ISMEM 2017
- 2nd International Symposium on Multiscale Experimental Mechanics: Multiscale Fatigue

DTU

KompZert: a step ahead on the road towards subcomponent testing for rotor blades

Arno van Wingerde

Chief Scientist, Fraunhofer IWES

ISMEM 2017
- 2nd International Symposium on Multiscale Experimental Mechanics: Multiscale Fatigue

DTU

How to set up a presentation

PAPERS - Instructions for authors: Heading, 20 pt, font Calibri (or similar), flush left, running full width of page

Bent F. Sørensen[1], Henrik Stang[2] – one or two authors can be represented
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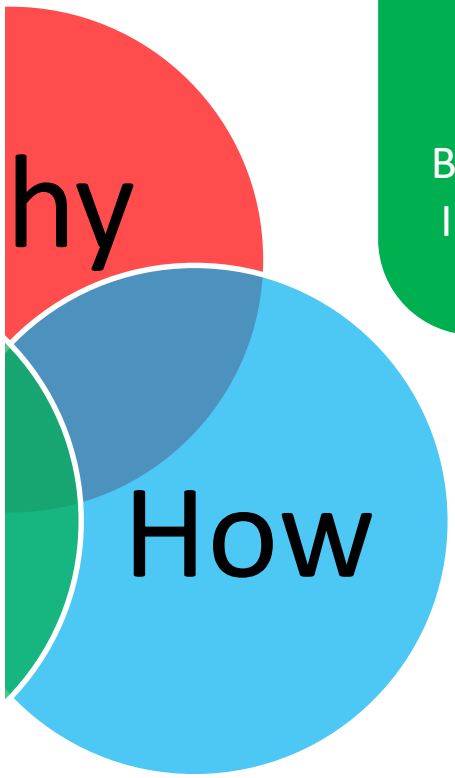
Bent F. Sørensen xxx xxx xxx xxx Box for brief

Henrik Stang xxx xxx xxx xxx Box for brief

Paper

Main paper text should be 12 pt. Please emphasize the technical aspects, for instance, how to design and perform good experiments, loading devices etc. and briefly mention how measured information can be used in e.g. materials law or model of structures. If the experimental work is part of a specific project, it is also relevant to explain this project shortly in terms of motivation and scope. Papers that focus on connections between length scales (both theoretically and experimentally) are particular welcome.

Figures, images and a limited number of references are welcome. The paper including presentation of authors, figures and images should be limited to 2-10 pages.



Hi Guys, during my presentation on Wednesday I will ask you guys why you do subcomponent tests and rotor blades. Because I am a nice guy, I give you a few days to think about it…..

You are so nice … But we already have thought about it ;-)

/14

Fraunhofer IWES

Why? That's why!

https://boyle.house.gov/media-center/in-the-news/boyle-addresses-climate-change-lower-moreland-town-hall

Why

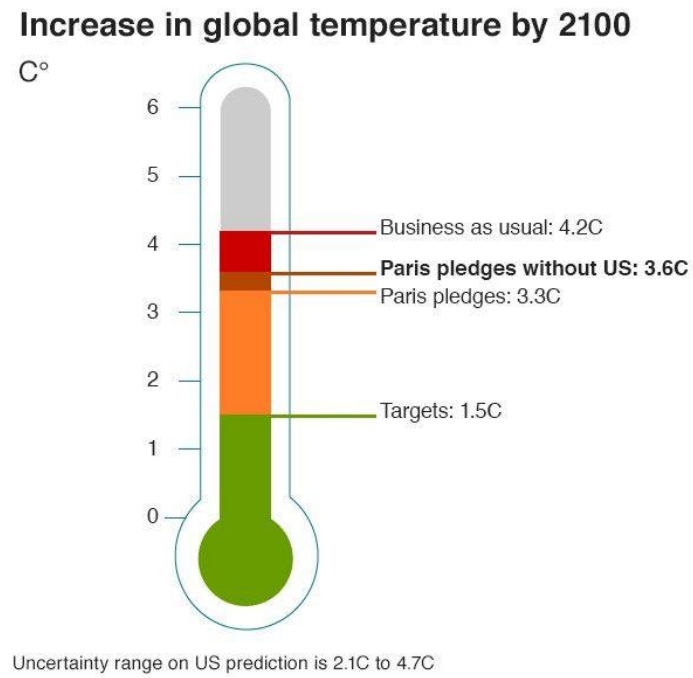
Climate Change

source: climate.nasa.gov

Why

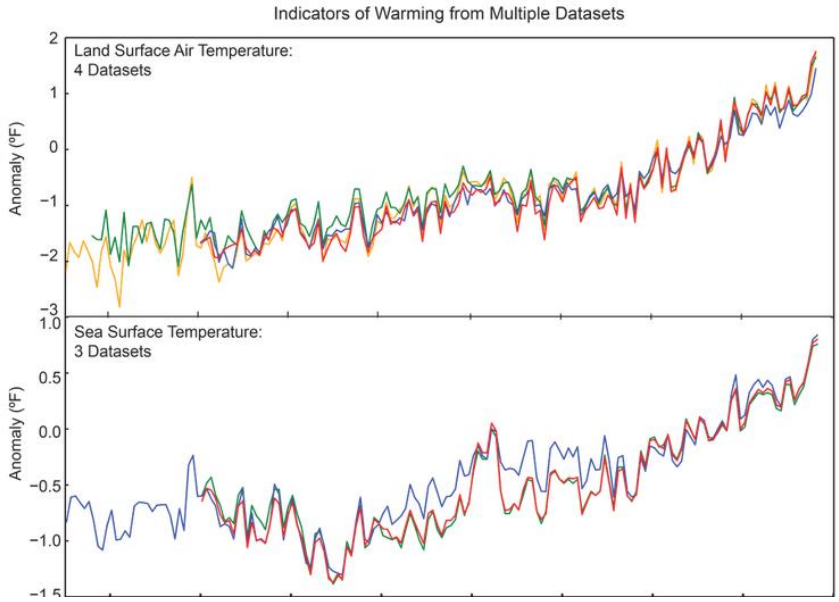
3 Nov. 2017: 4th National Climate Assessment (NCA4) "US report finds climate change >90% manmade"

