Meeting the Paris Agreement and Supporting Sustainability - quantifying synergies and trade-offs

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Abstract

This paper explores trade-offs and synergies between climate goals as foreseen in the Paris Agreement and other sustainable development goals (SDGs) based of an integrated scenario analysis. Economic, environmental but foremost social impacts of a transition to a low-carbon-society are analysed from a global and European as well as from a national perspective by means of dynamic model simulations: By applying the Global Multi Region Input Output (GMRIO) model GINFORS, we are able to present projection results for key socio-economic and environmental result indicators for European Union member states, the US and China.

Two scenarios have been defined and numerically projected with the global model GINFORS: The Business as Usual (BAU) scenario describes the development without further ambitious low-carbon policies until 2050. The MeetPASS scenario comprises policies and measures inducing changes in behaviour and consumption that support the goal to limit the global temperature increase below 1.5 °C and foster progress towards more sustainable consumption patterns in light of planetary boundaries.

Our key findings, which are supported by more detailed national analyses based on an application of the IO model e3.at (economy-energy-environment in Austria) can be summarized as follows:

- The Paris goal can be reached. But it will take decades to implement the required long-term transformations of contemporary production and consumption patterns. Hence, the successful in time implementation of these processes demands for immediate and ambitious political and societal actions.
- Ambitious climate policy actions should take synergies into account: Improvements in resource efficiency can make significant contributions to achieving the climate target.
- The systemic combination of climate and resource conservation actions does not only facilitate substantial progress towards sustainable consumption and production structures but appears also economically benefical.

The Austrian model e3.at provides a detailed analysis of the impacts of both scenarios on the sustainability dimensions for the Austrian society until 2050. The policy measures of the global MeetPASS scenario are transferred to Austria and investigated with the e3.at model in more detail. Synergies and trade-offs among the various policy objectives for Austria are explored. The results are specifically useful for a critical discussion of the relationship between the international climate policy and SDG agendas as well as for the identification of strict and socially acceptable mitigation pathways.

1 Introduction

In 2015, the international community has appointed two important agreements for the world's future: The Sustainable Development Goals (SDGs)[1] were adopted as part of the international development strategy "Agenda 2030" and the Global Agreement on Climate Change (Paris Agreement[2]) was accepted by all 196 parties to the United Nations Framework Convention on Climate Change (UNFCCC) at COP21 in Paris.

The Paris Agreement has the aim to hold the increase in the global average temperature to well below 2° C compared to pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5° C by reducing greenhouse gas (GHG) emissions towards zero. The contribution that each individual country should make in order to achieve the worldwide goal are determined by all countries individually. At the COP24 conference, the rules for the implementation of the Paris Agreement were determined, including the national reduction contributions for each country.

For European Union (EU) member states like Austria, EU Climate and Energy Policy objectives can be identified as a key reference framework. The most recent (2018) key objectives of EU climate and energy policy[3] are (1) the reduction of GHG emissions in 2030 compared to 2005 by at least 40%, (2) an increase of the share of renewable energy (RE) by at least 32% and (3) improvements in energy efficiency by at least 32%[4].

In contrast to the Paris Agreement which is legally binding, the implementation of the SDGs is not and each state has to decide on the measures to achieve the objectives. The SDGs comprise a set of 17 goals with 169 targets to end all forms of poverty, protect the planet and ensure prosperity for all.

Although there is no formal interrelationship between the 2030 Agenda for Sustainable Development and the Paris Agreement they are interdependent. E. g., climate action itself is one of the 17 goals (Goal 13: 'Take urgent action to combat climate change and its impacts') of the SDGs.

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[1] http://www.un.org/sustainabledevelopment/sustainable-development-goals/

[2] http://www.un.org/ga/search/view_doc.asp?symbol=FCCC/CP/2015/L.9/Rev.1&Lang=E

[3] https://ec.europa.eu/clima/policies/strategies/2030_en

[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC

This study provides an assessment of the implications of climate policy measures amongst others on SDG indicators on the global and European level as well as for Austria and thus can help policy makers to develop strategies that support the Paris goals and the SDGs at the same time.

This paper builds on the results of the study "Meeting the Paris Agreement and Supporting Sustainability - quantifying synergies and trade-offs" in Germany conducted by SERI[5] and GWS.

In the second section of this paper, the underlying methodology of the analysis is presented including a brief description of the two models applied for the integrated scenario analysis and the scenario itself. Next, macroeconomic results are shown (section 3). In section 4 conclusions are given.

[5] The authors thank A. Stocker (SERI) for valuable contributions to this conference paper.

2 Methodology

In order to provide a comprehensive depiction of the interplay between measures aimed at achieving the objectives of the Paris Agreement and the SDGs, we followed a three-stage approach. Based on an initial literature survey, relevant SDG indicators were identified and incorporated into the simulation models. In a next step, a qualitative scenario of a transition towards a low-carbon society was developed. Complemented by individual policy parametrizations, the impacts, causal relations and feedbacks on selected key indicators have then been quantified by means of integrated economic model analyses. The following subsections report briefly about the implied indicator analysis (2.1), the applied macro-econometric Input-Output (IO) simulation frameworks (2.2 and 2.3) and our applied scenario parametrizations (2.4).

2.1 Indicator analysis

Indicator systems are usually used for (ex-post) monitoring sustainable development by comparing target values with historical developments (BMWI, 2015; Kettner-Marx et al., 2018; StBA, 2017; Worldbank, 2017). The selection of indicators should be appropriate to give an overview of the degree of target achievement and how the goals in the defined areas such as economics, environment, energy security are met (Flues et al., 2012; IAEA/UN, 2005; Lutz et al., 2015).

