Design drivers

Siemens Gamesa Renewable Energy

13 September 2017

We are **stronger** than ever

Order Book
€20 b

Products and technology in
90+
countries

close to
27,000
employees

Annual revenue
€10 b

Installed capacity
75 GW

Market capitalization
€14 b

Figures as of May 2017

SIEMENS Gamesa
RENEWABLE ENERGY

A message from **Markus Tacke, CEO**

"Our company, Siemens Gamesa Renewable Energy, has tremendous capabilities. We have a unique opportunity to establish ourselves as a market leader and a technology leader, while at the same time delivering sustainable value to our many stakeholders. I am proud to lead this effort."

Markus Tacke, CEO

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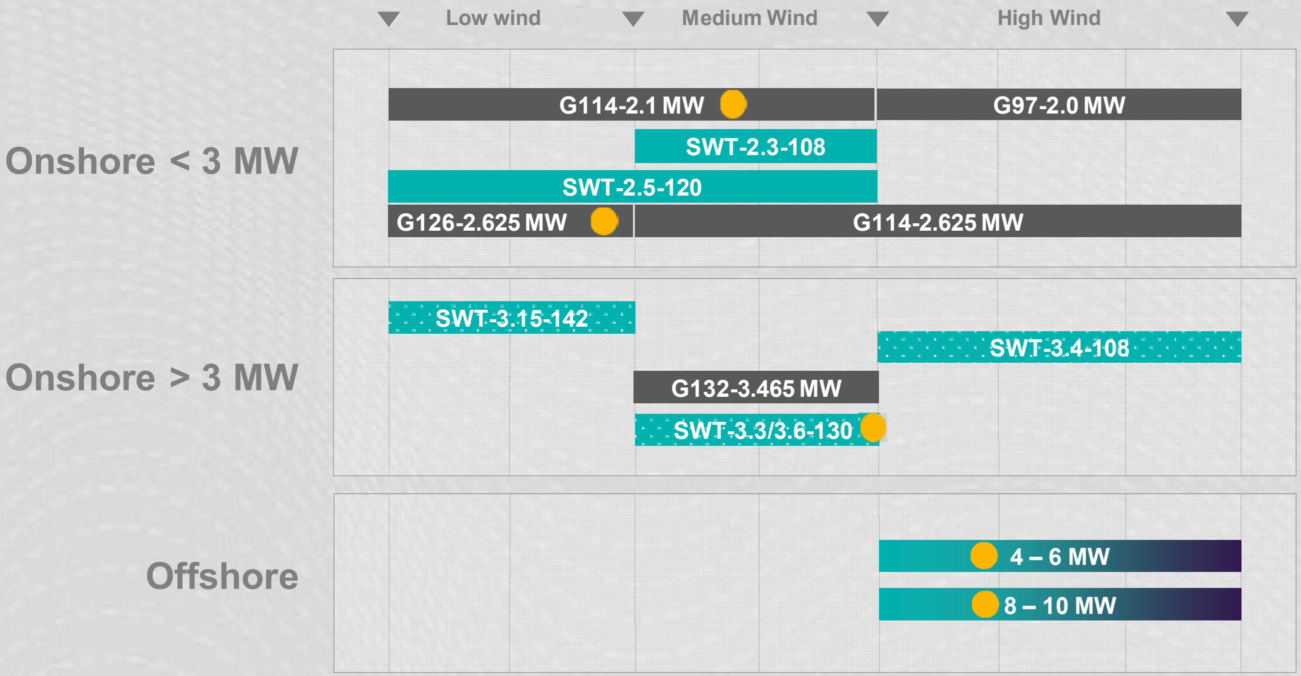
A broad and versatile **Product Portfolio**

- Siemens platform
- Gamesa platform
- Adwen platform
- Industry Awards 2014-2016 "Wind Power Monthly"



Gamesa 2.0 MW platform: Geared turbine with DFIG
Gamesa 2.5 / 3.3 MW platforms: Geared turbine with DFIG (PMG + FC optional)
ADWEN 5.0/8.0 MW platform: Geared turbine with PMG + FC

Siemens G2 platform: Geared turbine with asynchronous generators and FC
Siemens D3/D6 platform: Direct Drive turbine with PMG + FC

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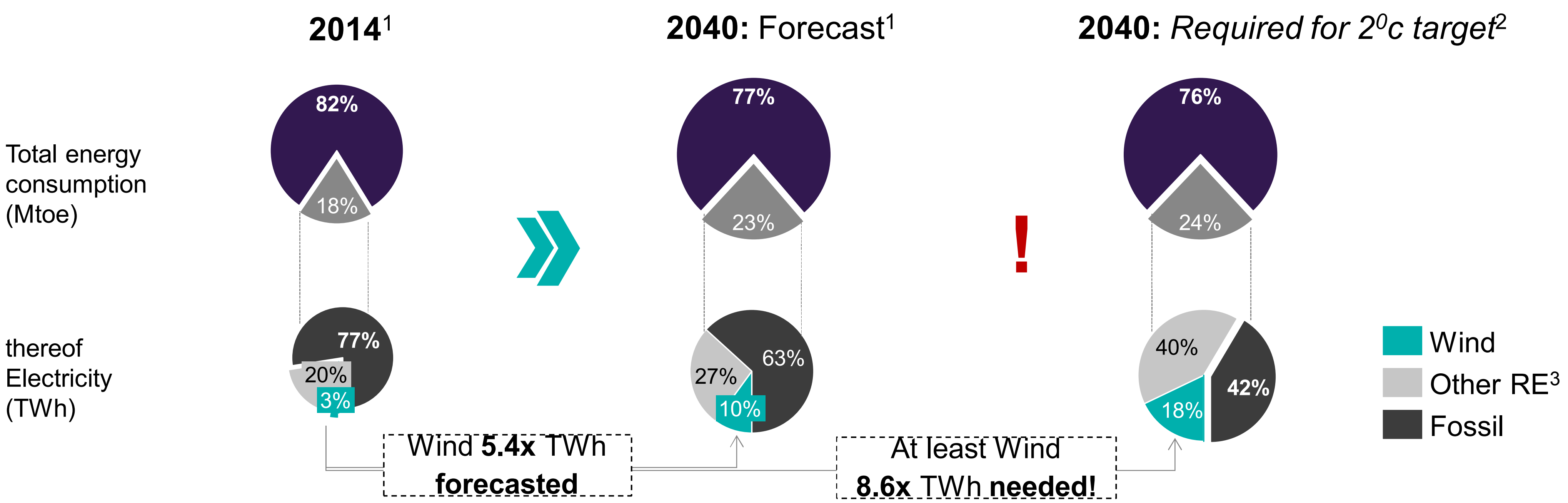
There is a market for renewables

