Food System Economics Commission

WORKING PAPER

# FSEC – cost of action for the food system transformation

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# FSEC – cost of action for the food system transformation

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## 1. Introduction to the project

The Food System Economics Commission (FSEC) is an independent academic commission set up to equip political and economic decision-makers with tools and evidence to transform food and land use systems. Convened by EAT, Potsdam Institute for Climate Impact Research (PIK), and FOLU, FSEC builds on the vanguard of integrated assessment modelling and evidence-based policy design to study and synthesize knowledge on the inclusion, health and environmental dimensions of the economics of food systems. The Commission's overarching objective is to further the transition to healthy, inclusive and sustainable food systems by providing a comprehensive assessment of

- the economics of current food systems,
- the unaccounted costs of food systems, defined as environmental, dietary health and social costs, and
- the distributional impacts of the transition;

by rigorously assessing evidence and providing new tools to support policy design.

One key aspect of the research conducted within FSEC are Food System Transformation Pathways (FTPs) developed by the research team at the PIK, as described in a recent FSEC publication.

FTPs represent coherent pathways that incorporate all three critical food systems transformation objectives: environment, health and inclusion. FTPs are pathways which differ from Business as Usual (BAU), which is defined as the current food system's trajectory, with its current inefficiencies and externalities.

FTPs can be diverse in their composition of goal indicators for a medium- to long-term future and they can range from sustainable intensification to agroecological production and the diversity of practices that each encompasses. They are a combination of biophysical and qualitative storylines that can include elements of Share Socioeconomic Pathways and Nationally Determined Contributions.

The gap between BAU and FTP is defined as the desired ambition for transformational change and can be synthetized into discrete measures, such as income growth of the poor, shifts to healthy diets or technological changes to improve productivity.

The FTP can be compared with a BAU scenario in the future (for example, 2050), and the difference marks the level of change (or ambition) that needs to be achieved through a range of coherent food systems policies and measures, which can be identified to help closing the gap between a BAU and a FTP scenario.

In order to estimate the '**cost of action**' of a **global food system transformation**, FOLU has been working on estimating investment costs required for a successful transformation.

## 2. Selection of measures

The measures have been selected in the first phases of the project, relying on a previous SYSTEMIQ (SIQ) report for the **environmental** measures and relying on several meetings with experts in the field of food systems' transformation as well as commissioners from FSEC for the selection of the **health** and **social inclusion** measures.

The environmental measures have been selected following on the work of SIQ in the project of **Financing Nature-Based Solutions (FiNBS)**: the SIQ project aimed at understanding 1) the mitigation potential of NbS at a country level and the definition of the climate mitigation potential of 20 land-based measures (from avoided deforestation, to improved rice management, to reduced food loss and waste), relying on a paper from Roe et al. (2021)[1] and 2) the finance gap between the current flows and what is needed to unlock the full mitigation potential.

The land-based environmental measures had been selected by Roe et al. (2021) looking at their national and regional mitigation potentials, compiling and developing both technical and cost-effective (possible up to $100/tCO2eq) mitigation potentials implemented between 2020 and 2050 (averaged) using the best available data with country-level resolution. The mitigation potential quantified in the 20 measures initially selected by the scholars include reductions and removals of CO2 and reductions of N2O and CH4. The mitigation potentials are derived from individual and/or sectoral studies and datasets which use a range of methods, including sectoral economic modelling, optimization modelling, and spatial analysis.

Based on this, the following **environmental measures** have been selected for the current cost of action study:

1. Operational goal #3 - Protection of forests and other ecosystems
    a. Reduction of deforestation
    b. Reduce peatland degradation and conversion
    c. Reduce mangrove loss
2. Operational goal #3 - Management of forests and other ecosystems
    a. Improvement of forest management
    b. Improvement of grassland fire management
3. Operational goal #3 - Restoration of forests and other ecosystems
    a. Afforestation and reforestation
    b. Peatland restoration
    c. Mangrove restoration
4. Operational goal #4 - Agriculture - reduction of emissions
    a. Enteric fermentation
    b. Manure management
    c. Nutrient management
    d. Rice cultivation
5. Operational goal #4 - Agriculture - improvement of emission sequestration

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[1] Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., ... & Lawrence, D. (2021). Land-based measures to mitigate climate change: Potential and feasibility by country. Global Change Biology, 27(23), 6025-6058.

    a. Agroforestry
    b. Soil organic carbon in croplands
    c. Soil organic carbon in grasslands
    d. Biochar
6. Operational goal #4 - Reduction of food loss and waste

For the **health and social inclusion measures**, there have been several meetings held with selected **FSEC commissioners**: Ravi Kanbur, Professor Ravi Kanbur is T.H. Lee Professor of World Affairs, International Professor of Applied Economics, and Professor of Economics at Cornell University; Jessica Fanzo, Bloomberg Distinguished Professor of Global Food Policy and Ethics at the Berman Institute of Bioethics, the Bloomberg School of Public Health, and the Nitze School of Advanced International Studies (SAIS) at the Johns Hopkins University in the USA; Rachel Nugent, Vice President for Global Non-communicable Diseases at RTI International; Paul Winters, the Keough-Hesburgh Professor of Global Affairs in the University of Notre Dame's Keough School of Global Affairs.

The following health and social inclusion measures, which are directly related to a successful transformation of the food systems, have been selected:

7. Operational goal #1 - Diversification of protein supply
8. Operational goal #1 - Behavioural interventions for shift in demand
9. Operational goal #1 - Child nutrition
    a. School feeding programmes
    b. Breastfeeding programmes
10. Operational goal #1 - Restrictions, taxes and regulations
    a. Trans-fat acid regulation
    b. Restrictions on marketing
    c. SSB
    d. Salt reduction
11. Operational goal #2 - Cash transfers for poverty reduction
12. Operational goal #4 - Agricultural public R&D
13. Operational goal #2 - Rural infrastructure development
    a. Rural roads
    b. Access to electricity
    c. Access to internet
    d. Irrigation expansion
14. Operational goal #4 - Training of agricultural entrepreneurs
15. Operational goal #4 - Financing of smallholder farmers

Note that during the process of finalizing the paper the original estimate of Operational goal #2 - Cash transfers for poverty reduction has been harmonized with the calculations presented in Lord[2] (2023). These costs are also presented as a range, as discussed further below.

## 3. General methodology

As a first step, a narrative/traditional literature review has been performed. **More than 200 academic references** on food systems' transformations and their related environmental, health and social measures have been consulted and reviewed. Moreover, more than 20 reports from international organizations (e.g., **World Bank[3], IFPRI[4], FAO[5], WFP[6], IFAD, IPCC**, etc.) have been screened with the aim of better understanding.

Based on this first literature review, a second screening and filtering has been performed, selecting the most recent and widely cited sources in order to arrive at an approximate cost per measure (usually USD per person, or USD per hectare).

The general approach for the selection of the best sources has followed the following principles:

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[2] Lord, S. (2023). Comparative hidden costs of the Food System Economic Commission Current Trends and Food System Transformation Pathways to 2050.

[3] Gautam, M., Laborde, D., Mamun, A., Martin, W., Pineiro, V., & Vos, R. (2022). Repurposing Agricultural Policies and Support.

