Wind Energy is a Towering Success – but Why?

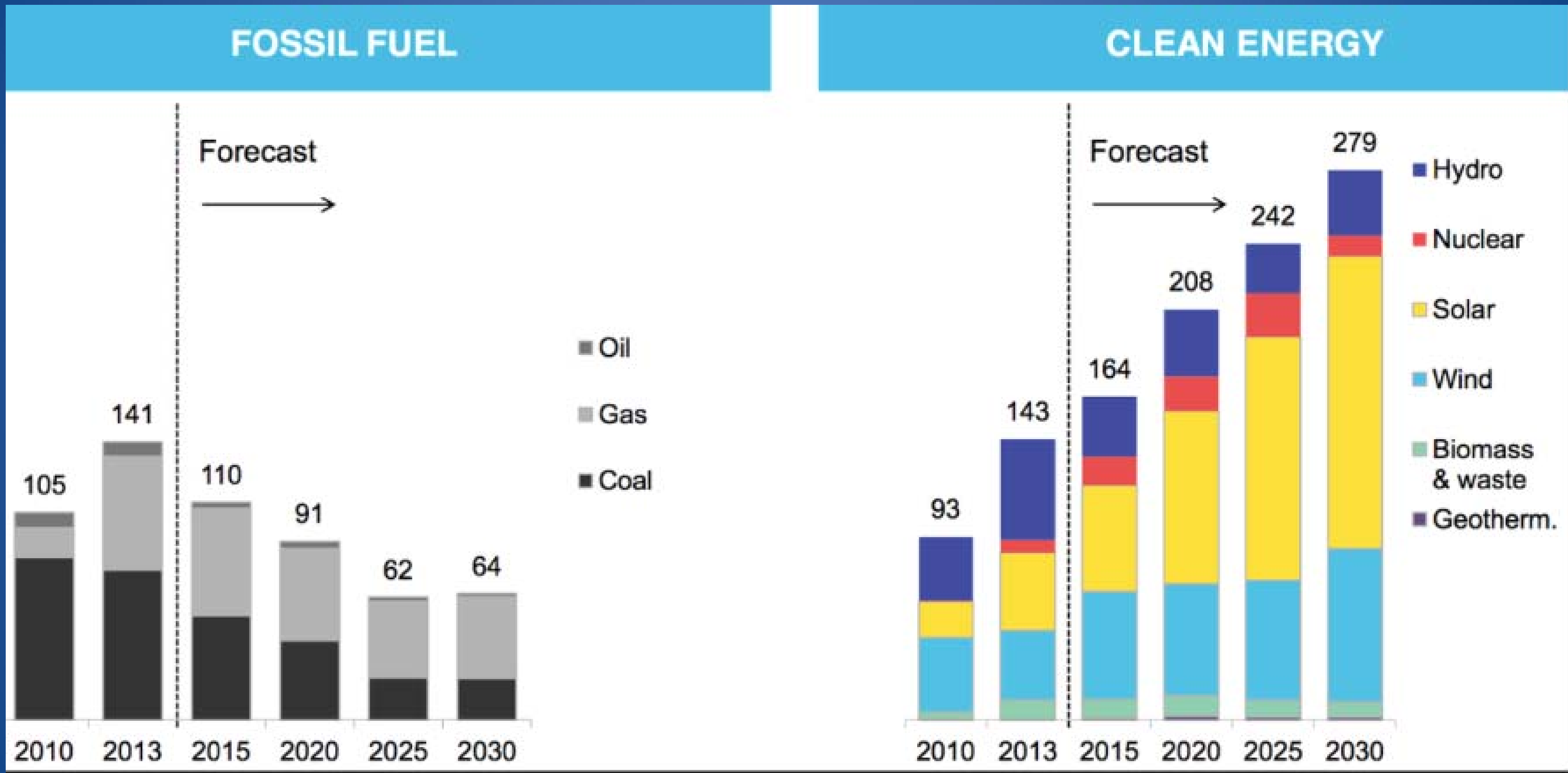
SuperGen
Strathclyde University
26th May 2016

Mark Hancock, GE

- Wind –Successful Energy
- Growth Factors
- Physics Matters e.g.Multi-Rotors
- ‘New’ Technologies & Gestation
- Gate-keeping in Industry

Success!

Power generation capacity additions (GW)

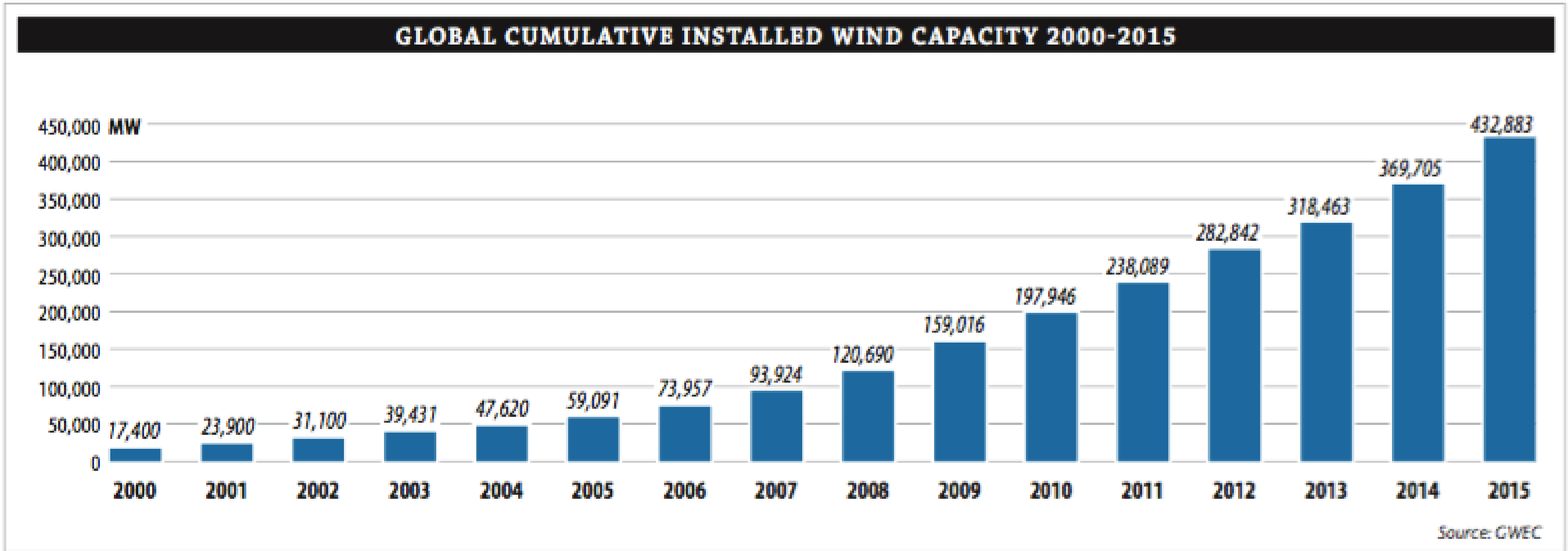


Globally Renewables overtook Fossil Fuels in GW/year installed in 2014

Bloomberg New Energy Finance

Global Installation of Wind was a record 63GW in 2015

(UK average electrical demand 38GW)



