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ENERGY

Wind turbine life extension assessment – *the practical challenges*

futureWind & Marine 2018, Glasgow

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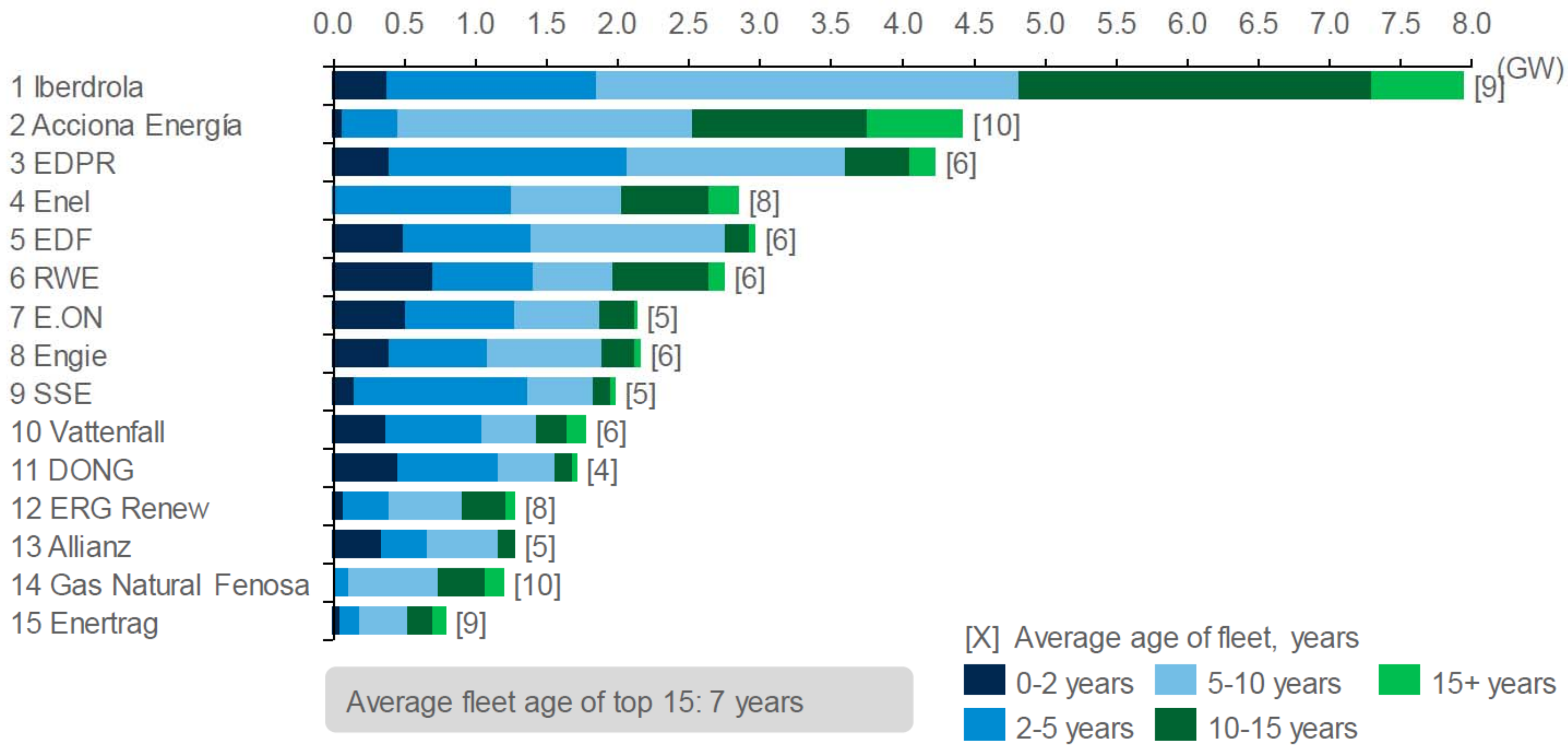
How old is the European fleet of wind turbines?



