GROOF
Greenhouses to Reduce CO_2 on rooFs

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ROOFTOP GREENHOUSE : A FINANCIAL PERSPECTIVE

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INTRODUCTION

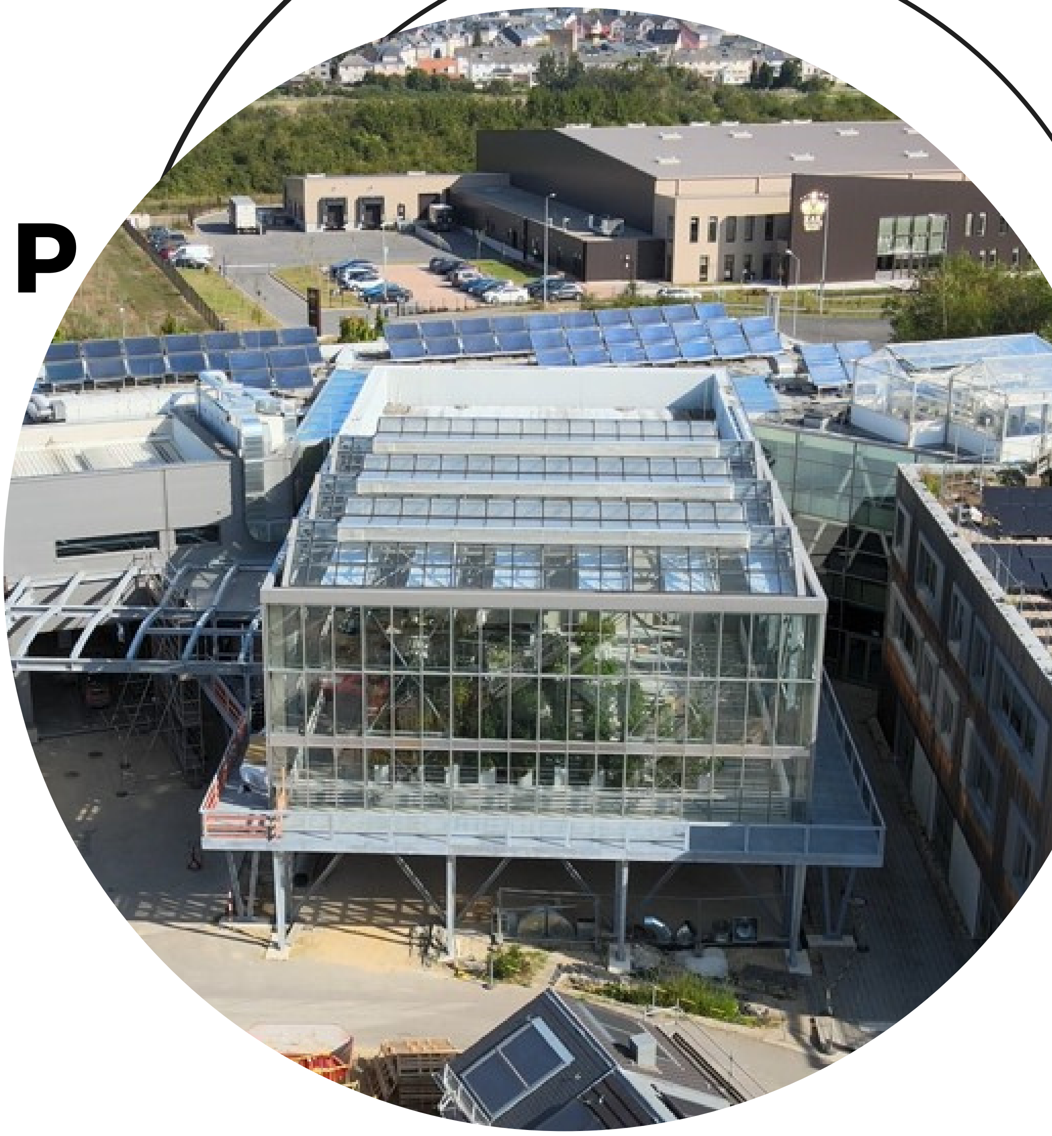
Land consumption is a major issue worldwide as it contributes to loss of fertile soils, biodiversity and ecosystem services (1). Every day, approximately 52 ha of land is lost this way in Germany (2). Along with the land consumption, the demand for food is growing proportionally with the population. It is therefore necessary to find holistic solutions to feed the humankind in the future while addressing the issue of climate change.

Urban farming is an emerging trend worldwide that can be part of the solutions. Specifically, rooftop greenhouses (RTGs) using existing urban roof space and fall out of the competition for land use. The fact that they can form synergies with their support buildings (use of waste heat, CO_2 from respiration, urine, grey- and rainwater) gives them an additional environmental benefit. Urban farming can also provide employment opportunities to less secure social groups and serve as education points (trainings, visits) in urban settlements.