From Lazard Investment Bank 2014

Plant Type (USD/MWh)	Low	High
Solar PV-Rooftop Residential	180	265
Solar PV-Rooftop C&I	126	177
Solar PV-Crystalline Utility Scale	72	86
Solar PV-Thin Film Utility Scale	72	86
Solar Thermal with Storage	118	130
Fuel Cell	115	176
Microturbine	102	135
Geothermal	89	142
Biomass Direct	87	116
Wind-Onshore	**37**	**81**
Energy Efficiency	0	50
Battery Storage	265	324
Diesel Generator	297	332
Gas Peaking	179	230
IGCC	102	171
Nuclear	92	132
Coal	66	151
Gas Combined Cycle	61	87

Even ignoring external costs …Wind is the cheapest (in many areas)

Cost Reductions 2010 -2015 solar photovoltaic (- 68%), onshore wind (-51%)

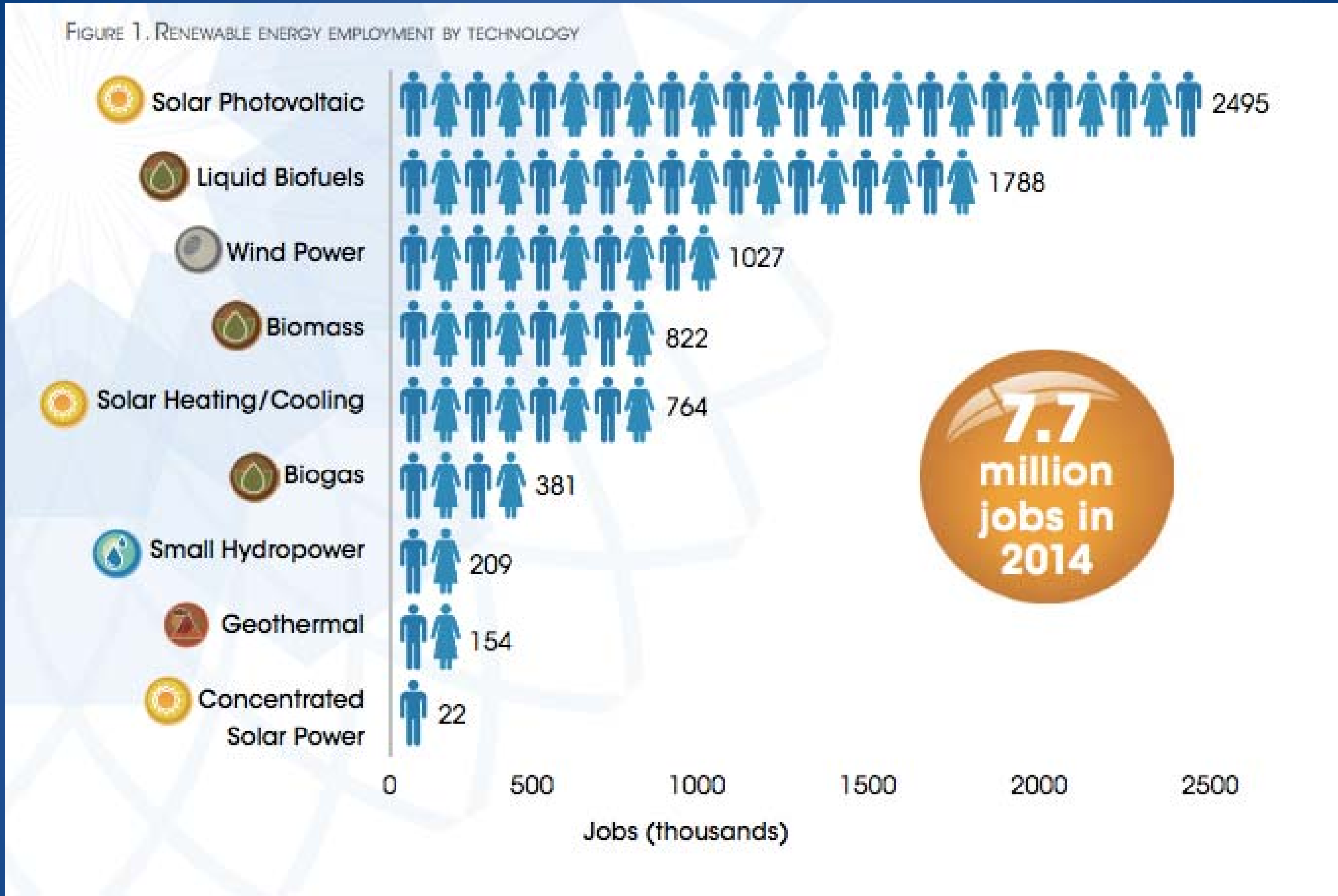
Lifecycle greenhouse gas emissions by electricity source.

Technology	Description	50th percentile (g CO2/kWh$_e$)
Hydroelectric	reservoir	4
Wind	onshore	12
Nuclear	various generation II reactor types	16
Biomass	various	18
Solar thermal	parabolic trough	22
Geothermal	hot dry rock	45
Solar PV	Polycrystalline silicon	46
Natural gas	various combined cycle turbines without scrubbing	469
Coal	various generator types without scrubbing	1001

Wind is almost the top technology for GHG saving
4 x better than Solar, 40x better than gas

Water Consumption per Energy

Energy source	Estimated water consumption (litres/MWh)
• Wind	1
• Gas	1,000
• Coal	2,000
• Nuclear power	2,500
• Oil	4,000
• Hydroelectric power	68,000
• Biomass (1st generation)	178,000



2013-14 UK 19k Jobs in Wind Onshore, 19k Offshore

Wind is a Relatively Popular Energy

‘Support for renewables …consistently high 75-80%

Unchanged from March ..

Onshore Wind	**66%,**
Offshore Wind	**73%,**
Wave and Tidal	73%,
Solar	82%.

For the use of nuclear energy 36% in favour’

From the UK Government’s DECC ‘Public Attitudes Tracker’ ‘Wave 15’ Sept 15

Growth Factors

Energy is too big <u>not</u> to be driven by Politics.

- Long term visions & beliefs
- Shorter term expediency, electoral appeal
- Pressure from Corporations (usually for status quo)

Some National & International Turning Points influencing Wind Energy

1970 Limits to Growth report 'We are going to run out of oil in 30 years'!

1973 Oil Shocks. OPEC raises oil price by 4 times overnight. Project Independence '75 – US to be self-sufficient in energy by 1980 by conservation & alternative energy

1980-86 Californian 'Wind Rush'. 17000 turbines put up in 3 years through generous tax incentives. Kick-started the wind industry

