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HI-TECHNOLOGY INITIATIVE QUANTIFYING THE IMPACT OF CLIMATE CHANGE ON WATER SECURITY AND ENERGY RESOURCES

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1.0 INTRODUCTION

Growing evidence of the effects of climate change on the planet has led to increasing interest in determining its potential impact on various sectors of the economy such as the hydropower industry, which has played a significant role in renewable and clean energy in the overall world energy supply in recent years. Every continent suffers from water scarcity and security; it is predicted that by 2030, nearly half of the world's population will experience high water stress conditions, and these will likely impact energy security. Unfortunately, while climate change will continue to have considerable impact on water and energy resources, the majority of our communities have little or no resilience to changing climate. Therefore, it seems necessary that various sectors of a community including the private sector, the public sector, and civil society work together to develop innovative approaches to mitigate the impacts of climate change on these essential resources.

We (ISOBARS and FAMS), are a specialist in including the effect of climate change in the estimation of the resource and production of the wind, solar, hydroelectric power, hydrology, risk assessment, the uncertainty in said production, the expected useful life of renewable assets and operation and maintenance (O&M), through a methodology based on projections of climate change, big data, own mathematical models, meteorological and oceanographic models and the application of supercomputing infrastructure (HPCC).

We help chart the course for companies in the renewable energy sector, helping them to identify and mitigate the risk that climate change represents. The owners, operator, investors, insurance companies, and developers must understand and mitigate all the risks before deciding to proceed with a renewable project. Project risks that might affect the project's profitability in the short, medium and long-term usually originate during the initial development stages. Our climate advisory hi-technology initiative can evaluate the project's technical feasibility through a technical due diligence during which the risks probability of occurrence and their potential impact on the project would be detected. On the other hand, this risk is hardly addressed in financing operations for renewable projects, in cash flow generation projections, in the design stages of renewable projects, or the costs derived from operation and maintenance (O&M). Our risk assessment can help to identify and take corrective actions to mitigate are:

- Weather related climate change risk
- Technical risk
- Market risk
- Operational risk
- Business and strategy risk
- Political/ regulatory risk
- Economic/Financial risk

In present paper, we have enumerated our experiences through for quantifying the impact of climate change on water security as well as energy resources.

Case Study 1: Vulnerability assessment for quantification of climate change impact on renewable energy

Renewable energies are potentially vulnerable to climate change. This global phenomenon involves changes in patterns in wind, radiation and precipitation. The highest frequency and intensity of extreme meteorological and oceanographic events have been observed in broad areas of the planet due to climate change, which implies a potential impact on renewable assets, present and future. At this point in the focus, the precise analysis of climate change is necessary for power plants with renewable technologies.

The requirement for climate change assessment for wind, solar, hydropower and nuclear energy projects. Fig. 1 depicts vulnerability flow chart of climate change effects such as change in wind, temperature, precipitations and extreme weather events for wind and solar energy projects.

