Chapter 3. Carbon pricing in 2015 – Detailed analysis

This chapter provides an overview of the state of carbon pricing in 2015. It shows effective carbon rates for all 42 countries combined and separately by country, discusses change between 2012 and 2015, and puts carbon pricing in a broader economic context.

This chapter provides an overview of the state of carbon pricing in 2015. It shows effective carbon rates for all 42 countries combined and separately by country. A comparison at the level of sectors reveals that effective carbon rates do not only vary substantially across sectors (as discussed in the previous chapter), but also across countries within sectors. Comparing carbon rates in 2015 with those in 2012 shows that, while carbon rates tend to increase slowly on average, some countries have made significant progress with pricing emissions more in line with social costs and long-term emission reduction commitments.

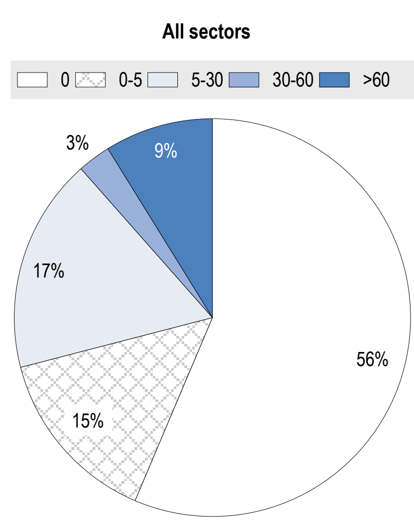
Effective carbon rates in 2015 consist of tax rates as of 1 April 2015 (OECD, 2018[1]) and average permit prices from emission trading systems for 2015 (see Annex A for details on emissions trading systems). Emission data is for 2015 and calculated from fuel use as provided by the Extended World Energy Balances (EWEB) of the International Energy Agency (IEA, 2017[2]). The coverage of emissions trading systems is estimated based on data by the authorities governing the respective systems. Effective carbon rates for 2012 consist of tax rates as of 1 April 2012, average permit prices and ETS coverage for 2012, and emissions levels in 2012.[1]

Share of emissions priced and price levels across countries in 2015

Across all 42 OECD and G20 countries covered in this report, 44% of carbon emissions from energy use were subject to an effective carbon rate in 2015. Rate levels remained low, with only 12% of emissions priced above EUR 30, a conservative low-end estimate of the social costs of carbon emissions in 2015. Only 9% of emissions were priced at EUR 60 or more, a midpoint estimate of the carbon prices needed in 2020 for countries to be in line with reaching their commitments from the Paris Agreement, according to the High Level Commission on Carbon Prices (2017[3]).

Figure 3.1. Proportion of CO_2 emissions priced at different price levels in 2015

Price levels in EUR per tonne of CO_2



Aggregate numbers on carbon pricing can hide substantial differences across countries. While on aggregate 56% of emissions were unpriced across the 42 OECD and G20 countries, the simple (unweighted) average of unpriced emissions for the 42 countries was substantially lower, at 33%. This means that large emitters tend to price fewer emissions than countries that emit a smaller amount of emissions. In addition, large emitters also tend to set lower rates for those emissions that are subject to a price. While on aggregate 12% of emissions were priced above EUR 30 per tonne CO_2, the simple average of emissions priced above EUR 30 across the 42 countries was 27%.

Table 3.1 shows that 15 countries priced more than 80% of carbon emissions and five (Ireland, Israel, Korea, Luxembourg and the Netherlands) priced more than 90% of carbon emissions in 2015. Price levels were generally low, with only four countries (Luxembourg, Norway, Switzerland and the United Kingdom) pricing nearly half or more of their emissions above the low-end estimate of climate costs of EUR 30 per tonne of CO_2. Generally, few emissions were subject to an effective carbon rate above EUR 60 in 2015, and most of these emissions were from road transport. Table 3.6 provides more detail on effective carbon rates in the road sector.

Between 2012 and 2015, Korea and Mexico progressed strongly in pricing emissions. Korea introduced an emissions trading system, which covered most sectors of the economy in 2015, increasing the share of priced emissions by 51 percentage points, and the share of emissions priced above EUR 5 by 65 points. Mexico introduced a carbon tax in 2014 as well as increased effective excise tax rates on transport fuels (Arlinghaus and Van Dender, 2017[4]). The share of emissions priced increased by 26 percentage points (mainly through the carbon tax) and the share of emissions priced above EUR 60 per tonne of CO_2 rose by 30 percentage points (through higher effective excise taxes on transport fuels). Quebec in Canada and California in the United States introduced emissions trading systems in 2013, so increasing the share of priced emissions.

The large decrease in priced emissions in South Africa results from a zero rate for the slate levy, a tax on coal products, in 2015 (South African Treasury, 2015[5]). The decrease in effective carbon rate coverage above EUR 5 in Turkey results from a depreciation of the Turkish Lira against the Euro in the same time period.

As explained above, aggregate numbers can hide the substantial progress made by some countries, because large emitters tend to price fewer emissions than countries that emit a smaller amount of emissions. Nevertheless, the share of priced emissions increased by more than 5 percentage points between 2012 and 2015 for the 42 countries as a group. The share of emissions with an effective carbon rate above EUR 30 increased by two percentage points and the share above EUR 60 by nearly four percentage points.

Table 3.1. Proportion of emissions priced per tonne of CO_2 by country

Country	Proportion of emissions priced at or above in 2015 (in percent)				Change, from 2012 to 2015, of emissions priced at or above (in percentage points)			
	EUR 0	EUR 5	EUR 30	EUR 60	EUR 0	EUR 5	EUR 30	EUR 60
ARG	73%	24%	24%	20%	na	na	na	na
AUS	23%	23%	20%	20%	-1	-1	1	2
AUT	64%	64%	34%	25%	0	0	-7	1
BEL	72%	64%	23%	23%	-7	-2	1	1
BRA	33%	25%	0%	0%	-1	-2	0	0
CAN	61%	61%	16%	0%	na	na	na	na
CHE	87%	78%	70%	36%	1	-4	0	1
CHL	20%	20%	20%	9%	4	4	4	2
CHN	22%	9%	9%	9%	11	1	1	9
CZE	79%	67%	15%	15%	7	2	1	1
DEU	88%	87%	19%	19%	5	4	0	1
DNK	78%	78%	32%	31%	5	5	-20	-1
ESP	86%	84%	34%	28%	15	14	5	5
EST	76%	71%	13%	11%	-4	3	0	0
FIN	62%	62%	42%	26%	-2	-2	1	1
FRA	83%	82%	42%	35%	7	8	9	2
GBR	76%	75%	49%	27%	-4	-4	20	3
GRC	90%	90%	31%	25%	-1	-2	2	4
HUN	64%	61%	22%	22%	2	0	4	4
IDN	16%	16%	0%	0%	0	0	0	0
IND	64%	18%	9%	2%	3	7	7	0
IRL	93%	93%	36%	29%	4	4	0	-1
ISL	78%	78%	38%	38%	0	0	-4	-4
ISR	98%	29%	27%	27%	1	-5	-5	-5
ITA	88%	87%	40%	37%	0	2	-2	1
JPN	85%	40%	21%	18%	-2	19	3	1
KOR	97%	97%	16%	16%	51	65	2	3
LUX	96%	85%	64%	64%	2	-1	2	2
LVA	55%	46%	24%	22%	na	na	na	na
MEX	62%	32%	30%	30%	26	2	30	30
NLD	94%	94%	38%	33%	8	9	2	-2
NOR	82%	81%	61%	56%	1	1	0	19
NZL	76%	20%	20%	19%	9	1	1	1
POL	83%	74%	15%	15%	9	4	1	1
PRT	78%	76%	28%	25%	5	6	0	-1
RUS	35%	0%	0%	0%	-6	0	0	0
SVK	79%	69%	26%	16%	-1	-1	-4	0
SVN	82%	82%	46%	42%	-1	1	7	9
SWE	58%	58%	25%	25%	5	6	1	3
TUR	49%	23%	21%	20%	2	-20	3	5
USA	37%	37%	3%	0%	5	9	3	0
ZAF	12%	11%	11%	10%	-46	-1	0	-1

Note: na: not available. The left side of the table shows the proportion of emissions with an ECR above EUR 0, 5, 30 and 60 in per cent. The right hand side shows the change in the proportion of emissions with an ECR above EUR 0, 5, 30 and 60 from 2012 to 2015, in percentage points. The table includes emissions from the combustion of biomass in the emission base. Annex 3.A shows results excluding emissions from the combustion of biomass in the emission base.

Priced emissions in the electricity sector in 2015

While in 2015 two-thirds of aggregate emissions from the electricity sector in the 42 countries as a group were not priced, the simple average of the share of priced emissions across the 42 countries was 62%. This means that countries with high emissions from the electricity sector tended to price fewer emissions than countries with a smaller amount of emissions. Only 1% of aggregate emissions were priced above of EUR 30 per tonne of CO_2, while the simple average across the 42 countries was 3%.

Thirteen countries priced close to 100% of emissions from the electricity sector, see Table 3.3. The effective carbon rates in the electricity sector arose mostly from emissions trading systems, but Argentina, India and Israel priced large shares of electricity emissions through taxes. Most countries with nationwide emissions trading systems covered nearly all of their electricity emissions. Coverage below 100% can occur through electricity generated from biomass, for which the rate is generally zero, and small power plants, often CHP plants, below the threshold for inclusion in the system.

Emission permits traded at values between about EUR 5 to 15 in 2015. Combined with the fact that emissions trading was the main carbon pricing instrument in the electricity sector, this means that the share of emissions priced above EUR 5 was similar to the share of priced emissions for many countries. Only a few countries priced a significant share of electricity emissions at EUR 30 and above in 2015. In the United Kingdom, 79% of electricity emissions where priced above EUR 30 per tonne CO_2 in 2015.