1986 The Chernobyl accident Not nuclear perhaps

1989 UK. Privatisation of Electicity Industry. Breaks up the huge CEGB monoply but creates uncertainty for years.

1992 Man-made Climate Change reality. IPCC set up. UN Framework Kyoto Protocol to limit GHG's signed by 192 parties.

2009 EU Renewables Directive 20% RE by 2020

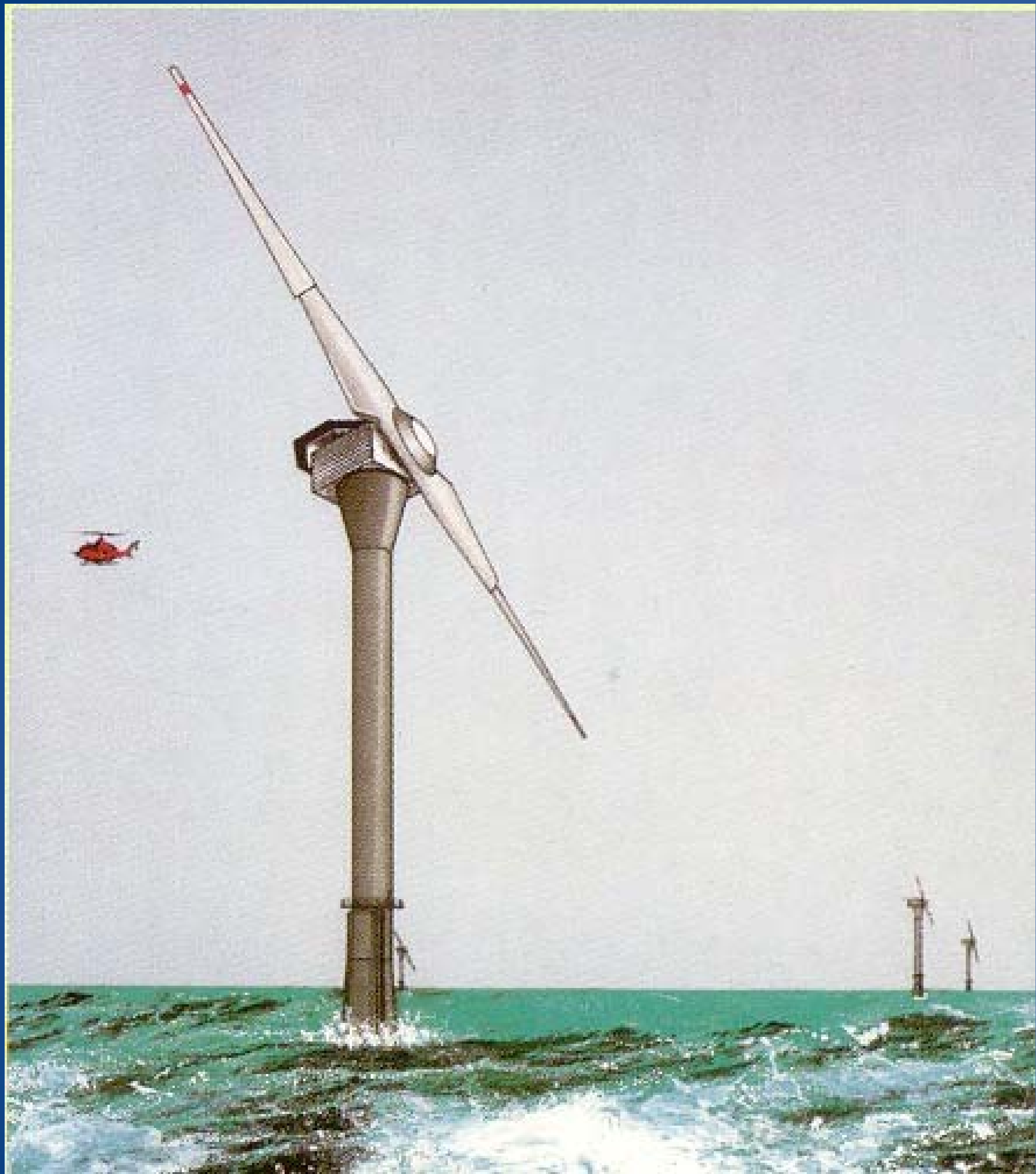
2015 UN Conference, Paris. 195 Countries sign legal agreemt. $<2^{o}$

1992 German Feed-in 2005 US PPA's 2008 UK Climate Change Act

Three Competing Visions at the birth of Modern Wind :-

- Big public utilities giving Wind a nod (slightly disbelieving nod away from nuclear!). UK, Germany, US
- Communitarian, self-sufficient, harmony with nature, good energy, artisanal. Denmark, US, UK
- Free market. California. Appeal to both environmentalists and wealthy tax avoiders

All contributed to Wind's success



Corporate Vision of Offshore Turbines

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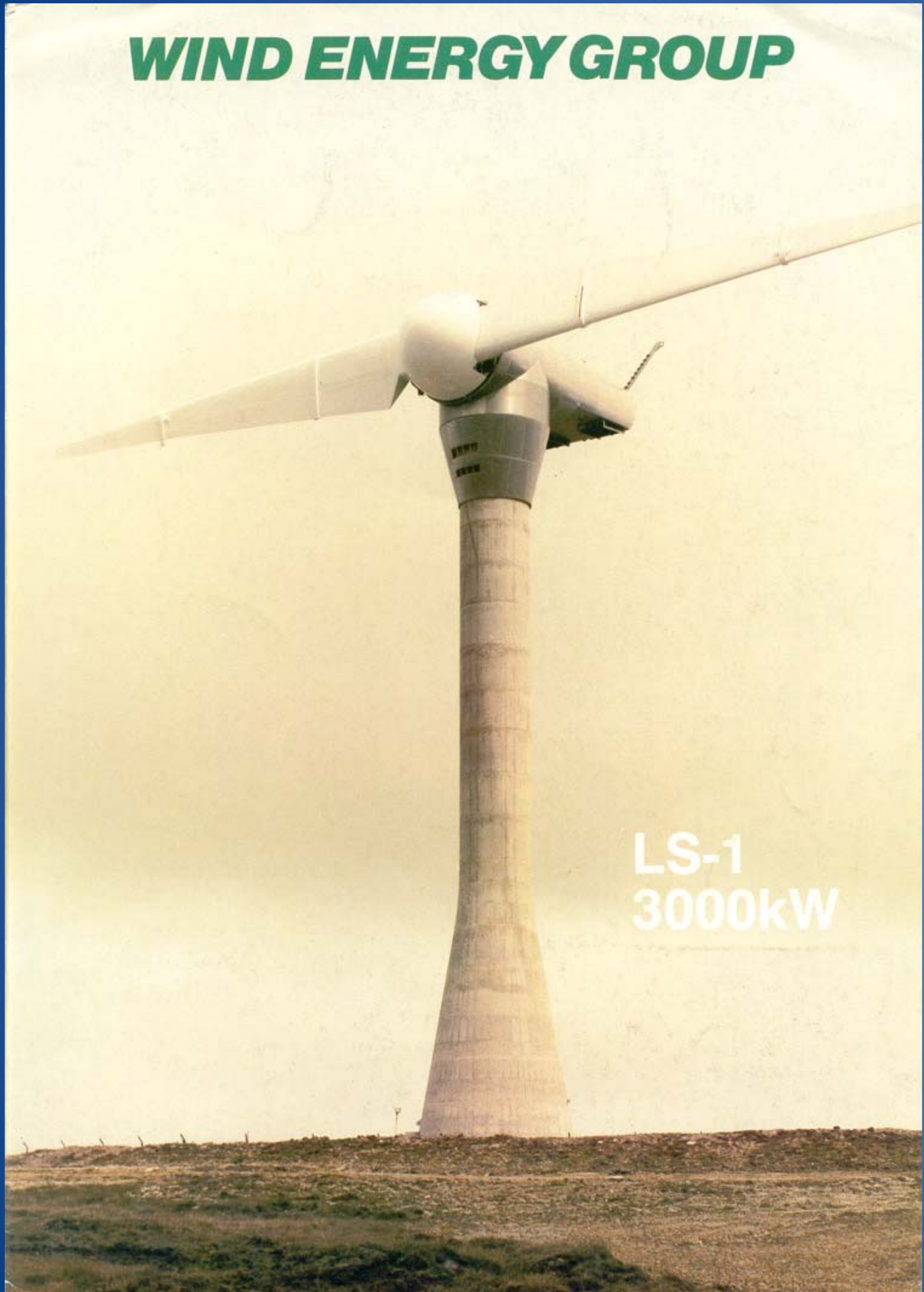
Late 70's



