Task 36

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Weather, Climate and the New Energy Economy – Session 11
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Best Practices for the Selection of Optimal Forecast Solutions for Renewable Electricity Generation Applications

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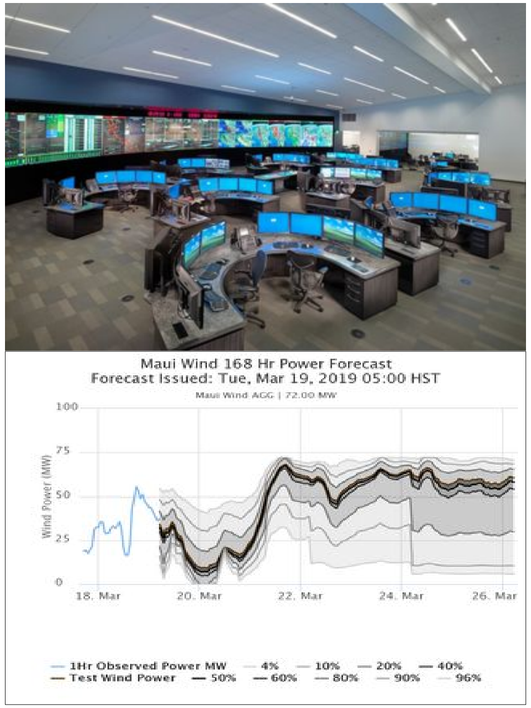
Overview

1. IEA Wind Best Practices for Forecast Solution Selection (John Zack)
    - The Challenge: Selection of Optimal Wind/Solar Forecast Solutions
    - Background: IEA Wind Technology Collaboration Programme (IEA TCP)
    - IEA Wind Recommended Practice for Forecast Solution Selection
        - Edition 1: Published as an IEA Technical Report in 2019
        - Edition 2: To be published in 2022
2. Value of Probabilistic Forecasting in Decision-making (Corinna Mohrlen)
    - Background: formulation and application of probabilistic forecasts
    - Forecasting game/experiment

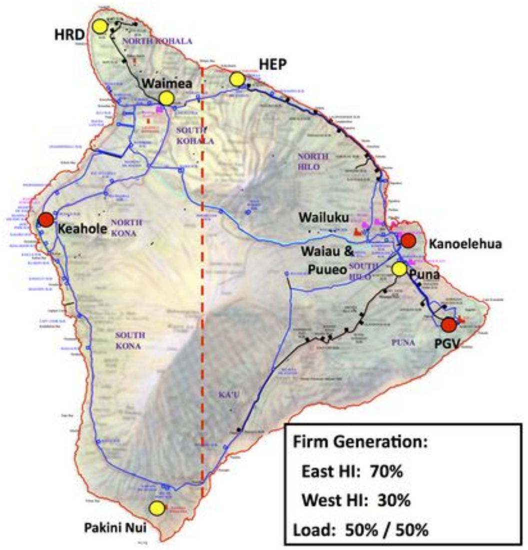
The Challenge

- **Documented Benefits:**
  - lower costs of variable generation integration (system)
  - high system reliability
- **Problem:**
  - Use of Non-Optimal Solutions
    - Specification of non-optimal forecast performance objective(s)
    - Use of non-optimal evaluation metrics for forecast evaluation
    - Poorly designed and executed benchmarks/trials of alternative solutions
    - Less than optimal availability of meteorological and operational data from wind and solar generation facilities
  - Ineffective use of probabilistic Information
    - Preference for deterministic forecast format
    - Ignores estimate of forecast uncertainty, which varies among forecast scenarios



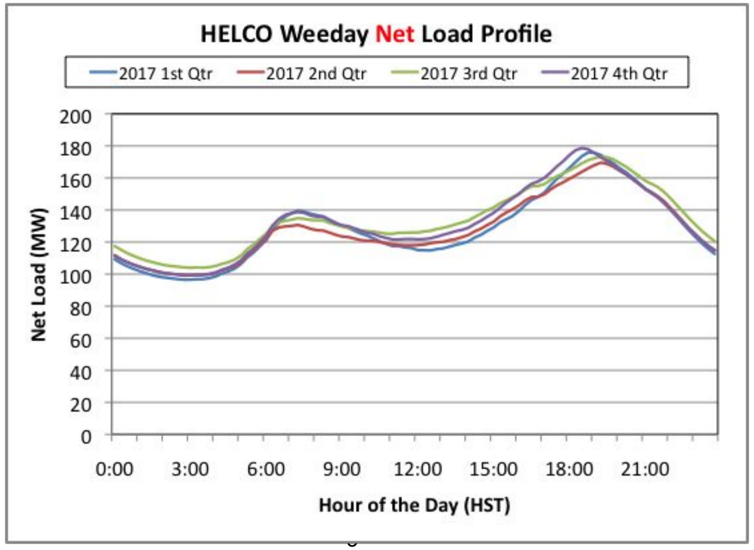
Non-optimal Forecast Objectives: An Example from the “Big Island” of Hawaii

SYSTEM OVERVIEW



Renewable Resource	Capacity
Geothermal (1 facility)	38 MW
Hydro (3 facilities)	16.2 MW
Wind (2 facilities)	31 MW
Solar (BTM Distributed)	90 MW

- **Weekday Net load: 2 daily peaks**
  - Morning (~0800): 130-140 MW
    - Morning rise in gross load followed by morning rise in PV production
  - Evening (~1800): 170-180 MW
- **Weekday Net load: 2 daily minima**
  - Nighttime (~0300): 95-105 MW
  - Daytime (~1200): 115-125 MW
    - Associated with peak of distributed PV