Source: MAKE

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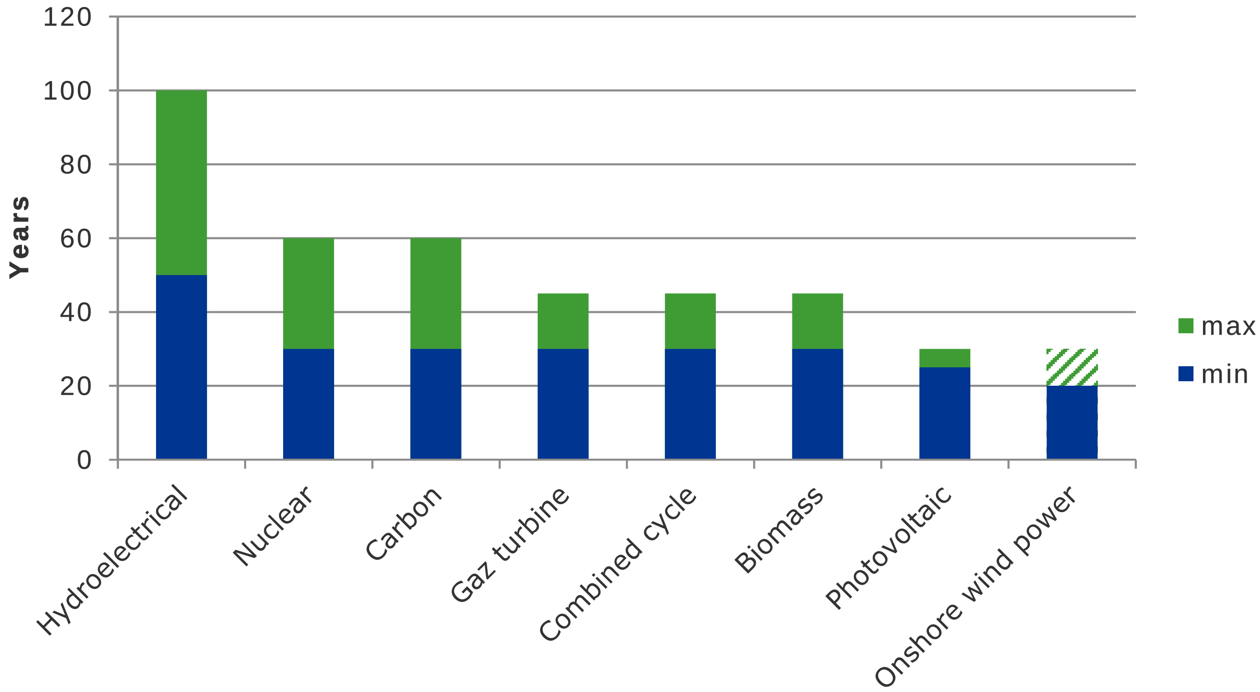
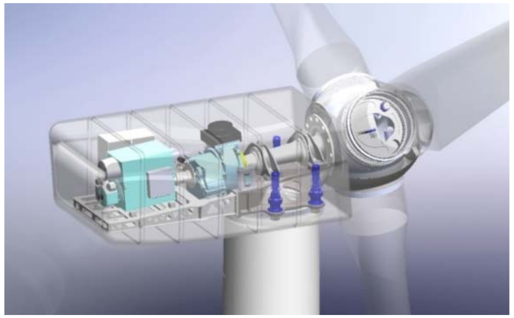
Typical lifetimes of electrical power stations



