FULFILL

Fundamental decarbonisation
through sufficiency by lifestyle changes

FULFILL: Assessment of Social Impacts

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Fundamental decarbonisation through sufficiency by lifestyle changes

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Project Partners

No	Participant name	Short Name	Country code	Partners' logos
1	**Fraunhofer Institute for Systems and Innovation Research ISI**	FH ISI	DE	
2	**Wuppertal Institut für Klima, Umwelt, Energie GGMBH**	WI	DE	
3	**Accademia Europea di Bolzano**	EURAC	IT	
4	**Notre Europe - Institut Jacques Delors**	JDI	FR	
5	**Association négaWatt**	NW	FR	
6	**Politecnico di Milano**	POLIMI	IT	
7	**International Network for Sustainable Energy-Europe**	INFORSE	DK	
8	**Zala Briviba Biedriba SA**	ZB	LV	

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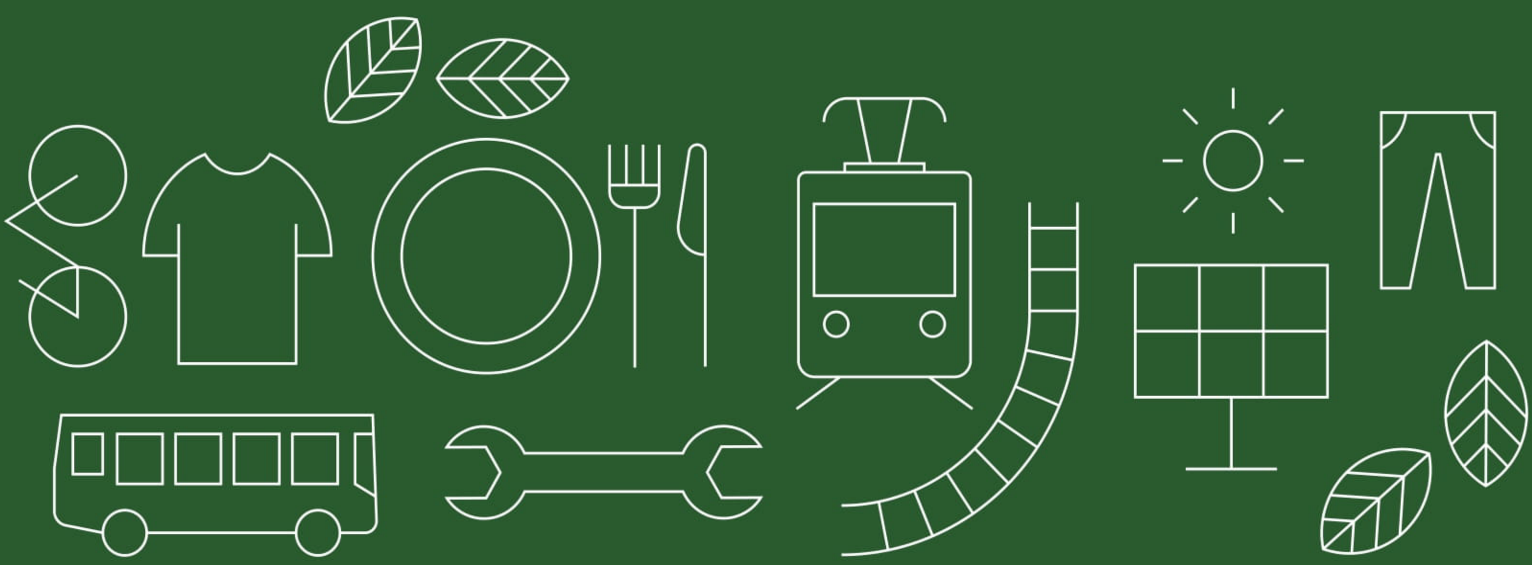

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List of Abbreviations

ACM	All- cause Mortality
AM	Active mobility
b	Background knowledge
BAU	Business as usual
BE	Bayesian Epistemology
BMR	Baseline Mortality Rate
BR	Bayesian Reasoning
BT	Bayes Theorem
CHD	Cardiovascular heart disease
cr	Credence
CVD	Cardiovascular Disease
DALY	Disease Adjusted Life Years
DK	Denmark
e/E	Evidence
EEA	European Environmental Agency
EU	European Union
FR	France
G-RA	Generic Risk Assessment
GDP	Gross Domestic Product
GE	Germany
GHG	Greenhouse Gas
H	Hypothesis
HSM	Hypotheses Sufficiency Measure
IBE	Inference to the best explanation
IT	Italy
JTM	Just Transition Mechanism
LE	Life Expectancy
LV	Latvia
LYS	Life Years Saved
MARIO	Multi-Regional Analysis of Regions through Input-Output
MET	Metabolic Equivalent of Task
MI	myocardial infarction
MS	Microsoft
NDC	National Determined Contribution
NO	Nitrogen Oxide
PA	Physical Activity
PM	Particular Matter
Pr	Probability
RA	risk Assessment
RD	Reduced deaths
RR	Relative Risk

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S-RA	Specific Risk Assessment
SDG	Sustainable Development Goal
SIA	Social Impact Assessment
SM	Sufficiency Measure
SME	Small and Medium Enterprises
SSH	Social Sciences and Humanities
SUV	Sport Utility Vehicle
T	Task
ToC	Theory of Change
WHO	World Health Organization
WTR	Work Time Reduction

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Summary

The following report is dedicated to **T6.3 on the "Assessment of social impacts"** (FULFILL proposal) with the aim of providing insights on the potential societal co-benefits and negative side-effects of sufficiency lifestyles. The scope of the assessment is mostly limited to a semi-quantitative investigation of these impacts based on the large-scale implementation of the eight so-called sufficiency scenario assumptions explicated in T5.3 (and further used for modelling in T6.1, T6.2 and T6.4). We look at the potential effects in relation to overarching sustainability goals in Europe in the areas of 'Health', 'Poverty Mitigation', Gender Equality', 'Time-Use' and 'Just Transition'. A benefit is achieved by a positive contribution to any of these overarching goals, whereas a negative side-effect can either slow the progress (barrier) towards one goal or constitute a negative trade-off between these areas (target conflict). The assessment is conducted in two parts.

Part I (chapters 3 and 4) investigates **benefits from the eight sufficiency measures** (SMs) studied in D5.3 **towards positive 'Health' outcomes or contributions to 'Poverty Mitigation'**. This is achieved by adopting a probabilistic and causal view with the help of Theories-of-Change (ToC) and Bayesian Reasoning (BR). We tested for each sufficiency scenario assumption, (i) whether and how desired impacts could be achieved, if the corresponding causal hypothesis are plausible (ii) and (iii) which type of effects, or ideal indicators, we would expect from an evaluation. We apply the language of causal set-theory for this purpose. A sufficiency lifestyle change can either be a sufficient, necessary, partially sufficient or partially necessary cause for a desired societal effect[1]. **The main insights from this step – in which we are either extremely or very confident in – can be summarized as follows**:

- The sharing of products (SM-1) and the sharing of space (SM-3) are either or both partially sufficient for poverty reduction in Europe IF (truth-condition) they reduce the monthly expenditures for housing (including capital costs) among relevant vulnerable groups.
- An increase in cycling activity (SM-8) is partially sufficient for a reduction of morbidity AND/OR mortality in Europe IF it increases physical activity and sufficient for such a reduction IF it decreases OR replaces fossil-fuelled mobility.
- Eating less meat and dairy (SM-5) is partially sufficient for a reduction of morbidity AND/OR mortality in Europe IF it leads to a more balanced diet. This is additionally conditioned on the requirement that such a diet entails enough dietary choices to achieve this balance.
- Reducing the size of cars in the market (SM-2) is sufficient for a reduction of morbidity AND/OR mortality in Europe IF it decreases tailpipe and non-exhaust air emissions by cars.
- Car-Pooling (SM-6) is partially sufficient for poverty reduction in Europe IF it reduces transport-related expenditures for vulnerable groups AND sufficient for a reduction of morbidity AND/OR mortality in Europe IF it decreases OR replaces fossil-fuelled mobility.
- An increase in cycling activity (SM-8) is partially sufficient for poverty reduction in Europe IF it reduces transport-related expenditures for vulnerable groups.
- Work-Time reductions (SM-10) are partially sufficient for poverty reduction in Europe IF it reduces stress AND/OR long working hours for vulnerable groups. This is additionally conditioned on the requirement that these persons have sufficient work-time control and recovery-time from long shifts.

A further outcome of Part I is the estimation of potential quantitative benefits in the area of 'Health'. Three such outcome pathways were investigated on the basis of publicly available data and methodologies as well as the predicted changes from T5.3. The following statements summarize these results and should be understood as an 'educated guess' rather than a fully-scaled empirical model of potential future changes:

[1] This is further discussed in section 2.2 and the use of 'sufficient' or 'sufficiently' should not be confused with 'sufficiency' in regard to lifestyles and policies. The main difference between sufficient and necessary causes is that sufficient causes do not have to be present, but always bring about the anticipated effect, whereas necessary causes are always present, but do not 'necessarily' lead to effects.

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- The sufficiency assumption of 'Cycling' leads to direct 'Health' benefits. We estimate that the physical activity increases by 1.4 'Metabolic Equivalent of Task' hours per week (MET.h / week) and person if the additional cycling activity is spread out evenly among Europeans. If, on the other hand, only people that already cycle increase their cycling activity accordingly, there is an overall increase of 4.9 MET.h/(week*person). We estimate that this range results in a **relative** risk reduction for All-Cause-Mortality of 2% (entire population spread) to 8% (only cyclists' cycle more).
- The sufficiency assumption of 'Car-Sizing' in combination with 'Cycling' will likely lead to a reduction in air pollutants. We estimate that the direct **exhaust** emissions of particular matter with 2.5 micrometre in diameter (PM 2.5) will be reduced by 89% on average in Europe. As these emissions are negatively associated with All-Cause-Mortality, it is thus expected that negative 'Health' outcomes will be mitigated as a result. However, this effect could not be calculated on the basis of the available data.
- The sufficiency assumption of 'Eating Less Meat & Dairy' is estimated to reduce the daily intake of animal protein by 19 grams per day and person for the average European citizen (a reduction of 52%). Our educated guess is that this reduction is equivalent to a reduction of the All-Cause-Mortality risk of 15 to 16% if an average European adopted this average diet today.

Part II of the report at hand (chapter 5) focuses on **potential risks to the five dimensions investigated**. Each of these risks was given a score between 0 (no risk) and 6 (policy should not be implemented) based on the likelihood of occurrence and size of the effect (with the highest risk of 6 not being attributed in any category). This risk assessment came to the following conclusions for each of the eight sufficiency assumptions.

- **'Product-Sharing'** has a very low probability of negatively affecting the area of 'Health' due to a slightly elevated risk for disease transmission. The more severe risk stems from a small likelihood of non-participation by vulnerable groups such as low-income households ('Poverty Mitigation') as well as women and parents ('Gender Equality'). This is due to the current services and tools for product-sharing not addressing the needs and preferences of these groups as well as their economic constraints. Similarly, we assessed that there is a high likelihood for time-constraints (severe violation of 'Time-Use'), since the available infrastructures and time scheduling tools might not suffice to avoid that (especially for the washing machine case assumed for this SM). Another risk is associated with 'Just-Transition' (severe violation), as such a policy has a high likelihood of affecting the demand for services and goods by local small- and medium enterprises with at least some of these SMEs being affected negatively.
- **'Car-Sizing'** is unlikely to lead to negative impacts in the areas of 'Health', 'Just Transition' and 'Time-Use'. There is some chance for small violations to 'Poverty Mitigation' and 'Gender Equality' in cases in which the needs (e.g. for families) and budgetary constraints of participants are neglected.
- **'Space-Sharing'** is unlikely to lead to negative impacts in the areas of 'Gender Equality' and 'Just Transition'. We also think that the likelihood of additional time-demand ('Time-Use') is low and that risks here are neglectable. The size and likelihood for diseases transmission is higher, but not overall high, compared to both these categories and compared to SM-1 on 'Product-Sharing'. This constitutes a moderate violation of 'Health'. The most severe risk is associated with the high likelihood of non-participation by low-income households, since they are the group that are also the most likely to not have the financial resources for the initial investment (severe violation of 'Poverty Mitigation').
- **'Eating Less Meat & Dairy'** is only weakly associated with negative impacts in the area of 'Time-Use' as a result of additional time-demand for meal preparation (during adaptation) and there is only a small chance of negative 'Health' effects due to malnutrition. However, it is likely that the currently low acceptance, social divide or health concerns of reduced meat consumption among some groups lead to lower implementation rates, which in turn can constitute the violation of goals for 'Gender Equality' and 'Poverty Mitigation' (less severe) as well as 'Health' (more severe). Moreover, the implementation of the measure on a large-scale in Europe is probably negatively affecting demand as well as the growth of jobs and the economy in the future. While all of these three risks are considered potential severe violations of 'Just Transition', the dimension of 'Poverty Mitigation' might be affected by this as well, especially concerning the low-skilled workforce.
- **'Car-Pooling'** is unlikely to affect 'Just Transition' negatively and there is only a weak relationship between the risk of non-participation of low-income groups because of a fear of loss of autonomy

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regarding 'Poverty Mitigation'. We further find that there is some likelihood that such a policy, once implemented for commuting, bears the risk of unwanted professional relationships for women in the workplace. It is very likely though that the mere necessity of organizing commuting via Car-Pooling (or using it for other mobility purposes) will affect how and when time can be spent by participants (severe violation of 'Time-Use'). The area of 'Health' is another, more severely, affected dimension, as the likelihood for disease transmission among passengers is high if they spent several hours per week in the same car. There is also a target conflict for some portion of the group for which the amount of some harmful pollutants increases as a consequence of policy implementation (compared to an overall expected decrease of these pollutants from lower driving performance).

- **'Cycling'** is unlikely to lead to negative impacts for 'Just Transition'. The measure has also only a small probability of reducing access to relevant infrastructures for vulnerable groups, which in turn might constitute less severe violations in the areas of 'Health' (the only risk here) and 'Poverty Mitigation', with the latter also being strongly associated with the risk of non-participation overall. The most risks are associated with the dimension of 'Gender Equality'. There is a high likelihood that a large-scale implementation of SM-8 impedes care-work, and some probability that it affects negatively the job opportunities of women, decreases social participation and leads to 'othering'. All of which depend on the assumption that car-travel and similar modes of transport enable 'Gender Equality' at the moment. This is why we also consider this measure to have a high likelihood of leading to longer commuting overall and additional time-demand for daily chores such as grocery shopping (severe violation of 'Time-Use').
- **'Flying Less'** affects all five areas of social risks but to different degrees. We find that, regarding 'Health', there is a small likelihood that it negatively affects the international cooperation in the area of medicine. We also find it likely that at least some groups will not participate, if other modes of long-distance trave are perceived to be more stressful for families with small kids (less severe violation of 'Gender Equality') or just more time-consuming (more severe violation of 'Time-Use'). Apart from a small likelihood of social exclusion for low-income households if the policy is price-driven ('Poverty Mitigation'), all of the remaining identified risk relate to potential economic effects of the policy. The implementation of the measure on a large-scale in Europe is probably leading to competitive disadvantages for SMEs in the tourism sector (less severe violation of 'Just Transition'), but also probably negatively correlated with overall economic growth (sever violation of 'Just Transition') and the growth of jobs (severe violation of 'Just Transition' and 'Poverty Mitigation').
- **'Working Less'** is unlikely to affect 'Time-Use' in a negative way in general, but there is a high likelihood that some time-savings are compensated by an increase of hidden or devalued work for women (severe violation of 'Gender Equality'). 'Poverty Mitigation' is likely to be negatively affected (severe violation), if such a policy is not accompanied by schemes for wage-compensation and SMEs in Europe could be confronted with competitive disadvantages compared to companies within or outside of Europe that do not implement such a policy (sever violation of 'Just Transition'). The area of 'Health' is the most affected social dimension. We think it very likely that a large-scale implementation of the policy would further strain the availability of medical staff in European countries and that many persons in the targeted groups could not participate because of a lack of worktime-control in general.

Both parts of the social impact assessment are discussed methodologically (chapter 2) and discussed in terms of limitations (chapter 6).
Our overall conclusion is that the societal benefits of each of these sufficiency lifestyle changes outweigh the potential negative trade-offs. However, there are many risks that constitute barriers that can and should be mitigated or even fully avoided. The main insight is that **sufficiency lifestyles, as currently practiced or adopted, often neglect the needs and preferences of vulnerable groups in society** (e.g. low-income households or women with families) and **that system-wide conditions for sufficiency are necessary to maximise their co-benefits**.

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1. Introduction and Overview

1.1. Purpose of this Document

The purpose of this document is to report on potential social benefits and risks from sufficiency lifestyles surmised in the FULFILL proposal as "up-scaled sufficiency action[s] on the European level" (T6.3 in FULLFILL). These lifestyles are understood to be future consequences of the eight sufficiency assumptions that were explicated, and further investigated, in antecedent and simultaneous tasks. Deliverable D5.3 from Task T5.3 in particular provides the necessary background information and parameters for these assumptions, which the report at hand operationalizes as sufficiency measures or SMs.

1.2. Project Summary

The project FULFILL takes up the concept of sufficiency to study the contribution of lifestyle changes and citizen engagement in decarbonising Europe and fulfilling the goals of the Paris Agreement. FULFILL understands the sufficiency principle as creating the social, infrastructural, and regulatory conditions for changing individual and collective lifestyles in a way that reduces energy demand and greenhouse gas emissions to an extent that they are within planetary boundaries, and simultaneously contributes to societal well-being. The choice of the sufficiency principle is justified by the increasing discussion around it underlining it as a potentially powerful opportunity to actually achieve progress in climate change mitigation. Furthermore, it enables us to go be-yond strategies that focus on single behaviours or certain domains and instead to look into life-styles in the socio-technical transition as a whole. The critical and systemic application of the sufficiency principle to lifestyle changes and the assessment of its potential contributions to decarbonisation as well as its further intended or unintended consequences are therefore at the heart of this project. The sufficiency principle and sufficiency lifestyles lie at the heart of FULFILL, and thus constitute the guiding principle of all tasks and deliverables.

1.3. Project Aim and Objectives

To achieve this overarching project aim, FULFILL has the following objectives:

- Characterise the concept of lifestyle change based on the current literature and extend this characterisation by combining it with the sufficiency concept.
- Develop a measurable and quantifiable definition of sufficiency to make it applicable as a concept to study lifestyle changes in relation to decarbonisation strategies.
- Generate a multidisciplinary systemic research approach that integrates micro-, meso-, and macro-level perspectives on lifestyle changes building on latest achievements from research into social science and humanities (SSH), i.e. psychological, sociological, economic, and political sciences, for the empirical work as well as Prospective Studies, i.e. techno-economic energy and climate research.
- Study lifestyle change mechanisms empirically through SSH research methods on the micro- (individual, household) and the meso-level (community, municipal):
    - achieve an in-depth analysis of existing and potential sufficiency lifestyles, their intended and unintended consequences (incl. rebound and spillover effects), enablers and barriers (incl. incentives and existing structures) as well as impacts (incl. on health and gender) on the micro level across diverse cultural, political, and economic conditions in Europe and in comparison to India as a country with a wide range of economic conditions and lifestyles, an history which encompasses simple-living movements, and a large potential growth of emissions.
    - assess the dynamics of lifestyle change mechanisms towards sufficiency on the meso-level by looking into current activities of municipalities, selected intentional communities and initiatives as well as analysing their level of success and persisting limitations in contributing to decarbonisation.

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- Integrate the findings from the micro and meso-level into a macro, i.e. national and European, level assessment of the systemic implications of sufficiency lifestyles and explore potential pathways for the further diffusion of promising sufficiency lifestyles.
- **Implement a qualitative and quantitative assessment of the systemic impact of sufficiency lifestyles**[2] which in addition to a contribution to decarbonisation and economic impacts includes the analysis of further intended and unintended consequences (incl. rebound and spillover effects), enablers and barriers (incl. incentives and existing structures) as well as impacts (incl. on health and gender).
- Combine the research findings with citizen science activities to develop sound and valid policy recommendations contributing to the development of promising pathways towards lifestyle
- Generate findings that are relevant to the preparation of countries' and the EU's next NDCs and NDC updates to be submitted in 2025 and validate and disseminate these findings to the relevant stakeholders and institutions for exploitation.
- Consider the relevance and potential impacts of sufficiency lifestyles beyond the EU.

1.4. Scope of Assessment in T6.3

Deliverable 6.3 has the title "**Qualitative evaluation of social impacts of up-scaled sufficiency action at the European level**". It aims to assess the impacts from up-scaled lifestyle changes in a semi-quantitative manner.

This assessment comprises of a qualitative assessment of the societal impacts of the sufficiency scenario assumptions, called Sufficiency Measures (SMs) in the report at hand, that were explicated and modelled throughout T5.3, T6.1, and T6.2. These SMs represent a large-scale implementation of sufficiency policies, and sufficiency lifestyle changes, on a European level between a base year and 2050 with the underlying datasets from deliverables D5.3 (Gabert et al., 2024) and D6.2 (Golinucci et al., 2024) being our main frame of reference in the report at hand (and thus only referred to as D5.3 and D6.2 from now on).

The original proposal for T6.3 suggested the use of macro-economic input-output relationships from the database PSILCA[3] as well as the adaption of modelling approaches from projects like COMBI[4] to achieve the desired research output. This has been shown, reasoned, and discussed to be not feasible in light of data and methodological constraints as well as an overall low overlap between indicators from PSILCA with the five social dimensions investigated in this report.

Instead, we assess the benefits and potential negative impacts in the dimensions of 'Health' and 'Poverty Mitigation' via credences[5] and scoring, whereas the quantification of potential benefits is limited to the effects of two such SMs on 'All-Cause-Mortality' and one outcome pathway that is limited to the reduction of direct air pollutant emissions.

Further generic risks are assessed, and scored, in these two dimensions as well as the additional dimensions of 'Gender Equality', 'Time-Use' and 'Just-Transition'. Such an assessment entails the integration of results on 'economic growth' and 'worker transition' from T6.2 (macro-economic effects of sufficiency).

The temporality of all results assumes, in line with D5.3, that the participation in sufficiency lifestyles increases until 2050 in decade or half-decade steps. The spatial frame of reference is the five FULFILL countries (Denmark, France, Germany, Italy, Latvia) and the European Union. This report therefore not assesses spillover effects on a global scale. However, we briefly discuss in the 'Synthesis' in chapter 6 if and to what extent similar benefits would be expected in countries outside of the EU if similar measures would be implemented there.

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[2] The report at hand is part of task 6 on "Impacts from up-scaled lifestyles changes" (FULFILL proposal).

[3] https://psilca.net/

[4] https://wupperinst.org/en/p/wi/p/s/pd/524

[5] Credence refers to the level of belief or confidence that someone assigns to the truth of a particular statement or proposition.

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1.5. Structure of Report

The report at hand is divided into the following chapters.

- **Chapter 1 (Scope and Structure of the Report)** provides an overview of the objectives and approach selected for the Social Impact Assessment (SIA) in FULFILL.
- **Chapter 2 (Methodology)** describes the approach to achieve the objectives of T6.3 in more detail. It includes a discussion of the methods applied both for the qualitative and quantitative assessment of the sufficiency measures (SM's) provided, and quantified, in D5.3 and D6.2.
- **Chapter 3 (Impact Assessment for 'Health')** shows the results of our assessments of benefits in the 'Health' dimension. It consists of three parts: (a) the identification and plausibility assessment of potential benefits along causal pathways, (b) the identification of potential ideal indicators and specific risks, and (c) the quantification of three of these indicators based on previous findings and results from D5.3.
- **Chapter 4 (Impacts Assessment for 'Poverty Mitigation')** repeats this process (causal pathways and potential indicators/risks) for the dimension of 'Poverty Mitigation' but does not provide quantified effects due to lack of data.
- **Chapter 5 (Risk Assessment)** assesses and scores potential risks (barriers and target conflicts) in all five societal dimensions with the help of decision-trees ('Health', 'Poverty Mitigation', 'Gender Equality', 'Time-Use', 'Just Transition'). It also includes the scoring of the specific risks identified in chapters 3 and 4 and discusses the results from D6.2 in the context of 'Poverty Mitigation' and 'Just Transition'.
- **Chapter 6 (Synthesis)** summarizes the results and provides key findings for all areas of interest from the original proposal in the Grant Agreement. It also discusses limitations of the chosen approaches and investigates future areas of research.

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2. Methodology

2.1. Approach to Assessment

The goal of this report is to identify, corroborate, qualify and where possible quantify the multiple impacts of energy sufficiency and sustainable lifestyles in Europe. It intends to show how and to what extent such behavioural or consumptive changes lead to additional societal benefits in the areas of health (**'Health'**) and mitigating energy poverty (**'Poverty Mitigation'**). It also highlights the potential risks of sufficiency associated with these dimensions as well as with **'Gender-Equality'**, **'Time-Use'** and **'Just Transition'**. This **Social Impact Assessment** (SIA) is embedded into and informed by other tasks in the project. The results of D5.3 (Report on the consolidation of quantified sufficiency hypotheses in decarbonisation strategies), D6.1 (Indicators and factors for the integration of energy sufficiency in models) and D6.2 (Assessment of climate, environmental and economic impacts) provide some of the necessary data and relevant information for this assessment.

Social Impact Assessment (SIA)

We start our SIA by describing eight sufficiency measures (SMs), as detailed in Table 1. This includes findings from previous studies and relevant literature to provide a comprehensive background. These measures are understood as truth-conditions for a logic model towards desired societal benefits and unintended societal risks (see next section).

Table 1: Numbering, Long-names, and Short-names of Sufficiency Measures (SM's) (used throughout this report)

No [a]	Long-Name Sufficiency Measure	Abbreviation	Data Available
SM-1	Products: Sharing products	Product-Sharing	yes
SM-2	Products: Moderate product sizing (cars only)	Car-Sizing	yes
SM-3	Shared Living Space [b]	Space-Sharing [a]	yes
SM-5	Eating less meat & dairy	Eating Less Meat & Dairy	yes
SM-6	Mobility: Carpooling	Car-Pooling	yes
SM-8	Mobility: Cycling	Cycling	yes
SM-9	Mobility: Flying less	Flying-Less	yes
SM-10	Cross-Sectional: Working less	Working-Less	no

[a] The original list contained ten measures that needed to be redacted to eight measures over the course of the project. We retained the original numbering throughout the assessment.

[b] The original list of SM's included the measures co-housing and collective housing. The quantified SM-3 is now limited to shared living space.

Source: own compilation based on T5.3 (January 2024)

The SIA is conducted in six steps (see Figure 1).

- Step 1 is the integration of these measures as truth-conditions and Activities into two linear Theories-of-Change (ToC) for each of the overarching goals 'Health' and 'Poverty Mitigation'. This requires (i) a clear definition of each goal ('Impact' in a ToC) and (ii) tangible targets for society ('Long-term Outcomes' in the ToC). It is thus assumed that all eight SMs are successfully implemented in the future in Europe.
- Step 2 translates these ToCs into testable hypotheses in form of propositional logic and assesses the credence of these propositions with the help of literature-supported Bayesian Reasoning.

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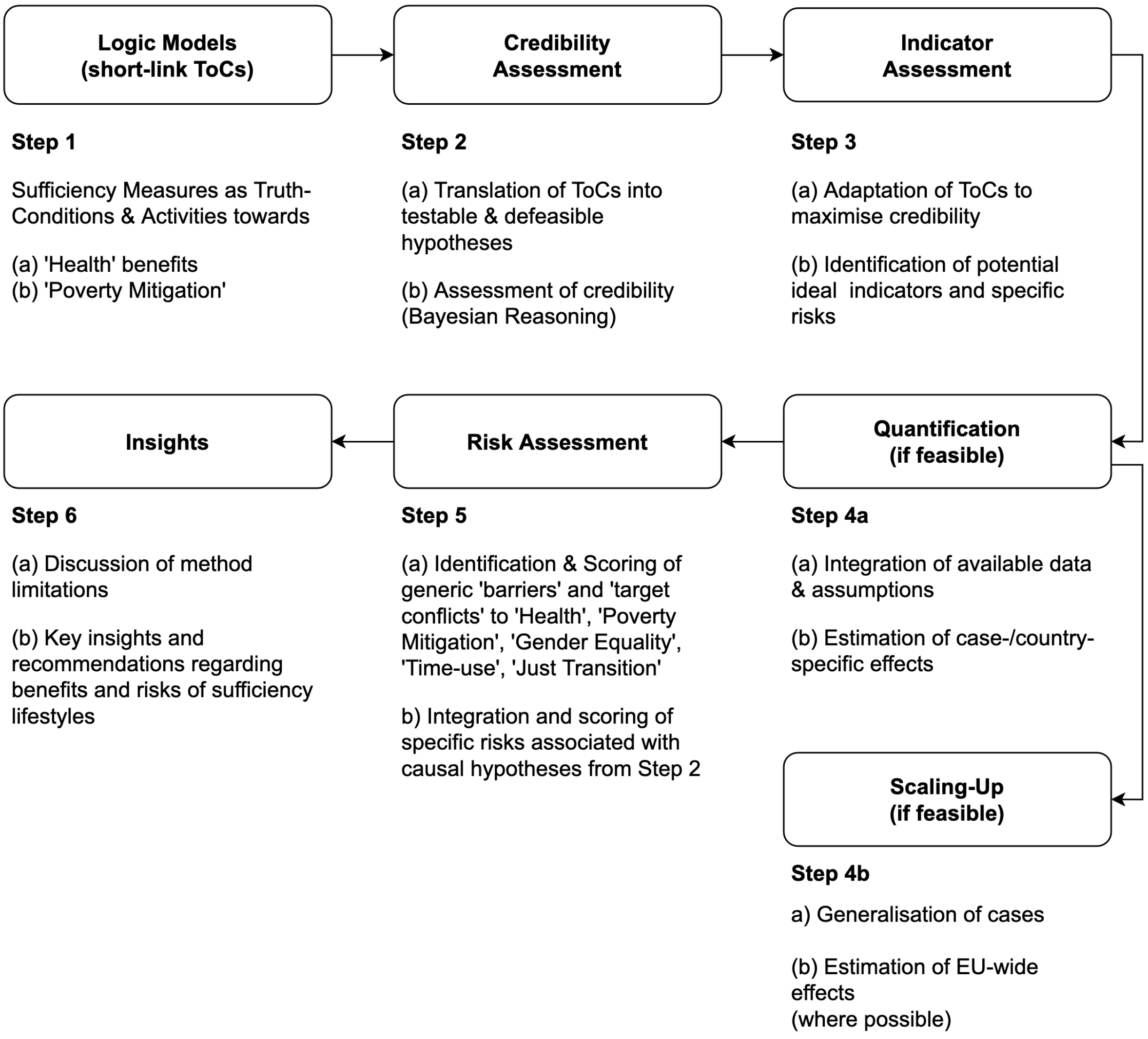
- Step 3 adapts the initial ToCs to increase their credibility and identifies as first set of potential (best-needed) indicators. It also identifies specific risks of reduced Outcomes towards 'Health' and 'Poverty Mitigation'.
- Step 4 integrates data and assumptions from previous tasks and empirical studies. The goal is to estimate the values for the most robustly attested and quantifiable (best-available) indicators within their respective scopes (and where feasible). This estimation is done for the years 2030, 2040, and 2050 in the countries for which data was provided by D5.3 and D6.1 and scaled-up the level of the European Union.
- Step 5 identifies generic risks from SM implementation towards 'Health', 'Poverty Mitigation', 'Gender Equality', 'Time-Use' and 'Just Transition. These risks, as well as the identified specific risks from Step 3, are scored according to the assessed scope and likelihood of the occurrence of barriers and/or target conflicts.
- Step 6 discusses of the limitations of the methodology and provides an interpretation of the findings.

Figure 1: Process steps for Social Impact Assessment (SIA) in T6.3



Source: own development

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Definition of dimensions

The societal dimensions in the proposal address different issues, target groups and can be evaluated from different perspectives. A key task is therefore to define these overarching goals in a such a way that conveys to policy-makers how an achievement or violation of goals would look like. They should, line with the scope of D6.3, be also closely aligned with the policies and strategies in the European Union.

The first step is to provide such a definition, so that benefits, barriers, and target conflicts can be identified and assessed against a target. Each definition is (i) drawn from an existing framework with policy relevance, (ii) selected with a priority on goals in the European Union, and (iii) as closely formulated to the original as possible. Only in cases where more than one definition adheres to all three principles, (iv) a definition is selected that is, at least in theory, easier to quantify. The following table provides an overview of the policy frameworks we used for our definitions.

These 'goals' and 'key objectives' are later discussed in more detail in chapter 5.

Table 2: Sources and policy frameworks used to define overarching goals for all five dimensions

Dimension	Goal type	Title (reference)
Health	Benefits	SDG Goal 3. Ensure healthy lives and promote well-being for all at all age (United Nations, 2015)
	Risks	EU4Health programme (European Commission, 2021a)
Poverty Mitigation	Benefits	SDG Goal 1. End poverty in all its forms everywhere (United Nations, 2015)
	Risks	European Pillar of Social Rights Action Plan (European Commission, 2021)
Gender Equality	Risks	EU Gender Equality Strategy (European Commission, 2020)
Time-Use	Risks	EU Work-life Balance Directive (European Commission, 2019)
Just Transition	Risks	Just Transition Mechanism (JTM) (European Commission, 2024)

2.2. Theories-of-Change

The term 'Theory-of-Change' was coined by Peter Drucker in the 1950s and originally informed the development of the 'management of objectives' by companies. A more scholarly approach designed for evaluations was then later developed in the early 90s by methodologists like Peter Rossi, Heléne Clark and Carol Weiss. Other names for ToCs found in literature are *program theory* (Weiss, 1997), *impact value chain* (Corlet Walker et al., 2018) or *logic models*, all of which describe similar ideas with distinctly different purposes.

The ToC used in this report is most closely aligned with a practitioner's application of a 'logic model', but it also draws on concepts from scholarly evaluation methodology and theory. First fully explicated in Teubler (2024)[6], it is based on the idea of interventions 'triggering' several logically conditioned causal mechanisms for a desired change to come about. Such a model is linear, since it does not entail the notion of feedback loops (effects reinforcing or hemming their causes), but complicated, because it allows for simultaneous or alternative causal strands to be present at the same time (see Rogers (2008) on a categorization and definition of simple, complicated, and complex ToCs). It is ontological deterministic but adheres to a probabilistic epistemology. Although it assumes that 'things happen for a reason', causes and effects can only be assessed in relation to their probability of occurrence (see Beach & Pedersen (2019) for a very similar ontology and epistemology regarding the method of Process-Tracing). More importantly, its causal claims are asymmetric. Using such a model investigates whether a certain cause leads to a certain effect but is silent on the absences of these causes (Goertz & Mahoney, 2012). It is also more closely aligned with case-based rather than population-based qualitative research (ibid.). It thus sheds light on the asymmetric causal

[6] This dissertation is mainly concerned with sustainability impacts of earmarked sustainable finance. As such, it is coined ESG Logic Model, or ESG-LM, to describe the effects of financing aligned with environmental (E), social (S) or governance (G) goals.

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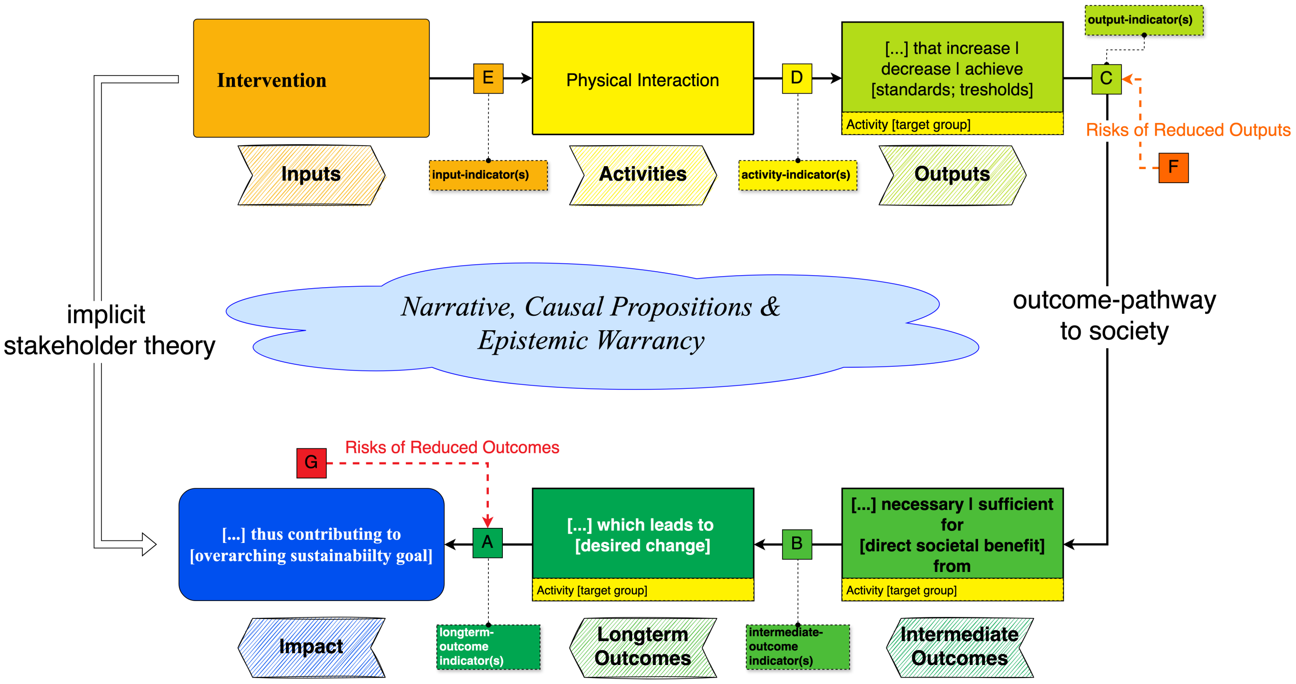
mechanism in a set of known cases, rather than 'black boxing' the symmetric relationships between variables in a large sample empirical study.
A full ToC according to this methodology has 6 entities: Inputs, Activities, Outputs, Intermediate Outcomes, Longterm Outcomes, Impacts (all of which remain capitalized throughout this work if such entities in the ToC rather than the more colloquial meanings are addressed). Each of its causal strands, or outcome-pathways from Inputs to Longterm Outcomes, is separated into two conjunct causal hypotheses. The first hypothesis proposes how an Input functions as a cause of an intervention (Input) that in turn triggers a causal mechanism (Activity) which then leads to a tangible result on a case-by-case basis (Output). The second hypothesis then proceeds to depict how this Output can function as a cause for a second causal mechanism on the societal level (Intermediate Outcome) leading to a desired persistent change (Longterm Outcome). If this causal chain can be shown to be true in the majority of cases[7], it then provides evidence for a contribution of the Intervention towards a connected overarching societal goal (Impact). The surrounding systems (e.g., energy provision in a given country) are mostly assumed to remain the same ('all other things being equal') for this causal inference. However, if additional pre-conditions outside of the ToC are required for a change, such pre-suppositions are described as "pre-conditions" and attached to their associated entity in the ToC. Indicators that are based on such a ToC are placed on the arrows between these entities. They are characterized by their quality (higher qualities for effects measured or estimated towards the end of the causal chain) and robustness. The following Figure 1 shows the basic framework of such a logical model.

Figure 2: Basic Framework of a linear ToC as adapted for FULFILL



Source: own development based on Teubler (2024)

Shortlink ToC for FULFILL

The ToC model used for FULFILL differs from such a fully explicated mechanistic ToC. Firstly, it is shorter since it starts with desired Outputs rather than the original intervention (which is why it is called 'shortlink ToC'). It is first assumed that the sufficiency measures are successful in triggering their associated Activities (Input and Activity are present in each case which is supported by the bottom-up model from T5.3). It is thus also assumed that the estimates for the number and type of persons that implement these measures are a reliable representation of reality. Such persons have pre-

[7] The underlying confirmation theory is described in Teubler (2024) and based on an adaptation of 'Fine-Grained Evidentialist Reliabilism' developed by Comesaña (2010).

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defined characteristics according to these previous assessments. If for example 50,000 people are estimated to implement 'Cycling' (SM-8) in a certain country over a certain amount of time or for a certain distance travelled, the same is assumed for the shortlink ToC – including the estimate distributions for gender, income, or other characteristics.

However, instead of a focus on climate change mitigation, such Activities are assumed to additionally trigger Outputs, which in turn are considered causes for desired Outcomes towards overarching social goals. This is the starting point for each causal strand assessed in this report. Such Outcomes can be triggered by more than one Output separately and each Activity can also be a causal condition for several Outputs at once. Cycling, for example, might merely increase the physical activity of target groups, but it could also, and additionally, decrease pollution in a region in cases where it replaces conventional motorized mobility.

Other changes to the original model in Teubler (2024) relate to the explication of negative side-effects. Instead of 'hazards' and 'rebounds', the identification and assessment of risks is limited to reduced Outputs (as 'barriers') and partially or over compensated Outcomes (as 'target conflicts'). These specific risks are later assessed in regard to their scale and likelihood and can be compared to the more generic risks outside of the explicated causal pathways (see also chapter 5).

The entities as well as components used and depicted in the two separate ToCs are defined according to Table 3.

Table 3: Terminology and definitions of the shortlink ToC for FULFILL

Terminology of shortlink ToC	**Purpose or Use**	**Definition**
Activity	Physical realization of pre-defined sufficiency measures	Activities are tasks performed by target groups in support of specific objectives.
Output	Representation of the cause for societal benefits	Outputs are tangible desired results from Activities by the target groups.
Intermediate Outcome	Representation of the causal mechanism that is triggered by Outputs and is required for desired long-term changes	Intermediate Outcomes are direct desired changes for individuals, groups or regions that follow from the successful delivery of Outputs.
Long-term Outcome	Representation of the desired effects of an intervention	Long-term Outcomes are persistent desired changes for groups or regions that contribute to overarching goals.
Impact	Representation of the social dimension that the intervention is shown to contribute to	Impacts are the ultimate, societal level changes that occur as a result of the sum of the processes that happen within the system.
Indicator	Representation of the presence of a ToC entity	Indicators are quantified metrics that show the extent to which desired effects are achieved.
Pre-condition	Representation of causal conditions outside of the explicated causal strand	Pre-conditions are requirements that are additionally needed for the presence of a ToC entity.
Specific Risks	Representation of reduced, overcompensated, or unintended impacts	(1) **Barriers** are potential risks for reduced Outputs caused by actors with different intentions or competing for the same resources. (2) **Target conflicts** are caused by insufficient or unintended interactions of the system with the explicated outcome-pathways in the ToC. They represent risks of negative contributions to the overarching goal.

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Heuristic tools for ToC development

Heuristics are usually understood to be mental short-cuts for explanations based on some form of background knowledge (e.g., with the help of a subject-matter expert or 'common sense') in light of insufficient information and data. They are a mode of abductive reasoning, that is, causal inferences from observed phenomena (see also Merziger, (1992)). Such reasoning is related to but differs from both deductive reasoning (insights based on known rules) and inductive reasoning (finding general rules based on case-specific evidence).

The heuristic development of a ToC can be considered an abductive process, as it leads to hypotheses for causal relationships that are tentative and defeasible. As such, ToC development can be easily aligned with other heuristic methods. For FULFILL, 'Inference-to-the-best-explanation' (IBE) is such a method that is applied in early ToC development[8].

IBE is commonly used to select a hypothesis that fits the data the best. It is a method that compares competing hypotheses (H_n) with each other and is compatible with Bayesian Epistemology (see next section) if these hypotheses are independent of each other (as in 'only one hypothesis can be true'). The result of an IBE is a ranking of all hypotheses based on either or both Explanatory Power and Antecedent Plausibility. These criteria are defined as follows (Teubler, 2024 based on Dellsén, 2018, S. 3):

- Antecedent plausibility: Other things being equal, H_1 should be preferred to H_2 if H_1 fits better than H_2 with what one already has reason to believe.
- Explanatory power: Other things being equal, H_1 should be preferred to H_2 if H_1 explains more facts (or more kind of facts) than H_2.

These criteria can be applied to guide the process of ToC development. It is operationalized in form of six questions resulting in a ranking of hypotheses as shown in Figure 3. Applying this heuristic tool has additional advantages, as it already forces the analyst to formulate research questions and hypotheses that are later refined and then assessed regarding their credibility (see next section).

Figure 3: Guide to heuristic IBE for ToC development in FULFILL

[8] Teubler, (2024) introduces and discusses two additional heuristic tools for ToC development and updates based on Process-Tracing.

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FULFILL

Guide to heuristic Inference-to-the-Best-Explanation (IBE)

Step	Instructions	*Example*
1 Formulate the Research Question	Consider the intervention to be assessed and the overarching goal this intervention is supposed to be aligned to. Now formulate a question that asks how the intervention contributes to this goal.	*How does the modernisation of Hospitals contribute to"Good Health & Well-being?*
2 Check for primary Data	Consider the available data from the Initiator. Is there evidence that is relevant to this question?	*Loan data indicates an expansion of and new equipment for intensive-care.*
3 Find two or more explanations	Assuming that the contribution is true, imagine how this change could come about. Sketch out at least two explanations in form of a narrative.	*(a) Hospital modernisations reduce hospital costs and thus costs of healthcare for patients.* *(b) Hospital modernisations result in better equipment and thus better health-care.* *(c) Hospital modernisations increase the number of beds and thus lead to better health-care.*
4 Assess Explanatory Power	Consider your explanations in light of the evidence. Which one of your explanations explains the evidence the best and/or the worst. If you can, rank your explanations accordingly.	(b) >> (a) AND (c) >> (a) AND (b) ≈ (c)
5 Assess Antecedent Plausibility	Now consider what you general know about the effects of your intervention. Do you find that one, or more, explanations are more likely – that is, are more frequent or more often observed?	(c) >> (b) AND (b) >> (a)
6 Find the best explanation	Given your ranking, which one of the hypotheses would you rank first? If you are unsure, pick the explanation that seems a bit more plausible (or pick randomly) and formulate the outcome-pathway but keep other competing explanations in mind for later on. You can also repeat the process for each pair of explanations.	*Inference to the best explanation:* *(c) Hospital modernisations increase the number of beds and thus lead to better health-care.*

Source: Teubler, (2024)

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Formulation of testable hypotheses

An initial ToC already provides a narrative on how the desired change is assumed to come about. It is thus only a translation that provides the analyst as well as any third party with testable hypotheses. We apply propositional logic (Kashef, 2023) to describe and operationalize these hypotheses, that is, each hypothesis is considered to consist of either a disjunct or conjunct of causes that trigger causal mechanisms which in turn lead to desired effect in an if-then-relationship.

The basic and most common form in FULFILL is a single cause *p* that triggers a causal mechanism *q* against the background of the system *s* as well as potential additional pre-conditions *z*, all of which *ought to be* present in conjunction ∧ for a desired effect *r* to be observed:

H_n: $p \wedge q \; (\wedge s) \; (\wedge z) \; \rightarrow r$

The variable *s* is usually omitted from the hypotheses in this report, as it represents the system as it is and is a placeholder for 'all other things being equal' (*s* is therefore always a necessary condition). The variable *z* on the other hand is an optional variable that is only depicted and considered, if additional conditions have to be met (necessary condition) that are not commonly expected to be present in the system.

The remaining variables can be understood to represent the Outputs (p), Intermediate Outcomes (q) and Longterm Outcomes (r) in the Shortlink-ToC. They can be further specified to introduce additional necessary causes, pre-conditions, or causal mechanisms in brackets (e.g., $(p_1 \wedge p_2) \wedge q \rightarrow r$), but also relationships of sufficiency in form of disjuncts ∨ (e.g., $p \wedge (q_1 \vee q_2) \rightarrow r$).

In regard to necessity and sufficiency, we apply a set-theoretic approach to causality. Necessary causes have to be present for effects but do not cause these effects on their own, and sufficient causes do not have to be present, but always induce at least a portion of the desired effects. Since most causal configurations are usually not purely necessary or purely sufficient, we also include the notions of 'partial sufficient' and 'partial necessary' (see also Teubler, (2024)). The first is considered to be synonymous with INUS or a "**i**nsufficient but **n**on-redundant part of an **u**nnecessary but **s**ufficient condition". The second notion is considered to be synonymous with SUIN or a "**s**ufficient but **u**nnecessary part of a condition that is itself **i**nsufficient but **n**ecessary".

The semantic relationship between the formulation of hypotheses in propositional logic and the narrative of the Shortlink-ToC is bi-directional. A well formulated ToC enables the formulation of its narrative (or 'language of the model') in form of conjuncts and disjuncts, but it is also possible to translate these equations of logic back into a hypothesis in plain English on how Outputs are assumed to lead to Longterm Outcomes.

2.3. Bayesian Reasoning

The chapter describes the method of Bayesian Reasoning used to test the credibility of the claims in the Shortlink-ToCs developed later on. We shortly introduce Bayesian Epistemology, describe the equations from Bayes Theorem, define ranged-credences used throughout the process and finally depict a four-step process for Bayesian Reasoning in FULFILL[9].

The basic process of a Bayesian Argument from Bayesian Reasoning is shown in the following Figure 4. It depicts the process of assessing our credence in propositions in form of a scale with the left side representing a credence of 0 (false) and the right side a credence of 1 (true). First, we look at our general background knowledge to assess whether we lean more towards false, true or neither of both. We then additionally weight the evidence contingent on this explanation, that is, we want to know whether the evidence is expected under the proposition in question, but also if it less expected under at least equally possible alternative explanations. The result then helps us, and other rational actors, to make a statement of the plausibility of a claim. This statement is then more informed than our original intuition and can further be updated with additional new relevant information.

Figure 4: Graphical representation of Bayesian Reasoning by a 'scale'

[9] All of the concepts and tools described here are only a small excerpt of a more thorough methodological discussion in Teubler, (2024).