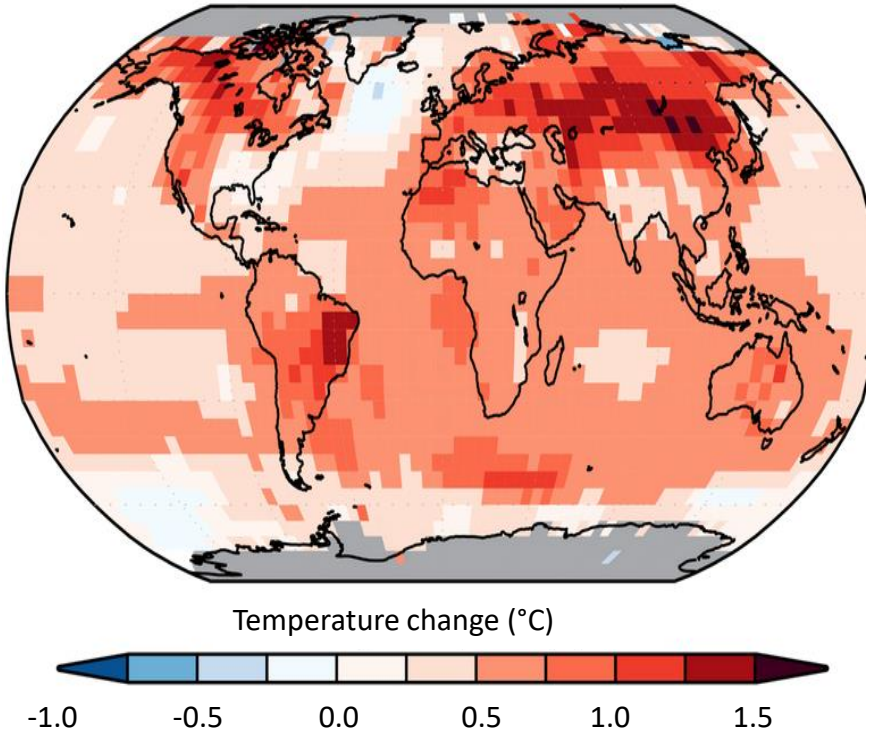
source: the Guardian 3-11-2017



source: climate interactive BBC

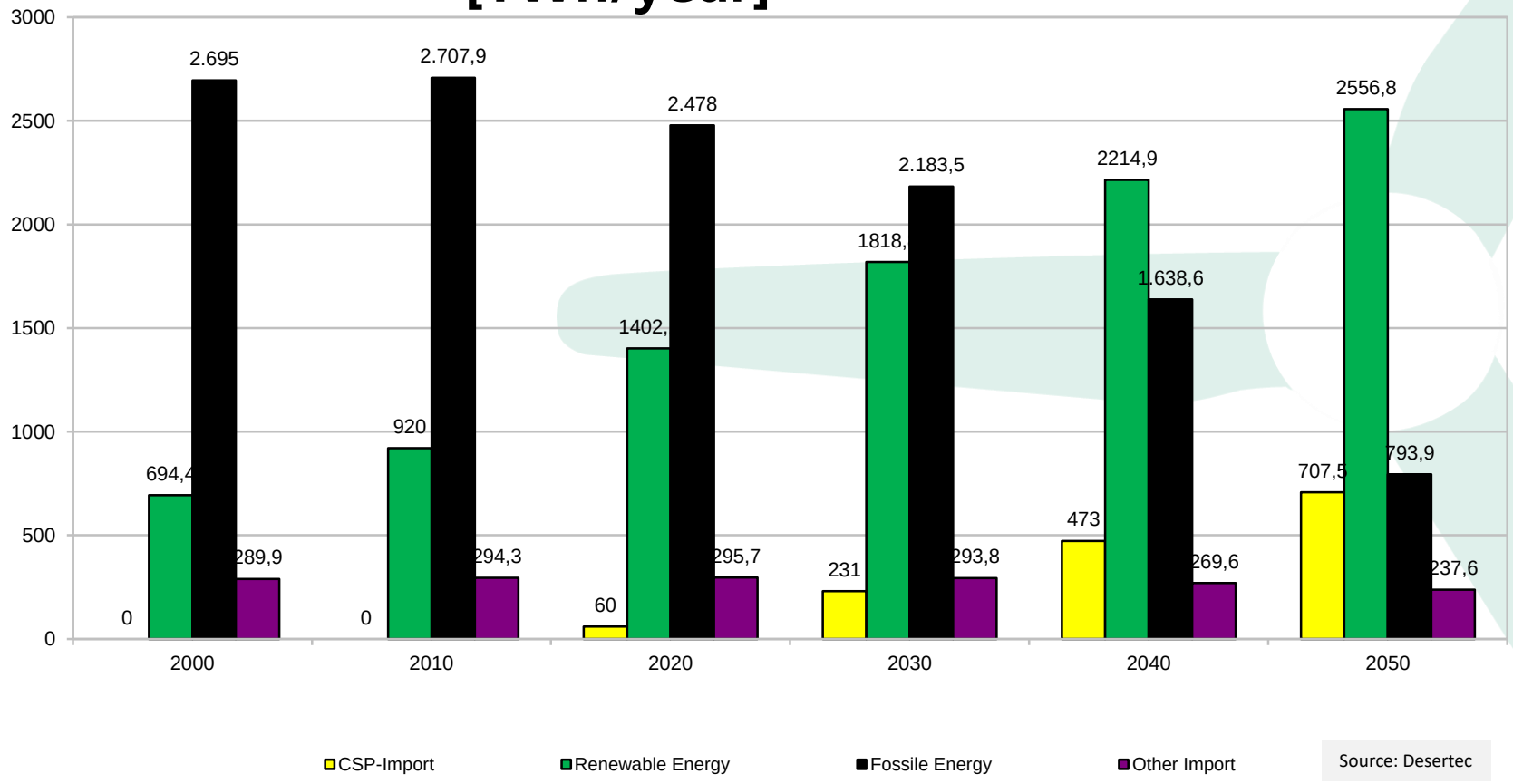
6-17 November UN Climate Change Conference in Bonn



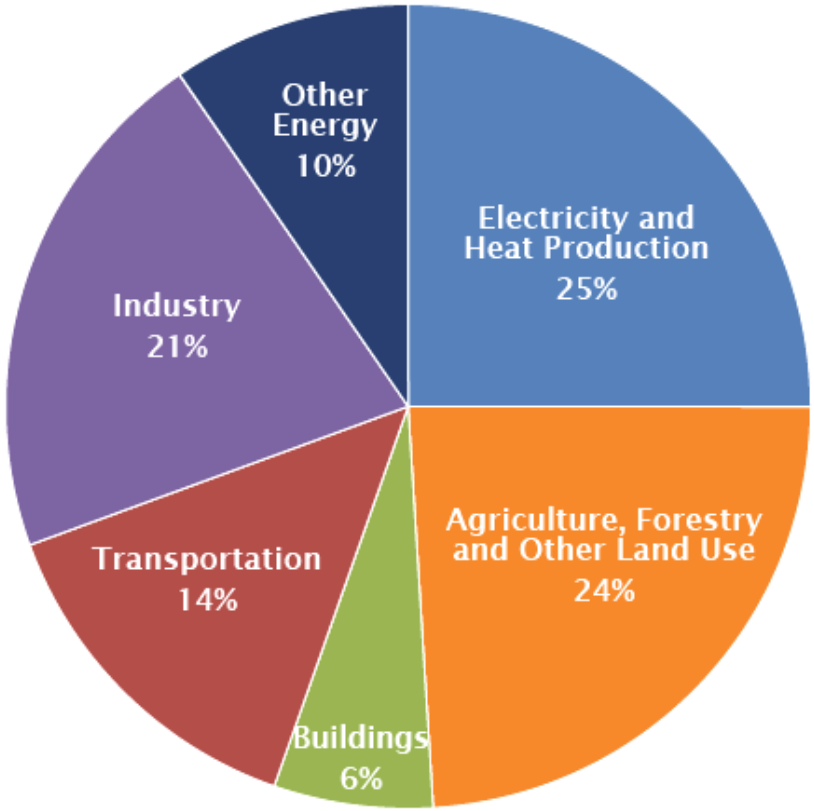


source: https://science2017.globalchange.gov/

Desertec-Prognosis: electricity production Europe [TWh/year]



