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INITIAL ASSESSMENT OF VARIABLE RENEWABLE ENERGY FORECASTING INFRASTRUCTURE

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DATA

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ACRONYMS

ºC	Celsius
AEMO	Australian Energy Market Operator
ASEFS	Australian Solar Energy Forecasting System
AWEFS	Australian Wind Energy Forecasting System
AWST	AWS True Power
BPTEMP	Back Panel Temperature
CAISO	California Independent System Operator
DIRD	Direct Irradiance
DNI	Direct Normal Irradiation
DUID	Dispatchable Unit ID
FTP	File Transfer Protocol
GEL	Georgian Lari
GHIRD	Global Horizontal Irradiance
GSE	Georgian State Electrosystem
HCPV	High Concentrating PV
hPa	Hectopascal
km / h	Kilometers per Hour
LCPV	Low Concentrating PV
LEPL	Legal Entity of the Public Law
LIDAR	Light Detection and Ranging
m / s	Meter / Second
MAE	Mean Absolute Error
MEPA	Ministry of Environmental Protection and Agriculture of Georgia
MW	Megawatt
NCAR	National Centre for Atmospheric Research
NEA	National Environmental Agency
NWP	Numerical Weather Production
PAIRD	Global Irradiance / Plane of Array
PV	Photovoltaic
QWF	Qartli Wind Farm
RMSE	Route Mean Square Error
SCADA	Supervisory Control and Data Acquisition
SODAR	Sonic Detection and Ranging
SPP	Solar Power Plant
USAID	United States Agency for International Development
VAT	Value-Added Tax
VDRAS	Variation Doppler Radar Analysis System
VRE	Variable Renewable Energy
WG	Working Group
WPG	Wind Power Generator
WRF	Weather Research and Forecasting

CONTENTS

EXECUTIVE SUMMARY

High forecast accuracy is dependent on an optimal combination of data from Supervisory Control and Data Acquisition (SCADA) System, representing the lower production and also the availability of meteorological data from wind turbine, and the input from Numerical Weather Production (NWP) models depending on the forecasting time horizon. The mentioned parameters relate to both solar and wind power forecasting. This is an initial report describing the actions taken to access the forecasting infrastructure and the progress achieved in this regard. The final assessment is still awaiting the response from developers and operators of wind and solar projects as well as results of wind speed and direction forecast in Test Mode.

In ideal cases, in which SCADA data are both online and of high-quality, statistical and hybrid prediction models generally produce the greatest degree of forecast accuracy. USAID Energy Program has applied the current practice of Australian Energy Market Operator (AEMO) and California Independent System Operator (CAISO) on forecasting. Both are using the centralized Variable Renewable Energy (VRE) Forecasting System and with the purpose to ensure the supply of timely and reliable data input, required for VRE forecasting, they developed and made obligatory the specific data requirement which covers the data provision on power production and meteorology.

The supply of static and dynamic data is obligatory. The technical specifications of solar and wind farm, together with geographical and topographical data are considered under the static, whilst the delivery of the real-time data on instantaneous measurement of power generation and measurement of certain meteorological parameters are obligatory under the dynamic.

For both Wind and Solar Power prediction, SCADA Instantaneous measurements are required. Instantaneous means, values updated at least every 4-10 seconds, with 4 seconds or even faster preferred. If only averages are available, maximum 15-second average update is required. The provision of historical data is preferred with the same granularity of data which is required for instantaneous measurement.

Both AEMO and CAISO set specific requirements regarding the existence of meteorological measurements and for the existence of the specific meteorological equipment. However, in case of wind, preference is given to meteorological parameters measured on nacelles of wind farm, whilst in case of solar, the priority on meteorological measurement goes to parameters measured at the surface and backstage of solar panels.

The mentioned data requirement of AEMO and CAISO, together with the VRE forecasting vendor survey results, were utilized for the development of the questionnaire which USAID Energy Program applied to the operators and developers of VRE Projects.

The questionnaire has been distributed among the developers of 4 wind projects. Currently, USAID Energy Program is in the process of collecting and analyzing the content of the feedback. Qartli Wind Farm (QWF) and Imereti and Didgori wind power plant projects are the locations at which in a very short period, due to the data availability, the forecast of wind power and/or wind speed could be launched.

Furthermore, to check the applicability of meteorological data input derived from NWPs, USAID Energy Program Organized the Working Group (WG) comprising the representatives of the National Environmental Agency (NEA), QWF and Georgian State Electrosystem (GSE) and supported the launch of wind speed and direction forecasting in Test Mode.

WG started working in May however, the first results became available from July 12. Only two weeks passed since the first forecast of wind speed and direction have been uploaded to the File Transfer Protocol (FTP) server created by USAID Energy Program. Currently, forecasting results in Test Mode could be characterized by both, amplitude and phase shifting error. The forecast error amplitude absolute value varies in the range of 8 m/s, which in case of being the final product means that error is quite high. However, due to a short period of time passed since the launch of the Test Mode, it could be neglected now.

Two weeks are not enough for training of forecasting model. Thus, the performance assessment, where the uncertainty metrics such as Mean Absolute Error (MAE) and Route Mean Square Error (RMSE) needs to be applied, are planned to be performed by the middle of September.

USAID Energy Program Identified the NEA services which under the specific cost might be utilized as an input for forecasting system. NEA can provide historical meteorological data and access to the observational data proximity to proposed wind projects locations. Moreover, with the consideration of specific cost, the list of NEAs services considers the provision of sector specific forecast of meteorological parameters.

Main Conclusions and Issues Found

1. Data input options from direct measurement
    - the input required for the forecasting system (wind speed, direction, and solar irradiance data) could come from the wind and solar power plants' SCADA system;
    - as an alternative, wind and solar data could come from the met masts installed in boundaries of wind and solar power plants.
2. Another source of data input is possible
    - data from existing meteorological radar might be utilized as an input for forecasting system.
3. Time requirement
    - more than one month of test mode is required to check how precise is the forecasting system which comes from numerical weather prediction model under the NEA.
4. Next step
    - after one month of test mode, Energy Project will assess the data input modes and sources;
    - we will use the assessment results for selection of the potential forecasting service vendors.

CAISO AND AEMO DATA REQUIRED FOR FORECASTING SYSTEM

Table 1 represents the Current Production – Meteorological and Turbine Availability Data requirement set by the AEMO to produce the forecasts through Australian Wind Energy Forecasting System (AWEFS) and Australian Solar Energy Forecasting System (ASEFS).

