# The Effectiveness of Energy Innovation Systems


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Policymakers are seeking a transformation of the energy system driven by concerns about climate change, energy security and energy costs. At the same time, developments in underpinning science and engineering, for example in materials science, the biosciences and information and communication technologies are opening up new possibilities across the energy technology spectrum. The combination of new opportunities and policy needs is driving a renaissance in energy innovation, with substantial increases in both public and private R&D efforts.

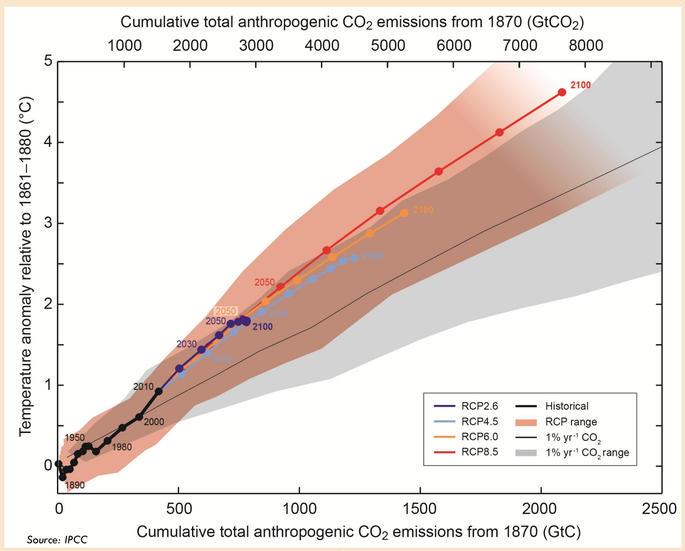

The ***objectives*** of the research are to:

- ***map out*** systems of energy innovation for a range of countries and technologies
- ***measure*** the effectiveness of different arrangements by analysing suitable indicators
- ***compare*** different approaches with a view to learning lessons for successful energy research and innovation policy…..
  …remembering that innovation systems cross national boundaries

We will do this through:

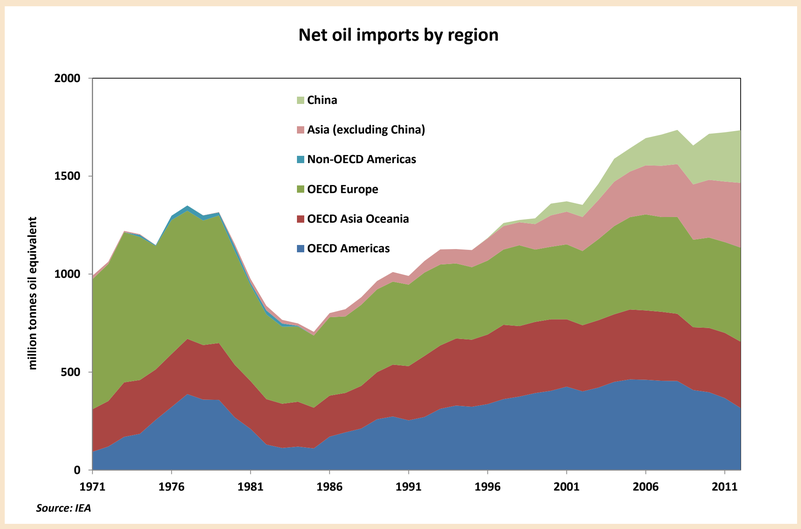
- documentary analysis and interviews with relevant experts and officials
- the development, collection and analysis of innovation indicators covering all parts of the energy innovation system
- testing hypotheses and findings against the views of experts inside and outside the countries concerned

