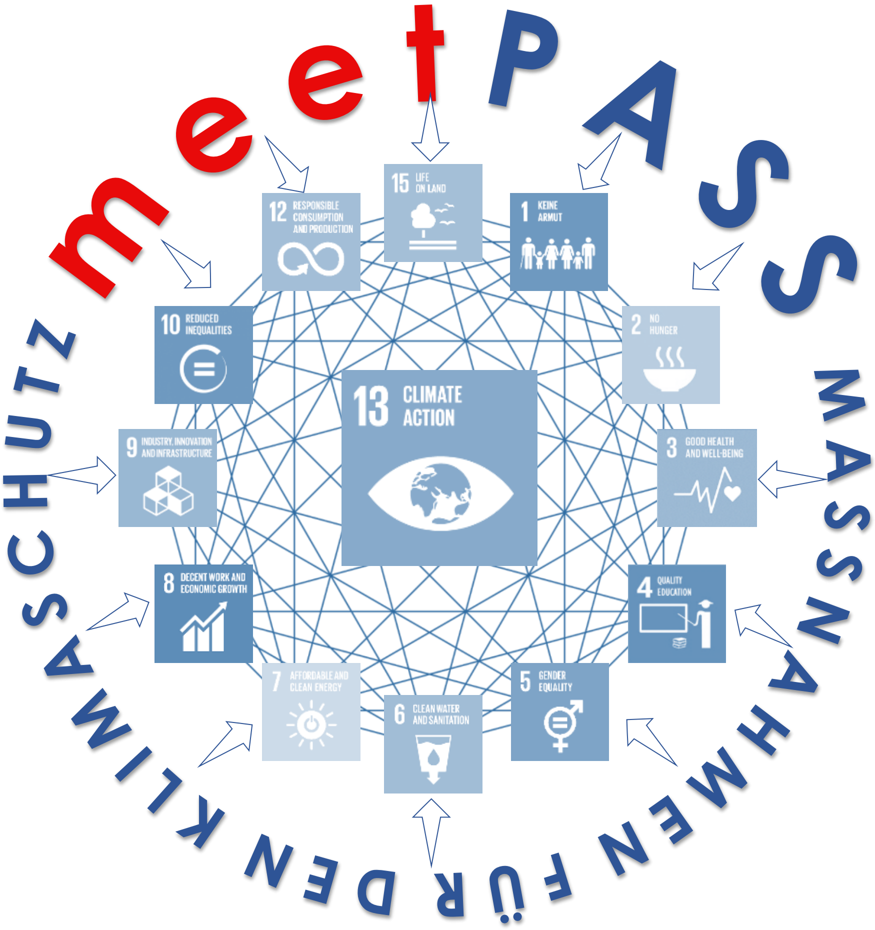
Analysis of the global meetPASS Mitigation Scenario



meetPASS: meeting the Paris Agreement and Supporting Sustainability

Working Paper No. 4

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GWS SPECIALISTS IN EMPIRICAL ECONOMIC RESEARCH

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Content

1 Introduction and Background

The central goal of meetPASS is to explore whether, and to what extent, achieving the goals of the Paris Climate Agreement reinforces or potentially impedes reaching the UN Sustainable Development Goals (SDGs). By conducting an integrated, model-based scenario analysis – involving stakeholders and experts – we analyse the economic, environmental and social impacts of a transition to a low-carbon-society from a global, European and Austrian perspective.

In December 2015, all 196 members of the United Nations Framework Convention on Climate Change (UNFCCC) adopted the Global Agreement on Climate Change (**Paris Agreement**[1]) at the COP21 meeting in Paris. The Paris Agreement aims to keep the increase in the global average temperature well below 2°C compared to pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C. Doing so means reducing net greenhouse gas emissions to zero by the middle of this century.

The contributions that each country should make to achieving the worldwide goal are determined by all countries individually. While recognising the need for the global community and EU Member States to act together in deciding on binding legislation to fight climate change, resource depletion as well as inequality and poverty, Austria must also prepare its own robust and independent strategies towards a sustainable and low-carbon-society.

In meetPASS, we therefore present and analyse the feasibility of a COP21-compatible future scenario and its global impacts, and then project the impacts on selected SDGs for Austria. The development and analysis of this scenario facilitates a first assessment of the mutual relationships between deep decarbonisation pathways and (selected areas of) the SDGs. In meetPASS we investigate the feasibility as well as the impacts of potential measures implemented in Austria. We also examine how these measures may affect selected SDGs, to demonstrate whether they can encourage progress within other important areas of sustainable development, or where they may be trade-offs.

We designed a global meetPASS Scenario that we initially quantified with the global GINFORS model to map the feasibility of a COP21-compatible future scenario and to project implied international impacts. Focusing on social and equality issues, we then avaluated the related impacts on the Austrian society and economy in more detail with the Austrian model e3.at.

The scenario modelling results are 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. They show which opportunities exist to meaningfully link these two processes. On the national level, where implementation, monitoring and review will (mainly) take place, the modelling results of meetPASS provide evidence as to whether measures that support the transition to a low-carbon-society may also have positive social and equality implications and lead to economic benefits.

The meetPASS Scenario has the primary intention to **limit the rise of the global average temperature to no more than 1.5°C above pre-industrial levels**.

The temperature development is largely determined by the greenhouse gas concentration in the atmosphere. This raises the question of how many tonnes of CO_2 may still be emitted

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

globally or in individual countries in order to limit warming 1.5°C. This question can be answered with the carbon budget.

The carbon budget (or CO_2-budget) is the amount of CO_2 emissions[2] from anthropogenic sources that can still be released (with a 50 – 66% probability) to comply with a defined limit, taking into account the amount that already has been released since the beginning of industrialization. This budget, which depicts remaining quantity, can be determined because of the approximately linear relationship between the cumulative total amount of greenhouse gases emitted and the resulting increase in temperature (IPCC, 2014, 5th Assessment Report).

A report by the Intergovernmental Panel on Climate Change (IPCC, 2018), the climate science body of the United Nations, published in autumn 2018 ahead of the climate change conference in Katowice, indicates that in order to limit global warming to 1.5° C above pre-industrial levels, humanity may only emit an additional 580-770 Gigatonnes (Gt) of CO_2. That is with a 50% probability. The carbon budget reduces to 420-570 Gt if the probability is 66%.

More information on the derivation of the carbon budget for the EU and Austria can be found in meetPASS Working Paper 3. The following table summarises the remaining global carbon budget and the carbon budget that is available for the European Union.

Table 1. Remaining carbon budget, global and for EU

	CO2 budget from 2017 onwards	
	50% probability	66% probability
	Gt	Gt
World	580-770	420-570
EU	40-53	29-39

In addition to the carbon budget target, meetPASS applies the following additional targets:

- No more than 45 Gt materials (abiotic and biotic) should be consumed (measured as TMC[3]), in order not to overshoot the earth's safe operating space[4]. This means a material footprint of less than 5 t/capita/year calculated on the basis of an expected world population of 9.7 billion people in 2050.
- No more than 15% of the global ice-free land surface should be converted to cropland. This means a cropland footprint of 0.15 ha per capita with a world population of 9.7 billion people in 2050.

[2] With respect to the carbon budget the IPCC only refers to CO_2 since CO_2 is both the most important greenhouse gas in terms of quantity and the fastest and easiest reducible greenhouse gas.

[3] Total **material consumption (TMC)** measures the global total amount of materials required for domestic consumption including indirect material requirements. TMC is a measure for all direct and indirect primary material extractions, both at home and abroad, which are associated to the consumption of an economy.

[4] The safe operating space ensures the functioning of the Earth system and its subsystems. Rockström et al. (2009) have defined nine planetary boundaries that effectively represent a "safe space" for human habitation, based on the idea that many subsystems of Earth react in a nonlinear way and are particularly sensitive around threshold levels of certain variables. When the variables pass those thresholds, rapid and unpredictable environmental changes might produce dangerous results, compromising the ability of the planet to support human societies in their present form.

The proposed targets are based on the results of the EU project POLFREE[5] and the IntRESS project[6] for the German Federal Environment Agency.

The rest of this working paper is laid out as follows: in the next chapter we describe the assumptions and settings as well as the results for the global Business as Usual (BAU) Scenario. Chapter 3 then features the alternative meetPASS Scenario. First, we explain the scenario measures, the assumptions and settings. Subsequently, we present the results from the scenario modelling with GINFORS by comparing the BAU Scenario with the meetPASS Scenario. Chapter 4 draws conclusions about the environmental, economic and social implications of the proposed climate policy measures.

2 The global Business as Usual (BAU) Scenario

The first stage involved developing a Business as Usual (BAU) Scenario. This shows the expected future development until 2050, under the assumption that no new policy targets are considered, beyond those already announced. Comparing the BAU Scenario with the meetPASS Scenario allows us to recognise the effects of changes induced by the scenario design.

The BAU Scenario does not account for the emissions reduction targets or adopted policies and measures central to the Paris Agreement. In addition, it does not include the possible costs of inaction (e.g. of adaptation to climate change).

This does not mean that the global energy, economy, environment system will not change until 2050. But the dynamics of these changes and their interdependencies are assessed on the basis of historical observations. 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 adjusted in the forecast period.

2.1 Relevant assumptions

Population dynamics, differentiated for three age groups (0-14 years, 15-64 years, 65+ years), for the period up to 2050 represent a core exogenous setting in all GINFORS scenarios. In meetPASS these settings are the same for both scenarios: the business-as-usual (BAU) scenario as well as the COP21 scenario.

For all EU countries these exogenous settings are based on the baseline projection by Eurostat, released in 2017 (see Eurostat 2017). For all other countries and the region “Rest of World” the population dynamics up to 2050 have been taken from the medium variant of the recent world population prospects (United Nations 2017).

[5] see http://polfree.seri.at/

[6] see www.intress.info

According to these exogenous settings the world population is expected to grow to 9.7 billion people by 2050. Whilst in the same period, the EU is expected to grow only marginally, for Austria the Eurostat baseline projection is for population growth of more than 15%. The following table summarises these findings and additional figures for selected countries. Figure 1 illustrates the expected global population development as well as the development for the European Union (EU member states without Croatia).

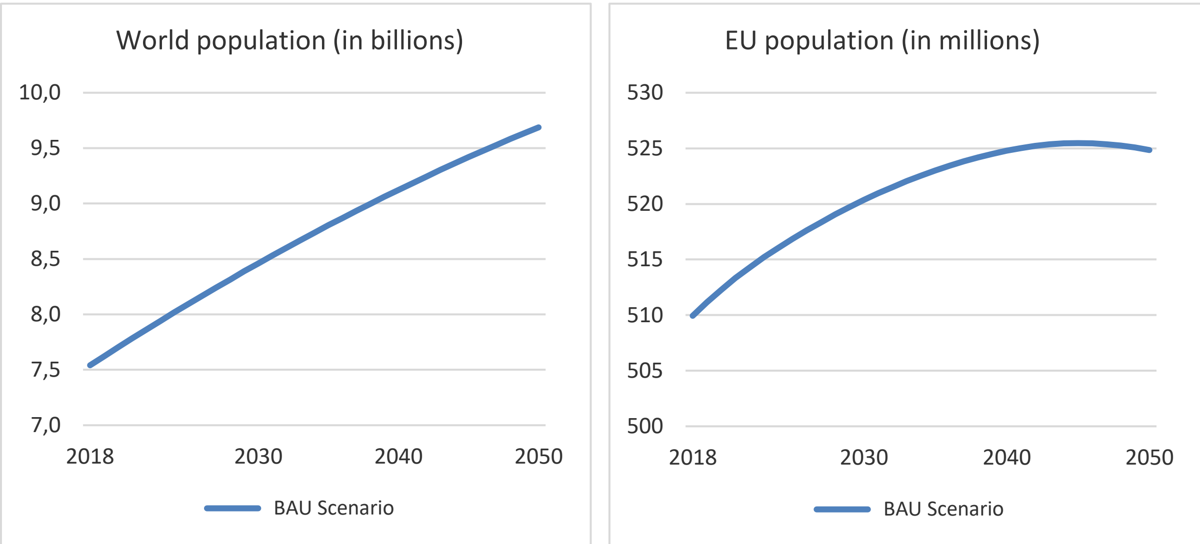
Table 2. Population dynamics for selected countries and regions

		2017	2025	2030	2040	2050
EU27*	millions	509	517	520	525	525
USA	millions	326	345	356	376	391
China	millions	1388	1420	1426	1409	1358
India	millions	1296	1405	1464	1554	1608
World	millions	7459	8093	8460	9123	9687

* EU member states without Croatia

Source: own representation based on Eurostat (2017) and United Nations (2017)

Figure 1. Development of population (worldwide and EU27)



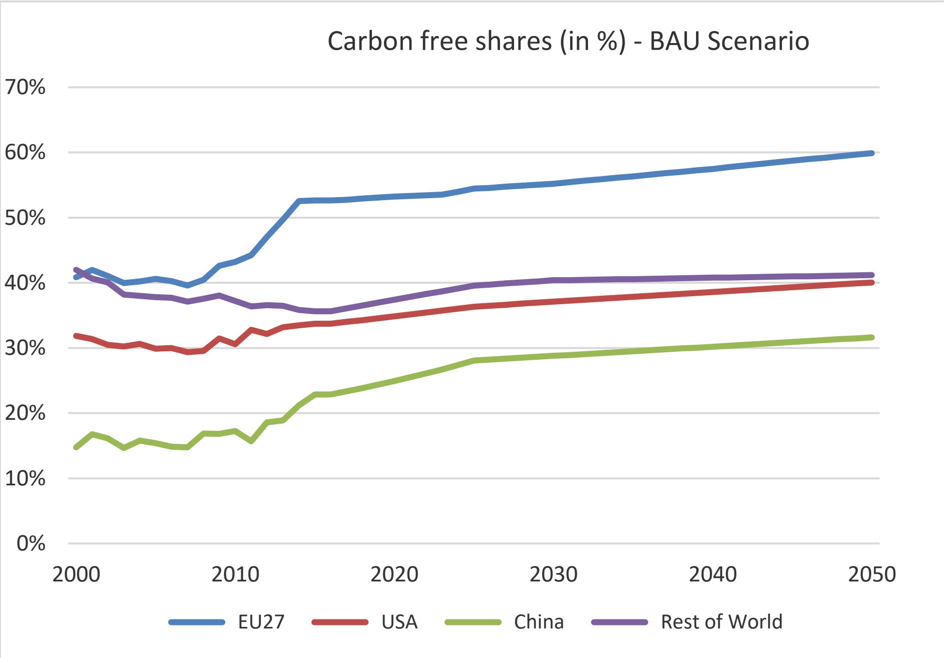
Source: own representation based on Eurostat (2017) and United Nations (2017)

Another key aspect in parametrizing the meetPASS BAU Scenario is the question of **dynamics in technology shifts in electricity generation**. How fast will the different renewable technologies evolve and force out the carbon-based technologies? And what is the future role of nuclear technology in Europe and world-wide, knowing that the construction of new nuclear plants in many parts of the world is becoming more and more expensive in comparison to renewable energy (RE) plants?

