Prospective Article: Energy and Utilities

1. Introduction

The goal of the PROTECT project is to enable public authorities to use state-of-the-art public procurement approaches in order to identify climate services based on Earth observation (EO) technologies that best fit the specific and systemic needs of the public sector. The focus of the project is on five application domains namely: Energy & Utilities, Sustainable Urban Communities, Agriculture, Forestry and other Land use, Marine and Coastal Environments and Civil Security and Protection. This article provides an overview of the first application domain, **Energy & Utilities,** the key challenges within the sector, the existing market solutions, and the emerging technological developments as well as some perspectives on the future of climate services for this sector, leveraging EO.

2. Definition of the application domain

According to the taxonomy defined in the PROTECT project, the Energy and Utilities application domain includes all activities related to water supply, sewage services, electricity, dams, and natural gas[1]. Climate-change-related risks affect water supply and utility infrastructures, as damages will have great impacts on operations and costs. The use of climate services can contribute to a better management of water flow, more resilient and independent energy systems, informed purchasing decisions based on accurate predictions, and others. EO data, in particular, can be used in climate services aimed at forecasting and nowcasting, planning and optimisation of renewable energy (onshore and offshore wind, solar, tidal and wave), and monitoring for the utilities sector infrastructure (e.g. dams, pipelines).

3. Application domain profile

The Energy and Utilities sector is a key contributor to climate change, accounting for more than two-thirds of global greenhouse gas emissions[2]. As such, the sector is expected to play a major role in the mitigation of climate change through investments in and deployments of technologies that would contribute to the reduction of greenhouse gas emissions. Climate services based on EO technologies have a crucial role to play in facilitating the energy transition process, in a majority of cases to move from non-renewable energy sources such as coal, fossil fuels and natural gas to renewable energy sources such as wind, solar, hydro and biomass[3].

However, in addition to mitigation, the Energy and Utilities sector is also directly impacted by the effects of climate change with extreme weather events which can cause critical damage to assets and infrastructure involved in the process. Therefore, EO-based climate services are also critical for supporting the monitoring of such assets with an aim to protect and prepare them for climate adaptation

[1] http://www.protect-pcp.eu/priority-domains/

[2] https://www.iea.org/commentaries/if-the-energy-sector-is-to-tackle-climate-change-it-must-also-think-about-water

[3] https://www.frontiersin.org/articles/10.3389/frsus.2022.910924/full

This project has received funding from the Horizon Europe Framework Programme (HORIZON) under grant agreement No 101060592

and building climate resilient solutions. According to a survey conducted recently, the utilities sector ranks highest in terms of risk for physical assets[4].

4. Value chain

The following figure summarises the value chain for the Energy and Utilities sector, comprising three segments: Generation, Distribution and Operation[5]. Given the fact that the energy and utilities sector is incredibly diverse and is organised differently across different markets and geographies, only a high-level segmentation is presented below.

