Accelerating the commercialisation of emerging renewable energy technologies

September 2014
The Carbon Trust wrote this report based on an analysis of primary and secondary sources. The Carbon Trust’s mission is to accelerate the move to a low carbon economy. It is a world leading expert on carbon reduction and clean technology. As a not-for-dividend group, it advises governments and leading companies around the world, reinvesting profits into its low carbon mission.

Element Energy partnered with the Carbon Trust in preparing this report. Element Energy is a strategic energy consultancy specialising in the analysis of low-carbon energy in the transport, buildings and power sectors. The company provides a range of services to private and public sector clients, from techno-economic analysis and policy advice to managing the demonstration and deployment of low carbon technologies.

The International Energy Agency’s Implementing Agreement on Renewable Energy Technology Deployment (IEA-RETD) provides a platform for enhancing international cooperation on policies, measures and market instruments to accelerate the global deployment of renewable energy technologies. IEA-RETD operates under the legal framework of the International Energy Agency. IEA-RETD aims to empower policy makers and energy market actors to make informed decisions by: (1) providing innovative policy options; (2) disseminating best practices related to policy measures and market instruments to increase deployment of renewable energy, and (3) increasing awareness of the short-, medium- and long-term impacts of renewable energy action and inaction. IEA-RETD member countries are Canada, Denmark, France, Germany, Ireland, Japan, Norway, and United Kingdom. For further information please visit: http://iea-retd.org or contact iea_retd@ecofys.com.
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Disclaimer

The report is prepared by an independent consultant and does not necessarily reflect the opinion of the IEA-RETD Member Countries.

This publication should be cited as:

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i. Executive Summary

Purpose

This report provides seven innovation policy recommendations to accelerate the development of emerging renewables such as offshore wind, marine and advanced biofuel technologies. Emerging renewable technologies have not been advancing fast enough. Despite the potential of new technologies to seed export markets, create jobs and help to meet global climate change targets, less than 5% of the US$244bn invested annually in renewables around the world is spent on early stage investments – for research, development and demonstration (RD&D) or venturing. Government funding levels for renewable RD&D are on average currently equalled by corporate spending, but better designed innovation programmes can achieve 5-10 fold private sector match funding for future programmes. This can be enabled by new programme designs, de-risking early stage investments and unlocking additional value from international collaboration and coordination. Improved innovation programme designs can only deliver this impact if they are supported by strategic policy frameworks that offer long term market certainty.

The governments of the IEA-RETD\(^1\) commissioned this report to synthesise internationally relevant insights from recent renewable innovation policy successes and failures. The Carbon Trust and Element Energy delivered this using workshops with leading policy makers and industry experts, detailed policy and technology case studies and a series of interviews with leading international sector stakeholders. Particularly valuable insights are taken from onshore wind and solar photovoltaic (PV), which have achieved double digit annual deployment increases and cost reductions over the past forty years.

This report makes recommendations to unlock the next generation of innovation policy, by building on successes from the past four decades of policy delivery and the insights of current leading experts. Governments can harness these lessons, to deliver lowest cost policy that is strategically aligned to national goals. To achieve maximum impact at lowest cost the next generation of policy must avoid the failings of uncertain, disjointed action. Policy makers can achieve this by placing greater emphasis on strategic long term innovation policy, coordinated across government and by using new approaches to reduce the risks of early stage investments for private sector actors.

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\(^1\) International Energy Agency – Renewable Energy Technology Deployment ‘implementing agreement’, with the following participating countries: Canada, Denmark, France, Germany, Ireland, Japan, Norway and the United Kingdom
Challenges

In most countries innovation policy for renewable energy technologies is the subject of multiple government departments, creating significant coordination and continuity challenges. Crucially, innovation policy which encourages the development of renewable energy technologies requires capital intensive funding for many years – often decades. Policy makers struggle to provide market driven policies that provide such long term confidence.

This challenge is exacerbated for emerging renewable energy technologies by the recent international recession and government budget cuts. Private sector finance has increasingly focused on lower risk, more established technologies, which offer higher returns.

Governments are frequently called on to increase funding to this topic, but have limited resources. In light of climate change targets, the IEA has called for >US$300bn additional funding to be spent annually on renewable energy deployment over the coming 20 years. Growing international competition in an increasingly globalised world makes it harder for policy makers to support additional policy costs incurred by rising deployment levels for subsidised pre-commercial technologies.

Recommendations

This report focuses on recommendations that can enable policy makers to achieve maximum gains by building on existing support levels. These recommendations build on proven policy successes found in international best practice, and novel recommendations developed by working with leading members of the international innovation community. These proven and novel recommendations are now covered in turn.

Proven approaches to delivering a comprehensive innovation policy support framework

A comprehensive framework to plan and deliver innovation policy is central to best practice policy making. While the recommendations to achieve this are accepted and understood, they are frequently not delivered across the IEA-RETD. These actions will enable governments to optimise deployment of established policy families to accelerate priority technologies in light of national goals.

1. Monitor the balance of resources allocated to the three key innovation policy families:

- Policies directly funded by the government for RD&D (referred to as ‘push’ policies);
- policies that stimulate and encourage private sector spend on innovation, such as investment and price support/incentives such as feed-in tariffs (FITs) (referred to as ‘pull’ policies); and
- enabling policies that unlock and connect the different actors delivering innovation

Push and pull policies are the dominant use of public funds in most countries. Technologies typically start out primarily push supported, transitioning quickly to being majority pull supported following early deployment. Pull support, such as price or investment policies, can unlock significant private sector resources.
Not all countries follow this pattern, as some are able to use the technologies of others to leapfrog technology development stages, additionally some countries prefer to focus on policies that most support national technology objectives – how to address this national focus is developed further in the following two points.

Enabling policies support technology across the innovation chain, removing barriers and unlocking the potential of push and pull policies. In particular, innovation support agencies are recognised as being amongst the lowest cost innovation support policies. Innovation support agencies also have the added benefit that they are able to flexibly adjust their support strategies in response to evolving technology challenges.

Crucially, for the delivery of effective policy, most countries do not have a clear understanding of the balance of resources allocated annually across their main innovation support policies, for instance the balance between feed-in tariff support (a pull policy) and direct R&D funding (a push policy). Furthermore, few countries have a view of how that balance will change over coming years as deployment increases and technology costs reduce. Future policy iterations must be informed by a clear understanding of this balance and its evolution.

2. Establish clear goals and focus for success

Policy makers need to have clear goals to design innovation support. In particular, they need to distinguish between aiming to deploy the technologies (to achieve national emissions targets and energy security) and/or aiming to develop them (to create value from exports).

Technology innovation needs should then be prioritised to make best use of limited resources – with increasing focus along the innovation chain as cost requirements increase. These priorities should be informed using private sector consultation, assessments of national competitive advantage and national energy system models. In addition, cross departmental strategy groups should be used to ensure that innovation policy is aligned with other relevant policy activities, e.g. for industrial development or planning regulation for construction.

3. Balance and integrate push and pull innovation policies

At a global level, emerging technologies need a combination of push and pull policies; push to ensure technologies that are far from revenue progress along the innovation chain, and pull to provide private sector investors with confidence in long term market attractiveness. While both of these policies are necessary at a global level for technology progression, for individual countries, it is not essential they use each policy type, as is mentioned above.

Individual countries should balance and design additional push and pull policies in light of whether their goal is to deploy and/or develop technologies. Countries with deployment goals should primarily focus on pull policies (as Italy has done for PV using a feed-in tariff) with push policy targeted at RD&D to reduce costs in nationally sourced elements of technology value chains such installation.
Countries seeking to develop competitive technologies for export should focus on additional RD&D push policy, integrated with industrial policy, targeted at internationally tradable technology value chain elements (as China has done with PV and Denmark has done with wind). These export focussed countries would nevertheless be best able to demonstrate valuable products with a strong domestic market, supported by pull policies.

Most important is to design complementary push and pull policies in pursuit of national goals over long term timelines. Countries like Japan have successfully achieved this for their PV industry using large scale demonstration activities that up-skill domestic firms, while supporting controlled deployment levels.

4. **Increase international coordination and collaboration** to disseminate best practice and initiate co-funded programmes. This enables countries to achieve more with less and to attain the required scale to make significant progress in international technology development. One approach to increasing international coordination would be to establish an IEA implementing agreement for innovation.

Coordination and partnering is especially critical for smaller countries struggling to compete at scale in international markets. Such countries should focus on areas of particular competitive international strength and utilise collaboration on non-competitive technology areas to achieve mutually beneficial partnerships.

*New policy developments to catalyse greater acceleration from the private sector and international partners*

These recommendations focus on improving the risk adjusted returns for private sector investors earlier along the innovation chain, to ensure the long term users of technologies guide their development.

5. **Seek to design increased certainty into policies.** Policy uncertainty increases risk for private sector investors. This is especially critical for future price and investment support mechanisms, but also for RD&D programmes and innovation support agencies, which unlock benefits over extended periods of time, in changing circumstances. Certainty should be achieved by building on successful policies currently implemented in country, to maintain existing confidence. Consistent political messaging is an additional, low cost, way to reduce uncertainty and the associated risk on investment. This can be made easier for politicians by establishing clear plans for reducing price based support policies in the early stages of policy development.

6. **Use novel public private RD&D programmes to remove barriers** to innovation and increase private sector investment earlier along the innovation chain. Unique designs can catalyse 5-10 times private funding on public spend and be used to create optimal circumstances for collaboration, bespoke to the needs of the project partners. Demonstration projects are particularly catalytic, especially when focused on reliability.
Increased incentives can be created for technology developers by providing them with exposure to technology users (primarily utilities), their future clients, and by focussing programmes on areas of non-competition, e.g. shared infrastructure. Increased funding from utilities can be encouraged by allowing them to direct innovation activities towards products they could use and by implementing policy frameworks that offer benefits to all market players, from the creation of a viable technologies.

An increase in push funding could be achieved by reallocating existing subsidies from fossil fuel technologies which would be expected to save money in the long term by enabling lower cost pull policies. IPCC estimates that current early stage investment in renewables could be quadrupled by appropriating fossil fuel subsidies, at zero additional cost to tax payers.

7. Establish risk taking public-private investment funds, supported by tax relief, to stimulate additional private sector funding. These should be designed to harness the strengths of corporate technology developers, utilities and venture capitalists to enable private sector led investments towards priority technology innovations. These funds can further unlock private sector investments in technologies that are considered to be marginally too risky by providing detailed due diligence and Front End Engineering and Design (FEED) studies.

Next steps

The main report provides policy makers with more detailed steps to achieve the recommendations outlined above. New, untested, concepts for innovation policy that combine these recommendations into tangible new programmes, funding approaches and policies are also overviewed in Appendix i. These ideas cover an example of new international RD&D programmes for offshore wind and innovative ways to harmonise push and pull policies (such as offering optional price support packages to utilities, combining RD&D grants with deployment price support). The next step for policy makers is to turn these ideas and concepts into reality, building on the frameworks in this report and applying them to the specific conditions in their countries. By working together, countries can tackle shared problems and pool solutions. The IEA-RETD can support this process by starting to build the international partnerships between governments and companies that are needed to accelerate innovation in these technologies in order to realise the technologies true potential.
ii. Introduction: The current context for emerging renewables

Renewable energy technologies such as wind and solar have had unprecedented success transitioning along the technology innovation chain in recent decades. The share of renewables in total power generation is predicted to rise from 20% in 2011 to 31% in 2035, supplying half of the growth in global electricity generation (IEA, 2012). Onshore wind, solar PV and hydropower provide c.18% of global electricity generation, make critical contributions to greenhouse gas (GHG) emission reductions and in some circumstances are near cost competitive with fossil fuels. They are also available at larger scales than ever, in increasingly diverse locations.

The great progress of advanced renewable energy technologies, such as solar PV and onshore wind, provide insights to guide future innovation policy for emerging renewable energy technologies (ERETs), such as offshore wind, advanced biofuels and marine energy. Increased activity on these technologies can create new markets and reduce the risk of not achieving long term global decarbonisation at lowest cost.

This section starts by introducing the innovation chain and overviewing the recent progress of these most advanced technologies. It continues by detailing the key challenges facing emerging renewable energy technologies due to current economic realities, technology specific factors and the recent policy ‘failures’ are identified for policy makers to address in future innovation policy.

What are emerging renewable energy technologies?

Emerging renewable energy technologies (ERETs) are identified as spanning the demonstration and early deployment proof points, shown in Table 1, below. In each of the major sources of renewable energy (hydropower, bioenergy, wind, solar, geothermal and marine) there is a range of possible technologies that are classified as ‘advanced’ and ‘emerging’.

To encourage the progress of emerging technologies along the innovation chain it will be necessary to:

i. bring new concepts to demonstration;

ii. show reliable long term operation, de-risk future investments; and

iii. enable on-going cost reduction through learning by doing and developing improved technology designs and components

Each of these ERETs is a new potential market and a source of economic growth that governments could unlock. Additionally, emerging technologies offer a means for governments to de-risk long term global decarbonisation, as no single technology can be deployed at sufficient scale to completely replace current use of fossil fuels for electricity, heat and transport (IEA, 2013).

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2 Renewable energy technologies at the more conceptual ‘basic research’ step are not included on this diagram as they are out of scope of this study, owing to their longer time lag to market relevance.
The IEA summarises the critical need for improved innovation in ERETs by stating that while advanced RETs are close to being on track to meet needed deployment targets for their decarbonisation scenario, ERETs are not. The most recent IEA ‘Tracking Clean Energy Progress’ report (2013) identifies a need for tens of billions of dollars increased spending on earlier stage innovation activities for these technologies. As is detailed further in this section, increased levels of spending will not always be possible for these technologies, showing a need for governments to deliver smarter, more efficient policy support using available resources.

Table 1 Generalised categorisation of renewable energy technologies for comparison by innovation stage, identifying the more advanced technologies that can offer insights to the more emerging technologies. Earlier stage technologies, still at the research and development stage, are identified as out of scope of this report.

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<td><strong>Hydropower</strong></td>
<td>Hydrokinetic turbines</td>
<td>Run-of-river, Reservoirs, Pumped storage</td>
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| **Bioenergy**                   | Aquatic plant-derived fuels
- Pyrolysis biofuels
- Gasification based biofuels or biomethane
- Fermentation of lignocellulosic material |
| Wind                             | Wind kites
- Higher-altitude wind generator |
| Solar                            | Solar fuels
- Solar cooling
- Solar cooking
- Concentrating PV
- CSP |
| Geothermal                       | Submarine geothermal
- Engineered geothermal systems |
| Marine                           | Currents/thermal conversion
- Salinity gradients
- Wave |
| **Note that technologies do not ‘linearly’ progress along this chain as it is enabled by is the product of complex interactions of multiple technology sub-components, that each have their own technology journey (e.g. foundation designs for offshore wind).**
Historic progress in advanced renewable energy technologies

Advanced renewable energy technologies, specifically onshore wind and solar PV, have made great advances in recent years. The global average turbine cost has decreased in real terms from €2.0mn/MW in 1984 to below €0.9mn/MW in 2011 (BNEF, 2011), while solar PV installations have shown a 25% annual average increase since 2006 (Hastings-Simon, 2014). As deployment increases and costs are reduced these advanced technologies are becoming deployable in increasingly diverse locations with improved technological performance. Each of these factors is outlined below to provide high-level insights into the relative progress of these technologies.

Current status of global renewable energy deployment

Onshore wind, solar PV and hydropower collectively provide c.18% of global electricity supply and make critical contributions to GHG emission reductions. Figure 1 shows the global average contribution against the energy mix of the IEA-RETD countries and some additional countries that have particularly high deployment levels.

Figure 1 Electricity generation by fuel type in RETD countries (denoted by *) and select renewable energy deployment leaders, contrasted against the global average for 2011 (IEA, 2011)
The relative share of advanced renewables is continually increasing, primarily driven by growth in onshore wind and solar PV. This is true across the key continents relevant to this report – Asia, Europe and North America:

- In the European Union, renewables accounted for almost 70% of new electricity generation capacity in 2012 (REN21, 2013)
- In China, wind power generation has increased more than generation from coal and passed nuclear power output (REN21, 2013)
- The United States added more capacity from wind power than any other technology, and all renewables made up about half of total electric capacity additions during the year (REN21, 2013)

In 2012, an estimated 5.7mn people were identified as working in renewable technologies worldwide with the potential for at least 9.5mn by 2030 under the IRENA REmap business as usual scenario (IRENA, 2013). However, while greater deployment is unlocking new technology markets and economic opportunities, further action is still needed. Excluding hydropower, renewables supply less than 5% of total global electricity consumption, which can be significantly improved upon.

**Rapid technology cost reduction has been achieved for advanced RETs**

Global new onshore wind installations reached 33.8GW in 2013 compared to 36.7GW for solar PV – the first year solar growth has outpaced wind (BNEF, 2013). The rapid increase in advanced renewable deployment for onshore wind and PV is coupled with significant cost reductions.

The median levelised costs for onshore wind are now comparable to fossil fuel sources, as they are for geothermal, hydropower and bioenergy combustion (IRENA, 2012).

The lowest cost PV deployments are also approaching similar levelised costs of energy as fossil fuel. This has been enabled by >600% module price cost reductions over the past 20 years, as shown in Figure 2.

Rapid, but sporadic, PV cost reductions in a volatile international market spearheaded by unparalleled growth in China has created additional challenges for innovation policy makers concerned about runaway costs and the creation of markets that domestic companies can access. These challenges are further outlined later in this section.
It is important to note that while the absolute levelised costs of advanced renewable energy technologies has made significant downward progress in recent years there is still significant need for additional reductions and innovations to integrate them into well-structured energy markets.

This is because these technologies are still predominantly only commercial with price support mechanisms, and higher levels of penetration might create situations where RETs struggle to sell at minimum needed prices due to their near zero marginal cost of generation and the intermittent nature of their generation (Joskow 2011; Hirth 2013).

Nevertheless, great historic progress in the cost reductions of these more advanced technologies offers valuable insights into future innovation policy for ERETs. This is especially relevant in light of minimising the associated policy challenges of runaway costs (potential windfall profits) and maximising chances of harnessing new international markets.

Improved technological performance to increase market penetration

In addition to achieving cost reductions, advanced RETs have also expanded their relevance to different market segments through performance factors. Wind turbines are now being deployed up to 7.5MW, compared to 1.5MW in 1985 (IEA, 2013) and wind turbine sizes have increased 17 fold in the same timeframe. Three common means of expanding their relevance are detailed below, with examples from onshore wind:

- **Flexibility/‘dispatchability’**: the ability to use energy from the technology when needed, e.g. increased pairing of technologies with storage
- **‘Applicability’**: the situations the technology can be used in, e.g. further offshore/in areas with more variable/lower wind speeds – enabled by turbine size as shown in Figure 3, below
- **‘Mobility’**: the ability to be constructed in country and then exported, e.g. through improved manufacturing or shipping systems

These factors are related to cost but they are also important to consider as independent components. Electricity utilities purchasing technologies from technology developers will not just assess potential acquisitions on the basis of costs but also on ‘softer’ technology performance factors.
Figure 3 Significant growth in turbine size (UpWind, 2011)
Challenges facing tomorrow’s innovation policy

Innovation policy needs to adapt to current conditions and future challenges. What has worked in the past will not necessarily work in the future. This forces governments and other regulatory bodies to assess what has been successfully achieved to date and what is relevant for technologies of the future.

This is a specific challenge for policy makers at present for multiple reasons:

- Innovation is a complicated, relatively intangible policy area used to deliver multiple, often conflicting goals
- Recent economic crises have drawn away resources, reduced available public funds and limited co-funding from the private sector
- ERETs face particular technological challenges that are difficult for policy makers to address

Policy challenges – Innovation at the interface of multiple issues

Innovation policy requires decision making under great uncertainty and is at the interface of four major areas of national policy, spanning the remits of multiple government departments:

- **Climate change**: The aim is the existence of lowest cost technologies needed to achieve global and national decarbonisation
- **Energy**: The purpose is national deployment of a resilient, secure, modern energy system at lowest cost
- **Business development/industrialisation**: Goals are typically measured in light of number of domestic jobs, value from exports, proportion of firms in the global market, proportion of intellectual generated
- **International development policy**: The goals are to support and enable developing countries to achieve a higher quality of life (beyond the scope of this report)

The conflicting nature of these goals is underlined by recent developments in international PV markets. Chinese engagement in PV markets from 2008 to 2011 resulted in accelerated PV module cost reductions and saw Chinese manufacturers take significant market share from other countries (see Figure 4 below). This has led countries like Germany to reassess the effectiveness of their price support policies – policies that had helped nurture new markets, but have not necessarily maximised domestic business development potential. Additionally, lower than anticipated production costs have led to concerns of windfall profits to developers and greater than predicted PV deployment in some regions, resulting in greater levels of resources than originally planned going to market support. Governments now face the challenge of developing innovation policy for ERETs to achieve multiple independent goals simultaneously.
Economic challenges

Due to the recent financial crisis, government budgets are increasingly challenged and private sector funding is harder to secure.

The effect of this has been limited to an extent, by recent stimulus spending on green energy technologies. Private sector investment has continued to grow in China, India and the rest of Asia, as is shown in Figure 5, right.

Nevertheless, it is generally more difficult for developers of innovative technologies to find capital to finance early-stage projects. Less than 5% of the US$244bn invested annually in renewables around the world is spent on early stage investments. Later stage projects and the manufacturing of technology continue to attract considerably more investment than for early stage R&D, see Figure 6, below. Additionally, investment from Europe and the USA (which has historically accounted for over half of global private sector investment) has declined in recent years which is making it particularly challenging for technology to step from R&D to commercialisation. Therefore there is a need for greater government intervention through future policy developed in light of more constrained resources, to best use available assets and maximise private sector funding.
Figure 6 Global trends in renewable investment 2004-2012. a) early stage investment b) later stage investment (Ren21, 2013)

**Technology challenges**

ERETs are predominantly high CAPEX technologies which develop over long time frames in highly complex international markets.

