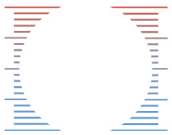

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Low carbon innovation in the UK: Evidence from patent data

Report for the UK Committee on Climate Change

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Executive summary

UK policy makers increasingly see new technologies related to the mitigation of greenhouse gas (GHG) emissions as a potential source of income growth for the UK economy. In this study we examine a comprehensive international patent database to determine the position of UK innovators relative to global competitors when it comes to "clean" innovation.

We identify relevant patents on the basis of a carefully selected list of categories from the patent classification system. We differentiate between 19 technology types. To ensure that our results are driven by commercially valuable patents we focus on international patents; i.e. patents that are filed in at least 2 countries. We also have to keep in mind that not all innovation is necessarily associated with a patent, although there is generally a strong correlation. Our main findings are as follows:

- Overall, the UK ranks on position 5 in terms of the share of clean patents that are held by UK inventors, behind Japan, Germany, USA and France.
- The UK position deteriorates if we take into account size differences between countries by looking at the ratio between global patent share and global GDP share. While the UK moves ahead of the US it falls behind countries such as Sweden, Denmark, Austria, the Netherlands, Switzerland, Australia and South Korea.
- The UK position equally deteriorates if only more recent clean patent filings are considered. In terms of the global clean patent share over the 2002 to 2007 period the UK falls behind South Korea. However, this is not because patenting activity is not growing in clean areas in the UK but because it is growing even faster in emerging economies such as South Korea.
- While the UK cannot be considered a leader in clean technologies overall there are important differences between technology types in terms of the shares in global patenting that are due to UK inventors as well as regarding changes in these shares over time.
- The UK has a very strong position in marine energy generation. Looking at inventions developed recently (between 2002 and 2007), the UK appears as the world leader in this technology in terms of the share of inventions worldwide in this area. However, the UK is lagging behind a number of smaller countries when this figure is set in relation to the share of the UK in world GDP.
- Other technologies where the UK has both a comparatively high global share as well as a higher rank include waste-to-energy and wind power technologies (see Table 1)

- The UK share has been improving strongest in Waste, Solar CSP, Geothermal, Cement and Solar PV (comparing 2003-2007 with 1980-1996).
- On the other hand there are a range of sectors where the UK share is declining. The strongest declines are recorded in Batteries, Electric & Hybrid vehicles, Fuel Injection, Lighting and Fuel Cells.
- Looking at patenting activity over time suggest that the decline in global shares of the UK is in most cases driven by a faster increase elsewhere rather than a decline in patenting in the UK.
- We also examine if UK inventors are among the dominant players in specific technology fields by looking at company-level patenting at the European Patent Office. While we identify a number of technologies where UK inventors are among the top 10 globally in terms of number patents held (in Cement, Nuclear energy, Fuel Injection and Insulation), there is no technology field where a UK company is leading. This is particularly surprising in relation to the dominant position of the UK in marine energy technologies. It seems that the UK has a larger number of smaller inventors in this area compared to other countries.

Table 1: The UK comparative advantage – summary results

Top UK Shares (in % of world's high-value inventions 2002-2007)	Marine (17.5%)	Wind (5.3%)	Geothermal (5.2%)	Waste energy (4.6%)	Hydro (4.2%)
Top UK Global Rank (2002-2007)	Marine (1)	Biomass (5)	Waste energy (5)	Wind power (6)	Fuel Injection (6)
Technologies with highest UK Global Share Increase (2003-2007 relative to 1980-1996)	Waste	Solar CSP	Geothermal	Cement	Solar PV
Technologies with highest UK Global Share continuous Decline (2003-2007 relative to 1980-1996)	Batteries	Electric&Hybrid	Fuel Injection	Lighting	Fuel Cells
UK has top 10 company within EPO patents	Cement	Nuclear energy	Fuel Injection	Insulation	

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1. Introduction

Accelerating the development of new low-carbon technologies and promoting their global diffusion is a key challenge in stabilizing atmospheric GHG emissions. Governments are increasingly promoting climate change policies with the promise of short term gains in terms of jobs and income from being global leaders in low carbon technologies. Where is the UK standing in terms of "clean" innovation? What progress has been made in these areas? What are the promising technologies where governement support could be targeted?

This study provides answers to these questions on the basis of a worldwide patent database. We compare both the relative level and the trends in "clean" innovation activity between different countries using patent counts as an innovation measure.

The primary aim of this study is to provide a picture of where the UK is standing in terms of climate change mitigation innovation relative to other countries. We provide disaggregated data by technology type on the performance of UK-based inventors with respect to other countries. We also look at the extent to which technologies are exported and imported. A UK technology is considered to be exported if a UK inventor applies for patent protection not only in the UK but also in other countries such as the US or Japan. To examine technology importing relevant to the UK we examine the origin of inventors applying for patent protection at the European Patent Office. Finally we examine the performance of individual UK-based companies.

The remainder of the report is organised as follows: Section 2 discusses our methods and definition in more detail. Section 3 reports statistics of patent stocks both by technology and for the main innovator countries. Section 4 examines innovation trends. Sections 5 and 6 look at exports and imports of patents, respectively. Section 7 looks at the distribution of patents across firms. In Section 8 we present a case study on Marine Energy. Finally, Section 9 concludes.

2. Methods

2.1. Data sources

Our data comes from the EPO/OECD World Patent Statistical Database (PATSTAT). PATSTAT is unique in that it covers more than 80 patent offices and contains over 70 million patent documents.

Patent applications related to climate change are identified using the International Patent Classification (IPC) codes, developed at the World Intellectual Property Organization (WIPO). The IPC classes corresponding to the climate mitigation technologies are identified in two alternative ways. First, we search the descriptions of the classes online to find those which are appropriate. Second, using the online international patent database maintained by the European Patent Office, we search patent titles and abstracts for relevant keywords. The IPC classes corresponding to the patents that come up are included, provided their description confirms their relevancy.

When building the data sets, two possible types of error may arise: irrelevant patents may be included or relevant ones left out. The first error happens if an IPC class includes patents that bear no relation to climate mitigation. In order to avoid this problem, we carefully examine a sample of patent titles for every IPC class considered for inclusion, and exclude those classes that do not consist only of patents related to climate change mitigation. This is why key technologies in terms of carbon reduction potential are outside the scope of this study. Important missing technologies include energy efficient technologies in industry, or clean coal technologies.

The second error—relevant inventions are left out—is less problematic. We can reasonably assume that all innovation in a given field behaves in a similar way and hence our datasets can be seen at worst as good proxies of innovative activity in the field considered. However, overall innovative activity may be underestimated.

2.2. Measuring innovation using patents

As a measure of innovation, we use counts of patent applications. Although patents do not provide a measure of all innovation, they offer a good indication of the results of innovative activity and allow for interesting cross-country comparisons. Consequently, they have been extensively used as a measure of innovation, and more recently as a measure of technology diffusion. For our purpose, the main advantage of patent data is that they are available both at a disaggregated technological level and on a global scale. Moreover – and contrary to data on

R&D expenditures – they focus on the output of the innovation process, rather than on the input.

Patent-based indicators also have a number of limitations[1]. The first is that patents are only one of the means of protecting innovations, along with lead time, industrial secrecy or purposefully complex specifications (Cohen et al., 2000; Frietsch and Schmoch, 2006). In particular, inventors may prefer secrecy to prevent public disclosure of the invention imposed by patent law, or to save the significant fees attached to patent filing. However, there are very few examples of economically significant inventions which have not been patented (Dernis and Guellec, 2001). In addition, the propensity to patent depends on the risk of imitation in the country. Accordingly, patenting is more likely to concern countries with technological capabilities and a strict enforcement of intellectual property rights. This may lead us to understate innovation activity in developing countries. A further limitation is that a patent grants only the exclusive right to use the technology in a given country. It does not mean that the patent owner will actually do so. This could significantly bias our results if applying for protection did not cost anything, so that inventors might patent widely and indiscriminately. But this is not the case in practice. Patenting is costly – in terms of the costs of preparation of the application, the administrative costs and fees associated with the approval procedure, and the possible litigation costs[2]. Inventors are thus unlikely to incur the cost of patent protection in a country unless they expect a potential market for the technology covered.

The fact remains that the value of individual patents is heterogeneous. Moreover, its distribution is skewed: as many patents have very little value, the number of patents does not perfectly reflect the value of innovations. As a way to adjust indicators according to innovation quality, in this study we present only statistics based on patents that have been filed in at least two countries. The fraction of multi-country patents in all inventions can be found in Table 3. As can be seen from this table, this approach leads us to focus on only 15% of all inventions for which patent protection is sought. This may sound very small. However, this is an average and this share varies greatly across countries. For example, implementing this method drops over 90% of Chinese patents and 80% of Japanese patents but only 40% of UK patents. Consequently, this method reduces the innovative outputs of Japan and of emerging countries much more than it does reduce that of European countries and of the US. The advantage of this method is to get rid of the many patents filed in only one country that

[1] For a good overview of the advantages and the limitation of patent data, see OECD (2009).

[2] The total cost of obtaining a patent in 2003 was €24,000 in Europe, €10,000 in the USA and €5,500 in Japan (see the study on the cost of patenting conducted by Roland Berger for the European Patent Office in 2005).

have been shown to be of very low value. For example, in Japan, numerous domestic patent applications are filed but never get examined by the patent office. In China, the number of patents filed by local inventors has recently rocketed and the value of patents filed only domestically is strongly questioned by patent experts. The drawback of this approach is that it might leave us with a statistically insignificant number of patents in some sectors (in particular in geothermal energy where patenting activity is very low).

2.3. Identifying clean technologies

We distinguish between 19 technologies with significant global GHG emission abatement potential. More precisely, we consider seven renewable energy technologies (wind, solar, geothermal, marine energy, biomass, hydropower, and waste-to-energy), nuclear energy, methane destruction, climate-friendly cement, thermal insulation in buildings, heat pumps, electric and hybrid vehicles, fuel injection technologies, fuel cells, and energy-efficient lighting. Since energy storage is key for the deployment of many renewable energy systems, we include data on rechargeable batteries (or secondary cells). We also provide disaggregated data on photovoltaic energy, concentrating solar power and thermal solar. The precise description of the fields covered by the study can be found in Table 2. The technologies included in our dataset represent nearly 50% of all GHG abatement opportunities beyond business as usual until 2030 – excluding forestry – identified by Enkvist et al. (2007).

2.4. Attributing innovation to countries

The PATSTAT database includes information on the country of residence of the inventors for the technologies for which patent protection is sought, independently of the country where applications are filed. We use this indicator to measure country performance.[3] Patents protecting the same innovation in several countries are only counted once. As mentioned above, all statistics presented in this section are based on patents filed in at least two countries, which can be considered as "high-value" inventions.

[3] Patents with multiple inventors are counted fractionally. For example, if two inventor countries are involved in an invention, then each country is counted as one half.

Table 2: Description of the technology fields covered

Technology field	Description of aspects covered
Rechargeable batteries	Secondary cells (accumulators receiving and supplying electrical energy by means of reversible electrochemical reactions)
Fuel cells	Fuel cells (electrochemical generators wherein the reactants are supplied from outside)
Biomass	Solid fuels based on materials of non-mineral origin (i.e. animal or plant); engines operating on such fuels (e.g. wood).
Cement	Natural pozzuolana cements; cements containing slag; iron ore cements; cements from oil shales, residues or waste; calcium sulfate cements.
Electric vehicles	Electric propulsion of vehicles; regenerative braking ; batteries; control systems specially adapted for hybrid vehicles
Fuel injection	Motor fuel-injection apparatus (allowing reduced fuel consumption)
Geothermal	Use of geothermal heat; devices for producing mechanical power from geothermal energy.
Heating	Heat pumps, central heating systems using heat pumps; energy recovery systems in air conditioning
Hydro	Hydro power stations; hydraulic turbines; submerged units incorporating electric generators; devices for controlling hydraulic turbines.
Insulation	Elements or materials used for heat insulation; double-glazed windows
Lighting	Compact Fluorescent Lamps; Electroluminescent light sources (LED)
Methane	Equipment for anaerobic treatment of sludge; biological treatment of waste water or sewage; anaerobic digestion processes; apparatus aiming at collecting fermentation gases.
Marine	Tide or wave power plants; mechanisms using ocean thermal energy conversion; water wheels.
Nuclear	Nuclear reactors, fusion reactors, nuclear power plants
Solar PV	Solar photovoltaic (conversion of light radiation into electrical energy), incl. solar panels
Solar CSP	Concentrating solar power (solar heat collectors having lenses or reflectors as concentrating elements)
Solar thermal	Use of solar heat for heating & cooling
Waste	Solid fuels based on industrial residues or waste materials; recovery of heat from waste incineration; production of energy from waste or waste gases; recovery of waste heat from exhaust gases.
Wind	Wind motors (mechanisms for converting the energy of natural wind into mechanical power, and transmission of such power to its point of use); blades; devices aimed at controlling wind motors.

2.5. Descriptive statistics

As shown in Table 3, our data set includes over 700,000 patents. However, around half of these patents are filed in only one country. Consequently, we do not use these patents in all sections dedicated to innovation performance.

The propensity to use patents as a means of protection against innovation differs widely across industries. For this reason, it is not possible to compare the absolute level of patenting activity across technologies. Table 4 shows that the average number of patents filed annually differs widely across technologies. For example, batteries, nuclear power, lighting, electric & hybrid vehicles and fuel injection have above 2,000 patents per year. By contrast, geothermal and biomass energy have less than 100 patents per year. We have to be cautious in interpreting this as evidence for variation of innovativeness between technology types as these differences might equally be driven by variations in the propensity to innovate as well as in the size of the industries underlying those technologies.

What is the trend of patenting activity over time? We report trends in Box 1 where we normalize the data to equal 100 in 1980 in each technology. The figures show that the evolution of patenting activity differs widely across technologies. The growth of innovation has been particularly strong in batteries, lighting, and electric & hybrid. Patenting activity has decreased in mature technologies such as nuclear power, hydro power, and solar thermal. The trend of patenting activity in most renewable energy technologies follows a U-shape curve: innovation increased during the 1980s before going up again at the end of the 1990s. This evolution closely follows that of oil prices. Interestingly, the level of patenting in renewable energy technologies in 2005 just about equals the early 1980s record high that followed the second oil shock.

Table 3: Descriptive statistics by technology

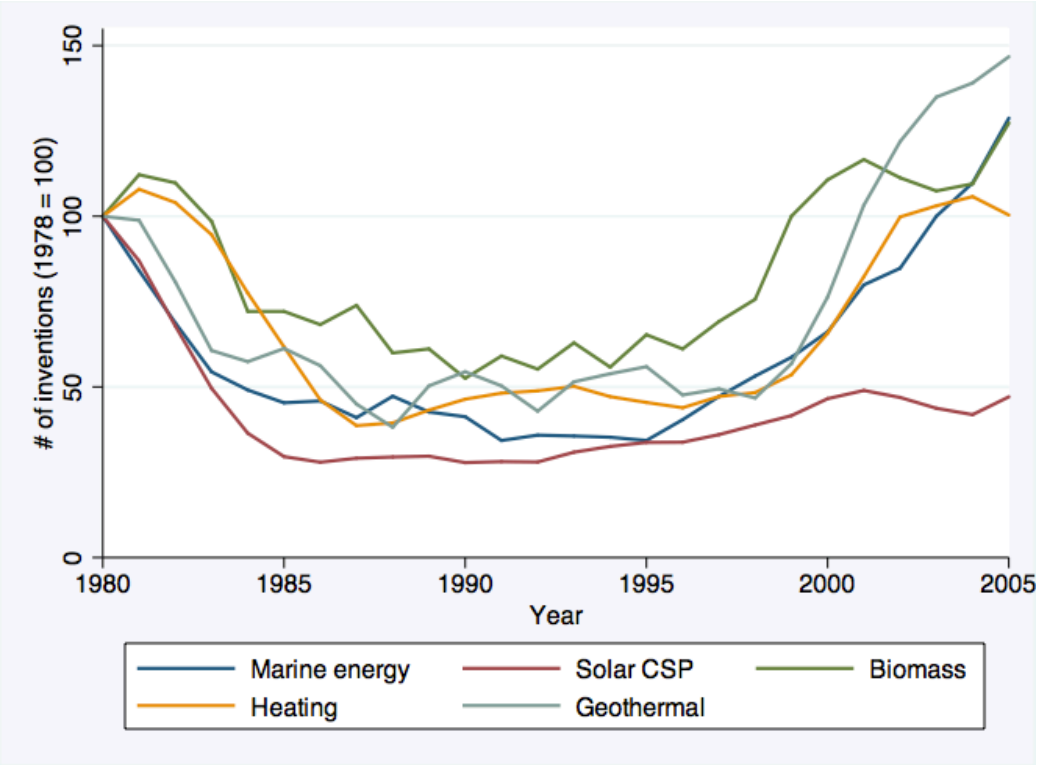
Technology	Total patents	Inventions	Single Country Inventions	Multi-country inventions	Share of multi country Inventions
Lighting	103699	58204	45629	12575	21.6%
Batteries	103514	60310	50724	9586	15.9%
Fuel cells	99983	55553	46374	9179	16.5%
Electric & hybrid	68688	39787	34196	5591	14.1%
Fuel injection	76692	35698	30981	4717	13.2%
Solar (all)	46180	28781	24484	4297	14.9%
Nuclear	70892	45181	41385	3796	8.4%
Insulation	27506	15282	12700	2582	16.9%
Solar PV	19585	11750	9424	2326	19.8%
Wind	24656	13768	11852	1916	13.9%
Solar thermal	22883	15207	13395	1812	11.9%
Waste	20310	11855	10314	1541	13.0%
Heating	16163	10329	8971	1358	13.1%
Methane	12736	7511	6604	907	12.1%
Solar CSP	6662	3522	2881	641	18.2%
Marine energy	7078	4102	3482	620	15.1%
Cement	6922	4143	3630	513	12.4%
Hydro	9587	7464	6975	489	6.6%
Biomass	2817	1806	1544	262	14.5%
Geothermal	2524	1737	1517	220	12.7%
Total	704111	406367	344896	61471	15.1%

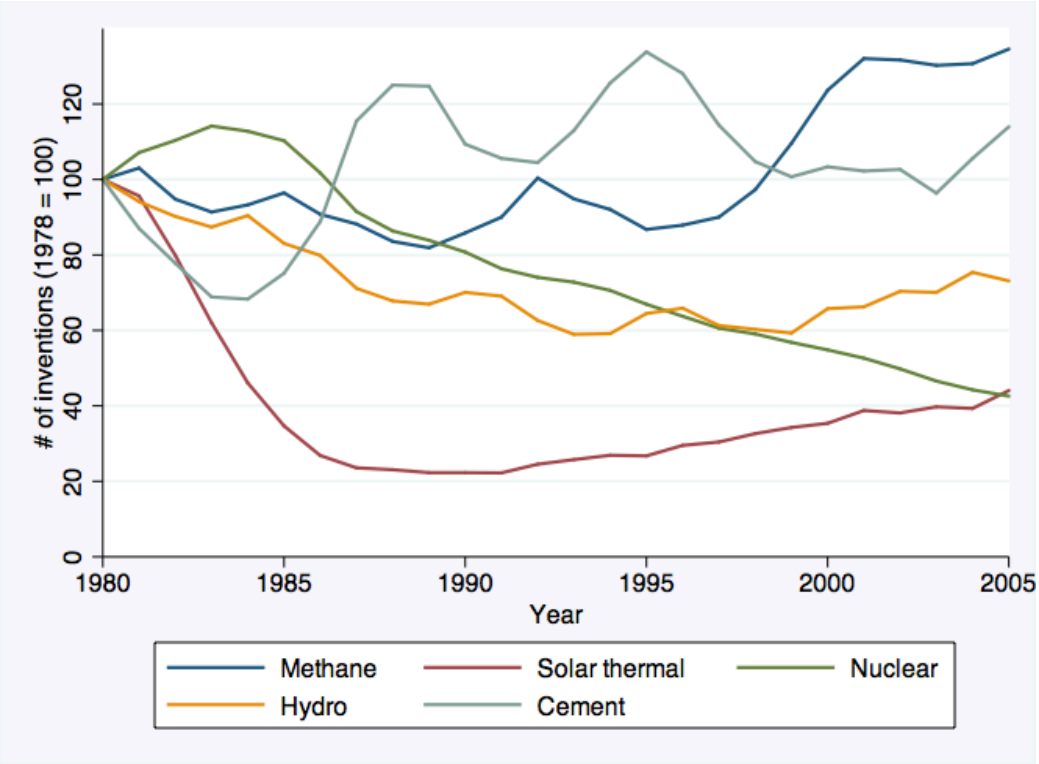
Note: A single country invention is a patent applied for in the patent office of only one country.

Table 4: Average number of annual patents by technology

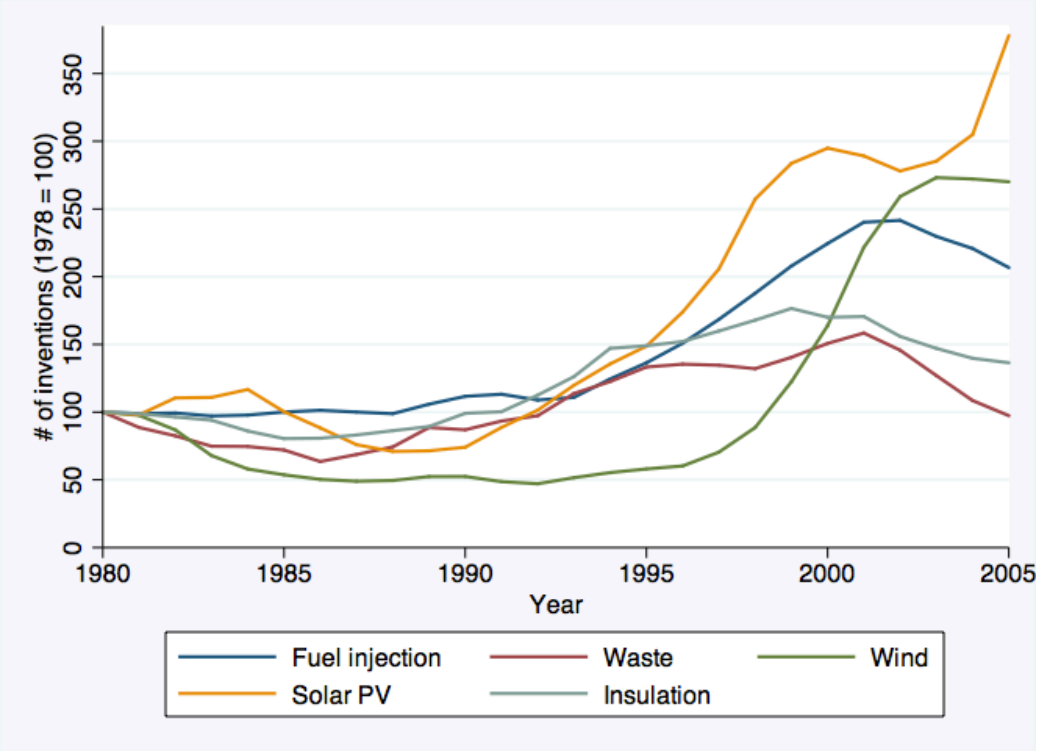
Technology	Average number of annual patents
Batteries	3549
Lighting	3518
Fuel cells	3276
Fuel injection	2744
Nuclear	2614
Electric & hybrid	2259
Insulation	989
Solar thermal	821
Wind	799
Waste	732
Solar PV	627
Heating	576
Methane	454
Hydro	341
Cement	249
Solar CSP	241
Marine energy	240
Biomass	97
Geothermal	85
Average	732

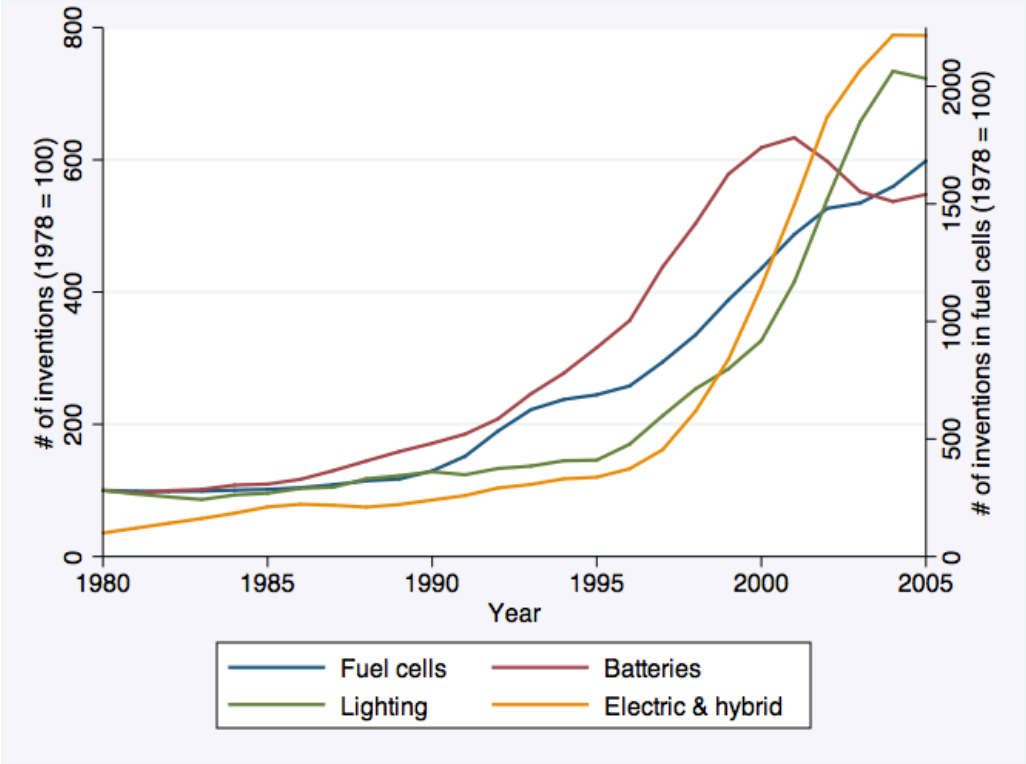
BOX 1. WORLDWIDE TRENDS IN PATENTING ACTIVITY BY TECHNOLOGY, 1980-2005[4]





[4] We stop the time series in 2005 as the delay between patent application and inclusion in our database might introduce spurious rather than actual dynamics in years after 2005.





