RENEWABLE POWER INTEGRATION TECHNICAL ASSISTANCE AND CAPACITY BUILDING IN SUPPORT OF USAID/DELOITTE TASK ORDER NO. AID-278-TO-13-00004, JORDAN ESCB

ELECTRIC POWER ENGINEERS INC, TASK 2 – INTERMITTENT RENEWABLE RESOURCES OPERATING PROTOCOLS

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General Overview

The USAID Jordan Energy Sector Capacity Building (ESCB) project has contracted with Electric Power Engineers, Inc. (EPE) to execute a scope of work focused on supporting the National Electric Power Company (NEPCO) to integrate renewable power projects into Jordan's transmission grid. The following outlines recommendations provided by the EPE team in support of Task 2.

Task 2: Intermittent Renewable Resources Operating Protocols. The major activities in this task are to provide recommendations to NEPCO on a roadmap and/or software to use in forecasting and dispatch of Wind and PV projects. Additionally, this task includes providing Operating Protocols for Wind and PV projects.

With goals set by the Government of Jordan with aims to increase the proportion of renewable energy in Jordan's energy mix to over 10% by 2020, with capacity penetration figures that will exceed 20% by 2020, renewable energy forecasting and generation operation become critical for both the economics and reliability of the system. Jordan is targeting an additional 1,000 MW of wind and 800 MW of solar energy by 2020, on a projected system peak load of around 5,500 MW.

A state-of-the-art renewable forecasting service is necessary in the Day-Ahead and Hour-Ahead (even sub-hourly) time frame to minimize errors in the unit commitment process. The accuracy and granularity of the load and renewable generation forecasts will affect unit commitment costs, and this effect can be very significant.

Not only system cost, but also the reliability of the system requires more granular and frequently updated forecast, in order to allow the generation dispatch to quickly respond to sudden changes in renewable generation forecast. Such forecast, however, is useful only if NEPCO deploys unit commitment and dispatch software optimization tools that automatically integrate with the forecasts and other grid data in a granular hourly and sub-hourly dispatch operation.

This report lists some solutions through software/service vendors for renewable forecasting and unit commitment and dispatch, with the reservation that these lists are based on vendors that EPE reached out to and that were responsive during the time frame of preparing this report. There are several other providers of the same type of service/product that may be more economical or more qualified, and this report does not claim that all solution providers were evaluated.

The Operating Protocols were completed to cover essential standard industry procedures applied at various Independent System Operator's (ISO) and utilities, based on EPE's experience, for the operation of Intermittent Renewable Resources (IRR) on the grid. The Operating Protocols also provide the data points that the IRRs must provide to NEPCO on forecasting as well as unit availability.

The report is divided into three sections: Renewable Energy Forecasting, Unit Commitment and Dispatch, and Operating Protocols. This report has some confidential cost information provided from third party consultants or vendors in Appendix C and D. These Appendices with confidential information must be deleted before making this report or any part of it public.

1. Recommendations for Wind and Solar Generation Forecasting

Renewable energy, particularly wind and solar, is intermittent in nature, which impacts the utility operation in terms of unit commitment and dispatch, as well as reliability. Currently there is less than 200 MW of utility scale renewable generation installed in Jordan, which is a small percentage of the overall system peak generation of over 3,000 MW; the margin of error therefore in forecasting does not significantly impact the system operation. As the percentage of renewable energy generation in NEPCO's system expands, the significance of accurate, frequent, and granular renewable energy forecasts becomes more prominent.

The following table shows what a few of the major ISOs in the US have adopted for variable generation forecasting. The source for this information did not include the Electric Reliability Council of Texas (ERCOT) centralized forecasting system, which is a rolling hourly forecast.

Table 1 Variable Generation (VG) Forecasting[1]

