Commercial Readiness Index Assessment

USING THE METHOD AS A TOOL IN RENEWABLE ENERGY POLICY DESIGN (RE-CRI)

May 2017

IEA-RETD
Renewable Energy
Technology Deployment

ABOUT THE IEA RETD TECHNOLOGY COLLABORATION PROGRAMME

The IEA Renewable Energy Technology Deployment Technology Collaboration Programme (IEA RETD TCP) provides a platform for enhancing international cooperation on policies, measures and market instruments to accelerate the global deployment of renewable energy technologies.

IEA RETD TCP aims to empower policymakers 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.

For further information please visit: http://iea-retd.org or contact info@iea-retd.org.
Twitter: @IEA_RETD

IEA RETD TCP is part of the IEA Energy Technology Network.

DISCLAIMER

The IEA RETD TCP, formally known as the Technology Collaboration Programme for Renewable Energy Technology Deployment and formerly known as the Implementing Agreement for Renewable Energy Technology Deployment (IEA-RETD), functions within a Framework created by the International Energy Agency (IEA). Views, findings and publications of IEA RETD TCP do not necessarily represent the views or policies of the IEA Secretariat or of its individual Member Countries.

COPYRIGHT

This publication should be cited as:

IEA RETD TCP (2017), *Commercial Readiness Index Assessment – Using the method as a tool in renewable energy policy design (RE-CRI)*, IEA Renewable Energy Technology Deployment Technology Collaboration Programme (IEA RETD TCP), Utrecht, 2017.

ACKNOWLEDGEMENTS

The Authors would like to thank the IEA RETD TCP RE-CRI Project Steering Group (PSG) members.

Project Steering Group

Lena Pedersen	Enova, Norway
Michael Paunescu	Natural Resources Canada, Canada
Joanne Sheahan	Sustainable Energy Authority of Ireland, Ireland
Louise Oriol	Ministère de la Transition Écologique et Solidaire (MTES), France
Una Dixon	Ministère de la Transition Écologique et Solidaire (MTES), France
Sascha Van Rooijen	Operating Agent IEA RETD TCP
Coraline Bucquet	Operating Agent IEA RETD TCP

The Authors are grateful for the contributions made by individuals from the following organisations during the expert consultation: Australian Renewable Energy Agency, Carbon Trust, Climate Policy Initiative, Department for Business Energy and Industrial Strategy, Export Credit Norway, Fraunhofer Institute, German Energy Agency, German Institute for Economic Research (DIW), German Solar Association, Green Investment Bank, InnovateUK, International Renewable Energy Agency, National Renewable Energy Laboratory, Organization for Economic Co-operation and Development, Offshore Renewable Energy Catapult, and the Scottish Government.

AUTHORS

CARBON TRUST

The Carbon Trust is an independent, expert partner that works with public and private section organizations around the world, helping them to accelerate the move to a sustainable, low carbon economy. We cut through uncertainty to provide insights that support better, often bolder, decisions. We design and manage complex projects and collaborations that overcome financial and behavioural barriers to deliver real results. And, when the time comes to celebrate success, we recognise achievement through assurance and certification of the outcomes.

Authors: Joshua Brunert, Adriana Carvallo, David Aitken.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Emerging renewable energy technologies (RETs) face a range of challenges to get to market, including high up-front capital requirements, long payback periods, regulatory uncertainty, and the perceived risks of new solutions. An understanding of the policy and market conditions that enable or hinder renewable technologies from getting to market is necessary for effective policy making. This is increasingly important given the evolving context of RET development and deployment. As these RETs mature, and their share in the energy mix grows, there is greater pressure to make an efficient use of scarce public funding.

The IEA RETD TCP has commissioned a study to assess the commercial maturity of RETs using the Commercial Readiness Index (CRI) framework in order to identify appropriate policy approaches for stimulating RET deployment. The target audience of this study are decision makers and policy makers. The project aims to answer the following key questions:

1. **How can the CRI be used by policy makers and what are its main advantages and limitations?**
2. **What are the most effective policies to support the commercialisation of RETs?**
3. **What are the opportunities to refine the CRI to address some of its limitations?**

There are a range of existing frameworks used to assess technology and commercial readiness of new solutions. The Technology Readiness Levels (TRLs) index is the de facto standard for assessing the technical development of emerging RETs on their journey from basic technology research to proven function. However, beyond technical development, RETs also need to prove their commercial viability.

The CRI is a novel framework developed by the Australian Renewable Energy Agency (ARENA) that aims to provide a complementary index to the TRLs by moving beyond assessing the technical performance of technologies towards an evaluation of the commercial readiness. The CRI independently evaluates a range of indicators according to qualitative criteria defined by ARENA. The indicators' scores are aggregated to form an overall market "Commercial Status Summary Level". The use of the CRI (as developed by ARENA) is illustrated in Figure 0-1.

We have explored the use of the CRI framework through case studies with the aim of illustrating the commercialisation journey of two RETs in two different contexts: solar photovoltaics (PV) in Germany and offshore wind in the UK. We conducted primary and secondary research, including detailed interviews with 20 experts from 15 organisations and an internal workshop with Carbon Trust's technology commercialisation experts. The policy journey of solar PV and offshore wind in their respective contexts was analysed to uncover which policies have been effective in supporting their commercialisation journey, and testing whether the CRI could be a useful tool for policy makers to extract lessons from these experiences.

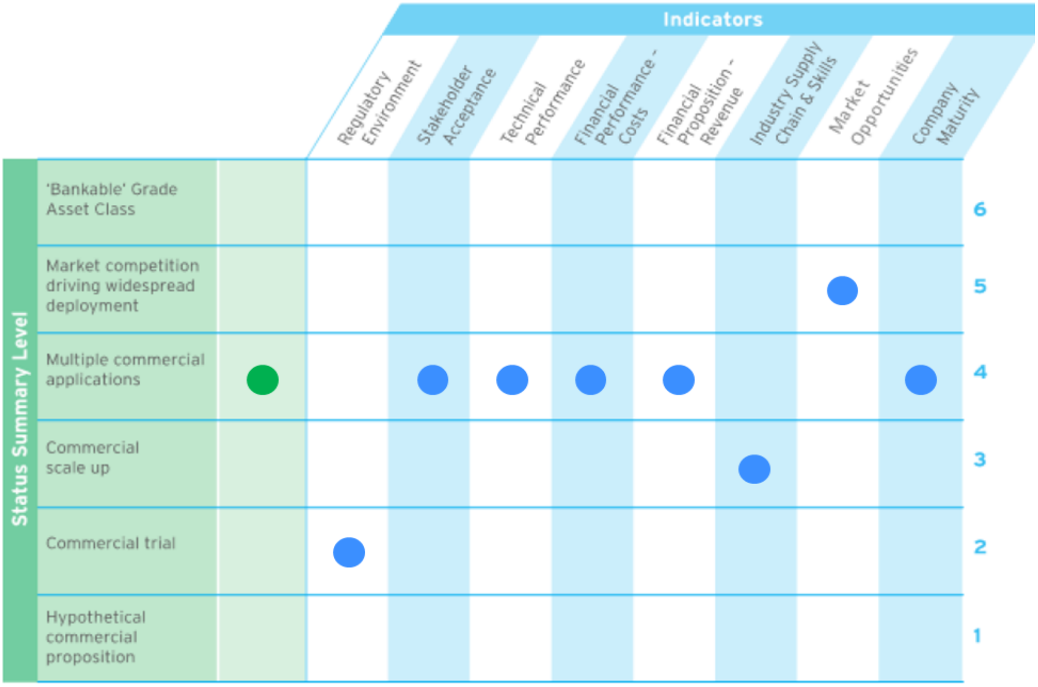


Figure 0-1: Illustration of the Commercial Readiness Index (CRI) framework (Source: ARENA (2014), Commercial Readiness Index for Renewable Energy Sectors).

● = the overall commercial maturity of the RET (an aggregate of the indicator scores)

● = the score for each individual indicator (on an independent scale from levels 1 to 6)

Advantages and limitations of the CRI and its potential applicability to support policy makers

Our case studies show the value of the CRI as a tool for communicating the importance of market conditions beyond technical performance for RETs and illustrating the historical commercialisation journey of a technology. The indicators assessed through the CRI help to prompt policy makers to consider a range of barriers faced by RETs and it can be used to show which historical policies were effective, or not, at addressing these commercialisation barriers. However, the CRI as a stand-alone tool does not direct policy makers towards the policy options that could be implemented to address these barriers. The main advantages and limitations of the CRI identified through our case studies are summarised in the following Table (0-1).

Advantages	Limitations
• A major benefit of the CRI framework is that **it assesses various indicators which influence the commercial and market conditions** of RETs beyond just the technical maturity that can be assessed using TRLs, therefore prompting policy makers to think about the different factors and stages that define the commercialisation process.	• The CRI **does not capture all of the factors** that enable or hinder the commercialisation of RETs – such as enabling infrastructure or political support. • The **CRI lacks sufficient complexity** to explain how and why policies were or could be effective. Policy makers need to understand what the impact of different policies is likely to be.

Advantages	Limitations
• The CRI helps **identify key barriers that need to be addressed** in order to support the commercialisation of RETs. For example, before the solar PV Feed in Tariff (FiT) reform was introduced in 2004 in Germany, a CRI assessment would have highlighted a low score in the financial proposition indicator which needed to be addressed to stimulate deployment at scale. • The CRI can also be used to **illustrate historically which policies have affected the performance of certain key indicators**. For example, the Renewable Obligation Certificates (ROC) policy in the UK directly increased the financial incentives and market attractiveness for offshore wind in the UK which enabled greater deployment. This is shown by an increase in the CRI scores for the financial performance and market opportunity indicators from level 2 to level 4.	• The **CRI in its current form only provides a snapshot of overall commercial maturity** and the score on the indicators **at one point in time**. • Despite assessing various indicators, **the CRI is insufficient for understanding the complexities and contingencies within different contexts**. This makes it difficult to translate lessons from one market or technology to another. This is also relevant within industries - for example, there are significant differences between utility-scale and residential solar PV markets that are hard to distinguish with the CRI. • The CRI **does not provide sufficient information to show the indirect effect of policies on indicators** that are not directly targeted by that policy. For example, ROCs were primarily a financial incentive for offshore wind but they indirectly improved the technical performance of offshore wind. • It is a **subjective tool based on qualitative criteria** that can lead different people to score different outcomes even when applying the tool to the same technology.

Table 0-1: Main advantages and limitations of the CRI

Effective policies to support the commercialisation of RETs

The CRI framework enabled us to illustrate how policies transitioned from push policies that supported the commercial viability of the RETs (e.g. capital grants), to pull policies to drive the initial phases of mass deployment (e.g. FiTs). Once there was enough traction in the market, capacity auctions were implemented to drive competition in both case studies.

The CRI emphasises that the most significant policies for scaling both emerging RET markets were subsidies for electricity production that were not limited by a capacity cap. For example, pull policies have been fundamental to Germany's solar PV market growth. Initially this was through the introduction of soft loans for the 100,000 Roofs programme in 1998. This was followed by a successful feed in tariff (FiT) reform in 2004. However, **the CRI analysis does not indicate why these policies were successful.** The 2004 FiT reform was effective because it provided confidence in long-term returns, enabling investors and developers to grow the market, but the CRI only illustrates the impact the FiT had on the indicators assessed.

Moreover, generalising the lessons from the German and British contexts is difficult given the unique set of individual circumstances that applied in each case: for example, the wider policy framework, economic capabilities, and strategic priorities. The independent feedback received during this study suggests there are a range of opportunities to improve the CRI to make it more useful for policy makers.

Opportunities to refine the CRI to address some of its limitations

We propose some modifications to the CRI which build on the existing framework that could make it more applicable for policy making. Our proposed recommendations are:

- **Additional indicators -** the CRI could include more indicators to capture additional commercialisation barriers that are currently not being evaluated (e.g. enabling infrastructure, political support). This would provide a more comprehensive view of other barriers that are faced by RETs in order to get to market.
- **Indicators assessed using a traffic light system -** a traffic light system (e.g. green, amber, red) rather than a (1 to 6 level) can show the priority areas requiring policy support. The CRI could provide detailed guidelines describing what a green, amber, or red status represent for each indicator to facilitate the assessment.
- **Indicators linked to policy options** – the CRI framework does not provide information on the policies that can be implemented to address the barriers assessed. It could be useful to create a matrix that lists potential policy interventions that could address specific technology commercialisation barriers and act as a menu of policy options available for consideration by policy makers. This additional table would make the CRI more operational by establishing a clear link between the indicators and the policies that can be used to address the commercialisation barriers (Table 4-2 in 'Key Findings' is an example).

It is important to note that our insights are drawn from a limited sample of case studies. Hence, further research on testing and improving the CRI framework in additional geographical contexts and/or other technologies could be useful to validate our recommendations.

1. PROJECT BACKGROUND, OBJECTIVES, AND METHODOLOGY

The IEA RETD TCP has commissioned a study to analyse the role of pull policies in accelerating the commercialisation of emerging renewable energy technologies (RETs) by building on the Commercial Readiness Index (CRI) framework.[1] The project aims to focus on the use of the CRI as a method for the identification and selection of pull policies to stimulate the commercialisation journey of emerging RETs.

1.1 PROJECT OBJECTIVES

This project seeks to:

- Identify the strengths and gaps of existing methodologies that can be used to assess the commercial maturity of renewable energy technologies;
- Map selected RETs using the CRI framework to illustrate the historical policy and commercialisation journey;
- Explore if the CRI can be used by policy makers to select pull policies to support the commercialisation of emerging RETs;
- Identify opportunities to refine the CRI; and
- Develop recommendations to support policy makers to assess the commercial readiness of RETs and help them to identify the policies that could support their progression along the commercialisation journey.

1.2 PROJECT SCOPE AND TARGET AUDIENCE

The target audience of this study are decision makers and policy makers. The aim is to explore their interest in using the CRI framework to help in their policy selection process to support the commercialisation journey of emerging RETs. Through case studies, we explore how the CRI could be used by policy makers and draw conclusions around the policies used at different stages of technology commercialisation. We illustrate how the CRI framework could be refined to make it more useful for the target audience for making future policy decisions.

[1] ARENA (2014), *Commercial Readiness Index for Renewable Energy Sectors*.

1.3 APPROACH & METHODOLOGY

The project has been broken down into three main tasks, as illustrated in Figure 1-1-1.

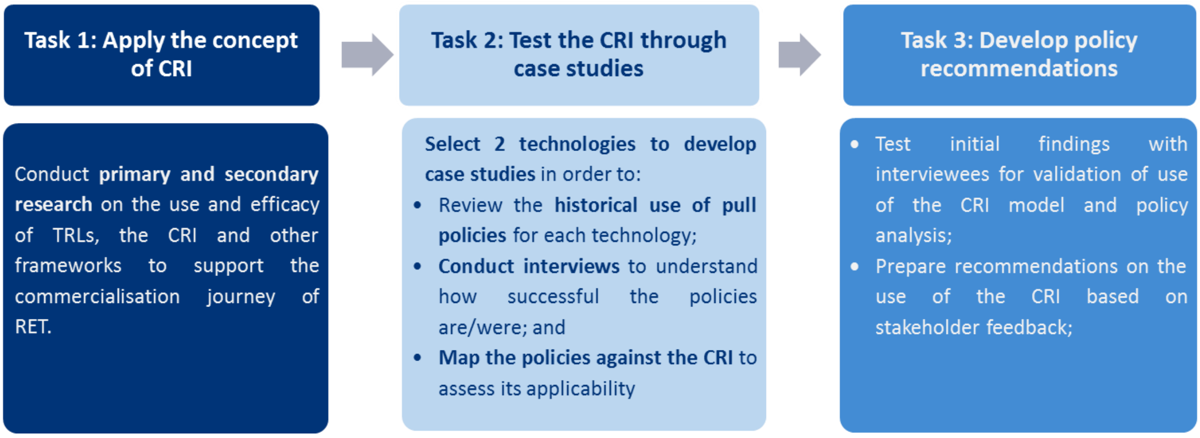


Figure 1-1: Summary of project approach and methodology

The aim of Task 1 is to gain a better understanding of a range of technology assessment frameworks, including the CRI and TRL, and to explore the CRI's applicability on policy-making.

Task 2 seeks to illustrate how the CRI could be used to map policies through two case studies. We identify:

- The stage of commercial development at which certain policies are most appropriate and effective;
- The barriers these policies seek to address; and
- The key factors that can influence their success or failure in supporting the commercialisation of RETs.

Task 3 aims to integrate the project's findings gathered in Task 1 and Task 2 to draw recommendations on the use and applicability of the CRI for decision makers and policy makers.

Further details on each of these activities are included in Section 5.1 in the Appendix.

2. COMMERCIALISATION OF EMERGING RENEWABLE ENERGY TECHNOLOGIES

RETs are being deployed rapidly around the world. Given the relative immaturity of emerging RETs and the range of commercialisation barriers they face, policies are needed to catalyse development and deployment. Crucial to formulating these policy interventions is an understanding of the commercialisation journey that emerging technologies embark on.