Note: fuel cells patents are reported on the right-hand side axis

3. Patents Stocks

3.1. Patent stocks by inventor countries

Table 5 displays the share of climate-related inventions developed by each inventor country between 1980 and 2007. Since the number of inventions by technology is very heterogeneous, Table 5 displays the average performance of each inventor country across all climate-related technologies. This method gives identical weights to each technology field.

With around 20% of the world's stock of high-value inventions in climate-related technologies, Japan and Germany are the world leaders. They are followed by the USA. Together, these three countries represent 55% of the world's stock of inventions developed since 1980. With 4.5% of the world's inventions on average across the 17 technologies, the UK ranks 5th.

In order to focus on recent trends in innovative activities, column 3 of Table 5 reports the share of inventions developed by each inventor country between 2002 and 2007. Although the picture does not change radically, the UK now ranks 6th. This is due to the recent performance of South Korea, which now innovates more than most European countries. However, with 4.3% of global innovation, the contribution of UK's inventors seems very stable. This contrasts with Germany, the USA, and Sweden, whose average share declined by more than 1 percentage point.

However, the figures underlying Table 5 do not account for the sizes of the different economies. In Table 5b, we compare the share of climate-related inventions developed by each country with its share in world's GDP during the same time period. The ratio of these figures is an indicator of the country's performance relative to the size of its economy.

It turns out that the UK's share in clean patenting (4.5%) roughly corresponds to its share in world GDP (3.9%). As a consequence it moves ahead of the US whose share in clean patenting is considerably smaller than its share in GDP. However, there is a whole range of economies who are over-proportionally focused on clean patenting so that the UK's position deteriorates. Among the economies with the 15 largest shares in clean patenting the UK moves to position 11, behind countries such as Sweden, Australia, the Netherlands, Switzerland, Denmark, Austria and South Korea.

The UK position does not look any better if clean patenting is related to overall patenting (see table 5c). The UK clean patent share is almost identical to its overall patent share but there are a number of economies considerably more focused on clean patents.

Hence, according to these average results across all technology types the UK does not appear to be in a global leadership position. However, these average results hide considerable heterogeneity across technology types as the next section reveals.

Table 5: Top 15 inventors, with average % of total climate related inventions (1980-2007 and 2002 - 2007)

Country	Average % of world's inventions 1980-2007	Average % of world's inventions 2002-2007
Japan	20.2% (1)	20.8% (1)
Germany	19.8% (2)	17.8% (2)
USA	15.4% (3)	14.1% (3)
France	5.1% (4)	4.4% (5)
UK	4.5% (5)	4.3% (6)
Australia	3.8% (6)	2.9% (9)
Sweden	3.3% (7)	1.7% (14)
S Korea	3.1% (8)	5.6% (4)
Canada	2.2% (9)	3.0% (8)
Netherlands	2.1% (10)	1.8% (13)
Austria	2.0% (11)	2.1% (11)
Italy	1.9% (12)	2.3% (10)
Switzerland	1.9% (13)	1.3% (16)
China	1.9% (14)	3.9% (7)
Denmark	1.4% (15)	1.4% (15)
TOTAL	80.0%	79.6%

Table 5b: Top 10 inventors, with average % of total climate related inventions and % of world's GDP (1980-2007)

Country	1980-2007			2002-2007		
	Share of world's…		Ratio	Share of world's…		Ratio
	Innovation	GDP		Innovation	GDP	
Japan	20.2%	8.6%	2.36	20.8%	7.2%	2.88
Germany	19.8%	5.8%	3.43	17.8%	4.9%	3.62
USA	15.4%	24.0%	0.64	14.1%	22.9%	0.62
France	5.1%	4.0%	1.28	4.4%	3.5%	1.25
UK	4.5%	3.9%	1.16	4.3%	3.6%	1.19
Australia	3.8%	1.2%	3.12	2.9%	1.2%	2.40
Sweden	3.3%	0.6%	5.58	1.7%	0.5%	3.06
S Korea	3.1%	1.7%	1.80	5.6%	2.0%	2.73
Canada	2.2%	2.2%	1.01	3.0%	2.1%	1.42
Netherlands	2.1%	1.2%	1.82	1.8%	1.1%	1.64
Austria	2.0%	0.6%	3.46	2.1%	0.5%	4.06
Italy	1.9%	3.7%	0.51	2.3%	3.1%	0.73
Switzerland	1.9%	0.6%	3.16	1.3%	0.5%	2.66
China	1.9%	6.4%	0.29	3.9%	9.8%	0.40
Denmark	1.4%	0.4%	3.74	1.4%	0.3%	4.12

Table 5c: Top 10 inventors, with average % share of total climate related inventions and % share in all patents (1980-2007)

Country	1980-2007			2002-2007		
	Share of world's…		Ratio	Share of world's…		Ratio
	Climate Innovation	Total innov.		Climate Innovation	Total innov.	
Japan	20.2%	35.6%	0.57	20.8%	33.9%	0.61
Germany	19.8%	14.6%	1.35	17.8%	13.8%	1.29
USA	15.4%	20.6%	0.75	14.1%	19.9%	0.71
France	5.1%	5.3%	0.96	4.4%	4.5%	0.97
UK	4.5%	4.4%	1.02	4.3%	3.1%	1.39
Australia	3.8%	0.5%	7.63	2.9%	0.4%	6.77
Sweden	3.3%	1.3%	2.52	1.7%	1.0%	1.74
S Korea	3.1%	4.0%	0.78	5.6%	9.0%	0.62
Canada	2.2%	1.5%	1.49	3.0%	1.7%	1.77
Netherlands	2.1%	1.3%	1.62	1.8%	1.0%	1.69
Austria	2.0%	0.8%	2.43	2.1%	0.7%	2.88
Italy	1.9%	1.9%	0.98	2.3%	1.1%	2.10
Switzerland	1.9%	1.4%	1.40	1.3%	0.9%	1.42
China	1.9%	0.7%	2.63	3.9%	1.8%	2.14
Denmark	1.4%	0.4%	3.60	1.4%	0.3%	5.23

3.2. Patent stocks by technology

Table 6 shows the share of UK inventions[5] in the world's stock of high-value inventions by technology. Similarly to Section 3.1 above, we display the stocks for two time periods, namely 1980-2007 and 2002-2007.

Looking first at the 1980-2007 stock, the UK's share of patents is highest for marine energy (16.5%), followed by wind power (5.8%), fuel injection (5.3%), and biomass (5.3%). In all other technologies, the UK share is below 5%, with the lowest share for Electric & Hybrid, Fuel Cells, and Batteries (with around 2%).

[5] The top 15 inventor countries by technology over the 1980-2007 period are shown in Box 1.

Marine energy technology is clearly an outlier where the UK commands not only a considerable share of the world total but ranks only behind the US, an economy more than 6 times the size of the UK. When only the patents over the 2002 to 2007 period are considered the UK emerges as the world leader. Other promising areas over the 2002 to 2007 period include wind power (5.3%), geothermal energy (5.2%), waste (4.6%) and hydro (4.2%). The technologies with the highest global rank apart from marine energy include wind and biomass (both rank 5). In many technology areas the position of the UK seems to be however declining. We analyze these changing trends over time in more detail in the next section.

Table 6b examines in addition the share of a country's patents in a particular technology type in relation to its share in GDP. The main takeaway from this table for the UK is that despite its clear lead in marine technologies in absolute terms, there are a number of smaller countries whose performance in relative terms looks better. This includes Norway, Australia, Israel, Ireland, Sweden and Denmark, leaving the UK at position 7 worldwide.

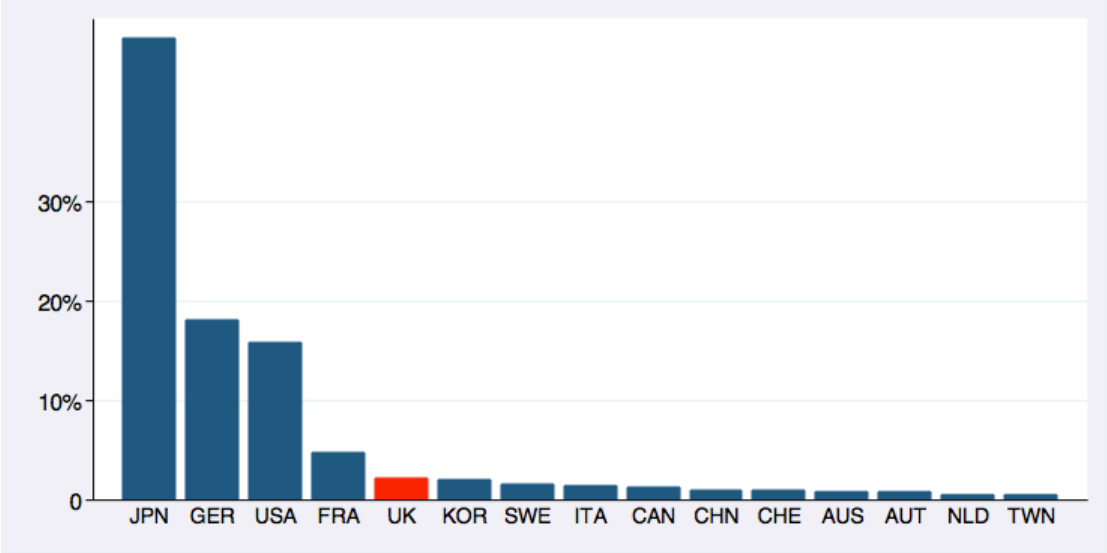
Table 6: Share of UK inventions in world innovation by technology

Technology	1980-2007		2002-2007	
	Share of world's inventions	Rank	Share of world's inventions	Rank
Batteries	2.0%	6	1.0%	9
Biomass	5.3%	6	4.1%	5
Cement	2.8%	6	3.1%	7
Electric & hybrid	2.1%	5	1.4%	8
Fuel cells	2.2%	6	1.8%	8
Fuel injection	5.3%	4	2.9%	6
Geothermal	4.0%	7	5.2%	7
Heating	3.5%	7	3.7%	7
Hydro	3.9%	7	4.2%	8
Insulation	4.1%	7	3.8%	7
Lighting	2.5%	6	1.7%	8
Marine energy	16.5%	2	17.5%	1
Methane	4.1%	7	2.8%	9
Nuclear	3.7%	6	1.5%	10
Solar (all)	3.1%	6	2.8%	10
Solar CSP	3.3%	7	3.4%	9
Solar PV	2.4%	7	2.6%	8
Solar thermal	3.7%	6	3.0%	9
Waste	3.5%	5	4.6%	5
Wind	5.8%	5	5.3%	6
All technologies	4.5%	5	4.3%	6

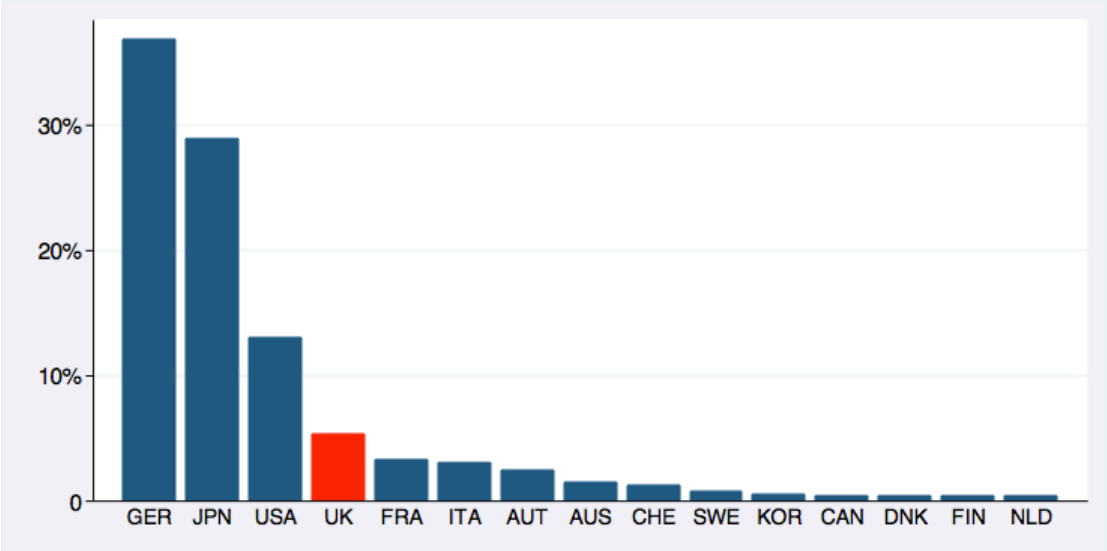
BOX 2. TOP 15 INVENTOR COUNTRIES BY TECHNOLOGY, 1980-2007

The following graphs display the top 15 inventor countries by technology over the 1980-2007 period (for high-value inventions only).