[4] International Food Policy Research Institute. 2022. 2022 Global Food Policy Report: Climate Change and Food Systems. Washington, DC: International Food Policy Research Institute. https://doi.org/10.2499/9780896294257

[5] FAO, Ifad, UNICEF, WFP & WHO. The State of Food Security and Nutrition in the World. (2021). Transforming food systems for food security, improved nutrition and affordable healthy diets for all. Rome, FAO.

[6] https://docs.wfp.org/api/documents/WFP-0000138913/download/?_ga=2.69435472.1701299980.1666097724-861126585.1652790848

- The measures and their unit costs needed to be directionally in line with the PIK model (towards improving health, improving livelihoods, making environment more sustainable and the food system more resilient);
- The **gap between BAU and FTP** has been defined as the desired ambition for transformational change and can be synthetized into discrete measures, such as shifts to healthy diets, social inclusion measures or technological changes to improve productivity and/or reduce emissions.
- The FTP can be compared with a BAU scenario in the future (2050), and the difference marks the level of change (or ambition) that needs to be achieved through a range of coherent food systems policies and measures, which have been identified to help closing the gap between a BAU and a FTP scenario.
- The final cost, selected, is the additional cost of the measure compared to the BAU scenario.

For the environmental measures the general methodology has consisted in getting costs in USD per tCO2e. The selection of the environmental data has relied greatly on the work done by SIQ during 2022 on the FiNBS project, where several hundred data points have been gathered thanks to a thorough literature review, experts' interviews and collection of real project investment data.

The environmental measures, additionally to the principles above-listed, have followed the following principles:

- Costs have been adjusted to 2020 values and comprise: transaction, establishment, enabling, and operational costs.
- In general, costs for countries at different income groups have been proxied using real project level data coming from Kenya, Colombia, and the USA.
- Costs reflect the forest or farm-level costs incurred when setting up an initiative and omit some additional costs related to a certain form of investment, such as measurement, reporting and verification (MRV) costs for carbon finance.
- For the agricultural measures, costs of Nature Based Solutions (NBS) practices have been compared to typical business as usual (BAU) agriculture or forestry, in order to understand what the additional cost or cost savings are over and above the costs being paid for today.

For the environmental measures, the total achievable for each measure has been adjusted to the Cumulative Emission Mitigation Potential (CEMP) of each country (see Roe et al., 2021), then summed up to the total CEMP for each income group.

In general, all the costs (environmental, health and social) have been adjusted to 2020 values.

The source for the data underlying the socio-economic assumptions in the model is described in this paper, and, whenever it is not, the source is the World Bank Indicators database[7].

## 4. Cost of action - Measures for food system transformation

The total cost of action for transforming the food systems until 2050, excluding cash transfers for poverty reduction, is **6.02 trillion USD**, or **215.32 billion USD a year**. All costs are in 2020 USD.

Table 1 presents the costs per country income group on an annual basis and the cumulative costs per country income group over the period from 2023 until 2050 are as shown in table 2.

Table 1: cost per country income group.

| | **Average annual cost (bill. USD)** | **Cumulative cost, 2023 to 2050 (bill. USD)** |
|---|---|---|
| **Low income countries (28 countries)** | 25.42 | 711.75 |
| **Lower middle income countries (54 countries)** | 42.38 | 1’186.56 |
| **Upper middle income countries (54 countries)** | 125.75 | 3’521.12 |

[7] https://databank.worldbank.org/source/world-development-indicators/

| | | |
|---|---|---|
| **High income countries (80 countries)** | 21.77 | 609.64 |

Table 2: cost per objective and measure.

| | **Average annual cost (bill. USD)** | **Cumulative cost, 2023 to 2050 (bill. USD)** |
|---|---|---|
| **Operational goal #1** | **22.6** | **632.9** |
| 7. Diversification of protein supply | 3.1 | 86.5 |
| 8. Behavioural interventions for shift in demand | 1.2 | 33.8 |
| 9. Child nutrition | 17.2 | 482.6 |
| 10. Restrictions, taxes and regulations | 1.1 | 30 |
| **Operational goal #2** | **31** | **867.54** |
| 11. Cash transfers | --- | --- |
| 13. Rural infrastructure development | 23.6 | 661.3 |
| 14. Training of smallholder farmers | 1.3 | 35.6 |
| 15. Financing for smallholder farmers | 6.1 | 170.6 |
| **Operational goal #3** | **87.7** | **2'456** |
| 1. Protection of forests and other ecosystems | 77.7 | 2'175.3 |
| 2. Management of forests and other ecosystems | 3.4 | 94 |

| | | |
|---|---|---|
| 3. Restoration of forests and other ecosystems | 6.7 | 186.8 |
| **Operational goal #4** | **74** | **2’072.6** |
| **4. Agriculture: reduction of emissions** | 27.6 | 773.5 |
| **5. Agriculture: improvement of emissions’ sequestration** | 41.8 | 1’170.8 |
| **6. Reduction of food loss and waste** | 1.7 | 48.3 |
| **12. Agriculture public R&D** | 2.9 | 80 |

In addition to these costs, putting in place cash transfers to cushion poor and vulnerable groups from possible price increases in the course of the transition has been estimated to require up to 300 billion a year. This estimate is anchored in Lord (2023) estimate of the global income gap (i.e. the amount of money that would be required to bring all poor people to the poverty line in 2050). This estimate is presented as a range as it needs to be refined depending on local circumstances including the extent to which commodity prices rise in a given context as food systems are transformed, how much commodity price increases are translated into consumer food price increases, national programs’ ambition and how they are scaled up over time, the specific income groups expected to benefit, local household vulnerability to price increases and the availability of resources and capacity needed to operate transfer programs.

## a. Operational goal 3 - Protection of forests and other ecosystems

### Definition and impacts

When forests are cleared or burnt, stored carbon is released into the atmosphere, mainly as carbon dioxide. Averaged over 2015—2017, global loss of tropical forests contributed about 4. 8 billion tonnes of carbon dioxide per year (or about 8-10% of annual human emissions of carbon dioxide).[8] Protecting forests and other ecosystems means avoiding emissions form deforestation, from degradation and/or anthropogenic loss of carbon stocks in mangrove ecosystems, as well as avoided GHG emissions (CO2, CH4, and N2O) from degradation of intact peatlands (does not include conversion of vegetation).[9]

The measure is divided into:

- **Reduction of deforestation**
    - This measure seeks to avoid emissions that would have otherwise occurred as a result of deforestation, which is defined by when forests are reduced to below 30% of tree cover. Commodity-driven agriculture in tropical regions – including the production of soy, palm oil, timber, cattle, rubber & cocoa - is a major driver of deforestation.
    - Example of project
        - Three REDD+ pilot initiatives in Tanzania, representing an area of 327,825 h, help to shift away from unsustainable forestry and fuel wood collection. Initiatives aim to provide alternative income via pasture instead. Profit from unsustainable charcoal and timber production can serve as a proxy for opportunity costs as it is a main driver for deforestation in the region.
- **Reduction of mangrove loss**
    - This measure seeks to avoid emissions that would otherwise have occurred as a result of degradation of mangroves. Major drivers of mangrove degradation include shrimp farming and deforestation for mangrove poles.
    - Example of project
        - Generating carbon credits and sharing benefits with local communities to protect and restore mangroves that are otherwise threatened by logging, fishing and land clearing.
- **Reduction of peatland degradation**
    - This measure involves avoiding greenhouse gas emissions through the protection of intact peatlands.