2.1 POLICY SUPPORT TO COMMERCIALISE RET

There are different types of policies that are used across the commercialisation journey of RETs which can be classified in three main categories:

- **Push policies** stimulate supply by supporting technology development through research and development (R&D) efforts to prove technical feasibility and reduce the cost of emerging technologies;
- **Pull policies** build off the back of push policies and seek to drive market demand by encouraging greater levels of investment through demand-generation initiatives; and
- **Enabling policies** create favourable governance frameworks and infrastructure to support the development and deployment of RETs.

Generally, at earlier stages of the commercialisation journey, technology push policies are most appropriate. Governments, universities, private research facilities, and large corporations all play important roles in supporting technology development (e.g. many corporations have their own research facilities and test centres, and have carried out large scale demonstrations for innovative technologies).

At the later stages of commercialisation, pull policies are needed to stimulate investment and drive market demand. Pull policies are relevant once the technical feasibility of a RET has been proven but there is a need to address other barriers (e.g. financial risk and return) that limit private sector investment and RET deployment. Public interventions are required to create mechanisms that mitigate the perceived risks by private investors and/or enhance their rate of return.

Enabling policies provide the favourable environment for push and pull policies to be effective. They are less focused on delivering measureable outcomes in terms of cost reductions or private sector investment, but are still essential for creating the conditions in which these outcomes are possible. For instance, ensuring that intellectual property (IP) protection is respected within a country is important to ensuring that researchers and developers are prepared to invest in emerging technologies, in order to later reap their rewards without the fear of losing out on future revenue.

Examples of the use of push, pull and enabling policies at different stages in the commercialisation chain are illustrated in Figure 2-1.

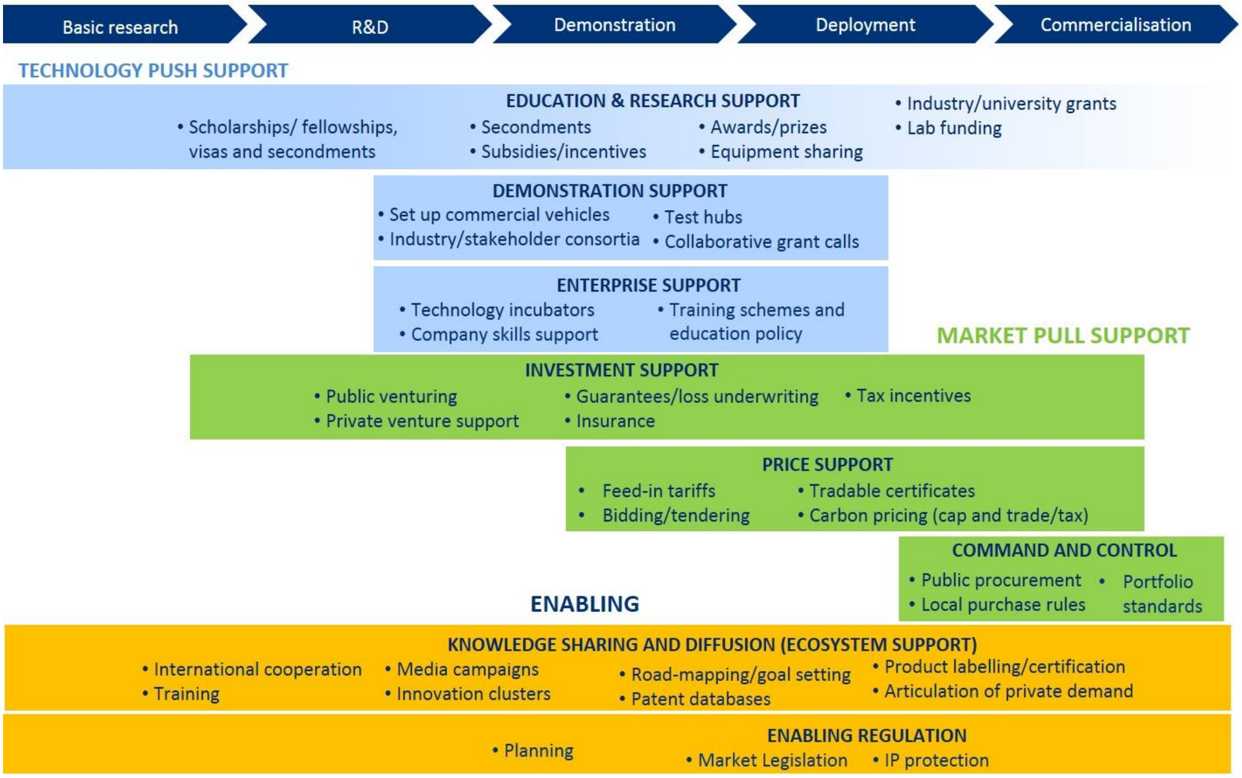


Figure 2-1: Relative stages of commercialisation where push, pull and enabling policies are used (Source: Carbon Trust (2015))

Understanding when, where, and how to use policies for the development and deployment of emerging RETs is a central concern of policy makers. The menu of policy options outlined above does not lend itself to answering these questions on its own. A complementary analysis is required to identify the barriers that hinder commercialisation and select the optimal policy responses. Fundamentally, this requires mapping and assessing the commercialisation journey of emerging RETs and its relationship to different policies.

2.2 TECHNOLOGY ASSESSMENT FRAMEWORKS

A widely used framework for assessing the maturity of technologies is the TRLs. They are often used to inform technology developers, finance providers, and policy makers on the maturity of a given technology and help identify the type of support that could enable the technology to progress. The TRLs have proven to be popular and resilient. They remain a framework of reference for organisations involved in accelerating the commercialisation of RETs.[2]

[2] Carbon Trust interviews, 2016.

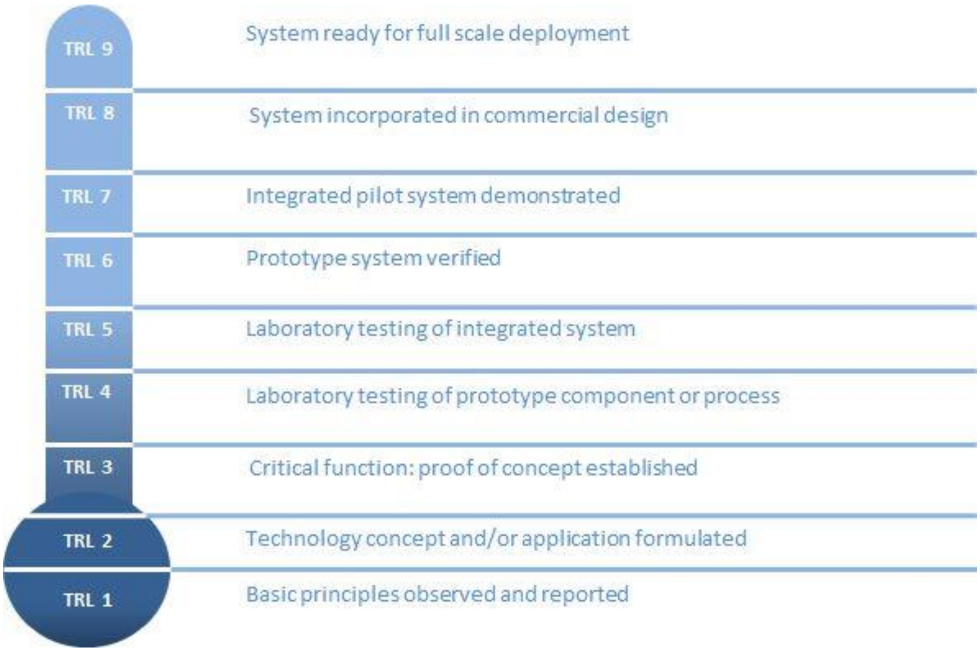


Figure 2-2: TRLs (Source: Innovation Seeds)

The strengths of the TRLs lie in its ability to communicate a "shared understanding of technology maturity and risk".[3] It uses standardised language that can be used across different applications. They remain a framework of reference for organisations involved in RET development and commercialisation.[4] However, there is also widespread recognition of its limitations. For instance, Sauser identified that TRLs can be too focused on the individual component level, thus are insufficient for explaining the development of whole systems[5]. **Perhaps the biggest shortcoming when considering the deployment of RETs is related to the need to go beyond proof-of-function.** Beyond technical development, RETs also need to prove their commercial viability and sustainability to get to market.

There is a need to move beyond the TRLs to assess the stage of commercial maturity of a technology. This assessment is helpful to identify the type of instruments that are necessary to help the technology to progress across the different stages of the commercialisation journey (e.g. to move from proof of function to a bankable asset class).

ARENA's predecessor organisation, the Australian Centre for Renewable Energy, had been using the TRLs as way of assessing the technical maturity of renewable energy technologies to inform their selection of projects. However, the TRLs did not capture the kinds of variables that come into play once a technology had moved into the demonstration phase of the innovation chain. The Centre (later ARENA) wanted to have a systematic way of measuring how renewable energy technologies were advancing towards a viable commercial outcome. This need resulted in their design and development of the Commercial Readiness Index (CRI). **The CRI was developed specifically to assist ARENA to make**

---

[3] A. Olechowski, S. D. Eppinger, and N. Joglekar (2015), "Technology Readiness Levels at 40: a study of state-of-the-art use, challenges, and opportunities", in *MIT Sloan School Working Paper 5127-15*.

[4] Carbon Trust interviews, 2016.

[5] B. J. Sauser, R. Gove, E. Forbes, and J. E. Ramirez-Marquez (2010), "Integration maturity metrics: Development of an integration readiness level," in *Information Knowledge System Management*, vol. 9, pp. 17–46.

better informed decisions about which projects to support and to track how projects were helping advance a technology along the commercialisation pathway.[6]

The CRI is a framework that aims to classify the commercialisation journey of technologies beyond the TRLs (Figure 2-3).

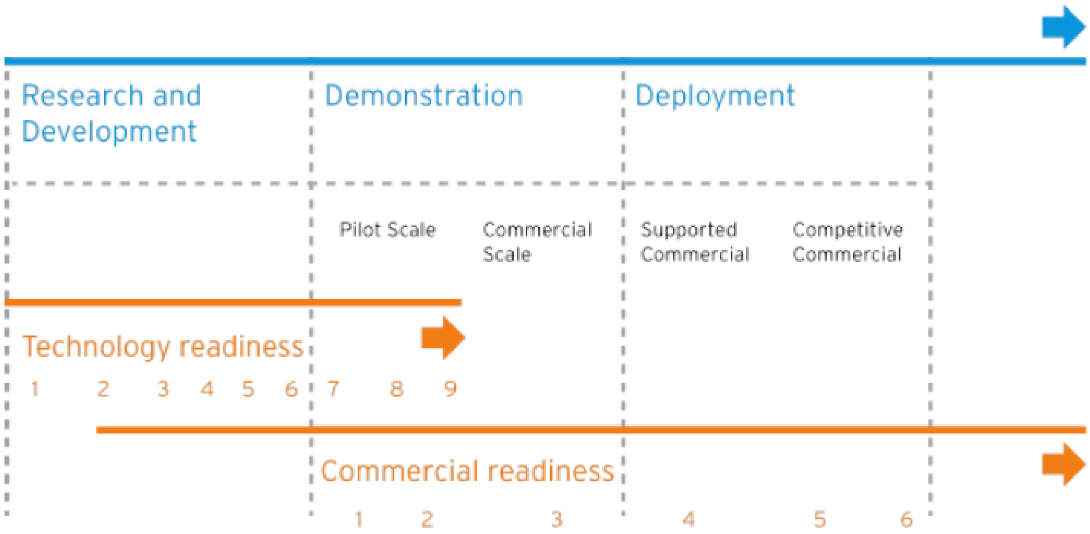


Figure 2-3: CRI levels in relation to the TRLs (Source: ARENA (2014), Commercial Readiness Index for Renewable Energy Sectors)

The CRI ranks the commercial readiness of a technology or "commercial summary level" according to six levels that start from a hypothetical commercial proposition and lead to a self-sufficient, bankable asset class (Figure 3-1). In doing so, it embodies a positive move towards understanding the various factors that influence the commercialisation of emerging RETs.

In addition to the "commercial summary level," the CRI assesses 8 indicators, which represent the factors that can help or hinder a technology from being deployed at large-scale in a given market. For example, stakeholder acceptance and development of industry supply chain and skills are two of the indicators evaluated in the CRI. These are crucial factors for understanding the speed and scale at which RETs can be deployed.

The indicators are graded on a 1 to 6 level independently of the "commercial summary level". For instance, the overall commercial summary level might be "hypothetical commercial proposition" (commercial summary level 1) but an individual indicator (e.g. regulatory environment) may be level 2 or 3. A technology may display high technical performance (level 5), and even attractive rates of return on investment, but without the necessary supply chain and skills to deliver the deployment (level 2), it will not reach a significant deployment.

In addition to the TRLs and CRI, there are other frameworks that can be used by policy makers and decision makers to assess the stage of policy, technology, or venture readiness. We have assessed the main strengths and limitations of the following four frameworks. Further details on the aims, uses and limitations of these frameworks can be found in Section 5.2.

[6] Interview with ARENA on 24.05.2017.

- Carbon Trust's Business Analysis Tool
- IEA's Clean Energy Technology Assessment Methodology
- IRENA's Renewables Readiness Assessment
- IRENA's Renewable Energy Technology Innovation Policy

These existing frameworks and tools provide a structure for assessing RET commercialisation maturity, challenges, and potential interventions. They rely on the judgment and experience of the user, and they are best thought of as an aid to better decision making rather than as a substitute for sound judgement and experience. We have used these insights to help inform our thinking about how the CRI could be used by policy makers.

3. APPLYING THE CRI THROUGH CASE STUDIES

We explored the applicability of the CRI to illustrate the commercialisation journey of two RETs and its usefulness in helping policy makers to identify policy interventions. These case studies aimed at analysing and illustrating the policy and commercialisation journey of solar PV in Germany and offshore wind in the UK using the CRI. The key questions framing the empirical analysis were:

- What were the most successful policies in supporting the commercialisation journey of the technology in that country?
- Is the CRI useful to map the policy-commercialisation journey?
- What are the main benefits and limitations of the CRI?

In order to do this, we have slightly modified how the CRI is used. Whereas the CRI was originally intended to be used as an assessment of the commercial maturity of a RET at one point in time (Figure 3-1), our analysis seeks to show the policy and commercialisation journey of solar PV and offshore wind through time. To achieve this, we have broken up the CRI into two parts, to enable us to illustrate the impact of policies on both the status summary level (Figure 3-2) and the indicators (Figure 3-3).

To illustrate this approach, Figure 3-1 shows how the CRI was originally intended to be used by ARENA for a particular technology at a particular time.