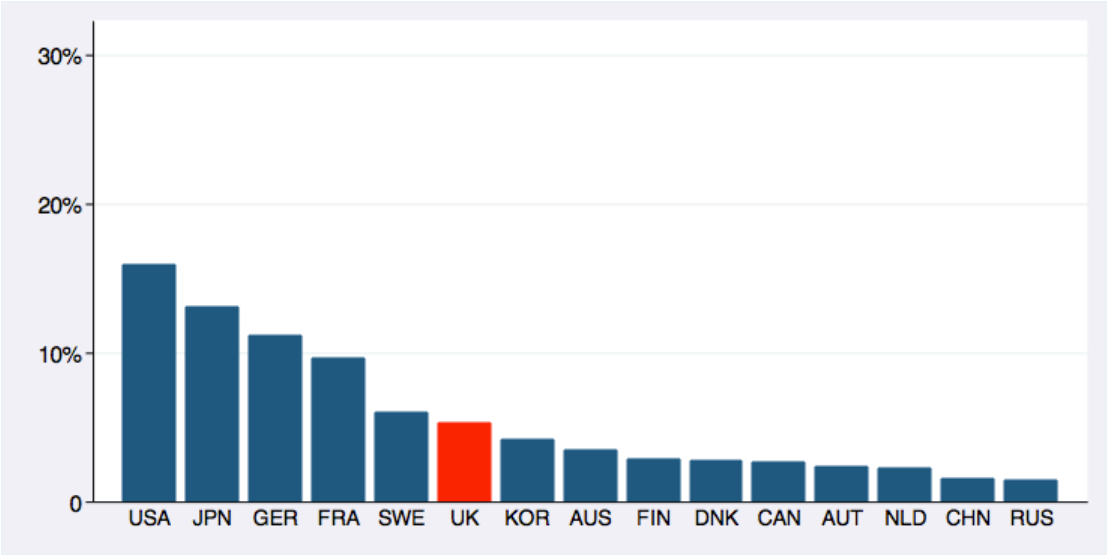
Electric & hybrid vehicles



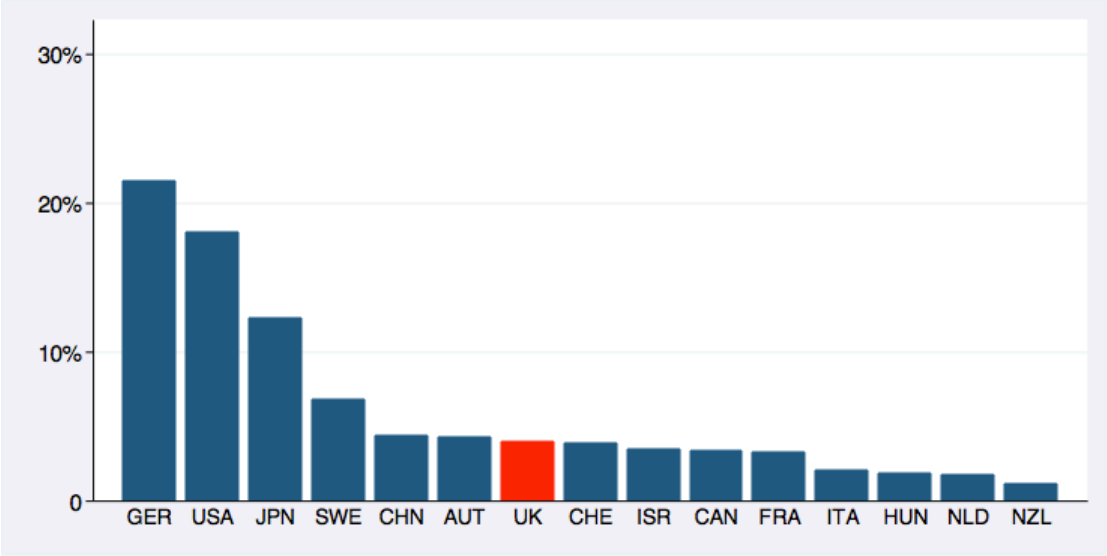
Fuel injection



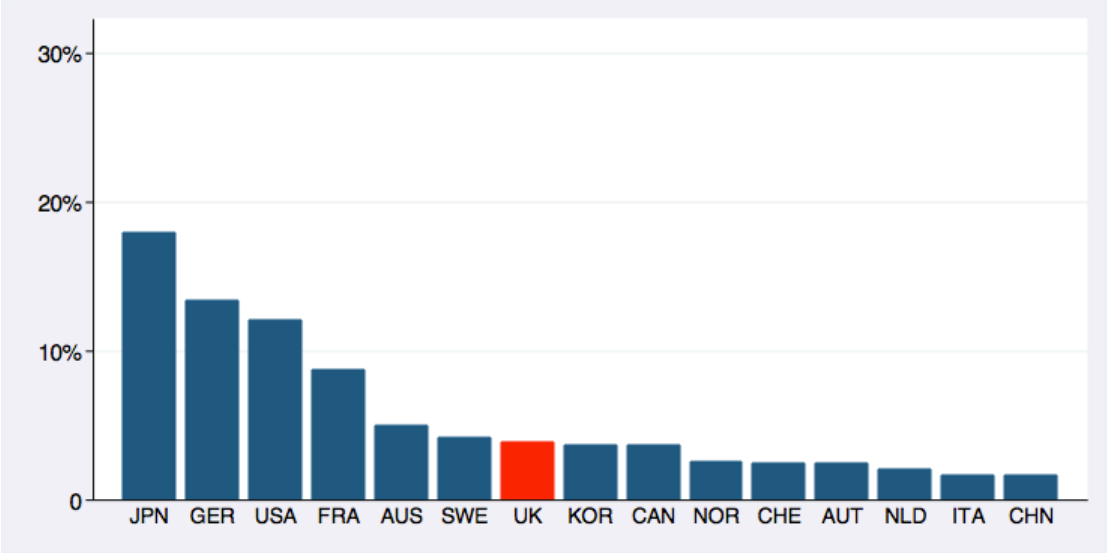
Biomass



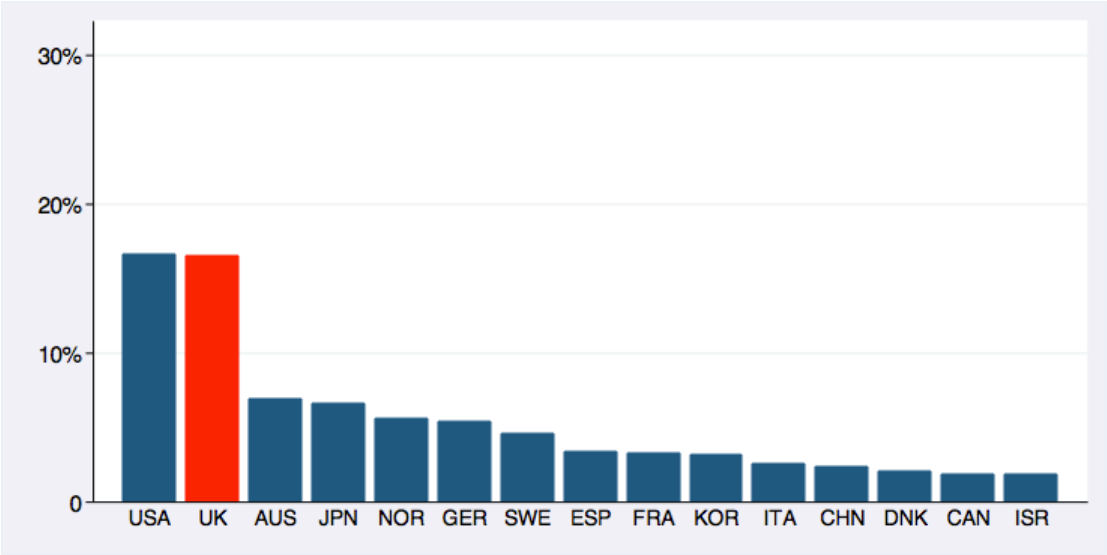
Geothermal energy



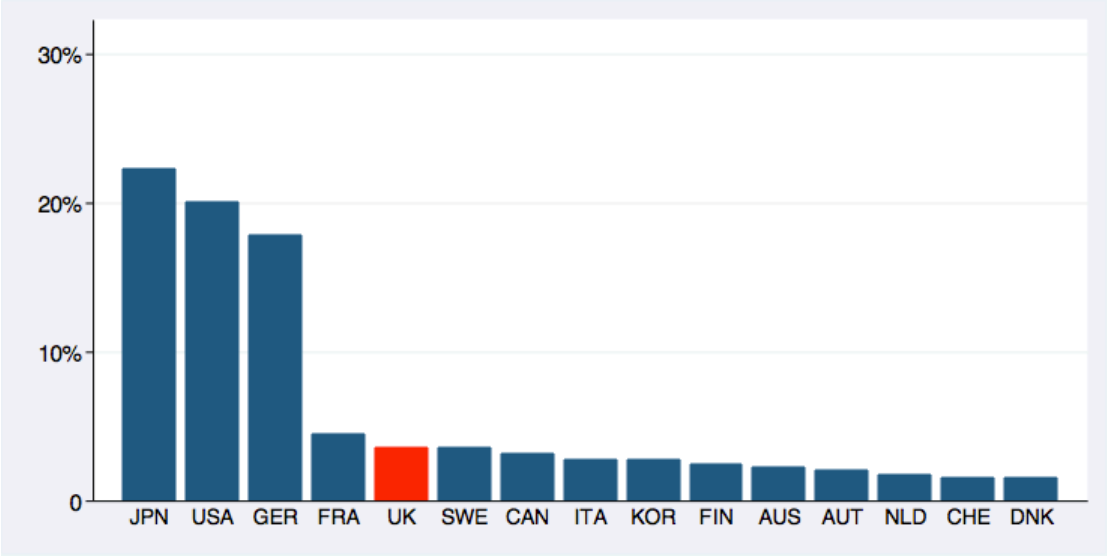
Hydro power



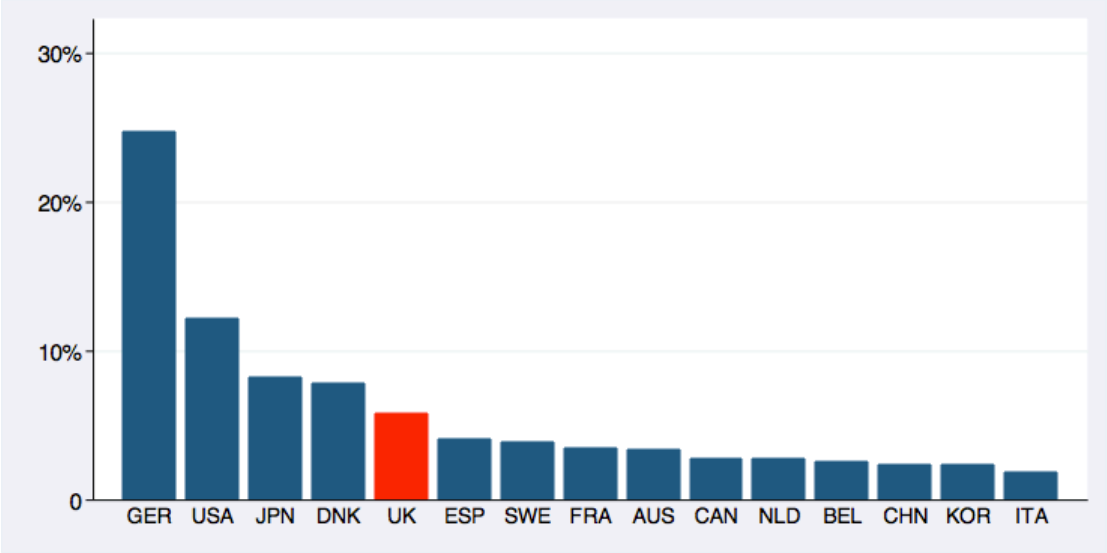
Marine energy



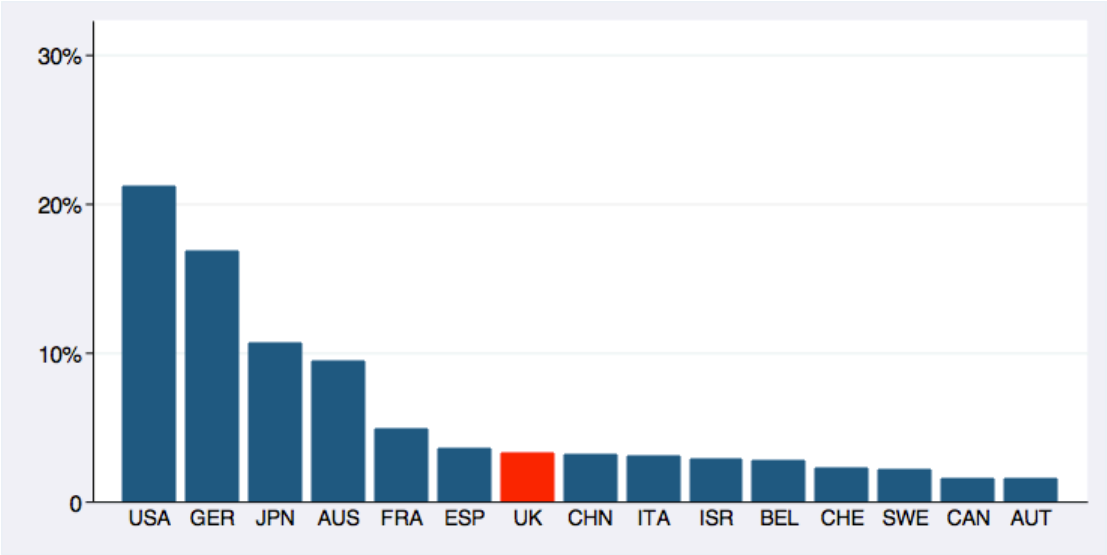
Waste-to-energy



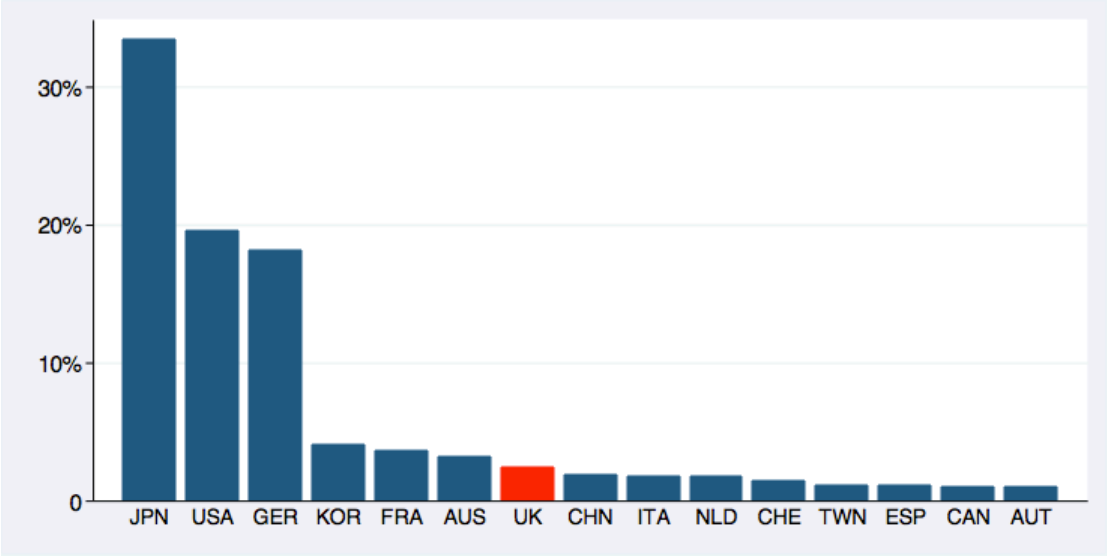
Wind power



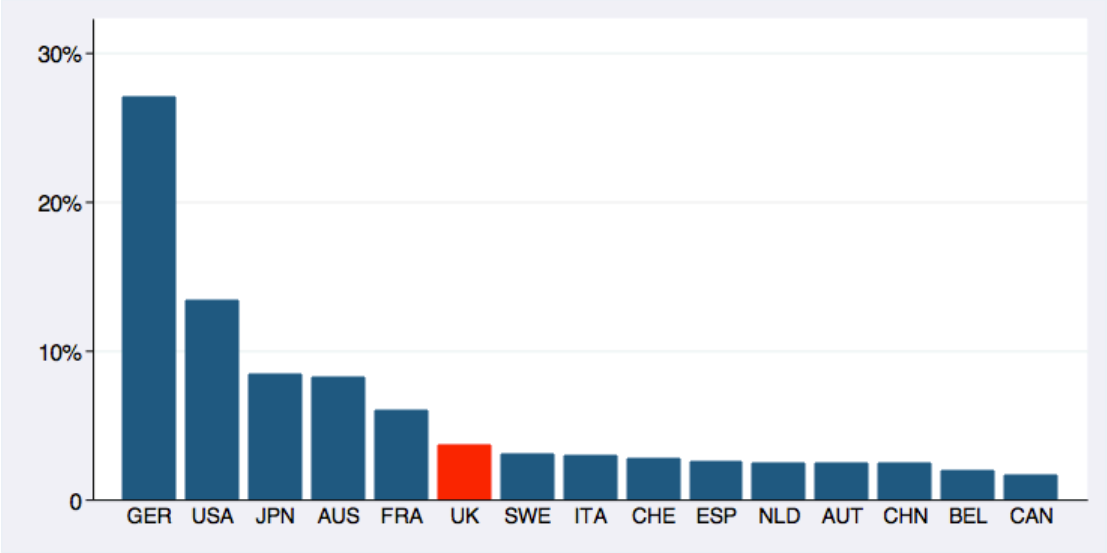
Solar CSP



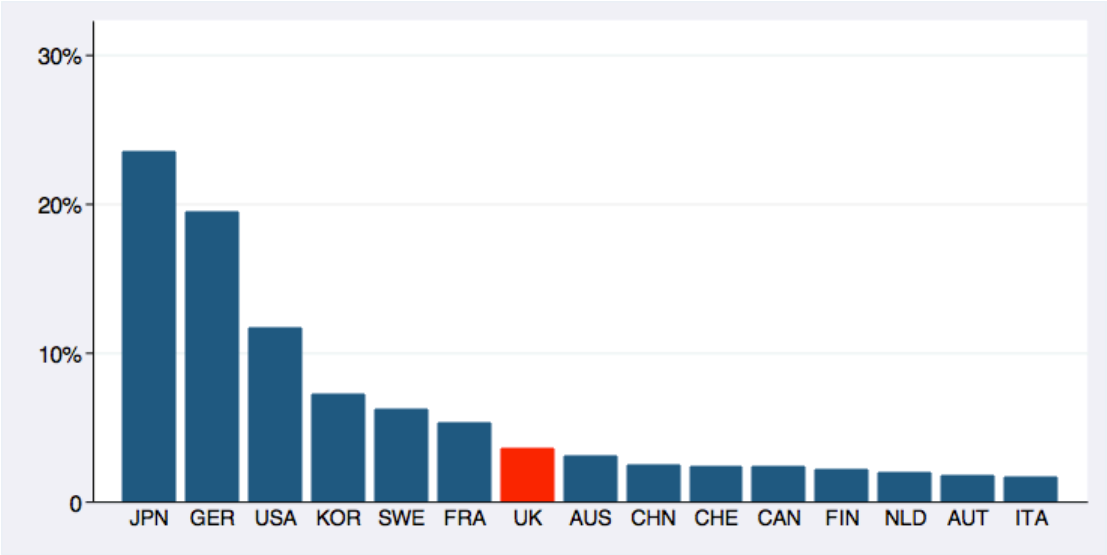
Solar PV



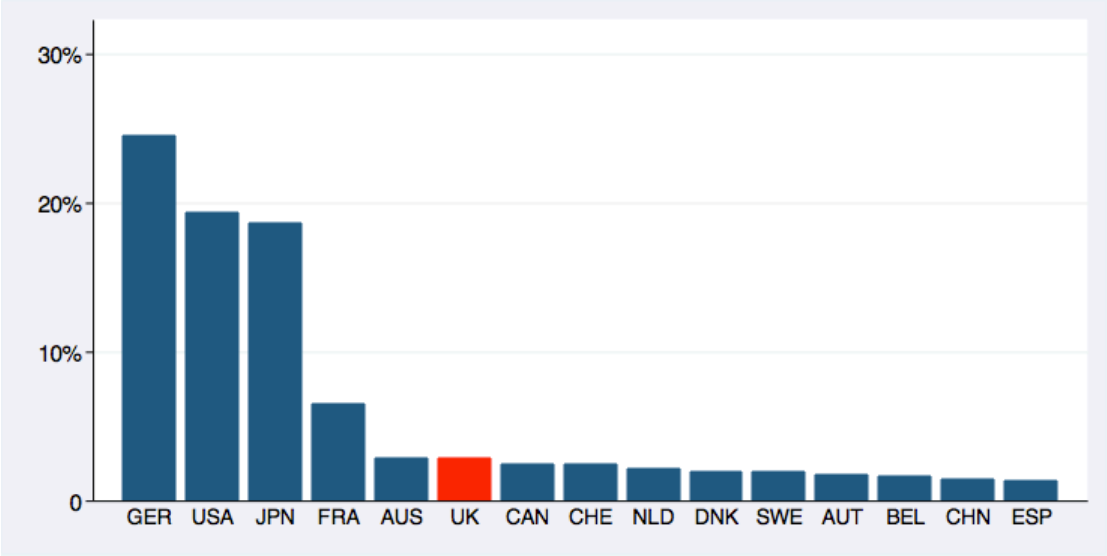
Solar thermal



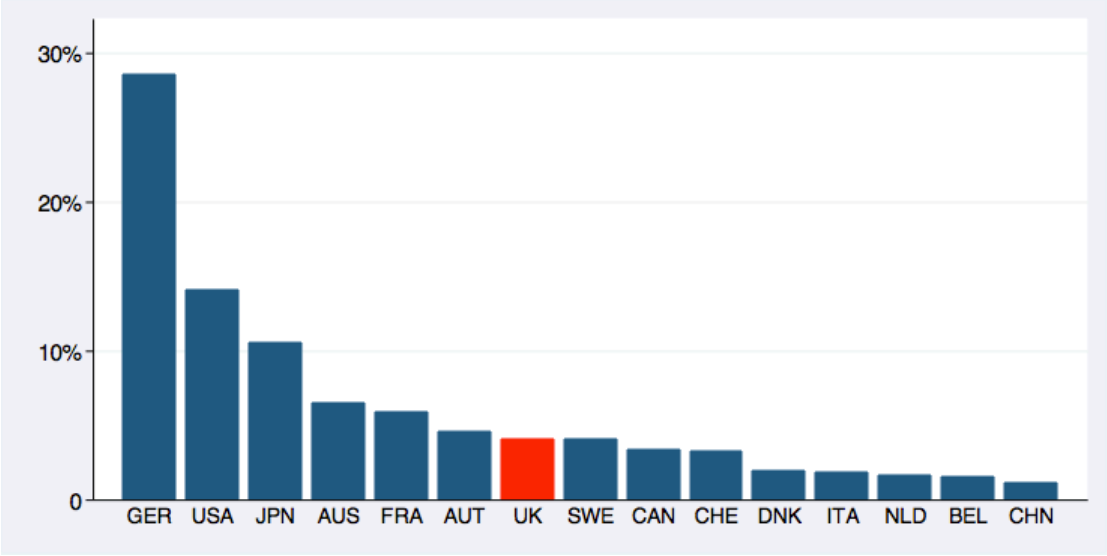
Heating



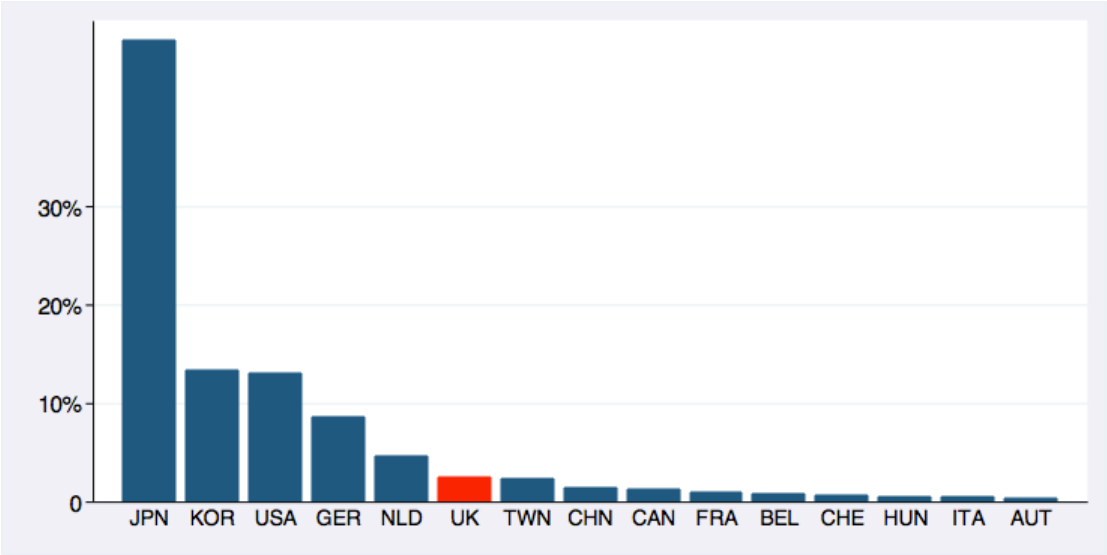
Cement



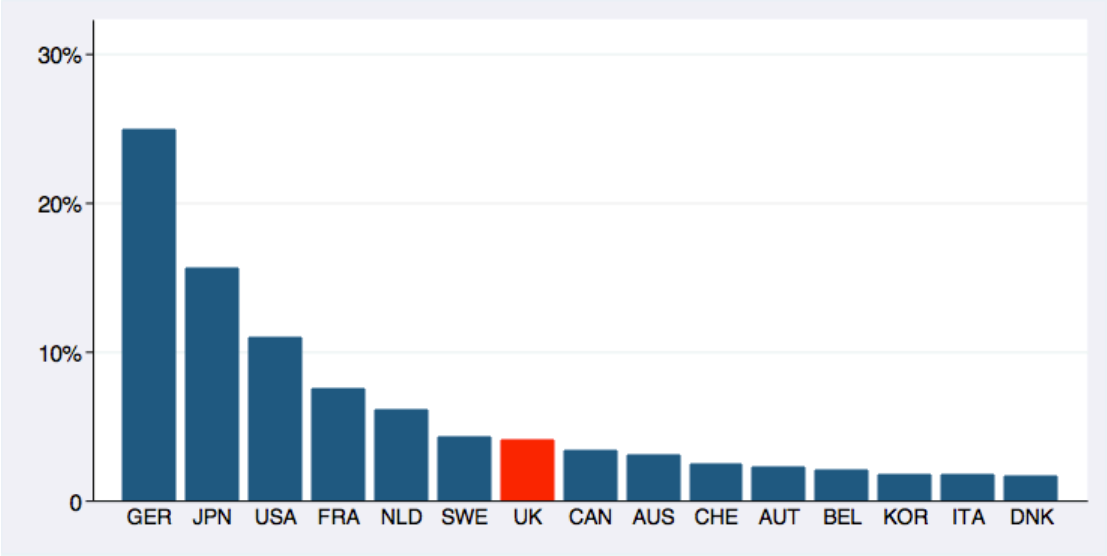
Insulation



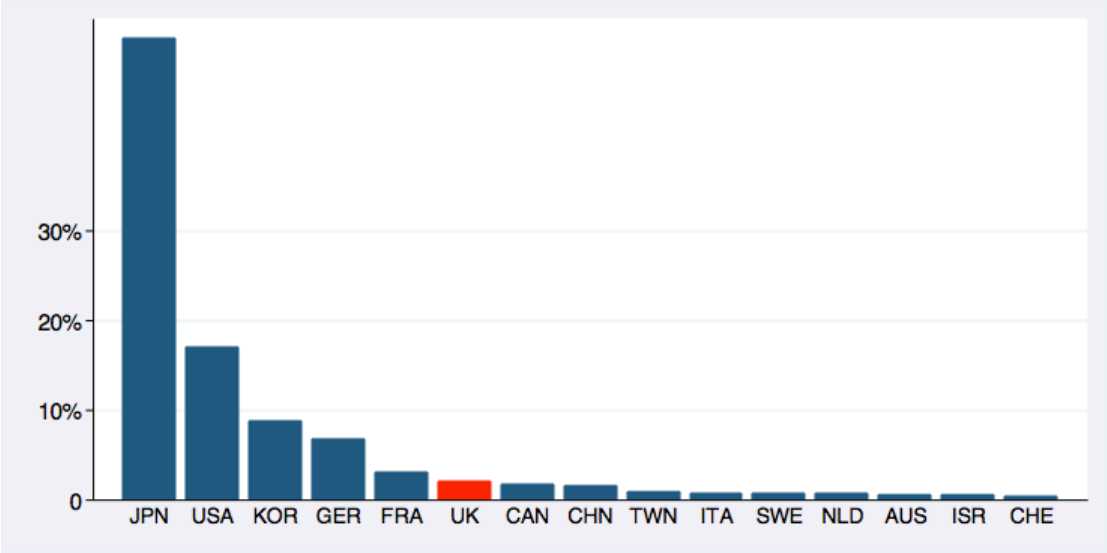
Lighting



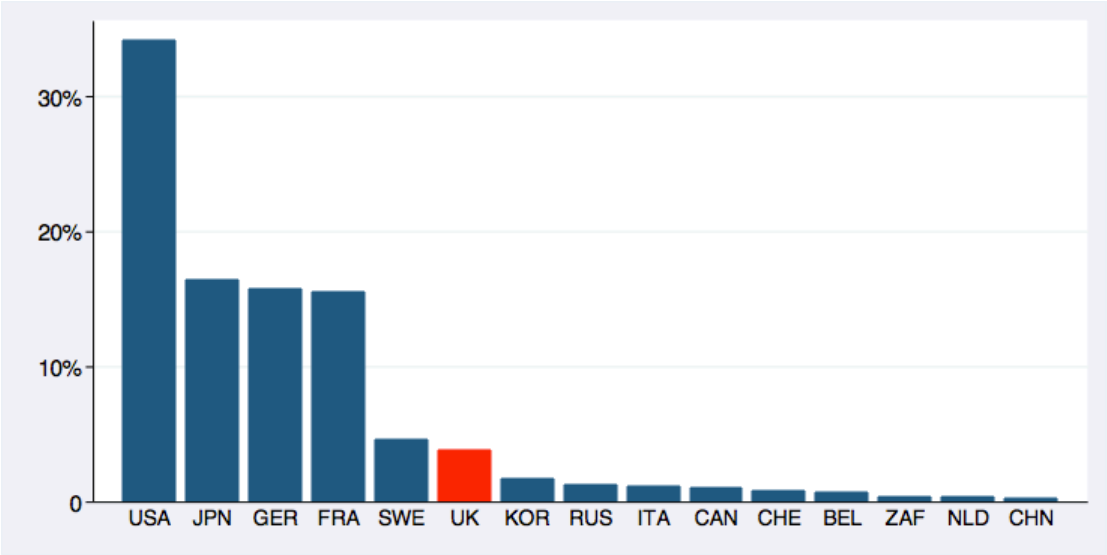
Methane destruction



Batteries



Nuclear



Fuel cells

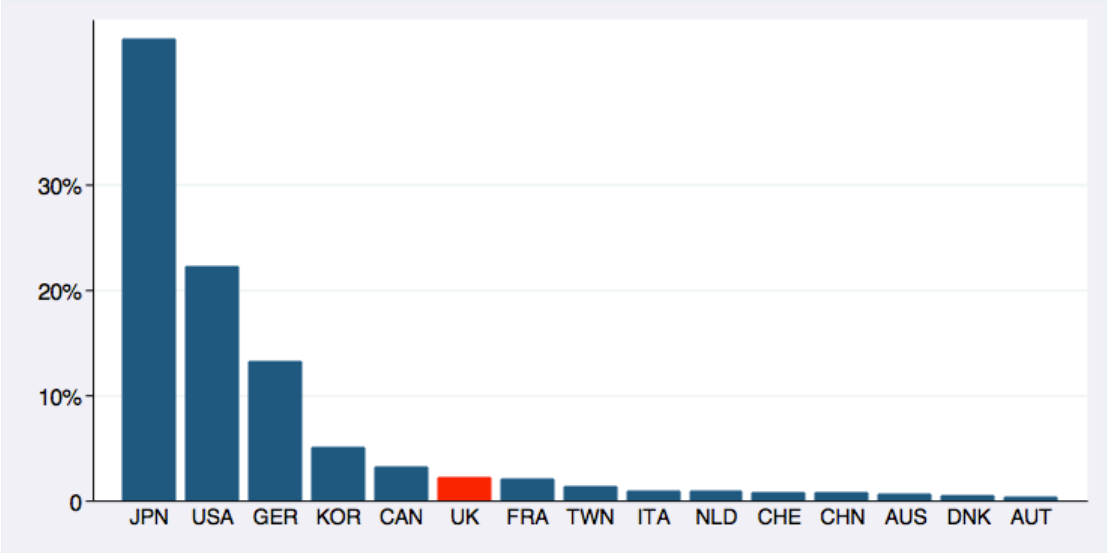


Table 6b: Share of UK inventions in world innovation by technology

Country	Biomass	Geothermal	Hydro	Marine	Waste	Wind
Australia	1.3	0.2	**3.8**	**6.3**	5.2	10.8
Austria	**1.8**	**2.9**	**3.8**	3.1	**9.9**	6.4
Belgium	0.8	0.4	1.3	1.2	3.6	**14.0**
Canada	0.5	0.6	1.5	0.9	4.0	4.8
Czech Rep.	**1.4**	0.9	3.3	0.3	2.9	2.1
Denmark	**3.2**	0.2	1.9	5.7	**10.9**	**78.3**
Finland	**4.0**	1.4	1.3	4.4	**20.7**	**11.7**
France	1.1	0.3	2.0	0.9	3.2	3.3
Germany	0.9	1.5	2.1	1.0	**8.6**	**16.6**