The selection of SDG indicators which are integrated into the model e3.at is based on the UN indicator set which comprises 17 SDGs and 169 targets. 13 are identified to be relevant for Austria showing interactions with climate mitigation measures (Stocker et al., 2014). The SDGs 1 ("End Poverty in all its forms everywhere"), 7 ("Ensure access to affordable, reliable, sustainable and modern energy for all"), 8 ("Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all"), 9 ("Resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation"), 10 ("Reduce inequality within and among countries") and 12 ("Ensure sustainable consumption and production patterns") are in focus of the analysis.

The national indicator set developed by Statistik Austria is the main basis for the indicators that are implemented into the e3.at model. Supplementary data for household types from Statistik Austria is used to evaluate the social implications. Socio-demographic household characteristics, such as income and household size, provide an indication of the financial situation and, derived from this, the consumption possibilities, including the consumption of fuels, electricity and heating energy.

In order to assess the impacts of climate protection measures on socio-economic and environmental indicators, not only retrospective (ex-post) analysis is important, but also a forward-looking (ex-ante) analysis.

The combination of indicators with environmental-economic forecast models enables the evaluation of futures under certain assumptions. On the other hand, these models take a variety of economic and environmental interactions into account. The combination of forecast models and indicator sets can reveal both reinforcing and counteracting effects of policy measures for indicators from the same and different areas.

2.2 The global MRIO-model GINFORS

Based on a comprehensive Environmentally Extended Multi-Regional Input-Output (EE-MRIO) database,[6] GINFORS$_3$ represents a dynamic EE-MRIO simulation model with global coverage. Figure 1 provides a conceptual visualization of key model elements.

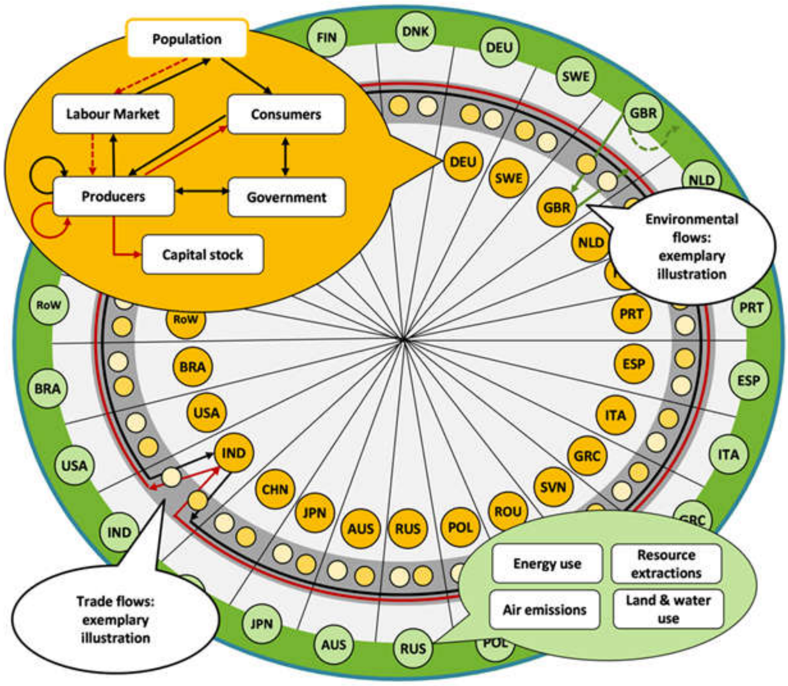

Figure 1: Conceptual framework of GINFORS$_3$ (Simplified illustration)
source: GWS

The model roots on a deep mapping of country and sector structures. These structures depict mutual international as well as inter-sectoral economic interdependencies by means of a bottom-up

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6 For introductory surveys of well-established MRIO databases see Tukker, Dietzenbacher (2013) and Wiedmann, Barrett (2013).

approach. This means that projections for macroeconomic indicators (like GDP) are consistently derived from dynamic mappings of their constitutive parts (like expenditures of private households, government spending, gross fixed capital formation, exports and imports). Hence an economic module builds the core of the $GINFORS_3$ model. It encompasses 35 industries with 59 products groups in 38 national economies (including 27 EU Member States, the USA, Japan and the BRIC-countries) and a Rest of World (RoW) region, thus allowing to assess changes in (i. a.) production, basic prices, intermediate demand, value added; international supply chains (bilateral trade matrices; the grey circle in Figure 1); final demand (consumption expenditures by households and non-profit organisations, government spending and gross fixed capital formation by industries); labour markets (labour demand, wages, employment).[7]

This economic module is rooted on the WIOD database (Timmer et al., 2015). Global economic developments are thus totally endogenized within the model. For each modelled economy, all relevant monetary flows are completely integrated on the macroeconomic scale. The economic activities on the demand and supply side are consistently interlinked with approved statistical accounting schemes capturing the generation, distribution and use of income for individual transactors (e. g. private households, government). Given this complete mapping of well-defined accounting and balancing interrelationships, the model is able to provide a thorough account for complex response relationships on a macroeconomic scale. This modelling philosophy corresponds to the tradition of INFORUM-type models (Almon, 1991) and features post-Keynesian system properties.[8] With regards to the later attribute, $GINFORS_3$ is thus comparable to the E3ME model developed and maintained by Cambridge Econometrics.[9] Moreover, $GINFORS_3$ provides extensive insights into the globalization effects from international trade developments.

The environmental extensions comprise an energy module and resources modules. The energy model simulates endogenously energy demand (differentiated for 20 energy carriers) of the different industries and private households as well as the evolution of the energy carrier mix in electricity production with regards to central scenario parameters (nuclear energy, total share of renewables) and individual shares for specific renewable technologies and fossil energy carriers. Thus, the energy module captures resulting CO_2-emissions.

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7 A labour market model is not available for the region “Rest of World”.

8 See Meyer, Ahlert 2019 for complementary methodological annotations on the implied simulation properties contrasted to commonly applied CGE approaches.

9 „There are only two post-Keynesian macro-econometric models that are used for E3 [Energy-Environment-Economy] analysis at global level: the E3ME and GINFORS models. The general principles underlying both models with regards to money and finance are the same, although the models differ somewhat in terms of detail.“ (Pollitt, Mercure 2018, p. 190).

