



Projet SURFER: Les besoins en matériaux et métaux de la Transition Énergétique de la France

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The SURFER project: the materials and metals needs of France's energy transition

Congrès international avniR 2019

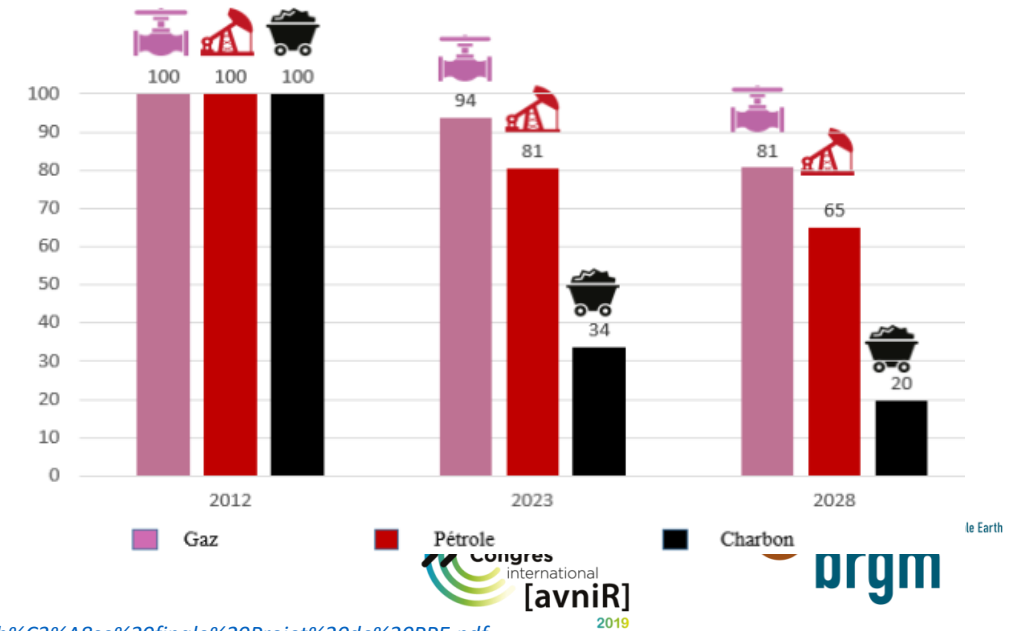
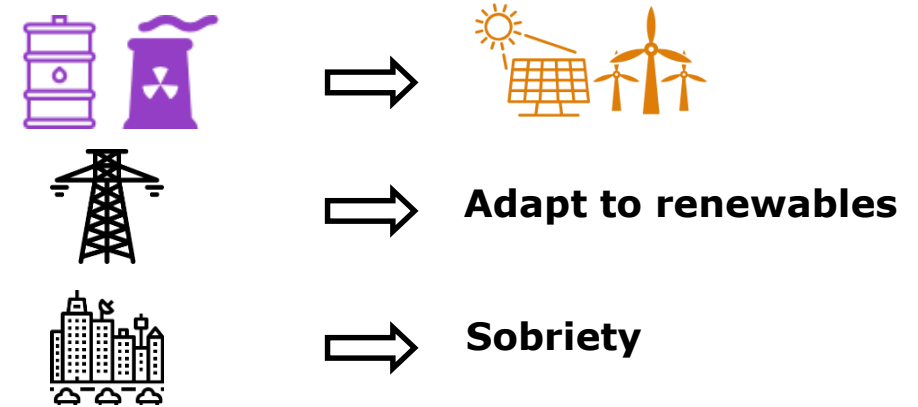
6th November 2019

D Monfort, F Laurent, B Rodriguez, F Lai, S Muller, J Villeneuve

Context: Energetic transition – A needed step to tackle climate change

Goals set by the French energetic transition act (August 2015)

