

# Exploring Wood Vaulting to Reduce the Greenhouse Gas Impacts of Wildfires

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## 1 Equations

### 1.1 Flight emissions

The average emission factor for long-haul flights is based on the UK Government greenhouse gas conversion factors [1]. Flight distance between Paris-Charles de Gaulle and New-York JFK is obtained using Air Miles Calculator [2]. For a round trip:

$$E_{\text{flight}} = EF_{\text{long-haul}} \cdot d_{\text{km}} \cdot 2 \quad (1)$$

with  $EF_{\text{long-haul}} = 0.142\,53\,\text{kgCO}_2\text{e}/(\text{person km})$  and  $d_{\text{km}} = 5849.3\text{km}$ .

### 1.2 Green wood volume, dry mass and wet mass

The source gives the amount of available green wood volume, with  $3.5\text{Mm}^3$  available [3]. By definition, infradensity is the ratio of the dry mass of wood to its green volume:

$$ID = \frac{m_{\text{dry}}}{V_{\text{green}}} \quad (2)$$

with  $ID = 444\,\text{kg m}^{-3}$  the infradensity of the maritime pine [4]. Therefore,  $m_{\text{dry}} = V_{\text{green}} \cdot ID = 1.55\text{Mt}$  of dry wood. To determine the amount of wet wood to be transported and calculate the associated transport emissions, the wet mass of the wood must first be determined. For that, we define the humidity rate  $h$  as

$$h = \frac{m_{\text{water}}}{m_{\text{dry}}} = \frac{m_{\text{wet}} - m_{\text{dry}}}{m_{\text{dry}}} \quad (3)$$

such that a tree containing equal amounts of dry biomass and water has a humidity rate of 100%. The humidity rate for maritime pine is  $h = 86.39\%$ , based on the XyloDensMap project [4]. The annual average value across all seasons is used as a conservative assumption, although the wood is expected to be drier. The wet mass of wood is thus given by

$$m_{\text{wet}} = V_{\text{green}} (1 + h) ID \quad (4)$$

Therefore,  $3.5\text{Mm}^3$  corresponds to  $m_{wet} = 3.5M \cdot (1 + 0.8639) \cdot 444 = 2.9\text{Mt}$  of wet wood.

### 1.3 Carbon dioxide stored in biomass

The mass of  $\text{CO}_2$  contained in the stems is calculated as :

$$M_{\text{CO}_2} = m_{dry} \cdot f_C \cdot \frac{44}{12} \quad (5)$$

where and  $f_C$  is the carbon fraction of dry biomass and  $\frac{44}{12}$  the carbon dioxide-to-carbon mass ratio

For maritime pine (*Pinus pinaster*), a carbon concentration of 53.62% in the stem is reported by Bert and Danjon [5]. It is assumed that most wildfire-damaged wood will be recovered as stems. Therefore the carbon dioxide stored in wildfires damaged wood is  $M_{\text{CO}_2} = 3.05\text{MtCO}_2$ .

### 1.4 GHG emissions due to transport

As several sources are available, two different approaches are used to estimate the GHG emissions associated with transporting wood from the Saumos wildfire site to Arjuzanx. A transport distance of 120 km is assumed. It is then assumed that each truck can carry 33 tonnes of wood per trip from the forest to the Arjuzanx site [6].

#### Computation based on the Global Logistics Emissions Council (GLEC) Framework

The first estimate is based on the GLEC Framework emission factor for a diesel articulated truck with a maximum gross vehicle weight (GVW) of 60 tons. The GLEC Framework provides an emission intensity of  $60\text{ gCO}_2\text{eq/tkm}$  on a well-to-wheel (WTW) basis, assuming a 100% load factor and 38% empty running [7].

In our scenario, trucks are assumed to transport a full load of wood to the Arjuzanx site and return empty to the wildfire site. The resulting load factor is therefore 50%. To account for this difference from the GLEC assumptions, the emission intensity is adjusted by a factor of  $\frac{1-0.38}{0.50} = 1.24$

For the transport of 2.9 Mt of wet wood from Saumos to the Arjuzanx site, the resulting emissions are:

$$M_{\text{CO}_2} = 2.9 \cdot 10^6 \cdot 120 \cdot 60 \cdot 10^{-6} \cdot 1.24 = 25.89\text{ktCO}_2\text{eq} \quad (6)$$

#### Computation based on *Institut technique FCBA*

In this study, the authors estimate that transporting 33 tonnes of wood over a distance of 91 km results in approximately  $0.019\text{ tCO}_2\text{eq}$  per trip. This corresponds to  $\approx 0.2\text{ kgCO}_2\text{eq}$  per tonne-km [6]. This estimate accounts only for the

loaded trip. The emissions associated with loaded transport of 2.9 Mt of wet wood are estimated to :

$$M_{\text{loaded}} = 0.2 \cdot 10^{-3} \cdot 120 \cdot 2.9 \cdot 10^6 = 69.6 \text{ ktCO}_2\text{eq} \quad (7)$$

To account for the return journey, the GHG emissions associated with an empty truck are also estimated. The fuel consumption of an empty truck is assumed to be 29.3 L/100 km [8]. Assuming B7 diesel, with an emission factor of 3.96 kgCO<sub>2</sub>eq/kg and a fuel density of 0.836 kg/L [7], the emissions associated with the empty return trips can be estimated. As a conservative upper-bound estimate, it is assumed that every loaded trip to the Arjuzanx site is followed by an empty return trip to the wildfire site. Therefore, transporting 2.9 Mt of wood requires  $\frac{2.9 \cdot 10^6}{33} = 87'879$  return trips. For a transport distance of 120km, the volume of fuel consumed is therefore :

$$V = 87'879 \cdot 120 \cdot 0.293 = 3'089'818 \text{ L} \quad (8)$$

Using a fuel density of 0.836kg/L, that corresponds to 2'583'088kg of biodiesel B7. Using the emission factor of B7, 3.96 kgCO<sub>2</sub>eq/kg, emissions associated with an empty return are estimated to  $M_{\text{empty}} = 10.23 \text{ ktCO}_2\text{eq}$ .

Finally, total emissions associated with the transport of 3.5Mm<sup>3</sup> (2.9Mt of wet wood) from the wildfire site to the Arjuzanx site are estimated to be:

$$M_{\text{CO}_2} = M_{\text{loaded}} + M_{\text{empty}} = 69.6 + 10.23 = 79.83 \text{ ktCO}_2\text{eq} \quad (9)$$

### 1.5 Carbon credits

Similar credits for deep-vaulted biomass were sold in 2024 at prices of up to 384 per tonne of CO<sub>2</sub>, with most of the supply coming from Vaulted Deep [9]. Zeng et al. (2024) estimate that, prior to the industrialization of wood vaulting, the cost of removing one tonne of CO<sub>2</sub> through this process would range from 100 to 200 [10]. Using an exchange rate of 1USD = 0.858EUR [11], the potential value of 3.05 MtCO<sub>2</sub> can therefore be estimated as:

$$P = 3.05 \cdot 10^6 \cdot (180-280) \cdot 0.858 = (471-733) \text{ M€} \quad (10)$$

## 2 GHG emissions

The estimated GHG emissions in the Nouvelle-Aquitaine department in 2023 is [12]:

$$M_{\text{CO}_2} = 7950.4 \text{ ktCO}_2\text{eq} \quad (11)$$

The estimated GHG emissions in Paris intra-muros in 2022 is [13]:

$$M_{\text{CO}_2} = 5.07 \text{ MtCO}_2\text{eq} \quad (12)$$

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