INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 41 (2016) 8337–8346

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Integration of transportation energy processes with a net zero energy community using captured waste hydrogen from electrochemical plants

Shahryar Garmsiri [a,*], Seama Koohi-Fayegh [a], Marc A. Rosen [a], Gordon Rymal Smith [b]

[a] University of Ontario Institute of Technology, Faculty of Engineering and Applied Science, 2000 Simcoe St. North, Oshawa, ON, L1H 7K4, Canada

[b] Change Energy Services, 2140 Winston Park Dr., Oakville, ON, L6H 5V5, Canada

ARTICLE INFO

Article history:
Received 31 July 2015
Received in revised form
6 November 2015
Accepted 11 November 2015
Available online 31 March 2016

Keywords:
Hydrogen energy
Waste-hydrogen recovery
Net zero energy community
Greenhouse gas emissions
Fuel cell
Transportation energy integration

ABSTRACT

Currently, hydrocarbon fuels are the main source of energy used in the transportation sector. However, these fuels are responsible for a relatively large proportion of the overall greenhouse gas emissions in many societies. In an effort to reduce greenhouse gas emissions, alternative energy carriers such as hydrogen can be used to allow renewable energy resources to replace hydrocarbon fuels in the transportation sector. Electrochemical and other process industries frequently vent or flare hydrogen into the atmosphere. These electrochemical industries use sodium chlorate or chlor-alkali as a reactor for water purification and paper bleaching processes in which hydrogen is produced as a by-product. The vented or flared hydrogen can be captured for use in the transportation sector.

When considering a net zero energy community, the transportation energy sector is often viewed as independent from the building sector of the community. In this paper, the integration of transportation energy with a net zero energy community utilizing captured waste hydrogen from chlor-alkali plants is examined. Methods integrating the energy use in transportation using hydrogen to meet the community energy demands and to achieve net zero energy balance in a community, are discussed.

Introduction

A net zero energy community (NZEC) is a community that offsets all of its energy consumption by using renewable energy sources available within the community's built environment. Most net zero energy communities use the electrical grid as a buffer to avoid the need for energy storage. Energy is typically generated on-site through a combination of renewable energy sources such as solar and wind. A net zero energy community often greatly reduces its energy needs through efficiency measures so that the balance of energy needed within the community, both thermal and electrical, is met by renewable sources of energy.

The European Strategic Energy Technology Plan and the "Smart Cities & Communities Initiative" encourage cities and regions to progress by 2020 towards a 40% reduction of greenhouse gas (GHG) emissions through the sustainable use and production of energy from renewable sources [13].

Building energy regulatory policies in many countries are moving towards achieving net zero energy or net zero carbon

* Corresponding author.
E-mail address: Shahryar.garmsiri@uoit.ca (S. Garmsiri).

http://dx.doi.org/10.1016/j.ijhydene.2015.11.191

[9]. In the United Kingdom, the target has been set at net zero carbon for new dwellings by 2016 [24]; in Europe, the European Union (EU) Directive on the Energy Performance of Buildings [13] specifies that by the end of 2020 all new buildings shall be near net zero energy buildings; and other nations such as the USA and Korea have begun exploring a policy path to net zero energy buildings by the 2020s [36].

Climate change has become an important topic world-wide, as have reduction targets for GHG emissions. The transport sector is identified as one of the key sectors contributing to climate change [7,37]; in industrialised countries, it contributes to approximately 20% of all GHG emissions [20,22].

In June 2014, the Toronto Atmospheric Fund and Toronto Environment Office reported that the majority of locally generated air pollutant emissions in Toronto were from road vehicles, estimated to be 80.5% with 35.5% of all air pollutants generated from cars and light trucks, 7% from heavy gasoline trucks and 38% from heavy diesel trucks [17]. Along with the growing gap between oil supply and demand globally, and the need to reduce GHG emissions, the use of alternative fuels and energy efficiency improvements are receiving increased attention [25].

