MAJOR PROJECT

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Table of Contents

Table of Table

Table of figure

Introduction

The goal of the design report is to satisfy the electricity demand in the state of South Australia. The types of energy we plan to utilize are solar, wind, biomass and geothermal energy. The average demand in the South Australia is 1299.73 MW.

Our design satisfied the demand of electricity with a competitive levelized cost. Most of the plant rely on clean resources which has very low emissions on the pollutants. We also considered the intermittency problem of some of our energy resources by adding storage unit so that the demand is meeting during the peak.

Technology review

Solar power

Solar energy and their related technologies have been developed into globally utilized renewable energy source. Given that the relatively high installation cost, low conversion efficiency and battery life issues, using solar energy to provide residential electricity is still faced with problems compared with conventional energy sources. However, many new approaches and technologies are improving solar energy system in order to be applied widely. This section will analyse the solar generation and energy storage issues for our system and give a review about economics, resource availability, conversion efficiency and environmental issues. Build up a trade-off table to discuss both advantages and limits within our current design

Capital cost

Some important terms describing the economics of solar power or photovoltaic system will be discussed in this paragraph. The most common PV economics parameters including the capital cost which is the total costs of installing a PV system, expenditure on electricity, feed-in tariff and payback time. The cost of PV system is measured in dollars/peak power(watt) e.g. \$AUD/W or \$/kW. Peak watt means the power at a standard condition (solar irradiance $1000W/m^2$, 1.5 atm pressure and temperature is 25 degrees).

The following table 1 will show the average costs of installing a solar system in Australia compared with national average:

Table 1 Installation cost of various power solar system *(Residential Solar Power System Prices – September 2019, Solar Choice)*

	1.5 kW	3 kW	4kW	5kW	6kW	7kW	10kW
SA	\$2,530	\$3,230	\$3,740	\$4,100	\$4,520	\$5,630	\$8,330

National average	$3,114	$3,970	$4,670	$5,140	$5,750	$7,170	$9,680

Typically, half of those investments will spend on the PV modules, inverters, electrical cables and all supporting equipment, and the installation will take up the rest.

Despite the kinds or brands of solar PV system, the power of solar panels that are chosen to install will affect its price largely. Even though the price is not a small number, Australian government is still offering a heavy subside on PV system for whatever the price it is, this is run by the solar-rebate scheme. For the current price, a rebate saving around $650 per kW can be applied to the installed system. For example, a typical cost of an 3kW solar system with price $3230 can has a government rebate $1950, and the final price that a household would pay becomes $1280.

Land usage

In Australia, the total current energy demand around 45GWcan be satisfied by an area of $30 * 30km = 900km^2$ solar system. And this is only 0.01% of land area of Australia. And if we build integrated solar PV cells into buildings which have lower rise can also minimise the land usage.

Resource availability

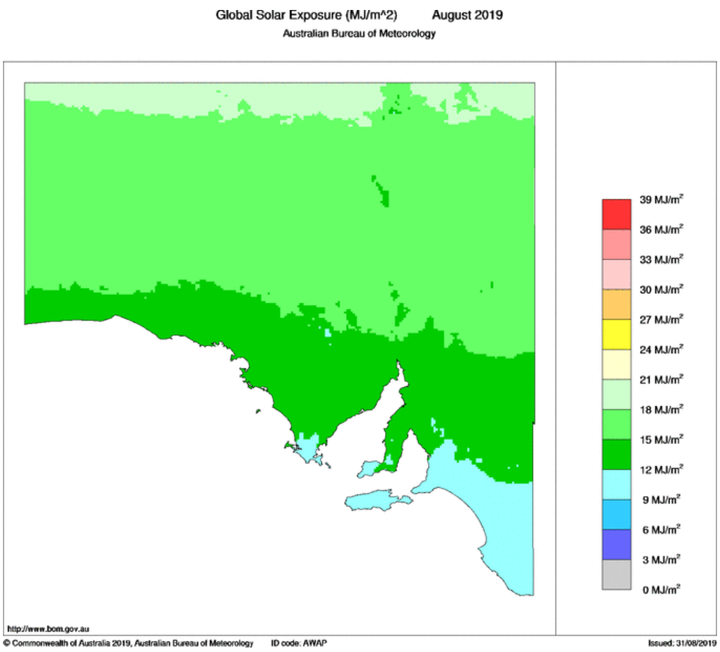


Fig 1 Solar exposure map

The figure above shows a monthly solar exposure in South Australia in August. The maximum average monthly solar irradiation is up to 39 MJ/m^2 in lower latitude.

About the direct normal irradiance map of south Australia, all areas in dark yellow indicates that annual average DNI is above 23.5 MJ/m^2, and all areas in light yellow indicates the annual average DNI is above 20.5 MJ/m^2.

As for the cloudiness in south Australia, the picture below shows an annual average cloud amount in 3pm. And it can be found that the smallest cloud area is the northeast part of SA, so it may be a good site to build the solar power station and give the most intensive energy collection.

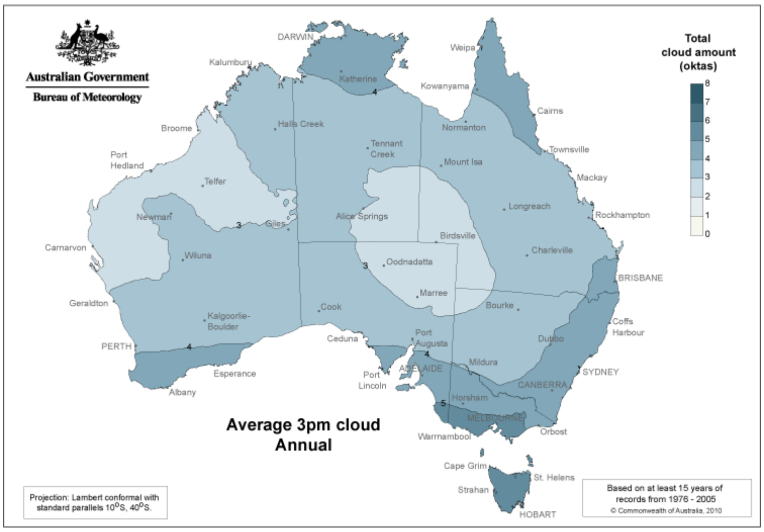


Fig 2 Cloudiness map

Conversion efficiency

One of the biggest concerns of solar power is the intermittency, since that will affect the energy transfer efficiency to a great extent.

Table 2 Conversion efficiency table for solar energy

solar system	efficiency	discussion
Solar hot water collector	Typically 60-90% solar fraction	1. provides higher resistance to convective losses 2. maintains better angle for absorption due to cylindrical shape 3. Higher storage gives higher solar fraction but higher cost
Solar collector	68.7% for aperture	Efficiency may vary with the geometry of aperture such as for flat plate collector, the peak efficiency is 75%
Parabolic trough concentrators	30-40%	Concentration factor:100-1, capacity factor is around 38%
Photovoltaic cell	Around 20-25%	Maximum theoretical efficiency = “Shockley-Queisser Limit” (~32% for single junction crystalline silicon cells)
PVcell (polycrystalline Silicon)	13%	Lower efficiency but cheaper

PVcell (CdTe thin film)	20%	Lower efficiency but cheaper
Multi-junction PV cell	30%	Efficiency will increase to 40% with tracking sun

Environmental impact

Use of solar energy generates no green-house gases such as CO2, SO2, or NO2 and won't contribute to global warming. Generally speaking, it has a very low impact.

Many social impacts and benefits involved in solar energy developing process include job creation, public health, and oil dependence. When cities or communities decided to build and use solar energy system, these projects will help to create many kinds of jobs. Also, using solar energy will stimulate a country's economy in many ways, with more employment are generated during the projects launching, more people will contribute to a nation's economy. Furthermore, utilizing solar energy has a less cost than fuel and oil exploitation, reduce the damage caused on forest and farms. Many families and communities will export their saving money through electricity bills to other business activities and improve social economy.

Reliability

Typically, a photovoltaic cell has a low maintenance and good durability around 20 years lifetime. Furthermore, a PV cell lifetime is more dependent on the battery life. For solar thermal collectors, the lifetime will be more dependent on environmental factor. If the water outside and outdoor environment are at a very low temperature, a freezing situation may be caused. And if a high temperature is followed by rain, then thermal shock is easily happened.

What's more, another factor affect solar collector lifetime is degradation of fluid, those impacts will be on the structure and the loss of solidity of absorber.

Trade off table

Table 3 Trade off table for solar energy

Characteristic	Central Solar thermal	Photovoltaic cell
LCOE cost	19-35 cents per kWh	18-43 cents per kWh
Use	Direct sunlight	Direct and diffuse sunlight
Energy Size	10MW to a few hundred MW	From watts to MW
Installation	Flat unused land	Everywhere (rooftop etc.)
Capacity	2000-7000 full load hours	700-2000 full load hours

Proofed life time	Over 20 years	Over 20 years
Time to build 50 MW system	24-36 months	14-16 months

By constructing a trade-off table above, we could say that PVs are more suitable for off-grid applications. They don't have large and moving parts and work quietly, which means the maintenance cost can be relatively lower than CST. CST is more appropriate for large industrial country power plant, combined with another energy delivery system to provide energy for further areas.

Wind power

Economics

The construction cost of the wind farm depends on various factors such as location and size. For example, the Woodlawn wind farm in New South Wales spend 115 million dollars. The wind farm has 23 wind turbines and has a capacity of 48.3 MW.

A large part of the wind farm cost comes from the land use. The spacing between the wind turbines is crucial because the wind flow past the turbine blades will become turbulent and affect efficiency of other turbines. The spacing depends on the size of the wind turbine and usually the spacing is 8-10 diameters in the downstream and 3-5 in the cross stream.

