COP 21 can become a turning point towards sustainable energy systems: paper on behalf of the secretariat of the Club of Rome preparing for COP 21

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No. 189 · Febuary 2016
ISSN 0949-5266

Wuppertal Papers

Publisher:

Wuppertal Institute for Climate, Environment and Energy
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Wuppertal, February 2016

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1. Introduction

At COP 21 in Paris global climate diplomacy will be at a crossroads: Either an effective global climate regime will never be established if the conference fails, or the conference will decide on promising roadmaps and implementation mechanisms for ambitious climate mitigation. Even with a diplomatic success in Paris 2015 the following questions have to be answered concerning the implementation processes after COP21:

1. Will climate change stay below the 2 degree target (2dt) in the 21st century on the basis of the COP 21 results?
2. Can a further introduction of risky elements into energy systems, like e.g. the use of nuclear energy, oil and gas from unconventional resources (e.g. fracking; hydrocarbons from Deep Sea and Arctic environment), carbon capture and storage (CCS) or geo-engineering be avoided globally or at least strictly limited?
3. If COP 21 does not provide a sufficient framework, what are the main challenges and barriers against a 2dt and how can they be overcome?
4. From an evidence based point of view, what are the most important risk minimizing energy strategies, and which key drivers and opportunities exist for an ambitious deployment path of those options?

Based on recent literature this paper tries to answer some of these questions on a global level, for the case of China with its growing efforts to combine economic development with a stronger ecological orientation (vision: „ecological civilisation“) and for the „good practice example“ of the German energy transition (vision: „Energiewende“).

We will focus on the energy sector as the production and use of energy from fossil sources (process emissions from cement production included) account for almost two thirds of global GHG emissions (62% in 2010; IPCC SYR, 2014, Fig. 1.6). But an urgent ‚low carbon' (low GHG emitting) transformation strategy of land use systems – contributing a quarter to global GHG-emissions – is of crucial importance as well.

Heading for COP 21 in Paris there are more encouraging signals from Parties to the Convention worldwide than ahead of previous COP events. This time the most important players, countries like China, the USA, the EU and some influential companies and business leaders (Ceres 2015). as well as more and more forward-looking city mayors seem to be prepared and willing to make 2015 a year of turning points to ambitious mitigation actions. But is this recent political momentum strong enough to induce economies to leave the path dependencies of fossil fuels embarked on since more than a century behind and switch to a 2dt–trajectory? By itself alone probably not. COP21 in Paris can only be an indicator of the future course of a more general movement, and in any case it has to be translated into real political and economic action.

To keep the momentum after Paris and to increase transformation velocity the "Post-Paris-Process" needs a new and promising and positive narrative, an underlying common understanding of how the future should look like! Against that background, chapter 2 discusses a new narrative for ambitious climate mitigation strategies and – in that context - summarizes some driving forces for the feasibility of a 2dt-strategy. Chapter 3 of the paper discusses selected strategic challenges, while in chapter 4 a more in-depht analysis of the opportunities is presented. Chapter 5 and chapter 6 proceed with stressing two important country case studies (China and Germany) which show that concrete action is possible and ambitious future plans do already exist, but nevertheless successful transformation pathways are linked with various challenges. The paper concludes with a brief summary.

2. In brief – a new narrative for ambitious climate mitigation

In a recent article Hunter Lovins observed: "We stand on the cusp of the biggest transformation of our lives... Humanity is in a horse race against catastrophe... And we might be winning. The speed with which renewable energy especially solar, is growing means we can solve the climate crisis, create jobs, reinvigorate manufacturing and buy the time needed to do the more fundamental work of implementing the Regenerative Economy – an economy in service to life".[1]

Yes, cheap renewable energy options will change much: There are more and more indications and practical experience that due to enormous cost reduction effects in the last years and additional unexploited potential for instance electricity from wind mills or solar modules will become the most competitive energy option in more and more countries and applications. But this will not be a self-dynamic effect in times where subsidies for fossil fuels still outstrip financial support for renewables by a factor of two, infrastructure requirements for the establishment of a renewable energy world is challenging (e.g. grid extension) and persistence forces of incumbents are still powerful in many countries of the world. Hence, cheap renewable energy options will change much, but most likely not everything and not fast enough without more ambitious policies.

This paper argues that only a **policy triangle** – a rapid market deployment of renewable energies in combination with an energy efficiency revolution accompanied by energy-conscious behaviour and more sustainable life styles – will indeed change everything. This perspective is possible and promising and triggered by recent developments will lead to a pathway that was forty years ago already described as the **soft energy path**[2] .

The energy transformation in the second half of the 20th century was driven by cheap barrels of oil and cubic feets of natural, leaving abundand tons of coal in the ground. The transformation to a sustainable energy pathway in the 21st century will be driven by the smartest way of **satisfying the demand for energy services,**, via a combination of cheap energy efficiency technologies and renewable energy options, leaving many billion tons of climate harmful fossil fuels in the ground and offering choices for a risk minimizing, nuclear free energy system.

This transition to sustainable energy pathway will lead to a completely decarbonisation of all sectors of the global energy system and will help to limit global climate change at about 2° C above pre-industrial levels within the 21st century. As the greenhouse gas mitigation strategy provides significant additional benefits, amongst others universal access to modern energy by 2030 and eliminating indoor and ambient air pollution, there are many more excellent reasons to support such a transformation process.

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[1] http://unreasonable.is L.Hunter Lovins, The Triumph of Solar in the Energy Race (31 July 2015), p.1

[2] Here we refer to A.Lovins´ visionary publication in Foreign Affairs (1976), because this was the birth of the transition path to sustainable energy and the first conceptual impuls for the German „Energiewende". Compare Lovins, Amory B.,The road not to be taken, 1976, in: Foreign Affairs, October 1976 and Lovins, Amory B. , Soft Energy Paths: Towards a Durable Peace. Pelican Books 1977

Is this narrative to nice to become true? Not, if humanity – standing at the cross roads – chooses the soft energy pathway with all its tremendous economic and social opportunities derived from low cost renewables and huge, cost-effective resource efficiency potentials. However, as starting in many countries from a centralized fossil and nuclear energy systems that is less flexible and seeks for a sufficient amortisation barriers are still high in not most parts of the world. Thus a global soft energy pathway will only become a reality if innovative **policies take the lead**, good practice examples of countries, cities, businesses and consumption shifts are scaled up and transformation processes started immediately. Smart policies have to play the important role as facilitator for the transformation process and can help to provide an appropriate institutional, cultural and social framework for market deployment of more climate friendly technology options.

Against that background more than a technological revolution is necessary, a „Great Transformation“ is needed[3], that sets the tight framework and does at the end not only decarbonize all energy sectors (power, buildings, transportation), but decouples the energy and resource use – absolutely in developed countries – from the increase of quality of life[4] . And it brings energy back from powerful multinationals to society and closer to customers. But no doubt: This is a challenging and long-term transformation process under quite different frame conditions and development stages of countries with a still uncertain outcome!

There are good reasons, to be a concerned optimist, but we should no be overoptimistic and encourage illusions. For example: Overoptimistic visions focus too much on pure **technical** options to decarbonize the power sector and its growing interface to other sectors[5]. No doubt: Cheap and getting cheaper power from photovoltaic modules will be a global game changer for these areas. But the suggestion „Think of energy like you think about an iPhone“ (Paul Gilding) is misleading as well as the daring thesis „..the fossil fuel age is coming to an end .. within 15 to 30 years..“ (p.1). Will we really see a future with abundant renewable energy based electricity generation nearly free of charge and will this lead to a future where electricity consumption does not matter?

Probably not as there are significant differences between the energy and the telecommunication sector: First, power plants and the power infrastructure are not at all comparable with consumer goods like cell phones; even if cost-effective and firm power from photovoltaic modules and wind mills (e.g. in combination with storage) can push **new** coal and nuclear power plant out of the market, renitency of the existing infrastructures will be intensive as the life time of **existing** centralized power systems can be up to 40 years and number of jobs in traditional energy sectors is still high. Therefore, it needs good arguments to overcome these challenges and to provide new opportunities. Courageous climate and resource protection policies and diversification strategies have not only the potential to protect jobs but to set impulses for regional economies. Second, to transform and decarbonize not only the power sector, but the

[3] See WBGU of „Great Transformation“

[4] See Development Alternatives / Wuppertal Institute (2014)

[5] see the article by Paul Gilding (2015), http://reneweconomy.com.au/2015/fossil-fuels-are-finished-the-rest-is-just-detail-71574

building stock and the mobility sector (e.g. cars, trucks, air planes) in developed countries as well will take decades. A fully unreflected decarbonized economy could increase renewable power capacities to frightening amounts (e.g. too much on shore wind power spoiling the countryside)[6] that it will neither be accepted by the public nor supported by sufficient supply of critical and rare metals needed[7] if it does not go hand-in hand with the reduction of energy demand by the efficiency revolution and more sustainable consumption patterns such kind of development pathway will fail.

Transforming the global energy system implies disruptive system innovations and social tipping points. Barriers and market-failures have to be overcome, old path dependencies have to be stopped, lock-in effects into long-term less flexible infrastructures (e.g. buildings, transportation) have to be avoided, countervailing vested interests have to be controlled and counterproductive rebound-, growth-, comfort- and life style effects have to be discouraged.

These are strong prerequisites and nobody can be certain that such a combination of strategies can be realized and maintained over decades. However, following the optimistic narrative that will be derived in this paper and justified by evidence based trends and facts, a two degree target (2dt) is still within reach, though the danger is growing that humanity is running out of time.

It will be elaborated below in more details that there are strong reasons for a new momentum and for more optimistic perspectives:

- The mindsets and motivations of politicians, research community and business has changed in favour of more ambitious action. For example: China (e.g. „Road map for ecological civilisation"; C02-peak 2030 or earlier) , the US (e.g. „Clean Power Plan") and the EU (e.g. energy package 2030; goals on C02-reduction, renewables, energy efficiency) announced more encouraging INDCs. The research agenda has „..shifted from warning and call for action to the strategic anticipation of options for action".[8] Thus, the scientific community is better prepared to contribute to a collective learning process of the international climate governance to increase regularly and rapidly the ambition of commitments.
- The non climate co-benefits of strong climate mitigation strategies have been acknowledged in most countries, especially in China and other emerging economies: "The GEA pathways that meet sustainability goals generate substantial benefits accorss multiple economic and social objectives…An Appraoch that emphasizes the local benefits of improved end-use efficiency and increased use of renewable energy would als help address ghlobal concerns" (GEA 2012, p.xiii)
- Energy efficiency has been accepted at least as the second pillar of any energy transition process according to a 2dt-strategy. Based on recent publications of the IEA (2015) and the GEA (2012) the plea in favor of implementing energy efficiency is even stronger: "Efficiency improvements is proving to be the most cost-effective, near-term option with multiple benefits, such as reducing adverse environmental and health impacts,

[6] See the scenarios (up to 2050/ 2060) for the case study of a completely decarbonized Germany; e.g. https://www.umweltbundesamt.de/sites/default/files/medien/376/publikationen/germany_2050_a_greenhouse_gas_neutral_country_langfassung.pdf

[7] See for example https://setis.ec.europa.eu/system/files/Critical%20Metals%20Decarbonisation.pdf

[8] see laLettre de L` IDDRI, July 2015, Nr.61

alleviating poverty, enhancing energy security and flexibility in selecting supply options, and creating employment and economic opportunities" (GEA, 2012, p.xvi). From the perspective of risk-minimizing an due to the flexibility characteristics energy efficiency should get highest priority: "The single most important area of action is efficiency improvement in all sectors. This enhances supply side flexibility, allowing the GEA challenges to be met without the need for technologies such as CCS and nuclear".(GEA 2012, p.xvii). The "missing link" to harvest this undoubtedly huge opportunities is the adaption of the energy conservation and efficiency governance structure, including innovative policies and measure to reduce rebound-, growth- and comfort effects (see below, p.25 ff). But binding targets (see EU Energy Efficiency Directive 2012) are a first signal that the necessary paradigm shift has been put on the agenda.

- As mentioned above the "green power (cost) revolution" is on the way. To put this amazing development into a systemic framing and into a plea against overoptimism does not mean to deny the disruptive potential of "Cheap Power for the World". It will indeed foster rural electrification in developing countries as well as customer based innovations ("prosumer") and interlikages between the power, the transport, the buildings and the ICT sector in highly developed countries.
- Globally, the green power revolution implies on the one hand a huge leap forward to decentralisation, remunipalication and democratisation of power production. On the other hand it could start a "death spiral" [9] for traditional centralized power producers. This is quite evident e.g. in Germany and Japan if no ambitious restructuring and diversification activities of the power companies are started in time.[10] At the press conference Johannes Thyssen, CEO of E.on, announced the split of the company according to the "old" and "new" energy world. Interestingly, what he discribed as the "new world" is close to what has been called the "soft energy path" in this paper: „The portion of customers that want to play a more active role in designing their energy supply is growing steadily... Above all, they want clean, sustainable energy they can use efficiently and in a way that conserves resources... This new world, which is emerging around customers and their changing needs, is fundamentally different from the conventional energy supply system which is based on large-scale systems". (ibid)

This statement can be understood as a strong signal at the business level that even traditional power companies perceive the "soft energy path" as a more promising perspective than the maintaining the conventional energy supply system. But to scale this micro perspective up to a global picture of climate mitigation strategies more challenges and opportunities have to be reviewed and interpreted.

To demonstrate the feasibility of a two degree target (2dt) strategy in a plausible and comprehensive way this paper selects and weighs strategically important challenges and opportunities. To reduce uncertainty back casting scenarios are included into the analysis. This eclectic methodology should not be misunderstood as a probability forecast, which nobody can deliver up to now. The paper can only offer arguments on the pros and cons for a 2dt-strategy and how it still can be achieved to facilitate a dialogue and more in-depth analysis.

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[9] See for example: http://unreasonable.is L.Hunter Lovins, The Triumph of Solar in the Energy Race (31 July 2015)

[10] Johannes Teyssen (CEO) Press Conference, December 1, 2014

But it might be just in time to weigh the still huge challenges for a 2dt–strategy against current opportunities of ambitious climate mitigation strategies. We are well aware that it can eventually not be reached. But the paper shows that this is not an argument against a strategy which keeps the 2dt as **strong global orientation** – trying to get as close as possible to it.

3. Huge challenges ahead

3.1 Carbon's remaining budget: How much, how long, how distributed?

A clear signal that mankind is running out of time for climate mitigation is indicated by the (carbon or GHG) budget approach. Basis of this calculation is the thought experiment by climate science that the resulting increase in global average temperature is the effect of CO_2 emissions only, mainly irrespective of the time of its release. On that basis it is possible to calculate the total global budget of CO_2 emissions from fossil fuel sources (including that from cement production; in the following in short „fossil CO_2") since the beginning of the area of industrialisation (1750), which is sufficient to stick to the 2dt. As the CO_2 already released in the course of history since 1750 (till 2010) is roughly known, the remaining budget is determined by the difference of both terms. A boundary condition of that kind of calculation is that future emissions of the remaining long-lived GHG, which of course also contribute to future warming, is determined elsewhere.

The most recent calculation of both, the budget of CO_2 emissions from fossil sources already released as well as the remaining budget is included in IPCC's AR5[11] . An approach with > 66% probability of compliance with the 2dt is chosen and the term „against pre-industrial times" has been operationalized as „against 1870" (midst of 1861 to 1890). Under this circumstances, the total budget is about 2900 Gt CO_2 (range of 2550-3150 GtCO_2). Until 2011, about 1900 [range: 1650 to 2150] Gt CO_2 were already emitted. The conclusion: a budget of about 1000 Gt CO_2 is only consistent with the 2dt. Considering the increase in CO_2 emissions in the first half of the current decade, cumulating in 2013 at a new record high of 35.3 Gt CO_2 (PBL/JRC 2014), the resulting ambition level becomes obvious. Even if this increasing trend is successfully stopped until 2020, the year, in which the COP21 Agreement is planned to become effective, one third of the remaining budget will already be exhausted.

