CLIM4ENERGY – Technical Solution

Background

The CLIM4ENERGY project in the context of Copernicus Services

The new Copernicus Climate Change Service (C3S), operated by ECMWF, is a public European service to inform the development of solutions for society facing climate change mitigation and adaptation challenges. It is intended to deliver a number of climate datasets of essential climate variables (ECVs) and indicators derived from these data blended with sector-specific information (relevant thresholds, socio-economic datasets), demonstration of use and guidance. These indicators, developed in the Sectoral Information System (SIS) should provide information for EU industry and policy development.

CLIM4ENERGY will bring together the complementary expertise of 7 climate research and service centers and 10 energy practitioners to demonstrate, from case studies, the value chain from ECVs to actionable information in the energy sector. It will deliver 9 energy-relevant pan-European indicators of climate trends and variability with a cross-sectoral consistency, appropriate documentation and guidance, estimation of uncertainties, and a demonstration of use. It will contribute to other Copernicus services by sharing experience and tools on quality control, data access with distributed systems, visualization of complex multi-dimensional data and their uncertainties.

A rapidly evolving energy mix and ongoing impacts of climate change increases the vulnerability of the European energy system

Climate-related challenges constrain a rapidly evolving energy sector. Currently energy is the largest greenhouse gases emitting sector (35% of total emissions worldwide). Ambitious climate change mitigation requires that low-carbon energies grow very fast in the coming decades, exceeding a 50% share by 2050 for total energy supply and 80% for electricity supply[1]. EU has developed a climate-energy package with low-carbon targets for 2020 and 2030 for which renewable energies share (wind, solar, hydropower and bio energy) increases to 20% in 2020 [ref. 2], and 27% in 2030 [ref. 3]. This rapid transition towards renewables makes the energy production, transmission and distribution increasingly sensitive to weather and climate variability. Energy producers need to anticipate resources, their variability at seasonal time scales and their trends over decades. Grid operators need to identify black-out risks. Electricity traders need to anticipate energy prices depending on the availability of combined resources in all European areas. Climate change also modulates the weather impact to energy systems. Changing precipitation patterns may affect the management of hydropower resource. Changes in winds, temperature and radiation may affect the variable renewable resources. Investments for infrastructures and networks, refining and distribution must account for unavoidable climate change effects such as future sea level rise.

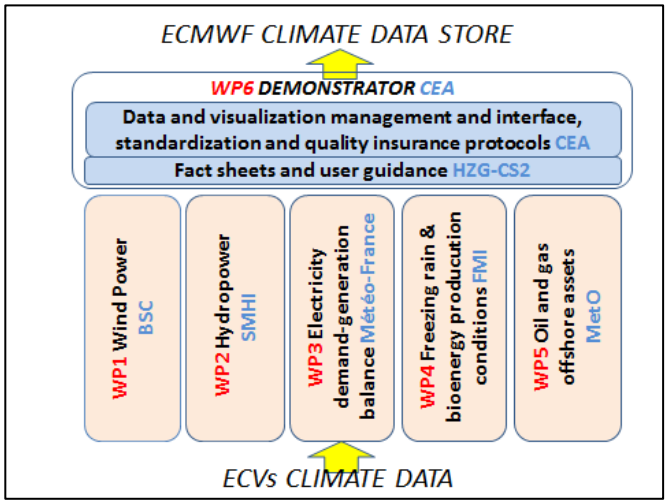
A service providing climate change indicators tailored for the European energy sector, with full consistency across climate information sources, uncertainty analysis, guidance and demonstration, would foster solutions to these challenges, but does not currently exist.

The energy industry has long developed awareness of weather and climate risks and their changes, and benefits from collaborations with individual research institutes and weather services for climate information provision. However climate information bears unavoidable uncertainties and a collective assessment of climate data and dedicated indicators will strengthen this experience, using the best observations and ensembles of climate simulations with different models from a community of experts. With this aim, a few climate service

research initiatives have already taken place and developed indicators at national and international level in EU research projects such as CLIMRUN[4], ECLISE[5], EUPORIAS[6], SPECS[7], IMPACT2C[8], IS-ENES[9], CLIP-C[10], projects from the Climate KiC (eg the E3P[11] project). The integration of these research results, providing co-designed energy indicators, in a fully operational service for Europe dedicated to energy remains to be done. The challenge for the Copernicus Climate Change Service for the energy sector is therefore threefold:

- **Addressing both mitigation and adaptation**: it must provide information for mitigation and adaptation together because energy stakeholders are facing both;
- **Providing consistency**: it must provide information on which trust can be built. This requires a high degree of coherence across products, underlying data sets, processing methods, uncertainty assessments, time scales;
- **Providing innovation**: it should make operational recent developments from research, with innovative knowledge, methods and technologies to answer real-world issues, requiring stringent requirements definition, verification and quality control.