The question of RTGs profitability will be addressed in this study within the framework of the GROOF (Greenhouses to reduce CO_2 on Roofs) project. The specific case of the pilot greenhouse of the company IFSB will be studied.

[1] Marquard, et al., 2020; p. 2
[2] BMU, 2020; retrieved July 2021, from https://www.bmu.de/themen/europa-internationales-nachhaltigkeit-digitalisierung/nachhaltige-entwicklung/strategie-und-umsetzung/reduzierung-des-flaechenverbrauchs/

ROOFTOP GREEN HOUSES



According to Buehler & Junge (2016), among the commercial rooftop farms two main groups can be found: rooftop greenhouses with hydroponic systems (mostly growing tomatoes, leafy greens and herbs) and open-air soil-based farms (growing a variety of crops). (3) Hydroponics means producing plants with no soil but in water that contains essential for the plants mineral nutrients. Recirculating hydroponics – the most efficient and modern method – allows to harvest crops using 5-10 times less water and 10-20 times less land than conventional agricultural practices. (4)

Cultivating crops in rooftop greenhouses (RTGs) is a suitable option in countries with colder climate conditions to allow for year-round production in protected environment. Moreover, RTGs can exercise synergies with the supporting buildings and thus allow for a reuse of material and energy outflows that would otherwise be considered wasted. Therefore, such practices require high technology, operation, maintenance, and investment standards. (5)

Ideal settings for RTGs can be provided by numerous building types: “supermarkets, hotels, convention centers, hospitals, schools, apartment blocks, prisons, warehouses, and shopping malls” (6)

[3] Buehler & Junge, 2016; abstract
[4] Caplow, 2009; p. 55
[5] Specht, et al., 2014; p. 34
[6] Caplow, 2009; p. 56

Financial performance of horticulture business and rooftop greenhouses

Several KPI's can be used to compare the performance of greenhouses. As the data collected refer to a wide range of greenhouses size, m² will be used as a common denominator for the ratios. We took three kinds of ratios for this study:

-**The production ratios**

-**The cost ratios**

-**The investment ratios**

Production ratios :

We have gathered data to compare the yield of one of the main crops you can find in greenhouses: tomato. Out of the 17 tomatoes conventional greenhouses analysed, the average yield of kg/m²/year is **47.6 kg** (appendix 1) within a minimum value of 22.6 and a maximum of 60.

Cost ratios :

WATER

Tomato production requires a lot of water. The 8 studies considered provide us with an average of 943.6 l/m²/year. (Appendix 2) As the average cost of 1 m³ of water in France in 2021 is **2.56€** (appendix 3), the average cost of water for tomato production is then 3,91€.

FERTILIZER

The four studies providing us with an overview of the cost of fertilizers per m² give us an average of **3.06€ / m²** / year. (appendix 4)

YOUNG PLANTS

The six analysed studies result in a **2.68€** average cost per m². (appendix 5)

LABOUR

The labour costs vary according to the country where the farm is. It is then pointless to speak in terms of €/m² but more relevant to talk about h/m²/year. The financial feasibility can then be calculated according to the average cost of labour in the targeted country. As we can see on the table below, really small farms have a big competitive disadvantage in terms of labour costs. The average h/m²/week is 0.07, so 3.64 per year (appendix 5). While the average cost of labour in Europe reaches 28.5€ in Europe in 2020, (7) it means our yearly average cost/m² is **103.74€**. This cost will obviously vary according to the targeted country.

MARKETING

The marketing is important for such businesses. The average yearly expense is **11.63€/m²** (Appendix 7).

ENERGY

Energy for both heating and lighting is also an important cost to consider. Out of the four analysed studies we gathered, the average value is **15.6€/m²**. (Appendix 8)

