Centrum für Umweltmanagement, Ressourcen- und Energie

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EU 2030 EMISSIONS TARGET - A REALITY CHECK

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- Dekarbonisierung betrieblicher Produktions- und Leistungsprozesse,
- Arten- und Ressourcenschutz

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Die Discussion Paper Reihe publiziert Beiträge, die im CURE erarbeitet wurden.

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ABSTRACT

In 2014 the European Council agreed a binding -40% CO_2 reduction target for 2030 and recently contemplated an even tighter target of up to -55%. The purpose of this independent project undertaken at the university faculty's initiative is to make a simple reality-check based on how annual effort in respect of renewables build and efficiency measures would have to increase to meet these targets as compared to actual progress between 2005 and 2018, which serves as plausible benchmark as to what over the period is realistically achievable.

Based on simple extrapolation of such progress **the EU is currently not on track to meet its -40% emission target by 2030 and will likely only reach -37%.** To meet the target the average level of effort in renewables build and energy efficiency measures must increase by 20% compared to that realised 2005-18, even allowing for lower demand in transport and industry following the Covid-19 crisis. The -55% target would require a doubling of the effort.

The outlook is not promising because **even before the Covid-19 crisis the annual level of renewables build had been decreasing from 2012.** IEA data shows that annual expenditure on renewables power has since decreased by 50%. Good progress with offshore wind was more than offset by declining build-rate of other types. Financial constraints from Covid-19 will add to the challenge.

But even assuming the same annual gross rate of renewables build in 2005-18 (585 TWh in total), **the renewable capacity built 2018-30 will achieve less than half the net emission reduction managed over the earlier period** for two reasons:

- It will have to offset more nuclear capacity closures than over the preceding 13 years (260 vs. 170 TWh)
- It will have to replace first generation renewables plants older than 25 years (70-120 TWh).

The renewables power build rate is the most important factor in reducing future emissions and will determine:

- **The net availability of power for Europe as a hard limit** after the planned closure of large quantities of nuclear and coal capacity
- The quantity of clean electricity available for electric vehicles and heat pumps, without which the benefits of electrification are limited
- **Whether there is any clean electricity available for hydrogen production,** which achieves only around one third of the emissions reduction as compared to its use in replacing coal plant, for electric vehicles or heat pumps.

Between 2005 and 2018 renewables accounted for 62% of emissions reduction, fuel-switching for 25% and reduced final demand for 13%. Energy efficiency efforts are scarcely offsetting the growth driven by GDP. For the future more effort will come from the end-use sector. Electrification of transport with clean power will be one of the main means to reduce emissions.

The route to meeting the 2030 goals will depend on strong targeted incentives, with market-driven mechanisms being pushed into the background. The administratively-driven coal plant closures will seriously weaken the EU flagship Emissions Trading System.

JEL: Q2, Q5

KEYWORDS: CO_2-Reduction, Emission Reduction, Emission Target, Energy Transition, Renewables

1 HOW EMISSIONS WERE REDUCED

Figure 1: EU28 - Emission reduction vs. 2005 by sector

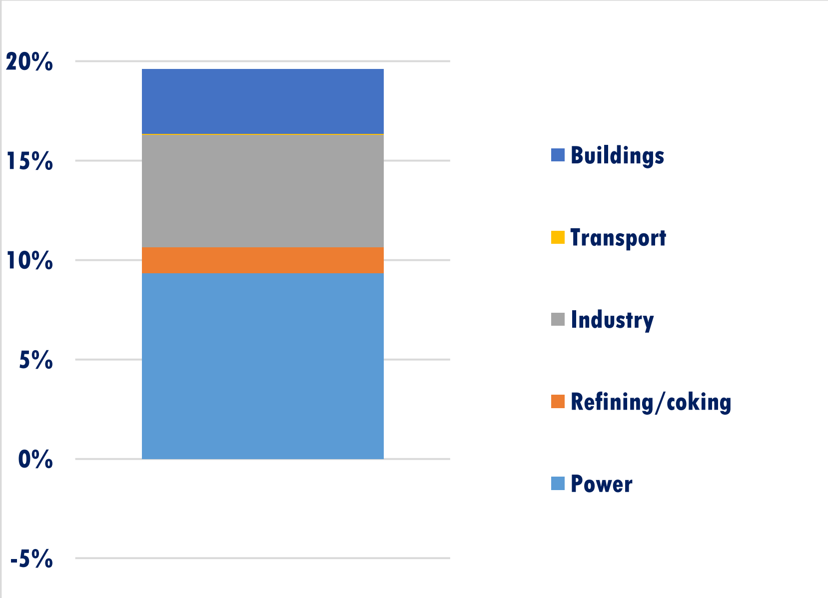
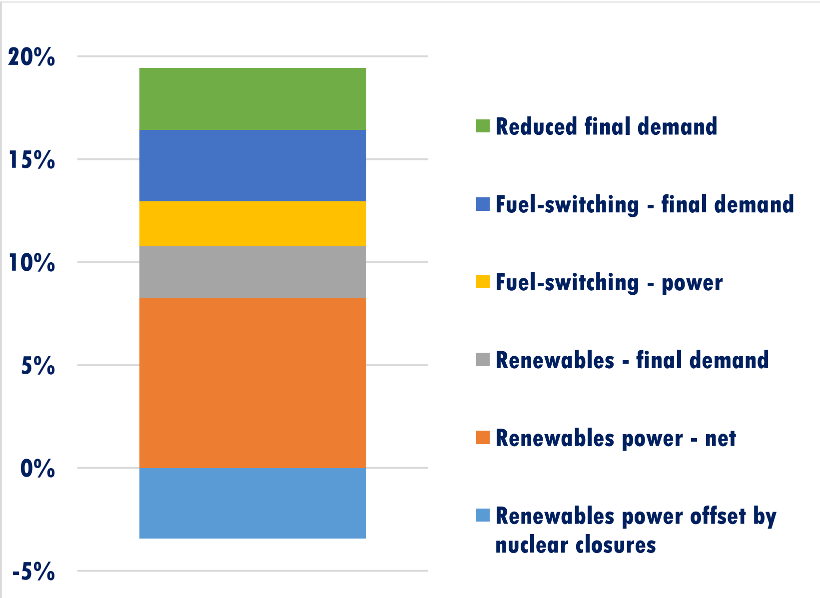


Figure 2: EU28 - Emissions reduction vs. 2005 by means



The headline findings shown in Fig. 1 and Fig. 2 are:

- Almost exactly half the emission reduction was achieved in the power sector, followed by nearly 30% in the end-use industry sector
- Renewables, primarily in the power sector, was by far the most important means to achieve the reduction and effectively accounted for 62% of the reduction, although of this 18% was offset by nuclear closures
- Fuel switching in the power and final demand sector accounted for respectively 10% and 15% of the reduction
- Lower demand in the final sector through efficiency measures and deindustrialisation accounted for 13%.

The charts on the following pages show by what percentage the EU28 and different Member States have reduced their respective energy-related emissions in 2018 as against the 2005 levels. There are three means to reduce emissions: (i) reducing energy demand through efficiency measures in the transformation or final use sector and (ii) reducing the CO_2 content of energy used through renewables and (iii) reducing the content by fuel-switching. The methodology behind the calculations is set out on page 29.

Figure 3: EU28 - Emission reduction split by scheme

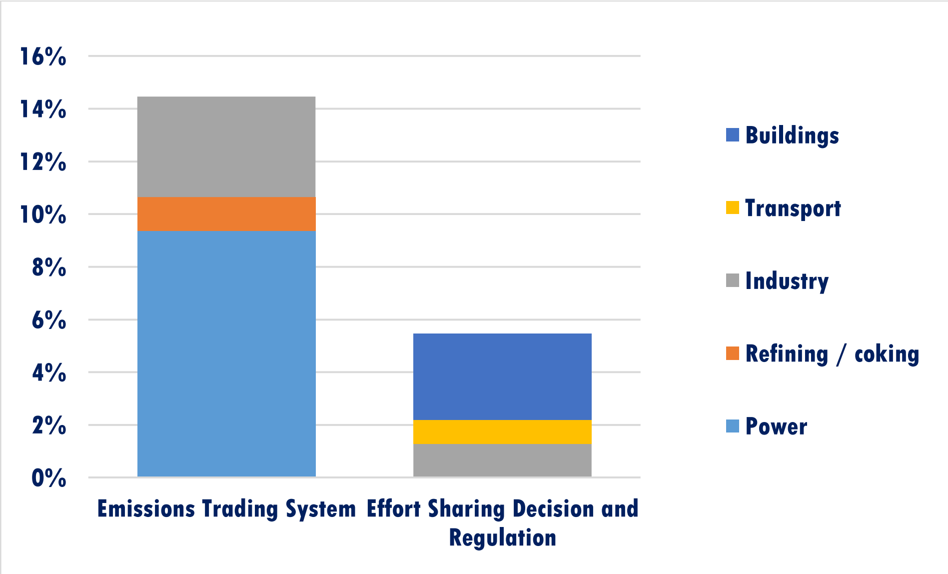
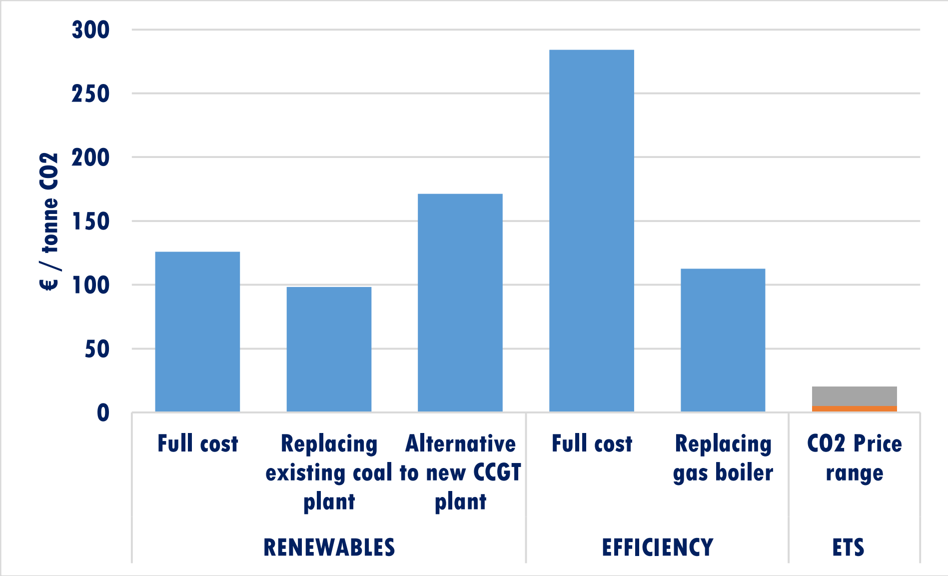


Fig. 3 shows that over 70% of emissions reduction between 2005-18 was within the Emissions Trading System (ETS) sector: the power sector, refining/coking and majority of the industry sector. However this does not mean that the ETS cap and resultant CO_2 price was the main driver of such reductions. Within the power sector two factors which were not market-driven explained most of the reduction: the large contribution from subsidised renewables and government decisions to close coal plants.

Figure 4: Cost per tonne CO_2 saved - basis EU28 investments 2014-2018



From IEA data (see Fig. 9 and Fig. 13) we calculate that the real cost of emission reductions within the ETS shown in Fig. 4, whether through renewables or efficiency measures, was ca. € 100 / tonne CO_2 saved, as compared to the carbon price of between only € 5 - 25 / tonne. The fact that most of the ETS reduction was achieved by administrative means had two detrimental consequences: (i) it rendered the scheme relatively superfluous, causing only a mild fuel-switching effect between coal and gas and (ii) it prevented the scheme from achieving what it was originally designed to do, namely provide investment incentives for low carbon production and efficiency measures.

