5643.96756	574.7978889	603.537783	4168.8
11	5795.724376	11	5672.675757	702.5338333	737.660525	4168.8
12	5835.058545	12	5717.303329	769.9458333	808.443125	4168.8
13	5825.158921	13	5706.547713	724.0130278	760.213679	4168.8
14	5802.286031	14	5685.273289	571.6353056	600.217071	4168.8
15	5564.393841	15	5428.931635	444.4752222	466.698983	4168.8

16	5400.387717	16	5256.543724	326.2562222	342.569033	4168.8
17	5427.316526	17	5289.482529	185.7569862	195.044836	4168.8
18	5382.618975	18	5259.711667	71.30794378	74.873341	4168.8
19	6128.794328	19	6003.07174	11.54197248	12.1190711	4168.8
20	6476.523346	20	6349.80165	0	0	4168.8
21	6242.900185	21	6109.390208	0	0	4168.8
22	5814.298796	22	5669.451998	0	0	4168.8
23	5513.415604	23	5377.877137	0	0	4168.8
24	5369.590018	24	5237.06949	0	0	4168.8

Hours	**Energy Solar**	**Avg Energy Demand**	**Energy**	**Excess/Deficit**	
1	0	5152.07075	4168.8	-983.2707499	
2	0	5055.788616	4168.8	-886.9886156	
3	0	4991.123846	4168.8	-822.3238458	
4	0	4955.339709	4168.8	-786.539709	
5	4.801591512	4931.581689	4168.8	-762.7816889	
6	38.73984522	5083.149747	4168.8	-914.3497469	
7	142.9777728	5377.013724	4168.8	-1208.213724	
8	307.5858931	5649.953302	4168.8	-1481.153302	
9	500.3152657	5775.87724	4168.8	-1607.07724	
10	670.5991542	5785.446598	4168.8	-1616.646598	
11	773.051825	5815.391461	4168.8	-1646.591461	
12	784.3284021	5830.108733	4168.8	-1661.308733	
13	680.215375	5813.722476	4168.8	-1644.922476	
14	533.4580271	5683.339936	4168.8	-1514.539936	
15	404.6340083	5482.390779	4168.8	-1313.590779	
16	268.8069344	5413.852121	4168.8	-1245.052121	
17	134.9590883	5404.96775	4168.8	-1236.16775	
18	43.49620604	5755.706651	4168.8	-1586.906651	
19	6.05953555	6302.658837	4168.8	-2133.858837	
20	0	6359.711765	4168.8	-2190.911765	
21	0	6028.59949	4168.8	-1859.79949	
22	0	5663.8572	4168.8	-1495.0572	
23	0	5441.502811	4168.8	-1272.702811	
24	0			0	
Total	5,294.03	127,753.16	95,882.4	(31,870.76)	Deficit
0.85	4,499.92			0	Surplus
	4,499.92	Total PHSP		0	after PHSP
	2307.7	Power Deficit at peak		(27,370.83)	Final Deficit