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Sustainable Heating or Cooling and Ventilation of Affordable Zero-energy Housing

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Abstract

This paper updates the ongoing research, by simulation and experimentation for a sustainable low-energy method to heat or cool and ventilate affordable housing. Renewable sources are used to heat or cool water which is circulated to low temperature (22-25°C) radiators (LTRs) on inside faces to make houses as thermally comfortable as caves. In cool (15°C annual average temperature) Melbourne, Australia, water from 100m-deep VGHEs has been measured at 22-24°C. Using the 25-30°C increase in ground temperature per kilometre depth given by the International Panel on Climate Change, the depth should be about 200m. Most of the inhabited places have annual average temperature of more than 0°C, and the estimated depth would be less than 1 kilometre. Literature review is included in the introduction and discussion. Method for heating (experimental house/s in Melbourne, Australia) is grouped with simulated results and experimental findings. Next subsection presents experiments in hot tropical Kuching, Malaysia and simulated results. The heat extracted from VGHE in winter is sustainable because in summer, solar-heated water is used for replenishment. In summer and tropical climates, the fan, which can create a cooling sensation of up to 4°C can enable 30.5°C indoors comfortable. Low power is required to circulate water and operate fans and can come from photovoltaics on the roof, enabling off-grid or zero-energy houses. Plans for May-August 2018 experiments include the use of a 300W photovoltaic thermal (PV/T) i.e., outdoor air will be drawn through the gap between the metallic roof and insulated ceiling, to be preheated ventilation air in winter. In Kuching, Malaysia, the water is cooled by radiation to the night sky to 25°C. The cooling coil of a PV or PV/T powered chiller is proposed to make the water colder. Hotter days would likely have more solar radiation to generate more power for the photovoltaic to make the coil colder. The ground source heat pump is not used, thus the VGHE-LTR could be comparable in cost to conventional e.g., horizontal GHE with heat pumps and high temperature (about 50°C) radiators. LTRs could be integrated into the inside metal that clads structural insulated panels and housing would be affordably constructed. Funding is sought for an experimental house in cool/cold climates with LTRs heated by a 23°-bottom temperature VGHE.

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1. Introduction

This paper reports the latest in an ongoing use of simulation and experimentation to find a sustainable method to cool or heat, and ventilate affordable housing. Renewably-heated or renewably-cooled water is circulated to low temperature (about 22-25°C) radiators (LTRs) on inside surfaces to make houses as thermally comfortable as caves. Figure 1 shows cool/ cold places with annual average temperature (AAT) of 15°C/ 0°C and 30°C for hot places.

The first preferred renewable heat for cool to cold places is the vertical ground heat exchanger (VGHE) that can thermally stabilise water to 22-24°C for circulation, directly to LTRs. The depth is about 200m to 1km (25-30°C temperature increase/km depth, Intergovernmental International Panel on Climate Change, IPCC 2008 [1]). Measurements at 100m-deep (Ooi K., and Masa Noguchi 2016 [2]) and 50m-deep (Ooi K. et al 2015 [3]) VGHE in cool Melbourne Australia, which has an annual average temperature of 15°C, gives hotter water of 22-24°C and 15-17°C respectively. The cost of VGHE without heat pumps could be comparable with GHE with heat pumps studied by P.M Congedo et al. 2012 [4] and Xiong Z. et al. 2015 [5].

In hot places, the primary renewable coldness for water is radiation to night sky, which in Kuching, Malaysia has, since June 2015, cooled water to less than 25°C. Simulated and June 2017 experiment results are later discussed.

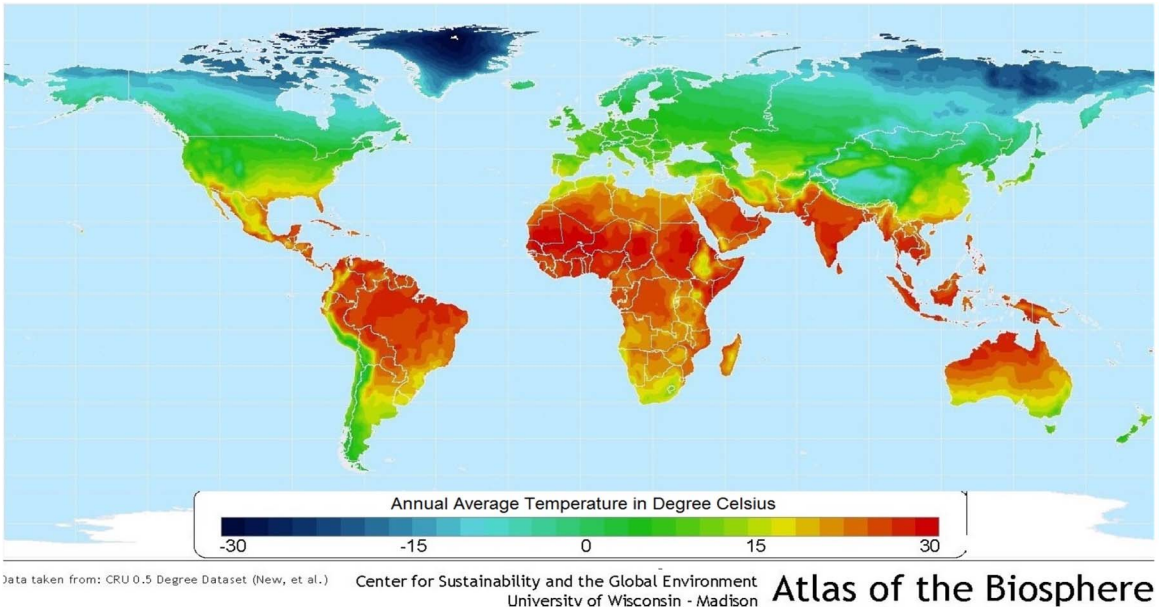

Fig 1 The annual average outdoor temperature of the world

Below are three pieces of information that support this ongoing research, followed by a literature review.

Nomenclature

LTR	Low temperature radiators on inside faces e.g., wall-LTR
VGHE	Vertical Ground Heat Exchanger i.e., water flow through U-tubes in vertical boreholes in the ground
PV/T	Photovoltaic (PV)/Thermal. i.e., PV cooled by air or water. This increases the efficiency of PV.