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Gilt für Studien aus der Programmlinie Forschung

A) Projektdaten

Allgemeines zum Projekt	
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Zitiervorschlag:	Köppl, A., Schleicher, S., Sommer, M., Köberl, K. (WIFO) Bachner, G., Mayer, J., Dugan, A., Fischer, L., Steininger, K.,(WegC) Jonas, M., Schinko, T., Weifner, A., Zebrowski, P., (IIASA) (2021), Embedding climate policies into deep economic transformations, Vienna.
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Allgemeines zum Projekt	
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B) Project Overview

1 Kurzfassung

Die Eindämmung des Klimawandels erfordert einen tiefgreifenden Strukturwandel. Damit im Zusammenhang steht die Frage nach relevanten Bewertungsgrößen für eine erfolgreiche Transformation und wie diese in gesamtwirtschaftlichen Modellen abgebildet werden können. In früheren Studien (siehe z. B. das ACRP-Projekt ClimTrans2050, (Köppl et al., 2016)) wurde das Konzept der Energiedienstleistungen und Funktionalitäten für die ökonomische Modellierung entwickelt. Das Konzept der Funktionalitäten verschiebt den Fokus von konventionellen ökonomischen Indikatoren, wie dem BIP, hin zu aussagekräftigeren sozioökonomischen Indikatoren. Funktionalitäten werden somit als eine Erweiterung bzw. Alternative zu herkömmlichen ökonomischen Modellierungsansätzen für Transformationsprozesse vorgestellt. Die grundlegende Idee ist, dass Funktionalitäten letztlich der eigentliche Grund für wirtschaftliche Aktivitäten sind und (Grund-)Bedürfnisse des Menschen, wie Wohnen, Ernährung oder Mobilität beschreiben. Sie sind damit ein wichtiger Baustein zum Verständnis des menschlichen Wohlbefindens. Funktionalitäten beschreiben im Allgemeinen die Wechselwirkungen von Beständen und Strömen (stocks and flows). Bestände sind Kapitalbestände wie Gebäude, Fahrzeuge oder Verkehrs-infrastruktur; Ströme entsprechen den benötigten Energie- und Materialflüssen und den damit verbundenen Zahlungsströmen. Eine bestimmte Funktionalität kann durch unterschiedliche Kombinationen von Beständen und Strömen bereitgestellt werden und unterscheidet sich in ihrem jeweiligen Ressourcen-bedarf bzw. den damit verbundenen Emissionen. Kombinationen von Beständen und Strömen sind als zusammengehörige Paare zu verstehen, z. B. Fahrzeuge und ihr Kraftstoffverbrauch oder Gebäude und ihr Heizenergiebedarf. Die Abbildung dieser Wechselwirkungen in der empirischen Modellierung wird in EconTrans für ausgewählte Funktionalitäten demonstriert.

EconTrans diskutiert das Konzept der Funktionalitäten im Kontext der Literatur zu Wohlbefinden und menschlichen Bedürfnissen. Eine umfassende Literaturrecherche und eine Reihe von Stakeholder-Interviews im Rahmen des Projekts zeigen, dass ein besseres Verständnis der Auswirkungen von Transformationsprozessen auf das Wohlbefinden unerlässlich ist. Unser Fokus auf Funktionalitäten, die letztlich für das Wohlbefinden relevant sind, ist mit der internationalen Literatur gut vereinbar. Die Stakeholder-Interviews zeigen wiederum, dass Energiedienstleistungen das kritische Bindeglied zwischen Energienutzung (und damit verbundenen Emissionen) und menschlicher Bedürfnisbefriedigung sind.

Um die Einbindung Österreichs in globalen Strukturen abzubilden, wurden nationale Emissionsbudgets abgeschätzt, die innerhalb eines globalen Temperaturanstiegs von 1,5°C und 2°C bleiben und die mit den globalen Emissionsbeschränkungen konsistent sind. In einem nächsten Schritt werden die

Treibhausgas (THG)-Emissionen des nationalen Emissionsinventars den Funktionalitäten zugeordnet, wobei notwendige Emissionsreduktionen für die Funktionalitäten aufgezeigt werden, um innerhalb des Emissionsbudgets für Österreich zu bleiben.

Der Schwerpunkt des Projekts liegt auf der Weiterentwicklung makro-ökonomischer Modellierung. Dafür wurde ein neues Input-Output-Modell mit dem Fokus auf Funktionalitäten entwickelt, sowie ein bestehendes CGE-Modell um den Aspekt der Funktionalität erweitert. EconTrans demonstriert für zwei Funktionalitäten, Wohnen und Mobilität (shelter und access), die Operationalisierbarkeit des Funktionalitäten-Ansatzes in der makroökonomischen Modellierung. Damit stellt EconTrans ein erstes Demonstrationsprojekt für die weitere Entwicklung von makroökonomischen Modellen dar, die für die Analyse von Transformationspfaden eingesetzt werden können.

Die Simulationen der Transformationspfaden zeigen, wie Emissionsreduzierungen unter Beibehaltung der Funktionalität erreicht werden können. So spielen z. B. Quartiere eine wichtige Rolle, weil sie die Funktionalitäten shelter und access gleichermaßen betreffen: Mobilitätsbedürfnisse werden durch eine effektivere Organisation des Raumes beeinflusst, während gleichzeitig die Umsetzung innovativer Energielösungen in Quartieren (Anergienetze oder Gebäude als Speicher zum Ausgleich von Spitzenlasten) realisiert werden kann. Eine der größten Herausforderungen bei der Abbildung solcher innovativen, technologischen Lösungen (teilweise noch im Demonstrationsstadium) in makroökonomischen Modellen sind fehlende Daten, die als Inputs Voraussetzung für die makroökonomische Modellierung sind. Um dennoch eine Operationalisierung zu ermöglichen, werden für die Szenarioanalysen grobe, informierte Annahmen getroffen.

Drei Erweiterungsschritte der IOT werden durchgeführt. Erstens wird eine geeignete Zuordnung von Energiebereitstellung und -nachfrage zu den Sektoren getroffen. Dies ermöglicht die Verbindung der monetären Struktur mit physischen Einheiten der Gesamtenergie- und Nutzenergiebilanz, die in einem zweiten Schritt integriert wurden. Drittens wurden zusätzlich Treibhausgas-emissionen und andere Materialverbräuche der sektoralen Produktion zugeteilt. Gütergruppen des privaten und öffentlichen Konsums sowie Exporte wurden nach Funktionalitäten zugeordnet.

In Bezug auf das CGE-Modell liegt die Herausforderung in der Erweiterung des Begriffs der Nutzengenerierung. CGE-Modelle gehen davon aus, dass Nutzen durch materiellen Konsum generiert wird. Die Funktionalitätsperspektive versucht, Nutzen anders darzustellen, zu messen und zu generieren z. B. durch verschiedene Bestands-Flow-Kombinationen mit jeweils unterschiedlichen ökonomischen Auswirkungen, aber letztlich konstanter Funktionalitätserfüllung.

Die Projektergebnisse zeigen, dass EconTrans gut zur Forschung über Wohlbefinden und menschliche Bedürfnisse passt und es demonstriert die

Herausforderungen, das Konzept der Funktionalitäten in die makroökonomische Modellierung zu integrieren.

2 Executive Summary

The mitigation of climate change requires a profound structural change, which raises questions about relevant valuation variables for a successful transformation as well as the mapping in macroeconomic models. In previous studies (see e.g. the ACRP project ClimTrans2050, (Köppl et al., 2016)), the concept of energy services and functionalities for economic modelling was developed. The concept of functionalities shifts the focus from conventional economic indicators, such as GDP to more meaningful socio-economic indicators. Functionalities are thus presented as an extension or alternative to conventional socio-economic modelling approaches of the energy transition. Functionalities are based on the idea that they are the ultimate reason for economic activities and thus describe (basic) human needs, such as housing, nutrition or mobility, and are an important piece of understanding human well-being. In general, they describe the interaction of stocks and flows. Stocks are capital stocks such as buildings, vehicles or transport infrastructure, flows correspond to the associated required energy and material flows and the related payment flows. A specific functionality can be provided by different combinations of stocks and flows and differs in its respective resource requirements or the emissions triggered. Combinations of stocks and flows are to be understood as pairs belonging together; for example, vehicles and their fuel consumption, or buildings and their heating energy demand. The representation of these interactions in empirical modelling is demonstrated in EconTrans for selected functionalities.

EconTrans discusses the concept of functionalities in the context of existing literature on well-being and human needs. A comprehensive literature review and a series of stakeholder interviews within the EconTrans project show that a better understanding of the impact of transformation processes on well-being is essential. We conclude that our focus on functionalities that are ultimately relevant to well-being is compatible with the international literature. In addition, the stakeholder consultation process shows that energy services are the critical link between energy use (and associated emissions) and human need satisfaction.

