SR Onshore Wind: Optimisation, Life Extension & Storage CPD Seminar

Event Sponsor

Wind Farm Optimisation

David Robb

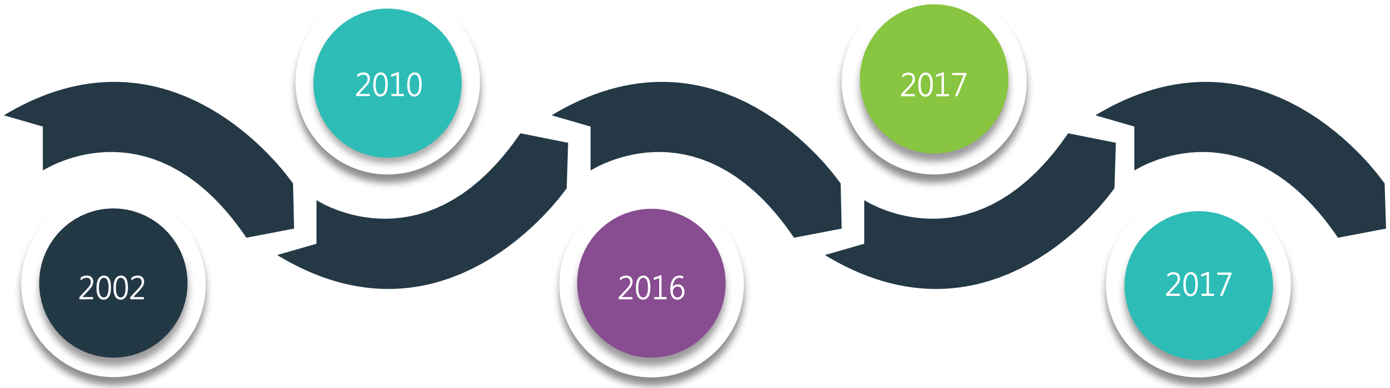
Director of Control, Wood

Windfarm Optimisation Early Lessons for the Industry

David Robb, Director of Optimisation Services

woodplc.com

Wood



Incorporation of SgurrEnergy

SgurrEnergy acquired by Wood Group

SgurrEnergy rebrand to Wood Group - clean energy

Wood Group acquires Amec Foster Wheeler

Wood is formed

A new global leader in technical, engineering and project services

$10BN
over $10bn revenue

60+
Operating in more than 60 countries

Forestry optimisation

Yaw error correction

Advanced controls

Noise management

50+ Optimisation projects assessed

3GW+ Assessed globally

Average AEP gain of 4%

Aerodynamic enhancements

Life extension

Grid services

Battery storage

Optimisation at all stages of the project

Development

- Energy yield
- Lowest LCOE
- PPT
- Owner's engineer (forestry, noise)

Operational

- M&A
- Energy yield
- Asset management
- O&M

Life Extension

Life extension assessment and observations

- Initial life extension assessment
  - Examination of current site conditions and turbine performance
- Detailed life extension plans
  - Rigorous engineering analysis of loads
  - Management plan for asset/O&M strategy
  - Advanced control solutions for load reduction

- Many sites assessed have potential for life extension
- One example of portfolio assessment showed £28-61m NPV gain

Faults

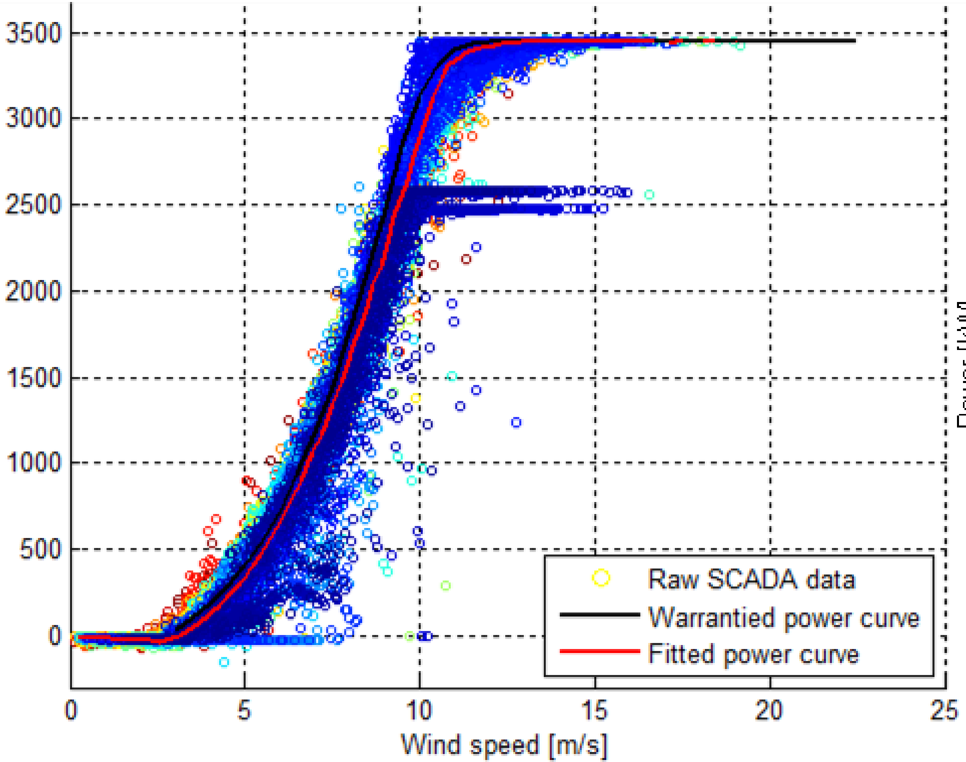
Faults/events observations

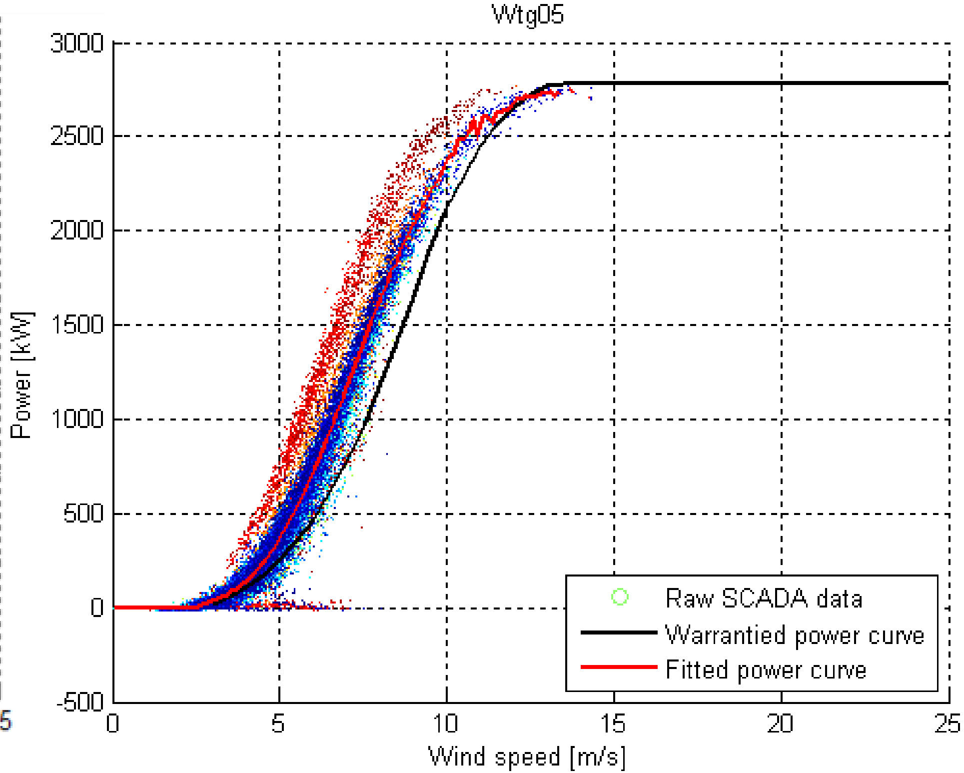
- Categorisation of faults and events to identify targets for improvements/optimisation
- Largest areas for improvements
  - Pitch faults
  - Converter faults
  - Vibration alarms
- In warranty turbines – providing evidence to OEMs
- Out of warranty turbines – improved O&M strategies