Greece	0.8	0.0	0.2	1.8	0.8	2.9
Hungary	0.3	**2.1**	0.0	1.0	3.0	2.7
Ireland	0.5	0.0	2.7	**7.0**	1.4	4.2
Israel	1.0	**4.9**	3.7	**6.9**	1.9	8.6
Italy	0.1	0.2	0.4	0.7	2.1	1.9
Japan	0.7	0.6	1.9	0.8	7.3	3.7
Netherlands	0.9	0.6	1.6	1.2	4.2	9.1
Norway	1.0	0.8	**5.3**	**14.3**	4.1	11.3
Portugal	0.2	0.0	0.2	1.8	0.4	2.0
Russia	0.2	0.0	0.4	0.4	0.8	1.2
S Korea	1.1	0.2	2.0	2.0	4.5	5.3
Singapore	0.3	0.0	1.9	0.8	1.2	1.5
South Africa	0.5	0.0	0.2	0.5	0.5	1.2
Spain	0.1	0.1	0.3	1.6	0.3	6.9
Sweden	**4.6**	**4.6**	**6.3**	**8.4**	**16.4**	**25.1**
Switzerland	0.9	**2.6**	**3.7**	1.8	7.3	6.3
UK	0.6	0.4	0.9	4.6	2.5	5.7
USA	0.3	0.3	0.5	0.8	2.3	2.0

Country	Fuel cells	Nuclear	Batteries	Solar CSP	Solar PV	Solar thermal
Australia	8.6	1.8	7.7	**9.0**	**10.2**	**23.9**
Austria	10.0	3.5	11.3	2.9	6.6	14.6
Belgium	3.7	7.3	1.8	**4.5**	3.1	9.8
Canada	**22.7**	3.7	13.0	0.8	1.8	2.6
Czech Rep.	0.7	2.7	1.7	0.0	0.6	3.5
Denmark	**21.0**	0.3	10.5	1.4	1.2	7.3
Finland	7.4	2.0	12.0	2.2	2.5	11.0
France	8.2	**30.1**	12.5	1.4	3.6	5.3
Germany	**36.5**	**21.1**	**18.8**	3.4	**12.2**	**16.5**
Greece	1.8	0.3	0.2	1.8	0.7	1.2
Hungary	1.3	1.8	5.7	2.4	0.4	5.4
Ireland	1.9	0.1	1.8	1.0	0.9	4.6
Israel	18.6	4.1	**27.1**	**11.5**	**10.6**	**17.7**
Italy	3.8	2.4	2.9	1.0	1.9	2.8
Japan	**82.3**	**14.9**	**97.6**	1.4	**15.2**	3.5
Netherlands	11.8	2.0	8.6	0.8	5.8	7.5
Norway	3.9	1.2	2.9	0.9	3.8	4.4
Portugal	0.7	0.5	0.2	1.1	0.2	1.6
Russia	1.9	3.7	2.3	0.3	0.5	0.8
S Korea	**47.4**	7.5	**83.0**	0.9	**9.3**	1.6
Singapore	1.6	1.3	5.6	0.6	2.5	1.0
South Africa	1.1	3.8	6.5	0.6	0.6	1.3
Spain	1.1	0.5	1.2	1.8	1.9	4.0
Sweden	9.2	**58.8**	**17.7**	**4.1**	2.2	**18.1**
Switzerland	20.8	9.9	11.6	**4.3**	9.1	**15.9**
UK	8.9	7.4	8.4	1.0	2.4	3.3
USA	14.9	**11.0**	11.4	1.0	3.2	2.0

Country	Cement	Electric hybrid	Fuel inj.	Heating	Insul-ation	Lighting	Methane
Australia	2.1	8.2	16.2	6.8	**25.3**	4.6	4.6
Austria	**2.6**	**15.1**	**54.7**	8.2	**36.9**	11.6	6.8
Belgium	2.1	2.8	2.8	3.0	10.4	19.8	5.0
Canada	1.0	6.2	2.4	2.8	7.1	10.3	2.7
Czech Rep.	1.3	2.9	2.7	3.4	4.3	0.6	2.0
Denmark	**4.5**	2.2	13.2	5.0	**24.3**	2.6	**7.5**
Finland	2.1	5.9	12.9	**17.4**	14.7	10.7	4.9
France	1.4	13.7	10.8	3.5	7.0	4.9	3.4
Germany	**3.8**	**36.3**	**83.7**	**9.0**	23.5	**29.0**	**7.7**
Greece	0.0	0.0	0.6	0.3	0.9	1.2	0.6
Hungary	1.3	2.3	1.6	1.3	4.1	**27.1**	2.7
Ireland	0.0	1.5	1.2	0.8	10.1	4.4	2.1
Israel	1.0	8.0	3.5	3.7	4.6	12.5	1.8
Italy	0.1	4.5	10.9	1.2	2.3	2.6	0.8
Japan	1.9	**62.8**	**44.2**	7.3	5.9	**106.4**	3.3
Netherlands	1.6	5.4	3.6	4.4	6.7	**75.8**	**9.3**
Norway	0.4	3.7	0.8	5.0	6.5	1.5	2.0
Portugal	0.0	0.4	0.3	0.5	0.7	0.0	0.4
Russia	0.2	0.6	0.3	0.4	0.3	1.9	0.2
S Korea	0.4	13.7	3.7	**11.2**	2.5	**151.2**	1.8
Singapore	0.0	1.1	0.3	1.6	0.3	10.7	0.2
South Africa	0.3	1.5	0.1	0.1	0.3	0.2	1.3
Spain	0.5	1.4	1.1	0.2	1.3	0.4	0.4
Sweden	**2.8**	**29.1**	16.5	**27.8**	**32.2**	9.5	**12.7**
Switzerland	**3.6**	**16.9**	**25.3**	**10.6**	**25.5**	19.6	**7.3**
UK	0.6	6.1	**17.8**	2.4	4.9	12.4	1.9
USA	0.7	7.6	7.1	1.3	2.8	10.5	0.8

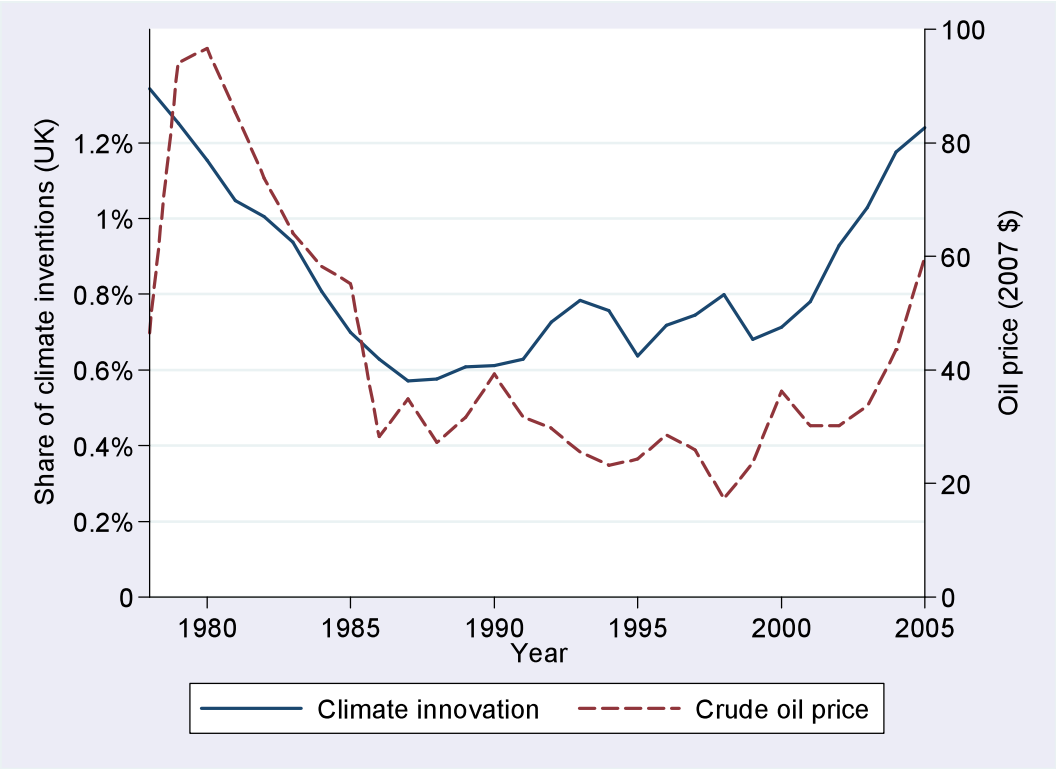
Note: The tables report the number of patent applications by technology during 1980–2007, classified by inventor country, and normalized by country's GDP (in trillions (10^{12}) of US dollars, using 2000 prices and PPP). Countries in the top five for each technology are indicated in bold face. Note that we only display countries that are in the top 15 for at least one technology. We drop countries with a world GDP share smaller than 0.2%.

4. Trends in Patenting Activity

4.1. General trend

Figure 1 presents the evolution of UK's climate innovation since 1978. Since the growth of innovation in environmental technologies could reflect a general growth of innovation in all technologies (including non-environmental ones), the graph presents the *share* of climate-related inventions in the number of inventions in all technology areas. The graph also displays the evolution of the price of oil since incentives for innovation related to climate change mitigation are likely to be influenced by energy prices.

Figure 1: Share of UK climate-related innovation in total innovation in comparison with oil prices



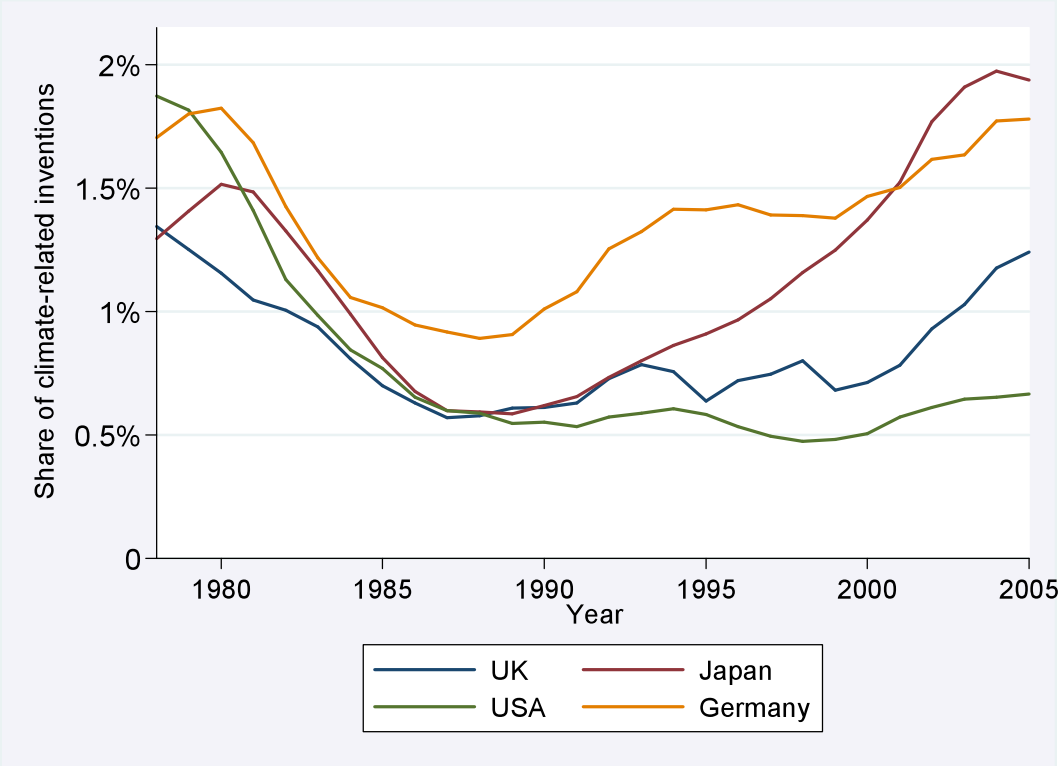
The trend of innovation in the UK indeed seems to closely follow oil prices. However, Figure 1 shows a slight decoupling since the beginning of the 1990s. This is suggestive of a limited influence of environmental and climate policies.

In Figure 2, we compare the performance of climate-related innovation in the top 3 inventor countries (Japan, the US, and Germany) with that of the UK. Innovation has risen sharply in

Japan and in Germany, especially during the 1990s, while oil prices were remaining relatively stable. This suggests a significant influence of environmental policies and climate policies in these countries since the beginning of the 1990s. The post-2000 acceleration may be interpreted as the innovators' response to the signing of the Kyoto Protocol in 1997 and the subsequent implementation of climate policies in ratifying countries.

Unlike Japan and Germany, US innovation efforts have remained strikingly stable since the end of the 1980s. The UK stands in the middle. While it clearly outperforms the US since 2000, it is lagging behind Germany and Japan.

Figure 2: Share of climate-related innovation in UK and the top 3 inventing countries



4.2. Trends by technology

The evolution of UK inventors' performance is presented in Table 7. For each technology, we display the share of high-value inventions developed by UK inventors[6] over three time-periods: 1980-1996, 1997-2002 and 2003-2007. Figure 3 summarises the shares graphically. We also report the average annual number of UK inventions for each time period. We can see from these figures that there is a great deal of heterogeneity when it comes to the dynamic

[6] We graph this information for the top 10 inventor countries in box 2.

patterns these technologies display. We can group technologies according to three types of pattern. Firstly, there are technologies where Britain increased or maintained its share in world patenting in the last period (2002-2007) relative to its 1980 to 1996 position. This is the case for 7 technologies (see Table 7b): Cement, Geothermal, Hydro, Marine Energy, Solar CSP, Solar PV, and Waste. Except for Solar CSP, all these technologies did not only gain relative to the 1980-2002 period, they also display an increase in 2003-2007 over the 1997-2002 period. Solar CSP on the other hand is the only technology category that did *not* display a decline in 1997-2002 relative to 1980-1996.

Secondly, we can identify technologies which lost shares in 2003-2007 relative to 1980-1996 but which saw an increase in 2003-2007 relative to 1997-2002. This applies to Biomass, Heating, Insulation and Wind.

Thirdly, there are technologies that declined in 2003-2007 with respect to both 1980-1996 and 1997-2002. This is the case for Batteries, Electric and Hybrid, Fuel Cells, Fuel Injection, Lighting, Methane, Nuclear as well as Solar Thermal technologies. Except for Nuclear, all technologies in this category were equally declining in 1997-2002 relative to 1980-1996.

Looking at the average patenting activity across these groups displayed in columns 2, 4 and 6 of Table 7, we see that almost all technologies – even those where UK inventors display declining shares – show an increase in the average number of patents filed every year. For example, in Fuel Cells where the UK share dropped by almost 50%, UK inventors were filing more than 7 times as many patents on average annually over the 2003 to 2007 period than in 1980 to 1996. The only technologies which saw a decline in patenting are Fuel Injection – likely a consequence of the general decline of the car industry in the UK – and Nuclear.

Hence, it appears that in most technologies the UK has declining shares, not because innovative activity in these sectors is declining but because innovative activity is expanding at a faster rate in other countries. For each technology type we can investigate with the help of the figures in Box 3, which countries are gaining or losing over time. For example in the case of Fuel Cells the main countries that are gaining shares are Japan and South Korea. Interestingly, China is also gaining shares although its absolute share is still relatively small.

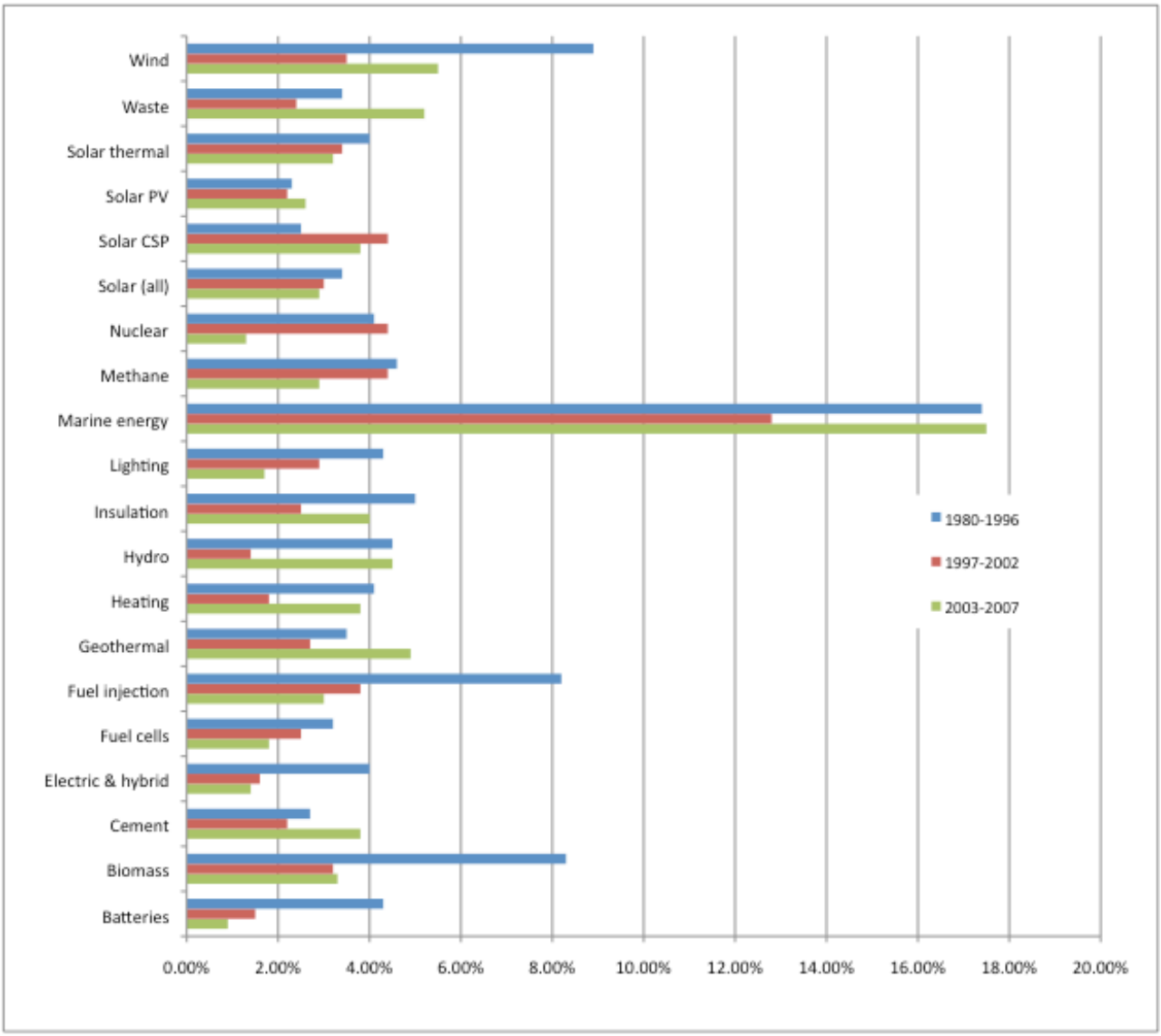
Table 7: Evolution of UK innovation performance by technology

Technology	1980-1996		1997-2002		2003-2007	
	Share in world's innov.	Avg annual inv.	Share in world's innov.	Avg annual inv.	Share in world's innov.	Avg annual inv.
Batteries	4.3%	11.5	1.5%	18.1	0.9%	11.9
Biomass	8.3%	0.9	3.2%	0.6	3.3%	1.2
Cement	2.7%	0.8	2.2%	0.9	3.8%	1.5
Electric & hybrid	4.0%	6.9	1.6%	11.3	1.4%	15.6
Fuel cells	3.2%	3.9	2.5%	27.9	1.8%	32.4
Fuel injection	8.2%	26.6	3.8%	32.1	3.0%	23.7
Geothermal	3.5%	0.3	2.7%	0.4	4.9%	1.8
Heating	4.1%	3.2	1.8%	2.2	3.8%	6.5
Hydro	4.5%	1.1	1.4%	0.6	4.5%	3.1
Insulation	5.0%	7.1	2.5%	6.8	4.0%	9.6
Lighting	4.3%	9.3	2.9%	34.1	1.7%	36.2
Marine energy	17.4%	3.9	12.8%	5.7	17.5%	19.0
Methane	4.6%	2.7	4.4%	3.5	2.9%	2.9
Nuclear	4.1%	13.4	4.4%	12.2	1.3%	3.1
Solar (all)	3.4%	6.4	3.0%	10.8	2.9%	18.7
Solar CSP	2.5%	0.9	4.4%	2.1	3.8%	2.8
Solar PV	2.3%	1.3	2.2%	4.6	2.6%	10.9
Solar thermal	4.0%	4.4	3.4%	4.8	3.2%	7.3
Waste	3.4%	3.1	2.4%	3.7	5.2%	6.4
Wind	8.9%	5.1	3.5%	7.2	5.5%	22.6

Table 7b: Evolution of UK innovation performance by technology

Pattern	***Technologies***
Group 1: Increase or no decline in 2003-2007 relative to 1980-1996	• Cement • Geothermal • Hydro • Marine energy • Solar CSP (decline relative to 1997-2002) • Solar PV • Waste
Group 2: Increase in 2003-2007 relative to 1997-2002 but decline relative to 1980-1996	• Biomass • Heating • Insulation • Wind
Group 3: Decline in 2003-2007 relative to 1997-2002 and 1980-1996	• Batteries • Electric & hybrid • Fuel cells • Fuel injection • Lighting • Methane • Nuclear (increase in 1997-2002 relative 1980-1996) • Solar thermal