Global Greenhouse Gas Emissions by economic sector



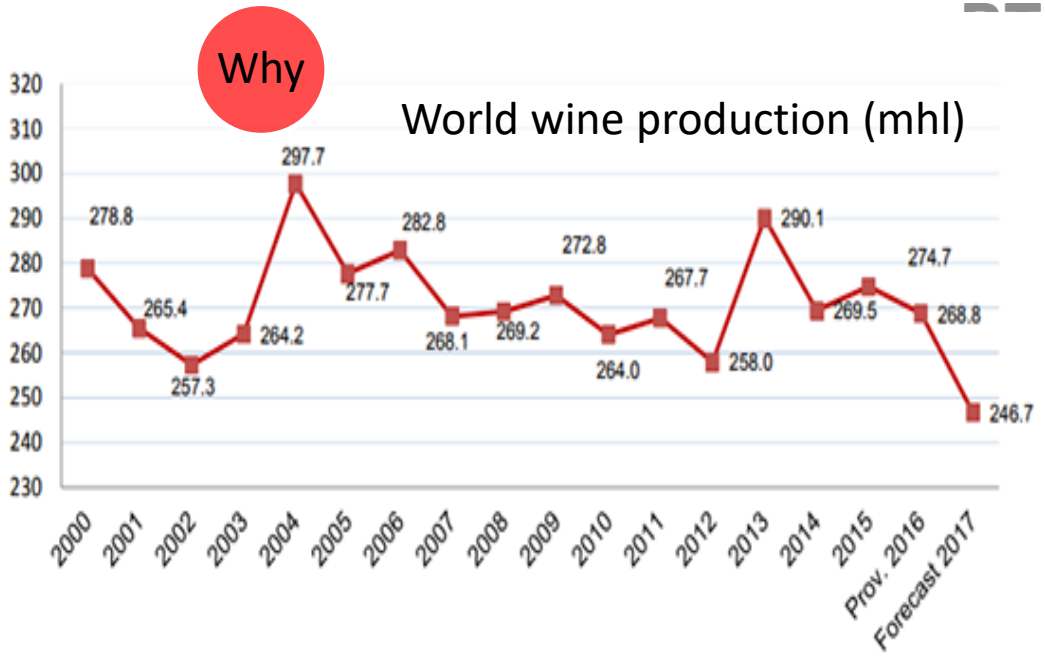
https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

Why

A problem for our grandchildren?

Let's not drink this…

Why



Sources: OIV

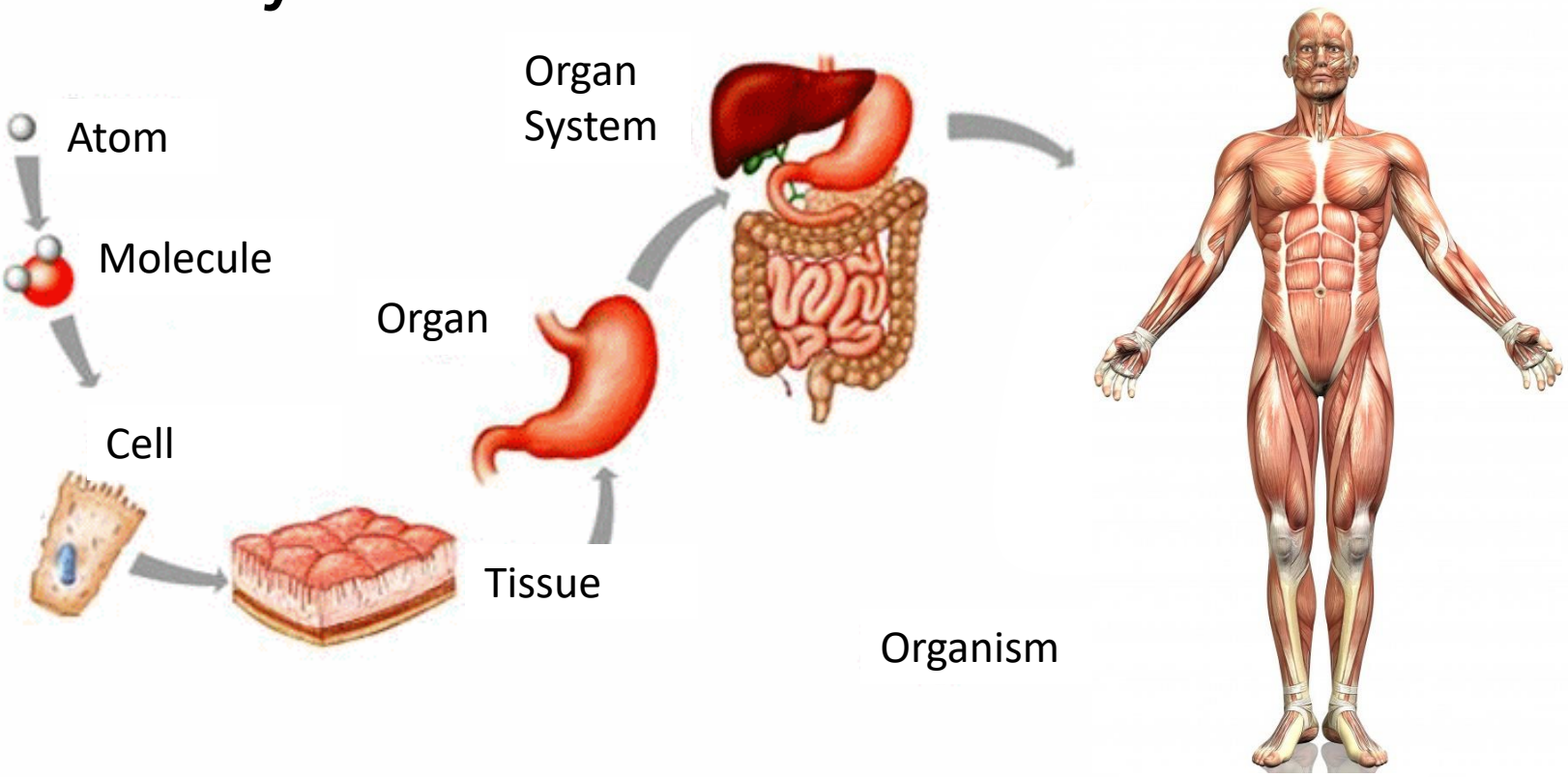
Severe spring frosts and a spike of hot weather dubbed the 'lucifer heatwave' mean that Italy is facing its smallest harvest for 60 years and France is expected to produce one of its lowest grape hauls in the post-Second World War era.

Spain and Germany are also expected to see harvests shrink, although the US is expected to produce the same as last year – despite the recent fires in California wine country.

Italy, France and Spain are the world's biggest three wine producing nations and these three expected to register declines of **23%, 19% and 15%** respectively on last year, to 39.3, 36.7 and 33.5 million hectolitres.

