KUUSAKOSKI RECYCLING

RECYCLING SOLUTIONS FOR RENEWABLE ENERGY INDUSTRY:

WIND TURBINES & SOLAR PANELS

Anu Söderena, Business Development Manager
Aalto University Energy Forum
30th, November

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Family enterprise, founded **1914**

REVENUES
625.9 M€

EMPLOYEES
974

Avoided emissions globally:
1,490 000 tonnes CO^2e =
600,000 passenger vehicle

Unique research centre:
900
SAMPLES, THOUSANDS OF ANALYSES EACH YEAR

96.8%
utilisation rate of recycled materials

Recyclable materials collected
1,178,555 tonnes

Solid recovered fuels and recovered
82,534 tonnes

Recycled products
997,352 tonnes, including **745,871** tonnes of metals

Statistics: Kuusakoski's global recycling operations in 2021

AGENDA

Recycling basics

Wind turbine recycling

- Markets
- Recycling methods
- Challenges
- Kimura -project

Solar panel recycling

- Markets
- Recycling methods
- Challenges
- Economic Viability

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RECYCLING BASICS

Driving forces	Money and energy saving Market: shortage on material Law and directives
Boundary conditions	Thermodynamics
Positive vs. negative value	- Negative value (=processing them costs more than the secondary market value) - Positive value (metals) – London Metal Exchange
Quality in the secondary material	Some material loose their quality and material properties in the cycle, some remain the same


LONDON METAL EXCHANGE
THU 11 SEPT 16:53
THU 11 SEPT 16:53

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Business of Sport

What happens to all the old wind turbines?

By Padraig Belton
Technology of Business reporter

7 February

Bloomberg Green

Wind Turbine Blades Can't Be Recycled, So They're Piling Up in Landfills

Companies are searching for ways to deal with the tens of thousands of blades that have reached the end of their lives.

By **Chris Martin**

February 5, 2020, 12:00 PM GMT+2 *Updated on February 7, 2020, 6:54 PM GMT+2*

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CAN THEY BE RECYCLED?

MATERIALS IN A WIND TURBINE & RECYCLABILITY

Copper	95-98 %
Steel	95-98 %
Aluminium	95-98 %

Concrete 70-80 %

- Can be utilized as aggregate in civil engineering or in new cement

Rare Earth Elements 0-90 %

→ Up to 1600 tons of material 85 to 90% of a wind turbine's total mass can be recycled

Blades – composite 30 tons = 2 % of total mass

What would be the best solution?

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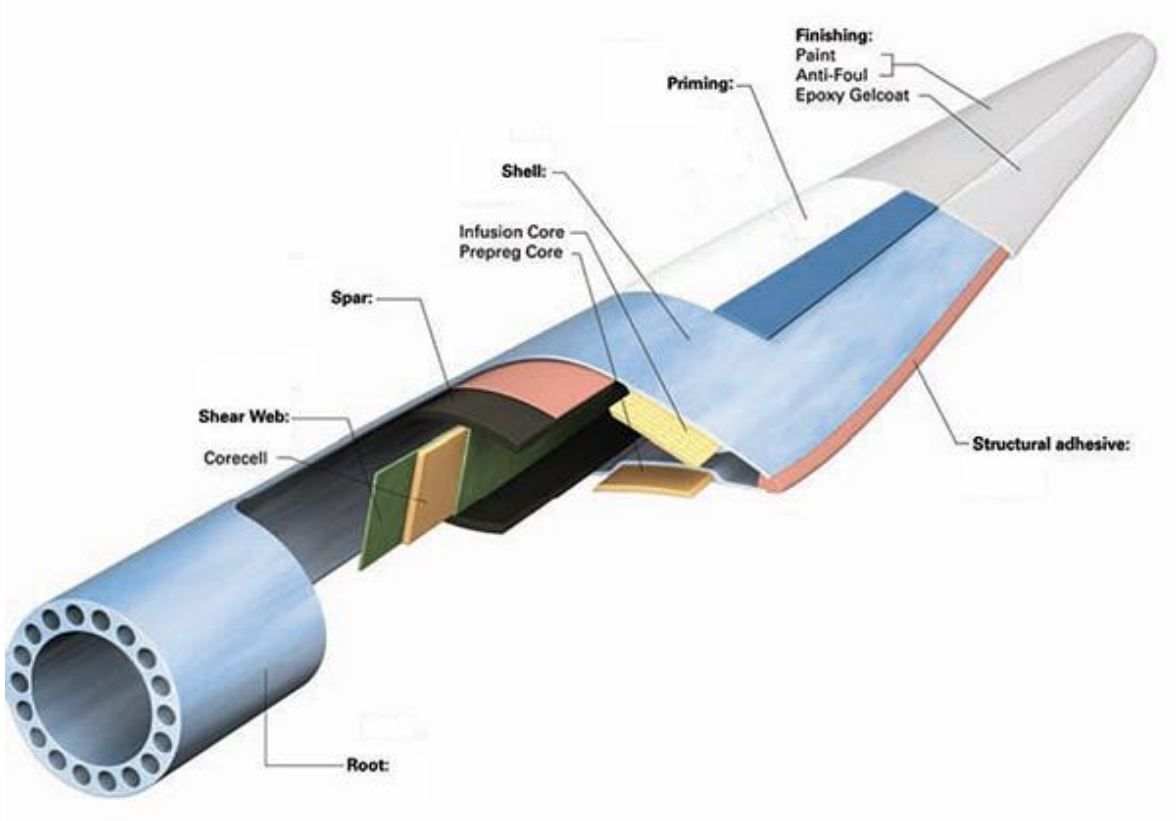
BLADE STRUCTURE

- **Reinforcement fibers**
  - Glass and carbon fibers
- **Polymer matrix**
  - Thermosets such as epoxies, polyesters, vinyl esters, polyurethane, or thermoplastics.
- **Sandwich core**
  - Balsa wood or foams such as polyvinyl chloride (PVC), polyethylene terephthalate (PET)
- **Structural adhesives**
  - Epoxies, polyurethane (PUR)
- **Coatings**
  - Polyester, polyurethane (PUR)
- **Metals**
  - Copper or aluminium wiring (lightning protection system), steel bolts



BLADE WASTE RECOVERY TREATMENT METHODS

- Cement co-processing (cement kiln route)
- Mechanical grinding
- Pyrolysis
- High voltage pulse fragmentation
- Solvolysis
- Fluidised bed