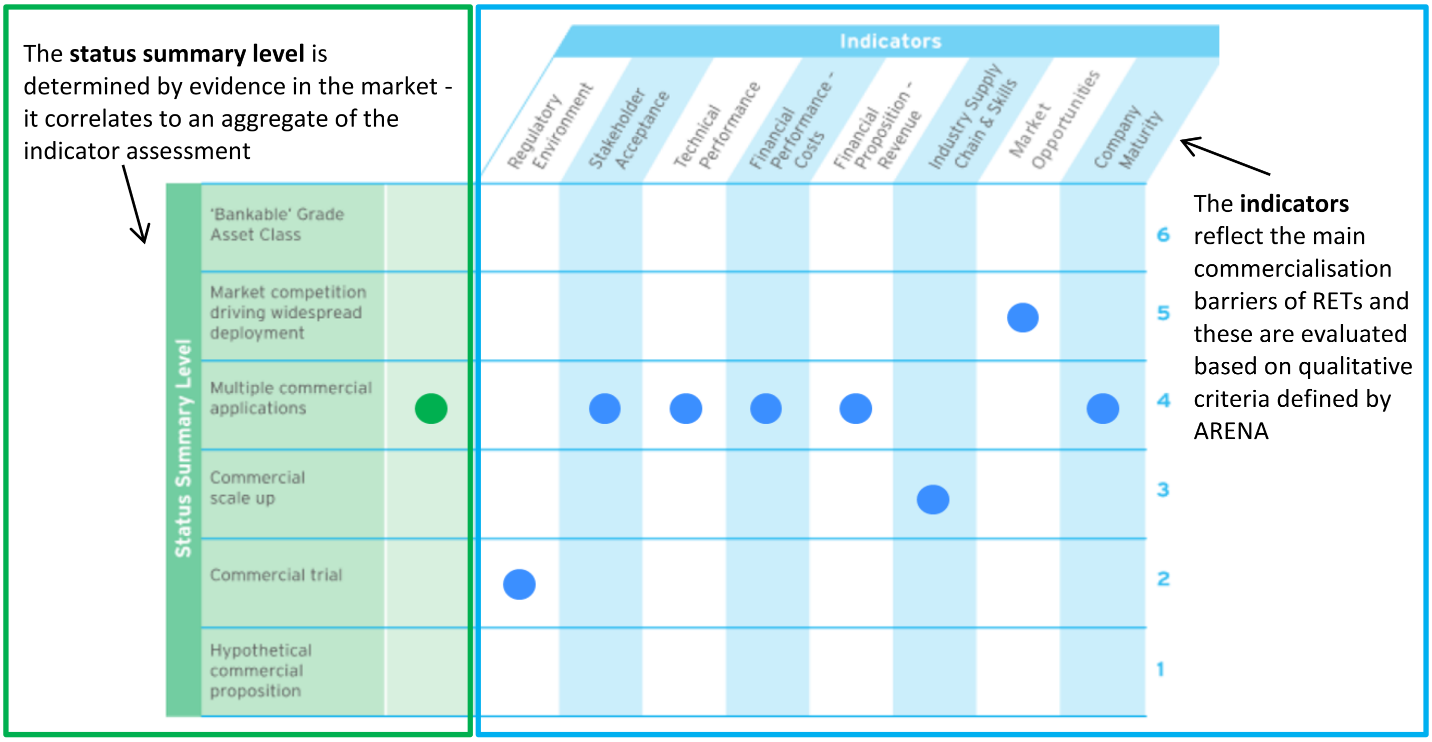
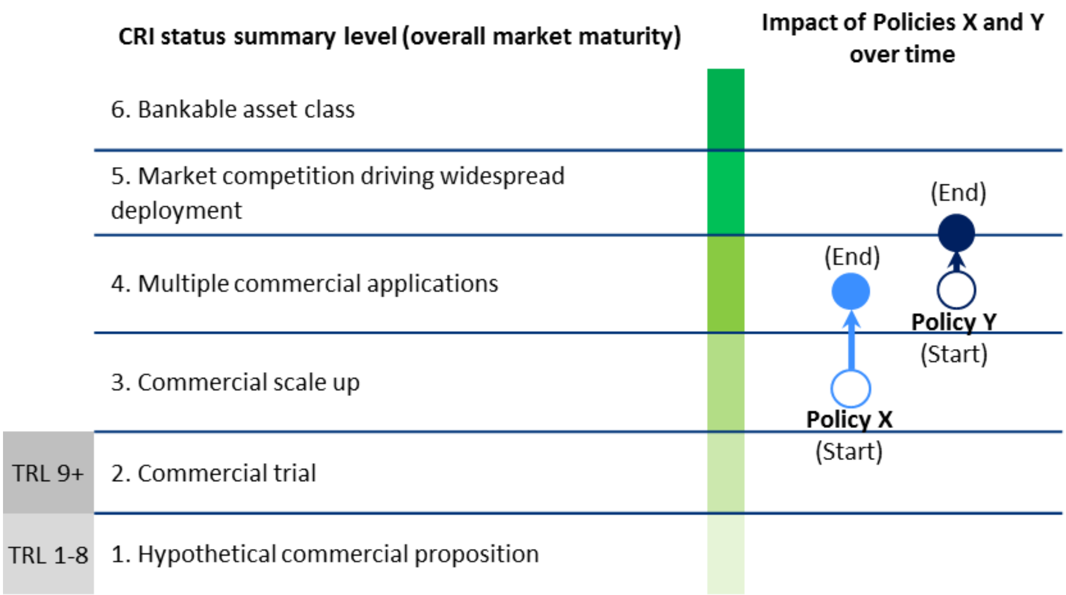


Figure 3-1: Illustration of the CRI developed by ARENA

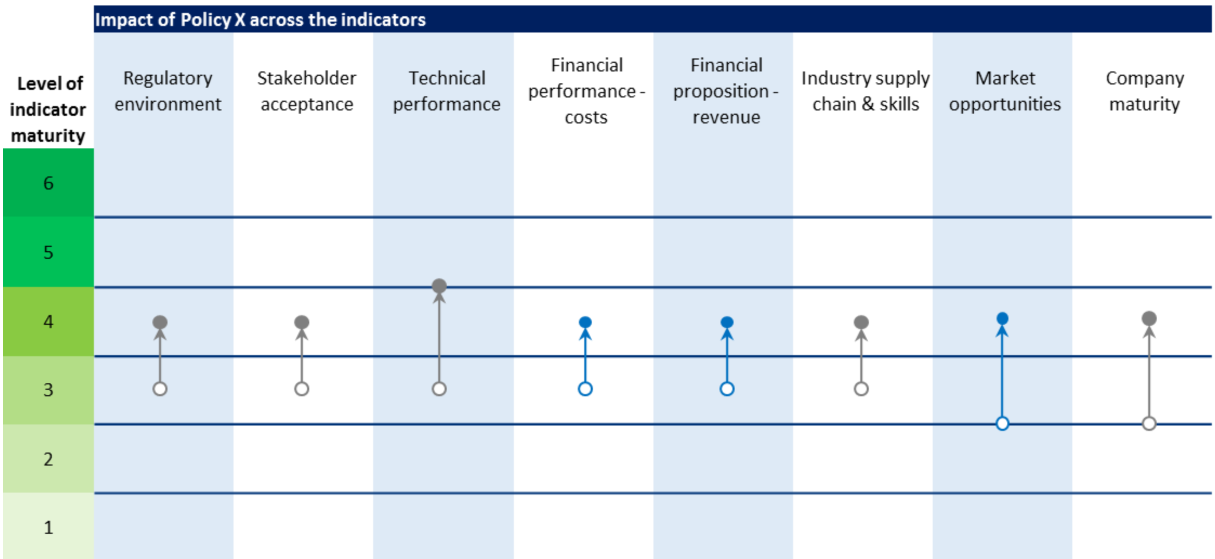
For this study, we have separated the CRI status summary level (in the green rectangle) from the CRI indicators (in blue). Figure 3-2 below shows how we have illustrated the impact of Policies X and Y on the overall status summary level of the CRI – depicting a policy pulling the RET further along the overall commercialisation scale.



○ = at what point in the commercialisation journey the policy was initially employed (start point)
● = where the policy was successful in moving the commercialisation journey to (end point)

Figure 3-2: Impact of policies on the CRI commercial summary levels

Following this analysis on the overall commercial maturity of RET, we can select an impactful policy (e.g. Policy X) to show the direct and indirect impacts it had across the various CRI indicators, as shown in Figure 3-3. In addition to driving specific indicators (direct influence), Policy X may also have indirectly affected other indicators (e.g. technical performance, stakeholder acceptance, etc.) alongside a range of other policy measures. For example, technical performance could have been indirectly influenced by Policy X alongside Policies Y and Z.



○ = at what point in the commercialisation journey a policy was initially employed (start point)
● = where the policy **directly** influenced the commercialisation journey (end point)
● = where the policy **indirectly** influenced the commercialisation journey (end point)

Figure 3-3: Impact of Policy X on the CRI indicators

In both case studies, we have used this approach to illustrate the impact of policies over time and across different areas of the commercialisation chain, as opposed to a single CRI assessment at one point in time, which would have provided more limited information.

3.1 SOLAR PV IN GERMANY

Germany has been a pioneer of solar PV deployment. It was the world's leader in installed capacity from 2005 until 2015, when it was overtaken by China (Figure 3-4).

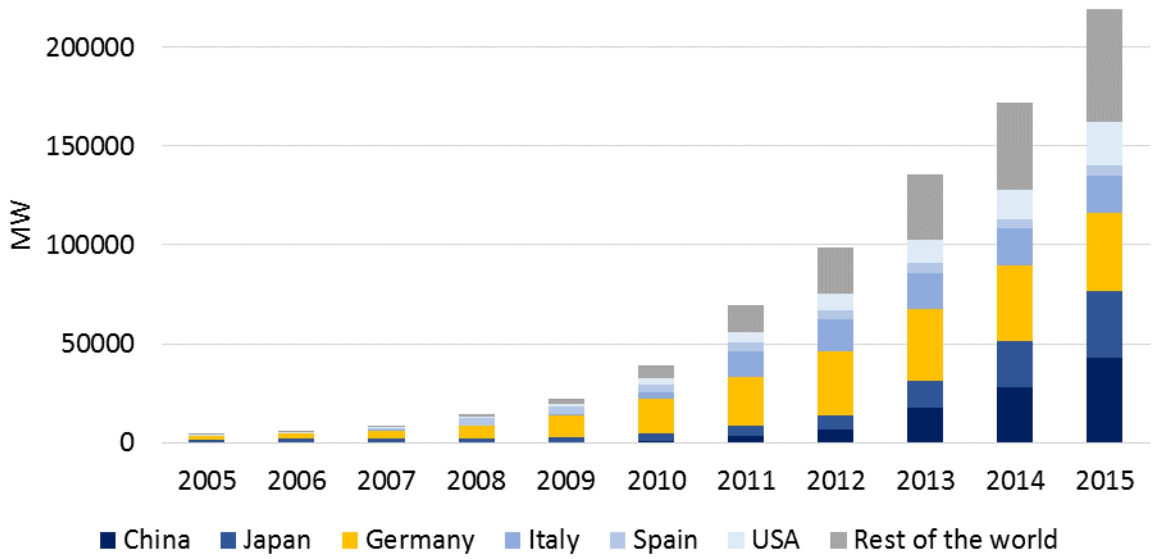


Figure 3-4: Solar PV global capacity, by country/region, 2005–2015 (Source: REN21 (2016), Renewables 2016: Global Status Report)

Demand-focused policies have been fundamental to Germany's solar PV market growth. Germany built on the research and development (R&D) efforts of the two other major players in the nascent solar PV industry, Japan and USA, in order to drive market demand. Germany's policy strategy since 1990 has been concentrated first on proving, and then on scaling, the market for solar PV. Germany's main motivations for embarking on this policy strategy were to:

i) Reduce dependence on fossil fuels (and later nuclear power) for electricity generation;
ii) Grow a domestic market capable of driving down the costs of solar power via economies of scale; and
iii) Build-up world-leading export potential through the development of local supply chains.

The presence of technology manufacturers and consumers willing to invest within Germany provided a strong market base to spark early market growth. However, despite the provision of various government-backed incentives, Germany's domestic market took over a decade to reach significant scale. The turning point arrived in the early 2000s, when increased subsidies and soft loans for end-users were provided to address the persistently high costs. Although deployment gathered pace as a result, it was not until the caps on solar PV system sizes and capacity eligible for subsidies were removed that installed capacity began to increase exponentially.

From 2004 until 2012, Germany witnessed unprecedented growth following the government's commitment and the concurrent boost in consumer and business confidence. Moreover, broader investment support policies at the state and federal level for manufacturing industries helped boost the growth of the solar supply chain, particularly in eastern Germany. These included grants and cash incentives through the Joint Task and Investment Allowance programs, as well as reduced-interest loans and public guarantees.

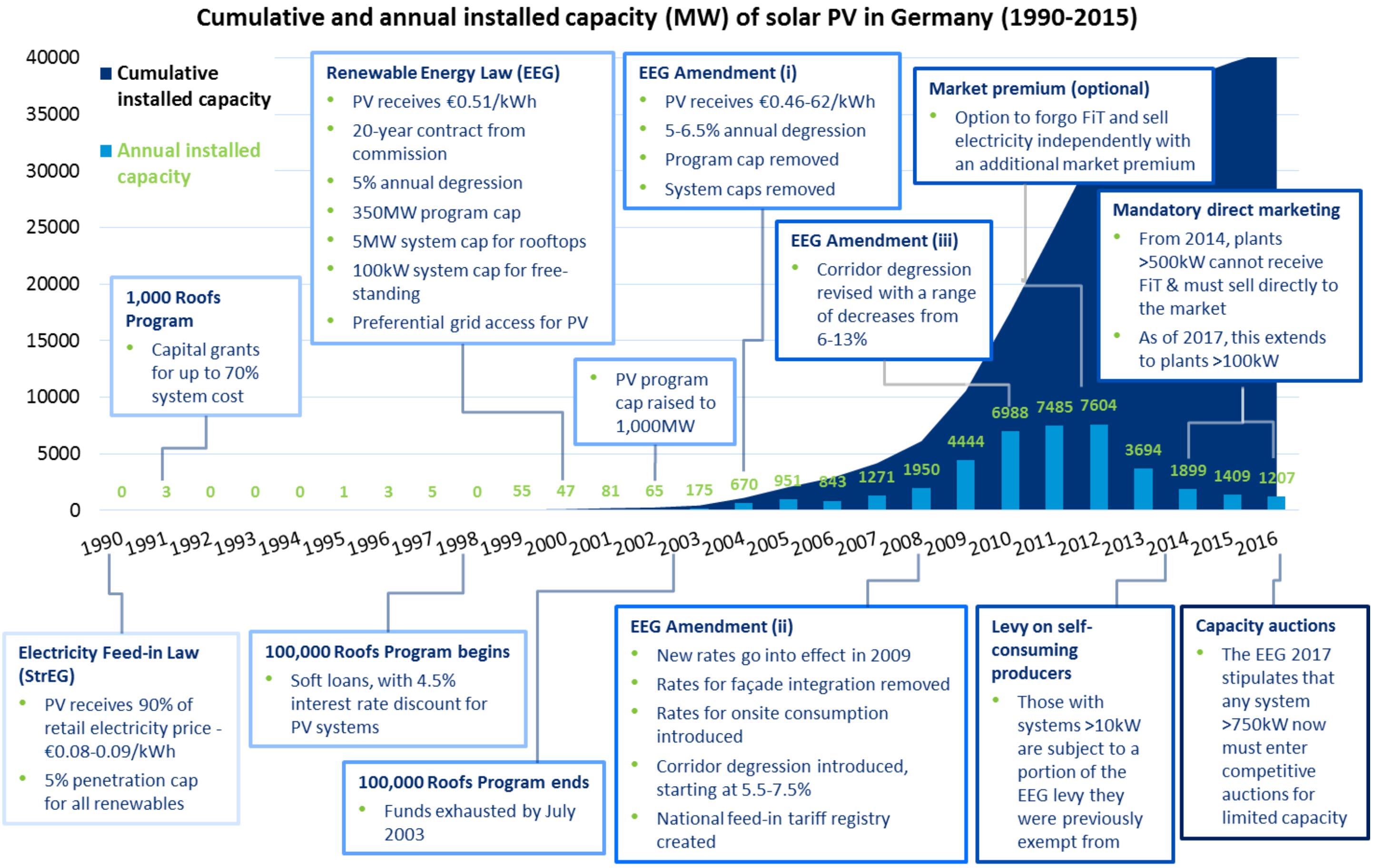


Figure 3-5: Key policy measures to support solar PV installed capacity (MW) of solar PV in Germany (1990-2015) (Sources: Carbon Trust analysis; IRENA RESource)

In more recent years, Germany's export dominance in the solar PV sector has been superseded by the Chinese solar PV manufacturing industry. China's ability to produce large quantities at a lower cost than its German competitors has enabled it to become the world leader. Germany has become a key export market for China. In 2010, Chinese solar PV exports to Germany were nearly equal to Germany's solar PV exports to all countries, at $7.6 billion.[7] China is now indisputably the world leader in solar PV production and exports.

Policy measures have recently been put in place (e.g. market premium, mandatory direct marketing and capacity auctions) to reduce the level of support to solar PV in Germany, and there has been a noticeable slow-down in annual installed capacity. Germany's priorities have now shifted from increasing deployment of solar PV to addressing grid management issues, reducing subsidies, and integrating storage technologies. Figure 3-5 summarises this policy timeline in relation to the cumulative and annual installed capacity of solar PV in Germany.

[7] Fortune (2016), "China's Solar Panel Glut Undermines Its Agreement with the EU", http://fortune.com/2016/09/14/china-solar-panel-production/, last accessed 14.03.2017.

Table 5-6 in Section 5.4.1 provides more detailed information on the aims of the various policies and their impact in the solar PV market in Germany.

The analysis below (Figure 3-6) illustrates the policy journey of solar PV in Germany using the CRI framework developed by ARENA. The CRI in its existing form (as developed by ARENA) presents the summary level at one single point in time. For example, the CRI summary level for solar PV in Germany in 1998 would have resulted in a 2.5 score. However, in order to show the policy journey of solar PV in Germany through time, we have modified the approach to allow us to represent how the different policies advanced the RET. We have undertaken the mapping in a two stage process:

1. Figure 3-6 represents the overall commercialisation journey of solar PV in Germany in relation to the CRI status summary level from commercial scale-up in 1998 to almost reaching bankable asset class status in 2017. The most influential policies are illustrated in relation to when they were initially employed (using a hollow circle), the progress they made (the arrow symbolising increasing commercial maturity score), and the level of commercialisation they achieved (the filled circle).

This exercise is useful in presenting the story outlined in Figure 3-5, where the effect of the policies on the commercial maturity of solar PV in Germany is represented. However, the CRI does not explain *how* each policy was effective in advancing the commercialisation of solar PV in Germany. For example, it does not tell the user which barriers the policy addressed. This problem is partly addressed by mapping a specific policy (in this case we selected the EEG (FiT) reform in 2004) onto the CRI and identifying the indicators the policy influenced and to what extent. This is illustrated in Figure 3-7.