	PJM	NYISO	ISO-NE	Midcontinent ISO
Type of VG Forecasting System	Centralized wind forecasting since April 2009. PJM does not currently have a solar power forecasting system.	Centralized wind forecasting system in place since June 2008; used for individual wind plant economic dispatch decisions since May 2009.	Centralized wind forecasting since January 2014. No solar forecast but under consideration.	Centralized wind forecasting since June 2008.
Description of VG Forecasts	Long-term: Provided hourly, from 48 hours ahead to 168 hours ahead. Medium-term: Updated from six hours ahead to 48 hours ahead. Short-term: Updated with frequency of every ten minutes, forecast interval of five minutes for next six hours. Forecast on the following aggregation levels: wind projects; electrically close wind farms; Transmission Owners; Regional – West, Mid-Atlantic; Council – RFC or SERC (currently none in SERC); and PJM RTO.	Medium-term: DA forecasts updated twice daily (4:00 a.m. / 4:00 p.m.), covering the next two operating days. Short-term: Updated every 15 minutes on a 15-minute interval basis, covering an 8-hour time horizon.	Long-term: 7-day aggregate wind forecast for each hour, updated hourly. Medium-term: 48-hour-ahead wind forecast that updates every three hours. Short-term: 4-hour-ahead wind forecast that updates every five minutes. ISO-NE does not forecast solar or intermittent hydro at present.	Long-term: MISO receives hourly updated forecasts for each hour for the next seven days, for the same Commercial Pricing (CP) nodes. Short-term: 5-minute granular forecasts for each CP node (DIRs and non-DIRs, 180+) are provided for the next six hours and are updated every five minutes. Forecast on the following four aggregation levels: CP nodes, zones, regions, and all of MISO.

Although forecasting software is available as a stand-alone package, however the set up and operation of such software can be complicated and requires dedicated staff to control data and quality of forecasts. Additionally, the forecasting being critical to generation dispatch, downtime should be minimized which requires investment in duplication of setup and staff.

Procurement of the forecasting service from specialized companies that deploy sophisticated renewable forecasting expertize is recommended. The quality of the forecast is additionally improved from such forecasting service providers who are focused on improving and controlling their forecasting techniques. The preferred solution is further recommended to be a Centralized Forecasting solution, where the forecasting service provides the forecast for all the resources that NEPCO hosts.

[1] Source: UWIG, March 2015 "Variable Generation and Electricity Markets"

Centralized Forecasting solutions improve the quality of the forecast, particularly for wind data, which enjoys strong geographical aggregation benefits. Aggregating wind power plants over a region significantly reduces forecasting error. In some third party studies, in Germany for example, forecast error was reduced 50% from a single site prediction to a regional prediction of measured power production. Combining different wind-forecasting models into an ensemble wind forecast can also improve wind-forecasting accuracy by up to 20%, as measured by root mean square error. Additionally, several utilities in the United States share the experience that forecasts provided from the individual projects were not adequate/reliable.

Currently however, and in the absence of a Centralized Forecast, NEPCO shall continue to request the individual projects to provide their own forecast until NEPCO deploys a Centralized Forecasting solution.

There are several companies that provide renewable forecasting services, a few of which are listed below. Most of these provide Centralized solutions as well, and some of which also support the grid integration aspect by providing additional critical data to the utility such as significant change in the forecast, or expectation of a sudden ramp in renewable resource output.

- AWS Truepower (USA)
- Vaisala (Finland/USA)
- Vortex (Spain)
- DNV GL short term wind power forecasting (UK, USA, Worldwide)
- European research project ANEMOS
- Wind power forecasts for the intra-day and the day-ahead markets (Netherlands)
- Enercast (Germany) | Wind energy forecasting and Nowcasting (Worldwide)
- ConWx (Denmark)
- WPPT - Wind Power Prediction Tool (Denmark)
- Meteologica (Spain)
- Meso-to-micro CFD downscaling forecast - Meteodyn(France)
- AleaWind - AleaSoft (Spain)
- Nnergix (Spain)

EPE contacted two of the vendors in order to get a general high level estimate on providing the renewable forecasting service in Jordan, and obtained the information shown in Appendix C, High Level Costs for Wind and PV Forecasting [CONFIDENTIAL]. At least one of the vendors also indicated that they will provide a free high level trial for NEPCO if so desired.

In conclusion, based on current industry practice, coupled with EPE's experience in working with utilities and ISO's in the US, EPE recommends the following guidelines for the renewable energy forecasting regime that NEPCO may want to deploy:

- **NEPCO may continue to request a rolling hourly forecast. This will be used in the short term prior to implementation of the Centralized Forecasting solution. Also may be useful as additional information to the final forecasting process.**
- **NEPCO must ensure that IRR projects are capable also of providing 5 minute or finer data on their individual unit and system output, unit availability, wind and metrological parameters as dictated in the Operating Protocols. The more granular the real data, the better the forecasting process. This will become valuable when**

NEPCO moves forward with more granular and automated unit commitment and dispatch operation.

