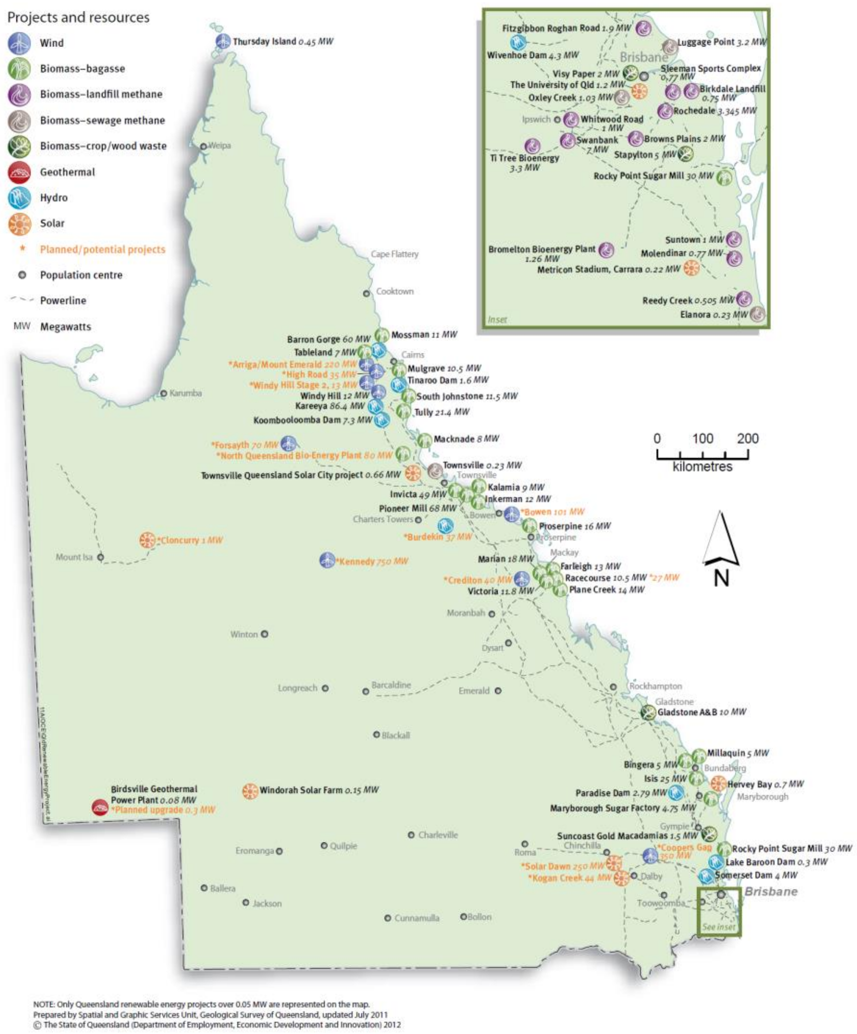
# Sustainable Queensland – Transitioning to a Clean and Efficient Energy System




Source: DEEDI, Qld. RE Plan 2012

## Policy Discussion Paper prepared for Sustainable Queensland

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# Acronyms

ACF – Australian Conservation Foundation

AEMO – Australian Energy Market Operator

ALP – Australian Labor Party

ASC – Australian Solar Council

ATA – Alternative Technology Association

BZE – Beyond Zero Emissions

CEC – Clean Energy Council

DEEDI – Department of Employment, Economic Development and Innovation

DERM – Department of Environment and Resource Management

DEWS – Department of Energy and Water Supply

DIP – Department of Infrastructure and Planning

DIRD – Department of Infrastructure and Regional Development

EE – Energy Efficiency

EROEI – Energy Return on Energy Invested

ESQ – Energy Skills Queensland

EV – Electric Vehicle

FTE – Full-time Equivalent Jobs

GBR – Great Barrier Reef

IEA – International Energy Agency

IMF – International Monetary Fund

LNP – Liberal National Party

RMI – Rocky Mountain Institute

# Executive Summary

This paper aims to be a stimulus to discussion and implementation of sustainable energy policy in Queensland, focusing on electricity generation. It aims, to assist in a rapid transition to a renewable energy and energy efficient future. This policy is urgently needed to address the global warming challenge facing the world, whilst helping to establish an alternative economic base to coal and gas mining by investing in innovation in renewable energy and energy efficiency.

Globally, an energy transition to renewable energy and energy efficiency is already happening in many countries. Queenslanders strongly support these technologies and Government policy should reflect the peoples' wishes. Whilst recent State Government commitments to renewable energy, including a target of 50 percent renewable energy electricity generation by 2030, are to be applauded, Queensland lags behind most other States in this regard (CEC, 2014:9).

This discussion paper outlines political, economic, environmental and social reasons why government should strongly support renewable energy and energy efficiency. It reports on the current status of and barriers to renewable energy contributing to electricity generation in the State. Finally, it outlines a range of supportive policy initiatives.

Key findings are:

- **Energy issues played a significant role in the recent State election**. The lack of support by the LNP government for renewable energy in the State, in particular roof-top solar PV, concerns over coal and gas mining expansion, and its impact on the Great Barrier Reef, contributed to an electoral backlash against the LNP.
- **Renewable energy contributed almost 10 percent to electricity consumption in 2014**. This has increased from about 6 percent in 2008. This includes the contribution from domestic solar hot water. **However, this is well below the renewable energy contribution in some States and/or their targets such as South Australia and the ACT**.
- **Energy efficiency's contribution to saving energy has not been fully measured and reported. This is a major policy failure of previous governments**.
- **Electricity demand continues to fall** Australia-wide but is predicted by the AEMO to increase in Queensland. This is disputed by some including large energy users in the State.

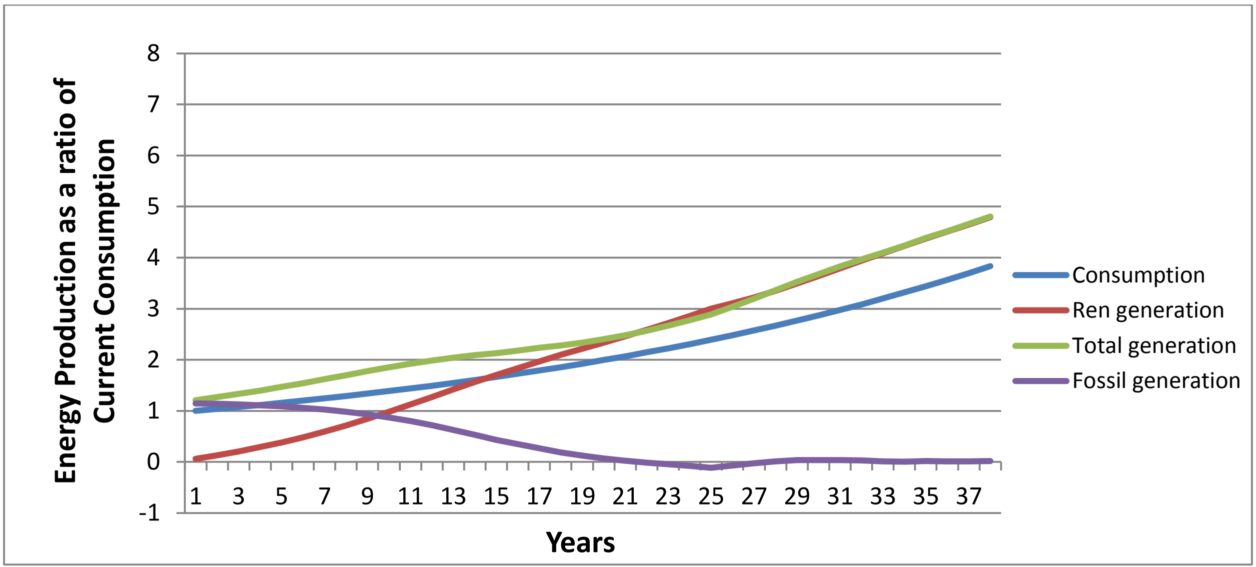
Key suggested policy measures include:

- **Re-establishing an Office of Clean Energy or a similar department** to oversee the development and implementation of renewable energy and energy efficiency policy and associated targets.
- **Implementing both the target of 50 percent for electricity generation from renewable energy, and an energy efficiency target for electricity consumption and transport energy use by 2030.** These should aim to reduce greenhouse gas emissions from the energy sector by at least a similar amount below 2000 levels.
- **Removing subsidies, including infrastructure expenditure, to the fossil fuel industry** and redirecting these monies to the development and deployment of renewable energy and energy efficiency. **Full policy details are given in the section titled "Transitioning to Renewable Energy and Energy Efficiency – What we need to do to get there".**

# Energy Systems in Transition

There is an energy transition happening internationally (IEA, 2013:5; IEA, 2015) and in Australia, away from fossil fuels to clean renewable energy combined with energy efficiency. Germany and other EU countries are leading the way (Vorrath, 2015). Modelling has shown that a transition to a largely renewable energy (RE) based electricity system in Queensland had started under the former Labor Government's Queensland Renewable Energy Plan (QREP) (DEEDI, 2009 & 2012). It showed that this transition could have been achieved over about 20 years as shown in figure 1 if the Plan's momentum had been maintained.

**Figure 1 – Modelling of former Labor Government RE Plan and Projected Transition to 100% RE Electricity**




Notes: (Source: Berrill, 2012)

1. Growth in consumption of 3.7% pa. as per government budget paper projections. In reality, consumption across the whole eastern National Electricity Market (NEM) has been decreasing for the past 5 years so this is a very conservative assumption.
2. Initial contribution of renewables of 6.1% is based on the estimated energy output in 2008 from 746MW mix of renewables outlined in the Qld. Renewable Energy Plan (QREP), and commonly used values for capacity factor for each technology.
3. Maximum growth in renewables of 12% per year is based the QREP projection of 2900MW RE capacity by 2020.
4. The weighted average Energy Return on Energy Invested (EROEI) value of 7.4 was that for a mix of wind farms, solar thermal electric with storage, solar water heating, and photovoltaic (PV) systems.
5. Makes no allowance for improvements in energy efficiency and hence this is a conservatively weighted study.