OTHER COSTS

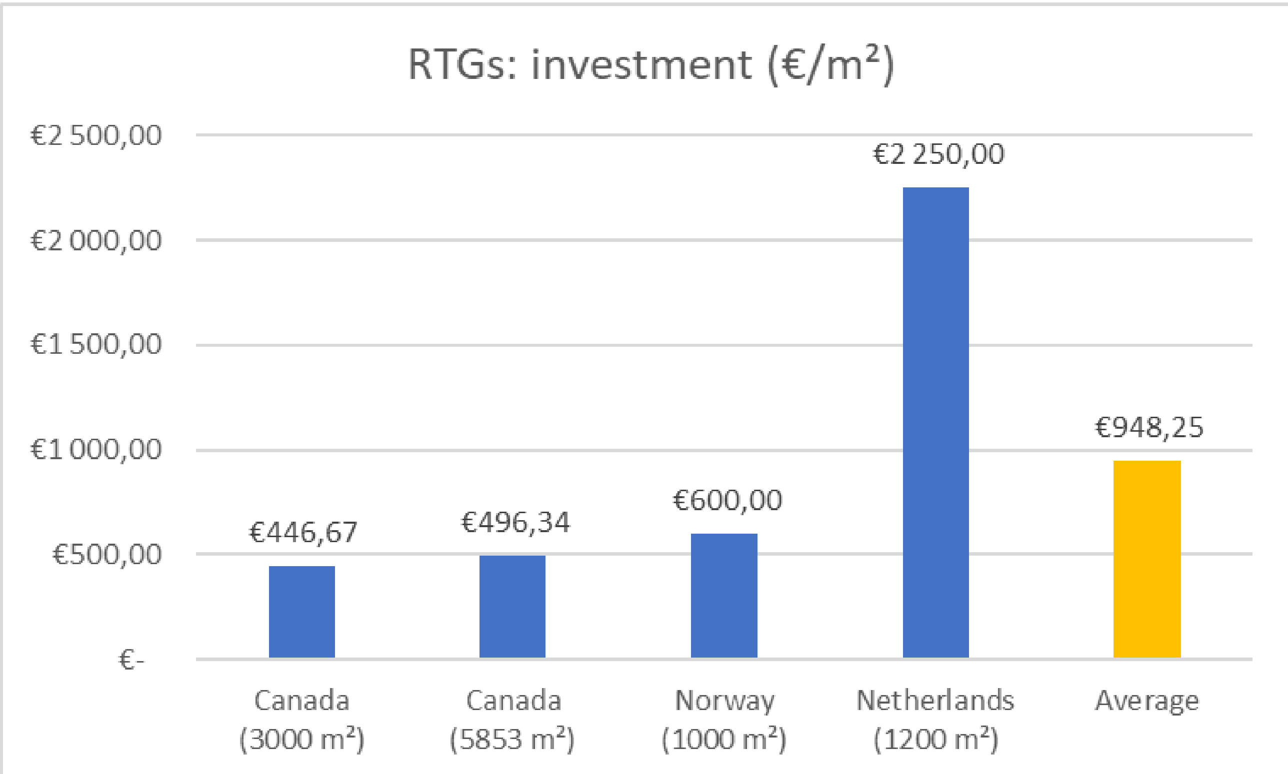
The average cost of the other costs (pest and pollinators) reaches an average of **2.28€/m².** (Appendix 9 & 10)

Financial performance of horticulture business and rooftop greenhouses

Investment ratios:

As we can see on the appendix 11, the investments required for a conventional greenhouse average to **460,34€/m²**. We can note that the difference between projects is important as the investment required for the greenhouse in Norway (1,084.32€/m²) are 17x higher than the ones from the Dutch study.

For the RTG's, the investments are higher, this can be explained by the technical constraints of the construction, the feasibility studies necessary to build on a roof and the additional administrative work required. The investments are then 3 almost 3x higher in average. Taken into account an interest rate of 0.5% and a useful life of 20 years for a RTG, the annuity factor is 5.27% (8). The yearly cost of capital for a RTG is then 948.25€*5.27% = **49.94€/m².**



[8] Annuity factor = $\frac{i}{1-(1+i)^{-t}}$

Summary of the costs and revenues

Here is an average of the costs for an RTG producing tomatoes exclusively based on the assumptions we made earlier in this chapter. As we can see on the figure below, labour costs account for more than half of the total (54%).

Type of costs	€/m²/y	%
Water	2.56	1
Fertilizer	3.06	2
Young plants	2.68	1
Labour*	103.74	54
Marketing	11.63	6
Energy*	15.6	8
Others	2.28	1
Cost of capital	49.94	26
TOTAL	191.49	100

*depends on the country

The main expected revenue/m² for a tomato RTG is obviously its yield*the price of tomato. The average price of 1kg of tomato is 2.2€ at the Rungis market (France) for December 2021 (9). Since the products of the RTG can be sold more expensively as they are sold locally in most cases, we can count on a **2.4€/kg** price. Multiplied by the 47.6 kg calculated above, the average revenue/m² is then **114.24€/m².**

We can then expect a loss of 191.49-114.24=77.25€/m² for a European RTG selling only tomatoes.

However, there are several ways to increase the revenue/lower the costs that could help the projects reach their break-even point:

-Finding subsidies and state support;
-Commercializing more expensive products (microgreens, snack tomatoes, eatable flowers, ...);
-Maximizing the production area in the greenhouse;
-Organizing seminars, trainings, visits or any kind of activity where low new investments are required;
-Creating synergies with the support building to lower both water and energy bills which is one of the aims of the GROOF Project;
-Think about the possibility to build a greenhouse on the roof while designing the support building to lower the investment costs;
-Use free/cheaper labour (interns, neighbours community, students, ...) to lower the labour costs;
-Etc, ...

