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Original Article

The Taxonomy of Agricultural Residues for Sustainable Eco Building Materials, Biomass Plant and a Hybrid Heat Pump

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Abstract - *There are practical endorsements that agricultural residues have been utilized as additives for soil stabilization, advancement of geotechnical properties, concrete and cement supplements, road construction, etc. Sustainability is multifaceted and has to be retained. One kilogram of cement induces 800 kg of CO_2 gas. Over 50 % of all biomasses in the world are made of crop residues. The solid biomass constitutes around 50 % of overall production, liquid and gaseous 25 % each individually. According to certain EU documentation, in 2050th, it is going to be feasible to produce 1000 TWh of biomethane. This manuscript serves as a technical paper - a reminder of how building materials can be sustainably composed and as a technical map of binding the biomass plant and a hybrid heat pump. The novelty of the manuscript is summing up all research on the utilization rate of agricultural residues for sustainable eco-building materials upon now.*

Keywords - *Agricultural residues, Sustainability, Solid biomass, Biomethane, Technical map.*

1. Introduction

A circular economy is a relatively novel trend, resulting in the greenwashing of fruit and vegetable crops, which are reused in the building's lifecycle. In [1], a banana peel powder was mixed with polystyrene in different weight ratios and showed exquisite thermal insulation traits ranging from 0.028 to 0.030 W/mK. The rice husk and sugar cane bagasse ashes are some of the most prominent agricultural residues in building practices, even in road construction. In the forms of ash, granules, fibers, or shredded particulate matter for building engineering can be found: soybean, corn, coffee and coconut husks, wheat, pineapple, grapes, cotton stalks, etc. [2]. Building on this fact, the United Nations' Food and Agriculture Organization appraised that the EU is accountable for less than 7%, i.e. 1.3 billion tons of global food waste per year [3].

The palm oil wood, when gathered up from the plantations, comprises around 70 % of wood trunks. Their mixture with fine particles in the panels shows the lowest water absorption of 54.75 %, extremely low thickness swelling of 18.18 %, and very low thermal conductivity in the range from 0.067 to 0.154 W/mK [4]. The apple pomace, with its extraction techniques, is appraised as a significant recrement of an agro-food industry [5]. The manufacture and disposal of by-products originating from agro waste in Puglia, Molise, Albania, and Montenegro, so-called EUSAIR provinces, were explored [6].

This manuscript serves as a technical note for binding the notion of agricultural residues for sustainable, eco, building materials, biomass plants and a hybrid heat pump. The novelty of the manuscript is summing up all research on the utilization rate of agricultural residues for sustainable eco-building materials upon now.

2. Methodology

The methodological approach consists of theoretical premises, in-depth analysis of existing scientific literature, blog browsing, etc. Throughout this paper, it has attempted to find a bridge between two industries, the agro-food industry and the civil engineering industry.

2.1. The Civil Engineering Practices Towards Agro-Recycled Bricks

There are plenty of lightweight, agro-recycled, and sustainable building materials on international markets, with modified binders and aggregate replacements in percentages. A green cement brick, despite its lower strength than conventional brick, higher water absorption traits, and low density [7], shows amenities regarding materials' sustainability and better waste management. It has been documented that the waste red brick can be used as an agricultural fertilizer, soil melioration and goaf backfilling after several treatments [8].

The customary clay for bricks is in extinction. Favorable replacements for silica, alumina, and lime in the bricks are sludges of different origins, i. e., dredged sludge, glass sludge, and alum sludge.

In the article [9], water treatment plants' sludge substituted the 50% content of clay in (clay) bricks. One slurry was a referent, and others contained agro waste, such as rice straw ash, sugarcane bagasse ash and wheat straw ash, with ratios of 5%, 10 % and 15% by weight of sludge content. The agro bricks showed the best performances, containing the lowest dose of ashes, 5% rice straw ash, 5% sugarcane bagasse ash and 5% wheat straw ash.

When baked, the clay brick gets dehydrated, so the additives improve the performance of the brick's paste, viscosity, and compactness.