Large Turbines in Practice…

Took British Aerospace, Taylow Woodrow & General Elctric £12million and 7 years to build and it was sold for a £1

Started in the era of Public funding, ended in the period of privatisation

Same story in Germany & USA

The Communitarian Approach

Riso Test Station, Denmark 1979

Courtesy F Rasmussen DTU

A burst of creativity from agricultural engineers

Wind might have died but for the Californian Wind Rush 1982-86

Turbines did not even have to work- at first

But solid Danish Turbines were sucked in too

Wind has become a Disruptive Technology

Innovation that creates a new market and values eventually disrupts existing markets and values network, displacing established market leaders

Disruptive innovations tend to be produced by outsiders. …market leaders resist them , because they are not profitable enough at first and …can take scarce resources away from innovations to compete against current competition.

1985-24 UK Turbines joining the 17000 built in Ca in 3 years

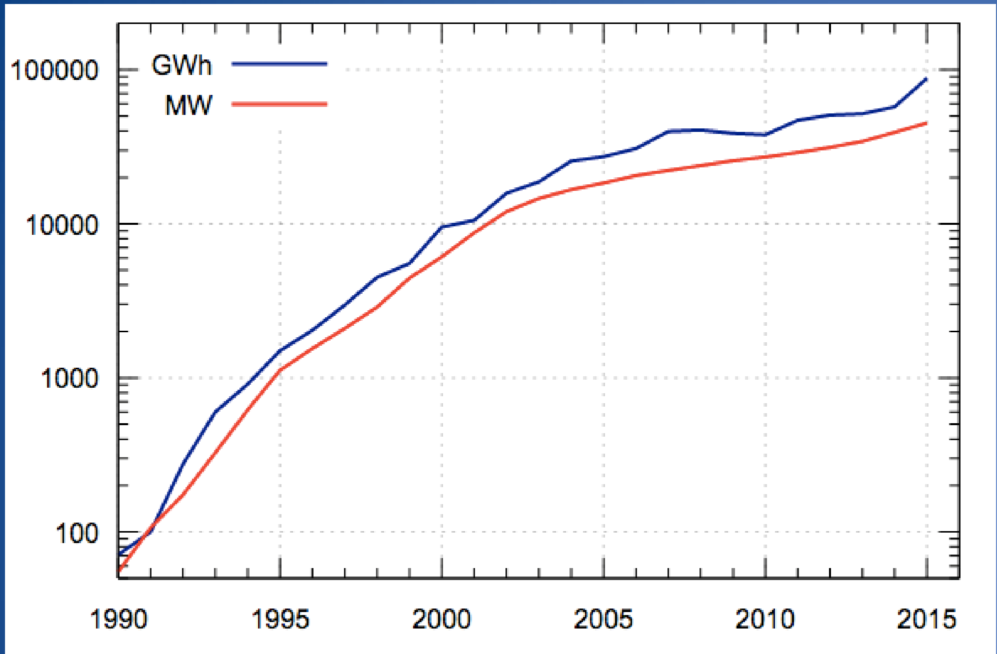
WEG Wind Farm using 12m Composite Technology Blades

Still in action today, 30 years later!

Jobs Created!

UK 1984-5 Production of Blades for Howden in Vosper Hovermarine Southampton

Politics Needs to be Favourable:Conditions Nurturing Example of Germany:



Logarithmic Increase

150,000 jobs

91-9 Electricity Feed-In Act

- Community–led
- 90% euro/kWh for Wind
- Favourable Building Code
- Subsidies to States

2000-12 RE Sources Act

Tarifs Stable for 5+15 years
Utilities obliged to buy RE

2010 "Energiewende"

Climate targets
Transmission 400kV HVDC
Demo Sites, Fraunhofer IWES
co-operatives created to decentralize control and profits.

Why did Wind break through?

Answers from those with decades in the Wind industry:-

Varied but much more about people, society, that wind addressed problems.. than the technology– other than it is accessible

•Didn't arise from aerospace & defense but ..owes success to prosaic farm machinery.. Gipe, US

•Fundamentally simple…it didn't overpromise but kept delivering..not prone to massive cost and time overruns like nuclear…of course subsidy needed. Palmer UK

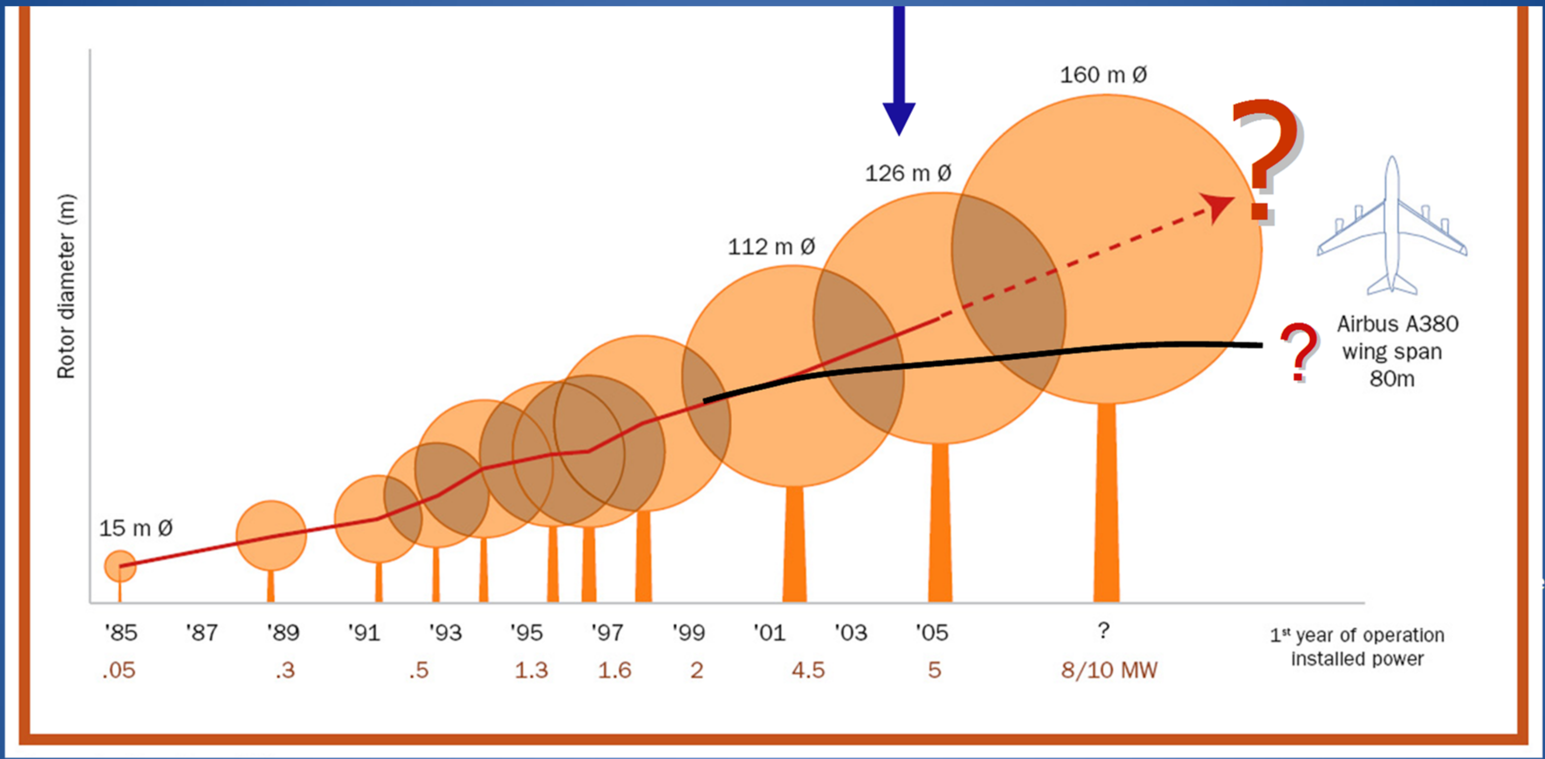
•In the beginning..a network of people around the world…who simply wanted to make the world a better place..created an industry…& it still maintains that spirit, now employing 1 million people... the driver of technical success against insurmountable odds. We work for humanity mot for money. Platts, UK.

