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Joint Research Centre

European Commission

Decarbonisation of the EU energy sector: Resilience to supply of materials, technological developments and recent trends in wind energy

Speakers: Claudiu Pavel, Darina Blagoeva, Cristina Vázquez and Thomas Telsnig

Contributors: Patricia Dias Alves and Alain Marmier

Energy, Transport and Climate Directorate

Webinar

20 April 2018

European Commission

Outline and speakers

Speaker: C. Pavel

- Critical raw materials (CRM) for the EU's economy and materials role in decarbonisation of the EU energy sector

Speaker: D. Blagoeva

- EU resilience to supply of materials and mitigation strategies

Speaker: C. Vázquez

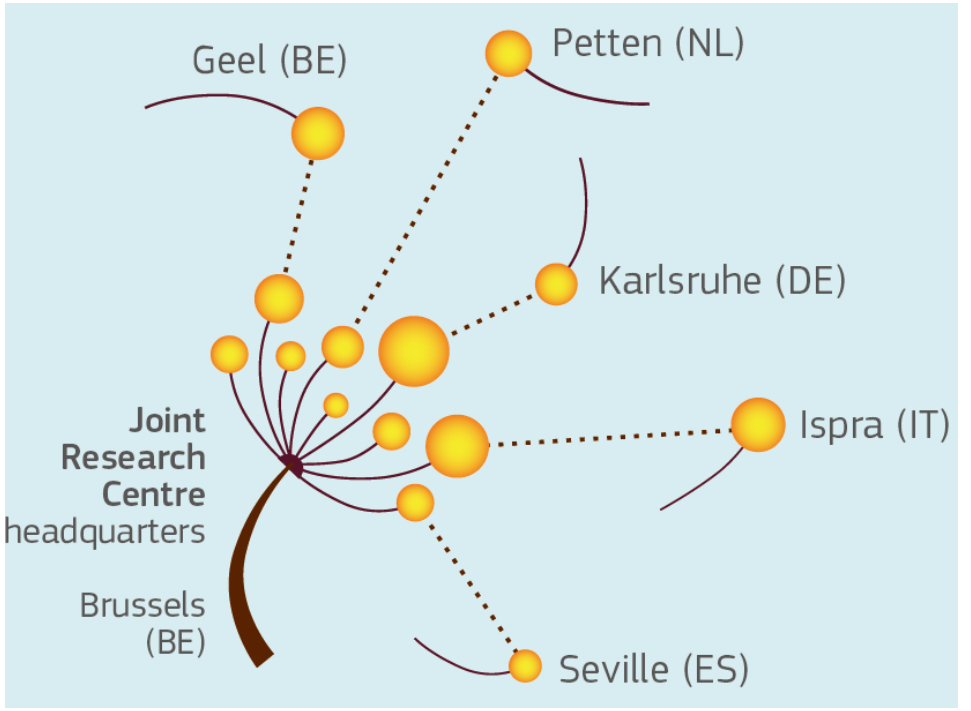
- Current status of wind energy and technology trends

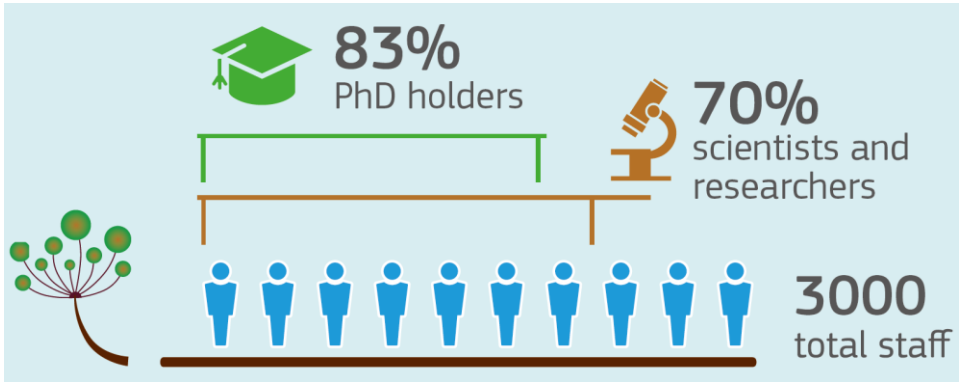
Speaker: T. Telsnig

- Research focus, EU policy and strategy on offshore wind

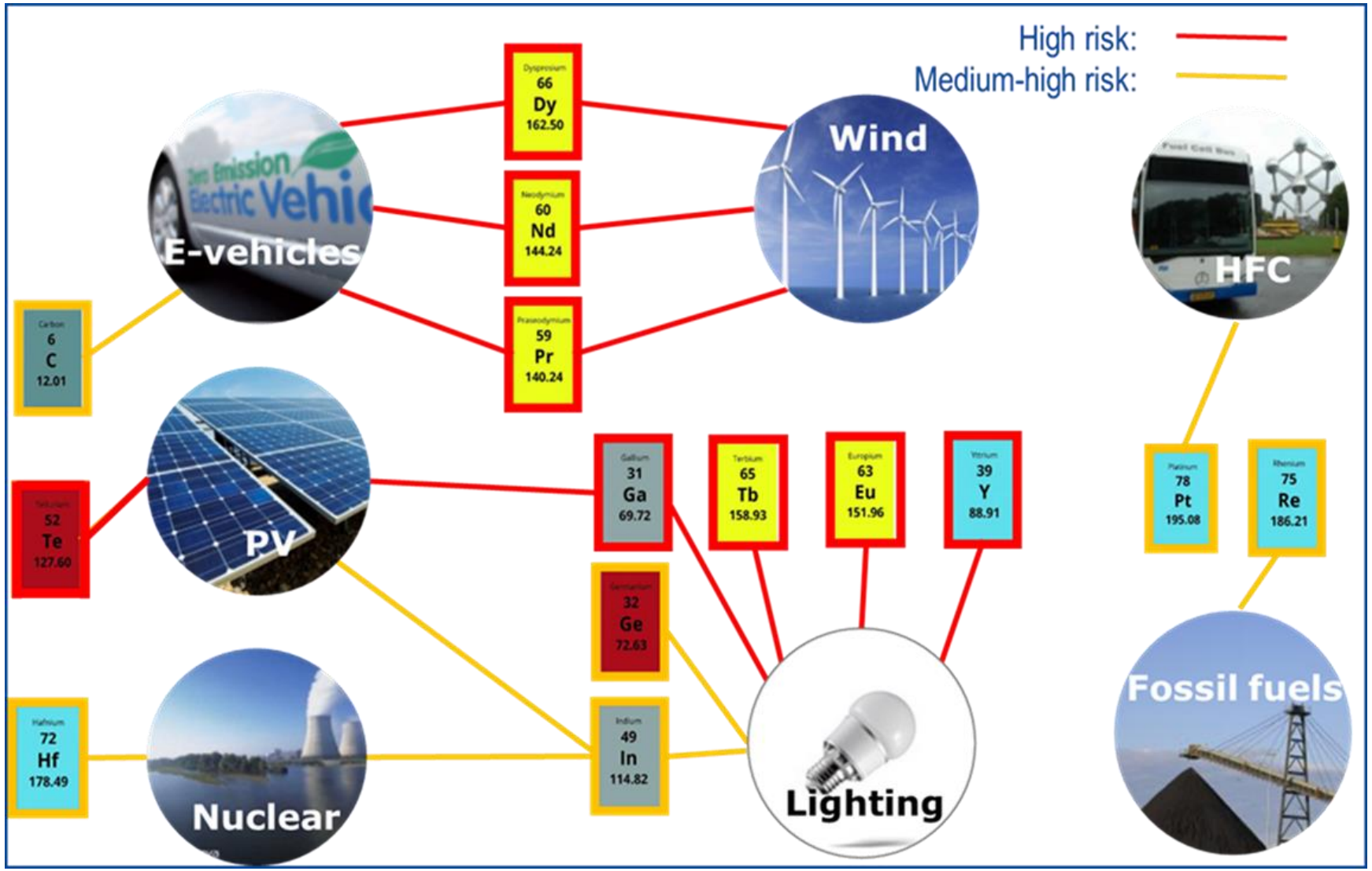
Joint Research Centre: Facts & Figures

- In-house science and knowledge service of the European Commission, providing independent scientific advice and support to EU policy
- Expertise in a wide range of areas: environment, secure energy supplies, sustainable mobility and consumer health and safety
- Budget: € 330 million annually, plus €70 million earned income
- About 1300 publications p.a.

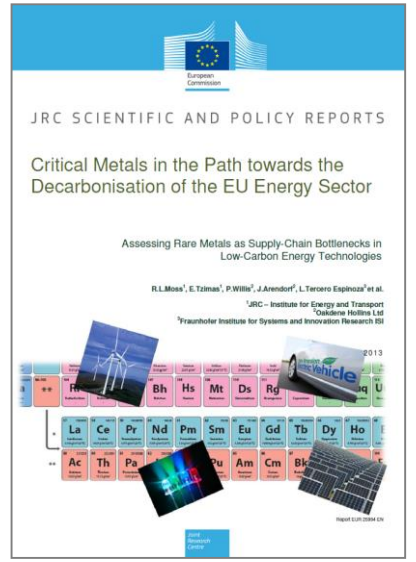




Previous JRC work on critical materials for the decarbonisation of the EU energy sector



2013 JRC assessment study



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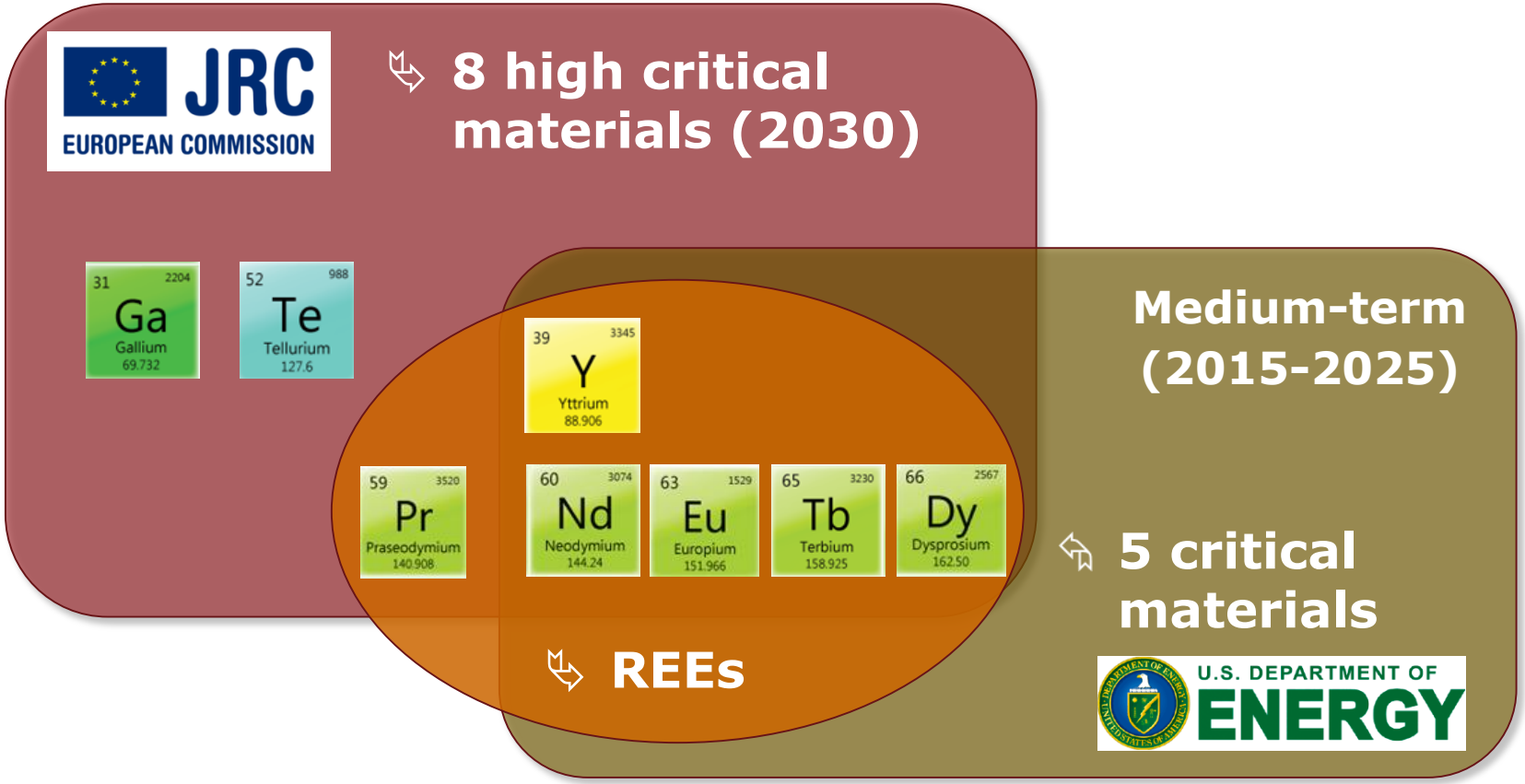
Critical materials for low-carbon technologies



- **Five materials (rare earths)** are assessed **critical** for low-carbon energy technologies in both EU and US economies
- Several other materials are assessed **medium-high critical** (e.g. Re, Hf, graphite, Ge, Pt, In)