There are earlier attempts in fixing the remaining CO_2 budget, e.g. by WBGU even trying to allocate the carbon budget to single countries. According to a „historical responsibility allocation" (taking the already consumed budget 1990-2009 into account) on the one hand there

[11] Literally in SYR Long Report P 24:

"Multi-model results show that limiting total human-induced warming (accounting for both CO_2 and other human influences on climate) to less than 2°C relative to the period 1861-1880 with a probability of >66% would require total CO_2 emissions from all anthropogenic sources since 1870 to be limited to about 2900 GtCO_2 when accounting for non-CO_2 forcing as in the RCP2.6 scenario, with a range of 2550-3150 GtCO_2 arising from variations in non-CO_2 climate drivers across the scenarios considered by WGIII (Table 2.2). About 1900 [1650 to 2150] GtCO2 were emitted by 2011, leaving a budget of about 1000 GtCO_2 consistent with this temperature goal. "

would be no budget left in the future for countries like the USA, Russia, Japan or Germany if an equal distribution of per capita CO_2-emissions was assumed (WBGU, 2009, Solving The Budget Approach; an updated calculation is given in WBGU 2014, Box 3.3-1). On the other hand, based on the same frame conditions and assuming annual emissions as in 2008, the reach of the budget for China would be 26 years (WBGU, 2009).

One important message derived from this (theoretically equitable) allocation exercise is that without a trajectory of „reduction" (e.g. drastic **absolute** decrease of per capita CO_2-emissions in industrialized countries (Annex 1)) and of „convergence" (rising quality of life but keeping the increase of per capita CO_2-emssions in developing and emerging economies as low as possible) with regard to the climate change issue „planetary boundaries„ (Rockström et 2009) would be exceeded. Thus, for an ambitious climate mitigation action after 2015 the principle of „common, but differentiated responsibilities" still gives a quite more convincing orientation than the blaming of single countries (e.g. China) for their undoubtedly frightening increase of CO_2-emissions (see e.g. R. Smith, 2015).

In any case the global peak of CO_2-emissions should be reached soon as a postponement into the future would mean to make climate mitigation in line with the 2dt much more expensive (IPCC AR 5, WG III) or even unfeasible at all because the required CO_2-reduction rates per year seem to be too great (see WBGU. 2009). If a global peak of CO_2-emission was to happen shortly after 2020 (WBGU, 2009), it would mean for instance that China must peak before 2030, and the USA and EU (together origin of 27% of global (fossil) CO_2-emissions) are to reduce their emissions drastically (at least 40% in 2030 against 1990).

Until today, a consequent reference to the approach is not common practice. The ambitious vision of a 2000-Watt-per capita society, which is the official framework for Swiss long-term energy policy (up to 2100), seems to be the only consequent policy orientation worldwide based on the concept of reduction and convergence (see: Energie Schweiz, 2012, see also page 21ff).

3.2 Carbon bubble: „Unburnable tomorrow drives drilling today"?

The focus in chapter 2.1 was on the emissions from burning processes, while the producers behind the combustible substances, which will be transformed into emissions, have not been touched so far. Actually it is the consumption (burning) of fossil fuels that causes the emissions. Considering that any fuel consumption requires the same amount of fuel production, from the ground, the message derived from the global budget approach is that possible fuel production is restricted. In other words: there is a strong limit for the extraction of coal, oil and gas from the ground. IPCC (2011)has demonstrated that there is far more carbon (especially coal) in the ground than projected to be emitted in any baseline scenario. That means that whatever disastrous global warming under a baseline trajectory you can imagine, the world would be a still more „comfortable" living space in comparison to catastrophically heating the planet by burning every ton of fossil fuel in the ground! A rough calculation says that 80% of the recoverable coal resources and 60% of oil and gas resources should be left in the ground („unburnable") if mankind was to have a chance to stay below the 2dt

How to deal with this complementary message? The addressee of this message of restriction is particularly the business and financial community, not only the political arena. The message is about vested interests of countries and companies, which are, so the manner of speaking, "invested in fossil fuels". There are two different meanings of this term:

(i) invested in know-how and physical investment specialized on fossil fuel extraction and processing.

(ii) invested in facilities which depend on (fossil) fuel usage.

Both types of investment can under certain conditions reveal itself as inappropriate "strandes investments"; and both types create "vested interests" for the owners. Often governments are owners of the infrastructure, which determines the fuel dependency, they are in some states also owners of the national extraction companies, they are at least beneficiaries of any rent income, which is so typical for the economy of fossil fuel extraction. Consequently, many states are main investors in fossil fuels. Governments of states being rich in fossil resources are obviously in a situation of a 'conflict of interest' when it comes to GHG mitigation. For this reason, it cannot be assumed that a global physical regime of binding targets and regulating total quantities of fossil fuels (including extraction) under UN conditions (equity principle: one state, one vote regimes) can be a promising strategy to keep „unburnable", but still profitable gigatonnes of fossil fuels in the ground. There must be a complementary economic approach which promises to recognize the character of "profitability" from extraction and combustion of fossil sources.

In general such kind of development can only be expected under two prerequisites: (i) **disincentives** to invest in fossil fuel (production as well as consumption) would grow rapidly[12] and (ii) in parallel **incentives** to invest in alternatives like renewables and energy efficiency will develop quicker than in the past.[13] If this kind of movement takes place, there might be a chance to see fossil fuels driven out of the markets in due time.

We concentrate here, as an example, on the disincentive for the fuel extraction industries which emerged with the proclamation of the 2dt in 2010 (CoP16) and its recalculation as limited carbon budget. Even if the political will behind that declaration and the resulting political action at the level of various states is undetermined and uncertain as well, there is, nevertheless, a negative economic effect, a strong negative impulse, leading to a disincentive.

With the carbon budget concept two possibilities came to light, two kinds of risks; (i) at macro-level: the carbon bubble risk, in parallel to the housing bubble which did just emerge few years ago; (ii) at industry level: the carbon budget constituted two parts of fossil fuel resources: the eventually burnable and the eventual unburnable one. That created the individual risk of any company to be on the wrong side of fuel extraction. The companies – the big companies of conventional and also of unconventional fuels – in the fuel industry themselves are not really interested in that risk as they are – by definition – conglomerates of vested interests specialized in fuel extraction. But their shareholders are severely interested in that newly emerged kind of risk and ask for professional clarification, in the possibility of misinvestments. This development in itself driven purely from sources inside the economic system,

(i) contributes to the disincentives as required as well as

[12] E.g. through reducing subsidies on fossil fuels (e.g. IEA 2015; see below), internalizing external costs would be realized (IMF 2015), divestment trends would scale up.

[13] E.g. strong barriers removal, rapid cost degression and fast market deployment.

(ii) is subject to a self-inforcing development: As this new kind of risk grows in attention, the incentive for early disinvestment in potentially risky assets increases, even without in depth investigations. Risk perception at capital markets is not a stable situation.

A recent analysis of the fossil fuel business shows that business interests are heavily affected when taking the carbon budget approach seriously. Carbon Tracker (2013) has compared the listed reserves of fossil fuels from 200 major companies listed at the world´s stock markets. According to the carbon budget about 2/3 of the listed assets of the companies are „unburnable“ if with a 50% probability warming are to stay below 2dt. (ibid., p.15) . Assuming a common interest of the owner of the respective companies to remove the huge economic risks of this CO_2-bubble a strong trend to divestment from coal, oil and natural gas would probably result in a rapid diversification process in alternative business fields. In reality, this process of rapid divestment seems to be, at best, still in its infancy. Carbon Tracker has recognized that the level of capital expenditure (CAPEX) of the 200 companies has amounted to US$674 billion „... over the last 12 months... If CAPEX continued at the same level over the next decade, it would face up to $6.74 trillion in wasted capital developing reserves that is likely to become “unburnable“ (p.16).

Of course, not the exact amount of „unburnable assets“ matters in this context, but the rough magnitude. The numbers reveal what is to be expected: that the companies, specialized on extraction, are far away from respecting their common interests, at least the interests of their shareholders. They are guided by a very short sighted competitive behavior which can be summarized under the heading: „The unburnable part of fossil fuel resources is part of the assets of our competitors – our assets are on the burnable side.” For the industry as a whole, the motto is consequently: “Unburnable tomorrow drives drilling today“! As long as each company tries to dig and sell as much fossil fuels as quickly as possible to please its shareholders in the short run, the collective race of the fossil fuel business continues existing.

This means: as long as the capital markets and strong divestment movements will not force the fossil fuel companies to change their traditional patterns of behavior, there will be a very strong alliance against any ambitious climate regime to be established at COP 21 and beyond.

Interestingly major companies from the oil and gas sector (e.g. BP, Shell, Statoil, Total) wrote a letter to the UNFCC secretariat (May 29th, 2015) saying that it is „...needed to limit the temperature rise to no more than 2 degrees... The challenge is how to meet greater energy demand with less CO_2. We stand ready to play our part ...Therefore, we call on governments... to introduce carbon pricing systems where they do no exist at the national or regional levels...“. One might understand this as a selfish plea („dash for gas“), but it could also be a sign of rising consciousness within the fossil fuel business as we know it.

3.3 Heading for „decarbonizing“ or for „risk minimizing“ – why energy efficiency and renewable energies are the better alternative than nuclear, CCS or geo-engineering

Looking into the relevant recent literature a new term seems to be on top of the analysis and policies of climate mitigation strategies: „Decarbonizing“. Very prominently this target has been highlighted in the G7 summit declaration in June 2015. But it should be made clear that „decarbonizing“ does not necessarily mean to foster only energy efficiency and renewable energies, but could also imply „more nuclear", creating unstable „CO_2-sinks" by CCS or step into incalculable experiments in the form of „geo-engineering". And nothing has been said about the potential risks to use renewable energies (particularly biomass) in an „unsustainable manner". Thus, one key question remains in respect of „decarbonizing" strategies: Does mankind has **to choose** between different global risks (e.g. less nuclear – more climate change) or will a **risk minimizing** 2 dt-trajectory be technically and economically feasible by focussing on energy efficiency and the sustainable use of renewable energy? The global scenarios of the GEA (2012; Riahi et al 2011) and of WWF/Ecofys (2011) as well as IPCC (2015) indicate that a comprehensive risk minimizing trajectory (including the 2dt) might be technically and also economically feasible. But a more in depth analysis of a consistent multi-level policy approach, appropriate national frame conditions of key players (e.g. USA, China, EU, Japan), a more systemic view of the complex interactions in the energy system and a better understanding of the interplay between climate protection targets and other social and political goals (including Sustainable Development Goals; SDG's) seem to be necessary to really develop a risk minimizing strategy.

3.4 How much „lock in effects" in building-, power- and transportation infrastructures are decided each day?

When it comes to ambitious climate mitigation policies, time might be the scarcest factor of all. Unfortunately, huge „lock-in effects" occur each day when investments in inefficient long-lasting (lifetime 20-50 years) infrastructures being typical for the building-, transportation- and power sector are decided. It is a challenging exercise for scenario experts to model the **time factor** of long-term infrastructures adequately. The lifetime of buildings can be 20-50 years (depending on the region and development stage). In order to establish a more sustainable public transportation system (comparable e.g. to Japan) will not only cost a huge amount of capital, but needs much time (at least two to three decades), and investing in new coal power plants instead of renewables means to stabilize a high amount of CO_2-emissions for their typical lifetime of 30-40 years. It can be assumed that many global and long-term scenarios underestimate lock-in effects and thus tend to be overoptimistic when it comes to evaluate carbon reduction trajectories.

To give an example: Comparing the resulting cumulative emissions of investing in state of the art or moderate standards of heating and cooling equipments in buildings, the difference („lock in effect") adds up to nearly 80% in 2050 (GEA 2012). Unfortunately, current buildings standards in emerging economies with very high new construction rates like China and India are far away from being state of the art and probably will stay at suboptimal levels for the near future.

3.5 When does a global paradigm shift to ambitious energy efficiency policies happen?

Comparing scenario analyses and policy programs of the last century (e.g. from the IEA or the WEC) there is a striking shift to give much more attention to energy efficiency than in the past. For example the flagship publications of the IEA (World Energy Outlook (WEO)) or special publications of the IEA on energy and climate (e.g. IEA, Energy and Climate Change (IEA 2015)) advocate strongly ambitious strategies in favour of an energy efficiency increase. According to the publications of the IEA about 50% of the necessary CO_2-reductions to reach the 2dt are attributed to an end-use energy efficiency increase (IEA 2015). This means that energy efficiency is now officially recognized not only as the largest, but also as the most cost-effective, the quickest and the least regret option (eg. huge co-benefits) for climate mitigation.

This can be seen as major step forward in communication as energy efficiency potentials have been neglected or not considered seriously for decades. But there might be a danger in communicating this finding too often. An uncritical perception of the „swing to energy efficiency“ could have the following unintended placebo effect for politics, the private sector and the civil society: Don´t worry on behavioral aspects or lifestyle changes, just rely on the "feel good message" that 50% of the climate problem can be „easily solved" just by harvesting the technically feasible energy efficiency potentials. The problem is that to implement these potentials in reality is neither „easy", nor should the existence of big untapped potentials be misunderstood as a signal to give the all- clear. Because it can also be read like this: **Without** a successful contribution of about 50% CO_2-reduction by an energy efficiency increase and energy conservation (which is as we will see not an easy task) there will be no 2dt-trajectory at reasonable costs and supported by public acceptance.

Looking into the realities of global energy policies the world is still far away from giving highest priority to saving energy because of two main reasons: First, in some parts of the world (e.g Germany) energy policy pushes renewable power sources quite successfully. But conceptually most of the enabling mechanisms (e.g. like the Renewable Energy Act; EEG) are still part of **a supply driven framework**. At the early stages of structural change to green power of course a challenging **supply** management is necessary to substitute base load fossil and nuclear power plants by a rising share of power from wind and solar and by guaranteeing grid stability by a sufficient amount of flexibility options (e.g. demand side management, energy storage) as well as grid extension. Second, although more ambitious energy efficiency policies have been decided (e.g. the Energy Efficiency Directive of the EU, 2012) there is still no systematic integration of energy efficiency and sufficiency policies influencing consumer behavior to mitigate **rebound-, growth and comfort effects** (see bullet point below) and to guarantee the necessary absolute energy consumption reduction**.**

3.6 Will the unsustainable patterns of production and consumption in OECD countries be globalized by „the new middle classes"?

Projections of the rise of the „new middle classes" (EEA, SOER 2010;) show a tremendous increase of middle-class consumption especially in India and China. It is assumed that the global share of new middle classes both in India and China increases from below 5% at the beginning of the 21st century to more than 50% in 2050. Copying the unsustainable consumption patterns and high per capita material and energy consumption of the current middle classes in OECD countries will not only put huge resource and pollution constraints on the Chinese and Indian development, but would make a global development according to the 2dt out of reach.

Is there any chance that the global patterns of unsustainable production and consumption converge to a sustainable and more equitable level of quality of life for 9 billion people globally? If there was no positive answer to this question, the global 2dt scenario perspective might be technically feasible - but it will never happen. Here is an indicator why change in OECD countries could happen:

For 17 OECD countries GDP/capita and Genuine Progress Indicator (GPI)/capita developed in parallel from 1950 until about 1978, but then decoupled (see Development Group). Other analyses confirmed that this „perverse decoupling“ might be the „new normal“ in countries after a certain threshold of per capita income. If further quantitative growth of income and consumption does not make average people happier, will this gradually shift the behavior and consumption patterns of a growing population share in a more sustainable direction?

Leisure instead of burnout, cultural services, education for all, care for elderly or handicapped people instead of endless growth of material goods, public health care for all instead of privileged health services for the rich? Sharing instead of owning cars, durable goods, appliances, apartments?

There are many societal niches where these and other new models of wealth and social innovations are growing in OECD countries. But could this minority shifts be mainstreamed and even transferred to the developing world? This raises fundamental questions: What policies are suited to enable this mainstreaming and to invert the “perverse decoupling” of GDP growth and life satisfaction in OECD countries? Could it be transferable to the raising segments of middle class consumption in the global „South“? Are these middle class segments e.g. in China and India already confronted with the phenomena of „perverse decoupling“? Can we expect and enable technical, societal and structural “leap frogging” options for the global „South“ and the global „North“ as well that the consumer classes everywhere choose more sustainable consumption patterns and how could we foster such a process? We are still at the very beginning of finding appropriate answers to these questions. One step forward of course might be the insight that we need alternative forms of measuring global welfare. With the discussion of suitable “human well being indicators” amongst others OECD sets a discussion impulse[14].

