Large scale energy storage

CryoHub

Developing Cryogenic Energy Storage at Refrigerated Warehouses as an Interactive Hub to Integrate Renewable Energy in Industrial Food Refrigeration and to Enhance Power Grid Sustainability

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Report on RES mapping

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- On the project Portal
- On the CryoHub Intranet (http://cryohub.psutec.com/)

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1. Executive Summary

One of the activities of the CryoHub project is to map renewable energy installations in EU-28, with a view to identifying those which are close (<1 km) to refrigerated warehouses. Such a preliminary analysis is the basis for identifying potential food refrigeration facilities, which are close to the identified PV and wind installations, where the CryoHub technology could be successfully applied.

These installations are visually presented in ***Deliverable 2.2- Report on RES mapping***, which also highlight areas with a high concentration of PV and wind installations. An Excel database, which lists the installations, as well as some relevant parameters for our analysis, such as power output per installation, and location (using NUTS code), is made available to the partners via the CryoHub intranet.

In order to present a complete picture, some scenarios on the evolution of renewable energies by 2030, and 2050 are also discussed.

2. Context

2.1. CryoHub overview

The CryoHub innovation project will investigate and extend the potential of large-scale Cryogenic Energy Storage (CES) and will apply the stored energy for both cooling and energy generation. By employing Renewable Energy Sources (RES)[1] to liquefy and store cryogens, CryoHub will balance the power grid, while meeting the cooling demand of a refrigerated food warehouse and recovering the waste heat from its equipment and components.

The intermittent supply is a major obstacle to the RES power market. In reality, RES are fickle forces, prone to over-producing when demand is low and failing to meet requirements when demand peaks. Europe is about to generate 20% of its required energy from RES by 2020, so that the proper RES integration poses continent-wide challenges.

The CES, and particularly the Liquid Air Energy Storage (LAES), is a promising technology enabling on-site storage of RES energy during periods of high generation and its use at peak grid demand. Thus, CES acts as Grid Energy Storage (GES), where cryogen is boiled to drive a turbine and to restore electricity to the grid. To date, CES

[1] For the purpose of our analysis, it has been decided to focus on variable renewable energy (PV and wind). Other renewable energies are out of the scope of this report, but might be mentioned where their share is important in a given country.

applications have been rather limited by the poor round trip efficiency (ratio between energies spent for and retrieved from energy storage) due to unrecovered energy losses. The CryoHub project is therefore designed to maximise the CES efficiency by recovering energy from cooling and heating in a perfect RES-driven cycle of cryogen liquefaction, storage, distribution and efficient use. Refrigerated warehouses for chilled and frozen food commodities are large electricity consumers, possess powerful installed capacities for cooling and heating and waste substantial amounts of heat. Such facilities provide the ideal industrial environment to advance and demonstrate the LAES benefits.
CryoHub will thus resolve most of the above-mentioned problems at one go, thereby paving the way for broader market prospects for CES-based technologies across Europe.

2.2. Overview of Work Package 2- Refrigerated warehouse and renewable energy mapping

Work Package 2 has three main objectives:

- To map locations of large refrigerated warehouses and food factories in Europe (> 0.5 MW average power input), their power usage, waste heat generation and these profiles over time.
- To map whether these stores have access to RES on site or locally (within 1 km). Potential for stores without access to RES to install RES.
- To determine the potential for CryoHub application with resulting benefits (to be further determined in WP3).

2.2.1. Purpose of deliverable

Deliverable 2.2 is dedicated to the **mapping of the location and the power output of renewable energy sources**.
For our analysis, it was decided to focus on PV and onshore wind installations, since PV and wind are two fluctuating renewable energy sources, whose integration in the existing transmission grid poses the majority of challenges, and for which storage solutions need to be implemented.

The analysis covers two levels:

- First of all, a general analysis of the existing PV and onshore wind installations is presented in the form of maps. Such a general analysis allows identifying areas where renewable energy installations are located all over Europe, and where additional potential is available
- Then, some food refrigeration sites, close to relevant renewable energy installations, are identified

Deliverable 2.3- Report on potential opportunities for CryoHub in Europe will use the information provided by D2.2, as well as **Deliverable 2.1- Report on refrigerated food facility mapping,** to map the renewable energy installations close (within 1 km) to

the refrigerated food facilities, and, in this way, to identify opportunities for the development and application of the CryoHub technology in Europe.

3. Methodology

The total wind energy capacity in the EU 28 exceeded 129.08 GW in 2014. The wind power capacity installed by the end of 2014 could produce, in a normal wind year, 253.2 TWh of electricity, enough to cover 10.2% of the EU's electricity consumption (Eurostat 2015). The total PV installed capacity in EU-28 amounted to 89.09 GW in 2014 (Eurostat 2015), with a solar electricity production amounting to 97.8 TWh.
In situ power generation using Renewable Energy Sources (RES) (i.e. wind, tidal or solar) permits capture of a large portion of virtually free energy. This has the potential to dramatically reduce running costs and carbon footprint, while enhancing the overall system efficiency of food warehouses and food processing facilities. Simultaneously, the intermittent supply of RES is a major problem for development of the renewable power market. In reality, RES are prone to overproducing when demand is low and failing to meet requirements when demand peaks. Thus, surplus RES-generated electricity is often wasted when it is not required. Europe is on course to be able to generate 20% of its required energy from renewable resources (as planned for 2020), so the proper integration and storage of these resources poses new continent-wide challenges. Hence, RES involvement fosters Cryogenic Energy Storage (CES) developments and vice-versa, i.e. the RES and CES technologies are mutually enabling and should be deployed in parallel.

Refrigerated warehouses generally have large flat roofs which are ideally suited to solar panels. The work within ICE-E found that individual refrigerated warehouse roofs could be as large as 50,000 m^2 with at least 50% of roofs being at 7,000 m^2 or larger. Most warehouses are also located outside cities and urban areas and often already have RES (mainly solar or wind) installed or have the land and facilities to install RES. Warehouses are also often located at or near to ports and so there is also potential to utilise tidal energy.

The consortium decided, during its first meeting in April 2016, to focus its analysis on fluctuating renewable energies, such as PV and wind, since they are those renewable energies, whose introduction into the transmission grid, poses the most of difficulties in terms of maintaining its stability. Therefore, potentially, the application of cryogenic storage in combination with the use of wind and solar PV has the biggest potential.

3.1. Maps' acquisition

EUREC was in charge of finding the relevant information related to existing installations of wind and solar PV in EU-28[2]. After some search, it was decided to acquire these data from La TeneMaps (http://latenemaps.com/), which produces this type of data in cooperation with the major European renewable energy associations.

LaTeneMaps sent two shape files containing the following information:

- Major SolarPV installations: location of 3,200 built Solar PV installations in Europe (data available on June 2016)
- Major Onshore wind farms installations: location of 11,700 onshore installations in Europe (data available on June 2016). Offshore wind farms installations were not considered relevant for our analysis since they are not located close (less than 1 km, according to the project's Description of Work) to refrigerated warehouses and food factories.

This data was used by Cranfield University to produce the requested maps to be used for our analysis[3].

3.2. Data mapping analysis

The mapping software chosen by Cranfield University is ArcGis.
The selection of the ArcGIS tool is based on the following criteria:

- The ability to manipulate the data (for example, convert coordinate systems)
- The ability to analyse data (for example, determine the nearest cold store distance to every wind farm, solar facility etc.)
- The ability to create bespoke mapped outputs (from simple mapped outputs to processed outputs such as heat maps etc.).
- The wide-spread use of the software (ESRI is the leading producer of GIS software)
- The skills within the consortium (Cranfield are leading users of this software)

ArcGIS fulfils these criteria better than other software like google maps.
According to the received information, the following maps were produced:

- Map of wind and PV installations in EU-28
- Maps of wind and PV installations in the following groups of countries:
    - *Benelux* (Belgium, the Netherlands, and Belgium)
    - *Central and eastern Europe* (Bulgaria, Croatia, Czech Republic, Hungary, Poland, Slovakia, Slovenia and Romania).