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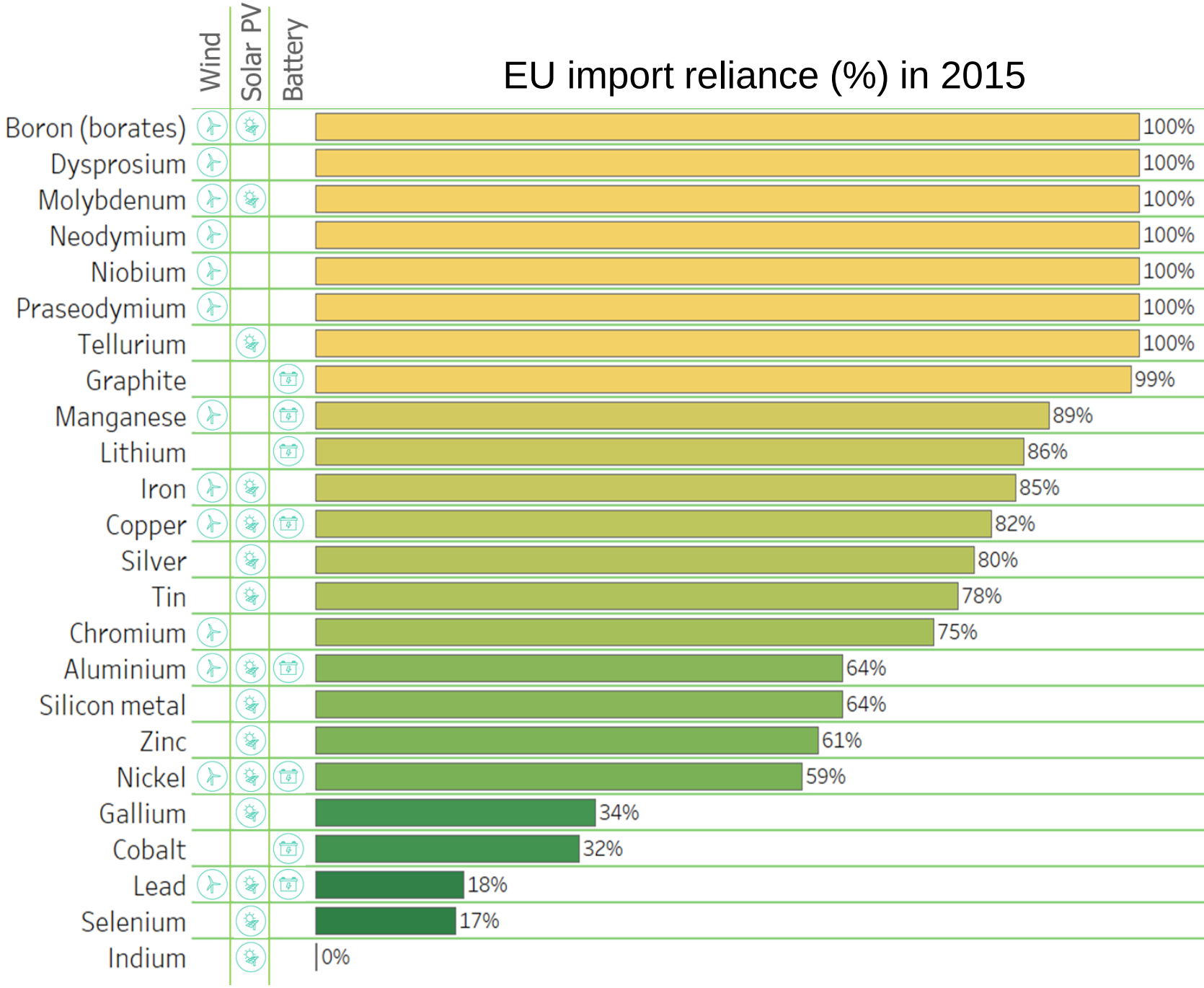
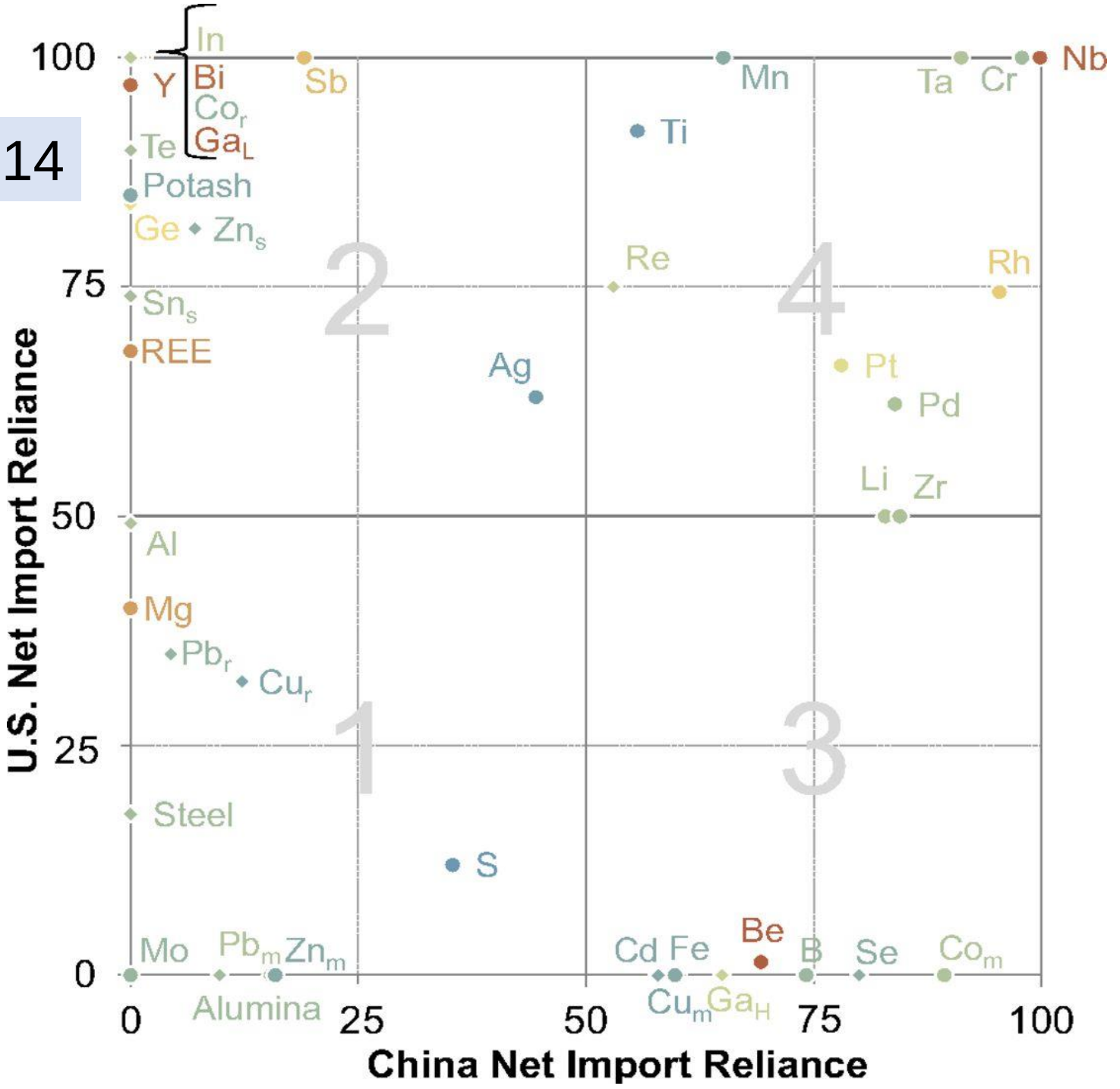
EU import dependence on relevant raw materials used in wind, solar PV and battery technologies



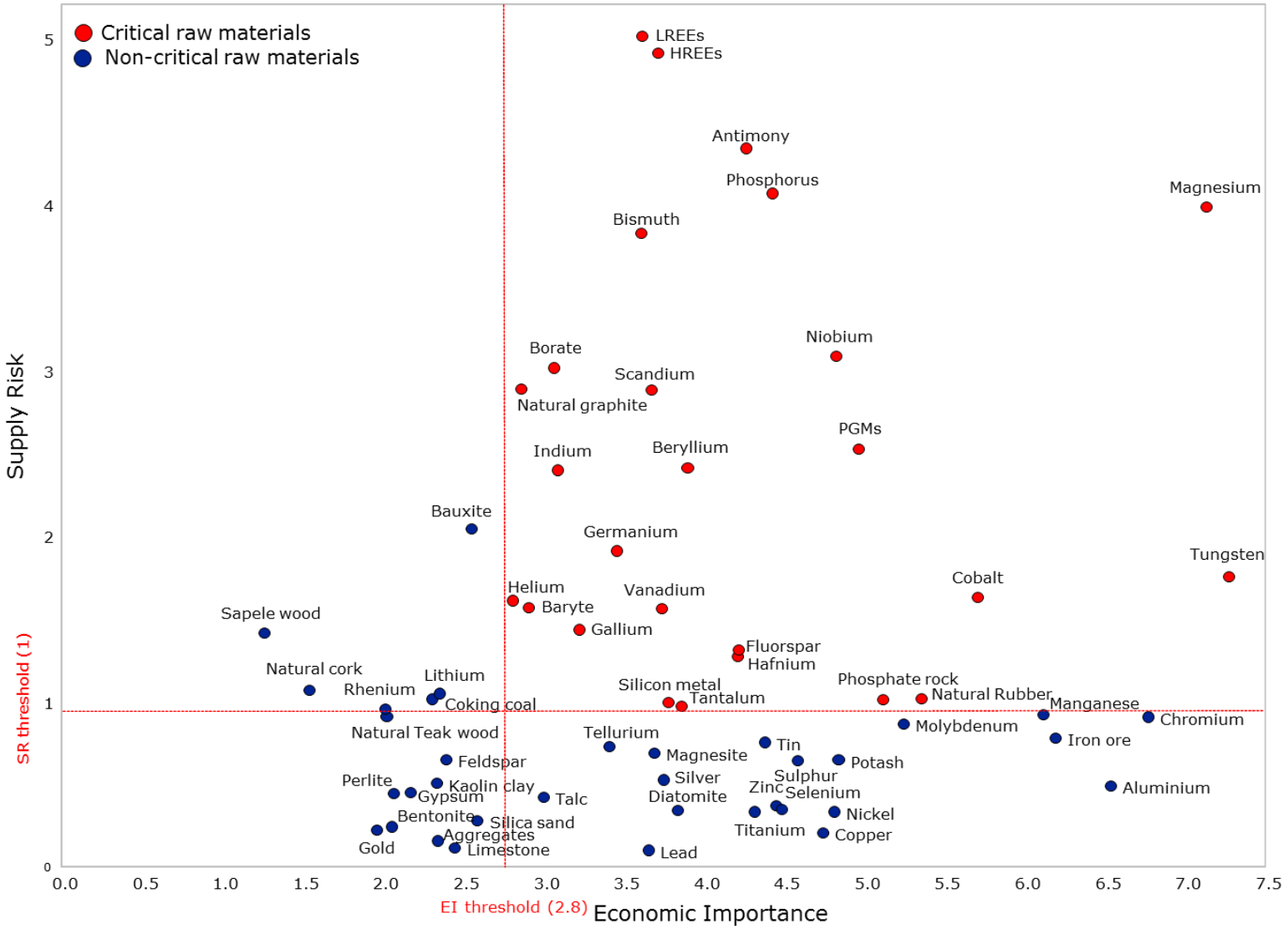
Source: JRC representation with data from the 2017 list of Critical Raw Materials for the EU report, 2017

Net import reliance of the United States and China as a percentage of domestic consumption



Source: Andrew L. Gulley, Nedal T. Nassar and Sean Xun, PNAS April 2, 2018

EU Critical Raw Materials: 2017 list



27 Critical Raw Materials (CRMs) for the EU economy

2017 CRMs			
Antimony	Fluorspar	LREEs*	Phosphorus
Baryte	Gallium	Magnesium	Scandium
Beryllium	Germanium	Natural graphite	Silicon metal
Bismuth	Hafnium	Natural Rubber	Tantalum
Borate	Helium	Niobium	Tungsten
Cobalt	HREEs *	PGMs*	Vanadium
Coking coal	Indium	Phosphate rock	

- A sustainable access to raw materials is crucial to strengthen the industrial basis and the value chain for renewable technologies

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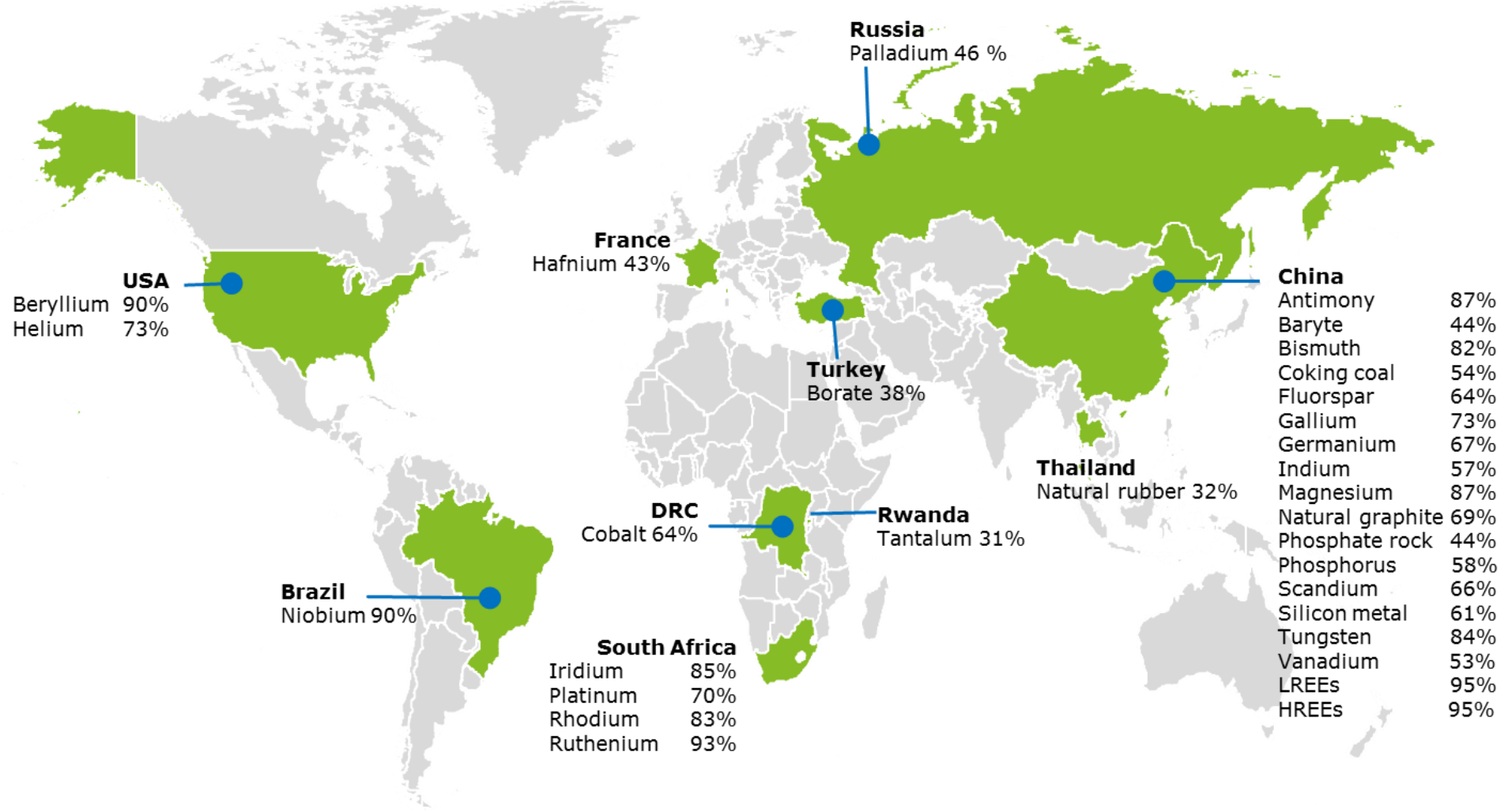
Global largest suppliers of critical raw materials