Figure 5: EU28 - Emissions reduction achieved and remaining from 2018

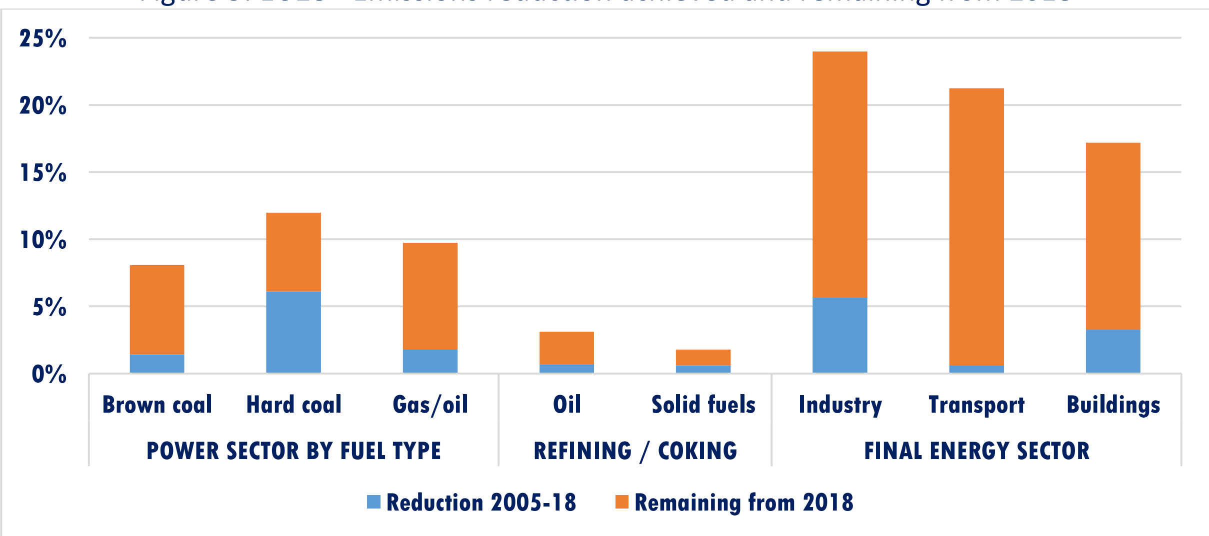


Fig. 5 shows that most of the emissions reduced between 2005-18 were from hard coal generation in the power sector and all forms of fossil fuel in the industry sector.
Emissions from both brown and hard coal need to be reduced further, but if this happens by switching to gas, rather than replacement by renewables power, then the net emissions reduction will be limited.

Even if the power sector would be completely decarbonised, then there is still a huge effort required in the final demand sector where remaining emissions are nearly twice as high as those remaining in the transformation sector (power along with refining and coking).

Figure 6: EU28 - Growth in renewable power vs. decrease in thermal generation

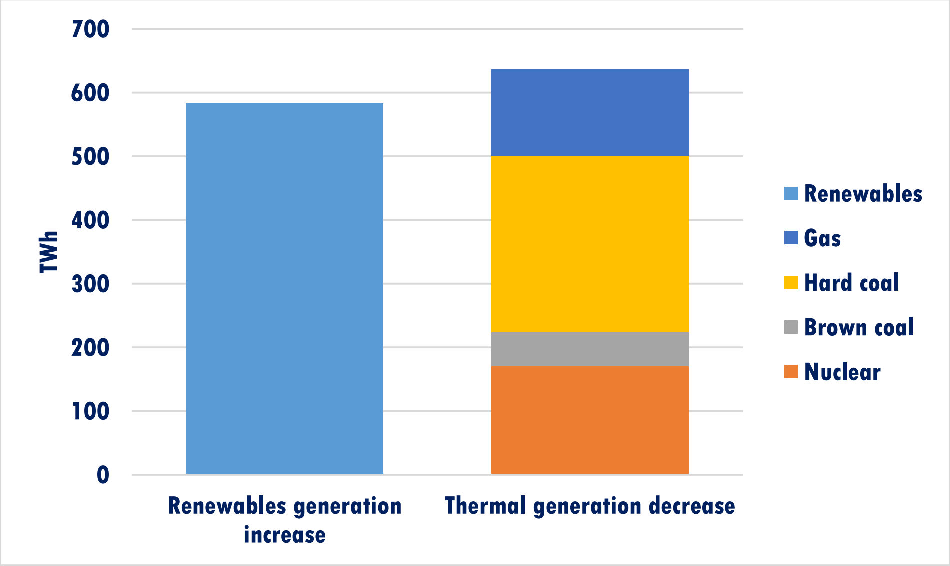


Fig. 6 shows that growth in renewables power was slightly more than offset by a reduction in all forms of thermal generation, made possible by a small decrease in demand.
Hard coal, rather than brown coal was displaced for two reasons. First some countries followed a strong policy of closing their hard coal plants. Second the variable costs of hard coal are higher than for brown coal so the fuel lost its place in the merit-order curve more quickly.

Figure 7: Contribution of renewables to reducing CO_2 emissions 2005-18

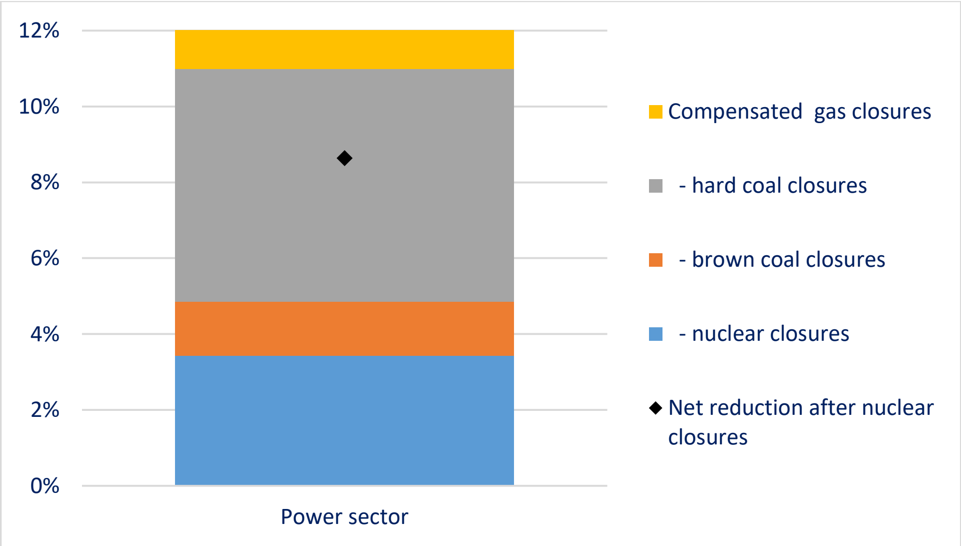
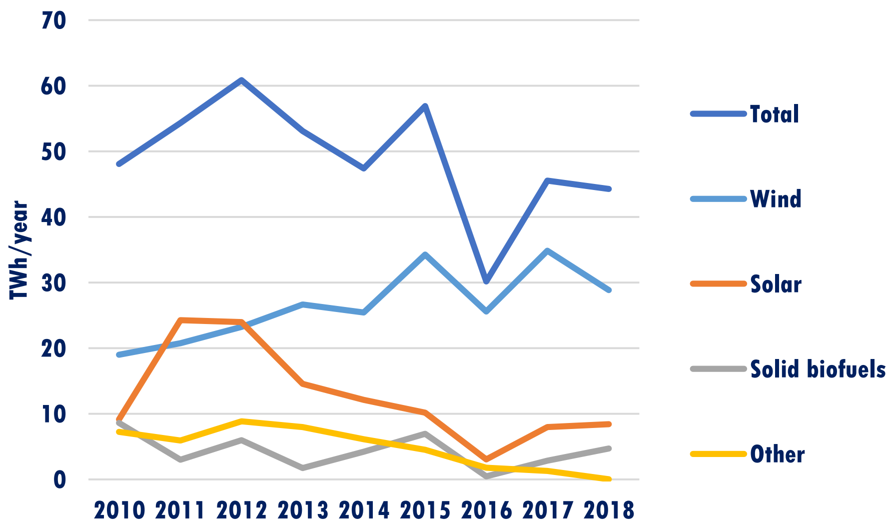


Fig. 7 shows that the net emission reduction from renewables in the power sector after compensating for nuclear closures was nearly 9% of the 2005 emissions.

Figure 8: Renewables power annual growth



As seen in Fig. 8 there is an alarming downward trend in annual growth of electric renewables (normalised for average meteorological conditions) and expenditure from the peaks in 2012/2010. The incentives for renewable development were particularly high in earlier years with developers making good profit margins, and this mainly explains the high development rates.

Whilst offshore wind has been making good progress, acceptance and permitting problems have greatly reduced the annual build of onshore wind. After three very promising years, solar build is at less than half the level of its peak; solid biofuels and other forms of renewables are making very limited contributions overall.

Figure 9: Expenditure on renewables power

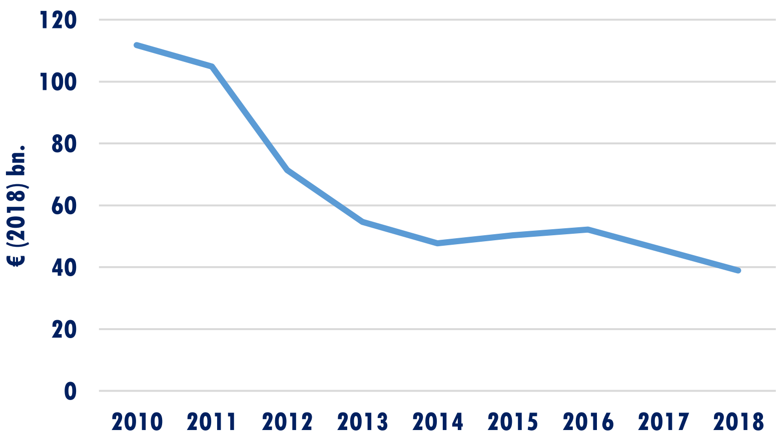


Fig. 9 shows the halving of expenditure on renewables power since the peak in 2010. The high spend in 2010-11 was due very much to the build-out in Germany, when each year around 8-10 GW of new solar plant was installed. It has reduced both because the building rates are lower and also the specific investment costs have been greatly reduced, especially for solar power.

If the 2010 expenditure levels would be maintained, given the strong reduction in unit costs, the build out rates would roughly double as would be required to meet a potential -55% target (see Fig. 28).

Figure 10: EU28 - Renewables for final demand annual growth

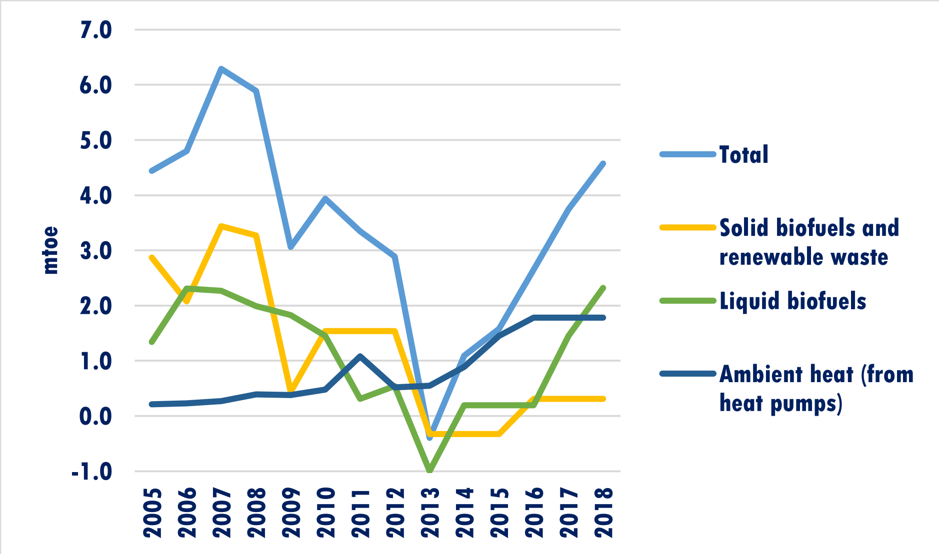


Figure 11: EU28 - Contribution of renewables to emissions reduction in final energy sector