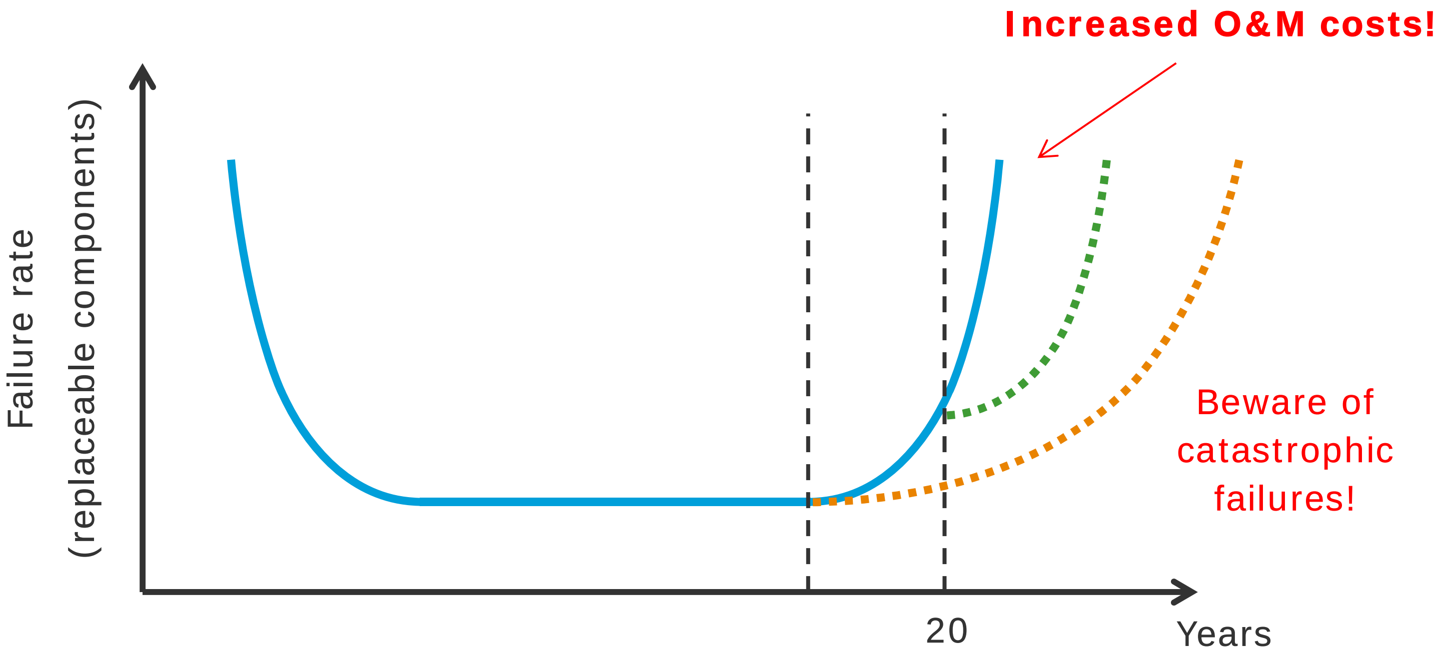
How long can we run a wind turbine?

- What does "turbine life" mean?
  – Structural failure? No longer profitable to operate?
- What are the risks after year 20?
  – Structural failure
  – Availability decrease
  – Supply chain problems
- When do we need to care about turbine life?
  – Decisions today impact operating life tomorrow
- Why should we care about turbine life?
  – Protecting investments and optimising returns
  – Managing risks of accidents



Wind turbine life depends on site conditions, O&M history,...

Different approaches to operate aging assets



"Simplest" option: operate business as usual accounting for increased costs

Improve operational strategies for life extension / in advance to end of life!

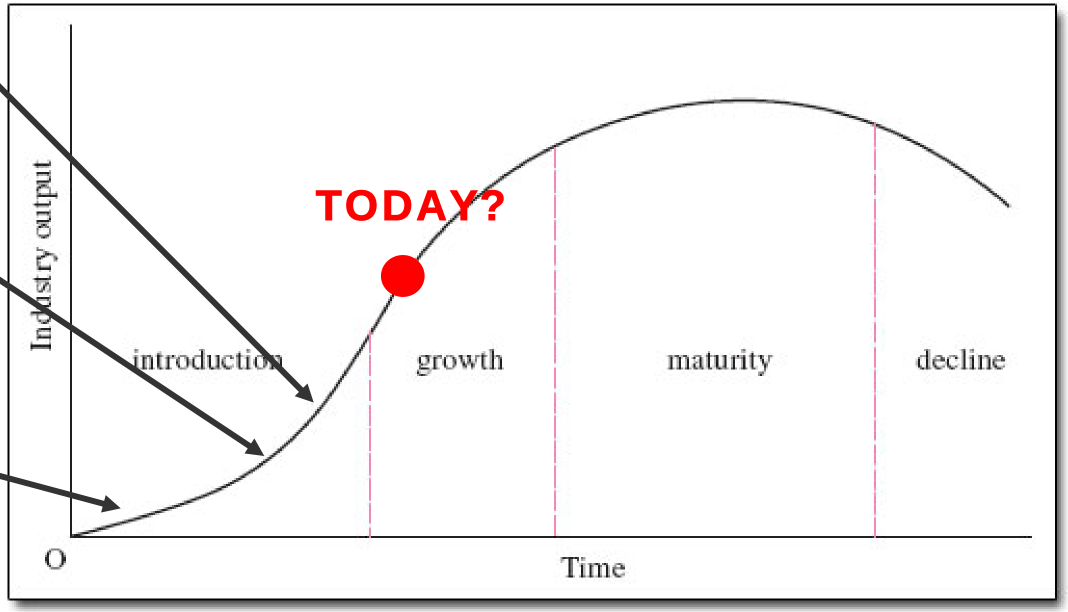
Wind turbine life extension "industry maturity": the last 5 years