The high CAPEX nature of ERETs (>90% for the example of the UK’s offshore wind farm Scroby Sands in Figure 7, right) is challenging for innovation policy makers as it exacerbates the challenges of limited capital availability. This is especially problematic when high risk, large scale demonstration projects are needed.

The complexity of ERETs and their international market dynamics are a challenge for innovation policy makers. Each technology is made up of multiple sub-components that undergo their own innovation journey. Evolutions, replacements and relative competitive advantage of any technology sub-component can incur subtle, but crucial changes to a technology’s evolution that does not necessarily result in a linear progression along the innovation chain. Understanding of individual technology subcomponents and their potential is important for government actors trying to accelerate the progression of technologies along the innovation chain.
Funding prioritisation challenges

Governments face calls to increase funding to (i) maximise chances of meeting international climate change targets at lowest cost, and (ii) unlock the economic benefits of new technology markets. However, appeals for increased funding competes with many other national priorities and are well summarised at a global and national level through recent analysis by the IEA and from looking at individual country assessments of required spend. The IEA has called for >US$300bn additional investment to be spent annually on renewable energy deployment over the next 20 years, while the IEA’s Energy Technology Perspectives report concludes that billions of dollars’ worth of investment are needed globally for RD&D in renewable energy technologies to meet international climate change targets (Figure 8).

The UK’s Low Carbon Innovation Coordination Group (LCICG) completed a national level analysis of the costs associated with the push focussed programmes that would enable the government to progress low carbon technology innovations needed to maximise chances of achieving mandatory 80% GHG emission reductions by 2050. This ‘bottom up’ analysis concluded that billions of dollars additional funding would be needed to progress technology development to the required timeframes. In addition it demonstrated that the UK would not be able to fund all of these activities and is therefore considering priorities in light of technology deployment potential, export values, market failures and international activity.

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4 The ETP report further underlines the need for this report, stating that ‘advanced’ renewable energy technologies (e.g. wind, PV and hydropower) are identified as nearly on track to meet deployment targets, while emerging renewable energy technologies (e.g. offshore wind, marine and concentrating solar power) are identified as not advancing quickly enough and requiring increased RD&D funding to accelerate development.
“We estimate that delivering all of the innovation support activities identified would require the UK Government to invest somewhere between £3bn and £4bn over the next 5-7 years. By comparison we estimate that the equivalent spend over the five years to 2016 is around £1-1.5bn.”

– LCICG (2014)

As requests for increased funding are extensively made in other publications this report focusses on how best to use currently allocated resources. The following method section details the research and analysis procedure that was used to achieve this.
Method: ‘Finding the blueprint for the innovation policy of the future’

This report seeks to provide useful insights and recommendations for governments seeking to deliver improved innovation policy for emerging renewable energy technologies (ERETs) in a time of constrained resources. A pragmatic focus was adopted early on in this project, seeking high impact areas where detailed recommendation could be focussed.

To enable policy families and stakeholder groups to be compared consistently across different countries a simple framework was developed. The framework and focus were then used to develop a process for data gathering that leveraged insights from:

- Published reports, synthesising over 100 articles
- The history of innovation policy, using onshore wind and solar PV as case studies
- Stakeholders currently developing innovation in emerging renewable energy technologies, using five technology-in-transition case studies and ten additional interviewees, covering Asia, Europe and North America

The insights and recommendations from this process were cross-referenced against internal experience from the Carbon Trust, a team of international external reviewers, and a project steering group with representatives from Enova (Norway), Ecofys and the Social and Economic Council of the Netherlands (Netherlands), and The Institute of Energy Economics (Japan).

This section provides an overview of the following in turn: the framework used to analyse innovation policy and stakeholders, the approach used in this project and the case studies and stakeholders used for detailed insights.
Frameworks for policy and stakeholders

Two simple frameworks for policy and stakeholder analysis are used to enable a clear international comparison of innovation policy families.

Policy framework

A clear categorisation of policy support types is needed for this report to enable consistent comparison and discussion of policy families across different countries. It is not possible to do this faultlessly as each country has a unique innovation policy support framework as a result of historic factors and national policy preferences. It is found that the definitions of different policy types are not used consistently, limiting the ability to compare policy success across different countries – other comparative reports state that, “when comparing support types across different countries the boundaries between the subsidy classes are vague and they can overlap each other” (Avril et al., 2012). This report classifies policies into three broad families, commonly seen throughout innovation research:

- **Push**: ‘Supply stimulating technology push’ policies that directly fund technology development – most commonly research and development (R&D) support to universities and demonstration support in the form of grants
- **Pull**: ‘Demand stimulating market pull’ policies that incentivise market actors to channel funds to innovation – most commonly investment support and price based support (for units of renewable electricity generated, or carbon abated)
- **Enabling**: Supporting policies aimed to address the barriers existing in the institutional environment to enable further innovation and deployment (e.g.: public innovation support bodies, incubation support, clustering). These are the least consistently defined and used across different countries
Two specific policy families are focussed on within push policies (R&D support and demonstration support) and also for pull policies (investment support and price support). These four groups are prioritised for comparison, as they cover the major areas of spend used by countries to fund technology innovation. These families of push and pull policies are shown along the four-step innovation chain used in this project, in Figure 9, below. Enabling policies are relevant across the whole innovation chain.

![Figure 9 Graphic representation of the categorisation used in this report for policy support types](image)

Many additional policy families are found to be used to support technology innovation (e.g. command and control regulation, public procurement and renewable portfolio standards). These were de-prioritised for analysis in this project, as: (i) they are not the major areas of spend for the majority of governments and (ii) their implementation is particularly dependent on a country’s political preferences, limiting the likelihood of replication of solutions for these policies across multiple governments.

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Stakeholder framework

A range of different stakeholders that make up the ‘innovation ecosystem’ enables successful technology transitions. These can be grouped based on their goals from innovation into five broad categories (Figure 10):

- **Technology Developers**: Organisations actively innovating. These range from universities to small novel technology companies and major corporate developers
- **Technology Users**: The eventual buyers of innovative technologies. These are most commonly utilities, especially when the technology has a high CAPEX, but can also be individual businesses and households when considering small distributed generation technologies
- **External Funders**: These include traditional financiers – angel finance, venture capital, project finance and public markets – and major corporate funders, which may be developers or users of technology, that also invest in innovation outside of their own activities. Governments can also create new, independent public funding organisations (such as the UK’s Green Investment Bank) to plug gaps left by existing external funders
- **Technology Enablers**: Organisations that act to enable the innovation ecosystem and remove barriers to action, typically set up by governments. These can play an integrating role in the innovation ecosystem connecting technology users, developers and funders to government policy. They can also prioritise, design and manage government innovation programmes, at arm’s length
- **Government**: The set of regional, national and international departments that deliver public policy. The four main categories of policies identified that governments deliver are legislation, regulatory structures, courses of action; and funding priorities. Regulatory structures and laws are the most tailored to individual countries’ existing market framework

It is noteworthy that two types of government intervention in the innovation ecosystem are prominently captured by this framework – the establishment of innovation enabling bodies and public funds.

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6 This is not a completely exhaustive list, it just seeks to categorise the main groups that governments can interact with to support innovation development. It is important to note that within the innovation ecosystem the other key stakeholder that these groups interact with, e.g. ‘technology opponents’ (from other industries or the general public). These additional groups are not focused on in this report.
The interactions between our policy and stakeholder framework

The frameworks chosen for policy families and innovation stakeholders are selected due to their simplicity in enabling consistent comparison across countries. Additionally, they complement each other and enable more detailed analysis of innovation policy. Push policies (research, development and demonstration support) for emerging technologies are typically targeted at technology developers. For pull policies, investment support activities are typically targeted at technology funders, while price support mechanisms seek to deliver innovation through the actions of technology users.
The approach of this project

This project followed five work-streams culminating in the production of this final report:

- **Task 1**: Synthesis report of 100 innovation publications, prioritisation of policies for future analysis based on their potential impact\(^7\) with consideration of the additional impact, likelihood of implementation and replication of recommendations in that policy area across multiple countries. Ten experts on innovation policy reviewed this report to guide further use of its output.
- **Task 2**: A framing workshop with 14 cross-industry organisations including four technology developers, three utilities and six investors in addition to the IEA-RETD project steering group, sharpening the project focus and objectives.
- **Task 3**: New research into key questions highlighted in tasks 1 and 2, presenting evidence and key insights.
- **Task 4**: Midterm workshop presenting Task 3 findings to multiple government representatives from Norway, the Netherlands, UK, Canada and the USA. A range of private sector actors also attended, including venture capital technology funders, SME novel technology companies and multinational major corporate utilities and technology developers.
- **Task 5**: This final report, presenting concrete policy recommendations and key project insights based on expert input from the IEA-RETD stakeholders and Task 4 expert workshop.

Focussed research was carried out in Task 3 after establishing an initial focus for study in the first two tasks. This research focussed on three issues: the balance of innovation support along the innovation chain; successful high-risk demonstration programmes, and new funding structures for renewable energy innovation. The following sources of information were used to inform these areas:

- Desk research on innovation policy supporting PV and wind over the past 20 years.
- Interviews with 18 individuals currently working to deliver ERETs (technology developers, users, funders and enablers).
- Five case studies of leading efforts transitioning three key ERETs (tidal current, offshore wind, and bioSNG) along the innovation chain.

As mentioned above, the findings from this research were cross-referenced against internal experience from the Carbon Trust, a team of international external reviewers, and a project steering group with representatives from Norway, the Netherlands, and Japan.

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7 The criteria used are further detailed as follows:

- **Potential impact** – does the policy family have a strong track record of innovation success that is likely to be relevant to emerging technologies over the next 5-10 years?
- **Additional** – would new research make a meaningful and additional contribution in light of current work?
- **Implementable** – are policy recommendations likely to be implemented given national priorities?
- **Replicable** – would new policy recommendations need to be bespoke to a country’s current suite of policies?
Interviewees

To gain key insights, interviewees were selected from leading actors currently working on ERET innovation. The set of interviewees are shown in Table 2. These organisations were chosen to ensure a diverse set of opinions were provided to the project. Each category of stakeholder was consulted (including small companies, public institutions, major multinational corporates and various financial institutions). Insights from these interviewees were cross-referenced with governments through the Task 4 project workshop. The list of interviewees span Asia, Europe and North America (the continents the RETD countries are located); the major families of RETs (bioenergy, wind, solar, geothermal, marine, hydropower) – with many of these organisations actively engaging in emerging technologies.
<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Organisation</th>
<th>Technology focus, country</th>
<th>Stakeholder/Case Study Role</th>
<th>Additional comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enabler</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offshore Wind Accelerator</td>
<td>OSW, UK</td>
<td>Co-funded programme between gov. &amp; utilities</td>
<td>Novel approaches to collaboration and development</td>
<td></td>
</tr>
<tr>
<td>Fraunhofer</td>
<td>Wind, Germany</td>
<td>University/ research units, part of an ‘innovation hub’</td>
<td>Located flagship centre in Bremerhaven – multi-stakeholder engagement in innovation cluster</td>
<td></td>
</tr>
<tr>
<td>Gussing</td>
<td>Bioenergy gasification to liquid/gaseous fuel, Austria</td>
<td>Multi-stakeholder innovation programme</td>
<td>Unique approach, designed model for ‘community’ ground up development</td>
<td></td>
</tr>
<tr>
<td>Natural Resources Canada</td>
<td>Multiple, Canada</td>
<td>Government department involved in increasing the utilisation of RETs</td>
<td>Works with industry, other government departments and academia to coordinate RD&amp;D and provide project financing</td>
<td></td>
</tr>
<tr>
<td><strong>Technology developer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marine Current Turbines</td>
<td>Marine, UK</td>
<td>Novel technology company</td>
<td>Owned by Siemens and first marine tidal tech. to complete journey from dashboard to corporate buyout</td>
<td></td>
</tr>
<tr>
<td>Artemis</td>
<td>Wind &amp; Marine, UK</td>
<td>Multi-stakeholder engagement</td>
<td>Innovative tech. company completed innovation journey to corporate buyout</td>
<td></td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>OSW, multinational</td>
<td>Major technology corporate, joint-venture in OSW</td>
<td>Recently moving into OSW market and tech. development</td>
<td></td>
</tr>
<tr>
<td>Doosan</td>
<td>OSW, multinational</td>
<td>Global energy technology developer, corporate venturing</td>
<td></td>
<td></td>
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<tr>
<td><strong>Funder</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Shell</td>
<td>Wind, multinational</td>
<td>Major international corporate providing venture capital</td>
<td>2007-2012 - $2.2bn on alternative energy R&amp;D spend</td>
<td></td>
</tr>
<tr>
<td>Google</td>
<td>Geothermal, wind, solar, multinational</td>
<td>Major international corporate, corporate venture capital</td>
<td>Innovative non-energy company - $1.4bn RE investment to date</td>
<td></td>
</tr>
<tr>
<td>350 Partners</td>
<td>Clean tech and energy efficiency, UK</td>
<td>Advisory, private equity, grants</td>
<td>26 investments in ‘Greentech’, typically invest between £250k-£4m</td>
<td></td>
</tr>
<tr>
<td>IGP Group</td>
<td>Multiple &amp; at different stages of innovation, UK</td>
<td>‘IP commercialisation’ VC, manages several VC funds</td>
<td>16 active investments in RE sphere</td>
<td></td>
</tr>
<tr>
<td>European Investment Bank</td>
<td>Wind/solar, Europe</td>
<td>Largest institutional investor in the world</td>
<td>25% commitment of funds to climate change related projects</td>
<td></td>
</tr>
<tr>
<td><strong>Technology user</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E.ON</td>
<td>Wind (secondary: marine/biomass), multinational</td>
<td>Major utility</td>
<td>Invested €9bn in cleantech since 2007 with significant OSW activity</td>
<td></td>
</tr>
<tr>
<td>RWE</td>
<td>Wind (secondary: hydro/biomass), Europe</td>
<td>Major RE utility</td>
<td>Significant wind activity and partner with Innogy Venture Capital – RET fund of &gt;€100m</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 - Full list of interviewed stakeholders (deep dive case studies in green) with the technology focus, main country of operation and type of stakeholder engagement
Transition case studies

Five of the interviewed organisations recognised as successfully enabling state of the art innovation activities in ERETs are used as case studies representing technologies in transition. These are: Marine Current Turbines, Artemis Intelligent Power, Güssing Renewable Energy, Carbon Trust’s Offshore Wind Accelerator and the Bremerhaven Wind Cluster. These were chosen for a number of reasons:

- The case studies span three diverse technology areas that have elements relevant across ERETs: offshore wind (early deployment stage technology), marine (demonstration phase), bioenergy gasification to methane (predominantly demonstration phase, with critical subcomponents at the R&D phase). Collectively these technologies have relevance across the RETD countries.
- They involve a range of innovation activities, novel technology companies, public-private research projects, government innovation programmes, and intercompany interactions through clustering.
- They represent multiple countries and involve all types of stakeholders.
- The Carbon Trust has close relationships with these organisations making them easily contactable.

**Marine Current Turbines**

Marine Current Turbines (MCT) is a UK-based novel technology developer aiming to commercialise tidal current devices. By using a bottom-mounted horizontal-axis, the world’s first tidal current device supplying electricity to the grid has been built, and the development of a 3MW system for deeper waters has begun. MCT is considered to be the world leading tidal energy company having catalysed the tidal industry through installing the world’s first offshore tidal turbine in 2003 (Seaflow 300kW), and the world’s first commercial scale tidal turbine in 2008 (SeaGen S 1.2MW). MCT’s core team began working together in 1990 with the company formally founded in 1999. In 2012 it was acquired by Siemens, which had been a shareholder in MCT since 2010.

**Artemis Intelligent Power**

Artemis Intelligent Power is a UK-based technology developer set-up in 1994 to develop hydraulic systems for wave energy applications through the commercialisation of ‘Digital Displacement’ hydraulic power technology. Since then, the company has expanded and following corporate acquisition by Mitsubishi Heavy Industries in 2010, Artemis has scaled its Digital Displacement technology and entered the demonstration phase in 2013. It is now used in Mitsubishi’s 7MW SeaAngel offshore wind turbine where the technology has got to a stage where it challenges wind-turbine gearbox and direct-drive transmissions on both performance and cost. In 2013 Mitsubishi Heavy Industries and Vestas announced plans to form a new joint venture dedicated to business in offshore wind turbines, indicating an important step forward with Artemis technology continuing to play a key role in Mitsubishi Heavy Industries’ offshore wind technology development.

Furthermore, biomethane can be stored and transported to any country to supplement fossil fuel gas consumption.
BioSNG at Güssing

Güssing Renewable Energy – a small, electricity company set up by local high net worth individuals in Güssing, Austria – has a pioneering 8MW gasification plant with an overall conversion efficiency from woodchip to methane of approximately 85%. It is one of only a few places in the world used to test componentry that can turn biologically derived syngas into methane. It aims to provide a decentralised source of renewable energy, help the region become independent from fossil fuels, and develop the region into a centre of technology excellence and innovation.

Gasification technology was selected to supply heat and power to the local area as it could utilise existing local district heat networks ultimately aiming to create regional energy self-sufficiency and job creation. The technology was developed at Vienna University and uses woodchip feedstock in a novel steam based process producing very clean syngas, which can be used to test catalytic components.

Offshore Wind Accelerator

The Offshore Wind Accelerator is a public-private innovation programme funded by the UK government and European utilities with the aim of reducing the costs of offshore wind by 10% by 2015. Set up in the UK in 2008 with a c. £30mn dedicated demonstration fund for use between 2008 and 2014, it is a joint industry consortium involving eight utilities and the Carbon Trust with 77% (36GW) of the UK’s licenced capacity. Two-thirds of the funding comes from industry while one-third is funded by the UK Department of Energy and Climate Change (DECC). Individual funding utilities can either all collectively fund projects (known as ‘core projects’), or opt in to ‘discretionary projects’ funded by only some of the partner offshore wind accelerator organisations.

Bremerhaven

Bremerhaven is a region in Germany recognised as a world-leading cluster of innovative activity for wind power. Following an economic downturn, Bremerhaven’s council developed a scheme to modernise the pre-existing port infrastructure resulting in the development of a strong maritime technology base. In 2001, the Bremerhaven Economic Development Company (BIS) was able to establish a network of member organisations focussed on promoting wind power developments in Germany’s northwest region by building on the modernised infrastructure.

The Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) established one of its flagship wind technology development centres in Bremerhaven in 2009 targeting research into wind energy and the integration of renewable energies into supply networks. This signifies the provision of R&D along the entire value chain of wind turbine production promoting collaboration between academic and private investment. Fraunhofer IWES has one of the world’s largest testing halls – with the capacity to accommodate blades up to 90m in length – and runs a variety of projects.
1. Strategic innovation policy framework

- **Establish national and departmental goals** for innovation policy on ERETs, based on industrial, climate change and energy policy needs. Consider whether innovation is sought to enable deployment – for energy and climate policy – or to develop exportable technologies for value creation.

- **Prioritise technologies** based on their needs, barriers and business/deployment potential.

- **Inform this with** technology development roadmaps, energy system models, assessment of national competitive advantage and industry consultation to enable best practice strategies to develop.

- **Consistently communicate** long term technology priorities and innovation policy goals to ensure stable national market development.

- **Pursue a portfolio** of innovative technologies and value chain components to avoid technology lock-in to the most expensive technologies and to account for the natural occurrence of failed potential in innovation.

- **Leverage** the motives and activities of the private sector and international partner governments to best utilise available funds.

- **Complement innovation policy with industrial policy** when seeking to compete for market share. This is most applicable for large countries, e.g. USA and China. Smaller countries should prioritise key areas of national competitive advantage and collaborate to build on their collective strengths.
Overview

This section covers the fundamental elements identified in a well-designed strategic innovation framework: clear policy goals and technology priorities; the ability to leverage funds from the private sector and other countries; support for a portfolio of technologies and companies; and cross departmental coordination and alignment to integrate innovation policy with other key policy families – especially industrial and planning policy. Particular reflections are made for smaller countries that will inevitably struggle to compete with major countries such as the USA and China.

This section primarily uses desk based research as input. The UK and Canada are used as leading national policy examples of technology goal setting and prioritisation. Company activity from over one hundred years of technology evolution in multiple industries is used to show the need for a portfolio of support across multiple countries. The recent history of national solar PV evolution is then further used to underline the fragility of international markets and the need for clear strategies that integrate across multiple policy areas.

The section concludes by reflecting on how strategic, goal orientated policy should work to balance resources across the major families of innovation policy support, push and pull, which is then explored in detail in the subsequent chapter.
Goals

Clear goals are critical to develop an effective strategy for any area of policy. The multidisciplinary nature of innovation policy – relevant to multiple government departments and possible national priorities – makes it a challenge to establish clear goals to design policies and assess their success. Across the countries assessed in this report, innovation policy in ERETS was found to be relevant to four major areas of government policy with distinct but often overlapping goals:

- **Climate change**: decarbonisation through development of low-cost technologies
- **Energy**: deployment of a resilient, secure, modern energy system at lowest cost
- **Economic development**: creation of domestic jobs, exporting products and services, growth of firms accessing the global market, and generation of intellectual property
- **International development**: supporting and enabling developing countries to achieve a higher quality of life (not the focus of this study)

These policy agendas can be grouped into two distinct categories to support the development of internationally relevant recommendations for governments:

- Technology deployment for domestic and international **climate policy**, domestic **energy policy** and **international development**
- Technology development for economic value from exports and domestic job creation

This categorisation enables a simple subdivision of policy recommendations, provides clear metrics to measure progress and enables policy makers to evaluate decisions that influence the direction of innovation policy. This will inform effective technology prioritisation, a core element of a strategic policy framework for innovation support.
Prioritising technology innovations to optimise government spend and catalyse action

There are many possible innovations that countries could pursue to progress ERETs towards commercialisation. Countries with limited available resources should prioritise technologies to ensure that their support targets innovations that can most likely deliver maximum impact against national goals. Such a prioritisation can then be used to develop a successful innovation support strategy. Additionally, by clearly communicating established national innovation priorities to all market stakeholders, governments can create increased confidence for investment. The UK and Canada are found to have effective means of doing this, which offer practical lessons to other countries around the world. Insights from the method used by the UK to establish technology priorities are followed by insights from the use of technology road-mapping in Canada to best form and communicate technology priorities (and support strategies).