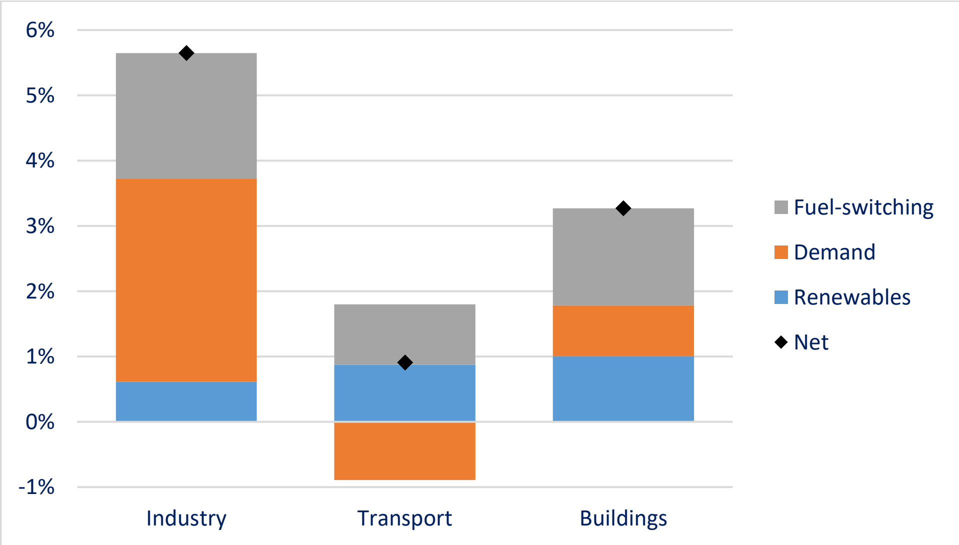
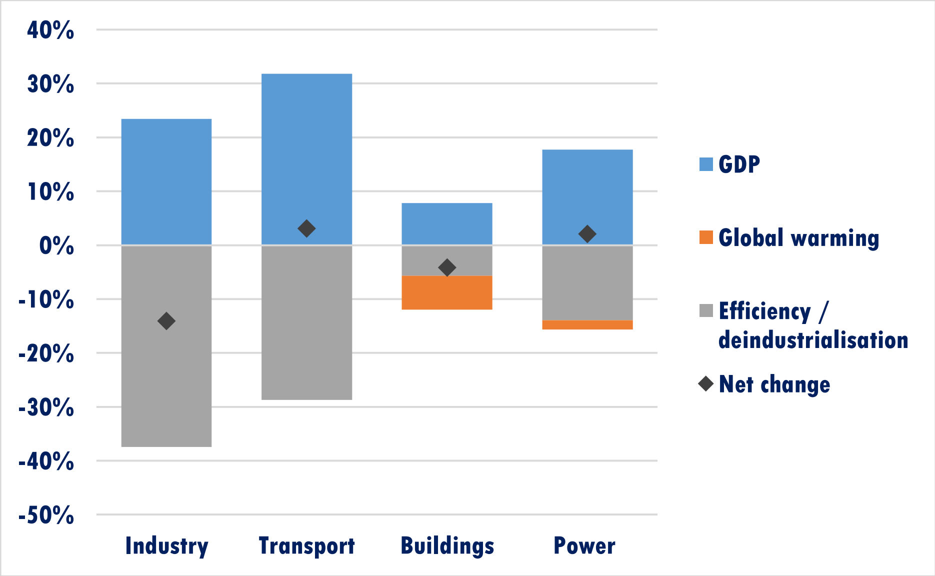


Fig. 10[1] shows that renewables in final demand sector are rising again mainly due to liquid biofuels (used in transport) and ambient heat from heat pumps, whereas Fig. 11 shows the relatively modest contributions being made to overall emission reduction compared to demand reduction and fuel-switching.
It is unlikely that the share of liquid fuels will increase much further in the transport sector, so decarbonisation will rely upon reduced transport activity overall, the rapidly tightening emission standards for new cars and on electric vehicles. Constraints in the supply of solid biofuels will similarly limit their growth in the building sector.
Conversely capturing more ambient heat through the installation of heat pumps is the most promising means to further increase the share of renewables in the final demand sector.

[1] Growth-rates were smoothed by author to assist visibility.

Figure 12: EU28 - Demand reduction 2005-18 by factor

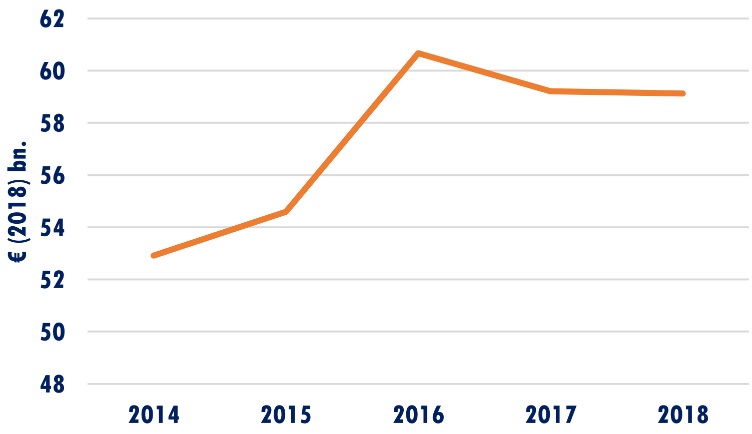


Statistical techniques enable estimates of the contribution to changes in final energy consumption to be made from three factors (GDP, global warming which reduces the heating requirement in winter, and genuine efficiency measures) and the results are shown in Fig. 12. It is seen that efficiency measures are almost exactly offset by the impetus from increased GDP. See p. 29 for further details.

The quality of the statistical results is highest for the transport and power sectors. In the former there is an annual efficiency saving of 2.1%, due to higher vehicle efficiency, but the latent increase in demand grows more quickly than GDP, so that net demand remains constant.

In the power sector the latent growth is slightly lower than the GDP. Increased global warming reduces the demand for electric heating, and there is robust statistical evidence of a 1.0% annual efficiency saving reflecting the rising efficiency of electric appliances. Provided this trends continues it will prevent power demand from growing at some of the higher levels expected.

Figure 13: EU28 - Expenditure on efficiency measures



Source: IEA World Energy Investment 2020
https://www.iea.org/reports/world-energy-investment-2020

Therefore, to make real progress with demand reduction it is essential to increase the effort and expenditure on efficiency measures in all three sectors. Fig. 13 shows that since 2014 expenditure has been rising, but it needs to almost double from the current position.

Figure 14: EU28 - Fuels and demand change 2005-17

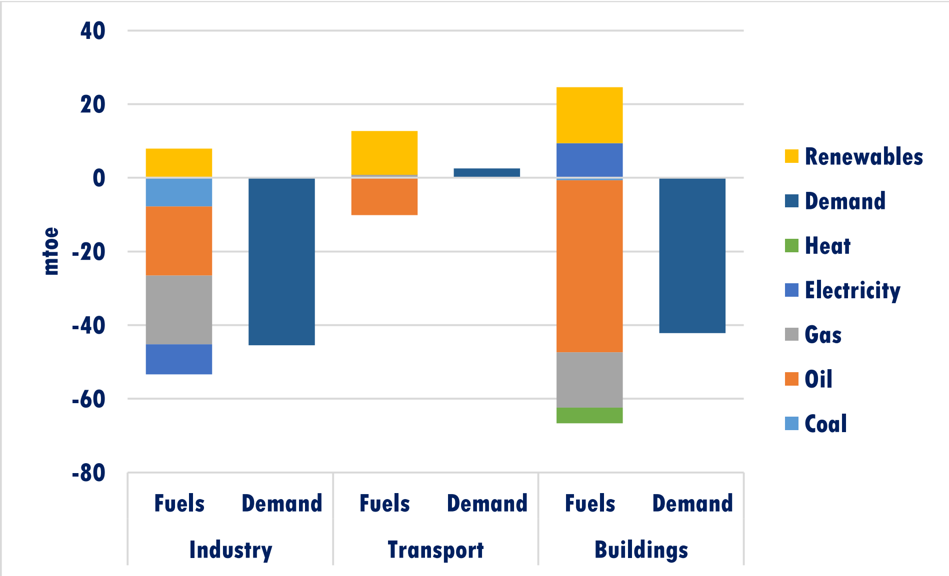


Figure 15: EU28 - Fuel shares switch 2005-17

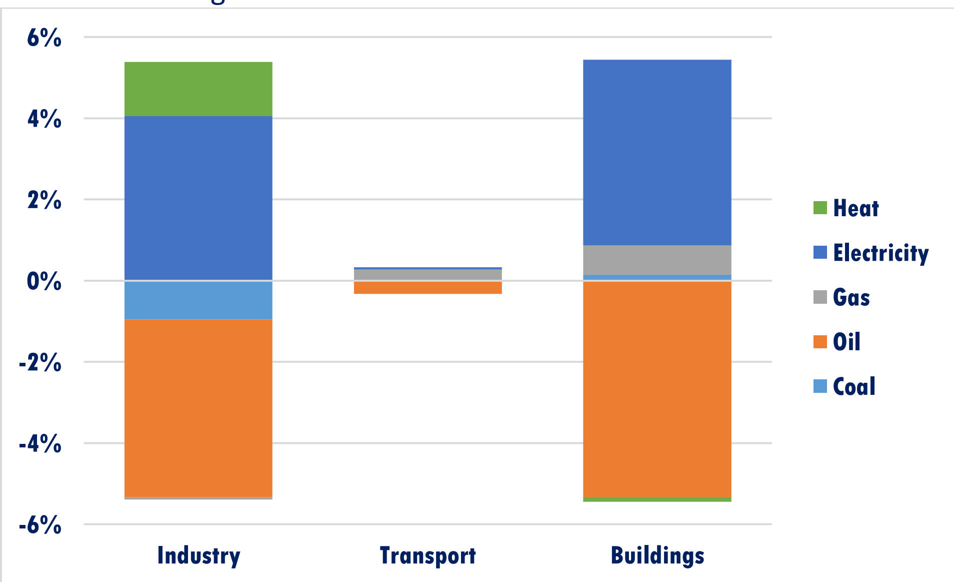


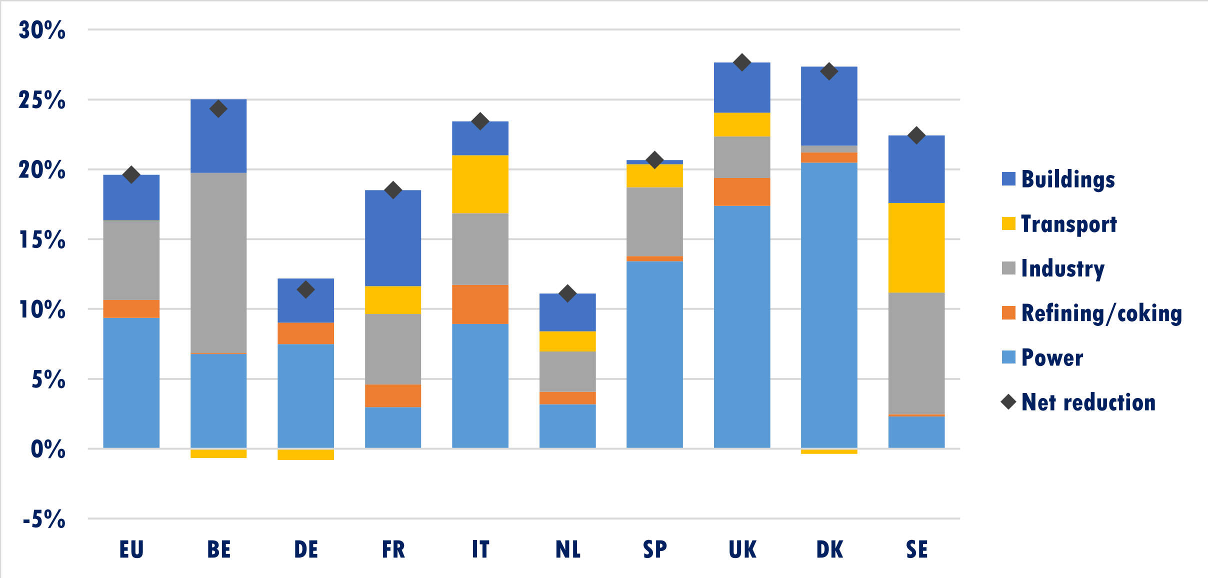
Fig. 14 and 15 provide some valuable insights into the combination of reduced demand fuel and fuel switching, which both contribute to reducing emissions.
Fig. 14 shows the absolute changes in energy demand by sector including the contribution of renewables and it can be seen that there has been no increase in heat use from cogeneration in industry and a decrease in the buildings sector.
Fig. 15 shows the change of fuel shares within each sector after the effect of renewables and demand change has been netted off.

- Industry: the share of heat and electricity has increased at the expense of oil and coal, although the absolute levels decreased.

