GREBE

Generating Renewable Energy Business Enterprise

Northern Periphery and Arctic Programme

Summary Report on Environmental Challenges & Solutions for Renewable Energy Technologies

August 2018

www.grebeproject.eu

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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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2. Work Package 4: The Influence of Environmental Conditions in NPA and Arctic Regions

There are significant climate challenges in the partner regions with different types of harsh weather. Low temperature, hard winds, and rain/snow conditions can be extreme in the NPA regions. The objective of Work Package 4 is to consider how to find the best process conditions for business in remote NPA communities, where harsh climate and other geographically related issues often bias knowledge transfers and business models.

Work package 4 is guided by the following objectives:

1. Gain a thorough understanding of the unique climatic and physical conditions including the infrastructure of NPA regions, particularly arctic regions, and how these influence the success of local SMEs and start-ups.

   Report Output - GREBE Report on the Influence of Environmental Conditions in NPA & Arctic Regions- August 2016

2. Identify existing deficiencies of renewable energy businesses and related technologies, business models and infrastructure that arise as a direct result of the climatic environment and operating conditions of the NPA regions, particularly the arctic and high north regions.

   Report Output - GREBE Report on Innovations from Local Technology and Business Solutions May 2017

3. Identify how NPA regions can harness the physical and climatic conditions of the sparsely populated areas in which they are located, so that these assets are utilized more effectively in order to support the delivery of smart business and technology solutions.

   Report Output - GREBE Technology Transfer – Nordkraft Northern Energy Expertise – February 2018

4. Review local specific (particularly coldness, precipitation and windy climates) innovations from technology providers and facilitate knowledge transfer from these providers to potential providers and new entrants to the renewable energy markets in other regions of the NPA.

   This report and associated database is the output for this objective.

2.1 Project Scope - Report and database compiling information on potential renewable energy business and technology solutions to overcome environmental challenges of NPA regions

The key requirement of this work package is the development of a database (and supporting summary report), compiling information for potential renewable energy business and technology solutions to help overcome environmental and climatic challenges in the NPA programme region. Technology solutions cover installation, operation and maintenance of equipment, not the design and manufacture of components.

The objective of the database is to identify the main environmental and climatic challenges, and outline technological and business solutions to these challenges, creating a database of these for 8 different categories of renewable energy technology.

It is designed for use by new and existing renewable energy businesses, to inform them of the challenges they may face in developing their business and how these will be overcome. A range of examples (where available) have been highlighted on how the challenges identified have been overcome.

Specific regional related innovations and smart solutions from local business on technology driven RE-solutions have been documented, with the intention of passing on this knowledge to other regions in the NPA not involved in the GREBE Project.

The 8 renewable energy technology categories, and subcategories identified by the GREBE Project partnership are:

1. **Biomass**
    - Harvesting
    - Transport/logistics
    - Storage
    - Drying
    - Processing (e.g. chipping)
    - Energy production
    - Energy distribution
2. **Wind (Onshore only)**
    - Site construction
    - Road access
    - Operations and maintenance
3. **Solar PV**
    - Installation
    - Operations and maintenance
4. **Solar Thermal**
    - Installation
    - Operations and maintenance
5. **Hydro**
    - Site construction and access
    - Installation
    - Commissioning

  - Operation and maintenance
6. **Ground source heat pump**
  - Site construction
  - Operation and maintenance
7. **Air source heat pump**
  - Site construction
  - Operation and maintenance
8. **Anaerobic Digestion (farm scale/agricultural)**
  - Site construction and installation
  - Feedstock management
  - Operation and maintenance

The database will be located on the Renewable Business Platform (http://www.renewablebusiness.eu/)

2.2 Background

2.2.1. The GREBE report, ***The Influence of Environmental Conditions in NPA and Arctic Regions-Report on specific challenges of arctic areas (August 2016)***[1] describes the weather systems in the NPA region, climate change effects and specific issues for GREBE regions in Northern Europe.

The report highlights the weather impact on societal infrastructure in the different NPA regions, which is considered to be affecting business activities. The phenomenon of "local extreme weather" is serious for the single business and may have significant consequences to competing in the open market. The economic outcome is therefore a vulnerable risk factor in these NPA regions that gives a negative bias for local business and a non-favourable competitive disadvantage compared to similar businesses in other EU regions.

The regional readiness towards local "extreme weather conditions" should be an important measure when establishing new enterprises and an in-depth risk analysis should be carried out before each activity starts, by taking into account the possibility for weather disturbance. The "local extreme weather" is always important to consider for both personnel and business operations.

The climate effects in the GREBE regions in Northern Europe are outlined and supported by statistical weather data from 2015 in the appendix of the 2016 report (Ref.1).

Ireland is reported as having most weather warnings in November and December relating to wind and rainfall. In Northern Ireland and Scotland, the situation is similar, but with more snow warnings. In the Scottish Highlands there can be more harsh conditions consisting of gale force winds, heavy rainfall and blizzards on high ground. Iceland experiences significant wind warnings which are present during the whole year, with more activities in the winter months. The weather situation is

[1] http://grebeproject.eu/wp-content/uploads/2016/10/GREBE-Report-on-the-Influence-of-Environmental-Conditions-in-NPA-Arctic-Regions.pdf

similar in Norway. Weather disturbances in these areas often result in societal disturbance such as loss of power and road closures due to storms. Parts of Finland have a high number of warnings related to fire, however, warning statistics show the majority of warnings are related to precipitation.

The weather phenomenon in northern Europe includes "atmospheric icing", which affects construction materials when ice accumulates on coastal or offshore installations. However, offshore installations such as wind turbines can be protected with heating systems that can be installed. Another weather situation occurring more frequently in northern parts of Europe is flooding which has serious impacts on society in coastal areas through transportation disruption.

The report concludes that although the regions experience harsh weather at times, the challenges are to find an appropriate level of preparedness and to learn from specific "local extreme" situations. Preparedness would be in the form of preparatory action which addresses Strengths, Weakness, Opportunities and Threat (SWOT) analysis for the business operation taking into account different weather scenarios. Weather phenomenon such as precipitation and wind involving a weather warning, will create business challenges for maintenance, repair and local monitoring of installations, especially where the installations may be in rural areas.

There are significant climate challenges in the partner regions with different types of harsh weather. Low temperature, strong winds, and rain/snow conditions can be extreme in the NPA regions. The question is how to find the best process conditions for businesses in remote NPA communities, where knowledge transfer is an important aspect. A harsh local/regional climate, sparsely populated areas, combined with rural geographic related issues and poor infrastructures have a tendency to bias the company's business models. All businesses will be directly or indirectly affected by climate change through the vulnerability of services on which they depend. This applies among other things to infrastructure, personal/operational safety or energy/communication failure.

However, climate change may also provide excellent renewable opportunities for business activities and value operations. For example, a consequence of more precipitation could lead to increased hydropower production in the electricity sector and increased profitability.

Extreme weather events will often induce costs required to restore the damage that has been incurred in the society. The learnings from an extreme weather event must be taken into account. The active response phases, described as a present mode and a future preventive mode, are also valid for infrastructure and human safety considerations, as well as for vulnerable businesses often located in rural and low populated areas.

2.2.2. The GREBE report on ***Innovations from Local Technology and business solutions, May 2017***[2] addresses the influence of environmental conditions in NPA regions, how society adapts to the new climate situation and includes an SME survey in the GREBE project partner regions.

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2 http://grebeproject.eu/wp-content/uploads/2017/06/GREBE-Report-on-Innovations-from-local-technology-and-business-solutions-May-2017.pdf

The report highlights how the regional readiness in local "extreme weather conditions" should be an important measure when establishing new enterprises and a serious risk analysis should be made before each activity starts, by taking into account the possibility for weather disturbances. Business strategies should be developed around the identified risks.

