Coming Clean: *The Cleantech Global Innovation Index 2012*

Cleantech Group & WWF

Cleantech Global Innovation Index 2012

Though climate change and energy security are formidable challenges for governments and the global economy, it is also a significant market opportunity. Countries are investing both human and monetary capital in supporting emerging innovation in their domestic cleantech sectors. Investments, innovation, and policy support differ widely from country to country, however – thus mapping the differences presents an enlightening view of the current cleantech landscape as well as its future prospects. That is the impetus for this Cleantech Global Innovation Index.

Executive Summary

- Thirty-eight countries were evaluated on 15 indicators related to the creation and commercialisation of cleantech start-ups, generating an index measuring each one's *relative* potential to produce entrepreneurial start-up companies and commercialise technology innovations over the next 10 years.

- The index highlighted the fundamentally global nature of cleantech innovation, with both eastern and western hemispheres giving rise to new companies and key players. North America and northern Europe do emerge as the primary contributors to the development of innovative cleantech companies, though the Asia Pacific region is following closely behind.

- Denmark topped the index, with its unique combination of a supportive environment for innovative cleantech start-ups, evidence of those start-ups gaining momentum, as well as a strong track-record of companies commercialising their cleantech innovations and scaling them up to widespread market adoption, particularly in wind.

- Scandinavia performed notably well, as Sweden and Finland also placed third and fourth respectively. These countries shared Denmark's supportive environment and high concentration of new cleantech companies, yet are behind on their ability to scale-up entrepreneurial cleantech companies to wider commercial success. (A pattern shared by fifth place country the United States.)

- Israel took second, as it leads the pack in its capacity to produce new innovative cleantech companies. Given its size, the country generates a large number of potential cleantech start-ups with relatively little input to the innovative process from government or private sources. However, to date at least, Israel lacks the domestic market and local expansion capital to match this innovation with strong company and product commercialisation.

- China and India placed 13th and 12th respectively, but stand out as having a strong potential to rise through the ranks in the coming years. While not currently creating innovative cleantech companies in great numbers relative to the size of their economies, they are already strong centres for cleantech production, and have increasingly supportive

governments, large sums of private money ready to be invested, and massive domestic markets.

- Overall the index shows countries that put significant resources into supporting cleantech innovation are rewarded with more emerging and commercialised cleantech companies, validating the approach many governments have taken to actively promote cleantech innovation nationally.

Foreword from the WWF – TO BE REWRITTEN BY 13 Jan

The Global Climate and Energy Challenges

> *"Climate change…is the greatest and widest-ranging market failure ever seen."*
> Stern Review on the Economics of Climate Change

The science is clear that, after two centuries of burning fossil fuels and emitting greenhouse gases at an exponentially increasing rate, the earth's climate is changing. Anthropogenic warming is disrupting a number of natural systems on which we depend, with predicted effects of temperature increases above 2°C to include more extreme weather events, sea level rises, precipitation changes, and ocean acidification[1]. The Stern Review estimated the costs of climate change in a business-as-usual scenario to be between 5–20% of annual GDP, depending on the scope of social costs taken into consideration. The cost drops to 2% of GDP for keeping global emissions between 500 and 550ppm CO_2e[2,3]. While exact numbers are unknowable, the potential economic and social impacts of climate change seem undeniable.

Climate change is not the only reason to transition to a clean energy future; there is also an imperative to embrace sustainability due to the state of the world's energy supplies and natural resources. The majority of the world's energy is created through the combustion of hydrocarbons, the global supply of which is ultimately finite. Oil production has already peaked in many countries, and there is a remarkable lack of transparency in assessing the reserves of many of today's major producers. In recent years, reserve depletion has led to increasing exploration of unconventional sources such as tar sands and shale gas, each of which carries higher economic and environmental costs than conventional sources. Add to this the continuing political instability in the Middle East and the Fukushima disaster's blow to nuclear power, and you have a picture of increasing scarcity and insecurity in non-renewable energy sources.

While there is much cause for concern about the world's climate change and energy challenges, solutions exist and can be enacted with the right combination of political, social and financial will. WWF's 2011 Energy Report demonstrates a viable scenario for reaching 100% renewable energy by 2050; this report, along with the Stern Review and other sources, estimate the climate could be stabilised at the cost of just 2% of global GDP[2,3]. Though some see climate change as the greatest and widest-ranging market failure in history, it is foolish not to include the market as key to a credible solution going forward. That is the impetus for this Cleantech Countries Innovation Index

Though there has been impressive growth in cleantech over recent years, this progress is not enough for the transformation we need to see. WWF Energy Report estimates that globally we need to reach energy investment levels of €1000 bn in this decade, climbing to overall investment levels of €3000 bn annually by 2030 - if we are to reach a 100% renewable future by 2050 and stay well below a 2 degrees temperature change. According to the International Energy Agency (IEA) fossil subsidies in 2009 were US$312 billion, 5-6 times more than renewable subsidies at around US$57 billion the

[1] IPCC Fourth Assessment Report: Climate Change 2007
[2] Stern Review on the Economics of Climate Change, 2006
[3] The Guardian, *Cost of tackling global climate change has doubled, warns Stern*, June 2008

same year[4]. These fossil fuel subsidies are only figures for consumption-based subsidies and don't include production subsidies or "hidden" subsidies for pipelines, LNG-terminals etc. Adding production and consumption fossil subsidies brings the amount to US$700 billion annually, according to OECD and the World Bank[5]. Imagine the progress that could be made if these subsidies were directed towards cleantech.

We are pleased to have had the opportunity to work with the Cleantech Group on producing this first-of-its-kind global study examining which countries are currently best at spawning market-based innovative companies to solve our greatest environmental challenges, and profiting from doing so. We trust you will find the results and analysis as interesting as we do.

[4] IEA, *Clean Energy Progress Report*, 2011

[5] IEA, OPEC, OECD and World Bank*, Analysis Of The Scope Of Energy Subsidies And Suggestions For The G-20 Initiative,* 2010

The Cleantech Countries Innovation Index 2011

Humanity today faces an unprecedented challenge. Climate change and natural resource depletion threaten to reverse the progress of the post-industrial era, raising the spectre of a generation of young people leading less prosperous lives than their parents. Averting this fate will require radically more efficient resource use and fewer greenhouse gas emissions across all aspects and in all corners of the global economy. It would seem that only a true sustainability revolution can help us avoid this uncertain, and potentially calamitous future.

Though we may all understand the urgent need to change human behavior, reversing existing trends requires more rapid behavior change than humans have historically demonstrated. Just as technological innovation facilitated incredible changes in lifestyle, consumption, and productivity since the 1800s, clean technology innovation must catalyze and facilitate a sustainability revolution to define the 21st century, and it must do so quickly.

Such innovation will doubtless come from a number of sources, in a variety of forms and vehicles. However, this report, and the concept of this first global Cleantech Countries Innovation Index, focuses on one source in particular: the founding and growth of innovative cleantech start-up companies developing and commercialising new, sustainable technologies. While climate change negotiations may prevaricate, market forces do not. Every day, from Amsterdam to Zhongguancun, a new cleantech company is being founded or invested in, setting out on its own journey to make its contribution to that sustainability revolution.

Most of the studies and the majority of the media attention on cleantech leadership tend to focus on either governmental policy and attitude to climate change or, if about companies, on the sustainability practices of large multi-nationals. Yet in our opinion, a large share of the disruptive innovations required will come from the entrepreneurial community – just as it has done in the ongoing Information Technology revolution. This study is concentrated on pinpointing where such companies will come from – from which countries is innovation emerging now and in future? A different question, we should point out, than 'where are the biggest markets, or where are the most climate change-friendly governments?'

These companies tend to get less of the mindshare and publicity. Yet they constitute one of the most important pieces of the sustainability puzzle, and are thus critical to understand and support. Thousands of such companies have been born in the last decade; US$30 bn of venture capital investment has poured into such companies over the last 4 years[6]. Drawing on the widest possible range of sources, this study seeks to answer the question:

Which countries currently have the greatest potential to produce entrepreneurial cleantech start-up companies which will commercialise clean technology innovations over the next 10 years?

We ponder the question on a relative basis. The US is producing many more such companies than any other country (just as it has done in the IT and social media world). Yet how does the picture change when size of economy (GDP) is accounted for?

[6] Cleantech Group data

The Importance of Cleantech Innovation

> *"Going green is the largest economic opportunity of the 21st century"*
> John Doerr, Partner, Kleiner Perkins Caulfield & Byers (KPCB)

Advocates have proposed a myriad of solutions for the environmental challenges we face, from individuals becoming vegetarian to nations forming emissions treaties. While all approaches are worth considering, new innovations and technologies are needed to make large-scale changes quickly; in the words of veteran cleantech investor Vinod Khosla, "the only way to get there is radical innovation." A brief look at history shows that technology can have a powerful impact. The past century has seen greater than 10-fold increases in energy efficiency in developed world energy supplies[7], an especially relevant trend given the fact that 74% of global greenhouse gas emissions are caused by energy production and use[8]. New technologies alone are not enough; they must be widely adopted in society. The most efficient solar panel in the world is useless unless it is sold and installed widely by new businesses down the supply chain.

From research to commercialisation, the life cycle of high-impact technologies include many players, from governments and universities to investors and multi-national corporations. In the centre of this complex web is the entrepreneurial start-up, the most common vehicle for taking an idea from the laboratory to the market. Innovation companies come in many different forms along this continuum. Most common are companies introducing incremental innovations; those transferring technological applications from one industry or geography to another; and those presenting business model innovations. Completely new science and technology breakthrough companies are rare, though they do exist.

The majority of small companies in these different realms eventually fail. From within their ranks, however, emerge a few enterprises creating truly disruptive businesses that revolutionise society and become embedded in our everyday lives— the Microsofts, the Googles, the Apples and the Facebooks. Political debate may paint sustainability as fundamentally at odds with economic value creation on a global, national, and company level. Yet the reality is that individuals, multinationals, and governments are waking up to the need for renewable energy, energy efficiency. and sustainable solutions in all sectors of the economy. This drives a growing market for new and innovative technologies and services. As the goal of all innovative technology entrepreneurs is ultimately a profitable exit, the growing number of talented business people focusing on the challenges of climate and energy indicates they think there is money to be made. The cleantech revolution is happening because it economically must, and now the countries of the world face critical choices as to whether they will fall ahead or behind the curve. In the tough economic climate which is likely to overhang much of the 2010's, where jobs and capital are in short supply, it is imperative for countries to think about fostering economic growth. One part of new policy could and should be to consider whether they as an individual country can give rise to a new set of growth companies, at the very least in proportion to their economic size. This study is the first known attempt to landscape that dynamic, to reason which countries look like they will perform strongly on that measure in the nearer term, and which have a long way to go if they too wish to do so.

We hope you find it thought provoking.

Richard Youngman
MD Europe & Asia, Cleantech Group

Vince Knowles
Analyst, Cleantech Group

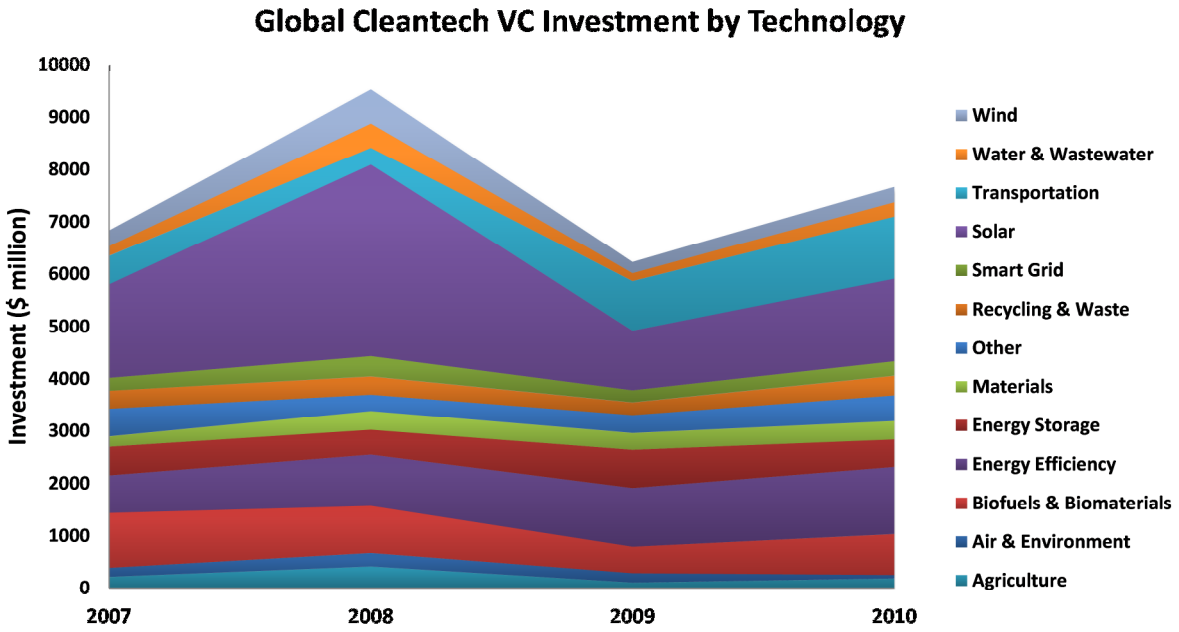
[7] Stern Review on the Economics of Climate Change, 2006
[8] Emission Database for Global Atmospheric Research, 2000

November 2011

The Global 'Cleantech Story'

The term cleantech, (sometimes used interchangeably with greentech, sustainable technologies, and environmental technologies) embraces a wide range of innovative products and services that contribute both financial returns and positive environmental impacts and outcomes. A large proportion of cleantech is made up of energy-related technologies - 77% of total cleantech VC investment in 2010 - though the definition also includes a broader range of technologies in water, agriculture, waste, and materials. The global market for clean technologies is growing every year: WWF and Roland Berger's 2011 *Clean Economy, Living Planet* report found that the global clean energy technology market has grown 31% per-annum between 2008 and 2010, from €104 bn to €179 bn. Within this growth industry, wind was the biggest player with a 30% market share, though solar was fastest growing (at around 100% per annum) with 24% of the pie. Biomass holds third place with a 20% share of the market. The supply of clean technology products will surely only continue to trend upwards in the decades to come, if not always in a straight line. Clean energy investments also weathered the 2008-09 financial crisis storm relatively well, with investment only dropping 6.6%, compared to a 19% fall for the oil and gas industry[9].

