Supplement

Potential LLM Planning Support for Living Labs

- An example for demonstration -



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Executive Summary

This report is in support of Living Labs who intend to engage in contingency planning for food security. Contingency planning involves a stepwise procedure, moving from a first initial plan based on available data, the analysis of various sources, and the consultation of stakeholders and experts through various phases of improvements dealing with the analysis of necessary and available resources, financial considerations, the balancing of objectives of policy, stakeholders, and consumers, the analysis of the feasibility and availability of actions, the analysis of difficulties in implementation, and much more..

For a first blueprint plan proposal, one might want to employ artificial intelligence tools like Large Language Models (LLM) which could facilitate the further planning process.

If appropriately used, these tools could deduct information from sources identified by users (e.g. by asking to only utilize information from public databases, journal publications, government documents or from specified years only) helping users to judge the reliability of feedbacks. This could allow the provision of a first initial plan without spending a lot of resources of expensive expert input.

However, the outcome of consulting LLM tools would need to be challenged by stakeholders and experts with background information before accepting it as a baseline contingency plan ready for further improvement. Actual developments support decisions on acceptance as AI feedbacks provide information on sources their feedback is based on and, if feedbacks involve some analysis, the line of arguments used in the analysis.

In this report, we have used a basic example provided by a Living Lab and demonstrate through various lines of communication with a LLM source how elements of a basic plan proposal can be deducted by Living Labs cooperating with the project ECO-Ready.

For keeping the description of the example easy, the interaction with the tool is kept to sequential questions avoiding complex ‘prompts’ which are frequently discussed for communication with Large Language Models. Furthermore, the report does not list information sources behind the feedback from the Large Language Model as this would be of no relevance for the presentation of the example.

The example demonstrates opportunities for Living Labs for entering into a planning process which allows adding own data, experiences, objectives, or opportunities to the initial proposal provide through the interaction with the tool. The approach will improve the planning competence of Living Labs in situations where expert advise is scarce or where the emergence of unexpected contingency situations require the creation of a contingency plan on short notice.

Disclaimer

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1 Introduction

This report provides a basis for entering into contingency planning activities in the Living Labs during the coming months and beyond. The exchange among Living Labs will allow them to gain experience in integrating Large Language Models (in our case the LLM 'ChatGPT') into their planning processes and to identify opportunities and limitations in utilizing interaction with Large Language Models in future planning needs.

In this report we simulate a contingency planning activity in a Living Lab, assuming that expert knowledge is scarce and the users will, in a first round, primarily depend on using Large Language Models, checking the results for plausibility.

The experiment picks up potential hazards formulated by a Living Lab (SECO-COLLAB) with relevance for its region, follows the steps of the contingency planning process, and employs artificial intelligence for providing information asked for in the various steps of the planning process. The results need to be discussed with the Living Lab and evaluated regarding their suitability. This whole procedure copies the regular planning process apart from inclusion of experts for an initial analysis.

The communication with the LLM took about 50 pages as the response to each of the questions was very much in detail usually covering 2 pages and more. A slightly condensed example is demonstrated in table 2.1 which outlines the calculation for estimating the probability of the hazard. In the following chapters we only consider the final conclusion in the communication with the LLM. In limiting ourselves to the conclusions, we omit all the listings of arguments, assumptions or alternatives in considerations and the cautioning comments provided in the feedback from the LLM.

The comments are final conclusions as one would expect from an expert in a discussion and are up for evaluation. If conclusions raise doubts, one can still go back to the LLM and evaluate the detailed communication, either refusing the conclusions from LLM or accepting it after having consulted with the detailed arguments.

2 The example hazard problem

The contingency plan is supposed to deal with the following hazard and its effects and impacts as brought forward by Living Lab representatives interested in formulating contingency plans for possible future hazards.

1. Hazard: Fertilizer price increase;
2. Region: Sweden;
3. Product: Leafy greens and herbs;
4. Effects of interest: Production and vertical farms;
5. Impact of interest: Consumers.

The problem description is not sufficient for developing a suitable contingency initiative. As a consequence, the communication with the LLM needs to involve 2 stages with

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a) stage 1 using LLM communication for further specifying the problem and
b) stage 2 for developing the contingency plan proposal in communication with the LLM.

It is apparent from a first look that a problem with leafy greens and herbs is not a food security issue in traditional terms as it is not a staple product but a niche product. In this case, the main food security focus would be linked primarily to keeping the diversity in a diet for whatever reason including health. However, with this limited link with food security one needs to clarify if entering into a contingency planning effort would be worthwhile.

3 The specification of the problem scenario with support of LLM

3.1 Initial analysis - clarification of contingency planning need

The primary question concerns the appropriateness of a contingency planning effort for a limited market such as a market for leafy greens and herbs in Sweden. The summary response of the LLM suggests continuing with a contingency planning effort through the following summary of arguments:

1. General: A fertilizer price hike in Sweden could potentially impact food security, particularly in the production and consumption of leafy greens and herbs.

2. Consumption. Leafy greens and herbs tend to be high-turnover, perishable goods, and even small price increases can lead to decreased demand. If prices rise due to higher production costs, it might reduce accessibility to fresh produce, particularly for lower-income households, creating a food security issue.

3. Vertical farms, a growing industry in Sweden, are somewhat insulated from this challenge because they often use more controlled systems such as hydroponics or aeroponics, which require less fertilizer compared to traditional agriculture. However, they still rely on nutrient solutions, and price hikes in the chemicals and materials used in these solutions could raise costs. This might make locally grown leafy greens and herbs less competitive compared to imports or conventionally grown produce.

In summary, it seems to be appropriate to further analyse the problem and to enter into a contingency planning effort.

3.2 Further specification of the example problem scenario

The further specification of the problem scenario and some clarifications are complementing some of the initial information for eliminating information gaps:

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1. Examples for necessary *specifications* concern the expected level of the price hike and the specification of the target group.

2. Further *clarifications* concern issues such as the probability of the hazard (table 3.2) or the role of leafy greens and herbs in the diet of the target group.

In summary, the following specifications and clarifications will complement the identification of the problem situation:

1. Hazard: Fertilizer price hike
a) *Specification*: Price hike of 50%
b) *Need for clarification*: Hazard probability in Sweden (see table 3.2).

2. Consumers
a) *Specification*: Low-income families as most vulnerable group
b) *Need for clarification (table 3.1)*:
- Percentage of consumers belonging to low-income families
- Expenditure for leafy greens and herbs in % of food expenditures of low-income families
- Product alternatives to leafy greens and herbs in diet?

3. Production
a) *Need for clarification (table 3.1)*:
- Source and destination of leafy greens and herbs (production, import, export)
- Number of farms producing leafy greens and herbs
- Number of vertical farms producing leafy greens and herbs
- Percentage of leafy green production produced by vertical farms and by traditional farms
- Contribution to farm profit of farms producing leafy greens and herbs
- Contribution to farm profit of vertical farms producing leafy greens and herbs

The further clarifications are summarized in table 3.1.

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Table 3.1.
Specification of the base situation regarding the probability of hazard, the consumption of low-income families, and the production of leafy greens and herbs

Hazard:

Probability of a price hike of 50% in fertilizer prices
➔ In today's volatile situation with energy prices increasing, a war in supplying countries etc., the probability is calculated as 9% (see table 3.2).

Consumers (appendix A1)

Percentage of consumers belonging to low-income families
➔ Approximately 15-18% of families, earning less than 60% of the median disposable income.

Expenditure for leafy greens and herbs in % of food expenditures of low-income families
➔ Low-income families in Sweden spend approximately 20-30% of their household income on food, (national average around 12-14%.), typically 10-15% on fresh produce like leafy greens and herbs.

Product alternatives to leafy greens and herbs in diet if leafy greens and herbs are too expensive
➔ Low-income families in Sweden would typically turn to more affordable, longer-lasting alternatives such as frozen and canned vegetables, root vegetables, dried herbs, legumes, and carbohydrate-rich staples like potatoes, pasta, and rice. These substitutes provide a mix of nutrition and affordability, though they may lack some of the specific nutrients offered by fresh leafy greens and herbs. However, these alternatives still enable low-income households to prepare nutritious and cost-effective meals.

Production

Source and destination of leafy greens and herbs (production, import)
➔ Due to climate and a short growing season, the majority of leafy greens and herbs consumed in Sweden are imported, with the share of imports making up 60-70% of total annual consumption.

Number and percentage of traditional farms producing leafy greens and herbs
➔ Estimated number of farms producing leafy greens and herbs: 350-950 farms out of about 58.000.
➔ Percentage of all farms in Sweden: 0.6% to 1.6% (rough judgement).
These farms are primarily smaller operations often located near urban centers to serve local markets.

Number and percentage of vertical farms producing leafy greens and herbs
➔ Estimated number of vertical farms producing leafy greens and herbs: 50-150 farms
➔ Percentage of all farms in Sweden: 0.09% to 0.26% (rough judgement).

Percentage of leafy green production produced by vertical farms and by traditional farms
➔ *Traditional Farms* with a strong seasonal production dominate production with a share of about 70-80%.
➔ *Vertical farms* are gaining prominence with a main focus on high-demand, high-value crops like lettuce, grown year-round in a controlled environment. Their share is about 10-15%.
➔ *Greenhouses* (a blend of traditional and controlled environment agriculture) contribute about 10-15%.

Contribution to farm profit of farms producing leafy greens and herbs
Leafy greens and herbs are high-value crops with significant market demand, especially in urban regions where consumers prioritize freshness, sustainability, and local sourcing. The exact contribution will vary depending on the farm's scale, location, and level of crop diversification.
➔ *Specialized farms*: Leafy greens and herbs contribute 70-90% of profit.
➔ *Diversified farms*: Leafy greens and herbs contribute 30-50% of profit.
These estimates reflect the fact that leafy greens and herbs contribute considerably to farm income.

Contribution to farm profit of vertical farms producing leafy greens and herbs
High percentages reflect the strong profitability of leafy greens and herbs in vertical farming.
➔ *Specialized vertical farms* (focused on leafy greens and herbs): 80-95% of total profit.
➔ *Diversified vertical farms*: Leafy greens and herbs contribute 60-80% of total profit.
Vertical farms' profits are primarily dependent on income from leafy greens and herbs.