•Has the potential to be the backbone of future secure and sustainabable electricity supply...important to perceive Wind as long term. Cost reduction potential still high. Rasmussen Denmark

•Many years it was idealists – but the entry of big players, GE, Siemens made it an industry. Suddenly turtle necks out and ties in! Support Programmes. Now known superiorty against nuclear. Nath, Germany

•Passionate people who wanted to make it happen. Can-do. Offshore because onshore couldn't deiver in the UK. Valpy, UK

The Physics Cannot be Ignored



Swept area α Length^2 (>Energy capture > earnings)

Volume α Length^3 (>Mass> cost)

(but smaller effect V_{wind} α $H^{1/7}$ so Power α Length$^{3/7}$)

It's Possible for Physics to be Ignored…

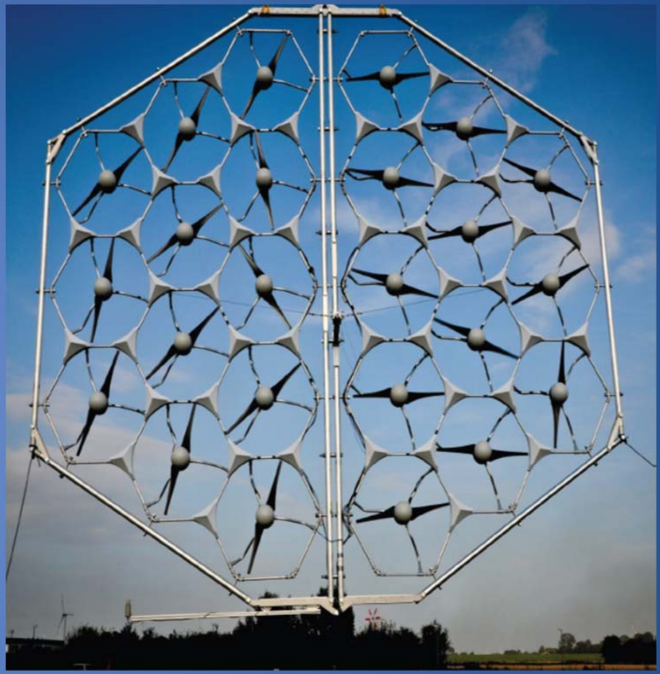
Swept area α Length^2, Volume α Length^3

a wee while!

Multi-rotor System

Honnef 1930, Lagerway 1990!!

EU Innwind report 2016



Total mass/cost of rotor blades and drive trains for 20MW, 45 rotor system is 1/6th of a single equivalent turbine's.

80% turbine CAPEX saving.

15%-20% CoE Advantage.

Also: Support loads lower, component standardisation & production volume and development risk improved, easier maintenance, lower failure impact, improved AEP/area

Peter jamieson, Strathclyde University

Multi-rotor announced on 18th April 2016

Long Gestation periods are common

Bend Twist example

≈1983 Offaxis fibre coupled twist and bend in BWEA conference – but not sure how to use it!

1997 Bend twist coupling for avoiding load peaks

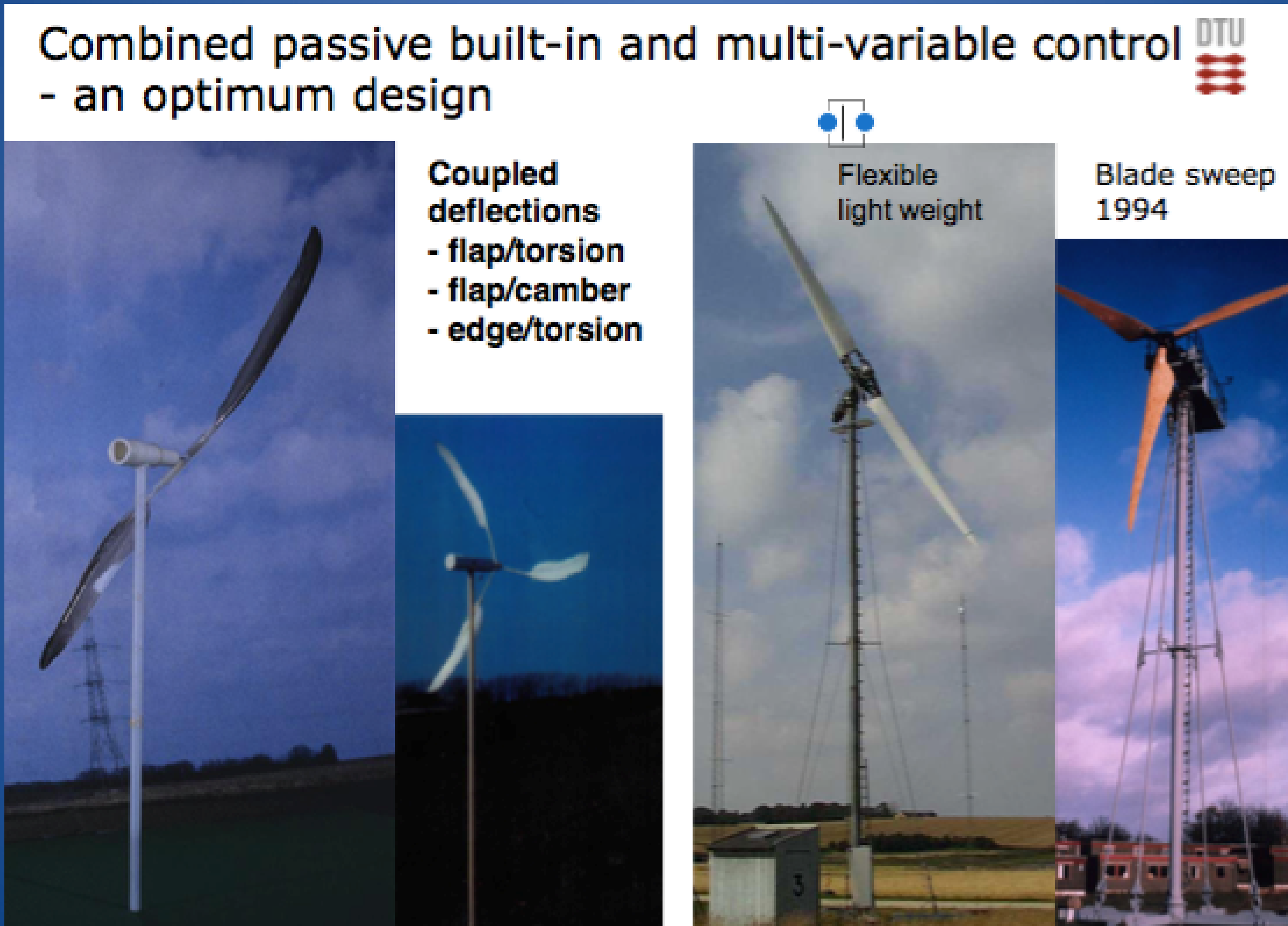
A98-16853

AIAA-98-0029

AEROELASTIC BEHAVIOR OF TWIST-COUPLED HAWT BLADES

Don W. Lobitz and Paul S. Veers
Sandia National Laboratories
Albuquerque, New Mexico 87185-0439