The United Kingdom introduced a Carbon Price Support (CPS) in 2013 at GBP 9 per tonne of CO_2 for emissions in the electricity sector. The carbon price support is charged on top of permit prices and increased to GBP 18 by 1 April 2015. The total effective carbon rate has been slightly over EUR 30 per tonne CO_2 since then.

Table 3.2. Emissions from electricity generation fall sharply with the introduction of a carbon price support

Carbon dioxide emissions in the United Kingdom before and after the introduction of the carbon price support

		2012	2016	Change (2012-2016)	Change in %
Electricity sector	CO_2 emissions in Mt	158	66	-92	-58%
	Coal use in Mt	54	12	42	-78%
	Carbon Price Support (CPS) per tonne of CO_2	*0*	*GBP 18 (EUR 24.80)*	*GBP 18 (EUR 24.80)*	
	Permit Price in EU ETS in EUR per tonne of CO_2	7.24	7.6	0.36	+5%
	Effective Carbon Rate in EUR per tonne of CO_2	*7.24*	*32.40*	*25.16*	+347%
Entire economy	CO_2 emissions in Mt	474	356	-118	-25%
	Reductions from electricity sector			-92	-19%

Sources: Hirst (2018[6]), European Energy Exchange (2015[7]), UK Department for Business, Energy & Industrial Strategy (2017[8]), UK Department for Business, Energy & Industrial Strategy (2018[9])

Emissions from the electricity sector decreased by 58% from 2012, before the CPS was introduced*, to 2016, the first full year for which total effective carbon rates equalled about EUR 30* (see Table 3.2). The decrease in emissions is explained by a sharp drop in the use of coal for the generation of electricity. Coal use fell by 78% in the same period.

Coal was partly replaced natural gas, which is about half as emission intensive as coal per unit of energy, and partly by zero-carbon renewables.

Overall UK emissions from energy use fell by 25% in between 2012 and 2016, of which 19 percentage points can be attributed to cleaner electricity generation. British greenhouse gas emission are now below the level of 1890 (Hausfather (2018[10]), Ward (2018[11])). The British experience show how fast emissions can decline if carbon prices are at levels high enough to encourage a switch to cleaner fuels. The Dutch coalition treaty of 2017 follows on the British example by including the introduction of a minimum price for emissions covered by the EU ETS.

California included a minimum auction price for its permits when it started its cap and trade program in 2013. The minimum price increases by 5% plus inflation each year. While prices were still fairly moderate in 2015 at about USD 13 per tonne of CO_2, the mandated increase in the auction price ensures that carbon price levels reach at least about EUR 30 in 2030. Ontario and Quebec follow the same approach.

The EU will introduce a Market Stability Reserve (MSR) for its ETS in 2019 (European Union, 2018[12]). The market stability reserve will remove 24% of surplus permits from the market, if the surplus of permits exceeds 833 million. A surplus of permit occurs when aggregate verified emissions are below the emission cap. The MSR will release permits into the market if the surplus falls below 400 million permits. From 2023 onwards, allowances held in the reserve that exceed the total number of allowances auctioned during the previous year they will become invalid. Research by Enerdata (2018[13]) suggests that even with the MSR, permit prices will hardly increase up to mid-2030s.[2] The authors expect that the cap becomes binding only in the 2030s. Once the surplus of permits disappears, prices may soon increase. A fast increase in carbon emission prices, projected from the mid- or end-2030s onwards, can trigger a sudden loss of value of carbon intensive assets; especially if the price rise is unexpected (see the section discussing the *carbon pricing gap*). A minimum auction price that increases by a fixed percentage plus inflation would allow a smooth increase of carbon pricing and prevent sudden asset price revaluations.

Korea and Mexico significantly expanded their carbon pricing base in the electricity sector from 2012 to 2015. The new Korean ETS increased the share of priced electricity emissions by 77 percentage points. Mexico's carbon tax increased the share of priced electricity emissions by 45 percentage points. China's ETS pilots increased the share of priced emissions in the electricity sector to 14%.

As already mentioned in the previous subsection, the large decrease in priced emissions in South Africa results from a zero rate for the slate levy in 2015 (South African Treasury, 2015[5]). The significant decrease in the share of electricity emissions priced above EUR 5 in Turkey results from a depreciation of the Turkish Lira against the Euro. Israel used less oil products in 2015 compared to 2012, which are taxed at relatively high effective carbon rates, to generate electricity.

Table 3.3. Proportion of emissions priced in the electricity sector per tonne of CO_2 by country

Country	Proportion of emissions priced at or above in 2015 (in percent)				Change, from 2012 to 2015, of emissions priced at or above (in percentage points)			
	EUR 0	EUR 5	EUR 30	EUR 60	EUR 0	EUR 5	EUR 30	EUR 60
ARG	74%	13%	13%	0%	na	na	na	na
AUS	0%	0%	0%	0%	0	0	0	0
AUT	66%	66%	0%	0%	-5	-5	0	0
BEL	70%	69%	0%	0%	2	1	0	0
BRA	10%	10%	0%	0%	-10	-10	0	0
CAN	54%	54%	0%	0%	na	na	na	na
CHE	29%	29%	29%	0%	6	6	29	0
CHL	0%	0%	0%	0%	0	0	0	0
CHN	14%	0%	0%	0%	14	0	0	0
CZE	96%	96%	0%	0%	0	0	0	0
DEU	90%	90%	0%	0%	-1	-1	0	0
DNK	73%	73%	0%	0%	-5	-5	0	0
ESP	95%	95%	0%	0%	-2	-2	0	0
EST	88%	88%	0%	0%	2	2	0	0
FIN	70%	70%	0%	0%	4	4	0	0
FRA	91%	91%	0%	0%	-6	-6	0	0
GBR	87%	87%	79%	0%	-10	-10	79	0
GRC	99%	99%	12%	2%	0	0	-2	0
HUN	77%	77%	0%	0%	-8	-8	0	0
IDN	0%	0%	0%	0%	0	0	0	0
IND	98%	0%	0%	0%	2	0	0	0
IRL	97%	97%	0%	0%	0	0	0	0
ISL	0%	0%	0%	0%	0	0	0	0
ISR	100%	1%	1%	1%	0	-13	-13	-13
ITA	88%	88%	0%	0%	-2	1	0	0
JPN	89%	13%	0%	0%	-2	11	-2	-2
KOR	100%	100%	0%	0%	77	81	0	0
LUX	64%	64%	0%	0%	-27	-27	0	0
LVA	64%	64%	0%	0%	na	na	na	na
MEX	47%	1%	1%	1%	45	0	1	1
NLD	97%	97%	0%	0%	5	5	0	0
NOR	66%	66%	0%	0%	-2	-2	0	0
NZL	82%	0%	0%	0%	12	0	0	0
POL	94%	94%	0%	0%	0	0	0	0
PRT	93%	93%	0%	0%	0	0	0	0
RUS	0%	0%	0%	0%	-4	0	0	0
SVK	85%	85%	0%	0%	-5	-5	0	0
SVN	98%	98%	0%	0%	0	0	0	0
SWE	30%	30%	0%	0%	6	6	0	0
TUR	32%	0%	0%	0%	-4	-36	0	0
USA	8%	8%	0%	0%	4	8	0	0
ZAF	0%	0%	0%	0%	-100	0	0	0

Note: na: not available. The left side of the table shows the proportion of emissions with an ECR above EUR 0, 5, 30 and 60 in percent. The right-hand side shows the change in the proportion of emissions with an ECR above EUR 0, 5, 30 and 60 from 2012 to 2015, in percentage points. The table includes emissions from the combustion of biomass in the emission base. Annex 3.A shows results excluding emissions from the combustion of biomass in the emission base.

Priced emissions in the industry sector in 2015

In the industry sector, 65% of aggregate emissions from the 42 OECD and G20 countries covered in this report were unpriced in 2015. Only 2% of emissions faced an effective carbon rates larger than EUR 30 per tonne CO_2. In 2012, 72% of aggregate emissions had no price.

Countries with high emissions tended to price fewer industry emissions than countries with lower amounts of industry emissions. The (unweighted) average of priced emissions across the 42 countries was 60% for industry emissions. At the same time, over a quarter of all countries analysed priced 80% of industry emissions. Rates are often above EUR 5 but significantly below EUR 30 per tonne CO_2.

Few countries price a significant share of industrial emissions above EUR 30 per tonne of CO_2. In Norway, natural gas used in oil and gas extraction is covered by a carbon tax in addition to being covered by the EU ETS. In Finland and Slovenia, all firms pay carbon taxes for fossil-fuel use independently of whether they participate in the EU ETS or not (OECD, 2018, p. 20[1]), Slovenia expanded the carbon tax base to include all fossil fuels, whereas in 2012, the carbon tax applied only to natural gas.

The new Korean ETS increased the carbon price base in industry between 2012 and 2015 by 55 percentage points, to 98% (Table 3.4). The share of industry emissions priced above EUR 5 increased by 86 percentage points.

This report, including Table 3.4 shows the share of emissions priced above benchmark values of effective *marginal* carbon rates for the 42 countries. More than 35% of the effective marginal carbon rates in industry stem from emissions trading systems (see Table 2.2). Industrial facilities subject to an ETS often receive a significant share of emission permits for free. The effective *marginal* carbon rate does not account for the free allocation of permits; it only takes the marginal permit price into account.

Flues and Van Dender (2017[14]) discuss how free allocation of permits can lower the incentives of firms to invest in clean technologies. They calculate an effective *average* carbon rate that takes into account free permit allocation and provides information on the strength of the incentives to invest in clean technologies.

