Towards a circular greenhouse construction industry in the Netherlands

Focus on vegetable production

Why greenhouses:
- Horticulture contributes 2.7% to the Dutch GDP and 39% of the total agricultural complex GDP, but it only uses 0.5% of all agricultural land in the Netherlands (van Buitenlandse Zaken, 2023).
- Glass greenhouses contain significant amounts of steel, aluminum, glass, and cement.

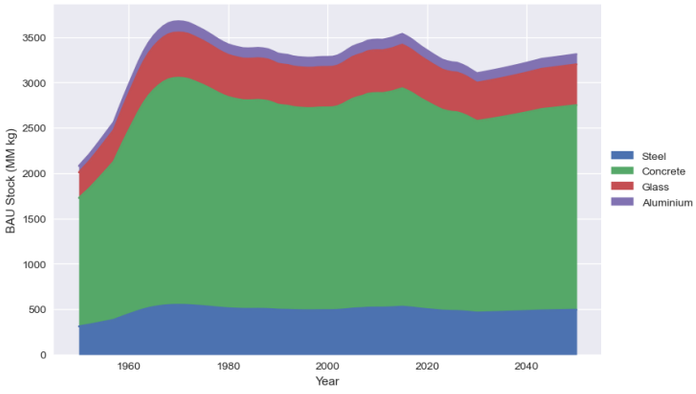
Problem statement:
- Previous studies evaluate the circular operational aspects of the horticulture industry (van Tuyll et al, 2022), and many LCAs have focused but few focus on greenhouse operations and downstream supply chains; however, few studies look at the infrastructure necessary to operate these greenhouses. As the Dutch greenhouse industry which has been growing since the 1950s ages, greenhouses will continuously need to be rebuilt. Meanwhile, the Dutch government intends to achieve a circular economy by 2050 implementing a circular economy by 2050 (Government of the Netherlands)

Research question:
- How will the Dutch greenhouse industry be able to achieve a circular economy with regard to the construction materials of its greenhouses?

Objectives:
- To understand what role exports, crop productivity rates, and population play in driving the past and future stock of materials.
- To examine three different scenarios to see how much material may become available annually to recirculate into maintaining the greenhouse stock.

How:
- Using data from Statistics Netherlands (CBS, 2022) and material intensity and average lifetime data for steel, concrete, glass, and aluminium from two LCA studies (Theurl, 2008; Karlsson. 2012), we calculated annual stock levels for greenhouses:

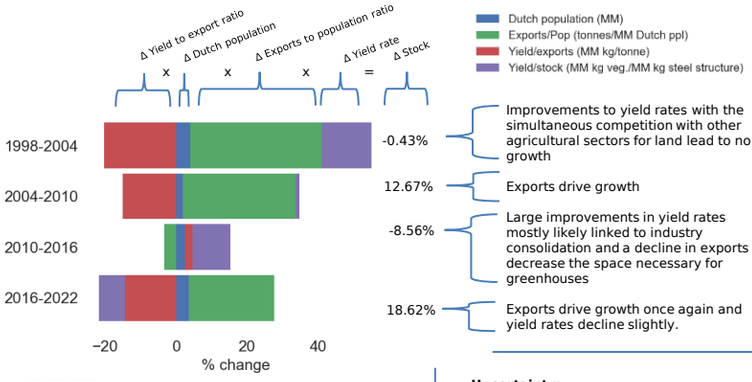
$$stock(y) = Surface\ area\ under\ glass\ (y) \times Material\ intensity\ (x)$$



- We calculated the Inflow, net additions to stock (NAS), and outflows using the following equations based on a normally distributed survival curve ($sf(0)$) with y and t representing the current year previous year, respectively. The mean lifetime of the materials is an average of the two LCAs cited previously.

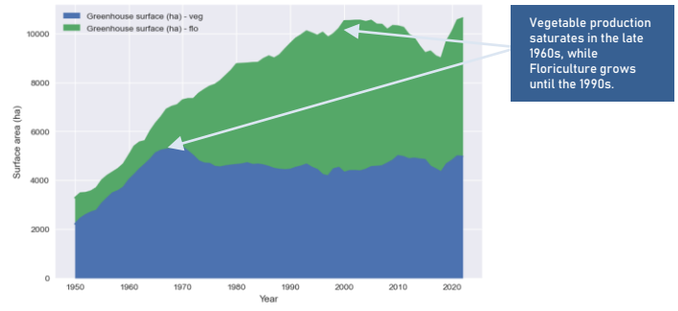
$$inflow(y) = \frac{stock(y) - \sum_{t=y_0}^{y-1}[inflow(t) \times sf(y-t)]}{sf(0)} \qquad NAS\ (y) = stock(y) - stock(y-1) \qquad outflow(y) = inflow\ - NAS\ (y)$$

- We then created a structural decomposition analysis (SDA) to understand the past trends driving the greenhouse industry and how they may develop moving toward 2050.
- The BAU scenario is developed by historic trends in yield rates as a means to project future yields using regression and implementing drivers such as demand, productivity, and oversupply (Ewert et al., 2005). Donnellan et al., (2012) estimated an increase in tomato yields of 1% annually within the E.U. with small growth in the land use for production.
- We created a historic trend of Dutch greenhouse yield to Dutch vegetable export ratio (FAOSTAT 2022; CBS 2022). The Netherlands' growth in tomato production shows an increase upwards due to an increase in surface area and yield rates and it plays an important role in the re-export of vegetables (Capobianco-Uriarte et al., 2021). We assume a constant rate of re-export based on historic trends (CBS, 2022).