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[8] https://www.climatecouncil.org.au/deforestation/#:~:text=When%20forests%20are%20cleared%20or,human%20emissions%20of%20carbon%20dioxide).

[9] https://onlinelibrary.wiley.com/doi/epdf/10.1111/gcb.15873

- Example of project: Increase fire management and monitoring water levels to prevent further damage to peatlands, including community engagement to stop intentional fires.

### Cost of action

The cost of action is **77.7 billion USD a year** until 2050, for a total cost of **2'175.3 billion USD** until 2050.

- Reduction of deforestation
    - Cost per year: 71 billion USD
    - Cost until 2050: 1'986.9 billion USD
- Reduction of peatland degradation and conversion
    - Cost per year: 4.9 billion USD
    - Cost until 2050: 138 billion USD
- Reduction of mangrove loss
    - Cost per year: 1.79 billion USD
    - Cost until 2050: 50.2 billion USD

## b. Operational goal 3 - MANAGEMENT OF FORESTS AND OTHER ECOSYSTEMS

### Definition and impacts

The measure comprises

- **Improved forest management**
    - Involves managing both natural and forest plantations to avoid carbon emissions and to increase carbon sequestration within these forested areas.
        - Example of project: A cost overview of a new ecologically sound eucalyptus plantation in Kenya that is well managed through sustainable practices (e.g., proper tree density, spot weeding, efficient nutrient use) that reduce harm to the local environment.
- **Grassland fire management**

- It aims to avoid emissions from fires in grasslands. For example, starting early-season fires when there is less organic matter, emits fewer emissions compared to late-season fires.[10]
    - Example of project: Reducing early season grassland fires by improving fire management and control. Cost covered and revenue generated by sales of carbon credits.

#### Cost of action

The cost of action is **3.4 billion USD a year** until 2050, for a total cost of **94 billion USD** until 2050.

- Improvement of forest management
    - Cost per year: 3.4 billion USD
    - Cost until 2050: 94 billion USD
- Improvement of grassland fire management
    - Negligible costs

### c. Operational goal 3 - RESTORATION OF FORESTS AND OTHER ECOSYSTEMS

#### Definition and impacts

The measure comprises:

- **Afforestation and reforestation**
    - It enhances carbon sequestration of degraded land by planting trees to shift it from non-forest to forest cover, which is defined as 30% tree cover.
        - Example of project: Restoration from degraded marginal crop lands and un-stocked plantations to sustainably managed commercial bamboo and tree plantations. Profits from farming serve as a proxy for opportunity costs of reforestation initiatives.
- **Mangrove restoration**
    - It increases the carbon sequestration of degraded coastlines by replanting mangroves.

[10] https://onlinelibrary.wiley.com/doi/epdf/10.1111/gcb.15873

        - Example of project: mangrove replanting initiatives.
- **Peatland restoration**
    - It involves avoiding emissions by re-wetting degraded peatlands to restore the natural water flow and saturation level.[11]
        - Example of project: replanting and restoring peatlands via canals, wells and planting. Costs include community engagement to reduce intentional fires in peatlands.

#### Cost of action

The cost of action is **6.7 billion USD a year** until 2050, for a total cost of **186.8 billion USD** until 2050.

- Afforestation and reforestation
    - Cost per year: 3.3 billion USD
    - Cost until 2050: 93.6 billion USD
- Peatland restoration
    - Cost per year: 3.3 billion USD
    - Cost until 2050: 92.4 billion USD
- Mangrove restoration
    - Cost per year: 26 million USD
    - Cost until 2050: 727 million USD

### d. Operational goal 4 – AGRICULTURE, REDUCTION OF EMISSIONS

#### Definition and impacts

Reducing agricultural emissions includes reducing enteric fermentation emissions, as well as improving manure management, nutrient management, and rice cultivation.

- Reducing **enteric fermentation** emissions means livestock digestion. This could be done through changing feed and grazing strategies.
    - Example of project: an integrated farm system model was used to simulate the economic and environmental impact of changing feed management strategies to more sustainable practices to reduce enteric fermentation on dairy farms.

[11] https://onlinelibrary.wiley.com/doi/epdf/10.1111/gcb.15873

- **Managing manure** requires using technologies such as digesters to reduce emissions associated with manure.
    - Example of project: implementation of small-scale biodigesters.
- **Nutrient management** requires reducing the use of nitrogen fertiliser on farms.
    - Example of project: change in cost (compared to BAU) for the application of Urea and urease inhibitors on a single rice-cropping area, as well as controlled release of fertilizer through inhibitors.
- **Cultivating rice more sustainably** can include better water and fertiliser management.[12]
    - Comparative analysis between conventional rice farming and System of Rice Intensification (SRI) practices for smallholder farms (e.g., 0,4 hectares). Alongside intensification, practices include wider planning and intermittent watering.

### Cost of action

The cost of action is **27.6 billion USD a year** until 2050, for a total cost of **773.5 billion USD** until 2050.

- Enteric fermentation
    - Cost per year: 652 million USD
    - Cost until 2050: 18.2 billion USD
- Manure management
    - Cost per year: 20.8 billion USD
    - Cost until 2050: 584 billion USD
- Nutrient management
    - Cost per year: 4.4 billion USD
    - Cost until 2050: 122.3 billion USD
- Rice cultivation
    - Cost per year: 1.7 billion USD
    - Cost until 2050: 48.4 billion USD

[12] https://onlinelibrary.wiley.com/doi/epdf/10.1111/gcb.15873

## e. Operational goal 4 - AGRICULTURE, SEQUESTRATION OF EMISSIONS

### definition

Sequestration of emissions in agriculture means soil carbon sequestration in four areas.

- In **agroforestry**, it involves increasing the carbon sequestration of farmland by embedding trees within the area.
  - Example of project: production of organic coffee combined with trees in Laos.
- The **application of biochar**[13] from crop residues means that biochar is created through the pyrolysis of biomass. It can then be added to farmland to increase the carbon sequestration of the soils.
  - Example of project: cost of biochar at a 12 t/ha application rate on cereal farming in Kenya.
- **Enhancing soil organic carbon** in croplands is achieved by shifting from current practices to no-till management, and in **grassland** by transitioning to more sustainable management and grazing practices.[14]
  - Example of project: natural pasture rehabilitation through reseeding in Kenya. A comparison between various grass types. Main driver for grassland reduction is overgrazing

In general, for these measures the cost of action pertains:

1) for agroforestry, establishing trees on farms. Agroforestry diversifies revenue streams for farmers, providing additional revenue from fruit, timber or fuelwood.
2) for biochar, helping farmers purchase and apply biochar onto their farm;
3) for enhancing soil organic carbon in croplands and grasslands, helping farmers with technology and techniques for adopting no-till strategies on croplands and helping farmers transitioning their pastureland management strategies. More sustainable processes include rotational grazing, improved feed management and pastureland rehabilitation.

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[13] Biochar is defined as a carbon-rich material produced during pyrolysis process that is a thermochemical decomposition of biomass with a temperature about ≤700°C in the absence or limited supply of oxygen

[14] https://onlinelibrary.wiley.com/doi/epdf/10.1111/gcb.15873

### Cost of action

The cost of action is **41.8 billion USD a year** until 2050, for a total cost of **1'170.8 billion USD** until 2050.