The UK’s ‘Technology Innovation Needs Assessments’

The UK has carried out Technology Innovation Needs Assessments (TINAs) for 11 high priority technology families: bioenergy; carbon capture and storage; domestic and non-domestic buildings; electricity networks and storage; heat; hydrogen for transport; industrial sector; marine energy, nuclear fission, and offshore wind. These TINAs identify high priority interventions for the UK government to pursue across multiple government departments\(^9\). As they have been developed and agreed by all UK government departments relevant to innovation, the TINAs establish interconnected goals ensuring a consistent focus for funding.

The level of detail achieved in the TINA process is shown in Text box 1. This was achieved using a method developed by the Carbon Trust that considered the following metrics:

- **Deployment**: the potential role of the technology in the UK’s energy system to 2050
- **Value from cost savings**: the value to the UK economy from reduced costs of technology through innovation, which depends on deployment levels and technological improvement
- **Export value**: value to the UK economy from green growth through exports
- **Market failures**: assessment of whether private sector actors are already sufficiently incentivised to deliver potential innovations
- **International progress**: the extent to which the UK can rely on other countries to deliver innovations specific to its conditions (e.g. offshore seabed type) or in required timeframes

These metrics are informed by several information sources that all countries should consider using to enable effective prioritisation. These include, national energy system models, detailed assessment of innovation technology innovation potential and assessments of national competitive advantage.

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\(^9\) Core members of Low Carbon Innovation Co-ordination Group (LCICG) who coordinate the TINAs: Carbon trust, Department for Business, Innovation & Skills (BIS), Department of Energy & climate Change (DECC), Energy Technologies Institute (ETI), Engineering and Physical Sciences Research Council (EPSRC), Scottish Enterprise, Scottish Government, Technology Strategy Board (TSB)
Figure 11 shows the ranking of UK competitive advantage across different low carbon technology families. A detailed industry consultation process was used to guide the development of findings to ensure that the conclusions were well informed and acceptable across government departments.

Figure 11 The competitive advantage of the UK for different sub areas assessed in the TINAs (unweighted)
Text box 1: Marine TINA: An example of UK prioritisation

Marine energy could play an important role in the UK’s energy profile by 2025 with the potential to deliver over 75TWh/year. Applying a consistent methodology allowed the TINAs to identify the UK’s competitive advantage for each of the technologies and the sub components with the largest potential for value creation. The results indicate the high competitive potential in marine energy, (see Figure 11):

- **Deployment:** The UK has a large natural resource of marine energy with more marine devices being tested in the UK than anywhere else in the world
- **Cost savings value:** Innovation to reduce costs and improve performance is critical if marine is to compete with OSW – success could save the energy system £2.8bn and contribute £1.4bn to GDP by 2050
- **Export value:** The UK is well positioned to capture potentially c.15% of global market share by 2050
- **Market failure:** The UK cannot rely on other countries to develop the technologies within the required timeframes to achieve the cost reductions needed, therefore public sector intervention is vital to leverage private sector investment and increase collaboration of RD&D activities
- **International progress:** Innovation support is needed across the whole value chain with sustained R&D investment for the deployment of first arrays to demonstrate proof of value and viability of future cost reductions by leveraging support to accelerate development of single device demonstration into first arrays. Additional R&D and collaboration in non-competitive sub componentry is needed to address the problems identified in first array deployment

Future development of marine technologies in the UK depends upon the ability to prove scalability and realistic cost reductions in the timeframe identified. To drive step-change cost reductions support will be required for evolution of component capabilities which will be relatively low cost compared to the large-scale demonstration programmes needed to accelerate deployment. The TINA provides a clear strategic outline assisting the leverage of funding for RD&D activities including:

- Expected investment by LCICG of up to £60mn between 2011 & 2015 for marine technology innovation projects
- A total of £38mn through DECC’s Marine Energy Array Deployment fund and the Scottish Government’s Marine Renewables Commercialisation Fund (MRCF), managed by the Carbon Trust to support the first marine energy arrays in the UK, and array-level infrastructure
- LCICG member support in the design, construction and installation of individual full scale devices including the ReDAPT project – an innovative 1MW buoyant tidal turbine tested by Alstom with funding from the ETI

The Marine TINA has prioritised technology areas based on their ability to deliver the greatest benefits to the UK based on national goals. On-going R&D is required to deliver the cost reduction potential of 50 to 75% and make marine energy a competitive contributor to the UK’s energy mix.
Strategic support in Canada

Canada has prioritised support for innovation in technologies such as marine energy using world leading technology roadmapping techniques (Marine Renewables Canada, 2011). Canada has prioritised marine energy as a technology area with great national potential due to industrial competitive advantage and future deployment potential, especially for tidal stream devices. Canada’s roadmapping was delivered by a consortium of government (the Federal Secretariat was Natural Resources Canada), industry and academia, to ensure it incorporates leading thinking and has broad stakeholder buy-in.

This consortium used roadmapping to develop an innovation support strategy for Canada, based on technology development potential while also assessing the potential economic opportunities from developing a functioning supply chain and best harnessing its marine relevant expertise (in electrical engineering, ocean engineering and marine operations). This strategy is presented in Figure 12, below.

Figure 12 Canada’s marine renewable energy technology and expertise deployment plan (Marine Renewables Canada, 2011)

This strategy provides three core elements to enable prioritised support: (i) a vision for the role of marine energy in Canada; (ii) pathways to deliver the vision, and (iii) critical enablers of the vision. The vision for marine energy is “for Canada to become a global leader in the delivery of clean wave, in-stream tidal, and river-current energy-production systems and technologies...that could provide 2GW power by 2030 – bringing in CA$2bn in annual economic value” (Marine Renewables Canada, 2011). The pathways identified for Canada to achieve this include, “developing critical technology components”, “ensuring Canada’s advantage in river current technologies” and defining marine solutions to meet utility needs” (ibid). The critical enablers identified are “technology incubators to accelerate innovation” and “full scale demonstration activities to showcase Canada’s engineering procurement and construction capabilities”.

Leveraging the funding of others to do more with less

Increased allocation of resources would inevitably assist innovation policy, however in many countries this will not be an easily implementable action. Policy makers can also seek to deliver more efficient innovation policy by leveraging the activity of two other actors: other governments and, the private sector to optimise programme design.

Private sector

Governments can access additional funds more efficiently by utilising co-funding from private actors. This has the additional benefit of ensuring that there is market demand for funded innovations; private sector support can be used as a ‘litmus test’ for assessing the effectiveness of programme design. Therefore policy frameworks and programme design should be optimised to encourage additional funding from the private sector earlier along the innovation chain. Such activities particularly need to address the higher risks of failure from high cost activities for technologies that are far from deployment and the associated revenue generation. Detailed policy recommendations of how to achieve this are overviewed in the following sections on push and pull policies, emphasising new, risk taking co-funding models in the pull section and public-private international consortia based large scale demonstration activities in the push section.

Other governments

Leveraging the spending of other governments is another way for countries to increase the overall impact of their funding activities, by achieving greater scale and by sharing lessons from multiple activities. While there are great potential benefits from this, it is nevertheless complicated and difficult to do well – especially due to the administrative complexity of such collaborations and the challenges in ensuring benefits are appropriately shared.

Increased international collaboration for innovation activities could be further pursued through the IEA’s implementing agreement platforms10, which already exist for technologies such as wind and solar (the IEA-RETD is also an IEA implementing agreement). The creation of a specific Implementing Agreement for innovation (represented by innovation enabling agencies in different countries) is also a possibility that should be considered as a cost-effective means to (i) share lessons about best practice in innovation policy and programme design; (ii) enable greater co-funding of joint innovation projects; and (iii) increase international understanding of the potential roles and needs for ERET commercialisation (refer to Chapter 5 for more detail).

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10 Implementing Agreements consist of 40 multilateral technology initiatives which, ‘provide flexible mechanisms for governments, industries and businesses, international and non-governmental organisations from IEA members and non-member countries to leverage resources and multiple results through research of energy technologies and related issues’.
Pursuing a portfolio of technologies and companies to compensate against naturally occurring dropouts

Countries need to pursue a suite of emerging technologies to maximise the chances of creating successful industries. This is especially important for countries seeking to use price subsidised renewable energy deployment to decarbonise their energy supplies, as in almost all countries, a range of sources will have to be harnessed to reliably and sustainably substitute current fossil fuel use.

Additionally, price subsidies provide greatest support to the technologies that are closest to market deployment, although these could be more expensive than subsequent generations of technology. A broader portfolio of support maximises the chances of achieving decarbonisation at lowest cost and ensuring that, in the long-term, lowest cost technologies are developed.

A broad portfolio of support can also help countries mitigate the impact of natural technology and company losses. The natural drop out of technology players across multiple US industries over the past 120 years is shown in Figure 13, below.

Figure 13 The dropout of firms in emerging industries as they form dominant designs. Left: The number of firms in various US industries. Right: an illustration of the formation of a dominant design in an example technology (Utterback & Suarez, 1993)
This process has been observed in both the solar PV sector, through multiple firm bankruptcies, and in the wind industry, through design consolidation. In the solar PV industry, international competition in fast evolving markets has seen over a hundred solar companies drop out of the market over recent years (further detail is provided in the following chapter). The consolidation of technology design in the wind industry is another way that this has been seen. An example of this from Germany is shown to the right, illustrating how wind turbine designs have consolidated over the past 20 years.

Similar processes should be expected in emerging technologies such as wave power, which has around 100 developer companies iterating independent designs across five different technology families. As the market develops for these technologies, dominant designs will emerge causing a dropout of market participants.

Governments must realise that this is a natural part of market dynamics that is occurring in tandem with rapid global market growth, the creation of new industries and reduced risk of not achieving decarbonisation at lowest cost.

“So, is cleantech failing? In a word, no. Rather, the sector has experienced a cycle of excitement followed by high (and often inflated) expectations, disillusionment, consolidation, and then stability as survivors pick up the pieces”

– Hasting-Simon (2014)

Governments therefore need to minimise the potential negative impacts of this by (i) pursuing a suite of technologies; (ii) supporting them with business development incubation support – detailed later in this chapter; and (iii) maintaining stable policy support to prevent unnecessary premature failure of newly established companies dependent on government support – detailed in Chapter 4.
Complementing innovation policy with industrial policy to compete for international market share

The recent history of PV underlines the need to complement innovation policy with industrial policy when countries are looking to develop world leading company presence. This section shows that scale is a core driver of industrial success in PV and discusses the implications this has for smaller countries.

Solar PV was chosen as the main example in this section because it was found that the recent history of the solar PV industry has made policy makers uncertain about future action. However, solar PV has particular features that make it different from other RETs. Importantly, the PV industry is particularly tradable internationally, due to its easily scalable modular components. This is less the case for large scale components like wind turbine blades, which are often most economically produced in factories relatively close to where they will be installed. Other significant value chain elements such as installation are also predominantly provided domestically. The ways that different policy types can be used to target different technology value chain elements, depending on their tradability and country needs is further explored in Chapter 2 on how push and pull policies can be focussed to maximise countries' chances of achieving their goals.

Case study: A short introductory overview to the history of PV

The recent history of PV is now overviewed to further illustrate the turbulence of international market dynamics and the great progress that can be achieved through successful innovation policy. Events in the PV market are further referred to in this chapter with regards to pairing industrial policy with innovation policy, and in Chapter 2 on balancing between policy types to best achieve national goals.

This paper identifies four main phases in the history of PV over the past forty years, building on the research of Peters (2012). These phases have seen PV transition from a technology at the R&D phase in the 1970’s and early 1980’s to a globally deployed technology competing with fossil fuel generation, in an advanced market stage of consolidation. Core elements of international PV market dynamics between 1995 and 2009 are visualised for the reader in Figure 15, below:

- **First boom (1974-1985):** Two exogenous oil price shocks in the 1970s led to a spike in public PV R&D funding (particularly in USA, Germany & Japan), and an intensification in innovation activities while pull policies played a minor role
- **Stagnation (1986-1994):** Funding stalled, innovation slowed and patent activity decreased as oil prices declined and the 1970s cost targets initiated by the German and U.S. policymakers were missed by an order magnitude. Gradual growth in demand at an average yearly rate of 16% partly encouraged by German federal FiTs, established in 1991

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11 Readers are referred to Peters (2012) for a more detailed overview of this history
- **Second boom (1995-2009):** Increase in global price support (market pull) policies, for example generous FiTs in many European countries, as increasing climate change concerns lead policy makers to regard renewable energy deployment as increasingly important. Cumulative global PV installations grew from ~c. 0.5 GW in 1994 to c. 23 GW in 2009 with a significant portion of this market captured by new Chinese firms.

- **Consolidation (2009-2014):** Continued growth in deployment leads to over 100 GW global installed capacity – 65% of which is in Europe. European companies, especially in Germany, continue to lose market share to China. Hundreds of PV firms drop out of the market place during a phase of consolidation initiated by rapid changes in price support policies, particularly FiTs in Europe, which have led to demand volatility and overcapacity. Turbulent markets and anti-dumping tariffs in the U.S. and Europe also result in multiple large firm bankruptcies in China. Despite significant negative publicity the overall trend in the PV industry is growth, accompanied by increasing investment.

Figure 15 Aspects of value creation in global PV industry in 1995 and 2009 as a % of total. Since 2009 Chinese manufacturers have continued to gain global market share, particularly at the expense of the German industry (Peters, 2012)
The importance of scale and the implications for industrial policy

Between 2005 and 2012 the market share of Chinese PV modules increased from less than 10% to over 60%, predominantly due to their lower prices (Goodrich et al., 2013). Lower labour costs and currency advantages are frequently attributed as the reason for China’s competitive advantage. However, recent analysis by the US National Renewable Energy Laboratory (NREL) indicates that manufacturing at scale and supply-chain development – both regional factors, rather than inherently specific to a country – have been the greatest contributing factors in enabling China’s success, see Figure 16. Further analysis of the innovation specific policies implemented by China are provided in Chapter 2 on balancing between push and pull.

![Figure 16 Analysis of the historical factors which have differentiated the markets in the U.S. and China (Adapted from, Goodrich et al., 2013)](image)

The ability to rapidly scale manufacturing output using considerably cheaper domestically available equipment in supportive regional business environments has beneficially promoted clustering of specialised production associated with material discounts. This has allowed manufacturing machines sold exclusively in China to be up to 90% cheaper than those available globally (Goodrich et al., 2013). That said, while Chinese high-end products have not yet gained market support, central state support aligning innovation and industrial policies is helping to promote collaboration between manufacturers and equipment wholesalers resulting in an increase in the product quality and capacities.

NREL’s analysis further indicates that large countries such as the USA can compete with Chinese production costs through manufacturing advanced technologies at scale, shown in Figure 17, overleaf.
Reflections on the challenges of competitive industrial scale for small countries

Industrial policies promoting manufacturing at scale are most achievable by the largest countries that are already market leaders and present the industrial skills necessary to become competitive across multiple value chain segments, such as USA, China and Germany. Smaller countries therefore have to act strategically to ensure that they do not waste national resources trying to outcompete other countries in manufacturing areas where they lack this advantage.

It is therefore recommended that smaller countries seeking to develop technology exporting capacity should pay particular attention to areas of national competitive advantage when establishing technology priorities and delivery plans for technologies that are highly tradable. These countries do not have to take a strong position in all of a technology’s value chain and can potentially just focus on the most relevant sub-components (e.g. offshore foundations in Norway or turbine blades in Denmark). This can be achieved by prioritising areas of national competence based on current renewable energy successes in parallel industries, which will allow smaller countries to exploit sections of the value chain, as Canada can be seen to be pursuing in marine energy, see Figure 18, below.
Smaller countries can also seek to maximise international competitiveness by collaborating with other countries when they have mutually beneficial technology strengths to develop globally competitive consortia (e.g. EU Horizon 2020 RD&D programmes typically have to be run by multiple nations to receive co-funding). Clustering of skills and activities is also recommended for smaller countries to best leverage supply chain benefits and pursue industrial support to complement innovation policies. Clustering is further discussed in Chapter 5 on enabling policies.

**Conclusions**

This section has clearly outlined the need for innovation policy to be strategically delivered to optimally use public funds. Many of the measures proposed (prioritisation, goal setting, coordination across government departments, and integration of policy agendas) are often relatively self-evident. Nevertheless, they are not found to be consistently implemented, to the detriment of national potential. Therefore these recommendations form an important foundation from which policy makers can design appropriate individual policies that have maximum chances of long term government support and effective results.

The balance of resources across the major policy families is a further key strategic issue for governments. This is addressed in the following section that analyses the benefits of different policy types and discusses possible ways to pursue balances of policy support aligned to strategic goals.
2. The balance and integration of push and pull

<table>
<thead>
<tr>
<th>All countries</th>
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<tr>
<td>• <strong>Understand the balance and trajectory</strong> of the main government cost levers: push and pull policies (see section iii – Method, for definitions)</td>
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<tr>
<td>• <strong>Understand national goals</strong> for innovation support policies: to develop national technology capacity for economic benefits or to deploy technologies</td>
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<th>Countries seeking to use innovation to enable technology deployment</th>
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<tr>
<td>• Use pull policy to enable initial market deployment tailored to national market conditions. In IEA-RETD countries this means building or strengthening existing market policies</td>
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<tr>
<td>• Complement with bespoke push policy to reduce cost of pull policy and enable necessary innovations to occur that would not be provided by other countries either to required timelines or specific to national conditions</td>
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<tr>
<th>Countries seeking to use innovation to enable technology development or create value</th>
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<tr>
<td>• Use push policy to progress technology towards commercialisation, focussing on technologies and sub-components that have significant potential for strong national competitive advantage or that are highly tradable</td>
</tr>
<tr>
<td>• Complement with bespoke domestic pull policy targeted at technologies that will be deployed domestically – especially elements of technology value chains that will likely be sourced locally, e.g. installation.</td>
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Overview

This chapter discusses the main cost levers for government innovation policy, categorised as ‘push’ and ‘pull’ support. Both policy families are required to achieve optimal technology development, but can also be used in different ways to pursue different national goals. This section starts with a discussion about the importance of understanding the balance of resources across these policy families – something that is commonly not monitored by governments, to the detriment of effective innovation policy development. Following this, a discussion of the typical balance of push and pull policies is provided in the context of progression along the innovation chain. Key technology factors are then explored to analyse what policy families could best achieve different goals. International technology tradability is shown to be an important factor in this, as is the ratio of technology ‘soft’ costs (for installation and maintenance etc.) versus ‘hard’ costs (primarily manufacturing of technology equipment).

A diverse range of international data on innovation policy and specific country case studies are used to reach conclusions in this section alongside expert opinion from leading reports. Analysis of the evolution of global innovation policy and resource allocation shows that typically the balance of innovation funding swings from primarily ‘push style’ RD&D support – prior to technology deployment – to pull support once deployment is achieved. Pull support then commonly becomes the dominant source of technology innovation funding. However, it is noted that this represents a generalised, global depiction of the balance of support; individual countries should therefore tailor policy, to support national objectives and technology priorities. This is highlighted by the example of PV in China, whereby pull support precedes greater levels of push support.

Country specific data is then used to further explore the technology specific factors mentioned above (international tradability, cost breakdown etc.). This analysis looks at the USA, Australia, Japan, Italy China and Germany in light of jobs, manufacturing presence and technology cost improvements and enables pragmatic conclusions to be determined about how push and pull policies can be combined and balanced to pursue national goals most effectively. A lack of more detailed data on individual policy impacts against their goals prevents a more rigorous analysis (a challenge consistently referenced in studies of innovation policy).

This chapter concludes by reflecting on idealised policy allocations for countries to develop and deploy technologies, drawing reference from the way Japan used PV demonstration projects to facilitate a manageable transition from R&D to price subsidised deployment, while up-skilling key national actors. This section then links to the following sections that look at best practice design of push, pull and enabling policies in turn, building on leading views as well as from historic lessons.
Understanding the current national balance and trajectory of push and pull support – governments’ main cost levers

Central to responsible governance is that policy makers understand the level of resource allocated to a policy goal. Three broad policy families are considered in this report: push, pull and enabling (see chapter iii – method for more details). The main cost levers for governments to consider are push and pull, through RD&D funding for push policies and price and investment support for pull policies. Governments should therefore understand the balance of spend across these policy families and their likely trajectory as deployment increases.

Initial dominance of R&D, followed by sporadic spikes in demonstration support

Renewable energy technologies at the pre-deployment stage are primarily supported by push type R&D mechanisms, with a significant time lag before deployment is enabled. This is reflected in the phasing of different innovation support policy families across OECD countries, as shown in Figure 19 overleaf. Note there is limited reporting of demonstration specific data, which is hence not shown. This is also because demonstration activities are frequently sporadic, unique events that constitute a small fraction of overall R&D spending, despite being frequently high cost, high impact programmes. In some cases, it is found that funding ratios of demonstration to R&D can approach one-to-one (e.g. for solar power in Japan over 2000-2010 – see Figure 20).
Renewables are estimated by the IEA to currently receive c. US$4bn per year for RD&D – around a quarter of global energy RD&D funding (see Figure 20, below). Over the past 30 years the majority of funding for energy RD&D has gone to nuclear power, which received more than 50% of total support in 1974, but now receives about 25% of support – the same as all renewable energy technologies combined.

Spikes in the level of government funding for energy RD&D, shown in Figure 20, have been driven in part by broader political issues relevant to energy security and climate change; total energy RD&D funding peaked in the late 70s and early 80s following oil price shocks, and funding has increased in recent years due to concerns around climate change.

