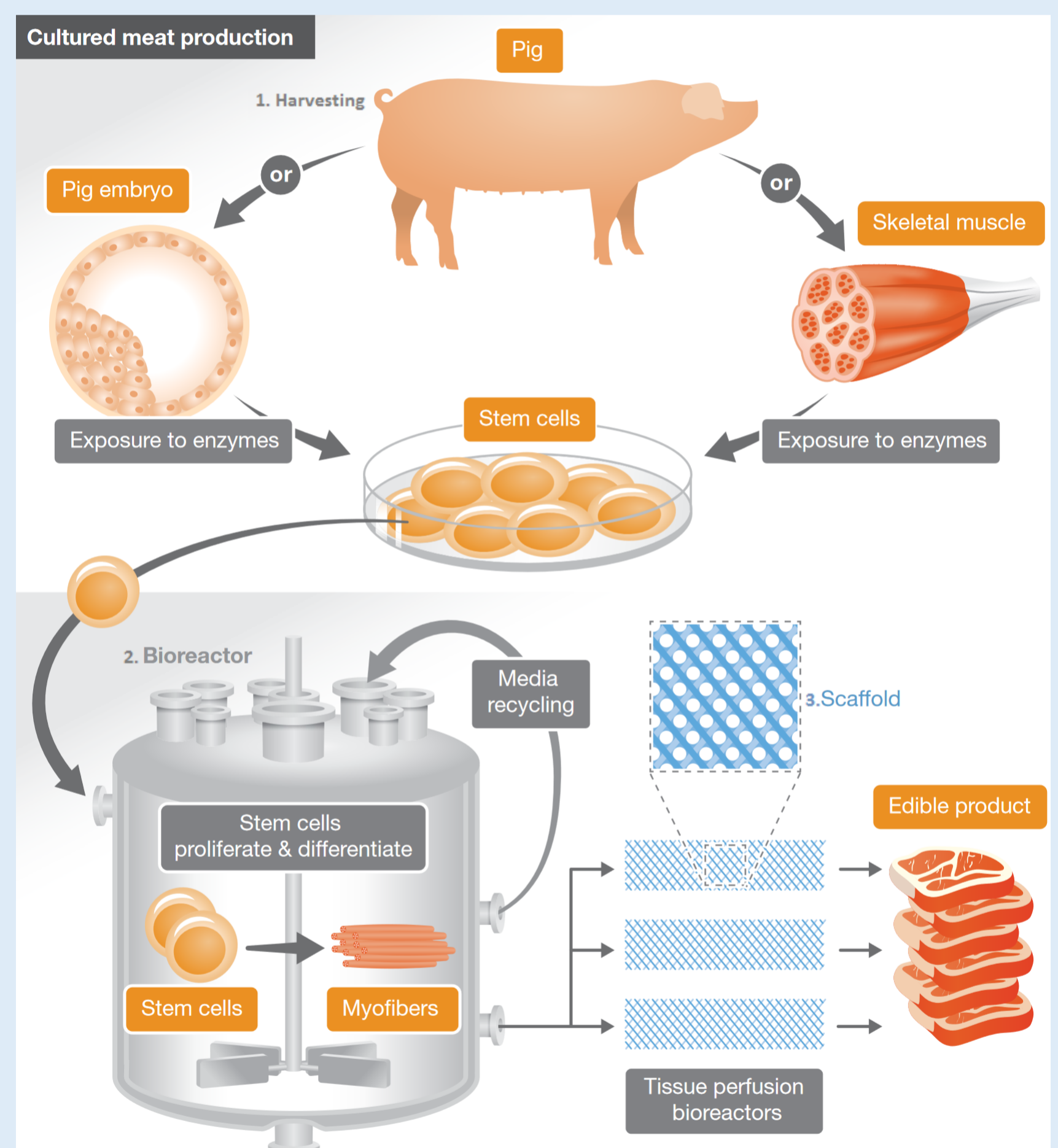


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## INTRODUCTION

Greenhouse gas emissions associated with food production account for about 30% of all global emissions<sup>1,2</sup>. The livestock industry has the greatest impact on the climate and the planet, contributing about 14.5% of all emissions<sup>3</sup>. The combined production of meat, milk, eggs and aquaculture uses 83% of agricultural land worldwide, contributing to 56% to 58% of emissions related to food production<sup>2</sup>. One of the biggest challenges ahead will be how to create a sustainable food system that provides healthy food to a growing population<sup>4</sup>. Without concerted action, the environmental impacts of the food system could increase by between 50% and 90% by 2050<sup>5</sup>. Even if we were to eliminate fossil fuel emissions, emissions from the food system would make it impossible to limit warming to 1.5 or 2°C<sup>6</sup>. According to the IPCC, producing meat from plants or growing it from animal cells could be critical