HORIZON 2020

SC5-01-2016 a – Climate Services[1]

Technical Annex Section 1-3

Title of Proposal:
Improved Energy Decisions using Seasonal Climate Forecasts
Acronym: EnDeCli

List of participants

Participant No	Participant organisation name	Country
1 (Coordinator)	UNIVERSITY OF EAST ANGLIA (UEA)	United Kingdom
2	ENEL TRADE spa	Italy
3	AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE (ENEA)	Italy
4	BARCELONA SUPERCOMPUTING CENTER - CENTRO NACIONAL DE SUPERCOMPUTACION (BSC)	Spain
5	KONINKLIJK NEDERLANDS METEOROLOGISCH INSTITUUT-KNMI	Netherlands
6	MET OFFICE	United Kingdom
7	WORLD ENERGY & METEOROLOGY COUNCIL (WEMC)	United Kingdom

[1] https://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/2190-sc5-01-2016-2017.html

Abstract

The objective of this project is to demonstrate how the use of climate forecasts, out to several months ahead, can add practical value to decision-making processes in the energy industry. Specifically, the project will assess the effect these seasonal climate forecasts have on portfolio management, such as hedging, thus enabling quantification of the value-add provided by such forecasts. Improvements in these energy management decisions will ultimately lead to an improved energy supply-demand balance and therefore to greater efficiency in the energy system with corresponding climate mitigation benefits.

To assess the effectiveness of seasonal forecasts in energy decision-making processes an innovative but simple methodology will be adopted. The energy companies involved in the project will establish two internal groups: a control and a test group. In terms of climate conditions, the control group will only access widely known climatological conditions based on historical averaged values – currently the most common approach – while the test group will also consider energy-tailored state-of-the-art seasonal climate forecasts. The methodology will be tested on challenging historical case studies, namely seasons which have displayed anomalous climate conditions that have led to volatility in energy prices and/or imbalances in the supply-demand balance. In the process, tailored probabilistic seasonal forecasts will be produced. The same methodology will then be incorporated into real-time regular decision-making carried out by the industrial partners, by utilising operational seasonal forecasts, typically updated monthly.

The end product will be a demonstrator for an operational climate service, including user-friendly access to seasonal forecasts and tools to assess them, tailored to the energy industry. This product will be offered to the wider energy industry to add value to their decision-making processes. The emphasis will be on a close interaction during the project with a wide number of energy industry stakeholders and users with the aim of communicating the added value of this climate service and facilitating the deployment of analogous ones.

Keywords: Seasonal climate forecasts, energy demand and supply, energy management, climate service, power prices, climate impacts, probabilistic information, multi-model approach, calibrated forecasts

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Improved Energy Decisions using Seasonal Climate Forecasts (EnDeCli)

Background

It is increasingly recognised by the energy industry that climatic factors play a key role in their energy management. Indeed, energy companies' board discussions have been increasingly pre-occupied with the unexpected effect on electricity price of marked large-scale seasonal climate anomalies. The 2015 summer heat wave, which affected a large part of Europe, is a case in point, as discussed later. This is happening against a backdrop of global climate negotiations such as COP21 in Paris. One of the major outcomes of this conference is the wide agreement that action should be taken to factor climate into energy-sector decisions. Such decisions include a steady increase in renewable energy uptake, as advocated for instance by the UN Sustainable Energy for All (SE4ALL) programme. The vision of SE4ALL is for governments, businesses and civil society to work in partnership to make sustainable energy a reality for all by 2030.

Energy planning and operations in general are markedly affected by meteorological events. This link is very clear for renewable sources such as wind, solar and hydropower and for electrical transmission systems, though less obvious it is also true that the more traditional energy sources can also be severely impacted by extreme climatic events (e.g. heat waves for thermal power plant production). In addition, energy demand also varies strongly with meteorological conditions. Thus, by properly taking into account weather and climate predictions, energy systems can considerably improve energy management decisions, including system planning, maintenance scheduling and resilience to weather extremes and climate variability. These form the basic elements of a climate service as described in this proposal.

While the energy sector has routinely been using weather forecasts out to 10 days ahead (Dubus 2010, Troccoli et al. 2014), climatological data (typically based on 30-year averages) are mostly used for longer time horizons. However, an increasing focus is being placed on the production and assessment of longer-range forecasts, out to several months (and beyond) especially since seasonal forecast skill has considerably improved over the last decade and is now considered useful for some societal applications (e.g. Alessandri et al., 2011, Hamlet et al. 2002, Makaudze 2005, Rubas et al. 2006, Hansen et al. 2009, Block 2011). Specifically for the energy industry, heat-wave forecasting at the seasonal time-scale over "hot-spot" land areas has recently been shown to have the potential to drive predictions of electricity demand anomalies over Europe due to increased summer refrigeration and air conditioning demand (De Felice et al., 2015). Therefore, seasonal forecasts are starting to be considered as an additional, potentially important, element for improved decision-making in the energy sector.

1. Excellence

This proposal is in response to the H2020 call SC5-01-2016-2017 *Exploiting the added value of climate services*. The proposed work responds to a formulated energy industry need for climate services. Indeed, this proposal has been co-designed and co-developed particularly with a major industrial partner, the multi-national ENEL Group, which also includes subsidiary companies such as Endesa Spain. This project will develop a demonstration climate service for the use of seasonal climate forecasts in support of energy management decision-making processes in the energy industry.

1.1 Objectives

The objective of this project is to demonstrate how the use of climate forecasts out to several months can practically improve portfolio management and hedging decision making in the energy sector. By assessing the forecast skill for selected case studies and associated energy situations (e.g. improved demand and renewable production estimation), this project will identify ways to add-value to current operational decision-making. Improvements developed through these case studies will then be incorporated into real-time decision-making later in the project. These assessments and developments will be carried out through close cooperation between the research and industrial partners in this project.

The choice of the selected case studies in relation to the climate will be assessed with a view to aiding energy management decision-makers and grid managers in the development and operation of the electricity grid. This is becoming increasingly critical since the energy transition to renewable energy sources such as wind and solar energy production leads to a larger variability in energy supply. Also, the return period of extreme weather situations such as the heat wave of July 2015 and other such anomalies in the seasonal weather will be investigated: such extremes in the seasonal climate will provide the necessary context for the integration and tailoring of current seasonal climate forecasts in energy decision-making.

The end product will be a demonstrator for an operational climate service, including user-friendly access to climate forecasts of meteorological variables which will enable prediction of scenarios in the energy market and tools to assist with the tailoring of these forecasts. This product will subsequently be offered to the wider energy industry and policy makers to add value to their decision-making processes. Thus, emphasis will be placed within the project on a very close interaction with a wide number of stakeholders and users with the aim of communicating the added value of the services.

1.2 Relation to the work programme

This proposal relates to the demonstration of climate services. Specifically, this work will provide an assessment of the added value of the use of seasonal climate forecasts in operational decision-making in the energy sector, as effected by our main industrial partner, ENEL, but also TenneT, the Dutch Transmission System Operator (TSO), which are providing input to the project as a 'dedicated' stakeholder via the Dutch Meteorological Service, KNMI, an EnDeCli partner (see TenneT letter of support and Case Study 5 later). Other energy users who have been already engaged in the preparation of this proposal – e.g. the UK National Grid – and other stakeholders will be contacted during the execution of the project according to our stakeholder engagement plan. Stakeholder engagement, a key aspect of the project both with the climate community but especially the energy sector, will be led by the World Energy & Meteorology Council (WEMC), an organisation whose expertise is the creation and strengthening of links between the scientific community and the energy industry, as well as knowledge transfer.

By developing a climate service with a distinct emphasis on the use of seasonal climate forecasts, other energy companies will benefit from this development. Indeed, a number of energy companies will be involved during the implementation of this project. These include companies such as Endesa Iberia, which is part of the ENEL group as well as entities in Latin

America in order to address highly hydro-dependent power generation capacity. The climate service developed with this project will therefore be clearly based on a stated user need – this is indeed what has shaped this proposal throughout. It will benefit from the close interaction between industrial partners and scientific partners. Such interaction will ensure that the end product – the climate service – is co-designed and co-developed by all project partners and with further input provided by additional energy industry stakeholders, engaged through the numerous communication activities to be implemented with this project.

1.3 Concept and methodology

(a) Concept

The overall concept underpinning the project is the optimal utilization of seasonal climate forecasts for energy decision-making as a way to reduce volatility in energy/electricity prices. While the concept is clearly user-driven (energy industry) the project will require close interaction between the producers of seasonal climate forecasts (scientific/operational organisations) and energy stakeholders. Such interaction will ensure that seasonal climate forecasts are properly communicated and adapted to users need rather than scientists trying to second-guess what could be relevant for end-users. As a result there is going to be a high degree of inter-disciplinarity in this project.

Although seasonal climate forecasts have routinely been produced for about two decades, their skill is considered to be relatively low for supporting decision-making. This is particularly true over regions like Europe, while tropical regions benefit from an enhanced predictability related to the El Niño Southern Oscillation (ENSO). On the other hand, it is well established, for instance, that the North Atlantic Oscillation (NAO) has a profound influence on wind (therefore wind power), temperature (therefore demand), precipitation (therefore hydro power) and solar radiation (therefore solar power) over many regions of Europe (Ely et al. 2013, Brayshaw et al 2011, Trigo et al 2004, Pozo-Vázquez et al 2004). Forecast potential for the winter NAO has improved in recent years (Scaife et al 2014). It is important to also note that forecast skill is still better in summer over the Euro-Mediterranean region than during winter.

Meteorological variables have a significant impact both on the power and gas market. Specifically in the case of the power market, meteorological variables influence the power price through renewable production (solar, wind and hydro) and power demand (mainly as a function of temperature), while for gas, they have a relevant impact on gas demand, especially in winter periods. To provide further justification for the close connection between climate variables and energy decisions, which is at the core of the concept of this work, the impact of climate on power demand, power prices and gas demand, as viewed by the energy industry, is now described in more detail.

Climate impact on power demand – Electricity demand forecasting is essential for the analysis of power markets and more generally for energy management that leads to business decisions. Electricity demand depends on economic and other indicators at the country or regional level and obviously on climatic ones. Seasonal climate scenarios, based on forecast climatic variables, are essential to a more precise and accurate demand forecast one to a few seasons ahead.

Climate impact on power prices – In terms of the power market, power price is correlated positively with the demand and negatively with the renewable production because in the bidding curve the renewable power plants are offered at zero price; therefore a measure of tightness could be defined as the demand net of renewable production. The role of renewables on power prices emphasises again the key role of meteorological variables on power prices themselves. The day-ahead market hosts most of the electricity sale and purchase transactions and participants submit offers/bids where they specify the quantity and the minimum/maximum price at which they are willing to sell/purchase. Bids/offers are accepted by the market operator after the closure of the market sitting based on the economic merit-order criterion and taking into account transmission capacity limits between zones. All the supply offers and the demand bids are valued at the marginal price of the zone to which they belong. This price is determined by the intersection of the demand and supply curves and is differentiated from zone to zone when transmission capacity limits are saturated. Different scenarios of climate driven supply and demand have a critical impact on price dynamics both at spot and forward level.

Climate impact on gas demand – The industrial, residential and power generation sectors constitute the main components of gas demand. Their relative contributions, although always significant, have changed in accordance with structural shifts and economic contexts over the past 20 years. Nowadays the residential sector is the biggest source of demand growth and, in the case of Italy, it accounts for over 50% of natural gas demand and is particularly sensitive to temperatures, as most residential gas is used for winter season space heating. The power generation sector represents a third of the total demand; the main driver for power and heat consumption in this sector is electricity demand which is mainly affected by temperatures and renewable generation especially during the summer season when its relative weight on total demand is inverted with the residential sector.

Given the relatively high level of maturity of seasonal climate forecasts this work will provide an effective way to adapt and tailor a scientific/operational product into useful information for the energy industry. In this sense, this project is much closer to the ‘lab to market’ end of the spectrum than to the opposite ‘from idea to application’. Specifically, this project will provide an important demonstration of the use of uncertain (probabilistic) products in real decision-making processes.

This work is placed in the context of other key European and Global activities in the area of climate services such as Copernicus Climate Service Services (C3S) and the UN Global Framework for Climate Services (GFCS). It is worth noting that the partners involved in this project also have a strong expertise in the development and use of climate services. For instance, UEA is leading the C3S European Climatic Energy Mixes (ECEM) in which ENEA and Met Office also participate and the Met Office and BSC contribute to the C3S CLIM4Energy. This will ensure that this project can leverage on those developments whilst avoiding duplication of effort.

(b) Methodology

Given that the focus of this project is on the demonstration of the value-add of seasonal climate forecasts for energy decision-making, it is critical to set up a clear framework for assessing and measuring this added value. Accordingly, in order to properly establish this framework, it is necessary to understand how energy management decisions in the energy sector are normally taken.

Firstly, we need to consider which methodologies and models are currently used in energy management decisions. The key models used are demand and production, particularly for wind and solar as these are mostly dependent on climate variables.

**Demand models – **At ENEL the forecast of market price is a two stages process: firstly the future power demand is forecast using econometric models (developed in-house) based on meteorological variables and other inputs. These models are statistically trained on historical behaviour. Then a market model to forecast the future prices based on the demand/supply ratio is applied. The validation of the demand can be done on a monthly basis because the Italian TSO TERNA only publishes monthly aggregate consumption measurements. The validation of the added value of seasonal climate forecasts on the demand model can be done in a statistical way through a comparison between the econometric forecasts made using the climatological forecasts (control) and the forecast made using mean climate models, with respect to actual historical prices. For the real-time demonstration period or case study a control run will be undertaken using climatological temperatures (i.e. historical temperature averages). The same econometric model will be fed with the seasonal climate forecast information and the sensitivity of simulated demand will be validated over the past market data.

Production models – The renewable production forecast, specifically for wind and solar power, will be validated with the same approach described above comparing the predicted productions with the actual past data.

Wind production models – They are physical models that use wind forecasts provided by an external meteorological service. A topographic correction is applied to the predicted wind in order to take account of the local and boundary layer effects. The corrected wind is converted to the produced power using characteristic power curves.

Solar production models – As well as for the wind production forecast, physical models have also been developed for the photovoltaic production forecast. The primary source is a combination of cloud cover and temperatures also provided by an external meteorological service. Then a proprietary algorithm is applied in order to take account of the tilt angles, atmospheric transparency and the technology of the photovoltaic plants.

Energy management decisions and subjective validation – The output of the demand and production models then forms a key element in the decision making process for energy management activities. However, the evaluation of the impacts of using climate predictions on corporate business is complicated and it is not possible to proceed in a completely systematic and objective way. This is due to the complexity inherent in decision-making, involving a large number of variables. In many cases these variables are qualitative or not easily quantified. Business decisions involve meetings of several different groups who consider a broad picture of how markets are evolving: many variables are discussed such as risk, expected profits and macroeconomics. Political issues are clearly also another important factor in energy management decisions.

It becomes apparent then that in most cases all these complex factors – political, technical, climatic, etc. – are weighted according to the experience and the subjective judgement of the people taking the decisions (typically a board or a technical group). This means that in the day-to-day decision-making there is no specific model which combines these factors to arrive at an 'optimal' decision. Such a model, if it existed, might provide a quantitative output but likely not matched to the actual required decision. However, even in the absence of such a decision-making model it is possible to measure the effect of using an additional piece of information in the mix of the decision-making. A possible strategy could be to reproduce several plausible scenarios of decision processes, within the corporation, including improved sources of climatic information. By considering the decision scenarios, an estimation of the profit/loss and potential value-add due to skilful climatic forecasts is enabled, as well as a more efficient decision-making/competitive edge relative to only using climatological averages.

In other words, this project will measure the value-add of using seasonal climate forecasts through a relatively simple methodology (Figure 1). A control group and a test group will be established for each industrial partner participating in the project (possibly also extended to other interested industrial stakeholders). In terms of climate conditions, the control group can only access widely known climatological conditions – currently the most common approach – while the test group will also be given current tailored seasonal climate forecasts. In the case of electricity price, the net result of this methodology will be to provide a price differential. Namely, how different is the estimated price when seasonal forecasts are used compared to when they are not? These differentials in the estimated prices will then be compared to the actual electricity price, by means of standard statistical metrics, to quantify the value-add of the use of seasonal climate forecasts in energy management decisions.

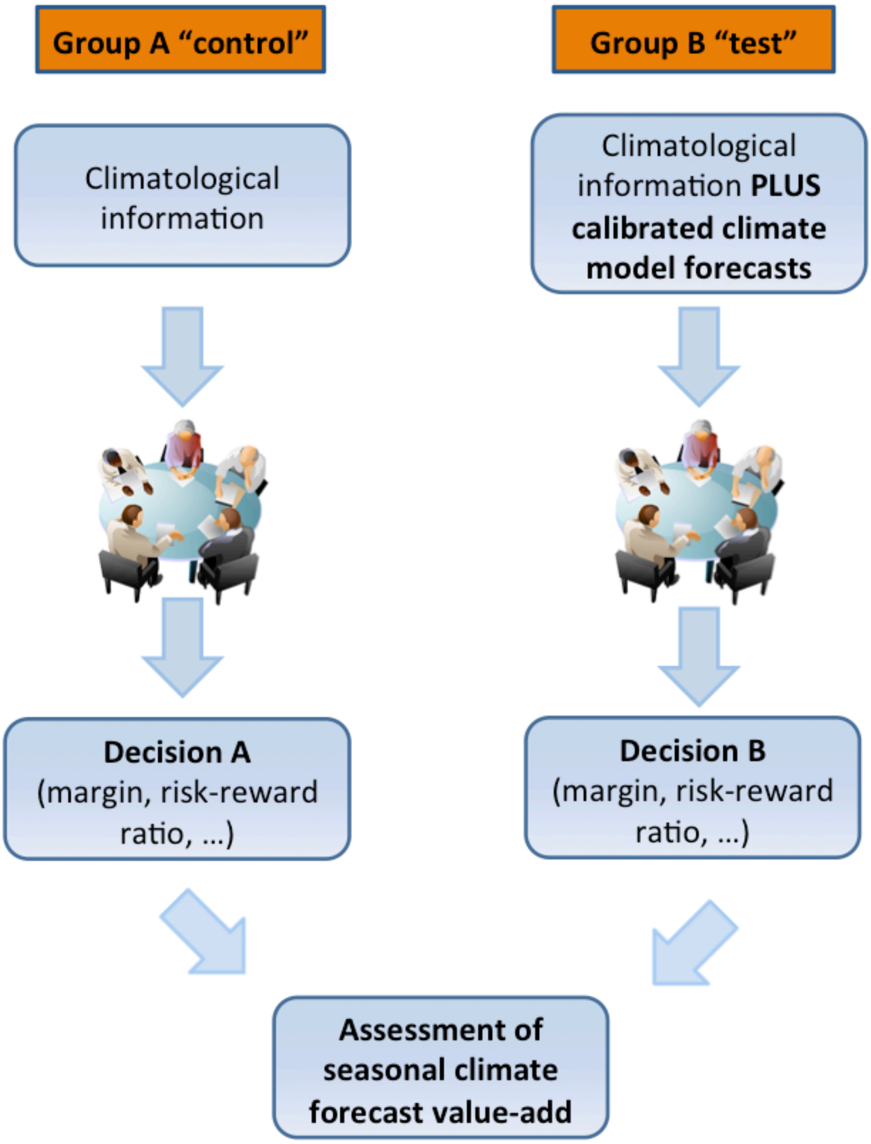


Figure 1 – Schematic showing the experimental set up used in EnDeCli to assess the value-add in the use of seasonal climate forecasts in the case of energy management decisions.

