IEA WIND RECOMMENDED PRACTICES FOR THE IMPLEMENTATION OF WIND POWER FORECASTING SOLUTIONS
Part 1: Forecast solution selection process

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Abstract—**In this paper, the progress of the first part of a recommended practices guideline Forecast Solution Selection Process is presented that deals with the selection and background information necessary to collect and evaluate when developing or renewing a wind power forecasting solution for the power market. This is part of the IEA Wind Task 36 project 2016-2018. The work aims to provide a series of three recommended practices that deal with the development and operation of forecasting solutions of wind (and solar power) in the power market.**

The effectiveness of forecasts in reducing the variability management costs of power generation from wind and solar resources is dependent upon both the accuracy of the forecasts and the ability to effectively use the forecast information in the operational decision-making processes. With increasing amounts of forecasting methods and vendors, it has become more difficult to obtain forecasts of high quality with a fit-for-purpose that can effectively be used as input to operational processes in system operation, trading, market management, unit commitment etc. The recommended practices guideline is intended to provide guidance to forecast users who are seeking a forecasting solution that fits their purpose and enables them to work efficient and economically responsible. In this paper we summarize some of the important aspects in this respect from the document under review and explain, how the decision support tool to establish procedures for the selection process, can be applied.

I. Introduction

In recent years, many forecast users carried out trials or benchmarks in the belief that their decision process would be easy and straight forward. For many it has been disappointing and frustrating to go through long processes and hardship without being able to find an appropriate solution. And even more so, when forecast users chose a wrong solution due to a wrong outset of a test, forecasting solutions came under criticism for the wrong reason! Bad decisions are twofold: (1) they are costly and take confidence from the client that the right solution exists and (2) it can lead to a wrong perception of forecast providers ability to provide suitable solutions for the industry. Providers that may have had the right solution at hand, but did not score best at a maybe simplified test, may be deselected. This guideline will therefore focus on the key elements to consider in order to find a forecasting solution that fits its purpose and to be able to ask the questions required to identify, whether or not a providers methodology is suitable. The part 3 of this guideline is dealing with the topic of verification and evaluation of forecast solutions in more detail [5]. Here, it should only be mentioned that by extending an evaluation to hour ranges or error ranges instead of one metric for all forecast horizons and products, the randomness of outliers can be detected and excluded from the performance evaluation. In that way, even short test or trial periods can become fair, transparent, representative and have significance. mds

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II. Initial Considerations

As forecasting matures and more different techniques are entering the scenes, both from academia and industry, it becomes more and more difficult for forecast users to distinguish among vendors or methods. However, there are methodologies that serve certain purposes, but not others. Some methodologies are very cheap, but limited in their applicability, others expensive and at first glance not distinguishable from simple and cheap methods. Besides the performance in a statistical measuring space, there are a number of other aspects that have influence on the choice of forecasting solution and vendor, such as IT implementation requirements, support, reliability, consistency and performance improvement strategies, etc. Such aspects are in reality equally important than a statistically averaged performance metric.

III. Finding the most suitable forecasting solution

Taking the initial considerations into account, the following decision support tool is constructed to assist evaluation and analysis of needs and requirements for forecasting solutions. It's objective is to carry out structured procedures to find the best possible solution for the challenges an intermittent energy source such as wind energy poses on the operational environment. With the correct planning and analysis, even complex and inflexible systems can incorporate wind power with a minimum of risk. The key to this is to understand the limitations and the strengths of such resources and plan the implementation with the right tools. Advanced methods often seem more complex than known methods and therefore preferable. Complexity should however never be a criteria for ignoring a well functioning technology, if it is structured and follows clear evaluation criteria. In that way complexity becomes manageable. This recommended practices guide is intending to assist in decomposing complexity into a structure in order to help forecast users choose the best possible solution for their system.

A. *Decision Support Tool*

Independent on the experience with forecasting solutions, the high-level thought construct shown in Figure 1 is targeted to assist in considering the required resources and involvement of departments and staff for the decision process when starting to plan, renew a forecasting system or engage a new forecast provider with new technology.

The decision tool is constructed to begin with initial considerations to establish a "Forecast System Plan". The tool is constructed to take a decision on the major dependency to the planned item. There are cross references in the decision tool and referrals to a different decision stream, dependent on the answer at each step of the decision flow.