- Buildings: almost the entire increase in electricity can be considered as a replacement for oil.

The respective emissions reduction resulting from the residual fuel switching (Fig. 11, p. 12) are some 2% of 2005 emissions in the industry and buildings sector and 1% in the transport sector.

Figure 16: EU28 and selected countries emission reduction by sector: 2005-18 vs. 2005



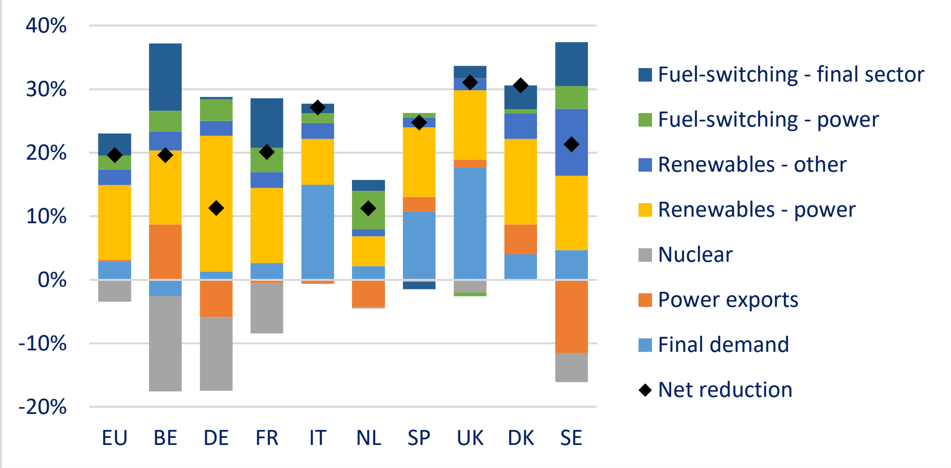
A comparison of emission reductions by country is a valuable means to learn from those who have been most successful in particular sectors so that lessons can be applied in other countries.

In the power sector those countries were most successful which had strong renewables policies not offset by nuclear closures, and which forced coal closures by edict (or a national carbon price in the UK).

In the industry sector Belgium, France, Italy, Spain and Sweden achieved the highest reductions. In some cases, such reductions were reached through renewables and fuel-switching, whereas in others deindustrialisation would have played a role, with implicit carbon leakage to the trading partners.

In the transport sector Italy and Sweden were significantly more successful than other countries considered.

Figure 17: EU28 - Total Emissions Reduction by Means: 2005-18 vs. 2005



The build-up of electric renewables has been the single most important factor reducing emissions in the EU28. Because they are considered as 100% efficient their increase has the joint effect of both reducing primary energy demand and also the CO_2 content of the energy used for electricity generation.

But a considerable amount of the reduction which would otherwise have been achieved by this renewables source has been offset by the closure of nuclear plants, particularly in Germany.

Final demand reduction and the increased use of other renewables have been the next most significant factors and of equal importance.

Italy, Spain and the UK have reduced their final demand most. Italy has a system of White Certificates and the UK applied other means to reduce final demand.

Figure 18: Power generation emissions reduction 2005-18 by means

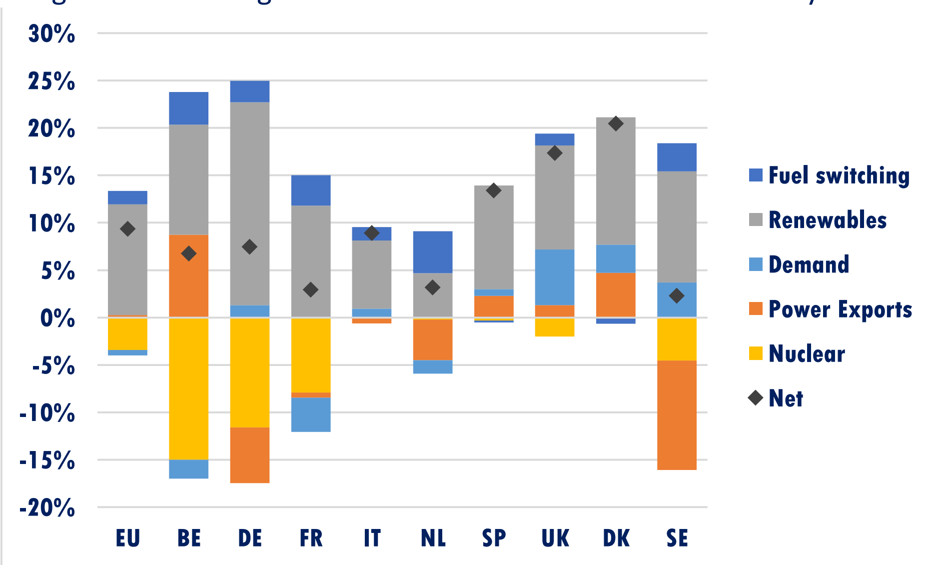


Fig. 18 shows that renewables power has been in every Member State the main means to reduce emissions in the sector. However, the net benefit depends upon how much nuclear power has been closed over the same period.

Fuel-switching (coal to gas) has played a relatively minor role, but what has made a greater difference in respect of some countries (Belgium, Germany and Sweden) is the change to net imports/exports: a country which generates more power to export effectively increases its emissions and helps its trading partners reduce theirs. (The apparently large impact of increased power exports from Sweden needs to be put in the context of overall low emissions.)

Figure 19: Industry sector emissions reduction 2005-18 by means

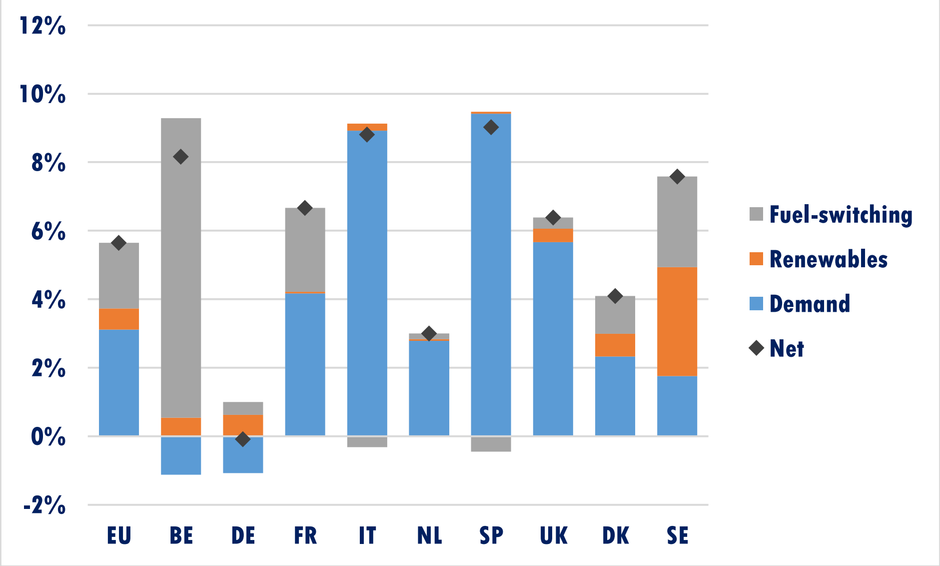
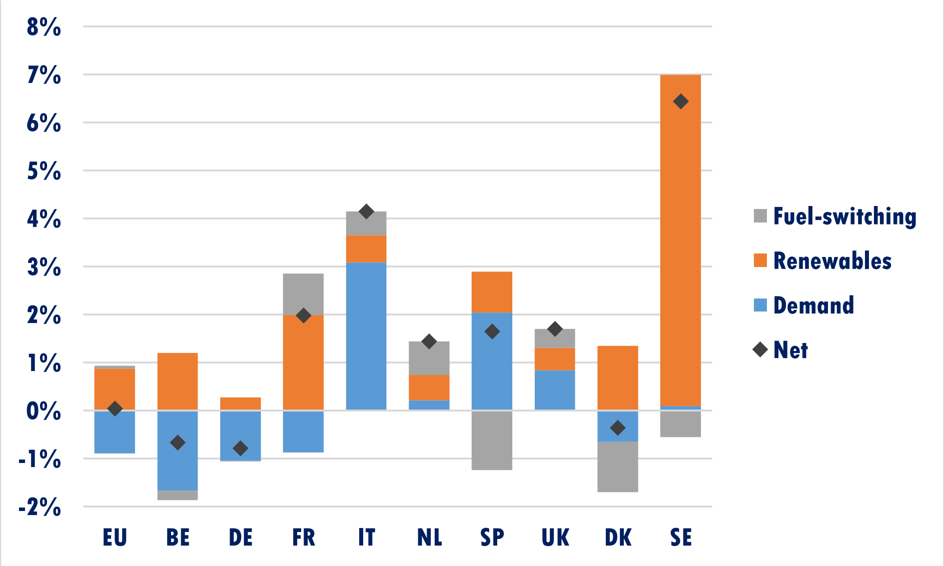


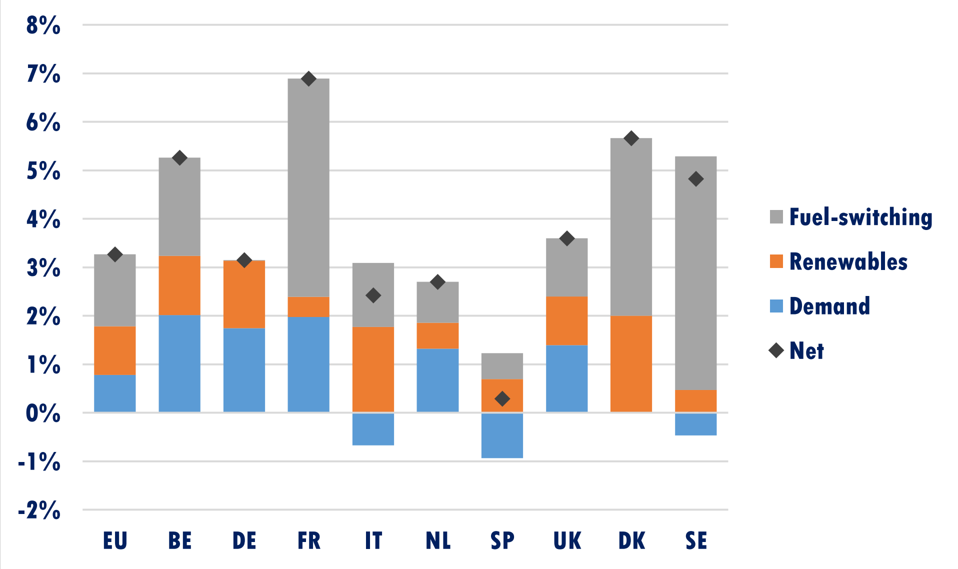
Fig. 19 shows that in the industry sector most of the reduction has been achieved by lower demand, which may be due to improvements in the efficiency of industrial production and/or to deindustrialisation with implicitly an increase in imports of energy-intensive products and carbon leakage to the trading partners.

Figure 20: Transport sector emissions reduction 2005-18 by means



The transport sector remains a problem-child with a minor increase in demand for the EU28, although Spain and Italy have reduced demand.
Most of the emission reduction came from slightly reducing the CO_2 content of energy used through renewables and fuel-switching. Sweden has done much better than other countries, with France and Italy also well above the average; these countries increased the use of compliant biofuels.
Only Italy and Spain reduced the energy demand significantly.

Figure 21: Buildings sector emissions reduction 2005-18 by means



In the buildings sector also a lower CO_2 content of final energy (renewables and fuel-switching) explained more than half the reduction. France, Italy, Denmark and Sweden have performed particularly well through the increased use of heat pumps of which the ambient heat collected is treated as part of the renewables.
The UK had a very strong programme to replace older boilers with condensing units and thereby reduced energy demand significantly: also there were strong supplier obligations to reduce the quantity of energy sold through efficiency measures.