In order to take account of Austria being integrated in the global world, national emissions budgets were estimated that stay within a global temperature increase of 1.5°C and 2°C and which are consistent with global emissions constraints. In a next step, the GHG emissions of the national emission inventory are allocated to functionalities, showing necessary emission reductions for the functionalities in order to stay within the emission budget for Austria.

The main focus of the project is on progressing economic modelling by integrating these aspects into macroeconomic modelling, namely into a newly developed Input-Output model and by extending an existing CGE model by the

functionality aspect. In this first attempt to operationalise this new concept, functionalities access and shelter have been the focus of EconTrans. Thus, EconTrans represents a first demonstration project for further development of macroeconomic models that can be used for the analysis of transformation paths.

The focus for the simulation on transformation pathways is on access and shelter to show how emission reductions can be achieved while maintaining the supply of the functionality. For example, city quarters/districts play an important role because they affect both functionalities equally: mobility needs are influenced by a more effective organisation of space, while at the same time the implementation of innovative energy solutions in districts (anergy grids or buildings as reservoirs for balancing peak loads) can be realised. One of the major challenges in mapping such innovative, technological solutions (partly still in the demonstration stage) in macroeconomic models, is the very limited data availability of necessary inputs for modelling. In order to enable an operationalisation nevertheless, rough, informed assumptions are made for the scenario analyses.

The new Input-Output model shows three development stages: First, an appropriate allocation of energy supply and demand to sectors from a functionality perspective is made. This allows linking the monetary structure with physical units of the total energy and useful energy balances, which were integrated in the second step. Third, greenhouse gas emissions and other material consumptions were additionally allocated to sectoral production. Product groups of private and public consumption as well as exports were allocated according to functionalities.

With respect to the CGE model, the challenge lies in extending the notion of utility generation. CGE models assume that utility is generated by material consumption, which is described by economic "welfare" in a narrow sense as typically depicted in conventional models. The functionality perspective goes beyond this view and tries to represent, measure and generate utility differently: utility results from functionalities (see Schinko et al., 2021), and not per se from consumption flows. The functionality access, for example, can be served by different stock-flow combinations with different respective economic impacts, but ultimately the utility form functionality fulfilment stays constant.

In the context of the CGE model, this means that - in monetary terms - the same benefit can be generated with less consumption expenditure or lower costs. This in turn means that traditional measures such as GDP and welfare in the narrow sense become less meaningful, since less production is needed for the same level of utility, which is reflected in lower monetary income, GDP and welfare in the narrow sense.

The project results show that EconTrans fits well with the research on well-being and human needs and it demonstrates the challenges to integrate the concept of functionalities in macro-economic modelling: with respect to data needs, but also

extending the model logic underlying e.g. conventional CGE models. This model demonstration provides the basis for integrating the achieved results in further macroeconomic modelling.

3 Background and objective

The motivation for the research project EconTrans was to embed climate policies into profound economic transformations, as this is seen as essential for assessing long term development. EconTrans is motivated by capturing the economic and emission impact of emerging disruptive technologies and by embedding climate policy in a broader context of economic and societal change.

EconTrans wants to offer an approach that enlarges the scope of economic modelling by rethinking the indicators of well-being, extending the scope of resources used for economic activities and deepening our understanding of the complex relationships that ultimately relate well-being to climate change.

EconTrans is motivated by a very ambitious research plan aiming at realising three building blocks for replacing and extending conventional thinking. First, welfare relevant functionalities – such as shelter and access to persons, goods and locations – are discussed as option to replace commonly used measures for well-being such as GDP or consumption. Second, in view of the indicators needed for evaluating climate policies as well as in a broader context, also with a view to the SDGs, an extended list of resources that economic activities draw upon, is aimed for. Third, these blocks are represented in a comprehensive modelling framework that builds on familiar input-output and general equilibrium methods and extends them for long-term analysis objective.

An operational concept for measuring wellbeing

In the context of research on long-run transformation, research interest is growing on how to define and measure human well-being meaningfully. EconTrans takes up this research and confronts our concept of functionalities with the broader discussion on well-being.

Aiming at making this concept of well-being operational, we identify key functionalities such as shelter (for residential and other use), access (to persons, goods and locations), and other life support services (including nutrition, health, education and cultural experiences). The functionality access deliberately includes in addition to physical modes of transport also information technologies. Each functionality is represented by appropriate indicators that allow operationalisation.

Another initial objective of EconTrans concerns an extended list of flows and stocks of resources for forward looking analyses, acknowledging their interaction. The interaction between flows and stocks of resources and the integrated handling of stocks and flows is one important aspect of EconTrans. This can be exemplified for buildings: a better quality and higher quantity of the stocks (such as buildings) changes the flows of resources (as energy) and thereby improves the resource productivity in providing the required functionalities. On the one hand, EconTrans considers the formation of these stocks via investment and the impacts on resource flows. On the other hand, it demonstrates this interaction of

stocks and flows by taking into account the time dimension of investment strategies and the durability of the stocks. Each functionality consists of specific services, e.g. shelter includes the thermal services of a building. Each service builds on the interaction of flows and stocks of resources. In the case of thermal services for buildings, the relevant flows are amounts of energy and the relevant stock is the structure of the building (e.g. which building material) with its thermal characteristics.

The modelling thus should demonstrate that the quantity of flows depends on the quantity and quality of the stocks. Additional restrictions can be imposed on this core modelling framework, in particular those captured by the market mechanisms and aggregate resource constraints of general equilibrium models. The objective of the proposed comprehensive modelling framework exhibits an improved structural representation of the complex interactions between the functionalities relevant for well-being and the related use of resourcesthat also matter for achieving climate targets and SDGs.

A deepened understanding of targeted transformations in a globally consistent emissions context

The deepened understanding of economic structures facilitates analysing the impact of behavioural and technological changes that result in different resource use. A range of transformation paths can be designed that are triggered by aspired functionalities for well-being, and the emergence of disruptive technologies. In addition, these transformation paths provide information about resulting cumulative GHG emissions, which may be evaluated against the allowed emissions budget.

EconTrans draws these emissions constraints from the fact that economic transformations take place in the context of internationally agreed efforts to mitigate global warming, keeping the increase in global average temperature well below 2°C above pre-industrial levels in accordance with the Paris Agreement. EconTrans delineates the constraints of both global and (consistently embedded) national budgets of allowed GHG emissions for the period until 2050.

The national emission paths compatible with the target of the Paris Agreement also inform about the investments needed to establish and support economic structures capable of realising this path. Finally, the deepened understanding of transition options offers strategies for targeted transformations towards decarbonisation.

4 Project content and results

The functionality approach used in EconTrans is scrutinised against international literature on well-being and human needs and is confronted with the view of Austrian stakeholders from different areas. The stakeholder involvement was operationalised by means of 26 semi-structured interviews.

A further activity in EconTrans refers to the downscaling of global emission budgets to the Austrian level which has been carried out to present boundary conditions for pathways for Austria. This also includes the allocation of greenhouse gas emissions of the Austrian emission inventory to the considered functionalities in EconTrans.

The core activity in EconTrans concerns macroeconomic modelling through the lens of functionalities. This includes on the one hand the search for and linking of databases, in order to ensure usable and appropriate databases, consistency and compatibility between the different available databases for the core model based on an I-O structure.

On the other hand, it means the preparation of input data and underpinning of the model assumptions for the simulation scenarios with available literature sources as well as discussions with experts on technological developments. This implies more or less the transfer of detailed technological information and analyses and results into model assumptions for the aggregated macro models in a rather rough but informed way.

EconTans is organised along 5 work packages which are interlinked with each other:

Identifying the transformation challenge

The main objectives of the first work package was a thorough literature review complemented by a comprehensive stakeholder consultation, focusing on the interaction of energy-related GHG emissions and human well-being, and embedding functionalities (energy services) in this discussion. This research in has been successfully completed with the publication of a working paper "The interaction of energy services, breakthrough technologies and human need satisfaction" (Schinko et al., 2021).

We researched the complex multidimensional transformation challenges humanity faces today. We found that the overarching task in this discourse is to enhance human well-being in a way that respects planetary boundaries and other intrinsically linked transformational challenges, such as tackling climate change, implementing the Sustainable Development Goals (SDGs) and dealing with potentially disruptive technological changes. Hence, we applied the concept of "well-being generating energy services" (or 'energy related functionalities'), which has been developed in the pre-project ClimTrans2050, and situated it in the broader discussion on human well-being and climate change mitigation.

A comprehensive review of the most relevant theories of human-wellbeing, particularly in the context of climate change mitigation and sustainable development argues for a eudaimonic understanding of well-being. In particular, we build on 'A Theory of Human Needs (THN)' by (Doyal & Gough, 1984), which we identified to be of great relevance when facing the threats from climate change.