CLIM4ENERGY will demonstrate the possibility to achieve these challenges. **CEA**[12], working with **CNRS**[13] through two joint research units (see implementation plan), will contract with 6 climate/weather services having complementary experience on the use of climate information in the energy sector from previous projects and collaborations. **BSC**[14], **FMI**[15], **Météo-France**[16], **MetO**[17], **SMHI**[18] will each lead a Work Package (WP) aiming at designing, producing, evaluating and demonstrating one or two indicators for different types of use (see attached figure). **HZG-CS2**[19] will provide fact-sheets and user guidance. Each contractor will work with one or several industry co-designers for the development of the indicators, and results will be provided to **CEA** to be integrated in a demonstrator. The work packages and data flow across them is described in the attached figure.



Contractors will access themselves existing ECVs for observations, re-analyses and seasonal forecasts, for the development of indicators. **CEA**, through its participation to the **IPSL ESGF node**[20], will provide to contractors climate projections data (EUROCORDEX and CMIP5) from 5 models under two scenarios (RCP4.5 and RCP8.5), using methods developed in CLIP-C and IMPACT2C EU projects. The selection will be co-designed with **EDF**[21] and relies on metrics relevant for the energy sector and a sufficient representativeness of uncertainty.

Each indicator will be co-designed by a strong partnership between a contractor and one or two "co-designers" from the energy sector. Co-designers will (i) help define user requirements and useful visualizations, (ii) evaluate the indicator on a case study and (iii) provide necessary ancillary data for the demonstration. They will be part of a larger expert advisory panel. The co-designers of CLIM4ENERGY are **BG Group**[22], **EDF**[19], **EDPR**[23], **FINGRID Oyj**[24], **METSÄTEHO OY**[25], **NENA AS**[26], **RTE**[27], **SHELL**[28], **STATKRAFT**[29], **VATTENFALL**[30]. A few other experts and a representative of the EEA will also be invited to help co-designing the products and be part of the expert advisory panel.

Indicators

CLIM4ENERGY will provide 9 co-designed indicators responding to mitigation and adaptation issues. Indicators will cover a variety of topics encountered in different European regions. The indicators will be calculated, in most cases, for re-analyses (ERA-Interim), seasonal forecasts (ECMWF ensemble covering 35 years), and the 5-member ensemble of EUROCORDEX/CMIP5 climate projections. For a few indicators (I1, I3.1, I3.2, I5), near-real time experimental seasonal forecasts will be produced by contractors. Indicators were selected on the basis of issues raised by practitioners of different branches of the energy sector:

I1: Wind power generation: Improved forecasting beyond the first two weeks of renewable power generation can improve the strategic and operational management of wind power during the pre- and post-construction phases. Seasonal forecasts are thus useful for (i) determining optimal periods for the maintenance and project development scheduling, (ii) trading (evaluation of price volatility in regional markets), (iii) evaluating cash flow needed to pay back project loans and (iv) evaluating risk of congestion in grid management. Over longer time scales to the middle of the century, documentation of load factors can support EU or national mitigation policies[2], as well as project planning to facilitate better loans and site selections. CLIM-RUN, EUPORIAS and SPECS have started to demonstrate the state-of-the art in seasonal predictions and their tailoring to end users in the energy sector. Projected wind resource changes have been investigated in research projects like IMPACT2C[31]. However for practical use, there is a need to further tailor, validate, harmonise and improve the presentation and communication of climate information, which will be achieved here.

I2: Hydropower: Hydropower becomes an all more important component of the energy mix acting as a battery, due to the increasing trend in other renewable weather dependent power sources. Most hydropower producers know their own power plants and reservoirs, but there is still a lack of knowledge about future impacts of climate variability changes on hydropower across Europe at seasonal to multi-decadal time scale. Climate information will allow companies to gain an overview of hydro power potential for the European energy market. The project will provide demonstration of the practical use of seasonal forecasts and future projections of anomalies with respect to historical conditions. Previous projects have developed the basic data and tools[32,33], but fully operational pan-European products, with consistency of information and data with other branches of the energy sector do not exist.

I3.1 and I3.2: Electricity demand-generation balance: The electricity generation demand balance is an everyday challenge for transmission system operators especially during winter time under severe weather conditions. With the increase of intermittent renewable energies and the European goal to extend these renewable energies in the energy mix, it is important to help anticipate the temporary risk of imbalance between a strong demand and a poor renewable energy potential. Best potential energy mix using intermittent renewable energies across Europe has been investigated[34]. The evolution of wind potential in the future, according to climate projections, has also been investigated[35]. Wind atlas and solar atlas can be accessed easily[36]. Yet, the current climate data portals do not display climate indicators tailored for transmission system operators. There are no on-line climate services available to help European countries and Electricity Transmission System Operators to assess the risk of imbalance on climate basis. Our goal is to produce two sectoral climate impact indicators dedicated to most problematic winter weather conditions.

I4: Freezing rain: Extreme winter events, such as storms and freezing rain belong to costliest impact phenomena as much for the energy sector as for forestry causing significant damage to power distribution infrastructure, roads and forest yield (leading to timber losses for bioenergy). An assessment of probability of such events on European scale in the present and

projected climate for the energy infrastructures has not been provided so far. A freezing rain indicator will be evaluated and demonstrated here.