- Agroforestry
  - Cost per year: 149 million USD
  - Cost until 2050: 4..2 billion USD
- Soil organic carbon in croplands
  - Cost per year: 27.6 billion USD
  - Cost until 2050: 772 billion USD
- Soil organic carbon in grasslands
  - Cost per year: 14.1 billion USD
  - Cost until 2050: 393.2 billion USD
- Biochar
  - Cost per year: 51 million USD
  - Cost until 2050: 1.4 billion USD

## f. Operational goal 4 - REDUCTION OF FOOD LOSS AND WASTE

### Definition and impacts

Food waste leads to overproduction as well as emissions from decomposition. Emissions can be reduced by reducing food loss and waste **across the value chain** from production to consumption. Investment in this measure goes across the value chain, from educational campaigns to limit household waste to refrigeration technologies at a farm-level to reduce food loss.

Food loss and waste is a common feature in the agricultural and food value chain. Globally, an estimated 1.3 billion tonnes of food produced for consumption ends up not being consumed or wasted each year (FAO, 2011). The food loss and waste occurs throughout the value chain – on-farm, during transport, storage and processing, at the market and at the consumer end – the proportions varying significantly across countries. An array of complex technical, social and economic drivers are perceived to be responsible for these losses. In developing countries, food loss primarily occurs at the production points due to poor harvesting methods, storage infrastructure and processing capabilities, while in developed countries the food waste is primarily at the market and household level, due to products passing their due dates.

The list of measures which can be implemented are: 1) optimization of the harvest; 2) enhancement of the product distribution; 3) refinement of product management; 4) maximization of product utilization; 5) reshape of consumer environments; 6) strengthening of food rescue; 7) better recycling of anything remaining.

The reduction of food loss and waste within the food value chain can potentially increase the availability of food. Action to reduce food loss will require different approaches for developing and developed countries. Particularly for developing countries, investments in infrastructure that foster efficient crop harvesting and improved storage and transportation facilities will potentially stem food loss (Rosegrant et al., 2015; FAO, 2019).

### Sources used

Lipinski (2020) and data about ending food loss and waste across the U.S. food system gathered by ReFed[15] has allowed to estimate the measures for reducing the Co2 emitted across the value chain, at the level of "distribution, storage and processing" and at the level of "consumption". Roe et al. (2021) has been used for the CEMP numbers.

### Methodology and calculations

From Lipinski (2020) data have been gathered on the share of tonnage per region where the majority of the loss and waste happens. These percentages have been adjusted to the income group of the countries and assigned to the different countries based on the income level group they are in. Data on Cost effective mitigation potential (CEMP) have been gathered from ReFed:

- 17.92 USD per ton of Co2 for distribution, storage and processing;
- 14.27 USD per ton of Co2 for consumption.

For each country, data have been collected from Roe et al. (2021) on the potential annual CEMP. The annual CEMP has been multiplied by the value chain process % and subsequently by the cost per ton.

[15] https://refed.org/about/who-we-are/#about-us

### Cost of action

The cost of action is **1.7 billion USD a year** until 2050, for a total cost of **48.3 billion USD**.

## g. Operational goal 1 - DIVERSIFICATION OF PROTEIN SUPPLY

### Definition and impacts

To reduce demand for crops to feed to animals, cut land and water use and reduce methane and carbon emissions, the consumption of meat and dairy needs to decrease. Rapid development of diversified sources of protein would complement the global transition to healthy diets, with all its advantages. Over the next decade, three categories of alternative proteins can be scaled up:

- plant-based meat substitutes,
- proteins from insects, algae and worms, and
- proteins grown in the laboratory or "clean meat".

These could compete with traditionally raised beef and other animals on price, offering consumers competitive alternatives to meat and dairy that will often be better for human and planetary health.[16]

According to Morach et al. (2021), about 13 million metric tons of alternative proteins were consumed globally in 2020, just 2% of the animal protein market. The scholars also expect that consumption will increase to more than seven times that size over the next decade and a half, to 97 million metric tons by 2035, when the three types of alternatives will very likely make up 11% of the overall protein market. Assuming average revenues of $3 per kilogram, this amounts to a market of approximately $290 billion.

According to the same report, moreover, for alternative proteins to reach parity with animal proteins, three characteristics need to be taken into consideration:

- **Taste**. Alternative proteins must effectively imitate the well-known flavour—and smell—of meat, seafood, dairy, and eggs.
- **Texture**. Alternatives must also look and feel the same as animal proteins. The experience of eating meat depends largely on its fibrous structure. Fish

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[16] https://www.foodandlandusecoalition.org/wp-content/uploads/2019/09/Critical-Transitions-5-Diversifying-Protein-Supply.pdf

appears flaky, cheese feels hard or stretchy. Alternative eggs and dairy must also behave like real eggs and dairy when being cooked.
- **Price**. At present, alternative proteins are usually not the bargain option, compared with animal proteins. If large groups of consumers are to repeatedly purchase alternative proteins, the cost must match or undercut that of protein from animals farmed under nonorganic conditions.

### Sources used

The source used is a report from Morach et al. (2021), called "Food for thought: the protein transformation.". The report gives a good analysis on the future of alternative proteins and lays out an investment plan for the market to reach a certain market share by 2035.

The report has been compared to several other sources: Meticulous Research[17], Barclays[18], McKinsey[19], ClimateWorks foundation[20], EY[21], Bloomberg[22].

The Morach et al. (2021) report gives an estimated market share for alternative proteins at 11% of the overall protein market, with the assumption that the growth of the alternative-protein market will have a consistent pattern of consumer acceptance, regulatory support, and technological change.

This market share is in line with the forecasts given by the cited reports and also in line with the forecasts collected by the OECD (2022)[23] in their report on the "Meat protein alternatives".

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[17] https://www.meticulousresearch.com/product/alternative-protein-market-4985

[18] https://www.cib.barclays/content/dam/barclaysmicrosites/ibpublic/documents/our-insights/InsectProtein/Leaflet%20Alt%20Meat_WEB.pdf

[19] https://www.mckinsey.com/industries/agriculture/our-insights/cultivated-meat-out-of-the-lab-into-the-frying-pan

[20] https://www.climateworks.org/wp-content/uploads/2021/11/GINAs-Protein-Diversity.pdf

[21] https://www.ey.com/en_us/food-system-reimagined/protein-reimagined-challenges-and-opportunities-in-the-alternative-meat-industry

[22] https://www.bloomberg.com/company/press/plant-based-foods-market-to-hit-162-billion-in-next-decade-projects-bloomberg-intelligence/

[23] https://www.oecd-ilibrary.org/docserver/387d30cf-en.pdf?expires=1663934447&id=id&accname=guest&checksum=7020A51921126D4F227B4F6D3486A267

### Methodology and calculations

Following Morach et al. (2021), substantial capital must be invested across the protein value chain to support the protein transformation. The extrusion[24] capacity needed for plant-based proteins, for example, will require up to 11 billion USD to reach the baseline case of 11% adoption by 2035 and a total ca. 22.8 billion USD by 2050, following the trend and reaching an adoption rate of 18% by 2050.