With its publication “Better Growth. Better Climate”[15] the „The Global Commission on the Economy and Climate“ (GCEC) underlines the necessity of a different approach. This publication is especially interesting because it looks in-depth into the interlinkages of climate mitigation, economic structural change and the „quality“ of growth: „…The choice we face is not between „business as usual“ and climate action, but between alternative pathways of growth: One that exacerbates climate risk, and another that reduces it... This underpins the Commission´s concept of „better growth“: growth that is inclusive (in the sense of distributing its rewards widely, particularly to the poorest); building resilience; strengthen local communities and increase their economic freedom; improves the quality of life in a variety of ways, from local air quality to commuting times; and sustains the natural environment. All these benefits matter to people, but they are largely invisible in GDP, the most widely used measure of economic output. In this sense the quality of growth matters as much as its rate“ (GCEC, p.15/19).

[14] http://www.oecd-ilibrary.org/economics/how-s-life_9789264121164-en and http://www.oecd.org/std/47917288.pdf

[15] GCEC, Better Growth. Better Climate. The New Climate Economy Report. The Synthesis Report, Washington, September 2014

4. Unprecedented global opportunities

Considering all the challenges and current trends summarized in chapter 2, it could lead to a very pessimistic or depressing perspective of the future. But this picture would at least be incomplete if not misleading without confronting it with a view on promising current structural, technological and social changes as well as opportunities unfolding in the global economy.

4.1 IPCC scenarios and the technical prerequisites of 2dt-trajectories

Scenarios are regularly used to describe and discuss different development options and to distinguish between more pessimistic and more optimistic pathways. They can help to explore the options switch from the current to a more sustainable path. For this reason, scenarios can play an important role for reducing or at least assessing uncertainties, encouraging social learning, create more open mind-sets and visions on future choices and raising awareness of future risks and opportunities.

In respect to climate mitigation, to use scenarios in the „back casting“ mode is the politically most relevant one: Do we have sufficient technical options to stay below the 2dt? What are the economic and social implications if we compare this target oriented trajectory with alternative pathways? These are the questions typically addressed by scenarios and picked up below.

In the most recent IPCC report (AR5), a new approach of collaboration was followed: The community of climate modellers agreed on a set of four so-called "RCP" scenarios, which elaborated the required course of radiative forcing (rf) in the earth's atmosphere, if a certain rf-limit, which is equivalent to a limit in temperature increase, should be respected. To develop socio-technical scenarios in the usual understanding which fit to a given RCP scenario is then up to the respective modeller teams. There has not been a coordinated approach to induce the development of a consistent set of scenario storylines or data sets, especially with respect to the technical prerequisites.

In sum, the IPCC authors were able to compile more than 900 detailed scenarios – but unfortunately especially in the RCP-class (RCP 2.6) that describe potential future pathways near the 2td border, there was only a representation, which was so limited, that a statistical analysis of scenario outputs would be prohibited. To solve this situation, it has been decided to include overshooting scenarios in the family of scenarios consistent with the 2dt – a decision, which obviously leads to two major consequences:

1) Those scenarios cannot be consistent with any limited carbon budget numbers, as now "lending from future" is allowed. The term "carbon budget" is now turned into a net-budget concept, the limiting character of the concept is thus weakened. That is the main reason, why one cannot conclude from the RCP2.6, which reveals a clear switch to (net) negative emissions in about 2070, to a similar remaining carbon budget as allowed by the 'sample' of IPCC scenarios and as authoritatively used in Figure SPM.4 (SYR). If lending is allowed, the remaining budget in 2051-2100 can increase.

2) The inclusion and probably dominance of overshooting scenarios in the sample represented in Figure SPM.4, which stands for the IPCC 2dt scenarios, result in technological respect in a high degree of prominence given to technologies like CCS (Carbon Capture and Storage) and (BE)CCS (BioEnergy use, Carbon Capture and Sequestration) especially.

Due to the fact, that the IPCC process is based on an assessment of existing literature, not a process of consistently studying topics under new assumptions and scenario modelling, the technical prerequisites of 2dt-trajectories are addressed in AR5 only very generally, not in that detail, which would be necessary. In general, the insight is, that there is a trade-off relation. If overshooting is allowed, then (BE)CCS is the most prominent technology addressed in the respective scenarios. Or one restricts the RCP2.6-trajectory to a remaining carbon budget without allowing for negative emissions (by creating additional sinkes) – then energy efficiency technologies are absolutely essential and consequently addressed in the respective scenario studies. In the technical summary of the 5th Assessment report from IPCC this reads as follows:

"The availability of carbon dioxide removal technologies affects the size of the mitigation challenge for the energy end use sectors... There are strong interdependencies between the required pace of decarbonisation of energy supply and end-use sectors. The more rapid decarbonisation of supply generally provides more flexibility for the end-use sectors. However, barriers to decarbonizing the supply side, resulting for example from a limited availability of CCS to achieve negative emissions when combined with bioenergy, require a more rapid and pervasive decarbonisation of the energy end-use sectors in scenarios achieving low CO2eq concentration levels (Figure TS.17)."

In this quote the rigorous trade-off between (BE)CCS and energy efficiency is not directly mentioned; the relation is instead formulated for a "decarbonisation of the energy end-use sectors". But if one takes the task to decarbonise the final energy carriers by going renewable (or nuclear, as assumed by some IPCC-scenarios) at the most urgent path for granted, the remaining trade off is that of (BE)CCS (deployed later on the time axis) and energy efficiency technologies (consequently implemented from the very beginning).

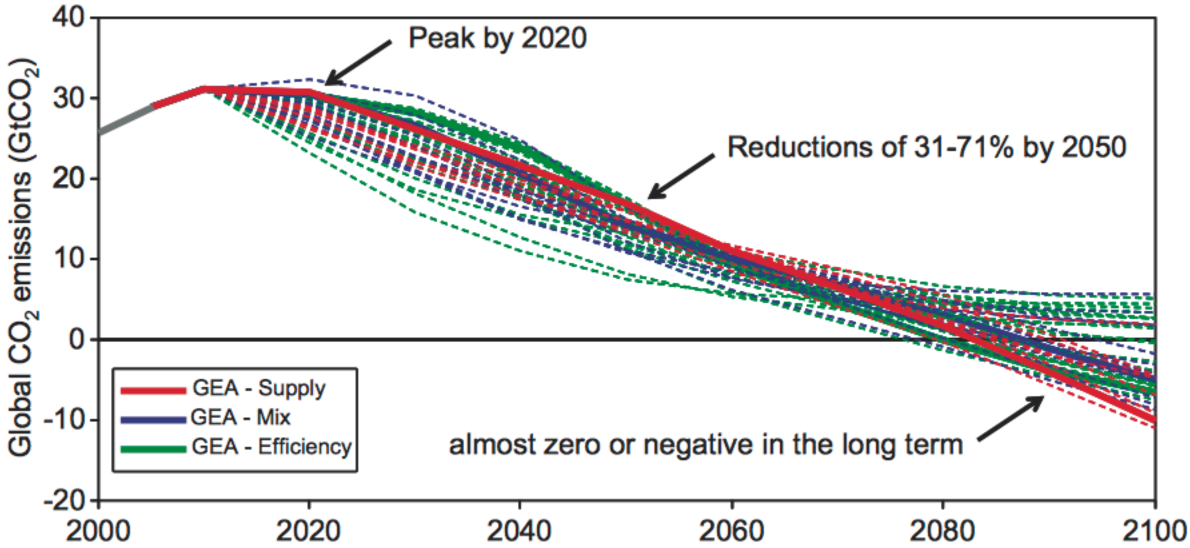
Given this shaping of the general dichotomy, there is on one side a seemingly big and single technology und on the other side a huge basket of very sector specific and highly differentiated efficiency technologies, for which we only have a unifying title: (final) energy efficiency technologies. One can expect, that similar to the general public and political discussion from the view of authors who elaborate global scenarios, the "one big technology" is far more attractive to study and to elaborate than the basket of bottom up technologies on the demand side which in many scenarios are not well understood. Accordingly selective is the reviewed literature. To draw the possible technology pictures, which may "exhaust" the 450ppm-scenarios in Figure SPM.4, especially the RCP2.6 scenario, is therefore a challenge yet to be done in future.

In a certain contrast to the IPCC-scenarios the Global Energy Assessment (2012) explored 60 possible transformation pathways and found that 41 of them satisfy the following GEA goals:

- Stabilizing global climate change to 2°C above pre-industrial levels up to 2100
- Enhanced energy security by diversification and resilience of energy supply (e.g. reducing import dependency on oil)
- Eliminating household (in door) and ambient air pollution associated with the burning of fossil fuels, and
- Universal access to modern energy services by 2030 for 1.4 billion people without access to electricity and for 3 billion people who cook with solid fuels today.

Figure 1: Development of global CO2-emissions to limit temperature change below 2´C

(with a success probability of >50%)



Source: Global Energy Assessment.Toward a Sustainable Future, Cambridge/New York 2012, Key Findings, p.6

Again the trajectories demonstrate the emission need to peak around 2020. The later the peak occurs, the steeper the decline needs to be and the more net "negative" emissions must be taken into account.

In this respect the GEA results are in line with the IPCC findings. But there is one important difference: The GEA explicitly presents an in depth analysis of the potentials of energy efficiency in all sectors and develops specific scenarios which are based on it. The result is quite striking: The report advocates strongly the necessity of an integrated energy system strategy with a strong focus on energy efficiency: "The single most important area of action is efficiency improvement in all sectors. This enhances supply side flexibility, allowing the GEA challenges to be met without the need for technologies such as CCS and nuclear" (GEA, 2012, p.xvii). This is the rationale of our plea in favor of risk-minimizing strategies presented above. To avoid the choice of risky options like nuclear or CCS the potentials of energy efficiency have to be harvested as ambitious and cost-effective as possible.

4.2 How to come from Intended Nationally Determined Contributions (INDC's) to a 2dt-trajectory?

Nationally determined pledges are the foundation of COP 21. It has been calculated, by the IEA[16] that the „Intended Nationally Determined Contribution (INDC`s)" submitted by countries in advance to COP21 will only slow down the energy-related GHG-emissions, „...but there is no peak by 2030 in the INDC Scenario...If stronger action is not forthcoming after 2030, the path in the

[16] As of 1 May 2015, accounting for 34% of energy related CO_2-emissions only on officially submitted INDCs, i.e. mainly EU, Mexico, USA and Russia; the rest is determined by inofficial anouncements or by inserting figures as derived from the "New Policies Scenario" of IEA's WEO-2014

INDC Scenario would be consistent with an average temperature increase around 2.6° C by 2100 and 3.5°C after 2200"(IEA, 2015, p.12). But the authors admit, that this INDC scenario will reflect probably the "lower limits of the global climate efforts to underlie the climate summit" (ibid., p. 31).

Against this background the IEA developed **a (near term) bridging strategy**, which maintains the same level of economic growth or development as underlying in the INCDs. IEA expects that this strategy could deliver a peak in global energy related emissions by 2020. The **Bridge Scenario** proposes five policy measures:

- Increasing energy efficiency in the industry, buildings and transport sectors.
- Progressively reducing the use of the least-efficient coal-fired power plants and banning their construction.
- Increasing investment in renewable energy technologies in the power sector form $270 billion in 2014 to $400 in 2030.
- Gradually phasing out of fossil-fuel subsidies to end users by 2030.
- Reducing methane emissions from oil and gas production. (ibid., p. 67)

It is expected that by these measures „..coal use peaks before 2020 and then declines while oil demand rises to 2020 and then plateaus... China decouples its economic expansion from emissions growth by around 2020, much earlier than otherwise expected, mainly through improving the energy efficiency of industrial motors and the building sector, including through standards for appliances and lighting" (ibid., p. 13).

The Bridge Scenario „…can keep the 2°C climate goal within reach in the near term, but goals beyond 2025 need to be strengthened in due course" (p.14). Thus the IEA´s expectation is that agreeing at COP 21 to review the level of ambition every five years and then tighten the INDCs could extend the „bridge" to a 2dt-strategy.

The global IEA bridging concept again is technically feasible and encouraging, but one key policy question remains. Why should the biggest polluters, the US, China and EU, be interested to walk across the bridge? Is this in their own national interest? Are there economic and societal national driving forces which can steer national energy transition processes via the „five-year revision"-clause into a more risk-minimizing direction?

4.3 The „swing" of global cost-/benefit analysis to „benefit sharing"

Although it would be interesting to historically analyze the interdependencies of energy research and the economics of climate change, this paper can only briefly comment on an amazing „swing" of a global cost-/benefits analysis of climate change.

In the 1990s the dominating view especially of US-based economists like e.g. Bill Nordhaus or Hope et al has been to weigh the perceived heavy cost -„burden" of ambitious climate mitigation strategies much higher than the monetarized benefits (avoided current energy and future damage costs) of climate change. The political message derived from this economic analysis supported the attitude of e.g. US Governments to take a reluctant „wait and see"-position to international climate mitigation regimes. Strong mitigation action was interpreted as a challenge against „the American Way of Life" (G.W.Bush).

This traditional perception was based on a double misunderstanding: First, the so called „American Way of Life" of the US was neither compatible with inclusive growth, rising quality of life for all Americans and sustainable development nor was it transferable to a growing world population without inducing a global desaster. Second, there was no sound (net) cost calculation e.g. the costs of strong mitigation actions were not systematically compared with the huge potentials of energy cost savings through energy efficiency and the learning and cost degression effects of renewable energies. In general the external costs and the subsidies on nuclear and fossil fuels were not internalized in cost calculations. Even up to now, in most countries there has not been a serious effort of „putting the prices right“ so that that they could tell the „ecological and societal truth“.

The Stern-Report ("Stern Review on the Economics of Climate Change", commissioned by the British government, released in 2006 as "The Stern Review Report", in 2007 under the title "The Economics of Climate Change. The Stern Review": Cambridge: Cambridge University Press) represents the turning point towards economic arguments in favour of strong mitigation policies.[17] Recently the Global Commission on the Economy and Climate (GCEC 2014; 2015; so called Calderón Commission) promised to elaborate a „New Climate Economy“.

Economics of Climate Change is first of all a comparison between costs and benefits of mitigation – assumed that mitigation, the switch to a 2dt is a burden, is costly. This calculus is straightforward. It results in a relation that the benefit by far outweighs the (assumed) costs; by about a factor of three Hohmeyer (in: Gaia 23/3 2014). This factor increases within the 21st century: "Climate mitigation is therefore in the longrun the best investment into the future" (Hohemeyer ibid; our translation)

There is secondly a huge discussion on the topic if the sign of mitigation cost is really negative, whether mitigation is really a burden. Mitigation cost is derived also as net cost as it is the difference between a mitigation and a business as usual (bau) scenario.

In this (latter) respect, the Calderón Commission puts this calculation swing to a moderate (net) cost increase as follows: „Most of the economic models which have attempted to estimate the net costs of achieving a likely 2°C pathway suggest that they are relatively small, amounting to 1-4% of GDP by 2030. They are almost certainly outweighed by the future economic damages associated with warming of more than 2°C that they would avoid“ (GCEC, 2014,p.25).

This view has been strongly reaffirmed by the WG III (IPCC AR5): „Reaching 450ppm CO2eq entails consumption losses of 1.7% (1% to 4%) by 2030, 3.4% (2% to 6%) by 2050 and 4.8% (3% to 11%) by 2100 relative to baseline (which grows between 300% to 900% over the course of the century). This is equivalent to a reduction in consumption growth over the 21st century by about 0.06 (0.04-0.14) percentage points a year (relative to annualized consumption growth that is between 1.6% and 3% per year).