I5: Bioenergy production conditions: Bioenergy in a sustainable future will play a bigger role in energy production. Its share in energy economy is growing in value. For example pulp production has already now at least 50% of its output as energy or bio fuels. The Finnish forest industry estimates annual efficiency gains to be 100 m€ in handling the seasonal variation of wood supply operations. Terrain and forest road trafficability issues are causing significant production shortfalls and pose a risk in a future with shorter frost periods. Also in warm situations soil moisture hinders wood production operations. Production risk indicators, which indicate harvesting conditions from these combined factors in the past and projected future climate are missing, but have great potential value that will be demonstrated here.

I6.1 and I6.2: Oil and gas offshore assets: The complex and interconnected nature of the oil and gas sector across extraction, transportation, processing and delivery will create significant challenges to how the sector will respond and mitigate against risks posed by changing hazards. Any disruption in this interconnected system will have wide reaching consequences. For example, in the summer of 2005 Hurricane Katrina and a month later Hurricane Rita had wide reaching impacts on the US offshore Oil and Gas industry which resulted in an increase in global oil prices due to loss of production and refinery shutdowns in the Gulf of Mexico. Preparation for, and taking mitigating actions against, these changes in hazards is dependent upon identifying appropriate climate indicators and the associated critical operational thresholds of oil and gas assets across the whole system. An understanding of the likely changes in these indicators will form the basis for adaptation plans and mitigation actions. Two sector-relevant indicators will be designed and demonstrated here.

The table below describes the ECVs required for constructing the indicators. The total volume of data (climate, indicators, sub-indicators) that will be produced is estimated to **20 Tb**.

Indicator Title	**ECVs**	**Ancillary data**	**Time scale**	**Time resol.**
Wind Power Generation I1	sfcWind, tas,	Wind farm data from co-designer (under NDA)	RE SF CP	6-hr
Hydropower **I2.1**: Inflow anomalies **I2.2**: Yearly max. snow depth anomaly	pr, tas, Satellite snow cover	Water divides, land use data, discharge observations	RE SF CP	Daily
Electricity generation-demand balance **I3.1**: Climate references **I3.2** Weather regimes impacts	Tas sfcWind rsds, z500/psl	population data over Europe EUROSTAT	RE SF CP	Daily
Freezing rain I4	pr, tas, t850	Damage data (transmission syst.)	synop RE SF CP	6-hr
Bioenergy production conditions I5	tas, soil T, snow	Forest production data	RE SF CP	Daily
Oil and gas offshore assets I6.1 & I6.2	sfcWind, uas, vas		RE CP	Daily

Table 1: summary of indicator technical input data; sfcWind=10m wind speed; tas= 2m temperature; pr=precipitation; rsds= surface downwelling radiation; uas= 10m zonal wind; vas=10m meridional wind; psl=sea level pressure; t850=850 hPa temperature; z500=500 hPa geopotential; RE=re-analyses, resol=70-100km, SF=Seasonal forecasts, resol=70-100km CP=Climate Projections, resolution=12 km.

Work Packages Description

Work-package #	0	Start/End date	M1/M27
Work-package title	Management and communication (Lead: R. Vautard, CNRS)		
Participants (person months)	**CEA 12 ; CNRS 2.25 ; in-kind contribution: CEA 3; CNRS 12**		

Main objectives: (i) Management of the project, including reporting to ECMWF, link with ECMWF, with EEA, with partners, and (ii) dissemination (web site, conferences)

Description of activities

Task 0.1: Project meetings: Three main meetings will be organized: a kick-off meeting (M2), a mid-term meeting (M12) and a final meeting (M27), monthly progress teleconferences, send 3-month short progress reports to the expert advisory committee.
Task 0.2: Periodic (quarterly and annual) and final reports; provide each year an updated detailed plan of proposed activities including Deliverables and Milestones.
Task 0.3: Link with ECMWF, coordination with other C3S activities, link with EEA
Task 0.4: Web site & dissemination: development of the service web site, inclusion of all functionalities (data access, visualization, fact sheets and documentation, reporting, news & events, communication).
Task 0.5: Description of operational service, including data management plan, user support strategy, risk registry

Deliverables

#	*Responsible*	*Nature*	*Title*	*Due*
D0.1	CEA	Workshop	Project meetings (3)	M2; M12; M27
D0.2	CEA	Report	Periodic and final reports	Quarterly, annual, final
D0.3	CEA	Other	Prototype web site	M18
D0.4	CEA	Other	Web site including all elements	M27
D0.5	CEA	Report	Operational service description	M27

Work-package #	1	Start/End date	M1/M27
Work-package title	Wind power generation (Lead A. Soret, BSC)		
Participants (person months)	**BSC** 44.4; **CNRS** 3.25 ; **HZG-CS2** 0.5; **EDPR** in-kind participation		

Main objectives This work package has the objective of co-designing, producing and demonstrating the use of a **wind power generation indicator (I1)**

Description of activities

Task 1.1 Lead BSC; Part. CNRS, EDPR, HZG-CS2: Co-design: BSC and CNRS will bring together and harmonize methods primarily developed in SPECS, EUPORIAS and IMPACT2C, and collaborate with the fourth largest global wind power company, EDPR, to design a demonstrative, quasi-operational indicator focusing on wind power generation and

explore how to translate this into the capacity factor of wind power. The indicator will describe pan-European 10-m wind speed and energy density estimates for re-analyses, past seasonal forecasts and climate projections. Specifications of input data, production chain and use case will be described.