In this respect the BAU Scenario of the meetPASS project builds on the expertise of the IEA (2017) and calibrates the evolution of technology shares in electricity in conformity with the

"Current Policies Scenario" of the World Energy Outlook 2017. Figure 2 shows the development of carbon-free electricity shares in selected countries/regions.

Figure 2. Share of carbon free electricity generation in total electricity generation in the BAU Scenario



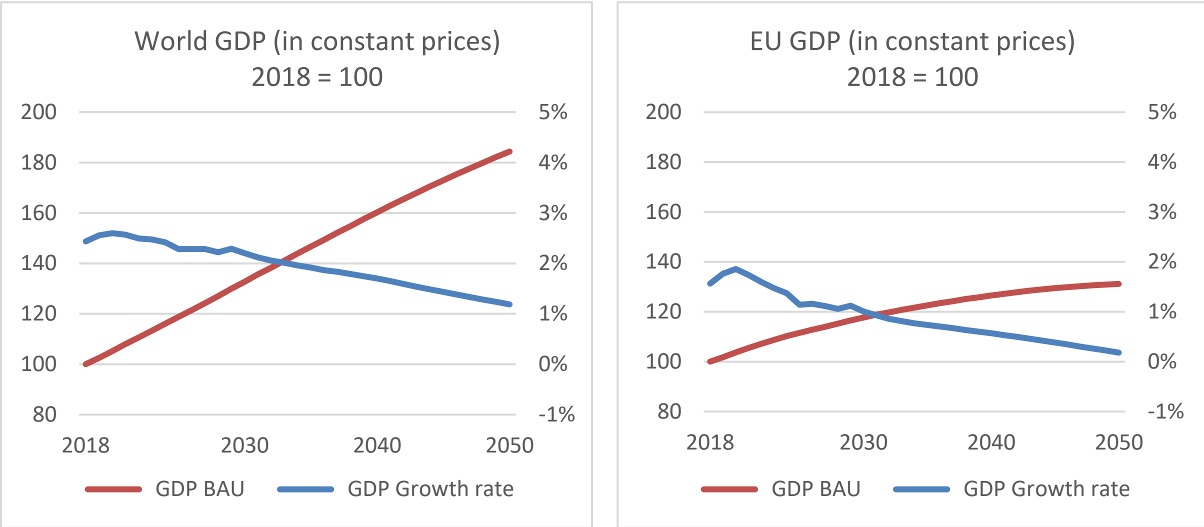
Source: own representation

In the BAU Scenario the **carbon price in the EU** is expected to grow only very moderately (up to 35 EUR per tonne in 2050, in 2017 prices). This assumption is more or less in line with the "Current Policies Scenario" of the WEO 2017 in which foresees a value of 35 EUR by 2040.

2.2 Results of the BAU Scenario

In the Business as Usual (BAU) scenario economic growth, measured by Gross Domestic Output (GDP) would increase from current levels, but the growth rate would decline (see Figure 3).

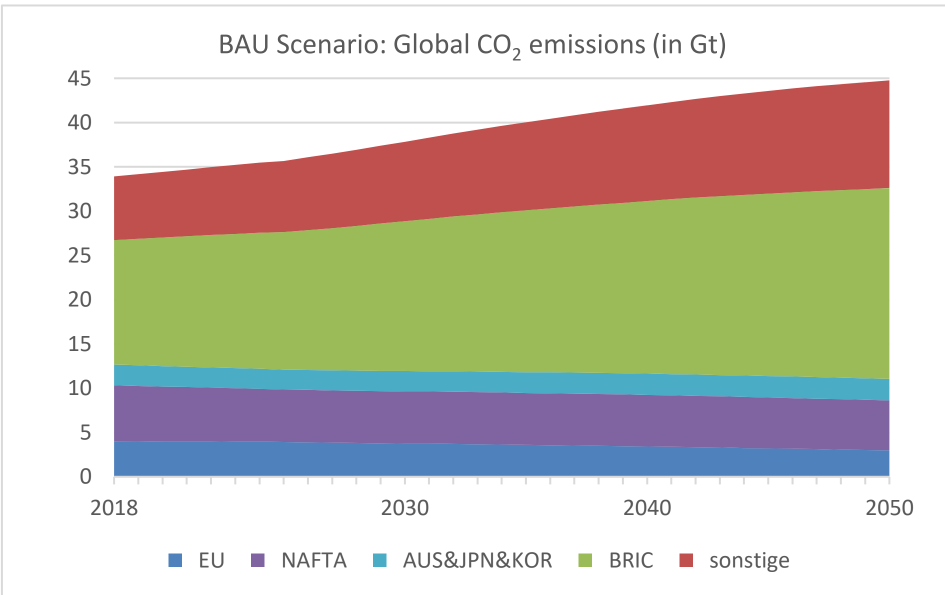
Figure 3. GDP developments in the BAU Scenario



Source: own representation

While global economic output would almost double to 2050 (+85%), CO_2 emissions would rise by a third (see the following figure). Thus, the celebrated "decoupling" of greenhouse gas emissions and economic growth seems to exist. But it is far from sufficient to actually reduce emissions. Especially in the BRIC countries and Australia, Japan and Korea, emissions would increase, while in the EU a slight decrease can be expected. Overall, emissions are currently 35 Gt / year and would rise to 45 Gt in 2050.

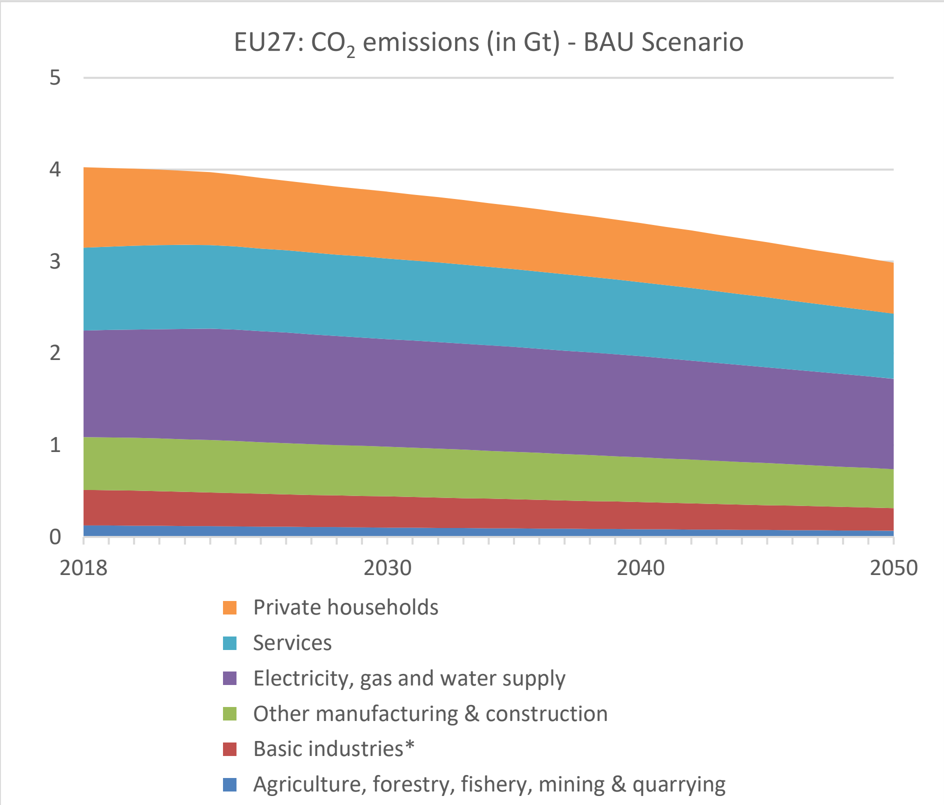
Figure 4. Global CO_2 emissions in the BAU Scenario



Source: own representation

The following figure shows the contribution of sectors to the EU emissions: electricity, gas and water supply currently have the highest share, which are not expected to change 2050. Private households and services are also major contributors to CO_2 emissions, while agriculture, forestry and mining and quarrying play a minor role.

Figure 5. EU CO_2 emissions by sectors in the BAU Scenario



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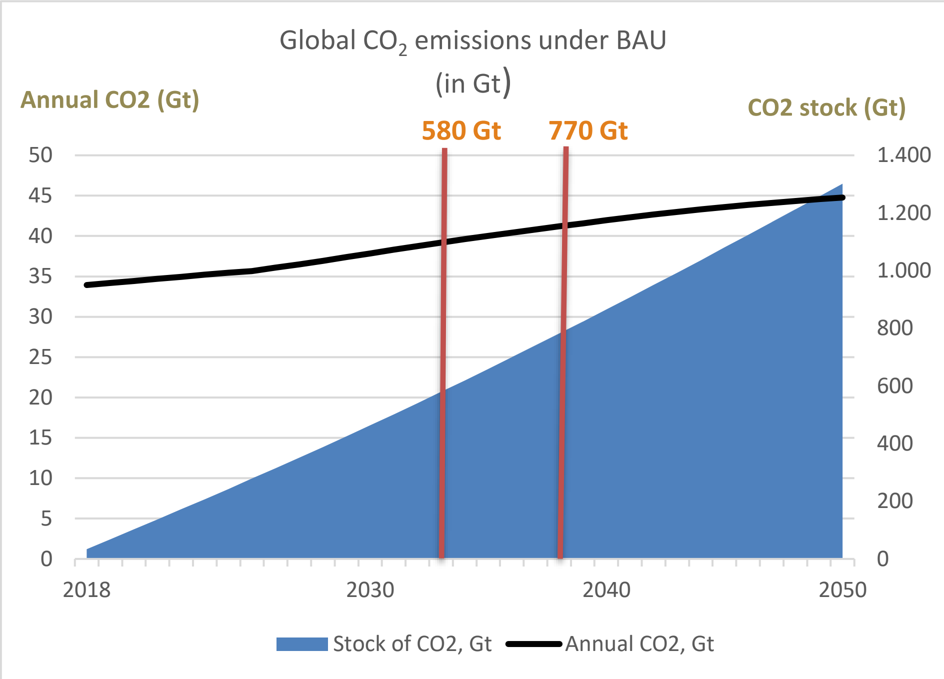
If current policies and trends in land and resource use continue, we would use up the remaining carbon budget by 2033-38 (14-19 years from now). By 2050, CO_2 emitted would be around 1,300 Gt – double the remaining budget (see 0). The cumulated CO_2 emissions of the European Union would be even greater (120 Gt instead of around 50 Gt) if we continue to act as usual.

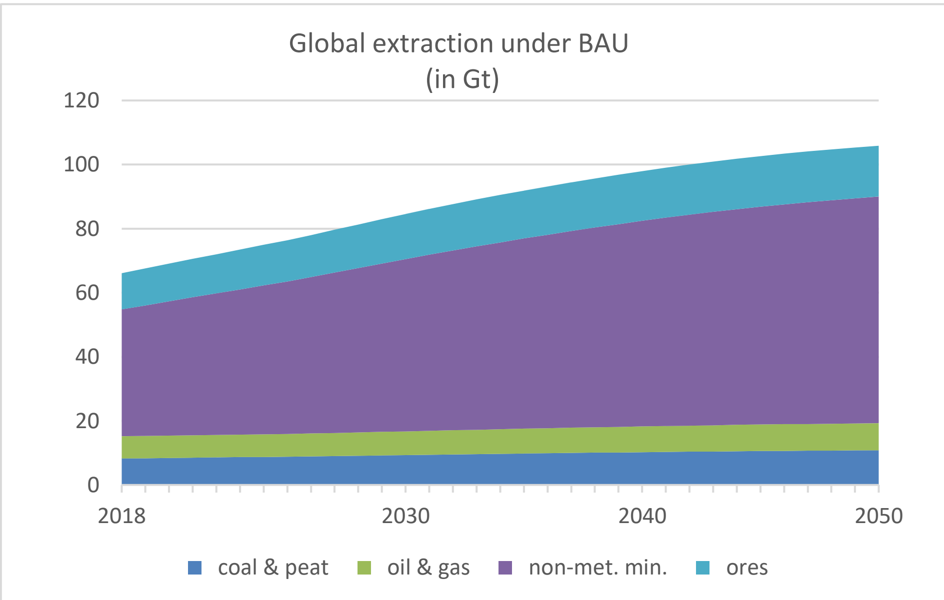
Figure 6. World annual and cumulative CO_2 emissions under the BAU Scenario



Source: own representation

The growth in global population (to 9.7 billion in 2050) and livestock to feed them, along with the lack of an ambitious climate and resource policy induces a rapid increase in demand for resources of all kinds (from fossil fuels to agricultural land). As can be seen from the following figure, global resource use would increase from 66 Gt today to 106 Gt by 2050, if we continue to act as now. While the material categories coal and peat, oil and gas as well as ores remain nearly constant, there would be a substantial increase in use of non-metal minerals.

Figure 7. Global extraction of abiotic resources in the BAU Scenario



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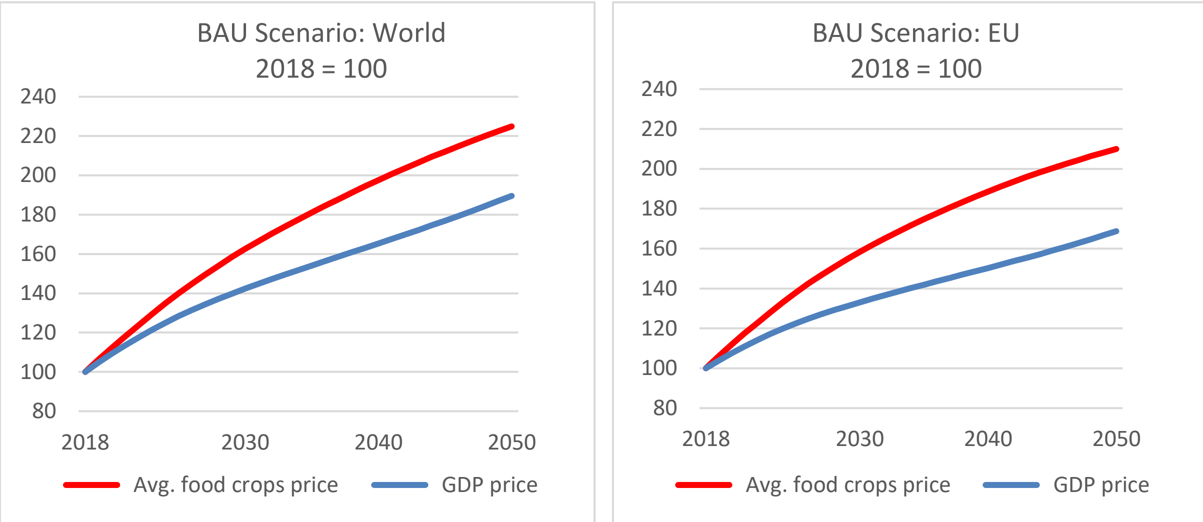
Rising demand would lead to increasing resource scarcity and a rapid rise in commodity prices, which would in turn lead to higher living costs, the effects of which would fall more harshly on low-income sections of society. This could lead to a substantial increase in levels of poverty.