[17] There are many methodological critics e.g. on the use of the discount rate or the unrealistic assumption of general economic equilibrium which question these results. The „Global Commission on the economy and climate“ summarizes these critics like follows: „There is a perception that there is a trade-off the short to medium term between economic growth and climate action, but this is due largely to a misconception (built into many model-based assessment) that economies are static, unchanging and perfectly efficient. Any reform or policy which forces an economy to deviation form this counterfactual incurs a trade-off or cost, so any climate policy is often found to impose a large short- and medium term cost. In reality, however, there are a number of reform opportunities that can reduce market failures and regidities that lead to the inefficient allocation of resources, hold back growth and generate excess greenhous gas emissions“ (REN21, p.41)

To repeat the general framing: Mitigation cost estimates exclude any benefits of mitigation, i.e that of reduced impacts from climate change as well as other benefits (e.g. improvements for local air quality)“ (quoted from Edenhofer 2015).

In other words: Recognizing

- the very small yearly reduction of consumption (0.06% p.a.) in comparison to yearly consumption growth between 1.6% to 3% p.a.
- the huge value of the co-benefits of climate mitigation strategies (see below)
- the avoidance of dramatic impacts (casualties and income losses) of climate change and/or adaptation needs.

a political „wait and see“-position justified with the old perception that strong climate mitigation strategies have to deal with global „burden sharing“ seems to be rather irrational and outdated.

Does this **global** „proof of benefits“ create enough **country specific** motivation to overcome differentiated and competing national perspectives and barriers? And will it impress the vested interests of the fossil fuel industry confronted with billions of „unburnable“ assets?

Looking at the country level, probably the „global benefit“-argument alone will not cause enough awareness and momentum to raise the ambition level of all parties. Thus, a better understanding of specific national co-benefits is necessary. While air quality improvements and reduction of energy import dependency might create additional driving forces for some countries, fostering innovation dynamic and ecological modernization as well as impulses for new technology markets (green technology markets) might raise the ambition level of other countries.

4.4 Unexpected cost degression of photovoltaic and wind power

It has been estimated that the average levelized costs of solar PV (photovoltaic) electricity decreased between 1990 (about 1.200 $/MWh) and 2013 (about 0.150 $/MWh) by a factor of 8 (REN21, p.39). Solar PV costs vary, depending on solar irradiation conditions, local non-technology costs, variations in capital and financing etc… For example in Germany the feed-in tariff for new large scale solar PV decreased in 10 years by about 80%, from 43 €cts/kWh (2005) to 8.7 €cts/ kWh (2015) (Agora;Fraunhofer ISE, 2015).

The costs of PV in Germany, in the US and Japan and other countries may differ within a reasonable range, but the most important message common to all national PV deployment schemes and crucial for further rapid deployment globally is the following: The cost-degression of the past is expected to continue driven by further technological progress, economies of scale and growing global competition - though with a lower degression rate - in the future. A study of Fraunhofer/ISE (on behalf of Agora 2015) has developed long-term scenarios for the market development and costs of PV Systems. The result is striking: „Depending on annual sunshine power costs of 4-6 €cts/kWh are expected in Europe by 2025, reaching 2-4 €cts/kWh by 2050. These results indicate that in the future power produced from large-scale solar photovoltaic plant will be cheaper than power produced from conventional technologies in large parts of Europe“(ibid., p.8).

The global projections for 2050 acording to the scenarios are within the following ranges:

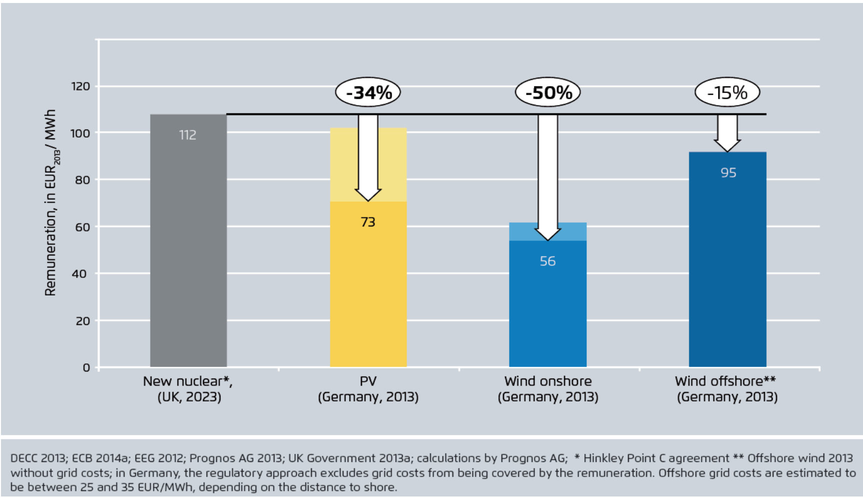
- in North America: 1,5-5,8 €cts/kWh
- Australia: 1,6-4,9 €cts/kWh
- India and Mena: 1,6-3,7 €cts/kWh

The study summarizes that „..most scenarios fundamentally underestimate the role of solar power in future energy systems" (p.10). This refers not only to the power sector, but also to heating (e.g. heat pumps), cooling (e.g. solar cooling) and the transport (e.g. e mobility).

A steep decline of costs could also be observed for wind energy over the last decades, however, as being a more mature technology with less dynamics than in the photovoltaic case. Further degression effects can be expected combined with technological steps forward comprising amongst others specific technologies for offshore wind energy as well as for inland sites typically characterized by lower average wind velocities.

Even in countries with rather low solar radiation as Germany PV is becoming a more and more competitive option as wind energy already is. Figure 2 compares the cost per kWh of PV and wind in Germany (2013) with the price guarantee[18] for the planned nuclear power plant in UK (Hinkeley point C agreement). It demonstrates that even today the cost range for PV and wind (onshore) is below the costs of a new nuclear power plant like Hinkeley point C. The range will be less, but still exists if comparable back-up systems (e.g. gas turbines) are included into the systems cost of nuclear, PV and wind (see Agora; Prognos 2014).

Figure 2 :Specific costs of solar or wind energy based electricity generation in comparison to new nuclear power plants



Source: see Prognos; Agora 2014.

With this background the impressive projection of Bloomberg (2015; see figure 3 =NEO2015) on the future market deployment of power generation of wind/solar in comparison to fossil-fuel power might even be an underestimation, and the expected rise of nuclear up to 2025 (as a seemingly „clean power") might be an overestimation.

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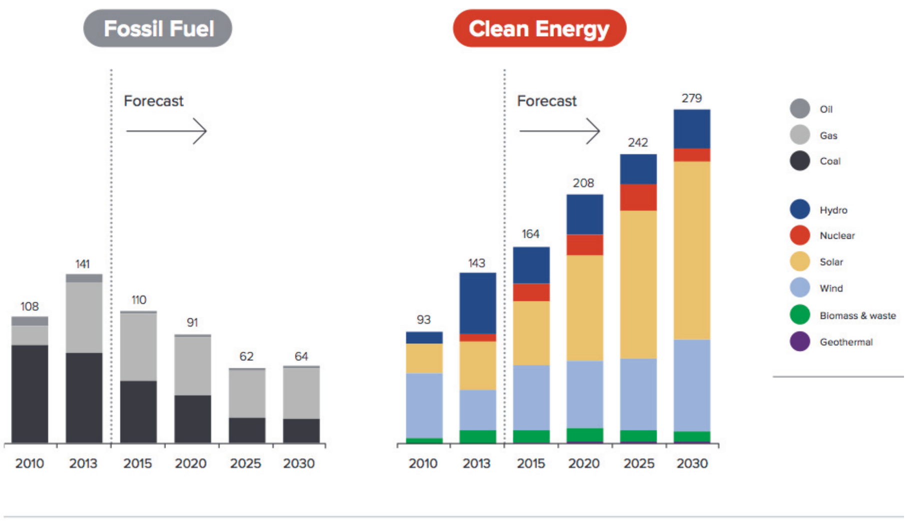
[18] The Hinkely Point C agreement implies a guaranteed renumeration of 11,2 cts/per kWh (real) for 30 years (a socalled „Strike Price", which is set at GBP 92.50 per MWh and fully indexed to the Consumer Price Index from the date of signature of the contract. „The Strike Price of GBP 92.50 per MWh corresponds to a (post-tax and nominal) rate of return of [9.75 to 10.25] per cent for the HPC project as a whole, i.e. taking into account the lifetime of the installation." Source: European Commission C(2013) 9073 final p, 12; http://ec.europa.eu/competition/state_aid/cases/251157/251157_1507977_35_2.pdf)

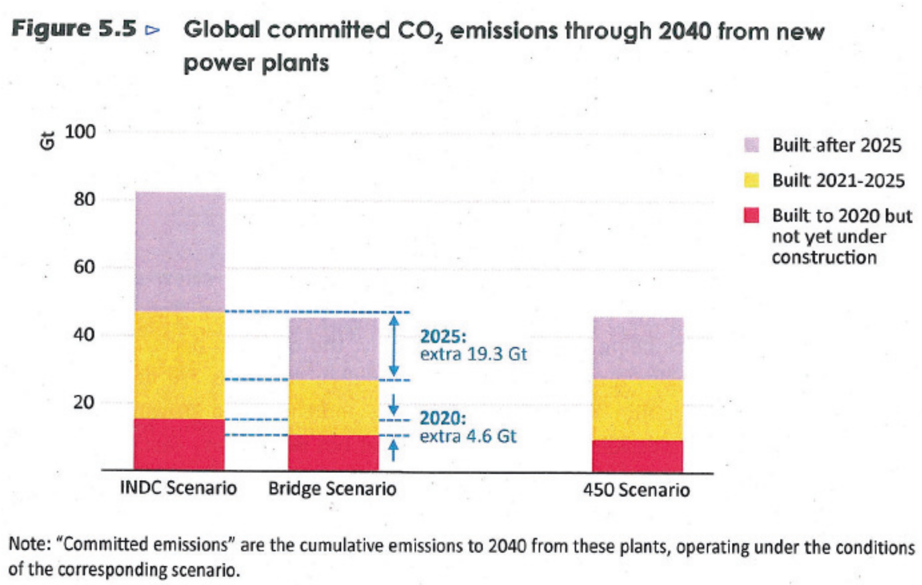
Figure 3 : Annual additions to global power generation capacity (GW)



Source: Bloomberg New Energy Finance, 2015.[13]

Power plants are long-lived investments. Once installed, they locked for about 40 years or more in the use of a special energy carrier. Investment decisions of the coming years, therefore, determine an essential part of future emissions, from electricity production. In its World Energy Outlook Special Report the IEA calculates the expected lock-in effect if following a scenario based on the assumption about expectable INDCs in comparison to a more ambitious scenario with regard to GHG mitigation (cf. also chapter 2.2).

Figure 4 : Global committed CO_2 emissions through 2040 from new power plants



Source: IEA 2015.

Illustrated is the amount of "determined" CO_2 emissions in power plants (in the year 2040) which result from earlier investment decisions according to the three scenarios analyzed in the IEA's WEO Special Report on Energy and Climate Change. The importance of the power plant decision taken in the next ten years, expressed in emissions commitments, is about 60 Gt CO_2

more or less. Given a remaining global budget of about 1,000 Gt, this difference is in a magnitude of 6 %.

4.5 A window of opportunity for energy transition and low carbon investments

The headline of an article in the Economist (January 17th, 2015) formulated the following message: "Seize the day. The fall in the price of oil and gas provides a once-in-a-generation opportunity to fix bad energy policies". This current opportunity is driven by at least three effects which can reinforce each other:

First, the low oil and gas prices make it less profitable to invest in fossil fuels (less stranded investments or „unburnable assests").

Second, the expected long period of low interests on financial markets makes it more attractive to invest in real capital accumulation (like e.g. renewables and energy efficiency) and as a macroeconomic driver

third, raising national investment rates through incremental investments in ecological modernization could create „better growth" (GCEC) in many countries: „Total investment in the global economy is likely to be of the order of US$ 300-400 trillion. Of this around US$ 90 trillion is likely to be invested in infrastructures across cities, land use and energy systems where emissions will be concentrated... it will inevitably result not in incremental or marginal changes to the nature of economies, but in structural ones. But what kind of structural changes occur depends on the path choosen...These investments can reinforce the current high-carbon, resource-intensive economy, or they can lay the foundation for low-carbon growth.. scaling up renewable energy sources rather than continued dependence on fossil fuels" (GCEC, 2015, p.15).

Stepping away from the traditional fossil fuel dominated energy pathway for strong technology oriented countries like Germany can build an important basis to participate in growing markets and to make use of forerunner advantages. On behalf of the German Government the consultant company Roland Berger (BMU 2014, GreenTech made in Germany 3.0) analyzed six global lead markets of GreenTech which are at the core of a process of ecological modernization and risk-minimizing energy transition.

Roland Berger estimated that the global volume of these markets raise from 2.044 billion € (2011) to 4.403 billion € (2025) comprising the following sectors (in billion €/2011):

- Energy efficiency (720)
- Sustainable water management (455)
- Environmentally friendly power generation and storage (313)
- Sustainable mobility (280)
- Material efficiency (163)
- Waste managment and recycling (93)

Germany´s share of the global market volume is estimated to be 15% (Berger 2014). There is a lot of evidence that the German energy transition („Energiewende") is already and will be in the future an important driver of the relative competitive strength of German industry on these global lead markets.

Future market chances are not exclusive for countries like Germany, renewable energy technologies and energy efficiency measures have in general the potential to trigger a innovation dynamically, to release significant local investments and to create employment impulses. However, policy support seems to be necessary to guide the way in the right direction. There are various options to stimulate new markets. For renewable energies feed-in tariffs (FIT) have been proved successful in many countries, in other countries renewable energy obligations have set significant market impulses.

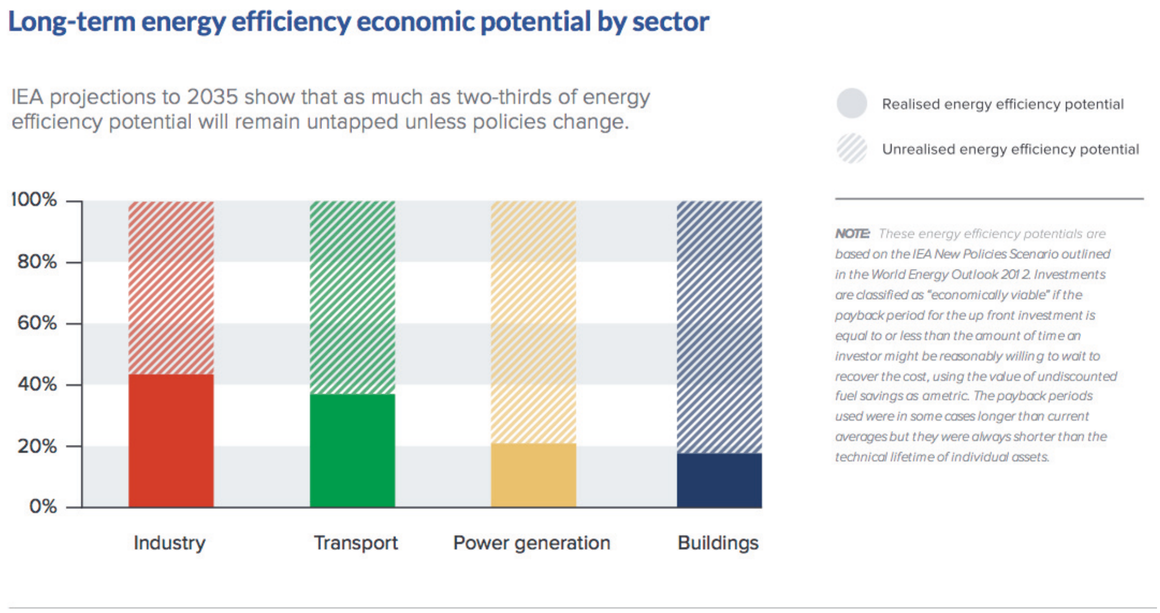
At the moment there seems to be a growing trend to implement carbon pricing systems. It has been shown by a recent World Bank report... "that about 40 countries and over 20 sub-national jurisdictions now apply or scheduled to apply carbon pricing through a carbon tax or emissions trading scheme (ETS). A further 26 countries or jurisdictions are considering carbon pricing. Together these schemes cover around 12% of global emissions" (cited by REN21 2014, p.42). It should be underlined that the disincentive of carbon pricing for a fossil-fuel driven energy path can be accelerated by taking a part of the revenues of a carbon tax or the ETS to incentivize the alternative market deployment of renewables and energy efficiency. In addition some part of the revenues could be used to smoothen the phase out of fossil fuel subsidies. While support for the poor and affected workers could be sustained, negative impacts of fossil fuel subsidy systems (e.g. high burden for the public budget, negative incentives for energy efficiency measures) could be reduced. The IEA calculated $540 billion of fossil fuel consumption subsidies (2012) in emerging and developing countries, with Iran (15.0%), Egypt (10.2%) and Saudi Arabia (8.5%) being the TOP 3 (percentage to GDP). Some countries have undertaken first steps to gradually phase out subsidies (see GCEC 2014).