Within cleantech, the primary focus of this report is the innovative start-up. One indicator of start-up activity is venture capital (VC) investment in innovative cleantech companies, which rose consistently from 2002 to 2008, peaking at over US$9.5 bn[10]. While the financial crisis knocked down 2009 investment totals, the upward trend resumed in 2010, and 2011 showed the largest first half-year investment on record, at over $4.7 bn. Recent trends have shown solar, energy efficiency and transport as the primary sectors to attract early-stage private finance.



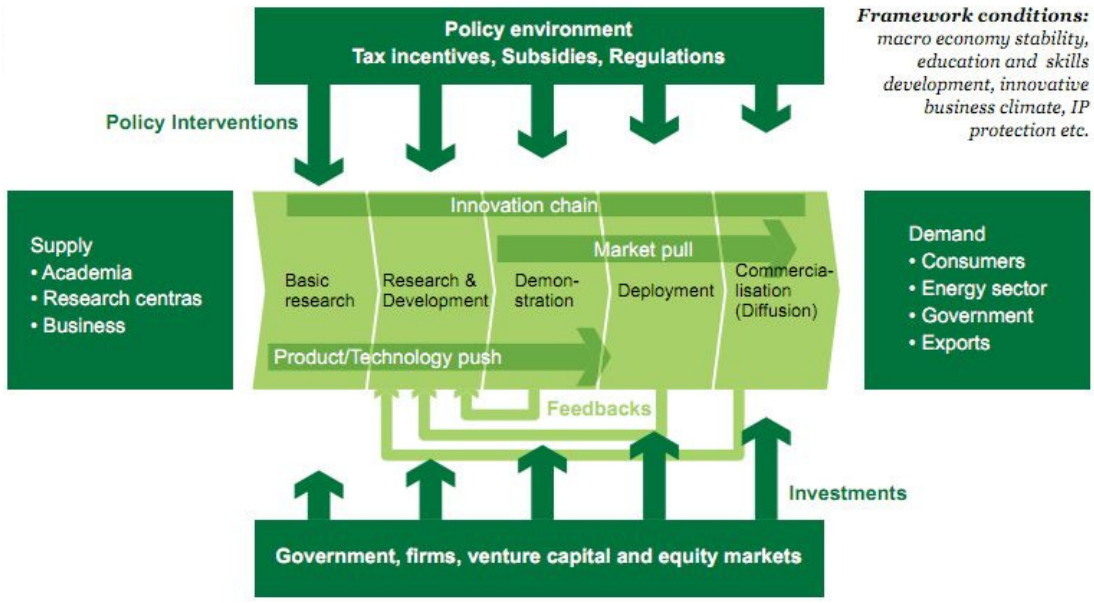
Source: Cleantech Group

[9] The Pew Charitable Trusts, *Who's Winning the Clean Energy Race?*, 2010
[10] Cleantech Group data

Measuring Cleantech Innovation

In 2009 and 2011 WWF published "*Clean Economy, Living Planet*" reports with Roland Berger, ranking countries by economic value added from manufacturing cleantech products. This report highlighted the progress that has been made in the sector, as well as which countries have effectively positioned themselves to be leaders in the scaling-up of new sustainable technologies. *The Cleantech Countries Innovation Index* seeks to complement *Clean Economy, Living Planet's* snapshot of the current situation by, rather than classifying established cleantech giants, measuring emerging upstart and start-up companies and the factors affecting them.

To inform our examination of innovative companies it is valuable to touch on the impetus behind them. Innovation is driven by two primary factors: technology supply, or 'push' from research, and market demand or 'pull'. A traditional linear model sees innovation as the simple sum of these push and pull effects, implying that measuring a country's R&D expenditures and end market size captures the innovation potential of that country. However, innovation is now understood to emerge from a far more complex ecosystem of influences interacting with the fundamental push and pull factors. As the IEA *Energy Technology Perspectives* report notes: "The process is not necessarily linear. RD&D[11] is only part of the innovation system required to develop and deploy new and improved technologies."[12] The graphic below shows the wider factors, including government policy, academic research, private finance, and market demand. This makes measuring any innovation sector challenging, and cleantech more so than most, as it spans a wide range of technologies and is subject to relatively volatile public policies in most countries.

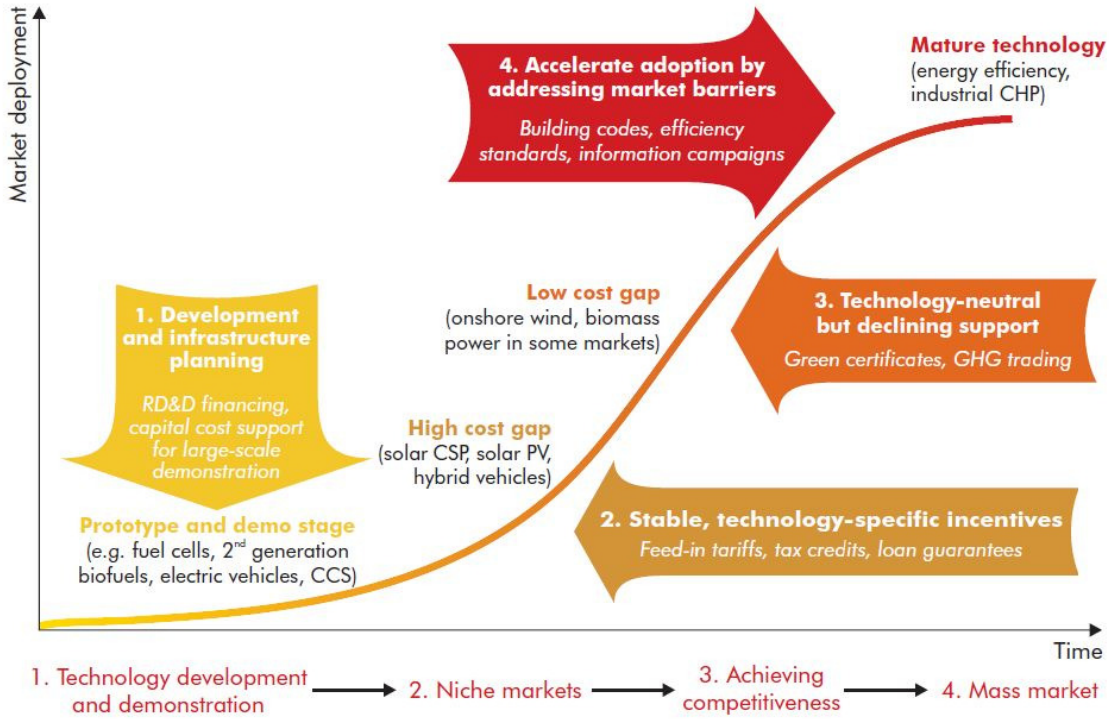


Source: IEA, Energy Technology Perspectives, 2008 (Adapted from Grubb and Foxon)

Governments can influence cleantech innovation at any of the 'pressure points' identified in the graphic below. These include: the 'push' of R&D spending; policies that help technologies bridge the cost gap to achieve competitiveness; and policies that influence market economics to facilitate wide adoption. Governments can also ensure that necessary infrastructure is in place for cleantech, which

[11] 'Research, development and demonstration'
[12] IEA, *Energy Technology Perspectives,* 2008

is especially important for the development of renewable energy generation technologies requiring effective governance around grid capacity and regulatory frameworks.



Source: IEA, Energy Technology Perspectives, 2010

Beyond government activity, availability of private finance is vital to fuel the growth of innovative cleantech companies and to bring technologies from the laboratory to the market. Private finance tends to be more strategically targeted than many blanket government incentives, filtering for the most disruptive technologies and backing them with investor experience and networks. Indeed, some have criticised public subsidies for artificially shielding technologies from market forces. For example, prominent cleantech investor Khosla Ventures advises companies that "subsidies bring cash flow forward but seldom create your market or build your business. In order to succeed, your product must be price competitive without subsidies."[13] While avoiding subsidy-reliant companies is a possible investment strategy, it is impossible to entirely separate policy and private finance. Deutsche Bank has found that government policy has a strong impact on the availability of private finance in a country, with the most attractive policy framework for investors providing transparency, longevity, and consistency[14].

Previous work has examined both innovation and entrepreneurism across the countries of the world[15], and there have been studies made of different dynamics of the cleantech market across the countries of the world[16]. However, none have delved into the specific question of where cleantech

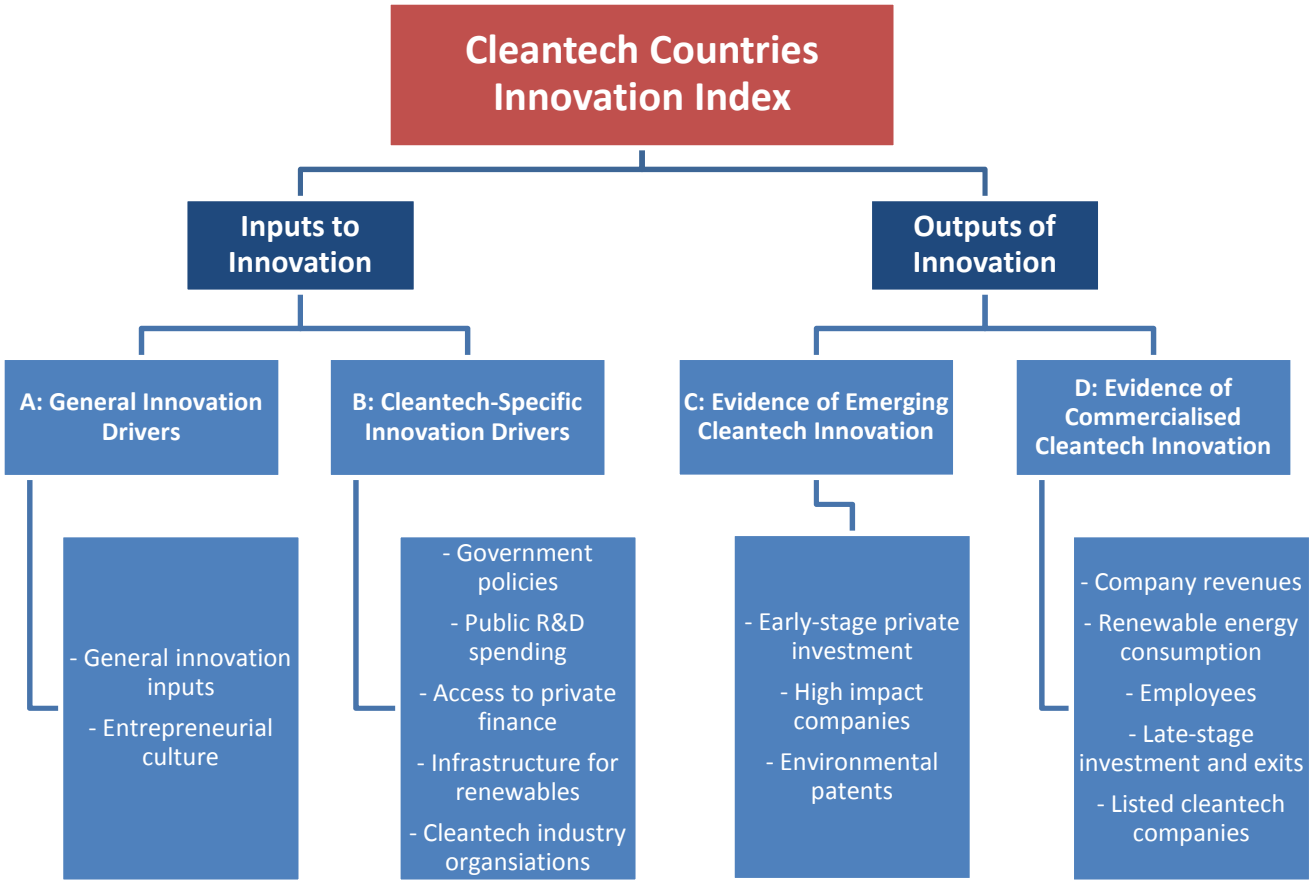
[13] khoslaventures.com
[14] Deutsche Bank, *Paying for Renewable Energy: TLC at the Right Price*, 2009
[15] INSEAD *'Global Innovation Index'*, *'Global Entrepreneurship Monitor'*
[16] WWF and Roland Berger '*Clean Economy, Living Planet'*, The Pew Charitable Trusts '*Who's Winning the Clean Energy Race?',* UK Department for Business Innovation & Skills, '*Low Carbon and Environmental Goods and Services'*

innovation companies are being created across the globe. This report is unique in that it draws on sources that reflect the whole lifecycle of cleantech innovation and paints a picture of where this vital innovation exists currently and where it will most likely emerge from in the coming years.