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Table 3.2
LLM calculation of the probability of a 50% price increase of fertilizer

Q: What is the probability of a short term 50% price increase of fertilizer in Sweden

A: The probability of a sudden 50% price increase for a commodity like fertilizer depends on several factors, and quantifying this in probabilistic terms requires a deep understanding of the market. To determine a specific probability of a 50% price increase, you would need:

- *Historical data*: Analyzing historical price fluctuations and their triggers.
- *Market models*: Using econometric models that consider supply, demand, geopolitical risks, and other factors.
- *Monte Carlo simulations*: These could help estimate the likelihood based on historical volatility and possible future shocks.

Quantifying the probability of a 50% price increase in fertilizer is challenging due to the complex and often unpredictable nature of the market. However, we can take a quantitative approach by using historical data and applying a stochastic model (like a lognormal distribution) to represent price changes over time. This method estimates the likelihood of large price jumps based on historical volatility and trends.

Sample Calculation Outline:

To simplify, let's assume we have historical data on fertilizer prices and that the annualized volatility is 30% (this is just an assumption, actual fertilizer price volatility may differ). We can use the formula for a lognormal distribution to estimate the probability:

$$P(S_t \geq 1.5 \times S_0) = 1 - \Phi\left(\frac{\ln(1.5) - (\mu - \frac{1}{2}\sigma^2)t}{\sigma\sqrt{t}}\right)$$

Where:

- $P(S_t \geq 1.5 \times S_0)$ is the probability of a 50% increase,
- Φ is the cumulative distribution function (CDF) of the standard normal distribution,
- μ is the drift or average price change,
- σ is the historical volatility,
- t is the time horizon (in years),
- S_0 is the current price, and S_t is the price after time t.

Assumptions for Calculation:

- **Volatility (σ)**: 30% annualized.
- **Time Horizon (t)**: 1 year.
- **Average Price Drift (μ)**: Let's assume the average annual return is 5%.

Let me calculate this probability for you using these assumptions.

Based on the assumptions of 30% annualized volatility, a 5% average price drift, and a 1-year time horizon, the estimated probability of a sudden 50% price increase in fertilizer within one year is approximately **9.1%**.

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4 Potential impact of a price hike of fertilizer on consumption and production (LLM feedback)

4.1 Consumers (low-income families)

According to LLM feedback, a 50% increase in fertilizer prices would likely result in higher prices for leafy greens and herbs, making them less affordable for low-income families. As a result, consumption of these nutrient-dense foods could decrease among this group, leading to poorer dietary quality and potential health consequences (appendix A5).

Of special concern are the following possible long-term effects which needed consideration:

1. *Widening Food Inequality*: If leafy greens and herbs become more expensive, it could exacerbate existing inequalities in food access. While wealthier households may absorb the higher costs, low-income families would likely experience reduced access to these nutrient-dense foods, leading to poorer dietary quality.
2. *Long-Term Effects on Health*: Over time, decreased consumption of fresh, nutrient-rich foods among low-income families could contribute to long-term health disparities, including increased risks of diet-related diseases such as obesity, diabetes, and heart disease.

4.2 Vertical farms and traditional farms

Vertical farms (see appendix A4)

A 50% fertilizer price increase would raise operating and production costs for vertical farms, but the impact might be more manageable compared to traditional agriculture due to the controlled, efficient use of nutrients in vertical farming. Although consumer prices for leafy greens and herbs might increase slightly, vertical farms' focus on sustainability and technological innovation could help mitigate some of the negative effects over time.

Of specific interest are the following arguments:

1. *Fertilizer prize relevance*: In vertical farming, energy (for lighting, climate control, etc.) is usually a much larger portion of operating costs than fertilizer. A 50% fertilizer price hike might be a smaller concern compared to energy prices and the overall cost structure of a vertical farm may not shift dramatically.

2. *Impact on Prices for Consumers*: Vertical farms often serve higher-end markets (restaurants, urban supermarkets, etc.) where consumers are willing to pay a premium for locally grown, fresh, and sustainable produce. In these markets, the price elasticity might be lower.

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Traditional farms (see appendix A2 and A3)

A 50% increase in fertilizer prices would likely have the following impacts on traditional farms:

1. *Negative impact on supply*
   - 10-20% reduction in crop yields if fertilizer usage is reduced.
   - Reduction in planted areas for leafy greens and herbs as some farms may switch to less fertilizer-dependent crops or reduce production.
2. *Negative impact on farms*
   - 5-15% increase in overall production costs.
   - 10-20% decline in farm profits, particularly if farms cannot fully pass the cost increase on to consumers.
3. *Negative impact on consumers*
   - Possible price increases for consumers (5-15%).

The overall result would be a likely reduction in local supply of leafy greens and herbs and higher market prices, which could further impact both producers and consumers.

4.3 Expected changes in production distribution

Given the more significant impact on traditional farms, the production distribution could shift in favor of vertical farms:

1. *Traditional Farms*: Their share of leafy greens and herb production might drop to around 65-75% as production decreases due to higher input costs.

2. *Vertical Farms*: They could see an increase in their production share from 10-15% to around 15-20% as they are less affected by the fertilizer cost hike and potentially expand production to capitalize on the market gap left by traditional farms.

The overall production of leafy greens and herbs would become increasingly concentrated in vertical farming, which is better positioned to absorb the cost increases and maintain or even expand production levels in a high-cost environment.

5 LLM proposals for activities limiting effect of hazard

The developments see disadvantages for low-income families and for traditional farms while the emerging vertical farms tend to gain. In this situation one need first to clarify, if the developments warrant interference by third parties, in the present context specifically by government.

Does the situation warrant government action?

Comment: A 50% increase in fertilizer prices would have wide-ranging effects on both food production and consumption, particularly for low-income households and small-scale farmers. Government intervention would be justified to protect food security, support the agricultural sector, and encourage a transition toward more sustainable farming practices.

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Such measures would help prevent inflationary pressures on food prices, reduce inequalities, and ensure the long-term viability of the agricultural sector, ultimately benefiting both farmers and consumers.

In a further discussion on actions in support of consumers and in support of producers, the activities overlap, meaning that certain support for farmers is in effect providing support for the accessibility of leafy greens and herbs for low-income families. However, we present the actions for support of farmers and of low-income families separately facilitating the link to the detailed summaries available in the appendix C.

5.1 Engagement for potential production support

To ensure the continued production of leafy greens and herbs in the face of a 50% fertilizer price increase, the government should prioritize support for small-scale farms, greenhouse and vertical farmers, organic farms, community-based farms, and those serving low-income urban markets. Supporting these groups with financial assistance, subsidies, and logistical aid will help stabilize production, prevent price hikes, and ensure that nutritious produce remains accessible to all consumers, particularly low-income families.

For each of the potential producers of leafy greens and herbs the public needs to clarify: Why support them, what's the impact, and how to support. A detailed discussion along these topics is provided in appendix A6. A summary of support alternatives for different farm situations can be summarized as follows:

1. *Small-Scale and Family Farms*
➔ Provide fertilizer subsidies, grants, or low-interest loans. Encourage participation in farmers' markets by offering logistical support or incentives.
2. *Greenhouse and Vertical Farmers*
➔ Provide subsidies for fertilizers or nutrient solutions, offer incentives for energy efficiency. Also, support expansion or innovation in vertical farming to increase production capacity.
3. *Organic and Sustainable Farmers*
➔ Provide subsidies for organic inputs and offer financial support. Promote organic certification and provide assistance to help farmers transition to organic or regenerative methods.
4. *Cooperative and Community-Based Farmers*
➔ Offer financial support for cooperative farming models, provide grants for community gardens and urban farming initiatives, and assist with marketing and distribution.
5. *Farmers Serving Low-Income and Urban Markets*
➔ Provide logistical support for distribution in urban areas, subsidies to cover transportation and market fees, and grants to help these farmers maintain production levels.
6. *Innovative and Technologically Advanced Farms*
➔ Offer incentives for adopting advanced technologies, provide research and development grants, and encourage public-private partnerships.

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5.2 Engagement for potential consumer support

To ensure low-income families continue consuming leafy greens and herbs despite a 50% increase in fertilizer prices, a multi-faceted approach involving government subsidies, increased support for sustainable and local farming, price controls, and community-based initiatives is needed. These measures can stabilize prices, maintain accessibility, and encourage the consumption of fresh produce, ultimately supporting public health and food security.

A summary of issues outlined in more detail in the appendix (appendix C7) includes:

1. Government Subsidies for Leafy Greens and Herbs
   - Direct Food Subsidies
   - Targeted Support for Low-Income Families
2. Support for Urban and Vertical Farming
   - Expanding support for urban/vertical farms
   - Community-Based Urban Agriculture
3. Promote Sustainable and Organic Farming Practices
4. Price Controls and Market Interventions
5. Promote Alternative Nutrient Sources for Vertical Farms
6. Nutritional Education and Promotion of Less Expensive Greens
7. Food Banks and Donation Programs
8. Encouragement of Cooperative Purchasing

6 Considering budget constraints in LLM initiation

Based on the previous general elaborations, this chapter relates activities to realities, including limitations in budget availability. In this first step we do not yet place a monetary value on budget availability but let the response by the LLM try to identify the activities where costs are considered relatively low while important goals can still be reached. It is a first step towards the consideration of costs and effects.

This could be further elaborated in a follow-up step by introducing monetary terms for costs and effects. We will not continue along this line but will demonstrate the introduction of biodiversity considerations into a first budget conscious proposal by the LLM. The comparison of the proposals with and without specific biodiversity considerations concerning

a) priorities in actions and support initiatives as well as in
b) differences in costs judgements

provides a first basis for reaching decisions on what to do. As above, this view could be further clarified beyond the discussion in this chapter by inserting monetary values as a final move before decisions are being made.

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6.1 Basic activity proposal

With the introduction of a general statement about budget constraints, feedback from LLM communicates priorities in activities where costs are relatively low compared to effects.

When public budgets are small, the country should focus on targeted, low-cost interventions that have high impact. The top priorities should be fertilizer subsidies for key farmers, support for urban and community farming, targeted food vouchers for low-income families, and encouraging vertical farming and sustainable practices.

These measures can stabilize both production and consumption of leafy greens and herbs while minimizing the financial burden on public resources.