4.6 Energy efficiency: A paradigm shift is possible

While it seems to be common sense today that energy efficiency is the largest, the cheapest and the quickest option to mitigate climate change, realizing the huge potential and the benefits of energy efficiency today is neither an easy task nor a self-dynamic process. A paradigm shift (i.e a less stronger focus on the supply side) is necessary that brings energy efficiency on the top of the agenda when it comes to concrete investment decisions and implementation of policy measures. Such a shift is possible but to initiate it is a quite different challenge and - due to its complexity - most likely a much more difficult task then the green restructuring of the supply side.

IEA projections (IEA 2014; see fig 4 below) show that about two-thirds of energy efficiency **economic** potential will remain untapped unless policy changes, the largest share of unrealized potentials (about 80%) is expected in the power generation and the building sector.

Figure 5 : Long-term energy efficiency economic potential by sector



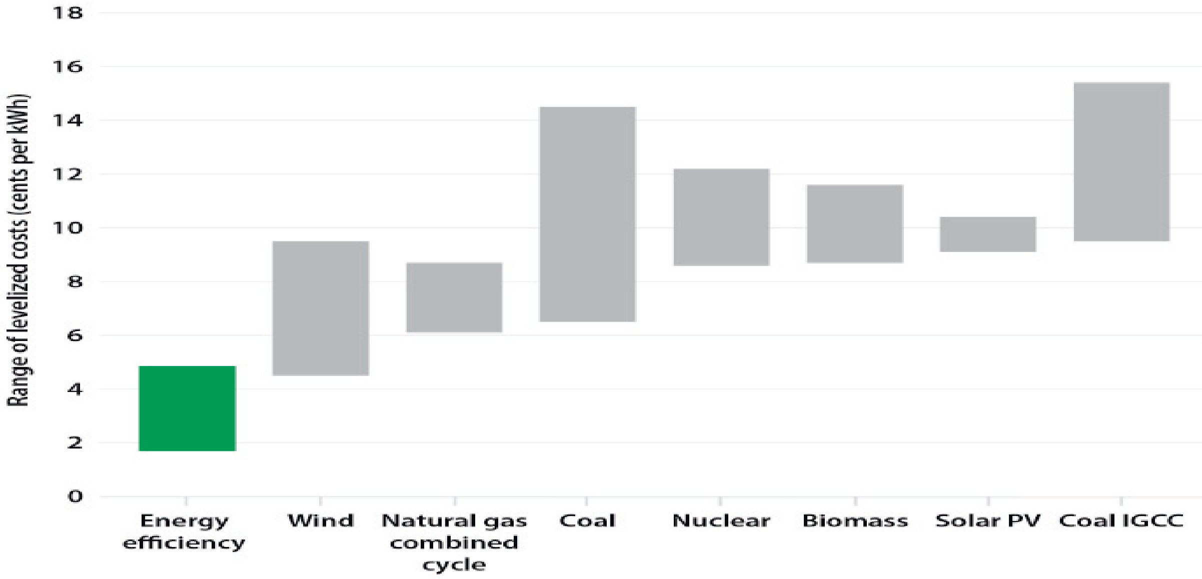
Source: IEA, 2014.[193]

Numerous studies e.g. published by American Council for an Energy Efficient Economy (ACEEE) or European Council for an Energy Efficient Economy (ECEEE) have demonstrated not only huge energy saving potentials from cross-cutting technologies (like e.g. electrical motors, pumps, pressurized air, appliances, lighting), industrial processes, buildings and vehicles. But they also analyzed in detail why large - in principle - cost-efficient potentials exist in market economies - „in principle“ meaning that they will only be implemented after a strategic barriers removal, after the correction of market failures and by establishing a new governance structure of efficiency policies.

There are many good examples showing that a pure concentration on the supply side is not justified. Here are four of them:

1. Larence Berkely National Laboratory (PPt-presentation by Marc D. Levine et al) compared the annual generation from China´s Three Gorges Dam with the annual savings in 2020 from ambitious energy efficiency standards of appliances. Refrigerators, air conditioners, washing machines, TV, computer, fans, stand-by-power and most other household appliances were included. The result: the energy savings (in kilowatthours) from ambitious standards are more than a factor 5 higher than the electricity generation of the highly disputed Three Gorges Dam.
2. UNEP (2014; unpublished) calculated the global savings effect of introducing best available technology standards (BAT) for six important appliances like refrigerators, electric motors, air conditioners, transformers, ICT, lighting. The global energy savings potential by moving to efficient appliances would lead to a reduction of global CO2 emissions by 1.25 billion tons/ year, and would save an electricity equivalent of 600 large coal power plants and save 350 billion US$ fuel cost each year.
3. ACEE (2014) compared the range of levelized costs (UScts/kWh) of evaluated energy efficiency programs of US utilities with different electricity supply options. Fig.6 shows that the costs for saved energy from utility energy efficiency programs in the US are on average 2.8 US cts/kWh – which finally means a factor of 2- 4 cheaper than to generate electricity in new power plants.

Figure 6: To save electricity in the US is much cheaper than to supply it by new power plants



The high-end range of coal includes 90 percent carbon capture and ompression. PV stands for photovoltaics. IGCC stands for integrated gasification combined cycle, a technology that converts coal into a synthesis gas and produces steam.
Source: ACEE 2014. Energy efficiency portfolio data from Molina 2014; all other data from Lazard 2013.

4. GEA (2012) presents very detailed global scenarios on buildings. In the study the possible huge „lock-in effects“ in the building sector were presented as a challenge for ambitious energy efficiency strategies. But the successful avoidance of „lock in effects“ can also be discussed as a promising opportunity to „leap frog“ into the age of efficiency, where countries get away from traditional path dependencies of past technology patterns. If e.g. China and India stepped forward to state of the art heating and cooling systems, they could avoid about 30-40% energy consumption in 2050 compared to suboptiomal standards. (GEA 2012)

These examples show that a paradigm shift to the demand side of the energy markets is possible and that there is initial evidence that it is on the way. But are we really prepared for such a significant or even drastic change? Because this would change everything: The perspective is turned down to the real customer needs („energy services“), to optimized efficiency gains along the value chain, to markets of energy services instead of kilowatthours, to energy service companies instead of pure energy suppliers and to prosumers feeding surplus energy into grid.

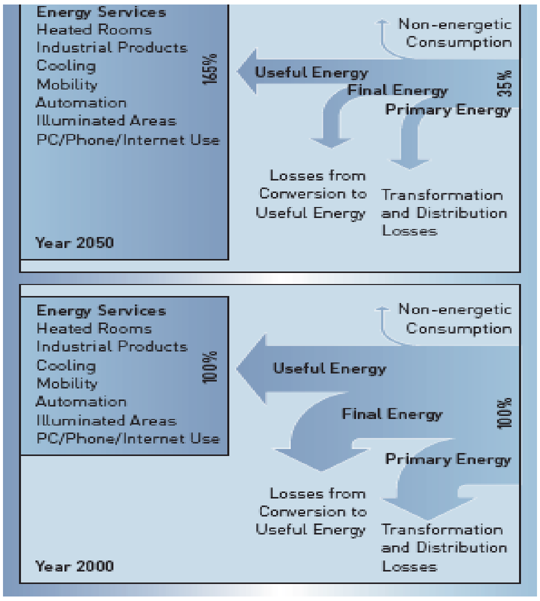
To make the technically feasible and economically promising stronger focus on energy efficiency really happen, some typical characteristics of the necessary paradigm shift should be clarified:

First: The technological background of stronger emphasis on energy efficiency

The worldwide „energy transforming machines“ are extremely inefficient, everywhere, on global and on national scales. Measuring the flow of energy through the world energy system demonstrates this point (Jochem; Reitze 2014): Putting 518,500 PJ (100%) primary energy into the system, delivers 157,550 PJ (32.4%) useful energy (e.g. space heat, process heat, mechanical power, Illumination, ICT). The most – namely 67.7% - are losses.

A comparable picture can be shown for relative energy efficient countries like Switzerland, but it can also be shown that a drastically reduction of the losses is possible. Taking for example the reference energy flow diagram of Switzerland in 2000 in comparison to a technically feasible Swiss 2000 Watt per capita society in 2050, which changes the efficiency of the energy system dramatically.

Figure 7: Swiss energy flow diagram in 2000 compared with a „2000 Watt society“ (2050)



Source: Jochem; Reitze 2014.

In 2000 approximately 2/3 of the primary energy demand is lost in energy conversion. In 2050 the losses are reduced by two thirds while energy services increased by 65%. Four main factors contribute to this effect: The significant and consequent increase of end use energy efficiency, a higher share of cogeneration/trigeneration technologies, the switch to more dezentralized renewable power systems in combination with an ongoing structural change in the country to less energy intensive sectors and business fields (including more incentives to foster recycling measures an step into a circular economy).

Second: Acceleration effects of integrated energy and resource efficiency policies

Up to now climate mitigation strategies have focused on the energy sector. But many interlinkages exist to the general use of bionic and abionic resources. Within the concept of a circular economy (see especially Ellen MacArthur Foundation (2014) the nexus between energy and resource efficiency becomes quite interesting - not only concerning the use of biomass, but especially concerning the use of technical materials. Most „circular“ processes of technical materials (e.g. recycling, refurbish/remanufacture, reuse/redistribute and maintenance) can typically reduce energy consumption.

There is some evidence that the integration of energy and resource efficiency policies can reinforce efficiency gains and cost reductions. Concerning a strong climate mitigation policy the integrated approach can even create macroeconomic win-win effects (see below the example for Germany). Thus, integrated climate mitigation strategies based on an in-depth analysis of mutually reinforcing energy and material efficiency effects could throw a new light on the feasibility of a 2dt-strategy.

Jochem / Reitze (2014) analyzed the effects of integrated energy and material efficiency policies. In addition to the technological option of material efficiency by improved properties and recycling, the substitution of energy-intensive materials by less energy-intensive materials (including bio-based polymers) and the intensification of product and plant use are other options that may play a more important role in reducing the quantity of materials produced and hence energy demand in the next decades. Entrepreneurial innovations and specific service offers will support these technical options to achieve for instance intensified uses of machinery and vehicles by pooling (leasing, renting, and car sharing): "The impact on reduced primary energy demand may range from approximately 0.3% per year (autonomous technical progress in material efficiency without specific policies) to more than 0.6% per year if supported by various policies oriented towards sustainable development in the future" (see above Jochem, E./ Reitze, F., manuscript 2013; 2014). The potential of material efficiency in combination with a more intensive use of products and in a broader sense sustainable consumption for GHG mitigation is also confirmed by the last IPCC Assessment Report (see IPCC WG III 2015 industry chapter).

A comparable accelerating effect by combining an ambitious climate mitigation strategy with resource efficiency policies has been shown for Germany. The Wuppertal Institute for Climate, Environment and Energy in cooperation with 30 partners from research and business conducted a comprehensive study of decoupling options in Germany on behalf of the Ministry of Environment on "Material efficiency and resource consumption" (MaRess)[9]. MaRess modelling results on the combination of resource and climate protection policies showed that for Germany even a limited use of resource policy tools would already lead to positive acceleration of economic and climate mitigation effects. The MaRess simulation assumed a selected portfolio of resource policies, including e.g. the introduction of a primary buildings material tax, certain quota obligations to encourage the use of recycled materials, information (audits) and incentives to identify and implement cost effective material reduction potentials especially in SMEs. Based on these policy strategies the simulation for the year 2030 resulted in the following effects – relative to a reference approach with pure climate protection measures (Distelkamp et al. 2010b):

- a reduction in the absolute material consumption of around 20%
- an increase of the gross domestic product by around 14%
- an increase in employment levels of around 1.9% (under consideration of demographic factors and productivity-oriented wage developments) and
- a cost reduction of 251 billion Euro in the federal budget by the year 2030.

Overall, the MaRess simulation came to the conclusion that a consistent resource efficiency policy strengthens Germany's international competitive position. The modelling analysis demonstrated for a high technology country for the first time that "...combining a committed climate protection policy with a policy to increase material efficiency can achieve an absolute

[9] See the project website at: http://ressourcen.wupperinst.org/en/home/index.html

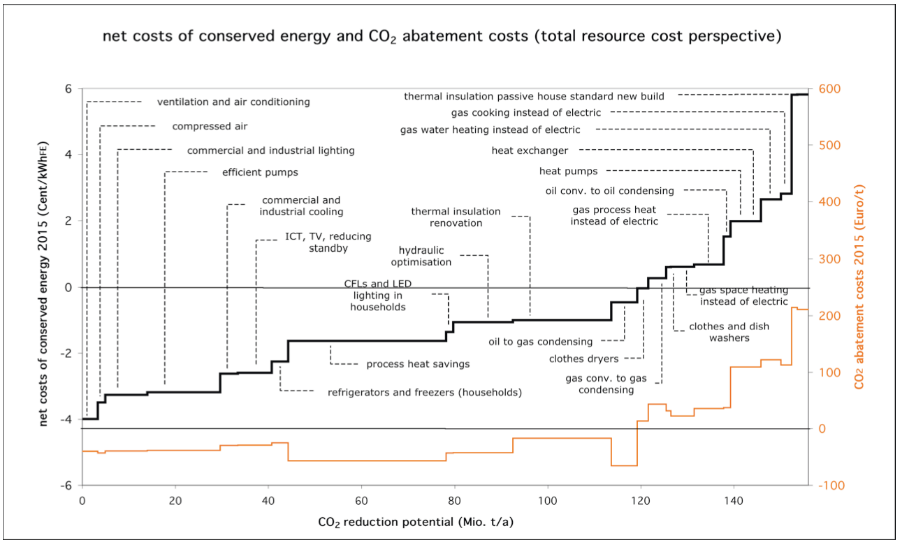
decoupling of economic growth from resource consumption" (Kristof & Hennicke 2010, p. 18; based on Distelkamp et al. 2010).

Third: Let´s talk about markets for energy services

The ultimate goal of energy production and use are energy services e.g. concrete services like heated rooms, cold beverages, high quality communication, transportation etc. which are satisfied by energy use. End use energy (e.g. electricity, oil, gas, district heating) needs a transforming technology (e.g. appliances) to deliver the needed energy services. Thus, it is not the price per kWh of the end use energy carriers which matters at the end of the day. Customers want „energy services" if possible „at least cost". Even if the price of energy (e.g. from renewable sources) is relatively high reduced energy consumption by most efficient transforming technologies could stabilize the costs and could lead to an acceptable or even lower energy bill. It is the combined package of the price of end use energy and the incremental marginal costs of energy efficiency technology which contributes to „least cost energy services".

Figure 7 shows a cost potential curve for Germany demonstrating that – after barriers removal - about 140 TWh of energy can be saved with a profit. This visualization could and should help to set investment priorities. Given scarce national, regional or actor specific capital the priorities how to allocate capital could be determined. As long as saving electricity per kilowatthour is cheaper than supplying, capital should be invested into efficiency options instead of building new power plants.

Figure 7 : Energy Saving Cost Potential Curve for Germany



Source: Wuppertal Institut 2006

Four: Avoid misconceptions of rebound effects

In the past (1980-2010) the average global decrease of energy intensity to a GDP energy efficiency increase was low (about - 1,2 to - 1.3% p.a) (CCEC, 2015), and thus (relative) decoupling of GDP growth and energy consumption has been weak, especially in developing countries. But to assume that energy efficiency does not work or will be always „eaten up" by counterproductive rebound effects[19] would be a mistake. Even ex post evidence shows clearly that strong efficiency policies of the past do have a measurable impact: Due to the energy efficiency programs in California since the 1970th the electricity consumption has stayed constant whereas it increased in the US on average about approx. 1/3.

