



SINTEF

Vindmøllematerialer

Dagens og fremtidens materialer i
et bærekraftsperspektiv

Jens Kjær Jørgensen
SINTEF Manufacturing
2022

Teknologi for et bedre samfunn



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Et av de største, uavhengige forskningsinstituttene i Europa

OMSETNING



3,8

mrd NOK

ANSATTE



2200

PROSJEKTER



6900

KUNDER



3200

INTERNASJONALT

540 mill NOK

PUBLIKASJONER (inkl
formidling)

6100

NASJONALITETER

80

KUNDETILFREDSHET

4,5 av 5

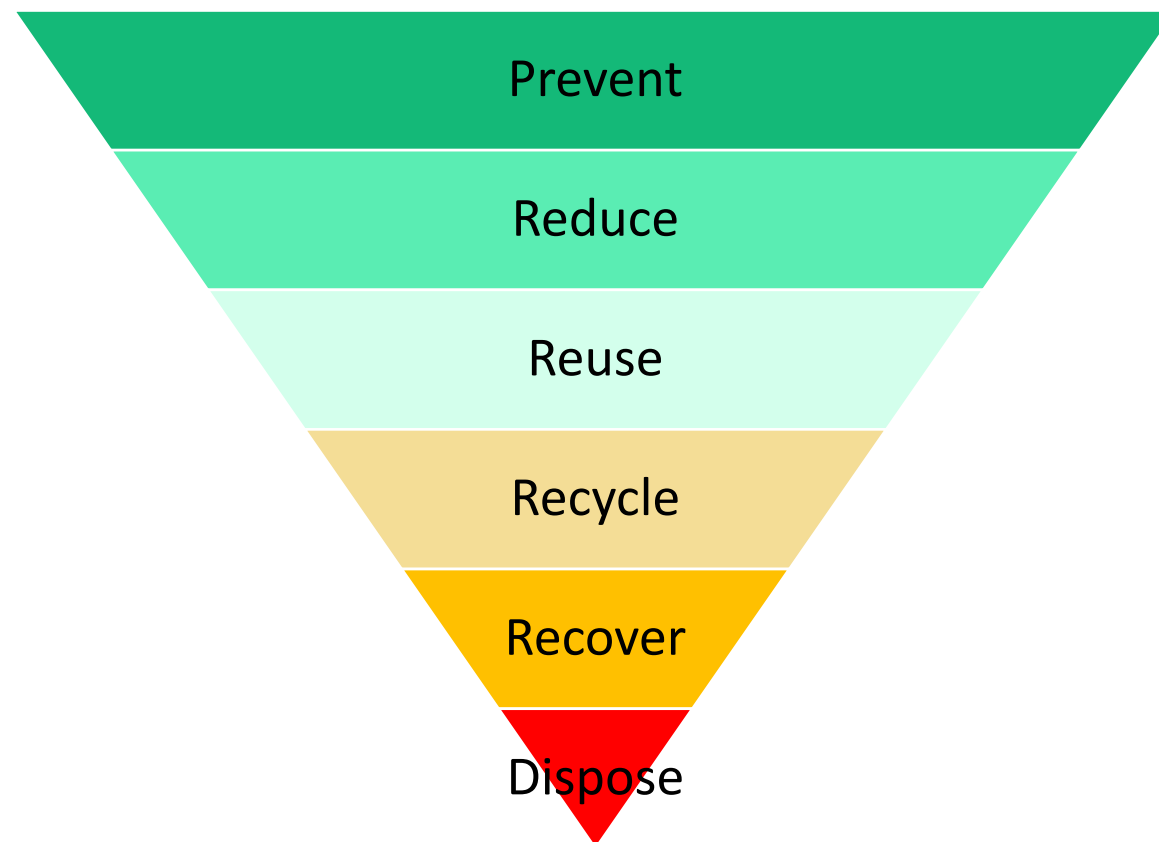
Visjon: Teknologi for et bedre samfunn

Bidra til konkurransekraft og samfunnsnytte gjennom å realisere FNs bærekraftsmål



Hvordan påvirker materialer?