Tailoring of seasonal climate forecast for decision making – In order to use climate forecasts within these models a three-stage process is proposed here (see Figure 2). This process is aimed at maximising the value of data to stakeholders at each stage of the project.

First the calibration of the forecast and the exploitation of the maximum prediction performance will be defined to ensure that the best predictands are in use throughout the project, as set out in Work Package (WP) 2 below. This is a vital step to ensure that downstream forecasts build on a strong base and are as skilful as possible. This processing provides generic data that are difficult for industry to use since they are not yet downscaled to regions of interest or translated to parameters of relevance.

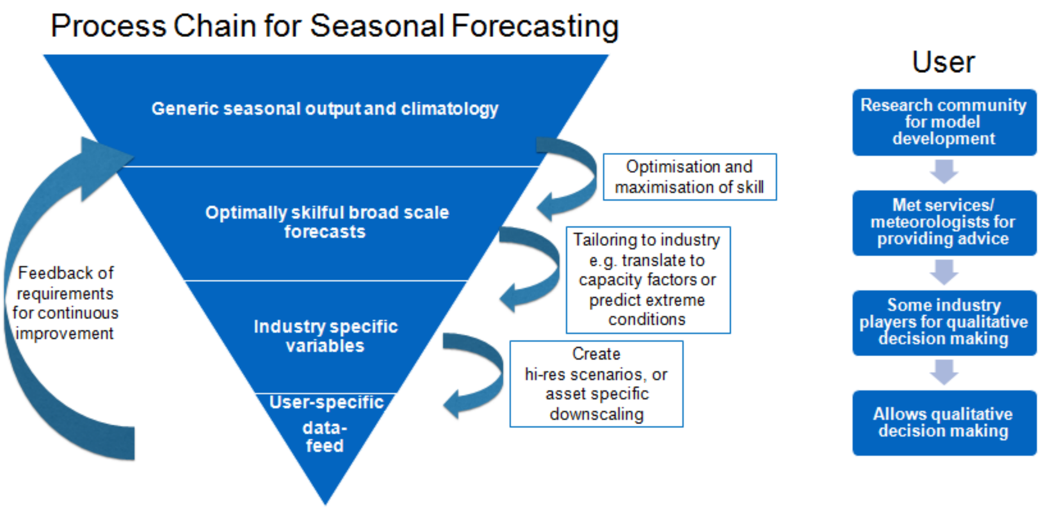


Figure 2 – Schematic showing how tailoring of seasonal climate forecast for decision making will be achieved in EnDeCli.

Second, a translation step is defined and performed (see WP3 below). Here the relationship between the generic meteorological parameters and parameters of interest to industry (such as extreme weather conditions or capacity factors) are calculated. This makes data suitable for visual display and will have wide interest within the energy industry.

The third step is to build on the industry specific data above by defining a tailoring process for individual users. This may involve calibrating data to predict conditions for very specific assets (e.g. through using 'measure correlate predict' methodology already popular in wind-resource assessment applications), or increasing the temporal resolution of data such that it is suitable as an input to existing econometric models. To increase resolution of the forecast data the broad-scale climate signals related to country-scale phenomena acting over several weeks must be downscaled to potentially up to 15 minute resolution (common in supply and demand modelling). Care must be taken here to take suitable account of uncertainty in the outputs as 15 minute resolution data must be treated as indicating a plausible scenario rather than a prediction per se. It may be necessary to generate many such plausible scenarios so as to sample likely outcomes. Communication and feedback is vital between all work packages to ensure that this process occurs effectively.

Evaluation of seasonal climate forecasts – In order to produce the most effective tailoring of seasonal climate forecasts for the specific energy management decisions following the models and methodologies described above, our initial step is to evaluate the value of seasonal forecasts when used as an input by energy demand and renewable (wind and solar) power production models. An assessment of the added value of climate seasonal forecasts on these models will be done through a statistical comparison using real market data. The demand and production thus computed will be compared to those for the same test period but using climatological meteorological variables.

Forecasts of climate and hydrological variables at time horizons up to several months ahead will be provided by the available State-of-the-art Seasonal Prediction Systems based on global-scale Coupled General Circulation Models (CGCMs). The meteorological variables relevant to energy supply and demand which will be taken into consideration in EnDeCli are listed in Table 1. As an example, air temperature has an impact on the energy demand and it can be split into two components: electricity for refrigerating engines during the warm season and as gas/fuel demand for heating purposes during the cold season.

The methodology will be tested over historical and relevant case studies, namely seasons which have displayed anomalous climate conditions that have led to volatility in energy prices and/or imbalances in the supply-demand balance. The same methodology will then be incorporated into real-time routine decision-making, by utilising operational seasonal forecasts, typically updated monthly. These assessments and developments will be defined and carried out in close cooperation with the industrial project partners.

Also, extremes in weather parameters relevant for energy demand and energy supply will be investigated using a dataset representing a 5000-year period of the present climate using techniques developed for extreme events by van den Brink et al. (2004, 2005). Investigation of such extremes in the seasonal climates can provide energy companies and grid managers with valuable information on the necessary energy demand, production and grid capacity.

Climate predictions for the upcoming seasons using dynamical models of the coupled global atmosphere-ocean system will be the key input used in this project, with the ultimate aim to help improve efficiency and profitable management in the energy sector. While forecast skill still needs to be improved to deliver robust climate services for economic, industrial and political planning (Troccoli et al. 2008, WMO 2015), the techniques and tools developed by EnDeCli will aim to overcome present limitations. Accordingly, a very powerful tool that will be adopted in EnDeCli is the combination of independently developed dynamical seasonal prediction systems (SPSs) into Multi-Model Ensembles (MMEs, Palmer et al., 2004, Wang et al. 2009, Alessandri et al. 2011). In this respect, MMEs have been shown to be more effective in enhancing performance with the increase of the independence of the contributing models (Yoo and Kang 2005, Wang et al. 2009, Alessandri et al. 2011).

Several state-of-the-art SPSs are being independently developed by the European (Weisheimer et al. 2009), the Asian Pacific (Wang et al. 2009) and the US (Kirtman et al. 2014) communities. The performance of the individually available SPSs is generally different depending on the variable/region/season/phenomenon under consideration so that different SPSs or MMEs could be better suited for the different climate service applications. One major aim of this project is to maximize the current level of prediction performance at the seasonal time-scale by selecting better combinations of independent SPSs that are able to maximize the usefulness, reliability and potential economic value to end-users for each specific energy application considered in the case studies. For each energy application, the potential of MMEs, obtained from the combination of the available SPSs, to maximize the performance for key predictands (climate variables considered at the time and space scales suitable for each application) will be evaluated. In close synergy with the industrial partners, this will enable an assessment of the optimal number of independent SPSs and the marginal contributions to performance, to support the quantification and maximization of the economic value added by climate predictions.

The Seasonal Predictions from the European (EUROSIP, SPECS), North American (NMME) and Asian Pacific (APCC) datasets that fit with minimum requirements (accessibility, variable availability, forecast issue dates, time and space resolution), and that are also operationally available, will be collated and homogenised in a dataset available to all partners in a dedicated project server. Selection of the SPSs to include in the MME dataset will also be made so as to maximize the time-coverage of the forecast verification.

The co-design and co-development of a Best Forecast Selection Concept (BFSC) will involve preliminary meetings that will be organized in order to ensure the industrial partners are aware of the state-of-the-art in the field and identify the climate variables (and related time and spatial scales) with better predictability and the potential, therefore, to feed useful applications to the case studies. The BFSC approach will be used to maximize the performance in forecasting key predictands, selected in each case study by performing an optimization/validation for the period covered by the MME hindcasts dataset. To this end, the better model or ensemble of models is selected by comparing all the possible combinations of the SPSs available from the MME hindcasts dataset.

To make the selection of SPSs more robust with respect to the relevant climate phenomena that may affect the key climate variables for the energy sector and over the region of interest, the choice of models aims to properly represent SPSs which are able to maximize both the skill coming from local processes (soil moisture, snow and vegetation) and the ability to maximize the skill originating from tropical-extratropical teleconnections. As an example of remote phenomena for boreal summer, the model capability to represent and predict Asian monsoons, due to the related teleconnections to the Euro-Mediterranean that may be triggered by westward propagating Rossby wave tracks from the South-East Monsoon region, will be evaluated (Rodwell and Hoskins 1996, Cherchi et al. 2014; Cherchi et al. 2015). A selection of the best forecast systems will be made based on a ranking according to the multi-variable skill scores.

It will also be important to investigate the probability of weather extremes on a seasonal timescale. How exceptional was, for example, the heat wave of 2015 and what is the return period of such an extreme situation? The probability of extremes in the seasonal weather would give energy producers and grid managers information which can help determine the range of possible variability in the energy demands and energy supply. Thus, we will make use of a climatological dataset to provide year to year variability, seasonal variability and so on. Investigation of correlations between different time periods (e.g. is a year which is preceded by a heat wave more likely to also have a heat wave) and of correlations between different geographical regions can also provide tools to assist in optimising the energy supply-demand balance. In the European region, energy balance may be further supported through investigation of correlations in the weather between different countries. Reduced sunshine in one country may be compensated by wind energy from local wind turbines or by solar energy produced in another country.

1.4 Ambition

The systematic use of seasonal climate forecasts in energy management decisions for the energy sector (and even more broadly) is in its infancy. As discussed above, recently there have been promising improvements in forecast skill both from individual dynamical models but also in techniques for blending output from different models. Therefore it is the ambition of this project to demonstrate how these forecasts can provide real value to energy management decisions. This process will require that: i) seasonal climate forecast developers and scientists understand the type of information required for energy management decisions in a detailed way; ii) key forecast features are clearly communicated to, and understood by, our industrial partners (ENEL Group, as well as TenneT, and other stakeholders); iii) forecasts are effectively embedded into the decision-making process of the industrial partners and their value appropriately assessed. This seemingly straightforward process in reality requires many iterations and refinements if it is to succeed. We are confident that the expertise and the breadth of the partners who are collaborating in this project will lead to a successful outcome, namely a well-integrated use of seasonal climate forecasts into energy management decisions, including through a demonstration climate service.

Table 1 – Summary of models, variables, regions in EnDeCli scope. (*) means desirable.

Energy Models	Demand (Gas and Power)
	Wind production
	Solar production
	Hydroelectric production
	Thermoelectric production
Meteorological Variables	Temperature (air at 2m and water)
	Rainfall
	Wind speed at a few heights
	Solar irradiation and/or cloud cover
	Offshore wind speed
	Wave height
	(*)Snow cover and river discharge
Regions	Europe (particularly Italy, Spain and Netherland)
	South America

2. Impact

2.1 Expected impacts

The integration and systematic use of seasonal climate forecasts into energy management decisions achieved with this project, including through a demonstration climate service, is expected to markedly facilitate the assessment of the value of using these forecasts. This would be a major step forward in the use of seasonal climate forecasts for energy decision-making. In fact, the only forecasting services available at the moment (free or paid for) are servicing qualitative decision-making (especially popular with commodity traders). Other players in the energy industry do take into account climatological factors, but this is done using decision-making models based on climatology (e.g. the Winter Outlook Report of the UK National Grid). These models are ripe for using seasonal forecast information, but this has not yet been achieved.

By developing a new operational procedure, which enables medium term (corresponding to the seasonal timescale for the energy industry) decisions to be taken by the industrial partners, while assessing the value which seasonal climate forecasts have in the process, we expect that several other energy industry stakeholders will be interested in evaluating the relevance of this climate service for their operations. Clearly this will require close engagement with a variety of stakeholders (e.g. grid managers, power plant operators, energy generators), something that is embedded in this project, and something the project team has substantial expertise in.

One of the most important aspects of this project is the potential to produce sensitivity tests on the climatic variables based on datasets that have a physical consistency. The process of creation of the method and its validation will be based upon real cases drawn from the direct experience of the industrial partners. Another important aspect of the project is the possibility to investigate the approach on the real time economic activity of the industrial partners over the real markets. Thus, the translation and adaptation of seasonal climate forecasts for these operational decision-making activities will provide a unique opportunity to overcome the current lack of knowledge in the real value of these forecasts and the consequent barriers that exist in the deployment of the systematic use of seasonal climate forecasts for energy management decisions.

The energy sector has been recently included as a priority area in the GFCS, and it is also a priority in C3S (with ECEM and CLIM4Energy), since it is strongly affected by climate in all of its aspects: energy supply, demand and infrastructure. By improving the performance in forecasting energy demand and renewable energy generation, this project will provide vital support to the industrial partner, and other stakeholders such as power grid operators and policy makers for the energy sector at the national, European and international level. The consequent growth of the climate services market in the energy sector will contribute directly or indirectly to job creation therefore addressing the call by the "Innovation Union" flagship initiative by the Europe 2020 strategy.

It is expected that specific opportunities for new jobs will arise from the need to develop services, which allow the timely and effective assessment of the impact of seasonal climate forecasts in a routine way. Given the potential applicability of seasonal forecasts for the energy sector, as partly developed with this work, but even beyond this sector, and the fast emerging role of climate service providers, it is not unconceivable that tens of jobs may be created over the next few years in the area of seasonal climate forecast provision and tailoring. Demonstration of the usefulness of climate services based on seasonal forecasts will also stimulate the use of the forecasts for increasing number of applications. Therefore more and more research and private companies (energy as well as other sectors) will be hiring personnel to operationally apply seasonal forecasting to optimize their decision processes. The growth of new professional roles between the climate scientists side and the application staff in private companies is also foreseen, therefore further increasing the number of new job opportunities.

By improving the energy management decisions the project will ultimately lead to an improved energy supply-demand balance and therefore to greater efficiency in the energy system with corresponding climate mitigation benefits. This will stimulate new policies towards a more efficient use of energy sources to mitigate GHG emissions, therefore contributing to the Union's Internal Security Strategy and to the objectives of the "Resource efficient Europe" Flagship initiative set out by the Europe 2020 Strategy.

2.2 Measures to maximise impacts

(a) Dissemination and exploitation of results

The EnDeCli consortium have identified three specific project outputs which provide key exploitation opportunities:

1. The discoveries, in WP2 (see WP descriptions below), of those multi-model combinations of seasonal climate forecasts which provide skill and enhanced performance in application to specific geographical areas when applied to particular energy sector user-defined questions;
2. The case study examples of quantified economic benefits, arising from the work undertaken in WP3, which have value for use in training materials and that partners can develop during or after the project;
3. The demonstrator, developed in WP4, which in conjunction with the market assessment in WP6 (led by WEMC) will be showcased within the project, and also disseminated to other energy stakeholders and to other climate service providers, for potential post-project adoption on a commercial basis.

It is apparent from the objective of the proposal that there are plans to exploit the EnDeCli results, particularly by the main industrial stakeholder, ENEL, during the project and beyond. For instance, ENEL plans to take the results of WP2 and carry out further optimization of the climate forecasts models/procedures beyond EnDeCli. Likewise, the demonstrator developed in WP4 will be adopted by ENEL, and possibly TenneT, as a decision supporting tool. Also, WEMC plans to use the case studies as training material for its capacity building activities.

Nonetheless the consortium recognise the need to develop a more thorough exploitation plan which will be developed during the project. As the lead organisation of WP6, on Dissemination and Exploitation, WEMC will provide overall coordination of the project exploitation pathway. Co-incident with other scheduled consortium meetings, WEMC will co-ordinate three project *stakeholder engagement and exploitation workshops*, at the beginning (Month 3), middle (Month 15) and end (Month 28) of the project. At the first workshop, the members of the consortium will record their project exploitation aspirations using the template table below – this exercise will likely be steered by expert facilitators who we will engage for the purpose – Greenovate is an example of such a facilitating organisation. The project IPR protection strategy will also be agreed at this first workshop and reviewed at each subsequent one, building on the management of intellectual property that will first be defined in the Consortium Agreement.

Project Output	Output co-owners	Innova tions	Partners wishing to exploit the output	Exploitation route imagined by each partner (own sale, licensing, free access for own use, further R&D), policy uptake)	Any additional supporting activities to be undertaken (not forming part of the project tasks)
1. Leading Multi-Model Combinations	Partner1 Partner 2 Partner 3		Partner 1	*Own Sale*	
			Partner 2	*Licensing*	
2. Energy Management Case Studies					
3. Demonstrator					

This resulting draft exploitation plan will be updated and expanded at the second exploitation workshop according to the results on the study on energy management decision making in WP1 and the market assessment generated in WP6. At this point, facilitators will assist by helping the consortium to identify any barriers to exploitation, with the mediation of joint agreements (as required) and with development of business plan timelines.