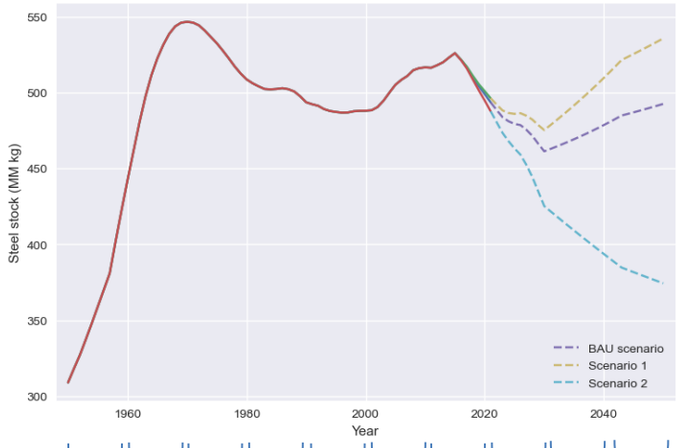


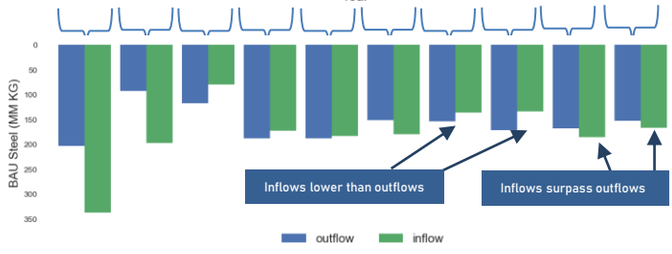
Limitations:
- More research is necessary to understand additional drivers such as the evolving nature of material intensities in the greenhouse sector, the ratio between farm size and yield rates, and maintenance versus repair cycles of Greenhouses.
- This study only analyzes scenarios for vegetable production and does not include forecasts for the floriculture sector.

Conclusions:
- Given that other regions in Europe may be more likely to have a decline in their vegetable production due to climate change, the Netherlands will continue to have a growing market for its greenhouse vegetables. However, only a reduction in greenhouse stock by continuously improving yield rates may enable the sector to move towards a circular economy in 2050.
- Exports and improved yields, not domestic population growth generally drive the growth of the Dutch greenhouse sector.



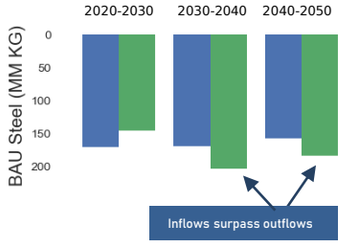
Vegetable production saturates in the late 1960s, while Floriculture grows until the 1990s.





Scenario 1: The government has asked to increase exports of greenhouse products to make up for the forecasted decrease in other exports due to expected drought conditions over the next 29 years due to climate change. Changes need to be made without improving the yield rate and instead by expanding the greenhouse surface area.

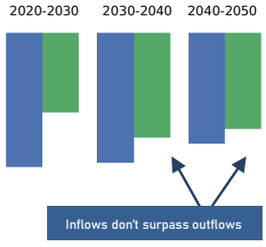
Action: Increase yield/export ratio increase by 10% in 2050 compared to BAU by holding exports constant. This impacts the yield, the yield rate and the stock of greenhouses.



Conclusions: Increasing production without improving yields will make implementing a circular economy for greenhouse materials less feasible.

Scenario 2: The Dutch government wants to reduce surface area of greenhouses by 20% from 2021 levels by 2050 to make room for new urban developments, what must the improvement to yield rates be?

Action: Set a goal to a 20% reduction in greenhouse surface area from the 2021 level by 2050. This only affects the yield rate and the remainder of the indicators were held constant unlike Scenario 1.



Conclusions: Improving yield rates may help promote a circular economy in the Dutch vegetable greenhouse sector. Attention, however, needs to focus on improving the yield rate without increasing environmental emissions (e.g., CO_2, N, P).

Uncertainty:
We ran a *Montecarlo Simulation* 10,000 times in which stock inputs (+/- 10%), mean lifetime, and standard deviation of material (+/-30%).