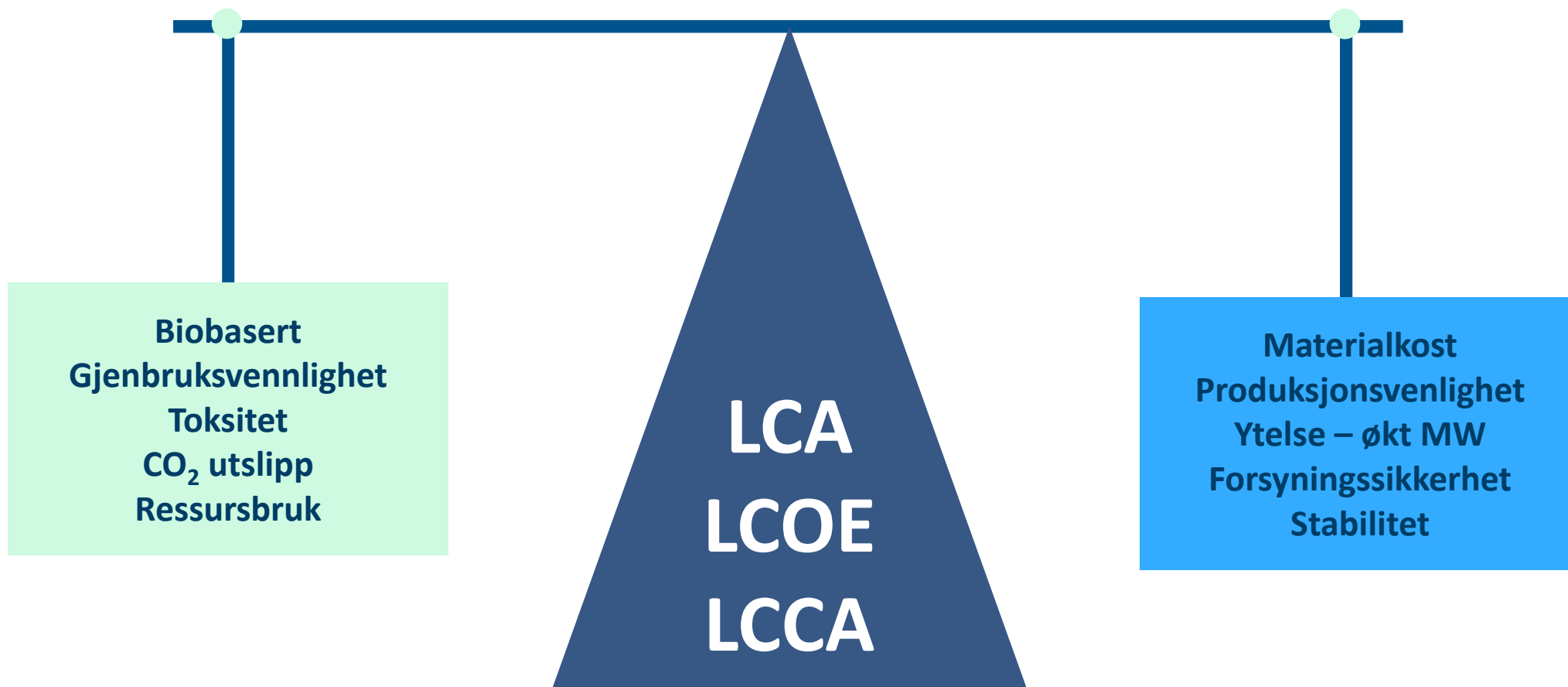
- Ressurs og energibruk i fremstilling
- Ytelse for konstruksjonen
- Levetid
- Vedlikehold
- Utslipp
- “End of life” - løsning





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Balance av mange faktorer





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De fleste
materialtyper
brukes i
vindmøller



Teknologi for et bedre samfunn

Hva forskes det på?

- Levetid - forlenge?
- Tilstandsovervåkning
- Resirkulerbarhet av eksisterende materialer
- Nye resirkulerbare materialer?
- Biobaserte materialer?
- Ikke toksiske materialer



Stål

- Energikrevende produksjon
- CO₂ utslipp direkte fra fremstilling
- Krever korrosjonsbeskyttelse
 - Maling
 - Aktiv korrosjonsbeskyttelse
- Resirkulerbart – kommersielt i dag.
- Større fokus på gjenvinning uten omsmelting
- Nye varianter produsert med hydrogen uten direkte CO₂ utslipp



Aluminium

- Nisjeanvendelser – landgang, nacelle hus ..
- **Energikrevende produksjon**
- Resirkulerbart
- Korrosjonsbestandig



Bladmateriale

- Erosjon
- Resirkulering
- Modulære materialer/konstruksjoner
- Biobaserte materialer