Source: Commission's Communication on the 2017 list of Critical Raw Materials for the EU, COM(2017)490, September 2017

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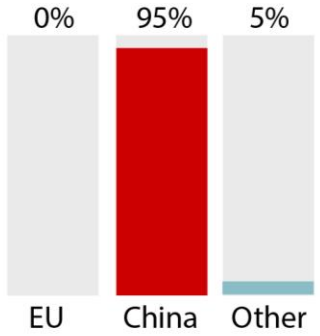
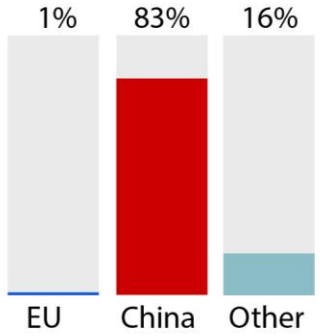
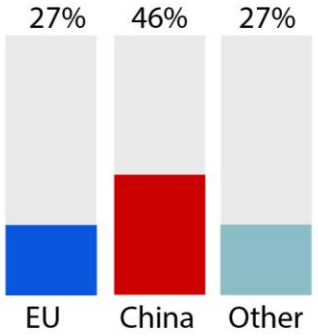
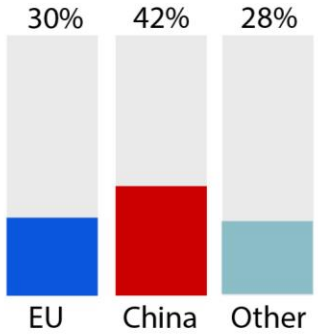
Supply chain dependency for **wind turbines**









- China is the major supplier of materials along the value chain

Source: JRC assessment (2015 data)

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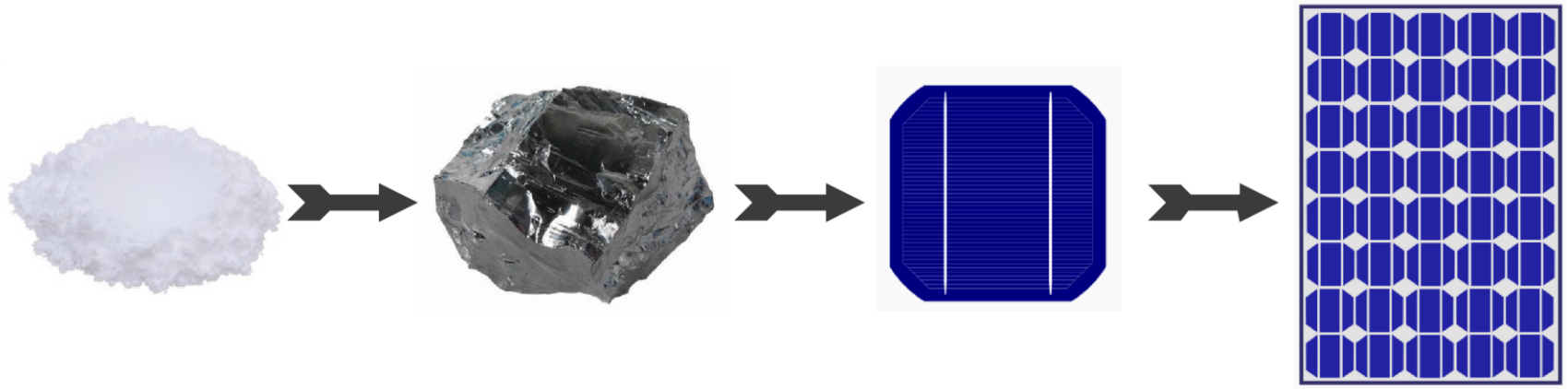
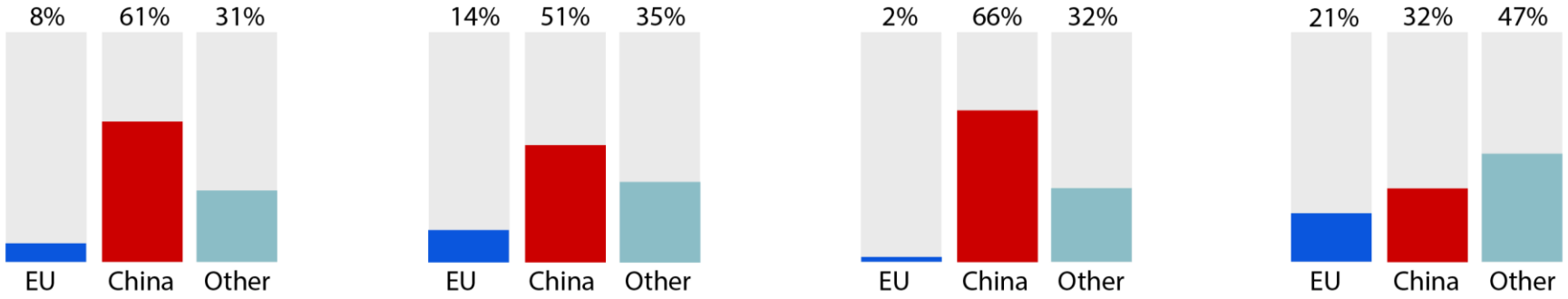
Supply chain dependency for **solar panels**





- EU is highly dependent on raw, processed materials and components
- China is the major supplier of materials and components for solar PV

Source: JRC assessment (2015 data)

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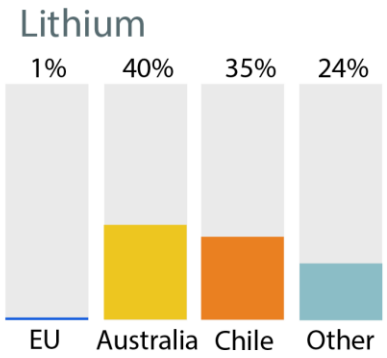
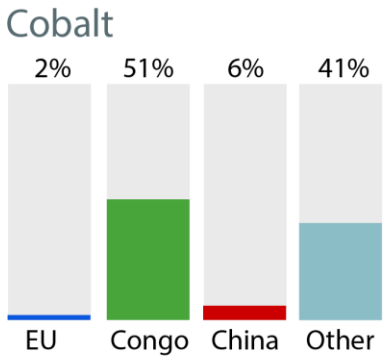
Supply chain dependency for **electric vehicles' batteries**

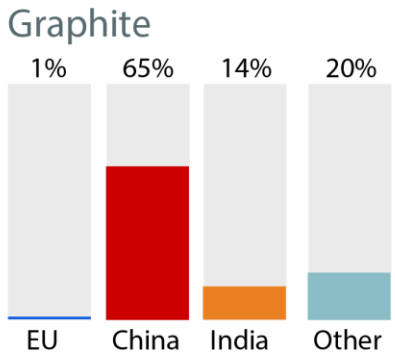
Raw materials

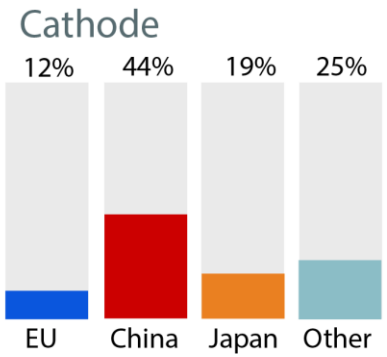
Processed materials

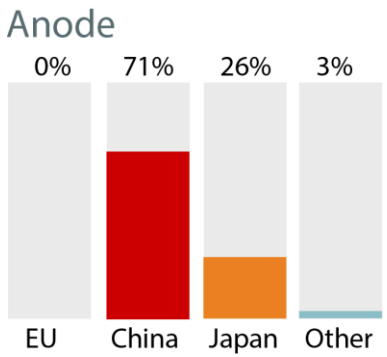
Cells/ Modules

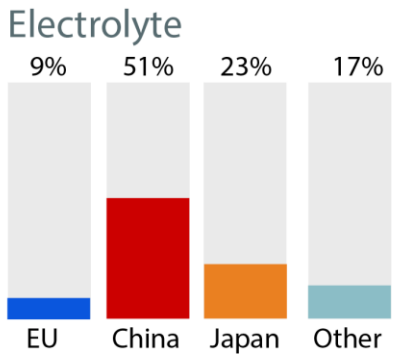


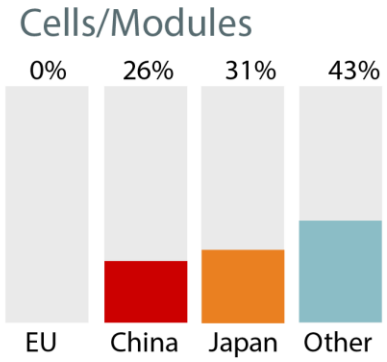


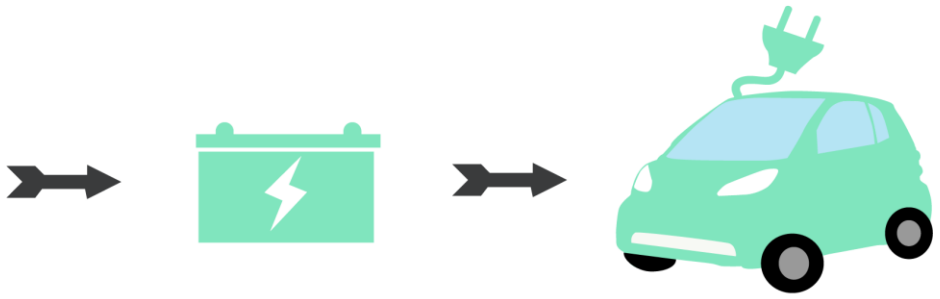












Source: JRC assessment (2015 data)

↳ High dependence on both materials & components for Li-ion batteries

European Commission

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JRC study: materials supply chain issues for deployment of low-carbon technologies

WIND

Wind turbines
- Neodymium
- Praseodymium
- Dysprosium

Blades
- Composites (CFC)

SOLAR

PV Modules
- Silicon
- Silver

- Copper
- Indium
- Gallium
- Selenium

- Cadmium
- Tellurium

ELECTRIC VEHICLES

Batteries
- Lithium
- Cobalt
- Graphite

Electric traction motors
- Neodymium
- Praseodymium
- Dysprosium

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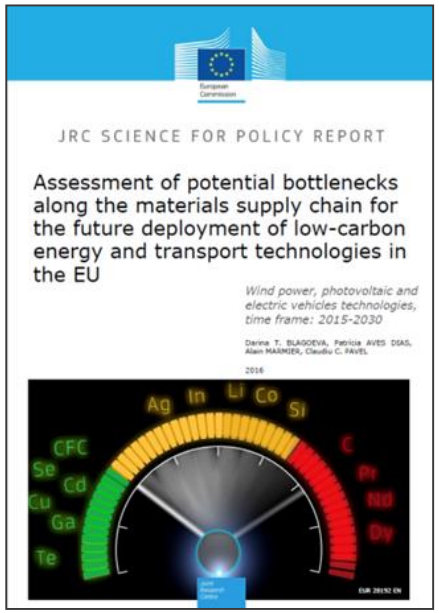
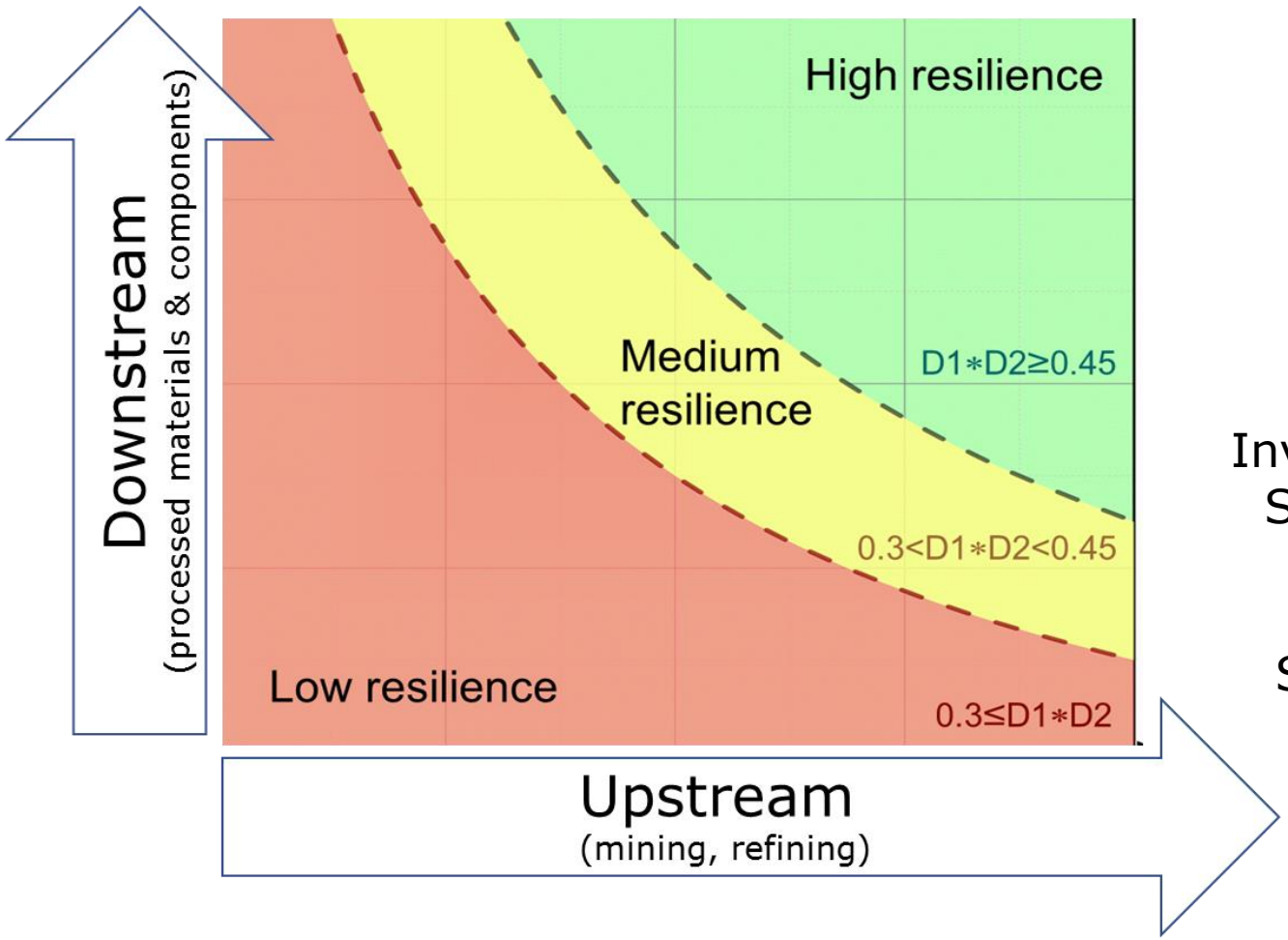
JRC methodology for assessing the EU future resilience to potential bottlenecks by 2030