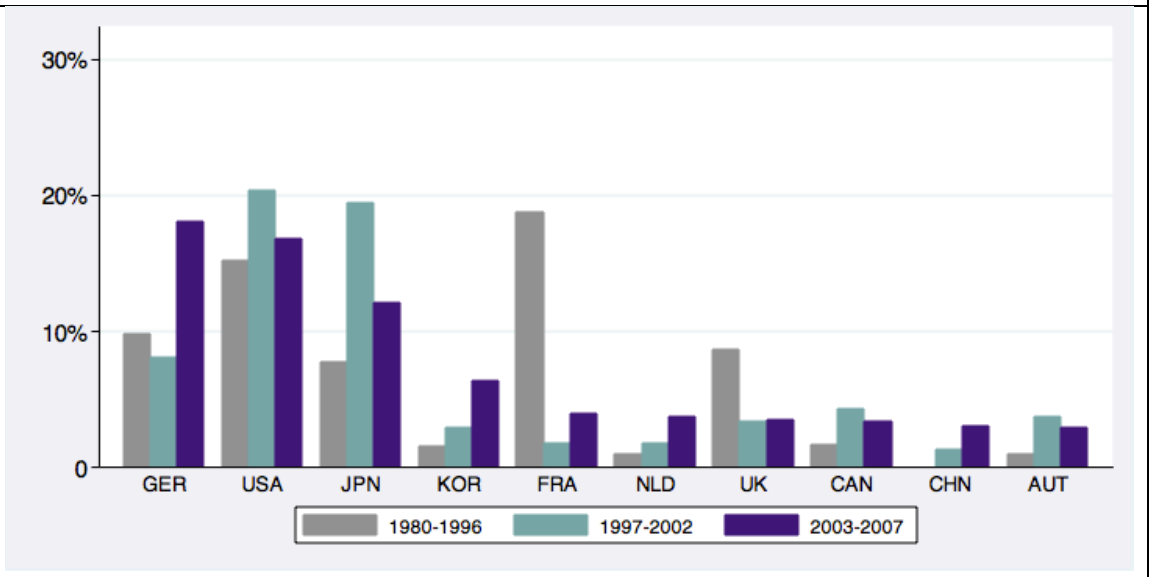
Figure 3 – UK share in global patents by technology type



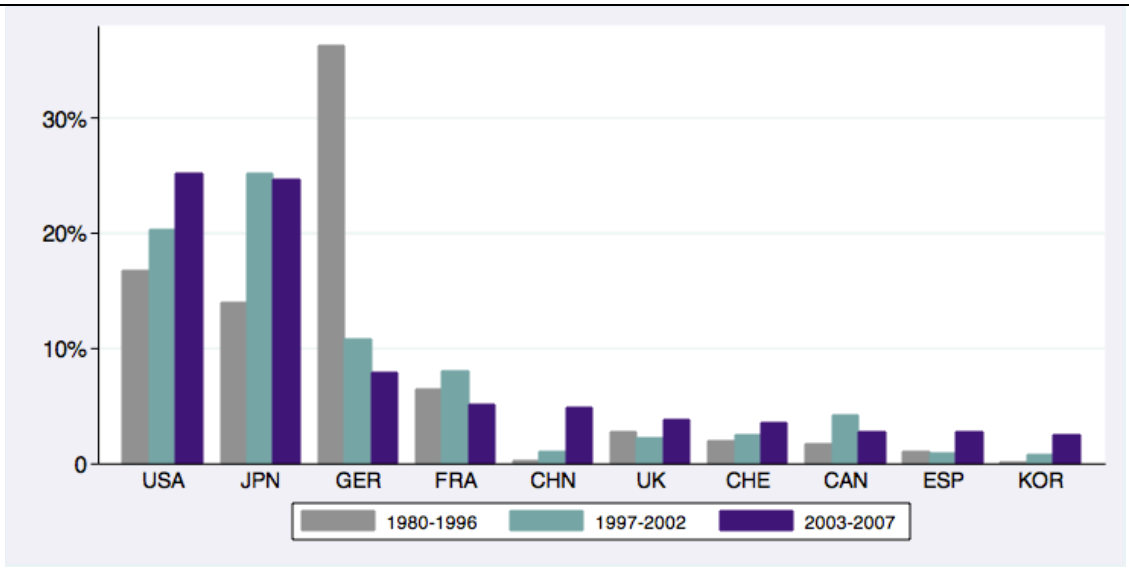
BOX 3. EVOLUTION OF INVENTOR COUNTRIES' PERFORMANCES BY TECHNOLOGY BETWEEN 1980 AND 2007

The following graphs display the share of high-value inventions developed by the top 10 inventor countries in each technology over three time-periods: 1980-1996, 1997-2002 and 2003-2007. Countries are sorted in decreasing order from left to right by the top inventors in the 2003-2007 period.