As a bridging concept between basic human needs and the culturally specific satisfiers, the THN introduces "intermediate needs", also called "universal satisfier characteristics (USC)". In a next step, we established the link between human well-being, energy use and greenhouse gas emissions (GHG) by focusing on "energy related energy services (or functionalities)" (Köppl et al., 2014; Köppl & Schleicher, 2018). It is energy services, not flows (e.g. expressed in kWh) of useful, final or primary energy, that eventually satisfy human needs (Brand-Correa & Steinberger, 2017). Hence, according to the literature, energy services represent the crucial link between energy use (and related GHG emissions) and human need satisfaction (see Figure 1).

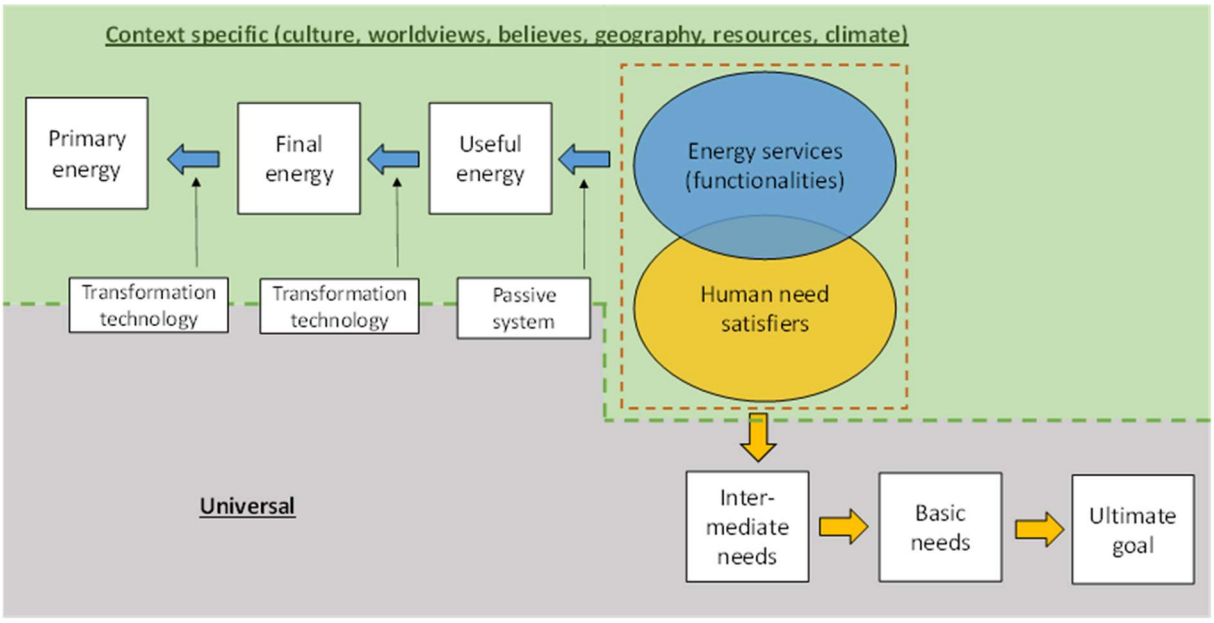

Figure 1: The conceptual framework for establishing the link between energy use, GHG emissions and human need satisfaction. Source: Own visualization

In a next step, we set out to consult with Austrian stakeholders where they see the link between energy use (and related GHG emissions) and human need satisfaction. We conducted 26 semi structured interviews with stakeholders from policy, practice, and science. Since qualitative samples tend to be purposive rather than random as for quantitative data, the selection of the interviewee sample depends strongly on the respective research questions. In the present study, we applied a reputational case selection approach. The first interviewees were chosen based on the recommendations within the research group. This first tranche of interviewed experts was then asked for further recommendations of

possible additional interview partners. The overall goal of the selection process was to have a sample as comprehensive as possible and across scientific disciplines, policy and practice. Our results of the interview analysis show that while other scientists also identify energy services as the crucial link between human need satisfaction and GHG emissions, a third of interviewed practitioners perceive the primary energy source as the most important link. Politicians emphasised that the whole energy chain matters but highlighted within the chain the importance of the energy services concept.

USC can be regarded as ends for which culturally specific satisfiers can act as the means. In this sense they provide a foundation on which to establish a list of derived or second-order goals (Gough, 2015), comprising:

- physical health: adequate nutritional food and clean water, adequate protective housing, a non- hazardous work environment, a non-hazardous physical environment, appropriate health care
- autonomy: security in childhood, significant primary relationships, physical security, economic security, appropriate education, birth control and child-bearing (those were identified through a model of (Brown and Harris 1978) which describes the depression amongst women)

In a next step, thermal, mechanical, and specific-electric energy services were mapped (Figure 2) to this list of intermediate needs (or USC) (Gough 2015) and interpreted as "energy related specific human need satisfiers". The mapping was done jointly by the EconTrans project team according to the question "Which energy services are needed to satisfy a specific intermediate need (USC)?". The size of the symbols for energy services reflect their relative importance as specific satisfiers for intermediate human needs.

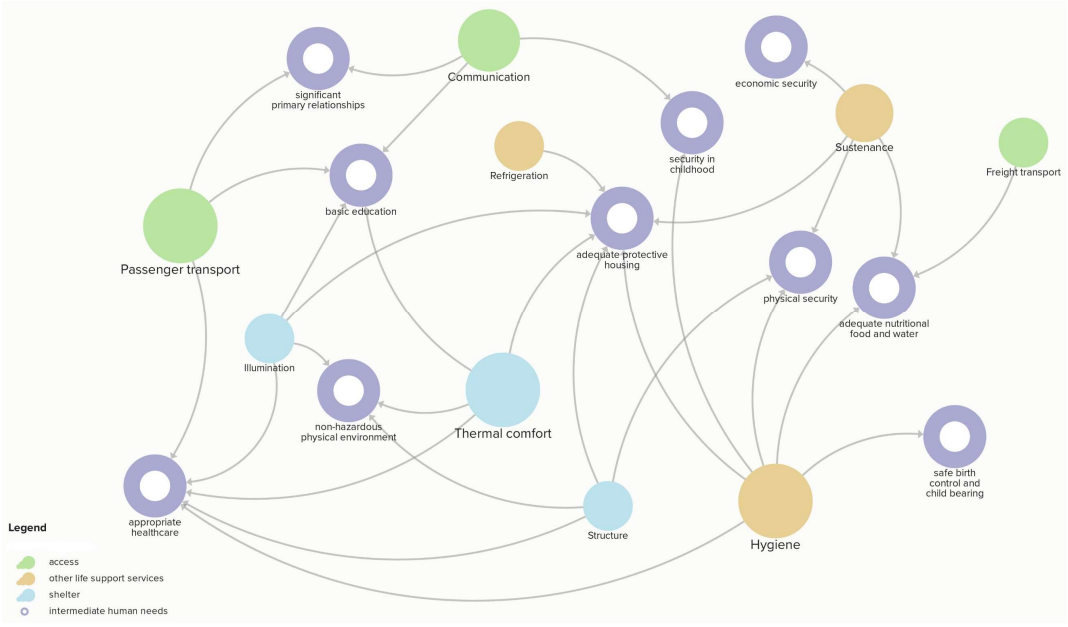

Figure 2: Mapping energy services (aka functionalities) to intermediate needs (i.e. USC). Source: own visualisation

To inform the operationalisation and measurement of human well-being via the concept of energy-related functionalities, we identified a first set of indicators for the thermal, mechanical, and specific-electric energy services based on the literature review conducted in reporting period 1 (Table 1).

Table 1: Preliminary list of indicators for measuring energy services

Energy services	Indicators
Access	
Passenger transport	passenger-km
Freight transport	tonne-km
Communication	bytes
Shelter	
Structure	Volumetric heat capacity [MJ/m³K]; m²/person
Thermal comfort	°C
Illumination	lumens
Other life support services	
Sustenance	calories; litres of water; % undernourished; % no access to drinking water
Hygiene	access to toilets; clean drinking water
Refrigeration	°C

This literature-based indicator list was complemented by stakeholders' recommendations for indicators to measure energy services and functionalities derived from the 26 semi-structured interviews (Table 2).

Table 2: List of indicators for measuring energy services derived from the stakeholder interviews

Energy services	Indicators
Shelter	
illumination	Lumens per square meter
thermal comfort	Temperature humidity; temperature (°C), access to electricity; energy poverty; electrification
Access	
communication	Connection to infrastructure; reach of communication; social contacts
freight transport	Availability; transportability; storability; amount of freight transports; local supply in the community; prices of goods, export levels
passenger transport	Walkability; access/distance to public transport; passenger kilometers; dependence on motorised individual transport; modal split; cycling infrastructure
Other life support services	
sustenance	energy per kilogram of food (in one culture); energy needed to deliver nutrients needed; access to food
Hygiene	amount of medicine available per person; electrification; health indicators (e.g. number of sick persons, productivity of people)

Moreover, we find that in disentangling human well-being, energy use and GHG emissions, the role of low carbon technological innovations is not straight forward. Without considering dynamic market feedback effects, the introduction of new technologies that improve individual well-being could end up in generating new socio-technical provision systems for existing energy services or create even new additional energy services that both could lead to net increases in energy use and GHG emissions. Hence, rebound-effects can render low-carbon technologies ineffective in reducing GHG emissions in absolute terms.

