Prospects and problems of increasing electricity production from mid-size (<30 MW) renewable energy generation facilities on the South-West Interconnected System (SWIS)

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Dissertation for Master of Science in Renewable Energy

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Declaration

I declare that this dissertation is based on my own research and is the product of my own work, unless otherwise indicated. To my best knowledge, this report or any parts of this report have never been submitted to any institution, at the exception of duly acknowledged materials.

January 2012

Delphine de Balbine

Acknowledgments

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Abstract

Western Australia (WA) is truly blessed by abundant and readily available renewable energy resources. Yet most of its energy use still comes from fossil fuel energy. In the case of the South-West Interconnected System (SWIS), which is the largest grid of the state, renewable energy represents only 2.9 percent of the total electricity production in 2009-2010. From these two facts, I look at the possible causes of such a small production of renewable energy and the future development of renewable energy technology for the SWIS in the coming decades. I found that the SWIS and its economic and political structure tend to create barriers to renewable energy through strict market rules and lack of political will. This is particularly true for mid-size renewable energy facilities of less than 30MW, which cannot compete with traditional electricity production and are faced with technical issues to be integrated in the energy mix. In addition, strong lobby groups, encouraged by abundant fossil fuel reserves in WA, deepen the obstacles preventing fast development of renewable energy for the SWIS. In my research, I found many opinions and studies of various experts and industrials that claim that the full production of electricity from renewable energy is technically and practically possible by 2050 in some parts of the world. This is also valid for the SWIS, as some scenarios developed by private organizations have shown possibilities of 80 to 100% of the electricity of the SWIS produced through a diverse renewable energy mix. However, with the current barriers and policies in place, it is very unlikely that the SWIS would achieve such scenarios. In my analysis of the cases of two other countries, I found that policy planning and liberal market seem to be driving factors in the renewable energy sector and its outcome for a country. Both the USA and China are leading the renewable
energy industries in two distinct ways. While China has become the world’s renewable energy manufacturer through strong policies, the USA is one of the leaders in renewable energy technology innovation through a more or less free market. I finally look at the possibilities for the SWIS to develop its renewable energy production through an active participation of the government in the energy market.
"We can't solve problems by using the same kind of thinking we used when we created them."

Albert Einstein
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<th>Description</th>
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<tr>
<td>APPEA</td>
<td>Australian Petroleum Production and Exploration Association</td>
</tr>
<tr>
<td>CPRS</td>
<td>Carbon Pollution Reduction Scheme</td>
</tr>
<tr>
<td>CST</td>
<td>Concentrated Solar Thermal</td>
</tr>
<tr>
<td>DSM</td>
<td>Demand Side Management</td>
</tr>
<tr>
<td>ESAA</td>
<td>Energy Supply Association of Australia</td>
</tr>
<tr>
<td>FCAS</td>
<td>Frequency Control Ancillary Services</td>
</tr>
<tr>
<td>GREL</td>
<td>The Goldfields Renewable Energy Lobby</td>
</tr>
<tr>
<td>IMO</td>
<td>independent Market Operator</td>
</tr>
<tr>
<td>IPPs</td>
<td>Independent Power Producers</td>
</tr>
<tr>
<td>LRET</td>
<td>Large-scale Renewable Energy Target</td>
</tr>
<tr>
<td>MRET</td>
<td>Mandatory Renewable Energy Target</td>
</tr>
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<td>NEM</td>
<td>National Electricity Market</td>
</tr>
<tr>
<td>ORER</td>
<td>Office of Renewable Energy Regulator</td>
</tr>
<tr>
<td>PV</td>
<td>Photovoltaic</td>
</tr>
<tr>
<td>RET</td>
<td>Renewable Energy Target</td>
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<tr>
<td>RPP</td>
<td>Renewable Power Percentage</td>
</tr>
<tr>
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</tr>
<tr>
<td>STEM</td>
<td>Short Term Energy Market</td>
</tr>
<tr>
<td>SWIS</td>
<td>South West Interconnected System</td>
</tr>
<tr>
<td>WA</td>
<td>Western Australia/ Western Australian</td>
</tr>
<tr>
<td>WEM</td>
<td>Wholesale Electricity Market</td>
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1. Introduction

The South West Interconnected System (SWIS) generates most of its electricity from fossil fuels. Renewable energy accounted for only 5% of the total generation. Currently, the electricity generation from renewable energy sources on the SWIS has little prospects as it faces many challenges and barriers. Lack of political will, market forces, lobby groups and technical limitations of the grid represent the main barriers for renewable energy. They are greatly emphasized in the case of medium-scale renewable energy facilities. Large-scale facilities are a preferred option, if renewable energy is considered, because they generate greater incomes. Therefore, the long battle of overcoming the SWIS barriers to renewable energy is more justified. However, mid-scale renewable energy facilities would be an advantage for the characteristics of the grid. The area covered by the SWIS is rich in readily available renewable energy sources. The connection of mid-scale renewable energy to the SWIS can help in providing long-term sustainable and fuel cost free energy to many towns around the SWIS. In addition, as the SWIS is an island grid (no connected to the main grid) and fairly small, a diverse energy mix could assure energy security. The state of Western Australia could greatly benefit from becoming a pioneer in renewable energy and maintaining its status quo of world’s leader in the energy sector and securing its energy independence in the future.

This dissertation will attempt to highlight the problems and prospects of connecting medium size renewable energy facilities to the SWIS. In order to understand the barriers, it is essential to be familiar with the current situation of the SWIS in regards to its energy production, as well as its market structure and the energy policy that influence the generation of electricity. Once the context is set, a detailed analysis of the barriers to the connection of mid-size renewable energy facilities to the SWIS can be undergone. The barriers are investigated at different levels including economic, political, social and technical factors. Following that, a brief international case study of the leading countries in renewable energy, China and the USA, will help identifying the factors that can bring
down barriers to renewable energy and enhance its development. Then, the prospects for renewable energy on the SWIS for medium size facilities are highlighted. Finally, a summary of the findings as well as some recommendations are discussed at the end of the dissertation.
2. Presentation of the study

2.1. The need for renewable energy and sustainable living

WA relies on fossil fuels for its energy needs. Mainly coal and gas are used for electricity production while oil is used for transportation and other energy requirements (Environmental Protection Authority 2007). It seems as if WA is not as concerned as it should be in regards to the status of its energy consumption mainly due to the abundance of available resources in fossil fuels. These resources may be plentiful at present; however, they are exhaustible. Moreover, they are certainly not providing the energy security and independence needed for present and future growth of WA. That is to say that in the case where fossil fuels would be running low or exhausted, it is unlikely that WA would find itself capable in dealing with its energy demands given the current nature of its energy sector. WA has faced with the scarcity of these resources in the past, where the consequence was severe for the economy. For example, the gas crisis of 2008, where an explosion occurred at the Alinta gas plant of the Varanus Island, one third of the WA gas supply was cut and forced part of the industry, including the booming mining industry to shut down or run at low production (Medlen 2011) (Megalogenis and Tasker 2008). Such event present risks for both the state and the nation’s economy, where in addition to the consequences mentioned above, prices rose significantly and electricity production was not secure, as at the time, no energy reserve existed to fill the gas caused by the explosion. When some policy makers are in charge in 2008, WA premier Alan Carpenter and Energy Minister Francis Logan were interviewed by reporter Claire Moodie on ABC on the 20th June 2008 along with a couple of academics and industrials. All of them agreed on the importance to have a diverse energy mix to avoid this kind of
situation from happening (Carpenter, et al. 2008). However, none mentioned renewable energy. The gas crisis of 2008 and future fossil fuels shortage emphasize the need for energy security and independence and should have acted as a warning sign of what the future may look like if no action is taken. Renewable energy can provide security and independence sought by the entire world at this time of energy instability and insecurity, where energy dependence created high risks for a country’s prosperity and international relations. WA is lucky enough to not be as energy dependant as other regions such as Europe or the North America. However, while China and the USA are growing strongly and rapidly in manufacturing and innovation of clean technology respectively, WA remains comfortable in enjoying the few years they have left of energy security through their fossil fuels resources. The questions to be asked are:

- Does Australia want to be dependent on countries like China in the near future to fulfil their energy needs once fossil fuels is depleted?
- Is it not time for the Australian government to actively seek sustainable solutions and hence become one of the future leaders in terms of renewable energy?
- Should WA, blessed with large and inexhaustible renewable energy sources, not start taking the steps towards a secure and independent energy future?