Starting at the very top, the first major dependency when planning a new or renewal of a forecasting system is the IT infrastructure. Dependent on the status of IT infrastructure, the recommended procedure splits up here and follows in different paths. This is not to be understood that the IT infrastructure has higher priority over the forecasting solution itself. It is rather to sharpen the awareness that if the IT infrastructure is not in place yet or needs renewal for a new technology to be implemented, the IT needs to be part of the decision process from the very beginning.

B. *Initial Forecast System Plan*

The planning of a forecasting system for renewables is a complex task and highly individual. This guideline therefore focuses solely on aspects that are of general planning and management tasks specific to the implementation of wind power or solar power forecasts into an operational environment. Note that the limited information and considerations about forecast technologies or methodologies has the objective to provide guidelines on the impacts of commonly implemented technologies in the implementation and decision process. On the other hand, there is strong focus on the IT infrastructure as one of the most crucial tasks in the implementation and integration of forecast solutions that are prone to become limiting factors for changes at later stages. For that reason, it is recommended that the IT infrastructure is established or, if already available, evaluated along with the planning of the forecast solution. Such consideration need to take place prior to and should be part of the decision process and the requirement list (see section III-D).

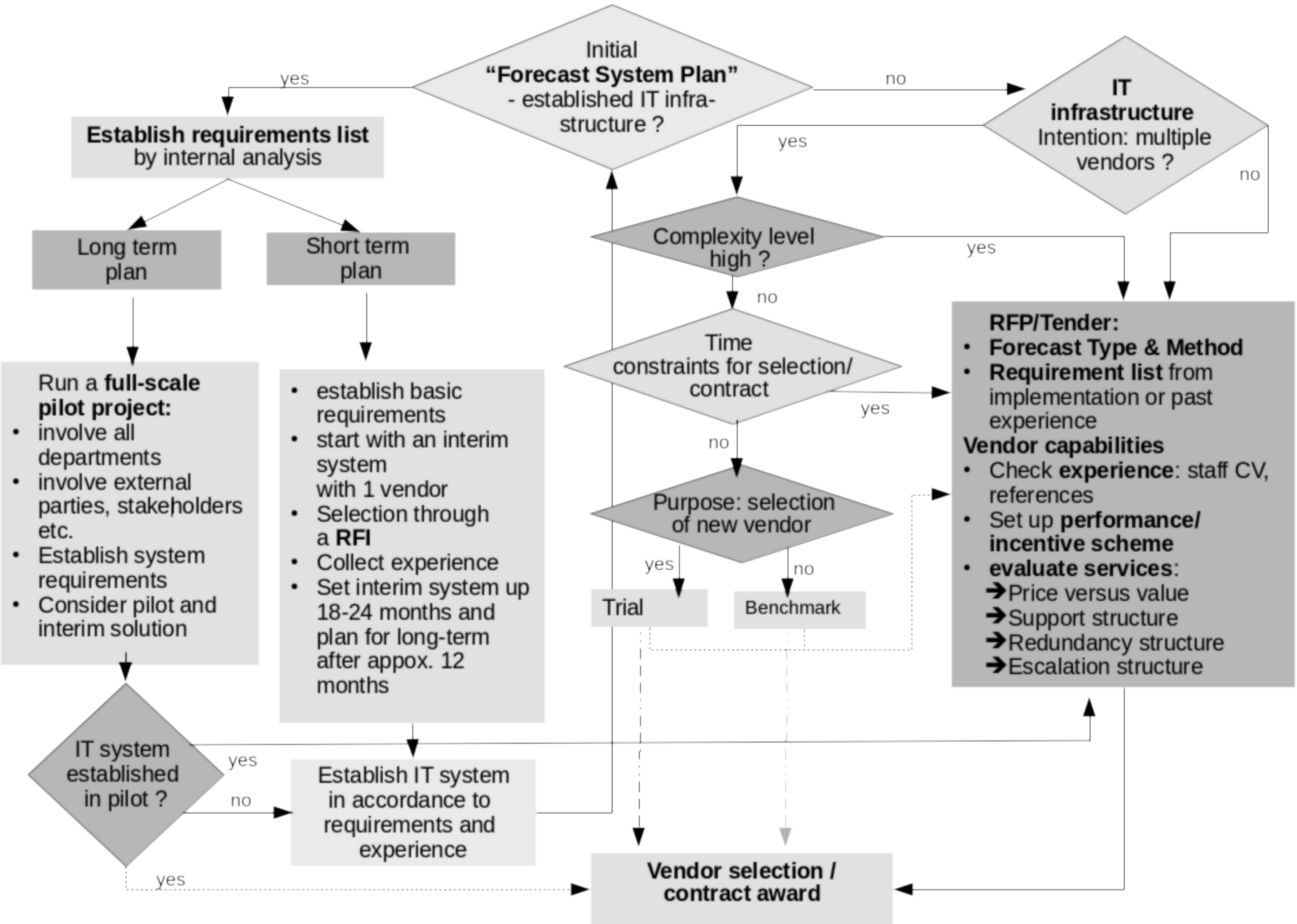

Fig. 1: Decision Support Tool

C. IT infrastructure and forecast solution architecture

The IT infrastructure is one of the most crucial points in the implementation and integration of forecast solutions and are often the limiting factor for changes at later stages. For that reason, it is imperative that the IT infrastructure is evaluated according to its ability to develop along with changes in forecast practices, possible statutory changes, etc. Databases are prone to have limitations that prevent changes to incorporate more information or store information in a different way.

The important aspects in the IT infrastructure to be considered are:

1) database structure
2) communication layer
3) monitoring and error handling
4) data storage and historic data accessibility
5) verification and evaluation of forecasts

In general a forecast system interface, whether in-house or outsourced requires multiple data streams, starting from measured power and weather variables. Usually, there is a connection to the power units SCADA (Supervisory control and data acquisition) system. However, the measurement data needs storage and a data flow to the forecaster needs to be added as one more of the various internal data flow processes. It needs to be decided, whether there is a need to access other external data sources, such as NWP data, or the forecast data itself. Dependent on the setup of the forecasting solution, it is necessary to evaluate how fast accessible historic data has to be, for example to carry out internal analysis, external data delivery to vendors, etc.