Recognising the emissions challenge

In a second step, of which the results are published in (Zebrowski & Jonas, 2021) we outline the geophysical constraints for Austria's transformation to a low-carbon economy in the period until 2050 that are in line with the goals of the

Paris agreement to limit the increase of global mean surface temperature to 2°C above the pre-industrial level and strive to keep it below 1.5°C. The constraints derived serve as a reference allowing to assess the feasibility of scenarios for Austria's green transformation modelled within the functionality-based framework.

We specify budgets for Austria's GHG emissions until 2050 that are globally consistent with the warming targets of the Paris agreement. We have reviewed existing literature on carbon budgets, which are based on a robust relationship between cumulative anthropogenic CO_2 emissions and the increase of global mean surface temperature, as well as the contribution of non-CO_2 greenhouse gases to global warming. Based on this state of the art knowledge we calculated global budgets of cumulative anthropogenic GHG emissions that keep the likelihood of overshooting the targets of the Paris agreement (i.e., 2 °C and 1.5 °C) below 50%. As the time horizon for these budgets is 2100 and beyond, we calculated a pool of GHG emissions humanity can emit until 2050 and retain a 50% chance of not overshooting the global warming targets of the Paris agreement. The 2018-2050 budgets of global cumulative GHG emissions are presented in Table 3.

To derive globally consistent GHG emissions quotas for Austria, we split these global budgets between nations. As this can be done in many different ways, to map the range of cumulative emissions until 2050 available for Austria we use three different principles: (1) proportionality to current share of national CO2 emissions (accounted using the standard IPCC scheme) in global CO2 emissions; (2) proportionality to current share of a nation's population in the global population; and (3) global convergence of per-capita emissions in 2050. Table 3 summarises our results:

Table 3: Global cumulative emissions for the period 2018-2050 giving 50% likelihood of not overshooting the 1.5 °C and 2 °C warming targets and corresponding Austria's allowed cumulative emissions for the period 2018-2050 calculated with different principles of allocating emission allowances.

Warming target	1.5 °C			2 °C		
Gas type	CO_2	Non-CO_2	GHG	CO_2	Non-CO_2	GHG
Global cumulative 2018-2050 emissions [Gt CO_2e]	570	290	860	1070	340	1410
Austria's cumulative 2018-2050 emissions [Mt CO_2e]						
Proportionality to current territorial CO_2 emissions	1033	531	1564	1955	629	2584
Proportionality to current population	660	339	999	1249	402	1650
Constant-rate convergence of per-capita emissions	836	268	1104	1345	322	1667

We created a data set encompassing up-to-date estimates of global and national GHG emissions as well as a derivation of Austria's GHG emission budgets until 2050. This data set will be made available as a supplementary material to the EconTrans working paper (Zebrowski – Jonas, 2021).

The functionality-based approach to economic modelling as demonstrated in EconTrans opens a possibility for a functionality-based accounting of GHG emissions. To this end, this covers the functionalities shelter, access and other life support. This means, that the functionalities considered in this project do not cover the entire GHG emissions resulting from human activities in Austria. One achievement in EconTrans is establishing a relationship between the functionality-based accounting of emissions and the IPCC's sectoral accounting used in national GHG inventories covering all emission sources. The extended input-output tables for Austria for the year 2014 developed for the macroeconomic modelling in EconTrans indicate that the three considered functionalities cover 99% of emissions in the energy sector, 87% of emissions in the industrial processes and product use sector and 98% of agricultural emissions. Not covered are the sectors land use, land-use change and forestry (LULUCF) and waste.

A literature-based assessment focussed on expected future GHG emissions resulting from agricultural production needed to satisfy nutrition needs of Austria's population, as well as on options for removing CO_2 from the atmosphere, both through improved land-use and forestry practices and through dedicated technologies. By downscaling comprehensive EU-wide scenarios of green transformation to Austria, we concluded that Austria's cumulative emissions from agriculture until 2050 will be at least 220 Mt CO_2e with at least 40 Mt CO_2e of further emissions from the waste sector. Afforestation and improved forestry practices can remove up to 200 Mt CO_2 but large-scale deployment of carbon dioxide removal technologies (CDR) before 2050 appears to be unlikely, with at most 20 Mt CO_2 captured and stored.

In a next step we formulated boundary conditions for the functionality-based modelling of Austria's green transformation (see Zebrowski – Jonas, 2021). The following tables present these reference emission pathways illustrating the constraints for Austria's total GHG emissions as well as disaggregated by functionalities and sectors.

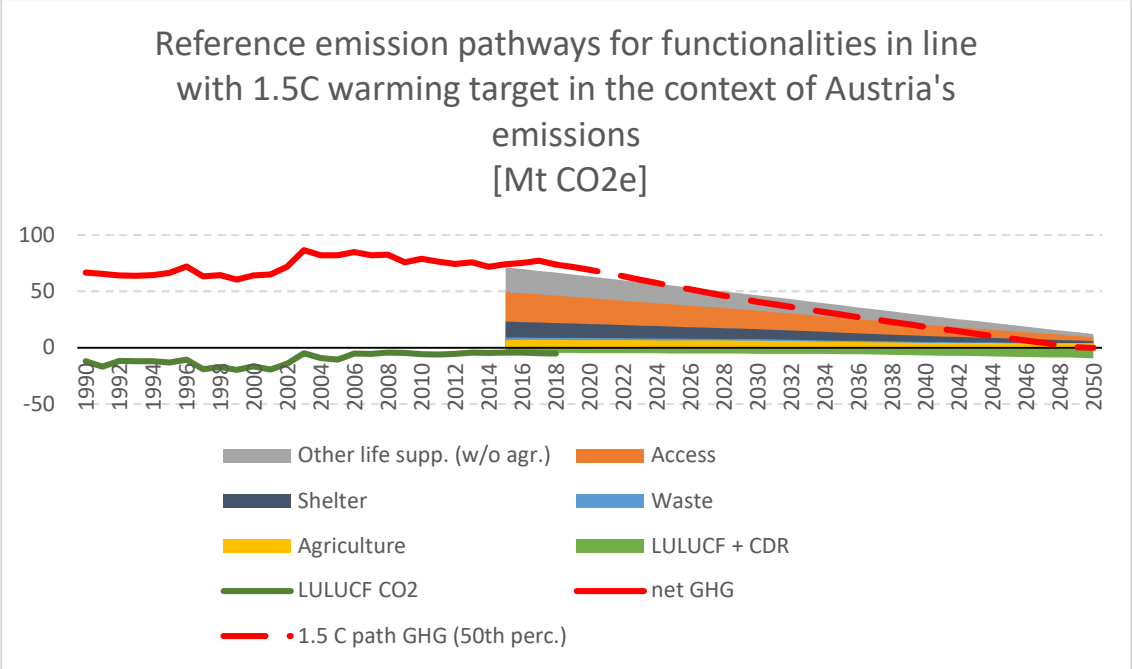

Figure 2: Reference emission pathways in line with the 1.5 °C target for functionalities Shelter, Access and Other Life Support (without agriculture) together with expected emissions from Austria's Agriculture and Waste sectors and net negative emissions for LULUCF sector aided by negative emissions technologies presented in context of Austria's historic GHG emissions and the 1.5 °C reference pathway for Austria's total net GHG emissions.

