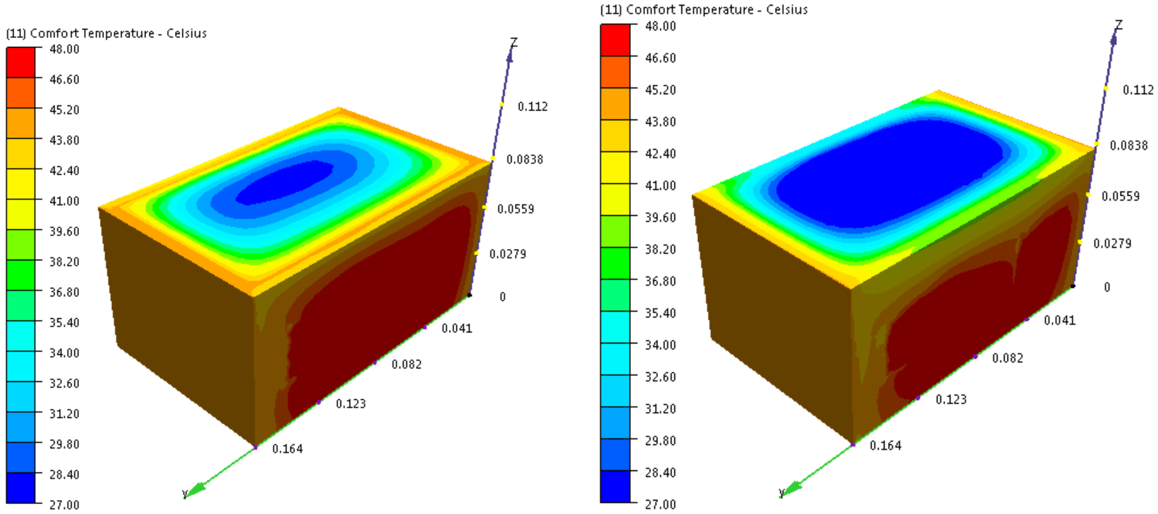

Figure 2 *(a) Temperature distribution without green roof and (b) Temperature distribution with green roof (both simulations at 2:30 PM, outside temperature: 44°C, humidity-13%, highlighting external surface temperatures around the room and roof)*

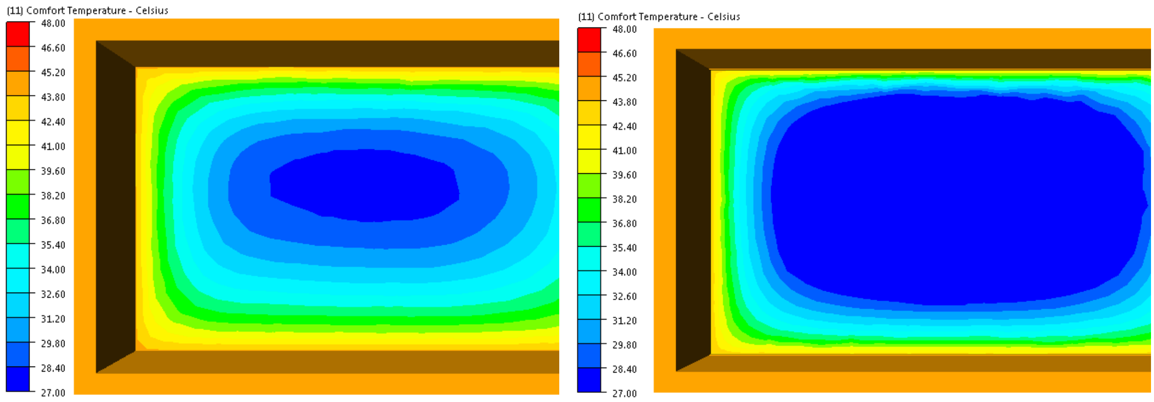

Figure 3 *(a) Temperature distribution without green roof and (b) Temperature distribution with green roof (both simulations at 2:30 PM, outside temperature: 44°C, humidity-13%, highlighting external surface temperatures around the roof)*