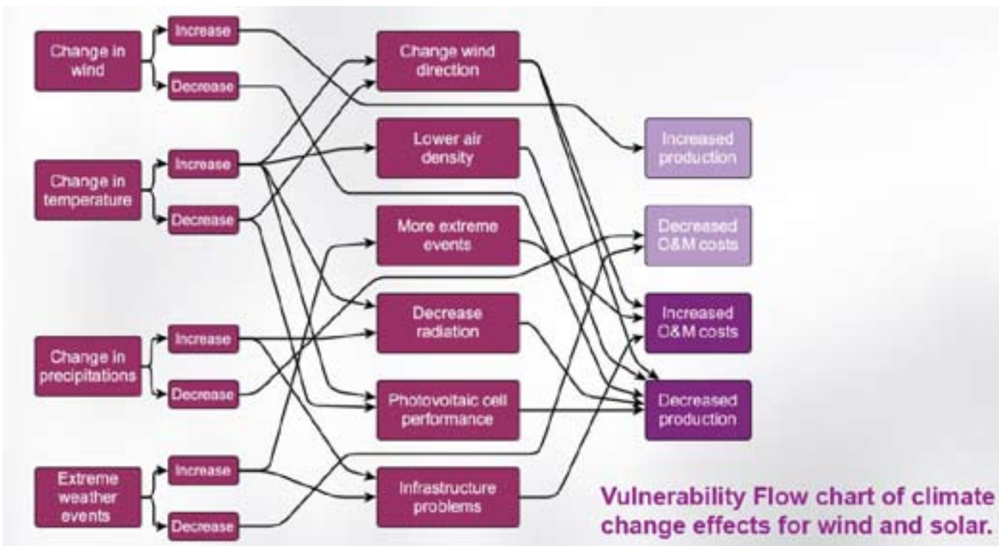

Fig. 1 : Vulnerability flow chart of climate change effects for wind and solar energy projects

The climate change may impact hydropower production, change in rainfall patterns, flooding, rainfall and other factors. This assessment is carried out through an extensive investigation current trends in hydropower as well climate change effects predicted to influence hydropower production. Fig. 2 shows vulnerability flow chart of climate change effects for hydropower production.

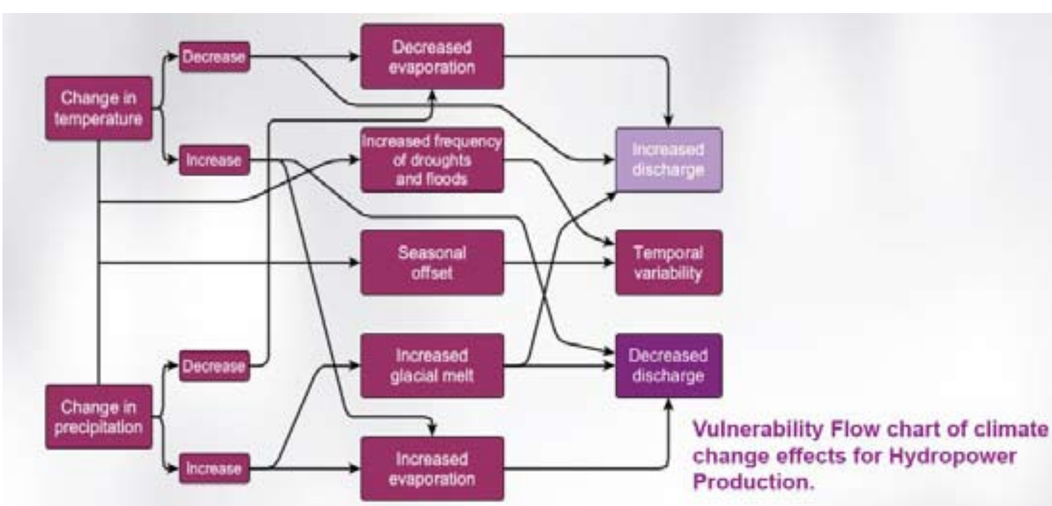

Fig. 2 : Vulnerability flow chart of climate change effects for hydropower production

The following steps need to be conducted for quantifying the impact of climate change on hydropower project considering project resource assessment, due diligence and vulnerability assessment.

Step 1 : Vulnerability assessment of hydropower plants

Step 2 : Evaluation of the company's exposure to climate change risk

Step 3 : Measure the impact from a financial point of view

Step 4 : Quantification of value of risk (VaR) of each of the assets

Step 5 : Set of mitigation/resilience measures and actions to be taken

Case Study 2: Forecasting, Analytics, Modelling and Simulation

The impact of climate change on banks, insurers, and asset managers (financial services companies) is likely to be multi-layered and significant over the medium term (between year 2025 and 2045). The climate change is a real phenomenon identified by the IPCC and accepted by most international organisations. Wind, solar and hydro portfolios are a low risk profile due to its geographic and technological diversification. Renewable assets are exposed to real risk, with a technical and financial impact associated with climate change. We suggest a comprehensive analysis to measure the risk, exposure, vulnerability of assets, and then conclude with a series of mitigation strategy measures that allow the organisation related to energy projects to be resilient.

