GREBE

Generating Renewable Energy Business Enterprise

Roadmap to market

Investigating market access paths of RE and energy storage technologies

Lasse Okkonen, Karelia UAS

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The GREBE Project

What is GREBE?

GREBE (Generating Renewable Energy Business Enterprise) is a €1.77m, 3-year (2015-2018) transnational project to support the renewable energy sector. It is co-funded by the EU's Northern Periphery & Arctic (NPA) Programme. It focuses on the challenges of peripheral and arctic regions as places for doing business, and helps develop renewable energy business opportunities in areas with extreme conditions.

The project partnership includes the eight partners from six countries, Western Development Commission (Ireland), Action Renewables (Northern Ireland), Fermanagh & Omagh District Council (Northern Ireland), Environmental Research Institute (Scotland), LUKE (Finland), Karelia University of Applied Sciences (Finland), Narvik Science Park (Norway) and Innovation Iceland (Iceland).

Why is GREBE happening?

Renewable Energy entrepreneurs working in the NPA area face challenges including a lack of critical mass, dispersed settlements, poor accessibility, vulnerability to climate change effects and limited networking opportunities.

GREBE will equip SMEs and start-ups with the skills and confidence to overcome these challenges and use place based natural assets for RE to best sustainable effect. The renewable energy sector contributes to sustainable regional and rural development and has potential for growth.

What does GREBE do?

GREBE supports renewable energy start-ups and SMEs:

- To grow their business, to provide local jobs, and meet energy demands of local communities.
- By supporting diversification of the technological capacity of SMEs and start-ups so that they can exploit the natural conditions of their locations.
- By providing RE tailored, expert guidance and mentoring to give SMEs and start-ups the knowledge and expertise to grow and expand their businesses.
- By providing a platform for transnational sharing of knowledge to demonstrate the full potential of the RE sector by showcasing innovations on RE technology and strengthening accessibility to expertise and business support available locally and in other NPA regions.
- To connect with other renewable energy businesses to develop new opportunities locally, regionally and transnationally through the Virtual Energy Ideas Hub.
- By conducting research on the processes operating in the sector to improve understanding of the sector's needs and make the case for public policy to support the sector.

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GREBE investigates the market access of RE technologies

Market access paths of RE and energy storage technologies are investigated by using a case-study approach. The market access paths are considered in detail; this includes technology descriptions, technology demonstration and deployment issues (demonstration/piloting routines, assessment of technical and financial risks, advisories used, and processes of delivery and adaptation in different partner region), and support systems. The case-based paths will provide information on important drivers and barriers, thus providing background for the business mentoring support of the GREBE project.

The case study approach

The data on the market access of renewable energy technologies was collected both from the case studies in different renewable energy technology projects and from the secondary sources. To collect specific project data, a template was established with following subsections:

- Technology description and a project summary
- Drivers and barriers in the RE technology project
- Cooperation partners and networks
- Assessment of the technical and economic risks
- Monitoring the performance
- Commercialisation of the technology
- Funding and support mechanisms
- Conditions for the technology transfer & adaptation in different partner regions
- Any additional information about the market access of the RE technology

The case studies are presented in separate case study documents produced by GREBE work packages of WP3 and WP4. The cases studies informing this roadmap to market were as follows:

- Iceland Deep Drilling Project
- IceWind
- Svartsengi Resource Park
- Glomfjord Hydrogen AS
- The Each Leim Microgrid
- Claremorris Energy Co-operative (Anaerobic digestion)
- Albatern WaveNET Device
- Nova Innovation Tidal Array
- Kuittila Power
- Dingwall Wind Co-Op
- Stormont (solar thermal system)
- Hillcrest day nursery (pellet boilers)

The case studies investigated provided in depth information on various RE technologies utilised in the northern peripheral regions. Technologies represented different maturity steps, or in other words, readiness-levels. They included both demonstrations in the actual operational environment and systems already proven and accessing larger consumer markets. The drivers and barriers, policies and supports and risks of technology development were identified and reported is technology case studies.

The market access included different types of partnerships and cooperation relations along the long up to 15-20 year development paths. These are described in specific for each technology case, and in general level in this roadmap document.

