S2S4E WHITE REPORT

HOW SUBSEASONAL AND SEASONAL FORECASTS CAN HELP THE INTEGRATION OF RENEWABLES INTO EUROPE'S ENERGY SECTOR

A report presenting three years of research on subseasonal and seasonal forecasts conducted as part of the EU-funded project S2S4E Climate Services for Clean Energy and the new forecasting tool developed by the project, the S2S4E Decision Support Tool.

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Oslo, November 2020

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EXECUTIVE SUMMARY

This report presents three years of research on subseasonal and seasonal forecasts conducted as part of the S2S4E Climate Services for Clean Energy project. The project has been funded by the EU's research and innovation programme Horizon 2020 and coordinated by the Barcelona Supercomputing Center.

The 12 partners in the project come from seven different countries in Europe, and together they have been working to make subseasonal and seasonal forecasts more useful to the energy sector. As part of this work, they have developed a new forecasting tool specifically tailored to the energy industry – the S2S4E Decision Support Tool – which is available at s2s4e.eu/dst.

The S2S4E Decision Support Tool features subseasonal and seasonal forecasts for renewable energy production and electricity demand. It shows the global climate outlook for up to three months ahead and can therefore be useful also to people working in other weather-dependent sectors, such as the agricultural and insurance industries.

This report provides a summary of the work done as part of the S2S4E project, focusing mainly on how subseasonal and seasonal forecasts can make the European energy sector more resilient to climate variability, and on how the energy industry can benefit from using these forecasts.

In the following, you can read about the research that has been conducted as part of the S2S4E project, both on subseasonal and seasonal forecasts, and on user needs and how the use of such forecasts can improve decision-making within the energy industry.

The report gives readers an introduction to the S2S4E Decision Support Tool and explains what kind of information it contains and the research behind its forecasts. It also explains why the need for subseasonal and seasonal forecasts will increase in line with the continued transition to renewable energy, and why more research is needed to improve the quality of these forecasts.

Moreover, this report presents several examples of decision-making processes within the energy sector that could benefit from increased use of subseasonal and seasonal forecasts. It also presents some of the case studies done as part of the project of unusual situations in the power market in several European countries, to show how subseasonal and seasonal forecasts could have brought added value to companies' decision-making ahead of these specific events.

The energy industry is not the only sector that could benefit from increased use of subseasonal and seasonal forecasts in its decision-making, and this report therefore also gives examples of other weather-dependent industries for which such forecasts could be useful.

It also gives an overview of existing policy support for the use of subseasonal and seasonal forecasts, both at national and EU level. Finally, it presents policy recommendations for how the EU can contribute to increasing both the use and the quality of subseasonal and seasonal forecasts.

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FOREWORD:

CHASING RESILIENCE IN THE ENERGY SECTOR

by Albert Soret,
Project leader
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Over the past few years, there has been a marked increase in the awareness across society of how decision-making in various sectors and contexts can benefit from having information about the weather to come weeks and months in advance

Decision-makers themselves are realising that such information can be useful to them and many scientists are becoming increasingly aware of how the outcomes of their research can be used by different businesses and organisations. In addition, the quality of forecasts for weeks and months ahead have improved significantly over the past decade, making them more trustworthy.

The idea behind the S2S4E project started developing in late 2015 following a discussion with someone from the energy industry. At the time, seasonal forecasts had started to become a familiar concept among climate scientists, but not among people in the energy industry.

Most people from the energy industry were used to getting information about future weather conditions only from forecasts for the next few days. For longer time horizons such as the following weeks or even months, however, they relied mainly on climatological data – typically 30-year averages – with the assumption behind this data being that future weather conditions will be similar to past conditions.

When discussing the issue of seasonal forecasts with the contact from the energy industry, we saw that there was a gap between the forecasts he was already working with and the potential use of the forecasts that we were explaining.

As a result, we realised there was a need to explore the potential use of subseasonal and seasonal forecasts that show predictions for the next few weeks and for the next few months and seasons, respectively. However, we then faced the challenge of assessing the value of these forecasts, as many have tended to think of them as unreliable.

> **The focus of the S2S4E project has been to develop an online forecasting service that is tailored to the energy sector**

The focus of the S2S4E project has been to improve the quality and usefulness of subseasonal and seasonal forecasts, and to develop an online forecasting service that is targeted towards the energy sector and that integrates subseasonal and seasonal climate predictions.

But the forecasting tool developed by the project, the S2S4E Decision Support Tool, can also be useful for people

working in other weather-dependent sectors, such as the agricultural and insurance industries. Many of the results and lessons learned during the project will also have a much wider application and relevance.

Rather than centring only on how to improve the utility of climate information to the energy sector, S2S4E has developed state-of-the-art research methods to explore weather conditions for future weeks and months. One of the assets of the project has been its interdisciplinary consortium, which has consisted of both research institutes and energy companies.

This has enabled us to involve future users from the energy sector in the development and further improvement of the S2S4E Decision Support Tool.

For me, leading the S2S4E project has been a challenging and rewarding task that I have learned a lot from.

The first challenge was coordinating a team with members from various disciplines and areas of expertise. It has been an incredible experience for me, and a unique opportunity, to co-develop a climate service and to ensure knowledge transfer between the different partners.

The second challenge was the actual development of the new forecasting service and ensuring that all the different pieces of the project were integrated into it.

This report provides a summary of the work done as part of the S2S4E project, focusing mainly on how subseasonal and seasonal forecasts can make the European energy sector more resilient to climate variability, and on how the energy industry can benefit from using these forecasts.

We hope other projects and initiatives will take advantage of this effort and seek engagement between the users of climate services and climate scientists to link climate information with decision-making.

I invite readers, particularly policymakers, climate scientists and active users of the S2S4E Decision Support Tool – from the energy industry as well as other sectors – to be inspired by the work presented here. We hope it will lead to the development of better-informed strategies to improve the integration of renewable energy into the electricity system.

We also hope that the results of the project can contribute to making Europe more resilient to climate variability and extreme weather events.

And that it can do this by helping people working in weather-affected industries better prepare for the weather to come and anticipate the impact of extreme events – such as heatwaves and floods – on everything from crops to public health, buildings and other infrastructure.

THE S2S4E DECISION SUPPORT TOOL

During the three years of the S2S4E project, the team involved has studied how energy companies and other weather-dependent sectors can benefit from using subseasonal and seasonal forecasts, and has developed a forecasting tool tailored to the energy industry: the S2S4E Decision Support Tool.

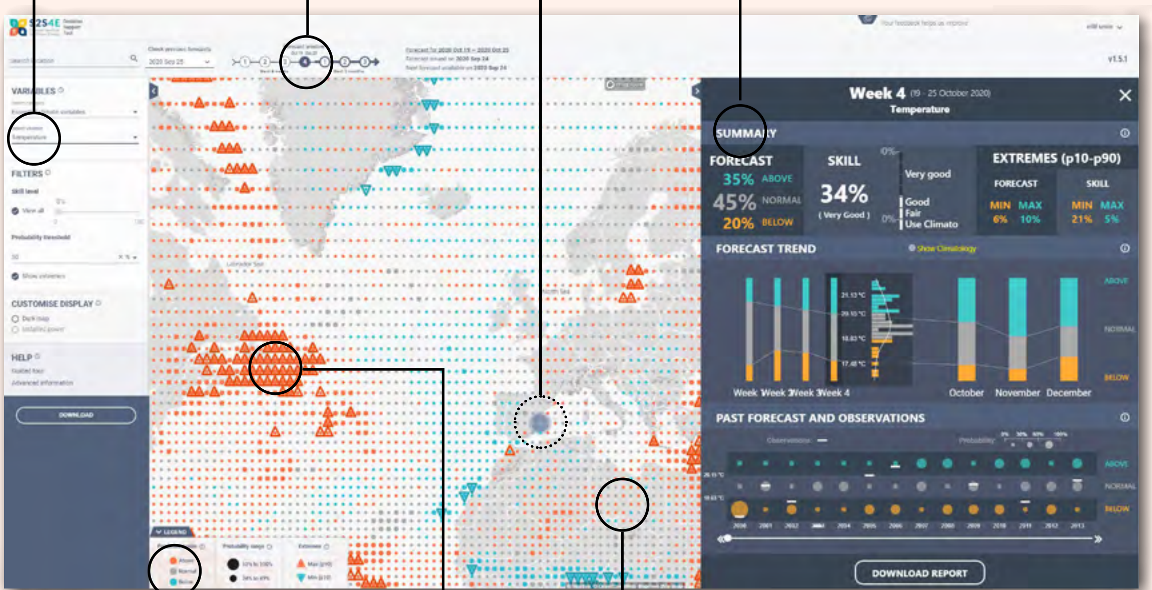
Desktop view. This is what the support tool looks like on your dekstop computer. It is also accessible on tablets and smartphones

Select the category and the variable to be displayed on the map. There are five categories, one for essential climate variables (ECV) and four for the different energy sources. For each energy category, there are both ECVs and derived climate indicators.

Set your forecast range, up to three months ahead.

Summary information of the forecast for the selected region and forecast window.

Selected region

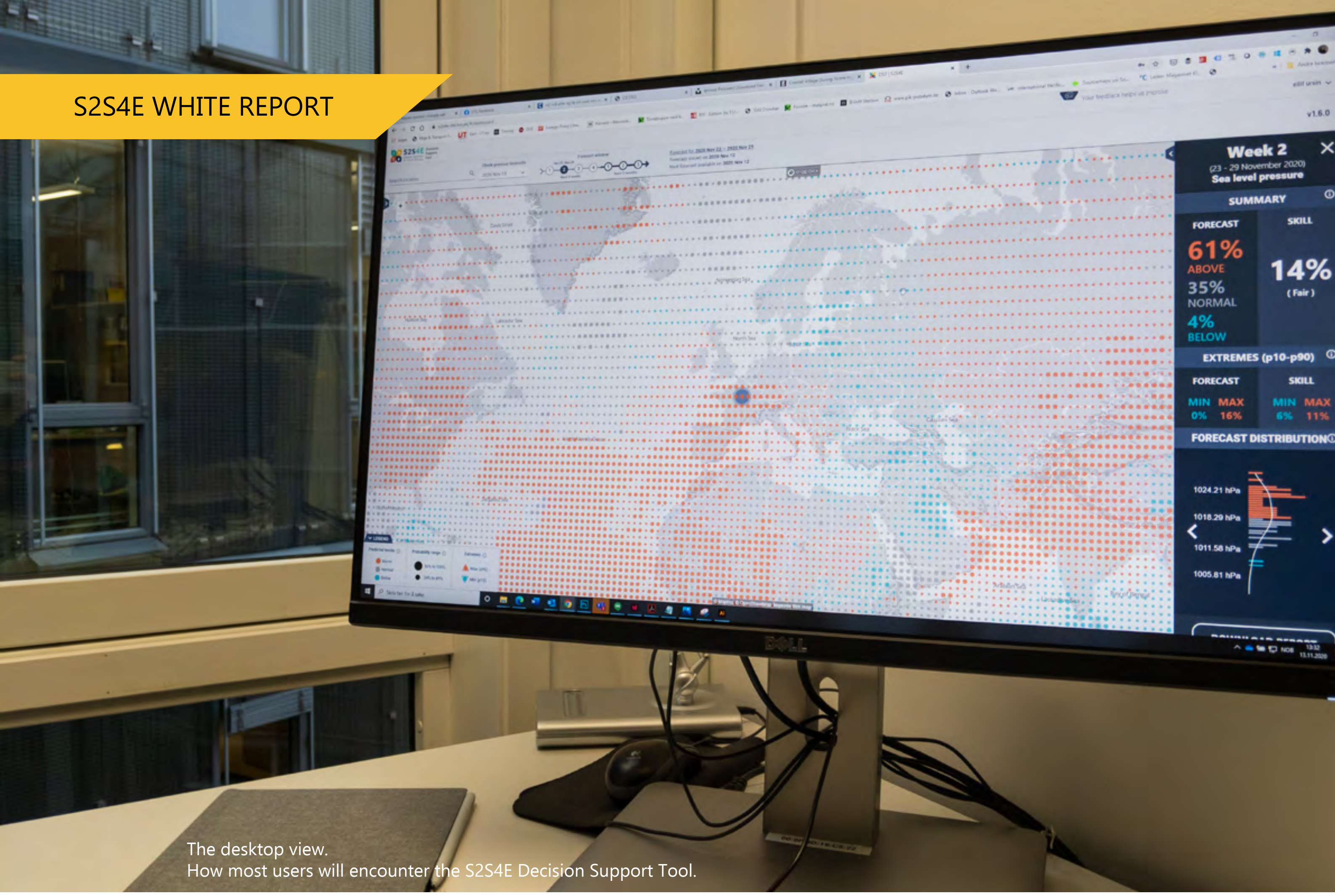


The colour of points on the map show if a variable will be in the normal range expected for that location and time of year (grey in the case or temperature), or if it will be above or below the normal values.