Readiness level for market:

Technological readiness levels (TRL)

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CEMENT CO-PROCESSING

- The blades are crushed and used as an in feed in the cement manufacturing process
  - The polymer matrix is burned as **fuel** for the process
  - Glass fiber is **recycled as a component** of cement mixes (cement clinker)

- Cement co-processing offers a **robust and scalable** route for treatment of composite waste

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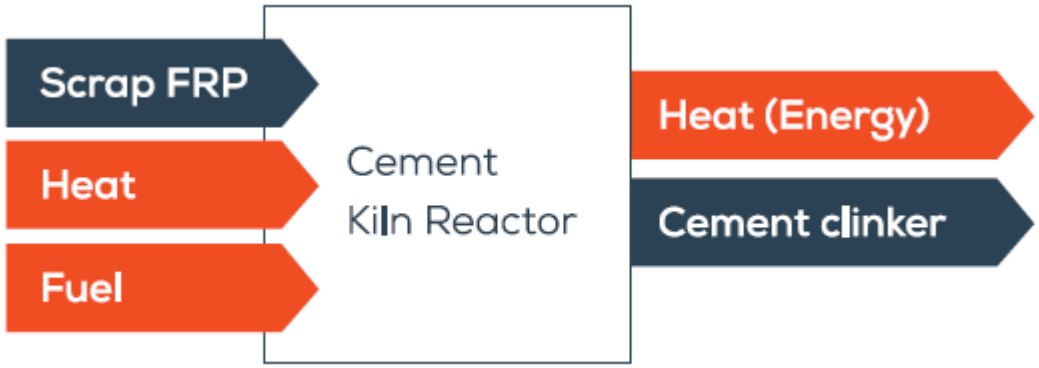
CEMENT CO-PROCESSING

- No ash nor other residues - utilization rate 100 %
  - 50 % material utilization & 50 % energy utilization



- In this process the fiber shape of the glass disappears and therefore cannot be used in other composites applications.

KIMURA-PROJECT

In Finland 2020-2022

- The goal of the project was to find an effective and sustainable way to sort and utilize composite waste.
  - It was important to identify materials that are not suitable for the cement manufacturing process: Chloride & Copper

MUOVITEOLLISUUS RY
Finnish Plastics Industries Federation

finn boat

FINNSEMENTTI
A CRH COMPANY

Patria

exel COMPOSITES

Suomen Tuulivoimayhdistys

Ympäristöministeriö
Miljöministeriet
Ministry of the Environment

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CRUSHED COMPOSITE

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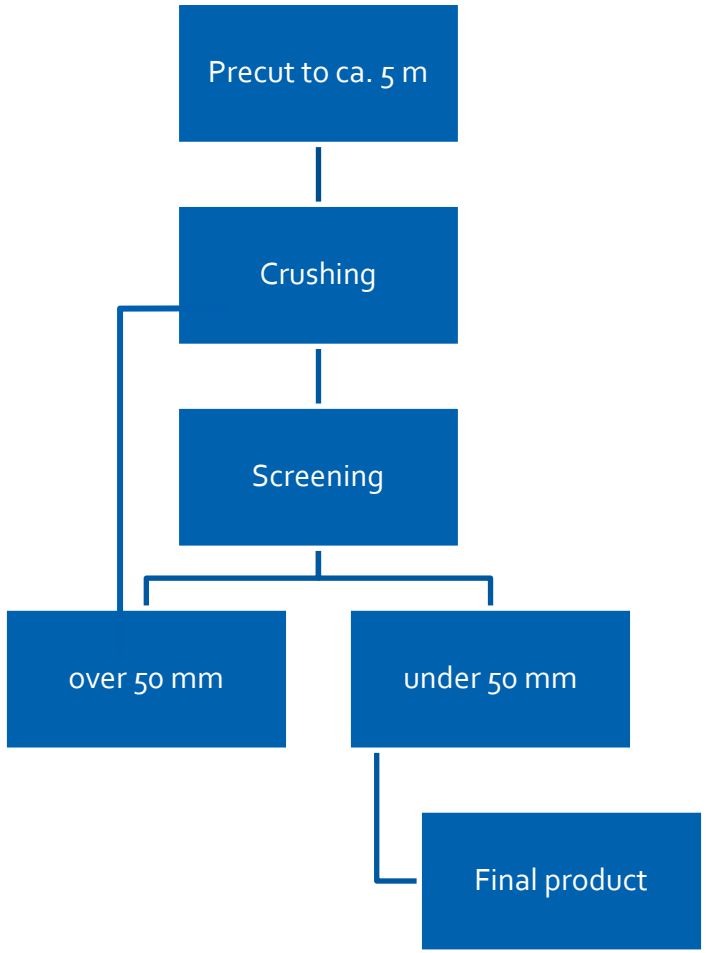
CRUSHING