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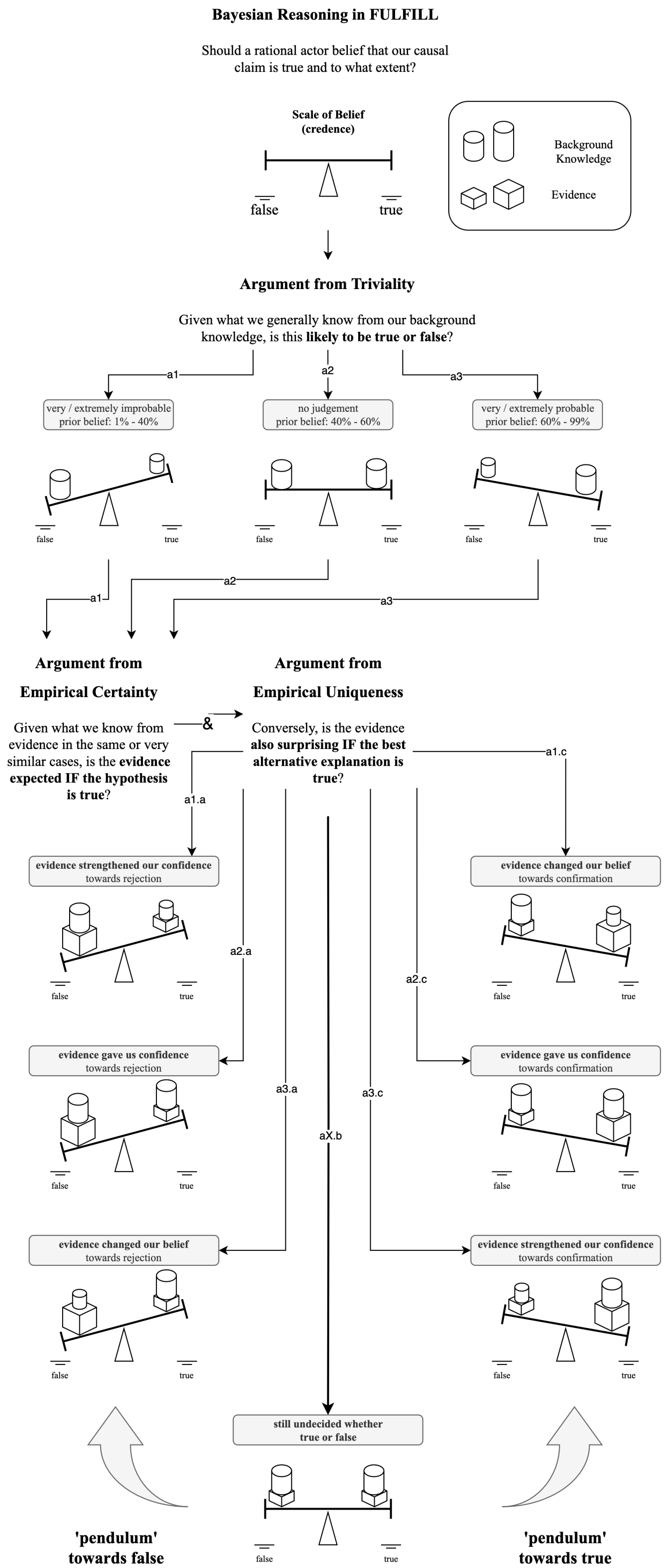

Source: own development

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Bayesian Epistemology

Bayesian Epistemology (BE) refers to any type of probabilistic reasoning that applies Bayes Theorem directly or indirectly. It describes a set of arguments for the belief-update of rational agents (see Titelbaum, (2022) for a more detailed explanation and discussion of the terms and concepts used for the methods described here). It adheres to five core rules, also called 'rational constraints', aligned with philosophical Probabilism (and confirmation theories): the three axioms by Kolmogorov (Non-Negativity, Normality, Finite Additivity), the Ratio Formula and the rule of conditionalization.

In a nutshell, BE defines how rational agents should update their initial belief in an explanation or hypothesis in light of evidence for and against a main hypothesis. This belief, or 'credence' cr, is depicted numerically on a scale between 0 and 1 (there is always a potential alternative explanation that can theoretically be true). It is compatible with a probability Pr of a proposition being true compared to the probability of any other, mutual exclusive, proposition. The result of a Bayesian Reasoning process improves with every piece of evidence that is considered (the consequent in Bayes Theorem) in such a way, that initial credences (the prior in Bayes Theorem) align with a final credence (the posterior in Bayes Theorem) over time. The latter, of course, is never achieved in a probabilistic epistemology as there is always some potential piece of evidence that has not emerged yet and there is always at least one additional explanation that has an ever so slight chance of being true.

One of the advantages of Bayesian Epistemology is that it is able to deal with data uncertainty and data gaps in a coherent and well-documented manner. A good Bayesian Argument, and especially a full Bayesian Analysis, conveys to the reader how reliable and how credible a proposition is considering our background knowledge and the evidence in a specific case. It is able to distinguish between trivial propositions that align perfectly with our everyday experiences (credences of almost 1) and cases where the available data merely allows us to prefer one proposition only slightly over another (credences slightly above 0.5). The main distinction between BE and other forms of Probabilism is its ability to weigh evidence in light of competing propositions.

It can thus be colloquially translated into Carl Sagan's famous quotation on extraordinary evidence, but also applies to more trivial claims (with 2. attributed to Gwern Barnwen according to Soares, (2016)):

1. Extraordinary claims require extraordinary evidence.
2. Ordinary claims require only ordinary evidence.

Bayes Theorem

Bayes Theorem (BT), going back to Thomas Bayes in the 18th century, lies at the core of Bayesian Reasoning (BR). There are different, but fully compatible, versions of BT with the probabilistic Odds-form often used to explain the concept (the | symbol represent 'given that' in a statistic sense so that Pr (A|B) describes the probability Pr of A occurring if B occurs):

$$\frac{Pr\ (H_1.b|E)}{Pr\ (H_{n-1}.b|E)} = \frac{Pr\ (H_1.b)}{Pr\ (H_{n-1}.b)}\ x\ \frac{Pr\ (E|H_1.b)}{Pr\ (E|H_{n-1}.b)}\quad (Odds-form\ of\ Bayes\ Theorem)$$

The result of BT describes the ratio of the probability Pr for a hypothesis H_1 being true given our background knowledge b and the body of evidence E (Pr (H_1.b|E)) over all cases where any other hypothesis H_{n-1} is true, so that Pr (H_1) + Pr (H_{n-1}) = 1 (rule of Finite Additivity if H_{n-1} is a placeholder for all possible propositions). It is called the posterior odds. It can be compared to a betting proposition or the simplest form of an expected utility (one of the reasons why it's called the Odds-form in the first place). If, for example, the posterior odds are 3:1 that the proposition is true, an agent would be rational in betting no more than 0.75$ on a 1$ bet (3/(3+1)=0.75).

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The first term of the multiplication describes the ratio of the prior odds. It constitutes the objective chance[10] of the main hypothesis being true before considering any evidence. More colloquially, this 'Prior' represents what we know about similar cases in general.
The second term is called likelihood ratio (or consequent or 'Bayes Factor'). It compares the probability of some piece of evidence being present, if the main proposition is true (Pr $(E|H_1.b)$ with the probability of this evidence if any other proposition is true (Pr $(E|H_{n-1}.b)$. This relationship is not governed by the rule of Finite Additivity[11], meaning that the probability of the presence of evidence can be equally high, in which case the second term would result in 1.
Looking at both terms combined, the equation has the following characteristics. If the prior odds are very high (or the resulting chance for H_1 approaches 100%), it is assumed that the proposition is almost always true (and vice versa for chances approaching 0%). It is therefore difficult to find evidence that shakes the initial belief of a rational actor. On the other hand, if the likelihood ratio is higher than 1, for example approaching odds of 10:1, 100:1 or even 10,000:1, it should raise our credence in the proposition, even if the initial odds were considered to be well below 1:1. A consequence of this relationship is that pieces of evidence can be compared to each other (splitting up the second term into several equal terms for E_1 to E_n) regarding their weight. Evidence that is unique to a certain proposition is more valuable than evidence that is equally expected under different explanations.
While the Odds-form of BT is commonly used in Bayesian Statistics or Bayesian Networks, it is less useful than its propositional form when formulating a Bayesian Argument. The following form of BT is mathematical equivalent to the Odds-form above and replaces the probability Pr with the credence of actors cr:

$$cr\ (E.b) = \frac{cr\ (H_1.b) \times cr\ (E|H_1.b)}{[cr\ (H_1.b) \times cr\ (E|H_1.b) +\ cr\ (\neg H_1.b) \times cr\ (E|\neg H_1.b)]}\ (propositional\ form\ of\ BT)$$

The equation above introduces the symbol ¬ that represents a hypothesis being 'not-true'. It is a placeholder for all remaining alternative explanations. The prior credence in a main hypothesis therefore also adheres to the rule of Finite Additivity, so that cr (H_1) + cr $(\neg H_1) = 1$. If we find for example, that a credence of 0.75 is warranted for our main hypothesis H_1 given our background knowledge, it follows that all the remaining hypotheses (explicated or not) occupy a prior probability space of 0.25.
One can also see from this equation that no logically viable proposition can ever achieve a posterior credence of 0 or 1, because the denominator always depicts a sum of credence for and against the proposition and each (logically valid) proposition has at least some chance of being true (otherwise dividing the numerator by zero). The propositional-form of BT can also be depicted using plain English as drawn from Teubler & Schuster, (2022):

Figure 5: Translation of propositional-form of BT for use in FULFILL

$$\textit{Probability of our hypothesis being true} = \frac{\textit{how \textbf{typical} our causal assumption is} \times \textit{how expected the evidence is if our explanation \textbf{is true}}}{\left\{\textit{repeat the above}\right\} + \left\{\textit{how \textbf{atypical} our causal assumption is} \times \textit{how expected the evidence is if our explanation \textbf{isn't true}}\right\}}$$

Ranged-credences and Canon-of-Probability

BT is open to conventional empirical methods, that is, it can be used to calculate a posterior credence from known probabilities. Credences on the other hand are depictions of how actors have different degrees of belief in the 'objective' chances of a proposition being true. It is sometimes difficult to find

[10] The approaches described here do not adhere to 'objective Bayesianism' in the normative sense. However, some 'objective' constraints are used for pragmatic purposes.

[11] However, the absence of evidence E (as in Pr (¬E)) is indeed final additive to its presence, so that Pr (E) + Pr (¬E) = 1.

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an exact value for that and there are cases where such a single numerical value is not warranted given additional conditions. An actor might for example be generally convinced that electrical vehicles reduce greenhouse gas emissions but might want to condition her credence in this proposition on the future development of renewable energy in the electricity mix. She might rank her confidence in this proposition higher, if current efforts towards a greener energy mix are increased in the near future compared to a baseline scenario in which the share of renewables is still too low to replace GHG emissions from energy production.

So-called ranged credences are one possible solution to this problem. They allow actors to estimate credences on a broader scale, thus allowing for conditions that have not been specifically considered or to express a that a judgement on the issue is still pending. A ranged credence of 0.4-0.6 for example indicates that a proposition could or could not be true, but that there is currently insufficient evidence to decide the case.

Working with credences in general, and with ranged-credences in particular, is also akin to probabilistic statements in everyday language. It is often easier to establish whether something is highly probable compared to being somewhat probable, then to identify a concrete credence value. This is where a so-called 'Canon-of-Probability' can be introduced as a helpful tool for translation.

The following Table 4 is used throughout this report and combines such a canon with ranged-credences. It translates notions of probability for the different parts of Bayes Theorem into cr-ranges. It thus not only facilitates the credibility assessment of the authors of the report, but also similar assessments by any third party. If, for example, the analysts find a piece of evidence to be extremely likely, but a third party disagrees with this assessment, this table makes it easier to estimate how this disagreement affects the warranty of the overall results.

Table 4: Canon-of-Probability and ranged credences for Bayesian Reasoning in T6.3

Prior **cr (H_i|b)** general credibility of H given our background knowledge	**Consequent** **cr (E|H_i.b)** likelihood of Evidence under the assumption of H	**Posterior** **cr (H_i.b|E)** warranty of H given background knowledge AND evidence	**Credence** **$0 \leq cr \leq 1$** lower and upper bound of probability
virtually certain	fully expected	certain of H_i	$cr \approx 1$
extremely probable	extremely expected	extremely confident in H_i	$0.95 \preccurlyeq cr \preccurlyeq 1$
very probable	very expected	very confident in H_i	$0.80 \preccurlyeq cr \preccurlyeq 0.95$
probable	somewhat expected	somewhat confident in H_i	$0.60 \preccurlyeq cr \preccurlyeq 0.80$
no judgement	not surprising / expected	unsure about H_i	$0.40 \preccurlyeq cr \preccurlyeq 0.60$
improbable	somewhat surprising	somewhat confident in $\neg H_i$	$0.20 \preccurlyeq cr \preccurlyeq 0.40$
very improbable	very surprising	very confident in $\neg H_i$	$0.05 \preccurlyeq cr \preccurlyeq 0.20$
extremely improbable	extremely surprising	extremely confident in $\neg H_i$	$0 \preccurlyeq cr \preccurlyeq 0.05$
virtually impossible	impossible	certain of $\neg H_i$	$cr \approx 0$

Source: own development based on Teubler, (2024) and Carrier, (2012)

Bayesian Reasoning: Operationalization for FULFILL

Bayesian Reasoning describes any form of probabilistic argument that applies the core mechanics of Bayes Theorem to come to conclusions for or against a confirmation. A full Bayesian argument therefore requires estimates for at least the prior probability of the hypothesis in question (with all other hypotheses occupying the remaining probability space), the likelihood of evidence given this proposition and the likelihood of this evidence if some other hypothesis is true. If one of these components is missing or not accounted for, one might therefore end up with a false or at least less reliable conclusion on the warranty of a claim. A common mistake in this regard is the so-called base-rate fallacy, in which some piece of evidence seems to confirm a hypothesis strongly while neglecting the overall

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low prior probability of the event. Equally faulty or biased conclusions can come from Bayesian arguments that do not account for all the available evidence or total available background knowledge.
Nonetheless, there are hypotheses that describe trivial causal relationships (prior credence approaching 1) or highly improbable events (prior credence approaching 0). In this case, a rational actor might at least initially be warranted in believing or disbelieving these claims without estimating the weight of each piece of evidence on all possible explanations. In this case, only highly unique (extraordinary) evidence would sway rational actors and if such evidence existed, it should be conveyed to the reader how it affected the final assessment. Similarly, there are cases in which one expects evidence to be present and where its absence therefore sheds doubt on the entire argument.

This is why FULLFILL accounts for such circumstance by applying a Three-Stage Bayesian argument that depicts how, if and why the initial assessment of the credibility of claims changed during the assessment.

Stage I is an **Argument from Triviality**. It is an assessment of the prior solely based on the available background knowledge. It usually represents the state of knowledge for similar cases or general relationships. Stage I arguments can point the reader to hypothesis that are usually true or false (the prior credence).

Stage II-a is an **Argument from Empirical Certainty**. It compares the evidence for the main hypothesis with the likelihood of its presence. This 'Smoking Gun Test' can be a defeater for propositions, if some evidence is expected but either not present or pointing to the opposite direction.

Stage II-b, the **Argument from Empirical Uniqueness**, looks at the other side of the equation. It responds to the question on how likely the available evidence is under the main hypothesis compared to any other plausible alternative explanation (the consequent credence).

Stage III (**Conclusion**) concludes the Bayesian Argument by combining the previous steps. Either both credences are aligned or at odds with each other. This can for example mean that we become more certain of a previously weakly attested hypothesis or that the strength of the evidence tilts the scale towards doubting the validity of a claim. There are three outcomes of this conclusion (the posterior credence): (i) we are more or less certain of H, (ii) we are more or less not convinced by H or (iii) we do not know or cannot decide.

The following table shows the template that is used for this purpose and contains the expected inputs by the analyst in each case (see Teubler, 2024 for a detailed discussion on the Four-Stage version the template here is based on).

Table 5: Bayesian Reasoning process in FULFILL

Stage	Reasoning	Credence
I: Argument from Triviality Priors cr (H|b); cr (¬H|b)	<u>Background knowledge b:</u> The first stage assesses the overall credibility of the claim before looking at the evidence. This is based on the background knowledge about how likely such and similar causal strands (the so-called reference class of cases) are in general. The base-line or null-hypothesis is “I do not know” and represented by a credence of 0.5 or a credence-range of 0.4 - 0.6. The relevant information or data here can be general background knowledge (e.g., bicycles have no end-of-pipe air emissions) or logically entailed conclusions (e.g., saving energy leads to reduced energy consumption). Such relevant information can also be drawn from literature or other sources (e.g., statistics on the frequency of events). In this case, it often relates to facts about individual entities in the ToC (e.g., air pollution having adverse effects on health) or relevant causal information on a broader set of cases that entail the specific case in question (e.g., the general health benefits of nutrients in diets). The relevance of the information is not necessarily restricted to the main hypothesis but can also affect the plausibility of non-true propositions (the alternative explanations in the probability space ¬H). There is no limit to the number of facts that can or should be considered here, although trivial propositions usually require less information (hence the name of the argument). However, background knowledge should be clustered according to its independence. Finding five sources that attest to the fact that smokers have a higher risk of lung cancer can increases the robustness of that	cr (H.b) ≈ estimate and cr (¬H.b) = 1 – cr (H.b) from cr (H.b) + cr (¬H.b) = 1 (Finite Additivity axiom)

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	information, but it cannot be considered five different pieces of relevant information that each increases our prior credence. Each piece or cluster of relevant background knowledge is usually depicted here and sourced if referring to literature rather than trivial known or brute facts. The overall weighting process is formulated in form of an argument or rationale and can include statements on the likelihood of competing hypotheses. <u>Assessment:</u> The analyst assigns a credence-range in accordance with their confidence in the main claim. To that end, it is often helpful to also look at potential other explanations on how desired changes can occur without or merely coinciding with the intervention proposed. Such alternative explanations can also relate to the probability that no desired effect can or is unlikely to be achieved at all (making H non-true directly). In cases in which more than one range is applicable or one credence is set, the lower credence should be selected in accordance with a a-fortiori argument (a fortiori: from the stronger argument). All remaining alternative hypotheses then occupy the remaining probability space as shown in the equation in the right column.	
II-a: Argument from Empirical Certainty **II-b: Argument from Empirical Uniqueness** Consequents cr (E|H.b); cr (E|¬H.b)	<u>Present the evidence E:</u> Each piece of evidence should be shortly introduced including its source and (if necessary) overall reliability. At this point, no background knowledge can be re-introduced as evidence without violating the process of Bayesian belief-updating but such background knowledge can define how evidence is affected by the hypotheses. The evidence often stems from empirical studies on the whole or parts of the causal pathway. Such relevant information should not mirror the background knowledge directly ($e_n = b_n$) but can specify it (e.g. finding a source that confirms a general known fact about reality is no evidence, but a source that looks at the particular causal relationship depicted in H and is entailed by general knowledge can be). Other types of evidence can be established scholarly theories or consensus among academics. It can, of course. also be directly monitored or extracted primary data in the specific case in question (usually the main input for any Bayesian Argument but less expected to be present in FULFILL models, which is also why so-called Arguments from Silence play no major role in the FULFILL methodology). The focus of the data collection here is on the question what either the main hypothesis or the most plausible alternative explanation predicts. If, for example, H predicts that a certain group in society is affected financially by the intervention and such information exists, it can either be evidence in favour (as expected) or against H (surprisingly not the case). The same is independently true for plausible alternative, or non-true, propositions. <u>Empirical Certainty:</u> The next step is to look at each piece of evidence and to decide whether this evidence is expected under the main hypothesis and by how much. Fully expected relevant information (cr (e_n|H.b) approaching a credence of 1) should be weighed against less expected (or less likely) relevant information to conclude on the overall likelihood of the presence of the entire body of evidence under the assumption that H is true. <u>Empirical Uniqueness:</u> The third step is to assess the likelihood of each piece of evidence under all alternative explanations independent of the previous assessment. Again, pieces of evidence can be weighed against each other, although different explanations can justify different weights. The overall conclusion on cr (E|¬H.b) should reflect this by selecting the highest credence out of the total set of alternative explanations (a fortiori). <u>Assessment:</u> The result of this step is the ratio of the likelihood of evidence under the main causal assumption over the likelihood of the same	cr (E|H.b) ≈ estimate cr (E|¬H.b) ≈ estimate with $e_n \in E$

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	evidence under at least one alternative explanation (consequent credence). The assessment should reflect this by summarizing all ranged-credences and compare them to each other. In most cases such an assessment can be made looking at the overall trends and then assign a ranged credence to both E|H and E|¬H (with the ratio representing the overall odds). In cases where these trends are not easy to obtain or to assess, a more formal mathematical approach can be applied. According to probabilistic reasoning, the overall probability of E given H is the result of multiplying the probability of each individual piece of evidence with each other piece of evidence. This reflects the mechanism by which additional assumptions reduce the overall probability of a proposition (more than one relevant information being true at the same time or all sets of e given H intersecting). We can therefore apply the following to equations to quantify both credences (as well as their lower and upper ranged-credences) if we have n pieces of evidence being an element of E ($e_n \in E$): 1: cr (E|H) = Pr (E|H) = Pr (e_1|H) * Pr (e_2|H) * … * Pr (e_n|H) 2: cr (E|¬H) = Pr (E|¬H) = Pr (e_1|¬H) * Pr (e_2|¬H) * … * Pr (e_n|¬H) The ratio between these terms describes whether the evidence is in favour or against the hypothesis. $E\ in\ favour\ of\ H\colon \frac{cr\ (E\mid H}{cr\ (\neg H)} > 1$ $E\ against\ H\colon \frac{cr\ (E\mid H)}{cr\ (\neg H)} < 1$ The result are the odds of E being true given H over E being true given ¬H (the so-called Bayes Factor). They can be directly put into the odds-Form of Bayes Theorem or calculated back into an overall probability: $odds\ of\ (H) : (\neg H)\ in\ [1] = Pr\ \frac{(H)}{[(H) + (\neg H)]} in\ [\%]$	
III: Conclusion Posterior cr (H|E.b)	<u>Assessment:</u> The posterior ratio can be estimated by multiplying the ratio of the priors (Step 1) with the ratio of the consequents (Step 2). Plausible results are those with an overall ratio larger than 1, with higher ratios implying credences approaching 1 or a probability of 100% (e.g., a ratio of 2 represents a credence of 2/3 or 66%). A more informal arguments does so by responding to the question on how the evidence affected the initial prior assessment from background knowledge. Did the evidence re-enforce or weaken an already established conviction or was it strong enough to overcome the initial prior and thus pointing to a different conclusion? However, the conclusion can also be ambiguous at this point, meaning that a rational actor should neither be convinced nor in doubt (as in: we do not know if H is true). In a more formal manner, the credence or ranged-credences can also be directly put into the propositional-form of Bayes Theorem: $cr\ (H\mid E.b) = \frac{cr\ (H_1.b) \times cr\ (H_1.b)}{[cr\ (H_1.b) \times cr\ (H_1.b) +\ cr\ (\neg H_1.b) \times cr\ (\neg H_1.b)]}$ Alternatively, the odds-form of Bayes Theorem can be used and recalculated into an overall probability as shown in the previous section: $\frac{cr\ (H\mid E.b)}{cr\ (\neg H\mid E.b)} = \frac{cr\ (H\mid b)}{cr\ (\neg H\mid b)} \times \frac{cr\ (E\mid H.b)}{cr\ (E\mid \neg H.b)}$	cr (H|E) ≈ estimate or cr (H|E) ≈ argument or cr (H|E) = BT result

Resolving disagreements with Bayesian Arguments

The results of the Bayesian Reasoning process represent the analyst's (here the authors of this report) confidence in the causal claims towards desired societal changes to the best of their knowledge. Others might find the resulting ranged-credences to be too timid or might even fully

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disagree with them. Some assessments might also be against the intuition[12] of the reader. In each case, there are valid and invalid ways to address the problem.
The following Table 6 lists valid sources of possible disagreement and proposes strategies to address them in a manner that is consistent with probabilistic epistemic standards. These strategies were also applied by the authors in cases where no initial consensus could be achieved or in cases in which the reviewers of the report disagreed with the assessment. Such disagreements can usually be resolved by looking at only parts of the argument, or parts of the equation, that are affected by a deviating assessment.

Table 6: Solutions for the most common disagreements (with the credibility assessment in FULFILL)

No	Source of deviation	Description	Solution in line with Bayesian Epistemology
1	neglected evidence	The reader might have access to additional primary data or literature that affects H or ¬H or both.	The previous posterior credence cr_i (H|E.b) can be used as prior credence cr_j (H|b) in a belief-update. The new evidence E' is then applied to assess the consequent in light of this information (Stage II of the Argument). As a result, a new posterior compares prior and consequent credence with a potential different result.
2	faulty information	The reader may have access to expertise or information that renders some portion of the background knowledge or evidence to be wrong or to misrepresent the facts.	Either the prior or consequent credence has to be adjusted. The quickest way to do so is by looking at the effect of this piece of information in the previous assessment. Did the consideration help to confirm or disconfirm H? If so, the information being wrong should tilt the scale towards the opposite direction, but not necessarily to a degree that negates the overall credibility/non-credibility of the claim.
3	disregarded dependence	Pieces of relevant information might be presented as independent (alluding to different facts), but the reader might find or know them to directly depend on each other. This can occur between clusters of information within a Stage or between Stages of the argument. An example for this is evidence that seems to attest to a separate fact but is found to mirror directly the previously assessed background knowledge.	The body of information (at least two pieces of relevant information to be independent) should be grouped (pertaining to one fact only) and only considered once. This can mean that evidence is shifted to background knowledge or vice versa. Similarly to No 2 (faulty information), the third-party having access to the new information should consider the effect on the initial case presented. Again, this leads to a re-assessment that usually shifts the credence in the opposite direction but does not have to change the overall credibility/non-credibility of the claim.
4	disregarded alternative explanations	The reader might think of some portion of ¬H ($¬H_{new}$) that is plausible or probable as well but has not been considered before.	While such a new non-true proposition might affect the prior credence as well, it is usually sufficient to only look at the effect of E on $¬H_{new}$, and compare this consequent to the initial consequent of E on H. If the assessment is found to be less confirming/disconfirming than on previously assessed $¬H_n$, no change of the overall assessment (the posterior) occurs.

[12] Arguments from intuition are, contrary to popular belief, valid forms of obtaining knowledge in philosophy, if other means of reasoning cannot be applied. It can for example (according to Spinoza and Bergson), refer to "[...] supposedly concrete knowledge of the world as an interconnectable whole, as contrasted with the piecemeal, abstract knowledge obtained by science and observation" (Brittannica, 2023). Differences in intuition can affect all parts of the argument operationalized here but are more common when looking at the rationale for the prior credence in a hypothesis or formulating the hypothesis itself.

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No	Source of deviation	Description	Solution in line with Bayesian Epistemology
			Otherwise, it is possible to come to an entirely different conclusion on the credibility of the claim.
4	logical fallacies	The reader might find that some part of the argument is logically not sound, that is, the conclusion does not follow from the premisses. Typical fallacies are conclusions that are not necessarily entailed by the background knowledge but presented in this manner. For example, presenting data on health issues for the female sex, does not entail that all people with a female gender can have them. Another type of fallacy common to Bayesianism are appeals to possibility (*possibiliter ergo probabiliter*). Here the analyst follows from the fact that something can possibly be true that it is also probable, or mistakes something to be probable with it being certain.	Most, if not all, Bayesian arguments rely on probabilistic sets. Some portion of events, or some portion of persons, or some portions of activities are assumed to be in a causal relationship with other sets in the ToC. Most logical fallacies directly affect the number of items in these sets in relation to each other or affect the way in which these sets can overlap. Resolving a logical fallacy can therefore be thought of as a change in frequencies (the number of cases in which X and Y are both true), and these frequencies (per Principal Principle) are reflected in our credences. This means that reducing the size of a set usually leads to a lower number of matches between causes and effects and this in turn reduces the credence. Note that this process is the opposite of ToC revisions, in which we change the definition of sets in the hypothesis (rather than the available information) in order to increase the credence for a smaller portion of the population.
5	stark differences in epistemic intuition	The reader might strongly disagree intuitively with the analysts' assessment of plausibility or probability for some part of the argument.	The quickest way to resolve this issue is to isolate the statement(s) and assigning one's own individual credence assessment with the help of the credence-table. Similarly to 2 and 3, this can but does not have to affect the overall credibility of the claim.

Source: own development

The purpose of Bayesian Reasoning for FULFILL

Applying Bayesian Reasoning in FULFILL is time-consuming both in regard to the required literature research and the assessment. The alternative to this approach is to fully or partially adopt an already existing quantification model for the estimation of societal effects in its scenarios. In this case, only input data and indicators that are considered in such a model could be assessed. This would not only restrict the size of the potential outcomes of the Social Impact Assessment, but would require additional, often ad-hoc, assumptions to fill in the blanks in data with the risk of interpreting assumptions rather than sufficiency measures. More importantly, it could also lead to the replication of causal inferences that are not sound or not valid, such as deductions from mere correlations (ignoring the inference to the sufficiency interventions that are supposed to be assessed).

The main purpose of BR in FULFILL is therefore to identify valid causal inferences in the first place and restrict the assessment to interventions (rather than available models or data space) **that are likely to cause desired societal changes**. In cases where more than one explanation is plausible in light of the academic consensus, the analyst's (and any interested third party) can also compare the credences towards each proposition for a ranking.

The second purpose of BR is to revise these causal inferences themselves. The credence in a causal hypothesis can be improved by changing the definitions of the considered causal sets. We often find (as evidenced in this report) that our credence is low when considering the benefits to a large portion of the population, but high if we restrict it to a certain target group (such as mitigating poverty by only looking at households at or below the national poverty line). However, this process is also subject to weighing different priorities. Very small and very specific causal sets usually come with very high credences (as in: a higher share is affected), but such restrictions may also neglect

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significant benefits for other groups in society (see Mahoney & Barrenechea, (2019) for a discussion of this 'Empirical Importance').

The third purpose of BR in FULFILL relates to the indicators. By applying rational reasoning on the plausibility of a causal inference, the indicators do not longer have to play the role of evidence (although they still can have this function). This independence between the reasons for the effects compared to their estimation is particular useful when working with models about future changes in a scenario (as present in FULFILL).

Another advantage of the approach (fourth purpose) stems from the fact that both the formal hypotheses and their depiction in a ToC enables the analysts to identify ideal potential indicators on what we *ought to* measure. This facilitates the interpretation of the later actualized results, since they can now be analysed not only in regard to their robustness, but also in the context of goal certainty. Such a comparison responds to the question whether and to what extent the estimated effects correspond to contributions to overarching societal goals.

2.4. Revisiting the ToCs and potential indicators

The previous steps compare the initial heuristic development of plausible causal strands with their overall credibility given our background knowledge and the available evidence. This process provides the analyst with insights on (i) a possible ranking of the more plausible over less plausible hypotheses and on (ii) how the less plausible causal explanation could be adapted to increase their credence. This can, but does not have to, result in one or more of the following steps for a re-work of the initial ToC:

- discarding entire causal strands for their lack of credibility (e.g., H_n with cr < r < 0.5),
- re-assessing the credibility of ambiguous claims by looking at additional background knowledge or new evidence,
- introducing additional pre-conditions for change or re-assessing the causal relationships between entities in the ToC (e.g., changing sufficient to necessary conditions),
- increasing the empirical importance by either further specifying necessary causes (thus decreasing the set-size) or generalizing sufficient causes (thus increasing the set-size).

The resulting ToC then represents the best-case on how Sufficiency Measures (SMs) in FULFILL can and in all likelihood will contribute to desired societal changes.

Once the ToC has been improved or found to be sufficiently plausible in the first place, indicators are identified. We distinguish two types of indicators for this purpose:

1. Potential *ideal* indicators
2. Actualised *best-available* indicators.

Ideal indicators (1) are all metrics that we would expect to change as a consequence of the interventions at the different stages of the ToC. They do not rely on the available data, but describe what we *ought to* measure, if all the necessary data was collected. To that end, we want to depict these indicators as results of Outputs (quality C and starting point of intervention), intermediate Outcomes (quality B and causal mechanism of intervention) and long-term Outcomes (quality A and desired persistent changes in society).

Best-available indicators (2) on the other hand quantify what we *can* measure given (i) the restraints of the models for the quantified SM's, (ii) the availability and applicability of selected measurement methods and (iii) the availability and accuracy of the available data. Their quality mirrors the quality of ideal indicators (A: long-term Outcomes | B: intermediate Outcomes | C: Outputs), but they are also indexed regarding their robustness (ranging from 1 for primary data to 5 for third-party evaluations). The following table shows such a robustness-evaluation that is also used in the results section of this report. For example, the reduction in air pollutants that is calculated based on changes in distance travelled by car and the typical specific emissions of cars per distance travelled, would warrant a robustness of 3 and a quality (depending on the explicated pathway) of C or B (e.g. C_3).

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Table 7: Attribution criteria for the robustness of actualized indicators in FULFILL D6.3

Robustness	Criteria	Examples from impact assessment in D6.3
1	primary data (directly reported or monitored)	the current population in a European country
2	directly calculated from primary data	the increase in cycling activity per week from an annual increase in cycling activity in the projected pathways in D5.3
3	calculated with the help of secondary data, auxiliary variables, share of financing assumptions	PM 2.5 exhaust emission reductions from relative emissions of cars per distance travelled
4	estimated on the basis of models or relations that simplify the cause-effect-relationships	reduction of relative ACM risks from increased physical activity
5	results from 3rd party reporting without the possibility for validation or future effects	potential reduction in PM 2.4 concentrations in Europe based on annual average emissions in cities in Europe

Source: own depiction based on (Teubler & Flynn, 2024)

Comparing ideal to best-available indicators (and their robustness) offer a number of insights to the analyst and policy-makers. It shows (i) to what degree the quantified effects actually represent desired societal effects, (ii) what type of data or method would be necessary to operationalize a better goal certainty and (iii) which part of the change process could actually be assessed. Moreover, it is usually easier to quantify indicators at the beginning than at the end of the impact chain and these indicators are usually also more robust. This means in turn, that indicators on the level of desired Outputs are easier to manage as they react directly to changes in the interventions. Conversely, indicators at the end of the impact change depict desired changes on the societal level (long-term Outcomes) and therefore contributions to overarching goals but can often not be easily reduced to single or specific interventions in the system.

This issue is very pronounced for the two main categories for the impact assessment in this report. Benefits to the health of target groups as well as the mitigation of poverty are usually not the result of individual policies or single changes in behaviour, but the aggregated, and often strongly distributed, effects of numerous causal configurations at once. It is thus helpful to not only estimate the effects on the societal level, but also to show what happened beforehand in direct relation to the interventions.

2.5. Risk Assessments

Impact assessment methods are designed to show the contributions to overarching goals. These goals are usually grounded in some form of policy, but such frameworks or regulations seldom address negative trade-offs explicitly. Negative impacts are often either (i) not addressed at all, (ii) excluded by previous regulations and underlying premises, or (iii) excluded by a logical conjunction, that is, by requiring more than one criterion to be true at the same time for a contribution to goals (e.g., sustainable, AND affordable housing).

FULLFILL intends to show when and where potential societal benefits of sufficiency can be expected, but also how the implementation of measures towards sufficiency lifestyles affect distinct demographics in a different manner. A single measure that increases non-motorized mobility might very well be net beneficial to society in terms of climate change mitigation or health. However, its implementation might also have negative impacts for some groups or in other areas of interest. Care-work for example has its own distinct modes of mobility that can be necessitated by constraints in time, money, or other resources (Ravensbergen et al., 2020). For persons that rely on motorized vehicles to provide such care work, 'more cycling', or the changes to infrastructure this entails, could thus have negative side-effects. At the very least, it can be considered a conflict of targets from a policy perspective.

These **target conflicts** or **barriers** constitute risks of either reduced societal benefits or negative societal effects. They are expressed with their own set of qualitative indicators and explicitly shown

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for assessed hypotheses in the ToCs for ‘Health Benefits’ and ‘Poverty Mitigation’. In addition, there can also be such risks for SM’s not seen as beneficial on their own or related to other areas of interest. For this report, these other areas of interest or ‘dimensions’ are: ‘Gender Equality’, ‘Time-Use’ and ‘Just Transition’.
The report at hand distinguishes two types of risks for the dimensions of interest.

- **Type-1 or Specific Risk Assessments** (S-RA) predict reduced (barrier) or overcompensated (target conflict) Outcomes from explicated causal hypothesis towards 'Health' and 'Poverty Mitigation’. They are part of the process of developing, warranting, and updating causal hypotheses during the impact assessment for ‘Health’ and ‘Poverty Mitigation’.
- **Type-2 or Generic Risk Assessment** (G-RA) predict generic and potential barriers or target conflicts from implementing the sufficiency measures regarding these two areas as well as 'Just Transition', 'Time Use' and 'Gender Equality'.

Risks of type 1 derive from pre-conditions and a restriction of causal conditions in the final Theory-of-Change for benefits towards ‘Health’ or ‘Poverty Mitigation’. We focus our identification and assessment of such risks on barriers or target conflicts that had to be accounted for to increase the credibility of the claims towards desired changes. The health benefits from meat reduction for example explicitly rely on a sufficient variety of dietary options and a balanced diet overall (a pre-condition for SM-5 towards lower morbidity and mortality in a country). It follows, that there is **potentially some portion** of the participants that do not benefit in the same manner or even experience negative health outcomes (e.g., vegans).

Risks of type 2 are generic in nature. Since we did not explicate ToCs for these dimensions, the risk assessment here is restricted to a broad and highly aggregated causal relationship between each sufficiency measure and the impact dimensions (SM -> ? -> negative impact) or between the total estimated effects (results from T6.2) from all measures and an impact dimension. This assessment aims to identify negative trade-offs between each measure and the five areas of interest and predicts whether certain groups in society benefit less from the measures or might even be negatively affected. This assessment is heuristic, informed by literature-based evidence and is conducted via three steps.
The first step in any G-RA is to define how a contribution to this overarching goal looks like and which objectives can potentially be violated. The second step is to identify heuristically how this goal might be hindered (barrier) or affected in a negative manner (target conflict) with the help of a decision-tree for the analysts. The third step then involves a scoring of each risk based on logic and evidence in light of the likelihood and scale of the effect.

The heuristic methodology for the risk assessment has been developed exclusively for the report at hand. However, it is grounded in an earlier, and similar, assessment of risks regarding the potential violation of Do-No-Significant-Harm criteria by projects selected for the Green Bond Baden-Württemberg that were aligned with the EU Taxonomy on 'sustainable activities' (Teubler & Flynn, 2024). This methodology already distinguished between 'no risks', 'low risks' and 'high risks' in terms of likelihood and the scale of damage anticipated. It also used an existing framework (here the technical screening criteria for DNSH) to investigate a set of explicated projects against a set of "control-questions" as well as a frame of reference. This process is compatible with the assessment at hand, that formulates control-questions in a decision-tree against a set of 'key objectives' from EU strategies.

2.6. Impact Measurement

T6.3 additionally intends to provide insights on the size of the anticipated benefits by estimating the effects of SMs on society. This is challenging because there is almost no information on relevant parameters for such a task and many of the potential empirical relationships are spurious for both ‘Health’ and ‘Poverty Mitigation’. For example, any potential benefits regarding ‘Poverty Mitigation’, even in the most constrained sense of economic benefits for vulnerable groups, requires not only

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input data on the current and future economic conditions of these persons (e.g., the available disposable income), but additional information on the development of prices and the socio-economic distribution of these groups in their respective countries and among those that participate in the SMs. And any type of health effect is only predictable, if there is sufficient information on the health characteristics of participants (such as e.g., smoking, regularity of exercise, and diet). We also must be aware of the fact that despite an abundance of scientific studies in the peer-reviewed literature, researcher regularly come to different conclusions when assessing poverty or health of groups in the society.

Any type of modelling would have to take these parameters into account by assuming future values for them based on (i) the conditions in the models in D5.3, (ii) the availability of these values for the current Status Quo and (iii) the availability of data in projections for these values in applicable scenarios. It has thus been decided early on in the project, that such an undertaking would not only be highly complex but also of little value to policy makers, as the results would be predominantly influenced by assumptions rather than the results from previous tasks, the available empirical data and our insights in the report at hand.

Instead, we look at the available data in the models from D5.3 as well as reasonable simple empirical relationships to estimate values based on as few additional assumptions as possible. We start this task by assessing this data.

Assessment of available data

The final data sets for the sufficiency hypotheses (bottom-up model in D5.3) have been provided in the form of tables (understood as truth-conditions for sufficiency measures in the context of D6.3). They include both descriptive status-quo data of the underlying systems and ex-ante estimates of changes over time in five European countries. However, they are intended to (i) inform the macroeconomic models in D6.1 and D6.2 and to (ii) facilitate the estimation of the main benefits of sufficiency policies (e.g., changes in GHG emissions). Only few of the provided data points for the SMs include information relevant to the societal dimensions of 'Health' benefits or 'Poverty Mitigation'. For example, there is no sufficient data on the economic situation, sociodemographic characteristics and distribution of households involved in a large-scale implementation of the policies. Moreover, temporality in these datasets is limited to one pathway in discrete time-intervals (5 or 10 years) without referencing a business-as-usual effect. The latter is important because the benefits are highly dependent on parameters in the systems such as changes in powertrains for cars. There is also no spatial distribution beyond country borders, which makes for it example impossible to quantify reasonable robust outcomes for the concentration of air pollutants.

As this type of information is necessary to quantify changes to groups in poverty or at the risk of poverty, no quantitative effects for 'Poverty Mitigation' could be estimated. The quantification of 'Health' benefits is limited as well for the same reasons. However, we could identify the following three cases for which at least **'ballpark figures'** could be estimated based on sufficiently available information. That is, **we understand the results in chapter 5 to be an educated guess for the size of the anticipated effect** rather than a robust and accurate prediction of results in a given scenario.

Selection of cases for an educated guess

The input data from D5.3 on the SM's 'Less Meat & Dairy', 'Cycling' and 'Car-Sizing' all include data and predictions[13] that can be related to 'Health' outcomes in a physical constraint manner despite possible difference within the population of countries.

[13] The usage of the term 'prediction' can be misleading in the context of the results of deliverable D5.3. We understand a prediction to be merely a projection into the future, whereas (Gabert et al., 2024) clarify in D5.3 that the term 'sufficiency scenario assumption' alludes to *"[…] investigating a specific sufficiency lever by projecting the lifestyle and societal changes that could occur if political institutions and policy makers were to implement sufficiency measures, invest in sufficiency infrastructure, and propose a political and cultural framework to foster said lever. Instead of trying to predict what will happen, the goal is rather to project what could happen"* (Gabert et al., 2024, p. 14).

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Potential direct 'Health' benefits from 'Cycling'

The available dataset provides information on predicted changes over time regarding averaged daily cycling activity, modal-shift and overall mobility performance in the five FULFILL countries. Moreover, there is unambiguous evidence in the scientific literature that physical activity improves health outcomes (see also section 3.3). We find it is therefore justified to estimate these health outcomes in a generic manner and solely based on these changes.

This requires an empirical grounding for the effects of this physical activity on reduced health risks, which we provide in the following section on All-Cause-Mortality risks or ACM risks.

Potential direct 'Health' benefits from 'Eating Less Meat & Dairy'

The available dataset provides information on predicted changes over time regarding the share of different types of diets in the five FULFILL countries, but no information on potential nutritional changes within these diets. That is, while a shift between two diet types can occur over time (e.g. from 'omnivore 170g' to 'omnivore 100g'), the daily amount of food types and nutrients within each diet stays the same.

Although there is convincing evidence in the scientific literature that reducing meat consumption, and particular red meat consumption, is beneficial to health outcomes, it is less clear to what extent this also requires an overall balanced diet (see also our credibility assessment in section 3.3). This means that the difference in health outcomes between a flexitarian, pescatarian and vegetarian not only depends on the overall lifestyle (e.g. regarding exercise and negative pre-conditions) but on the particular composition of foods and nutrients consumed besides meat.

This is why we decided that we can give a rough estimation of reduced ACM risks based on a simple and linear relationship, but that we are not justified in making bold claims regarding all diets, even if our results are restricted to an educated guess. Thus, the estimation here is limited to the changes in animal protein intake for the average diet in each country based on the distribution of foods for the entire sample in each given year. Any relative risk reduction than corresponds to a range among the five FULFILL countries and their arithmetic mean as a representative for all European countries.

Potential indirect 'Health' benefits from 'Car-Sizing' and 'Cycling'

The available D5.3 data for 'Cycling' and 'Car-Sizing' is sufficient to obtain the mobility performance of cars in the five FULFILL countries until 2050. We also know from the scientific literature that (i) high concentrations of air pollutants contribute to respiratory disease, that (ii) the direct exhaust emissions of cars contribute to this effect and (iii) that the exhaust emission of PM 2.5 and other pollutants increases almost linearly with the mobility performance (km driven per year by cars with internal combustion engines for diesel or petrol). Unfortunately, we also know (iv) that the causal mechanism for these health impacts depends on the concentration of these particles in a given area, rather than the overall emission to air.

We find that it is therefore justified to draw on a first-order linear relationship for the total reduction in PM 2.5 emissions based on the implementation of these two SMs. That means for example, that predicting the doubling the mobility performance also predicts doubling the amount of PM 2.5 emissions and vice versa. Such a direct relationship of course depends on the D5.3 assumptions for powertrains (with higher shares of batter-electric-vehicles reducing emissions directly) as well as the (implicit) assumptions that current cars with internal combustion will not become more pollution-efficient.

On the other hand, it is not justified to make numerous additional assumptions of the spatiality and temporality of these emissions in the future to accurately predict the concentration of these pollutants in a given future year as required by professional models such as GAINS[14]. It is thus even less justified to use such a value to also predict reduced risks for ACM or any other health outcome metric. This means that this case is restricted to the cause (or Output in the ToC) rather than the potential impact. We will however estimate, in a very rough and direct way, the size of the effect on PM 2.5 concentration throughout Europe (representing a rough ballpark figure for the Intermediate Outcome).

[14] See also https://gains.iiasa.ac.at/models/

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Empirical grounding for educated guess regarding 'Health'

All-Cause-Mortality Risks

Empirical studies on the cause-relationships between pre-cursors for health and negative outcomes often report on disease-specific effects, such as disease-specific mortality. However, these types of studies rely on the assumption that the cause of death can be reported and evaluated accurately. In cases where this cannot be established in a reliable manner (e.g., cancer as the sole cause for death), the so-called All-Cause-Mortality is usually investigated instead, as this metric merely relies on the death itself and the point in time when it occurs (Black et al., 2002). This also holds true for many inverse statistical relationships between health choices and health benefits.
We therefore rely on the following definition for All-Cause-Mortality, or ACM, to investigate benefits in the dimension of 'Health':

> *"[All-Cause-Mortality] […] refers to death from any cause. In statistics, all-cause mortality is usually a measure of the total number of deaths from any cause in a specific group of people over a specific period of time. For example, all-cause mortality may be reported for people who live in one area of the country or who are of a specific gender, age, race, or ethnic group" (NIH, 2011).*

The benefit itself can then be regarded as a change in the risk for ACM. It is common to report the relative risk (RR) for populations rather than the difference in risks (Stare & Maucort-Boulch, 2016). If the probability of an event in group 1 is π_1 and π_2 is the probability the same event in group 2, the relative risk RR can be defined as follows:

$$RR = \frac{\pi_1}{\pi_2}$$

Relative risk quantifies how much more likely (RR > 1) or less likely (RR < 1) an event is to occur in one group compared to another. For the calculation of the relative risk, the absolute risk (AR) in the intervention group is divided by the AR in the control group (Stare & Maucort-Boulch, 2016). In our case, the two groups being compared are the population at the starting point and the population at the end of the implementation of the measure. This can, and does mean, that a population in the year 2020 already has a lower risk than 100% (e.g. from cycling) and that the implementation of the SMs 'adds' to the effect via further risk reduction.

To interpret the relative risk, we further calculate the Life Years Saved (LYS) by applying the following methodology: First, we determine the baseline mortality rate (BMR), which is the number of deaths per 100,000 inhabitants and calculate the number of reduced deaths (RD) in a direct linear relationship:

$$RD_{c-SM} = BMR_c \times RR_{c-SM}$$

with
$RD_{c\text{-}SM}$: Reduced Death in country c from sufficiency measure SM [1/100,000]
BMR_c: number of deaths in country per 100,000 inhabitants [1/100,000]
$RR_{c\text{-}SM}$: Reduced Risk for All-Cause-Mortality in country c from sufficiency measure SM [1]

Then, we identify the average life expectancy (LE) in the population, which allows us to directly calculate the Life Years Saved (LYS):

$$\mathrm{LYS}_{c-SM} = RD_{c-SM} \times \mathrm{LE}_c$$

with
$LYS_{c\text{-}SM}$: Life Years Saved in country c from sufficiency measure SM [years]
$RD_{c\text{-}SM}$: Reduced Death in country c from sufficiency measure SM [1/100,000]
LE_c: average life expectancy in country [years / 1]

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These indicators are easier to understand but also come with caveat of additional required data. However, both the mortality rate (BMR) and the average life expectancy (LE) relate to current values in European countries. This introduces an additional cause for uncertainty in the results, which is why we recommend reporting these values only alongside the initial risk reduction values.

Relationship between ACM and physical activity

To quantify the health impacts of increased cycling on a country level, we adopted a linear-dose response relationship methodology. Kelly et al., (2014) conducted a systematic literature review of prospective cohort studies reporting walking or cycling activity and mortality outcomes. Eligible studies were assessed for various parameters including population characteristics, follow-up duration, and adjustments for covariates. Random-effect meta-analysis was employed to investigate the beneficial effects of regular walking and cycling on mortality outcomes.

To quantify these effects, walking and cycling activities were converted into "Metabolic Equivalent of Task" (METs), as recommended by the Compendium of Activity (Ainsworth et al., 2011). This approach provides a standardized measure of physical activity (PA) impacts on health by multiplying the average speed of cycling with a corresponding MET factor. The resulting linear-dose response relationship aims to provide researchers with a logical framework for estimating the reduced relative risk (RR) for all-cause mortality (ACM) in certain exposure ranges. It consists of three discrete intervals for the effect of MET on relative risks for ACM. As shown in Figure 6, the effect is the strongest for persons that do not exercise a lot (-0.0148 for 1 MET.hour per week) and then further diminishes quickly for cycling with additional physical activity (-0.0034 and -0.0018 respectively).

Figure 6: Intervals for the relationship between relative risks for ACM and MET

	Walking			Cycling		
Exposure category	Exposure range in MET. hours per week	Exposure range in minutes per week (@ 4.0 METs)	Change in relative risk for 1 MET. hour per week increase ($x10^3$)	Exposure range in MET. hours per week	Exposure range in minutes per week (@ 6.8 METs)	Change in relative risk for 1 MET. hour per week increase ($x10^3$)
Category 1	0.1 to 8.0	1-120	13.75	0.1 to 11.5	1-101	14.78
Category 2	8.0 to 22.5	120-338	2.07	11.5 to 32.0	101-282	3.41
Category 3	22.5 to 50.0	338-750	2.91	32.0 to 65.0	282-574	1.82

Source: Kelly et al., (2014)

This RR estimation serves as the basis for the impact assessment regarding the direct health benefits of SM-8 on 'Cycling' (assessed as causal hypothesis $H_{SM\text{-}8.1}$ in section 3.3). Our study utilizes country-level data received from T5.3 and T6.1 via bottom-up models conducted to assess cycling activity in Denmark, France, Germany, Italy and Latvia.

We employed different cases to accurately quantify the potential impact of increased cycling activity on all-cause mortality. Initially, population-wide cycling data was gathered for the baseline year (2020), with accumulative data projected for the years 2030, 2040, and 2050. This data represents anticipated increases in cycling activity due to implemented sufficiency measures in each of the countries.