The expected increases in average food crops prices (compared to average GDP prices) can be seen in the following figure.

Figure 8. Price developments in the BAU Scenario



Source: own representation

As no efforts would be made to reduce the consumption of fossil fuels (beyond market dynamics in response to price increases), the global emissions trajectory leading would set the world on course for at least 3°C of warming. As such an increasing incidence of climate change-related events, along with conflict over scarce global resources, would definitely exacerbate economic and social strife (see e.g. IPCC, 2018).

3 The global meetPASS Scenario

While the BAU (business as usual) Scenario represents a world in which the historically observed dynamics and behaviours of the different actors do not change in the forecast period, the meetPASS Scenario represents a world in which the Paris agreement transforms into ambitious climate policy action around the world.

The storyline behind the meetPASS Scenario is described in Working Paper 3. It formed the basis for the derivation of a set of measures that we summarise briefly below.

3.1 Overview of measures

Climate policy is assumed to include a substantial increase of the carbon price in the emission trading system, which would be extended to a world-wide system by 2020 in all industries. In addition, a regulation of the share of renewables in electricity production would ensure that, by 2050, in most countries 100% of electricity would be produced by means of renewable resources. This policy would be supported by feed-in tariffs and green certificates. Additionally, we assume a stepwise phase-out of nuclear energy in the EU up to 2050 and worldwide up to 2060.

In **transport**, set of regulations and economic instruments would also be introduced favouring e-mobility. We foresee an introduction of binding emission standards for new cars and taxation of fossil fuel burning engines, which would be used to subsidise the use of hybrid and electric cars, so that industries and households overall are not adversely impacted. Furthermore, the use of electric cars in cities would be promoted via better parking conditions, exemptions from city taxes, etc. All subsidies on air and water transport would be reduced linearly, and phased out completely by 2030, while taxes on air transport services would increase linearly by 50% in the period to 2050.

With regard to **housing and living**, subsidies for investment in the energy efficiency of buildings should ensure that higher renovation rates are reached. All new buildings would be at least nearly zero-energy, and many would produce energy (energy-plus houses) and would be highly material efficient. 100% of non-hazardous construction and demolition waste would be recycled.

For the required deep **decarbonisation pathway**, it is necessary to add measures from other areas, like **resource policy** (e.g. regulation for recycling of ores and non-metallic minerals, upstream tax on ores and non-metallic minerals and a public innovation fund for material efficiency) and agricultural policy (e.g. information programmes to avoid food waste and reduce meat consumption). These additional policy measures form part of the aim to stay within the planetary boundaries (see Steffen et al. 2015) and within the carbon budget levels derived in Working Paper 3 and discussed briefly in Chapter 1 of this paper.

Thus, it is crucial to link resource policy more closely with climate protection and the implementation of the Paris Climate Agreement. IPCC (2014) emphasises that an ambitious resource policy is an important climate change mitigation strategy and a report by the International Resource Panel (IRP, 2017) shows that without an ambitious resource policy the 2.0 or 1.5 degree climate target cannot be achieved (cost-effectively) (UNEP 2016).

Since the 1.5°C aim is very ambitious, we have to assume that the intrinsic motivation of individuals and households would lead to a structural change in the economy to such a degree that the ambitious environmental targets are achieved. Behavioural changes would alter the structure and volume of consumption, reducing environmentally harmful commodities like consumer durables; high-carbon, material-intensive transport; and meat consumption. Furthermore, employees would seek to reduce the number of hours worked in the formal economy, inducing an increased share of part-time employment.

Thus, the scenario also assumes that NGOs and businesses would drive decarbonisation through **voluntary changes** in preferences and behaviour. A comprehensive policy programme would facilitate such **lifestyle changes** using the aforementioned economic instruments, information campaigns and regulations.

3.2 Relevant assumptions and settings

In the following we describe the relevant assumptions for the measures that we have derived for meeting the 1.5° C target. The parametrization of direct and indirect impacts of many of the different policy measures derive from Wilts et al. (2014).

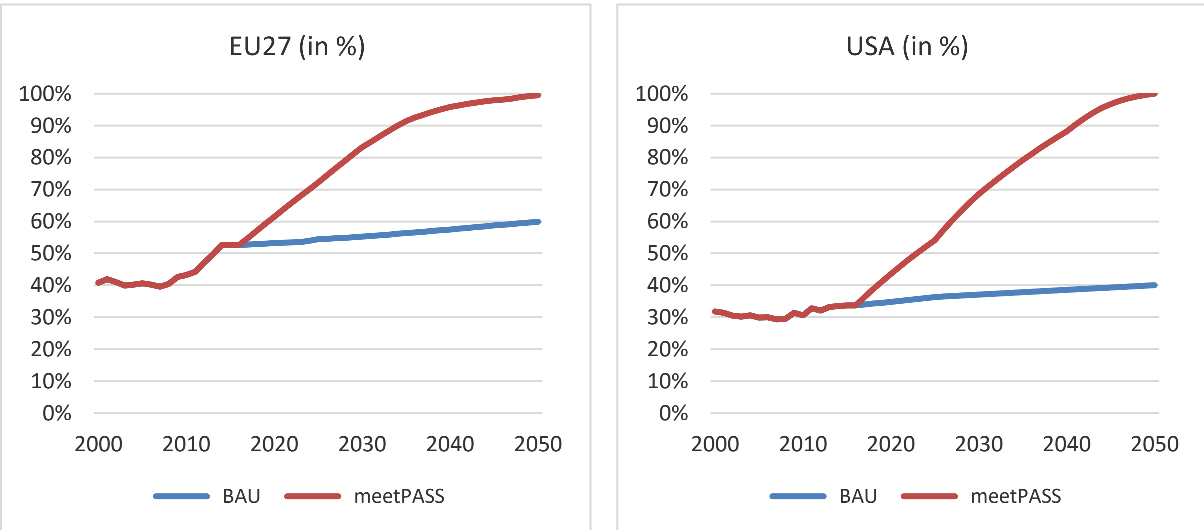
3.2.1 Energy related assumptions and settings

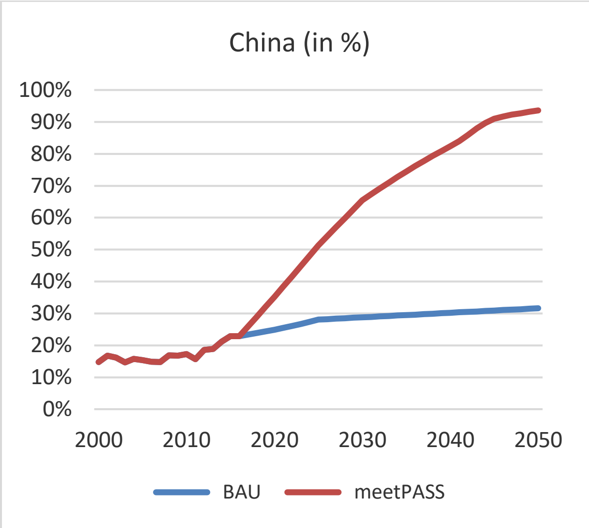
Electricity generation

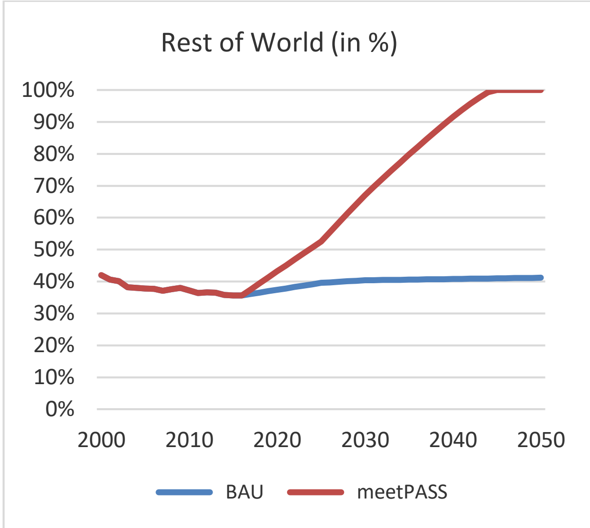
We have already explained that the development of the energy system and the electricity generation in the BAU Scenario is based on the “Current Policies Scenario” of the IEA. For the meetPASS Scenario we have applied the “Sustainable Development Scenario” of the IEA, which is consistent with the aims of the Paris Agreement. For the evolution of the share of carbon-free electricity generation this would imply that electricity is produced nearly carbon free in 2050. Figure 9 illustrates the development of carbon-free power in the meetPASS Scenario in selected regions.

In addition to the “Sustainable Development Scenario” we have assumed a nuclear phase out in the EU up to 2050 and worldwide up to 2060 (see also Tables 5 and 6).

Figure 9. Share of carbon free electricity generation in total electricity generation by scenario







Source: own representation

Fossil and carbon prices

The exogenous assumptions for fossil prices are derived from the World Energy Outlook 2017 (IEA 2017). Whilst the settings for the BAU Scenario refer to the "Current Policies" scenario, those for the meetPASS Scenario use the "Sustainable Development" scenario as source for parametrization. As the following table shows, these assumptions mean that the crude oil price would more than treble up to 2050 in the BAU Scenario. By contrast, in the meetPASS Scenario crude oil price is expected to peak in the mid-2020s. In the long run the scenario assumes a decrease in world market prices for crude oil as well as for coal.

In GINFORS these exogenous settings drive the development of gross output prices for the product groups "coal and lignite, peat" and "crude petroleum and natural gas" in the different countries and regions.

Table 3. Fossil prices by scenario

Real terms ($2017)			BAU				meetPASS			
		2017	2025	2030	2040	2050	2025	2030	2040	2050
Coal	$ per tonne	86.6	106.4	109.3	115.0	120.7	100.8	100.2	99.1	97.8
Crude oil	$ per barrel	51.2	105.2	119.3	147.4	175.6	90.1	87.2	81.4	75.9
Natural gas	$ per MBtu	5.0	7.7	8.5	9.9	11.4	7.2	7.5	8.0	8.5

Source: own representation based on IMF (2018) and WEO (2017).

In the meetPASS Scenario we assume that the carbon price would grow even faster and higher than in the "Sustainable Development" scenario of the WEO 2017. As Table 3 shows, by 2040 the EU's carbon price would reach 206 USD or 185 EUR (in 2017 prices). This value exceeds the respective assumption in the WEO 2017 by more than 40%. The rationale behind this excess is the character of the meetPASS Scenario: this scenario tries to find a model solution which goes as far as possible in achieving the COP21 goal – and this is not the case using the lower carbon prices of the WEO 2017. For non-EU countries and regions we have set a carbon price of starting at 10 USD or 9 EUR per tonne in 2021, reaching 225 USD or 202 EUR per ton in 2050.

In the BAU Scenario, we expect the carbon price in the EU to grow only very moderately (reaching just 40 USD2017 per tonne in 2050).

Table 4. Carbon price in the meetPASS Scenario

Real terms (USD2017)		2017	2025	2030	2040	2050
EU	$ per tonne	11.2	68.2	122.6	206.3	265.0
Other countries	$ per tonne	0.0	50.0	100.0	175.0	225.0

Source: own representation inspired by WEO, 2017.

Renewable energy (RE) expansion

Another important set of climate policy assumptions refers to the question of how power is generated. The following two tables summarise these assumptions for the EU and for the global level. Again, these specifications for the BAU Scenario as well as for the meetPASS Scenario are inspired by respective developments in the WEO 2017 scenarios. But there are also some important differences:

- In contrast to the "Sustainable Development" scenario of the WEO 2017, the faster shift towards climate neutral technologies in the meetPASS Scenario does not imply an expansion of nuclear power generation, neither in the EU nor worldwide. On the contrary, we assume a nuclear phase out in the EU up to 2050 and worldwide up to 2060
- In the meetPASS Scenario the expansion of RE technologies, in the EU as well as worldwide, is substantially faster than assumed in the WEO 2017 "Sustainable Development Scenario".

Table 5. Mode of electricity generation in the EU by scenario

EU27*		BAU				meetPASS			
	2017	2025	2030	2040	2050	2025	2030	2040	2050
Coal	26%	23%	19%	15%	10%	10%	5%	2%	0%
Gas & oil	19%	21%	24%	26%	29%	15%	9%	2%	0%
Nuclear	26%	19%	17%	16%	14%	15%	11%	3%	0%
Renewables	30%	37%	39%	43%	47%	60%	75%	93%	100%
Hydro	11%	12%	10%	12%	13%	17%	18%	20%	18%
Wind	10%	15%	17%	19%	21%	25%	33%	45%	51%
PV	3%	4%	5%	5%	5%	7%	9%	10%	10%
other RE	6%	7%	8%	8%	8%	12%	15%	19%	21%

* EU member states without Croatia

Source: own representation inspired by WEO, 2017.