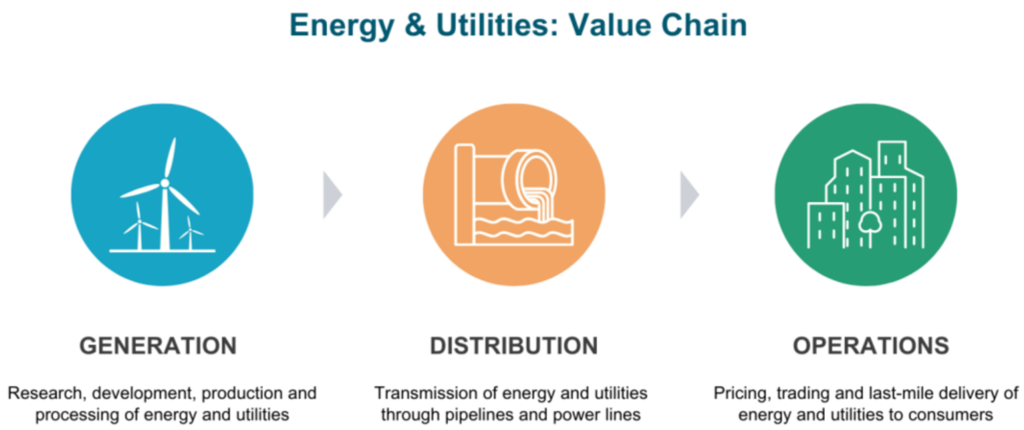

Figure 1: High-Level Value Chain of Energy & Utilities Sector

- **Generation:** This segment consists of the steps involved in the generation of the energy and/or utility from the research and development phase to scalable production. For the energy market, this would involve steps such as site exploration, infrastructure construction and energy generation from various sources whether it is coal, fossil fuels, natural gas, solar, wind, biomass, hydroelectric etc. For the utilities market, this comprises aspects of resource extraction and processing before distribution.

- **Distribution:** This segment consists of the transmission of the value generated from energy and utilities to the consumers through pipelines and power lines. For the energy market this would involve the construction and maintenance of distribution networks such as power grids and transmission lines. For the utilities sector, this comprises aspects such as pipeline network management for transmission of water, sewage system development and maintenance and so on.

- **Operations:** This segment deals with the last-mile delivery of the extracted resources to the consumers, whether it is in the form of electricity, gas, water or waste disposal services. This also includes aspects such as pricing and trading which is particularly relevant in the energy market, given the existence of energy trading companies, hedge funds and the like. The operational use of energy and utilities also requires continuous monitoring of aspects such as

[4] https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/utilities-face-greatest-threat-as-climate-risks-intensify-66613890

[5] https://cdn.ihs.com/www/pdf/Energy-Value-Chain.pdf

This project has received funding from the Horizon Europe Framework Programme (HORIZON) under grant agreement No 101060592

greenhouse gas emissions, overall energy efficiency, water quality monitoring, waste management monitoring and so on.

5. Key challenges

Given the ongoing climate crisis that affects the entire value chain, the energy and utilities sector is facing some key short-term and long-term challenges both from a climate mitigation and climate adaptation perspective. According to the World Meteorological Organization (WMO), the supply of energy from renewable sources needs to double within the next eight years to limit global temperature increase[6]. The three major challenges of the sector are described below:

- **Real-time intelligence on weather and climate conditions:** The reliance on natural energy sources such as solar, wind, hydro and biomass means that the relevance of variability in weather and climate on local, regional, national and even on global scale increases. Research has shown that climate change will lead to extreme changes in weather, leading to the intensification of events such as droughts, floods, storms and so on[7]. As such, the sector is required to pivot towards searching for solutions that would not only provide information related to weather and climate conditions but also provide such information continuously over any selected area of interest. In addition to weather data, climatological data also needs to be taken into account in order to be able to anticipate changes in the long-term. This is critical for estimating aspects such as capacity factors, energy demand and volatility of energy production[8].

- **Continuous monitoring of pipelines and transmission networks:** Climate change threatens the entire supply chain of the energy and utilities sector. Transmission lines are prone to damage during extreme weather conditions such as heavy snow, wildfires, and extreme winds. Further, as temperatures rise, the carrying capacity of transmission lines decreases. Pipelines that carry water, waste and other utilities are also likely to be damaged by weather events such as floods and storms, thus capable of cutting off supply to consumers and businesses. As such, it is crucial that the energy and utilities sector has a continuous monitoring system installed that can observe and analyse changes in and around the pipelines and transmission networks.

- **Understanding of water risks to identify impact on energy production**: According to the WMO, about 87% of global electricity generated from thermal, nuclear and hydroelectric systems directly depends on water availability. Climate services that provide insights on water availability and predictions on water stress are crucial for the operational maintenance and production of energy systems in and around Europe. In addition, this solution needs to be available on a high spatial resolution at a granular level in order to be able to predict vital information such as streamflow forecasts and flood risk assessments. As such, it is critical that climate services are not only available on a continuous basis, but also provide information at a specific level, across all areas of interest for the energy and the utilities sector.