In the village near Abuja, Nigeria, the four specimens of organic brick blocks were investigated, containing different types and sizes of fibers mixed with clay. They were developed as facades, 3D printed modules, printed on a Delta Wasp 3D printer [10].

Fig. 1 An example of recycled red bricks - Grade Cream Bricks [11]

2.2. Agricultural Garbage Transformed into Sustainable Eco-Materials

The waste from agro-food industries has been yet utilized for wooden boards, thermoplastic adhesives, biopolymers, and composites. Among oat hulls, flax shives and other agricultural garbage in Melbourne, Australia, grapevine prunings are known. Yearly, approximately 42 million tonnes of grapevine prunings are disposed of as agricultural garbage. The grapevine prunings are a significant feedstock of particleboards, where the soft particles are pressed with resins under high temperatures [12].

There are testimonials that geopolymer concrete has been increasingly used, with agricultural by-products such as granulated blast furnace slag and metakaolin. Agricultural residues in geopolymer concrete lift the compressive strength, reduce the environmental footprint, and strengthen the waste-to-energy binding [13]. As alternative feedstocks of cement composites were used the olive and olive oil residues. The greener masonry mortars tailored with corn cob ash, fly ash and ceramic waste powder showed a lesser carbon footprint, better cost efficiency, and improved compressive and flexural strengths [14].

Fig. 2 The particleboards made of the grapevine (prunings) [12]

2.3. The Correlation Between a Biomass Plant and a Hybrid Heat Pump

The biomass-fired, combined heat and power plant can have various designs for integration into a district heating system. Numerous feasibility studies were carried out to assay whether the BCHP can be plugged into a photovoltaic module, a wind generator or a thermal energy storage tank [15].

In Poland, for example, in 2018th, the main stake of renewable energy resources, 90.5%, in the households' heating was assigned to biomass, while the stake of a heat pump was 0.4%.

One exploration showed that the biomass combustion, co-generation heating plant, releasing up the flue gases at 485.9 K, extracts the raised heat from the ground by 7.6 %, 14.4 % and 23.7 % per unit length of a borehole in relation to different storage temperatures [16].

It is further quoted that in the future, the hybrid heating pumps will be harnessed by blended or pure hydrogen and biofuels such as BioLPG. On-grid households with integrated hybrid heating pumps will have mixed natural gas with 20 % hydrogen by 2023. This will contribute to the carbon savings of approximately 7 % [17]. One of the heating pump technologies is also the transcritical CO2 heat pump, where the CO2 behaves as a refrigerant in its phase-changing state, resulting in the very high operating pressure of the system. Some non-governmental organizations quote that the heat supplied by heat pumps now is approximately more than 60 %, while in 2050th should be up to 90 %.

Fig. 3. is given a map of a paired biomass power plant and gas, oil or LPG boiler of a hybrid heat pump as a co-generation heating plant.

The hybrid heat pumps can have either a continuous operating regime or a time-scheduled, disruptive operating regime. Just installing the hybrid heat pump in the household can achieve up to 55 % of carbon savings without further renewals of the building envelope. One of the factors affecting the operating regime of a heat pump in a hybrid mode is the building type [18]