Table 3.4. Proportion of emissions priced in the industry sector per tonne of CO_2 by country

Country	Proportion of emissions priced at or above in 2015 (in percent)				Change, from 2012 to 2015, of emissions priced at or above (in percentage points)			
	EUR 0	EUR 5	EUR 30	EUR 60	EUR 0	EUR 5	EUR 30	EUR 60
ARG	62%	2%	2%	1%	na	na	na	na
AUS	3%	3%	3%	3%	-6	-6	3	3
AUT	54%	54%	11%	3%	1	1	-6	0
BEL	59%	57%	0%	0%	-14	-10	0	0
BRA	16%	2%	0%	0%	3	0	0	0
CAN	51%	51%	0%	0%	na	na	na	na
CHE	84%	49%	18%	0%	2	-15	-1	0
CHL	0%	0%	0%	0%	0	0	0	0
CHN	19%	2%	2%	1%	11	0	0	1
CZE	85%	50%	0%	0%	33	7	0	0
DEU	85%	82%	1%	0%	20	19	-2	0
DNK	86%	86%	13%	10%	16	16	-52	-3
ESP	74%	68%	4%	0%	14	9	1	0
EST	63%	45%	4%	0%	-20	6	0	0
FIN	60%	60%	42%	17%	-2	-2	1	4
FRA	79%	75%	2%	0%	1	4	-1	0
GBR	81%	79%	8%	4%	0	-2	-13	-3
GRC	91%	90%	16%	5%	-1	-2	-6	-2
HUN	79%	67%	3%	3%	0	-8	1	1
IDN	0%	0%	0%	0%	0	0	0	0
IND	71%	25%	1%	0%	2	21	0	0
IRL	72%	72%	3%	0%	-3	-1	-14	-8
ISL	24%	24%	0%	0%	3	3	0	0
ISR	85%	6%	0%	0%	7	4	-2	-2
ITA	97%	96%	2%	2%	4	10	-19	-5
JPN	70%	34%	5%	4%	-3	27	4	4
KOR	98%	97%	2%	2%	55	86	0	2
LUX	89%	77%	0%	0%	11	19	0	0
LVA	51%	29%	0%	0%	na	na	na	na
MEX	44%	4%	4%	4%	24	1	4	4
NLD	90%	89%	17%	2%	18	23	15	1
NOR	80%	79%	46%	46%	-7	-8	-9	28
NZL	54%	1%	1%	0%	10	0	0	0
POL	91%	65%	1%	1%	8	-4	0	0
PRT	65%	60%	3%	0%	11	8	1	0
RUS	44%	0%	0%	0%	-12	0	0	0
SVK	72%	56%	11%	0%	1	1	-5	0
SVN	86%	86%	39%	38%	1	13	32	32
SWE	54%	54%	4%	3%	8	8	1	3
TUR	41%	13%	4%	0%	-8	-23	-5	-1
USA	7%	7%	0%	0%	7	7	0	0
ZAF	4%	4%	4%	1%	-5	0	0	-3

Note: na: not available. The left side of the table shows the proportion of emissions with an ECR above EUR 0, 5, 30 and 60 in percent. The right hand side shows the change in the proportion of emissions with an ECR above EUR 0, 5, 30 and 60 from 2012 to 2015 in percentage points. The table includes emissions from the combustion of biomass in the emission base. Annex 3.A shows results excluding emissions from the combustion of biomass in the emission base.

Priced emissions in the residential and commercial sector in 2015

In the residential and commercial sector, 79% of aggregate emissions in the 42 OECD and G20 countries covered in this report were unpriced in 2015. Six percent of emissions faced a price above EUR 30 per tonne CO_2. In 2012, 81% of emissions from the residential and commercial sector were unpriced.

Like for other sectors, inter-country differences are large, and many countries price a significant share of emissions from the residential and commercial sector. The unweighted average of the share of priced emissions is 46% across the 42 countries, the unweighted cross-country share of prices above EUR 30 and EUR 60 per tonne CO_2 is 13% and 7% respectively.

Several countries price almost all residential and commercial emissions and some price these emissions at significant rates. Eight countries price more than 90% of emissions. The Netherlands and Switzerland price more than 80% of residential and commercial emissions above EUR 30 per tonne CO_2. The effective carbon rate in the residential and commercial sector generally consists of both excise and carbon taxes.

In France, the share of residential and commercial emissions priced above EUR 30 increased by 23 percentage points between 2012 and 2015. Energy taxes in France have a carbon component which increases over time (Ministère de la Transition écologique et solidaire de la République Francaise, 2018[15]). In 2017, the carbon component reached EUR 30.5 per tonne of CO_2, meaning that at the time of publication of this report, the vast majority of residential and commercial emissions will be priced above EUR 30 per tonne. By 2022, the carbon component is set to reach EUR 86 per tonne of CO_2.

In Japan, the share of emissions priced above EUR 30 in the residential and commercial sector increased strongly as tax rates rose. The Swiss carbon tax, which applies to fuels used in the residential and commercial sector, increased from CHF 36 (about EUR 30) to CHF 60 (about EUR 50) per tonne of CO_2 in 2014, because Switzerland had not reached its CO_2 emission reduction goal for 2012 (Le Conseil fédéral suisse, 2013[16]). In 2016, the carbon tax increased to CHF 84 (about EUR 70) per tonne of CO_2 (Le Conseil fédéral suisse, 2015[17]), so that now the majority or commercial and residential emissions are priced above EUR 60 (not shown in Table 3.5)

A number of countries expanded carbon rate coverage at rates below EUR 30 per tonne significantly between 2015 and 2012, mainly through taxing previously untaxed fuels. Iceland increased the share of priced emissions by 74 percentage points by expanding its carbon tax base to gaseous fuels. Mexico increased the share of priced emissions by 39 percentage points, mainly through the introduction of a carbon tax (OECD, 2018[1]). Spain expanded its taxbase to include biofuels for heating purposes and removed tax exemptions for natural gas and LPG. The share of priced emissions increased by 42 percentage points between 2012 and 2015. Ireland introduced a tax on solid fossil fuels in 2013, increasing the share of priced emissions in the residential and commercial sector by 23 percentage points. Poland introduced an excise duty on gaseous fuels in 2013. Its share of priced residential and commercial emissions increased by 23 percentage points.

Table 3.5. Proportion of emissions priced in the residential and commercial sector per tonne of CO_2 by country

Country	Proportion of emissions priced at or above in 2015 (in percent)				Change, from 2012 to 2015, of emissions priced at or above (in percentage points)			
	EUR 0	EUR 5	EUR 30	EUR 60	EUR 0	EUR 5	EUR 30	EUR 60
ARG	92%	1%	1%	0%	na	na	na	na
AUS	0%	0%	0%	0%	-15	-15	0	0
AUT	49%	49%	23%	0%	-3	-3	-26	0
BEL	73%	43%	0%	0%	-15	1	0	0
BRA	0%	0%	0%	0%	0	0	0	0
CAN	25%	25%	0%	0%	13	13	0	0
CHE	80%	80%	80%	0%	-1	-1	0	0
CHL	3%	3%	0%	0%	3	3	0	0
CHN	8%	6%	6%	5%	3	0	0	5
CZE	14%	13%	0%	0%	-21	-1	0	0
DEU	79%	78%	1%	1%	-3	-3	0	0
DNK	37%	37%	28%	28%	-8	-8	-16	-16
ESP	68%	68%	23%	0%	42	43	1	0
EST	18%	18%	5%	0%	1	2	-1	0
FIN	30%	30%	30%	29%	-2	-2	-1	0
FRA	66%	66%	23%	0%	21	24	23	0
GBR	27%	27%	4%	0%	-4	-4	-6	0
GRC	63%	62%	10%	9%	-3	-3	5	4
HUN	18%	18%	0%	0%	1	1	0	0
IDN	0%	0%	0%	0%	0	0	0	0
IND	4%	0%	0%	0%	0	0	0	0
IRL	97%	97%	23%	0%	23	23	2	0
ISL	100%	100%	0%	0%	74	74	0	0
ISR	97%	97%	0%	0%	34	34	0	0
ITA	68%	68%	52%	46%	-1	-1	-1	-1
JPN	100%	64%	31%	18%	0	48	30	17
KOR	86%	86%	16%	12%	-2	10	8	12
LUX	94%	47%	0%	0%	-1	-9	0	0
LVA	22%	20%	1%	1%	na	na	na	na
MEX	40%	1%	1%	1%	39	0	1	1
NLD	90%	90%	90%	90%	-1	-1	-1	-1
NOR	29%	29%	29%	25%	0	0	1	-1
NZL	63%	4%	4%	0%	38	0	0	0
POL	31%	24%	0%	0%	23	21	0	0
PRT	44%	44%	7%	5%	15	35	-1	-2
RUS	8%	0%	0%	0%	-1	0	0	0
SVK	93%	84%	28%	0%	3	2	-3	0
SVN	34%	34%	18%	0%	-3	-3	-6	0
SWE	20%	20%	20%	20%	-2	-2	-2	-2
TUR	45%	4%	4%	4%	13	-28	1	1
USA	5%	5%	0%	0%	5	5	0	0
ZAF	2%	0%	0%	0%	0	-1	0	0

Note: na: not available. The table includes emissions from the combustion of biomass in the emission base. Annex 3.A shows results excluding emissions from the combustion of biomass in the emission base.

Priced emissions in the road sector in 2015

Nearly all emissions (97%) of the road sector were priced in 2015. Effective carbon rates were significantly higher than in other sectors. 56% of aggregate emissions of the 42 countries covered have a rate above EUR 30 per tonne of CO_2, and 47% also exceed EUR 60 per tonne of CO_2. Compared to 2012, the share of emissions priced above EUR 60 increased by about 17 percentage points.