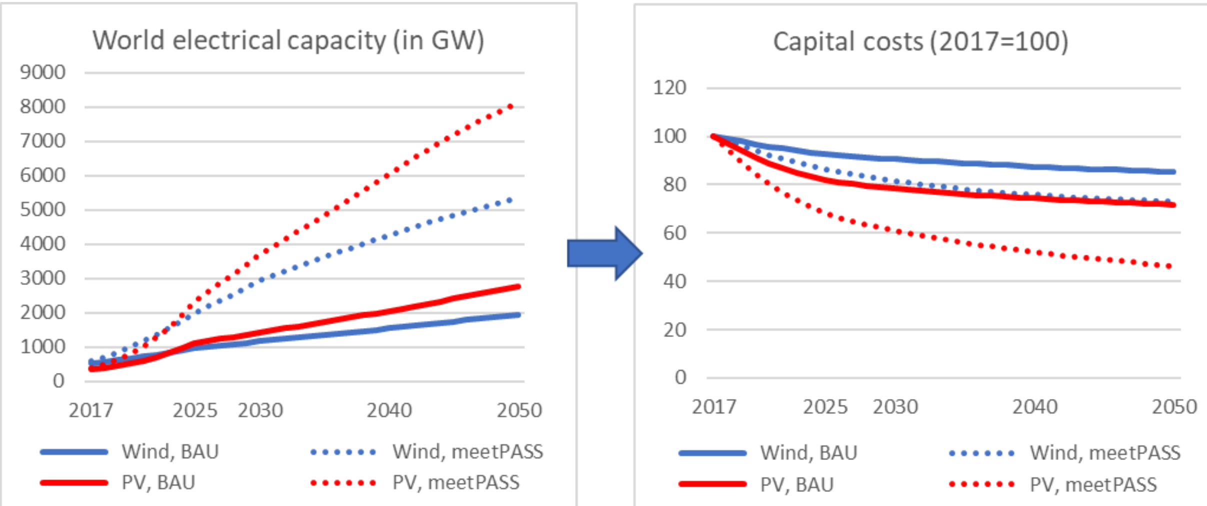
Table 6. Mode of electricity generation in the world by scenario

World		BAU				meetPASS			
	2017	2025	2030	2040	2050	2025	2030	2040	2050
Coal	40%	39%	38%	38%	37%	23%	14%	4%	0%
Gas & oil	27%	25%	26%	26%	27%	23%	19%	9%	3%
Nuclear	11%	10%	10%	9%	8%	10%	10%	9%	6%
Renewables	23%	26%	27%	27%	28%	44%	57%	78%	91%
Hydro	16%	15%	15%	14%	13%	21%	23%	26%	23%
Wind	4%	6%	6%	7%	7%	12%	17%	25%	32%
PV	1%	3%	3%	4%	5%	6%	10%	17%	24%
other RE	2%	2%	3%	3%	3%	4%	7%	10%	13%

Source: own representation inspired by WEO, 2017.

In terms of capacity, the meetPASS Scenario anticipates the highest growth rates for wind and photovoltaics, which also reduces capital costs – over the time as well as compared to the BAU Scenario (see following figure).

Figure 10.Wind & PV: World electrical capacities and capital costs by scenario



Source: own representation

E-mobility in road traffic

Sustainable transportation and mobility systems are crucial pre-conditions to achieve global climate targets. Combined with increased electricity generation from renewables, electro-mobility represents a viable means of achieving sustainable (urban) mobility. There is a worldwide trend toward electric vehicles, which is also considered in the meetPASS Scenario. In passenger as well as freight traffic the shares of e-mobility would rise considerably, as can be seen from the following table.

Table 7. E-mobility shares by scenario

			BAU				meetPASS			
		2017	2025	2030	2040	2050	2025	2030	2040	2050
Passenger traffic	EU27* & industrialized countries	0%	1%	2%	5%	9%	6%	12%	36%	72%
	Other countries	0%	1%	1%	3%	6%	5%	9%	27%	54%
Freight traffic	EU27* & industrialized countries	0%	1%	1%	3%	6%	4%	8%	24%	48%
	Other countries	0%	0%	1%	2%	3%	3%	6%	18%	36%

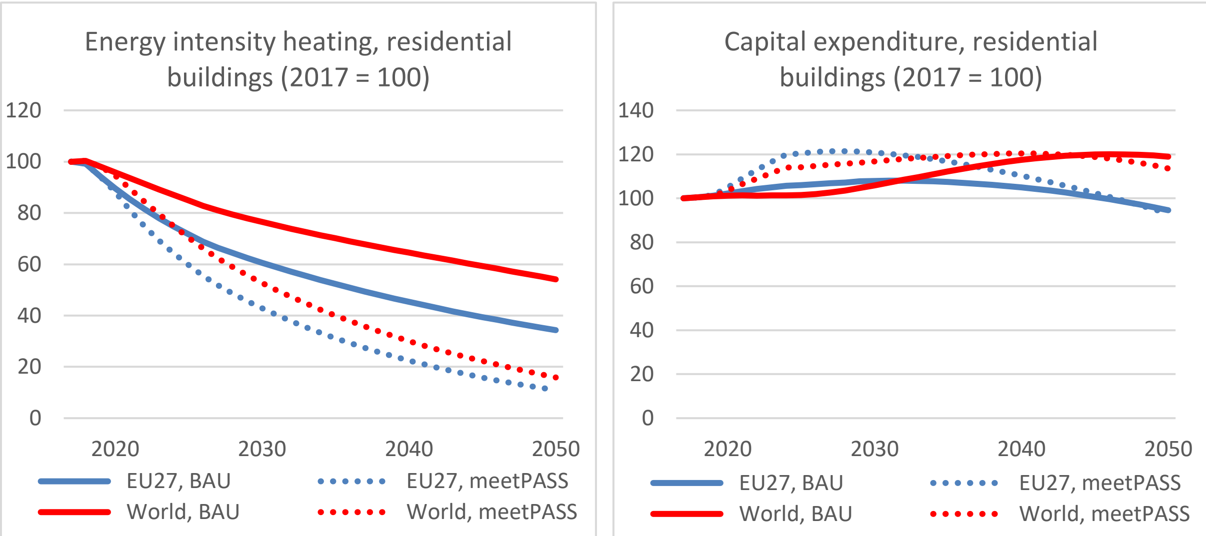
Source: own representation

Fostering energy efficiency

With regard to energy efficiency improvements of residential and office buildings, we assume that both in the EU and globally, public initiatives (e.g. credit programmes) would incentivise upgrades to building energy performance so as to double existing renovation rates (to 3%). However, this would require substantial investments. Based on Prognos (2013), we assume annual investments of 60-90 billion EUR per year in the EU.

The following figure compares the respective developments of **energy intensity for residential buildings** in the EU and globally in the two scenarios.

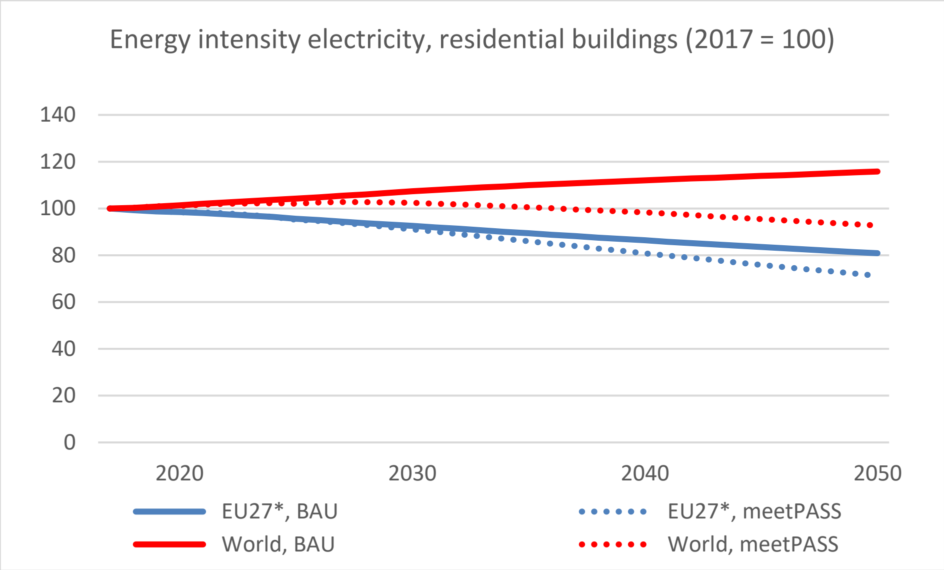
Figure 11.Residential buildings: Energy intensity, heating and capital expenditures by scenario



Source: own representation

The meetPASS Scenario also assumes additional improvements in the **energy intensity of electricity**, compared to the BAU Scenario. The following figure shows the respective developments in the EU and globally. But in contrast to the heating case, no assumptions for additional investment needs have been made, since these are more likely to be replacement investments that augment energy efficiency (e.g. the broken refrigerator will be replaced by an efficient one instead of a bigger one).

Figure 12.Residential buildings: Energy intensity of electricity by scenario



Source: own representation

3.2.2 Resource-related assumptions and settings

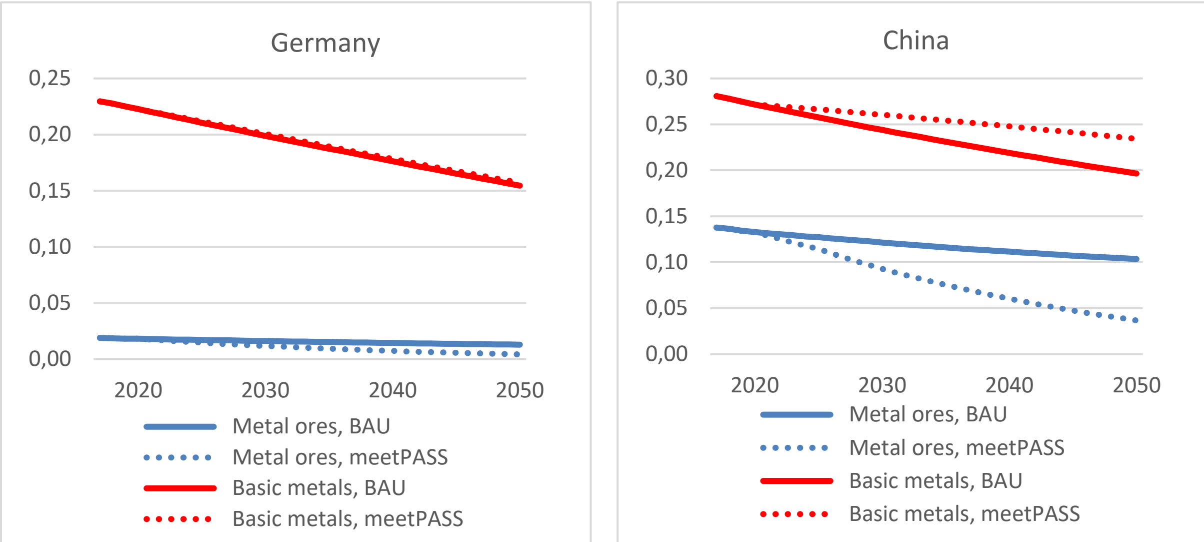
The scenarios also require a shift to a so-called “circular economy”, such as promotion of a sharing economy, greater emphasis on repair and remanufacturing, higher rates of recycling and more efficient (zero-waste) production methods.

Metal ore & non-metallic mineral recycling

The meetPASS Scenario assumes that by 2050 half of the primary metal ore inputs in basic metal production would be substituted by secondary metal ores.

The following figure shows the implications on input coefficients of the basic metal manufacturing in Germany and China. While the difference between the BAU and the meetPASS Scenario is rather minor in Germany, metal ore recycling has a greater impact in China.

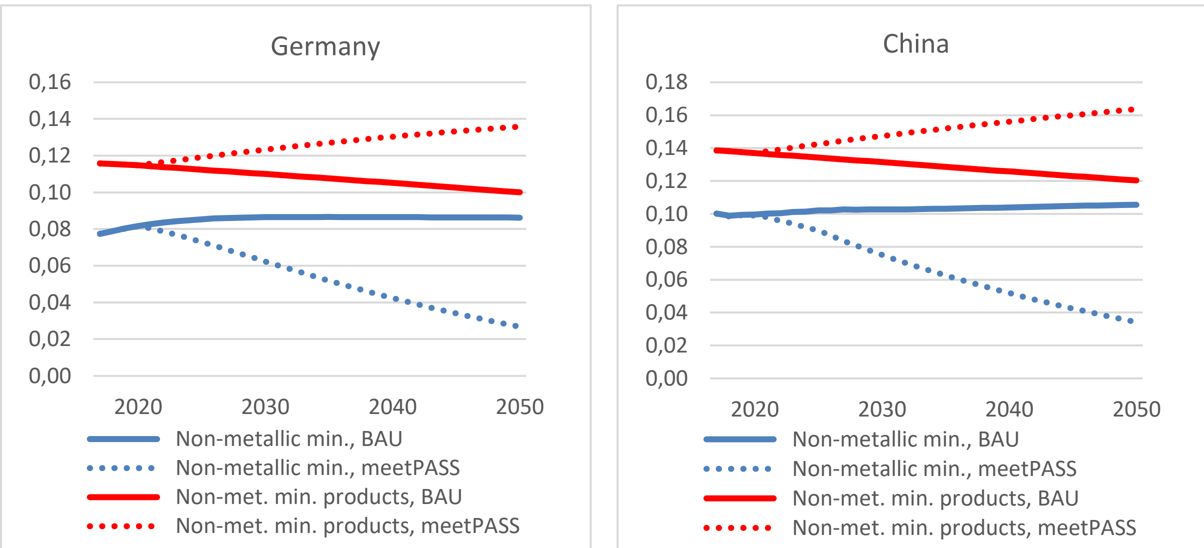
Figure 13.Examples for parametrisation of increased metal ore recycling



Source: own representation

The same assumption is made in the meetPASS Scenario for the substitution of primary non-metallic minerals by secondary non-metallic minerals in the manufacturing of other non-metallic mineral products. Again, the figure provides the examples of Germany and China. In contrast to metal ores, this triggers strong recycling efforts in Germany, where current recycling rates of non-metallic minerals are lower than for metals.

Figure 14.Examples for parametrisation of increased non-metallic mineral recycling



Source: own representation

Upstream tax on metal ores and non-metallic minerals

The meetPASS Scenario assumes a global upstream tax on the use of primary metal ores and primary non-metallic minerals in production. The tax rate would increase linearly from 0% in 2020 to 25% in 2050.