## *It's time to renew the process of this energy system transition.*

The 2015 Labor Party's election promises were confirmed as goals recently by the Minister and this is to be applauded. This includes a commitment to a "50 percent renewable energy electricity generation target by 2030", "a million solar rooftops by 2020" and to "determine a fair price for families who export the solar power they produce at home into the grid" (ALP, 2015). **These proposals are a step in the right direction. But they are will need strong and lasting policy initiatives to achieve.**

**This discussion paper outlines some reasons why renewable energy (RE), in conjunction with energy efficiency (EE), should be strongly supported by the new Queensland Labor Government. It outlines the current status of renewable energy electricity generation in Queensland and compares this to other States. Finally it examines barriers to renewable energy and energy efficiency and outlines some policy directions that should guide the RE and EE policy discussion in Queensland.**

While the focus of this discussion paper is on electricity generation, since this is the largest contributor to greenhouse gas emissions, other sectors such as transport, mining and agriculture need to be carefully considered in order to transition all sectors to renewable energy and energy efficiency**.** For example, electric vehicles (EVs) powered by renewable energy are the cleanest form of public and private transport. In the distributed, smart grids that are emerging all over the world, EVs' on-board energy storage is already being used to benefit network peak power management, as power can be drawn to and from EV batteries while vehicles are stationary. In WA, remote area mines are investing in solar energy with storage to reduce dependence on diesel generation.

# Why Renewable Energy and Energy Efficiency are Important

There are important political, economic, environmental and social reasons why Queensland should put in place policies that strongly support the adoption of renewable energy and energy efficiency. These are outlined below.

## Political Reasons

**The public overwhelmingly support the uptake and use of renewable energy and energy efficiency.** They want a clean energy future. This has been shown time and again in independent surveys for government agencies, industry and community organisations (Reark, 1994; Ashworth, 2008; Pacific Hydro, 2011; AFR, 2012; CEC, 2013). For example, according to the Australian Solar Council:

> *Community support for renewable energy and rooftop solar is strong. Of 1,000 Australians surveyed in 2012, 74 per cent would prefer to have their electricity supplied by renewable energy compared to 12 per cent for nuclear and only 6 per cent for fossil fuels.* (ASC, 2014).

In recent years, the public and businesses have put their money where their mouths are. There are now in Australia over 2 million households (over 400,000 in Queensland) with either solar PV or solar hot water on their roofs, or both. Many businesses are now doing the same.

Under LNP Federal and State Governments, growth in the photovoltaic (PV) has slowed but not stopped. However, the large-scale renewable energy industry is struggling under national policy uncertainty.

**A clean energy future is now a significant political issue** at both State and Federal levels as demonstrated by:

- The recent Queensland State election in which the issue of a fair deal for home owners with roof top solar played a crucial role.

- The ongoing protests in both Queensland and New South Wales over the expansion of the coal and coal seam gas industries.
- Rural communities are actively seeking alternative economic initiatives to coal and gas such as solar and wind farming in conjunction with food production to help diversify farmers' incomes. (Berrill, 2012; Berrill, 2014).
- The attack on the renewable energy industry by the LNP at both State and Federal levels, attempting to shut down the industry by the removal of supportive policy such as the Renewable Energy Target.
- The increasing support by the trade union movement as they saw the job growth in renewable energy with about 25,000 full-time equivalent jobs created by 2012 (CEC, 2012). **Many construction job skills are transferrable from the fossil fuel industry to the renewable energy industry** (ESQ, 2011).

## Economic Reasons

Renewable energy provides:

- **Longer term energy price certainty** as the fuel cost is free and the infrastructure costs continue to decrease. This puts downward pressure on the wholesale price of electricity via the Merit Order effect (see glossary). Renewables such as solar thermal for low and medium grade heat, and solar PV, wind, hydro and biomass power systems for electricity are now cost competitive against fossil fuels in many situations (HSBC, 2015) and are predicted to be the cheapest fuels by about 2030 (Bloomberg, 2013).
- **Job creation and associated skills training** – There were about 25,000 full-time equivalent jobs (FTEs) in renewable energy industries across Australia by 2012 (CEC, 2012), about the same as the coal industry now in Queensland (Dept. Energy and Water Supply, 2014). Globally the renewable energy industry is booming with over 800,000 jobs created between 2012 and 2013. But growth has stopped in some sectors of the Australian industry under LNP governments. Queensland needs to reverse this trend as there will be many more jobs in renewable energy in the future than in coal and gas (Climate Council, 2015:1), as renewable energy tends to be more labour intensive than the fossil fuel industry (Union of Concerned Scientists, 2013; Blyth, 2014; Vorrath, 2013).
- **Economic / regional diversification** away from reliance on fossil fuels - The export of minerals has always been associated with boom and bust cycles. Economic diversification acts to offset the negative impacts of both boom and bust cycles. Solar and wind farms on agricultural land are examples of how regional economies can be strengthened by giving farmers a diversified income stream. As well, job losses in the coal industry can be offset by continued growth in the renewables industry, as many construction jobs are transferable.
- **As the international demand for coal slows**, there is an increased likelihood of our coal reserves, mining infrastructure and power stations becoming "stranded assets". This has been highlighted by former Liberal leader and economist, John Hewson (Caldecott, 2014) and major banks (HSBC, 2012). Hence the finance industry is becoming increasingly reluctant to invest in fossil fuel projects as Adani is finding with the Galilee Basin project proposal. The reasons for this are clearly shown by a new Reputational Risk report released recently. (RepRisk, 2015). This report rates the Abbott Point port development as the third most controversial project in the world at the moment due to its "high level of exposure to

environmental, social and governance risks; more specifically, its threat to the World Heritage-listed Great Barrier Reef, links with waste disposal and pollution issues, and potential contribution to climate change" (Vorrath, 2015).

- **Households and businesses can greatly reduce and secure their cost of electricity** by on site generation. Rooftop solar PV has now reached better than grid parity across much of Australia. This is resulting in the so called "death spiral" of decreasing demand for electricity from large, centralised coal and gas generators, and hence reduced profitability for these generators (See glossary for more information). Utilities across the developed world are reinventing their business models to become **energy service providers** rather than just selling units of energy. Both AGL and Origin are strategically moving slowly in this direction.
- **Increased resilience** of the electricity system against extreme weather or acts of terrorism via a distributed, intelligent (or smart) grid. - During cyclone Yasi (2011), the output of both Gladstone and Stanwell coal fired power stations had to be reduced by 50 percent as they were running out of coal and supply routes were damaged by flooding (Berrill, 2012). This had the potential to cause major supply disruption if coal reserves had run out. CSIRO's work regarding the intelligent grid has shown a diversified, distributed electricity system provides a more cost effective, resilient, cleaner and more energy efficient electricity system. (CSIRO, 2011:8).
- **Opportunities for the development of innovative products/services** and resulting in new market opportunities.
- **Opportunities to build energy self-sufficient new suburbia or villages** in regional areas without upgrades to transmission and distribution systems (E.g. Currumbin Eco Village - http://theecovillage.com.au/).

Note that while there is presently an overcapacity of electricity generation along the whole of the eastern seaboard, there is a high proportion of large coal plant that is aging and should be retired. In Queensland, there are four power stations that are about 40 years old or more with a total capacity of 2300MW. These are Gladstone (coal), Callide A (coal), Swanbank B (gas) and Mackay (gas) (Qld. Government Business and Industry Portal, 2015).

**Energy Efficiency consists of three components:**

1. More efficient technology which has a lower operational and life cycle energy consumption.
2. Demand side management where energy use is shifted from peak to off-peak periods to reduce peak demand and associated infrastructure costs.
3. Behavioural change to improve energy management practices.

These measures provide:

- Ongoing reduction in energy costs for businesses and households.
- Reductions in the need for new construction or delays in upgrades to power generation, transmission and distribution systems.
- Job creation and skills training for energy auditors/managers, product development, manufacturer, sales, distribution and installation/maintenance staff.
- Opportunities for the development of innovative products/services and resulting new market opportunities.

## Environmental Reasons

- **Queenslanders have one of the highest environmental footprints per capita in the world**, including greenhouse gas emissions (DERM, 2009). This is due to our heavy dependence on coal and gas. Coal is the most carbon and pollution intensive form of energy production and is the major contributor to global warming. The environmental and social impacts of coal mining and coal seam gas extraction, including exports, create global impacts via global warming and land, air and water pollution (Rockstrom, 2009). Nowhere is this more apparent for Queensland than from the impacts of the use of coal, locally and overseas, on the Great Barrier Reef (GBR). This fuel poses a serious threat to the estimated 60,000 tourism and fisheries jobs and about $6 billion economic value of the GBR to Queensland, let alone the aesthetic and ecosystem value of this natural wonder (Hughes, 2015; McCook et al, 2015; AMCS, 2014).
- **Renewable energy, when combined with energy efficiency, is the cleanest and cheapest** option to reduce climate changing greenhouse gases and other pollution from fossil fuels (Diesendorf, 2014:95; HSBC, 2015; Bloomberg, 2013). This is even more so when full life cycle external costs of fossil fuel mining, processing, production, fugitive emissions, use and rehabilitation are included in the price consumers pay for electricity or gas (Epstein et al, 2011). These impacts are seen nowhere more clearly than in the Hunter Valley (Climate and Health Alliance, 2015) and across Australia generally as outlined in the Australian Academy of Science's recent report (AAS, 2015).

## Social Reasons

- **Communities are less likely to suffer social and economic disruption** with a decentralised distributed generation system as this provides a more resilient electricity supply. For example, distributed generation reduces the likelihood of widespread power failures from extreme weather events or acts of terrorism.
- **Renewable energy such** as wind and solar PV farms can **assist regional development** by providing additional long term jobs and revenue for cash-strapped primary producers and rural communities.
- **Home owners and businesses can reduce energy costs** and take greater personal responsibility for **pollution reduction** from fossil fuels.
- **The jobs created are long term jobs** that are not subject to mining boom/bust cycles. This provides for stability in jobs, families and society generally and hence increased social cohesion. By comparison, current mining of coal and gas is largely undertaken with a fly-in/fly-out workforce. This has led to serious social problems in regional towns near mines (Carrington et al, 2011; ABC Radio National - Background Briefing, 31/5/15). The boom/bust cycle has not been a sustainable social and economic model of development for regional centres.