According to Australian NEM reported on OpenNEM, the average cost of the wind power is 81 cents per kilowatt hour. It is twice more than the average electricity price of Australia which is only 35 cents per kilowatts. It is expensive because a large amount of money is spent in storage, conversion and distribution. However, it is still important to continue invest in wind power because it is good for the environment.

Resource availability

The wind resource in South Australia mainly located in the North and South East. The lake Eyre is located in the South East of the South Australia and it is a large water body which will result in "sea breeze" and generate a lot of wind power.

In the south of South Australia near the sea, the wind resources are also ample in different locations near Adelaide. The wind speed map of January is shown in figure one as an example of the wind resource distribution in Australia. According to the map of other month, we can see that in some time during the year, the wind speed in the north east is too low to harvest. However, the north east of Source Australia has a lot of hydro resources which can be used to store the power generated by the wind in terms of potential energy.

The maximum efficiency of the wind turbine is 59.3% in theory. The modern time turbine is around 45%. Then, the kinetic energy will be converted to the electricity through the generator. The combined efficiency can range from 35% to 40%.

Environmental and social impact

Wind power is clean compared to other non-renewable energy. It consumes almost nothing to operate and has only negligible emission which majorly comes from the construction phase of the wind farm to the environment. However, it will still create some impact to the local environment. The first impact will be the habitat loss due to the land use of the wind farm. In order to increase the efficiency of some wind farms, the vegetation in the ground has to be removed to reduce the friction loss in the ground. As long as the wind farm is still operating, the ground has to remain as flat as possible so no tall plantation can grow where the farm is. For some wind farms, such action is actually causing more carbon dioxide to release than it can save since the vegetation which can absorbs carbon dioxide is removed.

The wind turbine also has impact on the wildlife living in nearby area. The direct effect would be the death of flying creatures such as bats and birds. The wind farm also has indirect impact on the habitat due to the change of wind development. However, these impacts also depend on the location and height of the wind farms. The wind turbine will cause little harm if the location and height are chosen properly.

Another big impact would the change of weather and climate. The wind turbine will harvest the energy in the wind which will change the speed and direction of the wind. The wind has the functions such as distributing heat and rainfall and purifying pollutants. Some research predicts that using wind farm in a global and large scale might affect the atmospheric circulation and cause climate change.

Finally, the noise created by the wind turbine can be viewed as a type of pollution. The noise created will remain audible within a really long distance. The noise will increase the stress level in people, even livestock living nearby. Therefore, a lot of wind farms are located far away from the city and village to avoid noise pollutions.

The wind farm also has some effect on the aesthetics. Wind farms in some particular location is viewed as damages to the local historical site. However, in some area, the wind farm is viewed as a pleasant symbol of prosperity and tourism location.

Reliability

The maintenance cost of wind turbines is relatively low compared to other electricity generation device. The gearbox are important components in a wind farm which also require constant maintenance. The generation of electricity largely depends on the performance of the gear box and due to the variable and unpredictable loads of the winds, the gearbox needs more maintenance than the turbine blades. The regular scheduled maintenance for wind turbine is usually twice a year and 12 hours for each wind turbine. However, in some situations, the poorly designed wind turbine will caught on fire and during the winter, some ice chips formed on the surface of blades will fly away as the turbine is rotating. These situations are considered as safety hazards and need to repair.

The typical life span of a wind farm is from 20 to 25 years. However, study made by several scholars suggests that the wind turbine operates most effectively in its first 15 years. The efficiency loss due to wear is quite significant and reduce the power output from 10 to 39 percent.

	Wind Power	Traditional electricity generation
Levelized cost	81 cents/kWh	35 cents/kWh
Emissions	Clean energy	High
Social impact	If the location is chosen properly, almost no impact socially	May cause protest from the environmental groups
Environmental impact	Will affect wild life and create a lot of noise	Will create a lots of greenhouse gas
Maintenance cost	Low	High

Table 4 Trade-off table of wind energy

Biomass power

Economics

A large (40-Megawatt gross) biomass power station may have a capital cost equivalent to A$2.5 million per megawatt of installed capacity while a small-scale(<1MW) biomass power plant cost A$8000 per kW.[8]

The installed cost for a small-scale power plant is $3,000 to $4,000 per kW, While the capital cost for large-scale power plant is $1,700 to $3,500 and the levelized cost of energy is $0.8 to $0.15 per kWh.

For land-usage, it is chosen to build the power plant in south-east of south Australia where there is a heap of residues from vegetables and fruit& nuts. A minimum of 10 acres of land is required to build a biomass power plant. The land required of fuel storage is an extent of 20 acres depending on the cost of land in different regions.

Resource availability

Bioenergy can be produced from organic matter derived from plants, animals or manufactured food waste. In south Australia, Agricultural land occupies 522,300 square kilometers, which is about 53 per cent of the state and is able to provide the biomass for bioenergy.[10] Biomass and fuel products can be easily stored and are transportable. To minimize the problem for an interrupted supply, resource should be available with 50-kilometre radius.

Although all wood, crops, agriculture and forest can be resource of biomass, in this project we decide to use residues from agriculture, horticulture, winery and livestock and build a biomass power plant in south-east of South Australia where there is a heap of waste that can be used and transported easily.

In the power plant, fermented residues from winery and agriculture are converted to biofuels such as ethanol and residues from horticulture are burnt for heat and electricity. Moreover, the residues from livestock are good source of biodiesel since it contains lots of animals fat or vegetable oils.

The biomass can be converted to methanol which is more expensive and contain carcinogenic combustion products such as formaldehyde which is the reason why we prefer to convert to ethanol.

Conversion efficiency

Biomass has an efficiency of 75-80% convert to heat or thermal energy while the efficiency of generation of electrical energy is only 20-25%. 1kg to 0.75 kwh

Environmental and social impact

Biomass resources are sustainable and environment friendly since the biomass power plant works at a low temperature (700-1200), nitrogen oxides emission is limited. It utilizes waste streams which reduce the cost of disposing them. However, it is not as clean as the wind and solar energy since the combustion of ethanol and methanol releases harmful substances.

In terms of the social impact, with the development of bioenergy technology, the employment through new industry activity in South Australia will be increased. However, the social impact it creates is not always positive since large production will increase the food price which will easily leads to resentment from the public opinion.

Reliability

Compared to wind and solar, Bio-energy is able to supply energy at any time in any circumstances when solar and wind energy rely on their energy storage during low input periods. It is possible to develop a bioenergy project in 18 months and the power plant can run for 20 years with properly maintenance.

Table 5 The trade-off table of using biomass

Advantage	Disadvantage
Resource widely available	Less efficient than fossil fuels
Reduce the reliance of fossil fuels	Not entirely clean
Cheaper than fossil fuels	Power plant needs a lot of space
Less garbage in landfills	

Geothermal power

Economics

Binary cycle power plants are the most common type of geothermal power generation used today. The secondary fluid used in these plants is typically isobutylene or isopentane.[18] Since the geothermal fluid flows from the production well, heats the secondary fluid, and then returns along the well, the binary cycle power plant is a closed-loop system. Therefore, almost no substance is released into the atmosphere. The model of the plant shows as below:

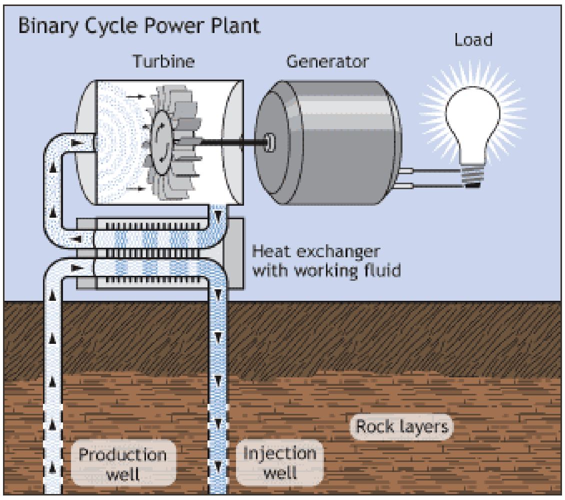


Fig 3 Binary cycle power plant[18]

The cost of geothermal power plants can be simply divided into three parts: construction, operation and maintenance. The construction includes drilling, pipeline construction, resource analysis and power plant design. The total capital cost for geothermal power plants is approximately $2,500 per kilowatt. However, operating and maintenance costs only takes a small portion of the capital cost which are between $0.01 and $0.03 per kWh.[18]

In terms of land usage, the entire geothermal field uses 1-8 acres per megawatt (MW), nuclear power operates 5-10 acres per megawatt, and coal-fired power plants are 19 acres per megawatt. Coal power plants also need a lot of lands mining their fuel. These mining operations can involve large-scale Earth motion for the construction of underground mines and tunnels, waste dumps and/or open pits. Disturbed surfaces in open pit mining also limit plant life's participation in carbon cycling and evapotranspiration, thereby replenishing water in the atmosphere. Proper repair of the strip-mining area is also expensive.