(1) To align with the model proposed by Kelly et al. (2014), which quantifies activity on a weekly basis, daily average distance per person was converted to a weekly equivalent by multiplying by a factor of 7.

$$Weekly\ Distance_{person} = Daily\ Distance_{person} \times 7$$

(2) Subsequently, the distance was translated into time spent cycling weekly based on the Compendium of Physical Activities (Ainsworth et al., 2011). An average speed of 17.7 km/h (10 – 11.9 mph) converts to 6.8 Metabolic Equivalent of Task (METs).

$$Weekly\ Time_{cycling} = \frac{Weekly\ Distance_{person}}{17.7\ {}^{km}/_{h}}$$

(3) The average daily cycling time per person was then converted to METs, using the same factor as the speed, as proposed by Kelly et al, 2014 (6.8 METs/hours per week).

$$Weekly\ METs_{person} = Weekly\ Time_{cycling} \times 6.8\ {}^{METs}/_{hour}$$

(4) These METs were the input into the linear-dose response relationship for cycling described above. The linear dose- response, exposure intervals ranging from 0.1 to 11.5, 11.5 to 32.0, and 32.0 to 65.0 MET-hours per week correspond to a change in relative risk (RR) for a 1 MET-hour

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per week of 14.78×10^{-3}, 3.41×10^{-3}, and 1.82×10^{-3}, respectively. This facilitated the calculation of the change in relative risk for all-cause mortality (ACM), thereby describing the overall RR risk for ACM.

We investigated two cases, since it is unclear from the input data alone, how the additional physical activity is distributed among the populations in the five countries. **Case 1** attributed the health benefits equally to the entire population. Relevant data from D5.3 included population size and average distance covered by bicycle per day. **Case 2** limited the result to data on the share of the population that already cycles, which was also provided by input data from D5.3.

Case 1 therefore constitutes a lower bound (or minimum) of the average individual lower mortality risks for the entire population (each individual increases cycling by a lower amount), whereas Case 2 results in a higher bound (or maximum) average individual lower mortality for only a portion of the population.

To upscale our findings from the five FULFILL countries (Denmark, France, Germany, Latvia, and Italy), we adopted the methodology detailed above. We based our EU-wide extrapolation of cycling behaviour on the report 'Support study on data collection and analysis of active modes use and infrastructure in Europe,' which was commissioned by the European Union (COWI et al., 2017). The following steps outline our process:

(1) We extracted data on 'average distance per person per day travelled' from the report for 13 representative countries: Germany, Portugal, Poland, Denmark, Romania, Belgium, Italy, Netherlands, Austria, Latvia, Slovenia, Croatia, and Greece. We calculated the mean value of this data, which we then used to represent the average for the 27 European countries under consideration for calculating the health benefits of increased cycling.

(2) We also gathered data on the 'share of travel mode on the travel distance per person per day' for the same countries and calculated the mean value of this share.

(3) By multiplying the average distance travelled per person per day with the mean share of travel by bike, we derived the 'average distance covered by bike per person daily.' This provided the average daily distance cycled by a European citizen in our baseline year 2020.

(4) To model the growth in the 'share of distance covered by bike daily,' we first determined the average for our five FULFILL countries for the relevant year. We then calculated the average percentage increase for each ten-year interval, including data from all five countries. Using this percentage increase, we updated the baseline data from the European Union computed in Steps 1-3. With the updated share of distance cycled, we could then determine the 'average distance covered by bike daily' by European residents for every ten-year interval.

(5) The final step then concludes the assessment by repeating the previous approach for the quantification of changes to relative risks for ACM. Additionally, we extracted from the data that the total percentage of people who cycle regularly (at least once a week) was 28%. This information allowed us to estimate the reduced risk of ACM attributable to cycling for the 27 European countries for both cases.

Relationship between ACM and meat intake

For the purpose of determining the impact of decreased meat consumption on the risk for all-cause mortality (ACM), we utilized an empirical investigation by Song et al., (2016). The study showed a positive relationship between animal protein intake and mortality risk. An increase of 10% in animal protein consumption, was associated with a 3% rise in the risk of ACM, largely due to cardiovascular diseases.

For measuring the impact of meat reduction on the health of our targeted population, we hypothesize an inverse relationship based on the findings by Song et al., (2016); thus, we suggest that a 10% decrease in animal protein intake may result in a 3% reduction in ACM risk. We further assume a linear relationship between meat consumption and animal protein intake, since the input data from D5.3 does not account for different food or nutrient compositions among the changes to overall diets.

Our quantitative estimation towards an educated guess thus requires the evaluation of animal protein content.

We start by using the input data from D5.3 to derive the share of each diet for each time interval and year, as well as the generic information on the amount of daily animal product consumption for each

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diet. This results for the year 2021 (starting year) in a range of daily animal production consumption between 375 (Germany) and 422 (Latvia) g per person and day on average.
Since each diet comes with a generic daily intake of 'bovine and ovine meat', 'pork, offals and other', 'poultry', 'dairy' and 'seafood', we then can derive the animal protein intake for all diets, countries and timeframes. This is achieved by multiplying the daily intake in a corresponding food category with its protein content (see Table 8). The 'omnivore 170g' diet for example has a daily intake of 515 g/(d*a) of animal products and a daily intake of animal protein of 51 g/(d*a).

Table 8: Protein content of animal-derived foods

Animal-derived foods	Protein content (g/100 g)	% energy from protein
Beef (average)	16.9	48
Chicken	20.2	44
Fish (weighted average)	18.9	53
Eggs (without shell)	12.6	38
Cheese (average)	23.4	34
Pork (average)	18.9	39
Milk (3.5% fat, boiled)	3.1	19
Yogurt (plain, 2.5% fat)	3.0	22

Source: European Commission, (2021)

We then multiply these values with a time frame of one year (365 d/a) and the number of persons in a country (with the latter being based on EUROSTAT data) to derive the total amount of protein intake for each country and time interval. This results in a total reduction of annual animal protein intake between now (2021) and the projected dietary choices in 2050.
Each percentage of reduction than equals 0.3% ACM risk reduction from the previously discussed assumed inverse relationship. This means that we estimate the relative ACM risk reduction of an average person that reduced her animal protein intake by the same amount over one year as suggested by the projections over 29 years.

Although we calculated the country-specific and accumulative specific results over each decade (shown in the Annex), we decided to limit our interpretation to the range of effects across all five FULFILL countries and to the arithmetic mean value of this range as our best educated guess for the impact across all countries in the European Union.
This decision to use the average value instead of any type of clustering or weighting has two reasons. First, the available sample of countries is too small to derive any cultural similarities or dissimilarities in regard to nutritional behaviour in other countries. Secondly, using the size of the population, or other public available socio-economic data for EU countries, could very well misdirect the interpretation of results, because there is no reason to assume that dietary preferences correlate with any of these metrics to a significant degree. We thus decided that using the mean value does in fact provide the best basis to interpret the results, as it does not depend on additional ad-hoc assumptions.
It is also important to clarify that this method assumes that reductions in protein from meat directly correlate to average reductions in ACM risk (anticipating higher or lower reductions depending on the type of diet a person adopted before). The results therefore do not account for other factors that may influence health outcomes, such as the nutritional value of different meats, the impact of other dietary components, or individual health conditions. It is also not clear from the empirical evidence alone that a reciprocal relationship is a valid and sound assumption in the first place.

Relationship between mobility performance, pollutant emissions and pollutant concentration

We obtained data on the mobility performance of cars over time from D5.3 datasets for both SMs ('Car-Sizing' and 'Cycling') as well as the size and types of cars in stock contributing to this performance for 'Car-Sizing'. Since we do not have any further information, we also have to assume that the cars that drive today are the same cars predicted to drive in the future.
If that is the case, then average pollution intensities (g air pollutant per km) can play the role of a multiplier in a simple linear relationship between mobility performance and emission of pollutants. We further decided to restrict our results to exhaust emissions of PM 2.5 (fine particular matter with particles that are 2.5 microns or less in diameter), as this pollutant is expected to distinctly different

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degrees for different powertrains (and non-existent as exhaust emission for batter-electric vehicles or BEVs). We thus exclude other forms of pollutants and other forms of PM 2.5 non-exhaust emissions such as PM 2.5 emissions from tire abrasion.

We obtained emission intensity data (PM 2.5 emissions per car type and car size) from the EEA guidebook for road transport (EEA, 2024). This allowed us to multiply the PM 2.5 intensity of car types (powertrain and size) with the car performance (in km per year) in the input data for every given time interval and FULLFILL country (summarized as stock model in the input data from D5.3). The resulting total PM 2.5 emissions can directly be attributed to SM-2 on 'Car-Sizing'.

For SM-8 on 'Cycling' an additional step has to be taken, since the composition of cars changes over time. The isolated effect (upper bound) stems from reduced car performance over time compared to the fuel type and car size composition depicted for the starting point of 'Car-Sizing'. This effect is stronger, because it assumes that the current stock of cars is also representative of the stocks in 2050. Conversely, the integrated effect of 'Cycling' (lower bound of PM 2.5 reductions) accounts for these changes from the predictions for 'Car-Sizing'. This effect is weaker, because the reductions in car performance over time are compared to a stock model of cars that increasingly emits less pollutants per km over time.

Both the separate effects and the integrated, or accumulative, effects are understood as indicators for Outputs. The total change in PM 2.5 between the starting and end year thus also results in relative reductions of tailpipe PM 2.5 emissions from cars.

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3. Impact Assessment for Health

3.1. Definition of societal goal

Health goals and targets are addressed by both the United Nations and the European Union[15]. 'Health' benefits are usually understood to encompass more than merely the absence of disease and often also highlight the necessity of adequate health services. We adhere to the third Sustainable Development Goal (SDG 3) of 'Good Health & Well-Being' for our definition of the impact 'Health' benefits from sufficiency:

> *" Goal 3. Ensure healthy lives and promote well-being for all at all age (United Nations, 2015)".*

T6.3 in FULFILL mainly investigates **tangible** societal benefits as a consequence of interventions. In this sense, it is sufficient to address 'Good Health' in terms of physical and mental well-being or rather – the improvement thereof. We therefore apply the logic of national indicators for sub-goals in SDG 3 to identify desired long-term changes as necessary causes for a contribution to the overarching goal (such as targets for lower obesity rates in a country). This is shown in the next section.

3.2. Initial shortlink ToC

The following Figure 7 depicts the initial ToC for the Impact 'Health' benefits. Only five out of eight SMs are initially assumed to be able to contribute to this goal: SM-5 (Eating Less Meat & Dairy); SM-10 (Working Less); SM-8 (Cycling); SM-2 (Car-Sizing); SM-6 (Car-Pooling). These five measures are all associated with "lower morbidity rate or mortality rates in a country" (r_A).

This persistent desired change comes about by means of four different causal mechanisms, of which three are restricted to the target groups themselves and one is assumed to impact a regional level (reducing air pollution in a region). The SMs cause these mechanisms in form of six different Outputs and seven hypotheses overall. Although SM-8 (Cycling) and SM-10 (Working Less) are associated with two hypotheses each, these causal pathways are not necessarily accumulative, because the different individuals could be affected by only one intervention.

No pre-condition was identified from the outset. However, this initial ToC has already gone through several iterations to identify plausible causal pathways in the first place (based on our initial screening of the literature).

[15] The European Health Strategy for example defines 'Good Health' as "a state of physical and mental well-being necessary to live a meaningful, pleasant and productive life. Good health is also an integral part of thriving modern societies, a cornerstone of well performing economies, and a shared principle of European democracies" (European Commission, 2004, p. 5).

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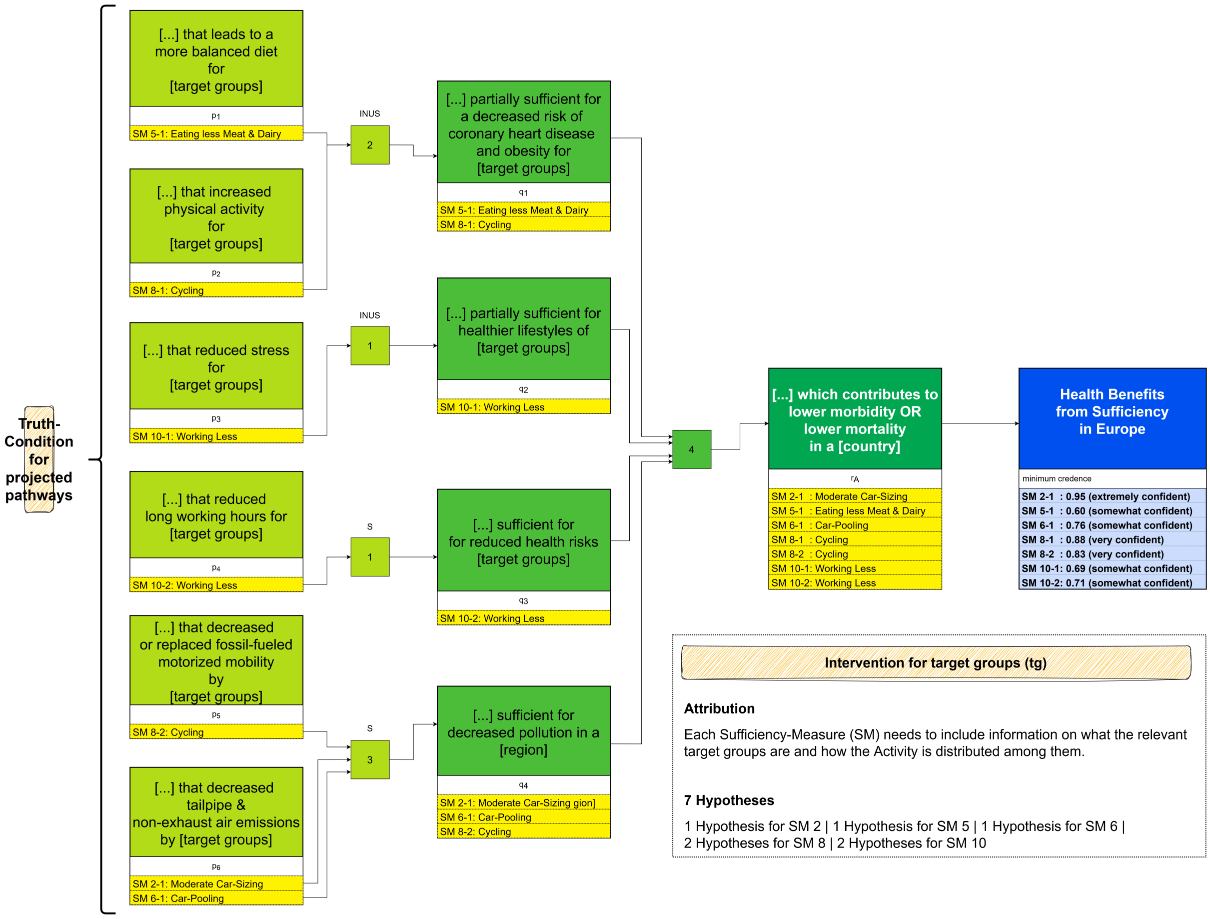
Figure 7: Theory-of-Change (before causal assessment)
(for 'Health' benefits from Sufficiency Measures (SMs))



Source: own development

3.3. Credibility Assessment

The main section of this chapter is concerned with the plausibility of the causal hypotheses depicted in the shortlink ToC. This assessment is conducted in line with the 3-stage Bayesian argument discussed in the methodology (see section 2.3). There are seven causal hypotheses to be considered (one for each Longterm Outcome q and each Output p).

SM-2: Moderate Car-Sizing

H_{SM2_1}: $p_6 \wedge q_4 \rightarrow r_A$

> *Decreased tailpipe and non-exhaust air emissions from moderate car-sizing is sufficient for decreased pollution in a region, which contributes to lower morbidity or mortality rates in a country.*

Table 9: Credence for HSM2_1

Step	Reasoning	Credence
Priors cr (H|b); cr (¬H|b)	<u>Background knowledge b:</u> b_1: Private car use is associated with negative health outcomes including inactivity, obesity, death and injury from crashes, cardio-respiratory disease from air pollution and noise (Douglas et al., 2011). For example, even short-term exposure to NO_2 of several hours per day is associated with increases in all-cause mortality as well as a variety of respiratory and cardiovascular effects (Rojas-Rueda & Turner,e 2015). b_2: Diesel cars have been emitting four to seven times more NO_x in on-road driving than in type approval tests. It is estimated that 50%	cr (H.b) ≈ 0.80 – 0.95 cr (¬H.b) = 0.20 – 0.05

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Step	Reasoning	Credence
	of premature deaths (from $PM_{2.5}$ and ozone in adult population) could have been avoided if diesel limits had been achieved and 80% if diesel cars emitted as little NO_x as petrol cars (Jonson et al., 2017). b_3: A large portion of emissions of particular matter (PM) is mainly caused by tyres and brake trains and is thus independent of power-trains (Sisani et al., 2022). It is estimated that almost 50% of these non-exhaust emissions (affecting battery-electric vehicles also) can be attributed to these causes (Rojas-Rueda & Turner, 2015). b_4: If a car drops 10% of its weight, its fuel efficiency increases by 3% to 8% (with the higher value corresponding to reducing engine size as well) (Wenzel, 2008). Smaller and slower cars are generally associated with lower mass and thus lower fuel-use and air pollution as a consequence (Moriarty & Honnery, 1999). <u>Assessment:</u> It is trivially true that motorized vehicles, and fossil-fuelled vehicles in particular, are associated with air pollution and that this air pollution leads to negative health outcomes in regions (b_1; b_2). It is also general knowledge, that vehicles are a main contributor to crashes with other vehicles, bicycles, and pedestrians. **It follows that any reduction in air emissions from car-use (including emissions from tyres and brakes) should lead to health benefits (b_1; b_3). It stands to reason that smaller cars weigh less and usually have smaller engines. Opting for a smaller car should therefore lead to lower harmful air emissions from lower weight, speed, and fuel consumption (b_4).** There are, of course, other influencing factors for reducing air pollution from traffic such as the choice in powertrain and the alternative use of non-motorized vehicles in general. However, none of these alternative explanations for potential health benefits negate potential and sufficient benefits from moderate car-sizing. A more plausible non-true proposition ¬H is therefore that the benefits from lower air pollution from smaller cars are outweighed by an increased risk of accidents for or from drivers of smaller vehicles (assuming for example that sport-utility vehicles are safer for both drivers and society). We find that such a non-true hypothesis is possible but less likely than our main proposition. However, not having this information decreases our credence in H from being *extremely probable* true to *very probable* true.	
Consequents cr (E|H.b); cr (E|¬H.b)	<u>Evidence e:</u> e_1: Lightweighting in diesel vehicles is an important measure for improving traffic emissions that would otherwise have to be achieved by the force substitution by new vehicles. This measure alone could significantly contribute to the reduction of PM_{10} concentration from road traffic (Cecchel et al., 2018). e_2: Smaller vehicles have less mass and, as a result, are less lethal when a crash occurs. Smaller vehicles also allow drivers to avoid crashes in the first place due to their better manoeuvrability and sightlines (Chiarenza et al., 2018). Sport-utility vehicles (SUVs), pickup trucks and minivans are found to be more protective for their drivers and more harmful to the other driver in two-vehicle collisions (Fredette et al., 2008). SUVs and pickups in particular represent a disproportionate danger to other road users, particular pedestrians and drivers of conventional cars (Saylor, 2021). <u>Assessment:</u> An intensive literature research did not reveal any direct evidence for the proposition, since most of the recent research seem to focus on either GHG emissions, diesel vehicles, alternative modes of transport or alternatives in powertrains. This *silence* on the evidence	cr (E|H.b) ≈ 0.99 cr (E|¬H.b) ≈ 0.20 – 0.05

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Step	Reasoning	Credence
	is not surprising to us though and thus should not count in favour or against any of the hypotheses[16]. Looking at the available evidence given the main hypothesis, it is *fully expected*. By comparison, evidence e_1 is *fully expected* (¬H allows for reduced air pollution from smaller vehicles), but e_2 is *very surprising* (larger cars are less safe for society) under the most plausible non-true proposition (negative health outcomes from lower safety for smaller vehicles outweigh health benefits from lower pollution). **We conclude that H predicts the evidence, whereas ¬H does not. This should raise our credence in the main hypothesis to a large degree.**	
Posterior	Assessment: The evidence confirmed our initial credence that was high to begin with. As a consequence, we are at best *certain*, and at least *extremely confident* in H.	cr (H|E) ≈ 0.95 – 0.99

SM-5: Eating Less Meat & Dairy

H_{SM5_1}: $p_1 \wedge q_1 \rightarrow r_A$

A more balanced diet from a reduced intake of meat and dairy products is partially sufficient for a decreased risk of coronary heart disease and obesity of the target groups, which contributes either to a lower morbidity or mortality rate in a country.

Table 10: Credence for HSM5_1

Step	Reasoning	Credence
Priors cr (H|b); cr (¬H|b)	Background knowledge b: b_1: Increased amounts of red meat, and in particular processed meat, are associated with increased risks of total mortality, cardiovascular disease, colorectal cancer and type 2 diabetes (Battaglia Richi et al., 2015; Xie et al., 2022; Zhong et al., 2020). b_2: Processed meat is negatively associated with dietary quality, but consumers of red meat have relatively high intakes of micronutrients (Cosgrove et al., 2005). b_3: Reducing meat intake completely is likely to show negative health effects and shortcoming in nutrients (Seves et al., 2017; Xie et al., 2022), but a balanced vegetarian diet will have no significant negative health effects (Marsh et al., 2012). b_4: High dairy consumption shows no risk for CVD (Givens, 2018) and there is insufficient evidence that increased dairy consumption is associated with weight status (Louie et al., 2011). b_5: There is in fact evidence that exceeding recommendations for consumption of dairy products in combination with health dietary patterns improves the health status Rice et al., 2013) Assessment: Given our background knowledge, the hypothesis is not fully expected. It is even somewhat likely (b_3; b_4; b_5) that strongly decreasing the intake of animal products (in particular dairy products) will have no health benefits or that health benefits that occur have other explanations (such as overall healthier lifestyles or balanced diets without changes to the overall intake of animal products). **However, given the strong indication of negative health effects from increased red and processed meat intake (b_1; b_2), we still find the initial hypothesis at least to be *probable* true.**	cr (H.b) ≈ 0.6 – 0.8 cr (¬H.b) = 0.4 – 0.2
Consequents	Evidence:	cr (E|H.b) ≈ 0.5 – 0.6

[16] Teubler (2024) discusses in which cases such arguments from silence affect Bayesian credences and the robustness of the assessment. It corresponds to the truism that "absence of evidence is not necessarily evidence of absence".

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Step	Reasoning	Credence
cr (E|H.b); cr (E|¬H.b)	e_1: Long-term vegetarians show an improved CHD risk profile (Szeto et al., 2004) or even lower mortality (Orlich et al., 2013) and benefits on weight- reduction (Pilis et al., 2014) compared to non-vegetarians. Vegetarians and vegans have also significant reduced levels of body index and significant reduced risk of incidence and/or mortality from ischemic heart disease (but not of total CVD) (Dinu et al., 2017). e_2: Improperly applied vegetarian diets can lead to lower levels of Vitamin B12, which is associated with cardiovascular morbidity, a reduction in the blood levels of sex hormones and disruption of the menstrual cycle (Pilis et al., 2014). e_3: Replacing 25-50% of animal-derived foods with plant-based foods on a dietary energy basis lowers health risks from reduced intake of saturated fats and red meat (Westhoek et al., 2014). e_4: Although replacing red meat with vegetables or potatoes is associated with a lower risk of myocardial infarction (MI), replacing fatty fish with vegetables or potatoes is associated with a higher risk of MI (Würtz et al., 2016). It also remains unclear if the absence of red meat or the variety of food in a vegetarian diet is reducing diet related diseases (McEvoy et al., 2012). Moreover, the correlation between meat intake and health has not adequately been proven and often lacks clear scientific understanding (Klurfeld, 2015). e_5: There is no increase in risk of CVD per unit of increase in milk and cheese consumption, but a significant reduction in risk of stroke (Givens, 2018); dairy intake may even have a role in CVD risk reduction (Alexander et al., 2016). Assessment: Under the main hypothesis, reductions of all types of animal products lead to persistent health benefits if the diet remains or becomes "balanced". This is fully expected (~100%) on e_1 and e_3, but somewhat surprising on e_4 and very surprising on e_5, whereas H seems to be neither expected nor surprising on e_2 (assuming a balanced diet anyway). The most plausible other explanation affected by the evidence would be changes towards a balanced diet without reducing the overall intake of animal products, e.g. by replacing red meat with fish. The hypothesis that such a diet leads to the same or similar health benefits is fully expected on e_4 and e_5. It is extremely surprising under e_1 and at least very surprising under e_3. Again, under e_2 it is neither expected nor surprising (making it in fact no evidence in favour or against any hypothesis). **The evidence therefore strongly favours H over ¬H (cr (E|H) > cr (E|¬H)) assuming a best-case scenario and neither favours any explanation if assuming a more conservative credence assessment (lowest cr for each E|H and highest cr for reach E|¬H)**.	cr (E|¬H.b) ≈ 0.5 – 0.6
Posterior	Assessment: Given both our prior assessment based on our background knowledge and our consequent assessment based on the available evidence, we can – at best – be *extremely confident* in H. However, assuming our most conservative estimates, we are at least *unsure* about H. This wide range reflects the ambiguity of the evidence found in literature.	cr (H|E) ≈ 0.60 – 0.99

SM-6: Car-Pooling

H_{SM6_1}: $p_6 \wedge q_4 \rightarrow r_A$

Decreased tailpipe and non-exhaust air emissions from car-pooling is sufficient for decreased pollution in a region, which contributes to lower morbidity or mortality rates in a country.

Table 11: Credence for HSM6_1

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Step	Reasoning	Credence
Priors cr (H|b); cr (¬H|b)	<u>Background knowledge b:</u> b_1: Private car use is associated with negative health outcomes including inactivity, obesity, death and injury from crashes, cardio-respiratory disease from air pollution and noise (Douglas et al., 2011). For example, even short-term exposure to NO_2 of several hours per day is associated with increases in all-cause mortality as well as a variety of respiratory and cardiovascular effects (Rojas-Rueda & Turner, 2015). b_2: A large portion of emissions of particular matter (PM) is mainly caused by tyres and brake trains and is thus independent of powertrains (Sisani et al., 2022). It is estimated that almost 50% of these non-exhaust emissions (affecting battery-electric vehicles also) can be attributed to these causes (Rojas-Rueda & Turner, 2015). <u>Assessment:</u> In line with our previous assessment for SM2_1 (smaller and slower cars leading to societal health benefits), we have general background knowledge on the harm of air pollution and accidents from motorized vehicles. It therefore also follows that any reduction in air emissions from car-use (including emissions from tyres and brakes) should lead to health benefits (b_1; b_2). In the case of car-pooling, it is expected that the overall amount of car-use is reduced (H_{SM6_1}) rather than the specific pollution from cars (H_{SM2_1}), since more people share the same car that *could have* used individual cars instead for the same way. Moreover, we can logically predict that for any type of car-sharing that entails cases of carpooling, the effects for carpooling are more pronounced since only the latter requires more than one person per trip. The most plausible non-true hypothesis ¬H in our opinion alludes to the fact that car-pooling does not necessarily reduce car-use from the occupants in the car. Some co-drivers might not own a car in the first place and some drivers might had opted for alternative modes of transport without these co-drivers (e.g., due to lack of fuel-cost savings). Moreover, the option to car-pool might also encourage longer driving distances or encourage persons to relocate farther away from locations of work. We find that such a non-true hypothesis is plausible and should at least occupy some portion of the possibility space. However, we also find it to be less likely than the main hypothesis looking at the background knowledge alone. Not having this information thus decreased our credence in H from being *extremely probable* true to merely *probable* true.	cr (H.b) ≈ 0.60 – 0.80 cr (¬H.b) = 0.40 – 0.20
Consequents cr (E|H.b); cr (E|¬H.b)	<u>Evidence e:</u> e_1: Car-pooling is associated with reduced vehicle miles travelled, reduction in fuel consumption and thus reduction in adverse air pollution impacts on low-income, and other environmental justice populations (Shaheen et al., 2018). However, traffic reduction from carpooling is mitigated by rebounds from mode switching, distance and relocation effects (Yin et al., 2018). e_2: Persons that use car-sharing usually drive less, but also shift to other modes of transport, which constitutes a rebound effect. As a result, car-sharing rather than private driving does not lead to lower GHG emissions if the total demand for per-person kilometre travelled (PKT) remains constant (otherwise it does). Given a constant PKT, ride-sharing or carpooling behaviour leads to more significant reduction in per-PKT and thus total car emissions (Amatuni et al., 2020). e_3: One study finds that factors such as number of employees, partner matching programmes, and fixed work schedule have a strong effect on carpooling, whereas judgemental factors (such as motivation to save costs) only have a small influence on the likelihood of carpooling (Neoh et al., 2017). By contrast, another meta-study comes to the conclusion that judgemental factors, such as fuel prices, have	cr (E|H.b) ≈ 0.50 (1*1*0.5) cr (E|¬H.b) ≈ 0.24 – 0.20 (0.5*0.5*0.95) to (0.5*0.5*0.80)

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Step	Reasoning	Credence
	become more important in recent years for the choice to carpool (Olsson et al., 2019). Assessment: We find that e_1 and e_2 are *fully expected* under the main hypothesis (predicting net reduction in car-use from car-pooling). The fact that judgemental factors play no major but an increasing role in car-pooling choices (e_3) is not fully expected. Moreover, this also entails that environmental judgements play no significant role, which in turn is *neither expected nor surprising* for e_3 on H. The total body of evidence therefore has a likelihood of 50%. The most plausible non-true proposition ¬H predicts unintended rebound effects that overcompensate the health benefits from reduced car-driving. Under this hypothesis, e_1 and e_2 are not fully expected but still *neither expected nor surprising* (there are rebounds but they do not negate the net benefits on average). Evidence e_3 suggests that environmental concerns play no major role in the decision to car-pool. Thus, we have no reason to assume that persons that car-pool have any intention to reduce their overall car-driving and any individual benefit might be incidental. However, we find e_3 to be *very likely* under ¬H rather than *extremely likely*, given the fact that judgemental factors play at least an increasing role in decisions for carpooling. The total evidence therefore has a likelihood between circa 20% and 25%. **Comparing the consequents for both hypotheses let us conclude that two pieces of evidence are clearly in favour of H, but one piece of evidence is more likely on the alternative explanation. When weighing the evidence together, we find that the overall body of evidence is more likely under H than ¬H.**	
Posterior	Assessment: The evidence confirmed our initial credence in a hypothesis that we initially thought to be at least *probable*. As a consequence, we are at best *very confident*, and at least *somewhat confident* in H.	cr (H|E) ≈ 0.76 – 0.91

SM-8: Cycling

H_{SM8_1}: $p_2 \wedge q_1 \rightarrow r_A$

Increased physical activity from cycling is partially sufficient for a decreased risk of coronary heart disease and obesity for target groups, which contributes to a lower morbidity or mortality rate in countries.

Table 12: Credence for HSM8_1

Step	Reasoning	Credence
Priors cr (H|b); cr (¬H|b)	Background knowledge b: b_1: Active transportation (including cycling) is positively associated with lower obesity Flint et al., 2014). Physical activity in general reduces Disability Adjusted Life Years (DALYs) Woodcock et al., 2013) and existing physical activity prevalence has contributed to averting premature mortality (Strain et al., 2020). However, it is also associated with poverty, which in turn can increase obesity rates and other health problems (Chaufan et al., 2015). b_2: Most cycling related research and politics focuses on urban areas (Kircher et al., 2022). b_3: Decreased motorised mobility from increased cycling or walking reduces air pollution in societies Buekers et al., 2015) but may lead to increased individual exposure during active mobility (AM) WHO, 2021). b_4: Fatal injury rates in the US are highest for motorcyclists, pedestrians, and bicyclists, whereas nonfatal traffic injury rates are highest for motorcyclists and bicyclists (Beck et al., 2007). Cycling in rural areas is associated with considerable shares of cyclist fatalities and	cr (H.b) ≈ 0.4 – 0.6 cr (¬H.b) = 0.6 – 0.4

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	there is a trend that cyclist crashes in rural areas have a higher likelihood of ending in the death of the cyclists (Kircher et al., 2022). Assessment: Given this background knowledge b, it seems at least plausible that an increase in cycling leads to health benefits in a country (and extremely likely for the intermediate Outcome alone). It is both trivially and empirically true that an increase of active transportation comes with direct health benefits (b_1). However, it is unclear from the background knowledge alone whether (i) this benefit entails lower risks of cardiovascular diseases as well as (ii) outweighs the increased risks for accidents (b_4) and (iii) from additional exposure to pollution (b_3). The most plausible non-true hypothesis would thus entail that additional cycling leads to net negative health effects for a society as a whole. It is also unclear whether any potential net effects are somewhat skewed due to the focus of the research on urban areas (b_2). This ambiguity as well as the fact that active transportation modes are associated with poverty which in turn is associated with adverse health effects (b_1), lets us conclude that our initial credence is neither in favour nor against the hypothesis (no judgement).	
Consequents cr (E|H.b); cr (E|¬H.b)	Evidence: e_1: Walking and cycling reduce the risk of all-cause mortality Oja et al., 2011; Rojas-Rueda et al., 2016). Cycling is associated with lower risks of cardiovascular diseases (Celis-Morales et al., 2017) and there is a U-shaped association between cycling and lower CVD mortality with an optimum at 130 min/week of cycling (Zhao et al., 2021). People also lower their BMI when starting or increasing cycling (Dons et al., 2018). e_2: Larger cycling networks in cities would contribute to avoided premature deaths from additional cycling activity (Mueller et al., 2018) and health benefits from cycling are larger than risks relative to car driving and pollution (De Hartog et al., 2010; Mueller et al., 2018). e_3: There is no significant difference in prevalence for cycling in urban compared to rural areas in the United States (Tribby & Tharp, 2019). e_4: Changes in transport modes from car-travel to cycling are associated with small health benefits for the general population, but slightly increased health risks among those who shifted to cycling (Raza et al., 2018). Assessment: Given the evidence conditioned on the hypothesis, it is fully expected on e_1, e_2 and e_4 whereas the presence of e_3 is neither expected nor surprising under the assumption that there are overall net benefits for a country if the target groups increase their cycling activity. Given the most plausible alternative hypothesis that the overall net effects are negative, e_1 is neither expected nor surprising on ¬H (since it still allows for some individual health benefits), but at least very surprising on e_2 (benefits outweigh the risks). On e_4, it is indeed still very likely but less under ¬H than under H (since H predicts overall net benefits). Evidence e_3 is also silent on ¬H (*neither expected nor surprising*), but would have been influenced by ¬e_3, since exposure to pollution is a major contributor to negative health effects and this exposure is higher in rural areas. **Thus, the evidence clearly favours the main hypothesis over the most plausible alternative (cr (E|H) >> cr (E|¬H)).**	cr (E|H.b) ≈ 0.5 (1*1*1*0.5) cr (E|¬H.b) ≈ 0.05 – 0.01 (0.5*0.2*0.5*0.95) to (0.5*0.05*0.5*0.8)
Posterior	Assessment: Given both our prior assessment based on our background knowledge and our consequent assessment based on the available evidence, we can at least be (lower bound) *very confident* and at best be (upper bound) *extremely confident* (cr = 0.99) that H is true.	cr (H|E) ≈ 0.88 – 0.99

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H_{SM8_2}: $p_5 \wedge q_2 \rightarrow r_A$

Decreased OR replaced fossil-fueled motorized mobility from cycling is sufficient for decreased pollution in a region, which contributes to a lower morbidity or mortality rate in a country.

Table 13: Credence for HSM8_2

Step	Reasoning	Credence
Priors cr (H|b); cr (¬H|b)	<u>Background knowledge b:</u> b_1: Decreased motorised mobility from increased cycling or walking reduces air pollution in societies (Hurley et al., (2005) in Buekers et al., 2015;) but may lead to increased individual exposure during active mobility (AM) (Götschi et al., 2016; WHO, 2021). Decreasing car-trips leads to lower urban PM concentrations contributing to lower mortality rates (Grabow et al., 2012). b_2: It is unclear whether interventions promoting more active transport behaviour (such as cycling) also lead to a reduction in car-travel or frequency; some literature reviews find positive effects (Scheepers et al., 2014) and others find no evidence for that (Arnott et al., 2014). b_3: The provision of cycling and pedestrian infrastructures is not sufficient for a modal shift from car travel to non-motorized mobility, but it is a necessary condition for that (Y. Song et al., 2017). b_4: Childbirth, job change, and a longer commute increase the probability of stopping to cycle, while residential relocation, job change, and getting a shorter commute are associated with a shift toward cycling (A. M. Oakil et al., 2011; A. T. M. Oakil et al., 2016). <u>Assessment:</u> Looking at our background knowledge, it is trivially true that bicycles do not cause end-of-pipe air emissions and that conventional fossil-fuelled vehicles do. It therefore follows that a reduction of conventional driving as a consequence of increased cycling decreases pollution and it is also trivially true that exposure to such pollution is not beneficial to the health of exposed persons (b_1 but also general knowledge). However, looking at the specific background knowledge depicted here, it is unclear whether the promotion of active transport modes also leads to a reduction in car-travel or frequency (b_2). Changes to infrastructures can be a necessary condition for such a change (b_3) but are not sufficient to do so (with the latter being not considered by the hypothesis). Regardless of some potential positive relationship for some policies, there is evidence that modal shifts towards cycling are also associated with independent variables such as the distance to work, time demand for commuting and childbirth (b_4). Moreover, even if there is a modal shift from car-travel, it can be partially the result of a shift towards other types of transport (public transport, e-scooters, etc.). We therefore find the hypothesis to be plausible under the assumption that additional cycling is in a causal relationship with a decrease in car-use (the truth-condition from T5.3). However, we also reduce our prior credence due to alternative explanations for reductions in fossil-fuelled vehicle use. Considering that such explanations can very well occupy a significant portion of the probability space, we consider the hypothesis to be *probable*, but not in any way *certain* before looking at the evidence.	cr (H.b) ≈ 0.6 – 0.8 cr (¬H.b) = 0.4 – 0.2
Consequents cr (E|H.b); cr (E|¬H.b)	<u>Evidence e:</u> e_1: Persons that use bike-sharing programs have been found to draw from all transport modes in terms of a modal shift, including personal driving and taxi use (S. Shaheen et al., 2013). Policies that promote bicycle sharing programs were also shown to be effective to improve the modal shift towards cycling (Fuller et al., 2013). e_2: (i) Reducing air pollution, e.g. from reducing traffic, can result in prompt and substantial health gains (Schraufnagel et al., 2019). (ii) Higher shares of cycling (compared to car-travel) reduce mortality rates from decreased pollution (Buekers et al., 2015; Rodrigues et al., 2020), but the health benefits for the cyclists from the actual	cr (E|H_R.b) ≈ 0.64 – 0.90 (1*0.8*0.8*1) to (1*0.95*0.95*1) cr (E|¬H_R.b) ≈ 0.20 – 0.05 (overall estimate)

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Step	Reasoning	Credence
	physical activity are a lot stronger and better evidenced (Buekers et al., 2015). (iii) There is evidence that changes in transport modes from car-travel to cycling are associated with small health benefits for the general population, but they also slightly increase health risks among those who shifted to cycling (Raza et al., 2018). e_3: Modal shifts from car-travel to cycling lead to an increase of road injuries but not to an increase in fatalities, since the additional accidents do not involve other vehicles (Schepers & Heinen, 2013). e_4: The travel mode choice is influenced by numerous factors such as travel satisfaction, travel mode attitude, desired mode use and intended mode use. However, it can also influence these factors (resulting in a circular relationship between all factors) and may depend on several indirect variables such as habit or opportunity and constraint (De Vos et al., 2022). Assessment: Looking at the evidence in favour of H, e_1 and e_4 are fully expected. The indication of higher personal risks for the cyclist on e_2 and e_3, are not surprising (since H predicts overall net benefits for society) but are not fully expected either. Nonetheless, we think that this evidence is still at least very likely under H. The most plausible explanation for ¬H is that some portion of the population that decreased their car-usage did so independent of their change in cycling behaviour (such as shorter home-work distances after a re-location). This does not lead to a different consequent probability for ¬H though, since this case predicts any type of reductions in car-use with the same or different rates of cycling (e.g. walking or cycling to work, but also driving shorter distances due to relocations). However, given the hypothesis that cycling *replaces* car-use (disjunct in H considered as H_R), alternative transport modes or mere reductions in car-use are no longer entailed in the probability space. In this case, the only relevant alternative explanation $\neg H_R$ is that at least some portion of the target group mainly wanted to reduce its car-use and ended up cycling as the preferred mode of travel. This reverses the cause-effect relationship at the start of the impact-chain but does not contradict the remaining pathway (replaced car-travel decreasing pollution and thus leading to health benefits for society). It is also fully expected on e_4 independent of the causal direction in each single case. We therefore find that the body of evidence is at least very surprising under any alternative hypothesis not entailed by H_R, if we restrict the assessment to target groups that exchanged car-travel with cycling. One such potential explanation could be that *all health benefits* are the consequence of upholding H_{SM8_1} (direct benefits to cyclists), but this would be very surprising under e_2.	
Posterior	Assessment: We found the hypothesis plausible from the start, but lowered our prior due to the plausibility of other explanations for car-use reduction that could happen to coincide with an increase in cycling. The initial assessment of the consequent did not change this credence on its own, but it allowed to analyse the two distinct different causal pathways. As a consequence, we found that societal health benefits from *replacing* fossil-fuelled car travel with biking (rather than mere reductions of car travel) as a truth-condition, is indeed fully supported by the evidence and less likely under any alternative explanation that is not already entailed by this condition or H. We can therefore be at least *very confident* (lower bound) or at best *extremely confident* (upper bound) in H_R.	cr $(H_R\|E) \approx 0.83 - 0.99$

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SM-10: Working Less

H_{SM10_1}: $p_3 \wedge q_2 \rightarrow r_A$

Reduced stress from working less is partially sufficient for healthier lifestyles of target groups, which contributes to lower morbidity or mortality rates in a country.

Table 14: Credence for HSM10_1

<table>
<tr>
<td>Priors
cr (H|b);
cr (¬H|b)</td>
<td><u>Background knowledge b:</u>
b_1: Stress is associated with negative physical and mental health outcomes, both directly and indirectly (Huang et al., 2013; O'Connor et al., 2021). The negative physical health impacts of psychological stress include a higher risk for CVD (Huang et al., 2013).
b_2: High work-load is one of the main causes of work-related stress (Blaug et al., 2007; Kortum, 2011).
b_3: There is a positive impact of healthy lifestyle behaviours on the association between perceived stress and self-rated health (Nordgren et al., 2022). There is also experimental support that physical activity buffers the effects of stress on general and mental health (Klaperski & Fuchs, 2021).
b_4: Employees in high-strain jobs (i) do less exercise, although (ii) they do not intend to do so (Payne et al., 2002).
b_5: Job stress is an important contributor to occupational injuries (Soori et al., 2006) and excess mortality (in particular from cardiometabolic diseases) is higher for persons with job strain (Kivimäki et al., 2018).
<u>Assessment:</u>
The available background knowledge mainly attests to a relationship between work-related stress and negative health outcomes. Job stress is also seen as an important contribution to occupational injuries and excess mortality (b_5).
It is therefore plausible to assume that reduced working time reduces stress due to a healthier lifestyle (b_2; b_4) and contributes to health benefits (b_1), although healthier lifestyles could also be the cause of reduced stress rather than an effect of working less (b_3).
The most plausible alternative proposition would be that such a positive relationship is restricted to persons with high job strain only (b_5), but such an explanation would be undistinguishable from the sample of all persons with work-related stress ($H_{job\ strain} \subset H$). A non-true hypothesis therefore has to assume either that (a) stress and working hours are not causally related, that (b) healthier lifestyles do not lead to health benefits, or that (c) any relationship between stress and health outcomes is merely a correlation caused by other circumstances.
We find any of these propositions to be less probable than the main hypothesis given our background knowledge. The least surprising, but still improbable, proposition is that only other factors than stress reduction are sufficient or necessary for a healthier lifestyle ($\neg H_c$). This leads us to believe that H is at least probable.</td>
<td>cr (H.b) ≈ 0.6 – 0.8
cr (¬H.b) = 0.4 – 0.2</td>
</tr>
<tr>
<td>Consequents
cr (E|H.b);
cr (E|¬H.b)</td>
<td><u>Evidence:</u>
e_1: There is a positive relationship between work-time reductions and working life quality, sleep, and stress reduction (Barck-Holst et al., 2021; Voglino et al., 2022).
e_2: There is a positive relationship between work-time-reductions (WTRs) and health benefits (including mitigation of health and respiratory symptoms), if WTR is accompanied by wage compensation. WTRs to a larger extent is also more strongly associated with these benefits than WTRs to a lesser extent (Hanbury et al., 2023).
e_3: WTR induce individuals to exercise regularly and decrease the likelihood of smoking, whereas it does not significantly affect the likelihood of frequent or daily drinking habits (Ahn, 2016).
e_4: Working long hours is related to circulatory hearth diseases, a depressive state, feelings of anxiety and reduced sleep quality. Additionally, an increase in working hours has been found to be related</td>
<td>cr (E|H.b) ≈ 0.006 – 0.064
(1*0.2*1*1*0.6*0.05) to (1*0.4*1*1*0.8*0.2)
cr (E|¬H.b) ≈ 0.004 – 0.00006
(0.2*0.5*0.2*0.2*1*1) to (0.05*0.5*0.05*0.05*1*1)</td>
</tr>
</table>

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	to an unhealthier lifestyle, including smoking, alcohol consumption and weight gain (Spiegelaere & Piasna, 2017). e_5: Higher mortality is associated with job strain in the presence of a weak sense of coherence, whereas the link between work stress and mortality is not significant in the presence of a strong sense of coherence (Nilsen et al., 2016). e_6: Risk of all-cause mortality is associated with low job control, whereas high job demands, job strain and shift work are not associated with it (Taouk et al., 2020). <u>Assessment:</u> The evidence is fully expected to be present for e_1, e_3 and e_4 under H as they are all predicted by the hypothesis. We find e_5 still *somewhat likely* since this could very well be an additional cause for work-related mortality. However, e_2 is *somewhat surprising* because it describes a non-predicted necessary component. Evidence e_6 is *very surprising* under H, because it specifically excludes high job demands and shift work as risks of mortality (although it is silent on morbidity). Conversely, we find that only e_5 and e_6 are fully expected under $\neg H_c$, as these provide explanations how job conditions affect negative health outcomes regardless of working time. Evidence e_2 is *neither surprising nor expected*, as wage compensation can be merely an additional factor. Evidence e_1, e_3 and e_4 on the other hand are all *very surprising*. Comparing both consequents (3 pieces of evidence very strongly in favour, 2 pieces weakly against and 1 pieces of evidence strongly against H) therefore leads to a clear confirmation in favour of H.	
Posterior	<u>Assessment:</u> The evidence increased our confidence in a main hypothesis that was already found to be plausible. We are at best *extremely confident* (cr = 0.99), and at worst *somewhat confident* in the credibility of the claim (cr = 0.86).	cr (H|E) ≈ 0.69 – 0.99

Source: own assessment

H_{SM10_2}: $p_4 \wedge q_3 \rightarrow r_A$

Reduced long working hours from working less is sufficient for reduced health risks, which contributes to lower morbidity or mortality rates in a country.

Table 15: Credence for HSM10_2

Priors cr (H|b); cr (¬H|b)	<u>Background knowledge b:</u> b_1: In males, long working hours (51-60 hours per week) are associated with poor mental health, hypertension, job dissatisfaction, smoking, shortage of sleep and no leisure-time physical activity (Artazcoz et al., 2009). It is also associated with negative health outcomes for the general population including a higher risk for coronary heart disease (Bannai & Tamakoshi, 2014). Extended work hours are related to an elevated risk of occupational injury (Salminen, 2010) and they are a small risk factor for cardiovascular disease (Virtanen & Kivimäki, 2018). b_2: Long working hours may lead to weight gain from lack of exercise and substituting home prepared meals with fast or pre-processed food (Courtemanche, 2009). b_3: The term "long working hours" is ill-defined in literature (Bannai & Tamakoshi, 2014). <u>Assessment:</u> Given our general background knowledge, it is logically true that working less positively affects individuals' health. Given the specific background knowledge depicted here, it also seems likely that a reduction in working hours for workers with long working hours (the target group) at least negates or mitigates negative health outcomes (b_1; b_2). It is therefore reasonable to assume that "Working Less" would mitigate morbidity and mortality factors such as poor mental health, poor sleeping conditions, lack of physical activity or risks for	cr (H.b) ≈ 0.80 – 0.95 cr (¬H.b) = 0.20 – 0.05

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	heart diseases, even if it is sometimes difficult to ascertain at which point a person works too long (b_3). As a consequence, we find the initial hypothesis to be *very probable* true.	
Consequents cr (E|H.b); cr (E|¬H.b)	Evidence: e_1: A meta-study found four studies with positive effects of work-time reduction on stress, fatigue, exhaustion and similar symptoms, two studies without a clear effect (from only a two-hour reduction) and one study with significant benefits to self-reported health only in women (Hanbury et al., 2023). e_2: Worktime-related means for decreasing the negative health effects of workhours are (i) to regulate overtime and excessive work-hours, (ii) to increase worktime control, and (iii) to increase recovery from shift work (Härmä, 2006). Assessment: Neither e_1 nor e_2 are fully expected under H. However, we find it still *very likely* (for e_1) that there are cases in which worktime reductions have no clear effect and extremely likely (for e_2) that there are other means as beneficial or even more beneficial to health outcomes than worktime reductions alone. The most plausible non-true proposition (¬H) is that not the total amount of work hours is relevant for negative health effect, but the way in which these work hours are regulated. Such an alternative proposition would not be fully expected on e_1 but might be *very likely* as well (resulting for the ratio of consequents to not being in favour or against H). However, e_2 would be fully expected on ¬H, since all three means to decrease worktime-related health issues have additional requirements while also entailing changes to work-time alone. We therefore find that the evidence is slightly in favour of ¬H and thus should slightly reduce our overall confidence in the initial claim.	cr (E|H.b) ≈ 0.48 – 0.76 (0.6*0.8) to (0.8*0.95) cr (E|¬H.b) ≈ 0.8 – 0.6 (0.8*1) to (0.6*1)
Posterior	Assessment: The hypothesis predicts that worktime reductions for persons with long working hours is sufficient for health benefits. Given the fact, that at least one alternative explanation requires additional conditions in some cases, we slightly reduced our initial high credence from the background knowledge alone. However, we are still at least *somewhat confident*, and at best *extremely confident* in H.	cr (H|E) ≈ 0.71 – 0.96

Overview of credibility assessment

The following Table 16 lists all hypotheses and the results of the assessment of their credibility. Our credence is depicted in two ways. The upper bound shows our credence from a favourable point of view. On this end, any type of uncertainty or missing knowledge is not used as an argument against the proposition that these sufficiency measures lead to health benefits. The lower bound on the other hand reflects a more conservative approach. This is our minimum credence that these propositions are true. This is why Table 8 ranks the hypotheses according to their minimum credence, with the hypotheses at the bottom end of the table being the ones that are less likely to be true.