- **Circle size** indicate probability that the predicted range will happen at this location. Large circle indicate 50% probability range, a small cicrle 34 - 49%

▲ Triangles indicate a high probability of **extreme conditions** happening at a specific region of the map

Try the tool at **www.s2s4e.eu/dst**



The desktop view.
How most users will encounter the S2S4E Decision Support Tool.

The S2S4E Climate Services for Clean Energy Project is funded by the EU's research and innovation programme Horizon 2020 and is coordinated by the Barcelona Supercomputing Center. The project seeks to improve the management of intermittent renewable energy, and its long-term goal is to make the European energy sector more resilient to climate variability and extreme weather events. The 12 partners in the project come from seven different countries in Europe – Spain, France, Norway, Germany, Italy, the United Kingdom and Sweden – and together they have been working to make subseasonal and seasonal forecasts more useful to the energy sector.

As part of this work, they have developed a new forecasting tool – the S2S4E Decision Support Tool – which is available at [s2s4e.eu/dst.](s2s4e.eu/dst)

The tool features subseasonal and seasonal forecasts for renewable energy production and electricity demand. It shows global forecasts for essential climate variables and energy indicators such as temperature, near-surface precipitation, solar radiation, wind speed, wind and solar power capacity factors, snow coverage, and inflows to hydropower plants. The subseasonal forecasts focus on week-to-week changes in weather conditions and show the outlook for the next four weeks. Meanwhile, the seasonal forecasts focus on month-to-month changes and present predictions for the next three months. In addition to seeing the latest forecasts, users of the tool can opt to get more information on the forecasts for the specific locations they are interested in and see past forecasts.

SKILL SCORES

Unlike traditional forecasting applications, the subseasonal and seasonal forecasts in the Decision Support Tool feature skill scores that measure the quality of the forecasts for different climate variables and regions when compared with many previous predictions for the same location. If the skill score is positive, this means that the forecast is an improvement on 'climatology', indicating that it is better than relying on past observations alone. Climatology remains, however, a common basis for decision-making in weather-dependent industries.

A climate service developed in cooperation with the energy sector

The S2S4E Decision Support Tool is a climate service specifically developed for the energy sector. It features scientifically based climate information intended to enhance users' knowledge of expected weather conditions over the coming weeks and months so that they can use this knowledge in their decision-making. To ensure that the tool is user-friendly and responds to the needs of companies in the energy industry, the S2S4E researchers first had to understand the decision-making processes of energy companies, building on lessons learned from previous EU-funded research projects. They also needed to identify how climate information can be relevant to these decision-making processes. To increase their understanding, the S2S4E researchers interviewed the energy companies involved in the project about their decision-making processes, and about their needs for weather and climate data.

The results of this study on user needs have influenced the design and features of the S2S4E Decision Support Tool and the kind of information it contains. The tool is intended to be used mainly by companies producing renewable energy, energy wholesale traders and grid operators, and it has been created based on how these users need it to be. The tool has been developed in close cooperation with the energy companies involved in the S2S4E project, and with additional support from transmission and distribution system operators (TSOs and DSOs).

Presents forecasts in a way that is easy to understand

The tool developed by the S2S4E project is the first forecasting service that offers integrated subseasonal and seasonal forecasts for electricity demand and power generation from solar panels, wind turbines and hydropower plants. It presents the information in the forecasts in such a way that it can also be understood by people who are not meteorologists.

To ease the interpretation of the forecasts in the S2S4E Decision Support Tool, visualisation features have been developed to make understanding of the information more intuitive:

- Colours are used to give an indication of how the forecasts compare with the seasonal norm for the location of interest.
- Circles are used to show the probability of the forecasts of anomalous behaviour. The bigger the circle, the higher the probability.
- Triangles are used to warn users of forecasts of extreme weather events. A triangle is only used when there is a high probability of a large-scale, unusual weather event occurring in a specific region.

Forecast information in the tool

The forecasts in the S2S4E Decision Support Tool are inherently probabilistic. This means that rather than seeking to predict the specific weather conditions that will take place, they estimate the relative likelihood of different weather conditions occurring. As such, they do not seek to forecast specific weather events – for example that a windstorm will take place on a particular date – but rather provide intelligence about the overall nature of the weather conditions which are likely to occur over the following weeks and months.

The forecasts that are displayed in the tool are all compared with many years of previous forecasts to provide information on the potential for anomalous weather conditions. Users of the tool can thus easily see how the forecasts for each location and lead times compare with the seasonal norm or if, for example, they are expected to be markedly wetter, drier, hotter, or colder than normal. Specialist users can opt to see the full probability distribution of the forecasts, which gives important information about their uncertainty.

Responsive design allow you to access the tool on the go.

Try the tool at
www.s2s4e.eu/dst

S2S4E WHITE REPORT

THE TRANSITION TO RENEWABLE ENERGY INCREASES THE NEED FOR SUBSEASONAL AND SEASONAL FORECASTS

The increasing share of weather-dependent renewable energy makes it more important to have early information about the weather to come. The energy transition therefore increases the need for subseasonal and seasonal forecasts.

A couple of decades ago, when most of the electricity consumed in Europe was produced either by conventional power plants fuelled by fossil fuels or by nuclear power reactors, the amount of power generated was largely independent of the weather.

Back then – in power systems characterised by a low share of renewable energy – only electricity consumption tended to vary in line with changing weather conditions. Electricity consumption usually rose both when it got so cold that people turned on their electric heaters to stay warm, and when it became so hot that they used air-conditioning systems to cool down.

However, due to the expansion of renewable energy, this has now changed. There are today many wind turbines, solar panels and hydropower plants supplying European consumers with clean electricity, and the share of weather-dependent power generation is increasing in line with the further development of wind, solar and hydropower.

Renewable energy is weather-dependent

One of the main challenges with electricity produced from renewable sources is that they are weather-dependent. The amount of wind or solar power produced varies depending on how windy or how sunny it is, respectively. Power production at run-of-river-hydropower power plants is also weather-dependent and varies depending on how much water there is in the rivers where they are located. Many hydropower plants have reservoirs, however, where they can store water and use it when needed. The reservoirs fill up during periods with heavy rainfall and snowmelt, and the water levels in them fall during periods with dry weather. This means that hydropower production is less dependent on the weather conditions on any given day than is wind and solar power generation.

The increasing integration of renewable energy into the power mix is making the electricity supply more vulnerable to changing weather conditions and climate extremes such as droughts, storms and floods, and is leading to increased weather-related risks for both grid operators and energy producers. As a result, both accurate weather forecasts and high-quality and skilful subseasonal and seasonal forecasts are becoming increasingly important to ensure that there is enough available generation at any time to meet demand.

Risk of blackouts to become highest on days with low wind

As part of the S2S4E project, researchers have analysed modelled power consumption across 28 European countries, and in Europe as a whole, over the past 40 years to identify the meteorological situations with the highest demand. The researchers found that in the period from 1979 to 2018, the highest power demand events have occurred on cold, sunny winter days with lower-than-average temperatures, near to average wind speeds and above-normal solar radiation. Situations with very high electricity demand are stressful for grid operators, as they can lead to blackouts if power demand is higher than supply.

However, on these days, the higher the installed capacity of solar and wind power, the bigger the supply of electricity would be from wind turbines and solar panels. Because average wind speeds and solar radiation translate into average wind and solar power production, the weather conditions that can lead to a risk of blackouts are likely to change as the share of renewables in the electricity supply increases.

In a future characterised by a high share of renewable energy in Europe's electricity system, security of supply will no longer be at risk mainly on very cold, sunny winter days. The S2S4E researchers found that potentially stressful conditions will instead be associated with relatively milder temperatures and particularly low wind over the North Sea region, where many of Europe's offshore wind power farms are located.

Subseasonal and seasonal forecasts are still at an early stage

To ensure security of supply, improve risk management and plan their future energy supply, energy companies and grid operators need information about the likelihood of different weather conditions occurring over the coming weeks and months.

Subseasonal and seasonal forecasting is still at an early stage, and it is very challenging to link the complex probabilistic information it provides to specific industry applications. Scientists have been investing considerable effort and resources to improve these forecasts over the past decade, and have made substantial progress.
Subseasonal and seasonal forecasts are now able to predict the evolution of some large-scale extreme weather events several weeks in advance, and to show whether the upcoming season is likely to be drier or wetter, or hotter or colder, than normal.

However, more research is needed to increase the reliability and accuracy of subseasonal and seasonal forecasts, and research programmes should therefore continue to focus on further developing and improving these forecasts and on how such forecasts may become more user-friendly.

SUBSEASONAL AND SEASONAL FORECASTS REMAIN UNDERUSED BY THE ENERGY INDUSTRY

A study by the S2S4E project has shown that subseasonal and seasonal forecasts remain underused by the energy industry, and that the industry’s main motivation for using such forecasts is to manage risk and improve their financial performance.

At the beginning of the S2S4E project, a thorough mapping was done of previous studies and projects on climate services, energy, and user needs to find insights and to learn from them.

The S2S4E researchers also conducted several in-depth interviews with people working at eight different energy companies and grid operators about how they were using subseasonal and seasonal forecasts. This was done to explore their thinking about subseasonal and seasonal forecasts and to find out how information from these forecasts could be adapted and made relevant to their decision-making needs, and how to increase their use of such forecasts.

Most of the respondents in this study, which was completed in August 2018, said their main motivation for using weather and climate forecasts was financial – to secure profits and limit losses through better management of renewable power plants.

Little use of forecasts for weeks and months ahead

The energy sector is highly dependent on weather and climate information, and each step in the electricity value chain is impacted by weather conditions.

Unsurprisingly, the energy companies interviewed for this study confirmed that they were already accustomed to using weather information in their decision-making processes, such as for estimating future renewables production, planning their operations and for deciding when is a good time to purchase or sell contracts for future electricity output.