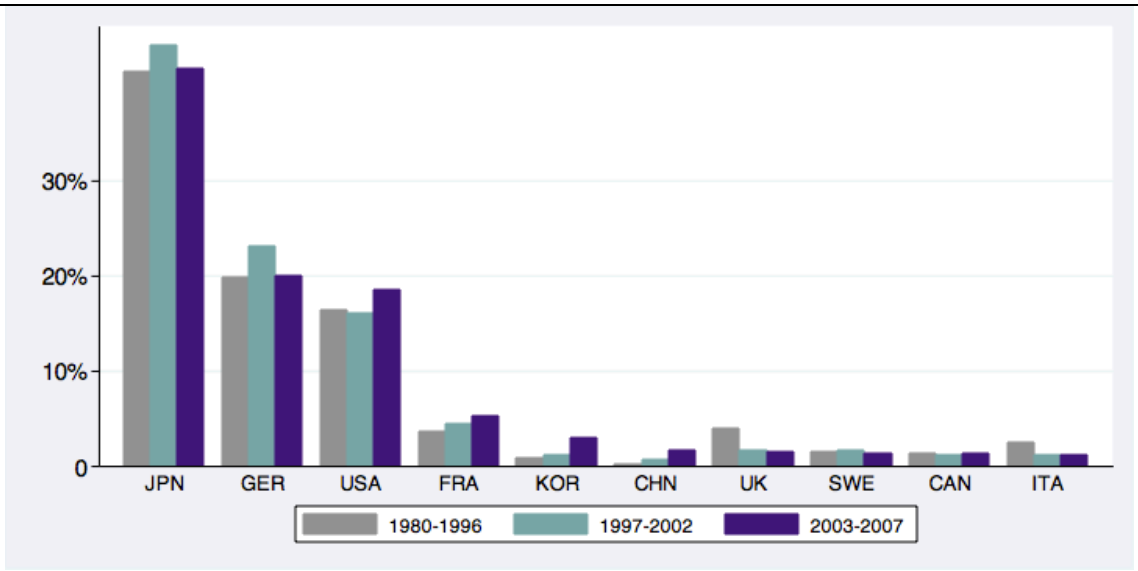
Biomass



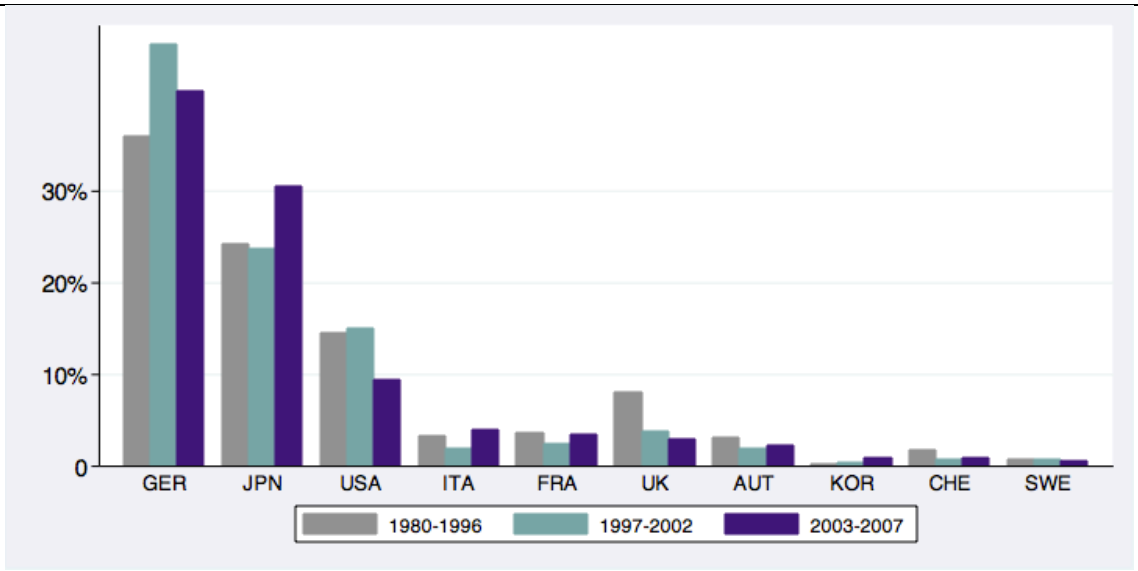
Cement



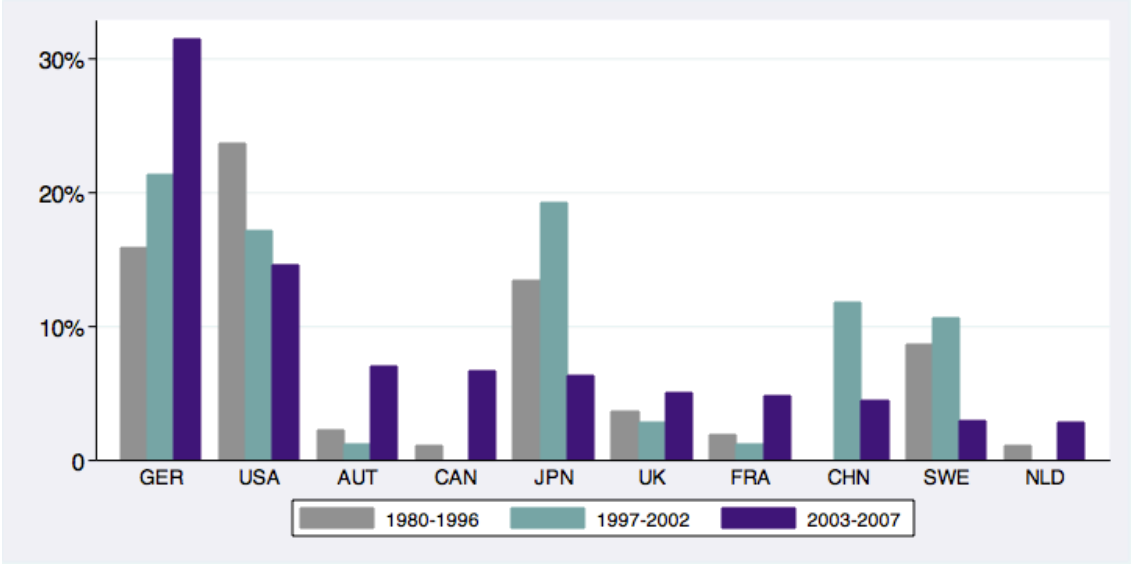
Electric & hybrid



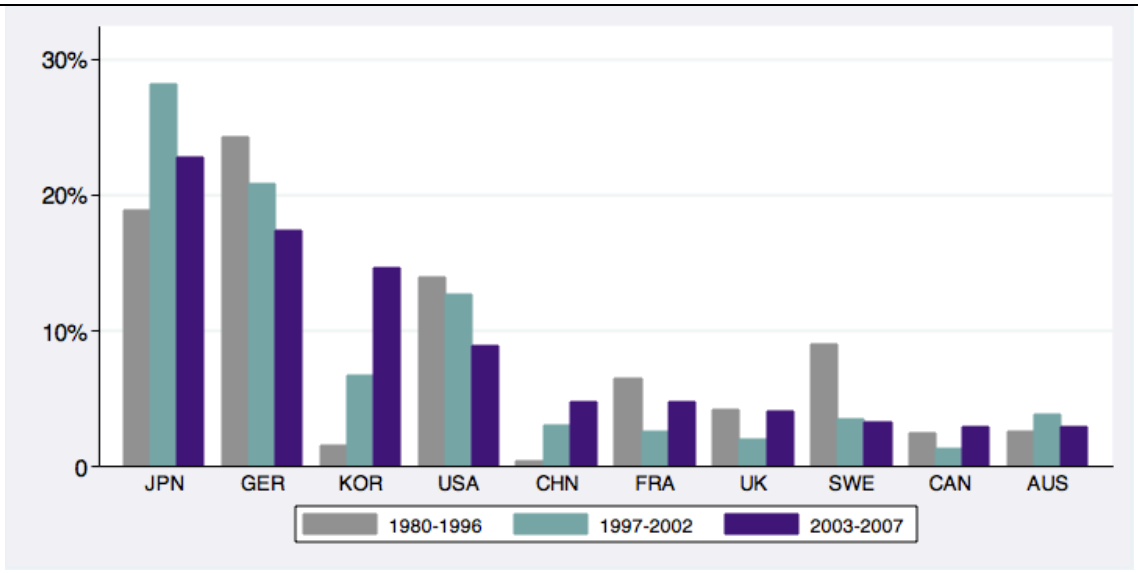
Fuel injection



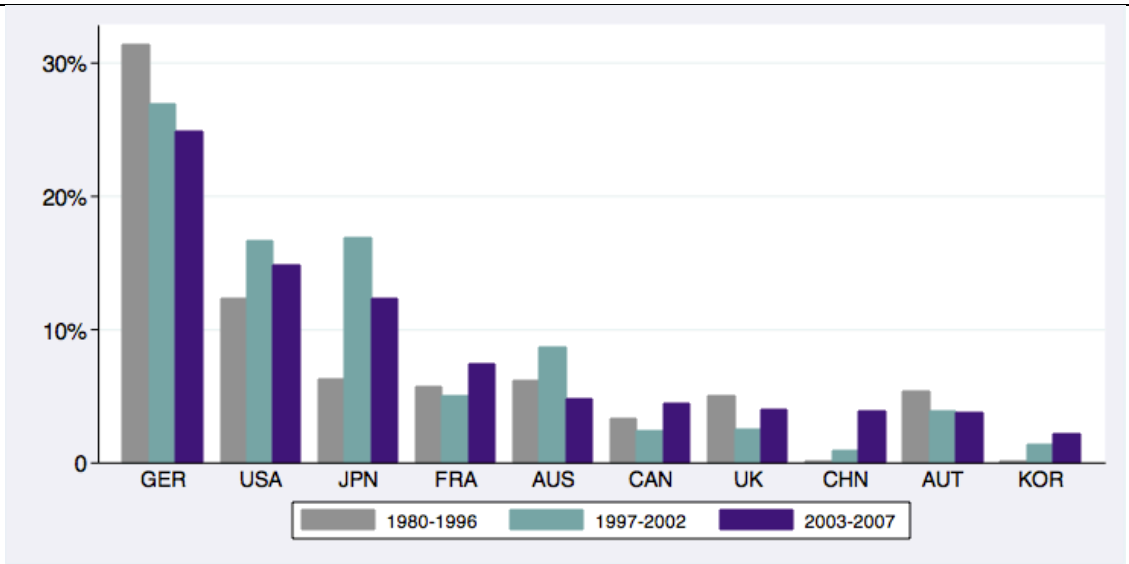
Geothermal



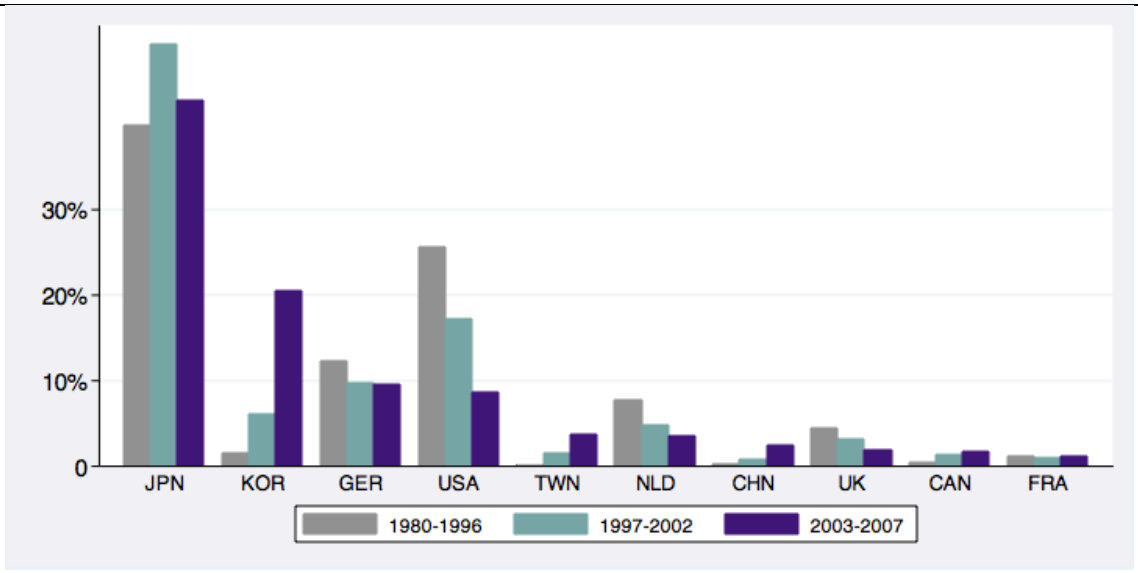
Heating



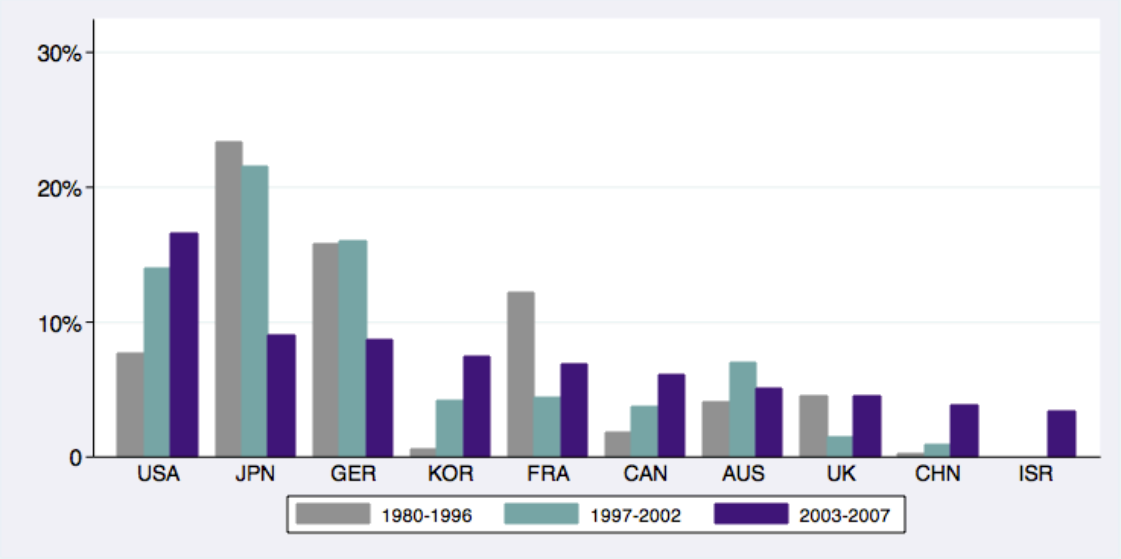
Insulation



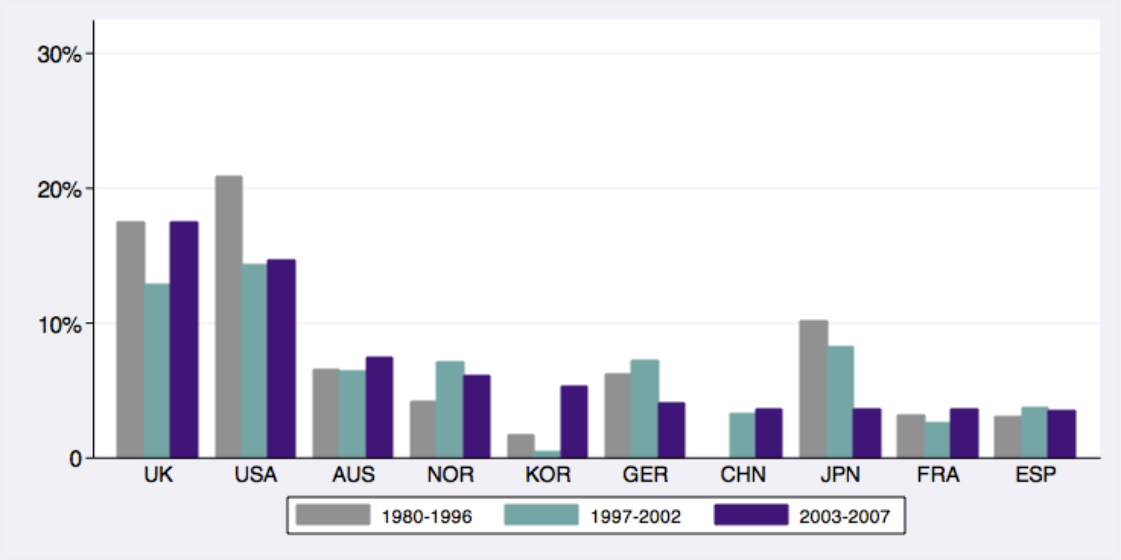
Lighting



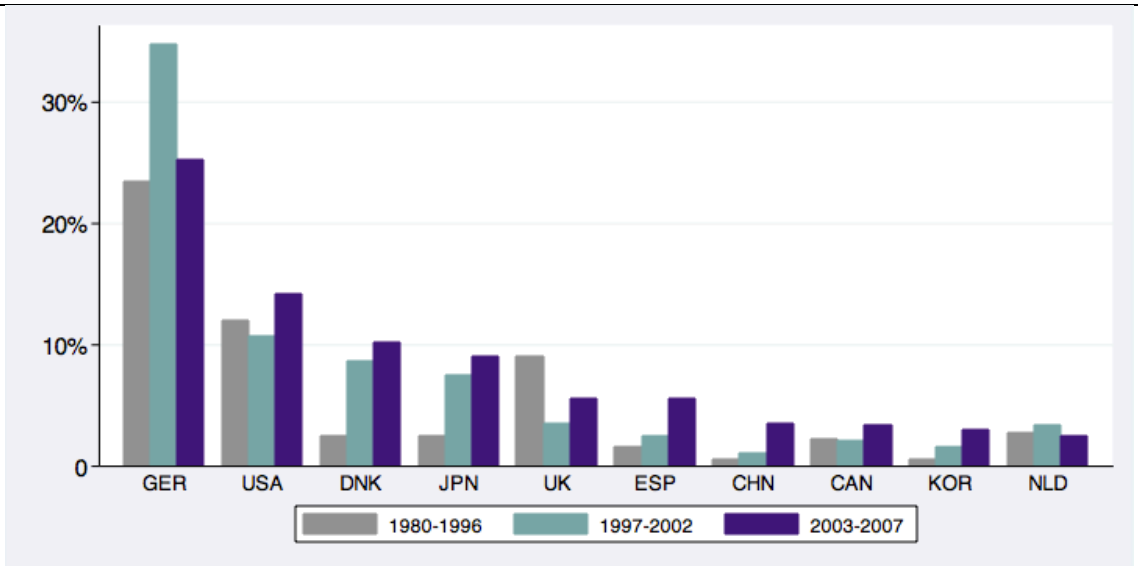
Hydro



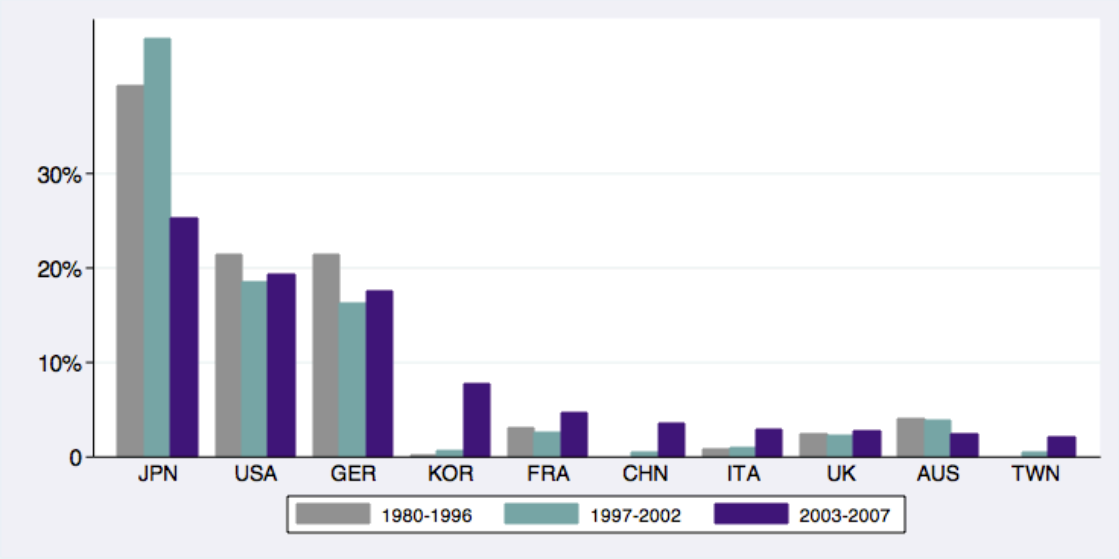
Marine



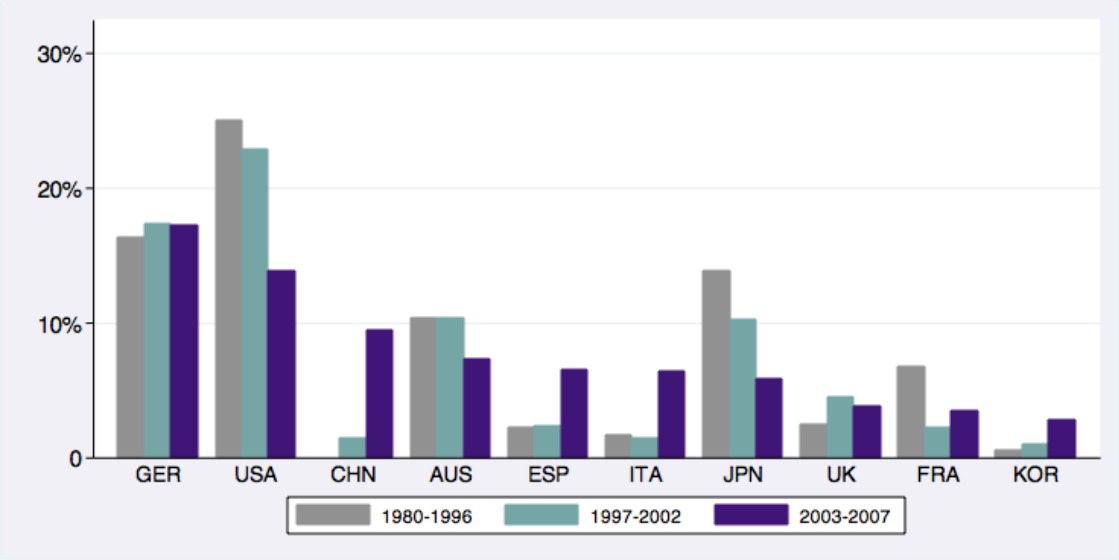
Wind



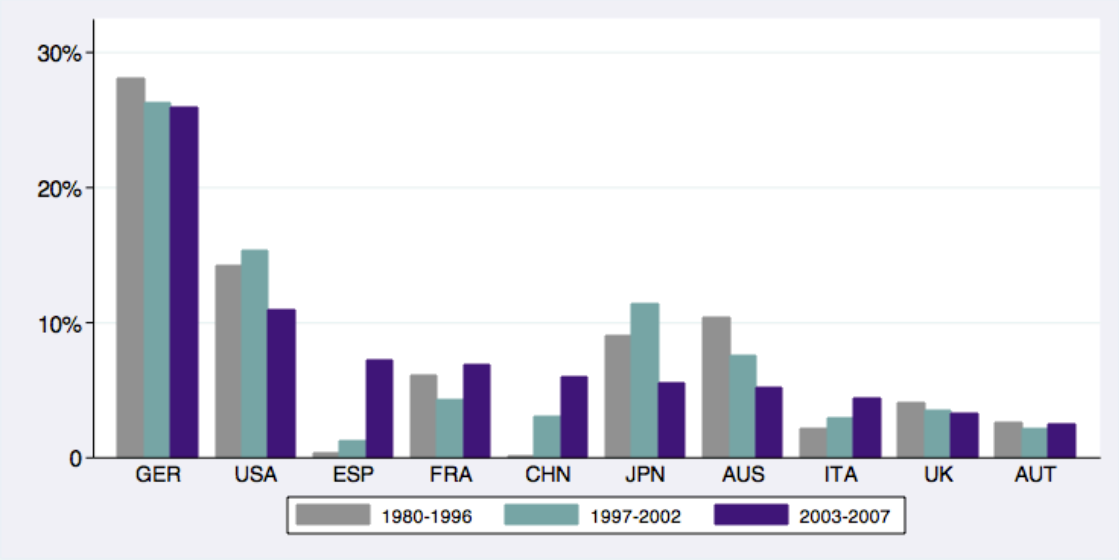
Solar PV



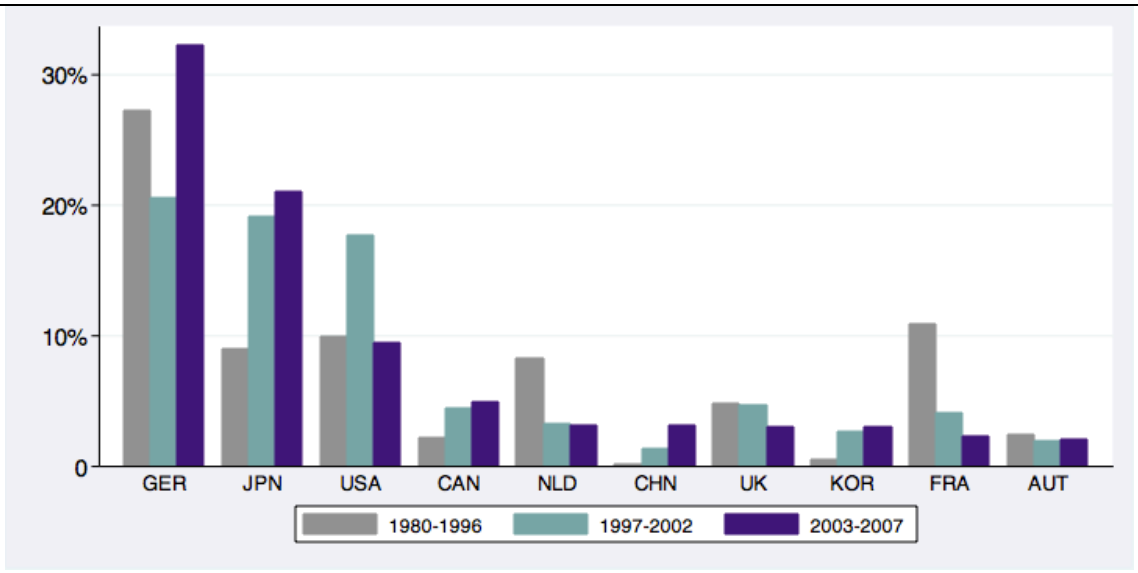
Solar CSP



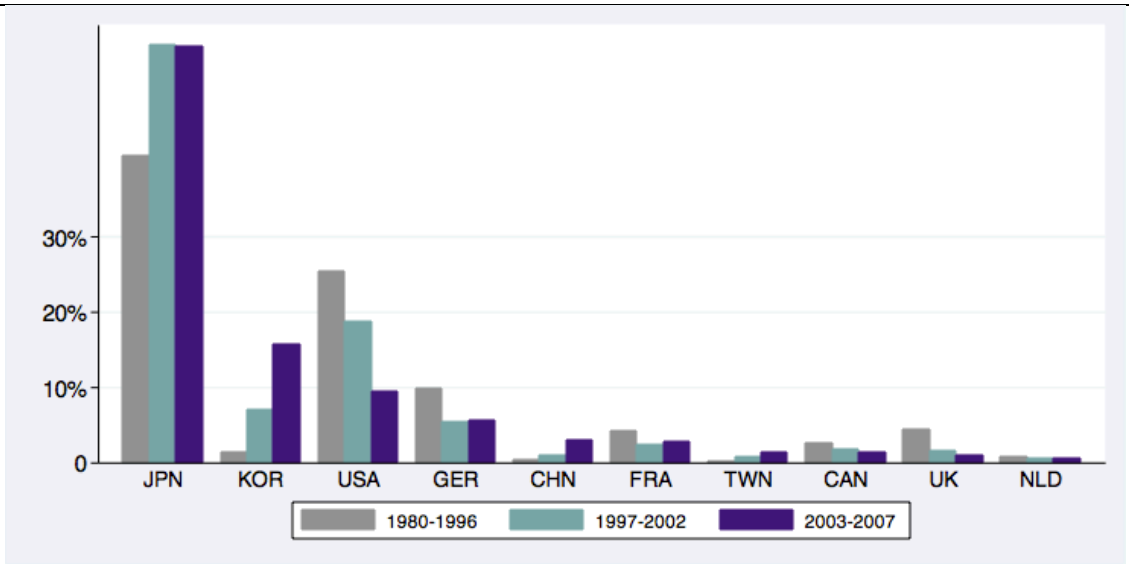
Solar thermal



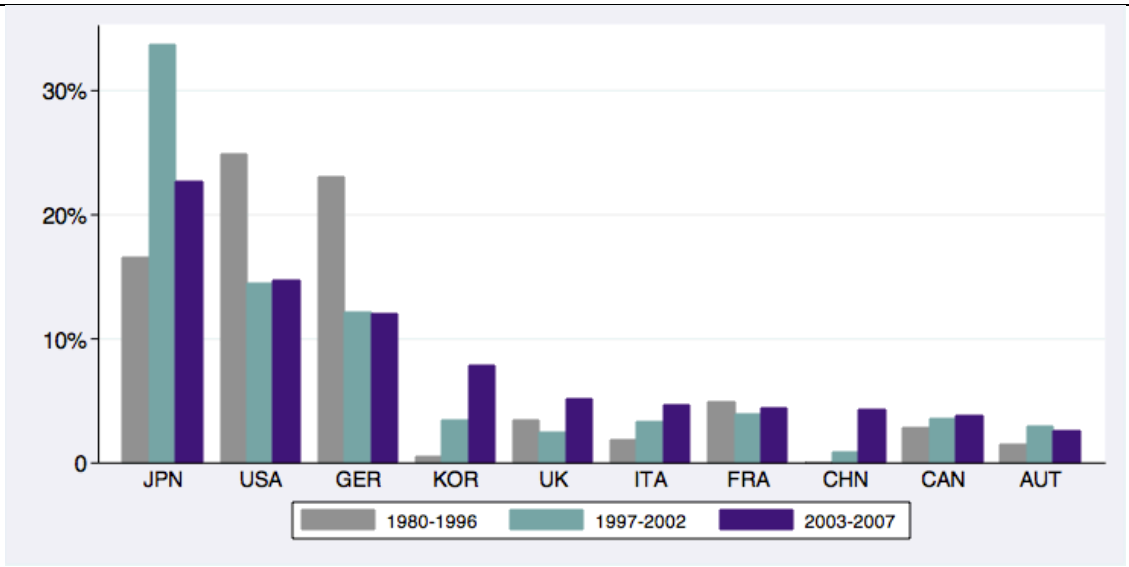
Methane



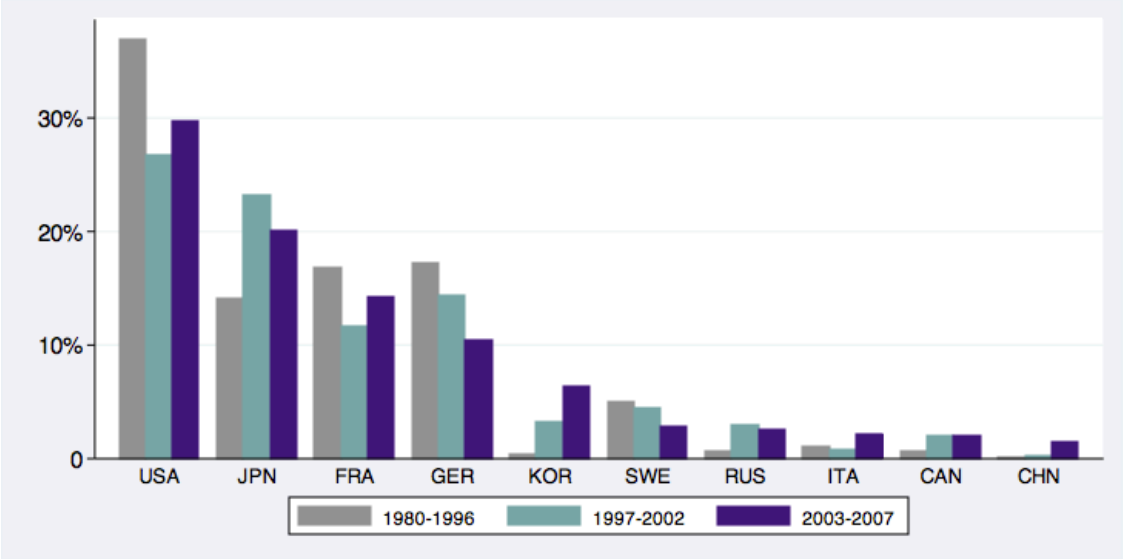
Batteries



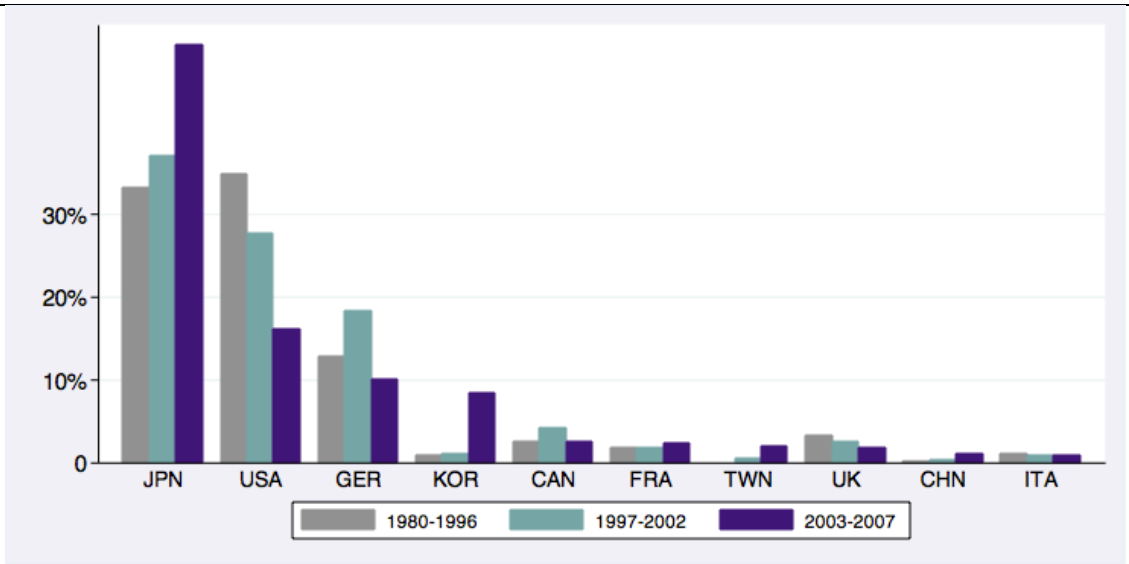
Waste



Nuclear



Fuel cells



5. Patent Exports

For each patent, the PATSTAT database includes information on the country where the application is filed and on the country of residence of the inventor. We use these data to analyze the international transfer of technology through the patent system.

We define an exported patent as a patent for which the country of filing differs from that of the inventor – for example, a US patent filed by a UK-based inventor. Similarly, we define an exported invention as an invention patented in at least one country other than that of the inventor. For example, a UK invention patented both in the UK and in the US is an exported invention. A UK invention patented only in France is also considered as an exported invention[7].

At the country level, the share of exported inventions can be seen as the country's technology export rate. Table 8 displays the export performance of the 12 main inventor countries. With export rates ranging between 40% and 90%, countries in Europe and North America are the world leaders in technology exports. Some of that might reflect the success of economic integration in the EU and NAFTA areas as many of these transfers occur between their member countries. By contrast, Korea, Japan and Australia have poor exporting performances. This is especially striking in the case of Japan, which is the leader in climate-related innovation but fails to diffuse its technology abroad.

With 60% of inventions patented in foreign countries, UK inventors have very strong exporting capacities. The number of patents filed by UK inventors in foreign countries has increased steadily since the mid-1980s. In recent years, around 300 climate-related patents were filed abroad by UK inventors every year. Most of these transfers concern automobile patents (fuel injection technologies and patents related to electric and hybrid vehicles) and energy-efficient lighting. Table 9 shows the export performance of UK inventors in each technology field.

Figure 4 examines the relationship between export rate and the share of worldwide inventions the UK is holding. We exclude Marine energy from the figure because of its clear outlying position. The figure shows a negative correlation between the two variables. A possible explanation is that, in sectors where they have a strong position, UK innovators also file relatively more patents at home. This would suggest that high-value patents and domestic (and hence lower-value) patents are complementary.

[7] For this reason, the export rates presented in this section differ slightly from the rates of high-value patents across inventor countries. Indeed, patents filed in only one country by a foreign inventor are also considered as exported.

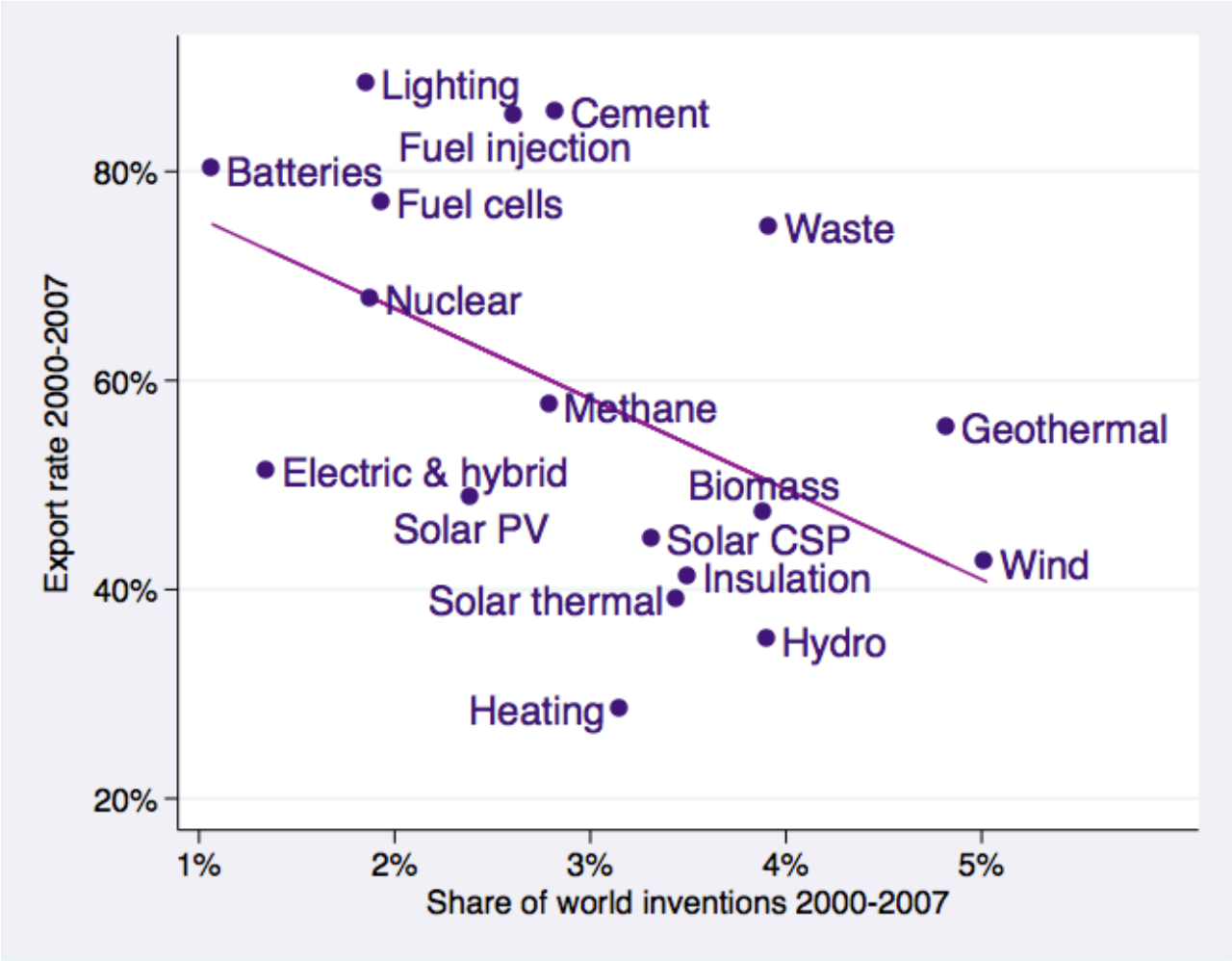
Table 8: Export rate of climate-related inventions by inventor country (2000-2007)

Inventor country	Export rate of inventions
Netherlands	89.9%
UK	60.3%
France	46.1%
Germany	56.1%
Canada	56.9%
USA	42.3%
Korea	24.5%
Japan	21.7%
Australia	15.8%
China	6.8%
Brazil	6.9%

Table 9 – UK export performance by technology (2000-2007)

Technology	UK export rate
Lighting	88.4%
Cement	85.7%
Fuel injection	85.3%
Batteries	80.2%
Fuel cells	77.0%
Waste	74.7%
Nuclear	67.8%
Methane	57.6%
Geothermal	55.6%
Electric & hybrid	51.4%
Solar PV	48.7%
Biomass	47.4%
Solar CSP	44.8%
Solar (all)	43.6%
Wind	42.6%
Insulation	41.2%
Marine energy	39.9%
Solar thermal	39.1%
Hydro	35.1%
Heating	28.6%

Figure 4 – UK export performance by technology (2000-2007)



NB: The evolution of the volume of patent exports is difficult to analyze because of the growing role of the European Patent Office. The drop in exports at the beginning of the 80s is due to the creation of the EPO, which has reduced the number of patents filed abroad in national patent offices. A recent change in the administrative procedures associated with EPO patents also makes it difficult to analyze the trend in the recent period (since 2000). However it is possible to compare the export performance across technologies during the same time period.