2. The indicators highlighted in Figure 3-7 are graded on an independent 1 to 6 level based on qualitative criteria defined by ARENA. For example, as depicted by Figure 3-7, the EEG reform in 2004 helped move the “Financial performance – costs” indicator:
   i. From Level 4: “Key costs elements of projects in public domain. Commoditisation of major components occurring. Cost drivers are understood with roadmaps in place to bring costs to being market competitive.”
   ii. To Level 5: “Price and value proposition clear and attractive with open access to cost trends and projections based on actual project data from a wide range of applications.”

Figure 3-7 represents the impact that the FiT reform in 2004 had on the CRI indicators (when the caps on system and program size were removed). This FiT policy was very effective in helping to address barriers, either directly or indirectly, across all of the key indicators. It supported the creation of the first mass market for solar PV in the world. In particular, it was highly influential in promoting greater market opportunities for companies to grow and mature. This visual overview shows how the solar PV market was able to grow and mature, highlighting the indicators the reformed FiT helped to address.

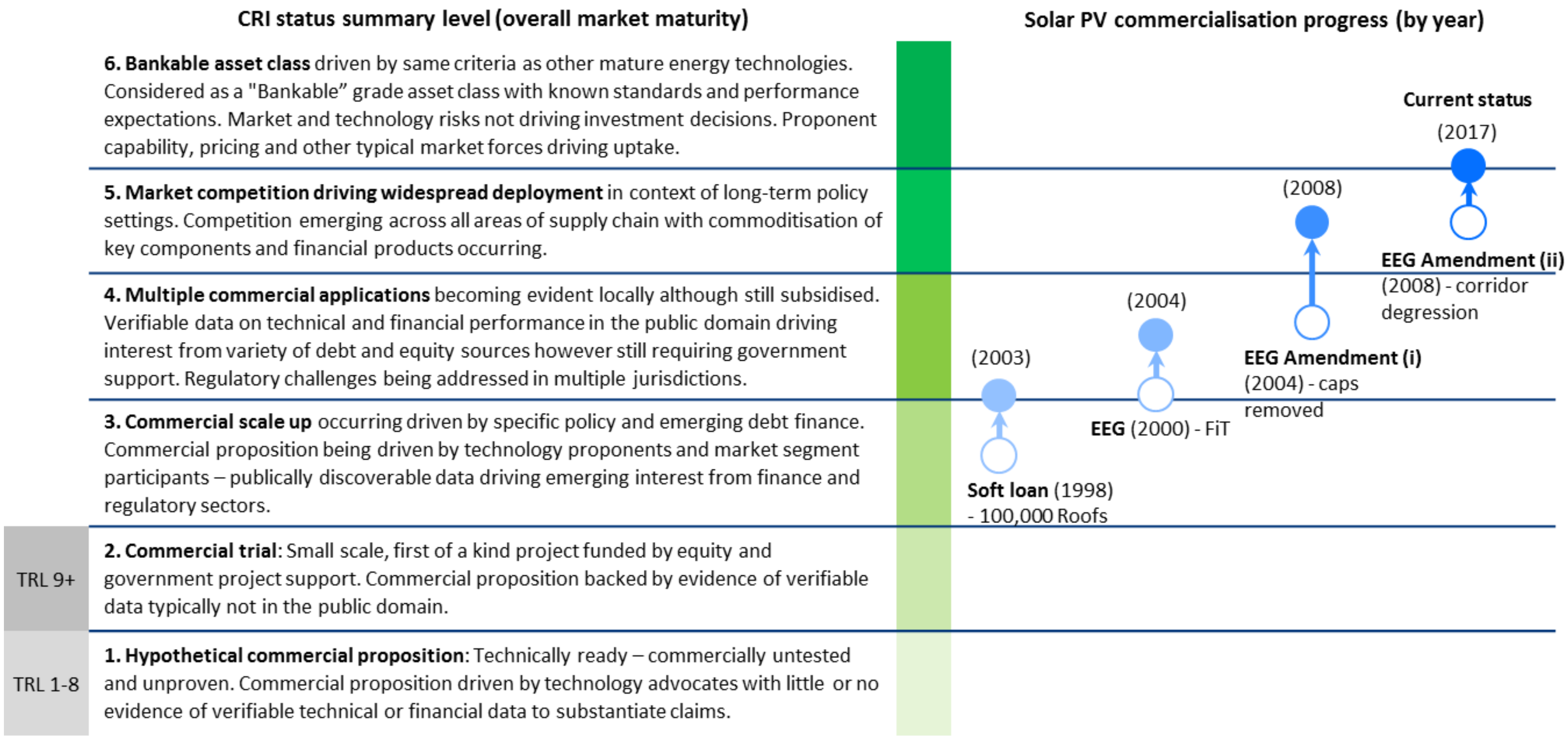


Figure 3-6: Mapping key policies of German solar PV against the CRI summary levels, highlighting overall market maturity through time

○ = at what point in the commercialisation journey a policy was initially employed (start point)

● = where the policy was successful in moving the commercialisation journey to (end point)

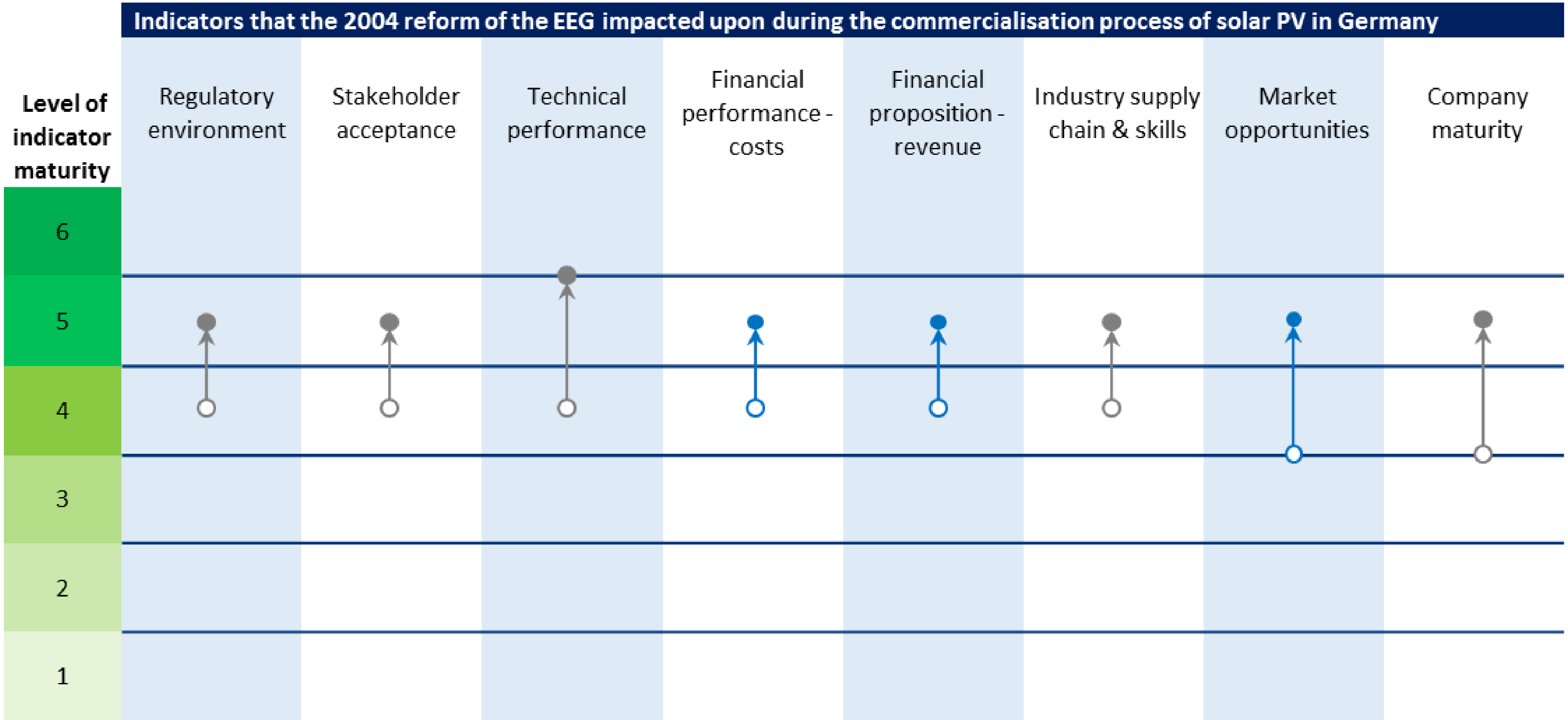


Figure 3-7: Mapping the 2004 FiT reform against the relevant CRI indicators - displaying the starting and end points and whether the policy directly or indirectly influenced each indicator

○ = at what point in the commercialisation journey a policy was initially employed (start point)

● = where the policy **directly** influenced the commercialisation journey (end point)

● = where the policy **indirectly** influenced the commercialisation journey (end point)

Germany has one of the highest installed solar PV capacities in the world.[8] The German policy support was a crucial stimulus for driving down costs through economies of scale – providing a long-term, visible market for both customers and suppliers. However, the policies were less effective at securing Germany's position as the dominant exporter of solar PV. Instead, international competition, particularly from China, has been able to capitalise on the growth, and future visibility, of Germany's domestic market to mass produce cheaper units. This outcome supports the hypothesis that demand-focused policies can have major spill-over effects,[9] therefore limiting their value for creating an indigenous export market.

3.1.1 What were the most successful policies in supporting the commercialisation journey of solar PV in Germany?

The journey illustrated in Figure 3-5 shows how the initial attempts to drive the commercialisation of solar PV were not successful. Overall, these demand-focused policies were either not adequately priced (in the case of the original feed-in law), or of sufficiently large scale (e.g. the 1,000 Roofs program) to have a significant impact on any of the CRI indicators. This is reflected by the lack of installed capacity from 1990 to 1998.

Germany's 100,000 Roofs soft loans program was much more successful. By the time of its implementation in 1998, the development of solar PV had matured to the point where demand-focused policies could have more traction. The soft loans were simple to understand and implement for end-users which increased demand due to the attractive offering and substantial size of the program. This contributed to a growing level of confidence and skills within the market. The CRI illustrates the impact of the policy in Figure 3-6, showing how it influenced the progression up from the 'specific policy and emerging debt finance' of level 3 towards the boundary of level 4.

The influential feed-in-tariffs (FiTs) built upon the 100,000 Roofs soft loans success. In Germany, the model which was most impactful was the 2004 reform, when the tariff structure was tied to the true cost of solar PV units, without limits placed on system size or installed capacity. This created a strong business case for individual consumers to deploy solar PV and provided future market visibility which gave the supply chain the confidence to invest in growth. Since then, the subsequent FiT reforms have continued their effective work in supporting the commercialisation of the solar PV market.

However, whilst the FiTs have been effective, they have also been inefficient. FiTs are policy instruments that provide an attractive financial incentive, but they can be difficult to flex as appropriate. Consequently, as the German solar market expanded rapidly, the cost burden for consumers grew without much constraint. Recent attempts to slow down the pace of deployment appear to be taking effect, with FiTs now being limited to smaller system sizes, and others having to compete for limited capacity at competitive auctions. The annual installed capacity has thus decreased year-on-year since 2012 as the market slows down and operates on a more commercial basis.

---

[8] IEA (2013) *Energy Policies of IEA Countries: Germany 2013 Review*.

[9] Michael Peters, Malte Schneider, Tobias Griesshaber, Volker H. Hoffmann (2012), *The impact of technology-push and demand-pull policies on technical change – Does the locus of policies matter?*

At present, solar PV in Germany is considered to be nearly a fully commercial, bankable asset class. However, a key limitation is the remaining disparity between the costs of energy from solar PV in Germany and fossil-fuelled sources – justifying continued, although decreasing, policy support.

Interestingly, the demand-focused policy of the FiT that Germany implemented was judged to have had a significant indirect impact on the technical performance of solar PV along its commercialisation journey. It is important to note that this is driven by the fact that Germany created the first mass market for solar PV, therefore there was a strong feedback loop into improving technical performance and, consequently resulting in cost reductions.

3.1.2 Is the CRI useful to map the policy-commercialisation journey?

The policy-commercialisation journey of solar PV in Germany is one of the most extensive and complex due to the nature and number of policies employed. Our main findings are outlined below.
It is initially difficult to understand how the policies on the CRI are mapped and how the indicators are graded. The user requires an understanding of what the different levels and indicators represent which requires deeper knowledge of the CRI's scoring criteria.[10] However, once the CRI framework and its assessment methodology is understood, it can be a useful framework to illustrate the commercialisation journey of a particular technology. However, the subjectivity of the tool means that scoring is not consistent across different people.

This case study highlights the value of the CRI as a tool for illustrating the wider context of commercialisation of a particular RET in a particular context. However, it is constrained in its ability to demonstrate generalizable lessons that can be taken across different technologies and contexts because of its simplicity.

The applicability of using the CRI to draw lessons from a technology's commercialisation journey in a specific context with the aim of applying it to a different context is limited. In reality, expert judgement, experience and detailed evidence will be critical to developing effective policies. For example, what tariff level and contract length would a country need to offer to encourage deployment? The CRI is unable to show this level of detail which is important for policy makers.

This is compounded by the problem of applying lessons across different contexts. TRLs can be difficult to interpret, but their focus on engineering and physical properties makes it easier to generalise and apply to different contexts than the CRI, where markets will register inconsistent variations across time, location and environment. Indeed, it is not just difficult to generalise across countries, given their different capabilities and priorities, but this can also be challenging within industries. For example, there are significant differences between utility-scale and residential solar PV markets that are hard to distinguish with the CRI.

---

[10] As found at: ARENA (2014), *Commercial Readiness Index for Renewable Energy Sectors*.

3.2 OFFSHORE WIND IN THE UK

The UK has an extensive coastline, with high potential for generating wind power, making it a key technology to help the UK achieve its commitment of an 80% reduction in greenhouse gases by 2050. It is the world's leader in offshore wind deployment with just under 6GW of installed capacity, representing c. 40% of the world's total installed capacity in 2015. As Figure 3-8 shows, it was the world's leader in annual installed capacity until 2014. More recently, other European countries are deploying offshore wind capacity in greater numbers, but the UK retains the largest cumulative installation.

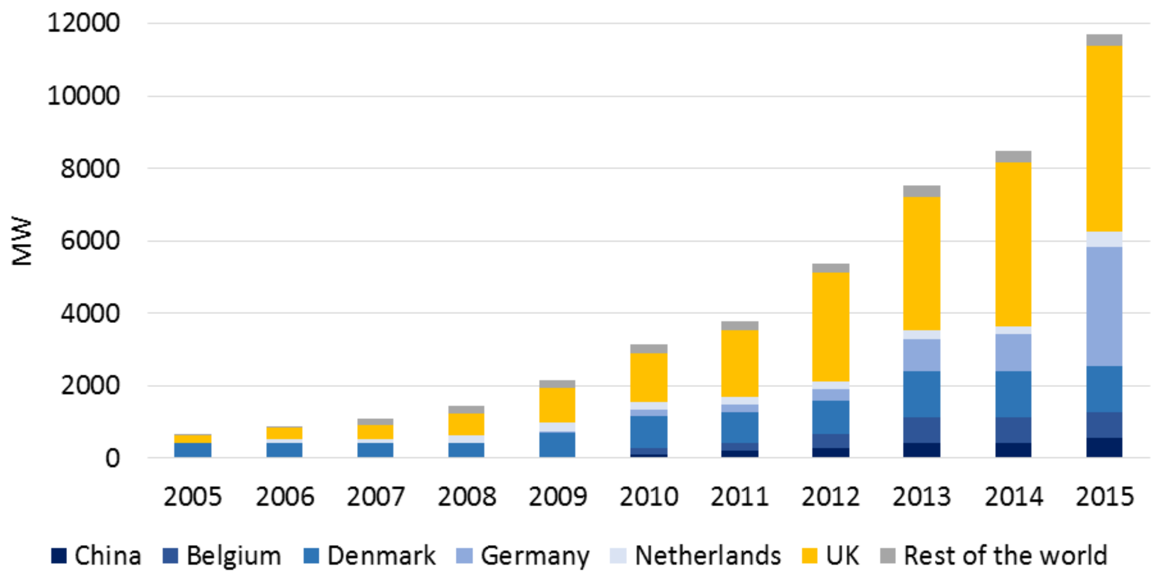
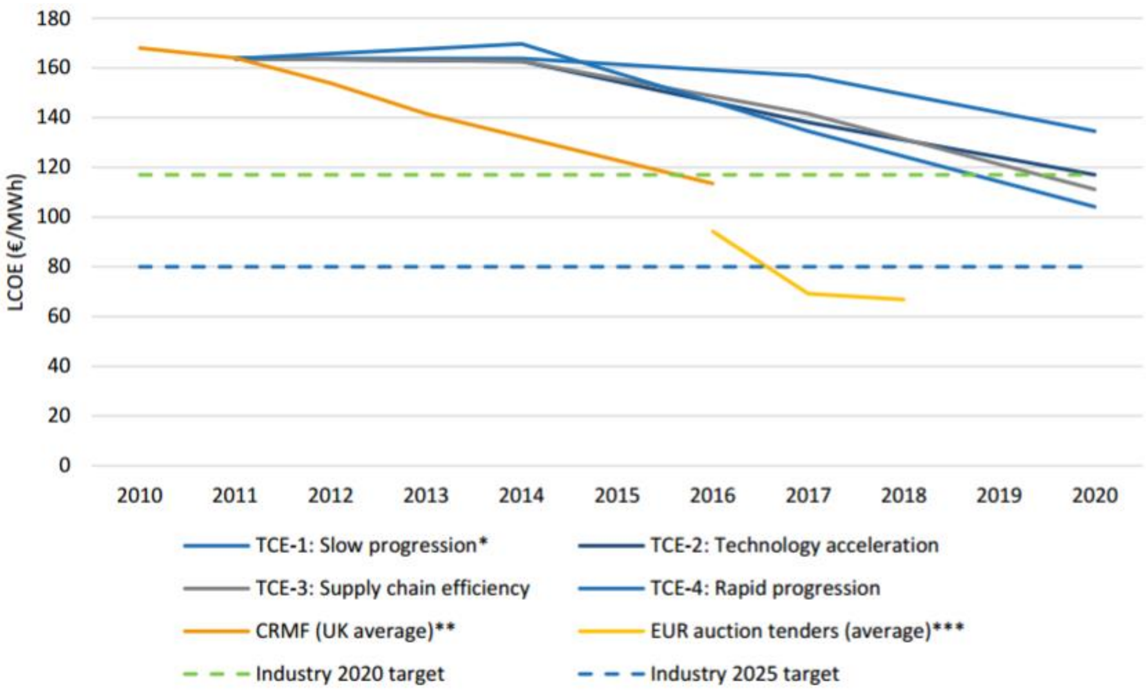


Figure 3-8: Offshore wind global capacity, by country/region, 2005–2015 (Sources: 4coffshore; WindEurope; Carbon Trust analysis)

Over the years, the UK has invested in a combination of technology-push and demand-pull policies to become the global market leader in terms of offshore wind innovation and deployment. The former has been institutionalised with programmes and bodies such as the Offshore Wind Accelerator and the Offshore Renewable Energy Catapult, which have unlocked significant public and private sector investment in R&D. This has strengthened the local supply chain and reduced the cost of components. Deployment has been incentivised through grants, subsidies, and the visibility of future development opportunities which provide confidence to investors and developers.