However, the energy companies in this study have mostly relied on historical climate data or meteorological forecasts with short lead times, and have used subseasonal and seasonal forecasts to a very limited extent.

This is problematic because forecasts with short lead times do not allow for long-term planning, and access to longer-term forecasts therefore allows for more long-term planning.

Seasonal forecasts were perceived to lack credibility and be difficult to use

The subseasonal and seasonal forecasts that were available at the time the S2S4E project started were not seen as attractive to companies invested in renewable energy, due to their complexity and poor quality, particularly for longer lead times.

As a result, energy companies had low confidence in them and tended not to use them very widely when making decisions. Half of the eight companies interviewed said they were not using subseasonal and seasonal forecasts for any decisions. Furthermore, none of them said they were using such forecasts for making decisions on when to perform maintenance work on their assets.

The interviews confirmed, however, that there was an opportunity for high-quality subseasonal and seasonal forecasts to offer value because they could help companies better manage weather-related risks and, potentially, their exposure to such risks.

Many respondents feared that failed forecasts could result in losses

A commonly perceived barrier among several respondents was the belief that the costs of a "failed" forecast would normally be greater than the benefits of a "successful" one. This was because they tended to expect the losses associated with an individual "incorrect" decision to be greater than the benefits that accrued from an individual decision which turned out to be "correct".

This suggests that many users still viewed forecasts from a deterministic perspective (i.e., a binary "yes/no" forecast), rather than assess their own risk tolerances and make full use of probabilistic predictions (i.e., ascribing probabilities to both "yes" and "no" outcomes).

Increased use of subseasonal and seasonal forecasts therefore requires several different challenges to be addressed. While further research and development is undoubtedly needed to continue to improve the quality of the meteorological predictions – and to make them more skilful and reliable – increases in skill alone are unlikely to be sufficient to promote widespread uptake.

A strong emphasis therefore needs to be placed on evaluating forecasts for specific applications, such as specific decision-making tasks, and on supporting users in making full use of the probabilistic information provided in the forecasts.

> **"The interviews confirmed that there was an opportunity for high-quality subseasonal and seasonal forecasts to offer value (..)**

THE RESEARCH BEHIND THE S2S4E DECISION SUPPORT TOOL

Several research teams have been involved in improving the quality of the forecasts in the S2S4E Decision Support Tool. This work has included comparing predictions with observational data, analysing past forecasts, and studying how the weather impacts electricity demand and supply.

Interviews conducted as part of the S2S4E project have revealed that energy companies tend to be risk averse when it comes to using subseasonal and seasonal forecasts.

They are often more concerned about making a decision error due to a poor forecast than making potential gains from using a good forecast. This indicates that it is important that climate services provide information about the reliability and uncertainties of the forecasts.

The S2S4E Decision Support Tool does this by providing calibrated forecasts and presenting information about their uncertainty. A forecast is only useful if it is reliable, and that means that the forecasted probability of an event must match the observed frequency of such events.

The forecasts that are fed into the tool come from the European Centre for Medium-Range Weather Forecasts (ECMWF), one of the world's six leading weather agencies. These forecasts are carefully calibrated against historic observational data. This process is important because model bias could result in poor-quality forecasts, which in turn could lead to bad decisions by those using them in their decision-making.

Studied how the weather impacts energy production and demand

Both energy demand and the production of renewable energy are highly weather-dependent. Temperature affects the demand for energy, while solar radiation, wind speed and precipitation impact how much electricity is produced from solar panels, wind turbines and hydropower stations, respectively.

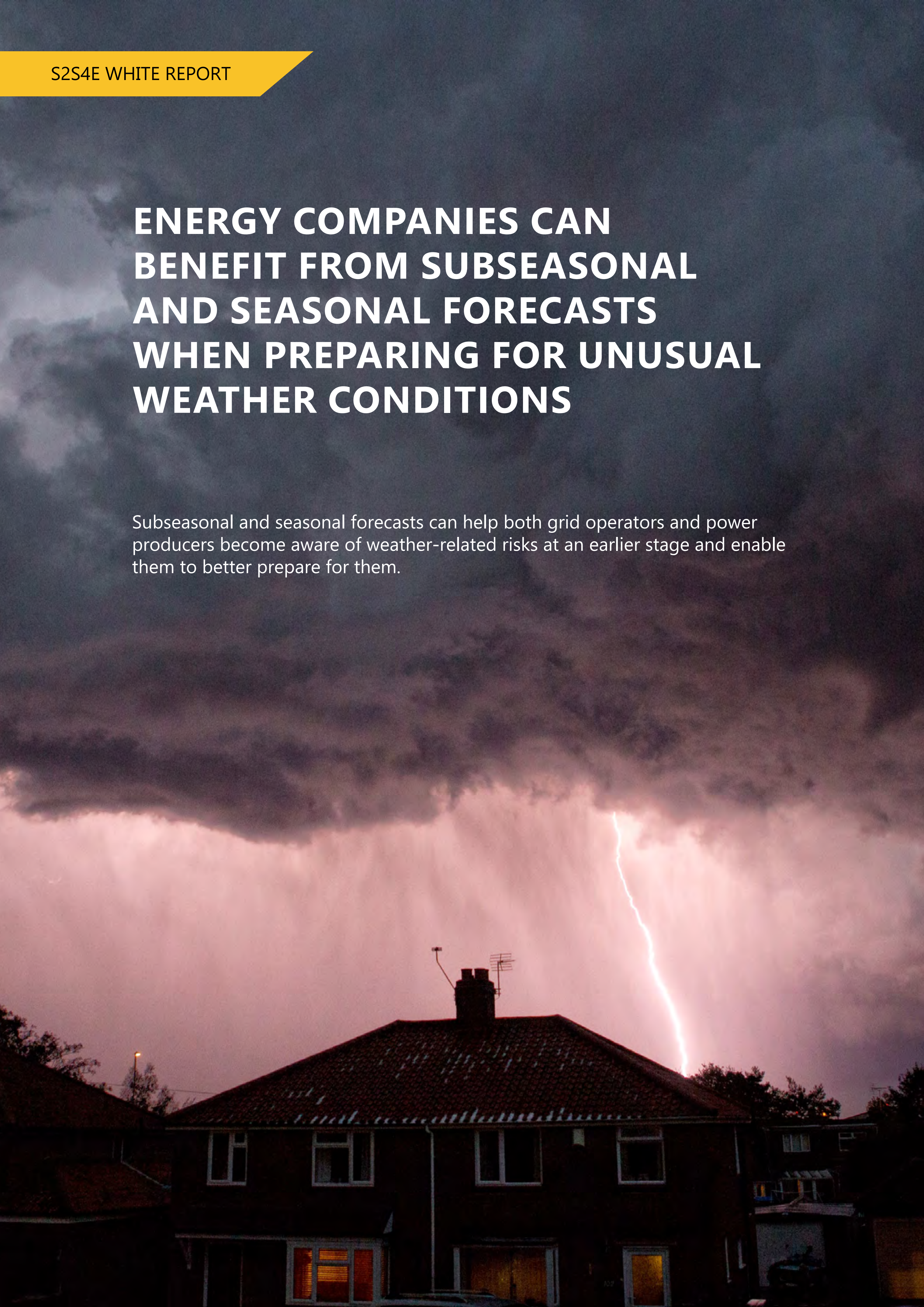
To create the new forecasting tool and make the information in it more useful to people working in the energy sector, the climatologists, meteorologists, and hydrologists involved in the S2S4E project have analysed and processed large amounts of gridded climate information.

They have studied how the weather impacts electricity demand and the production of renewable power in Europe. They have also analysed past forecasts and compared these with historical data of observed weather to understand the quality of these predictions in specific case-study settings to find out whether they would have aided decision-making in these events.

They have then used knowledge about the energy sector and its need to produce a service which is useful to decision-makers in the energy industry and which features information that is tailored to them.

> **It is important that climate services provide information about the reliability and uncertainties of the forecasts.**


S2S4E
Climate Services
for Clean Energy



S2S4E WHITE REPORT

ENERGY COMPANIES CAN BENEFIT FROM SUBSEASONAL AND SEASONAL FORECASTS WHEN PREPARING FOR UNUSUAL WEATHER CONDITIONS

Subseasonal and seasonal forecasts can help both grid operators and power producers become aware of weather-related risks at an earlier stage and enable them to better prepare for them.

The sooner energy companies and grid operators get information on how weather conditions are likely to evolve over the coming weeks and months, the more time they will have to prepare for them and to protect both power plants and power lines from potential hazards. Grid operators can, for example, use subseasonal forecasts for planning their maintenance activities so that these do not take place during a week with stormy weather. Storms can lead to blackouts and have potentially fatal consequences for critical public services such as hospitals, which are dependent on having a stable and secure electricity supply.

Weather conditions always have an impact on how much renewable electricity is produced. However, some weather-related drops in power generation can be avoided or their impacts mitigated. Heavy snowfall can, for example, lead to reduced solar power production because solar panels that are covered with snow do not produce electricity. And when it turns very cold, wind turbine blades may freeze and then stop to prevent engine damage.

If operators of wind and solar power plants know in advance that weather conditions will soon turn very wintry, they can, for example, organise snow removal to minimise the risk of the snow reducing power production and ensure unhindered access to their power plants. Similarly, if hydropower operators know that heavy rain is expected in a couple of weeks or next month, and that it could lead to a risk of flooding, they can reduce the filling levels in their reservoirs to make room for all the water to come.

Seasonal forecasts can help companies identify risk of cooling water problems

Conventional power plants are often located near rivers and lakes to ensure access to plenty of water to cool down the steam produced during the electricity generation process. However, during prolonged periods of very hot and dry weather, the water used for this purpose might get too hot or the river levels too low, which can result in the power plant having to shut down or reduce its electricity production significantly.

Such situations can occur during heatwaves in the summer, when electricity demand tends to be high because people use their air-conditioning systems to cool down. Because problems with too hot cooling water or low river levels can result in lower supplies of power from conventional sources, they can lead to a risk of blackouts.

Moreover, many coal power plants are dependent on getting the coal they need for their power production delivered by ships. However, if the water levels in the rivers drop too low, transporting coal by ship may become impossible. If that happens, the power plant managers may need to order coal delivery by rail or road transport instead.

Subseasonal and seasonal forecasts can be used to predict when conventional power plants may experience problems with too hot cooling water or low water levels in nearby rivers and thereby help energy producers prepare for such events. Used in this way, subseasonal and seasonal forecasts can help increase the security of supply during prolonged periods of unusually hot and dry weather.