Shortly before the project end, Exploitation Workshop 3 will document the exploitation achievements to that point and confirm the intended ongoing pathways to impact post-project, both commercial and non-commercial. Associated with dissemination events, focus groups and questionnaires will also be used to acquire specific feedback from stakeholders to assist especially with optimizing the demonstrator tool user experience.

(b) Communication activities

Stakeholder engagement and communications is central to EnDeCli. While the project has a strong focus on ENEL requirements, the consortium plans to involve as many energy management stakeholders in the project as a way to raise awareness about the use of seasonal climate forecasting in their decision making and to possibly contribute to the development of the EnDeCli demonstrator.

The EnDeCli consortium will deploy a wide variety of communication methods to enhance the visibility of our project and its impacts. Work Package leaders and the Project Manager have responsibility for targeting promotional opportunities which emerge during the lifetime of EnDeCli. Our target audiences, methods of communication and information types are summarised in the table below. Also, in terms of provision and exchange of data, EnDeCli plans to use Open Data sources.

The EnDeCli consortium will develop and utilise professionally designed and written communication resources. The project's brand, including logo and templates, a project flyer, a poster and a pull-up stand will be prioritised, each fully acknowledging our funders.

Target audience	Energy producing companies, TSOs, Energy Market Operators	National, regional and international organisations	Climate and energy service providers
Method of Communication	• Website • Dissemination material • Specialized workshops & training sessions • Focus groups & questionnaires • Conference presentations • Questionnaires • Social Media • Direct contact and 1:1 meetings	• Website • Dissemination material • Scientific publications • Specialized workshops & training sessions • Focus groups & questionnaires • Conference presentations • Social Media	• Website • Dissemination material • Scientific publications • Focus groups & questionnaires • Conference presentations • Questionnaires
Information Type	• Best practices • Lessons Learned • Summary of case studies • Training on the tools	• Best practices • Summary of case studies • Lessons Learned	• Information on the compete technology and its application
Aim	• Ensure tools developed are directly relevant • Share experience • Motivate early adopters	• Share experience • To promote project results as potential guidance to policy making	• Raise awareness and mobilize sector interest in compete solutions

An EnDeCli website will be developed for use by all partners, led by partner WEMC. The website, updated at least monthly, also acts as a focal point for all project external stakeholders, providing essential background project information, news updates and press releases, plus event attendance management. We will also take full advantage of LinkedIn as a platform on which to promote EnDeCli to professional groups, helping to maintain a continuous dialogue. Twitter will also be used to communicate important project milestones as well as to exchange information before and during project events.

All communication activities will be regularly evaluated for their effectiveness and impact and reviewed and discussed at project meetings. In this respect the project communication plan should retain agility in order to respond to the lessons learned and for maximum impact. Statistics tools (e.g. Google web analytics) will be adopted as important response assessment.

3. Implementation

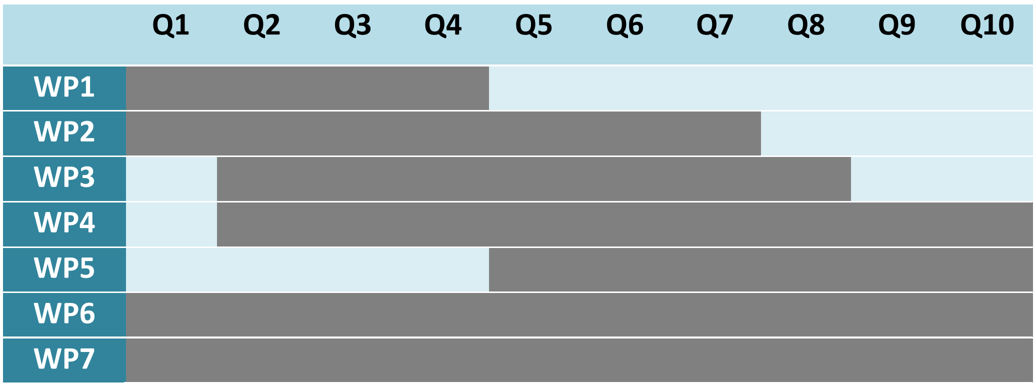
3.1 Work Plan – Work packages, deliverables

The project will be divided into 7 work-packages (WPs). The first (WP1) will define the precise issues decision-makers face in energy management decisions. After selecting a number of case studies in cooperation with WP1 and WP3, WP2 will exploit and optimize the performance of climate forecasts for the related specific decision-making problems. WP3 quantifies the value-add of climate forecast to energy decision-making. WP4 will focus on the development of the demonstrator. WP5 will implement the demonstrator in real-time decision-making. WP6 will be responsible for stakeholder engagements, dissemination and exploitation of results and WP7 will provide the project management.

As indicated in Table 2, the technical and scientific work (WPs 1 to 5) are staggered, with WP1 and WP2 starting first, at the beginning of the project. As soon as initial input from the decision making methodologies work in WP1 and some initial work on seasonal climate forecast output is available, WP3 and WP4 will also start (Q2). The implementation of the demonstrator in WP5 will then start in the second year of the project. Stakeholder engagement and communications (WP6) will occur at all stages of the project, given its key role in ensuring the profile of EnDeCli is effectively raised and a wide stakeholder base engaged in the development of the project. WP7 naturally flows across the project, from start to finish.

A detailed Gantt chart, showing the start and end dates of each task in each WP, including the sequence of deliverables and milestones per task/WP, will be prepared prior to the project. In the meantime, the details required to construct the detailed Gantt chart are provided in the WP description of work (Tables 3.1a).

Table 2 – Summary Gantt chart by quarter (Q, 10 Qs for the 30-month project duration) for each WP.



The relevance of the stakeholder engagement and communications, as well as the exploitation of results, is highlighted in the Pert chart in Figure 3: WP6 cuts across all WP and is the main link to the wider energy industry and scientific community. Also interactions amongst WPs, as indicated by the arrow in the Pert chart, will ensure constructive and fruitful internal communication and interaction in the development of all the EnDeCli outputs.

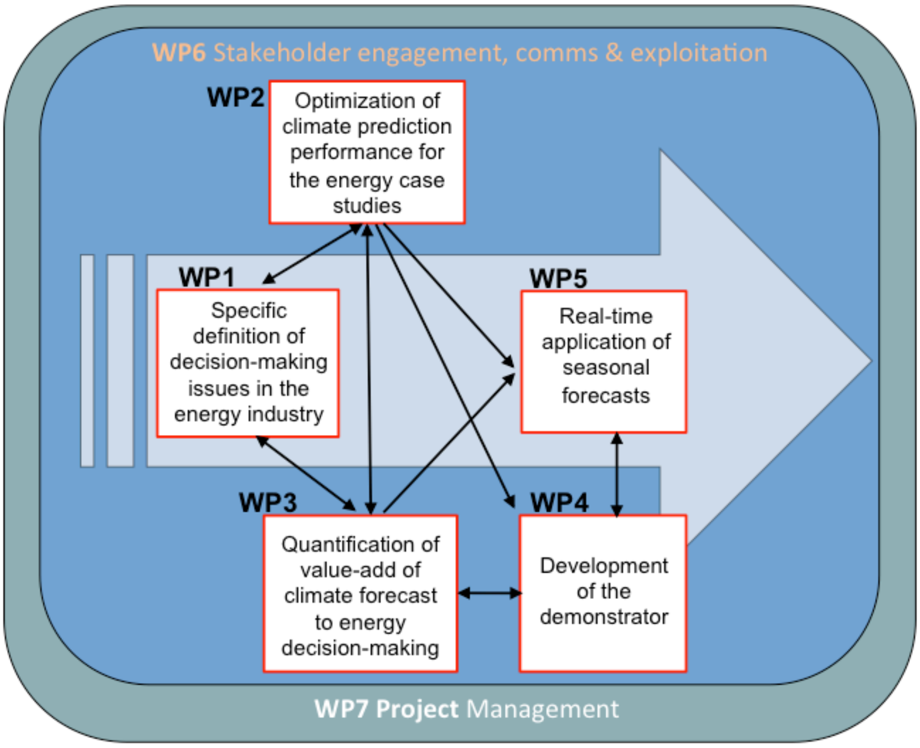


Figure 3 – EnDeCli Pert chart.

WP 1 – Specific definition of decision-making issues in the energy industry

To manage its own risk linked to its assets, a utility company has to hedge its own power production, gas & commodity supplies, and provide proper sourcing to gas/power customers. In order to do that, hedging strategies are defined, taking into account its own expectations in terms of risk strategies and market views on the main relevant commodities with a direct/indirect impact on the energy markets. Several factors have a critical influence on the final economic result and must be taken into account, such as power and gas demand forecasts, as well as power production estimation, particularly renewable-based production.

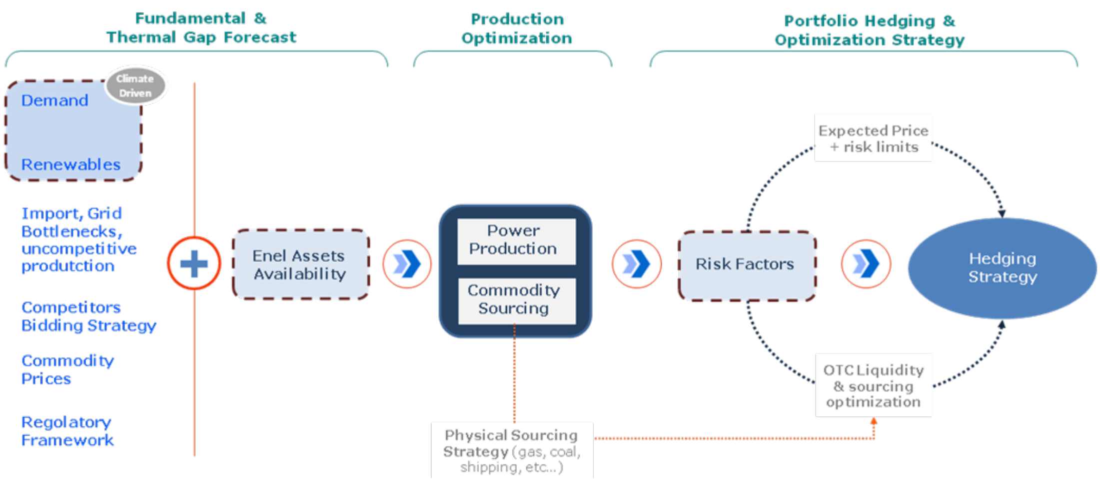


Figure 4 – Simplified diagram on the influence of meteorological variables on power/gas market

Some of these factors are driven by meteorological variables and any forecasted scenario (together with other geopolitical, macroeconomic, financial and fundamental elements) results in a specific volumetric and expected price assessment, calculated by in house developed models that translate the meteorological variables into energy variables.

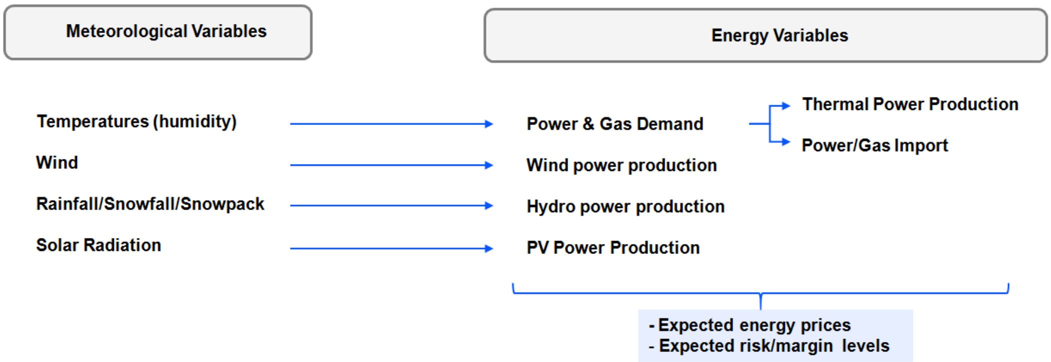


Figure 5 – Schematic relationship between meteorological variables and energy (power/gas) variables

Hedging decisions are taken on the basis of forecasted volume and price. Currently, historically normal values are used as meteorological variables beyond the 30-day time horizon. Power and gas demand models are run in real time using the historical averages of relevant meteorological variables: these will provide the benchmark for the seasonal climate forecast value-add estimation later in the project.

The potential of seasonal climate forecasts to identify significant savings in the costs related to operational expenditures in harvesting renewable energy will also be assessed in an offshore grid management case. Identifying cost savings in this sector is important since it is under continuous pressure to increase efficiency and achieve cost reduction. Thus, questions such as *How good and how far ahead is it possible to determine the accessibility of an offshore platform by boat based on weather parameters such as wind low periods and wave heights, wave period and wave direction?* will be considered.

This WP will therefore provide the basic framework for i) evaluating all the climate-dependent factors relevant to energy management decisions and offshore operational expenditures and ii) embedding seasonal climate forecasts into these decisions.

Specifically in the context of energy management decisions, the evaluation of the use of seasonal climate forecasts will be performed comparing two metrics: the *margin* and the *risk-reward* ratios. Both metrics will be evaluated for the control and test run. For each of the two metrics, the difference between the values in the two runs will provide the quantification of the value-add in the use of seasonal climate forecasts. This process is depicted in the schematic in Figure 1, for the case of energy management.

WP 2 – Optimization of climate predictions performance for the energy case studies

Cases identified by the industrial partners will be considered for specific analyses aimed at maximizing the performance of the prediction of key climate variables that will feed the assessment in WP3 of the value which climate forecasts may add to the current decision-making processes. The main focus is for the European region but South America will also be considered given the strong response to climatic factors such as ENSO (no extra modelling would be required as climate models produce global forecasts).

A workshop jointly organised by WP1, WP2 and WP3 will be arranged at a very early stage of the project to initiate discussion between climate-prediction and industrial partners. The workshop will result in final selection of case studies identified by the industrial partners and determine key climate variables/predictands for each case study.

The following case studies have already been identified amongst those which have had both a strong impact on the energy sector and for which sufficient data is available to perform a proper assessment of the added value provided by seasonal climate forecasts – additional ones may be included based on stakeholders' interest and available resource. Justification for these case studies is given on the basis of both climatological conditions and, importantly, effect on energy systems. Given the dependency of seasonal forecast skill on factors such as regions and seasons, these will also be taken into account when selecting case studies, so as to ensure robustness in our estimation of seasonal forecast value. The same case studies are discussed in more detail in terms of impact on the energy supply, demand and market in the WP3 description.

Case study 1: European heat wave of July 2015 (Lead KNMI) – In July 2015 a strong heat wave affected most southern European countries due to a persistent expansion of the Sahara anticyclone over the Continent. This circulation pattern led to an influx of very warm air to southern Europe coming from sub-tropical regions. This configuration was similar to the circulation pattern seen during summer 2003 when record temperatures were registered across almost the whole of Europe. After the latter event there was a massive rise in installation of air conditioning systems, particularly in Italy (De Felice et al., 2015), triggering an increased sensitivity of the electric market to heat episodes. The corresponding increase in electricity demand caused a strong increase in market prices to levels that were not forecasted by the econometric models, based on climatology, in the preceding spring. During this persistent heat wave an additional issue experienced by the producers was the extremely high temperatures of rivers and sea water causing severe problems for thermal electricity generation plant cooling.

Case study 2: Mild/dry NH European winter 2015-16 (Lead KNMI) – During the period of November 2015 – January 2016 a persistent high-pressure system was present over the Mediterranean basin and southern France. This synoptic configuration extended through the Alps region and southern Germany (even the UK saw the mildest December on record with marked impact on gas demand). The consequence of this weather pattern was a prolonged drought. In November 2015, only about 30 % of the normal precipitation for this month was recorded over Northern Italy. The prolonged and strong drought caused a reduction of hydroelectric power production with an associated reduction of volume of sold energy. At constant price the volume reduction produces a margin contraction but in a competitive market the scarcity of supply could cause a relevant increase of the power prices. Therefore the reduction of hydro production can force the system to activate thermal power plants, in particular the combined-cycle gas-turbine (CCGT), usually used as backup units that can be quickly powered on.

Case study 3: Strong El Niño for South America in 2015-16 (Lead UEA) – The 2015-16 El Niño is one of the largest such events of the last 50 years and, notably, the largest since the 1997-98 El Niño that shocked global food, water, health, energy and disaster-response systems. Ocean temperatures in the central and eastern tropical Pacific Ocean exceeded

2.0°C above average between October 2015 and February 2016. Atmospheric indicators showed very strong El Niño patterns such as lower than normal atmospheric pressure across the central and eastern Pacific Ocean, weakened and on occasion reversed low-level Pacific trade winds, and above-average cloudiness and increased rainfall near and east of the International Date Line. A dry period was also present in the preceding April-August 2015. This case study will therefore analyse both the El Niño 2015-16, which peaked in the SH summer, as well as its precursor period, namely from April 2015. The The ENEL group also has interests in South America where it has several assets. The direct interest of the Corporation is in Chile where it has several power plants but one cannot restrict analysis to an individual country (Chile) since the market is strongly interconnected across South America as are electricity prices. In most of South America the main source of power is hydroelectric, especially in Brazil where it provides around 75% of the national power production. The electricity market is therefore highly sensitive to meteorological shocks, particularly in terms of precipitation.

Case study 4: Spain/Wind 2014 (Lead BSC) – Two case studies have been selected: a period of below-normal average wind speed in Spain (December 2014 – January 2015) and a period of wind speed higher than usual (January 2014 – March 2014). The ENSO is the main source of predictability at seasonal time scales, especially in the tropics. In Europe, a recent work (Scaife et al. 2014) has demonstrated that key aspects of European and winter climate and surface NAO index are highly predictable months ahead. During both periods of study the NAO index value was positive. Positive phase of the NAO is associated with a decrease of the wind speed all over Southern Europe. However while the first period (December 2014 – January 2015) showed a very positive NAO index the second period (January 2014 – March 2014) showed a lower index. The 2014 annual report of Red Eléctrica de España, the Spanish TSO, states that about 21% of total power was produced by wind. This is a high level of wind power penetration that can have a significant impact on the electricity market. ENEL spa has important assets in Spain through its controlled company ENDESA so a useful prediction of the wind power production with some months of time lag can give a competitive advantage for performing portfolio adjustments. The wind power forecasts primarily have an impact on the price forecasts because the latter are a result of the ratio between supply and demand.