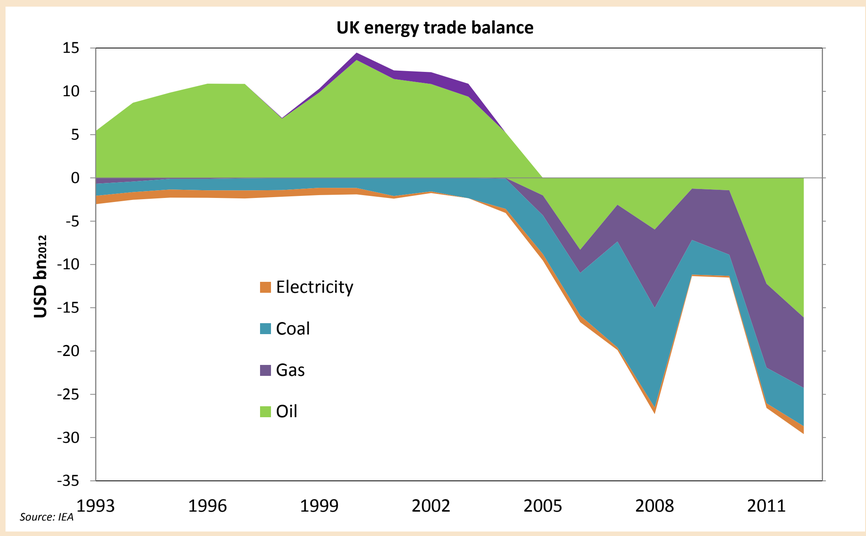
## Energy drivers: security, costs and sustainability




Capping global temperatures implies a ***global budget for $CO_2$ emissions.*** The Intergovernmental Panel on Climate Change (IPCC) concluded in its Fifth Assessment Report that global emissions would be 40% to 70% lower in 2050 than in 2010 in scenarios consistent with meeting the 2 degrees C target agreed under the Climate Convention. This would require a wholesale transformation of the global energy system and a major up-scaling of low-carbon energy supply.

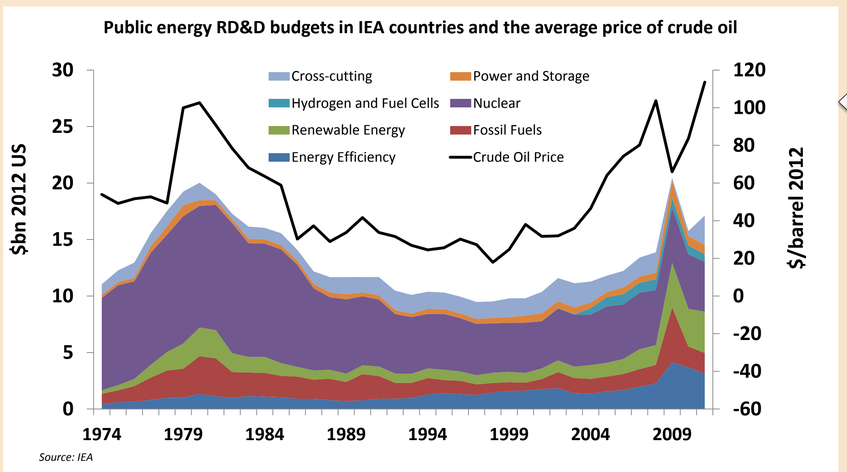
***Dependency on energy imports*** has been rising in many part of the world having fallen sharply in the 1970s and 1980s. Dependence on oil is particularly acute but trade in natural gas is also rising. These trends, coupled with high and volatile prices, are seen to pose both security and economic risks in importing countries.