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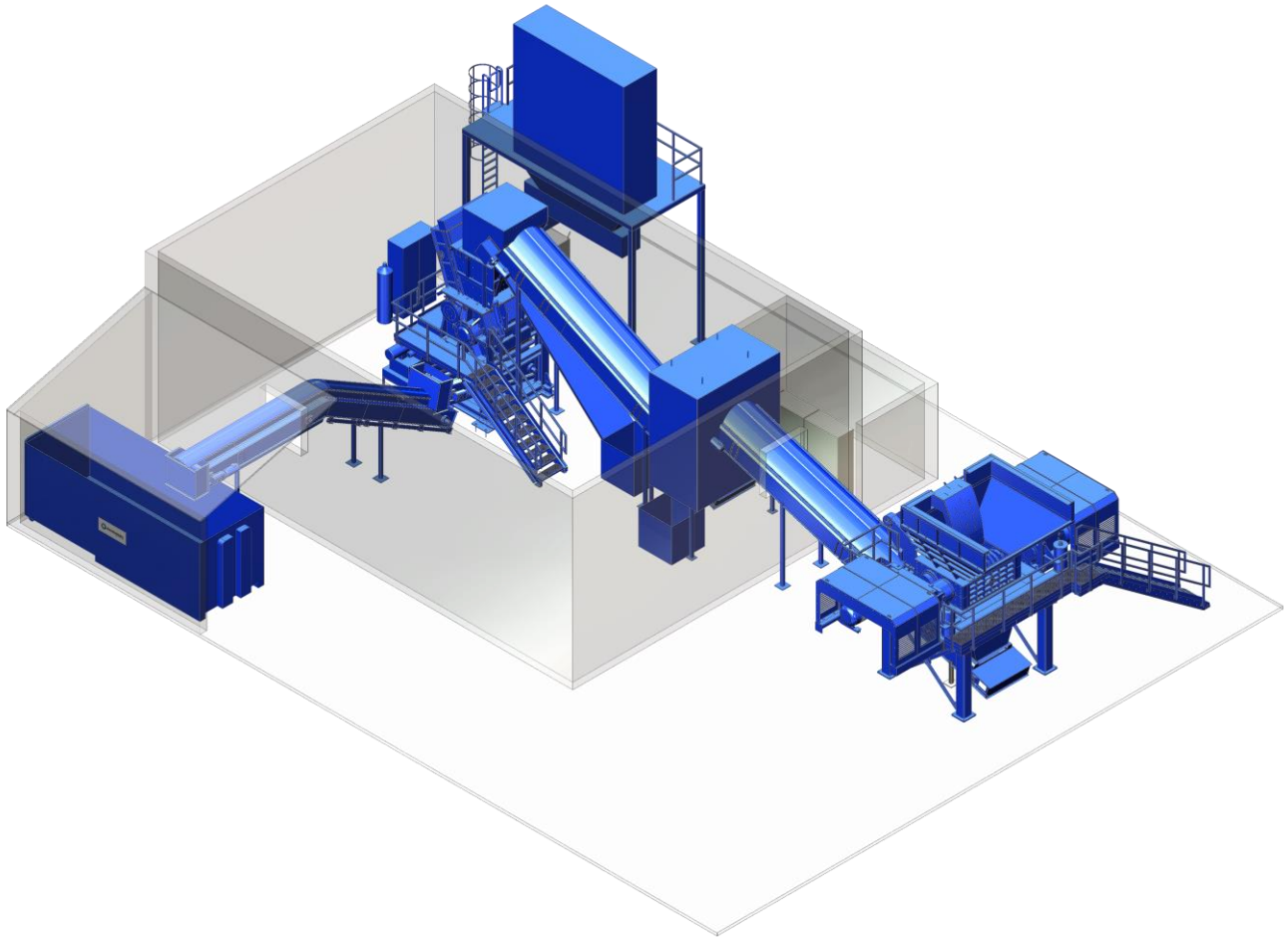
PROCESSING IN 2024

BUSINESS FINLAND

- Kuusakoski will build the first composite treatment plant in Northern Europe
  - Plant will be located in Hyvinkää, Finland
- Business Finland grand of 35 % of the investment
- The facility will consist of two shredders, metal separators and dust suppression system
- The building will start in 2023 and the production will start in 2024
- The treatment will be more efficient in the facility



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NEXT CHALLENGE: SOLAR PANELS

Harvard Business Review

Sustainable Business Practices | The Dark Side of Solar Power

Sustainable Business Practices

The Dark Side of Solar Power

As interest in clean energy surges, used solar panels are going straight into landfill. by Atalay Atasu, Serasu Duran, and Luk N. Van Wassenhove

June 18, 2021

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SUSTAINABLE BUSINESS

The Solar Boom Will Create Millions of Tons of Junk Panels

Harvesting valuable materials from old equipment presents a commercial opportunity and technical challenges

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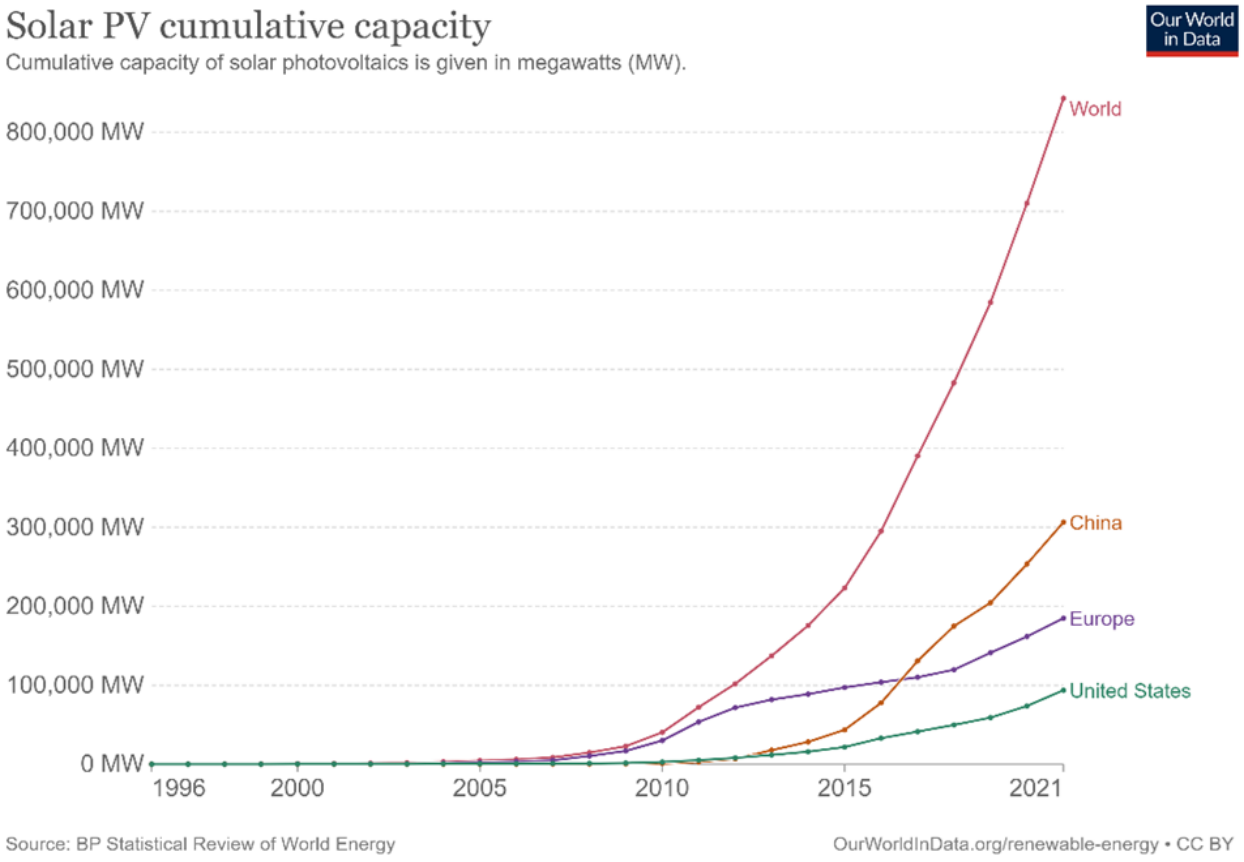
SOLAR PANEL CAPACITY HAS GROWN EXPONENTIALLY

Solar energy is on fast track!