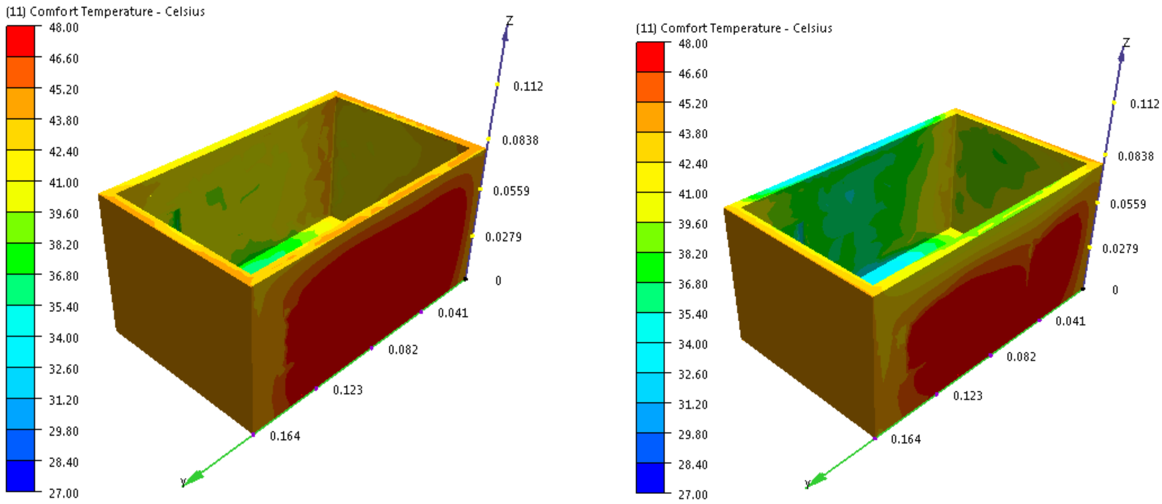

Figure 4 *(a) Temperature distribution without green roof and (b) Temperature distribution with green roof (both simulations at 2:30 PM, outside temperature: 44°C, humidity-13%, highlighting internal and external surface temperatures)*

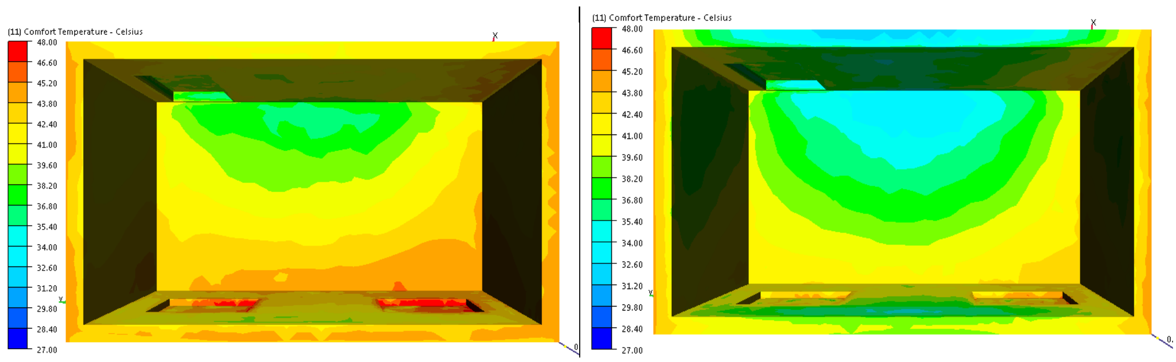

Figure 5 *(a) Temperature distribution without green roof and (b) Temperature distribution with green roof (both simulations at 2:30 PM, outside temperature: 44°C, humidity-13%, highlighting internal surface temperatures)*