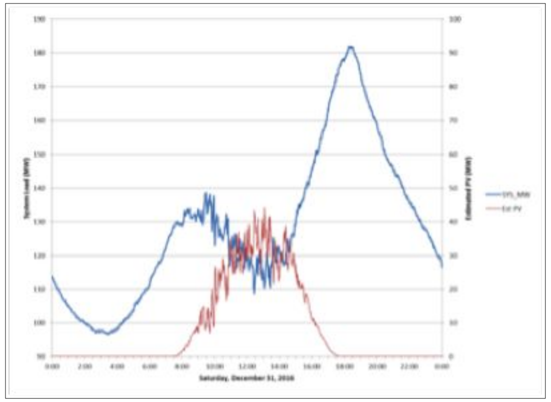
Non-Optimal Forecast Objectives: An Example from the "Big Island" of Hawaii

WHAT THEY REQUESTED VS. WHAT THEY NEED

REQUESTED: Forecasts that minimize the squared error for every 15-min interval (based on quantile regression)

- Produced from multi-method (NWP, statistical, satellite cloud advection) forecast ensemble
- Two Forecast Time Frames
    - **Intra-day**
        - 0-6 hrs ahead in 15-min time steps
        - 15-min updates
    - Multiple Day
        - 0-7 days ahead in 1-hr time steps
        - 1 hr updates
- **Resulting Forecast Attributes**: phase and amplitude errors in small scale cloud features at 15-min scale force squared error optimization to create a smooth forecast (minimal temporal variability)

Issue: large mid-day net load variability driven by distributed PV variability



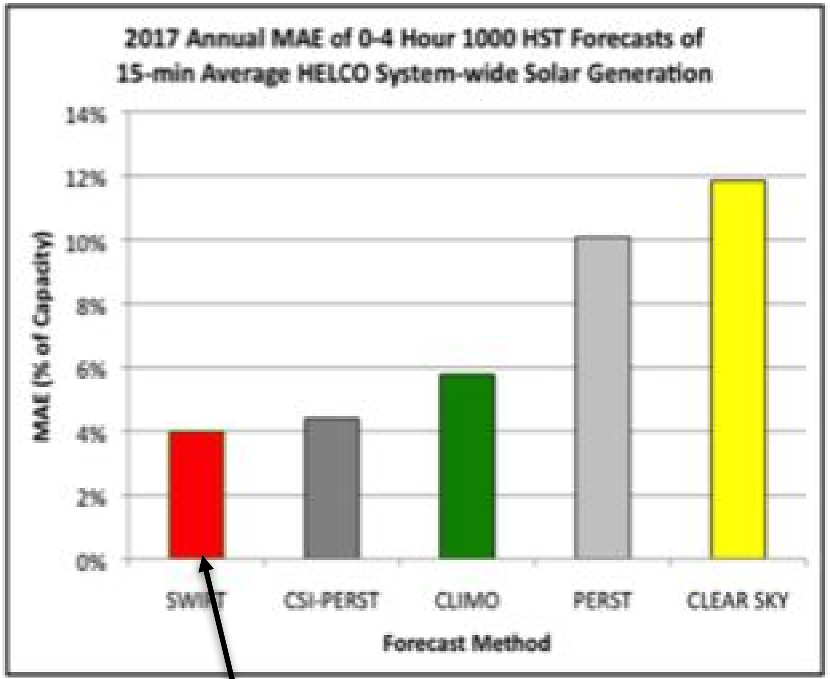
- Adequate ramping capability must be available with the online units to ensure that the system frequency doesn't go too high or too low
- Key Question: What will be the optimal mix of online and offline (quick-start) ramping resources for the midday period?

NEED: Mid-day (1000-1400) range of variability forecast (not necessary to have each 15-min period correct – just the generation envelope)

Non-Optimal Forecast Objectives: An Example from the "Big Island" of Hawaii

THE RESULT

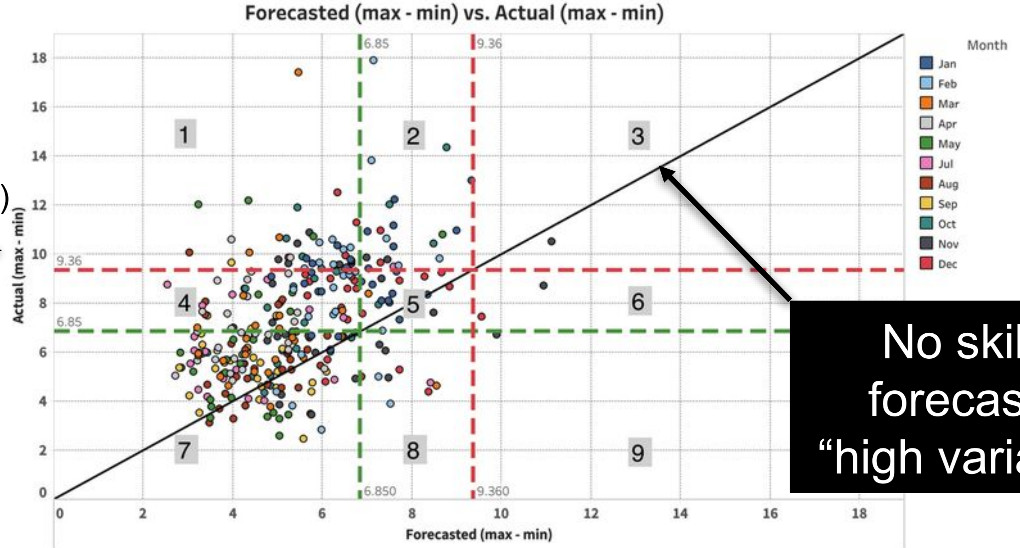
Mean Absolute Error (or RMSE) looks good!



Same period (2017)

Prediction of Variability is Inadequate for Decision-Making on Mid-day Reserves

Actual vs Forecasted Mid-day Range of 15-min Solar Gen (MW)



No skill at forecasting "high variability"

MAE for 0-4 hr forecasts for mid-day period is 4 % of Capacity and 15% lower than "smart persistence"

Count	Forecasted				
	Category	Low	Moderate	High	Obs %
Observed	High	40	21	1	20.0%
	Moderate	72	20	2	30.3%
	Low	143	10	1	49.7%
	Forecast %	82.3%	16.5%	1.3%	100.0%

To Address this Issue: International group of experts have interacted under the framework of IEA Wind TCP Task 36 to formulate a set of documents that specify the “best practices” for selecting a renewable energy forecasting solution…….