Engineer: actually it's quite complicated (but fun)

Lawyer: at some point we'll have to talk about regulations…

Engineer: it's more than just changing one input cell in excel…

Finance: let's introduce 25 years wind farm's life in our financial models



Wind turbine life extension “industry maturity”: TODAY

- Generally understood that life extension requires a careful assessment, not just economics
- Life *extension* is only one more option within a range of possibilities – might be country specific

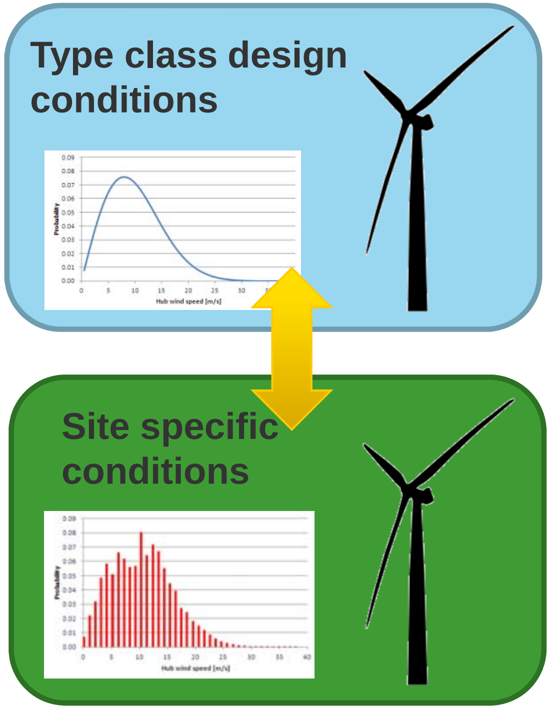
- Driven by wind farm Owners & Operators (OOs), Turbine OEMs not necessarily engaged in this
- OOs rely on third party consultancies offering a range of services…
- … a range of methods to assess wind turbine life expectancy

- Some standards exist (e.g. DNV GL-ST-0262)
- However generally not too specific/detailed
- And regulatory market not up to speed and very different accross countries

TURBINE LIFE IS ORIGINALLY A *DESIGN INPUT*

Original wind turbine design

- Designed to type wind class conditions (IA, IIA, etc)
- Standards assume a specific reliability level: typically annual probability of failure of 1e-4 at year 20 (1 in 10,000)



Wind turbines are installed in real wind farms

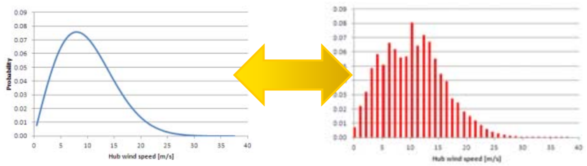
- Site suitability assessment is performed, typically by the OEM ("MLA")
- External conditions extrapolated from met mast measurements (typically 1-2 years), correlated with neighbouring data stations… *to predict the next 20 years conditions!*
- (Tower) and foundation designed to site spec conditions

Traditional wind farm design philosophy: for turbine integrity **"to pass"** whilst maximizing AEP