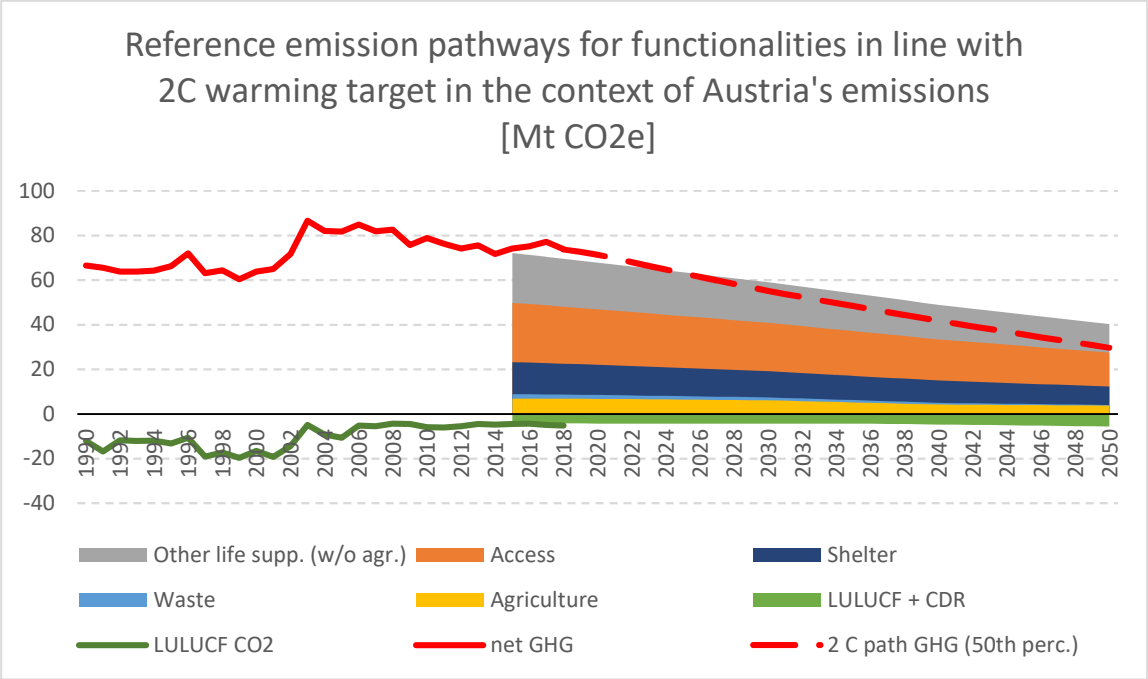

Figure 3: Reference emission pathways in line with the 2 °C target for functionalities Shelter, Access and Other Life Support (without agriculture) together with expected emissions from Austria's Agriculture and Waste sectors and net negative emissions for LULUCF sector aided by negative emissions technologies presented in context of Austria's historic GHG emissions and the 2 °C reference pathway for Austria's total net GHG emissions.

Linking functionalities and resource use and developing a comprehensive modelling framework

One core task was the compilation of data that is suitable to adapt and extend the conventional Austrian input-output table to reflect the functionality perspective. This comprises two steps: First, a data screening with respect to an extended list of resources related to functionalities was conducted, second data that meaningfully provide a basis for the interaction of flows and stocks for providing a particular functionality were compiled.

Starting point is the official input-ouput table (IOT) which depicts the linkages between enterprises and between enterprises and consumers in monetary terms. The entire economy is aggregated into 74 enterprise groups (sectors) and 74 goods groups (products and services). The focus is on "final demand" from consumption, investment and exports, for which the associated value-added effects are assessed. Three extensions of the IOT are performed: (1) an appropriate allocation of energy supply and demand to sectors is made. (2) This allows linking the monetary structure with physical units of the total energy and useful energy balances. (3) greenhouse gas emissions and other material consumption were additionally allocated to sectoral production. Groups of goods of private and public consumption as well as exports were allocated according to their functionalities (see (Sommer et al., 2021).

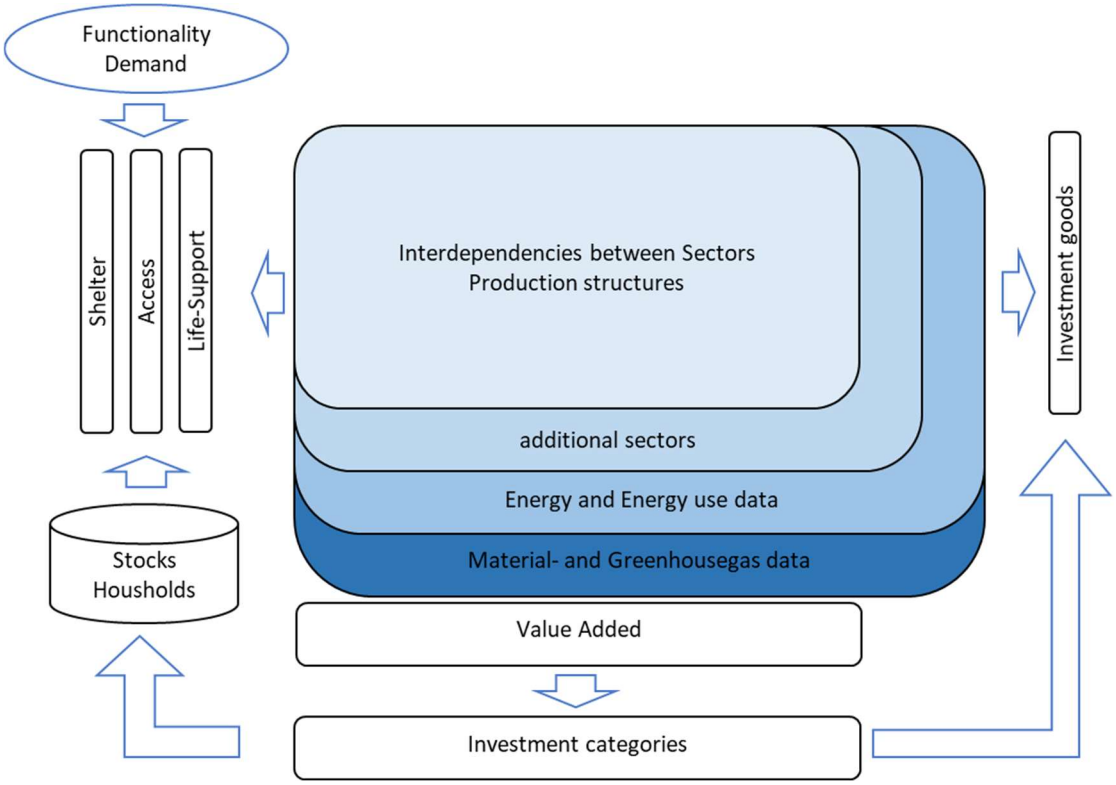

Figure 4: Main Structure of the Core Model

The aim of the rearrangement was to put the focus on three functionalities (shelter, access and other life support) and the commodities, services, investments and energy needed to satisfy a certain level of the functionalities. Investments of companies are linked to their economic activity and interpreted as necessity to maintain the capital stock to produce the demanded goods and services. This rearrangement is complemented by the expansion of the economic structure that allows to allocate physical data on energy demand, GHG emissions and material consumption to economic sectors. Using the Input-Output-Analysis approach and this modified IOT allows us to reveal the underlying emissions and material consumption linked to the satisfaction of functionalities.

The following graph illustrates the allocation of Austrian GHG emissions in 2014 to the single functionalities. Based on these inputs direct, indirect and investment related emissions are revealed for each of the functionalities in the time span until 2050. The direct emissions relate to emissions that are directly emitted for the satisfaction of the functionality. I.e. from fuel combustion in heating systems of dwellings and in fossil engines for traction in cars. Indirect emissions are emissions that are emitted along the value-added-chain in the production of a specific commodity, service, electricity or district heat. Investment related emissions are related to commodities needed for the investment activities in the economy. This covers for instance emissions caused by the need for concrete or steel to construct a manufacturing site or road.

