3 Assessment: stationary sources

This section examines how Andalusian, Spanish and EU-level pricing of emissions from stationary relate to climate change and air pollution. While climate change and air pollution are two separate environmental issues, they partly overlap. Climate change is mostly due to Greenhouse Gas (GHG) emissions and their impact are at the global level. Even if GHGs are emitted in a specific area, their concentration in the atmosphere will contribute to climate change across the globe. Air pollution, on the other hand, is mostly due to other pollutant emissions with generally local impacts.

After a brief exposition of GHGs and air pollutants, this section presents the taxes or similar instruments[1] that apply in Andalusia on stationary sources for these two types of emissions. The main part of the stationary sources analysis covers power plants and industry.[2] The buildings sector (residential and commercial heating) is also part of the stationary source category, but as it represents a somewhat smaller share of emissions and is not subject to any regional tax in Andalusia, it is not covered in this analysis. Activities in the agricultural sector (to be understood as livestock farming and cultivation) generate emissions that may fall into both categories: stationary and non-stationary sources (non-stationary emissions in that sector arise from the use of agricultural engines such as tractors). For ease of exposition and given that a large share of emissions in that sector are from stationary albeit diffuse sources, agriculture is analysed in this stationary source section. The focus on the agricultural, electricity and industry sectors enables an alignment with the Polluter Pays Principle, as these are the main sectors responsible for stationary source GHG and air pollutant emissions taken together.

3.1. Greenhouse gases and air pollutants

3.1.1. Greenhouse gases

There are seven main GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6) and nitrogen trifluoride (NF3). GHG emissions are directly responsible for climate change through global warming: by absorbing long-wave infrared radiation reflected by the earth's surface, they prevent part of the infrared radiation from being reflected back to space. This results in the absorbed energy being converted into heat.

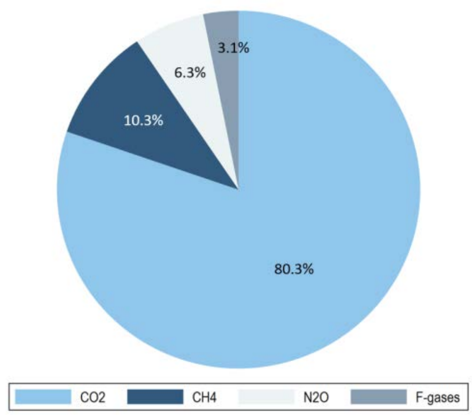
The global warming impact of GHGs is generally independent of where the emissions occur, but it can change over the years. These changes are mainly measured for GHGs relative to one another: when GHG concentrations change, so does the relative energy absorption of one additional tonne of a given GHG. For example, the energy absorption of CH_4 and N_2O have increased over the years.

Some GHGs have a stronger global warming impact than others. This mainly depends on their radiative forcing and their lifetime.[3] The 100-year global warming potential (GWP_{100}) index takes CO_2 as the reference and indicates its relative radiative forcing (the amount of warming) over 100 years[4] following the release of one unit mass of GHG into the atmosphere. For example, according to the IPCC Fifth Assessment Report (AR5) (IPCC, 2014[1]), 1 tonne of N_2O causes 265 times more warming over 100 years than 1 tonne of CO_2, so that N_2O has a GWP_{100} of 265. CH_4 has a GWP_{100} of 28. GHG emissions can then be expressed in CO_2-equivalent (CO_2e), which is obtained by multiplying the unit mass of emissions of a GHG by its GWP_{100}.

In Andalusia, GHG emissions are principally from CO_2 and have steadily declined since 2007. Indeed, they have gone from about 75 $MtCO_2e$ in 2007 to about 54 $MtCO_2e$ in 2019. In 2019, CO_2 emissions represented 80% of GHG emissions in Andalusia (see Figure 3.1), close to the national share of 78% (Spanish Ministry for Ecological Transition, 2020[2]). CH_4 represent about 10% of emissions in CO_2-equivalent, N_2O 6% and F-gases, 3%. In total GHG emissions in Andalusia represent about 16% of the national total.

Figure 3.1. GHG emissions in Andalusia

2019, percentages based on CO_2e



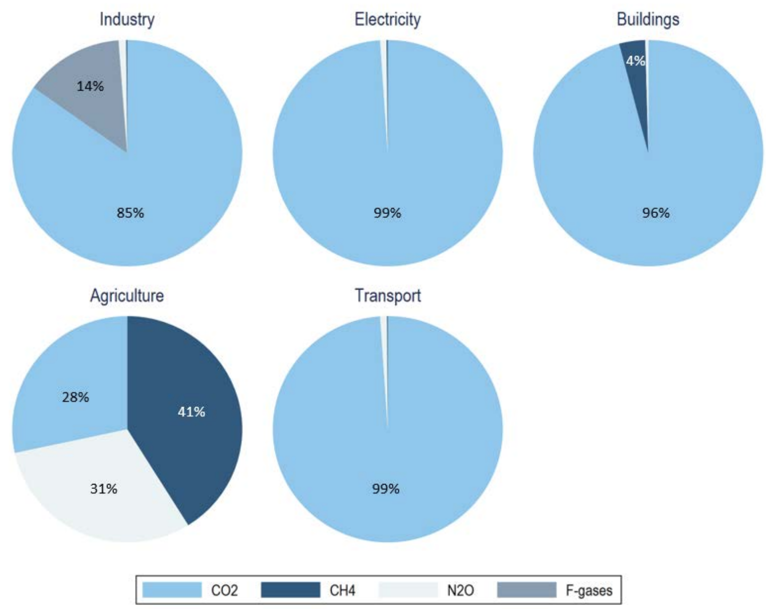
Note: The CO_2-equivalence was calculated using the IPCC AR5 GWP_{100} indicator.
Source: Consejería de Agricultura, Pesca y Desarrollo Rural de la Junta de Andalucía.

StatLink https://stat.link/kqe72v

The sources of GHG emissions vary across GHGs. The main sectors responsible for CO_2 emissions are the electricity (29%), industry (24%) and road transport (31%) sectors. The main sources of CH_4 emissions are the agriculture sector (56%), waste (29%) and biogenic activities (11%). N_2O emissions principally come from agriculture (68%) and biogenic activities (15%). F-gas emissions overwhelmingly stem from the industry sector (above 99.9%), and more specifically almost entirely from the use of refrigerants and propellants. This is reflected in the GHG emission breakdown by sector (Figure 3.2).

Figure 3.2. GHG emissions by sector

Industry, Electricity, Buildings, Agriculture, Transport sectors, 2019, percentages based on CO_2e



Note: The CO_2-equivalence was calculated using the IPCC AR5 GWP_{100} indicator.
Source: Consejería de Agricultura, Pesca y Desarrollo Rural de la Junta de Andalucía.

StatLink https://stat.link/v9u4pk

GHG emissions emanate both from fuel use and from other sources such as industrial process, cattle or waste. A specificity of CO_2 is that its emissions from fuel use are directly proportional to the amount of fuel used. Indeed, CO_2 emissions are constant per unit of fuel used.[5] Exact carbon emissions associated with the combustion of a given fuel may vary with local fuel characteristics but not the end-of pipe technology or combustion process chosen (U.S. EPA Center for Corporate Climate Leadership, 2016[3]). For example, on average the combustion of one litre of diesel generates around 2.76 kilograms of CO_2 be it combusted in a vehicle or by stationary machinery. CO_2 emissions from fuel use represent about 80% of worldwide CO_2 emissions.

The proportionality of CO_2 emissions from fuel use to the amount of fuel used makes fuel taxes a good policy instrument to reflect CO_2 emissions in consumer prices (and thus mimicking carbon taxes) or to relate tax levels to specific carbon benchmarks. This is reflected in the OECD effective carbon rates indicator (ECRs), which evaluates carbon pricing across countries, i.e. how CO_2 emissions from fossil fuel use are priced not only through carbon taxes and permit prices from emissions trading systems, but also through fuel excise taxes. Box 3.1 provides additional detail on these three components as well as on sectors, fuels and years covered by the OECD ECR. The ECR profile for the Andalusia industry and electricity sector is represented and analysed in Section 3.2.2.

Box 3.1. The OECD Effective Carbon Rates

The OECD Effective Carbon Rates (ECR) database (OECD, 2021[4]; OECD, 2019[5]) provides a breakdown of CO_2 emissions from energy use and corresponding effective carbon rates for 44 OECD and G20 countries by sector and fuel. Taken together, these 44 OECD and G20 countries represent 80% of worldwide CO_2 emissions from energy use. Effective carbon rates are the sum of explicit carbon taxes, emissions trading systems (ETSs) and fuel excise taxes.

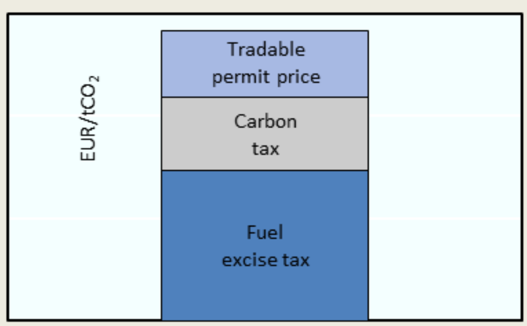
More precisely, the three components of effective carbon rates, depicted in Figure 3.3, should be understood as follows:

Carbon taxes generally set a rate on fuel consumption based on its carbon content (e.g., on average, a EUR 30/tCO_2 tax on carbon emissions from diesel use would translate into a 7.99 eurocent per litre tax on diesel).

Fuel excise taxes typically set a rate per physical unit (e.g., litre, kilogram, cubic metre) or per unit of energy (e.g., gigajoule), which can then be translated into rates on the carbon content of these fuels.

The price of tradable emission permits, regardless of the permit allocation method, represent the opportunity cost of emitting an extra unit of CO_2.[1]

Figure 3.3. Components of Effective Carbon Rates



Source: Based on Figure 3.1 in OECD (2016[6]).

The database covers six sectors that together span all energy uses: agriculture and fisheries, buildings (i.e., residential and commercial heating), electricity, industry, off-road transport and road transport. More detail on sector definitions can be found in Annex Table 3.A.1.

Fuels are grouped into ten categories, which in turn can be grouped into two broad classes. Fossil fuels are composed of the categories *coal and other solid fossil fuels*, *diesel*, *fuel oil*, *gasoline*, *kerosene*, *liquefied petroleum gas* (LPG), *natural gas* and *other fossil fuels* (a category consisting in those fossil fuels that cannot be classified under the first seven categories in the list). Other combustible fuels are composed of biofuels and non-renewable waste. More detail on fuel categorisation can be found in Annex Table 3.A.2.

Note:
1. Thus, effective carbon rates are sometimes also referred to as effective marginal carbon rates. In the following, the discussion centres around those, but the sector-level discussion goes into more detail and highlights the share of free allocations in different sectors.
Source: OECD (2016[6]).

3.1.2. Air Pollutants

The main air pollutants are sulphur oxides (SOx) and nitrogen oxides (NOx) (generally expressed as quantities of SO_2 and NO_2), carbon monoxide (CO), ammonia (NH_3), volatile organic compounds excluding methane (NMVOC), particulate matter[6] (PM). These gases and particulate matter are directly responsible for air pollution.

Air pollution has effects on human health and on the environment. The World Health Organisation (WHO), for instance finds that 7 million premature deaths annually are linked to air pollution.[7] Even at the European Union (EU27) level, the European Environmental Agency estimates that, in 2019, approximately 307,000 premature deaths were attributable to $PM_{2.5}$, 40,400 premature deaths to NO_2 and 16,800 premature deaths to ground-level ozone. The OECD's *Air pollution effects* indicator, uses estimates of the "Value of a Statistical Life" (VSL) and computes the number of premature deaths attributable to ambient particulate matter (OECD, 2022[7]). It finds that in 2019, Exposure to $PM_{2.5}$ caused a mortality of 190 per 1 000 000 inhabitants in Spain. Additional details on the types of effects air pollutants might have are provided in Box 3.2. .

Box 3.2. Principal air pollutants and their impacts

Air pollutants may be harmful in and by themselves but also through their reaction with water, oxygen and other chemicals in the atmosphere, which can lead to the formation of other toxic substances.

For example, high concentrations of SO_2 in the air can lead to the formation of other sulfur oxides (SOx). NOx, SOx and NH_3 can react with other chemicals in the air to form particulate matter. Moreover, the reaction of NOx or CO with other chemicals in the atmosphere can result in the production of tropospheric ozone (O3). VOCs exacerbate the production of ozone in the lower atmosphere. The interaction of NO_2 and SO_2 with one another or with other substances, such as water can cause acid rains.

Environmental impacts

High concentrations of gaseous SOx can damage foliage and decrease plant growth. Particulate matter, either emitted directly or created through the reaction of other air pollutants with chemicals in the air can make the air hazy, hence reducing visibility as well as stain and damage stone and other materials. NOx in the atmosphere can contribute to nutrient pollution in coastal waters. This can result in algae growing faster than manageable for ecosystems. This damages water quality and decrease the oxygen that fish and other aquatic life need to survive. NH_3 is also harmful for the fish and aquatic life more generally. At high levels, ground-level O_3 damages vegetation, including crop yields.

Health impacts

Most air pollutants harm the human respiratory system, and some can cause further damages by increasing the risks of certain illnesses and conditions. For example, it has been found that longer exposures to elevated concentrations of NO_2 may contribute to the development of asthma. Breathing air with a high concentration of CO reduces the amount of oxygen that can be transported in the blood stream to critical organs like the heart and brain.