A detailed elaboration of various initiatives focusing on priority, budget efficiency and proposed action is provided in appendix A8. The following overview is limited to the proposals for efficient and budget conscious actions:

1. *Subsidies for Fertilizers or Nutrient Inputs for Key Farmers*
   - Target farmers most reliant on fertilizers, such as small-scale vegetable farms and vertical farms.
   - Focus on temporary subsidies to buffer the impact of the price hike.
2. *Promote Urban Farming and Community Gardens*
   - Partner with local municipalities to set up and expand community gardens in cities.
   - Provide starter kits (seeds, soil, and basic tools) for household or community-level production.
3. *Targeted Food Vouchers for Low-Income Families*
   - Implement a food voucher program, specifically earmarked for purchasing vegetables.
   - Partner with grocery stores or local markets to offer discounted prices.
4. *Support Vertical Farming and Efficient Technologies*
   - Provide small-scale grants or low-interest loans for vertical farms.
   - Encourage public-private partnerships with private investors to scale vertical farming operations.
5. *Promote Sustainable Farming Practices*
   - Offer training for farmers on how to use organic fertilizers and other sustainable practices.
   - Provide small incentives for farmers who adopt organic or low-input farming methods.
6. *Leverage Existing Food Banks and Donation Programs*
   - Partner with farmers and retailers to donate unsold produce to food banks etc.
   - Create tax incentives for producers and retailers that donate fresh leafy greens and herbs.
7. *Encourage Cooperative Purchasing Models*
   - Promote and support food cooperatives where groups can buy leafy greens and herbs in bulk.
   - Provide logistical support or small grants to start cooperatives in urban or low-income areas.

A further elaboration could deal with actual costs for supporting decisions on what to select from the “wish list”.

6.2 Budget constraints with a view on biodiversity

With the introduction of biodiversity preferences, we guide the LLM towards considering an additional aspect in its elaboration which, in turn, might require the tool to consider other publications than used for the basic proposal.

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The detailed description of the specific activities and their cost-benefit balance is outlined in appendix A11. The following overview is limited to the major activity initiatives and their biodiversity impact:

1. *Subsidies for Organic and Biodiverse Produce*
   Biodiversity impact: Organic and biodiverse farming reduces chemical inputs, encouraging ecosystems that support pollinators, soil organisms, and beneficial insects.
2. *Food Vouchers for Farmers' Markets and Local Produce*
   Biodiversity impact: Local small-scale farms are often more biodiverse, using practices like crop rotation and intercropping, which benefit local ecosystems. Supporting these farms intensifies biodiversity-friendly agriculture.
3. *Incentives for Urban and Community Gardens*
   Biodiversity impact: Community gardens promote biodiversity in urban settings, providing habitats for insects and plants, reducing urban heat, and contributing to local food resilience.
4. *Education and Training on Low-Input Gardening Techniques*
   Biodiversity impact: Promoting organic, biodiversity-friendly gardening techniques helps increase local biodiversity, soil health, and water retention, benefiting both the environment and communities.
5. *Subsidies for Regenerative and Organic Farming Practices*
   Biodiversity impact: Regenerative agriculture builds soil health, supports beneficial microbes, and enhances ecosystem resilience, fostering biodiversity at multiple levels.
6. *Support for Agroecological Initiatives and Food Hubs*
   Biodiversity impact: Agroecology promotes diverse cropping systems, soil health, and ecosystem services, supporting biodiversity and making local food systems more resilient to environmental shocks.
7. *Partnerships with Food Banks for Fresh, Biodiverse Produce*
   Biodiversity impact: This approach directs demand toward farms practicing biodiversity-friendly agriculture, encouraging more sustainable practices across the region.

For reaching a decision we need to better understand the differences between the two proposals, the general budget conscious proposal and the proposal which asks for consideration of biodiversity aspects as well.

6.3 Comparing basic with biodiversity alternative

The difference between the two lies in the focus and prioritization of biodiversity. The first approach focuses solely on immediate and cost-effective food security, while the second approach incorporates food security goals with actions that actively promote biodiversity, ensuring long-term environmental and ecological benefits alongside social support. Both scenarios operate under budget constraints but differ in their primary objectives:

1. *Basic proposal: Limited Budget*
   - *Primary Goal*: Address food security efficiently with low-cost initiatives, focusing on providing immediate support to low-income families to ensure access to nutritious food.
   - *Biodiversity Consideration*: May not explicitly prioritize biodiversity but could include actions with incidental biodiversity benefits.
   - *Example Actions*:
     - Subsidizing fertilizer costs to stabilize crop yields.
     - Providing food vouchers for leafy greens and herbs from any local source, regardless of farming methods.
     - Expanding food bank services to include fresh produce from conventional farms.
     - Supporting home gardening with any available seeds or inputs (not necessarily biodiversity-friendly).

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2. Biodiversity proposal: Limited Budget but Preferences for Biodiversity Initiatives

- *Primary Goal*: Balance food security objectives with initiatives that explicitly promote biodiversity and ecological sustainability.
- *Biodiversity Consideration*: All actions prioritize or encourage practices that benefit ecosystems, soil health, pollinators, and diverse cropping systems.
- *Example Actions*:
  - Supporting community gardens that promote biodiversity (e.g., native plants, intercropping, composting).
  - Partnering with small, biodiverse farms or agroecological producers for food vouchers or food bank supplies.
  - Promoting home gardening with biodiversity-friendly practices (e.g., companion planting, native seeds).
  - Encouraging composting or reduced synthetic input use to improve soil biodiversity.

This analysis of differences is summarized in table 6.1

Table 6.1.
Summary of key differences between basic and biodiversity proposal for limited budget.

Aspect	Limited Budget	Limited Budget with Biodiversity Preference
Focus	Ensure food security cost efficiently.	Ensure food security cost efficiently while prioritizing biodiversity.
Biodiversity Priority	Incidental or secondary consideration.	Central to decision-making and implementation.
Inputs Provided	Any available resources to ensure affordability.	Resources like native seeds, organic compost, or sustainable practices.
Farming Practices	No strict preference for farming methods.	Preference for organic, low-input, agroecological methods or any sustainable agricultural practices
Example Partnership	Any local farm or producer.	Biodiversity-focused farms or producers with sustainable practices.

6.4 Comparing magnitude of costs

The budget needs differ between the two approaches due to the additional costs associated with implementing biodiversity-focused initiatives. Programs focused on biodiversity-friendly initiatives require higher upfront investments due to the costs of sustainable inputs, sourcing, and education. However, they deliver long-term benefits by building ecological resilience, improving soil health, and supporting sustainable food systems, which can reduce future budgetary demands for food security interventions. The differences in budgetary requirements are as follows:

1. Basic proposal: Limited Budget

- *Goal*: Address food security efficiently with minimal additional considerations for biodiversity.
- *Budget Needs*:
  - Focuses on low-cost interventions that address immediate food security issues, such as direct subsidies or expanding existing programs.
  - Relies on conventional farming and food supply systems, which are often more cost-efficient in the short term.
- *Example Costs*:
  - Subsidizing food vouchers for leafy greens and herbs from any supplier.
  - Expanding food bank capacity using surplus produce from conventional farms.
  - Providing general-purpose gardening kits or fertilizer subsidies.
- *Estimated Costs*: Low to Medium—Basic support mechanisms without specific criteria for biodiversity require minimal investment but may not have long-term ecological benefits.

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2. Biodiversity proposal: Limited Budget but Preferences for Biodiversity Initiatives

- *Goal*: Address food security while prioritizing biodiversity through sustainable and environmentally friendly practices.
- *Budget Needs*:
  - Higher due to sourcing from sustainable or organic farms, which often have higher production costs.
  - Additional funding required for promoting biodiversity-friendly practices, such as native seeds, compost, and training.
  - May require investment in capacity-building, education, or small grants for farmers and community groups.
- *Example Costs*:
  - Food vouchers specifically targeting produce from organic or biodiversity-friendly farms (which may cost more than conventional alternatives).
  - Support for community gardens with biodiversity-focused inputs (e.g., native plants, organic compost).
  - Educational campaigns or workshops on biodiversity-friendly practices (e.g., intercropping, companion planting).
- *Estimated Costs*: Medium to High—Targeting sustainable sources and promoting biodiversity increases costs but provides long-term ecological and food system resilience benefits.

This analysis of differences is summarized in table 6.2 and 6.3

Table 6.2.
Summary of key differences in budget consequences between basic and biodiversity proposal for limited budget.

Aspect	Limited Budget	Limited Budget with Biodiversity Preference
Cost of Inputs	Low-cost inputs (e.g., conventional seeds, surplus produce).	Higher-cost inputs (e.g., native seeds, organic compost).
Sourcing Costs	Any supplier, including conventional farms.	Sustainable farms with higher production costs.
Program Scope	Basic food security interventions.	Includes biodiversity-related components (e.g., workshops).
Training/Education Costs	Minimal to none.	Moderate to high, depending on training scope.
Long-Term Savings	May incur long-term costs (e.g., soil degradation, food insecurity).	Promotes resilience, reducing future costs.

Table 6.3.
Comparison of relative budget levels between basic and biodiversity proposal for limited budget.

Budget Level	Limited Budget	Limited Budget with Biodiversity Preference
Overall Cost	Low to Medium	Medium to High
Short-Term Cost Efficiency	High (cheaper inputs).	Moderate (sustainable inputs).
Long-Term Overall Value	Moderate (basic support).	High (resilience and biodiversity benefits).

6.5 Discussion

The interaction with LLM has provided a first understanding of the difference between a basic budget conscious proposal and a proposal with added consideration of biodiversity

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issues. However, this discussion could go on for further clarifications. There are still many questions open which could be dealt with. Just a few examples:

a) Specifying various monetary budgets and analysing consequences;
b) Estimate costs and effects in monetary terms;
c) Identify the time frame for implementing actions, realizing costs and receiving effects;
d) Scheduling costs over time;
e) Specify various intensities of biodiversity preferences, specify specific needs;
e) Clarifying actors who could get engaged for activities, related costs, coordination needs.