What

Scalability

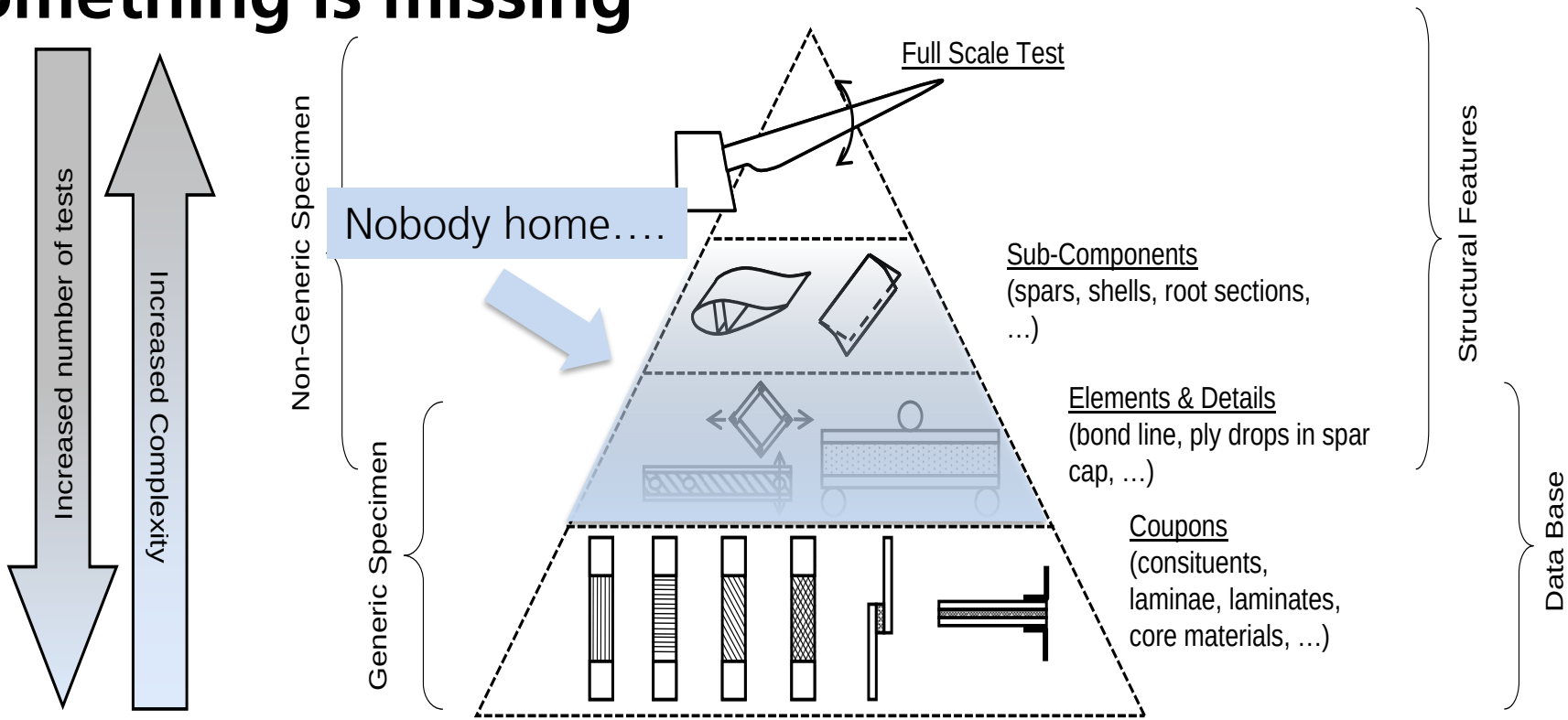


source: http://www.studyblue.com/notes/note/n/introduction-to-the-human-body-chapter-1/deck/282266

What
Why

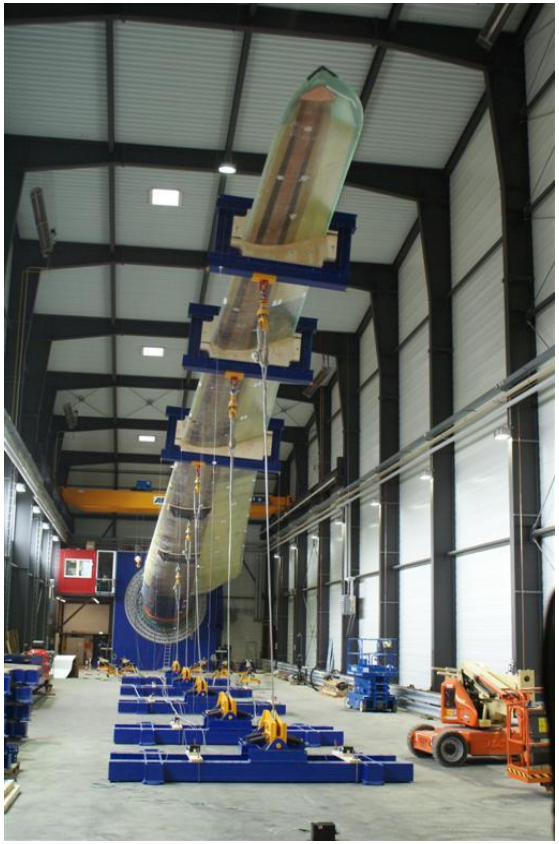
DTU

Rotor Blade Testing…….
Something is missing



Source: IEC 61400-5 (draft version)

Full scale blade test: static test 56m blade



What

Purpose of blade test (IEC-61400-23)

Demonstrate to reasonable level of certainty

- That specified limit states are not reached
- blades possess strength and service life provided for in design
- when manufactured according to certain set of specifications
- Blade must be shown to withstand both ultimate loads and fatigue loads

Full-scale tests are normally tests on limited number of samples

- Only one or two blades of given design are tested
- no statistical distribution of production blade strength can be obtained

Tests give information valid for blade type

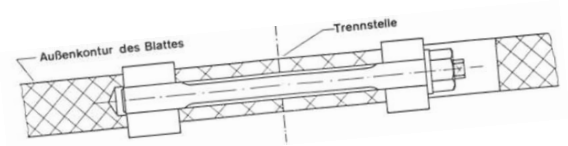
- No replacement for rigorous design process
- No replacement for quality system for series blade production

Why is that a problem?

- Even a single material or structural blade test would require a full scale blade test, costing up to 1 year and 1M€ - plus a blade -
- Serious impediment to the development of new rotor blades
  - Risks associated with failure of the full scale blade test are millions of Euros
  - Full scale blade tests are unsuitable for “what-if” scenarios
- The available worldwide test capacity, especially for larger blades, is insufficient to carry out all required tests, causing major delays in blade development
- Lack of statistical data for the blades, since typically only one blade is tested