Other aspects to consider at IT architecture level are forecast types:

1) Single versus Multiple Forecast Vendors
   a) Impacts for multiple vendor solution:
      i) infrastructure more complex
      ii) database requirements are higher
      iii) strategy required for forecast: mixing versus primary/secondary forecast
   b) Impacts for single vendor solution:
      i) reliability requirement of solution high
      ii) monitoring requirement high
      iii) higher requirements for quality control of forecasts
      iv) less data volume than for multiple-vendor solutions
      v) database structure less complex than for multiple-vendor solutions

2) Deterministic versus Probabilistic forecasts
   a) Impacts for deterministic solution:
      i) more simple data handling
      ii) less storage requirements
      iii) reduced future compatibility
   b) Impacts for probabilistic solution:
      i) increased storage requirements
      ii) more complex data handling

From an IT infrastructure and architectural perspective, deterministic and probabilistic forecasting solutions are quite different. The data base requirements are by a factor of 10 to 100 higher for the latter. Dependent on the way the probabilistic forecasts are used, they add significant amounts to the storage requirements. Nevertheless, storage and computational resources are changing with changing requirements in industry and hence should not per se be considered a barrier or limitation for the integration or implementation of new technologies. But, they need consideration and careful planning to not become a barrier.

D. Establishment of a Requirement List

Establishing the requirements for a forecasting solution is highly individual and depends on many factors. Every forecast user will have very specific needs to fulfill. There are however common areas that require consideration. Therefore, a recommendation list has been established as a guideline or starting point. Two of the fundamental aspects when establishing a requirements list are:

1) ***Description of the current situation***
   In this process, it is imperative to describe exactly all processes, where forecasting is required and how these processes are interlinked. Here it is essential to get the different departments involved, also the IT department. The more accurate you can describe the situation at hand, (e.g. integration plans, use of forecasts, market situation, statutory aspects, IT restrictions, limitations and methods for data exchange, current or future challenges, etc.), the more straight forward it will be to (1) ask questions to the vendors regarding forecasting methodology, but also (2) get clarity of the involved processes enabling forecasting.
2) ***Engage with the vendor(s)***