The answers to these questions seems obvious to me and hopefully to you too. However, Australia and WA are not working efficiently or rapidly towards the goal in energy security and independence through the use of renewable energy. Australia may become dependent on pioneers of clean energy countries like China.
2.2. Scope and aim of the study

This study encompasses the barriers and drivers for the development of renewable energy facilities on the SWIS with a generating capacity between 1 to 30MW. The study aims to answer the following questions:

- In a time where the world’s political agenda and technological innovations are turned towards clean energy, why does the SWIS energy mix is still dominated by fossil fuels with little prospects of increasing renewable energy in the near future and in the coming decades?

- Why is it that so little prospects is conceivable for a high penetration of renewable energy in the SWIS energy mix in the near future, despite the excellent renewable energy resources and land availability to exploit those resources in WA?

- What sort of issues are the SWIS facing in regards to the connection of mid-size renewable energy facilities?

- What are the possible solutions to these issues?

- What are the potentials for mid-size renewable energy in the SWIS energy mix?

2.2.1. Medium-scale renewable energy power generation

Often in the literature, among government bodies and inside the industry and market, renewable energy power generation is considered at two levels, small and large scales. Small scale is often defined as a system of less than 1 MW and is limited to domestic and small community and refers to PV solar system, hot water
system or small-scale wind and hydro energy. Large is often categorized as more than 30MW, frequently aiming for a 3 digit system and is considered to be a power station with no limitations regarding its type of energy sources (Premier Solar 2011). In this dissertation, I attempted to focus on medium-scale renewable energy plants, which for the purpose of this study would be rated between 1 to 30 MW with no regards to the type of renewable energy sources used. Such size system presents various advantages in regards to the particular case of the SWIS. First of all, developing medium-scale renewable energy power generation for the SWIS would offer a unique, strong, diverse and stable generation mix that would be valuable for the characteristics of the SWIS and answer to future demands as well as solving some of the current technical issues (Gates and Wilkes 2010). In addition, the diversification of the energy mix of the SWIS through mid-size renewable energy facilities would allow more distribution along the network, answering to the need for localized energy demand and weaknesses of the grid. In relation to this last point, it would permit a smoother integration of electricity produced from renewable energy into the grid and reduce the risk of major drop out as it would be the case with large scale renewable energy power generation facilities using resources such as wind or sun. At the same time, such size systems are big enough to provide full electricity or most electricity to large town. For example, the Albany wind farm can provide up to 60% of the town’s needs in electricity. Moreover, medium scale facilities can help meeting the load by providing over the long-term secure and fuel costs free energy. Finally, it would allow the creation of a new dynamic in the energy market, encouraging competition and slowly replaces the current unsustainable and expensive fossil fuel market. However, it is essential to note that to date, such size renewable energy facilities are disadvantaged as to their capital costs, general transmission,
distribution costs and returns. Mid-size renewable energy facilities proportionally cost as much as large-scale renewable energy facilities with less return. In addition, transmission and distribution costs would be essentially the same for any size of renewable energy facilities on the SWIS at the moment. These two factors, and among others, tend to discourage the development of medium-scale renewable energy to large-scale system, if renewable energy is envisaged. The potential drivers to overcome this major economic factor were taken into account and the great benefits that SWIS would profit from the development of mid-size renewable energy facilities in its energy mix was highlighted in this dissertation.

2.2.2. Deliberate exclusions in the study

This study considers the potential and barriers to the development of mid-size renewable energy facilities on the SWIS. Hence large-scale, small and domestic scale grid-connected facilities and systems, their barriers, drivers or characteristics have been excluded of this study because they are not the focus of this dissertation. Similarly, small-scale systems connected to the grid are not addressed in this dissertation. That means that solar energy, which represents 3% of the renewable energy of the SWIS is not studied as mainly comes from home or community owned small PV systems (Office of Energy 2011).

2.3. Method

This dissertation is a desktop study, involving a large and broad literature review. It is placed in the current context of the renewable energy situation of the SWIS and WA. The research is drawn from current situations and past experiences from various factors involved in the running and shaping of the renewable energy
sector. The literature review consists of reports, articles and other reviews from the following sources and for the following goals:

- The analysis of the present policies and energy agenda, but also of the possible future of the energy policy of Australia and the state of WA; the sources used include the Federal Government, the WA Government and their various bodies such as the Australian Energy Regulator, The Office of the Renewable Energy Regulator, the Department of Climate Change and Energy Efficiency or the WA Office of Energy;

- The investigation of the roles, actions and prospects of the players and industries involved in SWIS. Such players and industries involve Verve Energy, Western Power or the Independent Power Producers (IPPs).

- The review of reports from independent organizations such as Sustainable Energy Association (SEA) or Engineers Australia to understand the barriers and prospects of the renewable energy market for the SWIS;

- And finally the study of various articles and reports from diverse sources such as academics or journalists for broadening the different views and opinions regarding the generation of electricity from renewable energy sources.

3. Setting the context: electricity, renewable energy and the SWIS today

3.1. The South-West Interconnected System

3.1.1. An introduction to the SWIS

The SWIS is the main electrical network of Western Australia, providing electricity to almost a million customers in the Perth metropolitan area and
extending from Geraldton at the North of Perth, Albany at the South of Perth and stretching to Kalgoorlie-Boulder at the East of Perth (Perth Energy 2010). In 2009, the SWIS has an installed capacity generation of 5134 MW (Australian Energy Regulator 2009). Figure 1 is a map of Western Australia where the SWIS is located in the region highlighted in yellow.

The SWIS has a hierarchal structure that ensures the generation, transmission and distribution of electricity along its network. On the top of the pyramid is the Independent Market Operator (IMO), which set strict and inflexible market rules and guarantees the energy quality and security of the SWIS through various means (IMO 2006). Then, there are three major companies, formally known as a single identity, Western Power Corporation that was then responsible for the generation, transmission, distribution and retail of electricity on the SWIS (Perth Energy 2010). Nowadays, these three processes are carried out by three distinct companies. Verve Energy generates electricity through various energy sources. Western Power ensures the transmission and distribution of the electricity. Lastly, Synergy is responsible for the retail of electricity (Western Power 2011). In 2010, Verve Energy provided over 60% of all the electricity in the SWIS by generating 2967 MW and selling 90% of the electricity produced to Synergy (Verve Energy 2010). Finally, there are different smaller actors, the IPPs, which also generate and supply a certain amount of electricity into the SWIS, providing some sort of market competition and increasing private investment. Those actors vary in capacity and include the following groups: Alinta, ERM Power Ltd, Griffin Energy, Landfill Gas and Power Pty Ltd; Perth Energy, TransAtla, Wesfarmers Premier Power Sales Pty Ltd and Worsley Alumina Ltd (Office of Energy 2011).
In 2010, a little less than 40% of the electricity capacity of the SWIS was produced by the IPPs (Western Power 2011).