Task 1.2 Lead BSC, part. CNRS: Production, evaluation and documentation: BSC will calculate the indicator from past ECMWF seasonal forecasts along with variability estimates known to affect wind power generation (extremes relevant for the industry such as percentiles 10, 90 and 95, stratification for a set of weather types, as calculated from WP3, and teleconnections like the NAO) and an assessment of the influence of climate change. The indicator will be evaluated against EDPR wind observations and generation data wherever available. Uncertainty estimates and reliability will be estimated using ensemble prediction standard methodologies. CNRS will use the mandatory climate projections ensemble from EUROCORDEX and CMIP5 designed in WP6 (Task 6.1) and calculate the indicator from 1971 to 2100. Documentation on indicator calculation will be provided.

Task 1.3 Lead BSC, part. CNRS, EDPR: Demonstration of use: BSC, CNRS and EDPR will blend the indicator with local observations at relevant sites and technical wind farm data to estimate wind power generation. Both the pan-European indicator and the local demonstration will be applied to specific case studies identified in collaboration with the co-designer that for the first time will illustrate how the indicator can strengthen decision-making in an operational context for the applications stated above, with a wider aim to facilitate the synthesis of climate information for the wind energy sector as a whole. An economic analysis will be conducted on the use of the indicator as part of EDPR evaluation. BSC will provide a few near-real time experimental forecasts at project end. Preliminary visualizations will be proposed by BSC at Month 18 for the prototype. Reliability, which is arguably the aspect of the climate information to which users are most sensitive, will be estimated using standard methodologies[37] and provided along with the indicator.

Deliverables

#	*Responsible*	*Nature*	*Title*	*Due*
D1.1	CEA	Report	Report on specifications	M9
D1.2	CEA	Data	Indicator data for all time scales	M24
D1.3	CEA	Report	Indicator demonstration of use	M27

Milestones

#	*Responsible*	*Title*	*Means of verification*	*Due*
M1.1	CEA	Data & documentation provision by BSC and CNRS	Through web site	M21
M1.2	CEA	Demonstration provision by BSC	Preliminary report	M24

Work-package #	2	**Start/End date**	**M1/M27**
Work-package title	**Hydropower (Lead B. Johansson, SMHI)**		
Participants (person months)	**SMHI** 10.3 ; **CNRS** 0.25 ; **HZG-CS2** 0.5; in-kind: **STATKRAFT, VATTENFALL**; subcontracting of SMHI: **NENA AS**		
Main objectives This work package has the objective of co-designing, producing and demonstrating the use of **two hydropower indicators (I2.1 and I2.2)**			

Description of activities

Task 2.1 Lead SMHI, part: CNRS, NENA AS, VATTENFALL, STATKRAFT, HZG-CS2: Co-design of the indicator: SMHI and co-designer companies will build upon previous projects (GEOLAND2, ECLISE, IMPACT2C, ECOSUPPORT and SWITCHON) to co-design two indicators for hydropower that ensures comparability on the European scale. The proposed indicators are (I2.1) **Inflow anomalies** (**ΔQinf**) as a measure of the amount of water available for hydropower potential at a given point and Yearly annual maximum snow depth anomalies (I2.2) (**ΔSWE_{max}**) as a measure of the natural storage and the seasonal redistribution of precipitation/inflow.

Task 2.2 Lead SMHI: Production, evaluation and documentation of the indicators: To calculate indicators, the E-HYPE hydrological model requires daily precipitation and temperature for simulations and observed discharge, in-situ and satellite snow depth observations and in-situ, evapotranspiration from sentinel satellite for calibration and validation. ECVs are observations, re-analysis, seasonal hindcasts and climate projections (as provided by CEA in Deliverable 6.1). The model runs on a daily time resolution for time periods 1969 to 2100 and the spatial resolution median is 215 km^2 (irregular catchments). The present E-HYPE version 3.0 is validated against > 700 independent discharge stations. The chain of calculation will be documented.

Task 2.3 Lead SMHI, part. NENA AS, VATTENFALL, STATKRAFT: Demonstration of use of the indicator: For demonstration of use of these indicators, the potential energy (**TWh**), that relates the available inflow to existing infrastructure for hydropower production, will be calculated for a few catchments. The main area for the demonstration case is Norway and Sweden which have a major role in the European hydropower production. A pilot study will made for switzerland. For the hindcast demonstrations, the product will be evaluated against data on discharge and hydropower production. An economic analysis will be conducted on the use of the indicator as part of the evaluation for the demonstrated cases. Preliminary visualizations will be proposed by SMHI at Month 18 for the demonstrator prototype.