- Yearly growth 45% in 2022 compared to previous year and 43% growth expected in 2023.

- Energy crisis in 2022 boomed solar energy growth. Policymakers are making faster decisions to back up the transformation.



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GLOBAL PV PANEL WASTE PROJECTION

- Solar electricity generation is projected to achieve a cumulative capacity of 2840 GW by 2030 and 8519 GW by 2050, amounting to 18x the global capacity recorded in 2018.
- **Transformation of the energy system will require the use of up to six times more minerals in 2050, compared to today.**
- Europe is highly dependent on metal imports, particularly precious metals, and it is critical to meet the PV growth demand (*European Parliament, 2023*).
- **IRENA has also estimated that the material recovered from dedicated PV recycling plants could have a value of $450 million by 2030 and potentially surpass $15 billion by 2050 (*IRENA, 2016*).**
- In 2030, 8 million metric tons of solar panels will reach their lifetime globally. In 2050 the waste will be around 80 million tons annually, and PV waste could exceed 10% of the global WEEE (Waste Electrical and Electronic Equipment) waste stream by 2050.

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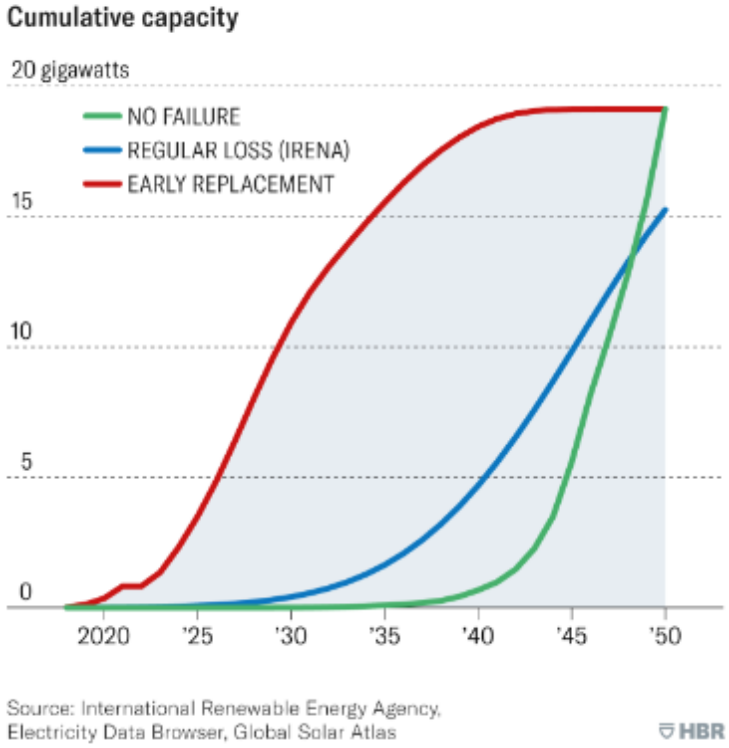
The Solar Trash Wave

According to our research, cumulative waste projections will rise far sooner and more sharply than most analysts expect, as the below graph shows. The green "no failure" line tracks the disposal of panels assuming that no faults occur over the 30-year life cycle; the blue line shows the official International Renewable Energy Agency (IRENA) forecast, which allows for some replacements earlier in the life cycle; and the red line represents waste projections predicted by our model.



SOURCE: HBR, 2021. The Dark Side of Solar Power. Atalay Atasu, Serasu Duran, and Luk N. Van Wassenhove. June 18, 2021

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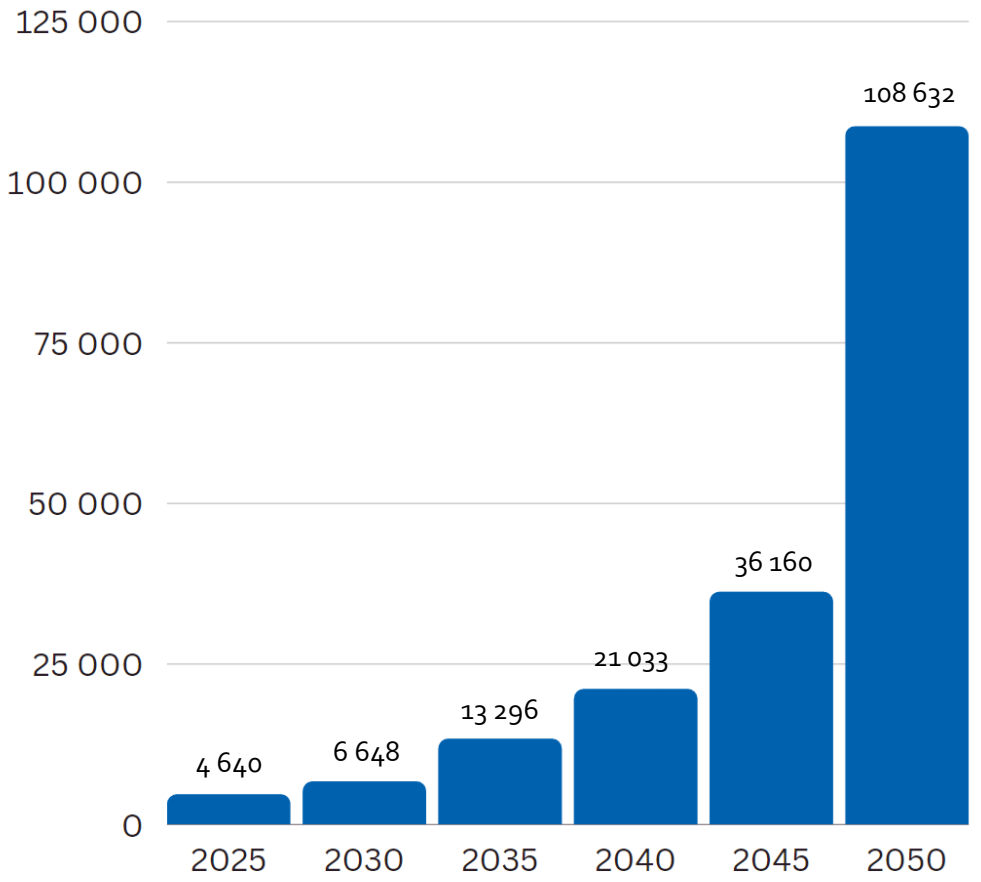
WASTE IN FINLAND, SWEDEN AND ESTONIA