Table 16: Results of the credibility assessment for Sufficiency Measure Hypotheses (HSM_n)

Measure	**Hypotheses**	**cr : lower bound**	**cr : upper bound**
Moderate Car-sizing (H_{SM2_1})	*Decreased tailpipe and non-exhaust air emissions from moderate car-sizing is sufficient for decreased pollution in a region, which contributes to lower morbidity or mortality rates in a country.*	0.95	0.99
Cycling (H_{SM8_1})	*Increased physical activity from cycling is partially sufficient for a decreased risk of coronary heart disease and obesity for target groups, which contributes to a lower morbidity or mortality rate in countries.*	0.88	0.99

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Measure	Hypotheses	cr : lower bound	cr : upper bound
Cycling (H_{SM8_2})	*Decreased OR replaced fossil-fuelled motorized mobility from cycling is sufficient for decreased pollution in a region, which contributes to a lower morbidity or mortality rate in a country.*	0.83	0.99
Car-pooling (H_{SM6_1})	*Decreased tailpipe and non-exhaust air emissions from car-pooling is sufficient for decreased pollution in a region, which contributes to lower morbidity or mortality rates in a country.*	0.76	0.91
Working Less (H_{SM10_2})	*Reduced long working hours from working less is sufficient for reduced health risks, which contributes to lower morbidity or mortality rates in a country.*	0.71	0.96
Working Less (H_{SM10_1})	*Reduced stress from working less is partially sufficient for healthier lifestyles of target groups, which contributes to lower morbidity or mortality rates in a country.*	0.69	0.99
Less Meat & Dairy (H_{SM5_1})	*A more balanced diet from a reduced intake of meat and dairy products is partially sufficient for a decreased risk of coronary heart disease and obesity of the target groups, which contributes either to a lower morbidity or mortality rate in a country.*	0.60	0.99

Source: own development

3.4. Qualitative Assessment

Re-Work of ToC

Credences are considered to be a probabilistic representation of our beliefs and can thus also be interpreted from a frequentist perspective. This means **that a minimum credence of 0.76, as assessed for HSM6_1, represents at least a probability of 76% of being true or – that this claim is at least expected to be true in 76 out of 100 cases.** Credences below 100% (true for every Bayesian Argument that is not a tautology) therefore represent our belief that not all persons that successfully implemented the sufficiency measures contribute to these desired changes towards the end of the ToC.
Every one of the seven hypotheses assessed here is assumed to be true at least in the majority of cases ($cr_{lower\ bound} > 0.5$). We are even *extremely confident* in three of the claims, given that we translated extreme confidence into a credence range above 0.8. However, we are also only *somewhat confident* in four of the hypotheses ($0.6 > cr < 0.8$). While this is, according to our methodology, sufficient for a quantitative estimation of suitable indicators, we can also look for ways to improve the causal configurations in ToC. This can either be achieved by defining additional pre-conditions beyond that systems as they are, or by further specifying the sets of cases in which these propositions are supposed to be true. Either way, this can, and usually will, decrease the overall number of cases for which an indicator will be estimated.
The first adaptation relates to SM-6 on Car-Pooling. The previous ToC merely focused on decreased tail-pipe emissions, but a stronger causal relationship is achieved, if it is based on an overall decreased fossil-fuelled mobility (similar to the causal condition for Cycling). This removes cases for which participants use this option to save mobility costs and switched from other options with an overall lower pollution to achieve that. We now find that, under this causal pathway, the upper bound of confidence of “very confident” is justified.
Two additional adaptations relate to SM-10 on Working Less. Both assessments have come to ambiguous results (at least on the lower confidence level) because work-time control and recovery time play a crucial role in achieving positive health outcomes. This is why this pre-condition is introduced to the ToC. As a consequence, both Intermediate Outcomes are now considered “partially sufficient” and refer to a smaller sample, but we can raise our minimum confidence to “extremely confident”.

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For SM-5 on Eating Less Meat & Dairy, the lower confidence level is a consequence of other factors that play a crucial role for health benefits. We introduce a pre-condition of having a "sufficient variety in dietary choices to obtain a balanced diet" to this causal pathway, to decrease our set of causal conditions, but achieving a confidence level of at least "extremely confident".

Ideal indicators and specific risks

The following table shows a set of potential ideal indicators, to which any type of actual measured or estimated indicator can be compared to.

Table 17: suggestions of ideal indicators
(to assess the effects of the explicated SMs for 'Health' benefits)

Indicator Suggestion		
A_A	change in mortality rate in a given country [deaths/100,000 people]	
	B_1	change in relative risk for coronary heart disease [%]
	B_2	change in "Healthy Lifestyle Index" [0-7] (see also Hu et al., (2022))
	B_3	change in relative risk for All-Cause-Mortality [%]
	B_4	change in index of air pollutants in a given country (see for example Wilke, (2017))

Source: own assessment

Moreover, some specific risks can already be identified from assessing potential barriers that might reduce the size of desired changes or target conflicts that could potentially lead to negative outcomes for 'Health'. We identify three such risks from our adaptations to the causal conditions (see previous section).
The first risk pertains to veganism as a potential cause for negative health outcomes (SM-5) if it leads to malnutrition from an unbalanced diet. The second risk relates to work-time reductions without worktime control (SM-10), as the latter is found to reduce potential health benefits. The third risk results from limiting our sample to persons that participate in car-pooling (SM-6) while also reducing the overall combustion of fossil-fuelled vehicles that would otherwise occur. For those that do not (e.g. if a group of people would have used the train instead), there is a risk that they enable additional pollution instead of reducing it.
The likelihood and scale of these risks will be assessed in chapter 6.

Table 18: suggestion for potential specific risks from the explicated SMs for 'Health'

Index	**Risk**	**Risk Type**
$R_{SM\ 5\text{-}1}$	negative health outcomes from vegan diet	target conflict
$R_{SM\ 10\text{-}1}$	no health benefits due to lack of work-time control	barrier
$R_{SM\ 10\text{-}2}$		
$R_{SM\ 6\text{-}1}$	increased pollution from additional driving	target conflict

Source: own evaluation

Results of qualitative assessment

The following figure depicts the final shortlink ToC. We showed that any of these seven pathways is plausible and confirmed by evidence. **The strongest causal relationships are found for Product-Sizing (SM-2), Less Meat & Dairy (SM-5) and Cycling (SM-8), as we are *extremely confident* in the prediction that a large-scale implementation of these measures would lead to health benefits in Europe at least for a portion of the population.** We are also *very confident*, that such health benefits occur from Car-Pooling (SM-6) and Working Less (SM-10), but we could not identify similar effects for Flying Less (SM-9), Space-Sharing (SM-3) or Product-Sharing (SM-1). This does not imply that such effects do not occur, but merely that there is not sufficient evidence to claim so confidently.
As a result, we would expect the following results from a long-term evaluation of such policies:

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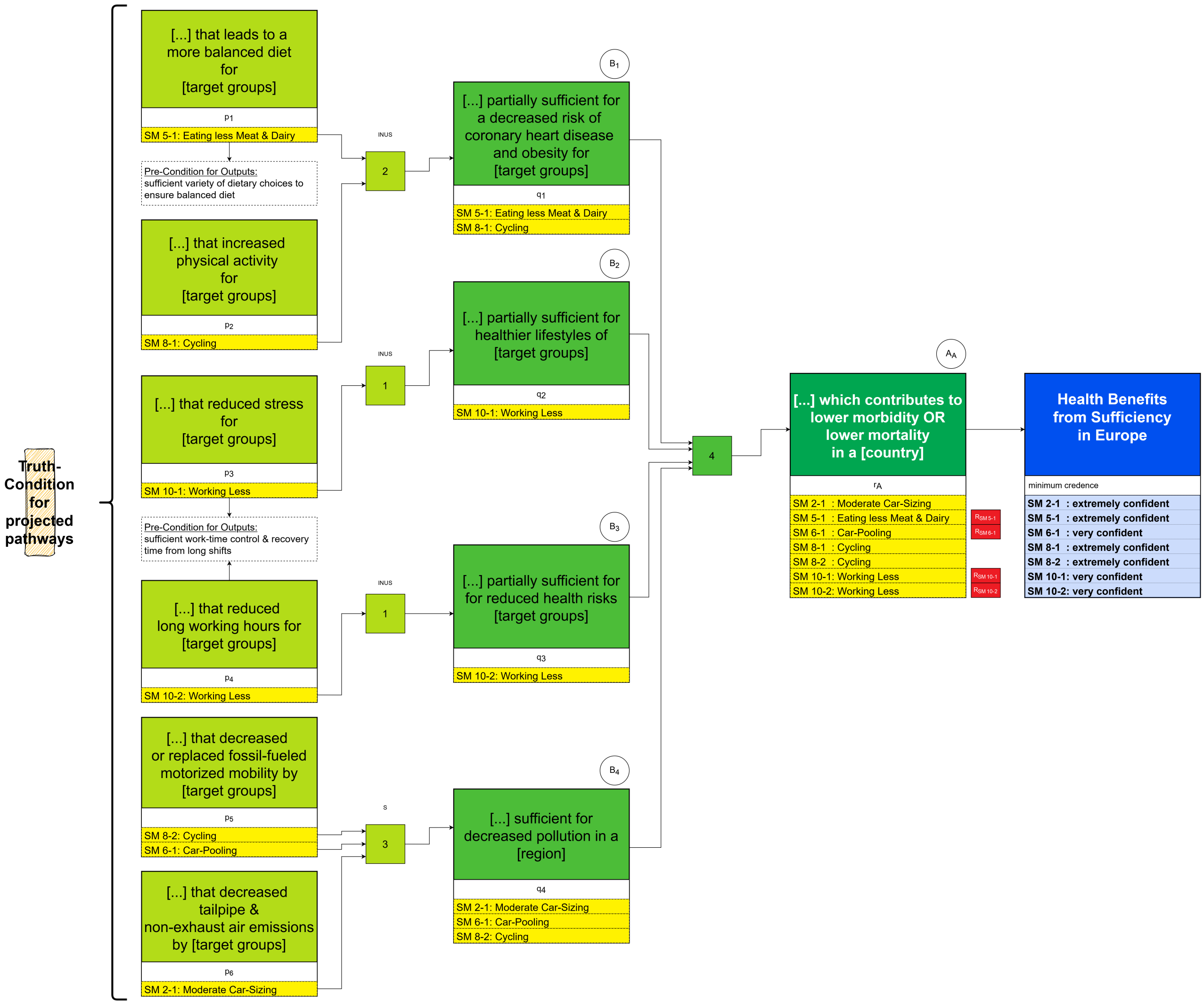
- Reduction of mortality rates per country (accumulative over all measures)
- A lower risk for coronary heart disease from SM-5 (Eating Less Meat & Dairy) and SM-8 (Cycling)
- An improvement of the Healthy Lifestyle Index from SM-10 (Working Less)
- A reduction of the relative risk for All-Cause-Mortality from SM-10 (Working Less)
- A reduction of an index of air pollutants from SM-2 (Product-Sizing), SM-6 (Car-Pooling) and SM-8 (Cycling)

Figure 8: Re-Worked Short-Link ToC for Health Benefits



Source: own development

3.5. Quantitative Assessment

Four of the seven hypotheses could be quantified in terms of anticipated health benefits: (a) direct health benefits from cycling (H_{SM8-1}), (b) direct health benefits from lower meat consumption (H_{SM5-1}), and (c) indirect health benefits from cycling (H_{SM8-2}) as well as reduction of car size (H_{SM2-1}). In these four, and only cases, there was both sufficient input data from T5.3 and an established empirical relationship in the scientific literature to estimate the Outcomes ((a) and (b)) or Outputs ((c)). Each of the pathways consists of three parts. Part 1 shows the input data and calculation steps to derive indicators for one country (France). Part 2 then shows the results for the five countries France, Denmark, Germany, Italy and Latvia between the starting point and endpoint (2050). Part 3 then scales up these effects to the entire European Union for the same time-frame.

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Direct Health benefits of Cycling (H_{SM8-1})

To measure the direct benefits of cycling activity on health outcomes, we applied the methodology described in Section 2.6. This allows us to translate data on the cycling activity in the input data from T5.3 into physical activity metrics (so-called MET), and subsequently assess the reduction in all-cause mortality (ACM) for a portion (Case 2) or the entire population in a country (Case 1). The objective of this section is to provide an overview of the calculation steps and intermediate results for each of the five countries specified in T5.3, to derive an up-scaled effect for the EU and to interpret the results.
The set of input data provided from T5.3 included demographics (e.g., population size), framing factors (e.g., road density), modal shift metrics (e.g., share of trips taken by bike), car use reduction statistics (average distance covered by bike), and cycling infrastructure data (e.g., extent of cycling infrastructure) for our five European countries: France, Denmark, Germany, Italy, and Latvia. These data sets describe specific factors relevant to the enhancement of cycling infrastructure and were modeled from the baseline year 2020 in 10-year increments up to 2050.
While some input data remained stable and were not modeled, such as the average distance covered daily, other variables showed an increase in cycling activity, such as the average daily distance covered by bike daily resulting from an increase in trips covered by bike. Overall, the modeled data from T5.3 indicate an increase in cycling activity across all five countries, leading more frequent use of bikes for daily activities. However, the input data does not specify which parts of the population participate or how the increase in cycling activity is distributed across the entire population.

We used the following input data for our results:

1. Modeled Individual Average Distance Covered by Bike Daily (in km/person/day): This data, which showed an increase from 2020 to 2050, was essential for assessing changes in cycling activity over time in the five countries. It served as the baseline data for the increasement of physical activity.
2. Population Size (in millions): This data was obtained through surveys detailed in T5.3. Population for the other European countries stemmed from Eurostat (Eurostat, 2023b).
3. For case 2, we received extended data including the share of people cycling frequently (at least once a week to a few times a week).
4. For the upscaling approach on European Level we had to recalculate the average distance covered by bike daily as outlined in the methodology.

The introduction of relevant terms such as All-Cause Mortality (ACM) and Relative Risk (RR), along with detailed quantification steps, is provided in section 2.6 in this report. The following section provides the results for France, while the detailed results for the other four countries are outlined in the Annex. Limitations of the quantification are discussed in Section 6.2 of the report.

Results for France, Germany, Italy, Latvia and Denmark (Case 1: Entire Population)

The following section provides a detailed overview of the results for France. Table 19 shows the results for case 1, in which the entire population participates in the increased cycling activity within the country. It depicts the underlying input data on population and cycling activity, the translation of these values to METs as well as the resulting relative risks for ACM. The first column shows the overall population estimation, which steadily increases for France (data provided by our partners). The average distance covered by bike daily is shown in the second column, rising from 0.3 km/person/day in the baseline year to 2.5 km/person/day by 2050. In the third column, the average distance covered by bike weekly (km/person/week) is presented. The fourth column displays the average time a person cycles per week, which is crucial for calculating the Metabolic Equivalent of Task (METs) for individuals. METs increase from 0.81 in the baseline year to 6.72 in 2050.

Table 19: Detailed Results RR for ACM (Case 1 - France)

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(MET: Metabolic Equivalent of Task | RR: Relative Risk | ACM: All-Cause-Mortality)

Year	2020	2030	2040	2050
total Population (in Mio.)	65.24	66.747	67.769	67.972
average distance covered by bike daily (km/person*day)	0.3	1.0	1.8	2.5
average distance covered by bike weekly (km/person*week)	2.1	7.0	12.6	17.5
average time person cycling per week (h/person*week) [a)]	0.12	0.4	0.71	0.99
METs (Hours/Week*Person) [b)]	0.81	2.69	4.84	6.72
Reduction in relative risk (RR) of ACM [c)]	0.01	0.04	0.07	0.10
RR for ACM (1- Change in RR)	**0.99**	**0.96**	**0.93**	**0.90**
a) Calculation based on 17 km/h average speed according to (Ainsworth et al., 2011) b) One hour of cycling equals 6.8 METs according to (Ainsworth et al., 2011) c) The RR is depicted in reference to a population of the same size that does not cycle at all (MET = 0 hours/week). Until 11.5 METS one MET equals a reduction in RR of 1.478% and 0.341% for METs between 11.5 and 32.0 according to (Kelly et al., 2014)				

Source: own calculation based on input data from T5.3

The results indicate that the relative risk (RR) for all-cause mortality (ACM) decreases from 0.99 in 2020 to 0.90 by 2050, reflecting a 9% reduction in risk. This demonstrates an overall health benefit for the population. Comparing 2020 to 2050, the relative risk for ACM is projected to be 91% of the 2020 level, showing a decreasing trend over time. When calculating the life years saved, we assume that there are 990 deaths per 100.000 inhabitants in France in the baseline year 2020 (statista, 2024a), from here we can recalculate the reduced deaths due to the increase in cycling activity:

This means we have 89.01 fewer deaths per 100.000 inhabitants. To now calculate the life years saved (LYS), we use the average life expectancy of 82 years (statista, 2024b).

This results in 7,299 life years saved per 100.000 inhabitants in France.

Since the population size in this case is based on the average distance covered by bike daily per person, the results can be compared with those from other partner countries, providing a consistent basis for analysis. Figure 9 provides such a comparison, showing the results for the decreased relative risk for of ACM for all five European countries, investigated in this task.

Figure 9: Over time RR for ACM after cycling activity for five European countries (Case 1)

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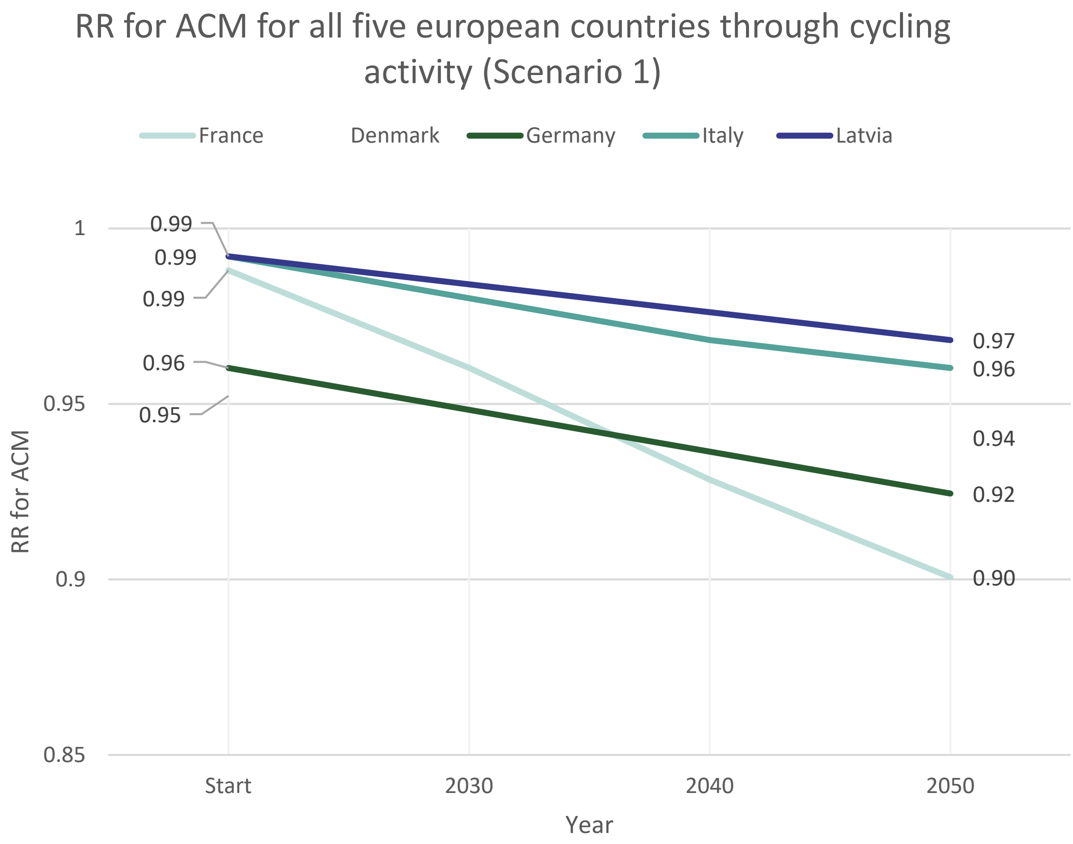

Source: own calculation based on input data from T5.3

Due to the linear dose-response relationship, an increase in cycling activity correlates with a reduction in ACM. Each country experiences a reduction in ACM, with France demonstrating the most substantial decrease from 0.99 (baseline) to 0.90 (2050). Germany follows with a reduction from 0.96 (baseline) to 0.92 (2050). Italy shows a decrease from 0.99 to 0.96, while Latvia experiences a reduction from 0.99 to 0.97. Denmark, starting with a relatively low baseline of 0.95, shows a modest decrease to 0.94 by 2050. Detailed results for Denmark, Germany, Italy, and Latvia can be seen in the Annex of this report. It is important to note that the initial level of cycling activity affects the risk reduction in all-cause mortality (ACM). For instance, countries like Denmark, with a high average of kilometres cycled, see a modest risk reduction of 1%. Conversely, France, with fewer cyclists, experiences a higher decrease of 9%. Similarly, Germany starts relatively low but achieves the second-highest risk reduction of 4%, indicating the influence of country-specific cycling activity on the results.

The life years saved for the four countries (see France above) within the European Union can be calculated as outlined in methodology section. Detailed results and data acquisition are provided in the Annex. For Denmark (RR reduction of 1%), there are 761.4 life years saved per 100,000 inhabitants from increased cycling. In Germany (RR reduction of 4%), 3,855.6 life years are saved per 100,000 inhabitants. In Italy (RR reduction of 3%), 3,112.5 life years are saved per 100,000 inhabitants, and in Latvia (RR reduction of 2%), 2,280 life years are saved per 100,000 inhabitants. These variations show that all five countries benefit from increased cycling, but the degree of reduction varies based on their initial cycling levels and the rate of increase in cycling activity.

Results for France, Germany, Italy, Latvia and Denmark (Case 2: Share of Cyclists)

In case 2, the overall calculation for reduced All-Cause Mortality (ACM) through increased cycling activity was consistent with the first scenario. However, the key difference was that only a portion of the population in each country increased their cycling activity. The share of the population that cycles frequently is provided by the T5.3. We considered this scenario to exhibit an upper bound for

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ACM risk reduction, as fewer people increase their cycling activity. The table below presents the results for case 2.

Table 20: Detailed Results RR for ACM (Case 2 - France)

(MET: Metabolic Equivalent of Task | RR: Relative Risk | ACM: All-Cause-Mortality)

Year	**Start (2020)**	**2030**	**2040**	**2050**
total population (in Mio)	65.24	66.747	67.769	67.972
average distance covered by bike daily (km/person*day)	0.3	1.0	1.8	2.5
total distance covered by entire population (mio km/day)	19 572	66 747	121 984	169 930
population who rides a bike (total*0,18) (in Mio)	11 743	12 014	12 198	12 235
average distance by population who rides a bike daily (km/person*day)	1.67	5.56	10.00	13.89
average distance by population who rides a bike weekly (km/person*week)	11.67	38.89	70.00	97.22
average time person who cycles cycling per week (h/person*week)	0.66	2.20	3.95	5.49
METs (hours/week*person)	4.48	14.94	26.89	37.35
Reduction in relative risk (RR) of ACM c)	0.07	0.18	0.22	0.25
RR for ACM (1- Change in RR)	**0.93**	**0.82**	**0.78**	**0.75**

a) Calculation based on 17 km/h average speed according to (Ainsworth et al., 2011)
b) One hour of cycling equals 6.8 METs according to (Ainsworth et al., 2011)
c) The RR is depicted in reference to a population of the same size that does not cycle at all (MET = 0 hours/week). Until 11.5 METS one MET equals a reduction in RR of 1.478% and 0.341% for METs between 11.5 and 32.0 according to (Kelly et al., 2014)

Source: own calculation based on input data from T5.3

Due to the fact that only 19% of the French population is responsible for the increase in the average distance covered by bike daily, there is a stronger reduction in the relative risk (RR) of All-Cause Mortality (ACM), but for these persons only. The linear dose-response relationship of the model described by (Kelly et al., 2014) here can clearly be seen, as the RR response decreases with increasing cycling activity for larger METs Intervals.

In total, the RR for ACM decreases from 0.93 in the baseline year to 0.75 by the year 2050, which results in a total of 18% in risk reduction.

Following France, Germany exhibits a reduction from 0.91 (baseline year) to 0.83 (2050). Italy follows with a reduction from 0.98 to 0.92, while Latvia shows a decrease from 0.98 to 0.93. Denmark, starting with the lowest initial risk for ACM at 0.86, shows a modest reduction to 0.85 by 2050.

These results highlight that with a partial population increase in cycling activity, significant health benefits can be achieved, particularly in reducing ACM. The estimated life years saved per 100,000 inhabitants in Case 2, due to increased cycling activity, are as follows: 14,612.4 years for France, 1,522.8 years for Denmark, 7,711.2 years for Germany, 6,225 years for Italy, and 5,700 years for Latvia. Compared to Case 1, there is a greater increase in life years saved, resulting from a higher reduction in the risk of all-cause mortality (ACM). Detailed calculations are shown in the Annex.

Figure 10: Over time RR for ACM after cycling activity for five European countries (Case 2)

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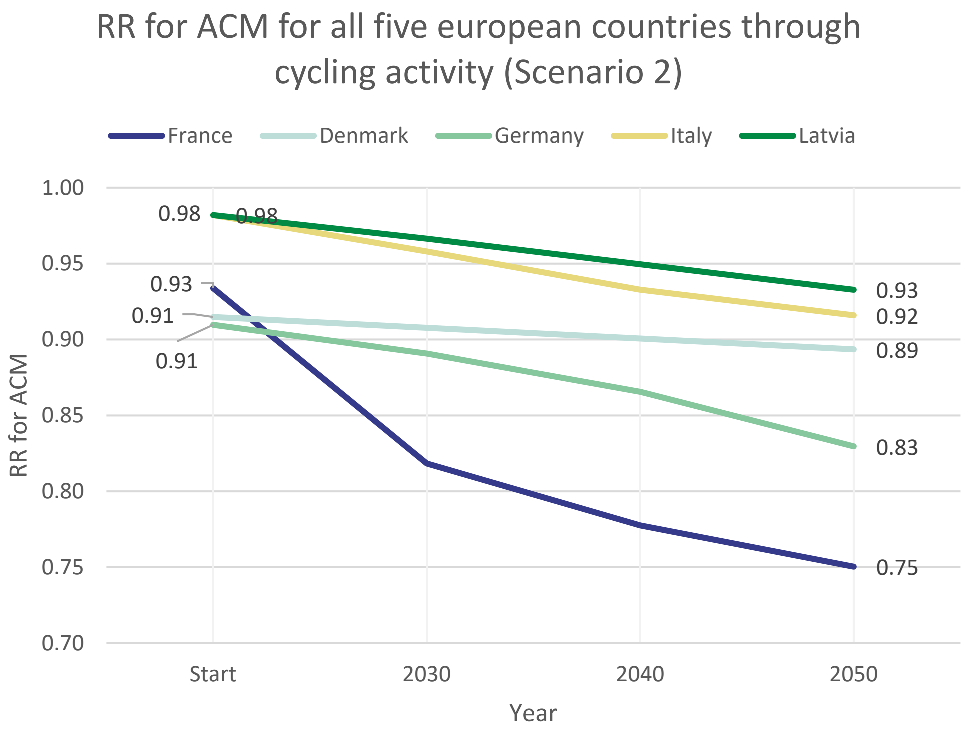

Source: own illustration based on input data from T5.3

Effects for Europe

The approach to scaling up for the European Union employed the same modeling methodology used for France. Baseline data for the share of Europeans cycling frequently were taken from (COWI et al., 2017). The increase in kilometres cycled by the EU was calculated using the average from the five other European countries depicted above.

The results show a decrease in the relative risk (RR) for All-Cause Mortality (ACM) across the European Union due to increased cycling infrastructure and activity, particularly when focusing on the proportion of people who cycle frequently. In case 1, the ACM reduction is from 0.98 to 0.96, indicating a total RR reduction of 2%. In case 2, where only 28% of the European population that cycles frequently is considered, the effect of increased cycling activity on the RR for ACM is even more pronounced, showing a reduction of 8% from 0.93 to 0.85.

These findings highlight the significant health benefits that can be achieved through increased cycling activity, not just nationally but across the entire European Union.

Figure 11: Over time RR for ACM after cycling activity for the European Union (Case 1 + 2)

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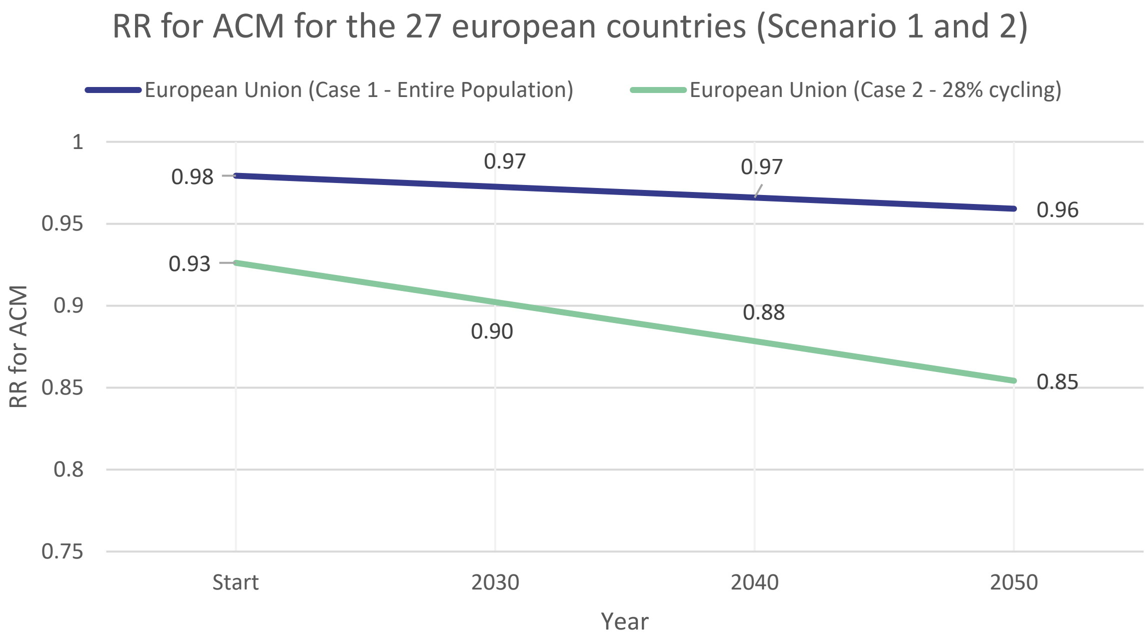

Source: own illustration based on input data from T5.3

Direct health benefits of meat reduction ($H_{SM\ 5\text{-}1}$)

We aim to assess the quantitative health benefits of SM-5 on 'Less Meat & Dairy', for which we specifically looked at meat reduction. The empirical grounding for the assessment assumes an inverse relationship between the reduction of animal protein and relative risks for All-Cause-Mortality. As discussed in our methodology (see section 2.6), we find that both the available data and this assumption only justifies an **educated guess** for range of ACM reduction among the five FULFILL countries. We further assume that the average reduction among these countries constitutes our best 'ballpark figure' for an average effect of this SM throughout Europe.
We first calculated the animal protein intake for each diet type and each decade based on the input data in T5.3 as well as the typical protein content of animal products. The following Table 21 summarizes the results by depicting the average values for all five countries between 2021 (starting year) and 2050 (end year). These values therefore already consider that the population is predicted to shift away from omnivore diets (either by shifting to a diet with less meat or to diets without meat).

Table 21: Average daily animal protein intake based on projected changes in diets in FULFILL

Country	Average daily animal protein[a)] intake			
	2021	**2030**	**2040**	**2050**
Denmark	35.0 g/(d*p)	30.3 g/(d*p)	24.1 g/(d*p)	16.0 g/(d*p)
France	37.5 g/(d*p)	33.5 g/(d*p)	27.5 g/(d*p)	18.6 g/(d*p)
Germany	32.2 g/(d*p)	28.8 g/(d*p)	23.6 g/(d*p)	15.8 g/(d*p)
Italy	35.6 g/(d*p)	32.3 g/(d*p)	26.7 g/(d*p)	18.1 g/(d*p)
Latvia	38.2 g/(d*p)	33.7 g/(d*p)	27.3 g/(d*p)	18.4 g/(d*p)

[a)] 'animal products' and their animal protein content are bovine and ovine meat (16.9%), pork, offals and others (18.9%), poultry (20.2%), dairy (3.1%) and seafood (18.9%)

Source: own calculation based on diet shares and diet compositions in T5.3 as well as protein content

The next step is to calculate the annual animal protein consumption for any given year and each of the countries by multiplying it with the current and predicted population. This then allows us to estimate the total and relative reduction of animal protein over the course of the SM.

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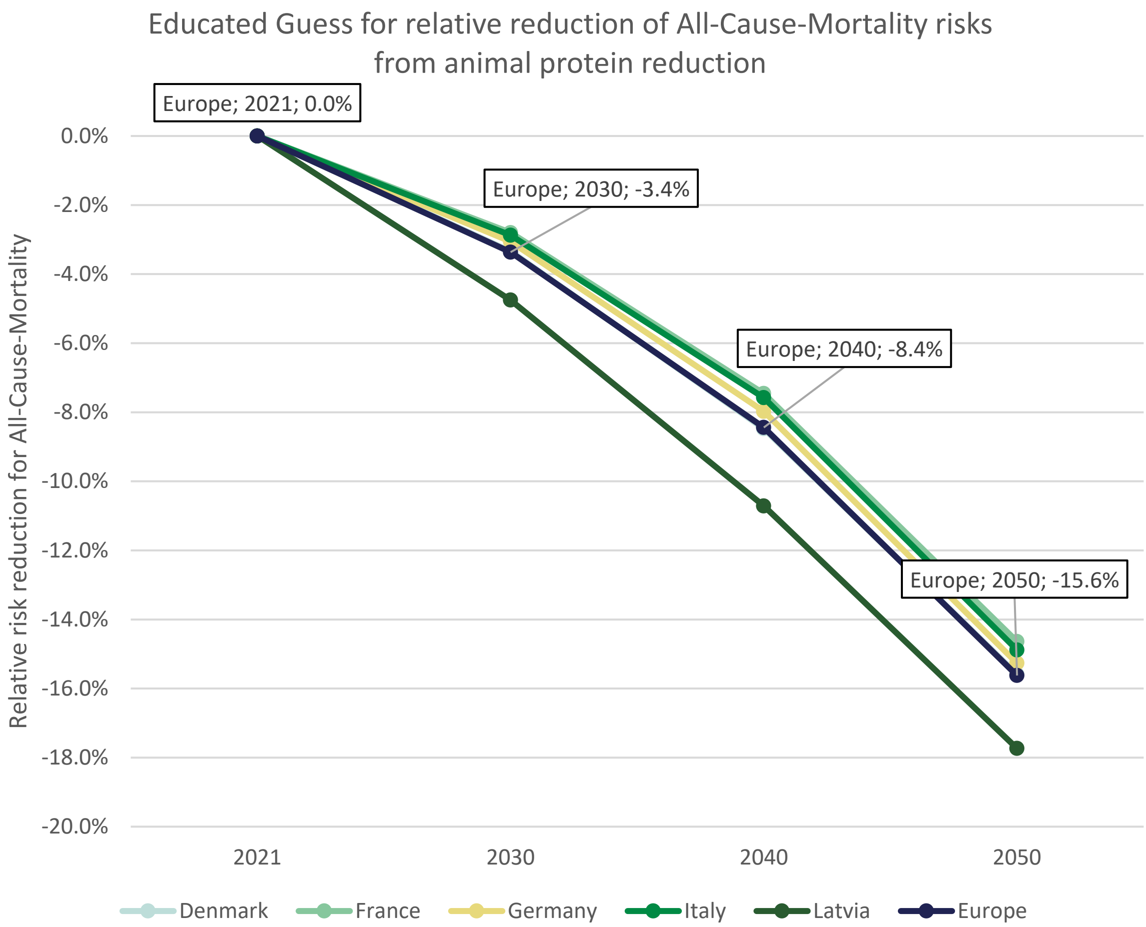
As discussed in the methodology, we then assume an inverse linear relationship based on Kelly et al.,(2014), for which every 10% reduction in animal protein intake corresponds to 3% decrease of relative ACM risks. The country-specific results of this estimation are shown in Annex 1.
The final results for all five countries as well as the European average are depicted in Figure 12.

Figure 12: Results for relative ACM reduction in Europe and FULFILL countries (from SM-5 on 'Less Meat & Dairy')



Source: own calculation

The figure can be interpreted as follows. If an average European person would change its diet in such a way that it corresponds to the predicted changes for 2030, we would expect a relative ACM risk reduction of 3.4%. For a diet corresponding to the dietary changes in 2040, this value would increase to 8.4% and for 2050 to 15.6%. These values are insofar stable, as the results for the five countries do not differ to a large extent. Only Latvia, with the highest animal protein intake today, seems to benefit slightly more from the dietary changes than the other countries (17.7% relative ACM risk reduction compared to 15.6% in Europe overall that is based on the mean value of all five FULFILL countries).
Moreover, these risk reductions depend on the diet that each person is currently adopting. This means that the risk reductions would be higher if for example an omnivore with 170g of daily meat intake shifts to a vegetarian diet. Vice versa, the risk reductions would be expected to be lower for a pescetarian that no longer consumes seafood.
It also has to be noted that the original input data from T5.3 only accounted for optimized diets as a variation of the basic diet types and not for changes in the food or nutrient compositions of the diets themselves. It is thus reasonable to assume that these 'ballpark figures' do not account for the possibility of more (or less) healthy variants of each diet type.

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Pollution reduction from 'Car-Sizing' and 'Cycling'

Pollution reduction from 'Car-Sizing' (H_{SM2-1})

The estimation of reduced PM 2.5 exhaust emissions (see section 2.6) for SM-2 on 'Car-Sizing' is based on three assumed changes from T5.3: shift towards smaller cars, reduced mobility performance in total, shift from liquid fuelled cars to battery-electric vehicles.

We estimate the total reductions by comparing the mobility performance for small, medium and large cars in 2019 with the mobility performance of these shifts based on the specific emissions per km passenger car travel shown in Table 22. This means that, for the purpose of this estimation, only powertrains with liquid fuels are assumed to cause direct exhaust emissions of PM 2.5 pollutants.

Table 22: PM 2.5 emission factors used for estimation of PM 2.5 reduction effects

PM2.5	**Petrol**	**Diesel**	**Mean Value**
Mini	0.0014 g PM2.5/km	-	0.0014 g PM2.5/km
Small	0.0018 g PM2.5/km	0.0076 g PM2.5/km	0.0047 g PM2.5/km
Medium	0.0018 g PM2.5/km	0.0425 g PM2.5/km	0.0222 g PM2.5/km
Large SUV Executive	0.0018 g PM2.5/km	0.0453 g PM2.5/km	0.0236 g PM2.5/km

Source: based on EEA, (2024)

The results from the following Table 23 then take the more detailed differentiation of car-sizes into account by extrapolating the contribution of these four car-sizes to a total of 100%. This means that some input assumptions will not be fully accounted for. The additional European average given in the table, and understood as 'educated guess', is further based on current mobility performance for passenger cars in the five FULFILL countries (weighted average based on values for 2022 from Eurostat, (2023)).

Table 23: PM 2.5 changes due to SM-2 on 'Car-Sizing'

Country	**PM 2.5 emissions**		**PM 2.5 changes 2019 - 2050**		performance passenger cars, 2022
	2019	2050	in total	in %	
Denmark	597,484 kg	56,809 kg	-540,676 kg	-90.5%	61,143 million pkm
France	6,452,629 kg	965,873 kg	-5,486,756 kg	-85.0%	809,404 million pkm
Germany	10,623,198 kg	821,568 kg	-9,801,630 kg	-92.3%	840,834 million pkm
Italy	3,895,436 kg	937,411 kg	-2,958,025 kg	-75.9%	602,862 million pkm
Latvia	220,119 kg	24,910 kg	-195,209 kg	-88.7%	12,694 million pkm
EUROPE, average weighted by passenger transport (pkm) in 2022				**-85.5%**	

Source: own calculation based on T5.3, emission factors from EEA, (2024) and car performance from Eurostat, (2023)

The results for changes in PM 2.5 emissions between 2019 (starting year) and 2050 range from 76% to 92% reduction and constitute an average reduction of 86% for Europe. This strong effect is only partly due to changes in car-sizes alone though. We therefore additionally investigated to what extent the size of cars is responsible for the effect. The following Table X shows the alternative results, if both car performance and powertrain distribution. We can thus estimate that roughly 42% of the reduction is a consequence of stock changes in car-size, rather than changes for mobility performance or powertrains.

Table 24: PM 2.5 changes due to SM-2 on 'Car-Sizing' but limited to changes in size of cars

Country	**PM 2.5 emissions without powertrain & performance changes**		**PM 2.5 changes 2019 - 2050**		**share of car-size effect**
	2019	2050	in total	in %	
Denmark	597,484 kg	276,225 kg	-321,260 kg	-53.8%	37.3%
France	6,452,629 kg	2,831,885 kg	-3,620,744 kg	-56.1%	39.8%

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Country	PM 2.5 emissions without powertrain & performance changes		PM 2.5 changes 2019 - 2050		share of car-size effect
	2019	2050	in total	in %	
Germany	10,623,198 kg	3,234,822 kg	-7,388,376 kg	-69.5%	43.0%
Italy	3,895,436 kg	1,631,214 kg	-2,264,222 kg	-58.1%	43.4%
Latvia	220,119 kg	74,334 kg	-145,785 kg	-66.2%	42.8%
EUROPE, average weighted by passenger transport (pkm) in 2022				-61.5%	41.8%

Source: own calculation based on T5.3, emission factors from EEA, (2024) and car performance from Eurostat, (2023)

Pollution reduction from 'Cycling' (H_{SM8_2})

The pollution reduction from a modal-shift towards cycling can be calculated based on the predicted changes from T5.3 for 'Cycling' as well as the previously discussed conditions for 'Car-Sizing'. The estimated effect here is expected to be much lower, since the assumed reductions in passenger car performance are only a fraction of the reductions for 'Car-Sizing'. For example, SM-2 on 'Car-Sizing' predicts a reduced mobility performance of 15.9 billion km for Denmark between starting and end year, whereas SM-8 on 'Cycling' only predicts a modal-shift of 0.5 billion km.

A maximum for 'Cycling' would be achieved if this modal shift occurs in the current system of car-sizes and powertrains. The results for this case are shown in Table 25.

Table 25: PM 2.5 changes due to SM-8 on 'Cycling' in isolation

Country	PM 2.5 emissions		PM 2.5 changes Start - 2050	
	Starting Year	2050	in total	in %
Denmark	491,128 kg	483,354 kg	-7,774 kg	-1.6%
France	5,802,010 kg	5,234,595 kg	-567,414 kg	-9.8%
Germany	8,160,841 kg	7,851,581 kg	-309,260 kg	-3.8%
Italy	3,621,421 kg	3,472,904 kg	-148,517 kg	-4.1%
Latvia	187,404 kg	183,965 kg	-3,439 kg	-1.8%
EUROPE, average weighted by passenger transport (pkm) in 2022				-5.9%

Source: own calculation based on T5.3, emission factors from EEA, (2024) and car performance from Eurostat, (2023)

The predicted modal-shift from 'Cycling' thus leads to an estimated decrease of 5.9% in PM 2.5 emissions.

Health Outcomes based on a combined pollution reduction from 'Car-Sizing' and 'Cycling'

The input data from T5.3 predicts an overall, and relative shift towards passenger cars, which is equivalent to emission reductions over each decade. We include this information in our table for emissions reductions from 'Car-Sizing' by applying the combined emission factor that reflects the composition of fuel trains and car types in this decade. According to this calculation (see Table), we estimate that the overall PM 2.5 emission reduction increase by an additional 3.1% from 85.5% to 88.5%.

Table 26: PM 2.5 changes due to combining 'Car-Sizing' with 'Cycling'

Country	PM 2.5 emissions	PM 2.5 changes 2019 - 2050		PM 2.5 emissions	Total reduction	'Cycling'
	2019	'Car-Sizing'	'Cycling'	2050		
Denmark	597,484 kg	-540,676 kg	-4,227 kg	52,581 kg	-91.2%	-0.7%
France	6,452,629 kg	-5,486,756 kg	-345,304 kg	620,569 kg	-90.4%	-5.4%
Germany	10,623,198 kg	-9,801,630 kg	-157,710 kg	663,857 kg	-93.8%	-1.5%
Italy	3,895,436 kg	-2,958,025 kg	-99,077 kg	838,335 kg	-78.5%	-2.5%
Latvia	220,119 kg	-195,209 kg	-2,066 kg	22,844 kg	-89.6%	-0.9%
EUROPE, average weighted by passenger transport (pkm) in 2022					-88.5%	-3.1%

Source: own calculation based on T5.3, emission factors from EEA, (2024) and car performance from Eurostat, (2023)

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These high emission reductions do not necessarily imply an equally strong health benefit, as health risks associated with particular matter depend on the length of exposure and the concentration of these pollutants in the air.

As discussed in the methodology section, the effect of PM 2.5 emission reductions on PM 2.5 concentration cannot be estimated with the data at hand. However, it is useful to show how relevant the size of this effect could be in terms of the prevention of negative health outcomes.

The current PM 2.5 levels in capitals in Europe range from 7.9 ug/m3 in Copenhagen to 28.6 ug/m3 in Sarajevo (Statista, 2024). And we know that roughly 9% of the total PM 2.5 emissions can be attributed to road transport according to the European Environmental Agency (EEA, 2022). We should further account for the fact that non-exhaust emissions by road transport play a crucial role as well. This effect, mostly associated with tyre wear, has not been accounted for in our estimation and can make up to 10% of road transport PM 2.5 emissions (Giechaskiel et al., 2024).

Using these values as rough guard rails, we come up with a 'ballpark figure' of a potential average reduction in PM 2.5 concentration of 7%.

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4. Impact assessment for 'Poverty Mitigation'

4.1. Definition of societal goal

Poverty in general, and energy-poverty in particular addressed by both the United Nations and the European Union. Poverty is usually understood to encompass more than economic constraints and can include lack of access to other forms of social capital as well.
We adhere to the first Sustainable Development Goal (SDG 1) of 'No Poverty'* for our definition of the impact 'Poverty Mitigation' benefits from sufficiency:

> *" Goal 1. End poverty in all its forms everywhere (United Nations, 2015)".*

T6.3 in FULFILL mainly investigates **tangible** societal benefits as a consequence of interventions. This is achieved, in our opinion, if either the number of persons living in poverty (or at risk thereof) is reduced or if sufficiency improves the resilience of this and other vulnerable groups in society.

4.2. Initial shortlink ToC

The initial shortlink ToC consists of four causal hypotheses that are deemed plausible from the outset and is shown in the following Figure 13. All of these causal mechanisms are concerned with economic deprivation or the levitation thereof rather than other potentials descriptors of poverty or concepts that can, but do not have to, overlap with it (such as social exclusion). One might argue for example that SM-3 on 'Space-Sharing' leads to more social contacts and thus, ultimately, to better social cohesion for vulnerable groups. However, it is unclear in which way and how such a causal relationship would look like in terms of 'Poverty Mitigation', since social deprivation can be a consequence of economic deprivation and vice versa (or independent thereof) and not all groups with a social stigma or low accessibility to services are considered to be poor by national standards.
We are aware of these difficulties (see Dean & Platt, (2016) for a more thorough discussion of the terminology, concepts and paradigms throughout history) and do not advocate to ignore these relationships. Nor do we assume that there are no benefits from sufficiency that go beyond or permeate economic restraints of vulnerable groups. We decided instead to focus our qualitative assessment on the most direct and simple causal relationships between expenditures by poor households and the ability of *some* sufficiency measures to reduce these expenditures as a mean to mitigate (energy or economic) poverty in European countries.

Only four out of eight SMs are initially assumed to be able to contribute to this desired outcome: SM-1 (Product-Sharing), SM-3 (Space-Sharing), SM-6 (Car-Pooling) and SM-8 (Cycling).
These measures are all associated with a "a reduction of people living in poverty or at the risk of poverty" in a country (r_A). This persistent desired change comes about by means of an "increase in disposable income" (q) for groups in poverty or at the risk of poverty and is either achieved by lower expenditures for mobility (Car-Pooling, Cycling) or lower expenditures for housing (Product-Sharing, Space-Sharing). Only one pre-condition was identified from the outset: the accessibility and affordability of Co-Housing.
This initial ToC has already gone through several iterations to identify plausible causal pathways in the first place (based on our initial screening of the literature).

Figure 13: Initial Short-Link ToC for benefits toward 'Poverty Mitigation'

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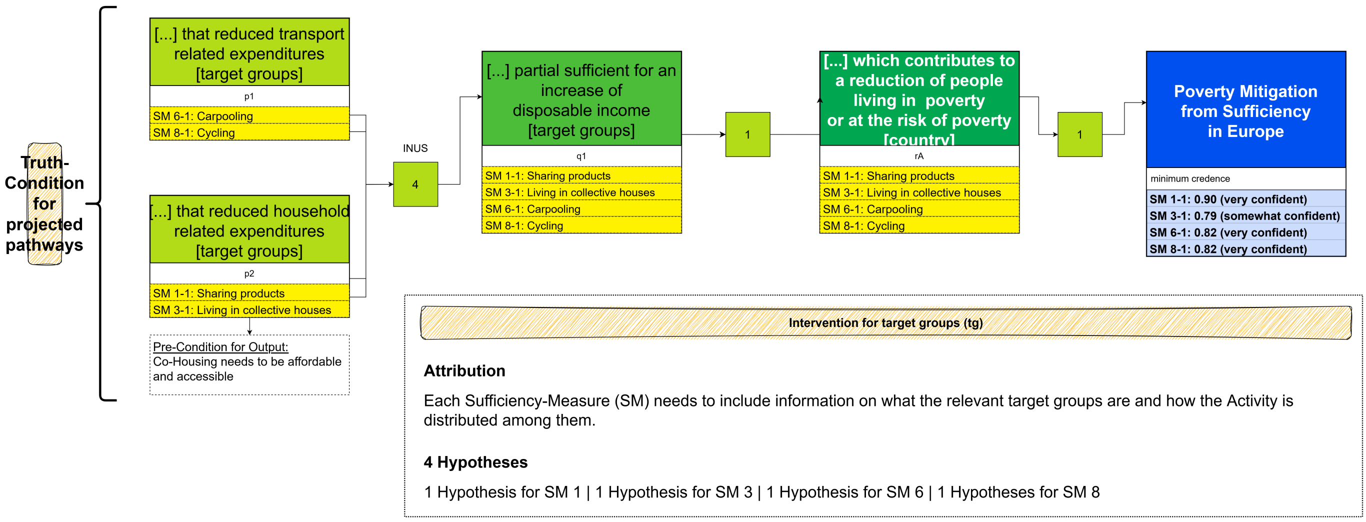

Source : own development

4.3. Credibility Assessment

The main section of this chapter is concerned with the plausibility of the causal hypotheses depicted in the shortlink ToC. This assessment is conducted in line with the 3-stage Bayesian argument discussed in the methodology (see section 2.3). There are four causal hypotheses to be considered (two for each Output p).

SM-6: Car-Pooling

$H_{P\text{-}SM6\_1}: p_1 \wedge q_1 \rightarrow r_A$

A reduction of transport related expenditures from people participating in Carpooling is partially sufficient for an increase of disposable income of these target groups, which contributes to a reduction of people living in poverty or at the risk of poverty in a country.