Case study 5: North Sea/Wind (Lead KNMI) – Case studies relevant for offshore activities and maintenance planning such as a long persistent low wind period (December 25th 2005 – January 17th 2006) will be investigated to assess the usefulness for stakeholders, particularly the Dutch TSO TenneT. A long period of low wind eases the accessibility of an offshore platform for maintenance and other activities by boat. During this specific period, a long period of low winds was seen in the North Sea region due to an extensive high-pressure area resulting in a persistent calm sea. This project will assess how good and how far ahead this low wind period, and analogous ones, can be forecasted. Similar questions will be addressed for December the 4th-6th 2013, which is a high wind period resulting in high wave heights on the North Sea, although for these shorter-lived events seasonal climate forecasts may not provide a strong enough signal. The weather parameters of interest for this case are: precipitation, wind speed, wind direction and wave heights. For these parameters we can: a) make a climatology for different periods (days, weeks, months, seasons); b) investigate the forecast skill for these periods for different area sizes and different forecast periods and c) assess the value add of using seasonal forecasts for offshore operations in terms of e.g. fuel saving (and therefore cost and emission reduction).

WP 3 – Quantification of value-add of climate forecast to energy decision-making

Based on the control and test groups described in the Methodology section, this WP will measure the value add of using seasonal climate forecasts for energy management decisions. The same case studies highlighted in WP2 will be considered here to test whether the tailored climate forecasts can improve energy management decision-making. Also, during the project several stakeholders will be consulted with the view to broaden the value-add assessment by considering additional case studies.

Case study 1: Heat wave of July 2015 in Italy – As highlighted earlier, in July 2015 there was a strong heat wave over most southern European countries with a significant impact on power and gas prices, mainly due to a large increase in both power and gas demand. Figure 6 shows the average temperatures registered in Italy during July and August 2015 compared with the 15-year average. Temperatures in July were ~ 5 °C above the climatological values. Figure 7 shows the effects of the weather extreme on the power demand; for July 2015 it reached a value of ~ 32 TWh, above the maximum over the last five years. It is interesting to compare the July situation with respect to August when more "normal" weather predominated; temperatures were close to normal values and so the power demand remained within the 5-year range.

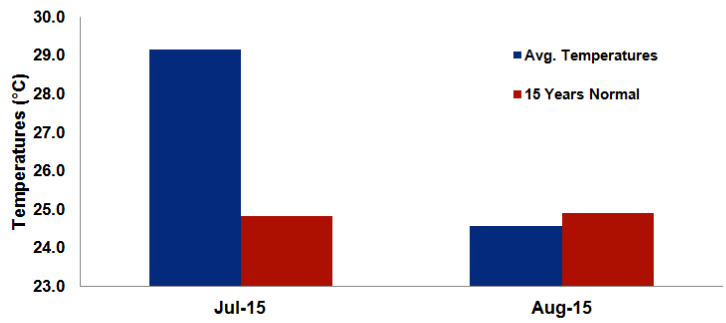


Figure 6 – Average temperatures in Italy in July and August 2015 relative to long-term average.

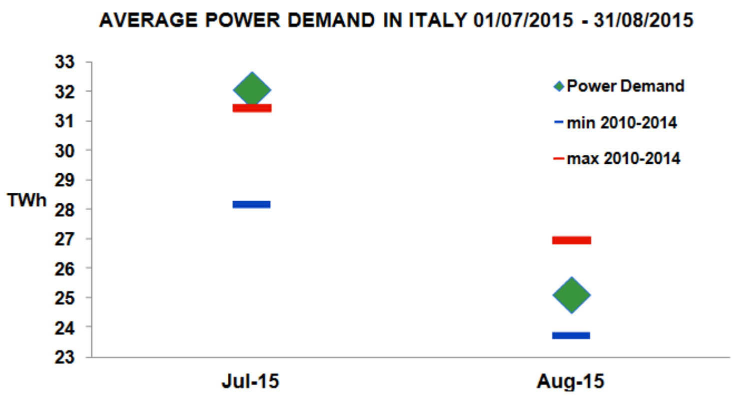


Figure 7 – Monthly demand of power in Italy during July and August 2015 compared with the 5-year period 2010-14. The green diamonds represent the actual power demand

For the purpose of managing generation assets, suppose that in May a generator decides to cover part of Q3/2015 power production by selling it at a market price level that seems to be appropriate at that moment, according to a power price market view. This power price market view takes into account several factors, such as power/gas demand scenarios coherent with climatological temperatures and a general commodities market overview. If in May the producer had access to a reliable forecast of temperatures for Q3/2015, it would have been possible to optimize the generation portfolio in a different way, not covering committing its own production and keeping a long position till the delivery period. Assume now a decision to sell 1 TWh (Figure 8) for the Q3/2015 product at a power price level consistent with market prices in May, within the range 45-55 €/MWh; if skilful temperature forecasts had been available and acted upon, correctly identifying enhanced heat wave risk, the producer could have taken the decision to keep its long position till the delivery period, selling its own production later at about 60 €/MWh (hence a differential of +10 €/MWh or 20%).

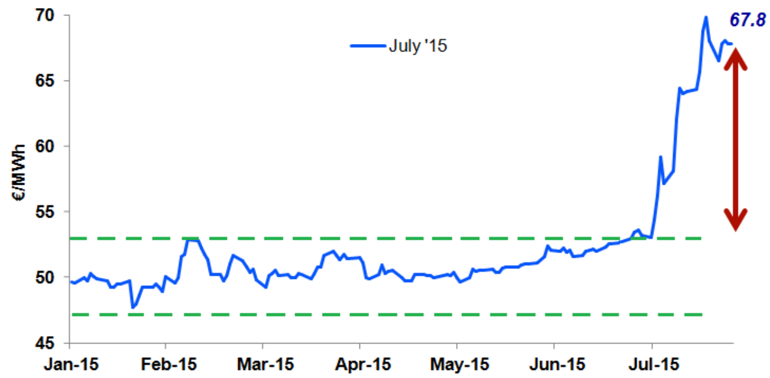


Figure 8 – Spot power prices registered in Italy during the first eight months of 2015 (blue curve). The green lines represent the range of prices within which the stakeholder decided to take some short positions. The brown arrow shows the profit potentially achieved with a better forecast of temperatures for July

Such extreme hot weather can have an indirect consequence on power production due to the reduction of cooling capability of the coal thermal power plant. Any thermal machine needs a cold source and for the coal power plant this is usually in the form of sea/river water. The cold water is pumped within the condenser of exhausted steam and then expelled at higher temperature to the sea. The Italian legislation caps the maximum temperature of waste water at 35 °C to protect the marine environment. Given this technical framework when the sea surface temperatures reach approximately 27 °C a reduction of effective plant power is necessary (*derating*). This is what happened during the end of July and August of 2015 for some plants in southern Italy. Figure 9 shows the sea surface temperature (SST) measured by the satellite infrared sensor SEVIRI close to the coal power plant at Brindisi. Mid-July the SST started to increase towards 30 °C and it remained within the range 28 – 30 °C for about 20 days.

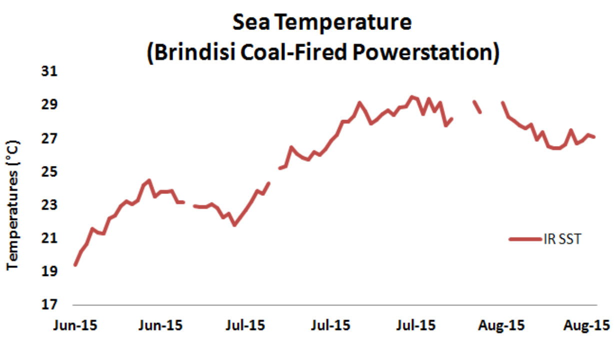


Figure 9 – The SST measured by the IR Meteosat sensors close to the Power Plant of Brindisi (Southern Italy)

The price/demand will be reforecasted using as input the macroeconomics variables known (GDP) in May 2015 and the 5 years average temperature for July as meteorological variable. This will constitute the control run. Another reforecast will be run using the forecasts of temperatures provided by ENEA using the climate models, which have been tailored specifically for use in the ENEL econometric models. The model, developed by WP2 has to be run as it would be in May 2015 i.e. using initialization data of April 2015. The demand forecasted for control and test will be compared with the actual data for the test period to get classical statistical skills (RMSE, AC, etc..). The test will be repeated on June.

With similar approach used for the demand validation, extra two sensitivity analyses will be performed in the control scenario (historical temperature average) and test climate forecasts. The simulated strategies will be created taking in account the macroeconomics, commodity and industrial data known at the test time (May 2015). At the end of the test period (30 July 2015) the risk and economic return (Expected Margin, Profit At Risk) of the two simulations will be compared.

During this task there will be a continuous sharing of information between ENEL and other WP3 partners in order to identify potential issues related to integration of seasonal climate forecasts into the econometric models.

For the same case study the sea surface temperatures (SST) will be forecasted for the period of July 2015 over some sites of interest. They will be points close to the coastline in correspondence of the main fuel power plants of ENEL. This dataset will constitute the basis for the management of the risk of power plant derating.

Case study 2: Mild/Dry Winter 2015 in Italy – Due to a prolonged drought with an extremely dry fall and mild temperatures, the end of 2015 and the beginning of 2016 were characterized on one hand by a low level of power and gas demand and on the other hand by a deficit in hydro supply production (Figures 10 and 11). During the first three months of 2016 the actual hydroelectric production (red line) was almost half of the energy produced during the same period of 2015 (red ellipse). It was even lower than the minimum of 5-year range. There was a similar situation in the period of October – December 2015 (green circle).

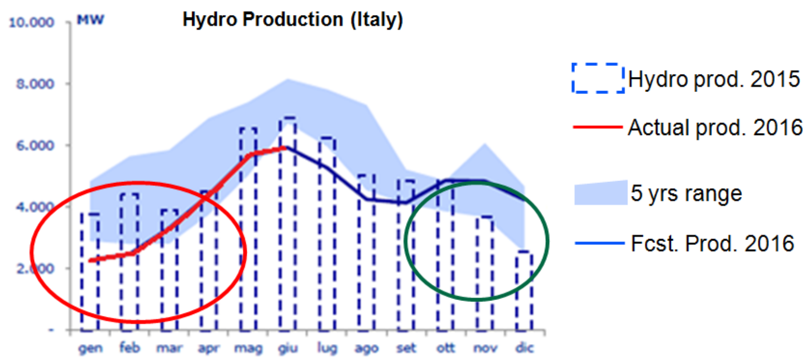


Figure 10 – Actual production hydro for the first months of 2016 (red curve) compared with the 5-y range and actual values of 2015

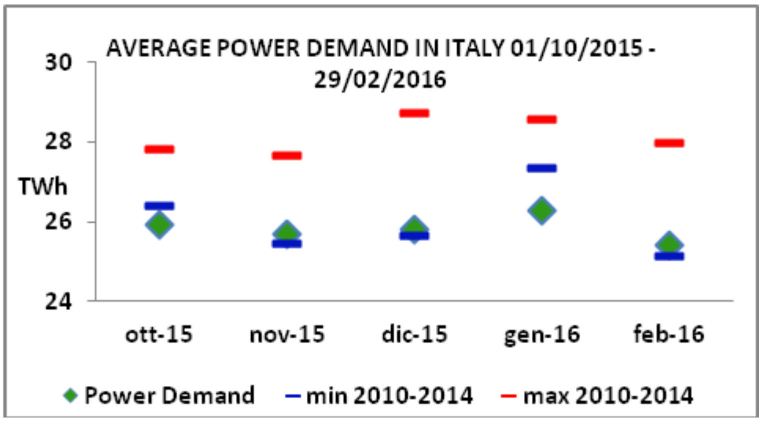


Figure 11 – Monthly demand of power in Italy during October 2015 – February 2016. The green boxes represent the actual power demand

The combined effect of low demand and hydro deficit led to an increasing Italian spark spread level. The spark spread level is the difference between power prices and gas prices, in other words the revenue of a power generator minus the costs linked to the power energy produced. Suppose now that in September a power generator decides to hedge a part of its own CCGT electricity production, 1 TWh (example figures), for Q4/2015 at a spark spread level coherent with the current market level which was equal to ~4 €/MWh in mid Sept'15, because of its own bearish view of the market. If, say, in August the power generator had a reliable forecast of temperature and precipitation for Q4/2015, it would have been possible to optimize the generation portfolio in a different way, keeping a spare position till the delivery period. With the term "spare position" we mean that the generator does not sell the product until closer to the delivery time. Looking at Figure 12 a "posteriori", selling the Q4 2015 product in September is not the best choice when, with a "good" forecast of hydro production, we could get more income selling the product later. In this case the generator would have sold its own production at a spark spread level equal to about 12€/MWh (the delivery spark spread level of Q4/2015).

The main variable will be rainfall/snowfall contribution over the regions of Alps/Appenini region and temperatures. The spatial/time resolution of the variable will be defined upon the needs of ENEL and the scientific advice of WP3 partners**.** The scientific partners will provide knowledge on the best choice in terms of resolution of the meteorological variables and any possible combination of them as source input, and the MO will choose the most suitable tailoring techniques from the tailoring toolbox to make the climate model output suitable for use in ENEL models.

The hydroelectric production will be predicted feeding an ENEL proprietary physical/industrial production model with the rainfall/snowfall/snowpack coming from the climate model (WP2) and also using the historical average for comparison purposes.

As an additional impacting factor, the forecasts of temperatures are important for the prediction of the gas demand, which ultimately drives gas prices. The gas demand will be predicted up to 6 months in advance using ENEL proprietary model of gas demand. The model will be fed with the macroeconomics data available at the proper start time (i.e. October 2015) and with the temperatures forecasted by climate model. A control run will be done using the 5-years average of temperatures as forecast input.

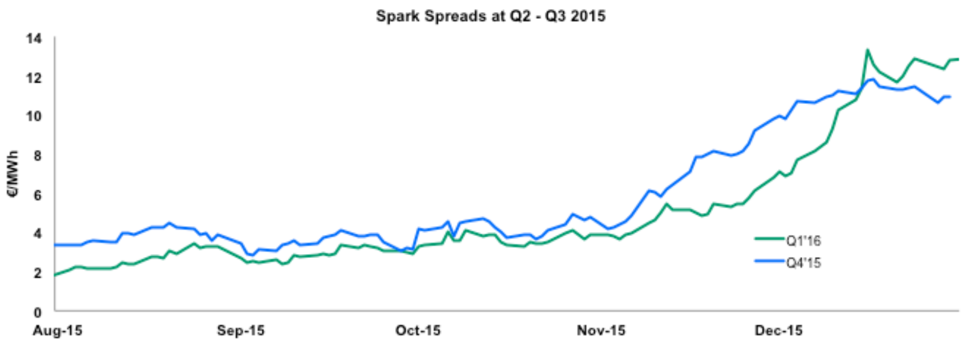


Figure 12 – Financial product future "spark" with delivery as Q4 2015 and Q1 2016

Case study 3: Dry period in South America in April-August 2015-16 – In South America hydro technology is a very important component of total electric production. Table 1 shows the contribution of hydro sources in several countries; in Brazil it reaches a value of about 75% of the total production. Given such a system it is quite obvious the impact that precipitation variability can have on the power market and associated risk exposure.

Table 3 – Contribution of the hydroelectric production for some South American countries

	Total Elec Production (GWh)	Hydro sources (GWh)	Hydro sources	Year
Argentina	125,929	32,720	**26%**	2013
Brazil	552,498	415,342	**75%**	2012
Chile	69,964	23,459	**34%**	2014
Colombia	62,197	18,839	**30%**	2014
Peru	45,549	22,210	**49%**	2014

When droughts occur the electricity system needs to cover the hydro shortage using thermoelectric technology. The traditional thermo power plants are usually quite old and inefficient and their use leads to peaks in power prices. In the event of severe droughts in some countries the thermo plants may not be sufficient for covering the hydro shortage and black outs can occur.

The power market in South America is less developed relative to that in Western Europe. It is less liquid and mainly driven by long term auctions (10-20 years). In some countries (Brazil, Chile) there is a rising open market for the big consumers (industries, mines,..) but the retail market is still regulated by the public Authorities.

Our case occurred in June 2015 when in Chile there was only about 30% of the normal rainfall during the rainy season. This scarcity of water forced producers to start up thermoelectric power plants with the consequence of buying fossil fuels. If the producer had reliable rainfall forecasts 2 or 3 months in advance it may have been possible to better balance the generation portfolio. Brazil, Colombia, Argentina and Peru are other regions of special interest for ENEL because the main concentration of the company's assets is in these regions.

This case will involve mainly the variables linked to the hydrology. As well as for the case 2 the hydroelectric production will be predicted feeding an ENEL proprietary physical/industrial production. The power demand will be predicted in order to derive the prices on the market. The numerical results will be validated with statistical approach with respect to the actual historical data of power consumption and prices. Then the effects on the margins and on the risk-reward management will be verified for the two strategies implemented upon the control and test forecasts.

This task will involve a relevant extra effort due to the collection of financial data. In addition the econometric models have to be optimized for the characteristics of the market of Southern America. It will be needed to share the work with representatives of the controlled divisions operating on the market under consideration (Endesa Chile, Endesa Brazil, ...) and to undertake a good level of communications with local specialists.

Case study 4: Wind power in Spain – With the high wind power penetration into the Spanish electricity market, wind is the main driver of the spot price in Spain, and sometimes there is a negative correlation between wind production and the spot prices.

Figure 13 shows historical data of wind production (green line) and spot prices (brown line). The green and red circles show two interesting cases with opposite characteristics:

1. January 2014 – March 2014. Wind was stronger than average during this period and the spot prices reached very low values (almost a record low for this time series)
2. December 2014 – January 2015. Wind speeds were lower than average and the spot prices were sustained due to this shortage of wind power.