What

Blade components



Root connections

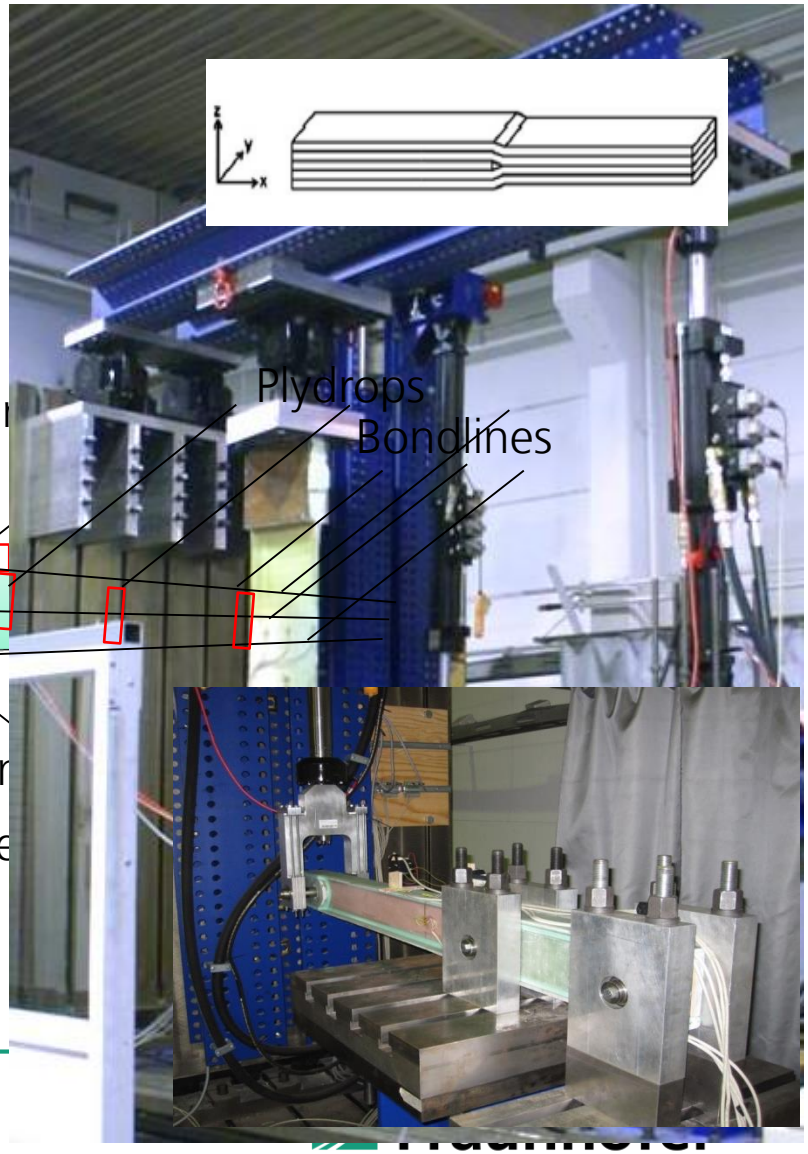
Buckling panels

Trailing edge segr

Transition part

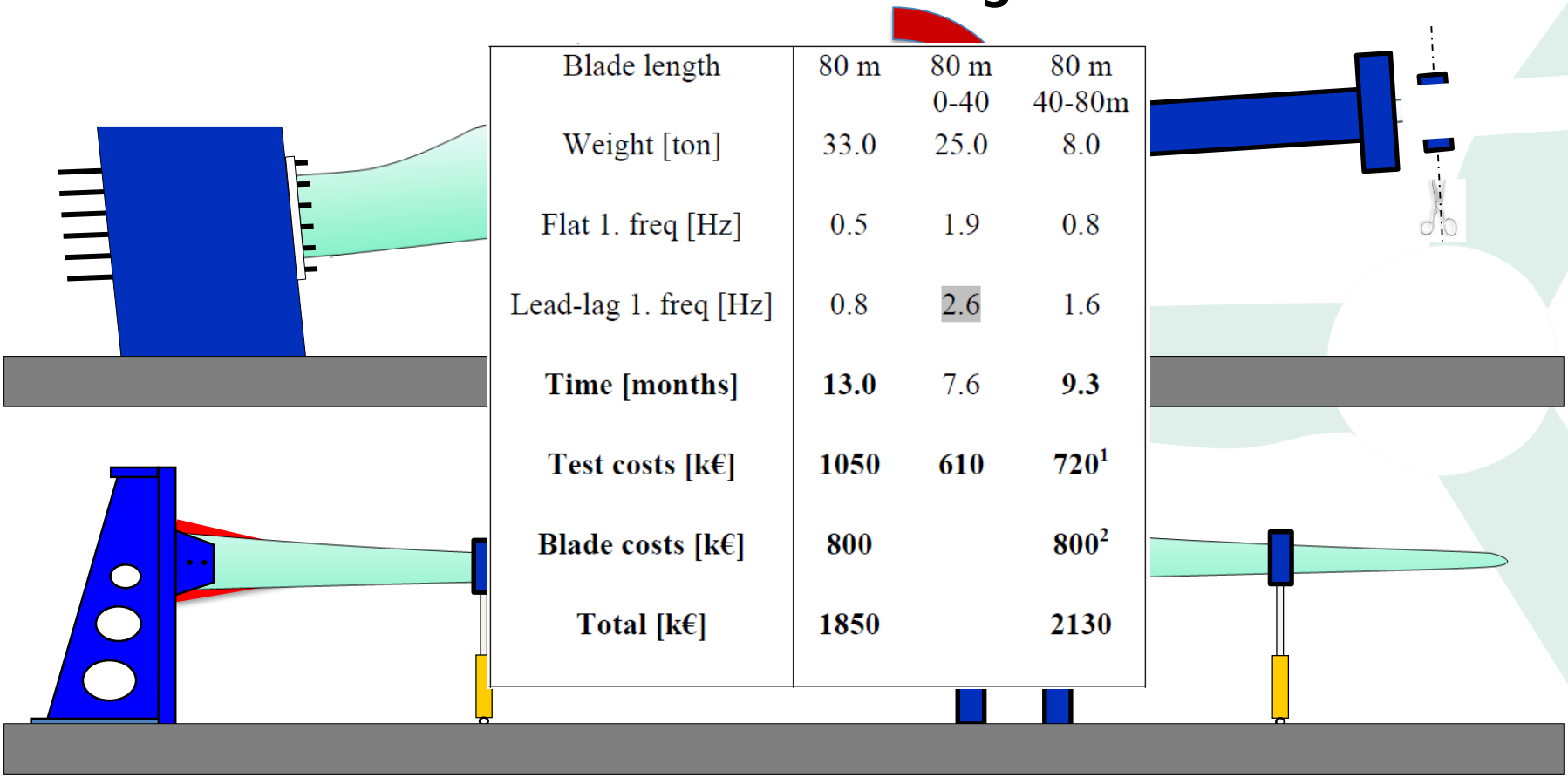
Leading edge segr

Chord, Chord-we



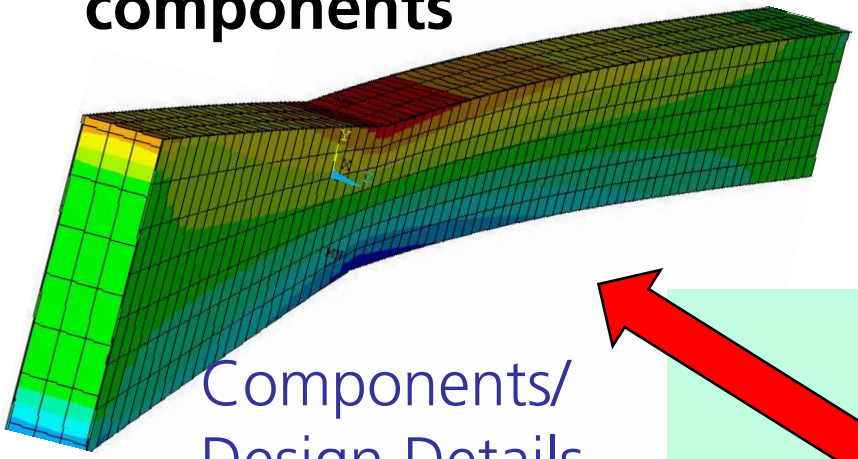
How

Blade division ⊥ Blatt axis: Blade segments

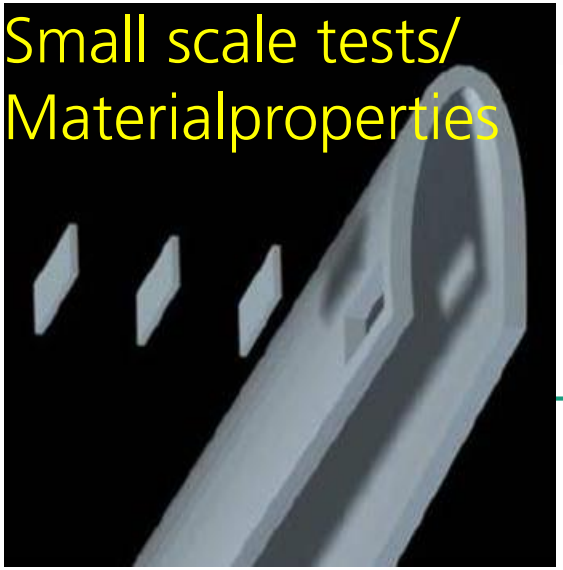


Blade length	80 m	80 m 0-40	80 m 40-80m
Weight [ton]	33.0	25.0	8.0
Flat 1. freq [Hz]	0.5	1.9	0.8
Lead-lag 1. freq [Hz]	0.8	2.6	1.6
Time [months]	**13.0**	7.6	**9.3**
Test costs [k€]	**1050**	**610**	**720[1]**
Blade costs [k€]	**800**		**800[2]**
Total [k€]	**1850**		**2130**