Many countries price close to or even 100% of road emissions above EUR 60 per tonne of CO_2. The unweighted average of the share of emissions priced above EUR 60 across the 42 countries is 81%. More than three quarter of all analysed countries price 90% of road emissions above EUR 30.

From 2012 to 2015, Mexico increased the share of emissions priced above EUR 60 by 98 percentage points through reforming its excise tax regime for road fuels (Arlinghaus and Van Dender, 2017[4]). India increased the share of emissions priced above EUR 30 by 73 percentage points in the same period by increasing tax rates on road fuels.

The shares of priced emissions are calculated on the basis of fuel sold in the respective countries, as recorded in the IEA's (2017[2]) extended world energy balances. This implies that countries that sell more fuel than used in their territory record higher emissions than if fuels used were the emission base. The energy balances do not record the amount of fuel used in a country. Countries with a high share of transit traffic and non-residents filling up their vehicles in its territories may thus record more emissions on the fuels sold compared to the fuel used base, especially when fuels are priced at a lower rate than in neighbouring countries. Other countries correspondingly show fewer emissions from sales than would be recorded on the basis of usage. OECD (2016, pp. 48-49[18]) provides more detail on countries' shares of emissions from road transport in their overall emissions.

Table 3.6. Proportion of emissions priced in the road sector per tonne of CO_2 by country

Country	Proportion of emissions priced at or above in 2015 (in percent)				Change, from 2012 to 2015, of emissions priced at or above (in percentage points)			
	EUR 0	EUR 5	EUR 30	EUR 60	EUR 0	EUR 5	EUR 30	EUR 60
ARG	92%	92%	92%	92%	na	na	na	na
AUS	99%	99%	99%	95%	-1	-1	3	0
AUT	92%	92%	92%	92%	-2	-2	-2	-2
BEL	96%	96%	96%	96%	1	1	1	1
BRA	74%	74%	0%	0%	-7	-7	0	0
CAN	100%	100%	67%	0%	na	na	na	na
CHE	99%	99%	99%	99%	-1	-1	-1	-1
CHL	100%	100%	100%	43%	0	0	0	3
CHN	93%	93%	93%	93%	-1	-1	-1	93
CZE	95%	95%	95%	93%	0	0	0	0
DEU	99%	99%	99%	99%	-1	-1	-1	-1
DNK	94%	94%	94%	94%	0	0	0	0
ESP	100%	100%	99%	99%	8	8	7	7
EST	99%	99%	99%	99%	0	0	0	0
FIN	87%	87%	87%	87%	-13	-13	-13	-12
FRA	100%	100%	100%	100%	0	0	0	0
GBR	100%	100%	100%	100%	0	0	0	0
GRC	100%	100%	100%	100%	0	0	0	0
HUN	100%	100%	100%	100%	4	4	4	5
IDN	97%	97%	0%	0%	-1	-1	0	0
IND	97%	97%	97%	29%	0	0	73	5
IRL	100%	100%	100%	100%	0	0	0	0
ISL	95%	95%	95%	95%	-5	-5	-5	-5
ISR	100%	100%	100%	100%	0	0	0	0
ITA	100%	98%	98%	98%	0	0	0	0
JPN	100%	100%	100%	98%	0	0	0	0
KOR	99%	99%	96%	96%	0	0	0	0
LUX	100%	100%	100%	100%	2	2	2	2
LVA	99%	99%	99%	93%	na	na	na	na
MEX	100%	98%	98%	98%	1	-1	98	98
NLD	100%	100%	100%	100%	0	0	0	3
NOR	100%	100%	100%	100%	0	0	0	0
NZL	100%	55%	55%	54%	0	-2	-2	-2
POL	99%	99%	99%	99%	4	4	4	4
PRT	94%	94%	94%	94%	-1	-1	-1	0
RUS	99%	0%	0%	0%	0	0	0	0
SVK	93%	93%	93%	93%	-3	-3	-3	-3
SVN	98%	98%	98%	98%	1	1	1	1
SWE	85%	85%	85%	85%	-7	-6	-6	-6
TUR	100%	100%	100%	100%	0	0	0	0
USA	100%	100%	9%	0%	0	0	9	0
ZAF	100%	100%	100%	100%	0	0	0	0

Note: na: not available. The table includes emissions from the combustion of biomass in the emission base. Annex 3.A shows results excluding emissions from the combustion of biomass in the emission base.

Box 3.1. External costs in road transport

Many countries price all of their emission from road transport above EUR 60 per tonne CO_2. Does this mean that effective carbon rates in the road sector are high enough? Not necessarily.

Road use gives rise to a range of external costs including congestion, noise, accidents and local air pollution in addition to the damage caused by CO_2 emissions. Taxes on transport fuels, which account for 99% of the effective carbon rate in road transport, are a second-best instrument to internalise road use related externalities. This implies that ideally the prevailing taxes on transport energy should be compared to the full range of external costs that they are intended to cover.

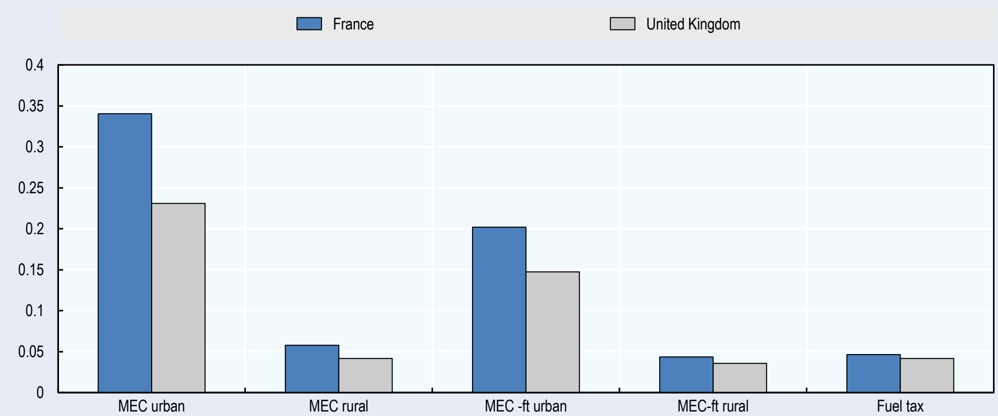
A comparison of all road use related external costs is beyond the scope of the report, but an effective carbon rate of more than EUR 30 now, and EUR 60 forward looking, is justifiable. The first reason is that EUR 30 per tonne of CO_2 is a low-end estimate today's climate costs from carbon alone, EUR 60 is a low-end estimate of the climate costs in 2030 (High-Level Commission on Carbon Prices, 2017[3]) and true climate costs can be substantially higher than the low-end estimates. The second reason is that other external costs matter, and these can be high. While detailed information on the level of these costs is not at hand for all countries, some rough indications is extracted from Van Dender (2018[19]), which itself builds on sources from the European Union, France and the United Kingdom.

Based on back-of-the-envelope calculations, Figure 3.2 shows the sum of marginal external costs associated with a litre of fuel use, for France and the United Kingdom, averaged across gasoline and diesel and distinguishing between urban and rural driving. As can be seen, in the two leftmost columns, the external costs are much larger for urban driving. This is mainly because of higher congestion costs, and to a lesser extent because of greater exposure to air pollution.

In order to compare excise taxes with external costs, to know if they are approximately aligned, the external costs of congestion need downward adjustment to account for the fact that car users respond to higher fuel taxes partly by driving less (which reduces congestion) but also by investing more in fuel economy (which does not reduce congestion). Since evidence indicates that both responses are about equally large in the long run, the adjustment factor for congestion costs is 50%, as an order of magnitude. The scaled down external costs estimates are shown in the middle two columns of Figure 3.2, label mec-ft (for marginal external costs relevant to fuel tax comparison).

The adjusted marginal external costs are compared to the prevailing excise taxes. Keeping in mind that both sets of numbers (taxes and marginal external costs) are estimates, the insight is that fuel taxes appear adequately aligned with the marginal external costs of rural driving, and well below those of urban driving.

Figure 3.2. Estimates of marginal external costs and of fuel tax, France and United Kingdom, in EUR per litre of gasoline and diesel



Note: MEC = marginal external cost; urban = driving in urban environments; MEC-ft = MEC as relevant to the fuel tax, i.e.. after correction for indirect impact of fuel costs on driving-related external costs; rural = driving in rural environments (to be understood as non-urban).
Source: (OECD, 2018[1])

Are fuel taxes then on average too low? The main difference between urban and rural driving pertains to congestion costs. Since congestion costs in rural driving are very low, the answer to this question depends on one's view on how to address congestion best. As explained in more detail in Van Dender (2018[19]), fuel taxes are not very well suited for curbing congestion, and electronic charging mechanisms allow for better internalisation of congestion costs. If, however, the view is that more sophisticated congestion pricing or other congestion management policies remain elusive, then higher fuel taxes appear to be justified based on the estimates presented in Figure 3.2.

However, to allow for better congestion management and anticipating on eventual decarbonisation of road transport, it may be better to argue for more sophisticated congestion pricing than for increasing fuel taxes to reflect average congestion. Fuel taxes then would be 'about right' based on Figure 3.2. At this point, however, it is worth noting that the marginal external cost estimates used for Figure 3.2 should be considered as low-end estimates, particularly for air pollution, where they assume compliance with emission standards.

In sum, since fuel taxes appear to align with low end estimates of marginal external costs, and since they are in the vicinity of marginal external costs only where congestion costs are very low, current fuel taxes in France and the United Kingdom are at the low end of appropriate levels. Moderate increases are likely to engender further social benefits. If fuel taxes are thought to have a role in curbing congestion, then they at present appear to be too low. These results are similar to those of a more comprehensive exercise for EU countries (Santos, 2017[20]).