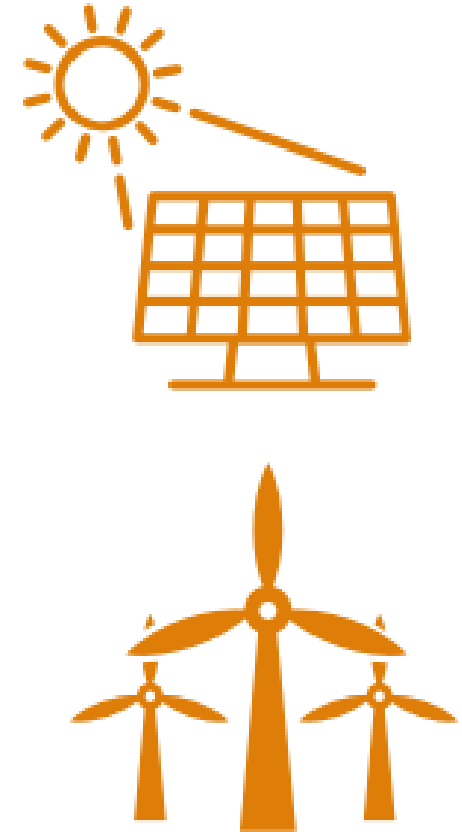
- By 2050:
 - **Reduction** of final energetic consumption, of the share of nuclear and primary fossil energy carriers
 - **Increase** of the renewable energy share in the final energetic consumption
- Examples in the *PPE*
 - **Sobriety**: Reduction of 7% in 2023 and 14% in 2028 (from 2012 level)
 - **Primary fossil energy**: Reduction of 20% in 2023 and 35% in 2028 (from 2012 level)
 - **Renewables**: 74 GW in 2023 (+50% from 2017 level) – 102 to 113 GW in 2028 (+100%)



Context: Energetic transition – A needed step to tackle climate change but requires new infrastructures

Some figures

- **Photovoltaic panels**
 - Almost 1 MWc by ha
 - Load factor +/- 15% (*)
 - Almost 8 ha/MW eq
 - 5200 ha (52 km², half of Paris area) to replace a 1 GW nuclear reactor operating at 75%(*)
- **Windmills**
 - Almost 100t steel per MW
 - Load factor +/- 22% (*)
 - Almost 1700 2 MW windmills to replace 1 GW nuclear reactor operating at 75%(*) ~ 340000 t steel, 50 times the steel needed for the Eiffel tower
 - For a nuclear power plant: 30 to 60 t of steel /MW ~ 30000 to 60000 t steel per GW



Do renewable energies require more raw materials (minerals and metals) than the actual energy mix?

(*) From : Bilan de l'énergie RTE

Context: Energetic transition – A needed step to tackle climate change but requires new infrastructures

Material requirements vs energy transition: a highly topical issue!

PERSPECTIVE

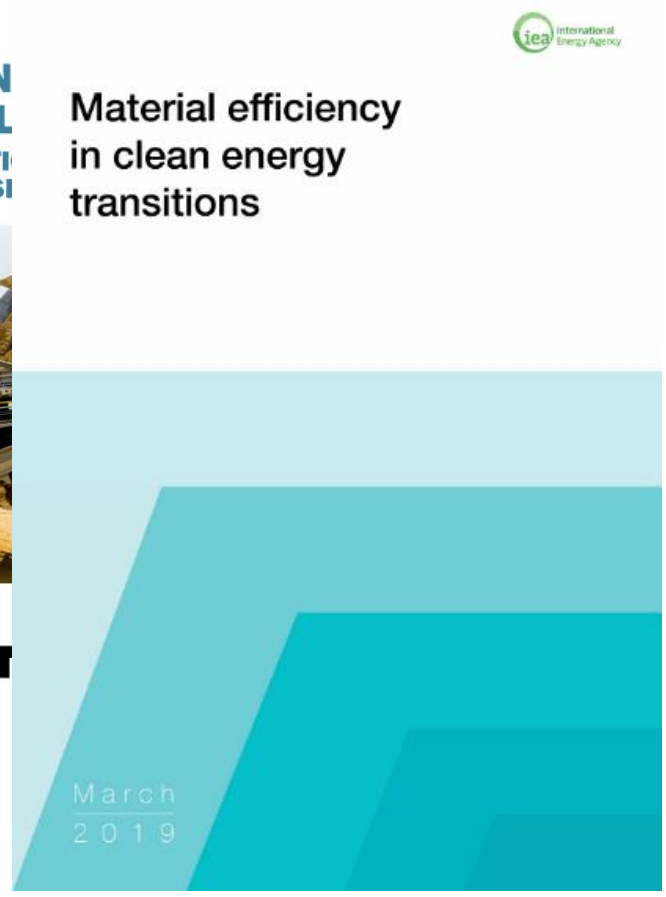
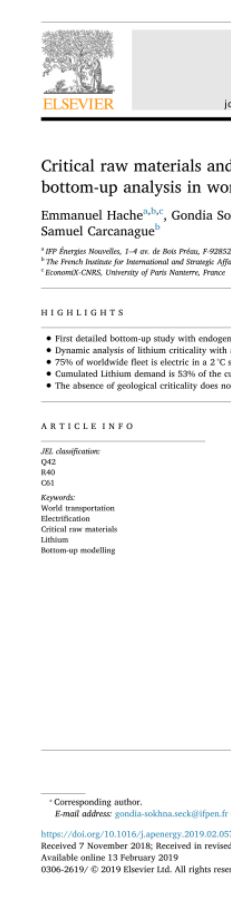
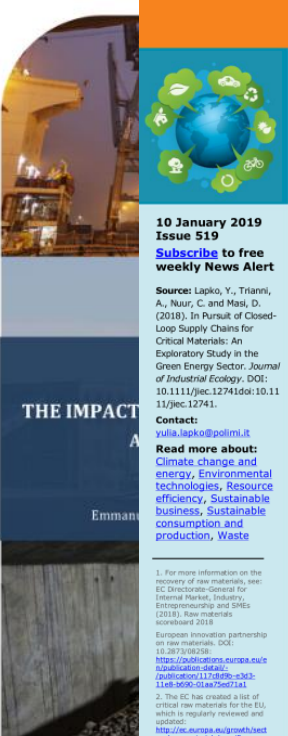
Mineral supply requirements