Canada is making significant progress towards meeting its 2020 GHG emissions target of 607 Metric Tonne (MT) CO_2e [12]. The emissions target is expected to be reached with the upcoming federal policies and provincial measures, in particular oil and gas regulations [12]. However, to meet these emission targets by 2020, alternative methods of energy production must be considered. Though hydrogen energy technology has received attention in the last decade with significant progress in performance, reliability and cost, producing hydrogen gas from fossil fuels is not a clean, sustainable approach. Solar, wind, and hydro are some examples of renewable, clean and sustainable sources of energy for electricity production.

Although there are economic implications of hydrogen generation from renewable energy sources, there still exists the issue of waste in the community. Electrochemical and other process industries such as chlor-alkali plants frequently vent or flare hydrogen process gas into the atmosphere. These electrochemical industries use sodium chlorate or chlor-alkali as a reactant for water purification and paper bleaching processes in which hydrogen is produced as a by-product. The vented hydrogen is captured by the chlor-alkali plants and used as fuel to generate power for their processes. This hydrogen waste gas can be captured for use in a hydrogen fuel cell vehicle and stationary electrical power generation for electric vehicle and community energy needs.

A study of the economics of hydrogen production, storage and delivery was conducted by Balat [20] for transportation use. The environmental benefits were outlined, with key points demonstrating the potential benefits of renewable hydrogen production, and utilization for various modes of transportation. Other studies have considered various ways of combining hydrogen fuel cell operations to create a hybrid system for idle operations [19].

The Integrated Waste Hydrogen Utilization Project (IWHUP), the world's first waste-hydrogen capture system, was installed at a chemical plant in North Vancouver, British Columbia [23]; with additional waste-hydrogen capture systems in development. Modelling waste hydrogen gas recovery can present several challenges; since this vent waste hydrogen gas is often not considered as a usable potential source for community and transportation energy. In the IWHUP project, the waste hydrogen from the chlor-alkali plant is captured and purified at the source and the clean hydrogen gas is then transported [23] to a local distribution facility within a community where it can be used for many applications including transportation energy.

When considering a net zero energy community, the transportation energy sector is often viewed as independent from the building sector of the community. In this paper, the integration of transportation energy with a net zero energy community utilizing captured waste hydrogen from chlor-alkali plants is examined. Methods are described and discussed for integrating the energy use in transportation by using hydrogen for a net zero energy community, to meet the community energy demands. The objective of this paper is to demonstrate gaseous waste reduction and waste energy recovery for use in community and transportation. Furthermore to demonstrate the benefits of integration of transportation energy with a net zero energy community while utilizing vehicle's energy storage.

Background

Net zero energy buildings

A Net Zero Energy Building (NZEB) is a building that offsets all of its energy consumption by using renewable energy sources available within the building's built environment. The net zero energy performance may be achieved with two fundamental steps: 1) reduce building energy demand, and 2) generate electricity through energy recovery methods and integration of transportation energy using vehicle to grid energy transfer methods. In the first step, passive approaches play a fundamental role in addressing NZEB design; as these directly affect the loads on the mechanical and electrical systems of the buildings. The second step affects storage requirements indirectly, due to the energy recovery and energy storage capabilities on the vehicles.

Solar energy

In a photovoltaic (PV) module, a portion of the incident solar energy is converted into useful electricity, while the rest is either reflected or dissipated as heat. There are two ways of incorporating PV into the building envelope. The first is building added photovoltaic (BAPV) and the second is building integrated photovoltaic (BIPV) systems. In a BIPV system the PV modules are part of the building envelope, whereas the BAPV is an addition to the existing building envelope. In both BAPV and BIPV systems, the PV modules require cooling, and active heat recovery can be utilized using a closed loop liquid cooling unit or an open loop with forced air. If a heat recovery system is incorporated in either a BAPV or BIPV, the system is referred to as a building integrated photovoltaic/thermal (BIPV/T) system. In addition to generating electricity and useful heat, the BIPV/T system allows for a reduction in the building heating loads and