Assessing climate change, a complex but important issue. All renewable energy projects require the best starting point (Design) and an in-depth understanding of their operation and maintenance stage (cash flow and mechanical stress). We intensively apply mathematical supercomputing (HPCC platforms) and already validated global climate models (IPCC AR5/AR6), which describe and represent the state of the atmosphere and the ocean, at high spatial and temporal resolution. With uses advanced numerical analysis techniques that include computation fluid dynamics (CFD), mesoscale models, and internally developed interfaces coupled with standard renewable industry software to determine the incidence or impact of climate change.

Our business intelligence and agile methodologies can analyse the large amounts of raw data in the wind, solar, hydroelectric sectors. The result, generates actionable insight information to make commercial, strategic, and operation decisions in the renewable industry environment. We simulate very complex models and extreme systems around renewable assets, such as tropical systems, monsoons, the El Nino phenomenon and predicts and analyse extreme events like floods, sand storm or drought. Among the sources of information to use for the development of such work are among others:

- Wind Reanalysis Data:
  - CFSR 30 Years, ERA5 18 years
  - MERRA2 20 years, ERA-Interim, ECMWF, others.
- High-resolution weather and marine model:
  - WRF 4.3, ROMS, SWAN
  - CFD-OpenFoam models
- Wind, Solar and Hydro analysis tools:
  - Furow, OpenWind, WAsP, archelios CALC
  - OpenFlows, Flow-3D, ETAP
- IPCC AR5.AR6 Climate Change Scenarios:
  - ECHAM6 (Max Plank Institute, IPM, Germany)
  - CESM (National Center for Atmospheric Research, NCAR, Colarado).
- Digital Terrain Model: Global Digital Elevation Model (GDEM V2) of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) of NASA and Japan's METI.
- Bathymetry: Multibeam Bathymetry Database of NOAA
- Hydrological Parameterization:
  - Soils: Harmonized World Soil Database (FAO, IIASA, ISRIC, ISSCAS, JRC).

- o Land Uses: GlobCover 2009 land cover map, National Land Cover Database 2006.
- o Temperature and Precipitation: ERA5 Reanalysis
- o Precipitation Frequency Data Server (PFDS) Hydro meteorological Design Studies center, NOAA's National Weather Services

We are on the forefront of the rapidly expanding field of renewable power generation, always taking into account the risk of climate change. We provide the capability and experience to adapt to changing power generation needs by providing comprehensive services to the power industry in all aspects of renewable project execution, including:

(a) Feasibility studies

(b) Site resource assessment

(c) Due diligence risk

(d) Life extension and re-powering

(e) Management risk assessments

(f) Operation and Maintenance Forecast

(g) Weather Monitoring services

(h) Testing and inspection services

(i) Hybrid, battery and storage services

(j) Policy, regulatory and commercial services

We are helping client to navigate the changing power generation landscape can make difference from being a trend follower to an industry leader. Our capabilities span the entire spectrum of renewable energy technology, including solar, wind and hydro as well as multiple technology applications.

We carry out feasibility studies to support the development of a renewable project that allows lenders, owners, developers, and their shareholders to assess accurately the economic feasibility of the project and to identify next steps for its implementation considering IPCC AR5/AR6 climate change scenarios. A staged approach to the feasibility, technical development, and consenting phases of a wind farm, solar and hydro development, which allows:

(a) Key issues and risks to be identified and quantified,

(b) An informed a decision on whether to progress the project,

(c) More detailed work to be focused on critical risks, reducing overall development costs

To support wind, solar, hydro energy projects from initial site identification through to the planning stages, we provide a comprehensive and flexible package of following services:

- Site selection, wind, solar, storage and hydro resource
- Potential site identification
- Selection and screening studies
- Candidate turbines/module and preliminary layout design
- Detailed renewable energy feasibility study
- Wind, solar and hydro resource modelling and preliminary energy yield estimates
- Storage technology selection and feasibility study
- Hybrid, storage project design and engineering

The key to realising successful renewable energy project lies in making the correct strategic decisions in the early stages of project development.