Table 27: Credence for HSM6_1

Step	Reasoning	Credence
Priors cr (H|b); cr (¬H|b)	<u>Background knowledge b:</u> b_1: Regional, and country-, specific approaches that exert income growth, together with inequality changes and education (Janjua & Kamal, 2011) are strategies strongly suggested for optimal poverty reduction (Fosu, 2010). The growth of income is also the main reason for the reduction of poverty in the last decades of the 20th century (Sala-i-Martin, 2006). b_2: Economic growth (and related income gain) is unlikely to eradicate poverty completely because past benefits have already been distributed selectively and unequally. Fighting extreme poverty also requires investments into institutions and physical infrastructures (Page & Pande, 2018). <u>Assessment:</u> It is trivially true that a reduction in expenditures is sufficient for an increase in disposable income and that any absolute cost saving has a stronger relative effect on low-income households. We also know from our background knowledge that income, or growth thereof, is a key but not the only strategy for poverty mitigation (b_1). The literature on poverty also suggests that additional infrastructures and institutions for capacity building are necessary for effective poverty mitigation (b_2). We therefore think that the hypothesis is plausible from the outset, but that these additional conditions strongly reduce the portion of the target group that benefit in such a way that they avoid poverty or come out of poverty. A reasonable prior credence should therefore	cr (H.b) ≈ 0.60 – 0.80 cr (¬H.b) = 0.40 – 0.20

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Step	Reasoning	Credence
	not exceed *probable true* under the assumption that the most plausible non-true proposition is that cost-reductions from carpooling do not suffice for a reduction of persons in poverty or at the risk of poverty.	
Consequents cr (E|H.b); cr (E|¬H.b)	Evidence e: e_1: The benefit of carpooling is estimated at $US 30.0m per year including conserving an estimated 1.7 - 3.5 million litres of fuel, mostly as impact on the rest of the traffic and time savings (Minett & Pearce, 2011). Together with considering rebound effects, carpooling is saving 3% of transport-related energy use and GHG emissions, across all U.S. households, primarily through mode shifts, avoided travel, savings in parking demand and fuel consumption (T. D. Chen & Kockelman, 2016). However, while carpooling is decreasing individual fuel consumption, additional distances and time expenses to pick up passengers can reduce the savings (Jacobson & King, 2009). e_2: While environmental-based motivation to participate in carpooling is rather low, monetary saving is a key motivator (S. A. Shaheen et al., 2016). Economic efficiency is the most advantageous benefit users perceive in carpooling, while there are also some negative perceptions as lack of flexibility (Ciasullo et al., 2018). e_3: Carpooling can increase accessibility and mobility for low-income and minority households (Shaheen, Susan; Cohen, Adam; Bayen, Alexandre, 2018b). Assessment: The screened literature is mostly, but not entirely (e_3), silent on the benefits of carpooling for vulnerable groups, as it is more concerned with the environmental benefits and fuel cost savings (e_1). These savings also seem to be a key motivator to participate(e_2). We therefore find that both e1 and e2 are *fully expected* on H, but equally likely under ¬H (cost savings insufficient for poverty mitigation). This means that increased accessibility and mobility for low-income households (e_3) is the only piece of evidence that is at least *somewhat likely* under H, but *very surprising* under ¬H. This raises our confidence in the main hypothesis.	cr (E|H.b) ≈ 0.60 – 0.80 (1*1*0.6) to (1*1*0.8) cr (E|¬H.b) ≈ 0.24 – 0.20 (1*1*0.2) to (1*1*0.05)
Posterior	Assessment: The evidence confirmed our initial, rather tentative, credence in the proposition. As a consequence, we are at best *extremely confident*, and at least *very confident* in H.	cr (H|E) ≈ 0.82 – 0.98

Source: own assessment

SM-8 : Cycling

$H_{P\text{-}SM8\_1}$: $p_1 \wedge q_1 \rightarrow r_A$

A reduction of transport-related costs from people increasing their cycling activity is partially sufficient for an increase of disposable income of these target groups, which contributes to a reduction of people living in poverty or at the risk of poverty in a country.

Table 28: Credence for HSM8_1

Step	Reasoning	Credence
Priors cr (H|b); cr (¬H|b)	Background knowledge b: b_1: Regional, and country-, specific approaches that exert income growth, together with inequality changes and education (Janjua & Kamal, 2011) are strategies strongly suggested for optimal poverty reduction (Fosu, 2010). The growth of income is also the main reason for the reduction of poverty in the last decades of the 20th century (Sala-i-Martin, 2006). b_2: Economic growth (and related income gain) is unlikely to eradicate poverty completely because past benefits have already been distributed selectively and unequally. Fighting extreme poverty also requires investments into institutions and physical infrastructures (Page & Pande, 2018).	cr (H.b) ≈ 0.60 – 0.80 cr (¬H.b) = 0.40 – 0.20

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Step	Reasoning	Credence
	Assessment: Our assessment for this hypothesis follows the previous conclusion for disposable income benefits from carpooling based on the same background knowledge. It is trivially true that lower mobility costs are positively associated with poverty mitigation, but that these cost reductions might not suffice for such benefits on their own — at least for a majority of participants. Our prior reflects that by assigning a credence of *probable*, but not more.	
Consequents cr (E|H.b); cr (E|¬H.b)	Evidence e: e_1: The cost of a km cycling is six times lower than the cost of driving a car (Gössling & Choi, 2015) and cycling requires lower energy consumption when travelling the same distance as with other forms of transportation (vehicles, buses) (Baptista et al., 2015). A study further found that cyclists in South-Africa save about 20% to 45% of their monthly income if they go by bicycle instead of public transport (Bechstein, 2010). e_2: A study in the Netherlands found, that for households living at the risk of transport poverty, the bicycle plays an important role in accessing important destinations (Martens, 2013). Assessment: Similar to the previous hypothesis, it is fully expected that an increase in cycling reduces mobility costs (e_1), but that this is also true for the main non-true hypothesis (cost reductions insufficient for poverty mitigation). Along the same line of reasoning, it has been found that it provides better accessibility for poor households (e_2), which is why the latter is at least *somewhat likely* under H, but *very surprising* under ¬H.	cr (E|H.b) ≈ 0.60 – 0.80 (1*0.6) to (1*1*0.8) cr (E|¬H.b) ≈ 0.24 – 0.20 (1*0.2) to (1*1*0.05)
Posterior	Assessment: The evidence confirmed our initial, rather tentative, credence in the proposition. As a consequence, we are at best *extremely confident*, and at least *very confident* in H.	cr (H|E) ≈ 0.82 – 0.98

SM-1 : Product-Sharing

$H_{P\text{-}SM1\text{-}1}$: $p_2 \land q_1 \rightarrow r_A$

Sharing products between households leads to a reduction of household related expenditures on goods and services is partially sufficient for an increase of disposable income, which contributes to a reduction of people living in poverty or at the risk of poverty.

Table 29: Credence for HSM1_1

Step	**Reasoning**	**Credence**
Priors cr (H|b); cr (¬H|b)	Background knowledge b: b_1: Regional, and country-specific approaches that exert income growth, together with inequality changes and education (Janjua & Kamal, 2011) are strategies strongly suggested for poverty reduction (Fosu, 2010; Sala-i-Martin, 2006). b_2: Ending poverty requires different strategies. Economic growth (and related income gain) is unlikely to eradicate poverty completely. It will further need political infrastructural changes (Page & Pande, 2018) and social aid strategies (Caminada & Goudswaard, 2009). b_3: Without energy efficiency policies, income support alone is not sufficient to mitigate the risk of energy poverty (Bollino & Botti, 2018; Bouzarovski et al., 2012). b_4: Improving the financial situation of households is an effective way of mitigating energy poverty, as low household incomes are a main factor generating energy poverty (Maxim et al., 2016; Neacsa et al., 2020).	cr (H.b) ≈ 0.6 - 0.8 cr (¬H.b) = 0.4 - 0.2

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Step	Reasoning	Credence
	b_5: Consumers that participate in collaborative consumption benefit economically by fulfilling consumption needs at lower costs (Perren & Grauerholz, 2015). Lower costs are also the main motivation to participate in it in the first place (Hamari et al., 2016). <u>Assessment:</u> It seems logically plausible that persons benefit economically from sharing products. We therefore expect in general, that (i) some fractions of these persons are already at the risk of poverty and mitigate these risks, and (ii) that at least some other fraction could mitigate the risk of becoming poor by means of sharing products if their economic situation deteriorates. The most plausible non-true hypotheses on the other hand are that (iii) no such persons participate in such lifestyles or (iv) that there are usually no overall cost savings since the products shared are purchased additionally. Given the background knowledge shown here, it also seems probable that an increase of disposable income is equivalent to income growth for some groups and that this is decreasing the risk to live at the risk of poverty or in poverty (b_1; b_4). However, we should be careful with this assertion, as the reduction of poverty is a complex interplay of different interactions, and often infrastructural in nature (b_2). There is reason to believe that mere income growth is not sufficient for mitigating poverty in general and energy-poverty in particular (b_3). Nonetheless, collaborative consumption, and with that sharing products, seems to be economically beneficial for target groups that participate in it and these benefits seem also be the main reason to participate in it (b_5). Overall, we find that we should restrain from a too optimistic view on the poverty mitigation effects from sharing products alone. However, it can and *very likely* is, a partial sufficient (INUS) condition for it. We therefore find the hypothesis to be at least *probable* true.	
Consequents cr (E|H.b); cr (E|¬H.b)	<u>Evidence:</u> e_1:Trust-based economic sharing will lead to an income gain for producers and consumers (C. Köbis et al., 2021; Dillahunt & Malone, 2015). And effective sharing models can save households up to 7% in the household budget (Demailly & Novel, 2014). e_2: The motivation for sharing products is highly dependent on the socioeconomic status, value, and typology of products. Especially expensive goods are economically very motivating for sharing. Moreover, younger, and low-income groups are more economically motivated to use and provide shared assets (Böcker & Meelen, 2017). e_3: Sharing in social networks is supporting low-income households. However, social creative strategies seem just as important as financial ones (Snow et al., 2017). <u>Assessment:</u> The main hypothesis predicts that disposable income gains are a consequence of product sharing and that this leads to the mitigation of poverty risks. The most likely non-true proposition predicts that no or almost no households with poverty risks participate in such lifestyles. Looking at the evidence, e_1 is fully expected under H (income gains and household budget savings from product-sharing). Conversely, it is still extremely likely under ¬H (poor households not benefiting since they cannot or do not participate). Evidence e_2 (motivation for sharing products) and e_3 (sharing supporting low-income households) are fully expected under H as well (low-income groups more likely to share), but at least somewhat surprising under ¬H. As a result, we find that all the provided evidence is in favour of H over ¬H, even if we consider other alternative explanations such as some portion of products not contributing to cost savings.	cr (E|H.b) ≈ 0.97 (0.99*0.99*0.99) cr (E|¬H.b) ≈ 0.16 - 0.04 (0.99*0.4*0.4) - (0.95*0.2*0.2)
Posterior	<u>Assessment:</u>	cr (H|E) ≈ 0.90 - 0.99

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Step	Reasoning	Credence
	We found that the evidence is in favour of an already plausible initial hypothesis. Both our background knowledge and evidence support the notion that product-sharing leads to higher disposable income and that this mechanism is likely to mitigate poverty for certain target groups. We are at least *very confident* (cr = 0.90) and at best *extremely confident* (cr = 0.99) in this proposition.	

Source: own compilation

SM-3: Space-Sharing

$H_{P\text{-}SM3\text{-}1}$: $p_2 \wedge q_1 \rightarrow r_A$

A reduction of household expenditures from an increase of people living in co-housing is partially sufficient for an increase of disposable income which contributes to a reduction of people living in poverty or at the risk of poverty, if such an option is both available and affordable.

Table 30: Credence for HSM3_1

Step	Reasoning	Credence
Priors cr (H|b); cr (¬H|b)	<u>Background knowledge b:</u> b_1: Regional, and country-specific, approaches that exert income growth, together with inequality changes and education (Janjua & Kamal, 2011) are strategies strongly suggested for poverty reduction (Fosu, 2010; Sala-i-Martin, 2006). b_2: Ending poverty requires different strategies. Economic growth (and related income gain) is unlikely to eradicate poverty completely. It will further need political infrastructural changes (Page & Pande, 2018) and social aid strategies (Caminada & Goudswaard, 2009). b_3: Housing costs should be considered when determining the disposable income of households, as it is an important consumption indicator for capturing poverty (Lee, 2019). b_4: Collaborative housing design is more affordable than mainstream housing on a per square-metre basis, because it provides less expensive units while it includes larger common spaces (S. Brysch et al., 2023; Vestbro, 2012). b_5: The initial costs of Cohousing initiatives often rather seem as a threat for participants (Williams, 2005). Especially in urban areas, high initial investments are not affordable for people living in poverty (Scanlon & Arrigoitia, 2015). <u>Assessment:</u> It seems logically plausible that persons benefit economically from co-housing or more generally 'Space-Sharing'. We expect in general, that (i) some fractions of these persons are already at the risk of poverty and mitigate these risks, and (ii) that at least some other fraction could mitigate the risk of becoming poor by means of reduced household expenditures. The most plausible non-true hypotheses on the other hand are that (iii) no or not enough such persons participate in such a lifestyle or (iv) that (iv) no such persons can afford it. Given the background knowledge shown here, it also seems probable that an increase of disposable income is equivalent to income growth for some groups and that this is decreasing the risk to live at the risk of poverty or in poverty (b_1; b_3; b_4). However, we should be careful with this assertation, as the reduction of poverty is a complex interplay of different interactions, and often infrastructural in nature (b_2). Moreover, relative cost savings (b_4) are not equivalent to total cost reduction and there is reason to believe that poor households in particular cannot afford the sometimes high initial investments necessary for this lifestyle (b_5).	cr (H.b) ≈ 0.6 - 0.8 cr (¬H.b) = 0.4 - 0.6

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Step	Reasoning	Credence
	We are therefore extremely confident in the assertation that co-housing is economically beneficial for participants to achieve a certain lifestyle but are only somewhat convinced that these participants include households living in poverty or at the risk of poverty. We find that the background knowledge slightly favours the hypothesis tough to being *probable* (some households in poverty participate in co-housing of which some benefit economically in such a way that it helps to mitigate poverty).	
Consequents cr (E|H.b); cr (E|¬H.b)	Evidence: e_1: In collective housing, the potential energy reduction by saving strategies is 69% compared to 56% compared for single family housing typologies (Zagora et al., 2017). Its collaborative design is often based on the minimum needs of the residents and therefore shows higher space efficiency and affordability (S. L. Brysch & Czischke, 2022). There is also evidence that things are being shared more in multi-person than single-person households (Yates, 2018). e_2: Collective housing members associate their lifestyle with monetary savings through sharing activities (Daly, 2015) and reduced living expenditures (Verhetsel et al., 2017). However, social and environmental sustainability as well as financial aspects are the top priorities for people considering joining cohousing communities in the UK (Wang et al., 2021). e_3: Cohousing is seen as a beneficial model for low-income households (Arbell, 2022). Although it could appeal to a much broader audience, the current membership is dominated by white, educated, liberal, high income, older and female (Arbell, 2022). However, there are cohousing projects that focus on diversity and explicitly include members of marginalized members in society such as homeless or new migrants (Arbell, 2022). Assessment: Looking at the evidence, it is fully expected under H (e_1, e_2, e_3). At least e_1 and e_2 are also fully expected under the non-true hypothesis that there are benefits, but that these benefits do not affect households in poverty or at the risk of poverty. However, e_3 is at least somewhat surprising under ¬H. If no vulnerable groups benefited from co-housing, there would be no indication that such cohousing project exists and if it would not potentially be economically beneficial for low-income households, there would be no scholarly literature attesting to its poverty mitigation potential. The evidence therefore favours H over ¬H and increases our credence in the proposition.	cr (E|H.b) ≈ 0.97 - 0.97 (0.99*0.99*0.99) cr (E|¬H.b) ≈ 0.39 - 0.20 (0.99*0.99*0.4) - (0.99*0.99*0.2)
Posterior	Assessment: Our initial credence based on our background knowledge was tentative. We were convinced that cohousing leads to economic benefits, but questioned whether a sufficient number of poor or low-income households could participate for causing a poverty mitigation potential. However, the evidence was clearly in favour of both parts of the proposition, which is why we are at least *somewhat confident* (cr = 0.79) and at best *very confident* (cr = 0.95) in H.	cr (H|E) ≈ 0.79 - 0.95

Source: own compilation

Overview of credibility assessment

The following Table lists all hypotheses and the results of the assessment of their credibility. Our credence is depicted in two ways. The upper bound shows our credence from a favourable point of view. On this end, any type of uncertainty or missing knowledge is not used as an argument against the proposition that these sufficiency measures lead to health benefits. The lower bound on the other hand reflects a more conservative approach. This is our minimum credence that these propositions are true.

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Table 31: Results of the credibility assessment for Sufficiency Measure Hypotheses (HSM_n)

Measure	**Hypotheses**	**cr : lower bound**	**cr : upper bound**
Product-Sharing (H_{SM1_1})	*Sharing products between households leads to a reduction of household related expenditures on goods and services is partially sufficient for an increase of disposable income, which contributes to a reduction of people living in poverty or at the risk of poverty.*	0.90	0.99
Cycling (H_{SM8_1})	*A reduction of transport-related costs from people increasing their cycling activity is partially sufficient for an increase of disposable income of these target groups, which contributes to a reduction of people living in poverty or at the risk of poverty in a country.*	0.82	0.98
Car-Pooling (H_{SM6_1})	*A reduction of transport related expenditures from people participating in Carpooling is partially sufficient for an increase of disposable income of these target groups, which contributes to a reduction of people living in poverty or at the risk of poverty in a country.*	0.82	0.98
Space-Sharing (H_{SM3_1})	*A reduction of household expenditures from an increase of people living in co-housing is partially sufficient for an increase of disposable income which contributes to a reduction of people living in poverty or at the risk of poverty, if such an option is both available and affordable.*	0.79	0.95

Source: own development

4.4. Qualitative Assessment

Re-Work of ToC

All four hypotheses are deemed plausible from the credence assessment, since each clearly achieves a threshold of more than 0.5. The already high initial credence can be explained by limiting the desired changes to the portion of the participants that benefit economically from the measures (the truth-condition in the ToC) and the credences of the entire pathways could be further increased by limiting the size of that population even further.

Two of the hypotheses also rely on the assumption that the disposable income increases despite possible additional investment costs. This effect is more pronounced for 'Space-Sharing' but could also be a limitation for 'Product-Sharing'. We find that such investments would exclude households in poverty or at the risk of poverty anyway, which is why we opted to adapt the causal set of the Output instead. By removing the pre-condition but changing the Output to the "reduction of monthly expenditure for housing including capital costs", we think that the upper bounds of credences are justified (*extremely confident* in both propositions) even if this excludes a minority in the target group that would be willing, and able, to afford the additional capital costs of e.g. a loan to acquire a house (see Teubler & Schuster (2022) for a discussion of such loans for low-income households).

Ideal indicators and specific risks

The following table shows a set of potential ideal indicators, to which any type of actual measured or estimated indicator can be compared to.

Table 32: suggestions of ideal indicators
(to assess the effects of the explicated SMs for 'Health' benefits)

Indicator Suggestion		
A_A	change in number of people in poverty in a given country [1/100,000 people]	
	B_1	change in disposable income [%/month]

Source: own assessment

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Moreover, some specific risks can already be identified from assessing potential barriers that might reduce the size of desired changes or target conflicts that could potentially lead to negative outcomes for 'Health'. We identify two such risks from our adaptations to the causal conditions, both of which are related to the initial investment costs of 'Product-Sharing' and 'Co-Housing'. Since the target groups is expected to have low or no equity, and such equity as well as the income determines the capital costs of potential loans, poor households are more likely to suffer from debt. We think that the lower investment costs for 'Product-Sharing' (in particular for the explicated case of washing machines in T5.3) constitute a barrier, whereas the higher investment costs for housing (at least in the absence of state-funding) would constitute a target conflict.
The likelihood and scale of these risks will be assessed in chapter 6.

Table 33: suggestion for potential specific risks from the explicated SMs for 'Health'

Index	Risk	Risk Type
$R_{SM\ 1\text{-}1}$	risk of non-participation due to investment costs	barrier
$R_{SM\ 3\text{-}1}$	risk of long-term debt due to investment costs	target conflict

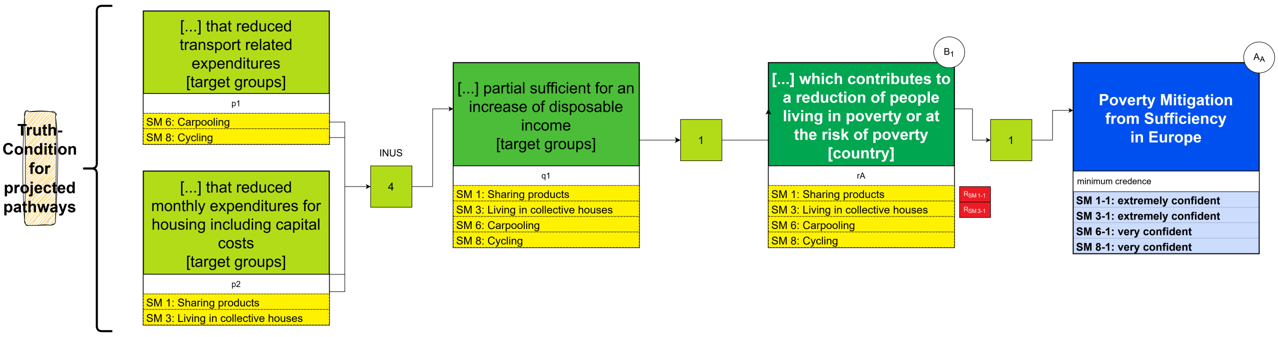
Source: own evaluation

Results of qualitative assessment

The following figure depicts the final shortlink ToC. We showed that all of these pathways are plausible and confirmed by evidence. **The strongest causal relationships are found for Product-Sharing (SM-1) and Co-Housing (SM-3) as we are *extremely confident* in the prediction that a large-scale implementation of these measures would mitigate poverty in Europe**, if the affordability of these measures can be ensured. **We are also *very confident*, that both Car-Pooling (SM-6) and Cycling (SM-8) can contribute to 'Poverty Mitigation'.** No similar, direct and convincing, causal relationships could be identified for the remaining measures of Product-Sizing (SM-2), Eating Less Meat & Dairy (SM-5), Flying-Less (SM-9) or Working Less (SM-10).
As a result, we would expect the following results from a long-term evaluation of such policies:

- Reduction in poverty rates in each country (accumulative over all measures)
- A higher disposable income for households in poverty or at the risk of poverty.

Figure 14: re-worked shortlink ToC for 'Poverty Mitigation'



Source: own assessment

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5. Risk Assessments

Type-2 or Generic Risk Assessments (G-RA, see also section 2.5) apply a broader perspective on the barriers from and the target conflicts with sufficiency measures and policies. This chapter is intended to shed light on potential future or evidence actualized issues of the promotion of sufficiency lifestyles in regard to 'Health', 'Poverty Mitigation', 'Gender Equality', 'Time Use', and 'Just Transition'.

Each G-RA entails the following steps:

1. Definition of key objectives and risks potentially to be violated
2. Development of decision-tree for risk assessment
3. Assessment of barriers and target conflicts

A key challenge for this assessment is the overlapping of the five dimensions. Some consequences of sufficiency policies, such as additional time-demand or lower economic growth, affect more than one dimension at once. The societal goal of 'Gender Equality' for example has links to all other dimensions but focuses on distinct key objectives. And whereas economic challenges affect the entire population, their consequences materialize differently under aspects of 'Just Transition' compared to 'Poverty Mitigation'.

This issue cannot be avoided without re-defining the societal goals in such a way that makes them mutual exclusive and additive to each other[17]. We decided for an alternative approach instead. Each dimension is looked at from the perspective of overarching goals and strategies in Europe, which are expressed in the form of key objectives. These key objectives are attributed to only one dimension during the assessment (sections 5.1 to 5.5) for each sufficiency measure (SM). The final section (5.6) than changes the perspective by looking at what risks are associated with each SM, how this risk is scored and if it might affect more than one dimension at once.

For two of the societal dimensions, 'Health' and 'Poverty Mitigation', the aforementioned and identified specific risks are assessed as well (see section 3.4 and section 4.4). These Type-1 or Specific Risk Assessments (S-RA) are predicted consequences of the explicated ToCs, that is, they pose a partial compensation of desired changes (barrier) or potential unintended negative side-effects (target conflicts).

Each risk is assessed according to the scoring in Table 34. This scoring represents an individual assessment of the authors based on the assumed likelihood and scale of each risk to each dimension based on the available background knowledge, evidence and results from other tasks.

Table 34: Scoring and assessment of generic and specific risks to societal dimension in FULFILL

[17] „Additivity" is one of Kolmogorov's axioms in epistemic probabilism that requires that possible states of affair are mutual exclusive (only one can be true at the same time). The proposed societal dimensions clearly violate this axiom as unintended negative side-effects of sufficiency can be present in more than one dimension at once to a different degree of severity.

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Score	Criteria	Assessment
0	no barriers | target conflicts identified	no actions needed
1	barriers | target conflicts with a very low likelihood on a very small or small scale	neglectable
2	barriers | target conflicts with a low likeli-hood on a small scale	policies can be improved
3	barriers | target conflicts with a low likeli-hood on a large scale	need for consideration of affected groups
4	barriers | target conflicts with a high likeli-hood on a small scale	minor policy adjustments recommended
5	barriers with a high likelihood on a large scale	major policy adjustments needed
6	target conflicts with a high likelihood on a large scale	policy should not be implemented

Source: own development

The final section of this chapter synthesizes the results and evaluates the results.

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5.1. Risk Assessment for 'Health'

The social dimension of 'Health' is looked at from two perspectives. First, the specific risks identified during the process of impact assessment are further qualified and evaluated. Secondly, a generic risk assessment is conducted for all potential barriers or target conflicts beyond the explicated causal hypotheses.

Definition of key objectives

In the "EU4Health programme" the EU sets the clear target of building "stronger, more resilient and more accessible health systems" (European Commission, 2021a). The underlying strategy, which runs from 2021 - 2027, was adopted as a response to the Covid- 19 pandemic to reinforce crisis preparedness in the EU. It contains four general and ten specific objectives representing the areas of intervention.

- Improve and foster health
- Health promotion and disease prevention, in particular cancer
- International health initiatives and cooperation
- Protect people
- Prevention, preparedness, and response to cross-border health threats
- Complementing national stockpiling of essential crisis-relevant products
- Establishing a reserve of medical, healthcare and support staff
- Access to medicinal products, medical devices, and crisis-relevant products
- Ensuring that these products are accessible, available, and affordable
- Strengthen health systems
- Reinforcing health data, digital tools and services, digital transformation of healthcare
- Enhancing access to healthcare
- Developing and implementing EU health legislation and evidence-based decision making
- Integrated work among national health systems

The following table selects the objectives to be assessed in G-RA for health and provides our reasoning for this decision. As a consequence of this selection, only four out of ten objectives are considered explicitly to be negatively affected by the sufficiency measures (SM's) in FULFILL.

Table 35: Key objectives to be included for the G-RA for 'Health'

Key Objective	Abbreviation for report	Reasoning for explicit inclusion in the definition
Health promotion and disease prevention, in particular cancer	health promotion	Health promotion and disease prevention plays a central role in enhancing health outcomes in Europe. While some SMs positively impact health, others may reduce either the promotion or prevention of health.
international health initiatives and cooperation	international cooperation	International cooperation is crucial to tackle the immense effects of disease outbreaks and to implement effective research methods. However, some SMs might hinder effective communication and collaboration between strategic health actors.
establishing a reserve of medical, health care and support staff	staff reserve	Many countries face a shortage of medical, healthcare, and support staff. Qualified personnel are essential for effective health sector management, but some SMs might threaten the increase of qualified staff.

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Key Objective	Abbreviation for report	Reasoning for explicit inclusion in the definition
Enhancing access to healthcare	access to healthcare	Access to healthcare is vital for a fair and inclusive health system. Yet, some SMs may further limit access, especially for marginalized groups and in regions relying on advanced health technologies.

Source: own reasoning based on (European Commission, 2021)

Based on this selection, the following definition for a positive contribution to the goal and its potential violations can be formulated:

***A positive contribution** to 'Health' means that the entire society, especially the most vulnerable groups in society, have complete access to healthcare while receiving adequate health promotion and disease prevention. Moreover, the European Union is thriving for more international cooperation and the medicinal staff reserve is further increased.*

***This goal can be endangered** if sufficiency lifestyles are risking either progress in health promotion, international cooperation, strengthening the medicinal staff, or the access to healthcare.*

Decision-tree for assessment

The following figure shows the control questions for the risk assessment on 'Health' in form of a decision-tree for evaluators. It aims to (i) identify potential negative side-effects of the eight SM's, (ii) provide reasons and scholarly evidence for them, (iii) display which key objectives in the EU Gender Equality Strategy are affected, (iv) estimate the likelihood of their occurrence after or during large-scale implementation, (v) estimate the size of the share of the target groups in the goal affected, (vi) provide a semi-quantitative assessment of the risks for the overall SM, and (vii) identify conditions that enable these potential risks.

Figure 15: Control-Questions for G-RA of 'Health'

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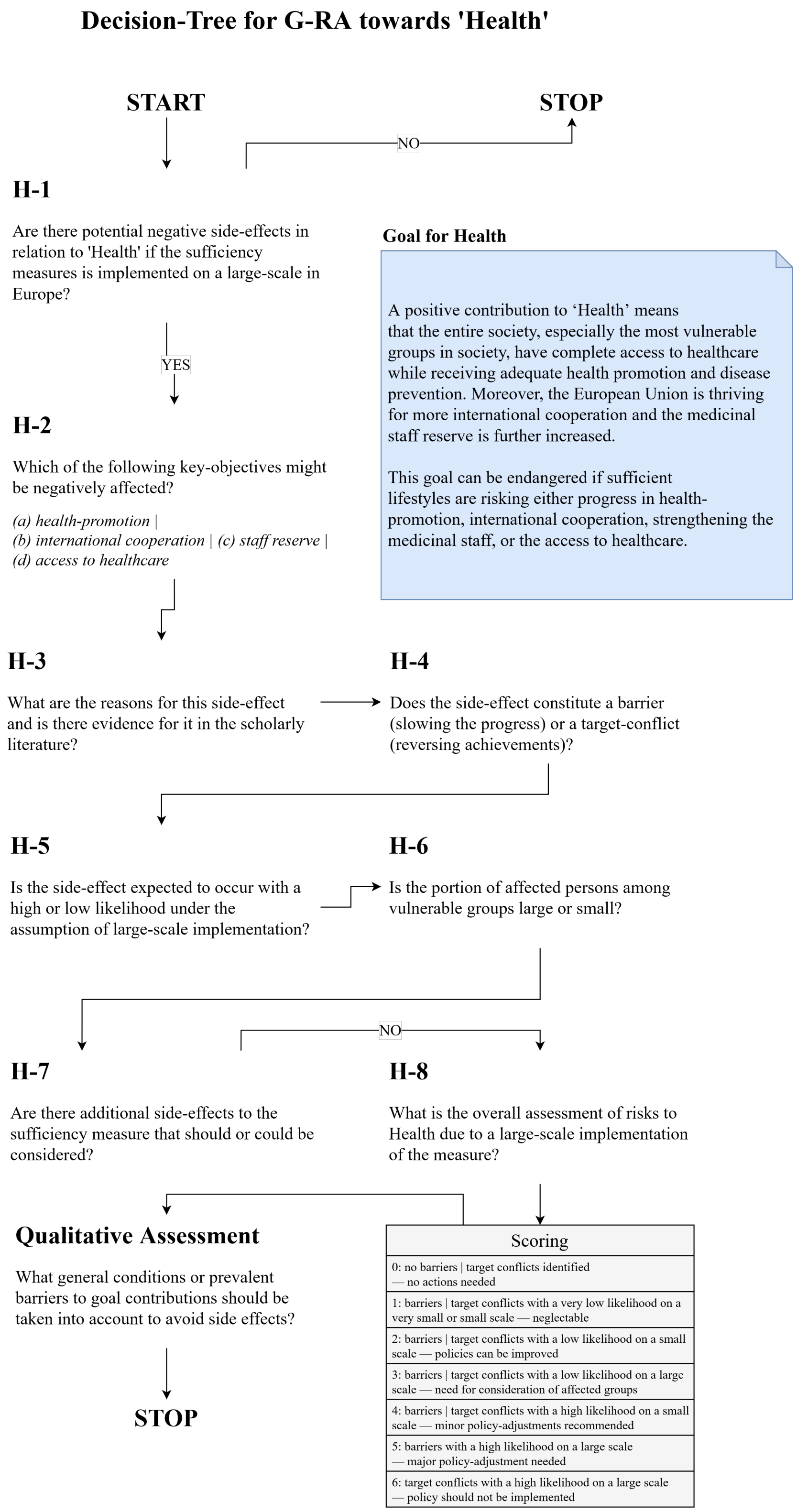

Source: own development

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Specific Risk Assessment for 'Health'

The following table lists the identified specific risks from the original impact assessment in chapter 3. It provides a scoring of each risk based on the assumed likelihood and scale of the negative effects.

$H_{SM\ 5\text{-}1}$: Eating Less Meat & Dairy

Our qualitative assessment in chapter 4 concluded that meat reductions in particular are beneficial to 'Health'. However, it conditioned this conclusion on a well-balanced diet, since there is scientific evidence that a lack of certain nutrients can lead to negative health outcomes. This potential risk for a target conflict is usually restricted to vegan diets as shown by for example Marsh et al., (2012). It can easily be avoided and since vegans as well as vegetarians and flexitarians are more likely to have the relevant information on how to adapt to malnutrition (Groufh-Jacobsen et al., 2023), we find that this risk is neglectable (very low likelihood for a small sample of the population). We therefore assess this risk with a score of 1 (neglectable) and do not see the need to adapt the policy in this regard.

$H_{SM\ 6\text{-}1}$: Car-Pooling

Our qualitative assessment concluded that 'Car-Pooling' is at least partially sufficient for a reduction of air pollutants and thus for health benefits in European countries. However, we also found evidence that the reasons for adopting this practice are usually not grounded in the goal towards a more sustainable lifestyle, but much more by pragmatic reasons such as mobility costs (Olsson et al., 2019). Although this is contested in the literature (e.g. Neoh et al., (2017) found that other factors are more important), it constitutes the risk of additional pollution for some portion of the target groups, if the choice for Car-Pooling results in additional fossil fuel combustion. For example, if the process of picking up passengers results in additional emissions that would have otherwise been avoided by the same passengers opting for climate-friendly options. Another example are Car-Pooling schemes that affect one type of air pollutant emission more than another, such as the association between diesel cars and NO_x (Arbeláez Vélez, 2024).

We find that such a risk is warranted but that there is only a small likelihood and that it affects only a small size of target group (and a much smaller part of the overall population). As such, we assess this risk with a score of 2 (policies can be improved) and suggest implementing such a policy non-isolated, by which we mean, in concordance with other policies towards environmentally friendly mobility (especially for commuting).

$H_{SM10\text{-}1}$ & $H_{SM10\text{-}2}$: Working Less

We concluded in our qualitative assessment that work-time reductions are partially sufficient for both healthier lifestyles (SM 10-1) and lower health risks (SM 10-2) and thus constitute 'Health' benefits in Europe. This conclusion is conditioned on adequate work-time control as well as adequate recovery time from long shifts (Härmä, 2006) — especially for those groups that would benefit the most.

We find that this constitutes a barrier with a high likelihood on a small scale and assess this risk therefore with a score of 4 (minor policy adjustments recommended). Any large-scale implementation of this SM should be guided by additional principles in our opinion, such as explicated for example by Spiegelaere & Piasna, (2017).

Generic Risk Assessment for 'Health'

The following sections apply the decision-tree from the previous section for a G-RA in a tabled form.

SM-1: Product-Sharing

The following Table shows the G-RA for increased sharing of products among households from a large-scale implementation in Europe. The overall assessment concludes that some risks are involved, but that they merely have the ability to slow the progress towards the overarching goal. Since product-sharing often involves meetings in-person, it is necessarily the case that there is a higher risk for the transmission of diseases. Although there is — apart from pandemic periods — only a very low likelihood of occurrence that affects only a small portion of the society, people might be reluctant to participate in schemes that require such in-person meetings due to fear of transmission. This is why we assign a score of 2 (slowing progress for some groups).

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This barrier might be mitigated by an explicit consideration of the needs, preferences and capabilities of the target groups related to co-consumption (e.g. by minimizing the time of exchange and finding options to exchange products in a safe manner).

Table 36: G-RA of SM-3 Product-Sharing towards 'Health'

Indicator	**Reasoning & Evidence**	**Type of Effect**	**Key Objectives**	**Likelihood**	**Scale**
Risk of disease transmission due to insufficient hygiene protocols	The sharing of goods increases the risk of disease transmission. Goods sharing platforms thus developed guidelines "not to meet in person if sick, minimise the time of exchange, practice good hygiene, and consider other means of exchanging items" (Mont et al., 2021) .	barrier	health promotion	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Overall Score	2				

Source: own compilation and reasoning as well as provided references in the table

SM-2: Car-Sizing

We cannot identify generic barriers or target conflicts of this SM in relation to 'Health' (Score 0: no further actions needed).

SM-3: Space-Sharing

Shared Living-Space increases the risk of disease transmission to some extent. We find that the likelihood is low — except for pandemic periods — and that it would also only affect a portion of the target groups. However, given that policies for shared living space often address the elderly, we find that this risk warrants a score of 3 (need for consideration of affected groups). Policies should consider these and other vulnerable groups before and during a large-scale implementation.

Table 37: G-RA of SM-3 Space-Sharing towards 'Health'

Indicator	**Reasoning & Evidence**	**Type of Effect**	**Key Objectives**	**Likelihood**	**Scale**
Risk of increased disease transmission due to close living conditions	Space in homes must be adequate to allow for interpersonal distance and spatial relationships. "Several studies have shown a direct association between crowding and certain negative health effects" (D'Alessandro et al., 2020; p.65). Space sharing can contribute to these outcomes and is thus constitutes increased risks for disease transmission in objection to the key objective of health promotion.	target conflict	health promotion	low	large
3: barriers | target conflicts with a low likelihood on a large scale ➡ need for consideration of affected groups					
Overall Score	**3**				

Source: own compilation and reasoning as well as provided references in the table

SM-5: Eating Less Meat & Dairy

The direct and specific risks to a contribution of this measure to health benefits have already been considered. In addition, we find that there is a risk that an implementation of this policy on a large scale in Europe can be slowed or opposed, if many people consider meat and dairy to be a crucial part of a healthy lifestyle.
This constitutes a barrier to implementation with a high likelihood on a small scale that can be mitigated by addressing misinformation and involving the population in the explication of the policy.

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Table 38: G-RA of SM-5 Eating Less Meat & Dairy towards 'Health'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
Risk of non-implementation due to low acceptance	Meat and dairy products are considered by many to be a necessary part of a healthy diet. Promoting a reduction, or even a full vegetarian or vegan diet, might have adverse effects on the acceptance of such a policy (Pohjolainen et al., 2015; Varela et al., 2022).	barrier	health promotion	high	small
4: barriers | target conflicts with a high likelihood on a small scale ➡ minor policy adjustments recommended					
Overall Score	**4**				

Source: own compilation and reasoning as well as provided references in the table

SM-6: Car-Pooling

We find that there is a very low likelihood that Car-Pooling contributes to the transmission of diseases, because occupants will be confined to the same small space for often longer periods of time. We consider this effect to be neglectable, since we could not find any evidence in the literature that this is a serious risk that affects larger groups. However, people might be unwilling to accept such a policy on a large scale due to fear of disease transmission. We therefore score this risk as 2 (policies can be improved).

Table 39: G-RA of SM-6 Car-Pooling towards 'Health'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
Risk of increased disease transmission due to confined shared conditions	We assume that the risks for disease transmission are slightly elevated for persons that share the same vehicle on a regular basis or for a longer period of time. Although we did not find any evidence for this in the literature, there is evidence that the Covid-19 pandemic has affected the modal choices of people in such a way that e.g. public transport modes have been, at least for some time, less attractive (Mashrur et al., 2022). Since there is also evidence that this might have changed with the end of pandemic (ibid), we assume that this risk has a low likelihood on a small scale.	barrier	health promotion	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Overall Score	**2**				

Source: own compilation and reasoning as well as provided references in the table

SM-8: Cycling

We find that there is a small likelihood that access to medical facilities might be reduced for some portion of the population, if changes to transport infrastructures in favour of cycling lead to longer response times for first-responders or increase the time necessary to reach them. This requires better spatial planning ahead of policy implementation and enhancement.

Table 40: G-RA of SM-8 Cycling towards 'Health'

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Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Like-li-hood	Scale
Risk of decreased access to relevant infrastructure for medicinal supply	Increase in cycling might be contingent on better infrastructures for cyclists at the cost of other means of transport (in particular car travel). This in turn might lead to a restricted access to medical facilities for some portion of the population, because "[…] equitable provision of cycling infrastructure may not lead to an equitable cycling environment […]" (Jahanshahi et al., 2023,p.1).	target conflict	access to healthcare	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Overall Score	**2**				

Source: own compilation and reasoning as well as provided references in the table

SM-9: Flying Less

There is a small chance that reduced air travel also affects the international cooperation in the medical sciences. However, we find that this risk is neglectable, since it is very unlikely that professional travel to that end would be limited by the policy.

Table 41: G-RA of SM-9 Flying Less in relation to 'Health'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Like-li-hood	Scale
Risk of decreased international cooperation in relevant fields of health	Decreased air travel is associated can have negative impacts on the "productivity, success, excellence, internationality, quality of research, teaching, visibility and presence, role modelling, consistency, freedom, and the humanitarian impact of […] research" (Kreil, 2021;p.52). This can therefore also negatively affect the area of international cooperation in the field of medical science.	barrier	international cooperation	very low	very small
1: barriers | target conflicts with a very low likelihood on a very small or small scale ➡ neglectable					
Overall Score	**1**				

Source: own compilation and reasoning as well as provided references in the table

SM-10: Working Less

The assessment of causal hypotheses for the contribution of this measure towards health benefits provided ample evidence that the target group that benefits the most from working less (ideally with wage compensation) are workers with a lot of overtime as well as workers that work long shifts. Both is the case for many employees in medical facilities (e.g. nurses in hospitals). As this public service is already under constraints in many European countries, we find that this warrants a high likelihood for a target conflict. Already understaffed hospitals and similar medical service providers are likely to cut back on their services, if this SM is implemented on a large scale.

This issue requires, in our opinion, minor policy adjustments (e.g. future financial needs of hospitals and other health-providers) as well as ex-ante planning and evaluations regarding the implementation of such a policy on a large scale (Score 4).

Table 42: G-RA of SM-10 Working Less towards 'Health'

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Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
Risk of insufficient medicinal staff reserve in the future health sector	The implementation of this policy would benefit health workers, but this industry already suffers from a lack of work-force. It is therefore likely that already existing constraints in work-force would amplify and constitute a direct target conflict for themselves and all persons in need of health services (Llop-Gironés et al., 2021).	target conflict	staff reserve	high	small
4: barriers | target conflicts with a high likelihood on a small scale ➡ major policy-adjustment needed					
Overall Score	**4**				

Source: own compilation and reasoning as well as provided references in the table

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5.2. Risk Assessment for 'Poverty Mitigation'

The social dimension of 'Poverty Mitigation' is assessed in the same way as the risks towards 'Health' (specific and generic risk assessment). Given the scope of the project, as well as the projected pathways for sufficiency lifestyles, it also focuses on poverty and conceptions of poverty in Europe. Potential goal violations in Europe might translate to a global scale, but we are hesitant to do so. One reason for this is that although 'Poverty' can be operationalized in a number of ways, it usually depends on local socio-economic conditions. For example, the sharing of space might already very well be the most prevalent form of living in some areas of the world for some low-income groups (e.g. multi-generational housing). It would thus not be justified to transfer the identified risks from this sufficiency lifestyle in Europe to another region or cultural background.

Definition of key objectives

Within the 2021 published "European Pillar of Social Rights Action Plan" the European Commission sets new ambitions aiming for a strong and social Europe within the next decade. One of the three key Targets is "Poverty Mitigation" stating:

> *"The number of people at risk of poverty or social exclusion should be reduced by at least 15 million by 2030" (European Commission, 2021)*

The strategy itself then proceeds to address certain "key objectives" to achieve the target of "Poverty Mitigation":

1. fostering Social Inclusion
2. foster equal opportunities for all children in the EU, and prevent children in poor families from becoming adults at risk of poverty
3. invest in social services and social policies
4. ensure by minimum income schemes that no one is left behind
5. ensure access to affordable housing and end homelessness by 2030
6. ensure effective access to essential services of sufficient quality

We think that, for the purpose of operationalizing the overarching goal in FULFILL, the above cited goal should focus on groups that are in risk of financial poverty. We also decided in light of the SM's to be evaluated, that some key objectives should be prioritized for our assessment – especially since many of them are interrelated.
The following table lists these objectives and provides our reasoning for this decision. As a consequence of this selection, the key objectives on 'invest in social services and social policies', 'ensure by minimum income schemes that no one is left behind' are not considered explicitly to be negatively affected by the sufficiency measures (SM's) in FULFILL.

Table 43: Key objectives to be included in the G-RA for 'Poverty Mitigation'

Key Objective	Abbreviation for report	Reasoning for explicit inclusion in the definition
fostering social inclusion	social inclusion	"A strong social Europe is about people and their well-being," states the EU strategy (European Commission. Directorate General for Employment, Social Affairs and Inclusion., 2021; p.5). While some SM's, such as Space-Sharing can improve social contacts and foster inclusion, there is a risk that these practices might further marginalize already socially excluded groups. This can occur through sufficiency practices that form exclusive identities, such as vegetarians, or through initiatives like product sharing, which may be designed for privileged groups.

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Key Objective	Abbreviation for report	Reasoning for explicit inclusion in the definition
foster equal opportunities for all children in the EU, and prevent children in poor families from becoming adults at risk of poverty	equal opportunities for children	"Breaking the intergenerational cycles of disadvantage starts with investing in children to reduce the gap between children in need and their better-off peers when it comes to access to key services"(European Commission. Directorate General for Employment, Social Affairs and Inclusion., 2021; p.27) However, some implementations of the SMs might reinforce existing disparities, affecting for example children from low-income groups who are especially dependent on income from extra working hours to provide for their families.
ensure access to affordable housing and end homelessness by 2030	access to affordable housing	While EU strategies aim to tackle issues of unaffordable housing, energy poverty, and homelessness, certain implementations of the SMs might undermine these efforts. For instance, cohousing schemes, though designed to alleviate housing affordability, often face high initial costs. Effective policy regulations must therefore be incorporated to provide the necessary support and ensure the affordability of these housing solutions.
ensure effective access to essential services of sufficient quality	access to essential service	"Support for access to such services shall be available for those in need (European Commission. Directorate General for Employment, Social Affairs and Inclusion., 2021; p.46)," according to the EU strategy. However, some SMs may not be accessible to vulnerable groups or may create barriers to effectively accessing necessary infrastructure. For example, carpooling, while intended to be inclusive, is often perceived as more time-consuming. Similarly, cycling may not be feasible for certain groups due to physical or logistical limitations. These barriers can prevent vulnerable populations from benefiting from intended supports and services.
ensure by minimum income schemes that no one is left behind	minimum income	“Minimum income schemes are essential to ensure that no one is left behind” (European Commission. Directorate General for Employment, Social Affairs and Inclusion., 2021; p.27). Vulnerable persons often work in low-income jobs or have no jobs at all. Any sufficiency policy that affects the number of workers in minimum income jobs in a negative manner or lead to job loss may also prevent people from escaping economic poverty.

Source: own reasoning based on EU Poverty Mitigation Strategy 2021-2030

We derive the following definition of Poverty Mitigation' for the purposes of our Social Impact Assessment in FULFILL.

Definition of 'Poverty Mitigation' (PM) for T6.3

***A positive contribution** to 'Poverty Mitigation' means that specifically those in financial constraints or threatened by the risk of poverty, are socially included, and their access to affordable housing and sufficient infrastructures is ensured. Children have, regardless of their background, equal opportunities.*

***This goal can be endangered** if sufficiency lifestyles impede or even prevent solutions to overcame poverty mitigation efforts.*

Decision Tree for assessment

Figure 5 shows the control questions for the G-RA for 'Poverty mitigation' in form of a decision-tree for evaluators. It aims to (i) identify potential negative side-effects of the eight SM's, (ii) provide reasons and scholarly evidence for them, (iii) display which key objectives in the EU Poverty Mitigation Strategy are affected, (iv) estimate the likelihood of their occurrence after or during large-scale implementation, (v) estimate the size of the share of the target groups in the goal affected, (vi) provide

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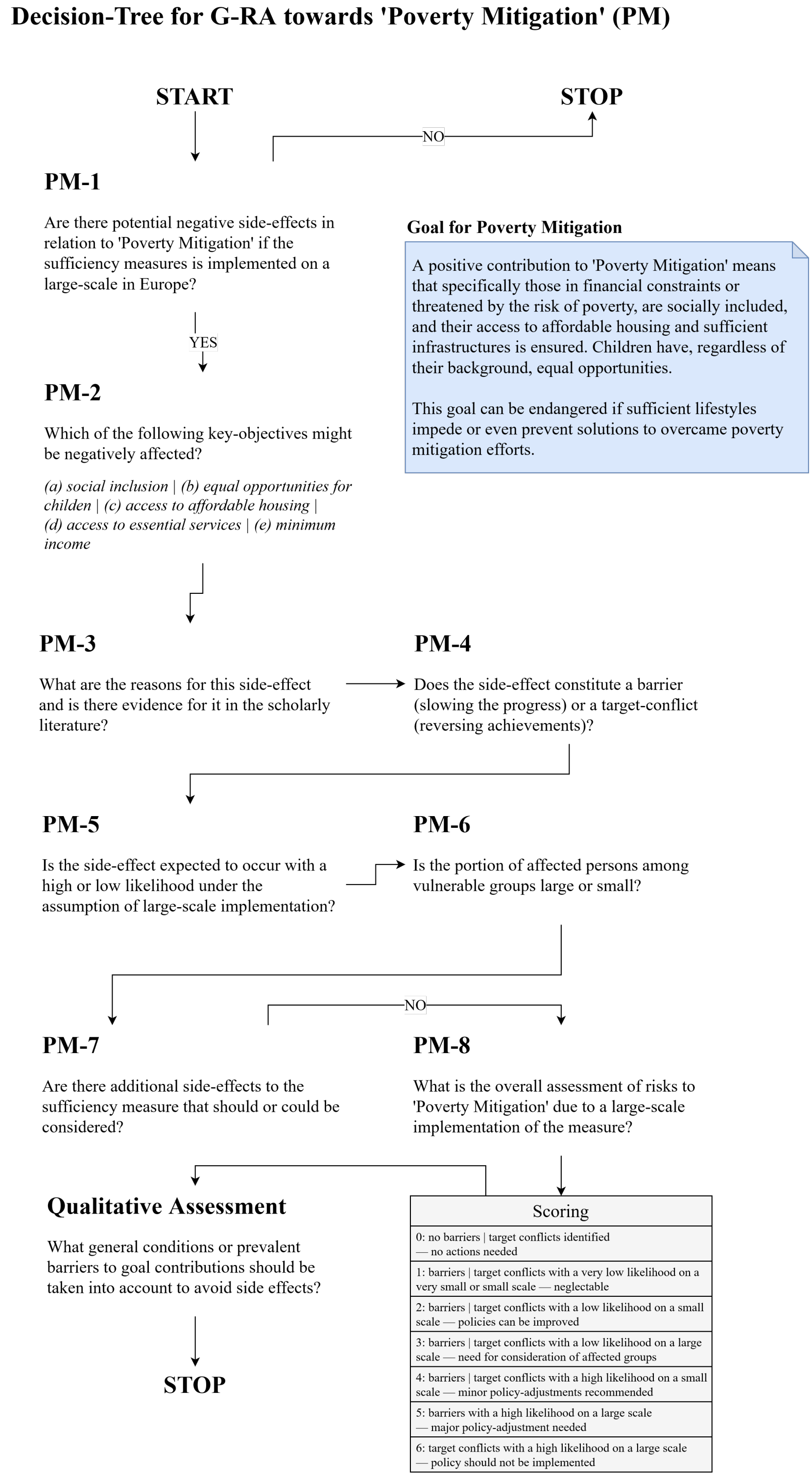
a semi-quantitative assessment of the risks for the overall SM, and (vii) identify conditions that enable these potential risks.