Forestry

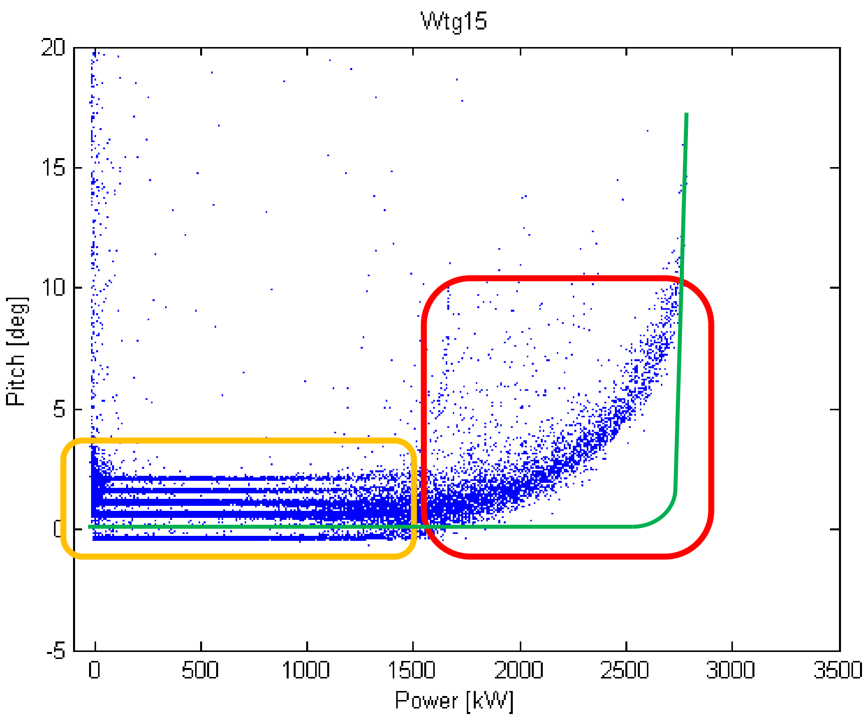
Wind Turbine Control

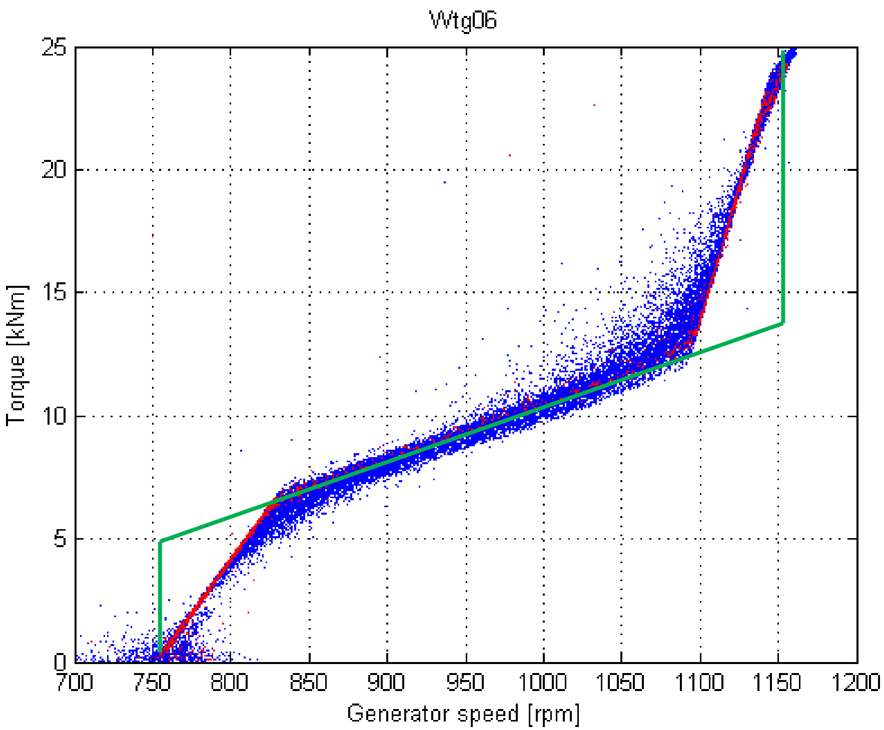
Power curve analysis examples





Pitch and torque control examples



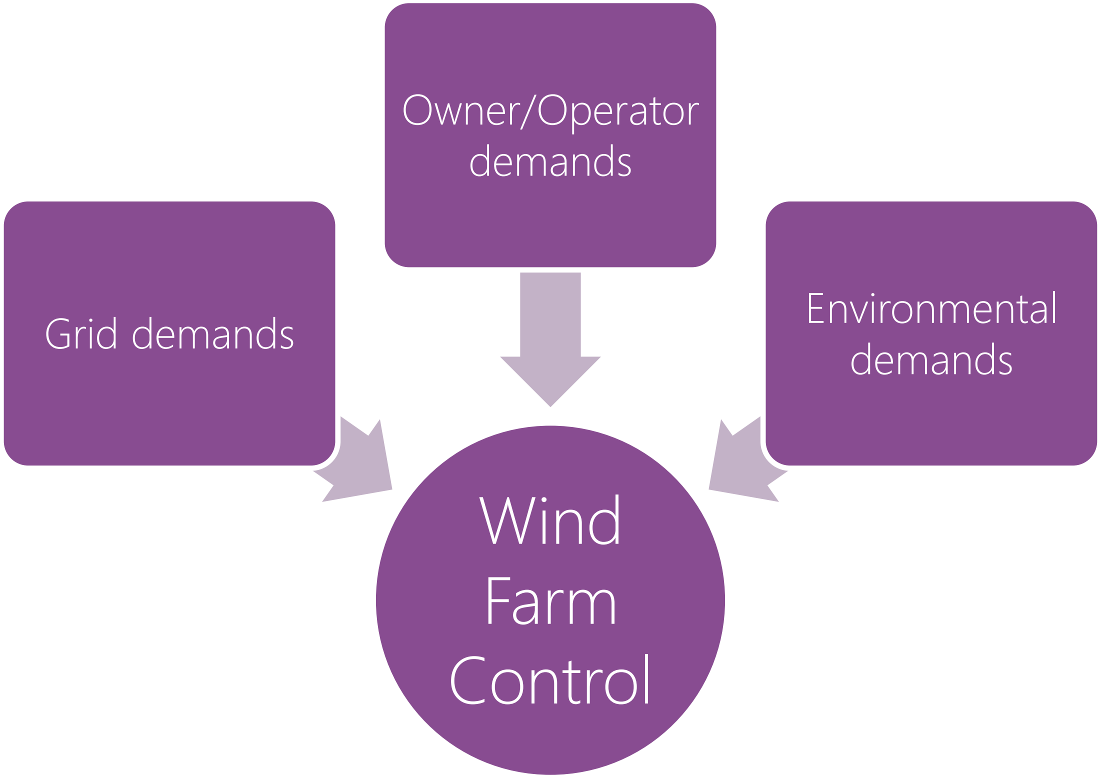


Wind turbine control observations

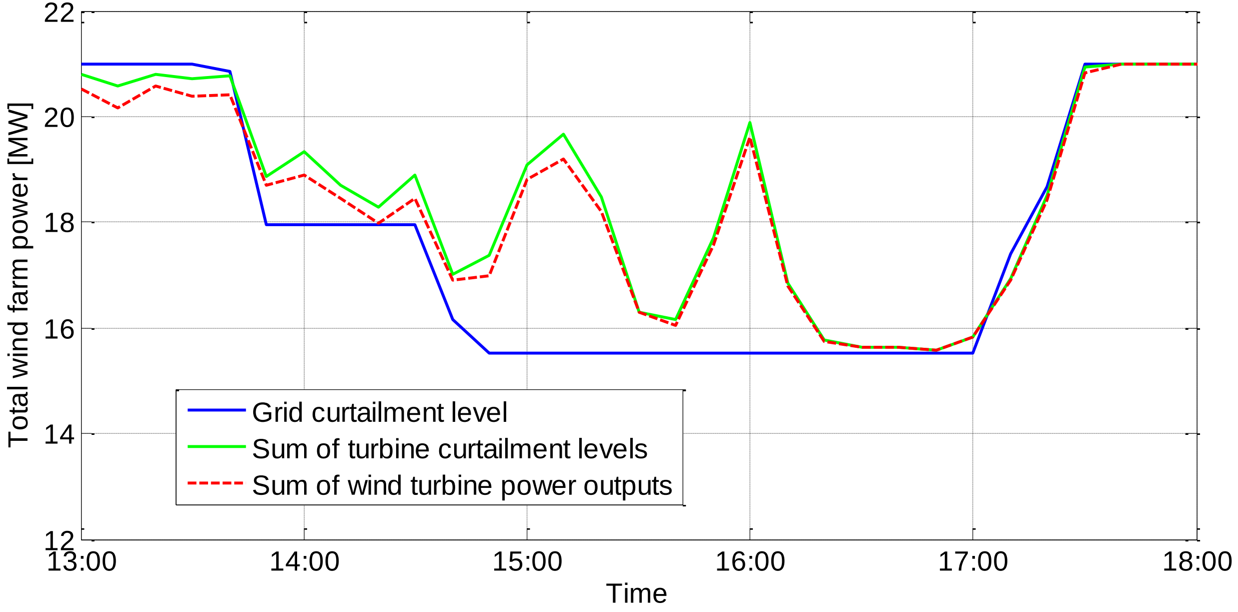
- Power curves very difficult to interpret due to poor nacelle anemometry and nacelle transfer functions
- Loss of power at the knee of the power curve very common
- Pitching prior to rated power is common leading to loss of power. Improved control strategies required.
- Torque control inefficiencies are less common but could be improved through better control
- Partial deratings, which were not obvious to owners/operators, are common

Wind Farm Control

Wind farm control performance assessment

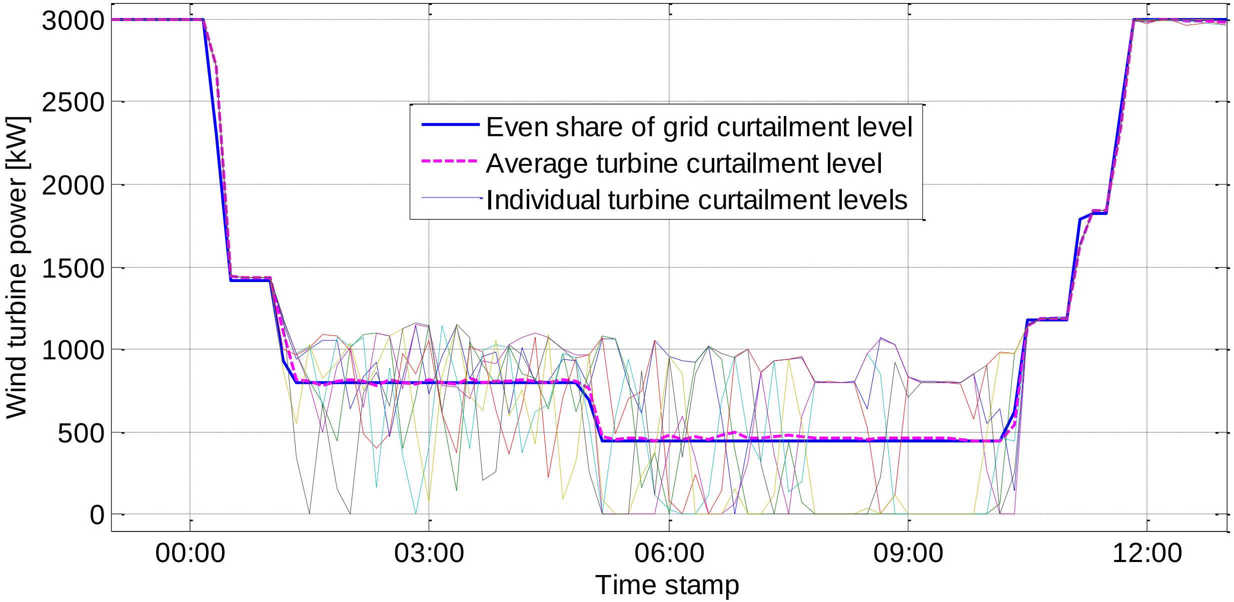


Poor wind farm control examples



- Failure to meet curtailment demands
- Leading to large penalties from the grid operator

Poor wind farm control examples



- Excessive switching between modes
  - Massively increased loads on the turbine and decreased lifetime
  - Due to poor farm level control

Wind farm control observations

- Grid services – e.g. synthetic inertia and droop control – are not common
- Some curtailment strategies are not working and implemented poorly
- Noise control modes can be overly conservative and not optimised
- Minimal wind farm control to reduce loads

Summary

Summary

- No one size fits all solution
- Complete data assessment looking at all aspects is necessary to determine all areas of optimisation potential and establish the business case for implementation
- Average 4% AEP gain identified over 50 projects, so huge potential for the industry