Resource availability

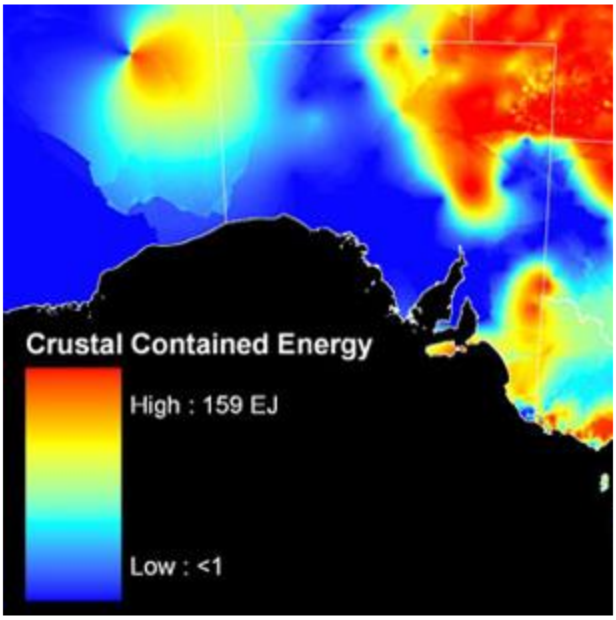


Fig 4 The geothermal heat map of South Australia

Most of the geothermal energy in South Australia concentrated in the North-East region which is very close to the neighboring states. With the data obtained from Geoscience Australia, we find that only a small portion of the red area shown in the fig 4 is qualified for excavation due to various factor such as the highest temperature underground and depth of the geothermal well we need to drill.

Conversion efficiency

According to the Environmental Protection Agency, the geothermal ground source heat pump system is one of the most energy-efficient, environmentally friendly and cost-effective space conditioning systems. About 70% of the energy used in geothermal pump systems comes from renewable sources on the ground. Efficient geothermal systems are 48% more efficient than gas furnaces, 75% higher than oil furnaces, and 43% more efficient in cooling mode.

Because geothermal heat pump systems do not burn fossil fuels on-site to generate heat, they produce far less greenhouse gas emissions than conventional furnaces and completely eliminate potential sources of toxic carbon monoxide in homes or buildings. Even considering the emissions generated by the geothermal heat pump system in power plants, the total emissions are much lower than in conventional systems.

Environmental impact

Experts say geothermal energy is cleaner, more efficient, more cost-effective than burning fossil fuels, and can reduce our dependence on foreign oil. Geothermal energy is considered to be renewable because heat is constantly being replaced. After using the heat, the removed water is returned to the ground.

According to data from Geothermal Technologies, nearly 40% of CO2 emissions are the result of heating, cooling and hot water systems in buildings. It is roughly equivalent to the amount of carbon dioxide contributed by cars and public transport.

Since geothermal pump heating systems will not burn fossil fuels for heat generation, they produce much lower greenhouse gas emissions than conventional furnaces. They also provide higher air quality because there are no carbon monoxide emissions. Typically, a 3-ton residential geothermal heat pump system produces an average of approximately one pound of carbon dioxide per hour compared to conventional systems. In an average 20-year life cycle, installing 100,000 residential geothermal systems can reduce greenhouse gas emissions by nearly 1.1 million metric tons of carbon equivalent. This is equivalent to removing 58,700 cars or planting more than 120,000 acres of trees from our highway.

Reliability

Geothermal power plants are capital intensive, but they are relatively inexpensive to operate. Costs range from $0.01 to $0.03 per kWh and can be run at 90% or higher. If the availability of geothermal power plants exceeds 90%, maintenance costs will increase. This high price is reasonable because maintenance costs are covered by increased production at the factory.

Advantages:

1. Geothermal energy procurement is conducive to the environment

First, geothermal energy is extracted from the earth without burning fossil fuels, and the geothermal field produces almost no emissions. More importantly, geothermal energy is very beneficial because it can save up to 80% in cost compared to traditional energy use.

2. Geothermal is a reliable source of renewable energy

Geothermal energy also has many advantages over other renewable energy sources such as solar, wind or biomass. It is a very constant source of energy, which means it is neither dependent on the wind nor dependent on the sun and can be used all year

round. When looking at the availability factor, underground heat is at the highest level, higher than other groups, which supports its independent arguments in different external environments when providing energy.

3. High Efficiency of Geothermal Systems

Geothermal heat pump systems save 25% to 50% of power compared to conventional heating or cooling systems, and because of their flexible design, they can be adjusted to different conditions, requiring less hardware space than traditional systems.

4. Little to No Geothermal System Maintenance

Since the geothermal system has only a few movable parts that are shielded inside the building, the geothermal heat pump system has a relatively high life. Heat pump tubes can even be guaranteed for 25 to 50 years, while pumps can usually be used for at least 20 years.

If managed properly, geothermal is a form of renewable and sustainable energy because it uses the earth's natural heat to generate electricity. When not developed responsibly, the ground temperature below the surface may be reduced. Geothermal energy is an environmentally friendly technology because it produces almost no greenhouse gas emissions.

Advantages	Disadvantages
Very high efficiency	Scarcity of suitable sites
Moderate net energy at accessible sites	Can be depleted if used too rapidly
Lower CO2 emissions than fossil fuels	Environmental costs not included in market price
Low cost at favorable sites	CO_2 emissions
Low land use and disturbance	Moderate to high local air pollution
Moderate environmental impact	Noise and odor (H_2S)
	High cost except at most concentrated and accessible sources

Table 6 Trade-off Table of Geothermal energy

Design and modeling

Location of the plant

Solar

The initial stage would be selecting the optimal place to site the solar plant for getting a most renewable energy resource. And this requires us to obtain the climate and solar irradiation information about the area of interest. There are two sites are selected as the solar plant and their corresponding storage plant are located beside the one of plants. The detailed latitude and longitude are showed in the picture below:

City	Latitude	Longitude
Woomera	31.16°S	136.81°E
Oodnadatta	27.56°S	135.45°E
Tarcoola	30.71°S	134.58°E

Solar farms are placed at Woomera, Tarcoola, and Oodnadatta. Also, the transmission substations are placed at Woomera and Olmpic Dam as well.

Wind

There are three locations in South Australia which are suitable for building wind farms. The location is choose based on the 2017 wind data of weather stations in South Australia.

Table 7 Location of the wind farm

	Latitude	Longitude	Available power density(kW)
Site 1	-35.34	136.12	14
Site 2	-32.18	133.63	7.21
Site 3	-35.84	138.13	8.01

All three sites are located near the southern coast of Australia and they are close to the main cities in South Australia and therefore the need for storage plant and transmission loss is less than other source of energy.

Biomass

There are six biomass power plant required that locate near Naracoorte.

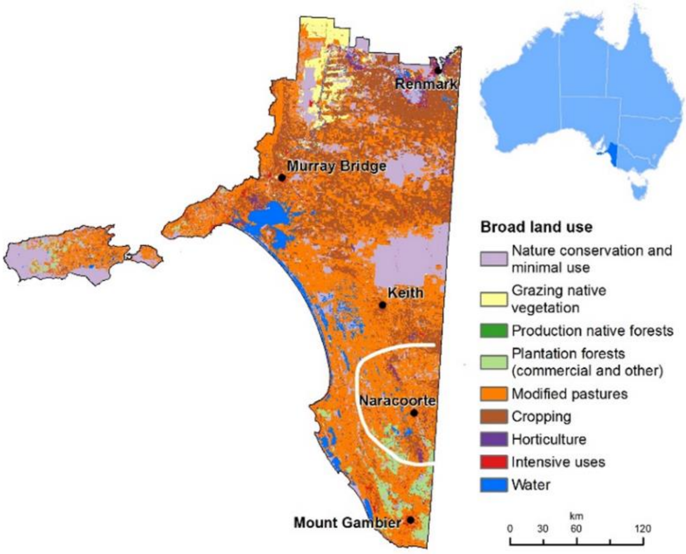


Fig 5 The location of the biomass plants

The reason of choosing this site is because that this region contains most of the South Australia biomass resources. If the plant is built somewhere else, the transportation cost of the biomass resources is very high and increase the cost of the electricity.

Table 8 Biomass plant location

	Latitude	Longitude
Site 1	-36.97	147.746

Geothermal

There is little amount of Geothermal energy in South Australia. However, in the borderline of the South Australia, there is some geothermal wells which can provide some energy. The location of the geothermal well is located at -36.7, 147.746