in mitigating climate change<sup>7</sup>. Therefore, alternative proteins sources like cultivated meat, a promising technology in which animal stem-cells proliferate and differentiate with cell engineering, may provide good quality protein with less environmental impact. However, there are uncertainties regarding their real environmental impacts.



**Figure 1** – General process of cultivated meat production<sup>8</sup>: 1) Stem cells taken from muscle tissue or embryos are first expanded and then differentiated into muscle cells; 2) These cells are further grown in a bioreactor to increase their number; 3) The cells are then transferred to a scaffold to grow these into muscle fibres and larger tissue. (Figure reproduced under the Creative Commons Attribution 4.0 Unported Licence (CC BY), <https://creativecommons.org/licenses/by/4.0/>).

## OBJECTIVES

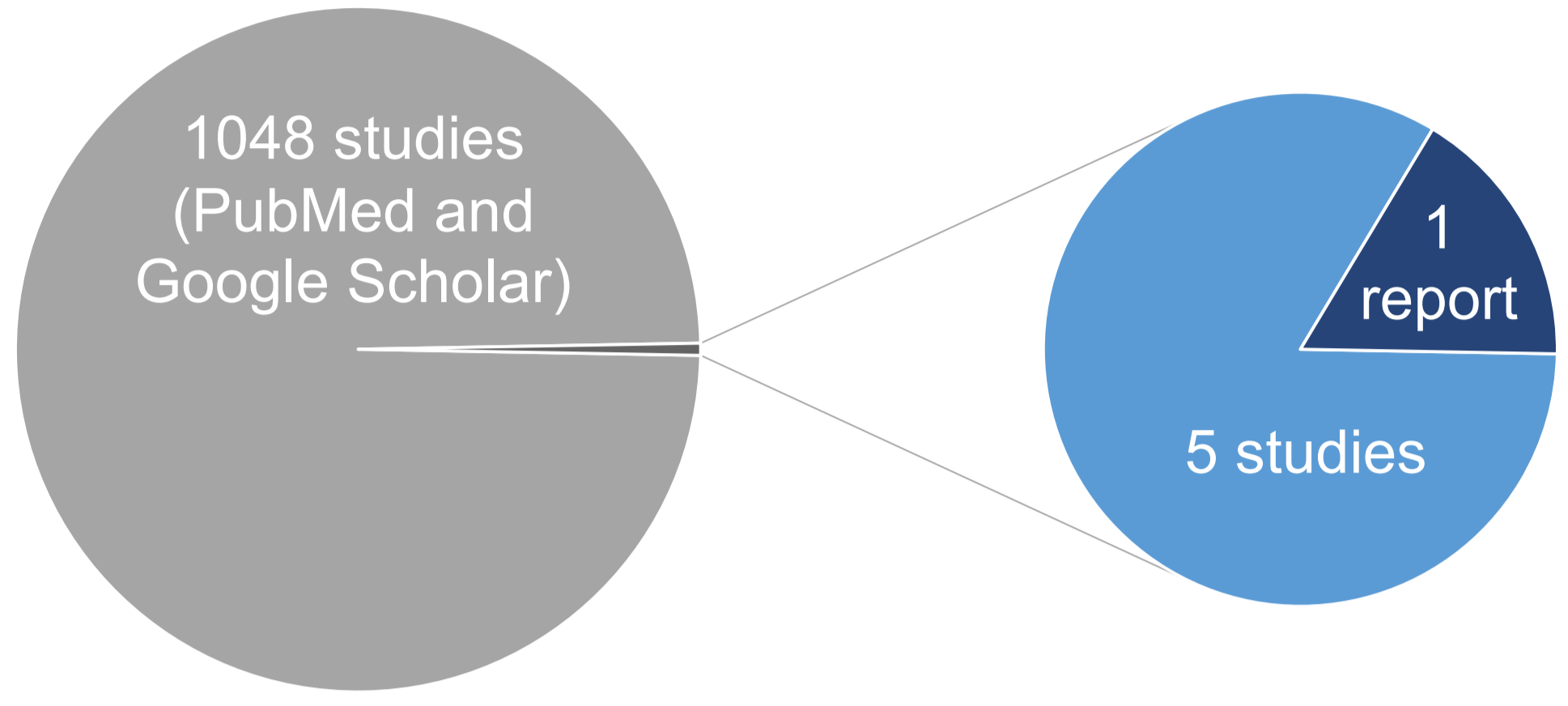
This study aimed to assess the available Life Cycle Assessment (LCA) studies of cultivated meat and to compare their results regarding those of conventional beef.