Table 1: AEMO Forecasting Data Requirement [1]

	Wind farm identification		**Solar farm identification**
1 W	Name	1 S	Facility Name
2 W	DUID	2 S	DUID
3 W	Region	3 S	Region
W	**Wind farm Status**		**Solar farm status**
4 W	Status of the wind farm	4 S	Status of the solar farm
5 W	From which date is or will the wind farm be fully operational?	5 S	From which date is or will the solar farm be fully operational?
6 W	From which date will the wind farm be first connected to the grid or energised?	6 S	From which date will the solar farm be first connected to the grid or energised?
	Wind farm nominal data		**Solar farm nominal data**
7 W	Nameplate Rating	7 S	Nameplate rating
8 W	Maximum Capacity	8 S	Maximum capacity
9 W	Wind Turbine Characteristic Curves for each turbine		
	Wind farm location & terrain data		**Solar farm location and terrain data**
10 W	Geographical coordinates (UTM WGS-84)	9 S	Facility latitude
11 W	Geographical coordinates	10 S	Facility longitude
12 W	Wind farm altitude	11 S	Facility altitude
13 W	Wind farm geometry	12 S	Facility map
14 W	Orography information	13 S	Facility time zone
15 W	Mesoscale roughness coefficient	14 S	**Solar farm miscellaneous**
16 W	Roughness of surrounding area	15 S	Number of clusters
17 W	Met mast measuring height	16 S	
18 W	Met mast Geographical coordinates		List of measurement devices (Device ID)
19 W	Air density		
	Wind Farm SCADA to AEMO:		**Solar farm SCADA to AEMO**
20 W	Wind farm active power	17 S	Active power generation
21 W		18 S	Reactive power generation
22 W	Number of wind turbines available for generation data	19 S	Number of inverters available
23 W	Number of wind turbines actively generating	20 S	Module surface temperature
24 W	Local Limit	21 S	Local limit
25 W	Estimated Power	22 S	Estimated Power
26 W	Wind speed data	23 S	Global horizontal irradiance
27 W		24 S	Wind speed
28 W	Wind direction data	25 S	Wind direction
29 W	Temperature data	26 S	Solar farm control system set-point
30 W	Wind Farm Control System Set-Point	27 S	Relative humidity
31 W	Pressure or humidity data	28 S	Ambient temperature and Barometric pressure
		29 S	Global inclined irradiance
		30 S	Reduction through soiling
32 W	SCADA data available from this wind farm	31 S	Actual tracking slope angle
		32 S	Actual tracking azimuth angle
		33 S	Tracking share of modules not on track
		34 S	Trackers online

DUID – Dispatchable Unit ID; SCADA – Supervisory Control and Data Acquisition; UTM WG S – Universal Transverse Mercator : AEMO – Australian Energy Market Operator.

For both Wind and Solar SCADA, Instantaneous measurements are required unless otherwise agreed by AEMO. Instantaneous means values are updated at least every 4-10 seconds, with 4 seconds or faster preferred. If only averages are available, the maximum 15-second average update is required.

For the AEMO, measurement of wind speed and direction from turbine nacelle anemometers are much preferred over measurements from meteorological mast(s).

CAISO, in his data requirement, goes farther and sets requirement on the number of installations and the type of equipment to support an accurate power generation forecasting and the communication of such forecast, meteorological and other required data.

Apart from the meteorological data from met-towers and meteorological stations, CAISO is requesting nacelle wind speed from Wind Power Generators (WPGs) and direction from the Designated Turbine[2].

These are the CAISO required wind meteorological data points for WPG participating in CAISO markets.

[1] Australian Energy Market Operator Energy Conversion Model
[2] Designated Turbine - A turbine designated by the CAISO, in which nacelle wind speed and generation in MW is required.

Table 2: CAISO Required Meteorological Data[3]

Element	Device(s) Needed	Units	Accuracy
Wind Speed (Meter / Second)	Anemometer, wind vane and wind mast	m/s	± 2m/s
Air Temperature (Degrees Celsius)	Temperature probe & shield for ambient temp	ºC	± 1º
Barometric Pressure (hectopascals)	Barometer	hPa	± 60 hPa
Real Time Data	Metering of Power	MWs	

m / s – Meter / Second; ^{0}C – Celsius; hPa – Hectopascal; MW – Megawatt.

A wind power generator with the installed capacity of more than 5 MW, requires the installation of a minimum one meteorological tower and two meteorological stations, measuring the barometric pressure, temperature, wind speed and direction. The meteorological tower should be located on the windward side of the wind farm. One meteorological station is required to be installed at the average hub height of the wind turbines. The second meteorological station may be co-located on the primary meteorological tower and be installed approximately 30 meters below the average hub height.

Where the placement of meteorological station tower(s), in accordance with this requirement, would cause a reduction in production or violation of a local, state, or federal statute, regulation or ordinance, the CAISO, in coordination with any applicable forecast service provider, will cooperate with the WPG to identify an acceptable placement of the meteorological station tower.

The use of Sonic Detection and Ranging (SODAR)[4] and / or Light Detection and Ranging (LIDAR)[5] equipment may be an acceptable substitute for wind direction and velocity, based on the consultation and agreement with the forecast service provider and the CAISO.

The measurements for telemetry data points should be sent to the CAISO in real time (i.e., 4 seconds) from wind power generators.

According to the same manual, each Solar Power Plant (SPP) with the capacity of 1 MW or greater shall install a minimum one meteorological station, whilst generators with the installed capacity of 5 MW and greater shall be equipped with minimum two meteorological stations.

Table 3 below provides a list of meteorological data CAISO is requesting from SPP participating in CAISO markets as applicable to technology.

Table 3: CAISO Solar Power Forecasting Data Requirement[6]

Element	Device(s) Needed	Units	Accuracy
Wind Speed (Meter / Second)	Anemometer, wind vane and wind mast	m/s	± 2 m/s
Wind Direction (Degrees - Zero North 90 CW)	Anemometer, wind vane and wind mast	Degrees	± 5º
Air Temperature (Degrees Celsius)	Temperature probe & shield for ambient temp	ºC	± 1º
Barometric Pressure (Hectopascals)	Barometric Temp	hPa	± 60 hPa
Back Panel Temperature (Degree C)	Temperature probe for back panel temperature	ºC	± 1º
Plane of Array Irradiance Watts\Meter Sq.	Pyranometer or Equivalent	W/m²	± 25 W/m²
Global Horizontal Irradiance Watts\Meter Sq.	Pyranometer or Equivalent	W/m²	± 25 W/m²
Direct Irradiance Watts\Meter Sq.	Pyranometer or Equivalent	W/m²	± 25 W/m²

m / s – Meter / Second; ^{0}C – Celsius; hPa – Hectopascal; W/m² – Watt per square metre.

