Use of steel for towers of wind turbines and support structures

Arno van Wingerde

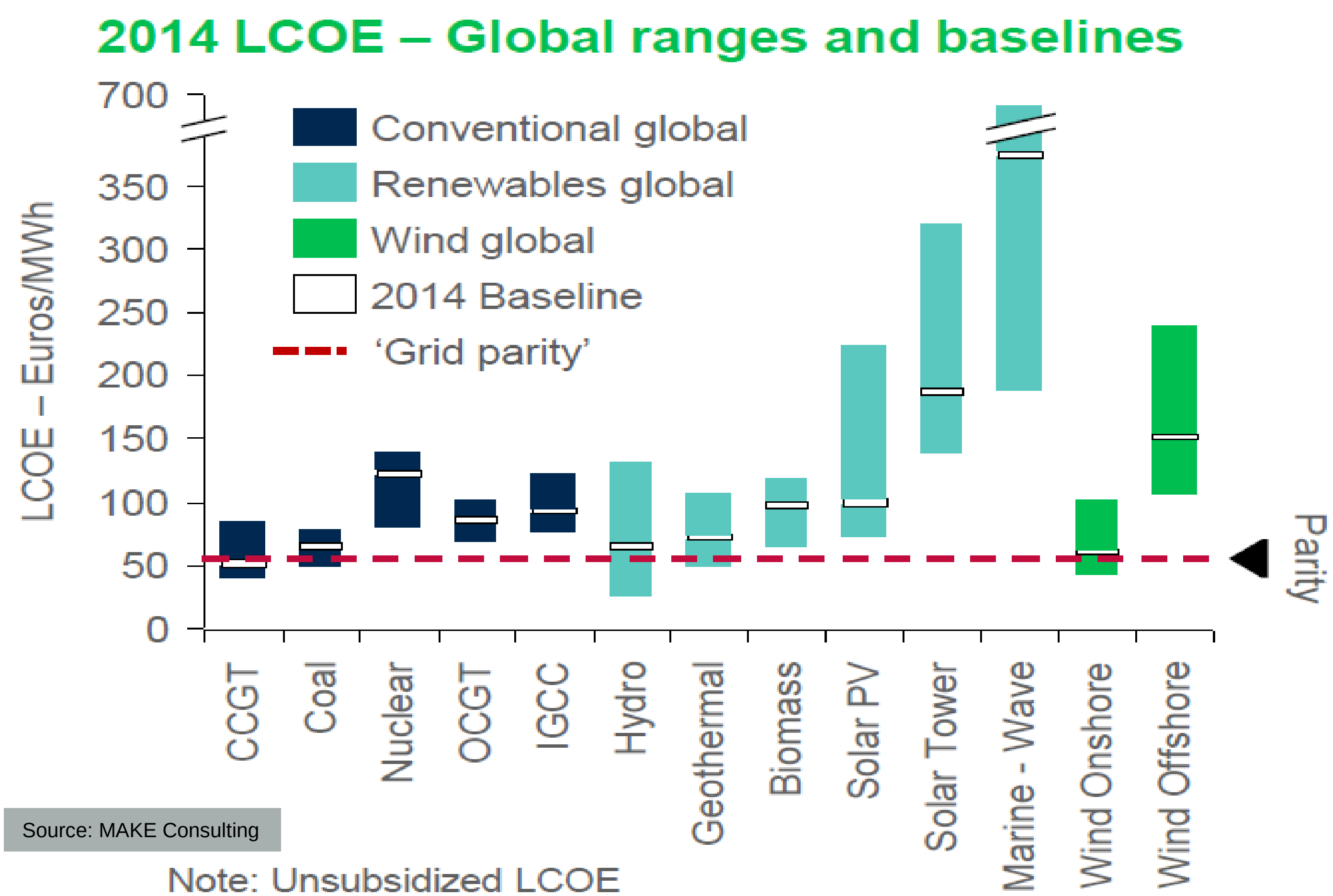
Arno.van.wingerde@iwes.fraunhofer.de

Fraunhofer IWES

Overview

- Background
- State of the Art
- Problems and possibilities