Map

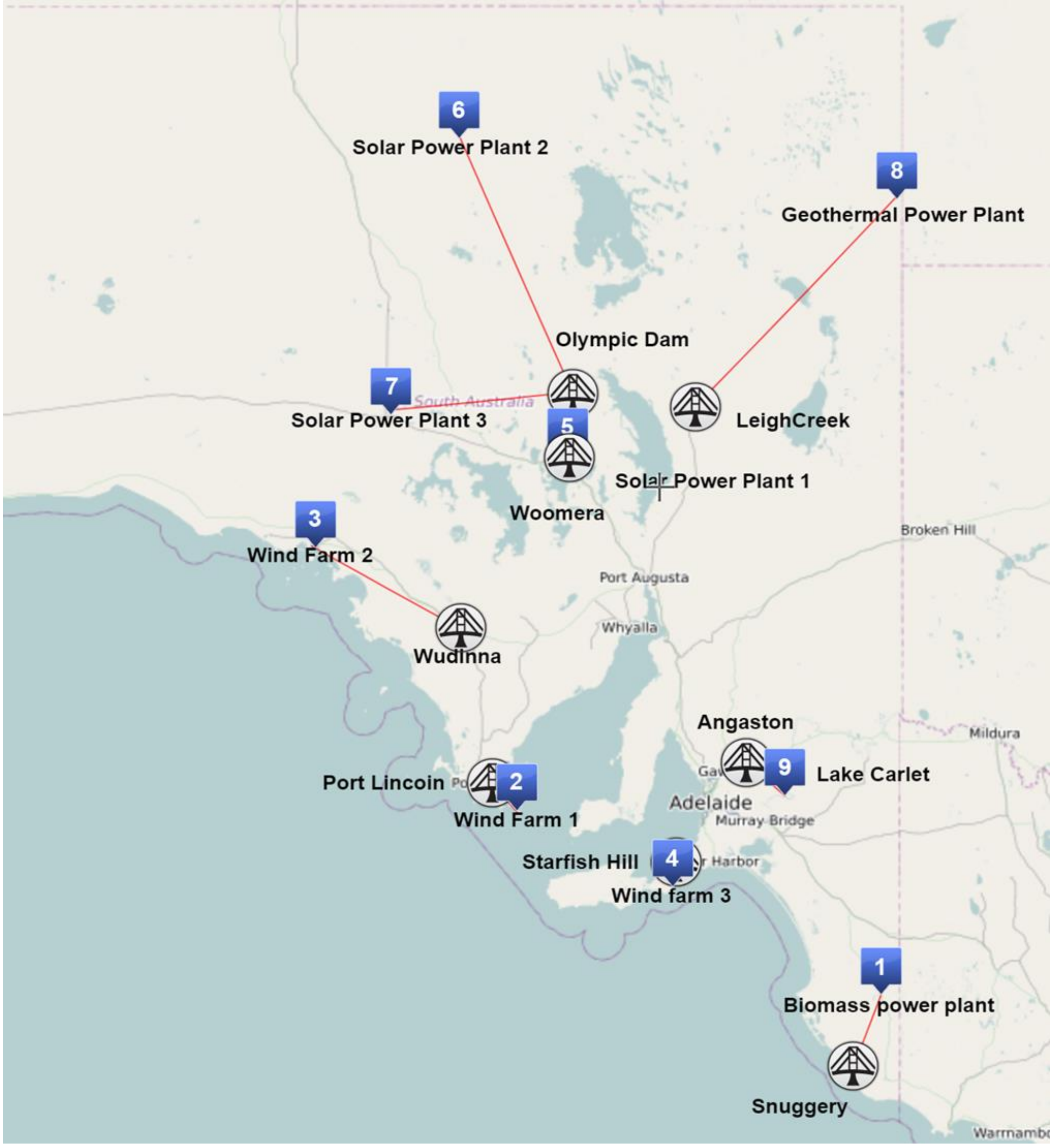


Figure 1 Location of each plant and the transmission substation they connect to

Design and modeling-Solar

Plant design

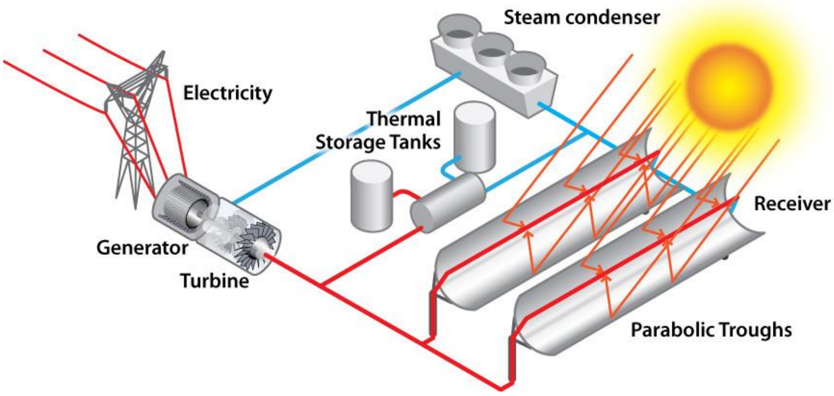


Fig 6 The schematic of the solar plant

The main working procedure for concentrated solar power is that: a field of tracking solar collector focuses sunlight to receive DNI onto a glass receiver containing water inside that can be heated to over 750°F, and the heated water can be circulated through miles of pipes. Next, if necessary, water will be sent to heat exchanger for additional heating using natural gas to make high pressure steam, in this project the solar farm plant can be located closer to the biomass plant in order to obtain biomass. Then the steam is fed to turbines which generate electricity, and finally electricity is transferred to storage substation.

For the solar collector, generally there 2 types, one is tracking collector and the other one is fixed collector. In this project the one-axis concentrating tracking solar collector which fixed at tilt angle and rotates about polar axis will be used. In detailed, the solar collector will be fixed at a tilt angle normally equal to a site's latitude for a maximum annually solar irradiation. And tilt angle can be adjusted for optimizing the collector efficiency, during winter, collector can be tilted 15° greater than the latitude, and during summer, it can be tilted 15° less that latitude. (Marion & Wilcox, n.d.) For polar axis tracker, it has a relatively small angle of incidence and it is within a limit ±23.45°. Also, by calculating the cosine of incidence angle, it can be obtained that the mean cos i for polar tracking is 0.95 over a year, which is nearly as good as the two-axis tracker. (M. Kutz, 2007)

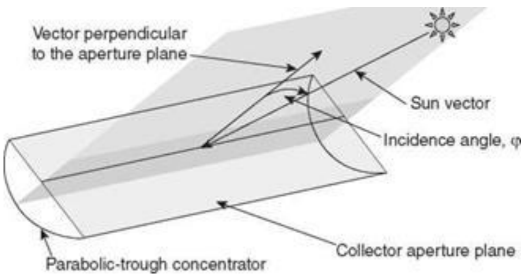


Figure 2 layout of parabolic trough (solar energy, 2019)

The specifications of the parabolic trough are listed in table below:

Table 9 Parabolic trough specification

Plant specifications	value	units
Aperture width	20	m
Tube length	40	m
No. of trough in one plant	3200	NA
No. of plants	3	NA

The total area covered for each plant is: 2.2 million square meters of reflective area covering 3 square miles of solar field.

Energy generated

In this part, utilize Matlab to model the solar plant, consider the DNI data given by BOM as input and electrical energy as output. Some basic plant parameters are listed in the table below.

Receiver efficiency	0.536	%
Collector efficiency	0.798	%
Thermal efficiency	0.4	%
Cloudiness factor	35	%

Table 10 Parameters of plant (USYD, 2019)

The total annual power generated form three stations and energy output are tabulated below:

Table 11 Annual power and energy output for three stations

Stations	**Yearly mean power**	**Annual energy output (kWh)**
Oodnadatta	129.57 MW	1135 million
Tarcoola	114.37 MW	1001.9 million
Woomera	117.32 MW	1027.7 million

We select 21 Mar to see a half hourly power variation in one day.

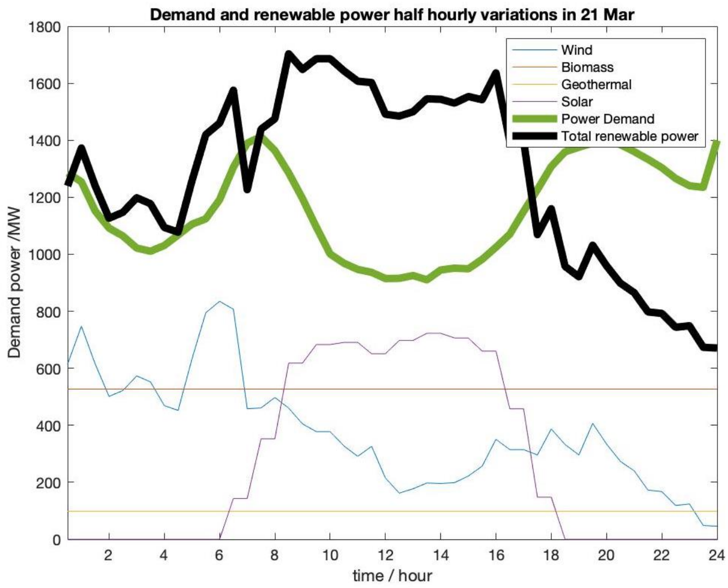


Fig 7 Total power generated from three plants across 21 Mar

From the **错误!未找到引用源。** we can see that the solar power will only be available in the daytime from 6pm until 18pm. The highest solar power in total can reach 700 MW, for the nighttime region where no solar power is not offered, the energy stored has to be used for supplying electricity.

Cost of electricity

	Installed cost (2010 USD/kW)	Capacity factor (%)	O&M (2010 USD/kWh)	LCOE (2010 USD/kWh)
Parabolic trough			0.02 to 0.035	0.14 to 0.36
No storage	4 600	20 to 25		
6 hours storage	7 100 to 9 800	40 to 53		
Solar tower				0.17 to 0.29
6 to 7.5 hours storage	6 300 to 7 500	40 to 45		
12 to 15 hours storage	9 000 to 10 500	65 to 80		

Note: the levelised cost of electricity (LCOE) assumes a 10% cost of capital

Fig 8 Cost of solar farm equipment (IRENA,2012)

According to the table above, all three stations peak power around 3MW, this would need installation cost:

$$3(MW) * \$8000 * 3200 = \$76800000$$

Operating and maintenance cost:

$$3(Mw) * \$0.03 * 3200 = \$288\ per\ kWh$$

LCOE for station Oodnadatta:

$$\frac{Total\ cost}{Total\ energy\ ouput} = \$0.067/kWh$$

Considering the similar size and same plant specification for each site, the capital cost will be the same, and total energy output and LCOE are tabulated below:

Table 12 The LCOE table for solar energy

Stations	**Total cost (USD)**	**LCOE (USD/kWh)**	**Annual energy output (kWh)**
Oodnadatta	76800288	$0.067/kWh	1135 million
Tarcoola	76800288	$0.076/kWh	1001.9 million
Woomera	76800288	$0.075/kWh	1027.7 million

Design and modeling-Wind

Plant design

The wind energy is ample near the large bodies of water. Therefore, it is plausible to assume that we can harvest energy from the sea breeze near the south coastlines. To assesses the exact potential of the wind energy, we analyse the mean cubic velocity in the South Australia weather stations and picked the top three locations to build wind farm.