Technology path toward the market access

Energy technology innovation

Energy-technology innovations (ETI) include both new inventions and improvements in the performance or attributes of technologies, such as gasification, solar PV or thermal, batteries, or energy-efficient solutions, and ways on how firms develop and market and how different end-users relate to and utilize the technologies. Therefore, social innovations resulting in changes in behaviour of technology suppliers and users can be as important as improvement of technological performance of an energy solution. Energy system includes both supply technologies, end-use technologies, and also practices and knowledge in energy use.[1]

Energy Technology Innovations is also described as a multistage process[2], including

> *"The stages include research, development, demonstration, market formation, and finally, the culminating pervasive diffusion of successful innovations."*

In the most general definition[3]*:*

> *"Energy technology change is the capital-embodied result of institutionalized R&D and collective learning processes between developers/suppliers and users of technologies, operating within specific innovation and adoption environments that are strongly shaped by policies."*

This systemic view of the ETI's encourages studying the market access paths of the renewable energy technologies through case studies with information on place-based context and different actors and policies.

Technology readiness levels (TRL's)

Technology Readiness Level or "TRL" is a common indicator of degree of development of a technology, measured on a scale of 1-9, with stage 9 being ready for deployment. The scale of TRL's was introduced by the NASA as "a discipline-independent, program figure of merit (FOM) to allow more effective assessment of, and communication regarding the maturity of new technologies". The scale was needed to assess the maturity of the technology, and to compare the maturity of different types of technologies. Later on, the TRL concept was adopted in different sectors and scale was modified according their needs. It got applications in different institutions, such as EU and OECD, the European Investment Bank (EIB).

The OECD distinguishes four research levels including "basic research (TRL1-3), Development (TRL3-5), Demonstration (TRL 6- 7), and Early deployment (TRL8-9)" (See also Figure 1). The EIB applies levels of "Research (TRL1-3), Development (TRL 3-6), Innovation (TRL6-8) and Production support (TRL9)". The TRL's became also an element of funding instruments, e.g. EU Horizon 2020 Programme

[1] Gallagher et al. 2006; Grubler et al. 2012.
[2] Grubler et al. 2012, 1672.
[3] Enos 1962 and Watson 2004, cited by Grubler et al. 2012.

and ERDF funding. At the EU level, the TRL's were adopted as a "tool for assessing the results and expectation of the projects". [4]

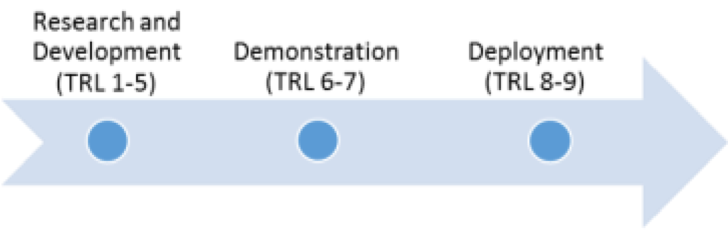

Figure 1: Main stages of the Technology Readiness Levels.

The EU Framework Programme for Research and Innovation, The Horizon 2020, provides following definitions for the TRL's[5]:

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

The TRL's may oversimplify the technology development steps and paths to the market, which are often much more complex than the linear path. In addition, innovations can take place in each step, and there are often loops back to the earlier development stages. However, the TRL's follow the generic steps of **research**, **development**, **demonstration** and **deployment**, and provide opportunity to categorise analyse different types of technology cases.

Research and development of renewable energy technologies

As defined earlier in GREBE project's context, "Research and development (R&D) refers to the investigative activities a business conducts to improve existing products and procedures or to lead to the development of new products and procedures"[6]. Therefore, the focus is not in basic research of the research institutions or universities, but more on the applied aspect of technology development. Both the public and private sectors finance energy technology research: governments, utilities and industry. As many of the technology developing companies are small and not capable to sustain the

[4] EARTO 2014, 3-5.
[5] European Commission 2014.
[6] GREBE Project 2016, 11.

research as their own, public financing remain essential. There is continuing development need in development of better devices, components and systems, to gain more affordable solutions for competing the prevailing systems.[7] For the policy and support mechanisms, the GREBE has earlier established Showcase Examples of Best Practice Policy Initiatives[8] and a Business Supports Catalogue[9], providing information on R&D policies and supports for the enterprises in RE sector.

Demonstration of renewable energy technologies

Energy technology demonstration is considered here to cover technology readiness levels TRL 5-7, including technology validation and demonstration in relevant environment as well as prototype testing in operational environment.

