POLICY SHIFT FOR THE LOW-CARBON TRANSITION
IN A GLOBALLY EMBEDDED ECONOMY

Identifying the potential for eco-innovation in Austria

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Contents

1. Introduction: Identifying the potential for eco-innovation in Austria based on patent data

The purpose of this paper is to identify the potential for eco-innovation in Austria based on patent data (Task 4.2 of the SHIFT project). It contributes to the overall aim of Work Package 4 of developing instruments – standards in particular – that can foster eco-innovations in Austria in order to reduce greenhouse gas (GHG) emissions in the long run. As a first step therefore, this task evaluates the current status of eco-innovation in different sectors in Austria, with a focus on emission-intensive sectors and those that national policies can address well. Based on the OECD classification of environment-related technologies (ENV-TECH) and patent data provided by the OECD, Austria's areas of specialization in different technology fields are investigated. Combined with insights into the country's economic specialization, approximated by its comparative advantage in international trade, sectors with further potential for eco-innovation are then determined.

Methodologically, the analysis follows the approach applied by Fankhauser et al (2013) to China, Germany, France, Italy, Japan, South Korea, UK and the US and by Dechezleprêtre et al (2013) to the Netherlands, but departs from it in some ways due to data availability. In general, as in Fankhauser et al (2013), the aim is to identify sectors that represent opportunities for future green growth through a combination of the sectors' relative performance in innovation and in international trade. However, the analysis here is based on aggregate patent data at the level of technology classes following the OECD ENV-TECH classification rather than on firm-level patent data as available to Fankhauser et al (2013) and Dechezleprêtre et al (2013). Hence, the matching of innovation data to economic sectors can only be approximated.

Our starting point - which is also reflected in the OECD ENV-TECH classification - is the emission sector classification of the United Nations Convention on Climate Change (UNFCCC), based on which the transport sector is by far the most emission-intensive sector in Austria. In 2016, it was responsible for 45.4% of all emissions outside the European Emission Trading System ETS (Zechmeister et al 2018), followed by agriculture (16.2%), buildings (16%), the energy and industry sectors not covered by the ETS (12%) and the waste sector (6.1%).[1] For these sectors, the OECD provides data on the number of patents applied for by a country's inventors for a range of climate change mitigation technologies, independent of the jurisdictions where patent protection is sought (i.e., all patents they apply for worldwide). For each of these technologies, an approximate matching to product groups according to the Standard International Trade Classification (SITC) was then undertaken, in order to combine the OECD patent data with trade flow data from the UN Comtrade database, which is the one also used by Fankhauser et al (2013).

Overall, the analysis carried out in Task 4.2 covers Austria's relative performance in innovation and trade for the years 2010 to 2014 in the sectors transport, buildings, energy, industry and agriculture. The waste sector as well as carbon capture and storage are also considered as far as possible. The results indicate further potential for eco-innovation particularly in transport (both conventional and alternative vehicles technologies, electric vehicle charging), buildings (lighting, heating) and some energy and industry fields (hydro energy, smart grids and other enabling technologies; metals and minerals processing).

[1] Including the sectors covered by the ETS, the ranking is as follows: Energy and industry ETS (36.4%), transport (28.8%), agriculture (10.3%), buildings (10.1%), energy and industry non-ETS (7.8%) and waste (3.9%). However, given that the focus in the SHIFT project is on sectors that *national* policies can address well, the non-ETS ranking is more appropriate.

2. Method and data

2.1 Measuring relative innovation performance

The status quo of Austria's eco-innovation performance is measured using the index of revealed technological advantage (RTA) for selected environment-related technologies based on the OECD ENV-TECH classification. The RTA index is a measure of relative technological specialization and expresses a country's share of worldwide patent applications in a particular technology field relative to the country's share of worldwide patent applications in all technology fields. It takes the value 0 when the country holds no patent in a given technology field, the value 1 when the country's share of patent applications in a given technology field is equal to its share of patent applications in all fields (no specialization) and a value greater 1 when its share in a given technology field is greater than its share in all technology fields (positive specialization or revealed technological advantage). The RTA index for country *j* and technology field *d* can be written mathematically as follows:

$$\mathbf{RTA}_{d,j} = \frac{\boldsymbol{P}_{d,j} / \sum_j \boldsymbol{P}_{d,j}}{\sum_d \boldsymbol{P}_{d,j} / \sum_{d,j} \boldsymbol{P}_{d,j}}$$

where *P* refers to patent applications.

The RTA index is computed using patent data by environment-related technologies provided by the OECD. The organization processes and makes available on its website patent statistics extracted from the Worldwide Patent Statistical Database (PATSTAT) of the European Patent Office (EPO). For Task 4.2, the indicator "technology development" is used, which for each country and technology field consists of the number of patents applied for by a country's inventors, independent of where patent protection is sought (all jurisdictions worldwide). The data are presented by country of inventor (fractionally attributed in case a patent was applied for by inventors from more than one country), priority date (i.e. the date of first filing of the patent application worldwide) and patent family size, which refers to the number of patent applications protecting the same priority filing worldwide. The patent family size available in the OECD database ranges from one and greater, covering all inventions worldwide, to four and greater, covering only those inventions for which patent protection is sought in at least four jurisdictions worldwide. The larger the family size, the higher is the expected value and thus the quality of the invention, since it is costly to apply for patent protection. For Task 4.2, we choose a patent family size of three or greater in order to capture higher-quality patents. Some remaining caveats regarding the use of patents as a measure of innovation are that not all innovations are patented, not all patents represent innovations (commercially successful inventions), and firms in different economic sectors are characterised by different propensities to patent and different speeds of innovation diffusion.

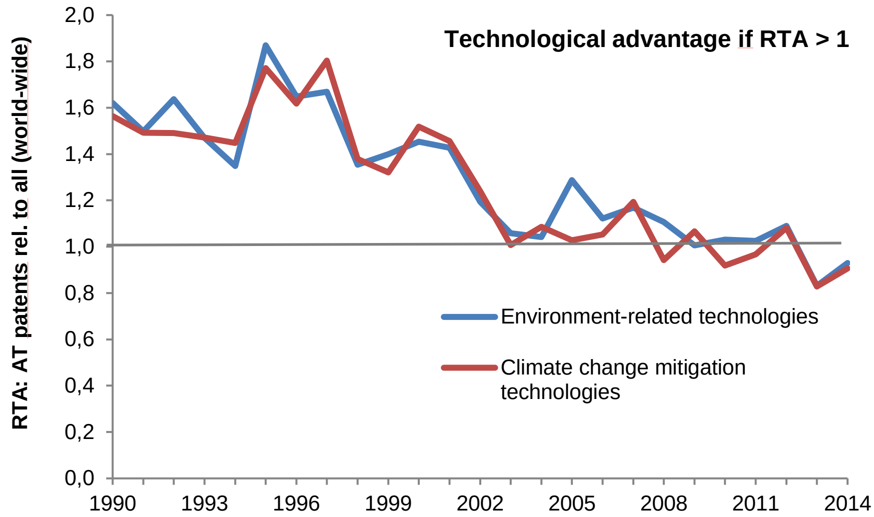
The OECD ENV-TECH classification allows identifying the number of patent applications in environment-related technologies and several sub-fields based on the International Patent Classification (IPC), which groups the technical content of patent applications into technological fields. The ENV-TECH classification contains as major sub-categories of environment-related technologies: environmental management, water-related adaptation technologies, biodiversity protection and ecosystem health, and climate change mitigation. Given the focus of the SHIFT project on reducing GHG emissions, we focus on the latter group of technologies in Task 4.2. It contains climate change mitigation technologies as classified in Table 1.

Table 1: **OECD ENV-TECH** climate change mitigation technologies related to:

Transportation:
Road transport (conventional, hybrid or electric vehicles)
Rail transport
Air transport
Maritime or waterways transport
Enabling technologies in transport (electric vehicle charging, application of fuel cell and hydrogen technology to transportation)
Buildings:
Integration of renewable energy sources in buildings
Energy efficiency in buildings (Lighting, heating, home appliances, elevators, ICT)
Architectural or constructional elements improving the thermal performance of buildings
Enabling technologies in buildings
Production or processing of goods:
Metal processing
Chemical industry
Oil refining and petrochemical industry
Processing of minerals
Agriculture, livestock and agroalimentary industries
Final industrial or consumer products
Sector-wide applications
Enabling technologies with a potential contribution to greenhouse gas emissions mitigation
Energy generation, transmission or distribution:
Renewable energy generation (wind, solar, hydro etc.)
Energy generation from fuels of non-fossil origin (e.g. biofuels)
Combustion technologies with mitigation potential
Efficiency in electrical power generation, transmission or distribution
Enabling technologies in the energy sector (batteries, hydrogen technology, fuel cells, smart grids in the energy sector)
Wastewater treatment or waste management:
Wastewater treatment
Solid waste management (waste collection, processing or separation, and reuse, recycling or recovery technologies)
Enabling technologies or technologies with a potential or indirect contribution to greenhouse gas emissions mitigation
Capture, storage, sequestration or disposal of greenhouse gases:
CO2 capture and storage
Capture or disposal of greenhouse gases other than CO_2 (N_2O, CH_4, PFC, HFC, SF6).

Figure 1 shows the RTA index for Austria in all environment-related technologies and in the sub-group climate change mitigation technologies since 1990. While the country enjoyed a positive specialization in both technology fields until the early 2000s, this technological advantage has been eroding steadily, and the index fell below 1 for the first time in 2008. Given the challenges of a low-carbon transition, it is therefore timely to consider ways to boost environment-related technologies in general and climate change mitigation technologies in particular.

