HBGD Ecosystems Testbed: CLEAN ENERGY

Clean On-Site Energy Generation: Reducing Indoor Air pollution while Improving Access to Energy for Mothers and Children in Rural Settings

Keywords: *clean renewable energy, reducing cook smoke, energy independence, transparent concentrating solar, air quality, reduced respiratory illness, reduced heat stress*

Executive Summary:
The Center for Architecture Science and Ecology (CASE) at RPI and it's collaborators are proposing a strategy for enabling residential solar energy collection which mitigates the adverse health effects to women and children from cooking with solid fuels and provides on-site energy generation and daylighting for improved quality of living. In order to better adapt to changing outdoor environmental conditions, energy and building researchers are integrating built environments with multifunctional energy transformation technology that deliver year-round qualitative requirements for human comfort and well-being (Heiselberg, 2012). Energy demands for cooking, in addition to lighting, ventilation, cooling, refrigeration, and mobile devices could be met by integrating a transparent, solar concentrating energy harvesting technology into the roof of residential homes, providing a seamless installation with reduced theft potential. The proposed system provides clean thermal and electrical power for occupants, reduces heat stress on the interior, and maintains desirable daylight conditions without glare or heat. Developing on-site solar energy capabilities for rural regions can improve the health of children and mothers by reducing exposure to harmful emissions from solid fuel combustion and promote well-being through improved access to energy.

Problem Statement:
According to the World Health Organization (Rehfuess, 2006), "The problem of indoor air pollution (related to solid fuel combustion) has been around since the Stone Age, yet international development agendas still fail to recognize that missing out on clean energy equals missing out on life." The WHO has labeled cooking and indoor air pollution from the burning of solid fuel as one of the top ten global health risks, responsible for 1.6 million deaths and respiratory illnesses that account for 2.7% of the global burden of disease every year (Rehfuess, 2006). In additions to adverse human health implications from household stove pollutant emission, continued biomass cooking practices could have effects on agriculture, fuel use, deforestation, and global climate change (Jetter, 2015).
To address the harmful effects of burning solid fuels, the Global Alliance for Clean Cookstoves was established by the United Nations Foundation (UNF) to provide 100 million clean cookstoves by 2020 (Smith, 2010). However, due to the energy poverty gap, three billion people worldwide still depend on the burning of solid fuels to cook with no access to electricity and natural gas until reaching a high income status (Rehfuess, 2006).
It is not only important to address reducing indoor air pollution, but also increase the access to reliable clean energy. Modern energy is essential for fulfilling basic social needs, driving economic growth and fueling human development because it has effects on productivity, health, education, safe water and communication services (Gaye, 2007). While many groups in the developing context are seeking to increase energy consumption with non-renewable resources, the challenge arises of how to sustainably and economically meet growing energy demands while simultaneously attempting to reduce adverse health effects of fossil fuel consumption in addition to mitigating emissions contributing to climate change.
Prior research and development has yet to deliver a building solution that can meet the quantitative environmental performance requirements for on-site clean energy, while also accommodating year round

qualitative requirements of human comfort and well-being within most building and climate types. Previous solar home initiatives to improve the access to clean renewable energy have failed due poor organisational structures, lack of solar maintenance and panel theft (Maegaard, 2008). More recent off-grid electrification program have been deemed unsustainable due to high operational cost and lack of user satisfactions from energy needs not being met (Azimoh, 2015).

Scope and Approach:

The mitigation of solid fuel combustion with clean energy sources has an immediate effect in improving indoor air quality and will reduce health risks to mother and child. The hypothesis is: if mother and newborn households in rural areas which primarily used solid fuels for cooking and with limited access to energy instead reside in homes with integrated solar energy harvesting which provides a clean alternative energy source for cooking, then the risk of pneumonia and acute infections link to cook smoke inhalation in children under the age of five, and chronic obstructive pulmonary disease (COPD) and lung cancer in women would be reduced by half (Rehfuess, 2006).

In the US, many state and local government programs have implemented clean energy policies that explore energy efficiency and renewable energy initiatives in order to reduce criteria air pollutants, such as ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead (DOE, 2008) (EPA, 2011). Integrating homes with clean on-site energy generation capabilities reduces emissions from combustion of nonrenewable fossil fuels and, in addition, can decrease air pollution attributed to transportation losses from conventional grid supplied energy.

Our approach to produce clean on-site energy built environments is to incorporate Integrated Concentrating Solar Facade (ICSF) system into mother and child households. ICSF uses high efficiency solar cells, heat transfer fluid, and transparent solar concentrating lens to generate electricity and high-grade thermal energy on the exterior surfaces and roofs of buildings. The generated electrical energy can be used for cooking, refrigeration, lighting, ventilation, HVAC or stored for later occupant demand. Thermal energy can provide hot water for cleaning, cooking, heating, or can be incorporated into air desiccation systems to improve indoor comfort.

