



Noise related activities at the ORE Catapult Levenmouth Demonstration Turbine

03/03/2019

Hamish Macdonald

Agenda

- Summary of OREC
- Summary/History of Levenmouth Demonstration Turbine
- Noise Investigation
- Initial Control Strategy
- Revised Control Strategy

10

Innovate UK

- Designed to transform the UK's capability for innovation
- Core grant leveraged with industry and other public funding

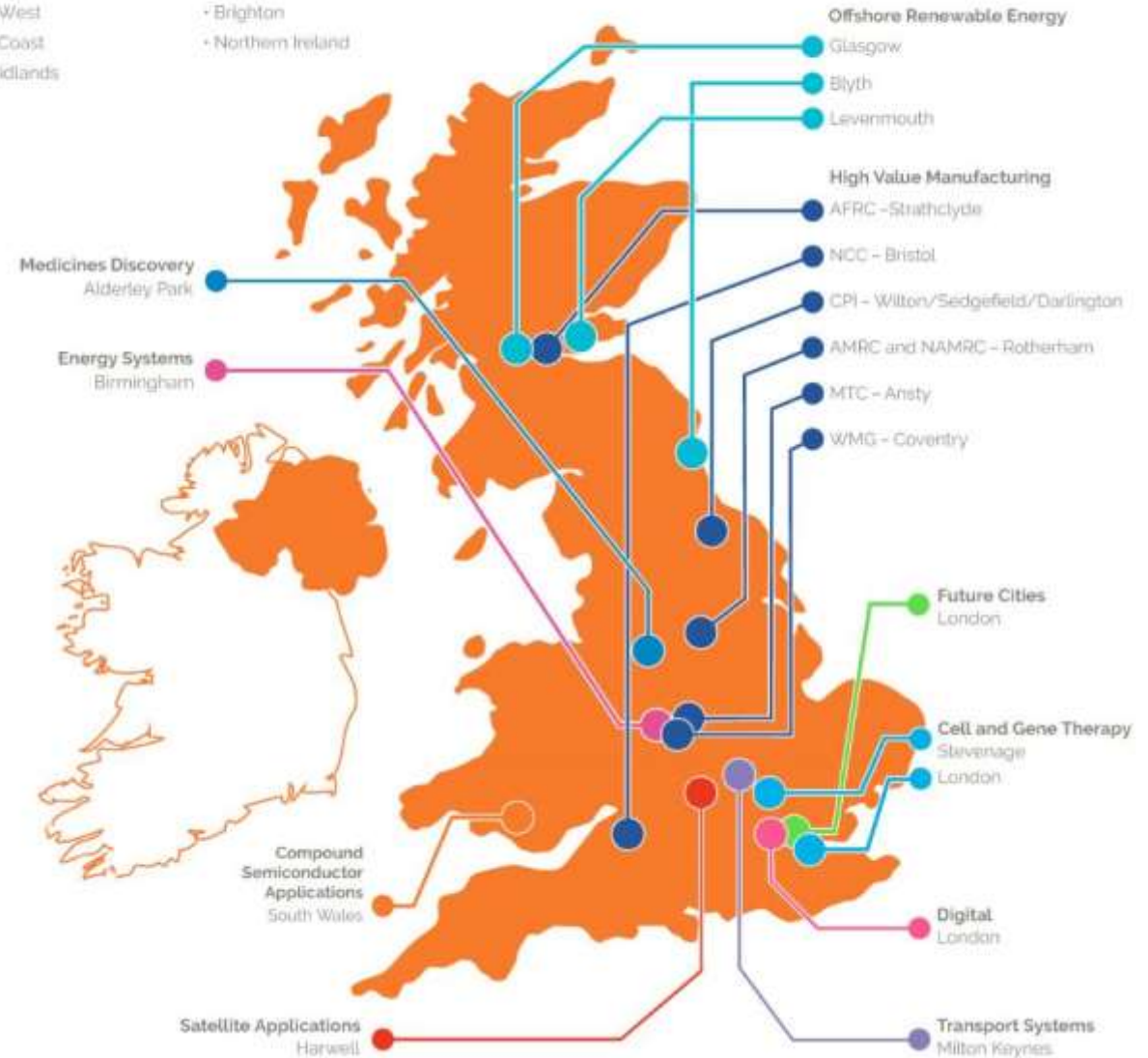
Regional Centres

Satellite Applications

- North East
- Scotland
- South West
- South Coast
- East Midlands

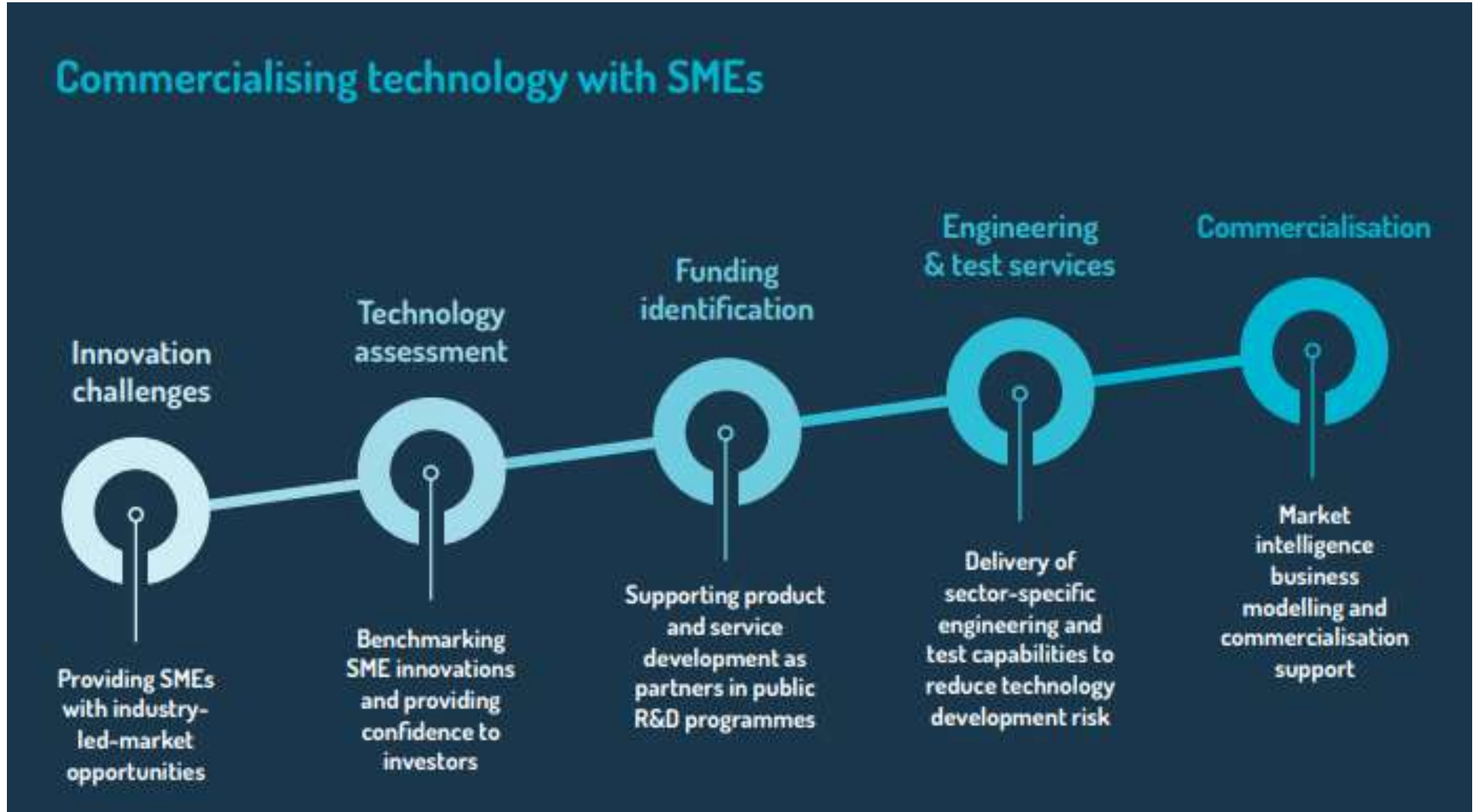