2 HOW EMISSIONS CAN BE REDUCED 2018-30 IN FOUR CASES

Figure 22: EU28 - Emission reductions by sector (2018-30 vs. 2005 level)

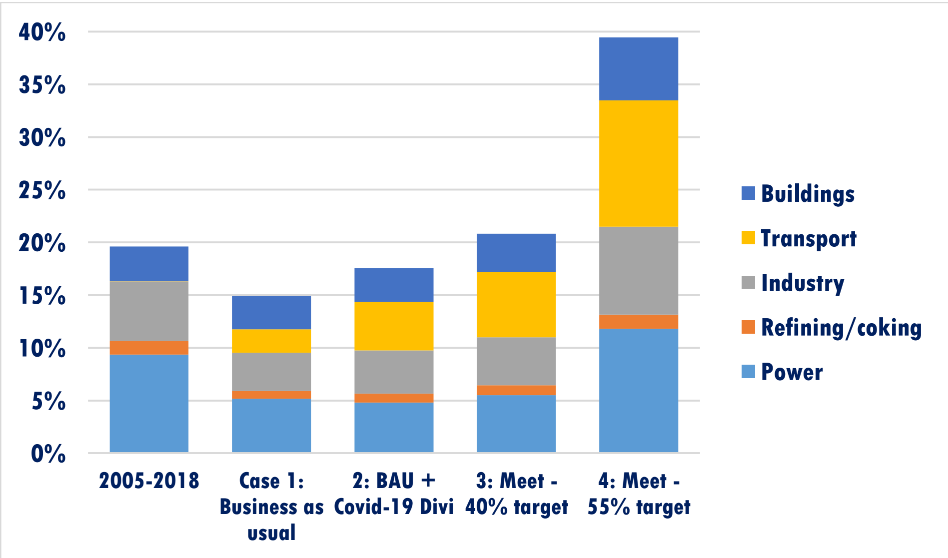
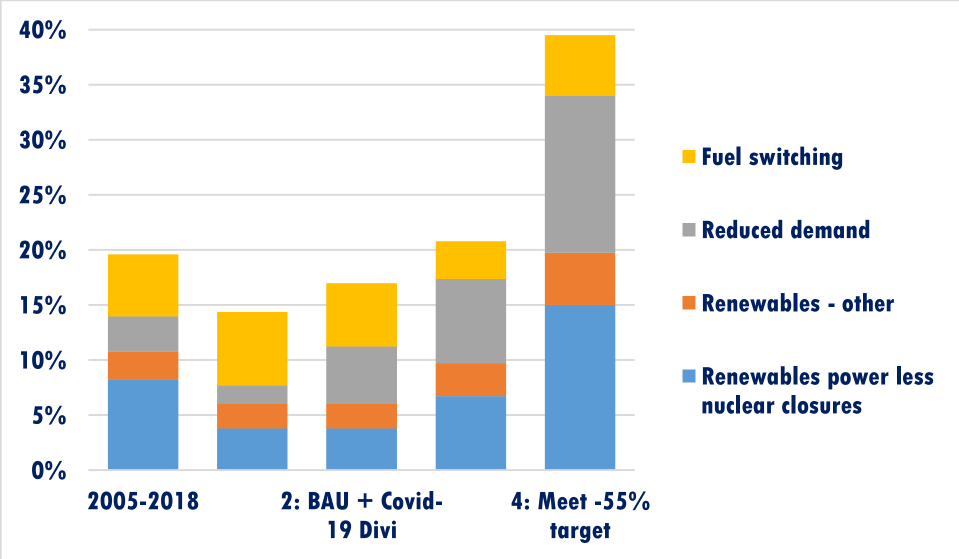


Figure 23: EU28 Emission reductions by means (2018-30 vs. 2005 level)



Four different cases have been considered and compared with the actual emission reduction of 2005-18:

1. A simple extrapolation of the annual average effort in building renewables and energy efficiency realised 2005-18
2. Case (1) with Covid-19 dividends: 10% less energy in the transport sector and 2.5% less in the industrial sector
3. Case (2) but increasing the annual effort in building renewables and energy efficiency to meet the -40% target
4. Case (2) but increasing these efforts to meet a potential -55% target.

The findings are that in Case (1) the reduction 1990-2030 would be only -35% vs. the -40% target; in Case (2) it would be -37%.

To meet the current -40% target 20% more annual effort in renewables build and efficiency measures would be required compared with the achievements of 2005-2018. The -55% Green Deal target would require a doubling of efforts.

Figure 24: EU28 - Emission reduction p.a. by case 2018-2030

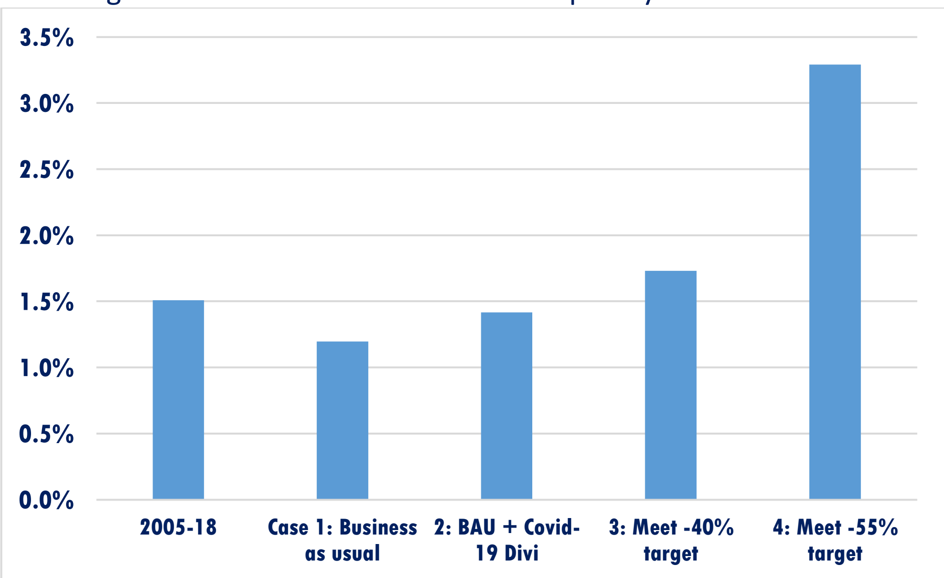
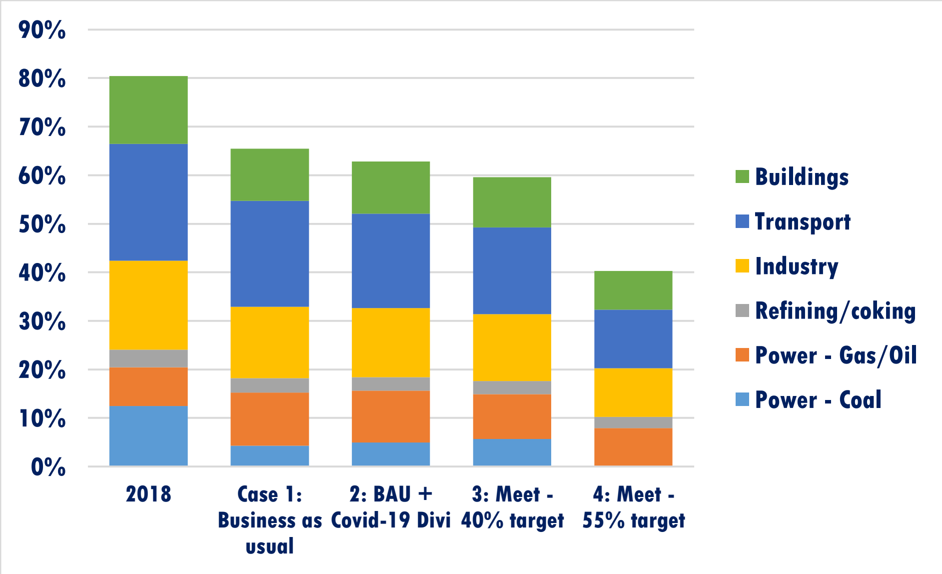


Figure 25: EU28 - Emissions remaining in 2030 vs. 2005

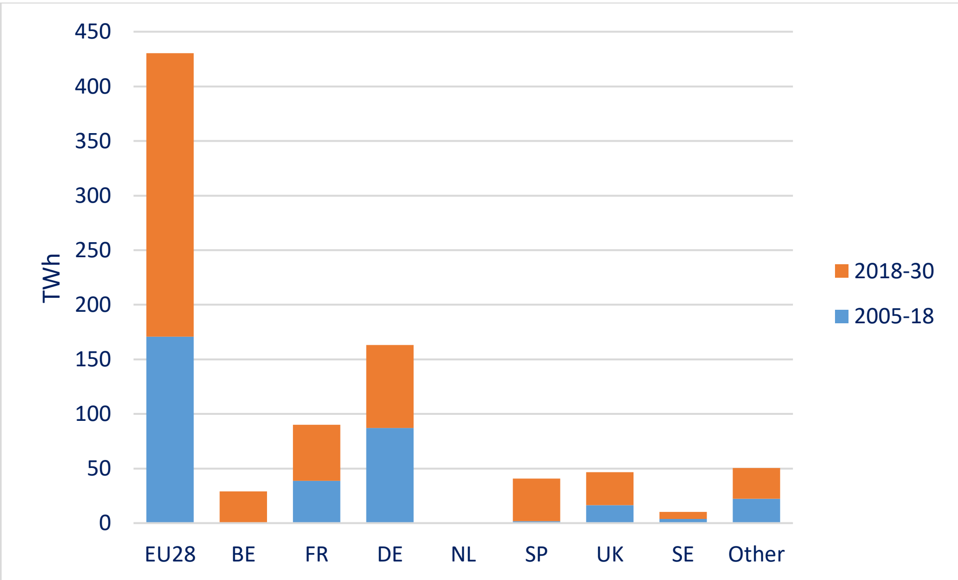


The challenge can be seen in the average annual emission reduction required (Fig. 24) to meet the -40% target, some 15% more than was actually realised between 2005-18. Governments are challenged to convince their voters that such an increase is realistic.
The main factor which could help a higher annual rate is that renewables costs have continued to decline, even if they may have reached a plateau. Factors hindering an improved rate are

- Major acceptance and permitting problems with onshore wind
- Rising 'cannibalisation' of renewables, and therefore rising hours with negative prices
- With regard to energy efficiency, especially in industry, the fact that the quick-wins have all been implemented and with currently lower energy prices there is simply not a business case to invest in further efficiency measures
- The very high national debt levels resulting from the Covid-19 crisis.

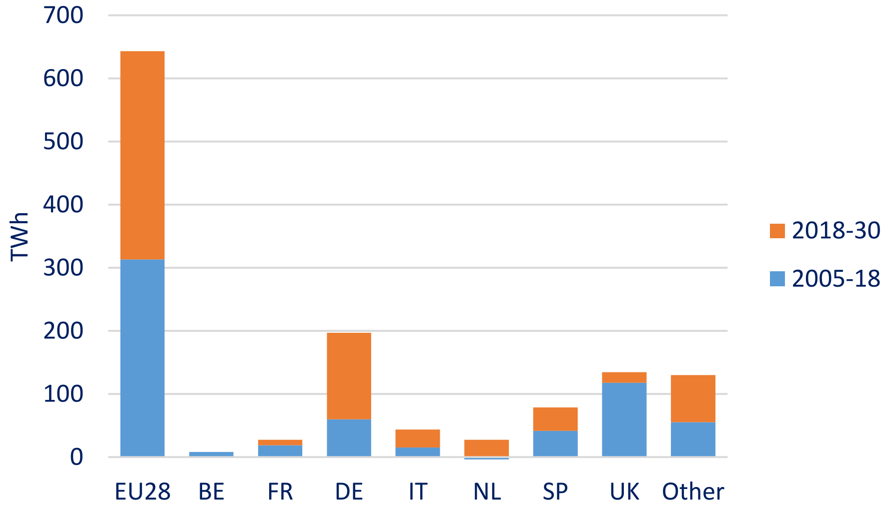
Fig. 25 shows in which sectors emissions will remain in 2030 and the implicit challenge to work them off by 2050.

Figure 26: Nuclear plant closures - actual and plans



Nuclear plants (Fig. 26): the reductions are based on stated policies and declared closure dates for particular plants. In the case of France, the proposal to reduce the share of nuclear generation from currently 75% to 50% by 2035 has been applied.

Figure 27: Coal plant closures - actual and plans



Coal plants (Fig. 27): several countries have policies to close their remaining coal plants. In the case of Germany at the time of writing a law was being finalised which envisaged a closure trajectory to 2038.

There are two important considerations relating to further coal plant closures apart from the environmental benefits:

- A considerable share of the coal capacity currently in operation is in a combined heat and power (CHP) configuration, providing district heating. Therefore, such plants have rather to be converted to gas (or biofuels) rather than closed.
- The operators need an economic incentive to either convert a plant or build a new gas-fired replacement. The current wholesale price does not provide an adequate margin to cover the fixed costs, so an additional source of income is required. In the case of Germany subsidies for CHP plants play this role and effectively act as capacity payments.