The resource modules encompass different kinds of resource extractions (abiotic and biotic materials) as well as land and water use. The mapping of global material flows is primarily based on historical analyses of extraction data provided by the WU Global Material Flows Database (Lutter et al., 2014). Based on historical time series information on multi-national extraction dynamics, $GINFORS_3$ is thus able to explain and project the evolution of used and unused extractions of abiotic resources (Non-metallic minerals, metal ores, coal, oil and gas). Additionally, the model also maps demand and supply/production for 13 different crop groups and 3 different livestock categories together with their resulting impacts on prices and agricultural land use. Overall, this comprehensive representation of the global use of primary raw materials enables us to calculate and project sophisticated material footprint indicators (like raw material consumption RMC and raw material input RMI) that consider the environmental impacts of domestic activities along the diversified international supply chains.[10]

The applied dynamic mapping of the interplay between economic development, energy and resource use controls for national variations in respective socio-economic metabolic profiles. Global development trends can thus be traced back to national drivers by means of $GINFORS_3$ simulations. Furthermore, the respective impacts of altered metabolic system statuses can be endogenously derived (on national or multi-national levels as well as on the global level) by means of $GINFORS_3$ simulation studies.

Due to this level of detail, the models can be used for various policy assessments. This also applies for a majority of SDG indicators. As illustrated in section 3.1, these analyses are distinguished by the fact that they can also trace the contributions of individual countries or regions to global environmental phenomena. Currently, this school of thought is not well reflected within global indicator frameworks (with the exception of the material footprint as an indicator to monitor the SDG 12 “Responsible consumption and production”). But this situation is certainly first and foremost due to the fact that such complex indicator calculations necessitate the availability of extensive data sets which were scarcely available until the recent past.[11] We are, therefore convinced that such approaches can and will be much more frequently applied in the future.

[10] See, for example, Bringezu (2015) for additional methodological details on as well as suggested sustainability target values for these material footprint indicators.

[11] See, for example, corresponding methodological annotations of Hertwich and Peters (2009) in their global assessments of historical CO_2-footprints.

2.3 The Austrian IO model e3.at

The core of e3.at is an economic model including the input-output (IO) framework and the labour market. e3.at is following two main principles: bottom-up and full integration (Almon, 1991; Großmann et al., 2017). Bottom-up modelling takes into account each economic sector in great detail within an input-output-framework. Macroeconomic variables such as GDP or investment are derived by explicit aggregation. Full integration stands for complex and consistent modelling within the framework of SNAB (system of national accounts and balancing items), for instance, simultaneously accounting for income creation and distribution in four institutional sectors, redistribution among those sectors and the use of income for intermediate and final products. Furthermore, it is highly endogenized, only a few variables like tax rates, population development, global trade and world energy and food prices are exogenous. The equation system comprises behavioural (estimated) equations and definitions. The behavioural equations are based on the assumption of bounded rationality rather than strictly optimising behaviour. The model is tested and equations are adapted until the development of endogenous variables tracks the historical data very closely. Thus, the model is validated empirically.

Moreover, the core model includes several modules in order to show the manifold relationships between the economy, the energy system, and the environment. The three modules give the Austrian model its name e3.at (economy, energy, environment, Figure 2).

The environmental module depicts different resources (fossil fuels, biomass and minerals) and CO_2 emission. Direct material inputs (domestic extraction and imports) are calculated according to Eurostat (2001). The model covers the extraction in Austria as well as those material imports induced in other countries by Austrian imports. The energy module shows the energy flows in physical units according to the energy balances energy supply, transformation and demand as well as energy prices for different energy carriers. This module is linked to a regional housing inventory module showing the energy consumption of private households on a regional level and a transportation module for private households that enables the analysis of mobility and gives valuable insight on the effects of transport on total energy consumption and CO_2 emissions. To display social and distributional impacts, a socioeconomic module was developed, comprising 25 household groups according to their income and size of household. e3.at is also linked to the global model GINFORS to illustrate the effects of foreign trade on the Austrian economy.

The selected SDGs indicators are implemented accordingly into the model system. For example, indicators which belong to SDG 7 ("Ensure access to affordable, reliable, sustainable and modern energy for all") are linked to the energy module while SDG 8 ("Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all") is associated with the economic model.