Almost 30 million tons of bioreactor capacity for microorganisms and animal cells will also be needed in the base case, requiring up to $30 billion in investment capital by 2035 and a total of 62 billion USD by 2050.

### Cost of action

The cost of action to reach 18% market share in 2050 is an additional **3.1 billion USD a year** until 2050, for a total cost of **86.5 billion USD**.

## h. Operational goal 1 - BEHAVIOURAL INTERVENTIONS FOR SHIFT IN DEMAND

Addressing climate change requires profound behaviour change, not only in consumer action, but also in action as members of communities and organisations, and as citizens who can influence policies.[25]

In the context of climate change, the term "behavioural interventions" refers to a class of initiatives that may, either by themselves or in conjunction with the more typical policy tools (e.g., infrastructure, incentives), achieve greater GHG reductions than have been achieved by the typical tools alone. Such initiatives apply understandings of the social, motivational, cognitive, cultural, and contextual processes underlying behaviour. They consider the effects on choice of cognitive heuristics and biases, values and norms, individual habits, political processes, challenges of policy implementation, and other individual, organizational, and social processes that are not typically considered in the design of policy interventions.[26]

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[24] During extrusion, proteins undergo thermal and mechanical stresses by heating of the barrel and shearing of the screws. As a result, protein structure is altered leading to the formation of soluble and/or insoluble aggregates

[25] https://pubmed.ncbi.nlm.nih.gov/33991862/

[26] https://www.sciencedirect.com/science/article/pii/S2542435120303263

In this exercise, two key behavioural interventions have been modelled:

- Public education campaigns – i.e., behaviour change communication and mass media campaign for healthy diets;
- Sustainable public procurement – i.e., shifting publicly procured meals (e.g., prison meals, military meals, etc.) towards sustainable and healthy diets.

### Sources used

The key source for the collection of data has been the Draft Updated Appendix 3 of the WHO Global NCD action plan 2013-2030[27], together with the assumptions used in the FiNBS project for the implementation of sustainable public procurement.

### Methodology and calculations

A cost per person per year has been calculated for the implementation of public educational campaigns. The cost per person has been applied to the populations of the income group countries and the total cost per year has been calculated until 2050.

For the sustainable public procurement, the total number of public employees, military personnel and prison inmates has been collected and a cost per person for the shift of the meals towards healthier options has been calculated.

### Cost of action

The cost of action is **1.2 billion USD a year** until 2050 (with sustainable procurement at 240 million USD/year and public educational campaigns at ca. 1 billion USD/year), for a total cost of **33.8 billion USD** until 2050.

[27] https://cdn.who.int/media/docs/default-source/ncds/mnd/2022_discussion_paper_final.pdf?sfvrsn=78343686_7

## i. Operational goal 1 - CHILD NUTRITION: SCHOOL FEEDING PROGRAMMES AND BREASTFEEDING PROGRAMMES

### Definition and impacts

More than a million infants and young children die annually from diarrhoea and related infections because they are deprived of the right milk (breastfeeding).

- **School feeding programmes** are programmes that provide meals regularly to schoolchildren. These programmes make use of various operation models (including procurement and preparation).[28] Interventions during early childhood and the school years to reduce undernutrition can maximize developmental, educational potential and educational attainment. They can also enhance lifelong health and well-being.[29]
- **Breastfeeding programmes** - For the mothers, the short duration or no breastfeeding increases breast cancer risk, and postpartum haemorrhage.[30] Breastfeeding promotion programs provide education and information about breastfeeding to women throughout pre- and post-natal care and offer counselling from health care providers or trained volunteers, and support groups for nursing mothers.[31]

### Sources used

The sources used for the modelling of these two measures are:

- Gelli et al. (2011) for calculating the cost of providing school feeding programmes to one child in low income countries;

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[28] https://www.fao.org/3/ca2773en/CA2773EN.pdf
[29] https://www.sciencedirect.com/science/article/pii/S0738059315300134
[30] https://www.researchgate.net/publication/266383145_The_need_to_invest_in_babies_-_A_global_drive_for_financial_investment_in_children's_health_and_development_through_universalizing_interventions_for_optimal_breastfeeding
[31] https://www.countyhealthrankings.org/take-action-to-improve-health/what-works-for-health/strategies/breastfeeding-promotion-programs#:~:text=Breastfeeding%20promotion%20programs%20provide%20education,support%20groups%20for%20nursing%20mothers.

- The WFP document[32], providing information on the state of school feeding programmes worldwide;
- The World Bank document[33], providing information on the cost of providing school feeding programmes in other income countries.
- Holla et al. (2013)[34], for calculating the one-time cost of setting up a breastfeeding programme;
- A WHO report[35], outlining the total cost per new-born per year for a breastfeeding programme.

## Methodology and calculations

**School-feeding programmes** - the cost of 50 USD/year for feeding a child in school (from Gelli et al., 2011) has been adjusted to 2020 dollars. Then the number of children currently receiving school meals today and the number of children supposed to receive school meals has been calculated: the difference in children is the base to which the cost of meals per children has been applied. The targets of school children receiving meals have been adjusted so that all children in school would receive meals, irrespective of income groups.

**Breastfeeding programmes** – the total cost per new-born has been applied to the projections of birth-rates over the years until 2050. The birth-rates are changing based on the income-group of the countries. The costs include hiring national and international consultants, holding workshops and consultations, developing documents, building consensus, printing and dissemination. Estimates also include multi-sectoral coordination and regular review and analysis of the progress. In general, the estimate include 1) one-time costs such as making of policies and laws; 2) recurring costs such as training in skilled counselling, and monitoring, reviewing

[32] https://www.wfp.org/publications/state-school-feeding-worldwide-2020

[33] https://openknowledge.worldbank.org/bitstream/handle/10986/28876/9781464804236.pdf?sequence=3&isAllowed=y

[34] Holla, R., Iellamo, A., Gupta, A., Smith, J., & Dadhich, J. P. (2013). The need to invest in babies-a global drive for Financial Investment in Children's health and development through Universalising interventions for optimal Breastfeeding. Delhi, India: Breastfeeding Promotion Network of India (BPNI)/International Baby Food Action Network (IBFAN)-Asia.

[35] GLOBAL BREASTFEEDING INVESTMENT CASE, 2017 | The Investment Case for Breastfeeding: Nurturing the Health and Wealth of Nations. UNICEF and WHO

and updating, providing refresher courses, media campaigns, maternity protection and monitoring of actions.

### Cost of action

The cost of action is **17.2 billion USD a year** until 2050 (with school feeding programmes at 16.5 billion USD/year and breastfeeding programmes at ca. 709 million USD/year), for a total cost of **482.6 billion USD** until 2050.