Figure 16: Control-Questions for G-RA of 'Poverty Mitigation'



Source: own development

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Specific Risk Assessment (S-RA) for 'Poverty Mitigation'

The following table lists the identified specific risks from the original impact assessment in chapter 5. It provides a scoring of each risk based on the assumed likelihood and scale of the negative effects.

$H_{SM\ 1\text{-}1}$: Product-Sharing

Our qualitative assessment concluded that, under the assumption of affordability, the sharing of products is likely to contribute to poverty mitigation. However, we also find that low-income households in particular might be unwilling to pay potential investments costs for common goods or facilities. We think that there is a high likelihood that this occurs, but that the size of the effect is small. This barrier is thus assessed with a score of 3, which warrants the "need for the consideration of affected groups" before and during implementation. This could be, among other things, achieved by minimizing the initial investment costs or by providing means to participate without additional payments.

$H_{SM\ 3\text{-}1}$: Space-Sharing

The qualitative assessment also concluded that the sharing of living space would be an effective measure to mitigate poverty in Europe, assuming that low-income households could participate. This is insofar unlikely, because many of the existing projects for co-housing or collective housing require initial investments costs that poor households could probably only afford by applying for a loan. We think that this constitutes a target conflict, because the capital costs could overcompensate the targeted savings in monthly expenditures for rent or food. We think that there is a small likelihood that this occurs, and that the portion of the target groups that would suffer from that is small, because most people in this group would not be able to get such a loan in the first place. On the other hand, and similar to 'Product-Sharing', it will also prevent most people in this group to participate in a programme for co-housing in the first place. We therefore assess this risk as being both a target conflict and a barrier with a score of 5 (major policy adjustment needed). If this measure is intended to alleviate or even mitigate poverty, there is a lack of projects and programmes that are accessible to low-income households.

Generic Risk Assessment (G-RA) for 'Poverty Mitigation'

The following sections apply the decision-tree from the previous section for a G-RA in a tabled form. However, due to the findings from T6.2, an additional risk assessment is required to account for job-losses as an effect of sufficiency policies that constitutes a risk towards 'Poverty Mitigation'. This can also be considered evidence in line with the original proposal for T6.3 that aims to discuss the issue of "employment transitions of local economies" (Proposal, Part B, p. 48).

Job-loss for low-skilled workers across Europe

One of the main disadvantages of sufficiency policies can be their negative effect on demand from a macro-economic perspective. The lower consumption of goods can lead to lower production rates in some industries and thus to long-term job loss. This can pose a risk to 'Poverty Mitigation' if it affects industries with large low-skilled workforces without a positive trade-off. An example for this is the sufficiency measure that aims to lower the consumption of meat. Workers in the meat industry are usually unskilled or low-skilled, but this might also be true for helpers in plant-based agriculture. Whether low-skilled workers in one industry can and will replace low-skilled workers in another industry, or whether more sufficiency oriented societies are able to compensate the negative effects via training and education, cannot be fully investigated in FULFILL.

The macro-economic I-/O-Model from T6.2 is therefore not able to account for all interdependent effects, but it predicts an overall loss of workers in Europe from the implementation of the SMs from a purely demand-side perspective. We thus identify this as a risk to 'Poverty Mitigation' that is a consequence of all SMs but affects vulnerable groups differently in relation to the affected industries.

The following table shows the results from T6.2. on a European scale for the years 2040 and 2050 in relation to each of the SMs that were integrated into the **Multi-Regional Analysis of Regions through Input-Output (MARIO)**.

Table 44: Total change in low-skilled workforce from implementation

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(of SM-1, SM-2, SM-3, SM-5, SM-8, SM-9)

Case	Employment for low-skilled workers	Employment growth for low-skilled workers	Loss of jobs from lower demand
Reference 2020	87.1 million	-	-
BAU until 2050	127.7 million	46.6%	0
All Measures until 2050	123.2 million	41.4%	4.5 million

Source: own calculation based on results in T6.2

According to this calculation, about 4.5 million low-skilled workers would not be employed as a result of six SMs, that would have been otherwise employed in a business-as-usual (BAU) scenario. The largest portion of these 'lost' jobs can be attributed to the sectors 'Services' (2.56 million) and 'Manufacturing' (1.34 million). Another 0.39 million jobs would have otherwise been available in 'Transport' and 0.20 million in 'Agriculture'.

However, these effects are strongly unevenly attributed among the six measures in question. From SM-8 on 'Cycling' (7,000) and SM-3 on 'Space-Sharing' (4,000) less than 12,000 jobs over 30 years would not be available. Similarly, the effects from SM-2 on 'Car-Sizing' (23,000) and SM-1 on 'Product-Sharing' (42,000) seem to be neglectable as well. We think that all four of these effects are well within the errors of margin (less than 2% of the total effect combined), but also that these effects strongly depend on the underlying assumptions from the projected pathways. That is, by limiting e.g. 'Product-Sharing' to washing machines only, any economic outcome assessment is limited as well.

Instead, more than 93% of the 4.5 million jobs would be an effect of SM-5 on 'Diets' (4.22 million) and at least 5% can be attributed to SM-9 on 'Flying Less' (240,000). We find that only the latter two constitute a risk to 'Poverty Mitigation', with SM-5 on 'Diets' requiring at least a major policy-adjustment (Score 5) and SM-9 on 'Flying Less' attesting to at least a minor policy adjustment (Score 4).

SM-1: Product-Sharing

The following Table shows the G-RA for increased sharing of products among households from a large-scale implementation in Europe. The overall assessment concludes that vulnerable groups in particular may be less motivated to participate in the sharing economy and thus benefit less from the societal benefits in terms of social inclusion.

We find that this risk affects only a small portion of the affected groups and can thus be mitigated with the help of policy adjustments by for example explicitly addressing and enabling those vulnerable groups that are less likely to participate (thus maximising the social inclusion benefit).

Table 45: G-RA of SM-1 Product-Sharing towards 'Poverty Mitigation'

Indicator	**Reasoning & Evidence**	**Type of Effect**	**Key Objectives**	**Likelihood**	**Scale**
Risk of less participation due to underrepresentation of vulnerable groups	Motivations to participate in the sharing economy vary by role and age: Buyers in the sharing economy are predominantly middle-income households, including families with children, and are mainly within the age range of 18-34. Sellers, on the other hand, come from all income levels but are typically college-educated and also primarily aged 18-34. (Zhu & Liu, 2021).	barrier	social inclusion	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Overall Score	**2**				

Source: own compilation and reasoning as well as provided references in the table

SM-2: Car-sizing

A potential risk stems from the fact that groups in or at the risk of poverty cannot or will not participate in the measure because they have the lowest car-ownership rates in Europe. While there are benefits from smaller car-sizes for their costumers, others will therefore not be able to participate and benefit from the policy as intended.

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We find that this risk affects a small part of the overall population, but a large portion of the group of vulnerable people in Europe. The policy should therefore be improved in such a way, that in-voluntary car-ownership among those groups is reduced or compensated by better access to alternative mobility options overall (especially for poor households in rural areas).

Table 46: G-RA of SM-2 Car-Sizing towards 'Poverty Mitigation'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
Risk of non-participation of vulnerable groups due to economic constraints	Low-income households have the lowest rates of car-ownership among all income groups (OECD, 2023), are more likely to be car-less involuntarily(Van Eenoo, 2023), and are more often subject to "forced car-ownership"(Mattioli, 2017). There is thus a risk that some portion of this group cannot benefit from a large-scale implementation, even if some other portion does.	barrier	access to essential services	small	large
3: barriers | target conflicts with a low likelihood on a large scale ➡ need for consideration of affected groups					
Overall Score	**3**				

Source: own compilation and reasoning as well as provided references in the table

SM-3: Space-Sharing

We find that those groups that benefit the most from this measure in terms of social inclusion and long-term economic advantages (e.g., elderly people, or low-income families) will also be the least likely to be able to afford shared space in cohousing. This is especially the case if the group wants to integrate parties with few assets (Hacke et al., 2019) and constitutes a risk to the access to affordable housing with a high likelihood on a small scale.

This can be mitigated if some of the financial risks are covered by the State or other institutions and if such financing is ensured to alleviate poverty instead of reinforcing economic constraints of people in poverty or at the risk of poverty.

As this risk has already been accounted for from the specific Risk Assessment, and the root cause is the same in both cases, it is not included as a generic risk here.

SM-5: Eating Less Meat & Dairy

We identify a potential risk of lower participation among vulnerable groups due to the social exclusion effect of lowering meat consumption. Although there is low likelihood that this occurs, we also concluded that the overall perception of red meat consumption can and likely will change in society as a consequence of these policies.

The policy should address this issue by highlighting the benefits of flexitarian, vegetarian, and vegan diets.

Table 47: G-RA of SM-5 Eating Less Meat & Dairy towards 'Poverty Mitigation'

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Indicator	Reasoning & Evidence	Type of Ef-fect	Key Objec-tives	Like-li-hood	Scale
Risk of social exclusion due to less meat consumption	Red meat consumptions is linked to positive perceptions of national identity, social status, prestige and masculinity (Bogueva et al., 2017). Low-income households might be less inclined to reduce their meat consumption and thus benefit less from the benefits due to fear of social exclusion.	bar-rier	social inclu-sion	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Overall Score	**2**				

Source: own compilation and reasoning as well as provided references in the table

SM-6 : Carpooling

There is a small risk that Carpooling constitutes a barrier for some groups, as it is associated with a loss of independence. However, we do not think that vulnerable groups are particularly affected by this, or more affected than other, more affluent, groups in society.

Table 48: G-RA of SM-6 Carpooling towards 'Poverty Mitigation'

Indica-tor	Reasoning & Evidence	Type of Ef-fect	Key Objec-tives	Like-li-hood	Scale
risk of non-par-ticipa-tion	Some persons might be unwilling to participate since it could entail the loss of independence represented by a self-owned car. How-ever, there is no evidence that such a risk is prevalent or affects vulnerable groups more than other groups in society (Aguiléra & Pigalle, 2021).	bar-rier	social inclu-sion	very low	very small
1: barriers | target conflicts with a very low likelihood on a small or very small scale ➡ neglectable					
Overall Score	**1**				

Source: own compilation and reasoning as well as provided references in the table

SM-8 : Cycling

We identify two risks from a large-scale implementation of the policy.

In cases where the policy entails changes to infrastructures in favour of bicycles the effective access to infrastructures might be impeded. Although there is no evidence that vulnerable groups are more likely to experience this barrier than non-vulnerable groups, they are, nonetheless, more affected by it due to lack of alternatives. Any policy to this end should account for this and ensure that such alternatives exist or are implemented. Another option to mitigate this risk is by considering this issue when designing the necessary infrastructure changes in the first place. Since lanes for cycling require less space than lanes for cars or busses even when multi-laned, it stands to reason that they can be designed without impeding for example motorized emergency services (the same way that an emergency car is allowed to drive through an otherwise car-free zone in a city).

The second potential risk relates to the lower likelihood of participation for people living in deprived areas. Since such people are more likely to belong to a vulnerable group, it is thus also more likely that they are less willing, or able, to participate. Any large-scale implementation of a cycling policy should account for that and accompanied by respective investments in the infrastructures and modal mobility capabilities of people living in deprived areas.

The third potential risk we identified in principle but did not include in our assessment (representing a score of 0) relates to driving license ownership of deprived groups. Although there is a low likelihood that a modal shift to cycling at the expense of car-use also entails lower job opportunities from not having a driving-license for vulnerable person, we find that this outcome is very unlikely in conjunction as a consequence of a large-scale implementation of 'Cycling' in Europe.

Table 49: G-RA of SM-8 Cycling towards 'Poverty Mitigation'

FULFILL has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003656.

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
Risk of insufficient access to relevant infrastructure for some groups	Policies that enable cycling will, with at least a low likelihood on a small scale, also entail changes to local infrastructures. This in turn, might impede access to essential services for some portion of vulnerable groups.	barrier	access to infrastructure	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Risk of not non-engagement of deprived groups	"This research found that the likelihood of cycling in England is lower among people living in deprived areas than among people living in non-deprived areas" (Vidal Tortosa et al., 2021; p. 705). Since vulnerable persons, or persons at the risk of poverty, are more likely to live in more affordable, but deprived areas, they are more likely to not participate in policies that aim at increasing cycling.	barrier	access to infrastructure	high	small
4: barriers | target conflicts with a high likelihood on a small scale ➡ minor policy adjustments recommended					
Overall Score	**6**				

Source: own compilation and reasoning as well as provided references in the table

SM-9: Flying Less

We find that there is a potential risk affecting the key objective of social inclusion, if a large-scale implementation of this policy is mainly driven by higher prices. While affluent households might be able to afford more expensive flights, low-income households might not and will be thus not only be flying less but not flying at all. This affects their ability to participate in society, especially in relation to cultural experiences from vacations in other countries.

However, we also find that an implementation would also likely change the attitudes towards flying overall and thus mitigate this risk, in particular if the success depends on providing alternative mobility options for less affluent households.

Table 50: G-RA of SM-9 Flying Less towards 'Poverty Mitigation'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
risk of non-participation	A price-driven policy of Flying Less can constitute a barrier that affects vulnerable persons more than more affluent persons (Randles & Mander, 2009). This in turn might lead to a lower social inclusion of these groups.	barrier	social inclusion	very low	small
1: barriers | target conflicts with a very low likelihood on a small or very small scale ➡ neglectable					
Overall Score	**1**				

Source: own compilation and reasoning as well as provided references in the table

SM-10: Working Less

We find that work hour reductions constitute a potential risk for lost income in low-income families, because they are often associated with lost wages. There is, in our opinion, a high likelihood that this risk materializes for a relevant portion of low-income households.

Policies that aim at Working Less can and should mitigate this risk via wage compensation.

Table 51: G-RA of SM-10 Working Less towards 'Poverty Mitigation'

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Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likeli-hood	Scale
Risk of insufficient wage	The negative effects of work hour reductions are particular prevalent for working-class employees, since work restructuring leads to lost overtime hours and strains on family finances (Kallis et al., 2013; Lautsch & Scully, 2007). This in turn might increase poverty risks or prevent poverty mitigation for a relevant portion of the most vulnerable groups in society.	barrier	minimal income	high	large
5: barriers with a high likelihood on a large scale ➡ major policy adjustments needed					
Overall Score	**5**				

Source: own compilation and reasoning as well as provided references in the table

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5.3. Risk Assessment for Gender Equality

The following section provides a generic risk assessment for potential negative side-effects from up-scaled sufficiency measures (SM's) for the goal of 'Gender Equality'. We focus on barriers slowing the intended progress and target conflicts that might endanger the overarching goal.

Definition of key objectives

The European Commission defines 'Gender Equality' in their most recent "Gender Equality Strategy" as follows:

> *"The goal is a Union where women and men, girls, and boys, in all their diversity, are free to pursue their chosen path in life, have equal opportunities to thrive, and can equally participate in and lead our European society."*
> (European Commission, 2020)

The strategy itself then proceeds to address seven so-called "key objectives" (ibid.):

1. Ending gender-based violence
2. Challenging gender-stereotypes
3. Closing gender gaps in the labour market
4. Achieving equal participation across different sectors of the economy
5. Addressing the gender pay and pension gap
6. Closing the gender care gap
7. Achieving gender balance in decision-making and politics

We think that, for the purpose of operationalizing the overarching goal in FULFILL, the above cited goal should focus on groups that are marginalized due to their gender (women, girls as well as LGBT+). We also decided in light of the SM's to be evaluated, that some key objectives should be prioritized for our assessment – especially since many of them are inter-related.
The following table lists these objectives and provides our reasoning for this decision. As a consequence of this selection, the key objectives on 'ending gender-biased violence', 'equal participation across different sectors of the economy' and 'achieving gender balance in decision-making and politics' are not considered explicitly to be negatively affected by the sufficiency measures (SM's) in FULFILL.

Table 52: Key objectives to be included in the 'Gender Equality' dimension of T6.3

Key Objective	**Abbreviation for report**	**Reasoning for explicit inclusion in the definition**
Challenging gender-stereotypes	gender-stereotypes	"Gender stereotypes are a root cause of gender inequality and affect all areas of society" (from the EU strategy). Some realizations or implementations of the SM's might indirectly reinforce such gender biases, especially in relation to care-work or the gender pay gap.
Closing gender gaps in the labour market	labour-gap	"Social and economic policies, taxation and social protection systems should not perpetuate structural gender inequalities based on traditional gender roles in the realms of work and private life" (from the EU strategy). Some realizations or implementations of the SM's might reinforce the existing disparities regarding work-life balance and job opportunities, especially for second earners in households.
Addressing the gender pay and pension gap	pay-gap	Women are more likely to work less and to earn less than men (pay-gap). At the same time, higher shares of their work are invisible or unpaid. Consequently, older women are also more at risk of poverty than men (pension-gap). Some realizations or

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Key Objective	Abbreviation for report	Reasoning for explicit inclusion in the definition
		implementations of the SM's might undermine efforts to alleviate these gaps in work time (paid versus unpaid), salary and pensions.
Closing the gender-care gap	care-gap	"Women often align their decision to work, and how to work, with their caring responsibilities and with whether and how these duties are shared with a partner. This is a particular challenge for single parents, most of whom are women" (from the EU strategy). Some realizations or implementations of the SM's might reinforce this problem by not accounting for the conditions under which care-work is conducted in a more efficient or effective manner.

Source: own reasoning based on EU Gender Equality Strategy 2021-2025

We derive the following definition of 'Gender Equality' for the purposes of our Social Impact Assessment in FULFILL.

Definition of 'Gender Equality' (GE) for T6.3

A positive contribution *to 'Gender Equality' means that women and girls, in all their diversity (including non-binary persons), are free to pursue their chosen path in life, have equal opportunities to thrive, and can equally participate in and lead our European society.*
This goal can be endangered *if sufficiency lifestyles impede or even prevent solutions to overcame gender stereotypes or to reduce pay-, pension-, care- or labour-gaps.*

Decision Tree

The following Figure shows the control questions for the risk assessment on 'Gender Equality' in form of a decision-tree for evaluators.

Figure 17: Control-Questions for G-RA of 'Gender Equality'

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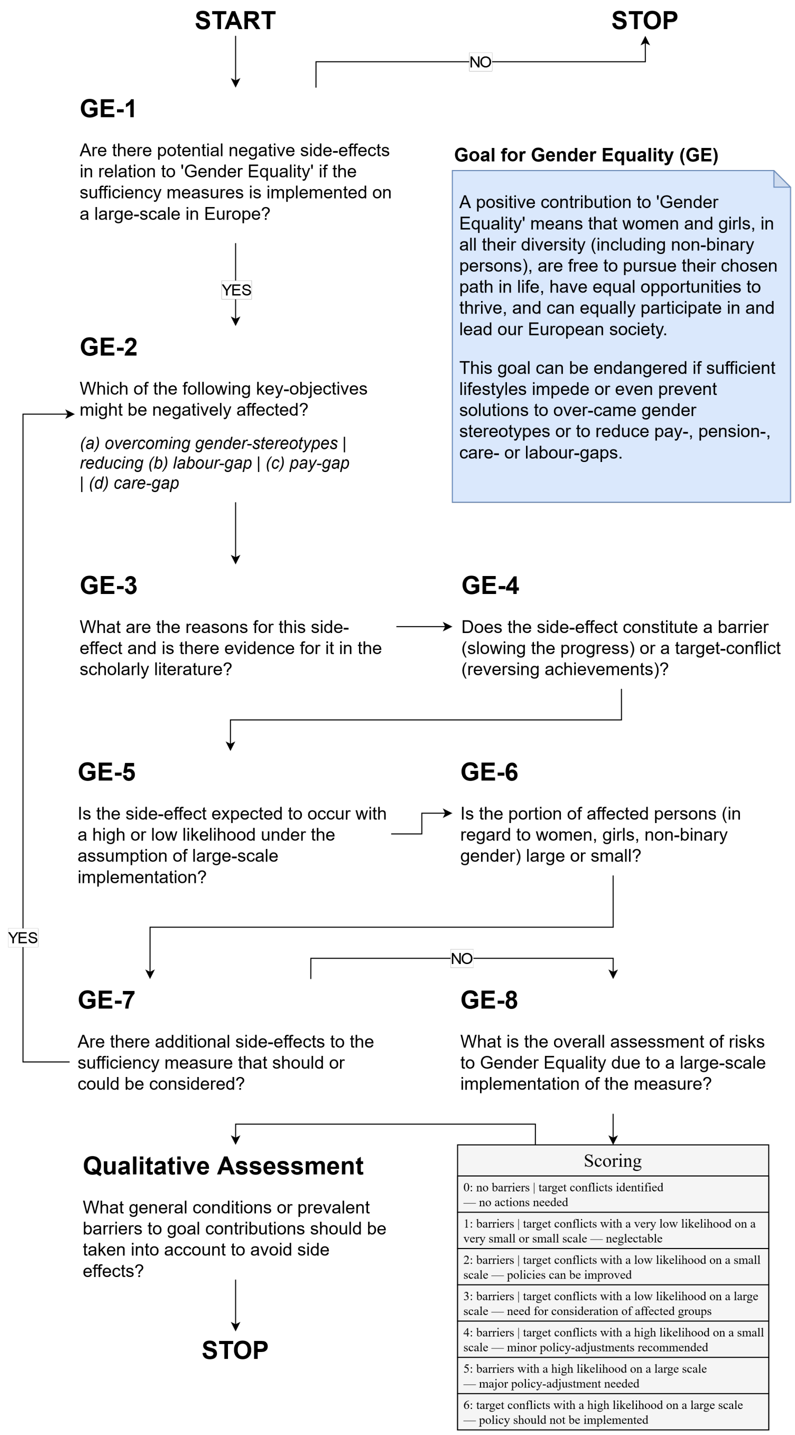
Decision-Tree for G-RA towards 'Gender Equality'



Source: own development

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Risk Assessment (G-RA) for 'Gender Equality'

The following sections apply the decision-tree from the previous section for a risk assessment in a tabled form.

SM-1: Product-Sharing

The overall assessment concludes that some risks are involved, but that they merely have the ability to slow the progress towards 'Gender Equality'. Persons with a high demand for effective care-work might not be sufficiently considered in product-sharing schemes. We think that the likelihood for a particular person that this occurs is low and that this effect is limited to a small portion of the relevant population. Furthermore, there is a low likelihood that gender-stereotypes are reinforced on a small scale if the co-consumer[18] preferences of women, girls, and non-binary persons are neglected when designing or implementing such policies.

These barriers might be mitigated by an explicit consideration of the needs, preferences and capabilities of the target groups related to co-consumption.

Table 53: G-RA of SM-1 Product-Sharing towards 'Gender Equality'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likeli-hood	Scale
Risk of impeding care-work	Many products in sharing policies are not tailored towards care-work. Such products and services might also not be adopted due to "non-negotiable needs" of young children and "linked lives" in family and friend relationships (Burningham & Venn, 2017; Hargreaves & Middlemiss, 2020).	barrier	care-gap	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Risk of neglecting co-consumer preferences and needs	Male consumers' ability to accommodate female co-consumer preferences is limited (Yang et al., 2015).	barrier	gender-stereotypes	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Overall Score	**4**				

Source: own compilation and reasoning as well as provided references in the table

SM-2: Car-Sizing

The following Table shows the G-RA for using smaller, lighter and more fuel-efficient cars among households from a large-scale implementation in Europe. The overall assessment concludes that there are no major risks involved. Prevalent gender stereotypes might be reinforced due to the strong associations of large cars with masculinity and small cars with femininity. Moreover, the perception of the lower safety of smaller cars might cause some parents trying to accommodate by either avoiding car-use (increasing a 'time-squeeze') or by having to pay more for a 'safer' car. Both risks are considered to have a low likelihood and affect only small portions of the target group.

These barriers might be mitigated by an explicit consideration of the needs of families when switching to smaller and lighter vehicles but also by providing robust information on car-safety.

Table 54: G-RA of SM-2 Car-Sizing towards 'Gender Equality'

[18] A co-consumer is an individual who consumes a product or service alongside other consumers, influencing and being influenced by their collective consumption experience.

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Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likeli-hood	Scale
Risk of neglecting co-consumer preferences and needs	Large cars are often necessary for larger families and safety concerns for children prevent some from using a small instead of a large car (Kent, 2023).	Barrier	care-gap	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Risk of reinforcing gender-stereotypes for cars	Cars have – at least in the past – "galvanized stereotypical representations of femininity and masculinity", which in turn might be further reinforced by policies aiming to promote smaller, lighter, and more efficient cars (Christensen et al., 2022).	Barrier	gender-stereotypes	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Overall Score	**4**				

Source: own compilation and reasoning as well as provided references in the table

SM-3: Space-Sharing

We do not identify any potential negative side-effects of a large-scale implementation of this policy in regard to 'Gender Equality'. Although there can be concerns that multi-family and/or multi-generational housing has negative implications for the already existing care-cap among women that care both for children and the elderly (e.g., relatives), there is no reason to assume that this issue would be aggravated by policies tailored to affordable co-housing. Instead, we assume that it comes with potential benefits that might or might not be realized depending on actual materialization of the policy (lower housing costs, more and better-quality social interactions, sharing care-work).

Table 55: G-RA of SM-3 Space-Sharing towards 'Gender Equality'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
0: no barriers | target conflicts identified ➡ no actions needed					
Overall Score	0				

Source: own reasoning

SM-5: Eating Less Meat & Dairy

We identify one barrier that could occur in the relationship between a large-scale implementation of this policy and the goal of 'Gender Equality'. The health of children, and thus the provision of a healthy diet is a major concern for parents. Some portion of the population might associate meat and dairy as necessary components of such a diet and therefore be less willing to reduce the consumption of such products for their children, and as a spill-over, for themselves. We assume that this occurs with a low likelihood on a small scale. Misconceptions about healthy diets have changed over the last years and the policy itself still allows for meat and dairy consumptions (albeit less frequently).

The risk can therefore be mitigated by a better communication regarding the health benefits of the policy and a better penetration of such a communication among less educated or more resistant groups in society.

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Table 56: G-RA of SM-5 Eating Less Meat & Dairy towards 'Gender Equality'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likeli-hood	Scale
Risk of non-participation due to health concerns	Meat and dairy products are still considered to be necessary for healthy lifestyles among a large part of the society (Michel et al., 2021), which is why policies towards vegetarianism or veganism are still facing biases. This might also carry over to opposition to a mere reduction of meat and dairy products in regard to families and children.	barrier	care-gap	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Overall Score	**2**				

Source: own compilation and reasoning as well as provided references in the table

SM-6: Car-Pooling

We do not think that major risks are involved from a large-scale implementation of Car-Pooling policies, if this merely translates into car-pooling in cases where it is feasible for participants and is independent of car ownership. Here we find that there is a very low likelihood that a small sub-set of the target group experiences unwanted professional relationships or that such a policy excludes females from existing male networks among colleagues. (risk related to the key objective of labour-gap).

It is difficult to foresee how such a risk might be mitigated, but it is reasonable to assume that ensuring a safe environment for Car-Pooling could be at least alleviated by digital tools and professional service providers that deal with complaints.

Table 57: G-RA of SM-6 Car-Pooling towards 'Gender Equality'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likeli-hood	Scale
Risk of unwanted professional relationships	Car-Pooling to work might involve commuting with more senior colleagues or lower inhibitions for unwanted sexual advances. Moreover, the exclusion from car-pooling among male networks might hinder professional advancement (Mao et al., 2020).	target conflict	labour-gap	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Overall Score	**2**				

Source: own compilation and reasoning as well as provided references in the table

SM-8: Cycling

We identify two potential target conflicts and two barriers from a large-scale implementation. The most severe risk is associated with impeding care-work. We think that there is a high likelihood that the policy might increase time-demand on a small scale. This could result from switching to cycling or from the necessary changes to (the then remaining) car infrastructures. Although both likelihood and scale of this effect are thus not independent of the type and design of the overall infrastructures,

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we find that this could enhance the already existing care-gap. This is more severe if cycling by parents or children is also additionally associated with less safety. Similarly, such a policy might also impede the participation of children in extracurricular activities (barrier) and the access of women and diverse persons to job opportunities. Lastly, we also anticipate a very low likelihood of a social stigma for the portion of the target groups that do not participate in such a "sustainable lifestyle", due to these reasons.

These barriers and target conflicts might be mitigated by considering the local mobility options and infrastructures as well as the social structure in neighbourhoods when implementing the measures.

Table 58: G-RA of SM-8 Cycling towards 'Gender Equality'

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Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likeli-hood	Scale
Risk of impeding care-work	There is likely an increase in time demands due to less infrastructures for cars & public transport with the likelihood of occurrence depending on the type and design of these infrastructures. Time-use (affected by cycling over other modes of transport) is also contingent on the needs, preferences, and schedules of other household members (Godin & Langlois, 2021). In addition, there are safety concerns (especially for children) in relation to "non-negotiable needs" of young children and "linked lives" in family and friend relationships as well as target conflicts from the alignment of priorities of new motherhood towards "less sustainable consumption" (Burningham & Venn, 2017; Hargreaves & Middlemiss, 2020).	target conflict	care-gap	high	small
4: barriers | target conflicts with a high likelihood on a small scale ➡ minor policy-adjustments recommended					
Risk of less extra-curricular activities and social participation for girls	Transport of children to extra-curricular activities can often only be achieved by car travel (Kent, 2023).	barrier	labour-gap	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Risk of social stigma / 'othering'	The non-participation in or exclusion from sustainable lifestyles can lead to a social stigma (Hargreaves & Middlemiss, 2020; Sahakian, 2022).	barrier	gender-stereotypes	very low	small
1: barriers | target conflicts with a very low likelihood on a very small or small scale ➡ neglectable					
Risk of exclusion from job opportunities	Less infrastructures for cars & public transport can reduce job opportunities due to a lower accessibility (Bastiaanssen et al., 2020).	target conflict	labour-gap pay-gap	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Overall Score	**9**				

Source: own compilation and reasoning as well as provided references in the table

SM-9: Flying-Less

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We do not think that there are any major risks involved from a large-scale implementation in regard to ‘Gender Equality’. However, there is a very low likelihood that a small portion of target groups is unwilling to switch to alternative mobility options due to the real or perceived care-work disadvantages. Especially families might be less willing to opt for trains (or similar options) to reach holiday destinations if this is associated with a longer and/or more stressful trip for both children and parents.

Table 59: G-RA of SM-9 Flying-Less towards ‘Gender Equality’

Indicator	**Reasoning & Evidence**	**Type of Effect**	**Key Objectives**	**Likeli-hood**	**Scale**
Risk of non-participation due to stress concerns	Long-distance trips with families can be stressful for children and parents. Some portion of this target group might associate flights to be less stressful in this regard due to lower travel times (Dällenbach, 2020).	barrier	care-gap	very low	small
1: barriers | target conflicts with a very low likelihood on a very small or small scale ➡ neglectable					
Overall Score	**1**				

Source: own compilation and reasoning as well as provided references in the table

SM-10: Working-Less

We identify a potential target conflict from a large-scale implementation of the policy. We think that there is a high likelihood that work-time reductions increase the “hidden work” of some small portion of the target group in order to maintain their current lifestyle. It might also encourage second earners in families to obtain entirely from full-time work or pursuing a career.

This risk can be mitigated by ensuring that work-time reductions are enabled for those groups that rely on it the most (workers in industries with shift-work or frequent overtime) without encouraging additional work-time reductions for women that are already in part-time and thus more likely to increase their economic dependence.

Table 60: G-RA of SM-10 Working-Less towards ‘Gender Equality’

Indicator	**Reasoning & Evidence**	**Type of Effect**	**Key Objectives**	**Likeli-hood**	**Scale**
Risk of increase in hidden work	Especially middle-class households are considered to be a key target group for sustainable consumption, but they rely on the hidden and devalued work of marginalized groups to maintain their lifestyles (Godin & Langlois, 2021). Work-time reductions for middle-class groups might therefore have the adverse effect of increasing economic disparities among genders and increasing the amount of hidden work for women.	target conflict	labour-gap care-gap	high	small
4: barriers | target conflicts with a high likelihood on a small scale ➡ minor policy-adjustments recommended					
Overall Score	**5**				

Source: own compilation and reasoning as well as provided references in the table

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5.4. Risk Assessment for Time Use

Definition of key objectives

There is no specific, or overarching, goal regarding time consumption or use in European policies. However, 'Time Use' is addressed in the *Work-life Balance Directive* that entered into force in 2019(European Commission, 2019). It stems from the European Pillar of Social Rights, and covers the following objectives (European Commission, 2021b):

- better supporting a work-life balance for parents and carers,
- encouraging a more equal sharing of parental leave between men and women, and
- addressing women's underrepresentation in the labour market

Looking at these objectives, most of the underlying issues have already been assessed in the G-RA towards 'Gender Equality'. This is why we opt for a different approach to assess the generic risks of the SM's towards 'Time Use'. This approach is based on the following two premisses.

First (i), we think that "work-life balance" is the main area for which negative side-effects can occur if the large-scale implementation of the sufficiency policies leads to time constraints for activities related to well-being. That is, people perceive additional 'Time-Use' as negative if it results in a lower allocated amount of time dedicated to activities that they want to spend more time on. However, whether a specific activity is 'wanted' or not, is an individual choice.

Secondly (ii), we also think that this negative trade-off in 'Time-Use' between tasks that are considered 'mandatory' (such as work) and 'voluntary' (such as hobbies) mainly constitutes a barrier for a large-scale implementation of sufficiency lifestyles and not necessarily a target conflict by itself.

This can be described by the distinction between 'voluntary' and 'non-voluntary' time consumption in the following definition of a goal contribution of our own design:

Definition of 'Time Use' (TU) for T6.3

A positive contribution *to 'Time Use' means that persons have the opportunity to spend more time on voluntary activities related to their well-being, such as time spent with family and friends, leisure activities or exercise.*
This goal can be endangered *if sufficiency lifestyles impede these opportunities because additional time has to be spent on non-voluntary activities that can, but does not have to, comprise of work and work-related activities (e.g. commuting) or household chores.*

Criteria for assessment

The previous G-RA's utilized a so-called decision-tree for the assessment. This allowed us to identify whether a risk constitutes a target conflict, barrier, or both in respect to key objectives in a social dimension. It also enabled us to score the risk in regard to the likelihood and size of the potential negative effect.

However, we (i) already assume that effects here are usually barriers and that (ii) the distinction between voluntary and non-voluntary is an individual choice. Any assessment of the risk is therefore restricted to the likelihood and scale of additional time-demand rather than the particular effects of this time-demand on individual well-being. This additional time demand can only be assessed compared to a frame of reference though, that will be provided in the next section for each sufficiency measure (SM's). For example, SM-8 on Cycling will only increase the time demand if compared to a previous option that got a person quicker from point A to point B. Someone who walked to work before, but now cycles, will probably not experience a higher time-use.

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We select these frames of reference in regard to the overall policy goals for sufficiency lifestyles, in particular related to its direct benefits towards climate change mitigation. As a result, scoring will also be restricted to scores from 0 (no actions needed) up to 5 (major policy-adjustments required). This means that applying this scope for our assessment excludes the possibility of finding that 'policies should not be implemented'. It will also be conducted comprehensively instead of looking at each SM in a separate section.

Risk for additional 'Time-Use' from SM's

The following Table summarizes the assessment of the risks to non-voluntary 'Time-Use' as a consequence of a large-scale implementation of the sufficiency measures. Each case represents the risk from a worst-case frame of reference. For example, reducing air-travel by participation of an online conference for work will not constitute such a risk, whereas taking the train to reach a distant holiday destination will do so with a high likelihood.

Overall, five of the eight SMs are associated with such risks, that is, the risk that additional time needed for adopting a sufficiency lifestyle leads to a negative time trade-off with other activities. Of these five risks, one does not require any actions on the side of policy-makers, as these risks occur with a very low likelihood on a small scale. Of the remaining four risks, two are considered to requiring major, and two minor policy-adjustments.

SM-1 on Product-Sharing currently focuses on energy- and ownership savings from shared washing machines. Such an option is very likely to increase time demand both in regard to locality (moving laundry to location of the washing machine) and scheduling (washing when a slot is available). These effects can be mitigated, if the policy is accompanied by online tools for scheduling and better accessibility of the washing machines.

SM-6 on Car-Pooling is associated with higher time-use for similar reasons. Car owners are usually more flexible regarding their time demand for commuting and daily chores compared to groups that share the same car for similar purposes. This might be alleviated, if the implementation is accompanied by flexible work-time regulations (allowing to align starting and finishing hours) and pragmatic (digital) tools for scheduling. The success of the policy also relies on the availability of alternative mobility options if such a scheduling is not possible.

Cycling (SM-8) is often associated with the risk of additional time-demand and is thus a typical barrier that prevents people from a modal shift from car to bicycle. Especially in cases for which cycling is not deemed a viable alternative (e.g. long commuting distances), this additional time demand might prevent the adoption of such a policy in the first place. A large-scale implementation therefore requires appropriate infrastructures that (i) ensure safety, (ii) speed and (iii) flexibility of intermodal transportation (e.g. trains/subways equipped with wagons for travellers with bicycles, to facilitate the integration of different means of transport to appropriately reach sub-urban/rural areas).

The worst-case 'Time-Use' barrier for SM-9 on Flying Less is represented by long-distance vacation destinations. Even in cases for which alternative modes of transport exist, they often require a higher time demand (real or perceived). A large-scale implementation, and penetration, of such a policy has to account for that by encouraging people to restrict air-travel to destinations for which there is no alternative, and by enabling other modes of speedy transport for the rest.

Table 61: Assessment of potential risks to non-voluntary 'Time-Use'

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Measure	Frame of reference	Likelihood – Size: [0-5]	Actions needed	Mitigation options
SM-1 Product-Sharing	owned washing-machine in own household	high – large: 5	major policy-adjustments	ensuring availability of nearby or in-house washing facilities and tools for scheduling
SM-2 Car-Sizing	ownership and use of cars of any size	none – none: 0	none	-
SM-3 Space-Sharing	living confined to own household	very low – very small: 1	none	-
SM-5 Eating Less Meat & Dairy	previous meal preparation	very low – very small: 1	none	public communication might mitigate increased time-use for meal preparations during early adaptation phase
SM-6 Car-Pooling	use of car confined to the own household	high – small: 4	minor policy-adjustments	flexible working hours and availability of ad-hoc alternatives
SM-8 Cycling	commuting / daily chores by car	high – large: 5	major policy-adjustments	availability of appropriate infrastructures and ad-hoc alternatives (e.g. for bad weather)
SM-9 Flying Less	air travel for holiday destinations	high – small: 4	minor policy adjustments	availability of alternatives both in terms of mode of transport and destination
SM-10 Working Less	full-time working	none – none: 0	none	-
Overall Score	**20 from six identified risks towards 'Time-Use'**			

Source: own assessment

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5.5. Risk Assessment for 'Just Transition'

The term 'Just Transition' is used in different policy contexts and has increasingly been communicated as a necessary constraint regarding climate change mitigation strategies. The IPCC for example defines "Just Transition" as:

> *"A set of principles, processes and practices that aim to ensure that no people, workers, places, sectors, countries or regions are left behind in the transition from a high-carbon to a low carbon economy" (IPCC, 2023, p. 1806).*

'Just Transition' is, in this sense, also akin to the notion of "Leave No One Behind" that "[...] is the central, transformative promise of the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs)" (UNSDG, 2024).
However, the task at hand in this deliverable, is to fit this goal into a broader set of aspirations for better and even more sustainable societies. The following section therefore focuses on 'Just Transition' in Europe and the smaller sub-set of interlinkages between these aspirations and the projects pathways for sufficiency lifestyles.

Definition of key objectives

The Just Transition Mechanism is mainly established as part of the European Green Deal investment plan. It is placed within the framework of cohesion policy, which is the main EU policy instrument to reduce regional disparities and to address structural change in Europe's regions, specifically in the context of the desired transition towards climate neutrality. While this is not an eligibility criterion, the resources from the mechanism should complement the other resources available. The European Commission defines the primary goal of the *Just Transition Mechanism* as follows: *"The primary goal of the mechanism is to provide support to the most negatively-affected regions and people and to help alleviate the socioeconomic costs of the transition"* (European Commission, 2024).
Within the cohesion policy the EU targets the following main objectives for the time period of 2021 - 2027:

- job creation
- business competitiveness
- economic growth
- sustainable development
- improvements to citizens' quality of life

In line with the primary goal of the European Commission, we think that the G-RA should focus on the "most negatively-affected regions and people" (ibid.). We also think that the key objective of "sustainable development" is not negatively affected by sufficiency policies and the explicated sufficiency measures (SM's) in FULFILL. As to "improvements to citizens' quality of life", any relevant negative trade-offs should be, in our opinion, already covered by the G-RA towards 'Health' and 'Poverty Mitigation' and 'Gender Equality'. We therefore treat 'Just Transition' as the social dimension that focuses on regional economic development in Europe (e.g., structural weak regions).

The following table lists these objectives and provides our reasoning for this decision. As a consequence of this selection, the key objectives on 'sustainable development', 'improvements to citizens' quality of life' are not considered explicitly to be negatively affected by the sufficiency measures (SM's) in FULFILL.

Table 62: Key objectives to be included in the 'Just Transition' dimension of T6.3

Key Objective	**Abbreviation for report**	**Reasoning for explicit inclusion in the definition**
Job creation	job creation	"The Just Transition Mechanism shall support the Investment for jobs and growth goal in all Member States" (ibid.). Some SM's, such as 'Sharing Products', 'Car-Pooling' and 'Flying Less', may impact this objective.
Business competitiveness	competitiveness	Business competitiveness is crucial for strengthening Europe's role as an industrial site and player in the global economy. However,

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Key Objective	Abbreviation for report	Reasoning for explicit inclusion in the definition
		certain implementations of the SM's might contradict these European goals, as mentioned in the Cohesion Policy of the EU.
Economic growth	economic growth	Similarly, while economic growth is a central goal for securing prosperity, sufficiency is often linked to a reduction in economic growth. Therefore, the potential reversing effects of the SMs on economic growth should be carefully analysed.

Source: own reasoning based on EU Cohesion policy framework from 2021 – 2027

We derive the following definition of 'Just Transition' for the purposes of our Social Impact Assessment in FULFILL.

Definition of 'Just Transition' (JT) for T6.3

A positive contribution to 'Just Transition' means that those who stand to lose economically when transiting to a green economy, do not suffer job loss, and further business competitiveness as well as economic growth is ensured in the affected industries.

This goal can be endangered if sufficiency lifestyles impede or even prevent solutions to overcame just transition efforts.

Decision Tree for assessment

The following Figure shows the control questions for the risk assessment in line with our methodology and the previous G-RA's.

Figure 18: Control-Questions for G-RA of 'Just Transition'

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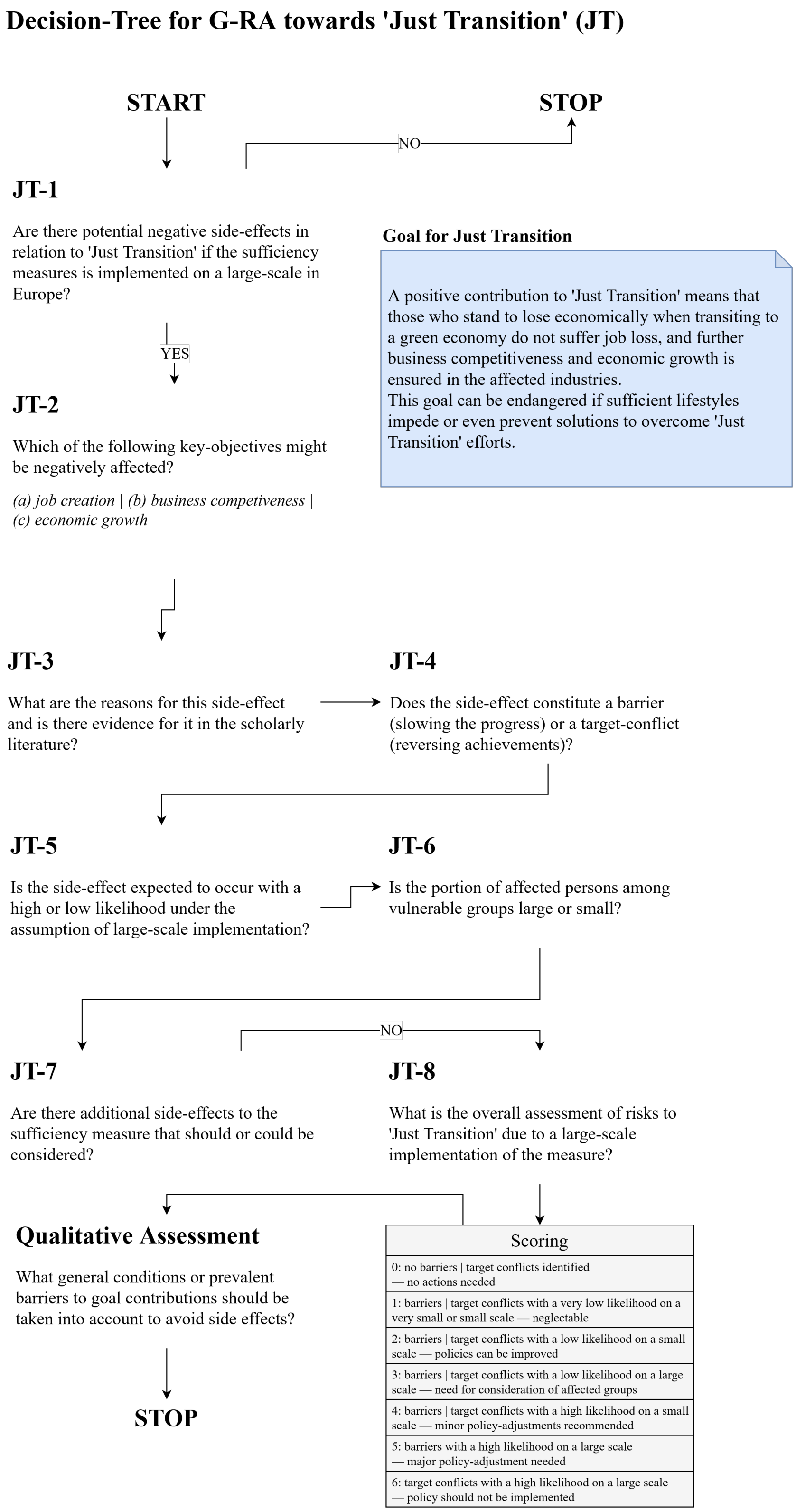

Source: own development

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Risk Assessment (G-RA) for 'Just Transition'

As already shown in the G-RA towards 'Poverty Mitigation', some of the macro-economic effects and thus potential risks of sufficiency policies are already investigated in tasks T6.1, T6.2 and T6.4.
We therefore use the results from T6.2 on GDP development and loss of workers, to assess the risks to the objectives of 'job creation' and 'economic growth' in manner that is comprehensive with our risk assessment for 'Poverty Mitigation'. This also means that the following individual measure-specific assessment are limited to violations of the key objective of 'business competitiveness'.

Job-loss for medium and high-skilled workers across Europe

We use again the results from the macro-economic I-/O-Model MARIO in T6.2 to assess the severity of job losses for the objectives. In this case, the predicted changes in the workforce of medium- and high-skilled workers are used as the metric.
The following table shows the results from T6.2. on a European scale for the years 2040 and 2050 in relation to each of the SMs that were integrated into MARIO.

Table 63: Total change in low-skilled workforce
(from implementation of SM-1, SM-2, SM-3, SM-5, SM-8, SM-9)

Case	Employment for medium- and high-skilled workers	Employment growth for medium- and high-skilled workers	Loss of jobs from lower demand
Reference 2020	143.4 million	-	-
BAU until 2050	206.4 million	43.9%	0
All Measurers until 2050	194.9 million	36.0%	11.4 million

Source: own calculation based on results in T6.2

According to this calculation, about 11.4 million people in either the medium- or high-skilled workforce would not be employed as a result of six SMs, that would have been otherwise employed in a business-as-usual (BAU) scenario. The largest portion of these 'lost' jobs can be attributed to the sectors 'Manufacturing' (4.18 million), 'Services' (3.80 million), 'Agriculture' (2.86 million) and 'Transport' (1.16 million). There are no job losses in the residential sector and only 27,000 jobs lost in the 'Power' sector (with the latter being neglectable as a result from such a model). This is clearly different from our findings for job losses of low-skilled workers in regard to 'Poverty Mitigation', which was mainly attributed to 'Services' and 'Manufacturing'.
The findings are similar though, when looking at the distribution of these job losses over the six measures. Again, the majority of these jobs lost are attributed to SM-5 on 'Diets' with 10.76 million jobs lost (94% of the total effect from all measures). Moreover, the second most relevant effect is found for 'Flying Less' as well (with 0.55 million jobs lost or 4.8% of the total).
We come to two conclusions as a consequence. Since it was justified to only assert relevant risks for these two measures under 'Poverty Mitigation' with very similar relative effects, it is justified here as well. SM-5 on 'Diets' requires at least a major policy-adjustment (Score 5) and SM-9 on 'Flying Less' at least a minor policy adjustment (Score 4), when designing these policies to avoid a violation of 'Just Transition'.
Moreover, we also suspect that the parameters of all involved models up to this point play a crucial role that could very well be strongly associated with the setting of these parameters. One indication for that is the fact that SM-5 on 'Eating Less Meat & Dairy' is responsible for almost all of the job losses, but the sector of 'Agriculture' does not seem to be affected by it to a relevant degree. This means, that the modelling process itself could very well be a deciding factor here, rather than some underlying root cause that makes these two sufficiency policies more prone to job losses. There are numerous reasons that separately or jointly could come into play here such as

- the differences in the ambition level between SMs from the original bottom-up model,
- the over-determinism of physical changes for some SMs over other SMs as a consequence of the ability of the models to account for them (e.g. meat production easier to represent monetary than space-sharing),
- the apparent differences in 'todays' economic value for different services and goods in a macro-economic model (expressed as value-added and/or the total amount spent on salaries),

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- and the lack of modelling options to robustly predict job transitions to other sectors and/or services.