- Optimisation should be considered at all stages of a wind farm life

Any questions?

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John Matthew

VP Asset Management,
Allianz Capital Partners

Allianz Capital Partners

Onshore Wind - Optimisation

Glasgow / April 2018

Allianz

Optimisation Topics

1. Introduction to Allianz
2. Environmental Curtailment (Germany)
3. Forestry – (Sweden)
4. Nacelle mounted LIDAR (Italy)
5. DATA Analytics

Profile

John Matthew

Vice President Asset Management

- Entered the Energy Industry 1987 – Renewables Business since 1993 (ScottishPower)
- Experience in Construction Management, Operations and Maintenance. Regions – UK, Spain, Portugal, Japan, Italy, Germany, France and Scandinavia
- ACP since 2005
- Currently responsibilities: Director for Scandinavia and Italian Assets
- Responsible for Technical issues, Performance and Optimisation of our European fleet

Expert team in Renewable Energy

Infrastructure

Private Equity

Marc Groves-Raines
Managing Director / Global Head of Renewables

Origination & Transaction
7 People
Country and regional responsibilities

Construction & Operations
6 People
Regional allocation of responsibilities

- London based team of 14 investment professionals with industry and finance backgrounds

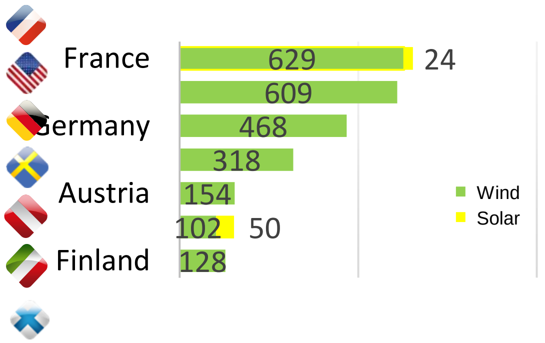
Renewable investments at a glance

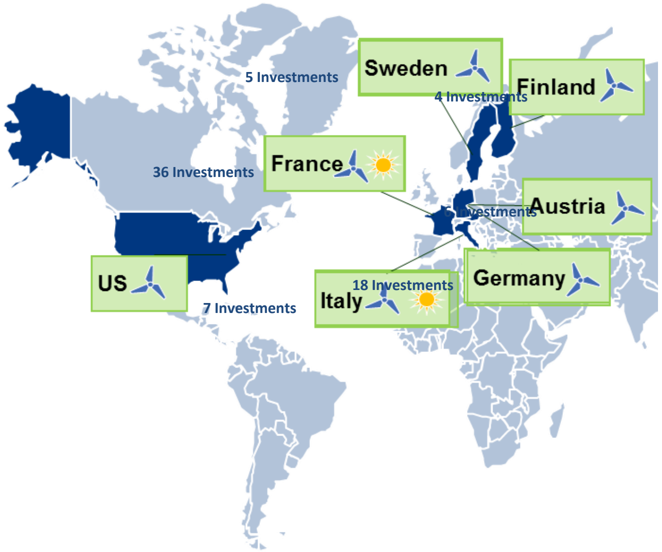
We have been committed to renewable energy investments since 2005. Since then we have gradually increased our portfolio to almost 2,5 GW.

We have invested over €4.0bn in 76 wind and 7 solar parks.

Installed capacity per country (MW)

We are diversified in Europe and the US.