The wind, radiation and water resources is the most fundamental factor in a successful wind, solar and hydropower project. All projects require best estimations of the wind, solar and hydro resources to enable design, financing and optimal operation.

We analyse the wind, solar and hydro energy resource available with IPCC AR5/AR6 climate change scenarios, either by helping you to establish a measurement campaign or using your existing wind, radiation and hydro data to provide site suitability, feasibility and bankable (acceptable to financiers and investors) energy yield estimates. Also, we assess operating assets to determine the performance of the project.

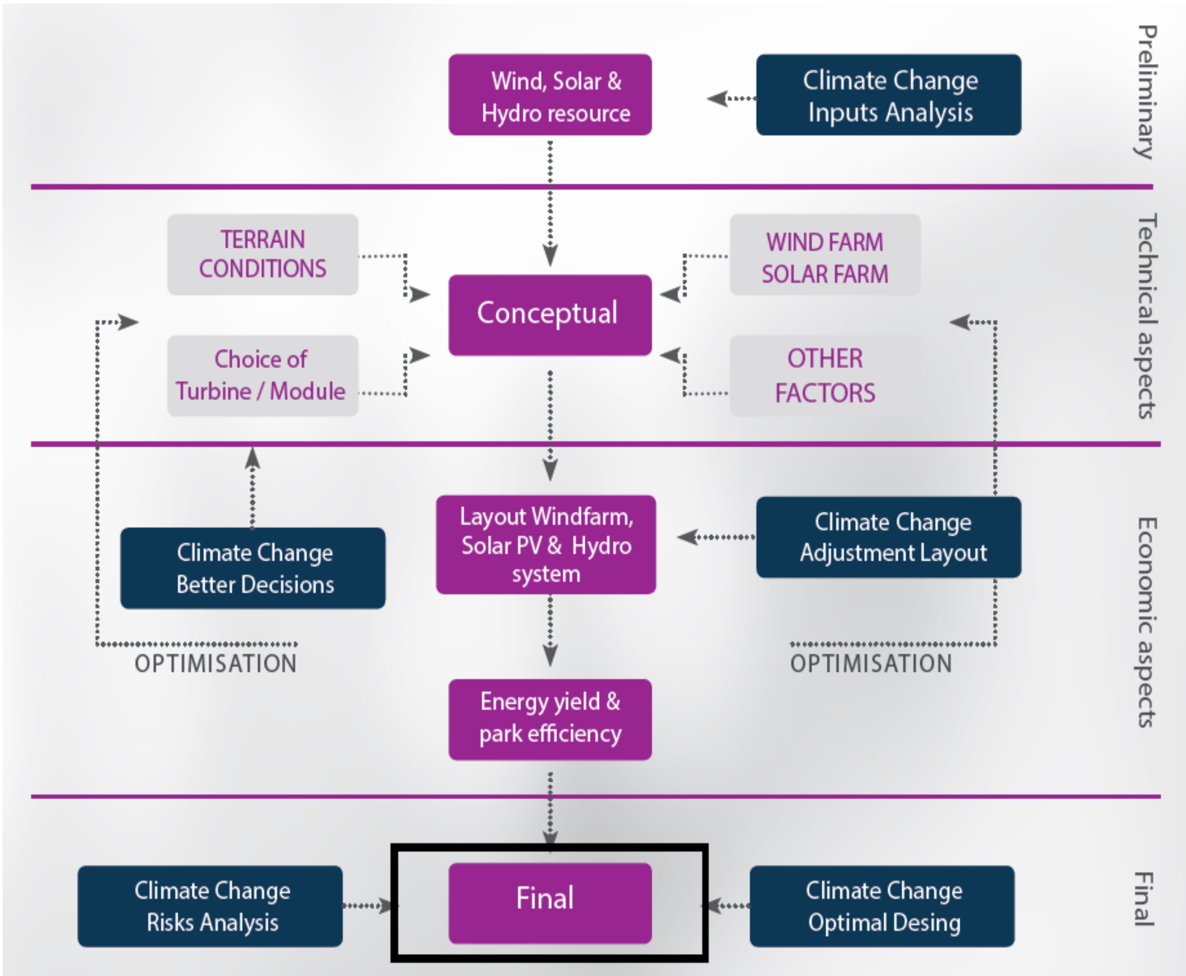

Fig. 3 : Assessment of operating assets to determine the performance of the project

The energy forecasting of renewable energy power plants is a very active field of application, since reliable information on future power generation, allows safe operation of the electricity grid and helps to minimize the operating costs of these energy sources. We developed ad-hoc of a global and scalable wind production forecasting system for existing and future wind farms.

Wind forecast horizons:

(a) Short term forecast: the forecast horizon is up to 72 hours. It will be of interest to be able to act in the control of wind turbines and for security reasons for decision making regarding stops or starts of wind turbines and the provision of the secondary reserve.

(b) Medium term predictions: Horizons can vary between several days or even reach several weeks. These predictions are of interest for forecasting the dispatch of power plants and scheduling maintenance work in some of these power plants and in general, adopting the necessary measures to minimize the risks to the system's stability in the face of possible future contingency.

Weather Forecast Systems:

(a) Short term prediction: WRF-CFD_RNA_Scada model

(b) Medium term forecast: WRF-CFD-EPS model

(RNA; neural networks; EPS; and ensemble prediction system)

Forecast horizons:

(a) Short term (72 hours),

(b) Medium term (up to 15 days)

Update cycles of the prediction system:

(a) Short term -> 4 times a day (resolution 10 or 15 min)