We should therefore take these results with a grain of salt and obtain from an oversimplified interpretation equalling e.g. dietary changes with loss of jobs. This is, of course, also true of the results on GDP in the next section.

Impact on economic growth in Europe

The Input-/Output-Assessment from T6.2 also modelled an expected reduction of the Gross Domestic Product (GDP) from the implementation of measures. Although this value does not, and cannot, account for other changes in the economy, it can be considered a worst-case scenario from considering the variables that were integrated to estimate changes to the demand in European and global economies.

Under this premise it is estimated that:

- The EU GDP will increase from EUR 13.1tn in 2020 to EUR 19.2tn in 2050, if the SMs are not implemented. This represents an economic growth of 46.6% over 30 years or circa 1.5% per year.
- The EU GDP will increase from EUR 13.1tn in 2020 to EUR 18.4tn in 2050, if all the SMs are implemented. This represents an economic growth of 40.5% over 30 years or circa 1.3% per year.

It can thus be concluded that — at worst and under the conditions explicated in T6.2 — the GDP loss from the SMs amounts to EUR 800bn or an overall loss in GDP growth of 6.1% over three decades. On average, an otherwise expected annual GDP growth of 0.2% would thus not materialize.

By comparison, the EU's GDP[19] grew annually by 2.2% on average over the course of 5 years between 2015 and 2019. It declined by 5.6% in 2020, recovered against that with an increase of 6.0% in 2021 and 3.5% in 2022 compared to 2021. The last year (2023) reports an annual real GDP growth of 0.4% compared to 2022.

We score this risk by comparison with the annual growth between 2015 and 2019 (+2.2% per year on a five-year average). A severe risk to the key objective of "economic growth" would be scored with a maximum score of 6 and would be achieved if a single SM would lead to a loss of GDP of 1/5 of that (loss of annual GDP growth of 0.44% or more). Such a measure should indeed not be implemented in our opinion. A high risk or a score of 5 is attributed to SMs that lead to a loss to 1/10 of more than 2.2% (0.22% to <0.44%) and a moderate risk (Score 4) to an annual GDP loss of 1/20 (0.11% to <0.22%). Anything less is either attributed a score of 3 (need for consideration of affected groups) or with a score of 0 (no GDP loss from the calculations in T6.2).

The following Table shows the loss in annual GDP growth from all measures also accounted for by the I-/O-Model (three measures were not assessed). Only two measures lead to a lower GDP: SM-5 Eating Less Meat & Dairy and SM-9 Flying Less. Of these two, only the change to diets has an impact that requires an adaptation of the policy.

[19] Data from EUROSTAT (Real GDP growth rate – volume; https://doi.org/10.2908/TEC00115; accessed at 17th of May 2024)

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Table 64: G-RA for risks to "economic growth" in 'Just Transition"

Sufficiency Measure (SM)	annual loss in GDP growth (2020-2050)	Score	Assessment
SM-1 Product-Sharing	+/- 0%	0	no actions
SM-2 Car-Sizing	+/- 0%	0	no actions
SM-3 Space-Sharing	not assessed		
SM-5 Eating Less Meat & Dairy	-0.178%	4	minor policy-adjustments recommended
SM-6 Car-Pooling	not assessed		
SM-8 Cycling	+/- 0%	0	no actions
SM-9 Flying Less	-0.025%	3	need for consideration of affected groups
SM-10 Working Less	not assessed		
Overall Score	**7 from 2 identified risks to "economic growth" in 'Just Transition'**		

Source: own assessment based on results from T6.2

Such an assessment is of course, by and large, subject to further considerations. Policy makers might find that these GDP losses are not acceptable for the European economy or should be scored differently (adjusting for the thresholds selected here). Some countries might also be affected more in regard to the sectors where this loss occurs, or the size of the effect compared to the national economy (see D6.2 for a detailed description of the results). In addition, some of the measures might very well be realized even more ambitiously and thus lead to an additional negative impact to economic growth.

On the other hand, many of the adverse effects might not materialize after a three-decade long transformation and some economic benefits have not been considered at all. For example, both the findings in previous tasks as well as our assessment in the current report, anticipate health benefits for the population, in particular from a change in diets. This should, in turn, lead to lower health costs in the economies and thus mitigate some of the adverse effects by other mechanisms.

SM-1: Product-Sharing

We find that there is a low likelihood that local small and medium enterprises (SME's) suffer from a large-scale implementation of the policy. However, we also think that the scale of this effect is small and that the same business can, at least in theory, also benefit by introducing and providing product-sharing services.

The potential negative effects of this policy can therefore be mitigated by integrating local businesses in the process of implementation and provide opportunities for them to participate in the policy.

Table 65: G-RA of SM-1 Product-Sharing towards 'Just Transition'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
Risk of decreased demand for local SME's	Some local businesses, in particular SME's, might not be able to accommodate product-sharing services and thus will not be able to compensate the lower demand for their products (Plepys & Singh, 2019).	target conflict	competitiveness	low	small
2: barriers | target conflicts with a low likelihood on a small scale ➡ policies can be improved					
Overall Score	**2**				

Source: own compilation and reasoning as well as provided references in the table

SM-2: Car-Sizing

We cannot identify any relevant risk to business competitiveness from smaller cars alone. Some car-vendors might suffer from a decreased demand, but we think that this comes with a very low likelihood on a very small scale and affects all related business alike (both in and outside of Europe).

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Larger companies on the other hand might adapt their product portfolio in an appropriate manner without risks to their competitiveness on the European market.
A large-scale implementation therefore does not require any action on the side of policy makers, other than already assessed in the previous assessment on economic growth and job creation.

Table 66: G-RA of SM-2 Car-Sizing towards 'Just Transition'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
0: no barriers | target conflicts identified ➡ **no actions needed**					
Overall Score	0				

Source: own compilation and reasoning as well as provided references in the table

SM-3: Space-Sharing

We cannot identify any relevant risk to the competitiveness for European companies. Since any potential negative economic and job-related effects are already accounted in previous sections, there is, in our opinion, no reason to assume that European companies in particular suffer any competitiveness disadvantages from more people sharing the same living space.

Table 67: G-RA of SM-3 Space-Sharing towards 'Just Transition'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
0: no barriers | target conflicts identified ➡ **no actions needed**					
Overall Score	0				

Source: own compilation and reasoning as well as provided references in the table

SM-5: Eating Less Meat & Dairy

We find it reasonable to assume that any large-scale change in dietary habits towards less animal products will negatively affect the competitiveness of businesses in animal-focused restaurants and kitchens as well as the related business that provide these goods in the first place (e.g., farms and meat-processing). We assess this potential risk to occur with a high likelihood on a small scale. Although the affected companies are often small and family-owned, only a minority of these companies cannot adapt to changes in dietary styles over time. We also think that this risk constitutes both a barrier (towards sustainable transformation) and target conflict.
The potential negative side-effects of this policy towards 'Just Transition' can be mitigated, if animal-focused companies are enabled to transition and if consumers are willing to pay higher prices for animal food while also reducing their overall animal food consumption.

Table 68: G-RA of SM-5 Eating Less Meat & Dairy towards 'Just Transition'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
Risk of decreased demand for local SME's	Food providers that focus and/or specialise on animal-based foods will likely experience a disadvantage in terms of competitiveness compared to their peers that already adapted to plant-based food trends.	target conflict | barrier	competitiveness	high	small
4: barriers | target conflicts with a high likelihood on a small scale ➡ **minor policy-adjustments recommended**					
Overall Score	4				

Source: own compilation and reasoning as well as provided references in the table

SM-6: Car-Pooling

We do not think that a large-scale implementation of this policy is likely to lead to disadvantages in regard to the competitiveness of European companies. There is, in our opinion, no reason to assume that e.g. some car-vendors benefit from decreased car-sales while others in or outside of Europe do

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not. There will be of course disadvantages by comparison with similar providers (e.g. in the bicycle industry), but these effects are already accounted for in the previous assessment in regard to GDP and job losses.

Table 69: G-RA of SM-6 Carpooling towards 'Just Transition'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
0: no barriers | target conflicts identified **➡ no actions needed**					
Overall Score	0				

Source: own compilation and reasoning as well as provided references in the table

SM-8: Cycling

We do not think that there are any potential competitiveness risks related to additional cycling by the population. While the car industry and related industries in Europe might be negatively affected overall, these effects have already been assessed in terms of economic growth and job creation in other parts of the risk assessments.

Table 70: G-RA of SM-8 Cycling towards 'Just Transition'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
0: no barriers | target conflicts identified **➡ no actions needed**					
Overall Score	0				

Source: own compilation and reasoning as well as provided references in the table

SM-9: Flying Less

We think that there is a potential risk that companies in the tourism industry, especially small and medium-sized vendors, might experience competitiveness disadvantages compared to companies that mainly rely on the broader population for consumer demand. However, we think that likelihood of this effect is very low and affects only a small portion of the industry.

Table 71: G-RA of SM-9 Flying Less towards 'Just Transition'

Indicator	Reasoning & Evidence	Type of Effect	Key Objectives	Likelihood	Scale
Risk of competitiveness disadvantage for SMEs in the tourism industry	**Small vendors in touristic regions might rely on international guests**	target conflict	competitiveness	very low	small
1: barriers | target conflicts with a very low likelihood on a very small or small scale **➡ neglectable**					
Overall Score	1				

Source: own compilation and reasoning as well as provided references in the table

SM-10: Working Less

A large-scale implementation of work time reductions in Europe might very well put European companies at a competitive disadvantage compared to companies that do not implement such a measure. We think that there is a high likelihood that this would occur and that the effect of this potential negative effect is large if and where it occurs (e.g. in industries in which employees benefit the most from the policy). This issue might be aggravated if the work time reductions are accompanied by wage compensation (which is, as shown in section 3.4, an important pre-condition for quality-of-life improvements from this sufficiency measure).

This barrier should therefore be addressed before and during implementation of such a policy (major policy adjustments needed). Although we cannot provide a solution, or rather set of solutions, within this project, it is clear from the academic literature that such solutions would have to address the productivity disparities within Europe as well as the already pre-existing challenges to the competitiveness Europe versus the rest of the world (Jacques Delors Centre, 2023; Pinkus et al., 2024).

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Table 72: G-RA of SM-10 Working Less towards 'Just Transition'

Indicator	Reasoning & Evidence	Type of Ef-fect	Key Ob-jec-tives	Likelihood	Scale
Risk of compet-itive disad-vantage com-pared to com-panies without hour reductions	It stands to reason that work-time reductions affect the productivity of companies in different ways. While there is evidence that it can improve the quality of life and health of employees (see also section 3.4), the reduction would also very likely reduce production output in many industries. This affects those companies in particular that (i) heavily rely on manual labour and (ii) compete with companies that exceed the typical weekly work time hours in Europe (e.g. in Asia).	bar-rier	com-peti-tive-ness	high	large
5: barriers with a high likelihood on a large scale ➡ major policy-adjustments needed					
Overall Score	5				

Source: own compilation and reasoning as well as provided references in the table

5.6. Results of risk assessments

The following Table presents the results of the risk assessment in a matrix that sums up the number and scores of risks for each dimension and SM. Overall, 48 risks were identified that lead to a total score of 137 with scores ranging from 0 to 5 for each identified risk (no risk with a score of 6 was identified). These scores indicate 'no risk' (0), 'neglectable risks' (1), 'policies can be improved' (2), 'need for consideration of target groups' (3), 'minor policy adjustments recommended' (4), 'major policy adjustments needed (5), 'policy should not be implemented' (6).

The measures that were associated with risks the most are SM-5 on 'Eating Less Meat & Dairy' (with a total score of 28), SM-10 on 'Working Less' (with a total score of 23), SM-8 on 'Cycling' (with a total score of 22), SM-9 on 'Flying Less' (total score of 19) and SM-1 on 'Product-Sharing' (total score of 18). Conversely, SM-6 on 'Car-Pooling' (total score of 11), SM-3 on 'Space-Sharing' (total score of 9) and SM-2 on 'Car-Sizing' (total score of only 7) are associated with the fewest and lowest risks. However, these finding are insofar skewed, as three of these measures ('Space-Sharing', 'Car-Pooling', 'Working Less') were not assessed in the macro-economic models that helped to assess additional risks from potential job losses and lost GDP growth.

The total scores should therefore not be converted into direct quantitative differences. A total score of 22 for 'Cycling' does not indicate that the risks here are 'twice as severe' compared to 'Car-Pooling' with a score of 11. Rather, the differences in values here indicate that SMs with higher scores **tend to be associated** with more risks, and in some cases, more severe risks. Although there is a theoretical minimum of a score of 0 in each case, there is no symmetrical maximum a total score can be compared to.

Table 73: Matrix of the number and total score of identified risks in T6.3

Sufficiency Measure (SM)	Health		Poverty Mitigation		Gender Equality		Just Transition		Time-Use		in Total	
	Risks	Score	Risks	Score	Risks	Score	Risks	Score	Risks	Score	Risks	Score
SM-1 Product-Sharing	1	2	2	5	2	4	1	2	1	5	7	18
SM-2 Car-Sizing	0	0	1	3	2	4	0	0	0	0	3	7
SM-3 Space-Sharing	1	3	1	5	0	0	0	0	1	1	3	9
SM-5 Eating Less Meat & Dairy	2	5	2	7	1	2	3	13	1	1	9	28
SM-6 Car-Pooling	2	4	1	1	1	2	0	0	1	4	5	11
SM-8 Cycling	1	2	2	6	4	9	0	0	1	5	8	22
SM-9 Flying Less	1	1	2	5	1	1	3	8	1	4	8	19
SM-10 Working Less	2	8	1	5	1	5	1	5	0	0	5	23
in Total	10	25	12	37	12	27	8	28	6	20	48	137

Source: own compilation

A further finding is that the dimension of 'Poverty Mitigation' is the most severely affected societal goal (12 risks with a total score of 37) and 'Time-use' the least affected societal goal (6 risks with a total score of 20). It has to be noted though, that these findings are not independent of the methodology applied. For one, no individual risk has been added to more than one category. This makes it less likely that social dimensions that were assessed later (e.g. 'Time-Use' versus 'Health') achieve high scores. Secondly, some dimensions were looked at more closely (in particular 'Health' and 'Poverty

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Mitigation') and one dimension, 'Time-Use', even excluded the possibility of a score of 6 based on its premisses.

For example, while there are clearly reasons to believe that 'Poverty Mitigation' is stronger negatively affected by sufficiency policy than e.g. a better work-life balance, it is also true that the definition of overarching goals and objectives is neither exhaustive nor exclusive. This means that an individual risk might very well affect more than one category at once, but that our process of risk identification no longer considered a risk in a new dimension after it has already been found to be an issue in one of the previous dimensions. And the process of determining risk for 'Time-Use' as also unique in the sense that it represents not a comprehensive view of target conflicts and barriers with particular objectives (as assessed for all other dimensions), but rather 'additional' potential barriers. In addition, both 'Poverty Mitigation' and 'Health' were assessed with the help of causal hypotheses, but other dimensions were not. This means that there are likely additional specific risks in these other dimensions that were not be identified due to lack of their own shortlink ToCs.

Keeping these caveats in mind, we can nonetheless draw a couple of insights from the risk assessments regarding specific measures and their relationship to potential violations of societal goals. The statements in the following table summarize these findings but are intentionally phrased in a language of probability to account for the limitations of both the underlying data and models as well as the risk identification and scoring methods.

Table 74: Summary of Risk Assessment

SM	Key insights pertaining to barriers and target conflicts of the explicated Sufficiency Measures (SM)
SM-1	'Product-Sharing' has a very low probability of negatively affecting the area of 'Health' due to a slightly elevated risk for disease transmission. The more severe risk stems from a small likelihood of non-participation by vulnerable groups such as low-income households ('Poverty Mitigation') as well as women and parents (Gender Equality). This is due to the current services and tools for product-sharing not addressing the needs and preferences of these groups as well as their economic constraints. Similarly, we assessed that there is a high likelihood for time-constraints (severe violation of 'Time-Use'), since the available infrastructures and time scheduling tools might not suffice to avoid that (especially for the washing machine case assumed for this SM). Another risk is associated with 'Just-Transition' (severe violation), as such a policy has a high likelihood of affecting the demand for services and goods by local SMEs with at least some of these SMEs being affected negatively.
SM-2	'Car-Sizing' is unlikely to lead to negative impacts in the areas of 'Health', 'Just Transition' and 'Time-Use'. There is some chance for small violations to 'Poverty Mitigation' and 'Gender Equality' in cases in which the needs (e.g. for families) and budgetary constraints of participants are neglected. Some of these risks are also the consequence of perceptions, rather than actual facts. Safety concerns for example are a barrier for non-participation, but do not seem to be justified from the size of a car alone.
SM-3	'Space-Sharing' is unlikely to lead to negative impacts in the areas of 'Gender Equality' and 'Just Transition'. We also think that the likelihood of additional time-demand ('Time-Use') is low and that risks here are neglectable. The size and likelihood for diseases transmission is higher, but not overall high, compared to both these categories and compared to SM-1 on 'Product-Sharing'. This constitutes a moderate violation of 'Health'. The most severe risk is associated with the high likelihood of non-participation by low-income households, since they are the group that are also the most likely to not have the financial resources for the initial investment (severe violation of 'Poverty Mitigation').
SM-5	'Eating Less Meat & Dairy' is associated with only a small chance for negative impacts in the area of 'Time-Use' due to meal preparation and an equally small chance in 'Health' due to malnutrition. However, it is likely that the currently low acceptance, social divide or health concerns of reduced meat consumption among some groups lead to lower implementation rates, which in turn can constitute the violation of goals for 'Gender Equality' and 'Poverty Mitigation' (less severe) as well as 'Health' (more severe). Moreover, the implementation of the measure on a large-scale in Europe is probably negatively affecting demand as well as the growth of jobs and the economy in the future. While all of these three risks are considered potential severe violations of 'Just Transition', the dimension of 'Poverty Mitigation' might be affected by this as well, especially concerning the low-skilled workforce. However, predicted changes here depend on a static view of the economy that (i) does not change as a consequence and (ii) experiences no additional economic risks from non-action regarding climate change.

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SM	Key insights pertaining to barriers and target conflicts of the explicated Sufficiency Measures (SM)
6	'Car-Pooling' is unlikely to affect 'Just Transition' negatively and there is only a weak relationship between the risk of non-participation of low-income groups because of a fear of loss of autonomy regarding 'Poverty Mitigation'. We further find that there is some likelihood that such a policy, once implemented for commuting, bears the risk of unwanted professional relationships for women in the workplace. It is very likely though that the mere necessity of organizing commuting via Car-Pooling (or using it for other mobility purposes) will affect how and when time can be spent by participants (severe violation of 'Time-Use'). The area of 'Health' is another, more severely, affected dimension, as the likelihood for disease transmission among passengers is high if they spent several hours per week in the same car. There is also a target conflict for some portion of the group for which the amount of some harmful pollutants increases as a consequence of policy implementation.
8	'Cycling' is unlikely to lead to negative impacts for 'Just Transition'. The measure has also only a small probability of reducing access to relevant infrastructures for vulnerable groups, which in turn might constitute less severe violations in the areas of 'Health' (the only risk here) and 'Poverty Mitigation', with the latter also being strongly associated with the risk of non-participation overall. The most risks are associated with the dimension of 'Gender Equality'. There is a high likelihood that a large-scale implementation of SM-8 impedes care-work, and some probability that it affects negatively the job opportunities of women, decreases social participation and leads to 'othering' (social stigma). All of which depend on the assumption that car-travel and similar modes of transport enable 'Gender Equality' at the moment and that future efforts of transforming infrastructures do not account for accessibility and increased speed from reduced car-travel. This is why we also consider this measure to have a high likelihood of leading to longer commuting overall and additional time-demand for daily chores such as grocery shopping (severe violation of 'Time-Use').
9	'Flying Less' affects all five areas of social risks but to different degrees. We find that, regarding 'Health', there is a small likelihood that it negatively affects the international cooperation in the area of medicine. We also find it likely that at least some groups will not participate, if other modes of long-distance trave are perceived to be more stressful for families with small kids (less severe violation of 'Gender Equality') or just more time-consuming (more severe violation of 'Time-Use'). Apart from a small likelihood of social exclusion for low-income households if the policy is price-driven ('Poverty Mitigation'), all of the remaining identified risk relate to potential economic effects of the policy. The implementation of the measure on a large-scale in Europe is probably leading to competitive disadvantages for SMEs in the tourism sector (less severe violation of 'Just Transition'), but also probably negatively correlated with overall economic growth (sever violation of 'Just Transition') and the growth of jobs (severe violation of 'Just Transition' and 'Poverty Mitigation'). All of which are not independent of overall economic changes as a result of sufficiency policies (e.g. in regard to value-added in other sectors) as well as the economic costs of non-action regarding climate change mitigation.
10	'Working Less' is unlikely to affect 'Time-Use' in a negative way in general, but there is a high likelihood that some time-savings are compensated by an increase of hidden or devalued work for women (severe violation of 'Gender Equality'). 'Poverty Mitigation' is likely to be negatively affected (severe violation), if such a policy is not accompanied by schemes for wage-compensation and SMEs in Europe could be confronted with competitive disadvantages compared to companies within or outside of Europe that do not implement such a policy (sever violation of 'Just Transition'). The area of 'Health' is the most affected social dimension. We think it very likely that a large-scale implementation of the policy would further strain the availability of medical staff in European countries and that many persons in the targeted groups could not participate because of a lack of worktime-control in general.

Table: own compilation

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6. Synthesis

The final chapter in this report is dedicated to a summary and interpretation of the overall results. It also reflects on the limitations of the applied methods, as well as the underlying data and assumptions. The last section then concludes the report and provides an outlook for future research needs.

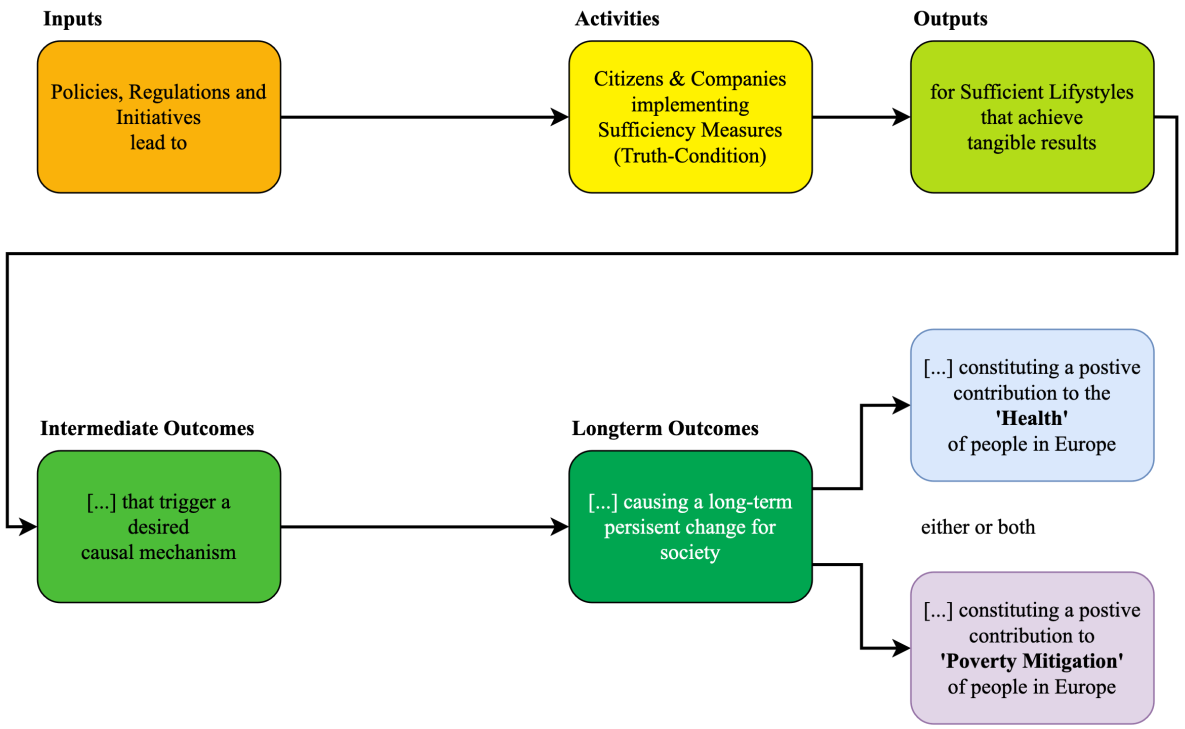
6.1. Interpretation of results

We have analysed the eight assumptions from D5.3 for large-scale sufficiency measures (SMs) in Europe and assessed their potential benefits as well as risks to society. Our interpretive framework aligns these social effects with the dimensions of 'Health', 'Poverty Mitigation', 'Gender Equality', 'Time Use' and 'Just Transition'. Whereas risks are assessed for all five dimensions, benefits are only assessed for 'Health' and 'Poverty Mitigation'.
We perceive these dimensions to be overarching goals for the European Union, that are overlapping and non-exclusive, but attribute each potential effect to one dimension only. This entails that a risk in one dimension might very well be also present in another dimension, and that a positive effect might also affect another area of interest in a desired or non-desired way. This is why we opt to present the results in a comprehensive manner with the intention to highlight and summarize the most important findings.

Social benefits from impact assessment of sufficiency lifestyles

The following figures summarizes our results regarding the benefits of sufficiency towards 'Health' outcomes and 'Poverty Mitigation'. Figure 19 depicts the general approach for finding causal hypotheses that explain how and which benefits might occur. It is based on a Theory-of-Change heuristic (see section 2.1 in 'Methodology') that treats both the interventions and the actions of all participants as truth-conditions (if and only if the SMs are implemented throughout Europe as modelled in D5.3 for each of the five FULFILL countries and further scaled up in tasks T6.1 and T6.2).

Figure 19: Theory-of-Change schematic for finding causal explanations



Source: own development

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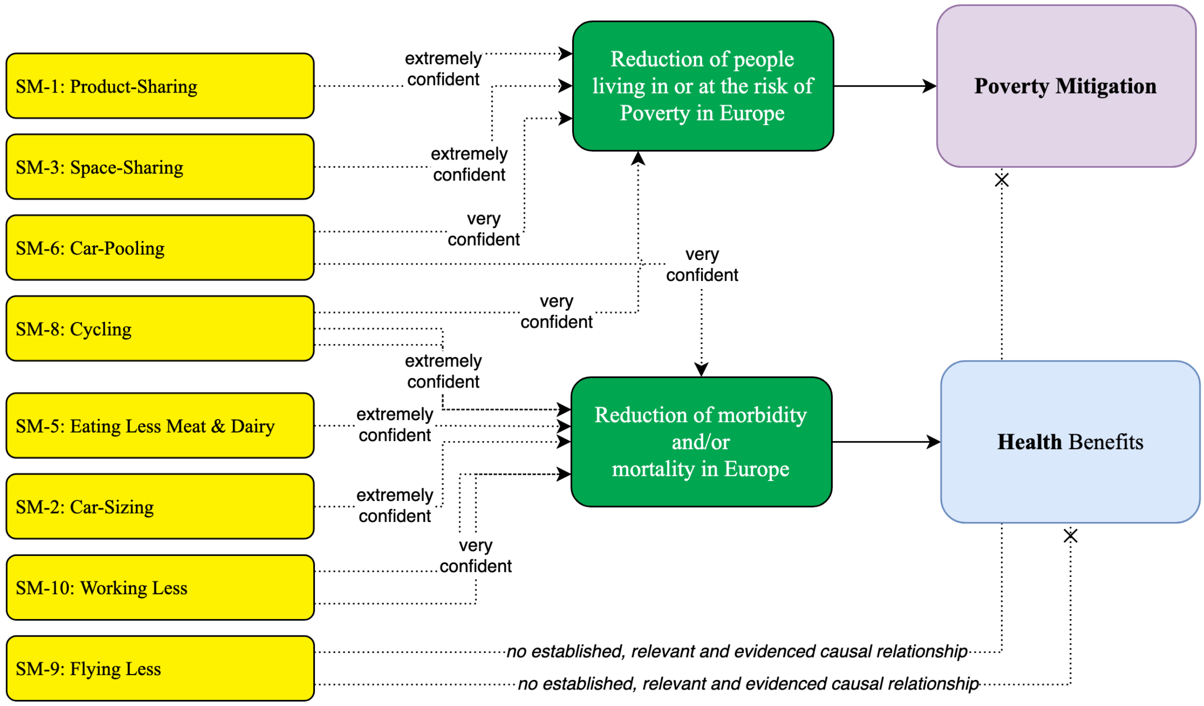
Figure 20 then summarizes the results of the credence assessment towards societal benefits (persistent Longterm desired changes), that investigated how confident a rational third party can be in the anticipated benefits with the help of evidence-based Bayesian Reasoning.
11 such causal hypotheses ended up in the final iteration of the ToCs and are deemed to be reliable predictions (credence well above 0.5 on a credence-range between 0 and 1)

Figure 20: Results of the credence assessment of desired persistent benefits of the SMs



Source: own assessment

Out of these eleven pathways, we are *extremely confident* in six of them. That is, we have a credence of above 0.95 in the following four statements:

- The sharing of products (SM-1) and the sharing of space (SM-3) are either or both partially sufficient for poverty reduction in Europe IF (truth-condition) they reduce the monthly expenditures for housing (including capital costs) among relevant vulnerable groups.
- An increase in cycling activity (SM-8) is partially sufficient for a reduction of morbidity AND/OR mortality in Europe IF it increases physical activity and sufficient for such a reduction IF it decreases OR replaces fossil-fueled mobility.
- Eating less meat and dairy (SM-5) is partially sufficient for a reduction of morbidity AND/OR mortality in Europe IF it leads to a more balanced diet. This is additionally conditioned on the requirement that such a diet entails enough dietary choices to achieve this balance.
- Reducing the size of cars in the market (SM-2) is sufficient for a reduction of morbidity AND/OR mortality in Europe IF it decreases tailpipe and non-exhaust air emissions by cars.

We are also very confident in another five of these pathways. This means that we have a credence above 0.80 in the following three statements:

- Car-Pooling (SM-6) is partially sufficient for poverty reduction in Europe IF it reduces transport-related expenditures for vulnerable groups AND sufficient for a reduction of morbidity AND/OR mortality in Europe IF it decreases OR replaces fossil-fueled mobility.

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- Car-Pooling (SM-6) is partially sufficient for poverty reduction in Europe IF it reduces transport-related expenditures for vulnerable groups AND sufficient for a reduction of morbidity AND/OR mortality in Europe IF it decreases OR replaces fossil-fuelled mobility.
- An increase in cycling activity (SM-8) is partially sufficient for poverty reduction in Europe IF it reduces transport-related expenditures for vulnerable groups.
- Work-Time reductions (SM-10) are partially sufficient for poverty reduction in Europe IF it reduces stress AND/OR long working hours for vulnerable groups. This is additionally conditioned on the requirement that these persons have sufficient work-time control and recovery-time from long shifts.

Only one of the eight SMs could not be associated with the same kind of benefits: Flying Less (SM-9). This does not mean that there are not any health- or poverty-related benefits for some portion of the society (either now or in the future) from adopting this policy. For example, it is very conceivable that some health risks that are associated with the activity of flying, such as venous thrombosis (Kuipers et al., 2007), could be reduced as a consequence of reducing flying and thus constitute a 'Health' benefit. This exclusion therefore merely means that we did not find enough evidence in the literature that reports or predicts such benefits on a relevant scale or with a sufficiently high likelihood that allowed us to formulate an initial plausible causal hypothesis.

Among all causal hypotheses, only three SMs could be further investigated in a quantitative manner. The following Figure 21 summarizes the results for Europe. It depicts the estimated and predicted changes from a successful implementation towards a desired change (reduced mortality or morbidity in Europe) and the anticipated impact on the goal of 'Health' benefits. All quantitative results shown here can be understood as an 'educated guess' rather than an accurate depiction of a range of values over time. Although the values before the Outcome are more robust in all three pathways than the results afterwards, the available data and empirical grounding does not justify more than these 'ballpark figures'. In terms of robustness (see section 2.4) three indicators are attributed with a score 3 (out of scores between 1-5) which represents calculations with the help of secondary data or auxiliary variables. The two Outcome-indicators have a robustness of 4, and thus heavily rely on models or relations that simplify the cause-effect-relationships. The weakest robustness is attested to the anticipated decrease in PM 2.5 concentrations, which we consider to be more of a proxy for potential reductions.

Figure 21: European results from quantitative assessment

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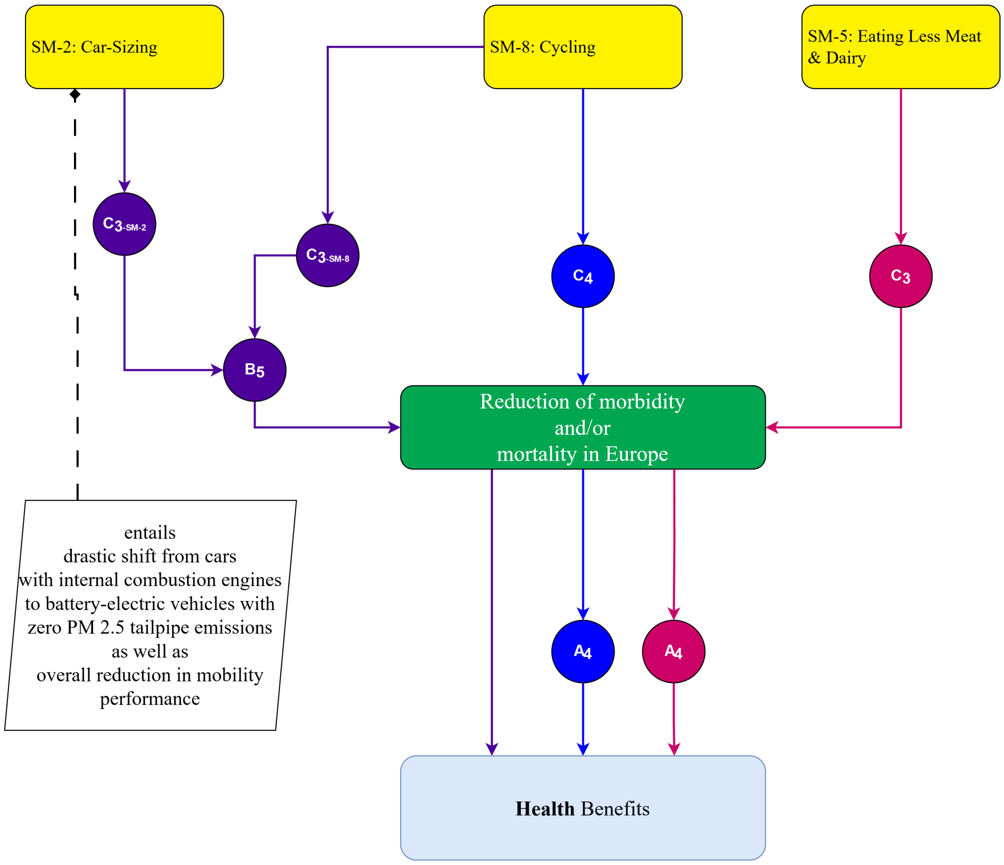
Graphical Overview of anticipated quantitative health benefits (**Educated Guess**)
from *more cycling*, *reduced car-sizes* as well as shifts in drive trains, and *eating less meat*



Indicator Quality Robustness	Indication	Value
C3-SM-2	**decreased PM 2.5 pollution** from SM-2 on 'Car-Sizing'	-85.5% in Europe (exhaust emissions) until 2050 on average (-42% from smaller cars alone)
C3-SM-8	**decreased PM 2.5 pollution** from SM-8 on 'Cycling'	-3.1% in Europe (exhaust emissions) until 2050 on average
B5	**relative reduction in PM 2.5 concentration** from SM-2 & SM-8	-7.2% on average in Europe (without spatial & temporal contributions)
C4	**increased physical activity** from SM-8 on 'Cycling'	1.4 in 2020 to 2.8 MET.h / (week*person) in 2050 (entire population) OR 5.0 in 2020 to 9.9 MET.h/ (week*person) in 2050 (only cyclists)
A4	**reduction in relative risk for All-Cause-Mortality** from SM-8 on 'Cycling'	2% for entire population OR 8% for population that already cycles
C3	**reduced average consumption of animal protein** from SM-5 on 'Eating Less Meat & Dairy'	from 36 in 2021 to 17 g per day and person in 2050 (overall reduction of 51%)
A4	**reduced in relative risk for All-Cause-Mortality** from SM-5 on 'Eating Less Meat & Dairy'	15.6% for an average European adopting the average diet distribution in 2050

Source: own estimation and compilation

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For the indirect health benefits of 'Car-Sizing' and 'Cycling', we estimated that the **exhaust** emissions of particular matter with 2.5 micrometre in diameter (PM 2.5) from car passenger transport could be reduced by circa 89% on average in Europe. This entails other relevant changes in the systems such as changes in the powertrains (mainly shifting towards exhaust-free electric vehicles) as well as lower drive performance overall. Out of the direct reduction from 'Car-Sizing' of circa 86% only 42% can be attributed to smaller car sizes. This would certainly also decrease PM 2.5 concentration in air, which is an important pre-cursor for respiratory and other diseases. Although neither of these effects could be modelled solely based on the available data, we expect that the mere effect on concentrations is roughly -7% on average.

For the direct health benefits of 'Cycling', we estimated an increase in physical activity for either the entire population or the portion of the population that already cycles. For the entire population, there is an estimated increase from 1.4 to 2.8 'Metabolic Equivalent of Task' hours per week and person (MET.h / (w*p)) between the starting year and 2050. If only the portion that already cycles is considered (case 2), there would be an increase from 5.0 to 9.9 MET.h / (w*p) over the same period. This in turn is equivalent to a relative All-Cause-Mortality (ACM) risk reduction of either 2% (lower bound but entire population) or 8% (upper bound but only for the population that already cycles).

For the direct health benefits of 'Eating Less Meat & Dairy', only the reduction in animal protein intake could be considered that stems from the implementation of SM-5. We estimate that the daily intake of animal proteins will be reduced from 36 gram per day and person (g/(d*p)) to 17 g/(d*p) for the average European between 2021 and 2050. This can have a positive effect on ACM risks under the assumption that (i) a current average European opts for a diet matching the 2050 dietary composition and that (ii) animal protein reduction correlates linearly with relative ACM risk reduction. If both assumptions hold, we predict an 15.6% relative ACM risk reduction from future diets on average in Europe.

All three outcome pathways and their results heavily rely on the provided sufficiency assumptions and their modelling from D5.3. They are also based on simplified relationships that do not account for numerous important interrelationships affecting health outcomes. Nonetheless, **these 'ballpark figures' show that they can be quantified in principle and that the size of these impacts is large enough to justify additional efforts towards the realization of the corresponding sufficiency policies**.

Social risks of sufficiency lifestyle changes

Social risks were assessed for two types (barriers and target conflicts) and for two perspectives (generic risks and risks specific to the explicated outcome-pathways for 'Health' and 'Poverty Mitigation'). In total, 47 risks were identified with a total score of 136. The scores in each of the five dimensions range from 19 for 'Just Transition' to 37 for 'Poverty Mitigation'.
For the synthesis, each SM is visually connected to each identified risk and individual score (see section 5.6 for a list of probabilistic statements for each of the measures) as shown in the following figures. We further assess which of the measure require, in our opinion, policy-adjustments before implementation.

Figure 22 assigns SM-5 on 'Eating Less Meat & Dairy', SM-10 on 'Working Less' and SM-8 on 'Cycling' to the category of '**urgent policy-adjustments required'**. We think that the societal benefits of more climate-friendly diets justify SM-5 (as discussed before), but that a broad and non-targeted implementation might lead to the exclusion of vulnerable groups and can potentially lead to indirect economic harm to European economies. Similarly, 'Working Less' is beneficial to society but requires a number of pre-conditions for a successful implementation, such as wage-compensation, job-growth in the health sector and higher worktime control for those workers that would benefits the most from it. Policies for increased 'Cycling' on the other hand are considered to be highly beneficial for numerous environmental and social reasons. However, any large-scale implementation should consider that some vulnerable groups might not be able to participate for all kinds of pragmatic reasons and that it can, depending on the realization, impede 'Gender Equality'.

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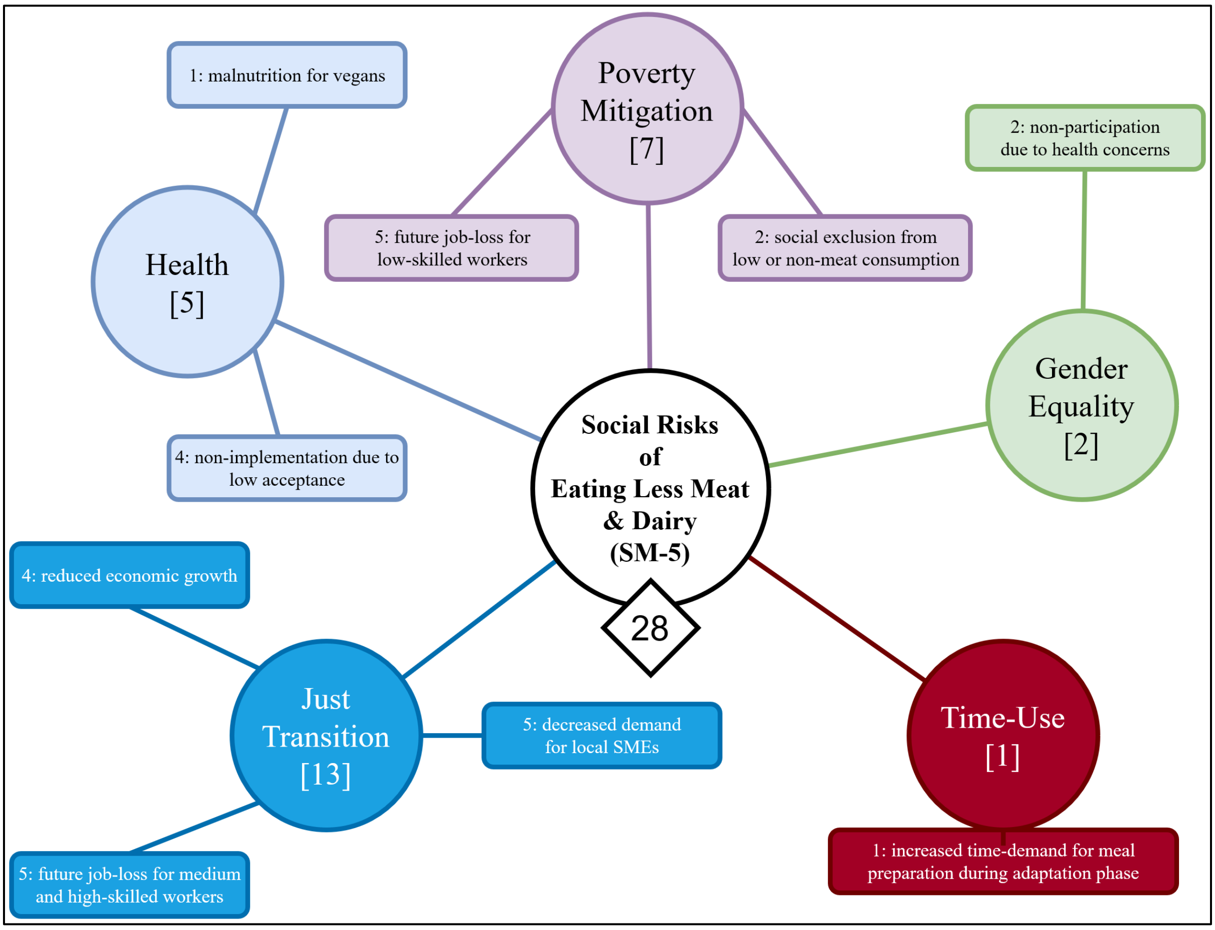
It has to be noted though that all three policy options were assessed in the broadest, and most unconstrained, way possible. That is, existing policies can and likely already have taken some of these issues into account. Moreover, the assessments of direct negative impacts on European economies have not been compared to the consequences of non-action. A business-as-usual scenario based on current mitigation efforts is likely to lead to additional and non-recoverable economic costs that would very probably outweigh the decreased GDP and worker growth values quantified in D6.2.

Figure 22: Policies that require urgent policy-adjustments aimed for large-scale implementation



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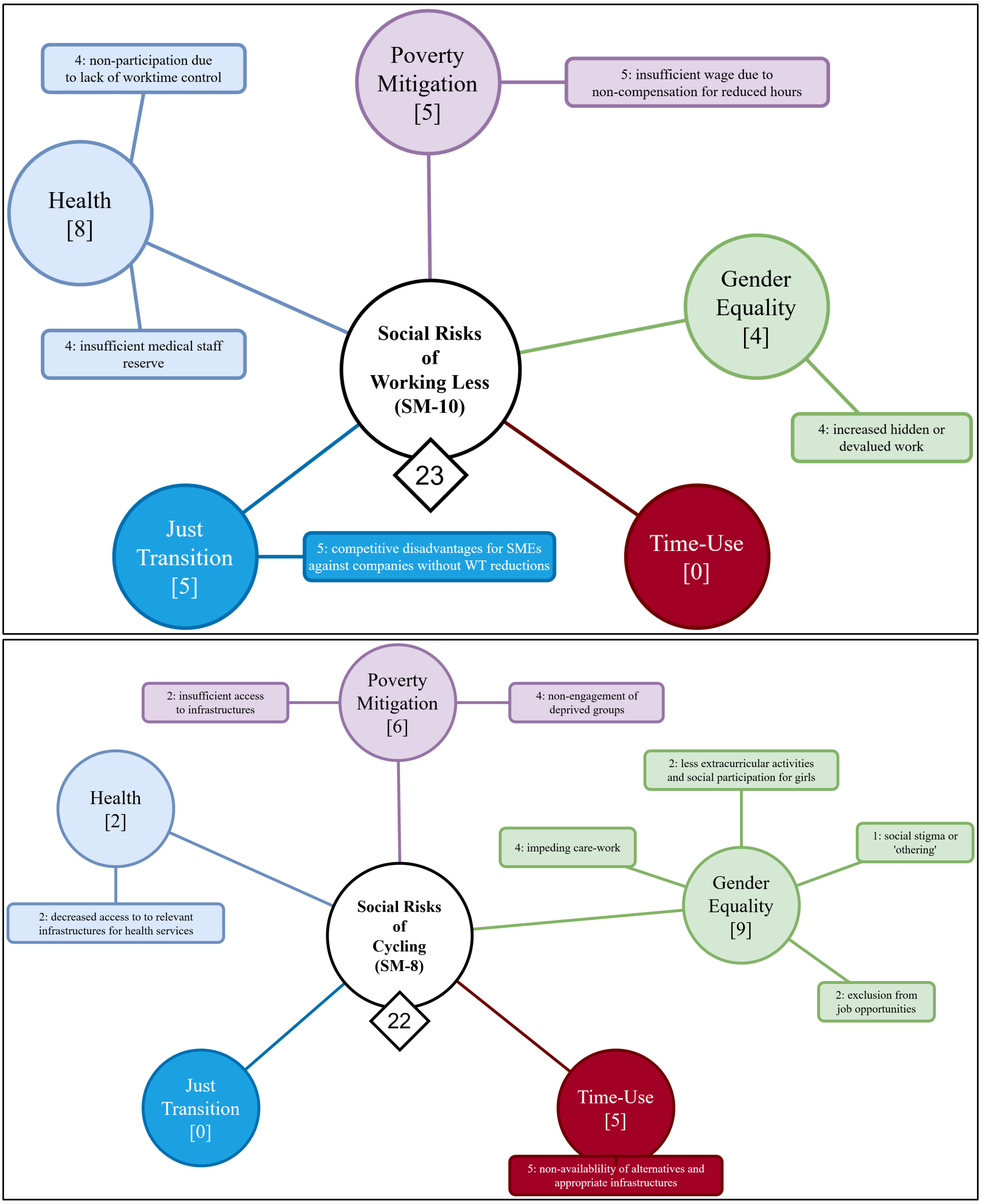

Source: own assessment and compilation

In a second step, SM-1 on 'Product-Sharing' and SM-9 on 'Flying Less' are assigned to the category of '**moderate policy-adjustments helpful**' (see Figure 23). Although both are considered to be relevant measures towards climate change mitigation, their other social benefits do not necessarily outweigh their risks. For the sharing of products in general, and the sharing of washing machines in particular, we find that there is a high likelihood of non-participation among vulnerable persons as well as women with families. The needs, preferences and capabilities of these target groups should be considered specifically during the design of product-sharing schemes and tools. Similar concerns arise for policies that reduce flying, but the more severe risks are associated with changes in relevant economic sectors as a consequence of a successful implementation. Especially workers in the

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tourism sector might be negatively affected in more than one way (lower economic growth, lower job growth, lower competitiveness for small and medium-sized enterprises). A successful policy towards 'Flying Less' can mitigate these negative side-effects early on by enabling job and business opportunities in other sectors or parts of the tourism industry and by enabling other social as well as environmental benefits in areas where tourism causes social and economic issues today.

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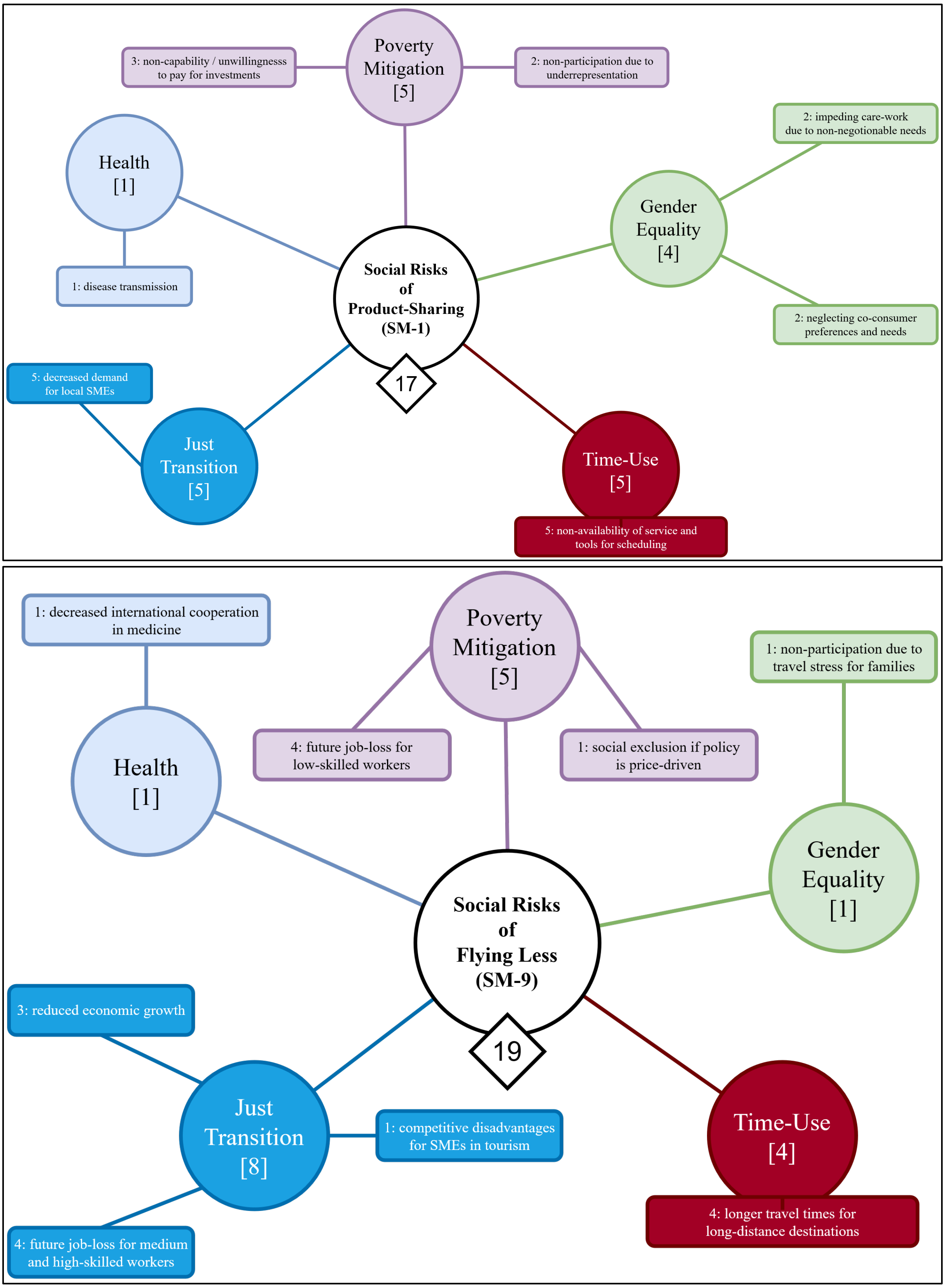
Figure 23: Policies that benefit from moderate policy adjustments (before large-scale implementation)



Source: own assessment and compilation

The remaining three measures regarding SM-1 on 'Car-Sizing', SM-3 on 'Space-Sharing' and SM-6 on 'Car-Pooling' are all attributed to the category '**no policy adjustments required**' (see Figure 24).