But what about the future? Most long-term scenarios e.g. of the IEA and the GEA and energy politics in favour of the German Energiewende assume the feasibility of a very strong (absolute) decoupling through the availability of more efficient technologies. Is this really feasible? Do they underestimate rebound effects?

Without any doubt rebound effects on energy consumption are real, and so are comfort-, lifestyle-, income- and growth effects. But the cause/impact mechanisms of these effects in relation to energy are quite different and so are the policy packages which can mitigate them. Increasing energy and resource use through unsustainable consumption and production, larger living space per capita in buildings, more long distance holiday flights, stronger and bigger cars (SUV) and larger TV-screens etc. must primarily be explained by general growth-, income- and lifestyle effects, but only to a minor part by rebound effects.

It has been estimated that the combined direct, indirect and macro-related rebound effects „eat up" about 25% of the energy savings by efficient technologies.[20] If this holds true in general only 75% of the estimated effects of a technically feasible energy efficiency pathway contribute to climate mitigation. This is still a major contribution, but it makes it more difficult to step to risk-minimization strategies.

For this reason specific policies to increase consumer awareness have to accompany energy efficiency policies. In the future smart combined policies must have a double effect: They should encourage as much efficiency increase as necessary for climate and resource protection at reasonable societal costs, and at the same time they should anticipate and mitigate possible counterproductive effects. In short: If the target is absolute decoupling of GDP from primary energy consumption at best no kilowatthour saved by efficiency should get lost by counterproductive effects.[21]

On the policy side a successful strategy needs a „disruptive" policy design, which means more then just adding additional policies and measures to existing policy packages. We call it a new „policentric governance structure" which follows an integrative approach and integrates policies on all policy levels. This also includes the establishment of new institutions taking over for

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[19] For defintion of rebound effect see Hennicke/Thomas 2014. Particularly due to an alternative use of saved energy costs and macro economic (systemic impact) effects the realized energy savings from the use of more efficient technologies can be lower then expected by pure technical analysis. This definition of rebound effects focusses on economic reasons and assumes a clear causality between the use of a more efficient technology and less reduced or even higher („back firing") energy consumption.

[20] See Hennicke/Thomas 2014

[21] See Hennicke/Thomas 2014

instance the responsibility to develop energy services markets and exhaust energy efficiency potentials.[22]

The recent energy efficiency directives of the EU is based on the assumption that binding energy saving targets for all 28 Member States of the EU are a necessary step forward to foster the implementation of energy efficiency policies and to mitigate counterproductive effects like rebound effects. This has been supported by a most effected industries (e.g. for efficiency technology and insulation material) looking for clear guidelines for their long-term investment and innovation perspectives. Interestingly, the Environmental (ENVI) and Industry Committee (ITRE) of the European Parliament as well as the majority of the Parliament demanded a binding 40% energy efficiency target up to 2030. Although this has not yet been accepted by the EU Commission and the EU Council, it is a strong signal to industry, politics and the civil society that energy efficiency, energy savings and the mitigation of counterproductive effects (like e.g. rebound effects) are taken much more serious in practical policy making than in the past. That´s why it is justified to talk about a possible paradigm shift in energy policies.

4.7 Harvesting the co-benefits reinforces climate mitigation ambition

One of the most interesting developments in theory and practice of international climate mitigation and energy policies is the perception of so called „co-benefits". The IEA calls this phenomena the „non climate drivers" (IEA 2014). They are understood by IEA as follows: By reducing GHG emissions especially from fossil fuels manifold additional benefits like energy security, fiscal balance, road congestion alleviation, air quality improvements, liveable communities and economic development are generated. This list might be not complete as macroeconomic effects like „better growth", new business fields, more and better jobs, global competitiveness by reducing resource conflicts e.g. should be mentioned and evaluated as well.

It seems quite reasonable that national climate mitigation strategies will be more encouraged, the more national co-benefits are associated with it. It might even happen that from a pure national perspective maximizing these benefits could be the main policy and development target whilst the contribution to global climate mitigation could be appreciated as a „Co-benefit".

Conceptually it is important to differentiate between three levels of preceiving and dealing with „co-benefits". All these perceptions reinforce the argument that even whithout any climate change, the global and national phasing out of fossil fuels should be implemented as quickly as possible.[23] Most of these „co-benefits" do have a major national impact, but some might have a global background as well.

As explained above the first perception deals with environmental, social and economic benefits which are uno actu realized (but often not measured and recognized) with the reduction of fossil fuels by conducting ambitious climate mitigation strategies. With this context measuring,

[22] Wuppertal Institute has developed a concept for a „Federal Energy Effciency Agency and Energy Efficiency fund" (WI 2014)

[23] In the following we concentrate on the „co-benefit" arguments of the phasing out of fossil fuels. Netherthless, there are important „co-benefits" connected with phasing out nuclear (e.g. risk reduction, possible extreme damage costs, nuclear waste management, costs decommisioning) which are important arguments to focus on „risk-minimizing" and not only „decarbonizing" strategies.

reporting and cost/benefit analyses are important to raise awarness of politics, industry and civil society.

The second perception deals with counterproductive direct subsidies on fossil fuels. In this respect policy should phase out subsidies stepwise, but as quickly as possible. Negative distributional effects should be compensated .

The third deals with external effects of fossil fuels, which probably might by huge (see below IMF, but highly controversial concerning measurement, monetarization and internalization into prices (e.g. via a tax or ETS). Nevertheless, somebody has to pay – may be in the future – for external costs of fossil fuels. In this respect it is important that ambitious mitigation strategies should always consider avoided external costs if not internalized into current costs and prices.

In the following there are some quantitative indicators how important these „Co-benefits“ might be especially under a national perspective:

1. The GCEC has developed an interesting „marginal abatement benefits curve“ for the year 2030. The „Marginal Abatement Cost Curve“, popularized by McKinsey, was modified by adding monetary estimates of the multiple benefits per tonne of CO2 abated, in relation to four key actions:

- Improved health due to lower local air pollution resulting from the reduction of coal consumption.
- Rural development benefits from better land use management practices as well as forest restoration.
- Benefits from reduced volatility of energy prices due to lower use of fossil fuels.
- Benefits from reduced air pollution, avoided accidents and congestion due to shifts on transport modes – from driving to walking, cycling and public transport (ibid., S. 25).

2. The cost of mortality from outdoor PM 2.5 exposure as % of GDP has been estimated by Hamilton 2014 (cited by GCEC, p.21). The share of costs amounts to about 11% (China), 8% (Russia), 5% Germany and nearly 4% USA (Ebenda, 21). „Between 350,000 and 500,000 Chinese die prematurely each year because of the country's disastrous air pollution, says China's former health minister“. (The Telegraph, 9. 3. 2105).[24]

3. N.Höhne et al quantified three major co-benefits of climate mitigation strategies for the most important CO_2-emitters China, US and EU. These calculations are especially interesting to bridge the interest of the current generation on jobs and health care with the well-being of future generations by implementing ambitious climate protection strategies.

[24] R.Smith has summarized the political challenge of air pollution in China as follows: “There’s no better illustration of this government-industry collusion and pollution’s catastrophic impact on the health of China’s people than journalist Chai Jing’s sensational new documentary on China’s smog *Under the Dome—Investigating China’s Smog* (Wumai diaocha: qiongding zhixia) which went online in late February and is being rightly hailed as China’s *Silent Spring´.* “

https://www.youtube.com/watch?v=T6X2uwlQGQM.

Figure 8 : Total potential co-benefits of a 2°C compatible trajectory with 100% renewable energy compared to current policies trajectories

Co-benefit	EU	US	China	Total
Cost savings from reduced fossil fuel imports	USD 170 billion per year saved	USD 160 billion per year saved	USD 190 billion per year saved	USD 520 billion per year saved
Premature deaths from excessive ambient exposure to fine particulate matter prevented	46,000 deaths	27,000 deaths	1.2 million deaths	1.3 million deaths
Creation of additional green jobs in the wind, solar and hydro energy	430,000 jobs	650,000 jobs	1.9 million jobs	3 million jobs

Source: Höhne et al 2015

The authors of the study summarized their calculations like this: „Recognition of both the achieved and potential co-benefits may increase the willingness of decision makers and influential stakeholders to embark on more ambitious climate change mitigation strategies by highlighting the directly tangible synergies between climate change mitigation measures and national development goals. The benefits highlighted in this study – national cost savings, health and job creation – are economy-wide issues that are of key relevance to the development objectives of all imaginable stakeholders“ (ibid., p.24).

4. The International Monetary Fund (2015) recently published a paper on a comprehensive approach of global energy subsidies. „It focuses on post-tax energy subsidies (consumer prices are below supply costs) plus a tax to reflect environmental damage and an additional tax applied to all consumption goods to raise government revenues... These subsidies primarily reflect underpricing from a domestic (rather than global) perspective, so that unilateral price reform is in countries' own interests“. The key findings of the study are the following:

- Post-tax energy subsidies are projected to further significantly raise in the future.
- Energy subsidy reform is as urgent as ever, in particular to tackle with the externalities from energy consumption. Coal accounts for the biggest subsidies, given its high environmental damage. Therefore, reforming coal subsidies through an environmental tax should be at the top of the policy agenda.
- The current low international energy prices provide a window of opportunity for countries to eliminate pre-tax subsidies and raise energy taxes as the public opposition to reform is likely to be weaker, but distributional effects should be minimized. Therefore, the poor and energy intensive industries should be supported.
- Post-tax subsidies are large and pervasive in both advanced and developing economies and among oil-producing and non-oil-producing countries alike, but they are especially large (about 13–18 percent of GDP) in emerging and developing countries.
- The fiscal, environmental, and welfare impacts of energy subsidy reforms are potentially enormous. Eliminating post-tax subsidies in 2015 could raise government revenue by $2.9 trillion (3.6 percent of global GDP), cut global CO_2 emissions by more than 20 percent, and cut pre-mature air pollution deaths by more than half.
- The distributional effects of a subsidy reform are important: „While energy subsidy reform is... beneficial from the view of the entire society, there are potentially important distributional issues... For example, most of environmental benefits may go to urban populations. This creates winners and losers from energy subsidy reform, which can introduce major obstacles to achieving energy subsidy reform. In addition, energy subsidy reform should protect the poor and vulnerable, making sure their well-being is not adversely affected. The proper use of the fiscal gain would be crucial in addressing

this issue as well as the overall distributional impact of reform benefits. Higher energy prices will also harm energy-intensive firms... transitory assistance may be needed, such as worker retraining programs and temporary relief for firms" (ibid, p.30)

- Last but not least, the authors formulate a caveat concerning the quantification of „co-benefits": „These findings must be viewed with caution. Most important, there are many uncertainties and controversies involved in measuring environmental damages in different countries our estimates are based on plausible but debatable assumptions" (ibid., p.6).

Though the uncertainties might be high, huge national and international „co-benefits" of climate mitigation strategies are real as well. What matters to encourage more ambitious GHG mitigation efforts in all countries are robust figures to demonstrate that protecting the global climate is not only in the interest of all further generations to come, but compatible with current national interests as well.

4.8 Policies&Measures: How to finance the Energiewende?

To evaluate the necessary governance structure of ambitious mitigation policies an indepth analysis of smart packages of policies and measures (P&M) to foster the deployment of energy efficiency and of renewables and – at the same time – to reduce rebound-, growth- and comfort effects would be necessary. This would go far beyond the scope of this paper. Thus we leave it below to some general remarks and a focus on financing.

To demonstrate the feasiblity of a 2dt-strategy the question has to be answered whether financing could be a bottleneck for implementation.

Scenarios, technology portfolios and policy analyses demonstrate quite convincingly that neither the availability of technological options nor missing knowledge on possible packages of policies and measures (P&M) for removing barriers and fostering implementation of efficiency and renwables are bottlenecks for implementing a 2dt-strategy. What is missing is the ambition level of politics and a consensus on most succesful strategies selected from an existing huge portfolio of P&M. One general problem might be to reduce complexity and to concentrate on key packages of instruments. [25] An other problem is knowledge management and targeted knowledge transfer on lessons learned and how to replicate good practice. Following the plea to give energy effciency a higher priority the channels for information and knowledge exchange should be extended, e.g. by establishing an Annual World Efficiency Conference or by creating National and International Agencies on Energy Efficiency. Or building up Internet platforms on energy efficiency which are more target group and user oriented. For example, there are many platforms at the Internet available either on technologies or P&M but often they are not connected to encourage action[26]

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[25] For example a European evaluation of the renewable energy targets and policies found „...900 single barriers ...preventing RES deployment in all sectors in the 28 Member States of the EU" (The European Forum for Renewable Energy Forum (Eufores) et al, EU Tracking Roadmap 2015, Brussels 2015, p.13.)

[26] With the Internet Platform bigEE.de (bigEE stands for „Bridging the implemenation gap on energy efficiency in buildings") Wuppertal Institute tries to fill this gap concerning the building sector.

After COP 21 a global assessment of the macroeconomic impacts of integrated policy packages to foster efficiency and renewables should be conducted. With this background the " negative reduction agenda" (**reducing** GHG e.g. by Emission Trading Systems (ETS)) should be combined with a "positive deployment agenda" of targets, roadmaps and P&M packages for the market transformation of efficiency and renewables.

Supporting adaptation (especially for vulnerable developing countries) und financing climate mitigation strategies should be a special focus. The International Research Network for Low Carbon Societies (LCS-RNet)[27] formulates the following expectations: "COP 21 can provide critical policy hooks for the step changes necessary in financial intermediation such as public guarantees on credit lines including: an agreed social value of carbon mitigation activities to be incorporated in the diverse low carbon financial initiatives; strong Measuring, Reporting and Verification (MRV) guaranteeing the efficiency of support for implementing Nationally Determined Contributions (NDCs) and the environmental integrity of the investment; and a framework securing the transparency of voluntary commitments of countries, clubs of countries and non-state actors. "(ibid). LCS-Rnet especially emphasises the importance of financing: "Innovative financial mechanisms must be established to reduce the risks attached to potentially profitable low- carbon projects that are blocked by high upfront costs, and to attract private savings and institutional investors, by valuing low carbon assets " (ibid).

In principle it seems to be quite evident how the costs of the global „Energiewende"can be financed by combining the following four elements: 1. Internalizing external costs (e.g. for coal: about 8 cts/kWh28), 2. Phasing out subsidies for fossil fuels (see below), 3. Raising awareness of stranded investments and a possible carbon bubble (see below), fostering the divestment movement from coal and – last not least – 4. Redirecting only a small part of the gigantic financial capital assets floating around the globe.

Option 3 and 4 could be win-win options: Avoiding a financial or a new carbon bubble by redirecting as much financial capital as possible into the productive use of investments into efficiency and renewables to foster the Energiewende.

After the global financial and economic crisis in 2008 the world was flooded with liquidity. Interest rates are percieved to stay close to zero for a longer periode. This causes troubles for all actors dependent on capital earnings and gigantic opportunities for „Financing the global Energiewende"29 (WBGU 2012). In general capital for the Energiewende can be provided e.g. by the public sector, venture capital and private equity investors, institutional investors such as sovereign wealth funds, pension funds, insurance or investment companies, foundations, family offices (which administer large private fortunes), as well as industry and smaller private investors (comp.WBGU 2012). Worldwide investment in the entire energy sector in 2010 has

[27] See: http://lcs-rnet.org/wp-content/uploads/2015/08/LCS-RNet-7th-Annual-Meeting-Statement_as-of-7th-July.pdf

[28] Compare for example http://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/4210.pdf

[29] http://www.wbgu.de/fileadmin/templates/dateien/veroeffentlichungen/politikpapiere/pp2012-pp7/wbgu_pp7_en.pdf

been calculated by the WBGU at around US $ 1,200 billion; this compares to about US$ 3500 billion[30] (less then 1% of total private capital assests) for the global investment requirements of the entire energy sector in 2050 (scenario assumptions: no nuclear energy, universal access to modern energy-related services by 2030, improved energy security, reduced air pol-lution and compliance with the 2° C guard rail)[31]. The interests of „Big Money" in large scale renewable investment and in transmission lines is growing: „The large scale investment and stable income returns of the offshore wind sector have continued to attract institutional investors, who are increasingly looking at assets under construction " (p.6., The European Wind Energy Assocition. EWEA, The European offshore wind industry – key trends and statistics 1st half 2015, July 2015) For example, the German Insurance Company Talanx recently took the lead of a consortia to finance the biggest German off shore wind park (Gode Wind 1) with 556 Million € (Hannoversche Allgemeine eitung, 11.9.2015). COP 21 should be a starting point to develop strategies how this beginning redirection of capital into the Energiewende and the implementation of a 2dt-strategy could be scaled up.