Saleem H. Al-Jalil^{1,2}, Damien Guirco³, Maria Amélia Enriquez⁴, Judith K. Richard Schodde^{5,6}, Gabi Schneier⁷

Successful delivery of the UN requires technologies that utilize contribute to sustaining supply, remain available to industry, sourcing of minerals, trajectory effects of consumption. Here interdisciplinary perspective coming decades.

The current oversupply of raw materials is a persistent underlying global challenge. Materials to an expanding global reach 8.5 billion by 2030—the target date development goals¹. Three events high of the challenge. First, on 12 December agreement on climate change was form momentous to a transition to a low-carbon require vast amounts of metals and minerals climate change are inextricably linked, a large amount of energy, but also to climate change without an adequate supply clean technologies^{2,3}. Likewise, the UN launched in September 2015, will also not but scant attention has been paid to these targets⁴. Second, the global mining size, despite some stabilization in consumption response to future increases in demand should be directed towards exploration an improvement in the recovery efficiency events such as the Samarco tailings dam perils of supply disruption and the crisis can be caused by major accidents at its subject to far more stringent regulation by local communities, which will prevent reader exploitation of others more difficult in this perspective, we evaluate these the crisis that is looming in the operation, recycling and the governance of Recent evaluations of shorter-term suggest that, over the next 2–3 decades (w recycling is expected to remain low^{5,6}), will struggle to meet demand for several

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⁶IFP Energies nouvelles, Institut Français du Pétrole, 1 rue de la Fontaine, 92852 La Défense Cedex, France
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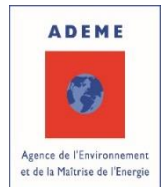


The SURFER project: materials and metals requirements for the French energetic transition

Project's ambition

- **Temporal assessment of direct and indirect materials requirements**
 - Raw materials consumption for energy transition?
 - Requirements in terms of energy, water, land?
- **Feasibility of the energy transition**
 - What is the « weight » of these requirements within the national consumption?
- **What impacts?**
 - How many, where, when?
 - From a dependency to fossil energies to a dependency to metals? When?
- 4 years project – December 2016 – December 2020