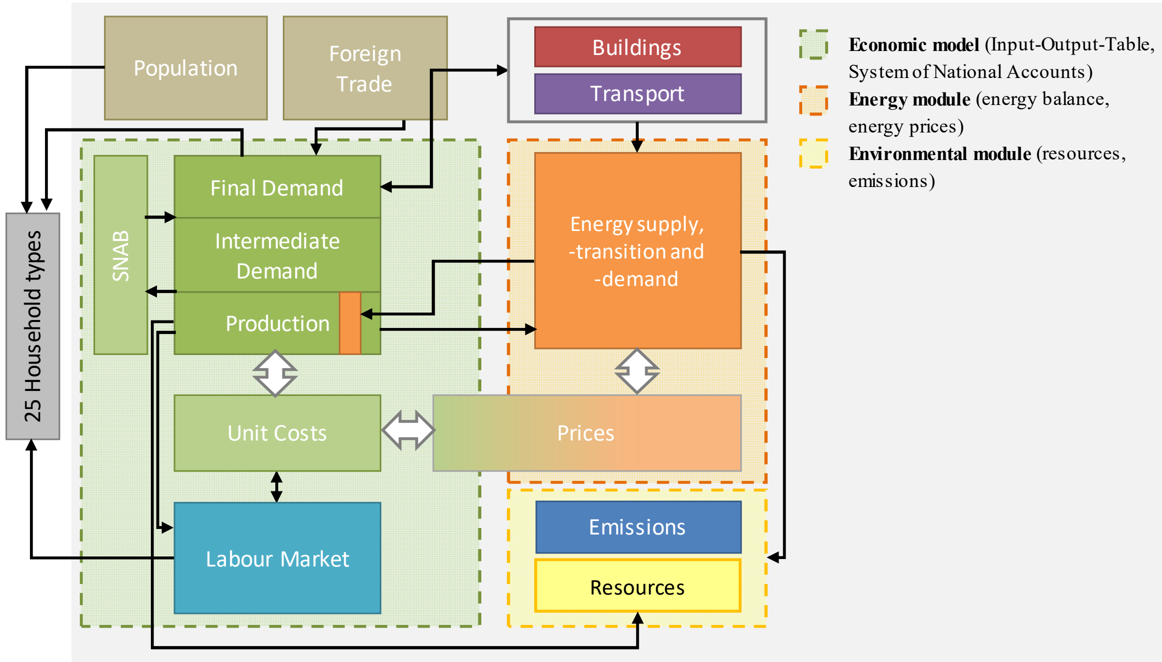

Figure 2: **e3.at at a glance**
source: GWS

2.4 *Scenario definition*

The basic idea of model-based scenario analyses is exemplarily shown in Figure 3. First, a Business As Usual (BAU) scenario is implemented. As any other model simulation, the BAU rests on parametrizations for exogenous variables (in case of GINFORS$_3$, for example, population dynamics and world market prices for fossils). Compared to so-called scenario projections it is however intended to project prospective future developments of endogenous variables in absence of any further policy measures. Concerning the work documented in this paper, the BAU projection therefore assumes that, until the year 2050, current climate and sustainability policies are neither refined towards the needs of the Paris Agreement nor refined towards a systemic adoption of the SDG agenda. This does not mean that energy, economic or environmental systems are assumed to maintain contemporary structures until the end of the simulation period. It is rather assumed that these systems remain stuck to historical development dynamics. With regard to policy interventions it is implicitly assumed that non-market-based instruments will be developed further with the same dynamics as in the past. For market-based instruments (taxes and subsidies) the general assumption of the BAU scenario is that tax rates (on products, income, etc.) will not be altered in the simulation period. Furthermore, our BAU scenario does not intend to depict possible costs of inactions (e. g. of adaptation to climate change).[12]

For selected model variables, the BAU projection results are then compared to respective results from an alternative model simulation. In our case, the so-called MeetPASS scenario represents mimics a future in which the Paris agreement leads to ambitious climate policy actions around the world. Furthermore, this scenario assumes that resource conversation, representing a key element of the SDG agenda, evolves (not only by ambitious political actions but also by varied preferences of producers and consumers) to a focal point of ambitious behavioural change.

Comparing both, the results from the BAU and the MeetPASS scenario, then reveals differences that can be interpreted (at a specific point in time and over time) as reactions to the impulses induced by altered scenario assumptions.

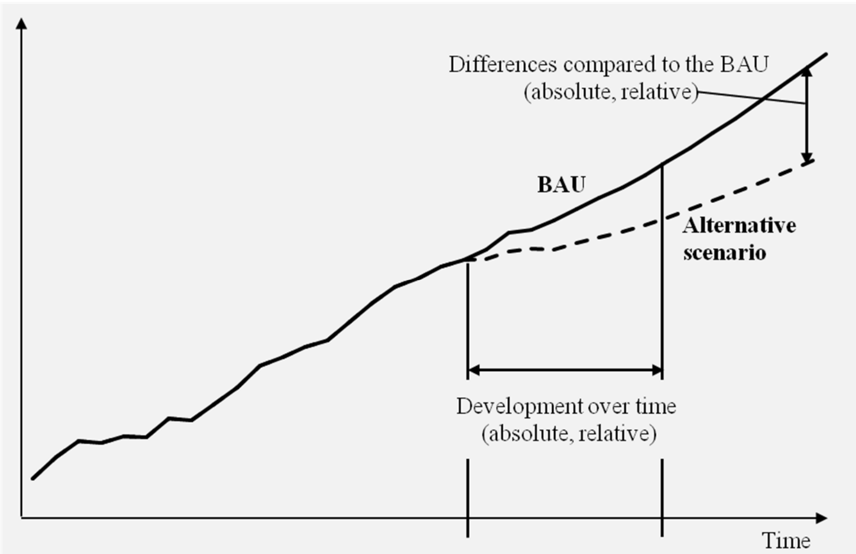

Figure 3: Comparison of model-based scenario projections
source: GWS

The applied parametrizations for our MeetPASS scenario are outlined on the following pages. Table 1 summarizes assumptions for selected key policy instruments and behavioral changes in GINFORS to parametrize the meetPASS scenario.[13]

[12] Please note that this implies that all indicated positive benefits from intensified environmental policies can be classified as rather moderate estimates as they tend to underestimate the overall positive effects.

[13] For more details see Stocker et al. 2019.

Table 1: The meetPASS scenario in GINFORS: selected key policy assumptions

Policy instrument| Behavioral change	Parametrization
Carbon pricing	EU: integration of additional sectors from 2020 onwards Other countries: launch of ETS in 2020 ETS price increase (in 2017 US-$): -> 123 (2030) -> 265 (2050)
RE expansion	Significantly faster than in the Sustainable Development Scenario by WEO 2017 (IEA 2017), e. g. Germany: -> 86% (2030) -> 100% (2040) -> 100% (2050) United Kingdom: -> 70% (2030) -> 95% (2040) -> 100% (2050) USA: -> 52% (2030) -> 77% (2040) -> 100% (2050) China: -> 56% (2030) -> 73% (2040) -> 84% (2050)
Support for energy refurbishment in buildings	Additional energy refurbishment of 1.5% of residential building stock from 2020 onwards
Shift to e-mobility	In industrialized countries the share of e-cars will increase rapidly: -> 12% -> 36% -> 72%
Fostering of metal recycling	Due to enhanced recycling patterns the need for primary ores in basic metal production can be halved until 2050
Shift to less meat-based dietary patterns	Altered dietary patterns lead to a reduced per capita meat demand compared to BAU, e. g. Germany: -> 26% (2030) -> 37% (2040) -> 46% (2050) United Kingdom: -> 23% (2030) -> 34% (2040) -> 44% (2050) USA: -> 18% (2030) -> 32% (2040) -> 44% (2050) China: -> 8% (2030) -> 24% (2040) -> 34% (2050)