   The questions to the vendors should be of technical character regarding forecast methodology, but also on available data exchange methodologies, required input data for the models and system support. If you already have a forecast vendor, it is recommended to engage with the forecaster to discuss the current situation and where the forecaster sees limitations and potential for improvements. Often, forecast providers need to adopt their forecasts to a specific need and even though a new technology may be available, it is not used due to current limitations. That does not mean that other vendors should not be engaged, when it comes to establishing a renewal of a forecasting system. If it is a new system, it is recommended to engage a number of forecast vendors to provide insight. In all cases, it is essential to describe the planned objective and name limitations, if they are already known. The more information that can be shared the better a vendor can evaluate what is considered the most appropriate solution.
   Recommendation in short: describe the forecast objective in as much detail as possible and ask specific questions that are required in the decision process in an internal process and an external request to forecasters

that can provide information and insights from their experience in other jurisdictions or areas.

3) ***Description of the envisaged Situation***
The description of the envisaged situation is most important for the implementation of a solution. Analysis of the current situation, the forecast vendor(s) input and other organizational and statutory requirements should lay the basis for an envisaged new system. It is recommended to put as much detail into this part as possible.

The following requirement list assists in defining all aspects for the planning phase of a forecasting system.

Example Requirement List

1) IT infrastructure
   a) Communication with the forecast vendor(s)
   b) Communication with the asset operation (wind/solar parks)
   c) Database and storage implications
   d) Accessibility of data information of internal users
   e) Application interfaces to internal tools (e.g. graphics, models, verification, metering)
   f) Information security policies
2) Forecast Methodology and Attributes
   a) Methodology of weather to power model
   b) Weather input
   c) Application/model background for each forecast product
   d) Forecast time horizons
   e) Forecast frequency
3) Support and Service
   a) Service level for each product (e.g. 24/7, business hours etc.)
   b) System recovery
   c) Failure notifications and reporting
   d) Escalation procedures
   e) Service documentation
   f) Contact list for different services
   g) Staff training
4) Performance and Incentivization
   a) Verification methods
   b) Verification parameter
   c) Definition of payment structure (boolean or sliding areas)
   d) Expected accuracy for each forecast horizon
5) Contracting
   a) Contract length
   b) Amendment possibilities
   c) Additional work outside contract
   d) Licenses
   e) Insurances
   f) Sub-contracting
   g) Price table for each product category

E. Other aspects

There are a number of other aspects to consider that will here only be named briefly.

- Short-term interim Solution
  If a short-term solutions is sought, the emphasis should lie on practicability and experience. In some cases a short-term or intermediate solution is also used as a starting point to establish a long-term solution. In that case the focus should be on the long term plan and how an intermediate solution can add value to that plan.
- Long-term Solution
  Long-term solutions need careful planning. The most important points of consideration are:
  1) Involvement of all relevant departments (internal and external parties/stakeholders)
  2) Analysis of the statutory environment (long-term planning possible ?)
  3) Establish system requirements
  4) Pilot maybe used as interim solution

IV. TENDER EVALUATION CRITERIA FOR A FORECAST SOLUTION

If complexity levels are high and if time constraints do not allow for a lengthy trial or benchmark, a tender or RFP (request for proposals) should be compiled with care in order to fulfill all requirements and yet not ask for more than needed. The most important evaluation criteria for a forecast solution to be defined in a tender process is:

1) required type of forecast(s) (e.g., hours-, day-, or week-ahead)
2) required methodology to generate such forecast products
3) compliance to technical and contractual requirements

It is recommended that the first step should be vendor independent. And, if this cannot be defined, it is recommended to first conduct a RFI (request for information) to scan the industry on their capabilities and their recommendation which type and methodology should be applied for the specific needs (see section III-D). Only when the forecast type and methodology is defined, the vendor comes into play. The important factors to consider here are:

1) Forecast solution Type
   a) Deterministic versus Probabilistic
   b) Single versus multiple forecast providers
   c) Forecast horizons
2) Vendor Capabilities
   a) Experience and Reliability
   b) Ability to maintain state-of-the-art performance
   c) Performance incentive Schemes
   d) Evaluation of services
   e) Price versus Value
3) Vendor Service Structure
   a) Support maintenance service Structure
   b) Redundancy Structure
   c) Escalation Structure

A. Forecasting Methodologies

There are many different forecast methodologies. Describing these is not within the scope of this guideline. In general it is recommended to ensure that the forecast methodology that is employed fits it's purpose. With forecasting maturing, there has come many different approaches on the market and it can be difficult to distinguish between different approaches. One way to ensure that the approach that is contracted fits purpose, is to ensure that vendors describe their methodology in the tendering process and how it solves the challenges at hand.