Figure 28: EU28 - Renewables growth assumptions by case

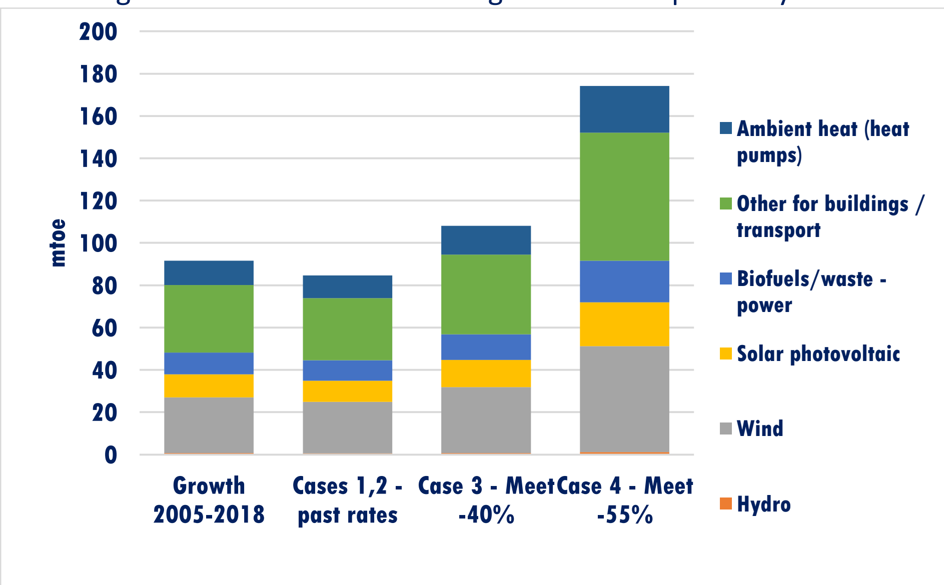
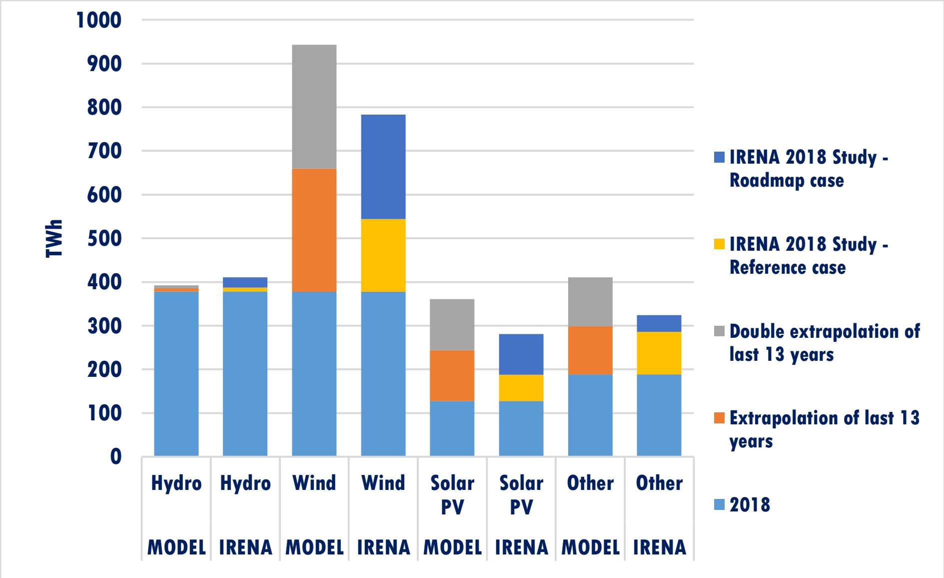


Figure 29: EU28 - Renewables power 2030 - comparison of Model (extrapolating average growth rate 2005-18) with IRENA cases

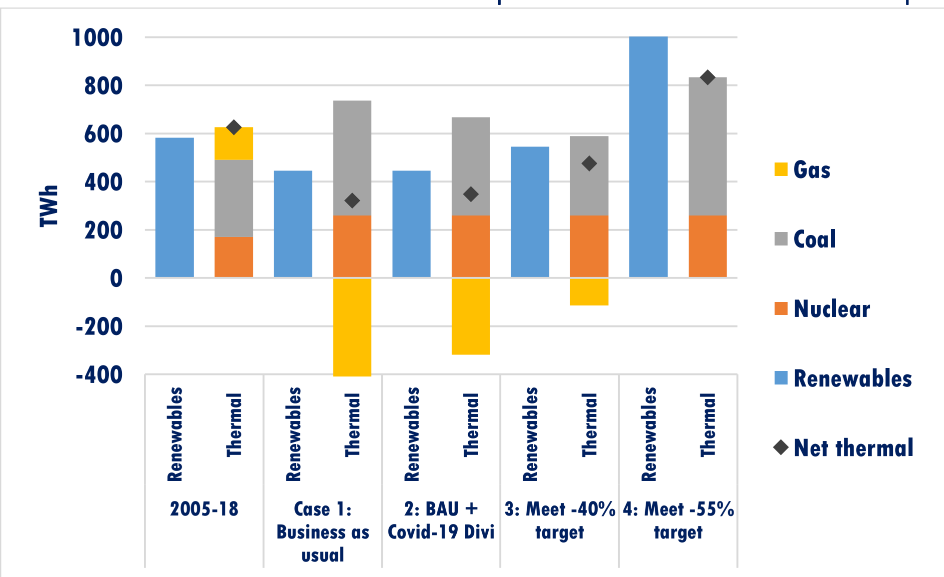


The future renewables growth rate is for Cases 1 and 2 based on the average achieved between 2005-18, using data normalised for average meteorological conditions in the case of renewables power. Cases 3 and 4 show the higher effort required to meet the -40% / -55% targets.

As noted in Fig. 8 (p. 11) the rate of renewables power build has been declining since 2012, so even the average rate of the last 13 years may be optimistic. The results of a simple extrapolation of the growth rates and a doubling are shown in Fig. 29 and compared with forecasts from IRENA (International Renewables Association). This comparison shows that the simple extrapolation would yield slightly more energy than the IRENA Reference case forecast, whereas the doubling for all forms of renewables to around 15% more than assumed in their higher Roadmap case.

With respect to other renewables for buildings and transport even the simple extrapolation forecast may again be optimistic. There are limits as to how much liquid biofuels internal combustion engines will accept, and also constraints on the availability of solid biomass for heat for buildings.

Figure 30: EU28 - Increase in renewables power vs. reduction in thermal power



The actual growth in renewables net of forced nuclear and coal closures will set an upper limit on the availability of power.
Based on current information we expect 330 TWh of coal plant and 260 TWh of nuclear plant to be closed between 2018-30.
Fig. 30 shows the challenge in building out sufficient renewables power to first offset nuclear reductions and then to be able to compensate for the planned coal closures:

- In Cases (1) and (2) the renewables build-out is not quite sufficient (after netting off nuclear power) to compensate for coal closures. Therefore, at the margin additional gas-fired generation will be required, reducing the effectiveness of their closures.
- In Case (3) there is an exact balance, and in Case (4) the growth will be more than sufficient to compensate the closure of the entire coal fleet.

Figure 31: EU28 - Emissions saved through renewables increase

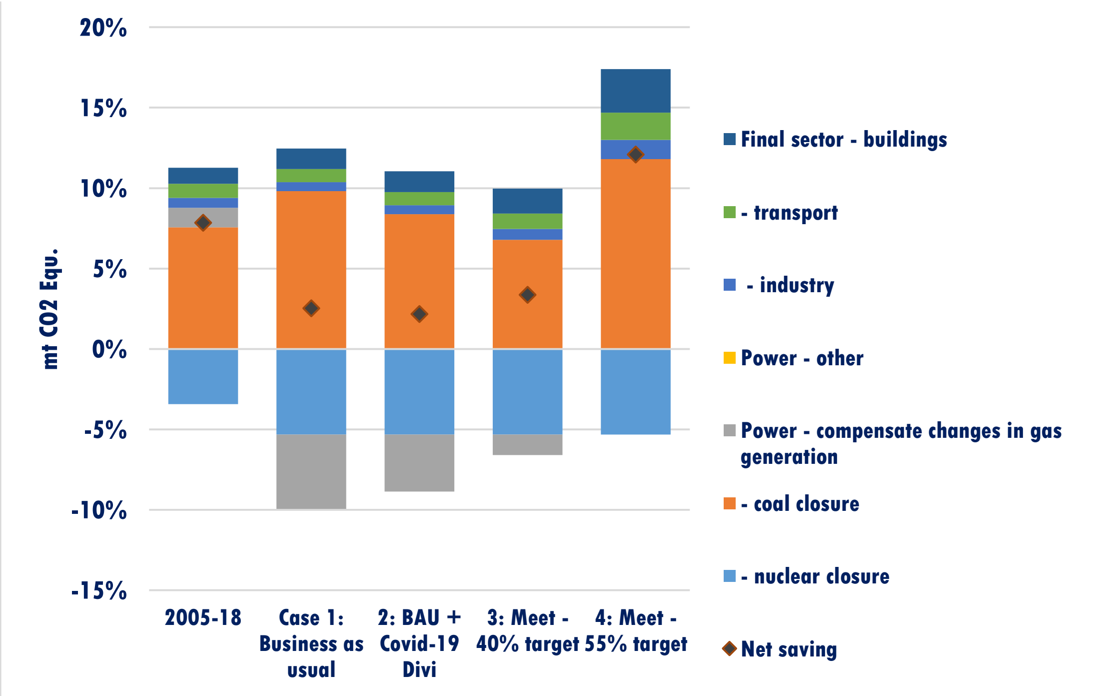
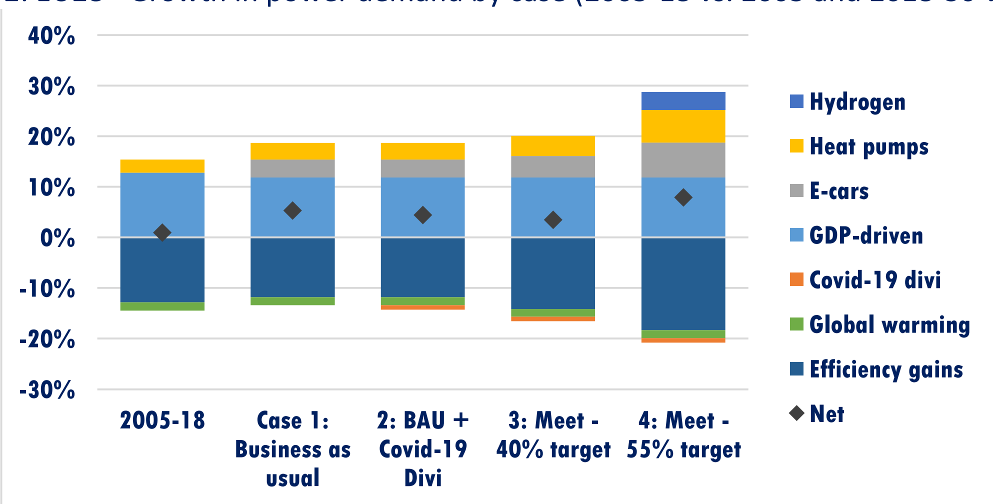


Fig. 31 shows how much less the growth of renewables will contribute to emission reduction as compared to the 2005-18 period. Gas-fired generation will increase as a consequence of the coal closures and renewables will have to offset the associated emissions.

Figure 32: EU28 - Growth in power demand by case (2005-18 vs. 2005 and 2018-30 vs. 2018)



A very significant result (Fig. 32) is that net power demand will grow by a maximum of 8% by 2030 even taking account electrification of the transport and heating sector. This is mainly due to the assumption that endogenous efficiency gains will continue at least of the rate realised between 2005-18. The global-warming effect, reducing the need for heating will also make a small contribution.