VOCs can be carcinogenic.

Through their impact on nutrient pollution and algal blooms, NOx emissions can cause sickness when humans come into contact with polluted water, consume tainted fish or shellfish, or drink contaminated water.

PM_{10} and $PM_{2.5}$ can get deep into the lungs and in some cases even into the bloodstream. $PM_{2.5}$ is the air pollutant that poses the greatest risk to health globally and affects more people than any other pollutant.

Climate impacts

O3 is a short-lived GHG, hence it also contributes to climate change. Its radiative forcing effect however, is mainly at regional level.

PM can influence climate "through both interactions that scatter or absorb radiation and through interactions with cloud microphysics and other cloud properties, or upon deposition on snow- or ice-covered surfaces thereby altering their albedo and contributing to climate feedback" (IPCC, 2019[8]).

Economic impacts

Evidence shows that beyond the health and environmental impacts, air pollution, and in particular particulate matter may also have detrimental effects on firms and more generally the economy through productivity of workers (Zivin and Neidell, 2018[9]; Dechezleprêtre, Rivers and Stadler, 2019[10]). For example, Leroutier and Ollivier (2022[11]) find that by negatively affecting workers' health and cognitive functions, $PM_{2.5}$ exposure impacts workers' absenteeism and firms' monthly sales. At the national level, this can have important consequence. For instance, they estimate if air pollution in France had been in line with the World Health Organization's guidelines, this would have saved at least 0.3% of GDP annually through avoided sales losses.

The economy can also be affected by air pollution through increase in public health expenditure and loss of crop yields. For example, Deryugina et al. (2019[12]) find that in the United States (US) $PM_{2.5}$ concentration increases lead to more emergency room visits, more hospitalizations, and higher inpatient spending. Mink (2022[13]) estimates that reducing NO_2 concentrations by 27% would results in an annual saving of EUR 5.2 billion in healthcare costs in France. Regarding crop yields, Lobell et al. (2022[14]) find that reducing NOx emissions by about half in Western Europe would improve yields by nearly 10% in the region. SOx and NH_3 may also be harmful to plants.[1]

Note:
1. https://www.ontario.ca/page/effects-air-pollution-agricultural-crops#:~:text=Agricultural%20crops%20can%20be%20injured,premature%20death%20of%20the%20plant.
Source: OECD (2020[15]; 2022[7]),https://www.epa.gov, IPCC (2019[8]) for environmental, health and climate impacts and Zivin and Neidell (2018[9]), Dechezleprêtre et al. (2019[10]), Leroutier and Ollivier (2022[11]), Deryugina et al. (2019[12]), Mink (2022[13]), Lobell et al. (2022[14]) for economic impacts.

The direct impact of air pollutants is often local, and their harmfulness generally depends on local conditions, such as population density, and local weather conditions (e.g. rainfall, wind regime or atmospheric stability). Age, standards of living and prevalence of certain pathologies can also impact the health effects on population. The impacts can also depend on pollutant densities in the air and can be more important beyond certain density levels. The United States, for example, have defined an Air Quality Index (AQI),[8] which depends on ground-level ozone, PM, CO, SOx and NOx emissions and ranges from "Good" to "Unhealthy" to "Hazardous" (it has a total of six categories). Individual threshold levels are also defined for each of these air pollutants (U.S. Environmental Protection Agency, 2018[16]). Air pollutants might also indirectly impact climate change.

In Andalusia, air pollutant emissions have followed a downward trend since 2003, with reductions of up to 80% for SO_2. NH_3 emissions went through a significant decrease up until 2011, but have gone up since, resulting in the lowest air pollutant decrease since 2004 of about 6%.

The main sources of air pollutants differ (Andalucia, 2021[17]). The main anthropogenic sources of SO_2 in 2019 are the industry sector (about 50%, with 22% from the petrochemicals industry, 11% from the metal industry and 11% from the non-metallic materials industry, 3% from the oil production industry and 2% from the chemical industry), maritime traffic (22%) and electricity production (20%). For NOx, these are road traffic (28%), agriculture (21%), maritime traffic (13%) and electricity production (11%). For CO emissions the main sources are agriculture (34%), domestic activities (23%), forest fires (13%) and road traffic (13%). Those for NH_3 are livestock (47%) and the rest of agriculture (46%). Those for NMVOC are the use of solvents. Finally, direct $PM_{2.5}$ emissions are mostly from domestic activities (38%), agriculture (30%), forest fires (9%) and road traffic (8%).[9]

Air pollutants, contrary to CO_2 are not necessarily proportional to fuel use. Indeed, their emissions intensity also depends on the end-of-pipe technology used and the combustion process (OECD, 2019[5]).

3.1.3. Interactions between GHGs and air pollutants

Air pollution and climate change interact and can influence each other.[10] For example, an increase in levels of GHGs leads to temperature changes that affect the chemical composition of the atmosphere, and can make air pollution impacts worse. On the contrary, certain air pollutant emissions may actually have negative radiative forcing, i.e., have a cooling effect on the climate – SOx emissions for example form light *reflecting* particles (Arneth et al., 2009[18]). Moreover, as explained in Box 3.2. , the interaction of air pollutants with other substances in the atmosphere can result in the production of other components, which do have a direct effect on climate change (e.g., black carbon, O_3).

In addition, the management of climate change and air pollution have consequences for each other. First, pricing GHG emissions can encourage a reduction in fuel use, which in turn not only reduces GHG emissions but also air pollutant emissions (and vice versa). Co-benefits of climate policy therefore include better health and environmental outcomes. However, this can also create trade-offs, due to the complex interactions between air pollutants and GHGs described above. This is the case, in particular if, at least in the short-term, reducing a pollutant's emissions leads to additional atmospheric warming rather than cooling. Second, trade-offs can also arise because of the consequences of pricing. This is particularly the case if fuels are replaced by more sustainable fuels such as biofuels and not by non-combustible renewables such as wind and solar. If sustainably sourced, the combustion of biofuels may result in lower GHG emissions over the life cycle because before being burnt, feedstocks have previously absorbed a similar amount of CO_2 from the atmosphere. However, it does all the same lead to higher PM in the air. The first issue can be dealt with, for example, by associating bioenergy expansion with effective implementation of post-combustion PM-control measures, such as filters and precipitators (Portugal-Pereira et al., 2018[19]). Similar issues can arise with carbon capture and storage technologies, which may induce larger amounts of primary energy requirements and hence higher air pollution overall.

3.2. Pricing emissions from stationary sources in Andalusia

This subsection deals with carbon and air pollutant taxes on stationary sources in the Andalusian context and focuses on the Andalusian tax on the emission of gases into the atmosphere (IEGA). A description of this tax is followed by its analysis in the more comprehensive context of carbon and air pollution pricing policies. This leads to the identification of how the current tax system compares with a system that covers emissions more comprehensively and more accurately according to sound environmental tax principles, including considerations for potential economic and behavioural impacts. Proposals for strategic reform options in the Andalusia context are made and best practice examples from other countries are presented throughout. First, this subsection provides a description of the Andalusian tax on the emission of gases into the atmosphere. Then, the first part of the analysis deals with GHG emissions, first with a focus on the industry and electricity sectors and CO_2 emissions from energy use: the Andalusian tax on the emission of gases into the atmosphere within the context of other national and European-level taxes dealing with carbon emissions. The second part of the analysis deals with air pollutant emissions. Finally, the agriculture sector is discussed, both from a GHG and air pollutant perspective.

CO_2 emissions from energy use in Andalusia

In Andalusia, the electricity and industry sectors[11] taken together represent more than 80% of stationary sources of CO_2 emissions from energy use. The rest of CO_2 emissions from energy use from stationary sources is principally from the buildings sector – or in other words residential and commercial heating. Stationary sources are responsible for 64% of overall CO_2 emissions from energy use – with the road and off-road transport sectors being responsible for the rest.

3.2.1. The Andalusian Tax on the Emission of Gases into the Atmosphere or the IEGA

In 2003, Andalusia introduced its Tax on the Emission of Gases into the Atmosphere (*Impuesto Sobre la Emisión de Gases a la Atmósfera*[12] *or IEGA*), which deals both with GHG and air pollutant emissions. It covers direct and indirect[13] emissions of CO_2 and of two important air pollutants, NOx and SOx. The tax applies to installations in the industry, electricity and agriculture sectors.[14] Inclusion thresholds for covered installations exist. They depend on physical characteristics of installations, such as levels of thermal power, impact energy of material used, production capacity, volume, treatment capacity, storage capacity, quantity dealt with or surface. Emissions from landfills and facilities for the intensive rearing of animals as well as those from the combustion of biomass and biofuel are exempt. Since 2005, the exemption has been extended to CO_2 emissions beyond free allocation of installations subject to the EU ETS, "except for the excess that entails non-compliance with the obligation to surrender allowances under that legislation". There are tax deductions for firms investing in emissions reduction, called investment deductions. The formal design of the IEGA is presented in Box 3.3.

The revenue from Andalusian ecological taxes, such as the IEGA is meant to be used to finance the actions of the Administration of the Junta de Andalucía in matters of environmental protection and conservation of natural resources.[15] Moreover, 5% of the revenue collected annually is to constitute a reserve fund to attend to emergency situations caused by environmental catastrophes. In 2020, this tax generated about EUR 1.96 million for Andalusia.

In 2019, the tax covered about 70 installations, all in the industry and electricity sectors.[16] In total, these represented about three quarters of CO_2 emissions in these sectors.[17] The firms they belonged to had an average of 543 employees, and average sales of about 559 million euros. About 40% of installations belonged to the electricity sector or to the autoproduction of electricity (subsector of industry) and the other 60% were all in the manufacturing industry.

Box 3.3. The IEGA design, polluting units and reference values

The IEGA design and polluting units

The tax schedule is a function of "polluting units", which bundle together CO_2, NOx and SOx emissions, according to "reference values". More precisely, the polluting units are calculated as follows. First, each substance has been assigned a yearly reference value. For CO_2, this is 200 000 tonnes[1], for NOx, 100 tonnes and for SOx, 150 tonnes. Second, each tonne of substance emitted is divided by its respective reference value. Third, these resulting polluting units are added up to form one taxable base. The tax schedule is then progressive. An exemption bracket has been added to the statutory schedule, such that below 3 polluting units, the effective marginal rate is of 0. The effective base and marginal tax rates are referenced in Table 3.1.

Table 3.1. Effective tax rates and brackets for the Andalusian Tax on the Emission of Gases into the Atmosphere

Base (in polluting units)	Effective marginal rates (in EUR per polluting unit)
0-3	0
3.001-13	5 000
13.001-23	8 000
23.001-33	10 000
33.001-53	12 000
More than 53	14 000

Source: Article 32 of BOE (2004[20]).

The IEGA reference values and European Pollutant Emission Register (EPER) threshold levels

The yearly reference values are based on the threshold levels set in the European Pollutant Emission Register (EPER) Decision,[2)] which specify the lower bound beyond which firms have to declare their emissions. Those threshold levels are either the same or of the same order of magnitude as the Andalusian tax's reference values; they are of 100,000 tonnes for CO_2, 100 tonnes for NOx and 150 tonnes for SOx. These thresholds do not constitute emission limit values (Cañón-de-Francia, Garcés-Ayerbe and Ramírez-Alesón, 2008[21]): they have been set to capture the majority of emission sources and limit administrative burden (European Commission, 2017[22]).

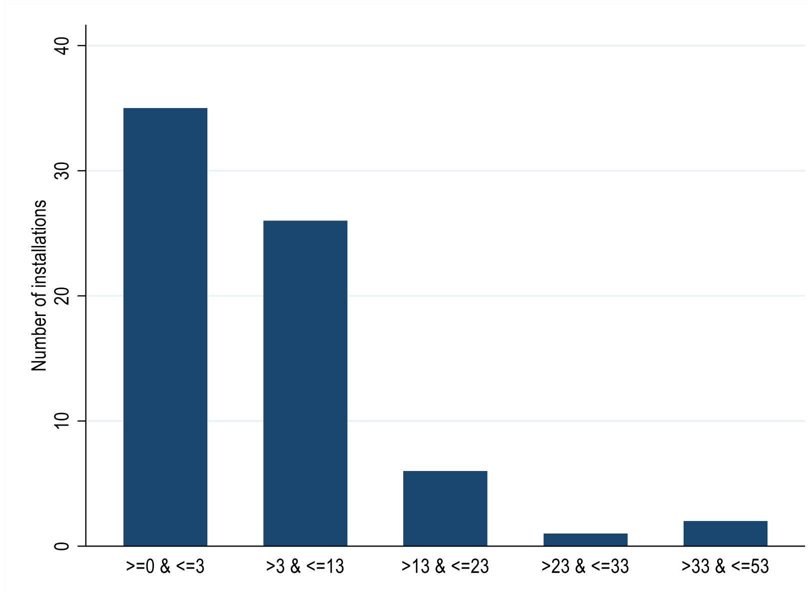
Notes:
1. This was 100 000 from 2003 to 2005.
2. 2000/479/EC.
Source: Exchanges with Junta de Andalucia and https://www.boe.es/buscar/act.php?id=BOE-A-2004-1739&p=20100809&tn=1&se-9.