A balanced use of pull and push policies has positioned the UK as a world leader in offshore wind. Pull policies have resulted in increased confidence in the strength of the future offshore wind market, which in turn demands investment to grow its supply chain and reduce costs, supported by push policies.

It is important to note that from the mid- to late-2000s, the costs of offshore wind actually increased.[11] The rise is attributed to increased material costs, supply chain constraints and planning farms at more ambitious locations, in particular in deeper waters and further from the shore.[12] Since the turn of the decade, costs have declined sharply – between 2011 and 2014 lifetime costs fell by 11% in the UK.[13] This trend has continued along with market expansion with developers indicating they can produce offshore wind power under £100/MWh (including transmission costs).[14]



** The Crown Estate (TCE) Cost Reduction Pathways (2011); ** Cost Reduction Monitoring Framework (2017)*
**** Includes grid connection and site development costs for NL and DK projects (uplift of €14/MWh). It should be noted that many of the 'actual' projects reaching FID have not yet been built.*

Figure 3-9: Offshore wind cost trends in Europe (Source: IEA-RETD (2017) REWind Offshore)

Witnessing this significant cost reduction, the UK government has begun to move towards pull policies that place an emphasis on competition. The progress of an emerging commercial market is evident in the capacity auctions results, where project developers bid to undercut each other for a limited available capacity.

Major international firms have capitalised on the UK's long-term policy goals, stable regulatory environment and attractive financial support. As a result, the UK has begun to implement policies that

---

[11] UK Energy Research Centre (2010), *Great Expectations: The cost of offshore wind in UK waters – understanding the past and projecting the future*.

[12] Ibid.

[13] Offshore Renewable Energy Catapult (2015), "Cost of offshore wind energy falls sharply", https://ore.catapult.org.uk/press-release/cost-of-offshore-wind-energy-falls-sharply/, last accessed 27.03.2017.

[14] Financial Times (2017), "UK wind farm costs fall almost a third in 4 years", https://www.ft.com/content/e7cce732-e171-11e6-9645-c9357a75844a, last accessed 27.03.2017.

aim to increase the native share of the marketplace, for example the GROW: Offshore Wind programme.

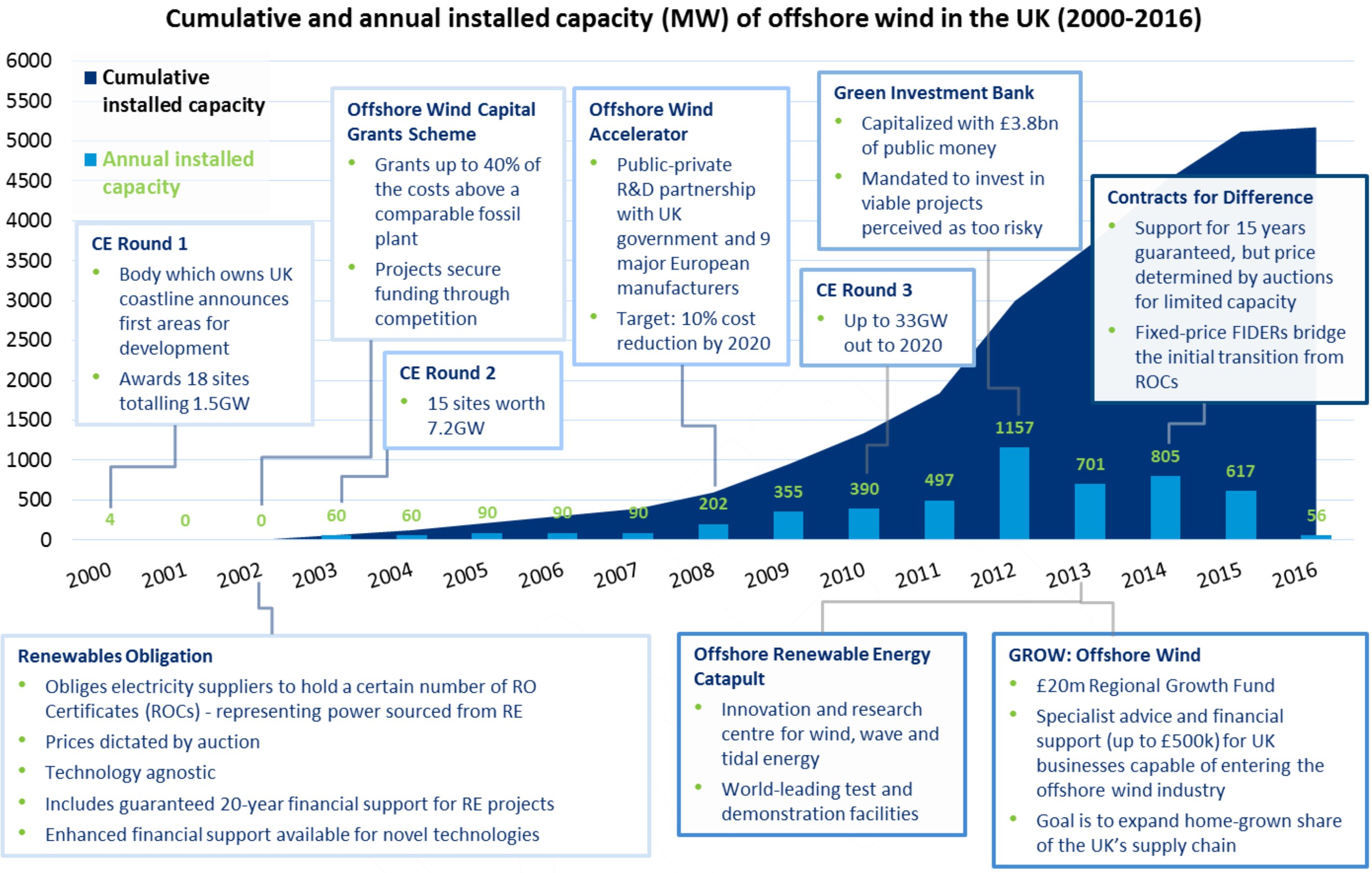


Figure 3-10: Key policy measures to support installed capacity (MW) of offshore wind in the UK (Sources: Carbon Trust analysis; IRENA RESource)

Table 5-7 in Section 5.4.2 describes the aims of the various policies and their impact in the offshore wind market in the UK in more detail.

Figures 3-11 and 3-12 demonstrate the policy-commercialisation journey of offshore wind in the UK using the CRI framework developed by ARENA. We have undertaken the mapping in a two stage process, following the same approach taken with the solar PV case study described in Section 3.1.

Figure 3-11 illustrates the commercialisation journey of offshore wind in relation to the main policies that supported its development and deployment. Figure 3-12 shows the impact of the Renewable Obligation Certificates (ROCs), mapping its direct and indirect impact on the different CRI indicators. The ROC subsidies provided through the mechanism were very influential in improving the financial outlook for offshore wind. Their ability to guarantee a stable source of revenue over a long period of time combined with an increase in the level of the obligation made it an attractive financial proposition for developers and investors alike.

Once the number of projects began to grow, as highlighted by the increasing market opportunities, the supply chain and skills level also improved. This development resulted in improvements in the technical performance (e.g. more efficient turbines, construction of sites in deeper waters and further from shore).

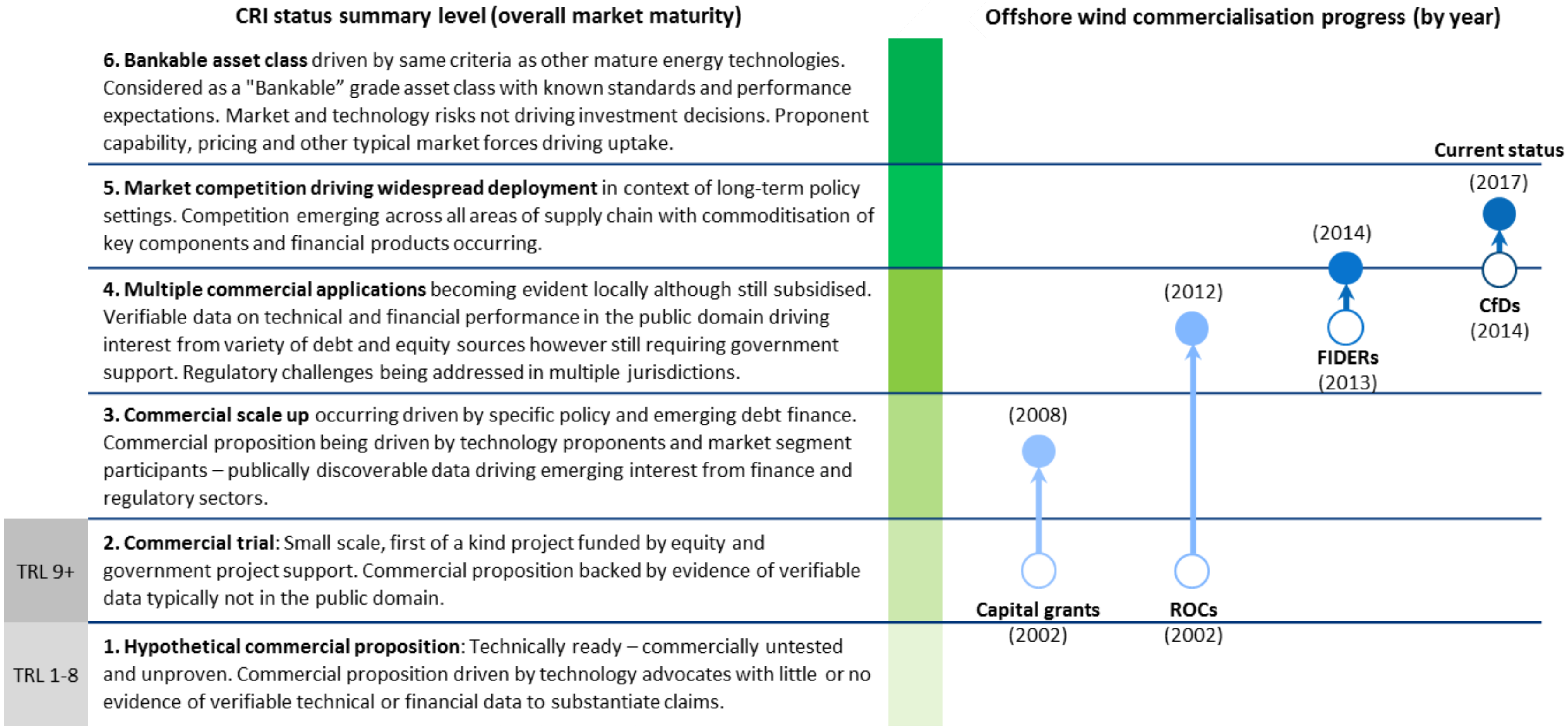


Figure 3-11: Mapping the policy journey of offshore wind in the UK against the CRI summary levels, highlighting overall market maturity through time

○ = at what point in the commercialisation journey a policy was initially employed (start point)

● = where the policy was successful in moving the commercialisation journey to (end point)

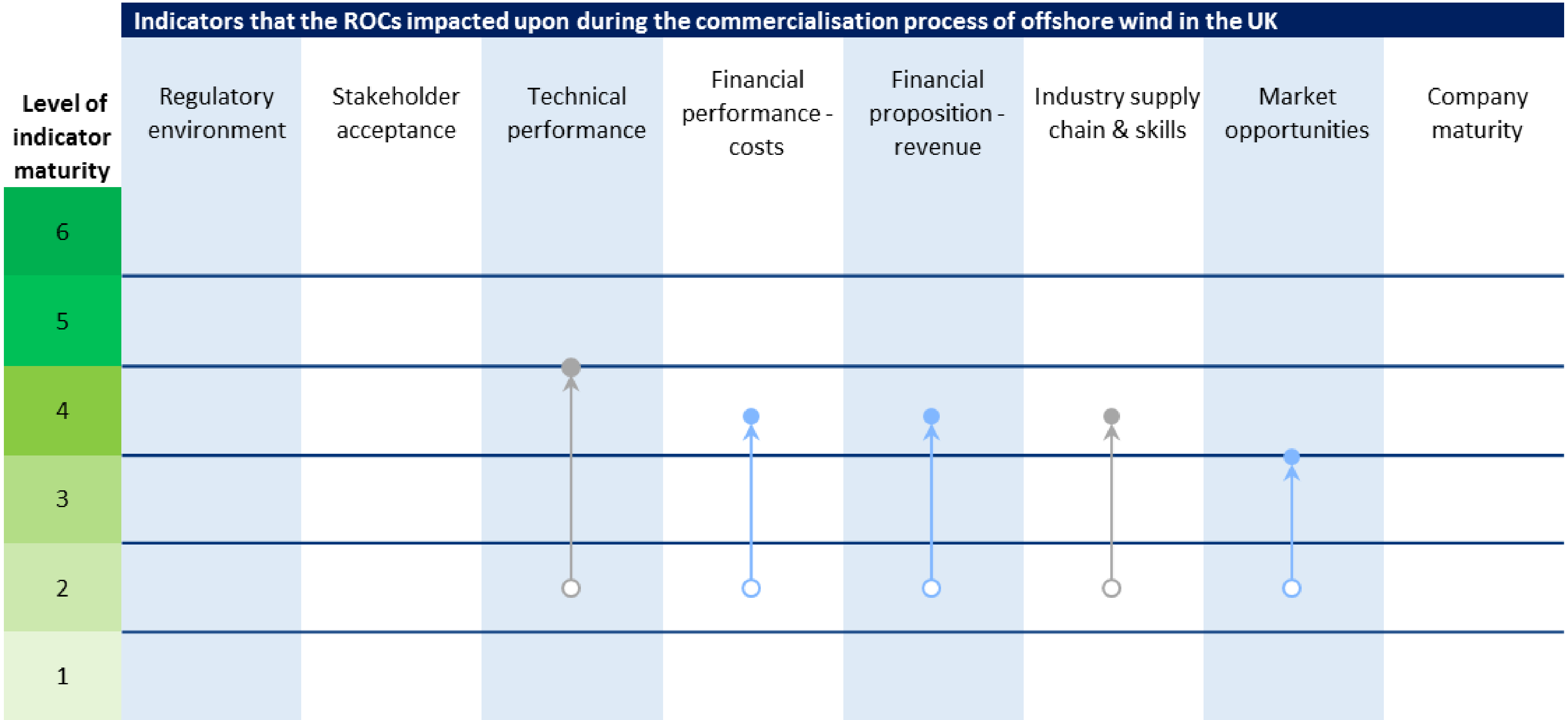


Figure 3-12: Mapping the ROCs against the relevant CRI indicators - displaying when it was employed and where it was successful

○ = at what point in the commercialisation journey a policy was initially employed (start point)
● = where the policy **directly** influenced the commercialisation journey (end point)
● = where the policy **indirectly** influenced the commercialisation journey (end point)

The UK has emerged as the global leader in terms of offshore wind deployment. Its substantial and consistent policy support has been fundamental to provide confidence to developers and investors. The UK Government's commitment to provide ongoing support to the offshore wind industry has resulted in reduced costs and the growth of a robust supply chain.