The specification of the wind farm is listed in the table 13.

	Mean cubic velocity	No. Turbine	Area used
Wind farm 1	9.25 m/s	90	7.08 km^2
Wind farm 2	7.62 m/s	55	4.33 km^2
Wind farm 3	7.89 m/s	77	6.05 km^2

Table 13 Specification of each wind farm

The area is calculated based on the spacing between them. The wind turbines in the downstream needs to by 8-10 diameters away from the turbines in the upstream and the spacing for wind turbines in the cross stream is much shorter. The specification of the wind turbine used in each farm is listed in the table 14 below

Turbine type	Cut in speed	Cutout speed	Blade length
Vestas VM72	3m/s	15.6 m/s	41 m

Table 14 Specification of the wind turbine

Energy generated from the plant

The energy can be generated from the wind farm is listed in the table 15 below

Table 15 Wind power generation

Wind Farm	Mean power (MW)	Annual output (GWh)	Capacity factor
Wind Farm 1	267.57	2343.9	20.67%
Wind Farm 2	89.2	781.4	11.27%
Wind Farm 3	139.49	1221.9	12.6%
Total	496.26	4847.2	

The daily energy output is shown in Figure 8

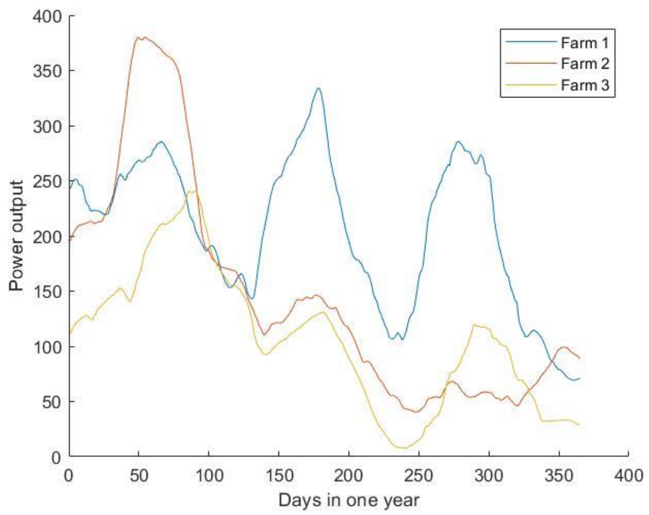


Fig 9 Wind farm power output through the year 2017

We can see that the wind power output is seasonal. There is huge different between the peak power and bottom power. The seasonal change in the output leads to great challenge to the intermittency problem which will address later in the storage section.

Cost of electricity

The wind farms construction costs including installation, transportation, and labor cost is hard to obtain the actual number without talking to the manufacture and contractors. However, we are able to find the total cost of a similar size wind farms. The Starfish Hill wind farm and Wattle Point wind farm in Australia is the similar size to the wind power plant we are building.[23]

The capital cost also includes the cost spent in operation and maintenance in addition to the construction cost. The operation cost and maintenance cost are assumed to be $48,000/MW which is AUD$60726.4/MW.[22][24]

Assuming that the wind turbine can operate for 25 years, we can calculate the levelized cost of electricity of the three wind farms and the results are listed in table 16

Table 16 The total cost spent in 25 years and levelized cost of electricity

	Total capital cost of 25 years	Cost of electricity	Traditional fossil fuel plant cost
Wind farm 1	2291 million dollars	3.9 cents/kWh	4.8 cents/kWh
Wind farm 2	1068 million dollars	5.5 cents/kWh	
Wind farm 3	1501 million dollars	4.9 cents/kWh	
Average		4.8 cents/kWh	

As shown in the table, we can see that the cost of electricity is competitive to the electricity generated in the traditional way which is using coal-fire station to generate.

Design and modeling-Biomass

Plant Design

For bioenergy, there are two parts in the power plant, one is to convert the biomass to methanol fuel cells and the other is to convert the biomass to Ethanol and burn it to produce the electricity. Although it is expensive to convert biomass to methanol, the reason why we use two methods is because we have different source of biomass such as plant residues that can be converted to Ethanol and used for heat-led combined heat and power while corn is worth to convert to liquid biofuels to have a wider use or high efficiency. In addition, combustion will result in green house emission while methanol fuel cells have higher efficiency and low NOx emission since the working temperature is lower.[9]

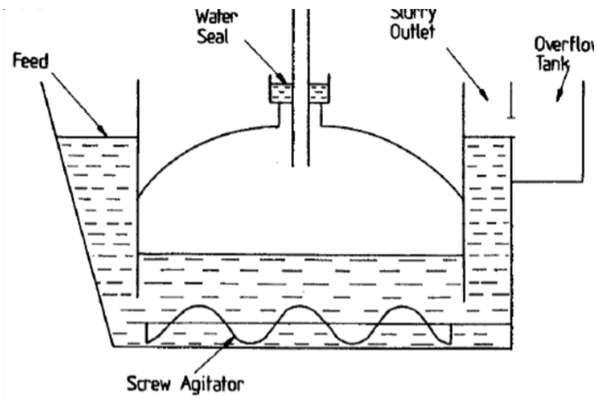


Fig 10 Conversion of biomass to methanol

The method of conversion of biomass to methanol used Biochemical production anaerobic digestion method is illustrated above that contains Hydrolysis, Acid formation and Methanation to produce methanol.

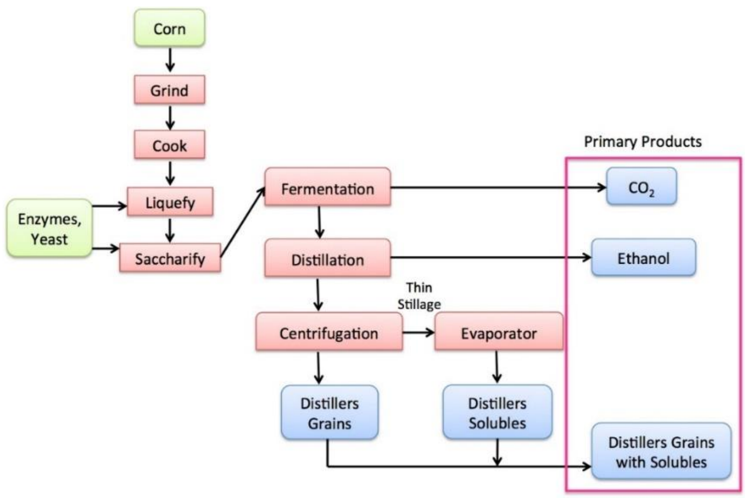


Fig 11 Conversion of biomass to Ethanol

Ethanol will be produced from plant biomass with fermentation and distillation.

The figure below shows the schematic of biomass power plant on how to produce the electricity.

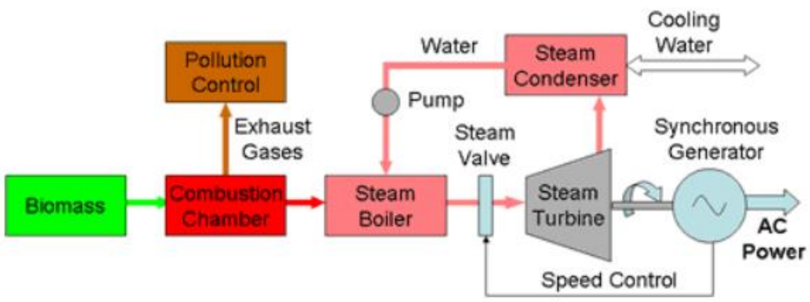


Fig 12 Schematic of biomass power plant

Biomass are burnt in combustion chamber and the exhaust gases from the combustion will be absorbed and treated to reduce the air pollution. The water will go into steam boiler and gain heat to produce steam. Then the steam turbine is used to produce electricity.

Energy generated

One tone of biomass can be converted to 721 Litres of methanol.

The convert ratio for ethanol from plant feedstock is 10.6L per 25 kg.

Maintenance is $100/kwe per year.

For methanol, density = 792 kg/m^3, Molar mass = 32 g/mol

The data given in table 1 is the biomass resource generated in a whole year in South Australia. Not all residues from Manure are used as biomass since it can be illustrated in farming area.

From the data, the amount of biomass we can get is listed in table 17:

Source	tonnes

Residues from Vegetables	517945
Residues from Manure	9379960
Cereal Straw Residues	2278000
Non-Cereal straw residues	674230

Table 17 Biomass data[9]

From model, we calculate the electricity produced from direct burning and Methanol fuel cells:

Ethanol burning = 1105 kwh/tonnes

DMFC = 854 kwh/tonnes

In our design, biomass is separated into two part: biomass from poultry and sheep are converted to methanol and biomass from vegetables, cereal and non-cereal straw residues are converted to ethanol. The output electricity can be produced from biomass is 5.57 Twh per year which means we need 636MW power plant, therefore, 6 110 MW power plant will be constructed and operating 24 hours per day.

Cost of Electricity

The total cost for the biomass plant that include capital cost and maintenance cost for ten years is:

Six 110 MW power plant:

$$\text{Capital Cost} = \$2.5 \times 110 \times 6 = \$1650 \text{ million}$$

Delivered biomass: $30 per tones:

$$\text{Delivered Cost} = 10 \times \$30 \times 8160155 = \$2448 \text{ million}$$

Operating and maintenance:

$$O\ \&\ M = 10 \times \$3.4 \times 7 = \$238\, million$$

Production cost:

$$\text{Production Cost} = \frac{\$0.078}{\text{kwh}}$$

Design and modeling-Geothermal

Plant design

The graph shows the main structure of a geothermal power plant that contains a water reservoir, a pump house a heat exchanger, a turbine hall, injection and production well, porous sediments observation well and a monitoring center.