Installations subject to the IEGA are rather heterogeneous in the emissions they declare. In 2019, they declared CO_2 emissions of 179 301 tonnes on average, ranging between 0 and 1.7 million tonnes.[18] For NOx, the average was of 399 tonnes, ranging between 0 and 2.3 thousand tonnes. And for SOx, the average was of 234 tonnes, ranging between 0 and 3 thousand tonnes.

Only two installations received investment deductions in 2019. This stands in contrast to the first years of the IEGA where many more installations invested in relevant emission reductions.[19]

Despite the heterogeneity in declared emissions, in 2019, half of installations (50%) end up falling into the first tax bracket of the tax schedule presented in Table 3.1 (i.e., polluting units lower than 3). 37% fall into the second bracket. This implies that their tax burden is at most EUR 65 000, which represents less than 0.013% of average annual sales. About 9% of installations then fall into the third tax bracket and 4% into the fourth and fifth. Figure 3.4 presents the distribution of installations according to the IEGA tax brackets.

Figure 3.4. Number of installations per bracket of polluting units



Source: Statistics provided by Junta de Andalucía.

StatLink https://stat.link/lmoskq

The administrative organisation of the tax reveals good practice in the **coverage of installations**. Indeed, the inclusion of installations into the base of the tax is based on physical characteristics, which are more straightforward to verify than emissions, for instance. Moreover, the activities covered are very clearly specified, and avoid confusion.

Andalusia plays a **pioneering role** in setting up a tax tackling air pollution, which is an important issue for environmental and health reasons, as well as economically. Its tax was set up in 2003, following Galicia, which introduced such a tax in 1995. Other Autonomous Communities have since set up similar taxes, including Murcia and Castilla-La-Mancha in 2005, Aragon in 2007, Valencia in 2012 and Catalonia in 2014. The implementation of the tax has helped Andalusia gain the administrative capacity to manage and collect such an environmental tax. This can be important even in the context of a generalisation of such taxes at a national level. Indeed, in 2014, an expert committee (CERSTE-*Comisión de Expertos para la Reforma del Sistema Tributario Español*)[20] had suggested a state-level tax on air pollutant emissions, which could be ceded to the Autonomous Regions for management and collection.

Moving on to points for improving the design of the IEGA, the remarks start with the use of **reference values**, which don't appear to be used correctly. The reference values are based on the threshold levels set in the EPER Decision, but it is not clear why such reference numbers should be used to divide the emissions amount to be taxed. Given the way the taxable base is calculated, the division of emissions by these reference values ensures that this tax applies lower rates to the release of one tonne of CO_2 into the air than to that of SOx or NOx. However, there does not seem to be any scientific reason to implement such relative rates, given that the reference values are based on numbers that are not related to relative harmfulness of different gases. Moreover, the exemption threshold then ensures that if CO_2, NOx and SOx are emitted below these reference values then the installation faces no tax liability. As a reminder, the EPER threshold levels were set for countries to report the majority of their emissions and limit administrative burden. They do not constitute a limit of acceptable amounts of emissions (see Box 3.3.).

Second, there is no clear rationale in the documentation surrounding the design of the IEGA as to why the **calculation of the taxable base bundles all three gases**. A potential reason – but not explicitly mentioned – might be to ensure, for example, using the progressive rate structure, that the release of one tonne of SOx is taxed more highly when occurring on top of the threshold of 2 million tonnes of CO_2 emissions than on top of no CO_2 emissions. Indeed, in the first case the additional tonne would then be taxed at EUR 53.3 and in the second case at EUR 33.3. If this was indeed the explanation, it would be better justified if complemented by scientific evidence. In fact, as highlighted when discussing the interactions between GHG and air pollutant emissions, it does not appear that the negative impact of one of the gases was worse when released in the presence of the other. Moreover, such a tax base provides the possibility for offsetting the tax on the emissions of one gas with the decrease in emissions of another gas. Instead, covering all three gases (with separate taxes or bases) can make sense from an environmental point of view, to avoid effects whereby, in abating one type of emissions, a firm does not pay attention to the potential increases in another type of emissions.

Third, the **progressivity of the rates** is not grounded in classical environmental economics principles, especially for GHG emissions (i.e. here, CO_2). For GHGs, the harmfulness of one extra tonne of emissions does not depend on how many tonnes have been previously emitted. Moreover, the progressivity of rates does not ensure the cost-effectiveness of environmental taxes, which calls for an alignment of tax rates in order to encourage abatement cost minimisation. Unless the progressive structure can be justified on an efficiency[21] or equity[22] ground, it is not clear that the principle of progressivity should be applied in this context.

Fourth, the whole design of the IEGA is **complex** and reduces its **salience**. Recent research shows that complexity in tax systems can make incentives harder to understand and undermine their efficiency (Boccanfuso and Ferey, 2021[23]). Regarding salience, the tax structure does not highlight the rate paid for each tonne of CO_2, NOx or SOx released into the air. For example, a firm emitting 10 000 tonnes of CO_2, 3 000 tonnes of NOx and 5 000 tonnes of SOx cannot know how much it is paying for each gas separately. The division of the emissions by the reference values and the bundling of the three gases into a same base hence affects the salience of the tax, potentially limiting firms' responses to it. Indeed, evidence finds that salience is key to ensuring responsiveness to taxes (Chetty, Looney and Kroft, 2009[24]).

Fifth, the **reduction of the taxable base** is not necessarily grounded in environmental economics or scientific evidence. The reduction is meant to align with the regulatory field of the EU EPER and is calculated based on the three reference values used to compute the polluting units. Indeed, it sets an effective tax-free threshold at 3 polluting units, which stems from a rationale of providing one polluting unit for each gas free of tax. This, however, even if aligned with the EPER threshold levels, is not aligned with their rationale (see Box 3.3.). They are set to capture the majority of countries' emissions and ease administrative burden, not to provide an order of magnitude of minimum levels of acceptable emissions. Moreover, the bundling of the three gases into one base results in this reduction calculation having cross-effects on exemptions for different gases. Taking the example of an installation emitting 50 000 tonnes of CO_2, 700 tonnes of NOx and 150 of SOx, the way the reduction of the base is calculated along with the bundling of the bases provides additional polluting rights in terms of NOx due to the fact that the CO_2 emissions of the installation are much below 200 000 tonnes. Indeed, in this example, the polluting units due to CO_2 are 0.25, to NOx, 7 and to SOx, 1. Hence, the reduction of 3 polluting units in the base "cross-subsidises" NOx emissions because of the fact that CO_2 emissions are lower than 200 000 tonnes. Because of this, emissions from NOx have a tax-free threshold of 1.75 instead of 1.

3.2.2. Carbon pricing in Andalusia

The focus of the GHG pricing analysis for stationary sources in Andalusia is on CO_2 emissions from energy use. This is for at least two reasons. First, carbon emissions are the main source of GHG emissions in Andalusia. Second, the stationary sources of emissions covered by the Andalusian Tax on the emission of gases into the atmosphere are from the industry and electricity sectors, which are mostly responsible for CO_2 emissions (see Figure 3.2), with a majority of those being from energy use. A discussion on ways forward for coverage of CO_2 and other GHG emissions from the agriculture sector, which is responsible for the emission of CO_2, CH_4 and N_2O in similar proportions, is present at the end of the subsection on stationary sources.

In Andalusia, four instruments price (directly or indirectly) CO_2 emissions from stationary sources in the industry and electricity sectors occurring at three different levels of governance. At the Andalusian level, as just described, the Andalusia Tax on the Emission of Gases into the Atmosphere acts as a carbon tax. At the Spanish level, the Tax on Hydrocarbons and the Special Tax on Coal are both fuel excise taxes. At the European level, the EU ETS applies to certain GHG emissions from the two sectors.

At the Spanish level, fuel use in stationary sources is subject to two fuel excise taxes: a Tax on Hydrocarbons (*Impuesto sobre Hidrocarburos*) and a Special Tax on Coal (*Impuesto Especial sobre el Carbón*). The Tax on Hydrocarbons applies to specified uses of liquid and gaseous fuels, including biofuels, coal tar, crude oil, waste oils, coal and coke-related gases. Hydrocarbons are untaxed when used to produce electricity in power plants or to cogenerate electricity and heat in combined power plants. The Special Tax on Coal applies to specified uses of coal and coke products, excluding peat. Together these results in the selected rates presented in Table 3.2, which leaves out exemptions. As in many countries, however, fuels used for electricity generation and some industry sectors are exempted from taxation. Exemptions are covered (but not enumerated) in the subsequent analysis.

Table 3.2. Selected excise tax rates for stationary sources in Spain, 2021

Fuel	Rate in EUR per unit	Unit
Biodiesel and diesel (agriculture, heating and stationary motors)	96.71	1000L
Biogases and natural gas (non-industry heating, stationary motors)	0.65	GJ
Biogases and natural gas (agriculture)	1.15	GJ
Biogasoline (heating, stationary motors)	472.69	1000L
Coal and coke (CHP heat, residential)	0.65	GJ
Coal and coke (agriculture, business and stationary motors)	0.15	GJ
Fuel oil (heating, stationary motors) and waste oils	17	1000Kg
Gasoline (heating, stationary motors)	503.92	1000L
LPG (heating)	15	1000Kg
LPG (stationary motors)	57.47	1000Kg

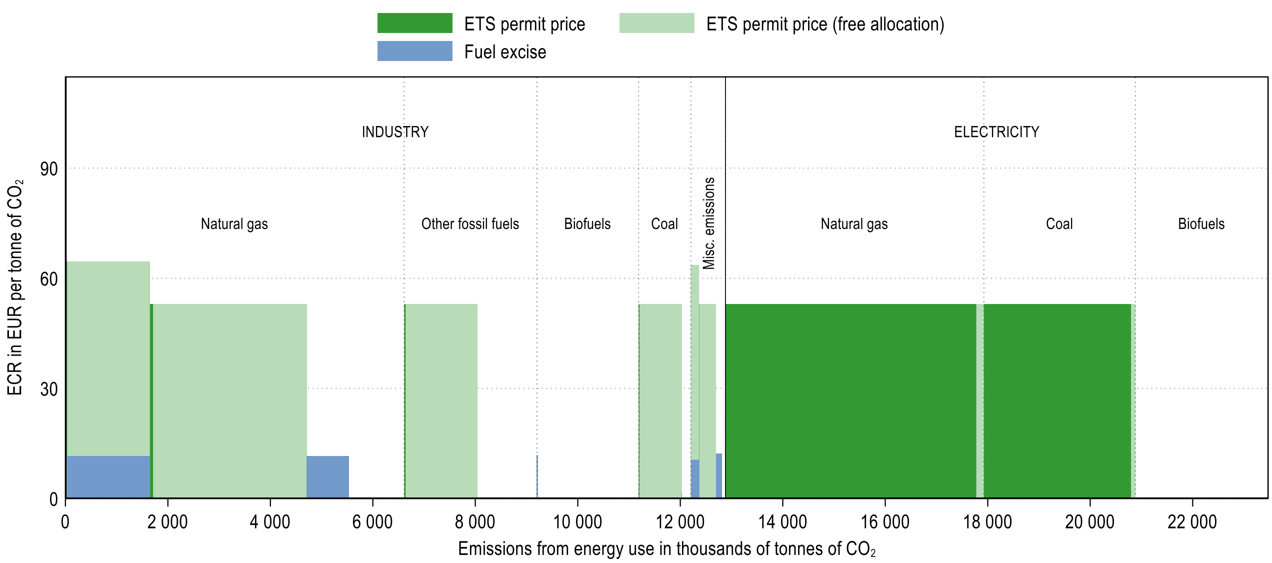
Note: Taxes as of 1 April 2021.
Source: Taxes in Europe database, https://boe.es/buscar and OECD (2022[25]).

At the European Union level, the EU ETS was introduced in 2005 (Section 2.1.1). It covers CO_2, N_2O, PFCs emissions from the industry and electricity sectors[23] in all EU countries as well as Iceland, Liechtenstein and Norway. Inclusion thresholds vary with the type of installation. In 2020, the EU ETS covered 828 stationary installations in Spain and 81 in Andalusia – respectively 831 and 82 in 2019. This represented 81% of emissions from energy use in the Andalusian industry and electricity sectors.

The different carbon-pricing instruments are summarised in the OECD effective carbon rate (ECR) (see Box 3.1 focusing on three components: carbon taxes, fuel excise taxes and permit prices from emissions trading systems. Figure 3.5 presents the price that applies to CO_2 emissions from energy use in the industry and electricity sectors in Andalusia.[24] The emissions base is divided into the fuel types used in the sectors. The width and height of the different blocks depict coverage and rates, and their colour, the type of instrument used. In blue are fuel excise taxes and in green the EU ETS. Rates of the Andalusian Tax on the emission of gases into the atmosphere are too low to be visible on the figure, but the tax, its rates and overlap with the EU ETS are described and analysed further in the following.

The ECR profile enables to analyse the carbon pricing instruments used, the effective coverage and rates of carbon pricing in Andalusia, and to compare these with benchmark costs (see Box 3.5). After an analysis of federal and EU-level carbon pricing instruments, the analysis turns to the Andalusian tax on the emissions of gases into the atmosphere. It highlights what it adds to the existing national and EU-level carbon pricing instruments and develops recommendations on whether or how to improve this tax – as reforming this tax is in the legal competence of Andalusia.