New certification method: Representatives & blade components



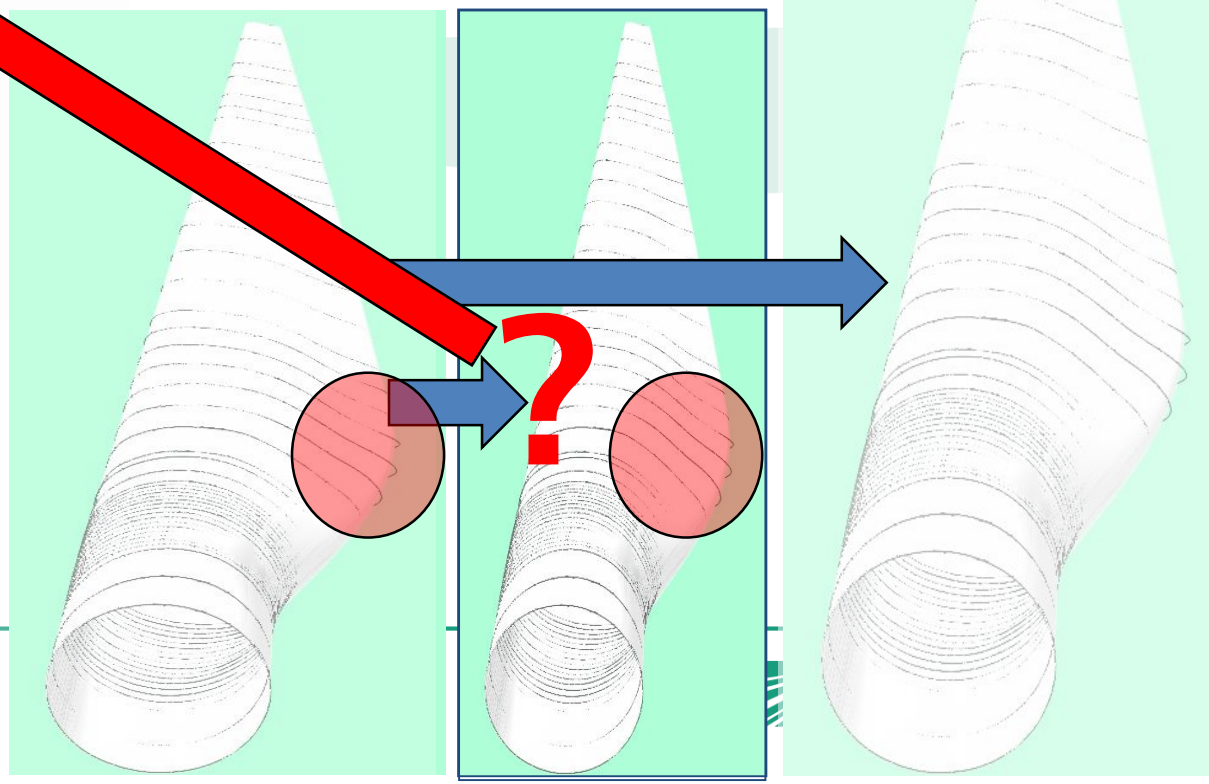
Components/
Design Details



Small scale tests/
Materialproperties

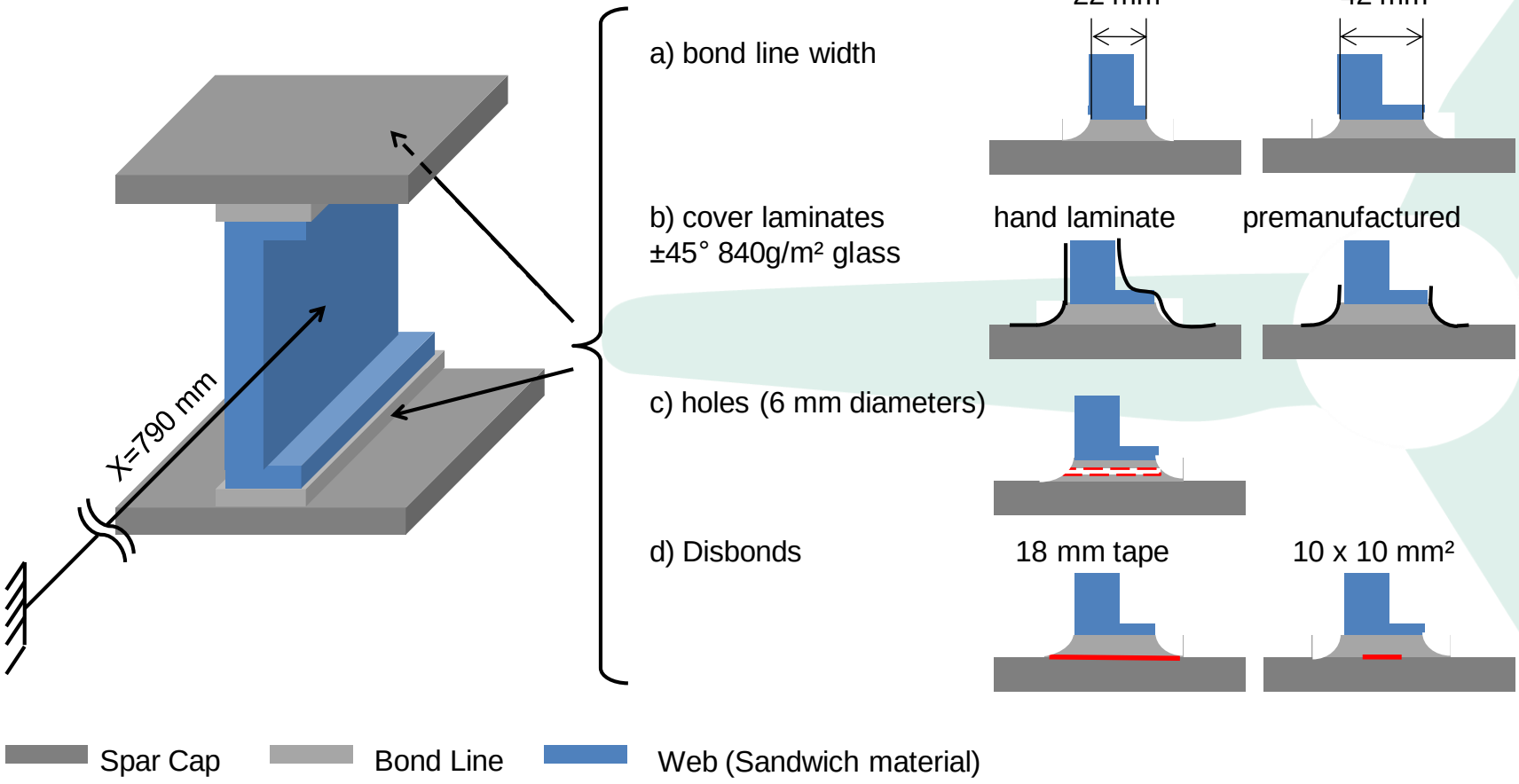
Blade family with representatives

Up/down scaling



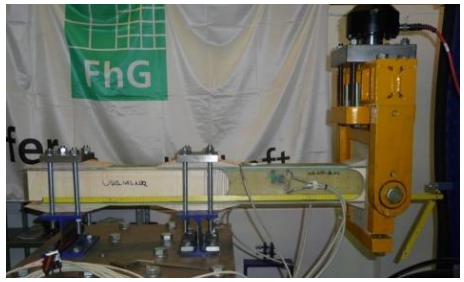
How

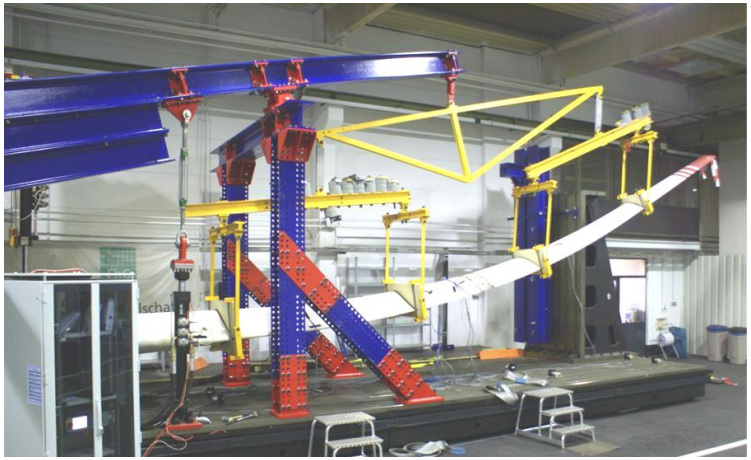
Sub-Component testing – spar cap to web bond line

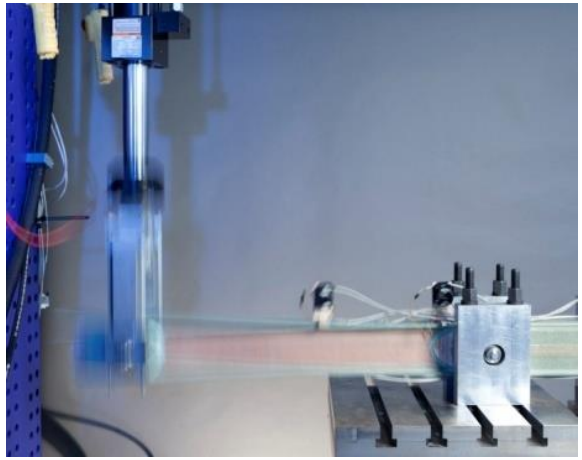


What
How

- Sub-component tests (generic specimen)
- Component tests (real blade parts)
- Blade section tests (real blade sections)
- Test of small wind turbine blades





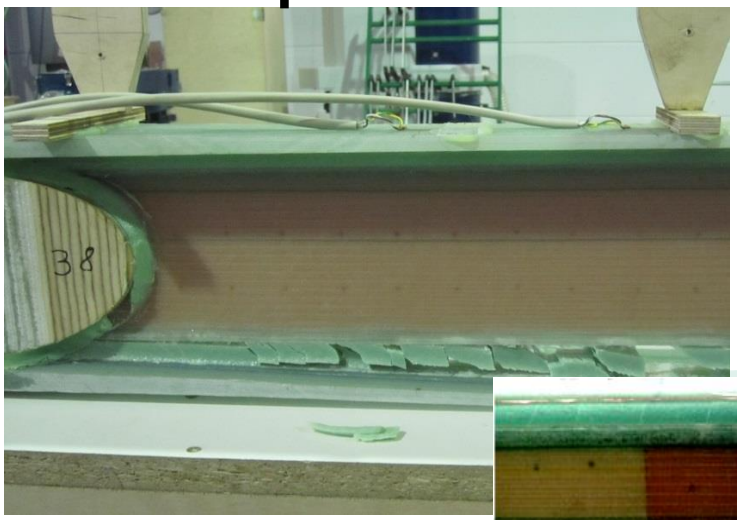


What

Blade segments: Time and Costs

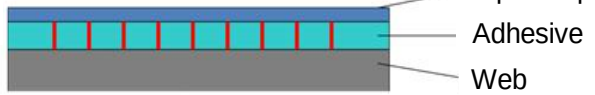
Blade length	40 m Blade 0-20 m	40 m Blade 20-40 m	80 m Blade 0- 40 m	80 m Blade 40-80 m	80 m Blade 0-60 m	80 m Blade 60-80 m
Weight [ton]	4,4	1,4	25,0	8,0	30,6	2,4
Flap 1. freq [Hz]	3,4	1,4	1,9	0,8	0,8	1,9
Edge 1. Freq [Hz]	5,2	3,2	2,6	1,6	1,2	4,8
Static load frames	2	1	3	3	4	1
Dynamic load frames	1	1	1	1	1	1
Add.Dyn.load frames	0	0	0	0	0	0