IEA Wind TCP Task 36 - Forecasting for Wind Energy

What is the IEA (International Energy Agency)? (www.iea.org)

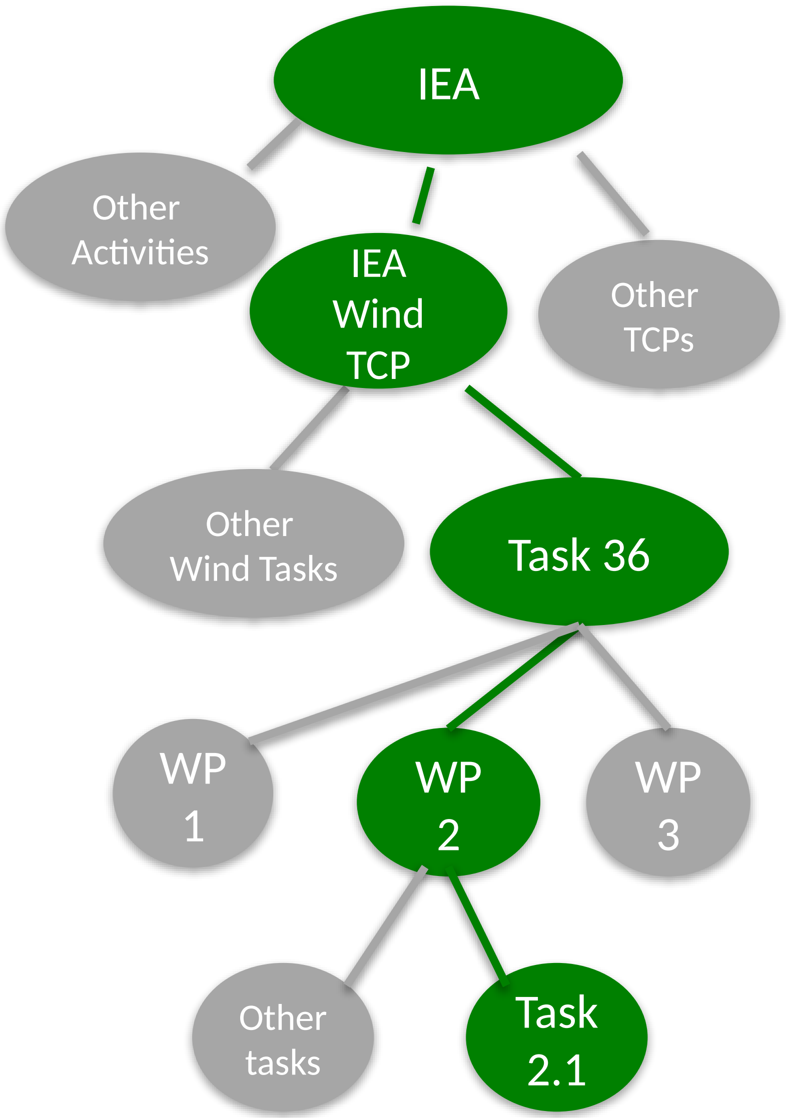
- International organization within OECD with 30 members countries and 8 associates
- Promotes global dialogue on energy, providing authoritative analysis through a wide range of publications
- Has established a framework for international collaboration on a range of energy technologies – these are called Technology Collaboration Programmes (TCPs)
- **One of these is IEA Wind TCP (https://iea-wind.org) – promotes collaboration on specific issues related to wind technology**

Task 36: Forecasting for Wind Energy: (www.ieawindforecasting.dk)

- One of several ongoing tasks of IEA Wind
- Objective: **facilitate improvements in performance** & **value of wind energy forecasts**
- Participants: (1) research organization and projects, (2) forecast providers, (3) policy-makers and (4) end-users & stakeholders
- Active from 2016-2021; transitioning to broader forecasting Task 51 in 2022
- Co-operating agents: Gregor Giebel of DTU & Caroline Draxl of NREL

Task 36 Scope: Three "Work Packages" (2016-2021)

- WP1: Global Coordination in Forecast Model Improvement
- WP2: Benchmarking, Predictability and Model Uncertainty
    - **Task 2.1: Recommended Best Practices for Forecast Solution Selection**
- WP3: Usage of Probabilistic Forecasts and Scenarios



Recommended Practice: Current Status

Target: Guidance for the optimal implementation of **renewable** energy forecasting solutions for a wide range of user types and applications

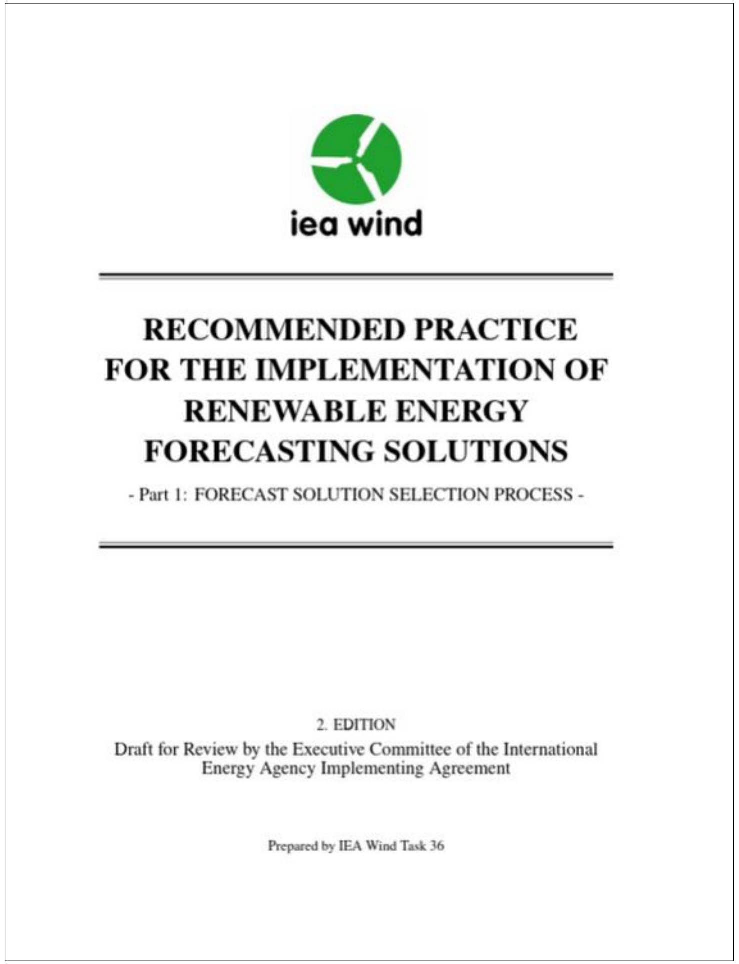
Result: Set of 4 documents specifying IEA Wind Task 36 Recommended Practice for the Implementation of Renewable Energy Forecasting Solutions