In a similar way to Italy, when there is a shortage of an important power production asset the market players have to increase the production from other sources, typically from coal and gas. Also, hydro can provide an important contribution to the power production. If, as an example, in October 2014 the operator had a reliable forecast of wind production and temperatures it would have been possible to optimize the commercial strategy and the production assets. For example it would make sense to sell most of the Q1 ’14 in October - November 2013 in order to maximize the margin.

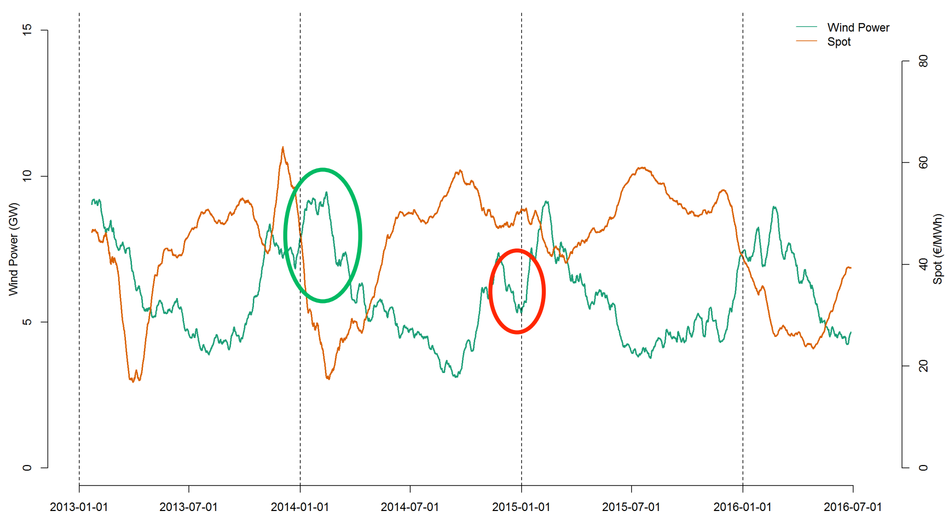


Figure 13 – Actual wind production compared to spot prices for Spain. The red circle shows a period of abnormally low winds. The green circle shows a period of wind higher than usual – the corresponding spot prices were at record low

For both periods, the wind power production will be forecasted applying the predicted winds to a wind power model. As with the previous cases, in case study 3 there will also be a control run using climatological averages of the wind as forecasts and a test one performed using the winds predicted by climate models. These two periods are interesting because they explore the situations whereby a shortage or an oversupply of production has occurred. From the point of view of the market they have opposite effects on the power prices and consequently different energy management decision need to be taken. In addition a better forecast of the wind production can help the TSOs to an achieve an improved grid balance. In fact the wind farm are not equally distributed over the country and strong winds can create local congestions on the transmission/distribution grid.

Case study 5: North Sea/Wind – For off shore maintenance planning meteorological parameters such as windspeed, significant wave height and mean wave period are important. The effect of meteorology on maintenance planning for wind parks in the North Sea is illustrated for the Doggersbank, located in the centre of the North Sea. For the winter months December and January, the number of days that meet the criteria for access by boat are compared for the winters of 2005/2006 and 2013/2014. Using the preliminary values for the thresholds provided by one of the stakeholders it can be concluded that the winter of 2005/2006 maintenance planning was hardly hampered by the weather. On the other hand, in winter 2013/2014 there are only a few days when the criteria for the most cost efficient form of maintenance are met. A reliable forecast of these parameters will help in the cost reduction. This case study will be used to determine the meteorological parameters of interest for decision making in off shore activities and assessment of the value add of forecasts.

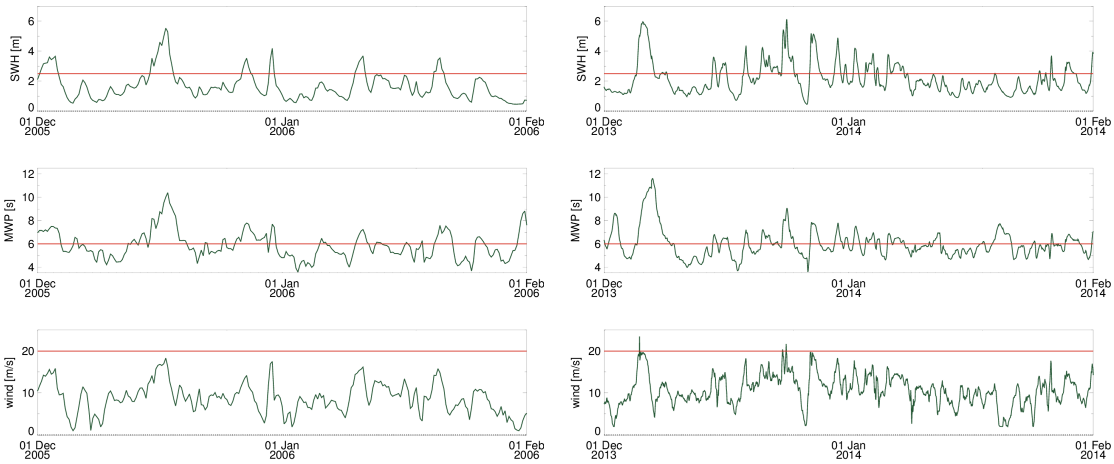


Figure 14 – Significant wave height, mean wave period and windspeed for the winter of 2005/2006 (left panel) and 2013/2014 (right panel). Thresholds for offshore maintenance planning are indicated by the red lines. The timeseries are indicative for the central area of the North Sea

The results obtained with this WP will feed into WP4 and mainly WP5. In fact the best practice developed in this phase of EnDeCli will be applied for the real time application of the seasonal forecast to the decision-making processes implemented within ENEL, and possibly other stakeholders (e.g. TenneT).

WP 4 – Development of the demonstrator

An online interactive demonstrator/prototype will be developed to provide a demonstrator climate service during the evaluation of the case studies based on the ongoing output of WP2 and WP3. It will be developed according to energy industry user needs, and in close collaboration with the industrial partners in this project. This demonstrator will allow analysis of seasonal climate forecasts for different variables and regions and will include a user friendly way to assess past performance of the required forecasts.

The demonstrator will leverage work developed by other projects such as the FP7 EUPORIAS' prototype for the wind energy sector and the demonstrator being developed under the Copernicus Climate Change Service (C3S)'s European Climatic Energy Mixes. This WP will also produce a roadmap on operationalization of the service based on the proposed demonstrator. The roadmap will address issues such as: data dependencies; data stream requirements; procedures for climate and energy variable calibration; update cycles and system improvements.

As for the software development of the demonstrator, several options are available. Given this is a fast evolving area, we believe more effective solutions can be selected shortly after the project starts. In fact, several new important developments are currently happening, including with the direct involvement/lead of some of the partners in the EnDeCli consortium (e.g. the UKKO project led by BSC or the ECEM climate service led by UEA). Therefore, we will properly assess what the market offers nearer the time, rather than locking ourselves now into a fixed solution that may turn out to be unsuitable or not cost effective. A proper selection process will be put in place at the early stages of EnDeCli (note that the cost of this task is estimated to be around 2% of the overall EnDeCli budget).

WP 5 – Real-time application of seasonal forecasts

With the demonstrator developed in WP4, this WP will assess the effectiveness of seasonal climate forecasts of the upcoming seasons in an operational setting. Operational seasonal forecasts will be accessed and post-processed (according to findings in WP2-3) in near-real time. These forecasts will then be used for portfolio management decision-making, following the approach in WP3, and ensuring the value-add of seasonal forecasts is appropriately measured and reported. Results obtained from decision-making processes of the different industrial partners will enable a more robust quantitative estimation of the use of seasonal forecasts for energy industry decisions.

Offshore grid management is used as an additional minor example to prove the useful value of seasonal climate forecasts. Specifically, accessibility of an offshore platform by boat will be used to demonstrate the use of the demonstrator. The value-add of forecasts for maintenance planning may also be considered.

WP 6 – Stakeholder engagement, communications and exploitation of results

The World Energy & Meteorology Council will engage stakeholders and communicate the added value of the tools developed by EnDeCli to other relevant energy management stakeholders. The development of concepts and best practices will lead to replicability and marketability of the proposed climate service. This will lead to ready-to-use services that will demonstrate the added value of using climate information and services by end-users in their operational decision-making.

The activities of this WP will be guided by a carefully developed stakeholder engagement and communications plan, as well as a plan for the exploitation of EnDeCli results. Initial plans have been drafted in section 2.2. These will be expanded at the start of the project, and then regularly refined and evaluated during the project. The aim of this plan is to markedly broaden the stakeholder base of EnDeCli results and products and to pro-actively seek opportunities for their exploitation. The target communities are: i) the energy industry, which will be provided with distinctive examples of how seasonal climate forecasts can be used to ameliorate decision making, along with practical tools but also inspiration for further climate services development, ii) operational climate service providers, who could further refine or replicate the tools developed by EnDeCli to turn them into a commercial product, and iii) the scientific climate community, which may use the project results in order to improve the formulation of climate models and therefore their skill.

WP 7 – Project Management

The UEA will manage the project by ensuring that each partner is fully engaged with the goals of the project and has allocated adequate resources to produce the planned deliverables, that all pre-requisites to achieving them are in place, and where needed that they are adjusted to take into consideration any intervening issues. A project communication plan will also be produced.

Importantly, this WP will ensure deliverables are completed within the planned timeline. Financial aspects as well as report preparation & coordination of the project are also the responsibility of this WP. The project manager will also be responsible for the preparation and maintenance of a project risk register.

A draft management and implementation plan, which will be refined before the start of the project, is presented in Section 3.2.

Work Package description (Tables 3.1a)

Work package number	1	**Lead beneficiary**			ENEL	
Work package title	Specific definition of decision-making issues in the energy industry						
Participant number	1	2	3	4	5	6	7
Short name of participant	UEA	ENEL	ENEA	BSC	KNMI	MO	WEMC
Person months per participant:	0	18	2	2	2	2	2
Start month	M1			**End month**	M12		

Objectives

The goal of this WP is to define the needs of energy stakeholders in terms of meteorological variables and predictability. While the initial focus of this WP is on ENEL's requirements , this assessment will be extended to a wider range of stakeholders. Accordingly, this WP will provide the basic framework for i) evaluating all the climate-dependent factors relevant to energy management decisions and ii) understanding how seasonal forecast can be embedded into these decisions for a variety of stakeholders.

Specific targets are:

- Definition of the meteorological variables of interest for the Stakeholders. They will be chosen upon the their impacts on the power market and it will define the basic ground for the WP2 activities through the definition of the spatial resolution of each predictand on the basis of the needs of ENEL and other stakeholders and the limits of models's skills, compared to the state of the art scientific capabilities available.;
- Definition of decision making process applied to energy management and hedging evaluations from climate-driven energy forecasts based on processes of ENEL and other stakeholders. Understand how real time forecasts could be embedded in existing decision making processes. For ENEL, embed current state of the art real-time forecasting in existing processes for use as a baseline to WP3. For Tennet, identify climate-dependent factors relevant for offshore operational expenditures and investigate the options to quantify the value add of seasonal forecasts for use as a baseline to WPs 2 and 3.
- A literature search and a possible survey about the decision-making methods being used by other industrial players in the context of seasonal climate forecasts, even within different business lines, will also be conducted. For example, shipping companies could be interested to climate forecasts in order to assess risks for navigation.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

Task 1.1 – Drafting of reports with details on the decision making-issues, and current use of long-range forecast or climate information, across the energy sector. There will be reported which variables are important for each industrial process and/or for the power market. Dedicated work will have to be done to describe the power market of Iberia and Latin America and to define procedures for portfolio strategies. Dedicated work will also be done to describe decision making-issues related to off shore energy production in the North Sea. This work will also draw on ongoing EU projects to understand the needs of the energy industry with respect to climate information (e.g. EUPORIAS, CLIM4Energy, ECEM)

M1–M6[2] [PM 17]: **ENEL** [9], BSC [2], KNMI [2], MO [2], WEMC [2]

Task 1.2 – At ENEL power and gas demand models will be run in real time using the historical averages of relevant meteorological variables: these will provide the benchmark for the seasonal climate forecast value-add estimation.. During this process there will be a sharing of information with WP2 in order to define what can be precisely obtained from the climate models. This process will proceed step by step within the WP1 work using mainly the usual communications tools (email, phone,…) and with informal meetings.

M1–M6 [PM 11]: **ENEL** [9], ENEA [2]

Deliverables (brief description and month of delivery)

D1.1 Delivery of the basic framework for evaluating all the climate-dependent factors relevant to energy management decisions. [Lead ENEL; Month 3]

D1.2: Description of current state of art use and potential uses of climate forecasts within ENEL and other stakeholders (example, Use of historical averages and NMME). [Lead ENEL; Month 6]

D1.3 Real time application of current methodologies within ENEL aimed to provide WP2 with basic data as input for first level optimizations and details about the type and spatial resolution of meteorological variables chosen for the forecasts. Description of the framework of the decision process. [Lead ENEL; Month 12]

D1.4 Workshop with other stakeholders for sharing of details on the decision making-issues and current procedures used within the Stakeholders, and to elicit potential future uses. [Lead ENEL; Month 6]

[2] Conventions in WP tables: total PM per task, lead partner in bold and allocated PM by partner in square bracket.

Work package number	2	Lead beneficiary				KNMI
Work package title	Optimization of climate prediction performance for the energy case studies					
Participant number	1	2	3	4	5	6	7
Short name of participant	UEA	ENEL	ENEA	BSC	KNMI	MO	WEMC
Person months per participant:	15	2	7	12	27	4	0
Start month	M1			End month	M22		

Objectives

Cases identified by the industrial partners will be considered for specific analyses aimed at maximizing the performance for the prediction of key climate variables that will feed the assessment in WP3 of the value climate forecasts may add to the current decision-making processes.

To go behind current limitations of prediction performance for the key climate variables considered in the case studies the multi-model approach will be used. A multi-model seasonal prediction dataset from independent sources will be developed.

Multiple strategies will be implemented in order to obtain the better combinations of independent Seasonal Prediction Systems (SPSs) that are able to maximize the reliability, usefulness and potential economic value to end-users for each specific energy application considered in the case studies. This will constitute the fundamental knowledge that will be later used for the development of the demonstrator in WP4 and the operational real-time tailored application of seasonal forecasts in WP5.

Robust spatio-temporal correlations between climate variables that may affect energy demand/production will be identified, by using long observational data records together with the multi-model Seasonal predictions, to assess conditional probabilities of specific events of relevance for the energy applications.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

Task 2.1 Development of seasonal prediction dataset from independent sources such as European, North American and Asian Pacific.

The Seasonal Predictions from the European, US and Asian Pacific datasets that fit with minimum requirements (accessibility, variables availability, forecasts issuing dates, time and space resolution), and that may be operationally available for WP5, will be collected in a retrospective dataset available to all partners in a dedicated project server.

Preliminary quality check and selection of the models passing specific minimum requirements (resolution, output variables, start dates, etc...) and space/time homogenisation for each key predictand. Different bias-correction and calibration techniques will be tested by KNMI (Case Study [CS] 1 and 2), UEA (CS3) and BSC (CS4), also accounting for the sensitivity of the forecast bias on climate change and/or internal variability modes (Alessandri et. al. 2011, Lee et al., 2013; Fuckar et al, 2014). MO will perform preliminary evaluation of different tailoring techniques and will provide example files of tailored data to stakeholders in WP1 and WP3 to decide upon format of final calibrated data outputs

M1–M10 [PM 20]: **UEA** [8], BSC [5], KNMI [3], MO [4]

Task 2.2 Observational and reanalysis datasets, hindcasts and extreme events assessments

Observational datasets are compiled by the European National Meteorological Services (NMSs) in the European Climate Assessment & Dataset and made available as the E-OBS gridded observations for temperature (daily max., min. and average) and daily precipitation amount (Haylock et al. 2008). E-OBS extends back to 1950 and is updated monthly. The horizontal resolution is currently 0.25˚x0.25˚, it is expected that the resolution will be increased to 0.1˚x0.1 at the start of this project.

The data relevant for the different case studies can be extracted from this dataset and combined to obtain relevant indices, for example for case study 1 (heat wave July 2015) a relation between energy demand and high summer temperatures can be quantified using the Cooling Degree Days index.

For Case Study 3, the South America case, daily precipitation observations from South America will be obtained from the Latin American Climate Assessment & Dataset (LACA&D, http://lacad.ciifen.org/), which has been set-up in collaboration with KNMI. The observed rainfall for this case, as well as for other (more severe) El Niño years are used in a hind cast analysis to estimate the skill of the seasonal forecast with a lead time of 2 to 3 months.

Extremes in weather parameters relevant for energy demand and energy supply will be investigated using a weather forecast model-based dataset representing a 5000-year period of the present climate (van den Brink et al. 2004, 2005).

Observational data from energy stakeholders will be cross correlated with these datasets to assess the added value of these observations.

Sub Task 2.2.1 Host the datasets and create data-access tools for the consortium partners for the purpose of processing/analysing. The amount of data is estimated to be several TB's.

M1–M10 [PM 10]: **KNMI** [10]

Task 2.3 Maximization of the performance of the MME seasonal predictions using multiple strategies in selecting the better combinations of independent SPSs

A best forecast selection concept (BFSC) approach will be implemented to maximize the performance for key predictands (climate variables considered at the time and space scales proper for each application) for each energy application.

To obtain the climate predictand at the time and spatial scales required by the industrial partners, ENEA will further perform statistical downscaling/upscaling including exploitation of the prediction signal from the local scale and from remote teleconnections.

KNMI will carefully evaluate the skill of the seasonal forecasts for precipitation as a function of the space-time scales at which this predictand is averaged. To obtain appropriate (and relevant) areas/times at which the skill can be increasingly useful for the energy applications, the procedure of using amounts of rainfall cumulated in longer/larger time/space scales will be pursued.