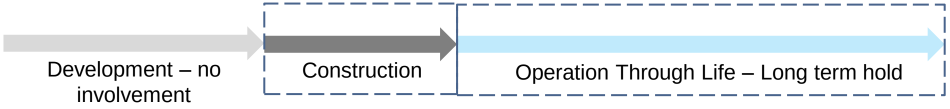




Environmental Curtailment

Investment Model

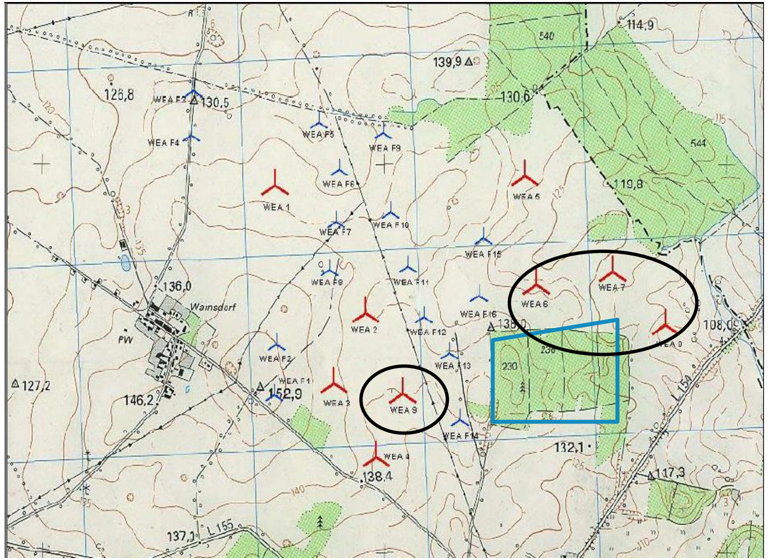
- Only acquire assets once project is fully permitted and ready to build
- Acquire Assets once built and completed (EPC)



As we only become involved at these later stages of the project, we don't have any input into the consents and permit approval process and need to accept these conditions

- Curtailments due to bats, birds, noise, shadow and other environmental restrictions
- Chosen example:- Halenbeck Wind Farm, Brandenburg Germany – Focus on Bat Restrictions

Environmental Curtailment



- 9 x Vestas V90 2MW on 105m towers

  - Area of concern

  - WTGs with curtailed operation
  - Seasonally and annually shutdown from June – September – average 5 hours per day
  - Effective Yield Loss – 1.8% annually through life

Environmental Curtailment

- Engaged a renowned bat expert to undertake a detailed study – with cooperation of planning authorities.
- Studied behaviors and mortality rates over 2 year period
- Expert presented report to authorities in person to ensure authorities understood the findings.

- Result
  - Authorities removed the permit restrictions
  - Post analysis concluded the saving were very close to prediction

- Can we conclude anything from doing such studies?

Environmental Curtailment

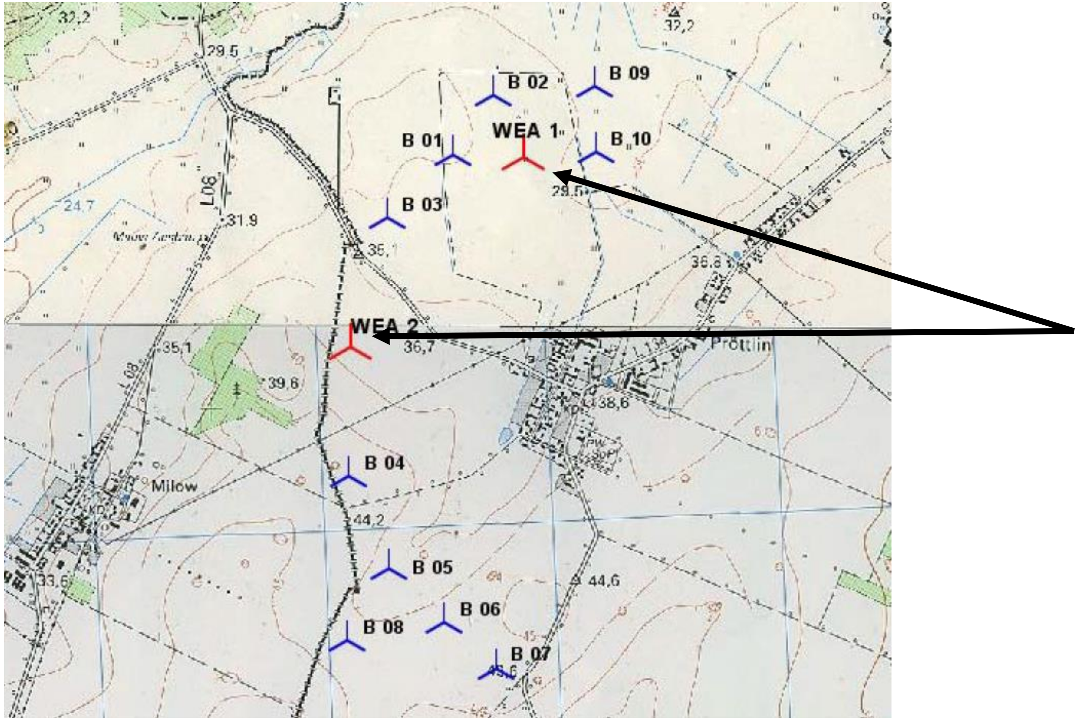
- Sometimes very difficult to find an expert that is trusted by the authorities
- Always a difficult exercise to persuade authorities to change their point of view
- Different regions have different views on changing early planning permit assumptions.
- Does not always work
- We have tried this approach to noise curtailment and shadow flicker with some success

- If conditions in the permit don’t feel right then its worth challenging

- Future thoughts

- Curtailments tend to be passive :
    - Utilise active controls such as noise – specifically at sensitive areas
    - Shadow flicker sensors at sensitive locations rather than close to the WTG
    - Explore other curtailment measures such as sector management for WTG loading

Environmental Curtailment



Example of unsuccessful challenge

2 Extension Turbines Noise Curtailed

Original Site 10 WTG's– no Curtailment

WTG's identical size and rating

External Influences

Effects of Commercial Forestry on WTG Performance

Started Investing in Sweden in 2014 – 2016

Most sites constructed in forested areas

External Influences

<u>Forestry Effects on WTG Performance</u>

WTG's rated at 3.3 MW
16 units with 119m hub and 56m canopy clearance

- Turbines located in a heavily forested area.
- Turbines capable of delivering 3.45MW but curtailed to 3.3MW due to Turbulence Intensity (TI) and loads on the turbines
- What TI decrease would be needed to increase the capacity of the turbines to 3.45 MW?
- Engaged Wood to perform an in depth analysis to explore the possibility of TI reductions and what yield increases we could expect by analysing local forestry conditions.

External Influences

<u>Sattravallen Wind Farm - Sweden</u>

- In cooperation with Wood a Galion LIDAR was deployed at a strategic location within the windfarm. Data collected was used to calibrate and validate Computational Fluid Dynamics (CFD) wind flow modelling. The LIDAR data was used in conjunction with operational and tree height data.

- Following a comprehensive analysis strategic areas of forestry were identified where removal or thinning of the trees would have a significant impact on both TI and annual yield

- TI reduction is also important from a project life point of view

- The way forward:

External Influences

The way forward

- We have and continue to collaborate with commercial forest owners and agreeing ways to modify their felling plans 2018 – 2022 and possibly beyond. However, any changes to felling plans must be done in compliance with the Sustainability Criteria and he Swedish Forestry Act.

- Turbulence intensity data for a range of scenarios have been forwarded to the OEM for further analysis to establish the 3.45MW upgrade potential. The potential upside with increased WTG output is around a 1% gain in AEP alongside possible life extension benefits.

- The effect on yield on forestry removal is significant and we expect a conservative yield increase based on the 3.3 MW model of around 1.6% - 3%.

- Once forestry is removed we will be able evaluate the overall impact on yield.

Other wind plants in Sweden and Finland have also been analysed for forestry impact and the prognosis looks very positive.

These external optimisation solutions do take time to assess fully but are well worth the effort

Thank you for your attention

Contact John Matthew
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Energy Storage, Life Extension and Repowering

Joss Boxford

Partner, Everoze

Growing old gracefully?