(b) Medium term -> 2 times a day (resolution 10 to 15 min)\

Information support:

(a) Access in digital document format

(b) Access to interactive visualisation platform

(c) Notices/alerts by email and SMS

Case Study 3: Climate and Flood Risk assessment for water security and energy projects

Climate change and climate policy affect insurers through the risks they accept or take from their clients. We support risk management, providing insurers and reinsurers with a new vision of the possibility of having adequate protection against the occurrence energy fluctuations or extreme events on energy infrastructures. The insurance, financial and technical risk contemplated from the perspective of climate change has become one of the most significant environmental challenges on a global scale. The greater frequency of 'extreme event' has been observed in large areas of the globe due to climate change, which implies a potential impact on renewable assets that must be taken into account during their exploitation.

Vulnerability and claim analysis against climate change scenarios:

- Tropical systems/monsoons/ typhoons
- Frequency of storm surge
- Cyclogenesis/extreme winds
- El Nino phenomenon
- Stormy/electrical/dust events
- Heatwave/cold/flooding events

Analysis of extreme weather events aimed at asset owners and wind farm, solar and hydro operators. To determine the frequency of extreme events that may affect the integrity of wind farms and directly impact their operation. Predict production and other complex meteorological variables in real-time to improve the organisation of preventive maintenance and increase the parks' availability.

Analysis and estimation of lost profit for wind farm aimed at asset owners and operators of wind farms. We construct financial models for the calculation of profit losses of the energy business associated with wind farms due to business interruption, associated with:

- Meteorological incidents
- Extreme events
- Compliance with power curves
- Availabilities
- Energy losses
- Loss of profits from maintenance actions, etc.

The plant's financial, energy production, and operational loss would be measured to justify before the insurers and others.