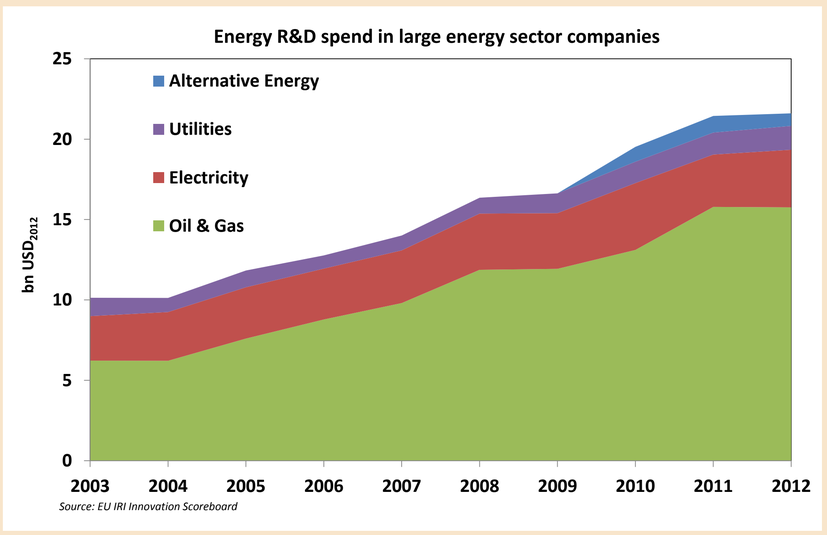




The ***UK's balance of trade in energy*** has moved sharply since North Sea oil and gas went into decline. Import costs represent a significant fraction of GDP and there is now greater exposure to volatile global energy markets. Reducing energy demand and developing indigenous resources, including renewables and unconventional oil and gas onshore, can help to manage this challenge.

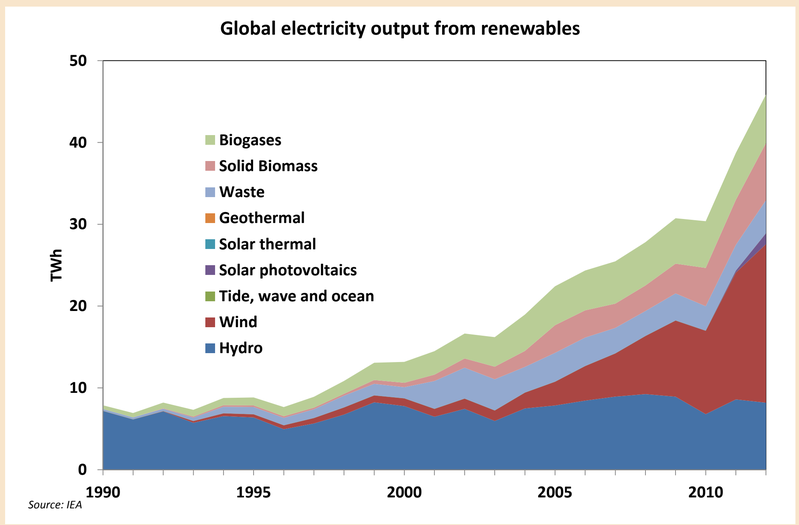
## The resurgence of energy innovation




***Public sector energy RD&D budgets*** have roughly doubled in the US and Europe since 2000, in spite of the financial crisis. Budgets for renewables, energy efficiency, hydrogen, fuel cell and energy storage technologies have all increased. The correlation between crude oil prices and RD&D budgets is striking, but any link is indirect. The broad goals of public sector RD&D appear to be to transform the current energy system and promote low-carbon technologies.

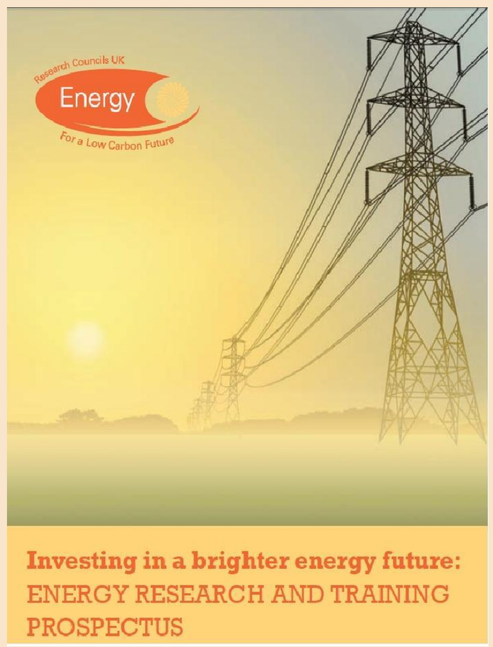



***Investment in R&D in major companies*** operating in the energy sector has doubled in the past decade. Most of the increase has been in the oil and gas sector. Compared to the public sector, there has been little investment in alternative energy R&D. One interpretation is that private sector R&D broadly reinforces the existing energy paradigm by extending the fossil fuel resource base and reducing the costs of utilising existing sources.




The global output of ***electricity from renewable sources*** has grown by an order of magnitude since 1990, with most of the increase in the last decade. The biggest absolute increase has come from wind energy with capacity growing from 48 GW in 2004 to 318 GW in 2012. Solar PV capacity has grown most rapidly, from 3.9GW in 2004 to 102 GW in 2012, an average annual increase of 50%.