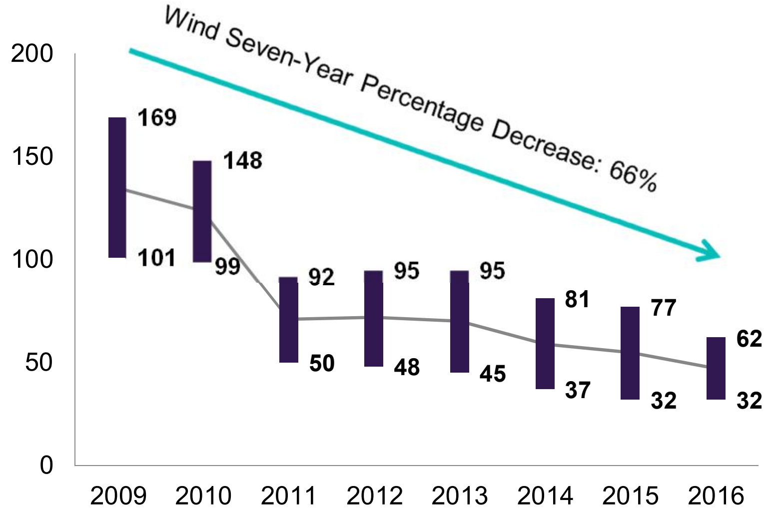


1) IEA WEO 2016 NPS   2) 450 scenario - Required scenario for 2^0c Paris target   3) Other RE incl. Hydro

Significant growth of renewables beyond all current FC required to reach the ambitious 2ºC target

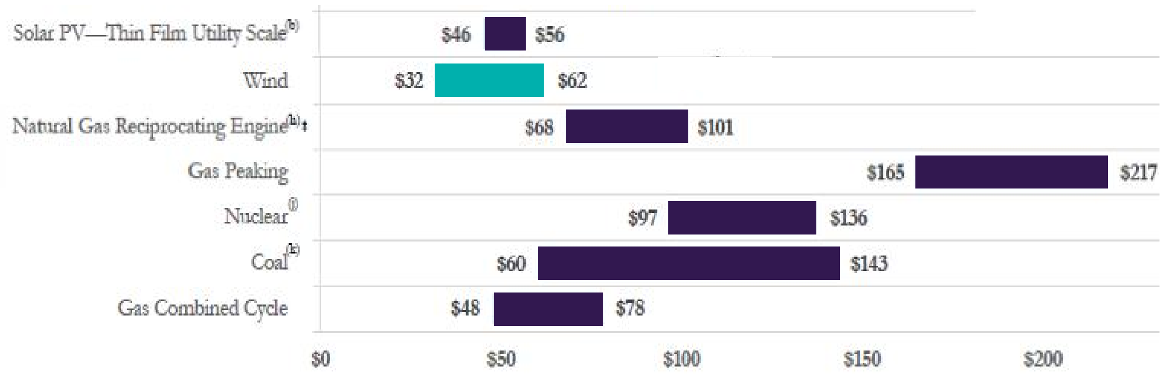
Wind power needs to be competitive with all energy sources

Levelized Cost of Electricity – Wind



Source: Lazard – Levelized Cost of Electricity ver 10.0, December 2016

Unsubsidized Levelized Cost of Energy Comparison



Continuous focus on cost required to compete with alternative energy sources

Wind market is characterized by high development cost and complexity

Automotive

- High R&D cost
- Short product life cycle
- High volume
- Fast development

Aircraft

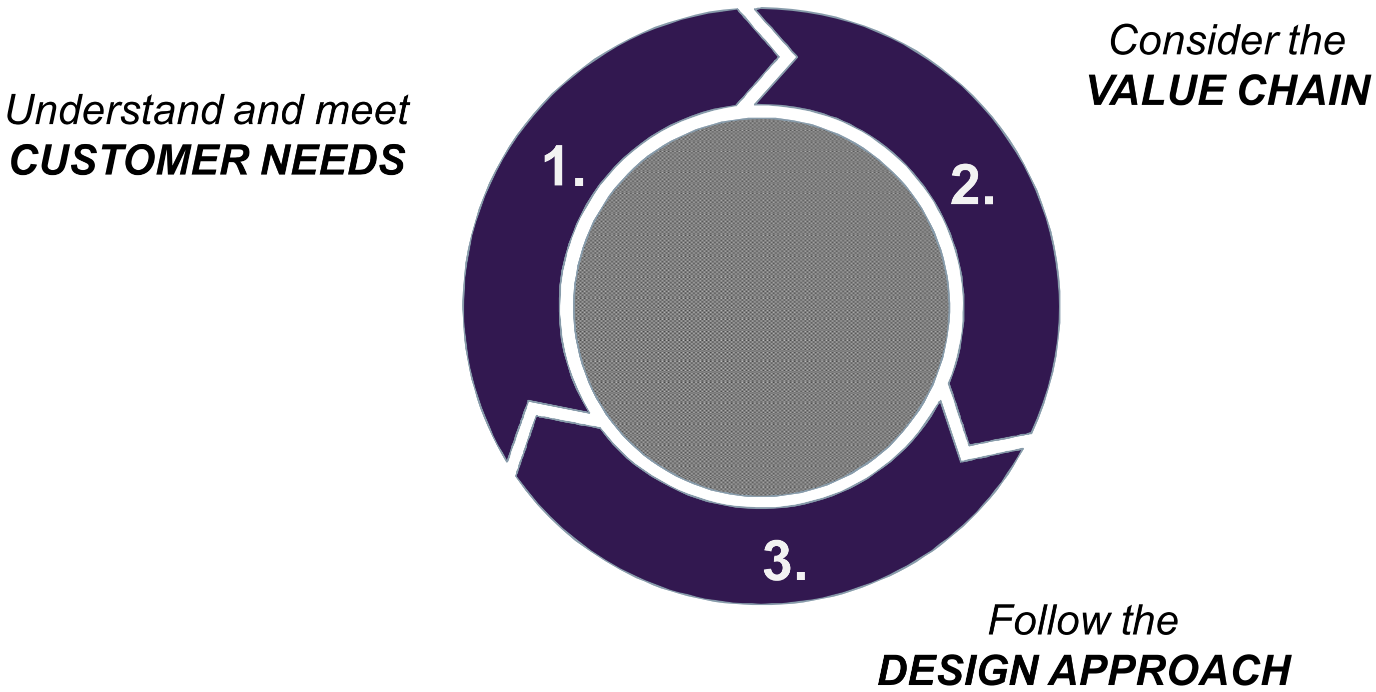
- High R&D cost
- Long product life cycle
- Low volume
- Slow development

Wind turbine

- **High R&D cost**
- **Short product life cycle**
- **Low volume**
- **Fast development**

Innovation is required to handle the wind market development conditions

How do we deliver best design solutions to customers?



What matters to the customer?