Historically, the majority of renewable energy spending has been on solar (43%) while wind has received lower levels of continuous R&D spending over the same period and achieved a higher installed capacity (c. 283GW vs c. 100GW) (REN21, 2013). The greatest level of spend across all technologies has been provided by the USA, which has funded 39% of total RD&D spend since 1974. Forty percent of total renewable energy RD&D spend since 1974 has come from IEA-RETD member states.
Figure 20 Historic IEA country RD&D spend on renewable energy technologies against additional annual deployment increases for wind and solar power with the deployment line graph depicted on the right-hand axis (IEA, 2012)
Dominance of pull support once early deployment is achieved

Over the years as pull policies have been introduced, advanced technologies have reached a stage where they can be deployed with price support (e.g. FiTs) achieving technology cost reductions.

Pull policies are now the dominant source of funding for deployed technologies such as PV and wind (shown for PV in Japan, France, Germany and the USA in Figure 21, right). Future global pull policy support levels are projected to increase and rises in deployment will not offset gains from technology cost reductions. Laleman (2014) predicts that in Europe the current c. 40:1 pull to push ratio of spend for wind and solar could grow to c. 100:1 by 2020\textsuperscript{13} (Figure 22 below).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Figure21.png}
\caption{Distribution of the major policies to promote PV in four countries at the end of 2010. Adapted from Avril et al. (2012)}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Figure22.png}
\caption{The estimated ratio of pull to push policies in Europe for 2010 and 2020, based on a bottom up assessment of member states’ deployment and support levels (Laleman & Albrecht, 2014)}
\end{figure}

\textsuperscript{13} Laleman & Albrecht (2014) also estimates that push and pull were supported at around a 1:1 ratio back in 1998 in the US, growing to over 10:1 (pull: push) today.
Despite the importance of understanding this allocation of resources, stakeholders do not have a clear perspective on the balance of spend across these primary innovation levers, according to discussions and interviews with government representatives and country experts. Governments should therefore seek to better understand this balance. Strategies that governments could adopt to change these ratios and improve future support levels in light of their goals and pursued technologies, are discussed in Chapter 1.

**Contrast to China: ‘Pull-push-pull’**

Innovation support typically transitions from push, to support high risk RD&D activities, to increasing levels of pull once initial deployment is achieved. This is especially true at a global level as technologies evolve. Individual countries do not have to follow this pattern of technology support, as was found in the development of China’s PV industry over the late 1990’s to today. Over this period China initiated support through favourable province level investment support conditions (pull) that were harnessed by proactive entrepreneurs targeting export markets. In 2004 the Chinese government followed this support with a series of push policies that sought to develop competitive domestic technologies. In 2011 China established a nationwide FiT for PV. This pull-push-pull approach is detailed below. Importantly it is a strategy that can only be implemented when initial technology development has already been delivered.

1. **Pre 2003 - 2007 (Pull)**

Up to 2003 China’s initial steps towards its now dominant PV industry were taken through pull type investment support policies that encouraged domestic companies to supply foreign deployment. This was done at the province level, not by the central state government. The companies benefiting from these policies harnessed foreign technology licences and skilled diaspora (especially from the USA) to initiate a rapid expansion of factories that were able to produce simple PV modules at scale (de la Tour et al., 2011). This approach contrasts with the initial steps typically taken in other countries to support renewable technology development using R&D programmes (push).

Over 2004-2007 Chinese PV firms continued to target export opportunities as the European PV market continued to grow and the domestic market was not supported by central policy – wind power was favoured. Provincial governments however offered greater pull support, competing with one another to support start-ups, through tax breaks, access to low or free land, and direct grants (Deutch & Steinfeld, 2013). Additionally, policies were introduced to support construction of assembly factories, all of which resulted in rapid manufacturing scale-up.

2. **2008-2010 (New push policies)**

China built on the export strengths it developed using pull policies with a targeted programme of push policies that produced more advanced domestic technologies. It initiated public-private joint ventures, established public research institutes and funded multiple large-scale domestic RD&D programmes such as the demonstration focused 2009 ‘Golden Sun’ programme. This government support actively encouraged many of the larger Chinese manufacturers to increase spending on R&D.
China developed its own low cost PV technologies over this period, enabled by the policies above and the domestic reverse engineering and re-innovation of existing foreign technologies. The declining costs of domestic PV led to a surge in China’s domestic market and strengthened its advantage in new export opportunities (Long & Izuchukwu, 2013).

3. 2011- present (nationwide pull)

In 2011 a national FiT was introduced across China for PV. Domestic deployment was still at a relatively early stage compared to manufacturing potential. Export dependent Chinese firms were set back during this period as the global recession reduced international solar market size and anti-dumping tariffs were imposed on Chinese PV technologies by the U.S. This led to turbulent market dynamics and less competitive companies dropped out of the market place. As detailed in the chapter above, this process is naturally found in maturing markets as dominant designs start to emerge – greater numbers of firm bankruptcies were found in Europe, Japan and the USA.

In response to oversupply against domestic deployment levels, the Chinese State Council has further announced plans to: (i) encourage corporate mergers and acquisitions to consolidate the industry reducing overcapacity; (ii) strengthen coordination in the PV industry with mandatory certification for critical technology; (iii) actively encourage domestic deployment while also continuing to explore the international markets; (iv) improve pull support policy; and (v) prohibit local governments from supporting failing companies.
Balancing future push and pull policies in light of goals and technology characteristics

How push and pull policies can deliver different national goals

At a global level, the delivery of ERETs needs both push and pull policies, with RD&D activity being most crucial for technologies that have not yet entered early deployment and need high risk, large scale demonstration programmes (e.g. bioSNG and wave energy). However, each country does not have to deliver all policies for all technologies. It is recommended that countries take into consideration innovation goals, technology characteristics (e.g. international tradability) and an assessment of international progress against national technology needs when deciding whether push or pull policies should be the focus of future delivery and how to target these policies.

National technology goals broadly divide into two sets, each related to a series of policy goals:

- **Domestic deployment**, which is related to emissions reduction, energy security, system modernisation and jobs growth in system installation, operation and maintenance; and
- **Domestic industry development**, which is related primarily to manufacturing jobs and exports (this may also include internationally tradable skills and services), in turn driven by the country’s international competitiveness, manufacturing capabilities and supply chains

Deployment goals broadly align with a focus on pull policies. However, there is also scope for push policies that support domestic installation and maintenance expertise as well as technology adaptation to country-specific conditions.

Industry development goals typically align with both push and pull policies. Push policies, such as national RD&D programmes, are essential to the development of in-country ‘upstream’ manufacturing capacity and boosting export competitiveness. Pull policies support domestic markets, somewhat insulating national manufacturing capacity from foreign policy changes that have traditionally strained renewable export industries. However, pull policies are not strictly essential for internationally tradable technology development where strong and relatively stable pull policies exist in foreign markets.

Many countries will regard both technology deployment and development as goals of their innovation policies. These countries will primarily have concerns about balancing push and pull, seeking to best balance the long term costs of price based pull support with the individual project costs of discrete RD&D funding. There is no perfect mix identified for these countries, however the analysis of Avril et al., (2012), assessing the balance of renewable energy innovation support across the USA, France, Germany and Japan, leads to a logical conclusion for countries to consider:
“to our point of view a recommended policy would be starting, as Japan did with PV, with a focus on (i) demonstration programmes, to control the PV development (which systems, where, how many) in the first phase when the technology is not mature; and (ii) strong R&D support in order to improve the technologies. In a second phase when the technology is more mature, feed in tariffs and other demand pull policies are relevant to boost the penetration in the market. In this phase a sufficient R&D level should be proceeded to maintain an adequate equilibrium”

– (Avril et al., 2012)

This approach can be seen in Canada’s marine renewable energy technology and expertise deployment plan (visualised in Figure 12 in chapter 1) to initiate domestic construction and enhance national reputation, followed by targeted exports of technology systems and expertise to develop profitable businesses. International build out and domestic market expansion would then be pursued to lower unit costs and increase market competitiveness (Marine Renewables Canada, 2011).

However, for some countries, innovation policy will be pursued to deliver solely technology deployment (e.g. price support to initiate PV uptake in Italy – detailed later in this section) or with a focus on technology development (e.g. wind power in the USA and Denmark – detailed in Chapter 3). A focus on technology development and value extraction alone has the potential for concerning consequences. For technologies that are at an early deployment phase, such as offshore wind, it is possible that countries collectively could reduce commitments to national pull policies and focus on push policies in pursuit of export industry creation. This could lead to insufficient global pull support, especially in technologies with high upstream value or high levels of international tradability, which could cause insufficient progress of ERETs against global targets leaving countries exposed to the policy trajectory of other nations. International joint agreements on pull activities could ensure that countries collectively maintain market activity; though based on historical trends, it is recognised that reaching such agreements would be very challenging.

Nevertheless, there are logical reasons why certain goals will be the focus of national innovation policies and they must be considered to develop and focus national policy. The ways that push and pull policies can be balanced to achieve these national goals, and be complemented by industrial policy, is presented in Figure 23 below. The underlying analysis for this figure is then provided in the rest of this chapter, starting with insights for countries seeking to use innovation to enable technology deployment and followed by countries seeking to use innovation to enable technology development.
Figure 23 Push and pull policies need to be balanced with national goals and complimented with industrial policies

Countries seeking to use innovation to enable technology deployment

**High level views on policy focus**

The PV case studies shown in Figure 24 illustrate that it is possible to achieve significant technology deployment using a primarily pull policy focus (i.e. market stimulation) with minimal investment in push policies (i.e. R&D and demonstration). This approach is of course, reliant on the availability of internationally tradable technology imports at a post-demonstration phase. These PV case studies also highlight that national RD&D programmes (i.e. push policies) are essential to the development of national manufacturing production capacity, which will be discussed in further detail later in this chapter.

Consequently for countries interested only in deploying emerging renewable technologies, pull policy measures can often be effective on their own once the technology is ready for market deployment. However, it should also be noted that some push policy measures will typically be required to minimise pull policy costs and support deployment timelines. This is particularly the case where unique national characteristics necessitate the development of country specific technology features or installation and operational know-how (e.g. in demanding marine conditions for offshore wind and marine energy).
Domestic deployment – a crucial element of national cost reductions

Technology “soft costs” such as installation, transaction and other balance-of-system costs are significantly reduced as domestic deployment levels increase. This trend is related to domestic learning behaviour linked to the development of local expertise, supply chains and economies of scale as well as labour and commercial efficiencies. Comparing installed capacity increases with declining costs indicates that deployment is a crucial driver for achieving significant reductions in regional installation costs, see Figure 25. It is also worth noting that soft costs have become proportionally more important for PV as progress has been made on reducing hard technology costs that were initially high while soft costs were effectively ignored. Therefore, consistent and sustained increases in national deployment levels are an important aspect of national renewable energy system cost reductions. Relying solely on international deployment and economies of scale will not address these significant domestic components of system cost.

14 Data was interpolated for the USA between 2003-2008 (for R&D spending), 2004-2006 & 2006-2008 (for demo spending), 2004-2006 & 2010-2011 (for market stimulation). All spending data was interpolated for Australia between 2004-2006.
Figure 25 The impact of national deployment levels on historical residential PV system prices in Japan, Germany, China and the USA (EPI, 2013; BP, 2013; IEA, 2002-2012)

The impact of push versus pull support on jobs growth: manufacturing versus deployment

In recent years, the downstream employment opportunities for both wind and solar PV have outperformed those available in upstream manufacturing for the case studies, shown in Figure 26 below. This is especially true for small scale solar PV, owing to the distributed nature of installations for this technology.

For countries pursuing a focus on renewable job growth, this balance is of particular importance, and the role of technology deployment in developing local jobs growth should not be underestimated, especially in the case of emerging technologies with significant downstream requirements and distributed installation characteristics.
Countries seeking to use innovation to enable technology and industry development

The role of push R&D funding and the development of national manufacturing capacity

Since there is “no evidence that domestic technology-push policies foster innovative output outside of national borders” (Peters, 2012), national R&D programmes are essential to the development of in-country manufacturing capacity and global technology availability.

However, as illustrated in Figure 27, early stage spending on R&D does not necessarily translate into a strong national technology manufacturing base (e.g. USA versus China, Japan and Germany). Existing national competencies, supply chains and manufacturing capabilities also play a crucial role. Therefore, when defining rational R&D priorities for emerging renewable energy technologies, consideration should be given to existing national competencies, supply chains, research capabilities, international tradability and resource availability.

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15 Total manufacturing and total other jobs in Japan were interpolated for 2004-2005, and 2008. Total manufacturing jobs in the USA were interpolated from 2005 to 2009, total other jobs interpolated for 2005. No information is available on the number of jobs displaced in other sectors by the renewable jobs shown here.
Implications of technology “tradability” for national industry development strategies

The examples of more mature renewable energy technologies, such as wind and solar PV, have demonstrated that highly “tradable” technologies can be supported by foreign pull policy funding alone, or in addition to national pull funding. In this situation the higher international tradability of solar PV panels creates greater import and export opportunities relative to the less tradable technology components found in wind (see in Figure 28).
As a consequence, several PV manufacturing countries have been able to rely heavily on foreign pull policies to support national manufacturing industry development. For example, domestic manufacturing capacity in Japan was effectively supported by foreign demand for much of the 2000’s (Figure 29 below). Similarly, China has developed a large PV manufacturing industry based on foreign market demand driven largely by FiT pull policies.

In the case of solar PV, there is “no indication that market growth induced by domestic demand-pull policies leads to more national innovative output than market growth induced by foreign demand-pull policies” (Peters, 2012). However, manufacturing countries relying on a high proportion of foreign exports to support their domestic industry are exposed to shifts in foreign policies. The pitfalls of this approach have been exemplified by recent changes to the PV industry (e.g. following the FiT cuts in Germany, UK, Italy and Spain).
In summary, emerging technologies that are more easily traded internationally offer greater market opportunities for national innovative output and can be supported by both domestic and foreign demand-pull funding. However, countries that rely primarily on foreign demand-pull policies to support export markets are subject to detrimental and often rapid changes in foreign policies. Conversely, technologies with low tradability offer some shelter to local manufacturers from cheaper foreign competition, but will require support by local pull policies in the early stages of development.

Conclusions

This section has collected leading evidence from multiple sources about the potential balances of government funding across the key innovation support policy families (push and pull). It has revealed how at a global level this balance typically starts out as being predominantly push style support and transitions over to pull support as technologies reach early deployment. It is shown that not all countries follow the same path though, using the example of China’s approach to PV support as an example Best practice use of push and pull support was then shown to be dependent on national goals (to develop or deploy technologies) and several technology specific factors (such as international tradability).

Recommendations for exact ratios for the use of these policies are not determinable from current data sets. It is recommended that future work should be undertaken to gather more consistent data for detailed analysis of what has best achieved individual policy goals.

The following sections continue by going into further detail on the individual policy families covered in this report – including enabling policies, which use less resources than push and pull, but are still an important part of an effective policy set. These sections use historic policy analysis and significant expert input, providing policy makers with actionable recommendations on what to do now.
3. Push policy delivery

- **Target push policies at barriers** that prevent the private sector from delivering required activities
- **Use novel programme designs to address these barriers** and to improve private sector risk-adjusted returns – these can enable public:private funding leverage ratios of over 1:10
- **Achieve improved collaboration through market consultation and analysis of common stakeholder motives.** It is generally easier to achieve with technology users, though they have limited funding for RD&D. Technology developers can be better incentivised to collaborate on areas of non-competition, such as shared infrastructure, and if the programme provides greater exposure to technology users
- **Upscale government activity on large scale demonstration programmes,** seeking to de-risk private sector investments and leverage international partners – focus these programmes on reliability over cost reductions and maintain support for second round demonstrators, that still have high risks
- **Improve grant design** through simplifying the application process, preventing IP mothballing and by enabling longer term provision of funding through monitoring criteria
- **Develop improved programme monitoring criteria** to also enable greater comparability of innovation activities to improve analysis of their relative successes
Overview

Technology push policies are those that directly fund technology development to stimulate supply. There are many possible ways to design and deliver such policies, and based on a review of international approaches, can be broadly categorised as research, development and demonstration (RD&D) support for universities and private sector actors. Such approaches are disparate, diverse and generally designed bespoke to specific market circumstances, making direct numeric comparisons challenging.

A lack of comparable data across different policy instruments reveals significant need for increased international coordination of programme reporting and a necessity to establish clearer metrics for programme success. This in turn would better motivate and guide innovation programme managers, leading to greater returns on public spending. Conclusions on best practice push policy are made by drawing on the recent evolution of the wind power market, the Carbon Trust’s historic activities, five technology in transition cases and leading interviewee insights (see Section iii – Method, for a detailed overview). The key elements assessed in the recent history of the wind market are overviewed in Text box 2, overleaf.

The conclusions covered in this section start by recommending that future push programme designs focus on addressing critical market barriers that prevent the private sector from delivering early stage RD&D activities. Novel programmes which achieve this, by de-risking private sector funding and achieving public: private funding leverage ratios of over 1:10, are overviewed. Collaboration is shown to be critical to achieving success from such programmes. This is found to be best achieved through detailed consultation with relevant bodies to target the shared motives of different actors. Areas of non-competition, such as shared infrastructure, are identified as priority areas for competitors to collaborate on. Following this, demonstration programmes are highlighted, owing to their catalytic potential and popularity with interviewees. It is recommended that demonstration programme activities are up-scaled, leveraging international partners. Finally, suggested improvements to grant design and monitoring are made which could simplify their use, better motivate programme participants to develop needed innovations, and enable improved innovation policy analysis in the future.
**Text box 2: A case study on Danish strength in wind power**

The development of the wind industry offers useful insights into best practice push policy. This technology has transitioned from an R&D phase in the early 1970’s to a fully commercial technology heavily deployed in current markets. Denmark and the USA have been identified as largely driving the industry forward during its emerging stages. The countries adopted different innovation support approaches, which provide useful insights into best practice push policy.

Between 1970-2000 Denmark entered the wind energy market place which was initially dominated by the USA, and gained significant advantage – capturing 60-80% of global value (see Figure 30, below). This was achieved despite the USA spending on average nine times that of Denmark on wind R&D (IEA, 2014).

![Figure 30 Relative share of global wind market by country, 1970-2012 (IEA, 2014)](image)

The analysis of Vestergaard et al., (2004) and Harborne and Hendry (2009), identifies three actions which enabled Denmark to achieve this advantage: (i) the role of demonstrator programmes; (ii) the focus of national push policy programmes on reliability; and (iii) the management of collaboration and competition.

It should be noted that the eventual decline of Denmark’s overall market share in the wind industry is attributed to international market factors, as more countries seek to enter the market. Importantly, during the late 2000’s Denmark’s wind industry continued to maintain strong growth and Vestas Wind Systems A/S, the leading Danish manufacturer, produced 13% of global wind turbines in 2011 despite the fact that Denmark was not among the top 10 countries for installed wind capacity.
Existing market barriers to innovation

Barriers along the innovation chain prevent optimal market behaviour and hinder private sector investment, justifying public sector intervention for technology like renewables which provide long-term public benefits. The current innovation system is not well suited to the radical innovation required to promote beneficial change in the renewable technology sector.

The Carbon Trust has carried out recent analysis on market barriers, categorising eight key barriers to innovation, listed below. Future push style innovation support programmes should acknowledge these barriers and be designed to address them. This requires programme designers to have a deep understanding of technology market trends:

1. **Technology investors are unwilling to invest.** Investors see too much risk in a technology’s future market and are unwilling to invest without risk mitigation measures, or greater confidence in the technology area.

2. **Supply chain not fully engaging with innovators.** Suppliers of components and integrators, and installers of devices do not have enough confidence in a technology to develop their offerings to match innovators’ needs.

3. **Organisations lack skills and resources to grow.** Without confidence in future market prospects, the right business or technology skills do not migrate towards smaller and early stage organisations, impeding growth.

4. **Insufficient (hard to capture) returns to RD&D.** Insufficient returns to RD&D is applied to the technology areas where the future economic prospects are uncertain, due to lack of clarity about future energy policy, spillover risks, etc.

5. **Lack of co-ordination amongst players.** The absence of common purpose means that players within a sector may not be aware of each other and so opportunities for complementary work are missed.

6. **Key component technologies are missing.** The absence of an overall framework means that key pieces of the picture may be missing whilst too much focus is applied to other areas.

7. **Enabling infrastructure and facilities are unavailable.** Physical infrastructure may be necessary for the development, testing or deployment of a technology, but far too expensive for a single organisation to build.

8. **Existing regulations obstruct testing and demonstration.** Regulations created for other purposes (e.g. health and environmental safety) make it unnecessarily difficult to test or demonstrate low carbon technologies.
Targeting barriers with novel programme designs

Bespoke novel programme designs can be used to address market barriers and channel funds more effectively to increase the likelihood of leveraging private finance. Select push style programmes by the Carbon Trust are illustrated below, in Table 3. These programmes were developed by the Carbon Trust following an expert study of technology status and national capabilities.

Table 3 Push style programmes operated by the Carbon Trust

<table>
<thead>
<tr>
<th>Programme</th>
<th>Overview</th>
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<tbody>
<tr>
<td>Directed research accelerators Pre-demonstration focus</td>
<td>• Proactively support research in promising low carbon technology areas (e.g. Pyrolysis Challenge). These programmes typically pull together different innovators doing different elements of research to enhance their delivery. They can be initiated by proposing a challenge to research organisations and offering funding to the most promising concepts • Primarily addresses a lack of co-ordination amongst players and missing key component technologies • Typical public : private funding leverage achieved 1:2</td>
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<tr>
<td>Technology accelerators Demonstration - Early deployment technologies</td>
<td>• Form consortia of industry players to accelerate demonstration and deployment of key technologies (e.g. Offshore Wind Accelerator) • Primarily addresses barriers caused by technology funders being unwilling to invest, insufficient (hard to capture) returns to RD&amp;D and unavailable enabling infrastructure and facilities • Typical public : private funding leverage achieved 1:2</td>
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<tr>
<td>Enterprises Pre-demonstration to early deployment</td>
<td>• Create and develop commercial vehicles (enterprises) in high potential markets – e.g. through the Carbon Trust’s Entrepreneur’s Fast Track programme. This programme can often be used to commercialise innovations from directed research accelerators and is frequently paired with incubation support • Primarily addresses barriers that are due to organisations lacking the skills and resources to grow and the supply chain not fully engaging with innovators • Typical public : private funding leverage achieved 1:10</td>
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</table>
The Entrepreneurs Fast Track programme, overviewed above, supports the commercialisation of start-up companies, by providing them with access to skills and training. Through this programme the Carbon Trust has assessed over 3,500 low carbon start-up companies and supported over 350 with incubation support and research grants, catalysing follow-on investment of $225mn (Carbon Trust, 2013). By helping to build and strengthen novel technology companies this programme was designed to support a structure inherently seeking additional private sector finance – maximising the leverage opportunity.