Figure 1: RTA for Austria in environment-related and climate change mitigation technologies

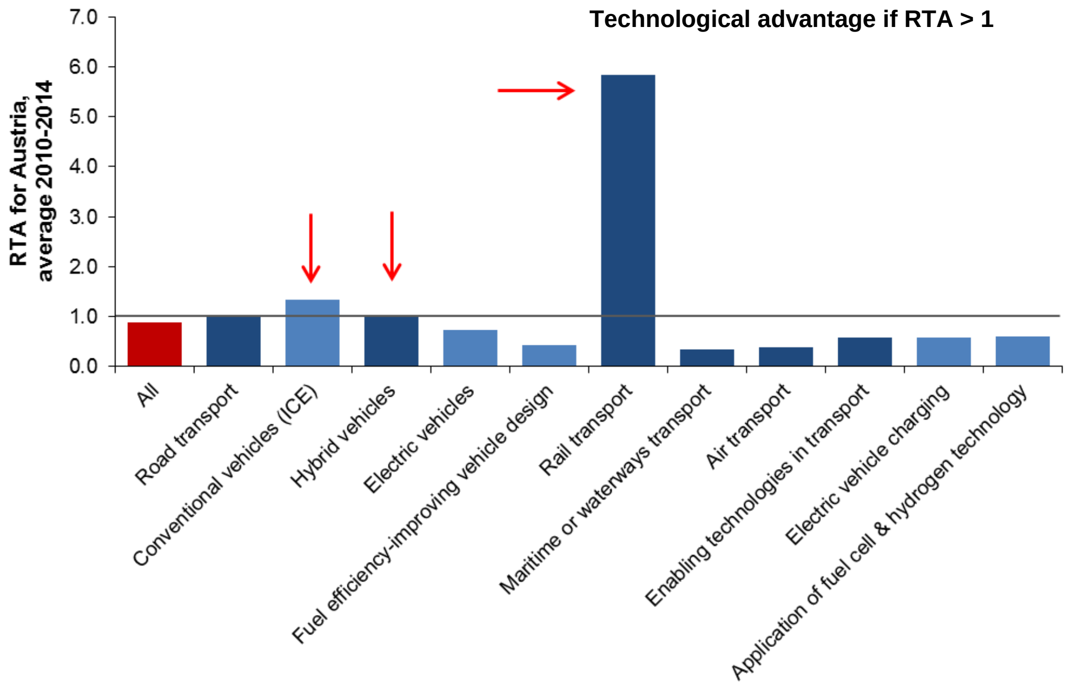


Source: Own elaboration, based on OECD patent statistics (technology development indicator)

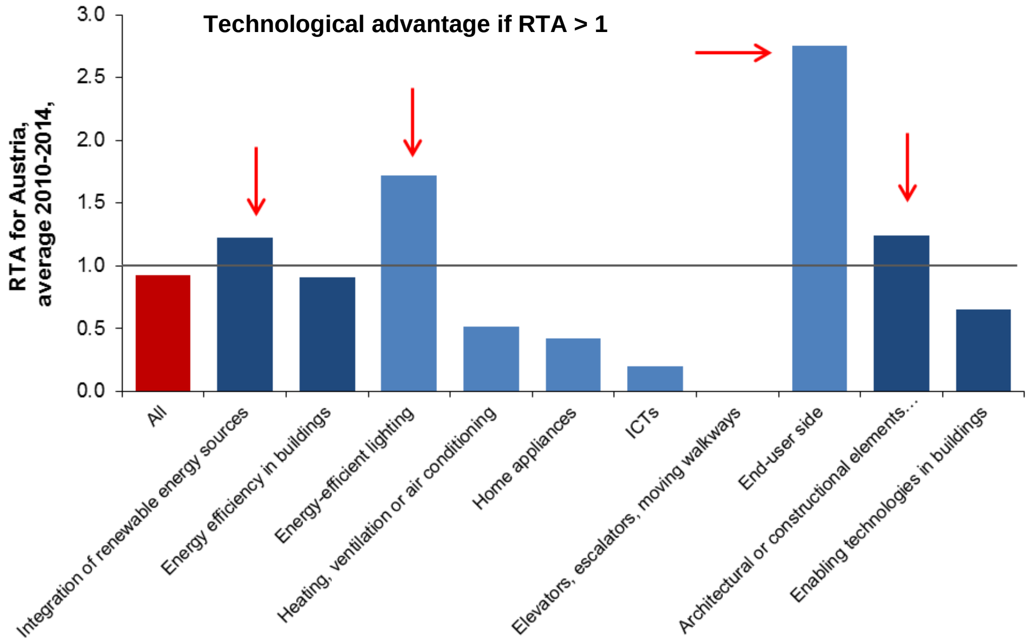
Panels a to f in Figure 2 show the RTA indices for each sub-group of climate change mitigation technologies for the latest available years. Since time series data on patent applications are notoriously jumpy (e.g. 2 in one year, 0 in the next two), the RTA indices are based on averaged patent applications data for the five-year period 2010 to 2014, where 2014 is the last year for which data are currently available. Dark blue columns represent the main sub-categories of each technology group, and light-blue columns in turn represent the sub-categories of these. Red arrows indicate a relative technological specialization (RTA > 1).

Figure 2: RTA for Austria (average 2010-2014) in climate change mitigation technologies related to:

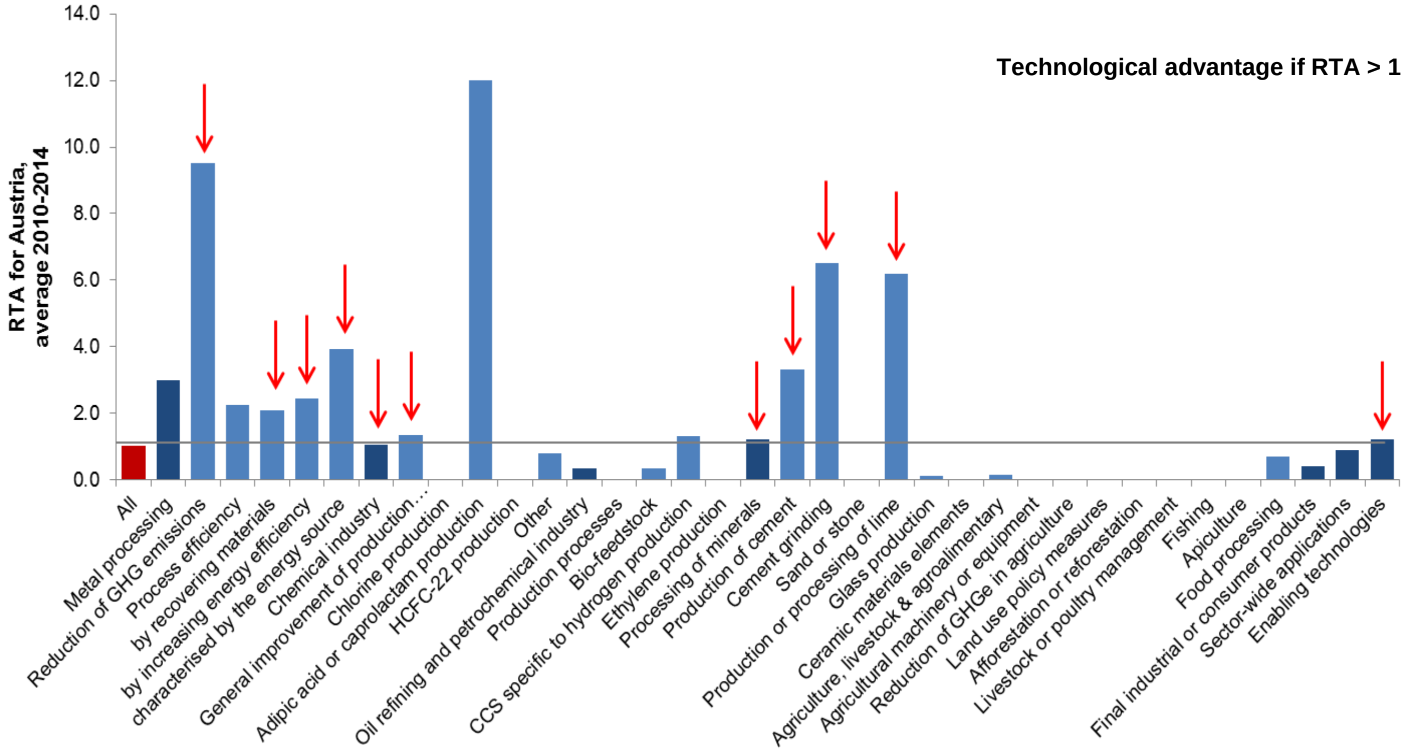
Panel a: Transport



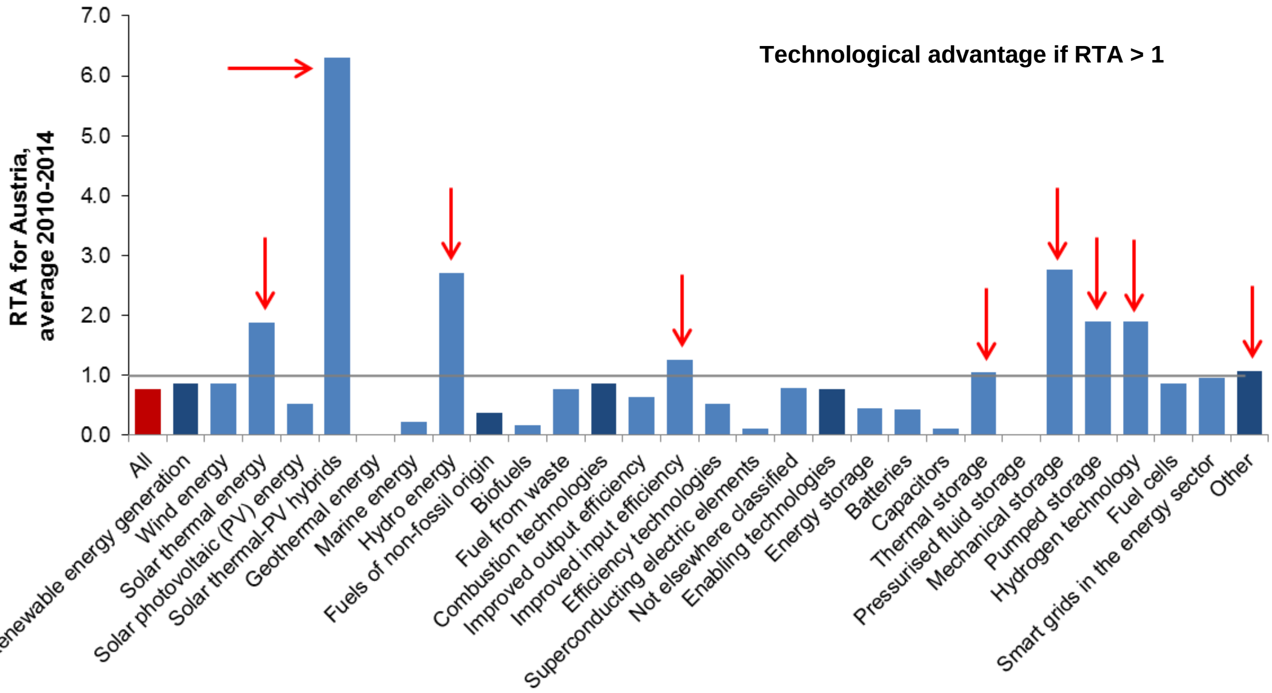
Panel b: Buildings



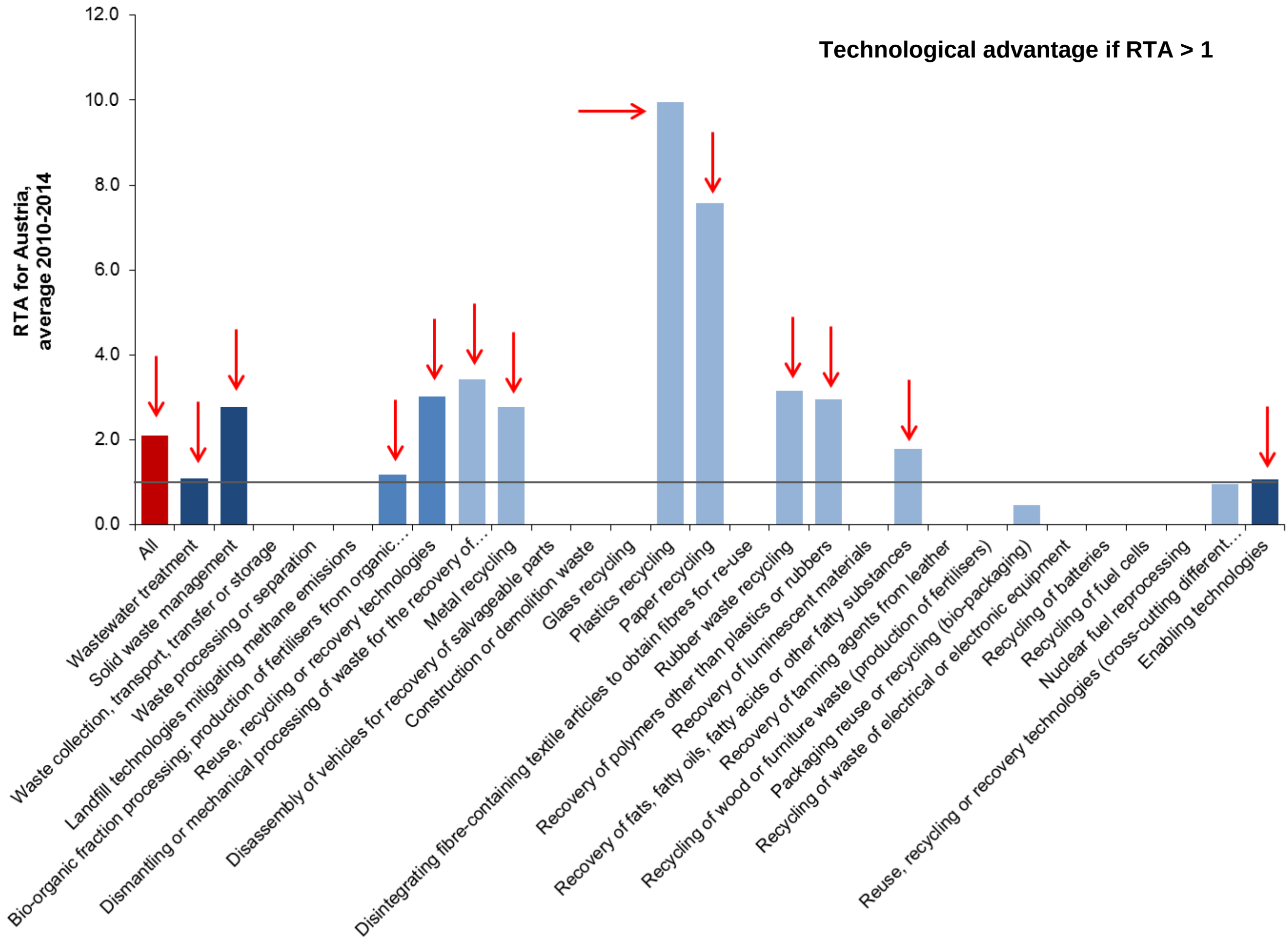
Panel c: Production and processing of goods



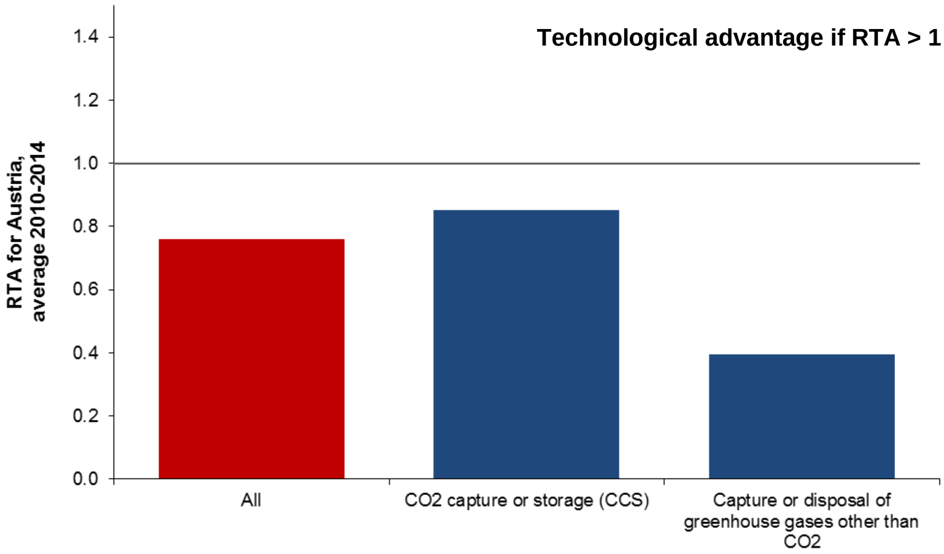
Panel d: Energy generation, transmission and distribution



Panel e: Wastewater treatment and waste management



Panel f: Capture, storage, sequestration or disposal of greenhouse gases



Regarding climate change mitigation technologies in **transport** (panel a), Austria enjoys a substantial advantage in rail transport and a smaller one in conventional vehicles technologies based on the internal combustion engine. For hybrid vehicles, the RTA index is just above 1 (1.037), while for electric vehicles, the index value is 0.728. Hence in the latter field, which is rapidly emerging as one of the key technologies for a low-carbon transition in European and Austrian policy, the country does not yet have an advantage according to these data. Other areas where no specialization exists include enabling technologies such as electric vehicle charging and the application of fuel cell and hydrogen technologies to transport.

In **buildings** (panel b), Austria's areas of specialization lie in the integration of renewable energy sources like PV and heat pumps into buildings; in energy-efficient lighting; in technologies for efficient end-user side power management and consumption, such as energy-saving modes for electronic equipment, demand response systems and smart metering; and in architectural or constructional elements improving the thermal performance of buildings like insulation. Austria's inventors appear to be less active in heating, ventilation or air conditioning; home appliance technologies; ICTs aiming at a reduction of own energy use (e.g. energy-efficient computing and communication networks); elevators, escalators and moving walkways; and in enabling technologies such as the application of fuel cells in buildings.

Regarding climate change mitigation technologies related to the **production and processing of goods** (panel c), Austria has a specialization in technologies related to metal processing, the chemical industry (with an RTA of 1.07) and mineral processing, particularly in cement and lime. These sectors are also among the country's largest manufacturing sectors: taken together, between 2010 and 2014 they represented 4.7% of value-added on average (cf. Complementary to Figure 3, Table 2 lists the RTA and RCA index scores for all technologies where a matching to SITC product groups was feasible. To give an indication of the size of the production sectors related to each technology, the last column of Table 2 provides the average share of the corresponding NACE (rev.2, two-digit) industries in total Austrian value-added for the years 2010 to 2014. Since the two-digit NACE classification is in most cases more aggregate than the OECD ENV-TECH and SITC classifications, the value-added shares are not computed for all technologies and should be interpreted with caution, keeping in mind the respective NACE sectors considered (given in parentheses).

In Figure 3, the top part of panel a shows all climate change mitigation technologies related to **transport** (cf. Figure 2a) that could be matched to product groups (all except fuel efficiency-improving vehicle design and the application of fuel cell and hydrogen technologies to transport). Panel b shows all technologies except rail transport in order to get a clearer picture of the remaining technologies - given that rail transport is clearly Austria's main area of advantage in the field, with both RTA and RCA indices taking on values around 5. Climate change mitigation technologies related to conventional vehicles (based on the internal combustion engine) are another area of strength, while electric and hybrid vehicles technologies are under threat, as are electric vehicle charging, air and maritime transport technologies. These results are broadly consistent with the structure of the Austrian transport industry: air and maritime transport play a negligible role, while the automotive sector (manufacture, trade and repair of motor vehicles) contributed on average 2.8% per year to Austrian value-added between 2010 and 2014 (see Table 2). In this sector, the country has specialized in supplying components for the large German car manufacturers, which are only slowly moving towards alternative vehicles technologies. The share of the latter in Austrian value-added is - although not easy to gauge from the available NACE two-digit industry data - therefore likely small, given that the share of electric vehicles in new passenger car registrations was only 1.5% in 2017 and 2018. Austria's innovative capacity in these emerging technologies (electric and hybrid vehicles and electric vehicle charging) thus requires further stimulation, for instance via innovation standards, in order for them to develop into areas of strength that can contribute to a low-carbon transition.

In climate change mitigation technologies related to **buildings** (panel b), a matching to product groups was done for all technologies in the category energy efficiency in buildings. Of these, Austria enjoys both a trade and a technological advantage in energy-efficient lighting technologies, making this an area of strength. Heating, ventilation and air conditioning as well as elevators, escalators and moving walkways are areas under threat. Home appliances and ICTs aiming at the reduction of own energy use are weaknesses, with neither a trade nor a technological advantage. Standards for stimulating eco-innovation could thus be useful in heating, ventilation and air conditioning technologies and those relating to elevators etc. Diffusion standards could, on the other hand, be useful in energy-efficient lighting.