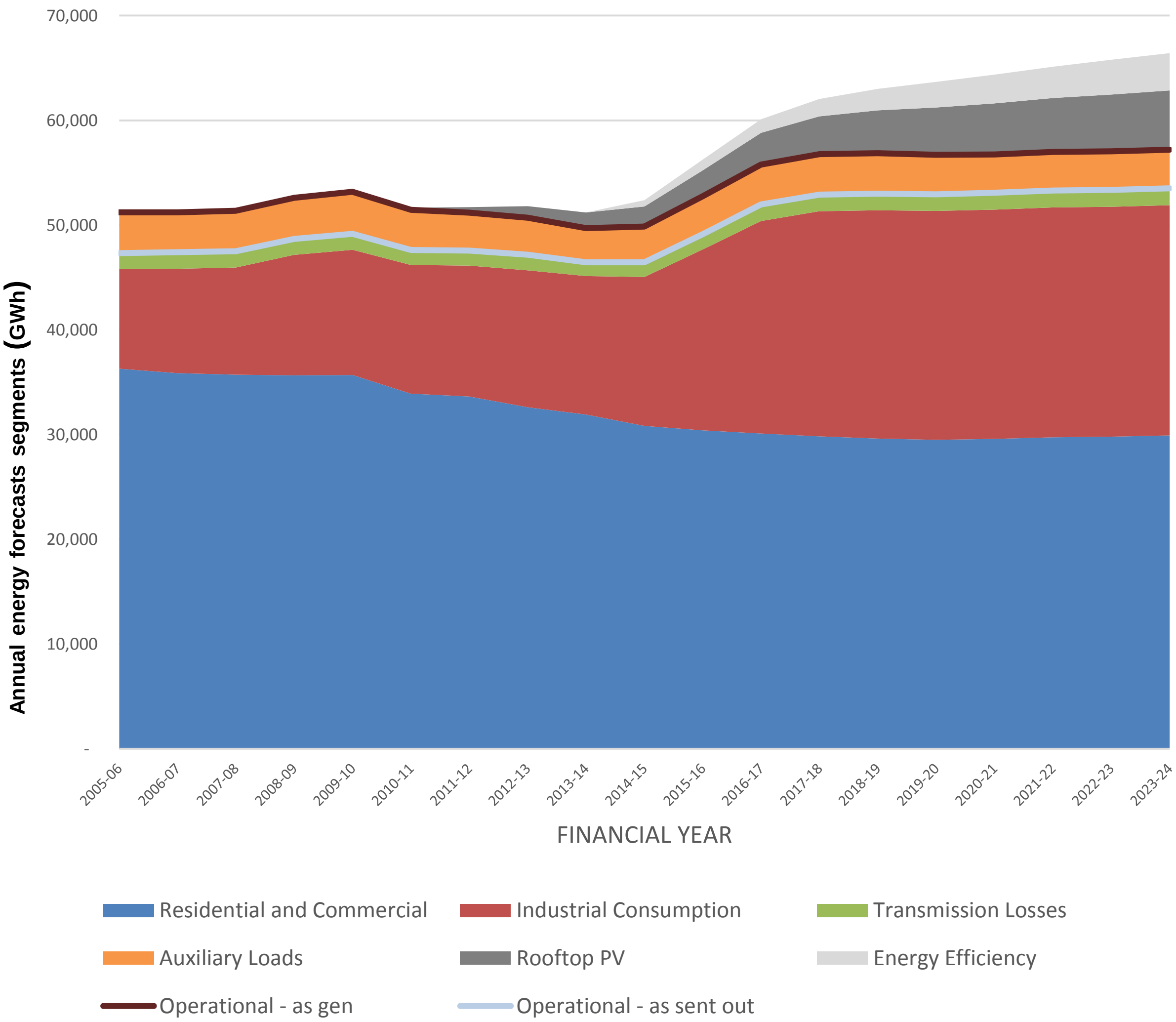
# The Facts - Where is Queensland at Present?

Figure 2 below shows Australian Energy Market Operator past and projected electricity generation and consumption for Queensland as follows:

- Electricity Consumption (top of red/blue segments = sum of industrial, commercial and residential sectors)
- Transmission losses and Auxiliary Loads
- Rooftop PV (from 2011/12) and Energy Efficiency (from 2013/14 only)
- Operational Energy Generated (Note: this includes large RE generators such as sugar mills, hydro-electric plant and a wind farm)
- Operational Energy Sent Out (Generated Energy less Auxiliary Loads)

**Figure 2 – Projected Queensland Electricity Consumption and Generation**

Source: AEMO, 2015



Queensland electricity consumption was 46,422 Gigawatt-hours in 2013/14 as shown in figure 3, with 28 percent for industrial use, 69 percent for residential and commercial use and about 3 percent for transmissions losses.

**Figure 3 – Queensland Electricity Consumption by Industry Sector 2013/14**

Source: AEMO, 2015

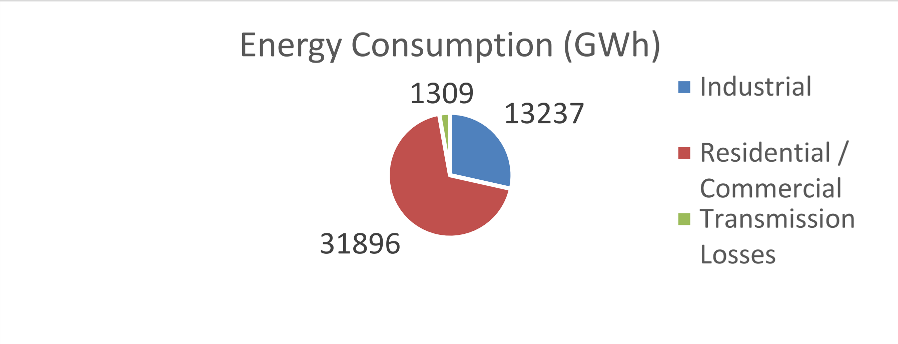



Table 1 shows the estimated installed capacity (MW) and energy production (GWh) from renewable energy generators in 2014.

**Table 1 – Comparison of Renewable Energy Installed Capacity (MW) and Generation (GWh) in Queensland.**

| **Technology** | **2009 QREP 2008 Capacity (MW)** | **2008 Estimated Energy (GWh)** | **2012 QREP 2011 Capacity (MW)** | **2011 Estimated Energy (GWh)** | **2014 Estimated Capacity (MW)** | **2014 Estimated Energy (GWh)** |
|---|---|---|---|---|---|---|
| Biomass | 415 | 1818 | 407 | 1783 | 464 | 1301 |
| Hydro | 169 | 740 | 167 | 731 | 167 | 895 |
| Solar Hot Water | 144 | 252 | 295 | 517 | 397 | 493 |
| Wind | 12 | 32 | 12 | 32 | 12 | 30 |
| Solar Thermal Electric | 0 | 0 | 0 | 0 | 0 | 0 |
| Geothermal | 0.08 | 0.60 | 0.08 | 0.60 | 0.12 | 0.89 |
| PV | 6 | 11 | 355 | 622 | 1267 | 1676 |
| | **MW** | **GWh** | **MW** | **GWh** | **MW** | **GWh** |
| **Renewable Energy Totals Capacity and Generation** | **746** | **2853** | **1236** | **3685** | **2307** | **4395** |
| **Energy Efficiency and Demand Management** | >1 | NA | >4.7 | NA | >246 | NA |
| **Qld. Electricity Consumption from AEMO** | **2007/08** | **47514** | **2010/11** | **47621** | **2013/14** | **46442** |
| **Renewable Energy as a Percentage of Consumption (%)** | | **6.0** | | **7.7** | | **9.5** |

Notes:

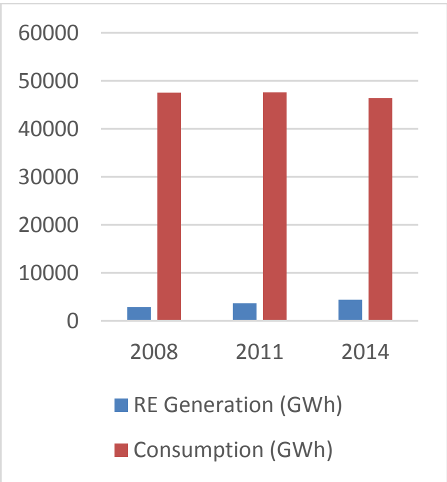
Data for 2008 and 2011 are from Queensland Renewable Energy Plans 2009 and revised 2012 (DEEDI, 2009 & 2012) as estimated by Berrill, 2012..

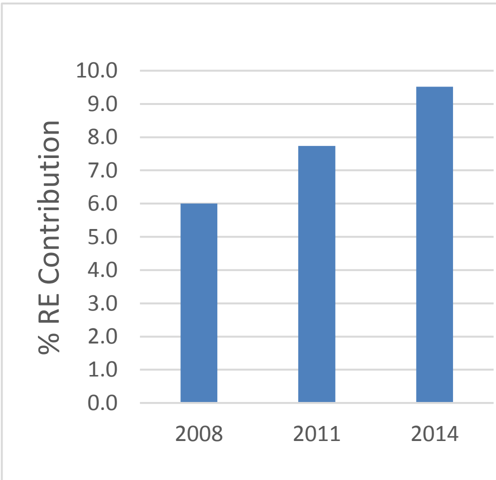
Data for energy production for 2014 are from:

- R. Brazzale (http://greenmarkets.com.au/resources/review-of-the-nem-in-2014 and GEM Estimates based on LGC creation and baselines.
- Clean Energy Council 2014 annual report.
- For solar water heating, system numbers are estimated from CEC 2014 report at about 238,000 systems. The capacity (MW) is calculated as equivalent to this number of 1.67kWp PV systems. This equates to the savings from electric hot water systems using 7kWh/day, by solar water heaters with a solar fraction of 0.81 (Australian Standard 3500.4) I.e. (238000 x 7kWh x 0.81 x 365days)/ 1,000,000 = 493GWh
- Consumption data is from Australian Energy Market Operator: National Electricity Forecasting Report 2014 - Summary Spreadsheet (AEMO, 2015).
- Demand management and energy efficiency programs by both Ergon and Energex have quantified demand savings (MVA) but have not measured or estimated fully energy savings (GWh).

Figure 4 shows the estimated contribution of renewable energy to electricity consumption for 2008, 2011 and 2014.