[9] https://www.terre-net.fr/marche-agricole/rungis-fruits-et-legumes/tomate

APPENDICES

Appendix 1 : Tomato production

Tomato yield analysis		
Yield [kg/m²*a]	Remark	Country
22,0	snack tomatoes	Germany
25,0	special type tomato	France (NW)
33,0	cocktail tomatoes	Germany
37,0	average value	Netherlands
42,0		Austria
46,7	cluster tomato	Netherlands
50,0	bulk tomato	France (NW)
50,0	tomato on the vine	France (NW)
52,0	average value	Germany
53,4	beefsteak tomato	Netherlands
55,5	tomato weighted average	Canada
56,0	trusses of tomatoes	Germany
56,5	trusses of tomatoes	Netherlands
56,5		Germany
56,5		Netherlands
57,0		Sweden
60,0	average value	Netherlands
47,6	**Average**	

Sources: Müller-Lindenlauf, et al., 2013; Peet & Welles, 2005; Montero, Antón, Torrellas, Ruijs, & Vermeulen, 2011; Boulard, et al., 2011; Lattauschke, 2006; Bosona & Gebresenbet, 2018; Ruijs, 2011; Theurl, 2008; Dias, et al., 2017; Sanyé-Mengual, et al., 2017; Golzar, Heeren, Hellweg, & Roshandel, 2019

Appendix 2 : Water demand

Tomato water demand		
Water demand [l/m²*a]	Remark	Country
1.250,0	average value, substrate: rockwool	France
441,3	average value from 3 greenhouses with equal area: 345,6 m², soil	Germany
559,1	average value from 3 farms, substrate: soil	Morocco
947,4	average value, soilless [not specified]	Austria
1.650,0	average value, soilless [not specified]	not country-specific
794,4	40.000 m² greenhouse, substrate: rockwool	Netherlands (1)
1.150,0	1.000 m² greenhouse, substrate: rockwool	Germany
900,0	average value	Netherlands
800,0	average value	Canada
943,6	**Average**	

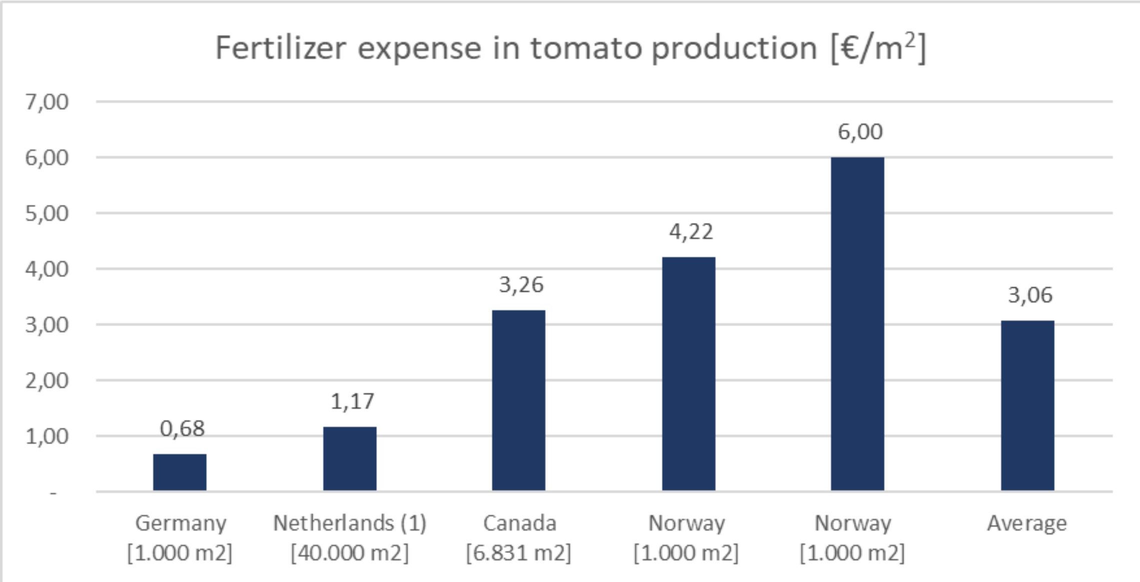
Sources: Boulard, et al., 2011; Ntinas, Tsadilas, Meyer, & Neumair, 2017; Payen, Basset-Mens, & Perret, 2015; Theurl, 2008; European Innovation Partnership for Agricultural productivity and Sustainability Focus Group, 2019; Montero, Antón, Torrellas, Ruijs, & Vermeulen, 2011; Lattauschke, 2006; Peet & Welles, 2005