The Energy Strategy Fellowship team previously conducted an independent review of energy research and training needs for the Research Councils. The ***Energy Research and Training Prospectus*** was published in November 2013. The current project builds on the Prospectus and is intended to provide further insights to inform UK energy innovation policies.

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# The Effectiveness of Energy Innovation Systems – Case Studies


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The case studies cover a range of contrasting technologies and national circumstances. The chosen technologies are at different levels of maturity, ranging from modular products through to site-assembled installations and even entire energy systems. The country case studies cover three continents and include the world's largest investors in energy R&D. They also include smaller countries that have become global leaders in specific technologies.

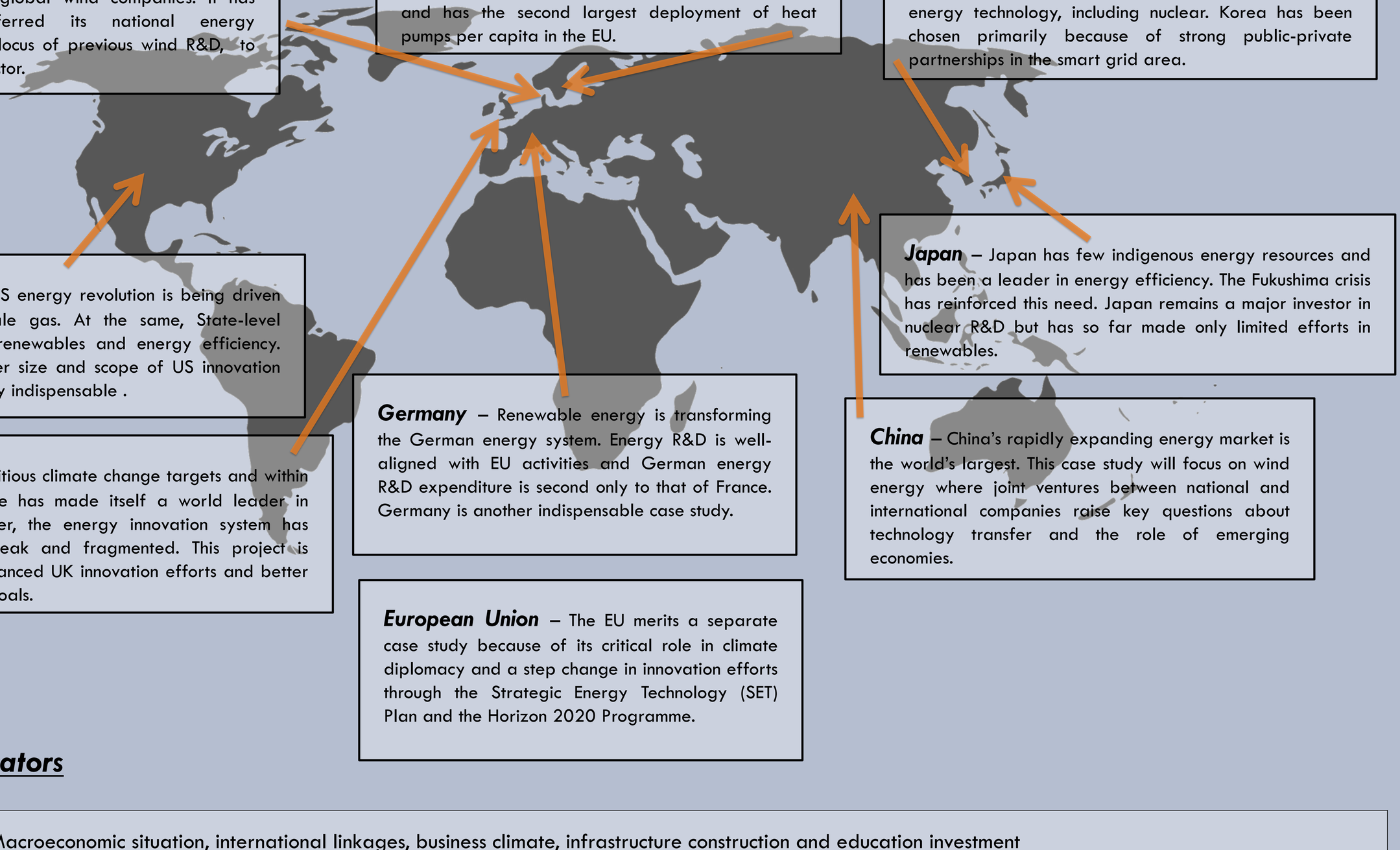
***Unconventional Gas*** – Shale gas production has expanded rapidly in the United States, enabled by a cluster of innovations. The pace has largely been set by the private sector and, unlike the other case studies, has not been driven by the low-carbon agenda.