A survey was undertaken of locally based, small energy businesses in the GREBE partner countries (Ireland, Northern Ireland, Scotland Iceland, Norway and Finland). The aim of this survey was to investigate how weather challenges specifically impact on renewable energy related technologies and businesses. The responses from small energy businesses assisted in identifying existing deficiencies in renewable energy technologies and businesses that have arisen as a direct result of the climatic and physical challenges identified in ***the Report on the Influence of Environmental Conditions in the NPA Arctic Regions. (Ref 1)***

A total of 23 SMEs located in the GREBE partner regions completed or partly completed this survey. The aim was to establish a trend in how renewable energy related SMEs in Northern Europe experience the impact of weather on their business. The survey results showed that the majority (63%) considered weather constraints affecting business budget and identified a need for specific skills and competence within business operations.

The majority of SMEs did not need specific external skills because of weather constraints. Also, a majority confirmed they did not have an internal strategic document or knowledge in relation to weather constraints.

SMEs did confirm how they compensate for weather constraints and disruptions by:

- Timing, operational planning and using experienced contractors
- Compensating investments in fertiliser storage capacities
- Avoiding challenging times in transportation (thaws)
- Planning in construction phase (needed insulations) for arctic conditions
- In Process by preventing freezing (heating, antifreezes)

The report states that a strategic plan and a vulnerability analysis for all businesses working in rural regions is needed, which would most certainly limit the consequences of severe weather conditions.
2.2.3. The GREBE report, ***Nordkraft-Northern Energy Expertise-Knowledge and Technology Transfer Case, February 2018***[3] highlights Nordkrafts' energy business model. The case study highlights how local knowledge regarding the operational conditions and applying appropriate technology can be

[3] http://grebeproject.eu/wp-content/uploads/2018/04/GREBE-Technology-Transfer-Nordkraft-Northern-Energy-Expertise-February-2018.pdf

essential for the success of the technology transfer. The successful demonstrations of Siemens variable wind turbines identified excellent wind resources, local learning and capacity for development, and created new opportunities to expand with an external investor. The business model where investor and operator share the technical risk (borne by Nordkraft) and economic investment risk (borne by Fortum) provide growth opportunities for both.

3. Database Development & Challenges

3.1 Assumptions

In developing the database of climatic challenges and technological, operational and business solutions, the following assumptions were made in relation to how renewable technology businesses apply their technology;

- Site selection and planning considerations have been addressed prior to proposed renewable technology installation.
- Appropriate equipment and project warranties are in place for each project stage.
- Health and safety risk assessments have or will be carried out.
- Project financial and insurance risk assessments have been prepared.
- Timing, operational planning and identifying experienced contractors are considered during installations and maintenance.
- Technology applied is appropriate for the site weather conditions and meets industry standards, as appropriate.

3.2 Database Development Approach

The development of the database involved the following stages;

- Desktop review of relevant source information, in order to get a better understanding of how and where renewable resources are deployed in NPA region and specific challenges, see Appendix 1
- Consultation with GREBE project partners in relation to any specific case studies or research, see Appendix 2
- Direct contact with industry representatives, see Appendix 2
- Direct contact with industry, see Appendix 2

3.3 Challenges

There is a lack of case studies providing specific technological solutions for climatic situations for the NPA renewable technologies. There is limited best practice sharing in relation to technological and business solutions, to address climatic challenges and climate adaptation in order for businesses of any scale to increase resilience.

While there are a significant number of case studies for most of the 8 technologies, the case studies focus on project financing and funding and the design and project outputs, very few addressed specific challenges relating to weather events or climate adaptation.

3.4 Database Outputs

The database is located on the Renewable Business Platform (http://www.renewablebusiness.eu/).

As there were no relevant case studies found through research and consultation, a 'common sense' approach had to be taken to identify specific challenges and appropriate solutions.

The database is matrix style in MS excel and provides climatic challenges and associated technological/operational and business solutions for each renewable technology. The country to which the challenge and solution relates is indicated with a **Y** or **N**.

The database provides filters for users to select a specific technology, challenge and solution.

Where no climatic challenge, technological or business solution is identified in the database, this is not to say conclusively that there is no challenge or solution, but that none were identified during this study.

Common Climatic Challenges

In general, the common challenges caused by any of the climatic conditions on the 8 renewable technologies are;

- Delays in installation and construction (due to flooding, strong winds or snow)
- Delays in scheduled maintenance
- Operational loss
- Feedstock cannot be delivered (biomass/AD)
- Equipment or spare parts cannot be delivered

Common Technological/Operational and Business Solutions

There are common solutions that can be applied to each of the technologies across the NPA region. The key technological solutions are at project scope and design stage, where the appropriate technology and associated infrastructure would be selected and designed relevant to site terrain and predicted conditions and equipment fit for purpose under extreme weather conditions.

Key business solutions include;

- Preparedness in the form of vulnerability analysis and preparatory action which addresses Strengths, Weakness, Opportunities and Threat (SWOT) analysis for the business operation taking into account different weather scenarios and would also address contingency actions relating to weakness and threats. The analysis and actions should be addressed in an overall business strategic plan that includes a section on Weather Preparedness Action and Contingency Plan.
- Weather forecasting and monitoring, winter, spring, summer operation and maintenance planning.

- Ensure that wind turbines, solar PV arrays etc are only operated under the conditions that they have been certified for, and consider warranty of equipment for icing/wind/hailstorm conditions.
- In relation to biomass, good forest management is key as well as considering and managing harvest timing to maximise beneficial ground frost conditions. To reduce the problems of forest road access and maintenance, co-operation between forest owners and government/ stakeholders should be encouraged.
- Plans should be developed for installation, operation, inspection and maintenance, taking into account scenarios of extreme and more frequent weather events.
- Construction contingency planning to ensure equipment/machine use is appropriate for specific weather events.
- Business planning to address cash flow & expenditure relating to unexpected weather events/consider insurance/contractual issues.

4. Conclusions

4.1 Overview of renewable energy sector in Europe.

Annually Eurostat publish an assessment of renewable energy sources in Europe[4]. For the purposes of this report a summary of the renewable energy gross final consumption and contribution of renewables for 2016 was prepared specific to the countries in which the NPA region is located. There is no data for anaerobic digestion and solar thermal in relation to heating consumption and no electricity generated data for anaerobic digestion and air/ground heat pumps.

As can be seen from the table below, there are certain technologies which dominate more than others across the countries in terms of consumption and contribution of renewables to overall energy consumption.

Norway generates more electricity from hydropower than it requires, at 103%; and Iceland is next highest generating 95.31% of electricity from renewables, mainly from hydro, with none generated from biomass, wind or solar pv/thermal. The United Kingdom has the lowest generation of electricity from renewables at 24.62%, mainly sourced from wind.