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Erosjon av belegg

- Alvorlig erosjon vil føre til utslip men noen postulerte mengder har vært langt over realistiske mengder.
- Teknisk mulig å minimere med gode rutiner
- Belegg generelt uten BPA
- Nye beskyttelsesløsninger basert på energiabsorberende elastomerer
- Løsninger for nye blader og retrofit
- ..manglende studier av faktisk kontaminering under turbiner



8/12/

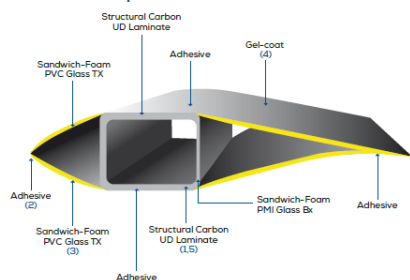


Resirkulering

ETIP-wind oversikt

Blade composition and upcoming volumes of composite waste in the industry

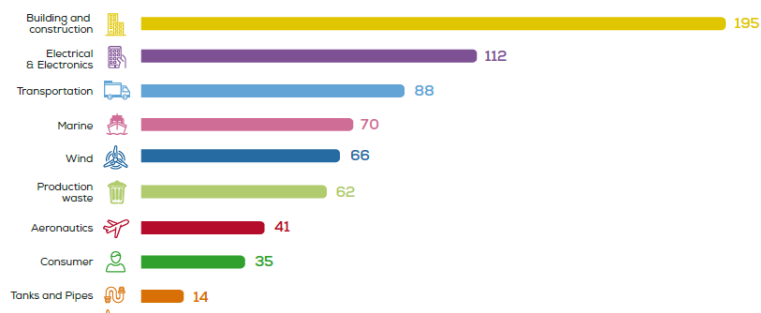
Generic composition of a wind turbine blade



Wind turbine blades are considered a composite structure, consisting of various materials with different properties. The material compositions vary between blade types and blade manufacturers, but blades are generally made of:

- 1) Reinforced fibres (glass, carbon, aramid or basalt)
- 2) A polymer matrix (thermosets such as epoxies, polyesters, vinyl esters, polyurethane, or thermoplastics)
- 3) A sandwich core (balsa wood or foams such as polyvinyl PVC, PET)
- 4) Coatings (PE, PUR)
- 5) Metals (copper wiring, steel bolts, etc.).

Estimated composite waste per sector in thousands of tonnes in 2025



The life cycle of a wind turbine blade



End-of-Life strategies for composite materials

Waste treatment hierarchy

Keep parts for longer.
Design for easier dismantling and recycling.
Minimise number of materials in design manufacture.

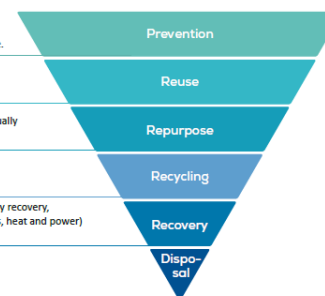
Check, clean, repair, refurbish, repair whole items or spare parts.

Re-use an existing part for a different application, usually of lower value than the original.

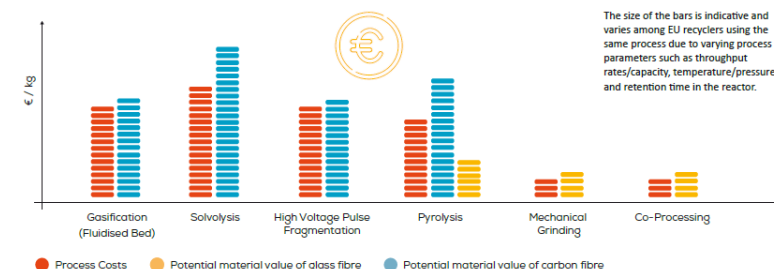
Convert waste into a new substance or product.
Includes composting if it meets protocols.

Includes anaerobic digestion, incineration with energy recovery, gasification and pyrolysis which produce energy (fuels, heat and power) and materials from waste.

Landfill and incineration without energy recovery.