3.2.1 What were the most successful policies in supporting the commercialisation journey of offshore wind in the UK?

The ROCs were the key support mechanism for providing the emerging offshore wind industry in the UK with revenue streams at attractive rates of return. Their financial impact was crucial for unlocking large-scale deployment and growth of the industry. The ROCs' success was also due to the visibility of future market opportunities which was provided by the Crown Estate's leasing rounds. This outlined the capacity potential and created a significant market opportunity for early movers in the industry.

The Contracts for Difference (CfDs) have begun to move the market towards a more competitive market, where we have seen a reduction in costs. However, a major criticism highlighted by our interviewees is that the limited cap on capacity places an increased risk onto the project developers, who may not see viable sites commissioned. Hence, this restricts the potential for new entrants, who lack the capital and balance sheets of industry incumbents, to take such risks.

The push policies associated with spending on world-leading innovation centres and programmes, such as the Carbon Trust's Offshore Wind Accelerator and the Offshore Renewable Energy Catapult, have also played an important part in advancing technological developments to reduce the cost of offshore wind. In addition, they have played a key role in forming a coherent platform bringing together government, industry and academia to collaborate and advance the deployment of offshore wind in the UK.

3.2.2 Is the CRI useful to map the policy-commercialisation journey?

Overall, the CRI is an interesting attempt to represent the policy journey of offshore wind, but it lacks sophistication and requires guidance on how to assess the different indicators. These indicators are relevant and highlight the importance of different market conditions beyond the technical performance of offshore wind. However, policy makers require more detail to understand the impact of the policies implemented.

Furthermore, the CRI does not provide sufficient information on how indicators were directly or indirectly affected by policies. For instance, it is difficult to determine the level of indirect impact the ROCs had on technical performance.

In addition to the lack of detail, the static snapshot of the CRI fails to account for important changes in the commercialisation journey; for example, the increasing costs of offshore wind at the turn of the decade. Policies can progress certain indicators whilst limiting or regressing others.

There are a number of limitations to generalise the findings from the CRI. Taking policy lessons from the UK and applying them into another context is challenging. The importance of various factors that define a market is not captured by the high level approach of the CRI and this limits its usefulness for applying it to policy making. This problem is compounded by the lack of objectivity, which can lead to different interpretations even for the same technology and market.

4. KEY FINDINGS ON USING THE CRI & RECOMMENDATIONS FOR POLICY MAKERS

The innovation and policy community agrees on the need to assess technologies beyond the traditional "technology maturity" to consider additional stages and factors which reflect the technologies' commercialisation status in the market. Our case studies show the value of the CRI as a framework to illustrate the policy-commercialisation journey of a technology, but its direct applicability to policymaking is limited. This section summarises the key findings of our study.

4.1 ADVANTAGES AND LIMITATIONS OF THE CRI AND ITS POTENTIAL APPLICABILITY TO SUPPORT POLICY MAKERS

The feedback gathered through our interviews suggests that the main benefit of the CRI is the recognition of the need to assess various indicators that influence the commercial maturity of RETs. The CRI is useful as a tool to help policy makers to think about the different commercialisation stages a technology goes through before becoming a bankable asset class.

Despite not being widely-known amongst our interviewees, they understood the CRI case study illustration (Figure 3-6 and Figure 3-11) once we explained how the CRI indicators are assessed.

The CRI helps identify key barriers that need to be addressed in order to support the commercialisation of RETs. For example, before the solar PV Feed in Tariff (FiT) reform was introduced in 2004 in Germany, a CRI assessment would have highlighted a low score in the financial proposition indicator, which would have suggested a need to address it to stimulate deployment at scale.

The CRI can be used to illustrate the historical policies which have had an impact on the performance of indicators. For example, the ROC policy in the UK provided financial incentives for investors and enabled a greater deployment of offshore wind. The direct impact of the ROC is highlighted by an increase in the CRI scores for the financial performance and market opportunity indicators from level 2 to level 4.

Box 1: Advantages of using the CRI

- The CRI framework can be used to assess **how a technology ranks in terms of commercial readiness** which is generally not captured in other commonly used frameworks such as the TRL.
- The CRI can be used **to illustrate the historical policy journey** of technologies**.**
- Through the CRI assessment, policy makers can **identify some of the key barriers** that need to be addressed in order to support the commercialisation of RETs.

Despite the advantages described above, our case studies also highlighted some limitations on using the CRI in policy making. The CRI was not intuitive for many of our interviewees as it requires an understanding of the methodology used to assess its indicators in order to understand the policy journey illustration. In addition, the indicators are assessed using qualitative criteria, which is difficult to standardise.

Independent feedback suggests that the CRI could serve as a tool to identify the barriers that policies can help address, but it lacks sufficient complexity to explain how and why policies are or could be effective. Policy makers need additional detail that enables them to understand what the impact of these policies is likely to be. For example, it will not provide information on how to implement the policy or the level of effort required.

Although the indicators represent important factors that influence the commercial maturity of technologies, they do not account for all of the barriers faced by RETs (e.g. enabling infrastructure) nor provide sufficient detail (e.g. what type of regulatory environment already exists in a country) to be useful when selecting policies. This level of detail is essential for policy makers so the CRI as a stand-alone tool would be insufficient to support policymaking.

The lack of flexibility within the CRI framework restricts it to a snapshot of a technology's commercial maturity in a specific point in time, place, and under certain market conditions. This limits its operational value. In addition, the CRI fails to account for the non-linear process of the commercialisation journey (e.g. regression as well as progression of certain indicators).

The CRI does not account for the geographical, economic, social and political variations across countries. Therefore, it is challenging to generalise the lessons learned from one particular case study to another context, limiting the CRI's replicability.

Box 2: Limitations of using the CRI for policy making

- The CRI framework is **not intuitive** and requires a more detailed understanding of how the indicators are assessed.
- The indicators' assessment is based on **subjective, qualitative judgements** that are difficult to standardise.
- The CRI **lacks sufficient detail** to explain **how and why policies were effective** or not.
- It has **limited flexibility** making it challenging to represent the impact of policies across different indicators over time
- It is **challenging to replicate lessons** from one case study to another given the different contexts.

4.2 EFFECTIVE POLICIES TO SUPPORT THE COMMERCIALISATION OF RETS

Pull policies are fundamentally geared towards improving the business case (or driving demand) for renewable energy investments. Their *direct* impact is focused on improving the financial performance of a technology (e.g. increasing revenues through subsidies, decreasing costs through creating a mass market). However, our case studies also highlight that pull policies also have indirect effects in other areas (e.g. technical performance). For example, the creation of an attractive business case and market opportunities for solar PV in Germany and offshore wind in the UK led to an improvement in the technical performance and supply chain indicators for both technologies.

The policy journey illustrated in our case studies shows how policies transitioned from push policies to support the commercial viability of emerging technologies to pull policies in order to generate traction in the market. For example, the UK's Offshore Wind Capital Grants Scheme was used to stimulate early offshore wind development. Once the market has confidence that there is a working product, subsidies (e.g. FiT, ROCs) are required to support the first phases of mass deployment. The market visibility and attractive financial returns mitigate perceived risks and provide confidence to private investors.

Lastly, capacity auctions were implemented in both case studies with the aim of driving market competition. This limits the amount of deployment potential that can receive financial support from government, which may limit market growth and the speed of the transition to renewable energy. This limited capacity is subject to a bidding process which aims to increase competition to drive down costs.

Whilst capacity auctions have led to cost reductions, they represent a new risk for the industry, particularly where projects have already started to be developed. For example, potentially viable projects which have received multi-millions worth of investment could be unsuccessful in securing long-term funding through the capacity auctions because of the deployment limits that the capacity auctions introduce. How this risk is managed and absorbed, either by the public or private sector, can determine how many, and what type, of firms can afford to enter the capacity auction. If this risk has to be absorbed by the private sector, then the policy inherently favours established players with a large enough balance sheet, potentially hindering small, new firms from entering the market.

Box 3: Pull policy key takeaways

- The transition from a hypothetical commercial proposition to a bankable asset class can be enabled by initially providing **capital grants to support a novel business case**, followed by operating **subsidies to enable market growth.**
- Pull policies create **financially viable markets** that drive market demand and can have significant international spill-over effects by catalysing the growth of global supply chains.
- Beyond improving the financial performance, pull policies can also have **positive indirect effects** on RET (e.g. improved technical performance and stronger supply chains).

4.3 OPPORTUNITIES TO REFINE THE CRI

In order to address some of the CRI's limitations outlined in Section 4.1, we propose some modifications to make it more useful for policy makers and decision makers.

In addition to the eight indicators currently assessed in the CRI, it would be valuable to assess more indicators which are currently not being evaluated that capture additional commercialisation barriers faced by RETs. This would provide policy makers a more comprehensive view of the range of barriers that are faced by RETs to get to market. For example:

- Enabling infrastructure (e.g. grid integration);

- Planning and permitting;
- Level of political support;
- Society's willingness to pay;
- Risk-return profile; and
- Resource availability.

Two existing CRI indicators could be broken up to provide more granular analysis:

- Regulatory environment could be broken down into: i) planning and permitting, and ii) level of political support; and
- Industry supply chain and skills into: i) supply chain, and ii) skills.

Furthermore, the CRI framework could include a series of prompt questions to stimulate policy makers' thinking to help them assess which indicators are of particular concern for unlocking deployment.

A summary table that provides the user with an overview of the indicators' assessment can help policy makers to quickly identify the main barriers or areas of concern that the RET might face. A traffic light system (e.g. green, amber, red) rather than a (1-6 level) can show the priority areas requiring policy support. For example:

- If the renewable energy resource is widely available in that country, this would result in a green shade, suggesting it is not a barrier for the technology's deployment; and
- If the risk-return ratio of the technology is unattractive for investors, it will be assessed using a red colour, highlighting it as a key barrier to address.

The CRI could provide detailed guidelines describing what a green, amber, or red status represent for each indicator to facilitate this assessment. An indicative table showing the proposed indicators and their assessment is shown below in Table 4-1.

Indicators		Assessment
Enablers	Enabling infrastructure	
	Planning and permitting	
	Stakeholder acceptance*	
	Level of political support	
Financial attractiveness	Availability of funding	
	Society's willingness to pay	
	Risk-return profile	
	Financial performance – costs*	
	Financial performance – revenue*	
	Market opportunities*	
Capacity to deliver	Resource availability	
	Technical performance*	
	Supply chain	
	Skills	
	Company maturity*	

Table 4-1: Proposed summary view of indicators assessment
*Existing indicators used in the CRI

The traffic light view will highlight the main areas of concern or barriers that the technology might face.

The CRI framework does not show the potential interventions that policy makers could use to address the commercialisation barriers of RETs. A table that indicates the interventions commonly used to address specific commercialisation barriers (e.g. FiT to address low financial performance) could be helpful for policy makers. The added layer of granularity in the indicators would provide policy makers with a clearer view of the types of policies and programs that could be implemented to support the commercialization journey of the technology being assessed.

We present an indicative matrix of how indicators could be linked with a range of push, pull, and enabling interventions in Table (4-2) below. This matrix could be completed to show which policies are typically relevant to support specific indicators. This could help policy makers to identify the most relevant policies to investigate in more detail to help them address the different barriers faced by RETs.

Policies		Enablers				Financial attractiveness						Capacity to deliver				
		Enabling infrastructure	Planning and permitting	Stakeholder acceptance	Level of political support	Availability of funding	Society's willingness to pay	Risk-return profile	Financial performance – costs	Financial performance – revenue	Market opportunities	Resource availability	Technical performance	Supply chain	Skills	Company maturity
Push policies	Scholarships / fellowships, visas and secondments															
	R&D grants, subsidies, prizes and other funding															
	Soft loans															
	Test hubs															
	Industry / stakeholder consortia															
	Set up commercial vehicles															
	Technology incubators															
	Company skills and capacity building															

Pull policies	Public venturing
	Private venture support
	Guarantees / loss underwriting
	Insurance
	Tax incentives
	Feed-in tariffs
	Bidding / tendering
	Tradable certificates
	Carbon pricing
	Public procurement
	Local purchase rules
	Portfolio standards
Enabling policies	International cooperation
	Industry training
	Media campaigns
	Innovation clusters
	Patent databases
	Planning and permitting
	Market legislation
	IP protection

Table 4-2: Matrix linking indicators with push, pull and enabling interventions

Although testing this revised framework is beyond the scope of the study, our proposed modifications to the CRI could be used to develop a framework that provides policy makers with more relevant information that helps them to explore in more detail the policies that address the barriers faced by RETs at various stages of the commercial development chain.

Box 4: CRI proposed refinements

- Include **additional indicators** that reflect other important factors that affect a technology's commercial maturity.
- Provide a summary view **of the CRI indicators' assessment** using a simple traffic light system that highlights the key areas in need of intervention.
- **Add a table that indicates the policy interventions** that can be put in place to address commercialisation barriers to help guide policy makers.

5. APPENDICES

5.1 METHODOLOGY

5.1.1 Task 1 – Applying the concept of the CRI

The aim of Task 1 is to gain a better understanding of a range of technology assessment frameworks, including the CRI, to explore the CRI's applicability on policy-making. The main tasks conducted were:

i. Conducted a literature review on the use and efficacy of the TRLs, the CRI and other frameworks to assess the commercialisation journey of technologies;
ii. Conducted 10 interviews with external technology commercialisation experts from different stakeholder groups to gain their feedback on the applicability and challenges of the CRI to support policy-makers;
iii. Organised an internal workshop with Carbon Trust commercialisation and renewable energy policy experts to discuss the applicability of the CRI based on prior research, including the identification of critical features for sub-indexes and important contingent limitations of the CRI; and
iv. Synthesised early findings on the advantages and limitations of the different frameworks assessed and highlighted initial thoughts on how the CRI could be refined in order to provide a more comprehensive framework for policy-makers.

Interviews

In Task 1, we initially gathered primary feedback from 10 experts from 7 different stakeholder groups. In advance of our interviews, we shared a 2-page summary of our project, describing the aims of the study and providing an overview of the CRI framework. The aim of our interviews was to test:

- Interviewees' familiarity with the CRI
- Applicability/usefulness of the CRI for policy makers
- Aims and effectiveness of the different pull policies used to deploy the technology in each country
- Opportunities to improve the CRI

We conducted semi-structured interviews. Examples of the questions we raised include:

1. Baseline / existing frameworks (e.g. CRI and TRLs):
   - Have you seen the CRI being used? Where?
   - Are you aware of other tools (frameworks/indexes) that policy makers (and others) use to assess technologies and select interventions to support their commercialisation?
   - What is the problem that these tools are trying to solve?
   - How are these tools being used?
   - What is the process that policy makers undertake to identify and assess policy options?
   - What role do these tools play in policymaking?

2. Opportunities to refine the CRI:
- What could a revised framework achieve?
- What is the problem that could be solved?
- Who would be the right audience for using a refined CRI?
- What should be the scope of the framework?
- What additional stages of commercial development should be considered?
- Are there other indicators that would be useful to include?

3. Opportunities and limitations to link our revised framework with a set of policies:
- What is the applicability of a revised framework in policymaking?
- How could the CRI be linked with a pool/basket of policies?
- What policies should be considered?
- Could the framework be used/replicated across different technologies and geographies?
- Could the framework be used in other applications (e.g. project assessments to allocate funding)?
- Should the revised framework highlight potentially appropriate pull policies based on CRI scores/assessment?

Internal technology commercialisation experts' workshop

The Carbon Trust has many international experts involved in the commercialisation of low carbon technologies. We leveraged their experience and expertise in a half-day workshop to discuss how the CRI could be used by policy-makers to support the deployment of RET through the use of pull policies in different contexts. We also tested initial hypotheses on the advantages and limitations of the CRI and other existing frameworks. An overview of the methodology for this workshop is outlined in Figure 5-1.

Figure 5-1: Summary of the methodology for the internal workshop

5.1.2 Task 2 - Case studies

Task 2 aimed to illustrate how the CRI could be used to map policies through two case studies. We aimed to identify:
- The stage of commercial development at which certain policies are most appropriate and effective;
- The barriers these policies seek to address; and
- The factors that can influence their success or failure in supporting the commercialisation of RET.

The following Figure (5-2) illustrates the main activities conducted in Task 2.