Compared to own previous research (Distelkamp, Meyer 2019), the global meetPASS Scenario therefore can be classified as a very ambitious combination of policy measures which had been originally derived for the individual scenario projections (Global cooperation, EU goes ahead and Civil society leads) of the POLFREE project.[14]

The scenario inputs for Austria were broken down from the global MeetPASS scenario and expanded by Austria-specific developments and measures in order to meet the goals of the Paris Agreement. Austria is also part of the global GINFORS model. Thus, from the GINFORS modelling results we have seen, that the carbon budget derived for Austria is depleted far before 2050 if only the measures of the global meetPASS scenarios are introduced. The modelling results of GINFORS indicate that additional measures are required to fulfil Austria's responsibility for reaching the 1.5°C target. Thus, we have to adapt and supplement the global meetPASS storyline and the derived measures. Important sources in this respect were the WAM+ and the Transition Scenario (see AEE 2017, EEG 2017, IVT/TU Graz 2017, IVT/TU Wien 2017, Meyer et al. 2018, UBA 2017 and the mission 2030, the integrated Austrian climate and energy strategy (BMNT and BMVIT, 2018).

The main assumptions are given in Table 2[15].

Table 2: The meetPASS scenario in e3.at: selected key policy assumptions

Targets / Sectors	Measures	Policy instruments / Behavioral change
Cut in GHG emissions		- Carbon pricing
Expansion of RE		
Energy sector	- Deployment of renewable energy - Integrated energy management	- Feed-in tariffs - "Green Electricity-Law"
Transport sector	- E-mobility (100% by 2045) - Charging infrastructure for e-vehicles - Freight transport: shift from road to railways	- Financial support - Regulatory law - Taxation of gasoline and diesel - Flight tax

[14] The POLFREE project received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 308371. Between 2012 and 2016, eight partner institutions explored together diverse policy options to foster economy-wide improvements in resource efficiency. The project was led by the University College London.

[15] For more details see Stocker et al. 2018.

	- Passenger transport: shift from air transport to railways	
Building sector	- Phasing out of oil-fired heating - Primary use of solar and ambient heat	- Financial support - Regulatory law - Prohibition of oil boilers - Spatial planning
Improvement of energy efficiency		
Energy sector	- Expansion of electricity and gas grid infrastructure - Investments in storage	- Financial support
Building sector	- Refurbishment of existing buildings - Replacement of heating systems - Improved efficiency in new buildings	- Investment promotion - Regulatory law - Consulting
Transport sector	- Promoting public transport - Expansion of pedestrian and bicycle traffic - Electrification of transport - Car sharing	- Regulation law - E.g. road toll for freight and passenger transport, taxation of gasoline and diesel, lower usage fees for public transport - Emission standards for new cars - Awareness-raising; intrinsic motivation - Infrastructure expansion
Industry	- Implementation of the EU Energy Efficiency Directive	- Consulting - Regulation law - Energy management
Improvement of resource efficiency		
Industry	- Fostering of metal and construction material recycling - New production structures	- Upstream tax on ores and non-metallic minerals - Regulation law
Households	- Prevention of food waste - Promoting sharing economy	- Awareness-raising - Information programs to avoid food waste

3 Scenario results

3.1 GINFORS

The following figure summarizes key simulation results of the GINFORS model for the World, the EU, the USA and China. Each diagram shows a comparison of the respective expected development up to 2050 in the BAU scenario with the meetPASS scenario.