Indicators
Supply chain adequacy
Purchasing potential
Material cost impact

More info: JRC report, 2016





Indicators
Demand
Investment potential
Stability of supply
Reserves
Import reliance
Supply adequacy
Recycling
Substitution

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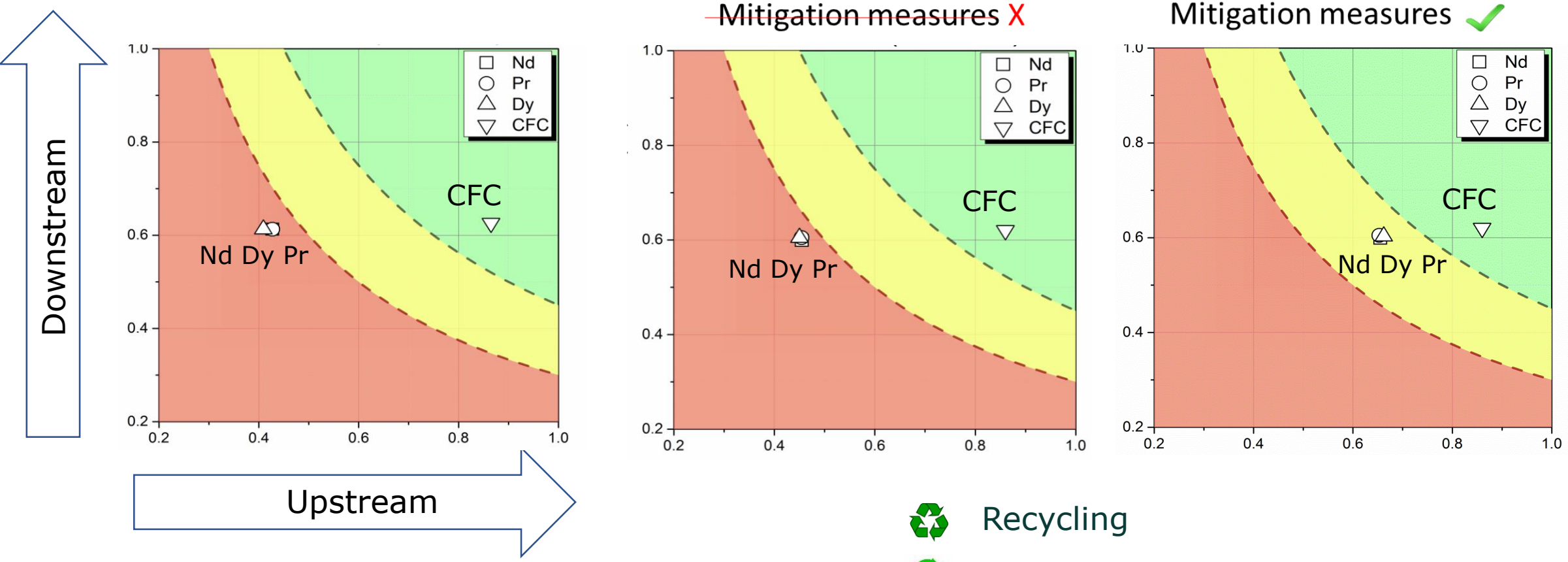
Materials resilience matrix: wind energy

2015

2030

~~Mitigation measures X~~

Mitigation measures ✓



Recycling

Substitution

Domestic production

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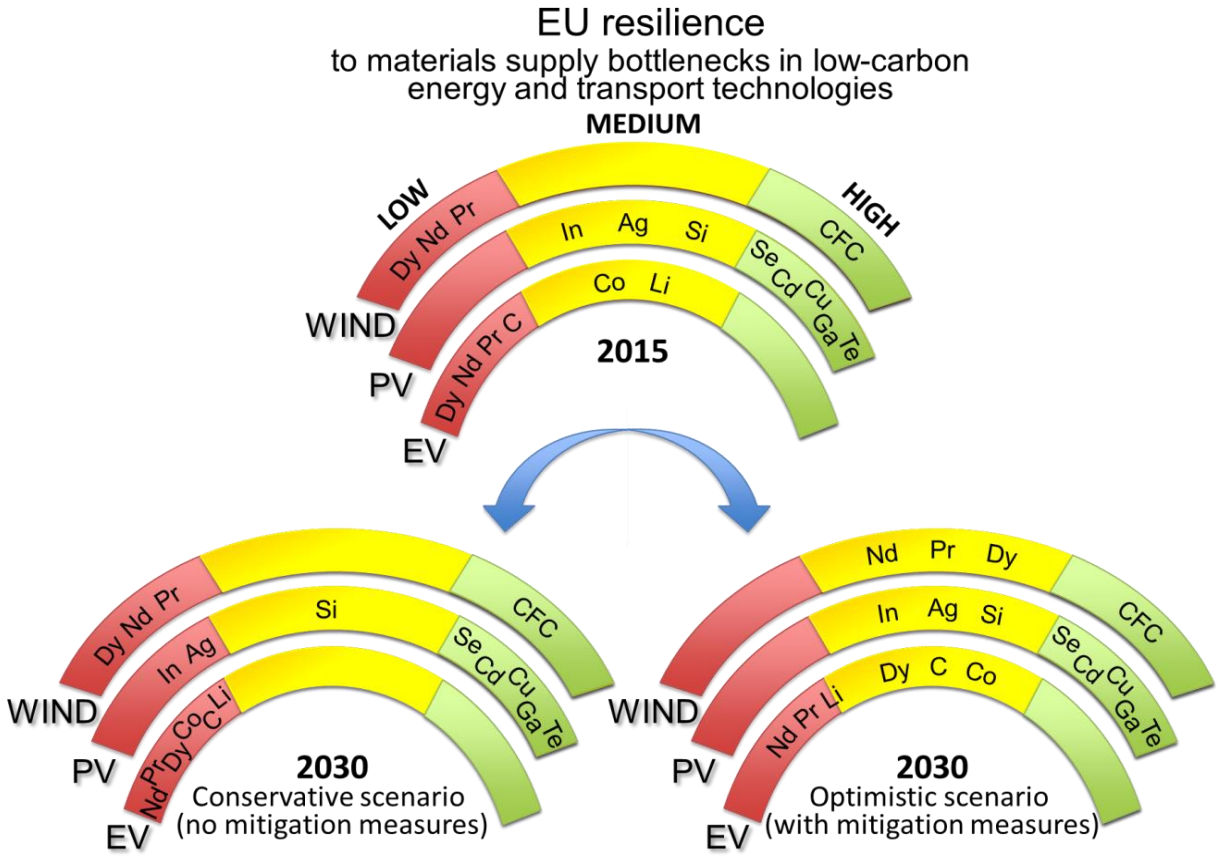
Key messages

- **High dependency on imports of key raw materials** needed in wind, PV and EVs
- **EV technology: the most critical** when considering **full supply chain**!
- **Strong dependency on manufacturing capacities downstream!**
- EU resilience to potential supply issues deteriorating by 2030 unless **mitigation measures** are taken
- **Mitigation measures:** increasing recycling, substitution and domestic RM production, as well as supply chain improvement



Recycling and substitution – important mid- and long term mitigations

Supply chain and its diversification/ expansion are essential!

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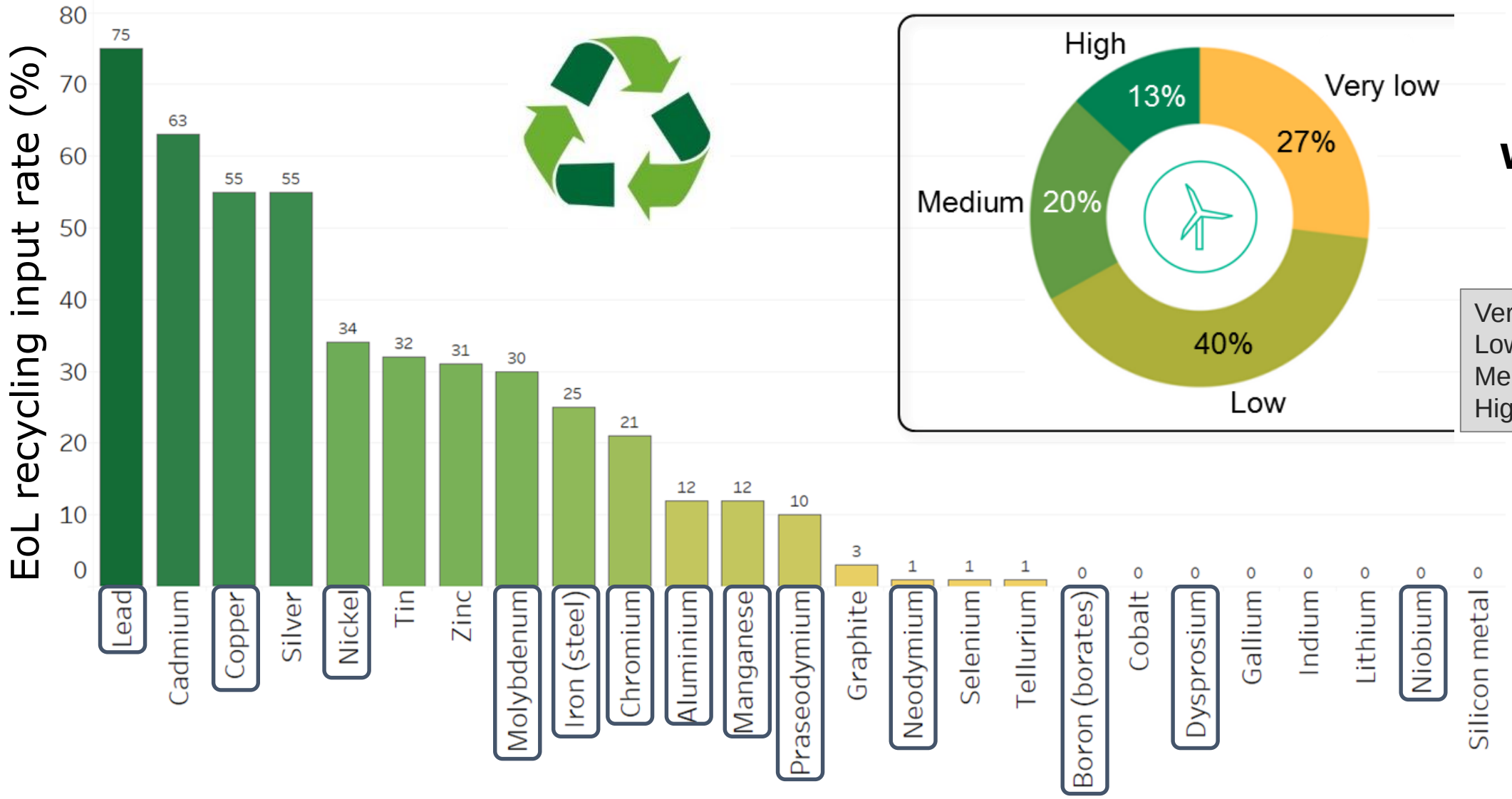
Recycling potential (EoL-IRR) of relevant materials for renewable energy and batteries