Figure 3.5. Effective Carbon Rates in the industry and electricity sectors, Andalusia



Note: This figure shows CO_2 emissions from energy use in Andalusia taken at the point of combustion and the effective carbon rate they are subject to in the industry and electricity sectors. “Misc.” groups together fuels that each represent less than 5% of total energy use from combustible fuels in the sector. In the industry sector, “Misc.” is composed of emissions from diesel, fuel oil and LPG. In the electricity sector, “Misc.” is too small to be represented on the graph. It is composed of diesel and fuel oil, the emissions of which account for less than 1% of sectoral emissions when taken together. CO_2 emissions are calculated based on energy use data for 2019 from IEA (2020[26]), World Energy Statistics and Balances as well as the Andalusia energy balances. Fuel excise taxes are for 1 April 2021 and permit prices are the average over 2021. Coverage is for 2021. The methodology to estimate the overlap of taxes and ETS permit prices is explained in detail in OECD (2016[6]).
Source: OECD.

StatLink https://stat.link/vr6mcl

Industry is the largest emitting sector from stationary sources in Andalusia in terms of CO_2 emissions from energy use, representing 29% of CO_2 emissions from energy use. Firms in the industry sector mainly face a price signal from the EU ETS, with a permit price of about EUR 53 per tonne of CO_2 on average over 2021. The EU ETS cover roughly 60% of emissions in the industry sector (70% when leaving out emissions from biofuel combustion), i.e. 40% (resp. 30%) of emissions are not covered by the EU ETS. However, 97% of EU ETS emission permits were allocated for free in 2021 (light green). In addition, fuel excise taxes apply to very few fuel categories, with several exemptions from the tax, and at comparatively lower levels per tonne of CO_2 than permit prices. Emissions from the use of natural gas, which constitutes the main fuel category in this sector (51%), face fuel excise rates of about EUR 11.6 per tonne of CO_2, when they are not exempted; more than half of natural gas emissions are exempt. Diesel and LPG used in industry are subject to fuel excise rates of about EUR 19 per tonne of CO_2 on average but taken together represent only a minor share of CO_2 emissions from energy use in industry (less than 1%). The rest of industrial emissions (28%, mainly fuels belonging to the category "coal and other solid fossil fuels" or "other fossil fuels") face excise rates lower than EUR 2 per tonne of CO_2 (1.41 on 83% of emissions coal and other solid fossil fuels – not visible on Figure 3.5) or are not covered by fuel excise at all. The vast majority of emissions from biofuels (99%) in the industry face no excise tax, while 1% face an excise tax rate of about EUR 12 per tonne of CO_2.

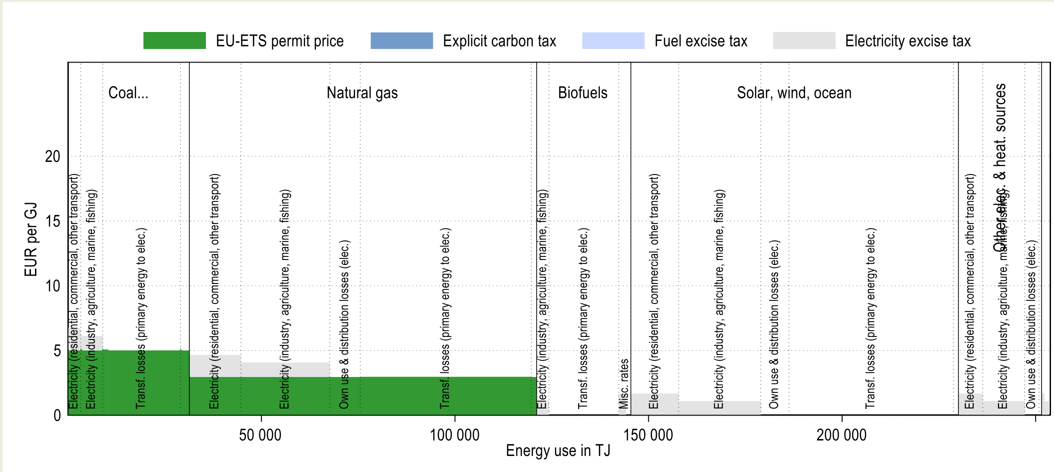
The electricity sector (which consists here in plants for which the main activity is to produce electricity[25]) is responsible for 24% of CO_2 emissions from energy use in Andalusia and its emissions from fossil fuels are exclusively covered by the EU ETS. In 2019, free allocation represents about 2% of verified emissions. Emissions from biofuel combustion are not subject to the EU ETS. No fuel excise taxes apply. In Andalusia, CO_2 emissions from energy use in electricity plants stem mainly from natural gas use (48%) and then in almost equal shares from coal and biofuel combustion (respectively 28% and 24%). Compared to the industry sector, the EU ETS provides stronger long-term investment incentives in the electricity sector, where only 4% of emission permits were allocated for free in 2021. In addition, a specific electricity tax applies in Spain. Because it does not send a specific carbon pricing signal, it is not discussed here (Box 3.4.).

Box 3.4. The Spanish electricity tax and the electrification using clean power sources

The current design of the Spanish electricity tax (*Impuesto sobre el valor de la producción eléctrica*) applicable in Andalusia presents several misalignments with the objective to achieve a reduction of 39% of GHG emissions in Andalusia by 2030 compared to 2005 levels. On the one hand, the tax reduces incentives to electrify the economy by increasing the relative prices of electricity. On the other hand, the current design of the tax does not directly encourage producers to switch towards clean sources of electricity production and to decarbonise the power sector.

The tax design does not provide specific incentives for decarbonisation because the tax rate is not differentiated by the type of energy used in electricity production. Thereby, it increases the Terajoule (TJ) price of electricity also when it is produced from clean sources like solar, wind and ocean energy. Figure 3.6 represents the effective electricity price deriving from energy taxation and EU ETS permit prices in the electricity sector in Andalusia, by mapping policy instruments to the amount of electricity consumed in production and to the final user.

Figure 3.6. Effective energy rates in the electricity sector, Andalusia 2021



Note: Electricity taxes are for 1 April 2021 and EU-ETS permit prices are the average auction price over 2021. The ad-valorem rate of the electricity tax is translated into effective rates based on information from the European Commission's TEDB database. Energy use data is for 2019 and from IEA (2020[26]), World Energy Statistics and Balances as well as the Andalusia energy balances.
Since 1 January 2019, all hydrocarbons that are used to produce electricity in power plants or to cogenerate electricity and heat in combined power plants are exempted from the fuel tax (*Impuesto sobre Hidrocarburos*). The Andalusia carbon tax (*IEGA*) is not visible in the profile due to the low rates that currently apply.
Source: OECD Taxing Energy Use model, data provided by Andalusia Energy Agency (*Agencia Andaluza de la Energía*).

StatLink https://stat.link/0qsceo

On the horizontal axis, the figure displays electricity use in Andalusia in TJ split into the main primary energy carriers that are used to produce electricity (coal, natural gas, biofuels, renewable energies, and other sources), as well as the main electricity users (residential, commercial, industry, agriculture, etc.). Note that a large part of electricity is lost through processes that transform primary energy into electricity ("Transf. Losses") plus electricity used at plants and distribution losses ("Own use & distribution losses"). On the vertical axis, the figure depicts the price level of policy instruments that electricity users in Andalusia pay in EUR per TJ: the electricity tax (grey bars) and the price signal deriving from the EU ETS (green bars). No fuel excise tax applies in the electricity sector. Combining information on rate and base, the profile gives an indication of the effective price that applies in the sector.

The figure differs from the figure used in the main text in that it is based on TJ, instead of CO_2 emissions which helps observing two additional features. The focus on TJ allows including zero-carbon sources in the energy base that were not part of the profile based on CO_2 emissions, but that become visible in a TJ profile. It also allows mapping the electricity tax to the energy base, which was not depicted in the profile based on CO_2, because it is not considered a carbon pricing instrument.

Figure 3.6 shows that the Spanish electricity tax risks discouraging the electrification of the economy, as it applies to electricity use in the commercial, residential, industry, agriculture and transport sectors, independently of the energy source. The tax rate and coverage (grey part) do not change with the energy carrier used to produce electricity (coal, natural gas and renewables). The opposite is the case for the carbon pricing signal deriving from the EU ETS (green part) which prices electricity depending on the CO_2 intensity of the TJ produced, thereby encouraging the use of clean sources in electricity production.

The electricity tax is set at the national level, and the ETS at the EU level, which leaves only limited leeway for adjustments to the region. The IEGA could be used to further strengthen the carbon price in the electricity sector and encourage the use of clean energy sources. However, the IEGA strongly overlaps with the EU ETS in terms of coverage, and because the IEGA rates are currently low it does not send a significant additional price signal to encourage decarbonisation (see discussion in main section). Other countries use national carbon pricing systems to put a floor price on emissions from electricity generation covered by the EU ETS. Yet, the current rates of the IEGA fall well below the EU ETS permit price and therefore do not serve this goal (see Box 3.6.).

Removing the Spanish electricity tax could help strengthen signals for clean electrification of the economy, as also suggested in the White Book for Tax Reform in Spain. To avoid conflicts between environmental and fiscal objectives (i.e. revenue raising), the phasing-down of the electricity tax could be co-ordinated with the phasing-in of an effective carbon floor price in electricity and the removal of energy tax exemptions on fossil fuel use to generate additional revenue. Eventually, as the energy system is approaching full decarbonisation, electricity taxes could be reintroduced if so desired, e.g. for revenue raising reasons or to incentivise savings.

Electricity taxation still incentivises electricity savings in general. In liberalised power markets, fossil fuel powered generators are frequently the marginal electricity producer. Energy savings induced by electricity taxes could thus indirectly decrease emissions. Electricity taxes also have the advantage that they can be levied on electricity imported from abroad.

Source: Author’s own elaboration, based on OECD (2019[5]).

The lack of complementary policies to the EU ETS pricing of Spanish (and hence Andalusian) carbon emissions may be an issue given free permit allocation for the industry sector and price volatility. These issues are further developed in the following.

The EU ETS covers a large part of fossil fuels in the industry and electricity sector, but extensive free allocation in the industry sector erodes the average price signal. Effective carbon rates are typically expressed in *marginal rates*, which means that these are rates faced by fuel users for an extra tonne of CO_2 emissions. Marginal rates assign permit prices to the respective emissions base independently on whether allowances are auctioned or freely allocated. As such, the ETS price component (green area in the Figure 3.5) should be understood as the opportunity cost of emitting an extra unit of CO_2 for firms (see Box 3.1) which provides an incentive to contain emissions at the margin. Figure 3.5 thus partitions the price signal deriving from the EU ETS (green area) and provides an estimate of how much of the EU ETS emissions are covered by an auctioned (dark green) or freely allocated emissions allowance (light green).

By driving a wedge between the marginal and the average carbon price faced by firms, freely allocated emissions permits can affect long term decision making in imperfectly competitive markets. Indeed, they can affect investment decisions since they can discourage investment of firms in low-carbon technologies (Flues and Van Dender (2017[26])). Other evidence also highlights lower green innovation in firms where a larger share of allocations are distributed for free (Martin, 2013[27]).

Free allocation shares are gradually being decreased in the EU ETS. Free permits do help alleviate carbon leakage and competitiveness concerns of energy-intensive and trade-exposed firms. Under current discussions at the EU level, in particular in the context of a potential carbon border adjustment mechanism (CBAM), there are increasing discussions to phase-out free permits going forward.

Permit prices alone may not provide a stable price signal for investment decisions. Despite the dramatic increase of EU ETS permit prices over 2021 and 2022 (having reached about EUR 78/tCO_2 in May 2022 from EUR 34/tCO_2 in January 2021[26]) which has strengthened the carbon price signal faced by firms under EU ETS, their volatility might weaken this signal as it results in uncertainty for investors. This uncertainty lowers incentives for firms to invest in low-carbon technology and projects (Flues and van Dender, 2020[28]).

The difficulty to predict prices for the following years, in turn, also reduces the possibility for firms to plan, adapt and avoid investing in projects that a few years later may cause them to have stranded assets. Despite the introduction of the EU ETS Market Stability Reserve (MSR), carbon price support mechanisms such as those in the United Kingdom (UK) or the Netherlands (see Box 3.6.) may be useful to further address permit price volatility.

A strength of emissions trading systems is that they impose a uniform carbon price on emissions from different fuels and sectors. Contrary to existing fuel excise taxes, which are generally fuel-specific and are set per physical unit or per unit of energy and include generous exemptions, emissions trading systems permit prices are expressed per tonne of CO_2, so result in all fuels within the covered share of the sector facing the same carbon price. This can help avoid switching to fuels that may be less polluting, but remain carbon-intensive all the same, and increases efficiency, by leaving it up to the polluters themselves to decide on which fuel to cut emissions in the least costly manner. Note however, that this is not to say that fuel excise taxes cannot result in the same rate per tonne of CO_2. If first expressed per tonne per CO_2 and transformed per litre or GJ for example, this could be the case. However, this is generally not how fuel excise tax rates are set.