## j. Operational goal 1 - RESTRICTIONS ON MARKETING, SSB regulations, salt reduction regulations and TRANS-FAT ACIDS REGULATION

### Definition and impacts

- **Restrictions on marketing**
    - According to UNICEF (2021)[36], consistent evidence from around the world shows that the majority of food and beverage marketing, across all media and settings, is classified as unhealthy and dominated by ultra-processed foods. Both younger and older children up to the age of 18 years are exposed to large volumes of unhealthy food marketing, with negative consequences for their diets and health. Clear evidence shows that unhealthy food marketing is highly persuasive and powerful in influencing children. The Committee on the Rights of the Child and Special Rapporteurs on the Right to Food have noted that the food industry spends billions of dollars on persistent and pervasive marketing strategies to promote unhealthy food to children, and have called for such marketing to be regulated. International. resolutions and frameworks on the prevention of overweight, obesity and noncommunicable diseases support the implementation of restrictions on the marketing of unhealthy foods to children.
- **Sugar Sweetened Beverages (SSB) regulations and taxes**
    - According to several studies (e.g., Lee et al., 2020)[37], intake of sugar-sweetened beverages (SSBs) increases weight gain and is strongly linked to type 2 diabetes mellitus and cardiovascular disease (CVD).

[36] https://www.unicef.org/media/116691/file/Marketing%20restrictions.pdf
[37] https://www.ahajournals.org/doi/10.1161/CIRCULATIONAHA.119.042956

SSB taxes are a widely considered policy tool with some evidence of effectiveness in reducing consumption and are now being implemented across multiple countries.

- **Salt reduction regulations**
  - Excess salt intake can lead to high blood pressure, heart disease, and stroke.[38] Salt substitution regulations can reduce the presence of sodium products onto the market.
- **Trans-fat acid regulations**
  - Trans-fats come in both natural and artificial forms. Natural trans fats occur in meat and dairy as they form naturally when bacteria in ruminant animals' stomachs digest grass.[39] However, artificial/industrial trans fats are created during a process called hydrogenation, which is aimed preventing them from becoming rancid and keeping them solid at room temperature. They may be particularly dangerous for heart health and may pose a risk for certain cancers.[40] There are different strategies to reduce trans-fat acids in products: the labelling of an ingredient, a limit on the amount of the ingredient in food products and a ban on the production technology that creates the ingredient. The model takes in great pat the implementation of regulations limiting the amount of ingredients in food products.

## Sources used

The sources used are:

- Marketing restrictions – a report from the WHO (2021)[41] and the Draft Updated Appendix 3 of the WHO Global NCD action plan 2013-2030[42];

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[38] https://www.hsph.harvard.edu/nutritionsource/salt-and-sodium/
[39] https://anon.healthline.com/
[40] https://medlineplus.gov/ency/imagepages/19514.htm
[41] World Health Organization. (2021). Implementing policies to restrict food marketing a review of contextual factors.
[42] https://cdn.who.int/media/docs/default-source/ncds/mnd/2022_discussion_paper_final.pdf?sfvrsn=78343686_7

- TFA regulations – Bloks (2019)[43], Marklund et al. (2020)[44], and Cohen (2014)[45];
- For the SSB tax and regulations – Lee et al. (2020);
- For the salt reduction regulations – Taylor et al. (2020)

### Methodology and calculations

The cost of the four measures has been calculated by extrapolating a cost per person per year for the implementation of the regulations and it has been multiplied for the populations of the country for the years in which the regulations will be in place. The costs are mainly for devising the regulations and for checking their implementation in the markets. What is important to highlight is that for TFA regulations, there is a decrease in cost every year due to the fact that after a certain period of implementation (i.e., 5 years) from the start of the regulation, all the products in the markets are assumed to have been changed by the companies to be compliant with the regulation. Therefore, there is a decrease in cost over the years because the need to check for compliance decreases.

### Cost of action

The cost of action for implementing the four measures is **1.2 billion USD a year** until 2050, with:

- Marketing restrictions at 557 million USD a year;
- SSB at 275 million USD a year;
- Salt reduction regulations at 172 million USD a year;
- TFA regulations at ca. 64 million USD a year.

The total cost of action until 2050 is **30 billion USD**.

[43] Bloks, S. A. (2019). The Regulation of Trans Fats in Food Products in the US and the EU. Utrecht Law Review, 15(3).
[44] Marklund, M., Zheng, M., Veerman, J. L., & Wu, J. H. (2020). Estimated health benefits, costs, and cost-effectiveness of eliminating industrial trans-fatty acids in Australia A modelling study. PLoS medicine, 17(11), e1003407.
[45] Cohen, J. T. (2014). FDA's proposed ban on trans fats: How do the costs and benefits stack up?. Clinical Therapeutics, 36(3), 322-327.

### k. Operational goal 2 - CASH TRANSFERS

#### Definition and methodology

The simplest possible definition of cash transfers has been considered for this estimate, focusing on perfectly targeted interventions (with no administrative costs). The estimate is based on the average global income gap estimated by Lord ( 2023) and the share of food in the consumption basket of the poor in low income countries, approximated with evidence from Sub-Saharan Africa (World Bank 2021)[46]. The implicit assumption in this estimation is that poor people would allocate all the extra income received through the transfers to food. At the same time, by assuming a very high share of food into total income for the calculations, there is an expectation that most households would be able to cover their nutritional needs even if they were to allocate some of the transfer income to other uses.

#### Cost of action

The cost of action for implementing the measure is estimated at up to 300 billion a year. The estimate is purposely presented as a range as it is a very rough estimate of needs

### l. Operational goal 4 - AGRICULTURAL PUBLIC R&D

#### Definition and impacts

Continued investment in agricultural R&D is crucial for addressing the challenges of food security and providing healthy sustainable diets for all, today and for the future (Fears, ter Meulen, & von Braun, 2019).

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[46] World Bank (2021). Food Finance Architecture: Financing a Healthy, Equitable, and Sustainable Food System (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/879401632342154766/Food-Finance-Architecture-Financing-a-Healthy-Equitable-and-Sustainable-Food-System

Sustained growth in agricultural productivity is vital to match the growing demand for food and to ensure food security. Agricultural R&D investments represent a possible solution to the food security challenges of food availability, accessibility and utilization. According to Chichaibelu et al. (2021)[47], innovations in improved crop varieties, methods to improve soil fertility, and efficient irrigation technologies can increase agricultural productivity and address food availability. The resulting increase in agricultural productivity further contributes to increased agricultural income, improved purchasing power and reduced food prices, which when combined with innovations in post-harvest technologies can improve access to food, increase calorie consumption, increase dietary diversity, and thus enhance food accessibility and utilization. Biofortified crop varieties also offer a potential solution to increase dietary intake of essential nutrients, complementing preferred fortification and supplementation programmes (Kristkova, van Dijk, & van Meijl, 2016; UNCTAD, 2017).

Investment in agricultural R&D efficiency enhancement represents a possible solution to the challenges of food security, especially in developing countries where agricultural productivity is still well below the global average. Rosegrant et al. (2017) simulated the impact of increased investment in agricultural R&D efficiency enhancement on global hunger and malnutrition by 2030. According to the scholars and Chichaibelu et al. (2021), a higher CGIAR research efficiency is simulated to achieve a 30 percent yield gain from the additional US$ 2.96 billion per year investment. Research efficiency is achieved by **advancing breeding techniques and effective regulatory and intellectual property rights systems** that speed up the time needed to identify and disseminate new varieties.

According to the source selected, Chichaibelu et al. (2021), investment in research efficiency enhancement would lead to a reduction of a further 69.9 million undernourished persons by 2030.

[47] Chichaibelu, B. B., Bekchanov, M., von Braun, J., & Torero, M. (2021). The global cost of reaching a world without hunger: Investment costs and policy action opportunities. Food Policy, 104, 102151.