Sources: Adapted from OECD (2018[1]), OECD (2016[18]) and Van Dender (2018[19])

Carbon pricing gap across countries in 2015

The carbon pricing gap at EUR 30 was 79.5% for the 42 countries as a group in 2015. As described in Box 2.1 in more detail, the carbon pricing gap is a summary indicator to assess the extent to which countries make use of carbon pricing.

A zero gap signals to investors that a country maximises abatement and low-carbon infrastructure for each dollar invested and that its companies are on a good track to compete and thrive in a low-carbon economy. A high gap indicates countries spend more money than needed on abatement or that their climate policy is not on track to meet their commitments to decarbonise their economies as agreed at the UN Climate Conference in Paris.

The simple unweighted cross-country average of the carbon pricing gap at EUR 30 across the 42 countries was 62% in 2015, showing that countries with fewer emissions tend to price emissions more strongly than countries with large emissions.

The carbon pricing gap at EUR 30 varied significantly across countries, ranging from 27% to 100%. This shows that some countries had significantly advanced in pricing emissions, while others had hardly started doing so.

Carbon pricing progressed compared to 2012, also in countries with high emissions. The aggregate gap declined by 3 percentage points compared to 2012, the unweighted cross-country average by 2 percentage points.

Korea, Mexico and the United Kingdom substantially reduced their carbon pricing gaps between 2012 and 2015, see Table 3.7. Korea's carbon pricing gap shrank by 30 percentage points to 43% in 2015, mainly through the introduction of its emission trading system. Mexico reformed its excise duties on transport fuels and introduced a carbon tax, reducing its carbon pricing gap by 23 percentage points. The United Kingdom lowered its gap to 42% in 2015 from 56% in 2012 by introducing a price floor for carbon emission from the electricity sector.

France decreased its carbon pricing gap by nine percentage points each between 2015 and 2012, increasing the carbon component rates in its excise duties on fuels. The Chinese gap declined slightly, mainly through its regional pilot emission trading systems. A substantially bigger drop in the Chinese gap is expected through the introduction of its national ETS, see the section on *How countries can reduce the carbon pricing gap* on page 31 in Chapter 2.

Note that the carbon pricing gap can also change unintentionally over time for several reasons. First, where substitute fuels subject to different rates exist, fuel substitution can affect the carbon pricing gap. For example, dieselisation of road transport tends to increase the carbon pricing gap, given the relatively low taxes on diesel. Second, by leaving tax rates unchanged in nominal terms and not adjusting them for inflation, tax rates will decrease in real terms over time. Over time, this increases the carbon pricing gap.

Table 3.7. Carbon pricing gap at EUR 30 in 2015

Country	2015	2012
ARG	76%	na
AUS	79%	78%
AUT	51%	52%
BEL	65%	65%
BRA	94%	88%
CAN	65%	na
CHE	27%	20%
CHL	80%	84%
CHN	90%	92%
CZE	70%	71%
DEU	53%	53%
DNK	52%	40%
ESP	51%	56%
EST	71%	71%
FIN	53%	51%
FRA	41%	50%
GBR	42%	56%
GRC	46%	47%
HUN	66%	70%
IDN	95%	91%
IND	86%	90%
IRL	42%	45%
ISL	42%	41%
ISR	65%	61%
ITA	46%	47%
JPN	69%	75%
KOR	43%	73%
LUX	30%	31%
LVA	67%	na
MEX	68%	91%
NLD	43%	49%
NOR	34%	32%
NZL	76%	78%
POL	67%	69%
PRT	59%	60%
RUS	100%	100%
SVK	60%	53%
SVN	42%	46%
SWE	63%	62%
TUR	75%	77%
USA	75%	83%
ZAF	89%	89%

Note: na: not available. The table includes emissions from the combustion of biomass in the emission base. Annex 3.A shows results excluding emissions from the combustion of biomass in the emission base.

The carbon pricing gap at EUR 60 was 85% on aggregate for 2015, 3 percentage points lower than in 2012. The simple unweighted average of the carbon pricing gap at EUR 60 is 69% across all countries. It decreased by three percentage points compared to 2012.

The carbon pricing gap at EUR 60 varied significantly, between 30% and 100% across countries. Few countries priced a significant share of emissions above EUR 60 outside the road sector, as Section 4.1 has shown. This means that the carbon pricing gap at EUR 60 in 2015 depended to a significant extent on how fuels in the road sector were priced and what share of total emissions of a country stem from the road sector. Still, emissions priced below EUR 60 contribute to a lower carbon pricing gap at EUR 60.

As explained in the introduction, EUR 60 per tonne of CO_2 is a midpoint estimate of carbon costs in 2020, as well as a low-end estimate of carbon costs in 2030, according to the High Level Commission on Carbon Pricing (2017[3]). While at least some countries have already advanced substantially to closing their carbon pricing gap at EUR 30, much more needs to be done for closing the gap at EUR 60 in the years to come.

Table 3.8. Carbon pricing gap at EUR 60 in 2015

Country	2015	2012
ARG	76%	na
AUS	79%	80%
AUT	62%	63%
BEL	71%	71%
BRA	97%	94%
CAN	81%	na
CHE	30%	42%
CHL	85%	88%
CHN	90%	94%
CZE	78%	79%
DEU	67%	67%
DNK	60%	48%
ESP	61%	66%
EST	80%	80%
FIN	62%	61%
FRA	52%	58%
GBR	56%	64%
GRC	60%	63%
HUN	72%	76%
IDN	97%	95%
IND	89%	94%
IRL	55%	56%
ISL	52%	49%
ISR	69%	65%
ITA	54%	54%
JPN	74%	79%
KOR	64%	80%
LUX	33%	35%
LVA	72%	na
MEX	69%	95%
NLD	54%	56%
NOR	38%	45%
NZL	78%	80%
POL	76%	78%
PRT	67%	67%
RUS	100%	100%
SVK	69%	64%
SVN	48%	56%
SWE	69%	70%
TUR	78%	80%
USA	88%	91%
ZAF	89%	89%

Note: na: not available. The table includes emissions from the combustion of biomass in the emission base. Annex 3.A shows results excluding emissions from the combustion of biomass in the emission base.

Carbon pricing – a bigger picture

Carbon prices vary significantly across countries and sectors. This section relates the extent to which countries price carbon emissions, as measured by the carbon pricing gap, to some general macro-economic variables to gain a better understanding of patterns in how countries price carbon emissions.

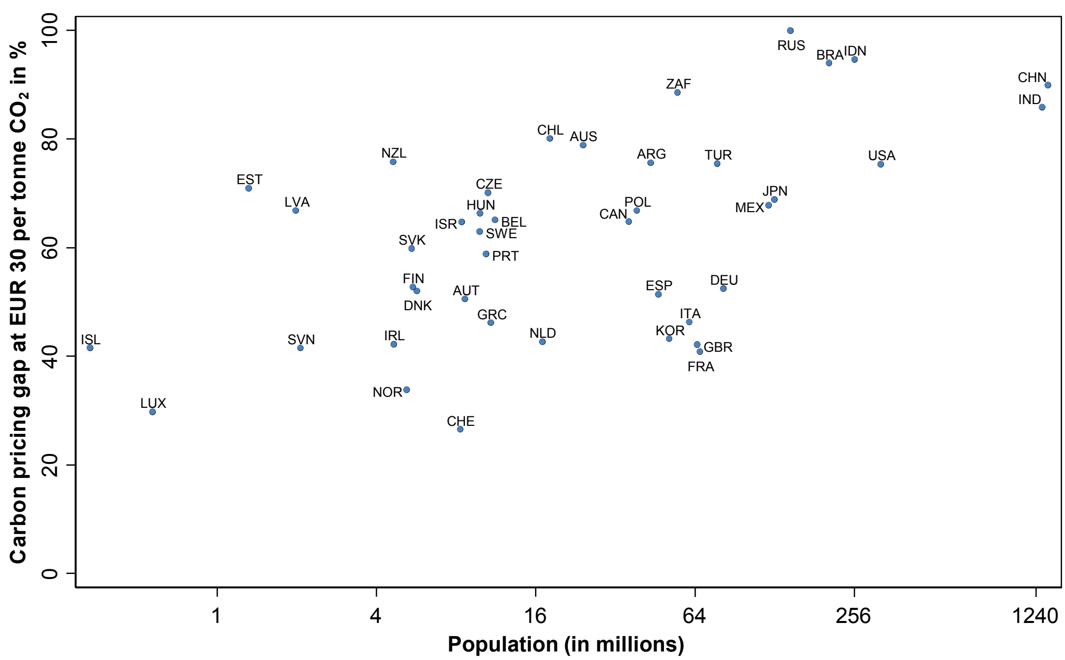
Figure 3.3 shows that less populous countries tend to have a smaller carbon pricing gap than more populous countries. To the extent that larger countries emit more carbon emissions than smaller ones, this pattern helps to explain findings in the preceding section that on aggregate the carbon pricing gap is large. While some countries price a significant share of their emissions at non-negligible rates, their impact on aggregate numbers is generally limited when their share in overall emissions is low.

The current pattern may soon change with introduction of the Chinese national ETS, see Chapter 2. Once China prices a large share of its emissions significantly, the aggregate carbon pricing gap will decline substantially (see also Chapter 2).

Some fairly populous countries have recently started to decrease their carbon pricing gap as described in the previous sections. The recent carbon pricing efforts by Mexico, France, the United Kingdom and Canada also contribute significantly to lowering the aggregate gap.