[6]https://public.wmo.int/en/media/press-release/climate-change-puts-energy-security-risk

[7]https://public.wmo.int/en/resources/world-meteorological-day/world-meteorological-day-2022-early-warning-early-action/climate-change-and-extreme-weather

[8]https://climate.copernicus.eu/energy

PROTECT

This project has received funding from the Horizon Europe Framework Programme (HORIZON) under grant agreement No 101060592

6. Existing Market Solutions

Given the challenges described above, there are several solutions available in the market specifically aimed at the energy and utilities sector. As the PROTECT project is specifically aimed at identifying climate services based on EO technologies, the following section covers an overview of the key advancements that have led to the development of climate services, followed by a section presenting some EO-enabled climate services.

Earth Observation Technologies

For the energy and utilities sector, some of the major technological advancements in EO that have been crucial include: the launch of meteorological and imaging satellites to collect weather and remote sensing data, the development of data processing algorithms using artificial intelligence (AI) and the creation of use-case specific, EO-based climate services that are aimed at solving a particular problem within the sector.

The first major trend in EO impacting the energy and utilities sector is the *increasing number of launches of meteorological and imaging satellites*. As of 2022, over 1,000 satellites in orbit are categorised as EO satellites, which includes those that monitor the land, the oceans and the atmosphere[9]. One of the largest EO programmes in the world is the Copernicus programme from the European Commission, with an objective to monitor and forecast the state of the environment on land, sea and in the atmosphere. With a constellation of Copernicus Sentinel satellites, the data collected is then integrated with non-satellite sources to provide reliable and up-to-date information about six thematic areas. For the energy and utilities sector, at least four of the thematic areas including land, marine, atmosphere and climate change remain relevant[10].

The second major trend is the *emergence of AI*, which has a profound impact on the processing of data collected by satellites. With the explosion in the amount of data, it is important that only the useful subset data, for the energy and utilities sector, is processed to provide actionable insights. The Copernicus programme, for instance, collects over 16 terabytes (TBs) of data per day[11]. As such, AI has a crucial role in the growth of the EO sector, specifically to convert the raw data collected by satellites into useful information that can be used by the energy and utilities sector.

The final trend is the *growth in use-case specific climate services* for energy and utilities applications. Data collected from satellites is processed with the help of AI and then integrated into climate solutions that solve a particular problem for the sector. An example of this is the Copernicus Climate Change Service which provides seasonal forecasts and longer-term projections for energy planning by leveraging data such as solar radiation, wind speed, mean sea level pressure, temperature and precipitation, that are collected from the Sentinel and Eumetsat satellites.[12]

Climate Services for Energy & Utilities

The following figure presents an overview of some examples of EO-based climate services for the energy and utilities sector. While the figure provides an expanded summary of the climate services positioned on the value chain, this section will detail some of the key climate services.

[9] https://www.geospatialworld.net/prime/business-and-industry-trends/how-many-satellites-orbiting-earth/

[10] https://www.copernicus.eu/en/copernicus-services

[11] https://www.copernicus.eu/en/access-data

[12] https://climate.copernicus.eu/sites/default/files/2021-07/C3S_Energy_factsheet_20210616.pdf

This project has received funding from the Horizon Europe Framework Programme (HORIZON) under grant agreement No 101060592