SURFER



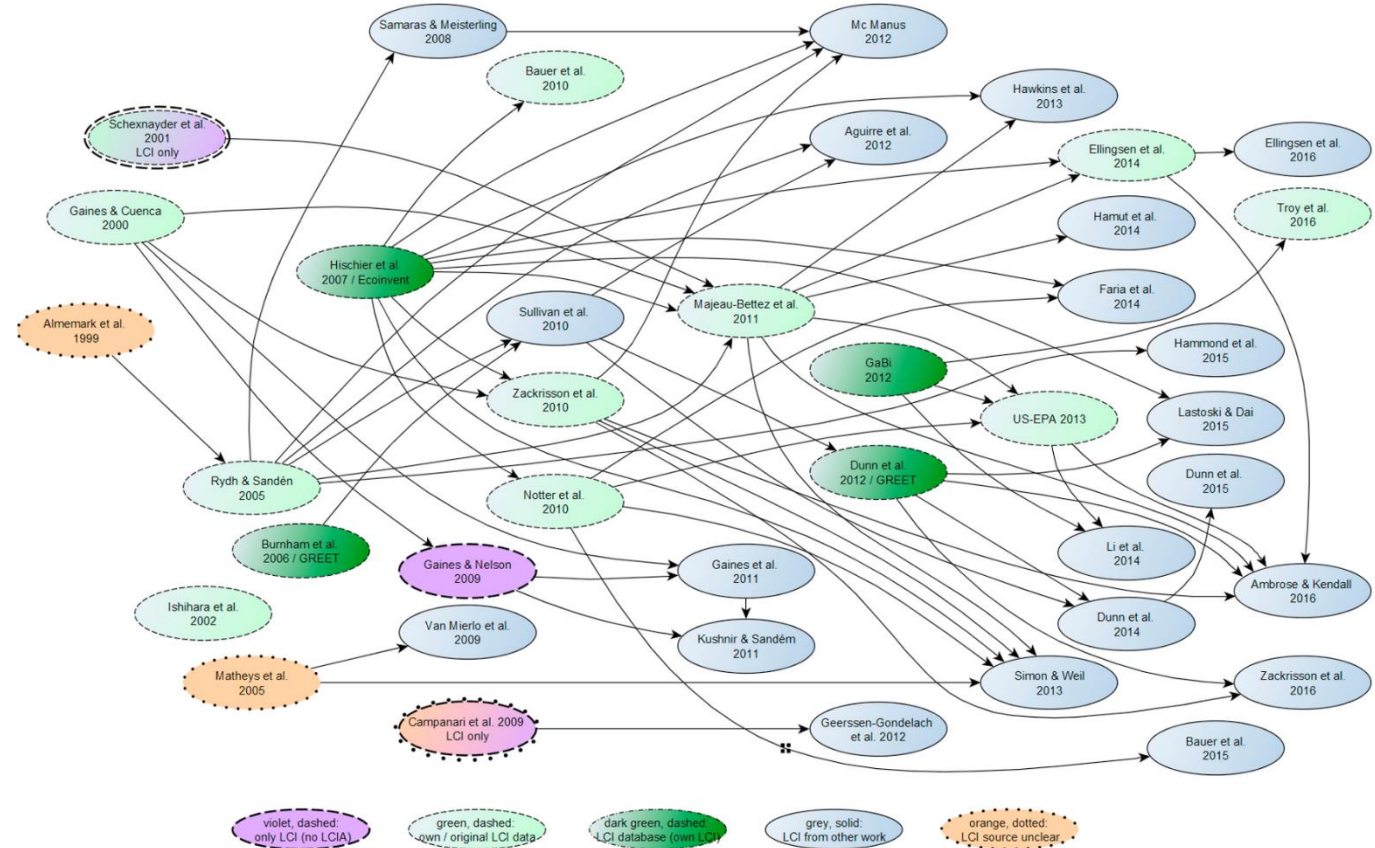
Assessing the direct material requirements – Material intensity

Concept of Material intensity

- Materials contained within the energy production infrastructures for a given installed capacity/power
→ e.g. *t of steel within a wind turbine for 1 kW installed capacity*
- Amount of fuels (fossil, nuclear...) consumed for energy production
→ e.g. *kg of uranium for producing 1 kWh*
- Materials contained within the fuels supply infrastructures (production + transport)
→ e.g. *t of steel within the uranium mining and processing infrastructures*

One goal of SURFER: build a database gathering the « material intensities » of different energy technologies