Table 4 represents the minimum required (R) measurement of solar irradiance component and backplane temperature by solar generating technology.

[3] California Independent System Operator Business Practice Manual for Direct Telemetry
[4] SODAR – Sonic Detection and Ranging- a meteorological instrument also known as a wind profiler which measures the scattering of sound waves by atmospheric turbulence.
[5] LIDAR – Light Detection and Ranging - a meteorological instrument which measures the properties of scattered light waves caused by atmospheric turbulence.
[6] California Independent System Operator Business Practice Manual for Direct Telemetry

Table 4: Measurement of Solar Irradiance Component[7]

	Direct Irradiance (DIRD)	Global Horizontal Irradiance (GHIRD)	Global Irradiance/ Plane of Array (PAIRD)	Back Panel Temperature (BPTEMP)
Flat-Plate Photovoltaic (PV) (fixed / horizontal / flat roof)			R	R
Flat-Plat PV (fixed angle / azimuth tracking)			R	R
Flat-Plate PV (DNI zenith & azimuth tracking)			R	R
Flat-Plate PV (DNI zenith & azimuth tracking)			R	R
Flat-Panel Solar (thermal fixed angle mounted)			R	R
Flat-Panel Thermal Collector (azimuth tracking)			R	R
Low Concentrating PV (LCPV)	R	R		
High Concentrating PV (HCPV)	R	R		
Concentrated Solar Thermal (solar through zenith tracking)	R	R		
Heliostat Power (tracking focusing mirrors)	R	R		
Greenhouse Power Tower (hot air convection turbine)			R	
Stirling Engine (concentrated solar power generation)	R	R		

PV – Photovoltaic; DNI – Direct Normal Irradiation; LCPV – Low Concentrating PV; R – Required.

[7] California Independent System Operator Business Practice Manual for Direct Telemetry

VARIABLE REENABLE ENERGY FORECASTING SERVICE VENDORS SURVEY RESULTS - DATA REQUIREMENT

USAID Energy Program surveyed 20 suppliers of VRE Forecasting Services. The table below provides the list of vendors who have remained in contact with the Program due to their responses and expression of interest either in the provision of VRE forecasting services or in-house capacity development for forecasting.

Table 5: Forecasting Data Requirement from Survey

	DENMARK	Norway	Spain
	ENFOR	DNV GL	Meteorological
Data requirement	Real Time Data	Real Time Data (10min or hourly averages) with hourly updates	Unspecified
	1-2 year historical data (meteorological and generation)	1 year meteorological and power generation data (10min or hourly averages)	Historical production data for calibration purposes Historical values of the meteorological variable to predict (if available)

	US	US	US
	AWST	NCAR	VAISALA
Data requirement	Real Time Data	Real Time Data	Real Time Data
	Historical data on meteorological parameters and generation	Historical data on meteorological parameters and generation	Historical data on meteorological parameters and generation

AWST – AWS True Power; NCAR – National Centre for Atmospheric Research.

According to the survey results, the supply of real time data on generation is a must. The supply of real time meteorological data would improve the uncertainty of predictions. The historical data is acceptable with the 10-minute averages on both power generation and meteorological parameters.

SURVEY QUESTIONNAIRE ON FORECASTING DATA REQUIREMENT FOR DEVELOPERS AND OPERATORS OF VARIABLE RENEWABLE ENERGY PROJECT

With the consideration of both, VRE forecasting service vendors and the data requirement set by CAISO and AEMO, USAID Energy Program developed a questionnaire and applied to the VRE project operators and developers (Please see Annex 1). The questionnaire was supplemented by the guidelines for filling each line.

Currently, the feedback is available only from the three Wind Projects - Infinite Energy and Caucasus Wind Company and operator of QWF, whilst the remaining 1 project developer is in the process of filling the questionnaire. With the consideration of data requirements, set by CAISO and AEMO regarding the forecasting system data input, as well as data requirements provided by the potential vendors of forecasting services and feedback received from the Infinite Energy and QWF, it can be stated that the trial benchmarking for the selection of potential supplier of wind power forecasting services could be performed at list at 3 points.

Picture 1: Infinite Energy

Meteorological Masts

Picture 2: Qartli Wind Farm

Measurement of Wind at Nacelles

Picture 3: Caucasus Wind Company

Table 6: Infinite Energy

Element	Units	Type of Measurement Device		Measurement Device Location	Datalogger Yes / No	Measurement Currently Performed Yes/No	Instantaneous measurements YES / NO (Instantaneous means values updated at least every 4-10 seconds) with 4 seconds or faster preferred.	
		Installed on Nacelle	Installed on Met-mast				Historical 1-2Years Yes/No	Real Time Data Access Yes/No
1	2	3	4	5	6	7	8	9
Wind Speed (Meter / Second)	Units	N/A	20 Units of First Class Anemometer 20/40/60/80m	Met-Mast	Data logger	Yes	Yes	
Wind Direction (Degrees - Zero North 90 CW)	m / s	N/A	8 wind wane 58/78m	Met-Mast	Data logger	Yes	Yes	
Air Temperature (Degrees Celsius)	ºC	N/A	4 Thermometer 10m	Met-Mast	Data logger	Yes	Yes	
Humidity %	%	N/A	4 Humidity Sensor10m	Met-Mast	Data logger	Yes	Yes	
Barometric Pressure (Hectopascals)	hPa	N/A	4 Barometer 5.4m	Met-Mast	Data logger	Yes	Yes	

m / s – Meter / Second; ^{0}C – Celsius; hPa – Hectopascal.