The Cleantech Countries Innovation Index

Much work has been done measuring and monitoring innovation. We have unashamedly drawn upon such work and leveraged existing data sets in the creation of the Cleantech Countries Innovation Index. This report is well informed by previous work in measuring global innovation, primarily the INSEAD Global Innovation Index. However the methodology has been adapted to fit our specific focus on innovative sustainable, especially energy related, technology start-up companies, as opposed to general innovation across all business areas and types. Following previous models, the index has been built from a number of indicators, 15 in total, drawn from both 3rd party research and Cleantech Group's proprietary data. More detail on the specifics of these indicators can be found in the appendix. These indicators are grouped into four factors, which represent different aspects of and influences on the cleantech innovation lifecycle, shown below. Each of these four factors is equally weighted in the overall Cleantech Countries Innovation Index. The raw data for each indicator was normalised to allow comparisons as well as averaged and weighted by importance, to give the factor scores. These separate factor scores were then averaged to create *inputs to innovation* and *outputs of innovation* sub-indices and, finally, an overall *cleantech innovation index* score for each country. The scope of the study was the EU27 and G20 countries, with Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovakia omitted for lack of data. Israel, Switzerland, and Norway were added, as data was available and the countries were regarded as being of relevance in looking at emerging cleantech innovation companies internationally.

The Framework of the Cleantech Countries Innovation Index



The following sources of data were drawn upon to populate the above framework and to derive the scores:

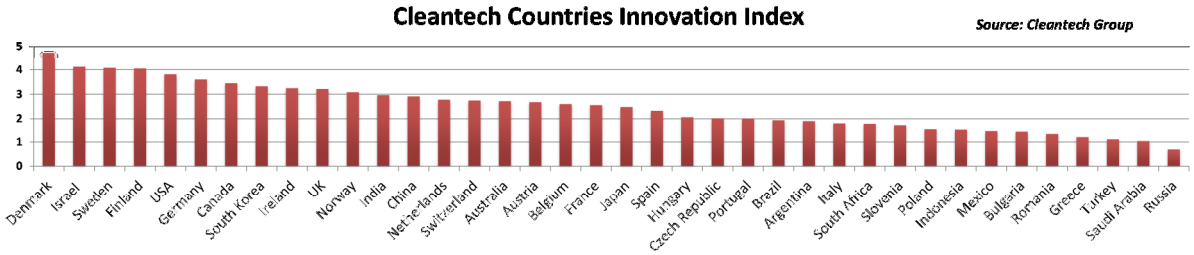
INSEAD, *Global Innovation Index,* 2011
Global Entrepreneurship Monitor, 2010
The Pew Charitable Trusts, *Who's Winning the Clean Energy Race?*, 2010
IEA, *Global Gaps in Clean Energy RD&D*, 2010
IEA, *Energy R&D database,* 2009
Ernst & Young, *Renewable Energy Country Attractiveness Index*, 2011
Cleantech Group, *Global Cleantech 100,* 2009 - 2011
OECD, *Patent Cooperation Treaty database*, 2008
WWF and Roland Berger, *Clean Economy, Living Planet*, 2009, 2011
UK Department for Business Innovation & Skills, *Low Carbon and Environmental Goods and Services*, 2011
BP, *Statistical Review of World Energy,* 2011
Cleantech Group, FTSE, Ardour and WilderHill indices of public cleantech companies, 2011
Cleantech Group data, 2011
World Bank indicators 2009 - 2011

The Cleantech Countries Innovation Index – the 2011 Table

Country	Rank	Cleantech Innovation Index	Inputs to Innovation	Outputs of Innovation	General Innovation Drivers	Cleantech-Specific Innovation Drivers	Evidence of Emerging Cleantech Innovation	Evidence of Commercialised Cleantech Innovation
Denmark	1	4.7	3.5	6.0	2.9	4.1	6.2	5.7
Israel	2	4.1	2.5	5.7	2.9	2.2	8.6	2.7
Sweden	3	4.1	3.3	4.8	3.5	3.2	6.2	3.4
Finland	4	4.0	3.6	4.5	3.5	3.7	5.7	3.2
USA	5	3.8	3.3	4.3	3.5	3.1	6.0	2.6
Germany	6	3.6	3.1	4.1	2.7	3.6	4.9	3.2
Canada	7	3.4	2.8	4.1	3.5	2.1	4.8	3.5
South Korea	8	3.3	3.2	3.5	2.8	3.5	5.0	2.0
Ireland	9	3.2	2.9	3.6	3.5	2.3	3.5	3.7
UK	10	3.2	3.2	3.2	3.3	3.2	4.2	2.3
Norway	11	3.1	2.6	3.5	3.3	2.0	5.1	2.0
India	12	3.0	2.8	3.1	2.1	3.4	2.2	4.0
China	13	2.9	3.1	2.8	2.7	3.4	1.7	3.8
Netherlands	14	2.8	2.8	2.8	3.3	2.2	4.0	1.5
Switzerland	15	2.7	2.8	2.6	3.4	2.3	2.6	2.7
Australia	16	2.7	3.4	2.0	3.5	3.3	2.0	2.1
Austria	17	2.7	2.4	2.9	2.7	2.1	3.0	2.8
Belgium	18	2.6	2.4	2.8	2.5	2.2	3.6	2.0
France	19	2.6	2.9	2.2	2.5	3.3	2.9	1.5
Japan	20	2.5	2.0	2.9	2.1	2.0	4.6	1.3
Spain	21	2.3	2.5	2.2	2.1	2.9	0.7	3.6
Hungary	22	2.1	2.3	1.8	2.3	2.4	1.4	2.2
Czech Republic	23	2.0	1.8	2.3	2.3	1.2	2.2	2.4
Portugal	24	2.0	2.0	2.0	2.1	1.9	0.7	3.3
Brazil	25	1.9	2.3	1.6	2.6	2.0	0.4	2.7
Argentina	26	1.9	2.5	1.3	2.7	2.3	0.1	2.5
Italy	27	1.8	2.5	1.1	1.6	3.3	0.8	1.5
South Africa	28	1.8	2.0	1.6	2.4	1.7	0.8	2.4
Slovenia	29	1.7	2.4	1.1	2.2	2.6	0.8	1.3
Poland	30	1.5	1.8	1.2	1.7	1.9	0.4	2.0
Indonesia	31	1.5	1.6	1.4	1.3	1.9	0.0	2.8
Mexico	32	1.4	1.8	1.1	1.5	2.0	0.2	2.1
Bulgaria	33	1.4	1.6	1.3	1.6	1.5	0.7	1.8
Romania	34	1.3	1.8	0.8	1.2	2.4	0.2	1.4
Greece	35	1.2	1.7	0.7	1.4	1.9	0.2	1.3
Turkey	36	1.1	1.3	0.9	1.6	1.0	0.2	1.6
Saudi Arabia	37	1.0	1.5	0.6	2.9	0.0	0.1	1.1
Russia	38	0.7	0.7	0.7	1.0	0.3	0.3	1.1

For comparison, the Index and indicators have a mean score of 2.4 – 2.6, see Appendix B for profiles of individual countries.

Results and Analysis



Interestingly, the higher ranks of the overall Cleantech Countries Innovation Index are dominated by small countries, which represent concentrated potential to produce their 'fair share' (and then some) of the innovative companies to take the global economy forward on a more sustainable basis. As home to three of the four top countries, Scandinavia emerges as a clear regional 'winner'. Its small-country power is followed by the larger economies of the USA and Germany.

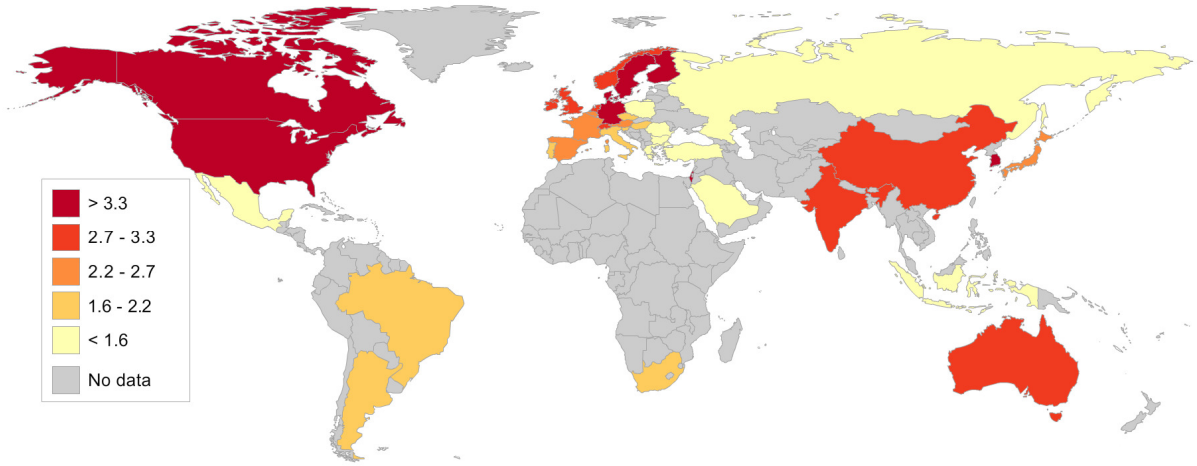
Each country shows different strengths. Israel excels in the factor "*evidence of emerging cleantech innovation"*, while Denmark leads in "*cleantech-specific innovation drivers"* and "*evidence of commercialised cleantech innovation".* Denmark also scores second for fostering emerging cleantech companies. Finland takes fourth place overall by coming second in both "*inputs to innovation"* factors, as well as scoring well for emerging cleantech companies. Sweden and the USA show a common pattern, scoring well on "*evidence of emerging cleantech companies"* and "*general innovation drivers"*. Sweden edged out the USA by scoring stronger (on a relative basis) on the " *evidence of commercialised cleantech innovation"* factor mainly due to its relatively strong deployment of renewable energy.

China and India did not top the index in 2011, but they stand out as having a strong potential to rise through the ranks in the coming years. They are already strong centres for the production of cleantech products and have increasingly supportive governments, large sums of private money ready to be invested, and massive domestic markets. Signs suggest that in the near future these countries have many of the favourable ingredients to be not only manufacturing cleantech products, but founding, and being home to, more and more of the next generation of innovative cleantech companies.

Finally, Canada and Ireland stood out as they scored surprisingly well given their lack of reputation for cleantech innovation and indeed, in Canada's case, a actual negative reputation at a federal level for political leadership on climate change. Yet both countries scored in the top 10 for *general innovation drivers* and *evidence of commercialised cleantech innovation*, though they both did relatively less well on the other factors. It appears that these countries have active later-stage cleantech companies that are contributing strongly to the commercialisation of clean technologies, though less to underlying innovation.

The map below shows the fundamentally global nature of the cleantech innovation revolution, with both eastern and western hemispheres giving rise to new companies and key players. North America and northern Europe emerge as primary contributors to the development of innovative cleantech companies, with the Asia Pacific region following closely behind. China and India promise to help the Asia Pacific region challenge North America and Europe in the coming years, and are already

demonstrating their ability to do so. Israel, barely visible on the map, leads in the creation of young cleantech companies, on a relative basis, providing the standout exception to the main geographic trends defining the global cleantech innovation company landscape.