Forecast tropical systems and EL Nino Phenomena

- Forecast of cyclone/hurricane/typhoon frequency indicating:
    - o Path, trends, trends in the events' intensity, trends in wind direction, analysis of the change in wind patterns vs seasonality vs monthly and annual variability. Study in main components to analyse the how the different synoptic patterns are modified in the area, observing how much variability they introduce.

- o Analysis of extreme events that affect renewable assets (risk to property)
- o Prediction of the frequency of explosive cyclogenesis (intense storms)
- o Analysis of the incidence of the EL Nino

Studies of impact on tropical systems and EL Nino Phenomenon in solar sites (such as fixed tables, trackers) impact on the loads that the wind can exert on the infrastructure and determine their degree of exposure to adverse meteorological phenomena and manage this fact with the insurers (annual premium) and others.

Flood frequency forecast

- Development of hydrological models distributed and physically based on the watersheds that affect the wind farm, solar and hydro infrastructures
- Development of a coastal hydrodynamic model to simulate flooding due to storm surge caused by hurricanes/typhoons and simulating past events.
- Generation of river-type flood risk maps for different return periods for a current situation context, through 2-dimensional hydrodynamic modelling
- Hydrological and maritime simulation uses the atmospheric models derived from the RCP4.5, RCP 6.0, and RCP 8.5 climate change scenarios AR5/AR6 – IPCC.

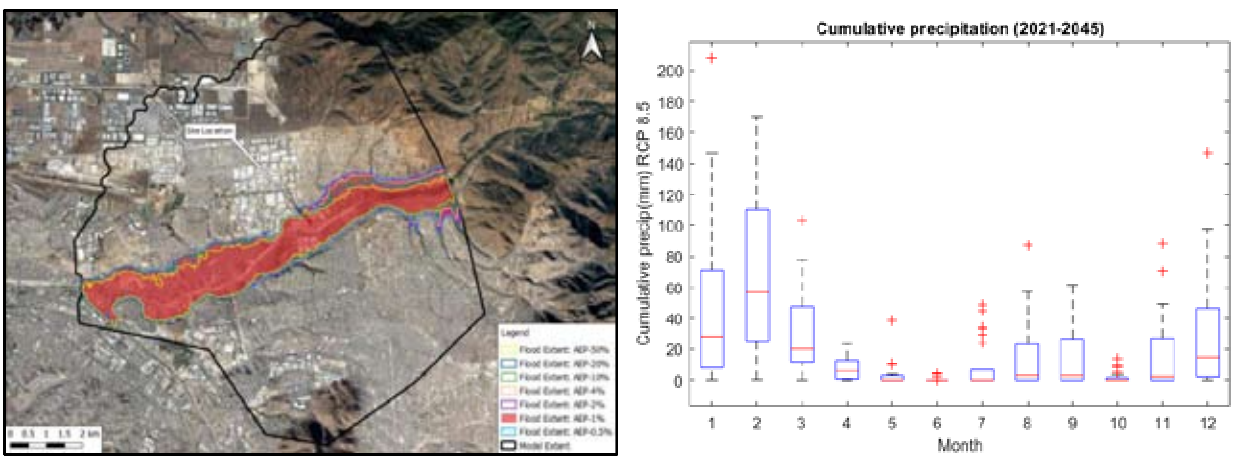

Fig. 4(a) : 2-Dimensional Flood Inundation Mapping using HEC-RAS 2D, (b) Climate variability analysis in a upstream of reservoir

Hazard	Physical asset impact	Operational impact	Economic impact
Water scarcity			
Reduced river flow (chronic)	Reduced cooling water intake over long term	Production, efficiency; resource availability	Adaptation expenses – improved water extraction, changing pump location
Drought (acute)	Temporary loss of cooling water; more frequent reliance on emergency water supply	Production, efficiency; resource availability	Revenues – reduced power output

Fig. 5 : Impact of different hazards associated with water scarcity

Impact by dust storms

Studies of the attenuation of solar radiation, due to the incidence of dust storms and other aerosol particles; study of the behaviour of the solar site from a seasonal point of view, that is, number of dust storms and degree of impact and their impact on the future performance of the solar power plant, evaluation of the 'performance ration' (PR).