The SWIS is known for having a few weaknesses. The grid is weak towards the end of its network, when frequency stability and security of supply can be difficult. The grid has limited capacity and would be expensive to upgrade. This is mainly an issue for the connection of intermittent power plants that demands greater frequency control and strong network than fossil fuel plants.
Figure 1 Western Australia Energy Resources and Infrastructure, September 2010

(Office of Energy 2010)
3.1.2. Electricity production for the SWIS

Energy resource allocation

In WA, the total production of electricity from renewable energy accounts for 3.1% in 2008-2009. For the SWIS, it was estimated at about 5% (Office of Energy 2010). In 2009-2010, there was a decrease of this production and renewable energy was accounted for 2.9% of the total production for the state (Office of Energy 2011). This means that although the electricity production increased to match a growing demand, the share of renewable energy was the same. These figures include small scale grid connected systems, such as PV systems from household, where the power is consumed on the spot. The amount of renewable energy consumption is of 755 GWh from a total of 15,113 GWh (Office of Energy 2010). Most of the electricity from renewable energy is produced by 18 facilities, which are mainly powered by landfill gas and wind (Office of Energy 2010). As the data suggests, the production of electricity from renewable energy for the SWIS is fairly small and not constant, and the use of coal and gas dominates the rest of the electricity generation. Figure 2 represent the different energy sources used to produce electricity on the SWIS and the distinctively small share of renewable energy. Figure 3 shows a more detailed repartition of the energy resources used on the SWIS, and again shows the major use of fossil fuels in the SWIS energy mix. DSM stands for Demand Side Management and will be discussed in Section 3.
Figure 2 Installed Capacity of the SWIS by energy resources as in 2009

(Waters 2009)

Figure 3 Distribution of energy sources for the SWIS installed generation capacity

(The Australian Energy Market Commission 2009)
Load profile of the SWIS and the Independent Market Operator (IMO)

The load profile of the SWIS is characterized by its diurnal and seasonal variations with high load peak during summer and winter, and very low peak at night (ESAA 2009). Figure 4 represents the typical summer day on the SWIS. The peak demand increases constantly during the day until 5 to 6pm, where it reaches its maximum point, which then started to decrease and disappears at 8pm. This peak demand is clearly marked by the use of air-conditioning during summer days. The typical winter load has a different shape on the peak demand, where there is a use of more electricity, characterized by the use of heating systems, in the morning from 7am to 10am and at night from 5pm to 10 pm, as it can be seen in Figure 5. In addition to the peak and off peak characteristics, the SWIS must answer to general load (Waters 2009).
Figure 4 Typical SWIS summer load profile

(Waters 2009)

Figure 5 Typical SWIS winter load profile

(Waters 2009)
Due the great distances between the SWIS and the national grid, it is highly unlikely that the SWIS and the national grid will be connected in the future; therefore the SWIS is treated independently from the National Electricity Market (NEM) and hence follows special regulations set by the IMO (Landfill Gas & Power Pty Ltd 2008). The Wholesale Electricity Market (WEM) has been specifically designed to ensure a fair, safe and reliable electricity supply to the consumers of the SWIS and has been running since the 21st September 2006 (IMO 2006).

Answering to the SWIS load profile requires careful planning and coordination. The SWIS has three levels of power generation plants: baseload, mid-merit load and peaking load plants. The baseload of the SWIS is mainly provided by coal plants with some additional support from gas-fired power plants (IMO 2006). These plants are economically justified by the government and the WEM by the nature of the SWIS load. Baseload power plants have a high initial cost but are relatively cheap to run as per unit produced as they run most of the time. Mid-merit plants help filling the gap between baseload generation and peak load generation. They are usually coal-fired or gas plants, and as their name suggest, are in between baseload and peak plants for costs and performance. Peak load power plants, on the contrary, have a low initial cost but are relatively expensive to run. They are usually economically justified by the fact that they are supposed to run only a limited time to meet the peak load. On the SWIS most of the peak plants are gas and/or liquid generators (Went, Newman and James 2008). A very small percentage of renewable energy generation is also available and is integrated according their allocated capacity credits (discussed further down). In
addition to those, there are a number of schemes in place to ensure the security of supply of the SWIS (IMO 2006).

The Frequency Control Ancillary Services (FCAS) of the IMO, FCAS, ensures the stability, security and extra-generation of the grid. The FCAS are compulsory components of the energy mix of the SWIS but are not traded in the energy market. The FCAS are a set of components with various purposes (The Australian Energy Market Commission 2009). First of all, the Spinning Reserve provided by two main sources: a generating plant that runs at half capacity and a set numbers of consumers that can be instantly cut off from the SWIS in order to provide the necessary Spinning Reserve (IMO 2011). Secondly, the Frequency Control helps in the stability of supply according to the demand and ensures a constant supply of 240V at 50Hz (Went, Newman and James 2008). Then, there is the Reserve Capacity Mechanism. It consists of securing generation capacity from the retailers to ensure the load is met at its highest peak point (IMO 2011). There are three levels of reserve margin. The first share of the reserve margin must cover either 8.2% of the generation capacity or the potential drop out of the largest generation unit. The second share is designed to deliver power frequency stability during peak time (IMO 2011). Finally the last share of the reserve margin ensures the possible coverage in case of drop out of intermittent loads where the generators are located at the same site. Demand side management or DSM is also a method used on the SWIS to control generation capacity. In this case, electricity consumption is targeted where the consumers are encouraged to reduce their electricity used. However, this method is very expensive and has no guarantee of working due to behavioral change. Changing people’s behaviour is a long and costly process. DSM on the SWIS will only be used when very high peaks are
reached because it will be cheaper to run a peak generator to meet the load rather than expecting the consumers to reduce their consumption (IMO 2006).

**Renewable Energy on the SWIS**

As we have seen earlier, the production of electricity from renewable energy is small on the SWIS. There are a total of 17 renewable energy facilities connected to the grid, as listed in Table 1. Most of the facilities are landfill gas. However, wind energy represents the biggest portion of the renewable energy distribution on the network, with 79% of the total renewable energy generation generated from 5 facilities. (Clark 2011). Biomass represents 18% of this distribution with a total of 11 facilities. Hydro has a very minimal amount of this share with the one facility of 0.13MW. Finally solar energy has no generating facilities on the SWIS but represents 3% of the renewable energy distribution. This is mainly due to the multiple solar systems, mainly in households, connected to the grid. Table 6 shows the distribution of each renewable energy resources on the grid.
<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Capacity (MW)</th>
<th>Suppliers</th>
<th>Location</th>
<th>Year commissioned</th>
</tr>
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<tr>
<td>Landfill gas</td>
<td>2.65</td>
<td>Landfill Gas and Power Pty Ltd</td>
<td>Red Hill</td>
<td>1993</td>
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<td>2.6</td>
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<td>Canningvale</td>
<td>1995</td>
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<td>Landfill gas</td>
<td>0.6</td>
<td>Landfill Gas and Power Pty Ltd</td>
<td>Kalamunda</td>
<td>1996</td>
</tr>
<tr>
<td>Sewage Gas</td>
<td>1.8</td>
<td>Water Corporation</td>
<td>Woodman Point</td>
<td>1998</td>
</tr>
<tr>
<td>Wind</td>
<td>21.6</td>
<td>Verve Energy</td>
<td>Albany</td>
<td>2001</td>
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<td>1.7</td>
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<td>Rockingham</td>
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<td>Gosneils</td>
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<td>2004</td>
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<tr>
<td>Wind</td>
<td>0.66</td>
<td>Verve Energy</td>
<td>Bremer Bay</td>
<td>2004</td>
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<tr>
<td>Landfill gas</td>
<td>1.1</td>
<td>Landfill Management Services</td>
<td>Noranda (Atlas)</td>
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<td>Landfill gas</td>
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<td>Landfill Management Services</td>
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<td>Walkaway</td>
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<td>80</td>
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<td>Emu Downs Wind Farm</td>
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<td>Hydro</td>
<td>0.13</td>
<td>South West Development Commission</td>
<td>Pemberton</td>
<td>2006</td>
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<td>Mount Herron Engineering</td>
<td>Mandurah</td>
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<tr>
<td>Wind</td>
<td>1.6</td>
<td>Verve Energy</td>
<td>Kalbarri</td>
<td>2008</td>
</tr>
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</table>

Table 1 Renewable energy facilities connected to the SWIS

(Office of Energy n.d.)
3.2. Producing and distributing electricity of the SWIS: The SWIS market rules

This section intends to describe the principals of the energy market of the SWIS in order to understand the barriers to renewable energy. The structure of the market is very complex and the elements mentioned in the following paragraph reflect only the general structure of the market. For further details, please refer to the IMO website (www.imowa.com.au).