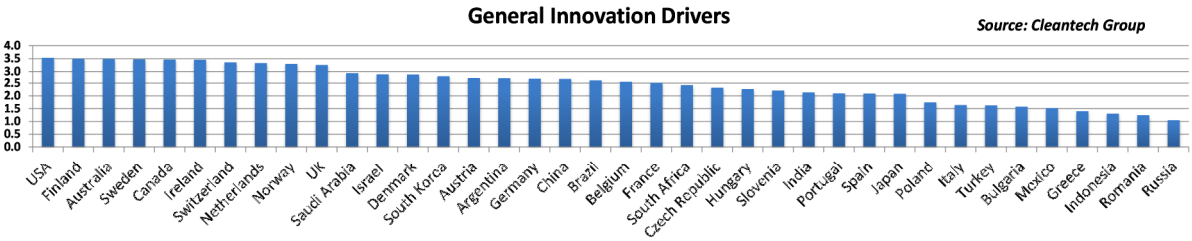


Map of overall *cleantech countries innovation index* scores *Source: Cleantech Group Analysis*

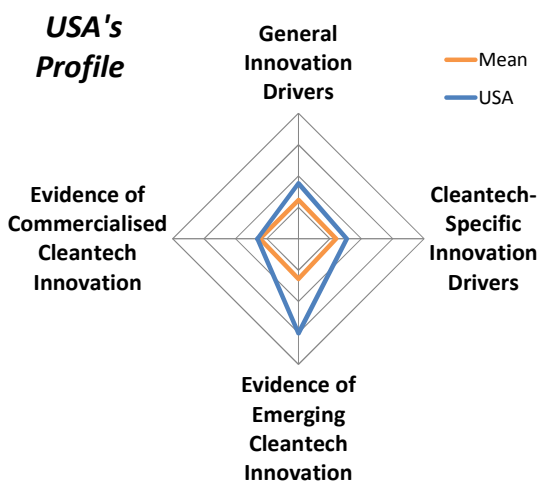
A: General Innovation Drivers

The *general innovation drivers* factor addresses the general conditions that facilitate the development of innovative start-ups in a country. Like any other form of technological innovation, cleantech innovation requires supportive institutions, enabling infrastructures, and a culture of ingenuity as well as a 'championing' of entrepreneurial zeal. Entrepreneurial culture plays an especially important role in innovation, as it is primarily through entrepreneurial ventures that technologies achieve impact beyond the laboratory doors, out in the market where it counts. Even the most impressive ideas need drive and business skill to reach a wide market and realize their potential to achieve financial or environmental impact, hopefully both.

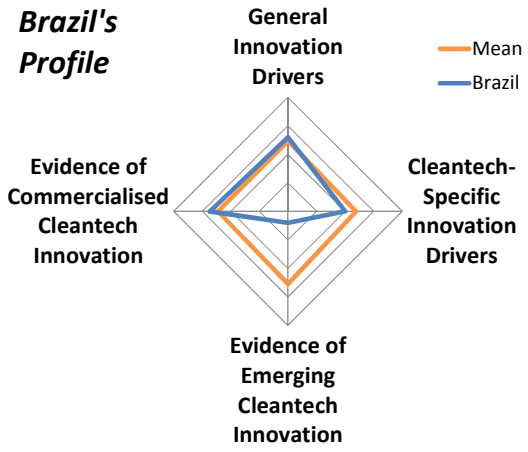
This factor is a blend of the general innovation inputs as measured by the INSEAD *Global Innovation Index* and entrepreneurial culture as measured by the *Global Entrepreneurship Monitor*.



USA tops this scale, with Silicon Valley representing a case in point for how the above factors interact to foster the creation of innovative companies. Driven by the rich resources and strong research culture of San Francisco, Stanford University, and UC Berkley, this tiny area is home to a vibrant community of entrepreneurs that has spawned such titans as Google and Apple, as well as a new generation of cleantech companies like Miasole and Solazyme. Emerging US start-ups are supported by a strong venture capital market; even accounting for the nation's enormous GDP, the US has by far the most venture capital spending on cleantech amongst countries surveyed for this study, with over US$5bn invested in 2010 alone[17]. The private sector's enthusiasm for cleantech is matched by mixed support from the US government. Policies in the nation's states vary massively: California has a target to produce 33% of its energy renewably by 2020, while Pennsylvania's target for the same period starts with 8%[18]. The federal government is similarly inconsistent: while the Department of Energy has supported cleantech start-ups with US$38.6bn in loans issued to date[19], Republicans in Congress are seeking to undercut the Environmental Protection Agency and forthcoming regulation under the Clean Air Act. Thus, while the US is currently a world leader in the creation of cleantech companies, without serious support for the industry and environmental policies to incentivise a domestic market, some of the potential profit and jobs from cleantech commercialisation may be lost to foreign competitors.



Brazil is an interesting case as the *Global Entrepreneurship Monitor* scores it highest for entrepreneurial culture. The country has policies supportive of renewable energy and world-leading biofuels production, but lacks significant numbers of innovative cleantech companies. Brazil has been developing its biofuels industry since the 1970s, when Brazilian companies began creating a first generation of biofuels innovations including agricultural techniques, processing and refining technologies, and ethanol-fuelled combustion engines. However, Brazil's biofuels industry has by now become relatively mature, and Brazil is arguably not at the cutting edge of next-generation biofuels or, indeed, any other cleantech sector. Given its strong population of entrepreneurs and large domestic market, Brazil has some strong potential to become a leading cleantech innovator if its government can foster more sustainable



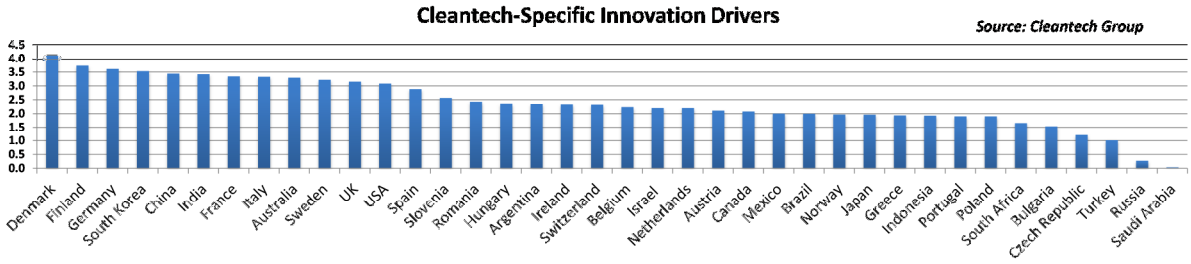
[17] Cleantech Group Data
[18] US DoE State Renewable Portfolio Standards
[19] US DoE Loan Program Office

technology R&D, and produce conditions that give birth to more start-ups with an international agenda and outlook from the outset.

Along with Brazil, Argentina and China are highly ranked for general entrepreneurial culture by the *Global Entrepreneurship Monitor*. This suggests that these countries produce many owner-operated businesses and SMEs yet lack, relatively speaking, the infrastructure and institutions to also produce innovative technologies for those start-ups to commercialise. Conversely, Japan is producing plenty of new technology but, as shown by its scoring lowest for entrepreneurial culture, the country lacks the capacity to commercialize that technology through innovative entrepreneurial start-ups. It could be argued that the rigid structures and expectations of Japanese society do not lend themselves to the informality, vigour, and risk-taking required to build a strong, Silicon Valley-esque start-up culture.

B: Cleantech-specific innovation drivers

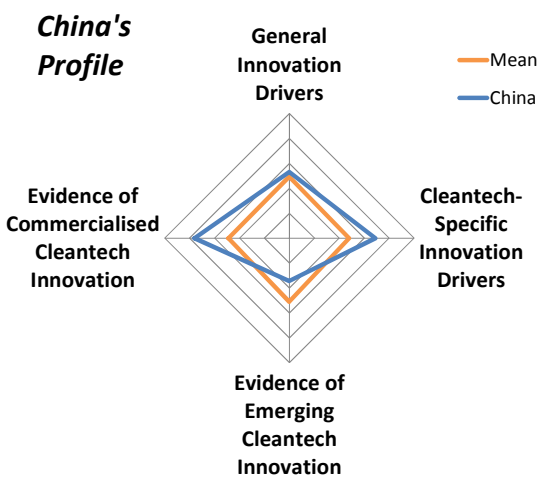
The creation of innovative cleantech companies is also influenced by a number of *cleantech-specific innovation drivers*. Such drivers act to promote technology invention, commercial adoption, or company growth and work from both the public and private sphere. This factor is derived from cleantech friendly government policies, as reported in the PEW *Clean Energy Race* report, and supplemented by Cleantech Group research, and IEA data on public cleantech R&D spending. The suitability of national infrastructures - physical, legislative and financial - for renewable energy as measured by the Ernst & Young *Renewable Energy Country Attractiveness Index* were also used, along with Cleantech Group indicators of access to private finance, and density of cleantech industry support organisations.



Results show no single country taking top marks in all cleantech-specific indicators. Denmark and South Korea stand out as having relatively strong R&D, both around 0.04% of GDP spent on clean energy, and a broad portfolio of supportive government policies, yet this performance is not matched with renewables-friendly infrastructure. Conversely, Germany has the strongest policy framework and a solid infrastructure for renewables, but does not match this in access to private finance and public R&D budget, only spending around 0.01% GDP on public cleantech R&D, compared to 0.07% for world-leading Finland.

China follows these top four countries, and despite often being painted as a villain of sustainability due to pollution and greenhouse gas emissions, the country has taken a strong initiative in cleantech. The centralized nature of China's political power means China can move very quickly and strategically: for instance the country's 12th Five-Year Plan, covering 2011 - 2015, has set a target of 11.4% of energy to come from non-fossil fuel sources - this means a huge amount of renewable

energy will be needed for the largest population in the world. Progress towards this goal can be seen in China's annual doubling of installed wind capacity between 2005 and 2009[20], facilitated by its renewables infrastructure, for which it received the top score Another example of China's strategic power in cleantech is the recent move by the government to consolidate control over the rare earth mining industry. Rare earth metals are important components of many cleantech products, and China already produces 95% of the world's supplies. The question stands as to whether China will be able to grow companies that can develop—as well as manufacture—their share of cleantech innovations for the international market. The country spent only 0.001% GDP on cleantech R&D in 2009. Greater expenditure, allied to learning how to leverage that spending into innovative and global companies, will be needed if it is to reach its full innovation potential over the next 10-20 years. In its favour, China has had the most private finance raised, and the second most per GDP, suggesting that the availability of funding will not be the key barrier for entrepreneurs wanting to take innovations to the huge domestic market and beyond.



Inputs to Innovation

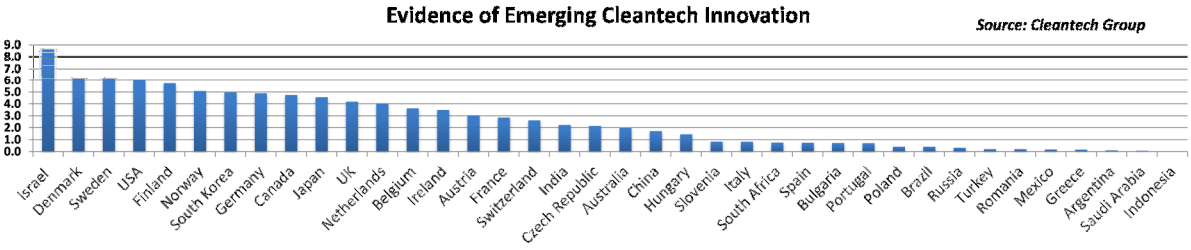
When comparing *general innovation drivers* and *cleantech-specific innovation drivers,* Russia and Saudi Arabia stand out as having low cleantech-specific drivers compared to general drivers of innovation. Serious engagement with cleantech may seem less urgent to these players, particularly given their positions as major fossil fuel producers. However, both stand to gain significantly from cleantech investment, especially Saudi Arabia, which has both water scarcity challenges and a natural environment highly conducive to solar generation.

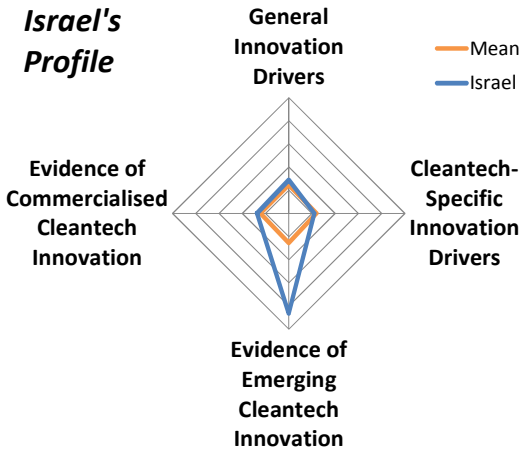
Conversely, India and China scored comparatively higher for cleantech-specific than general innovation drivers. This suggests that these emerging economies are leapfrogging the decades of broad innovation capacity building undertaken by more developed countries, to focus instead on the current opportunities presented by cleantech.

[20] US Energy Information Administration, *International Energy Statistics database*

C: Emerging cleantech innovation

The *evidence of emerging cleantech innovation* factor assesses the emergence and early-stage progress of cleantech innovations and entrepreneurial cleantech companies. This factor is made up of OECD records of environmental patents filed under the Patent Cooperation Treaty; Cleantech Group data on cleantech venture capital (VC); and records from the three annual *Global Cleantech 100* lists, 2009-11 (Cleantech Group's annual ranking of the top 100 private cleantech companies globally).