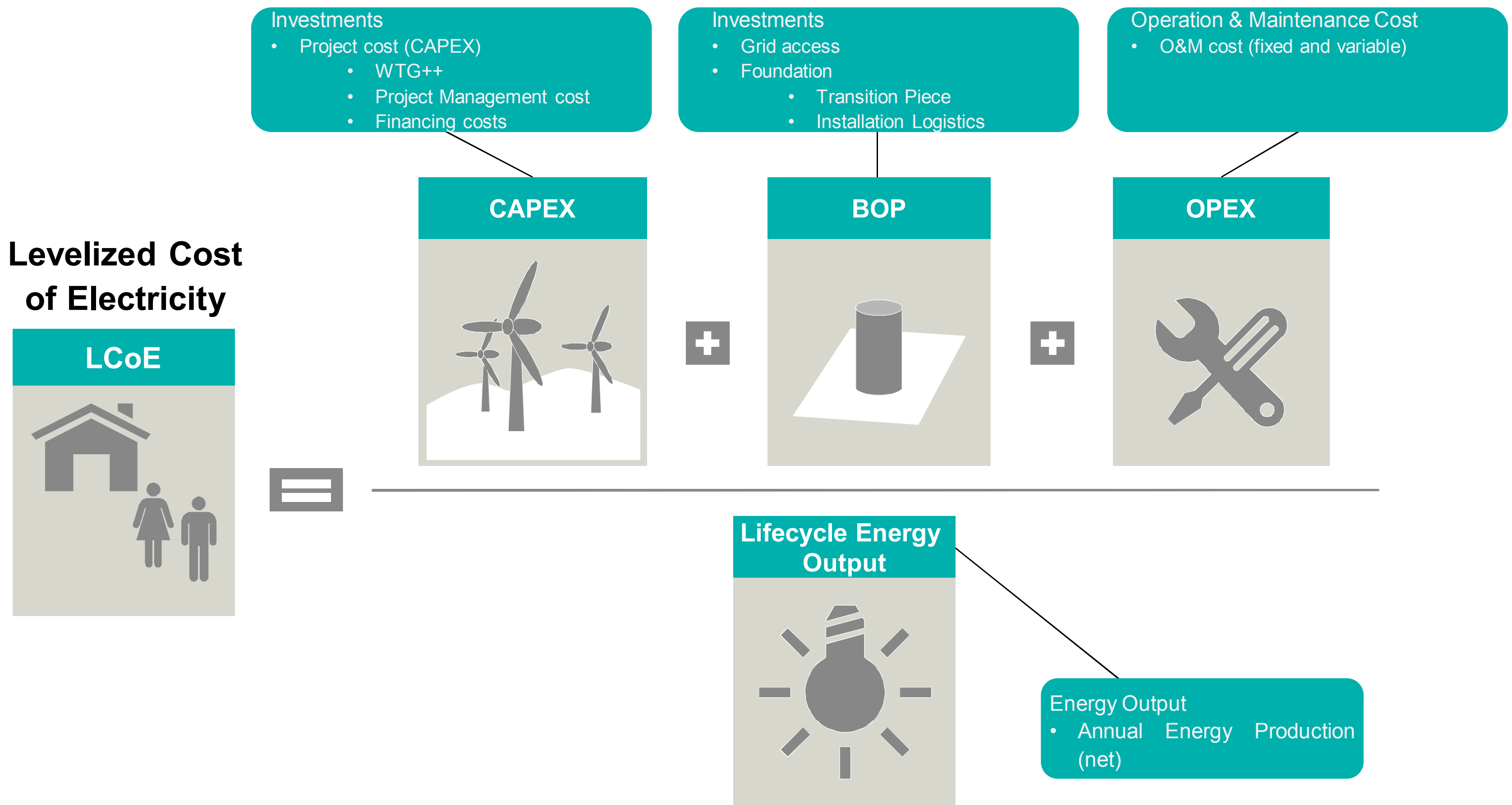
Levelized cost of electricity

Capacity factor

TCO Service Warranty

Customer focus is key – and broader than LCoE

Holistic view on the costs and performance is the key for success



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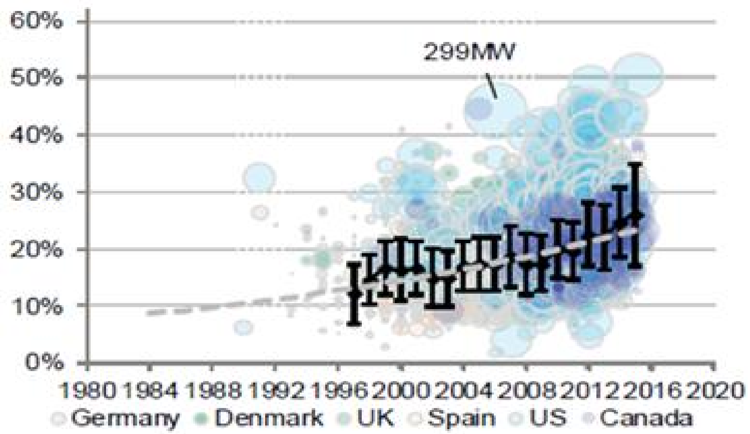
Innovative thinking is necessary to further increase the capacity factor

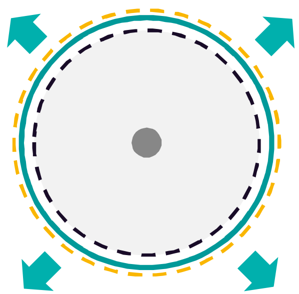
Onshore wind capacity factor



Source: Bloomberg New Energy Outlook 2017

Capacity factor drivers

- Some subsidy schemes (PTC)
- Auction based tender system
- Large scale integration in utility system



Capacity constraints in some onshore and offshore markets drives development towards larger rotor size

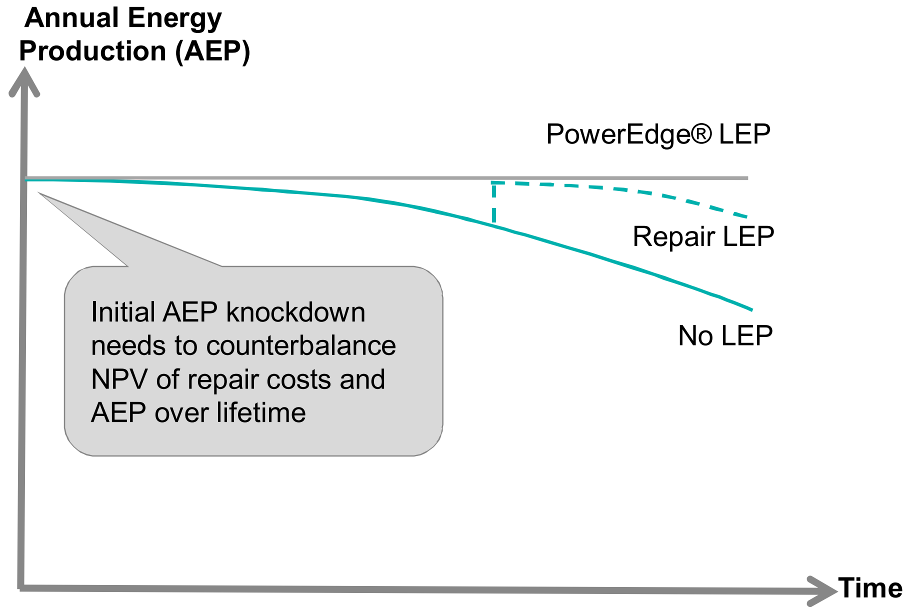
Total Cost Of Ownership (TCO)