Digital

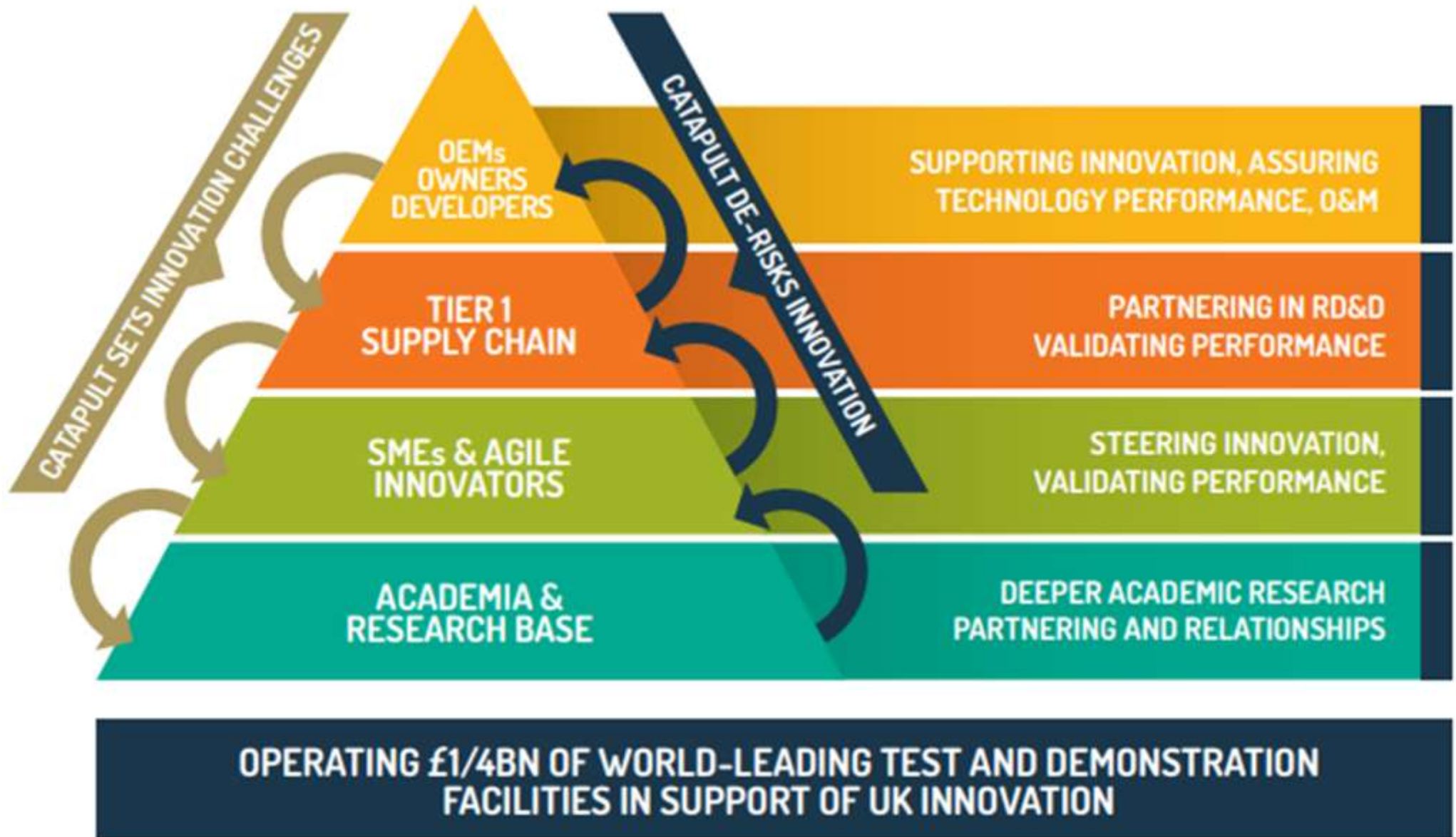
- North East and Tees Valley
- Yorkshire
- Brighton
- Northern Ireland



164 SMEs
supported
in 2017/18

410 SMEs
supported
since 2013





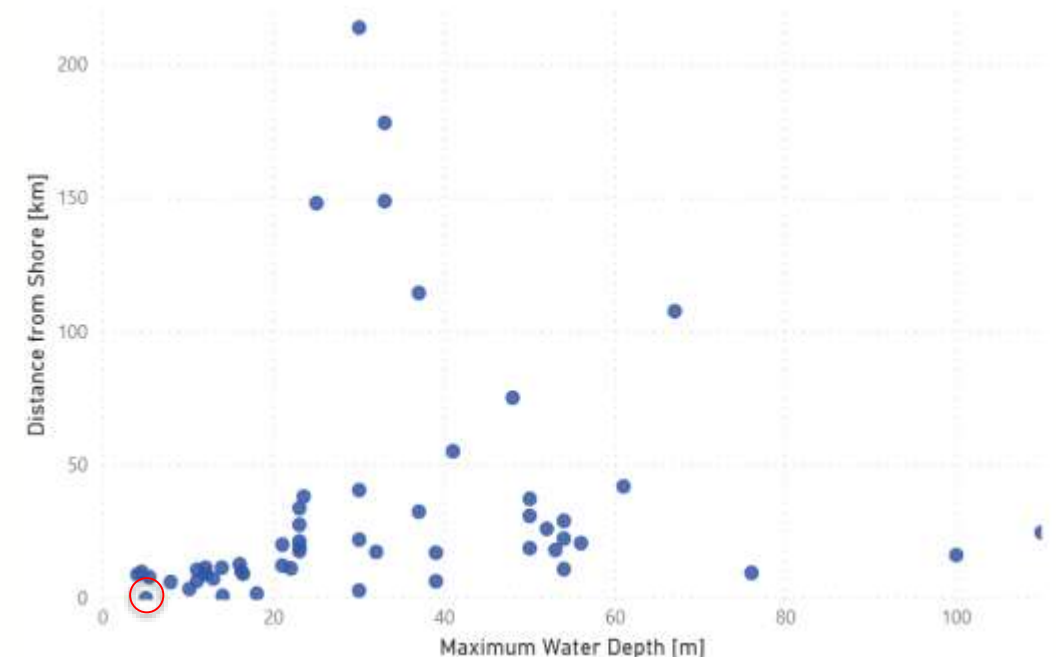
Summary/History of Levenmouth Demonstration Turbine

- Samsung Prototype (Levenmouth)
 - 7 MW Rated Capacity
 - Hub Height 110 m
 - Blade Length 83.5 m
 - Rotor Diameter 171.2 m
 - Total Height 195.6 m
- GE Haliade X Prototype (Rotterdam)
 - 12 MW rated Capacity;
 - Hub Height 150 m
 - Blade Length 107 m;
 - Rotor Diameter 220 m
 - Total Height 260 m