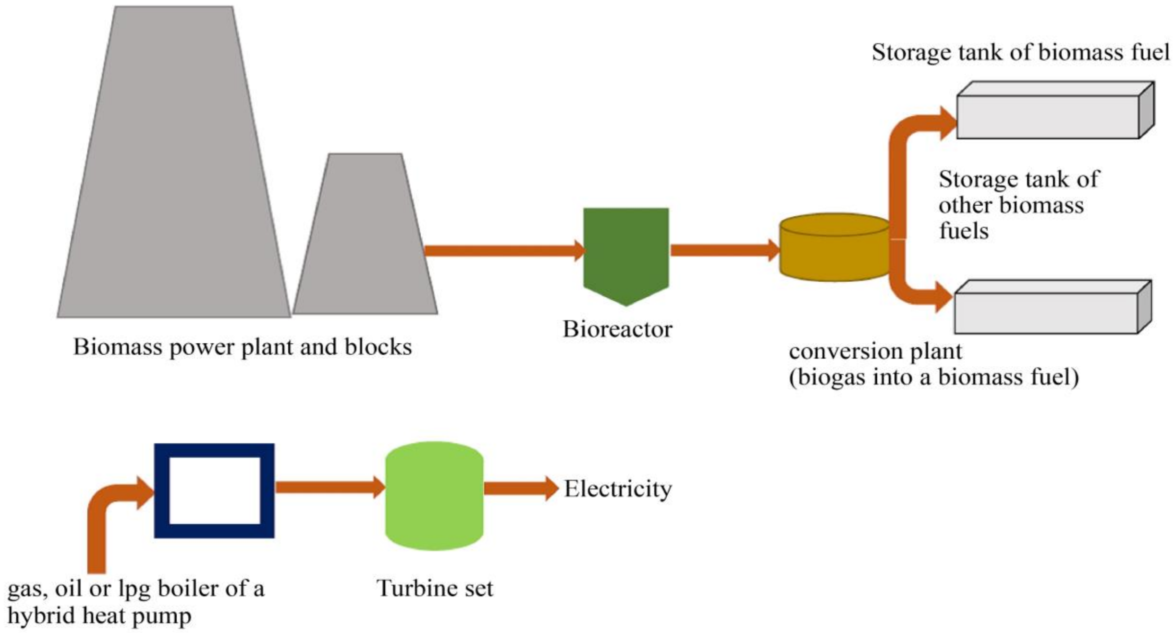

Fig. 3 The map of biomass, co-generation heating plant (paired biomass power plant and gas, oil or LPG boiler of a hybrid heat pump) (by author)

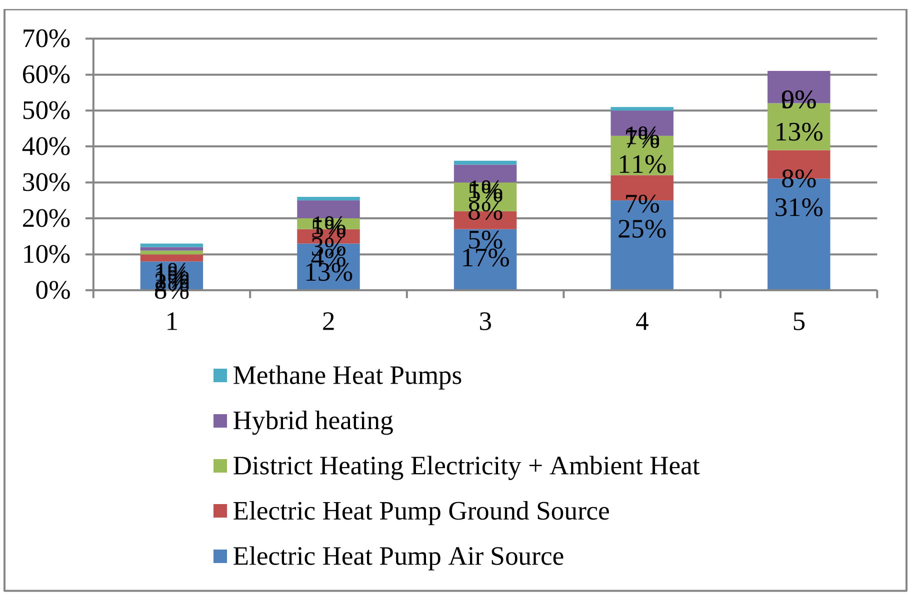

Fig.4 The future projections of the utilization rate of different heating pump sorts in households [18]

According to the schematic prognosis from Figure. 4., the share of 1% for methane heat pumps indicates that they are pretty unknown for beneficiaries. The highest utilization rate can be attributed to the electric, air-sourced heat pumps, up to 31% in the 2050s. Ground-laid electric heat pumps are not represented that much, probably because of the difficulties in its assembly, laying down in the soil and its weight. The district heating and hybrid heating utilization rates have similar shares, signifying that they are also not so known