2016 Values Eurostat (gross final consumption or TFC)

Energy T	Renewable	Unit	Ireland	UK	Norway	Finland	Iceland
Electricity	Biomass	ktoe	33.8	1,685.0	1.7	911.7	-
	Wind	ktoe	565.1	3,506.4	195.9	266.8	0.8
	Solar PV & Thermal	ktoe	0.4	896.0	-	1.5	-
	Hydro	ktoe	62.8	481.4	11,708.2	1,223.4	1,083.7
	Others	ktoe	24.7	924.6	1.1	79.9	435.7
	Sub total	**ktoe**	**686.8**	**7,493.4**	**11,906.9**	**2,483.3**	**1,520.2**
	Total Electricity		2,529.1	30,437.3	11,369.1	7,541.1	1,595.0
	Biomass	% E	1.34%	5.54%	0.01%	12.09%	0.00%
	Wind	% E	22.34%	11.52%	1.72%	3.54%	0.05%
	Solar PV & Thermal	% E	0.01%	2.94%	0.00%	0.02%	0.00%
	Hydro	% E	2.48%	1.58%	102.98%	16.22%	67.94%
	Others	% E	0.98%	3.04%	0.01%	1.06%	27.32%
	Sub total	**% E**	**27.16%**	**24.62%**	**104.73%**	**32.93%**	**95.31%**
				ktoe	ktoe	ktoe	ktoe
Heating	Final energy consumption (Biomass?)	ktoe	253.2	3,236.9	753.6	5,207.2	83.4
	Solar Thermal	ktoe	no data	no data	no data	no data	no data
	Heat Pumps	ktoe	54.7	665.8	393.0	425.6	-
	Derived Heat (CHP)	ktoe	-	17.7	227.0	1,949.4	802.5
	Anaerobic Digestion	ktoe	no data	no data	no data	no data	no data
	Sub total	**ktoe**	**307.9**	**3,920.4**	**1,373.5**	**7,582.2**	**886.0**
	Total Heating & Cooling		4,525.4	55,824.5	4,329.3	14,122.1	1,246.8
	Final energy consumption (Biomass?)	% H&C	5.60%	5.80%	17.41%	36.87%	6.69%
	Solar Thermal	% H&C	no data	no data	no data	no data	no data
	Heat Pumps	% H&C	1.21%	1.19%	9.08%	3.01%	0.00%
	Derived Heat (CHP)	% H&C	0.00%	0.03%	5.24%	13.80%	64.37%
	Anaerobic Digestion	% H&C	no data	no data	no data	no data	no data
	Sub total	**% H&C**	**6.80%**	**7.02%**	**31.73%**	**53.69%**	**71.06%**
Transport	Renewables	ktoe	207.3	2,031.4	767.3	371.3	23.2
	Total Transport	ktoe	4,107.7	41,126.3	4,510.6	4,401.7	322.2
		% T	**5.05%**	**4.94%**	**17.01%**	**8.43%**	**7.19%**

[4] SHARE 2016 Results-Short Assessment of Renewable Energy Source- Eurostat http://ec.europa.eu/eurostat/web/energy/data/shares

4.1.1 Biomass

Biomass is used for both electricity production and the generation of heat. Eurostat data for the contribution of biomass to both electricity (E) and heating & cooling (H&C) demands is reproduced in the table below (Eurostat 2016).

Energy Type	Unit	Ireland	UK	Norway	Finland	Iceland
Electricity	ktoe	33.8	1,685.0	1.7	911.7	-
	% E	1.34%	5.54%	0.01%	12.09%	0.00%
Heating	ktoe	253.2	3,236.9	753.6	5,207.2	83.4
	% H&C	5.60%	5.80%	17.41%	36.87%	6.69%
Total Renewables	ktoe	287.0	4,921.9	755.3	6,118.9	83.4
	%RE	23.9%	36.6%	5.4%	58.6%	3.4%

The use and importance of biomass is very diverse in respective GREBE Project partner countries:

- **Ireland** – Combined biomass contributed 23.9% of the Renewable Contribution to Gross Energy (ktoe) in 2016 (Eurostat 2016). There is the opportunity to increase this share: Donegal's forestry sector for example can become a major player in the biomass industry through the production of wood chip and wood pellets (Agriland, 2016[5]).

- **Northern Ireland** - The use of large scale biomass is possible in Northern Ireland; however Northern Ireland has the lowest forest cover of any country in the UK at only 6.5% (CleaverFultonRanking, 2015[6]).

- **Scotland** - Forests as a whole make up 60% of the UK resource base (hi-energy.org.uk[7]). Forestry is already an extremely important part of Scotland's economy - forests covered around 17% of the land area in 2007 and produces around 7 million m^3 of timber a year, with this production set to increase over the coming decade. A production forecast for Scotland's forests estimated available volumes of 6.9 million m^3, peaking at 8.9 million m^3 in 2017-2021 (Scottish Government, 2007[8]).

- **Finland** - Biomass provides 58.6% of the renewable energy (Eurostat, 2016).

[5] https://www.agriland.ie/farming-news/biomass-great-job-creation-potential-rural-communities-td/ accessed on 9th July 2018
[6] http://www.cfrlaw.co.uk/site/wp-content/uploads/2015/08/future-of-energy-in-ni.pdf accessed on 10th July 2018
[7] http://www.hi-energy.org.uk/Renewables/Biomass-Energy.htm accessed on 11th July 2018
[8] http://www.gov.scot/Publications/2007/03/12095912/9 accessed on 9th July 2018

- **Norway** - Biomass provides 5.4% of renewable energy (Eurostat, 2016).
- **Iceland - T**he share of biomass to the renewable energy contribution in Iceland is very low at 3.4%, due to the large share of other renewables (Eurostat, 2016).

One main challenge in the Nordic countries (Finland, Norway and Iceland) is the early thawing of ground frost, which increases difficulties in harvesting and transporting the timber. This problem does not exist in Ireland and the UK, but storms, forest fires and flooding, which increase difficulties especially in harvesting operations, may occur in all countries.

Heavy snow and ice can cause an impact in all countries, but in Finland, Norway and Iceland the authorities are more familiar with extreme weather and have already adapted their infrastructures, especially in the area of transport.

More precipitation with associated humidity due to global warming may lead to an increase in mould which causes problems with storage of wood products in all countries.

There is little published material on the solutions to how climatic challenges are overcome. Of the little material found, most of the solutions were management based solution rather than technological. Generally, the enhancement of good forest management, special management plans, and co-operation between forest owners, government and forest industry offer the best way to be extreme weather ready.

4.1.2. Wind (Onshore only)

Wind energy is used for both electricity production and the generation of heat. Eurostat data for wind energy's contribution to both electricity (E) and heating & cooling (H&C) demands are reproduced in the table below (Eurostat 2016). This data relates to on shore and off shore sources, as no differentiated data is available.

Energy Type	Unit	Ireland	UK	Norway	Finland	Iceland
Electricity	ktoe	565.1	3,506.4	195.9	266.8	0.8
	% E	22.34%	11.52%	1.72%	3.54%	0.05%
Total Renewables	ktoe	565.1	3,506.4	195.9	266.8	0.8
	% RE	47.0%	26.1%	1.4%	2.6%	0.0%

Wind technology is one of the most mature and proven technologies on the market, having been around since the early 20th century. In 2015, the wind energy industry installed 12.8GW in the EU – more than gas and coal combined.

The business of exploiting wind energy to produce electricity is carried out at various scales from single turbines to large windfarms. There is a wide variety of difference in scale wind turbines available, ranging from small (0.05kW to 50kW), to medium (50kW to 500kW) to large above 500kW.

There are two main types of wind turbine design: Horizontal Axis Wind Turbines and Vertical Axis Wind Turbines. Overall, Horizontal Axis Wind Turbines are more feasible as they are highly efficient and they are the only turbines that can be used for large-scale applications. However, they do have a number of drawbacks, the most significant being the lack of power output at very low and very high wind speeds.

As such these turbines have generally not been employed in the more hostile areas of the NPA region. Vertical Axis Wind Turbines are more suitable for small-scale applications and for extreme weather conditions.

Across the NPA regions high winds and storm conditions affect all countries, in particular Northern Finland, Northern Sweden, Norway, Scotland, and Ireland. High winds challenge wind turbines due to a high wind cut-out (usually above 25m/s) which occurs to protect the mechanics of the turbine. This leads to a loss in power generation. High winds can also cause electrical failures and mechanical fires in turbine wiring.

High winds during hot dry summer conditions have increased the risk of forest fires which can impact windfarms constructed in forest clearings. This has occurred in Ireland in 2016.