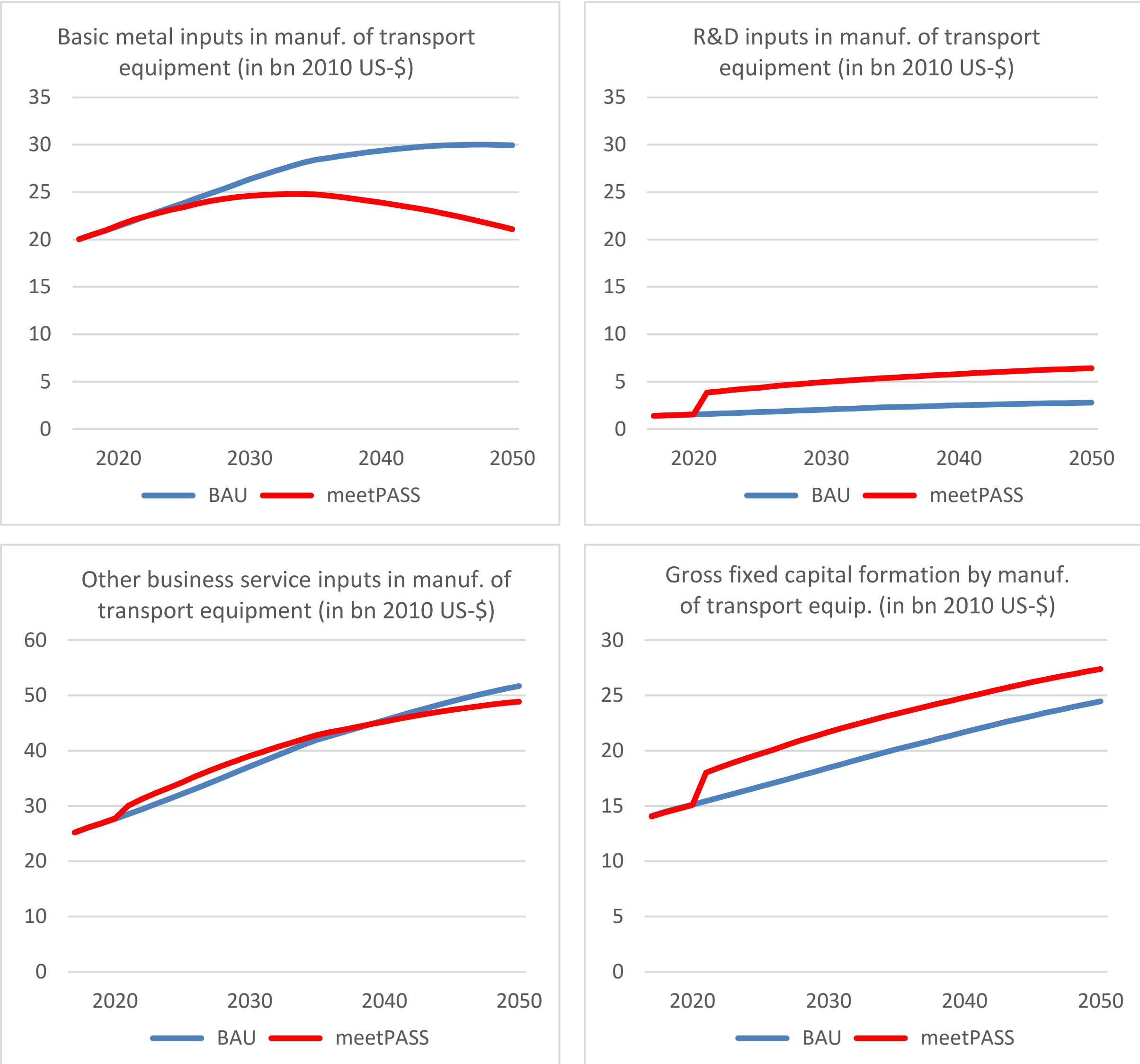
Information programme for fostering resource efficiency in manufacturing

Consultants' expertise suggests that considerable raw material inputs in manufacturing could be saved if a profound and detailed information programme for fostering resource efficiency could be established (see e.g. Arthur D. Little et al., 2005 and Hollins, 2011). In setting the parametrisation of this policy measure for the meetPASS Scenario, we incorporated findings of our earlier projects including POLFREE (see Meyer et al., 2015) and the German SimRess-project (see Distelkamp and Meyer, 2018). Compared to these precursor projects, the assumptions for the impacts of the information programme in the meetPASS-project are quite conservative, since:

- The efficiency improvements cover only a narrow selection of 50 technologies (input-coefficients).
- The potential improvements in resource efficiency with regard to the selected technology are rather low (+ 1% p.a.).
- The assumed costs, which are necessary to harvest the efficiency gains, are rather high (two times the achieved savings of one year for research & development expenditures, one time the achieved savings of one year for consultancy expenditures and two and half times the savings of one year for capital expenditures).

One of the 50 technologies with assumed efficiency improvements is the intermediate use of basic metals in manufacturing of transport equipment. For this technology (input-coefficient), Figure 15 shows the respective parametrisations for Germany.

Figure 15. Example for parametrisation of the information programme for Germany



Source: own representation

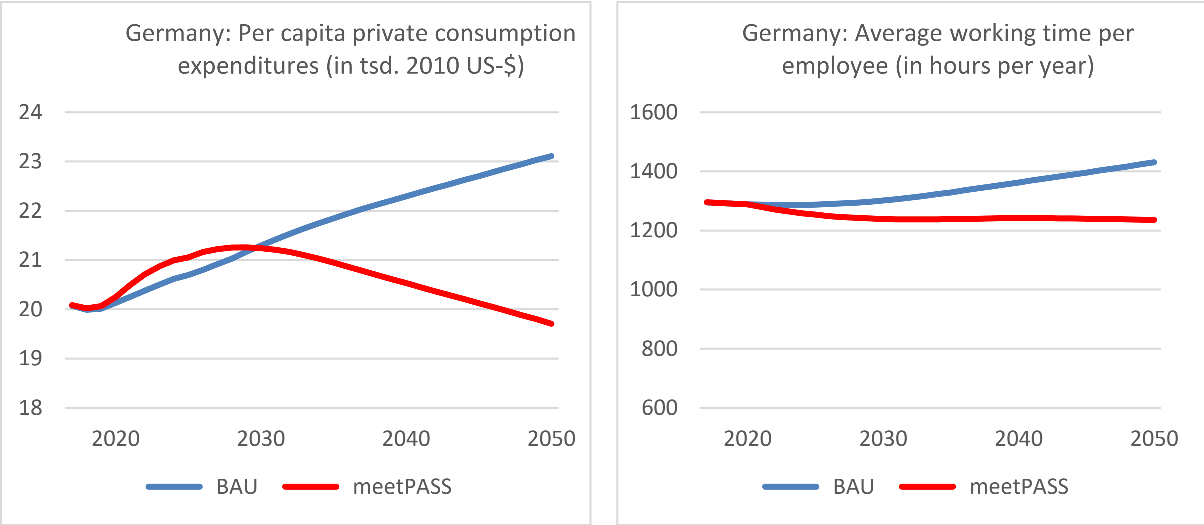
3.2.3 Lifestyle-related assumptions

Changes in lifestyle, consumption habits and working time

Up to this point the instruments and assumptions predominantly address a more efficient handling of natural resources, whether this is achieved by price signals, by regulatory interventions or by information programmes. In addition, we assume that more and more people **reduce their working hours** and therefore would also **decrease their consumption expenditures**, as they come to value the gains in leisure time more than the losses in (material) consumption. We applied this assumption **for industrialised countries** only.

Regarding the speed of transformation, we assume a gradual shift in working hours such that by 2050, working hours would be 20% lower than in the BAU Scenario. Figure 16 shows the implications of these assumptions in Germany.

Figure 16.Implications of an increase in leisure time under meetPASS, Germany



Source: own representation

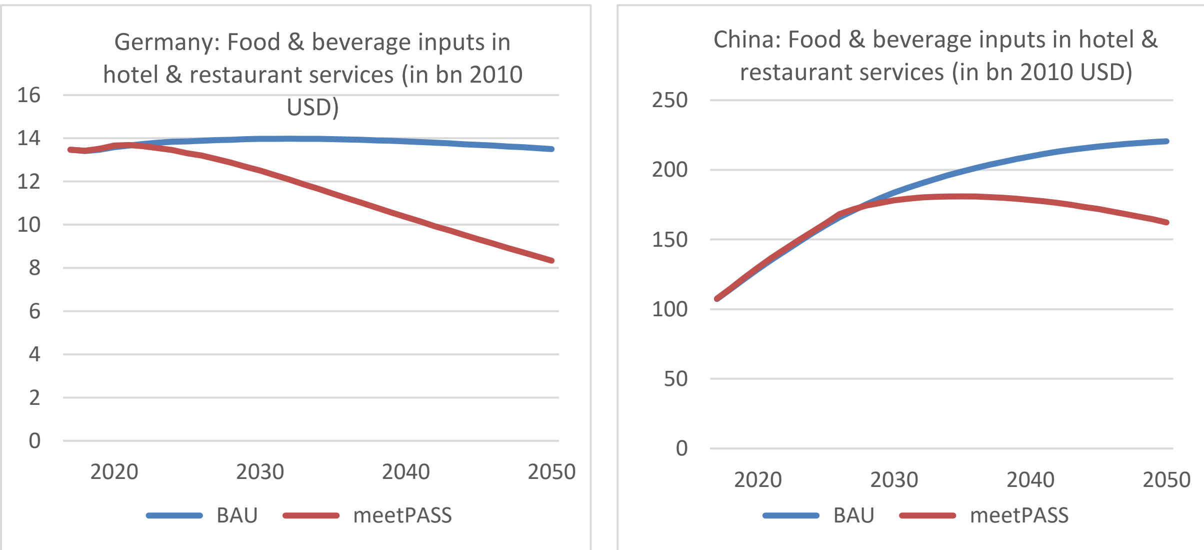
Fostering sustainable dietary habits

We made two assumptions with regards to dietary habits in the meetPASS Scenario.

The first one regards **food waste**. The Scenario assumes that within the next three decades, it would be feasible to achieve a 10% reduction in food waste at each stage (biomass inputs in food production, food & beverage inputs in restaurant services, final consumption expenditures for food & beverages) without a reduction in quality.

The following figure shows the development of food & beverage inputs (in billions of 2010 USD) in hotel & restaurant services in Germany and China.

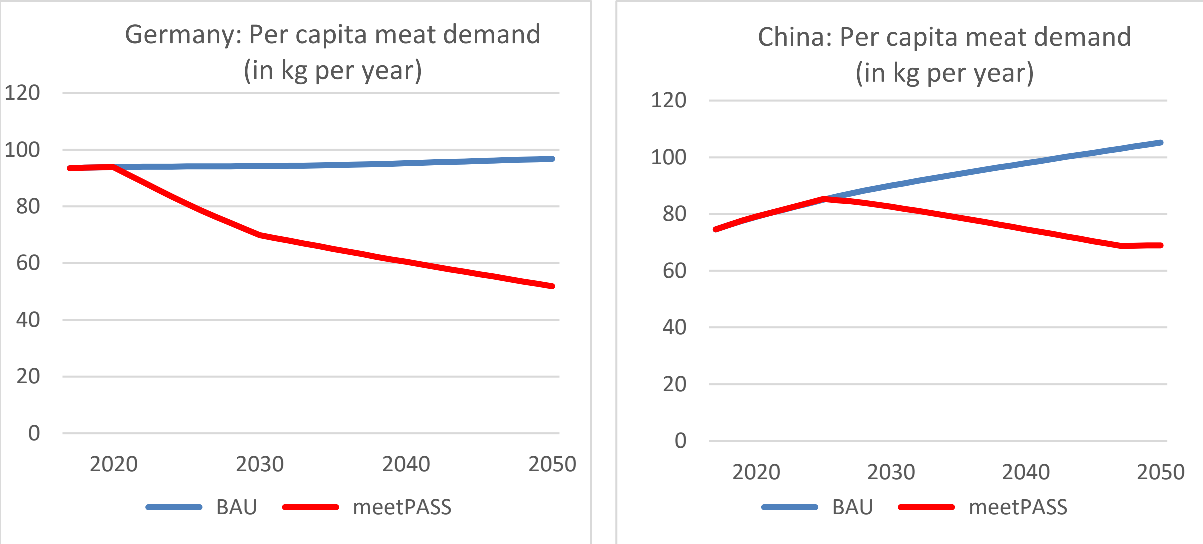
Figure 17.Example #1 for parametrisations of more sustainable dietary habits



Source: own representation

The second assumption concerns the **per capita meat demand**. Here, the meetPASS Scenario assumes a growth rate 2-3 percentage points below the BAU Scenario. As the following figure for Germany and China shows, this assumption leads to considerable reductions in per capita meat demand (in kg per year) in both countries. However, in some developing countries, meat consumption would continue to rise towards the global median

Figure 18.Example #2 for parametrizations of more sustainable dietary habits



Source: own representation

3.3 Results of the meetPASS Scenario

The policy measures included in the meetPASS Scenario support three transitions indispensable for meeting the climate and sustainable development targets: an energy transition, a resource transition and a lifestyles transition.

3.3.1 Energy transition

An important part of the required energy transition is the **substitution of fossil fuels by renewable energy sources**. Central to this goal is an increase in CO_2 prices, rising gradually to reach 200-240 EUR per tonne by 2050. This is a tenfold increase compared to the 20 EUR per tonne price under the European Union's current Emissions Trading Scheme (EU ETS). Moreover, the price would have to be set globally (as yet, such a system does not exist). The later countries decide to follow such a path, the faster prices would have to rise to reach the overall target.

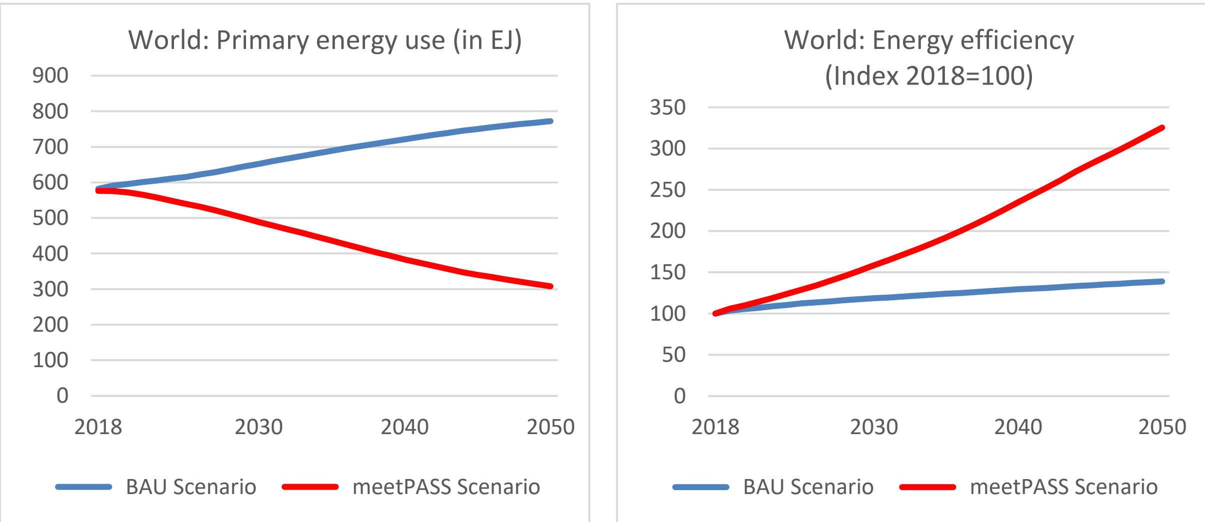
If emissions are to reach net-zero by 2050 then virtually all **electricity** would also have to be produced **carbon-free**. The meetPASS Scenario assumes that upstream carbon taxes or a cap-and-trade system would be complemented with regulations to ensure that at least 90% of electricity is produced with renewable energy by the end of the period (and 100% within the EU). Since this would help to make wind and solar PV more competitive compared to both fossil fuels and nuclear, it also assumes a **nuclear phase out** in Europe by 2050 and in the rest of the world by 2060.