## METHODOLOGY

A search for “cultured meat” OR “cultivated meat” OR “alternative protein” OR “lab-grown meat” OR “cell-based meat” OR “clean meat” OR “in vitro meat” AND “sustainability” OR “environmental impact” OR “life cycle assessment” OR “climate impact” OR “environment” was conducted in the PubMed and Google Scholar databases through September 2022. Studies that did not perform a LCA were excluded.

## RESULTS

Five studies (0.3% of the PubMed studies for cultivated meat and synonyms) and one report (currently under peer review, in the process of being published), published between 2011 and 2022, performed a LCA of cultivated meat<sup>9–14</sup>.



**Figure 2** – Search results from PubMed and Google Scholar before and after applying exclusion criteria.

All studies reported that both greenhouse gases emissions (GHG) (2.0-14.2 kg CO<sub>2</sub>eq/kg) and land use (0.2-5.5 m<sup>2</sup>/kg) were lower for cultivated meat compared to conventional beef (99.5 kg CO<sub>2</sub>eq/kg and 326.2 m<sup>2</sup>/kg). However, most studies<sup>12–14</sup> showed greater energy consumption of cultivated meat (28.5-286.1 MJ/kg) compared to beef (51.5 MJ/kg).

**Table 1** – Greenhouse gases emissions average values (kg CO<sub>2</sub>eq/kg of cultivated meat or conventional beef).

Study	GHG EMISSIONS (kg CO <sub>2</sub> eq/kg product)
Tuomisto & Teixeira de Mattos (2011)	2.0
Tuomisto et al. (2014)	3.4
Mattick et al. (2015)	7.5
Sinke & Odegard (2021)	8.0
Tuomisto et al. (2022)	14.2
Poore & Nemecek (2018)	99.5