The Carbon Trust’s Offshore Wind Accelerator is a £45mn research programme seeking to reduce the costs of offshore wind by 10%. This programme addresses the common barriers to investment overviewed above by establishing a co-funding consortium across nine European utilities and the UK’s Department of Energy and Climate Change (DECC). These private sector funders are natural competitors but are incentivised to co-fund RD&D as the scheme pursues goals common to all of them and which individually, they would be unable to afford. The ways that this scheme achieved collaboration are further explored in the following section, alongside other case studies.

"Offshore wind needs 'lumpy investments' beyond reach of small balance sheets and therefore requires increased large scale government activity"

– Technology developer

Optimising collaboration to unlock national potential

Cross-market collaboration is critical to enable early stage, high risk technologies to reach commercialisation – as exemplified by wind industry developments in Denmark and the USA shown in Text box 3, below. However, collaboration can be a challenge to deliver, especially closer to commercialisation, where many barriers prevent action that can unlock crucial innovations – e.g. due to lack of coordination among players when technology developers have to compete strongly for market share, necessitating strong IP protection. Policy makers have to design nationally bespoke programmes to achieve the challenging but rewarding goal of cross sector collaboration.

Below the collaborative relationships across the different technology in transition stakeholders are overviewed, showing various ways to enable and deliver collaboration, with each stakeholder type discussed in turn (technology developers, users, funders and enablers). This is followed by a deeper assessment of the Carbon Trust’s Offshore Wind Accelerator programme that seeks to enable industry co-funding and collaboration to deliver commonly needed innovations. Common across these examples, collaboration is pursued by targeting areas of non-competition such as mutually beneficial infrastructure – especially for technology developers, who struggle to collaborate. It is generally easier to achieve with technology users, though they have limited funding for RD&D.
Competition and collaboration in the technology in transition case studies

In the technology transition case studies (overviewed in the method section) collaboration is consistently identified as a fundamental success factor – for both the innovation programme case studies and the novel technology company case studies.

The roles of the different types of actors involved in these activities are summarised in Table 4, categorised as technology developers, technology users, technology enablers and funders. The motives of each of these stakeholder groups to collaborate is then also analysed in the following sub sections. A more detailed overview of the Carbon Trust’s Offshore Wind accelerator is provided after that, for further insights.

A key insight, found from this assessment of motives, is that it is generally easier to achieve collaboration with technology users, though they have limited funding for RD&D. Technology developers can be better incentivised to collaborate if the programme provides greater exposure to technology users. Collaborative programmes are easiest to create through staged processes that start by agreeing common aims and build to larger scale activities once successful partnerships have been formed.

Text box 3: Competition and collaboration in Denmark and the USA

Denmark and the USA took opposite approaches to collaboration in developing the wind industry: Danish developers collaborated while American developers competed. This difference is regarded as critical in enabling Danish developers to capture the majority of the global wind market within just a few years at a much lower total cost (Sovacool & Sawin, 2010).

Denmark focussed on enabling collaboration between the actors in the wind energy industry, where actors were incentivised to share useful lessons. In contrast, American developers were much more competitive and secretive, in some cases not even allowing developer employees to speak with other engineers about new designs in order to protect IP. Collaboration in Denmark allowed for co-development of designs within the industry. The wind industry in Denmark also worked more closely with government, such that standards and understanding within government developed alongside industry. The American example saw more lobbying of government to set regulations to meet their needs, with less intra-industrial collaboration (Vestergaard et al., 2004).
The competition/collaboration dynamics across these four different categories of stakeholder are analysed in further detail as follows.

**Technology developers**

Technology developers – whether small novel developers or large corporates – fundamentally invest in innovation out of a desire to develop a better product to earn increased revenue. They want exposure to technology users who may be future clients and are able to provide insight into market requirements to better inform research. Additionally, they are keen to retain IP as this maintains their competitive advantage over other developers. At early stages, novel developers also have an interest in seeing their competitors survive as this increases confidence in the sector as a whole and increases the likelihood of a future market, which encourages funders to invest. Universities are keen to access the opportunity to see their research turned into products and companies.

“We need to see strong competitors in this sector. One technology saying that tidal is the way to go – with no real competitors – is not a market. Competitors with more products would be good for the market.”

– Technology Developer

**Technology users**

Technology users are incentivised by the potential for early access to new technologies and the ability to influence early stage innovation. At their peak in 2008, the top 20 European utilities had a collective market capitalisation of €1 trillion, but significant losses, amounting to approximately €500bn in 5 years, have left them cautious about investing in R&D (The Economist, 2013). As a result, most users would prefer to have a suite of cheap, low-risk options presented to them. They are not motivated by acquiring intellectual property, as they are more likely to licence a technology.

“Uncertainty is restricting investment - particularly damaging at a time when utilities have significant financial challenges”

– Technology user
**Funders**

Funders are motivated by the promise of a financial return on investment and are acutely aware of possible risks. Funders in early stage RETs broadly divide into two types – venture capital and corporate R&D investors. Venture capital is motivated by the desire for a very large return from some investments (enough to mitigate small returns or failures from other investments), and they require it quickly, typically within five to ten years, and with a very clear exit strategy. Corporate investors – especially where they are also technology developers – are motivated by strategic interests that will ultimately enable them to develop better products to outcompete their rivals. When strategic interests align, they are able to provide significant funding for a long period of time, however there is a risk that novel technologies will be abandoned or mothballed if those strategic interests change.

“A big challenge of RET's is that they are very capital intensive, which leads to an enormous risk premium”

– Technology funder

**Enablers**

Delivery bodies facilitating government interactions with the private sector are motivated by the success of individual programmes or a technology as a whole. They are interested in encouraging a number of different stakeholders to engage productively, and are not motivated by high financial return, but hope for the wider success of a sector rather than any one actor within it. Further detail on enabling bodies in given in section 5.

“It is crucial for governments to have a good policy framework in place”

– Technology enabler
Table 4 The relative role and interaction between stakeholders in this reports deep dive case studies

<table>
<thead>
<tr>
<th>Technology developer</th>
<th>Offshore Wind Accelerator (OWA)</th>
<th>Güssing</th>
<th>Bremerhaven</th>
<th>Marine Current Turbines</th>
<th>Artemis Intelligent Power</th>
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<tbody>
<tr>
<td>Developers are <strong>funded</strong> by the OWA to progress innovative ideas - they retain IP they create</td>
<td>• Multiple organisations work to collaborate on technology development: Repotech (SME); GE Jenbacher and the Technical University of Vienna</td>
<td>• Large number of OSW developers are active (private and academic)</td>
<td>• Acquired by Siemens</td>
<td>• Acquired by Mitsubishi Heavy Industries Europe - now <strong>funded</strong> technology development</td>
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<td>None of the major funders (technology users) are developers, which avoids IP constraints for novel technology companies</td>
<td>• A small amount of <strong>funding</strong> from external developers paying to test technology using available syngas</td>
<td>• Major corporates have <strong>funded</strong> technology development</td>
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<td>• University of Edinburgh provided access to test facilities</td>
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<td>• RWE npower developing array with MCT</td>
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<td>Technology user</td>
<td>The OWA is <strong>funded</strong> by a consortium of nine European utilities which provide 2/3 of the funding and control the programmes research direction</td>
<td><strong>Funding</strong> and project leadership from the local utility – Güssing Renewable Energy – which generates revenues from heat and electricity sales locally</td>
<td>Primarily technology developers are active</td>
<td>Technology development <strong>funded</strong> by licencing sales to users (sometimes in tangential sectors): BMW, Sauer Danfoss, Bosch Rexroth, Vestas</td>
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<td>Interested in having better technology on the market – not owing it</td>
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<td>Technology enablers</td>
<td>Established and managed by the Carbon Trust (CT)</td>
<td><strong>Provide funding</strong> through grants (from the Austrian government and the EU)</td>
<td><strong>Early funding</strong> provided through innovation grants - UK &amp; EU</td>
<td><strong>Early funding</strong> provided through Innovation grants - UK &amp; EU</td>
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<td>CT responsible for sourcing 1/3 of the <strong>funding</strong> for the facility through DECC</td>
<td>Established a ‘competency centre’ to facilitate collaboration between different technology developers and potential users</td>
<td><strong>Funding</strong> provided ongoing business support</td>
<td>UKTI facilitated relationships between Artemis and MHIE</td>
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<td>Existence of publicly <strong>funded</strong> test sites</td>
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<td>Carbon Trust helped to incubate the business</td>
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<td>External funders</td>
<td>External private finance has been avoided</td>
<td><strong>Actively funding</strong> local novel technology companies and the local utility</td>
<td><strong>Has also been funded</strong> by Venture Capital support and high net worth individuals</td>
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Assessment of the Offshore Wind Accelerator – An example of non-competitive collaboration

The Offshore Wind Accelerator (OWA) offers particular insights into how policy frameworks can best incentivise market stakeholders to engage in non-competitive collaboration. This innovation programme model follows a unique model, co-funded by a consortium of nine European utilities which provide two-thirds of the funding, with the remaining being provided by the UK’s Department of Energy and Climate Change (DECC). The OWA targets 10% cost reductions in offshore wind technology and is on track to deliver that. The OWA does not work with the venture capital community or banks to provide demonstration funding, but helps innovative technology developers gain credibility so they can attract private funding themselves.

Lessons for establishing similar programmes can be drawn from the consultation process used to achieve collaboration and from the incentives used in the programme to maximise benefits all parties involved.

Achieving collaboration through extensive consultation

The OWA was created following extensive consultation with actors across the offshore wind industry. This initial consultation resulted in a research paper called ‘Offshore Wind: Big Challenge, Big Opportunity’ (Carbon Trust, 2008) that detailed the potential for the technology in the UK and presented the required next steps from UK policy makers to unlock the potential of the private sector. Following this guiding document, continued consultation was carried out with senior people in government and the UK utilities. An acceptable model was achieved by developing the IP terms overviewed below, establishing a family of research activities which all partner utilities would fund (referred to as ‘common R&D’), and by defining another set of activities that select sub-sets of utilities could optionally fund (referred as ‘discretionary R&D’). The results of discretionary R&D are only available to the partners that funded that activity.

The Carbon Trust manages this programme. As an independent, not-for-profit organisation, it is trusted to facilitate commercial relationships and to appropriately manage sensitive intellectual property. It was also able to carry out the programme facilitation within its mandate to, ‘accelerate the transition to the low carbon economy’.

Maximising incentives to collaborate through exposure to utilities and allowing technology developers IP

Credibility is achieved by providing technology developers with exposure to technology users, their future potential clients. Technology developers are funded by the programme to progress innovative ideas and they retain any IP they create. None of the major funders are technology developers, which avoids conflicts for novel technology companies for whom intellectual property may be of key commercial importance.
“Collaboration was enabled as no IP was taken out (due to fear of investing in it and it being of no use if a large company chose to take it)"

– Technology enabler

Technology users have a common motive to collaborate in the UK as they are all deploying under government-coordinated licensing rounds and are guaranteed sales once they are generating power. Technology users under this policy framework have a common incentive to ensure that the market develops towards a cost competitive source of energy. The nine utilities are most interested in having better technology on the market – they have no interest in owning it.

However, interviewees indicated that good results cannot be guaranteed if companies are forced to collaborate. Based on experience from the OWA programme, there appears to be a sentiment across Europe that developers only want to collaborate at very early stages where risks are highest. When a technology is closest to market – and therefore sensitive – corporates feel less inclined to collaborate. Furthermore, programmatic collaboration can present challenges as each individual developer may attempt to steer the programme’s development in their favour.

“Governments should encourage co-investment in non-competitive mutual needs to get technologies off the ground (e.g. installation vessels)”

– Technology enabler

**The importance of demonstration programmes**

Demonstration activities were highlighted by interviewees as a critical area for government funds, owing to the risk profile of such activities. Additionally, they have been critical across the entire history of wind power, to enable it to progress to market – see Text box 4.

To unlock the catalytic effect of demonstrator programmes, governments should increase funding support to them to improve risk adjusted returns for private sector actors. Best practice early stage demonstrators should focus on reliability, not just lowest costs. Funding support is not just needed for first of a kind demonstrators, as the risk profiles of second generation demonstrations (showing scaled commercial operation, in the transition to early deployment) are not significantly improved, but often the scale of operation has significantly increased.
Demonstration programmes are a catalytic use of public funds

Interviewees consulted for this report consistently commented that they saw great need and benefit from large government funded demonstration programmes, owing to: the limited ability of private sector actors able to fund the technology risks independently; and the catalytic ability to transition emerging renewable energy technologies along the innovation chain. Although specific reference was made to marine and offshore wind technology as shown in the select quotes below, these views are also relevant to other ERETs.

"Demonstrator programmes are especially relevant to emerging technologies”

– Technology funder

"Renewable technologies like offshore wind need 'lumpy investments' beyond reach of small balance sheets and therefore requires increased large scale government activity"

– Technology developer

In the tidal market government funding demonstration programmes were shown to have a catalytic effect that could not have been achieved without public support to fund technology development.

"Marine Current Turbine’s [MCT] demonstration programme shifted the market perspective on leading marine technologies from wave to tidal - this was enabled most strongly by public grants, which leveraged private sector spend, creating market credibility”

– Technology developer

Focus on reliability, not lowest cost, for early stage demonstrators

A focus on reliability does not only increase nation-wide opportunities to gain skills and enable learning by doing from RD&D activities, it also lowers the risk of novel technology companies failing, by reducing early stage technology setbacks. Small novel technology developers identified this as a critical risk and recommended that funding structures should be designed to be sufficiently flexible to accommodate potential setbacks, so that they can continue the journey to reliable demonstration.

“We were able to survive as we had access to ‘emergency reserves’ (c.20%) insulating us against critical setbacks. Other innovators will have stumbled here and missed out on potential progress”

– Technology enabler
Government support is not just for first of a kind demonstrators

Technology users also commented that government support is not only catalytic for first of its kind demonstration programmes but also to continue initial technology scale up and continually de-risk technologies.

"There is a crucial need for large amounts of funding for second of a kind demonstration projects, going from the first device, to 'the first 50 devices. This second generation still has very high risks and comparable unit costs"

– Technology user
**Text box 4: The catalytic historic role of demonstrator programmes in the history of wind power**

Key demonstration landmarks are presented below in Figure 31, spanning from the first prototype 12kW turbine in the USA to the first offshore floating turbine deployed off the Norwegian coast.

Figure 31 A timeline summary of key landmarks in the history of wind power, including prominent demonstration activities

Denmark’s use of demonstrator programmes enabled the development of national technological skills and capacity improvements. This is identified as one of the crucial factors assisting Denmark to outcompete the USA during the 1970’s, 1980’s and 1990’s, where there were ten times the number of wind demonstration projects in Europe over 1970-2004 compared with the USA, see Figure 32 below (Harborne & Hendry, 2009).

Figure 32 Number of test fields and demonstrations of wind turbines in the EU and the USA, per 5 year period (Harborne & Hendry, 2009)
Grant design, policy monitoring and assessment metrics

RD&D is preferably grant funded through flexible, long term structures that don't enable IP mothballing

Grants were regarded most popularly, especially by technology developers, to fund RD&D activities, and also as a successful way to create market credibility through de-risking technology. However, they are hard to sell politically as they may be perceived as free money which can result in failures.

“Success was enabled as small government grants were available”
– Technology developer

“Grants are a pretty hard sell politically...performance based rewards can help mitigate the risk to policy makers.”
– Technology funder

“Most of the programmes that governments fund are over too short a timeline...if I was given a certain amount of money I would prefer it go over a long period of time...policy makers forget it takes 30 years for technology to progress from concept to commercial operation”
– Technology enabler

Flexibility critical

A critical issue identified by innovators is a lack of flexibility in grant funding structures that makes money difficult to access at critical times and adjust plans once underway. As innovation is inherently hard to predict, a lack of flexibility in funding can lead to companies being unable to progress innovations, resulting in wasted public funds. Grant applications were also criticised by small innovators as being a challenge to write and requiring too many resources. It was recommended that simpler application procedures are adopted, that allow innovators greater influence on the use of allocated funds.

“Government funding would be better if it were more flexible, and worked around more fluid timelines”
– Technology developer
“Governments should consider streamlining them, use well qualified staff to assess them and allow flexible applications (flexible to the needs of the innovator)”

– Technology enabler

“Grants in the EU are very hard to write, overly prescriptive, feel pre-decided, and lead to assisting consultancies sucking away too much value”

– Technology enabler

Prevent IP mothballing

Private sector co-funding is a good way for governments to leverage additional funds, improving grant delivery and reducing the risk of supporting an innovation that does not have a future. This can be encouraged through equity returns but must be carefully designed to ensure co-funded IP cannot be monopolised by individual companies:

“Cross industry public/private collaboration is a productive way to fund innovation - especially for common infrastructure-enabling expenses”

– Technology user

“Government shouldn’t allow co-funded IP to be monopolised by single companies via obligations to licence these at commercially reasonable terms, with strong governance and punishment mechanisms, e.g. linked to funding disbursement; it should seek to develop the wider industry and stimulate competition (royalty free irrevocable licences preferred)”

– Technology user

Future push policies should be better monitored – not just based on cost criteria

Better monitoring is needed to compare and track success

Clear monitoring criteria against sensible goals and metrics were suggested by interviewees to ensure that public funds are not wasted. Establishing a methodology for impact analysis can help to convince policy makers of RD&D programme value. This can also better support assessment of innovation policy success.

"Great failure of public funds around the world to date has been insufficient reporting on demonstration performance post commissioning"
A recent innovation impact review of ~ 200 evaluation reports and 580 academic analyses concluded that consistent conclusions were hard to infer, due to inconsistent and limited reporting: “we must concede … each instrument has its specific design and context issues, and evidence often differs not only for different contexts, but also because of the different methodologies applied… learning would improve if policy design and evaluations would … develop a shared core approaches, which would allow a more explicit discussion of country and instrument commonalities and specificities.” (Edler et al., 2013)

*Programmes should not just be assessed by cost related metrics*

Monitoring criteria should not just be cost related, especially for early stage technologies that have to focus on reliability to enable widespread learning. This was emphasised by project interviewees and is underlined by the relative performance of Denmark and the USA commercialising wind technologies (see Text box 5, below).

“First goal is not the cheapest option, but the most viable.”

– Technology user

Possible alternative metrics suggested are: greatest reliability, highest quality output and length of operation period. It was recommended by interviewees that these be incorporated into performance based reward structures. Such structures could be designed to make additional funding available to innovators that achieve set targets or best performance. It is recommended that governments consider implementing such structures.

“Having some kind of monitoring process is vital for well-run grant programmes”

– Technology developer

“Public money should be well spent against clear criteria that qualified public staff can assess, as is seen in TSB funding model (doing rigorous quarterly monitoring)”

– Technology developer

“Policy requirements should be focussed on simple, achievable, controllable objectives, as closely as reasonably possible”

– Technology user
“Use performance based metrics on grants, i.e. give X if project succeeds, Y (covers costs) if project fails - remove downside risk for early investors”
– Technology funder

Text box 5: Different approaches to wind industry development – Denmark and the USA
Denmark’s focus on operational reliability over cost improvements is identified as another key factor to the successful development of its wind industry and corresponding advantage over the USA (Vestergaard et al., 2004; Harborne & Hendry, 2009). The USA sought to build on experience in aeronautics, focusing on aerodynamic efficiency and pursuing ‘NASA’ like programmes that aimed to deploy lowest cost solutions immediately. Developers in the USA regarded existing devices as simplistic and focussed on developing more sophisticated and complex designs. The Danish approach, however, was to start from existing, proven devices and make iterative improvements using trial and error and the use of improved materials (e.g. wood, and later fibre glass) and components (e.g. existing lorry gears). This difference in approach resulted in strong improvements; for example, in 1985, US-manufactured wind turbines experienced a failure rate of 62% in contrast to 2% for Danish wind turbines (Neij & Andersen, 2012). Danish programmes produced more reliable technology solutions, offering decreased production time and greater opportunities for skills development and learning to guide future improvements.

Front End Engineering Design
Push funding does not have to be used to fund equipment. Front End Engineering Design (FEED) studies can be funded for programmes that are on the boundary of qualifying for grants. This ensures a programme of pre-project planning and in-depth technical studies, helping to support a project’s development. Commonly, the technology is required to pass through clearly defined stage gates during the FEED study in order to receive funding for demonstrations and prototypes. FEED studies ensure that public funds are efficiently allocated and improves the chance of success in uncertain projects, while reducing the chance of premature failure.

Natural Resources Canada (NRCan) prominently use FEED studies to support renewable energy development within their ecoENERGY Innovation Initiative (EcoEII). This programme supports demonstration projects where there is uncertainty surrounding financing or technical issues making it difficult to secure private sector investment.

"...by fronting 50% of the FEED funding, we find people start to bring their cheque books"
– Technology enabler
NRCan funded six FEEDs with the understanding that only around half of the projects would receive capital funding. Unexpectedly, even the sponsors of projects that did not progress were happy with this process as it saved them from investing in uneconomical trials and generated useful insights in the process.

"even if our FEED studies rule out the next steps of project funding the project proponents were still happy with the studies...they prevented wasted funding"

– Technology enabler

**Conclusions**

This section has presented a set of best practice pull policy recommendations that can significantly increase their effectiveness and leverage greater private sector funding. These recommendations include establishing barrier targeted programmes and focus on maximising collaboration. Demonstration programmes are particularly emphasised, owing to their catalytic potential and popularity with interviewees. It is recommended that demonstration programme activities are increased, with governments seeking to increase co-funding from international partners.