- **NEPCO must also ensure that their agreement with the project owners allows NEPCO to share the above data, including project location and technology type, with vendors or consultants of NEPCO, particularly for application to the Centralized Forecasting.**
- **EPE recommends that NEPCO proceed to procure services for a Centralized Forecasting solution for all utility scale wind and solar resources in Jordan.**
- **EPE recommends that NEPCO procure the forecast to be a rolling hourly forecast. Short term 5-minute forecast is a plus:**
    - **Mandatory immediate provision for rolling hourly forecast for the next 168 hours (1 week). This is necessary to improve the operation of the system in terms of unit commitment and dispatch for day ahead operation.**
    - **Capability to provide 5-minute rolling forecasts are needed looking 6 hours ahead and will help improve system reliability, which NEPCO can request now or in the future.**

While the standard approach would be for NEPCO to procure the Centralized Forecasting solution, however, NEPCO may consider selecting a vendor and requesting all the renewable projects to procure their forecasting from the same service provider in order to improve the quality of the forecast, and pass on discounts to the project owners as more projects procure the service.

EPE further recommends that the Centralized Forecasting be implemented before the end of 2016, in anticipation of more renewable energy projects that will be coming onto the grid. Additionally, this should be coupled with the implementation of the automation of unit commitment and dispatch as recommended in the following section.

In order to kick off this process, EPE suggests that NEPCO issues a Request for Proposals (RFP), along the guidelines provided in Appendix A, Requirements for Centralized Renewable Power Production Forecasting. The recommendation is to select around five companies, and then short list three of them for Trial and further negotiations.

If NEPCO needs assistance evaluating the bids, EPE recommends contacting a third party entity to evaluate the bids, which could be any of the companies listed above, or other third parties that EPE can recommend as well.

2. Recommendations for Unit Commitment and Dispatch Software

In general, utilities can experience an improvement in their overall energy production costs from 0.5% to 3% from the optimization of unit commitment. System reliability also improves significantly including ability to plan the amount of regulation reserve and amount and number of short start units that the system needs. The savings figures are derived from several IEEE publications as well as from documented actual implementation. The percent savings from optimization and automation of unit commitment and dispatch varies from one system to the other and on the current operation. In some parts of the world, the savings were higher than 10%. Even at 0.5% improvement, this may result in several million dollars in savings a year for NEPCO.

As part of supporting NEPCO to integrate Intermittent Renewable Resource (IRR) projects into Jordan's transmission grid in the ESCB mission, EPE met extensively with the unit dispatch and load forecast team at NEPCO and reviewed the current procedures that NEPCO currently follows for load forecasting and generation dispatch. EPE also worked side by side with the EU Twinning Project mission in supporting training and possible implementation of a unit commitment and dispatch tool (Marea) that Red Electrica provided to NEPCO as part of that mission. Despite the extensive training provided by the EU Twinning Project, and that the Marea tool is free to NEPCO (with the exception of a $6,500 investment in a CPLEX[2] mathematical optimization engine), NEPCO operations has not adopted Marea in their daily operation, nor invested in the CPLEX engine.

The current NEPCO load forecast and generation dispatch methodology consists of a multi-step manual process that deploys good use of spreadsheet automation for calculations, however does not use any optimization engine nor is the process automated. This process is updated no more than once or twice per day at the most, however with human intervention instructions for response to outages in the system where needed. EPE provided, as part of the Inception Mission Report – Appendix C, recommendations on how to best continue utilizing the current methods for the near future, until NEPCO adopts more advanced methods.

Optimizing unit commitment and dispatch depends on numerous system variables, to where finding the most economical and secure configuration for generation dispatch can be significantly improved by computer simulations. The application of mathematical optimization engines through advanced software is strongly recommended and is adopted by most central utilities all over the world for solving for the optimal dispatch.

The addition of significant amounts of renewable generation into NEPCO's system introduces an additional layer of variability that will necessitate more granular and dynamic updates to generation dispatch.

[2] CPLEX: An IBM engine – a mathematical programming technology that enables decision optimization for improving efficiency, reducing costs, and increasing profitability.