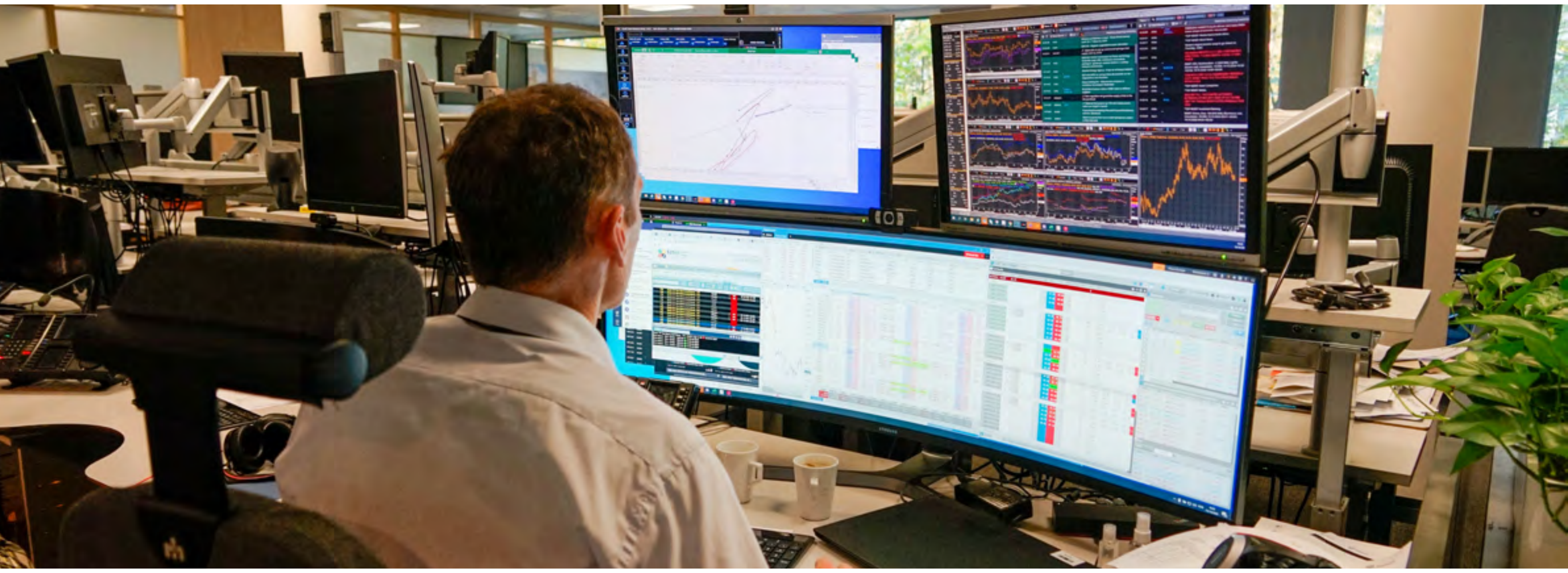
Can help plant operators plan both power production and maintenance

Energy companies can also use subseasonal and seasonal forecasts to plan their power production with greater accuracy and for longer time frames under more typical weather conditions. Weather variables such as solar radiation, temperature, wind speed and precipitation can be used for estimating future electricity production from solar panels, wind turbines and hydropower plants. Subseasonal and seasonal forecasts can thus be used for production planning for renewable energy plants.

Moreover, these forecasts can help operators of both renewable and conventional power plants decide when is the best time to plan maintenance outages. Power plants usually need to be shut down to undergo maintenance, which will lead to a reduction in power production. Maintenance outages can thus create a risk to the security of electricity supply, particularly if a power plant is taken offline when power demand is high.

USE OF SUBSEASONAL AND SEASONAL FORECASTS CAN POTENTIALLY LEAD TO MORE SUCCESSFUL ENERGY TRADING

When subseasonal and seasonal forecasts show skill and prove accurate, they can potentially help increase the earnings of the energy companies using them, as research by the S2S4E project shows.



One of the main challenges with electricity produced from renewable sources is that it is weather-dependent. Very little wind and solar power is generated when the wind does not blow and the sun does not shine, and hydropower production drops in periods with little rain and low snow melting.

Subseasonal and seasonal forecasts have the potential to predict weather conditions weeks and months in advance. By giving companies in the energy industry early information about the weather conditions that are likely to occur, such forecasts can help them improve their trading strategies, which in turn can lead to better financial outcomes.

Renewables production is a major price driver in the power market

Weather conditions are a key factor in the formation of wholesale electricity prices because both renewable power production and electricity demand are weather-dependent. Temperature forecasts are the most important climate variable for estimating electricity demand. This is particularly the case in countries that rely heavily on electricity for heating, such as France and Norway.

Moreover, in countries that often experience very hot summers – such as those in southern Europe – power demand also tends to increase when the weather gets so hot that many people use air-conditioners to cool down. Power demand thus tends to increase both when it gets very cold and when it gets very hot.

How much clean power is produced has a huge impact on power prices, and because the fuel needed for renewable power generation – wind, sun and water – is available free of charge, the marginal costs of such electricity generation are close to zero. This means that electricity prices tend to fall when clean energy production is high and to rise when renewables generation is low.

Use of climate forecasts can lead to more successful energy trading

Electricity is not just traded in the spot market on the day before delivery. Energy companies often sell their electricity output in the forward market well in advance, and prices on power contracts for the next few weeks and months are to a large degree dependent on the expected power demand and supply of clean energy.

Whether the energy market participants have made a good deal becomes clear with the publication of the spot settlement on the day before delivery. If the settlement price on the energy exchange – known as the electricity spot price – out-turns lower than the price for delivery for the same day in the forward market, then the forward contract was overvalued. And vice versa: if the forward price is lower than the spot out-turn, the forward contract was undervalued.

Weather conditions that are not in line with the seasonal norm – such as extremely cold winters or unusually hot summers – can result in both electricity demand and renewable power production being higher or lower than normal. Having information about how hot, cold, wet, dry, or windy the upcoming weeks and months are expected to be can be critical for estimating how high or low both electricity demand and renewable power production are likely to be. Predicting the weather thus plays a key role in electricity price forecasting. This means that when subseasonal and seasonal forecasts are skilful and accurate, they can help energy companies improve their trading strategy.

Forecasts can give indications of when to buy or sell power

In countries with high installed solar and wind power capacity, forecasts of unseasonably high wind and solar power production indicate that electricity prices are set to drop. They therefore usually lead to price falls for the period when clean power output is expected to be high. However, if the operators of the wind and solar power plants get early information about this, they will perhaps be able to sell their electricity production for this period in the forward market before prices start to fall and thus get a higher price for their output. Subseasonal and seasonal forecasts can help them with that, as they can give them information about how the weather is likely to evolve in the weeks and months ahead.

Such forecasts can also be useful for hydropower producers, because if they know that very wet weather is expected next month – which is likely to lead to lower prices – they can increase their hydropower production now, before prices start falling, in order to achieve higher earnings.

However, this selling strategy only works if most of the competitors do not have access to the same forecasts, and hence do not know that the weather is soon likely to turn very wet. If they all start increasing their hydropower production now, the spot market will be affected by the higher output, which will lead to weaker prices.

Moreover, hydropower producers can also use subseasonal and seasonal forecasts to decide whether to store water in their reservoirs for longer periods of time instead of using it to produce electricity now. Storing it could be a good idea if both demand and prices are expected to rise at some later point, which could happen during, for example, prolonged periods of cold and dry weather.

Can reduce the earnings loss caused by maintenance outages

Power plant operators can also use subseasonal and seasonal forecasts when scheduling maintenance outages, to ensure that these will occur when both power prices and demand are expected to be low. By doing this, they can reduce the earnings loss caused by lower electricity sales during the maintenance period, as electricity production is usually reduced or stopped completely when power plants undergo maintenance.

A combination of high energy demand and low supply of electricity from renewable sources usually indicates higher power prices. Energy companies that shut down their plants during such periods will therefore suffer a greater drop in earnings due to the shutdown than they would if the maintenance occurred at a time when demand and prices were lower. Moreover, wind and solar power operators will also see their earnings reduced if they shut down their plants for maintenance during periods with strong wind or sunny weather because they will then experience lower electricity sales. Operators of wind turbines and solar panels should thus ideally schedule maintenance for periods when wind speeds or solar radiation is forecast to be low. Subseasonal and seasonal forecasts can help them with that.

CASE STUDIES

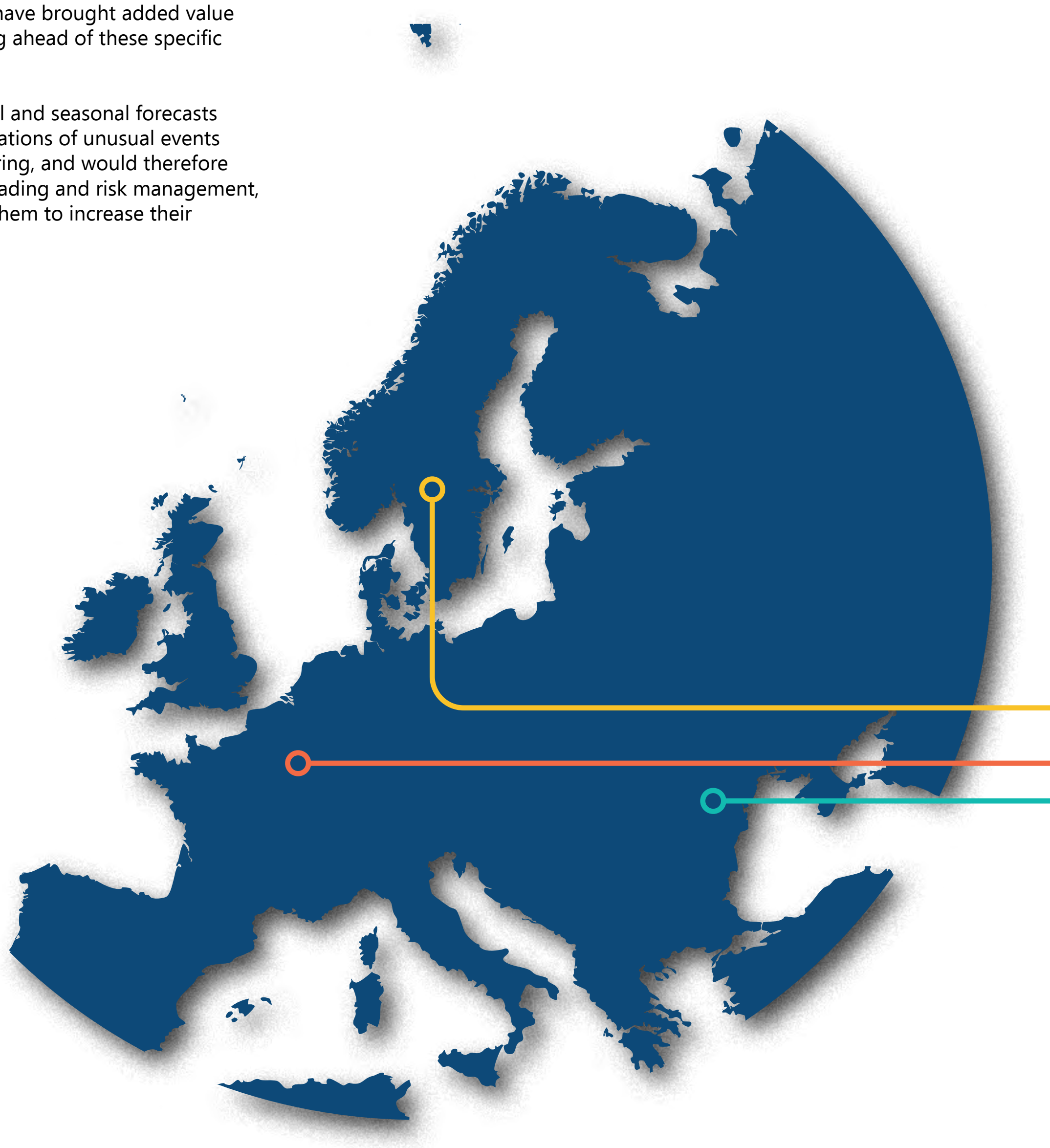
UNUSUAL SITUATIONS IN THE POWER MARKET

Studies by the S2S4E project of specific, unusual situations in the power market in several European countries show that subseasonal and seasonal forecasts could often bring added value to companies' decision-making.