### Sources used

The documents used for the assumptions on the agricultural public R&D are Mason-D'Croz et al. (2019)[48] and Chichaibelu et al. (2021).

### Methodology and calculations

The cost of action in this case has been calculated by taking the estimates by the scholars, and applying them to the different regional income groups.

### Cost of action

The cost of action for implementing an improvement in agricultural public R&D is **2.9 billion USD a year** until 2050. The total cost of action until 2050 is **80 billion USD**.

## m. Operational goal 2 - RURAL INFRASTRUCTURE DEVELOPMENT, RURAL ROADS, IRRIGATION EXPANSION, ACCESS TO ENERGY AND ELECTRICITY

### Definition and impacts

In many countries' rural areas, the provision of reliable and effective infrastructure remains a major challenge.[49] Almost a billion people globally have limited access to road infrastructure which limits their access to safe transportation and, hence, to employment.[50] Among other factors, transport connectivity is an essential part of the enabling environment for sustained and inclusive growth. In developing countries, particularly in Africa, the vast majority of farmers does not have good access to the local, regional, or global market, and depends on subsistence farming with few advanced inputs.

**Rural roads -** Limited connectivity is a critical constraint in accessing social and administrative services, especially in rural areas where the majority of the poor live. Africa's manufacturing and other local businesses are also lagging behind in the

[48] Mason-D'Croz, D., Sulser, T. B., Wiebe, K., Rosegrant, M. W., Lowder, S. K., Nin-Pratt, A., ... & Robertson, R. D. (2019). Agricultural investments and hunger in Africa modeling potential contributions to SDG2–Zero Hunger. World development, 116, 38-53.

[49] https://www.ilo.org/asia/WCMS_099466/lang--en/index.htm

[50] https://blogs.adb.org/blog/rural-roads-are-key-helping-societys-most-vulnerable

global market, except possibly for a few textiles, agrobusiness, and mining activities (Dinh et al. 2012).

The literature is supportive of the importance of **transport connectivity**. In the short term, transport costs and travel time can be reduced by improved road conditions (Lokshin and Yemtsov 2005; Danida 2010). Over the longer term, agricultural productivity will be increased (Khandker, Bakh, and Koolwal 2009; Bell and van Dillen 2012), and firms will become more profitable with more jobs created (Mu and van de Walle 2011). Poverty will then be alleviated (Dercon, Hoddinott, and Woldehanna 2008; Khandker and Koolwal 2011).

The **Rural Access Index (RAI)** developed by Roberts, Shyam, and Rastogi (2006) is perhaps among the most important global indicators for measuring transport sector development. The RAI was originally defined by the proportion of people who have access to an all-season road within an approximate walking distance of 2 kilometers (km). The RAI has been used to estimate the how the access to roads develop across the years until 2050, and to estimate the investment costs necessary for the building of roads so that the RAI reaches certain target values for the different countries in the four income groups.

According to Chichaibelu et al. (2021), an important part of the food system is the enabling infrastructure for moving agricultural products from producers to consumers and supplying agricultural inputs to producers. Infrastructure development ensures that farmers or food producers can reach consumers at a low cost, in terms of transaction cost, food loss and waste. Accordingly, an affordable, reliable and accessible network of physical infrastructure, such as roads, rail networks and electricity, that ensures easy market access for both food producers and consumers, can boost agricultural productivity and income and in turn improve food security. Essentially, while it is vital to invest in agricultural efforts to ramp up food production, it is equally important to invest in infrastructure that ensures the quick and seamless distribution of the produced food (HLPE, 2014; Rosegrant et al., 2017; Turley & Uzsoki, 2018).

Rosegrant et al. (2017) also simulated the impact of a substantial investment in expanding and improving energy and transportation infrastructure, including road, rail and port capacity. The investment scenario in infrastructure improvements was estimated based on an empirical analysis of the impact of infrastructure development on food availability and the unit cost of infrastructure (Rosegrant et al., 2015). The scholars estimated that, in total, about US$ 10.8 billion annual incremental investment in infrastructure is needed across developing countries to enhance productivity along the food value chain and reduce marketing margins by better matching supply and demand over time.

According to this simulation, infrastructural development can help rescue 33.8 million people from hunger and 1.41 million children from being stunted.

**Irrigation expansion** - could reduce vulnerability to water stress and improve crop productivity to feed up to 300 million additional people. [51] According to Chichaibelu et al. (2021), while irrigation in Africa can potentially improve agricultural production by about 50 percent, the majority of agricultural production is rainfed. The irrigated area, estimated at 17 million hectares, only accounts for 6 percent of all of Africa's cultivated area, primarily in Egypt, Algeria, Morocco, South Africa and Sudan (AUDA-NEPAD, 2013). Thus, the potential for irrigation expansion in Africa is high, given the amount of water resources available, the high return from irrigated crop production on the continent, and the large mass of the rural poor that would benefit from enhanced productivity arising from irrigation investment (You et al., 2011).

Chichaibelu et al. (2021) estimate the additional number of individuals rescued from hunger due to expansion of small-scale irrigation expansion as the difference between the new NoU and the business as usual scenario, i.e. about 142.3 million people rescued from hunger. To estimate the annual investment required for small-scale irrigation expansion in Africa, the scholars follow You et al.'s (2011) estimate of 7.3 million hectares of potential expansion with an investment cost of US$ 37.9 billion. Based on this estimate, about US$ 3.8 billion per year would be required over a period of 10 years.

Stability of agricultural production and food security largely depends on water availability (Rosegrant et al., 2014). Climate change and population growth has caused the gap between water demand and supply to rapidly increase over time, necessitating the implementation of water supply enhancement and water demand reduction measures (Addams et al., 2009). Investment in efficient irrigation systems is seen as one important option to adapt to socio-environmental change (Mbow et al., 2019).

Rosegrant et al. (2017) have estimated the impact of increased investment in water use efficiency or efficient irrigation systems that affect agricultural production

[51] https://www.pnas.org/doi/10.1073/pnas.2017796117

through changes in water availability. To estimate the additional investment cost for water use efficency, basin efficiency is assumed to increase by about 15 percentage points by 2030, increasing agricultural output while conserving water.

The water use efficiency gained through adopting a sprinkler technology on the entire 412 million hectares of irrigated land in developing countries would cost about US$ 4.59 billion per year, which is 30 percent more than expanding irrigation with conventional technology. The results indicate that irrigation efficiency improvement can help reduce a larger number of the undernourished, about 18.6 million persons by 2030.

**Access to internet and electricity** - can alleviate poverty of people living in rural areas by improving the access to employment opportunities, financial accessibility, medical accessibility, education accessibility, and personal development capabilities.[52]

### Sources used

- **Rural roads**: a World Bank Policy Research[53] working paper and a document[54] explaining the necessary costs for maintenance of roads in the USA have been used to estimate the cost of operation and maintenance for rural (gravel) roads and paved roads across the world; information on the rural access index has been collected from the World Bank Data Catalog[55].
- **Access to electricity and internet** – for the access to electricity and the estimates of people coming online every year, the Growing Better report has been used; for the access to electricity, the World Bank has been used for the number of people without access to electricity and a real-life cost of a project, documented in an online report[56].