Appendix 3: Water price in European cities

Member state	City	Price tap water (EUR/m3)
Norway	Oslo	5.51
Germany	Stuttgart	4.67
Denmark	Kopenhagen	4.37
Netherlands	Rotterdam	3.99
Netherlands	Amsterdam	3.65
Sweden	Stockholm	3.6
France	Lyon	3.57
Germany	Hamburg	3.49
Belgium	Brussels	3.49
Germany	Munich	3.45
Germany	Frankfurt	3.33
Switzerland	Geneva	3.2
Czechia	Prague	3.09
Germany	Cologne	3
Germany	Berlin	2.85
Austria	Vienna	2.85
France	Marseille	2.76
Austria	Innsbruck	2.74
Finland	Helsinki	2.52
Switzerland	Zürich	2.39
France	Paris	2.14
Spain	Barcelona	2
Spain	Almeria	1.95
Italy	Florence	1.9
Ireland	Dublin	1.85
Croatie	Zagreb	1.68
Portugal	Porto	1.68
Spain	Madrid	1.65
Portugal	Lisbon	1.63
Poland	Warsaw	1.42
Italy	Naples	1.29
Hungary	Budapest	1.23
Greece	Athens	1.16
Italy	Rome	1.05
Estland	Tallinn	0.82
Italy	Milan	0.4
AVERAGE		2.56583333

Source : https://www.waternewseurope.com/water-prices-compared-in-36-eu-cities/

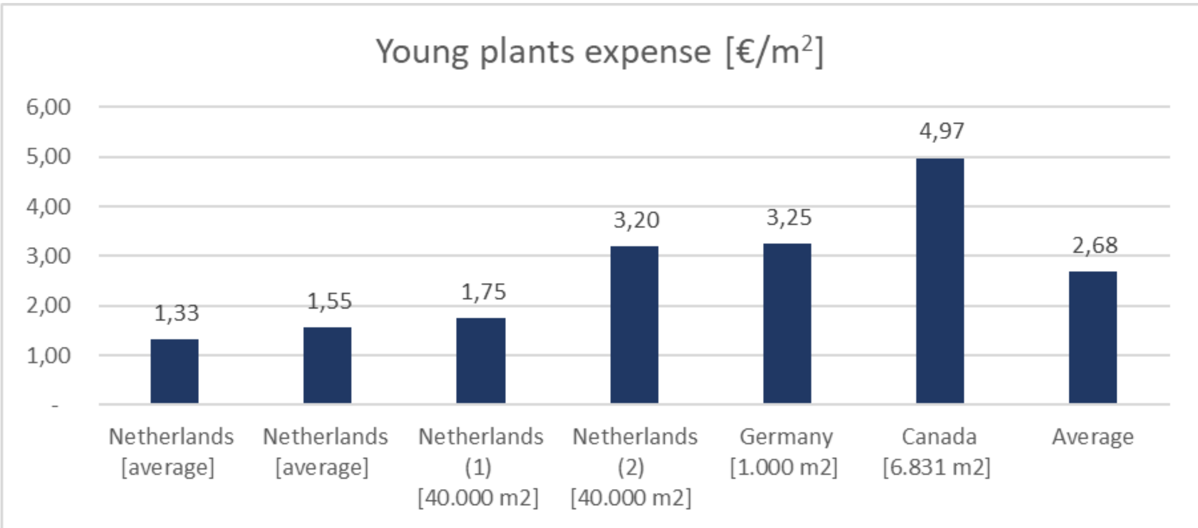
Appendix 4 : Fertilizer expenses



Sources: Laate, 2018; Milford, Kårstad, & Verheul, 2019; Lattauschke, 2006; Montero, Antón, Torrellas, Ruijs, & Vermeulen, 2011