Summary/History of Levenmouth Demonstration Turbine

- “Offshore”
 - Distance from shore 35m
 - Ramp and personnel bridge
 - Jacket structure
- Commercial Research & Development (Oct 2019)
 - 119 SMEs have accessed the facility
 - 45 ongoing R&D projects
 - 122 new packages of instrumentation
 - Local Engagement
 - Training for Fife College turbine technicians
 - Full time STEM Principle position
- Operational Turbine
 - Capacity factor not a priority
 - Generated Production Over 25MWh
 - Over 5 million rotations

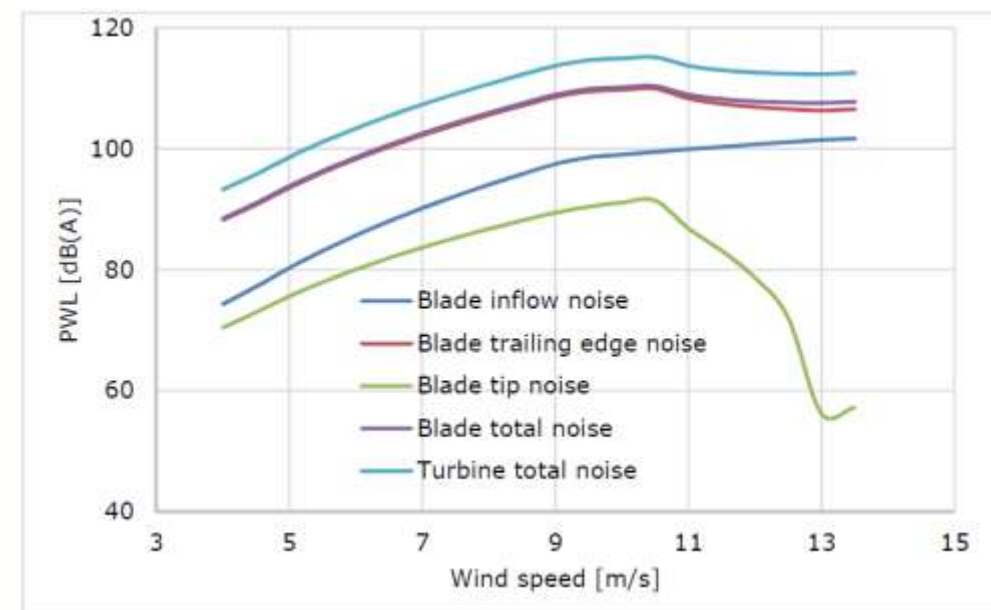
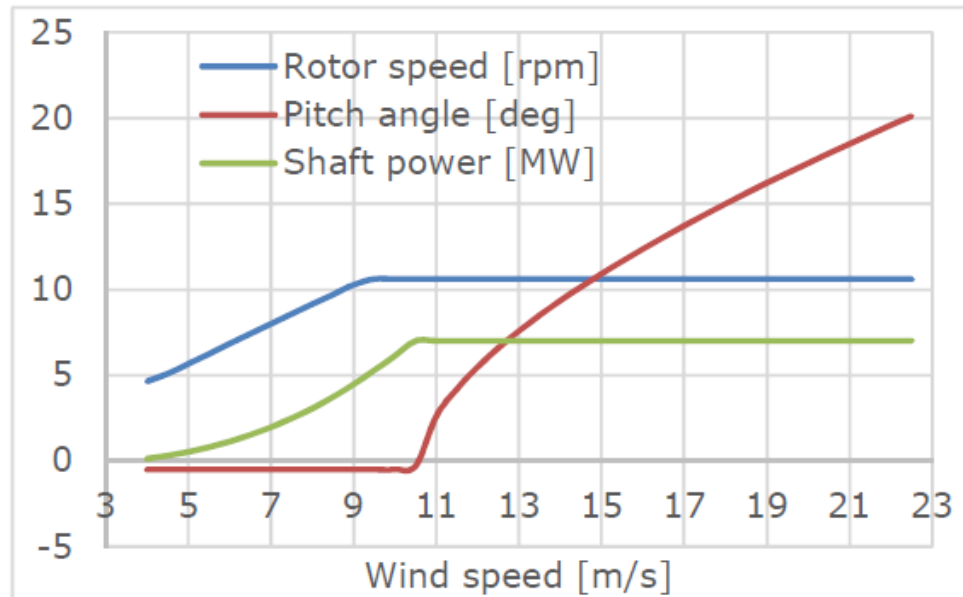


Summary/History of Levenmouth Demonstration Turbine

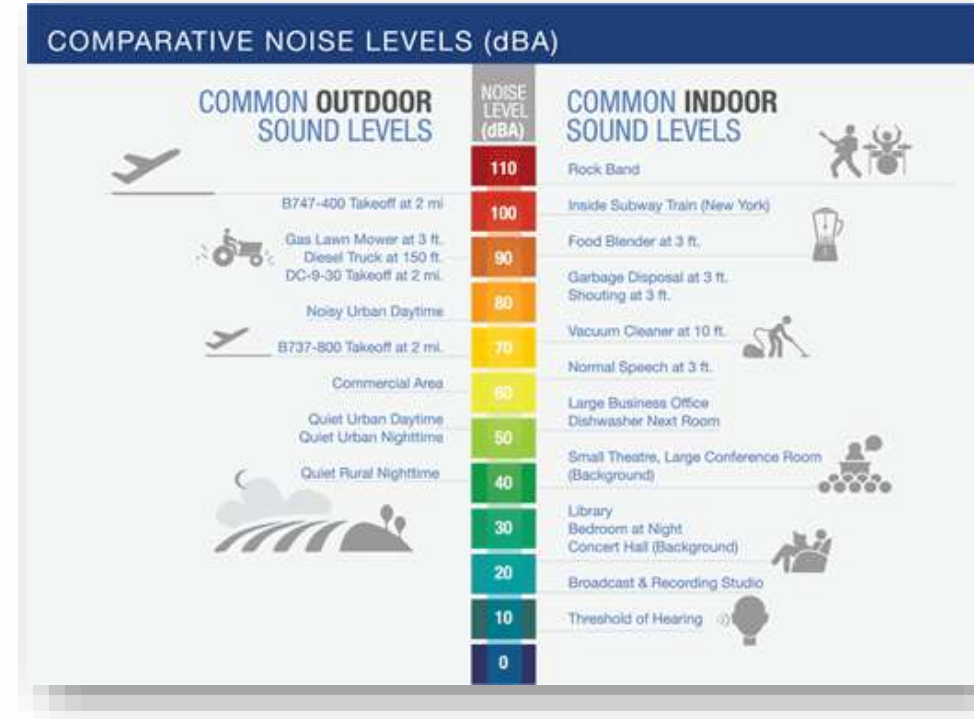
- Timeline
 - July 2012 – Consent Submitted
 - Nov 2012 – Met Mast Installation
 - May 2013 – Consent Authorised (Samsung)
 - Sep 2013 – Construction Starts (Largest in the World)
 - Jan 2015 – Fully Commissioned
 - Nov 2015 – Consent and Ownership assigned to OREC
 - Oct 2017 – Application for life extension
 - Set to expire in 2029
 - Planning statement publicly available
- Proximity of turbine
 - “Nice Neighbours”
 - Transparent
 - Reactive



- Greater noise intensity from one side of the rotor because of convective amplification
 - Higher Sound Pressure Level (SPL) when blade is moving downwards
 - “Location and quantification of noise sources on a wind turbine” [Oerlemans *et al.* 2006]
- Samsung turbine
 - Rotational direction: clockwise looking downwind
- Trailing edge noise is the source that dominates