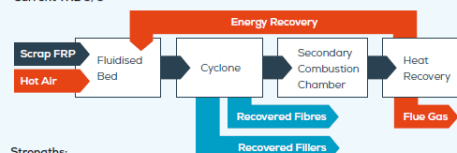
Estimated relative costs and values of composite recycling technologies



Composite recycling technologies and technology readiness level (TRL)

Gasification (Fluidised Bed)

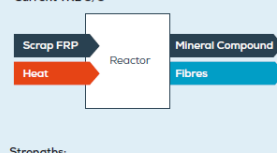
Current TRL 5/6



- Strengths:**
- Highly flexible and simple process;
 - Recovery of energy and potential precursor chemicals;
 - High efficiency of heat transfer.
- Limitations:**
- Recovery of low-quality material;
 - Economically viable at > 10,000 t/year;
 - Fluidised bed can locally collapse.
- Point of attention:**
- Process-related emissions.

Solvolysis

Current TRL 5/6

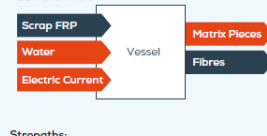


- Strengths:**
- Recovery of clean fibres in their full length;
 - Recovery of resin which can be re-used.
- Limitations:**
- Low efficiency;
 - High energy consumption due to the high-temperature and high-pressure;
 - Large amounts of solvents required.
- Point of attention:**
- Human health impacts and ecotoxicity from gas emissions.



High Voltage Pulse Fragmentation

Current TRL 6

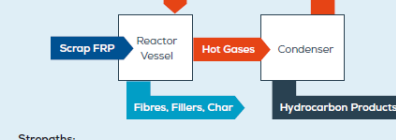


- Strengths:**
- Scalable to treat large amounts of waste;
 - Low investments required to reach the next TRL.
- Limitations:**
- Only laboratory- and pilot-scale machines are available;
 - Heavily decreased modulus of glass fibres.
- Point of attention:**
- Technology might be suboptimal to recycle the current stock of wind turbine blades.



Pyrolysis

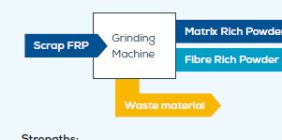
Pyrolysis Current TRL 9
Micro Current TRL 4/5



- Strengths:**
- Pyrolysis gas and oil can be used as energy source in the same process or in chemicals production;
 - Easily scaled up;
 - Microwave Pyrolysis: easier control. Lower damage to the fibre.
- Limitations:**
- Fibre product may retain oxidation residue or char;
 - Degradation of the chemical structure of fibres;
 - Not yet economically viable.
- Point of attention:**
- Potential leaks of gases from waste treatment chambers.

Mechanical Grinding

GFRP Current TRL 9
CFRP Current TRL 6/7

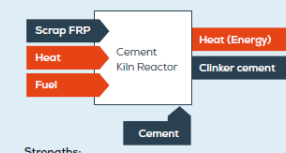


- Strengths:**
- Efficient and high throughput rates.
- Limitations:**
- Cost efficiency;
 - Low quality of recyclate. High content of other materials;
 - Up to 40% material waste.
- Point of attention:**
- Requires dedicated facilities with closed protective area to limit environmental impacts.



Co-Processing

Current TRL 9



- Strengths:**
- Highly efficient, fast and scalable;
 - Large quantities can be processed;
 - No ash left over.
- Limitations:**
- Loss of original material form;
 - Additional energy needed to reach high processing temperatures.
- Point of attention:**
- Pollutants and particulate matter emissions.