De-risk of TCO

- Low CAPEX
- Known O&M cost
- Long Term Program - LTP ®
- Proven technology

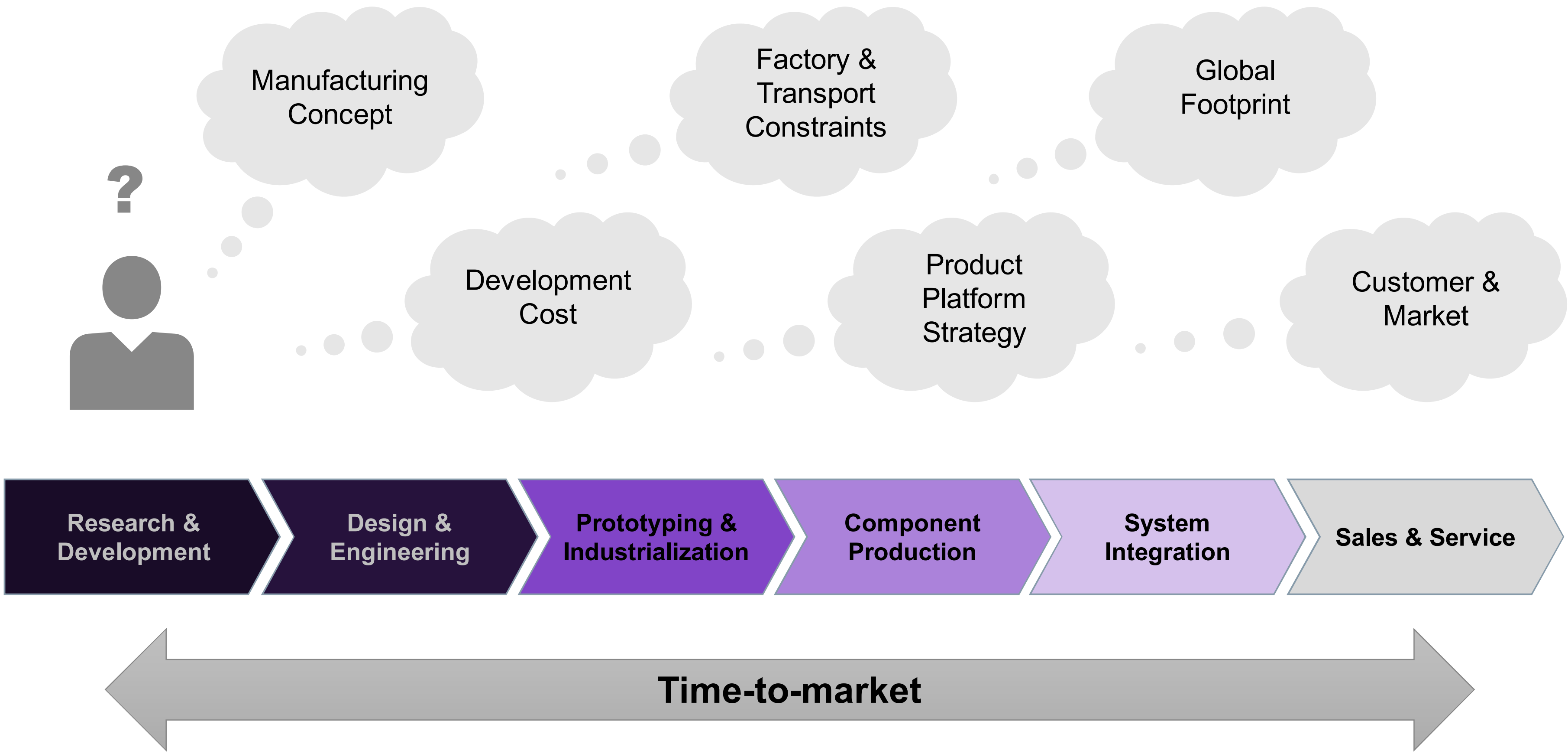
Net present value (NPV)

Leading edge protection example

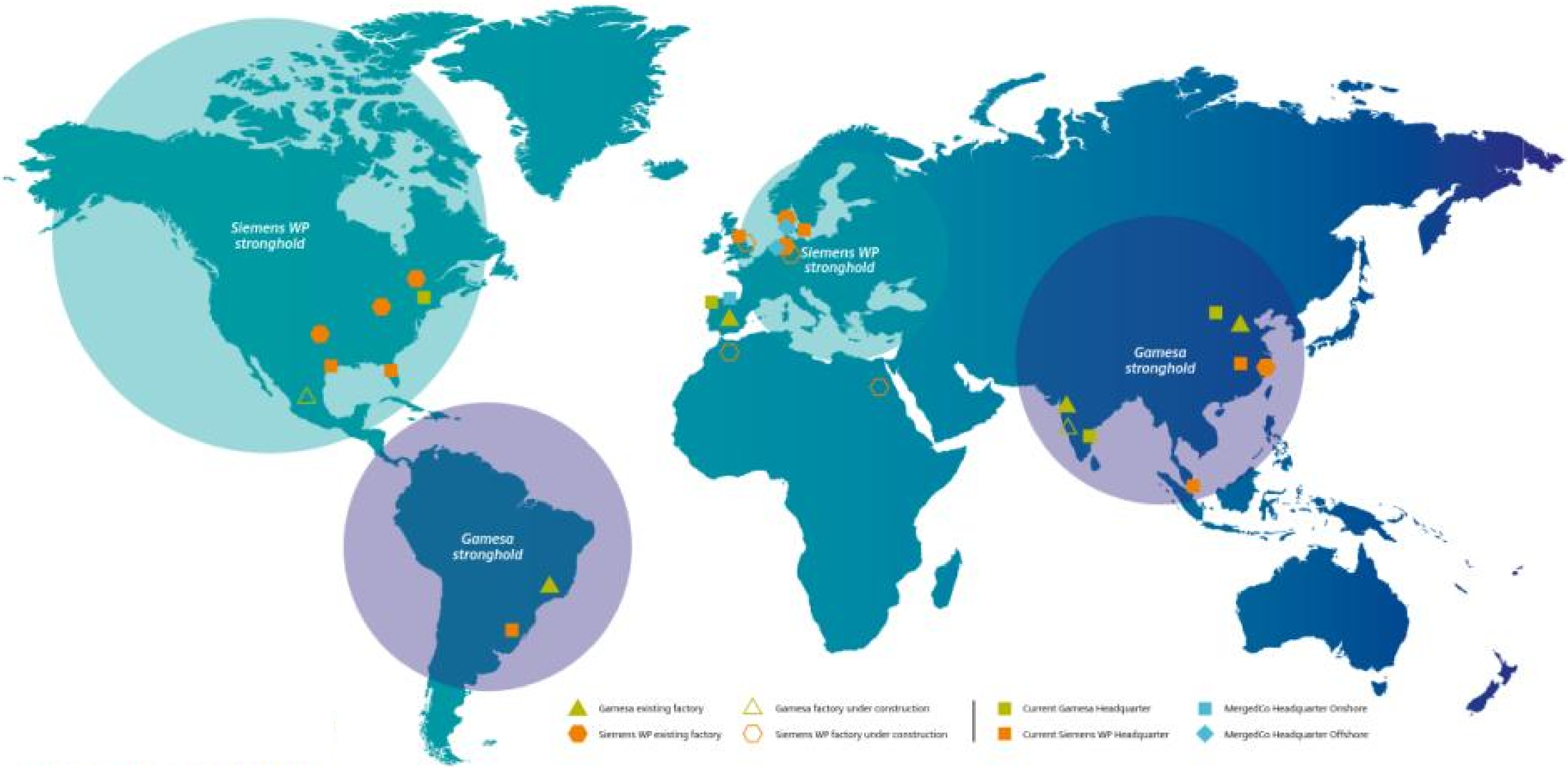


Initial CAPEX is certain, whereas NPV of future energy production (AEP) and O&M is uncertain