A very general discussion on the basic methodologies follows hereafter.

1) Deterministic versus Probabilistic Forecasting Solutions: Due to the fact that weather forecasts and hence also power forecasts of intermittent resources such as wind and solar power, contain inherent uncertainties, probabilistic forecast products are becoming more and more important tools to handle intermittent energy sources also in the power industry. The conditions, where probabilistic forecasts are most beneficial are in areas with high penetration ($> 30\%$ of energy consumption), high wind speeds and significant variability to cause strong ramps and high-speed shutdown, typically in areas with complex terrain and areas with a mix of mountains, deserts and ocean.

The most common products of uncertainty forecast products are the probability of exceedance (PoE) values, typically given as PoE05, PoE50 and Poe95, quantiles, or percentiles.

The advantage of such uncertainty forecasts in comparison to the pure deterministic best guess is the possibility to act upon the probability of an event to occur, rather than being surprised and insecure upon further actions, when the deterministic forecast is wrong (see e.g. [1], [4]).

Especially in areas where there are power markets, for example, a probability of exceedance of 50% (PoE50) is an important parameter for a system operator. That means, if the chance of the true value can be found in the upper or lower band is equally high, such forecasts prevent the market to be able to speculate against system imbalance. A detailed review of probabilistic forecasting products and applications in the power system has been published in 2017 in [1].

2) Single versus multiple forecast providers: It has been widely documented (e.g. [2], [3]) that a composite of two or more state-of-the-art forecasts will often achieve better performance (accuracy) than any of the individual members of the composite over a statistically meaningful period of time. Indeed, many of the FSPs internally develop their approach and services on that basis. And, there are well founded reasons for a forecast user to consider the use of multiple FSPs to achieve better forecast accuracy. However, in a practical sense, there are several advantages and disadvantages that should be considered. When building up a solution, it is recommended to consider the following aspects:

Positive impacts of using multiple vendors:

- There are a number of FSPs in todays forecast market that exhibit performance that is close to the state-of-the-art. It may be advantageous for reliability to assemble a set of state-of-the-art forecasts, unless they are highly correlated.
- Higher accuracy can often be achieved by blending forecasts from multiple uncorrelated forecasts.

Negative impacts of using multiple vendors:

The benefits of having multiple vendors also contain inherent challenges for the forecast user:

- Increased internal costs.
  Employing multiple vendors increases internal costs significantly due to increased amounts of data and IT processes.
- Blending algorithms need to be intelligent.
  The algorithm must consider missing forecasts and needs to be easy to retrain, if forecast statistics change.
- Forecast improvements are difficult to achieve with a multi-forecast provider solution.
  When improvements are achieved on the vendor side, the blending algorithm is becoming inconsistent and can result in worse scores than before, unless long-term historic data can be delivered.
- Multi-vendor Solutions cannot be incentivized as easily to achieve continuous performance increase over time.
  Although incentive schemes can be a good way to provide resources to the FSP for continuous improvements, in a multi-vendor environment, this can be counter productive, as changing statistical characteristics of forecasts can have a bad influence on the resulting blended forecast.
- Multiple points of failure - with multiple forecast providers, the IT infrastructure needs to contain more logic to deal with one or more data streams when there are, for example, delivery disruptions, timeliness, or quality issues.

B. Evaluation and Decision Process

The recommended practice in any evaluation is to consider a number of factors that contribute to the value that a user will obtain from a forecast service.

It is not possible to provide a complete list of factors to consider. However, the most important factors that should be addressed are the following elements:

1) Price versus value and quality
2) Solution Characteristics
3) Support structure
4) Redundancy structure
5) Reliability and Speed of delivery
6) Escalation structure

Only the first three point will be discussed in more detail hereafter.