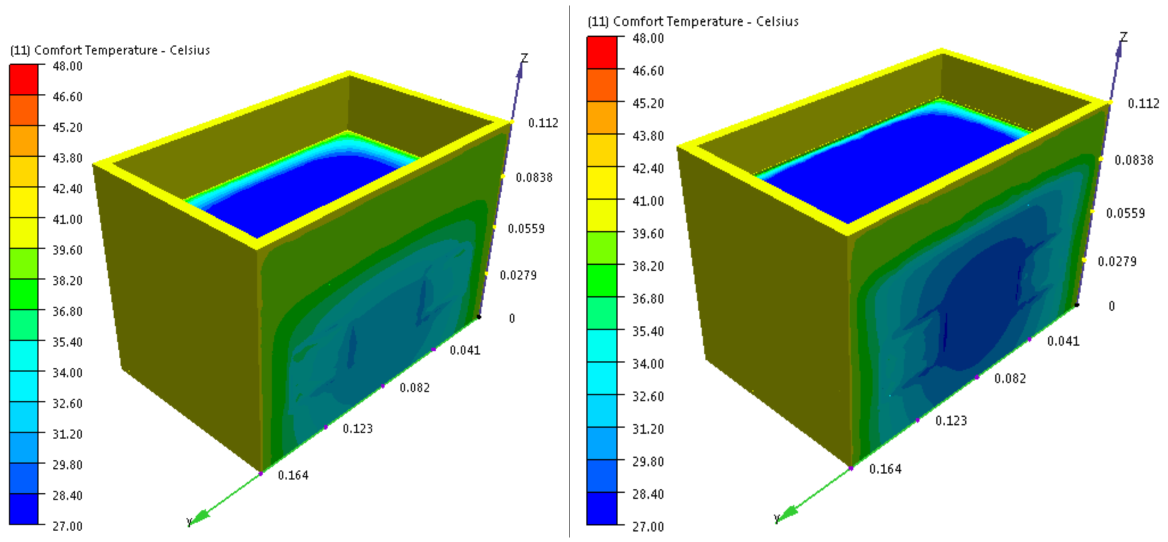

Figure 6 *(a) Temperature distribution without green roof and (b) Temperature distribution with green roof (both simulations at 6:00 PM, outside temperature: 40°C, humidity-12%, highlighting external surface temperatures around the room and roof)*

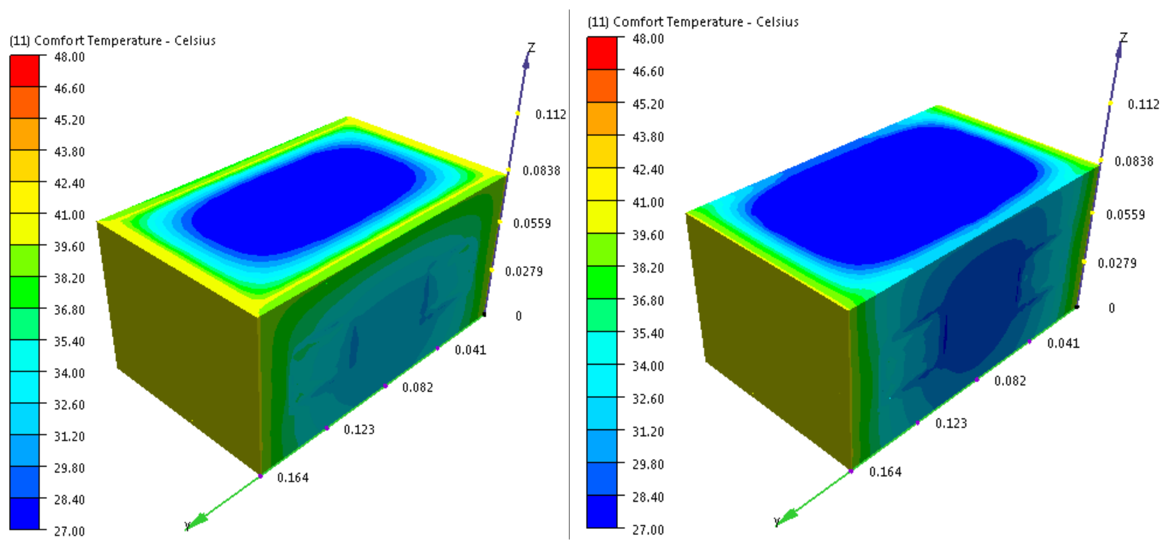

Figure 7 *(a) Temperature distribution without green roof and (b) Temperature distribution with green roof (both simulations at 6:00 PM, outside temperature: 40°C, humidity-12%, highlighting external surface temperatures around the room and roof)*