As mentioned above, the IMO is responsible for the energy market of the SWIS and sets its rules through the WEM. The rules are designed for generators directly connected to the SWIS regardless of their size. In this study, the entities responsible for the monitoring of the WEM were deliberately omitted as they were irrelevant to the problem. The WEM rules are strict and inflexible. They represent many constraints for the energy industry but are designed to ensure the
energy security of the SWIS at 99.9%. To achieve this goal, the IMO applies a scheduled generation policy, where the electricity generation of the SWIS included the FCAS and other measures to ensure the energy security of supply to the grid are planned in advance. The WEM contains two main components (IMO 2011). The first one is the trading component. On a day to day basis and through the Short Term Energy Market (STEM), generators and retailers trade electricity through a bilateral agreement. The IPPs (and hence excluding Verve Energy) informs the IMO on the amount of electricity they intend to produce everyday while retailers buy this electricity, both actions are done according to the expected consumption will be on a daily basis (IMO 2011) (The Australian Energy Market Commission 2009). The System Management, which is operating the STEM, assures the frequency stability through a constant match between the supply and the demand. It is the balancing mechanism, which means that it connects or disconnects plants according to the need of the grid. “In deciding which balancing actions to take, System Management uses a dispatch merit order, which at a high level is ordered:

1. Verve Energy non-liquid plant;
2. Independent non-liquid plant;
3. Verve Energy liquid plant;

Liquid plant is defined as plants using fossil fuels (The Australian Energy Market Commission 2009). Non-liquid plant therefore refers to any other types of plants, including renewable energy plants. While the STEM usually occurs the day before, the balancing mechanism functions in real time (IMO 2006).
The second component of the NEM is the Reserve Capacity Mechanism, which is the long-term planning of the electricity generation of the SWIS. To ensure the stability and security of energy supply, the IMO plans ahead the production of electricity. This incorporates both, the capacity to meet the actual loads of the SWIS and the FCAS and any other capacity surplus for energy security. This is mainly achieved through the capacity credit schemes, where the IMO produces capacity credits to the generators and the DSM that obligates them to have available electricity capacity for both the STEM and the reserve capacity (e.g. FCAS) (IMO 2006).

3.3. Connecting renewable energy to the SWIS

3.3.1. Renewable energy policy in Australia and WA
The federal government has several policies to tackle climate change. The Carbon Pollution Reduction Scheme (CPRS), that included the newly amended Carbon price, has for main objectives to reduce carbon emission in the energy sector. This policy will not be discussed in details in this paper as the policy concerned mainly electricity generation from high carbon emissions technology (fossil fuels). For the SWIS, the CPRS is not likely to influence much the energy mix of the grid. One of the possible consequences however of this policy is that gas supply for baseload or peak load is not likely to increase because of the relatively high price of the gas; adding to the CPRS, this energy source becomes very expensive (The Australian Energy Market Commission 2009). However, that does not mean that the use of gas for the electricity production of the SWIS would be reduced. On the contrary, the Mandatory Renewable Energy Target, newly expanded to the Renewable Energy Target (RET) of the Australian Government
does and will influence the energy mix and energy market of the SWIS. The RET aims that 20% of Australia’s electricity is delivered by renewable energy by 2020 (Australian Government, 2011). RET is divided into two parts, the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES) (ORER 2011). SRES concerns only on “correctly installed eligible solar water heaters, heat pumps, and small-scale solar panels, wind and hydro systems” (ORER 2011). The LRET deals with power stations and requires a certain amount above their baseline electricity production to come from renewable resources (ORER 2011). The LRET’s yearly targets are set at 4,000 GWh to reach 41,000GWh by 2020 (Australian Government: Department of Climate Change and Energy Efficiency 2011). Both parts of the RET have a certificate system, where each certificate is the equivalent of 1MWh produced from an eligible renewable energy sources (Parliament of Australia 2010). For the purpose of this study, we are concerned only on LRET. The LRET requires electricity retailers to purchase renewable energy certificates, distributed by eligible renewable energy facilities above their baseline in order to meet the Renewable Power Percentage (RPP). The RPP is the rate of liability for each certificate and is established every year by the Office of the Renewable Regulator (ORER). Penalties apply if a retailer fails to comply. Hence the LRET is an incentive for the production of electricity from renewable energy through both a financial encouragements for renewable energy facilities. This is because the scheme ensures part of their production are to be sold and distributed, and also through lawful and official obligations for electricity producers and retailers to purchase a certain amount of renewable energy to meet the RPP (Biofuels Association of Australia 2010) (Premier Solar 2011) (ORER 2011).
In addition to the national energy policy, the WA government has a few incentives to help increase the share of renewable energy in the energy mix. Such incentives include the Low Energy Emissions Development Fund, which provides financial aid for technologies which reduces greenhouse gas emissions or have low emissions (Department of Environment and Conservation 2012). Since the start of the program, more than $20 million have been allocated to projects as diverse as renewable energy power station (e.g. wave energy) and geothermal cooling system (Office of Energy 2012). However, no specific targets or policy surrounds this fund. Currently, the WA government is working on a new policy strategy, baptized “The Strategic Energy Initiative, Energy 2031” that aims towards the development of “secure, reliable, competitive and cleaner energy” (Office of Energy 2011). This initiative should be finalized in 2012 and put into practice in the following years (Office of Energy 2011).

3.3.2. Renewable energy production and the IMO

Renewable energy generation mostly follow the same market rules as traditional generation. The IMO declares understanding the intermittent nature of renewable energy and does not force these generators into the strict planned schedule of the SWIS. Instead, renewable generators must buy capacity credits according to their expected output. The IMO claims to have designed the market rules in order to facilitate the integration of renewable energy on the SWIS. The STEM theoretically allows renewable energy generators to:

- “Sell their output to the market while they build up their customer base”.
- “Purchase additional energy as their customer demand increases”.
- “Cover any temporary supply shortages”. (IMO 2011)
In addition, the balancing mechanism may allow renewable energy generators to be connected when producing output and meet part of the load. This means that renewable energy generators can be connected to the grid when capacity is available and regardless whether or not the generators were scheduled to be connected. Moreover, the IMO states that the Reserve Capacity Mechanism:

- “Places significant value on the capacity provided by both demand management and generators.
- Recognises the contribution towards overall system reliability that is made by intermittent renewable generators.
- Allows demand side management to make a substantial contribution to the spinning reserve requirement.” (IMO 2006).

Finally, it is important to point out that Verve Energy has been limited to a total capacity of 3000MW by the government, with the exception of renewable energy generation (Perth Energy 2010).

3.4. **A note on the WA economy**

The WA economy is one of the strongest in Australia. It enjoys prosperity, low unemployment, abundance of resources and it is forecasted to continue a healthy growth in the coming years (Commonwealth Bank 2011). The strongest industries in the state are the mining industry and its related services, the oil and gas industry and the engineering and construction industry (especially in relation to the mining; and the oil and gas industries) (Commonwealth Bank 2011). It is clear that the WA economy is mainly based on the resource sector. Hence WA is faced with crucial decisions in regards to its energy future to keep powering its growth. However, the state does not have to choose between economic prosperity and
unsustainable development. Renewable energy offers the possibility to power the
main industries and replace the oil and gas industries while maintaining WA
status quo as a leader in the energy sector. This could only be achieved if WA
switches its focus from fossils fuels to renewable energy.

- This section brings into context of understanding the issues that arise in
  regards to connecting renewable energy facilities to the SWIS.