- Outlook

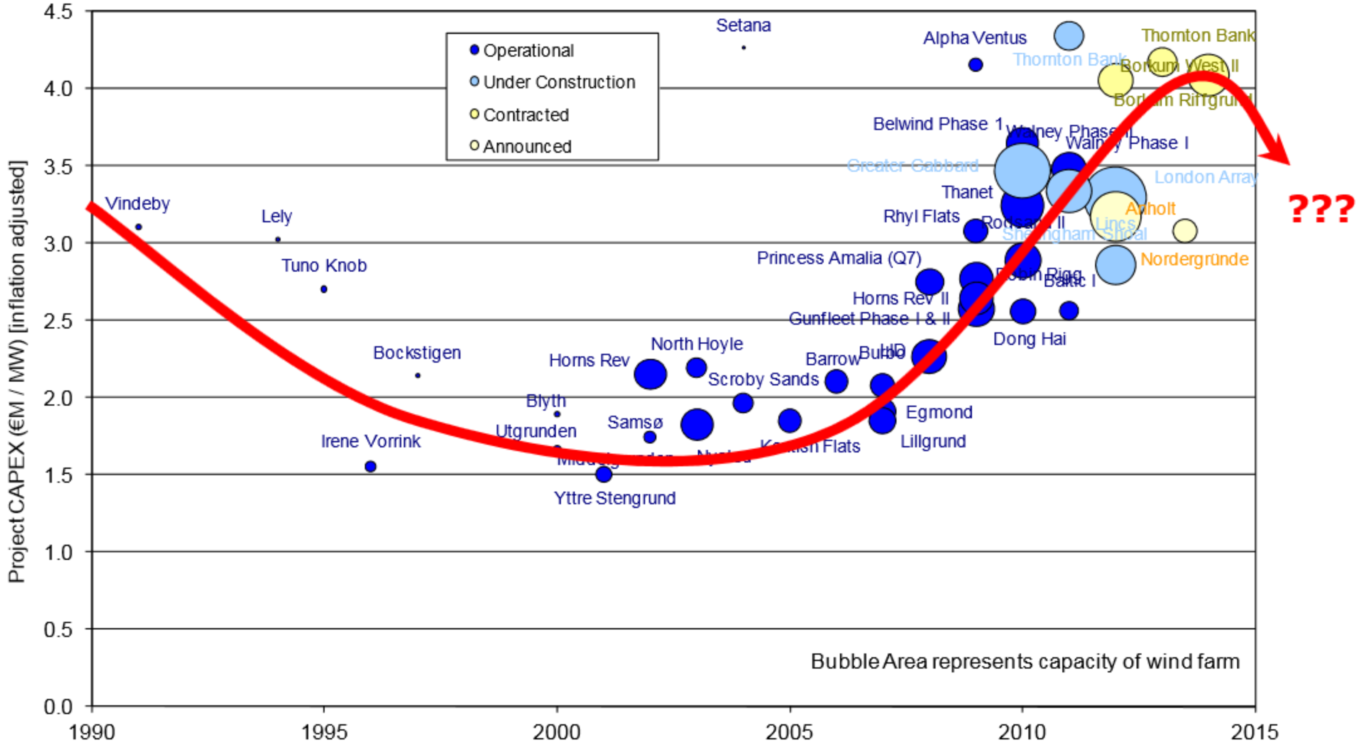
Wind Energy and other energy sources



Source: MAKE Consulting

Fraunhofer IWES

Offshore Wind levelized Cost of Energy



Source: DNV-GL

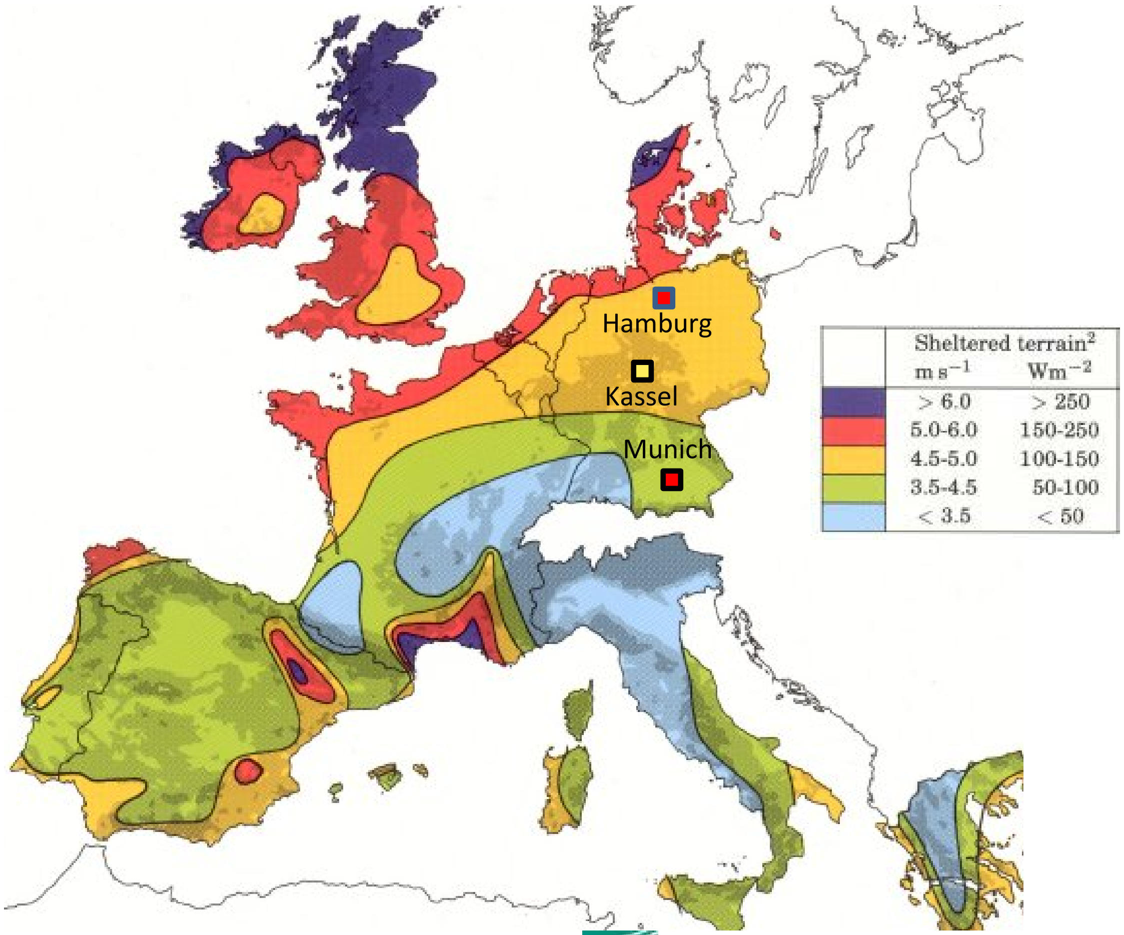
Fraunhofer IWES