Thickness of frames	0,2	0,2	0,5	0,5	0,5	0,5
Pitch bearing incl.	yes	no	yes	no	yes	no
Linear SG blade	40	40	80	80	100	60
Rosettes on Blade	10	10	20	20	25	15
SG on bolts	24	0	24	0	24	0
# Static tests (1.)	4	4	4	4	4	4
Cycles Flapwise	1,000,000	1,000,000	3,000,000	3,000,000	3,000,000	3,000,000
Cycles Edgewise	1,500,000	1,500,000	3,000,000	3,000,000	3,000,000	3,000,000
# Static tests (2.)	4	4	4	4	4	4
Ultimate test	no	no	no	no	no	no
Time [months]	**5,2**	**5,0**	**7,6**	**9,3**	**9,8**	**7,2**
Personal [€]	210.000	210.000	370.000	420.000	440.000	330.000
Material [€]	60.000	70.000	170.000	170.000	200.000	140.000
Energy [€]	10.000	10.000	70.000	140.000	140.000	70.000
Testing costs per subcomponent [€]	280.000	290.000	610.000	720.000	790.000	540.000
Testing Cost Total		570.000		1.330.000		1.330.000
Prototype		150.000		800.000		800.000

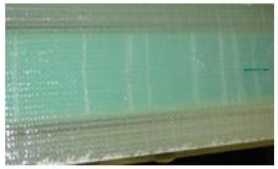
Sub – Component test: Bond lines



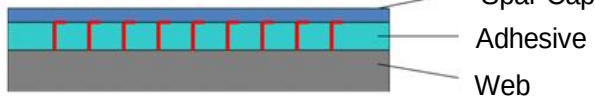
- Transversal cracks (mode I), 10% N_f
- Cracks extend into laminate
- Longitudinal crack (mode II), 60-70% N_f
- "kissing" cracks: ultimate failure