This example demonstrates how far one can get in an initial communication with LLMs. However, we still need to be aware that with the present status of LLM developments, the results require "approval" by experts and affected stakeholders even if they are not proficient in details. It might be helpful if the LLM provides information about the sources it builds the feedback on and the line of arguments in used for interpreting information from sources. If sources or arguments are not convincing, one might request the use of other sources or a change in argumentation.

7 Some speculation about possible futures

LLMs are helpful tools in employing a "what-if" approach, playing with different scenarios. We are adding such an approach to the hazard discussion related to increase in fertilizer prices in an attempt to identify the costs and benefits of moving the production organization of leafy greens and herbs to different futures in Sweden.

In the wake of increasing production costs due to an increase in fertilizer prices of 50% one might check the costs and benefits of three extremes on a production scale:

1. Promotion of imports: All leafy greens and herbs needed for consumption are imported
2. Promotion of local production: Reaching self-sufficiency
2. Promotion of vertical farms: All leafy greens and herbs are produced in vertical farms.

7.1 Promotion of imports

Increasing imports of leafy greens and herbs to cover 100% of demand in response to a fertilizer price hike would according to LLM feedback lead to economic, environmental, and social damage. It would undermine domestic agriculture, increase Sweden's vulnerability to global supply chain disruptions, and raise the country's carbon footprint. Moreover, it would likely lead to higher prices, negatively affecting low-income families and exacerbating food insecurity (appendix A10). A calculation of costs is complex as it would have to monetarize non-monetary issues such as environmental damage or loss of jobs. However, apart from these deficiencies, one could try to calculate 'artificial' costs in support of reaching a decision. With all due reservations, an 'artificial' cost estimate could be calculated reaching from 3+ Mrd. to 9+ Mrd. Swedish Crowns (SEK) based on

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1. Additional cost of imports: ~400+ million SEK to ~1.7 billion SEK
2. Loss of revenue for domestic farmers: ~700+ million SEK to ~3.4 billion SEK
3. Environmental costs: ~119 million SEK
4. Additional consumer costs: ~280 million SEK to ~1.3 billion SEK
5. Job losses in agriculture: ~1.5 billion SEK to ~3 billion SEK.

Without elaboration on the appropriateness of the cost calculations, one issue is obvious: A loss of local production would be a costly development.

7.2 Promotion of self sufficiency

The costs of pursuing self-sufficiency in leafy greens and herbs in Sweden, especially with a 50% increase in fertilizer prices, would be substantial, including higher production and energy costs, infrastructure investment, and potential price increases for consumers. However, the benefits—including increased food security, job creation, innovation in sustainable agriculture, and improved health outcomes—could make the strategy worthwhile, reducing reliance on imports and enhancing resilience to global market shocks.

In an effort to estimate total costs and benefits including monetary and non-monetary developments over a 10-year period, benefits of 3.2 to 6.3 Mrd. SEK are judged slightly higher than costs of about 2.2 to 4.4 Mrd. SEK. A summary of potential costs and benefits includes:

Costs
Increased production costs (fertilizer and energy); Investment in infrastructure (greenhouses, vertical farms), higher consumer prices for locally grown leafy greens; environmental costs (energy usage, fertilizer impact); market disruptions and reduced import options; energy dependency for year-round production

Benefits
Enhanced food security, reduced import dependency; potential job creation and local economic stimulation; innovation in agriculture and support for local farmers; access to fresh, local produce with health benefits; sustainability (renewable energy, circular practices); resilience to external shocks (trade, price volatility).

Without elaboration on the appropriateness of the calculations of costs and benefits, one could state that benefits slightly outweigh costs but that the balance could easily change with small changes in the valuation of non-monetary inputs.

7.3 Promotion of vertical farms

The picture looks different if production of leafy greens and herbs is primarily located at vertical farms (appendix A9). The country could gain several economic advantages through improved efficiency, sustainability, and innovation. While there would be some challenges (such as the initial investment in infrastructure), the long-term economic benefits could be substantial including

1. Reduced imports and transportation costs, potentially saving hundreds of millions of SEK annually.

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2. Higher resource efficiency, leading to reduced water and fertilizer use.
3. Job creation in high-tech farming sectors and positioning Sweden as an agri-tech innovation leader.
4. Improved food security and resilience to global supply chain disruptions.
5. Reduced environmental impact and alignment with Sweden's climate goals.
6. Potential for export opportunities in both produce and vertical farming technology.

While the initial investment in vertical farming infrastructure could be significant, the impact would likely outweigh the costs with a judgement of potential annual monetary savings of between ~1+ Mrd. to ~2.8 Mrd. SEK including the following estimates:

1. *Import Reduction Savings* with about ~250 Mio SEK to ~900 Mio SEK
2. *Water and Fertilizer Efficiency Savings* with about 150 Mio SEK to 190 Mio SEK
3. *Transportation and Logistics Savings* with about 85 Mio SEK to 296 Mio SEK
4. *Reduced Food Waste Savings* with judgements of 423 million SEK to 1.27 billion SEK
5. *Energy Cost Savings* with judgements of 20 million SEK to 40 million SEK
6. *Environmental and Carbon Tax Savings* with about 83 Mio SEK to 160 Mio SEK.

The wide range of estimates underlines the difficulty in reaching an appropriate estimate for cost savings. However, without elaboration on the appropriateness of the calculations, one could state that the long-term economic advantages of transitioning to a vertical farming model for leafy greens and herbs warrant initial investments.

8 Reflection

The discussions about consequences of a hike of fertilizer in Sweden in the preceding chapters are totally based on feedback from Large Language Models. They are not linked with expert knowledge of any kind or an interference by people with knowledge about the region or the specific situation of consumers or farmers operating in Sweden.

The present results are not meant to provide the "right" answers but are first feedbacks which need to be improved through

a) the continuation of a stepwise interaction process with LLMs entering preferences of user stakeholders and
b) the incorporation of own judgements by stakeholders, experts and potential actors.

However, this approach will facilitate the contingency planning process for Living Labs and improve their planning competence even if expert judgements are scarce or if the development of unexpected contingency situations require the conclusion of a planning process on short notice.

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Appendix A1: Question: Role of leafy greens and herbs in diet of low-income families?

The portion of leafy greens and herbs in the diet of low-income families in Sweden can be difficult to quantify precisely due to the variability in dietary habits and food choices among different families. However, based on research into food consumption patterns and the challenges faced by low-income households, we can make some estimates and observations.

General Insights:

1. Lower Consumption of Fresh Produce:
   - Studies and surveys conducted in Sweden and across Europe indicate that low-income households generally consume less fresh produce, including leafy greens and herbs, compared to higher-income groups. This is largely due to cost concerns, prioritization of more energy-dense foods, and accessibility issues.
   - Low-income families may spend a larger proportion of their budget on staple foods that are cheaper and have longer shelf lives, such as bread, pasta, potatoes, and rice, which are more affordable per calorie than fresh vegetables.
2. National Surveys on Fruit and Vegetable Intake:
   - According to *Swedish national dietary surveys*, the average intake of fruits and vegetables among low-income families tends to be lower than the national average. In particular, low-income households might fall short of the recommended daily intake of vegetables (around 500 grams per day), which includes leafy greens and herbs.
   - The *Public Health Agency of Sweden* has reported that individuals with lower socioeconomic status tend to consume about 10-20% less fruits and vegetables than higher-income groups.
3. Estimated Portion of Leafy Greens and Herbs:
   - Based on typical consumption patterns and assuming that low-income households in Sweden consume 10-20% less vegetables overall, it is likely that the portion of leafy greens and herbs in their diet is proportionally smaller compared to the general population.
   - For example, if the average person consumes about 100-150 grams of leafy greens and herbs per week, low-income families might consume 80-120 grams per week, depending on their budget, access to fresh produce, and preferences.
   - As a proportion of total vegetable intake, leafy greens and herbs likely represent 10-20% of the total vegetable consumption for low-income families, which is lower than that of higher-income families who tend to have more varied diets with a higher proportion of fresh produce.

Factors Affecting Consumption of Leafy Greens and Herbs:

1. Cost and Prioritization:
   - Fresh leafy greens and herbs, though nutritionally valuable, are often more expensive per unit weight than other vegetables like root vegetables or frozen options. As a result, low-income families may prioritize cheaper vegetables over fresh leafy greens and herbs.
2. Availability:
   - Access to fresh produce can vary depending on location, with rural or underserved urban areas sometimes offering less variety in fresh vegetables, including leafy greens and herbs.
3. Cultural and Dietary Habits:
   - In some cases, leafy greens and herbs might be incorporated into traditional dishes (such as dill in Swedish cuisine), but overall, these foods may not constitute a large part of the daily diet, particularly in low-income households where budget constraints limit food choices.
4. Education and Awareness:
   - Public health campaigns promoting the importance of vegetables, incl. leafy greens and herbs, may not always reach or resonate with low-income households, especially if the foods are perceived as unaffordable or difficult to access.

Government and School Programs:

1. School Meals:
   - In Sweden, free school meals are provided to all children, which can play an important role in ensuring that children from low-income families have access to leafy greens and herbs in their diet. School meals typically meet national dietary guidelines, which include vegetables as a core component.
2. Food Assistance Programs:
   - Social supermarkets like Matmissionen offer discounted food to low-income families, which sometimes includes fresh vegetables. These programs can help improve access to fresh produce, including leafy greens and herbs, but are not widespread enough to significantly alter overall consumption patterns.

Conclusion:

The portion of leafy greens and herbs in the diet of low-income families in Sweden is likely lower than the national average. While exact data is hard to pinpoint, estimates suggest that low-income families consume 10-20% less fresh vegetables, including leafy greens and herbs, than higher-income households. As a result, these foods may represent a smaller share of the diet, with low-income families consuming 80-120 grams per week on average, or roughly 10-20% of their total vegetable intake. Programs that increase access to affordable fresh produce and educational initiatives about the health benefits of leafy greens and herbs could help raise consumption levels among low-income families.

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Appendix A2: Question: Impact of fertilizer price hike on production of leafy greens and herbs in traditional farms

1. Increased Production Costs:

- Leafy greens and herbs typically require substantial inputs of nitrogen, phosphorus, and potassium, which are key components of fertilizers.
- A 50% rise in fertilizer prices would raise the overall cost of production, making it more expensive for traditional farms to maintain their current levels of production.
- Many traditional farms operate with tight margins, and this increase in cost could force them to reduce fertilizer use or look for alternative solutions, which could negatively impact yields.

