Options for Sustainable Energy Planning for Australia

Merched Azzi

CSIRO Energy Technology 11 Julius avenue North Ryde 2113 Australia
E-mail: merched.azzi@csiro.au

Abstract -

Access to sustainable, affordable and secure energy is one of the major Australian strategic priorities to maintain and improve the health of Australians, sustain economic growth, and to mitigate climate change. Australia is investing in clean, efficient, reliable energy systems to secure a prosperous and, environmentally sustainable future. In addition, exploring the options to ensure energy security by diversification of energy sources is an important aspect for securing stability in meeting and delivering the future energy requirements of different industry sectors.

This paper discusses options to manage the production of electricity in Australia using available Australian resources while maintaining international competitiveness.

Keywords -

Future energy; sustainable energy; distributed generation; centralised power generation; Post combustion Capture; ISARC 2014

1 Introduction

Ensuring the availability of clean, abundant and affordable energy will play a key role in developing economic prosperity and enhanced environmental quality. Coal is a key source of energy for power generation. Anticipated growth in energy demand is likely to extend the use of coal for electricity generation. However, moving towards a low-carbon economy requires industry to use coal more efficiently and to reduce its environmental footprint.

It is now well accepted that emissions from fossil fuels burning should be limited because of their contribution to local and regional pollution in addition to their contribution to global warming. Stringent environmental regulations and the proposed future limits on greenhouse gas emissions from fossil-fuelled power plants have played a key role in initiating new research opportunities to overcome these difficulties.

Currently, efforts are being made by major research organisations to develop and demonstrate the availability of ultraclean, efficient, affordable fossil fuel energy technology that can be used to meet future requirements for energy production and use. If technological success is achieved it will be likely for coal and natural gas to remain major energy sources for power generation and will continue to meet the growing energy demand because of their abundant supply and relatively low cost when compared to other energy sources.

Carbon Capture and Storage (CCS) has been developed as a ready option to curb greenhouse gas emissions from industrial sources. The technology is based on (i) cleaning the flue gas stream then separating and capturing CO_2, (ii) compression and transport of CO_2, (iii) underground storage of CO_2. The wide deployment of CCS will reduce CO_2 emissions from industrial sources while ensuring that coal will remain as a relatively cheap option to power a sustainable economy.

Post combustion capture (PCC) of CO_2 using amine solvent is a readily available technology to capture CO_2 from coal-fired power plants. The process would be retrofitted downstream of the cleaned flue gas. The aqueous amine solvent will undergo a reversible chemical reaction with CO_2 and will selectively capture CO_2 from the flue gas stream. Under elevated temperature the CO_2 will be released and the lean solvent will be recycled back to absorb more CO_2 from the flue gas stream of the power plant. The flue gas exiting the power plant to enter the PCC includes different compounds such as sulphur oxides (SO_x), nitrogen oxides (NO_x), oxygen (O_2), particulates and other compounds. Some of these compounds interact with the solvent to produce different by-products which may affect the solvent performance. There is potential for selected by-products to leave the plant and undergo additional chemical reactions in the atmosphere. The full understanding of these chemical transformations is needed for plant operating approval where emissions from the plant should not exceed defined limits.

Over the last seven years CSIRO has been engaged in improving knowledge associated with the operation of PCC plants, development of new solvents to resist degradation, elucidating the chemistry of amines in the process and their fate in the atmosphere, and acquiring information to carry out environmental assessment for future PCC deployment in Australia and internationally.

2 Low-Carbon Electricity

There is an urgent need to explore practical options that can help Australia to use available energy resources for electricity production as we move forward to a reliable and sustainable energy future. In Australia and globally, electricity generation from fossil fuelled plants has been subject to stringent environmental regulations because of concerns about their effects on air, water quality and their contribution to greenhouse gas emissions.

Centralised large fossil fuels power plants and decentralised energy generation from renewable sources will present the new mix of electricity generation in Australia. The new generation mix represents an attempt to shift from conventional centralised fossil fuels generation to more efficient emission-free or near zero emissions from a variety of energy sources.

How well can we plan and implement sustainable energy systems in Australia?

For centralised power plants, it is crucial to assess the use of high efficiency centralised large fossil-fuelled power plants equipped with emissions reduction technologies and potentially carbon capture systems.

