



The cost of conserved water for power generation from renewable energy technologies in Alberta, Canada



Babkir Ali

Donadeo Innovation Centre for Engineering, Department of Mechanical Engineering, University of Alberta, Edmonton, Alberta T6G 1H9, Canada

ARTICLE INFO

Keywords:

Sustainability
Water conservation
Electricity
Environmental impacts
Generation cost

ABSTRACT

The main objective of this paper is to integrate water demand coefficients with the levelized cost of electricity to study the impact of renewable energy technologies on the sustainability of the power generation pathways. The cost of conserved water was developed for each of the 60 renewable energy pathways based on a reference case. The current case of power generation in the Province of Alberta, Canada was considered to be the reference. Nuclear energy has the lowest cost of conserved water (CCW) compared to the other renewable energy pathways. The CCW for nuclear energy pathways in Alberta is in the range 0.42–0.55 USD per m³ of water consumption saved during the complete life cycle followed by 1.11 USD/m³ as a corresponding CCW for wind energy. The cost of conserved water for nuclear energy pathways using the closed loop cooling system in Alberta is in the range 0.34–0.42 USD per m³ of water withdrawals saved during the complete life cycle followed by 0.84 USD/m³ as a corresponding CCW for wind energy. Levelized cost of electricity from wind energy in the reference case of Alberta has to be reduced by 32% and 4% based on the water consumption for the power generation stage and complete life cycle, respectively, to achieve a cost of conserved water of one USD per m³ of water saved.

1. Introduction

The developed knowledge of water demand for power generation through water-energy nexus can result in a more sustainable solution if it is extended from the relationship boundary of “water for energy” and “energy for water” [1] to include the economic impacts. Water-energy nexus used in the research community as a useful tool for sustainability assessment [2] and the economic impacts as a sustainability pillar would add a new dimension for this assessment. Macknick et al. [3] reviewed the operational water demand coefficients for conventional and renewable energy technologies and highlighted that these developed coefficients could be accompanied with energy-economic aspects to evaluate water use for different electricity generation scenarios. To achieve a comprehensive solution with the most sustainable pathways for power generation, the concept has to be extended to cover different views. These views should not be limited to environmental factors but to cover socioeconomic aspects and better management of natural resources [4]. Lee et al. [5] integrated economic and environmental concepts to optimize the design parameters of wastewater treatment plant with combined power generation systems.

Renewable energy technologies were proposed as clean pathways to mitigate the greenhouse gas (GHG) emissions. Nugent and Sovacool [6] studied GHG emissions from wind and solar photovoltaic (PV) based on the complete life cycle and concluded that these two pathways have low

carbon emissions. Raadal et al. [7] studied the complete life cycle GHG emissions from six offshore wind power plants each with a capacity 5 MW and found this technology can compete for the GHG emissions from nuclear, photovoltaic, and hydroelectricity. Evaluation of renewable energy sustainability from a single isolated viewpoint of GHG emissions can be limited if not integrated with impacts on water demand and economic factors. Currently, renewable energy technologies suffer from high initial costs, and still, the competition is very sharp with the conventional energy. Trainer [8] has concluded that Europe cannot depend 100% on renewable energy due to its very high capital cost. Renewable energy technologies are still under research and development and have more opportunities to improve and to be cost-effective in power generation sector. Energy storage and hybrid systems are examples of new improvements have been substantially researched to make renewable energy more reliable and competitive with the conventional energy sources [9]. A questionnaire conducted by Zyadin et al. [10] found that the insufficient support from the governmental decision makers, the sharp competition with conventional energy sources, and less support and awareness from the public are the most challenges facing the utilization of renewable energy.

Levelized cost of electricity (LCOE) and water demand coefficients were developed independently as indicators in the earlier studies to conduct a comparative assessment of power generation technologies. LCOE indicator has been used for projection of the feasibility of

E-mail address: babkir@ualberta.ca.

<http://dx.doi.org/10.1016/j.enconman.2017.08.019>

Received 1 June 2017; Received in revised form 10 July 2017; Accepted 6 August 2017
0196-8904/ © 2017 Elsevier Ltd. All rights reserved.

Nomenclature

AESO	Alberta Electric System Operator	MW	megawatt, equal to 10^6 watt
CCW	cost of conserved water	MWh	megawatt-hour, equal to 10^6 watt-hour
C-Si	crystalline silicon	m^3	cubic metre, a unit of volume in the metric system, equal to a volume of a cube with edges one metre
DOE	U.S. Department of Energy	NETL	National Energy Technology Laboratory
EGS	enhanced geothermal system	NREL	National Renewable Energy Laboratory
EIA	the U.S. Energy Information Administration	PV	solar photovoltaic
GHG	greenhouse gas	TWh	terawatt-hour, equal to 10^{12} watt-hour
LCOE	levelized cost of electricity	USD	the United States Dollar
LCOEA	levelized cost of electricity in USD/MWh for the reference case	WDCA	water demand coefficient in m^3 /MWh for the reference case
LCOER	levelized cost of electricity in USD/MWh generated from a renewable energy technology pathway	WDCR	water demand coefficient in m^3 /MWh generated from a renewable energy technology pathway
m^3 /MWh	cubic metre of water per megawatt-hour of power generated	η	conversion efficiency of the power generation from renewable technology

renewable energy pathways [11] and also used as an economic indicator for comparative assessment after retrofitting new technologies [12]. Mari [13] investigated the viability competitiveness of nuclear energy compared to the fossil fuel-based power generation through LCOE indicators and highlighted that nuclear energy is of high potential to compete with conventional energy if the risk for investors is kept at low levels.