4. Understand the barriers to the development of mid-size
renewable energy facilities in the energy mix of the SWIS

4.1. The limitations of the WA energy market

Some claim that the introduction of the WEM in 2005 facilitated market
competition and helped the boom of renewable energy on the SWIS since the
implementation of the new market rules. In reality, the results were quite limited.
(WA Sustainable Energy Association, HAC Consulting and Future Smart
Strategies 2010). If the market rules did allow a small increase in market
competition and facilitated the connection of new generation plants from IPPs,
they probably will not much help in meeting the national targets by 2020. These
rules and the WA energy market in general still stand in the way of renewable
energy. The market competition is weak, limiting the possibilities for mid-size
renewable energy facilities. In addition to that, mid-size renewable energy would
have to face the same connections and distribution charges as large-scale facilities
with high capital costs and less return proportionally (Western Power 2006). That
is to say, in addition to the higher capital costs, and hence higher generation price
than fossil fuels, renewable energy facilities still have to bear with the full price of the connection and distribution of their electricity on the SWIS. In addition, the RET is unsuccessful in matching the price of renewable energy electricity production to the one of fossil fuel. It also seems unlikely that such costs are reduced in the future as no market competition exists. Western Power is the only entity to manage the connection and transmission of electricity (Moran 2004).

Furthermore, the balancing system of the WEM, if plants need to be disconnected, it would first go with the Verve Energy’s renewable energy power plants followed by the IPPs ones before eventually considering being disconnected from a coal or gas plant (which would be very unlikely) (The Australian Energy Market Commission 2009).

Moreover, both the structure of the SWIS and the market themselves are limiting renewable energy in the energy mix. The huge amount of extra capacity needed (e.g. FCAS) constantly to ensures the security of supply and frequency of the SWIS maintains the need for coal and gas generation. Adding to that, the baseload and peak load systems encourages the supply of electricity by coal and gas, for reasons mentioned in section 3.2.2.2.

To conclude, all these factors limit industry players that could enlarge the renewable energy markets on the SWIS. Developing renewable energy on the SWIS is made difficult because the energy market at this stage is not competitive for renewable energy and enhances the price of electricity produce from renewable energy sources. Overall, the market fails to address essential services to the society by proving itself inefficient in the production of renewable energy power and by being rather conservative of traditional generation.
4.2. The weakness of the renewable energy policy

Section 3.5.1 has highlighted the current policy situation in Australia and WA. As observed, the national policy is limited to two main policies and the WA state does not have to date its own policy and follows the national guidelines through a few initiatives. Climate change has been on the national policy since 1989, 10 years after the first World Climate Conference in Geneva, when the government started to look at possible carbon emissions reduction policies and schemes (Staples 2009). More than 20 years later, however, not much progress has been achieved in developing policies and reducing carbon emissions while politicians still act as if climate change and the need for a sustainable future is a new discovery on the agenda (Staples 2009). The national energy policy helps in the development of renewable energy electricity generation in Australia to a certain extent. The policy framework of the RET encourages renewable energy development indirectly, by requiring power producers to purchase some electricity generated by renewable energy and matching the price with theirs. Nevertheless, a lack of specific targets for each state may create a heterogenic development of renewable energy in the country. In addition, the certificate scheme, which has a definite number of certificates that can be issued, may limit the potential for the development of renewable energy as the target is likely to be met in majority through the SRES, which does not included renewable energy power stations (Parkinson 2011). For the state of WA, the lack of specific targets has great chances to minimize the potential for renewable energy on its grids. In WA, given the current state of renewable energy facilities, it seems unlikely that all the required certificates that have to be bought from the SWIS traditional
power plants come from WA renewable energy facilities. If this is the case, the purpose of the RET is defeated because renewable energy in WA will not likely increase. The last issue with the RET is that it does not promote the development and commercialization of renewable energy as a whole. That is to say that most certificates would most probably be fulfilled by wind and hydro energy, both mature technologies. It does not encourage the use and development of other renewable sources and helping maturing other technologies as well as reducing their costs. Moreover, both wind and hydro power present its limits if not integrated in a diverse energy mix. Wind energy requires high level of monitoring due to wind fluctuations whilst hydro power has its consequential environmental impacts (Manning 2011).

In addition, the lack of consistency in energy policy greatly reduces opportunities for renewable energy and blocking the blossom of a renewable energy market for the SWIS. Such weaknesses in policy tend to make renewable energy more expensive and perceived as a dangerous investment by the industry (WA Sustainable Energy Association, HAC Consulting and Future Smart Strategies 2010). The WA is more concerned about its economic prosperity and energy security than its sustainable future, and seems incapable of reconciling the three of them. While energy needs still increase, renewable energy production seems stagnant. Figure 7 shows the consumption of renewable energy on the SWIS since the beginning of the WEM. Renewable energy consumption increases from 1% in 2004/2005 to 5.4% in 2006/2007 but has kept decreasing since then. The actual amount of renewable energy on the SWIS remains the same as 2006/2007. This graph means that the energy production on the SWIS has increased, but that the part of renewable energy has been steady in 2006/2007. Longer data records are
needed before analysing the potential success of the WEM in facilitating renewable energy production. However, it is clear that traditional sources are still preferred for meeting the needs of the SWIS.

![Consumption of Renewable Energy on WA’s largest grid since 2004/05](image)

**Figure 7 Consumption of renewable energy on the SWIS since 2004/2005**

(Office of Energy 2010)

In regards to the CPRS policy and new carbon price, the policy also presents weaknesses that are likely to limit the development of renewable energy and have more disastrous consequences for the environment. This policy does not promote renewable energy as a solution to carbon reduction, it encourages the innovation and large-scale production of technology that enables fossil fuels to emit less greenhouse gas. Hence, if such technology (e.g. Carbon Capture and Sequestration (CCS)) comes to maturity, electricity from fossil fuels is likely to increase continually.
Finally, in the case of the SWIS, which is an islanded and relatively small grid, there is no special aid or policy regarding to the development of mid-size renewable energy. Despite the fact that a greater variety of energy facilities on the SWIS could be both economically and environmentally beneficial, given the current policies, larger-scale renewable energy facilities are more liable to prosper; with wind energy continues to be the dominating renewable energy source, as we will see in Section 6.

In conclusion, the current national and state policies in regards to renewable energy have some positive outcomes on the development of renewable energy and reduction of greenhouse gases. However, it is clear that they greatly limit the full potential of the renewable energy sector by dressing unwanted barriers and somehow indirectly encouraging traditional electricity generation to keep growing.

4.3. The power of lobby groups

One of the strongest barriers to renewable energy nowadays is probably the power lobby groups can have on the WA energy market and on clean energy policies. In WA, the fossil fuels and mining industries are the pioneers of the strong growing WA economy, as the state is a global leader in these two sectors (The Chamber of Mineral and Energy n.d.). Obviously opposed to the idea of renewable energy, lobby groups, such as the Australian Petroleum Production and Exploration Association (APPEA) prefer the development of cleaner technology such as CCS technology or Coal Seam Gas (APPEA 2012). In addition, the APPEA had strongly engaged against the Australian government to make natural gas classified as a clean energy under the RET (APPEA 2009). These lobby groups tend to argue that renewable energy is not capable of providing the security of supply of
the baseload or the peak load when needed, due to its intermittency. In addition, they claim that their unreliability reduces the frequency stability of the grid and generates extra costs for little benefits. These lobby groups are directly and indirectly encouraged by the economy nature of the state, which greatly benefits from the fossil fuels industry. Of course, they are rarely open about opposing the use of renewable energy. Rather, they hide themselves behind claims of wanting to protect the environment and the economy through the use of cleaner technology. For example, anti-wind farms lobby groups, such as the Institute of Public Affairs or the Australian Environmental Foundation accused wind farm to have too many socio-economic and environmental hazards (Chapman 2011). Lobby groups can take up different forms, from individuals from various backgrounds (e.g. private, politicians, industrials, etc.) to whole organizations (Chapman 2011). Although anti-renewable energy lobby groups are quite numerous and active, it is definitely the fossil fuels lobby groups that have the most influence in the case of the SWIS.