How about inshore, instead of offshore?

$v_{av.,\,50\,m}$ Hamburg: 5 m/s
$v_{av.,\,50\,m}$ near the coast:6 m/s),

$v_{av.,\,50\,m}$ Munich: 4 m/s

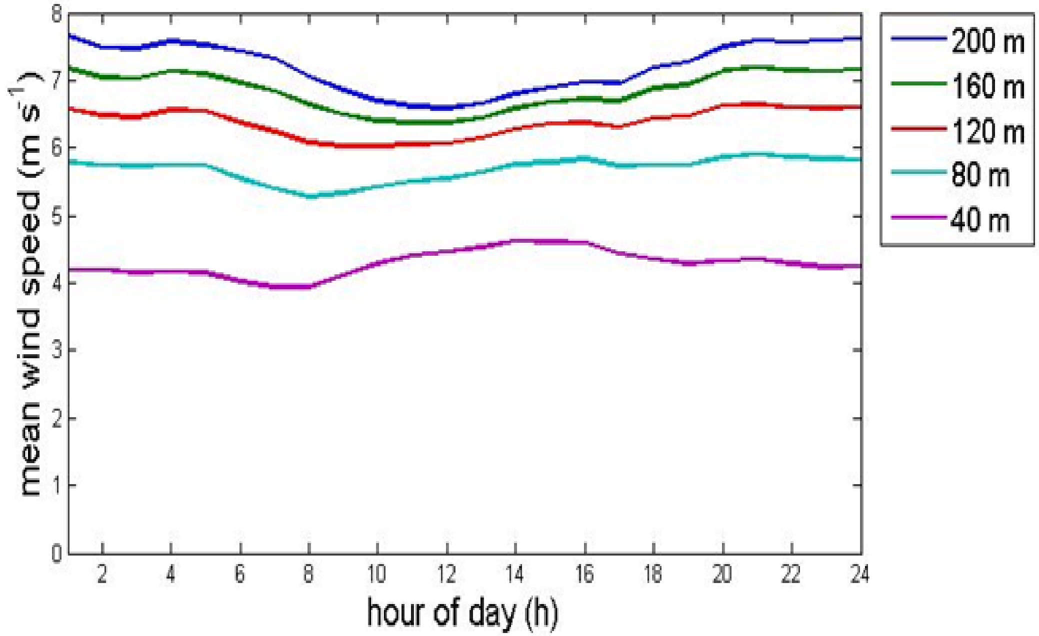
$E_{wind} \sim v^3$
so $E_{Coast} = 2E_{Hamburg} = 4E_{Münich}$