It is also worth stressing that the many exemptions from the Spanish fuel excise which are depicted in Figure 3.5 (no blue bar) can lead to inefficiencies and distributional concerns across firms. For example, fuels used for chemical reduction are all exempt from the national fuel excise tax. This results in a lack of incentives for mitigation emissions for that activity even though it might be highly emitting. Often such exemptions are included to address competitiveness concerns that domestic users may face compared with firms in countries where energy taxes are lower. However, the current structure of the fuel excise does not provide relief based on the actual exposure of a sector to international competition. Alternatively, in the EU ETS, measures to address competitiveness concerns relate to the trade-exposure and energy-intensity of production. Additionally, this may generate distributional concerns between firms if firms conducting chemical reduction are larger than others. Moreover, the low rates observed for coal and hence coal emissions are not aligned with the high emission intensity of this fuel. The much lower rates observed for coal (EUR 1.6/tCO_2) than for natural gas (EUR 11.6/tCO_2) do not incentivise switching to cleaner fuels. Finally, the exemption of most biofuels from fuel excise taxes is generally justified through a life-cycle perspective on biofuels. Indeed, if sustainably sourced, biofuels may be carbon-neutral over the life cycle.[27] However, biofuel combustion raises other issues such as air pollution, which are further discussed in section 3.2.3 of the analysis.

ECRs in Andalusia in 2021 deriving from national fuel excise taxes and the EU ETS were already more or less aligned with price levels that are either consistent with attaining 2030 emissions-mitigation goals or that reflect the externalities caused by CO_2 emissions. This is even more so with recent EU ETS permit prices going beyond EUR 70/tCO_2.[28] Such benchmark prices are further discussed in Box 3.5 showing that several studies find that carbon prices of EUR 30/tCO_2 in 2021, of at least EUR 60 in 2025 and around EUR 125 in 2030 would be consistent with carbon neutrality goals – under complementary policies and technological development and deployment assumptions. Regarding external cost pricing, a recent study by the European Commission (Mottershead et al., 2021[29]) highlights a central estimate for the social cost of carbon (SSC) of EUR 100/tCO_2.

Focusing on the low-end EUR 30/tCO_2 benchmark in 2021, the analysis above shows that priced emissions in both sectors of interest go beyond this benchmark, but this stems from the EU ETS. In the industry sector, about 60% of emissions are covered by the EU ETS and 76% in the electricity sector – respectively 70% and 100% when leaving out emissions from biofuel combustion. However, the price signal stems almost exclusively from the EU ETS, raising potential issues discussed above. First this implies that the benchmark is only reached for marginal rates and not average rates that take into account free allocation – especially in the industry sector, where also generous tax exemptions are prevalent. Second, price volatility may result in lower prices – and therefore low incentives for decarbonisation – in the future. This is difficult to control without a carbon price floor. Moreover, even when leaving out emissions from biofuel combustion, 23% of CO_2 emissions in the industry sector remain unpriced, and 8% priced at an average rate of about EUR 12/tCO_2. Hence, about a quarter of emissions in the industry sector face no price induced signal to mitigate emissions, and the remaining emissions face a price signal that is too low to trigger the required level of emissions mitigation.

In the coming years, the EUR 60 benchmark would be reached on emissions subject to the EU ETS if permit prices stabilise or continue increasing at the same rate – at least for marginal prices. If they increase, they could enable attaining the EUR 100 social cost of carbon estimate. However, fuel excise rates on emissions not covered by the EU ETS remain too low to induce the transformational changes that would need to take place in the industry sector. Moreover, for emissions subject to the EU ETS they provide no underlying price stability or average price signal. While this could be reformed at the national level – and more effectively and efficiently so, Andalusia could use its regional tax to help achieve these goals.

Box 3.5. Benchmark costs for carbon pricing

Externalities and net-zero targets

As a result of the impact of GHG emissions on climate, any activity involving GHG emissions results in a climate externality imposed on others. However, emitters do not necessarily internalise the full costs that their behaviour imposes on others in their decision-making and might hence produce more emissions than socially optimal.

Moreover, steadily increasing global warming caused by these GHG emissions could ultimately result in crossing tipping points beyond which sever and disruptive changes to human society would become irreversible. In line with this, the objective of the Paris Agreement is to face the threat of climate change by keeping the increase in the global average temperature to well below 2ºC above pre-industrial levels and to preferably limit the increase to 1.5°C above pre-industrial levels.[1] In order to implement this objective, countries are seeking to attain carbon neutrality by 2050 with, possibly, mid-term objectives to 2030 such as the European Union's Fit for 55 proposal.

Carbon pricing benchmarks

Related costs for GHG emissions can be established in two ways. The first relies on the calculation of the social cost of carbon (SSC) and the second on the calculation of the price of carbon that is compatible with a specific target of emission reductions (e.g. keeping the rise in global temperature from pre-industrial levels below 1.5 degrees Celsius).

A recent study by the European Commission (Mottershead et al., 2021[29]) focuses on calculations of the SSC[2] and, based on a wide range of studies, highlights a central value of EUR 100/tCO_2 through 2030.

Several studies use models to establish carbon prices consistent with mid-term or longer-term emission reduction objectives. These models depend on assumptions about energy price pathways, current and future technologies, complementary policies, and carbon capture and storage development and deployment. Kaufman et al. (2020[30]) find that for the United States, carbon prices to reach 2030 goals should be between USD 34 and 64/tCO_2 in 2025 and at USD 77 and 124/tCO_2 in 2030. These figures are slightly lower than the IEA's latest carbon price trajectory for the electricity, industry and heat sectors in advanced economies (IEA, 2021[31]), which finds prices at EUR 75/tCO_2 in 2025 and EUR 130/tCO_2 in 2030.

Notes:
1. 2°C has been established as a critical global temperature after which changes may become dramatic and irreversible; 1.5°C would further reduce the risks and impacts of climate change.
2. The SCC is defined by Nordhaus (2014[32]) as the economic cost caused by an additional tonne of CO_2 emissions or its equivalent; it rests on the concept of internalising externalities and includes considerations on inter- and intra-generation equity.

The Andalusian Tax on the Emission of Gases into the Atmosphere hardly adds to EU-wide and national-level price signals both because of its coverage and because of its rate levels. Indeed, its marginal rate can never be higher than EUR 0.07/tCO_2.[29] In practice, no installation goes beyond the fourth bracket of the effective schedule, implying a maximum marginal rate of EUR 0.06/tCO_2. Out of about 90 installations covered by the EU ETS or the IEGA, 59% are covered by both, 13% only by the IEGA and 28% only by the EU ETS. Only one installation covered by the IEGA faces a positive tax liability. The average (weighted by CO_2 emissions) marginal rate faced by installations covered by both is EUR 0.036/tCO_2. Out of the 13% of installations covered by IEGA and not the EU ETS only one installation faces a positive tax liability (with a marginal rate of EUR 0.025/tCO_2) – the others face a null tax.

Many reasons could underlie the introduction of the IEGA: (i) base broadening; (ii) increasing carbon price levels to benchmark costs; (iii) providing a backstop to volatile EU ETS permit prices or (iv) raising revenue. The first three would be aligned with environmental considerations and are discussed below.

Base broadening would increase carbon pricing coverage of emissions to smaller firms or other sectors but given the large overlap between EU ETS covered firms and firms subject to the IEGA, the tax has not achieved such an objective. Moreover, the rates faced by firms covered only by the IEGA are almost all null, and the IEGA thus does not strongly extend carbon-price coverage to emissions in the industry sector that currently do not face a carbon price. As highlighted in the above analysis, in effect, it does not extend coverage to other sectors (e.g., agriculture) either.

Given the very low marginal rates, the IEGA hardly increases carbon price signals either. These rates do not bring marginal price levels close to benchmark costs, nor do they provide enough incentives to decrease emissions by a significant amount. Recent evidence (D'Arcangelo et al., 2022[33]) shows that a EUR 10/tCO_2 increase in effective carbon rates would lead to a decrease of about 4% of emissions in the industry and electricity sectors in the long run. As a reminder, the average (weighted by CO_2 emissions) marginal IEGA tax rate faced by installations covered by both the IEGA and the EU ETS is of about EUR 0.04/tCO_2. However, the responsiveness estimates just mentioned imply that an increase in rates of EUR 0.04/tCO_2, imply an decrease in emissions for these installations of 0.016% in the long run – much below the efforts currently required to reach net zero emissions.

At such low rates, the IEGA cannot provide a backstop to volatile permit prices. Indeed, as highlighted above, such rates cannot provide a strong, stable and complementary price signal to the EU ETS. Moreover, its design does not lend itself to such an opportunity. This could occur if it were designed with similar features to the UK carbon price floor or the Dutch carbon levy described in Box 3.6. , with credible price signals, aligned to a certain extent with marginal abatement costs in these sectors. Moreover, the price signal could gradually increase over time to enable firms and investors to adapt and plan.

The opportunities for an Andalusian-level carbon tax of increasing base coverage (to smaller firms for instance), of increasing price levels or of providing a strong, stable and complimentary price signal to the EU ETS could come with political, competitiveness, leakage and administrative costs. The extension to smaller firms could engender high administrative costs if the tax were to be applied downstream, as the emissions measurement costs could be very high, given that their emissions are currently not measured – neither for the EU ETS nor for EPER. Moreover, the difficulty of introducing a significant unilateral carbon tax in smaller jurisdictions must be acknowledged. First, given that climate change is a global issue, the impacts of which are not necessarily felt locally, political support for an increase in rates may be limited. Second, competitiveness concerns for industries that are highly emitting already exist at a national level, and may be exacerbated at a regional level, where firms could relocate easily to neighbouring regions (which would result in carbon leakage). Combining carbon pricing with complementary policy measures can help alleviate competitiveness concerns, while keeping the incentive to mitigate emissions in place, as discussed below. Finally, in terms of effectiveness, climate change and GHG mitigation are best dealt with at a national or even supranational level. Indeed, this enables emissions cuts where they are the cheapest at a much larger scale and can help avoid carbon leakage. Hence, taxing greenhouse gas emissions is not necessarily recommended at a regional level.

The potential administrative issues highlighted above may be tackled through various means. The administrative burden of monitoring, reporting and verifying that would be faced if a downstream tax were to be applied to smaller firms could be tackled through an upstream implementation of the Andalusia tax. This could also be done through the introduction of a carbon tax component on fuel taxes, aligned with their CO_2 emissions. However, this may only be possible at a national level.

Potential political, competitiveness and relocation concerns from unilateral carbon pricing were recently tackled by the Netherlands who introduced a gradually increasing carbon price floor in industry, through a careful phase in of base and rates, and the provision of (costly) subsidies. The Netherlands introduced a national carbon levy in 2021 (Box 3.6.). Political hurdles were addressed by engaging in dialogue with key stakeholders in the industry. Competitiveness issues were addressed by a careful and pre-announced phase-in of base and rates (see Table 3.3). This decreases uncertainty for investors and enables firms to adapt and plan, in order to switch to cleaner modes of production. Going forward, this also avoids the risk of stranded assets, and ensures firms remain competitive in a cleaner production environment. Finally, the careful use of technology subsidies to ease the transition for firms was another way competitiveness concerns were tackled by the Netherlands. Such subsidies can be at the research and development (R&D) or at the adoption and deployment level. These could also help deal with affordability concerns facing firms, especially if the carbon price were increased.

Finally, the tax could cover other GHGs not covered by a national tax, such as methane or nitrous oxide, but the issue of the lack of effectiveness of tackling climate change at a regional level would remain. It may make more sense to try and tackle more local issues, such as air pollution, which is what this Section now turns to. The possible extension of the tax to farming is addressed last.

Box 3.6. Carbon pricing floors in practice

The Carbon Price Floor in the United Kingdom

In 2013, the United Kingdom (UK) introduced a carbon price floor (CPF) for fossil fuel emissions in the electricity sector covered by the EU ETS (and now covered by the UK ETS). The CPF consists of two elements: the ETS allowance price and a carbon price support (CPS) mechanism, which is a fixed element charged on top of permit prices. In 2013, the CPS was at GBP 9/tCO_2 emissions and rose to GBP 18 in 2015 (Hirst, 2018[35]). In 2018, this allowed the average effective carbon rate in the electricity sector to reach about EUR 26/tCO_2 while the average EU ETS permit price over 2018 was at about EUR 16/tCO_2.

Leroutier (2022[34]) finds that the UK CPS induced emissions from the UK power sector to drop by 20% to 26% per year on average between 2013 and 2017.

The Dutch carbon levy

The Netherlands, as part of its 2020 Climate Agreement, implemented a new carbon levy for industry on 1 January 2021. The new carbon levy complements the permit prices from the EU ETS and effectively puts a domestic price floor for Dutch industrial emissions. It consists of a floating contribution added on top of the EU ETS price – so that if the price of emissions allowances exceeds the floor price, the floating contribution becomes zero. The total price (EU ETS price plus carbon levy) is intended to increase gradually over time from EUR 30/tCO_2 in 2020 to EUR 125/tCO_2 in 2030, as shown in Table 3.3. The carbon price path was designed based on current and planned abatement cost curves in the Dutch industry sector.

This carbon levy was implemented in the industry sector, where the risk of EU ETS price drops threatens investment in low-carbon assets. The price path was announced from the start of its implementation (with a foreseen review after five years) to allow firms to plan and invest accordingly. To give firms additional lead time, the levy base phases in over time.

Table 3.3. The Dutch carbon price path for industrial emissions

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Floor price (in EUR per tonne of CO_2)	30	40.56	51.12	61.68	72.24	82.80	93.36	103.92	114.48	125.04

Source: Adapted from Anderson et al. (2021[35]).
Note: Additional details on the approach taken in the United Kingdom and the Netherlands are provided in Annex Table 3.B.3 and Annex Table 3.B.6.