4.4. Technical difficulties of the grid

The SWIS faces issues regarding the connection of renewable energy. The connection of mid-scale renewable energy facilities presents a problem regarding the capacity of the SWIS to integrate various inputs that are likely to fluctuate during the day, affecting the security of supply for baseload and peak load (Gates and Wilkes 2010). In addition, renewable energy facilities are often located away from transmission and distribution lines as well as centres of consumptions. Developing such lines, often located at the extremity of the grid where the renewable energy sources are most available, are expensive especially with the
4.5. Tradition versus modernity

Behavioural and mentality change is a difficult challenge for our society. The development of renewable energy is constraint by its lack of acceptance by society (this includes governments, industries and people). In the case of WA where the economy and high standard of living relies their wealth from the mining and fossil energy sector, it seems obvious that switching to renewable energy and sustainable living seem overwhelming, risky and scary in whole.

- It is clear from this analysis that the barriers blocking most of the development of renewable energy in the SWIS energy mix is heavily drawn from political and economic issues. That is to say that if the technical barriers were to be solved, a strong intervention by the government would be necessary through specific policies would be necessary to achieve a more liberal market (Wan and Parsons 1993).

5. International case studies: mid-size renewable energy facilities connected to grids in Germany, China and the USA.

Different countries have different approach to renewable energy. While some countries actively developed the renewable energy industries through active
policy or strong market structure, others are relatively slow in the switch to alternative energy. We will have a look at the case of China and the US, which seem to be competing in a green race to be the leader in this developing industry.

5.1. China

The People’s Republic of China is a communist country where the government apply a five-year plan system to most of its political and economic affairs. In 2010, China was ranked first energy consumer of the world, making history by surpassing the United States. For the same year, China ranked second in grid-connected renewable energy facilities and first in wind power. China, as for WA, enjoys a large range of abundant renewable energy resources. However, the country faces the challenge of making the best use of this energy, which is mostly located away from the big centres of energy consumption.

5.1.1. China’s renewable energy policy and market context

China’s renewable energy policy plays a major role in the continually increasing renewable energy market of the country. The Chinese government has long understood the importance of available and cheap energy to power its growth. As China is the manufacturer of the world, it was clear that the country will sooner or later outgrow the United States in term of energy consumption. Accordingly, the government increases its priority in energy production since 2004 in its strategic five year plans, with an emphasis on renewable energy. In order to help the renewable energy industry to achieve the set targets, a Renewable Energy Law is enforced. The purpose of the law is “to promote the development and utilization
of renewable energy, improve the energy structure, diversify energy supplies, safeguard energy security, protect the environment, and realize the sustainable development of the economy and society” (The People's Republic of China 2009). This law was designed as an incentive for industry to develop renewable energy as market barriers are removed by the government whilst penalties are applied when targeted industries fails to comply to the law and meet the set targets. China’s government is therefore strongly involved in the energy market. It dictates the rules and interferes to prevent market failure in the renewable energy field. In addition, it ensures that the industry meets its renewable energy targets through a strong and dictatorial leadership.

5.1.2. Renewable energy production

Such policy has been efficient and favourable to the growth of renewable energy for the country. During the 10th five year plan of 2005-2009, the “Total renewable power capacity in China reached 226 GW in 2009, including 197 GW of hydro, 25.8 GW of wind, 3.2 GW of biomass, and 0.4 GW of grid-connected solar PV. This total was more than one quarter of China’s total installed power capacity of 860 GW.” (Martinot and Junfeng, Renewable Energy Policy Update For China 2010). This success is especially remarkable for the wind industry, which started at just 0.8GW in 2004. Such production also enable Chinese company to ranked top 10 for the same year on the global market, as it is the case for Sinovel, Goldwind and Dongfang in the wind industry (Martinot, Renewable power for Chine: Past, present, and future 2010). Hence, the Chinese renewable energy sector is mainly based on the manufacturing part of the industry, greatly omitting research and development that could lead to innovation technology. China is
clearly the leader in renewable energy manufacturing but relies on other countries
for developing a more efficient and advanced renewable energy technologies. In
the mean time, China has been capable of mastering the technologies it
manufactures and creating a competitive market through the mass production of
such technology and the decrease in market prices.

5.2. USA

The United States share several similarities with Australia regarding its political
systems and its approach to renewable energy policy. Both countries have a
federal government, states governments and local governments. Hence, as for
Australia, the USA renewable energy policy is developed on all levels of
governments. However, the USA is one of the leading countries, alongside with
China, in regards to renewable energy. While China has become the leader in
manufacturing and mass production of renewable energy, the USA seems to be
the leader in innovation technology, despite its lack of strong renewable energy
policy.

5.2.1. USA’s renewable energy policy and market context

The USA is lacking of a clear and consistent national renewable energy policy.
Over the years, initiatives have come and go. The USA has experienced taxes,
incentives or mandatory targets but no policy have been enforced for long period
of time. This has made the USA lose its dominancy as the world’s leader in
renewable energy as the market has suffered the consequences the uncertain clean
energy policy (Martinot, Wiser and Hamrin, Renewable Energy Policies and
Markets in the United States n.d.). During the eight years of the Bush administration, the US energy policy was focus of continuing heavily subsidizing the oil industry and look at nuclear option for cleaner option (Croisier 2008). At the election of President Barrack Obama, climate change was definitely an issue his administration intended to tackle. The promises were not fulfilled. Nonetheless, some progress in energy policy was made. President Barrack Obama stated: “Now, clean energy breakthroughs will only translate into clean energy jobs if businesses know there will be a market for what they're selling” (Appleyard 2011). The energy policy of the US encourages technology innovation as the country believes in a liberal market system. The government would provide tools to encourage a strong competitive market. For example, the creation of the Advanced Research Projects Agency for Energy and the introduction of the American Recovery and Reinvestment Act provide funds to help renewable energy innovation projects. Although it is argued that the funds provided were not sufficient, they clearly show the tendency of the US to invest in its research and development (Cutt 2010).

On a different note, the lack of national policy has pushed many of the states of the USA to develop on their own renewable energy targets. Some states have preferred a mandatory approach with specific requirements and targets while other have simply established goals that they would like to achieve given a certain period of time (Center for American Progress n.d.).

5.2.2. Renewable energy production

In 2009, the share of renewable energy of the total electricity generation in the US was 10%. Excluding hydro power, this represents 53 GW of installed capacity
(US Department of Energy 2010). Wind and solar power are the dominant renewable energy sources used, followed by biomass, at the exception of hydro. Hydro power has an important share of the nation’s electricity production with 10% in 2005.

5.3. **Lessons for WA and the SWIS**

- It seems clear that the renewable energy industry has fewer chances of growing without the help from the government. Without strong and focused government policies that engage in the development and commercialization of renewable energy, the growth of the industry is most likely stopped by funding. This is because funds are influenced by market forces which favour cheaper and more profitable energy sources such as fossil fuels. At the same time, if the market is fairly liberal, an energy market can developed itself and encourage the growth of the renewable energy innovation sector. WA can learn from these two countries by strengthening its renewable energy policy that will help in the creation of the renewable energy market.

6. **WA renewable energy resources and possible scenarios for renewable energy generation on the SWIS**

6.1. **WA renewable energy resources**

As Martin Ferguson, minister for resources and energy, have stated in a recent interview: “Western Australia has some of the best renewable energy sources in
Australia ranging from solar, ocean, wind and geothermal, yet has the lowest renewable energy capacity among the states” (Office of Energy 2011). In addition to having excellent resources, the state enjoys the availability of large areas of free land to exploit those resources. The following figures show the resource capacity for different renewable energy.

6.1.1. Solar

Solar energy for the SWIS area is abundant as it can be seen in Figure 8. Solar radiation ranges from 16 to 21 MJ/m$^2$ on a daily basis. In addition to that, the area enjoys long sunshine hours, with an average of 6 to 9 hours per day. The resource is generally good around the SWIS area, with higher availability at the north of the grid. Intermittency in solar resource is not an issue as the resource is predictable. Solar energy could be used to meet daily load and peak loads if well planned in the energy mix of the SWIS.