1) Price versus skill and service quality: The value of a forecast may or may not be directly measurable. In most cases however, the value can be defined for example in terms of cost savings or obligations and in that way provide an indication of the expected value from a certain solution. Prices are difficult to evaluate. A low price often indicates that not all requirements may be fulfilled in operation or not all contractual items are accepted and left to the negotiations. Care has to be taken in the evaluation process. Some services and methods are more expensive than others. Therefore, a price often is coupled to the requirements and acceptance of contractual items. Some items such as reliability can cost a lot and can be negotiated to a different level for a lower price. If a vendor provides a lower price in the expectation of a negotiable item in the contract, it can easily lead to a bad decision.

Recommendation: Following a decade of experience in the forecasting industry, the recommended practice on price evaluation is to connect technical and contractual aspects to the price and consider to let vendors detail contractual aspects that may be associate with high service costs separately, especially, if a fixed cost price is requested. An example could be the requirement of full system recovery within 2 hours in a 24/7/365 environment. If there is no penalty associated, a vendor may ignore this requirement, which will result in a much lower price. This eases evaluation and makes sure that speculations regarding negotiable aspects of a service can be compared objectively.

2) Solution Characteristics: The solution characteristics of a forecast service also contains much value for a forecast user and should get attention in the evaluation. It can be defined in terms of the available graphical tools, ease of IT services for retrieving data or exchanging data in real-time as well as historical data, customer support setup and staff resources connected to the forecasting solution. This can be key for the operational staff to accept and be comfortable with a forecast service as well as having confidence in the service. Additional work that may be connected, but outside the scope of the operational service can also be key elements for a well functioning service.

Recommendation: Ask the vendor to describe how the system will be built up, how communication and support is envisaged and let them provide examples of graphics (if applicable).

3) Support Structure: Customer service is often underestimated and in most cases second to an accuracy metric when selecting a vendor. Support can be a costly oversight if, for example, costs are related to a continuously running system or extreme events, where the user needs an effective warning system and related customer service. Support can have a relatively large cost in a service contract and may provide a false impression on service prices, if, for example support is only offered at business hours.

Recommendation: Definition of the required support structure should be part of the requirement list for any forecasting solution. For real-time forecasting solutions forecast users need to ensure that there is an appropriate support structure in place. Considerations of the real-time environment, own resources and which of the forecasting business practices are of significance to the user should be carried out. Especially, where processes are supposed to run every day in the year.

Key elements for the customer support is:

- the responsiveness of the provider, when issues arise
- live support in critical situations

A support structure and its management for operational processes additionally need to bind the following strategic areas together:

(a) Customer Support
(b) Operations Software and Service
(c) IT Infrastructure

The customer support (a) should be handled by a support platform, ideally with different forms for contact, e.g. telephone hotline and email ticket system. Any forecast user needs to ensure that operational software (b) that is licensed is renewed and maintained according to the licensing partys recommendations. The IT infrastructure (c) should ideally be ISO 9001 and ISO 27001 certified in cases, where real-time operation and security is of paramount importance.

V. Summary and Outlook

While every forecasting solution contains very individual processes and practices, there are a number of areas that all forecasting solutions have in common. For any industry it is important to establish standards and standardized practices in order to streamline processes, but also to ensure security of supply with a healthy competition structure.

This paper has been summarizing an IEA Wind Task 36 Recommended Practice guideline under review that is providing state of the art practices that have been carefully collected by experts in the area and are being reviewed by professionals and experts in an appropriate number of countries with significant experience in wind energy forecasting.

The key element of the recommended practice is to provide basic elements of decision support and thereby encourage forecast users to analyze their own situation and use this analysis to design and request forecasting solutions that fits their own purpose rather than applying a doing what everybody else is doing-strategy. It is highly recommended to "engage with the forecast vendors" in order to discuss the vendors recommendations. It is often most beneficial for all parties to issue a request for information, conduct vendor meetings and explain the goal and objective of a solution and let the forecasters give their recommendations. This guideline provides therefore not only aspects for the selection process to forecast users, but also for vendors new to the market or those wanting to evolve to a new level of service and support as a guideline to state of the art practices that are recommended to be incorporated into business practices.

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