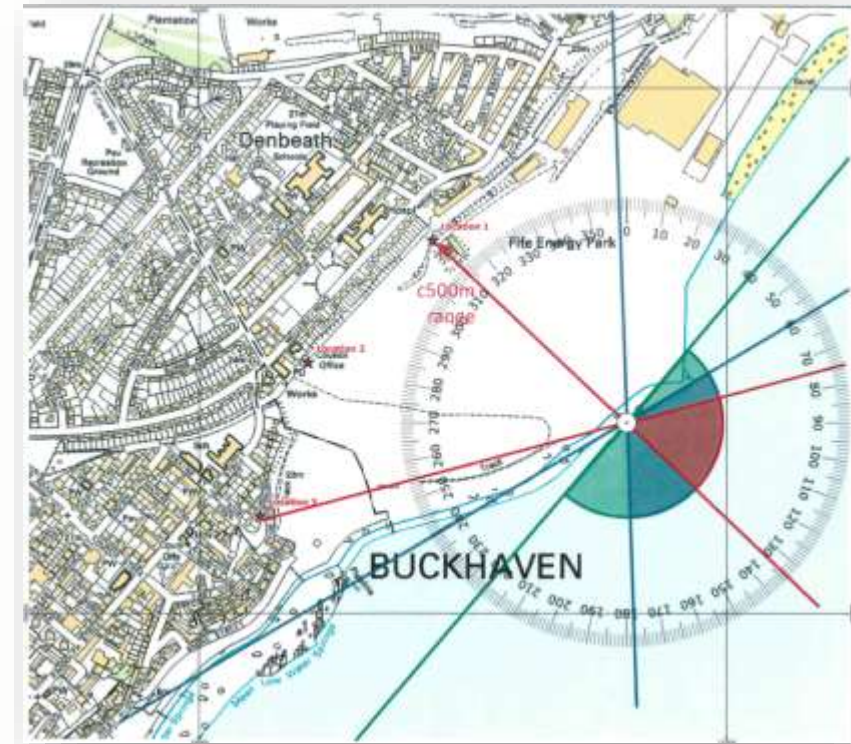


- Arcus Operational Noise Report (May 2014)
 - Background noise levels higher than original Fife Energy Park (FEP) Environmental Statement (2010)
 - *"If the noise limits had been derived from the background noise levels measured at the time of the operational noise measurements, the measured turbine noise levels would not be considered excessive due to the resulting increase in the noise limits"*
 - Variation proposed that the turbine should not exceed:
 - *"35 dB(A) or 5 dB above the prevailing background noise (LA90,10 min) between the hours of 07:00-23:00; and*
 - *"43 dB(A) or 5 dB above the prevailing background noise (LA90,10 min) between the hours of 23:00-07:00."*
 - Variation consented in March 2016



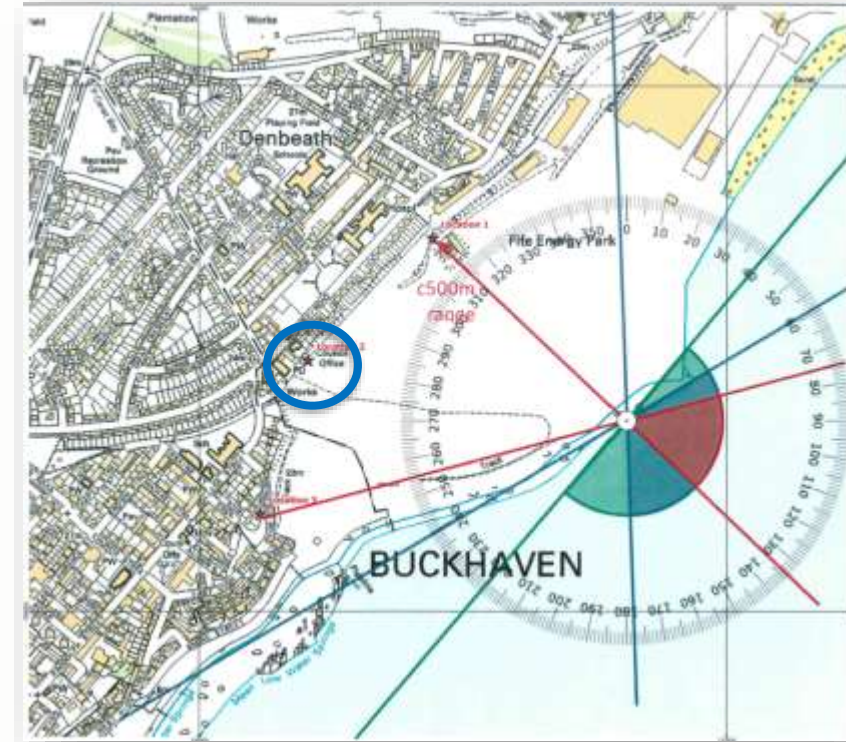
Source: FAA

- Oct 2015 – HOARE LEA Acoustics Noise Monitoring Report (Initial)
 - Campaign: 13/08/2015 to 19/10/2015
 - BiFAB fabrication site was not operating during the night
 - Objective – Establish both the variation of background noise levels and the variation of turbine noise levels with wind speed and wind direction
- Location 1
 - *"Not likely to be exceeded under any wind speed or direction"*
- Location 2
 - *"Likely to be exceeding the originally consented noise limits under a limited range of wind speeds, by less than 1 dB during the daytime and by up to 2 dB during night-time, under all wind directions."*
- Location 3
 - *"Likely to be exceeding the daytime noise limits by up to 4.1 dB under easterly and southerly wind directions and under a limited range of wind speeds."*



Location 2: Daytime

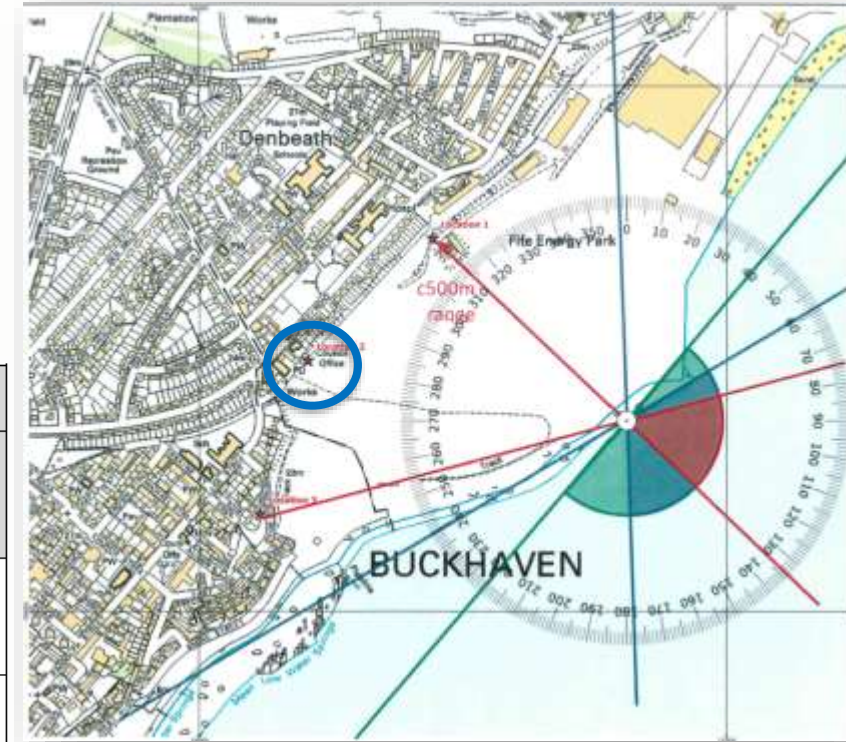
Wind Direction Sector Centre	Standardised 10m Height Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
0° (N)	-7.4	-3.4 [†]	-1.5	0.4	-0.3	-	-	-	-	-
90° (E)	-2.4	-2.0	0.6	-	-	-	-	1.1	-	-
180° (S)	-6.6	-3.6	-1.2	0.3	-0.2	-3.9	-	-3.1	-2.7	-
240° (WSW)	-5.7 [†]	-6.6	-1.2	-0.6	-2.0	-3.5	-3.1	-4.7	-2.7 [†]	-
270° (W)	-5.7 [†]	-6.3	-0.7	-0.6	-2.3	-3.2	-2.8	-4.8 [†]	-	-