(Australian Government, Department of the Environment, Water, Heritage and the Arts 2008)
6.1.2. Wind

The wind resource for the SWIS is excellent, with wind availability everywhere along the network with a wind speed from 6.7m/s to up to 10m/s (offshore) at 80m above ground level (Australian Government, Department of the Environment, Water, Heritage and the Arts 2008). Wind power is a mature and well developed technology that is already used on the SWIS. As for solar energy, this resource is intermittent but highly predictable. Hence, this energy could be exploited for maximum benefits for the SWIS load if carefully planned.
6.1.3. Wave

The wave resource on the cost of the SWIS is exceptional (Figure 9). “Carnegie Wave Energy estimates that there is enough wave energy along WA’s coastline between Geraldton and Bremer Bay to produce more than five times the SWIS peak electricity demand” (Sustainability Energy Now n.d.).

![Figure 9 Waver Energy sources for South West Australia](Carnegie 2011)

6.1.4. Biomass

Biomass energy is easily available as all is requires is a biogenic source. Around the SWIS such source is largely available wherever there are landfill sites or any other types of recovery centers such as abattoirs or agricultural waste. The Oil Mallee Association of Australia (Inc) estimates that: “biomass could sustainably meet up to 46% of today’s electricity consumption across the SWIS (or 93% of the additional electricity required between now and 2021)” (The Oil Mallee Assoviation of Australia (Inc) 2011).
6.1.5. Geothermal

The geothermal resource around the SWIS seems to be limited as we look at figure 10. However, the figure suggests that there is a very good geothermal resource for the Perth basin (figure 11). Such resource could be exploited for the energy needs of the Perth metropolitan area and used to provide baseload generation as the resource is constant.

Figure 10 Australia hot rock source

(Energy Research and Development Corporation 1994)
6.1.6. Hydro and tidal

Hydro energy is the most mature energy of all renewable energy, as it has a long history. In the context of the SWIS, however, this technology presents little interest due to the lack of available resource and the potential environmental impacts of the use of hydro power station (office of energy). As for tidal energy, the resource is very limited in Australia. The only potential site for a tidal power generation facility would be located in the Kimberley area which very far away from the SWIS and therefore economically unviable as transmission lines would be of unimaginable length and costs (Western Power n.d.).
6.2. Possible energy mix for the SWIS

As we have seen earlier in this paper, the SWIS enjoys a great variety of abundant renewable energy resources. In addition, we know that currently, renewable energy represents only a small amount of the energy mix of the SWIS. This section has for main objectives to establish the feasibility of a greater part of renewable energy in the energy mix of the SWIS, pushing it to a scenario where 100% of the electricity of the SWIS comes from renewable energy.

6.2.1. Is 100% renewable energy mix possible for the SWIS?

In recent years, the question whether electricity could be entirely produced from renewable energy have been raised and studied by many everywhere in the world. Most of the studies are interested to find out the technical and economic feasibility of such claim. Such studies are often the result of externalities that reinforce the lack of energy security of countries or regions of the globe. For example, Reunion Island’s energy supply is greatly dependant on imported fossil fuels has developed a scenario where the island would be energy independent by 2025 by the only use of renewable energy (DCNS, Region Reunion and ARER 2009). The Fukishima incident has been an incentive for Japan and Germany as both countries decided to phase out nuclear power completely from their energy mix and has invited governments, academics and industrials to developed scenarios where 80-100% of the electricity for these countries comes from renewable energy resources. Some studies have even analyzed the feasibility of switching the whole world’s electricity production to renewable energy. Conclusions tend to be the same in all these studies. It is definitely possible both economically and technically to meet the world’s electricity needs from
renewable energy. It will of course require a massive production of renewable energy technologies and facilities that could be achieved fairly soon. The most optimistic studies concluded that such switch is possible by 2030. However, the main barrier to such future remains the same due to the lack of will power.

In the case of Australia, several studies have concluded the positive feasibility of an energy mix 100% renewable in the coming decades. For example, the 2010 report “Beyond Zero Emissions” establish a scenario where Australia has an emission free electricity production network (Wright and Hearps 2011). This scenario has several unique points. In the report the authors proposed that this goal is achievable by 2020 though certain characteristics. The authors proposed that creating a national interconnected grid, where transmissions lines are built to connect the SWIS, the NWIS and the NEM together, and power the country mainly through the use of solar and wind energy is achievable. They argue that the use of Concentrating Solar Thermal (CST) Power and adequate storage (in this case Molten Salt storage which can supply steam on demand) could supply 60% of the national electricity need. Wind energy could provide the remaining 40%. Finally they claim that biomass and hydroelectricity could be providing up to 2% of the national annual demand in backup power. This scenario seems economically unprofitable as the costs of transmissions lines to connect the 3 main grids together alone would be excessively expensive. However, the authors argue that this scenario has been developed to be achievable with the current technologies. They claim that with the continuous technology development and decreasing technology costs such scenario could be achieve with a lesser costs (Wright and Hearps 2011).
Another study realized by the University of New South Wales in regards to Zero Carbon emissions have found that a greater variety of energy sources in the energy mix and the non-connections of the three main grids would greatly lessen the costs of producing 100% of the Australian electricity from renewable energy. In addition, as the transmissions lines between the SWIS, NWIS and the NEM are nonexistent in this scenario, it is clear that it makes the proposed plan much more financially possible.

A few other studies have been realized. All conclude that providing the totality of the Australian electricity from renewable energy is definitely possible. The arguments raised by sceptics and lobby groups, such as the need for base load and the incapability of renewable energy to meet the load because of its intermittent nature is now dismissed. Experts agree that although renewable energy and such scenarios demand a very heavy initial capital costs, major economy would still be made as there is no permanent fuel costs as it is the case with traditional electricity generation.

These kinds of studies show what little technical barriers exist to renewable energy generating capacity. For the SWIS, an upgrade of the system would permit better integration of renewable energy to the energy mix. As we have seen earlier, the barriers mostly lay on the side of policy and market regulations, emphasized by strong lobby groups and market dynamics.

6.2.2. Possible scenario

In the last few years, the introduction of the RET and the development of further clean energy policy by the WA state, various possible scenarios have been developed by private sectors. These scenarios range from a very dark future for renewable energy on the SWIS, with little increase of this resource into the energy mix, to very positive scenarios, that prospects large amount of renewable energy generation. The recent introduction of the carbon tax, which will impose a price on carbon from the 1st of July 2012, will definitely enhance further development of renewable energy project across the country. As this tax has only been recently amended, most of the scenarios developed were realized prior an actual and real price on carbon. Although some studies have investigated possible scenarios for the SWIS according to an existing carbon tax, new studies have to be carried out in order to provide a more accurate estimate and realistic expectation with the increase of renewable energy on the SWIS.

I have decided to select a scenario developed by SEN that more or less join the argument developed by the report Beyond Zero Emissions, where the SWIS enjoys between 80 to 100% of renewable energy by 2050. The SEN has published the following scenario in its discussion paper “Renewable energy scenarios for Western Australia” (Sustainability Energy Now n.d.). In this scenario, the SEN assumes that the desired outcome is progressively implemented in a well-planned and organized manner. It also assumes an electricity consumption of twice the rate of 2020, or 52,000 GWh. The following table shows the possible energy mix for this scenario. Wind and solar thermal energy are predominant in this scenario, followed by geothermal, wave, solar PV (mainly small-scale connected to the grid) and finally biomass. (Sustainability Energy Now n.d.)
Table 2 "Total installed capacity of various renewable energy conversion technologies for an 80-100% scenario"

(Sustainability Energy Now n.d.)