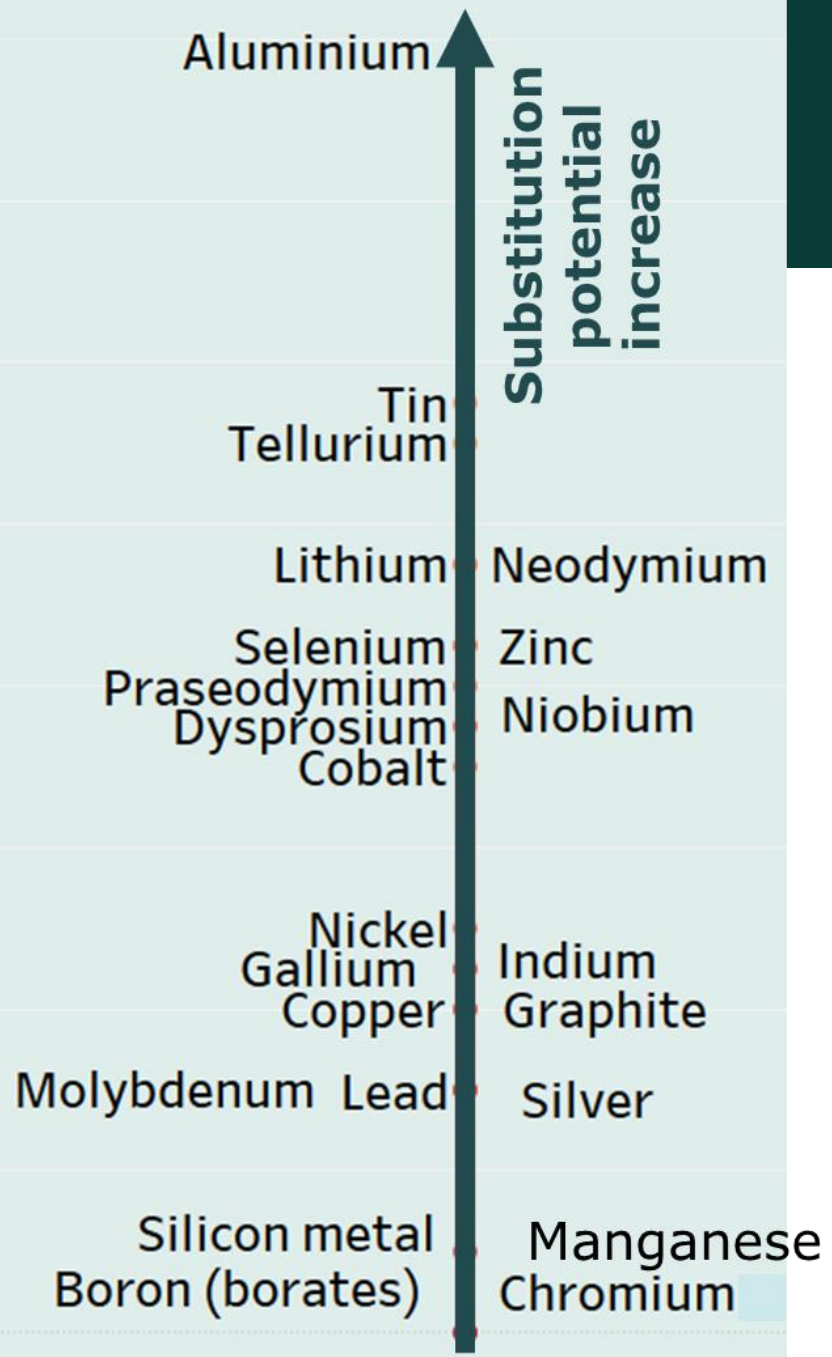


Wind energy

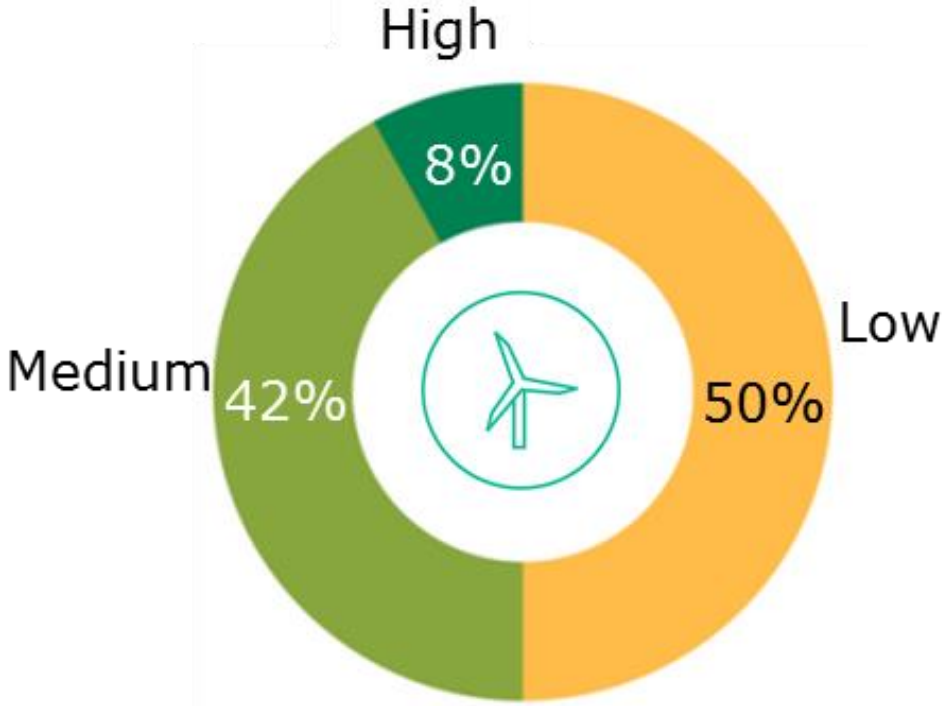
Very low: less than 10%
Low: 10-30%
Medium: 30-50%
High: more than 50%

Source: JRC representation with data from*: Study on the review of the list of Critical Raw Materials, Criticality Assessments*, 2017

Substitution potential of materials in wind technology



- Substitution potential of materials used in wind turbines is generally low



Note: substitution potential is calculated as the average of the substitution indexes of materials used for different end-use applications as determined in the 2017 CRM list

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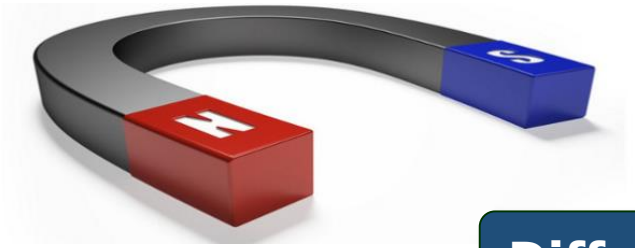
Substitution paths of REEs in permanent magnets for wind generators

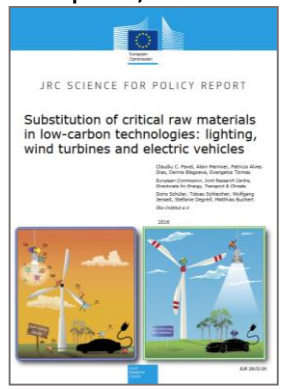


↳ **NdFeB** magnet: key role in **wind generators and electric traction motors**

Critical materials

Nd Pr Dy Tb

More info: JRC report, 2016



Different substitution strategies

Limited

Direct material substitution

- (?) Neodymium magnets with Ce and Co — Nd/Pr↓ — Dy-/Tb-free

On-going

Higher materials efficiency

- (≈) Reduced Dy-content magnet production — Dy/Tb↓
- (≈) Improved NdFeB-magnet production — Nd/Pr↓ — Dy/Tb↓
- (+) Improved system design, lower working temperature — Dy/Tb↓

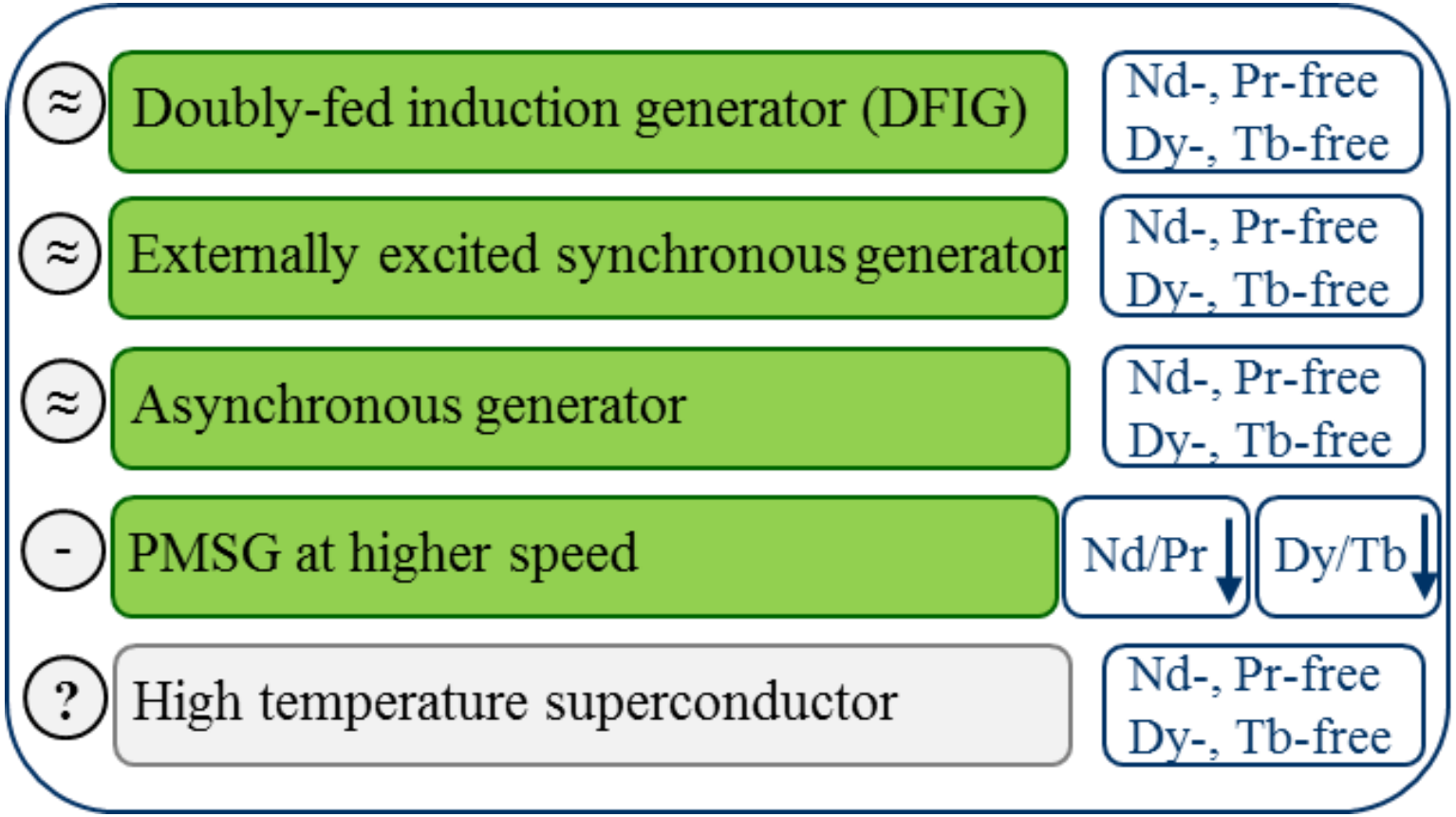
Legend technology status:

- xyz — In operation
- xyz — R&D stage
- (?) Uncertain
- (≈) Similar or slightly lower technical or economic performance
- (+) Higher technical or economic performance
- ↓ Lower content of rare earths

Component substitution: more feasible?

WIND TURBINES

Permanent magnet synchronous generators (PMSG)



Legend technology status:

- xyz — In operation
- xyz — Prototype, niche product
- xyz — R&D stage

- (+) Higher technical or economic performance
- (≈) Similar or slightly lower technical or economic performance
- (-) Considerably lower performance
- (?) Uncertain
- ↓ Lower content of rare earths

Source: Pavel, C.C., Lacal-Arántegui, R., Marmier, A., Schüler, D., Tzimas, E., Buchert, M., Jenseit, W., Blagoeva, D., *Substitution strategies for reducing the use of rare earths in wind turbines*, Resources Policy, 52, 2017, pp. 349-357

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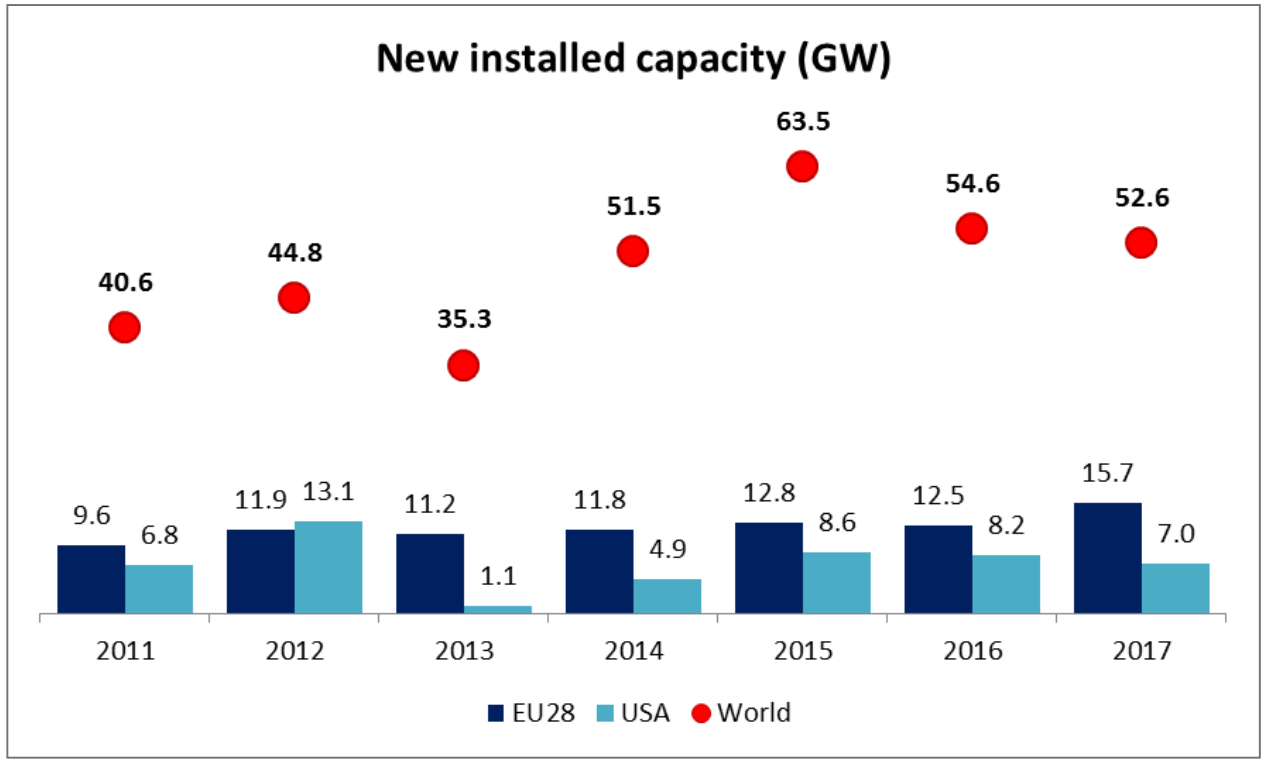
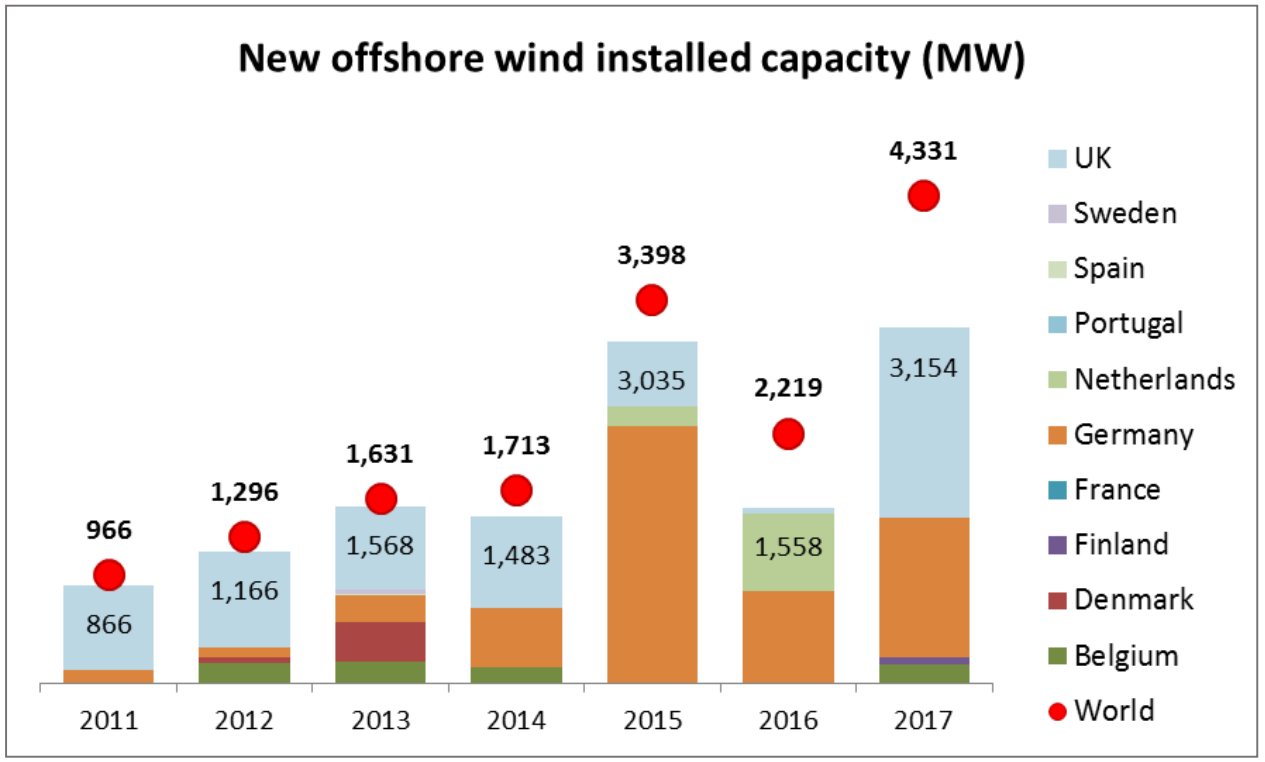
Current status of wind energy – Capacity installed