Figure 33: EU28 - Final demand reduction (2005-18 vs. 2005 and 2018-30 vs. 2018)

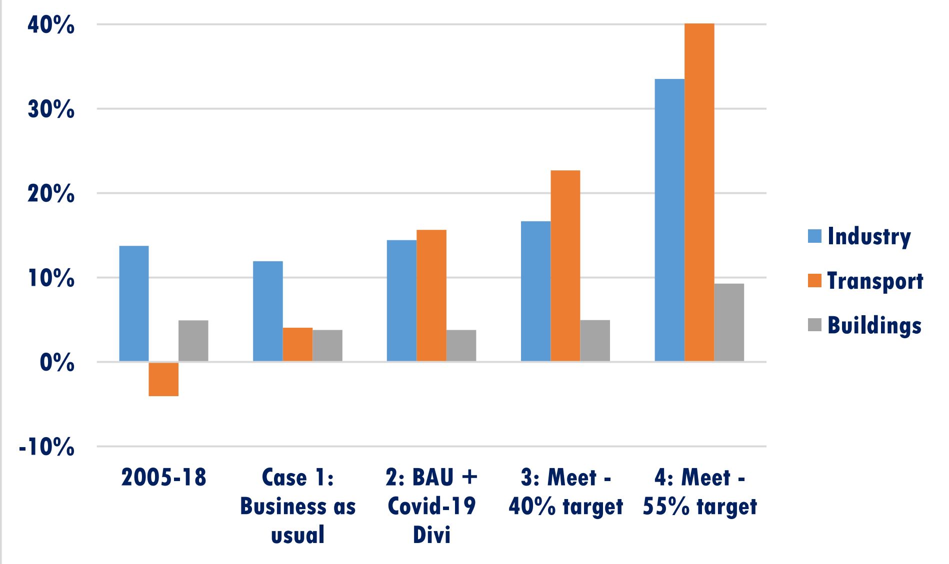


Fig. 33 shows how final demand will reduce:

- In industry limited further reductions are assumed because most of the economically-driven efficiency measures have already been implemented. Only further deindustrialisation might lead to further demand reduction, with the benefits from the circular economy and recycling most likely to be realised only after 2030.
- Significant gains will be made in the transport sector because the replacement of motor fuels in low efficiency engines with electricity in high efficiency motors will directly reduce demand. In addition, the consequences of the tighter emission standards (and therefore higher efficiency) for new vehicles will work through. A 10% Covid-19 dividend is assumed.
- The buildings sector is less promising, mainly because the renovation rates remain at only half the necessary level.

Figure 34: EU28 - Industry emissions reduction by means
(2005-18 vs. 2005 and 2018-30 vs. 2018)

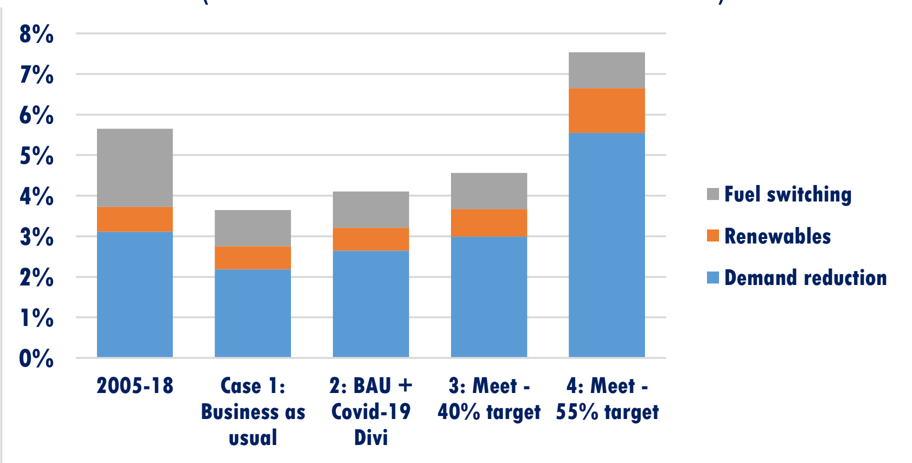


Fig. 34 shows the assumptions behind the emission reductions in the four cases. Demand reduction will play the greatest role, but a lower role than previously because most of the economically-driven efficiency measures have already been implemented. Fuel-switching in Case (4) includes a small contribution from hydrogen.

Figure 35: EU28 - Electrification assumptions (2005-18 and 2018-30)

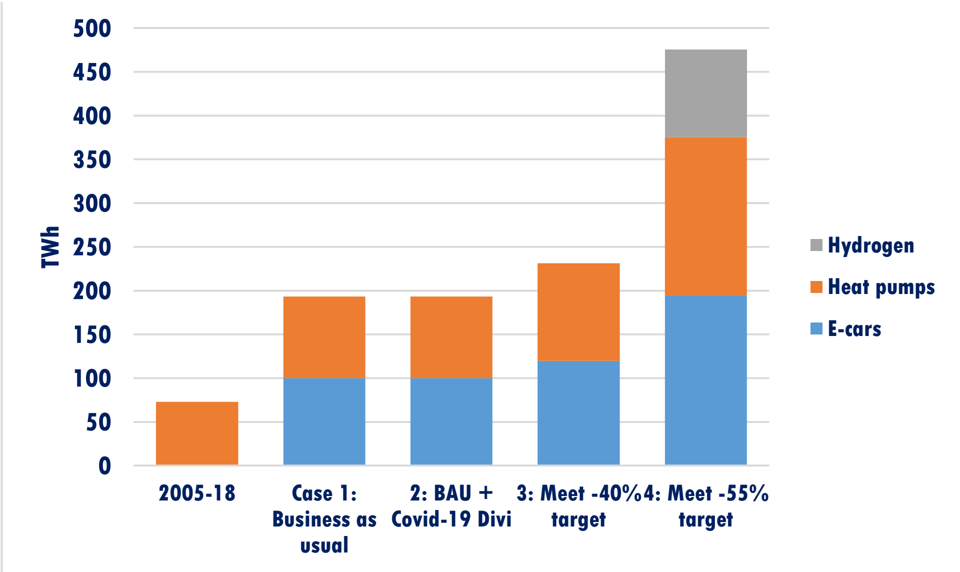
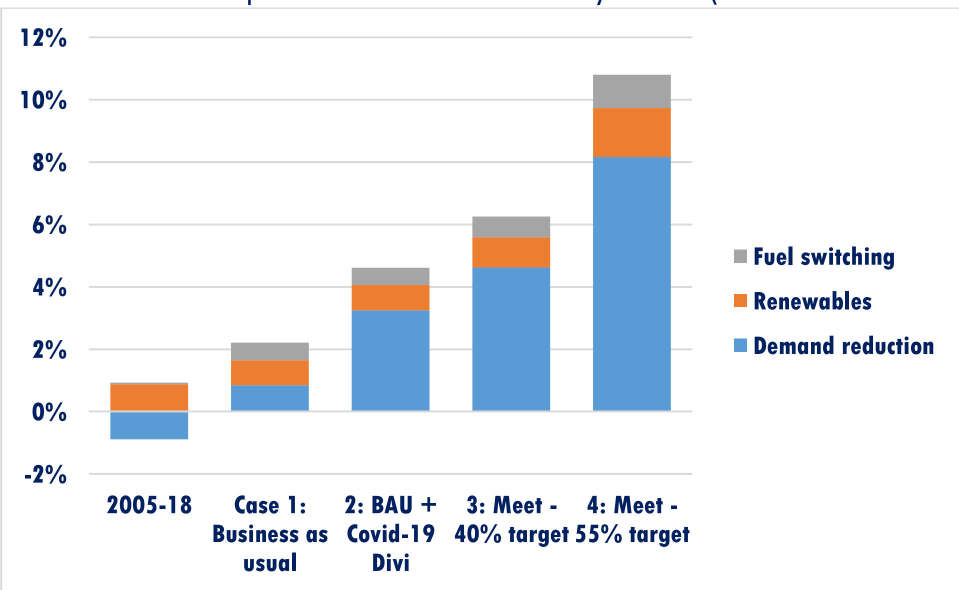


Fig. 35 shows the electrification assumptions:

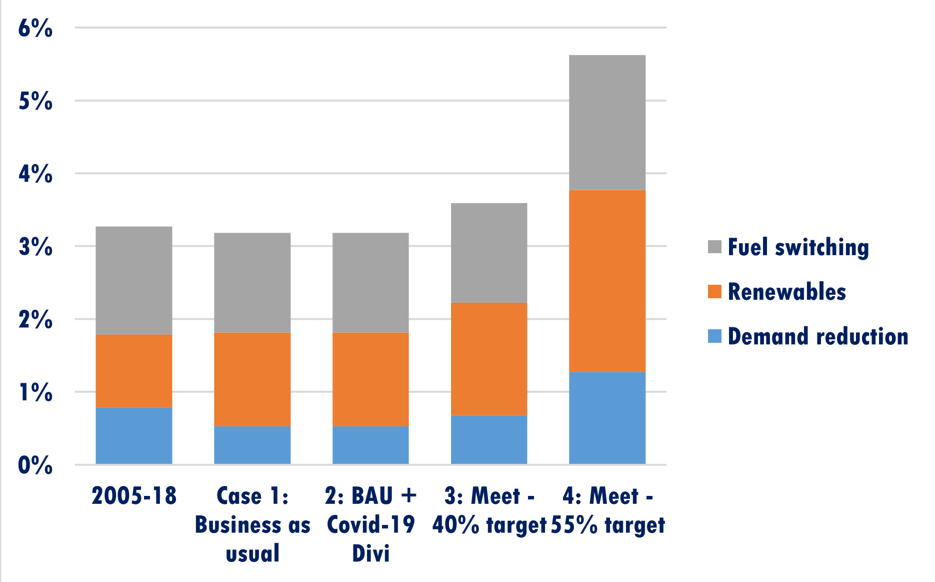
- For electric vehicles we take the lower end of the IEA forecast in Cases (1) - (3) and the upper end in Case (4).
- For heat pumps we have modestly increased the rates in Cases (1) and (2) compared with the previous period, with higher increases in Cases (3) and (4).
- There will only be surplus clean electricity for hydrogen production in Case (4) with a much higher growth rate of renewables power.

Figure 36: EU28 - Transport emissions reduction by means (2018-30 vs. 2005 level)



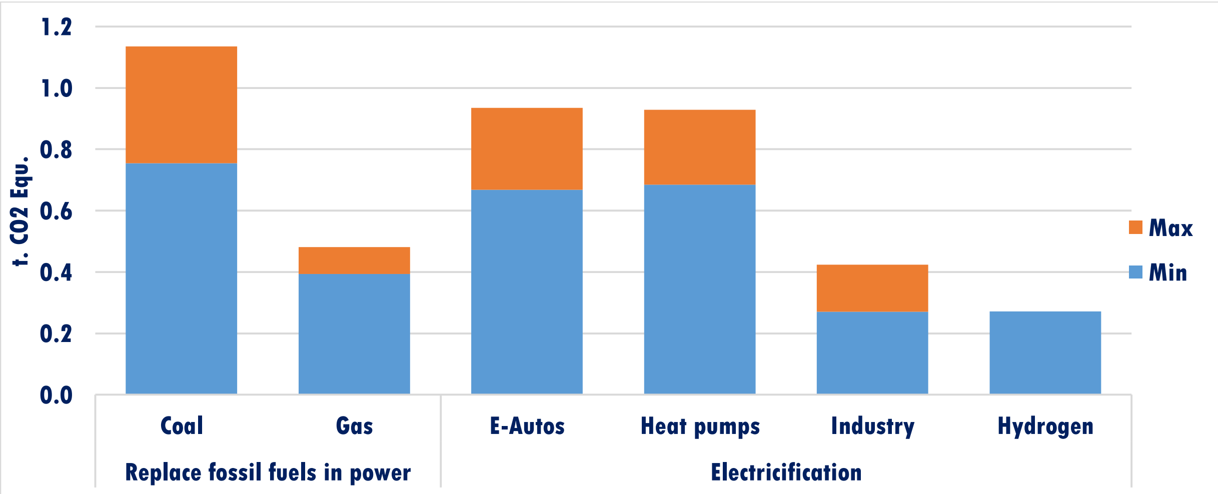
The forecasts for the transport and buildings sector depend substantially on our electrification assumptions. The demand outlooks have been set out in Fig. 33.
In the transport sector the contribution of electrification to reduced emissions is divided between demand reduction (because electric motors are much more efficient than the internal combustion counterparts) and fuel-switching. The assumption of further renewables (biofuels) growth may be optimistic.