The following map (Figure 12) shows the repartition of the energy facilities, a typical summer load and the proportion of each energy source to meet the load. From the map we can see that the energy facilities are located near the high demand centers. It seems clear that geothermal is used as the baseload, as it is a constant and non-intermittent energy sources. In this case, geothermal plants are used the same way current baseload plant of coal and gas are used. Mid-load merit seems to be met mostly by solar energy and completed by both wave and wind energy and solar fails. Peak loads are mainly met by wind and completed with a mix of wave, biomass, some fossil fuels and solar energy. This scenario does not analyze the financial side of such projects in details (Sustainability Energy Now n.d.).
Figure 12 “80-100% renewable energy scenario for 2050”

(Sustainability Energy Now n.d.)
To conclude this paragraph, I would like to make a critical note on the process of developing scenarios. It is important to remember that to conceive a scenario, many assumptions have to be made. Although, it is possible that most of the assumptions made would realize themselves in the future, they are, when made, just speculations. Hence, scenarios are just possible indications that can be taken for rough estimations.

6.2.3. Renewable energy projects for the SWIS

This dissertation has drawn a quite pessimist portrait of the status of renewable energy for the SWIS. However, as we have seen, there are several renewable energy facilities connected to the SWIS and there a more projects under construction. The following table 3 gives an overview of the current facilities under construction. Of the 3 facilities, two are medium-size facilities. In addition, the Goldfields Renewable Energy Lobby (GREL), formed in August 2011, is currently promoting Kalgoorlie-Boulder as the perfect site for the construction of a Concentrating Solar Thermal (CST) power plant (Body 2011). The GREL claims that up to 15 CST of 220 MW each could be installed to meet future electricity needs. Given the opportunity, WA has the possibility to become a leader in renewable energy technology as well as powering its electricity up to 100% with clean energy (GREL 2011).
<table>
<thead>
<tr>
<th>Project name</th>
<th>Location</th>
<th>Technology</th>
<th>Companies and costs</th>
<th>Supports</th>
<th>Capacity</th>
<th>Additional Information</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenough River Solar Farm</td>
<td>Ellendale (50km Southeast of Geraldton)</td>
<td>PV: &gt; 150,000 thin film PV modules</td>
<td>Verve Energy and GE Financial Services (joint venture Partner) &gt;50million</td>
<td>Office of Energy, Department of Regional Development and Lands, and Mid West Regional Development Commission</td>
<td>10MW or 28GWh per annum</td>
<td>Expected: mid 2012 Project site: 80 hectares</td>
<td>(Verve Energy 2012)</td>
</tr>
<tr>
<td>Mumbida Wind Farm</td>
<td>Mumbida (near Geraldton)</td>
<td>Wind: 25 turbines of 2.5MW</td>
<td>Verve Energy and Macquarie Capital (joint venture Partner) &gt;150,000 million</td>
<td></td>
<td>55 MW</td>
<td>Expected: end of 2012 100% of the electricity produced will be buy by the Water Corporation to power the Southern Seawater Desalination Plant Greenough River Solar Farm and Mumbida Wind Farm are a joint project</td>
<td>(Verve Energy 2012)</td>
</tr>
<tr>
<td>Grasmere Wind Farm</td>
<td>Albany Wind Farm</td>
<td>Wind: 6 additional wind turbines to the Albany Wind Farm</td>
<td>Verve Energy &gt; 40 million</td>
<td></td>
<td>14MW</td>
<td>Expected: early 2012 With the 6 new turbines, 80% of Albany’s electricity will come from renewable energy</td>
<td>(Verve Energy 2012)</td>
</tr>
</tbody>
</table>

Table 3 Future Renewable Energy Facilities for the SWIS
This section has highlighted the potential for renewable energy along the SWIS. A diverse energy mix is necessary for providing secure and reliable energy on the SWIS. A vast range of renewable energy sources could provide the entire energy needs of the SWIS. Mid-scale renewable energy facilities are in this case an attractive solution to power the SWIS and offer a sustainable future for the state.
7. Recommendations and Findings

I found that WA is certainly rich with renewable energy sources that can be exploited to create an electricity market free of fossil fuels. However, given the current situation and prospects of the SWIS, an 80 to 100% of electricity from renewable energy sources by 2050 seems utopian. In my research, I conclude that the Australian energy policy, which aims at increasing the use of clean energy, appears to surround itself with barriers. In regards to the SWIS, it is clear that the lack of specific targets from the energy policy limits the potential for the development of the renewable energy sector. In addition, the policy tends to desire the increase of the share of renewable energy alongside the remaining of intense fossil fuels use. To add to that, the market structure of the SWIS, the WEM, is strict and discourage renewable energy investments and development through the various and numerous rules that aim to ensure the energy security of supply of the grid. That is reinforced by the technical weaknesses of the grid, which is certainly not ready to accommodate a large penetration of renewable energy into the energy mix. Finally, the nature of the WA economy and its abundant fossil fuels reserve strongly add to the resistance to the increase share of renewable energy. The barriers being interlinked, it seems difficult to bring them down, nonetheless achievable.

The use of mid-scale renewable energy facilities for the electricity production is highly appropriate in the case of the SWIS. Medium power stations could bring energy autonomy to small towns, increasing the share of renewable energy into the grid while slowly updating it in order to achieve maximum penetration. However, because of the renewable energy market failure of the SWIS, it seems to me that a greater intervention of the government is necessary. In my opinion,
energy is an essential service to our society. Hence, it is the government’s duty to ensure it is distributed in the safest way possible. That is to say that such service should be ranked as the same title as water of air and be environmentally, economically and socially safely provided. As we have seen in the case of China, a strong governmental interference in the energy sector seems to benefit renewable energy. At the same time, and in the case of the USA, a liberal market seems to be favourable to the development and investment of renewable energy. WA meets all the requirements to be both a leader in manufacturing renewable energy components and a leader in renewable energy technology innovation. I believe this could only be achieved with strong and active support from the government in creating a renewable energy market. If the renewable energy market become as safe and profitable as the current fossil fuel market as safe as it could be, it can be said with few doubts that the renewable energy in WA would be booming and maybe compete with the mining industry.

➢ The prospects of renewable energy for the SWIS could be limitless if the policy and economic barriers were solved.
8. Conclusion

In the report “Zero Carbon Australia Stationary Energy Plan” Professor Robin Batterham said “With our natural advantage, Australia can and should be positioning itself as a global renewable Super Power for future prosperity” (Wright and Hearps 2011). The SWIS and WA have the natural resources and the opportunity to lead Australia towards becoming this Super Power. However, many economic and political barriers are on the way. Dissolving these barriers would require a strong political will, determined to assure Australia future energy independence, and helping developing a free and competitive renewable energy market. The case of China and the USA has underlined the importance of both strong energy policies and free competitive markets to the success of the development of renewable energy in a country.

This dissertation has aimed to highlight the prospects and problems of connecting medium scale renewable energy facilities to the SWIS. The barriers and their potential solutions were clearly identified. The prospects for renewable energy and the future projects of the SWIS were also described along this dissertation. Some limitations were found in the prospects of connecting medium scale renewable energy facilities. Although the advantages of such size facilities and their potential for creating a secure energy mix for the SWIS were brought to light, it seems difficult to identify their actual potential from an economic point of view. If a competitive renewable energy market is created on the SWIS, it seems obvious that these kinds of facilities have high prospects of development. However, to date and given the current situation, competition is almost impossible and only big company, such as Verve Energy and very mature renewable energy, such as wind and landfill gas, would keep the share of renewable energy on the SWIS.
The newly amended Carbon Tax will greatly influence the future of renewable energy in Australia and on the SWIS. It will be interesting to see to which extent the share of renewable energy on the SWIS will increase and if the market will allow more competition for the industry and helped smaller facilities to grow.

In conclusion, this dissertation has shown the importance of having a diverse energy mix on the SWIS made from renewable energy sources in order to ensure energy security and independency as well as economic prosperity and growth for the state of WA. Currently, the SWIS market structure and the technical weaknesses of the SWIS greatly limit a high penetration of renewable energy. In addition, the energy policy is not strong enough to help towards a more sustainable future. However, there are actions that can be taken to dissolve these barriers and the SWIS, as for the rest of Australia, has great potential to be a leader in renewable energy. To reach its maximum potential, the SWIS, and Australia, must allow the government to interfere to solve the current renewable energy market failure.
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