† Indicates that the background correction has not been performed due to the “turbine on” and “turbine off” data being too similar

Location 2: Night-time

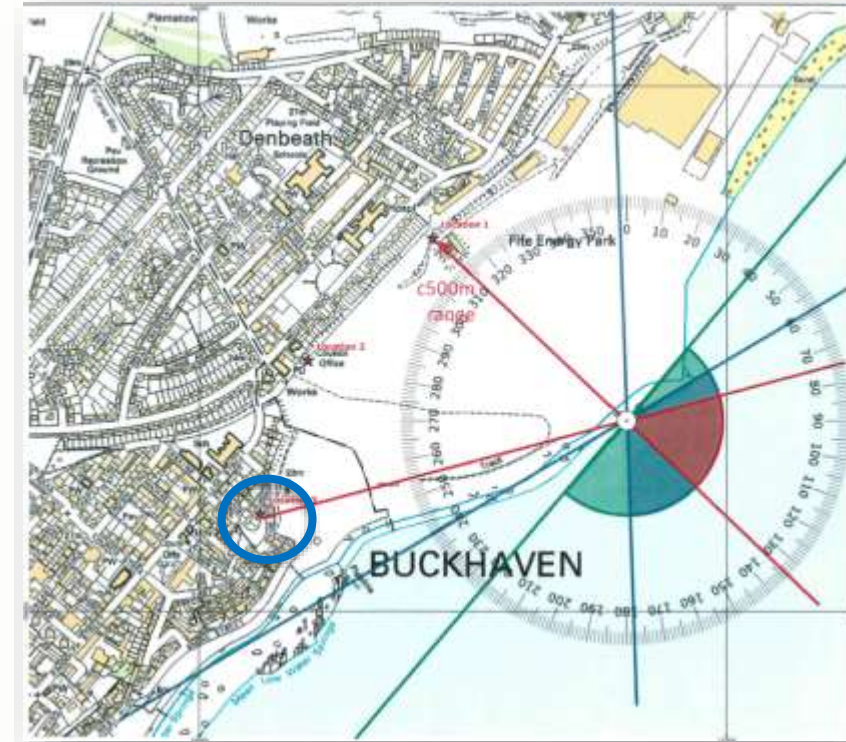
Wind Direction Sector Centre	Standardised 10m Height Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
0° (N)	-8.9	-5.1 [†]	-3.0	0.1	1.8	-	-	-	-	-
90° (E)	-3.9	-3.7	-0.9	-	-	-	-	-0.1	-	-
180° (S)	-8.1	-5.3	-2.7	0.0	1.9	0.6	-	-4.3	-4.7	-
240° (WSW)	-7.2 [†]	-8.3	-2.7	-0.9	0.1	1.0	-1.9	-5.9	-4.7 [†]	-
270° (W)	-7.2 [†]	-8.0	-2.2	-0.9	-0.2	1.3	-1.6	-6.0 [†]	-	-



† Indicates that the background correction has not been performed due to the “turbine on” and “turbine off” data being too similar

- Location 3: Daytime

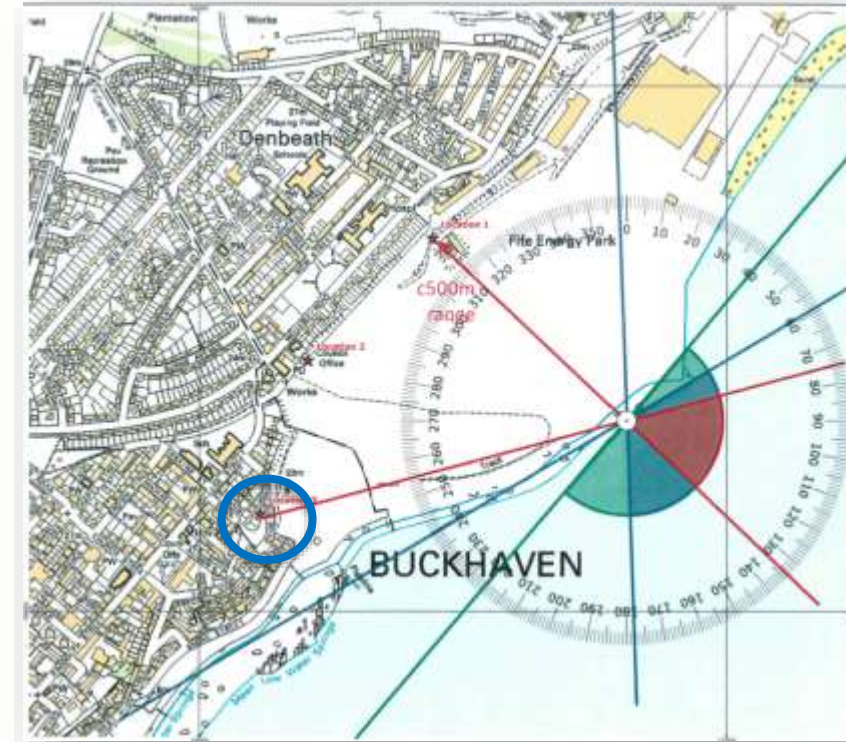
Wind Direction Sector Centre	Standardised 10m Height Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
0° (N)	-4.3 [†]	-4.5 [†]	-5.1	-0.9	-	-	-	-	-	-
90° (E)	-1.5	0.2	0.9	-	-	-	-	-	-	-
180° (S)	-1.6 [†]	0.3	2.0	4.1	-	-	-	5.0[†]	-	-
240° (WSW)	-4.5 [†]	-2.6	1.5[†]	2.9[†]	-0.2	-1.4	2.3[†]	4.7[†]	-	-
270° (W)	-4.7 [†]	-3.5 [†]	0.7[†]	2.2[†]	-0.8	-2.6	1.9[†]	3.9[†]	-	-



† Indicates that the background correction has not been performed due to the “turbine on” and “turbine off” data being too similar