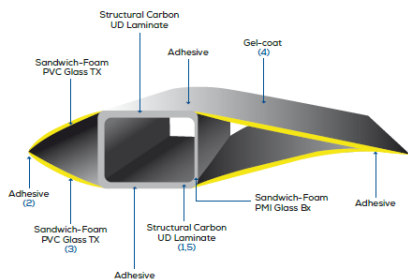


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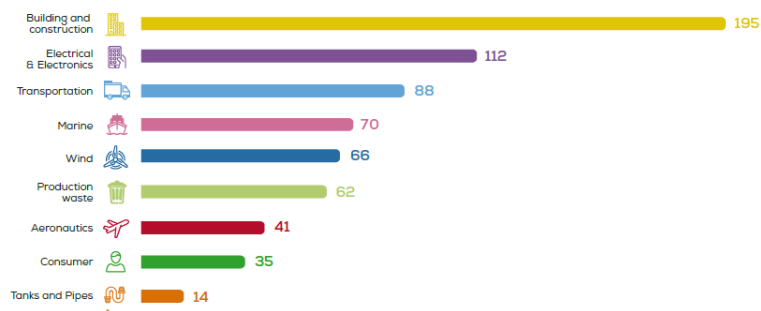
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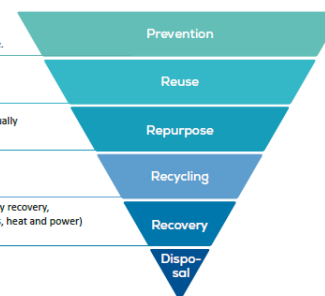
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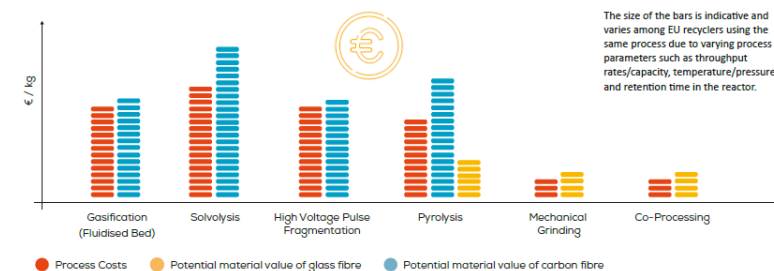
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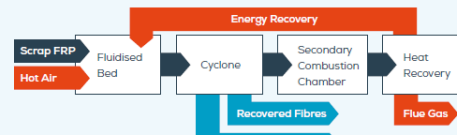
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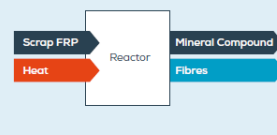
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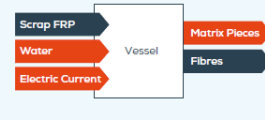


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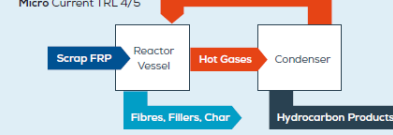


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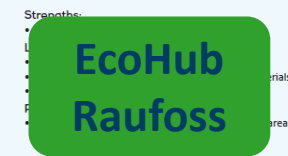
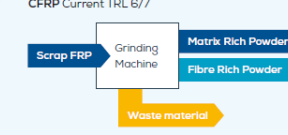
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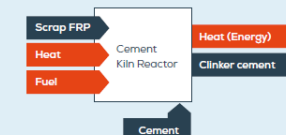
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Mye på gang men kompleks teknologi og næringskjeder må skaleres

TECH > RENEWABLES | 28 May 2021 | updated 05 Nov 2021 9:32am

Wind turbine blades to be 100% recyclable by 2024, says Vestas

A new technology enabling total circularity for wind turbine blades has been developed by industry and academic leaders, reports wind turbine manufacturer Vestas.

By Energy Monitor Staff



Wind turbines are already 85–90% recyclable. Now, a [new solution](#) developed by the Circular Economy for Thermosets Epoxy Composites ([CETEC](#)) initiative proposes the recycling of epoxy resins, the highly stable polymer chains used in turbine blades.

SIEMENS Gamesa
RENEWABLE ENERGY

Home > Newsroom > Commanding circularity: Siemens Gamesa

Commanding circularity: Siemens Gamesa announces RecyclableBlade for onshore wind power projects

ARKEMA

Investors Careers Media Main Brands Arkema

Group Innovation Social responsibility Market Solutions

Home > Media > News Overview > The world's largest 100% recyclable blade made from our Elium® thermoplastic resin

Corporate Innovation Products

03/21/2022 - NEWS

The world's largest 100% recyclable blade made from our Elium® thermoplastic resin

Tomas Kellner
March 16, 2022



Wind has been powering the world's energy transition to a more sustainable future, but the turbines that convert wind energy into electricity come with their own carbon footprint. As a result, companies that make turbine components have tried to make the footprint smaller.

Take LM Wind Power, a GE Renewable Energy business, which manufactures wind turbine blades — some 107 meters long. Last year, the company committed to producing zero-waste blades by 2030 by using new materials and reducing and recycling manufacturing waste as much as possible. It also joined the [ZEBRA](#) consortium, which stands for Zero waste Blade ReseArch.

ZEBRA aims to develop a recyclable blade, and this week it delivered the first prototype. LM Wind Power designed and made the 62-meter blade at its plant in Ponferrada, Spain, using a special resin from the French chemicals company Arkema and new high-performance glass materials supplied by Owens Corning.