Table 7: Qartli Wind Farm

Element	Units	Type of Measurement Device		Measurement Device Location	Datalogger Yes/No	Measurement Currently Performed Yes/No	Instantaneous measurements YES/NO (Instantaneous means values updated at least every 4-10 seconds) with 4 seconds or faster preferred.	
		Installed on Nacelle	Installed on Met-mast				Historical 1-2Years Yes/No	Real Time Data Access Yes/No
1	2	3	4	5	6	7	8	9
Wind Speed (Meter / Second)	Units	12 Units of Ultrasonic Anemometer	5 First Class Anemometer 30/60/78/80/80 m	Nacelles and Met-Mast	SCADA and Data logger	Yes	Yes	10-minute granularity
Wind Direction (Degrees - Zero North 90 CW)	m/s	12 Units of Ultrasonic Anemometer	3 wind wane 30/78/78m	Nacelles and Met-Mast	SCADA and Data logger	Yes	Yes	
Air Temperature (Degrees Celsius)	ºC	6 units Ambient temperature sensor	Humidity/Temperature Sensor 6.8m	Nacelles and	SCADA and	Yes	Yes	
Humidity %	%	N/A	Humidity/Temperature Sensor 6.8m	Met-Mast	Data logger	Yes	Yes	
Barometric Pressure (Hectopascals)	hPa	N/A	Pressure Sensor 5.4m	Met-Mast	Data logger	Yes	Yes	

SCADA – Supervisory Control and Data Acquisition; ^{0}C – Celsius; hPa – Hectopascal.

Table 8: Caucasus Wind Company

Element	Units	Type of Measurement Device		Measurement Device Location	Datalogger Yes / No	Measurement Currently Performed Yes/No	Instantaneous measurements YES / NO (Instantaneous means values updated at least every 4-10 seconds) with 4 seconds or faster preferred.	
		Installed on Nacelle	Installed on Met-mast				Historical 1-2Years Yes/No	Real Time Data Access Yes/No
1	3	5	6	7	8	9	10	11
Wind Speed (Meter / Second)	Units	N/A	Anemometer	Meteorological Mast	yes	yes	yes	yes
Wind Direction (Degrees - Zero North 90 CW)	m/s	N/A	Wind Vane	Meteorological Mast	yes	yes	yes	yes
Air Temperature (Degrees Celsius)	ºC	N/A	Temperature & Humidity	Meteorological Mast	yes	yes	yes	yes
Humidity %	%	N/A	pressure	Meteorological Mast	yes	yes	yes	yes
Barometric Pressure (Hectopascals)	hPa	N/A		Meteorological Mast	yes	yes	yes	yes

m / s – Meter / Second; ^{0}C – Celsius; hPa – Hectopascal.

The basis for the above provided statement is that, in case of Infinite Energy and Caucasus Wind Company, all the parameters provided in the questionnaire are measured and are available in high granularity, whereas in case of QFW it is already proved, the historical and at some extent the real-time data is available since data was provided for Test Mode on permanent basis.

As soon as the developers of VRE projects respond to USAID Energy Program by filling the questionnaire, the map indicating the locations, with the available data forecast, would be developed and updated.

NATIONAL ENVIRONMENTAL AGENCY SERVICES

NEA is a Legal Entity of the Public Law (LEPL) under the Ministry of Environmental Protection and Agriculture of Georgia (MEPA). It was established as an Agency on June 31, 2008. The Agency is independent of the public governance bodies but is subject to control by the state. NEA Hydro Meteorological Department is among USAID Energy Program counterparts related to VRE Forecasting System Development.

At some extent, funds for NEAs activities derive from service provision on forecasting, historical data and access to the measurement data, modeling the climatological parameter, performing studies, surveys and design works etc. In 2017 customers (82% legal entities and 18% citizens) applied with 1204 applications on the provision of services. The fee for the provision of services is approved with the ordinance of the MEPA.

Below provided Table 9 provides the list of services which in our view might serve as a supplementary data input for the proposed forecasting system.

Table 9: NEA Services[8]

Appendix 6				
Access to automatic meteorological station observation data on atmospheric pressure, air temperature, air humidity, precipitations, wind speed and direction				
Unit	GEL Including VAT			
1 Station	GEL 1,500			
2 Station	GEL 2,500			
3 Station	GEL 3,600			
4 Station	GEL 4,700			
5 Station	GEL 5,800			
6 Station	GEL 6,750			
7 Station	GEL 7,650			
8 Station	GEL 8,500			
9 Station	GEL 9,300			
10 Station	GEL 10,000			
Appendix 5				
Service for different sectors of economy - weather and hydrological prognosis and recommendations				
Current Day (12 hr.)	GEL 10			
Next Day	GEL 20			
Next Two days	GEL 30			
Next Three Days	GEL 50			
Appendix 1				
Fees for primary data on hydrometeorological observation				
Meteorology	Measurements in 24 hr.	Cost per measurement	I day cost for 1 year	2 to 4 years
Barometric Pressure	8	GEL 1.5	GEL 2.9	GEL 2,125
Air temperature according the observation time	8	GEL 1.5	GEL 3.5	GEL 2,560
Air temperature according the self-recorder	24	GEL 0.5	GEL 5.0	GEL 3,660
Water Vapor Parcial Pressure according the self-recorder	8	GEL 1.3	GEL 2.6	GEL 1,900
Water Vapor Parcial Pressure	24	GEL 0.5	GEL 5.0	GEL 3,660
Wind direction	8	GEL 1.8	GEL 5.0	GEL 3,660
Wind Speed	8	GEL 1.6	GEL 4.3	GEL 3,110

VAT – Value-Added Tax; GEL – Georgian Lari.

The provision of services related to the historical data and access to the real time observational data, ensured by the hydrometeorological databases are kept on servers of NEA and hydrometeorological network under the disposal of the NEA.

It may be beneficial to deploy meteorological sensors in proximity (for example, a nearby Meteorological station to the VRE project) of the generation facility to monitor the weather conditions and utilize it as supplementary inputs to a forecast system. The usefulness and representativeness of measurements from nearby meteorological stations vary greatly depending on the area, location, topography, landcover and climate variations. Respectively, the best criteria and approach to test the

[8] The Government of Georgia Resolution #502 dated August 18, 2014, on approval of service types and fees undertaken by Legal Entity of Public Law NEA

accuracy of utilizating the observational data from nearby meteorological stations, considers the use of such data in practice. At this stage, the non-availability of forecasting system limits USAID Energy Program's effort to access the usefulness and reliability of meteorological data input from the vicinity of the VRE project meteorological stations.