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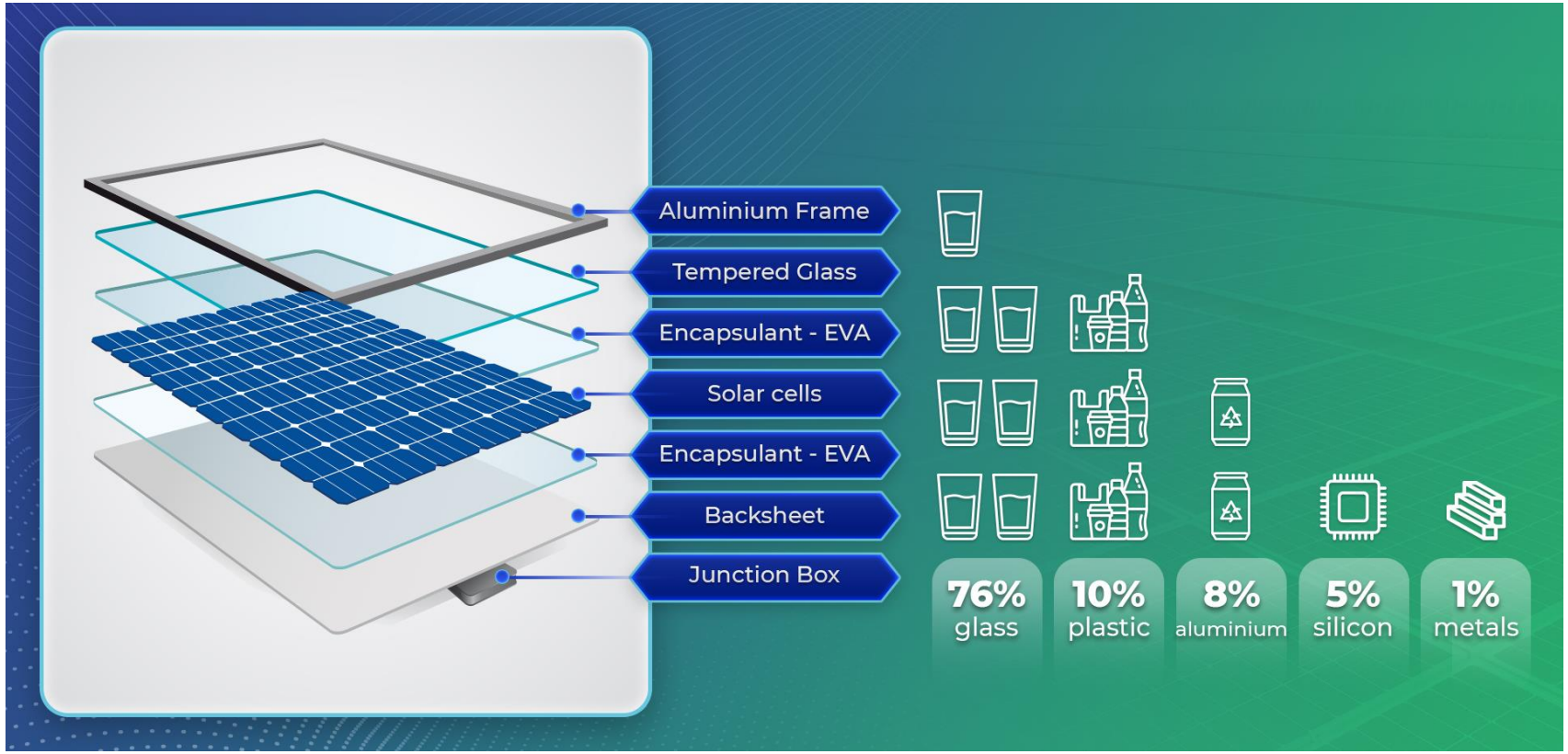
CAN SOLAR PANEL RECYCLING PANELS BE RECYCLED?