2. Reduced Fertilizer Application:

- To manage higher costs, farmers might opt to reduce the amount of fertilizer they use, which could lead to:
- Lower crop yields as plants receive fewer nutrients.
- Reduced quality of crops (e.g., smaller or less nutritious leafy greens and herbs).
- In extreme cases, farmers may reduce the area of land dedicated to growing these crops in order to minimize input costs.

3. Shift Toward Less Fertilizer-Dependent Crops:

- Some farmers may switch to crops that require less fertilizer or are more resilient to reduced inputs. Leafy greens and herbs, being relatively high-demand crops for nutrients, could see reduced planting in favor of less nutrient-intensive crops.

4. Financial Strain on Small Farms:

- Smaller, traditional farms with limited resources could be more affected than larger operations, as they may not have the financial flexibility to absorb the cost increase.
- This could lead to reduced production or even force some farms to exit the market, further decreasing the overall supply of locally grown leafy greens and herbs.

5. Price Increases for Consumers:

- The cost increase in fertilizer would likely be passed on to consumers through higher prices for leafy greens and herbs. As a result, demand may soften if consumers are unwilling to pay significantly higher prices, further discouraging production.

6. Long-Term Solutions (Organic Farming/Alternative Fertilizers):

- In response to a significant rise in fertilizer costs, some farms might explore organic farming methods or alternative, less expensive fertilizers (such as compost or manure). However, transitioning to these methods takes time, investment, and expertise, so this may not be an immediate solution for all traditional farms.

Conclusion:

A 50% increase in fertilizer prices would likely lead to reduced production of leafy greens and herbs on traditional farms in Sweden, especially for smaller farms and those that rely heavily on chemical fertilizers. The extent of the reduction would depend on the farm's ability to absorb costs, adjust fertilizer use, or switch to alternative farming methods. In the short term, the overall supply of leafy greens and herbs could decrease, potentially leading to higher prices for consumers and reduced availability of locally grown produce.

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Appendix A3: Question: Consequences of a fertilizer price hike on traditional farms

1. Increase in Production Costs:
- *Fertilizer Dependency*: Leafy greens and herbs, particularly nitrogen-rich crops like spinach and lettuce, rely on fertilizer to maximize yields. A 50% increase in fertilizer prices would result in a direct increase in production costs for traditional farms.
- *Cost Structure*: Fertilizer can account for 10-30% of the total input costs for traditional farms, depending on the farm's size, location, and crop management practices. A 50% increase in fertilizer prices would lead to an overall production cost increase of around 5-15%, assuming fertilizers account for about 20% of total costs on average.

2. Reduced Fertilizer Usage:
- *Lower Application Rates*: To manage increased costs, farmers may reduce the amount of fertilizer applied to crops. This could result in lower crop yields and potentially reduced quality (e.g., smaller or less nutrient-dense leafy greens and herbs).
- *Yield Decline*: Reduced fertilizer use could lead to a 10-20% decline in yields, as nutrient availability directly affects plant growth, particularly for high-demand crops like leafy greens and herbs.

3. Impact on Profit Margins:
- *Tighter Margins*: Many traditional farms operate with slim profit margins, and the increased cost of fertilizer would further squeeze these margins. If the farms are unable to pass the increased costs onto consumers through higher prices, they may face significant reductions in profitability.
- *Profit Decline*: Given that leafy greens and herbs are relatively high-margin crops due to their shorter growing cycles and market value, the profit decline could be 10-20% or more, depending on how well the farm can manage cost increases and maintain productivity.

4. Pass-Through to Consumer Prices:
- *Higher Consumer Prices*: Some of the increased fertilizer costs may be passed on to consumers through higher prices for leafy greens and herbs. However, there is a limit to how much farmers can raise prices without affecting demand. For example, if prices increase too much, consumers may shift to cheaper alternatives (such as frozen or canned vegetables) or reduce consumption of fresh produce altogether.
- *Market Sensitivity*: The price sensitivity of leafy greens and herbs means that a significant increase in consumer prices (perhaps 5-15% for leafy greens and herbs) could reduce overall demand, especially among lower-income consumers.

5. Crop Switching or Reduction in Planting Areas:
- *Alternative Crops*: To mitigate the increased costs, some traditional farms may switch from leafy greens and herbs to crops that are less fertilizer-dependent or that offer better margins under higher input cost conditions. This could lead to a reduction in the area planted with leafy greens and herbs, particularly on smaller farms that struggle with increased input costs.
- *Reduction in Production*: Farms may also reduce the overall planting area dedicated to leafy greens and herbs to minimize fertilizer use and focus on higher-yield, lower-input crops, further reducing supply.

6. Environmental and Sustainability Considerations:
- *Shift Toward Organic or Alternative Practices*: The sharp increase in fertilizer costs could incentivize some traditional farms to explore organic farming practices or use alternative fertilizers, such as compost, manure, or other organic amendments. However, transitioning to organic farming takes time, and not all farms have the resources or knowledge to make such a shift quickly.
- *Sustainability Trade-offs*: While the use of less fertilizer may reduce environmental impacts like nutrient runoff, it could also result in lower productivity, making farms less sustainable economically without adequate support or market adjustment.

7. Potential Decline in Local Supply:
- *Supply Reduction*: If many traditional farms reduce their output or switch to other crops, the local supply of leafy greens and herbs could decrease. This could lead to increased reliance on imports to meet consumer demand, raising prices for locally sourced leafy greens and herbs.
- *Import Dependence*: Sweden already imports a portion of its fresh produce, particularly in winter months. Reduced local production due to high input costs could increase import dependency, with potential knock-on effects on prices and availability.

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8. Impact on Small and Medium-Sized Farms:
- *Financial Strain on Small Farms*: Smaller traditional farms are likely to be more vulnerable to a 50% increase in fertilizer prices, as they typically have less financial flexibility to absorb higher input costs. Some small farms may be forced to reduce production significantly or even cease operations if they cannot make their production financially viable under higher fertilizer costs.
- *Consolidation*: Larger farms with more capital may be able to absorb the increased costs or invest in more efficient fertilizer use, leading to further consolidation in the farming industry.
9. Possible Government Intervention:
- *Subsidies and Support*: To mitigate the impact of higher fertilizer prices, the Swedish government could potentially intervene with subsidies for fertilizer or financial support for farmers to help them maintain production levels.
- *Encouraging Alternative Practices*: Government policies may also promote the adoption of more sustainable farming practices, such as precision agriculture or organic farming, to reduce reliance on chemical fertilizers and lower long-term input costs.

Conclusion:
A 50% increase in fertilizer prices would likely have the following impacts on traditional farms producing leafy greens and herbs in Sweden:
- 5-15% increase in overall production costs.
- 10-20% reduction in crop yields if fertilizer usage is reduced.
- 10-20% decline in farm profits, particularly if farms cannot fully pass the cost increase on to consumers.
- Possible price increases for consumers (5-15%).
- Reduction in planted areas for leafy greens and herbs as some farms may switch to less fertilizer-dependent crops or reduce production.

The overall result would be a likely reduction in local supply of leafy greens and herbs and higher market prices, which could further impact both producers and consumers.

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Appendix A4: Question: Consequences of a fertilizer price hike on vertical farms

Even though the direct impact on production volumes is relatively small (0.25-1% reduction), the 50% fertilizer price increase could have several indirect effects on vertical farms and the overall market for leafy greens and herbs.

1. Increased Prices for Consumers:
- Vertical farms, like any business, will pass on increased input costs to consumers when possible. With a small but noticeable increase in production costs due to the fertilizer price spike, vertical farms could raise prices for leafy greens and herbs.
- However, vertical farms often cater to premium markets (e.g., health-conscious consumers, restaurants, etc.), where demand is less price-sensitive. Even a small price increase may not significantly reduce consumer demand.

2. Pressure on Profit Margins:
- While vertical farms have more efficient fertilizer usage, they also operate on high fixed costs (e.g., energy for artificial lighting, climate control). Any increase in operational costs, including fertilizer, could squeeze profit margins, especially for smaller or newer vertical farms that may not yet be operating at scale.
- Some vertical farms might absorb the costs to avoid passing them on to consumers, impacting profitability in the short term.

3. Shift in Crop Selection:
- Vertical farms could respond to the fertilizer price increase by focusing more on crops that require less fertilizer. For instance, herbs generally require fewer nutrients than leafy greens.
- Farms may increase production of herbs (e.g., basil, parsley) relative to leafy greens to optimize cost efficiency in light of higher fertilizer costs.

4. Increased Adoption of Organic or Alternative Nutrient Sources:
- Vertical farms might look for alternative fertilizers, such as organic options, compost-based nutrients, or recycled nutrients from waste products, to reduce dependence on traditional chemical fertilizers.
- While the transition to alternative nutrient sources might have upfront costs, it could help mitigate long-term exposure to fertilizer price volatility.

5. Technology and Efficiency Upgrades:
- Vertical farms are highly dependent on technology to monitor and optimize crop growth. A fertilizer price spike could push farms to further improve nutrient efficiency by investing in better nutrient delivery systems, sensors, and AI-driven crop management systems.
- Precision agriculture advancements, like real-time nutrient monitoring and optimized dosing, can reduce fertilizer waste and lower input costs in the long run.

6. Competitive Advantage Over Traditional Farms:
- Vertical farms are already more resource-efficient than traditional farms, particularly in terms of water and land use, but also in fertilizer usage. If fertilizer prices remain high, vertical farms could gain a competitive edge over traditional farms, which are more affected by such price spikes.
- This competitive advantage could result in a larger market share for vertical farms, especially in urban areas where local, pesticide-free, and resource-efficient produce is in high demand.

7. Potential for Vertical Farm Expansion:
- High fertilizer prices could make traditional farming less profitable, especially for crops like leafy greens and herbs, which may push more farmers to explore vertical farming as a long-term solution.
- If vertical farms can maintain stable production despite rising input costs, this could encourage further investment and expansion in the vertical farming sector, particularly in regions with high demand for local and sustainable produce.