Squeezing maximum value out of your wind farm

Joss Boxford

Scottish Renewables Onshore Wind event, April 2018

DEFINITION

Engineers by training, deep technical knowhow

Enabling innovations to allow renewables to go further

Everoze

noun

A technical and commercial energy consultancy, specialising in renewables and storage

Est. 2015

Depth of market experience to take the commercial view

Solar PV, onshore wind, offshore wind, storage

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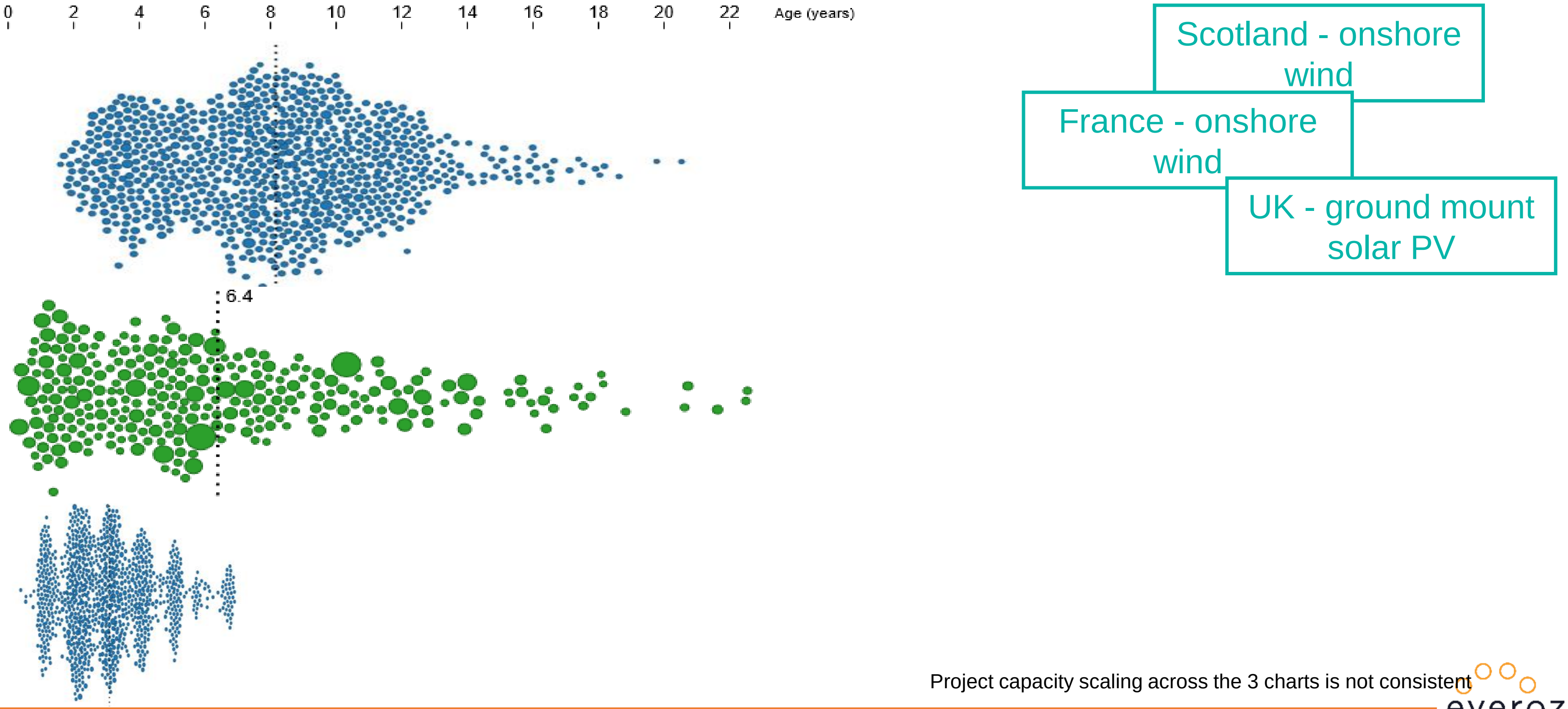
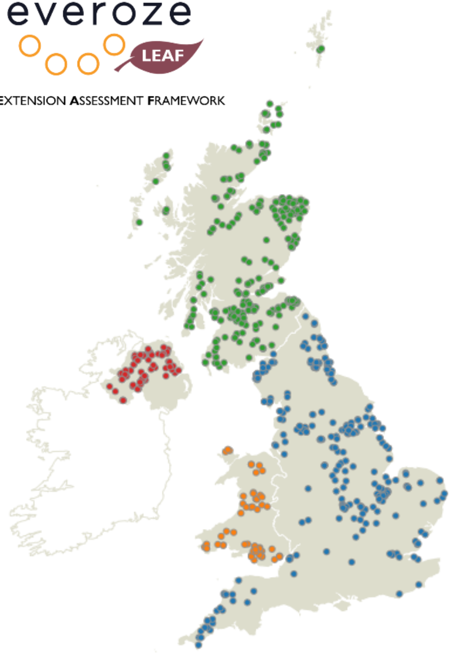
Demographics

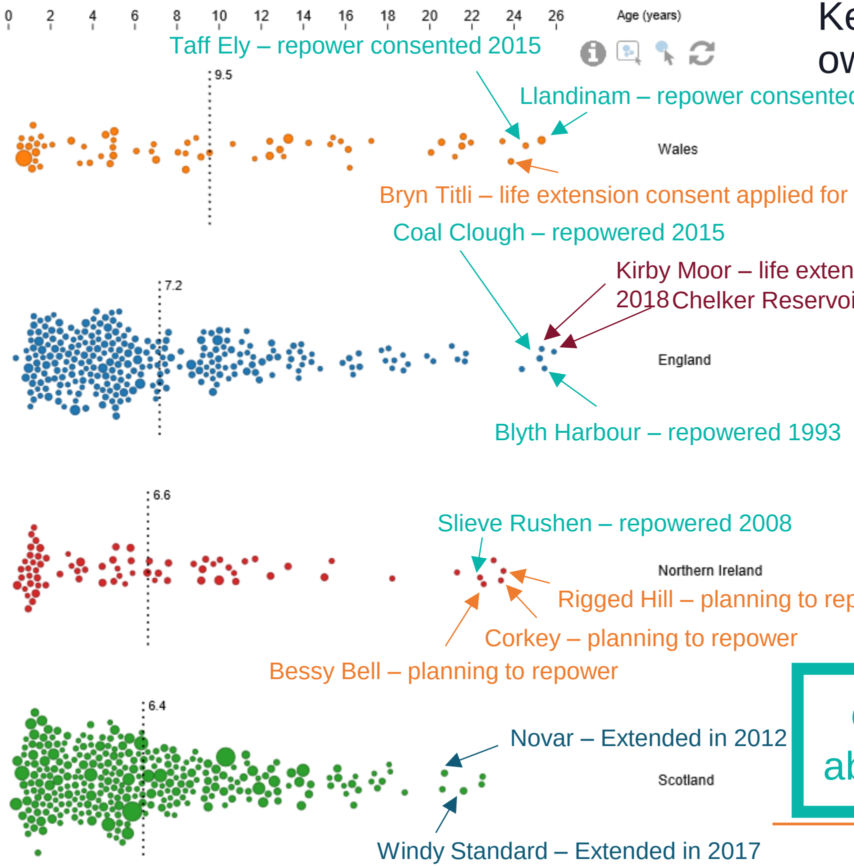


Project capacity scaling across the 3 charts is not consistent

Scotland onshore wind: lots of questions

everoze LEAF
LIFE EXTENSION ASSESSMENT FRAMEWORK





Key questions for asset owners:

- What can I do ?

  (feasibility)

- What should I do?

  (economic viability)

- How do I get it done?

  (risk mitigation)

Oh…and what about batteries??