COMPONENTS OF SOLAR PANELS

Silicon-based – 95 % of panels on the markets



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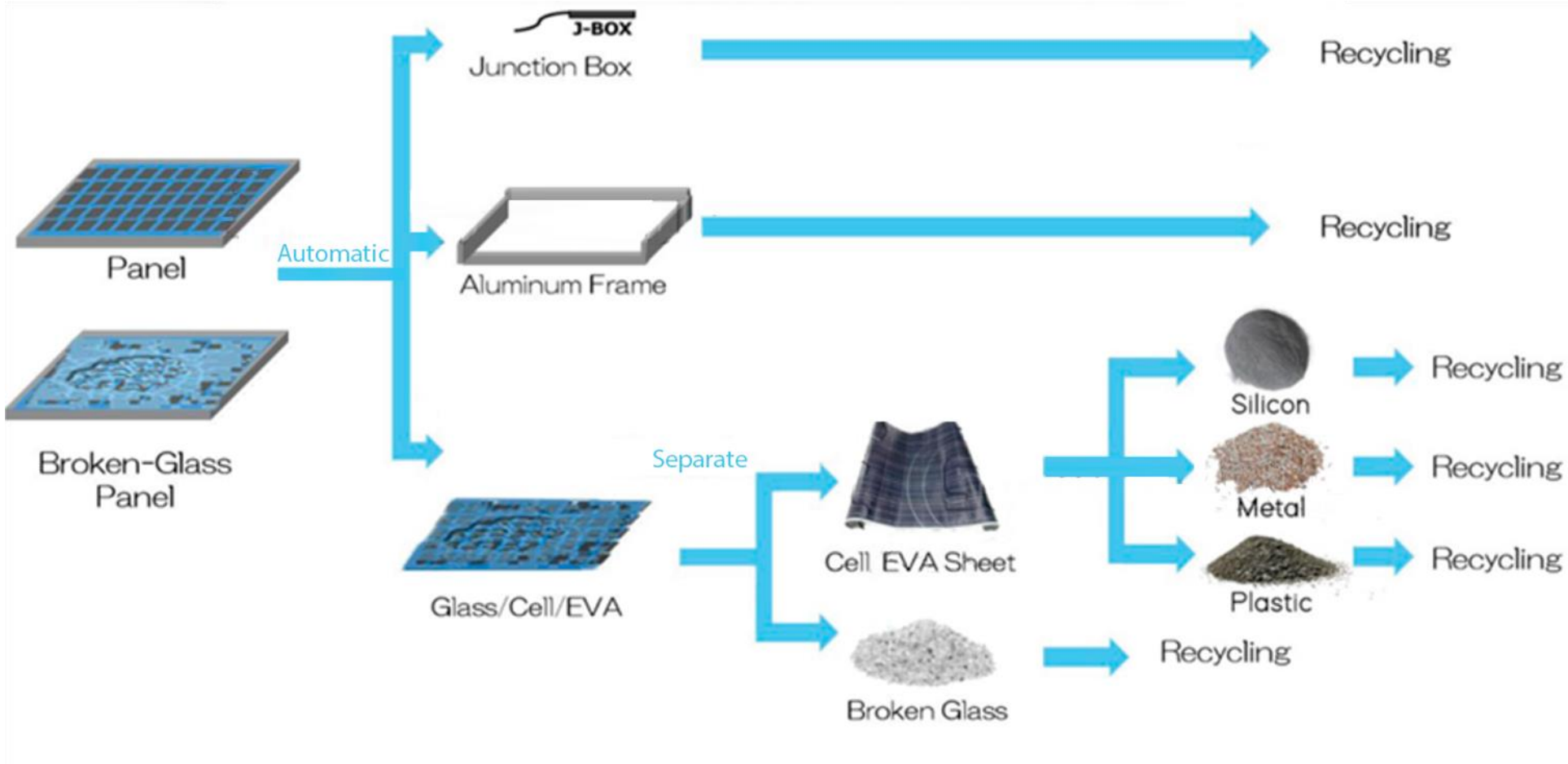
RECYCLING PROCESS



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ECONOMIC FEASIBILITY

SCENARIO BUILDING

Waste accumulation	Market share
Waste gate-fee	Discussions with Producer Responsibility Organizations
Secondary raw material prices	Glass Polymer Metals Silicon

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INVESTMENT – BASIC CASE

Reuse percentage
Annual PV tonnage
Recycled panels (t)

SCENARIO DATA

DATA FROM TRIALS

CHOSEN TECHNOLOGY

Investment EUR

	Composition	Recycling rate	Annual tons
Glass	80 %	80 %	
Silicon	3 %	70 %	
Aluminium	8 %	95 %	
Copper	0,9 %	90 %	
Circuit board	0,1 %	90 %	
Silver	0,001 %	0 %	
Polymer	8 %	100 %	

€/t	
X	Gate fee
X	Eletricity
X	Reuse treatment expense
X	Pretreatment expense
X	Treatment expense
X	Glass price
X	Silicon price
X	Alumiunium price
X	Copper price
X	Circuit Board price
X	Silver price
X	Waste price
X	Yard expenses

xxxxxxxxxx **Net revenue**

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SCENARIOS & INVESTMENT CALCULATION

Sensitivity Analysis		Market share	Variables			Copper price	Aluminum price	Repayment period	IRR%		NPV	
			Waste amount (t)	Recycled waste (t)	Waste gatefee (€/t)	€/t	€/t	years	5 years	10 years	5 years	10 years
Base Case	Realistic											
Scenario I	Realistic											
Scenario II	Negative											
Scenario III	Positive											

INPUT DATA

INVESTMENT CALCULATIONS

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SENSITIVITY ANALYSIS

Sensitivity Analysis		Variables			
		Waste amount (t)	Waste gatefee (€/t)	Copper price €/t	Aluminium price €/t
Base Case	Realistic				
Scenario I	Realistic				
Scenario II	Negative				
Scenario III	Positive				

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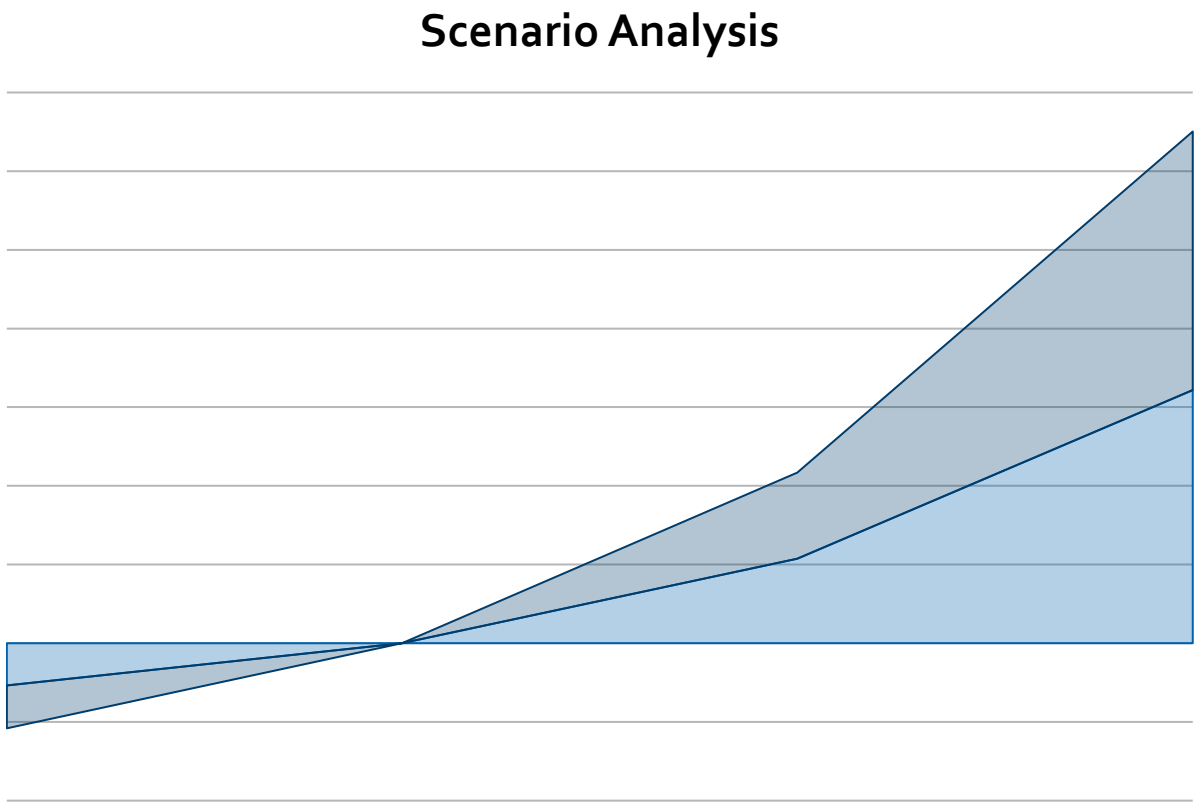
SENSITIVITY ANALYSIS



Copper price

Aluminium price

LAWS MAKES ALL THE DIFFERENCE

U.S.