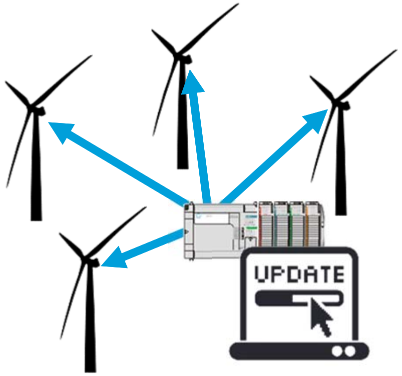
→ Wind Sector Management (WSM) might be proposed to meet requirement

REAL LIFE CONDITIONS ARE DIFFERENT FROM DESIGN CONDITIONS
...and change over time!

- **External conditions** might differ from those initially predicted!
  – Effect can be different for each turbine component



- **Operational conditions**:
  – Wind farm design changes during construction?
  – WSM changes throughout life?
  – Wind turbine controller/operation updates?

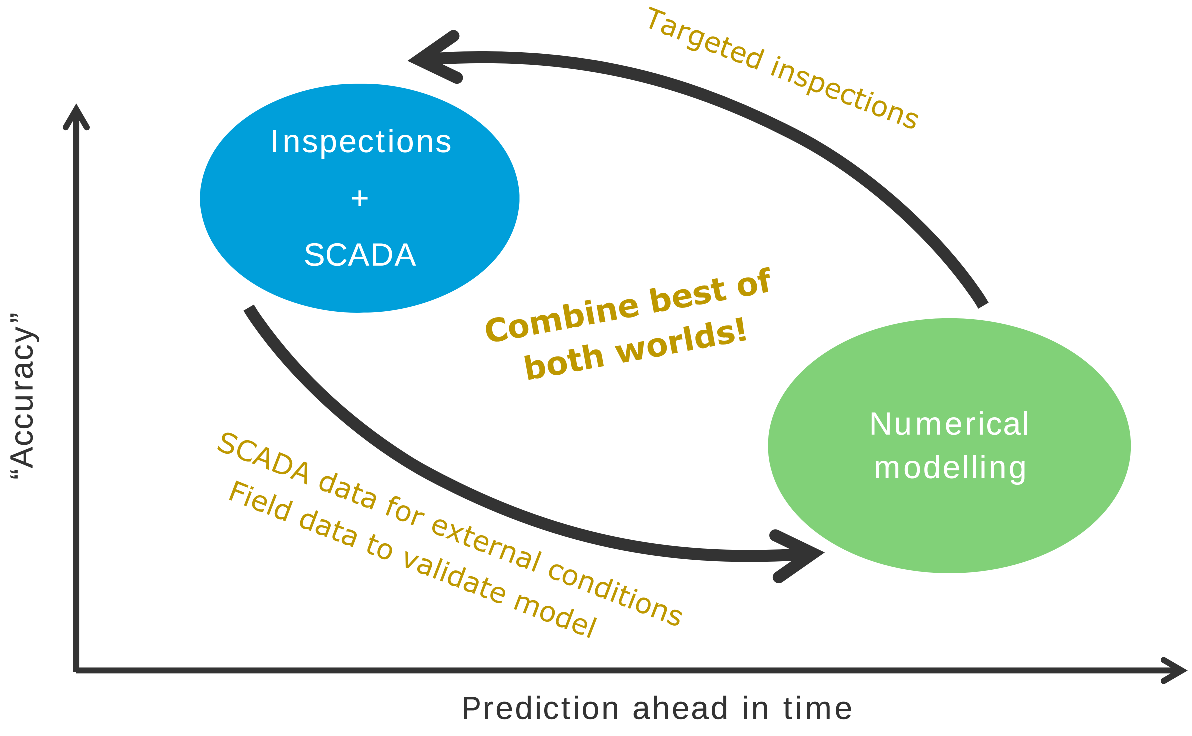


➢ Already a lot of **uncertainty** for the standard 20 years operation

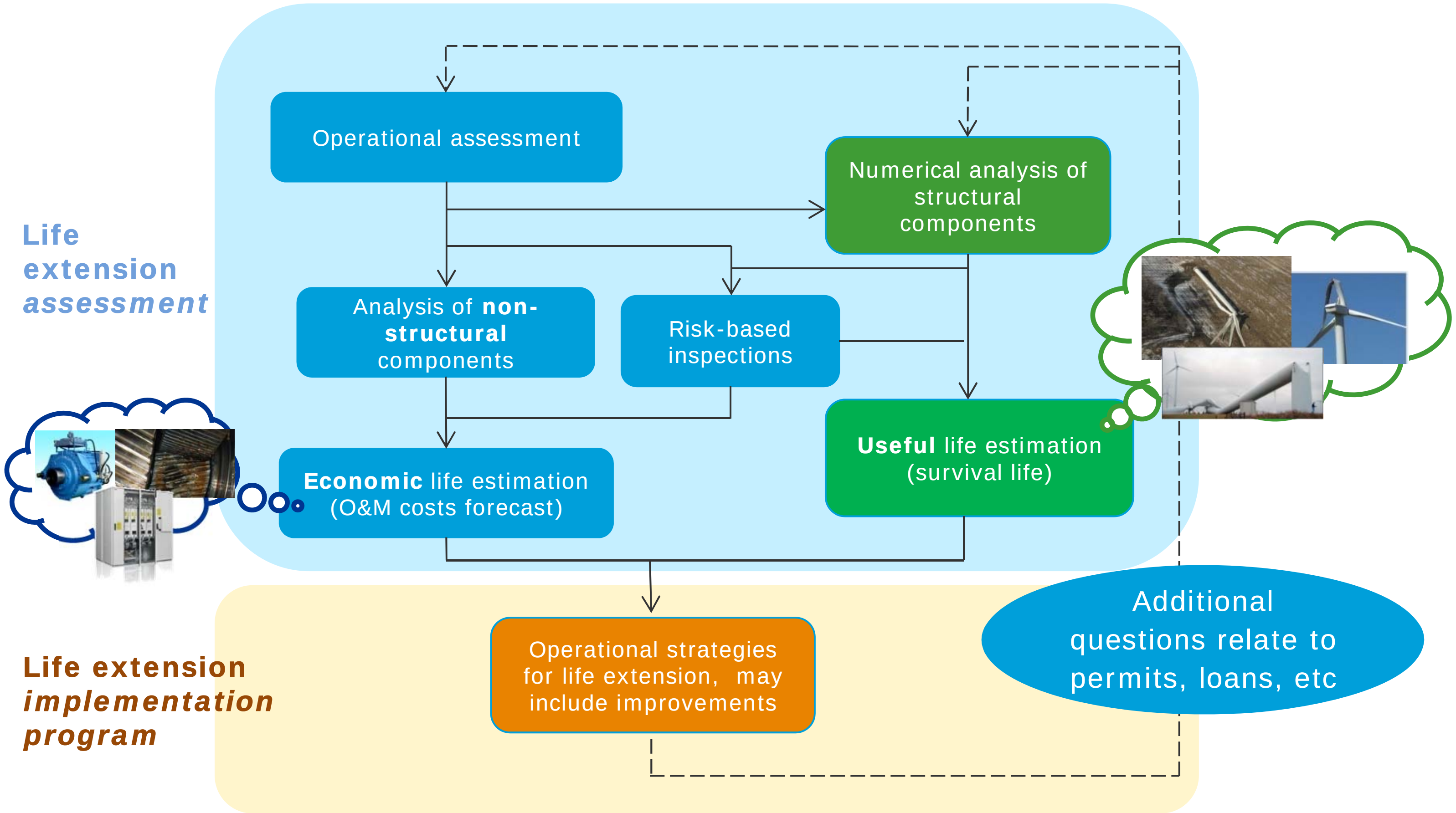
➢ Hopefully good **safety margins** in design (but less and less with more optimised designs)