***Heat Pumps*** – Heat pump technology is more than a century old. Heat pumps can contribute to energy sector decarbonisation by allowing low-carbon electricity to be used for heat. Heat pumps have rapidly gained market share in countries from the Mediterranean to Scandinavia, but have had limited take-up in the UK.

***Smart Grids*** – The convergence of information/communication and energy technologies could transform electricity distribution as well as relationships between suppliers and consumers. Innovation is occurring not just in technology, but also in business models and consumer engagement.

***Wind energy*** – Wind energy contributes more to electricity production than any renewable technology other than hydro. Output has been growing at more than 25% annually. Falling costs have been associated with economies of scale and market entry by diversified engineering majors.

***Wave Energy*** – Wave energy has a huge resource potential but a dominant design has yet to emerge and there has been limited progress towards commercialisation. This case study helps us understand better the barriers to innovation.



***Denmark*** – Denmark has been a world leader in the development of wind energy and hosts one of the largest global wind companies. It has recently transferred its national energy laboratory, the locus of previous wind R&D, to the university sector.

***Finland*** – Finland spends more on energy R&D per unit of GDP than any other OECD country. Finland has been a global leader in mobile communications and has the second largest deployment of heat pumps per capita in the EU.

***South Korea*** – South Korea has a rapidly expanding economy and is positioning itself as an exporter of energy technology, including nuclear. Korea has been chosen primarily because of strong public-private partnerships in the smart grid area.

**United States** – The US energy revolution is being driven by the expansion of shale gas. At the same, State-level initiatives are promoting renewables and energy efficiency. These trends, plus the sheer size and scope of US innovation efforts, make this case study indispensable .

***Japan*** – Japan has few indigenous energy resources and has been a leader in energy efficiency. The Fukushima crisis has reinforced this need. Japan remains a major investor in nuclear R&D but has so far made only limited efforts in renewables.

***UK*** – The UK has ambitious climate change targets and within a short period of time has made itself a world leader in offshore wind. However, the energy innovation system has been perceived as weak and fragmented. This project is intended to inform enhanced UK innovation efforts and better alignment with policy goals.

***Germany*** – Renewable energy is transforming the German energy system. Energy R&D is well-aligned with EU activities and German energy R&D expenditure is second only to that of France. Germany is another indispensable case study.

***China*** – China's rapidly expanding energy market is the world's largest. This case study will focus on wind energy where joint ventures between national and international companies raise key questions about technology transfer and the role of emerging economies.

***European Union*** – The EU merits a separate case study because of its critical role in climate diplomacy and a step change in innovation efforts through the Strategic Energy Technology (SET) Plan and the Horizon 2020 Programme.

## *Innovation Indicators*

| **Contextual indicators:** Macroeconomic situation, international linkages, business climate, infrastructure construction and education investment | | | |
|---|---|---|---|
| **Input indicators** | **Throughput indicators** | **Output indicators** | **Outcome indicators** |
| Research and development expenditure | Publications | % of innovative firms with significantly improved or new products/services | Export and market shares of commodities and services |
| Human resources in science and technology | Patents | % of innovative firms with significantly improved or new processes | Revenues of international technology transfers |
| Science and research hubs, e.g. top universities, top think tanks and top corporate R&D investors | Trademarks and designs | % of innovative firms with new organisational practices | Labour and energy productivity |
| | International flows of researchers | % of innovative firms with new marketing practices | Energy mix and self-sufficiency |
| | Government budgets for demonstration, deployment and public procurement of new products or services | | $CO_2$, $SO_X$ and $NO_X$ emissions |