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Committee Secretary
Senate Economics Committee
Department of the Senate
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SUBMISSION TO INQUIRY INTO MATTERS RELATING TO THE GAS EXPLOSION AT VARANUS ISLAND, WESTERN AUSTRALIA

CALCULATIONS SUMMARY

This document is intended to be a supplement for the Sustainable Energy Now Inc. submission to the Senate Economics Committee Inquiry into matters relating to the gas explosion at Varanus Island, WA. It provides the calculations supporting the claims made in the submission:

In simplistic terms, WA's South West Interconnected grid System (SWIS) electrical energy demand could be met by either of the following renewable energies (Ref: Appendix calculations)[1]:

- *Solar thermal plant area:* *15 km x 15 km*
- *Solar PV collector area:* *21 km x21 km*
- *Wind area:* *50 km x50 km*
- *Wave farm along coastline:* *300 km*
- *Geothermal:* *20 km x 20 km (x 1 Km thick granite underground)*

The above statement assumes that the each energy type would need to meet both the following requirements:

SWIS peak demand: 3.8 GW
SWIS average demand: 2.6 GW

To be conservative about the capability of the various renewables to meet the SWIS demand, and the areas needed, it will be assumed that the required capacity of each is:

4.0 GW continuous which equates to approximately 35TWh/year.

[1] *While the above numbers would supply adequate energy for the SWIS demand, some energy types such as wind, solar PV and other variable sources without storage, are not necessarily available on-demand and may need to be supplemented by other fuels, which could be other renewables (with or without storage) and/or gas/distillate. However, solar thermal with storage, geothermal and wave (rated at 90+% baseload), would not require this to address variability because these technologies are, or can be sized and designed to produce constant power, ie. baseload and load-following supply.*

CONTENTS

1. Electricity Generation

Calculation 1 – Solar Thermal

Assumptions & References:

400 MW solar thermal plant requires 3,985,714m^2 of collector area (say 4,000,000 m^2) [1]

Location with clear sunny conditions, and approx 6kWh sunlight per day, per AUSRA's design conditions

Land area & plant = 5 times the collector area

[1] AUSRA Inc.: Report on the design of a 240MW solar power plant Design of a 240 MWe Solar Thermal Power Plant, by *D. Mills, G.L. Morrison, and P. Le Lièvre*: http://www.ausra.com/

Calculations:

Land area req'd for 4.0 GW (4,000 MW):

$$A = \frac{4{,}000 \text{ MW} \times 4{,}000{,}000 \text{ m}^2 \times 5 \text{ factor}}{400 \text{ MW}}$$

= 200,000,000 m^2

Square size = (200,000,000)^0.5

= 14,100 m

= 14.1 km, say 15 km on a side

Calculation 2 - Solar Photo-voltaic

Assumptions & References:

1 MW solar thermal plant requires 5 acres of land area [2]

Assume a worst case day of only 4 hours of sunshine (4kWh/m^2 per day) in a sunny dry area of the state

Power requirement is 4GW continuous.

[2] Leitner.A: Fuel from the Sky: Solar Power's Potential for Western Energy Supply, July 2002. Report sponsored by NREL, July 2002. Available - http://www.nrel.gov/csp/pdfs/32160.pdf (Extract: *In order to calculate the potential solar generation that could come from this land, we used the following values for the land requirements and efficiencies of a thermal solar power plant. In the analysis of Exhibit 24 we assume that 1 MW of solar power requires five acres of land and that the solar fields of these plants would have the following capacity factors: 25% in premium, 22.5% in excellent, and 20% in good solar resource areas. These figures are a reasonable estimate for assessing the generating potential and are typical for CSP technologies.*) (Page 50)

Calculations:

The solar PV capacity required for 4 GW 24 hour operation with 4 hours of sunshine is:

Capacity to meet load during 4 hours of sunshine:

= 4 GW

Storage required during non-sunshine hours:

= 20 hours x 4 GW

= 80GWh

Additional capacity required to meet storage requirements (GW):

= 80GWh / 4 hours

= 20GW

Total capacity required (4 GW continuous):

= 20 GW + 4 GW

= 24 GW

Land area required 24GW capacity (4 GW continuous)

A = 24,000 x 1MW x 5 acres / MW

= 120,000 acres

= 486 km^2

= approximately 22 km x 22 km

Calculation 3 - Wave

Assumptions & References:

CETO buoys operating in design water depth 25 – 100m and approx 2-5 m underwater

Buoys installed on 20m x 20m grid

Buoys installed up to 3 rows along coastline

Location: Wave energy density at least 44 kW/m of coastline (see CETO map showing Australia's coastline suitable)

4.0 GW (4,000 MW) from wave energy (CETO technology) would require approximately 300 km of coastline (subsurface) between Geraldton and Bremmer Bay (Ref: Carnegie Corporation).