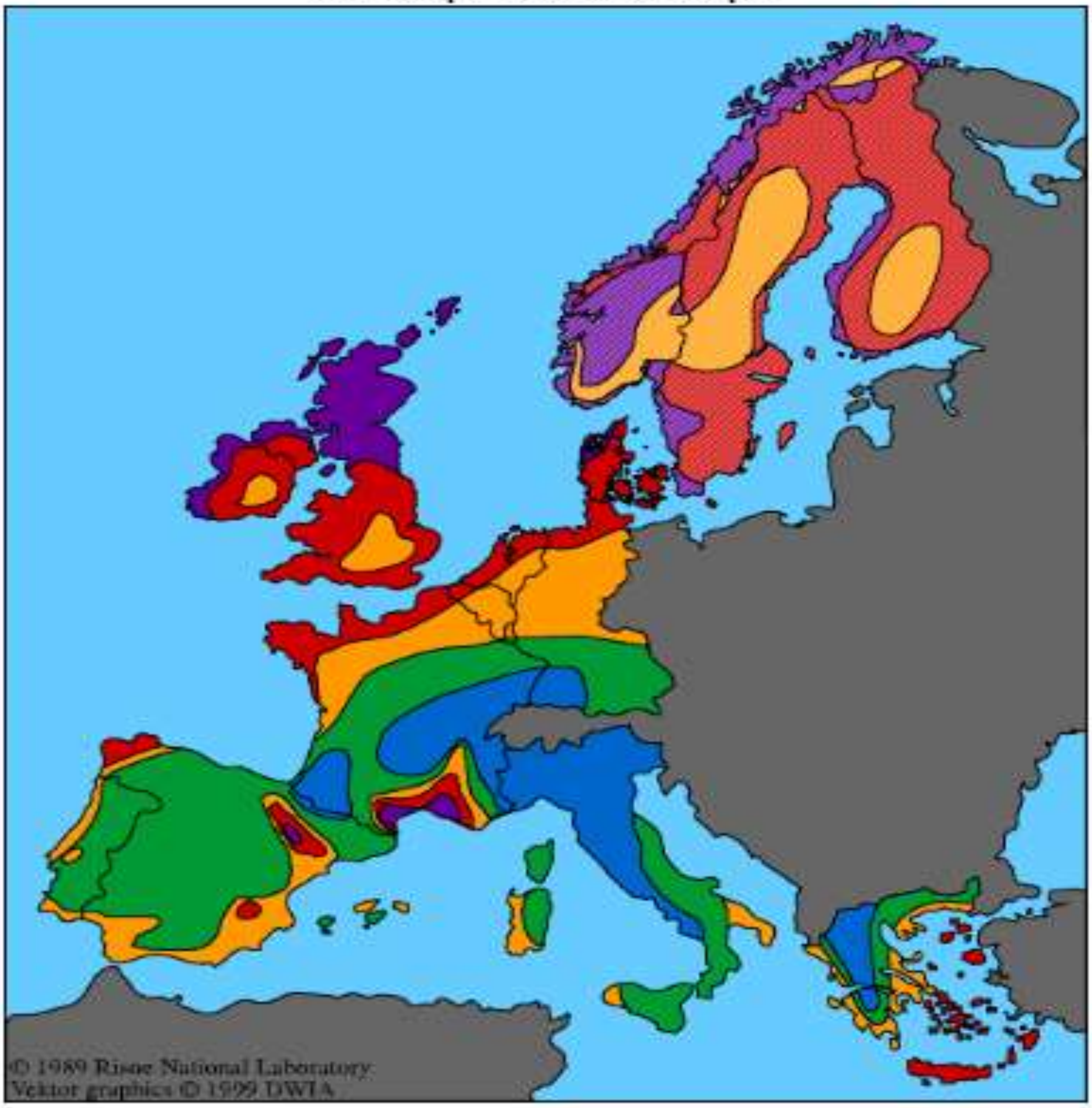
Floods can cause turbine damage due to ground instability issues and the risk of water ingress into cable ducts of mechanical housing /critical areas due to flooding.

In Iceland, Norway and Finland, Cold Climate conditions give rise to icing on the turbine mast, rotors and guy-wires. For icing and cold conditions technology is advancing in developing de-icing applications for wind turbines. The International Energy Agency IE Task 19[9] recommends performance warranties for wind turbines in icing climates to be developed based on actual testing experiences derived from the industry.

Many challenges must be assessed prior to development in the planning and risk assessment phase. For individual wind turbines under high risk conditions, it may be prudent to consider vertical turbines instead of horizontal.

[9] International Energy Agency, Task 19 , Wind Energy in Cold Climates Recommended Practices Report 13

Wind Map of Western Europe



Wind Resources at 50 (45) m Above Ground Level

Colour	Sheltered terrain		Open plain		At a sea coast		Open sea		Hills and ridges	
	m/s	W/m²	m/s	W/m²	m/s	W/m²	m/s	W/m²	m/s	W/m²
	>6.0	>250	>7.5	>500	>8.5	>700	>9.0	>800	>11.5	>1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0-8.5	400-700
	<3.5	<50	<4.5	<100	<5.0	<150	<5.5	<200	<7.0	<400
			>7.5							
			5.5-7.5							
			<5.5							

http://xn--drmstrre-64ad.dk/wp-content/wind/miller/windpower%20web/en/tour/wres/euromap.htm

4.1.3. Solar PV and Solar Thermal

Solar PV and Solar Thermal are used for both electricity production and the generation of heat. The Eurostat data for Solar PV and Solar Thermal's contribution to both electricity (E) and heating & cooling (H&C) demands is reproduced in the table below (Eurostat 2016).

Energy Type	Unit	Ireland	UK	Norway	Finland	Iceland
Electricity	ktoe	0.4	896.0	-	1.5	-
	% E	0.01%	2.94%	0.00%	0.02%	0.00%
Heating	ktoe	no data	no data	no data	no data	no data
Total Renewables	ktoe	0.4	896.0	-	1.5	-
	% RE	0.0%	6.7%	0.0%	0.0%	0.0%

Solar PV and thermal are not deployed on a large scale in Iceland and Norway; however, it is deployed to a certain extent in Scotland, Ireland, Finland and Northern Ireland, mainly through large solar farms. In the summer the NPA region get around 17 to 19 hours of daylight and those in the Arctic Circle get 24 hours. Solar PV requires daylight (solar irradiation), rather than sunshine and high temperatures, which makes it a viable technology choice for businesses in the NPA region. In the winter especially in Finland, Iceland and Norway daylight hours can be limited and in some areas darkness prevails all the time. When there are daylight hours the sun barely rises over the horizon.

There is opportunity to increase solar in each NPA country, although Finland, Norway and Iceland are focusing on other renewables such as wind and hydro in their respective countries. The main potential is in Ireland, Northern Ireland and Scotland.

Key challenges are mainly during the operational phase where extreme snow events may result in the panels covered in snow and impacting energy yield. The design and specification of the PV array mounting systems whether ground or roof mounted should take into account the wind and snow loads to be expected.

Strong wind has the potential to be the biggest challenge; however this is overcome by use of proper fixings and anchor systems that can withstand wind speeds of 200mph.

There is little published material on the solutions to how climatic challenges are overcome. Most solutions were management based solutions rather than technological.

4.1.4 Hydro

Hydro is used for electricity production. Eurostat data for the Hydro contribution to electricity (E) is reproduced in the table below (Eurostat 2016).

Energy Type	Unit	Ireland	UK	Norway	Finland	Iceland
Electricity	ktoe	62.8	481.4	11,708.2	1,223.4	1,083.7
	% E	2.48%	1.58%	102.98%	16.22%	67.94%
Total Renewables	ktoe	62.8	481.4	11,708.2	1,223.4	1,083.7
	% RE	5.2%	3.6%	83.3%	11.7%	44.6%

Norway is the frontrunner on hydropower usage in Europe, although hydropower potential is similarly high in Iceland. Sweden, Finland, Scotland and Northern Ireland have a lower hydropower potential, and in Ireland the potential is quite limited.