1. Axial Cracks

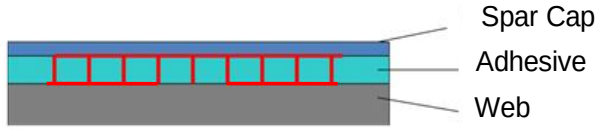




2. Start of Interface Failure

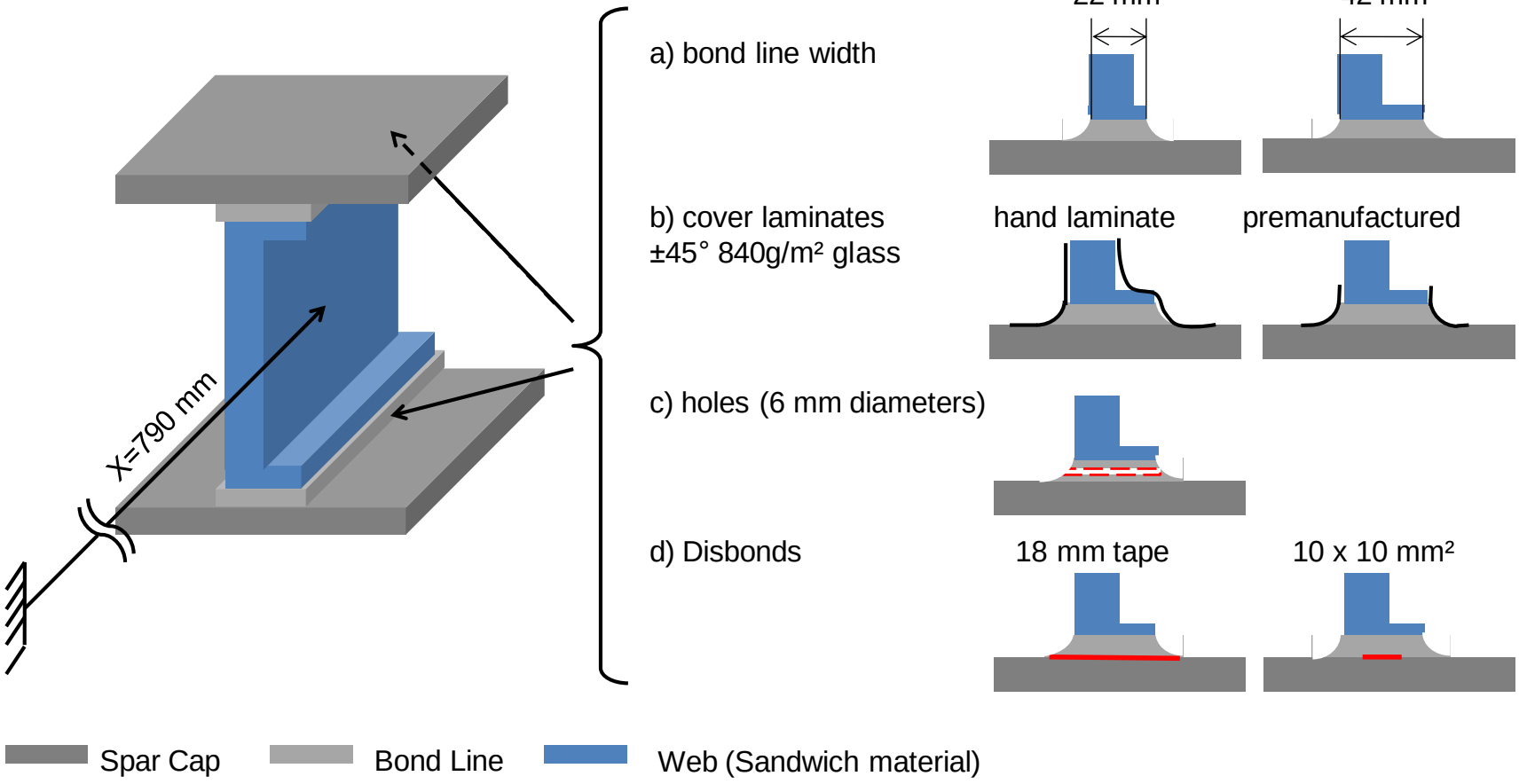


3. Interface Failure

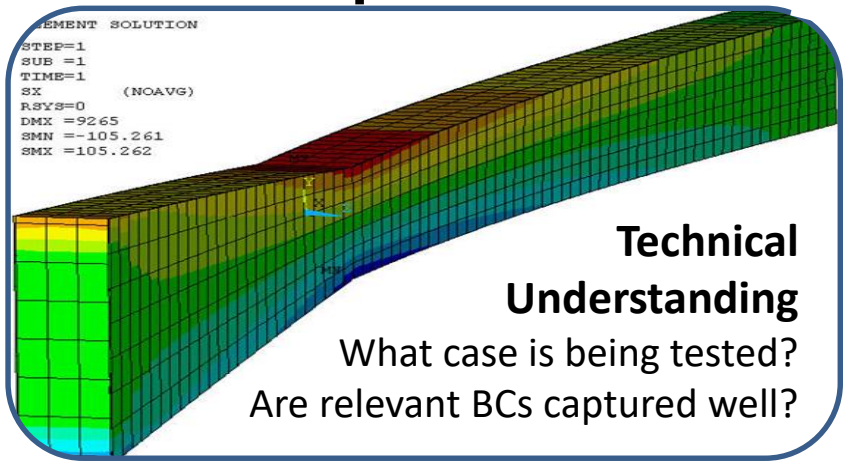


How

Sub-Component testing – spar cap to web bond line



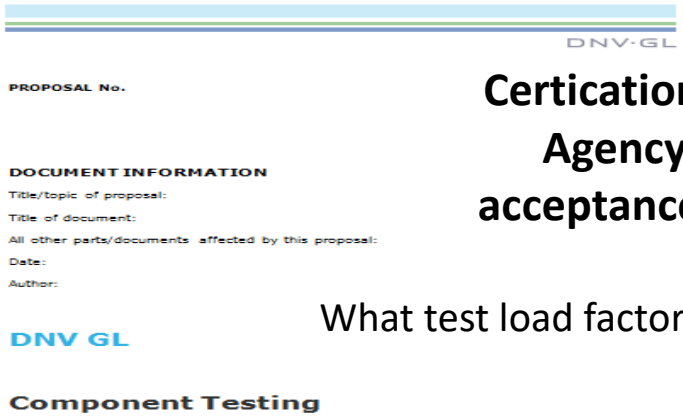
What is needed for subcomponent tests



Technical Understanding

What case is being tested?

Are relevant BCs captured well?



Certication Agency acceptance

What test load factors

Economical feasibility

Unique test set-up

Blade in one go

Danksagung
Das Fraunhofer IWES wird gefördert durch

BMWi
Bundesministerium
für Wirtschaft und Energie

Bundesministerium
für Wirtschaft
und Energie

BMBF
Bundesministerium
für Bildung und Forschung

Bundesministerium
für Bildung
und Forschung

Europäischer Fonds für regionale Entwicklung (EFRE):

Europäische Union
Investition in Bremens Zukunft
Europäischer Fonds für
regionale Entwicklung

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Land Bremen

- Senator für Umwelt, Bau und Verkehr
- Senator für Wirtschaft, Arbeit und Häfen
- Senatorin für Wissenschaft, Gesundheit und Verbraucherschutz
- Bremerhavener Gesellschaft für Investitionsförderung und Stadtentwicklung mbH

Bremen Bremerhaven

Land Niedersachsen

Europa fördert Niedersachsen

Niedersachsen

Freie und Hansestadt Hamburg

Hamburg

VILLUM FONDEN

Fraunhofer IWES

Thanks for your kind attention
Vielen Dank für ihre Aufmerksamkeit

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