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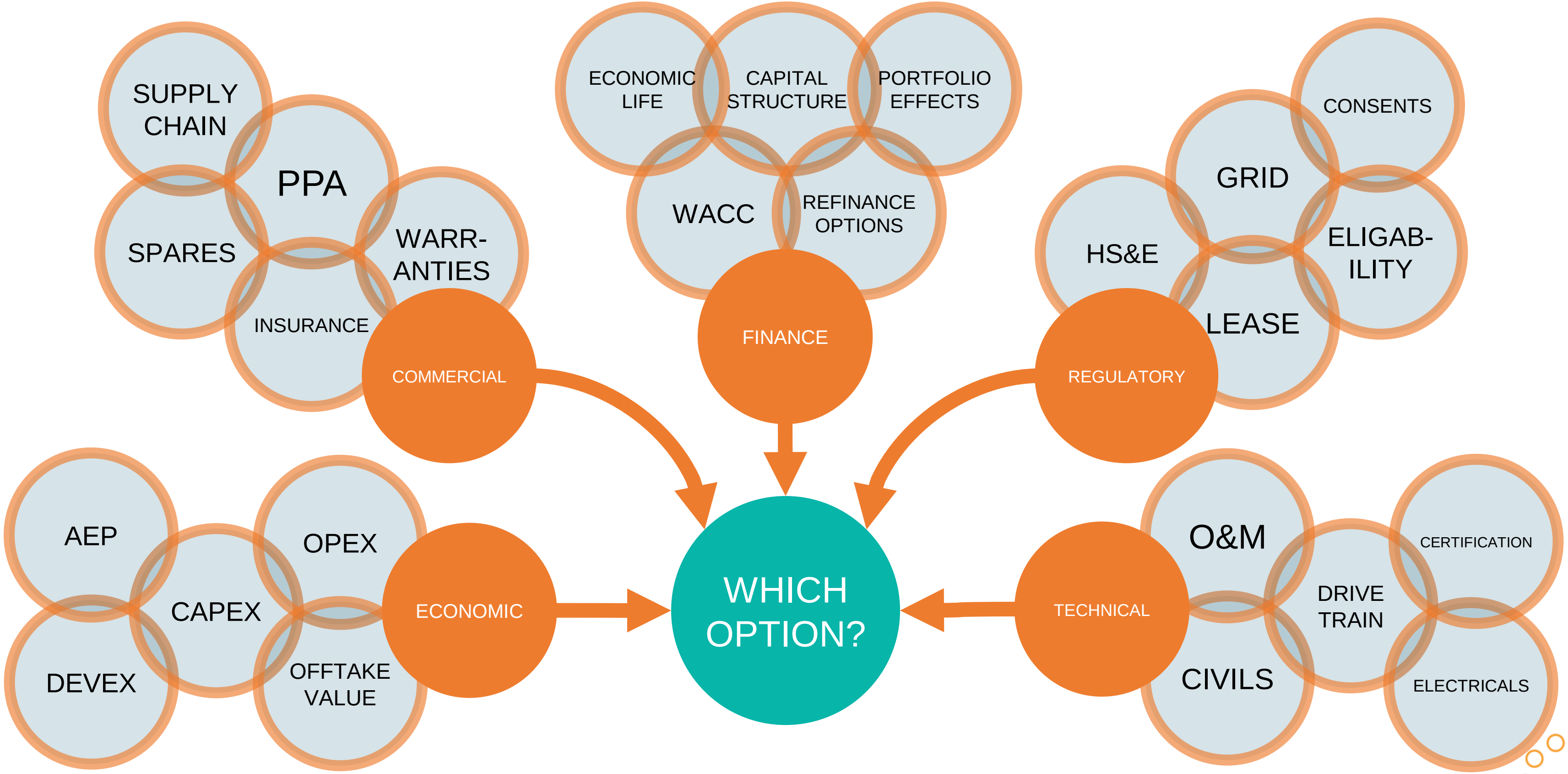
The holistic view: strategic options

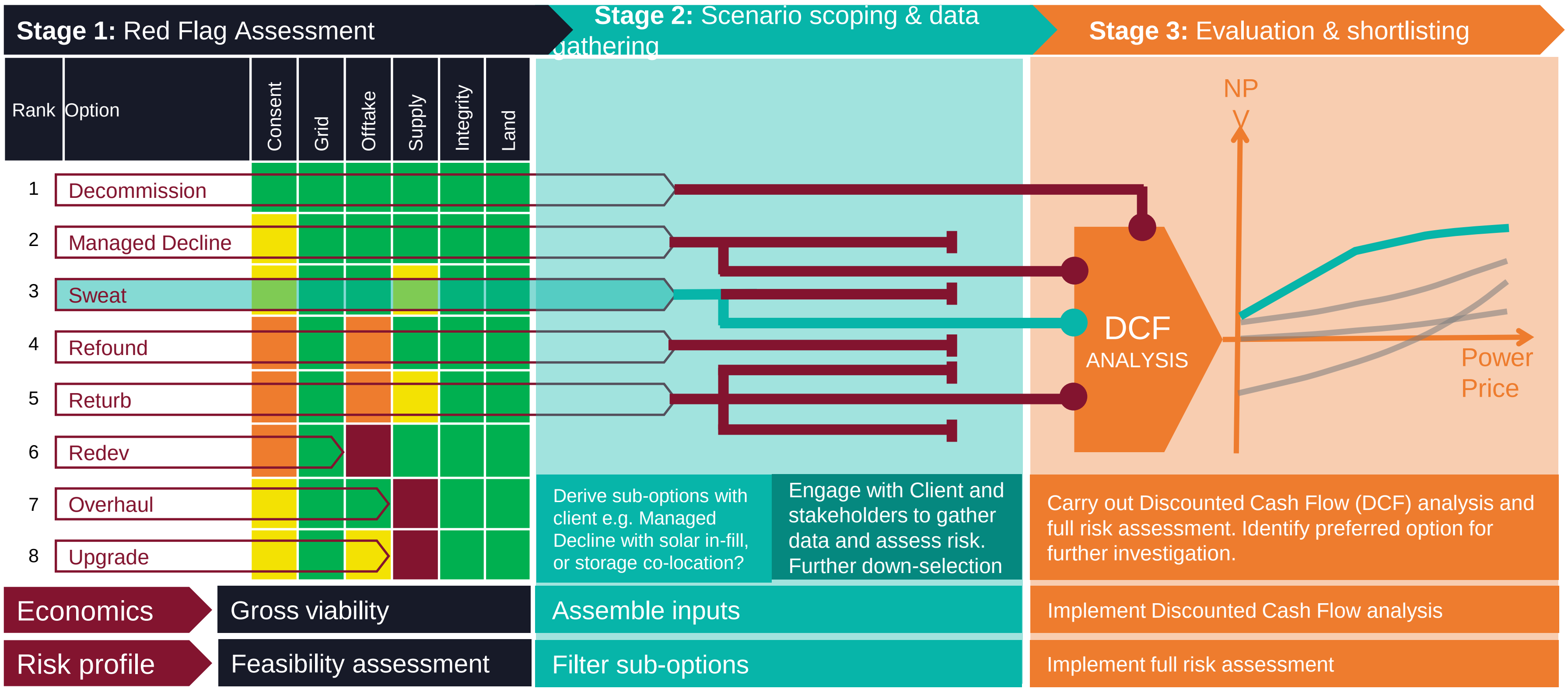
LOW — Level of Intervention — HIGH

	Life Extension			Decom-mission	Repower			
	Managed decline	Sweat	Overhaul	Decom.	Upgrade	Returb	Refound	Redev
Capacity	Declining	No change	No change	Zero	Same / higher	Same / higher	Same / higher	Same / higher
WTGs	No change	No change	No change	Remove	Rotor / DT / ctl	New	New	New
Foundations	No change	No change	No change	Remove	No change	Same / upgrad	New	New
BoP Electricals	No change	No change	No change	Remove	No change	Same / upgrad	Same / upgrad	New
Locations	No change	No change	No change	-	No change	No change	No change / New	New
CapEx	N / A	N / A	Moderate	Moderate	Mod-High	High	High	V High
OpEx	Reduce	Increase	Maintain	Zero	Maintain	Maintain	Maintain	Maintain

The holistic view: the drivers



The LEAF process



Lessons learned

1. A complex challenge

Getting the end of life decisions right requires a multi-perspective approach and deep engagement with the asset team. This takes time.

2. It is not about life extension v repowering

Good sites will be repowered eventually. A smart analysis figures out when it makes sense to life extend and then repower. This is about timing and trigger points.