6. Patent Imports

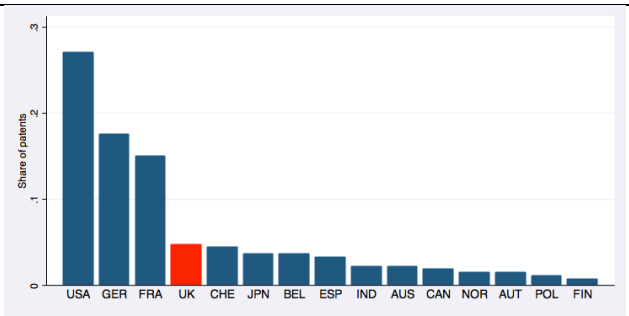
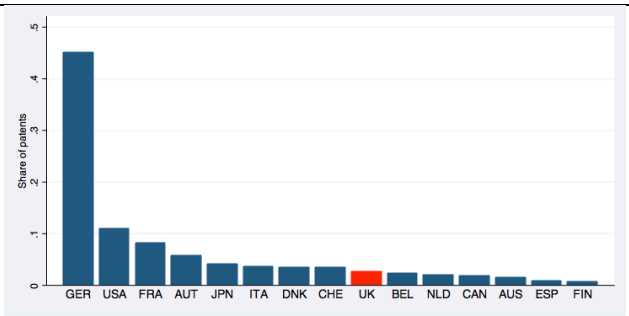
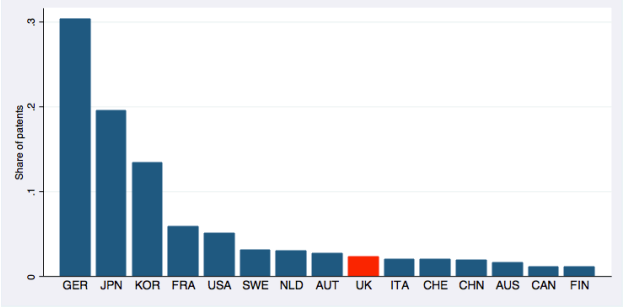
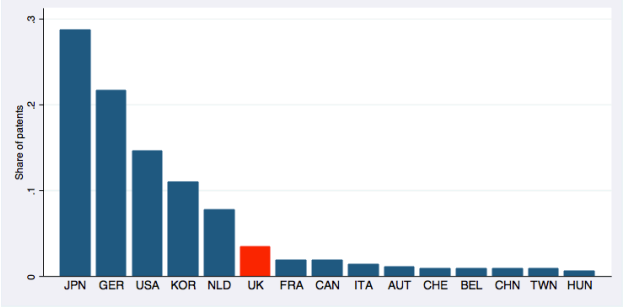
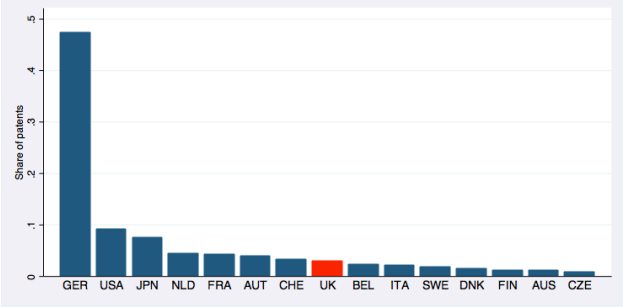
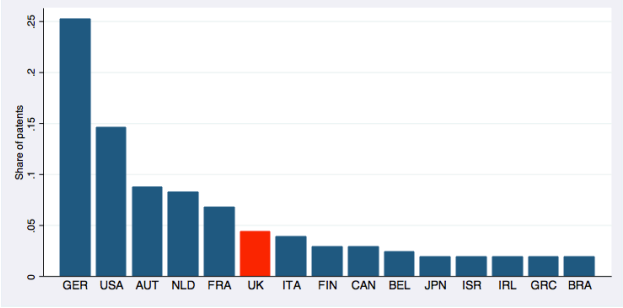
Where do inventions used in the UK come from? Looking at patents filed at the UK patent office produces a result that is biased towards UK companies and towards low-value innovations. Because the European Patent Office is now the main channel for transferring innovations into the European Union, looking at patents filed at the EPO offers a good proxy of inventions flowing into the UK[8]. The graphs presented in Box 4 show the top 15 inventor countries of patents filed at the EPO since 2000, by technology.

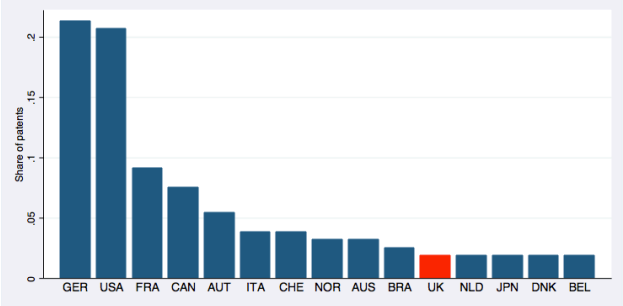
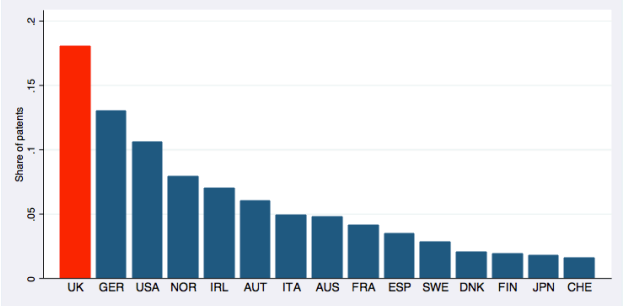
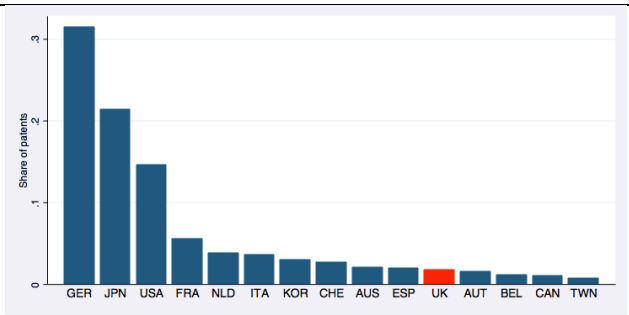
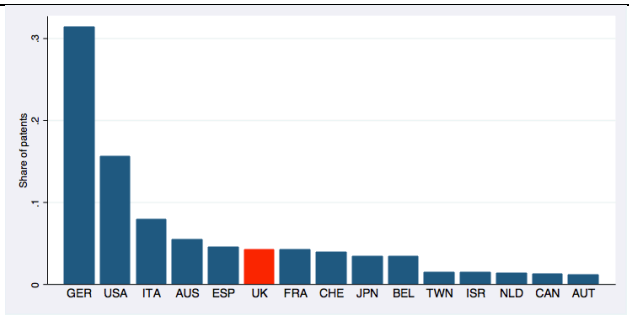
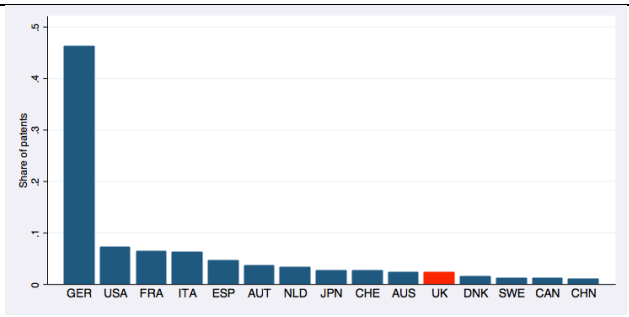
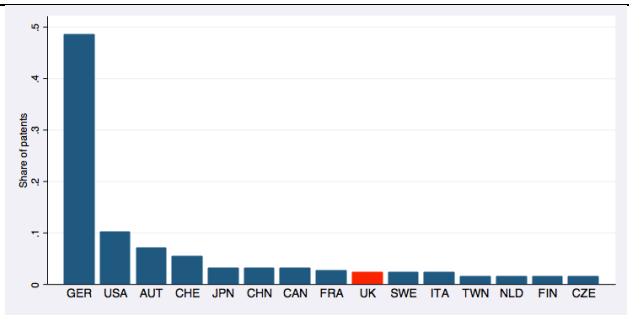
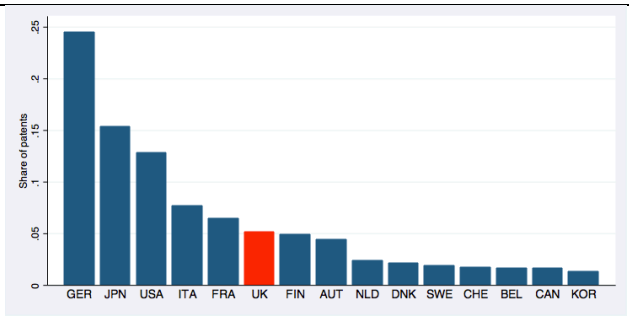
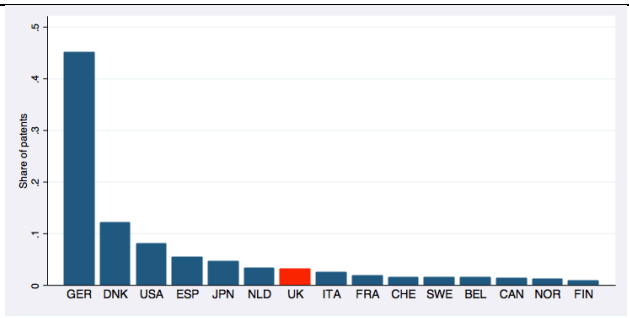
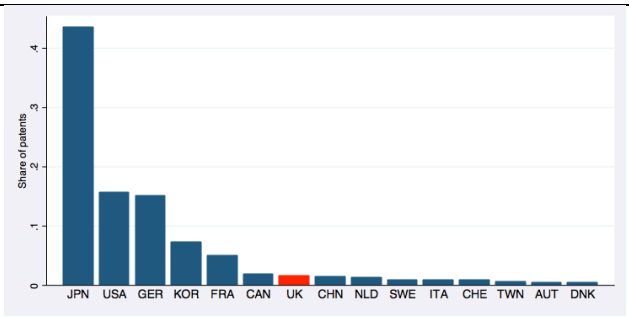
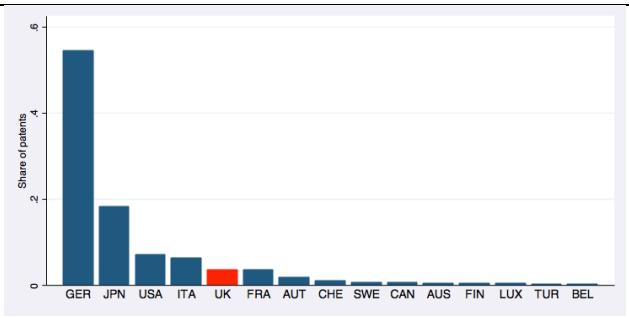
These graphs show the leading role of Germany in transferring technologies to other European countries. Not surprisingly, the US and Japan are the other two main holders of European patents, although not in every technology.

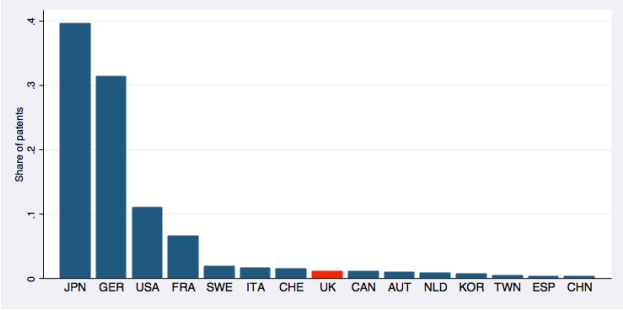
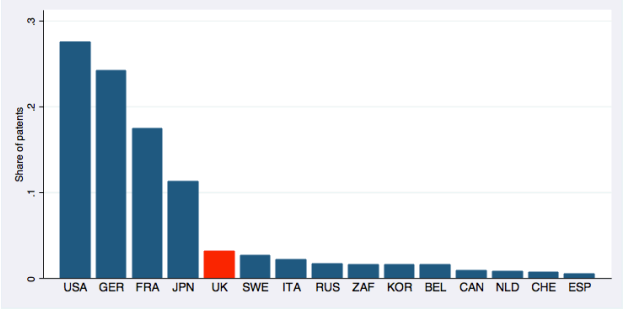
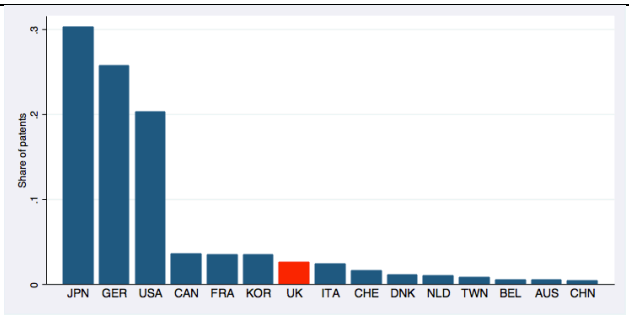
[8] When filing a patent at the EPO, applicants must designate the country in which they intend to transfer their patent after the EPO has examined the patent. More than 90% of patents filed at the EPO designate the UK.

BOX 4. TOP 10 INVENTOR COUNTRIES FOR EUROPEAN PATENTS FILED BETWEEN 1980 AND 2007

The following graphs show the top 15 inventor countries of patents filed at the European Patent Office (EPO) since 2000, for each technology. As previously stated, all patents filed at the EPO are considered as "high-value" inventions.

Cement	Insulation
	
Heating	**Lighting**
	
Methane	**Biomass**
	

Hydro	Marine
	
Solar PV	**Solar CSP**
	
Solar thermal	**Geothermal**
	
Waste	**Wind**
	
Batteries	**Fuel injection**
	

Electric & hybrid	Nuclear
	
Fuel cells	
	

7. Main patent holders

This section deals with patents at the firm level. As in section 6, we focus on patents filed at the European Patent Office. Focusing on EPO patents ensures that only patents with a high market potential are included. This is because filing a European patent is more expensive than filing a single national patent, hence only the more valuable patents will go through the European patent system. Moreover, filing a European patent signals that the potential market for that invention is larger than a single country.

Looking at patent holders is useful for several reasons. Firstly, it addresses concerns that between-country differences in the stock of patents might be driven by differences in the size of countries. Secondly, it can provide insights into the market structure that is prevailing in the markets for the different technology; e.g. if a market is dominated by few big companies or many small or a mixture of both.

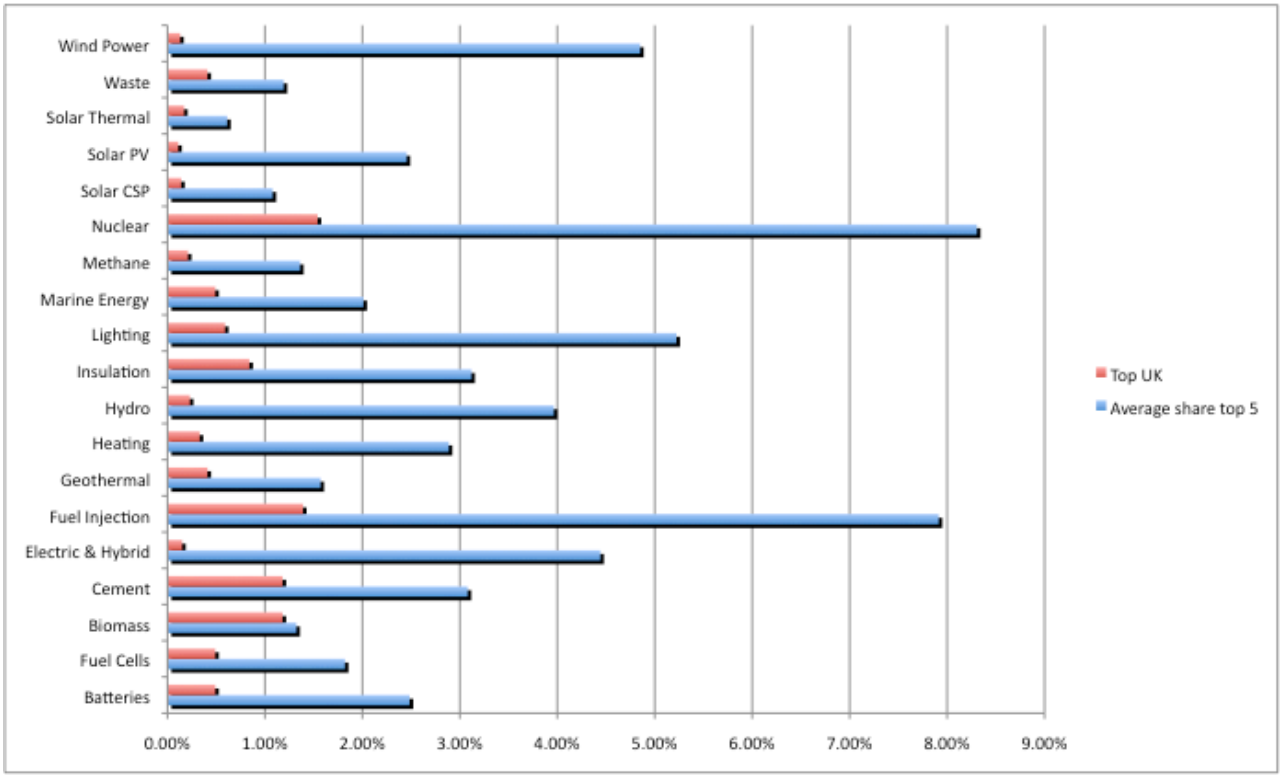
The tables in Box 5 below show by technology type the main UK-based holders of EPO patents. For each of these companies we report the number of patents they hold – in absolute numbers and as a share of total EPO patents – as well as their rank at the EPO within the technology type. This shows the British leaders in each technology. In order to compare UK companies with their main competitors we also report in Box 6 the top 5 companies in each technology.

For the technologies analysed, no UK company is a leader in its field. However, a few UK companies belong to the top 10 patent holders: BPB Industries (Cement, 7th), Lucas Industries (Fuel injection, 9th), Pilkington (Insulation, 9th), British Nuclear Fuels (Nuclear energy, 10th). The comparison with the tables in Box 6 shows a clear gap between UK leaders and international leaders. Figure 5 illustrates this by plotting the average patent share of the global top 5 patent holders as well as the share of the top UK patent holder for each technology category.

An important case to consider are Marine technologies where by various aggregate measures the UK ranked top world wide. Interestingly, this does not seem to translate into a UK inventor taking on a dominant position globally relative to other industry players. This raises two issues for further consideration which are beyond the scope of this study. Firstly, this could imply that UK innovators in this area, while having been successful in the past, might face fierce competition in the future from larger rivals abroad. A first step to examine this further would be to match the patent data with other company characteristics of both UK

inventors and foreign competitiors. Secondly, it could be the case that the presence of a large number of smaller players are behind the dominant aggregate position of the UK in this area. The following section examines the Marine energy technology category further, which seems to be central for the UK.

Figure 5 – Average share of Global Top 5 patent holders and top UK share in EPO Patents



Notes: For every technology category the figure shows the average share of total patents at the EPO of the global top 5 patent holders as well as the patent share of the top UK patent holder.

BOX 5. TOP UK COMPANIES FOR EUROPEAN PATENTS FILED BETWEEN 1980 AND 2007

Batteries

Company	# of EPO patents	Share of EPO patents	Rank at EPO
CHLORIDE SILENT POWER LIMITED	53	0.63%	24
TBS ENGINEERING LIMITED	15	0.18%	89
FORD MOTOR COMPANY LIMITED	13	0.15%	97
ABSL POWER SOLUTIONS LTD	6	0.07%	208
OXIS ENERGY LIMITED	5	0.06%	246

Fuel cells

Company	# of EPO patents	Share of EPO patents	Rank at EPO
JOHNSON MATTHEY PUBLIC LIMITED	57	0.49%	26
ROLLS-ROYCE PLC	14	0.12%	131
REGENESYS TECHNOLOGIES LIMITED	13	0.11%	136
INTELLIGENT ENERGY LIMITED	13	0.11%	136
VICTREX MANUFACTURING LIMITED	10	0.09%	188

Biomass

Company	# of EPO patents	Share of EPO patents	Rank at EPO
DAINTON LIMITED	1	0.41%	23
FI-PRO LIMITED	1	0.41%	23
ADVANCED NATURAL FUELS LIMITED	1	0.41%	23
RECLAIM RESOURCES LIMITED	1	0.41%	23
BLACK BAG ENERGY LIMITED	1	0.41%	23

Cement

Company	# of EPO patents	Share of EPO patents	Rank at EPO
BPB INDUSTRIES PUBLIC LIMITED	4	1.18%	7
IMPERIAL CHEMICAL INDUSTRIES	2	0.59%	27
FOSROC INTERNATIONAL LIMITED	2	0.59%	27
BTG INTERNATIONAL LIMITED	2	0.59%	27

Electric & hybrid

Company	# of EPO patents	Share of EPO patents	Rank at EPO
LUCAS INDUSTRIES PUBLIC LIMITED	13	0.15%	67
AUTOMOTIVE PRODUCTS PUBLIC LIMITED	7	0.08%	125
FORD MOTOR LIMITED	7	0.08%	125
CHLORIDE GROUP PUBLIC LIMITED	6	0.07%	149
TOROTRAK (DEVELOPMENT)	5	0.06%	172

LIMITED			

Fuel injection

Company	# of EPO patents	Share of EPO patents	Rank at EPO
LUCAS INDUSTRIES	165	1.39%	9
FORD MOTOR UK	41	0.35%	32
PERKINS ENGINES	13	0.11%	97
RICARDO CONSULTING ENGINEERS	8	0.07%	179
KWIK EUROPE LONDON	5	0.04%	214

Geothermal

Company	# of EPO patents	Share of EPO patents	Rank at EPO
TOTAL ENERGY CONSERVATION & MANAGEMENT COMPANY LIMITED	1	0.41%	29
HANSON BUILDING PRODUCTS	1	0.41%	29
TFC POWER SYSTEM	1	0.41%	29

Heating

Company	# of EPO patents	Share of EPO patents	Rank at EPO
VAILLANT LTD.	5	0.33%	28
BORG-WARNER LIMITED	4	0.26%	41
ADVANCE DESIGN & MANUFACTURE LIMITED	3	0.20%	59
IMPERIAL CHEMICAL INDUSTRIES PLC	2	0.13%	91
VENT-AXIA GROUP LIMITED	2	0.13%	91

Hydro

Company	# of EPO patents	Share of EPO patents	Rank at EPO
AQUAMARINE POWER LIMITED	1	0.23%	51
WATER RESEARCH CENTRE	1	0.23%	51
HYDRO ENERGY ASSOCIATES LIMITED	1	0.23%	51
THAMESMEAD ENGINEERING LTD	1	0.23%	51
PENNONGRADE LIMITED	1	0.23%	51

Insulation

Company	# of EPO patents	Share of EPO patents	Rank at EPO
PILKINGTON UNITED KINGDOM	14	0.84%	9
THE MORGAN CRUCIBLE COMPANY	6	0.19%	42
UKAE LTD	4	0.24%	48
ROCKWOOL LIMITED	2	0.06%	171
IMPERIAL CHEMICAL INDUSTRIES PLC	2	0.06%	171

Lighting

Company	# of EPO patents	Share of EPO patents	Rank at EPO
CAMBRIDGE DISPLAY TECHNOLOGY LIMITED	62	0.59%	27
THORN EMI PLC	30	0.28%	50
PELIKON LTD.	16	0.15%	78
GE LIGHTING LIMITED	15	0.14%	85
ISIS INNOVATION LIMITED	8	0.08%	148

Marine energy

Company	# of EPO patents	Share of EPO patents	Rank at EPO
ROTECH HOLDINGS LIMITED	3	0.49%	18
TRIDENT ENERGY LIMITED	3	0.49%	18
APPLIED RESEARCH & TECHNOLOGY LIMITED	3	0.49%	18
MARINE CURRENT TURBINES LIMITED	3	0.49%	18

Methane

Company	# of EPO patents	Share of EPO patents	Rank at EPO
BIOMASS LIMITED	3	0.21%	41
S.C.S. BIOTECHNOLOGY LIMITED	2	0.14%	85
APV SYSTEMS LTD.	2	0.14%	85
PIRTFERM LIMITED	2	0.14%	85
FARM GAS LIMITED	2	0.14%	85
BIOMASS RECYCLING LTD.	2	0.14%	85
UNITED UTILITIES PLC	2	0.14%	85

Nuclear

Company	# of EPO patents	Share of EPO patents	Rank at EPO
BRITISH NUCLEAR FUELS PLC	87	1.54%	10
UNITED KINGDOM ATOMIC ENERGY AUTHORITY	28	0.50%	26
NATIONAL NUCLEAR CORPORATION LIMITED	14	0.25%	54
NUCLEAR DECOMMISSIONING AUTHORITY	4	0.07%	111
NEXIA SOLUTIONS LIMITED	3	0.05%	139

Solar CSP

Company	# of EPO patents	Share of EPO patents	Rank at EPO
THE MARCONI COMPANY LIMITED	1	0.14%	100
MONYMUSK LAND COMPANY	1	0.14%	100
WHITFIELD SOLAR LTD.	1	0.14%	100
HELIODYNAMICS LIMITED	1	0.14%	100