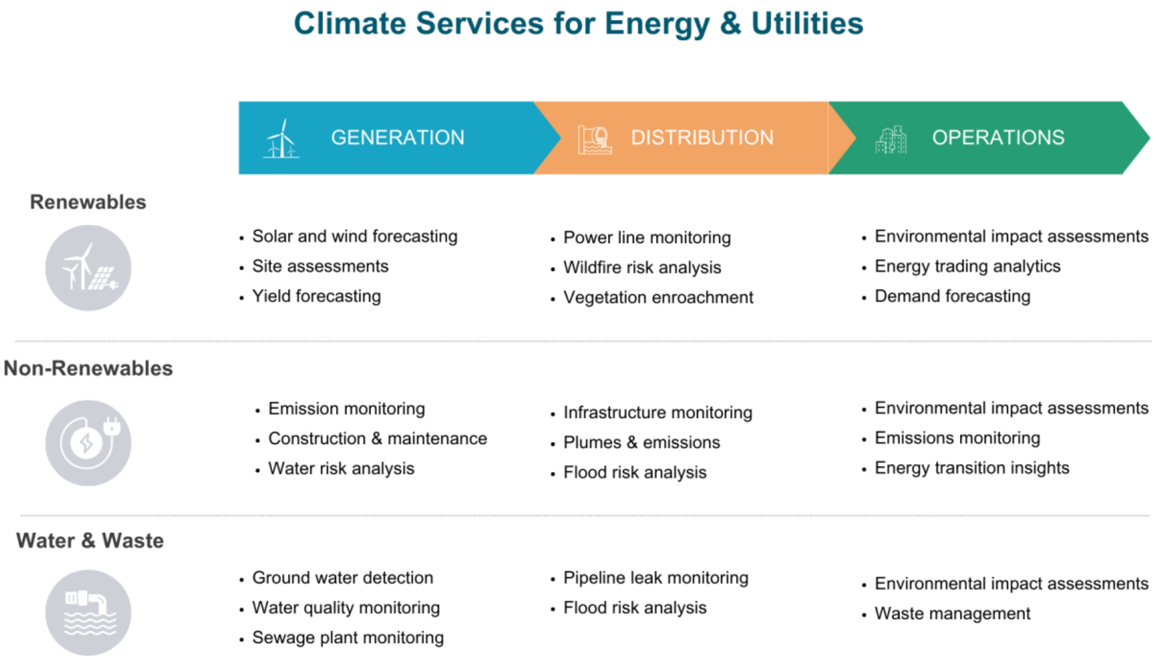

Figure 2: Examples of Climate Services for Energy & Utilities Sector

- **Solar and wind forecasting:** Solar and wind forecasting are vital applications for the energy and utilities sector, providing critical information on solar irradiance and wind speeds, both in near real-time as well as for the following few hours and days (called nowcasting). Leveraging data from weather satellites and combining that with other data sources, several climate service providers offer solar and wind forecasting solutions.

- **Site assessments:** The location for setting up renewable energy source plants such as solar, wind, geothermal and hydro are directly dependent on physical characteristics such as number of sunshine hours, average wind speed, geological subsurface composition and water risk respectively. In order for energy and utility organisations to plan for selecting a site and planning for the future, there are several climate services in the market that provide insights on the plants before selection for evaluation and after selection for operational maintenance, leveraging EO.

- **Flood and wildfire risk analysis:** In order to protect the assets installed, whether it is transmission lines, electric grids or other distribution infrastructure, it is necessary to monitor the impact of weather events such as floods and wildfires, which could cause considerable damage. As such, EO-based climate services provide crucial information on the level of flood risk and wildfire risk pre-event and damage assessments post-event, to maintain the infrastructure.

- **Pipeline monitoring**: Pipelines are an extremely important part of the distribution network, whether it is to transport fuels such as oil and natural gas or utilities such as water and waste. When such pipelines contain leaks, it may lead to huge economic losses while also cutting off supply to the consumers. As such, there are some climate services existing in the market that can monitor pipelines and observe them for leaks using high-resolution satellite imagery, combined with on the ground sensors that are connected via internet-of-things networks.