Teknologi for et bedre samfunn

Nye materialer for blader

- Biobaserte resiner
- Biofibrer..
- Termoplast komposit
- Modulære deler



Nye materialer

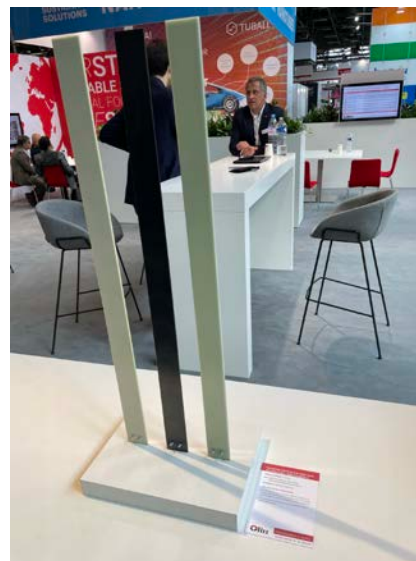
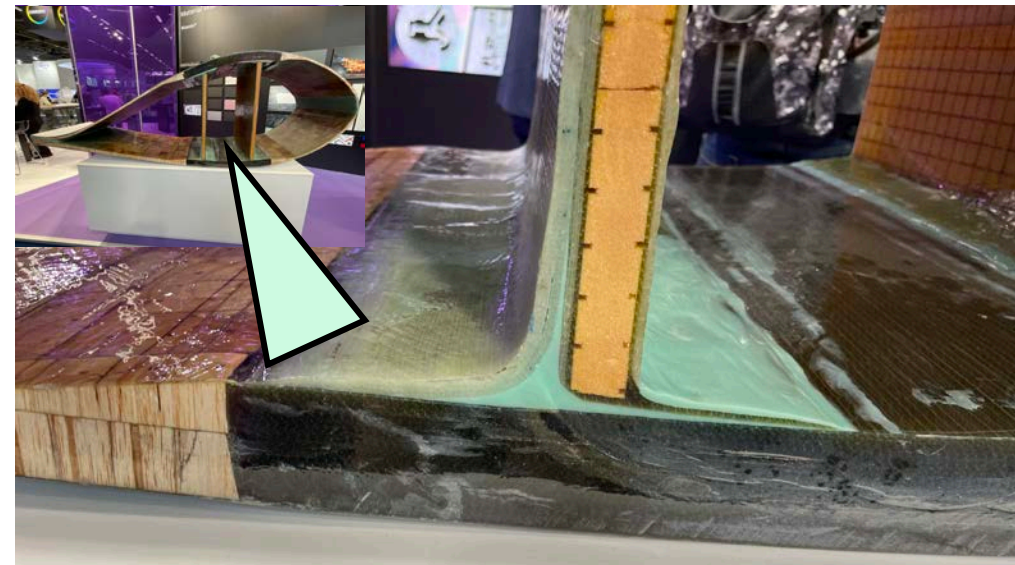
- Biobaserte resiner
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Source :Wikimedia

Nye materialer

- Biobaserte resiner
- Biofibrer..
- Modulære deler
 - Pultruderte planker i glass og carbon
 - Produktivitet
 - Gjenvinnbarhet
- Termoplast komposit





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Kabler



<https://www.nexans.com/en/csr/innovation-energy-transition/Nexans-recycling-solutions--your-cable-waste-has-never-been-more-valuable-.html>



SINTEF

Levetidsforlengelse – forskes mye

FME
**NORTH
WIND**

Turning wind R&D into a sustainable industry

FME NorthWind (Norwegian Research Centre on Wind Energy) brings forward outstanding research and innovation to reduce the cost of wind energy, facilitate its sustainable development, create jobs and grow exports.



The slide features a background image of several offshore wind turbines in a row. A semi-transparent white box in the center contains the title and subtitle. The DACOMAT logo is in the top right corner. At the bottom, there is a date and a small text block with a European Union flag.

Damage Controlled Composite Materials - DACOMAT

SCOPE and Technical Concept

31.10.2023

The DACOMAT project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 101019719. The information on this presentation reflects the views of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

The banner has a teal background with a faint image of wind turbines. The 'watereye' logo is in the top left. A navigation menu is at the top right. The main title is on the right side, and a subtitle is at the bottom right.

watereye
RESEARCH & INNOVATION ACTIONS

ABOUT PARTNERS NEWS RESULTS PUBLIC DATA RELATED PROJECTS CONT

O&M Tools Integrating Accurate Structural Health In Offshore Energy

O&M tools integrating accurate structural health in offshore energy



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Teknologi for et bedre samfunn