[2]Installations have been also identified in non-EU countries, such as Switzerland, Norway and Turkey. However, they have not been included in this report, since they are not part of EU-28
[3] One mistake was found in the output capacity for a PV site and was, consequently, removed from the analysis. Other mistakes are possible, on such a big dataset. The authors have tried to limit them as much as possible

  - *Germany and Austria*
  - *Mediterranean countries* (Cyprus, France, Greece, Italy, Spain, and Portugal)
  - *Nordic* and Baltic countries (Denmark, Estonia, Finland, Latvia, Lithuania and Sweden)
  - *United Kingdom and Ireland*
- Two EU-28 maps (one for' wind and one for PV) to identify overlapping areas where renewable energy installations are close to refrigerated facilities and food warehouses.[4]

4. Results

This section visually presents, with the support of maps, the locations of PV and wind installations in EU28, as well as their overlapping with refrigerated warehouses and food facilities, whenever possible.
The maps, first, cover the whole geographical area, as considered in our analysis, and, subsequently, present a snapshot of interesting geographical blocs. Finally, two summary maps, presenting those refrigerated sites which are in proximity of renewable energy installations, are also presented and discussed.

4.1. Europe

The map, which presents the mapping of variable renewable energy in the EU is shown below

[4] No relevant installations (power output > 0,5 MW) have been identified in Cyprus, Luxemburg and Malta

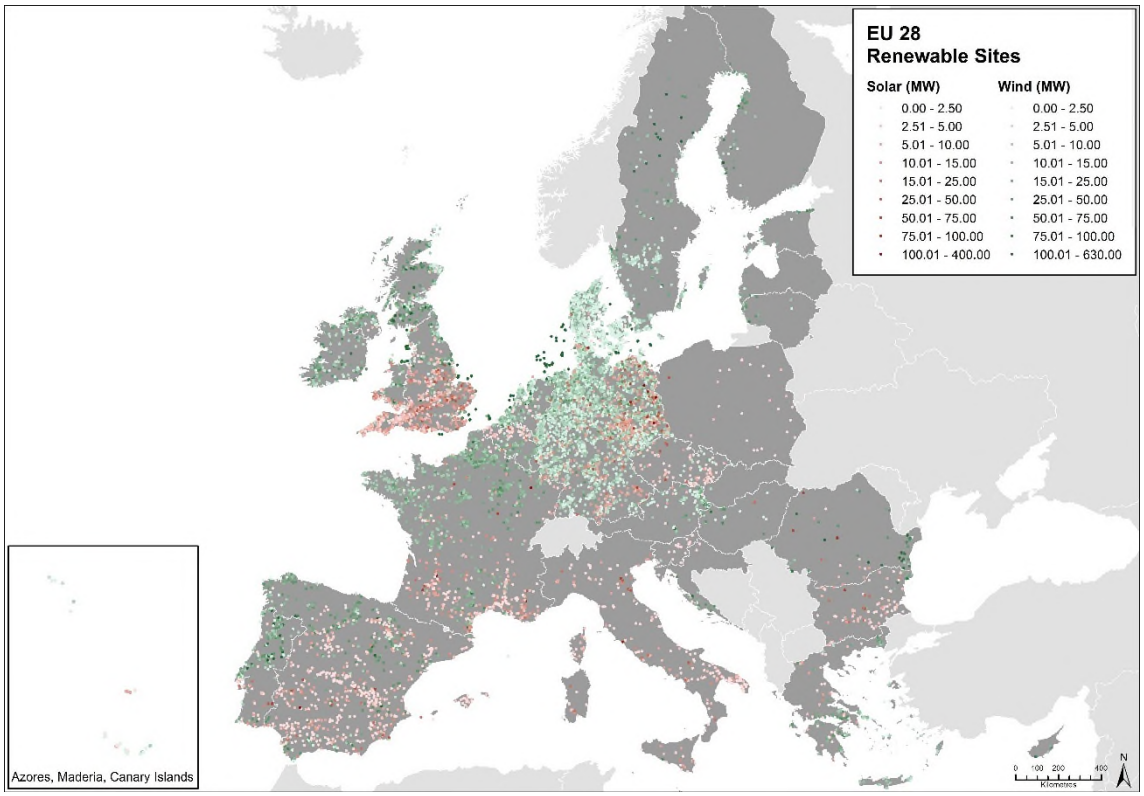

Figure 1- Renewable Sites (both wind and PV) in EU28

Figure 1- Renewable Sites (both wind and PV) in EU28 shows a clear concentration of interesting sites in Germany and Benelux, in the Northern block (Ireland and UK), as well as in the Mediterranean area with a focus on Spain.

Solar PV installations are spread all over Europe, but with an important presence in Spain, Germany, South of France, Italy, Bulgaria, Greece, and the UK (see Figure 2- Solar PV sites in Europe 2).

Wind installations are more geographically concentrated in Germany, Benelux, Spain, Portugal, UK, Ireland, France, and Sweden (see Figure 3- Wind installations in Europe 28).

The total power output covered by the renewables' installations, which have been considered in our analysis, amounts to 142GW, representing around 65% of the solar and wind energy installed capacity in EU-28 in 2014[5]. This represents a good approximation of the existing installed capacity for wind and solar in EU-28, considering that we are including only those installations which have a power output higher than 1 MW. Some discrepancies with the overall data presented in the Energy statistical pocketbook are highlighted below:

[5] EU energy in figures- statistical pocketbook 2016:
https://ec.europa.eu/energy/sites/ener/files/documents/pocketbook_energy-2016_web-final_final.pdf
(Eurostat 2015)

- The power output and number of wind installations located in Italy, Poland and Latvia is largely underestimated, with respect to the information presented in the Pocketbook.
- No data available for solar power installations in Cyprus, Lithuania and Slovakia. This might be due to the fact that installations in these countries are normally lower than 0.5 MW