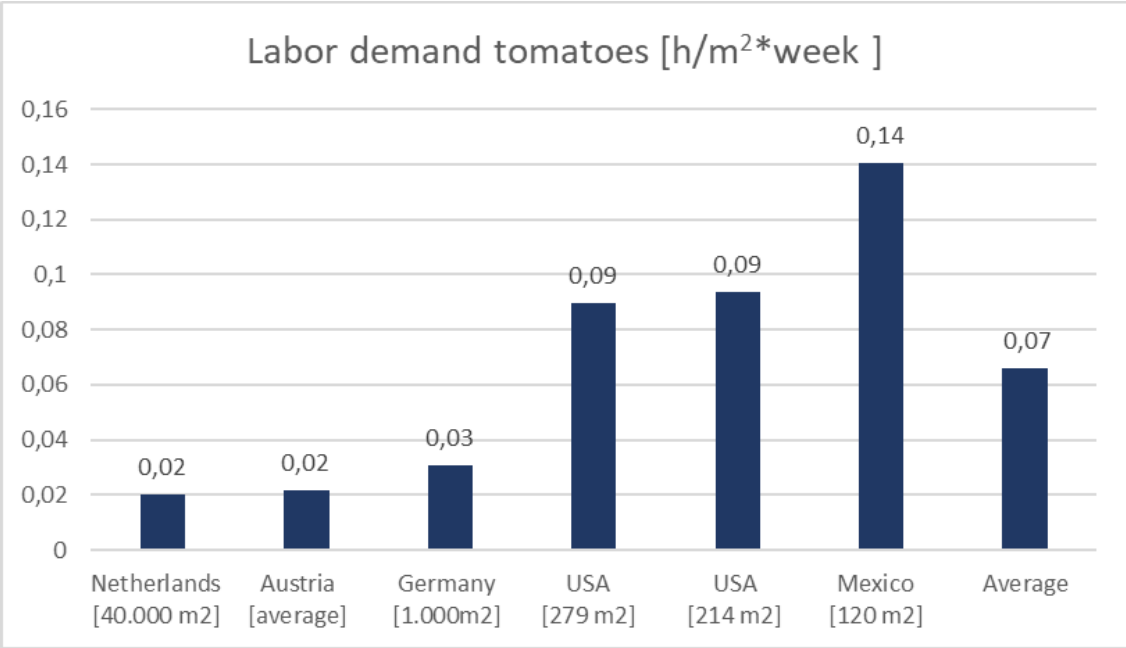
NB: The two Norway greenhouses reffer to a similar greenhouse with two different scenarios: with recycled water (4,22) and the other one without (6)

Appendix 5 : Young plants expense



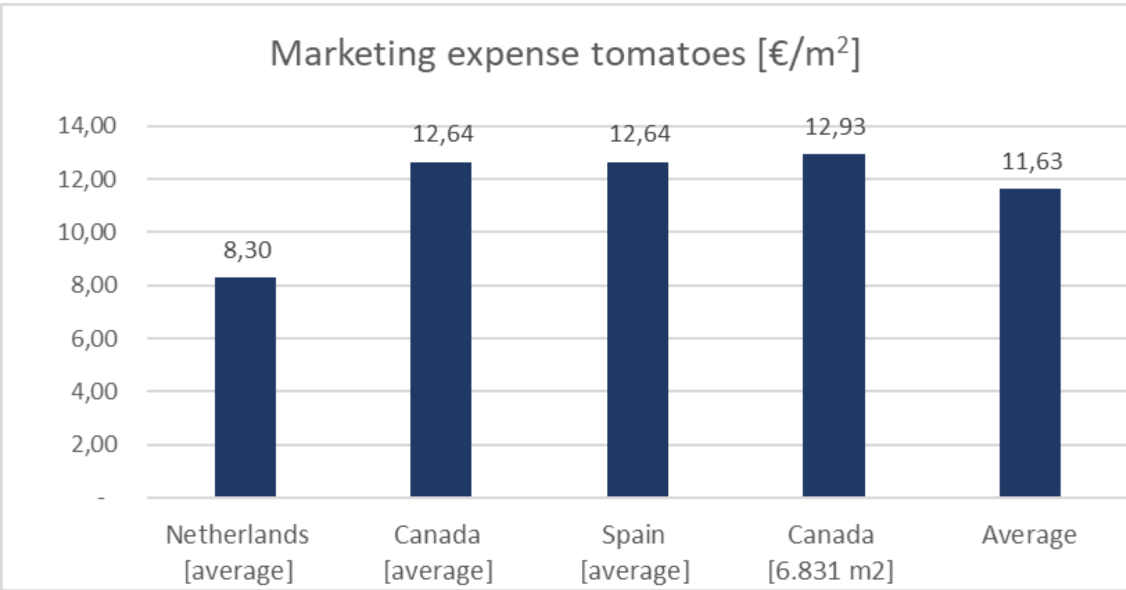
Sources: Laate, 2018; Lattauschke, 2006; Montero, Antón, Torrellas, Ruijs, & Vermeulen, 2011; Ruijs, 2011; Peet & Welles, 2005