1990's Small Turbines Experimenting with Flexible Rotors



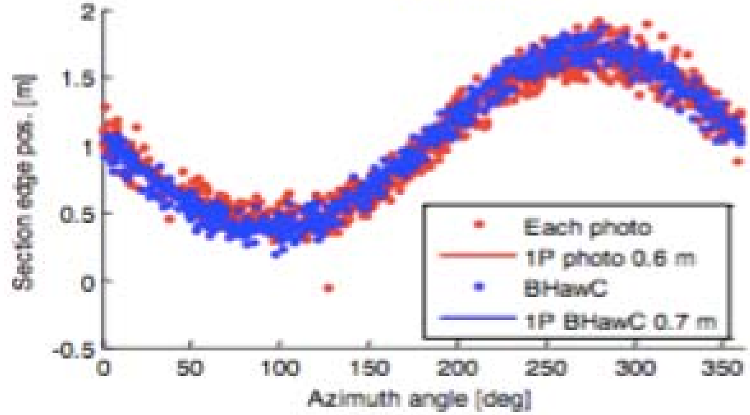
Aero-elastic response validation

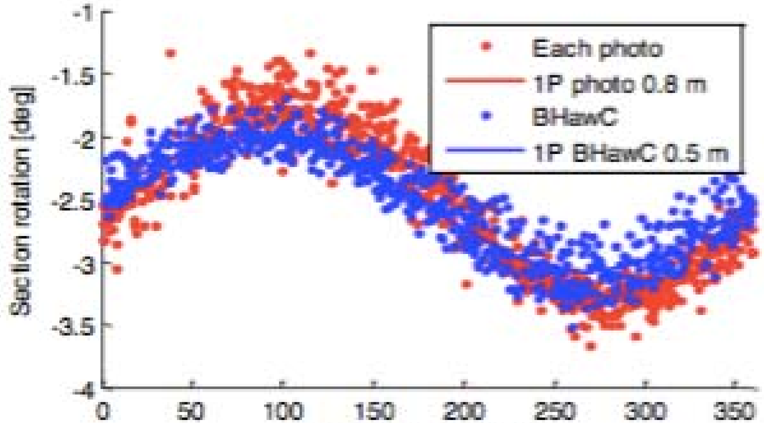
Test for performance

Targets on blade in operation

Show video…

Measurement
Simulation



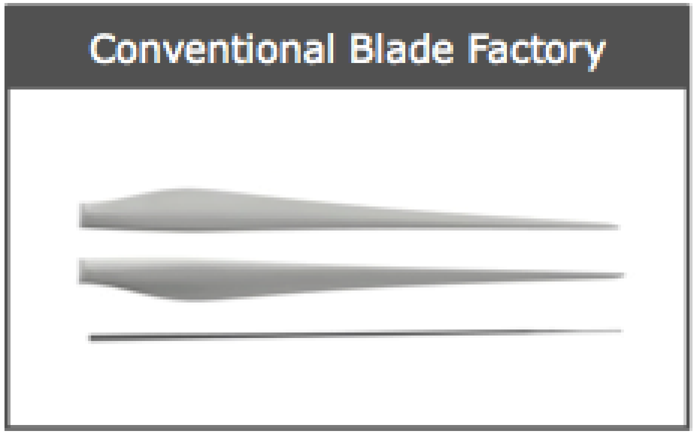


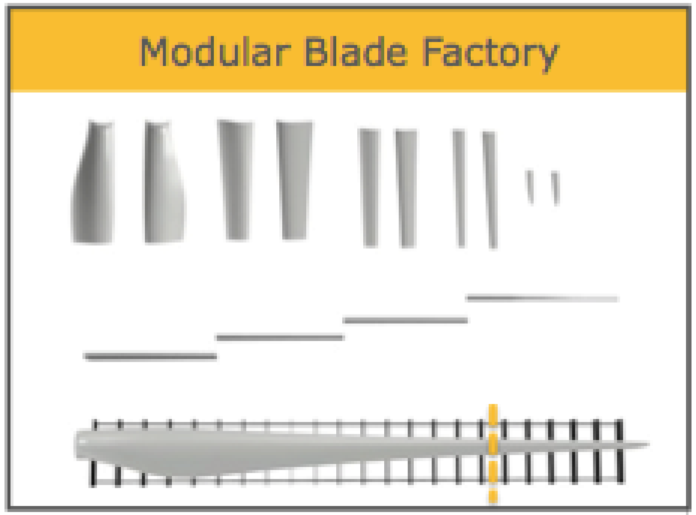
Bend Twist now Mainstream

‘Industrialisation’ will be
Big Step for Manufacturing
Quality & Cost

- Standardisation
- Customisation
- Modularisation

Example of Blade Modularisation





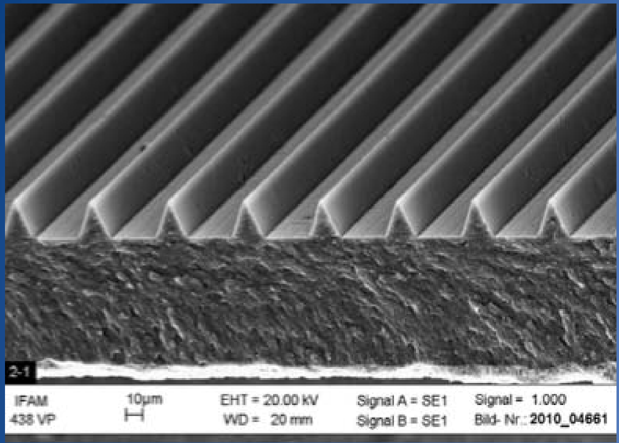
- Ultra-large components
- Manufacturing process challenges
- Quality challenges
- Tends to create heavy blades
- High, blade-specific tooling costs