To make the selection of SPSs more robust with respect of the relevant climate phenomena that may affect the key climate variables over the region of interest, the selection of models will try to properly represent SPSs able to maximize both the skill coming from local processes (soil moisture, snow and vegetation) and the ability to maximize the skill coming from tropical-extratropical teleconnections. As an example of remote phenomena for boreal summer: the models capability to represent and predict Asian monsoons will be carefully evaluated because of the related teleconnections to the Euro-Mediterranean region.

A reduced number of precursors, i.e. potential predictands for heat waves and droughts will be selected and multi-variable skill scores will be developed to compare the individual forecast systems from the EUROSIP, NMME and SPECS datasets in their ability to forecast these predictors (Prodhomme et al 2015). A selection of the best forecast systems will be made based on a ranking according to the multi-variable skill scores

A link will be established with ongoing and future international modelling efforts trying to improve the available prediction systems (e.g. EU FP7 projects such as SPECS and NACLIM). This will be achieved by participating in international meetings/conferences and by inviting coordinators of related international programmes/projects to attend EnDeCli project meetings (e.g. joint WP1, WP2 and WP3 workshop; M1.1). When significant and robust advancements are verified from the very latest developments of the prediction systems that can be applied in the operational forecasts (Link to WP4 and WP5), we'll evaluate application of such modelling improvements in terms of added skill/value on the identified key predictands for each case study. BSC will analyse the advancements due to the implementation of new seasonal forecast systems for the wind energy indicator (e.g. ECMWF S5, when available).

M6–M22 [PM 35]: UEA [7], **KNMI** [14], ENEA [7], BSC[7]

Task 2.4 Feedback from industrial stakeholder

As the main industrial stakeholder of the project, ENEL will interact closely with WP2. Specifically, feedback from ENEL will be provided to both WP2 and WP4 about the response of the econometric models and renewable energy models to the climate input. This exchange will be performed using common communication tools (email, phone, Skype…) and through several informal meetings. ENEL will also share some basic experience acquired within the company on the use of the NMME system.

M1–M22 [PM=2]: **ENEL** [2]

Deliverables (brief description and month of delivery)

D2.1 Observational dataset delivered and preliminary analysis of return times of extremes in the seasonal climate variables relevant for energy demand and energy supply [Lead KNMI; Month 6]

D2.2 Report on preliminary evaluation of different calibration techniques and example files of calibrated data to stakeholders for WP1 and WP3. [Lead MO; Month 9]

D2.3 Report on the assessment and of maximum skill and procedure to maximize performance to end-users for each case study. [Lead KNMI; Month 19]

D2.4 Report on the response of the econometric models and renewable energy models to the climate inputs. [Lead ENEL; Month 19]

D2.5 Report on the capability of the very latest advancements in the prediction systems from the ongoing international efforts to overcome limitations in forecasting the key predictands, for each case study. [Lead ENEA; Month 22]

Work package number	3	Lead beneficiary			ENEL	
Work package title	Quantification of value-add of climate forecast to energy decision-making					
Participant number	1	2	3	4	5	6	7
Short name of participant	UEA	ENEL	ENEA	BSC	KNMI	MO	WEMC
Person months per participant:	2	34	9	12	15	14	0
Start month	M4			End month	M24		

Objectives

- Define and disseminate a 'toolbox' of tailoring techniques suitable for deployment in a range of industry models.
- Undertake specific tailoring of calibrated forecast output to the requirements of the econometric models of ENEL for use in case-studies, and to feed into WP5 real-time forecast.
- Quantification of the value-add of the climate forecasts for the management of industrial risk.
- As value-add we mean the improvement on effectiveness of the energy management and hedging decisions based on the skills of the enhanced climate forecasts.
- Define criteria of objective validation of the improvement on gas & power price/demand forecasts by statistical approach and price/renewable power production forecast by physical/industrial approach.
- Define criteria for the subjective validation of the improvement of decision process to portfolio management.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

The work will start with the collection of all historical financial data.

Task 3.1

a) Design and document verification methodology for value of long-range forecasts through the use in the case studies

b) Design, document and disseminate toolbox of tailoring techniques for use on generic and semi-generic long-range forecast data for integration directly in econometric models and decision making processes using intelligence on user need from WP1. Select and apply tailoring techniques from the toolbox for use by ENEL in case studies.

M4–M10 [PM 12]: UEA [2], ENEA [1], KNMI [1], **MO** [8]

Task 3.2 Case 1: Heat Wave

The price/demand will be reforecasted using as input the macroeconomics variables known (GDP) in May 2015 and the 5 years average temperature for July as meteorological variable. The multi-model developed in the WP2 will be considered for the summer 2015 (May, June and July) at one month lead time, i.e. using initialization data of April 2015, and the techniques from the tailoring toolbox will be further applied/developed for use by ENEL. The demand forecasted for control and test will be compared with the actual data for the test period to get classical statistical skills (RMSE, AC, etc..). The test will be repeated on June.

For this case the sea surface temperatures (SST) will be forecasted for the period of July 2015 in order to manage the risk of coal plants derating. During this task there will be a continuous sharing of information between ENEL and WP3 partners in order to catch potential issues generated by incorporating the climate forecasts onto the econometric models. After the work done in WP2 the optimization on the climate forecasts models/procedures will continue in tandem with their application within the industrial partner.

M4–M22 [PM 13]: **ENEL** [8], ENEA [4], KNMI [1]

Task 3.3 Case 2: Mild/Dry Winter 2015 in Italy

For this case study the main variable will be rainfall/snowfall contribution over the regions of Alps/Appenini region and temperatures. As well as for the previous case the spatial/time resolution of the variable will be defined upon the needs of ENEL and the scientific advice of WP3 partners**.** The scientific partners will provide knowledge on the best choice in terms of resolution of the meteorological variables and any possible combination of them as source input, and the MO will choose the most suitable tailoring techniques from the tailoring toolbox to make the climate model output suitable for use in ENEL models.

During this task there will be a continuous sharing of information between ENEL and WP3 partners in order to catch potential issues generated by incorporating the climate forecasts onto the econometric models and the MO will choose the most suitable tailoring techniques from the tailoring toolbox to make the climate model output suitable for use in ENEL models.

M4–M22 [PM 12]: **ENEL** [8], ENEA [3], KNMI [1]

Task 3.4 Case 3: Dry period in South America April-August 2015

This case study is similar to the previous one, it is focused on the effects of ENSO on the hydroelectric production in Southern America. WP2 will provide the best reforecasts of rainfall/snow pack over LATAM region with special attention for the Northern Brazil and Chile for the period April – August 2015.

The effects on Stakeholder margins will be verified for the control and test strategies used to construct the portfolio. In this case the strategies will be constructed taking on account of the peculiarities of the power markets in Southern America.

M9–M21 [PM 14]: **ENEL** [10], MO [4]

Task 3.5 Case 4: Spain/Wind

Based on financial data provided by ENDESA and in cooperation with it ENEL defined as case studies two periods of interest: January 2014 – March 2014 with winds stronger than usual and December 2014 – January 2015 for low wind case.

The wind production will be forecasted for the period of interest using the historical average and climate forecasts. Using the ENEL models the power demand and total production will be forecasted in order to predict the market prices. As well as for the previous. There will be a control run based on historical average of winds and the test run based on climate forecasts provided by WP2. As well as for the previous cases the forecasted values of power demand and prices will be validated against the actual data implementing two different portfolio strategies.

As well as for the WP1 information will be shared with WP2, WP4 and WP5 people on each technical aspect of the output from the climate models, prediction skills and the best way hot use them within the econometric models. The sharing will be done in a two-way approach: a feedback from WP3 will be provided to WP2, WP4 and WP5 about the response of the econometric and renewable energy models to the climate input. This exchange will be performed using common communication tools (email, phone, skype…) for the day-by-day work and with some informal meetings. Two or three main meetings are planned as listed in the milestone tables. There will also be a need to share some technical information about the proprietary renewable production model within the limits imposed by the industrial and corporate confidentiality and non-disclosure agreements.

M9 – M21 [PM 22]: **ENEL** [8], ENEA [1], BSC [12], KNMI [1]

Task 3.6 Case study 5: North Sea/Wind

Based on archived data from the ECMWF wind, precipitation and wavedata the issues defined in WP1 for the offshore energy industry are investigated. An example of use of seasonal forecasts where clear criteria for value add assessments can be identified are the decisions for offshore activities related to operational management. Tailoring techniques will be used to make the model output easily accessible for the end users. The most cost efficient maintenance access depends on parameters such as wind and wave height. The costs of this will be compared with the fall back option. Obviously depending on the skill of medium term forecasts you can better and longer ahead plan operational activities leading to a cost reduction. The quantification of the value add of seasonal forecasts is part of this task.

M9 – M21 [PM 11]: KNMI [11]

For all case studies the evaluation will be performed comparing two metrics: the margin and the risk-reward ratio. Both of these metrics will be evaluated for both the control and test run. The difference in each metric between the two runs will provide an estimation of the value-add in the use of seasonal climate forecasts.

Task 3.7 – Document and disseminate verification results

M22 – M24 [PM 2]: **MO** [2]

Deliverables (brief description and month of delivery)

D3.1 Delivery of the preliminary results from the objective and subjective validation. Review of the state of art of climate forecasts on the basis of econometric forecasts and economic performances. [Lead ENEL; Month 9]

D3.2 Delivery of preliminary results for case 3, 4 and 5 with the description of the case studies and first subjective validation results. [Lead ENEL; Month 18]

D3.3 Delivery of final results for objective and subjective validation for cases 1 and 2. [Lead ENEL; Month 21]

D3.4 Delivery of final subjective and objective validation results for case 3, 4 and 5. [Lead ENEL; Month 21]

D3.5 Dissemination of final verification results [Lead MO; Month 24]

Work package number	4	Lead beneficiary			BSC	
Work package title	Development of the demonstrator					
Participant number	1	2	3	4	5	6	7
Short name of participant	UEA	ENEL	ENEA	BSC	KNMI	MO	WEMC
Person months per participant:	6	6	0	22	4	2	0
Start month	M4			**End month**	M30		

Objectives

The objective of this WP is to create an online interactive demonstrator/prototype of a climate service that will be used as the source of seasonal climate information during the evaluation of the case studies in WP2 and WP3 and will integrate the real-time seasonal forecast produced in WP5.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

Task 4.1 Define the user's requirements

The demonstrator will be developed through a close cooperation between WP4 and ENEL as the main industrial stakeholder. There will also be a continuous exchange of information and feedback with WP5 about the accessibility and the organization of the final products developed by WP2 and WP3 so as to make the demonstrator easily usable by ENEL in the first instance, but possibly also by other interested stakeholders (e.g. TenneT).

The requirements of the users in terms of meteorological variables, energy indicators, definition of the spatial resolution and predictability will be based on WP1 outputs (e.g. D1.2) as well as the decision-making issues assessed and the climate information needs for the case studies defined in WP2 and WP3. The requirements and features expected for the demonstrator will also use baseline information of user's requirements reported in other projects such as the FP7 EUPORIAS' prototype for wind energy sector (www.project-ukko.net) or the demonstrators being developed under the Copernicus Climate Change Service (C3S)'s European Climatic Energy Mixes and Clim4Energy.

Additionally interviews with ENEL and other stakeholders in the energy sector will be carried out to refine the requirements and specify features for the interface. Other methods for gathering additional information and user's requirements such as workshops or on-line webinars might be used taking advantage of synergies with other projects that involve the EnDeCli partners.

Knowledge acquired in WP2 will be exploited for the demonstration and operational purposes. In cooperation with the industrial partner, the most important features from the BSFC and robust model selection criteria will be identified to be included in the interface for the base case studies (and additional ones considered on stakeholder's requests).

M4–M12 [PM 9]: **UEA** [3], ENEL [1], BSC [2], KNMI [2], MO [1]

Task 4.2 Build a mock-up demonstrator

A first mock-up version of the demonstrator will be created including the information requirements and the features gathered in Task 4.1. The aim is to have a preliminary version to provide a first preview of how information will be accessed and displayed through the on-line interface. To this purpose the case studies defined in WP2 and WP3 will be used.

M6–M18 [PM 9]: UEA [1], **BSC** [8]

Task 4.3 Evaluate the mock-up demonstrator

After the mock-up version of the demonstrator is built, an evaluation will be carried out with the participation of ENEL and other industrial partners to collect energy sector feedback. The evaluation will i) highlight the strengths/useful features of the demonstrator, ii) describe the weaknesses/difficult to understand or use features and iii) detect any missing aspects. The main goal is to verify that the demonstrator has an intuitive interface, is useful and usable and meets the needs of the project in terms of carrying out the BFSC.

M18–M22 [PM 11]: UEA [1], ENEL [3], **BSC** [4], KNMI [2], MO [1]

Task 4.4 Development of the final version of the demonstrator

With the feedback of the evaluation, an improved nearly-final version of the demonstrator will be implemented. A second round of evaluations will be carried out to ensure that only small not-so-important requirements are raised, which will be used in the final version of the demonstrator finishing the prototyping process.

To ensure an effective uptake of the demonstrator developed by EnDeCli, a roadmap for its exploitation and operationalization will be prepared. The roadmap will address issues such as: data dependencies; data stream requirements; procedures for climate and energy variable calibration; update cycles and system improvements.

M18–M30 [PM 11]: UEA [1], ENEL [2], **BSC** [8]

Deliverables (brief description and month of delivery)

D4.1: Summary report of the requirements for the demonstrator. [Lead UEA; Month 12]

D4.2: Summary report of the mock-up evaluation (Dissemination level: Private). [Lead BSC; Month 22]

D4.3: Final version of demonstrator, including documentation [Lead UEA; Month 30]

D4.4: Roadmap on the operationalization of a climate service for energy. [Lead BSC; Month 30]

Work package number	5	Lead beneficiary			MO	
Work package title	Real-time application of seasonal forecasts					
Participant number	1	2	3	4	5	6	7
Short name of participant	UEA	ENEL	ENEA	BSC	KNMI	MO	WEMC
Person months per participant:	2	6	0	2	8	12	0
Start month	M13			End month	M30		

Objectives

With the use of the prototype/demonstrator developed in WP4, this WP will assess the effectiveness of seasonal climate forecasts for the upcoming seasons in a routine way. Operational seasonal forecasts will be accessed and post-processed (according to findings in WP2-4) in near-real time. These forecasts will then be used for energy management decision-making, following the approach in WP3, and ensuring the value-add of seasonal forecasts is appropriately measured and reported.

As with WP4, there will be a strong and continuous input from the main industrial partner, ENEL. ENEL will provide guidelines about how to provide the forecasts in the most appropriate and effective way. Most importantly ENEL will perform real time simulations on a continuous basis. In sum, ENEL will provide:

- Feedback on the predictive skills of application of the operational climate forecasts to the econometric models based on the real time data,
- Feedback on the predictive skills of application of the operational climate forecasts to the renewable energy models,
- Feedback on the usefulness of the operational climate predictions used in a qualitative way for the portfolio strategies construction.

Using learning from WPs1-4 and through engagement with relevant European and international modelling efforts, this WP will optimise modelling, calibration and tailoring of data for delivery to ENEL and other stakeholders.

Finally WP5 will deliver real-time operational feed to ENEL for use in on-going decision making with the purpose of systematic verification of the added value of long-range forecasting information compared to baseline methods.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

Task 5.1. Optimise and finalise modelling, calibration and tailoring techniques for operational real-time applications

Subtask 5.1.1 Liaison between WP2, WP3 and WP4 to optimise and confirm modelling, calibration and tailoring methodologies.

Subtask 5.1.2 Analyse differences between modelling tools used for the hindcasts in WP2 and real-operational systems. Engage with relevant national and international projects with the aim of pulling-through cutting edge and identifying latest and robust advancements of the prediction systems that can be applied in the operational forecasts.

M12–M15 [PM 17]: UEA [2], ENEL [1], BSC [2], KNMI [8], **MO** [4]

Task 5.2 Deliver and validate real-time operational forecast feed for ENEL

Subtask 5.2.1 Apply processing chain identified in Subtask 1.2 to real-time forecast feeds produced by dataset in WP2 and/or prototype produced in WP4, and test delivery with ENEL.

Subtask 5.2.2 Based on feedback from test delivery of forecast, apply finalised tailored real-time forecast data to ENEL real time portfolio/industrial risk management process on a continuous basis.

M15–M30 [PM 8]: ENEL [5], **MO** [3]

Subtask 5.23 Systematic validation of the added value of the real-time forecasts according to methodologies set out for WP3, and dissemination of results.

M17–M30 [PM 5]: **MO** [5]

Deliverables (brief description and month of delivery)

D5.1 Test delivery of forecast to ENEL based on agreed methodology [Lead; MO Month 16]

D5.2 Meeting ENEL and MO to apply test forecast to ENEL's portfolio energy management decision-making [Lead; MO; Month 16].

D5.3 Automated delivery of forecasts to ENEL started [Lead; MO Month 17].

D5.4 Report quantifying the added value of long-range forecasts to energy management decision making based on automated forecasts. [Lead; MO Month 30].

Work package number	6	Lead beneficiary				WEMC
Work package title	Stakeholder engagement, communications and exploitation of results					

Participant number	1	2	3	4	5	6	7
Short name of participant	UEA	ENEL	ENEA	BSC	KNMI	MO	WEMC
Person months per participant:	4	2	0	0	0	0	30
Start month	1			End month	30		

Objectives

This WP will ensure the continuous involvement and iterative exchanges of viewpoints between all stakeholder groups in order to achieve broad acceptance, credibility and uptake of the results and recommendations of the project. First, a stakeholder framework is established. Regular exchanges on the project development and results via especially identified expert working groups and other ad-hoc consultations are undertaken within the stakeholder arena. Specifically, the initial stakeholder and exploitation workshop (Month 3) aims to identify energy sector players most interested in sharing their own experience in energy management decision making, and possibly contributing to the seasonal climate forecast value-add assessment and to the co-design of the demonstrator (and help in dissemination to the wider energy sector). Additional communication measures are designed and implemented with the goal to canvass expert views on the development of the calibrated and tailored forecasts as well as the demonstrator, and pro-actively seek opportunities to exploit the results of the project. Organisation and execution of one-to-one meetings and webinars will also be integral to this WP.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

Task 6.1 Devise stakeholder engagement, methodologies for exploitation of results and communication plan.