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52 https://www.mdpi.com/2071-1050/14/6/3488/pdf
53 Mikou, M., Rozenberg, J., Koks, E. E., Fox, C. J. E., & Peralta Quiros, T. (2019). Assessing rural accessibility and rural roads investment needs using open source data. World Bank Policy Research Working Paper, (8746).
54 https://connect.psats.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=db37f9d9-87e2-4bc0-85be-55723864456a#:~:text=This%20costs%20an%20average%20of,a%2025%20year%20life%20cycle.
55 https://datacatalog.worldbank.org/search/dataset/0038250
56 https://www.resources.org/archives/lighting-up-the-last-mile-the-benefits-and-costs-of-rural-electrification/

- **Irrigation expansion** – the Policy Research Working Paper of the World Bank from Palazzo et al. (2019)[57] has provided the key data and assumptions used for the calculations of the investment needed for irrigation expansion.

### Methodology and calculations

- For the investments in rural roads:
    - the RAI data have been collected for all the countries;
    - it has been calculated how many people are reached for each km of rural road built in the country;
    - based on these information, RAI targets (for 2050) have been set for all countries and, therefore, based on the current KM of roads in the countries and the people within the radius of the roads, also the total number of Km of roads to be built has been calculated;
    - assumptions have been made on the cost of building an additional km of road, based on the current status of the country;
    - data on cost per km for building a gravel and paved road have been collected and they have been applied to the different countries based on the starting level of each country.
    - The costs have been divided into capital costs (for new roads) and operational maintenance costs (for already built roads).
- Access to electricity and internet
    - The number of people without internet has been multiplied by a penetration target % to reach by 2050 and the number of people to come online until 2050 has been calculated. This number has been multiplied by the cost per person per year (capex and opex) to bring these people online.
    - The number of people without access to electricity has been transformed into number of households without electricity, and it has been multiplied by the last-mile cost of giving access to electricity to one household.
- Irrigation expansion
    - The additional costs for irrigation expansion are:
        - New irrigation infrastructure;

[57] Palazzo, A., Valin, H. J. P., Batka, M., & Havlík, P. (2019). Investment needs for irrigation infrastructure along different socioeconomic pathways. World Bank Policy Research Working Paper, (8744).

    - Updating current irrigation; and
    - Improving existing systems.
  - The source also listed depreciation as a cost, but that has not been taken as a cost of action for the calculations here.
  - In this case, therefore, 34% out of the total cost has been used as a needed investment for the irrigation expansion.

#### Cost of action

The cost of action for implementing the three measures **until 2050 is ca. 661.3 billion USD**. The cost of action per year by measure is:

- Improvement of rural roads: **ca. 11.3 billion USD a year**, with
- Access to internet and electricity is ca. **6.4 billion USD a year**, with around 47% of the investment needed in low income countries and 51% needed in lower middle income countries.
- The cost of irrigation expansion is ca. **5.9 billion USD a year**, with around 20% of the cost in low income countries, 24% in lower middle income countries and 46% in upper middle countries.

### n. Operational goal 2 - FINANCING AND TRAINING OF SMALLHOLDER FARMERS

#### Definition and impacts

The majority of farms worldwide are managed by smallholders who play a key role in environmental sustainability objectives, including climate change mitigation, by protecting biodiversity in agriculture.[58] But traditionally, smallholders in agriculture have been starved of capital.[59] They need **financing and training** to engage in more sustainable farming practices.

According to Chichaibelu et al. (2021), improving access to knowledge and new technologies via timely dissemination of new and useful information is an important tool in the fight against hunger and undernourishment. For instance, in Sub-Saharan Africa where there is a relatively high prevalence of undernourishment, it is

[58] https://unctad.org/press-material/business-potential-smallholder-farmers-must-be-unleashed-sustainable-development

[59] https://academic.oup.com/book/25436/chapter-abstract/192599397?redirectedFrom=fulltext

estimated that agricultural productivity can be improved in two or three folds through better use of existing knowledge and technology (Foresight, 2011).

Therefore, agricultural training of smallholder farmers is a useful tool for helping farmers increase their productivity (UN, 2013). Training of farmers can help with the dissemination of knowledge and is therefore essential and vital in the context of food security. Agricultural training is also called "agricultural extension services", where the term 'extension' means advisory and other services that help rural families to make the best possible use of the productive resources at their disposal (Muyanga and Jayne, 2008)[60].

**Improved finance for smallholder farmers** is supposed to help smallholder farmers to access the information, tools and technologies that will help build their resilience to climate change. Financing can be short-term, i.e. is less than one year, and typically for trade finance, inputs or harvest costs; or financing can be long-term, i.e. more than one year, and typically for rehabilitation or equipment purchases. Extension services, if properly designed and implemented, provide farmers with important information that aid the farmers to optimise the use of their resources and ultimately increase crop productivity.

### Sources used

For the training costs, the sources used are: Muyanga and Jayne (2008) for the cost of training and Lowder et al. (2016)[61] for the number of farms worldwide.

For the financing costs, the sources used are: Carroll et al. (2012)[62].

### Methodology and calculations

Training of farmers: for low- and low-middle income countries a lower cost per training is assumed (averaging public and private training costs in SSA as proxy), with a higher number of trainings per farmer. For upper-middle income- and high-income

[60] Milu Muyanga & T.S. Jayne (2008) Private Agricultural Extension System in Kenya: Practice and Policy Lessons, The Journal of Agricultural Education and Extension, 14:2, 111-124, DOI: 10.1080/13892240802019063

[61] Lowder, S. K., Skoet, J., & Raney, T. (2016). The number, size, and distribution of farms, smallholder farms, and family farms worldwide. World Development, 87, 16-29.

[62] Carroll, T., Stern, A., Zook, D., Funes, R., Rastegar, A., & Lien, Y. (2012). Catalyzing smallholder agricultural finance. Dalberg Global Development Advisors, 48.

countries higher average seminar costs are used as proxy. For farms above 2 hectares, a separate, higher, cost is assumed as larger farms entail more complexity, various crops and/or more advanced techniques Cost per farmer trained (per region) is multiplied by the number of farmers trained (per region) per time period. Additionally, the costs of training all >2ha farmers globally by 2050 is calculated via the number of farms >2 ha multiplied by the cost per training program.

Financing of farmers: cost is calculated by looking at expected default rate of loans, assuming higher default rates on long term loans (10%) compared to short term loans (5%). Overall, a decrease in farms is assumed due to an increase in farm size and thus a decrease in number of smallholder and total farmers. Number of smallholder farmers is assumed to decrease faster in low- and middle-income countries, as the economy develops. Similar to farmer training costings. Cost is calculated as the number of farmers requiring short and/or long-term loan (# farmers) multiplied by the amount loaned (USD) and by expected default rate (%), giving the costs of short term loans and long term loans.

### Cost of action

The cost of action per year is **7.4 billion USD**, with 1.3 billion USD for training of farmers and 6.1 for financing.

The total cumulative **cost until 2050 is 206.2 billion USD**.

## 5. Further research

Further research can focus on understanding the impacts of each measure on selected environmental, social and health indicators (e.g., 1 USD spent in a specific measure has a reduction of people in hunger of x amount).

In general, also, further research could focus on how the combination of the different measures has a different outcome on the impacts.

## 6. References

References are listed as footnotes in each page.