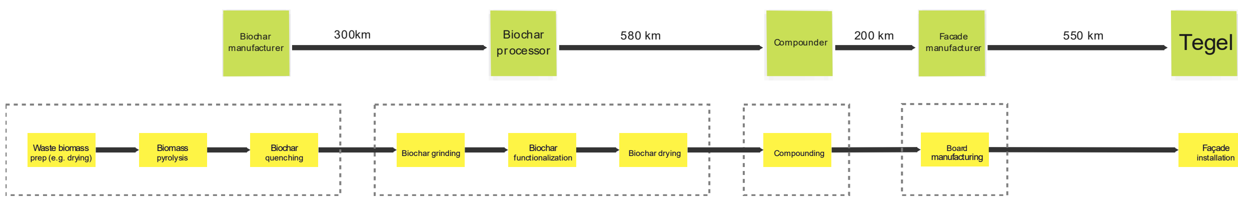
Estimating CO2 emissions from production of Made of Air panels for three different production chain scenarios

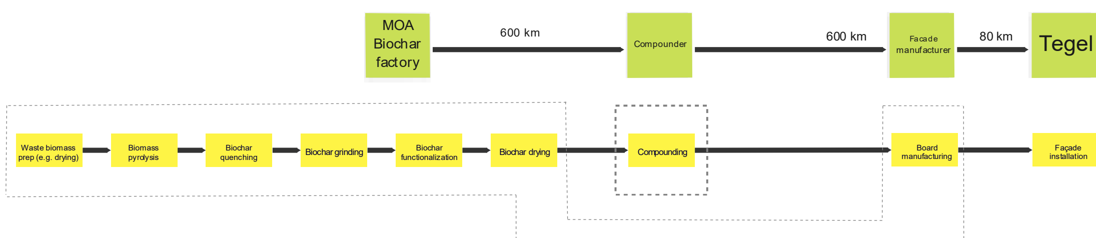
Made of Air (MOA) material is produced from biochar. The material and its supply chain are still under development so we assume that it can be produced according to three scenarios. Scenario one, conservative supply chain approach, when biochar production, its preparation for compounding, compounding and board manufacturing happen at four different locations (Figure 1 upper panel). In the second scenario, pilot factory version, biochar production, its preparation for compounding and board manufacturing are happening near the construction site, while compounding happens at a remote facility (Figure 1, middle panel). In third scenario, all manufacturing steps take place near the construction site in Tegel (Figure 1, lower panel).

Processes and Production Scenarios

Scenario 1: Conservation Supply-Chain Approach (Timeline: upto 2024)



Scenario 2: Optimized Pilot Factory version (Timeline: 2024 – 2026)



Scenario 3: Fully Integrated MOA Tegel Factory (Timeline: 2026 onwards)

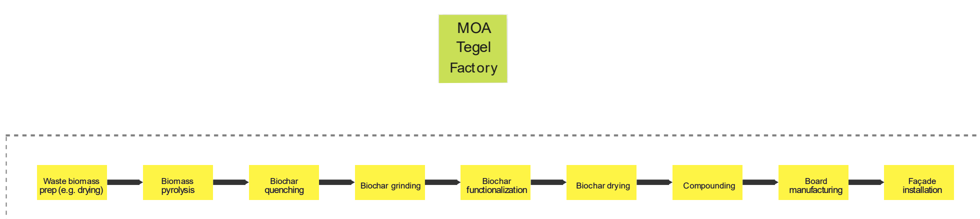


Figure 1. Production scenarios 1-3 of MOA for Tegel Project developed by the MOA team [1].

During compounding 30 % polymer by weight is added to the biochar. The resulting MOA granulate contains 70% biochar, with an elemental carbon content of 73%.

To estimate carbon emissions from production of this material the following equation was used:

$C_{MOA}=(E_p * C_{emis})/E_d$

E_p – energy needed for production of 1 kg material [MJ]. Here these values are extracted from Table 1.

E_d – energy density of 1 kg fuel [MJ] from [2]

C_{emis} – CO_2 emissions per 1 kg fuel [kg] from [2]

Table 2. Energy requirements for MOA façade board production [kg] supplied by the MOA team.

Process	**Energy Input (MJ)**		**Energy Output (MJ)**	
	Thermal	**Electrical**	**Thermal**	**Electrical**
Biomass hacking (at sawmill)		0.88		
Biomass drying*	3.14			
Pyrolysis of biomass into biochar		0.35	15.12	
Biochar quenching		0.0001		
Grinding		0.006		
Agglomeration and Mixing*		0.03		
Drying*	0.56	0.006		
Compounding		1.44		
Heat pressing to form MOA board	4.32	0.04		
Converting excess heat to electricity		0.0001		
Total Energy per kg of MOA facade	**8.02**	**2.75**	**15.12**	**3.02**
Electricity production from heat			-3.02	
Energy left after electricity production			12.10	
Energy left after 20 % losses			9.68	
In-house electricity use				-0.96
Excess energy			**1.66**	**2.06**

Results

The highest CO_2 emissions from production of MOA are generated in the first scenario, where production of MOA is taking place in four different locations. In this case, energy generated during pyrolysis cannot be used for other processes involved in MOA manufacturing. It is assumed that in this scenario as well as in the scenario 2, the energy is sources from either burning gas, liquid fuel, or solid fuel. The emissions are almost eight-fold lower if only compounding happens at a different location, while energy generated from pyrolysis is used for other processes involved in the manufacturing MOA such as the biomass hacking, drying, biochar quenching, etc. In scenario 3, all production processes are happening on site and access energy generated during pyrolysis is used to power other processes involved in production of MOA. In this case there are no CO_2 emissions generated but excess energy ~ 3.72 MJ is produced, which can be potentially channeled into an electrical grid if there is any.

The emissions from production of polymer used for compounding are not accounted for in these estimates. Adding these emissions would increase the emissions in all three scenarios.

Table 2. Emissions of CO2 [kg CO2] from production of 1 kg of MOA using three scenarios described above assuming different sources of fuels. In scenario 3 the emissions from MOA production are equal to zero because energy generated from pyrolysis is used in manufacturing**.**

	Gas (methane, natural gas, etc.)	Liquid Fuel (diesel, crude oil, etc.)	Solid Fuel (coal or biomass)
Scenario 1	**0.54**	**0.76**	**1.32**
Scenario 2	**0.07**	**0.10**	**0.15**
Scenario 3	**0.00**	**0.00**	**0.00**

References

1 Made of Air GmbH. <https://www.madeofair.com/> (2023).

2 Ringsmuth, A. K., Landsberg, M. J. & Hankamer, B. Can photosynthesis enable a global transition from fossil fuels to solar fuels, to mitigate climate change and fuel-supply limitations? *Renewable and Sustainable Energy Reviews* **62**, 134-163 (2016). https://doi.org:https://doi.org/10.1016/j.rser.2016.04.016