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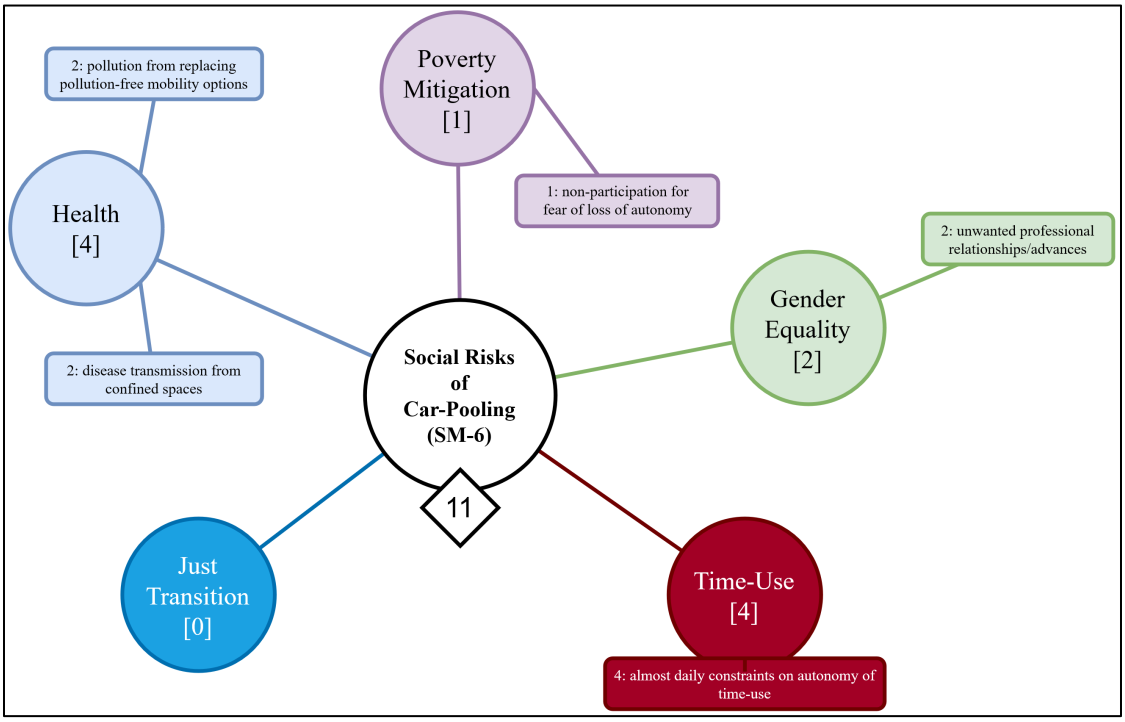
We find that there are neither strong societal benefits nor strong societal risks associated with such policies. Risks like an increase rate of disease transmission ('Space-Sharing' and 'Car-Pooling') could not fully be avoided by such policies anyway, whereas the more moderate risks of non-participation do not necessarily translate into less successful policies overall (especially regarding the main goal of decarbonisation). Nonetheless, the latter can be mitigated in a similar manner as for 'Product-Sharing' by considering the needs, preferences and capabilities of low-income households and women with families.

Figure 24: Policies that do not require policy-adjustments before large-scale implementation



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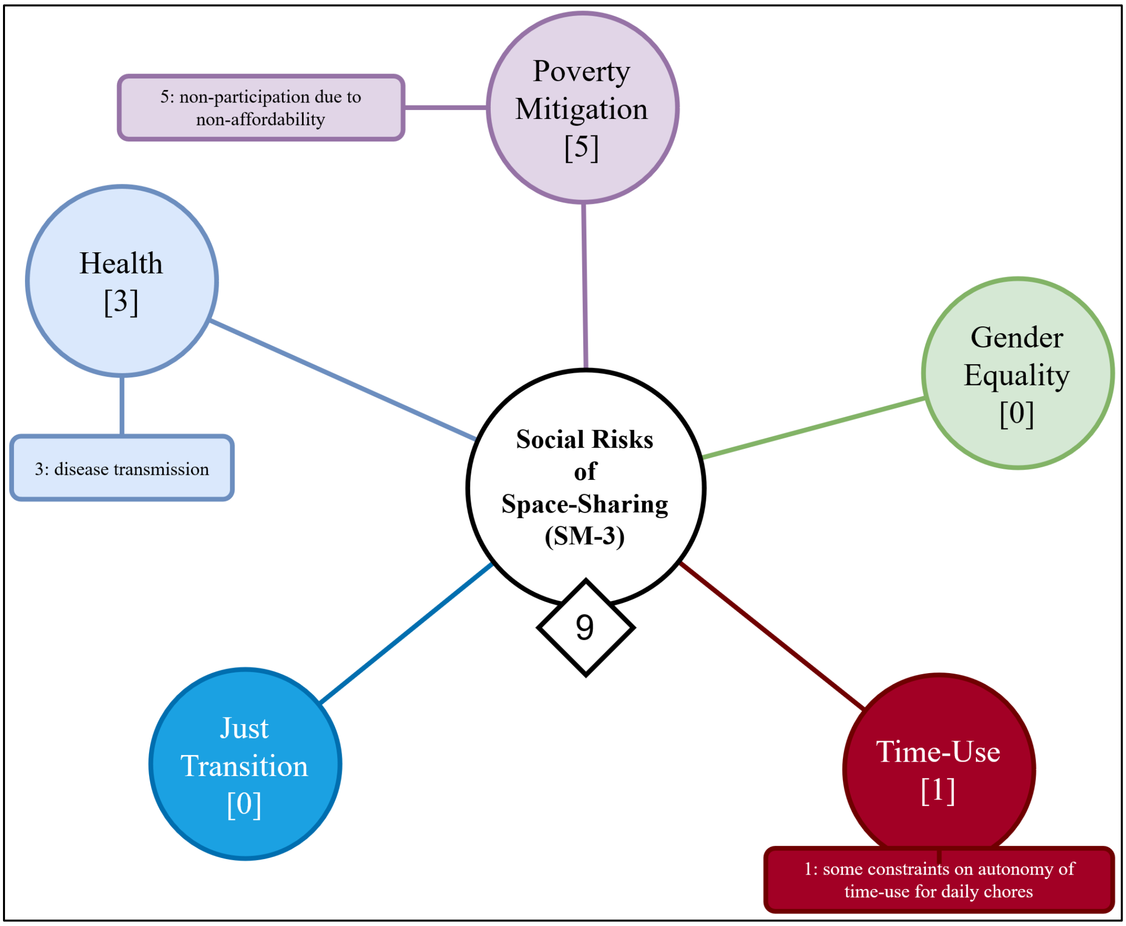

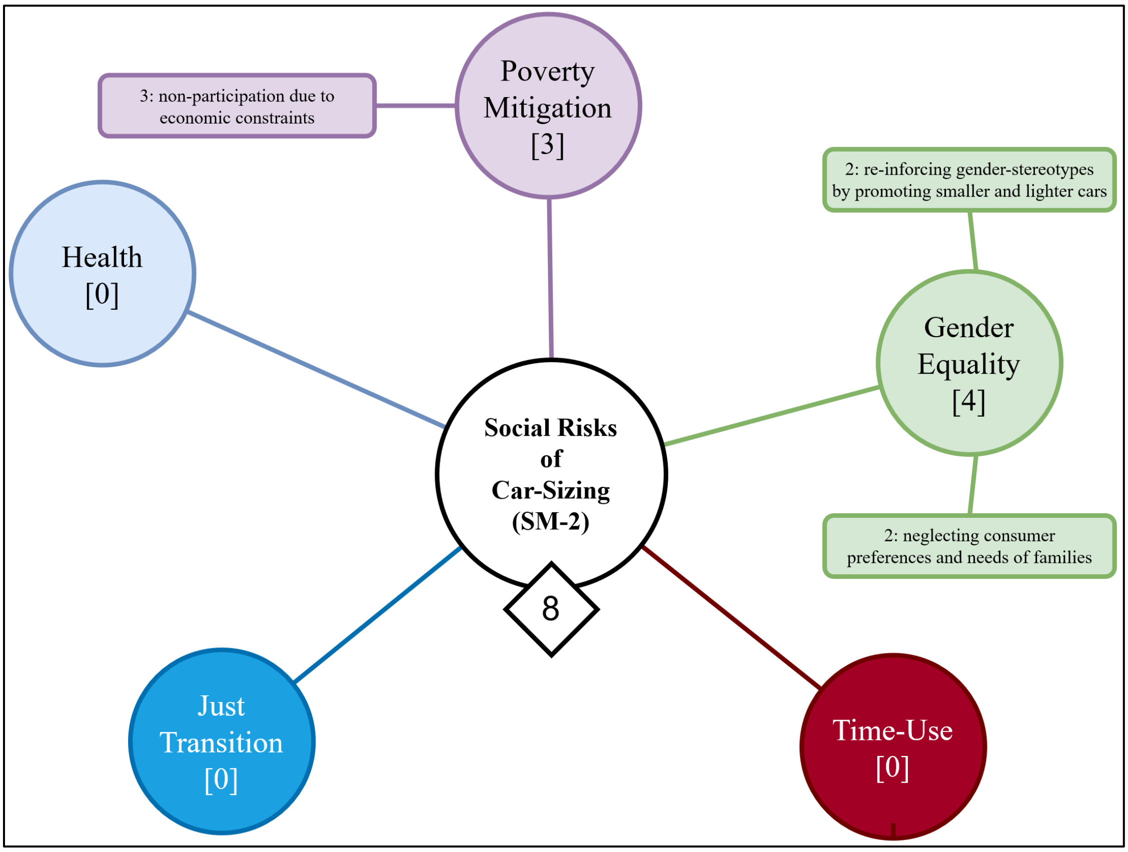

Source: own assessment and compilation

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All of the previous statements regarding social risks should not be interpreted in isolation. One reason for that is the fact, that we did not assess benefits in three out of five dimensions and limited our assessment of benefits in two other dimensions to cases we could be reasonably confident in. **This assessment therefore does not account for damages from non-action, and neither does it account for direct trade-offs**. For example, an indication of a risk to 'Health' due to lower accessibility could not be compared to the overall benefits across the entire population and – from an economic point of view – reduced costs for health care as a result of overall healthier lifestyles in Europe. **Another reason for a cautious interpretation of the risk assessment results is the fact that we looked into the future based on current policy implementations rather than *sufficiency-policies*.** A score of 4 regarding 'minor policy adjustments recommended' refers to a state of affairs as we find it typically to be realized in the current environment and not a future state of affairs in which sufficiency is an integral part of changes to infrastructures and systems. There is, for example, no reason to assume that an urban infrastructure friendly to cyclists and pedestrians has to reflect our current priorities regarding car-mobility and car-parking. In fact, there is evidence that it is possible, and feasible, to design infrastructures in such a way that they do not impede travel-time for cyclists in cities or prohibit motorized mobility in cases where it is beneficial to society (e.g. emergency services)[20]. Moreover, many of the risks associated with the lack of access or participation heavily rely on regulations regarding the accessibility and affordability of services in a given country. For example, a lack of participation of parents due to safety concerns (as explicated in this report regarding 'Cycling') could be mitigated if a State, or municipality, ensures that children can get to their schools or extracurricular activities in a safe and affordable manner[21].

6.2. Limitations

We are confident in the main findings of this report that were summarized in the previous section. Nonetheless, there are many limitations affecting the goal certainty, accuracy and robustness of our results that readers need to be aware of before applying them for their own purposes such as policy development.

All assessments of environmental or social effects have limitations and these are usually more pronounced if the subject matter to be assessed is a conditional or about the future or – as in the case at hand – both. Moreover, the methods that were applied here and, in some cases, newly developed have additional limitations that recipients of impact assessment might not be familiar with to the same degree to which they expect limitations from purely quantitative modelling.

We thus divide this section in line with our findings into limitations for qualitative social benefits, quantitative social benefits as well as qualitative social risks.

Limitations of the qualitative assessment of social benefits

The first caveat to be noted is the fact, that the qualitative assessment of social benefits is restricted to only two of the five dimensions. An additional assessment of the other dimensions with a similar approach might very well reveal additional benefits, but also provide additional confirmation of already existing benefits (making them causally more frequently expected or expected under a broader set of circumstances). For example, a similar assessment of the dimension of 'Gender Equality' might lead to additional insights and evidence on benefits that overlap with the areas of 'Poverty Mitigation' and 'Health'.

The second limitation relates to the development of the initial Theories-of-Change (ToCs, see section 2.2). These causal narratives are, as stated, heuristically developed based on the experience and background knowledge available to the authors. Other experts, and in particular other subject-matter experts, might have thought of additional, but also more relevant or more complex causal

[20] For example, if there is a need for cars to access an area large calibre bike paths are the ideal route for that. They can be made free for the emergency vehicle in a short amount of time, while a lane full of cars or a congested car-crossing might constitute a barrier that cannot.

[21] (Nawothnig & Spitzner, 2024) suggest for example a legislative right for a "safe way to school" which is understood as sufficiency policy for both children and care-giver. This is associated, among others, with improvements in health, learning ability and self-efficacy for children.

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relationships. This is not surprising given the method and broad scope of the assessment, but it also constitutes a limitation regarding the results. Some other relevant benefits might have been overlooked (e.g. for SM-9 on 'Flying Less') that would have shifted the focus of our synthesis or highlighting of particular insights.

The third limitation relates to the conditional configuration of the ToCs. We limited the assessment to those sufficiency assumptions that were assessed quantitatively regarding GHG emissions and climate change mitigation. Assuming these sufficiency measures (SMs) to be true in their modelled stage is a pragmatic solution to an otherwise almost impossible task (accounting for all actual and possible input variables). However, it also limits our findings to the parameters of these models, scenarios and assumptions. For example, one of the originally discussed SMs would have looked at shifts towards public transport as a sufficiency assumption. A measure that, whenever it is implemented, is even more strongly affected by intersectional policies regarding public funding, urban planning and infrastructures than the explicated SM-8 on 'Cycling'. And vice versa, SM-1 on 'Product-Sharing' could have entailed a wider range of products, which again, could have led to the identification of additional or better attested benefits.

The fourth limitation relates to the credence assessment in two ways. The overall approach of Bayesian Reasoning is already a simplified version of an otherwise more extensive process of a Bayesian Analysis (as for example explicated in Teubler & Schuster, (2022)). That is, not each and every piece of evidence is justified and computed separately under all possible explanations and the conjunction of conditions is assessed compared to each separate claim in the ToC. Instead, a more holistic and argumentative approach was chosen intended to convince a rational third party of the assessment. This is a limitation insofar as it required the introduction of ranged credences instead of point-values, which in turn, make the results more ambiguous. The second way in which the credence assessment limits the accuracy and robustness of its result relate to the evidence itself. Whereas a credence assessment based on Bayesian statistics would rely solely on direct empirical data tailored to each case (to directly assess frequency), the assessment here relies on literature about similar causal conditions. This literature can be incomplete, to be false or only true under current conditions or in other parts of the world. Especially in cases in which a single source was used to corroborate parts of the Bayesian equation, an assessment of other sources might very well come to contrary conclusions. This is not surprising given the task (future benefits from modelled future sufficiency lifestyles), but this is also why a separate section was introduced that is intended to help the reader with confronting the results (section 2.3 on 'Resolving disagreements with Bayesian Arguments').

Limitations of quantitative assessments

Four causal hypotheses could be translated into an estimate of quantified benefits with the help of three outcome pathways. A limitation that is equally present in all three cases is the lack of difference-making due to lack of a reference scenario. None of the datasets in the input data provide direct information on how the activities would have played out in a business-as-usual setting. We therefore cannot estimate the marginal differences between Europe in 2050 with and without these sufficiency lifestyles. We can only compare the effects between the starting and end point rather than between one scenario (sufficiency) over another (BAU). This entails that some portion of the benefits could have been achieved without the SMs or vice versa, that the benefits could have increased even more. It also means that any quantification of the influence of input parameters, and especially assumptions, could be equally over or understated. This limitation is particularly problematic for the estimating of PM 2.5 reductions from 'Car-Sizing' and 'Cycling', since the input predicts drastic shifts to the sales and stocks of cars with different powertrains. The overall strong shift toward electric mobility already entails strongly reduced PM 2.5 emissions that are independent of the effects of the smaller car sizes in the sufficiency assumptions. Conversely, while electric cars do not burn fossil fuels directly, they might be heavier due to the battery to their internal combustion engine counterparts, which can increase wear on the road and wheels.

In regard to limitations specific to the D6.3 models, the first case alluded to an increase in physical activity (and decreased risk for All-Cause-Mortality) as a direct consequence of an increase of 'Cycling' (SM-8) in Europe. We identify three limitations specific to this model.

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Firstly, the available dataset only provides information on the average daily distance covered by cyclists, which was then used to extrapolate the country-wide or EU effects with the help of the development of the population. This flat increase for either the entire population (case 1) or the population of cyclists (case 2) can never be an accurate reflection of a potential future, as the real distribution of additional activity could be heavily skewed to one direction. This also affects the size of the overall results for risk reductions. Although the dose-response model for METs is linear, the change in risks depends on three discrete intervals for the relationship between MET and relative risks. This means that larger risk reductions are expected for people that almost never cycle and now do, and smaller risk reductions for people that already cycle on a daily basis.
Secondly, there are also other lifestyle factors that influence the 'Health' outcomes, although the findings in Kelly et al. (2016) suggests that they may not impact our results to a large degree.
The third limitation relates to the upscaling approach on EU- level, which depended on data from only five countries. It is unlikely, but possible, that the remaining EU countries would exhibit very different characteristics and likely, that the use of population growth is not a very robust predictor for the overall effect.

The second model investigated reductions in relative All-Cause-Mortality risks from dietary changes explicated and modelled for SM-5. The first limitation relates to the underlying empirical grounding itself. Although there is evidence that reduced meat intake is linked to a reduction in All-Cause Mortality (ACM), this linkage is not always clear (as mentioned in the credibility assessment in section 3.3) and a linear dose-response might not fully comply with reality. This means that the results are likely either over- or underestimated to an unknown degree.
Secondly, the underlying study by Song et al. investigates the health of a prospective cohort of US healthcare professionals, comprising more than 100,000 individuals, rather than an entire country or continent. Therefore, the representativeness of the population under investigation must be questioned, even if there is clear indication in the literature, as well as national dietary health recommendations, that some health benefits can be expected for across the entire population in any given country.
Thirdly, the assumption that the relationship between meat intake and ACM is symmetrical lacks evidence. This assumption was necessary due to the absence of a robust empirical grounding for the relationship between plant protein intake and relative ACM risks in convolution with animal protein intake changes.
Regarding the calculation, no distinction was made between genders, which constitutes the fourth limitation. Although the underlying study by Song et al., 2016 differentiates between genders and dietary changes are covered in D5.3, we had to base our educated guess on the average person in each country for our estimation. As a result, we could only quantify the reduction in ACM risk for the entire population.
The fifth limitation relates to the calculation of raw animal products into animal protein, which is based on assumptions derived from data on protein content in animal products. Additionally, recalculations were needed as our model required protein change as an output. Both simplifications were necessary due to lack of data but impact the accuracy of the results to an unknown degree.
And finally, we lacked data on the amount of meat consumed and the changes over five-year intervals for the upscaling approach. Consequently, we used the arithmetic mean value from the five FULFILL countries as an approximation for the benefits within the European Union. Similarly, to the first case, differences between countries and rates of conversion are to be expected and thus should lower our confidence in the results on the European level compared to the country-specific results.

The estimation method for pollution reductions is highly sensitive to the changes in the systems that go beyond smaller car-sizes or modal-shifts from car-travel to cycling (such as overall decrease in passenger car travel and shifts towards electric vehicles). This limits the results, and their robustness, to the robustness of the input data from T5.3.
A second limitation is the fact that the emission-intensities of the car types only account for four sizes (small, medium, large, SUV) and do not change over time. It is at least partially expected that cars with internal combustion engines will continue to decrease in specific emissions of pollutants, which would in turn lead to weaker reduction effects.

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The third limitation relates to the focus of the estimation on both PM 2.5 emissions and direct PM 2.5 emissions. The educated guess for the overall reduction is very likely to be different for PM 2.5 than for other pollutants, especially considering other powertrains and their non-exhaust emissions of PM 2.5 or any other air pollutant of interest.

Limitations of the qualitative assessment of social risks

The qualitative risk assessment looks at potentials in a loose asymmetrical causal relationship between the SMs and either of the five areas of interest. That is, it assumes that the SMs are implemented on a large-scale in Europe and then scores the severity of the risks depending on the likelihood and size of violations. These violations are expressed as either barriers or target conflicts against key objectives and overarching societal goals. Each of these risks is determined heuristically and where possible, evidenced by literature. Either of these aspects results in limitations regarding the results.

The first limitation pertains, again, to the available information from the explicated previously developed models for SMs. It is, on the one hand, not possible to account for all explicit and implicit assumptions of these models and on the other hand, necessary to make additional assumptions for the assessment (for example regarding the target groups affected). This means that there is no perfect overlap between these two frameworks as some parameters might not have been accounted for and others were not considered in the original scenarios.

The second limitation derives from the definition of the overarching goals and their objectives. This requires an operationalisation of European strategies into objectives based on the understanding of the analysts. This limits the potential range of risks and their severity to these concepts. Other experts, and in particular subject-matter and policy experts, are likely to have a more nuanced understanding of the relationships between target groups and strategies. It would therefore be expected that other experts could identify additional risks from additional relationships or come to different conclusions on the severity of the identified ones.

The third limitation relates to the assessment itself. The process adopts a rather simplistic view of the potential negative impacts by conditionalizing them on their likelihood and the size of the effect. It is also based on the analysts' understanding of available policy options to mitigate or avoid the violations. The results of the third part of the Social Impact Assessment are therefore less robust than the results from other parts, since they do not only depend on accuracy of predictions into the future (which is true for all parts of the assessment) but also on the availability of future policy options as well as future attitudes and preferences of participants for the SMs.

The fourth and final limitation has already been discussed during the synthesis and summary of results. It can be an advantage for such an assessment if the overarching goals are non-exhaustive and non-exclusive categories, because a stricter framework bears the risk of oversimplifying complex interactions and feedback loops between different actors in society. However, it also results in a skewed synthesis, since the over- or under-prevalence of risks among SMs or among goals can merely be a consequence of the approach. This means in particular that third parties should not overstate the significance of single findings in their own interpretation and rather look at the bigger trends that could be identified such as meaningful differences in the total scores among the SMs. For example, it can very well be the case that the strong weight of gender aspects for SM-8 on 'Cycling' is not representative of the wider literature on the subject and that aspects of 'Poverty' are equally important. However, our risk assessment provides enough reasons for a policy maker to take note and account for it for policy adaptations.

Limitations of the scope of FULFILL

All of the above limitations discuss how the available data, the selected methodological approaches in this and previous tasks as well as the ambiguity of the social dimensions affected the accuracy and robustness of our results. There are also limitations regarding the scope of the project though. Firstly, other and additional sufficiency lifestyle policies could have been selected and investigated and the ones that were, could have been expressed over a different range of parameters. SM-1 on 'Product-Sharing' for example focused on washing-machines as the type of products that could be shared among households (mainly for pragmatic reasons of data availability). One can easily imagine

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additional products contributing to stronger and additional benefits, or other products being associated with fewer risks. The same is true for assumptions regarding any of the products and services across all SM's (e.g. planes without direct GHG emissions) or any of the infrastructures assumed. SM-8 on 'Cycling' for example would not be associated with the same risks if implemented in a car-free city. This limitation is not a lack of imagination, but a limit of an approach that aims to explicate plausible future pathways rather than the most optimistic, innovative or worst-cases future ways of life. Secondly, FULFILL is mainly concerned with five countries and mostly focused on sufficiency lifestyles in Europe. While difficult to qualify, it can convincingly be argued that both benefits and risks would look different in other parts of the world but would also not be entirely independent of the insights in the report at hand. Whereas the efficacy of the SMs is expected to be higher or lower depending on the situation in a given non-European country, the trends should hold in general. For example, any policy that successfully reduces the drive performance of conventional cars would also successfully reduce the emission of pollutants in an almost linear manner, whereas the resulting effect on respiratory disease incidences depends on numerous context-specific and localized variables. This is true regardless of the context and to a weaker extent also universally true for other benefits such as health benefits from reduced animal protein intake. The 'global effect' of sufficiency lifestyles can thus not be assessed only applying the information and tools in the report at hand, but we can very well predict how a 'global trend' could look like in a limited manner.

6.3. Conclusion and outlook

FULFILL understands sufficiency as a set of conditions that change individual and collective lifestyles in such a way that these lifestyles contribute to decarbonisation while also improving societal well-being. Task T6 looks at the impacts of these lifestyle changes in a mostly quantitative manner, whereas Task 6.3 specifically deals with social co-benefits as well as potential target conflicts and barriers among different parts of society. Our aim in this report was to highlight some of these benefits and to identify the most severe risks. The underlying assessment for this purpose is mostly concerned with qualitative and semi-quantitative effects, that is, with assessing the severity and size of desired as well as undesired changes in society. The five areas of society, or social dimensions, for this task are 'Health', 'Poverty Mitigation', 'Gender Equality', 'Time Use' and 'Just Transition'. None of these dimensions are understood by us as exclusive and exhaustive categories, but rather as overlapping sub-sets of more overarching goals in Europe towards more sustainable and socially-just societies.

We conclude that many of the claims regarding benefits associated with sufficiency are justified, and in the case of the explicated sufficiency assumptions in FULFILL, very likely to occur if they are implemented. This was specifically assessed regarding positive health outcomes and contributions to poverty mitigation. We have found, for example, that a large-scale realization of increased cycling combined with a modal-shift away from car mobility, is extremely likely to lead to lower mortality from reduced pollution and at least very likely to lower these mortality rates even further for those that participate. We also think that the evidence for health benefits from the reduction of meat consumption is sufficient for a rational actor to anticipate similar and maybe even stronger effects in this regard. The case for poverty mitigation is more difficult to make, since it requires a closer look at a smaller and very diverse part of society. Nonetheless, we find that direct economic advantages, such as higher disposable income for vulnerable group, not only can, but likely will be the result of different types of successful sharing policies (such as the sharing of space, products, or cars).

Despite our overall high confidence in these claims of positive impacts, we also think that there a several risks that can either reduce these impacts or lead to target conflicts between the dimensions. Most notably, we have found that the success of many of the explicated sufficiency assumptions strongly depends on accounting for the preferences and needs of certain parts of society. Both 'Poverty Mitigation' and 'Gender Equality' might otherwise very well be negatively affected. We find, for example, that policies for increased cycling are more successful if they are integrated into broader planning of urban and non-urban cycling infrastructures, but also that these very 'enablers' can constitute serious barriers for low-income persons or women with families. Another example of the role of system-wide conditions could be identified for policies that target work-time reductions. Here positive health outcomes can and will occur, but only if the affected persons have sufficient control

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over the work-time itself as well as their economic affairs (suggesting for example that wage compensation could be a necessary condition for social benefits).

Overall, we associate three of the sufficiency assumptions, or sufficiency measures (SM) in this report, with the need for policy adaptations to enhance a large-scale implementation in Europe: 'Cycling', 'Working-Less' and 'Eating Less Meat & Dairy'. We think that these measures are all worthwhile in terms of social benefits, and that the identified risks are lower from implementation compared to non-action. Nonetheless, we find that these measures specifically require a thoughtful integration into adjacent strategies for a sustainable Europe by either addressing vulnerable groups directly or by developing the surrounding system-wide conditions in such a way that target conflicts can be avoided and barriers reduced. For the second set of SMs, minor policy adjustments might be helpful in this regard, but they might very well be successful on their own as well. These are 'Product-Sharing' and 'Flying Less'. Again, accounting for the needs of specifically low-income households, children, elderly and women might make them more successful or at least more socially acceptable. For the remainder of assessed SMs no urgent need for policy adjustments was identified. 'Car-Sizing', 'Space-Sharing' and 'Car-Pooling' seem to be associated with only a few risks that, for the most part, do not constitute severe violation of European social strategies. **We also highlighted, that many of these risks and our score for them suffer from a selection bias insofar, that we can only assess them from a current state of affairs rather than against holistic changes of the systems and infrastructures that produce them.**

The overall assessment was incomplete. Moreover, only three outcome pathways could also be associated with potential quantitative benefits to society. This is insofar unsurprising as this was not the main goal of modelling efforts in T5 and T6. Another reason is that contributions to any of the five dimensions are usually more convoluted than, for example, GHG emission reductions from lower energy demands. Almost no positive societal impact can be achieved from adjusting only a few parameters in societies. Rather, their success and size usually rely on synergy effects between several initiatives at once. This could be, in parts, shown when we estimated the potential pollution reduction from smaller car-sizes in the future. Here, the stock model in the input data (see also T5.3) also relied on assumptions regarding the share of different powertrains in 2030, 2040 and 2050. However, these changes towards battery-electric vehicles made it difficult to isolate the pollution reduction effect from smaller cars alone, as the composition of powertrains in Europe also influence pollution from tailpipe emissions.

A future, or follow-up, study should therefore expand on our results, either by (i) integrating more sufficiency assumptions, (ii) assessing the benefits to more dimensions, (iii) investigating combined effects or by (iv) assessing their potentials through the lens of different scenarios. Any quantification efforts would also benefit from (v) a reverse-engineering of the approach in FULFILL. Instead of starting with plausible pathways in order to calculate GHG emission reductions, different sets of measures that achieve pre-defined GHG reduction thresholds could be used as a baseline. Such a model could then directly account for the resulting socio-economic distributions as well as input variables that can function as barriers or enablers. Thus, a future study should start with the main assumptions, so that the consequent model of social effects can be developed throughout the entire project duration and supported by subject matter experts.

Our final insight is, based on our assessments as well as the results from other deliverables in task 6 (in particular D6.2), that sufficiency lifestyles which are associated with stronger decarbonisation effects as well as anticipated stronger additional social benefits, also tend to be associated with more and more severe risks. Especially 'Cycling' and 'Eating Less Meat & Dairy' fall under this category. Although this could be a result of the approach chosen in this report, we recommend investigating in future studies whether this relationship could be significant and if so, if there is indeed an underlying direct causal relationship or if it is rather an expression of the strong interactions of these lifestyle choices with our current 'state of affairs'.

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Annex

Quantitative results for H_{SM-2_1}

'Car Sizing' – PM 2.5 emission reductions (direct exhaust emissions)

Country Results

Denmark	kg PM2.5 emissions for all driven kilometres						
share of liquid fuels	99%	98%	96%	94%	83%	59%	32%
Year	2019	2025	2030	2035	2040	2045	2050
Mini Cars	6,501	7,588	8,871	9,337	8,466	6,024	3,144
Small Cars	49,395	40,409	42,148	40,727	34,549	23,304	12,161
Medium Cars	174,956	103,096	92,708	77,729	57,483	33,908	17,694
SUVs	260,276	293,086	217,191	139,109	67,521	16,503	8,612
share of 4 car segments	82%	80%	79%	77%	75%	73%	73%
extrapolation to 100%	597,484	552,175	458,932	347,330	223,891	108,865	56,809

France	kg PM2.5 emissions for all driven kilometres						
share of liquid fuels	98%	97%	95%	93%	86%	70%	52%
Year	2019	2025	2030	2035	2040	2045	2050
Mini Cars	57,113	38,305	52,811	62,318	63,950	61,299	43,853
Small Cars	663,366	454,878	406,577	363,435	305,290	250,875	179,473
Medium Cars	1,239,391	927,651	820,224	725,928	604,213	492,313	352,196
SUVs	3,842,140	3,005,318	2,011,389	1,248,947	627,606	197,903	141,578
share of 4 car segments	90%	78%	77%	76%	75%	74%	74%
extrapolation to 100%	6,452,629	5,657,730	4,261,030	3,148,868	2,127,914	1,350,135	965,873

Germany	kg PM2.5 emissions for all driven kilometres						
share of liquid fuels	98%	96%	94%	91%	82%	59%	33%
Year	2019	2025	2030	2035	2040	2045	2050
Mini Cars	89,106	78,439	97,980	109,451	110,506	86,572	44,123
Small Cars	410,618	331,428	399,604	437,919	436,858	339,432	172,999
Medium Cars	2,936,886	2,302,173	1,775,848	1,336,372	945,690	526,243	268,212
SUVs	4,724,230	4,495,190	3,037,344	1,875,679	947,937	239,622	122,129
share of 4 car segments	77%	73%	73%	73%	74%	74%	74%
extrapolation to 100%	10,623,198	9,876,840	7,253,854	5,117,970	3,312,177	1,611,949	821,568

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Italy	kg PM2.5 emissions for all driven kilometres						
share of liquid fuels	84%	84%	83%	83%	80%	65%	44%
Year	2019	2025	2030	2035	2040	2045	2050
Mini Cars	80,737	89,262	79,541	72,755	65,641	50,093	32,552
Small Cars	303,811	311,390	300,732	295,302	283,798	229,211	148,948
Medium Cars	736,494	613,610	651,411	686,838	697,835	589,392	383,005
SUVs	2,500,380	2,597,431	1,780,160	1,163,527	650,548	206,084	133,920
share of 4 car segments	93%	85%	82%	80%	77%	75%	75%
extrapolation to 100%	3,895,436	4,266,812	3,424,439	2,787,807	2,203,795	1,442,547	937,411

Latvia	kg PM2.5 emissions for all driven kilometres						
share of liquid fuels	100%	100%	100%	99%	90%	67%	48%
Year	2019	2025	2030	2035	2040	2045	2050
Mini Cars	322	260	932	1,472	1,720	1,535	1,093
Small Cars	6,358	4,013	5,821	7,227	7,532	6,277	4,471
Medium Cars	62,968	42,088	34,778	28,343	20,698	12,484	8,891
SUVs	117,756	110,089	77,618	50,023	24,521	5,547	3,951
share of 4 car segments	85%	80%	78%	77%	75%	74%	74%
extrapolation to 100%	220,119	196,075	152,140	113,306	72,277	34,974	24,910

Changes in input variables

change in passenger car performance (km)					
Country	Start	2030	2040	2050	reduction
Denmark	34,426,708,124	34,212,146,524	34,032,323,191	33,881,782,996	-544,925,128
France	410,179,434,079	395,754,663,279	382,281,960,249	370,065,467,026	-40,113,967,053
Germany	495,341,437,206	488,299,055,666	482,103,704,939	476,570,175,972	-18,771,261,234
Italy	311,166,400,769	306,354,897,769	302,076,953,326	298,405,256,104	-12,761,144,665
Latvia	9,426,449,712	9,349,026,204	9,294,562,098	9,253,457,696	-172,992,015

Average PM 2.5 emission factor per km car-travel (mg/km)					
Country	2019	2020	2030	2040	2050
Denmark	14.3	14.0	12.0	7.4	2.2
France	14.1	14.6	12.7	8.4	4.0
Germany	16.5	16.5	13.7	7.8	2.3
Italy	11.6	11.3	10.3	8.1	4.0
Latvia	19.9	20.5	17.5	10.1	3.8

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Quantitative results for H_{SM-8_2}

'Cycling' – PM 2.5 emission reductions (direct exhaust emissions)

Country Results

kg PM 2.5 emission changes from 'Cycling' as part of the scenario for 'Car-Sizing' (in kg; reported results)					
	Starting Year	2030	2040	2050	total change
Denmark	491,128	-2,574	-1,324	-330	-4,227
France	5,802,010	-183,015	-113,030	-49,259	-345,304
Germany	8,160,841	-96,392	-48,446	-12,873	-157,710
Italy	3,621,421	-49,712	-34,777	-14,588	-99,077
Latvia	187,404	-1,358	-551	-157	-2,066

kg PM 2.5 emission changes from 'Cycling' without 'Car-Sizing' infrastructures (in kg; isolated effect)					
	Starting Year	2030	2040	2050	total change
Denmark	491,128	-3,061	-2,565	-2,148	-7,774
France	5,802,010	-204,039	-190,572	-172,803	-567,414
Germany	8,160,841	-116,025	-102,070	-91,166	-309,260
Italy	3,621,421	-55,997	-49,788	-42,732	-148,517
Latvia	187,404	-1,539	-1,083	-817	-3,439

Changes in input variables

Change in passenger car performance (km)					
	Start	2030	2040	2050	reduction
Denmark	34,426,708,124	34,212,146,524	34,032,323,191	33,881,782,996	-544,925,128
France	410,179,434,079	395,754,663,279	382,281,960,249	370,065,467,026	-40,113,967,053
Germany	495,341,437,206	488,299,055,666	482,103,704,939	476,570,175,972	-18,771,261,234
Italy	311,166,400,769	306,354,897,769	302,076,953,326	298,405,256,104	-12,761,144,665
Latvia	9,426,449,712	9,349,026,204	9,294,562,098	9,253,457,696	-172,992,015

Average PM 2.5 emission factor per km car-travel (mg/km) (equivalent to H_{SM-2-1})					
Country	2019	2020	2030	2040	2050
Denmark	14.3	14.0	12.0	7.4	2.2
France	14.1	14.6	12.7	8.4	4.0
Germany	16.5	16.5	13.7	7.8	2.3
Italy	11.6	11.3	10.3	8.1	4.0
Latvia	19.9	20.5	17.5	10.1	3.8

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Quantitative results for H_{SM-8_1}

Relative risk reduction for All-Cause-Mortality from an increase in physical activity ('Cycling').

Country Results

Denmark - Case 1: total population increases cycling activity				
	Start	2030	2040	2050
total Population (in Mio.)	5,812,000	5,964,000	6,056,000	6,098,000
average distance covered by bike daily (km/person*day)	1.20	1.30	1.40	1.50
average distance covered by bike weekly (km/person*week)	8.40	9.10	9.80	10.50
average time person cycling per week (h/person*week)	0.47	0.51	0.55	0.59
METs (Hours/Week*Person)	3.23	3.50	3.76	4.03
Reduction in relative risk (RR) of ACM	0.05	0.05	0.06	0.06
RR for ACM (1- Change in RR)	**0.95**	**0.95**	**0.94**	**0.94**

Denmark - Case 2: cyclists (56% of population) increase cycling activity				
	Start	2030	2040	2050
total Population (in Mio.)	5,812,000	5,964,000	6,056,000	6,098,000
average distance covered by bike daily (km/person*day)	1.20	1.30	1.40	1.50
total distance covered by entire population (km/day)	6,974,400	7,753,200	8,478,400	9,147,000
population which cycles	3,254,720	3,339,840	3,391,360	3,414,880
average distance by population which cycles (km/person*day)	2.14	2.32	2.50	2.68
average distance by population which cycles (km/person*week)	15.00	16.25	17.50	18.75
average time a person who cycles per week (h/person*week)	0.85	0.92	0.99	1.06
METs (Hours/Week*Person)	5.76	6.24	6.72	7.20
Reduction in relative risk (RR) of ACM	0.09	0.09	0.10	0.11
RR for ACM (1- Change in RR)	**0.91**	**0.91**	**0.90**	**0.89**

France - Case 1: total population increases cycling activity				
	Start	2030	2040	2050
total Population (in Mio.)	65,240,000	66,747,000	67,769,000	67,972,000
average distance covered by bike daily (km/person*day)	0.30	1.00	1.80	2.50
average distance covered by bike weekly (km/person*week)	2.10	7.00	12.60	17.50
average time person cycling per week (h/person*week)	0.12	0.40	0.71	0.99
METs (Hours/Week*Person)	0.81	2.69	4.84	6.72
Reduction in relative risk (RR) of ACM	0.01	0.04	0.07	0.10
RR for ACM (1- Change in RR)	**0.99**	**0.96**	**0.93**	**0.90**

France - Case 2: cyclists (18% of population) increase cycling activity				
	Start	2030	2040	2050
total Population (in Mio.)	65,240,000	66,747,000	67,769,000	67,972,000
average distance covered by bike daily (km/person*day)	0.30	1.00	1.80	2.50
total distance covered by entire population (km/day)	19,572,000	66,747,000	121,984,200	169,930,000

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France - Case 2: cyclists (18% of population) increase cycling activity				
	Start	2030	2040	2050
population which cycles	11,743,200	12,014,460	12,198,420	12,234,960
average distance by population which cycles (km/person*day)	1.67	5.56	10.00	13.89
average distance by population which cycles (km/person*week)	11.67	38.89	70.00	97.22
average time a person who cycles per week (h/person*week)	0.66	2.20	3.95	5.49
METs (Hours/Week*Person)	4.48	14.94	26.89	37.35
Reduction in relative risk (RR) of ACM	0.07	0.18	0.22	0.25
RR for ACM (1- Change in RR)	**0.93**	**0.82**	**0.78**	**0.75**

Germany - Case 1: total population increases cycling activity				
	Start	2030	2040	2050
total Population (in Mio.)	83,135,000	83,454,000	83,178,000	82,670,000
average distance covered by bike daily (km/person*day)	1.00	1.30	1.60	1.90
average distance covered by bike weekly (km/person*week)	7.00	9.10	11.20	13.30
average time person cycling per week (h/person*week)	0.40	0.51	0.63	0.75
METs (Hours/Week*Person)	2.69	3.50	4.30	5.11
Reduction in relative risk (RR) of ACM	0.04	0.05	0.06	0.08
RR for ACM (1- Change in RR)	**0.96**	**0.95**	**0.94**	**0.92**

Germany - Case 2: cyclists (44% of population) increase cycling activity				
	Start	2030	2040	2050
total Population (in Mio.)	83,135,000	83,454,000	83,178,000	82,670,000
average distance covered by bike daily (km/person*day)	1.00	1.30	1.60	1.90
total distance covered by entire population (km/day)	83,135,000	108,490,200	133,084,800	157,073,000
population which cycles	36,579,400	36,719,760	36,598,320	36,374,800
average distance by population which cycles (km/person*day)	2.27	2.95	3.64	4.32
average distance by population which cycles (km/person*week)	15.91	20.68	25.45	30.23
average time a person who cycles per week (h/person*week)	0.90	1.17	1.44	1.71
METs (Hours/Week*Person)	6.11	7.95	9.78	11.61
Reduction in relative risk (RR) of ACM	0.09	0.12	0.14	0.17
RR for ACM (1- Change in RR)	**0.91**	**0.88**	**0.86**	**0.83**

Italy - Case 1: total population increases cycling activity				
	Start	2030	2040	2050
total Population (in Mio.)	60,287,000	59,943,000	59,375,000	58,125,000
average distance covered by bike daily (km/person*day)	0.20	0.50	0.80	1.00
average distance covered by bike weekly (km/person*week)	1.40	3.50	5.60	7.00
average time person cycling per week (h/person*week)	0.08	0.20	0.32	0.40
METs (Hours/Week*Person)	0.54	1.34	2.15	2.69
Reduction in relative risk (RR) of ACM	0.01	0.02	0.03	0.04
RR for ACM (1- Change in RR)	**0.99**	**0.98**	**0.97**	**0.96**

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Italy - Case 2: cyclists (26% of population) increase cycling activity				
	Start	2030	2040	2050
total Population (in Mio.)	1,907,000	1,713,000	1,536,000	1,395,000
average distance covered by bike daily (km/person*day)	0.20	0.50	0.80	1.00
total distance covered by entire population (km/day)	381,400	856,500	1,228,800	1,395,000
population which cycles	839,080	753,720	675,840	613,800
average distance by population which cycles (km/person*day)	0.45	1.14	1.82	2.27
average distance by population which cycles (km/person*week)	3.18	7.95	12.73	15.91
average time a person who cycles per week (h/person*week)	0.18	0.45	0.72	0.90
METs (Hours/Week*Person)	1.22	3.06	4.89	6.11
Reduction in relative risk (RR) of ACM	0.02	0.05	0.07	0.09
RR for ACM (1- Change in RR)	**0.98**	**0.95**	**0.93**	**0.91**

Latvia - Case 1: total population increases cycling activity				
	Start	2030	2040	2050
total Population (in Mio.)	1,907,000	1,713,000	1,536,000	1,395,000
average distance covered by bike daily (km/person*day)	0.20	0.40	0.60	0.80
average distance covered by bike weekly (km/person*week)	1.40	2.80	4.20	5.60
average time person cycling per week (h/person*week)	0.08	0.16	0.24	0.32
METs (Hours/Week*Person)	0.54	1.08	1.61	2.15
Reduction in relative risk (RR) of ACM	0.01	0.02	0.02	0.03
RR for ACM (1- Change in RR)	**0.99**	**0.98**	**0.98**	**0.97**

Italy - Case 2: cyclists (44% of population) increase cycling activity				
	Start	2030	2040	2050
total Population (in Mio.)	1,907,000	1,713,000	1,536,000	1,395,000
average distance covered by bike daily (km/person*day)	0.20	0.40	0.60	0.80
total distance covered by entire population (km/day)	381,400	685,200	921,600	1,116,000
population which cycles	839,080	753,720	675,840	613,800
average distance by population which cycles (km/person*day)	0.45	0.91	1.36	1.82
average distance by population which cycles (km/person*week)	3.18	6.36	9.55	12.73
average time a person who cycles per week (h/person*week)	0.18	0.36	0.54	0.72
METs (Hours/Week*Person)	1.22	2.44	3.67	4.89
Reduction in relative risk (RR) of ACM	0.02	0.04	0.05	0.07
RR for ACM (1- Change in RR)	**0.98**	**0.96**	**0.95**	**0.93**

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Quantitative results for $H_{SM\text{-}5\_1}$

Relative risk reduction for All-Cause-Mortality from decreasing animal protein ('Eating Less Meat & Dairy').

Country Results

Denmark	Quantification of reduced ACM risks from reduced meat intake			
Data	**2021**	**2030**	**2040**	**2050**
Population in million Persons	5.81	5.96	6.06	6.1
Average daily intake of animal products in g/(a*P)	397	339	267	182
Average daily intake of animal protein in g/(a*P)	35	30	24	16
Average annual intake of animal products in t/(a*P)	0.14	0.12	0.1	0.07
Average annual intake of animal proteins in t/(a*P)	0.013	0.011	0.009	0.006
Total annual intake of animal protein for entire population in t	74,159	65,901	53,201	35,620
Reduction in annual intake of animal protein in %	0.00%	11.10%	28.30%	52.00%
Accumulative relative ACM risk reduction from meat reduction	0.00%	3.30%	8.50%	15.60%

France	Quantification of reduced ACM risks from reduced meat intake			
Data	**2021**	**2030**	**2040**	**2050**
Population in million Persons	65.24	66.06	66.75	67.33
Average daily intake of animal products in g/(a*P)	418	370	301	207
Average daily intake of animal protein in g/(a*P)	37	34	28	19
Average annual intake of animal products in t/(a*P)	0.15	0.13	0.11	0.08
Average annual intake of animal proteins in t/(a*P)	0.014	0.012	0.01	0.007
Total annual intake of animal protein for entire population in t	891,941	808,699	670,178	456,705
Reduction in annual intake of animal protein in %	0.00%	9.30%	24.90%	48.80%
Accumulative relative ACM risk reduction from meat reduction	0.00%	2.80%	7.50%	14.60%

Germany	Quantification of reduced ACM risks from reduced meat intake			
Data	**2021**	**2030**	**2040**	**2050**
Population in million Persons	83.14	83.48	83.45	83.32
Average daily intake of animal products in g/(a*P)	376	332	269	183
Average daily intake of animal protein in g/(a*P)	32	29	24	16
Average annual intake of animal products in t/(a*P)	0.14	0.12	0.1	0.07
Average annual intake of animal proteins in t/(a*P)	0.012	0.011	0.009	0.006
Total annual intake of animal protein for entire population in t	978,598	878,908	718,480	480,586
Reduction in annual intake of animal protein in %	0.00%	10.20%	26.60%	50.90%
Accumulative relative ACM risk reduction from meat reduction	0.00%	3.10%	8.00%	15.30%

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Italy	Quantification of reduced ACM risks from reduced meat intake			
Data	**2021**	**2030**	**2040**	**2050**
Population in million Persons	60.29	60.09	59.94	59.71
Average daily intake of animal products in g/(a*P)	404	363	297	205
Average daily intake of animal protein in g/(a*P)	36	32	27	18
Average annual intake of animal products in t/(a*P)	0.15	0.13	0.11	0.07
Average annual intake of animal proteins in t/(a*P)	0.013	0.012	0.01	0.007
Total annual intake of animal protein for entire population in t	782,982	708,012	585,191	394,543
Reduction in annual intake of animal protein in %	0.00%	9.60%	25.30%	49.60%
Accumulative relative ACM risk reduction from meat reduction	0.00%	2.90%	7.60%	14.90%

Latvia	Quantification of reduced ACM risks from reduced meat intake			
Data	**2021**	**2030**	**2040**	**2050**
Population in million Persons	1.91	1.82	1.71	1.62
Average daily intake of animal products in g/(a*P)	422	368	296	203
Average daily intake of animal protein in g/(a*P)	38	34	27	18
Average annual intake of animal products in t/(a*P)	0.15	0.13	0.11	0.07
Average annual intake of animal proteins in t/(a*P)	0.014	0.012	0.01	0.007
Total annual intake of animal protein for entire population in t	26,561	22,354	17,075	10,859
Reduction in annual intake of animal protein in %	0.00%	15.80%	35.70%	59.10%
Accumulative relative ACM risk reduction from meat reduction	0.00%	4.80%	10.70%	17.70%

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FULFILL