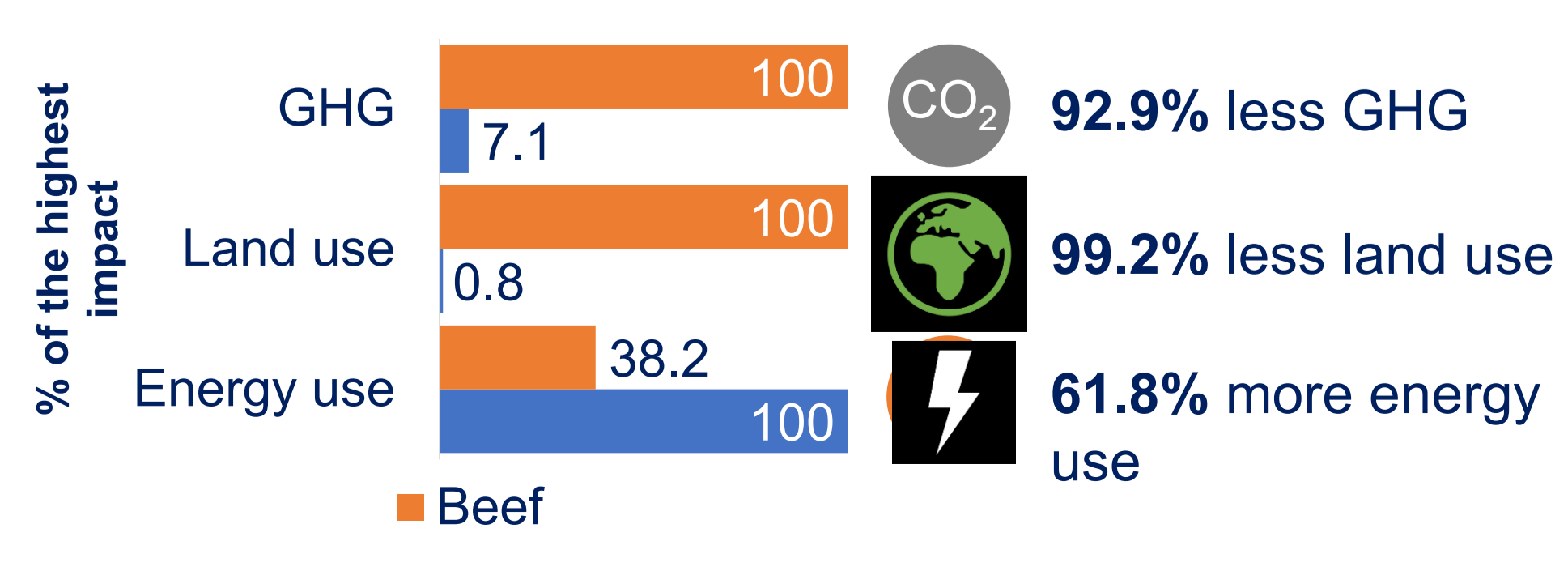
**Table 2** – Land use average values (m<sup>2</sup>/kg of cultivated meat or conventional beef).

Study	LAND USE (m <sup>2</sup> /kg product)
Tuomisto & Teixeira de Mattos (2011)	0.2
Tuomisto et al. (2014)	3.3
Mattick et al. (2015)	5.5
Sinke & Odegard (2021)	1.8
Tuomisto et al. (2022)	4.0
Poore & Nemecek (2018)	326.2

**Table 3** – Energy consumption average values (MJ/kg of cultivated meat or conventional beef).

Study	ENERGY USE (MJ/kg product)
Tuomisto & Teixeira de Mattos (2011)	28.5
Tuomisto et al. (2014)	47.7
Mattick et al. (2015)	106.0
Sinke & Odegard (2021)	205.5
Tuomisto et al. (2022)	286.1
Beef	51.5