1. Design and Execution of Benchmarks and Trials
2. Evaluation of Forecasts and Forecast Solutions
3. Selection of an Optimal Forecast Solution
4. Meteorological and Power Data Requirements for Real-time Forecasting Applications

Status: Edition 1: - **published** in Sept. 2019:
https://iea-wind.org/task-36/task-36-publications/recommended-practice/
Edition 2: - **accepted** by the IEA Wind Executive Committee (Jan 2022)
- in revision for publication with Elsevier

Part 1: Selection of an Optimal Forecast Solution

- Presents an overview of the factors that should be considered in the solution selection process
- Discusses the issues associated with each selection factor
- Provides a "decision support tool" to assist users in the design and execution of a solution selection process
- Provides practical lists and FAQ's for the RFI/RFP tendering process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RECOMMENDED PRACTICE FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

- Part 1: FORECAST SOLUTION SELECTION PROCESS -

2. EDITION

Draft for Review by the Executive Committee of the International Energy Agency Implementing Agreement

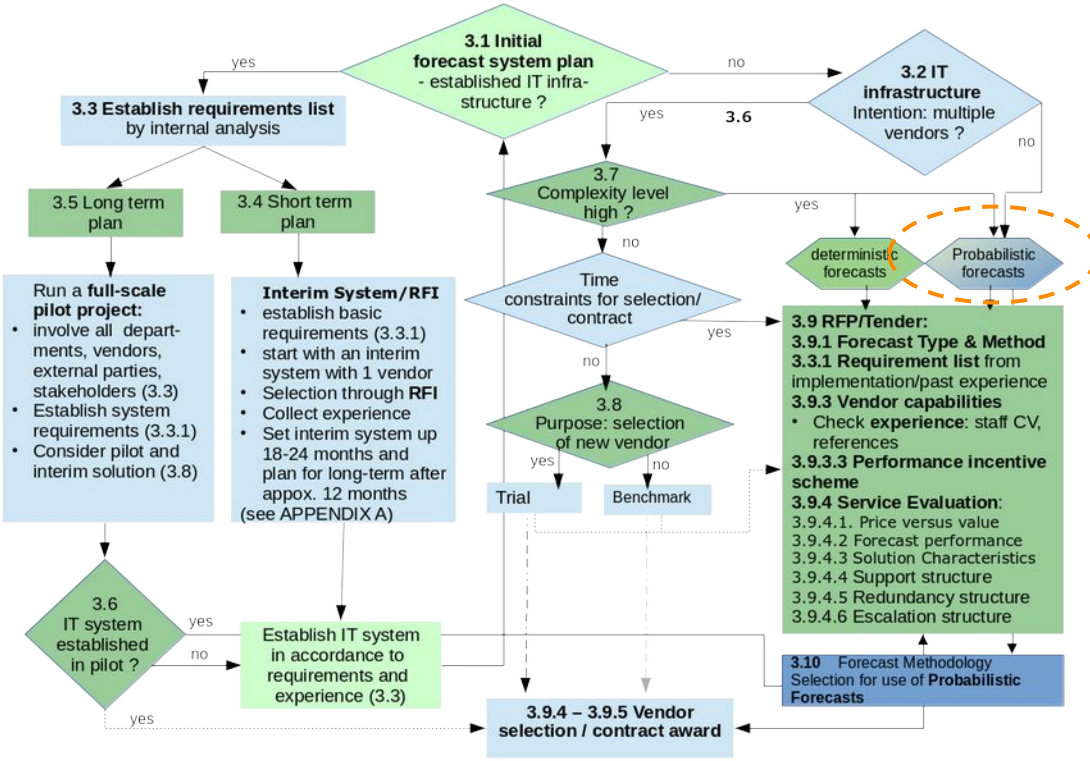
Prepared by IEA Wind Task 36

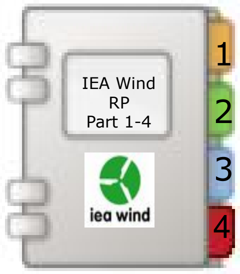
Part 1: Key Points

Issue: A poorly designed or executed benchmark or trial of alternative forecast solutions is more likely to lead to a less optimal selection than a selection process that clearly defines the problem to be solved

Advice: Part 1 provides a decision support tool for the design of a customized forecast solution selection process:
Remember: An optimal forecast solution needs careful formulation of the solution selection process, consistent with the problem size and the available expertise and resources