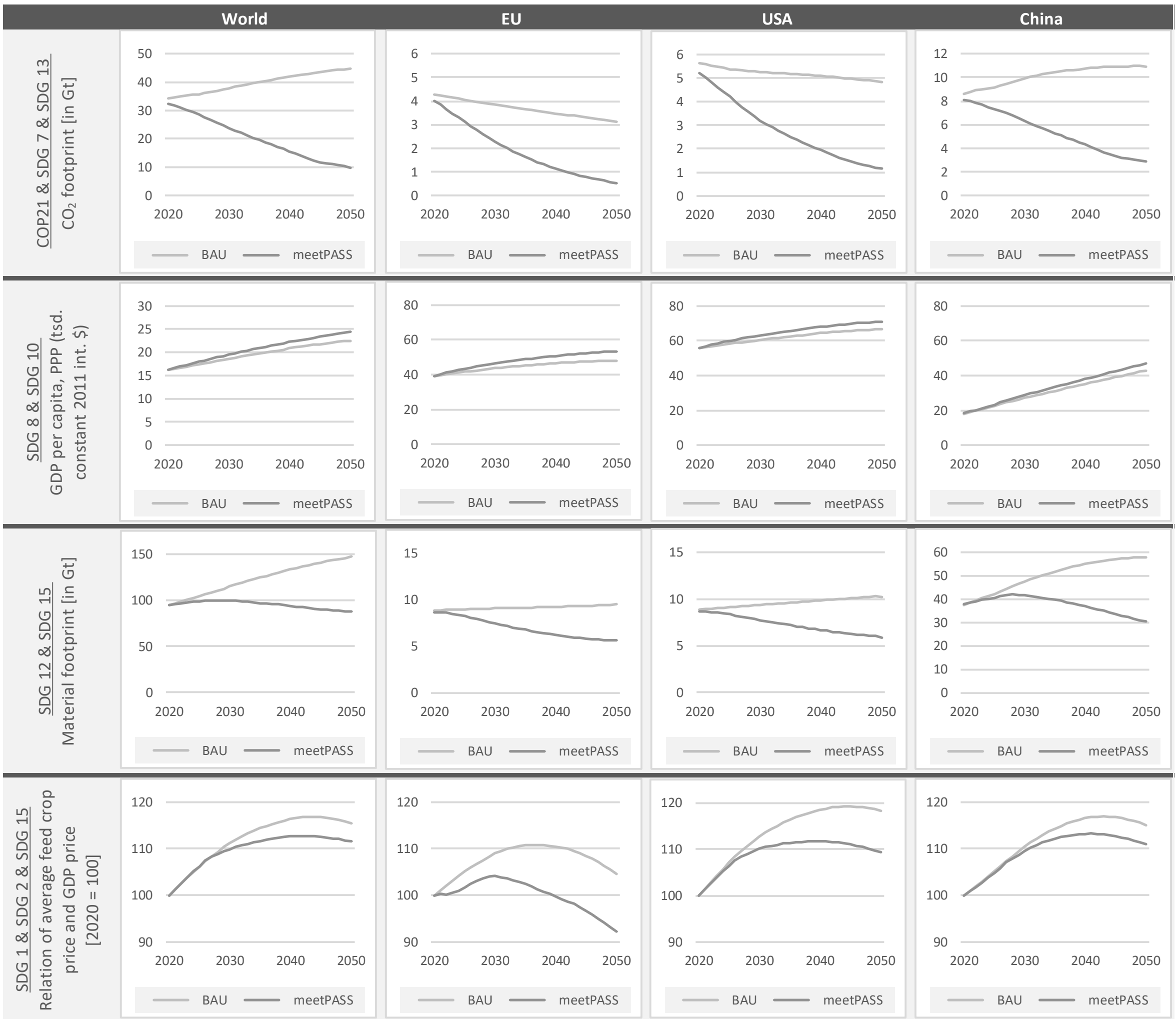

Figure 4: Key simulation results in GINFORS
source: own calculations

The figure starts in the top row with the simulation results for the CO_2 footprint. Whilst in a BAU surrounding a further increase of global CO_2 emissions towards 45 Gt is projected, the meetPASS scenario with its assumptions on ambitious climate policy action enables a reduction to below 10 Gt in 2050. The cumulative CO_2 emissions for the period 2020 - 2050 amount to 625 Gt, compared to 1233 Gt in the BAU scenario. As the diagrams for the EU, the USA and China show, they all contribute substantially to the achievements in GHG reductions.

The other rows of the figure try to answer the question whether the global compliance of the COP21 agreement might contradict with an achievement of other SDGs:

The diagrams in the second row show the simulation results for GDP per capita. A positive impact on economic growth is projected globally as well as for the EU, USA and China, which means that we cannot identify a conflict between COP21 and SDG 8. With regard to SDG 10 (Reduced inequalities) the results are not as clear: Neither in the BAU nor in the meetPASS scenario a substantial reduction in inequalities among countries are expected.

The diagrams in the third row show the simulation results for the material footprint. As in the meetPASS scenario a more sustainable raw material use is not only indirectly affected by climate policy action but is also directly addressed by a bunch of instruments the direction of impacts is not surprisingly. But maybe the extent of the impact. Compared to the BAU results up to 2050 in the EU, the USA and China nearly 50% of raw materials use can be avoided.

Last but not least the bottom row of diagrams looks at the impacts on hunger and poverty. As neither indicators on hunger nor on poverty are directly covered in GINFORS, we analyse the relation between average food crop prices and GDP price indices (which are both endogenously projected by the model). The assumption is, that a faster increase in food prices than in GDP prices has negative implications on hunger and poverty. The results in Figure 4 show that in the meetPASS scenario a reduction of this relation (compared to the BAU scenario) is expected, which means that we cannot identify a conflict between COP21 and SDG 1 & 2.

3.2 E3.at

The results of the MeetPASS scenario are based on the modelled interrelations of the (socio-) economic system, the energy sector and the environment in Austria as well as other central assumptions that are exogenously given to the model system as described in section 2.4. These include in particular the specification of the development of world market prices and global trade as projected by the GINFORS model and scenario inputs as the expansion of renewable energies, energy efficiency paths for the industry, the building and transport sector as well as carbon pricing.

In the MeetPASS scenario, the Austrian economy is on a consistently higher growth path than in the BAU (Table 3). This development is supported in particular by the fundamental change in the capital stock and the resulting investments required for a transition to a low-carbon and resource-efficient economy. Up to EUR 10 billion are invested additionally per year.

The weaker price development is the result of several opposing effects: On the one hand, lower global market prices have a dampening effect on prices in Austria. On the other hand, the increase in CO_2 and mineral oil taxes and elimination of environmental harmful subsidies will initially have a price-driving effect, but this will weaken over time due to the lower use of fossil fuels. At the same time, the expansion of renewable energies and infrastructure is expected to lead to higher costs, which will be reflected in electricity prices in particular. At the end of the simulation period costs for low carbon technologies are expected to be lower due to the massive expansion of renewable energies worldwide (Tsiropoulos et al., 2018).

As a result of the increase in resource efficiency, the costs for intermediate goods can be reduced with price-reducing effects for the industries along the value-added chain.