Product development value chain consist of various elements



Product development and the global footprint has to be aligned



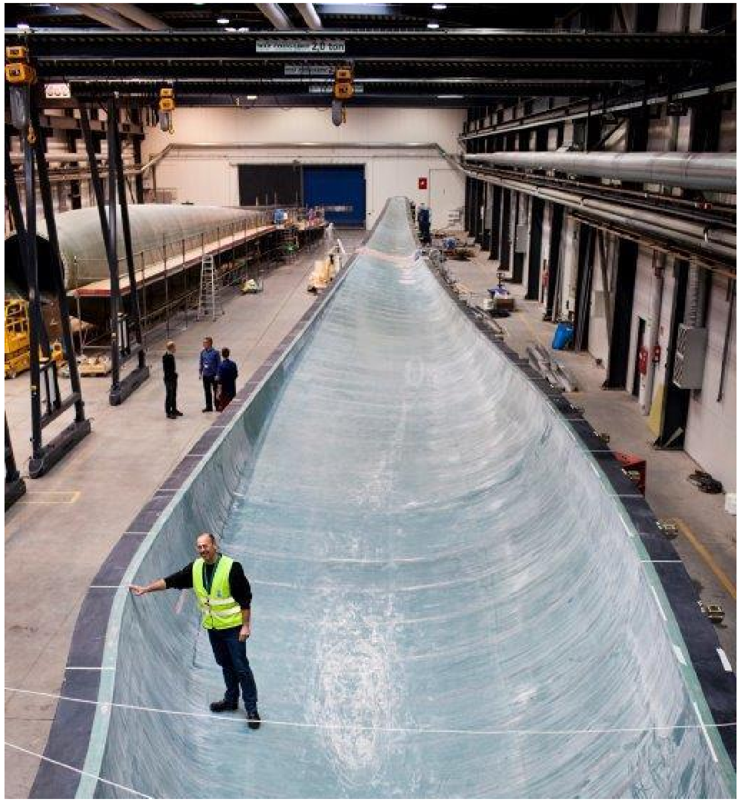
Blade factory in Aalborg, Denmark

Transporting 6MW nacelle to test site in Høvsøre

Manufacturing concepts for safe and innovative product portfolio

Why Integral Blades?

- One-shot manufacturing technology
- No adhesive joints
- Vacuum-assisted epoxy resin transfer molding (VARMT)
- Unrivaled strength and performance
- Reduced EHS risk

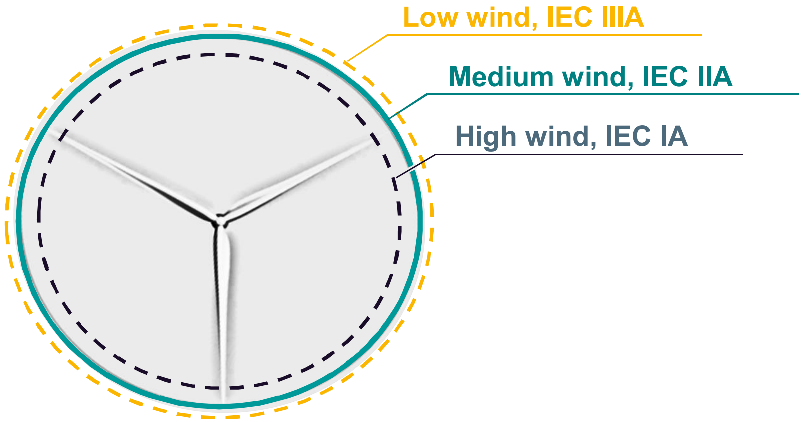


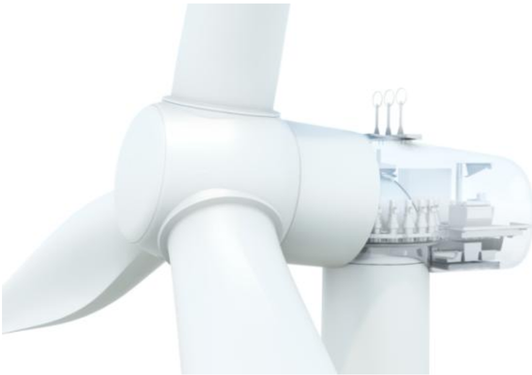
Product platform strategy that increases flexibility and minimizes cost

Different rotors with same nacelle, generator and hub

Onshore Direct Drive

Siemens D3 Platform





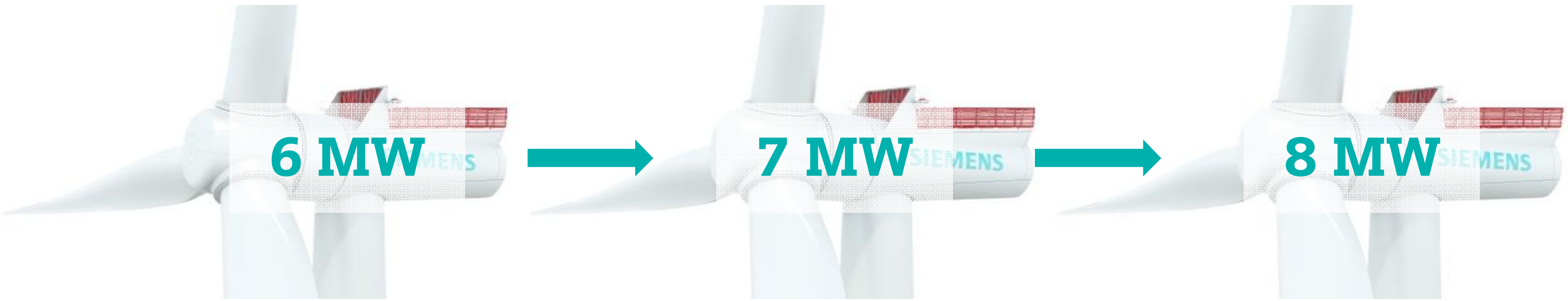
Modularization enables shorter time-to-market and lower CAPEX