Push policies alone will not enable technologies to transition to market readiness. Governments therefore need to use them alongside pull policies, which are further explored in the following section. By better aligning and tracking these different policy families, governments can pursue the most effective support frameworks. Additionally, by combining the leading elements of both policy families (direct government action to de-risk and private sector leadership to create markets) – it is possible to increasingly improve the delivery of both sets of policies.
4. Pull policy delivery

- **Regard the objectives of pull support as enabling** the private sector to see a long term path to market for ERETs and to enable technology learning by doing – policies for emerging technologies should be designed in light of the fact that risk of failure is the main restriction of private sector investment.

- **There is no single best practice price support policy** – it is more important to design them well and to deliver market investment certainty, than to select the ‘best’ policy choice – though in the long term a sufficient price on carbon was identified as the ultimate pull mechanism for low carbon based technologies.

- **Understand that certainty is critical** for pull policies to succeed and create stable investment frameworks by the private sector. Without more certainty, the billions spent to date on both push and pull policies could be wasted.

- **Maintain certainty** by developing future market framework policies that build on existing structures for price support mechanisms, tax relief and investment support.

- **Use clear price reduction plans** to avoid windfall profits/runaway costs, increasing the ability of politicians to adhere to agreed plans in an age of increasingly constrained resources.

- **Avoid unnecessary uncertainty** through consistent messaging – e.g. from political statements.
Overview

Pull policies are defined as demand stimulating policies that incentivise market actors to channel funds to innovation. The most common pull policies are investment support and price based support. Investment support activities are typically targeted at incentivising technology funders, while price support mechanisms alter market conditions to encourage technology users to purchase renewable technologies – primarily by pricing units of renewable electricity generated or carbon abated, e.g. feed-in tariffs. These policies act to create favourable conditions for technology investment and deployment, and are therefore frequently used to internalise technology externalities inherent in incumbent fossil fuel technologies (due to climate change) or to stimulate the growth of new renewable energy industries.

This chapter is split into three broad sections beginning with a review of the landscape of funders that pull policy seeks to support, identifying venture capital and corporate investors as natural investors in emerging renewable energy technologies. Case studies and interviews show that these investors face critical investment challenges due to the high capital, long time frames for renewable energy technology development. Expert insights are then synthesised to show possible ways of improving future pull support, often by integrating elements of push policies into pull policy design. It is recommended to establish risk taking public investment funds that further de-risk private investments.

The second and third part of this chapter looks at price support policies, using international examples of recent policy support systems – especially in the UK, Germany and Spain. This overviews possible approaches to price based support using examples of carbon pricing and price subsidies. No single policy is identified as ‘best’ – it is found that it is more important to design these policies well, than to select one leading type. Long term policy certainty is identified as the key criteria for this – a challenge for governments to deliver over long time frames. New, untested, ideas to increase policy certainty through price support mechanisms gathered during the production of this report are suggested in Appendix (i).

To conclude this section, a reflection on the key principle of long term policy certainty is discussed – also a common criteria for best practice push and enabling policies, overviewed in section 3 and 5, respectively.
The landscape of technology funders

The development and progress of ERETs requires funding to be allocated in two areas: (i) to projects that progress technologies along the innovation chain to enable deployment or to deliver cost reductions; and (ii) to companies, to enable them to grow and progress their IP towards commercialisation (shown in Figure 33, below).

Figure 33 The main funders operating to deliver innovation finance to technology projects and to develop companies doing innovation. Shading reflects the movement of funding to either earlier/later stages in recent years

There are a range of possible stakeholders that fund technology development along the innovation chain, including various finance focussed organisations (private equity, venture capital etc.), governments and corporates active in renewable energy technologies (primarily technology developers and users). The greatest levels of funding are found to be available for the lowest risk activities, at the end of the innovation chain, as is shown in Figure 34 below. This chart of funding levels by organisation type shows that of the sources of finance available to ERET development (between R&D and technology deployment), the only material sources are VC, governments and major corporates. The other sources of funding at these earlier stages, high net worth individuals and angel capital, are regarded as important but not sufficiently material to be the focus of policy conclusions in this report. For this reason, the pull policy recommendations in this section focus on how to stimulate and support investment in ERETs for VC and major corporates using government funding and policy frameworks. The recommendations nevertheless provide relevant insights that can be extrapolated to the other types of funders.
Funding is particularly challenging for technologies transitioning from R&D across to deployment – often referred to as ‘the valley of death’ (Murphy & Edwards, 2003). Policy makers will need to address this to deliver best practice policy that maximises the chances of achieving long term decarbonisation at lowest cost. This is due to the risks at these development stages which are exacerbated for renewable energy technologies due to their long timeframes to deployment and requirements for CAPEX intensive investment.

“Governments need to fund based on risk adjusted return expectations – currently funding doesn’t cover the additional risk of early stage technology”

– Technology user

The probability of failure along the innovation chain and cost of activities at a specific stage in the chain are the fundamental drivers of risk for developing technologies, as illustrated Figure 35. This figure shows that the probability of a technology failing to reach the market decreases along the innovation chain, but the costs involved in developing a technology peak between late stage R&D and early stage deployment. This underlines the point that the risks for investment in ERETs are higher than for fossil fuel technologies, as ERETs require high capital demonstration activities while still far from having a prominent role in commercial markets.
There are a limited number of relevant private sector funders for emerging technologies and the companies developing them. Furthermore, these organisations face specific investment challenges inherent in high CAPEX renewable energy technologies that progress along the innovation chain over long time frames.

This chapter continues by developing relevant solutions to these investment challenges by examining the strengths and limitations of venture capital investors, and contrasting it against the potential of corporate investors. A risk taking investment fund leveraging the strengths of these private sector actors is then proposed as a way for governments to progress ideas towards commercialisation. By focussing additional pull-style support on corporates, governments would be pursuing an approach to innovation policy better suited to progressing early stage technologies. This idea was endorsed in interviews from all categories of stakeholders and has since been cross-referenced against policy workers in IEA-RETD member states who saw great potential for this concept in their countries.

Limitations of Venture Capital investment

VC is the natural funder of small, innovative, technology companies. However they are currently found to play a smaller role than is generally expected in EREts due to a recent history of setbacks in cleantech VC investments and the fundamentals of investing in renewable energy technologies.
VC cleantech funding levels have decreased in recent years, with their relative contribution to early stage investments halving from 2008 to 2012 (Cleantech Group, 2013). Interviewees attributed this to prominent investment setbacks in the industry and lower levels of available credit following the recent international economic slowdown. Consequently VC investment has been found to be retreating to later stage investments with lower risks – as shown by the faded colouring in Figure 33, above.

Additionally, investing in renewable energy technologies is a fundamental challenge for VCs who typically invest millions of pounds (£0.5-10mn) in high risk ventures and require high financial returns (300-400%) over a short period of time (3-5 years) to meet the needs of their investors. This is in sharp contrast to the high CAPEX and significant on-going investment requirements of ERETs (often tens of millions of pounds), which can take up to 20 years to progress from R&D to large-scale demonstration and early deployment. This leads VCs to focus their earlier stage, riskier investments on low CAPEX technologies with shorter timelines to return (e.g. software based start-ups).

“The gradual development by engineers has meant funds could not be raised from traditional venture capital and thus government support has been crucial in our development.”

– Novel technology developer

In summary, the combination of lower capital availability to VC investors, their increasing focus on later stage investments and an incompatibility of investment needs, serves to reduce the relevance of VC to ERETs. It must be noted, however, that VC organisations have particular strengths and skills that governments would be well advised to leverage, especially in nurturing and commercialising early stage companies. Optimal innovation policy would seek to harness these skills and better support VCs to increase their investments in early stage renewable energy technologies.

Additional investment from major corporates

Major corporate investors have significant potential to play a greater role catalysing ERET developments. Recent global analysis by the Cleantech Group has found that while total VC contributions to early stage cleantech have halved over 2008-2012, corporate contributions increased by 25% (Cleantech Group, 2013). This potential is further underlined by the fact that the largest cleantech investment in recent years was not by a VC firm but a corporate, when Google invested $3.2bn in the smart meter company, Nest (Oreskovic, 2014).

All prominent categories of major corporate investors were interviewed and assessed in this project: technology users (e.g. RWE); technology developers (e.g. Mitsubishi); major corporates that primarily act outside of the renewable energy ecosystem/value chain - oil majors (e.g. Shell) and venturing technology firms (e.g. Google). The activities of these organisations investing in ERETs are overviewed in Text box 6.
Google

Google is a good example of a major corporate opting to invest in more risky technologies while still fundamentally only investing where there is viable potential to see investment returns. In 2007 Google launched RE<C (Renewable energy cheaper than coal) to target cost reduction in renewable energy by focussing $40mn of investment in five R&D companies: Makani Power, eSolar, Bright Source Energy, Alta Rock Energy, Potter Drilling. Although this programme was retired in 2011, Google has continued to invest in renewable energy innovation by supporting 15 projects with the combined capacity to produce 2GW of power (7 wind, 7 PV, 1 CSP) including making a further investment into Bright Source Energy and acquisition of Makani Power by Google X – a subsidiary Google organisation dedicated to improving technology by a factor of 10. Google has invested some $1.4bn in renewable energy to date.

Shell

Shell is an example of an organisation who has readjusted their strategy following renewable industry shifts. Up until 2009 Shell focussed on investments in biofuel R&D, but has since scaled back their operations citing lack of financial incentive to invest in biofuels until 2020 at the earliest. This highlights the potential for future corporate engagement if governments can demonstrate a stable long-term development pathway. Despite their scale-back, they have continued to invest in renewable energy, now focussing on wind by supporting 10 projects with a combined capacity of 500MW (8 in North America and 2 in Europe).

Mitsubishi

Mitsubishi Group consists of multiple autonomous companies including the Mitsubishi Corporation and Mitsubishi Heavy Industries (MHI) – the main Mitsubishi companies involved in renewable energy investment. Mitsubishi Corporation invests in renewable innovation through alliances with co-investors who are carefully selected as possessing technological capabilities or as having particularly useful regional knowledge. Projects span several continents including prominent investments in the U.S, Europe and Asia across solar PV, solar thermal, geothermal and wind power. MHI concentrates on R&D with particular focus on wind power following the Fukushima disaster. Having acquired Artemis Intelligent Power it now uses its pioneering Digital Displacement hydraulic transmission technology in its SeaAngel 7MW OSW turbine, in addition to setting-up a new joint venture dedicated to OSW between Artemis and Vestas in 2013 (FS-UNEP/BNEF, 2013).

RWE

RWE Innogy had a total of 2.9GW of renewable assets as of the end of 2013, set to rise to 3.4GW by the end of 2014. Business is focussed on Europe on wind and hydro due to their commercially mature status. RWE operate predominantly in Germany (total renewable operational capacities at the end of 2013 equalled 956MW) and the UK (935MW), although has also invested significantly in onshore wind in Spain (447MW) and the Netherlands (214MW). Responding to falling profits, RWE undertook a fundamental business model change at the beginning of 2014 to streamline investments. Previously it aimed to construct and operate 100% of its renewable investments; however, it has now announced this is unlikely to continue and that any future involvement will be limited to around 25% ownership. RWE’s renewables unit will invest €1bn from 2014 to 2016, a similar amount to last year alone, and with less money to invest, it will seek to partner with local authorities and corporates to access financing to help in the construction phase of future hydro and wind plants.
Interviewees highlighted that the motives and activities of major corporate technology investors could be better utilised by policy makers to leverage this sector. The motives of major corporates are more suited to ERET investments than VCs, as corporates are found to invest where there is a strategic motive, and not solely where there is a potential profit\textsuperscript{17}. This often results in a longer term outlook compared to VCs, and thus they are in a good position to husband innovative technology along the innovation chain. The core activities of major corporate technology developers also provides them with a relevant skill set to assess technologies and existing products and suppliers to integrate product sales into, both of which position them very well to take on technology performance and commercialisation risks.

Additionally, it is important to note that some interviewees were sceptical about the business development and commercialisation skills of venturing corporates. It was reflected that corporates typically do not have the same abilities as VC firms to develop commercially independent companies and can often purchase then drop companies once strategic interests change, leaving technologies either mothballed as stranded IP within the corporate, or unappealing to new investors, having been rejected by a company that was close to it. Governments would therefore be best advised to leverage the strengths of both VCs and corporates in the development of new funding support policies for emerging renewable energy technologies.

**Using public funds to leverage and unlock the best of the private sector**

Governments should seek to leverage the strengths of available funders to optimise and accelerate investments in ERETs, as mentioned above. The challenges and advantages of these investor classes are outlined in Table 5 below.

\textsuperscript{17} Anecdotally it is observed that: (i) technology developers such as Mitsubishi invest in technologies like Artemis power (see method section for more details) as the component technology does not only offer new revenues, but can also be integrated into products that are already being sold, boosting and expanding the relevance of existing offers; (ii) companies such as Shell are motivated to access further segments of energy market value chains and pursue investments that insulate against the risk of restricted fossil is sales; (iii) other venturing corporates such as Google invest in renewables to mitigate their emissions impact, develop technologies that could supply energy to data centres and to gain a positive public image by investing in technologies that could achieve a public good through mitigating climate change.
As neither VCs nor corporates are the natural investors likely to deliver the innovations which governments seek from ERETs within the timeframes required, governments should act using policy frameworks and available funds to de-risk and magnify the impact of private sector investment available. This is currently achieved largely through tax relief for venture capital. It is generally observed that governments can seek to further such activity by major corporate funders through the creation of similar tax benefits geared toward high priority ERET investments. This can serve as new pull policy, to complement existing push activities by governments.

"Public funds can plug the gap between earlier and later stage finance, by underwriting or warehousing projects"

– Technology user

**Public investment bodies**

Public investment bodies were identified as popular ways to further catalyse such action. These can be structured to leverage the existing strengths of potential private sector funders: (i) the ability of VC firms to successfully screen, develop and commercialise companies; and (ii) the ability of corporates (especially technology developers) to invest to longer timeframes based on strategic motives, using their significant internal resources and engineering ability.

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18 UK based VC firms interviewed during this project were particularly positive about the impact of tax relief policies such as the Enterprise Investment Scheme (EIS), which reduces the tax paid by high net worth (HNW) individuals on investments in ‘high tech’ companies. This complements similar tax status for Venture Capital Trusts that lower the tax of multiple VC firms investing collectively in start-up companies. It was commented that HNW investors now frequently ask “is this investment EIS-able”, showing the popularity it has.
Such public investment funds can further be developed in light of the risks faced by stakeholders, helping the corresponding risks to be taken by those best placed to understand and mitigate them. This can be structured to build on the commercialisation strengths of VC firms and the engineering strengths of corporates. Text box 7 shows a hypothetical model for this arrangement that governments can consider implementing, focused on the marine energy sector.

“Banks can operate at short end, institutional investors at long end - key to lock them in at beginning of project to provide clear exit options for developers”

– Technology developer
**Text box 7: A hypothetical risk taking public-private investment fund to stimulate ERET development in the marine sector**

A government/corporate funding platform that would collect funds to co-invest in developing marine energy companies and technologies. This funding model could evolve to pull in venture capital (VC) funding.

**Context**
- The wave sector is reliant on government and corporate support, with VC in retreat following recent losses in cleantech and renewables
- Deal scouting, due diligence and negotiating is time intensive for corporates who face risks picking a technology that does not become the market leader and can end up mothballing unsuccessful or stalled technologies; this is especially true for small investments
- Venture capital is uncomfortable with the timelines, required capital intensity for investments and technology risk

**Credible co-funding for leading designs**
- Government funding of a sufficiently credible amount spread across five years, with co-funding (potentially matched) by corporates; indicative amount of £20-25mn per company investment
- Support 3-5 companies through equity investments, reducing the exposure of a corporate to any one technology
- Structure fund such that it could be managed by VC fund managers, leveraging their funding skills
- Brand the fund as open to VC participation so that VC’s could partner with the fund and co-invest in specific company deals, while corporates would collectively invest in companies through the fund

**Open to support earlier investments**
- Consider a corporate sponsorship model to provide low levels of funding to very early stage technologies – establishing credibility, providing access to corporates and insights into technology progression
- Early co-funders could be given first refusal to gain further company ownership as it progresses

**Market framework price base support**

An overview of price based support which is regarded as crucial to the long term development of ERETs is overviewed, below. This is split into two subsections: a short introduction highlighting that price support is essential for technologies at all stages along the innovation chain, followed by a discussion underlined by the key message that generally it is not about the ‘best’ policy, but about doing them well. Key price support practices are highlighted, although it is noted that policy types have to be designed specifically for national markets and thus limits the extent to which detail is possible in this report.
1. **Price support is essential, even for technologies that are far from market**

Price based mechanisms are primarily applied to technology users, either to impose a cost on high carbon technologies (typically as a carbon price or tax) or to provide subsidy to favoured renewable energy technologies (primarily feed-in-tariffs, tradable green certificates and bidding schemes that target deployment and commercialisation of technologies). Thus, these policies act to create favourable conditions for technology investment and deployment.

Interviewees frequently underlined that price based support (typically considered relevant for later stage technologies) is crucial to commercialise renewable energy technologies, as private sector actors need to see a path to market.

"Without the feed in tariff in [our country] there would be no chance to develop emerging RETs"

— Technology enabler

2. **No “best” price policy**

The most important recommendation in this report regarding price support policies is not that a specific design stands out as leading, but that it is important to design any policy well against the needs of a country by encouraging long term support, while avoiding windfall profits as technology prices decrease. Getting this wrong can force unexpected redesign resulting in negative impacts on industry confidence. This is identified as particularly challenging for governments who need to deliver over short, four to five year voting cycles, with technologies undergoing continual evolution. A high level discussion of the pros and cons of two policies is provided below. These have been chosen to inform the reader on two common policies implemented globally, and most importantly, without committing to specific recommendations they highlight that market certainty is the most important criteria when designing policies.

**Carbon pricing**

Around 33 countries apply policies that impose a cost on carbon, including but not limited to the European Union, New Zealand, Korea, Kazakhstan and in specific regions within Japan, Canada and the USA (Talberg & Swoboda, 2013). Carbon pricing has recently suffered a number of prominent setbacks due to price drops in the EU and Australia who have abandoned their commitment to the policy. In the context of ERET innovation some evidence indicates that, under current prices, carbon pricing tends to stimulate developments in fossil fuel technologies and non-renewable solutions (such as pollutant capture or energy efficiency) as CO₂ reduction is the primary goal not renewable deployment (Rogge & Hoffman, 2010). Carbon prices tend to incentivise the use of the lowest-cost options available or bring forward disruptive technologies or new research (Hourihan & Atkinson, 2011; Arundel et al., 2011). At present they therefore have a limited impact in the progression of renewable technologies along the innovation chain.
Only in a system of dramatically higher carbon prices would renewable technology deployment be stimulated. Nevertheless, a sufficient carbon price is regarded as a core way for innovation policy to truly support renewable energy markets in the long term.

“A proper carbon price would be the best market pull across everything - you can't make a carbon price 100% certain but you can, say, give it a floor”
– Technology user

“All of these technology specific price support policies are just an over complicated web of policies trying to make up for the absence of a proper carbon price”
– Technology funder

**Renewable deployment price subsidies**

Out of a total of 127 countries employing renewable energy price subsidy policies in 2013, 71 have adopted feed-in-tariffs (FiTs) making it the most used price based policy of its type (REN21, 2013). There are several arguments that can be presented in favour of FIT style price based support, primarily based on their low risk and transparent nature (REN21, 2013; Kemp, 2011; Fagiani et al., 2013). They have polled as the most popular support policy by venture capitalists, though U.S. investors are found to be more sceptical of their effectiveness compared to European investors (Burer & Wustenhagen, 2009).

However, while FiTs are the most dominant policy type, their relative success compared to other price support mechanisms is not fully assured. Recent analysis indicates that the relative success of different price support policy measures depends on internal market conditions and investor perspectives of risk – things that are not consistent across different price support families or implementing countries (Fagiani et al., 2013). During 2012 while FiTs were introduced or expanded in Indonesia, Jordan, Malaysia, Rwanda and Ukraine they were also replaced with a renewable portfolio standard in South Korea (IEA, 2013). Different price support mechanisms can therefore be regarded as suitable to individual national contexts (Ragwitz, 2011).

“German FIT for solar PV could be considered the greatest act of innovation policy over the last 20 years, it created a global market for a new renewable energy technology”
– Technology funder
**Best practice design recommendations for maintaining certainty in market frameworks**

Policy certainty is regarded as crucial to implementing policies well. The final section of this chapter focuses on the critical need for greater policy certainty, presenting possible solutions that create acceptable paths for governments to follow.

The key policy recommendations to optimise policy certainty detailed at the beginning of this chapter are summarised below:

- **Certainty is critical** in the design of market frameworks
- **Clear political messaging** avoids unnecessary uncertainty
- **Use price reduction plans** and implement learning rates to avoid windfall profits/runaway costs

In recent years, poorly monitored pull policies, combined with retroactive cuts and policy moratoriums, alongside the recent international recession have contributed to the reduction in global investment levels in renewable energy technologies (see Figure 36). While it is recognised that price support levels should inherently reduce over time in line with system cost reductions, recent experiences have highlighted the importance that these reductions are predictable, gradual and regularly monitored as part of a clear, consistent and well-defined policy set that supports a stable investment market and investor confidence levels over extended time-horizons.

*Figure 36 The recent reduction in total global private sector investment in renewable energy (FS-UNEP/BNEF, 2014)*

**Low cost ways to increase certainty: political messaging**

Recent history has demonstrated the undesirable impacts of sudden changes in pull policies on investor confidence and deployment levels, see Text Box 8. In 2012, US$244bn was invested globally in new renewable energy capacity, the second highest value to date; however, it represents a decline of 12% from 2011 levels, predominantly as a result of policy support uncertainty in Europe, where investments declined 36% between 2011 and 2012 (REN21, 2013).
While it is challenging for governments to provide policy certainty while also responding to emission reduction commitments, budget constraints and changes in national strategies, there are examples emerging of well-defined, predictable and regularly monitored pull policies that support a greater degree of long-term planning and investor confidence.