...and now we want to extend their life **even longer!**

Life Extension Assessment approach

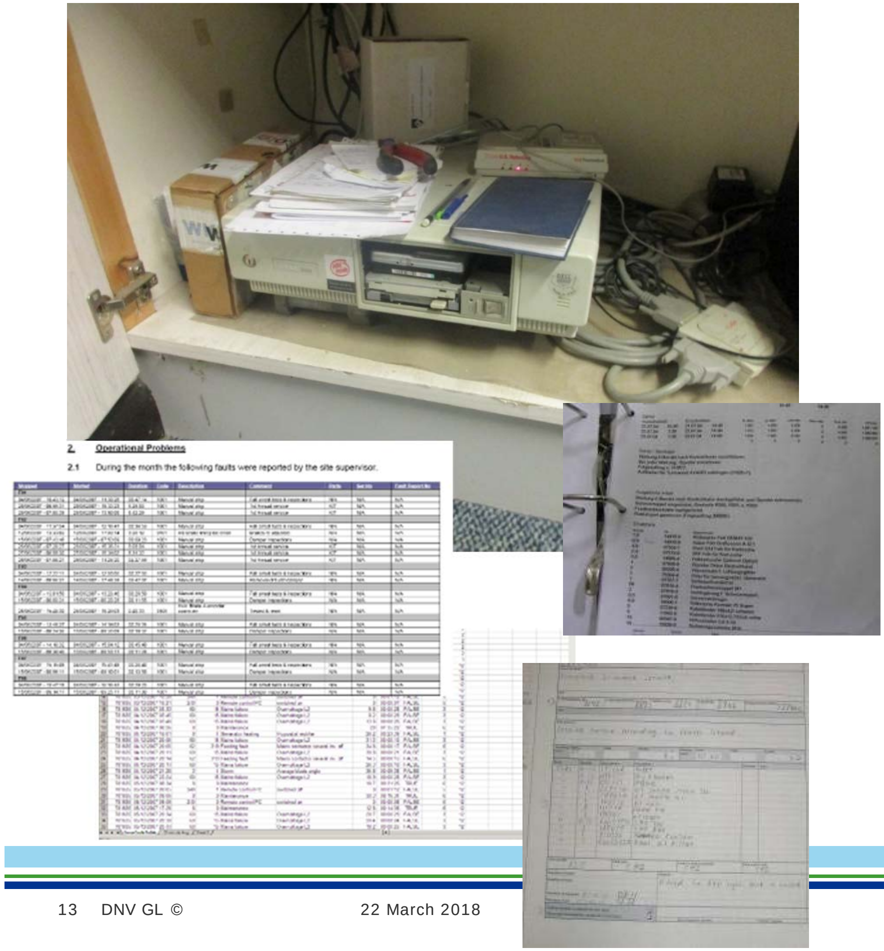


The *technical* analysis process



Wind Turbine Life Extension Asessment
Practical challenges

Data: The Real World



- Difficult to obtain **good quality operational data**
  - Poor coverage, not consistent
  - Poor formatting
  - Data often lost during transactions
- **Ideally:** combine both **pre** and **post**-construction data

Types of data required:

- External conditions: TI (from operational met mast, nacelle anemo?), wind speed, etc
- Operational conditions: shutdowns, availability, etc
  - Changes in WSM, controller, etc
- O&M strategy followed by operator: preventive maintenance, lubrication, etc

Building an aero-elastic model if OEM not engaged

Baseline: use publicly available data and *internal know-how*

Improve the **aero-elastic** turbine model if data is available:

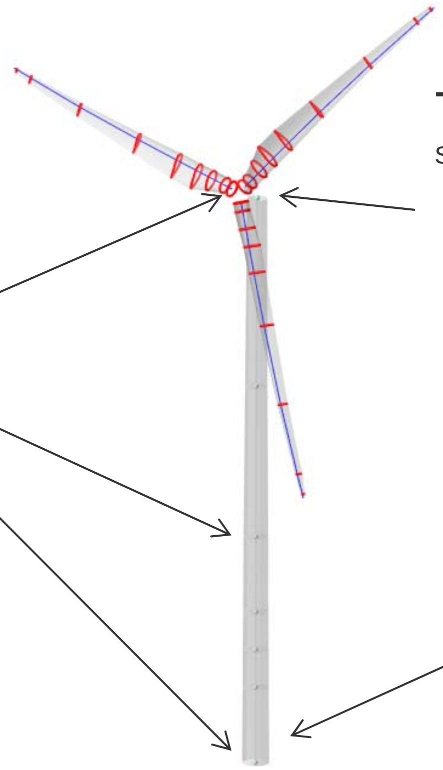
- Load measurements
- Power curve measurements
- Turbine System ID analysis
- SCADA data (1 Hz preferable!)