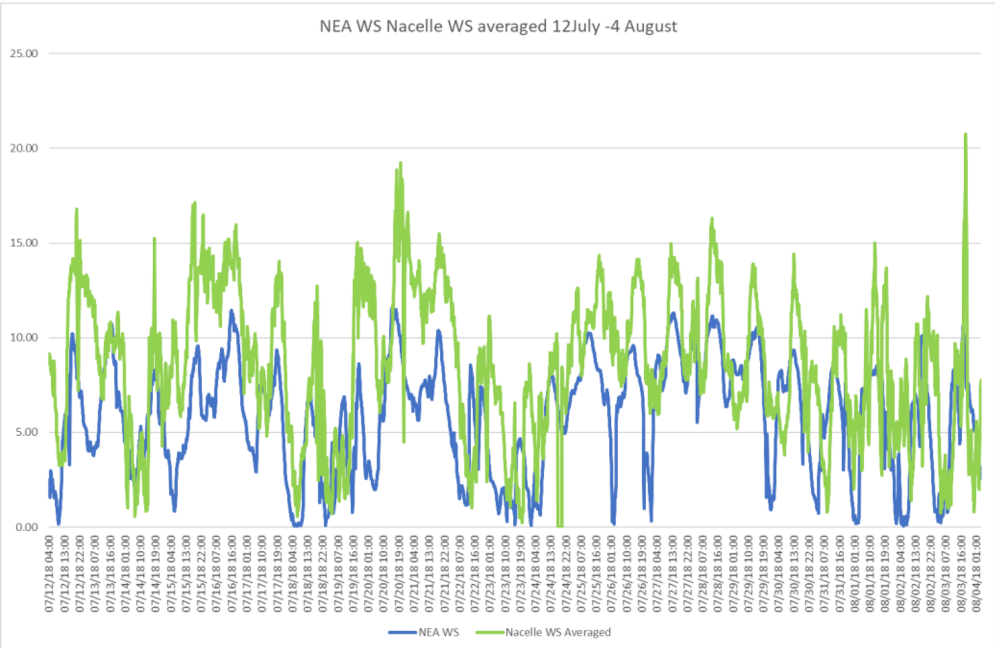
While the observational data from nearby meteorological stations is a useful alternative way to obtain information about the meteorological conditions at a generation facility, the deployment of several NWP Models, as a data input of VRE forecasting system for the forecasting time horizon of more than 6-12 hours, is a common practice. The "Integrator" which is a core of the forecasting system, for each weather condition, calculates and assigns specific weight to prediction of meteorological parameters derived from different NWPs.

NEA has access to several NWPs and for the cost mentioned in Table 9 Appendix 5, NEA can provide forecast specific to the sector of the economy. Respectively to check the applicability of meteorological data input derived from some NWPs, utilized by the NEA, USAID Energy Program organized the WG from the representatives of NEA, QWF and GSE and supported the launch of wind speed and direction forecasting in Test Mode. NEA employs The Weather Research and Forecasting (WRF) Model developed by the US National Center for Atmospheric Research.

Work started in May, however the first results become available from July 12 of the current year. Up to 20 days passed since the first forecast of wind speed and direction have been uploaded to the ftp server [9]created by USAID Energy Program. Below provided Figure 1 – 2 represent the preliminary results of NEA forecasting wind speed comparison to the actual measurement of wind speed performed on nacelles of QWF turbines.

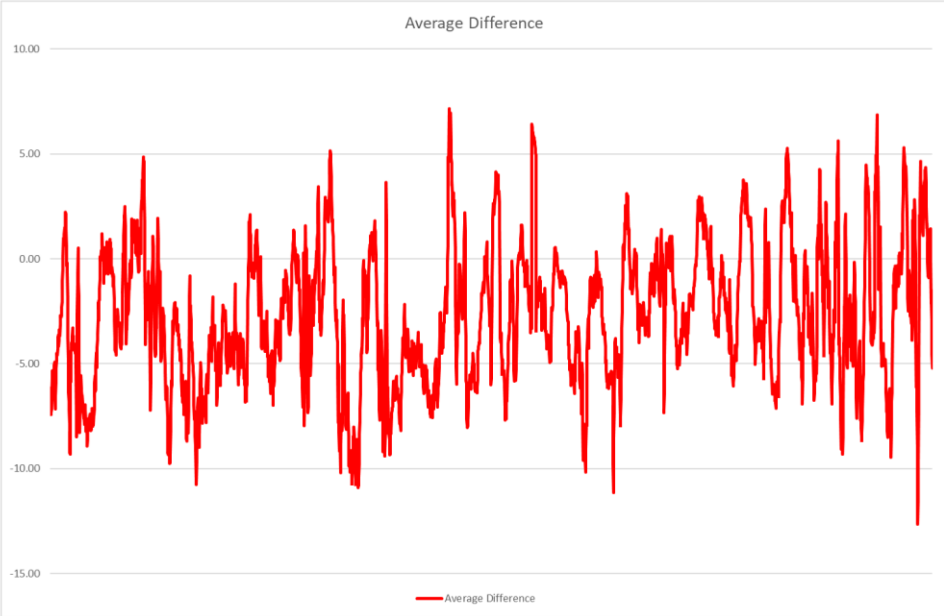
20 days in most of the cases are not enough for training of forecasting model. Therefore, the performance assessment where the uncertainty metrics, such as Mean Absolute Error and Route Square Error need to be applied, are planned to be performed by the end of August mid of September.

Figure 1: NEA Wind Speed Forecast Comparison to the measurement of Wind Speed on QWF Nacelles



[9]FTP server is a computer which has FTP address and is dedicated to receiving an FTP connection.
The FTP is a standard network protocol used for the transfer of computer files between a client and server on a computer network.

Figure 2: Difference between the NEA Wind Speed measurement of Wind Speed on QWF Nacelles



Currently, the forecast could be characterized by both magnitude and shifting error. The forecast magnitude absolute value varies in the range of 8 m/s, which in case of being the final product means that error is quite high. However, due to a short period of time passed since the launch of Test Mode, currently it could be neglected.

Furthermore, the data derived from meteorological radars could be utilized as an input for the forecasting system. There is an example for such an approach - Variation Doppler Radar Analysis System (VDRAS) is used to provide predictors related to the wind field and the input for VDRAS is data derived from the radars, surface meteorological stations and different mesoscale NWPs.