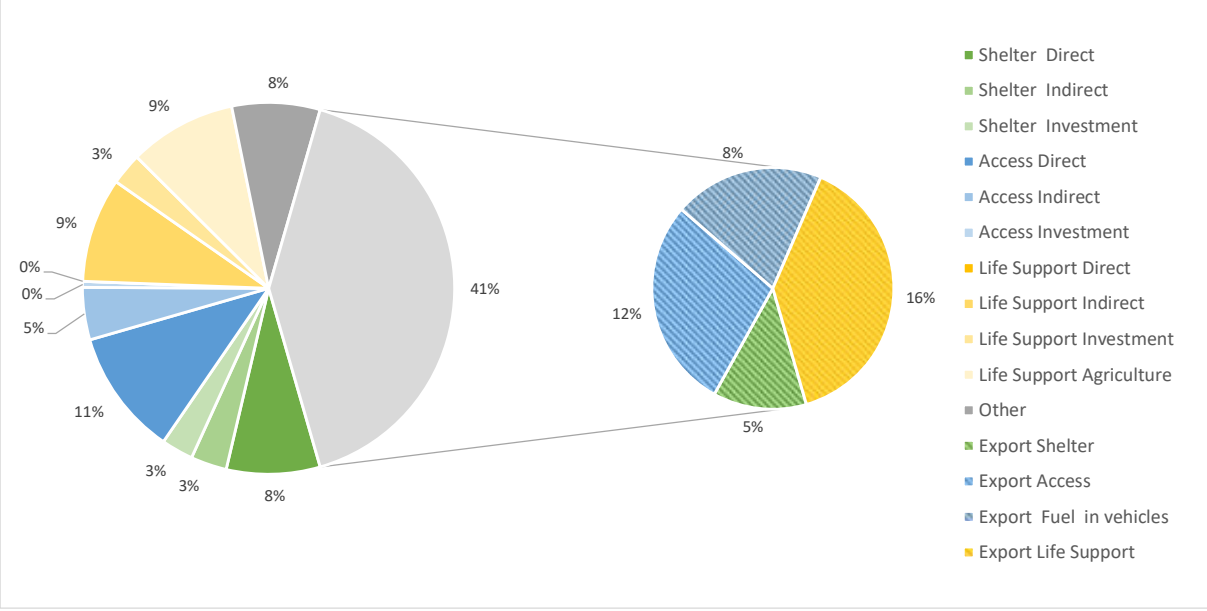

Figure 5: Share of emissions per functionality in 2014

We also extended the core model by means of aspects of computable general equilibrium (CGE) modelling, Specifically, the EconTrans "Extended Model" refines certain features of the Core Model by adding restrictions and changing assumptions with respect to the behaviour of economic agents, i.e. transforms the scenarios simulations in WP5 into a CGE model framework. The objective is deriving economy-wide feedback effects from changes in the provision of respective functionalities. To this end, the Extended Model adds two key features: First, restrictions in factor supply are set by endowing the model's agents with scarce production factors capital and labour, which mirrors income restrictions. Second, relative price mechanisms on goods/services and factor markets are added, i.e. prices are flexible and driven by supply-demand interaction. On top, the Extended Model allows exploring distributional impacts. For this purpose, we build on the small open economy CGE model for Austria (see (Mayer et al. 2021)) and improve the model's structure to account for an explicit representation of the functionalities shelter and access and its stock-flow interactions.

Analysis of feasible economic transformations

Drawing on the results of Schinko et al. (2021) on well-being and functionalities, and regional emissions constraints (Zebrowski – Jonas, 2021), the specific linkage of functionalities and resources (Sommer et al. 2021) and the economic evaluation tool thereof (i.e. the EconTrans Core Model as well as the Extended Model), the objective finally was to use this evaluation tool for the simulation of (i) emerging autonomous transformations in the Austrian economy embodied in the European and global context triggered by break-through technologies and new behaviours and (ii) targeted (climate policy) transformations enacted in such a world of transformation in order to reveal economy-wide effects or distributional implications.

For meeting this objective, we set up scenarios for the two functionalities shelter and access until 2050 and analyse them from a functionality perspective. These two functionalities cover changes in residential building structures for the functionality shelter, and changes in private transport patterns in the case of the functionality access. This means that not all aspects of shelter and access are covered, as for example freight transport or non-residential buildings. Furthermore, the functionality "Other Life Support" (which includes nutrition, public services etc.) is at this stage not modelled in detail.

Specifically, we compare two scenarios: First, an "Autonomous Transformation" scenario (AUTO) in which expected technological trends are implemented (e.g. an electricity sector mainly based on renewable energy sources by 2030, generic energy efficiency increases, moderate penetration of e-mobility, moderate improvements of the residential building stock). Second, a "Targeted Transformation" scenario (TARGET), which aims at climate neutrality by 2050. Compared to AUTO the TARGET scenario requires stronger interventions in the

socio-economic system. The TARGET scenario is then compared to AUTO in order to isolate economy-wide effects of a deviation from AUTO. The main results of WP5 are thus presented as difference between TARGET and AUTO.

For the scenario analysis we use two models. First, the EconTrans "Core Model" evolving from a I-O model, which assigns emissions as well as other resources to functionalities in its basic structure and allows to analyse how these changes, when policies/system interventions like new technologies are implemented. Second, we present results obtained with the EconTrans "Extended Model" which is based on a CGE model, showing the socio-economic impacts of serving functionalities shelter and access in a climate neutral way. These include effects on standard macroeconomic indicators (such as GDP and welfare) but contrasts these standard indicators with – in our view – more relevant indicators for assessing the low-carbon transformation. These are distributional effects which emerge via the interplay of changes in income and expenditure patterns, effects on wages and capital rents as well as a more accurate quantitative measure for human well-being, which combines changes in material consumption with co-benefits and a valuation of a potential increase in leisure. The output is a comprehensive working paper *Application of the Concept of "Functionalities" in Macroeconomic Modelling Frameworks – Insights for Austria and Methodological Lessons Learned* (Bachner et al., 2021).

A major task for the analysis of changes in shelter and access was to construct the specific scenarios, i.e. how these two functionalities can be served in the future (2050), how their development over time may look like and how changes in access and shelter are connected (both for the AUTO and the TARGET scenario). The scenarios have been structured along the Avoid-Shift-Improve concept (Creutzig et al., 2018) and are described in detail in Bachner et al. (2021). The very detailed description of the scenarios are an intermediate result which may also serve as input for other modelling teams in Austria.

The main results from the scenario analysis (i.e. comparison between AUTO and TARGET) are summarised as follows: First, we show that even from a traditional modelling perspective there are no macroeconomic costs involved (i.e. no GDP losses), when the functionalities shelter and access are served in a climate-neutral way. Our results even show a slight increase in GDP, Welfare and well-being due to economy-wide productivity increases. This in turn means that an absolute decoupling of CO_2 emissions and GDP is possible. Second, we show that substantial co-benefits from changes in access emerge, which are: reduced congestion, noise and air pollution as well as increased physical health. These co-benefits directly add to well-being. Third: When changing the standard CGE assumption of maximisation (of consumption) to an assumption of sufficiency, well-being can be further improved, whereas GDP and consumption decrease. The rationale behind this change in assumption is as follows. When less consumption expenditure is necessary for functionality fulfilment (e.g. cycling is less costly than driving by car), households might opt for reducing their labour supply (thereby increasing their leisure) rather than for increasing other

consumption to compensate their cost savings. This is illustrated by the arrows in Figure 6 , which shows the difference in GDP, Welfare and well-being[1] in 2050 when comparing TARGET to AUTO from a traditional CGE perspective (bars labelled TARGET) and when comparing TARGET to AUTO under the new assumption of sufficiency (TRGT-LEIS). Fourth: Following from the sufficiency assumption, we find that CO_2 emissions can be reduced even stronger. For more details and further results – including distributional effects – see (Bachner et al., 2021).

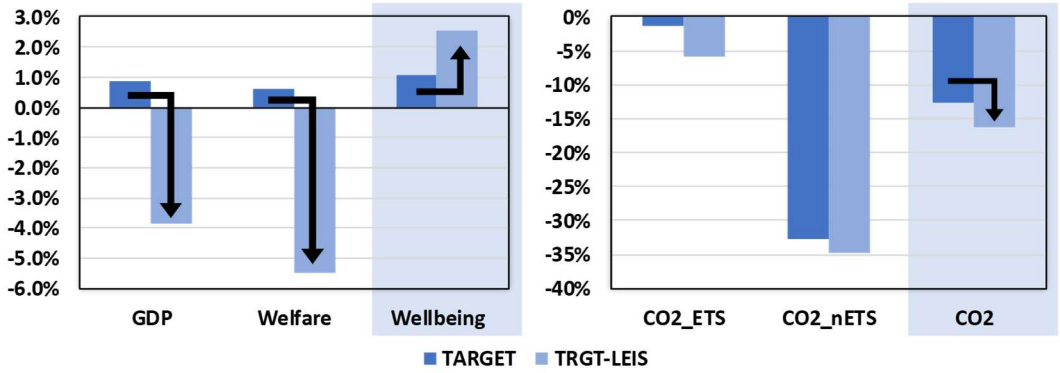

Figure 6: Economy-wide GDP, welfare and well-being effects from changing the fulfilment of functionalities shelter and access. TARGET = comparison of TARGET vs. AUTO. TRGT-LEIS = comparison of TARGET vs. AUTO under the new assumption of sufficiency with increased leisure.

[1] Well-being is defined as the sum of physical consumption of goods and services of the private and public households (i.e. Welfare), plus co-benefits, plus leisure evaluated at the wage rate.

5 Conclusions and recommendations

- The complexity of the research question calls for a stepwise extension of the model infrastructure with a focus on the functionalities shelter and access. The modelling approach developed for these subsegments can be used as guidance for an extension to other relevant parts of the economy. In addition, the research results make it transparent which challenges such a modelling approach faces and, particularly, how to develop the necessary data basis.

- EconTrans confronts our concept of functionalities with the broader discussion on well-being. Our research confirms that the functionality perspective with a focus in macroeconomic modelling fits well with literature and national stakeholder assessment.

- The downscaling exercise of global emission budgets to national boundary conditions for an Austrian carbon budget illustrates the huge challenge of needed emission reductions. The carbon budgets for Austria also provide a correspondence of the UNFCCC emissions inventory and the functionality based approach of emissions accounting.

- The newly developed I-O model integrates the connection of physical and monetary structures.

- For the CGE structures we show that the functionality perspective needs a broader view on utility and welfare: utility results from the functionality, and not per se from consumption flows. For example, the functionality access can be served via different stock-flow combinations, but the benefit from it remains the same.