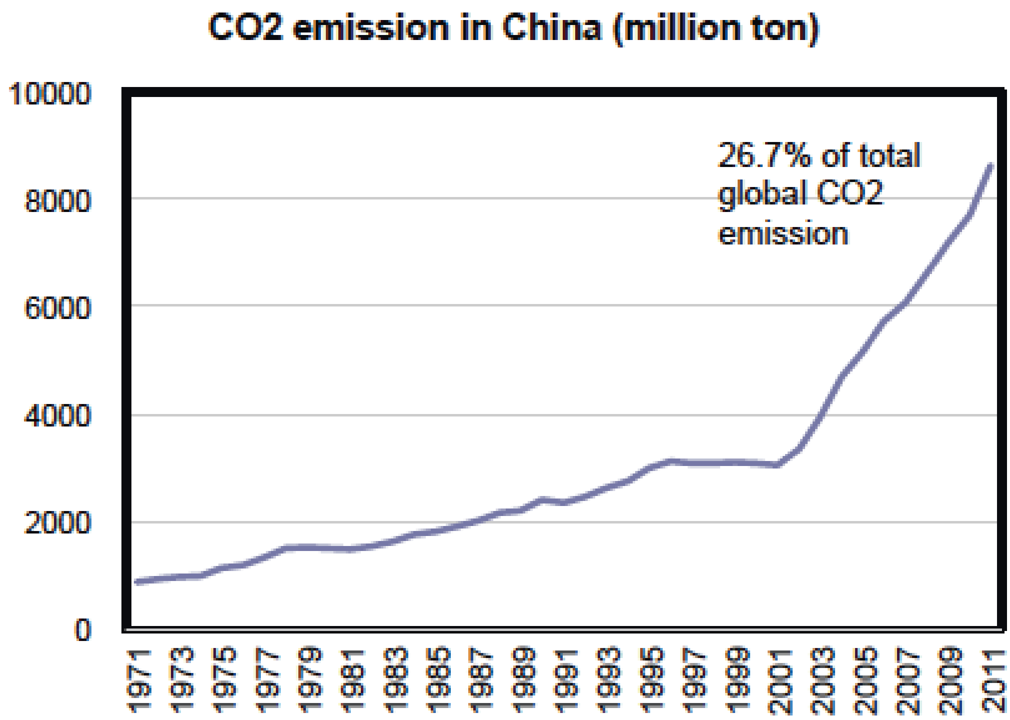
[30] According to the GEA the amount of investments are as follows: „GEA findings indicate that global investments in combined energy efficiency and supplies have to increase to about US$ 1.7-2.2 trillion per year compared with the present level of some US$1.3 trillion (2% of current gross world product). Given projected economic growth, this would be an approximately constant fraction of GDP in 2050". GEA, Global Energy Assessment. Key findings, Cambridge UK 2012, p.30

[31] see http://www.wbgu.de/fileadmin/templates/dateien/veroeffentlichungen/politikpapiere/pp2012-pp7/wbgu_pp7_en.pdf

5. China: a global game changer – in its own interest

China´s path to "decabonisation" and (potentially) to "risk minimisation" is essential for a 2dt-trajectory. With the steep increase of China's CO_2 emissions from the energy sector, 70 percent from coal use, mainly in the power production sector (cf. fig.),

Figure 9:CO_2 emission in China (million ton)



Source: Yu Wang, Tsinghua University, presentation as of 15 June, 2015 (FVEE workshop in Beijing), based on figures from IEA and China Statistical Yearbook 2014.

China's early peak in GHG emissions matters globally. Up to now, in its Intended Nationally Determined Contribution (INDC), which the Chinese government submitted on 30 June 2015 announcing its commitment to climate change mitigation actions in the post-2020 period, the (absolute) peak issue was only addressed tentatively:

- The explicit obligation is in terms of carbon intensity: that index shall decrease substantially against 2005 level: by 60 to 65 per cent.
- Peaking of (energy related) carbon dioxide emissions should be achieved around 2030 and the intention is to make best efforts to peak earlier.

Given this state of announcement, two questions are important:

1) What does this announcement in terms of carbon intensity mean in terms of consumption of the remaining global carbon budget?

2) What does the announcement of best peaking intentions beyond the explicit commitment mean in respect to the implementation power of the central state and the provinces in China? Is there any new development visible, which underscores these announcement?

This sub-chapter will follow these two questions.

Ad.1) The carbon budget consumption as implied in China's INDC

The (maximum) carbon budget (from the energy sector) implied in China's announcement, comprising an intensity aim as well as a peaking announcement at the latest in 2030, can be transformed in a figure which reveals the equivalent development of China's respective CO_2 emissions in both, the twenty five years before 2030 and twenty years after 2030, i.e. the 45 years from 2005 to 2050. Such a figure has been derived by NCSC and Renmin University and is shown in fig. 10

Figure 10: Change of major driving factors after the implementation of INDC in China (2005=100)

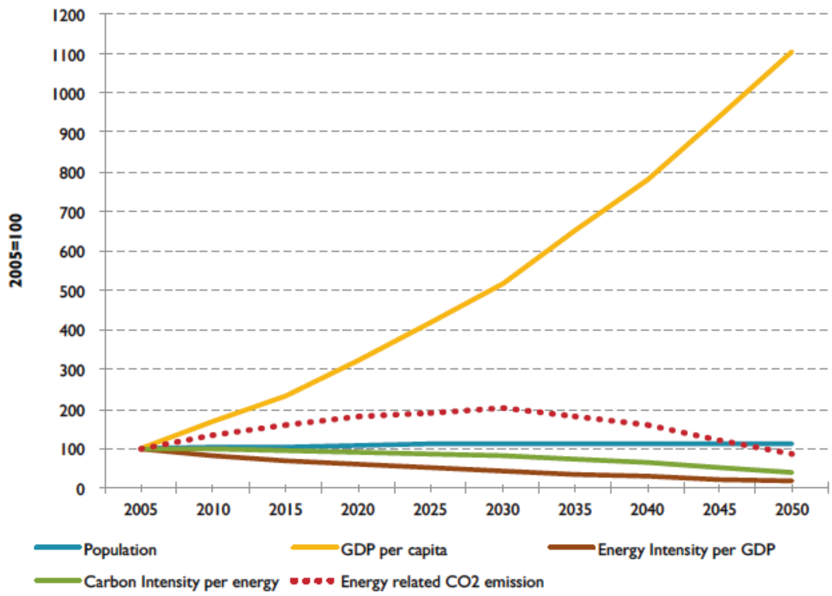


Figure 1-1 Change of major driving factors after the implementation of INDC in China (2005 = 100)

Source: Sha Fu et al. (NCSC) 2015

This figure can be translated in budget figures. In the base year, 2005, China emitted in the respective category less than 5 Gt CO_2/a. Given the worst case scenario which is implied in what has been officially announced, indicates the following: China pledges for a base load consumption of the global budget over the next 35 years of about 200 Gt and on top, for the peaking from 2005 to 2030 and back from 2030 to 2050, of about 100 Gt. Together it amounts to 300 Gt; that would be about on third of the remaining global budget. An impressive figure which provokes to look at the internal forces, which may support an earlier peaking date.

Some internal forces are quite obvious, as already the switch in China's position from that in the run-up to CoP 15 (Copenhagen) to that now in the run-up to CoP 21 in Paris is its outcome. A further effect of recent developments of new policy priorities can be expected (see ad 2).

Ad 2) The interior battle in China for realizing co-benefits – driving forces for an earlier switch to energy efficiency and decarbonisation path

China's situation with respect to its air pollution is, as is well-known, worrysome (see above) . It is mainly due to burning fossil fuels, especially to coal use; and has increased dramatically, i.e. proportionally to the increase of coal and oil consumption which occurred over the last decade, by a factor of about three. Consequently, the impact of the accompagnying air pollution, the damaging effects to health, crops and infrastructure (buildings) are huge and have increased accordingly.

At the other side of the coin of this dramatic development is that

(i) the potential benefit from reducing air pollution by switching the fuel used for energy services has massively increased, the option to decarbonize the energy sector has become much more attractive;

(ii) a much greater part of the Chinese society opposes those damaging circumstances; the environmental conciousness of the Chinese civil society has grown and has got much more attractiveness to an increasing part of the population in China.

The development concerning point (ii) is not only damage driven but also driven by economic structural change, which the Chinese society experienced over the last two decades. According to the traditional concept "grow first , clean up later", that kind of switch could be expected – it seems that it comes to the turning point. Surprising is not the switch to much more ambitious environmental policies by itself but only its early occurrence.

An indicator for the development of new priorities provides the three-year-battle for the new Environmental Protection Law (EPL) in China, which could be observed in the years 2011 to 2014 – it entered into force with beginning of the year 2015. It provides the regional authorities with some more powerful instruments to lead China into a cleaner future but nevertheless up to now with only limited strength: a view on details reveals, that the power of the new regulations depends mainly on the consistence and strength of its implementation. But the political processes how it was drafted , how the battle evolved, how the new allocation of responsibilities and accordingly power was brought through the institutions of the Chinese governance system is impressive and an indicator of a new balance of (interior) power. This is an indicator that the new balance of power in China - with a tendency to follow the subsidiarity principle - can result in further movements in the direction of an increase of cleaner energy sources and an earlier phasing out of dirty coal combustion. So, the momentum is there to get to an earlier peaking point, the respective expectation is not groundless hope but realistic. In the Bridge-scenario of the IEA (2015) coal and $C0_2$ peak in 2020 due to structural shifts in the economy, e.g. by a gradual decline in iron, steel and cement production and end use efficiency increase.

These perspectives of a structural change to "green transformation" can be supported by recent analysis of a Task Force of the China Council for International Cooperation on Environment and Development (CCICED) on "National Governance Capacity for Green Transformation"[32]. The recommendations are based not only on numerous good practice examples in China, Europe,

[32] Peter Hennicke serves as the International Co-Chair of this Task Force. Its final report is in preparation and will be presented to the public at the Annual General Meeting (AGM) in Beijing November, 9-11, 2015

USA and Australia but on remarkable official documents e.g. of the Communist Party of China on Ecological Civilisation (CPC 2015).

This document was reviewed by S. Geall (Chinadialogue)33 as follows: "Building an ecological civilisation", the environmental slogan the Chinese government has promoted over the past few years, might sound peculiar or vague to non-Chinese ears. But it is central to one of the highest-level, and so far largely unreported, state policy documents published this year, a document that makes ambitious pledges that could be decisive for China's environmental future" (S.Geall, 2015). Concepts like circular, resource efficient and green economy, well known from the international debate, are combined with quantitative targets, new ways to punish and reward officials and abondoning „economic growth as the only criterion in governance performance assessment" (ibd.). In sum, the vision „ecological civilisation", implies a real transformation of the old growth model and might serve as a roadmap for decarbonizing the economy by fostering energy efficiency and renewables.

[33] https://www.chinadialogue.net/article/show/single/en/8018-Ecological-civilisation-vision-for-a-greener-China

6. Germany´s Energiewende

So far the paper weighed the challenges and opportunities to implement a global 2dt-strategy. Summing up, there are promising indicators that under positive global circumtances a 2dt-trajectory is still within reach. Of course this jugdement is based on many assumptions and uncertainties. To get a better understanding how this might happen, we select the German „Energiewende" as an example how and why a highly industrialized country decided to realize a risk-minimizing strategy including the necessary national contribution to a 2dt-strategy. The main reasons are the perceived economic, social and environmental benefits for Germany.

The development of a climate policy in Germany started already in the early 1990s, but became more and more concrete and system relevant over time. In the face of the challenges linked to the mitigation of climate change, in 2010 the German government specified its vision for decarbonizing the economy and adopted its "Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung" ("Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply", BMWi/BMU 2010). In order to achieve the key targets of reducing greenhouse gas (GHG) emissions by 40% until 2020 and by 80 to 95% until 2050 (compared with 1990) a range of sub-targets was defined that have to be met at different points in time. These targets have been set either in the "Energy Concept" or in other documents. They include objectives for energy consumption reduction, an increasing share of renewable energy sources, increasing building refurbishment rates and the number of electric vehicles (cf. BMWi 2014).

Figure 12 gives an overview of the most important targets of the German Energiewende. The absolute reduction of primary energy consumption by 50% and a minimum share of 80% renewable energy based electricity generation are just two examples to show the degree of ambition associated with/behind the Energiewende concept. Thus, significant structural changes of the current energy system can be expected over the next decades in Germany.

Figure 11 : Overview of current political and energy policy targets of the German government

	Status quo	Target			
	2014	**2020**	**2030**	**2040**	**2050**
Greenhouse gas emissions					
Greenhouse gas emissions (versus 1990)	-27%	-40%	-55%	-70%	-80 to -95%
Energy efficiency/ energy savings (cross-sectoral and transformation sector)					
Primary energy consumption (versus 2008)	-9%	-20%	Not specified		-50%
Annual increase in final energy productivity	0.6% (2008-2013)	2.1% (2008-2050)			
Gross electricity consumption (versus 2008)	-6 %	-10%	Not specified		-25%
Combined Heat and Power (CHP) share in thermal electricity generation	approx. 22% (2013)	25%	Not specified		
Renewable energy sources					

Share in gross electricity consumption	28%	40 to 45% (2025)	55 to 60% (2035)		At least 80%
Share in final energy consumption for heating	10%	14%	Not specified		
Share in fuel consumption	5%	10%	Not specified		
Share in gross final energy consumption	12% (2013)	18%	30%	45%	60%
Buildings					
Heat demand (no reference period defined)	n.a.	-20%	Not specified		
Primary energy demand (no reference period defined)	n.a.	Not specified			-80%
Annual rate of energy-related building refurbishment	approx. 1% (2005-2008)	2%			
Transport					
Final energy consumption (versus 2005)	+1% (2013)	-10%	Not specified		-40%
Number of electric vehicles [34]	approx. 24.000	1 m	6 m	Not specified	

Sources: BMWi and BMU 2010, EEG 2014, EEWärmeG 2008, BMWi 2015a, b, EU 2009, UBA 2015, AGEB 2015a, b, c, Diefenbach et al. 2010, NPE 2014

As part of its Energy Concept in 2010 the German government also announced that the country's existing nuclear power plants (2010: 34,5% of total power production) would be allowed to run longer than previously planned – some of them more than a decade longer until at least the mid-2030s. This controversial decision was revoked a year later following the Fukushima nuclear accident and pressure from the German public to accelerate the phase-out. In the summer of 2011, the German government announced a complete nuclear phase-out by 2022, largely reverting back to the original schedule devised in the early 2000s. As decided on June 6th 2011, eight nuclear power plants had to shut down with immediate effect, the remaining nine will be phased out stepwise until 2022. The climate and energy targets of the Energy Concept, however, remained for the most part unchanged.

Waiving nuclear power (as well as CCS power plants which also lack public acceptance in Germany and consequently receive little support from the political arena) obviously limits the options available for decarbonizing energy supply mainly to the use of renewable energy sources. On the other hand researchers expect that removing existing overcapacities by phasing out nuclear energy would reduce barriers to investment and innovation[35]. Nevertheless: The

[34] The government target refers to all vehicles that can be charged through a plug. Thus, this definition of electric vehicles includes battery electric vehicles and plug-in hybrid electric vehicles but not conventional hybrid electric vehicles that cannot be charged through a plug.