As part of the S2S4E project, several case studies have been conducted for situations in the energy market which the energy companies involved in the project remember due to unseasonal weather conditions.

The case studies are based on in-depth interviews and continuous collaboration with the energy companies involved in the project. In the following, we will go through three of these case studies, and show how subseasonal and seasonal forecasts might have brought added value to companies' decision-making ahead of these specific events.

In some cases, the subseasonal and seasonal forecasts were able to offer strong indications of unusual events well in advance of them occurring, and would therefore have been valuable for both trading and risk management, helping the companies using them to increase their earnings and limit losses.



Case studies: Brief overview

Download all the case studies

FRANCE, 2017

A cold spell in France in January 2017 led to a jump in electricity demand and prices. Subseasonal forecasts could have helped power producers implement better trading strategies.

ROMANIA, 2014

In Romania in winter 2014, snow and sub-zero temperatures caused power production at several wind farms to stop. The subseasonal forecast produced for this event by the S2S4E project could **not** have helped the wind farm operators prepare for this situation.

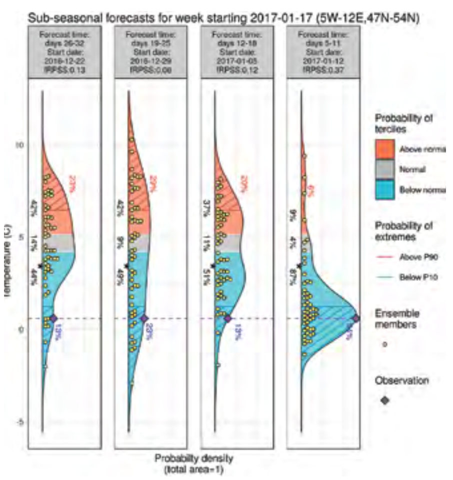
SWEDEN, 2015

Very wet weather in Sweden in summer 2015 caused power prices to plunge. The resulting losses for hydropower operators could potentially have been reduced if they had used seasonal forecasts in their decision-making.

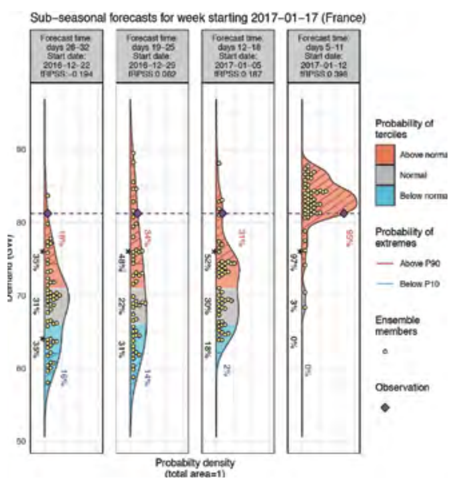
CASE STUDY

USE OF SUB-SEASONAL FORECASTS COULD HAVE LED TO MORE SUCCESSFUL POWER TRADING IN FRANCE IN WINTER 2017

A cold spell in France in January 2017 led to a jump in electricity demand and prices. Subseasonal forecasts could have helped power producers implement better trading strategies, research by the S2S4E project shows.



Sub-seasonal electricity demand forecasts for February 27th, 2018. Issued four, three, two and one week in advance. -seasonal electricity demand forecasts for February 27th, 2018. Issued four, three, two and one week in advance.



Sub-seasonal temperature forecasts for February 27th, 2018. Issued four, three, two and one week in advance.

In January 2017, a prolonged period in Europe with temperatures below the seasonal norm led to a large increase in electricity demand, particularly in France, where most households rely on electricity for heating.

At the same time, wind speeds in the country were low, resulting in low wind power production, and some nuclear power plants were offline for maintenance. The combination of high demand and tight supply led to a risk of blackouts and caused electricity prices to jump.

Subseasonal forecasts could have predicted the cold weather

A case study by the S2S4E project found that if the French power producers had used subseasonal forecasts in their decision-making, they would have had a strong indication more than three weeks in advance that power demand was likely to surge in the second half of January due to cold weather.

This could have enabled them to make better estimates for the electricity prices to come, and hence to implement more successful trading strategies.
For this case study, subseasonal forecasts were produced for the week when the power situation in France was at its most severe – from 16–22 January – based on data from the European Centre for Medium-Range Weather Forecasts (ECMWF).

These forecasts showed already three weeks in advance that temperatures in France would likely be around freezing in the week starting on 16 January, and the probability increased as the forecasts were updated. Three weeks in advance, these forecasts also indicated that power demand that week was likely to be above normal.

The subseasonal wind forecasts were less successful, and three weeks in advance they inaccurately indicated that wind speeds would be above or around normal. They changed two weeks later, and then started showing an increased probability of below-normal wind speeds. However, they markedly underestimated how extreme the low wind event would be.

The spot price out-turned lower than expected

In the week before the cold snap, weather forecasts also indicated that it would likely be unusually cold. This pushed up prices in the forward market, with the French power contract for the week 16–22 January trading as high as EUR 170/MWh.

As the spot settlement later showed, however, this contract was markedly overvalued, with the French spot price for this week out-turning much lower, and averaging EUR 89.61/MWh. Spot prices settled lower because the weather forecasts available at the time, and consequently also the market, had over-estimated how cold it would be.

For energy traders looking to buy power for that week, the overvalued contract for the week 16–22 January means that it would have been better to buy electricity in the spot market rather than in the forward market.

Subseasonal forecasts could have contributed to more successful trading

Analyses by the S2S4E project showed that the subseasonal forecasts produced for this case study would have provided more skilful temperature estimates for the week starting on 16 January than the weather forecasts available at the time did in the week before the cold snap.

The subseasonal forecasts could therefore have helped traders realise that the contract in the forward market was likely to be overvalued, which could have enabled them to implement better trading strategies.

This was confirmed by the energy company employees interviewed by the S2S4E project, who said that the subseasonal forecasts produced for this event could have helped their companies achieve higher earnings and reduce losses.

Could have helped traders buy power when prices were lower

The subseasonal forecasts could also have helped traders looking to buy electricity in the forward market realise when was a good time for them to buy the power they needed for the week starting on 16 January.

In the electricity forward market, prices move every day, and the price for that week reached its lowest level about two weeks earlier, on 5 January, when the contract traded at EUR 63/MWh.

The subseasonal forecasts indicated already then that the weather in the week starting on 16 January was likely to be colder than normal. If traders had seen those forecasts, they might have realised that this was a good price for the power contract for that week. Moreover, if they had bought the power they needed then, they could have saved 29% compared with buying electricity in the spot market.

The subseasonal forecasts produced for this case study could therefore have enabled energy companies to make better informed trading decisions which in turn could have led to better financial outcomes.

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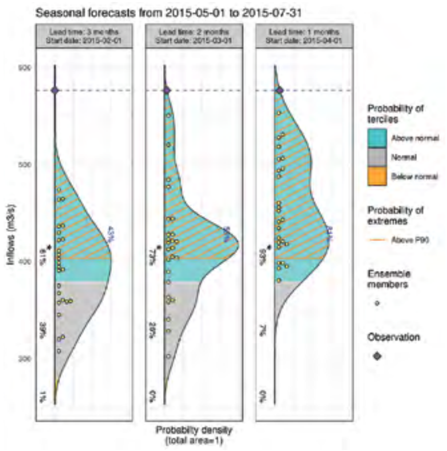
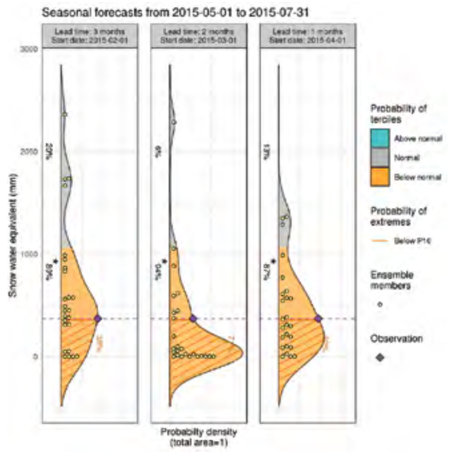
CASE STUDY

BETTER FORECASTS COULD HAVE PREVENTED LOSSES FOR SWEDISH HYDROPOWER IN 2015

Very wet weather in Sweden in summer 2015 caused power prices to plunge. The resulting losses for hydropower operators could potentially have been reduced if they had used seasonal forecasts in their decision-making, a study by the S2S4E project shows



Forecasts for inflows for May to July 2015, based on bias-adjusted ECMWF SEAS5 forecasts and the E-HYPE hydrological model. Lead times range from 1 to 3 months.



Forecasts for snow water equivalent for May to July 2015, based on bias-adjusted ECMWF SEAS5 forecasts and the E-HYPE hydrological model. Lead times range from 1 to 3 months.

In the period May–July 2015, precipitation levels in Sweden were well above normal for the time of year, with the rain filling up the country's hydropower reservoirs. At the same time, it was unseasonably cold, causing snow melting to occur slower and later than expected.

In early July, there was still a lot of snow left in the mountains. When this melted later that month, the water inflows to the hydropower reservoirs reached extreme levels. To reduce the risk of flooding, many hydropower producers therefore had to release water from their reservoirs without using it to generate electricity.

Not all hydropower plants have reservoirs, however, and the wet weather led to very high unregulated hydropower production. In addition, wind levels were also strong, causing high wind power generation.

Nordic spot slid to a 17-year low

The combination of very wet and windy weather caused wholesale power prices to plunge. After having fallen all summer, the Nordic system price hit a 17-year low on 26 July, at EUR 3.88/MWh, according to data from the NordPool exchange. At the time, this was the lowest ever Nordic spot price denominated in euros, and the last time it had been lower was in August 1998, about four months before the introduction of the euro.

Moreover, for the third quarter of 2015, Nordic spot prices averaged EUR 13.30/MWh, which was 58% lower than during the same period the previous year.
The weak power prices had a strong negative effect for the companies selling electricity in the Nordic market by reducing their earnings from power production.

Inaccurate forecasts

Both the unseasonably wet weather and the amount of snow left in the Swedish mountains in July had been underestimated by most available short-term forecasts. The result was that the water inflows to the hydropower reservoirs were much higher than expected. If the hydropower producers had known in advance how high the inflows would be in late July, their financial losses could potentially have been reduced, as they could then have increased their power production earlier when prices were higher. By doing so, they would also have reduced their hydro filling levels to leave more room for all the water that was to come later that summer.

A case study done as part of the S2S4E project has found that if the hydropower producers had used seasonal forecasts instead of the hydro-meteorological forecasts available at the time – which showed predictions only for the next 10 days – they would have had more reliable information in advance of how the situation was likely to develop. This could have enabled them to better prepare for it.

"The combination of very wet and windy weather caused wholesale power prices to plunge.

Seasonal forecasts were more reliable

For this case study, seasonal forecasts were produced for the May–July 2015 period, based on data from the European Centre for Medium-Range Weather Forecasts (ECMWF).

These forecasts showed already three months in advance that precipitation levels were likely to be above the seasonal norm, and that there was a high probability that water inflows to the Swedish hydropower plants would also be above normal.

However, like the short-term forecasts available at the time, the seasonal forecasts also underestimated the amount of rain and how high the inflows would be, indicating how challenging it can be to incorporate such forecasts into the decision-making processes of hydropower producers.