- Climate-neutral functionality fulfilment can reduce consumption expenditure substantially, thereby leading to potentially more leisure and well-being. This is especially the case for access, where we show that a given level of functionality can be served with much lower costs when compared to conventional functionality satisfiers (e.g. motorised individual transport).

- The macroeconomic models developed and extended in EconTrans show the complexity of implementing a new mindset in economic modelling. EconTrans demonstrates this for two functionalities, namely shelter and access. One key issue is to implement this mind set to other functionalities. The results of this project build a good basis and illustration how these extensions can be achieved and prove promising that work along these lines will be applied in future research projects and provide guidance for decision makers for transformation processes.

- We conclude that (climate) policy should shift their focus away from misleading indicators such as GDP or consumption, but rather look at broader concepts of human well-being. We have shown that even though GDP and consumption might decline, well-being can be increased substantially, when changing functionality fulfilment to a climate-neutral way.

- In the project we implemented a new modelling mindset that illustrates the importance of an integrated view on stocks and flows for providing well-being relevant functionalities and that determine energy use and emissions. Throughout the project the issue of data availability needed and data gaps for such a modelling approach became apparent. Thus, when it comes to assessing transformation processes it must be assured (by policy, statistical offices) that the data requirements are met.

The main impact of the project is:

- Provide suggestions for macroeconomic modelers for model extensions.
- Give guidance to policy makers as well as modelers with respect to transformation processes and the understanding of wellbeing-generating functionalities, such as shelter and access, as ultimate goals of economic activities.
- Highlight the relevance of physical data and structures for providing well-being-generating functionalities.
- Link physical and monetary structures emphasising the relevance of the physical basis of our economies.
- Allow evaluation of transformation scenarios.

C) Project details

6 Method

The main objective of EconTrans is macroeconomic model development along a functionality perspective.

In the aftermath of the financial crisis 2008 critical voices on macroeconomic models as well as the underlying neo-classical macroeconomic paradigm were raised. A critique of neo-classical macroeconomics with its concept visible in Dynamic Stochastic General Equilibrium (DSGE) is depicted in (Stiglitz, 2018). Among other arguments he stresses that these models miss insights from information and behavioural economics and exhibit limited explanatory power. In a recent article, (Stern & Stiglitz, 2020) address the need for ongoing improvements of models to provide the basis for informed climate policy. They argue that Integrated Assessment models (IAMs) face imitations as guidance for climate policy. An integrated analysis of the environment and the economy is complicated by several factors, such as the risks associated with climate change, the disparity of impacts within and across generations, the existence of market failures, and the limited policy options to address these market failures. They conclude that models commonly used tend to overestimate the costs and underestimate the benefits of climate policy.

A recent strand of thinking for reframing macroeconomics was triggered by the Covid-19 pandemic. Mazzucato & Skidelsky, (2020) open a discussion about record government spending for coping with the deep economic crisis. A new proposition for an adequate enhancement of macroeconomic thinking is required. They argue that the necessary emergency financing should be intimately tied with restoring the role of the state for stimulating innovation and transition of the economy.

Against the background of the diverse approaches in the literature, the question arises about relevant evaluation methods and measures for a successful transformation as well as mapping profound structural change in macroeconomic modelling.

In the EconTrans project we take up the strands of thinking that motivate for a rethinking and extension of macroeconomic modelling and take up the issue of what constitutes wellbeing beyond GDP growth and what needs to be considered for not further violating the planetary boundaries. In our modelling endeavour we start out with two well established model classes, an input-output model and a CGE model. We extend the model structures towards integrating the physical and monetary layers and the relevance of the stocks for resource flows and their impact on emissions from a functionality perspective in the newly developed input output model. What a functionality perspective means for conventional indicators in a CGE structure and how the perspective on welfare could be extended towards a broader understanding of well-being, is integrated in a CGE

type model structure. The results presented are far from final, but they point into directions that might prove to be more relevant for modelling transition processes than the prevailing evaluation tools.

A strand of literature which goes in a similar direction as the functionalities approach refers to human needs. Literature also suggests the potential for innovation and disruptive technologies to dramatically reduce GHG emissions from functionalities ((Schinko et al., 2021) and the literature cited there).

EconTrans takes up the challenge to integrate new aspects into macroeconomic modelling and to consider economic activities from an outcome-oriented perspective, so called functionalities. Functionalities are based on the idea that they are the actual reason for economic activities. Functionalities describe (basic) human needs, such as housing, nutrition or mobility, and are determinants of human well-being. A crucial aspect of functionalities is the interaction between stocks and flows. Stocks are capital stocks such as buildings, vehicles or transport infrastructure, flows correspond to the associated required energy and material flows. A specific functionality can be provided by different combinations of stocks and flows and differs in its respective resource requirements or the emissions triggered. Combinations of stocks and flows are to be understood as pairs belonging together; for example, vehicles and their fuel consumption, or buildings and their heating energy demand.

Methodologically EconTrans applies a variety of methods. We start with a comprehensive literature review and stakeholder survey. In the literature review we discuss the concept of functionalities in the context of the literature on well-being and human needs and extend this with stakeholder interviews emphasising the need for a better understanding of the impact of transformation processes on well-being. The literature review concludes that our approach to focus on functionalities, which are ultimately relevant for well-being, is compatible with the international literature and the stakeholder consultation process undertaken in the project EconTrans. Literature also suggests the potential for innovation and disruptive technologies to dramatically reduce GHG emissions from functionalities. This was in principle also confirmed by the stakeholder consultation in EconTrans, which stressed potential rebound effects. Affordability of innovative technologies as well as climate knowledge and awareness of climate risks as a prerequisite for behavioural change were also emphasised.

The objective of placing the project into the international context is met by presenting the results of a down-scaling exercise ensuring that Austrian emission pathways are compatible with global emission constraints. This down-scaling exercise is executed using three different principles. 1) proportionality to current share of national CO_2 emissions (accounted using the standard IPCC scheme) in global CO_2 emissions; (2) proportionality to current share of a nation's population in the global population; and (3) global convergence of per-capita emissions in 2050.

The main activities of EconTrans concern macroeconomic model development that builds on input-output and CGE modelling. The characteristics of the model structure is described above (see Figure 3).

The core model based on an I-O structure and newly developed in EconTrans was extended by means of aspects of computable general equilibrium (CGE) modelling, Specifically, the EconTrans "Extended Model" refines certain features of the Core Model by adding restrictions and changing assumptions with respect to the behaviour of economic agents, i.e. transforms the model into a CGE model. The objective is to derive economy-wide feedback effects from changes in the provision of respective functionalities. To this end, the Extended Model adds two key features: First, restrictions in factor supply are set by endowing the model's agents with scarce production factors capital and labour, which mirrors income restrictions. Second, relative price mechanisms on goods/services and factor markets are added, i.e. prices are flexible and driven by supply-demand interaction. On top, the Extended Model allows exploring distributional impacts. For this purpose, we build on the small open economy CGE model for Austria (see Mayer et al. (2021)) and improve the model's structure to account for an explicit representation of the functionalities shelter and access and its stock-flow interactions.

Finally, scenario analyses for transformation pathways for Austria for the functionalities shelter and access are performed using both model tools. Therefore, we prepare model assumptions based on literature research and expert interviews. One of the challenges in this project step is to translate technical and behavioural transformation potentials, often available as very detailed (technological) information, into usable inputs for macroeconomic models. The aim of this exercise is twofold: First, we demonstrate first steps towards an operationalisation of functionality approach in macroeconomic scenario analysis and derive quantitative results and insights for Austria. Second, we reveal important (data) gaps and potential limitations when it comes to operationalising the functionalities approach in macroeconomic models.

Specifically, we set up scenarios for the two functionalities shelter and access until 2050 and analyse them from a functionality perspective. These two functionalities as analysed in this project cover changes in residential building structures for the functionality shelter, and changes in private transport patterns in the case of the functionality access. This means that not all aspects of shelter and access are covered, as for example freight transport or non-residential buildings. Furthermore, the functionality "Other Life Support" (which includes nutrition, public services etc.) is at this stage not explicitly modelled but captured as with conventional macroeconomic modelling.

For the scenario analysis we use the EconTrans "Core Model" evolving from an I-O model, which assigns emissions as well as other resources to functionalities and allows to analyse changes like the implementation of new technologies. Also results obtained with the EconTrans "Extended Model" based on a CGE model

structure, showing the socio-economic impacts of a climate-neutral fulfilment of the functionalities shelter and access are presented. These results include effects on standard macroeconomic indicators (such as GDP and Welfare) but contrasts these standard indicators with – in our view – more relevant indicators for assessing the transformation towards climate neutrality. These are distributional effects which emerge via the interplay of changes in income and expenditure patterns, effects on wages and capital rents as well as a more accurate quantitative measure for human wellbeing, which combines changes in material consumption with co-benefits and a valuation of a potential leisure-consumption trade-off.