Firstly, an injection well will be drilled into hot basement which has limited permeability and fluid content. The reservoir would present an enormous energy resource. Cold water would be pumped down into the earth. Its force creates fissures in the dry rocks. It should be injected at sufficient pressure to ensure fracturing within the developing reservoir and hot basement rock. Then water flows into the fissures and be heated up by geothermal energy. Then the heated fluid would be pumped back up to surface and the stream is pumped off and used to turn turbines, creating large electricity at power plant. And the cooled water will be returned to the reservoir. In terms of hydro-fracture, pumping of water would continue to extend fractures and reopen old fractures from the injection wellbore and throughout the reservoir. A production well is drilled to intersect the stimulated fracture system and circulate water to extract the heat from the hot basement rock.

The figure below shows the process of electricity power generation in geothermal power plant:

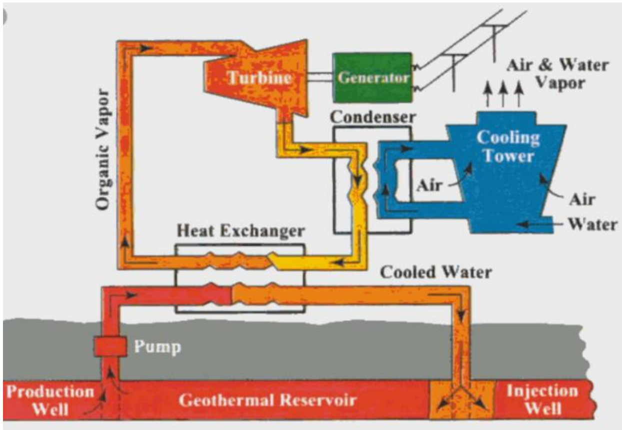


Fig 13 electricity power generation

Energy generated

1330 of points in South Australia are selected as suitable places to set up geothermal power generator. Since the underground temperature will neither change with time nor be affected by external factors, all these positions will be analysis as references of temperature in depth. We only selected the temperatures which are over 110 Celsius.

Assume that the mass flow rate of geothermal water is 440kg/m^3 due to the pump, the efficiency of turbine is 60% and 10% of the energy loss in generator.

The result obtained by Matlab shows that 3.5581 petajoules energy could be generated in one year by designed geothermal power plant, which has a power of 112.8253MW, and could provide 0.579% of annual Australia energy need.

Cost of electricity

Geothermal power plants are relatively inexpensive to operate. Operating and maintenance costs are estimated from $0.01 to $0.03 per kWh with the change of efficiency. Assuming the efficiency of power plant generator is 60%, the operating cost is about $ 0.02 AUD per kWh. The power of plant is about 4.06*10^8 KWH in average, which means that the operating and maintenance fee is about $8,120,000 AUD annually.

The table 18 shows the production costs for boreholes in 10 years lifetime. According to the power plant designed., the depth of holes are all less than 2500 meters, thus conventional drilling method is the most proper choice. The cost of drilling is about $17,052,000 AUD with $1,364,160 AUD interest rate and $852,600 AUD operation and maintenance fee.

10 years lifetime, 8% interest rate and 5% cost of operation and maintenance

Case	Drilling	Depth from->to (metres)	Energy Production (GWh/year)	Production costs		
				Power Plant ($/MWh)	Drilling ($/MWh)	Total ($/MWh)
A	Conventional	0 - >2,500	40	25 (59%)	17 (41%)	42
B	IDDP	2,500 - >4,626	320	25 (69%)	11 (31%)	36
C	Deep Drilling	0 - >4,626	320	25 (64%)	14 (36%)	39

Table 18 production costs for boreholes [14]

In terms of the construction cost of a 112MW power plant, the exploration and site development would surely need a large amount of money. Here is a table that basically estimates how much money has to be spent is listed in table 19:

Phase	Subphase	Cost per kW	Cost for 112 MW Plant
Exploration		$150	$16.8 million
Site development	Permitting	$20	$2.24 million
	Drilling	$750	$84 million
	Conventional		$17.05 million
	Stream Gathering	$250	$28 million
	Power Plant construction	$1500	168 million
	Transmission	S100	11.2 million
Total			327.29 million

Table 19 Cost table of building geothermal plant [14]

The total cost is about $327.29 million for building a 112MW geothermal power plant, with $10,337,000 operating and maintenance fee in 10-year lifetime.

Here is the cost distribution of the 112MW geothermal plant we designed：

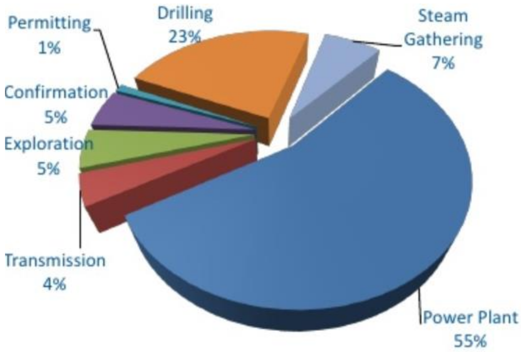


Fig 14 The cost distribution of geothermal plant

Energy Storage

For biomass, there is less need for storage because biomass plants create fuels and therefore the energy output is steady. For solar and wind, the intermittency problem would require the energy to be stored for a period of time.

The geothermal energy, however, gives really steady output but for later use, the energy still needs to be stored when solar and wind energy can cover all the need.

Solar Power and Geothermal

Solar and geothermal energy plant are all stationary large plant and therefore it is suitable to store the energy in the Sodium-sulphur and lithium ion batteries. The storage period for these two plants are relatively short since the duration of sunless time is usually within one or two days.

Wind Power

However, for wind energy, the output is seasonal, and it requires a long-term storage method. In this case, compressed air system and hydro storage seems a more ideal choice.

Compressed air energy storage is utilizing compressed air energy storage technology. Gas compression generates heat, so the higher the temperature of the compressed air. Conversely, the heat released gas expansion. If no additional heat into the system, the air temperature significantly decreased after expansion. If the heat generated by compression can be stored and released at the time of expansion, it can significantly improve the efficiency of energy storage.

Use hydro pumped-storage power generation, the use of off-peak electricity to pump water back, then release the water to make hydroelectric power. When the power overproduction, surplus electricity can supply to the electric pumps, to deliver water to higher ground reservoirs, to be increased demand for electricity, the gate open, water reservoirs height depending on the terrain begins flow to the original location of electric pumping pumps, turbines driven by water potential of the waterway between the regeneration.

All the plants introduced above can store the energy by creating fuels such as hydrogen which can be used in the directed fuel cell to generate electricity.

According to the daily demand in the August 21st, we can see that the largest gap is within 800 MW. Therefore, the rate of releasing energy should be at least 900MW for all the storage units which means the total storage should have at least 3000 GWh.

Design and modeling-Demand

Total energy harvested

Before we start calculating the total power generated in each plant, we need to find out the amount of loss in transmission. Many of our power plant is far away from the transmission substation and therefore we have to build transmission line to transport energy into the grid and therefore, there is lost associated with the transmission.

The formula for the transmission loss is

$$\mathrm{P_{loss}} = I^2 * 0.168\ ohm/km * length\ of\ transimission\ line$$

I is the current in the transmission line which is calculated using

$$\mathrm{I} = \frac{\mathrm{P_{plant}}}{\mathrm{V_{sub-station}} * \sqrt{3}}$$

The actual power output is listed in the table 20

Table 20 The actual power output (subtracting transmission loss)

Power plant	Transmission Substation	Distance Km	Transmission loss MW	Actual Power output MW
Biomass power plant (6 plants)	Snuggery	84.47	19.71	616.49
Wind farm 1	Port Lincoin	44.9	10.3315	257.23
Wind farm 2	Wudinna	201.18	5.1446	84.06
Wind farm 3	Starfish Hill	27.97	6.9965	132.4935
Geothermal plant (three plants)	LeighCreek	359.60	14.712	98.12
Solar Power Plant 1	Woomera	1.1	0.0137	129.49

Solar Power Plant 2	Olympic Dam	358.23	4.101	120.295
Solar Power Plant 3	Olympic Dam	222.64	2.2692	115.0508
Total			63.2873	1560

Production vs Demand

- Annual output vs annual demand

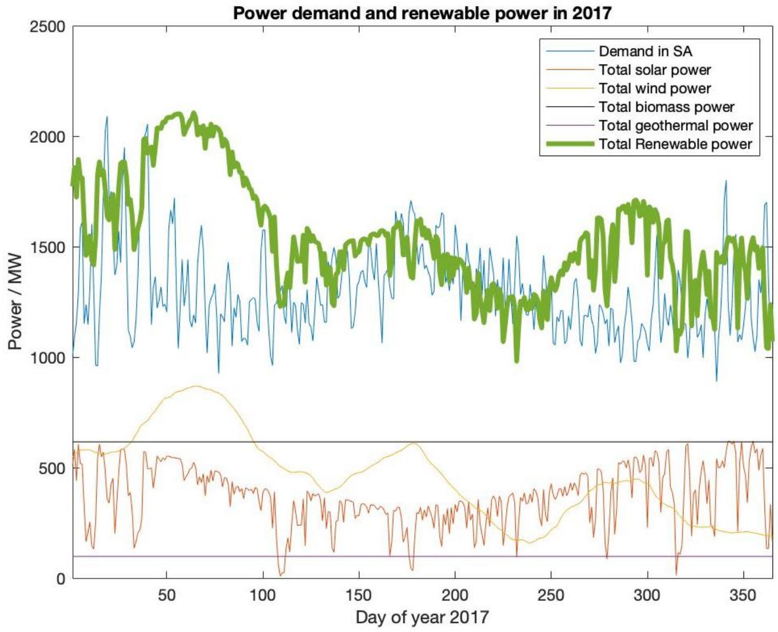


Figure 3 Annually renewable output and demand power

The total annual total renewable power generation and each type of power are all presented in Figure 3. Overall the mean power output satisfies the average demand through a whole year.