Decision support tool



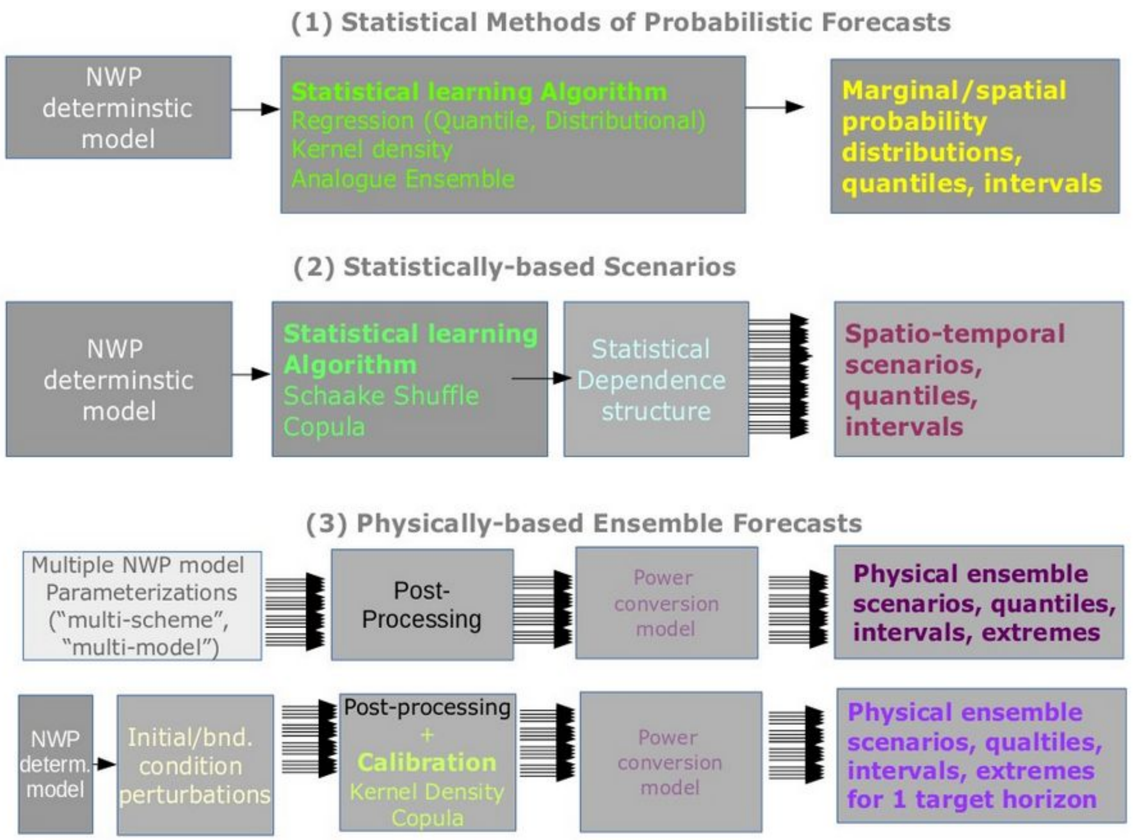


Forecast Solution Selection
Benchmarks and Trials
Evaluation of Forecast Solutions
Met & Power Data Requirements

Updates in Part 1

Probabilistic Forecasting Methods

<u>Part 1 Update</u>: Objective information about the attributes of different probabilistic methods to enable end users to have a guidance in the selection process for probabilistic forecasts for their specific applications



Forecast Solution Selection
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Updates in Part 1

Data Exchange Standards

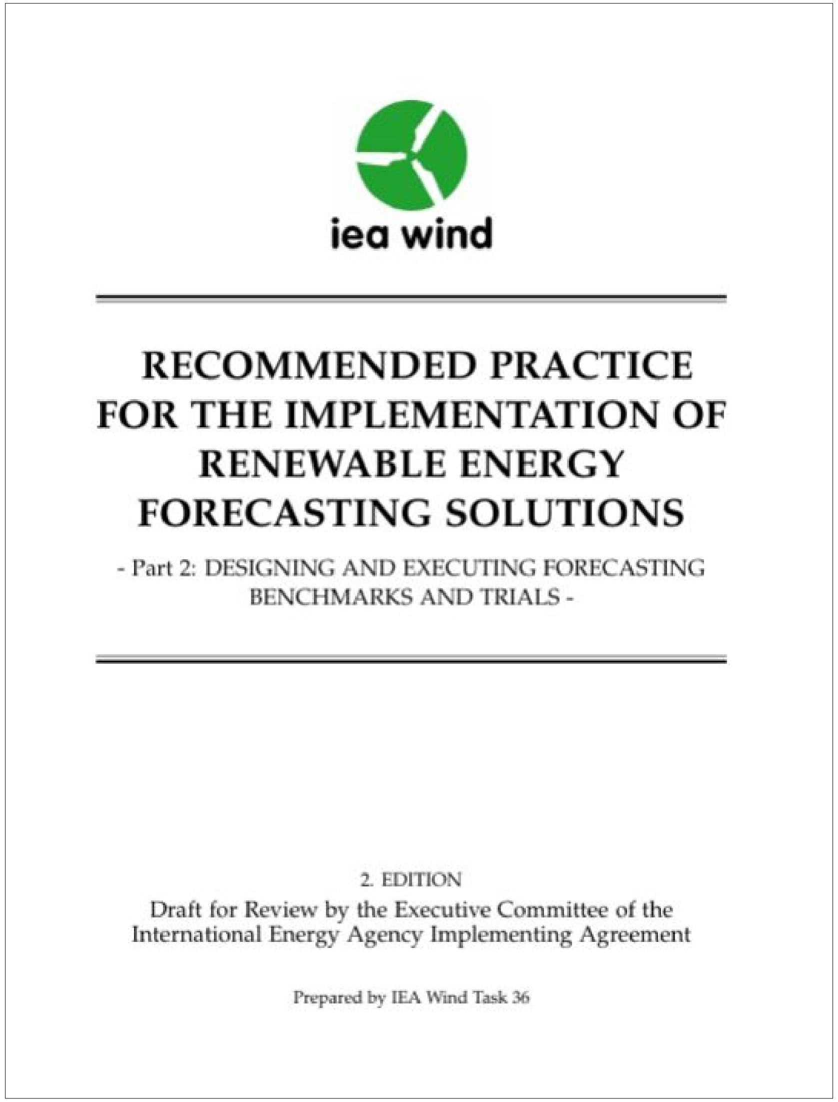
<u>Part 1 Update</u>: New section on data exchange standards that specifies proposed standards to facilitate a timely and reliable user-provider exchange of the data required to implement and operate an optimal forecast solution for a user's application

- **Approach: 2 levels of standards**
  - Level 1: A high-level description of the information and data required to carry out a successful trial and operation of a specific forecast solution
  - Level 2: A detailed specification of both the format and method, which should be used to exchange data between the renewable forecasting provider and the renewable energy forecasting customer.