Deliverables

#	*Responsible*	*Nature*	*Title*	*Due*
D2.1	CEA	Report	Report on specifications	M9
D2.2	CEA	Data	Indicator production for all time scales	M24
D2.3	CEA	Report	Indicator demonstration of use	M27

Milestones

#	*Responsible*	*Title*	*Means of verification*	*Due*
M2.1	CEA	Data & documentation provision by SMHI	Through web site	M21
M2.2	CEA	Demonstration provision by SMHI	Preliminary report	M24

Work-package #	3	**Start/End date**	**M1/M27**
Work-package title	**Electricity demand-generation balance (Lead S. Martinoni-Lapierre, Météo-France)**		
Participants (person months)	**Météo-France** 24.05; **CEA** 0.5 ; **CNRS** 0.25 PM; **HZG-CS2** 0.5		
Main objectives This work package has the objective of co-designing, producing and			

demonstrating the use of **two electricity demand-generation indicators (I3.1 and I3.2)**

Description of activities

Task 3.1 Lead Météo-France, part: CNRS, RTE, HZG-CS2: Co-design of the indicator: Météo-France and RTE will co-design two sectoral climate impact indicators in order to assist decision makers with energy mix issues in winter weather conditions: (I3.1) **climate references** and (I3.2) **weather regimes impacts** indicators.

Task 3.2 Lead Météo-France, part. CEA, CNRS: Production, evaluation and documentation of the indicators: The first indicator (I3.1) uses ECVs (wind speed, radiation, temperature) from re-analyses (ERA-Interim), past seasonal forecasts and regional climate projections, and first calculates three sub-indicators: (i) normalized degree-days (weighted by the number of households from EUROSTAT data) , (ii) normalized wind power (strictly based on meteorological data), as calculated from WP1 (iii) normalized solar power (strictly based on meteorological data). Climatology statistics of these sub-indicators are then established and contingency tables per region of the frequency of low wind and low solar radiation in case of high demand. In addition, conditional climatology statistics of winds and radiation will be calculated from a more classical cold spell sub-indicator, derived from previous projects and provided by CEA (eg. ANR SECIF and Climate KiC E3P).

The second indicator (I3.2) will use the same ECVs, with in addition sea-level pressure or 500 hPa geopotential, sub-indicators at daily time scale. The most problematic situations will be analyzed in terms of weather regime occurrence (for instance four main flow weather regime classes, NAO-, NAO+, Blocking, Atlantic ridge[38]) found over Euro-Atlantic domain. The probability distribution of circulation regimes in the future (from EUROCORDEX) will be estimated. Both indicators will use an ancillary data set: the population data over Europe, number of persons per household, population projections (from EUROSTAT).

Task 3.3 Lead Météo-France, part. RTE: Demonstration of use of the indicator: The indicators will be tested over France and its neighboring countries on past winters with the help of RTE-France, the public transmission operator in France. RTE will contribute to design the final service and help the visualization of the climate sectoral indicator. An economic analysis will be conducted on the use of the indicator. Preliminary visualizations will be proposed by Météo-France at Month 18 for the demonstrator prototype.

Deliverables

#	*Responsible*	*Nature*	*Title*	*Due*
D3.1	CEA	Report	Report on specifications	M9
D3.2	CEA	Data	Indicators production for all time scales	M24
D3.3	CEA	Report	Indicators demonstration of use	M27

Milestones

#	*Responsible*	*Title*	*Means of verification*	*Due*
M3.1	CEA	Data & docum. provision by Météo-France	Through web site	M21
M3.2	CEA	Demonstration provision by Météo-France	Preliminary report	M24

Work-package #	4	**Start/End date**	**M1/M27**
Work-package title	**Freezing rain and bioenergy production conditions (Leads H. Gregow and A. Vajda, FMI)**		

Participants (person months)	**FMI** 14 ; **CNRS** 0.25 ; **HZG-CS2** 0.5; in-kind : **METSÄTEHO OY**, **FINGRID Oyj**

Main objectives This work package has the objective of co-designing, producing and demonstrating the use of **two indicators** related to freezing rain **(I4)** and bioenergy production conditions **(I5)**

Description of activities

Task 4.1 Lead FMI, part. CNRS, FINGRID Oyj, METSÄTEHO OY, HZG-CS2: Co-design of the indicators: FMI, FINGRID Oyj and METSÄTEHO OY will co-design (i) a freezing rain indicator (I4) which has value in risk assessment and in the design of structures and operations exposed to ice accumulation damage, and (ii) a bioenergy indicator (I5) which has a value for informing the harvesting conditions of production of wood from forests.