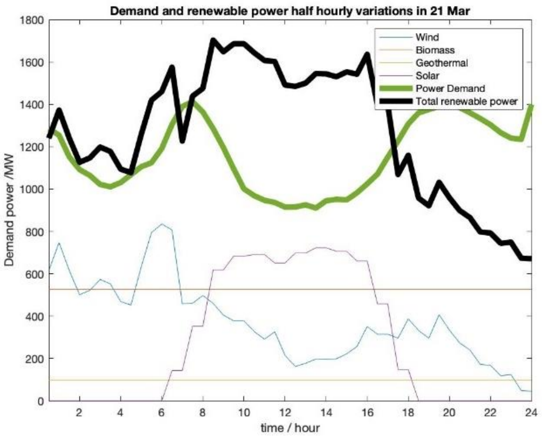
$$\text{Power output} = 1553.22\ \text{MW} > \text{Average Demand (1299.73 MW)}$$

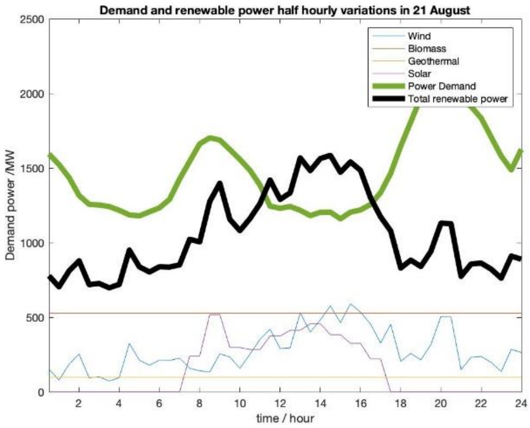
However, the daily output does not always meet the daily demand due to the variation on in different seasons. Due to the smaller output of the wind and solar energy provided during the winter, the plant provides more energy than needed during the summer and during the winter, the demand is larger than the output.

- Daily demand

March 21st

Aug 21st





It is also important to meet the demand within 24 hours, we choose two different days in summer and winter to test the energy output. We can see that during the nighttime, we need more energy and during the noon, we provide energy more than we need.

The way of addressing this problem is storing energy when the output is larger than the need and release the energy when needed.

All the storage unit in total should be able to release in the rate of 900 MW for 12 hours in order to satisfy the daily electricity need.

Emission

Solar and Wind

Wind and solar energy is a low-carbon energy source. There are several processes that include the greenhouse emissions such as manufacturing: extraction of raw material, transportation to the manufacturing factory, and component manufacturing process. Also, construction, operation, and maintenance contain greenhouse gas emission as well. During the steam production process when plant is working, natural gas is used for increasing the steam pressure for a larger power, so amount of CO_2 will be released owing to this.

Biomass

With bio energy, green house emission will reduce but some other problem such as formaldehyde may occur. Since the biomass is mainly delivered from waste and residuals that will have benefit on beautify environment and reduce the garbage pollution.

Geothermal

Since geothermal pump heating systems do not burn fossil fuels for heat generation, they produce much lower greenhouse gas emissions than conventional furnaces. They also provide higher air quality because there are no carbon monoxide emissions.[15] Typically, a 3-ton residential geothermal heat pump system produces an average of approximately one pound of carbon dioxide per hour compared to conventional systems. In an average 20-year life cycle, installing 100,000 residential geothermal systems can reduce greenhouse gas emissions by nearly 1.1 million metric tons of carbon equivalent. This is equivalent to removing 58,700 cars or planting more than 120,000 acres of trees from our highway.[18]

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Appendix

Wind code

```
clear
clc

S = dir('*.txt');
index = 1;
H = 41;
r = 20;
K = 3;
No = [90,55,77];

for i = [13,18,30]

    a = 0;
    % The file we need to read is the ith file
    N = S(i).name;

    fid = fopen(N);
    txt = textscan(fid,'%s','delimiter','\n,','Headerlines',1);
    fclose(fid);

    raw_data = txt{1,1};

    no_data = length(raw_data);

    v =[];
    direction = [];
    windgust = [];

  for n = 1:no_data/20

       thisWind1 = str2num(char(raw_data(13+a)));

       if thisWind1 > 56.327
           thisWind1 = 56.327;
       end

       if ~(isempty(thisWind1))
           v = [v ,thisWind1];
       elseif (isempty(thisWind1))
```

```
            v = [v, v(end)];
        end
        a = a+20;
    end

    % Then we calculate the average cubic velocity to assese the
potential
    % of the wind farm at this station
    % The first step is to find the shape and scale parameter
    % Velocity is m/s
    v = v./3.6;
    ave = mean(v);
    sta = std(v);
    k = 1.2785*(ave/sta)-0.5004;
    A = ave/gamma(1+1/k);

    % The cubic mean velocity is
    % The function of F*v^3 is
    density = 1.2;
    fun_mean_cubic = @(v) v.^3.*(k*A^(-k)*v.^(k-1).*exp(-
(v./A).^k));

    % Mean cubic velocity
    v_m_cubic(index) = (integral(fun_mean_cubic,0,inf))^(1/3);

    % The available wind power density
    ava_power_density(index) =
16/27*1/2*density*v_m_cubic(index)^3.*10^(-3);

    % Assume zero set up angle and U=28 and the postion angle is
0-360
    for nu = 1:length(v)

        if v(nu) == 0
            T_avg(nu) = 0;
            omega(nu) = 0;
            P_d(nu) = 0;
        else

            zeta = 0;
            v_nu = v(nu);
            speed_ratio = 5;
            U = speed_ratio*v_nu;
            p_angle = 5:10:355;
```

```
        % Find angle of attack
        constant =
sqrt(1+U^2/v_nu^2+2*U/v_nu.*sind(p_angle));
        costha = (U/v_nu+sind(p_angle))./constant;

        for d = 1:length(p_angle)
            if p_angle(d) >90 && p_angle(d)<270
                tha(d) = -acosd(costha(d));
            else
                tha(d) = acosd(costha(d));
            end
                alpha_2(d) = tha(d) + zeta;
        end

        % Find drag and lift coefficient
        cl_2 = 0.78*sind(2.*alpha_2)+0.65*sind(alpha_2);
        cd_2 = 0.42-0.34*cosd(2.*alpha_2);

        % Find lift and drag force
        Ap = K*H;
        W = constant.*v_nu;
        F_lift =1/2*density.*W.^2.*Ap.*cl_2;
        F_drag =1/2*density.*W.^2.*Ap.*cd_2;

        % Find lift and drag in direction of blade motion
        %F_cf = F_lift.*sind(tha);
        F_cb = F_drag.*cosd(tha);

        % Find torque on the blade
        torque = r.*( F_cb);

        % Calculate <T>(mean torque), P_d(power delivered)
        % omega(angular velocity)
        T_avg(nu) = mean(torque)*10^-3;
        omega(nu) = U/r;
        P_d(nu) = T_avg(nu)*omega(nu)*5;

    end
end
        P_mean(index) = mean(P_d)*10^(-3)*No(index)*0.85;
        capa_factor(index) = P_mean(index)/(max(P_d)*10^(-
3)*No(index)*0.85)*100;

        for day = 1:365
            power_day(day,index) =
```

```
mean(P_d(1+day:48+day))*10^(-3)*No(index)*0.85;
          end

          march_21 = 31+28+21;
          power_mar(:,index) =
P_d((march_21+1)*48+1:(march_21+2)*48)*10^(-3)*No(index)*0.85;

          June_21 = 31+28+31+30+31+21;
          power_june(:,index) =
P_d(June_21*48+1 :(June_21+1)*48)*10^(-3)*No(index)*0.85;
          ah = 1;


          Aug_21 = 31+28+31+30+31+30+31+21;
          power_aug(:,index) =
P_d(Aug_21*48+1 :(Aug_21+1)*48)*10^(-3)*No(index)*0.85;
          ah = 1;

          Dec_21 = 31+28+31+30+31+30+31+31+30+31+30+21;
          power_dec(:,index) =
P_d(Dec_21*48+1 :(Dec_21+1)*48)*10^(-3)*No(index)*0.85;


          index = index + 1;
end


sum_of_power = power_day(:,1)+power_day(:,2)+power_day(:,3);
% Daily data over a year
hold on
day = 1:365;
plot(day,power_day(:,1)');
plot(day,power_day(:,2)');
plot(day,power_day(:,3)');
xlabel('Days in one year');
ylabel('Power output');
legend('Farm 1', 'Farm 2','Farm 3')

% Hour data over a day
% Site 1
figure(2)
subplot(2,2,1)
hour = 1:48;
plot(hour, power_mar(:,1));
subplot(2,2,2)
```

```
plot(hour, power_june(:,1));
subplot(2,2,3)
plot(hour, power_aug(:,1));
subplot(2,2,4)
plot(hour, power_dec(:,1));

% Site 2
figure(3)
subplot(2,2,1)
hour = 1:48;
plot(hour, power_mar(:,2));
subplot(2,2,2)
plot(hour, power_june(:,2));
subplot(2,2,3)
plot(hour, power_aug(:,2));
subplot(2,2,4)
plot(hour, power_dec(:,2));

% Site 2
figure(4)
subplot(2,2,1)
hour = 1:48;
plot(hour, power_mar(:,3));
subplot(2,2,2)
plot(hour, power_june(:,3));
subplot(2,2,3)
plot(hour, power_aug(:,3));
subplot(2,2,4)
plot(hour, power_dec(:,3));

power_sum_mar = power_mar(:,1)+power_mar(:,2)+power_mar(:,3);
power_sum_june =
power_june(:,1)+power_june(:,2)+power_june(:,3);
power_sum_aug = power_aug(:,1)+power_aug(:,2)+power_aug(:,3);
power_sum_dec = power_dec(:,1)+power_dec(:,2)+power_dec(:,3);


E_1 = P_mean(1)*365*24*1000*25
E_2 = P_mean(2)*365*24*1000*25
E_3 = P_mean(3)*365*24*1000*25

% Construction cost, operating cost and maintenance cost
L_1 = (800*10^6+48000*P_mean(1)+1800*365*25*90)/E_1
L_2 = (160*10^6+48000*P_mean(2)+1800*365*25*55)/E_2
L_3 = (230*10^6+48000*P_mean(3)+1800*365*25*77)/E_3
```

```
mean = (L_1+L_2+L_3)/3;
```