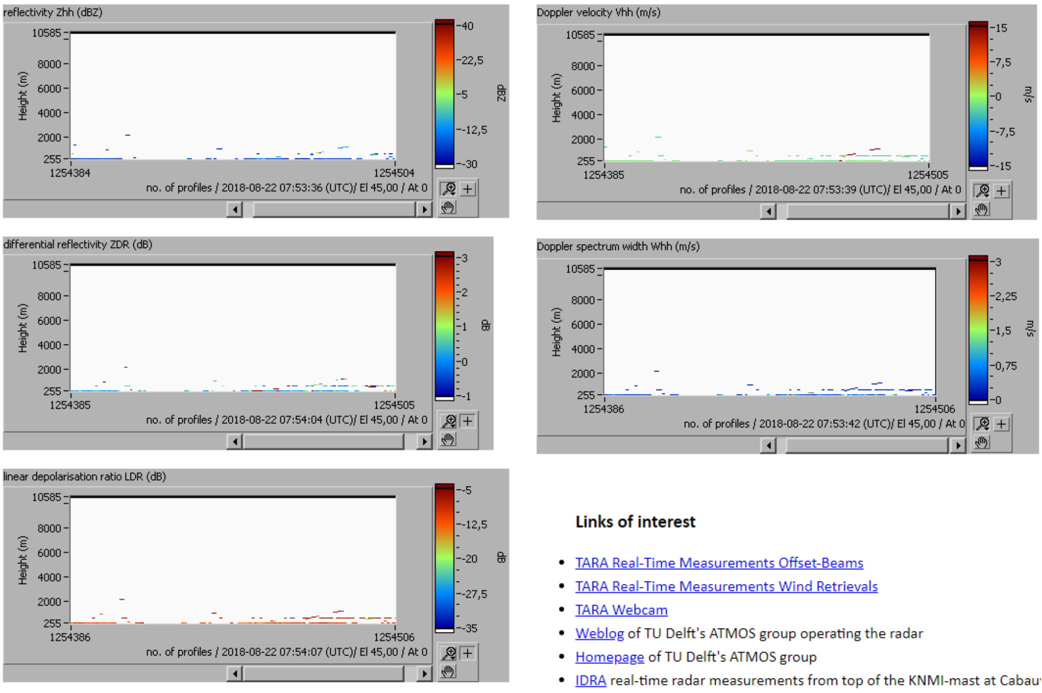
VDRAS is a 4-D variational assimilation system[10] that produces frequently updated (on the order of 10 minutes) analyses using Doppler radar, surface observations, and a mesoscale model background (Sun and Crook 2001). The mesoscale model is used to represent motion in the atmosphere, and velocities and reflectivity from single or multiple Doppler radars as well as surface observations to produce the VDRAS analyses.

The purpose of the use of meteorological radars is to make forecasts and warnings of 0-4 hour and short-term weather forecasts. Estimates can only be made with radars for the next few hours, as the range of coverage of the radar is limited due to the beam geometry and the globality of the globe, and the movement of air masses which is about 50 km / h (faster in winter and slower in summer).

Below provided example of TARA project radar derived data visualization which could be publicly accessed.

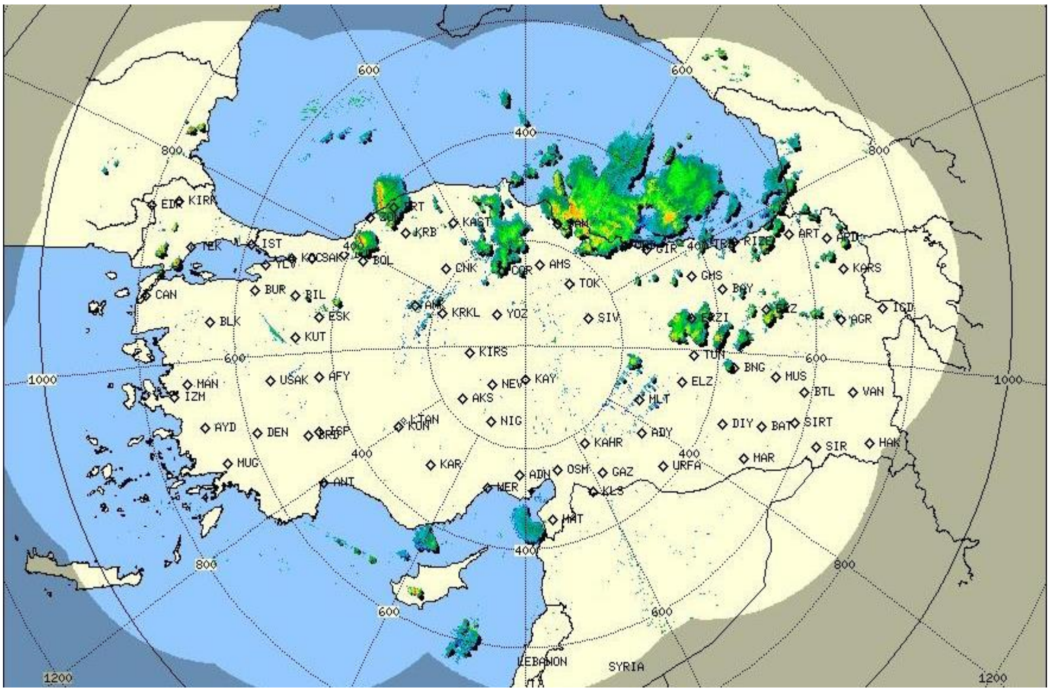
[10] Using Winds From The 4-D Variational Doppler Radar Analysis System (Vdras) To Nowcast Convection In Taiwan Amanda R. S. Anderson*, James W. Wilson, Tracy J. Emerson, Zhuming Ying, Juanzhen Sun, Rita D. Roberts National Center for Atmospheric Research, Boulder, Colorado

Figure 3: Near-Realtime Measurements of TARA[11]



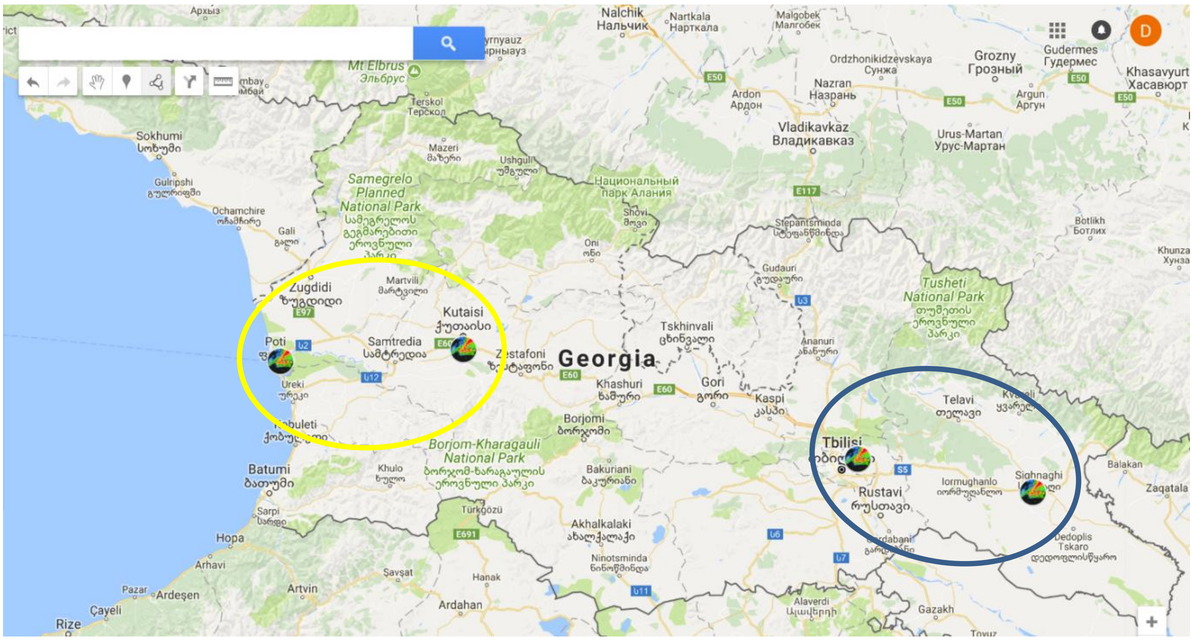
Currently there is an operational practice of NEA to utilize data derived from radars under the disposal of Delta[12], Sakaeronavigatsia[13] and Turkey Meteorological Service[14] for the prediction of heavy rainfalls. Below provided Figure 4 and Figure 5 represent the approximate location of operational radars and at some represent the extent planned radars.