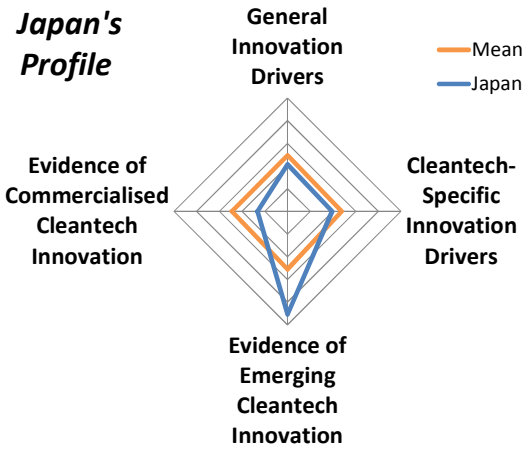




Israel is the clear winner in this factor, with by far the most Global Cleantech 100 companies per GDP and the second highest concentration of cleantech VC activity - around 0.03% GDP over the last two years. Israel also scored sixth for environmental technology patent filing, a key measure of emerging cleantech innovation. As well as playing host to a high concentration of cleantech start-up activity, Israel has also produced a disproportionate number of high-quality companies. A current example is TaKaDu, a water company that has combined an innovative technology and software as a service business model to address the huge problem of undetected leaks in water systems. Israel is especially strong in water innovation, driven by the serious water scarcity that affects the region and supported by Mekorot, the highly innovative water utility that regularly partners with local cleantech start-ups. More generally, Israeli cleantech companies benefit from the technical expertise coming from the country's strong defence sector. There exists a start-up culture that mirrors the 'start-up' quality of the 63 year-old nation itself. Despite Israel's general success in cleantech innovation, however, Israel's success in giving birth to cleantech companies is not matched by its performance on the *evidence of commercialised cleantech innovation* factor – the country places 14th. This is likely due to the limited domestic market in Israel as well as a scarcity of local expansion capital.

Japan has filed the largest number of environmental technology patents of any country considered, over 2800 in 2008, yet scores poorly for cleantech venture capital, and is yet to have a Global Cleantech 100 company. Its innovation has not translated into entrepreneurial cleantech start-ups. This can be attributed to Japan's innovation culture, dominated by large technology corporates such as Sony or Toshiba rather than start-up companies, and the lack of cleantech-specific early-stage private finance to help entrepreneurial companies demonstrate and scale their technologies. Though Japan is not producing many entrepreneurial cleantech focused start-ups, its large technology corporations are exerting an increasingly large impact on global cleantech innovation. A clear signal

of this was Toshiba's recent acquisition of Landis+Gyr, a leading Swiss smart metering company. The $2.3bn deal was Toshiba's biggest in five years[21] sending a strong statement of the company's intentions in the smart grid sector. Looking forward, Japan's energy politics have been transformed drastically by the Fukushima nuclear disaster. Japan's government has replaced its plan to build more nuclear power stations with a move towards a target for renewables to make up 20% of the country's energy mix by the 2020's.[22] Japan extended its existing feed-in tariff to include solar, wind, hydro, geothermal, and biomass electricity generation.



South Korea displays a similar, though less extreme, pattern as Japan, with the third most patents filed per GDP but a very moderate amount of venture activity and no Global Cleantech 100 companies. Ireland stands out as the only country with significant cleantech VC activity (on a relative basis) to have never had a company feature in the Global Cleantech 100. Though Ireland has the largest % of its population working in cleantech[23], a number of cleantech-focused corporates, and considerable cleantech private equity investment, its mediocre patent production suggests that the country is active in cleantech primarily at later stages of commercialisation. It is not bringing many technologies all the way from R&D to the market, and is thus not producing many high impact start-ups.

It is also interesting to note that the standard deviation of the *emerging cleantech innovation* factor was by far the highest of all the factors, showing that while many countries are putting their energies into promoting innovation and developing a cleantech economy, less are having real traction in the crucial phase of nurturing high impact technology start-ups.

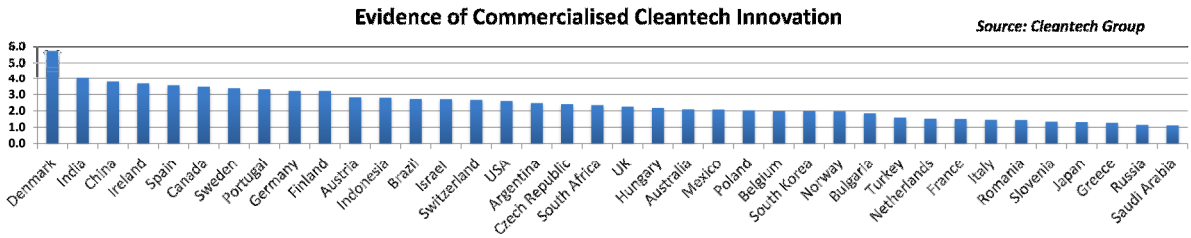
D: Commercialised cleantech innovation

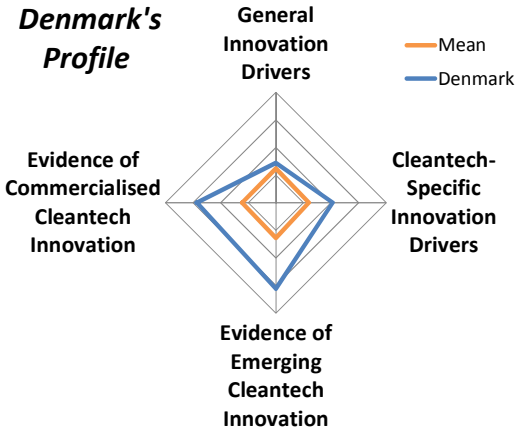
Evidence of commercialised cleantech innovation measures the ability of a country to scale-up innovations developed by cleantech start-ups. The increasingly global nature of the cleantech industry means that this is not necessarily a measure of where those innovations originated; however, a domestic market does help drive innovation and provide a test-bed where products and companies can develop before efforts begin to build an international customer base. This factor is derived from: cleantech manufacturing value-added as measured in the WWF and Roland Berger *Clean Economy, Living Planet* report; cleantech company revenues and employees data from the UK Department for Business Innovation & Skills *Low Carbon and Environmental Goods and Services*

[21] Bloomberg, *Toshiba to Buy Meter Maker Landis+Gyr for $2.3 Billion in Smart Grid Boost*, May 2011
[22] The Japan Times, *Kan sets 20% target for renewable energy*, May 2011
[23] UK Department for Business Innovation & Skills, *Low Carbon and Environmental Goods and Services*, 2011

report; renewable energy consumption data from the BP *Statistical Review of World Energy;* and *Cleantech Group* data on cleantech late-stage private investment, M&As and IPOs.

The *evidence of commercialised cleantech innovation* factor also represents the increasingly important role of corporate activity in the sector, as measured by the number of companies featured in the Cleantech Group's *Cleantech Index,* and in the *FTSE, Ardour* and *WilderHill* indices of publicly traded companies (selected for quality and cleantech or clean energy focus). 'Pure play' cleantech-focused companies retrospectively demonstrate that previous cleantech has been successfully commercialised in a country, while they also provide positive indications of future emerging innovation, as medium to large companies are increasingly proving to be a source of investments and partnerships for cleantech start-ups. Recent years have seen multinationals begin to engage with both sustainability and 'open innovation'[24], which together mean corporates are turning their attention and significant resources to sourcing innovation from entrepreneurial cleantech companies.





Denmark dominates the *evidence of commercialised cleantech innovation* factor by scoring well across the indicators, coming out on top for value-added in cleantech manufacturing, which represents a massive 3.14% of GDP for the country. The country's renewable energy consumption is strong, at 0.036 TWh/$bn GDP in 2010. In addition Denmark has a strong concentration of cleantech-focused corporates. Vestas, a major corporate player in the wind industry, is a significant contributor to Denmark's success in measures of commercialised cleantech. Vestas is a powerful example of a small innovative company that went on to commercialise and scale its technology: over the past few decades, the company has grown from a regional player into a multinational corporation selling over 5GW[25] of turbines annually. Denmark currently has an ambitious target of reducing greenhouse gas emissions by 40% by 2020 from 1990 levels[26] as well as one of the highest cleantech R&D budgets at around 0.4% GDP (2009). Support for cleantech R&D is matched by support for entrepreneurship in general, with streamlined patenting and company formation processes. Despite Denmark's success there is still room for improvement, especially

[24] 'Open innovation' describes a trend towards firms bringing in ideas from external as well as internal sources and monetising ideas through internal and external channels, challenging the conventional wisdom of internal R&D.
[25] Vestas.com
[26] Reuters, *Danish government aims to cut emissions by 40 percent by 2020*, October 2011

within the Danish venture capital market. While Danish cleantech venture capital has grown in recent years, it does not currently match Denmark's generally strong performance in the index, placing just 10th in this study's ranking. Similarly, while Denmark topped the table for commercialised innovation, this should not be assumed for the future, given the country's degree of focus on wind power and mediocre 3% cleantech manufacturing growth rate per annum between 2008-2010, compared to 77% growth for China and 28% growth for the US[27].

China scored well, albeit with a very different story, coming top for cleantech initial public offerings (63 IPOs in 2010 alone) and second for cleantech value-added from manufacturing at 1.42% of GDP. India is also a strong player, with the top score for revenues of low-carbon and environmental goods and services companies as well as number of cleantech private equity deals, indicating the presence of a number of later-stage cleantech companies perceived by investors to have strong growth potential. Canada was a winner on later-stage transactions, with the third highest concentration of private equity deals. The country also came out on top for cleantech mergers and acquisitions (M&As), driven by activity in the province of Ontario, which has made a strong play to become a cleantech hub. This pattern shows that Canada is building attractive mature cleantech companies, if not developing the most innovative technologies. Additionally, Japan's low position stands out, though this is less surprising given the focus of the factor on the commercialisation of cleantech start-up companies, which are relatively scarce in Japan.

Taking Emerging Cleantech to Commercialisation

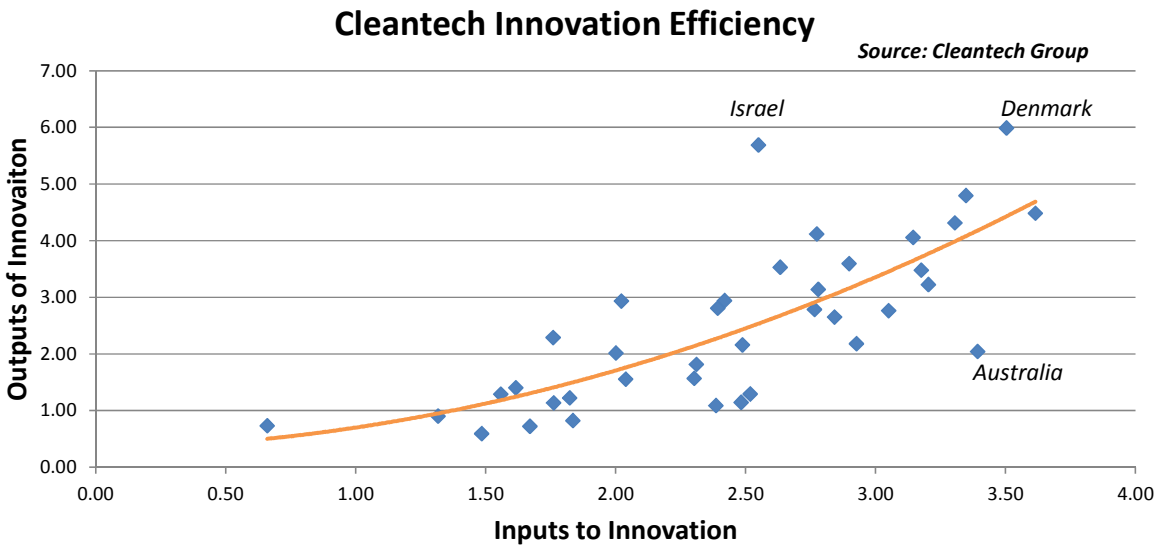
Much has been written on the 'demonstration gap', where innovations falter for lack of funding between initial venture capital and later need for private equity or project finance. A comparison of scores for *evidence of emerging cleantech innovation* and *evidence of commercialised cleantech innovation* suggests Norway, the Netherlands, and Israel are countries where this may be especially problematic. These countries score relatively low for commercialisation compared to emerging innovation, implying that companies are being created but are not being scaled-up effectively.

There are also a number of countries in the opposite camp, where there is much later stage cleantech activity but relatively little early stage innovation. Portugal, Spain, Canada, Ireland, India, and China fit into this category. However, the latter two stand apart as they also scored very highly for *cleantech-specific innovation drivers*, especially cleantech-specific venture capital and private equity funds raised. This suggests that while the first four will continue on their current paths, China and India can be expected to match their commercial clout with an emergence of innovative technology companies.