3.2.3. Air pollution pricing in Andalusia

In Andalusia, the only pricing instrument that applies directly to air pollutant emissions is the IEGA. By pricing GHG emissions, the EU ETS and national fuel excise taxes affect fuel consumption and hence air pollution (OECD, 2019[5]), but the effect is indirect. Hence these latter instruments are not discussed in this section and the focus is on the IEGA.

The calculation of the taxable base implies that marginal rates faced by an additional tonne of NOx (resp. SOx) range between EUR 0 and EUR 140 (resp. EUR 0 and EUR 93.3). Table 3.4 presents these rates according to the bracket which they belong to. The analysis of the 70 installations facing the IEGA in 2019 shows that in practice, 50% of installations face zero marginal rates for their NOx and SOx emissions and that 37% of installations face marginal rates of EUR 50/tNOx of EUR 33.3/tSOx. The maximal marginal rates faced are of EUR 120/tNOx and EUR 80/tSOx. This results in emissions-weighted average marginal rates of about EUR 40/tNOx and EUR 21/tSOx.

Table 3.4. Effective marginal rates faced by the emission of one extra tonne of NOx or SOx, and respective share of firms subject to these rates

Base (in polluting units)	Marginal rate faced by the emission of one extra tonne of NOx (in EUR/tonne of NOx)	Marginal rate faced by the emission of one extra tonne of SOx (in EUR/tonne of SOx)	Estimated share of installations subject to the specific marginal rate in 2019
0-3	0	0	50%
3.0001-13	50	33.3	37%
13.0001-23	80	53.3	9%
23.0001-33	100	66.7	4%
33.0001-53	120	80	
More than 53	140	93.3	

Source: Author's own calculations based on data provided by the Junta de Andalucía.

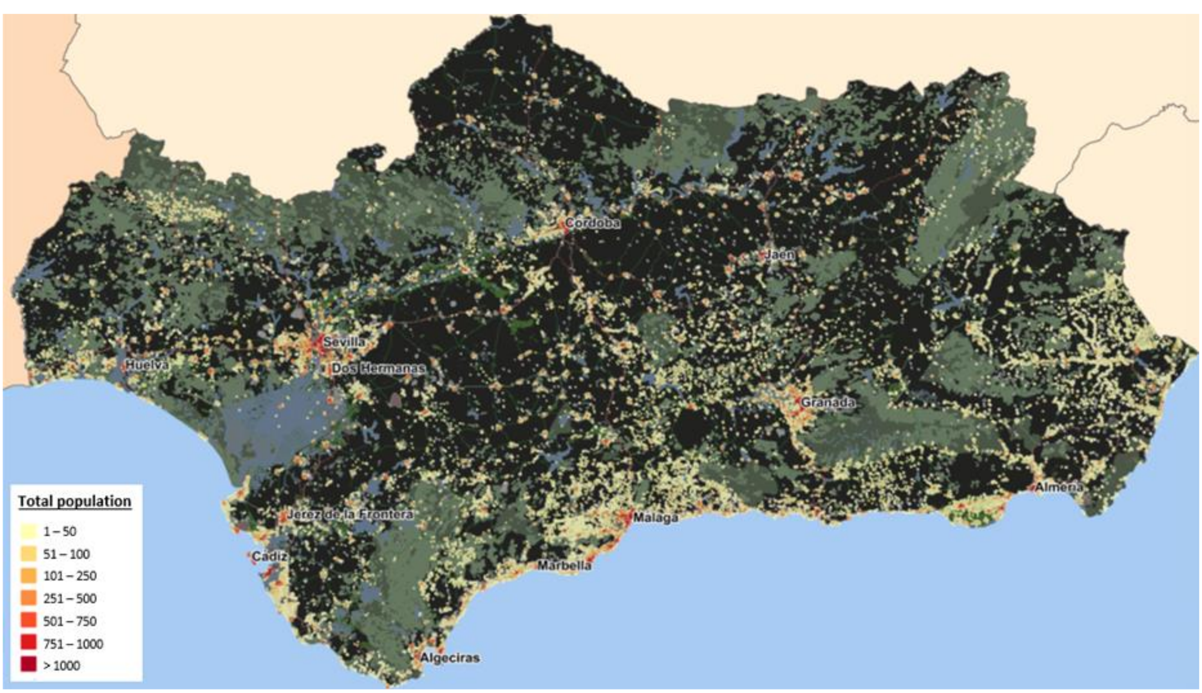
Usual estimates of NOx and SOx-associated costs generally show higher costs for NOx than for SOx. However, recent estimates provided by the European Commission (Mottershead et al., 2021[29]), find NOx costs of EUR 6/kg/year on average (i.e. EUR 6 000/t/year) and SOx costs of EUR 7.9/kg/year on average (i.e. EUR 7 900/t/year). However, these costs alone should not impact the level of tax set for these pollutants. The price elasticity of these emissions should also be accounted for.

Few elasticity estimates of air pollutant emissions to taxes exist. Descriptive evidence and models find that such taxes do coincide with decreases in emissions (Juřík and Braathen, 2021[36]; Mardones and Cabello, 2019[37]). Moreover, with increasingly emerging abatement technologies and the decrease in their price, elasticities are bound to increase in the coming years. Decreasing air pollutant emissions from stationary sources can be done through fuel switching, through the adoption of technologies, in particular abatement technologies, through efficient production processes or through decrease in production. The first three options are increasingly within reach for firms and enable them to maintain their output while decreasing local air pollution. Shapiro and Walker (2018[38]) find that the decrease by 60% of manufacturing firms' air pollution in the United States was accompanied by a substantial increase in manufacturing output. They show that these emissions reductions were primarily driven by changes in emissions intensity.

The Andalusian **rates** (EUR 63/tNOx and EUR 56/tSOx on average – i.e. weighted by emissions) are **in the lower range of air pollution tax rates** in other countries but similar to other rates observed in Spain. In Catalonia, they are of EUR 45/tSOx and EUR 75/tNOx and in Aragon they are equal to EUR 50/t for both SOx and NOx. In the Czech Republic, they are of EUR 152/tNOx and EUR 191/tSO_2. They are of the same order of magnitude than minimum rates in Chile (see Box 3.7). Increasing these rates might be considered an option, but this would also depend on technologies available and their costs.

A**ir pollution health externalities are local and depend in particular on local population density**. Population density is very heterogeneous in Andalusia, mostly concentrating around the largest cities and on the Southern coast (Figure 3.7). Hence, at the same emissions level, the air pollution impact on human health of a firm located in the Northern part of Andalusia should be lower than that of a firm located, for example between Malaga and Marbella.

Figure 3.7. Population density in Andalusia, 2020



Source: https://www.juntadeandalucia.es/institutodeestadisticaycartografia/VisorGrid/visor.htm#, generated on 15 November 2022.

The differential impacts of air pollution depending on population density are reflected in the Chilean green taxes on PM, SO_2 and NOx from stationary sources that were introduced in 2015. Box 3.7 provides additional detail on the design of this tax, and the different local conditions taken into account. Of course, many effects may be accounted for when considering the impacts of air pollution (wind for example), but at the first order, population density matters for health-related issues. The Chilean green taxes also account for levels of pollutant concentration: the higher the initial level of air pollutant concentration, the worse is the impact of the emission of an extra tonne of air pollutant.

Box 3.7 The Chilean Green Taxes on PM, SO_2 and NOx

Tax design

The Chilean taxes on PM, SO_2 and NOx were introduced as part of Chile's General Tax Reform Bill (Ley 20.780) passed in September 2014.

Each tax base consists in annual emissions of liable facilities. Rates were determined in terms of the respective marginal costs of each pollutant. They also depend on how "saturated" a zone is and on population density. These are two main elements in determining the health damages imposed by these air pollutants.

For each pollutant "i", tax rates depend on both characteristics of the pollutant and of the municipality "j" where it is emitted:

$$T_{ij} = 0.1 \times AQ_j \times SC_i \times Pop_j$$

Where:

- **T_{ij}** –tax rate on pollutant "i" in municipality "j" in USD/tonne.
- Characteristics of pollutant "i" are
  i. **SC_i** –social cost of pollutant "i", presented in Table 3.5.
- Characteristics of municipality "j" are
  i. **AQ_j** –air quality coefficient in municipality "j". AQ is equal to 1.1 if the municipality is in a latent zone, and 1.2 if in a saturated zone.
  ii. **Pop_j** –population in municipality "j".

Table 3.5. Social costs of pollutants

Pollutant	PM	SO2	NOx
Cost (USD/tonne)	0.9	0.01	0.025

Source: Pizarro (2019[39])

Chile also has a carbon tax, which does not depend on local characteristics as climate change impacts are not local.

Saturated and latent zones

In Chile, areas that exceed the air pollution standards as defined by the Chilean Air Quality Standards of CONAMA (*Comisión Nacional del Medio Ambiente*) are classified as non-attainment areas (similar to the United States). An area is then designated as a "latent" non-attainment area when pollutant concentrations are between 80 and 100% of the standard, and as a "saturated" non-attainment area, when pollutant concentration exceeds the set standard (Díaz-Robles et al., 2011[40]).

Comparison of tax liabilities for two firms located in different density areas

The tax structure implies that two firms located in municipalities respectively of 20 000 inhabitants and 500 000 inhabitants would have very different tax liabilities, even if they emitted the same amount of air pollutants. The latter firm's total tax liability would be 25 larger than the former's. For NOx, the rate would go from USD 55/tNOx to USD 1 375/tNOx and for SO_2, it would go from USD 22/tSO_2 to USD 550/tSO_2.

Note: Additional details are provided in Annex Table 3.B.1.
Source: Pizarro (2019[39]), Diaz-Robles et al. (2011[40]).

Taking into account **population density or levels** helps to better price external costs associated to local air pollutants and can discourage firms to settle in densely populated areas. Better pricing of environmental externalities implied by air pollution by adapting the tax to local characteristics is important. A price signal aligned with local population levels can help bring pollution to levels in line with how harmful they are. Moreover, this may be more easily sustained politically as well because air pollution impacts are generally very localised and occur on a shorter time horizon than climate change, so are felt more strongly by the population. Another effect can arise, which is to go beyond a reduction in existing firms' emissions and discourage new firms from settling in populated areas, where their activity would be much more harmful than in low density areas. As can be seen in the comparison presented in Box 3.7 , such a design of air pollutant taxes can make it prohibitively expensive for firms to settle in such areas. Hence such an adjustment to the tax could allow both intensive (reduction of emissions in a location) and extensive margins (less new polluting firms in a location) adjustment to be at play.[30] Accounting for **pre-existing air pollution density levels** (based on indicators such as the US AQI) would also help the design of the tax to better aligned with external costs and have similar effects as those just described.

Regional environmental authorities could provide high-resolution baseline air pollution maps, which would allow these additional factors to be incorporated in the design of air pollutant taxes in Andalusia. Dispersion studies, which would identify the exact areas affected by pollution, could be combined with the sophisticated population georeferencing that is maintained by the Institute of Statistics and Cartography of Andalusia (IECA). In addition to population values, the IECA provides details on other demographic, health, economic and social variables that would enable air pollutant taxes to account for other parameters related to population vulnerability that influence the estimation of the health impact of pollution. However, careful attention should be given to balancing design and administrative complexity with the precise alignment of rates with environmental and health externalities. Indeed, many factors influence the health and environmental impact of air pollution and accounting for all of them would make these taxes unmanageable – so a focus on the main factors is recommended.

Extending the base of the tax to cover PM emissions and emissions from the combustion of biofuels and biomass could be considered as options. Indeed, given the tax already covers NOx and SOx, which are closely linked to PM (see section 3.1.2), the extension to PM would be straightforward to implement. This could have a sizeable impact on one of the most harmful air pollutants on human health. Moreover, while the exemption of biofuel combustion from a tax on CO_2 emissions can be justified from a life-cycle perspective (see section 3.2.2), this is not the case concerning air pollutants. Indeed, biomass combustion may worsen local air pollution, especially from particulate matter (PM) and nitrogen oxides (NOx) emissions, which is not compensated for from a life-cycle point of view. The 2021 proposed revision to the EU ETD (European Commission, 2021[41]) goes in this direction, by considering minimum taxation rates for biofuels.

The rates might have been set to ensure progressivity between more or less polluting firms if this is linked to their size, but **distributional impacts or equity considerations can, and generally should, be addressed through other policy instruments**. Revenue recycling options could be considered, such as support to firms for adoption of abatement technologies. For example, the revenues of the French tax on air pollution were earmarked for abatement subsidies and the financing of air quality surveillance systems (Millock and Nauges, 2003[42]).

Regarding potential competitiveness issues, the Spanish context is such that these might be limited. Indeed, the examples of Aragon and Catalonia show that higher rates can be applied in the long term. Moreover, the higher rates or similar rates observed in other Autonomous Communities also alleviate competitiveness concerns for Andalusia with respect to other Spanish firms. In this respect, the White Book for Tax Reform in Spain recommends maintaining existing regional taxes and introducing a national tax that sets a minimum tax base and tax rates.

Finally, political hurdles might be easier to address in the context of local air pollution, as, contrary to GHG emissions, effects are very local and can be felt in the short term. Moreover, as highlighted in section 3.1.2, reducing air pollution may also be helpful for firms' economic output.