This report strongly recommends the adoption of state of the art unit commitment and dispatch software as soon as possible in the operations at NEPCO. In order to facilitate the selection of a software package, EPE procured from several software vendors high level cost estimates as well as a comparison of key functionalities. Appendix D, High Level Cost Estimates for Unit Commitment and Dispatch Software [CONFIDENTIAL] provides a very detailed comparison of these packages for NEPCO to consider. A list of these packages are shown below:

- UPLAN from LCG Energy On Line (USA)
- Plexos of Energy Exemplar (Australia/USA)
- Gridview from ABB (USA)
- Generation Operations from ABB (USA)
- Marea – Red Electrica Consultant (Spain)
- Aurora XP (not included in the comparison as the vendor did not supply the information in time)

It is to be noted that NEPCO currently has possession of an older version of a unit commitment and dispatch software package, Marea, which Red Electrica of Spain has donated to NEPCO as part of the EU Twinning Mission. Marea is a tool developed in-house by Red Elecctrica to use in their operations. EPE has carefully reviewed the Marea tool, and determined that it has the functionality and the optimization engine that are adequate for unit commitment and dispatch operation; however, the interface requires upgrade/improvement. NEPCO has not started using this tool to date. The Marea interface, is mostly in Spanish, and lacks the automated interface necessary to allow the operator to run frequent updates to generation dispatch optimization. This tool was written and is maintained by an employee of Red Electrica, Mustafa Pezic, who has provided training to NEPCO. EPE contacted Mr. Pezic who provided a high-level cost estimate for updating the Marea tool which is provided as part of the attached appendix comparing the software packages.

EPE sees that the adoption of a unit commitment and dispatch software at NEPCO could result in large amounts of savings, possibly exceeding $50,000 per day; however, that only can be verified by adopting a software tool in operations. In light of hesitation of NEPCO operations team and management in adopting Marea or other unit commitment and dispatch software, EPE strongly recommends that NEPCO procures consultancy for a real time demonstration of 30 days of cost savings from the implementation of an automated unit commitment and dispatch optimization method as a trigger to incentivize the procurement of such application.

Although outside the scope of this mission, EPE recommends adoption of a load forecasting tool. The load forecasting tool may very well be NEPCO's very own Network Manager (ABB SCADA),

Although outside this scope of work, EPE also strongly recommends that NEPCO adopt a load forecasting software in order to improve the load forecast procedures, which currently are based on human observation of historical data and correlating to weather forecast. NEPCO, in its Network Management System from ABB (version 3.8), currently has a load forecasting module, which the NEPCO operations team had tried to use, and likely need some assistance in configuration to make it operational, which is recommended to be remedied as soon as possible.

3. Intermittent Renewable Resources (IRR) Wind & PV Operating Protocols (OP)

NEPCO's Grid Code was originally developed assuming only synchronous generators that are not intermittent in nature. The addition of wind and solar photovoltaic generators to the NEPCO generation mix merit provisions to the Grid Code specifically for Intermittent Renewable Resources (IRRs). The NEPCO Operating Code within the Grid Code does not include specific provisions for the operations of IRRs. Therefore, as part of the deliverables of this mission EPE completed the Intermittent Renewable Resources (IRR) Wind & PV Operating Protocols (OP) which are attached to this report in Appendix B, Intermittent Renewable Resources (IRR) Wind & PV Operating Protocols (OP). The protocols were written by EPE based on extensive experience in the field of commissioning and operational protocols for IRRs, and drew the protocols based on international standards adopted by US and European ISOs, while merging those protocols with NEPCO's very own which were based on Al Tafila and Al Quatrana operating guides.

The NEPCO IRR Operating Protocols (OP) supplements the Transmission Interconnection Code IRR-TIC during the operation of IRRs, as well as Intermittent Renewable Resource - Grid Compliance Testing Procedures (IRR-GCTP). The IRR-OP establishes operating requirements and procedures to ensure that IRRs, specifically Wind and PV projects, comply with NEPCO grid code requirements during commercial operation. The operating requirements and protocols within the IRR-OP document are intended to be followed by the IRRs during the lifetime operation of the generation facility.

Appendix A, Requirements for Centralized Renewable Power Production Forecasting

The National Electric Power Company of Jordan, NEPCO, seeks bids for utility scale wind and solar power forecasting of production to be deployed in NEPCO's operations in support of unit commitment and dispatch in real time, as well as for day-ahead planning.