[27] WWF and Roland Berger, *Clean Economy, Living Planet*, 2009, 2011

Innovation Efficiency

When comparing aggregated scores for the *inputs to innovation* and *outputs of innovation* sub-indices, it can be seen from the graph below that greater inputs are related to greater outputs from the process of innovative company creation. This is an important finding in that it validates the general approach that many governments have taken to actively promote cleantech innovation. However this analysis also shows which countries are capitalising on their inputs most efficiently, with Israel far above the curve for transforming inputs into innovative cleantech companies, followed by Denmark. On the other hand Australia was the furthest below the curve, scoring relatively very low for *outputs of innovation* given the inputs, both general and cleantech-specific. Australia scored highly for inputs, well above Israel, but despite this managed to score significantly lower for outputs.



Finance

A theme running through the various factors of this study has been access to finance, whether from private or public sources. This is crucial, as no idea can progress from the drawing board, or these days from a CAD program, without financial backing. This report has taken a relative approach to scoring countries, taking into account GDP for most measures, however it is worth noting that in absolute terms the US dominates for cleantech finance. The US has the greatest public R&D budget (over US$2bn in 2009), the greatest number of investors, as well as the most venture capital, private equity, and M&A deals. When understanding this strong financing culture, especially in venture capital, it is often pointed out that the US stands out for being relatively comfortable with risk. This is in contrast to many other countries which have much innovation potential but are too risk averse for a strong culture of making financial gambles on start-ups with radical ideas, Japan being an extreme example of this case.

A notable exception to the dominance of the US in absolute terms is China's leadership for cleantech IPOs and amounts raised in cleantech-focused funds. More money has been raised in cleantech funds focused on China than in US equivalents (or any other country over the last two years), showing investors' recognition of the nation's cleantech potential. Growing access to funding is

supported by the recently established ChiNext stock exchange and the fact that in 2010 China saw over half of the global cleantech IPOs. This both means Chinese companies have access to growth capital to scale up, and is a good sign for future early-stage financing, as venture investors will see a strong IPO market as a source of domestic exits and so financial returns on Chinese companies.

Globally, 2008 saw a peak in fund-raising for cleantech investment. The wider economic crisis has impacted cleantech, and the number of active cleantech investors dropped for the first time in 2010. Despite this, cleantech VC investment recovered through 2010 and 2011, due in part to the increasing role of corporates, as the number of corporates actively engaging with cleantech innovation companies has increased every year since 2007. This means that in future we will need to look to the corporate, as well as the investor community, to understand the potential for innovative cleantech company growth.

Finally, the importance of consistency in financing should not be underestimated. Companies taking a technology through from development to commercialisation will face various 'valleys of death' in their funding journey, suggesting that consistency in access to finance is as important as the availability at any one stage of development. Lack of this consistency in financing may explain part of the discrepancy in performance of countries such as Israel, Norway, Sweden, and Finland, all of which have strong venture funding but have not been able scale up companies and hence scored much lower for commercialised innovation. As these are all small countries, lack of large domestic markets will also be an obstacle to later-stage company growth.

Concluding Remarks

The *cleantech countries innovation index* represents a first attempt at an important endeavour: measuring and mapping the emergence of innovative cleantech companies, one of the most important vehicles for the technology innovation needed to ensure a sustainable future for humanity.

The index demonstrates the true strides that have been made in cleantech innovation across the globe, as well as the variation in countries' progress. There are countries that have successfully wrestled with the challenges of fostering cleantech innovation, and countries that have barely begun the process. The index also demonstrates the variability of profiles that have taken countries to the top of the ranking, showing that no one country has the perfect recipe, and that various approaches can work for countries looking to identify pioneers to emulate.

This global mosaic of strengths has caused the cleantech world to be permeated with international partnerships. Leading solar producer Suntech Power demonstrates this, with Australian solar technology being commercialised to scale in China for sales in Germany and Spain, funded through a New York listing. India-based wind turbine producer Suzlon Energy has a similarly international footprint, with products sold to global markets, manufactured in India, China, and the US and based on R&D from Belgium, Denmark, Germany, India, and the Netherlands.

There are countless more examples of the private sector understanding the need for cooperation to solve the technological challenges of the 21st century, with the recent rise of open innovation in multinationals around the world. Governments must follow this lead and do the same, engaging with collective innovation challenges collectively. The current inwardly-focused mindset of *energy*

security needs to be replaced with one of *climate security,* to avoid a race to the bottom on emissions standards and foster greater R&D collaboration on key solutions that bring together technological development from different sectors. Many of the necessary solutions exist in a range of different sectors, and effective technology transfer is needed, as much as novel innovation in cleantech.

While climate change policies are key drivers for cleantech innovation, the two are not always one and the same, as the case of Canada demonstrates. Canada scores well on development and production of new sustainable technologies, innovations crucial to global emissions reductions, yet performs poorly on current national mitigation efforts.

Global climate and energy challenges will require complex, multi-faceted solutions, and we hope we have successfully argued the case for the role of innovative cleantech start-ups in bringing about a gradual, market-based sustainability revolution.

We also hope to have provided a tool to help countries above and below the curve understand their position and work towards building the transformative enterprises of the future.

Appendix A: Indicator Details

General innovation drivers

Indicator	Source	Date	Definition	Weight
General innovation inputs	INSEAD Global Innovation Index	2011	Insitutions, human capital, infrastructure, market sophistication and business sophistication facilitating innovation	50%
Entrepreneurial culture	Global Entrepreneurship Monitor	2010	Positive attitudes towards entrepreurship and percentage of population aged 18 - 64 who currently own or are setting up a new business	50%

Cleantech-focused innovation drivers

Indicator	Source	Date	Definition	Weight
Cleantech-friendly government policies	The Pew Charitable Trusts *Clean Energy Race* Report and Cleantech Group research	2010 - 2011	Government policies supporting clean energy including tax incentives, feed-in tariffs, renewable energy mandates and others	25%
Government R&D expenditure in cleantech sectors	International Energy Authority *Global Gaps in Clean Energy RD&D* report and energy R&D database	2010	Total budget for cleantech R&D as a proportion of GDP	25%
Access to private finance for cleantech start-ups	Cleantech Group data	2008 - 2011	Number of cleantech investors and cleantech-focused funds recently raised weighted by GDP	25%
Country-attractiveness of Renewable Energy Infrastructure	Ernst & Young *Renewable Energy Country Attractiveness Index*	2011	National renewable energy markets, renewable energy infrastructures and their suitability for wind, solar, biomass and other renewable energy technologies	20%
Cleantech cluster programs & initiatives	Cleantech Group research	2011	Number of industry associations, physical clusters and economic initiatives supporting the cleantech industry as a proportion of GDP	5%

Evidence of emerging cleantech Innovation

Indicator	Source	Date	Definition	Weight
Patents in cleantech sectors	OECD database	2008	Environment-related technology patents filed under the Patent Cooperation Treaty weighted by GDP	45%
Early-stage private investment	Cleantech Group data	2009 - 2011	Amount of venture capital invested in cleantech companies as a proportion of GDP	45%
High impact cleantech start-ups	Cleantech Group data	2009 - 2011	Number of companies included in the Global Cleantech 100 weighted by GDP	10%

Evidence of commericalised cleantech innovation

Indicator	Source	Date	Definition	Weight
Revenue of cleantech companies	WWF/Roland Berger Clean Energy, Living Planet and UK Department for Business Innovation & Skills, Low Carbon and Environmental Goods and Services reports	2009 - 2010	Value-added from cleantech manufacturing as a proportion of GDP and revenue of Low Carbon and Environmental Goods and Services companies as a proportion of GDP	50%
Renewable energy consumption	BP Statistical Review of World Energy	2010	Renewable energy consuption weighted by GDP	20%
Late-stage private investment and exits	Cleantech Group data	2009 - 2011	Number of cleantech private equity deals M&As, and IPOs weighted by GDP	15%
Successful public cleantech companies	Cleantech Group, FTSE, Ardour and WilderHill indexes of public cleantech companies	2011	Number of listed cleantech focused corporates weighted by GDP	10%
Employees in cleantech	UK Department for Business Innovation & Skills, Low Carbon and Environmental Goods and Services report	2009 - 2010	Percentage of population employed in cleantech SMEs	5%

Appendix B: Country Profiles

Argentina

Argentina excels in entrepreneurial activities and attitudes, but not in general innovation inputs. The country has strong government policies but little public cleantech R&D and access to private finance. Low scores on all emerging cleantech innovation indicators result in a score well below average. Argentina has a mix of indicator scores on commercialised cleantech innovation, with relatively strong cleantech company revenues but a lack of public cleantech companies and later-stage deals. Argentina bests neighbours Brazil and Mexico on all but the commercialised innovation indicator, indicating potential for Argentina to be a leader in the region.

Australia

Australia scores very well on both general and cleantech drivers, but ranks lower on emerging and commercialised cleantech innovation. The country's performance on innovation drivers was built on strong general innovation inputs, a reasonably entrepreneurial culture and strong public R&D spending. While Australia has seen a number of later-stage cleantech transactions, the country's commercialised cleantech innovation score is held back by low renewable energy consumption and cleantech company revenues, and by low density of public cleantech companies.

Austria

Austria has largely average scores in all factors. Strong general innovation inputs were tempered by a lack of entrepreneurial culture. Austria has solid government policies but lacks an infrastructure attractive for renewables, scoring slightly below average on cleantech-specific innovation drivers. The country produces a good number of environmental patents and has a high density of public cleantech companies yet has relatively weak cleantech company revenues. Austria falls in line with fellow European countries such as France but falls behind northern European neighbours, such as Germany.

Belgium

Belgium scores above average for emerging cleantech innovation, but otherwise does not stand out. Mediocre entrepreneurial culture pulls down the country's general innovation drivers score. As with cleantech-specific innovation drivers, good public R&D spending is in the country is counter balanced by small amounts raised in funds focused on the country. Belgium has seen a strong amount of cleantech VC activity in recent years, along with a number of M&As, however has relatively weak cleantech company revenues. Belgium sits in a similar position to Austria and France, behind Northern Europe, the US, and Asian leaders.

Brazil

Brazil has roughly average innovation drivers and commercialised cleantech innovation scores, though falls behind on emerging cleantech innovation. The country has a very strong entrepreneurial culture but lacks general innovation inputs, public R&D spending, and cleantech-focused investors. Brazil has a respectable score for commercialised cleantech innovation, primarily due to its established biofuels industry. Despite that, low VC investment and few new environmental patents contribute to a low emerging cleantech innovation score. Brazil and Argentina lead South and Central America for cleantech innovation.

Bulgaria

Bulgaria rates fairly low on all four factors, with a particularly weak emerging innovation score. Bulgaria stands out for having very few cleantech investors, VC investments, or later-stage deals. However, the country has an average consumption of renewable energy and proportion of its population working in environmental businesses. The country tops neighbours Romania, Greece, and Turkey in the overall index, though it falls short of higher ranked southern European countries such as Spain, Italy, and Portugal.

Canada

Canada scores in the top 10 for both general innovation drivers and commercialised cleantech innovation, but falls below average on cleantech-specific drivers. The country has very strong general innovation inputs but lacks strong government policies as well as public R&D funding in support of cleantech innovation. The country has seen strong VC investment, along with a good number of private equity and M&A deals, coupled with good density of public cleantech companies. On the downside, the country's commercialised cleantech score is held back by below average renewable energy consumption. Canada scores below its immediate neighbour the US.

China

China has average general innovation drivers and a strong entrepreneurial culture but low scores for general innovation inputs. This contrasts with the country's above-average cleantech-specific drivers due to top scores for attractiveness of infrastructure for renewables and amounts raised in cleantech funds. Despite this, currently limited numbers of early stage high-impact cleantech start-ups for the size of the economy and a low number of environmental patents kept the country's emerging cleantech innovation score below average. In contrast, China scored well on commercialised cleantech with the most cleantech IPOs as well as strong cleantech company revenues.

Czech Republic

The Czech Republic has very low public cleantech R&D spending, an unattractive infrastructure for renewables and general lack of a local cleantech investment community. Despite this, the Czech Republic sees average VC activity, though does not produce environmental patents in great number. The country scores average for commercialised cleantech, yet has not seen an IPO or significant public cleantech company activity in recent years. The Czech Republic stands out from its European neighbours for its weak cleantech-specific innovation drivers score. Overall, the country ranks poorly against neighbours Germany and Austria, though it comes ahead of Poland and just behind Hungary.

Denmark

Denmark places first on the overall index, despite a quite average score for general innovation drivers. The country has excellent general innovation inputs, though shows less in the way of entrepreneurial culture. Denmark's top score for cleantech drivers is primarily founded on strong government policy and public R&D spending. It has a number of high-impact cleantech start-ups, and is strong in VC investment and environmental patents. Its top score for commercialised cleantech was based on top revenues from cleantech manufacturing, and density of public cleantech companies. This was supported by strong M&A deals and renewable energy consumption.

Finland

Finland stands out with its fourth place finish on the overall index. The country scores second on both general and cleantech innovation drivers. It has very strong general innovation inputs and the top score for public R&D, though its government policy score is slightly below average. Finland's emerging cleantech innovation score is also quite high, due to considerable VC funding and many new environmental patents. Despite its high emerging cleantech innovation score, Finland is not as successful in commercialising cleantech innovation. The country has seen few M&As and IPOs, though it has strong renewable energy consumption. Finland scores below neighbours Sweden and Denmark but above Norway.