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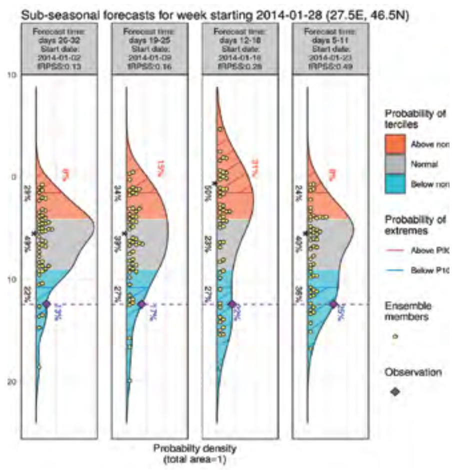
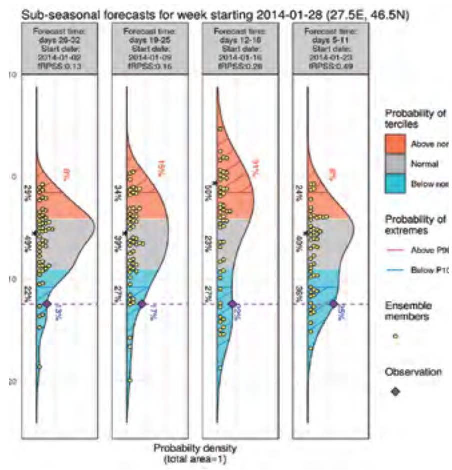
CASE STUDY

THE SUBSEASONAL FORECAST PRODUCED FOR THE ROMANIAN 2014 COLD SNAP SHOWS THAT MORE RESEARCH IS NEEDED TO IMPROVE THE QUALITY OF THESE FORECASTS

In Romania in winter 2014, snow and sub-zero temperatures caused power production at several wind farms to stop. The subseasonal forecast produced for this event by the S2S4E project could not have helped the wind farm operators prepare for this situation.



Sub-seasonal average temperature forecasts for January 28th through February 3rd, 2014. Issued four, three, two and one week in advance.



Sub-seasonal minimum temperature forecasts for January 28th through February 3rd, 2014. Issued four, three, two and one week in advance.

Romania experienced a prolonged period of unusually wintry conditions in January and February 2014, with temperatures well below the seasonal norm. This caused some of the wind turbines in the country to freeze and power production at the affected turbines to stop. As snow filled up the roads, it became difficult for the wind farm operators to reach their turbines to defrost them to make them restart. Due to the snow-covered roads, it also took some time before the operators realised what had happened.

Electricity producers must communicate every day to the market how much electricity they will deliver to the grid the following day. As a result of not being able to provide the amount of electricity that they had offered, the operators of the frozen wind farms had to pay penalties – known as deviation costs – to the transmission system operator.

The operators also suffered losses because of lower electricity sales. For some of the wind farms, the turbines remained frozen for nearly three weeks, meaning three weeks with zero power production at the affected turbines.

Operators could have prepared for the snow if they had known about it

If the wind power operators had known in advance that it was likely to turn so cold that the rotors on the wind turbines could freeze and that snow could potentially block access to the roads to the wind farms, they might have been able to better prepare for this situation. If they had foreseen that wind power production could be reduced because of the wintry conditions, they could have adjusted the amount of power they offered to the market accordingly.

Moreover, if they had known in advance that there was a high likelihood of heavy snowfall, they could have ensured access to the wind farms to monitor the conditions there by ordering snow ploughs to keep the roads clear. Both measures would have resulted in lower deviation costs for the companies, and the cost of ordering snow removal would likely have been lower than the penalties they had to pay.

S2S4E forecasts could not have helped predict this cold snap

The S2S4E project has produced a subseasonal forecast for one of the three weeks the cold snap lasted to see if that week's wintry conditions could have been foreseen.

In general, this forecast did not give a strong indication of the occurrence or intensity of this cold snap. At two weeks ahead, the temperature forecasts did indicate that temperatures were likely to be colder than normal, with a small chance of extremely cold temperatures, but there was much uncertainty in the prediction. It is therefore unlikely that this forecast could have helped the wind farm managers in Romania limit the losses resulting from the cold snap.

This case study shows how challenging it can be to produce accurate and reliable subseasonal forecasts, and that more research is needed to improve their quality.

If the subseasonal forecast produced for this weather event had been accurate – and if it had been available before the event – it could have enabled the wind farm operators to reduce the losses resulting both from the deviation costs they had to pay and from the lower electricity sales they experienced, by improving their trading, operation, and management activities.

> **“This case study shows how challenging it can be to produce accurate and reliable subseasonal forecasts, and that more research is needed to improve their quality.**

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SUBSEASONAL AND SEASONAL FORECASTS CAN BE USEFUL FOR ALL WEATHER-DEPENDENT INDUSTRIES

The sooner companies have access to reliable information about the weather to come, the sooner they can start planning for it. Subseasonal and seasonal forecasts thus have the potential to help all weather-dependent sectors better manage climate-related risks

All companies which must adapt their activities according to the weather and for which the weather has an impact on their income could potentially benefit from using subseasonal and seasonal forecasts.

Most weather forecasts only show predictions for up to 10 days ahead, which does not allow for long-term planning. However, by using subseasonal and seasonal forecasts, companies can obtain information about how the weather conditions are likely to evolve over the next six weeks and the next seven months, respectively.

Such forecasts could be of great value to a wide range of sectors and businesses which are affected by variability in climate, water, and energy and which could benefit from better understanding and managing climate-related risks.

S2S4E
Climate Services for Clean Energy

Useful for those working in the field of disaster management or health care

All sectors that are working to either limit the economic and social damage caused by unusual weather-related events – such as storms, floods, heatwaves, and wildfires – or to cope with their aftermath could potentially benefit from having information about the likelihood of different weather conditions occurring over the coming weeks and months. In addition to causing damage to buildings and infrastructure, unusual weather conditions can have detrimental impacts on people's health and well-being.

A heatwave can lead to people suffering from medical conditions such as heat strokes, dehydration, and heart problems, and the earlier the public health sector knows that there is a high likelihood that there will soon be a heatwave, the earlier they can start preparing for it.

Subseasonal and seasonal forecasts can thus be useful for those working in the public health or insurance sectors, or in disaster mitigation and management.

Useful for those working in the tourism industry

Subseasonal and seasonal forecasts can also be useful for those working in the tourism industry. If they get early information about how weather conditions are likely to be in the upcoming season, they can plan their activities and destination offers accordingly.

The result may be more satisfied customers because it would increase the likelihood of people traveling to places where the weather will be good while they are there. It could also lead to safer tourism because holidaymakers could avoid destinations where a heatwave or a storm is expected to occur during their holiday.

Moreover, subseasonal and seasonal forecasts could also be useful for people who are planning their holidays. If they are planning a skiing holiday, they can use the forecasts to see where and when wintry conditions are expected. If they want to travel to someplace warm and sunny, they can check the predictions to make sure that the weather is not anticipated to be unusually wet and cold at their planned destination before they book their holiday.

Seasonal forecasts provide useful information to farmers

The agriculture industry is another sector for which subseasonal and seasonal forecasts can be useful. By getting information about the likelihood of the upcoming season turning particularly dry or wet, or hot or cold, they could plan what they decide to grow, and when, accordingly.

Subseasonal and seasonal forecasts could thus give farmers a better idea of which plants, fruits, vegetables, and berries could – and which could not – blossom under the weather conditions that are likely to evolve over the next few months, when to plant their seeds and when to harvest their crops. The result could be more successful growing seasons and fewer years with failed crops.

BETTER RECOGNITION OF SUBSEASONAL AND SEASONAL FORECASTS NEEDED AT THE NATIONAL LEVEL

A better recognition of sub-seasonal and seasonal forecasts as a relevant solution to anticipate variations in renewable energy production is needed at the national level, an S2S4E analysis of energy policy in seven European countries showed.

Although it is possible for governments to support the use of subseasonal and seasonal forecasts – or of climate services more generally – measures designed specifically to that end at the national level remain rare.

At the national level, the main political driver for using subseasonal and seasonal forecasts is the strong willingness of governments to support the development of renewable energy, the S2S4E researchers behind the analysis concluded.

The promotion of renewable energy can be considered as indirect support for the use of such forecasts, as a higher share of weather-dependent renewable energy will make it more important to forecast clean energy output to ensure that overall electricity production will be high enough to meet demand.

The study was conducted in autumn 2018, and analysed policy support for climate forecasts in France, Germany, Italy, Norway, Spain, Sweden, and the UK – all the S2S4E partner countries.

The researchers involved in the study found no national policies in these countries that directly support the use of subseasonal and seasonal forecasts.

Climate services not mentioned in national research programmes

As part of the study, the researchers involved also analysed research and development programmes and measures in these seven countries that support the uptake of technologies aimed at increasing the resilience of the energy system to weather fluctuations. Again, they found no specific mention of climate services or subseasonal and seasonal forecasts.

One reason why there are few measures designed on the national level to influence the use of climate services may be that such services are not considered sufficiently mature compared with other solutions aimed at increasing the resilience of the energy system.
Another explanation could be that since the EU is giving considerable funding for research on climate services, national research councils do not see these as relevant to their portfolio. A third possible explanation could be that policymakers have little knowledge of subseasonal and seasonal forecasts and the benefits of using them, and therefore do not consider them when designing new policies.

Research programmes should focus on subseasonal and seasonal forecasts and their use

Although scientists have made substantial progress over the past decade when it comes to improving the quality of subseasonal and seasonal forecasts, such forecasts are still often considered to be unreliable or lacking in skill, and therefore remain little used. Subseasonal and seasonal forecasting is still at an early stage, and it is very challenging to link the complex probabilistic information they provide to specific industry applications.

More research therefore needs to be done to improve the quality of subseasonal and seasonal forecasts and, in particular, their use in decision-making. Such forecasts should be promoted by national governments in their energy policies and be integrated into the portfolio of technologies and services that should be further developed by their research and development programmes.

S2S4E
Climate Services
for Clean Energy

S2S4E WHITE REPORT

EU POLICY IS INCREASINGLY SUPPORTIVE OF CLIMATE SERVICES

Following successive amendments of the major energy directives, EU policy has in recent years become more supportive of the use of weather and climate services, a policy analysis by the S2S4E project shows.

The EU adopted its first rules for harmonising and liberalising its internal energy market in 1996, and the rules have since been updated four times. The last time was in 2019 with the completion of the fourth EU energy package, known as the Clean energy for all Europeans package, often referred to simply as the Clean Energy Package. Over the same period, the EU's targets for renewables in its final energy consumption have become increasingly more ambitious: from 12% in 2010 to 20% in 2020, and to 32% by 2030. And while the 2010 target was only indicative, the targets for 2020 and 2030 are legally binding. Of all legislative documents on EU energy policy, it is the directives and regulations related to the security of electricity supply that most strongly encourage the use of subseasonal and seasonal forecasts, the S2S4E researchers behind the analysis concluded. The EU's renewables targets also provide indirect support to the use of subseasonal and seasonal forecasts. A larger share of weather-dependent renewable energy will make it more important for both grid operators and energy companies to skilfully forecast clean energy production to ensure that the total electricity generation can be managed to adequately meet demand. That will likely lead to them becoming more interested in using tools or services that can help them make more accurate predictions of both electricity demand and the production of renewable energy.