A successful sustainable centralised power generation system will be measured by meeting the following targets: increasing efficiency, significantly reducing emissions while keeping costs low for consumers.

How to deploy sustainable decentralised power generation in Australian urban areas?

The most decentralised electricity generation will be produced from a variety of renewable sources including gas, solar, biomass and natural gas and winds. In contrast to conventional generation, decentralised generation consists of smaller scale generation sources interconnected to a utility's distribution grid.

It is expected that the new energy mix system will exhibit a tremendous complexity manifested by its diversity, dynamic behaviour, space and power output. The anticipated energy system would have to ensure the security of supply under different operating modes and be able to demonstrate the safe and environmentally sound operation of the selected system.

What Environmental Regulations and policies are needed?

Thermal power plants are currently the major source of electricity in Australia. Incorporating a large fraction of electricity generation from other sources such as concentrating solar power systems, photovoltaic and others will require changes to many existing regulatory aspects and policies to take account of the new energy sources.

2.1 Decentralised Power Generation

Decentralised energy generation has the potential to supply part of the needed electricity using multiple stationary power generators installed close to end-users. The approach is referred to as distributed generation (DG), which shifts the design and layout of power generation and distribution systems to reduce pollution by increasing efficiency and promoting the inclusion of renewable energy sources. The DG model operates on more efficient smaller-scale than traditional systems.

The DG configuration does not require transmission, as sources are connected directly to the lower-voltage distribution network. Advanced technological achievements in addition to more stringent environmental regulations have resulted in great interest for the deployment of distributed generation systems.

The integration of different decentralised energy generation sources with existing centralised power plants requires extensive management to secure the electricity supply to customers.

The distributed generators technologies that are likely to be implemented in major Australian cities include but are not limited to natural gas fired combustion turbines, natural gas fired reciprocating internal combustion engines, natural gas fired micro-turbines, solar photovoltaics and wind turbines. The mix may also include diesel and petroleum distillate fuelled units that can be used as back-up generators.

Economic, regulatory and environmental requirements will play major roles in the selection of the mix of DG technologies to be installed in a region.

It is expected that some candidate generator technologies will emit different or more pollutants than central power plants. Many of the proposed technologies that might be adopted within urban areas would result in displaced emissions. It is also anticipated that all electricity generators may experience some degradation in efficiency performance and consequent degradation in terms of pollutant emissions performance. A systematic methodology for the development of realistic distributed generation deployment scenarios is needed. This methodology will take into consideration all characteristics and factors needed to minimise the local concentration profiles of pollutants expected from operating these generators with the least environmental and health impacts.

To assess the environmental benefits of DG in an airshed it is important to consider the mix of technologies employed, total percentage of DG in the region, emission profiles, and the use of an appropriate dispersion model in order to quantify how the deployment of the new energy mix can result in improved air quality by increasing efficiency and reducing pollutant emissions.

A study carried out by Azzi et. al. 2012 [1], has investigated the air quality impacts of a scenario in which the energy generation paradigm moves from large centralised energy generation (such as coal-fired power station) to the wide spread deployment of small power units which are located close to the point of use. The study considers a scenario in which DG is deployed across the Greater Sydney Region (GSR, includes Newcastle to the north and Wollongong to the South).

It was found that emissions of NO_x, VOC and CO associated with the DG deployment caused a small increase in domain-wide mortality (changing by less than 0.01 %). The DG deployment contributed an additional 1% to the existing pollution burden in the GSR. When ranking pollutants by degree of impact, nitrogen dioxide was found to be the limiting pollutant, most likely because the pathway between emitted NO_x and NO_2 involves fewer steps than the generation of ozone or secondary $PM_{2.5}$.

This study demonstrates how decision makers and stakeholders in NSW can plan for the future penetration of combustion based distributed generation systems using modelling tools and thus investigate optimal approaches to meet the State's growing electricity demands while minimizing health risks.

2.2 Centralised Power Generation

Coal remains the largest provider of electricity generation. Over 75% of Australia's electricity is still generated by coal-fired power plants. The traditional Australian electrical power system model consists of centrally-located power plants, transmission lines and distribution networks. While renewable energy sources have started to make inroads in the production of electricity in Australia, centralised coal-fired power plants typically located in remote areas will continue to be the major sources for electricity generation. These power plants are known for their low efficiency, high emissions and large land disturbance. In addition, emissions of different pollutants with known environmental and health concerns have been associated with the operation of these plants. The major challenges to the continued use of coal are related to its environmental impact affected by emissions from coal combustion.