An initial draft of the stakeholder and communication plan has been presented in Section 2.2b. This draft will be further developed during the project, to include details of specific stakeholders, methods of engagement, promotional material, etc. A stakeholder group, with selected stakeholders who could act as EnDeCli champions, may also be set up. The plan will be regularly revised to take on board major stakeholder feedback and lessons learned.

M1–M3 [PM 2]: **WEMC** [2]

Task 6.2 Apply engagement plan, convene stakeholder engagement and exploitation workshops and organise other expert interactions (including one-to-one exchanges).

A variety of engagement methods, to be documented in the plan in Task 6.1, will be enacted. A good balance between remote communications (emails, phone, website, flyers and webinars) and physical meetings will be targeted; while we will carefully consider the need for the latter, as a way to limit travel and its related emissions and cost, stakeholder workshops and other targeted physical meetings are an essential component to effectively communicate the plans and results of EnDeCli and to strengthen its impact. Workshops will be professionally organised and held in carefully selected venues, and possibly conducted by professional moderators.

M1–M30 [PM 18]: UEA [4], ENEL [1], **WEMC** [13]

Task 6.3 Preparation of communication material, including website design and its development.

The most effective communication material for EnDeCli will be prepared, according to what described in the plan developed in Task 6.1. It is expected that material will include professionally developed: EnDeCli branding, a regularly updated web site, project banner, workshop flyers, EnDeCli poster and 'pitch' presentation.

M1–M30 [PM 6]: **WEMC** [6]

Task 6.4 User uptake, market analysis and fitness-for-purpose, including pathway for exploitation of the demonstrator and of other EnDeCli results/tools.

Exploitation of EnDeCli results and output will be a central component of the project. The initial draft plan presented in Section 2.2a, and further developed in Task 6.1, will be implemented with a clear focus to seek pathways for the three identified main EnDeCli impact opportunities – calibrated forecasts, case studies and demonstrator – which will lead to commercial products, job creation and further developments by a wider community (e.g. extra European projects).

M3–M30 [PM 10]: ENEL [1], **WEMC** [9]

Deliverables (brief description and month of delivery)

D6.1 Draft stakeholder engagement and results exploitation plan [Lead WEMC; M3].

D6.2 Revised stakeholder engagement and results exploitation plan [Lead WEMC; M12].

D6.3 User uptake and market assessment [Lead WEMC; M28].

D6.4 Lessons learnt from stakeholder and exploitation workshops and other interactions with energy management experts [Lead WEMC; M30]

Work package number	7	**Lead beneficiary**				UEA	
Work package title	Project Management						
Participant number	1	2	3	4	5	6	7
Short name of participant	UEA	ENEL	ENEA	BSC	KNMI	MO	WEMC
Person months per participant:	26	0	0	0	0	0	2
Start month	1			**End month**	30		

Objectives

This WP will ensure that each partner is fully engaged with the goals of the project and has allocated adequate resources to produce the planned deliverables, that all pre-requisites to achieving them are in place, and where needed that they are adjusted to take into consideration any intervening issues. An internal project communication and data management plan will be produced during the first phase of the project.

This WP will also ensure that data within and across WPs are exchanged in a timely manner. It will take a proactive role in the assessment of risks and their management should they occur. Importantly, this WP will ensure deliverables are completed within the planned timeline. Financial aspects as well as report preparation & coordination of the project are also the responsibility of this WP.

WP7 will prepare and hold regular meeting (teleconferences) to update project consortium as well as coordination meetings at regular intervals with a kick off in the first month of the project. The project manager will also be responsible for the preparation and maintenance of a project risk register.

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

Task 7.1 Preparation of project Communication and Data Management plans

M1–M2 [PM 2]: **UEA** [1], WEMC [1]

Task 7.2 Organisation and execution of project meetings and promotion of project at relevant energy industry and/or policy events

M1–M30 [PM 10]: **UEA** [9], WEMC [1]

Task 7.3 Preparation and submission of technical and financial reporting, as well as regular updates to the risk register

M1–M30 [PM 16]: **UEA** [16]

Deliverables (brief description and month of delivery)

D7.1 – Project Communication Plan [Lead UEA; M2]

D7.2 – Data Management Plan [Lead UEA; M4]

D7.3 – Annual Project report [Lead UEA; M12]

D7.4 – Annual Project report [Lead UEA; M24]

D7.5 – Final Project report [Lead UEA; M30]

List of work packages (Table 3.1b)

Work package No	Work Package Title	Lead Participant No	Lead Participant Short Name	Person-Months	Start Month	End month
1	Specific definition of decision-making issues in the energy industry	2	ENEL	28	1	12
2	Optimization of climate prediction performance for the energy case studies	5	KNMI	67	1	18
3	Quantification of value-add of climate forecast to energy decision-making	2	ENEL	86	4	24
4	Development of the demonstrator	4	BSC	40	4	30
5	Real-time application of seasonal forecasts	6	MO	30	13	30
6	Stakeholder engagement, communications and exploitation of results	7	WEMC	36	1	30
7	Project Management	1	UEA	28	1	30
				Total person-months	315	

List of Deliverables, in chronological order (Table 3.1c)

Deliverable (number)	Deliverable name	Work package number	Short name of lead participant	Type	Dissemination level	Delivery date (in months)
D7.1	Project Communication Plan	7	UEA	R	CO	M2
D1.1	Basic Framework of evaluation of climate factors	1	ENEL	R	PU	M3
D6.1	Draft stakeholder engagement and results exploitation plan	6	WEMC	R	PU	M3
D7.2	Data Management Plan	7	UEA	R	CO	M4
D1.2	Description of state of art in ENEL	1	ENEL	R	CO	M6
D2.1	Observational dataset delivered and preliminary analysis of return times of extremes in the seasonal climate variables relevant for energy demand and energy supply	2	KNMI	OTHER & R	PU	M6
D2.2	Report on preliminary evaluation of different calibration techniques and example files of calibrated data to stakeholders for WP1 and WP3.	2	MO	R	PU	M9
D3.1	State of art of climate and econometric forecasts: preliminary results for case 1 and 2.	3	ENEL	R	CO	M9
D1.3	Real time application of current methodologies	1	ENEL	R	CO	M12
D4.1	Summary report of the requirements for the demonstrator.	4	UEA	R	CO	M12
D6.2	Revised stakeholder engagement and results exploitation plan	6	WEMC	R	CO	M12
D7.3	Annual Project report (Year 1)	7	UEA	OTHER	PU	M12
D5.1	Test delivery of forecast to ENEL based on agreed methodology	5	MO	OTHER	CO	M16
D5.2	Meeting ENEL and MO to apply test forecast to ENEL's portfolio energy management decision-making	5	MO	OTHER	CO	M16
D5.3	Automated delivery of forecasts to ENEL started	5	MO	OTHER	CO	M17
D2.3	Report on the assessment and of maximum skill and procedure to maximize performance to end-users for each case study	2	KNMI	R	PU	M18

D3.2	Description of cases 3 and 4. Preliminary results.	3	ENEL	R	CO	M18
D2.4	Report on the response of the econometric models and renewable energy models to the climate inputs	2	ENEL	R	CO	M19
D3.3	Final results of validation for case 1 and 2	3	ENEL	R	CO	M21
D3.4	Final subjective and objective validation results for case 3 and 4	3	ENEL	R	CO	M21
D2.5	Report on the capability of the very latest advancements in the prediction systems from the ongoing international efforts to overcome limitations in forecasting the key predictands, for each case study.	2	ENEA	R	PU	M22
D4.2	Summary report of the mock-up evaluation.	4	BSC	R	CO	M22
D3.5	Dissemination of final verification results	3	MO	R	PU	M24
D7.4	Annual Project report (Year 2)	7	UEA	OTHER	PU	M24
D6.3	User uptake and market assessment	6	WEMC	R	PU	M28
D4.3	Final version of demonstrator, including documentation	4	UEA	DEM & R	CO	M30
D4.4	Roadmap on the operationalization of a climate service for energy.	4	BSC	R	PU	M30
D5.4	Report quantifying the added value of long-range forecasts to energy management decision making based on automated forecasts	5	MO	OTHER	PU	M30
D6.4	Lessons learnt from stakeholder and exploitation workshops and other interactions with energy management experts	6	WEMC	R	CO	M30
D7.5	Final Project report	7	UEA	OTHER	PU	M30

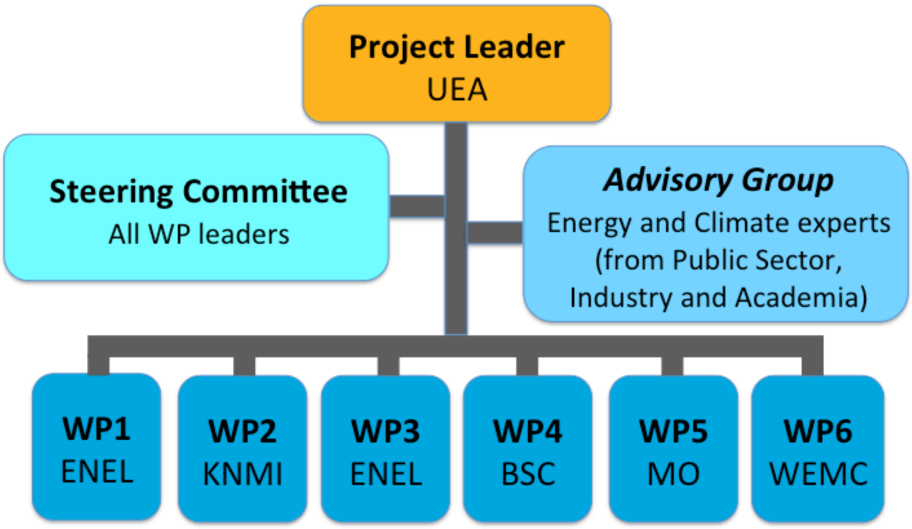
3.2 Management structure, milestones and procedures

Draft management and implementation plan

To assist with the execution of the project a management and implementation plan will be finalised before the start of the project. A draft plan is presented here.

Management Structure

The EnDeCli project will be led by the University of East Anglia (UEA) and in direct collaboration with its partners, all world leaders in their field of expertise (see Section 4). There will be direct and regular communication between the Project leader and the WP leaders. All WP leaders will form the EnDeCli Steering Committee. An advisory group composed of energy industry experts, as well as Academics and policy experts, will also be set up to assist with the direction setting of EnDeCli. The EnDeCli management structure is shown in the following diagram.



Project Management Approach

The Project Leader, Prof. Alberto Troccoli, has the overall authority and responsibility for managing and executing this project. The Project Leader is responsible for communicating with all people involved in the project, possibly via Institutional leads, on progress and performance of each project aspect. The Project Leader is also responsible for re-focusing efforts, whenever required, so as to effectively achieve project objectives.

All members of EnDeCli will play a role in quality management. It is imperative that the team ensures that work is completed at a high level of quality from individual work packages to the final project deliverable, the demonstrator. The Project Leader has overall responsibility for quality management throughout the duration of the project and will work closely with the project team to establish high quality standards. The Project Leader is also responsible for communicating and tracking all quality standards to the project team and stakeholders.

The list of milestones identified in Table 3.2a will assist the project leader and the WP leaders in setting the page for the project delivery. All deliverables and milestones will be reviewed and signed off according to the project management structure as presented above), i.e., the Task Leader will submit the output to the WP Leader and then to the Project Leader for final sign-off. All deliverables will go through an internal review phase – and where appropriate this will be extended to stakeholders engaged with EnDeCli. Procedures for handling situations where partners do not meet appropriate performance and related obligations will be specified in the consortium agreement.

The project leader will be supported by a project manager (Ms Lesley Penny). The Project Leader and Project Manager will work closely with the relevant staff in UEA's Research and Enterprise Division (RED) on contractual and financial issues. In particular:

- Contract Manager: Tracy Moulton
- Project Officer: Jason Rust
- Research Finance Officer: Shirley Brackenridge
- Research Finance Administrators: Stephen Le Grice and Colin McDermott

RED Finance Staff as well as the Project Leader will have access to EnDeCli accounts through the ABW (Agresso Business World) financial management and monitoring system. For the Project Leader, this provides a real-time view of budgets, actual expenditure and commitments. RED staff perform quarterly checks on all project accounts to ensure that expenditure is within expected budgets and allowable under the contract terms.

Internal Project Communication Plan

The project communication plan is integral to the management plan and defines how information will be exchanged between all partners of the project, and between the project and the EU. The main mode of communication between project members is by email; a wiki page hosted on the project website for internal use only may also be set up. Other standard communication methods (phone, skype, dropbox or googledrive, etc.) will also be considered and commonly used. A project team directory for all communications, with individual preference for mode of communication, will be set-up and distributed at the start of the project. Table 4 provides a reference for regular communications during the project execution.

Table 4 – Communications Matrix to be used as a guide for information flow amongst project members, and between Project Leader and the EU, during project execution

Communication Type	Description	Frequency	Format	Participants/ Distribution	Outcome	Responsability
Bi-Weekly Project Team Meeting	Meeting to review action register and status	Fortnightly	Phone	Project Team	Updated Action Register	Project Leader
Project monthly Review	Present project status, tasks completion, schedule and risks	Monthly	In person, phone or video	Project Team and EU	Status and Metric Presentation	Project Leader
Project half-yearly Review	Review progress and discuss outstanding issues	Six-monthly	In person	Project Team, Advisory Group and EU	Meeting minutes	Project Leader
Technical Design Review	Review of the demonstrator development	As Needed	In person, phone or video	Relevant Project Team	Demonstrator	Project Leader

Risk Management Plan

The approach for managing risks for the EnDeCli project includes a methodical process by which the project team identifies, scores, and ranks the various risks. Every effort will be made to proactively identify risks ahead of time in order to implement a mitigation strategy from the project's onset. The most likely and highest impact risks will be added to the Risk Register, to ensure that the assigned risk managers (the Institutions' leads) take the necessary steps to implement the mitigation response at the appropriate time during the schedule. Risk managers will provide status updates on their assigned risks in the bi-weekly project team meetings: an agenda item will be included in all meetings. Risks relating to data will be minimised by developing a Data Management Plan. Procedures for handling situations where partners do not meet appropriate performance and related obligations will be specified in the consortium agreements. Where problems occur we would follow processes set out in the contract terms to cover non-performance and dispute resolution.

Upon the completion of the project, during the closing process, the Project Leader will analyse each risk as well as the risk management process, in order to identify any improvements that can be made to the risk management process for future projects. These improvements will be captured as part of the lessons learned knowledge base.

List of Milestones, in chronological order (Table 3.2a)

Milestone number	Milestone name	Related work package(s)	Due date (in month)	Means of verification
M7.1	Kick off meeting	WP7	M1	Kick off meeting of the Project with all partners
M6.1	Initial stakeholders and exploitation workshop	WP6	M3	Workshop held
M3.1	Selection of tailoring methodologies for ENEL	WP3	M4	Definition of tailoring techniques based on intelligence on user need from WP1
M3.2	Meeting with WP2 workgroup	WP3	M4	Sharing of information and methods with WP2.
M1.1	WP1 Work in Progress Meeting	WP1	M6	Workshop involving climate-prediction and industrial partners to decide final selection of case studies identified by the industrial partners and determine key climate variables/predictands for each case study
M1.2	WP1 Work in Progress Meeting	WP1	M7	Check of progress of definition of the variables and
M3.3	Meeting with WP2 and WP4 workgroup	WP3	M7	Sharing of information and tool for data exchange

M7.2	Project meeting	WP7	M8	First work in progress check meeting
M2.1	Retrospective seasonal predictions dataset available on dedicated server.	WP2	M9	Delivery of a retrospective dataset of global-scale homogenised and calibrated Multi-Model-Ensemble Seasonal Predictions
M3.4	Cases studies datasets and framework	WP3	M9	Definition of all financial and climate datasets for all cases studies.
M3.5	Meeting with WP 2 and WP 4	WP3	M10	Check progress on the implementation of the forecasts for the past cases studies.
M1.3	WP1 Closing	WP1	M12	Final release of the framework of the decision making processes and on variables of interest
M5.1	Inter-WP meeting to finalise data flow for real-time forecast	WP5	M15	Refine conventions on data formats and exchanges and methods of interaction between WP partners
M6.2	Review of effectiveness of stakeholder engagement and of the potential for exploitation of results	WP6	M15	Internal report
M6.3	Second stakeholders and exploitation workshop	WP6	M15	Workshop held
M7.3	Project meeting	WP7	M15	Second work in progress check meeting
M4.1	Mock-up version of the demonstrator available on-line for evaluation.	WP4	M18	Internal presentation of the mock-up version of the demonstrator
M3.6	Final WP3 meeting	WP3	M21	Official presentation of all WP3 results
M7.4	Project meeting	WP7	M22	Third work in progress check meeting
M5.2	Meeting with ENEL	WP5	M23	Check reliability of forecast delivery and suitability of collection of verification data
M4.2	Final demonstrator available online.	WP4	M26	Demonstrator available online.
M6.4	Third stakeholders and exploitation workshop	WP6	M28	Workshop held
M7.5	Project meeting	WP7	M30	Final project meeting

Critical risks for implementation (Table 3.2b)

Description of risk (indicate level of likelihood: Low/Medium/High)	Work package(s) involved	Proposed risk-mitigation measures
Project member leaving the consortium due to various factors resulting in delayed or no delivery (Low)	All WPs	Engage alternate qualified staff within the project if possible, otherwise advertise if time allows.
As above, but specifically related to ENEL leaving the consortium (Low)	All WPs	The possibility of ENEL leaving the consortium is remote given that this proposal was initiated by ENEL and has been developed around ENEL's clearly stated needs. In the case of ENEL leaving, the project will put considerable effort in strengthening stakeholder engagement activities so as to attract possible alternate stakeholders; the fact that ENEL has a strong interest in this area is likely an indication that other energy companies may be interested to be involved in analogous applications of seasonal climate forecasts
Project member leaving the project due to various factors resulting in delayed or no delivery (Low)	All WPs	Engage alternate qualified staff within the project, if possible, otherwise advertise if time allows
Partners failing to deliver due to conflicting schedules resulting in delayed or no delivery (Low)	All WPs	Engage additional relevant people within partners organisations in the first place, otherwise consider quick solutions from other relevant organisations
Processing of seasonal climate forecast model output takes longer than expected (Medium)	WP2 and WP3	Select a subset of output to start with and to begin testing methodologies
Processing of climate and/or energy variables takes longer than expected, particularly for South America, due to difficulties in data collection and/or analysis (Low)	WP2 and WP3	Regular communication amongst project members and encourage 'good enough' solutions
Operational seasonal climate forecasts not readily available (Low)	WP5	Use available free output (e.g. from USA model). Possible purchase of a subset of model output from European models.
Limited user uptake of the EnDeCli tools due to limited external stakeholders interest (Medium)	WP2, WP4 and WP6	Enhance stakeholder engagement activities and requests for feedback

3.3 Consortium as a whole

The consortium of the EnDeCli project comprises the following Institutions:

1. University of East Anglia (UEA, UK) – Project Leader
2. Ente Nazionale per l'Energia Elettrica (ENEL, Italy)
3. Agency for new technologies, energy and sustainable development (ENEA, Italy)
4. Barcelona Supercomputing Centre (BSC, Spain)
5. Royal Netherlands Meteorological Institute (KNMI, The Netherland)
6. UK Meteorological Office (MO, UK)
7. World Energy & Meteorology Council (WEMC, UK)

The consortium, which has been built around a clearly stated need by EnDeCli's main industrial stakeholder, ENEL, has attracted an excellent balance of expertise in the areas of: seasonal climate science, general and specific (to energy) applications of this science, energy management and stakeholder engagement and communications. Traditionally scientific organisations such as UEA, ENEL and BSC, as well as the two National Meteorological Services, MO and KNMI, have been clearly demonstrating through a variety of projects (see below and section 5) that they excel in the translation of climate science into societal applications, including energy. This expertise has been built on top of a very robust understating of the climate system and its prediction.