First energy directives offered only indirect support

With each EU energy policy update, more detailed rules for how to ensure security of supply have been introduced. As a result, the legal incentives for using subseasonal and seasonal forecasts have become increasingly stronger. The first EU electricity directive of 1996, Directive 92/92/EC, only indirectly supported the use of weather and climate services by encouraging the development of renewable energy. This directive was replaced in 2003 by the Internal Market in Electricity Directive (Directive 2003/54/EC), which went one step further by requiring monitoring of electricity supply and demand. Two years later, Directive 2005/89/EC concerning measures to safeguard the security of electricity supply and infrastructure investments was introduced. This directive required Member States to also report on projected supply and demand and noted that there was a need for tools that could help anticipate demand-side variations. Meanwhile, the word "forecast" was not mentioned in relation to supply and demand in any EU directive before 2009. Directive 2009/72/EC was then introduced as part of the Third Energy Package – replacing Directive 2003/54/EC – which was the first EU energy directive to make explicit reference to weather services. It took another decade, however, before EU regulation explicitly acknowledged the risk that extreme weather conditions – such as cold spells and heatwaves – could pose to the electricity system. This was done with the comprehensive update of EU energy policy brought about by the implementation of the Clean Energy Package, which was completed in 2019.

Direct support introduced with the Clean Energy Package

The Clean Energy Package resulted in the introduction of the Risk Preparedness Regulation, which is the first EU regulation that explicitly mentions the need for forecasts for power demand and electricity supply at a seasonal timescale. For that reason, this regulation is the strongest policy support to date at EU level for using seasonal forecasts.

The Risk Preparedness Regulation requires that the European Network of Transmission System Operators for Electricity (ENTSO-E) carry out "seasonal adequacy assessments" twice a year – winter and summer – "to alert Member States and transmission system operators to risks related to the security of electricity supply that might occur in the following six months". The regulation also required ENTSO-E to develop a methodology to conduct these adequacy assessments. This methodology was adopted in March 2020. Moreover, the Risk Preparedness Regulation stipulates that the methodology should be updated "where significant new information becomes available".

Seasonal adequacy assessments require the use of weather data

The aim of the seasonal adequacy assessments is, according to the new ENTSO-E methodology, to monitor whether available electricity supply and transmission capacity "are sufficient to cover demand under various weather and operational conditions on a temporal horizon of up to six months ahead". The methodology emphasizes that the adequacy assessments should consider the variability of both electricity demand and power production from renewable energy depending on weather conditions, and the impact of variable weather conditions on electricity demand and supply. It also stresses that data related to hydro inflows, solar radiation, wind speed and temperature "shall consider weather forecasts when available". Moreover, the methodology stipulates that month-ahead adequacy assessments are to be carried out and led by ENTSO-E if supply or network availability changes significantly compared with the assumptions used in the seasonal adequacy assessments and thereby cause an adequacy risk, or if an extraordinarily low supply and/or transmission availability is foreseen. By referring to adequacy assessments for the month-ahead, the methodology also provides support for the use of subseasonal forecasts, as it is these predictions that offer insights into how the weather will evolve over the coming weeks.

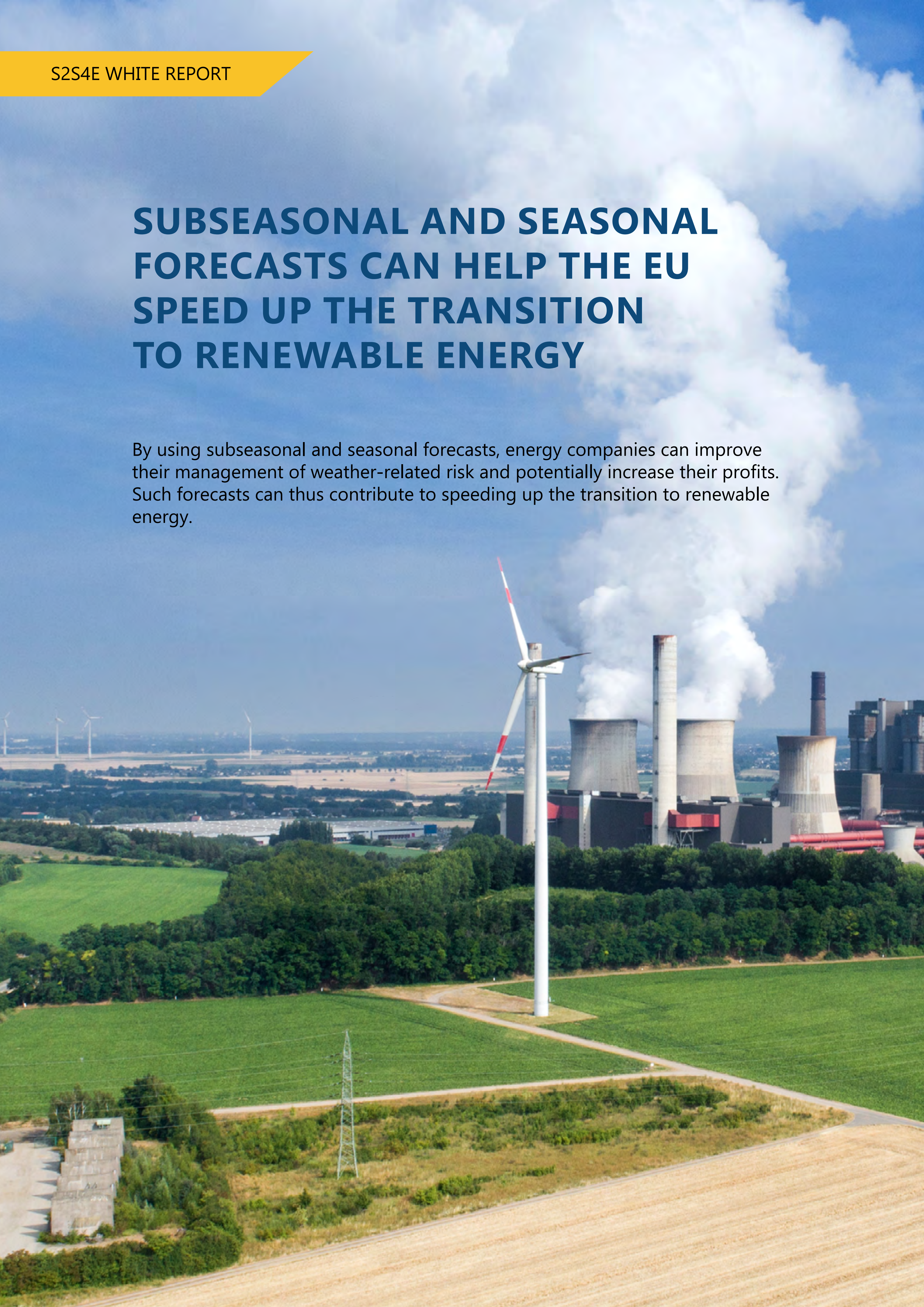
ENTSO-E methodology does not mention subseasonal and seasonal forecasts

One shortcoming of the methodology is, however, that it does not require the use of subseasonal and seasonal forecasts to carry out the seasonal adequacy assessments. Instead, it just mentions weather forecasts, which typically only cover time spans for up to 10 days ahead. Although the methodology here may refer to all kinds of weather and climate data, a future update of it should make the reference to subseasonal and seasonal forecasts explicit. By doing so, the methodology would stress the importance of such forecasts for estimating electricity supply and demand for longer time frames than just the next 10 days.

S2S4E WHITE REPORT

SUBSEASONAL AND SEASONAL FORECASTS CAN HELP THE EU SPEED UP THE TRANSITION TO RENEWABLE ENERGY

By using subseasonal and seasonal forecasts, energy companies can improve their management of weather-related risk and potentially increase their profits. Such forecasts can thus contribute to speeding up the transition to renewable energy.



At the Paris climate conference (COP21) in December 2015, the world's governments adopted the first-ever universal, legally binding global climate change agreement. Under this agreement, they have committed to strengthening the global response to the threat of climate change by keeping the global temperature rise this century well below 2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5°C.

To reach the ambitions of the Paris Agreement, the EU has pledged to cut its greenhouse gas emissions by at least 40% by 2030 compared with 1990 levels, and is currently debating whether to increase this target to 'put the EU on a balanced pathway to reaching climate neutrality by 2050'.

Putting Europe on track to climate neutrality

As set out in the European Green Deal strategy, which was launched by the European Commission in December 2019, the EU aims to be a global leader in climate policy and to make Europe the first climate-neutral continent by 2050. Increasing the share of renewable energy will be key to cutting Europe's greenhouse gas emissions.

Although the share of renewable energy in Europe has been increasing steadily, the pace of growth has slowed down in recent years. The share of renewables in the EU's gross final energy consumption stood at 18% in 2018, according to the latest figures from the EU's statistical office Eurostat. The EU aims to increase this to at least 32% by 2030.

One way to speed up the transition to renewable energy could be to help the companies already invested in the sector to improve their risk management and production planning activities, and to make them better informed about how much electricity their wind, solar and hydropower plants are likely to generate over the coming weeks and months. If renewable energy production became less risky, more people and companies would likely be interested in investing in it.

Clean energy is weather-dependent

Because renewable energy production is weather-dependent and it is challenging to know how much clean electricity will be produced on any given day, the increasing integration of renewables into the power mix is making the electricity supply more vulnerable to changing weather conditions.

When subseasonal and seasonal forecasts are skilful and accurate, they can help producers of wind, solar and hydropower get better informed estimates of how much electricity their plants are likely to generate in the weeks and months ahead.

Improved estimates of future power output can enable them to make better decisions on issues such as when to sell their electricity to the market, how much they should sell, which price levels to expect, and when to schedule maintenance of their power plants. Used in this way, subseasonal and seasonal forecasts can help improve risk management for companies invested in renewable energy, and potentially increase their earnings and limit their losses.

Climate services can contribute to ensuring security of supply

The increasing integration of renewable energy into the power mix is also leading to increased weather-related risks for grid operators, which at all times must maintain grid stability and ensure that sufficient levels of generation capacity are available to meet demand.

Electricity demand is also weather-dependent. Power consumption tends to increase both when it gets so cold that people turn on their electric heaters to stay warm and when it gets so hot that air conditioners are needed to cool down. Moreover, as many EU countries aim to electrify their heating systems to meet their carbon reduction targets, the link between electricity consumption and outside temperatures in Europe is expected to become stronger.

Because the weather-related risks for grid operators are increasing amid the growth of renewable energy, both accurate weather forecasts and skilful subseasonal and seasonal forecasts are becoming increasingly important to ensure security of supply.

Subseasonal and seasonal forecasts can help grid operators anticipate likely changes in both power demand and the production of electricity from renewable sources over the coming weeks and months.

Such forecasts can thus play an important role in maintaining grid stability and preventing blackouts, and their importance and usefulness for grip operators will continue to increase in line with the growth of weather-dependent renewable energy in the electricity supply.

> **Increasing the share of renewable energy will be key to cutting Europe's greenhouse gas emissions**

THE S2S4E PROJECT CALLS FOR MORE POLICY SUPPORT FOR SUBSEASONAL AND SEASONAL FORECASTS

With a rising share of renewable energy in Europe's electricity supply, there is a need for new policies that reduce the risks involved in weather-dependent energy production and to mitigate the risks posed to security of supply by the growth of clean energy.