Summary of Mitigation Strategies for Vertical Farms:
1. *Pass Costs to Consumers*: Increase the price of leafy greens and herbs slightly to absorb the additional fertilizer costs, particularly in premium markets.
2. *Optimize Crop Selection*: Focus more on lower-fertilizer-demand crops, such as herbs, or on crops with higher profit margins.
3. *Explore Alternative Fertilizers*: Investigate organic or alternative nutrient sources to reduce dependency on traditional chemical fertilizers.
4. *Enhance Precision Farming*: Invest in more advanced technology to monitor and optimize nutrient delivery, reducing overall fertilizer consumption.
5. *Leverage Competitive Advantage*: Use the cost efficiency of vertical farms to capture more market share as traditional farms struggle with increased fertilizer costs.

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Appendix A5: Question: Consequences of a fertilizer price hike on low-income families

1. Increased Prices for Leafy Greens and Herbs
- Higher Production Costs: A 50% increase in fertilizer prices would lead to higher production costs for farmers. These costs would likely be passed on to consumers in the form of higher prices for leafy greens and herbs.
- Price Sensitivity: Low-income families are more price-sensitive, so even a moderate increase in the cost of fresh produce could lead them to buy less. Leafy greens and herbs, which may already be seen as relatively expensive compared to other staple foods, would become less affordable.

2. Shift in Dietary Choices
- Reduced Consumption of Fresh Produce:
- Health Implications:

3. Substitution with Lower-Cost Options
- Frozen or Canned Alternatives:.
- Local or Seasonal Produce: Families might turn to more locally grown or seasonal leafy greens and herbs, which could be less affected by global price fluctuations. However, in colder months, this option may be limited in Sweden due to the short growing season.

4. Impact on Urban and Vertical Farming Consumption
- Vertical Farming Products: Low-income families may still find such products too expensive.

5. Government or Market Interventions
- Subsidies or Support Programs: To mitigate the impact on low-income families, the government could introduce food subsidies, price controls, or expanded access to food assistance programs (e.g., vouchers for fresh produce). Such programs could help maintain consumption levels of leafy greens and herbs.
- Community Initiatives: Local initiatives, such as community gardens, urban farming, or food co-operatives, could provide an alternative source of affordable fresh produce for low-income families. This could help offset the impact of rising prices.

6. Impact on Food Security and Inequality
- Widening Food Inequality: If leafy greens and herbs become more expensive, it could exacerbate existing inequalities in food access. While wealthier households may absorb the higher costs, low-income families would likely experience reduced access to these nutrient-dense foods, leading to poorer dietary quality.
- Long-Term Effects on Health: Over time, decreased consumption of fresh, nutrient-rich foods among low-income families could contribute to long-term health disparities, including increased risks of diet-related diseases such as obesity, diabetes, and heart disease.

Conclusion:

A 50% increase in fertilizer prices would likely result in higher prices for leafy greens and herbs, making them less affordable for low-income families. As a result, consumption of these nutrient-dense foods could decrease among this group, leading to poorer dietary quality and potential health consequences. Government intervention, community support, and sustainable food initiatives could play a crucial role in mitigating these effects and ensuring access to fresh produce for vulnerable populations.

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Appendix A6: Question: Government Role in reducing negative effects of a fertilizer price hike

Yes, the government should consider intervening if fertilizer prices increase by 50%, particularly because of the potential negative effects on food security, agricultural sustainability, and the economy. Here are several reasons why government intervention may be necessary:

1. Preventing Food Price Inflation and Protecting Low-Income Households
- Food Security: A sharp increase in fertilizer prices would raise the cost of food production, especially for crops that rely heavily on fertilizers, such as leafy greens and other vegetables. This could lead to higher food prices, which disproportionately affects low-income households. A 50% price hike in fertilizers could contribute to food inflation, reducing access to affordable, nutritious food for vulnerable populations.
- Mitigating Inequality: Low-income families spend a higher proportion of their income on food. If prices for fresh produce rise, they may reduce consumption of healthier items like leafy greens and herbs, opting for cheaper, less nutritious alternatives. This could widen the gap in nutritional health between different income groups.

2. Supporting Farmers and Protecting Agricultural Viability
- Profit Margins and Farm Viability: A significant increase in fertilizer prices could erode farmers' profit margins, particularly for small-scale farmers who lack the financial resources to absorb higher costs. This could lead to reduced agricultural productivity or even cause some farmers to exit the market, threatening the long-term viability of domestic food production.
- Preventing Farm Bankruptcies: Without government support, smaller and less efficient farms might face financial distress, leading to bankruptcies and reduced domestic food production. This would increase reliance on imports, making the country more vulnerable to global food supply disruptions.

3. Maintaining Domestic Food Production and Reducing Import Dependency
- Self-Sufficiency in Food Production: Fertilizer price hikes could reduce domestic agricultural output, making the country more dependent on food imports. In Sweden, where certain crops are already heavily reliant on imports due to the climate, increasing this dependency could make the country more vulnerable to global supply chain disruptions, trade restrictions, and international price fluctuations.
- National Food Security: Governments have a responsibility to ensure food security, particularly in times of global instability. An unregulated increase in fertilizer prices could compromise the ability of domestic farmers to produce enough food, raising concerns about long-term food security.

4. Encouraging Sustainable Agricultural Practices
- Subsidizing Sustainable Alternatives: Government intervention could encourage the adoption of more sustainable farming practices, such as organic farming, regenerative agriculture, or precision farming, which rely less on synthetic fertilizers. By supporting farmers in transitioning to these methods, the government could reduce dependency on fertilizers over the long term.
- Incentivizing Innovation: Governments could fund research and development into alternative fertilizers, bio-based solutions, and innovative farming technologies, such as vertical farming or hydroponics, which use fertilizers more efficiently. This would help create more resilient agricultural systems.

5. Stabilizing the Agricultural Sector
- Preventing Market Shocks: A sudden and substantial rise in fertilizer prices could lead to unpredictable shocks in the agricultural sector, with cascading effects on food prices, employment in agriculture, and the overall economy. Government intervention, such as temporary subsidies or price controls, could help stabilize the sector during times of volatility.
- Ensuring a Level Playing Field: Larger farms and corporations may be able to weather the storm better than small-scale farmers. Without government support, this could lead to further consolidation in the agriculture industry, reducing competition and diversity in the market. This could undermine the resilience of the agricultural system in the long term.

6. Environmental and Long-Term Sustainability Considerations
- Environmental Impact: If fertilizer prices rise sharply, farmers might reduce fertilizer use to cut costs, potentially leading to lower crop yields or the overuse of other inputs, such as pesticides or herbicides. Reduced fertilizer use could also result in soil depletion over time, undermining long-term agricultural sustainability.
- Balancing Production and Sustainability: Government intervention could help balance short-term agricultural needs with long-term sustainability goals. This might include providing incentives for sustainable practices that maintain yields without exacerbating environmental damage.

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Types of Government Interventions to Consider:

1. Subsidies for Fertilizers: The government could offer temporary subsidies to help farmers cope with the increased costs, allowing them to continue producing crops without raising prices significantly for consumers.
2. Support for Sustainable Farming: Incentives or subsidies for adopting more sustainable farming practices that rely less on synthetic fertilizers could be introduced. This might include promoting organic fertilizers, composting, or precision farming technologies that optimize fertilizer use.

3. Research and Innovation Funding: The government could fund research into alternative fertilizers, organic farming techniques, or vertical farming technologies that use fewer fertilizers while maintaining high productivity.
4. Direct Support for Low-Income Households: To mitigate the impact on food security, the government could expand food assistance programs, such as subsidies or vouchers for fresh produce, to help low-income families maintain access to nutritious food like leafy greens and herbs.
5. Regulatory Interventions or Price Controls: In extreme cases, the government might consider regulating fertilizer prices or introducing temporary price controls to prevent excessive price spikes, though this would need to be done carefully to avoid creating market distortions.

Conclusion:

A 50% increase in fertilizer prices would have wide-ranging effects on both food production and consumption, particularly for low-income households and small-scale farmers. Government intervention would be justified to protect food security, support the agricultural sector, and encourage a transition toward more sustainable farming practices. Such measures would help prevent inflationary pressures on food prices, reduce inequalities, and ensure the long-term viability of the agricultural sector, ultimately benefiting both farmers and consumers.

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Appendix A7: Question: What could be done to assure that low-income families continue consuming leafy greens and herbs

1. Government Subsidies for Leafy Greens and Herbs
- *Direct Food Subsidies*: The government could introduce or expand subsidies for fresh produce, particularly for leafy greens and herbs. This could take the form of direct subsidies to producers, which would offset the higher costs of fertilizers and keep consumer prices stable. Alternatively, subsidies could be provided directly to consumers, through programs like food vouchers.
- *Targeted Support for Low-Income Families*: Governments can provide targeted food assistance to low-income families, such as increasing the value of vouchers specifically for fruits and vegetables (similar to the US SNAP or WIC programs).

2. Support for Urban and Vertical Farming
- *Incentivize Local Production*: Expanding support for urban farms and vertical farms can help ensure a stable supply of leafy greens and herbs, reducing reliance on imports or fertilizer-heavy traditional agriculture. Vertical farming, which typically uses fertilizers more efficiently, may be less impacted by price hikes.
- *Community-Based Urban Agriculture*: Support for community gardens and urban agriculture projects can empower low-income communities to grow their own leafy greens and herbs. This can help reduce food costs and increase access to fresh produce. Governments and local organizations could provide the necessary infrastructure, such as soil, seeds, and training.

3. Promote Sustainable and Organic Farming Practices
- *Encouraging Alternative Farming Methods*: Promoting organic farming and regenerative agriculture, which rely less on synthetic fertilizers, can reduce the impact of fertilizer price hikes. If farmers shift toward these methods, production costs may be stabilized, and the impact on consumer prices for leafy greens and herbs can be mitigated.
- *Subsidies for Organic Fertilizers*: The government could subsidize or promote the use of organic or bio-based fertilizers, which may not be as affected by global price fluctuations as synthetic fertilizers.

4. Price Controls and Market Interventions
- *Temporary Price Controls*: The government could implement temporary price controls on essential food items, such as leafy greens and herbs, to prevent excessive price increases that result from the fertilizer price hike. This would ensure that low-income families can still access these foods at affordable prices.
- *Increased Competition*: Encouraging competition among retailers could also help keep prices in check. Support for smaller producers, cooperatives, or social enterprises that sell fresh produce at lower prices.