Figure 3.3. Less populous countries have a smaller carbon pricing gap

Carbon pricing gap at EUR 30 and population (in millions) in 2015



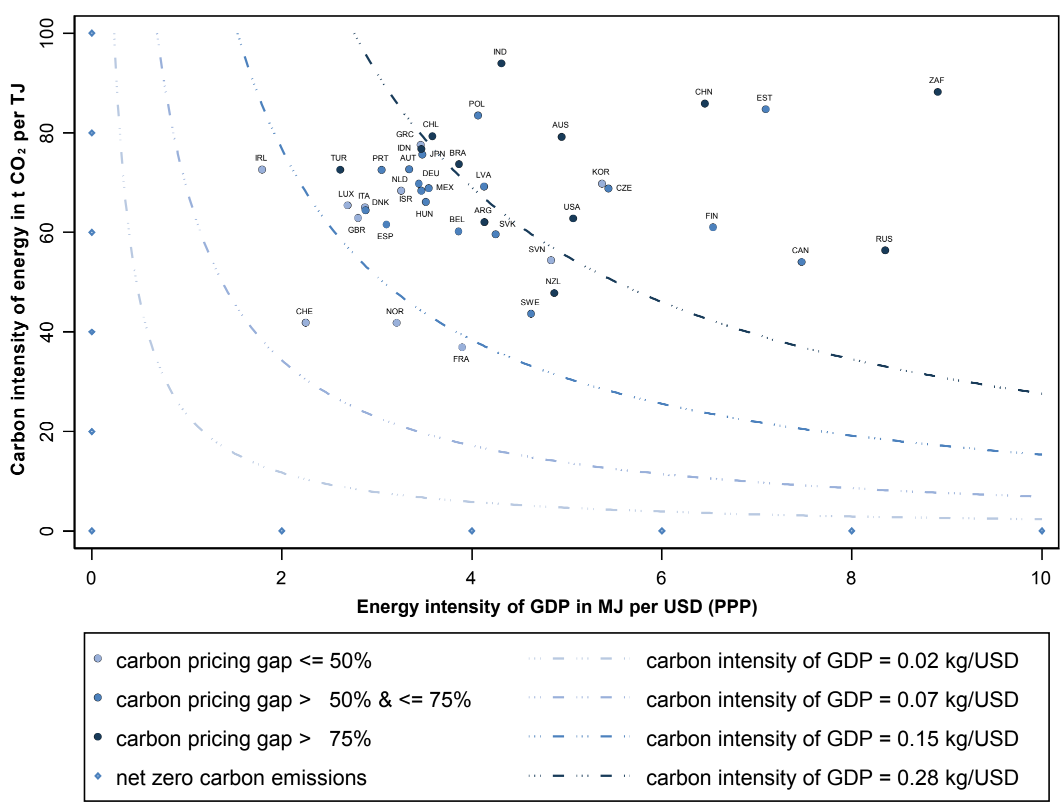
Source: Population data from OECD (2018[21]) and the World Development Indicators (World Bank, 2018[22]).

Figure 3.4 shows the carbon intensity of countries' energy uses and the energy intensity of countries' GDPs. Multiplying the carbon intensity of energy, $\frac{CO_2\ emissions}{energy\ use}$, with the energy intensity of GDP, $\frac{energy\ use}{GDP}$, gives the carbon intensity of GDP, $\frac{CO_2\ emissions}{GDP}$. Carbon intensities decrease towards the origin, i.e., the lower left corner of the graph.

Reaching the goal of the Paris Agreement to limit global temperature increase to well below 2°C requires net zero carbon emissions in the second half of this century. Scenarios congruent with the Paris Agreement by Peters et al. (2017[23]) show net zero carbon emissions for the World economy in the 2060s.[3] Net zero emissions imply that either the carbon intensity of energy is zero, the energy intensity of GDP is zero, or both, as shown by the small diamonds on the vertical and horizontal axis of Figure 3.4. While zero-carbon fuels already exist, it is hard to imagine that energy intensities of GDP decline towards zero. Hence, decarbonising economies implies that countries need to move towards the horizontal axis of the graph.

Figure 3.4. Countries with a low carbon pricing gap lead in decarbonising their economies

Carbon intensity of energy and energy intensity of GDP in 2015



Source: GDP data from the World Development Indicators (World Bank, 2018[22]), Energy use data from the Taxing Energy Use database (OECD, 2018[1]).

Equal carbon intensities of GDP are shown by four dashed-dotted *isocarbon* lines in Figure 3.4. A lighter colour corresponds to a lower carbon intensity of GDP. The values for the *isocarbons* are based on 2°C scenarios as shown in Figure 3 of Peters et al. (2017[23]). The highest carbon intensity, 0.28 kg/USD, corresponds to the level of carbon intensity for the World economy in central scenarios in 2020. The three lighter *isocarbons* correspond to carbon intensity for the World economy in 2030, 2040 and 2050 respectively.[4]

Figure 3.4 shows that many countries have a carbon intensity below the level required in 2020 by decarbonisation pathways for reaching the 2°C goal. A considerable number of countries with a large amount of emissions are still substantially above the level of carbon intensity required in 2020 for reaching the 2°C goal. On aggregate, considerable progress needs to be made for being on track with reaching the goals of the Paris Agreement.

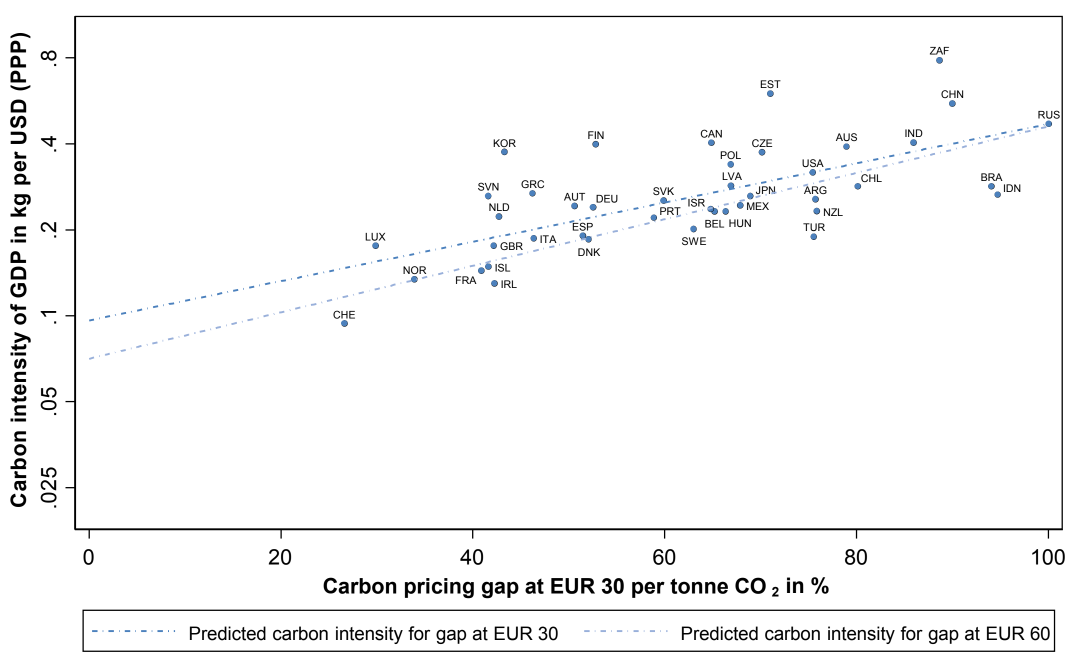
Countries with a low carbon pricing gap, shown by lighter colour in Figure 3.4, *tend to be more carbon-efficient*, i.e. they have a low carbon intensity of GDP. All countries emitting less than 0.15 kg CO_2 per USD in GDP have a carbon pricing gap of less than 50%. Many of the other countries with a gap below 50% show high carbon efficiencies as well.

Carbon prices raise the price of carbon-intensive energy compared to carbon-efficient energy, encouraging users to switch to more carbon-efficient fuels. Switching to more carbon-efficient fuels implies that countries move towards the horizontal axis in the graph. As long as countries use non-zero carbon fuels, carbon prices will also increase the price of energy through increasing the price of their carbon content. This encourages energy users to use less energy, making countries move towards the vertical axis.

One can expect that countries which increase and broaden carbon prices will soon improve their carbon- and energy-efficiencies. In Figure 3.4, such countries will move closer to the origin. Some countries that still had energy and carbon-intensive economies in 2015 recently broadened and increased carbon prices, among them Canada, Estonia and Korea. With their new carbon pricing efforts, one can expect that their energy- and carbon-efficiencies will improve, which will result in a movement toward the origin of Figure 3.4.

Figure 3.5. Countries with a lower carbon pricing gap are more carbon efficient

Carbon intensity of GDP and carbon pricing gap in 2015



Source: GDP data from the World Development Indicators (World Bank, 2018[22]).

Figure 3.5 shows that countries with a lower carbon pricing gap are more carbon efficient, as measured by fewer carbon emissions per unit of GDP. The relationship between comprehensive carbon pricing, i.e. a low gap, and low carbon emissions does not necessarily imply a direct causal effect in either direction. Low emissions per unit of GDP can be the result of comprehensive carbon pricing steering the economy to low-emission energy sources. Alternatively, however, countries with fewer emissions per unit of GDP may find it easier to price emissions. That said, empirical evidence clearly shows that higher carbon prices discourage emissions (Arlinghaus (2015[24]), Martin et al. (2016[25])), showing in lower emissions per unit of GDP.