Energy technology projects bring technologies closer to the market. The projects have following functions[10]:

- Test new technologies in conditions approximating real-world applications,
- Gather relevant technological and economic data to be used for improving technologies before their commercialisation
- Support in scaling-up/down the technologies (from laboratory scale to larger scale, or from large-scale to small/micro-scale)
- Demonstrate the feasibility of technologies for manufacturers and potential buyers (i.e. generate confidence)

Energy technology demonstrations can include e.g. building of one or more energy technology manufacturing, or production facilities for increasing the scale or proving technical and potential commercial viability of the technology.[11]

There is continuing need for RE technology demonstrations to highlight technological solutions, products, and associated cost reductions. [12] The demonstrations may also include other non-technical advances, such as innovative procurement processes or contracts, or business models / financing options, especially in cases with potential of replications. Demonstrations require also reliable monitoring to ensure the information is available for other potential users, investors or financiers.[13]
Private sector needs often partners for cooperation and risk sharing in demonstrations due to long-time horizons for returns, capital requirements, higher risks of new technologies, and reaching suitable operational environments[14].

[7] Watt & Outhred 2004.
[8] Ibid.
[9] GREBE Project 2016b.
[10] Gallagher et al. 2006, 203.
[11] Sagar & Gallagher 2004, 3.
[12] Watt & Outhred 2004.
[13] Ibid.
[14] Sagar & Gallagher 2004, 3.

The partners can be, for instance:

- Industry (suitable operational environments as demonstration sites)
- Public sector (public procurement of innovations, public support for new technologies)
- Research and development organisations with suitable testing facilities
- Communities interested in demonstrations and training
- Other technology developers (horizontal or vertical integrations with technology developers)

The market access of the RE technologies can also be supported by intentional or un-intentional industrial collaborations and synergies. In GREBE case studies, the Svartsengi Resource Park, located at the Reykjanes Peninsula in Iceland, is an example of an industrial ecosystem[15] based on the renewable geothermal energy and water resources. In industrial ecosystems, it is essential to develop industrial production and consumption systems towards the closed loops of materials and cascades of energy, thus reducing both the consumption of natural resource and the outputs of waste and emissions. In Svartsengi Resource Park, unintentional early stages of system evolution, typical for most of the industrial ecosystems, was followed by coordinated development actions with successful results.

On the other hand, In Glomfjord Norway, there has been the largest hydrogen production site at 1990's, and the objective is to re-establish this status. Industrial park provides potential synergies for the cluster development aligning with the vision of industrial ecosystem. Concerning the technology market access, industrial ecosystems provide opportunities in each stage form the R&D to the demonstration and deployment of the technologies.

Renewable energy technology deployment

As the system is complete and qualified, and proven in operational environment, we consider it as deployment project (TRL 9). This stage includes both drivers and barriers, such as:

- Information of the technology and its use
- Investment and operational costs that are often higher than in technologies already at market
- Regulations and policies that not necessarily recognize the new technology
- Markets: their organisation, development and fluctuations
- Infrastructural challenges, such as grid challenges and service/maintenance

As the pilot-plants are often the first-of-a-kind commercial solutions, they are not able directly to compete against the conventional solutions. In addition, the improvement of the technology may not provide directly value for a private consumer. For instance, if the reduced greenhouse gas emissions are not internalized to the energy costs, neither are they reflected in the market transactions.

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[15] Graedel & Allenby 2010.

The renewable energy technology deployment is supported through policy approaches, deployment programmes, and market-based mechanisms. These can include, for instance, public projects providing information on new technologies and higher support rates for investments in new technologies.[16]

The RE technology commercialisation often requires supportive actions, such as:[17]

- Governmental supports, including e.g. information on resource potentials, expert advises or funding
- Market stimulation activities to improve the confidence and industry interest, and to ensure required cash-flow
- Detailed monitoring and feedback from the customers, sales staff, service and maintenance, and other stakeholders to be passed on the technology developers.
- Development of supporting infrastructures, such as performance standards, installation guides, installer certificates for gaining the market acceptance
- Organising the training for the technology deployment and use to ensure first systems operate as they are expected.

Technology transfers

Market access of the technology can result also of technology transfer operations. Technologies transferred can also represent different readiness-levels, creating additional challenges for adopting in different operational environments. Thus, the transfer often require both technical and social innovations. In addition, the role of technology transferring agents is essential: they can bridge the projects together (building on the past), bridge solutions from different industries and introduce solutions from other geographical regions.