5. Promote Alternative Nutrient Sources for Vertical Farms
- *Invest in Research and Innovation*: Government or private sector investment in research and development of alternative nutrient sources for vertical and urban farms could lead to new, cost-effective solutions that are less dependent on conventional fertilizers. This could ensure that local producers remain unaffected by fertilizer price increases, helping to maintain the supply.
- *Encourage Circular Economy Practices*: Supporting the development of circular economy models in agriculture, where nutrient recycling and waste minimization are prioritized, can reduce reliance on external inputs like fertilizers.

6. Nutritional Education and Promotion of Less Expensive Greens
- *Educational Campaigns*: Governments and NGOs can run nutritional education campaigns to encourage low-income families to consume less expensive, nutrient-rich alternatives to imported leafy greens. This could involve promoting locally grown, seasonal greens that are less affected by fertilizer price fluctuations.
- *Increased Awareness of Community Resources*: Low-income families should be made aware of local resources such as food cooperatives, community gardens, and subsidized farmers' markets where fresh produce is available at lower costs.

7. Food Banks and Donation Programs
- *Expanding Food Banks*: Governments or non-profit organizations can expand the reach of food banks and fresh produce donation programs. This ensures that low-income families have access to leafy greens and herbs, even if market prices rise. These programs could include partnerships with local farmers or retailers to provide surplus or unsold produce.
- *Produce Gleaning Programs*: Initiatives that collect surplus produce from farms or grocery stores and distribute it to low-income communities could be expanded. These programs help reduce food waste.

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8. Encourage Cooperative Purchasing
- *Food Cooperatives*: Establishing or supporting food cooperatives where communities collectively purchase leafy greens and herbs in bulk can reduce costs and allow for better access to fresh produce. By leveraging cooperative purchasing power, low-income families can buy nutritious foods at lower prices.
- *Farm-to-Consumer Initiatives*: Governments or community organizations can promote farm-to-consumer programs like community-supported agriculture (CSA), where consumers purchase a share of a local farm's produce. This can reduce costs by cutting out middlemen, making it more affordable for low-income families.

Conclusion:
To ensure low-income families continue consuming leafy greens and herbs despite a 50% increase in fertilizer prices, a multi-faceted approach involving government subsidies, increased support for sustainable and local farming, price controls, and community-based initiatives is needed. These measures can stabilize prices, maintain accessibility, and encourage the consumption of fresh produce, ultimately supporting public health and food security.

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Appendix A8: Question: What could be done with limited budget

1. Subsidies for Fertilizers or Nutrient Inputs for Key Farmers
Why it's a Priority: Directly subsidizing fertilizers or nutrient inputs for small-scale and vertical farms can help mitigate the imme-diate impact of the price increase and ensure continued production without causing a substantial rise in consumer prices.
Budget Efficiency: This is a direct intervention with immediate benefits and relatively low cost compared to broader subsidies for all farmers. It ensures that production is stabilized without needing to support the entire sector.
Action:
- Target farmers most reliant on fertilizers, such as small-scale vegetable and vertical farms producing leafy greens and herbs.
- Focus on temporary subsidies to buffer the impact of the price hike.

2. Promote Urban Farming and Community Gardens
Why it's a Priority: Supporting community gardens and urban farming initiatives can increase local production of leafy greens and herbs, especially in low-income areas. These projects are often low-cost and have a significant impact on food security and local food supply.
Budget Efficiency: Community gardens require modest investments in infrastructure (such as soil, seeds, and tools) but can produce a considerable amount of fresh produce, reducing dependence on imports and large-scale farming.
Action:
- Partner with local municipalities or NGOs to set up and expand community gardens and urban agriculture projects in cities.
- Provide starter kits (seeds, soil, and basic tools) to incentivize household or community-level production.

3. Targeted Food Vouchers for Low-Income Families
Why it's a Priority: Ensuring that low-income families continue to have access to affordable leafy greens and herbs is crucial for public health. Providing targeted food vouchers or discounts can directly increase consumption without the need for complex programs or high administrative costs.
Budget Efficiency: This approach is targeted and temporary, focusing only on the most vulnerable populations and ensuring that subsidies go directly to those in need, minimizing wasteful spending.
Action:
- Implement a food voucher program for low-income families, specifically earmarked for purchasing vegetables etc.
- Partner with grocery stores or local markets to offer discounted prices for these items to voucher recipients.

4. Support Vertical Farming and Efficient Technologies
Why it's a Priority: Vertical farming is resource-efficient and can produce large quantities of leafy greens and herbs in a controlled environment with less dependence on external factors like weather and soil quality. It's an ideal method for ensuring a steady supply in urban areas.
Budget Efficiency: Vertical farms can maximize output with less land and water, making them more sustainable in the long term. A small investment in expanding or supporting vertical farms can yield significant returns in local food production.
Action:
- Provide small-scale grants or low-interest loans for existing vertical farms to cover the increased cost of nutrient solutions.
- Encourage public-private partnerships to scale vertical farming operations, reducing the burden on public funds.

5. Promote Sustainable Farming Practices
Why it's a Priority: Encouraging farmers to adopt sustainable practices, such as organic or regenerative farming, can reduce dependency on synthetic fertilizers and create a more resilient agricultural system over time. Supporting farmers in transitioning to these practices can lower their costs and stabilize production.
Budget Efficiency: Providing training and low-cost tools for sustainable practices requires a lower investment than long-term subsidies and helps reduce fertilizer dependency in the long run.
Action:
- Offer training or workshops for farmers on the use organic fertilizers and other sustainable practices.
- Provide small incentives for farmers who adopt organic or low-input farming methods.

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6. Leverage Existing Food Banks and Donation Programs
Why it's a Priority: Increasing the distribution of leafy greens and herbs through existing food banks and donation programs is a cost-effective way to reach low-income families. By leveraging existing infrastructure, it reduces the need for new programs while addressing food insecurity.
Budget Efficiency: Food banks and donation programs are already established, so increasing their supply of fresh produce involves minimal additional cost.
Action:
- Partner with farmers and retailers to donate surplus or unsold produce to food banks and charitable organizations.
- Create tax incentives for producers and retailers that donate fresh leafy greens and herbs, ensuring a continuous supply.

7. Encourage Cooperative Purchasing Models
Why it's a Priority: Cooperative models, where communities or groups of individuals buy food in bulk, can reduce costs for both producers and consumers. This approach can make leafy greens and herbs more affordable for low-income families.
Budget Efficiency: Cooperative purchasing involves low upfront costs and relies on community participation. It can be supported with minimal public funds while creating significant savings for consumers.
Action:
- Promote and support food cooperatives where groups can buy leafy greens and herbs in bulk, reducing the cost per unit.
- Provide logistical support or small grants to start cooperatives in urban or low-income areas.

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Appendix A9: Question: Monetary consequences of shifting all production of leafy greens and herbs to vertical farms

1. Savings from Reduced Imports
- *Current Import Levels*: Sweden imports approximately 60-70% of its leafy greens and herbs, especially during the winter months, primarily from countries like Spain and the Netherlands. If vertical farming replaced these imports, Sweden could eliminate these costs.
- *Annual Market Size*: Based on household food expenditure estimates, the total annual expenditure on leafy greens and herbs in Sweden is around 2.82 billion SEK to 8.46 billion SEK.
- *Import Replacement*: Assuming 60-70% of the current market is imported, that would translate to 1.69 billion SEK to 5.92 billion SEK in imported leafy greens and herbs.
- *Savings Estimate*: By eliminating imports, Sweden could save transportation costs, tariffs, and import markups. If we estimate a 15% cost premium for imports (due to transportation, logistics, and international trade costs), Sweden could save approximately 254 million SEK to 888 million SEK annually from reduced import-related expenses.

2. Savings from Water and Fertilizer Efficiency
- *Water Savings*: Vertical farms use up to 90% less water than traditional farming methods. If traditional farming for leafy greens and herbs uses, for example, 100 million SEK worth of water annually, vertical farming could reduce this cost to 10 million SEK, saving around 90 million SEK annually.
- *Fertilizer Savings*: Vertical farms optimize fertilizer use, potentially reducing fertilizer needs by 30-50%. Assuming that Swedish farmers spend 200 million SEK annually on fertilizers for leafy greens and herbs, vertical farming could save 60 to 100 million SEK in fertilizer costs each year.

3. Transportation Cost Savings
- *Reduced Logistics Costs*: Importing fresh produce, particularly perishable items like leafy greens and herbs, requires expensive transportation, often by air or refrigerated trucks. By shifting production to vertical farms located near urban centers, Sweden could eliminate much of this transportation cost.
- *Cost of Imports*: If transportation and logistics account for 10-20% of the cost of imported leafy greens and herbs, this could represent 169 million SEK to 592 million SEK annually. By shifting production to local vertical farms, Sweden could save a significant portion of this cost, potentially around 85 million SEK to 296 million SEK.

4. Reduced Food Waste and Longer Shelf Life
- *Less Spoilage*: Imported leafy greens and herbs have a shorter shelf life due to the long transportation time. Vertical farming could significantly extend the shelf life of these products, reducing food waste both at the retail and household levels. According to the FAO, roughly 30% of fresh produce is wasted due to spoilage.
- *Value of Wasted Produce*: If the annual market size for leafy greens and herbs is 2.82 billion SEK to 8.46 billion SEK, and 30% is wasted, this represents 846 million SEK to 2.54 billion SEK in wasted food each year.
- *Savings Estimate*: By cutting waste in half through vertical farming (which delivers fresher, longer-lasting produce), Sweden could save approximately 423 million SEK to 1.27 billion SEK annually.

5. Energy Efficiency and Integration with Renewables
- *Energy Cost Reduction*: While vertical farming can be energy-intensive (particularly in terms of lighting), integrating vertical farms with Sweden's renewable energy sources (hydropower, wind, solar) could reduce operational costs over time. Sweden's relatively low-cost renewable energy grid would allow vertical farms to run more efficiently compared to conventional farming systems reliant on fossil fuels.
- *Energy Savings Estimate*: Assuming vertical farms can reduce energy costs by 10-20% compared to conventional farms, and assuming energy costs account for 200 million SEK annually in traditional greenhouse operations, savings could range from 20 to 40 million SEK annually.