**Figure 4 – Renewable Energy Generation Contribution to Consumption, including solar hot water.**




**Some important observations are:**

**On the Consumption Side**

1. Commercial and residential consumption (GWh) does not include that part of roof-top solar PV that is supplied directly to the loads within a home or commercial premises and does not pass through utility meters. This results in an underestimate of final energy consumption within premises. Hence energy efficiency savings are not fully metered. This results from the use of net metering of roof-top PV systems via import/export meters. It can be rectified with gross metering using two separate meters (one for the load, one for PV output). Note that PV output is already metered via the inverter energy meter.

2. Australian electricity consumption (GWh) has been reducing since about 2009/10 due to a combination of roof-top solar PV, energy efficiency and reduced consumption from some large industry shutting down.
3. The Queensland consumption decline is consistent with the national trend although it is predicted by the AEMO to increase again sharply from 2015/16. This is based on predictions of proposed large industrial applications such as LNG processing coming on line soon. The AEMO has consistently overestimated growth in electricity demand in recent years and has been criticised for this (Rio Tinto, 2014).
4. Transmission losses are very low. This is in part due to local on-site generation from roof-top solar PV and energy efficiency measures, both of which reduce the need to transmit electricity over long distances.
5. Energy efficiency and demand (MVA) management programs have been in place for many years but measurement and reporting of the energy saving (GWh) seems very poor. For example, both Energex and Ergon have demand management programs in place (Energex, 2014; Ergon, 2014) and report regularly to the Australian Energy Regulator. Both these 2014 reports quantify the demand savings (E.g. 246 MVA reduction between 2010 and 2015) **but not all the energy savings (GWh) as a result of peak demand savings, or other efficiency measures**. As stated in point 1 above, net metering does not capture and record energy savings in homes and businesses. Separate gross metering of the loads and PV output is required.
6. Policies such as sustainable housing policy for homes, minimum energy performance standards for appliances, and the Greenstar commercial buildings rating system contribute significantly to reducing both energy and peak demand, but reliable data outlining the extent of savings are not available for Queensland.
7. There are some very large industrial users of electricity in Queensland. In particular, the mining and mineral processing industries currently consume more that 15 percent of electricity demand. This is expected to increase with LNG processing. This group wish to see electricity prices reduced. They argue this is necessary to maintain their international competitiveness (Rio Tinto, 2014).

**On the Supply Side**

1. Renewable energy (RE) generation (GWh) as a percentage of consumption has increased from about 6 percent in 2008 to almost 10 percent in 2014, include savings from solar hot water systems.
2. Most of the increase in RE capacity is from roof-top solar. No large scale (>30MW) solar PV or wind farms were approved and built.
3. If electricity demand begins to increase as forecast by the AEMO, then a higher growth rate in the adoption of renewable energy and energy efficiency will most likely be required to meet any targets such as for renewable energy and greenhouse gas emission reductions.

## How does Queensland compare to other States?

Figure 5 below shows the 2013 electrical energy generation from fossil fuels and renewable energy (in Gigawatt-hours) for each State.

**Figure 5 – Comparison of Renewable Energy Generation by State**

Source: Clean Energy Council, 2014 report, p. 9

PENETRATION OF RENEWABLE ENERGY - BY STATE

| State | Total generation (GWh)[7] | Fossil fuel generation (GWh) | Renewable generation (GWh) | Penetration of renewables |
|---|---|---|---|---|
| SA | 11,933 | 7115 | 4817 | 40% |
| WA | 18,425 | 16,082 | 2343 | 13% |
| VIC | 53,203 | 48,037 | 5166 | 10% |
| TAS | 11,004 | 584 | 10,420 | 95% |
| NSW | 60,594 | 57,226 | 3368 | 6% |
| QLD[8] | 57,683 | 53,797 | 3885 | 7% |

Notes: Renewable energy generation calculated above is a percent of total generation, as opposed to total consumption used in table 1, and does not include solar hot water savings in electricity consumption, which is included in table 1.

There are some significant differences between Queensland and other States. These include:

- Queensland has the lowest percentage of renewable energy generation of all the States in 2013/14, except New South Wales.
- South Australia is a shining example of where strong policy support for renewable energy has resulted in 40 percent of electricity generation now coming from renewable energy.
- Most of the growth in RE capacity in Queensland has been via small rooftop solar PV and solar hot water systems.
- While significant large scale project proposals for wind and solar farms were proposed in Queensland, including several hundred Megawatts of wind farming and 1.5Gigawatts of solar PV farming, the only large scale systems that were built were cogeneration systems using bagasse at sugar mills. Hence there exists a huge potential to build large scale solar and wind energy systems across the State as identified in the previous Labor Government's Renewable Energy Plan.

# Market Distortions - Subsidising the Fossil Fuel Industry

Government subsidies are designed to help emerging industries that Governments see as needing assistance to establish and grow, to achieve societal goals, or have been temporarily impacted by events beyond their control. In the past, extreme weather events have been one example. **Subsidies that support mature, profitable industries are perverse as they distort markets.** Note that there is no agreed upon definition of fossil fuel subsidies by the G20 group of countries (EIA, 2011; IMF, 2013).

In January, 2013, the International Momentary Fund (IMF) released “the most comprehensive estimates of energy subsidies currently available for 176 countries;” (IMF, 2013:1). The study showed that “On a post-tax basis which also factors in the negative externalities from energy consumption—subsidies are much higher at $1.9 trillion (2.5 percent of global GDP or 8 percent of total government revenues)”. A recent update of this work showed that the magnitude of these subsidies is much higher than previous estimates, at $4.9 trillion in 2013 or 6.5 percent of global GDP, and expected to increase to $5.3 trillion in 2015 (Coady, 2015:6).

The International Energy Agency (IEA) report, and more recently IMF report, have identified problems with subsidies to the fossil fuel industry and argue that these should be discontinued (IEA, 2011; IMF, 2013). These subsidies produce the following negative impacts:

- Distort markets and create barriers to clean energy investment
- Encourage wasteful consumption
- Increase $CO_2$ emissions and exacerbate local pollution
- Discourage investment in (clean) energy infrastructure

In 2009, the Australian Government, as part of the G20 countries, agreed to act to cut fossil fuel subsidies, recognizing that these subsidies were distorting the market and making it harder for renewable energy technologies to compete. Furthermore, G20 member countries agreed to cut fossil fuel subsidies, to foster green growth and to avoid encouraging overconsumption.

**The 2015 IMF report states that “Eliminating post-tax subsidies in 2015 could raise government revenue by $2.9 trillion, (3.6 percent of global GDP), cut global $CO_2$ emissions by more than 20 percent, and cut pre-mature air pollution deaths by more than half. After allowing for higher energy costs faced by consumers, this action would raise global economic welfare by $1.8 trillion (2.2 percent of global GP).”** (Coady, 2015:7)

The Grattan Institute (Wood et al, 2012:12) and an Australian Conservation Foundation report (ACF, 2011) state that Federal Government subsidies to fossil fuels in Australia currently range between about $8 and $12 billion annually, well in excess of that spent on renewable energy or energy efficiency, as shown by Riedy’s review in 2007 (Riedy, 2007).

The Grattan Institute’s report identifies a series of barriers that slow the deployment of cleaner energy technologies in Australia. The report states: “Early movers face higher costs than followers. Finance costs are higher for technologies that are not well understood. New infrastructure and regulatory frameworks must be developed, imposing delays and costs on early movers. Resource mapping is inadequate and some technologies lack long-term public support.” (Wood et al, 2012:1).

## Queensland Budgets – Energy Subsidies

Development of the fossil fuel mining and energy industry comes at considerable cost to tax payers. A detailed analysis by this author of the 5 years of Budget Papers (2007/08 to 2011/12), showed that the State Government was subsidizing this industry by about $1.38 billion per year or $6.92 billion over the 5 years to 2012 (Berrill, 2012).

Examples of subsidies include expenditure on:

- Port, road and rail infrastructure,
- Exploration development and data acquisition,
- Mining inspectorate, mine rehabilitation,
- Carbon capture and sequestration R and D,
- Fuel subsidies, fuel subsidy inquiry, gas hot water system rebates,
- Electrical power system upgrades,
- Sustainable resources communities funding Initiatives,
- AgForce landholder support for CSG contracts,
- Collingwood Park Mine Subsidence,
- CSG/LNG Industry Regulation Establishment Costs,
- Strategic Cropping Land Legislation and enforcement,
- Reef Vessel Tracking System,
- Coal to liquid technology research grants,
- Subsidies to new miners or junior miners to encourage development,
- Greenfields mining subsidies.

A more recent report by The Australia Institute confirmed this work. It showed that the State Government had paid $9.5 billion over 6 years in assistance to the fossil fuel industry in the Queensland (Peel et al, 2014:1). In 2013/14, this amounted to $1.49 billion, compared to $2.6 billion in royalties (Peel et al, 2014:8).

The Queensland Resources Council disputes that this assistance is a subsidy as there is a return on investment. However, these costs to Queenslanders do not include the full external costs. Rehabilitation and monitoring of an estimated 15,000 abandoned mines (all types) in Queensland is one such cost that is mostly being passed on the future generations (See Appendix 1 Map of Queensland's abandoned mines). Using Harvard University research for external costs from coal power generation of 20 cents per kilowatt-hour (Epstein et al, 2011), these costs in Queensland could amount to about $6.7 billion annually (See Appendix 1 for the full list of external costs of coal and Berrill, 2014:34). **This includes the impact of climate change and would potentially make coal mining and electricity generation in Queensland a net cost to the economy.** This is supported by US research suggesting that the costs of coal mining and use are greater than the value of the industry to the US economy (Muller et al, 2011).

University of Queensland economist, Professor John Quiggin, in reviewing the IMFs recent report, suggested that the Australian Government is in denial about these sobering external costs. He states that "the costs of burning fossil fuels outweigh the benefits in many cases" (Quiggin, May, 2015).