For climate change mitigation technologies in the **production and processing of goods** (panel c), the matching to product groups was possible for almost all the main technology categories as well as some sub-categories. As the first graph in panel c shows, one of Austria's main areas of advantage is metal processing, which is also an important industry with an average share of 3% per year in Austrian value-added for the years 2010 to 2014. As an example to illustrate the relevance of diffusion standards for technology areas of strength, one of the main Austrian companies in the sector, voestalpine, is currently running a costly pilot facility for a new steel production process powered by hydrogen rather than coal. Hence, the eco-innovation is there, but the technology is still very expensive, so that standardisation can help facilitate its wide-spread take-up and bring down costs. The chemical industry is another area of strength, with RTA and RCA values just above 1 but a small share of Austrian value-added (<1%). In minerals processing (middle graph of panel c), the cement grinding and lime sub-categories are strengths, while cement production represents an opportunity. On the other hand, the oil refining and petrochemical industry as well as the agriculture, livestock and agroalimentary industry (without machinery), respectively in the top and bottom graphs of the panel, are areas with neither a technological nor a trade advantage. The Austrian oil industry is an interesting case: technologically and economically, it is not very important - directly, it contributes less than half a percentage point to Austrian value-added - but it represents an industry with much to lose from the low-carbon transition. Finally, agricultural machinery and the minerals processing sub-categories production of glass, ceramics, sand and stone are areas under threat. These are technologies where innovation standards would be useful. The agriculture, livestock and agroalimentary industry is sizeable - it contributed 4.9% per year on average to Austrian value-added between 2010 and 2014 - while minerals processing is small (less than 1%).

Lastly, in climate change mitigation technologies related to **energy generation, transmission or distribution** (panel d), only a few technologies could be matched to product groups with confidence. This is mostly the case in the sub-category enabling technologies. Here, the data indicate that batteries and capacitators are a weakness, while smart grids technologies are an area under threat, calling for innovation standards. In the renewable energy generation sub-category, solar photovoltaic (PV) energy and combustion technologies are under threat and wind energy is a weakness, although matching confidence in these three fields is lower. In hydro energy, on the other hand, confidence is high, and this is an area of strength, in line with Austria's historically strong hydro and pumped storage capacities: in 2017 for instance, 61% of electricity were generated by hydro power (BMNT 2018).

Table 2). On the other hand, no technological advantage exists in the oil refining and petrochemical industry; the agriculture, livestock or agroalimentary industries; and in the production of final industrial or consumer products.

In **energy generation, transmission and distribution** (panel d), Austria has an advantage in some renewable energy technologies (solar thermal, solar thermal–PV hybrids, hydro energy) and some enabling technologies like thermal, mechanical and pumped storage as well as hydrogen technology (storage, distribution and production from non-carbon sources). However, it does not yet have a specialization in important technologies such as wind, solar photovoltaic and geothermal energy; fuels from non-fossil sources; and enabling technologies like batteries, capacitators and fuel cells.

Finally, panels e and f present RTA indices for Austria in climate change mitigation technologies related to **wastewater treatment and waste management** as well as the **capture, storage, sequestration or disposal of greenhouse gases**. The first of these is an area where Austria does particularly well: the data show a specialization in both main areas of the technology field, namely wastewater treatment and solid waste management. The country's good performance in the latter category is driven by the sub-category reuse, recycling and recovery technologies, and there especially by plastics, paper, metal and rubber waste recycling, the recovery of polymers other than plastics or rubber, the recovery of fats, fatty oils and fatty acids and the dismantling or mechanical processing of waste for the recovery of materials. Some areas of weakness remain, for instance packaging reuse or recycling (bio-packaging), recycling of waste of electrical or electronic equipment, and batteries and fuel cells recycling. The second technology field is of less relevance to Austrian inventors, judging from the lack of technological specialization in panel f. This might be due to the countries' permanent ban of commercial underground storage of waste gases (Shogenova et al, 2013).

2.2 Measuring relative economic performance

In order to judge whether Austria has a potential for eco-innovation in a particular technology field, the patent data are combined with data on economic performance in sectors related to the technology, as in Fankhauser et al (2013) and Dechezleprêtre et al (2013). The underlying idea here is that stimulating eco-innovation is most likely to pay off if Austria already has some industrial activity in the field. Otherwise, one reason why no patenting exists could simply be that there is no related industry, in which case efforts at stimulating innovation would be futile.

To measure Austria's relative economic performance, we use trade flow data for different product groups from the UN Comtrade database to construct an index of revealed comparative advantage (RCA), a standard indicator of relative specialization in international trade (Balassa, 1965). The RCA index expresses, in our case, a country's share of worldwide exports in a product group relative to the country's share of worldwide exports in all product groups. It takes the value 0 when the country has no exports in a given product group, the value 1 when the country's share of exports in a given product group is equal to its share of exports in all product groups (no specialization) and a value greater 1 when its share in a given product group is greater than its share in all product groups (positive specialization or revealed comparative advantage). The RCA index for country *i* and product group *g* can be written mathematically as follows:

$$\mathbf{RCA}_{g,i} = \frac{\boldsymbol{E}_{g,i} / \sum_i \boldsymbol{E}_{g,i}}{\sum_g \boldsymbol{E}_{g,i} / \sum_{g,i} \boldsymbol{E}_{g,i}}$$

where *E* refers to the value of exports.

The RCA index is computed using data on the value of Austria's exports of goods to the rest of the world (excluding re-exports) according to the Standard International Trade Classification (Rev. 4) (SITC) provided by the UN Comtrade database. This version of the index is widely used as an empirical measure of countries' comparative trade performance. Some caveats remain, however; for instance, using trade flow data to measure economic performance excludes sectors that are not exposed to international trade, like some services, and it cannot account for the role of tariff and non-tariff barriers to trade.

The RCA indices are linked[2] to the RTA indices described in the previous section by collecting together the SITC product groups that are considered most closely related to the respective technologies from the perspective of the components used in the production industries concerned. For some technologies, this was relatively straightforward: for example, product groups related to technologies in transport, buildings or the production and processing of goods were comparatively easy to identify. For these technology fields therefore, confidence in the results presented in the following section is high. On the other hand, for energy generation, transmission and distribution, only a few technologies could be linked to products, since the technologies were either too specific or too general to match them with confidence. For the same reason, no products were matched to technologies in wastewater treatment and waste management as well as in the capture, storage, sequestration or disposal of greenhouse gases. A detailed list of the matching is contained in the Appendix.

3. Results: Identifying the potential for eco-innovation

Combining the RTA and the RCA indices yields information on Austria's areas of comparative technological and/or economic specialization, similar to the presentations in Fankhauser et al (2013) and Dechezleprêtre et al (2013). Figure 3 shows, for each technology field in the climate change mitigation technologies group described in section 2.1, a cross-plot of the respective RTA and RCA indices. ***Technologies in the top right quadrant*** represent Austria's current areas of strength: the country enjoys both a technological advantage and a comparative advantage in trade. ***Technologies in the top left quadrant*** represent opportunities for the future: the country has a technological advantage but not (yet) an advantage in trade. Fankhauser et al (2013) consider a strong innovation performance as an indicator of future competitiveness in a technology, which could help the country break into this market and develop a comparative advantage in trade as well.

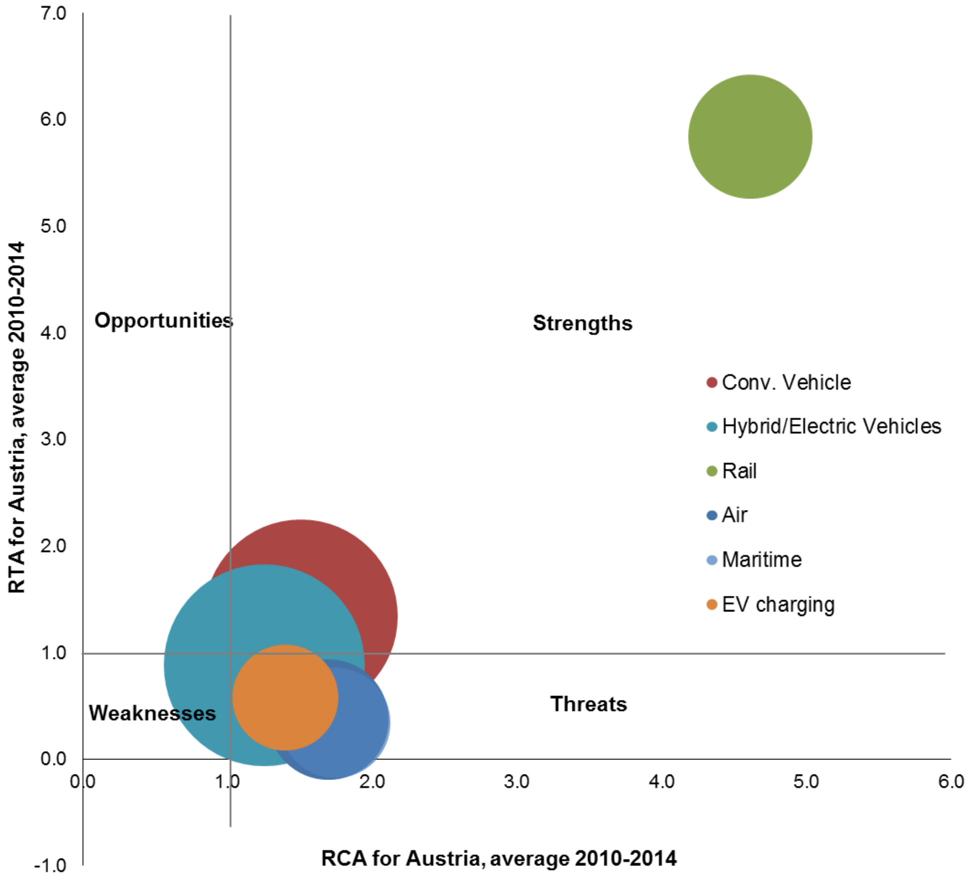
[2] This is in the spirit of Fankhauser et al (2013), who are able to connect trade data from Comtrade to patent data at the four-digit industry level due to the detailed nature of their patent data (Bureau van Dijk's Orbis database).

Technologies in the bottom left quadrant represent Austria's weaknesses: the country has neither a technological nor a trade advantage. Finally, ***technologies in the bottom right quadrant*** represent threats: these are fields where Austria currently enjoys a comparative advantage in trade, but not a technological advantage. This lack of innovative strength means that the country's current trade advantage is at risk of eroding in future.