“Smart governments’ can reduce uncertainty at low cost”
– Technology user

For example, in response to recent challenges for FiT schemes created by rapid PV cost reductions, several countries (e.g. UK and Germany) have refined their FiT policies to improve the frequency of monitoring (e.g. from annual to quarterly tariff level reviews) and the transparency around levels of price support reduction (i.e. degression based on deployment levels). These well-defined policy measures allow better investment planning and simultaneously minimise the boom-bust cycles typically observed for their less regularly monitored policy predecessors. This approach also benefits policy makers as spending towards funding allocation targets is more closely controlled, avoiding runaway costs and rapid use of spending caps which have prompted the large FiT policy shifts of recent years.

Well-defined policies are more likely to enable governments to stick to agreed plans and encourage long-term investment, however these instruments must be clearly communicated to market actors. Regular messaging by national governments through clear political statements reiterating energy technology plans and benefits is one such way to develop market confidence.

“Consistent political championing in our country made a great difference to the successful development of our technology”
– Technology developer
For wind energy in the USA, tax incentives have been used to encourage private sector investment. The Wind Production Tax Credit (PTC) has contributed significantly to the increasing number of wind farms in the USA, with wind power now generating around 3.5% of all electricity in the USA (Wiser & Bolinger, 2012).

However, the guaranteed expiry date of this policy measure introduces a boom-bust cycle into industry growth, creating a level of uncertainty and inconsistency in the market. For example, there were considerable reductions in new capacity installations (between 73% and 92%) following the lapse of the PTC in 2000, 2002, 2004 and 2012 causing the growth in wind power to be compressed into a small window of development following the renewal (see Figure 37).

Short-term extensions of PTCs are insufficient for sustaining long-term wind power growth as planning a project can take several years and thus developers who rely on the PTC to improve a facility’s cost effectiveness may hesitate to start. Last-minute renewals of the PTC also cause considerable uncertainty over access to financing for developers. This was exemplified in 2013, when wind development in the USA was at its lowest level since 2004 following the PTC renewal two days after the 2012 expiration.

### PV in Spain, Italy and the UK

- **Spain:** In 2008, three large retroactive changes to solar energy contracts were made: moving to an auction based system, differentiating between rooftop and ground systems and a 30% FiT reduction. These sudden changes strongly impacted investor confidence and installation levels.

- **Italy:** In 2011, falling PV system costs were not tracked by FiT reductions thus causing unanticipated growth. Furthermore, the FiT was set to stop once the annual support cost reached a fixed level. This tight cap on the FiT eligibility constrained long-term expectations for investors and was accompanied by a significant downturn in installation levels.

- **UK:** In early 2012, a large cut to the FiT for residential solar generation in the UK saw an approximate 50% reduction in price level followed by a further 24% reduction later in 2012 and shortening of the contract lifetime from 25 to 20 years. As in the cases above, these large FiT reductions were preceded by an extended period where considerable PV system cost reductions were not tracked by the FiT.
Low cost ways to increase certainty: price reduction plans

The rate of cost reduction (i.e. learning rate\(^{19}\)) for the various renewable energy technologies has an important bearing on levels of on-going pull support requirements. This is an important consideration when planning over the lifetime of pull policy support measures and also when defining national renewable energy strategies.

For most RETs, short-term mismatches in supply and demand are associated with temporary price fluctuations away from long-term learning rate trends (see Figure 39). Typically, these short-term pressures are corrected by market forces and prices revert back to longer-term learning trends within a few years (though exceptions do exist where disruptive technology, materials or manufacturing techniques are introduced). With this in mind, it is important that forecasts of long-term cost reductions are not based on extrapolations of these short-term price fluctuations, which may lead to artificially high or low long-term cost expectations. Text Box 9 examines the cost reduction differences between wind and solar PV, highlighting the need to consider learning rates on long term support policies.

\(^{19}\) The learning rate of a given technology is the percentage reduction in unit cost for a doubling of production.
Cost reduction differences between wind and solar

Solar has historically received more subsidies and investment per MW installed capacity than wind (see Figure 38), but the difference has been declining as PV costs have decreased rapidly in line with a higher learning rate (approximately 22% for PV and 7% for wind – see Figure 39).

Figure 38 Global annual investment (upper) and subsidy (lower) for solar and wind energy (BP 2013, FS-UNEP/BNEF 2013, IEA 2012)

The implications for emerging technologies is that even though current support levels might be high for some technologies, it is important to consider their learning rates which have an important bearing on long-term cost performance and grid parity.
Therefore when considering longer-term renewable technology support requirements and priorities, it is also important to consider the impact of technology learning rates on long-term support requirements and industry self-sufficiency. Table 6, below, provides a brief summary of the learning rates for various renewable energy technologies.

Table 6 Learning rates for renewable technologies (Hayward et al., 2011, Carbon Trust 2011, Lucon, 2004, Channell et al., 2012)

<table>
<thead>
<tr>
<th>Renewable technology</th>
<th>Learning Rate</th>
</tr>
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<tbody>
<tr>
<td>Solar PV</td>
<td>22%</td>
</tr>
<tr>
<td>Solar thermal</td>
<td>15%</td>
</tr>
<tr>
<td>Wind</td>
<td>7%</td>
</tr>
<tr>
<td>Geothermal</td>
<td>8%</td>
</tr>
<tr>
<td>Marine tidal</td>
<td>12%</td>
</tr>
<tr>
<td>Marine wave</td>
<td>8%</td>
</tr>
<tr>
<td>Biomass</td>
<td>5%</td>
</tr>
<tr>
<td>Biofuel</td>
<td>18%</td>
</tr>
</tbody>
</table>
Conclusions

This section has overviewed the primary pull type innovation policies, focusing on investment support and price support mechanisms. Two key recommendations are presented: establish risk taking investment funds led by co-funding corporates and venture funds which could incorporate ‘push style’ elements, and government funding to increase their attractiveness, and secondly where possible, to focus on increasing certainty in price support policies.

Pull policies are critical to enabling technologies to establish market presence and to achieve cost reductions from deployment, through learning by doing. Nevertheless, to enable technologies to pass along the innovation chain these policies are best complemented with push and enabling policies (overviewed in the previous and following chapters respectively). Importantly, push policies are fundamental to enable early deployment of technologies, and can further be used to accelerate cost reductions facilitated by technology learning by doing.
5. Enabling policy delivery

- Use innovation policy to create a **functioning innovation ecosystem**, e.g. by enabling communication and knowledge sharing between private sector funders.

- **Use national innovation enabling bodies** with long-term mandates and expert staff to facilitate public-private market development, implement best practice in policy delivery and create momentum for change, bringing new concepts into the mainstream.

- **Assess the potential for increased sharing of best practice** in innovation policy between national enabling bodies, potentially through an IEA Implementing Agreement for Innovation.

- **Use additional low cost enabling policies** to maximise the impact of existing push and pull policies, e.g.:
  - Align the focus of ongoing university courses and research around national priorities, building a highly skilled and relevant workforce.
  - **Use incubation support** to create companies with increased abilities to independently progress technologies along the innovation chain.
  - **Use clustering of innovators** and multiple technology value chain elements to increase learning and reduce technology production costs.
  - Pursue robust international regulatory frameworks for intellectual property (IP) protection.
Overview

The creation of well-connected innovation ecosystems are identified as fundamental to enabling successful innovation. Critical to this is the foundation of efficient enabling agencies and supportive low cost policies which should be integrated alongside other push and pull policies.

This section begins with an introduction to the innovation ecosystem and a case study look at the evolution of China’s innovation policy which demonstrates a country rapidly adapting its innovation activities to ensure greater interconnectedness between different actors (Text box 10). This is then followed by a discussion split into two sub-sections: enabling bodies, and low cost enabling policies.

Enabling bodies were repeatedly identified by interviewees as crucial mechanisms for governments to utilise to support innovation. An introduction to the role of these organisations within the innovation chain is provided which overviews common functions observed in successful enabling bodies from several IEA-RETD countries. The diversity in enabling body design and adaptive evolution of national innovation ecosystems is recognised through a case study examination of the UK and Denmark. This subsection concludes with a collation of best practice principles synthesised from interviews with experts and a reflection on the possibility of increased international collaboration between innovation support agencies.

The second part of this section looks at enabling policies, which are introduced as a low cost means to support the work of enabling bodies. The discussion focusses on four examples of policies which are commonly needed and have proven effectiveness. These are: alignment of university research activities, incubation support, clustering of innovators and regulatory support for intellectual property protection. Although it is recognised that the symbiosis between enabling bodies and enabling policies will vary between countries, the policy section is included to provide ‘thinking points’ for readers to reflect upon alongside possible recommendations for the specific areas overviewed. Greater detail is given to enabling bodies, as these are universal low-cost recommendations that are fundamental to developing a successful working innovation ecosystem.
Ecosystem creation

The innovation ecosystem is regarded to be a fundamental driver of innovative activity, which policy can support (Geels & Schot, 2007; IRENA, 2012; Kemp, 2011). This ecosystem spans the actors engaged in innovation in a country (including academics, technology developers, investors and government departments), the networks that connect them and the laws that govern them. This socio-economic perspective of innovation delivery has become more popular in recent years. As Kemp (2011) summarises:

“the focus of policy should be less on technical discovery and more on the national system in which innovation occurs, whose features shape interactive learning processes amongst innovation actors and the uptake of innovation in society”

– (Edquist, 2006; Mytelka & Smith, 2002; Lundvall & Borras, 1998)

It is therefore important that innovation policy seeks to support and structure this ecosystem of innovators, ensuring there are good channels of communication between stakeholders, and that national policy supports the development of new ideas, and the companies, industries and dominant national trends that they are trying to influence. An example of how innovation policy is evolving to bring greater interconnectedness between ecosystem actors in China is shown in Text box 10, below.
The use of enabling bodies to facilitate public-private communication reflects an evolution in innovation policy. The role of government is moving away from direct innovation deliverer, to a more subtle but crucial role as an ecosystem designer.

This is clearly seen in China’s approach to national innovation design, which has evolved significantly over a relatively short period of time. While innovation was generally directed by the state over 1975-1978, the role of universities and firms has since increased, tending towards a more cooperative and collaborative ecosystem. Today’s model sees a far more integrated approach between the various actors involved. Changes in the policy and institutional framework are increasing market-orientated operations within the public research institutes away from the previously strong state controlled strategy. Progression of China’s innovation ecosystem is displayed below (Figure 40), highlighting the increased interconnectedness between the different stakeholders.

Although China is an important actor in renewable energy with investments of US $66.6bn in 2012 (FS-UNEP/BNEF, 2013) innovation output has typically not reflected their high investment. In recent years China has focussed on the need for innovation by using a mixture of government mandate to encourage indigenous innovation and direct investment (Friedmann, 2011). However, state protectionism, e.g. in acquiring only Chinese technology through public procurement (Shapiro, 2012), means there is still potential for greater engagement with the international community, which will further aid coordination within the innovation landscape.
The role of enabling bodies within the innovation chain

Introduction

Independent, government-established enabling bodies (also referred to as ‘innovation support agencies’), were frequently identified by interviewees as highly successful mechanisms for governments to enable optimal low carbon innovation ecosystems. UK audits of national low carbon policies have also shown that such delivery bodies are amongst the most cost effective innovation policy measures available to governments (NAO, 2011).

These organisations have been found to provide many diverse activities: facilitating government interactions with the private sector (and communications between private sector actors); identifying priorities for national action, and managing and designing innovation programmes. They have also occasionally been used to support the progression of novel technology concepts into the mainstream national agenda.

“We run workshops under Chatham house-rules to bring together different government funded project stakeholders in a technical area...we convene groups to discuss ‘lessons learned’ in non-competitive areas”

– Technology enabler

There are many approaches to designing such bodies across different countries, especially regarding the degree of independence from government. Future bodies will have to be designed nationally, tailored to a country’s political landscape.

This section draws together insights into common approaches adopted by different countries and summarises recommendations from interviewees on best practice for government enabling bodies. This starts by describing the common features of a set of enabling bodies established in Japan, Norway, the UK and Canada. This introduction is then built upon by discussing the mix of enabling bodies in the UK – commenting on their design differences – and discussing on-going changes to the Danish innovation landscape. This section concludes with a synthesis of the recommendations for best practice from project interviewees. Further comparative analysis of leading enabling bodies would be required to form more detailed recommendations for such organisations.

“Intermediate bodies, that are technically and commercially competent, are needeed to enable efficient allocation of public financial resources”

– Technology user
Key common design elements of prominent enabling bodies

Comparable enabling bodies are found in several IEA-RETD countries. Japan’s New Energy and Industrial Technology Development Organization (NEDO) was established in 1980. In 2001 other organisations with similar founding principles were established in Norway (Norwegian National Energy Agency, ENOVA), the UK (the Carbon Trust) and Canada (Sustainable Development Technology Canada, SDTC). These enabling bodies are mostly found to be designed around common principles:

- Exist within the government framework whilst maintaining a degree of independence from government policy to enable efficient allocation of public resources
- Use a mission driven strategy to advance the dissemination of innovation, frequently complemented by a not-for-profit structure
- **NEDO**: To promote the development and introduction of new energy technologies that (i) address national energy and global environmental problems and (ii) enhance Japan’s industrial competitiveness
- **ENOVA**: To drive forward the changeover to more environmentally friendly consumption and generation of energy in Norway
- **Carbon Trust**: To accelerate the transition to a sustainable, low carbon economy
- **SDTC**: To act as the primary catalyst in building a sustainable development technology infrastructure for Canada
- Address existing barriers in the institutional environment to assist the movement of technology to market
- Facilitate communication between industry and government actors
- Design and deliver innovation programmes

Recent evolutions in the diverse roles of enabling bodies – UK example

Across the world there are many different approaches used to design enabling bodies, and through such bodies, the delivery of innovation. Insights into a variety of specific design elements are taken from the UK and Denmark to reflect on the diverse roles enabling bodies can play and the recent evolutions in national designs of such organisations. The evolving role of enabling bodies highlights both the need and drive to create a more integrated and coordinated innovation landscape.

The UK has a diverse set of enabling bodies that deliver innovation across the landscape of RETs. This mix has evolved over the years, leading to increased activity earlier along the innovation chain, see Figure 41, below.
Figure 41 A selection of enabling bodies in the UK acting to support innovation in emerging renewable energy technologies. Each organisation is named alongside a selection of relevant programmes they run and the year they were founded.

<table>
<thead>
<tr>
<th>R&amp;D</th>
<th>Demonstration</th>
<th>Early deployment</th>
<th>Near commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Strategy Board (2007)</td>
<td>• Catapults • SBRI • Innovation Knowledge Centres</td>
<td>• Energy Storage &amp; Distribution • Carbon Capture &amp; Storage</td>
<td>—</td>
</tr>
<tr>
<td>Energy Technologies Institute (2007)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Carbon Trust (2001)</td>
<td>• Polymer Fuel Cell Challenge</td>
<td>• OWA • Entrepreneurs Fast Track</td>
<td>—</td>
</tr>
<tr>
<td>Energy Savings Trust (1998)</td>
<td>—</td>
<td>• Heat pumps trial • Micro-CHP trial • Smart metering trial • Boiler trial</td>
<td>—</td>
</tr>
</tbody>
</table>

Key features in the strategies used by these delivery bodies are worth highlighting to show the different approaches to their design and delivery. This report focuses on the Technology Strategy Board’s creation of test centres and remit in sectors beyond low carbon technologies and the Energy Technologies Institute’s (ETI) private co-funding and national energy system model.

**Technology Strategy Board**

The Technology Strategy Board was established with the aim to accelerate economic growth through stimulating and supporting business-led innovation. It is active beyond energy, focussing on innovation in 14 diverse sectors, from space to transport and food. This enables it to pool a wealth of knowledge about innovation internally.

The Technology Strategy Board’s use of test centres under their Catapult programme is a useful example that can be considered by governments examining how best to leverage enabling bodies. The Catapults are independent technology and innovation test centres acting to bring businesses together with scientists and engineers to support progress along the innovation chain. By establishing such organisations the Technology Strategy Board is creating institutions specialised in select technology areas (e.g. offshore renewable energy) that are capable of attracting the highest qualified staff whose knowledge and learnings are subsequently made available – although the extent to which the knowledge produced is shared also depends on IP rules (see further detail on the Technology Strategy Board Catapults later in this section).

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20 It was commented by some interviewees that this was inspired by a similar model of test centres used by the Fraunhofer centre.
Energy Technologies Institute

The Energy Technologies Institute (ETI)\(^2\) was established in the UK in 2007 as a public-private partnership between the UK Government and global energy and engineering companies (founding members were BP, Caterpillar, E.ON, EDF Energy, Rolls-Royce and Shell). It is roughly 50% funded by government and 50% by the consortium of private sector companies. The ETI was set up as a new model to manage the delivery of innovation programmes over a ten year period enabling a system of continual support. Private sector co-funding is written into the design of the organisation to maximise leverage of government funds, ensuring that the demand for innovation programmes is market-led and that such programmes are designed to lead to a product that can be used by the market.

The ETI also manages the UK’s flagship energy system model, ESME (Energy System Modelling Environment). This model acts as a core input to the UK’s energy innovation strategies, providing detailed data on potential technology deployment levels and associated social costs in light of the UK’s target to reduce the national carbon footprint by 80% to 2050. The Carbon Trust recognises this as a great strength of the UK’s innovation planning environment, as it enables multiple stakeholders to have a structured, evidence based discussion about technology potential and the consequent national priorities. Future integration of such models into a unified European model is currently being considered, which when implemented will increase Europe’s ability to deliver strategic innovation support.

Proactive evolution of enabling bodies assists innovation delivery

The difference in operations both nationally and between innovation ecosystems internationally reflects the intrinsic complexity of innovation and the need for enabling bodies to be designed around national priorities and innovation needs. Interviewees consistently highlighted the complexity of navigating an innovation landscape with a large number of enabling bodies. Governments should consider the streamlining support channels to make it easier to access funding and steer technology through the innovation chain.

“A large number of semi-relevant public bodies can make it hard to know who to talk to”

– Technology enabler

\(^2\) The ETI’s mission is to accelerate the development, demonstration and eventual commercial deployment of a focused portfolio of energy technologies, which will increase energy efficiency, reduce greenhouse gas emissions and help achieve energy and climate change goals.
Denmark, for example, has responded to this need by developing a highly centralised public innovation system. The Ministry of Science, Innovation and Higher Education is the main executive body overseeing innovation programmes and research institutions, whilst funding for innovation is distributed through research councils. Additionally, Denmark recognises the need for both bottom-up research and targeted national prioritisation through the Danish Councils for Independent Research and the Council for Strategic Research respectively.

The government started implementing its new innovation strategy in 2013 so the innovation system is currently in a state of flux. The information presented in Figure 42 shows the status after the 2011 round of consolidation, but it is expected that the landscape will change again in the coming months. For example, the Danish Council for Strategic Research, the Danish Council for Technology and Innovation and the Danish National Advanced Technology Foundation will be merged into the Danish Council for Strategic Research, Innovation and Advanced Technology, which will perform all of the functions of its predecessors while simplifying the administrative structure. Additionally, the Business Fund will be changed into a Market Maturation Fund more specifically focused on public-private collaboration and commercialisation of projects, using public procurement as an incentive to innovation.

**Figure 42 Denmark’s streamlined innovation ecosystem**

![Diagram of Denmark’s streamlined innovation ecosystem]

**Best practice principles**

Recommendations for a set of best practice principles for policy makers, synthesised from insights gathered from interviews with stakeholders actively engaged in innovation, are presented below.
Enabling bodies should be used to facilitate interactions between industry and government to encourage private sector investment and assist technology prioritisation. This will enable efficient allocation of public resources helping to overcome problems often associated with government picking winners. Additionally, by providing project design and delivery services, enabling bodies can reduce transaction costs incurred from public-private interactions.

“What market will recognise ‘winners’ – governments are poor at that”
– Technology developer

“What difficult for government to pick winners – they have little real tech capacity”
– Technology developer

“One enabling body could have better supported Google”
– Technology funder

Governments should support novel technology companies entering the market by providing incubation services and credibility through due diligence of both firms and projects. They are able to identify barriers and interventions (other than financial e.g. lack of testing facilities), to help move a technology to market. For example, a UK technology company that was acquired had the following strengths: (i) strong track record and intellectual property; (ii) no private investors; (iii) a revenue stream; (iv) funding from a number of government schemes; (iv) a Carbon Trust award. Both the funding and the award helped build credibility.

It is vital that enabling bodies are well-resourced with technologically and commercially competent staff who are able to make informed decisions about both technological proposals and project delivery.

“What managing innovation programmes is always a nightmare – there’s no shortage of people trying to pitch those to the corporate market, but practically those things are hard to do”
– Technology funder

To have significant impact, enabling bodies should be rewarded by their outcomes and be designed around a long term mandate – more than ten years. Intellectual property ownership is a complicated issue for enabling bodies. It is often recommended that enabling bodies should not hold intellectual property, to encourage confidence and participation, though they should also seek not to fund the development of single private actors. The Fraunhofer centre at Bremerhaven allows private sector actors to have access to intellectual property for an initial period – two to three years – after which it becomes publically available.
“Enabling (knowledge sharing) body with long term time frame (7 years) was crucial to project success - this bridged engineers, operators and the university”

– Technology developer

Example of intellectual property management – Technology Strategy Board

A Catapult is a physical technology and innovation centre where the very best of the UK’s businesses, scientists and engineers work side by side on late-stage R&D, transforming ‘high potential’ ideas into new products and services to generate economic growth. Established and overseen by the Technology Strategy Board, there are nine Catapults covering areas such as offshore renewable energy, energy systems, and high value manufacturing.

The approach to IP is a particularly delicate area, and the Catapults provide a successful example of IP management. There is a tendency in immature technology sectors to be conservative and try to protect all IP. This makes standardisation of non-core technologies difficult and slows cost reductions. For example, the Offshore Renewable Energy Catapult helps technology companies to identify the core IP they need to protect, and provides mechanism to enable non-core IP (e.g. data on historical performance) to be shared, leading to standardisation and lower costs in the industry which benefits all participants.