Figure 37: EU28 - Buildings emissions reduction by means (2018-30 vs. 2005 level)



In the buildings sector only modest demand reduction is assumed (there is little basis for expecting that building renovation rates will increase significantly in relation to the ca. 1% of building stock rates p.a. achieved over recent years). Renewables, in particular ambient heat captured by heat-pumps, will be an important source of growth and linked to fuel-switching from fossil-fuels to electricity.

Figure 38: CO2 Emissions saved per MWh renewables power

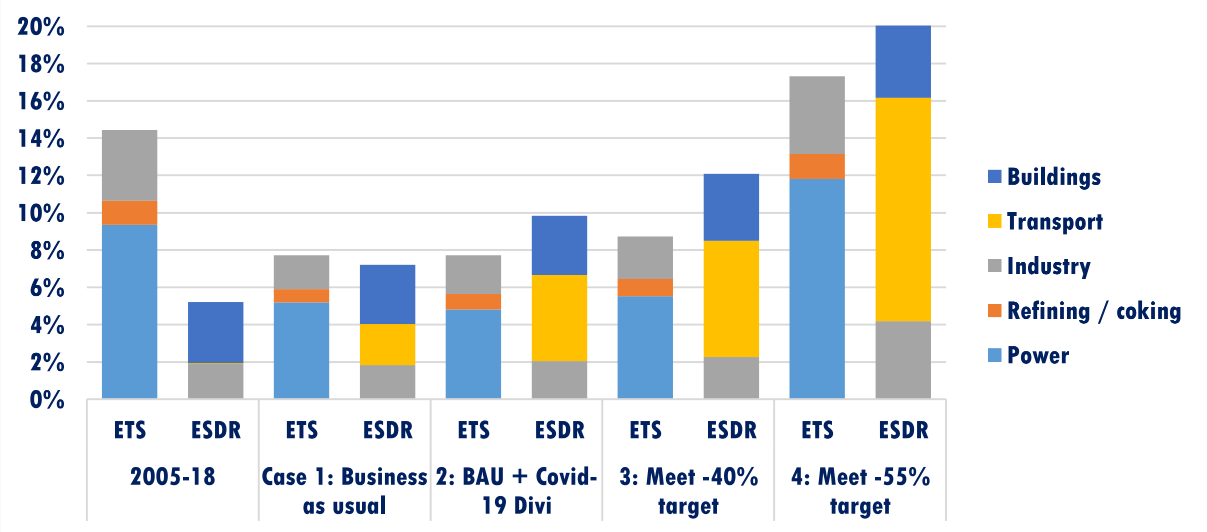


In order to proceed with energy transitions in the most economic manner it is important to be aware of how renewables power, the most important vector of change, can be most effectively applied.

Fig. 38 shows the level of CO_2-equivalent saved per 1 MWh of renewables power applied in different ways:

- Replacing coal-fired generation is most effective (especially for older, inefficient plant).
- The use of renewables power for electric vehicles and heat-pumps has comparable benefits.
- Lower in the merit-order come the use of renewables power to replace gas-fired generation or for direct electrification of industry.
- Right at the bottom of the curve is the use of such renewables for hydrogen, because of the ca. 20 % energy loss in the production process and the lack of any gearing-benefits as are found in other applications.

Figure 39: EU28 - Emissions reduction by scheme (2018-30 vs. 2005 level)



All emission reductions will fall into one of two categories: the Emissions Trading System (ETS) or Effort Sharing Decision and Regulation (ESDR).
In the 2005-18 period most of the reductions came from the ETS although they were not driven by the system carbon price, but rather by renewables subsidy schemes and mandated coal closures.
For the future we expect that such subsidy schemes and mandated coal closures will continue. But due to increased nuclear plant closures and also the need replace the first generation of renewables plants the net emissions reduction from within the ETS will be lower than achieved previously.
More of the reduction will come within the ESDR sector where incentives for electric vehicles and heat-pumps will be particularly important.
The total availability of clean power for such applications will depend directly on the rate of renewables power growth.

3 CONCLUSIONS AND RECOMMENDATIONS

Europe is not on track to meet its -40% goal in 2030 and needs to increase renewables and energy efficiency effort by 20% vs. that achieved between 2005-18. Even to maintain the rates of the past 13 years will be challenging because the annual renewables growth rates have been reducing and more closed nuclear plants will need to be offset.
The notion of a -50% or -55% reduction as considered in the Green Deal is extremely unrealistic as it would require an exact doubling of the effort managed since 2005.

The growth of renewables power must continue at the fastest possible rate, as the most important vector of decarbonisation. This requires higher targets and overall stronger incentives for new projects to be built.
Besides building new renewables power plants it is important that the highest proportion of the potentially available power can be made use of, which has two dimensions:

- Flexible load management and storage are important to avoid renewables power being "spilt" during hours of very high total renewable generation with the associated negative prices. But it can be challenging to invest in storage and load management facilities which will have a high enough utilisation to justify their costs.
- The transmission network needs expanding so that the renewables power can reach the end market, which at present is a particular problem in Germany.

The available renewables power must be used according to the merit-order of its effectiveness in reducing CO_2 emissions. In this respect only after such power has been used to compensate fossil-fuel generation, used as widely as possible for electric vehicles and heat pumps should it be used to produce hydrogen.
Europe needs to rethink its hydrogen strategy and ensure that all aspects of energy policy are considered from an integrated top-down approach rather than in individual silos.
Further effort must be given to efficiency measures to achieve better offsetting between GDP-driven demand growth and those measures.

4 METHODOLOGY

The main source document was the European Statistical Country Datasheets, a spreadsheet with over 500 time-series of data per Member State including energy demand by type/sector and detailed GHG emissions data by sector. (https://data.europa.eu/eu-odp/en/data/dataset/information-on-energy-markets-in-eu-countries-with-national-energy-profiles/resource/24184068-8ec3-470a-ba28-5ca2317c6f6f). From this emissions factors for each sector, and in the case of power for each fuel within the sector were calculated.
The other source documents used were:

- The IEA Data tables to give the fuel shares by sector in 2005 and 2017 (the latest year for which data was available). (https://www.iea.org/data-and-statistics/data-tables?country=EU28&energy=Balances&year=2017)
- The Eurostat Short Assessment of Renewables Energy Sources (http://ec.europa.eu/eurostat/web/energy/data/shares). This provided normalised renewable data as a basis for the trend projections in renewables growth rates (Fig. 8 and Fig. 10).
- The aim of the analysis for the period 2005-18 was to divide the actual emission reductions in each sector (power, refining and coking within the transformation sector, and the three end-use sectors – industry, transport and buildings) into three categories – emissions reduced by (i) increase of renewables (ii) reduced demand and (iii) fuel-switching between fossil fuels and/or to electricity and heat. The emissions reductions under categories (i) and (ii) were calculated simply based on the energy content replaced by renewables or reduced and the average emission coefficient for the sector. In the case of the power sector the weighted-average emissions factor for the fossil fuels present at the start of the period was applied. The balance of emissions reduction was allocated to fuel-switching.
- Regression analysis was undertaken on the annual demand in the power and three end-user sectors to determine its dependence upon GDP, HDD (heating degree days) and an implicit annual energy-efficiency saving. The resulting coefficients and annual energy saving percentage are shown in the table below. The confidence intervals differed considerably and were widest for the industry sector followed by buildings sector. The intervals were much smaller for the transport and power sectors thus giving a high level of confidence in the coefficients and methodology.

Table 1: Regression Analysis on the annual demand in the power and three end-user sectors

	Impact of 1% change of:		**Efficiency**
	GDP	**HDD**	**saving p.a.**
Final Energy	1.12	0.39	-1.8%
- Industry	1.19		-2.6%
- Transport	1.54		-2 .1%
- Buildings	0.38	0.79	-0.4%
- Power	0.86	0.21	-1.0%

1. The starting point for the outlook cases is that per year the same gross renewables build and effort in energy efficiency will be achieved as in the previous 13 years (2005-18). Whilst it may be thought that at least in respect of renewables more will be achieved than in the past, the actual trend is not so encouraging. Even to maintain the same average build-out rate both for renewables power and other forms may be challenging. The same average EU28 GDP growth rate (1.3%) as realised over that period is also applied; both periods include a serious economic crisis – in the earlier period there was the Global Financial Crisis and in the forecast period the Covid-19 related crisis.
2. Case (1) is a simple “business as usual” extrapolation of the past. However, in the case of the industry sector emission reductions were achieved by a significant reduction in energy demand and fuel-switching. There are doubts as to whether these will be repeated, so adjustments were made to reflect more realistic developments. For e-mobility the lower end of the IEA forecast for Europe is applied.
3. Case (2) includes Covid-19 dividends for emission reductions – 10% lower energy demand for transport in total and 2.5% less industrial production, as fewer transport units (vehicles and planes) will be built. We have also calculated how emissions would be linked to a further weakening of GDP: a weakening of each 0.1% throughout the outlook period would reduce emissions by 34 mt. by 2030, 0.74% of the 2005 level.
4. Case (3) builds on Case (2). The growth of renewables, energy efficiency and e-mobility effort is increased until the emissions target for 2030 is exactly met.
5. Case (4) also builds on Case (2) and increases the various efforts required to meet a -55% target.
6. The role of the Emissions Trading System is a critical factor and is subject to huge uncertainty regarding the number of emission certificates in circulation, in particular following the planned closure of coal plants in Germany and other countries. For Cases (1) and (2) we have assumed that it will be binding so that even after these planned closures further switching of coal to gas will be required. In Cases (3) and (4) the additional renewables and energy efficiency effort will take emission reductions well below the current target level, so it is assumed that the Market Stability Reserve will keep the supply of certificates tight, otherwise the gains made through coal-plant closures would simply open up space for increased emissions in the industry sector or through gas-fired generation in the power sector.

5 AUTHOR'S BACKGROUND

Graham Weale is since 2015 Honorary Professor for Energy Economics and Politics and member of the Centre for Environment, Resources and Energy (CURE) at the Ruhr-Universität Bochum, Germany. His research and teaching focus on the means of achieving Energy Transitions at the lowest cost to society.

Weale was Senior Advisor to the Energy Transitions Commission in 2016-17 and also worked as Consultant to PWC on a new market design for electricity supply (2016-19).

Between 2007 and 2016 he was Chief Economist at RWE AG, Germany's largest power generator and helped navigate the company through the German Energiewende (the move out of nuclear power into renewables). He therefore has extensive insight into the operations, challenges and political pressures on large European power companies operating a range of power plants in different countries.

Beforehand he was Director of European Services for IHS Global Insight (now CERA), one of the world's leading energy and economic consultancies. His work covered all forms of energy and all European countries and he was frequently engaged as an Expert Witness at high-profile gas contract arbitrations. He began his energy career with ExxonMobil in supply and refining.

Weale is a leading expert on Energy Transitions both in Europe and the USA. He has a deep understanding of their political, economic and technological dimensions and has the mission to explain how the end-goals can be achieved at the lowest cost to society. He has first-hand experience of all the major forms of energy. The combination of his technical and commercial background enables him to offer unique insights into the junction of these two disciplines. In the late 1980s he was credited as the first energy expert to highlight the potential of the Combined Cycle Gas plant as a major source of power generation in Europe.

Weale has also worked as advisor to the European Commission and other European Governments. He has been a guest speaker at the leading Think Tanks and other major conferences in Europe and the USA. He has a physics degree from Oxford University and an MBA.

Climate change, the energy transition, declining biodiversity and sustainability are the challenges of modern time. These are also the topics that form the core of research and teaching at the Centre for Environmental Management, Resource and Energy Economics.

CURE has been established within the Faculty of Management and Economics at the Ruhr-Universität Bochum to enhance the joint research activities of the scholars focusing on the following topics:

- Energy and climate economics
- Operational and economic sustainability economics in competition-based economic systems,
- Corporate environmental management,
- Decarbonisation of operational production and service processes,
- Protection of species and resources (animals, plants, water, soil, air)

The aim of the centre is, on the one hand, to bundle and coordinate the relevant teaching within the bachelor and master modules. On the other the centre enhances an integrative approach, which incorporates business administration, economics and legal perspectives. The aim is to set up a group of young researchers at CURE that advances the inter- and transdisciplinary social-ecological research in conjunction with other faculties at the Ruhr-Universität.

The centre consists of six professors and two post-doctoral students in the faculty, to whom will be added further scientific workers and doctoral students. The director is Prof. Helmut Karl.