Task 4.2 Lead FMI: Production, evaluation and documentation of the indicators: The computation of **I4** is performed using sub-daily SYNOP observations of freezing rain and the ERA-Interim reanalysis dataset in order to create an identification algorithm for freezing rain, using the precipitation amount, the temporal evolution of the 2-meter temperature and the temperature at several pressure levels[39,40]. First, the assessment of probability of impacting freezing rain events in the present climate will be calculated using re-analysis data. Changes in severity and probability of freezing rain events in the future climate will be carried out using the climate projection data. Uncertainties are reduced by comparing computed and observed occurrence frequency, in-situ and impact data primarily from Finland (provided by co-designer) and Europe. The RCM ensemble will help to analyse the uncertainty originating from the choice of resolution and/or model.

I5 is based on combined thresholds of soil frost and soil wetness for harvesting and for road stability. Terrain bearing capacity assuming a challenging wet soil type will be combined from soil frost, soil temperature and snow data classified into good bearing, variable and non-bearing conditions. These variables will be used according to thresholds to define the good, bad or variable terrain conditions. Frost depth will be derived from empirical equations with snow and air temperature. Soil wetness will use a hydrological modeling source (E-HYPE). The historical risk analysis will compare results to statistics of delays and harvesting shortfalls. The indicator will be calculated from re-analyses data sets for validation and risk analysis purposes. Seasonal and climate predictions will be used to calculate/predict these indicators for operational (e.g. seasonal) planning of harvesting. Upscaling for Europe for the topsoil type and vegetation chosen will be done.

Task 4.3 Lead FMI, part. FINGRID Oyj, METSÄTEHO OY: Demonstration of use of the indicator: The demonstration of I4 use will build upon previous projects (EXWE-SAFIR, FP7 RAIN), in co-design with Fingrid, providing expertise on the use of the indicator in electricity network business. For I5, Metsäteho Oy will estimate the value of climate predictions and seasonal forecasts to industry planning on short, medium and long term. As demonstration, past bad terrain conditions will be analyzed using industry data for some test forest areas to calibrate the indicator. Preliminary visualizations will be proposed by FMI at Month 18 for the demonstrator prototype.

Deliverables

#	*Responsible*	*Nature*	*Title*	*Due*
D4.1	CEA	Report	Report on specifications	M9
D4.2	CEA	Data	Indicators production	M24
D4.3	CEA	Report	Indicators demonstration of use	M27

Milestones				
#	*Responsible*	*Title*	*Means of verification*	*Due*
M4.1	CEA	Data & documentation provision by FMI	Through web site	M21
M4.2	CEA	Demonstration provision by FMI	Preliminary report	M24

Work-package #	5	**Start/End date**	**M1/M27**
Work-package title	**Oil and gas offshore assets (Lead C. Acton, MetO)**		
Participants (person months)	**MetO** 16 ; **CNRS** 0.25 ; **HZG-CS2** 0.5 ; **BG group & SHELL** in-kind participation		

Main objectives This work package has the objective of co-designing, producing and demonstrating the use of **two indicators (I6.1 and I6.2)** related to oil and gas offshore assets

Description of activities

Task 5.1 Lead MetO, part: CNRS, BG Group, SHELL, HZG-CS2: Co-design of the indicators: MetO, Shell and BG Group will co-design two industry-endorsed proposed climate change indicators for the North West European Shelf that will be accessed through web enabled technology to allow user interaction with the data. **TOTAL** may also join the team of co-designers. The indicators will be developed based on existing datasets, analysed to provide information of relevance to industry operations (for example, to provide analysis of likely changes in threshold exceedance). The specific details of the analysis will be agreed with industry experts.

Task 5.2 (Lead MetO): Production, evaluation and documentation of the indicators: The two indicators (**I6.1** and **I6.2**) will be selected among (i) Mean wind speed and direction calculated from CMIP5 / EURO-CORDEX projections; (ii) significant wave height and mean zero crossing period, spectral peak period, mean wave direction as calculated from existing data generated by the WAM wave model; (iii) surface current speed and direction as calculated from the existing POLCOMS 11-member ensemble driven by climate projections from UKCP09 [refs. 41-43] (iv) sea level based upon projections from CMIP5 / EURO-CORDEX.

Task 5.3 (Lead MetO), part: BG Group, SHELL : Demonstration of use of the indicators: For demonstration, the outputs of the project will be two industry-endorsed proposed climate change indicators for the North West European Shelf that will be accessed through web enabled technology to allow user interaction with the data. An economic analysis will be conducted on the use of the indicators. Preliminary visualizations will be proposed by SMHI at Month 18 for the demonstrator prototype.