- Small component manufacture

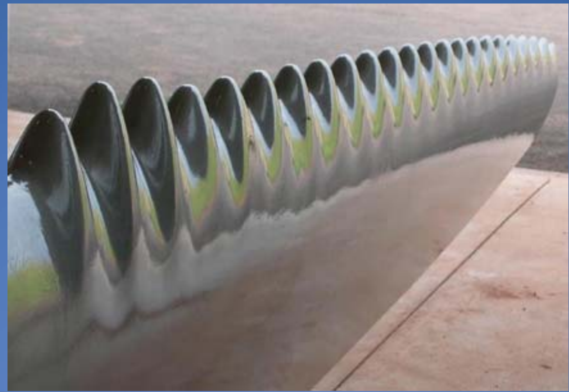
BLADE DYNAMICS

Example of Blade Modularisation

Some Useful Add-on Technologies

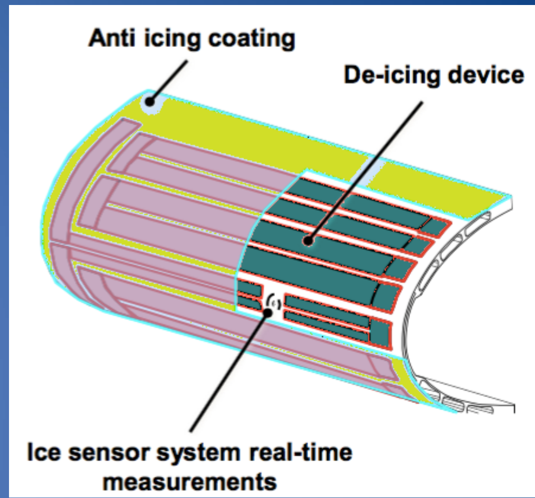


Riblets (America's cup 1987). Drag-Δ 5-6%. Wind:TRL1-2

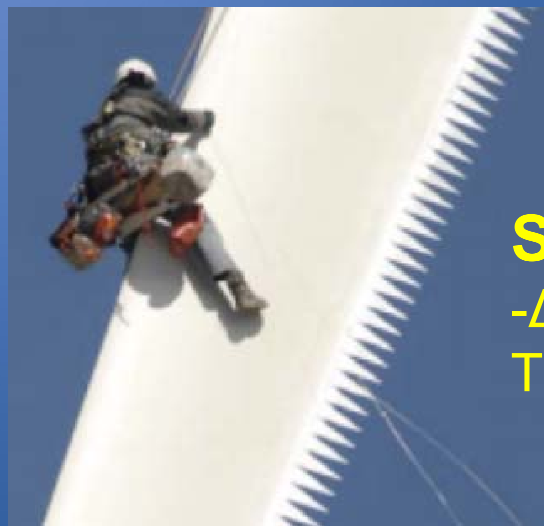


Tubercle LE's. Stall delay. TRL2-4?

Anti-Ice – TRL2-6

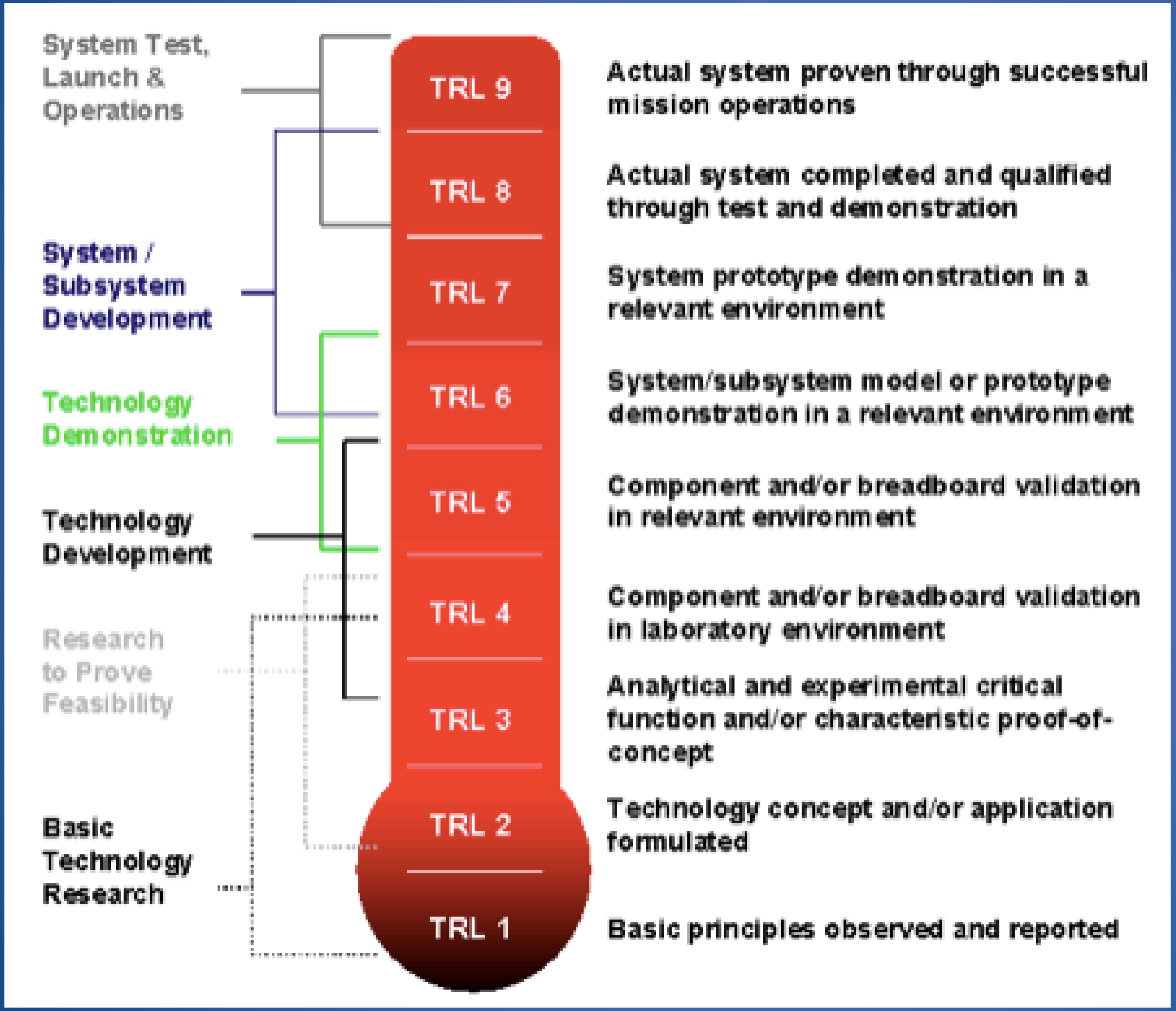


Erosion Free LE's
Only TRL3-5. Should be TRL 9!