## Key Issues & Barriers to a Clean Energy Future

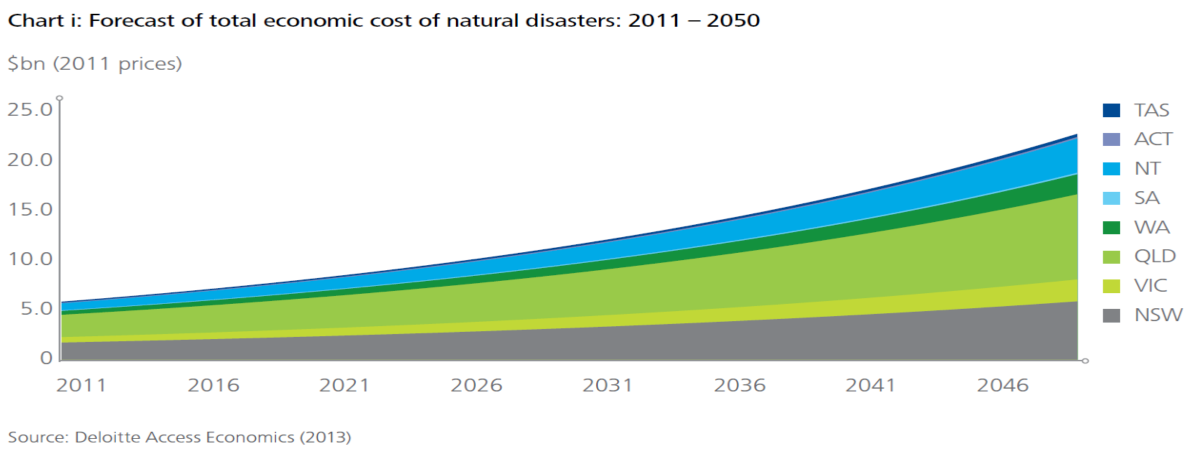
There are a number of key issues that need to be addressed before a clean and efficient energy future can be achieved. These include:

1. **Reforming the Electricity Industry** - The current revenue model of the electricity industry provides little incentive for the distribution companies to support variable (non-dispatchable) renewables such as wind and solar without storage. This is because distributors' costs and revenue are dominated by peak demand (MVA) and hence demand charges ($/MW), rather than sales of units of energy ($/kilowatt-hours). The distribution companies however do benefit from:
    a. Renewables with energy storage, both large and small scale, as it allows shifting of renewable energy to peak periods and hence peak demand (MVA) reduction,
    b. Energy efficiency measures as these measures generally reduce peak demand also.

2. **Over-investment in Fossil Fuels** - The State Government has invested about $1 to $2 billion each year in assistance to the fossil fuel industry over the past 6 years or so. There has been a commitment to coal and gas mining, including the Gallilee Basin and more recently oil and gas in the Cooper Creek Basin. Funding these projects assumes a healthy return on investment via royalties and other payments. The Adani project has been extensively reviewed now via the current court action by the Environmental Defenders Organisation. It have been found to be making vastly inflated claims to government about employment opportunities and royalties (Quiggin, April, 2015).

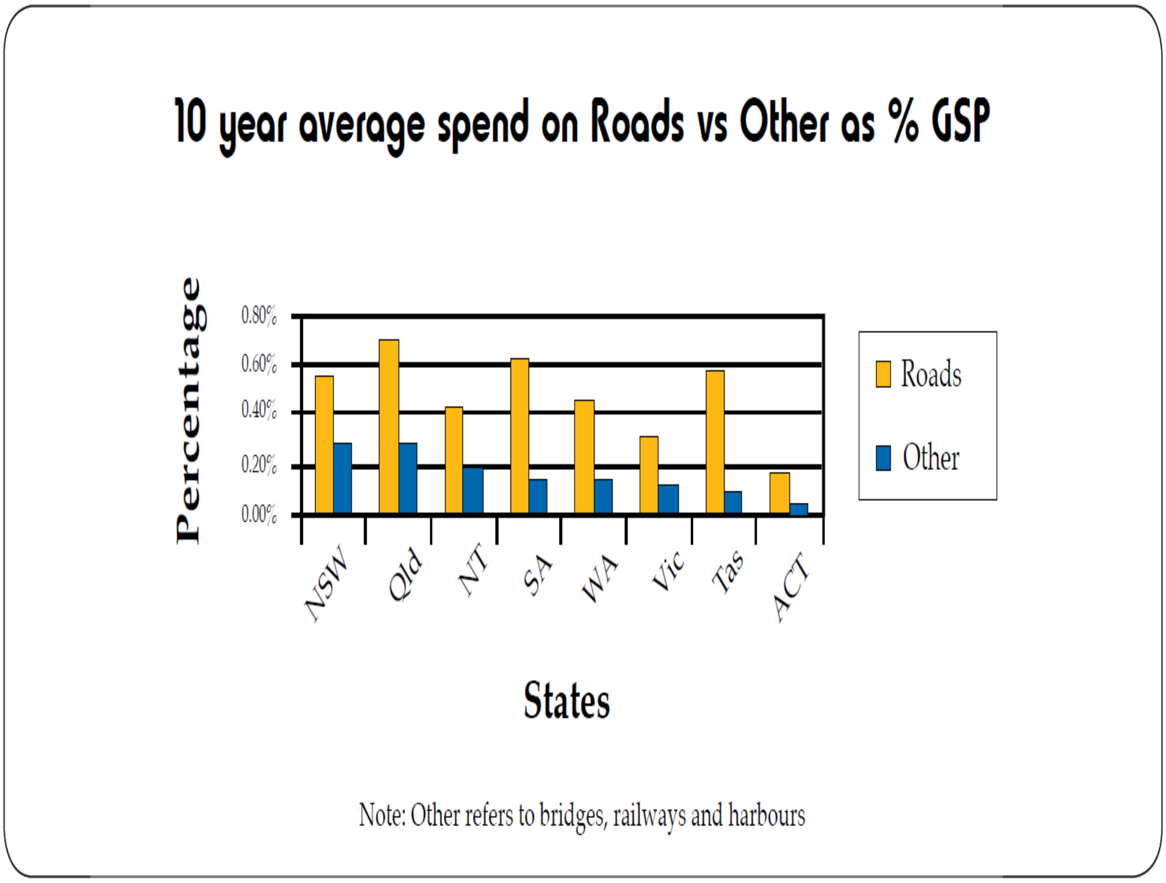
3. **Disaster Relief Cost Growth** - Disaster relief costs due to extreme weather event impacts are increasing. Disaster relief costs in Australia were about $6.3 billion in 2011 and are expected to grow at about 3.5 percent per annum (Deloitte Access Economics, 2013), as climate science has been predicting for decades as a consequence of more extreme weather events. Communities can be made more resilient to extreme weather events through distributed generation and hence renewables have a key role to play in reducing societal costs due to these extremes.

**Figure 6 -Projected Disaster Economic Cost ($billions/yr)**
Source: Deloitte Economics, 2013



4. **Transitioning Other Sectors** - If we are serious about transitioning to a clean energy future, government needs to give much more attention to transport and especially the impact on transport demand of urban planning. Current urban planning models are still predominantly locking people into car use, with spending on roads exceeding other transport modes for example by about 2.5 to 1 (See figure 7). This comes largely at the expense of public transport and has the effect of generating more road traffic, not less. While improvements have been made, Brisbane and other Queensland regional centres have poor public transport systems by international standards. There is also a need for greatly improved facilities for walking and cycling. Without these improvements, there will be continuing needless energy use and social costs. Congestion costs alone resulting from reduced energy efficiency are estimated at $15 billion each year across Australian capital cities (DIRD, 2014:10).

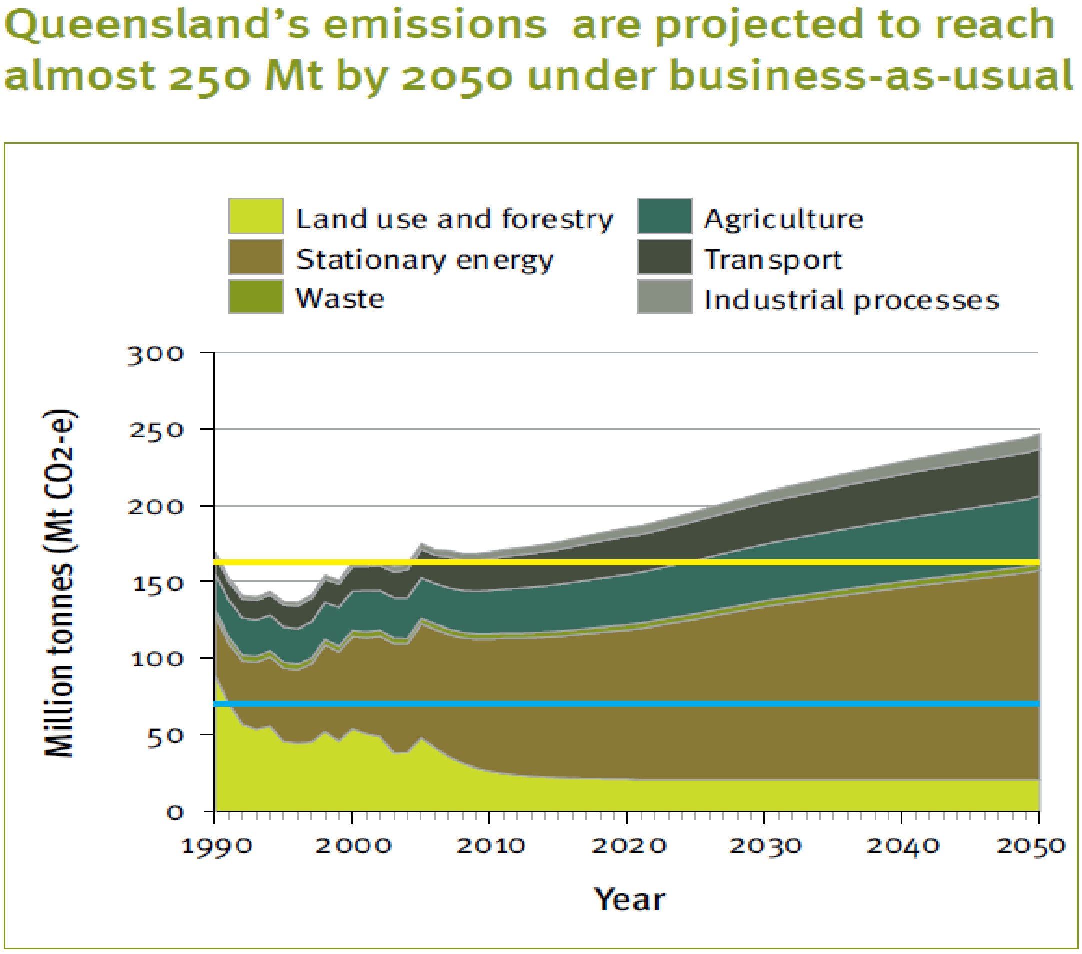
**Figure 7 – State Expenditure on Roads versus Other Transport**
Source: ACF, 2011:5