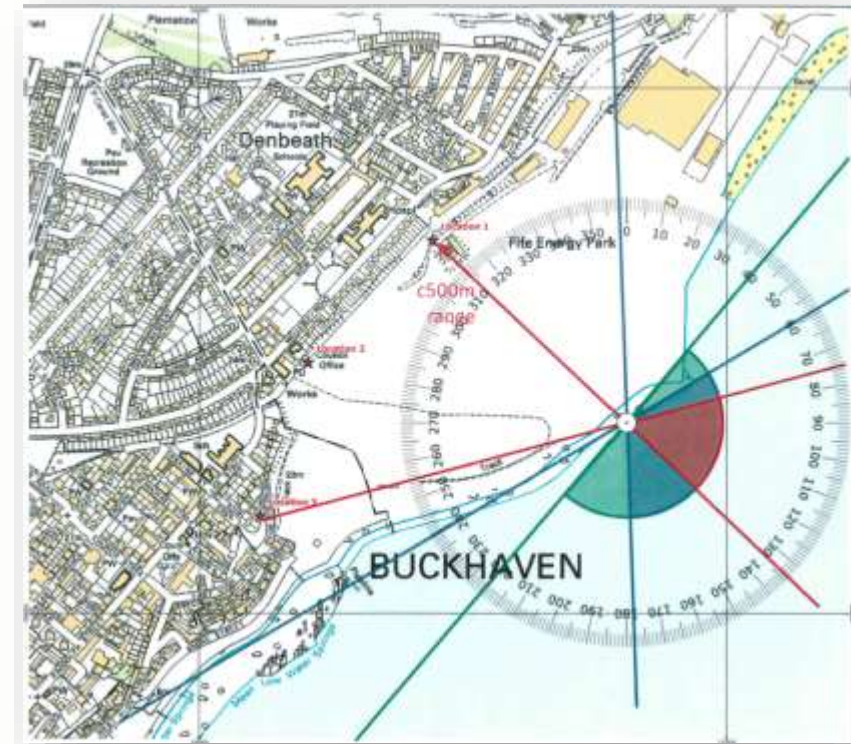
- Location 3: Night-time

Wind Direction Sector Centre	Standardised 10m Height Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
0° (N)	-8.4 [†]	-8.6 [†]	-9.2	-5.0	-	-	-	-	-	-
90° (E)	-5.6	-3.9	-3.2	-	-	-	-	-	-	-
180° (S)	-5.7 [†]	--3.8	-2.1	0.0	-	-	-	3.1[†]	-	-
240° (WSW)	-8.6 [†]	-6.7	-2.6 [†]	-1.2 [†]	-2.0	-0.3	2.2[†]	2.8[†]	-	-
270° (W)	-8.8 [†]	-7.6 [†]	-3.4 [†]	-1.9 [†]	-2.6	-1.5	1.8[†]	2.0[†]	-	-



† Indicates that the background correction has not been performed due to the “turbine on” and “turbine off” data being too similar

- Noise Complaint Report to Samsung Heavy Industries from MS LOT (Nov 2015)
 - Noise Diary
 - Turbine shutdown until investigation completed
- OREC Briefing Note – 14th April 2016
 - Additional measurement at Location 2 by OREC
 - 13/08/2015 to 07/04/2016
 - *"Based on the information available, turbine noise levels at the monitoring locations are typically 3 to 5 dB higher under easterly winds as compared to other wind directions."*
 - *"Based on the information available, background noise levels at residential properties are typically 3 to 7 dB higher under easterly winds and 2 to 4 dB higher under southerly winds as compared to other wind directions."*



- Technical Note: Proposed approach to ETSU-R-97 noise limit sharing between ORE Catapult and 2-B developments (Mar 2016)
 - Worst-case predictions
 - *"any identified exceedances do not necessarily require that development to mitigate by the amount presented for the entire wind direction sector under which the exceedance occurs."*
 - *"OREC turbine will not operate under onshore winds (20°-190°) where it has been found to individually exceed the ETSU-R-97 noise limit."*
 - Daytime 7-8 m/s
 - Night-time 6-7 m/s
 - 10 dB below the cumulative noise limit
 - Very cautionary

Table A8: Cumulative Headroom against Cumulative Noise Limit

Receptor	Wind Direction (Deg.)	Standardised Wind Speed at 10 m AGL, ms ⁻¹										
		4	5	6	7	8	9	10	11	12		
Daytime (0700-2300)												
20 Wellesley Road	20-190	-5.2	-4.6	-3.8	-2.4	-2.4	-11.0	-10.8	-10.7	-13.2		
94 Wellesley Road	20-190	-3.4	-1.4	-0.7	2.1	3.5	-4.8	-4.9	-6.7	-9.2		
12 Erskine Street	20-190	-7.0	-6.5	-5.1	-4.9	-5.9	-11.9	-12.6	-14.5	-15.7		
20 Wellesley Road	190-20	-7.7	-5.5	-3.2	-0.8	-1.4	-1.6	-2.7	-2.7	-2.7		
94 Wellesley Road	190-20	-6.0	-4.3	-2.6	-1.9	-2.0	-3.0	-4.6	-5.3	-6.7		
12 Erskine Street	190-20	-6.7	-4.0	-1.6	-2.8	-5.7	-9.4	-10.3	-10.3	-10.3		
Night-time (2300-0700)												
20 Wellesley Road	20-190	-3.5	-0.3	1.5	-3.6	-6.1	-6.9	-7.5	-7.3	-7.3		
94 Wellesley Road	20-190	-3.1	0.1	3.1	4.7	0.8	-0.7	-2.2	-3.7	-1.5		
12 Erskine Street	20-190	-5.3	-3.8	-1.4	-5.4	-8.8	-10.4	-12.6	-12.9	-12.9		
20 Wellesley Road	190-20	-6.6	-3.5	-0.5	1.9	2.1	0.2	-0.4	-0.4	-0.4		
94 Wellesley Road	190-20	-5.4	-2.2	0.8	3.0	2.3	0.7	-0.9	-2.3	-4.2		
12 Erskine Street	190-20	-7.0	-3.9	-0.9	1.4	1.7	-10.7	-11.2	-11.2	-11.2		