Source: the European Wind Atlas

Fraunhofer IWES

Too little wind inshore?



Source: Fraunhofer IWES

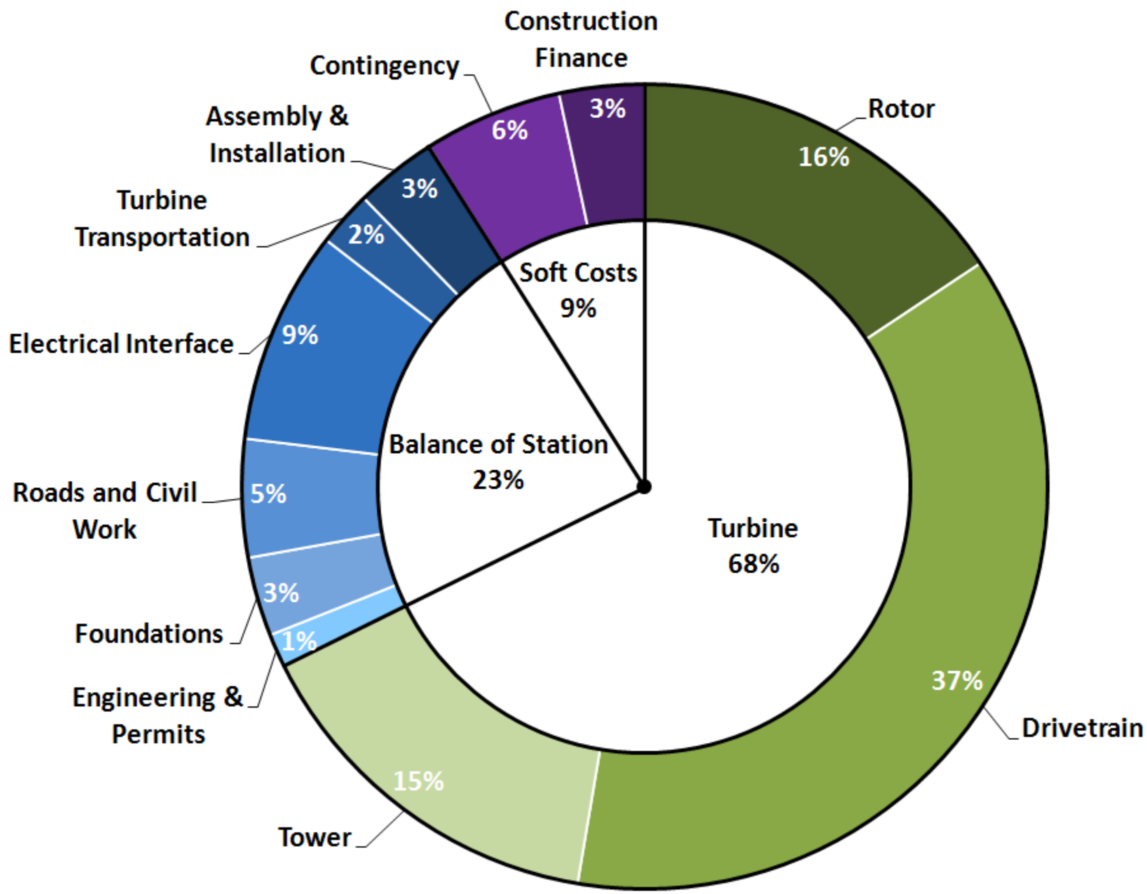
Fraunhofer IWES

Overview