This project has received funding from the Horizon Europe Framework Programme (HORIZON) under grant agreement No 101060592

- **Environmental impact assessments:** The energy and utilities sector is responsible for both greenhouse gas emissions and could cause biodiversity impacts in the environment around the site locations and along the distribution lines. Hence, monitoring the environmental impacts of the assets and infrastructure becomes vital. This is made possible through EO technologies such as synthetic aperture radar and multispectral imagery which can detect minute changes and effects on natural resources such as forests, water bodies as well as biodiversity.

7. Future Developments

While there are several existing climate service solutions based on EO available in the market for the energy and utilities sector, it is important to understand the upcoming developments that might have an impact on the future of the sector. As the EO sector keeps rapidly evolving, the amount of data collected from satellites also continues to increase. Some technologies that are expected to advance in the coming years include a diversification of sensors such as thermal infrared, synthetic aperture radar and hyperspectral, which have the potential to detect any change on, above or below the surface. In addition, because these satellites will be launched as constellations, the data shall be collected several times per day at a very high spatial resolution, providing unprecedented accuracy. This becomes crucial for energy applications that require continuous monitoring especially in cases where actionable alerts might contribute to economic savings as well as keep the smooth transition towards renewable energy.

The Copernicus programme is also expected to see an evolution in the following years with the launch of the second generation of Sentinel satellites, which will cover hyperspectral imaging that can support environmental impact assessments, microwave imaging that can support marine energy research and production, emissions monitoring satellites that will provide greenhouse emission reporting and thermal infrared imaging that can provide insights on the solar irradiation and site assessments[13]. The emergence of the so-called NewSpace era has meant that several commercial companies are also launching their own satellite constellations, which can complement data provided by public data sources, also thanks to the use of swarms of nanosatellites (e.g. CubeSats[14]).

Regarding the usability and application of EO-based climate services, some users of satellite data in the energy and utilities sector are interested in building their own climate services, while others are looking for readily available insights that they can directly integrate into their processes. In the future, it can be expected that satellite data becomes highly democratised for use by end-users in the energy and utilities sector such that some organisations might choose to develop their climate services in-house as opposed to acquiring services from the market. As the growth of AI continues, a new wave of climate services shall emerge that can not only help simplify the insights derived from EO, but also support the sector in its goal of renewable energy transition[14]. An increased awareness of the potential of EO-based climate services is also expected in the next few years, which would lead to the rapid growth in the adoption of EO-driven solutions, which can support both mitigation and adaptation strategies[15].

8. Conclusions

Climate change is causing extreme weather events globally leading to increase in droughts, floods and weather variability which is causing water stress, sea-level rise, and other geophysical changes. All of this raises questions about energy security and the need for investing in the development of climate services is paramount. The energy and utilities sector, on the other hand, is swiftly moving towards green transition, focusing on investments in renewable energy infrastructure, most of which is being built

[13] https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Copernicus_Sentinel_Expansion_missions

[14] https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/power-and-utilities-industry-outlook.html

[15] https://library.wmo.int/index.php?lvl=notice_display&id=22136

This project has received funding from the Horizon Europe Framework Programme (HORIZON) under grant agreement No 101060592

and will be built over the coming years. This means that there will be an inherent need for solutions that can contribute to the **sustainable development, maintenance and operations of the global energy infrastructure**.

Thanks to the advancement in space technologies and the rapid rise in the availability of satellite data, there is an expanding market for EO-based climate services, specifically aimed at the energy and utilities sector. Whether it is for crucial applications such as supporting renewable site assessments or providing solar and wind forecasting estimates or even large-scale pipeline monitoring, the use cases are varied. Given the upcoming increase in the launch of EO satellites, the outlook for the use of EO-based climate services within the sector looks bullish. Very few technologies exist that can provide actionable information in a scalable and cost-efficient way like satellites do. As such, the market for climate services in the sector will continue to expand especially as awareness and adoption of EO technologies increases over the coming years.

This project has received funding from the Horizon Europe Framework Programme (HORIZON) under grant agreement No 101060592