Source: ABS (2010) Engineering Construction Activity from Catalogue 8762.0 including Electronic Tables 13, 16, 19, 22, 28, 31, 34

**Figure 8 - Queensland's $CO_2$ Emissions Projection under Business as Usual**

Source: DERM, 2009, Chp.3:20

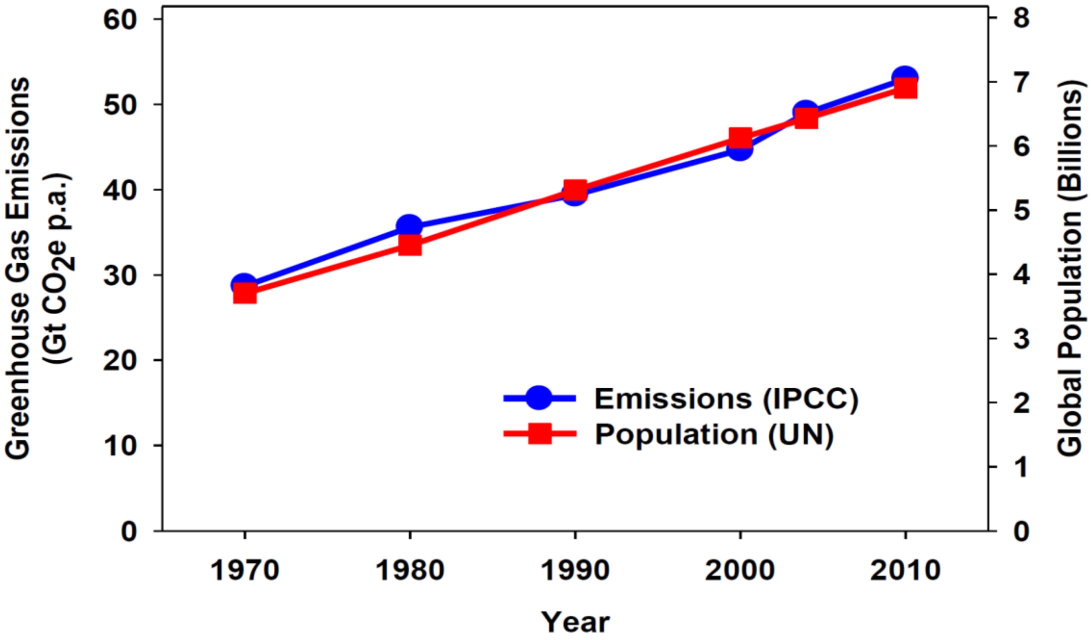



5. **Population Growth, Energy Consumption and Emissions** - The task of reducing energy use and associated emissions is dramatically impacted by a rate of population growth. Queensland's population growth rate of about 2 percent for the past 15 years (DIP, 2009) is more like that of a poor Third World country than a modern economy (World Bank, 2015), although it has slowed recently to about 1.5 percent (Queensland Economy Watch, 2015). As well, Queensland Governments have for many years encouraged a strong inter-State migration. Land released for housing is used inefficiently, with Australia having the dubious honour of the largest houses now on average in the world (ABC, 2011). This is at a time when the average household consists of about two and a half people.

   Some governments embrace population growth under the belief that it is good for the economy. The evidence for that is very weak (Cocks, 1996; O'Conner & Lines, 2008, O'Sullivan, 2014:7), but the evidence that it increases energy use and associated emissions is very strong (O'Sullivan, 2013:5). The current population growth rate makes the 2030 target much more difficult to achieve, as energy consumption then would be about 30% greater than today on a business-as-usual trajectory.

**Figure 9 - Historical Relationship of Population Growth, Energy Consumption and Emissions**

Source: O'Sullivan, 2013:5 (data from IPCC and UN Population Division).




6. **Energy Consumption re Processing/Transporting Fossil Fuels** – There is a large and increasing energy demand for exploration, mining, storage, transporting and processing fossil fuels for export, particularly liquefaction. There is very little local benefit from this energy consumption but very large global negative impacts. This includes global scale air, land and water pollution (Rockstrom et al, 2009). Nowhere is this more evident than in the massive scale of particulate pollution now over Asia, or from oil spills such as in the Gulf of Mexico, or Brisbane's air pollution, exacerbated by temperature inversions.

**Figure 10a – Air Pollution over China and Yellow Sea from Space (Left), Gulf of Mexico Oil Spill from Space (Right).** Source: Wikipedia & Google Images

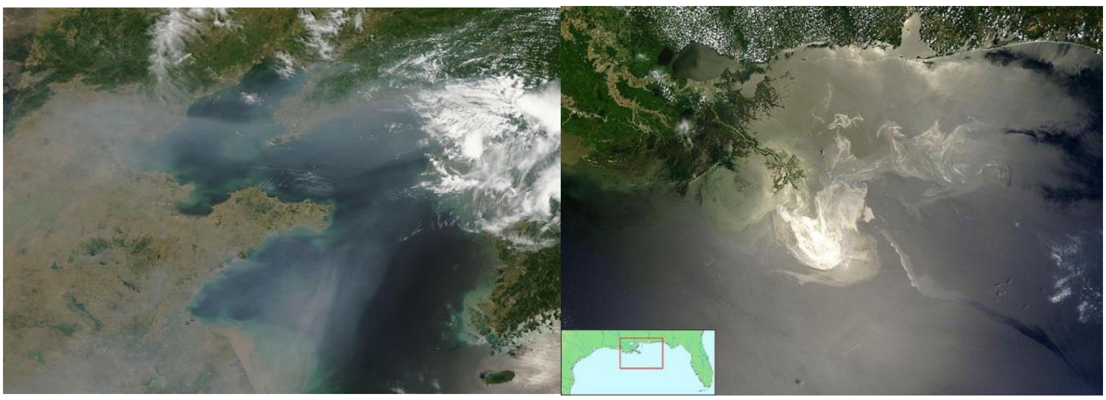


**Figure 10b – Air Pollution over Brisbane**

© Ian Bridge

7. **How GHG emission friendly is CSG?** - There is now growing evidence that coal seam gas's life cycle GHG emissions may be much higher than commonly suggested and in some cases may be no better than coal (Howarth, 2010; Tollefson, 2012). Research by Wigley from the US National Centre for Atmospheric Research and reported by Pears (2012) suggests:

   "The gas industry has promoted shifting to gas as the panacea to cut greenhouse gas emissions. A recent study by climate specialist Tom Wigley has challenged this……………………There are actually two independent factors at work in Wigley's study. First, there is the effect of a reduction in coal use, which cuts emissions of $CO_2$ and methane leakage from coal mines, reducing warming. But it also reduces air pollutants such as oxides of sulphur and carbon particulates, which reduces their short-term cooling effects. Wigley's paper suggests this loss of cooling will offset most of the reduction in warming from cutting coal use until mid-century, when the long-term effect of reducing $CO_2$ begins to swamp the air pollution effect."

   Not-for-profit research and education organization, Beyond Zero Emissions (BZE) argue that time should not be wasted subsidizing gas development as this infrastructure could become a financial liability quickly. This is because as global warming effects are increasingly felt and carbon pricing increases, the rate of uptake of RE and EE would need to increase. Instead BZE argue we should fund large scale development and deployment of solar thermal electric systems with storage and wind farms for the majority of Australia's electricity energy supply using their Zero Carbon Australia, Stationary Energy Plan as a model (Wright & Hearps, 2010).

   When BZE commissioned engineering consultants Worley Parsons to prepare a report on the life cycle GHG emissions from coal seam gas in Australia, the report was completed but then suppressed by Worley Parsons. BZE claim this is because the report shows that emissions are higher than generally argued by the coal and gas industry. (BZE Transcript from Radio National: Coal seam gas report 'suppressed', 14 Nov 2011).

   "Unconventional gas emissions up to seventy times worse than industry claims - immediate moratorium a must - Real time air sampling of gas fields in the US has shown leakage rates of up to over seventy times greater than the rates assumed by industry and accepted by government in Australia. The study by the US National Oceanic and Atmospheric Administration (NOAA) and the University of Colorado, has found rates of fugitive emissions up to 7.7%, with a mean of 4%." (BZE, 2012)

Finally, Queensland Government GHG emission estimates shown in the "ClimateQ: toward a greener Queensland" (DERM: 2009:Chp. 10, p.82) show fugitive GHG emissions becoming an increasingly larger proportion of total energy sector emissions when projected out to 2050 under business as usual, from the current estimate of 6 percent. This is a major concern as much of these fugitive emissions are methane, which is a much stronger GHG than $CO_2$. If the studies by Howarth, (2010) and Tollefson (2012) are indicative of fugitive emissions from CSG mining, then our "cleaner" gas industry may lose that image and sales quickly.

8. **Achieving Energy Efficiency** - There have been many starts and stops over the years in Australian government support for improving energy efficiency. It has been very similar to the boom/bust cycles imposed on the renewable energy industry. This has resulted in poorer policy outcomes. The incorrectly named 'pink batts' policy fiasco is one example. While achieving some worthwhile energy savings in many homes, it was hastily implemented and resulted in the death of some workers. This then brought about the shut-down of the scheme, rather than it being improved with higher quality training and appropriate safety measures. Australia is yet to implement a long term, nationally integrated energy efficiency plan.

   By comparison, many countries have implemented energy efficiency plans and use far less energy per capita than Australia. Denmark and Germany are two examples, using about half that of Australia (World Bank, 2015). Yet Germany has a goal to reduce electricity consumption by a further 50 percent by 2030 (Morris, 2015). Australia has much more low hanging fruit to harvest through efficiency gains. Setting an energy efficiency target (GWh reduction), in conjunction with a demand target (MVA reduction) will make the task of achieving a 50 percent renewables target by 2030 easier.