Table 3: Differences between the BAU und MeetPASS scenario for selected macroeconomic variables
source: own calculations

MeetPASS - BAU	Deviations in specified units								Deviations in %							
	2015	2020	2025	2030	2035	2040	2045	2050	2015	2020	2025	2030	2035	2040	2045	2050
Components of price-adjusted GDP (Bn. EUR)																
Gross domestic product	0,0	8,6	8,8	8,5	5,3	3,9	5,6	7,9	0,0	2,5	2,4	2,1	1,3	0,9	1,3	1,7
Consumption of private households	0,0	3,4	2,9	2,9	2,2	2,3	2,9	2,9	0,0	2,0	1,6	1,6	1,1	1,2	1,5	1,4
Government consumption	0,0	1,4	1,1	0,7	-0,3	-1,3	-2,1	-2,6	0,0	2,0	1,5	0,8	-0,3	-1,4	-2,2	-2,6
Gross fixed capital formation	0,0	6,3	7,5	8,4	9,1	9,3	9,7	10,0	0,0	7,9	9,2	9,9	10,6	10,4	10,4	10,4
Exports	0,0	-1,6	-0,3	-0,7	-5,2	-8,5	-9,0	-8,5	0,0	-0,8	-0,1	-0,3	-1,9	-3,0	-3,0	-2,9
Imports	0,0	1,4	2,9	3,3	0,5	-2,5	-4,7	-7,0	0,0	0,7	1,4	1,5	0,2	-1,0	-1,9	-2,7
Price indices (2010=100)																
Consumption of private households	0,0	1,3	1,0	-1,8	-4,9	-8,8	-12,7	-16,5	0,0	1,1	0,7	-1,3	-3,3	-5,6	-7,7	-9,5
Production	0,0	1,9	1,7	-1,3	-5,5	-10,0	-14,2	-18,0	0,0	1,7	1,4	-1,0	-3,9	-6,8	-9,4	-11,4
Imports	0,0	0,5	-2,4	-8,0	-14,3	-20,0	-24,2	-28,4	0,0	0,5	-1,9	-5,8	-9,8	-13,0	-15,2	-17,1
Employment and income																
Employed persons (1.000 persons)	0,0	37,1	43,5	51,7	43,6	40,8	43,6	49,2	0,0	0,8	1,0	1,1	1,0	0,9	1,0	1,1
Disposable income (Bn. EUR)	0,0	7,1	7,0	2,7	-6,2	-15,6	-23,3	-29,6	0,0	3,1	2,7	0,9	-1,9	-4,4	-6,1	-7,4

Lower price levels also have an impact on wage developments via the wage-price spiral. Although employment is higher due to a positive economic development, disposable income is growing more slowly compared to the BAU scenario. Nevertheless, consumer demand by private households is slightly higher as the overall consumer price index has risen less. A closer look at the individual consumer prices reveals differences: for example, prices for individual mobility are increasing due to higher taxes on fossil fuels and road tolls while public transport becomes less expensive.

The consumer goods structure is changing: new mobility patterns of private households are weakening demand for cars and fossil fuels on the one hand, and public transport and bicycles are becoming more popular on the other. Heat demand is falling due to better efficiency of residential buildings and changes in residents' behaviour. However, demand for electricity will increase as a result of the complete switch to e-mobility.

The efficiency measures and assumed behavioural changes on which the scenario is based lead to an absolute decoupling of energy consumption and economic growth. At 2.4% p. a., the reduction in energy intensity is higher than observed in the past despite weaker fossil energy price developments on the world markets.

Compared to the BAU scenario, final energy consumption is reduced by a total of 386 PJ or 36 %, with the transport sector making the largest contribution with 264 PJ (Figure 5).

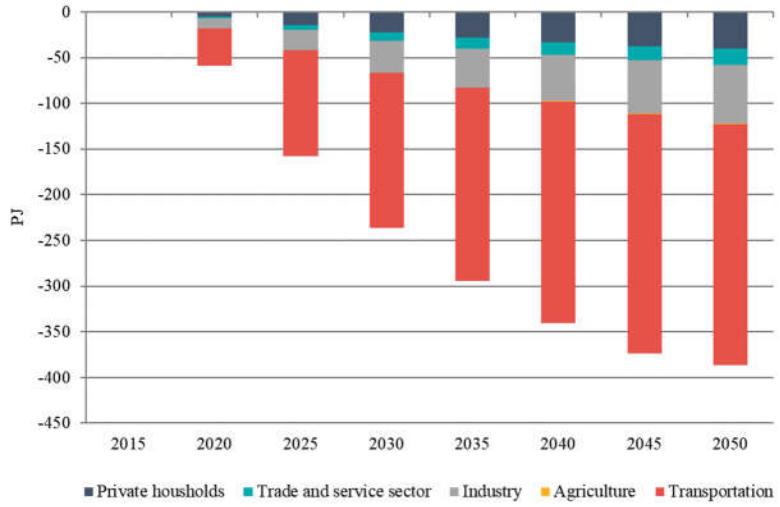

Figure 5: Final energy consumption by sectors (differences in PJ compared to BAU) source: own calculations

The switch to renewable energy will reduce the demand for fossil energy and thus reduce Austria's dependence on imports of coal, oil and gas. The increase in electricity consumption is mainly due to the expansion of e-mobility, the shift of traffic from road to rail and the conversion of the production process in the steel industry. In 2036, 100% of electricity will be generated from renewable sources. Austria achieves its goal to cover 100% of total electricity consumption from national renewable energy sources six years later than planned. Austria's objective to increase the ratio of renewable energy to gross final energy consumption to 45-50% by 2030 can be fulfilled.

The high share of renewable energies and improved energy efficiency is also reflected in the CO_2 emissions which decrease to 12 Mt CO_2 in 2050 which means a saving potential of 47 million tonnes of CO_2 or 80 % compared to the BAU scenario.

The goal of reducing emissions in the non-ETS sector by 16% or 36% (2030) compared to 2005 can be achieved in the MeetPASS scenario. By 2050, a significant reduction in emissions in the non-ETS sector of -62% can be expected resp. about 16,5 Mt (Figure 6). The transport sector is making the largest contribution (20 Mt CO_2) by switching to CO_2-free drives and shifting to environmentally friendly modes of transport.