- "With the current capacity, it costs an estimated $20–$30 to recycle one panel. Sending that same panel to a landfill would cost a mere $1–$2." (Source: HBR)

Europe

- European Union's WEEE Directive: Waste producer pays the recycling costs = Extended producer responsibility
- The Directive was amended in 2014 to include solar panels.

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NEXT STEPS

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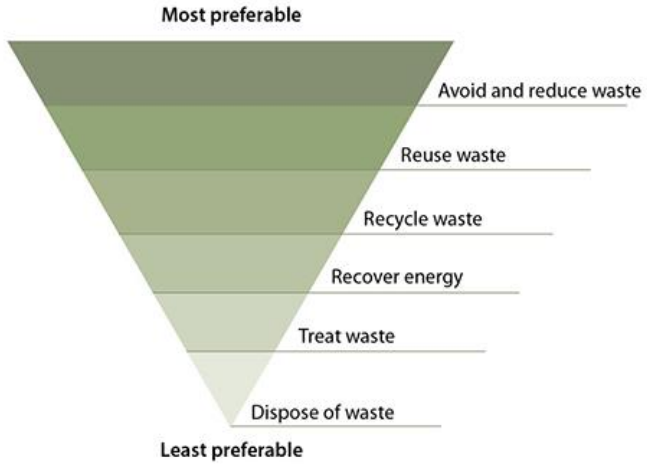
APPENDIX

LEGISLATION

- Today, there is limited legislation regulating treatment of composite or blade waste both at EU and national levels

- In Finland, the waste management is guided by Waste Law (646/2011)
  - Treatment must follow EU waste hierarchy

- Existing regulatory incentives
  - Landfill bans and taxes
    - In Finland, it is banned to landfill composite waste
    - For exceptional permit (Landfill tax 70 €/t)



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COMPOSITES

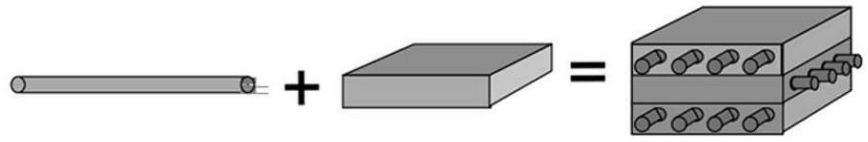
- The combination of fibers and polymers, also known as composites, represents the majority of the blade material composition: 60-70% reinforcing fibers and 30-40% polymer matrix by weight.

- Composites are crucial in wind energy:
  - high strength-to-weight ratio
  - Provide resistance to fatigue, corrosion, electrical and thermal conductivity important for the long-expected lifetime (20 to 30 years)
  - Provide flexibility in design and manufacturing, allowing to optimize the aerodynamic shape of the blade, resulting in high turbine efficiency

SIDENOTE

Based on estimates, wind energy sector will contribute 66,000 tons of thermoset composite waste in 2025.

- This is only 10 % of the total estimated thermoset composite waste



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SILVER-CONTENT IN PV PANELS: EXPECTED TO DECREASE

- The content will decrease drastically.
- Hence silver will not be a target metal to recover.

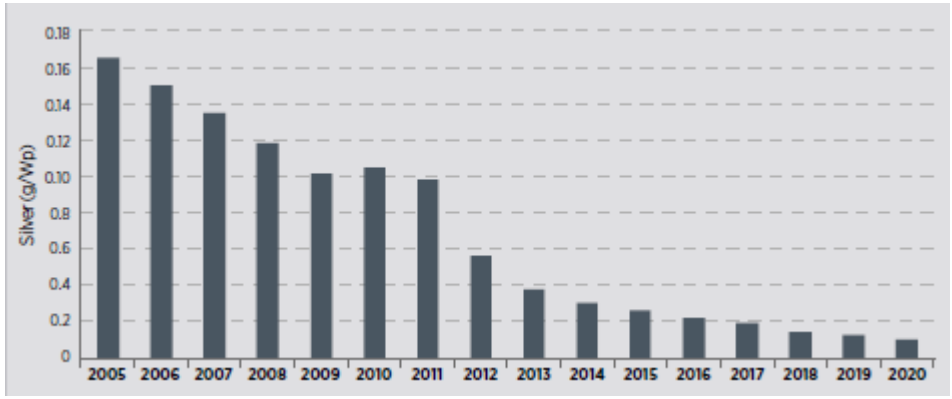

Figure 1. Historic silver consumption per watt-peak.

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PV RECYCLING IN EU

VEOLIA (Rousset, France)

- Co-operation with PV Cycle
- Capacity 4000 t / y, 95% material recovery rate.
- Mechanical process recovers glass, aluminum, and silicon.

FIRST SOLAR (Frankfurt, Germany)

- Closed loop-service for First Solar -panels. Recovers more than 90% of module materials for reuse, providing high-quality secondary resources for new solar panels, glass, rubber, and aluminum products. The company does not communicate the technology publicly.
- The company's current recycling capacity is sized to accommodate current demand, and the company expects to continue scaling capacity as demand grows.

TIALPI (Mottalciata, Italy)

- €2 million recycling plant in Italy.
- Capacity 5 000 tons of solar panels and is designed to gradually process up to 40,000 tons of PV waste annually.
- Using a method using infrared heaters and a vibrating knife to remove the glass
- 85 % mass recovery rate, including the glass, aluminum frame, and external electrical cables. In addition recovers metals such as copper and silver from the cells by involving nitric acid to leach the metals.
- Tialpi has estimated that it needs to process 20,000 tons of PV panels annually to be commercially viable.