Small hydropower (SHP) is characterized by the use of hydraulic energy by local, small hydropower plants that do not generally involve any significant environmental impact. Most of the plants are on small rivers and do not have a reservoir, as they use water basins of different sizes and construction.

The largest risk to small hydro plants is a reduction of precipitation in dry summers and consequent reduced water availability in the supply river or dam.

However, on rivers which are used for many sequential run-of-river hydro turbines flood conditions can be exacerbated due to siltation increasing downriver and potentially blocking the mechanisms of the lower installations.

The most immediate effect of a warmer climate in the Nordic area is a change in the seasonality of river flow, as the timing and amount of snow accumulation and glacier melt will change.

The problems can be classified in the following categories: changes in the mean and extreme values of the temporal and spatial distribution of runoff; changes in the river processes (e.g. erosion and sediment trans-port); ice formation; ice cover formation and break-up; and changes in the design practices and operational management of hydropower.

A new dimension has arrived in dam safety philosophy and work. Risk assessments have to take high flood levels and increased frequencies into account. Dam safety is extremely significant and the feasibility of dam restorations versus the building of new dams for hydro power generation needs to be assessed. The national standards for analysis of dam safety differ widely between the Nordic and other countries. Early stage risk assessment of dam capacity and safety is recommended.

4.1.5 Ground and air source heat pump

Ground Source Heat Pumps (GSHPs), may extract heat from either near surface soils or from ground water, and are distinct from geothermal heating which extracts heat emanating from the earth's core.

Air Source Heat Pumps (ASHPs), are also known as air-to-water heat pumps or air/air heat pumps.

Table 1 Share of Heat Pumps in GREBE countries (Eurostat, 2016[10])

Energy Type	Unit	Ireland	UK	Norway	Finland	Iceland
Heating	ktoe	54.7	665.8	393.0	425.6	-
	% H&C	1.21%	1.19%	9.08%	3.01%	0.00%
Total Renewables	ktoe	54.7	665.8	393.0	425.6	-
	% RE	4.6%	5.0%	2.8%	4.1%	0.0%

In Ireland, a national support scheme for renewable heat has secured government approval and commenced in April 2018. It is designed to financially support replacement of fossil fuel heating with renewable energy and will support investment in heat pumps (air source, ground source and water source heat pumps) with up to 30% of the cost (Irish Examiner, 2018[11]). It is expected that heat pumps will become more popular and the technology is likely to increase in use. Heat pumps, particularly ASHPs, are cost effective for new builds with underfloor heating. Ground Source Heat Pumps (GSHP) are more cost prohibitive if a borehole must be drilled, e.g. anecdotally it could cost €6,000 to drill a 150m borehole.

According to Eurostat (2016) Heat Pumps in Ireland provided 1.21% of total heating and cooling while the share within the UK is 1.19%. Within the respective GREBE project partner countries, Norway has the biggest share (9.08%) with the heat pump market still dominated by ASHPs: In 2008 more than 90% of the total heat pump installed was ASHPs and only 4% GSHPs (Midtomme et al, 2010[12]).

Finland has a renewable contribution of 3.01% (Eurostat, 2016) of its heating and cooling from heat pumps. Indeed, heat pumps have become the most popular main heating source in new built houses, being installed on more than 70% of new builds. More than 800,000 Heat Pumps have been already installed, with projections expecting 1 million running Heat Pumps in Finland in 2020 (Sulpu, 2018[13]).

In Iceland, Ground Source Heat pumps have not found much use, since sufficient cheap geothermal water for space heating is commonly available. However, a recent legislation has been implemented

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[10] http://ec.europa.eu/eurostat/web/energy/data/shares accessed 11th July 2018
[11] https://www.irishexaminer.com/breakingnews/farming/irelands-renewable-heat-incentive-starts-821225.html accessed 11th July 2018
[12] https://www.researchgate.net/publication/268303545_Geothermal_Energy_-Country_Update_for_Norway accessed 10th July 2018
[13] https://www.sulpu.fi/in-english accessed on 10th July 2018
https://www.sulpu.fi/documents/184029/189661/The%20future%20of%20Heat%20Pumps.pdf accessed on 10th July 2018

that allows users of subsidized electrical heating to get a contribution to improve or convert their heating system. The contribution corresponds to subsidies over 8 years. It is thus considered likely that heat pumps will become competitive in those areas of the country where water with temperature above 50°C is not found. In these places, heat pumps can be used to replace or reduce the use of direct electrical heating (Orkustofnun, 2018[14]).

Air Source Heat pumps seem to be extremely resistant against climatic challenges as they are designed to work in extreme environments (Vaillant, 2018[15]). No case studies were found on the effect of climatic challenges on air source heat pumps.

4.1.6 Anaerobic Digestion (farm scale/agricultural)

As with previous technologies discussed, Eurostat data was assessed for 2016, however, there is no data on consumption of anaerobic digestion generated electricity.

The main drivers for anaerobic digestion relate to regulations governing food waste, animal slurries, wastewater sludge, landfill diversions and water protection, coupled with targets for renewable energy and GHG emission reduction targets.

Farm scale plants usually rely on a feedstock of animal manures, slurries and crops. The resultant digestate is then a product that is used as fertilizer. Most farm-based plants use the biogas on the farm for electricity and heating, with some excess put back in to the grid.

Anaerobic digestion has become a popular diversification for farmers as the extra income often subsidises other parts of the enterprise.

The extent to which anaerobic digestion is employed in the NPA region is determined by the financial support systems especially in relation to feed-in tariffs and investment grant and tax systems in relation to use of biomethane as a fuel.

- **Ireland** - In Ireland 28 biogas plants (approx. 30MW) were in operation in 2014. This figure includes 11 facilities recovering landfill gas, and 17 biogas plants, the majority of which are integrated into wastewater treatment facilities. [16] The low level of development of AD in Ireland has largely been due to the feed-in tariff being too low. Since 2014 there have been approximately three industrial AD plants constructed.

- **Northern Ireland -** In Northern Ireland there are 103 AD sites either in construction or already approved (Nov 2017). [17]

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14 https://nea.is/geothermal/direct-utilization/heat-pumps/ accessed on 10th July 2018
15 https://www.vaillant.co.uk/for-installers/products/ake/ accessed on 10th July 2018
16 http://www.cre.ie/web/wp-content/uploads/2016/12/Report-1-Potential-Size-of-the-Anaerobic-Digestion-Industry-by-2030.pdf
17 https://www.agriland.ie/farming-news/103-anaerobic-digestion-plants-approved-in-northern-ireland-as-ad-sector-booms/

- **Scotland -** Scotland has 50 operational AD plants for recycling a range of wastes including animal slurries and manures, food waste, grass silage, sugar beet, and various grains and wheats from distilleries. Government energy strategy is focusing on 50% of energy supply from renewable sources by 2030.

- **Finland -** Finland is looking to upgrade biogas plants to supply vehicle fuel.[18]

- **Norway -** The Norwegian Government aims for 30% of livestock manure and food waste to be treated in biogas plants by 2020. In 2013, much of this waste was exported to Sweden and Denmark. The projected realistic production by 2020 is 2.3TWh.

- **Iceland -** Iceland is focusing attention on methane fuel from waste, but mainly from large industrial anaerobic digestion plants rather than from farms.

The main challenges in the Nordic countries (Finland, Norway and Iceland) are extremes of cold temperatures which can affect the operation of the plant's control system and plant and digester. If feedstock sources are reliant on input from neighbouring farms, access restrictions due to extreme snow and ice conditions can impact operation of plant.