Data	Type of Data	Description of the Type of Data
Master Data	Site information	A specification/description of the site(s). A description can contain one or more sites. A site can be an aggregate of multiple sites. All sites in the same description must have similar data structure as specified in the associated meta data descriptions. If the data structures are not similar, then the sites need to be split up into multiple Sites and multiple meta data descriptions.
Online Data	Measurements	Observational data from a site which will be used as input for training models produced by the forecast system.
	Future Availability	The data about expected future availability of the site(s) due to maintenance, curtailment or other planned schedules. Used as input to the forecast.
	Forecasts	The output data (results) produced by the forecast system.

Part 2: Conducting a Benchmark or Trial

- Presents the three phases of a forecasting benchmark or trial
  - Planning
  - Execution
  - Analysis
- Discusses the factors and issues that should be considered in each phase
- Provides a list of pitfalls to avoid



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RECOMMENDED PRACTICE FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

- Part 2: DESIGNING AND EXECUTING FORECASTING BENCHMARKS AND TRIALS -

2. EDITION

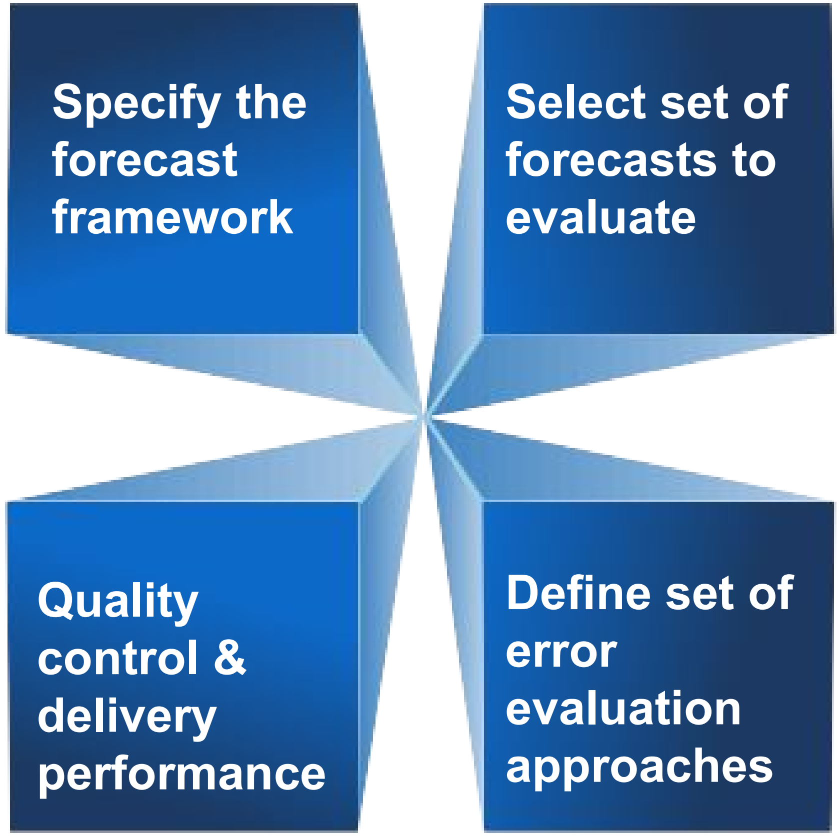
Draft for Review by the Executive Committee of the International Energy Agency Implementing Agreement

Prepared by IEA Wind Task 36

Part 2: Key Points

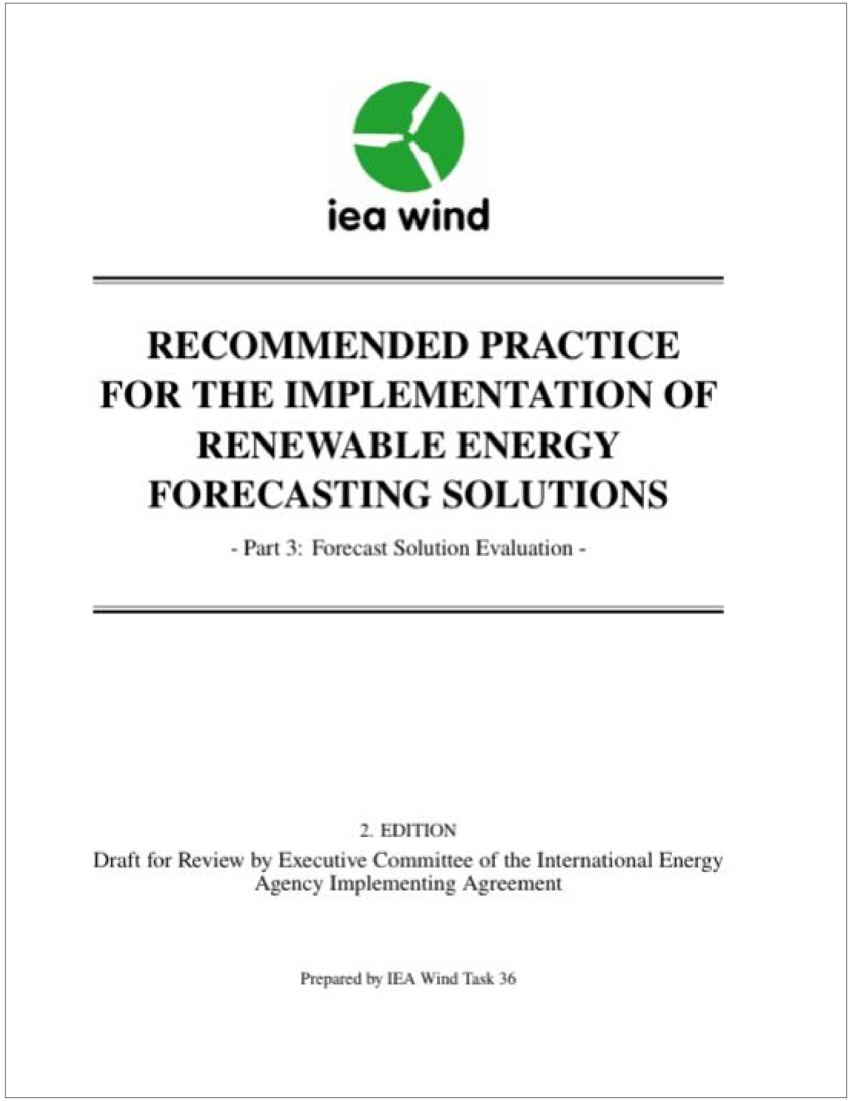
Issue: A benchmark or trial often fails to provide meaningful information to the solution selection process because it is poorly designed or executed and usually requires more resources than planned!