- 2017 was a record year for both onshore and offshore wind installations in Europe
- Europe dominates the offshore wind market although China is gaining ground

Source: JRC representation based on GWEC and WindEurope

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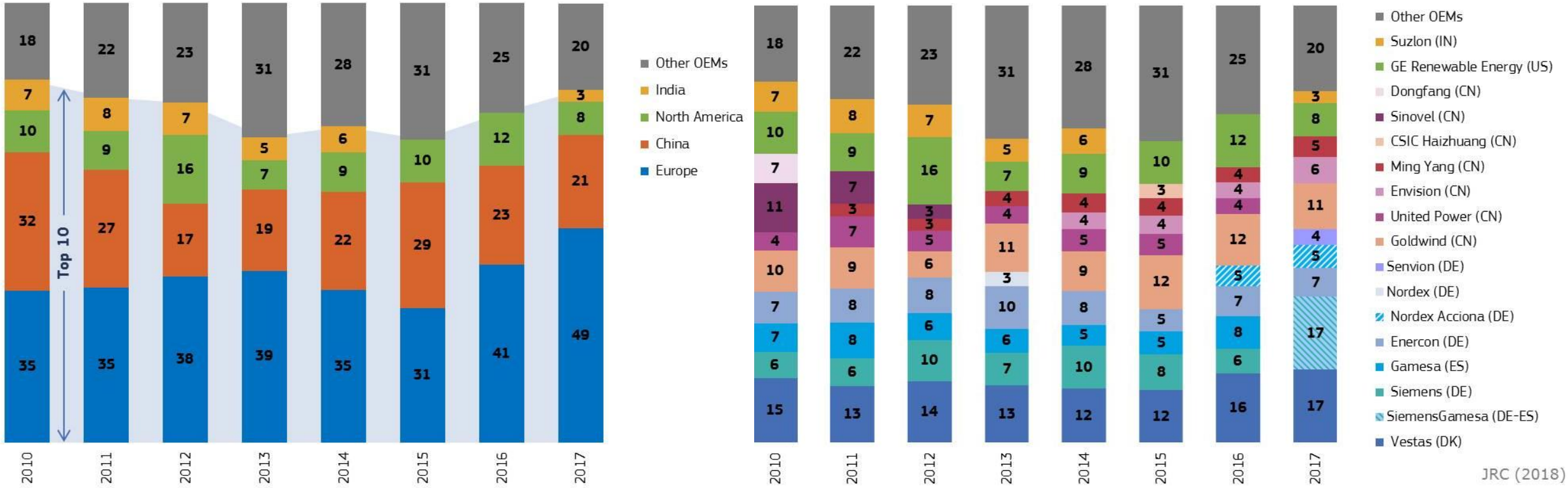
Market share of wind turbine suppliers



- Among the Top 10 wind turbine suppliers in 2017 European OEMs are leading with 49% market share
- In 2017 Vestas remained as the world's largest turbine supplier due to its wide geographic diversification strategy and strong performance in the US market

Source: JRC representation

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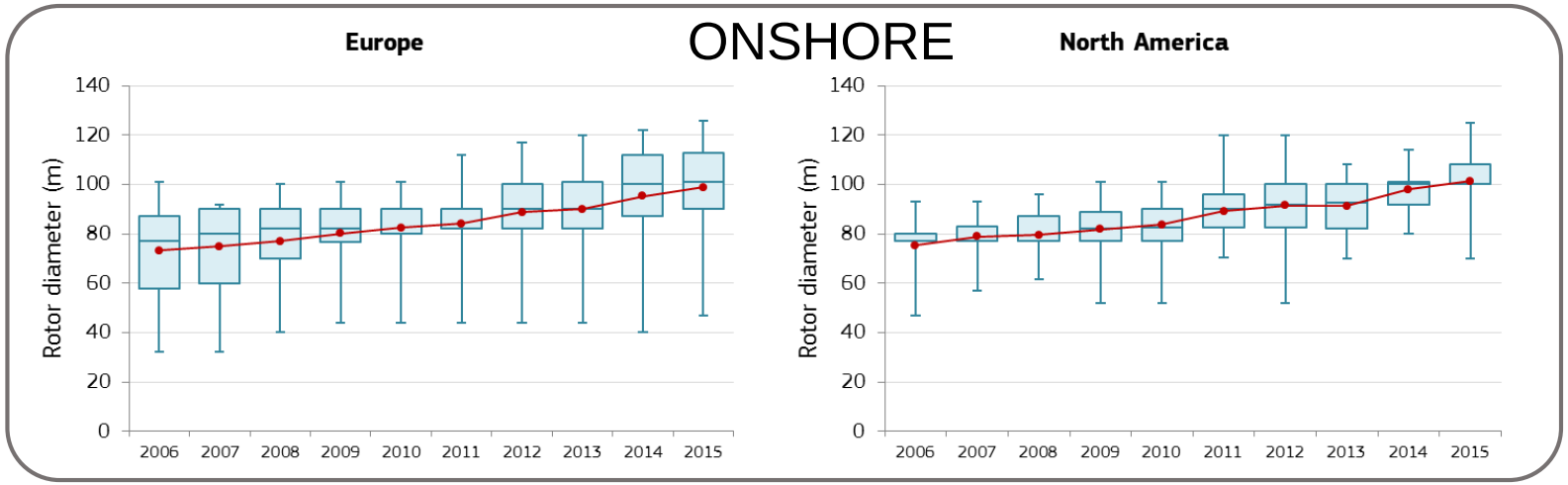
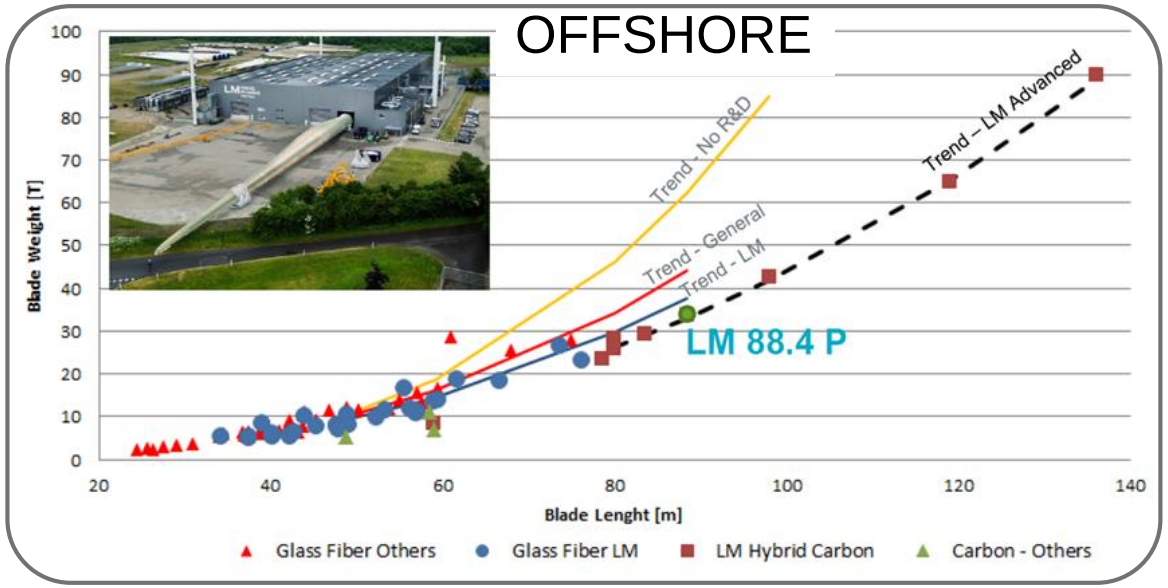
Technology trends of blades



Source: JRC Wind Energy Status report – 2016 Edition



Source: LMWind Power

- Strong tendency towards longer blades: in the last decade the average rotor diameter in onshore wind turbines increased by 45% doubling the swept area
- Next generation offshore wind turbines are expected to have a length >100m (e.g. 12MW GE Haliade X - 107 m rotor blade)
- Longer blades call for new materials and advanced blade designs to limit the blade weight and cost

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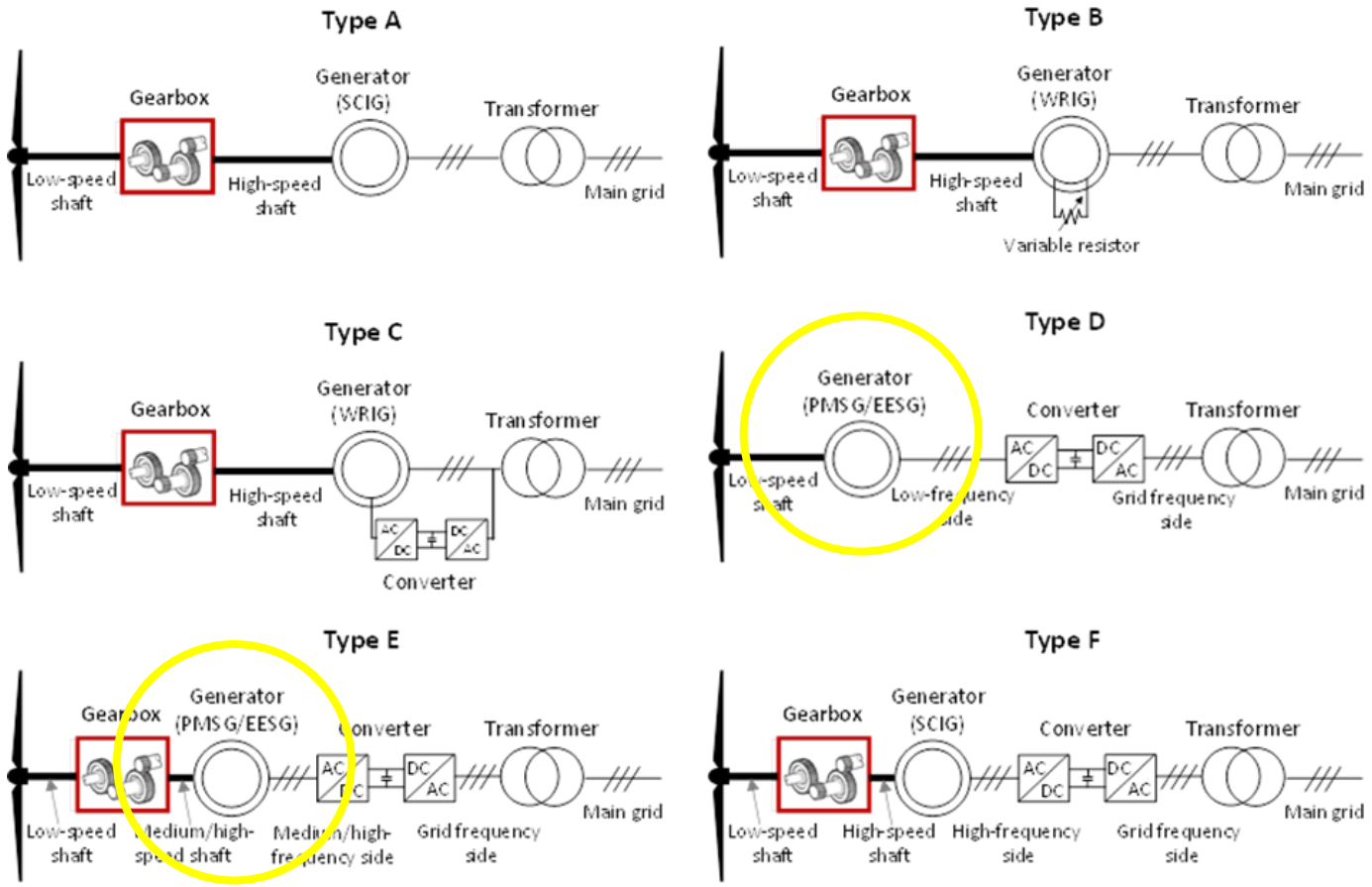
Drive train arrangements used in commercial wind turbines



- Types A, B and C are geared high-speed wind turbines
- Type D corresponds to direct drive configuration
- Types E and F are hybrid arrangements

↳ PMSG can be in either Type D or Type E

↳ Type E requires less amount of rare earths as the electric generator has a reduced size and weight