Deliverables				
#	*Responsible*	*Nature*	*Title*	*Due*
D5.1	CEA	Report	Report on specifications	M9
D5.2	CEA	Data	Indicators production	M24
D5.3	CEA	Report	Indicators demonstration of use	M27

Milestones				
#	*Responsible*	*Title*	*Means of verification*	*Due*
M5.1	CEA	Data & documentation provision by MetO	Through web site	M21

M5.2	CEA	Demonstration provision by MetO	Preliminary report	M24

Work-package #	6	**Start/End date**	**M1/M27**
Work-package title	**Demonstrator (Lead R. Vautard, CNRS)**		
Participants (person months)	**CEA** 25 ; **CNRS** 3.75 ; **FMI** 3.2 ; **HZG-CS2** 6.64 ; **EDF** in-kind participation		
Main objectives : to provide data access, visualization access, fact sheets and guidance			

Description of activities

Task 6.1 Lead CEA; participant: CNRS, EDF; Climate projections: CEA will prepare a set of 5 climate projections for 2 scenarios (RCP4.5 and RCP8.5 from EURO-CORDEX and possibly CMIP5. This set will be selected using metrics relevant for the energy sector as a whole, and co-designed with EDF. The selection will take into account the necessity to represent the range of uncertainty, and will come primarily from CMIP5 and EURO-CORDEX (about 10 GCM-RCM combinations are currently available). They will be provided with bias corrected data set for some variables when possible (eg. for T and precipitation). Methodologies of simulations selection and bias correction will also be based on preliminary CLIP-C work.

Task 6.2 Lead CNRS; Service and quality assurance protocols: A "product reference syntax" (PRS) will be designed to categorize provided indicators (spatial and temporal coverage, standard names, units, controlled vocabulary, used algorithms and methods, facet definition). This is fundamental to enable efficient data access and search engine capabilities by other systems such as the CDS. The PRS will be used to build OGC catalogues. CNRS (IPSL) will assess the feasibility of a machine to machine system enabling traceability of the project products. The system will detect version changes in datasets used as inputs to compute project products and will trigger a regeneration flag for the concerned products. The main goal being to identify if service components are missing for some inputs datasets (ECVs for example) to build such a system. CNRS (IPSL) will contribute defining a procedure to integrate new simulations coming along (CORDEX or CMIP6 simulations). All these tasks will be integrated in a data management plan that will be provided to ECMWF.

Task 6.3 Lead CNRS; part. CEA, FMI; High level data access and data processing capabilities will be provided for datasets and products developed by the project. Several options will be followed to provide access to the project products. OpenDAP and OGC web services like WCS, WMS and WPS will be made available to streamline and accelerate interactions with the CDS and third parties software. This will also make much easier the reuse of tools developed in other projects (EUPORIAS, SPECS, IS-ENES2, CLIPC) to analyze and visualize products. The data access services will be available right from the start of the project and will be configured following the outcome of Task 6.2. Products will be gradually integrated in those services when they fulfill ECMWF compliance requirements. In collaboration with CEA, FMI will also demonstrate how LUA scripts can be used for defining processing commands in the data query system. A scripted query will be able to calculate indicators during the data retrieval. Freezing rain will be a great showcase as the conditions are very rare and it is most efficient to only deliver the data when suitable conditions exist than to go thru all the time series of grids.

Task 6.4 Lead CEA, part. CNRS; Visualization: A harmonized interactive visualization of the pan-European indicator developed from WP1-WP5. This will follow specifications and

interactions with ECMWF, at M9 of the project. The visualization will rely on Open Geospatial Consortium (OGC) standards-based Web Services provided by task 6.3, including Web Map Service (WMS), Web Coverage Service (WCS), and Web Feature Service (WFS). Indicators and relevant geospatial data will be integrated into a Geographic Information System (GIS) accessible through a Web user interface. This WebGIS system will be compliant with (OGC) recommendations. It is anticipated that this approach will allow harmonization with other proof-of-concept SIS and CDS projects coordinated by ECMWF.

The pan-European indicators visualization will include (i) maps representation of the indicator at different time periods for climate projections or lead times for seasonal forecasts, with zooming functionalities, (ii) time series extraction, (iii) aggregated numbers per country or relevant regions, (iv) simple statistics such as time means, PDFs, centiles, return period diagnostics. Plots will include a representation of the uncertainty of the proposed prediction or projection, including skill and reliability measures of the seasonal forecasts present in the demonstrator. Demonstrations of use in WPs 1-5 will also include some visualization of case studies designed by the contractors using their systems. It is important that visualization be organized with co-designers and their requirements. Therefore, requirements will be collected in a first phase (M9). From these specifications, and following French regulation on subcontracting, an ITT will be issued and a professional visualization company be selected as a subcontractor, after agreement of ECMWF. A budget of 55000 euros is provisioned for visualization subcontracting.

Task 6.5 Lead HZG-CS2: Fact sheets and user guidance: The main aim of this component is to create a synthesis of how climate information is used by different energy producers, grid operators, traders, how they depend on climate and weather and how they can benefit from climate services. First, a literature review is conducted, with a summary condensed in a focus-paper about climate and climate change information usage within the energy sector. It will be complemented by fact-sheets, providing a synthesis of the climate change impacts, energy sector vulnerability and products created within this project. For each sector branch concerned by indicators of the project, an energy-fact-sheet will be created, using the well-established fact sheet methodology of the HZG-CS2. They also include expert judgments about the specific products identified together with the co-designers. A condensed overarching energy-fact-sheet will provide a synthesis of all sector branches concerned by indicators, including guidance on how to use the climate indicators. In order to obtain comparable results from the different activities, common standards for the results to guarantee the quality and consistency of the visualization will be established by HZG-CS2.