- Background
- State of the Art
- Problems and possibilities
- Outlook

Fraunhofer
IWES

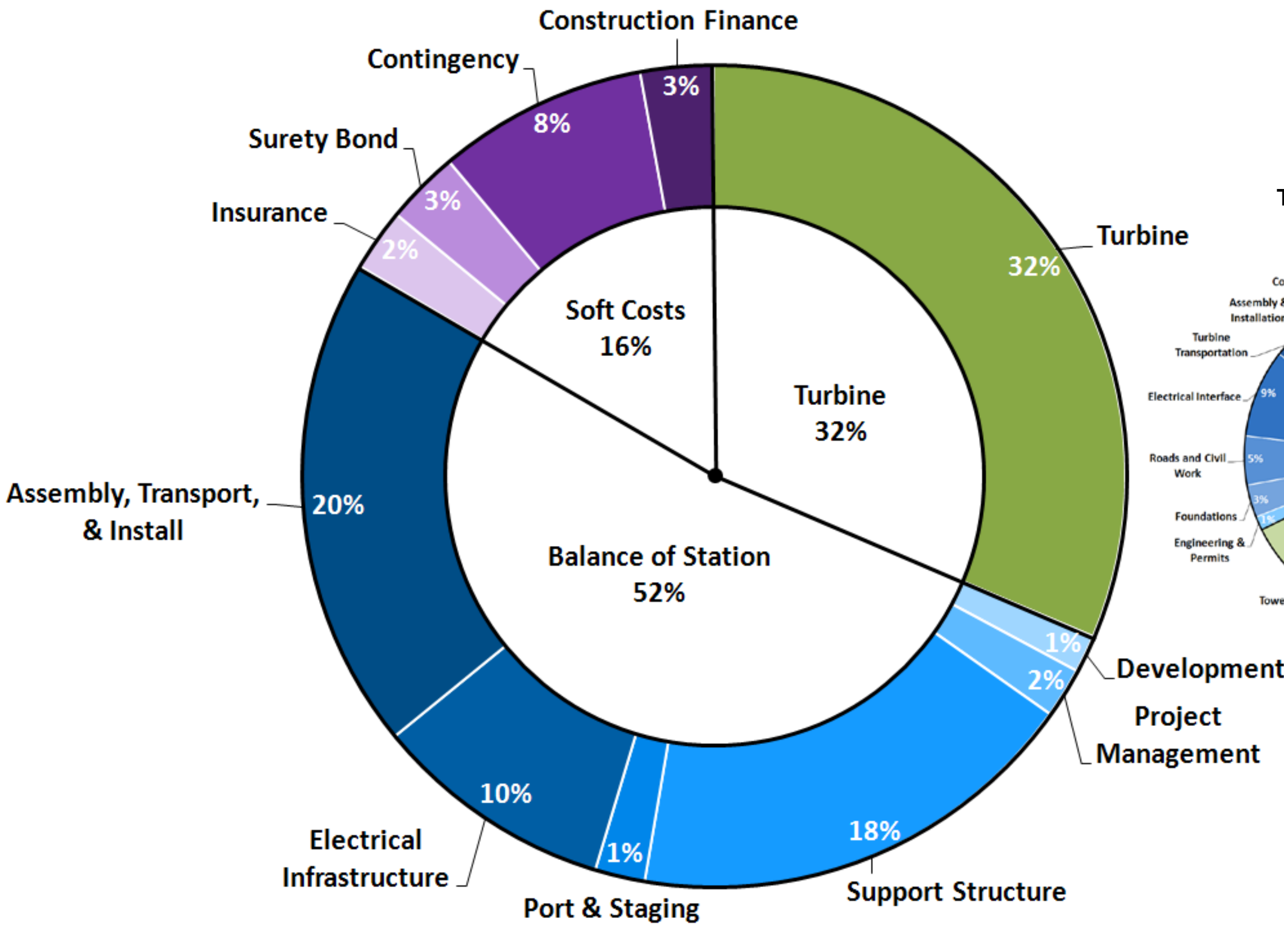
Costs of tower and support structures Onshore: 15%