Source: Vazquez Hernandez, Serrano González, & Centeno, *A Market-Based Analysis on the Main Characteristics of Gearboxes Used in Onshore Wind Turbines*, Energies, 10(11), 2017, p. 1686

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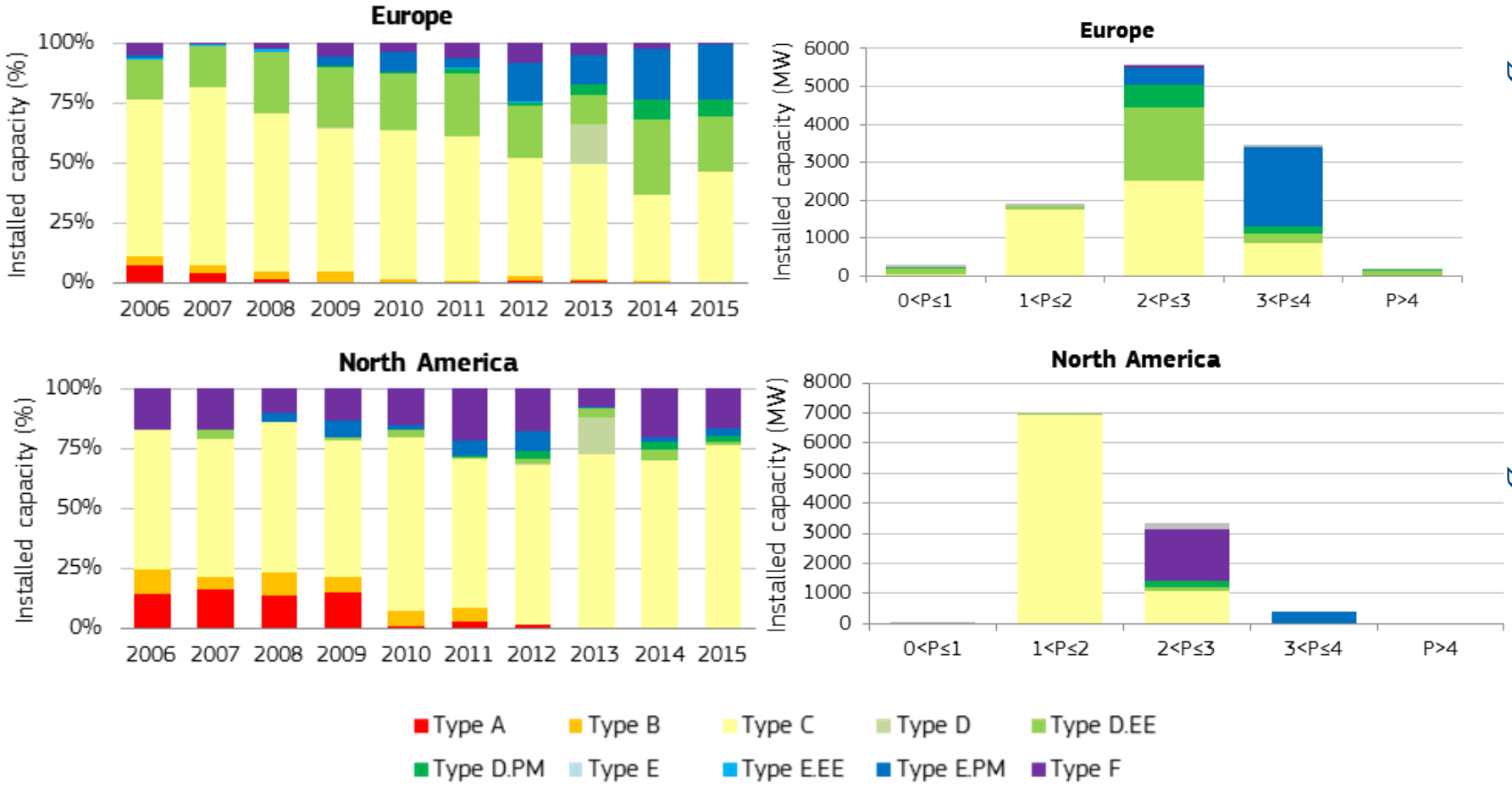
Drive train arrangements in wind turbines installed in Europe and North America



- Type C dominates the onshore wind market although hybrid arrangements have progressively gained ground: Type E in Europe and Type F in North America
- PMSG are more common in Europe than in the North American market

Source: JRC Wind Energy Status report – 2016 Edition

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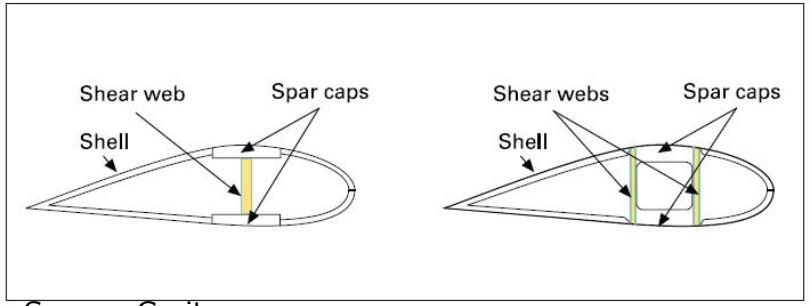
Innovations in blades and drive trains

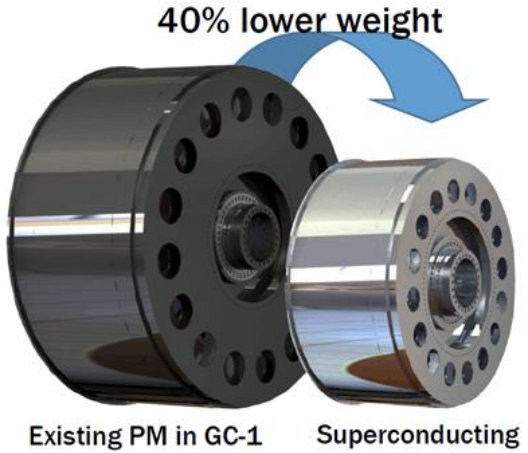
- **BLADES**
  - Innovative designs
    - Shift from structural box spar core to structural shell construction
    - Modular blades or variable tip lengths
    - Vortex generators
    - Trailing edge serrations or flaps
  - Materials
    - Carbon fibres
- **DRIVE TRAIN**
  - Reduction of the content of rare earths
    - Superconductor-based generators (EcoSwing EU-funded project)
    - Ferrite-based PMSG (GreenSpur Renewables)
  - Innovative designs
    - Modular design ((Permanent (PMSG), Enercon (EESG))

Structural Shell (left) and Structural Box Spar (right)



Source: Gurit

Superconductor direct drive generator



Source: Ecoswing

European Commission

Outline and speakers

Speaker: C. Pavel

- Critical raw materials (CRM) for the EU's economy and materials role in decarbonisation of the EU energy sector

Speaker: D. Blagoeva

- EU resilience to supply of materials and mitigation strategies

Speaker: C. Vázquez

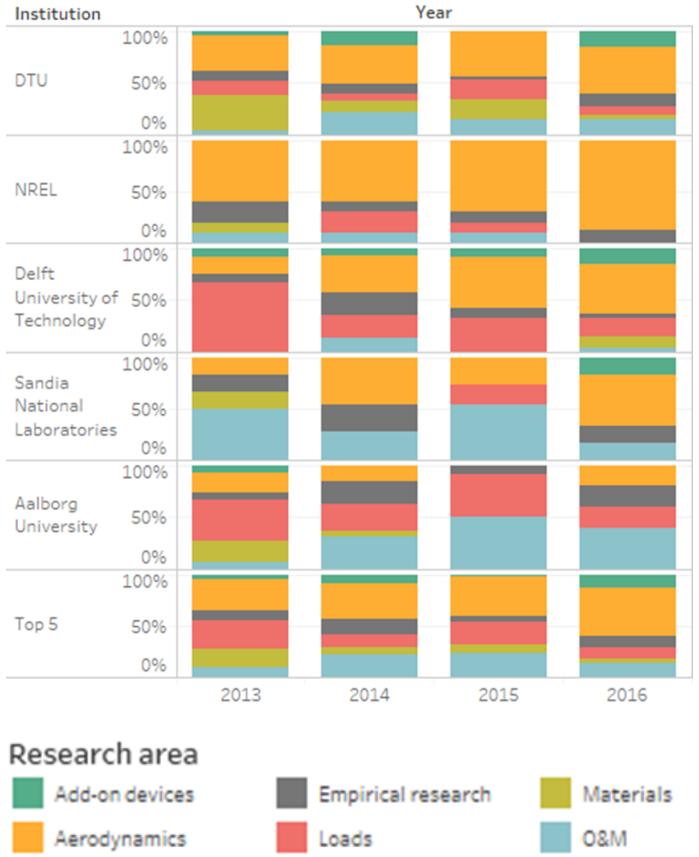
- Current status of wind energy and technology trends

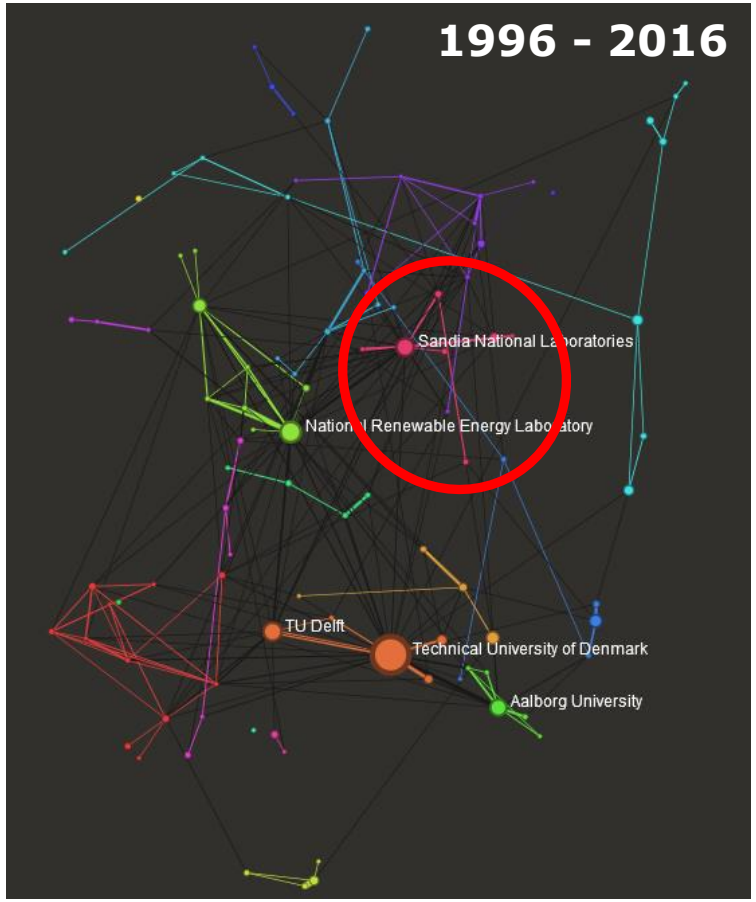
Speaker: T. Telsnig

- Research focus, EU policy and strategy on offshore wind

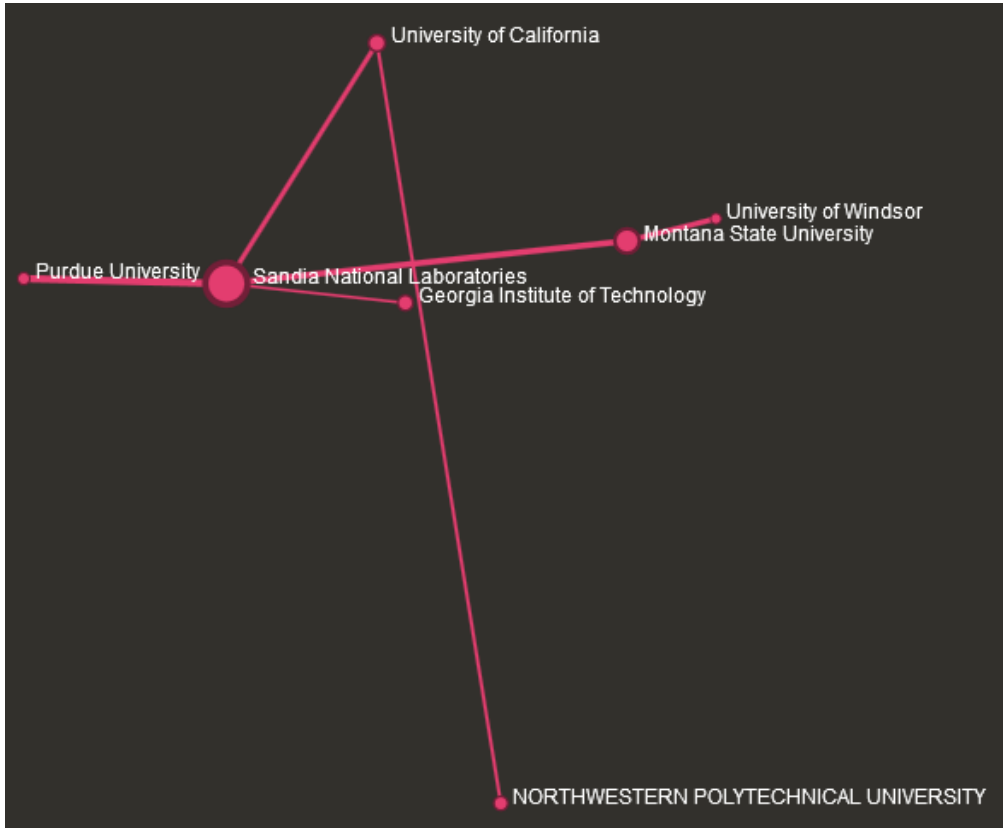
Research focus and collaboration patterns on wind blade research

Main research areas (Top5)





Research community of SANDIA:



Sources: JRC Report 2018 - Monitoring scientific collaboration trends in wind energy technologies.
Clustering approach - Network theory: Blondel et al. 2008, Fast unfolding of communities in large networks.