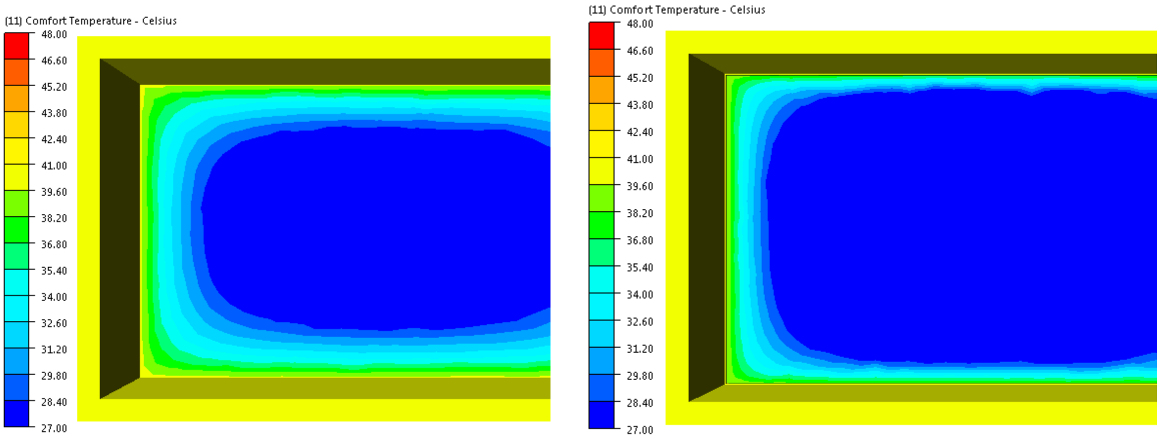

Figure 8 *(a) Temperature distribution without green roof and (b) Temperature distribution with green roof (both simulations at 6:00 PM, outside temperature: 40°C, humidity-12%, highlighting external surface temperatures around the roof)*

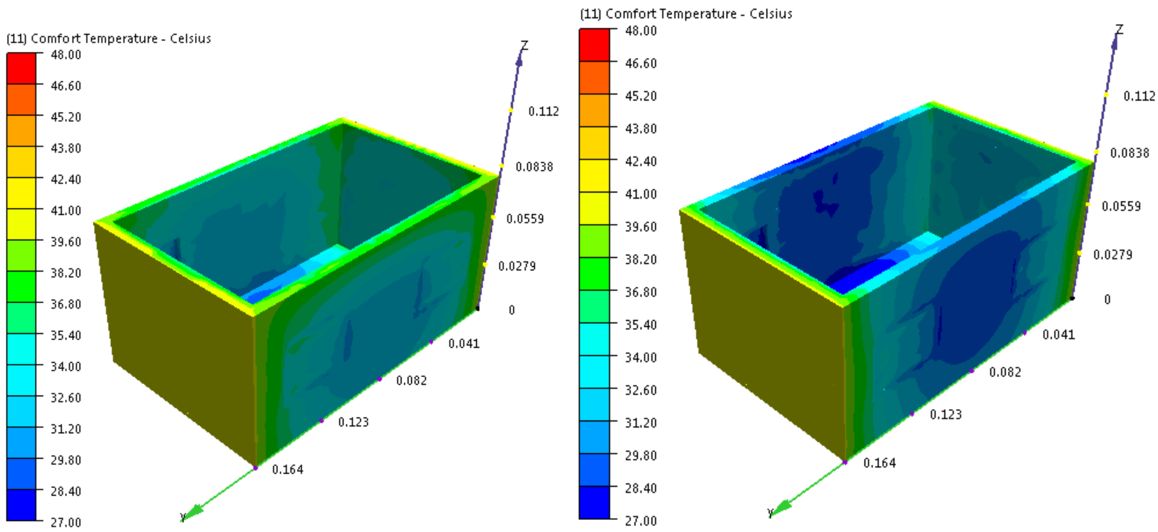

Figure 9 *(a) Temperature distribution without green roof and (b) Temperature distribution with green roof (both simulations at 6:00 PM, outside temperature: 40°C, humidity-12%, highlighting internal and external surface temperatures)*