Product platform strategy that increases flexibility and minimizes cost

Same rotor for further developed machine

Offshore Direct Drive

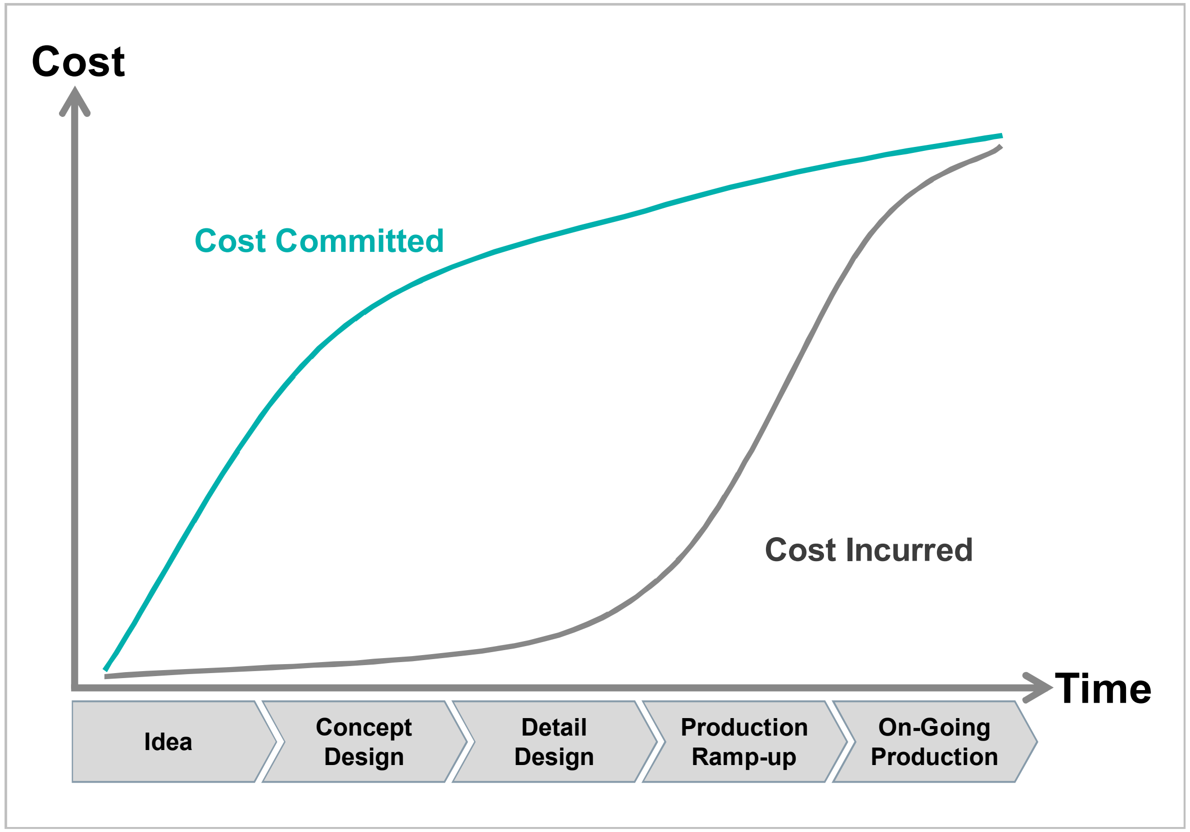
Siemens D8 Platform



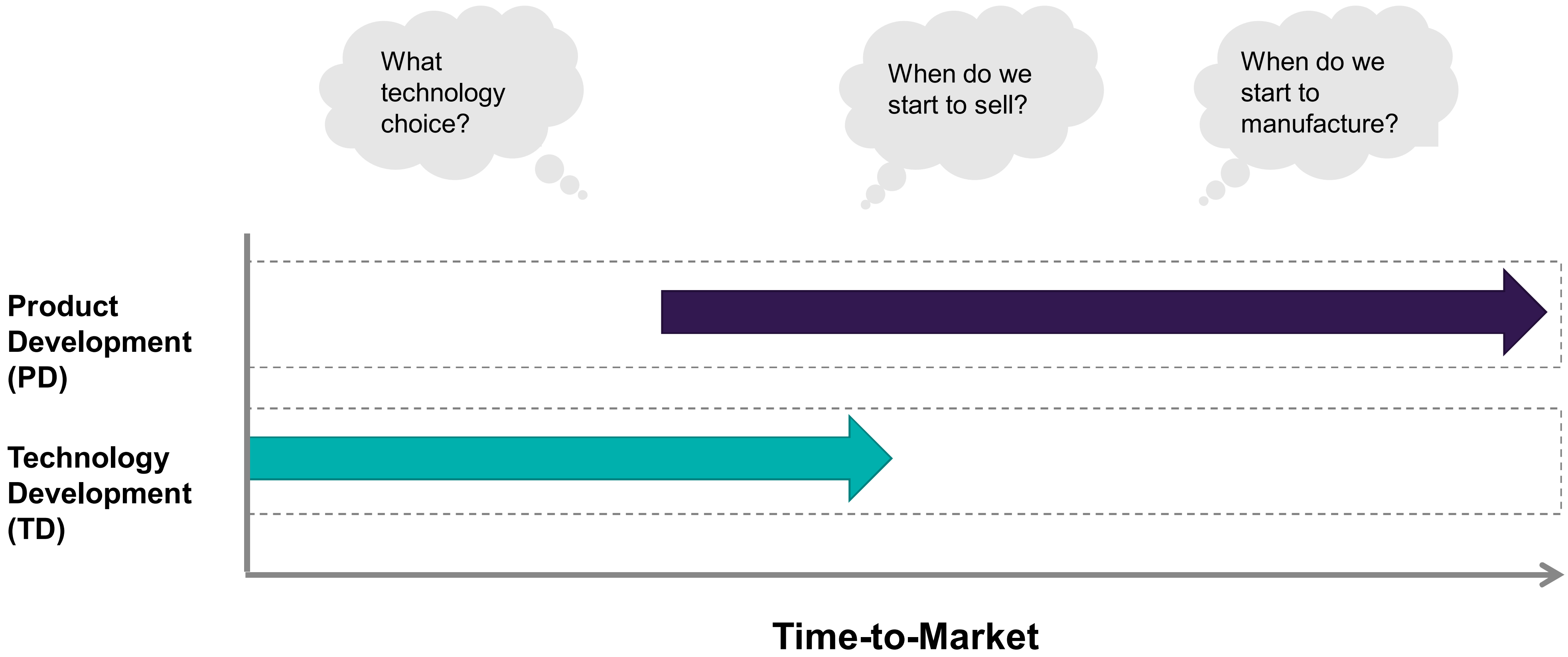
Modularization enables higher flexibility and larger volume

Most of the development costs are committed in the early design phases

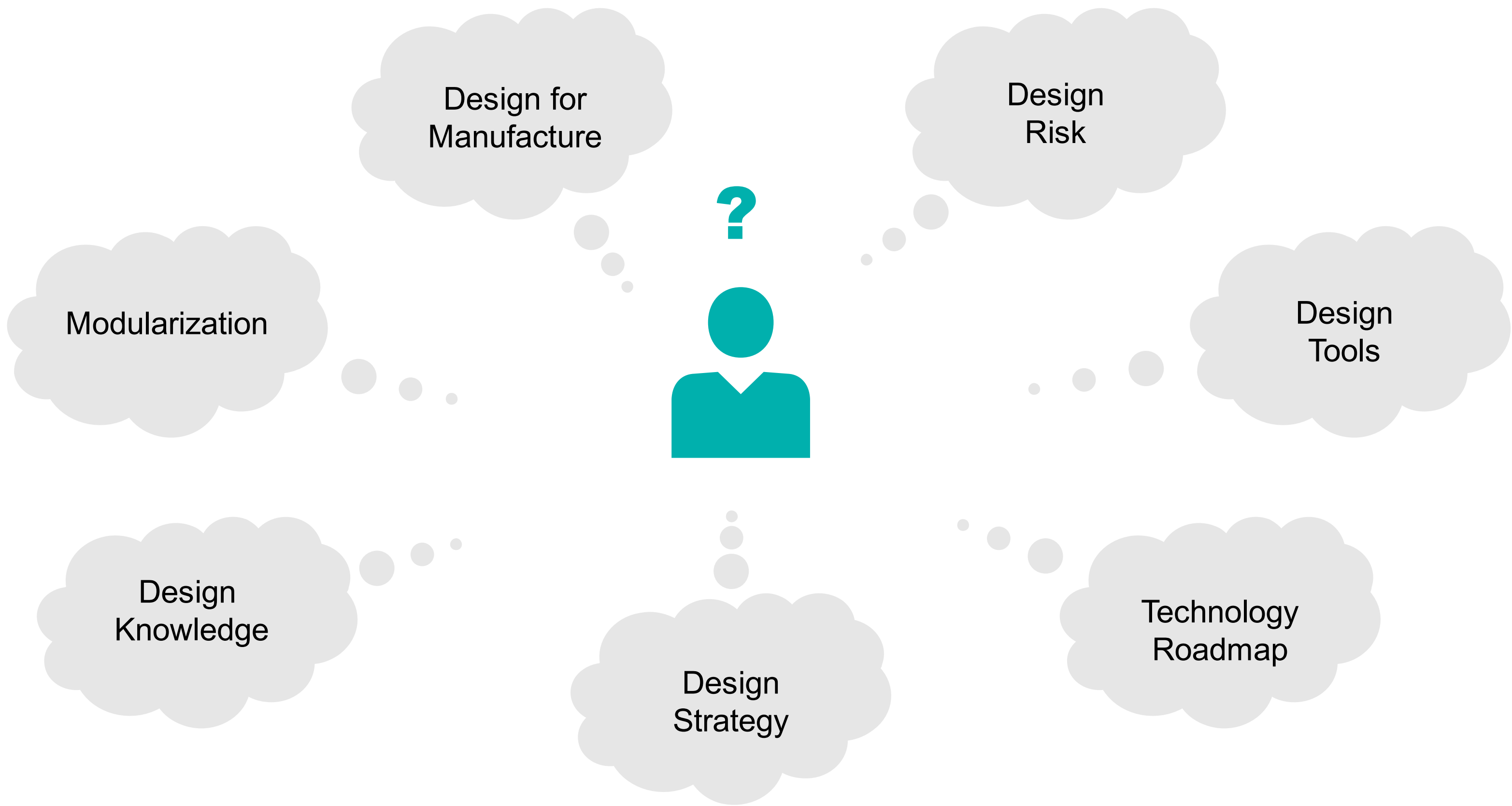
- The product cost is determined by
  - Development costs
  - Capital costs
  - Manufacturing costs
- The return of investment is governed by capital cost and time-to-market
- All cost factors tie back to the product development early phases