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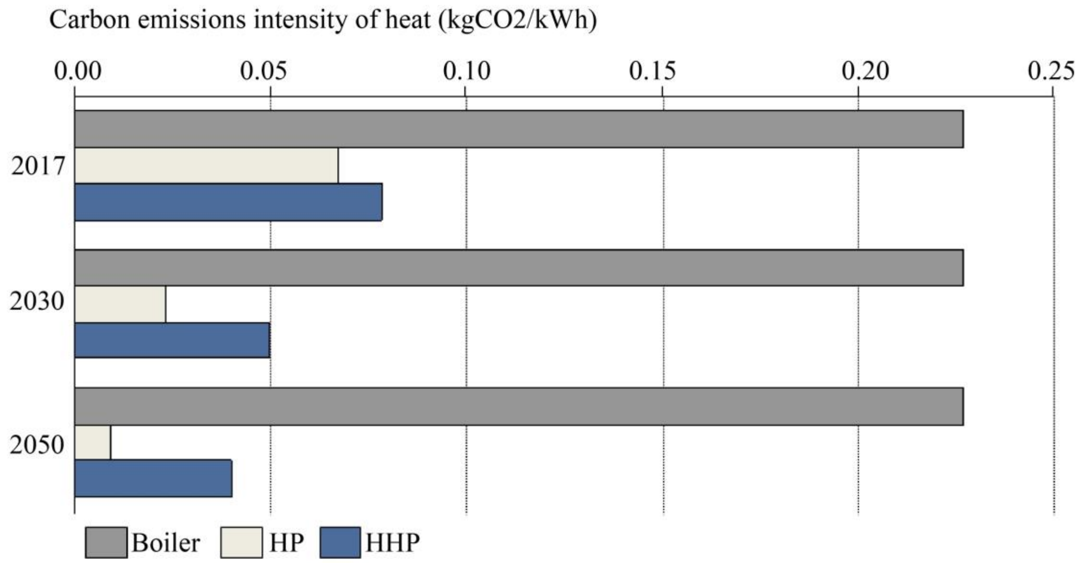

Fig. 5 Projected carbon intensity of heat for HHP, HP and boiler heating systems (zero-carbon semi-detached with low T emitters, domestic hot water met by the boiler component of HHP)- measured over a 15-year lifetime [19]

Referring to the illustrative scheme, the quantity share of carbon emissions released by the boiler (gas, oil or LPG) are pretty much identical, around 0.23 kg CO_2 / kWh, over the years, even decades. That means the boilers are the biggest environmental pollutants located in households, generating around 0.23 kg CO_2 per 1 kWh of electricity. On a daily basis, it is not a huge amount of emitted CO_2 in kilograms by a boiler, but on an annual basis it is close to a ton.

The demand for domestic hot water originates and is assumed to be met by the boiler part in a default hybrid heat pump system. That is why the hybrid heat pump system has a higher intensity of its emitted carbon emissions throughout the years, even decades. At the time of the set-up in 2017th, the difference between the CO_2 emissions of a standalone heat pump and a hybrid heat pump was fairly little, while in 2030th is two times less CO_2 emissions for a classical, standalone heat pump. In 2050th, this difference in CO_2 emissions is far more noticeable, with around 4 times less CO_2 emissions for a classical, standalone heat pump. A classical, standalone heat pump is an electric device with its gauges and is more simple than a hybrid heat pump system.

One more thing is that the classical, standalone heat pumps operate more efficiently at lower temperatures. Therefore, for a given heat demand, the electricity demand from the heat pump will be lower. Less electricity demand implies less CO_2 emissions.

3. Conclusion

In this manuscript, the utilization rate of agricultural residues for sustainable eco-building materials was discussed. Agricultural residues are still far less utilized in the civil engineering industry than they could have been. It was made a junction between agricultural residues, a biomass plant and a hybrid heat pump. The article is in the form of a review article. Future projections state that the highest utilization rate in comparison with the number of households will assume electric, air-sourced heat pumps. A hybrid heat pump system has a higher intensity of its emitted carbon emissions throughout the years, even decades, because of the demand for domestic hot water, which is assumed to be met by the boiler part in the default hybrid heat pump system. The boilers are the biggest environmental pollutants located in households, generating around 0.23 kg CO_2 per 1 kWh of electricity.

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