3.2.4. Pricing emissions from the agricultural sector

In Andalusia, the agricultural sector is responsible for a major share of air pollutant emissions, especially for NOx, NH_3 and PM emissions, as well as of GHG emissions other than CO_2 – it is the main source of N_2O and CH_4 emissions. Managing emissions from the farming sector hence requires the coverage of different emissions. Pricing these air pollutant emissions as well as N_2O and CH_4 emissions in this sector would be important to align with the Polluter Pays principle. Moreover, the growth of farming areas and the expansion of urban centres increases the exposure of the Andalusian population to these local air pollutants.

Given the difficulty of measuring emissions in this sector, which are generally diffuse (as opposed to point source), the administrative organisation of managing emissions in agriculture may need to be different from other stationary source sectors.

Given the economic importance of the agricultural sector especially in Andalusia, political hurdles may be important. This stresses the importance of building a strong dialogue and cooperation with this sector. Agriculture holds an important part in the Andalusian economy. It made up 6.7% of Andalusian Gross Value Added (GVA) in 2021[31] and represented 30.8% of Spanish agricultural GVA (INE, 2023[43]) – and agricultural areas in Andalusia have been increasing in the past years (Junta de Andalucia, 2019[44]). The NOx and direct PM emissions from the agricultural sector in Andalusia mostly stem from fuel combustion. This is best managed by fuel excise duties that reflect the fuels' environmental damage, as recently put forward by the proposed EU ETD reform. In the face of such high fuel emissions, reduced rates for the agricultural sector should be avoided.

NH_3 emissions in Andalusia almost entirely stem from agricultural activities. These include livestock waste and the heavy use of nitrogen fertilisers. For poultry farms, manure is the main NH_3 emitter. NH_3 then combines with other air pollutants from combustion (NOx and SOx) to create $PM_{2.5}$ (Bauer, Tsigaridis and Miller, 2016[45]; Lelieveld et al., 2015[46]). Some researchers point to the need of reducing nitrogen fertiliser use, while other researchers argue that the decrease in NOx and SOx emissions would be enough to limit the creation of PM and hence limit health damage of NH_3 emissions.[32] While in many regions and countries, NOx mostly stems from the road transport, electricity and industry sectors, in Andalusia, this gas is also a result of agricultural activities. Hence, limiting PM emissions in Andalusia could not only rely on other sectors, and the agricultural sector would have to be involved. Moreover, NH_3 also impacts soil and water acidification (see Part III, Section 6) and may harm animals themselves, resulting in short and long-term losses for farmers themselves.

NH_3 emissions might be better managed through the taxation of intrants and livestock numbers or through regulation and promotion of different agricultural practices. Indeed, NH_3 emissions are complex to measure directly (Herrero et al., 2021[47]). Hence, these emissions could for instance, be better managed through taxation of nitrogen fertilisers. A tax on livestock numbers, however, might not give the right incentives to decrease emissions and a tax on nitrogen fertilisers could be avoided by purchasing this intrant outside of regional borders. Regulation, through the promotion of certain agricultural practices could also contribute to decreasing emissions, through for example livestock waste management methods which are less polluting. Moreover, the type of manure management system that is used in livestock and poultry production can also affect emission levels (Dunkley and Dunkley, 2013[48]). Promoting the use of less polluting manure compositions and management can constitute a key element in decreasing NH_3 emissions in the sector. Finally, sustainable management practices to enhance nitrogen use efficiency are also key to mitigating NH_3 as well as N_2O emissions. Pan et al. (2022[49]) propose options.

Regarding other GHG emissions, CH_4 mostly stems from livestock, while N_2O emissions result from both livestock and soil management. NH_3 is also a precursor to N_2O.

Current proposals for the taxation of farm-level emissions include considerations on nitrogen fertiliser application as well as livestock rearing. Based on the GHG footprint of mineral fertilisers, Anderson and Bonnis (2021[50]) propose an average rate of EUR 1 to 2 for a tax on the surplus application of nitrogen. New Zealand is, at the time of writing, one of the first countries to consider taxing GHG emissions at a farm level. This is taking place within a long-term process of cooperation and dialogue with farmer associations,[33] and in a context where agriculture is responsible for about half of nation-wide emissions. The current consultation document (Ministry for the Environment and Ministry for Primary Industries, 2022[51]) proposes a model which accounts for farm area, stock reconciliation, livestock production data and total synthetic nitrogen fertiliser use. Such an approach could also be interesting for the taxation of NH_3 emissions.The risk of relocation to other Autonomous Communities or Portugal is limited. Political hurdles, however, may be important, as can be seen with the protests taking place in New Zealand following the government's confirmation of plans to price farm-level GHG emissions.[34] This is especially so when the sector is an important backbone of the local economy.

This stresses the importance of accompanying farmers through the transition, of enabling them to measure their emissions and to propose viable solutions for them to decrease emissions. A slow phase-in of tax rates can enable farmers to plan and adapt. Programs such as OverseerFM[35] can help farmers better manage their intrants and get a better grip of their environmental impacts. The promotion of new technologies and of better farming practices can also provide options for farmers to switch to less emitting practices. The New Zealand proposal also includes payments to farmers using approved mitigation technologies or approved on-farm vegetation. In the long run, it also includes revenue recycling in part to funding for R&D to lower on-farm emissions.[36] Improvements would be built into the system, as can already be seen with the consultation process, which leaves many questions open for farmer organisations to get a say (Ministry for the Environment and Ministry for Primary Industries, 2022[51]). Payments to farmers could also be made on the basis of adoption of recommended farming practices and could be based on proceeds of the tax. The recently published White Book for Tax Reform in Spain,[37] suggests a gradual introduction of such taxes along with a share of the revenues dedicated to technological improvements in the sector to facilitate their introduction.

Regarding GHG emissions, the recommendation for dealing with such emissions at least at the national level remain, though an engagement with farmers at this stage would be an important step for future pricing or regulation measures to be introduced in this sector. Moreover, given that the Andalusian agricultural sector represents an important share of the Spanish agricultural sector, dealing with GHG in this sector at the regional level could be justified.

3.3. Key findings and strategic recommendations

The Andalusian tax on the emission of gases into the atmosphere (IEGA) follows good administrative practice in designating covered entities through physical characteristics and plays a pioneering role in air pollutant emissions pricing in Spanish regions. It also presents an interesting feature through its effort to cover CO_2 emissions as well as NOx and SOx emissions.

However, the IEGA presents a design that is complex, which might mute its price signal and provide unintended incentives. This is mainly due to the bundling of all three gases into one single base, and through the calculation of polluting units. An application of a tax for each gas, applied per tonne of emission would be more straightforward, would make the price more salient, and would enable a better alignment of price levels with environmental costs and mitigation targets.

The current progressivity of rates as a function of a firm's emissions is not aligned with environmental economic principles (in particular cost-efficiency). According to such principles, the tax schedules should be flat – i.e. have a single rate with no exemption threshold (but could depend on location for air pollution). The progressivity of rates might be to deal with affordability or equity considerations, by giving a minimum emission right to all installations and making each tonne of emission more costly above certain thresholds. However, equity and affordability concerns are best dealt with by complementary instruments providing support to firms, which can be direct or indirect. Indirect support could include a time-progressive phase in of base and rates. Direct support could include subsidies for green technology adoption. To ensure equity, subsidies could be tailored to firm size. Such measures are costly and could be implemented using the general budget or the revenue from green taxes (revenue recycling). Such measures could also help deal with competitiveness issues.

Given that GHG emissions are a global issue, the regional level may not be the most suitable governance level for regulation in this area. CO_2 emissions in the industry and electricity sectors are already covered at the European level by the EU ETS and at the national level by fuel excise taxes. While the level of fuel excise taxes could be reformed to better align with benchmark carbon costs, this should be done at the national level.

Air pollutant emissions are principally a local issue, which makes them a suitable target for mitigation for regional level action. Current tax rates levied in Andalusia are on average similar to other rates observed in Spain and in the lower range when compared to other countries with similar taxes. This is useful for coordination with other Spanish Autonomous Communities but may be too low all the same to encourage enough abatement efforts. Having a better idea of target levels for SOx and NOx emission reductions as well as available mitigation technologies and costs could help adjust the price levels to reach such targets. If the objective is to reflect external costs for health in tax rates, Andalusia could consider including population density and pollution levels in the calculation of tax rates, similar to Chile. This would better align price levels with health and environmental costs (which are higher in more populated areas) and possibly discourage firms from settling in densely populated areas – where the negative impact of air pollution is higher – going forward.

An extension of the tax to PM emissions from industrial and electricity sector stationary sources could be considered. This would be relatively straightforward to implement given that NOx and SOx emissions are already taxed. Moreover, this would deal with one of the most harmful air pollutants for human health.

Finally, an extension of the tax to the farming sector would entail extending the coverage to other pollutants, such as NH_3 and to other GHGs such as N_2O and CH_4 as well as adapting the emissions measurement methods to this sector. This would require dialogue and engagement with stakeholders, proposals for and existence of alternatives, possibility of measurement of farm-level emissions and support for farmers in the transition. Examples based on the New Zealand 2022 proposal for taxing farm-level emissions are exposed. Dialogue with farmers should also stress the benefits that better air quality and mitigated climate change would have on their sector and employees.

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Annex 3.A. OECD Effective Carbon Rates: additional information

Annex Table 3.A.1. Sectoral decomposition in the OECD Effective Carbon Rates database

Sector	Definition
Road	All energy used in road transport.
Electricity	All fuels used to generate electricity for domestic use (rather than the amount of energy generated from each fuel). Note that fuels used in the auto-generation of electricity are classified under industrial production.
Industry	All energy used in industrial processes, in heating (incl. inside industrial installations) and in the transformation of energy, including fuels used for auto-generation of electricity in industrial installations.
Buildings	All energy used for commercial and residential heating.
Off-road	All energy used in off-road transport (incl. pipelines, rail transport, domestic aviation and maritime transport).
Agriculture & fisheries	Energy used in agriculture, fisheries and forestry. Energy used in on-road transport in this sector is included in the road transport sector.

Source: OECD (2016[6]).

Annex Table 3.A.2. Fuel category breakdown in the OECD Effective Carbon Rates database

Energy type	Fuel category	Energy Products
Fossil fuels	Coal and other solid fossil fuels	Anthracite; Bitumen; Bituminous coal; Brown coal briquettes; Oven coke; Coking coal; Gas coke; Lignite; Oil shale; Patent fuel; Peat; Peat products; Petroleum coke; Sub-bituminous coal
	Fuel oil	Fuel oil
	Diesel	Gas/diesel oil excluding biofuels
	Kerosene	Jet kerosene; Other kerosene
	Gasoline	Aviation gasoline; Jet gasoline; Motor gasoline
	LPG	Liquefied Petroleum Gas
	Natural gas	Natural gas
	Other fossil fuels	Additives; Blast furnace gas; Coal tar; Coke oven gas; Converter gas; Crude oil; Ethane; Gas works gas; Lubricants; Naphtha; Natural gas liquids; Other hydrocarbons; Other oil products; Paraffin waxes; Refinery feedstocks; Refinery gas; White and industrial spirit
Other combustible fuels	Non-renewable waste	Industrial waste; Non-renewable municipal waste
	Biofuels	Bio jet kerosene; Biodiesels; Biogases; Biogasoline; Charcoal; Municipal waste (renewable); Non-specified primary biofuels and waste; Other liquid biofuels; Primary solid biofuels

Note: Energy products are defined as in IEA (2020[52]), World Energy Statistics and Balances.
Source: OECD (2019[5]).

Annex 3.B. Detailed case studies: stationary sources

This section presents selected case studies in the domain of greenhouse gas emissions and air pollution across the world with a focus on the industry and electricity sector

Chile: Green Tax

Annex Table 3.B.1. Green tax (Chile)

Legal bases	Law 20.780 (2014)
Objective	To tax local air pollutant and GHG emissions from stationary sources generating thermal energy.
Level of responsibility	Central government (Chile)
Tax setter(s)	Central government (Chile)
Revenue beneficiary(ies)	Central government (Chile)
Tax payer(s)	Polluting industries generating thermal energy with power capacity greater than or equal to 50 MWt.
Tax base (including main exemption(s), credits or deductions)	Annual mass emissions in tonnes for CO_2, SO_2, PM and NOx classified according to the scale of their impact. The tax levied on the CO_2 component does not apply to emitting sources using biomass.
Tax rate(s) (including their calculation)	The tax calculation is different for SO_2, PM and NO_X as compared to CO_2, as the former are have a local negative impact, whereas the latter has a global impact. For PM, NOX, and SO_2, the tax is 0.1 per tonne emitted multiplied by the social cost of pollution, the local population, and an air quality coefficient using the formula: $$Tij= CCAji \times CSCpci \times Pobj.$$ Where Tij: tax rate per tonne of pollutant "i" emitted in municipality "j" measured in USD/ton, CCAji: air quality coefficient in municipality "j" for pollutant "i", CSCpci: social cost of pollution per capita of pollutant "i", and Pobj: population of municipality "j". The air quality coefficient applies to zones declared saturated or latent for a particular pollutant. In the former case, the coefficient is 1.2; in the latter, it is 1.1. The social costs per capita of PM, SO_2, NO_X are presented in Annex Table 3.B.2. For CO_2, the tax rate is USD 5 (EUR 5.02) per tonne.