RFP Date: _____

Questions Due by: _____

Proposal Due Date: _____

Trial Operation Requirement

The Vendors, if short listed, must be capable of providing a free trial operation which shall be provided to NEPCO 30 days after the Proposal due date and shall last for 60 calendar days. The success and effectiveness of the trial operation shall be part of grading the proposals. NEPCO will provide several months of recorded data for an existing wind farm production, meteorological data, and unit availability, as well as the location of the center of the wind farm, number of turbines, and their type. NEPCO may also provide similar information for a solar PV project.

Selection Criteria

The selection process will take place after the completion of the Trail Operation. In general, the following criteria will be applied to the selection process. NEPCO however reserves the right to select any or none of the proposals and may take other considerations not listed below during or after evaluation of the proposals.

- 30% Cost
- 30% Technical specifications, model accuracy
- 10% Data Integration and Grid Integration
- 10% Support and Quality Control
- 10% Experience and general Qualification
- 10% Trial operation

The proposal shall include each of the following sections. Any additional information shall be provided in a separate addendum to the proposal.

1-Proposal Summary

This section summarizes qualitatively what the solution and product(s) the vendor is proposing, with details provided in the following sections.

2-Data Input Requirements:

List all data input requirements that will be used in the forecasting model.

Separately list any data requirements that you expect NEPCO to provide.

3-Data Integration Features:

This section should describe the format and method of integration of data input and output of the forecasting proposal with the rest of the utility systems; this should at least cover the following:

- Specification of any data that is required to be provided by NEPCO
- Format of input data that the service may need from NEPCO
- Acceptable or recommended method(s) of delivery of input data from NEPCO
- Format of forecasts to be delivered to NEPCO
- Method of delivery of forecasts to NEPCO (Web service, ftp, direct integration with database etc.)
- Ability to set up and automatically integrate data with each of the following: Oracle Database, Microsoft Access, SQL Database, comma delimited files, or any other formats.

4-Grid Integration Features:

Describe the grid integration features that will be provided, including but not limited to the following:

- Ramp alert tools
- Probabilistic forecasts

5-Technical and Quality Control Measures

In this section describe the forecasting model, as well as quality control. This should include but not be limited to the following:

- List of data input into the model to improve forecasting (satellite, meteorological, historical, local, regional etc.)
- Mathematical forecasting model information and methodology, long term and short term
- Calibration of model information and methodology
- Wind forecasting model details
- Solar forecasting model details
- If there are any data sources that your firm may not use due to inaccessibility or cost (such as satellite information), this must be described here
- Method of detection of errors and/or interruption of forecast. Remedy methods and response time to fix such issues
- Provide range of expected margin of error in forecast for the next 6 hours, 12 hours, 24 hours, and 168 hours.

6-Cost

This section should provide the cost estimates for the proposed service in US dollars in the format provided below. If there are any services that are considered optional, these shall also be provided and described in detail with the cost increment of acquiring these optional services.

A-Annual Fees

Annual Cost with rolling hourly updates for 168 Hours (US $)		
1 project	**5 projects**	**10 projects**

Annual Cost with rolling 5 minute updates for 6 hours ahead (US $)		
1 project	**5 projects**	**10 projects**

Annual Cost for both 5-min AND hourly forecasts described above (US $)		
1 project	**5 projects**	**10 projects**

B-Support:

Confirm that support is included with annual fees. Describe the support services, providing at least the following information:

- Availability of support team (hours of operation)
- Support communication method (phone, email, live online support)
- Response to interruption of service (method of recognition and remedy, and average time to resume service)

C-Additional Fees:

NEPCO is not expecting additional set up costs, however if additional costs are associated with first time set-up, then provide the additional cost with detailed description on what these costs entail.

7-Qualifications

In this section provide general qualification documents for the type of service requested

- Qualification documents
- List of three references with similar deployment, preferably with one in the US and one in the Middle East or Europe

8-Client Relationships Alternate Model [OPTIONAL]

NEPCO may favor a set up where NEPCO facilitates the centralized service with all project owners, however the service provider will bill each renewable project separately for their service. Please indicate the following:

- Will your firm adopt such a billing arrangement?
- Will the costs bid in your proposal apply to this arrangement? If not indicate expected variation?
- Will the cost savings of aggregating projects in a Centralized service be passed to the project owners?
- Experience with such arrangements

Appendix B, Intermittent Renewable Resources (IRR) Wind & PV Operating Protocols (OP)

Refer to separately attached document.