As the power sector decarbonises, the **electrification of transport** can further help to accelerate the transition away from fossil fuels. Here, meetPASS assumes that a combination of policies such as vehicle emissions standards, fuel taxes and various subsidies and incentives (to offset the burden on households) result in almost three-quarters (72%) of passenger transport in Europe becoming electric by 2050, and almost half (48%) of all freight transport. The respective numbers for rest of the world are 54% (passenger) and 36% (freight).

The final element of the energy transition is greater **efficiency**. While a higher carbon price should encourage more efficiency overall, to shift completely from fossil fuels and offset any negative effects on households (especially where gas is used in central heating) a combination of policies to incentivise building upgrades and new building regulations should ensure that by 2050, most buildings are either energy-neutral or energy-positive (generating more than they use). However, this would require significant investments, essentially doubling current innovation rates and entailing up to a 20% increase in spending (first in Europe, later elsewhere).

Globally, energy efficiency in the meetPASS Scenario would increase at a considerably faster pace than in the BAU Scenario, leading to a reduction in primary energy use from around 580 EJ[7] in 2018 to 310 EJ in 2050, while in the BAU Scenario the primary energy use would continue to increase from 580 to 770 EJ (see Figure 19).

Figure 19.World primary energy use and energy efficiency by scenario

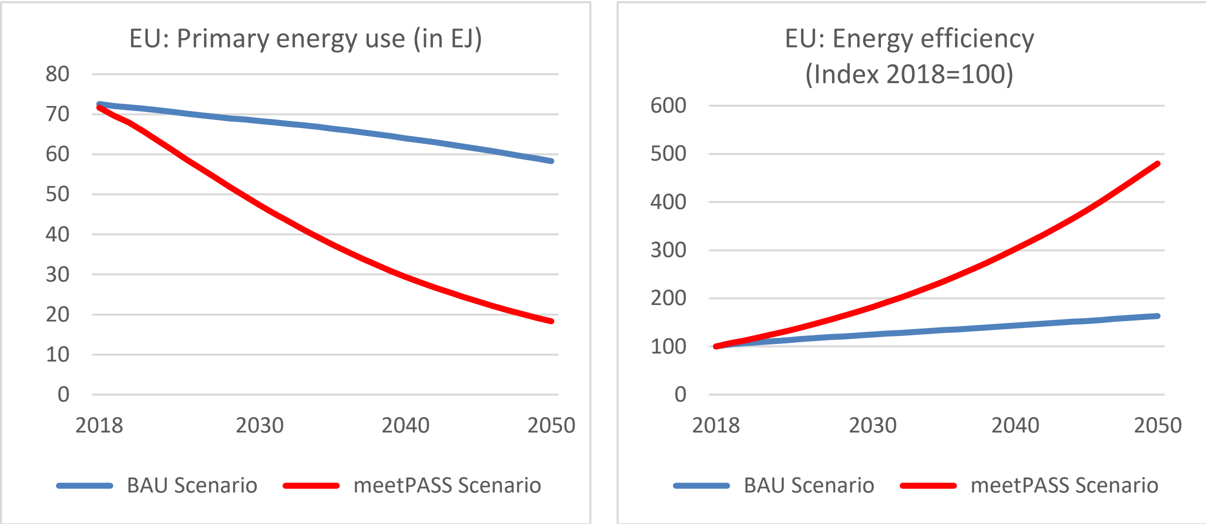


Source: own representation

As Figure 20 shows, the increase in energy efficiency in the meetPASS Scenario is even stronger in the European Union. Energy efficiency in the BAU Scenario develops broadly inline with the global trend. However, while global primary energy use in the BAU Scenario increases, in the EU, it falls gradually, indicating a decoupling of GDP and energy use.

[7] EJ = Exajoule = 1000 Petajoule

Figure 20. EU primary energy use and energy efficiency by scenario



Source: own representation

3.3.2 Resource transition

A credible decarbonisation strategy in line with the 1.5°C target must go beyond current energy efficiency and renewable energy policies by applying a more comprehensive approach, taking into account the resource input perspective. Behrens (2016) points out that GHG emissions account for over 80% by weight of global material output (not taking into account additions to stocks). Thus, he concludes that “the key to reaching ambitious climate change targets will be to shift the focus to promoting higher resource productivity, to increasing recycling and reuse rates, and more generally to reducing the overall consumption of material inputs. This will lead to immediate reductions in GHG emissions” (Behrens, 2016).

Core to the resource transition is **higher virgin material prices**. The meetPASS Scenario foresees an upstream tax on metal ores and non-metallic minerals, rising to 25% by the end of the period. Complemented by **higher recycling targets** and capabilities, by 2050, secondary materials should replace half of primary materials in production.

As with the energy transition, taxes alone will be unlikely to achieve a sufficiently swift transition; nor is recycling (which also requires energy, water and can create pollution) the only answer to greater resource efficiency. For example, remanufacturing, whereby producers reclaim, refurbish and then resell or lease products can save up to 99% of both materials and emissions (IRP, 2017). What is important, is that manufacturers have **access to the right skills and expertise**.

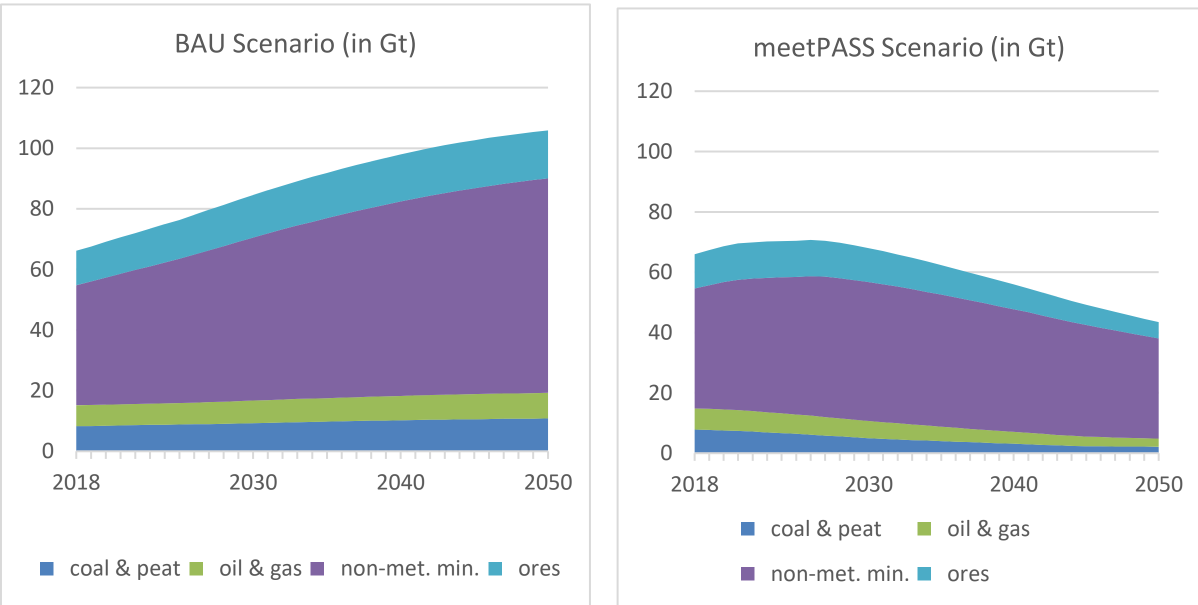
Taking all measures together, global abiotic resource consumption (measured by the indicator RMC[8]) would reduce from 65 Gt in 2018 to 43 Gt in 2050. In the BAU Scenario, however, resource use would increase to 106 Gt in 2050 (see Figure 21). The per-capita resource consumption ($RMC_{abiotic}$ per capita) would fall by 59% globally and 70% within the EU in the meetPASS Scenario, compared with an expected BAU increase of 20% worldwide.

[8] **Raw material consumption (RMC)** measures the total amount of raw materials required to produce the goods used within the territory of the economy (also called 'material footprint').

It is important to note that these figures refer only to raw abiotic materials. In 2018, the portion of biotic materials in total material consumption (TMC) was around 40% (IRP, 2019). This implies that, should this portion stay constant over the forecast period, then the resource target of 45 Gt and 5 t/capita/year of TMC would not be achieved. While further analysis of biotic materials was outside of the scope of the meetPASS project, it assumed that biotic materials would not replace abiotic materials to the extent that any material gains would be offset by great stress on biotic sources (e.g. leading to deforestation). Nonetheless, to meet the 45 Gt TMC target would require further dematerialisation measures, for both abiotic as well as biotic resources, than those included in meetPASS.

Resource productivity – the monetary earnings for each unit of material -- would also improve significantly in the meetPASS versus BAU Scenario, rising by a factor of 3 worldwide and by 4 within the EU.

Figure 21. Global extraction of abiotic resources by scenario

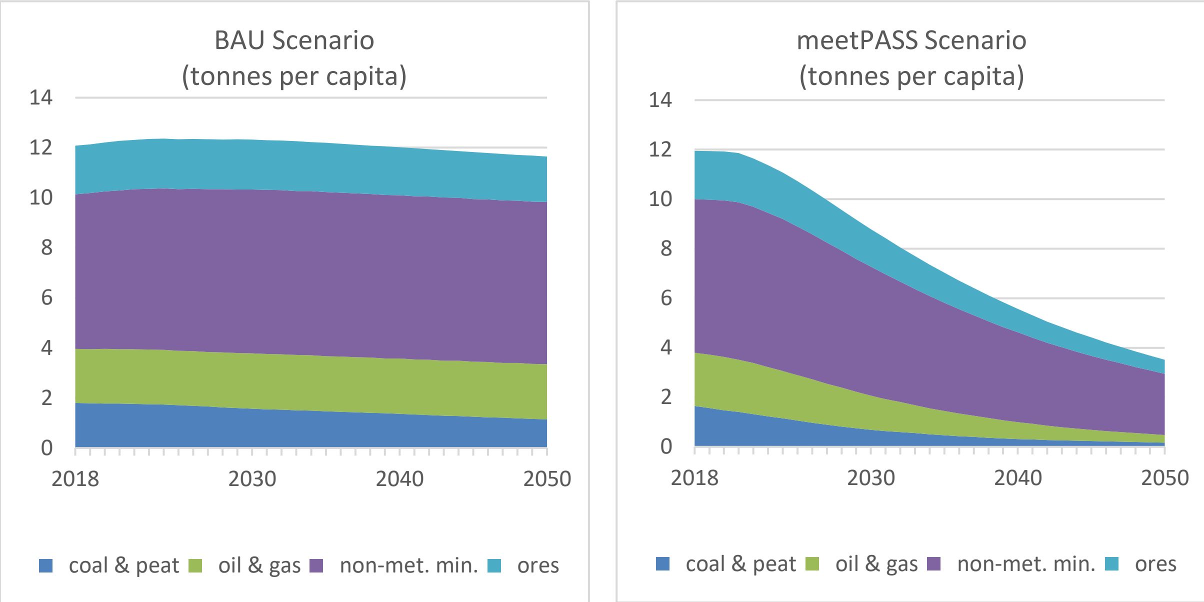


Source: own representation

The following figure shows the EU material footprint (Raw Material Consumption - RMC) of abiotic resources on a per capita basis for the BAU and the meetPASS Scenarios.

Without additional measures the per capita material footprint would only reduce slightly, while the meetPASS policies would lead to a strong decrease of per capita $RMC_{abiotic}$ from 12 tonnes in 2018 to 3.8 tonnes in 2050.

Figure 22. EU material footprint [RMC] of abiotic resources by scenario



Source: own representation

As with CO_2 emissions, there are both production- (i.e. extraction) and consumption-based (i.e. footprint) approaches for measuring material use. In the EU, the difference between domestic extraction[9] and material footprint is substantial (see Figure 23). In the BAU Scenario both indicators would not alter significantly over time and the material footprint would remain around 2 Gt higher than the figure for domestic extraction. In the meetPASS Scenario, however, the footprint would gradually fall to the level of domestic extraction by 2050.

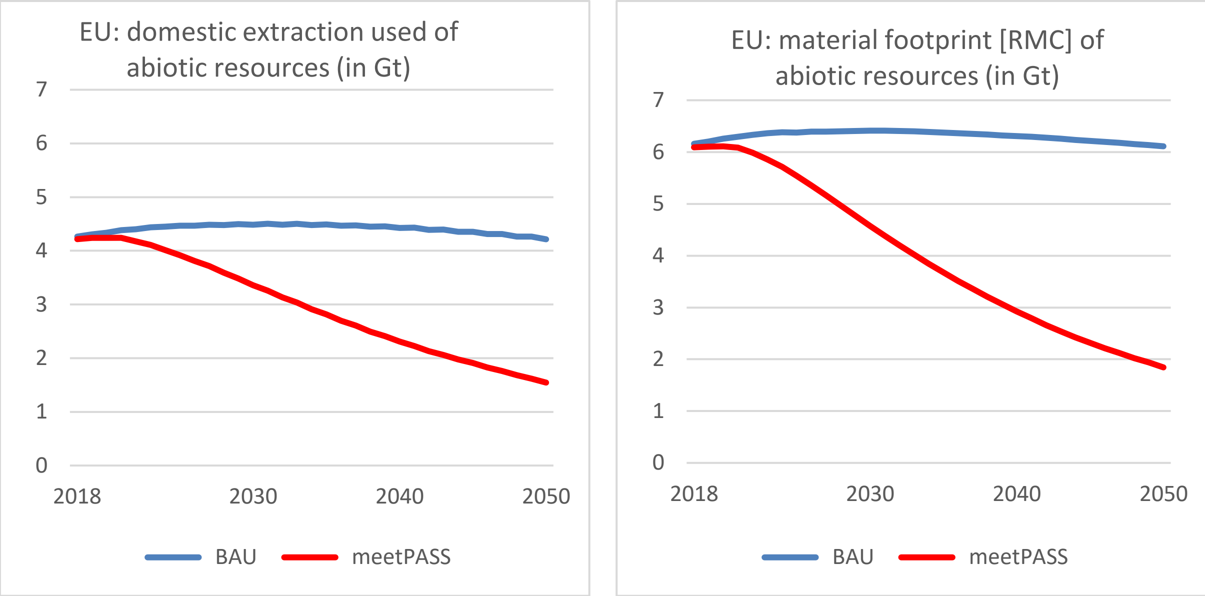
[9] **Domestic extraction** is the amount of raw material, extracted from the natural environment for use in the economy.

