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Sustainable Development with CO_2 Utilisation to Fast-Track Developing World's Transition to Carbon Negative Circular Bioeconomy: A Technical Assessment of Low-Cost Recyclable Prefabricated Homes in Pakistan

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Abstract

The take-make-forsake material flow model underpinned the western countries' unprecedented industrialisation and subsequent urbanisation in the twentieth century. This linear economy model achieved higher living standards at the expense of environmental degradation and resource depletion. Consequently, in the twenty-first century the entire planet is facing the onerous challenges of climate change and waste pollution. On the other hand, a large portion of the global population is still in the process of raising the living standards. A radical shift towards circular material flow chains with decoupling of economic activity from resource depletion and environmental burden is needed. Only this way the world can ensure the developing world achieves the living standards of the developed world whilst managing the twin challenges of climate change and waste pollution. If this transition to circular material flow is achieved with co-utilisation of waste and CO_2, the resultant carbon negative circular bioeconomy can boost the efforts to mitigate the climate change and waste pollution. In the current study, this concept is explored with the evaluation of low-cost recyclable prefabricated homes for developing countries like that of Pakistan.

Pakistan is currently facing a shortfall of 12 million homes. The government is taking policy measures to meet this and the anticipated future demand. In Pakistan, nearly all homes are of double brick construction with high cement and steel demand. As the bricks are produced in polluting brick kilns, the CO_2 and pollutant emissions are quite high. On average, around 0.5, 1 and 2 metric tonnes of CO_2 is emitted per metric tonne of bricks, cement and steel produced, respectively. A small 100 square metres home that requires upwards of 10,000 bricks has a carbon footprint of nearly 10 metric tonnes of CO_2. Other critical environmental issues are topsoil degradation and toxins emissions, while the social issues include bonded labour. A sustainable and better approach is low-cost prefabricated homes with carbon negative footprint constructed of composites produced from waste biomass and CO_2 feed streams.

The technology for long lasting prefabricated homes is mature. Prefabricated homes constructed of composites back in the 1960s and 70s have not only survived the past sixty years of weathering but continue to be occupied in some parts of the world. The technology in the past sixty years has further matured to replace the fossil fuel feed streams with non-food biomass and CO_2 to produce the same composites. Here, lignik as a composite of poly(methyl methacrylate)-lignin is used as a model composite for the prefabricated homes. A carbon negative biorefinery model has been developed to produce the composite.

This study presents the mass and energy balancing model and process-flow sheeting simulations of the carbon negative biorefinery, which were carried out in COCO-ChemSep. Results show that a carbon negative biorefinery scaled for

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10,000 metric tonnes per annum of feedstock can produce enough composite to construct nearly 300 prefabricated homes with 100 square metres of area. Results show that each home sequesters 10 metric tonnes of CO_2. This equates to hundreds of millions of CO_2 removed from the atmosphere if the current housing shortfall in Pakistan is met with carbon negative prefabricated homes. The biorefinery concept has been developed with the capacity to consume the composite as a feed stream, thus allowing for the recycling of the prefabricated home at its end-of-life and ensuring the CO_2 stays locked in the continuous cycle of the circular bioeconomy.

Similar strategy can be applied for plastics and composites used in the manufacture of cars, airplanes, furniture, toys and so forth. This would not only displace the fossil fuel demand with CO_2 and waste but with each carbon negative product, CO_2 would be removed from the atmosphere and waste would be eliminated, helping the world transition to a sustainable circular bioeconomy.

Keywords: Sustainable Development; Negative Emission Technology; Circular Bioeconomy; Waste; Recycling; Prefabricated Home