Subseasonal and seasonal forecasts have the potential to help increase security of electricity supply and better manage weather-related risks amid the growth of weather-dependent renewable energy. They can therefore help speed up the transition to renewable energy and contribute to reducing greenhouse gas emissions from the power sector.

Currently, however, there are few policy measures specifically designed to influence the use of subseasonal and seasonal forecasts at EU or national level, and such forecasts remain underused.

Details about proposed measures on following pages →

To increase the use of subseasonal and seasonal forecasts and improve the quality of such forecasts, **we propose the following six measures:**

The Copernicus Climate Change Service should make sub-seasonal forecasts easily accessible to everyone in its Climate Data Store

The Climate Data Store from the Copernicus Climate Change Service is the European initiative to provide a single point of access to a wide range of quality-assured climate datasets distributed online. The Climate Data Store already provides free access to seasonal forecasts, reanalysis, and observations. Sub-seasonal forecasts, however, are not available in this portal. To increase the use of sub-seasonal and seasonal forecasts it is necessary to ensure that both types of forecasts are easily accessible for everyone at the same time in operational real-time, ensuring a level playing field for all energy stakeholders. To encourage further work to improve these forecasts, sub-seasonal forecasts should be considered in the roadmap for inclusion of new datasets in the Climate Data Store. Furthermore, climate services providers should be encouraged to develop services that enable interested actors to integrate information from sub-seasonal and seasonal forecasts into their own existing decision-making structures.

Security of supply measures should promote the use of sub-seasonal and seasonal forecasts

Sub-seasonal and seasonal forecasts can support the adaptation of the energy system to the increasing share of renewable energy. All measures dedicated to guaranteeing security of electricity supply should therefore take such forecasts into account, or at least assess their potential inclusion. This means, for example, that the methodology the European network of transmission system operators (ENTSO-E) uses to conduct its seasonal adequacy assessments should be updated so that it recommends the use sub-seasonal and seasonal forecasts for assessments for time spans that are shorter than six months, such as month-ahead assessments. This methodology – adopted in March 2020 following the introduction of the EU's Risk Preparedness Regulation 2019/941 – currently only requires the use of weather forecasts, which typically only cover time spans for up to ten days ahead. A dialogue between transmission system operators (either individually or within the framework of ENSTO-E) and climate services providers should be encouraged, to ensure that the potential of sub-seasonal and seasonal forecasts to fulfil the requirements of such regulation is assessed. Further dialogue could also engage national gas transmission system operators within the framework of the European Network of Transmission System Operators for Gas (ENTSO-G).

Research into sub-seasonal and seasonal forecast systems should continue to increase their skill

Climate predictions – including both sub-seasonal and seasonal forecasts – have witnessed considerable technical improvements in the last decades demonstrating that probabilistic forecasting can inform better decision-making at some temporal scales and regions. However, despite these enhancements, further research is needed to improve the skill and reliability of these forecasts and advance the understanding of the sub-seasonal and seasonal timescales with special emphasis on high-impact weather events. Specific research priorities that need further effort include, but are not limited to: understanding systematic errors and biases, testing and evaluating multi-model combinations of sub-seasonal and seasonal forecasts and quantifying their uncertainty, identifying sources of predictability at different time scales and their impacts on weather variables, extreme events predictability and spread/skill relationship.

Promote the development of services consistent across all temporal scales

The S2S4E Decision Support Tool has demonstrated how it is possible to provide two different timescales while making transparent to its users the differences and challenges of presenting data in the same service from two different systems and models. This effort has focused on two timescales, but the energy sector also makes extensive use of shorter-range weather forecasts and longer-range climate projections. Future research and innovation actions should push the technical development of methods and services that bring together all relevant temporal scales from weather forecasts up to projections with a focus on the provision of indices and tailored products consistent across temporal and spatial scales. While sub-seasonal predictions have seen a major development in the last years, predictions on annual, multi-annual and decadal timescales need further research and the creation of an active research community to bring such predictions to operational climate services. Future research lines on decadal timescales should be fostered to mature the systems enough for decadal timescales to bridge the gap between climate predictions and climate projections as sub-seasonal forecasts do regarding weather forecasts.

Foster the integration of operational sub-seasonal and seasonal forecasts into quantitative models relevant to sectoral impacts and decision-making

Sub-seasonal and seasonal forecasts clearly have the potential to help companies invested in renewable energy improve their risk management, and the lessons learnt in the S2S4E project are a major step in understanding the challenges of the operationalisation of climate services for energy based on such forecasts. Barriers to uptake remain, however, particularly in the "last mile" of climate service provision - i.e., the creation of actionable information from raw climate forecasts. Further research on the integration of sub-seasonal and seasonal forecasts into quantitative energy-system models and quantitative decision-making is required to overcome this, supported by robust economic analysis of its value to specific users or sectors. This research should, for example, seek to identify and quantitatively express not only the behaviour of the energy system in response to the weather, but also the actions and risk-preferences of decision-makers responding to the resulting forecast. The development of operational demonstrators (and the underpinning research required to enable them) should therefore continue to be promoted in EU innovation and research actions to detect and overcome these "last mile" obstacles that hinder the adoption of sub-seasonal and seasonal forecasting technologies. Such research and innovation would also serve to strengthen the operational use of the Climate Data Store by the Copernicus Climate Change Service, spurring greater use of climate data in a wide range of sectoral applications, both by public and private sector service providers.

Need for more research to better understand the needs and decision-making processes of potential users of climate services

More research is needed to better understand the needs of the energy industry and other potential users of climate services. Future EU research policy on climate services should therefore focus more attention to the "demand side" of climate services, and particularly on understanding the extent to which the decisions faced can map onto the quantitative use of meteorological forecast information (e.g., risk tolerances and preferences). This could help uncover the barriers to the potential users' uptake of sub-seasonal and seasonal forecasts and could thus lead to increased use of such forecasts. Currently, the apparent benefits of using information from sub-seasonal and seasonal forecasts are not fully realised among potential users. While the attention among those who provide the forecasts tends to focus on improving their skill, users also benefit from knowledge-based insights about uncertainties related to the decisions they take.

VIEWS OF THE ENERGY PARTNERS IN THE S2S4E PROJECT

Three large energy companies have been partners in the S2S4E project: French utility EDF, German energy company EnBW and Spain's EDP Renewables. Here you can read their thoughts about what this project has meant for them.

Hiba Omrani, research engineer at French utility EDF

At EDF, weather and climate information are essential for the company's activities, and different climate services are used according to specific needs: the Climate Data Store for climate change impact studies, the World Climate Services for monthly and seasonal forecasts, and other platforms for short-term weather forecasts. The Research & Development department of EDF employs weather and climate experts to support the operational units in their use of weather and climate data and information.

At EDF, we joined the S2S4E project consortium particularly because of our need for monthly and seasonal forecasts, and since the launch of the S2S4E Decision Support Tool, we have used the tool regularly.

The Research & Development department of EDF uses the tool developed by S2S4E – among other sources – to analyse the different seasonal forecasts, and every month, EDF produces a synthesis of temperature and precipitation seasonal forecasts which is distributed to targeted units.

For its operational needs, EDF checks the subseasonal and seasonal forecasts once a week, mainly focusing on temperature forecasts, in order to anticipate changes in electricity demand and flows at the interfaces of the electricity system and to anticipate the trends for the next few weeks and the next season, particularly before the winter sets in.

EDF is quite satisfied with the S2S4E Decision Support Tool, but we have pointed out some blocking points, especially the fact that it is not possible to download any data, something which is crucial for our operational needs."

Daniel Cabezon Martinez, head of meteorological models and special tasks at Spanish utility EDP Renewables

When it comes to climate services, EDP Renewables is currently mainly using the ERA5 reanalysis provided by the European Centre for Medium-Range Weather Forecasts (ECMWF), which combines model data with data on historical observations. We use this service mostly to validate subseasonal and seasonal forecasts for wind speed and solar radiation.

We have not yet started using the S2S4E Decision Support Tool on a regular basis. We are now in the process of evaluating the subseasonal and seasonal forecasts in the tool to see how these compare with the ERA5 reanalysis, particularly for wind farm locations in Europe and North America. We will not be able to say whether we trust the forecasts in the tool before we have finished our internal validation phase. But in any case, it is very useful that the tool shows so clearly both the forecast skill and the probability thresholds for the forecasts!

EDP Renewables decided to join the S2S4E project because we wanted to learn more about subseasonal and seasonal forecasts. This is an emerging area of research and a new interest to us, and participating in this excellent consortium has been a very nice opportunity for us. The experience has been quite positive, so we would undoubtedly do it again.

Michael Christoph, weather analyst at German utility EnBW

EnBW uses a relatively high number of weather and climate service providers that offer specific products for the energy sector, most of which are not free of charge. Subscribing to the raw model data from national weather services and international research institutions – such as ECMWF – can be very expensive, and it is often more cost-effective to subscribe to intermediary service providers who can spread the costs for the raw data among their clients.

The most important reason why we at EnBW are using external forecast services is that it saves us time and money – because we don't have to hire staff to do these analyses for us – and because they require less computational and data storage power. Service providers transform raw model data into ready-to-use energy meteorology products and offer easy-to-use analysis tools via their websites. By using several such service providers, we at EnBW get more and more frequently updated information, as the analysis methods differ among the different providers.

Meteorologists at EnBW use the S2S4E Decision Support Tool on a weekly basis, on the days when the forecasts in the tool are updated. The tool has been useful as an additional opinion, particularly after it switched to using subseasonal forecasts from ECMWF in May 2020, as this model has a higher impact in the energy trading business than the model previously used in the Decision Support Tool.

EnBW has not used the seasonal forecasts in the tool regularly because these are published with a delay of eight days. For us to be able to use these forecasts, they would have to be uploaded no later than one day after they are made available by ECMWF.
In principle, meteorologists at EnBW trust the science and statistical methods on which the tool is based. However, building the same trust among energy traders will take some time.

We at EnBW decided to take part in the S2S4E project to be at the forefront of new developments in energy meteorology. We would do it again because helping to design the Decision Support Tool has been a good experience for us, and because when developing new tools, it is always more efficient when the end users themselves are involved in the process.

Mikael Sundby, hydrologist and planner of hydropower production at Swedish utility Vattenfall

Vattenfall is a leading European energy company whose main markets are Sweden, Germany, the Netherlands, Denmark, and the United Kingdom. We want to make fossil-free living possible within one generation. To do this, we are driving the transition to a more sustainable energy system through growth in renewable power production and climate-smart energy solutions for our customers.

In Sweden, hydropower accounts for more than 50% of the country's electricity production, and with renewable power generation growing both in Sweden and internationally, forecasting of both the weather to come and the expected electricity output is becoming extremely important. With the S2S4E Decision Support tool, we get forecasts on monthly and seasonal time scales, and we are using these in addition to our traditional climatological forecasts, which are based on statistics of previous weather. Although we are still relying mostly on traditional weather forecasts to get information on how electricity production and power demand will develop, we have been following the release of new subseasonal and seasonal forecasts in the S2S4E Decision Support Tool. One of our main priorities is to optimise our assets, and we believe better forecasts can help us to do so.

The probability of different weather developments is also important for electricity trading, and the Decision Support Tool gives our traders information which is useful to their work. Moreover, the hindcasting of the forecasts also gives us an opportunity to judge the reliability of the forecasts in the tool.

S2S4E

Climate Services for Clean Energy

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