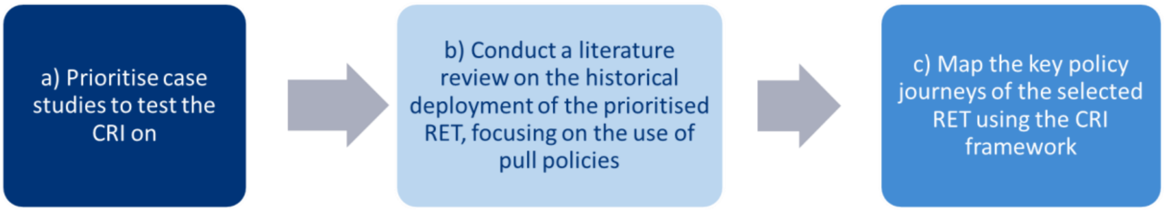


Figure 5-2: Main activities conducted in Task 2

We initially prioritised jointly with the PSG two emerging RETs in order to do one case study per technology. The process followed in this prioritisation exercise was:

i. We applied an initial filter according to the deployment levels of a range of RETs in all 8 IEA RETD TCP countries. The deployment thresholds considered were:
   a. Over 5GWe of cumulative deployment across the IEA RETD TCP members; and
   b. Deployment of at least 1GWe in at least 3 IEA RETD TCP members.

ii. We then screened this initial shortlist according to whether the technology can provide a clear, coherent commercialisation journey, such as:
   a. Regarded as an 'emerging technology' over the past decade;
   b. Subject to a range of pull policies across this time period; and
   c. Avoid technologies that are highly fragmented in their application.

iii. From this prioritised list of technologies, we selected the countries according to their:
   a. Geographical location;
   b. Breadth of pull policy strategies implemented; and
   c. Cross-over of policies between different countries and technologies.

Based on the criteria defined with the PSG we prioritised 2 in-depth case studies:

- Solar PV in Germany; and
- Offshore wind in the UK.

For each case study, we:

- Conducted a literature review on the history of the deployment of the RET in that country and the use of pull policies, including detail on their aims, resources and impact;
- Mapped relevant policies on the CRI, indicating at what status level and what indicators they were relevant;
- Analysed the benefits and limitations of using the CRI to illustrate the policy journey of the technologies; and
- Synthesised findings into two "case study" briefs, which we validated in Task 3 with industry and policy experts.

5.1.3 Task 3 - Recommendations

Task 3 aims to integrate the project's findings gathered in Task 1 and Task 2 to draw recommendations on the use and applicability of the CRI for decision makers and policymakers. We conducted primary research to gain independent feedback on the usefulness of the framework to support policy makers to identify appropriate policies or interventions and to test our policy journey mapping exercise using the CRI.

Some of the questions that Tasks 3 seeks to answer include:

CRI framework

- Are the proposed indicators providing a comprehensive view of the barriers faced by RETs?
- Is the CRI framework easily understood?
- Is the indicators assessment process suitable?
- Is the framework useful to identify interventions to address barriers?
- Can the framework be replicable across different technologies and geographies?
- Is it effective at gauging the commercialisation journey of technologies in the real-world?

Policies

- What type of policies or interventions should be included?
- What is the stage of commercial development at which certain policies are most appropriate and effective?
- What barriers do they address?
- What are the contingent factors that can influence their success or failure?

We engaged with experts to:

- Validate the CRI policy journey mapping exercise conducted in Task 2;
- Test initial thoughts on the use of the CRI with interviewees; and
- Identify opportunities to improve the CRI to support policy makers in identifying interventions to support the commercialisation readiness of RET.

Finally, we draw on recommendations targeted towards policy-makers and decision-makers, as well as for CRI users, which are summarised in Section 4.

5.2 ASSESSMENT FRAMEWORKS

5.2.1 Business Analysis Tool

The Carbon Trust developed its proprietary Business Analysis Tool (BA Tool) to assess the strengths and gaps of clean technology ventures. The aim of the tool is to help provide a common framework for thinking about the challenges that any clean technology venture needs to address and to help prioritise the type and level of support that would help a venture to get to market and deploy its solution at scale. The aim of this BA Tool is to help a venture rather than a technology sector.

The BA Tool benchmarks the status of a clean technology venture against a model company at a similar stage. The model companies are based on our extensive experience of assessing and supporting clean technology companies. The BA Tool focusses on four key areas, 12 commercialisation categories, and five development stages (Figure 5-3):

- **Technology** (technology development, product and operations);
- **Market** (market analysis, sales and business plan);
- **Team** (CEO, team and Board); and
- **Finance** (cash position, funding readiness and administration).

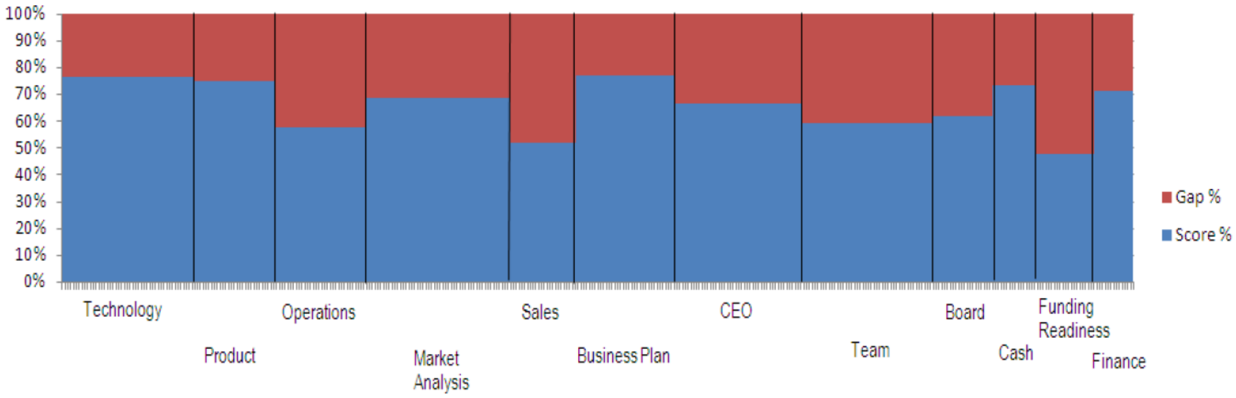


Figure 5-3: Example output from The Carbon Trust's Business Analysis Tool

In the BA Tool, each category is weighted for importance (the column width indicates the importance of each dimension given the stage of the venture) and the gaps between the venture being assessed and a model company at a similar stage is shown in red for each category. This framework and tool helps to highlight the critical areas for a venture to focus on addressing and enables a targeted approach to catalysing venture and deployment growth. It is designed to support clean technology ventures rather than enable policymaking but the thinking behind this BA Tool, and how we have evolved it over time, has informed some of our recommendations in Section 4.3.

5.2.2 Clean Energy Technology Assessment Methodology

To help policy makers and stakeholders understand the challenges and opportunities within a particular market, the International Energy Agency (IEA) have developed a methodology for prioritising clean energy technologies and policies – the Clean Energy Technology Assessment Methodology (CETAM)[15]. Its primary

[15] A. Brown, S. Landolina, E. Masanet and J. Sung (2016), "The Clean Energy Technology Assessment Methodology: A methodology for assessing renewable energy and energy efficiency technology markets", in *IEA Insights Series 2016*.

purpose is to assist programme developers and policy makers, such as multi-lateral development banks and governments, to assess the market opportunity for renewable energy and energy efficiency technologies with the aim of targeting the most promising options within a given location.

The objectives of policy makers and programme developers are important to prioritising which policy options and RETs to pursue. For example, different RET commercialisation policies could be more effective at pursuing energy security, as opposed to building an export market. Policy options will also be constrained by market maturity factors (e.g. deployment levels of RETs, or the types of capital available for a RET within that market).

The CETAM provides useful insights on how policy makers and programme developers can carry out this prioritisation exercise. Broadly, it classifies the prioritisation process according to five primary categories, which are ranked in descending order of importance:

1. **The renewable resource,** which outlines the technical potential, through the availability and accessibility, of energy;
2. **The likely cost of generated energy**, as determined by the renewable energy resource and the cost of finance;
3. In what ways the RET potential **aligns with the country's strategic priorities** such as energy security, growing an export market, or climate change commitments;
4. **Technology maturit**y will influence its availability and cost, whilst the strategic ambition to invest in R&D or other early-stage support for immature technologies will be a significant factor; and
5. **The market opportunities for the technology**, in particular the demand for the energy supplied, and the RETs ability to provide it.

Cross-examining these areas will provide an indication of what the most promising technology options are in a given context based on the market information. However, as IEA note, this market information is only one of a number of factors that influence an investment decision. Others include, the policy support on offer, the political stability within a country, recent trends in economic growth or contraction, rate of returns on offer, and the technical feasibility of a project, are also important.

The following stage, which aims to create an appropriate enabling environment focuses on addressing similar indicators to the ones assessed in the CRI, with an emphasis on understanding what can "enhance or hamper the prospects for cost-effective deployment"[16] . These include those related to:

- Policy, regulatory and institutional factors;
- Financial and market factors;
- Technical and infrastructure factors;
- Social factors; and
- Environmental factors.

CETAM takes a different approach to the CRI in classifying qualities. The CRI focuses on illustrating the characteristics of different sub-indicators across the various levels. For instance, the final level of the regulatory environment indicator in the CRI constitutes: "Regulatory, planning and permitting process documented and defined with ongoing process of review and refinement. Investment markets see policy settings long term, robust and proven"[17]. In contrast, the CETAM takes a more interrogative approach,

---

[16] Ibid.

[17] ARENA (2014), *Commercial Readiness Index for Renewable Energy Sectors*.

by formulating the questions that require answers for each indicator. For example, on the policy, regulatory and institutional factor, the CETAM includes questions on the very important permitting process in a country, such as:

- Is the permitting system transparent and efficient?
- Is guidance on permitting available?
- Are permitting times monitored?
- How long does permitting take?
- How many agencies are involved in the permitting process?

The CETAM enhances a decision-maker's ability to identify what is the purpose of scaling a RET. What remains lacking, however, is the practical next step of what policies to consider post-assessment.

5.2.3 Renewables Readiness Assessment

The International Renewable Energy Agency (IRENA) has substantial experience developing technology commercialization and policy frameworks. One of its main instruments for providing such advice is the Renewables Readiness Assessment (RRA), a country-led consultation process developed by IRENA to determine appropriate policy and regulatory choices and ensure the broadest possible buy-in from stakeholders.

The RRA was developed as "a comprehensive tool for assessing key conditions for renewable energy technology development and deployment in a country, and the actions necessary to further improve these conditions"[18]. Unlike other assessments, the RRA is a country-initiated, country-led process that identifies short- to medium-term actions for accelerating the deployment of renewables. Since its development in 2011, more than 10 countries in different parts of the world have undertaken the process. IRENA has published final RRA reports for Senegal, Mozambique, Kiribati and Grenada among others.

According to IRENA, their practical approach claims to have many advantages when compared to other frameworks:

1. It targets tangible deployment of RETs in the short- to medium-term;
2. Through hands-on research and analysis, it identifies and prioritises the services and resources that are most pertinent for a country;
3. It takes a holistic approach to identifying the barriers and generating responses, with five elements:
   (i) National energy policy and strategy
   (ii) Institutional, regulatory and market structures
   (iii) Resources, technologies and infrastructure;
   (iv) Business model (financing, developing renewable energy projects); and
   (v) Capacity needs.
4. The solutions to these elements can be applicable at a national and sub-national scale; and
5. The concrete Action Plan is developed the by relevant stakeholders and has targets for implementation within a defined period of time[19].

This comprehensive approach to local engagement is useful in linking the relative market development of RET to appropriate policies. It underpins a more tangible response to uncovering the most effective responses to the challenge of RET commercialisation. However, this bottom-up approach requires a

---

[18] IRENA (2013), *Renewable Readiness Assessment: Design to Action*.

[19] Ibid.

significant investment of time and resources to acquire the necessary knowledge and the policies derived from the in-country study are specific to that country and it may not be possible to derive common lessons and approaches for other countries to learn from.

5.2.4 Renewable Energy Technology Innovation Policy

In addition to the RRA, IRENA has developed a framework that takes a more general approach to formulating RET policy. The Renewable Energy Technology Innovation Policy (RETIP) platform is a methodology for policy makers facing a range of challenges with: i) the vast range of opportunities and options for RET innovation policies; and ii) the influential contextual factors that determine these opportunities and options[20]. The RETIP aims to provide a generic framework that its member countries[21] can leverage for deciding upon the most appropriate policy measures for commercialising RETs.
As an overview, it assumes three stages (Figure 5-4):

1. **Assessment stage** that evaluates the existing resources and capacities within a location, whilst outlining the modes of RET innovation that are possible and fit with strategic priorities;
2. **Strategy stage** focuses on isolating the most appropriate RETs for the particular context and on developing a complementary policy strategy to accelerate commercialisation; and
3. **Implementation strategy** concentrates on choosing and designing the policy instruments in parallel with developing favourable governance structures to deploy them.

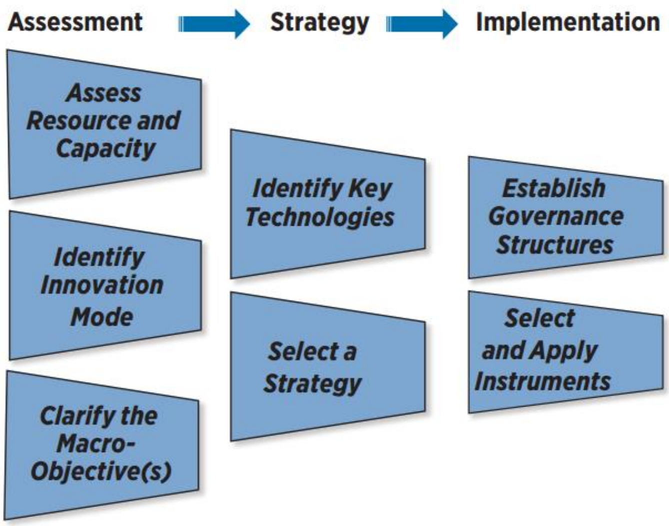


Figure 5-4: RETIP decision-making process (Source IRENA (2015), Renewable Energy Technology Innovation Policy: A Process Development Guide)

The benefits of the RETIP model include its holistic approach towards RET deployment, which targets identifying and implementing policy instruments, appropriate for specific country context, to foster innovation and commercialisation strategies for renewable energy technologies outside of the laboratory. It moves beyond the narrow focus on technology development and towards concerns such as supply chain and institutional evolution. On top of this, there is an important emphasis on creating the necessary

[20] IRENA (2015), *Renewable Energy Technology Innovation Policy: A Process Development Guide*.

[21] http://www.irena.org/Menu/Index.aspx?mnu=Cat&PriMenuID=46&CatID=67

enabling conditions, realising that commercialisation is “not forced, but enabled,” which requires looking at improving governance structures. Although this provides an important strategic framework for policy development and can be flexible to different contexts, it does not prescribe policy interventions but instead provides a detailed process for countries to identify the best instruments from a suit of policies available.

5.3 CASE STUDIES PRIORITISATION ANALYSIS

We have sourced the current deployment levels of a range of renewable energy technologies across all IEA RETD TCP member countries, which are presented in the table below.

IEA RETD TCP member countries	Deployment (MWe) as of 2015 by technology									
	Onshore wind	*Offshore wind*	*Solar PV*	*CSP*	*Biomass / Biogas*	*Waste to Energy*	*Geothe-rmal*	*Tidal*	*Hydro (large)*	*Hydro (medium / small)*
Canada	11205	0	2443	0	1368	207	0	20	77790	1079
Denmark	3792	1271	790	0	1267	329	0	0	0	9
France	10358	0	6549	0	1267	383	2	241	16227	2029
Germany	41652	3295	39634	2	8937	1944	38	0	3141	1283
Ireland	2461	25	1	0	69	16	0	0	196	41
Japan	2985	50	33300	0	4076	976	533	0	18537	3695
Norway	861	2	14	0	134	42	0	0	28135	1773
UK	9073	5118	8915	0	4464	1076	0	9	1409	324
Total	**82387**	**9761**	**91646**	**2**	**21582**	**4973**	**573**	**270**	**155678**	**10233**

Table 5-1: Current deployment of RE technologies across IEA RETD TCP member countries (Source: IRENA Resource)

We applied an initial filter according to the deployment levels of a range of technologies in all IEA RETD TCP countries. The deployment thresholds considered were:

- Over 5GWe of cumulative deployment across the IEA RETD TCP members; and
- Deployment of at least 1GWe in at least 3 IEA RETD TCP members.

The technologies which adhere to the thresholds defined are highlighted in bold in the table below (a blue cell indicates that it fulfils the criteria). Based on the technology deployment thresholds defined, we deprioritised CSP, waste to energy, geothermal and tidal energy.

Technology	> 5GWe of cumulative deployment across all countries	> 1GWe of deployment in at least 3 countries
Onshore wind		
Offshore wind		
Solar PV		
CSP		
Biomass / Biogas		
Waste to Energy		
Geothermal		
Tidal		
Hydro (large)		
Hydro (medium / small)		

Table 5-2: Initial prioritisation based on technology deployment criteria

Then, we screened the initial shortlist according to whether the technology can provide a clear, coherent commercialisation journey, such as:

- Regarded as an ‘emerging technology’ over the past decade;
- Subject to a range of pull policies across this time period; and
- Avoid technologies that are highly fragmented in their application.