Raw material consumption = Raw material input - Exports in RME.

Raw material input (**RMI)** is the amount of raw materials required to produce the goods which are available for use in production and consumption activities of the economy.

Exports in RME are the amount of raw material required to produce the goods exported from the economy.

Figure 23. EU domestic extraction used and material footprint [RMC] of abiotic resources by scenario



Source: own representation

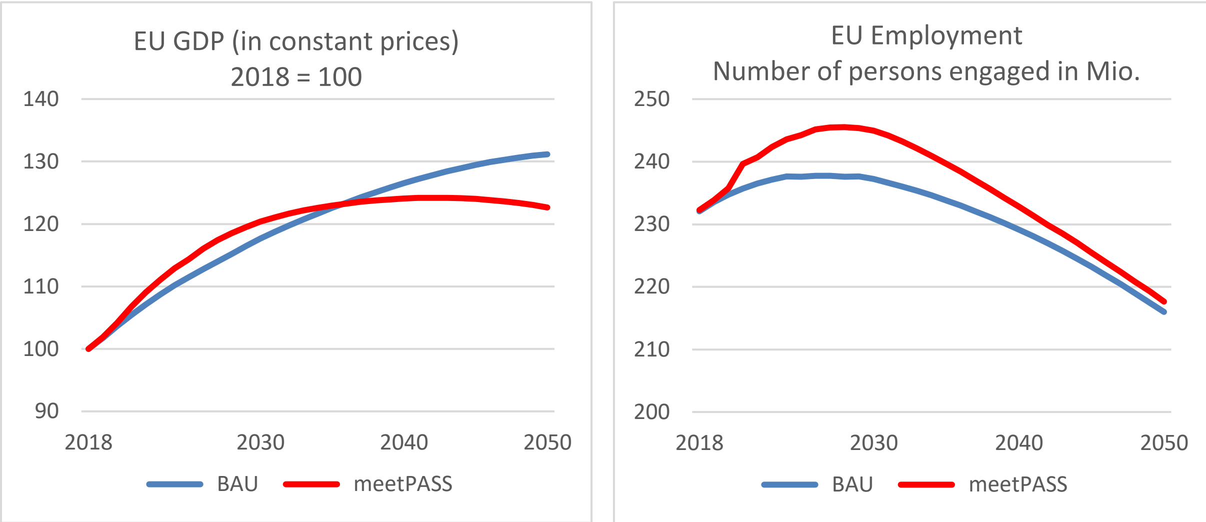
3.3.3 Lifestyles transition

Even an ambitious resource and energy transition cannot guarantee that the world would meet the 1.5°C target. It is important that households and businesses be intrinsically motivated to make changes to their consumption and production habits – not least to limit rebound effects from greater energy and resource efficiency. A final and important transition would have to take place within and across cultures and societies. These changes would not happen without policy interventions, however.

A key element is the decision by more and more people to **reduce their working hours**. Substituting some income for more leisure time would result in a drop in (material) consumption. We apply this assumption for industrialised countries only, envisaging that the average working week per employee would fall by 20% against a BAU Scenario.

The assumed **reduction in consumption habits** would negatively affect the development of GDP. In the European Union, GDP is higher in the BAU Scenario than in the meetPASS Scenario (after 2035). However, employment is higher in the meetPASS Scenario. This results from the assumed reduction in working time.

Figure 24.Development of GDP and employment in the EU27 (in current prices)



Source: own representation

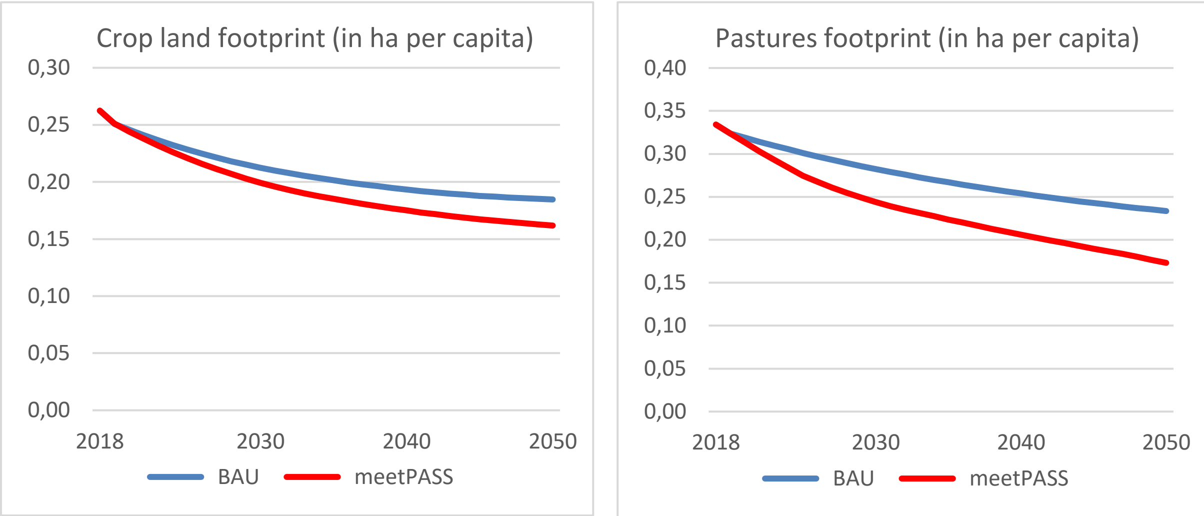
The meetPASS Scenario also contains two important assumptions about **dietary habits**. On food waste, the model assumes that the next three decades would see a reduction of waste by 10% within each stage of the food supply chain: in food production (compost, fertilisers etc); in food processing and in restaurant and catering services; and in households.

It also assumes that people would cut their meat intake, resulting in a global growth rate that is 2-3 percentage points lower than in the BAU Scenario. In many markets, meat consumption would fall overall, and most strongly in developed and in EU markets (in places by up to 50%).

These measures would reduce the footprints for cropland and pastures[10] compared to the BAU Scenario, as can be seen from the following graphic for the EU. In the meetPASS Scenario, the EU would come close to the land-use target of 0.15 ha per capita cropland footprint and would also reduce its pasture footprint to close to 0.15 ha per capita.

[10] Croplands and pastures have become one of the largest terrestrial biomes on the planet with around 40% of the terrestrial surface whereas the intensification of cropland covers alone around 12% (Foley et al., 2005). The cultivation of agro-fuel plants on large plantations for bio-energy demands versus food production and biodiversity is a major driver of land system change (Lutzenberger, 2015).

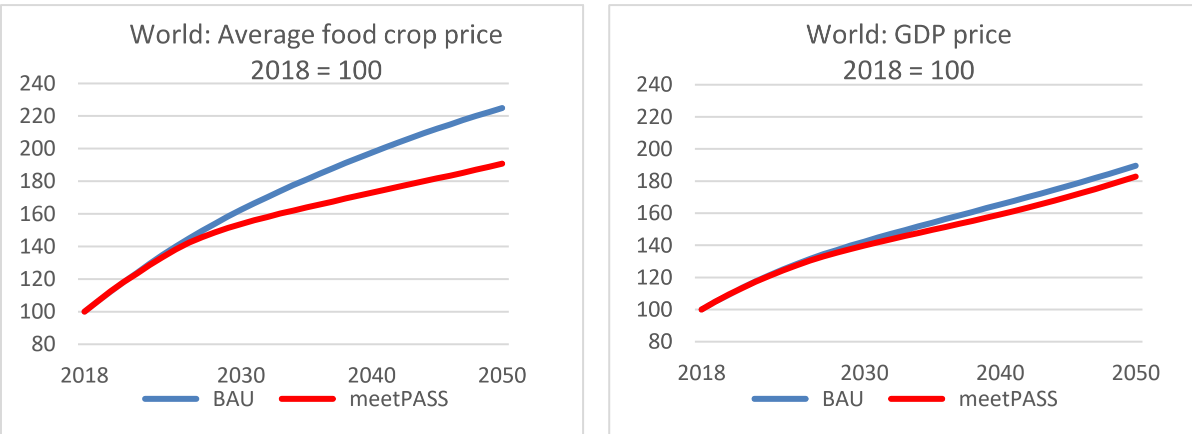
Figure 25. EU land footprints by scenario

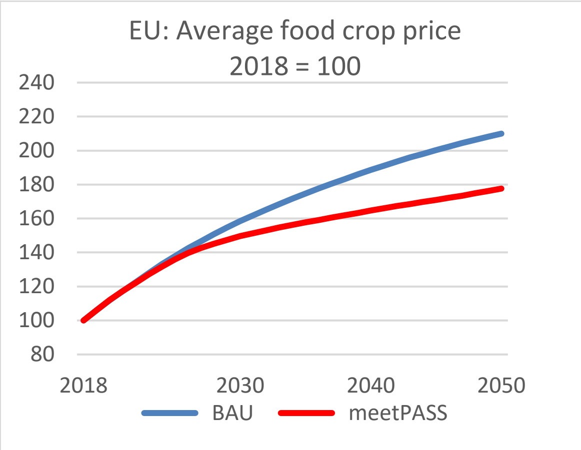


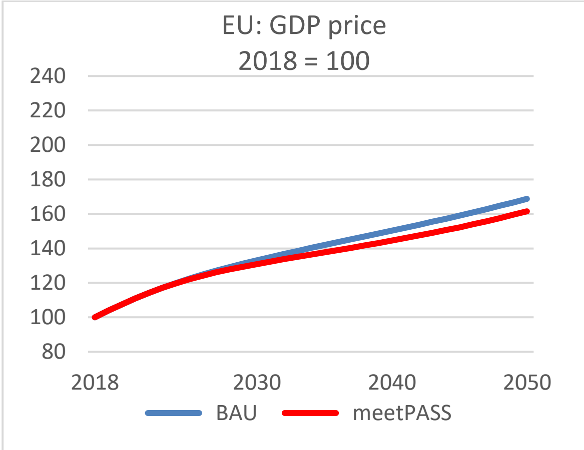
Source: own representation

The following figure shows the development of the food crop price in both scenarios: global, and in the European Union. While the GDP price in the BAU Scenario only slightly exceeds the GDP price, in the meetPASS Scenario great differences can be seen for the average food crop price. Thus, the meetPASS Scenario would dampen pressures on food prices.

Figure 26.Price developments in the BAU and the meetPASS Scenario







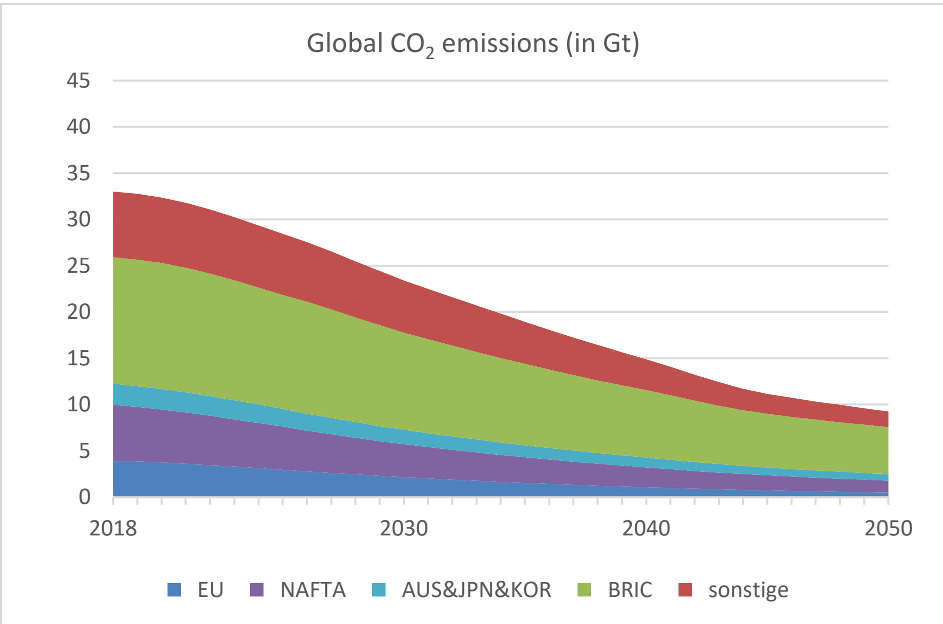
Source: own representation

3.3.4 The impact on people, prosperity and planet

Impact on CO_2 emissions:

The three transitions described above together would reduce global annual CO_2 emissions from 33 Gt to 9 Gt (see Figure 27).