Uncertainties on the numerical model can then be **reduced!**

... which can make a difference assuming other uncertainties in the numerical analysis process (namely input conditions) are low and well understood

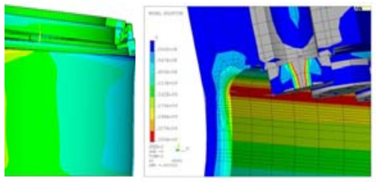
Risk Based Inspections: Informed by Modelling

How to marry numerical analysis with visual inspections?



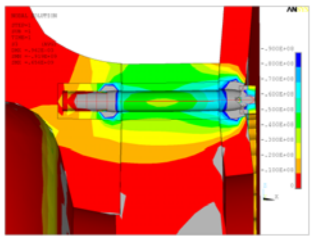
Tower top

Stress concentration



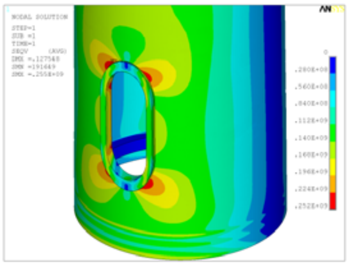
Bolted connections

Thread corrosion can give false indication of tightness

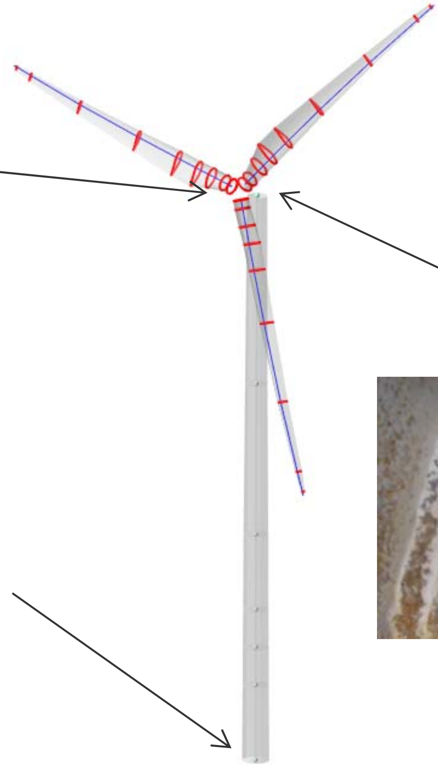


Tower door

Stress concentration

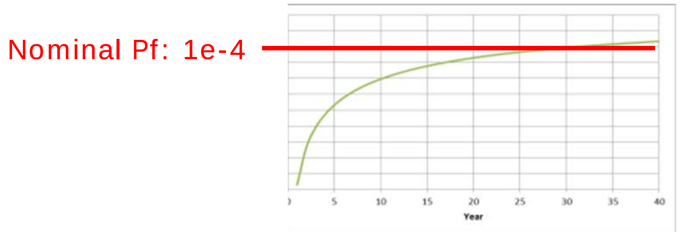


Risk Based Inspections: Typical Findings



Outputs of the life extension assessment

- Probability of failure rate curve per structural component



Component	Nominal Pf achieved
Tower	24 years
Hub	28 years
...	...

- Turbine state from inspections and recommendations for future inspections

- Economic model including: O&M costs forecast, AEP forecast, etc...

- Recommendations on the legal aspects

Wind Turbine Life Extension Asessment
Results and the future

Results so far from 17GW of 'life extension' analyses

Note this analysis is mostly based upon old wind farms (probably over designed)

Increase O&M provision?

Typical turbine design certification

Typical 'end of life' in financial models

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Further developments

- Main challenge: obtain good quality data, both from operational life and from OEM

- More validation required on numerical methods

- More engagement from OEMs and regulatory space

- Moving onto continuous (real time) life cycle assessment
  - Facilitates the automatic storage of operational data: WindGEMINI


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