TD planning and integration into the PD ensures short Time-to-Market

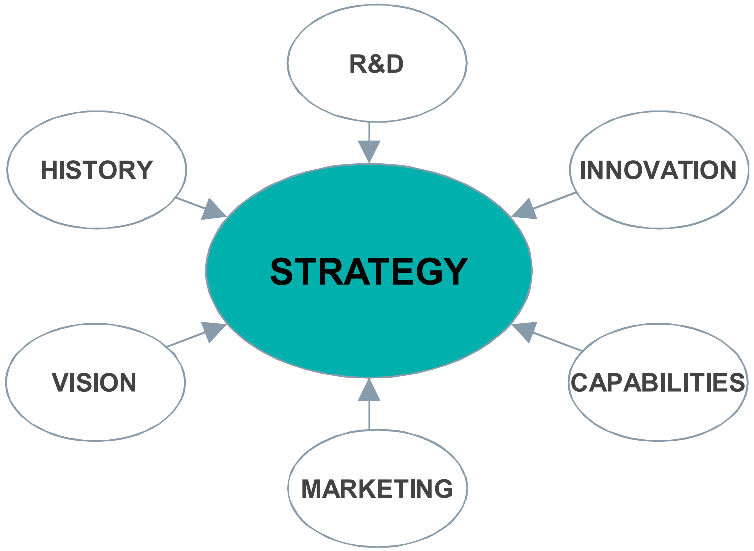


There are various elements to consider regading the design approach



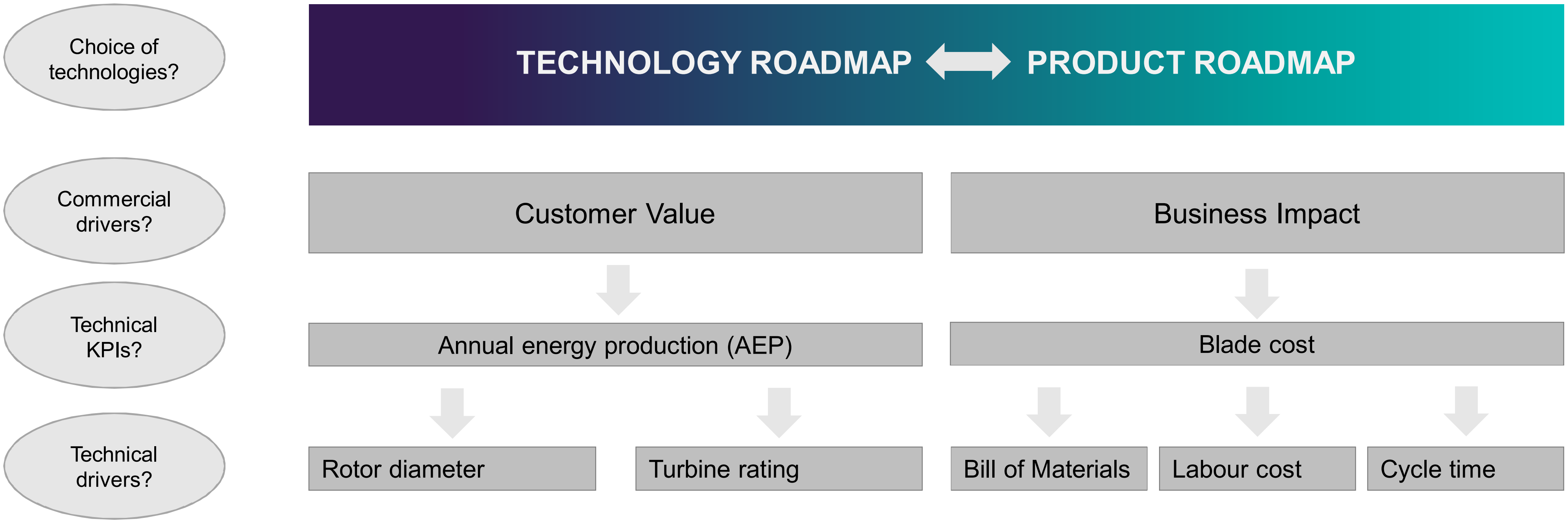
Initial design choices are governed by the design strategy

- Overall vision and marketing sets the direction
- Innovation and R&D profile sets the bar
- History and capability is the foundation



Design strategy is the foundation, it sets the bar and the direction for design choices

Technology Roadmap example - blades



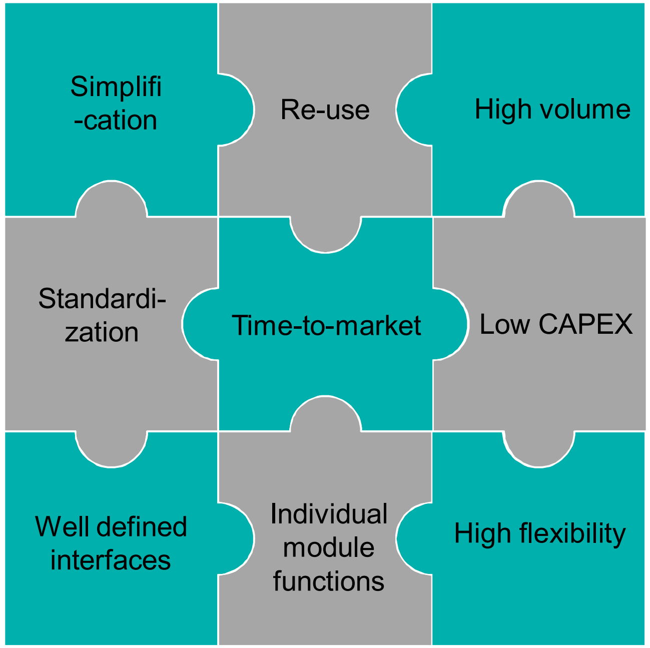
The demand for technology must come from product needs…

…therefore products must drive the technology development

Modularization approach allows to save cost and increase flexibility

Product architecture:

- Allocate product function to physical components
- Specify interfaces between physical components
- Design modules independently