Governance and implementation	Multiple government bodies work together in the implementation of the tax: • The Ministry of Environment establishes the methodologies and systems to monitor, report, and verify emission, • The Revenue Service receives declarations from establishments subject to the tax, • The General Treasury receives the payments. The implementation of the tax system required creating a registry system, developing and designing the Monitoring, Reporting, and Verification System (MRV) by the Ministry of the Environment. In addition, it was also necessary to promote social acceptance of the tax with taxable entities and run capacity-building workshops to instruct and support them in using the emission reporting systems.
Environmental, social & health impacts	An assessment prepared for the Ministry of Environment found a reduction of 1.1% in CO_2 emissions, of 7% in particulate matter present in the air, of 2% in NOx emissions, and of 0.01% in SO2 emissions between 2017 and 2018.

Source: (García Bernal, 2018[52]; Pizarro, 2019[53]; Ainzúa et al., 2020[54])

Annex Table 3.B.2. Social costs of pollutants per capita

Pollutant	PM	SOx	NOx
Cost (USD/tonne)	0.9	0.01	0.025

Source: (Pizarro, 2019[53])

The Netherlands: National Carbon Levy for Industry

Annex Table 3.B.3. National carbon levy for industry (the Netherlands)

Legal bases	National Climate Agreement of 2020
Objective	To supplement existing climate policy instruments in order to achieve the carbon emission reduction target of 14.3 million tonnes in industry by 2030.
Level of responsibility	Central government (the Netherlands)
Tax setter(s)	Central government (the Netherlands)
Revenue beneficiary(ies)	Central government (the Netherlands)
Tax payer(s)	Installations that are part of the EU ETS, waste incineration plants and nitrous oxide installations
Tax base **(including main exemption(s), credits or deductions)**	The tax base is the emission of CO_2 measured in tonnes. This mechanism follows the logic of the EU ETS system, meaning that emissions above the baseline are taxed, while emissions below the baseline can be traded. The baseline is defined by "dispensation rights", which analogues the levy to free allocation. These rights are the product of the installation's output, the EU ETS benchmark emissions and an annual reduction factor (Annex Table 3.B.4) that decreases yearly. They can be traded via bilateral contracts between entities.
Tax rate(s) **(including their calculation)**	The carbon levy adds a floating contribution on top of the EU ETS allowance price to yield a fixed price floor per tonne of CO_2. The total levy represents the sum of the floating national part and of the EU ETS price. It started at EUR 30 per tonne in 2021 to rise gradually to EUR 125 per tonne in 2030 with an annual increase of EUR 10.56 per tonne of CO_2 (Annex Table 3.B.5).
Governance and implementation	The national carbon levy has been developed as part of the National Climate Agreement in order to achieve the objective of greenhouse gas emission reduction of 49% by 2030 compared to 1990 levels in the Netherlands. Several stakeholders have been involved to draft the Climate Agreement, chaired by the central government, among which industry, labour unions, subnational governments, non-for-profit organisations (NGOs).
Environmental, social & health impacts	The expected environmental impact is to achieve its target of 14.3 million tonnes in industry CO2 emissions by 2030.

Source: (OECD, 2021[55]; European Commission, 2021[56])

Annex Table 3.B.4. Reduction factor to define levy-free base

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Reduction factor	1.2	1.14	1.09	1.03	0.97	0.92	0.86	0.8	0.74	0.69

Source: (OECD, 2021[55]).

Annex Table 3.B.5. Statutory price trajectory of carbon levy in 2021 (EUR/t CO_2)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Levy rate	30	40.56	51.12	61.68	72.24	82.8	93.36	103.92	114.48	125.04

Source: (OECD, 2021[55]).

The United Kingdom: Carbon Price Floor

Annex Table 3.B.6. Carbon price floor (the United Kingdom)

Legal bases	Finance Act 2011
Objective	The Carbon Price Floor (CPF) is a United Kingdom (UK) government's tool established to supplement the EU ETS (initially) and now the UK ETS and encourage low carbon investment.
Level of responsibility	Central government (the United Kingdom)
Tax setter(s)	Central government (the United Kingdom)
Revenue beneficiary(ies)	Central government (the United Kingdom)
Tax payer(s)	Owners of electricity generating stations or operators of combined heat and power stations
Tax base **(including main exemption(s), credits or deductions)**	The tax base of the CPF is tonnes of CO_2 and the tax base of the Carbon Price Support (CPS) depends on the fuel (natural gas in kWh, liquified petroleum gas or other gaseous hydrocarbons in a liquid state in kg, and coal and other solid fossil fuels in GJ on Gross Calorific Value). The only exemptions apply to generators that provide electricity supplies in emergency cases (i.e. when a building's usual power supply is cut) and generators with a rated thermal input smaller than 2 MWth.
Tax rate(s) **(including their calculation)**	The CPS, which is specific to the UK, tops up UK ETS (initially EU ETS) allowance prices to the CPF target. It applies to fuels used for electricity generation, as shown in Annex Table 3.B.6. The UK Treasury is responsible for setting CPS rates for the three following years and indicative rates for the next two years. The rates are calculated as follows: CPS rate = (CPF – market carbon price) * (emission factor of the fuel) The difference between the CPF target and market carbon price represents the 'carbon price support rates' per tonne of CO_2. In 2021, the CPF target was GBP 18 (EUR 29.9) per tonne of CO_2e.
Governance and implementation	The initial rate of the CPF was set at around GBP 5 per tCO2e (EUR 5.8). However, in 2014, the UK government decided to freeze the CPF rate to GBP 18 per tCO2e (EUR 29.9) until 2019-2020 after business representatives expressed concerns over the competitiveness of energy-intensive industries due to electricity generators passing on the tax cost.
Environmental, social & health impacts	The tax operated via three mechanisms: (i) a decrease in emissions at the intensive margin; (ii) the closure of some high-emission plants; and a (iii) higher probability of closure for plants already at risk due to European air quality regulations. Hirst (2018[27]) reported that coal electricity generation significantly decreased between 2013 and 2016, together with the closure of several coal stations. He stressed that the doubling of the CPF in 2015 from GBP9 to GBP18 is one of the main factors that accelerated the decline in 2016. Leroutier (2022[57]) also found that emissions from the UK power sector declined by 20 to 26% per year on average between 2013 and 2017.

Source: (United Kingdom government, 2016[58]; United Kingdom government, 2016[59]; United Kingdom government, 2022[60]; Hirst, 2018[61]; Leroutier, 2022[57])

Annex Table 3.B.7. Tax rates

CPS rate commodity	Gas	Petroleum gas or other gaseous hydrocarbon in a liquid state	Coal and other solid fossil fuels
Unit	GBP (EUR) per kilowatt hour (kWh)	GBP (EUR) per kilogram (kg)	GBP (EUR) per gigajoule (GJ) on gross calorific value (GCV)
1 April 2016 to 31 March 2025	0.00331 (0.00384)	0.05280 (0.06131)	1.54790 (1.79738)

Source: (United Kingdom government, 2016[58]; United Kingdom government, 2022[60])

Notes

[1] Cap-and-trade mechanisms should be understood as such.

[2] Non-stationary sources refer to vehicles, which are covered in Section 0.

[3] A gas's radiative forcing can be understood as "the ability of a gas to absorb energy" and its lifetime as "how long they stay in the atmosphere", see https://www.epa.gov/ghgemissions/understanding-global-warming-potentials, as accessed on 12 May 2022.

[4] This period of 100 years is the most standard, but GWPs also exist for, e.g., 20 years.

[5] Calorific factors from the IEA World Energy Statistics and Balances (IEA, 2020[62]) enable common units of fuels (e.g., kilograms for solid fuels, litres for liquid fuels, cubic metres for gaseous fuels) to be converted into energy units (e.g. GJ). In turn, these can then be converted into CO_2 emissions using the IPCC emissions conversion factors (Intergovernmental Panel on Climate Change's Guidelines for National Greenhouse Gas Inventories (2019[8]), volume 2).

[6] PMs are microscopic particles of solid or liquid matter suspended in the air. Some particles, such as dust, dirt, soot, or smoke, are sufficiently large or dark to be seen by eye. Others, such as PM_{10} or $PM_{2.5}$ are not as visible. PM_{10} (resp. $PM_{2.5}$) represent inhalable particles, with diameters that are generally 10 (2.5) micrometres and smaller.

[7] https://www.who.int/news/item/25-03-2014-7-million-premature-deaths-annually-linked-to-air-pollution, as accessed on 29 November 2022.

[8] See https://www.airnow.gov/aqi/aqi-basics/ (as accessed on 25 Januray 2023) for additional detail. In particular, "Good" stands for "Air quality is satisfactory, and air pollution poses little or no risk", "Unhealthy" for "Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects" and "Hazardous" for "Health warning of emergency conditions: everyone is more likely to be affected".

[9] These figures are similar for PM_{10}.

[10] https://ec.europa.eu/environment/integration/research/newsalert/pdf/24si_en.pdf, as accessed on 12 May 2022.

[11] As defined in the OECD effective carbon rates methodology (OECD, 2016[6]).

[12] See BOE (2004[20]) or https://www.boe.es/buscar/act.php?id=BOE-A-2004-1739&p=20100809&tn=1&se-9, section 2, for additional detail. The webpage provides the possibility to access latest modifications to the legislation.

[13] Direct GHG emissions are emissions from sources that are owned or controlled by the reporting entity. Indirect GHG emissions are emissions that are a consequence of the activities of the reporting entity, but occur at sources owned or controlled by another entity (https://ghgprotocol.org/calculationg-tools-faq).

[14] Annex 1 of Law 16/2002 of July 1 provides a list of the fourteen activities covered. These refer to certain combustion installations, production and transformation of metals, mineral industries, chemical industries, waste management, industry derived from wood, textile industry, leather industry, agri-food industry and livestock farms, organic solvents, carbon industry, wood preservation industry, water treatment and capture of CO_2.

[15] Article 15 of BOE (2004[20]).

[16] In 2018, it applied to 77 installations, and in 2020, to 66 installations.

[17] Excluding CO_2 emissions from the combustion of biofuels. This figure is of about 65% if including these emissions.

[18] Andalusian firms subject to the EU ETS had average verified emissions of about 231 thousand tonnes of CO_2, ranging between less than 10 and about 1.7 million tonnes. At the Spanish level, the average is at 139 thousand tonnes, ranging between 0 and about 5 million tonnes.

[19] Information provided by the Tax Agency of Andalusia (ATRIAN).

[20] https://www.hacienda.gob.es/es-ES/Prensa/En%20Portada/2014/Documents/Informe%20expertos.pdf.

[21] E.g., more effective in mitigating emissions.

[22] E.g., if a justification were made that larger polluters should be made responsible for proportionally more of their emissions.

[23] It also applies to emissions from aviation and to a very small share of emissions in the buildings sector, but this is not discussed here.

[24] Other greenhouse gases are excluded from this analysis, as they constitute a minor part of emissions in these two sectors.

[25] I.e., it does not include auto-generation of electricity in industrial plants.

[26] https://tradingeconomics.com/commodity/carbon, as viewed on 21/07/2022. It is also worth noting that the price signal arising from the EU ETS in 2018 was much lower, at an average of EUR 16/tCO_2.

[27] Indeed, while not all biomass is carbon neutral, it can be. Taken at the point of combustion, biomass releases CO_2. However, as discussed in OECD (2019[6]), sustainably sourced biomass may be carbon-neutral over the lifecycle because before being burnt, feedstocks have previously absorbed a similar amount of CO_2 from the atmosphere.

[28] See https://ember-climate.org/data/data-tools/carbon-price-viewer/, as accessed on 28 November 2022.

[29] According to Table 3.1, the highest marginal rate is of 14 000 per unit of pollutant. Hence, at that marginal rate, one extra tonne of CO_2 is equivalent to 1/200 000 polluting unit and is hence subject to a marginal rate of 14 000/200 000.

[30] Such effects could also help go beyond the use of best available technologies promoted in Andalusia (https://eippcb.jrc.ec.europa.eu/es/reference). Indeed, the extensive margin effect would not be at play in the context of technology requirements only.

[31] Agriculture made up 2.9% of Spanish GVA in 2021.

[32] "A Major Source of Air Pollution: Farms – Global Study Shows How Agriculture Interacts with Industry", https://www.earth.columbia.edu/articles/view/3281, as accessed on 29 November 2022.

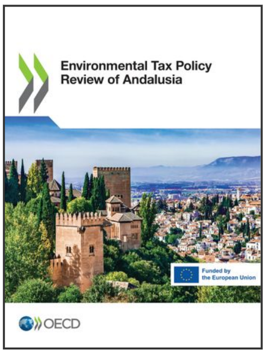
[33] See https://environment.govt.nz/news/consultaton-on-government-proposals-to-price-agricultural-greenhouse-gas-emissions/, as accessed on 08 November 2022.

[34] See https://www.reuters.com/world/asia-pacific/new-zealand-farmers-protest-agricultural-emissions-plan-2022-10-20/, as accessed on 08 November 2022.

[35] https://www.overseer.org.nz/, as accessed on 08 November 2022.

[36] https://www.bloomberg.com/news/articles/2022-10-10/new-zealand-accepts-farm-level-pricing-of-agricultural-emissions, as accessed on 30 November 2022.

[37] See https://www.realinstitutoelcano.org/en/work-document/taxation-and-ecological-transition-during-climate-and-energy-crises/ for a summary in English of the environmentally-related recommendations of the White Book.



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