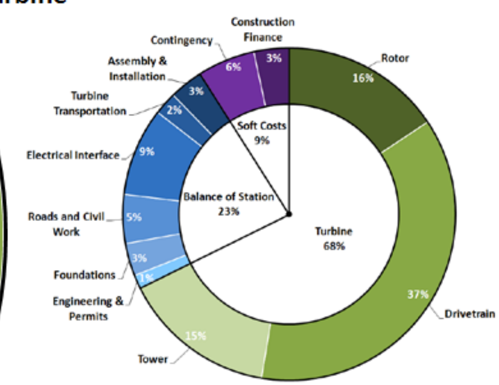
Source: NREL

Fraunhofer IWES

Costs of tower and support structures Offshore : 25%



Tower: 7% of total costs



Source: NREL

Fraunhofer IWES

State-of-the-art: towers of wind turbines

- Wind turbines: amongst the largest and highest loaded structures
- Due to growth of the industry and growth of installed capacity – repetition important
- Also: the industry is more driven by innovation than the construction industry
- Right now: S235, S355 are the main steel grades in use – as for the construction industry

Overview

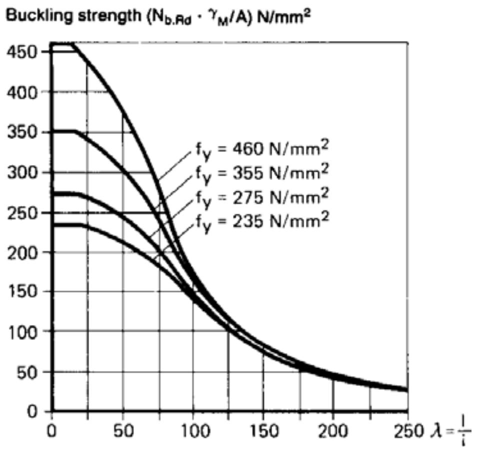
- Background
- State of the Art
- Problems and possibilities
- Outlook

Fraunhofer IWES

Arguments in favour of use of higher steel grades

- Static strength: increases linearly with f_y

- Buckling
  - Slenderness: $\lambda \approx l/D$ for thin-walled towers
  - For low slenderness, $\lambda \leq 50$ (e.g. 150 m high, 3 m ø), buckling strength increases almost linearly with the f_y



Fraunhofer IWES

Arguments against use of higher steel grades

- Weldability: more care needed
- Toughness (earthquake resistance)
- Fatigue
  - With high SCF, no weld measures:
    virtually no influence of f_y
  - Lower SCF, post-weld treatment to introduce compressive stresses:
    almost linear increase with f_y achievable
- Price
- Lack of standards

Fraunhofer IWES

Price

- Towers: dead weight no major cost post
- Transport and installation costs is a factor
- S235: 100%
- S355: 103%, practically a no-brainer
- S460: 110%, doable
- S690: 170%, hardly economical over S460, unless weight is a severe problem

Fatigue

- Welding:
  - Influence of the mean stress: typically unknown, a tensile mean stress equal to the yield stress has to be (conservatively) assumed, fatigue strength similar to lower grade steels, no benefit
  - Unless this mean stress can be lessened or even be converted to a compressive stress, e.g. UIT (ultrasonic impact treatment)
- Other connection methods, such as grouting or pre-stressed bolts can also help to utilize the higher potential strength, e.g. Siemens tower.

Standards

- EC 3: focus on mild steels, with no "bonus" for higher steel grades
- No bonus for fatigue improvement of post weld treatments
- Based on a rather rigid and simplistic classification of structural details
- The class σ_c is the stress range at 2 million cycles, S-N lines have a slope of 1:3 until 5 million cycles (at 0.73 σ_c) and a fatigue limit at 0.40 σ_c
- Can be used as a first, conservative approach