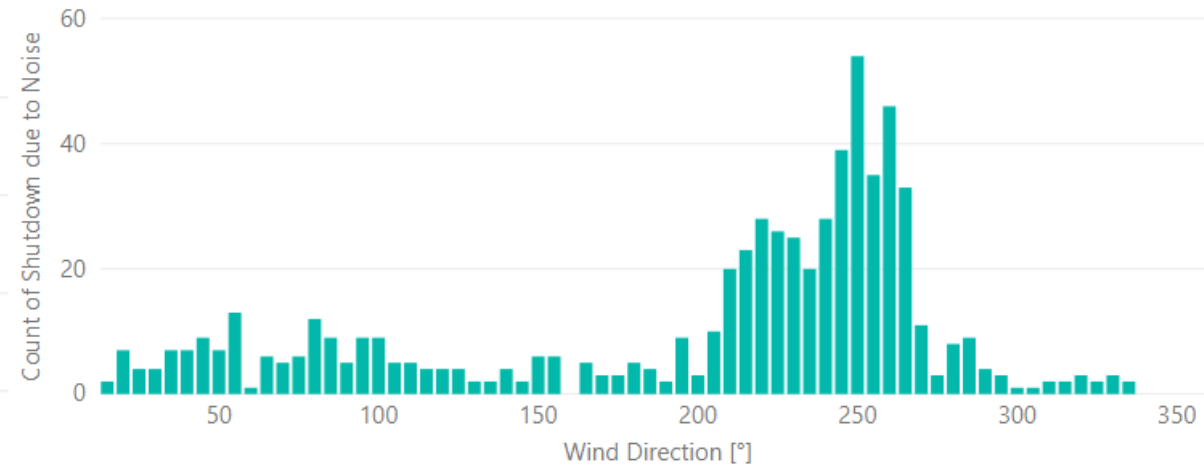
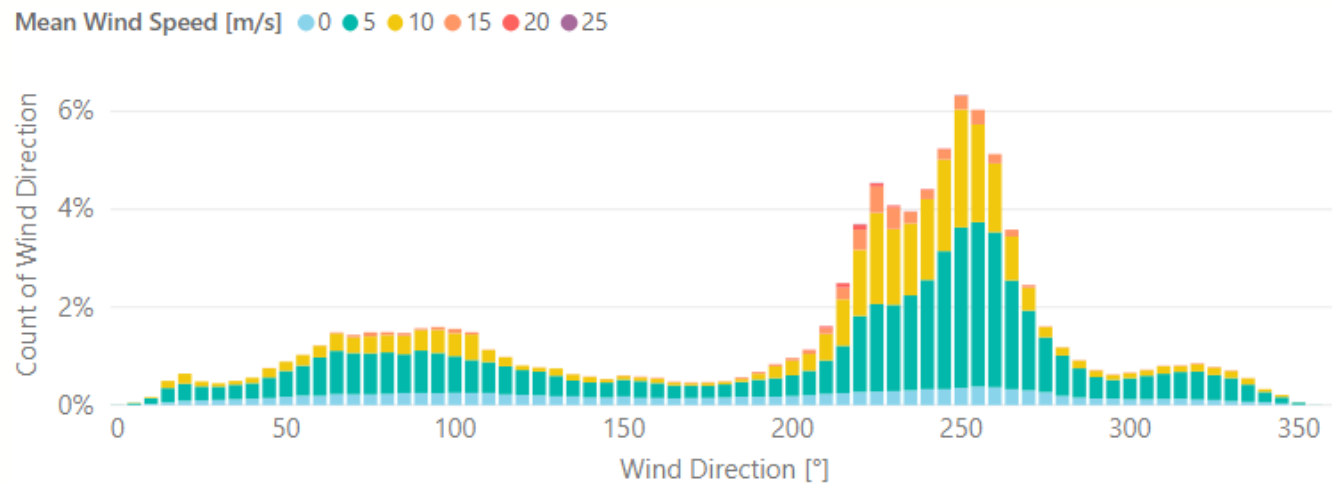
Table 3: Headroom Relative to Apportioned Noise Limits (OREC)

Receptor	Wind Direction (Deg.)	Standardised Wind Speed at 10 m AGL, ms ⁻¹										
		4	5	6	7	8	9	10	11	12		
Daytime (0700-2300)												
20 Wellesley Road	20-190	-5.2	-4.6	-3.8	-	-	-11.0	-10.8	-10.7	-13.2		
94 Wellesley Road	20-190	-3.4	-1.4	-0.7	-	-	-4.8	-4.9	-6.7	-9.2		
12 Erskine Street	20-190	-7.0	-6.5	-5.1	-	-	-11.9	-12.6	-14.5	-15.7		
20 Wellesley Road	190-20	-7.7	-5.5	-3.2	-0.8	-1.4	-1.6	-2.7	-2.7	-2.7		
94 Wellesley Road	190-20	-6.0	-4.3	-2.6	-1.9	-2.0	-3.0	-4.6	-5.3	-6.7		
12 Erskine Street	190-20	-6.7	-4.0	-1.6	-2.8	-5.7	-9.4	-10.3	-10.3	-10.3		
Night-time (2300-0700)												
20 Wellesley Road	20-190	-3.5	-0.3	-	-	-6.1	-6.9	-7.5	-7.3	-7.3		
94 Wellesley Road	20-190	-3.1	0.1	-	-	0.8	-0.7	-2.2	-3.7	-1.5		
12 Erskine Street	20-190	-5.3	-3.8	-	-	-8.8	-10.4	-12.6	-12.9	-12.9		
20 Wellesley Road	190-20	-6.6	-3.5	-0.5	1.9	2.1	0.2	-0.4	-0.4	-0.4		
94 Wellesley Road	190-20	-5.4	-2.2	0.8	3.5	2.5	0.7	-0.9	-2.3	-4.2		
12 Erskine Street	190-20	-7.0	-3.9	-0.9	1.4	1.7	-10.7	-11.2	-11.2	-11.2		

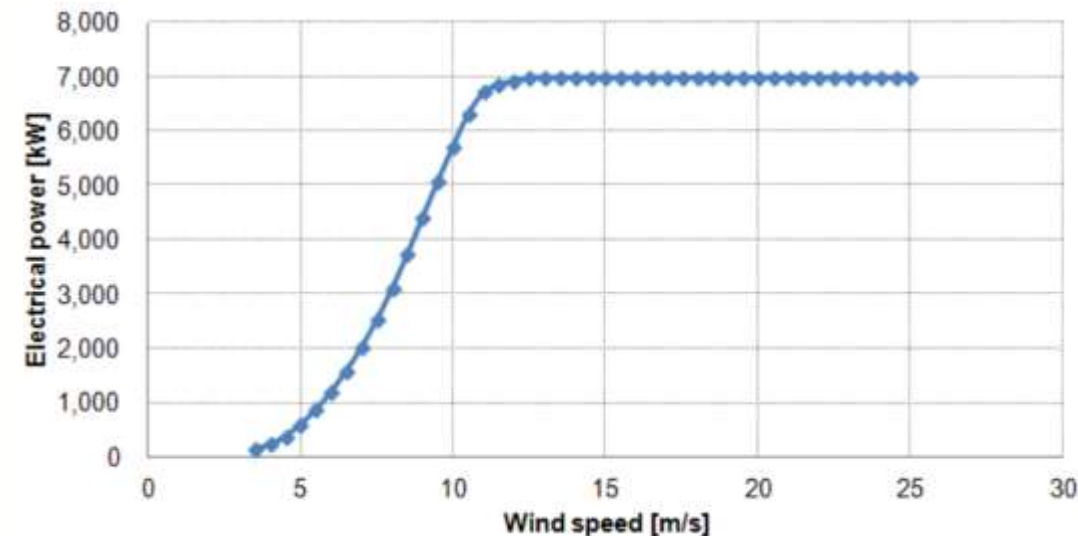
Initial Control Strategy

- Divided into centred sectors
- Key
 - DAY = Turbine OFF between 0700-2300
 - NIGHT = Turbine OFF between 2300-0700
 - OFF = Turbine OFF at all times
- Crude and cautionary strategy – turbine shutdown
 - 1/3 of shutdowns due to noise
 - Increased fatigue
 - Lost operation