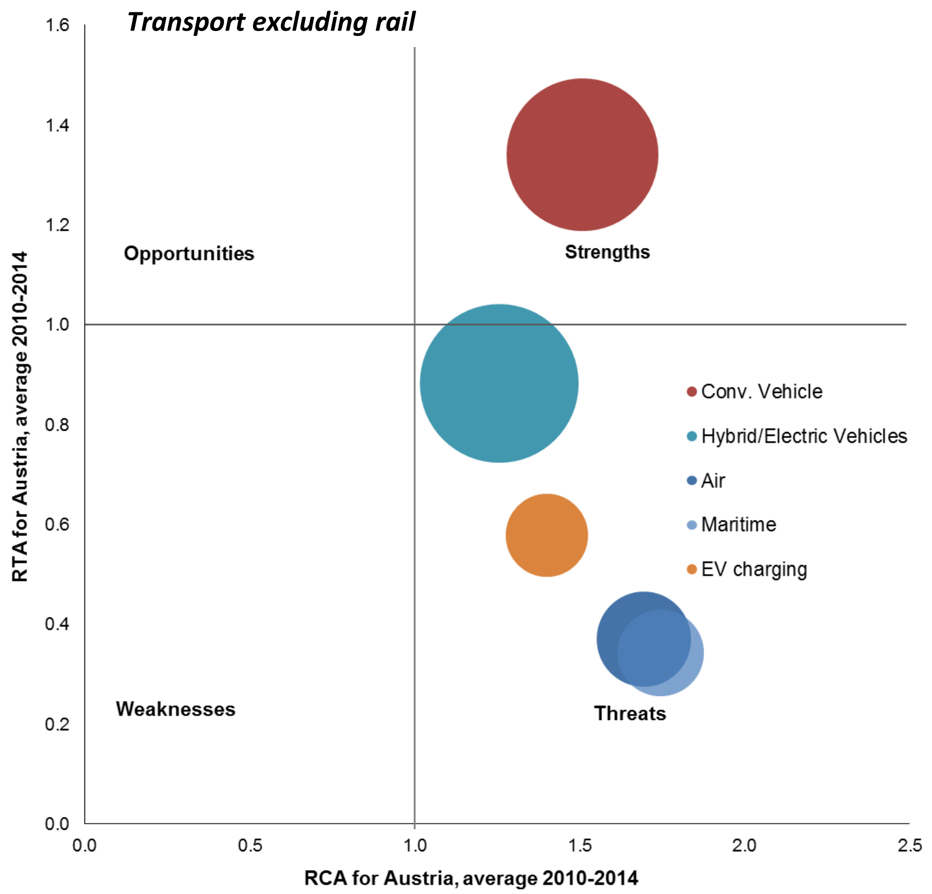
In terms of potential for eco-innovation, **areas of strength** and **areas under threat** can be considered. In both, Austria already enjoys a trade advantage, so there exists a substantial industrial base related to these technologies. Thus standards and other instruments should fall on fruitful grounds. Standards aimed at stimulating innovation are relevant for technologies in areas under threat, helping them to move up on the RTA score along the vertical axis. In areas of strength in the top right quadrant, standards for diffusion can help generate market demand for the technologies and thus spur their adoption.

Figure 3: RTA vs. RCA indices (averages 2010-2014) in climate change mitigation technologies related to:[3]

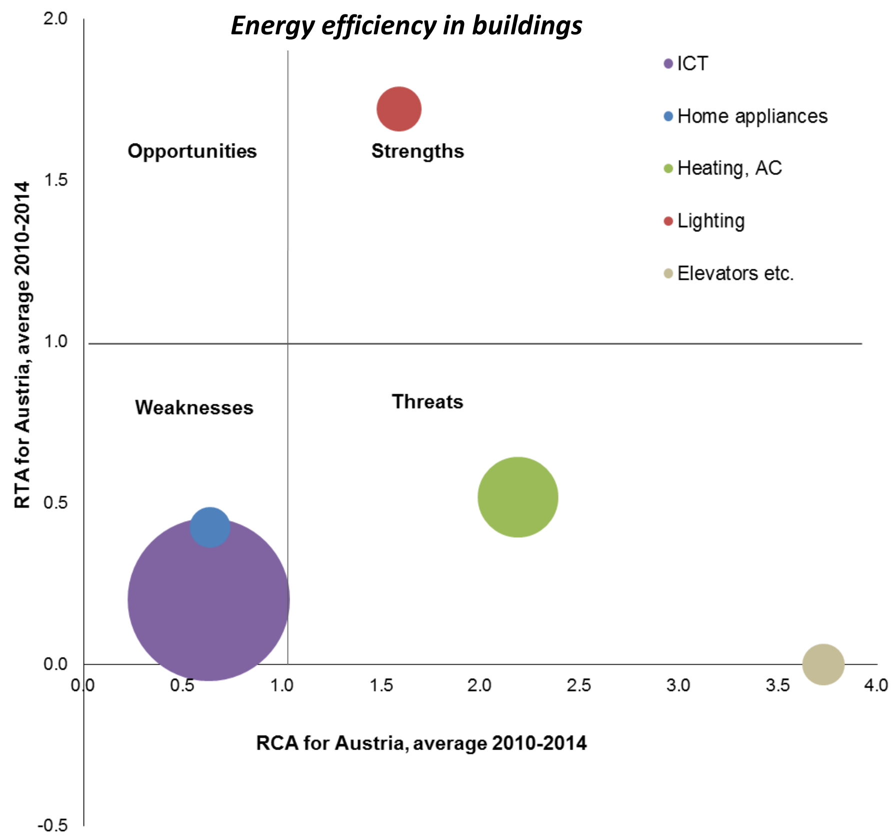
Panel a: Transport



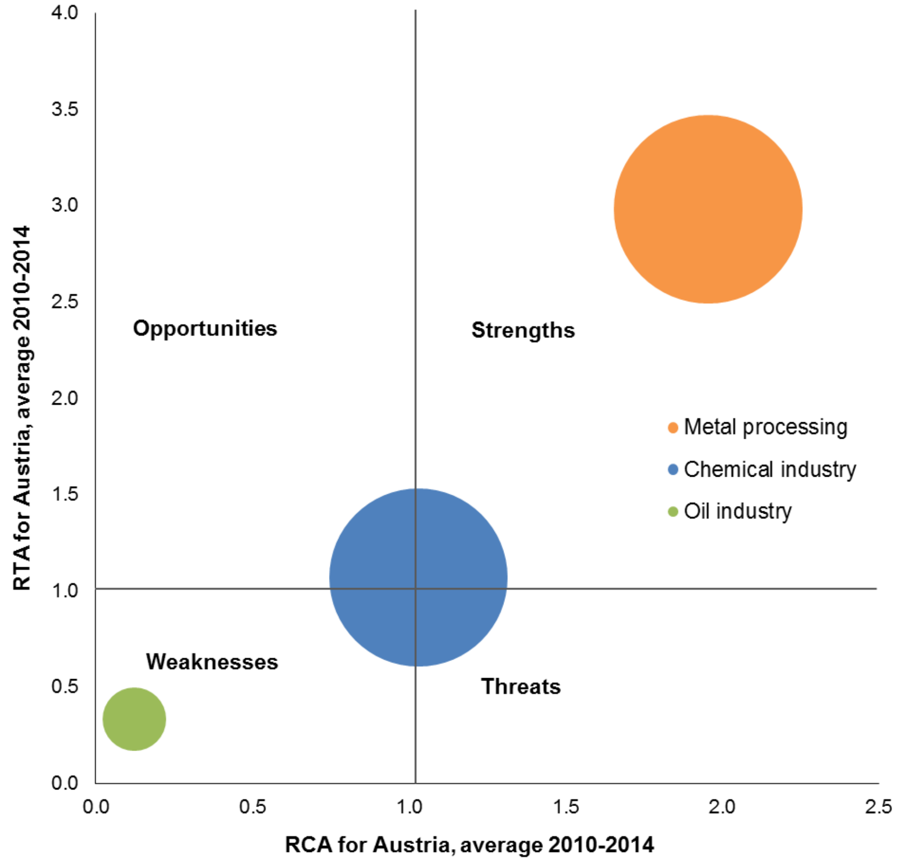
[3] The bubble size corresponds to the value of Austrian exports to the rest of the world in the product groups matched to each technology, relative to the other data points in each graph.