France

France ranks averagely on the overall index but scores well on cleantech innovation drivers. This high score is due to strong government policies and attractive infrastructure for renewables. France's other scores are unimpressive, with its average general innovation drivers score pulled down by a lack of entrepreneurial culture. The country fell below average for commercialised cleantech due to weak cleantech company revenues and a low density of public cleantech countries. France has fallen behind larger European neighbours Germany and the UK, with a closer score to smaller European countries such as Belgium and Austria.

Germany

Germany has strong scores on all factors except general innovation drivers, where it is slightly above average. The country has strong general innovation inputs but this is not matched by entrepreneurial culture. Given the size of the economy, Germany has seen relatively little money raised in cleantech-focused funds. However, the country has the strongest government policies in support of cleantech and an attractive infrastructure for renewables. Germany has produced the second highest number of environmental patents per GDP. The country has strong cleantech manufacturing and good density of public companies while high renewable energy consumption provides a strong domestic market. Germany is the top scoring country in Europe outside of Scandinavia.

Greece

Greece's scores low on the overall index and particularly badly on the emerging cleantech innovation factor. The country lacks both general innovation inputs and entrepreneurial culture. Moderately supportive cleantech government policies fail to offset very low public R&D funding and a lack of access to private finance, resulting in a low cleantech innovation drivers score. Few environmental patents and mediocre VC investment mean a low emerging cleantech innovation score. Finally, it has weak cleantech company revenues and has seen few later-stage deals, leading to a low commercialised cleantech innovation score. Greece is the lowest ranking EU country.

Hungary

Hungary scores just below average for all factors except emerging cleantech innovation, where it ranks lower. The country lacks: strong general innovation inputs; public cleantech R&D funding; and local cleantech investors. However Hungary does have relatively strong government policies. While it produces some environmental patents, they are not backed by venture investment from the private sector. In commercialised cleantech, the country has reasonable renewable energy consumption, but lacks later-stage cleantech deals and public cleantech companies. Hungary scores behind most Central European countries, but comes top in Eastern Europe and above neighbours Romania, Bulgaria, and Slovenia.

India

India has weak general innovation inputs but a very strong entrepreneurial culture, leading to an average general innovation drivers score. This contrasts with its high score in cleantech-specific innovation drivers, based on the country's attractive infrastructure for renewables and the large amount raised in cleantech funds. However India still has below-average public R&D spending on cleantech. A relatively small number of environmental patents and reasonable VC activity resulted in an average emerging cleantech innovation score. The country performs much better on commercialised cleantech, with strong revenue from cleantech companies, and the highest density of private equity deals (though the country still lacks public cleantech companies).

Indonesia

Indonesia shows mediocre performance in the overall index with the lowest emerging innovation score. The country has the lowest general innovation inputs but has a strong entrepreneurial culture. Government policy is lacking, along with local cleantech investors. The country scored very low for all emerging cleantech indicators, with little evidence of VC activity, high impact start-ups, or patents. However, Indonesia has strong revenue from environmental companies and high renewable energy consumption. Despite this, the country lacks later-stage cleantech deals.

Ireland

Ireland scores especially well on general innovation drivers and commercialised cleantech innovation, but falls below average on cleantech-specific innovation drivers. Ireland has very strong general innovation inputs, yet lacks public R&D spending, and has only average scores for supportive government policies and access to private finance. Ireland stands out less for emerging cleantech innovation due to its low output of environmental patents and lack of high impact cleantech start-ups. In contrast, the country scores well for commercialised cleantech innovation, with a large percentage of the population working in cleantech, and good numbers for private equity and M&A deals. Ireland falls just ahead of the neighbouring UK.

Israel

Israel places second on the overall index, primarily due to its very high score for evidence of emerging cleantech innovation. The country lacks cleantech supportive government policy, yet has a strong number of local cleantech investors (if not a large amount raised in cleantech funds). Israel's high emerging cleantech innovation score is based on strong VC activity, the greatest density of high-impact cleantech start-ups, and a good score for environmental patents. However, low renewable energy consumption and a dearth of cleantech IPOs hold back the country's commercialised cleantech innovation score.

Italy

Italy has above average cleantech-specific innovation drivers but lags on the other factors. The country has poor general innovation inputs and entrepreneurial culture, along with a lack of access to private finance. However Italy has a number of cleantech-friendly government policies, and an infrastructure attractive to renewables, resulting in an above average score on cleantech innovation drivers. The country has seen little VC activity and produced few environmental patents, leading to a low score for emerging cleantech innovation. Finally, Italy scored poorly on commercialised cleantech innovation due to having low renewable energy consumption, few public cleantech

companies, and poor cleantech company revenues. The country scores low for Europe - above southern European neighbour Greece yet below Spain.

Japan

Japan scored below average on all factors except emerging cleantech innovation. The country topped the list for environmental patents, in both relative and absolute terms, leading to its above average score on emerging cleantech innovation. However this emerging innovation is not taken to market by technology start-ups, as the country scores very low for VC activity and for high-impact cleantech start-ups. This is unsurprising given the country's high score for general innovation inputs but very low score for entrepreneurial culture. Japan also has very few cleantech focused investors and low renewable energy consumption. Japan scores in the middle of the list, below both China and South Korea.

Mexico

Mexico balances poor general innovation inputs with a strong entrepreneurial culture. Start-ups in the country do not have good access to private finance or local cleantech investors. The country scored especially low for emerging cleantech innovation, with little VC investment and few environmental patents. The country also lacks: renewable energy consumption, later-stage deals, IPOs, and public cleantech companies. Mexico scores below Canada and the US to the north, as well as Argentina and Brazil to the south. However, the Mexican entrepreneurship culture in combination with relatively ambitious climate targets for 2020 and 2050 provides an interesting platform for changing this.

Netherlands

The Netherlands has strong general innovation drivers and emerging cleantech innovation, but falls behind on commercialised cleantech innovation. The country has strong general innovation inputs and entrepreneurial culture. Netherland's cleantech innovation drivers' score is slightly below average, with mediocre public R&D spending, though the country has a good number of local investors. Many environmental patents, a number of high impact start-ups and VC activity mean the country scores well for emerging cleantech innovation. However a lack of late-stage deals (with the exception of M&As) and low cleantech company revenues mean the Netherlands scores lower for commercialised cleantech.

Norway

Norway scores well for emerging cleantech innovation, but falls below average on cleantech-specific innovation drivers and commercialised cleantech innovation. Norway has strong general innovation inputs, as well as above average entrepreneurial culture. The country lacks cleantech friendly government policies but provides solid public funding for cleantech R&D. Norway sees strong VC investment and M&A numbers, but this in not matched in private equity deals or IPOs. The country has high renewable electricity consumption and a high density of public cleantech companies. Norway scores well on the list, but falls below its Scandinavian neighbours Denmark, Sweden and Finland.

Poland

Poland scores very low on all four factors in the cleantech innovation index. The country lacks innovation drivers, has poor general innovation inputs, limited access to private finance and few

supportive government policies. The country has seen very little VC investment and has produced few environmental patents. On the bright side Polish cleantech companies have moderately strong revenues, and the country has seen a number of M&As, if not private equity deals or IPOs. Poland sits low in the list, with neighbouring Eastern European countries both above and below. Poland also neighbours high-ranking Germany which provides opportunities for collaboration in this field.

Portugal

Portugal scores well for commercialised cleantech innovation, though comes below average on the other factors. The country's lacks: general innovation inputs, an entrepreneurial culture, public R&D spending, and access to private finance, resulting in low scores on both general and cleantech-specific innovation drivers. The country has generated a small number of: environmental patents, VC investments, and high-impact cleantech start-ups. However, Portugal scored higher than average for commercialised cleantech innovation, enjoys strong renewable energy consumption, and has a density of public cleantech companies. Portugal scores above Italy but below Spain.

Romania

Romania received an average score for cleantech-specific innovation drivers, though it had well below average scores on all other factors. The country lacks: general innovation inputs, an entrepreneurial culture, and a local cleantech investment community. There is little emerging cleantech innovation, as seen by very low scores for VC activity, environmental patents, and high-impact start-ups. The country's commercialised cleantech score was held back by low renewable energy consumption, few IPOs, and low density of public cleantech companies scores. On the other hand, Romania has seen average numbers of private equity and M&A deals.

Russia

Russia takes the bottom spot on the overall index. The country has poor general innovation inputs and entrepreneurial culture. Russia's score was very low on all cleantech-specific innovation driver indicators with the exception of public R&D funding, where the country scored moderately below average. Russia's record on government policy and availability of cleantech-focused private finance is especially poor. Russia has little evidence of emerging cleantech innovation in either environmental patents or venture-backed companies. The country has a similar dearth of later-stage deals, public cleantech companies, and renewable energy consumption.

Saudi Arabia

Saudi Arabia has slightly above average general innovation drivers but scores very poorly on all other factors, coming second to last on the overall list. The country has a strong entrepreneurial culture but falls behind on all other measures of innovation drivers, especially cleantech-friendly government policy and number of local cleantech investors. Saudi Arabia has seen very little cleantech investment activity, early or late stage, especially given the wealth present in the nation. Additionally, the country scores on the bottom for renewable energy consumption. Saudi Arabia scores above only Russia, and far below Israel, the only other Middle Eastern country in the list.

Slovenia

Slovenia has average scores for cleantech-specific and general innovation drivers, but below for emerging and commercialised cleantech innovation. The country has moderately supportive government policy and access to private finance, but lacks local cleantech investors. Slovenia has

seen very little cleantech VC activity. This lack of cleantech transactions is also seen at later stages, with few IPOs, private equity, or M&A deals. Despite its weak emerging and commercialised cleantech innovation scores, Slovenia comes above Eastern European neighbours Bulgaria and Romania, but below Hungary.

South Africa

South Africa has average scores for general innovation drivers and commercialised cleantech innovation, but falls down the list due to its scores on cleantech-specific innovation drivers and emerging cleantech innovation. The country lacks general innovation inputs but has a strong entrepreneurial culture. The country has seen an average amount raised in cleantech-focused funds, but lacks cleantech-friendly government policies and local cleantech investors. South Africa lacks evidence of emerging cleantech innovation in the form of VC activity or environmental patents. There is a similar pattern in later stage deals, along with low renewable energy consumption. South Africa is the only African country in the list and has a unique role to play in the region also within cleantech. The country has an opportunity to push forward its position through its strong entrepreneurial culture in combination with ambitious long-term climate ambitions and "carbon budgets" for sectors coming out of the National Climate Change Response process.

South Korea

South Korea takes the last spot in the top 10, with strong cleantech-specific innovation drivers and emerging cleantech innovation scores, but a below average commercialised cleantech score. The country has strong general innovation inputs and an average entrepreneurial culture. Strong government policies and public R&D funding is countered by weaker access to private finance. The country's strong emerging cleantech innovation score is based on a very strong output of environmental patents, along with moderate VC activity. However, this performance is not matched in commercialised cleantech, with little renewable energy consumption or later stage deals. South Korea has the highest score in Asia, above both China and Japan.

Spain

Spain scores well on cleantech-specific innovation drivers and commercialised cleantech innovation but scores poorly on general innovation drivers and emerging cleantech innovation. The country lacks: a strong entrepreneurial culture, public R&D spending, and access to private finance, though Spain does have strong cleantech-friendly government policy. A dearth of VC investment and environmental patents holds back its emerging cleantech innovation score. However the country scores well on commercialised cleantech, with strong revenues from cleantech companies, good renewable energy consumption and a density of public cleantech companies. Spain is the highest-ranking Southern European country in the list.

Sweden

Sweden ranks third in the overall index, scoring well in all factors. The country has especially strong general innovation inputs, good public R&D funding, and a large number of cleantech investors. The country has much evidence of emerging cleantech innovation, producing many environmental patents, seeing strong VC activity, and being home to a number of high-impact cleantech start-ups. In commercialised cleantech, Sweden has high scores for renewable energy consumption, later-stage deals, and a good density of public cleantech companies. However the country has below average cleantech company revenues. Sweden scores above Scandinavian neighbours Finland and Norway, but below Denmark.

Switzerland

Switzerland's score is average on all factors except general innovation drivers, where the country is stronger than average. The country is ranked highest for general innovation inputs, though this is tempered by its weaker entrepreneurial culture. Switzerland's emerging cleantech innovation score is helped by strong environmental patent output. While the country only has average VC activity, it does see more later-stage deals, with private equity, M&A, and IPOs all above average. However the country's commercialised cleantech score is held back by low renewable energy consumption. Switzerland scores slightly above neighbours Austria and France, but below Germany.

Turkey

Turkey scores low on all factors, ranking third from the bottom of the overall index. The country has poor general innovation inputs, though its entrepreneurial culture is solid. Turkey has few government policies supporting cleantech, very little public R&D spending, and lacks access to private finance. Similarly, the country has seen little VC activity, produced few environmental patents, and shows little evidence of commercialised cleantech innovation across all indicators. The country ranks just below neighbour Greece and lands above only Saudi Arabia and Russia.