Feedstock supply is vital to the operation of an anaerobic digestion plant regardless of scale and specific process. These extremes are not as significant in Ireland, Northern Ireland and Scotland, but from time to time extended cold and ice periods can shut down plant controls. Feedstock is also impacted by extreme cold which can freeze the material and result in heating requirements of the feedstock.

There is little published material on the solutions to how climatic challenges are overcome. Most solutions were management-based solutions rather than technological.

[18] http://www.sgc.se/ckfinder/userfiles/files/Markets%20and%20trends%20in%20Nordic%20countries_.pdf

Overall Findings and Recommendations

Finding and Climatic Impacts

Climate change and mitigation of emissions are making most countries pivot to renewable energy technologies. The phenomenon of "local extreme weather" is serious for the single business and may have significant consequences to competing in the open market.

The regional readiness towards local "extreme weather conditions" should be an important measure when establishing new enterprises or even expanding existing enterprises. An in-depth risk analysis should be carried out before each activity starts, by taking into account the possibility for weather disturbance.

The weather phenomena in northern Europe includes "atmospheric icing", which affects construction materials when ice accumulates on coastal or offshore installations. Flooding events are occurring more frequently, and many areas of the NPA region are experiencing more frequent and longer periods of gale force winds and snow events.

The impacts on business can include direct effects such as equipment failure or breakdown and indirect effects such as road closures. The challenges are to find an appropriate level of preparedness and to learn from specific "local extreme" situations.

Extreme weather events will often give rise to costs required to restore the damage that has been incurred in the society. The learnings from an extreme weather event must be taken into account. The active response phases, described as a present mode and a future preventive mode, are also valid for infrastructure and human safety considerations, as well as for vulnerable businesses often located in rural and low populated areas.

The regions can learn from each other in terms of how extreme weather events are mitigated against, e.g. flooding preparedness of Anaerobic Digestion technologies at design and construction stage in Scotland and Northern Ireland would be of beneficial to businesses at planning stage in Finland or Norway. Business in Ireland, Scotland and Northern Ireland would benefit from challenges and lessons learned in relation to "local extreme" situations in Norway and Iceland in relation to planning, installation, operation and maintenance of hydropower technologies.

Business Solutions

Renewable energy technology manufacturers and businesses engaged in their installation must adapt to better planning around potentially volatile or extreme local and national weather phenomena in the NPA regions. Businesses will need to assess their operating models and how they are likely to be significantly affected by climate change's physical manifestations, related regulation, as well as threats, opportunities and adaptation requirements.

In order to strengthen preparedness of climate change risks, business solutions in the main consist of contingency planning and weather preparedness. These aspects need to be considered at each stage of a project, from site selection to design, construction, installation and maintenance. These are discussed in more detail below.

Contingency Planning

The main business strategy for climate change adaptation must be to engage with contingency planning at the design stage. This entails carrying out rigorous investigations into the proposed equipment to be installed, to ensure it is of suitable specification for the location and possible extreme weather conditions that may occur. Consideration may include assessing the ability of specific wind turbines to withstand storm or ice conditions, or the examination of specific solar PV fixings to ensure stability of panels during high winds.

Contingency planning may include the additional investment of installing drying sheds as part of bioenergy generation to ensure dry fuel availability, even during prolonged periods of rain, where outdoor drying cannot be guaranteed. Contingency Planning should also consider the availability of alternative equipment, such as additional pumps, in case motors get flooded in extreme weather events, or providing for a margin of delay, for instance where wood fuel cannot be transported to the bioenergy generator due to impassable road conditions.

All technology operators should ensure suitable contractual agreements, equipment warranties, operational insurance are put in place and that cash flow contingency is provided for unexpected expenditure due to extreme weather conditions.

Weather Preparedness

Preparedness would be in the form of vulnerability analysis and preparatory action which addresses Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis for the business operation taking into account different weather scenarios, and would also address contingency actions relating to weaknesses and threats.

Renewable businesses must move on from using historical data for planning, operation and maintenance of their energy investments and adopt dynamic modelling. This modelling would reflect extreme weather risks on a more frequent basis to facilitate cost benefit analysis of project financing. This would require sharing of data and best practice, but also probably requires the development of government policy and environmental standards. Dynamic modelling itself may be a challenge to SME's, therefore government support may be required to facilitate this.

The analysis and actions should be addressed in an overall business strategic plan that includes a section on Weather Preparedness Action and Contingency Planning. Weather forecasting and monitoring are critical aspects of a winter Operations and Maintenance (O&M) programme.

Overall, the equipment and systems must be in good operational condition before the start of winter. Similarly, post winter, spring and summer maintenance programmes should be established taking account of weather aspects specific to spring and summer weather events.

Specific Business Solutions

For some of the technologies reviewed there are specific issues and solutions that are not relevant to each technology. These are set out in the associated database and are briefly highlighted below:

Bioenergy:

For bioenergy, wood harvest timing is important to maximise beneficial ground frost conditions. This will become more critical as ice roads in the Nordic Countries may melt earlier, making the access to forests difficult, or not suitable for the heavy machinery that can be used during fully iced conditions, thus resulting in the use of longer routes. A shortening of the harvest season may have to be planned for, and cooperation between all users of ice roads and forest roads including forest owners and government/ stakeholders should be encouraged.

Good forest management is a priority to ensure a continued good supply of wood, even after storm or fire damage. The forest manager can select from a number of methods the most suitable conversion method for the wind damaged timber, depending on the susceptibility of the respective wood species, the working capacities and the duration of storage required.

Special contingency management plans for harvesting in fire damaged or flooded forests must be agreed with stakeholders, as the required fast action after an extreme event usually does not leave time for public consultations.

If the wood supply from a specific forest is too damaged the harvesting operator must have contingency planning in place to access biomass supply from alternative sites to fulfil contracts, or to consider investment in drying sheds to ensure a better supply of dried wood throughout the seasons.

Wind Turbines:

Prior to any wind farm investment in cold climates, mapping of all potential atmospheric icing and low temperature conditions and associated risks are vital. Future planning should take the expected changes in the natural environment into account. High Wind Modelling and Predictions of increased Wind impact on wind energy systems should be analysed and taken into account by the developer. ***(Norden Climate Change and Energy Systems (CES) – Risk Adaptation Report, Chapter 7*** sets out to project future wind climates in the Nordic and Baltic region and to assess the sources and magnitudes of uncertainties.)

The investor must be aware of the extra risks and costs involved in cold climate wind energy production at early stages of the project. It is important to ensure that the selected wind turbines are only operated under the conditions that they have been certified for, and warranty of equipment for icing conditions should be considered. (***For Warranty Guidelines see International Energy Agency (IEA) Task 19***)

Business planning must investigate the specific technical suitability of the wind turbines for the specific site. These issues include the strength of the wind turbine tower to withstand high turbulence, the proper functioning of the shut-down mechanism during high wind speeds and the knowledge of the turbine operator to manage pre-emptive shutdowns in the event of an extreme weather event being forecast.

Construction and set up of the wind turbines may have to be delayed in very icy or stormy conditions until the weather becomes more temperate. These delays need to be planned for.

Solar PV:

Extreme weather preparedness at the design stage should ensure the solar panel fixing system used to hold solar PV panels whether roof or ground mounted must be strong enough to support the weight of the panels in all weather conditions, including strong wind. They also need to be able to withstand a wide range of temperatures. They need to be installed to ensure so that there is no water ingress through a roof (if roof mounted) or ingress into the panel systems which may ice over in cold weather.

Hydro:

Business contingency planning for hydro generators includes early stage risk assessment of dam capacity and safety of the development in flood conditions, particularly where old dams are to be utilised for new hydro generation installations. Old dams may not have been constructed to withstand extreme floods as predicted under climate change conditions. Weather forecasting and monitoring are critical aspects of hydro generation Operation and mMaintenance (O&M) programme.