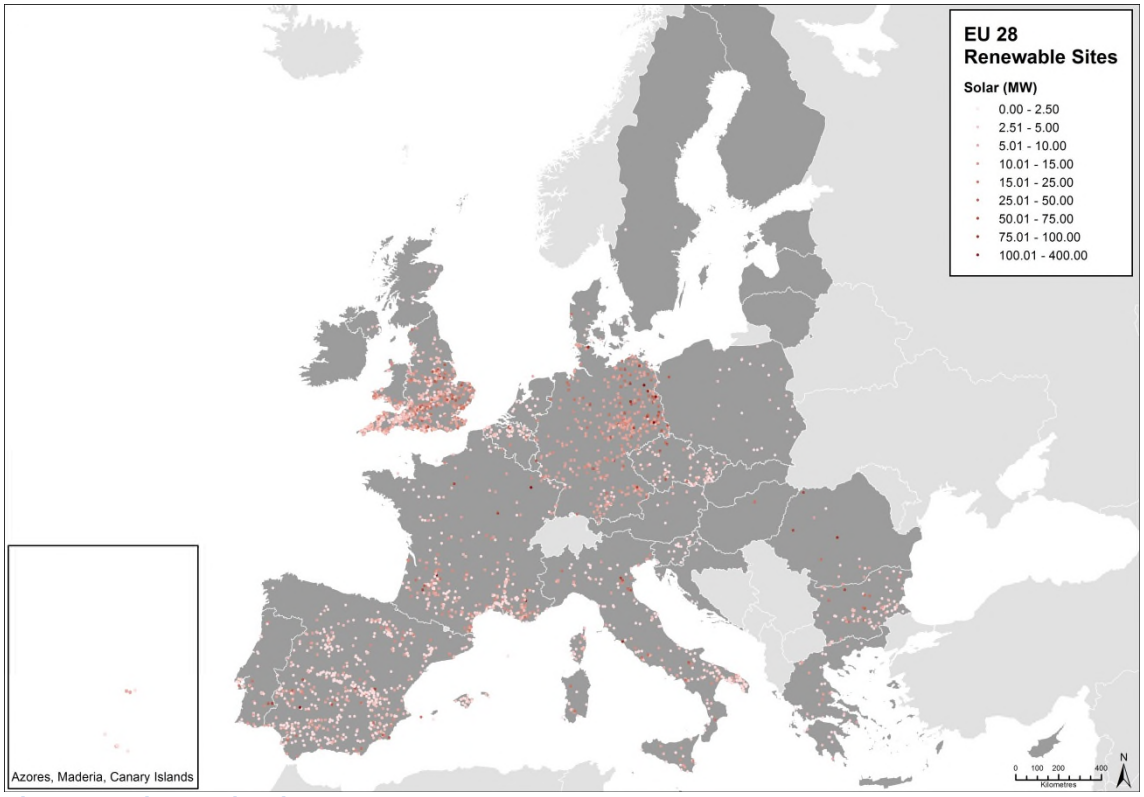

Figure 2- Solar PV sites in Europe 28

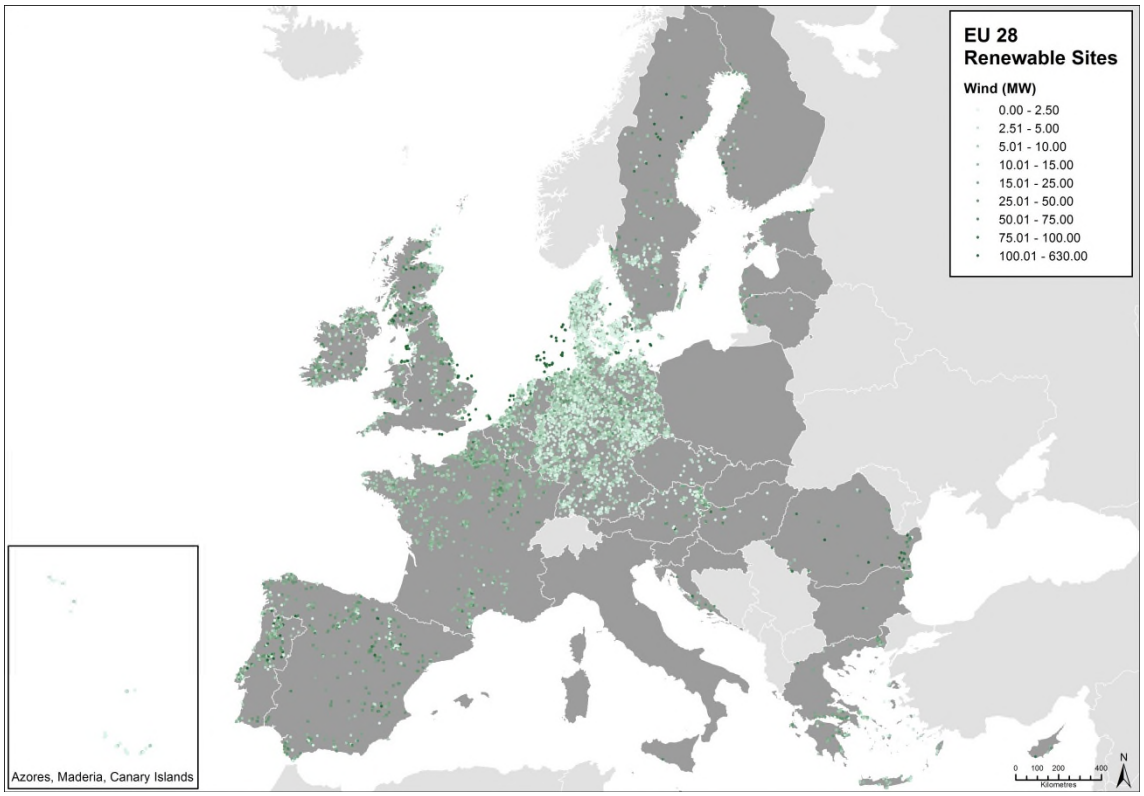

Figure 3- Wind installations in Europe 28

The Table below gives a summary of the PV and wind penetration in the EU-28 area. More precisely, the Table is divided into three columns, representing:

- The ***PV and wind share in the electricity mix***, as a proxy of countries where the introduction of cryogenic storage to balance the transmission grid could be more promising, given the high penetration of PV and wind. A more in-depth analysis of this topic is part of Work Package 3- Current and future benefits of CryoHub
- ***Wind and PV share in the renewable electricity mix***, respectively in columns 2 and 3, to give an order of magnitude of the importance of wind and PV, respectively, in the electricity mix, as a proxy to check the completeness of the available data on installations.

Country	PV and wind share in the electricity mix	Wind share in the renewable electricity mix	PV share in the renewable electricity mix
Austria	4.68%	6%	1%
Belgium	6.89%	34%	22%
Bulgaria	7.18%	18%	20%
Croatia	2.71%	7%	-
Cyprus	5.48%	66%	17%
Czech Republic	3.58%	5%	23%
Denmark	31.03%	69%	3%
Estonia	5.98%	46%	-
Finland	0.622%	2%	-
France	3.72%	17%	5%
Germany	14.34%	35%	21%
Greece	10.81%	32%	29%
Hungary	10.06%	25%	1%
Ireland	16.51%	79%	-
Italy	10.96%	14%	21%
Latvia	1.46%	3%	-
Lithuania	5.90%	43%	2%
Luxembourg	2.33%	23%	21%
Malta	1.34%	-	84%
The Netherlands	4.98%	45%	4.3%
Poland	3.85%	36%	-
Portugal	22.14%	43%	2%
Romania	8.63%	21%	2%
Slovakia	2.08%	-	10%
Slovenia	1.31%	-	4%
Spain	21.84%	52%	8%
Sweden	6.18%	10%	-
United Kingdom	7.65%	51%	4%

Table 1- Summary table on PV and wind penetration in the electricity mix in EU-28 (Eurostat, 2015)

4.2. Country groups[6]

In order to proceed to better visualise the location of major solar (red circles) and wind installations (blue circles), some countries' groups have been identified, and classified according to their geographical location, and climate similarities:

- *Benelux*
- *Central and Eastern Europe*
- *Germany and Austria*
- *Mediterranean countries*
- *Nordic and Baltic countries*)
- *United Kingdom and Ireland*

4.2.1. Benelux

- ***Belgium*** has a relatively low share of electricity produced by renewable energies, amounting to 12.3%. However, the combined share of PV and wind in electricity generation amounts to 6.89%, with wind representing 34% of all renewable electricity generation, and PV counting for 22%. The share of biomass and biogas amounts to 41%, while large and small hydro accounts for 3% of renewable electricity production. The majority of PV installations are located in the region of Flanders, while the majority of wind installations are located in Wallonia.
- ***The Netherlands*** has a renewable electricity share amounting to 10.1%, with a combined share of PV and wind in electricity generation of 4.98%. Wind generation represents 45% of all renewable generation, and PV represents 4.3%. Biomass and biogas cover 50% of renewable electricity generation, and the remaining 0.7% is produced by large hydro. Wind installations are mainly located in the Western region, while PV installations are located both in the Western and Eastern regions.

Given the limited availability of installations > 0,5 MW of data for Luxembourg, this country has not been included in our analysis.