Solar code

Code 1

```
%% this sciprt calculate one day power variation
clear;
clc;
% open files for 24 hours
%% find the DNI for 2017.each month
str1 = 'solar_dni_2017';
str2 = 'UT.txt';
month = [01 02 03 04 05 06 07 08 09 10 11 12];
date = [01:1:31];
hour = [00:1:23];

%set up the question parameters
phi_receiver = 0.536;   % receiver effiency
phi_collector = 0.798;  % collector efficiency
phi_thermal = 0.33;     % plant thermal efficiency

% find latitude and longitude of plants
left = 112.025005;   % left longitude in degrees
right = 153.971146;  % right longitude
top = 10.0281243;    % top latitude
bottom = 43.9750009; % bottom latitude
div = 0.0499954;     % division for both degrees

%%%%%%%%%%%%%%%%% define the three solar farms location at
Woomera %%%%%%%%%

   latitude = [27.56,31.16,30.71];   % latitude degree
   longitude = [135.45,136.81,134.58]; % longitude degree
    station_no = length(latitude);

%% sum each day 24 hour power, and get 365 days power.
    % loop through the date
 % convert to the grid point in txt file, first find the 4
closet point
 a=sprintf('%02d',12);     % solar_dni_201703
DNI = zeros(3,length(date));
G = zeros(3,length(date));
P = zeros(3,length(date));
trydata = zeros(3,length(date));
```

```
    for dat = 1:length(date)
       number_date = date(dat);
       b = sprintf('%02d',number_date);   % solar_dni_20170301

       % loop through hours
       for h = 1:24
           number_hour = hour(h);
           c = sprintf('%02d',number_hour);   %
solar_dni_20170301_01
           filename=[str1,a,b,'_',c,str2];
           data = dlmread(filename,' ',6,0);

        disp([ str1,a,b,'_',c,str2 ' being processed  '])

        [rows,cols]=size(data);
               %Display progress
            disp([ str1,a,b,'_',c,str2 ' being processed  '])
               % convert -999 to zero
                for i = 1:rows
                    for j = 1:cols
                        if data(i,j) == -999
                            data(i,j) = 0;

                        end
                    end

                end

                for s = 1:station_no
                    row_no = (latitude(s)-top)/div;
                    col_no = (longitude(s)-left)/div;
                    x = col_no;
                    y = row_no;

                    x1 = fix(col_no);
                    x2 = fix(col_no)+1;
                    y1 = fix(row_no);
                    y2= fix(row_no)+1;

                    Q11=data(y1,x1);
                    Q21=data(y1,x2);
                    Q12=data(y2,x1);
                    Q22=data(y2,x2);
                    star = ((y2-y)/(y2-y1)*((x2-x1)/(x2-
x1)*Q11+(x1-x1)/(x2-x1)*Q21))+((y-y1)/(y2-y1)*((x2-x1)/(x2-
```

```
x1)*Q12+(x1-x1)/(x2-x1)*Q22));
                    trydata(s,h) = star;
                end

        end
        for station = 1:3
            %% calculate the acutal electrical power for different
stations
            DNI(station,dat) = sum(trydata(station,:),'all')/24;  %
daily average DNI
             % total solar irradiance onto the receiver W/m2
             G(station,dat) = DNI(station,dat)*0.95;     %
cosi=0.95 for polar axis solar collector
             % the total electrical power output
             no_collector=2500;
             Area = 20*40*no_collector;
             P(station,dat) =
G(station,dat)*Area*phi_receiver*phi_collector*phi_thermal*10^-
6; % convert power to MW
        end
    end


total_power = sum(P);
day = 1:1:length(date);
figure
plot(day,total_power);
hold on
plot(day,P(1,:));
hold on
plot(day,P(2,:));
hold on
plot(day,P(3,:));

title('Monthly power variation across December');
legend('Total power','station1','station2','station3');
xlim([1,length(date)]);
ylabel('Power / MW');
xlabel('Days in December')
```

Code 2

```
clear;
clc;

%%%%%%%%%%%%%%%%% define the three solar farms location at
Woomera %%%%%%%%%

latitude = [27.56,31.16,30.71];   % latitude degree
longitude = [135.45,136.81,134.58]; % longitude degree
station_no = length(latitude);

% find latitude and longitude of boundaries
left = 112.025005;   % left longitude in degrees
right = 153.971146;  % right longitude
top = 10.0281243;    % top latitude
bottom = 43.9750009; % bottom latitude
div = 0.0499954;     % division for both degrees
%% Extract data at three stations
   %%%%%%% load every individual files %%%%%%%%%%
   myDir = uigetdir; %gets directory
   myFiles = dir(fullfile(myDir,'*.txt')); %gets all txt files
in struct
   station_DNI = zeros(3,length(myFiles));
for k = 1:length(myFiles)
     baseFileName = myFiles(k).name;
     fullFileName = fullfile(myDir, baseFileName);
     fprintf(1, 'Now reading %s\n', fullFileName);
     data = dlmread(fullFileName,' ',6,0);   %or readtable

     [rows,cols]=size(data);
            % convert -999 to zero
             for i = 1:rows
                for j = 1:cols
                    if data(i,j) == -999
                        data(i,j) = 0;

                    end
                end

             end


     for s = 1:station_no
```

```
            % convert to the grid point in txt file, first find
the 4 closet point
            row_no = (latitude(s)-top)/div;
            col_no = (longitude(s)-left)/div;
            x = col_no;
            y = row_no;

            x1 = fix(col_no);
            x2 = fix(col_no)+1;
            y1 = fix(row_no);
            y2= fix(row_no)+1;

                Q11=data(y1,x1);
                Q21=data(y1,x2);
                Q12=data(y2,x1);
                Q22=data(y2,x2);
                star = ((y2-y)/(y2-y1)*((x2-x1)/(x2-x1)*Q11+(x1-
x1)/(x2-x1)*Q21))+((y-y1)/(y2-y1)*((x2-x1)/(x2-x1)*Q12+(x1-
x1)/(x2-x1)*Q22));
                station_DNI(s,k)=star;

      end


end


% Transfer 1st station data into a matrix with format (24
hours, 365 days)
% data = load('station_DNI.mat');
% station_DNI = cell2mat(struct2cell(data));
% fake = station_DNI(:,1:8736);
 station_DNI = station_DNI(:,1:8736);

station1data = zeros(24,364);
DNI1 = station_DNI(1,:);

for j=1:364

    for i=1:24
        station1data(i,j)= DNI1((j-1)*24+i);
    end
end
station1DNI = sum(station1data);
```

```
% Transfer 2nd station data into a matrix with format (24
hours, 365 days)
station2data = zeros(24,364);
DNI2 = station_DNI(2,:);

for j=1:364

    for i=1:24
        station2data(i,j)= DNI2((j-1)*24+i);
    end
end
station2DNI = sum(station2data);

% Transfer 3rd station data into a matrix with format (24
hours, 365 days)
station3data = zeros(24,364);
DNI3 = station_DNI(3,:);

for j=1:364

    for i=1:24
        station3data(i,j)= DNI3((j-1)*24+i);
    end
end
station3DNI = sum(station3data);








%% calculate the acutal electrical power for different stations
% set up the question parameters

phi_receiver = 0.536;   % receiver effiency
phi_collector = 0.798;  % collector efficiency
phi_thermal = 0.33;     % plant thermal efficiency

% calculate for the first plant
% daily solar irradiance onto the receiver W/m2
G1 = station1DNI*0.95;      % cosi=0.95 for polar axis solar
collector
% the total electrical power output
no_collector=2000;
```

```
Area = 12*40*no_collector;
P1 = G1*Area*phi_receiver*phi_collector*phi_thermal*10^-6; %
convert power to MW


% calculate for the 2nd plant
% daily solar irradiance onto the receiver W/m2
G2 = station2DNI*0.95;     % cosi=0.95 for polar axis solar
collector
% the total electrical power output
no_collector=2000;
Area = 12*40*no_collector;
P2 = G2*Area*phi_receiver*phi_collector*phi_thermal*10^-6; %
convert power to MW


% calculate for the 3rd plant
% daily solar irradiance onto the receiver W/m2
G3 = station3DNI*0.95;     % cosi=0.95 for polar axis solar
collector
% the total electrical power output
no_collector=2000;
Area = 12*40*no_collector;
P3 = G3*Area*phi_receiver*phi_collector*phi_thermal*10^-6; %
convert power to MW


%% year sum files


% %write out a file to sum up all year DNI data
% year_DNI=dlmread('yearsum.txt',',');
```