Ground Source and Air Source Heat Pump:

These technologies may be affected by extreme cold and icing, and operational warranties should be required for fixings and anchors. Flash flooding may damage pumps that are below ground level, so contingency of backup pumps is recommended or design should consider over-ground pump systems in areas prone to flooding.

Anaerobic Digestion:

Business contingency at the design stage should consider investment in appropriate feedstock storage shed appropriate for type of feedstock, i.e. wet or dry. Insurance and cash-flow preparedness is required to cover the costs of supplying emergency feedstock from alternative sites to fulfil contracts if existing feedstock cannot be used immediately.

Site management should prepare written disaster recovery and contingency plans to ensure a rapid and effective response to worst case scenario events. These events could include failure of the outgoing power transformer or failure of a biogas engine, digester side wall rupture and major digestate release due to storm damage, resulting in pollution of adjacent land, or a major fire or explosion on site resulting in the uncontrolled release of biogas. (***Source: Munich RE Anaerobic Digestion: plan operation and risk management- A guide to loss prevention).***

Case Studies

A key challenge for this project was identifying case studies specific to climatic challenges and technological and business solutions for the renewable energy sector. There is a lack of case studies providing specific technological and business solutions for the NPA renewable technologies. The GREBE Advice Notes for each renewable technology provide lists of suppliers, and it is recommended that for every region the suppliers are requested to submit technological solution case studies for specific climatic challenges, e.g. mounting systems for Solar PV; this would enable these companies to address their unique selling points.

The energy industry (renewable and non-renewable) is being exposed to a greater number and increasing frequency of climate related risks. Indeed, climate change adaptation has never been more strongly in the public eye. Strong winds, floods, ice storms and increased cloud conditions can result in equipment damage, erratic output and lost revenue.

Current and new energy infrastructure must adapt to withstand climate challenges to ensure energy supply is reliable and secure.

Energy companies (of all sizes) must move on from using historical data for planning, operation and maintenance of their energy investments and adopt dynamic modelling. This modelling would reflect extreme weather risks on a more frequent basis to facilitate cost benefit analysis of project financing. This would require sharing of data and best practice, but also probably requires the development of government policy and environmental standards. Dynamic modelling itself may be a challenge to SME's, therefore government support may be required to facilitate this.

Appendix 1 - Documentation Reviewed

GREBE Publications

Project Reports

GREBE Technology Transfer – Nordkraft Northern Energy Expertise – February 2018
http://grebeproject.eu/wp-content/uploads/2018/04/GREBE-Technology-Transfer-Nordkraft-Northern-Energy-Expertise-February-2018.pdf

GREBE Report on the Influence of Environmental Conditions in NPA & Arctic Regions - August 2016
http://grebeproject.eu/wp-content/uploads/2016/10/GREBE-Report-on-the-Influence-of-Environmental-Conditions-in-NPA-Arctic-Regions.pdf

GREBE Report on Innovations from Local Technology and business solutions - May 2017
http://grebeproject.eu/wp-content/uploads/2017/06/GREBE-Report-on-Innovations-from-local-technology-and-business-solutions-May-2017.pdf

GREBE Project Case Studies and Advice Notes

Biomass

- Biomass -Hillcrest Nursery Biomass Boiler (Northern Ireland)
  http://grebeproject.eu/wp-content/uploads/2017/09/Biomass-Hillcrest-Nursery-Northern-Ireland.pdf
- Biomass CHP - Sinikasvis (Finland)
  http://grebeproject.eu/wp-content/uploads/2017/09/Biomass-CHP-Sinikasvis-Finland.pdf
- Small Scale Biomass CHP - Kuittila Power (Finland)
  http://grebeproject.eu/wp-content/uploads/2017/09/Small-Scale-Biomass-CHP-Kuittila-Power-Finland.pdf
- Advice Notes Biomass - Sept 2017
  http://grebeproject.eu/wp-content/uploads/2018/04/GREBE-Advice-Notes-biomass-2.pdf
- Advice Notes Biomass CHP - Sept 2017
  http://grebeproject.eu/wp-content/uploads/2018/04/GREBE-Advice-Notes-biomass-chp-2.pdf

Wind

- Small Scale Wind - IceWind (Iceland)
  http://grebeproject.eu/wp-content/uploads/2017/09/Small-scale-Wind-Energy-IceWind-Iceland.pdf
- Advice Notes - Wind -Sept 2017
  http://grebeproject.eu/wp-content/uploads/2017/10/GREBE-Advice-Notes-WIND.pdf

- Wind Energy - Dingwall Wind Co-op (Scotland)
  http://grebeproject.eu/wp-content/uploads/2017/09/Wind-Energy-Dingwall-Wind-Co-op-Scotland.pdf

Solar PV

- Advice Notes - Solar PV- Sept 2017
  http://grebeproject.eu/wp-content/uploads/2017/10/GREBE-Advice-Notes-SOLAR-PV.pdf

Solar Thermal

- Advice Notes - Solar Thermal - Sept 2017
  http://grebeproject.eu/wp-content/uploads/2017/10/GREBE-Advice-Notes-SOLAR-Thermal.pdf

Hydro

- Advice Notes – Hydro - Sept 2017
  http://grebeproject.eu/wp-content/uploads/2018/04/GREBE-Advice-Notes-Hydro.pdf
- Small Scale Hydro- BMJ Energy (Iceland)
  http://grebeproject.eu/wp-content/uploads/2017/09/Small-Scale-Hydro-BMJ-Energy-Iceland.pdf
- Tidal Energy - Nova Innovation (Scotland)
  http://grebeproject.eu/wp-content/uploads/2017/09/Tidal-Energy-Nova-innovation-Scotland.pdf
- Wave Energy - Albatern WaveNet (Scotland)
  http://grebeproject.eu/wp-content/uploads/2017/09/Wave-Energy-Albatern-WaveNet-Scotland.pdf

Ground Source Heat Pump

- Deep Geothermal-IDDP (Iceland)
  http://grebeproject.eu/wp-content/uploads/2017/09/Deep-Geothermal-IDDP-Iceland.pdf
- Geothermal-Svartsengi Resource Park (Iceland)
  http://grebeproject.eu/wp-content/uploads/2017/09/Geothermal-Svartsengi-Resource-Park-Iceland.pdf
- Geothermal Ground Source - Housing Association Kontiolahti (Iceland)
  http://grebeproject.eu/wp-content/uploads/2017/09/Geothermal-Ground-Source-Housing-Association-Kontiolahti-Iceland.pdf
- Advice Notes - Ground and Air -Sept 2017
  http://grebeproject.eu/wp-content/uploads/2017/10/GREBE-Advice-Notes-GSHP-ASHP.pdf
- Advice Notes - Geothermal- Sept 2017
  http://grebeproject.eu/wp-content/uploads/2017/10/GREBE-Advice-Notes-Geothermal.pdf

Air Source Heat Pump

- Advice Notes- Ground and Air -Sept 2017 http://grebeproject.eu/wp-content/uploads/2017/10/GREBE-Advice-Notes-GSHP-ASHP.pdf

Anaerobic Digestion

- Anaerobic Digestion- Bridge Energy (Northern Ireland) http://grebeproject.eu/wp-content/uploads/2017/09/Anaerobic-Digestion-Bridge-Energy-Northern-Ireland.pdf
- Anaerobic Digestion- Claremorris Energy Cooperative (Ireland) http://grebeproject.eu/wp-content/uploads/2017/09/Anaerobic-Digestion-Claremorris-Energy-Cooperative-Ireland.pdf
- Advice Notes- Anaerobic Digestion- Sept 2017 http://grebeproject.eu/wp-content/uploads/2017/10/GREBE-Advice-Notes-AD.pdf