Appendix 6: Labour demand



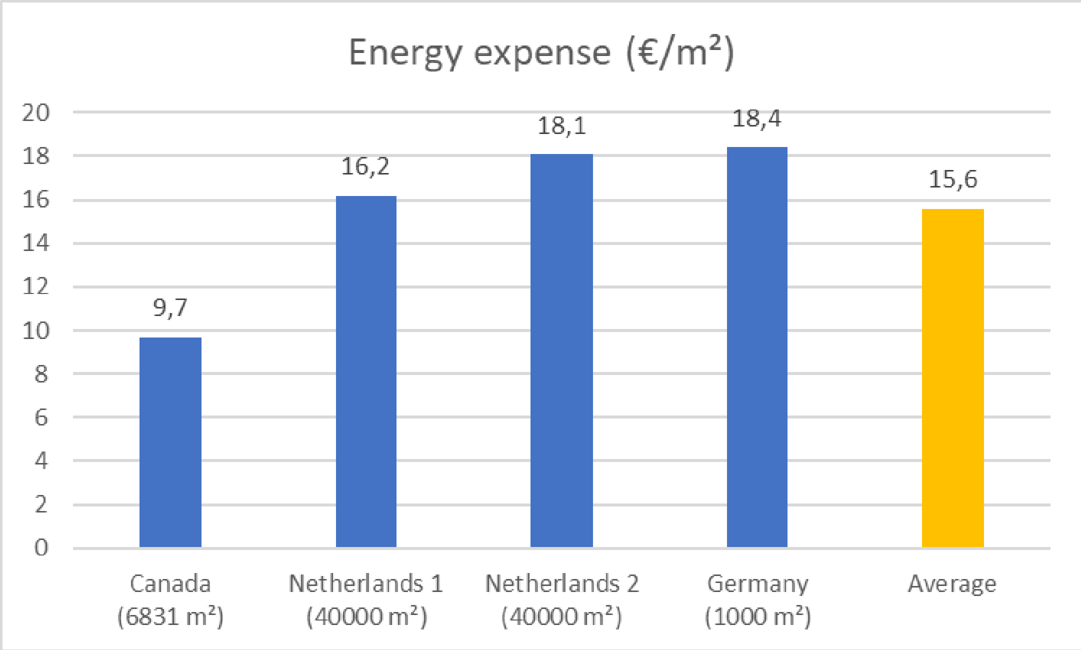
Sources: Lattauschke, 2006; Handler & Blumauer, 2006; Snyder, 2010; Rutledge, 2009; Montero, Antón, Torrellas, Ruijs, & Vermeulen, 2011; Salazar-Moreno, Sánchez-Martínez, & López-Cruz, 2020

Appendix 7: Marketing expenses



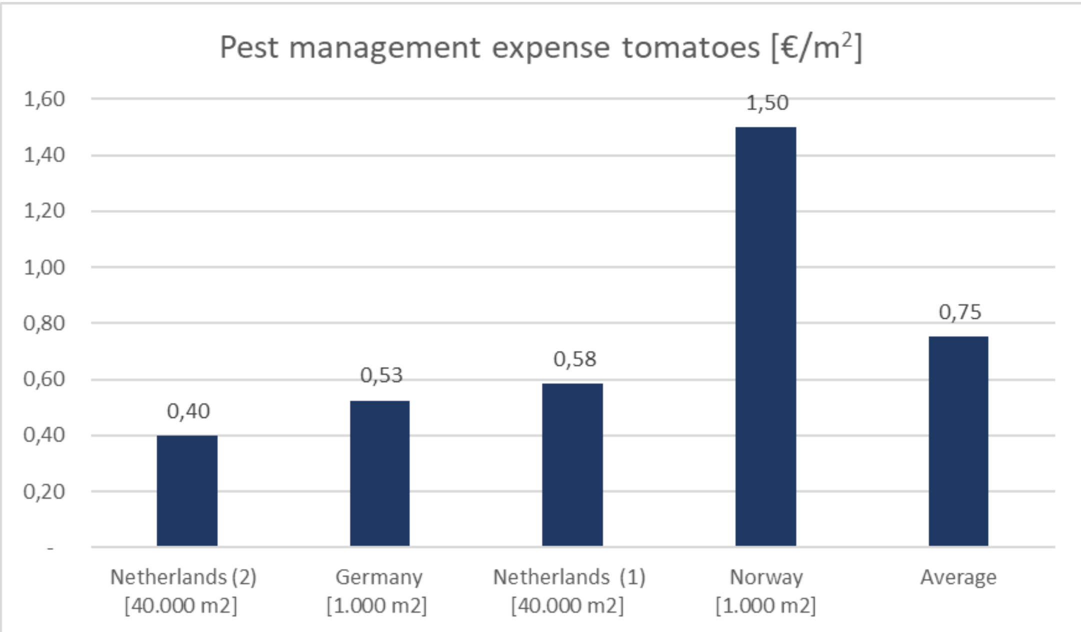
Sources: Laate, 2018; Peet & Welles, 2005