Additionally, ICSF concentrates and intercepts direct normal irradiance, reducing large quantities of solar heat gain to the interior and mitigating heat stress on mother and child. The transparent components allow the transmittance of diffuse irradiance for natural daylighting with reduced glare and heat (Novelli, 2015).

Integrated Concentration Solar Facade (ICSF) provides electrical and thermal energy, reduced heat stress, and natural daylighting, promoting the use of clean energy for cooking and on-site energy independence for mother and child.

To mitigate risk associated to ISCF, the discoveries from prototype installations and operations will be leveraged for a streamlined deployment. To address timeframes of poor solar resource, battery storage will be integrated. ICSF solar tracking and operation requires no occupant involvement and replacement motors are commonly available. The risk of tampering or theft is heavily mitigated due to its integration into the roof construction.

Measurement and Evaluation:

Through integration of on-site clean energy generation within the Built Environment EcoSystem (BEE) framework, CASE and its research cohorts hopes to answer the following questions.

- Does access to clean energy for cooking reduce in home exposure to harmful solid fuel byproducts and reduce respiratory issues for the mother and child?
- Can clean electrical energy and battery storage with biomass-to-energy natural gas to replace the combustion of solid fuels.

Determine the medical and public health indicators with air quality sensor nodes to evaluate exposure to carbon monoxide, small particles, and carcinogens.

Organizations Fit and Capacity:
CASE and its interdisciplinary team of mechanical engineers, electrical engineers, material scientists, and physicists have researched and developed ICSF for 7+ years (Stark, 2007). CASE and RPI has contributed to the continual development of prototypes and improvement of engineered parts. Industrial partners have been embedded in the design and manufacturing of ICSF from the beginning of research, providing knowledge on the cheapest and fastest means for manufacturing. Integration of CASE technologies into buildings, with other systems, is a research task that CASE is specifically positioned to achieve. Through CASE's research of multifunctional building systems, ecological integration provides the strongest benefits to energy and human health. ICSF will be integrated into the BEE unit as an energy source for cooking, air flow control, daylighting, and desiccant dehumidification by utilizing the multifunctional abilities of the systems integration.

Geographic Locations to be served and location(s) of the work:
Initial phases will focus on design and manufacturing of a system for the given geographic context. Health indicators will be outlined with partners to determine clean energy access effects on mother and child health. Scale-up will work on manufacturing and integration into the BEE unit which will be used within deployment. If access to clean energy through our strategy is found to be desirable to occupants and successful to improving mother and child respiratory risks, deployment to other homes will continue. If widely adopted in a region, this strategy could generate utility-scale power within less privileged settings, helping contribute to health, educational, and economic improvements.

References:

Azimoh, Chukwuma Leonard, et al. "Illuminated But Not Electrified: An Assessment Of The Impact Of Solar Home System On Rural Households In South Africa." Applied Energy 155.(2015): 354-364. ScienceDirect. Web. 22 July 2015.

Jetter, James J., and Peter Kariher. "Solid-Fuel Household Cook Stoves: Characterization Of Performance And Emissions." Biomass And Bioenergy 33.(2009): 294-305. ScienceDirect. Web. 22 July 2015.

Heiselberg, P. Integrating Environmentally Responsive Elements in Buildings (Annex No. 44). IEA/ECBCS. (2012).

Maegaard, Preben. “Energy Security in Africa with Renewable Energy”. The World Council for Renewable Energy, Denmark (2008)

Novelli, Nicholas, Mohamed Aly, and Anna Dyson. “Daylighting Autonomy Effects of Blocking Direct Insolation with an Active Envelope Technology (UPCOMING).” *PLEA.* Bologna: N.p., 2015. Print.

Rehfuess, Eva. “Fuel for life: household energy and health” World Health Organization, Geneva, Switzerland (2006)

Selkowitz, S., E. Lee, and O. Aschehoug. "Perspectives on advanced facades with dynamic glazings and integrated lightings controls." CISBAT, Lusanne, Switzarland (2003).

Smith, Kirk R. “What’s Cooking? A Brief Update.” *Energy for Sustainable Development* 14.4 (2010): 251–252. *CrossRef*. Web. 15 July 2015.

Stark, P.R.H., Jensen, M.K., and Dyson, A.H. Integrated Concentrating (IC) Solar Façade System. DOE, 2007.

U.S. Department of Energy (DOE). "Improving Air Quality With Solar Energy." (2008)

U.S. Environmental Protection Agency (EPA). “Assessing the Multiple Benefits of Clean Energy” (2011)