Figure 27.Global CO_2-Emissions in the meetPASS Scenario

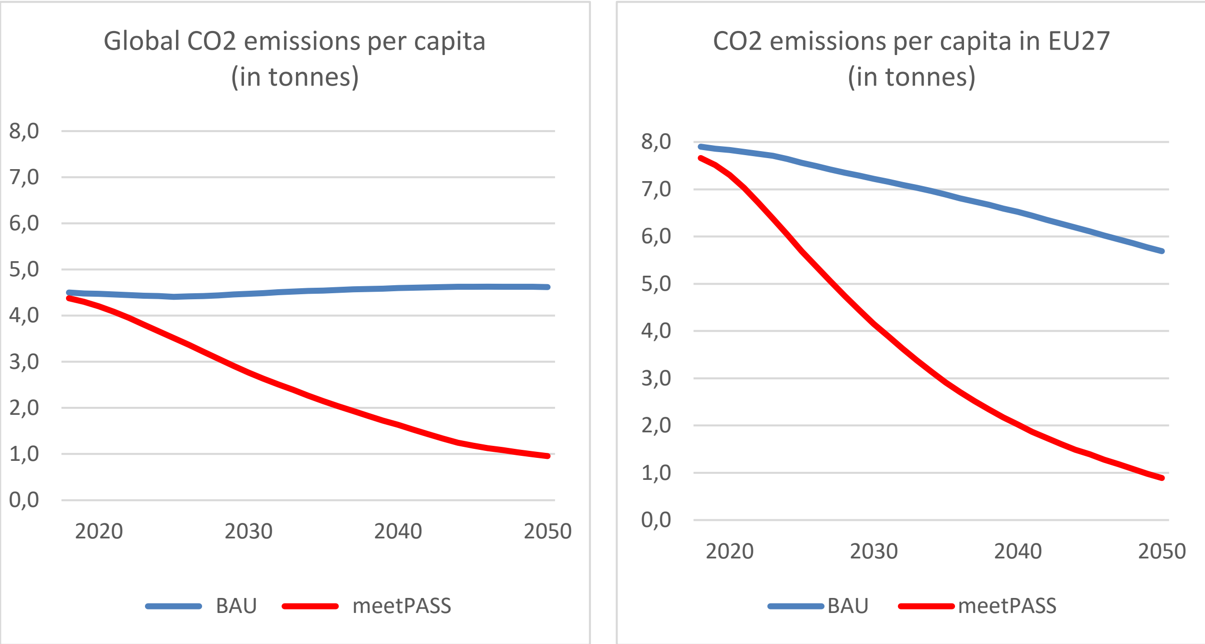


Source: own representation

While in the BAU Scenario, global CO_2 emissions per capita would remain relatively stable, in the meetPASS Scenario they fall from 4.5 tonnes per capita in 2018 to 1 tonne in 2050. CO_2 emissions in the EU fall even more sharply (by almost 90%). On a per capita basis, CO_2

emissions for the EU would reduce from 8 tonnes to 5.8 tonnes in the BAU Scenario, while in the meetPASS Scenario a substantial reduction (to 1 tonne per capita) could be achieved.

Figure 28. Development of per capita CO_2 emissions in the meetPASS Scenario compared to the BAU Scenario (global and for EU27)



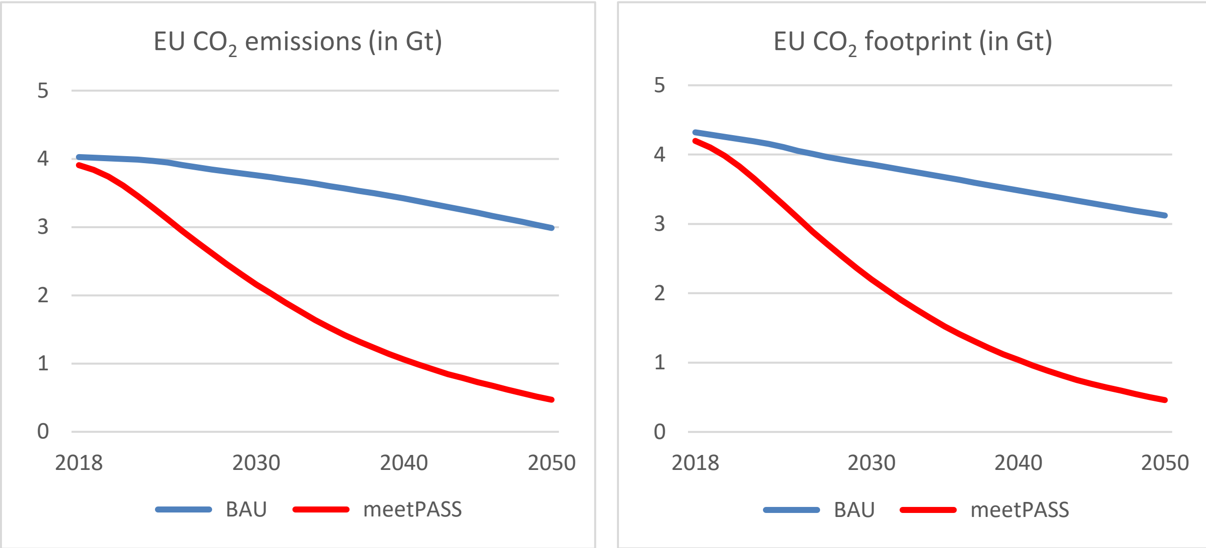
Source: own representation

The results for the European Union shown in Figure 28 are based on a production-based approach to calculate CO_2 emissions, as is used within the United Nations Framework Convention on Climate Change (UNFCCC).

While this approach considers CO_2 emissions that occur during production in a country (including the emissions of goods and services being exported), the **consumption-based approach** (i.e. carbon footprint) calculates the CO_2 emissions that occur along the entire value chain. Consumption-based accounting comprises all emissions caused by a country's consumption, no matter where they were actually emitted. Because production and consumption often occur in different geographical regions, the two methods result in different estimations of CO2 emissions (Kammerlander et al., 2019).

The following figure compares production-based and consumption-based CO_2 emissions in the EU27. The graphic shows that while in the BAU Scenario the carbon footprint exceeds the production-based emissions, in the meetPASS Scenario the emissions of both approaches are rather similar. Thus, the measures implemented in the meetPASS Scenario follow a comprehensive approach, including both consumer-oriented policies, focusing on final demand, and producer-oriented policies, focusing on industry.

Figure 29. Production-based vs. consumption-based CO_2 emissions in the EU27



Source: own representation

Overall, for the EU as a whole the differences are not very high. Greater differences can be observed in some member states (see the following table). While in France and the United Kingdom, the carbon footprint exceeds production-based emissions, in Bulgaria and Denmark the footprint is lower. The same is true for China.

Table 8. Production-based emissions vs. consumption-based emissions ***(CO_2 footprint)*** *in 2017 (rounded), for selected countries*

Country	CO2 emissions	CO2 footprint	Deviation
	in Mio. tonnes	**in Mio. tonnes**	**in %**
France	490	570	+16
United Kingdom	560	620	+10
Bulgaria	50	30	-40
Denmark	70	50	-29
EU27	**4,000**	**4,200**	**+6**
China	8,800	7,850	-10

Source: CO_2 footprint: calculations with GINFORS

The following tables compare the cumulated CO_2 emissions from 2017 to 2050 of the BAU and the meetPASS Scenarios with the remaining carbon budget. It can be seen that only if the probability of meeting the 1.5°C target is 50%, then the cumulated emissions in the meetPASS Scenario (708 Gt) stay within the limit of the carbon budget. For the BAU Scenario the cumulated emissions (1,335 Gt) strongly exceed the remaining budget.

However, for EU27, the remaining carbon budget is insufficient even if with a probability of just 50%. This indicates that some EU member states are using the allocation of other countries, which is not a fair and just global distribution of CO_2 emissions. There is scope for these countries to make greater efforts to comply with the Paris Agreement.

Table 9. Cumulative CO_2 emissions from 2017 to 2050 (66% probability of achieving the 1.5°C target)

	CO2 budget from 2017 onwards	**Cumulated CO2 emissions 2017 to 2050 (in Gt)**	
	in Gt	BAU	meetPASS
World	420-570	1335	708
EU27	29-39	122.6	66.3

Source: own calculation, based on IPCC (2018)

Table 10. Cumulative CO_2 emissions from 2017 to 2050 (50% probability of achieving the 1.5°C target)

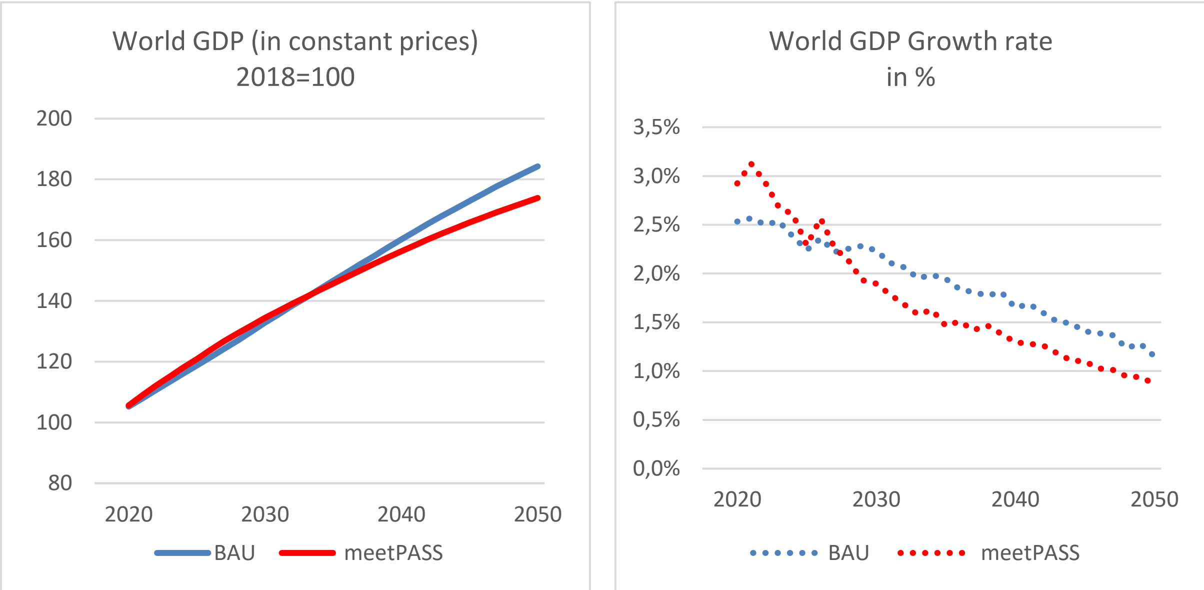
	CO2 budget from 2017 onwards	**Cumulated CO2 emissions 2017 to 2050 (in Gt)**	
	in Gt	BAU	meetPASS
World	580-770	1335	708
EU27	40-53	122.6	66.3

Source: own calculation, based on IPCC (2018)

Economic implications

The achieved reduction in CO_2 emissions and resource use is possible without economic collapse. The economy would grow globally by 75% instead of 85% in the BAU Scenario and the GDP growth rate would remain positive over the entire simulation period (see Figure 30).

Figure 30. Development of World GDP

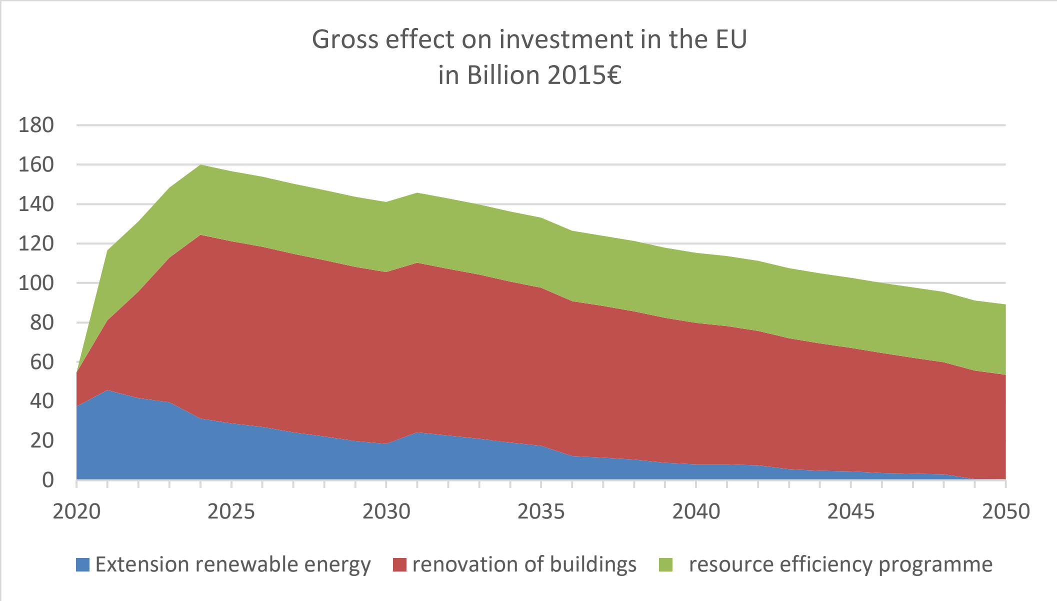


Source: own representation

Europe can also expect a positive impact on its economy, but less intense owing to the assumed changes in lifestyles and consumption patterns (see Figure 24). Initially, there would be stronger growth via increased investments. 0 shows the assumed investments (around 127 EUR billion per year or 3,820 EUR billion in total) in the meetPASS Scenario, in order to achieve the 1.5°C target.

However, the economic stimulus slows later (amounting to overall 23% instead of 31% in the BAU Scenario). Nevertheless, employment would actually be higher in the meetPASS Scenario than in the BAU, thanks partly to a reduction of working hours (by 20% over the period in EU and industrialised countries).

Figure 31.Gross effect on investment of the meetPASS Scenario in the European Union



Source: own representation

4 Summary and Conclusions

Within the project meetPASS we developed two narratives:

- The business as usual (BAU) Scenario. This scenario examines how European and global economies would evolve in the coming decades if current policies would not change, and the resulting environmental pressures considering the interdependencies within and between the different spheres.
- The meetPASS Scenario. This scenario examines the same questions, but under the assumption that policy, industry and consumers around the world cooperate to transform the system(s) in a way that the targets of the Paris agreement can be reached.

Business as Usual is not an option. The BAU Scenario indicates that rapid and strong action is inevitable. Currently, the global community emits approximately 33 Gt CO_2 emissions per year, or almost 4.5 tonnes per capita. On current trends this could rise to 45 Gt per year. This means that without additional measures, total emissions would increase to double the reasonably safe 580-770 Gt by 2050, or about 1,300 Gt. While global economic output would almost double in this period (+85%), emissions would increase by a third.

In order to reach the target of only 580-770 Gt in total, emissions per capita would have to decrease significantly – to about one tonne per capita of the world's population in 2050. That is a reduction to about one fifth – by almost 80%. Europeans (EU) are currently emitting 8 tonnes per capita. Here, the required reduction to one tonne is therefore even greater.

The modelling results of the meetPASS Scenario indicate that such a reduction is possible without economic collapse, if we start to act immediately. It is likely that some countries and sectors – especially "brown industries" – could lose out, requiring additional policies to ease the transition.

A second important insight is that three key transitions are needed to substantially decrease CO_2 emissions: an energy transition, a resource transition and a lifestyles transition.

A third important insight from global modelling is, that with regard to the speed of transition a linear thinking (for the time period up to 2050) will not deliver the necessary system change. Both policy interventions (like taxation) and behavioural adaptations need a substantial size especially in the period up to 2030. Any year of inaction will be fatal for the ability to achieve the targets.

The parametrization and evaluation of the global meetPASS scenario showed that a broad bunch of policy interventions and behavioural changes is necessary to realize the three transitions. Substantial (and budget neutral) carbon pricing around the globe is one of the key elements of this bunch.

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