[6] The data (reference year 2015) quoted in this chapter are based on the following documents:

- EU energy in figures- statistical pocketbook 2015: https://ec.europa.eu/energy/sites/ener/files/documents/PocketBook_ENERGY_2015%20PDF%20final.pdf
- http://www.keepontrack.eu/contents/publicationsscenarioreport/kot--2020-res-scenarios-for-europe-tu-wien-june-2015-final.pdf

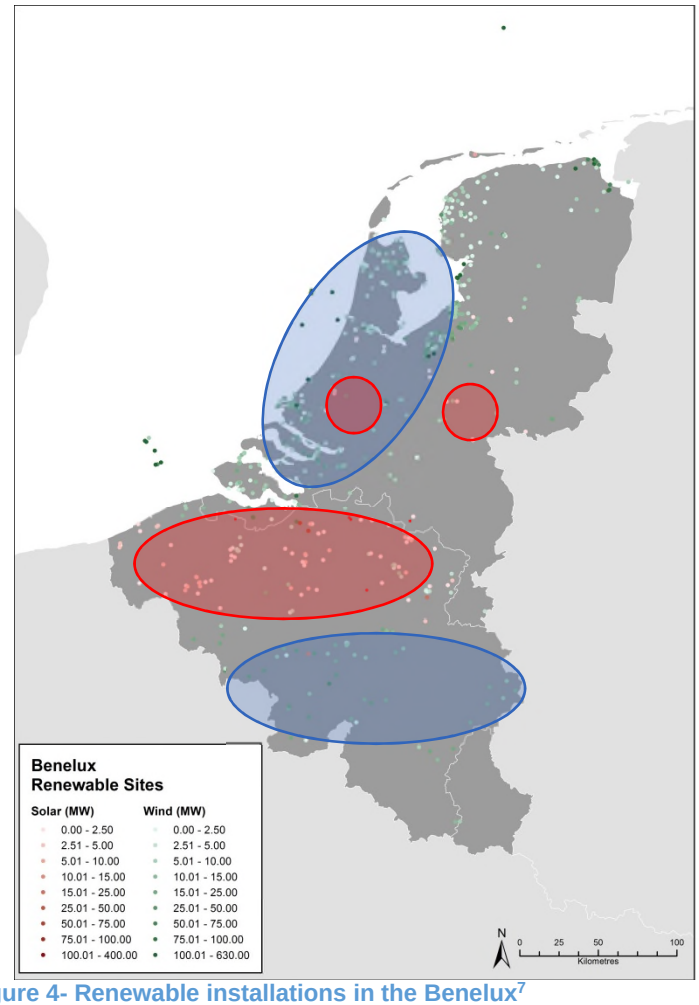

Figure 4- Renewable installations in the Benelux[7]

For the purpose of our analysis, Belgium has been chosen as a focus country, since the selected demo-site is located there.

4.2.2. Central and Eastern Europe

- The share of electricity produced by renewable energy in ***Bulgaria*** amounts to 18.9%. The combined share of PV and wind in the electricity mix amounts to 7.18%, with onshore wind representing 18%, and PV 20% of all renewable energy generation. Large and small hydro contributes to 61%, and biomass to 1%. PV installations are evenly located in Bulgaria, while wind installations are concentrated in the North-Western region.
- ***Croatia*** presents a share of electricity generated by renewables amounting to 38.7%, with the combined share of PV and wind amounting to 2.71% of the electricity mix. Wind generation represents a small share of 7%, while the majority of renewable electricity is produced by large and small hydro (91%). Wind installations are located in the Adriatic area.

[7] Blue ovals highlight those areas where there is a high wind capacity. Red ovals highlight areas with high concentration of PV installations.

- The share of electricity produced by renewable energy in Czech Republic amounts to 12,8%. ***Czech Republic*** has a combined share of PV and wind amounting to 3.58%, with wind representing 5% and PV 23% of renewable electricity generation. Biomass and biogas have a combined share of 46%, and the remaining 26% is covered by large and small hydro. PV installations are generally evenly distributed in the country, while wind installations are concentrated in the North-West Region.
- The share of electricity generation from renewables in ***Hungary*** amounts to 6.6%. Wind generation represents 25%, and PV 1%. Small and large hydro cover 8%, while biomass and biogas covers 66% of electricity generation from renewables. The majority of wind installations are located in the Transdanubian region, while the PV installations are located in the Northern Great Plain.
- The share of renewable electricity generation in ***Poland*** amounts to 10.7%, with a joint share of PV and wind amounting to 3.85%. Onshore wind generation represents 36% of total renewable electricity generation. Large and small hydro cover 14%, and the remaining 50% is produced by biomass and biogas. Unfortunately, no data on wind installations are available. Therefore, there is no available information on where the majority of wind installations are located. The majority of PV sites are located in the eastern part of Poland, even if the larger PV site is located in the north-western region.
- ***Romania*** has a share of renewable electricity production amounting to 37,5%, with a joint share of PV and wind amounting to 8.63% of the total electricity mix. Onshore wind represents 21%, and PV representing 2%. 76% is produced by large and small hydro, and the remaining 1% is produced by biomass. The majority of PV installations are located in the central region, while wind installations are mainly located in the south-east region.
- ***Slovakia*** has a renewable electricity share amounting to 20.8%, with a combined share of wind and PV of 2,08%. PV represents 10% in the renewable electricity mix, while large and small hydro cover 74%, and the remaining 16% is produced by biomass and biogas. The few wind installations are mainly located in Western, and central Slovakia. No PV installations > 1 MW have been located.
- ***Slovenia*** has a renewable electricity share amounting to 3.,8%, with a small combined share of wind and PV amounting to 1.21%. PV represents 4% in the renewable electricity mix. Large and small hydro cover 90% of renewable electricity generation, and the remaining 6% is produced by biomass and biogas. PV installations are mainly located in Eastern Slovenia, with few wind installations mainly in the Western part.

