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Toward sustainable energy usage in the power generation and construction sectors—a case study of Australia

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ABSTRACT

To be sustainable in energy usage in the future, there are two aspects that need to be considered: the energy supply or generation and the consumption side, including the closely linked construction and building industries which consume a large amount of energy. Essential requirements for energy efficiency are to produce less greenhouse gas emissions and to rely more on renewable energy sources for future sustainability. Policies for mitigation of the environment impact are having effects on both the supply and demand. While the former requires more alternate sources in smart grids and improved technologies for carbon capture and storage, the latter involves the reduction of energy wastes and greenhouse gas (GHG) emissions as prerequisites to green certification within the construction and building sector. Thus, access to sustainable, affordable, and secure energy is one of the major global strategic priorities to maintain and improve public health, sustain economic growth, and mitigate the effects of climate change. Toward this goal, many countries, including Australia, are investing in clean, efficient, reliable energy systems for a prosperous and environmentally sustainable future. Hence, exploring various options to ensure energy security by diversification of energy sources is an important step in meeting the future requirements and delivering clean energy to different industry sectors. This paper discusses options to manage the use of energy sources in the power generation and construction industries. Options for mitigation of environmental impact and for achievement of sustainable energy usage, such as building design with BIM, are discussed.

1. Introduction

As economies and populations are predicted to grow, the world demand for energy will increase. The US Energy Information Administration's (EIA's) "International Energy Outlook 2014" (IEO2014) [1] reported that world energy consumption will grow by 56% between 2010 and 2040. Fossil fuels will continue to supply nearly 80% of world energy use through 2040. Ensuring the availability of clean, abundant, and affordable energy will play a key role in developing economic prosperity and enhanced environmental quality. It is now well accepted that emissions from fossil fuels combustion should be limited because of their contribution to local and regional pollution as well as their contribution to global climate change [2].

Most of power generation and other energy-intensive industries rely on coal, a key source of energy. However, moving toward a low-carbon economy requires the existence of such industries that are capable of using coal more efficiently and of reducing its environmental footprint. From the consumption point, efficiency in energy usage is important in reducing emissions and mitigating impact on local environment such as air quality. In this regard, energy savings are essential in the major energy-consuming industries such as construction, building, and mining, in order to address the ultimate goal of improving environmental sustainability.

Construction industry uses energy at different stages of the project development, including preparation of land use, excavation, foundations, prefabrication, cement and concrete, manufacturing and transportation of building materials, construction equipment during the process, and disposal of construction wastes. Such activities are also associated with the emission of different types of air pollutants to the atmosphere that contribute directly to the greenhouse effect. Investigation of available options to mitigate emission in this industry sector will promote environmental sustainability. For example, activities related to the cement industry contribute to around 5% of global emission of carbon dioxide (CO_2) [3]. Options to effectively manage the use of energy on construction sites can also help reduce carbon emissions from the site. Therefore, efficient measures need to be taken to save energy, reduce hazardous wastes, and control GHG emissions in order to transform construction gradually into a low-carbon and sustainable industry.

Building construction consumes 32% of the world's resources and hence consumes a significant amount of energy. Buildings also produce 40% of wastes going to landfill and 40% of air emissions. With the

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ever-increasing world population and given that more and more anthropogenic activities are taking place indoor, building services are consuming a large fraction of the total electricity. In fact, 8% of Australian GHG emission is produced by commercial buildings, according to the Green Building Council of Australia (GBCA) [4]. In the United States, buildings are responsible for almost half of all greenhouse gas emissions and they consume about three-quarters of all electricity generated by power plants [5]. Therefore, design and development of built infrastructure, highly efficient energy usage, and ecological adaptation not only reduce the impact on environment and save the running cost hence bringing economic benefits but also create a sense of well-being and health for building occupants, resulting in increased productivity in the long run. The demand for sustainable buildings is increasing worldwide and many companies are vying for business in the design and construction of green buildings.

More stringent environmental regulations in addition to the proposed limits on greenhouse gas emissions from fossil-fuelled power plants have played a key role in initiating new research opportunities to help meet these new targets [2]. Currently, efforts are being made by major research organizations 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 this technological success is achieved, it will be likely for coal and natural gas to remain the 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.

Construction and mining sectors constitute an important link in the planning process for sustainability of energy usage, especially in countries with heavy economic reliance on the mining industry such as Australia. Automation and control technology hence play a key role in the contribution toward achieving future energy and environment sustainability.

Following the introduction, the following sections of this paper presents the carbon capture technology and discusses emission control options that can be applicable to the power generation and construction industries.

2. Carbon capture technology

Reduction of carbon emissions from anthropogenic activities is a complex challenge for all industries. Different options are being attempted to tackle this problem. One of the advanced options is the carbon capture and storage (CCS) option. The CCS technology has been developed for the purpose of curbing greenhouse gas emissions from industrial processes. The technology is based on (i) cleaning the flue gas stream then separating and capturing carbon dioxide (CO_2), (ii) compression and transport of CO_2, and (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.

Reducing CO_2 emissions from coal-fired power plants would have a significant impact on reducing the effects of 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 GHG emissions from coal and emissions of other pollutants. Chemical absorption with amines is presently the only commercially available technology for industrial applications in that regard. 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.

Post-combustion capture (PCC) of CO_2 using amine solvent, as illustrated in Fig. 1, is a readily available technology to capture CO_2 from coal-fired power plants and from the cement industry in construction. 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, 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 sulfur oxides (SO_x), nitrogen oxides (NO_x), oxygen (O_2), particulate matters, 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 years, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia has been engaged in improving the 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 other parts of the world.

The process flow sheet with various streams around CO_2 absorber and stripper with their steady state flow rate, temperature, and pressure values is simulated by using Aspen-Plus software, typically for the CO_2 capture plant during direct caustic wash.

It can be shown that cooling the absorber outlet gas and washing it with a large quantity of circulating demineralized water in the wash tower can minimize emissions of mono-ethanolamine (MEA) and its degradation products to the atmosphere [6]. In another study, it was also found that besides removing CO_2 from the flue gas of coal-fired power stations using an amine-based solvent, the PCC technology can be used also to reduce the emissions of nitrogen dioxide (NO_2), particulate matter (PM), and sulfur dioxide (SO_2), leading consequently to improved air quality [7]. It is important to note that retro-fitting a PCC plant has the potential to impact both the traditional air pollutants in addition to providing a source of new pollutants based on emission and degradation products of MEA.

It is expected that regional air quality modeling systems, currently used to access the impact of source emissions of different speciation profiles on air pollution, will be applied in the near future to access the impact of PCC emission profiles on the formation of secondary air pollutants such as ozone and secondary organic aerosols (SOA). Joint research efforts have been carried out to develop an enhanced ozone and particle formation model to access the impact of different source emission profiles on air pollution in the Sydney basin and surrounding regions [8].

3. Emissions from construction activities

Construction activities are a multi-stage process that includes the design, construction, use, and demolition of building and infrastructure. Construction also includes indirect activities that encompass earthwork handling, extraction of various raw materials, energy-intensive processes associated with manufacturing, and delivery of the building materials.

The carbon footprint of the construction industry extends to the supply chains where the footprint of individual products is needed to identify carbon "hot spots" and to focus efforts on carbon reduction from the identified suppliers. There is room for improving the performance in the process or operational management. For example, it has been shown that emission of CO_2 is increased while the engine of nonroad diesel construction equipment is idling [9].

Construction activities may have a certain environmental impact that extends from land use to emissions from energy use. The emissions commonly generated from the construction industry include exhaust