Figure 4: The Coverage Area of Radar Operated in Turkey[15]



[11] http://ftp.tudelft.nl/TUDelft/irctr-rse/tara/index.html
[12] http://www.delta.gov.ge/
[13] http://airnav.ge/
[14] https://www.mgm.gov.tr/sondurum/radar.aspx?rG=anm&rR=00&rU=ppi#sfB
[15] https://www.mgm.gov.tr/sondurum/radar.aspx?rG=anm&rR=00&rU=ppi#sfB

Figure 5: Meteorological Radars in Georgia[16]



Saqaeronavigatsia plans to install new radar near Poti[17], whereas with the support of USAID, NEA plans to install radar near Kutaisi[18]. In general, Georgia would have 4 operational radars and data derived from Turkey Meteorological Service Radar by the end of 2019.

The existence of data derived from 5 operational radars, together with the data derived from the meteorological network of Georgia, would provide necessary input for VDRAS system which could be utilized for both solar and wind power forecasting in time horizon less than 3-4 hours with the update frequency 15 minutes.

[16] World Meteorological Organization Radar Database http://wrd.mgm.gov.tr/db/search-country.aspx?l=en&c=GE&o=
Delta Anti-Hail System http://www.delta.gov.ge/en/product/anti-hail-system/
[17] World Meteorological Organization Radar Database http://wrd.mgm.gov.tr/db/radar-details.aspx?l=en&r=3154
[18] Government of Georgia Ordinance #260 2017 May 25. Annex 2 National Disaster Risk Reduction Action Plan for 2017-2020

SUMMARY

The real time and historical data supply represent a must for the proper functioning of VRE forecasting system

Historical data with different granularity might be acceptable for different vendors of VRE forecasting services.

Under the real time, CAISO and AEMO consider instantaneous measurement which means measurements updated each 4-10 seconds or more frequently. CAISO, in its requirement for forecasting system, goes beyond the data requirement and makes obligatory the existence of meteorological equipment at VRE project location.

In case of wind projects AEMO and CAISO, the preference is given to meteorological parameters, measured on nacelles of wind farm, whilst in case of solar, the priority on meteorological measurement goes to parameters measured at the surface and backstage of solar panels. The use of SODAR and/or LIDAR equipment may be an acceptable substitute for wind direction and velocity, based on consultation and agreement with the forecast service provider and the CAISO.

Currently, the feedback is available only from Wind Project - Infinite Energy, Caucasus Wind Company and QWF, whilst the remaining 1 project developer is in the process of filling the questionnaire. QWF is a member of WG on Test Mode and already provide data required for the wind speed forecast.

With the consideration of the data requirements, set by CAISO and AEMO, regarding the forecasting system data input, as well as data requirements mentioned by the potential vendors of forecasting services and the feedback received from the Infinite Energy and QWF, it can be stated that the reliable data input on place and trial benchmarking for the selection of potential supplier of forecasting services could be performed at list at 3 points. As soon as the developers of VRE projects respond to USAID Energy Program by filling the questionnaire, the map indicating the locations with the available data for forecasting, would be developed and updated.

It may be beneficial to deploy the meteorological sensors in the proximity (for example, a nearby Meteorological station to the VRE project) of generation facility to monitor the weather conditions and utilize it as supplementary inputs to a forecast system. The usefulness and representativeness of measurements from nearby meteorological stations vary greatly, depending on the area, location, topography, landcover and climate variations. Therefore, the assessment of such data input might be postponed until the launch of the forecasting system. Then, on demand with the consideration of cost for services, NEA can provide data at specific locations per request of vendor. Data from NEAs meteorological stations might be utilized and accessed for the reliability and usefulness. Data from the sensor together with the data derived from meteorological Doppler radars might be utilized for systems like VDRAS for a short-term prediction.

By the end of 2019-2020, under the disposal of NEA might be the measurement data derived from 5 meteorological radars. The existence of data derived from 5 operational radars together with the data derived from the meteorological network of NEA might provide necessary input for VDRAS system which could be utilized for both solar and wind power forecasting in time horizon less than 3-4 hours with the update frequency 15 minutes.

The forecasting results in Test Mode could be characterized by both magnitude and phase shifting error. The absolute value of the forecast error magnitude varies in the range of 8 m/s. which in case of being the final product, means that error is quite high. However, due to a short period of time passed since the launch of Test Model, currently it can be neglected.

USAID Energy Program Identified the NEA services which under the specific cost might be utilized as an input for centralized forecasting system. Considering the specific cost of services, NEA can provide historical meteorological data and access to the observational data, obtained from meteorological stations and radars at the proximity to the proposed wind projects locations. Moreover, with the consideration of specific cost, the list of NEAs services considers the provision of sector specific forecast of meteorological parameters. Respectively, if the point forecast is ordered for certain project location, it might be utilized as one of the inputs to the model employed either for centralized or decentralized forecast.