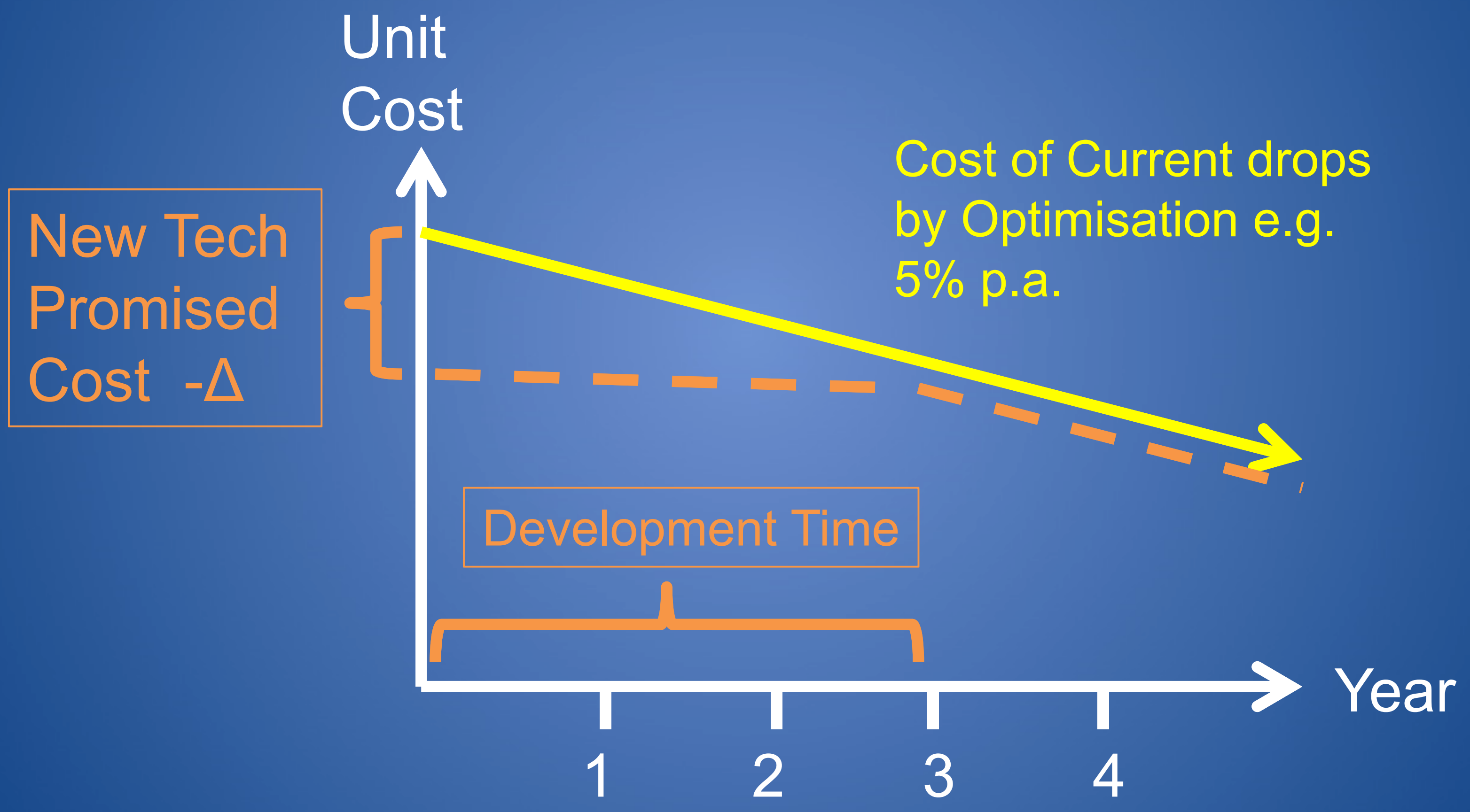
Serrated TE
-Δ 2dBA noise
TRL 7-8

Technical Readiness Levels



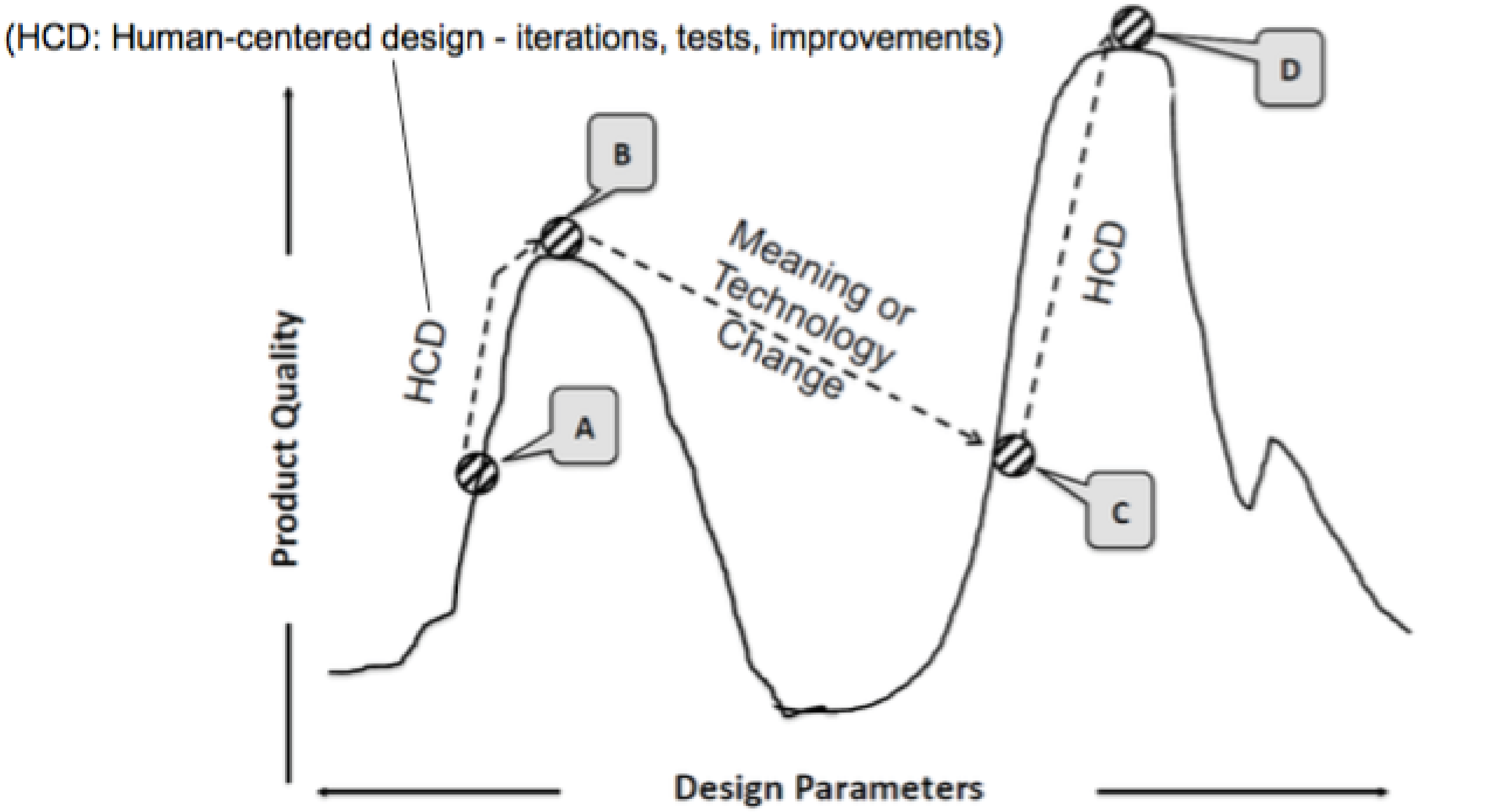
Industry often uses TRL's or similar as a common languag e

New Technology has to do <u>much</u> better than the Current one on Cost



The Production Dept. tends to look at the yellow line pessimistically and the Design Dept. the red line optimistically!

Quality Risks with a new Technology



Source: INCREMENTAL AND RADICAL INNOVATION: DESIGN RESEARCH VERSUS TECHNOLOGY AND MEANING CHANGE

Donald A. Norman and Roberto Verganti

Conclusions

- Wind energy is successful globally now but it is becoming more reliable, cost-effective year on year
- Realities of physics and business need to be respected for new technologies
- Really Disruptive technologies need long term vision and support

The End