A simple log-linear regression of the carbon intensity of GDP on the carbon pricing gap at EUR 30 reveals that a one percentage point increase in the carbon pricing gap is associated with a 0.016 percent increase in the carbon intensity of GDP in 2015. At EUR 60, a one percentage point increase in the carbon pricing gap is associated with a 0.019 increase in the carbon intensity of GDP. A reduction of the carbon pricing gap at a higher price level thus appears to associate with a stronger decrease in emissions per GDP than the same percentage point reduction of the carbon pricing gap at a lower level.

The log-linear association between the carbon pricing gap and the carbon intensity of GDP suggests that reducing the carbon pricing gap at EUR 30 would lead to a carbon intensity of about 0.1 kg per USD of GDP. At EUR 60, a zero carbon pricing gap associates with a carbon intensity of about 0.07 kg per unit of GDP. For reaching a net zero-carbon intensity of GDP price levels will need to be higher. Over time, technological progress can also reduce the carbon intensity of GDP.

Annex 3.A. CO_2 emissions from the combustion of biomass

This Annex provides tables on how excluding emissions from biomass affects the shares of emissions priced at different levels of effective carbon rates. It starts with a discussion of how evidence on life cycle emissions from biomass supports the choice for including these emissions as the default for this report and related reports.

In line with previous editions of *Taxing Energy Use* (OECD (2013[26]), OECD (2015[27]) and OECD (2018[1])) as well as of *Effective Carbon Rates* (OECD, 2016[18]), this report includes *emissions from* the *combustion* of biomass in the emissions base. This means that CO_2 emissions from the combustion of biomass are treated in the same way as CO_2 emissions from the combustion of fossil fuels.

An alternative approach would be to assume that the net effect of production and consumption of biomass for fuels is *carbon neutral* as plants bind carbon from the atmosphere as they grow. Emissions from combustion of biomass would then be excluded from the emission base. The assumption of carbon neutrality from a *lifecycle* perspective has increasingly been challenged in the scientific literature (see, e.g., Fargione et al. (2008[28]), Searchinger et al, (2008[29]) and Liska et al. (2014[30])). The fifth IPCC assessment report states that the "neutrality perception [of biofuel emissions] is linked to a misunderstanding of the guidelines for GHG inventories" (Smith et al (2014, p. 879[31]), see also the penultimate paragraph of this Annex).

Searchinger et al. (2008[29]) note that the *lifecycle* approach ought to account for indirect emissions from land-use change triggered by the cultivation of biofuel crops. One potential impact is that, when biomass is planted on fields traditionally used for food production, food prices will increase. This will increase the return on agricultural land and encourages farmers to grow food on previously native land. Native land generally binds more carbon than agricultural land, and the net effect is that emissions increase. A second possible impact is that biomass for fuel production is grown on previously native land. Plants for biomass production have a shorter lifetime than native plants, meaning CO_2 is bound for a shorter period, so that emissions increase.

The upshot is that taking emissions from land-use change into account is complex and quantitative modelling shows a wide range of estimates depending on the pathways, local conditions and technologies considered.

A recent study (Ecofys, IIASA and E4tech, 2015[32]) calculates the effects of land-use change for a wide range of biofuels consumed in European countries (see also Smith et al. (2014, p. 878[31]), Figure 11.24 for an earlier review of quantitative estimates) The study finds, among other things, that lifecycle emissions of biodiesel produced from food and feedstock *on average* exceed those of fossil fuels by about 80% (Transport & Environment, 2016[33]). This average conceals large variation. For example, there are large differences across crops: biodiesel produced from palm oil emits about three times as much carbon dioxide as fossil diesel, while biodiesel produced from sunflowers emits about the same amount as fossil diesel. Bioethanol from food and feedstock (e.g. maize, wheat, barley etc.) emits on average about two thirds of the carbon emissions from fossil diesel. Only advanced non-food based biofuels (e.g. from short-rotation coppice) are found to be potentially carbon neutral. In line with these findings, the ongoing (at the time of writing) revision of the European Directive on renewable energy (European Parliament and the Council, 2009[34]) which will update the Directive for the 2030 EU climate and energy goals, may no longer contain any target for biofuels. Instead a cap on biofuels produced from food and feedstock at 7% is being considered.

The present report calculates its emission base from the Extended World Energy Balances (EWEB) produced by the International Energy Agency (IEA, 2017[2]) as described in in Annex A of OECD (2016[18]). EWEB does not specify the source or the origins of biofuels, i.e. whether rape, soy, maize or some other input has been used to produce biofuels and where the inputs have been grown. This lack of evidence makes estimates of the lifecycle impact of biofuels more uncertain.

One indication can be extracted from one of the main scenarios of the joint ECOFYS, IASSA and E4tech (2015[32]) study, which assumes a 7% cap on biofuels produced from food and feedstock. In this scenario, overall biofuel consumption in 2020 consists of 60% biodiesel (which on average emits 80% more CO_2 than fossil diesel) and 20% bioethanol (which emits two-thirds of the emissions from fossil diesel). Given this mix, overall biofuel lifecycle emissions would be close to those of fossil diesel, and would be more likely to exceed than fall below emissions from fossil diesel. Against this background, the "combustion approach" to emissions taken in *Taxing Energy Use* (OECD (2013[26]) and *Effective Carbon Rates* (OECD, 2016[18]) may also be regarded as informative about *lifecycle* emissions. Of course, conditions may differ across countries and across time, but in-depth analysis of the life cycle emissions from biofuels at the country level is well beyond the scope of this report.

Taxing Energy Use (OECD (2013[26]), OECD (2015[27]) and OECD (2018[1])) and *Effective Carbon Rates* (OECD, 2016[18]) calculate emissions from energy use directly from the IEA's (2017[2]) EWEB as this database provides timely and consistent yearly data by fuel and user for all 42 OECD and G20 economies included in the study. By comparison, UNFCCC Greenhouse Gas inventories also cover emission sources beyond energy use (industrial process emissions as well as emissions from agriculture, forestry and other land use) and non-CO_2 greenhouse gas emissions. UNFCCC greenhouse gas inventories are more difficult to compare across countries than the IEA's EWEB as countries have significant leeway on how to report emissions. As a result, emission bases from *Taxing Energy Use* (OECD (2013[26]) and *Effective Carbon Rates* (OECD, 2016[18]) are not directly comparable with those from UNFCCC inventories.

In addition to the abovementioned differences, UNFCCC inventories account for emissions from biomass not in the category for emission from energy use, but in a different category, namely for emissions from agriculture, forestry and other land use (IPCC, 2008[35]). The present report only considers emissions from energy use, so it cannot account for emissions induced by the use of biofuels in a separate category for agriculture, forestry and other land use. The combustion approach taken here may nevertheless be informative about lifecycle emissions of biofuels as mentioned above.

The above considerations support the adoption of the *combustion approach* as the default for presenting results in this report. Nevertheless, the alternative assumption (neutrality from a life cycle perspective) may be of interest to specific countries or users, as it may better reflect local conditions or improve comparability with other inventories. Therefore, this annex provides tables showing results *excluding* emissions from the combustion of biomass. These tables can be described as showing the share of priced emissions at different levels of effective carbon rates if all biofuels used were carbon neutral. By providing this second benchmark, readers can also draw inferences on how results change given specific information about the lifecycle emissions from biofuels.

Annex Table 3.A.1. Proportion of emissions priced per tonne of CO_2 by country

Excluding emissions from the combustion of biomass in the emission base

	EUR 0	EUR 5	EUR 30	EUR 60
ARG	76%	26%	26%	22%
AUS	24%	24%	22%	21%
AUT	83%	83%	46%	34%
BEL	80%	71%	26%	26%
BRA	46%	41%	0%	0%
CAN	65%	65%	17%	0%
CHE	96%	91%	84%	43%
CHL	27%	27%	27%	12%
CHN	22%	9%	9%	9%
CZE	89%	76%	17%	17%
DEU	97%	96%	21%	20%
DNK	98%	98%	47%	46%
ESP	94%	92%	37%	30%
EST	87%	84%	16%	13%
FIN	96%	96%	68%	52%
FRA	94%	94%	47%	39%
GBR	81%	80%	53%	29%
GRC	97%	97%	33%	27%
HUN	80%	77%	27%	27%
IDN	25%	25%	0%	0%
IND	88%	22%	13%	3%
IRL	97%	97%	37%	30%
ISL	80%	80%	39%	39%
ISR	98%	29%	27%	27%
ITA	99%	98%	45%	41%
JPN	86%	40%	21%	19%
KOR	98%	98%	17%	16%
LUX	99%	88%	66%	65%
LVA	92%	89%	45%	42%
MEX	65%	35%	33%	33%
NLD	97%	97%	39%	35%
NOR	93%	92%	69%	63%
NZL	87%	23%	23%	22%
POL	91%	81%	16%	16%
PRT	95%	93%	35%	32%
RUS	35%	0%	0%	0%
SVK	87%	75%	30%	18%
SVN	100%	100%	56%	51%
SWE	96%	96%	57%	56%
TUR	51%	24%	22%	21%
USA	38%	38%	4%	0%
ZAF	14%	13%	13%	11%

Annex Table 3.A.2. Proportion of emissions priced in the electricity sector per tonne of CO_2 by country