In general, Catapult centres are not set up to be natural owners of IP, although they can hold some IP in special circumstances. Catapults receive a third of their funding from the public sector. This allows them to be independent with respect to IP and the general rule is for IP to be held by the technology companies.

For projects carried out exclusively with core government funding, the Catapult centre will retain and manage the IP, but will endeavour to make it as accessible as possible to companies, for example by not charging licensing costs.

For jointly funded work with private and public money, the Catapult follows existing regimes for collaborative research, with all partners agreeing upfront arrangements to share the IP rights and the Catapult centres safeguarding any IP brought by partners into the project. In addition, partners are expected to share the IP amongst themselves without licensing costs.

The Catapults can also work as a steward of IP, holding it for the benefits of the private sector at large, and helping the transfer of IP between sectors. For example, an aerospace project generated some patentable knowledge on carbon fibre which was not directly useful to the aerospace sector but had potential applications in the automotive sector. The High Value Manufacturing Catapult stepped in to finance the patenting process and make the technology available to the automotive sector, something that would not have happened otherwise, leaving valuable knowledge effectively stranded.
This function can also be useful in other situations; managing a full patent portfolio is considered quite expensive and some small companies might lack the resources to do that effectively.

Potential for increased international sharing

At a national level, encouraging interconnected well-functioning enabling bodies will assist in innovation delivery. However, to make significant contributions to greenhouse gas emission reductions, greater collaboration is needed to utilise multinational innovation expertise. One such way is through the use of shared knowledge platforms such as the IEA’s Implementing Agreements. These have been particularly successful in contributing to accelerated technological progress and innovation at lower costs by providing a framework for international co-operation in early stage energy technology development. They act to bring together international experts in different fields to address common challenges, helping to reduce the risks associated with technology development while streamlining innovative output to maximise resources. While there are currently nine Implementing Agreements targeted at renewable energy, the creation of a specific Implementing Agreement for innovation is a possibility that should be considered as a cost-effective means to increase international sharing of best practice in innovation policy between national enabling bodies.

Enabling policies should be used to maximise the impact of existing support policies

Additional enabling policies can be used at low cost to create a well-functioning innovation ecosystem and maximise the impact of existing push and pull policies. Four prominent examples are presented in this section for governments to consider implementing: alignment of university research activities, incubation support, clustering of innovators, and regulatory support for intellectual property protection. In each of these four areas, insights and overviews are complemented with recommendations to policy makers.

Align the focus of university courses and research around national priorities

All IEA RETD countries have strong existing university activity that can be leveraged to build and strengthen the renewable energy innovation ecosystem using the following three principles derived from best practice reports:

- **Support and direct university funding** through targeted research councils (Stennett, 2011; Royal Society, 2010)
- **Build strong links with industry** to encourage information sharing and private domestic and inward investment (Stennett, 2011).
- **Increase international collaboration** between universities with minimal bureaucracy to foster the sharing of ideas and maintain involvement in niche areas while growing a large research base (Royal Society, 2010) (Cunningham & Gok, 2012)
An example of how to achieve this is observed in the UK, which uses targeted academic governance bodies (e.g. the Engineering and Physical Sciences Research Council (EPSRC)) to coordinate academic research. Such research councils bring together government, industry and academic institutions to promote UK participation in international projects. These councils also input into UK innovation strategy for emerging renewable energy technologies. Therefore they do not only serve to guide the development of the UK’s innovation ecosystem and make best use of university funds, they also help develop a well-informed innovation strategy.

**Incubation support**

Technology incubators are facilities or consortia set up to support entrepreneurship and accelerate technology innovation by creating a platform to share resources, knowledge and expertise. Such activities are most useful for new companies, which are primarily staffed by technology developers and innovators but are lacking in business experience (Murphy & Edwards, 2003).

The Carbon Trust has been able to have a catalytic impact on multiple low carbon start-ups by establishing incubators that seek to create companies staffed with technology developers and experienced businessmen, auditing company business plans and connecting these companies to potential investors. Through its Entrepreneurs Fast Track programme the Carbon Trust has assessed over 3,500 low carbon start-up companies and supported over 350 with incubation support and research grants, catalysing follow-on investment of $225mn (Carbon Trust, 2013).

Technology incubators are also identified as a central component in Canada’s marine energy delivery roadmap. Canada does not only appear to be using these to improve company business skills, but also to provide a platform for companies to develop and commercialise from. For example, the Fundy Ocean Research Centre for Energy (FORCE) is designed to enable the development of commercial-scale arrays from single in-stream converters through the use of shared infrastructure assisting technology testing.

*Figure 43 Schematic illustration of role of incubators (Marine Renewables Canada, 2011)*
Governments can seek to use technology incubators as low cost means to help companies grow, commercialise and better prepare for market competition. This can be achieved through skills training, networking, staffing support (either to find legal, accounting and business staff, or by providing externally paid for resources to lower costs of core business services) and by providing testing infrastructure. It is found that enabling bodies have well suited skill sets to support the delivery of incubation activities, as they are typically staffed with industry experts and can be trusted with commercially sensitive information.

**Clustering of innovators increases learning and reduced production costs**

Clustering is regarded as a successful means of optimising knowledge sharing and diffusion, whereby the aggregation of multiple stakeholders (business, university, public authority) within close proximity of each other allows the free movement of knowledge, skills and innovations (Muller et al., 2012; European Commission, 2008).

> “Clusters are very good ways to have a platform for sharing ideas to enable small teams to develop initiatives and support companies accessing public funding”
> 
> — Technology developer

This approach is seen prominently in Silicon Valley, where technology firms and innovators have centred themselves on a strong university ecosystem. Renewable energy clusters are already found throughout the IEA-RETD member states. The EU identifies 29 renewable energy clusters in the North Sea and Baltic region, 21 of which are in IEA-RETD countries across Germany, Denmark, the Netherlands and Norway. A detailed overview of German’s Bremerhaven offshore wind cluster is provided in Text box 11 below. A recent international study of best start-up clusters, across all business sectors, did not reveal any in China or Japan, showing potential for improvement in these countries to better encourage clusters and start-up ecosystems.
Clusters are found to be successful as they facilitate more efficient R&D and bring together skilled staff, allowing greater sharing of ideas between experts and easing staffing constraints. They also enable company partnerships to be formed and allow for greater involvement of sectors not normally associated with individual stages of innovation.

Clusters can be encouraged and nurtured through regional government policies that seek to support companies of a particular sector setting up business in the area. Regions can be selected as targets for clusters by building on existing commercial strengths, including those that are tangentially related to a renewable energy sector (e.g. offshore oil and gas is relevant to offshore wind and marine energy).
Regulatory support for intellectual property

Robust enforcement of intellectual property rights encourages innovation as innovators are more willing to share knowledge. Although weak enforcement may encourage the rapid spreading of innovations, it may dissuade innovators from sharing ideas (Blind, 2012). Therefore, establishing an appropriate regulatory framework to support intellectual property is widely agreed to be important to create an environment in which innovation can occur, despite not being a critical driver of innovation itself (Kemp & Pontoglio, 2011; Butler & Neuhoff, 2004; IRENA, 2012). This becomes increasingly relevant as intellectual property is shared internationally. This is anecdotally supported by comments that intellectual property rights are not universally respected. There is therefore a case for establishing more robust international intellectual property processes, which would likely start through an increased intergovernmental dialogue not focussed solely on renewable energy technologies.

Text box 11: The Bremerhaven offshore wind cluster

The German North Sea port of Bremerhaven has developed perhaps the largest wind energy cluster in the world. As recently as 2001 the local economy was in serious decline, hit by competition from Asian and Eastern European shipyards, and by diminishing demand for its use as a supply port for US forces in Germany.

As part of a city council-led initiative to reverse this decline, an assessment of the area’s strengths and weaknesses identified the city’s deep water river and harbour, skilled shipbuilding workforce and proximity to planned North Sea wind farms as key differentiators. This led to a strategic focus on the then nascent offshore wind farm industry.

The city is now home to key international players including turbine manufacturers REpower and Multibrid, rotor blade manufacturer PowerBlade and foundation specialist Georgsmarienhutte, all of whom share a site where the council is creating facilities, including a loading terminal adapted to handle industry-specific equipment such as nacelles and turbine blades.

This manufacturing and commercial presence is supported by significant activity in related areas, including R&D centres with one of the largest wind tunnels in the world at Deutsche Windguard, and a new rotor blade test facility at the Fraunhofer Centre for Wind Energy and Maritime Technology. In addition, advanced degrees in wind energy are available at the local Fachhochschule Bremerhaven University.

In the space of less than ten years, the region has established an international reputation as a centre of excellence for offshore wind.
Conclusions

This section has highlighted the importance of creating a comprehensive innovation ecosystem to unlock national potential. Enabling policies are shown to be the lowest cost means of supporting this, with well-designed enabling bodies identified as particularly catalytic in bridging the public and private sectors and responding to evolving challenges. Best practice design elements are presented in this section. As with other policy areas, stable policy environments, long time lines, and collaborative action are key to success. Additionally, increased international collaboration through innovation support agencies can lead to improved sharing of policy insights, better monitoring of policy success and the development of new activities in other policy areas.

For maximum impact enabling policies and the recommendations in this section need to be combined with push and pull policies. These have to be monitored, balanced and designed against national goals through a strategic innovation policy framework that provides a long term vision and enables innovation policy to be integrated successfully across all relevant government departments.
Conclusions and recommendations for future work

Recommendations

This report presents recommendations across the three key families for innovation policy (push, pull and enabling – each is explained in the method section), the strategic planning that connects these policies and the balance of resources across them. Recommendations are presented for each of these areas, across five summary chapters. Each sub-recommendation is not summarised here for brevity, individual country policy teams are directed to the preceding conclusion chapters to identify additions they can make to their existing policy.

This report focuses on recommendations that can enable policy makers to achieve maximum gains by building on existing support levels. These recommendations build on proven policy successes found in international best practice and novel recommendations, developed by working with leading members of the international innovation community. These proven and novel recommendations are as follows:

Proven approaches to delivering a comprehensive innovation policy support framework

- Monitor the balance of resources allocated to the three key innovation policy families, which respectively unlock public and private funding and address barriers to innovation:
- Establish clear goals to focus for success
- Balance and integrate push and pull innovation policies in light of goals to deploy and/or develop technologies
- Increase international coordination and collaboration to disseminate best practice and initiate co-funded programmes

New policy developments to catalyse greater acceleration from the private sector and international partners

- Seek to design increased certainty into future push, pull and enabling policies
- Use novel public-private RD&D programmes to remove barriers to innovation and increase private sector investment earlier along the innovation chain
- Establish risk taking public-private investment funds, supported by tax relief, to stimulate additional private sector funding
Next steps

The next step for policy makers is to turn these ideas and concepts into reality, building on the frameworks in this report and applying them to the specific conditions in their countries. The IEA-RETD can support this process by working together – countries can tackle shared problems and pool solutions and start to build the international partnerships between governments and companies that can accelerate innovation in these technologies and realise their true potential.

Future work can also investigate innovation policy in further detail, building a greater shared understanding of best practice and key success criteria. This could be pursued through strategic working groups for innovation policy, such as an implementing agency for innovation.
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>BioSNG</td>
<td>Biogas and Synthetic Natural Gas</td>
</tr>
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<td>BNEF</td>
<td>Bloomberg New Energy Finance</td>
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<td>CAPEX</td>
<td>Capital expenditure</td>
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<td>CCS</td>
<td>Carbon Capture and Storage</td>
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<td>CSP</td>
<td>Concentrated Solar Power</td>
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<td>DDT</td>
<td>Digital Displacement Technology</td>
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<tr>
<td>DECC</td>
<td>UK’s Department of Energy and Climate Change</td>
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<tr>
<td>ENOVA</td>
<td>Norwegian National Energy Agency</td>
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<tr>
<td>ENS</td>
<td>Electricity, Networks &amp; Storage</td>
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<tr>
<td>ERETs</td>
<td>Emerging Renewable Energy Technologies</td>
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<tr>
<td>ESME</td>
<td>Energy System Modelling Environment</td>
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<tr>
<td>EPSRC</td>
<td>UK’s Engineering and Physical Sciences Research Council</td>
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<td>ETI</td>
<td>Energy Technologies Institute</td>
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<tr>
<td>EU</td>
<td>European Union</td>
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<tr>
<td>FEED</td>
<td>Front End Engineering and Design</td>
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<tr>
<td>FiTs</td>
<td>Feed-in-Tariffs</td>
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<tr>
<td>FORCE</td>
<td>Fundy Ocean Research Centre for Energy</td>
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<tr>
<td>GDP</td>
<td>Gross domestic product</td>
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<tr>
<td>GHG emissions</td>
<td>Greenhouse gas emissions</td>
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<tr>
<td>IEA-ETP</td>
<td>International Energy Agency-Energy Technology Perspectives</td>
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<tr>
<td>IEA-RETD</td>
<td>International Energy Agency-Renewable Energy Technology Deployment</td>
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<tr>
<td>IP</td>
<td>Intellectual property</td>
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<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<tr>
<td>IWES</td>
<td>Fraunhofer Institute for Wind Energy and Energy System Technology</td>
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<tr>
<td>LCICG</td>
<td>UK’s Low Carbon Innovation Coordination Group</td>
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<tr>
<td>LCOE</td>
<td>Levelised cost of electricity</td>
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<tr>
<td>MCT</td>
<td>Marine Current Turbine</td>
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<tr>
<td>MHI</td>
<td>Mitsubishi Heavy Industries</td>
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<tr>
<td>MIGA</td>
<td>Multilateral Investment Guarantee Agency</td>
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<tr>
<td>NEDO</td>
<td>Japan’s New Energy and Industrial Technology Development Organization</td>
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<tr>
<td>NRCan</td>
<td>Natural Resources Canada</td>
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<tr>
<td>NREL</td>
<td>US National Renewable Energy Laboratory</td>
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<tr>
<td>NDPB</td>
<td>Non-departmental public body</td>
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<tr>
<td>O&amp;M</td>
<td>Operations and Maintenance</td>
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<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
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<tr>
<td>OPEX</td>
<td>Operational Expenditure</td>
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<tr>
<td>OSW</td>
<td>Offshore Wind power</td>
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<tr>
<td>OWA</td>
<td>Carbon Trust’s Offshore Wind Accelerator</td>
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<tr>
<td>PE</td>
<td>Private equity</td>
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<tr>
<td>PTC</td>
<td>Production tax credit</td>
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<td>PV</td>
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R&D
Research and Development
RCUK
Research Councils UK
RD&D
Research, development & demonstration
RE
Renewable Energy
RETs
Renewable energy technologies
ROCs
Renewables Obligation Certificates
SDTC
Sustainable Development Technology Canada
SME
Small and medium enterprises
TINA
Technology Innovation Needs Assessment
TSB
Technology Strategy Board
UK RPIF
UK Research Partnership Investment Fund
UKTI
UK Trade & Investment
UNEP
United Nations Environment Programme
VC
Venture capital

Units of Measure

bn
billion
EUR
euro
GW
gigawatt
kW
kilowatt
kWh
kilowatt-hour
mn
million
MW
megawatt
MWh
megawatt-hour
tn
trillion
TWh
terawatt hour
USD
United States dollar
W
watt
°C
degrees Celsius
References


Appendix i – new ideas for innovation policy

Overview

During this project, many innovative ideas were discussed and developed. Two concepts that proved popular with interviewees are presented below. These are intended to promote further discussion and research, rather than act as fully developed actionable recommendations. These ideas include two ways to further integrate push and pull policies and one international offshore wind demonstration programme. These are now each overviewed in turn.

Ideas to harmonise push and pull policies

Further integration between push and pull policies was proposed by stakeholders during interviews for this project. The suggestions presented involved (i) mandating novel technology testing on government contracted deployment and (ii) integrating optional grant mechanisms into price support mechanisms. The measures proposed are new and untested and therefore require additional research to become implementable. These measures could offer lower cost ways to gain greater benefits from push and pull policies.

Mandatory R&D on early deployment activities

Governments spend significant funds on (i) price support mechanisms for early deployment of relatively proven technologies; and (ii) research and development activities through universities. Governments and the private sector struggle to finance demonstration projects due to the costs associated with the projects.

Governments could address this by mandating RD&D activity on early deployment sites to unlock early stage innovation using ongoing activities. It was suggested that agreeing to testing new concepts on procured sites could be a criteria to winning the initial contracts. For example, in the offshore wind industry this could enable ‘at sea’ demonstration activities which would not otherwise have been able to secure capital. Similar activities could happen with gasification plants, using a small percent of syngas or for future tidal array foundations.

This concept does have some significant challenges to success. It would increase complexity and add cost to already stretched projects. It would also increase a project developer’s bureaucratic burden. It is nevertheless recommended for further consideration, as an idea that can increase RD&D activities through market pull activities.

“I think governments should mandate testing novel technologies on near commercial offshore wind farms…one turbine in 50 could be used to test a new, cutting edge technology”
– Technology enabler
**Integrating optional grant mechanisms intro price support mechanisms**

It was proposed during interviews for this project that governments could integrate optional R&D funding into
price support mechanisms. Future price support mechanisms could also be developed to provide greater
opportunities to fund early stage innovation to prevent continually supporting incumbent technologies, and
therefore assisting in the progression of early stage concepts along the innovation chain. This could be
achieved by providing utilities two choices for price support: (i) current levels, or (ii) at lower levels, with an
upfront grant for RD&D.

The benefits of this system would be:

- To get utility input earlier along the innovation chain, providing the private sector with freedom to best
  spend innovation delivery funds
- To create greater incentives for utilities to achieve ongoing cost reductions
- To deliver early stage innovation alongside early deployment activities

The level of grant support could be carefully balanced so that greater levels of funding are provided for
innovation, using less initial capital. This can be achieved as government borrowing rates (around 3-5%) are
predominantly lower than those of the private sector (around 5-15%) meaning that government financed
RD&D could unlock more innovation funding on the same level of capital.

Governments could balance off the lifetime savings from lower price support with the loan repayments for
RD&D activities. Initial calculations by the Carbon Trust indicate that a 10% reduction in a £100/MWh onshore
wind price support level could result in a £5m up-front grant for a 10MW wind farm, if financed by the public
sector. If the private sector were to take a loan and pay back the same instalments over the same time period
they would only be able to borrow £3m.

**Offshore wind example**

A hypothetical offshore wind collaborative programme was developed during this project in iteration with
interviewees. This is a potential framework for an international innovation programme to collaborate on
demonstrating new large turbines, foundations and operation and maintenance systems for offshore wind.
This programme is built around the best practice lessons highlighted in Chapter 3 on the delivery of push
policy. Owing to the genuine interest and enthusiasm from interviewees and the engagement at workshops, it
is recommended that RETD member countries consider implementing the programme, initially by further
testing industry appetite to co-fund it. Potential partner countries, enabling bodies and timeline activities are
outlined below.
Example Countries

- RETD members: UK, Norway, Denmark, Germany, France, Netherlands, Ireland, Canada, Japan (more challenging for non-European Countries)
- Non-RETD members: China, USA
- Deploy in the country with the easiest planning regime, using the FiT of the highest country

Example private sector co-funding (utility focus)

- Offshore Wind Accelerator utility consortium (DONG Energy, E.ON, Mainstream Renewable Power, RWE npower, Scottish Power Renewables, SSE Renewables, Statkraft, Statoil, Vattenfall)
- Additional European Utilities:
  - ENECO (Netherlands)
  - ENBW (Germany)
  - EDF (France)
- Other non-European utilities?

Example enabling bodies

- Offshore Wind Accelerator (UK) – consortium of nine European utilities aiming to reduce the cost of offshore wind by 10% by 2015
- Technical University of Denmark (DTU) – internationally leading university, with a notable presence in offshore wind
- Fraunhofer Institute for Wind Energy and Energy System Technology (Germany) – prominent research institute
- SINTEF (Norway) – research institution that works with the Institute for Energy Technology (IFE) and the Norwegian University of Science and Technology (NTNU) on wind power R&D
- Flow (Norway) – programme enabling companies to participate in the international market for offshore wind farms

Timeline

Agreement – Phase 0 (12 months)

- Programme design and negotiation – a significant challenge that should be industry led, in collaboration with government stakeholders and expert enabling bodies
- The challenge is complexity - the programme could compromise on scale and funder number to reach buy-in
- Cost: 20 people’s time – 50% could be industry secondments

Technology selection & programme planning – Phase 1 (18 months)

- Organisations screen and prioritise the technologies to test in Phase II – led by utilities, who have the fundamental need
Further design is carried out of programme structure

Goal: reach concrete commitment to build. If this goal is not achieved the selection and screening work could still deliver material gains by developing market perspectives on future action plans

Cost: 20 people’s time – 50% could be industry secondments

Technology piloting – Phase II (1-3 years)

* Test 3 different designs of technology developer’s 8MW turbines at sea
* Do 4 demonstrations of each turbine type – 96MW total
* Developers hold the turbine IP, under ‘use it or lose it’ clauses
* Cost: c.£350mn, 40% public grant funded

Large scale deployment prize – Phase III (2 years)

* Prize of 100 installations of the leading 8MW turbine
* 800MW total installed
* Funding could be structured 30% equity (with some public grant funding), 70% debt financing (through EIB?) during construction – to utilities and developers
* Cost: c.£2.4bn – likely predominantly private sector funded, with significant price support
Appendix ii

Innovation policy frameworks

1) IEA framework demonstrating the Technology readiness Level (TRL) and how the policy dimension maps onto it (Koelemeijer et al., 2013)

2) Carbon Trust 4 journeys framework across each aspect of the innovation chain (Carbon Trust, 2014)
3) Framework mapping a different set of policies and subtypes to the TRL (IEA, 2011)

4) Diagram of how the management of policies and innovation changes over the journey (Kemp & Rotmans, 2009)
5) The multi-level perspective of innovation, portraying the transition from ‘niche’ (individuals) to ‘regime’ (industry, government, organisational) and finally ‘landscape’ (entire ecosystem) during the innovation journey (Geels & Schot, 2007)
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