Singh et al. [14] studied the integration of energy requirement and water consumption for biomass conversion pathways and found that bioethanol production from agricultural residues is the most water and energy efficient pathway. Liu et al. [15] evaluated water conservation and energy efficiency after integrating re-drying and water recovery technologies and found that moisture content is a key factor for improving environmental impacts of lignite-based power plants. Meldrum et al. [16] reviewed and harmonized water demand coefficients for the complete life cycle of electricity generation from conventional and renewable energy pathways and concluded that photovoltaics and wind energy are the lowest water use pathways and thermal power generation pathways are the highest. Water demand coefficients were developed for comparative assessment of 60 power generation pathways based on renewable energy technologies [17]. Extensive pathways were structured based on complete life cycle of fuel extraction, power generation technology, and cooling system, to study the water footprints of coal-based [18] and gas-fired [19] power generation. There is a scarcity of the studies to combine both indicators simultaneously to analyze water use and economical aspect of the technologies. Eco-efficiency can be achieved by improving competitiveness, increasing satisfaction, reducing environmental impacts, and utilizing minimum natural resources [20] and these improvements were measured through indicators taking into account the cost per unit of environmental output. In the same context, the cost of generation can be integrated with water demand for renewable power generation pathways to develop a new indicator for more comprehensive sustainability assessment. Integration of both water demand and LCOE indicators would give a brief background for the water pricing in power generation sector.

Considerable debates were conducted in Canada to discuss the role of water pricing in conservation. Assigning a price for water would be a useful tool for water management in Canada [21]. Renzetti [22] highlighted the importance of proper water pricing in the Canadian municipalities by using water meters, accounting for all costs, and adding the cost due to the extra water use during the summer season. Bodimeade and Renzetti [23] discussed the affordability of water supplies in Canada and stated that the current water pricing could negatively impact low-income households, while other studies stated that water revenue in Canada is not enough to face operation, maintenance, and new development costs [24]. The Council of Canadians supported by other public groups has established a framework that freshwater should be

treated as a human right and not as other normal goods in the market [25]. Water price was determined by DeNooyer et al. [26] after dividing the annual cooling cost by the average annual water withdrawals saved as a result of replacing once-through cooling systems in power plants by closed loop cooling systems.

The power generation in the Province of Alberta, Canada relies mainly on the fossil fuels based on coal and natural gas resources. This generation mix represents a challenge for the province regarding the climate change and high GHG emissions from coal power plants. The total GHG emissions in 2010 from energy used in Alberta for residential, commercial, industrial, transportation, and agricultural sectors was 107 million tonnes of CO₂ equivalent [27]. To mitigate GHG emissions, the Climate Leadership Report [28] recommended phasing-out of all coal power plants in Alberta by 2030 and the consequent power generation gap to be covered by increasing the share of generation from renewable energy pathways by 30% of the total. The impacts of this recommendation on natural resources such as water and land were overlooked. In 2007 about 24% of total water allocations in Alberta were for thermal power plants cooling, and in 2005 the estimated water consumed for industrial cooling was about 96 million m^3 mostly for coal-fired power plants [29]. Alberta produces and uses over 25 million tonnes of coal annually to generate electricity, about 70% of natural gas production in Canada, and the third petroleum oil reserves in the globe following Saudi Arabia and Venezuela [30]. Petroleum oil production in Alberta depends mainly on the oil sands recovery and the associated unit operations with this technology is of intensive energy use [31] and consequently have significant negative environmental impacts on water, air, and land. The potential of power generation from renewable energy technologies is very high in Alberta [32]. The identified potential hydroelectricity generation in Alberta is about 42 TWh/year [33], and the Canadian Hydropower Association estimated the undeveloped potential power capacity for hydroelectricity in Alberta as 11.8 GW [34]. Wind energy potential is very high in Alberta, and at the end of 2014, the installed wind energy capacity was 1471 MW as the third province in Canada to have this capacity [35]. Some industries are recovering waste heat and provides Alberta electric grid with the power generated from this pathway [36]. Hossein and Keith [37] studied the compressed air energy storage system utilizing waste heat in Alberta and found the technology with a positive economic and environmental impacts.

A renewable energy pathway could have impacts on water and cost of generation different than its impact on GHG emissions. The novelty of the present paper is the integration of water demand coefficients and LCOE for power generation pathways based on renewable energy sources to support the decision making regarding the sustainability assessment of these clean technologies with a more disciplinary view. The originality of this study is the introduction of new metric of the cost

Download English Version:

<https://daneshyari.com/en/article/5012250>

Download Persian Version:

<https://daneshyari.com/article/5012250>

[Daneshyari.com](https://daneshyari.com)