3. Focus on EBIT projections

A capitally depreciated site should be run like a successful small business. The focus should be on a robust baseline for financial metrics and modelling to project short-run profitability towards (and beyond) end of life.

Stephen Rose, Head of Wind Generation at SSE:

"The LEAF process has given us a clearer view on the relative merits of a range of future options for the asset in question. We were impressed by the rigour of the process, the insights which Everoze brought to the table and the clarity of the outcomes."

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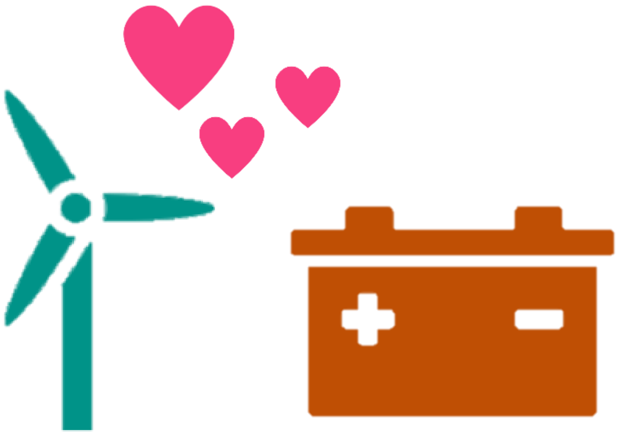
Wait…what about batteries!



Statoil launches Batwind: Battery storage for offshore wind

BP teams up with Tesla to venture into battery storage for windfarm

Vattenfall partners BMW for battery storage at largest onshore wind farm

Plenty of high profile wind+battery projects – a marriage made in heaven?

Firstly, a warning…

FUNCTION	**Clear:** generate clean electricity	**Multiple:** flexibility in all its forms
REVENUE HORIZON	**Long-term:** 15 yr ROCs	**Short:** mostly (up to 2 yrs for FFR)
ASSET MANAGEMENT	**Sweat:** maximise production	**Proactive:** revenue-hopping

Batteries offer a whole different commercial proposition to wind.
The risk profile is very different to onshore wind.

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Everoze view

1. Separate hype from reality

- See capacity market chart on the right…

2. Be clear on service offered

- In GB, early commercial projects have focused on frequency response – though market approaching saturation

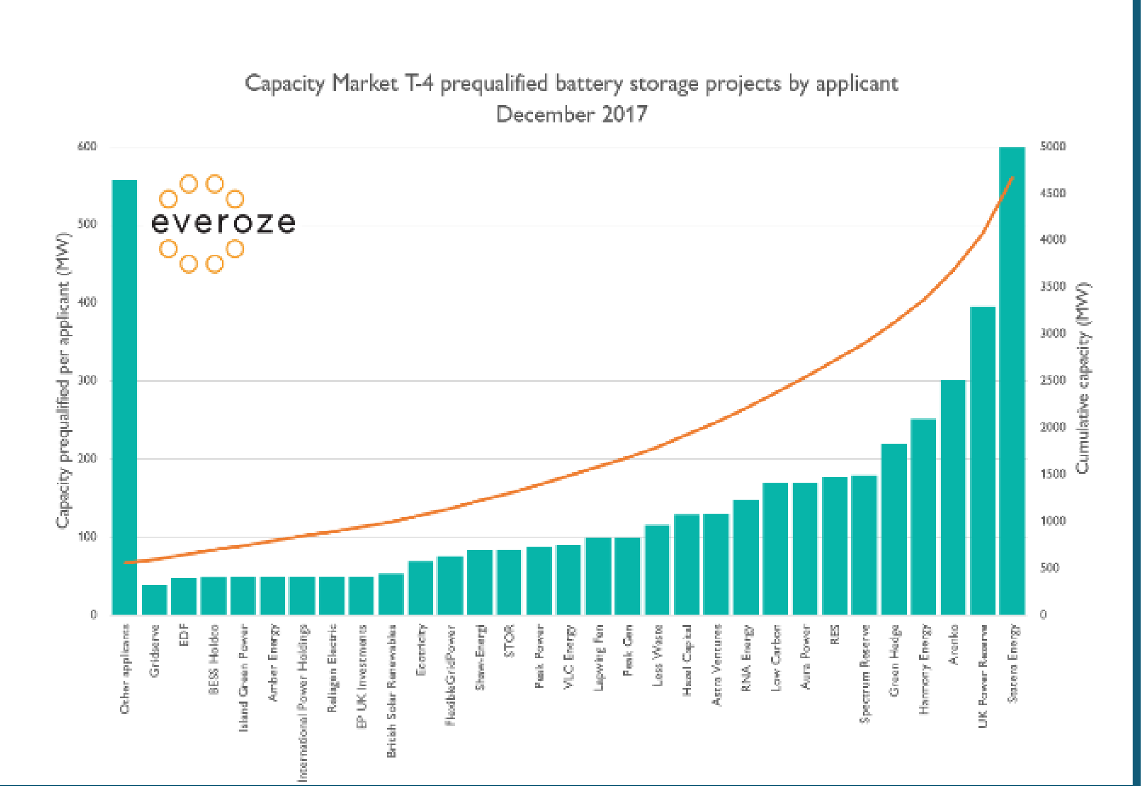
3. Be clear on why co-location

- Just cost savings, or storing wind energy?

4. Be clear on motivations

- Strategic/learning or commercial returns?

4.7 GW BATTERIES PREQUALIFY!



…but only 393 MW secure contracts

Wrapping up

- Life extension and repowering are happening already.
- It’s never too early to start planning and a holistic approach is needed.
- Battery co-location may be part of a project’s future but clarity on the purpose and risks is needed.

For new **business models** – speak to Zoe Barnes in the Fife office: zoe.barnes@everoze.com

Scottish Enterprise expert support is available.

For **life extension** – speak to Joss Boxford: joss.boxford@everoze.com

For more **storage insights** check out our blogs

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Thank you.

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experts | evolving | energy

David Malcolm

Principal Mechanical Engineer, Wood

Life Extension:
Fundamentals and Practicalities

David Malcolm, Principal Mechanical Engineer

Fundamental Principles

- The main components and structures of WTGs accumulate fatigue damage
  - Rotation – gravity and wind shear
  - Starts / normal stops / fast stops / idling
  - Wind and wave loads, turbulence intensity
- **No matter how well maintained or reliable a WTG is, fatigue will eventually cause components to fail**
- Life extension involves:
  - Understanding when such failures could occur
  - Managing the remaining life of WTGs to give safe and economic operation

Elements of Life Extension

- Assessment of remaining life
  - Analytical:
    - WTG design
    - Site conditions
  - Practical:
    - Operating history and current condition
- Extension of remaining life
  - Reducing rate of fatigue damage
    - Start early in operating life to maximise effect
  - Targeted retrofits
  - Assuring safe operation by mitigating increased probability of failure