Technology transfer has many definitions. The Association of University Technology Managers (AUTM) defines it as “the process of transferring scientific findings from one organization to another for the purpose of further development and commercialisation.” Typically, process includes phases of identifying the new technologies, IPR issues (patents/copyrights), and establishment of development and commercialisation strategies (integrating to existing companies through licencing, or establishing new start-ups, for instance). Technology is considered to include inventions, prototypes, finished products/devices, and expertise.

From the policy perspective, transfers often require research and development funding, systems to protect property rights, systems to encourage investment funds, and supports for international collaborations. New technology can also be defined broadly, it encompasses also “new-to-the-country” and “new-to-the firm” technologies.[18] Transfers require available resources, skilful site developers/operators (knowledge) and experience in technology maintenance, i.e. supporting structures. In GREBE project, technology transfers are investigated and promoted in dedicated WP “Knowledge & Technology Transfer and Business Delivery”.

[16] Sagar & Gallagher 2004, 3.
[17] Watt & Outhred 2004
[18] Innovation Policy Platform 2013.

Roadmap to market

The energy projects investigated in this activity included several technologies and their locations were across the NPA region. The projects were also in different stages, from research and development to demonstration and deployment (Table 1.). There were number of new technical solutions of different technology readiness levels (developing, testing, demonstrating, piloting, deploying - and sometimes returning to earlier phases). The cases included collective learning processes, social innovations, and cooperation between different stakeholders along the development paths affected by different types of policies.

Table 1. Energy technology innovation (ETI) stages in case studies

Case Study	**Research and development**	**Demonstration**	**Deployment**
Iceland Deep Drilling Project	X		
IceWind – Extreme energy	X	X	
Glomfjord Hydrogen AS		X	X
The Each Leim Microgrid		X	X
Anaerobic digestion, Claremorris Energy Co-operative		X	
Albatern WaveNET Device	X	X	
Nova Innovation Tidal Array, Shetland	X	X	
Kuittila Power - Small-scale CHP based on wood biomass			X
Dingwall Wind Co-Op			X
Stormont, solar thermal system			X
Hillcrest day nursery, pellet boilers			X
Svartsengi Resource Park, Reykjanes Peninsula, Iceland			X

The cases provided examples along the market access paths of RE and energy storage technologies, and each of them had a unique path toward markets. Paths differ in technologies, and often there is utilisation of place-based opportunities, such as available resources or industrial tradition. However, the cases provided better understanding of the processes of research and development, demonstration and deployment.

The case studies provided some essential elements of the market access of the RE technologies, i.e. for roadmap development:

1) **Coordinated technology planning** is considered here as an essential part of the roadmap to market, i.e. strategy to proceed from the technology development and demonstration to its successful market deployment. Technology planning covers both planning of the new technology development, but can be also applied as a process of updating and adopting new existing technologies for the business enterprises. The development paths of technologies included several steps building on the earlier ones, and time-span was up to 15-20 years. Without coordination and planning procedures, the market-access can be very difficult to reach, and innovations can be lost. As a part of the technology planning, ***technology transfers*** can be utilised: they can include technologies (or sub-technologies) of different readiness levels, and new to area solutions. The role of ***technology transferring agents***, i.e. persons (often multi-nationals) with experience of different industries and operational environments remains essential.
2) **Bridging the gap between demonstration and deployment remains as a key challenge.** Basing on the findings from the case studies, An evident gap between the technology demonstration and deployment can be reduced by establishing and utilising soft supports, industry clustering and partnerships in demonstration, for instance. Public sector has often an essential role in providing the supporting infrastructures (such as business and technology parks) and funding instruments.
3) **Partnerships** are essential for risk sharing in long and often capital intensive processes, as well as finding suitable sites for demonstrator projects. There were several types of partnership models applied in RE technology cases. They were often place-based and utilising local trust and previous experiences.
4) **End-user support is essential part of the early deployment.** Technologies typically have still improvement needs and often end-users need training and support for the deployment. This raises the importance of the development of the end-user supports along the technology development, and full availability of the service and maintenance as the technology reaches the market.

Coordinated technology plan as a roadmap to market

Technology planning is significant part of the business strategy and its implementation. The technology plan can focus in development of the new to market technologies, requiring significant resources before actual sales of the technology. On the other hand, is can focus on the adoption of the existing technologies, or new to area technologies, for the use of business enterprise. Overall, the business strategy affects to the technology needs and development processes (Figure 2). Technology plan can be serve as a roadmap for meeting the established long-term objectives, and as a tool to inform various stakeholders involved in the technology development process.