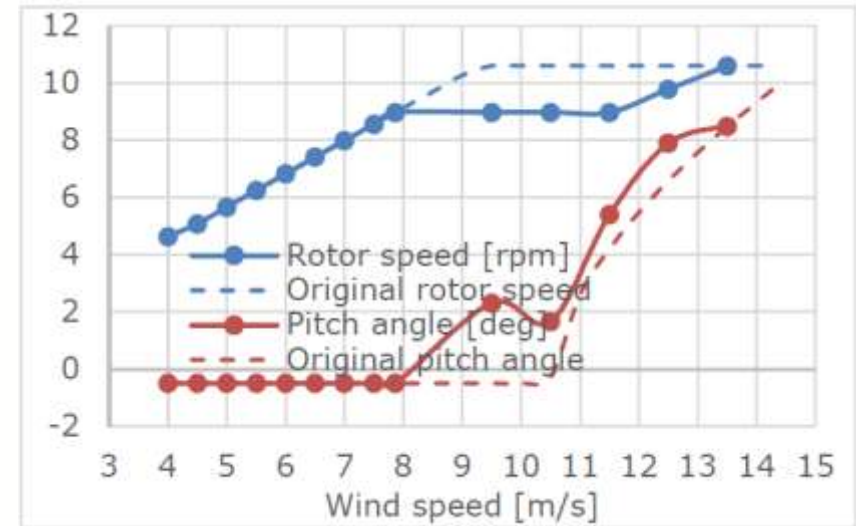
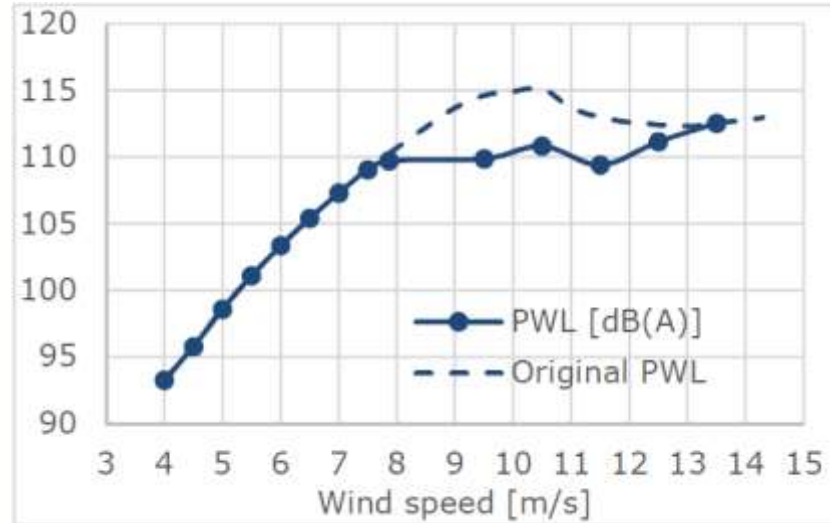
WS Hub	6	7	8	9	10	11	12	13	14	15
WS 10m	3	4	5	6	7	8	9	10	11	12
0 Bin 0 to 15				OFF						
0 Bin 15 to 30				OFF						
0 Bin 30 to 45				OFF						
90 Bin 45 to 60		DAY	DAY							
90 Bin 60 to 75		DAY	DAY							
90 Bin 75 to 90		DAY	DAY							
90 Bin 90 to 105		DAY	DAY							
90 Bin 105 to 120		DAY	DAY							
90 Bin 120 to 135		DAY	DAY							
180 Bin 135 to 150		DAY	DAY	OFF						
180 Bin 150 to 165		DAY	DAY	OFF						
180 Bin 165 to 180		DAY	DAY	OFF						
180 Bin 180 to 195		DAY	DAY	OFF						
180 Bin 195 to 210		DAY	DAY	OFF	OFF	NIGHT				
180 Bin 210 to 225		DAY	DAY	OFF	OFF	NIGHT				
270 Bin 225 to 240				OFF	OFF	NIGHT				
270 Bin 240 to 255				OFF	OFF	NIGHT				
270 Bin 255 to 270				OFF	OFF	NIGHT				
270 Bin 270 to 285				OFF	OFF	NIGHT				
270 Bin 285 to 300					OFF	NIGHT				
270 Bin 300 to 315					OFF	NIGHT				
0 Bin 315 to 330				OFF						
0 Bin 330 to 345				OFF						
0 Bin 345 to 360				OFF						



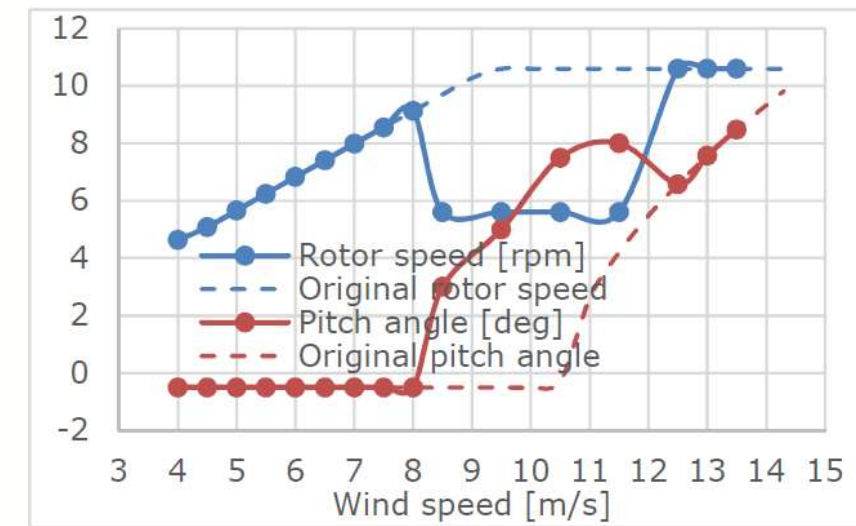
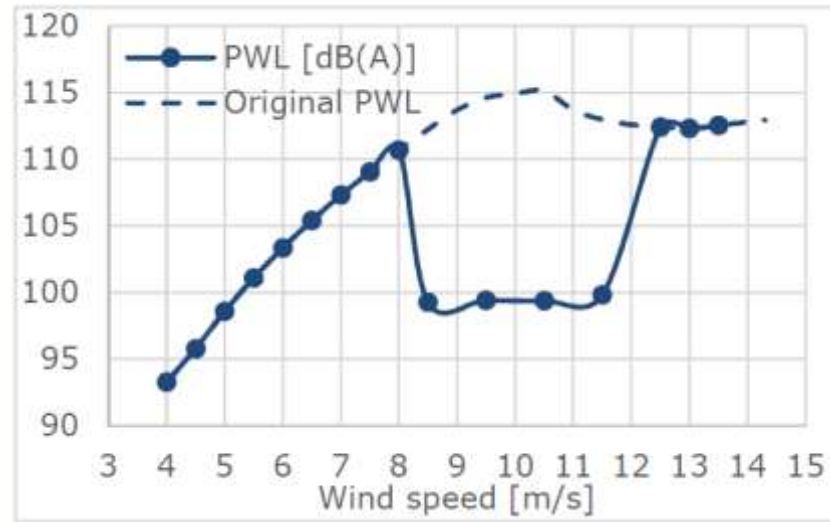
- Assumed that the only source of noise is aerodynamic, therefore it is possible to reduce by means of a more sophisticated **curtailment** strategy
 - Below rated wind speed
 - Modification of **rotational speed only**
 - Pitching the blade to feather is usually more effective at reducing power, rather than noise.
 - Above rated wind speed
 - Coupled modification of **pitch angle and rotational speed**
 - Keep torque to rated value
 - High torque and a low rotational speed preferable
 - Pitch angle tuning to for the West sector (270°).
 - Power maximisation
- Constraints
 - Constraints
 - Generator – rated speed and torque
 - Aerodynamic – ensure the blade does not stall
 - Structural – 1st tower mode



- North Sector (0°)



- West Sector (270°)



- Thorough investigation of Damage Equivalent Loads (DELs) still ongoing.
- Total Control - <https://www.totalcontrolproject.eu/>
 - Wind Power Plant Controller
 - Move the WPP controller design philosophy from individual optimization of WT operation to a coordinated optimization of the overall WPP performance.
 - Maximizing energy production
 - Reducing Operating Costs
 - Providing ancillary services (reserves)
 - Included in DNV GL Controller Update planned for April 2020

Contact us

Email us: info@ore.catapult.org.uk

Visit us: ore.catapult.org.uk

Engage with us:



GLASGOW

BLYTH

LEVENMOUTH

HULL

ABERDEEN

CORNWALL

PEMBROKESHIRE

CHINA