Level of analysis should match its purpose

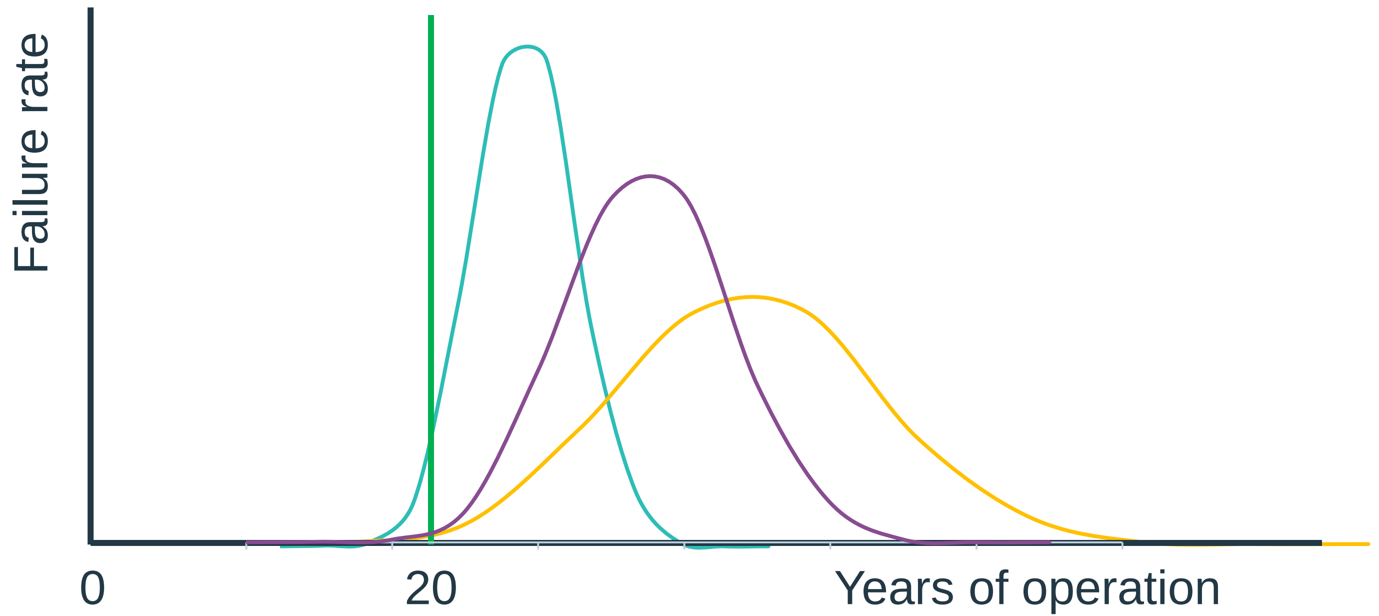
Sources of life extension potential

- IEC 61400-1: Design Requirements
  - Partial safety factors on loads and materials
    - Account for uncertainty
  - Changes between editions of the standard

- WTG selection
  - Permitting constraints
  - Use most severe conditions on the site
  - Use P50 conditions

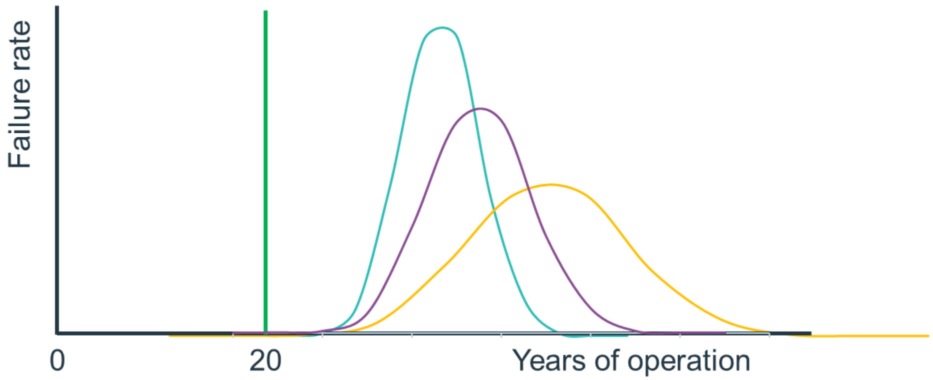
- Modern WTG designs and selection processes may exploit the margins that have contributed to the life extension potential currently being identified
  - Optimises levelized cost of energy for new projects

How long do components with 20 year design lives last?



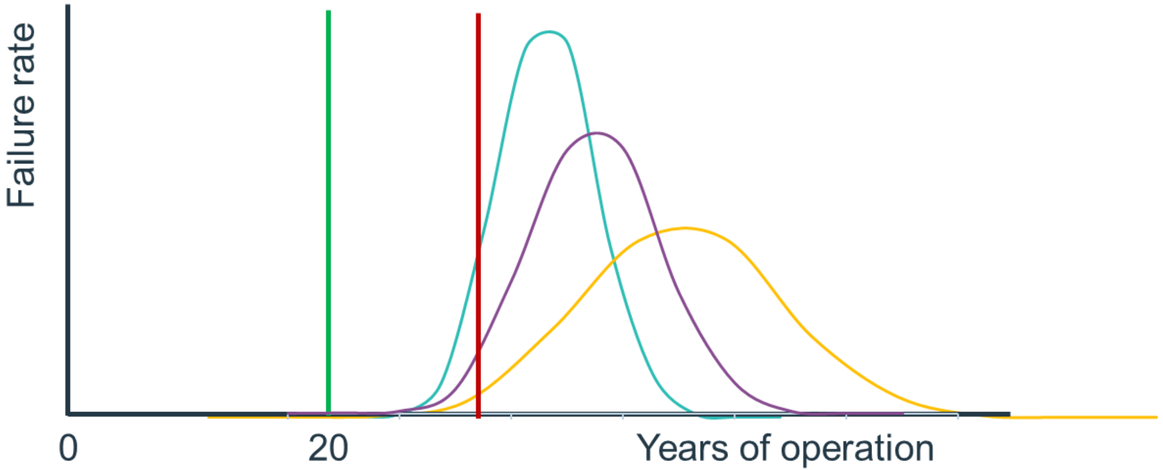
- The design life is certified in relation to probability of failure
- Average life will exceed the design life – but by how much?

Why might the fatigue life be longer than certified?



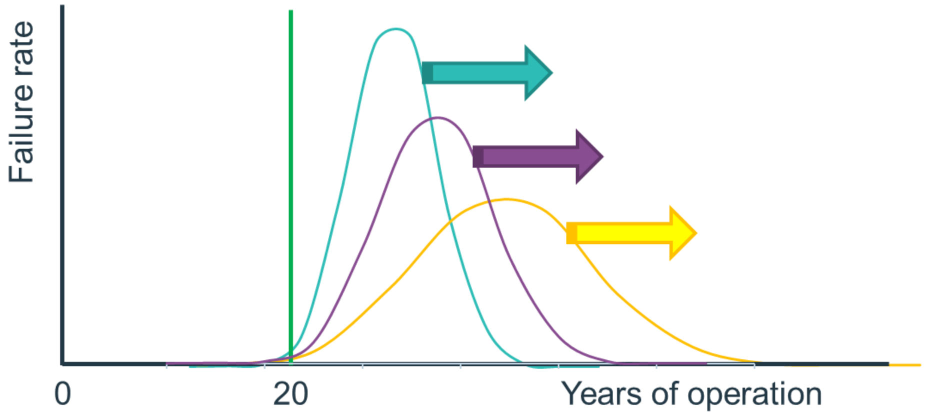
- Site conditions are generally more benign than the design conditions used for type certification
- Improved modelling techniques can allow more precise life calculation
  - Reduce factors of safety without increasing probability of failure

Is it safe to operate with an increased probability of fatigue failure?



- Yes, IF the failure mode is understood AND a valid inspection technique can detect it sufficiently far in advance to allow structural failure to be prevented
  - This needs detailed knowledge of the component and its loads
- While this allows continued operation, future revenues are uncertain

How can component life be increased?



- Control improvements can reduce the rate of fatigue damage:
  - If a small subset of conditions cause a disproportionate level of damage, limited curtailment might be viable
  - Upgrade control systems to reduce loads on older WTGs
    - Individual pitch control, response to gusts…

What if component life cannot be increased?

- Is scheduled / on condition replacement viable?
  - Bolted connections often have very limited fatigue lives
    - Cost of replacement is minimal
    - Cost of not replacing can be high!
  - Main frames of some WTGs may have limited lives
    - Repair / replacement may not be viable
- Decisions are both technical and economic

Life Extension Process should match its Purpose

Acquisition – quick response to opportunity	
Initial indication of potential	Supports bidding decisions
Limited data and analysis	Uncertain future ownership
Financing – enabling lending against extended operating life	
Planned activity	Avoidance of risk in loan
Long term ownership – strategy to maximise value over lifetime	
Use detailed site data	Analyse exact WTG type
Identify and implement	Start analysis early

Risks and Constraints

- Data availability
  - Wind, operating history, component quality
- Design information
  - WTG manufacturers’ core intellectual property
  - Independent modelling can be carried out
- Spares availability
  - OEM and aftermarket
- Existence of valid inspection techniques
- Feasibility of component repair / replacement

Summary

- There is huge potential for life extension
- Don’t just keep running and assume things will be OK!
  - Actual potential is specific to WTG types and sites
- Life extension assessment can reveal how much potential a site has
  - Informs development of technical solutions
  - Allows well-founded economic decisions
- Match the process to its purpose
- Start thinking about life extension at earliest opportunity

David Aldrich

Business Development Manager,
Denchi Group

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