# Transitioning to Renewable Energy and Energy Efficiency – What we need to do to get there.

The following points outline potential policy directions that we strongly encourage the Government to consider in the following areas:

## Planning and Targets

- **Clean Energy Office** - Establish a new Office of Clean Energy or similar department, dedicated to developing and delivering the "Renewable Energy and Energy Efficiency Transition Strategy". This office should report directly to the Premier.
- **Renewable Energy and Energy Efficiency Plans** - Develop and implement renewable energy and energy efficiency plans as done by the former Labor government.
- **Carbon Budgeting** – Investigate the implications of the carbon budget approach, that identifies the ''burnable proportion" of remaining fossil fuels to keep global temperature rise to no more than 2 degrees Celsius rise (Steffen et al, 2015).
- **Targets for Renewable Energy and Energy Efficiency - The ALP's target of 50 percent renewable energy electricity generation by 2030 is an appropriate target. It should be taken as a minimum target. In addition, an energy efficiency target for the reduction in electricity consumption and transport energy use should be set.** Ensure there are suitable measurement and reporting systems. These targets should be consistent with the carbon budget approach. These combined targets should aim to reduce $CO_2$ emissions by at least 50 percent below 2000 levels by 2030. That would place Queensland in line with the $CO_2$ emissions targets suggest by the Climate Change Authority (CCA, 2014:9).
- **Industry Consultation** – Consult with both the renewable energy and energy efficiency sectors to identify barriers, policy solutions and targets. This should include the Australian Solar Council, the Clean Energy Council, the Australian PV Institute, the Alternative Technology Association, Solar Citizens, the Energy Efficiency Council and associated local businesses.
- **Scenario Analysis** – Undertake hourly simulation modelling of the operation of the Queensland electricity system with 100 percent renewable energy electricity system, based on the work of the University of New South Wales (See Appendix 2 for more information re Elliston, et al, 2013;2014). This process helps to inform policy with regard to the best mix of renewable energy technologies that, in combination, can provide a reliable and affordable electricity generation system.
- **Energy Return on Energy Invested Ratio (EROEI)** – Select, whenever possible, those renewable energy technologies that give the highest EROEI ratio. This ensures the highest potential net energy generation is delivered from renewable energy and therefore displaces fossil fuel use more rapidly (See Berrill, 2012:23-27).

## Incentivising and Financing

- **Incentivise Projects and Remove Barriers** - Provide policy settings that incentivise the adoption of existing commercially available renewable energy and energy efficiency and remove barriers. This may include streamlining the application process for larger scale renewable energy projects connecting to the grid, and examining leasehold land legislation (See www.renewablessa.sa.gov.au/.../110628-guide-to-proposed-changes.pdf).

- **Financing Projects** – Help provide appropriate access to finance by working closely with the Clean Energy Finance Corporation (CEFC). This includes both renewable energy and energy efficiency projects. See http://www.cleanenergyfinancecorp.com.au/what-we-do.aspx. If the CEFC is shut down by the LNP Federal Government, then establish similar State based programs to those currently run by the CEFC.
- **Power Purchase Agreements and Tariffs** - Establish fair power purchase agreements and tariffs for the export of renewable energy fed into the electricity network. These tariffs should reflect fully the benefits to society and the network of distributed renewable energy generators. An important sector to consider here is the medium size commercial PV installations that have the potential to significantly reduce peak demand (MVA) during summer heat waves on local networks and aggregated demand (MVA) across the whole network. This is because solar output better matches the demand profile during these events.
- **Large Scale Renewables via Reverse Auction –** Reverse auctions are an excellent tool to facilitate the uptake of larger scale renewables. The State Government's suggested 40MW reverse auction proposal is welcomed, but is very small capacity (MW) by world standards. A stronger goal should be set. As coal plants are retired and if energy consumption (GWh) increases again, then much larger reverse auctions will be required.
- **Innovation and Threats to Business as Usual –** There are a range of innovative emerging technologies, that are rapidly developing and reducing in cost, that are already impacting on the current business model for electricity generation and sales. These include roof-top solar PV, energy management technologies, on-site energy storage and electric vehicles. Energy policy should embrace the adoption of these new technologies as there are clear environmental, economic and social benefits.
- **Incentivising the Distribution Companies to support Renewables –** Identify and implement strategies to incentivise Ergon and Energex to support distributed renewable energy electricity generation and storage, and energy efficiency technologies.
- **Energy Storage** - Implement measures to encourage the uptake of energy storage technology to facilitate integration of renewables to displace of fossil fuels. This should recognise the many benefits energy storage brings to network management, and hence the distribution companies, and ensures full utilisation of renewable energy. Energy storage can be both small and larger scale. An example of small scale storage is the Tesla energy storage "Power Wall" product recently released, which is set to make local storage for solar PV affordable (http://www.teslamotors.com/powerwall). An example of large scale storage is the potential use of pumped hydro-electric storage along the Great Dividing Range of Eastern Australia as outlined by ANU researchers (Blakers et al, 2010; 2014). Note that research by Elliston et al (2013; 2014), modelling a mix of renewable energy electricity generators, examines the extent of energy storage required for 100 percent renewable energy electricity with a diversified, distributed electricity system.
- **R&D** – Provide incentives for research and development projects by working closely with the Australian Renewable Energy Agency (ARENA). If the ARENA is shut down by the LNP

Federal Government, then establish similar State based programs to those currently run by the ARENA.

## Reinforcing Existing Polices

- **Electricity Market Reform** – Work with the Federal Government and AEMO to incentivise energy generators/retailers to shift to the ***energy services model*** **(RMI, 2011)**, rather than the outdated energy sales model, and to reward retailers and distributors for implementing energy efficiency and on-site generation and storage.
- **Regional Development** – Promote regional development through the use of renewable energy farming or energy storage (such as pumped hydro-electric storage) on marginal soil areas to complement traditional food production on good quality soil. This diversifies the farmers' income and improves resilience during weather extremes such as droughts. As wind and solar energy farming would still have to complete against low cost energy from old coal generators at $30 to $50 per Megawatt-hour (MWh), the currently higher cost of solar and wind farming could be funded, at least partly, from monies usually provided to farming communities after extreme weather events, and by redirecting subsidised funding away from the profitable coal and gas mining industries. Furthermore, the State Government has recently allocated $200 million over 2 years to support regional development programs. Some of this money could be directed to renewable energy and energy efficiency projects in regional areas.
- **Sustainable Buildings** - Establish ***best practice*** sustainable buildings policies, for both new and retrofitted buildings. These should assist the uptake of solar PV, solar hot water and energy efficiency and management systems, as well as energy storage. Best practice helps to raise the bar above minimum standards and encourages innovation.
- **Social Housing** – Establish programs for low income home owners or renters to access solar PV, solar hot water systems and energy efficient technologies in their homes. Examine the South Australian government's three-way contracting model as a possible model.
- **Government procurement polices** – Introduce government renewable energy and energy efficiency procurement plans for both State and Local Government.
- **Local Government** – Facilitate Local Governments' role in assisting a renewable energy transition. This could include ***community owned renewable energy*** systems on public buildings, and energy efficiency education and implementation programs.
- **Education and Training –** Provide one stop shops for consumer information and ensure **current training programs meet the needs of the rapidly changing energy industries**, both on the demand and supply sides.

## Removing Subsidies and Exemptions

- **Remove subsidies, including infrastructure expenditure, to the fossil fuel industry** and redirect these monies to the development and deployment of renewable energy and energy efficiency technologies.
- **Moratorium on New Fossil Fuel Power Stations** - Put in place a moratorium on the building of new coal fired and gas power stations unless they are fuelled by renewable energy sources such as biomass.
- **Exemptions for Large Industry and Projects -** Remove the exemption for major industries and ''significant projects" from the purchase of gas powered or renewable energy electricity. Note that a threshold consumption of 750GWh per year applies to these industries or projects.

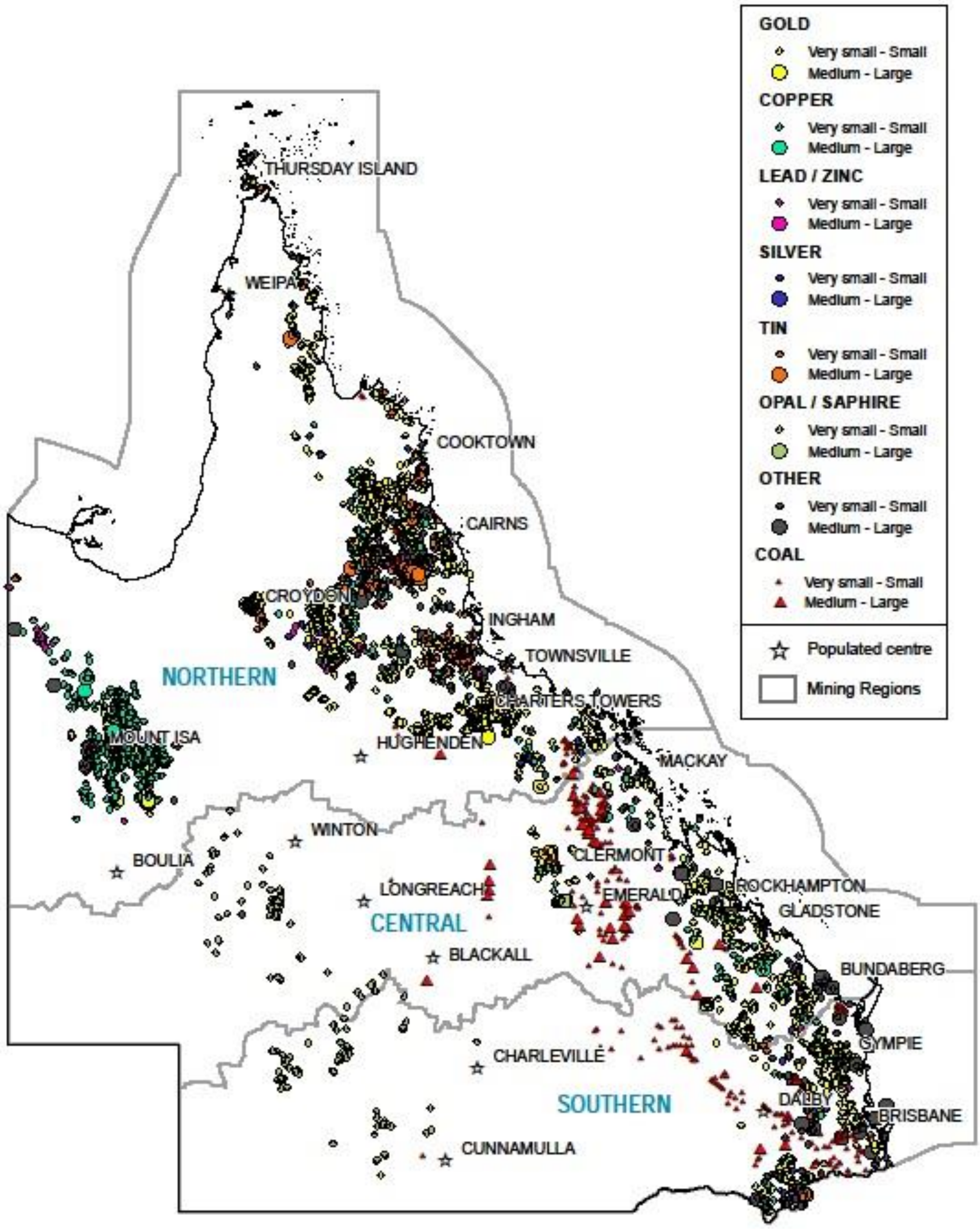
# Appendix 1 - External Costs of Coal-Fired Electricity over Life Cycle