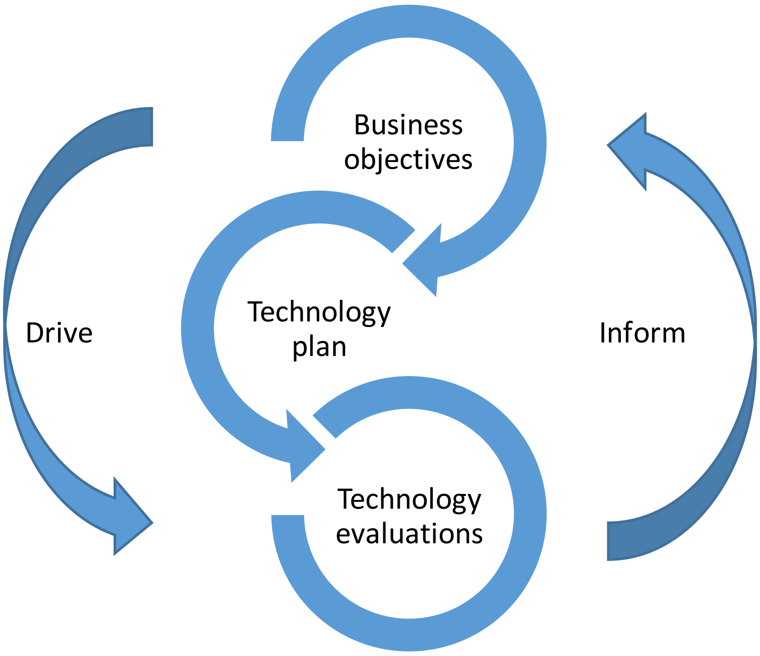

Figure 2. The process of technology planning, including business objectives (strategy) driving the technology needs. Technology evaluations inform the business objectives and technology planning activities to achieve the established vision. Technology plan serves as a roadmap for meeting the established long-term objectives.[19]

In technology planning process, following issues are considered[20]:

- **Phasing** (for up to 10-15 years), associated research and development investments, work plans and activity planning with allocated resources, and established priorities and follow-up/monitoring.
- Careful **definition and monitoring of the technology maturity** (i.e. readiness level) and progress
- Technology **life cycle costs assessments**, including the costs for technology development, demonstration, deployment, operation, maintenance, licencing etc.
- **Education of the staff** and **informing key stakeholders** on the plan and its implementation. The plan can support the stakeholder cooperation, e.g. for collaborating with R&D sector, investors, governance, and industry. It can provide information for organising finances, partnerships, R&D evidence and thus improving the market acceptance of the technology.
- **Implementation and review**. Plan is a tool for implementation and it review and adjustment is needed along the technology development process.

Basing on the case studies, technology demonstrations are often processes with several tests and require strategic thinking. For instance, in marine RE, robust structures are essential, but they have also impact on product price – testing and demonstrating the components and their materials can be critical part for the system design and require specific demonstration conditions.

[19] The Mitre Corporation 2017.
[20] Ibid.

Reducing the gap between demonstration and deployment

Energy technology projects often take long periods and include multiple risks as described by Christopher Guith, Vice President for Policy Institute for 21st Century Energy, US Chamber of Commerce:

> *"Energy projects face multiple risks, including engineering risks, construction risks, commodity risks, execution risks, resource risks, technology risks, permitting risks, and policy risks. While clean energy projects can mitigate a majority of these risks using normal project development processes, **overcoming the technology hurdle will take years if left to businesses-usual market processes**. … This lengthy process has resulted in multiple technologies demonstrating promising laboratory results but failing to meet national energy goals because they never reached full commercial scale."* [21]

The gap between the technology demonstration and deployment has also titled as ***Death Valley of Innovations***, emphasizing challenges experienced in the technology commercialisation. In research and development phase, there is often public support and interest from the technology developing actors, such as research institutes and universities. Market actors have most interest toward market proven technologies or those that are very close to market. The main challenge is between those steps, i.e. in demonstrations with capital requirements but not yet expected profits.