Appendix C, High Level Costs for Wind and PV Forecasting [CONFIDENTIAL]

AWS Truepower provided the most detail and information on cost, which is summarized in Table 1. Vaisala did not provide details, but indicated that their service will cost anywhere between $4,000 to $12,000 per year per project (from basic to premium service), however the cost will be lower per project if the portfolio contains several projects.

wind and Solar Forecasting Service Provider	Free Trial (Y/N)	Indicate method of delivery of forecast (web based, ftp, or email)	Sub-hourly Forecasting Options		
			Hourly (Y/N)	15 min & 30 min (Y/N)	Indicate smallest interval
AWS Truepower	Y	AWST can deliver in all 3 methods	Y	Y	5 minutes

Annual Cost with rolling hourly updates for 168 Hours (US $)		
1 project	**5 projects**	**10 projects**
$12,000 - $19,000 per year	$51,000 - $84,000 per year	$80,000 - $132,000 per year

Annual Cost with rolling 5 minute updates for 6 hours ahead (US $)		
1 project	**5 projects**	**10 projects**
$12,000 - $16,000 per year	$54,000 - $66,000 per year	$96,000 - $120,000 per year

Annual Cost for both 5-min AND hourly forecasts described above (US $)		
1 project	**5 projects**	**10 projects**
$18,000 - $29,000 per year	$75,000 - $111,000 per year	$132,000 - $180,000 per year

Notes: As demonstrated above, the cost for forecasting services is mostly driven by the number of sites and the forecast configuration.

Note that the cost to receive an hour ahead forecast and a 5-min ahead forecast is less than the sum of the individual costs for hour ahead and 5-min forecasts.

AWS True Power also provided the following information regarding data inputs that are needed for producing good forecasts as follows.

Data Inputs

1. Wind
    - Site metadata – location coordinates, nameplate capacity, turbine type/power curve
    - Historical data – met tower data, production/availability (if available, operating sites), turbine wind speed data (if available)
    - Real-time data (via FTP, at least 10-min granularity) – production/availability data, turbine wind speed data, met tower data (if available)
2. Solar
    - Site metadata – location coordinates, equipment data sheets, detailed layouts
    - Historical data – on-site irradiance data (if not available we will utilize our proprietary Global Satellite Derived Irradiance data set), on-site weather data (if available), production (if available)
    - Real-time data (via FTP, at least 10-min granularity) – production, irradiance (if available), weather variables (if available)

Contact Information for AWS Truepower and Vaisala are provided here below. These contacts may be approached for bids directly to NEPCO and/or to set up Trial operations.

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Appendix D, High Level Cost Estimates for Unit Commitment and Dispatch Software [CONFIDENTIAL]

Software Tool Name	Unit Commitment and Dispatch Real Time Operation (Y/N)	Sub-hourly dispatch			Generation Constraint Model	
		5 min (Y/N)	15 min & 30 min (Y/N)	Hourly (Y/N)	Zonal (Y/N)	Nodal (Y/N)
UPLAN-ACE (see Remark 1)	Y	UPLAN-ACE (see Remark 1)	UPLAN-ACE (see Remark 1)	Y	Y	Y
Energy Exemplar	Y	Y	Y	Y	Y	Y
Gridview	Y	Y	Y	Y	Y	Y
PROMOD	Y	Y	Y	Y	Y	Y
Generation Operations	Y	Y	Y	Y	Y	N
Marea	Y	N	N	y	y	N

Software Tool Name	Transmission Model		Method of input/import of real time operating data (such as forecasts, unit availability, etc.)	Backend Database	
	Full Transmission Model with Contingencies (Y/N)	Import Model from PSS®E (Y/N)		Name	Cost (US $)
UPLAN-ACE (see Remark 1)	Y	Y	User Interface, Application Programming Interface (API), .CSV File Upload	Microsoft SQL Server Express Local DB	Free
Energy Exemplar	Y	Y	.CSF Files, PSS®E raw file	.xml	0
Gridview	Y	Y	Import Excel format or run python code	MS Access, SQLite	0
PROMOD	Y	Y	Automated file based	Microsoft SQL Server	Typically, this is procured directly by the customer if they do not have a company-wide license
Generation Operations	N	N	Automated file based	Microsoft SQL Server	Typically, this is procured directly by the customer if they do not have a company-wide license
Marea	N (See Remark 8)	N (See Remark 8)	Import Excel or Manually	ACCESS	Typically, this is procured directly by the customer if they do not have a company-wide license