ANNEX 1: QUESTIONNAIRE FOR WIND PROJECTS

Questionnaire for forecasting infrastructure assessment

Element	Device(s) Needed	Units	Accuracy	Type of Measurement Device		Measurement Device Location	Datalogger Yes/No	Measurement Currently Performed Yes/No	Instantaneous measurements YES/NO (Instantaneous means values updated at least every 4-10 seconds) with 4 seconds or faster preferred.	
				Installed on Nacelle	Installed on Met-mast				Historical 1-2Years Yes/No	Real Time Data Access Yes/No
1	2	3	4	5	6	7	8	9	10	11
Wind Speed (Meter / Second)	Anemometer, wind vane and wind mast	Units	Accuracy							
Wind Direction (Degrees - Zero North 90CW)	Wind vane	m/s								
Air Temperature (Degrees Celsius)	Temperature Sensor, might be in combination with relative humidity and barometric pressure sensor	ºC								
Humidity %	Relative humidity Sensor otherwise known as hygrometers, might be in combination with temperature and barometric pressure sensor - relative humidity (%)	%								
Barometric Pressure (Hecto Pascals)	Barometric Pressure Senosr might be in combination with temperiture and relative humidity sensor	hPA								
	Ice Detection System	Units								

Explanatory Examples	If its convenient you can fill with answers below cells	
Please provide descriptive answer : **Type and Number** : 6 Ultrasonic Anemometers installed on nacelle of wind turbine or on met mast. In case if anemometers are installed on nacelles please indicate height of installation above the ground AGL.		
Please provide descriptive information Example: **Type and Number** : 3 Ultrasonic Anemometers installed on meteorological mast which height is 80 meter AGL. Please indicate height of anemometer installation like h1=10m h2=50m and h3=80m AGL.		
Measurement Device Location Please provide GIS coordinates WGS_1984_UTM_38N_37N or other compatible to Google Map KML or Google Earth KMZ format		
Please provide descriptive information: **Datalogger** - number of devices : 1 datalogger in encloser mounted on met-mast		
Please provide information currently measurements performed or not. If the measurement devices are active just indicate Yes. In case if No is the answered please provide descriptive information when ans why the measurements interrupted. Example: The met mast erected in 2014. The measurement of meteorological parameters required for resource assessment or to determine wind power density already accomplished. Met-mast dismantled in 2018 or was not calibrated since 2017.		
Yes means that historical data for last 2 years 2016/2017 and part of 2018 is available with the same granularity the instanteouse measurement requires. Instantaneous means values updated at least every 4-10 seconds, with 4 seconds or faster preferred. In case of No please describe for what the period data is available and what is the granularity of data. Example of QWF		
Yes considers that real time data is available, and access to instantaneous measurement data would become available to third party such as TSO or Vendor of forecasting services through the granted access to the Web application the datalogger is uploading measurement to or data would be uploaded directly to the TSO or Vendor servers, or third party would be granted access to dataloggers. In case of **No** please describe the challenging issues and for example indicate that SCADA data derives modified X hour later with the granularity 10 minute averaged because turbine manufacturer is responsible for the operation and maintenance of the plant or because the entity responsible for the operation of the met-mast gas limited access to the data with high granularity		
Wind Wane Type and Number: 6 units of counterbalanced, low threshold, optoelectronic wind vane installed on ay nacelles (please indicate the installation height AGL).		
Wind Wane Type and Number: 3 units of counterbalanced, low threshold, optoelectronic wind vane installed on meteorological mast h1=10m h2=50m and h3=80m AGL. If the wind wane is installed on nacelles of wind turbine please indicate the installation height AGL.		
Measurement Device Location: Just indicate that Wind Vane mounted on nacelle		
Measurement Device Location: If Wind Wanes mounted on met-mast just indicate and provide height of mounting like h1=10m h2=50m and h3=80m AGL		
Please provide information currently measurements performed or not. If the all Wind Vanes are active just indicate Yes. In case if No is the answered please provide descriptive information when ans why the measurements interrupted. Example: The met mast erected in 2014. The measurement of meteorological parameters required for resource assessment or to determine wind power density already accomplished. Met-mast dismantled in 2018 or was not calibrated since 2017.		

Yes means that historical data on ambient temperiture for last 2 years 2016/2017 and part of 2018 is available with the same granularity the instantons measurement requires. Instantaneous means values updated at least every 4-10 seconds, with 4 seconds or faster preferred. In case of No please describe for what the period data is available and what is the granularity of data.		
Yes considers that real time data is available, and access to instantaneous measurement data would become available to third party such as TSO or Vendor of forecasting services through the granted access to the Web application the datalogger is uploading measurement to or data would be uploaded directly to the TSO or Vendor servers, or third party would be granted access to dataloggers. In case of No please describe the challenging issues and for example indicate that SCADA data derives modified X hour later with the granularity 10 minute averaged because turbine manufacturer is responsible for the operation and maintenance of the plant or because the entity responsible for the operation of the met-mast has limited access to the data with high granularity		
Humidity Sensor Type and Number: Installed on nacells of 5-th and 6th wind turbine two thermal Conductivity 1000 Ω PRT humidity sensor mesures humidity and air temperature for the -40° to +60°C range.		
Humidity Sensor Type and Number: Installed on met mast thermal Conductivity 1000 Ω PRT humidity sensor at height 10m AGL mesures humidity and air temperature for the -40° to +60°C range.		
Just indicate is it installed on anceells of particular turbines or on met-mast		
Please just mentione that same as 5th and 6th turbine or if its mounted on met mast same as location of met-mast 10m AGL		
Please provide information currently humidity mesurments performed or not. If all the sensors are active just indicate Yes. In case if No is the answered please provide descriptive information when ans why the measurements interrupted. Example: The met mast erected in 2014.Met-mast and sensors dismantled in 2018 or was not calibrated since 2017.		
Yes means that historical data on humidity for last 2 years 2016/2017 and part of 2018 is available with the same granularity the instantons measurement requires. Instantaneous means values updated at least every 4-10 seconds, with 4 seconds or faster preferred. In case of No please describe for what the period data is available and what is the granularity of data.		
Yes considers that real time data on humidity measurement data is available, and access to instantaneous measurement data would become available to third party such as TSO or Vendor of forecasting services through the granted access to the Web application the datalogger is uploading measurement to or data would be uploaded directly to the TSO or Vendor servers, or third party would be granted access to dataloggers. In case of No please describe the challenging issues and for example indicate that SCADA data derives modified X hour later with the granularity 10 minute averaged because turbine manufacturer is responsible for the operation and maintenance of the plant or because the entity responsible for the operation of the met-mast was limited access to the data with high granularity		
Descriptive information of Icing Detection System: Ice prevention and detection system estimates meteorological icing if the temperature and humidity measurement exceeds particular limits.		

USAID Energy Program

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