For bridging the gap between the demonstration and deployment following strategies have been identified form the case studies:

- Established continuous support for demonstration through ***innovation ecosystems, technology platforms*** **or** ***demonstration test-beds*****.** The industrial ecosystems and science parks can facilitate those. In addition, they can provide synergies with other industries and technology spin-offs.
- Identifying and targeting ***support funding for the demonstration projects/ technologies*** (can be defined as part of the technology plan)
- Establishing ***partnerships for demonstration***, including public procurement of innovations, innovation partnerships and inter-industry partnerships
- ***Industry clustering*** and establishment of ***coordinated demonstration activities***
- ***Reducing the time-span*** of demonstrations, by:
  - utilising technology and knowledge transfers
  - building on the past experiences
  - establishing reliable data collection that provides evidence of the system operation and results reliable reference of operation in real operational environment

Establishing partnerships and risk sharing

Typically development and demonstration stages take long periods, and require strong background supports. There was established partnerships between the public and private, and successful

[21] Guith 2011.

facilitation of the process by incubation spaces/hubs, science parks and an eco-industrial area. Public sector attended often in risk sharing; by providing research and development funding. However, the supports were not always continuous in SME-based technology projects, i.e. risk bearing is mainly the private sector responsibility. In establishment of new sectors, such as deep geothermal of marine RE, the public sectors seems to provide more long-term funding and research and development support.

The cases provided following cooperation relationships between the public and private sectors supporting the market access of RE and energy storage technologies:

- **Public sector collaboration:**
  - Public funding supports
  - Research and development programmes/projects
  - Facilities, incubators/hubs, Science Parks
  - Public procurements (of innovations)
  - Coordination and support through industry clustering and networks
  - Training, mentoring, advisory and other soft supports
- **Private sector collaboration:**
  - Industry clustering and networks
  - Cooperation in demonstrations. Providing real operational environments for testing, developing and demonstrating new technologies
  - Cooperation with other technology developers, contracting and licensing (horizontal and vertical integrations)
- **Community collaboration:**
  - Demonstrating technology solutions through community projects (including both technology demonstrations as well as deployment schemes of community energy)

In establishment of the partnerships, place-specific opportunities have major role. It has been noticed, that the trust and confidence is often better in regional level compared to national or international levels. However, regional scale provides already more capacities and resources than staying at the local level.[22] The role of policies is also evident, as they define the resources and structures for public-private collaboration.

Partnerships are also often activities for risk sharing. The external investors (public funders or private investors) can take part of the economic risk. This is evident also in funding rates, as demonstration project typically receive higher support rates compared to conventional solutions. On the other hand, this has also resulted to a fact that sometimes deployment projects are named as demonstration projects to attract higher funding rates.

Partners can also share the technical risks, as new technologies are piloted in operational use and can face technical failures. Partners, such as communities investing in RE, should be aware of the provided technologies and associated technical and economic risks related to early deployments.

[22] Sterr & Ott 2004.

Ensuring the successful deployment

The demonstration phase is essential for the successful technology deployment: with objective data collection, it can create evidence of the system reliability and costs in real operational environment. However, early deployments often have challenges and significant support needs from the technology manufacturer. They are often controlled and supported by the technology manufacturer due to their critical role for later market development.

The end-users' challenges in the deployment phase can be in sizing the RE technologies for their requirements, finding reference sites of good practices, finding supporting experts and technology and service providers, and sometimes also overcoming the poor reputation of other schemes. The successful deployment requires technical expertise and utilising available supports for the market deployments. Economic supports are often essential for the long-term feasibility, and acquiring them requires specific expertise. These deployment barriers can be reduced by providing end-user support (public and private) and promoting proven business models and practices.

The deployment success is also dependent on the maturity of the sector in each country. The early deployments are technically less risky in areas with developed markets (of same type of technologies). On the other hand, in emerging markets, available higher economic supports can reduce the economic risk and attract new investments in pilot phase technologies. Basing on the case studies, the deployment projects in new market areas seem to require same type of coordinated support and partnerships as demonstration projects of new technologies in mature markets.

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Western Development Commission. 2016. Grebe case study pictures.

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Contact

Western Development Commission,
Dillon House, Ballaghaderreen,
Co. Roscommon, F45 WY26, Ireland.

Tel: +353 (0)94 986 1441
Email: paulineleonard@wdc.ie

Project Partners

GREBE will be operated by eight partner organisations across six regions:

- WDC
- Action Renewables – the future of energy, today
- Luke – Natural Resources Institute Finland
- FPN – Forskningsparken i Narvik
- eri
- Fermanagh & Omagh District Council – Comhairle Ceantair Fhear Manach agus na hÓmaí
- Innovation Center Iceland
- Karelia

About GREBE

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