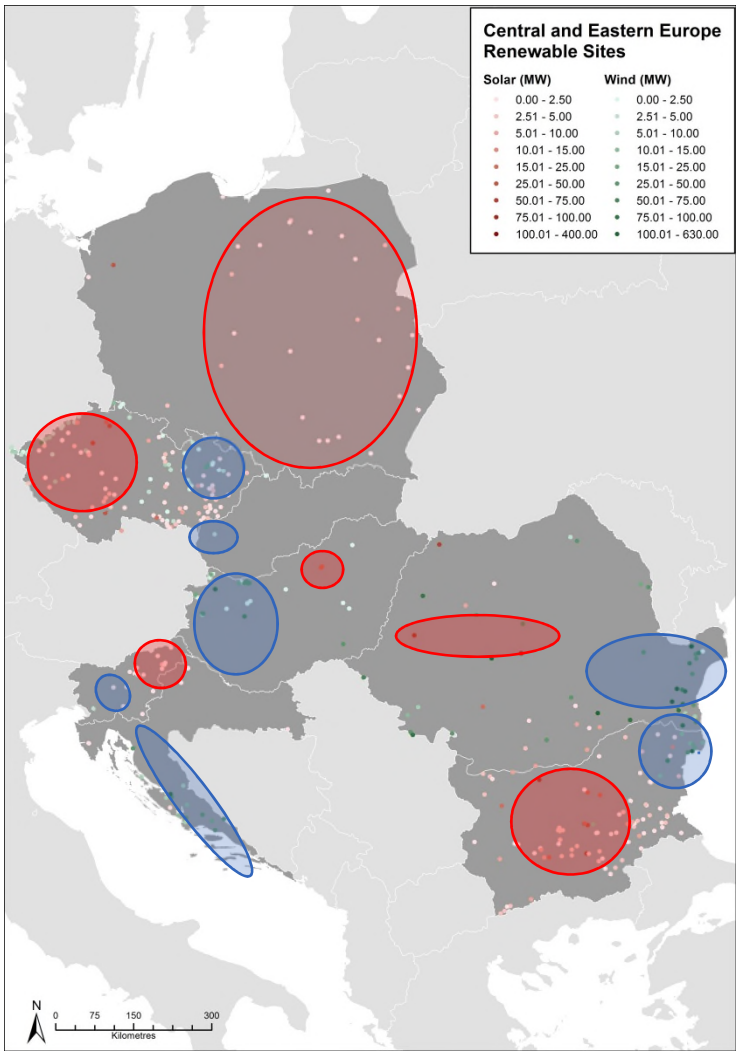

Figure 5- Renewable installations in the Central and Eastern Europe

4.2.3. Germany and Austria

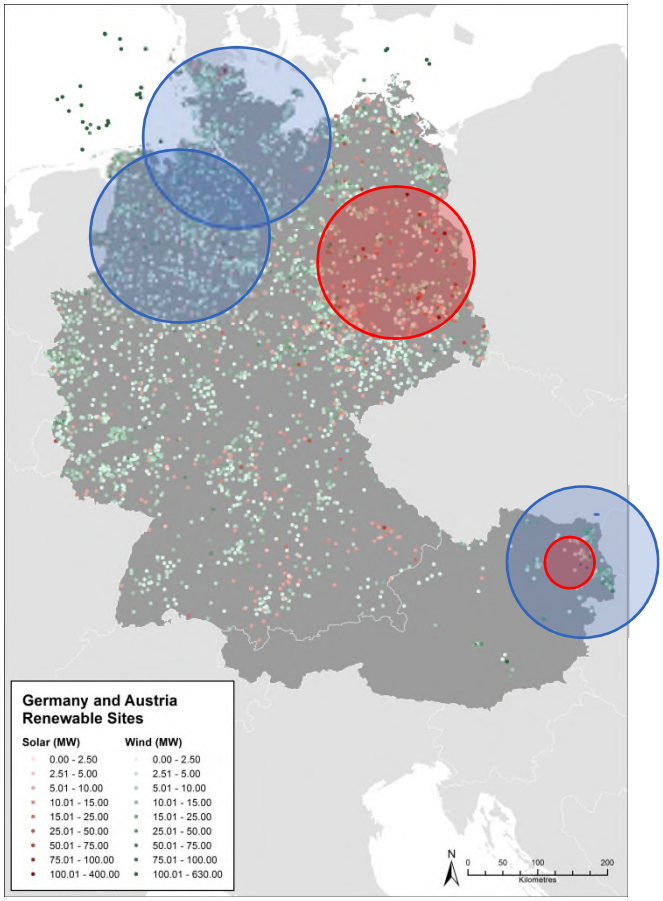

Figure 6- Renewable installations in Germany and Austria

- ***Austria*** has a high share of electricity (68.1%) produced by renewable energies. However, the combined share of PV and wind amounts to only 4.68% in the electricity mix, with wind representing 6% and PV 1% of all renewable electricity generation. Austria has an important share of renewable electricity (71%) produced by large hydro; small hydro accounts for 13% and biomass and biogas for 9%. East Austria is the region where the majority of PV and wind installations are located.
- The share of electricity production from renewable energies in ***Germany*** amounts to 25.6%, with a 14.34% share of PV and wind in electricity generation. Wind covers 35% of all renewable electricity generation, and PV 21%. Large and small hydro produce 14%, while biomass and biogas produce 30%. The regions with the majority of wind installations are Schleswig-Holstein, and Lower Saxony. The region with the majority of PV installations is Brandeburg.

4.2.4. Mediterranean countries

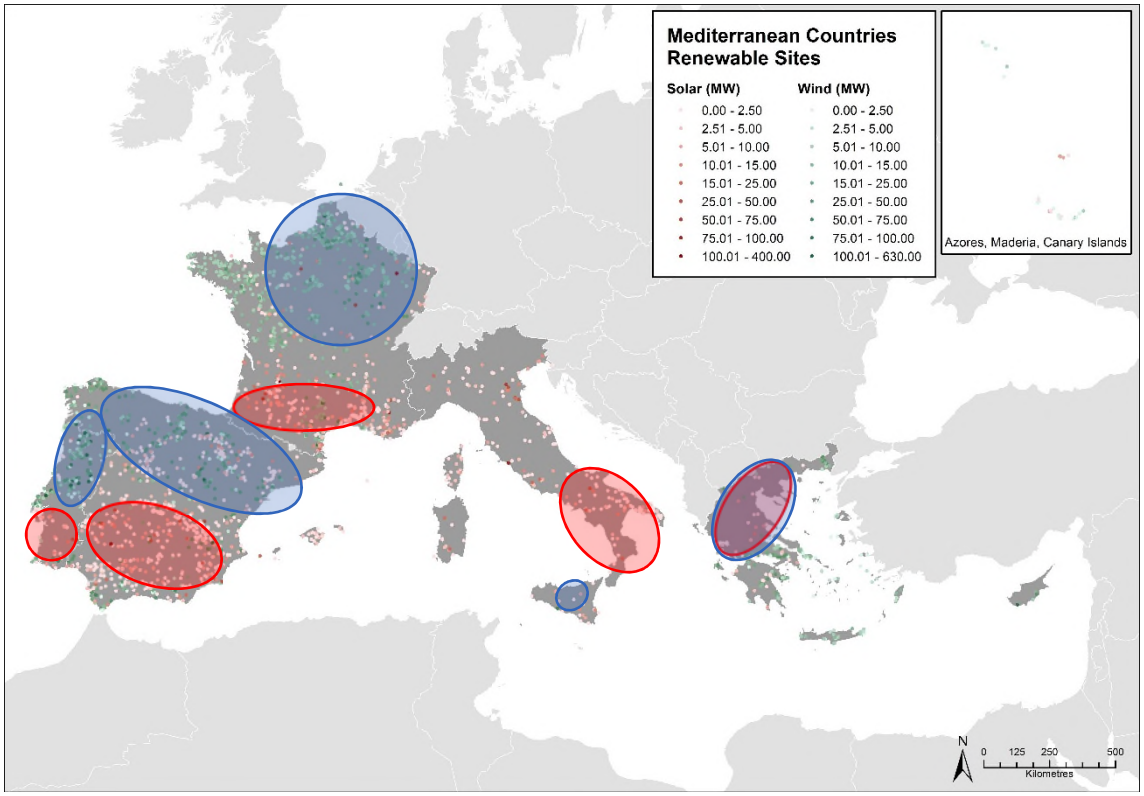

Figure 7- Renewable installations in the Mediterranean countries

- Only 6,6% of electricity is produced by renewable energies in ***Cyprus***. The combined share of PV and wind amounts to 5.48%, with wind generation representing 66%, and PV 17% (these are mainly small installations not included in our analysis). The remaining 17% is produced by biogas.
- In ***France***, the share of electricity production from renewable energies amounts to 16.9%, with a combined share of PV and wind amounting to 3.72%. Wind generation covers 17% and PV 5% in the renewable electricity mix. Generation from small and large hydro amounts to 72%, and the remaining 6% is produced by biomass and biogas. Wind installations are mainly located in the *Bassin Parisien*, which is the area covering the north-east and central eastern part of France. PV installations are mainly located in the South-West and Mediterranean region.
- ***Greece*** has a share of renewable electricity amounting to 21.2%, with a combined share of wind and PV of 10.81%. Wind generation amounting represents 32%, and PV 29% in the renewable electricity mix. Small and hydropower cover 37%, and biogas amounts to 2% of renewable electricity production. The majority of PV and wind installations are located in the central Greece,
- ***Italy*** has a share of electricity generation from renewables amounting to 31.3%, with a combined share of PV and wind generation of 10.96%. Wind generation has a share of 14%, and PV 21%. Large and small hydro amount to 44%,

biomass and biogas generation amount to 15%, and geothermal has a share of 5%. Wind generation is mainly located in Sicily, and PV installations are mainly located in the Southern region.