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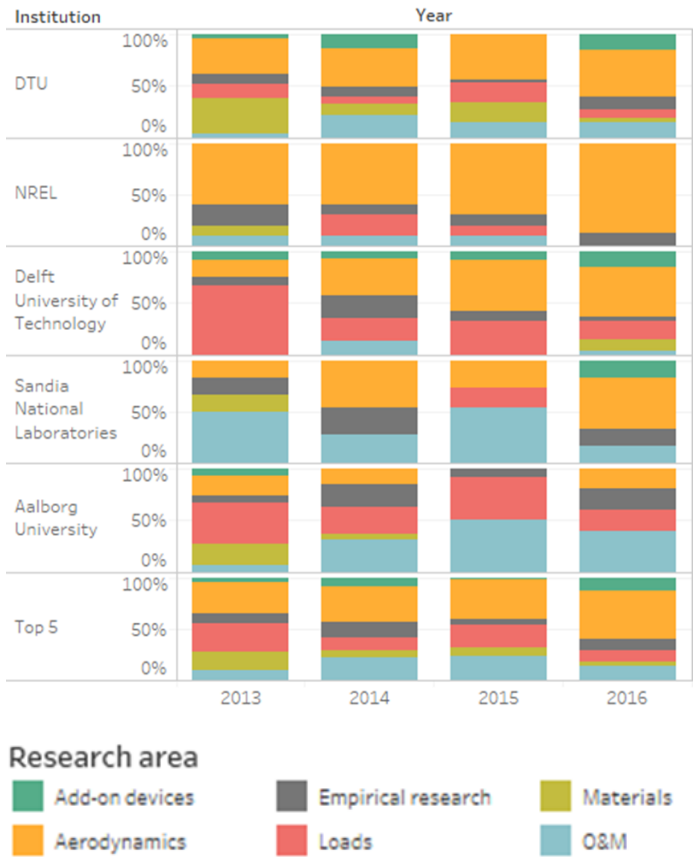
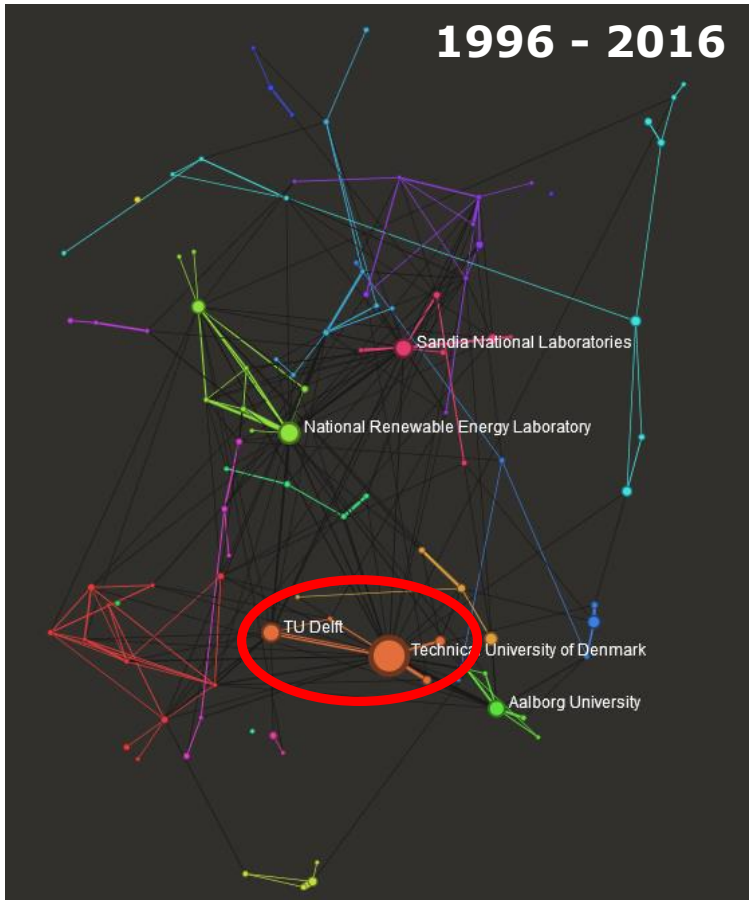
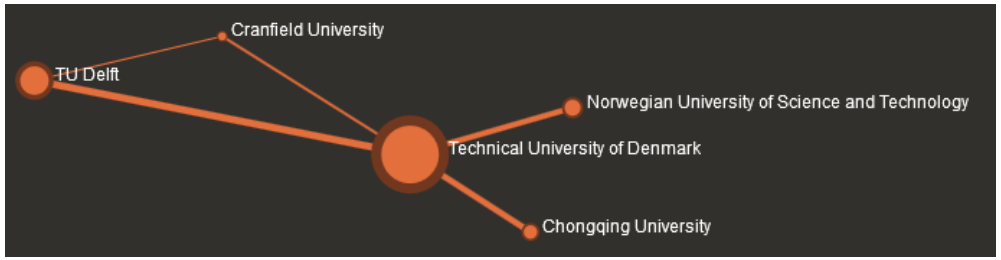
Research focus and collaboration patterns on wind blade research

Main research areas (Top5)





Research community of DTU and Delft



Sources: JRC Report 2018 - Monitoring scientific collaboration trends in wind energy technologies

European Commission

EU policy and research to ensure future competitiveness in wind energy

I. State Aid Guidelines for Environmental protection and Energy (EEAG) 2014 – 2020

II. Integrated European Strategic Energy Technology Plan (SET-Plan) identified offshore wind energy to accelerate the energy system transformation and create jobs and growth

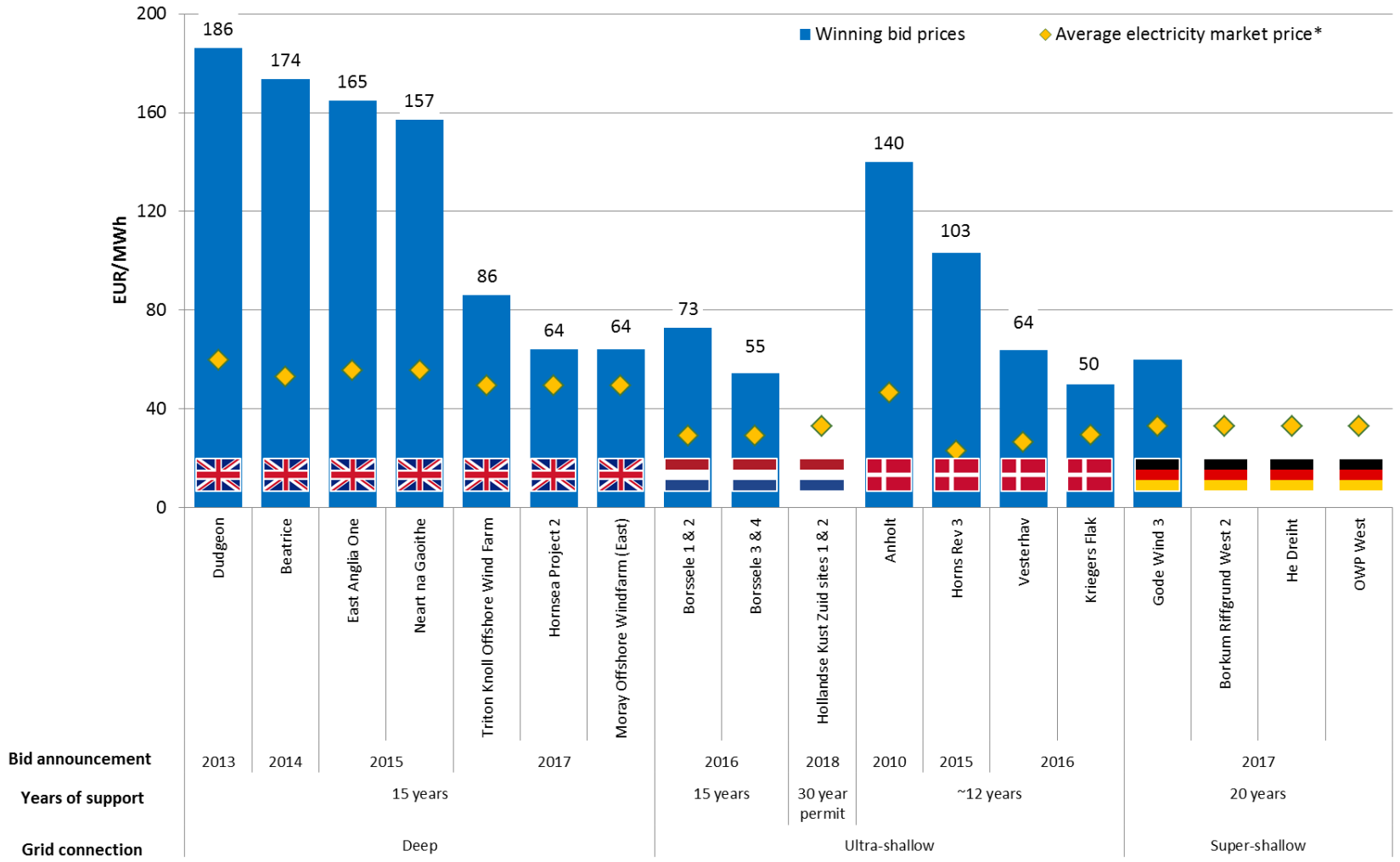
Strategic SET-Plan targets:

➔ **Reduce LCOE for fixed offshore wind** by improvement of the entire value chain (LCOE>10 ct€/kWh by 2020 and >7 ct€/kWh by 2030)

➔ Develop integrated wind energy systems including **floating substructures for deeper waters (>50m depth, 50km from shore)** or other marine climatic conditions to increase deployment possibilities
(LCOE>12 ct€/kWh by 2025 and >9 ct€/kWh by 2030)

European Commission

Competitive offshore wind auctions – Recent developments, differences and cost drivers



- Differences in project characteristics
- Long lead times could allow implementation of next generation wind turbines (10MW+)
- Differences in subsidy schemes
- Reduced financing costs
- Increased wholesale market electricity prices will be crucial for project realisation

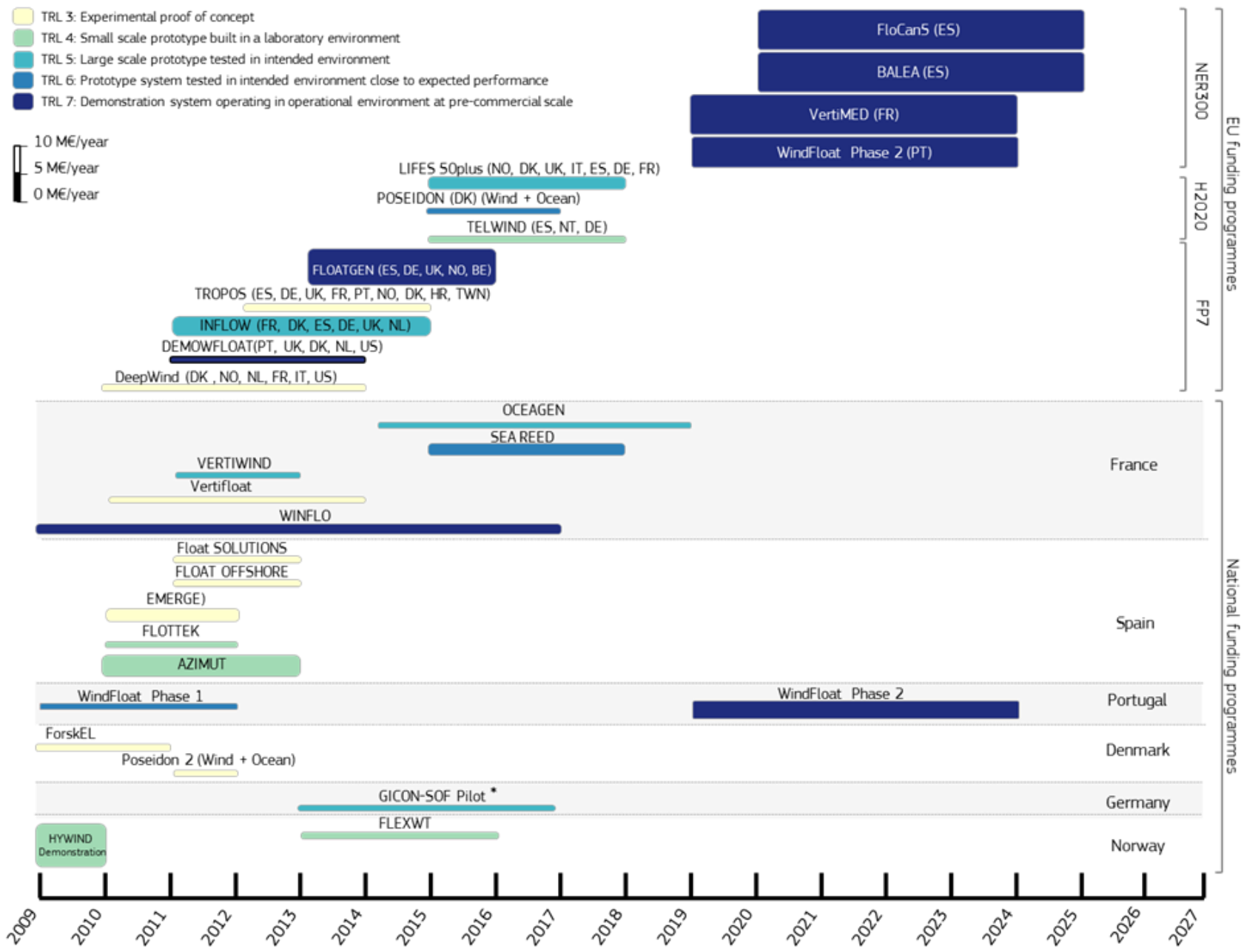
Note: All prices at date of bid announcement

Sources: JRC Report 2017 - Current offshore wind energy bid prices

European Commission

EU and national programme investment by TRL - Floating Offshore Wind

- National funding programmes incentivized floating offshore in the early stages of development
- EU funding through the FP7 and Horizon 2020 programmes
- Substantial increase in EU funding for pre-commercial floating concepts (NER 300 programme)



Source: JRC representation

European Commission

Conclusions

- **A sustainable access to raw materials is crucial** to strengthen the industrial basis and the value chain for renewable technologies
- The **EU is heavily dependent on imports** for the supply of key raw materials in wind, solar PV and batteries and well as on **downstream manufacturing** capacities
- The EU resilience to potential supply issues will deteriorate substantially by 2030 unless mitigation measures are taken such as **recycling and substitution**
- **Technology innovations** in major wind turbine components are crucial to **keep the costs down** as wind energy technology evolves towards larger designs
- Through **competitive auctions** and **substantial R&D funding** in offshore wind the EU is facilitating cost reductions and innovative technologies

Thanks

Any questions?

For contacts: claudiu.pavel@ec.europa.eu

European Commission

Sources

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