Given the complexity of the climate system and the corresponding seasonal climate forecasts, it is vital to have a robust understanding of the potential but also the limitations of seasonal climate forecasts. This is why the EnDeCli consortium includes a strong base of scientific expertise. However, each of these partners brings a distinctive input to EnDeCli, both in area of expertise or geographical focus, which will lead to definite strengthening of EnDeCli tools and products:

- UEA has strong expertise in the use of climate observations and worldwide climate forecast, and IPCC; it is also strongly contributing to climate service delivery for the energy sector;
- ENEA has strong expertise in the use of seasonal climate forecast, particularly for Italy, and has been contributing to several climate service projects;
- BSC has strong in the assessment of dynamical climate methods for the prediction of essential climate variables for various applications, including for energy, particularly for Spain;
- KNMI has strong expertise in climate, marine and weather, marine observations and modelling; it is also strongly contributing to IPCC, renewable energy management, short and medium term weather forecasts and high quality validated open data databases;
- MO has a proven capability and expertise in the use of observations and the production of world leading weather and climate models; it also has significant experience using the data to understand the value of forecasts to a range of industry stakeholders that include the onshore and offshore energy sector.

It is therefore apparent that the complementarity of skill of these scientific/operational organisations will be a definite asset to EnDeCli. It is also worth noting that the EnDeCli team will consist of highly skilled experts with skills covering all aspects required for a successful delivery of EnDeCli. These skills range across climate and energy data processing, including their quality and assurance, assessment of historical data and seasonal forecasts, computation and evaluation of energy demand and supply, economics of energy markets, communication, stakeholder engagement and website development.

Not only are the EnDeCli partners world leaders in their own right, as demonstrated, for instance, by the individual Institutional Track Records (Section 5), they have also already delivered highly effective collaborations with each other, as well as with other European and non-European organisations, through a number of activities, a selection of which is presented in the following:

- **UEA and MO** collaborated in the FP6 project, ENSEMBLES (2004-2009) whose focus was ENSEMBLE-based Predictions of Climate Changes and their Impacts (http://www.ensembles-eu.org)
- **UEA and ENEA** collaborated in the FP7 project CLIMRUN (2011- 2014) Climate Local Information in the Mediterranean region – responding to User Needs (http://www.climrun.eu)
- **MO and ENEA** are collaborating in the FP7 project, EUPORIAS (2012–2016) European Provision Of Regional Impacts Assessments on Seasonal and Decadal Timescales (http://www.euporias.eu). **UEA** is involved as a reviewer and participant in a number of workshops
- **BSC, ENEA, KNMI and MO** are collaborating in EU FP7 project SPECS (Seasonal-to-decadal climate Prediction for the improvement of European Climate Services) [2012-2017] http://www.specs-fp7.eu/
- **ENEA, KNMI, MO and UEA** are collaborating in EU H2020 project CRESCENDO (Coordinated Research in Earth Systems and Climate: Experiments, kNowledge, Dissemination and Outreach) [2015-2020] http://crescendoproject.eu/
- **UEA, ENEA and MO** are partners in the Copernicus Climate Change Service ECEM (2015-2018) European Climatic Energy Mixes (http://ecem.climate.copernicus.eu/)
- **BSC and MO** are partners in the Copernicus Climate Change Service CLIM4ENERGY
- **UEA, MO and WEMC** are part of the organising committee of the International Conference Energy & Meteorology (ICEM) biennial series, with the third, and latest, ICEM held in 2015 (http://www.wemcouncil.org/wp/conferences/icem2015/)

Taking into consideration this information with the track records presented later, it is apparent that the EnDeCli consortium is very robust and effective, including previous example of working together. The EnDeCli partners have also shown to be able to effectively provide results in a user friendly form for general access. In addition, all consortium partners have eagerly contributed to the proposal preparation and they look forward to working together should this proposal be selected.

The consortium is also supported by a ‘dedicated’ stakeholder, TenneT, the Dutch TSO, who will work closely with KNMI on case study 5, as stated in the following letter of support.

TenneT
Taking power further

Postbus 718, 6800 AS Arnhem, The Netherlands
Department R&D Weather and Climate Modelling
KNMI (Royal Netherlands Meteorological Institute)
Attn Dr. Geertsema
P.O. Box 201
3730 AE DE BILT
Nederland

DATE	August 1, 2016
OUR REFERENCE	ONL-TTB-03793
CONTACT	Saskia Jaarsma
E-MAIL	saskia.jaarsma@tennet.eu
ENCLOSURES	--

SUBJECT Support letter

Dear Mrs/Mr,

TenneT welcomes the opportunity to provide a letter of support to the Dutch Meteorological Institute (KNMI)'s project *Improved Energy Decisions using Seasonal Climate Forecasts* in response to the EU Horizon 2020's call SC5-01-2016a, "Exploiting the added value of climate services".

TenneT is one of Europe's leading electricity transmission system operator's with activities in the Netherlands and Germany and is responsible for the electricity supply in the high-voltage grid for some 41 million people. Our aim is to ensure that essential high-voltage infrastructure is developed, realised and managed efficiently, now and in the future.

The EnDeCli proposal aimed at demonstrating the use of climate forecasts up to several months ahead can add value to the decision-making processes in the energy industry and addresses a topical and important area for the energy sector and business more broadly. The assessment of the effect these seasonal climate forecasts may have is key to the uptake by business of this abundant and potentially beneficial forecast information. In case of application to TenneT's offshore maintenance management and offshore activities, potentially a significant cost saving for operational expenditures related to the offshore grid could be identified, in a sector continuously under pressure to increase efficiency and cost reduction.

We therefore regard this work of interest to TenneT and look forward to interacting with KNMI and its partnership in providing feedback on the added value of energy-tailored state-of-the-art seasonal forecast tools.

With kind regards,
TenneT TSO B.V.

Marieke Dirks
Manager Project Initiation

3.4 Resources to be committed

Summary of staff effort (Table 3.4a)

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	Total Person-Months per Participant
UEA	0	15	2	6	2	4	**26**	55
ENEL	**18**	2	**34**	6	6	2	0	68
ENEA	2	7	9	0	0	0	0	18
BSC	2	12	12	**22**	2	0	0	50
KNMI	2	**27**	15	4	8	0	0	56
MO	2	4	14	2	**12**	0	0	34
WEMC	2	0	0	0	0	**30**	2	34
Total Person Months	28	67	86	40	30	36	28	315

'Other direct cost' items (travel, equipment, other goods and services, large research infrastructure) (Table 3.4b)

UEA	Cost (€)	Justification
Travel	50,000	UEA will need these resources in order to effectively visit stakeholders, attend workshops and meetings, participate to relevant conferences and public events to promote the project
Equipment	20,000	UEA will need to buy mass storage equipment and portable hard drives, high-end workstation, analysis and visualization software, printings of dissemination material such as flyers and brochures
Other goods and services	50,000	UEA will need these funds to cover the EnDeCli workshops organisation and to purchase sample seasonal climate forecasts
Total	190,000	

ENEL	Cost (€)	Justification
Travel	30,000	Meetings and international travel costs accounted to 3/4 projects members over the life of the projects
Equipment	70,000	Required improvements of the ICT systems (hardware, specific software) that are presently not available at ENEL and will be required to carry out the work in this project.
Other goods and services	20,000	Daily dataset updates on worldwide scale
Total	120,000	

ENEA	Cost (€)	Justification
Travel	10,000	ENEA will need these resources in order to effectively visit stakeholder/end-user, attend workshops and meetings, participate to conferences and public events to advertise the project.
Equipment	10,000	ENEA will need to buy mass storage equipment and portable hard drives, desktops, high-end workstation, analysis and visualization software, publications, printings of dissemination material such as posters and leaflets
Other goods and services	5,000	No specific issues
Total	25,000	

BSC	Cost (€)	Justification
Travel	20,000	4 general meetings, 1 kick off meeting, 1 workshop, 1 conference - 2 persons for 2 or 3 days
Equipment	20,000	A disk and a fat node (a node with more memory). It will be needed to work with different climate forecast systems assessing their predictability at different scales and horizons.
Other goods and services	20,000	Operating
Total	60,000	

KNMI	Cost (€)	Justification
Travel	35,000	Workshops, conferences for advertising the project, meetings, stakeholder/end-user visits and STEMs (Short Term Exchange Missions) for the development of the dataset and interlace effective collaborations with North American and Asian Pacific Seasonal Prediction communities
Equipment	28,000	Data costs, data storage, server, disclosure software,
Other goods and services	35,000	Daily datasets updates, datasets quality monitoring quality and helpdesk function to assist the users.
Total	98,000	

Note that ENEA will devote considerable efforts in WP2 and WP3 for education and training of new young scientists working on the development of MME Seasonal predictions and related applications. To this end, ENEA commits to dedicate the necessary EnDeCli budget in order to offer at least one-year fellowship and/or recruit post-doc personnel.

It is worth commenting on the fact that the request for EU funding in this second stage submission is higher than that of the first phase, namely from 2.6 million EUR to 3.3 million EUR. There a number of reasons for such an increase but the more important ones are:

- Since our stage one proposal, we have acquired the interest of TenneT as a dedicated stakeholder. Also further discussions between the EnDeCli partners have highlighted the benefit of two extra case studies to investigate, and showcase, the added value of seasonal forecasts, namely the El Niño case in South America and persistent low wind case in the North Sea. Also it has become clear that the effort needed for collecting data in South America is larger than estimated in stage one
- An increased effort in engaging the wider stakeholder community (mainly energy industry, and to a lesser extent related areas such as agriculture and insurance) in order to:
    - Collect information from a variety of organisations in terms of their decision making processes and to understand how these might benefit from improved seasonal climate forecasts
    - Promote project results – particularly the calibration of forecasts, the case studies and the demonstrator – and to seek their regular feedback and possible more active participation
- An increased effort in the development of a state-of-the-art demonstrator so that it can be adopted as a routine decision-making tool by ENEL, but that it can also be adapted to other stakeholder as well as inspire development of similar tools by climate service providers and other energy industry organisations.

References

Alessandri A., A. Borrelli et al. 2011: Evaluation of probabilistic quality and value of the ENSEMBLES multi-model seasonal forecasts: comparison with DEMETER. Mon. Weather Rev., 139, 581-607

Block P (2011) Tailoring seasonal climate forecasts for hydropower operations. Hydrol. Earth Syst. Sci., 15, 1355–1368. doi:10.5194/hess-15-1355-2011

Brayshaw DJ, Troccoli A et al. (2011) The impact of large scale atmospheric circulation patterns on wind power generation and its potential predictability: a case study over the UK. Renewable Energy, 36 (8). 2087-2096.

Cherchi A, Annamalai H et al. (2015) 21st century projected summer mean climate in the Mediterranean interpreted through the monsoon-desert mechanism. Climate Dynamics DOI: 10.1007/s00382-015-2968-4

Cherchi A, Annamalai H et al. (2014) South Asian summer monsoon and the eastern Mediterranean climate: the monsoon-desert mechanism in CMIP5 simulations. J. Climate, 27(18), 6877-6903

De Felice, M, A. Alessandri, and F. Catalano, 2014: Seasonal Climate Forecasts for medium-term Electricity Demand Forecasting. Applied Energy, doi:10.1016/j.apenergy.2014.10.030.

Dubus (2010) Practices, needs and impediments in the use of weather/climate information in the electricity energy sector. In: Troccoli A (ed) Management of weather and climate risk in the energy industry, NATO Science Series, Springer Academic Publisher, pp 175–188.

Ely, C. R., Brayshaw, D. J., Methven, J., Cox, J. & Pearce, O. Implications of the North Atlantic Oscillation for a UK–Norway renewable power system. Energy Policy, 62, 1420- 1427 (2013).

Hamlet AF Huppert D and Lettenmaier DP (2002) Economic Value of Long-Lead Stream-Flow Streamflow Forecasts for Columbia River Hydropower. J. Water Res. Planning and Management, 91-101.

Hansen, J.W., A. Mishra, K.P.C. Rao, M. Indeje and R.K. Ngugi, 2009: Potential value of GCM-based seasonal rainfall forecasts for maize management in semi-arid Kenya. Agricultural Systems, 101(1–2):80–90.

Haylock, M. R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones and M. New, 2008: A European daily high-resolution gridded data set of surface temperature and precipitation for 1950-2006. J. Geophys. Res. (Atmospheres) 113:D20119,doi:10.1029/2008JD010201

Kirtman, B. P. and Co-authors, 2014: The North American Multimodel Ensemble: Phase-1 Seasonal-to-Interannual Prediction; Phase-2 toward Developing Intraseasonal Prediction. Bull. Amer. Meteor. Soc., 95, 585–601.

Lee, D. Y., Ahn, J.-B., Ashok, K. and Alessandri, A., 2013: Improvement of grand multi-model ensemble prediction skills for the coupled models of APCC/ENSEMBLES using a climate filter. Atmosph. Sci. Lett., 14: 139–145. doi: 10.1002/asl2.430

Makaudze, E.M., 2005: Do seasonal climate forecasts and crop insurance matter for smallholder farmers in Zimbabwe? Using contingent valuation method and remote sensing applications. PhD diss., Ohio St. Univ.

Palmer, T., and Coauthors, 2004: Development of a European Multimodel Ensemble System for Seasonal to Interannual Prediction (DEMETER). Bull. Amer. Meteor. Soc., 85, 853– 872.

Pozo-Vázquez, D., Tovar-Pescador, J., Gámiz-Fortis, S. R., Esteban-Parra, M. J., & Castro- Díez, Y. (2004) NAO and solar radiation variability in the European North Atlantic region. Geophys. Res. Letters, 31(5).

Rodwell, M., and B. Hoskins, 1996: Monsoons and the dynamics of deserts. Quart. J. Roy. Meteor. Soc., 122, 1385–1404, doi:10.1002/qj.49712253408.

Rubas, D.J., H.S.J. Hill and J.W. Mjelde, 2006: Economics and climate applications: Exploring the frontier. Climate Research, 33:43–54.

Scaife, A.A., Arribas, A., Blockey E. et al. Skillful long-range prediction of European and North American winters, Geophysical Research Letters, 41, 2514-2519, (2014) doi: 10.1002/2014GL059637

Trigo RM, Pozo-Vazquez D, Osborn T et al. (2004) North Atlantic Oscillation influence on precipitation, river flow and water resources in the Iberian Peninsula. Int. J. of Climatology, 25, 925-944.

Troccoli A, Harrison M, Anderson DLT and Mason SJ, eds (2008) “Seasonal Climate: Forecasting and Managing Risk”, NATO Science Series, Springer Academic Publishers, 467 pp.

Troccoli A, Dubus L and Haupt SE, eds (2014) “Weather Matters for Energy”, Springer Academic Publisher, 528 pp.

van den Brink HW, GP Können, JD Opsteegh, GJ van Oldenborgh, and G Burgers (2004) Improving 104-year surge level estimates using data of the ECMWF seasonal prediction system. GRL, 31, L17210.

van den Brink HW, GP. Können, JD. Opsteegh, GJ. van Oldenborgh, G. Burgers. Estimating return periods of extreme events from ECMWF seasonal forecast ensembles. Int. J. Climatology, 1, 2005, 25, 1345-1354.

Wang B and co-authors (2009) Advance and Prospect of Seasonal Prediction: Assessment of the APCC/CliPAS 14-model ensemble retroperspective seasonal prediction (1980-2004). Climate Dyn., 33, 93–117.

Weisheimer A et al (2009) ENSEMBLES: A new multi- model ensemble for seasonal-to-annual predictions—Skill and progress beyond DEMETER in forecasting tropical Pacific SSTs. Geoph. Res. Lett., 36, L21711.

World Meteorological Organisation (2015) Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services. Report No. 1153.

Yoo, J. H., and I.-S. Kang (2005), Theoretical examination of a multi-model composite for seasonal prediction, Geophys. Res. Lett., 32, L18707, doi:10.1029/ 2005GL023513.