- ***Portugal*** has a renewable electricity share of 49.2%, with a high combined share of PV and wind amounting to 22.14%. Wind generation represents 43%, and PV 2%. Large and small hydropower cover 42%, and the remaining 12% is produced by biomass and biogas. The majority of wind installations is located in the north-central part. PV installations are mainly located in the southern part of Portugal (Alentejo).
- ***Spain*** has a renewable electricity share of 36.4%, with a high combined share of PV and wind generation amounting to 21.84%. Wind generation represents 52% of renewable electricity generation, and PV 8%. Solar thermal electricity covers 4%, large and small hydropower 32%, and the remaining 5% is produced by biomass and biogas. The majority of wind sites are located in the centre-north of Spain, while PV sites are rather located in the centre-south.

4.2.5. Nordic and Baltic countries

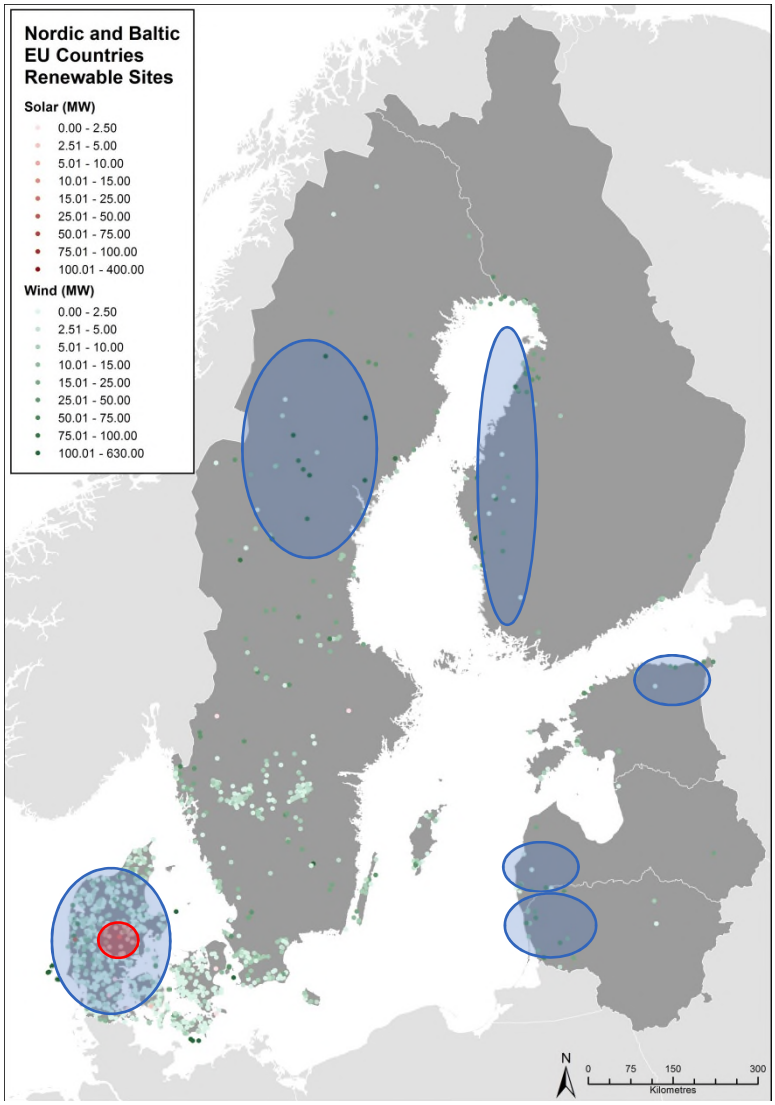

Figure 8- Renewable installations in the Nordic and Baltic countries

- The share of electricity production from renewable energies amounts to 43.1% in ***Denmark***, where the combined share of wind and PV generation in the electricity mix amounts to 31%. Wind production has share of 69%, and the PV share amounts to 3%. The remaining 28% is represented by production from biomass and biogas. In Denmark, the bulk of electricity production from onshore wind and PV is located in the Central region of Denmark.
- In ***Estonia,*** electricity generation from renewables amounts to 13%, with an accumulated wind and PV share of 5.98%. Wind represents 46% of renewable electricity generation, with the remaining 54% produced by biomass and biogas. The majority of wind installations is located in the north-eastern part of Estonia.
- In ***Finland***, the share of electricity produced by renewable energy amounts to 31.1%, with a very small combined share of wind and PV generation amounting to 0.62%. The wind generation has a share of 2% in the renewable electricity mix, and no PV generation. Large and small hydro cover 53%, and the remaining 45%

is generated by biomass. The majority of wind installations are located in the western part of Finland.

- ***Latvia*** has a share of renewable electricity production amounting to 48.8%, with a joint share between PV and wind for electricity production amounting to 1.46%. Wind generation represents 3% in the total renewable electricity generation, where the share of large and small hydro is 83%, and biomass and biogas represent 14%. Wind installations are mainly located in the Western region of Kurzeme.
- ***Lithuania*** has a renewable electricity share amounting to 13.1%, with a joint share between PV and wind generation of 5.90%. Wind generation represents 43%, and the share of PV is 3%. Large and small hydro cover 30%, while biomass and biogas production cover 24%. Wind installations are mainly located in the Western region of Klaipeda.
- ***Sweden*** has a share of renewable electricity amounting to 61.8%, with a combined share of wind and PV generation amounting to 6.18%. The share of wind generation amounts to 10%, while large and small hydropower cover 77%, and the remaining 13% is produced by biomass and biogas. The bulk of wind production is generated in the North part of Sweden.