Calculations:

Power per metre coastline $= \frac{100\text{ kW}}{1\text{ buoy} \times 1\text{ row}} \times \frac{1\text{ bouy}}{20\text{ m coastline}} \times 3\text{ rows}$

$= \frac{300\text{ kW}}{20\text{m}}$

$= 15\text{ kW/m}$

Therefore:

Length coast line for 4 GW $= \frac{4{,}000{,}000\text{kW}}{15\text{ kW/m}}$

$= 267{,}000\text{m}$

= 267km, so say <u>300 km</u>

This calculation has been verified by Dr L. Mann, Carnegie Corp.

Calculation 4 - Wind

Assumptions & References:

"Up to 0.5 million km^2 in southwest Western Australia may have average wind speeds above 6 m/sec at 60m height. This is 30 times more land than would be required to provide all of Australia's electricity from the wind. It is clear that Australia has much more land with good wind than would be required to meet our entire electricity demand." [3]
[3] *Solar and Wind Electricity in Australia", AW Blakers, Australian Journal of Environmental Management Vol 7, pp 223-236, 2000)*

A 2 MW wind turbine with a capacity factor of 0.2 will produce 3,504 MWh/y. [4]
[4] *Krewitt,Wand Nitsch, J (2003) The Potential for Electricity Generation from On-Shore Wind Energy Under the Constraints of Nature Conservation: A Case Study for Two Regions in Germany Renewable Energy Vol 28, Issue 10 pp 1645-1655*

The total energy requirement of the SWIS is 35 TWh/y (= 35,000,000 MWh/yr)

Calculations:

To calculate the area required for a wind farm to generate the energy requirements for the SWIS, the following calculations were completed.

The wind turbines installed were assumed to be 2 MW turbines, with rotor diameters of 82 m (Enercon E-82).

The number of turbines required is:

$$\text{Turbines} = \frac{35{,}000{,}000 \text{ MWh/yr}}{3{,}504 \text{ MWh/yr}}$$

= 10,000 each

Area required for each turbine:

The area required for a wind turbine, as defined by Krewitt and Nitsch is a square with sides with a length of 6 times the rotor diameter.

Area spacing of 6 times the rotor diameter of 82 m is 492 m. The area of a square with these sides is 0.24 km^2.

Total land area required:

Area for 10,000 turbines = 10,000 x 0.24 km^2
= 2,400 km^2.

This is a square of 49 km x 49 km, say 50 km on a side.

Calculation 5 - Geothermal

Assumptions & References:

GreenRock Energy on their website (www.greenrock.com.au) quotes: *" 1 cu km initially at 200 deg C has the potential to produce about 10 MW electricity annually if the rock temperature fall to 180 deg C over 20 years. "*

Beardsmore, G.R.,2008,Hot Rock Exploration Methods ,in Proceedings of the Sir Mark Oliphant International Frontiers of Science and Technology Australian Geothermal Energy Conference, Geoscience Australia record 2008/18
Beardsmore, 2008 states that "there are four factors that effectively control the viability of flowing hot fluid to surface. They are :

- the conductive heat flow
- total thermal insulation
- reservoir permeability-thickness

availability of an adequate water supply.

Useful technical background material on Geothermal Energy is contained in a report produced by the Massachusetts Institute of Technology Report entitled " The Future of Geothermal Energy " edited by Tester et al, 2006

Calculations:

Scaling up GreenRock's 10 MW to 4,000 MW

Rock volume required = $\frac{4{,}000 \text{ MW} \times 1 \text{ cu km}}{10 \text{ MW}}$

= 400 cu km of 200 deg granite with an appropriate blanket of sediments to act as a thermal insulator.

This could be made up of 20 x 20 x 1 km granite.

Calculation 6 - Biomass

SEN has not performed calculations on the potential for biomass to provide electrical energy for the SWIS.

2. FRESHWATER

Calculation 7 - Solar Distillation

The following is an excerpt from the reference below.

An approximate method of estimating the output of a solar still is given by:

$$Q = \frac{E \times G \times A}{2.3}$$

where:
Q = daily output of distilled water (litres/day) E = overall efficiency
G = daily global solar irradiation (MJ/m²)
A = aperture area of the still ie, the plan areas for a simple basin still (²)
In a typical country the average, daily, global solar irradiation is typically 18.0 MJ/m² (5 kWh/m²). A simple basin still operates at an overall efficiency of about 30%. Hence the output per square metre of area is:

$$\text{daily output} = \frac{0.30 \times 18.0 \times 1}{2.3}$$

= 2.3 litres (per square metre)

The yearly output of a solar still is often therefore referred to as approximately one cubic metre per square metre.

Ref: Practical Action Technology Challenging Poverty at:
http://itdg.org/docs/technical_information_service/solar_distillation.pdf)