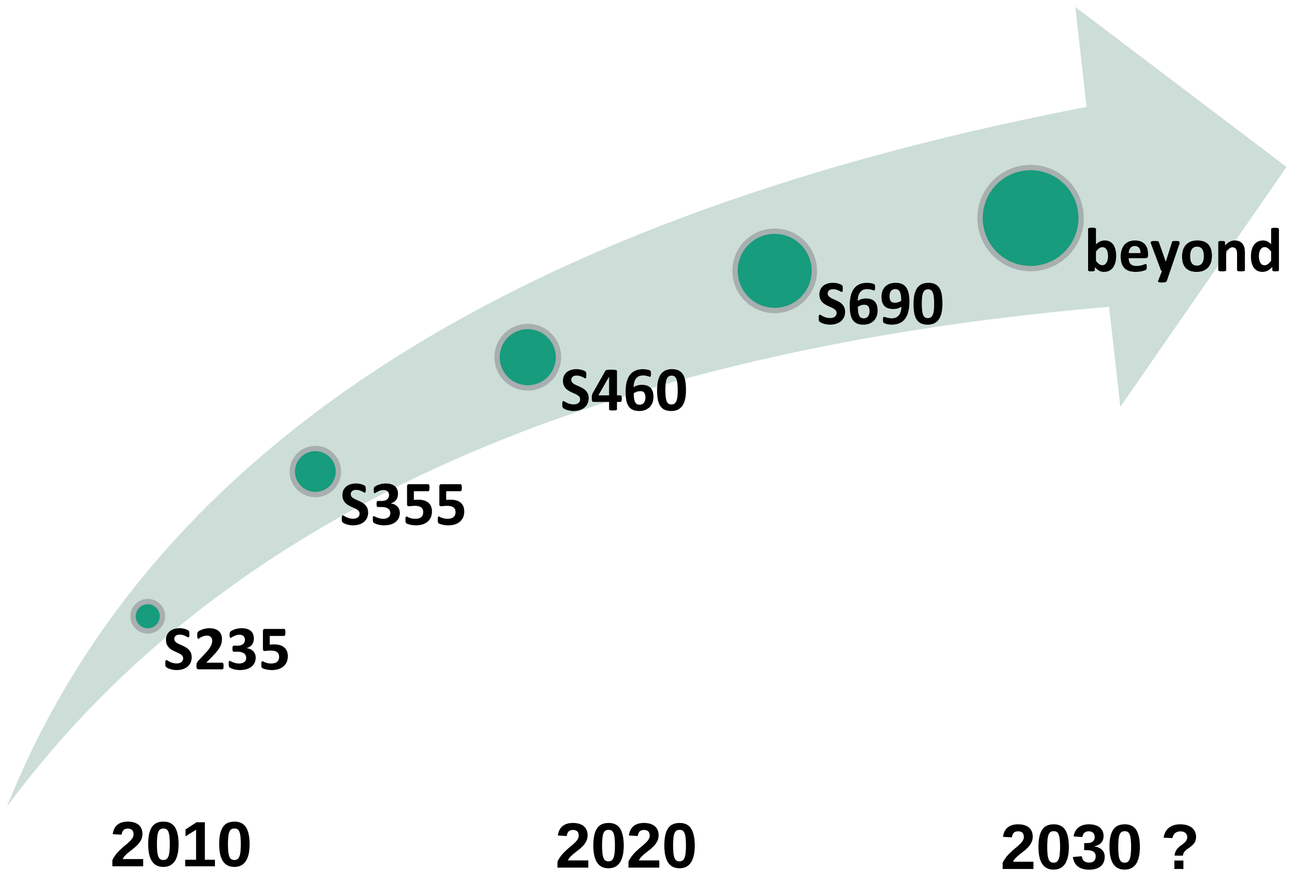
- GL: sceptical about use of steels exceeding S460:
- "high strength steels having nominal yield strengths (or 0.2% proof stresses) exceeding 460 N/mm^2 may be employed in exceptional cases only, with the corresponding technical justification and with GL consent

- Thus other standards need to be used (or developed!) in order to allow economical use of high strength steels for the fatigue loaded structures needed here

Overview

- Background
- State of the Art
- Problems and possibilities
- Outlook

The road ahead



Fraunhofer
IWES

Acknowledgements

Fraunhofer IWES is funded by the:

Federal State of Bremen

- Senator für Umwelt, Bau, Verkehr und Europa
- Senator für Wirtschaft und Häfen
- Senatorin für Bildung und Wissenschaft
- Bremerhavener Gesellschaft für Investitions-Förderung und Stadtentwicklung GmbH

Federal State of Lower Saxony

Federal Republic of Germany
Federal Ministry for Economic Affairs and Energy (BMWi)

with support of the European Regional Development Fund (ERDF)

Bremerhaven Bremen

Niedersachsen

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

EUROPEAN UNION
Investing in your future
European Regional Development Fund

Fraunhofer IWES

RAVE Offshore Wind R&D

International Conference on R&D for Offshore Wind Energy in the North Sea

October 13-15, 2015
Bremerhaven, Germany

Call for abstracts coming soon!

Fraunhofer
IWES

THANK YOU FOR YOUR ATTENTION

Any questions?

arno.van.wingerde@iwes.fraunhofer.de

Fraunhofer IWES