Appendix 8: Energy expense



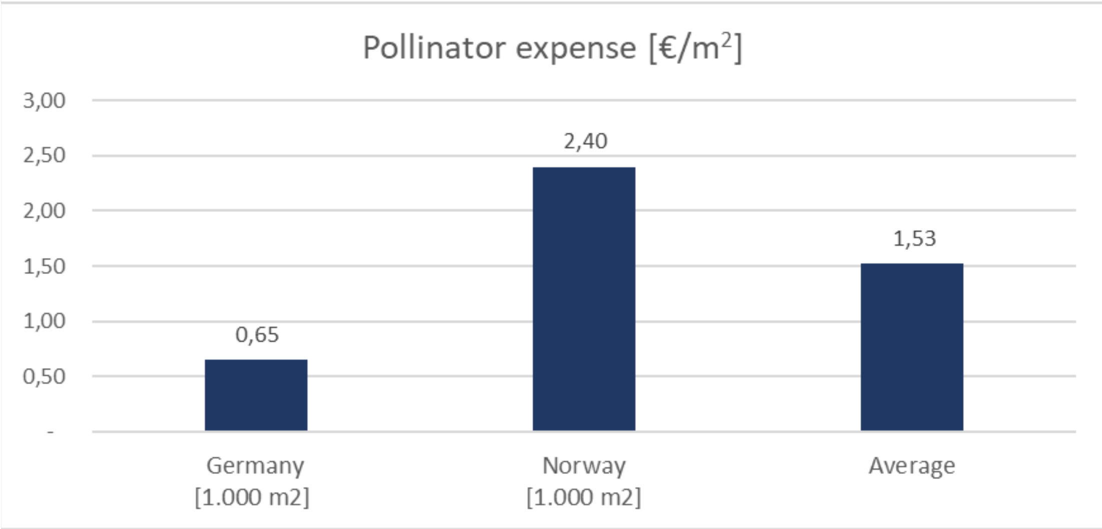
Sources: Laate, 2018; Lattauschke, 2006; Milford, Kårstad, & Verheul, 2019; Montero, Antón, Torrellas, Ruijs, & Vermeulen, 2011; Ruijs, 2011

Appendix 9: Pest management expenses



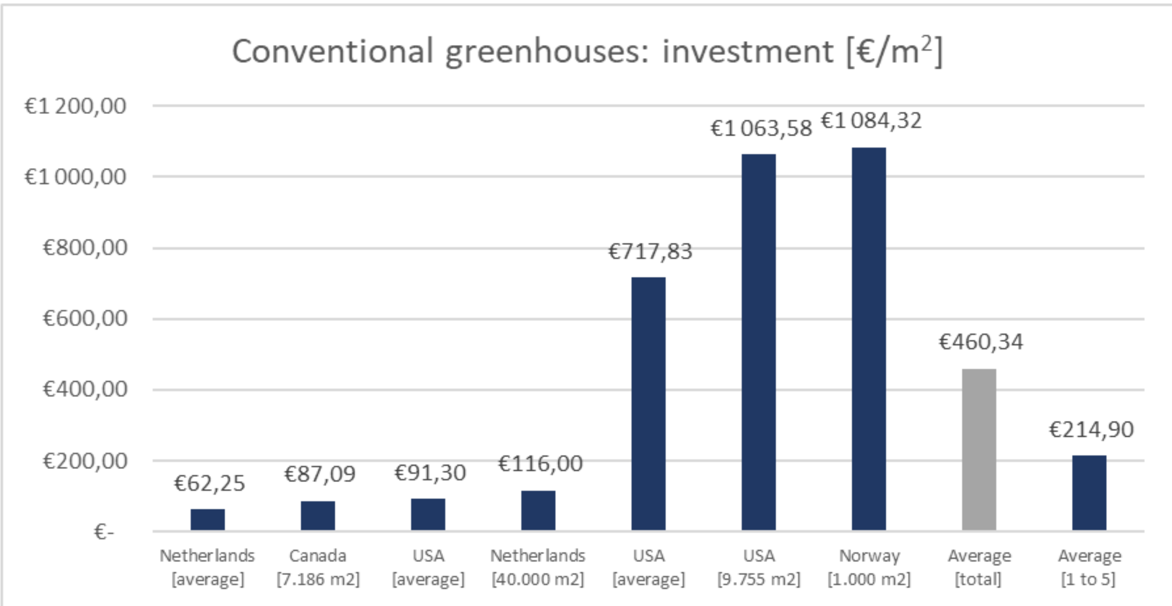
Sources: Lattauschke, 2006; Montero, Antón, Torrellas, Ruijs, & Vermeulen, 2011; Milford, Kårstad, & Verheul, 2019; Ruijs, 2011

Appendix 10: Pollinators expenses



Sources: Lattauschke, 2006; Milford, Kårstad, & Verheul, 2019

Appendix 11: Conventional greenhouses investment



Sources : Peet & Welles, 2005 ; Nickle, 2021 ; Laate, 2018 ; Montero, Anton, Torrellas, Ruijs & Vermeulen, 2011 ; Trotter, 2018 ; Milford, Karstad & Verheul, 2019

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Do not hesitate to visit GROOF website : www.groof.eu

Discover GROOF Guidelines : https://www.urbanfarming-greenhouse.eu/
This is a summary of GROOF's experience in designing and building an energy efficient rooftop greenhouse.

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