Emissions from fossil fuels combustion depend on the fuels used and the type of power plant that is using the fuels. Pollutants generated can include NO_x, SO_x, PM, and CO_2. There are other compounds expected to be produced resulting from incomplete combustion of fuels such as volatile organic compounds, unburned carbon and trace elements. It is recognised that natural gas is the least polluter of all fossil fuels resulting mainly in emissions of NO_x, CO_2 and very small amounts of other pollutants.

Over the last two decades, regulatory agencies have forced utility companies to meet more stringent emissions standards and improve efficiency. Many of the proposed solutions and policies to reduce emissions from these plants were achieved by technological improvements. The installation of pollution control and prevention equipments in order to reduce the amount of pollutants released to the atmosphere and meet environmental guidelines has helped the industry to operate under regulated limits of emissions.

The average efficiency of coal-fired power plants varies from under 30% to 45% (LHV,net). These differences arise from diverse factors including the age of plant, steam conditions and coal quality. Over 50% of operating plants use subcritical technology. Pulverized coal combustion in supercritical, ultra-supercritical steam cycle, and Integrated Coal gasification Combined gas turbine-steam Cycle (IGCC) technologies are proven efficient technologies which produce fewer GHG emissions per unit of power. These plants are being used in Asia, Europe and in the US. They provide more energy efficient systems for power generation from coal where more electricity is generated from the same amount of coal used with less emission. Different pollution control technologies are installed on modern coal plants to reduce emissions of atmospheric pollutants.

Reducing CO_2 emissions from coal-fired power plants would have a significant impact on climate change. Carbon capture and sequestration is a potential option to keep fossil fuels in the electricity mix. Incorporating carbon capture technologies into coal-fired power plants will reduce greenhouse gas (GHG) emissions from coal and also other pollutants emissions. Chemical absorption with amines is presently the only commercially available technology for industrial application. The CO_2 is first captured from the exhaust gas stream in an absorption tower. The absorbed CO_2 is then heated with steam to strip the CO_2 from the amine solution. . The regenerated amine is sent back to the absorber. The recovered CO_2 is cooled, dried, and then compressed to a supercritical fluid. At this stage the fluid can be piped to sequestration.

In a study carried out by CSIRO for the Australian National Low Emissions Coal Research and Development (ANLEC R&D) [2] it was found that Post Combustion Capture (PCC) technology to remove CO_2 from the flue gas of coal-fired power stations using an amine-based solvent has the potential to also reduce the emissions of nitrogen dioxides (NO_2), particulate matter (PM), and sulfur dioxide (SO_2), and hence lead to improved air quality. It is important to note that the retro-fitting of a PCC plant has the potential to impact on both the traditional air pollutants in addition to providing a source of new pollutants based on the emission and degradation products of monoethanolamine (MEA).

New generation sources have been introduced and pollution mitigation devices installed, but air quality impacts from electricity production still exist. Because of this, traditional systems have remained largely unchanged, with the exception of simple technological upgrades.

2.3 Environmental Regulations and policies

Concerns about the environmental impacts of fossil fuel production, processing and utilisation have pushed regulators to introduce regulations to reduce smog formation, air pollution, acid rain and other air pollution compounds. More recently, the reduction of GHG emissions has been the main focus because of its relationship with climate change concern.

These regulations are not the only environmental regulatory challenges facing the electric utility industry. Other new stringent regulations related to coal ash management and disposal and water discharge are being promulgated. Compliance with these new regulations will require new control devices and investment. Coal power utilities will be confronted unprecedented costs and management challenges to meet these new regulations.

The installation of different pollution control devices to meet existing and future environmental guidelines requires a cumulative assessment to avoid any counterproductive effects of these devices.

Decreasing reliance on fossil fuels by incorporating different energy sources from renewables and from natural gas will require different environmental regulations and policies to that designed for the existing thermal power plants. Future regulatory considerations for future energy mix technologies may include the future cost of carbon and increased control requirements for emissions.

References

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