Software Tool Name	Mathematical Optimization Model		Method of import of operating data (such as forecasts, unit availability, etc.)
	Name if from third party	Cost (US $)	
UPLAN-ACE (see Remark 1)	Default: N/A. UPLAN-NPM uses XA optimization engine which is provided free by LCG. If NEPCO adopts UPLAN-ACE, CPLEX* can be licensed for a fee.	CPLEX* is needed for UPLAN-ACE for an upfront fee around US$5,000 and US$1,000 for support thereafter	User Interface, Application Programming Interface (API), .CSV File Upload
Energy Exemplar	choice of 1) FICO Xpress MP, 2) Gurobi, 3) IBM CPLEX*	~US$5,000 (See Remark 5)	.csv files
Gridview	XA	No additional cost to customer	import Excel format or run python code
PROMOD	XPRESS	No additional cost to customer	Automated file based
Generation Operations	XPRESS	No additional cost to customer	Automated file based
Marea	CPLEX*	$13,000	Manual/Access Database (See Remark 8)

Software Tool Name	Annual Subscription Option		Perpetual License Option	
	Annual Cost	Support (US $)	Perpetual license onetime fee (US $)	Optional Annual Support Fees (US $)
UPLAN-ACE (see Remark 1)	$50K-$70K (see Remark 2)	Included	$150K - $210K (See Remark 3)	$20K - $30K (See Remark 4)
Energy Exemplar	$50,844 for first license, $12,711 for subsequent licenses	Included	not available	not available
Gridview	$120,000.00	Included	$290,000.00	$63,800.00
PROMOD	$120,000.00	Included	$287,500.00	$63,250.00
Generation Operations	$122,500.00	Included	$270,000.00	$59,400.00
Marea	$0 * (See Remark 8)	$3,000/Yr	$0 * (See Remark 8)	$3,000/Yr

Software Tool Name	First Time Set up and Training (US $)	
UPLAN-ACE (see Remark 1)	US$15K - US$20K (Web Based)	
Energy Exemplar	$15,000 and $18,000 (See Remark 6)	
Gridview	$9,000 (for 3-day training) plus travel cost in USA if database is available in Grandview format. Build database from scratch is available upon request.	
PROMOD	$40k – $60k (See Remark 4)	
Generation Operations	Basic Project	$80k – $90k* (See Remark 7)
	Complex Project	$250k – $300k* (See Remark 7)
Marea	Training Completed. Setup and CUSTOMIZATION $50,000 (See Remark 8)	

Software Tool Name	List here other uses for software for Grid Planner/Operator	List Utilities where Software is currently used in Operations for Unit Commitment and Dispatch
UPLAN-ACE (see Remark 1)	Congestion forecasting, Fuel planning, Generation and Transmission expansion planning, cost-benefit analysis, integration studies, storage and EV analysis	The UPLAN series of models are used extensively worldwide in electric system modeling. Its users cover a wide range of public and private electric utilities, power marketers, federal and state agencies, and energy research institutes, of which only a selected few are listed below: USA - City of Austin, Electric Reliability Council of Texas (ERCOT), Exelon, Lower Colorado River Authority (LCRA), NRG Energy, Sempra US Gas and Power, Shell Energy, U.S. Dept. of Energy, Energy Information Administration International - Electricity System Operator (IESO), Ontario, Canada, JSC InterRAO, Russian Federation, Korea Electrotechnology Research Institute, South Korea, Red Eléctrica de España, SAU., Spain, Slovenska Elektrizacna Prenosova Sustava, a.s. (SEPS, a.s.), Slovakia, and Taiwan Power Company, Taiwan
Energy Exemplar	Capacity expansion planning, economic transmission analysis and DC power flow optimization, ancillary services cooptimization, gas cooptimization, water system cooptimization, emissions modeling, fuel budgeting, renewable integration, market analysis, price forecasting, risk analysis, stochastic analysis, asset valuation, option valuation	Energy Exemplar doesn't release this information about their clients. There are however more than 20 such clients worldwide.
Gridview	SCE and PG&E use it for CRR allocation;	WECC, CAISO, NYISO, ISO-NE, SPP
PROMOD	Unit Commitment and Economic dispatch Complex Fuel Management Post Analysis (EX Post Reporting)	NV Energy Omaha Public Power District Northern Indiana Public Services company and Dairyland Cooperative Saudi Electricity Company have piloted using PROMOD for Economic Dispatch
Generation Operations	Unit Commitment and Economic dispatch Transmission congestion analysis Power Market Analysis Renewable Energy Curtailment Analysis	EO.N Benelux New York Power Authority New Brunswick Power
Marea	Planning Reserve and Capacity Expansion	Red Electrica

* CPLEX: An IBM engine – a mathematical programming technology that enables decision optimization for improving efficiency, reducing costs, and increasing profitability.