SOLARSTRUCTURE LIMITED	1	0.14%	100

Solar thermal

Company	# of EPO patents	Share of EPO patents	Rank at EPO
SOLAR CENTURY HOLDINGS LIMITED	4	0.17%	47
G.E.W.(EC) LTD.	3	0.13%	76
THE UNIVERSITY OF NOTTINGHAM	2	0.08%	120
THE TECHNOLOGY PARTNERSHIP PLC	2	0.08%	120
SOLARWALL INTERNATIONAL LIMITED	2	0.08%	120
INTEGRATION TECHNOLOGY LIMITED	2	0.08%	120

Solar PV

Company	# of EPO patents	Share of EPO patents	Rank at EPO
SOLAR CENTURY HOLDINGS LIMITED	3	0.11%	118
POWERTILE LIMITED	3	0.11%	118
CORUS UK LIMITED	2	0.07%	210
BP ALTERNATIVE ENERGY INTERNATIONAL LIMITED	2	0.07%	210
EEV LIMITED	2	0.07%	210

Waste

Company	# of EPO patents	Share of EPO patents	Rank at EPO
THE BRITISH PETROLEUM COMPANY	7	0.41%	13
EDWARDS LIMITED	5	0.29%	23
THE BOC GROUP	5	0.29%	23
HAMWORTHY COMBUSTION ENGINEERING LIMITED	2	0.12%	102
DEBORAH FLUIDISED COMBUSTION LIMITED	2	0.12%	102

Wind power

Company	# of EPO patents	Share of EPO patents	Rank at EPO
ITI SCOTLAND LIMITED	4	0.13%	49
DEWIND LTD.	3	0.10%	76
JAMES HOWDEN & COMPANY LIMITED	3	0.10%	76
ISKRA WIND TURBINES LTD.	2	0.07%	146
THE ENGINEERING BUSINESS LIMITED	2	0.07%	146
INTEC POWER SYSTEMS LIMITED	2	0.07%	146
WINDSAVE HOLDINGS PLC	2	0.07%	146
INSENSYS LIMITED	2	0.07%	146
CONVERTEAM LTD	2	0.07%	146
WIND POWER LIMITED	2	0.07%	146

BOX 6. TOP 5 COMPANIES FOR EUROPEAN PATENTS FILED BETWEEN 1980 AND 2007

Batteries

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
SONY CORPORATION	JP	261	3.09%	1
MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.	JP	236	2.79%	2
PANASONIC CORPORATION	JP	234	2.77%	3
TOYOTA JIDOSHA KABUSHIKI KAISHA	JP	174	2.06%	4
SANYO ELECTRIC CO., LTD.	JP	145	1.71%	5

Fuel cells

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
NISSAN MOTOR CO., LTD.	JP	292	2.50%	1
SIEMENS	DE	243	2.08%	2
TOYOTA	JP	240	2.06%	3
PANASONIC CORPORATION	JP	148	1.27%	4
DAIMLER AG	DE	139	1.19%	5

Biomass

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
DSM IP ASSETS B.V.	NL	4	1.65%	1
CARGILL, INC.	US	4	1.65%	2
DURAFLAME, INC.	US	3	1.24%	3
ARMINES	FR	3	1.24%	4
BERGWERKSVERBAND GMBH	GER	2	0.83%	5

Cement

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
UNITED STATES GYPSUM COMPANY	US	29	8.58%	1
GEBR. KNAUF WESTDEUTSCHE GIPSWERKE KG	GER	6	1.78%	2
SICOWA VERFAHRENSTECHNIK FUR BAUSTOFFE GMBH & CO. KG	GER	6	1.78%	2
LAFARGE PLATRES	FR	6	1.78%	2
PROMINERAL GESELLSCHAFT	GER	5	1.48%	5

ZUR VERWENDUNG VON MINERALSTOFFEN MBH				

Electric & hybrid

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
TOYOTA	JAP	696	8.06%	1
NISSAN MOTOR CO., LTD.	JAP	346	4.01%	2
ROBERT BOSCH GMBH	GER	331	3.84%	3
HONDA	JAP	317	3.67%	4
HITACHI, LTD.	JAP	227	2.63%	5

Fuel injection

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
ROBERT BOSCH GMBH	GER	2977	25.29%	1
SIEMENS	GER	749	6.36%	2
DELPHI TECHNOLOGIES, INC.	US	343	2.91%	3
TOYOTA	JAP	314	2.67%	4
CONTINENTAL AUTOMOTIVE GMBH	GER	275	2.34%	5

Geothermal

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
REHAU AG + CO	GER	7	2.89%	1
ENRO GEOTHERMIEENTWICKLUNG GMBH	GER	4	1.65%	2
FREE ENERGY SOLUTIONS INC.	CA	3	1.24%	3
EXERGY, INC.	US	3	1.24%	3
ENLINK GEOENERGY SERVICES, INC.	US	2	0.83%	5

Heating

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
LG ELECTRONICS, INC.	KOR	68	4.46%	1
DAIKIN INDUSTRIES, LTD.	JAP	50	3.28%	2
VAILLANT	US	40	2.62%	3
CARRIER CORPORATION	JAP	35	2.30%	4
SANYO ELECTRIC CO., LTD.	GER	27	1.77%	5

Hydro

Company	Country	# of EPO patents	Share of EPO	Rank at EPO

			patents	
VOITH SIEMENS HYDRO POWER GENERATION GMBH & CO. KG	DE	27	6.22%	1
GENERAL ELECTRIC COMPANY	US	23	5.30%	2
HITACHI, LTD.	JP	15	3.46%	3
VA TECH HYDRO GMBH & CO	AT	14	3.23%	4
KABUSHIKI KAISHA TOSHIBA	JP	7	1.61%	5

Insulation

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
SAINT-GOBAIN ISOVER	FR	204	6.45%	1
DEUTSCHE ROCKWOOL MINERALWOLL GMBH & CO. OHG	DE	145	4.59%	3
LENHARDT MASCHINENBAU GMBH	DE	80	2.53%	6
NIPPON SHEET GLASS CO., LTD.	JP	37	1.17%	7
CERA HANDELSGESELLSCHAFT MBH	DE	27	0.85%	8

Lighting

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
PHILIPS ELECTRONICS N.V.	NL	1340	12.65%	1
PATENT-TREUHAND-GESELLSCHAFT FUR ELEKTRISCHE GLUHLAMPEN MBH	GER	485	4.58%	2
SAMSUNG MOBILE DISPLAY CO., LTD.	KR	392	3.70%	3
GENERAL ELECTRIC	US	301	2.84%	4
PANASONIC	JAP	248	2.34%	5

Marine energy

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
VA TECH HYDRO GMBH	AT	17	2.76%	1
OPENHYDRO GROUP LIMITED	IRL	14	2.27%	2
VOITH PATENT GMBH	DE	14	2.27%	3
OCEAN POWER TECHNOLOGIES, INC.	US	11	1.78%	4
SEABASED AB	SE	6	0.97%	5

Methane

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
PAQUES B.V.	NL	25	1.77%	1
LINDE AKTIENGESELLSCHAFT	GER	24	1.70%	3
UTS BIOGASTECHNIK GMBH	GER	19	1.35%	2
DEGREMONT	FR	16	1.13%	7
BIOTHANE SYSTEMS INTERNATIONAL B.V.	NL	12	0.85%	6

Nuclear

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
WESTINGHOUSE ELECTRIC CORPORATION	US	704	12.48%	1
FRAMATOME	FR	521	9.24%	2
GENERAL ELECTRIC COMPANY	US	447	7.93%	3
SIEMENS	GER	374	6.63%	4
COMMISSARIAT A L'ENERGIE ATOMIQUE	FR	296	5.25%	5

Solar CSP

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
YEDA RESEARCH AND DEVELOPMENT CO. LTD.	IL	11	1.52%	2
DEUTSCHES ZENTRUM FUR LUFT- UND RAUMFAHRT E.V.	DE	10	1.38%	3
SCHOTT AG	DE	7	0.97%	4
FRAUNHOFER-GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG E.V.	DE	6	0.83%	5
ARCH DEVELOPMENT CORPORATION	US	5	0.69%	6

Solar PV

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
CANON KABUSHIKI KAISHA	JP	127	4.48%	1
SANYO ELECTRIC CO., LTD.	JP	65	2.29%	2
SIEMENS	DE	62	2.19%	3
KANEKA CORPORATION	JP	50	1.76%	4
SHARP KABUSHIKI KAISHA	JP	44	1.55%	5

Solar thermal

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
ADVANCED PHOTONICS TECHNOLOGIES AG	DE	19	0.80%	1
FRAUNHOFER-GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG E.V.	DE	15	0.63%	2
ROBERT BOSCH GMBH	DE	15	0.63%	2
PHILIPS ELECTRONICS N.V.	NL	12	0.50%	3
SIEMENS	DE	12	0.50%	3

Waste

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
EBARA CORPORATION	JAP	33	1.91%	1
JOHN ZINK COMPANY	US	24	1.39%	2
MEGTEC SYSTEMS, INC.	US	18	1.04%	3
SIEMENS	GER	15	0.87%	4
BAYER AG	GER	13	0.75%	5

Wind power

Company	Country	# of EPO patents	Share of EPO patents	Rank at EPO
ENERCON	GER	254	8.53%	1
GENERAL ELECTRIC COMPANY	US	193	6.48%	2
REPOWER SYSTEMS AG	GER	102	3.43%	3
VESTAS WIND SYSTEMS A/S	Denmark	93	3.12%	4
SIEMENS	GER	80	2.69%	5

8. Focus on marine energy

Marine energy (mainly tidal and wave energy) is at an early development stage, although some designs are already being demonstrated.[9] Patenting activity in this field is still limited but is growing fast. According to the data presented above, UK inventors enjoy a strong position in this technology. This section provides more information on these inventors.

Contrary to the previous section, which only looked at patents filed at the European Patent office, here we look at patent holders of Marine patents in all patent offices worldwide. We can identify over 300 UK-based patent holders in marine energy since 1980. Table 10 below presents the names of the top 15 patent holders along with the number of patents they have filed worldwide.

Table 10 – Main UK patent holders in marine energy (all patent offices)

Name	Number of patents
APPLIED RESEARCH & TECHNOLOGY LIMITED	41
A. U. R. HYDROPOWER LIMITED	35
MARINE CURRENT TURBINES LIMITED	26
ROTECH HOLDINGS LIMITED	25
SEA ENERGY ASSOCIATES LTD	23
OCEAN POWER DELIVERY LIMITED	21
HYDROVENTURI LIMITED	20
HYDRO ENERGY ASSOCIATES LIMITED	18
SOIL MACHINE DYNAMICS LIMITED	17
TRIDENT ENERGY LIMITED	15
TIDAL GENERATION LIMITED	13
THE UNIVERSITY OF MANCHESTER	13
ITI SCOTLAND LIMITED	12
SCOTRENEWABLES (MARINE POWER) LTD	7
AQUAMARINE POWER LIMITED	7

[9] There is evidence that technologies follow an S-shaped life cycle (see e.g. Haupt et al. 2007); i.e. initially technology development proceeds rather slowly, followed by a period of rapid expansion with increasing returns followed by a prolonged period of decreasing returns. While such are inherently difficult to predict it appears plausible that Marine energy technologies are at the beginning of such a cycle so that first movers in this area still have a chance to benefit from a period of rapid expansion.

The main patent holder in Marine energy is Applied Research and Technology, which trades as Voith Hydro Wavegen Limited[10]. The company is located in Inverness, Scotland and is a world leader in wave energy. Applied Research and Technology was founded in 1990. Since 2005, it has operated as a subsidiary of Voith Siemens Hydro Power Generation GmbH.

The data suggest that the UK is one of the most important markets for marine energy. As shown in Table 11, the main patent offices for marine energy patents are Japan and the UK. One should also keep in mind that the European Patent Office is the main channel used by foreigners to patent in the UK. Russia comes as a surprising third, and is followed by Australia and the US. UK companies own many patents in each of these patent offices, except in Russia where almost all patents are filed by local companies[11]. US companies own more patents in Australia than in Europe.

[10] http://www.wavegen.co.uk/index.html

[11] For this reason, Russia did not feature in earlier analyses. Patents filed by Russian inventors are almost exclusively patented in Russia and are therefore not considered as 'high-value' inventions.

Table 11 – Main inventor countries and main patent offices for marine energy patents (1980-2007)

Patent office (destination of patents)	Total patents	Inventor countries (origin of patents)								
		JAP	UK	RUS	AUS	USA	CHN	GER	KOR	CAN
Japan	1166	953	36	2	13	55	1	11	7	2
UK	565	19	464	0	2	15	0	3	6	6
Russia	554	0	4	494	0	6	0	2	3	0
Australia	534	14	72	7	139	100	3	15	8	4
USA	520	38	48	0	10	261	2	13	6	10
European Patent Office	472	14	73	4	18	74	3	53	1	6
China	470	10	15	0	8	21	347	8	4	1
Germany	461	14	32	2	3	32	2	264	1	1
South Korea	313	8	5	0	8	14	0	5	252	1
Canada	299	9	42	1	17	59	1	8	3	72

9. Conclusion

We examine a range of statistics based on counts of "Clean" patent applications in an effort to identify innovation areas related to climate change mitigation that are promising from a UK perspective.

Our results suggest that overall the UK is far from being a global leader in this area. Despite having a global clean patent share that corresponds roughly to the UK's share in world GDP, the UK falls behind a range of economies that are much more focused on clean innovation over the 1980 to 2007 period.

We consider evidence for the more recent period, from 2002 to 2007, showing that the UK's position is deteriorating – as in terms of global patent shares the UK has fallen behind South Korea. However, this is not because innovation in clean technologies has gone down in the UK, but because innovation is growing very fast in emerging countries.

However, the UK performance is not homogenous across technology fields. Indeed when it comes to Marine energy technologies the UK has not only a comparative but even an absolute advantage with a global share of more than 17%. This technology field is however a dramatic outlier with all other technologies commanding global shares of less than 6% and global ranks of 5 or less. Other areas with both a high global share and rank over the 2002 to 2007 period are waste and wind energy generation technologies. While the UK has a clear lead in Marine technologies in absolute terms we also find that when set in relation to GDP there are a number of smaller countries moving ahead of the UK.

Over the 2002-2007 the UK performance was weakest in Batteries (1%), Electric & Hybrid (1.4%) as well as Nuclear (1.5%). Nuclear is also the category where coming at global position 10, the UK has the lowest rank in the 2002-2007 period.

There is equally considerable heterogeneity regarding the performance of individual technology fields over time. We identify 7 areas where UK inventors increased or maintained their share in global patents in the 2003-2007 period relative to 1980 to 1996. The highest increase is for waste energy generation technologies with 53%. Moreover, there are 4 areas where UK inventors command a lower share in 2003 to 2007 than in 1980 to 1996 but where there has been an increase in 2003 to 2007 after a drop in 1997 to 2002. On the other hand there are 8 sectors where the UK position has deteriorated, most dramatically so in Batteries with a 79% drop. Interestingly, most areas which saw a decline in their share at the same time increased their average levels of patenting. Thus UK shares declined not because UK inventors activity declined but because foreign inventors where more active.

A final interesting fact emerges from our analysis of individual inventors. Despite a dominant position in aggregate it seems that compared to foreign inventors, UK inventors are much smaller than their foreign counterparts in terms of the total number of patents they hold. What implication this has for the future remains to be seen. It could imply that healthy competition between a larger number of smaller players is inducive of substantial amounts of further innovation. On the other hand it could mean that smaller UK players are likely to be taken over by larger foreign players.

In conclusion, it is also important to recall that, though patents are good proxies of innovative activity, not all inventions are protected by patents. Thus, this report does not cover all aspects of innovative activity. In this respect, it would be very interesting to complement this data with sector case studies and interviews of R&D managers.

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Annex 1: IPC Codes used for Climate Change Mitigation Technologies

Renewable energy technologies

WIND POWER	
Wind motors	F03D
SOLAR ENERGY	
Devices for producing mechanical power from solar energy	F03G6
Use of solar heat, e.g. solar heat collectors	F24J2
Drying solid materials or objects by processes involving the application of heat by radiation - e.g. from the sun	F26B3/28
Devices consisting of a plurality of semiconductor components sensitive to infra-red radiation, light – specially adapted for the conversion of the energy of such radiation into electrical energy	H01L27/142
Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation, specially adapted as devices for the conversion of the energy of such radiation into electrical energy, including a panel or array of photoelectric cells, e.g. solar cells	H01L31/042-058
Generators in which light radiation is directly converted into electrical energy	H02N6
GEOTHERMAL ENERGY	
Devices for producing mechanical power from geothermal energy	F03G4
Production or use of heat, not derived from combustion – using geothermal heat	F24J3/08
MARINE ENERGY	
Tide or wave power plants	E02B9/08
Submerged units incorporating electric generators or motors characterized by using wave or tide energy	F03B13/10-26
Ocean thermal energy conversion	F03G7/05
HYDRO POWER	
Water-power plants; Layout, construction or equipment, methods of, or apparatus for AND NOT Tide or wave power plants	E02B9 and not E02B9/08
Machines or engines for liquids of reaction type; Water wheels; Power stations or aggregates of water-storage type; Machine or engine aggregates in dams or the like; Controlling machines or engines for liquids; AND NOT Submerged units incorporating electric generators or motors characterized by using wave or tide energy	[F03B3 or F03B7 or F03B13/06-08 or F03B15] and not F03B13/10-26

BIOMASS ENERGY	
Solid fuels based on materials of non-mineral origin - animal or vegetable substances	C10L5/42-44
Engines or plants operating on gaseous fuels from solid fuel - e.g. wood	F02B43/08
WASTE-TO-ENERGY	
Solid fuels based on materials of non-material origin - sewage, town, or house refuse; industrial residues or waste materials	C10L5/46-48
Incineration of waste - recuperation of heat	F23G5/46
Incinerators or other apparatus consuming waste - field organic waste	F23G7/10
Liquid carbonaceous fuels; Gaseous fuels; Solid fuels; AND Dumping solid waste; Destroying solid waste or transforming solid waste into something useful or harmless; Incineration of waste; Incinerator constructions; Incinerators or other apparatus specially adapted for consuming specific waste or low grade fuels, e.g. chemicals.	[C10L1 or C10L3 or C10L5] and [B09B1 or B09B3 or F23G5 or F23G7]
Plants for converting heat or fluid energy into mechanical energy – use of waste heat; Profiting from waste heat of combustion engines; Machines, plant, or systems, using particular sources of energy – using waste heat. AND Incineration of waste; Incinerator constructions; Incinerators or other apparatus specially adapted for consuming specific waste or low grade fuels.	[F01K27 or F02G5 or F25B27/02] and [F23G5 or F23G7]

Motor vehicle technologies

ELECTRIC & HYBRID VEHICLES	
Dynamic electric regenerative braking for vehicles	B60L7/10-20
Electric propulsion with power supply from force of nature, e.g. sun, wind	B60L8
Electric propulsion with power supplied within the vehicle	B60L11
Methods, circuits, or devices for controlling the traction- motor speed of electrically-propelled vehicles	B60L15
Arrangement or mounting of electrical propulsion units	B60K1
Arrangement or mounting of plural diverse prime-movers for mutual or common propulsion, e.g. hybrid propulsion systems comprising electric motors and internal combustion engines	B60K6
Arrangements in connection with power supply from force of nature, e.g. sun, wind	B60K16
Electric circuits for supply of electrical power to vehicle subsystems characterized by the use of electrical cells or batteries	B60R16/033
Arrangement of batteries in vehicles	B60R16/04
Supplying batteries to, or removing batteries from, vehicles	B60S5/06
Conjoint control of vehicle sub-units of different type or different function; including control of energy storage means for electrical energy, e.g. batteries or capacitors	B60W10/26
Conjoint control of vehicle sub-units of different type or different function; including	B60W10/28

control of fuel cells	
Control systems specially adapted for hybrid vehicles, i.e. vehicles having two or more prime movers of more than one type, e.g. electrical and internal combustion motors, all used for propulsion of the vehicle	B60W20
Fuel injection	
Arrangements of fuel-injection apparatus with respect to engines; Pump drives adapted top such arrangements	F02M 39/00
Fuel-injection apparatus with two or more injectors fed from a common pressure-source sequentially by means of a distributor	F02M 41/00
Fuel-injection apparatus operating simultaneously on two or more fuels or on a liquid fuel and another liquid, e.g. the other liquid being an anti-knock additive	F02M 43/00
Fuel-injection apparatus characterized by a cyclic delivery of specific time/pressure or time/quantity relationship	F02M 45/00
Fuel-injection apparatus operated cyclically with fuel-injection valves actuated by fluid pressure	F02M 47/00
Fuel-injection apparatus in which injection pumps are driven, or injectors are actuated, by the pressure in engine working cylinders, or by impact of engine working piston	F02M 49/00
Fuel injection apparatus characterized by being operated electrically.	F02M 51/00
Fuel-injection apparatus characterized by heating, cooling, or thermally-insulating means	F02M 53/00
Fuel-injection apparatus characterized by their fuel conduits or their venting means	F02M 55/00
Fuel injectors combined or associated with other devices	F02M 57/00
Pumps specially adapted for fuel-injection and not provided for in groups F02M 39/00 to F02M 57/00	F02M 59/00
Fuel injection not provided for in groups F02M 39/00 to F02M 57/00	F02M 61/00
Other fuel-injection apparatus, parts, or accessories having pertinent characteristics not provided for	F02M 63/00
Testing fuel-injection apparatus, e.g. testing injection timing	F02M 65/00
Low-pressure fuel-injection apparatus	F02M 69/00
Combinations of carburetors and low-pressure fuel-injection apparatus	F02M 71/00

Energy efficiency in the residential, commercial, and industrial sectors (selected aspects)

INSULATION	
Insulation or other protection; Elements or use of specified material for that purpose	E04B1/62

Heat, sound or noise insulation, absorption, or reflection; Other building methods affording favorable thermal or acoustical conditions, e.g. accumulating of heat within walls	E04B1/74-78
Insulating elements for both heat and sound	E04B1/88
Units comprising two or more parallel glass or like panes in spaced relationship, the panes being permanently secured together	E06B3/66-677
Wing frames not characterized by the manner of movement, specially adapted for double glazing	E06B3/24
HEATING	
Hot-water central heating systems - in combination with systems for domestic hot-water supply	F24D3/08
Hot-water central heating systems **-** using heat pumps	F24D3/18
Hot-air central heating systems **-** using heat pumps	F24D5/12
Central heating systems using heat accumulated in storage masses - using heat pumps	F24D11/02
Other domestic- or space-heating systems - using heat pumps	F24D15/04
Domestic hot-water supply systems - using heat pumps	F24D17/02
Use of energy recovery systems in air conditioning, ventilation or screening	F24F12
Combined heating and refrigeration systems, e.g. operating alternately or simultaneously	F25B29
Heat pumps	F25B30
LIGHTING	
Gas- or vapor-discharge lamps (Compact Fluorescent Lamp)	H01J61
Electroluminescent light sources (LED)	H05B33
CEMENT MANUFACTURING	
Natural pozzuolana cements	C04B7/12-13
Cements containing slag	C04B7/14-21
Iron ore cements	C04B7/22
Cements from oil shales, residues or waste other than slag	C04B7/24-30
Calcium sulfate cements	C04B11

Batteries

RECHARGEABLE BATTERIES (SECONDARY CELLS)	
Secondary cells; Manufacture thereof	H01M 10
FUEL CELLS	
Fuel cells; Manufacture thereof	H01M 8

Other climate-change relevant technologies

METHANE CAPTURE	
Anaerobic treatment of sludge ; Production of methane by such processes	C02F 11/04
Biological treatment of water, waste water, or sewage: Anaerobic digestion processes	C02F 3/28
Apparatus with means for collecting fermentation gases, e.g. methane	C12M 1/107
NUCLEAR ENERGY	
Fusion reactors	G21B
Nuclear reactors	G21C
Nuclear power plant	G21D
Arrangements for obtaining electrical energy from radioactive sources, e.g. from radioactive isotopes	G21H 1
Arrangements for converting chemical elements by electromagnetic radiation, corpuscular radiation, or particle bombardment, e.g. producing radioactive isotopes	G21G 1