Excluding emissions from the combustion of biomass in the emission base

Country	Proportion of emissions priced at or above in 2015			
	EUR 0	EUR 5	EUR 30	EUR 60
ARG	74%	13%	13%	0%
AUS	0%	0%	0%	0%
AUT	100%	100%	0%	0%
BEL	90%	89%	0%	0%
BRA	10%	10%	0%	0%
CAN	55%	55%	0%	0%
CHE	75%	75%	75%	0%
CHL	0%	0%	0%	0%
CHN	14%	0%	0%	0%
CZE	100%	100%	0%	0%
DEU	100%	100%	0%	0%
DNK	100%	100%	0%	0%
ESP	100%	100%	0%	0%
EST	92%	92%	0%	0%
FIN	100%	100%	0%	0%
FRA	100%	100%	0%	0%
GBR	100%	100%	90%	0%
GRC	100%	100%	12%	2%
HUN	100%	100%	0%	0%
IDN	0%	0%	0%	0%
IND	98%	0%	0%	0%
IRL	100%	100%	0%	0%
ISL	0%	0%	0%	0%
ISR	100%	1%	1%	1%
ITA	100%	100%	0%	0%
JPN	91%	13%	0%	0%
KOR	100%	100%	0%	0%
LUX	77%	77%	0%	0%
LVA	100%	100%	0%	0%
MEX	47%	1%	1%	1%
NLD	100%	100%	0%	0%
NOR	100%	100%	0%	0%
NZL	84%	0%	0%	0%
POL	100%	100%	0%	0%
PRT	100%	100%	0%	0%
RUS	0%	0%	0%	0%
SVK	100%	100%	0%	0%
SVN	100%	100%	0%	0%
SWE	100%	100%	0%	0%
TUR	32%	0%	0%	0%
USA	8%	8%	0%	0%
ZAF	0%	0%	0%	0%

Annex Table 3.A.3. Proportion of emissions priced in the industry sector per tonne of CO_2 by country

Excluding emissions from the combustion of biomass in the emission base

Country	Proportion of emissions priced at or above in 2015			
	EUR 0	EUR 5	EUR 30	EUR 60
ARG	65%	2%	2%	1%
AUS	3%	3%	3%	3%
AUT	64%	64%	16%	4%
BEL	64%	62%	0%	0%
BRA	19%	4%	0%	0%
CAN	58%	58%	0%	0%
CHE	88%	63%	29%	1%
CHL	0%	0%	0%	0%
CHN	17%	2%	2%	1%
CZE	91%	52%	0%	0%
DEU	90%	87%	1%	0%
DNK	98%	98%	21%	16%
ESP	80%	74%	5%	0%
EST	67%	56%	5%	0%
FIN	94%	94%	70%	46%
FRA	85%	85%	2%	0%
GBR	84%	83%	9%	5%
GRC	98%	96%	17%	5%
HUN	83%	72%	4%	4%
IDN	0%	0%	0%	0%
IND	83%	24%	2%	0%
IRL	83%	83%	3%	0%
ISL	24%	24%	0%	0%
ISR	85%	6%	0%	0%
ITA	99%	98%	2%	2%
JPN	70%	32%	5%	5%
KOR	99%	99%	2%	2%
LUX	100%	86%	0%	0%
LVA	93%	85%	0%	0%
MEX	42%	4%	4%	4%
NLD	90%	90%	16%	3%
NOR	90%	89%	52%	52%
NZL	74%	2%	2%	0%
POL	99%	71%	2%	2%
PRT	88%	79%	5%	0%
RUS	44%	0%	0%	0%
SVK	78%	60%	13%	0%
SVN	99%	99%	48%	47%
SWE	93%	93%	13%	11%
TUR	41%	13%	4%	0%
USA	8%	8%	0%	0%
ZAF	5%	5%	5%	1%

Annex Table 3.A.4. Proportion of emissions priced in the residential and commercial sector per tonne of CO_2 by country

Excluding emissions from the combustion of biomass in the emission base

Country	Proportion of emissions priced at or above in 2015			
	EUR 0	EUR 5	EUR 30	EUR 60
ARG	99%	1%	1%	0%
AUS	1%	1%	1%	1%
AUT	100%	100%	47%	0%
BEL	81%	48%	0%	0%
BRA	0%	0%	0%	0%
CAN	29%	29%	0%	0%
CHE	99%	99%	99%	0%
CHL	8%	8%	0%	0%
CHN	14%	9%	9%	9%
CZE	25%	24%	0%	0%
DEU	100%	98%	1%	1%
DNK	99%	99%	76%	76%
ESP	100%	99%	33%	0%
EST	90%	88%	24%	1%
FIN	99%	99%	99%	98%
FRA	97%	97%	35%	0%
GBR	29%	29%	4%	0%
GRC	99%	99%	16%	14%
HUN	33%	33%	1%	1%
IDN	0%	0%	0%	0%
IND	29%	0%	0%	0%
IRL	100%	100%	23%	0%
ISL	100%	100%	0%	0%
ISR	100%	100%	0%	0%
ITA	100%	100%	76%	67%
JPN	100%	64%	31%	18%
KOR	94%	94%	17%	13%
LUX	100%	50%	0%	0%
LVA	92%	84%	2%	2%
MEX	89%	2%	2%	2%
NLD	99%	99%	99%	99%
NOR	100%	100%	100%	88%
NZL	93%	5%	5%	0%
POL	41%	31%	0%	0%
PRT	100%	100%	15%	12%
RUS	8%	0%	0%	0%
SVK	96%	87%	29%	0%
SVN	100%	100%	55%	0%
SWE	98%	98%	98%	98%
TUR	56%	5%	5%	4%
USA	5%	5%	0%	0%
ZAF	6%	1%	1%	1%

Annex Table 3.A.5. Proportion of emissions priced in the road transport sector per tonne of CO_2 by country

Excluding emissions from the combustion of biomass in the emission base

Country	Proportion of emissions priced at or above in 2015			
	EUR 0	EUR 5	EUR 30	EUR 60
ARG	100%	100%	100%	100%
AUS	100%	100%	100%	96%
AUT	100%	100%	100%	100%
BEL	99%	99%	99%	99%
BRA	83%	83%	0%	0%
CAN	100%	100%	67%	0%
CHE	100%	100%	100%	100%
CHL	100%	100%	100%	43%
CHN	94%	94%	94%	94%
CZE	100%	100%	100%	98%
DEU	100%	100%	100%	100%
DNK	100%	100%	100%	100%
ESP	100%	100%	99%	99%
EST	100%	100%	100%	100%
FIN	100%	100%	100%	100%
FRA	100%	100%	100%	100%
GBR	100%	100%	100%	100%
GRC	100%	100%	100%	100%
HUN	100%	100%	100%	100%
IDN	100%	100%	0%	0%
IND	98%	98%	98%	29%
IRL	100%	100%	100%	100%
ISL	100%	100%	100%	100%
ISR	100%	100%	100%	100%
ITA	100%	98%	98%	98%
JPN	100%	100%	100%	98%
KOR	100%	100%	97%	97%
LUX	100%	100%	100%	100%
LVA	100%	100%	100%	94%
MEX	100%	98%	98%	98%
NLD	100%	100%	100%	100%
NOR	100%	100%	100%	100%
NZL	100%	55%	55%	54%
POL	100%	100%	100%	100%
PRT	100%	100%	100%	100%
RUS	99%	0%	0%	0%
SVK	100%	100%	100%	100%
SVN	100%	100%	100%	99%
SWE	100%	100%	100%	100%
TUR	100%	100%	100%	100%
USA	100%	100%	10%	0%
ZAF	100%	100%	100%	100%

Annex Table 3.A.6. Carbon pricing gap at EUR 30 in 2015

Excluding emissions from the combustion of biomass in the emission base

Country	Carbon pricing gap at EUR 30
ARG	74%
AUS	78%
AUT	33%
BEL	61%
BRA	90%
CAN	62%
CHE	13%
CHL	73%
CHN	89%
CZE	66%
DEU	48%
DNK	31%
ESP	47%
EST	65%
FIN	25%
FRA	32%
GBR	38%
GRC	42%
HUN	58%
IDN	92%
IND	80%
IRL	40%
ISL	40%
ISR	65%
ITA	39%
JPN	68%
KOR	42%
LUX	28%
LVA	39%
MEX	65%
NLD	41%
NOR	25%
NZL	72%
POL	64%
PRT	49%
RUS	100%
SVK	55%
SVN	29%
SWE	24%
TUR	75%
USA	75%
ZAF	87%

Annex Table 3.A.7. Carbon pricing gap at EUR 60 in 2015

Excluding emissions from the combustion of biomass in the emission base

Country	Carbon pricing gap at EUR 60
ARG	75%
AUS	78%
AUT	47%
BEL	68%
BRA	95%
CAN	80%
CHE	17%
CHL	79%
CHN	90%
CZE	74%
DEU	64%
DNK	43%
ESP	58%
EST	75%
FIN	30%
FRA	45%
GBR	53%
GRC	57%
HUN	65%
IDN	96%
IND	84%
IRL	54%
ISL	51%
ISR	69%
ITA	48%
JPN	74%
KOR	63%
LUX	31%
LVA	47%
MEX	66%
NLD	52%
NOR	30%
NZL	75%
POL	74%
PRT	58%
RUS	100%
SVK	65%
SVN	37%
SWE	34%
TUR	77%
USA	87%
ZAF	87%

Notes

[1] Tax rates and permit prices are reported in 2015 price levels.

[2] Quemin and Trotignon (2018[92]) predict that permit prices will increase moderately to about EUR 38 per tonne CO_2 in absence of any major economic shock. In case of an economic crisis permit prices are expected to trade at about EUR 10.

[3] Net carbon emissions become negative from the 2060, meaning that the amount of emissions removed from the atmosphere need to be larger than the amount of emissions emitted.

[4] In line with recent data (OECD, 2016[18]) it is assumed that carbon emission from energy use account for 69% of total greenhouse gas emissions in 2020. Many scenarios assume that the energy use decarbonises faster than other sectors, e.g. agriculture or industrial processes (European Commission, 2011[93]). Therefore it also assumed that the share of energy use in total greenhouse gas emissions declines by one percentage point a year from 2020 onwards.

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