Deliverables

#	*Responsible*	*Nature*	*Title*	*Due*
D6.1	CEA	Data	Climate projections data set	M6
D6.2	CEA	Report	Specifications of data syntax, all elements of quality insurance and the visualization system	M9
D6.3	CEA	Data	Data access for indicators, clim. and ancillary data	M24
D6.4	CEA	Graphics	Pan-European indicator visualizations	M27
D6.5	CEA	Report	Fact sheets including user guidance	M27

Milestones

#	*Responsible*	*Title*	*Means of verification*	*Due*
M6.1	CEA	Prototype of demonstrator	Project web site	M18

References

1. IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.IPCC, 2014, WGIII
2. http://ec.europa.eu/clima/policies/package/index_en.htm
3. http://ec.europa.eu/clima/policies/2030/index_en.htm
4. http://www.climrun.eu
5. http://www.eclise-project.eu
6. http://www.euporias.eu
7. http://www.specs-fp7.eu
8. http://www.impact2c.eu
9. https://verc.enes.org/ISENES2
10. http://www.clipc.eu
11. https://e3p.lsce.ipsl.fr
12. Alternative energies and Atomic Energy Commission http://www.cea.fr
13. National Center for Scientific Research http://www.cnrs.fr
14. Barcelona Supercomputing Center http://www.bsc.es
15. Finnish Meteorological Institute http://www.fmi.fi
16. Météo France http://www.meteo.fr
17. Met Office http://www.metoffice.gov.uk
18. Swedish Meteorological and Hydrological Institute http://www.smhi.se
19. German Climate Service Center 2.0 http://www.climate-service-center.de/
20. http://esgf-node.ipsl.fr
21. Electricité de France http://www.edf.fr
22. BG Group http://www.bg-group.com
23. EDP Renováveis http://edpr.com
24. FINGRID Oyj http://www.fingrid.fi
25. METSÄTEHO OY http://www.metsateho.fi/
26. NENA AS http://www.nena.no

27. RTE http://www.rte-france.fr

28. SHELL http://www.shell.com

29. STATKRAFT http://www.statkraft.com

30. VATTENFALL http://www.vattenfall.com

31. Tobin, I., R. Vautard, I. Balog, F.-M. Bréon, S. Jerez, P. Ruti, F. Thais, M. Vrac, and P. Yiou, 2015: Assessing climate change impacts on European wind energy from ENSEMBLES high-resolution climate projections. Climatic Change, 128, 99-112.

32. Donnelly, C., Andersson, J.C.M and Arheimer, B. (in press) Using flow signatures and catchment similarities to evaluate the E-HYPE multi-basin model across Europe. DOI: 10.1080/02626667.2015.1027710.

33. Donnelly, C. Dahne, J. and Yang, W. 2014. River Discharge to the Baltic Sea in a Future Climate. Climatic Change, 122(1-2),157-170.

34. Heide D. et al.,2010: Seasonal optimal mix of wind and solar power in a future highly renewable Europe. Renewable Energy 35(2010) 2483 – 2489.

35. Pryor, S. C., and Barthelmie, R. J. (2010). Climate change impacts on wind energy: A review. *Renew. and Sustain. Energy Rev.* **14**, 430-437.

36. http://globalatlas.irena.org

37. Doblas-Reyes, F.J., J. García-Serrano, F. Lienert, A. Pintó Biescas and L.R.L. Rodrigues (2013). Seasonal climate predictability and forecasting: status and prospects. WIREs Climate Change, 4, 245-268, doi:10.1002/WCC.217.

38. Michelangeli, P.A., Vautard, R., Legras, B., 1995: Weather regimes: recurrence and quasi-stationarity, J. Atmos. Sci., 52, 1237-1256.

39. Kämäräinen M. and Jokinen P., 2014: Severe winter weather in Finland – Freezing rain and lake-effect snowfall. EXWE project report, Finnish Meteorological Institute, 25 p.

40. Jokinen P., Pellikka H., Johansson M., Saku S., Lahtinen M., Gregow H., Ruosteenoja K., Venäläinen A., Jylhä K., Rauhala J., Kahma K., Boman H., Karjalainen A., Leinonen K., 2013: Extreme weather and nuclear power plants, In SAFIR2014 The Finnish Research Programme on Nuclear Power Plant Safety 2011-2014, Interim Report, Ed. by Simola K., VTT Technology 80, p. 382-392

41. Lowe, J.A. et al. 2009: UK Climate Projections Science Report: Marine and Coastal Projections. Met Office Hadley Centre, Exeter, UK. Available from http://ukclimateprojections.defra.gov.uk

42. Howard, T. et al., 2014: Sources of 21st century regional sea-level rise along the coast of northwest Europe, Ocean Sci., 10, 473-483, doi: 10.5194/os-10-473-2014

43. Tinker, J. et al. 2015: Validation of an ensemble of climate projections for the northwest European shelf seas. Prog. Oc. (submitted)