These technologies are highlighted in the table below (in blue).

Technology	Regarded as an ‘emerging’ technology over the last decade	Subject to a range of pull policies	Avoid technologies that are very fragmented
Onshore wind			
Offshore wind			
Solar PV			
Biomass / Biogas			
Hydro (large)			
Hydro (medium / small)			

Table 5-3: Technology prioritisation

The technologies that fulfil all the criteria across stage 1 and 2 are:

- **Onshore wind;**
- **Offshore wind; and**
- **Solar PV**

We proposed taking forward **solar PV and offshore wind** to avoid looking into two different wind technologies. In addition, we believe that comparing the journeys of solar PV, a more mature ‘emerging’ technology, with **offshore wind**, a less mature ‘emerging’ technology, will provide the most interesting insights. Moreover, the Offshore Renewable Energy (ORE) Catapult in the UK has used the CRI to assess the development of floating offshore wind.

In order to prioritise the countries of interest for the case studies, we did an initial mapping of the relevant pull policies for each country across the two technologies (offshore wind and solar PV). In this analysis, we included those countries that fulfil the deployment level criteria (>1GWe).

Offshore wind			
Countries	**Continent**	**Current technology penetration (MWe)**	**Policy strategy (including past and present policies)**
Denmark	Europe	1271	• Feed-in-tariff (FiT) • Public procurement (capacity auctions) • Payment for loss of value to real property • Local ownership of shares • Subsidies for municipalities increasing social acceptance • Loan guarantees for wind turbine owners • Scrapping scheme for old, inefficient turbines • Tax break
Germany	Europe	3295	• FiT • Priority purchase, transport & distribution • Public procurement (capacity auctions) • Soft loans • Capital grants

UK	Europe	5118	• FiT • Contract for difference (strike price) • Public procurement (capacity auctions / Green Investment Bank) • Capital grants • Green certificates (Renewables Obligation) • Climate Change Levy
*Japan**	*Asia*	*50*	• *FiT*

**Japan has less than 1GWe of offshore wind installed, so we have not selected this country as a case study. However, if the PSG and the OA wish to have 4 case studies for offshore wind (4 countries), we could also include Japan.*

Table 5-4: Pull policies used to support offshore wind by country (Sources: IRENA, RESource; IEA/IRENA, Global Renewable Energy Joint Policies and Measures Database)

Solar PV			
Countries	**Continent**	**Current technology penetration (MWe)**	**Policy strategy**
Germany	Europe	39,634	• FiT • Priority purchase, transport & distribution • Soft loans • Capital grants • Partial debt acquittal • Public (auction) procurement • Renewable Energies Heat Act – certain buildings must use RE for a % of their heat
Japan	Asia	33,300	• FiT • Excess Electricity Purchasing Scheme • Subsidies for residential PV
UK	Europe	8,915	• FiT • Contract for difference (strike price) • Public procurement (capacity auctions) • Green certificates • Climate Change Levy • Green Investment Bank • Green Deal (on-bill financing)
France	Europe	6,549	• FiT • Tax breaks
Canada	N. America	2,443	• FiT • Production incentive • Public procurement • Green Municipal Fund • SD Tech Fund

Table 5-5: Key pull policies used to support solar PV by country (Sources: IRENA, RESource; IEA/IRENA, Global Renewable Energy Joint Policies and Measures Database)

Based on the criteria defined with the PSG we prioritised 2 in-depth case studies:

- **Solar PV in Germany**
- **Offshore wind in the UK**

5.4 CASE STUDIES – PULL POLICIES USED TO SUPPORT RET

The two tables below describe the aims of the various policies and their impact in the solar PV market in Germany and offshore wind market in the UK in more detail. The most influential policies are highlighted in blue.

5.4.1 Solar PV in Germany

Policy	Aim	Year of introduction	Year of expiry	MW at introduction	MW at expiry	Description	Impact
Electricity Feed-in Law (StrEG)	Kickstart solar PV market by breaking omnipresence of large-scale utilities producing electricity for the grid.	1990	1999	0	67	• Market-dominant utilities were mandated to buy electricity from small RE generators. • Generators were remunerated according to a FiT of 90% the retail electricity rate (EUR 8.45 – 8.84 cent /kWh).	The national FiT rate was not cost reflective and too low to drive take up, however municipal variations had more success.
Capital grants (1,000 Roofs)	Demonstrate the technical feasibility of solar PV for domestic use to spark consumer confidence in the market.	1991	1995	0	5	• Generators were eligible for capital rebates up to 70% of system cost, including installation. • For each state, there was a quota for installations. • Participants had obligations to provide information for research studies.	Initially, this policy had more success in driving deployment than the FiT with nearly 2000 installations. However, capital grants are not sustainable in the long-term.
Soft loans (100,000 Roofs)	Overcome financial barriers of high upfront cost and long payback times for consumers.	1999	2003	67	435	• Loans, with interest rates 4.5% below market conditions, were offered with a repayment period of ten years and two years of deferred payments. The possible share of financing was up to 100% and a maximum of EUR 500,000. • Minimum size of 1 kWp per installation. • Nationwide cap of 300 MW of newly installed capacity, with a total budget of EUR 0.56 bn.	The programme was popular, running out of budget in four years. It ended in July 2003 having supported 55,000 installations and 261 MW of additional capacity.
i) FiT reform (Renewable Energy Law - EEG)	Link incentives to retail rates to drive long-term deployment growth.	2001	2003	195	435	• National rates set a fixed price for a period of 20 years after installation – the first rate was set at EUR 0.51 cent /kWh. • The rate would decrease automatically by 5% each year, with formal reviews every 4 years. Deployment was capped for system sizes and an overall 1,000 MW nationwide. • Complemented by regulations ensuring preferential grid, where transmission system operators had to buy all the	The FiT provided long-term financial viability for investors and suppliers alike. Whilst the rate of deployment increased, the caps on

						power produced from PV systems at FiT prices, with costs recouped through a levy on consumers.	system size and nationwide prevented rapid growth.
ii) FiT reform (without caps)	When the 100,000 Roofs program ran out of funds, limits on the FiT were removed to uphold momentum and realise market expansion.	2004	2008	435	6120	• Caps on system size and national deployment were lifted. • Rates were set from EUR 46-62 cent/kWh depending on system size and application type, with annual decreases set at 5-6.5%.	Significant market growth followed these favourable rates and the removal of deployment caps, which built on from the long-term market visibility provided by the 20-year FiT payment.
iii) FiT reform ('corridor' degression)	Following significant growth in deployment, in order to limit the budgetary burden, rate decreases were tied directly to the volume of installed capacity	2009	Present	10564	40850	• The 'corridor' system would entail that the rate decrease (or increase if the deployment target was missed) would be set according to how much capacity was installed the previous year. • The 2012 amendment sets out legally binding targets for RE production – such as 35% by 2020 – outlining the energy transition plan. • The latest amendment also exempts storage systems from the levy to pay for the FiT, supporting their growth in deployment.	The reform has continued success in terms of deployment, but it has not alleviated the increasing budgetary pressures. Unscheduled rate reductions have been necessary twice in 2010 in response.
Market premium	To drive generators closer to market demand and its variations in time.	2012	Present	32641	40850	• Generators can sell electricity themselves, if they decide to forgo a FiT, and receive a market premium in addition to sale of their electricity – calculated as the difference between the EEG FIT and the monthly ex-post average price. • The goal is to encourage self-consumption during times of low prices and vice versa, making the solar PV market more adept at serving the grid at large.	After the initial few months, there had been very little take-up for this new system.
Mandatory direct marketing	Apply a brake on the incentive regime by mandating that certain systems must sell on the market, without a guaranteed price.	2014	Present	38234	40850	• New systems that range from 750kW (first implemented in 2014) to 100kW (2017 benchmark) must sell their electricity directly to the market, and are ineligible for a FiT – instead they receive a flexible market premiums	N/A

Levy on self-consuming producers	To distribute the costs of the FiT levy given self-consumption increases system costs.	2014	Present	38234	40850	• For systems above 10kW, energy that is self-consumed is now subject to a portion of the EEG levy, whereas previously these consumers were exempt from the charge.	N/A
Capacity auctions	Intended to replace the FiT by defining a market premium through competitive auctions for limited capacity	2017	Present	38234	40850	• Piloted from 2014 and in full force from 2017, the capacity auctions set specific capacity volumes that are put to competitive tender. • Market premium will be paid to successful auction participants. • All solar installations that are greater than 750kW must participate, with individual bids limited to 10MW – any system greater than 10MW receives no financial support.	N/A

Table 5-6: Details on German solar PV policies

Sources:

- Deutsche Bank (2011) - *The German Feed-in Tariff for PV* (*https://www.db.com/cr/en/docs/German_FIT_for_PV.pdf*)
- Fraunhofer Institute ISE (2017) – *Recent Facts about Photovoltaics in Germany* (*https://www.ise.fraunhofer.de/content/dam/ise/en/documents/publications/studies/recent-facts-about-photovoltaics-in-germany.pdf*)
- GIZ (2012) - *German Experience on the Support Mechanism and Technical Aspects of Grid Connectivity of Solar PV Rooftop-Systems* (*http://www.eclareon.com/sites/default/files/presentation_solar_guidelines_mnre_round_table_20032012.pdf*)
- Herbert Smith Freehills (2016) – *Changes to the German renewable energy regime from July 2016*
- IEA (2013) - *Energy policies of IEA countries: Germany 2013 review (http://www.iea.org/publications/freepublications/publication/Germany2013_free.pdf*)
- PwC (2010) - *Germany's photovoltaic industry at the crossroads* (*https://www.pwc.de/de/energiewirtschaft/assets/the_german_pv_industry_at_the_crossroads.pdf*)
- Solar Energy Industries Association (2014) - *Solar energy support in Germany: a closer look* (*http://www.seia.org/research-resources/solar-energy-support-germany-closer-look#_ftnref58*)

5.4.2 Offshore wind in the UK

Policy	Aim	Year of introduction	Year of expiry	MW at introduction	MW at expiry	Description	Impact
Crown Estate (CE) Round 1	Provide landowner permission and visibility on future capacity potential for developers	2001	2003	4	60	• The Crown Estate owns the rights to the majority of the UK's coastline, therefore it has to provide permission through leases to grant developers the right to build offshore plants. • Round 1 was the initial opening up of these territorial waters for licensing – providing visibility for developers on the areas that are available for feasibility testing and potential turbines.	Round 1 provided leases for 18 sites, amounting to as much as 1.5GW – signalling the beginning of a potentially large-scale, commercial market.
Offshore Wind Capital Grants Scheme	Create an initial pipeline to provide key, early-stage data on site and costs for future policies.	2002	2008	4	596	• Upfront grants that covered up to 40% of the extra investment costs required to build an offshore wind plant when compared to a conventional (fossil fuelled) equivalent. • Proposed projects had to fulfil certain eligibility criteria, including and compete for limited funds with other proposals.	An important keystone policy for the very immature commercial market because it enabled otherwise hypothetical commercial propositions to be realised, to prove the technology's viability through demonstration projects.
Renewables Obligation	Increase the market share for renewable energy technologies.	2002	2012	4	2995	• Electricity suppliers were obliged to source a portion of their power from renewable energy sources in order to fulfil a set quota. • This quota was allocated in the form of Renewable Energy Obligation Certificates (ROCs), which were allocated to plant developers via auctions. Suppliers had to hold a minimum of ROCs either through buying renewable electricity or trading ROCs with those who had a surplus. • It is important to note that this policy was originally technology agnostic – and not specifically targeting offshore wind - but eventually 'enhanced' ROCs were offered at 2 ROCs/MWh for offshore wind – revealing a bias towards deployment.	A very significant policy in enabling offshore wind in the UK to emerge as a mass market. The ROCs provided certainty in substantial revenue streams that mitigated investor risk and stimulated major deployment and industry development.
Offshore Wind Accelerator	Reduce the cost of offshore wind to under £100/MWh through innovation.	2008	Ongoing	596	-	• A collaborative RD&D programme run by the Carbon Trust funded jointly by the UK and Scottish Governments alongside 9 of Europe's leading offshore wind developers. • The offshore wind developer partners establish the research priorities within which innovators compete for public and private sources of funding.	Since its inception, the programme has undertaken over 100 R&D projects, worth over EUR 95m.

							It has been influential in driving down the costs of offshore wind components such as foundations, cables and electrical systems through developing and demonstrating innovative technologies.
Green Investment Bank	Fill a financing gap where projects that are bankable are missing investment capital.	2012	Ongoing	2995	-	• Initially capitalized with £3.8bn of UK government money, the GIB has now been sold to a Macquarie-led consortium. • Its guiding principle is to finance green projects, including offshore wind, that struggle to secure private sector investment, but on commercial terms. • It focuses its offshore wind investments in the construction and operation phases of the projects. • The objective is to demonstrate the commercial viability of green investments to the wider commercial investment community.	To date, the bank has invested £1.6bn in 9 offshore wind projects with a cumulative capacity of up to 3.2GW.
Offshore Renewable Energy Catapult (OREC)	Reduce the costs of offshore renewable energy through innovative R&D.	2013	Ongoing	3696	-	• The Catapult is the UK's flagship research centre for offshore wind and marine energy. • It combines public and private sector capital to fund projects from laboratory research to large-scale demonstrations, with side services such as training also offered.	The OREC has acted as an important platform for collaboration between the government, industry and academia – implementing significant R&D programs across the offshore wind technology chain.
GROW: Offshore Wind	To support the growth of UK businesses within the offshore wind supply chain.	2013	Ongoing	3696	-	• £20m was dedicated by the government to provide assistance for local companies, SMEs in particular, to enter the growing offshore wind manufacturing industry. • Tailored support for individual companies includes help accessing contract opportunities and funding, as well as developing innovative offers. • The aim is to increase the share of UK companies in the domestic supply chain within the offshore wind industry.	N/A

Contracts for Difference	Graduate towards a competitive commercial market whilst still providing necessary long-term financial support.	2014	Ongoing	4501	-	• The CfD regime replaces the ROCs by limiting the capacity available that developers could bid for in the hope of driving down industry costs. • If a project is successful, its compensation is set at a fixed rate for 15 years. The amount of compensation varies according to whether this rate is above the wholesale price (highly likely for the first plants). In theory, if the wholesale price rose above the CfD price, then plant would sell power at a reduced rate. • A ceiling price that dictates the upper limit of the CfD. • To bridge the transition from ROCs, the Final Investment Decision Enabling for Renewables program provided 15-year guaranteed compensation for projects before the CfDs.	The early signs for the CfD regime are mixed. The positive impact perceived is that the level of subsidies has decreased with the competitive bidding. However, due to the significant allocation risk associated with developing unsuccessful projects given the limited amount of capacity available, the market is dominated by a small number of major utilities and energy companies. The high risk perceived by smaller or independent organisations makes it challenging for them to break into the market.

Table 5-7: Detail on the UK's offshore wind policies

Sources:

- Her Majesty's Government (2014) - *Overview of Support for the Offshore Wind Industry* (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/319026/bis-14-880-support-for-the-offshore-wind-industry-overview.pdf)
- Department of Trade and Industry (2006) - *Offshore Wind Capital Grants Scheme (http://webarchive.nationalarchives.gov.uk/20090609003228/http://www.berr.gov.uk/files/file23956.pdf)*
- Renewables Consulting Group (2016) - *Winner takes all: High stages in the UK offshore wind CFD auctions* (http://renewablescg.com/wp-content/uploads/2016/01/Winner-takes-all-high-stakes-in-the-UK-offshore-wind-CfD-auctions.pdf)
- The Crown Estate (2013) - *Round 3 Offshore Wind Site Selection at National and Project Levels (https://www.thecrownestate.co.uk/media/5644/ei-km-in-pc-planning-062013-round-3-offshore-wind-site-selection-at-national-and-project-levels.pdf)*
- UK Energy Research Centre (2010) - *Great Expectations: The cost of offshore wind in UK waters – understanding the past and projecting the future*

MEMBER COUNTRIES OF THE IEA RETD TECHNOLOGY COLLABORATION PROGRAMME

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

Government of Canada / Gouvernement du Canada

Canada

Danish Energy Agency

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

Ministère de l'Écologie, du Développement durable et de l'Énergie

seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND

NEDO

Department of Energy & Climate Change

enova

The **International Energy Agency's Renewable Energy Technology Deployment Technology Collaboration Programme (IEA RETD TCP)** provides a platform for enhancing international cooperation on policies, measures and market instruments to accelerate the global deployment of renewable energy technologies.

IEA RETD TCP 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.

Current member countries of the IEA RETD Technology Collaboration Programme (TCP) are Canada, Denmark, France, Germany, Ireland, Japan, Norway, and United Kingdom.

More information on the IEA RETD TCP can be found at

www.iea-retd.org