Case Study 4 : Due Diligence Risk

Whether investing in an existing wind farm, solar or hydro asset or developing from a greenfield site, owners, operators, investors, insurers, and developers need to understand and mitigate a variety of technical, including risks from IPCC AR5/AR6 climate change scenarios. Risks that might compromise a project's profitability in the short, medium, and long term usually originate during the initial stages of project development. In this context, we help clients to evaluate their project's technical feasibility through a Technical due diligence risk. This process entails identifying both the probability of occurrence of risks and their potential impact on the project. The goal is twofold: (i) to ensure that the technical feasibility of the project makes for a sound investment and (ii) to ensure that all factors have been accounted for in the development process. We provide impartial, reliable and confidential due diligence services that includes:

(a) Technical due diligence

(b) Energy due diligence

(c) Risk advisory services

The understanding of targeted and focused due diligence investigations are critical in the pre and post construction acquisitions process. Due diligence support will reduce uncertainties and enable risks to be managed, ensuring that investment and insurance decisions are made from an informed position.

Step 1 : The process begins with an initial review of the project to understand how we can help the client to develop and conduct the investigation to maximize its value.

Step 2 : To undertake the investigation, which will be executed by the previously agreed to the client's requirement.

Step 3 : To undertake the investigation, which will be executed in accordance with the previously agreed to requirements of the client.

Step 4 : To report the investigation findings to the client and ensure that any technical issues identified are adequately addressed.

Step 5 : To develop and conduct the investigation to maximize its value.

Asset inspection covering the main turbine components such as rotor blades and hubs, mechanical transmission parts, gearboxes, nacelle and tower structures, generators, converters, and transformers. Assessment of actual track record of the specific wind turbines installed against their predicted performance. Review of maintenance records for inspections and repairs carried out to verify adherence to the defined maintenance manual and programme as well as the adequacy of the latter concerning the requirements of the installations and evaluation of the expected net annual energy production from individual turbines as well as the aggregate yield of the entire wind farm.

Estimation with greater certainty of the production of the assets, being able to obtain a set of sensitivities that allow evaluating the profitability range of the projects, limiting future uncertainty considering climate change scenarios. Review and studying pre-constructive or review site conditions based on operations data.

- Met tower data; monthly energy record at the connection point
- Information on wind farm stops associated with maintenance or network

Outages/restrictions; availability of the wind farm; information 10 min of the main wind turbine data; alarms, long-term analysis, future energy projection taking into account climate change scenarios, etc.

- RCP4.5, RCP6.0, and RCP8.5 on climate change
- Horizons, short and medium-term (year 2025-2045)
- Wind resource and production variation applying climate change corrections
- Production adjustment based on additional losses
- Uncertainty analysis of the complete process to establish P50, P75, and P90
- Impact on OPEX costs (expected and potentially unexpected)
- Review of site conditions based on operational data (if available)
- Variations in production (changes in generation patterns will be studied as well as variations expected in the future under the different scenarios, so that take on the base case can be quantified and the influence on the generation of income from the plants can be quantified)

- Verification of future cash flows and sensitivity of financial scenarios

We work with asset owners of all sizes, assessing their portfolios, providing independent, real world advance on their best life extension and re-powering strategy. Assessing a wind farm's lifetime at different stages of its life cycle benefits in a project. An assessment right at the start of a project helps to maximize its life expectancy – and as the project ages, knowing how much life is left in the turbines allows you to develop appropriate strategies to optimize maintenance spending and potentially extend the life of the project.

Wind farm lifetime assessment is a complicated task. But our Life-Extension and Re-powering service helps streamline the process and get more value from it. As a result, we can boost wind farm's value and output and keep it running as long as possible.