ROSI (Grenoble, France)

- Focuses on recovering silver, copper and high-purity silicon
- Physical, thermal, and soft chemistry mechanisms (no aggressive chemical reaction)
- 2,000 to 3,000 tons of panels per year needed to be profitable.

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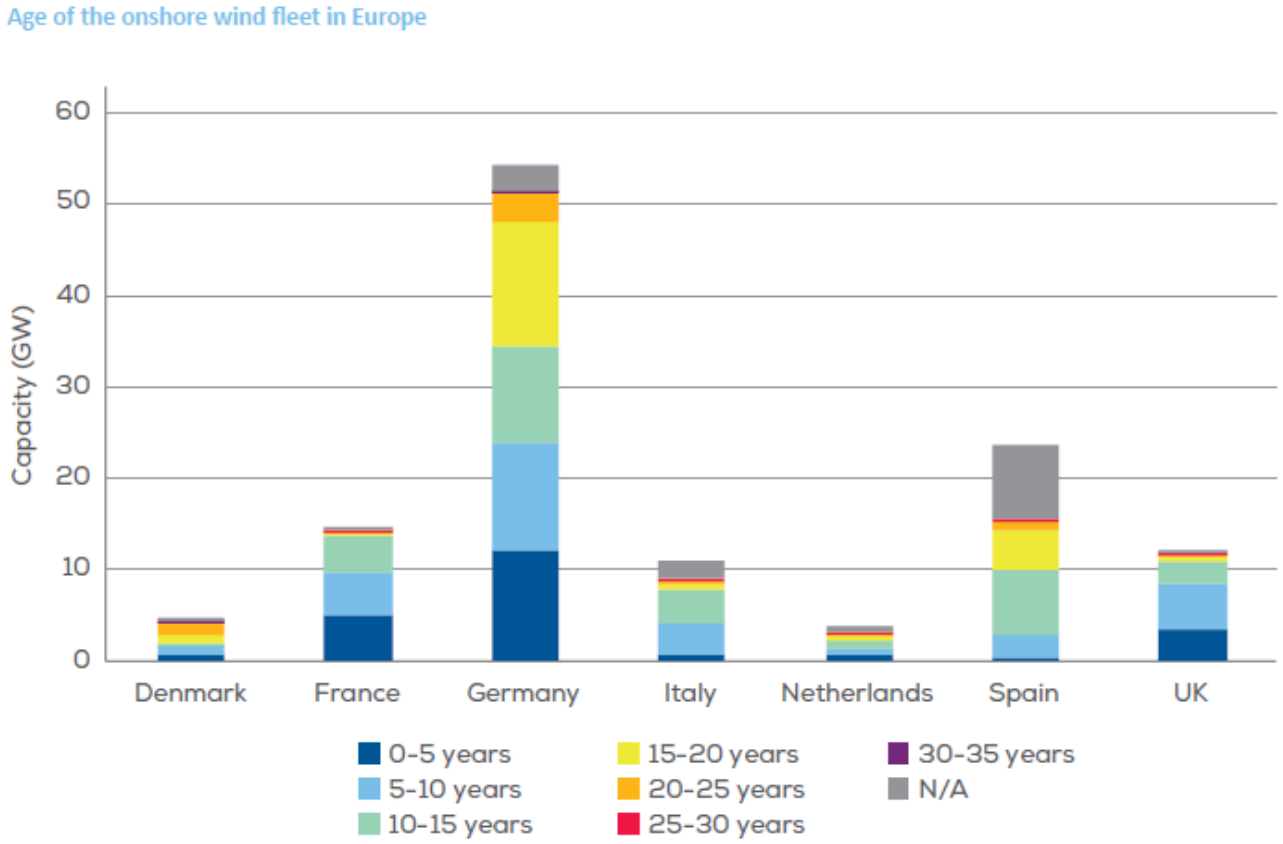
CAPACITY AND AGE OF THE WIND TURBINES

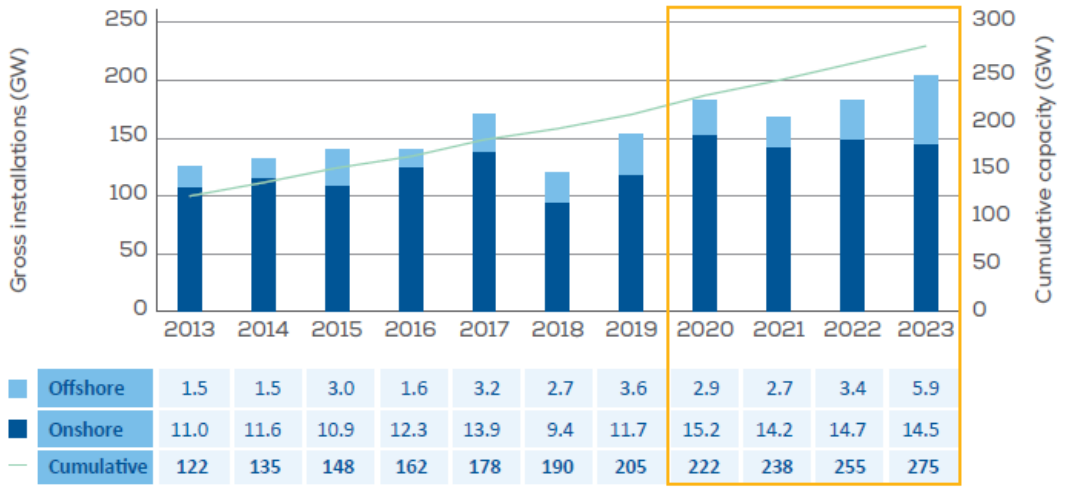


Source: WindEurope

UP TO 60 000 TONS OF DISPOSED COMPOSITE BY 2023

FIGURE 1

Gross annual installations in Europe



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Offshore	1.5	1.5	3.0	1.6	3.2	2.7	3.6	2.9	2.7	3.4	5.9
Onshore	11.0	11.6	10.9	12.3	13.9	9.4	11.7	15.2	14.2	14.7	14.5
Cumulative	122	135	148	162	178	190	205	222	238	255	275

Source: WindEurope

- The standard lifetime of a wind turbine is approximately 20-25 years, with some wind turbines now reaching up to 35 years through lifetime extension.
- About 14 000 wind turbine blades could be decommissioned by 2023

→ equivalent to between 40 000 and 60 000 tons


RESTORING VALUE