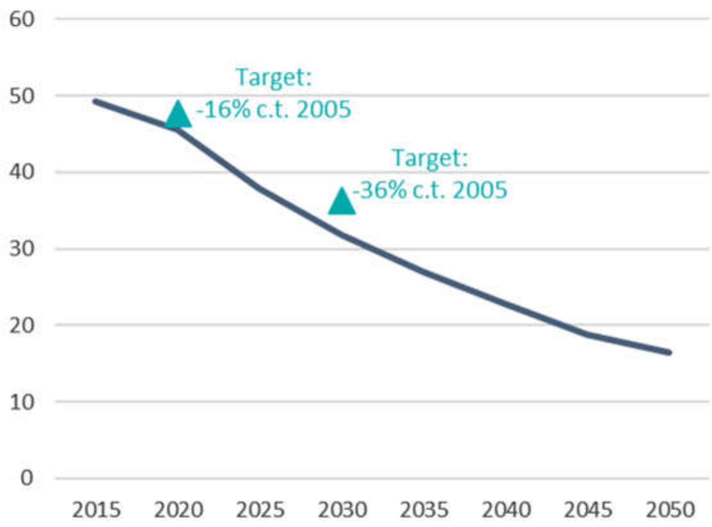

Figure 6: **CO_2 emissions non-ETS sector (Mt CO_2e)**
source: own calculations

The decoupling of material input from economic growth can be further strengthened compared to the BAU and an absolute reduction can be achieved. The decline in fossil raw materials shows the displacement effect of the expansion of renewable energy. Even the use of metallic and non-metallic raw materials can be reduced although there is a greater renovation activity and economic growth (Figure 7). This is mainly due to the increase in resource efficiency and higher recycling rates of metal and building materials. In addition, the material framework of the renewable energy technologies contributes to high recycling rates (Seiler et al., n.s.).

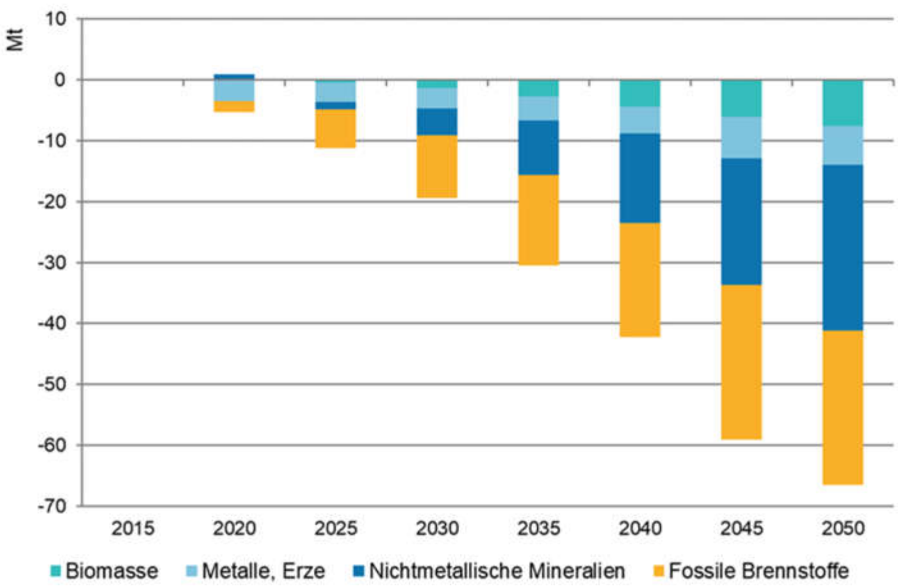

Figure 7: **Direct material input (differences in Mt compared to BAU)**
source: own calculations

With regard to the SDGs, it can be stated that the MeetPASS scenario has positive effects both on the economy (SDG 8) and on resource consumption and climate protection (SDG 7, 12 & 13). Successful energy and resource transformation require innovation and investment (SDG 9) in key sectors such as the automotive and steel industry as well as the energy sector. Information campaigns and advice are important accompanying measures that can trigger necessary behavioural changes. In order to reduce or avoid undesirable social effects, financial support for vulnerable households is also desirable (SDG 10). The collection of CO_2 taxes and tolls, for example, affects private households differently: while large households with low incomes suffer disproportionately from their relatively high expenditure on heat and mobility, small households with a high income would have advantages over the average household. Compensation payments can avoid undesirable burdens (Wolter et al., 2011, Kirchner et al., 2017).

4 Conclusions

The presented GINFORS simulation results showed neither from a global perspective nor for the EU, the USA or China any major contradiction of the COP21 target with the SDGs. A prerequisite to achieve these multi-level progresses is that globally a fast and ambitious turnaround in policy action occurs. If humanity does not want to trust in future carbon dioxide removal (CDR) technologies to meet the targets of the Paris Agreement, the time to act is now. As indicated by our simulation results, the complementary effects of an ambitious resource policy provide opportunities to achieve the goals of the Paris Agreement even in absence of any CDR technology.

However, this window of opportunity could soon be closed. In this respect, our global modelling work points to an urgent research question: Can the implied uncertainties of estimates for the potentials of resource policy measures on GHG mitigation effects be quantified in more detail? As a matter of fact, other research teams started only very recently to work on comparable integrative model-based assessment of the resources-climate nexus. See, for example, Riahi et al. (2017) for a reference to respective IPCC (Intergovernmental Panel on Climate Change)-related modelling activities or Hatfield-Dodds et al. (2017) for corresponding references to modelling activities at the International Resources Panel (IRP). A comparison of the published results indicates that projections of global resource use tend to be still associated with high degrees of uncertainties. In light of implied policy conclusions, we can therefore identify remaining urgent research needs. Ideally, this should be pursued through comprehensive inter-model comparison studies (similar to previous model comparison studies of climate policy projections in the IPCC environment). At least, we would like to contribute to such a research agenda.

For Austria, it could be shown as well that the path towards a low-carbon economy has positive effects on the SDGs under consideration. In addition to the necessary changes in behaviour, the pioneers for a resource-saving and sustainable society are innovations and investments. Accompanying measures for particularly severely affected and socially weak households are necessary in order to prevent from negative social impacts.

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