Technology readiness level (TRL) is the key factor in risk management

TRL 1	Basic principles observed and reported
TRL 2	Technology concept and/or application formulated
TRL 3	Analytical and experimental critical function and/or characteristic proof-of-concept
TRL 4	Component and/or breadboard validation in a laboratory environment
TRL 5	Component and/or breadboard validation in a relevant environment
TRL 6	System/subsystem model or prototype demonstration in a relevant environment
TRL 7	System prototype demonstration in a space environment
TRL 8	Actual system completed and “flight qualified” through test and demonstration
TRL 9	Actual system “flight proven” through successful mission operations

Simulation & Validation

System demonstration

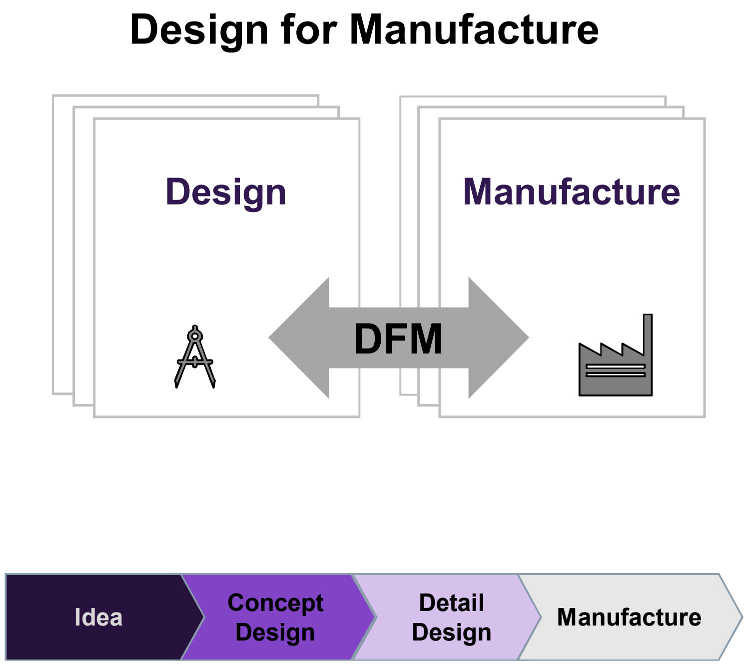
Field experience

Source: NASA, Technology Readiness Level (TRL), Oct. 28, 2012

Manufacturing has to be integrated into the design

Design to Manufacture (DFM) best practice:

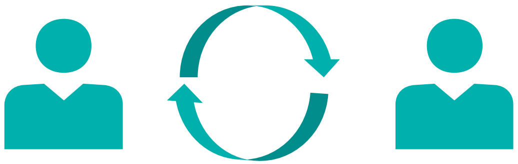
- Focus on manufacturing and product life cycle
- Focus on concept phase
- Use cost modelling to understand direct & indirect cost
- Set common objectives for product & manufacturing
- Use balanced scorecard to drive product design choices



1. Do the right thing → 2. Do things right

Design knowledge hand over plays a crucial role

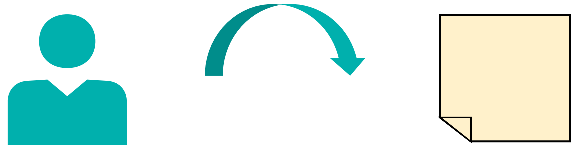
Tacit knowledge



Person-to-person

- In Peoples heads
- Exchanged person-to-person
- Learned on-the-job

Codified knowledge



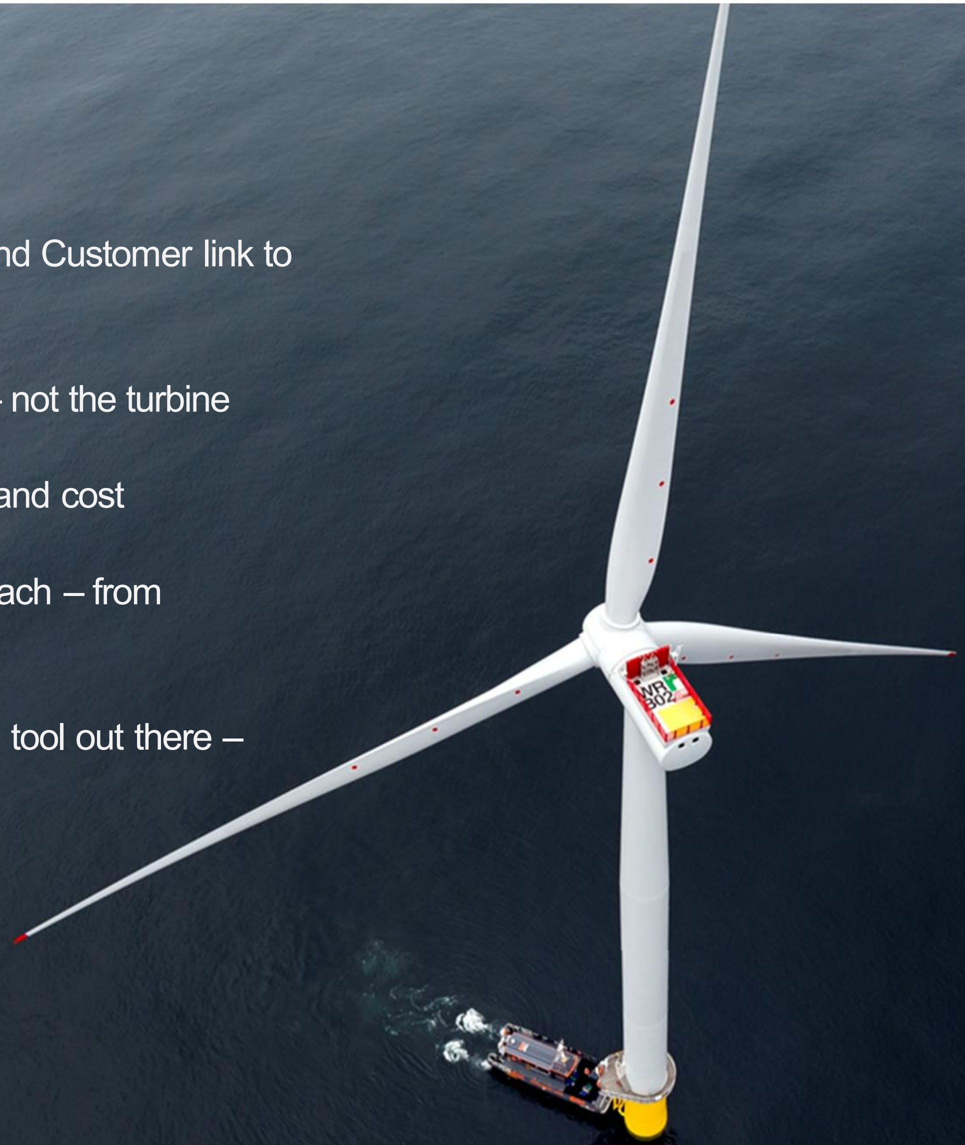
Person-to-document

- Written down in design rules & design manuals
- Documented fleet experience
- Basis for most design tools

Designers make a difference when combining results from tools with their design knowledge

Summary

- Understand how Market and Customer link to products and technology
- Optimize the value chain – not the turbine
- Design for manufacture – and cost
- Have a clear design approach – from strategy to design tools
- There is not a single grand tool out there – Use **your own** toolbox!



What are **YOUR** design drivers?

Thanks

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