4.2.6. United Kingdom and Ireland

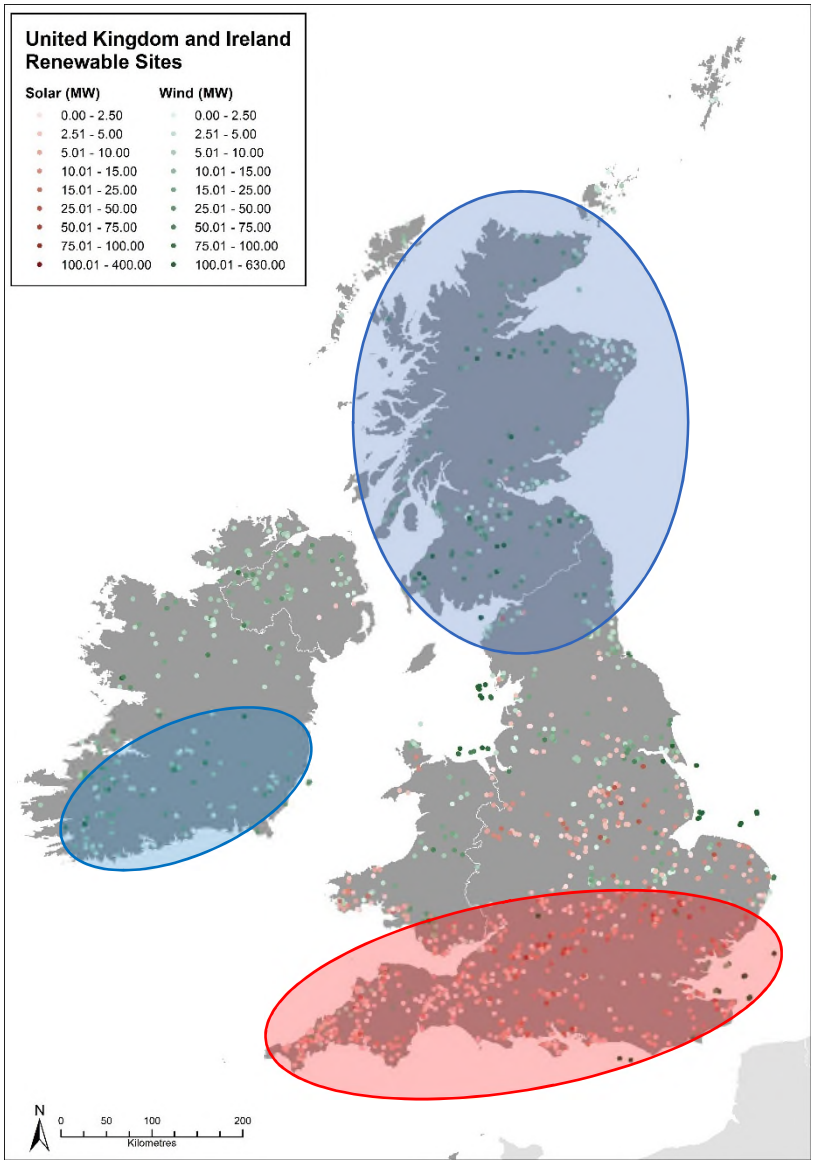

Figure 9- Renewable installations in the Northern bloc

- The share of electricity production by renewables in ***Ireland*** amounts to 20,9%, with a combined share of wind and PV generation of 16,51%. The wind share in the renewable electricity mix amounts to 79%, while small and large hydro cover 13%, and biomass and biogas represent 8% of renewable electricity generation. The majority of wind installations are located in Southern and Eastern Ireland.
- ***UK*** has a renewable electricity share amounting to 13,9%, with a combined share of wind and PV of 7,65%. Wind generation covers 51% of renewable electricity production, and the PV share amounts to 4%. 35% of renewable electricity is produced by biomass and biogas, while the remaining 10% is generated by large and small hydropower. PV installations are mainly located in the Eastern and Southern regions of the UK, while the majority of wind generation is produced in Scotland.

4.3. Renewable energy installations close to food refrigeration facilities

This chapter briefly presents the renewable energy installations which have been located close to (< 1 km) the refrigeration facilities, as listed in Deliverable 2.1.
A more in-depth analysis of this chapter will be presented in Deliverable 2.3.

4.3.1. Wind energy

The map below shows where food refrigeration facilities are located near (< 1 km) wind energy farms.

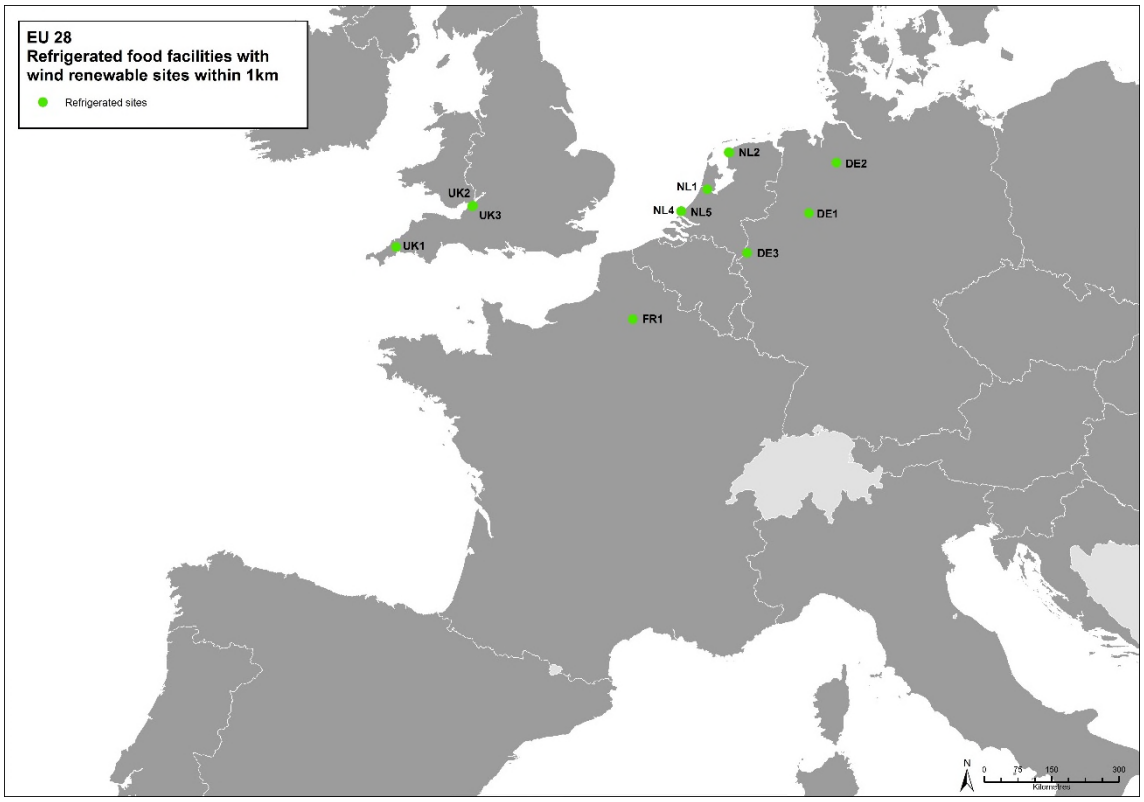

Figure 10- Refrigerated sites close to wind energy farms

Twelve refrigerated facilities have been found in proximity of wind installations:

- Three sites in Germany
  - *DE1* in Germany, close to the Versmold wind farm
  - *DE2* in Germany, close to the Oyten wind farm
  - *DE3* in Germany, close to the Niederkrachten wind farm
- Five sites in the Netherlands:
  - *NL1*, close to the Amsterdam I-VIII wind farm, and the Amsterdam-Westpoort wind farm
  - *NL2,* close to the Frysln/Midlum wind farm, and the Harlingen wind farm
  - *Nl3.*, close to the Harlingen Haven wind farm
  - *NL4.*, close to the following wind farms: Maasvlakte-Rotterdam, R'dam-distridam, R'dam-Slufter-N, Slufterdijk Noord

  - *NL5* close to Maasvlakte-Rotterdam, and R'dam-distridam
- Three sites in the UK:
  - *UK1*, close to Woodlands Barton
  - *UK2*, close to Bristol Port Wind Park Ltd Extension
  - *UK3,* close to the wind farm Bristol Sewage Treatment Works
- One site in France:
  - FR1, close to the Bois-Guillaume wind farm, and the du Chemin Blanc wind farm for a total output capacity of 22 MW

4.3.2. PV installations

Figure 11- Refrigerated sites close to PV installations

Eight refrigerated facilities have been identified close to relevant PV installations.

- One in Denmark:
  - *DK1*, close to the 244 TRE-FOR El-net A/S installation
- Four sites in UK:
  - *UK1*, close to the Victoria installation
  - *UK3*, close to the Moorhouse Lane installation
  - *UK4*, close to the MMD Shipping Services installation
  - *UK5*, close to the Marston Solar Farm

  An additional site UK6 has been found in the UK, close to the Yearsley PV Installation. However, it has a power capacity, which is slightly lower than the scope of our analysis (0.5 MW). It has been included in the Map above for information.
- Two refrigerated sites in Spain:
  - *ES1.,* close to the Alfaro PV installation, and the Cascaras de Cofin PV installation
  - *ES2.*, close to the Lingegas PV installation
- One refrigerated site in France:
  - *FR2,* close to the Beaucaire PV installation

4.3.3. Other refrigerated sites

The following renewable energy installations have also been identified as being installed on food refrigerated warehouses:

- A Delhaize (supermarket) distribution center has installed a 3 MW rooftop Solyndra solar system.
- Heineken Brewery installed solar panels with a capacity of 1.46 MW. Installed in 2011, it currently covers 25% of the company's energy needs.
- NPG International Warehousing installed solar panels with a capacity of 1.04 MW in 2011.
- Frigologix storage facility in Belgium has solar panels installed on the roof.
- Carrefour FM Logistic, since 2013, has a solar roof with an installed capacity of 1.4 MW.
- Aldi Distribution Centre has a roof mounted solar with a power capacity of 1.2 MW
- Aldi Stores has a roof mounted solar with a power capacity of 1.2 MW

5. Trends

To be able to better evaluate the potential evolution in the use of cryogenic storage as an effective technology to allow for a better, and more continuous use of renewable energies (especially PV and wind), this session briefly details the trends, and scenarios related to the evolution of renewable energies up to 2020, 2030, and 2050.