Advice: use the recommended practices guide and/or consult “unbiased” experts if you plan a benchmark or trial.
If it becomes an academic exercise, it’s expensive learning!



Part 3: Evaluation

- Presents the three key attributes of an evaluation process
  - Representativeness
  - Significance
  - Relevance
- Discusses the factors and issues that should be considered for each attribute
- Provides recommendations for conducting a high quality and meaningful evaluation



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RECOMMENDED PRACTICE FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

- Part 3: Forecast Solution Evaluation -

2. EDITION

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Prepared by IEA Wind Task 36

Part 3: Key Points

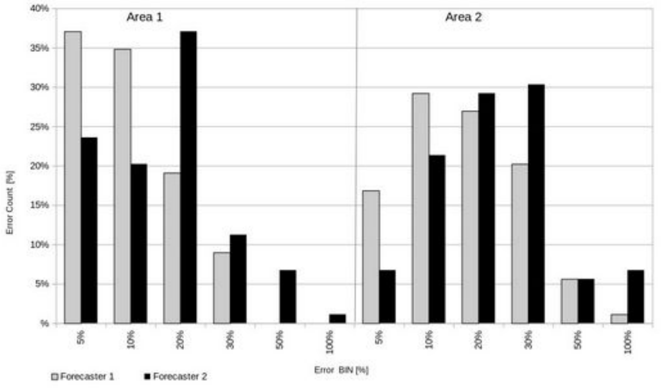
Issues: Many attempts to evaluate the accuracy of alternative forecast solutions yield misleading information to a user's solution selection process because of failures in one or more of the 3 key attribute areas:

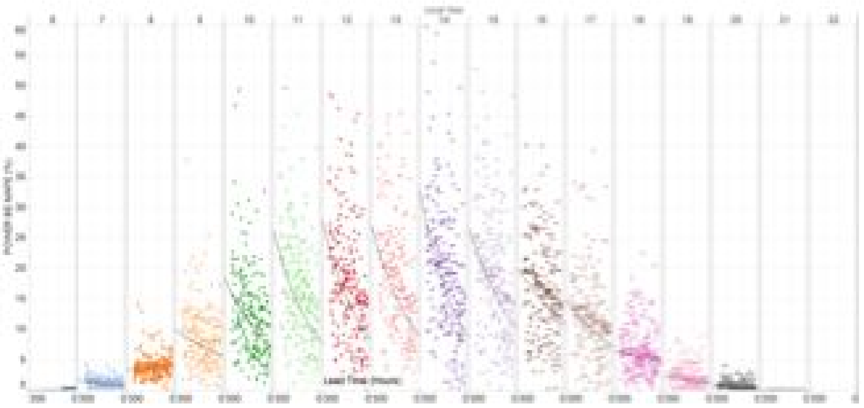
The most frequent and misunderstood mistake is with respect to "relevance"

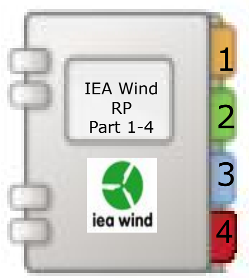
- The user employs a set of accuracy metrics that are not appropriate, i.e. "not relevant" for the user's application
- Often accuracy assessments may give a good solution for someone else's problem, but not one's own problem!

Advice: put considerable effort into understanding and incentivising the problem solution before employing a forecast provider.

<u>Remember: Inappropriate metrics lead to wrong solutions!</u>







Forecast Solution Selection
Benchmarks and Trials
Evaluation of Forecast Solutions
Met & Power Data Requirements

Updates in Part 3

Probabilistic Forecast Assessment Methods

Part 3 Update: New sections
– *“Probabilistic Forecast Assessment Methods” providing* information on how to verify:

- Reliability
- Calibration
- Consistency
- Categorical statistics

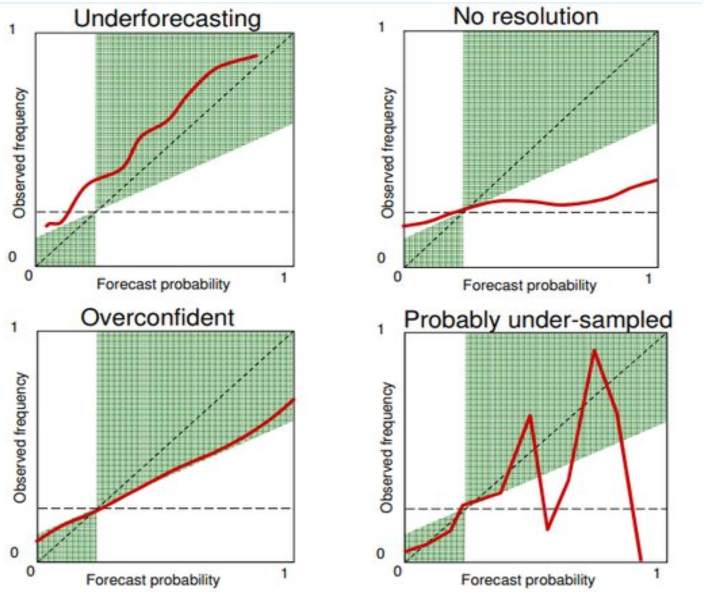
– *Examples for specific use cases:*

- Energy Trading and Balancing
- Ramping Forecasts
- Dynamic Reserve Allocation

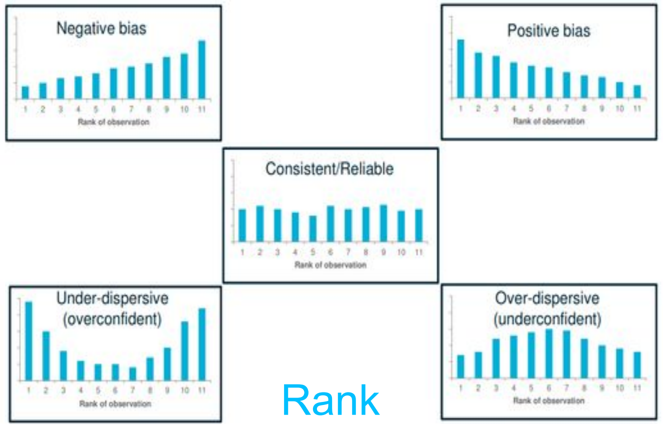
Add-ON: Development of a Verification platform with Code Examples from IEA Wind Task 36/51, WFIP Validation & Verification & “Solar Forecast Arbiter (SFA) benchmark platform”

(under construction .. expected end of Q1-2022)

RELIABILITY – CALIBRATION – CONSISTENCY



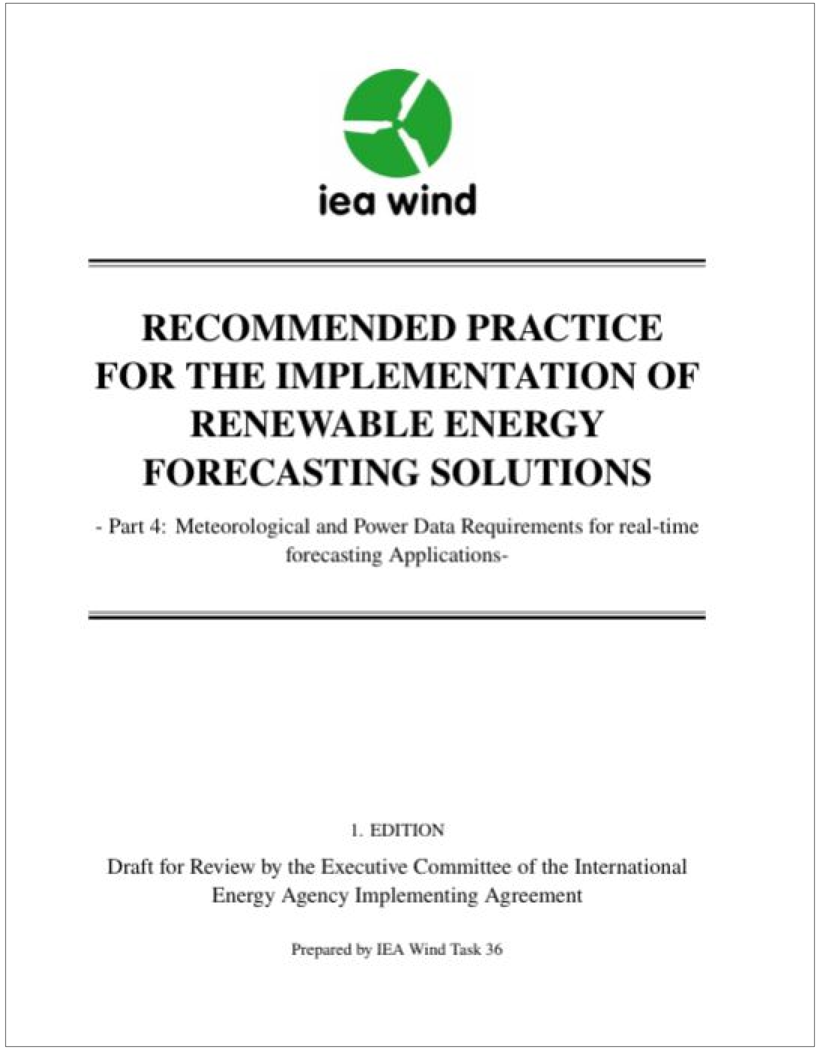
Reliability Diagrams



Rank histograms

New Part 4: Meteorological and Power Data Requirements for Real-time Forecasting

- **Purpose:**
  - Optimize the selection, deployment, maintenance and quality control of sensors and communication channels to produce the highest quality and timely on-facility meteorological and generation-related data to the RE forecast process
- **In response to the experience of many forecast providers that forecast quality is significantly impacted by the on-facility data they received are:**
  - Not from sensors that are representative of the ambient atmospheric environment experienced by the generation assets
  - Not qualified with respect to the actual operating conditions of the facility (e.g. outages and curtailment)
  - Have many embedded bad data elements due to poor quality control
  - Not provided in a timely manner
  - Characterized by incomplete sensor meta-data



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RECOMMENDED PRACTICE FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

- Part 4: Meteorological and Power Data Requirements for real-time forecasting Applications-

1. EDITION

Draft for Review by the Executive Committee of the International Energy Agency Implementing Agreement

Prepared by IEA Wind Task 36

Topic 2: Another Reason Forecast Value is Lost…

Opportunity: Using forecast uncertainty information (via probabilistic forecasts) results in better application outcomes

- User has more information than from a deterministic forecast
  - Estimate of the future value of the forecast target variable
  - Estimate of the uncertainty of the estimated value
- Forecast uncertainty shows variance among scenarios and prevents over-confidence
- Potential for better risk assessment and management for weather related applications

Problem: Despite the demonstrated practical and theoretical benefits uncertainty information in the form of probabilistic forecasts is not very widely underutilized. Why?

- Less familiarity & experience with probabilistic information
- Transformation steps missing from probabilistic information to deterministic decisions
- User's tools don't accept probabilistic information.

Corinna will dig deeper into this….