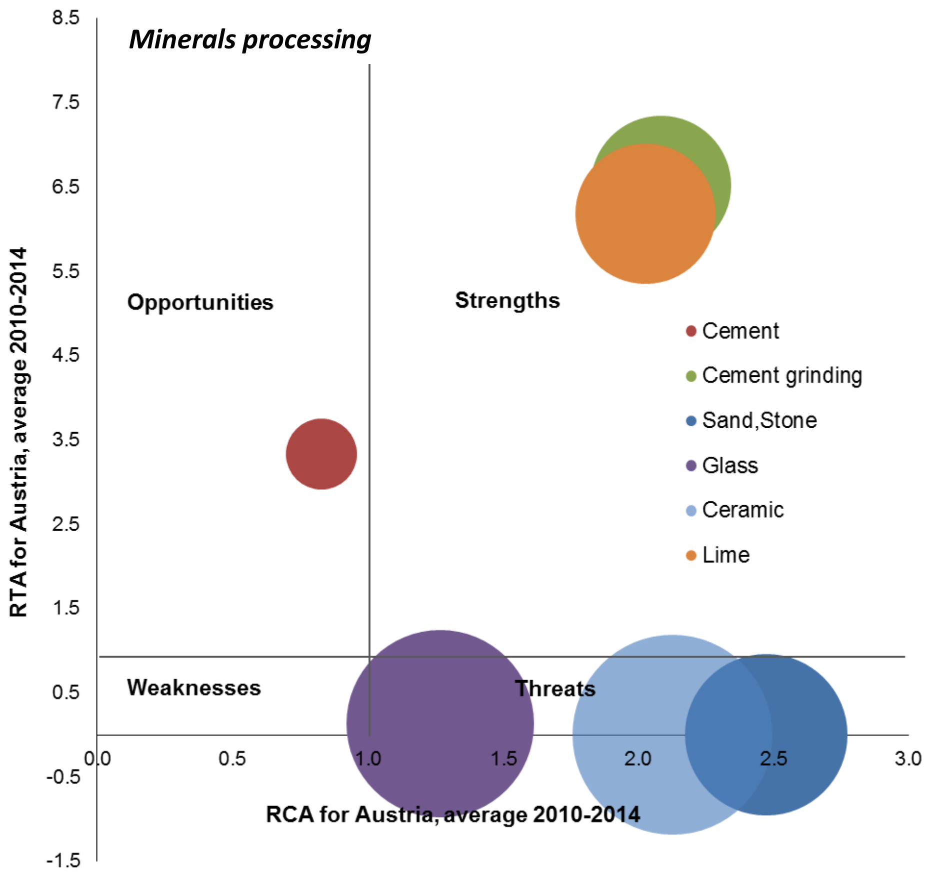


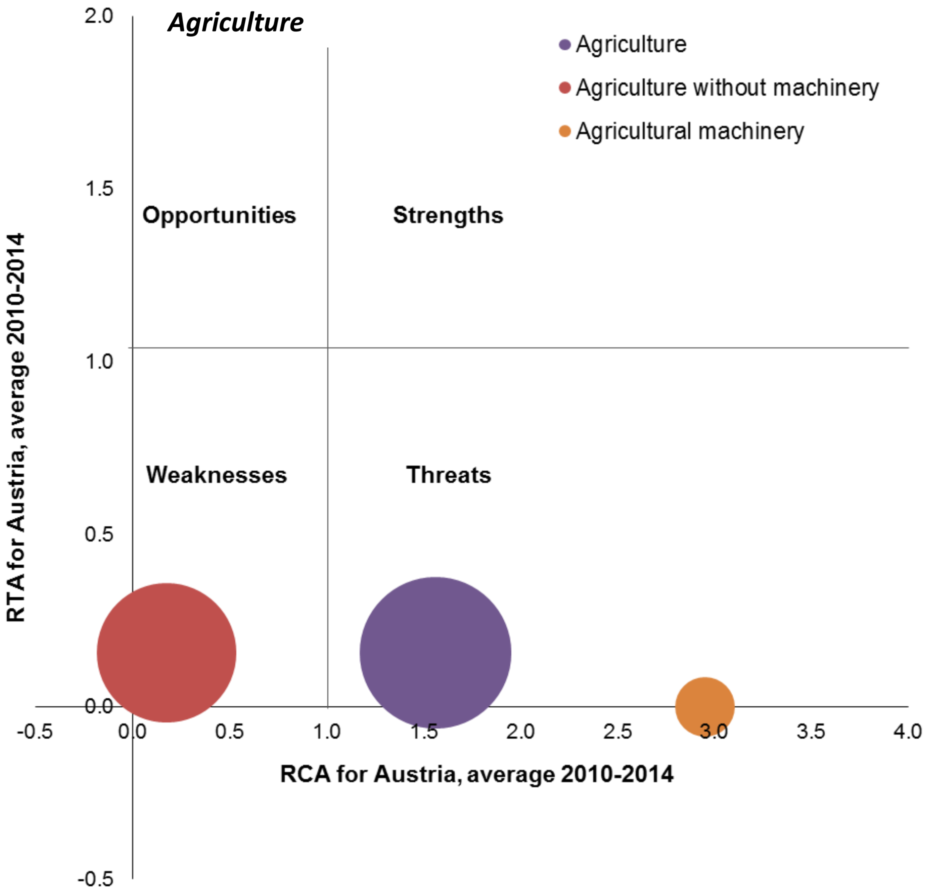
Panel b: Buildings



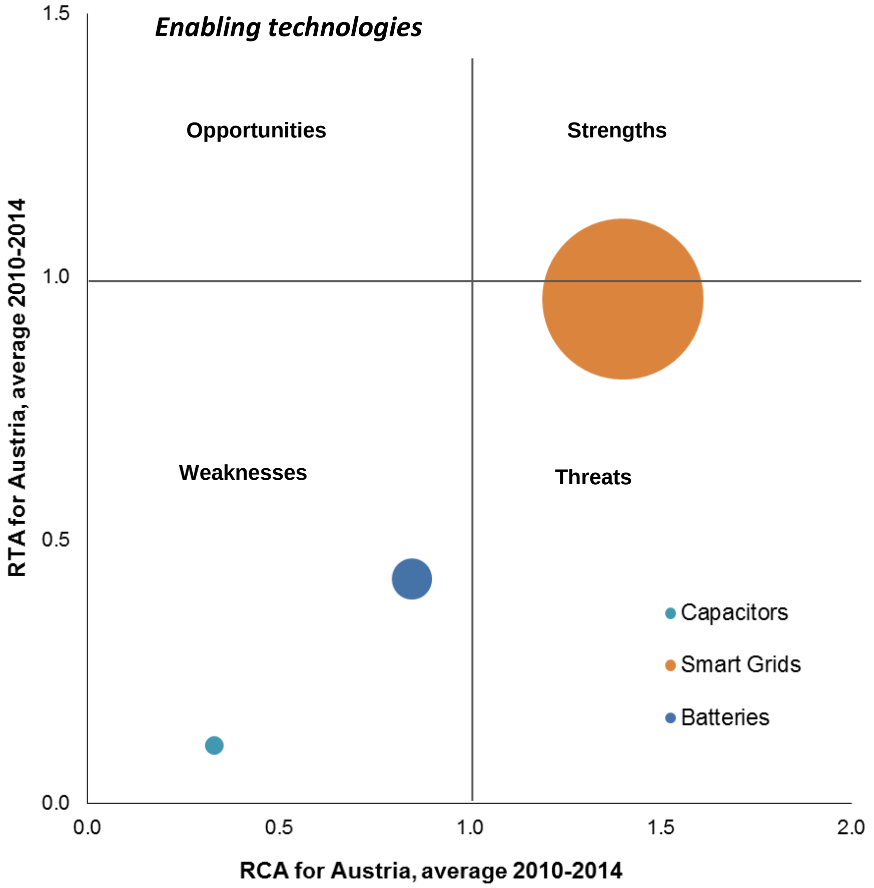
Panel c: Production and processing of goods

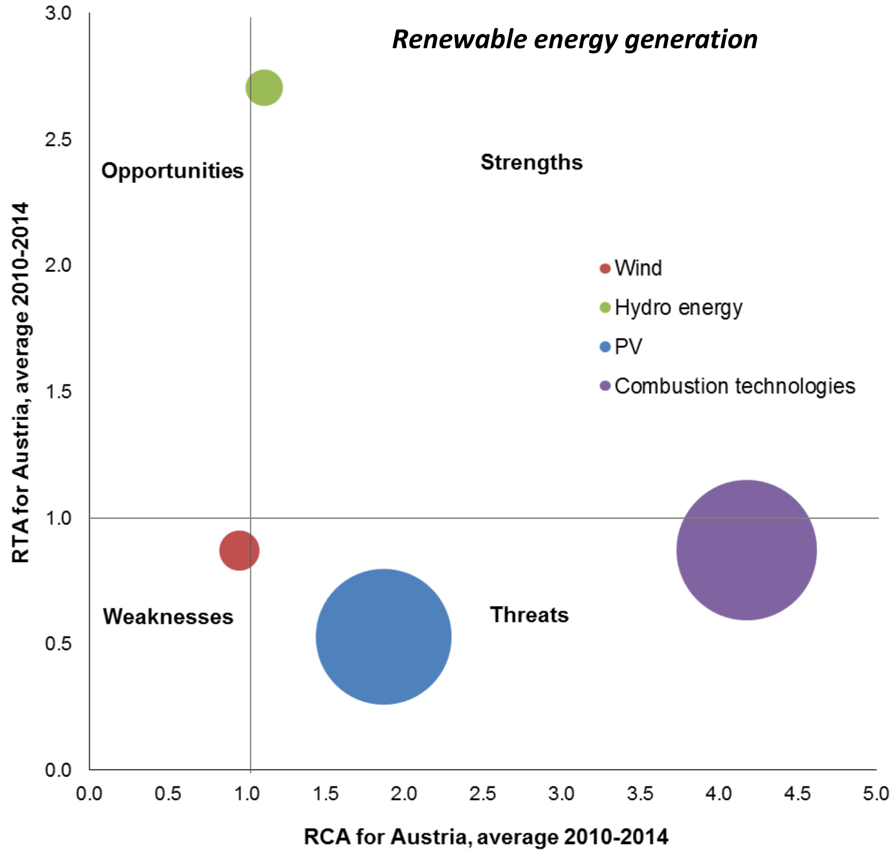






Panel d: Energy generation, transmission or distribution


Enabling technologies
Opportunities
Strengths
Weaknesses
Threats
Capacitors
Smart Grids
Batteries
RTA for Austria, average 2010-2014
RCA for Austria, average 2010-2014
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0


Renewable energy generation
Opportunities
Strengths
Weaknesses
Threats
Wind
Hydro energy
PV
Combustion technologies
RTA for Austria, average 2010-2014
RCA for Austria, average 2010-2014
3.0
2.5
2.0
1.5
1.0
0.5
0.0
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0.5
1.0
1.5
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2.5
3.0
3.5
4.0
4.5
5.0

Complementary to Figure 3, Table 2 lists the RTA and RCA index scores for all technologies where a matching to SITC product groups was feasible. To give an indication of the size of the production sectors related to each technology, the last column of Table 2 provides the average share of the corresponding NACE (rev.2, two-digit) industries in total Austrian value-added for the years 2010 to 2014. Since the two-digit NACE classification is in most cases more aggregate than the OECD ENV-TECH and SITC classifications, the value-added shares are not computed for all technologies and should be interpreted with caution, keeping in mind the respective NACE sectors considered (given in parentheses).

In Figure 3, the top part of panel a shows all climate change mitigation technologies related to **transport** (cf. Figure 2a) that could be matched to product groups (all except fuel efficiency-improving vehicle design and the application of fuel cell and hydrogen technologies to transport). Panel b shows all technologies except rail transport in order to get a clearer picture of the remaining technologies - given that rail transport is clearly Austria's main area of advantage in the field, with both RTA and RCA indices taking on values around 5. Climate change mitigation technologies related to conventional vehicles (based on the internal combustion engine) are another area of strength, while electric and hybrid vehicles technologies are under threat, as are electric vehicle charging, air and maritime transport technologies. These results are broadly consistent with the structure of the Austrian transport industry: air and maritime transport play a negligible role, while the automotive sector (manufacture, trade and repair of motor vehicles) contributed on average 2.8% per year to Austrian value-added between 2010 and 2014 (see Table 2). In this sector, the country has specialized in supplying components for the large German car manufacturers, which are only slowly moving towards alternative vehicles technologies. The share of the latter in Austrian value-added is - although not easy to gauge from the available NACE two-digit industry data - therefore likely small, given that the share of electric vehicles in new passenger car registrations was only 1.5% in 2017 and 2018. Austria's innovative capacity in these emerging technologies (electric and hybrid vehicles and electric vehicle charging) thus requires further stimulation, for instance via innovation standards, in order for them to develop into areas of strength that can contribute to a low-carbon transition.