The overall share of renewable energies in the energy mix amounted to 15% in 2013 (and 16% in 2014), with the share of electricity generation from renewable energies amounting to 25.4% in 2013 (27.5% in 2014).

Since there is a target of 20% of renewable energies in the mix to be reached by 2020[8] (and 27% in 2030[9]), the share of renewable energy generation is bound to increase over time, in order to reach these objectives. This represents a potential opportunity for the increased use of cryogenic storage as a mean of storing renewable energies on-site.
The Table below summarises the shares of PV and wind generation per country in 2013 and in 2020 (in a case of a business-as-usual scenario)[10].

Country	**2013**		**2020 (BAU)**	
	Wind	*PV*	*Wind*	*PV*
Austria	6%	1%	9%	4%

[8]DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32009L0028&from=EN

[9] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the promotion of the use of energy from renewable sources (recast), published on 30th November 2016

[10] Since we are here considering the Business-as-usual scenario, the slight decrease foreseen is some countries is due to the change in support policies to renewable energies

Belgium	34%	22%	49%	18%
Bulgaria	18%	20%	18%	19%
Croatia	7%	-	11%	4%
Cyprus	66%	17%	91%	4%
Czech Republic	5%	23%	7%	23%
Denmark	69%	3%	69%	4%
Estonia	46%	-	60%	-
Finland	2%	-	2%	-
France	17%	5%	29%	9%
Germany	35%	21%	40%	22%
Greece	32%	29%	34%	24%
Hungary	25%	1%	22%	1%
Ireland	79%		87%	-
Italy	14%	21%	19%	24%
Latvia	3%	-	5%	-
Lithuania	43%	2%	54%	5%
Luxembourg	23%	21%	22%	20%
Malta	-	84%	38%	54%
The Netherlands	45%	4,3%	56%	3%
Poland	36%	-	47%	-
Portugal	43%	2%	43%	2%
Romania	21%	2%	25%	2%
Slovakia	-	10%	-	9%
Slovenia	-	4%	2%	3%
Spain	51%	8%	50%	7%
Sweden	9%	-	16%	-
UK	51%	4%	58%	3%

Table 2- Wind and PV generation per country in 2013 and 2020 (BAU scenario)

The European Commission has recently published its EU reference scenario 2016[11]- Energy, transport and GHG emissions- Trends to 2050, which presents some figures for renewable energy generation up to 2050, with an analysis of the main factors and policies, which can influence the different shares of renewable energies.

A more detailed analysis addressing the countries' energy profiles will be part of Deliverable **8.2- Energy profile report per EU Member States**, which will also include an analysis of existing policies.

The share of wind and solar in the electricity generation is projected to grow from 6% in 2010 to 36% in 2050.

[11] https://ec.europa.eu/energy/sites/ener/files/documents/ref2016_report_final-web.pdf

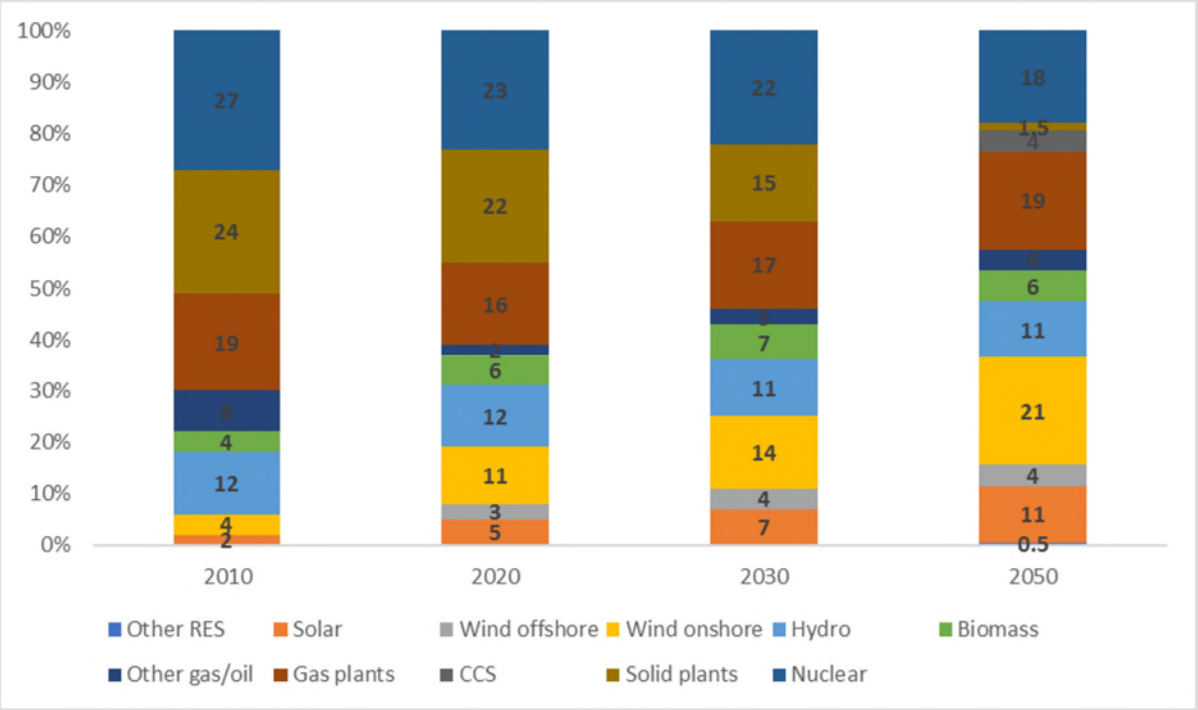

Figure 12- Evolution of shares of electricity generation per type of plant

6. Conclusions

The objective of this report is to map locations and power output of renewable energy installations in EU-28, focusing on wind and PV installations.

Several maps are presented to visualise the areas where the majority of installations is located.

Renewable energy installations are widely spread in the EU-28. Solar PV installations are spread all over Europe, but with an important presence in Spain, Germany, South of France, Italy, Bulgaria, Greece, and the UK. Wind installations are more geographically concentrated in Germany, Benelux, Spain, Portugal, UK, Ireland, France, and Sweden.

Countries with an important share (> 50%) of variable renewable energies, where an analysis for the potential introduction of the CryoHub technology could be focused, are: Belgium, Denmark, Germany, Greece, Ireland, Spain and the UK. Small countries, such as Malta and Cyprus, even if they have a large share of variable renewable energy, their installations are not big enough, in terms of generation capacity, to be included in our analysis > 0.5 MW average power input). However, given the results, the consortium should discuss internally whether this limit should be lowered in order to include additional renewable energy installations.

The share of wind and solar in the electricity generation is projected to grow from 6% in 2010 to 36% in 2050. This opens up interesting opportunities for the introduction of

storage technologies to ensure that variable renewable energies can be used at any time. Other countries will, then, become interesting to be analysed, given their high share of variable renewable energy: Estonia, Lithuania, The Netherlands.