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Solar heating and cooling in buildings – how sustainable?

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Abstract

Conventional heating and cooling systems are responsible for large amounts of carbon dioxide release to the environment, as well as for the use of harmful refrigerants regarding the greenhouse effect and the ozone depletion potential. Solar radiation is a clean form of energy, which is required for almost all natural processes on earth. In South Africa, the majority of produced electricity is generated from fossil fuels and the potential of renewable energy sources is vast, solar radiation in particular is in abundance. The upper limit for Global Horizontal Irradiance (GHI) in South Africa can be as high as 2 300 kWh/m²/a, whereas the Direct Normal Irradiance (DNI) value attains a maximum of 2 900 kWh/m²/a, which is significantly higher than it is in other regions worldwide. The global air conditioning systems market has been estimated to reach 78.8 million units by 2015 due to increasing living standards, comfort expectations and global warming. South Africa is not the best performer regarding renewable energy use among African countries and there is a long way to go to achieve a sustainable environment. This paper seeks to investigate the feasibility and the sustainability of solar driven air conditioning system in South Africa based on meteological weather data. Currently, renewable energy is a topic of interest in South Africa after the 2008 energy emergency when power outages were rolled out due to inadequate maximum load planning. Solar air conditioning technology remains an untapped technology in South Africa.

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1. Introduction

1.1. Renewable energy

On the 24th January 2008, South Africa issued a state of emergency when the national electricity grid was brought to near collapse. Inadequate maximum load planning, wider mass electrification and economic growth are the main areas that demanded more power and that began to outstrip supply [1]. It is for this reason that renewable energy remains a contested topic in South Africa. The demand for electricity is increasing day by day, which cannot be fulfilled by non-renewable energy sources alone. Renewable energy considers the primary energy from recurring and non-depleting indigenous resources. It is a clean form of energy, which is required for almost all natural processes on earth [2]. Projections indicate that the world primary energy demand will expand by almost 60% from 2002 to 2030, and the average annual increase percentage is 1.7% per year. The demand will be reaching 16.5 billion tons of oil equivalents compared to 10.3 billion toes in 2002 [3]. Renewable sources of energy now stand poised to lead the world in new electricity supply. These resources are enormous, non-polluting, and virtually inexhaustible. Moreover, solar energy is the driving mechanism behind other renewable energy sources such as wind, hydropower, biomass, and animal power [4]. Supported by policies aimed at enhancing energy security and sustainability, renewable energy expanded at its fastest rate [5].

1.2. Solar air conditioning worldwide

The growing demand for traditional air conditioning has caused a rise in demand for key energy resources around the world. Countries like Egypt are able to estimate that 32% of the electric generation is used by the domestic sector for air conditioning [6]. Air conditioning systems contribute more than 30% to the total electricity consumption of buildings worldwide [1, 7-11]. This is mainly due to global warming and comfort expectations. Conventional air conditioning systems are understood to consume large amounts of energy produced by the burning of fossil fuels. The greenhouse gases being emitted to the atmosphere from these systems are responsible for global warming and environmental damage such as acid rain and detrimental effects on human health, e.g. asthma [12, 13].Photovoltaic air conditioning systems are much more cost effective compared to thermal air conditioning system, conversely the electricity generation is more cost effective with solar thermal plants [14]. Solar thermal cooling technology is most preferred to photovoltaic based cooling systems since it can utilize more incident sunlight directly compared to photovoltaic system [15]. Also it uses the solar absorption cooling principle which makes it suitable for use on remote building in places where there is an excess of heat energy available [16].

1.3. Potential for solar air conditioning

As of 2000 to 2008, the worldwide installed capacity of solar heating and cooling systems increased globally, growing with an average of 20.1% annually [17]. Global Industry Analyst (GIA) Inc. [18] announced that the global air conditioning market will reach 137.8 million units by 2020, driven mainly by global warming, rising standards of living and urbanization. According to a report published by BSRIA Inc. [19] the world air conditioning market continued to expand in 2014 compared to previous years. It has reached US$97.7 billion in value, an increase of up to 7% compared to 2013.

1.4. Solar air conditioning markets

UNEP [20] reported that 789.6 million m² of solar heat capacity was installed by end 2015 compared to 77.3 million m^2 in 2012. Data collected from 58 countries including Europe, North America, Brazil, South Africa, India, China and Australia indicate that 95% of the solar thermal market is installed in these countries [21]. Globally, solar thermal accounts for about 1.2% of water and space heating in buildings [20]. According to Yang (2012) [22] China has 57.6% of the world's recorded solar heating and cooling capacity with 21.7 GWth of new installations which makes up 74.6% of the solar heating and cooling market in the world.