In climate change mitigation technologies related to **buildings** (panel b), a matching to product groups was done for all technologies in the category energy efficiency in buildings. Of these, Austria enjoys both a trade and a technological advantage in energy-efficient lighting technologies, making this an area of strength. Heating, ventilation and air conditioning as well as elevators, escalators and moving walkways are areas under threat. Home appliances and ICTs aiming at the reduction of own energy use are weaknesses, with neither a trade nor a technological advantage. Standards for stimulating eco-innovation could thus be useful in heating, ventilation and air conditioning technologies and those relating to elevators etc. Diffusion standards could, on the other hand, be useful in energy-efficient lighting.

For climate change mitigation technologies in the **production and processing of goods** (panel c), the matching to product groups was possible for almost all the main technology categories as well as some sub-categories. As the first graph in panel c shows, one of Austria's main areas of advantage is metal processing, which is also an important industry with an average share of 3% per year in Austrian value-added for the years 2010 to 2014. As an example to illustrate the relevance of diffusion standards for technology areas of strength, one of the main Austrian companies in the sector, voestalpine, is currently running a costly pilot facility for a new steel production process powered by hydrogen rather than coal. Hence, the eco-innovation is there, but the technology is still very expensive, so that standardisation can help facilitate its wide-spread take-up and bring down costs. The chemical industry is another area of strength, with RTA and RCA values just above 1 but a small share of Austrian value-added (<1%). In minerals processing (middle graph of panel c), the cement grinding and lime sub-categories are strengths, while cement production represents an opportunity. On the other hand, the oil refining and petrochemical industry as well as the agriculture, livestock and agroalimentary industry (without machinery), respectively in the top and bottom graphs of the panel, are areas with neither a technological nor a trade advantage. The Austrian oil industry is an interesting case: technologically and economically, it is not very important - directly, it contributes less than half a percentage point to Austrian value-added - but it represents an industry with much to lose from the low-carbon transition. Finally, agricultural machinery and the minerals processing sub-categories production of glass, ceramics, sand and stone are areas under threat. These are technologies where innovation standards would be useful. The agriculture, livestock and agroalimentary industry is sizeable - it contributed 4.9% per year on average to Austrian value-added between 2010 and 2014 - while minerals processing is small (less than 1%).

Lastly, in climate change mitigation technologies related to **energy generation, transmission or distribution** (panel d), only a few technologies could be matched to product groups with confidence. This is mostly the case in the sub-category enabling technologies. Here, the data indicate that batteries and capacitators are a weakness, while smart grids technologies are an area under threat, calling for innovation standards. In the renewable energy generation sub-category, solar photovoltaic (PV) energy and combustion technologies are under threat and wind energy is a weakness, although matching confidence in these three fields is lower. In hydro energy, on the other hand, confidence is high, and this is an area of strength, in line with Austria's historically strong hydro and pumped storage capacities: in 2017 for instance, 61% of electricity were generated by hydro power (BMNT 2018).

Table 2: RTA indices, RCA indices and value-added shares for Austria (averages 2010-2014)

TECHNOLOGY FIELDS (OECD ENV-TECH) 2010-2014 averages	**RTA**	**RCA** by matched* SITC product groups	**VALUE-ADDED SHARE** (%)** by approx. NACE industries (2-digit sectors in parentheses)
Climate mitigation technologies related to transportation	**0.8841**	**0.0094**	
Road transport	***0.9845***	***0.6280***	
Conventional vehicles (based on internal combustion engine)	1.3399	1.5083	2.78 (29+45)
Hybrid vehicles	1.0370	1.2556	
Electric vehicles	0.7282	1.2556	
Fuel efficiency-improving vehicle design (common to all road vehicles)	0.4171	matching not possible	
Rail transport	***5.8411***	***4.6145***	***3.03*** (30+49)
Air transport	***0.3425***	***1.6937***	***0.46*** (30+51)
Maritime or waterways transport	***0.3702***	***1.7442***	***0.28*** (30+50)
Enabling technologies in transport	***0.5840***	matching not possible	
Electric vehicle charging	0.5779	1.4001	
Application of fuel cell & hydrogen technology to transport	0.6054	matching not possible	
Climate mitigation technologies related to buildings	**0.9285**		
Integration of renewable energy sources in buildings	***1.2250***	matching not possible	
Energy efficiency in buildings	***0.9123***	***0.5727***	
Energy-efficient lighting	1.7208	1.5903	1.65 (27)
Heating, ventilation or air conditioning	0.5178	2.1905	1.81 (25)
Home appliances	0.4241	0.6381	1.65 (27)
ICTs	0.2006	0.6313	0.96 (26)

Elevators, escalators, moving walkways	0.0000	3.7288	1.81 (25)
End-user side	2.7538	matching not possible	
Architectural or constructional elements improving the thermal performance of buildings	***1.2418***	matching not possible	
Enabling technologies in buildings	***0.6575***	matching not possible	
Climate change mitigation technologies in the production or processing of goods	**1.0094**		
Metal processing	***2.9832***	***1.9558***	***3.07*** (24+25)
Reduction of GHG emissions	9.5177	matching not possible	
Process efficiency	2.2584	matching not possible	
by recovering materials	2.0890	matching not possible	
by increasing energy efficiency	2.4553	matching not possible	
characterised by the energy source	3.9389	matching not possible	
Chemical industry	***1.0702***	***1.0299***	***0.75*** (20)
General improvement of production processes	1.3578	matching not possible	
Chlorine production	0.0000	matching not possible	
Adipic acid or caprolactam production	12.0153	matching not possible	
HCFC-22 production		matching not possible	
Other	0.8142	matching not possible	
Oil refining and petrochemical industry	***0.3331***	***0.1232***	***0.40*** (06+19)
Production processes	0.0000	matching not possible	
Bio-feedstock	0.3368	matching not possible	
CCS specific to hydrogen production	1.3130	matching not possible	
Ethylene production	0.0000	matching not possible	
Processing of minerals	***1.2041***	***2.6932***	***0.88*** (23)
Production of cement	3.3305	0.8287	
Cement grinding	6.5196	2.0849	
Manufacturing or processing of sand or stone	0.0000	2.4739	
Production or processing of lime	6.1787	2.0275	
Glass production	0.1303	1.2678	
Production of ceramic materials or elements	0.0000	2.1282	
Agriculture, livestock & agroalimentary	***0.1552***	***1.5618***	***4.94*** (01+03+10+28)
Agricultural machinery or equipment	0.0000	2.9492	2.58 (28)
Reduction of GHGe in agriculture	0.0000	matching not possible	
Land use policy measures	0.0000	matching not possible	
Afforestation or reforestation		matching not possible	0.43 (03)
Livestock or poultry management	0.0000	matching not possible	
Fishing	0.0000	matching not possible	0.01 (03)
Apiculture	0.0000	matching not possible	
Food processing	0.7162	matching not possible	1.33 (10)
Final industrial or consumer products	***0.4156***	matching not possible	
Sector-wide applications	***0.8846***	matching not possible	
Enabling technologies	***1.2280***	matching not possible	
Climate change mitigation technologies related to energy generation, transmission or distribution	**0.7627**	2.3015	
Renewable energy generation	***0.8579***	***0.0094***	***0.39*** (35)***
Wind energy	0.8692	0.9514	

Solar thermal energy	1.8771	matching not possible	
Solar photovoltaic (PV) energy	0.5285	1.8719	
Solar thermal-PV hybrids	6.3023	matching not possible	
Geothermal energy	0.0000	matching not possible	
Marine energy	0.2296	matching not possible	
Hydro energy	2.7039	1.1110	
Fuels of non-fossil origin	***0.3741***	matching not possible	
Biofuels	0.1765	matching not possible	
Fuel from waste	0.7644	matching not possible	
Combustion technologies	***0.8716***	***4.1757***	***1.28*** (29)
Improved output efficiency	0.6426	matching not possible	
Improved input efficiency	1.2533	matching not possible	
Efficiency technologies	***0.5280***	matching not possible	
Superconducting electric elements	0.1085	matching not possible	
Not elsewhere classified	0.7866	matching not possible	
Enabling technologies	***0.7771***	matching not possible	
Energy storage	0.4508	matching not possible	
Batteries	0.4270	0.8491	
Capacitors	0.1107	0.3322	
Thermal storage	1.0446	matching not possible	
Pressurised fluid storage	0.0000	matching not possible	
Mechanical storage	2.7702	matching not possible	
Pumped storage	1.8954	matching not possible	
Hydrogen technology	1.8947	matching not possible	
Fuel cells	0.8659	matching not possible	
Smart grids in the energy sector	0.9580	1.4001	2.61 (26+27)
Other	***1.0734***	matching not possible	

* For a list of the product groups matched to each technology, see the Appendix.

** Average annual share in total Austrian value-added for the years 2010 to 2014.

*** Proxied using 2014 data on environment-related gross value-added in NACE industry 35 (energy supply) from data on the Environmental Goods and Services Sector, reported by Statistics Austria.

4. Conclusions

Inducing a low-carbon transition in Austria until 2050 requires adjusting existing instruments as well as applying new ones. Standards aiming at the stimulation and diffusion of eco-innovation can help bring about the technological change needed to effectively reduce Austria's CO_2 emissions from their current high and rising level. As background to the work on standards in the remainder of Work Package 4, this note provides an assessment of technology fields where further potential for fostering eco-innovation exists. To this end, the current status of eco-innovation in different sectors is first determined using OECD data on patent applications related to relevant climate change mitigation technologies. This is combined with an analysis of the country's economic specializations, using trade flow data in sectors related to these technologies, to identify areas with further potential for eco-innovation.