We compare two scenarios. An "Autonomous Transformation" scenario (AUTO) in which expected technological trends are implemented (e.g. an electricity sector mainly based on renewable energy sources by 2030, generic energy efficiency increases, moderate penetration of e-mobility, moderate improvements of the residential building stock). Note that the AUTO scenario should not be interpreted as a business-as-usual scenario, but already includes changes in terms of climate change mitigation, which however are not sufficient to reach climate neutrality in Austria by 2050.

A "Targeted Transformation" scenario (TARGET) aims at climate neutrality by 2050. Compared to AUTO this requires stronger interventions. As mentioned, we analyse the share of the functionalities shelter and access that concern private households, whereas for the rest of the economy no changes compared to the AUTO scenario are assumed. Nevertheless, we take account of all intermediate inputs for these two functionalities. By comparing TARGET to AUTO we can deduce deviations in the trend given by AUTO and thus isolate the socio-economic effects of switching to the TARGET trajectory.

For achieving climate-neutral shelter and access, we structure the assumed measures according to the Avoid-Shift-Improve (ASI) framework (Creutzig et al., 2018), which aligns well with the demand perspective of the functionalities approach. The logic of the ASI framework suggests starting climate change mitigation measures by avoidance of greenhouse gas emission intensive activities (e.g. avoiding physical transport needs by means of telework, less floor space due to new building concepts; focus on quarters/superblocks). This is followed by technological shifts towards more climate friendly activities for those fractions that cannot be avoided (e.g. shifting from motorised individual transport to public transport, change in heating systems; new building technologies). Finally, some aspects can neither be avoided nor shifted and are thus subject to improvement (e.g. use electric cars instead of fossil fuelled cars; refurbishment of buildings).

Table 4: The modelled changes for the functionalities Shelter and Access

	Shelter	Access
Avoid	- More efficient usage of living space	- More Telework - Work-time reduction
Shift	- Change in heating systems (replace oil heating) - Change in building technologies of new houses	- Modal shift towards more public and shared transport as well as active mobility
Improve	- Refurbishment of existing building stock	- Increasing the penetration of electric cars in motorized individual transport
	Superblocks/Focus on quarters	

For the EconTrans core model the original Input-Output-Table for Austria for the year 2014 has been rearranged and expanded from a functionality perspective with the focus on three functionalities (shelter, access and other life support) and the commodities, services, investments and energy needed to satisfy a certain level of the functionalities. Investments of companies are linked to their economic activity and interpreted as necessity to maintain the capital stock to produce the demanded goods and services. This rearrangement is complemented by the expansion of the economic structure that allows to allocate physical data on energy demand, GHG emissions and material consumption to economic sectors. Using the Input-Output-Analysis approach and this modified IOT allows us to reveal the underlying emissions and material consumption linked to the satisfaction of functionalities.

In the Core Model the amount and structure of commodities and services needed to serve a certain level of functionality are not constant. On the one hand it depends on the behaviour of companies and households. Examples are home office, the choice of where to live or the choice of the transport mode, e.g. the use of public transportation. Assumptions about such behavioural changes are important for significant emissions reductions. Exogenous assumptions on changes in behaviour can be implemented in in the Core Model exogenously, which then illustrates how these changes unfold in the IOT structure.

The inputs needed to serve a certain level of functionality is dependent on the existing capital stock and its quality in terms of energy efficiency (i.e. past investment decisions). The composition of the stock defines the flow and structure of commodities, energy and services needed to satisfy a functionality. Hence, a different stock or higher quality stock that serves the same functionality might use less materials and/or energy. Therefore, in EconTrans the IOT is complemented with the composition of household stocks, comprising buildings, heating systems and vehicles. These stocks define the energy inputs required for the satisfaction of functionalities, here with the focus on fractions of shelter and access. Investment activities change the existing stock over time which then also changes the flow of materials and energy. This modelling approach represents the implementation of a stock-flow relation and represents the trade-off between

the quality of the capital stock and the energy/material consumption determined by this stock.

The Extended Model refines certain features of the Core Model by adding restrictions and changing assumptions with respect to the behaviour of economic agents, i.e. transforms the model into a computable general equilibrium (CGE) model. The objective is deriving economy-wide feedback effects from changes in the provision of respective functionalities. To this end, the Extended Model adds two key features: First, restrictions in factor supply are set by endowing the model's agents with scarce production factors capital and labour, which in turn mirrors income restrictions. This restriction in the availability of production factors is crucial, since it implies that the model is closed and that neither value nor product can appear out of nowhere (Wing, 2004). This feature is especially important when it comes to the modelling of investments as it means that additional investment either crowds replaces other investment or is financed by higher savings (i.e. lower consumption). Second, relative price mechanisms on goods/services and factor markets are added, i.e. prices are flexible and driven by supply-demand interaction. On top, the Extended Model allows exploring distributional impacts. For this purpose, we build on the small open economy CGE model for Austria (see Mayer et al. (2021)) and improve the model's structure to account for an explicit representation of the functionalities shelter and access and its stock-flow interactions.

Another crucial methodological development compared to "conventional" macroeconomic models is the linking of flows to respective stocks. The EconTrans framework not only looks at the quantitative evolution of stocks (and its effects on future flows via annual investments and depreciation) but also puts emphasis on the (particularly environmental) quality of stocks (and thus future flows). Using spreadsheet tools, we connect time-series of capital stocks (vehicles such as e-cars or buildings), with the respective flows of satisfiers (investments and depreciation over respective life-times as well as operating expenditure).

Work Package	2018								2019												2020												2021	
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2
WP1 Identifying the transformation challenge																																		
Literature review			M1.1																															
Interviews and focus group														M1.2																				
Report																D1																		
WP2 Recognizing the emissions challenge																																		
Data set of GHG emissions and reduction targets																	M2.1																	
Boundary conditions for functionality-based modelling																								M2.2										
WP3 Linking functionalities and resource use																																		
Data set on the functionality shelter												M3.1																						
Data set on the functionality access to persons, goods and locations																				M3.2														
Data set on other life support functionalities																													M3.3					
WP4 A comprehensive modelling framework																																		
Functionality based Input-Output Table															M4.1																			
Executable basic model framework																									M4.2									
Executable extended model framework																																M4.3		
WP5 Analysis of feasible economic transformations																																		
Identified emerging transformations																				M5.1														
Aggregate implications																						M5.2												
Policy analysis and recommendation																																		M5.3
WP6 Dissemination and Project management																																		
Kick-off and ongoing project meetings	M6.1																																	
External workshops																							M6.3									M6.4		
Web-tool		M6.4																																
Project management, coordination and reporting												D6.1																						D6.2

8 Publications and other dissemination activities

Publications	
	Schinko, T., Weifner, A., Köppl, A., (2021) The interaction of energy services, breakthrough technologies and human need satisfaction. EconTrans Working Paper #1.
	Zebrowski, P., Jonas, M., (2021) Embedding scenarios of Austria's transition to climate-neutral economy within the context of global action to mitigate climate change. EconTrans Working Paper #2.
	Sommer, M. Köppl, A., Schleicher, S.P., Bachner, G., Mayer, J., Fischer, L., Steininger, K.W., (2021) The concept of functionalities in a macroeconomic modelling framework for Austria. EconTrans Working Paper #3.
	Bachner, G., Mayer, J., Fischer, L., Frei, E., Steininger, K.W., Sommer, M., Köppl, A., Schleicher, S.P., (2021). Application of the Concept of "Functionalities" in Macroeconomic Modelling Frameworks – Insights for Austria and Methodological Lessons Learned. EconTrans Working Paper #4.
	Bachner, G., Mayer, J., Steininger, K.W., Anger-Kraavi, A., Smith, A., Barker, T.S., (2020) Uncertainties in macroeconomic assessments of low-carbon transition pathways - The case of the European iron and steel industry. *Ecological Economics* 172, 106631. https://doi.org/10.1016/j.ecolecon.2020.106631
	Köppl A, Schleicher S (2018) What Will Make Energy Systems Sustainable? *Sustainability* 10:2537. doi: 10.3390/su10072537
	Köppl A, Schleicher S (2019) Material Use: The Next Challenge to Climate Policy, Intereconomics November 2019, Volume 54, Issue 6, pp 338–341.
Workshops and presentations on conferences	
	Presentation of the draft Working paper "Energy services, breakthrough technologies and human need satisfaction" at the Klimatag 2019 in Vienna by Ariane Weifner
	Presentation of the EconTrans project at the Klimatag 2019 by Angela Köppl https://econtrans.at/wp-content/uploads/2019/07/Klimatag_Slides3.pdf
	Presentation of WP1 results at the annual Euroleague for Life Sciences (ELLS) Conference in Uppsala (Sweden) November 2019 by Ariane Weifner
	15 internal project team workshop

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