REMARKS:

UPLAN Remark (1): UPLAN-NPM's companion model UPLAN Advanced Clearing Engine (UPLAN-ACE) does hourly unit commitment with 5-minute dispatch. UPLAN-ACE was developed in accordance with the specifications of Greek power authority and used by ISOs. If NEPCO desires, they may acquire ACE which will serve their purpose for hourly unit commitment and 5-minute dispatch for additional fees. However, if the requirement is 5-minute real time dispatch, ACE alone may serve the purpose. ACE has built-in AC as well as DC OPF. In addition, ACE includes 15-minute settlement.

UPLAN Remark (2):
UPLAN-NPM or UPLAN-ACE: US$50K-US$70K;
UPLAN-NPM + UPLAN-ACE: US$75K - US$100K
(LCG is offering US$50K-$70K for both for the 1st year since we believe such a package is valuable to NEPCO)

UPLAN Remark (3):
UPLAN-NPM or UPLAN-ACE: US$150K - US$210K;
UPLAN-NPM + UPLAN-ACE: US$220K - US$300K

UPLAN Remark (4):
PLAN-NPM or UPLAN-ACE: US$20K - US$30K;
UPLAN--NPM + UPLAN-ACE: US$30K - US$40K

Plexos Remark (5): FICO Xpress MP is $4094/license licensed from Energy Exemplar, support for CPLEX*/Gurobi is roughly $1000/license. The latter two must be licensed directly with the third party vendor.

Plexos Remark (6): This ranges depending on implementation criteria and training needs. We recommend 5 days of on-site training at $2,336/day + expenses. This will likely total between $15,000 and $18,000. The implementation fees depend heavily on the client needs. In some cases, the client or third party consultants complete all required work internally. In other cases, implementation labor may range from 100 to 800 hours at an average billing rate of US$240/hr.

Promod or Generation Operations Remark (7): The indicative price is a range as it depends on level of work required to enter data, configure the workflows, setup reports and exports, and any further configuration support required beyond the initial implementation. The training will enable customer to perform majority of these functions after some practice. Below is a high level description of services components:

Marea Remark (8):
For $40,000 Marea and within 2-3 months the author will provide the following
1. Adapt to Windows 7 + Office 2013 (all with English language) (now is Windows 7 + Office 2007 (with Spanish language)
2. Improve installation process (environment checking)
3. Translate to English (some labels, items on the screens etc.... presently are not in English…)
4. Revision and adaptation of external interface (demand forecast, RES forecast, unit maintains and real production)
5. Additional export results to MS Excel sheet (according with client/user)
6. Update User manual.
7. Testing

For additional $30,000, and when available upgrade to Marea is available, provide the following
TASKS
1. Modeling transmission network in MAREA
2. Convert PSS/E data model (file .raw) to MAREA transmission data model
3. Testing

Additional General Comments for Promod and Generation Operations:
• System and economic data entered manually or imported via ABB specified file formats. The customer to perform data transformation and formatting from existing systems. PROMOD can network topology from PSSE files.
• Setup of 2-3 typical workflows required for planning
• In-application reporting and setup of data exports to file formats supported by PROMOD
• Introductory and advanced training sessions Integration with third party systems for data input and output is possible, but not included in the above estimate. Pricing for integration will be provided with more information on the systems requiring integration.

Basic Project	Complex Project
• Assets of similar technologies • Standard use of unit characteristics and constraints library (library of over 800 constraints and variables) • All data provided in ABB specified formats • A single study horizon (e.g. day ahead) • Data typically entered manually or imported via standard ABB specified file formats (customer to perform data transforms from existing systems) • Out of the box reporting • No Integration with third party systems	• Large portfolio of assets with a mix of technologies • Nonstandard constraint modelling required • Some data cleansing required • Multiple run horizons (e.g. year ahead, week ahead, day ahead and intra-day) • Data interfaces to existing systems (ABB development) • Custom reports

The above gives an indication of the complexities which increase project cost	