In the sectors considered - transport, buildings, production and processing of goods (industry and agriculture) as well as energy generation, transmission and distribution - the results suggest that Austria has areas of strength in climate change mitigation technologies relating to: conventional vehicles (based on the internal combustion engine), rail transport, energy-efficient lighting, metal processing, minerals processing (cement and lime) and hydro power. In these fields, diffusion standards can be useful to encourage the spread of new technologies. Areas with further potential, where innovation standards can be employed to foster eco-innovation, include some fields that are emerging as key to the low-carbon transition: they are technologies relating to electric and hybrid vehicles as well as electric vehicle charging; heating, ventilation and air conditioning; smart grids; and the production of glass, ceramics, sand and stone. Finally, it is also important to mention areas of weakness, where Austria is less involved in patenting activities (and thus basic research and development) and in which net exports have been of minor relevance: these include ICTs applied to reduce own energy consumption in buildings; the oil industry; and batteries and capacitators as enabling technologies in the energy sector. Here, a more holistic approach is needed to develop both industries and technologies.

Data availability and differences between technology and economic classifications represent limitations to these results: the fact that our patent data are classified by technology field makes linking them to economic sectors difficult in some cases. This means that some important technology fields could not be analyzed in terms of their potential for eco-innovation. This is the case for enabling technologies such as the application of fuel cell and hydrogen technologies in transport and of fuel cells in the buildings and energy sectors; the integration of renewable energy sources in buildings as well as architectural or constructional elements improving the thermal performance of buildings; in the energy sector, energy generation from solar thermal energy, solar thermal-PV hybrids and geothermal energy; biofuels and fuels from waste; and various storage technologies like thermal, mechanical and pumped storage. In addition, the entire waste sector, where Austria has some remarkable technological specializations but also disadvantages in recycling (plastics and paper recycling vs. recycling of batteries and fuel cells), had to be excluded from the analysis. These areas thus remain as suggestions to be tackled by future, more in-depth research than was feasible within the scope of this project.

Despite these limitations, the results presented in this note provide an overview of Austria's specializations in different technology fields related to climate change mitigation. As far as possible, these were linked to economic specializations to yield areas that lend themselves to further stimulation or diffusion of eco-innovations through the application of appropriate policy instruments.

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5. References

Balassa, B. (1965): “Trade Liberalisation and Revealed Comparative Advantage”, *The Manchester School of Economics and Social Studies* 33: 99-123

BMNT (Federal Ministry for Sustainability and Tourism, 2018): “Energy in Austria 2018”, available (in German) here

Dechezleprêtre, A., Grover, D., Sato, M. (2013): “Position of the Netherlands in the emerging green economy”, Paper prepared for the Netherlands Environmental Assessment Agency (PBL).

Fankhauser, F., Bowen, A., Calel, R., Dechezleprêtre, A., Grover, D., Sato, M. (2013): “Who will win the green race? In search of environmental competitiveness and innovation”, *Global Environmental Change* 23, 902-913.

Shogenova, A., Piessens, K., Holloway, S., Bentham, M., Martínez, R., Flornes, K. M., Poulsen, N. E., Wójcicki, A., Sliaupa, S., Kucharic, L., Dudu, A., Persoglia, S., Hladik, V., Saftic, B., Kvassnes, A., Shogenov, K., Ivask, J., Suárez, I., Sava, C., Sorin, C., Chikkatur, A. (2014): “Implementation of the EU CCS Directive in Europe: results and development in 2013”, *Energy Procedia* 63, 6662-6670.

Zechmeister et al (2018): “Austrian Climate Change Mitigation Report 2018”, Umweltbundesamt Report REP-0660, Vienna, Austria. Available at http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0660.pdf

Appendix: OECD ENV-TECH technologies matched to SITC product groups

CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO TRANSPORT:

Conventional vehicles (based on internal combustion engine):	
SITC division	
713	Internal combustion Piston engines and parts thereof
78	Road vehicles: motor vehicles, parts and accessories of that group, motor cycles, trailers & semi-trailers
Hybrid / electric vehicles:	
716	Rotating electric plant (e.g. 716.1 +2 – electric motors)
77.1 to 77.3	Electrical machinery, apparatus and appliances except for medical equipment (electrical power machinery, electrical apparatus for switching or protecting electrical circuits, equipment for distributing electricity)
778.1	Batteries and electric accumulators and parts thereof
78	Road vehicles: motor vehicles, parts and accessories of that group, motor cycles, trailers & semi-trailers
Rail transport:	
791	Railway vehicles (79 – other transport equipment)
713	Internal combustion Piston engines and parts thereof
Air transport:	
792	Aircraft and associated equipment (79 – other transport equipment)
713	Internal combustion Piston engines and parts thereof
714.41	Reaction engines for turbo-jets (714 – Engines and motors, non-electric)
714.91	Parts of engines for turbo-jets or turbo-propellers
Maritime or waterways transport:	
793	Ships, boats and floating structures (79 – Other transport equipment)
713	Internal combustion Piston engines and parts thereof
Electric vehicle charging:	
77.1 to 77.3	Electrical machinery, apparatus and appliances except for medical equipment (electrical power machinery, electrical apparatus for switching or protecting electrical circuits, equipment for distributing electricity)
87.3	Meters and counters (87 – Professional, scientific and controlling instruments and apparatus)

CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO BUILDINGS:

Energy-efficient lighting:	
SITC division	
778.2	Electric filaments or discharge lamps (778 – Electrical machinery and apparatus nes)
813.1	Lamps and lighting fittings (813 – Lighting fixtures and fittings)
Heating, ventilation, air conditioning:	
741.5	Air-conditioning machines comprising a motor-driven fan (741 – Heating and cooling equipment)
812.1	Boilers, radiators and air heaters
Home appliances:	

775	Household type electrical and non-electrical equipment nes (laundry machines, refrigerators etc)
ICTs:	
75	Office machines and automatic data-processing machines
76	Telecommunications equipment and parts and apparatus
77.1 to 77.3	Electrical machinery, apparatus and appliances except for medical equipment (electrical power machinery, electrical apparatus for switching or protecting electrical circuits, equipment for distributing electricity)
874.77	Other instruments and apparatus, specially designed for telecommunications (87 – Professional, scientific and controlling instruments and apparatus)
Elevators, escalators, moving walkways:	
744.8	Lifting, handling, loading and unloading machinery
744.93	Their parts

CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO THE PRODUCTION AND PROCESSING OF GOODS:

Production of cement:	
SITC division	
661.2	Portland cement, aluminous cement, slag cement, supersulphate cement and similar hydraulic cements (66 – Non-metallic mineral manufactures)
661.8	Construction materials of asbestos-cement and fibre-cement of unfired non-metallic minerals
Cement grinding:	
273.2	Gypsum, plasters, limestone flux, limestone and other calcareous stone of a kind used for the manufacture of lime or cement
728.11	Machine tools for working stone, ceramics, concrete, asbestos-cement or like mineral materials
728.3	Machinery for sorting, screening separating, washing, crushing, grinding, mixing or kneading earth, stone, ores or other mineral substances; machinery for agglomerating, shaping or moulding solid mineral fuels, ceramic paste, unhardened cement, plastering materials or other mineral products
Manufacturing or processing of sand and stone:	
273	Stone, sand and gravel
728.11	Machine tools for working stone, ceramics, concrete, asbestos-cement or like mineral materials
728.3	Machinery for sorting, screening separating, washing, crushing, grinding, mixing or kneading earth, stone, ores or other mineral substances; machinery for agglomerating, shaping or moulding solid mineral fuels, ceramic paste, unhardened cement, plastering materials or other mineral products
Production or processing of lime:	
273.2	Gypsum, plasters, limestone flux, limestone and other calcareous stone of a kind used for the manufacture of lime or cement
661.1	Quicklime, slaked lime, hydraulic lime
728.11	Machine tools for working stone, ceramics, concrete, asbestos-cement or like mineral materials
728.3	Machinery for sorting, screening separating, washing, crushing, grinding, mixing or kneading earth, stone, ores or other mineral substances; machinery for agglomerating, shaping or moulding solid mineral fuels, ceramic paste, unhardened cement, plastering materials or other mineral products
Glass production:	
664	Glass (66 – Non-metallic mineral manufactures)
665	Glassware
728.11	Machine tools for working stone, ceramics, concrete, asbestos-cement or like mineral materials

728.41	… Machines for manufacturing or hot-working glass or glassware
Production of ceramic materials or ceramic elements:	
662	Clay construction materials and refractory construction materials
666	Pottery
728.3	Machinery for sorting, screening separating, washing, crushing, grinding, mixing or kneading earth, stone, ores or other mineral substances; machinery for agglomerating, shaping or moulding solid mineral fuels, ceramic paste, unhardened cement, plastering materials or other mineral products
Metal processing:	
67	Iron and steel
68	Non-ferrous metals
69	Manufactures of metals, nes
Chemical industry:	
50	Chemicals and related products
Oil refining and petrochemical industry:	
33	Petroleum, petroleum products and related materials
Agriculture, livestock and agroalimentary:	
0	Food and live animals
272	Crude fertilizers
562	Fertilizers other than those in 272
Agricultural machinery or equipment:	
721	Agricultural machinery
722	Tractors

CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO ENERGY GENERATION, TRANSMISSION AND DISTRIBUTION:

Wind energy:	
SITC division	
718.9	Engines and motors nes (wind engines e.g.)
716.2	Electric motors
716.4	Electric rotary converters
716.5	Generating sets
716.9	Parts
Hydro energy:	
718.1	Hydraulic turbines and water wheels and parts thereof
716.2	Electric motors
716.4	Electric rotary converters
716.5	Generating sets
716.9	Parts
PV:	
716.4	Electric rotary converters
77.1 to 77.3	Electrical machinery, apparatus and appliances except for medical equipment (electrical power machinery, electrical apparatus for switching or protecting electrical circuits, equipment for distributing electricity)
87.3	Meters and counters (87 – Professional, scientific and controlling instruments and apparatus)

Combustion technologies:	
713	Internal combustion Piston engines and parts thereof
Batteries:	
778.1	Batteries and electric accumulators and parts thereof
Capacitators:	
778.6	Electrical capacitators (fixed, variable and adjustable)
Smart grids:	
77.1 to 77.3	Electrical machinery, apparatus and appliances except for medical equipment (electrical power machinery, electrical apparatus for switching or protecting electrical circuits, equipment for distributing electricity)
87.3	Meters and counters (87 – Professional, scientific and controlling instruments and apparatus)