Inspections

- Technical due diligence
- Inspections review

Asset optimisation

- Power curve and availability assessment
- Failure root cause analysis
- Major component failure forecasts
- Predictive maintenance strategy

Life extension and re-powering assessment

- Our in-house models to estimate the remaining life of components recommendations
- End of design life inspection, assessment, and recommendations
- Engineering, commercial and legal guidance to maximize the internal rate of return (IRR) for asset's remaining life.

Case Study 5: Maximizing energy production from hydropower dams using short term weather forecasts

We explore the maximization of hydropower generation by optimizing reservoir operations based on short-term inflow forecasts derived from publicly available numerical weather prediction (NWP) models. Forecast fields from the NWP model of Global Forecast System (GFS) were used to force the hydrologic model (HEC-RTS; VIC) to forecast reservoir inflow for 1 day to 15 days lead time. The optimization of reservoir operations was performed based on the forecast of inflow. Results can be shown a significantly greater amount additional hydroelectric energy benefit can be derived consistently than the traditional operations without optimization and weather forecasts. Goals of flood control and dam safety can also be integrated but not compromised when exploring opportunities for hydropower maximization. Given the on-going effort to coordinate strategies for sustainable energy production from renewable energy sources, it is timely that this concept be expanded further to current hydropower dam sites across the globe.

BIOGRAPHICAL DETAILS OF THE AUTHORS

Leopoldo Alvarez, Founder and CEO, ISOBARS, Spain

Over 10 years of experience in strategic consulting, business development, operations management and executive management, with in leading, organizing and motivating multidisciplinary teams and organizations. Fully focused on the achievement of objectives. Management of an international wind and solar resource team for projects development and production analysis of operating wind farms in LATAM, NA, EMEA and APAC countries. Experience in the development of more than +2 GW wind energy. With strategic and innovative vision.

Leader in Renewable Energy Sector. Expertise in the renewable energy, managing national and international consultancy and research projects on energy and climate change issues for industry leaders, multinational companies and policy makers.

+ Climate Change vs wind, solar and hydro infrastructure renewables, evaluation of their impact.

+ Minimising technological, engineering related or financial risks.

+ Quantification of wind energy production in the future (projections).

+ Determination of the value of assets using climatic projections, due diligence.

Dr. Viraj Loliyana, Founder & CEO, FAMS Design Solution Private Limited, India

- Dr. Viraj Loliyana is a Founder & CEO of FAMS Design Solution Private Limited, Mumbai, India and he is acting COO of Badho India Private Limited, Pune, India. He is Chartered Civil Engineer and also, member of INCOLD YEF Group, Member of IEI, ASCE, IAHR, ISH, AWWA.
- He has published more than 30 papers in peer-reviewed journals and conferences of repute.
- Area of interest in forecasting, analytics, modelling and simulation in the field of water resources.
- Prior to starting FAMS, he was Hydrology Expert in Mechatronics Systems Pvt. Ltd., Pune, Maharashtra, India during July 2019 – September 2020.
- He worked as Faculty and Course Coordinator, Department of Civil and Construction Engineering, Rustomjee Academy for Global Careers, Dahanu, Maharashtra, India in association with University of Wolverhampton (UK) during November 2017-February 2020.
- He did Bachelor in Civil Engineering from Shantilal Shah Government Engineering College of Bhavnagar Univeristy, Bhavnagar, Gujarat, India
- Then, He pursued for M.Tech Degree and Doctoral Degree (under the guidance of Dr. Prem Lal Patel, Professor) subsequently with specialization in Water Resources Engineering from Department of Civil Engineering, Sardar Vallabhbhai National Institute of Technology (SVNIT), Surat, Gujarat, India.
- He was awarded Institute Gold Medal for securing first position in M. Tech. (WRE) for the batch 2009-2011.
- He worked as Research Scholar under a Centre of Excellence (CoE) on 'Water Resources & Flood Management' through research grant from World Bank sponsored TEQIP-II during 2013-2017 in the Department of Civil Engineering, SVNIT Surat.