1.- Business Impact

Financers use to measure the Investment profitability of any Project through IIR. Let’s analyze how 10%-deviation of investment assumptions affect to the IIR:

IIR Reduction (Absolute % Deviation) caused by Deviation in Estimation

- 10% in Energy Output  + 10% WTG Price  + 10% BoP Price  + 10% Other costs

-2 p.p

Theoretical Example for 70 MW Project, 2400 NEH & 1.35 M€ CAPEX/MW
2.- Models

**Scientifics Intend to Describe Nature by Creating Models**

- Even Static Models are never perfect.
- This lack of representativeness increases in time domain.

**Engineers try to Work with those Models through Simplifications**

- Models are designed based on:
  - Theoretical Formulation (*Knowledge*)
  - and Adjusted through Empirical Results (*Experience*)

**As a consequence of above statements, Models would work better in similar environment to those where they have been validated, and worse in others.**

- In the case that the environment under study doesn’t match with ‘design’ environment, Wind Model Engineer must:
  - Cover Theoretical Formulation gaps (*Knowledge*)
  - and correct the results based on *Experience*. 
3.- Modelling Techniques (MCP)
4.- Models

Models are based on:

1. Environmental Description,
   • Terrain Model
     • 3D Model (DTM)
     • Terrain description
   • Input data
     • Local Measurement.
     • WTG performance Model.

2. Parameterization Setting
   • Generic Atmospheric Condition
   • Calculation Domain
   • Spatial Resolution

3. Relationship between above info and wind conditions:
   • Initial conditions
   • Time domain evolution
5.- Models; Risks associated to Complex Terrain

If the Nature becomes more complex, there will be more difficulties to assure that the model works under controlled environment, with valid input data, and therefore, with reliable outputs.

- But, What are the Model risks associated to complex terrain?

1. Model Performing out of spec.
2. Wrong Environment Definition/Not Representative Input Data
3. Not Long Term Representative Input Data
4. WTG Performance out of Expectancies

Wind Model Engineer must evaluate those Risks, and Take the Mitigation actions needed to keep results under control.
6.- Model Performing out of Specifications

Under Complex Terrain conditions, there are some Intrinsic Risks into the Models:

• Symmetric Outputs in both sides of stepped hills.

• Overestimation / Underestimation depending on terrain complexity

• Unstable outputs in Complex Terrain in Highly Deterministic Models

• Unable to self-predict wind conditions properly

• Coastal influence together with complex terrain.

If appropriate mitigation techniques are not applied, error can be around 5% to 10% (% AEP Deviation)

• Mitigation techniques shall be based on proper measurement campaign and output stability checking.
7.-Wrong Environment Definition/Not Representative Input Data

Complex Terrain conditions implies a carefully definition of Measurement Campaign

- Terrain Description Errors
- Meteorological Masts number and characteristics, as a function of different complexity areas
- Met. Masts number, as a function of different wind conditions.
- Measurement can be affected by very specific site conditions:
  - Hub height errors
  - Very Specific wind direction distribution

If appropriate mitigation techniques are not applied, error can be around 10% to 15% (% AEP Deviation)

- Mitigation techniques shall be based on proper measurement campaign definition and experience based corrections.
8.- Not Long Term Representative input data

Under Complex Terrain conditions, long term correction shall take into account wind direction distribution

- Wind direction study takes additional importance, since different wind regimes (with identical reference $V_{ave}$) give large errors in wake effect estimation, and also in Gross AEP.

- Example:

![Diagram showing wind direction distribution and measurement locations.]

On-site Mast Long Term Mast

Time (years)

Long Term Correlation
Power Curves used to have discrepancies compared with those included into the WTG specification. “Each kWh of Wind Energy not caught, it is 100% lost.”

- WTGs perform in very similar conditions, in flat terrain.
- However, in complex terrain conditions, many different Power Curves could be experienced.

Mitigation Techniques are based on: Performances Deviation Forecasting and, Continuously Operational WTG Surveillance (Errors can be up to 10%).
9.- Complex Terrain; WTG performance (ii)

Power Curves use to have discrepancies compared with those included into the WTG specification “Each kWh of Wind Energy not caught, it is 100% lost”. These discrepancies can be hidden by Complex Terrain effects.

Mitigation Techniques are based on: Performances Deviation Forecasting and, Continuously Operational WTG Surveillance (Errors can be up to 20%)
Under Complex Terrain conditions, any wind study is affected by higher uncertainties, Wind Model Engineer shall keep these under control.

10. Complex Terrain; Uncertainties Impact.

Normal Distribution Example

Net Equivalent Hours

Occurrence Probability

P90; 2154
P90 uncert.; 1846

Gauss. Distr. LOW
uncert.
Models; Conclusions

- Scientists Intend to Describe Nature by Creating Models
- Engineers try to Work with those through Simplifications
- Models works right when they are properly used
- Uncertainties and Risks shall be controlled
- Wind Farm Performance Feed Back is the best way to maximize Knowledge and Experience, in order to maximize Model capabilities