Mean values from Study by Epstein, P. et al (2011). Full cost accounting for the life cycle of coal. Published in Annals of the New York Academy of Science: Ecological Economics Reviews

| Life Cycle | Externalities | External Cost (c/kWh) US |
|---|---|---|
| Mining | Subsidies – electricity/water/fuel rebates<br>Reduced Prop. Values<br>Displacement of other industries / Jobs / long term earnings – Agriculture/Tourism<br>Econ. Boom/bust cycle of commodities<br>Mortalities/Morbidity workers / community<br>Trauma surrounding communities<br>Accidents and Fatalities – workers/ transport /subsidence<br>Hospitalisation costs<br>Heavy metals and contaminated land / rivers /estuaries / GBR<br>Loss of habitat and species<br>Air pollution<br>Acid mine drainage<br>Methane emissions<br>Rehabilitation and monitoring | 4.4 |
| Transportation - 70% of rail traffic is for Coal (USA) | Subsidies<br>Rail and road repairs<br>Accidents and Fatalities<br>Hospitalisation costs<br>GHG emissions<br>Air pollution<br>Vegetation damage | 0.09 |
| Combustion | Mortality/Morbidity<br>Hospitalisation costs<br>GHG emissions<br>Other Air pollutants (NOx, mercury, arsenic, selenium , Ozone and particulates)<br>Infrastructure deterioration – acid rain<br>Rail and road repairs<br>Water and Marine pollution<br>Soil contamination, coal ash and other wastes<br>Freshwater use | 12.7 |
| Abandoned Mines and Waste Disposal | Heavy metal health impacts – contamination, trauma following spills, tailing dam failure | 0.44 |
| Transmission | Energy losses<br>Ecosystem disturbance<br>Vulnerability of grid to climate change events | 0.01 |

**Figure 11 - Abandoned Mine Sites in Queensland – An example of a very significant external cost that is not fully included in current mining costs.**

Source: https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0003/262659/abandoned-mines-map.pdf



# Appendix 2 – Modelling Renewable Electricity Generation on the National Electricity Market

Diesendorf and colleagues from the University of New South Wales have now undertaken thousands of simulations of the hourly operation of the national eastern electricity grid, when supplied by electricity from a geographically distributed mix of renewable energy technologies. “This research demonstrates that 100 percent renewable electricity in the NEM is technically feasible for the year 2010, meeting the NEM reliability standard with only six hours in the year where demand is unmet. This result is obtained by using renewable energy technologies that are either in full mass production (wind, PV, hydro and bio-fuelled gas turbines) or a technology in limited mass production (Concentrating Solar Thermal (CST) with thermal storage).” (Elliston et al, 2013; 2014). This work confirms similar modelling in the Beyond Zero Emissions (BZE) Stationary Energy Plan (Wright & Hearps, 2010). Similar studies have been undertaken in other countries such as Germany and the USA, all with similar results (NREL, 2012).

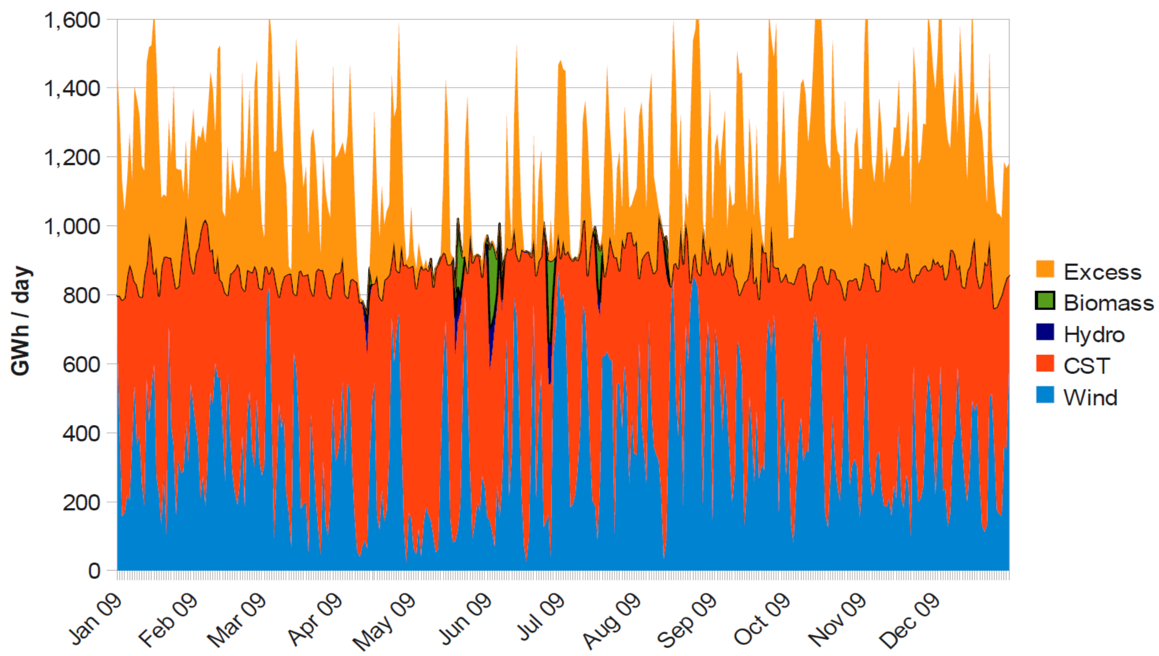
**Most importantly, these studies dispel the myth that renewable energy technologies cannot replace a fossil fuel based electricity system, including the provision of base load. They also show that this is the most economic option when combined with energy efficiency, and when a modest level of carbon price is included.**

### Figure 12 - BZE Modelling of NEM, 2009, showing 100% Renewable Energy Supply

Note: Demand Curve is the thin dark blue line at the top of the red section.

Source: Wright & Hearps, 2010:81.

FIGURE 4.2
ZCA2020 Grid Model, 2009 (Results shown in daily averages, underlying model on half-hourly data)



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# Glossary

## Death Spiral

The traditional model of electricity generation via large centralised plant is based on a return on investment mostly via sales of electricity (units of energy) and peak power demand charges (cost per peak MW over a half-hour period in any billing period). They also charge a fixed cost for maintenance and metering. The death spiral for these generators occurs when their ability to remain profitable is threatened. It occurs when large generators such as coal and gas fired power stations lose market share to on-site generators and energy efficiency measures as both reduce sales of electricity. In order to try to remain profitable, they increase fixed charges to customers. This increases customers' costs and encourages them to seek cheaper options such as more on-site generation or energy efficiency or both. Hence the large generators become increasingly less profitable which results in a ''death spiral'' for their business (Diesendorf, 2014:247).

## Energy versus Power (Demand)

Often different terms are used for energy and power, sometimes incorrectly and interchangeably. The term 'demand' is one such term that is used for both energy and power. For the purposes of clarity and consistency in meaning:

**Energy** (joules) is measured as the product of power (joules/second) and time. Energy in electrical systems is converted from joules to typically kilowatt-hours, Megawatt-hours and Gigawatt-hours (See Units section below). The terms for energy produced or used in this paper are energy generation or energy consumption or use. Typically they are stated in Gigawatt-hours.

**Power** is the rate at which energy is generated or consumed each second. It is measured in joules per second where 1 joule per second equals 1 watt. The common unit used here is the Megawatt (MW). For example, a power station might be rated at 200MW maximum power. However, when dealing with **peak power** of the alternating current (AC) electricity network, the term **demand** is used. It measured in MegaVolt-Amperes (MVA). This is called the apparent power within the electrical transmission and distribution system. It is calculated as the real power (MW) divided by the system power factor. Power factor accounts for the effect of different types of electrical loads on the relationship between voltage and current in alternating current systems.

## Merit Order Effect

Different power stations make offers to sell their power at each 15 minute time period throughout each day. Participants are incentivised to offer power at the short-run marginal costs of generation. This includes fuel and operating costs. The energy market operator then accepts the lowest to highest cost power providers in order until demand is met.

For wind and solar power, the fuel cost are zero and operating costs are very low. Hence these power providers can bid at very low prices and displace fossil fuel generators. This forces the fossil fuel generators to offer at prices lower than they would like and may be below profitable return rates (Diesendorf, 2014:244).

# Units

**Units of Energy** are listed as Gigawatt-hours (GWh) - 1GWh = 1,000Megawatt-hours (MWh) or 1,000,000 kilowatt-hours (kWh).

1 kilowatt-hour (kWh) = 1000 watt-hours (E.g. 10 x 20 Watt light-bulbs running for 5 hours)

1 megawatt-hour (MWh) = 1 million watt-hours

1 gigawatt-hour (GWh) = 1000 million watt-hours

**Units of Power** are listed as Megawatts (MW) – 1MW = 1000kilowatts (kW).

Units of Peak Demand are listed as MegaVolt-Amperes (MVA)

1000MW of power generated for 1hour = 1000MWh or 1GWh

## Conversions

1 kilowatt-hour = 3.6 megajoules

1 megawatt-hour = 3600 megajoules or 3.6 gigajoules

1 gigawatt-hour = 3600 gigajoules or 3.6 terajoules