Battery & Hybrid

- Battery Storage – Each Leim Micogrid (Ireland) http://grebeproject.eu/wp-content/uploads/2017/09/Battery-Storage-Each-Leim-Microgrid-Ireland.pdf
- Hybrid Energy Solutions- Itikan-Tila Lisalmi (Finland) http://grebeproject.eu/wp-content/uploads/2017/10/Hybrid-Energy-Solutions-Itikan-Tila-Iisalmi-Finland.pdf
- Advice Notes- Energy Storage-Sept 2017 http://grebeproject.eu/wp-content/uploads/2018/04/Advice-Notes-Energy-storage-2-3.pdf

BioPAD Project Reports

- Case Study of Farm-Scale Wood Energy Solution: Kuittila Farm CHP, Nurmes, Finland
- Case Study of AFBI Northern Ireland
- Case Study Report: Donegal Woodland Owners' Society, Ireland
- All case studies- https://www.biopad.eu/case-studies/

Additional Sources- Biomass

- Technical guide on harvesting and conservation of storm damaged timber, p.10-11; Nordic Cooperation (2012);
  Joint Fao/Ece/Ilo committee on forest technology, management and training (2004)
  https://videntjenesten.ku.dk/filer/Technical-Guide-on-harvesting-and-conservation-of-storm-damaged-timber.pdf
- Harvesting in Burned Forests. Issues and Orientations for Ecosystem-Based Management, p. 2, 5, 26; Gouvernement du Québec (2011)
  https://mffp.gouv.qc.ca/english/publications/forest/harvesting-burned-forests.pdf
- Prospects and Challenges of Timber Trucking in a Changing Operational Environment in Finland, p.89; University of Eastern Finland (2014)

https://hrcak.srce.hr/120241

Additional Sources-Wind

- To Catch The Wind: The Potential for Community Ownership of Wind Farms in Ireland; Western Development Commission, Ireland https://www.wdc.ie/wp-content/uploads/reports_To-Catch-the-Wind.pdf
- Wind turbine in Scotland on Fire due to Storm- https://www.telegraph.co.uk/news/weather/8944597/Blown-away-gales-wreck-wind-turbines-as-Scottish-storm-wreck-havoc.html
- Cloosh Valley Windfarm, Galway www.rte.ie/news/2017/0509/873614-galway-fire/
- International Energy Agency: Task 19 , Wind Energy in Cold Climates Recommended Practices 13;four documents https://community.ieawind.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=8c9d6075-cf94-ffac-ff9d-6ca9b6601881&forceDialog=0
- International Energy Agency: Task 25 Wind Design and Operations Guidelines , various five documents https://community.ieawind.org/home
- Climate change impacts on the power generation potential of a European mid-century wind farms scenario; Environ. Res. Lett. 11 (2016) 034013 http://iopscience.iop.org/article/10.1088/1748-9326/11/3/034013/meta
- The Impact of Climate Change on Wind Energy Generation in the UK https://www.era.lib.ed.ac.uk/handle/1842/4034
- C. Arbez, M. Boquet and R. Krishnamurthy, “Case study of Lidarin cold climate and complex terrain in Canada,” in Winterwind, Sweden, 2014.
- V. Lehtomäki, S. Rissanen, M. Wadham-Gagnon, K. Sandel, W. Moser and D. Jacob, “Fatigue loads of iced turbines: Two case studies,” Journal of Wind Engineering and Industrial Aerodynamics, vol. 158, pp. 37-50, 2016.

Additional Sources- Heat Pumps

- Heat Pump Troubleshooters, Cloonfad, Ballyhaunis, Mayo- http://www.heatpumptroubleshooters.ie/heat-pump-problems.html

Additional Sources -Solar PV and Solar Thermal

- http://bpva.org.uk/media/38266/new-guide-to-installlation-of-pv-systems-mcs_20130530161524.pdf
- https://www.sepco-solarlighting.com/blog/performance-and-maintenance-of-solar-panels-in-cold-climates
- https://www.solarpowerworldonline.com/2018/01/solar-industry-responding-increasing-intensity-natural-disasters/

- http://energyinformative.org/solar-panels-weather/
- https://news.energysage.com/solar-panels-hail-hurricanes/
- https://pdfs.semanticscholar.org/presentation/351c/2e1c0e665ef964e816265e4d26649c30ed75.pdf
- http://www.trustedreviews.com/opinion/what-is-ip68-ip-ratings-explained-2947135
- Nature Communications- The Impact of climate change on photovoltaic power generation in Europe, Article- Published 11 Dec 2015; Authors: Dougal Burnett, Edward Barbour, Gareth P. Harrison (Institute for Energy Systems, School of Engineering, University of Edinburgh, United Kingdom)
- Renewable Energy- An International Journal-The UK solar energy resource and the impact of climate change
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Appendix 2 – Organisations Contacted

Organisation Name	Location
GREBE PROJECT PARTNERS	
Western Development Commission	Ireland
Action Renewables (NI)	Northern Ireland
Fermanagh & Omagh District Council	Northern Ireland
Environmental Research Institute	Scotland
Natural Resources Institute	Finland
Karelia UAS	Finland
Innovation Center Iceland	Iceland
1. INDUSTRY REPRESENTATIVES & BIOMASS COMPANIES	
Irish Bioenergy Association	Ireland
Bord na Mona	Ireland
BioXL	Ireland
Teagasc	Ireland
UCD	Ireland
Sustainable Energy Authority Ireland	Ireland
Technische Universität München	Germany
Biomass UK	United Kingdom
Norwegian Water Resources and Energy Directorate	Norway
National Energy Authority of Iceland	Iceland
2. INDUSTRY REPRESENTATIVES & WIND ENERGY COMPANIES	
Sustainable Energy Authority Ireland	Ireland
Abo Wind	Ireland
DP Energy	Ireland
Highlands & Islands Enterprise	United Kingdom
Irish Wind Energy Association	Ireland
Dundalk IT	Ireland
3 & 4. INDUSTRY REPRESENTATIVES & SOLAR ENERGY COMPANIES	
BNRG PV Solar	Ireland

Organisation Name	Location
Irish Solar Energy Association	Ireland
Solar Electric	Ireland
Kingspan ESB (Funded Solar)	Ireland
Sustainable Energy Authority Ireland	Ireland
5. INDUSTRY REPRESENTATIVES & HYDRO POWER COMPANIES	
British Hydro	United Kingdom
Finish Hydro	Finland
Island Seafoods	Ireland
European Marine Energy Centre	United Kingdom
Sintef Applied Research	Norway
6&7. INDUSTRY REPRESENTATIVES & GROUND & AIRSOURCE HEAT PUMPS COMPANIES	
Ground Source Heat Pump Association, UK	United Kingdom
UK (Northern Ireland & Scotland) Heat pumps	Northern Ireland & Scotland
Finland Heat pumps	Finland
Norsk Bioenrgieforening	Norway
Iceland Heat pumps	Iceland
Department of Communications, Climate Action & Environment	Ireland
Green-house	Ireland
Energy saving trust UK	United Kingdom
Energia virasto Finland	Finland
8. INDUSTRY REPRESENTATIVES & ANEROBIC DIGESTION COMPANIES	
Demetra AD	Ireland
LSR Support Limited	Northern Ireland
Irish Bioenergy Association	Ireland

Northern Periphery and Arctic Programme 2014–2020

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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
- Forskningsparken i Narvik
- eri – Environmental Research Institute
- Fermanagh & Omagh District Council – Comhairle Ceantair Fhear Manach agus na hÓmaí
- Innovation Center Iceland
- Karelia

About GREBE

GREBE 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 will focus on the challenges of peripheral and arctic regions as places for doing business, and help develop renewable energy business opportunities provided by extreme conditions.