UK

The UK scored well in all factors, with the exception of commercialised cleantech, where it is less strong. While not having an especially strong entrepreneurial culture, Britain has good general innovation inputs. Good access to private finance, a strong local investor community, and an infrastructure attractive to renewables all boost the UK's cleantech-specific innovation drivers score. However the country fell below average on public R&D spending. Strong VC investment and a number of high-impact cleantech start-ups showed there is evidence of emerging cleantech innovation. However the UK performed less well on commercialised cleantech innovation due to low renewable energy consumption and cleantech company revenues. It has seen strong numbers of private equity and M&A deals. The UK scores well overall, but falls behind many other Northern European countries such as Germany, Denmark, Sweden, and Finland.

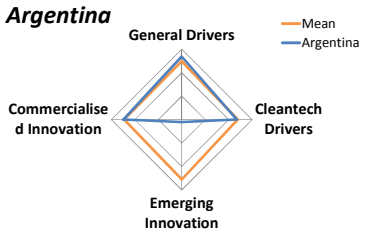
US

The US places fifth on the overall index, with the top score for general innovation drivers and strong emerging cleantech innovation. The US combines strong general innovation inputs with a strong entrepreneurial culture. The US has good public R&D spending and access to private finance, but lacks strong government policies in support of cleantech. It tops the list for VC investment, has strong M&A activity, and a high density of public cleantech companies. However the US lacks both strong renewable energy consumption and cleantech company revenues. The US is the highest scoring country outside of Europe and Israel.

Profile charts

(Factor names abbreviated)

Argentina



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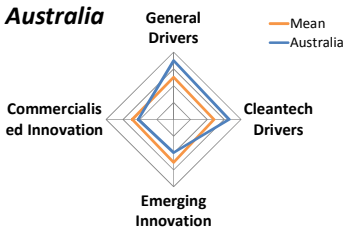

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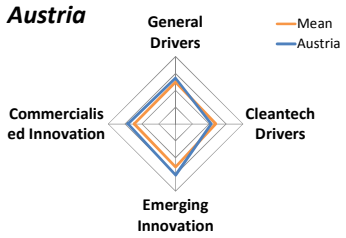

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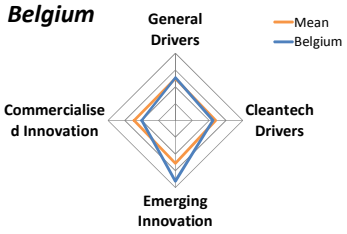

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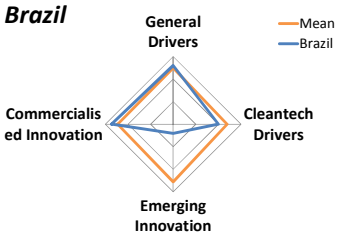

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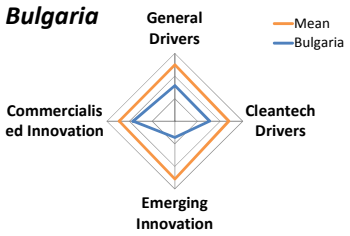

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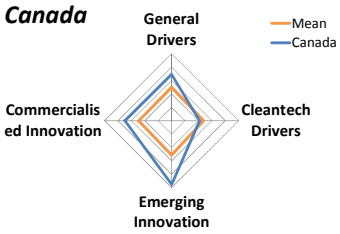
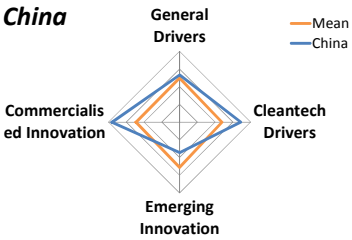


China



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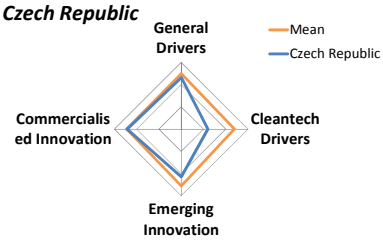

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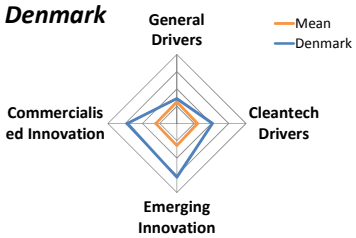

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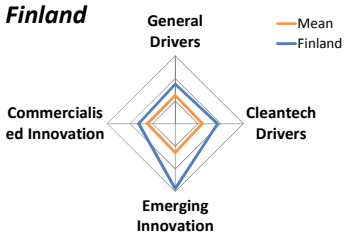

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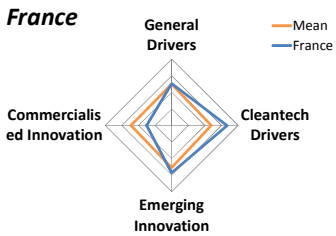

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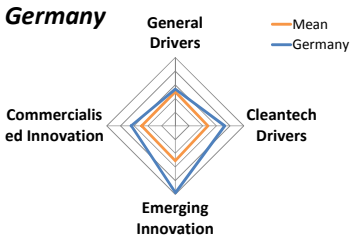

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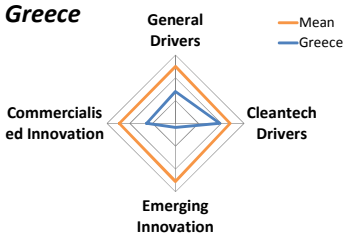

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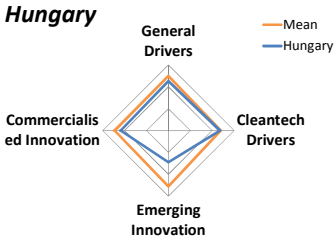

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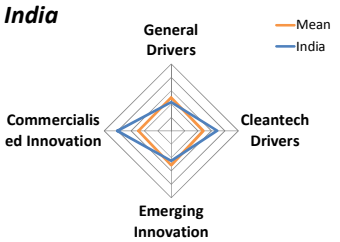

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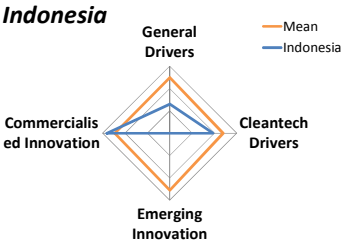

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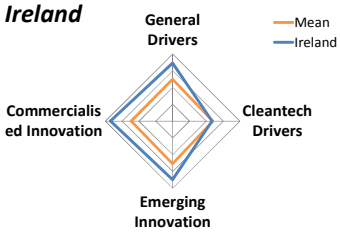

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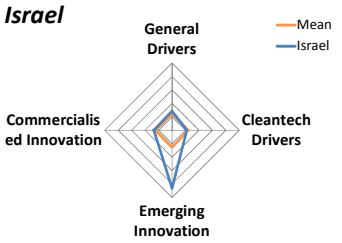

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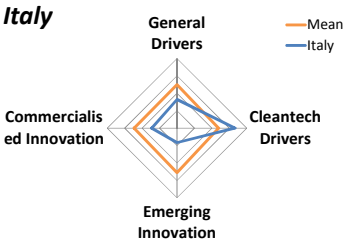

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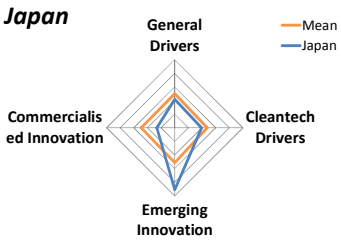
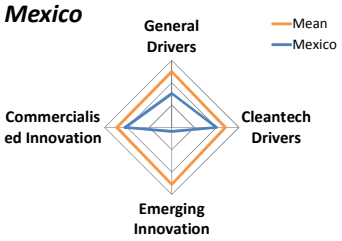


Mexico



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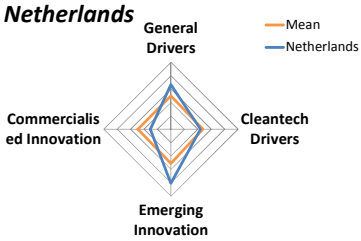

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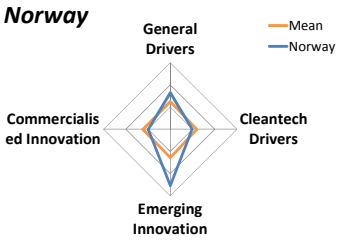

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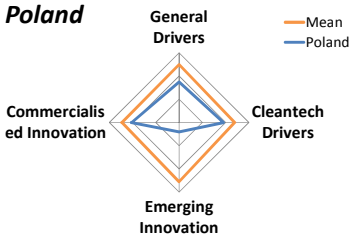
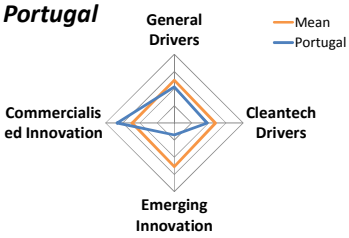
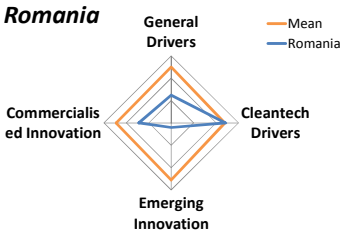


Portugal



Romania



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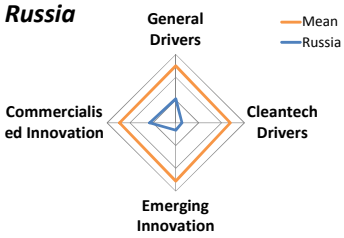

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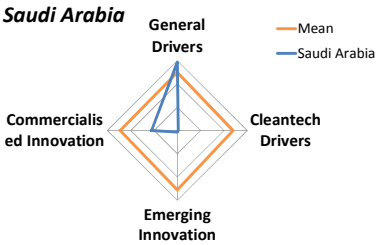

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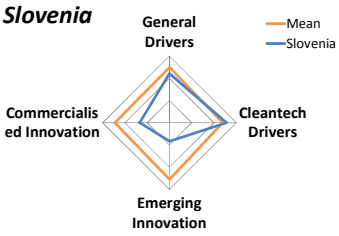

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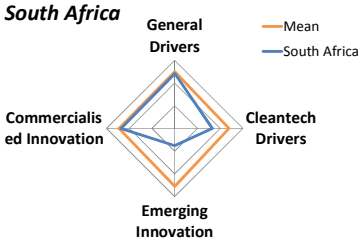

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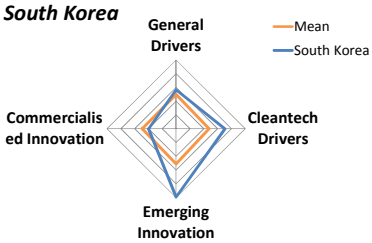

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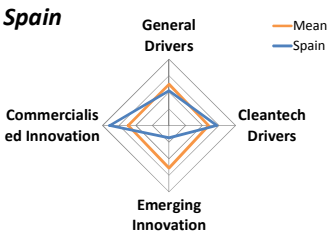
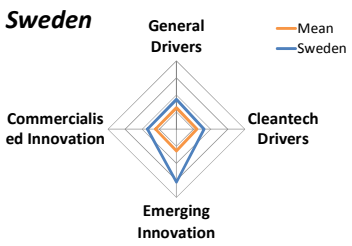
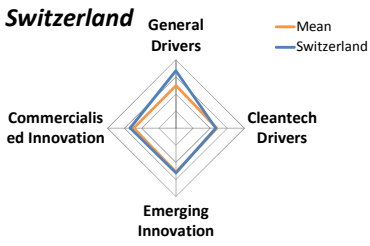



Sweden
General Drivers
Cleantech Drivers
Emerging Innovation
Commercialised Innovation
Mean
Sweden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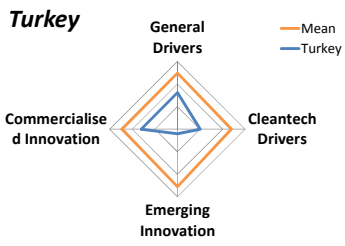
Emerging Innovation
Commercialised Innovation
Mean
Switzerland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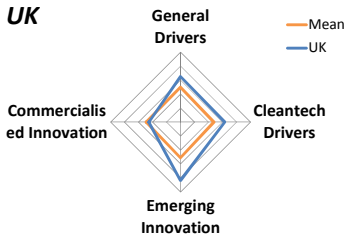
Cleantech Drivers
Emerging Innovation
Commercialised Innovation
Mean
Turkey


UK
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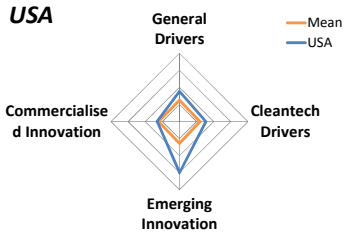
Cleantech Drivers
Emerging Innovation
Commercialised Innovation
Mean
UK


USA
General Drivers
Cleantech Drivers
Emerging Innovation
Commercialised Innovation
Mean
USA