**Table 4** – Average impacts of cultivated meat production versus beef (%).

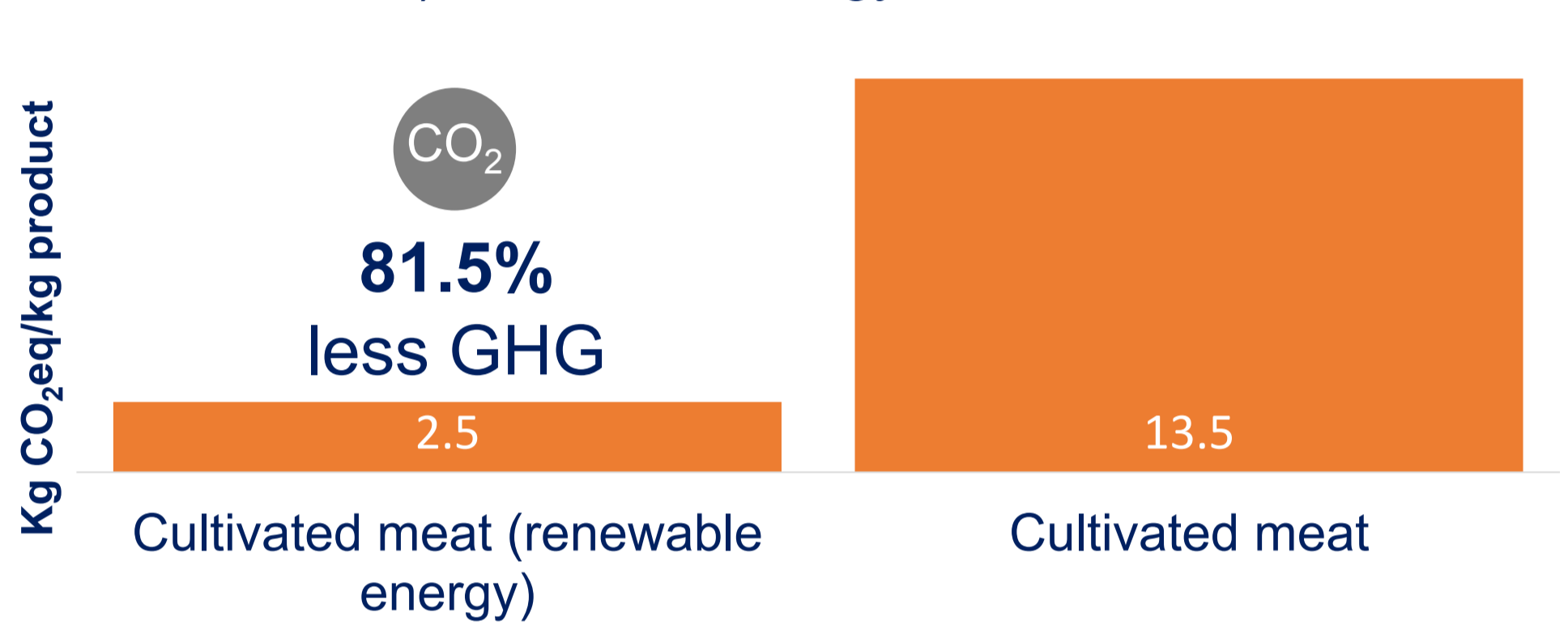


One study showed that in a sustainable energy scenario (wind and solar) the production of cultivated meat has a lower environmental impact compared to sustainable benchmarks of traditional meats and cultivated meat<sup>13</sup>. The comparative greenhouse gases emissions reduction of that sustainable energy cultivated meat are also reported<sup>16</sup>.

**Table 5** – Greenhouse gases emissions (kg CO<sub>2</sub>eq/kg of cultivated meat or conventional beef) in different energy scenarios<sup>13</sup>.

Scenario	Kg CO <sub>2</sub> eq/kg product
Cultivated meat (renewable energy)	2.5
Chicken	3.0
Pork	5.2
Cultivated meat	13.5
Poore & Nemecek (2018)	99.5

**Table 6** – Greenhouse gases emissions (kg CO<sub>2</sub>eq/kg of cultivated meat) in different energy scenarios<sup>13</sup>.



**Table 7** – Greenhouse gases emissions\* reduction of cultivated meat produced with renewable energy versus sustainable benchmarks for conventional chicken, pork and beef (%)<sup>16</sup>.

GHG reduction of cultivated meat (renewable energy)	chicken	pork	beef
	17%	52%	Up to 92%

\* Referred as Global Warming.

## CONCLUSIONS

Studies evaluating the life cycle of cultivated meat production are scarce and their results are heterogeneous. Overall, the estimated environmental impacts of cultivated meat could be lower than conventional meat. The differences observed between the studies reflect different procedures or inventory, as well as the energy source used in production. In that sense, although there is potential to improve the environmental impacts of cultured meat, the production of this new food may be more sustainable.

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