[35] http://www.unendlich-viel-energie.de/de/wirtschaft/detailansicht/article/432/fraunhofer-iwes-studie-weniger-platz-fuer-grosskraftwerke.html; http://www.umweltrat.de/cln_137/sid_1D14DCCAB5B6DCF0865F9031675BC1AF/SharedDocs/Pressemitteilungen/DE/AktuellePressemitteilungen/2010/2010_02_PM_100_Prozent_erneuerbare_Stromversorgung_bis_2050.html?nn=395730; VDW-Studie: http://www.prolignis.de/fileadmin/user_upload/aktuelles/VDW.pdf

rapid market deployment and reliance on renewables will make strong final energy demand reductions inevitable if the climate and energy targets of the Energiekonzept of the German government are to be achieved and if infrastructure challenges and costs are to be limited.

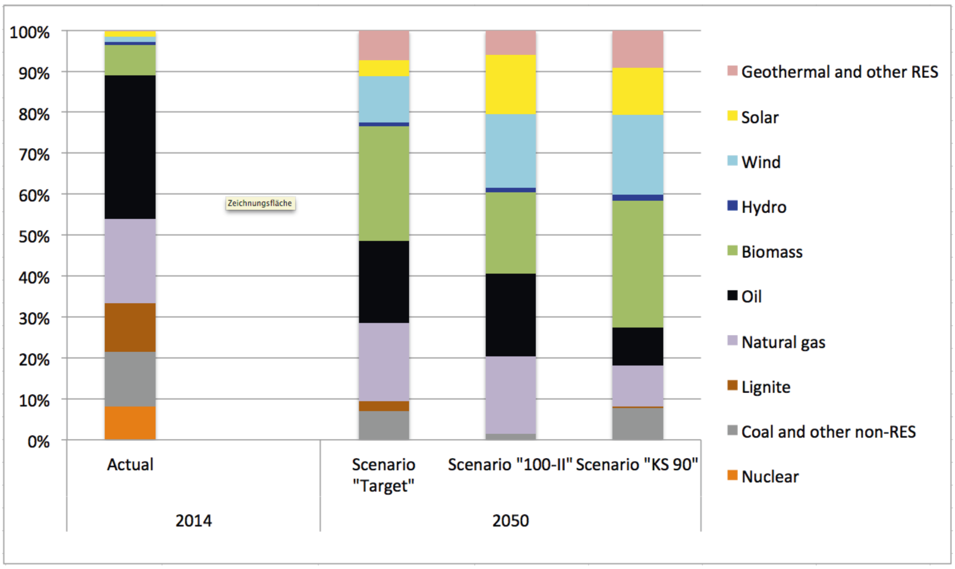
Due to the determination of a decarbonization pathway by political targets and societal circumstances, recently published scenario studies for Germany focus on low-carbon trajectories based on rapid market deployment of renewable energy sources and strong energy demand reductions. Therefore, differences among the scenarios concerning the future technology mix are rather small. They become relevant especially in the long term and depend to a great extent on the exact GHG emission reductions achieved by 2050 (e.g. -80 or -95% versus 1990).

For a brief analysis of potential decarbonization pathways for Germany we have chosen the following three illustrative and representative scenarios from the existing literature:

- *Scenario "Target"* from the study "Development of Energy Markets – Energy Reference Forecast"
- *Scenario "100-II"* from the study "GROKO II – German Energy Supply Scenarios Based on the EEG Draft Bill"
- *Scenario "KS 90"* from the study "Climate Protection Scenario 2050"

As shown in figure 13 in all three scenarios renewable energy sources make up more than 50% in 2050, growing from 11% in 2014.

Figure 12 : Primary energy supply by energy source



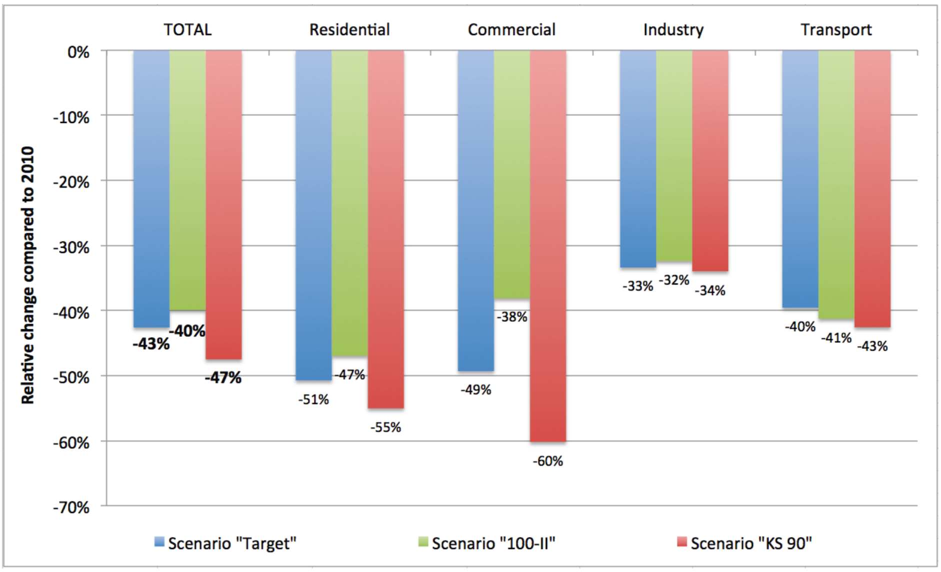
Sources: Schlesinger et al. (2014), Repenning et al. (2014), Nitsch (2014), AGEB (2015a)

At the same time, the three scenarios expect final energy demand to be reduced by 40 to 47% by 2050 (compared to 2010, see figure 14). Reductions in the final energy demand are expected to be achieved mainly by energy efficiency improvements[36] and – to a lesser extent – by reductions

[36] To some extent the energy efficiency improvements are a result of a switch from fossil fuels to electricity for some applications (e.g, an electric engine is more efficient than a combustion engine).

in energy service demand compared with a reference development. However, all scenarios assume that rebound effects are relevant and have to be limited to a certain extent to avoid a significant compensation of positive energy efficiency effects.

Figure 13 : Relative change in final energy demand (total and by sector) between 2010 and 2050



Sources: Schlesinger et al. (2014), Repenning et al. (2014), Nitsch (2014)

Besides the further dissemination of renewable energy sources and energy demand reduction, most available deep decarbonization scenarios consider electrification of processes and power-to-x („x" being a dummy e.g. for heat, hydrogen/methane or synthetic fuels in general) important decarbonization strategies for Germany. They can especially be implemented as means to reduce GHG emissions in transport and industry in the long-term.
Both, electrification of processes and power-to-x will gain importance as the share of renewable energy sources in electricity production increases. Considering the efficiency losses along the process chain, the point in time when to start with this strategy path is decisive. If electricity was not produced sustainably, true decarbonization by means of this strategy would hardly be possible because it results in relatively high amounts of electricity demand and involves large conversion losses. For Germany a power-to-x (particularly power-to-gas) strategy seems to be very promising as the existing gas infrastructure (gas grid, storage facilities) can by fully (methane) or at least partly (hydrogen) used.

The scenario analysis shows that besides these three key strategies there are other strategies used only in one or two of the three analyzed scenarios which can be regarded as more controversial:

- Final energy demand reductions through behavioral changes (modal shift in transport, changes in eating and heating habits etc.)
- Net imports of electricity from renewable sources or import of bioenergy
- Use of CCS technology to reduce industry sector GHG emissions

Due to their comparatively low current relevance, strategies to reduce non-energy related (often non-CO_2) emissions – especially in agriculture and industry – are not always discussed in mitigation scenarios. However, these strategies will gain importance in the future as deep decarbonization requires these emissions to also decrease considerably as compared to today.

Efforts to put these GHG emissions on the public and political agenda will need to be strengthened.

Overall, the analysis of the three illustrative scenarios shows that in order to reach very strong GHG emission reductions of 90% or more by 2050 (compared to 1990) it is necessary to implement most or all mitigation strategies mentioned above, as it is done in the most ambitious of the three scenarios analyzed here, the Scenario "KS 90".

In order to foster the actual implementation of the determined long-term decarbonization strategies, authorities at different political levels need to introduce an appropriate governance structure (e.g. extended policy packages and institutional innovations) supporting them. The achievement of deep decarbonization in Germany e.g. requires different types of policies targeting

- energy efficiency improvements, e.g. in form of
    - a considerable increase in the rate of building refurbishments ("deep renovation") stimulated by suitable investment conditions and tailor-made information and motivation programs
    - the provision of an appropriate institutional background for the implementation of energy efficiency measures (e.g. energy efficiency agency, energy efficiency fund)
    - the development and dissemination of low-carbon technologies for transport vehicles as well as a modal split change to public transport, urban e-mobility, cycling-adapted urban planning ("sustainable mobility")
- an increased use of renewable energy sources for electricity generation, e.g. in form of
    - the development and deployment of flexibility options that help keep the electricity grid stable
    - the introduction of a new electricity market design
    - stable investment conditions for the portfolio of relevant renewable energy options
    - public acceptance for required infrastructure projects
- the stronger penetration of renewable energies in the different end-use sectors and other applications besides electricity generation (e.g. heating, cooling, industrial applications), e.g. in form of
    - system solutions in buildings which combine energy efficiency measures with renewable energy options
    - cooperative activities such as heating networks in city districts

As transformation processes are subject to constraints, uncertainties and path dependencies, these policies must also allow to identify and address challenges at an early stage and have to be very flexible. Constant monitoring and the willingness to adapt the policy framework over time is decisive. However, shaping the process of energy system transformation remains a complex challenge. Five years after the adoption of the Energy Concept, some challenges to the German efficiency-renewables pathway have already been experienced[37]:

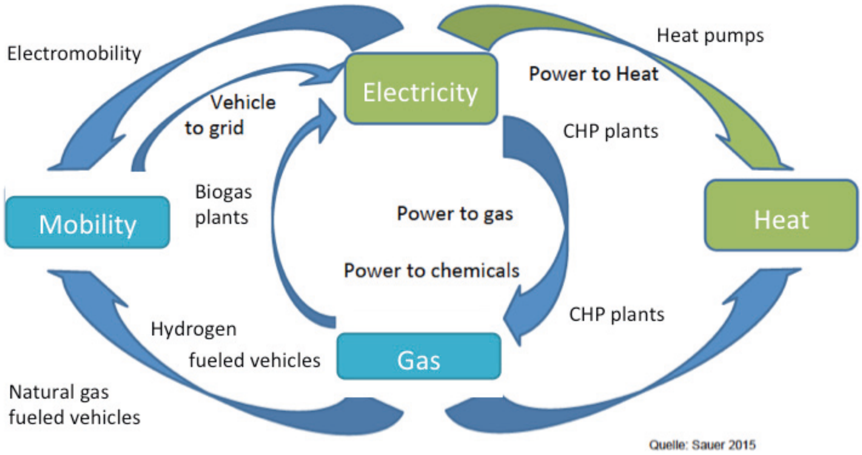
[37] This is underlined by the fact that Germany is at risk of falling short on several national climate and energy objectives for 2020: The country is e.g. currently not on track to reach its 2020 GHG reduction target, with one important reason being the below-target energy productivity improvements in recent years.

- Technological challenge: System integration of volatile supply of renewable energy technologies
- Compatibility challenge: Suitable cooperation scheme between conventional and new technology options
- Infrastructure challenge: Further development of appropriate infrastructures (e.g. smart and super smart grid)
- Investment challenge: Adaptation to different investment characteristics (high capital cost, low variable costs) and creation of stable and attractive investment conditions
- Resource challenge: Avoidance of negative resource impacts (e.g. critical resources) as potential future bottlenecks for manufacturing of key "Energiewende" technologies
- Stakeholder challenge: Overcoming resistance of established stakeholders
- Political challenge: Seeking for an integrated and consistent regional, national and international policy framework (multi-level approach)
- Innovation challenge: Development of system innovations (linking technical, infrastructure and social innovations)
- Social challenge: Securing societal acceptance of transformation process (including willingness to cover associated additional costs for interim period), active societal participation and adequate consumer behavior (sustainable consumption) (Fischedick 2014)

The different challenges and barriers for decarbonization can be tackled by a variety of additional policies. Overall, the complex 'Energiewende' transformation process

- requires a proactive approach of changing the political conditions (setting the right incentives – shaping the right political framework)
- needs more participatory elements (including sociopolitical discourses)
- needs to seek an appropriate and supporting implementation culture at different levels (regions, companies, citizens etc.)
- requires permanent trendsetter and independent driving forces to push and support the targets of the "Energiewende": in Germany the growing number of energy cooperatives (more than 800) and the high number of 100% renewable energy communities (more than 130 representing roughly one sixth of the German population) are good examples in that regard
- in general is about embedding technological innovations in a suitable institutional, social and cultural setting (system innovations)
- results in a stronger integration of different infrastructures (cf. Figure 15) and as such a higher complexity of the overall system and related optimization approaches (Fischedick 2014)

Figure 15 : Linking different parts of the energy system



Sources: Elsner et al. (2014)

The German government monitors progress of the Energiewende and publishes an annual report with progress indicators in different areas (for the most recent report cf. BMWi 2014). Following the report and an independent assessment of energy experts (for the most recent assessment cf. Löschel et al. 2014), the overall status of the Energiewende from a societal and macroeconomic perspective looks quite promising although more activities are currently necessary to meet the intermediate GHG mitigation goal for the year 2020. As a consequence, the German government launched a Climate Action Program in 2014 which comprises more than 100 concrete measures to close the gap.

As a side effect, the successful implementation of the "Energiewende" significantly supports the German manufacturing industry in maintaining their leading role in the global green technology market. The performance of the German industry in six "Global Lead Markets" (Buechele et al. 2014) in the area of green technologies is impressive – they all are connected with the "Energiewende". The study on behalf of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (Buechele et al. 2014) analyzed the following global lead markets: energy efficiency, sustainable water management, environmentally friendly power generation, sustainable mobility, material efficiency and waste management/recycling. The study calculated an average share of the German industry of about 14% in the growing potential of these six markets (2,536 trillion EUR in 2013 up to 5,385 trillion EUR in 2025). Given those numbers, it is not a surprise that an increasing number of companies supports the German "Energiewende" which is not only an environmental program, but also an important part of the German industry policy

7. Summary

To stay below the global 2dt is neither **a real choice** for the world nor for businesses and civil societies in specific countries. It is a global guideline, scientifically developed for global negotiations, which should be broken down to national interests and actors. Even though the huge monetarized benefits of climate mitigation have been proved, specific countries, industries and civil societies might not care about it. There is no institution like a global investor who invests in climate mitigation as the costs of successful mitigation actions are much less than the cost of inaction. Even the most sophisticated **global** cost-/benefits analyses of climate mitigation demonstrating huge benefits of strong climate mitigation will be not convincing enough to overcome national egoism all over the world.

Therefore, the key questions from the perspective of **national** interests are how to create and sustain a momentum for the inevitable energy transition, how to encourage disruptive innovations, avoid lock in effects, enable rapid deployment of energy efficiency and renewable energies etc. or in other words how to get to a competitive, economically benign, inclusive, low carbon and risk minimizing future energy system.

This paper has argued for the global scale that „burden sharing“ is a misleading perception of strong climate mitigation strategies. It might be much more realistic to talk about „benefit sharing“, using the monetary benefits of climate mitigation (e.g. energy cost savings, revenues from CO_2-tax or emission trading systems) to help vulnerable national and international actors to adapt to the unavoidable. But global analyses alone are not sufficient. To convince decision makers, it has to be demonstrated on country level that the technology and policy mix of strong climate mitigation and risk-minimizing actions are indeed „benefit sharing“ strategies which should be chosen anyhow, even if there was no climate change. For China and Germany this paper includes some findings supporting this view.

Based on the above arguments and numerous new studies COP 21 can send a much stronger signal then in the past, that climate mitigation strategies don´t harm the economy but will „...trigger multiple economic, health and development benefits by aligning strengthened short term economic growth with long term sustainable development“ (http://lcs-rnet.org/ Cop21- A moment of truth for climate and sustainable development).

Concerning the global perspective, each avoided overshoot of tenths of degrees would save millions of casualties and avoid huge monetary damages. Even if e.g. only a 2.2 degree target was reached at the end of the 21st century, it would be a huge advantage in comparison to ending up at 2.5 degrees. And no doubt: If a 1,5dt at the end of the century was the result of kick-starting very courageous national climate mitigation strategies at COP 21 in Paris not only Tuvalu but we all would be better off.

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