6. Job Creation and High-Tech Sector Development
- *Job Creation and Economic Multiplier*: Shifting to vertical farming would create high-skilled jobs in technology, engineering, and farm management. Each new high-tech job created could have a multiplier effect on the economy, generating additional income through increased consumer spending, taxes, and services.
- *New Jobs and Economic Impact*: If vertical farming could create 1,000-2,000 new jobs (based on an estimated increase in demand for skilled workers), and the average salary in agriculture is around 350,000 SEK per year, this would add 350 million SEK to 700 million SEK in annual economic activity. This does not directly translate into savings but represents a significant economic boost for Sweden.

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7. Carbon Footprint and Environmental Savings
- *Carbon Emissions Reduction*: Vertical farming would reduce the carbon footprint of Sweden's food system by cutting transportation emissions from imports and reducing water and fertilizer use. If current imports result in 100,000 to 150,000 tons of CO_2 emissions annually, vertical farming could reduce these emissions by 70-90%.
- *Carbon Cost Savings*: With Sweden's carbon tax of 1,190 SEK per ton of CO_2, reducing 70,000 to 135,000 tons of CO_2 through local vertical farming could save 83 million SEK to 160 million SEK annually in carbon costs.

Total Estimated Annual Savings:
By shifting all production of leafy greens and herbs to vertical farms, the potential monetary savings could be substantial across various factors:

1. Import Reduction Savings: 254 million SEK to 888 million SEK
2. Water and Fertilizer Efficiency Savings: 150 million SEK to 190 million SEK
3. Transportation and Logistics Savings: 85 million SEK to 296 million SEK
4. Reduced Food Waste Savings: 423 million SEK to 1.27 billion SEK
5. Energy Cost Savings: 20 million SEK to 40 million SEK
6. Environmental and Carbon Tax Savings: 83 million SEK to 160 million SEK

Total Annual Savings Estimate: 1.02 billion SEK to 2.84 billion SEK annually

These savings represent a significant economic benefit for Sweden. The shift to vertical farming would reduce import reliance, improve resource efficiency, lower environmental costs, and potentially stimulate job creation and innovation in high-tech agriculture. While initial investments in vertical farming infrastructure would be required, these annual savings demonstrate the long-term economic advantages of transitioning to a vertical farming model for leafy greens and herbs in Sweden.

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Appendix A10: Question: Monetary consequences of serving demand by imports only

1. Cost of Increased Imports
- Sweden currently imports a significant portion of its leafy greens and herbs, but assuming a shift to 100% imports, the increase would involve additional transportation costs and import duties.
- Let's assume leafy greens and herbs account for approximately 1-3% of household food expenditure in Sweden (as a rough estimate). According to Statistics Sweden (SCB), the average household expenditure on food is around 60,000 SEK annually. This means leafy greens and herbs account for approximately 600 to 1,800 SEK per household annually.
- Sweden has about 4.7 million households. Therefore, total annual expenditure on leafy greens and herbs is estimated at around 2.82 billion SEK to 8.46 billion SEK.
- Assuming imported products are 15-20% more expensive (due to transportation, tariffs, and global price volatility), the additional cost to consumers for 100% imports would be approximately 423 million SEK to 1.69 billion SEK annually.

2. Loss of Revenue for Domestic Farmers
- Domestic production of leafy greens and herbs provides income for small-scale farmers, greenhouse operations, and vertical farms.
- If 100% of leafy greens and herbs were imported, local farmers would lose revenue. The total value of leafy greens and herbs produced domestically could be estimated at 25-40% of the total market, or 705 million SEK to 3.38 billion SEK.
- A 100% shift to imports would cause these local producers to lose this revenue, potentially leading to farm closures, job losses, and a reduction in investment in local farming infrastructure.

3. Environmental Costs (Transportation and Emissions)
- Transporting fresh produce, especially leafy greens, is highly energy-intensive. If Sweden imports 100% of its leafy greens and herbs, transportation (often involving air freight) would significantly increase the country's carbon footprint.
- A study on food transportation emissions estimates that imported fresh produce increases the carbon footprint by 5-10 times compared to locally grown produce. For leafy greens, which are highly perishable, this could result in significant emissions costs.
- A rough estimate of carbon costs could involve calculating the increased transportation emissions and multiplying by a carbon tax or social cost of carbon. Assuming an additional 100,000 metric tons of CO_2 emissions (due to increased air freight) and applying a carbon cost of 1,190 SEK per ton (Sweden's carbon tax), this would add an estimated 119 million SEK annually in environmental costs.

4. Consumer Price Increases
- With the increase in import costs (logistics, tariffs, price volatility), consumers are likely to see a price hike of 10-15% in leafy greens and herbs. This increase will directly impact household food budgets.
- For low-income families, who are particularly sensitive to price increases, the added cost would disproportionately reduce access to fresh produce. The increase in annual household expenditure on these items could range from 60 to 270 SEK per household, which, across the 4.7 million households in Sweden, adds up to 282 million SEK to 1.27 billion SEK in additional consumer costs.

5. Loss of Jobs and Economic Activity in Agriculture
- Shifting to 100% imports would cause job losses in the agriculture sector, particularly in small-scale farming, vertical farming, and greenhouse production. The impact could be significant, as the agriculture sector in Sweden employs approximately 170,000 people.
- If the leafy greens and herbs segment represents 5-10% of horticultural employment, and a shift to imports leads to a 50% reduction in jobs in this segment, it could result in 4,250 to 8,500 job losses.
- The economic cost of lost employment, including unemployment benefits and lost productivity, could be estimated using average salaries in agriculture. Assuming an average annual salary of 350,000 SEK per worker, the total economic loss from job cuts could range from 1.49 billion SEK to 2.98 billion SEK annually.

Estimated Total Monetary Damage
1. Additional cost of imports: 423 million SEK to 1.69 billion SEK
2. Loss of revenue for domestic farmers: 705 million SEK to 3.38 billion SEK
3. Environmental costs: 119 million SEK
4. Additional consumer costs: 282 million SEK to 1.27 billion SEK
5. Job losses in agriculture: 1.49 billion SEK to 2.98 billion SEK

Total Estimated Damage: Between 3.02 billion SEK and 9.44 billion SEK annually.

This figure represents the potential economic, environmental, and social damages Sweden could face if it shifted to 100% imports of leafy greens and herbs due to a 50% increase in fertilizer prices. This estimate includes increased costs for consumers, loss of agricultural income and jobs, and environmental costs from transportation and emissions.

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Appendix A11: Question: What could be done with limited budget but preferences for biodiversity initiatives

1. Subsidies for Organic and Biodiverse Produce
Description: Provide targeted subsidies or discounts for organic and locally grown leafy greens and herbs that use minimal synthetic fertilizers and support biodiversity.
Cost-Benefit Balance : This approach helps low-income families afford fresh produce while promoting organic farming practices that enhance soil health and biodiversity.
Biodiversity Impact : Organic and biodiverse farming reduces chemical inputs, encouraging ecosystems that support pollinators, soil organisms, and beneficial insects.

2. **Food Vouchers for Farmers' Markets and Local Produce**
Description : Offer vouchers for low-income households to purchase locally grown leafy greens and herbs from farmers' markets or direct farm outlets.
Cost-Benefit Balance : Vouchers can be limited to seasonal produce, keeping costs lower than year-round subsidies. They support local farmers and help keep money within the community.
Biodiversity Impact : Local small-scale farms are often more biodiverse, using practices like crop rotation and intercropping, which benefit local ecosystems. Supporting these farms incentivizes biodiversity-friendly agriculture.

3. Incentives for Urban and Community Gardens
Description : Support community gardens, urban farms, and local gardening initiatives where families can grow leafy greens, herbs, and other vegetables.
Cost-Benefit Balance : Initial setup costs for community gardens are relatively low, and they can provide long-term access to affordable produce. Local governments or NGOs could supply seeds and compost as one-time investments.
Biodiversity Impact : Community gardens promote biodiversity in urban settings, providing habitats for insects and plants, reducing urban heat, and contributing to local food resilience.

4. Education and Training on Low-Input Gardening Techniques
Description : Provide workshops or informational materials on low-input, biodiversity-friendly gardening techniques, such as permaculture, composting, and companion planting, targeted to low-income families.
Cost-Benefit Balance : This approach has relatively low costs, focusing on building knowledge rather than direct financial support. It empowers families to grow some of their own food, reducing dependency on higher-cost market produce.
Biodiversity Impact : Promoting organic, biodiversity-friendly gardening techniques helps increase local biodiversity, soil health, and water retention, benefiting both the environment and communities.

5. Subsidies for Regenerative and Organic Farming Practices
Description : Implement subsidies or tax incentives for farmers who adopt regenerative farming practices, such as reducing synthetic fertilizer use and enhancing soil health.
Cost-Benefit Balance : While this approach does not directly lower consumer prices, it helps stabilize production costs for farmers, allowing them to keep prices more affordable while aligning with biodiversity goals.
Biodiversity Impact : Regenerative agriculture builds soil health, supports beneficial microbes, and enhances ecosystem resilience, fostering biodiversity at multiple levels.

6. Support for Agroecological Initiatives and Food Hubs
Description : Establish local food hubs that source and distribute fresh produce grown with agroecological methods (minimal synthetic inputs, diversified crops) at a reduced price for low-income consumers.
Cost-Benefit Balance : Food hubs can be partially subsidized by government funds and supported through partnerships with local farmers, creating a centralized way to provide affordable, sustainable produce.
Biodiversity Impact : Agroecology promotes diverse cropping systems, soil health, and ecosystem services, supporting biodiversity and making local food systems more resilient to environmental shocks.

7. Partnerships with Food Banks for Fresh, Biodiverse Produce
Description : Partner with food banks to ensure regular supplies of leafy greens and herbs from biodiversity-friendly farms. Government funding could cover the cost difference between conventional and sustainable produce.
Cost-Benefit Balance : Directing funds to food banks to purchase from sustainable sources can be a cost-effective way to reach vulnerable populations while supporting ecological farming.
Biodiversity Impact : This approach directs demand toward farms practicing biodiversity-friendly agriculture, encouraging more sustainable practices across the region.

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