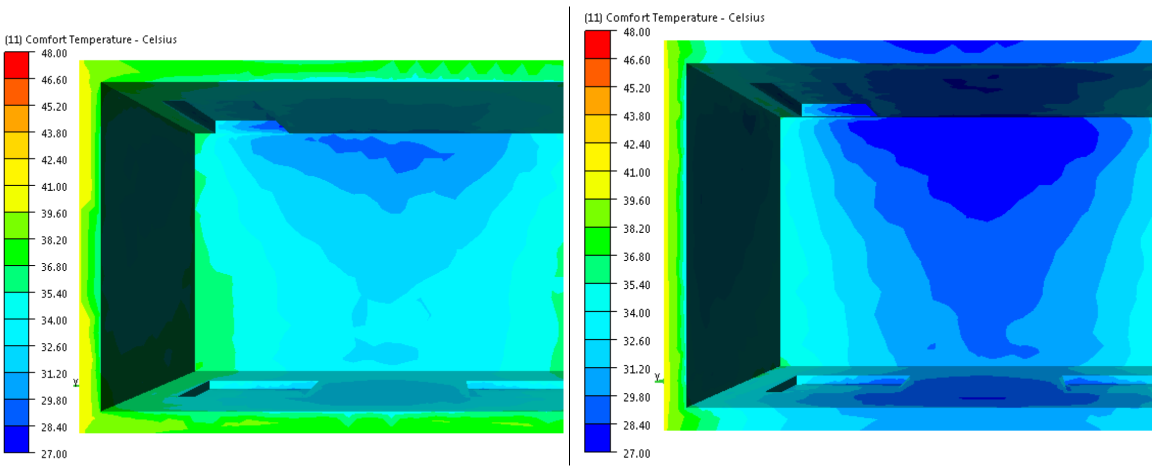

Figure 10 *(a) Temperature distribution without green roof and (b) Temperature distribution with green roof (both simulations at 6:00 PM, outside temperature: 40°C, humidity-12%, highlighting internal surface temperatures)*

RESULTS

As shown **in Figure 1 to Figure 5**, upto 4°C reduction in temperature difference is visible in simulation modeling above the green roof as well as inside the room in given location and environmental conditions as compared to that of bare conventional roof.

And in the same model changing timings of the simulation to 6:00 PM (shown **in Figure 6 to Figure 10**), shows difference more than 4°C temperature i.e interior of the room will be more than 4°C cooler because of the presence of a green roof and similarly temperatures above the green roof also show similar differences.

CONCLUSION

Review of various scientific research works shows the importance and potential of green roof in numerous ways. Energy required for conditioning of spaces is aggravated in urban areas through the exhaustion of natural resources spent for electricity production (electricity production in the state of Chhattisgarh, India is by coal fired thermal power plants). Harnessing conventional fossil fuels and heat emissions by AC systems further add to the temperature increment in the environment. Planting a green roof will reduce *a.* exterior temperatures: therby controlling micro climate because of plant's presence and will reduce the urban heat island effect and *b.* inside temperatures: thereby reducing cooling loads inside the buildings.

The analysis of the simulations done with the help of computational fluid dynamics (CFD), clearly highlight the importance of a green roof as a passive design measure to be incorporated in buildings which would decrease the cooling requirements or the burden on the Air Conditioning systems for Raipur city in geographical location of the state of Chhattisgarh in central India.

An extensive review of the computational fluid dynamics (CFD) simulation results have exposed the following key factors when assessing their energy saving potential in the context of building use:

1. Observations of simulations providing green roofs in the buildings in the city of Raipur showed that green roofs are effective in reducing heat flow through the roof, thus lowering the energy demand for space conditioning in the building.
2. The green roof was effective in reducing high temperature and temperature fluctuations experienced by the roof membrane in conventional roofing system in the summer.
3. Since the average mean temperature was greater then comfort level temperature therefore, thermal comfort cannot be achieved only by providing green roof but it can reduce the load on air conditioning systems to considerable levels.
4. Results proved highly satisfactory and provided enough confidence for the study to be extended further for a larger solution space in real life measurements.

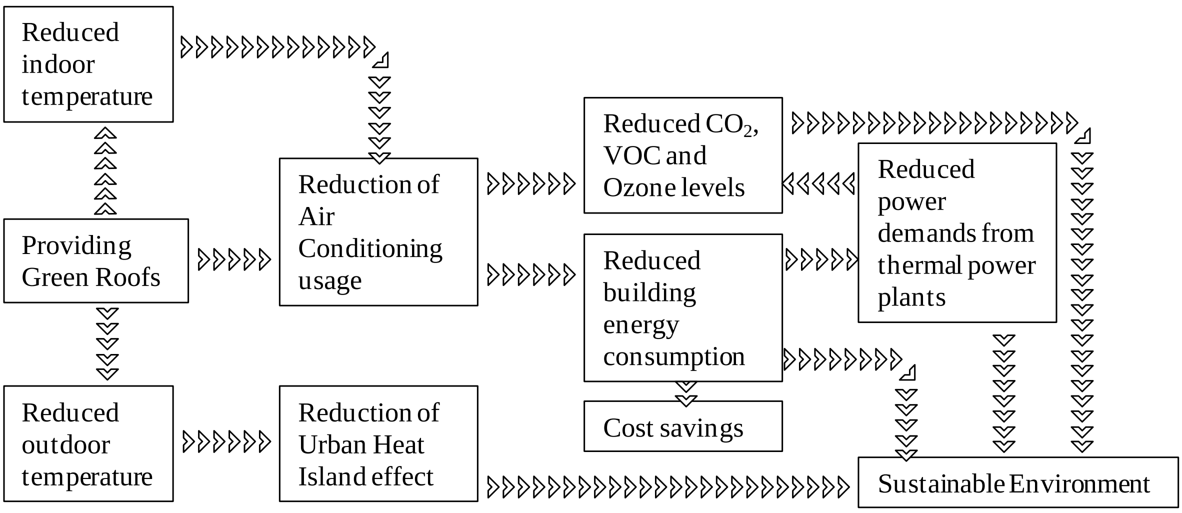

Figure 11 *Benefits of Providing Green Roofs*

Enormous use of ground for various purposes has lead to disappearance of green planted surfaces. In order to prevent dangerous and uncomfortable urban heat island effects the indispensable need of planted surfaces is quiet inevitable as is confirmed by many researchers. For example, a study estimated that an increase of 1°C in air temperature would require the addition of about 500 megawatts (MW) for air-conditioning of buildings in the Los Angeles Basin. Similar air temperature increases in urban areas are taxing the ability of developing countries to meet urban electricity demand while raising global greenhouse gas (GHG) emissions associated with energy use and power generation. Space constraints have further reduced the applicability of green surfaces in various areas surrounding the building envelope. Consequently, planting green roofs become very promising and stabilizing choice in the present scenario.

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REFERENCES

Baxevanou, C, Fidaros. D, Bartzanas. T, Kittas. C., 29 September -1 October 2010. Estimation of the reduced cooling needs from a typical green roof. Palenc 2010. Retrieved May 13, 2014, from http://ireteth.certh.gr/agrotechnology/files/2010/07/C01-2010.pdf

Blank, L et.al., Directions in green roof research: a bibliometric study, Building and Environment (2013), doi: 10.1016/j.buildenv.2013.04.017.

Castleton, H.F., Stovin, V, Beck, S.B.M, Davison, J.B, October 2010., Green roofs; building energy savings and the potential for retrofit. Energy and Buildings 42(10): 1582–1591

Evans, Martin, 1980. Housing, Climate and Comfort.

Koenigsberger, Ingersoll, Mayhew, Szokolay, 1997. Manual of Tropical Housing and Building-Climatic Design.

Kumar, Ashok., Suman, B.M., Experimental evaluation of insulation materials for walls and roofs and their impact on indoor thermal comfort under composite climate., Building and Environment (2013)

Kumar, Rakesh., Kaushik, S.C., Performance evaluation of green roof and shading for thermal protection of buildings, Building and Environment 40 (2005) 1505–1511

Pandeya, Shrikant., Hindoliya, D.A., Mod, Ritu., 2012. Artificial neural network for predation of cooling load reduction using green roof over building in Sustainable City. Sustainable Cities and Society 3 (2012) 37– 45

Urban Heat Islands (UHIs), The Urban Heat Island (UHI) Effect, Retrieved May 13, 2014 from http://www.urbanheatislands.com/

Xu, Tengfang., Sathaye, Jayant., Akbari, Hashem., Garg, Vishal., Tetali, Surekha., Quantifying the direct benefits of cool roofs in an urban setting: Reduced cooling energy use and lowered greenhouse gas emissions, Building and Environment, 48 (2012) 1-6

Yu, S., Evans, M., Delgado, A., March 2014. Building Energy Efficiency in India: Compliance Evaluation of Energy Conservation Building Code, Retrieved May 30, 2014, from http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23217.pdf