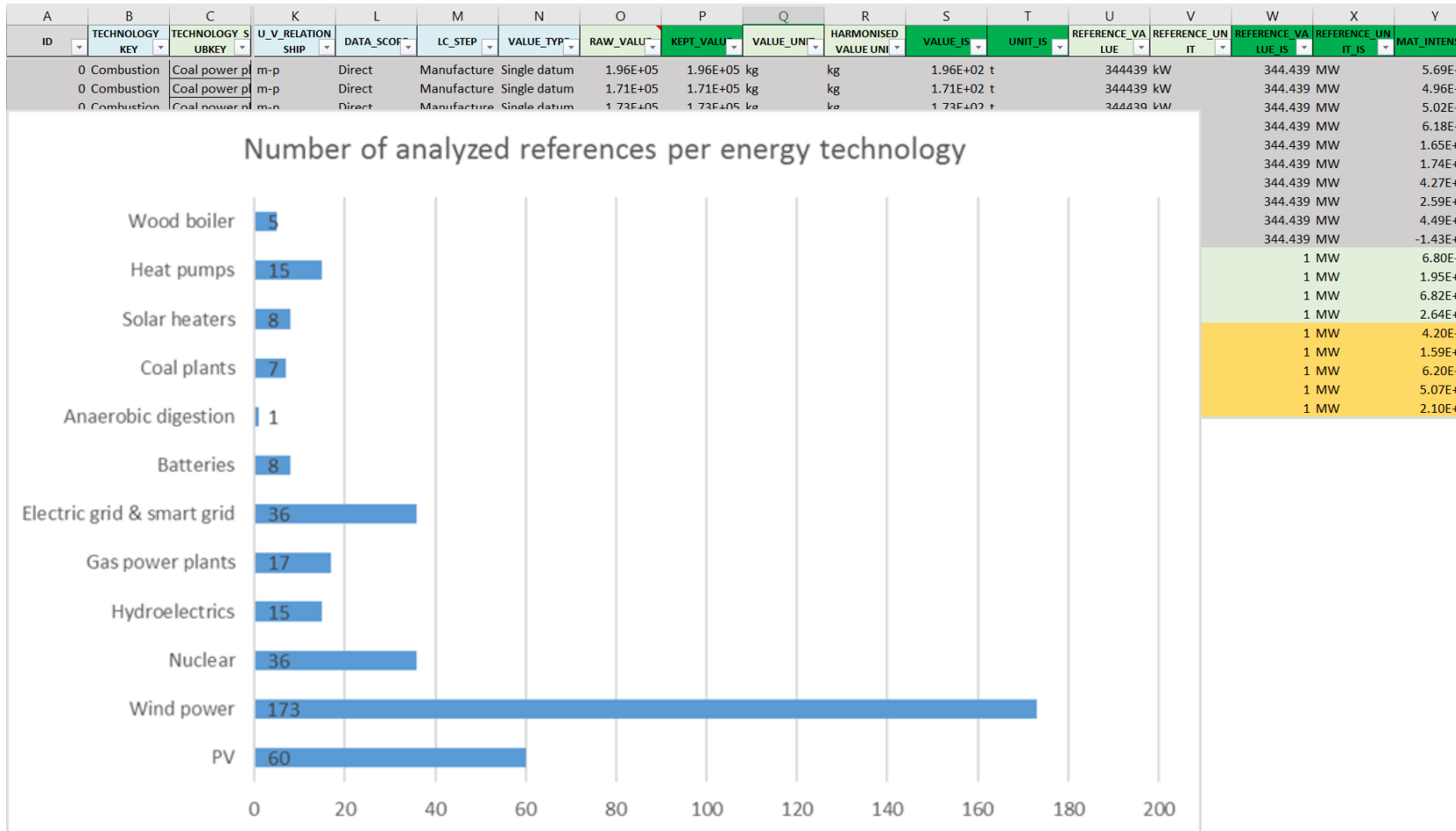
Literature as a source for material intensity, but...



Peters et al., 2017, The environmental impact of Li-Ion batteries and the role of key parameters – A review

Assessing the direct material requirements – Material intensity

From the SURFER database...



Multiple sources of data imply a lot of **heterogeneity** regarding material content to analyze...

Harmonization procedure (for each technology type)

1. Basic treatments

- Elimination of non original data and replicates
- Standardization of materials (e.g., steel alloys)
- Conversion in SI units

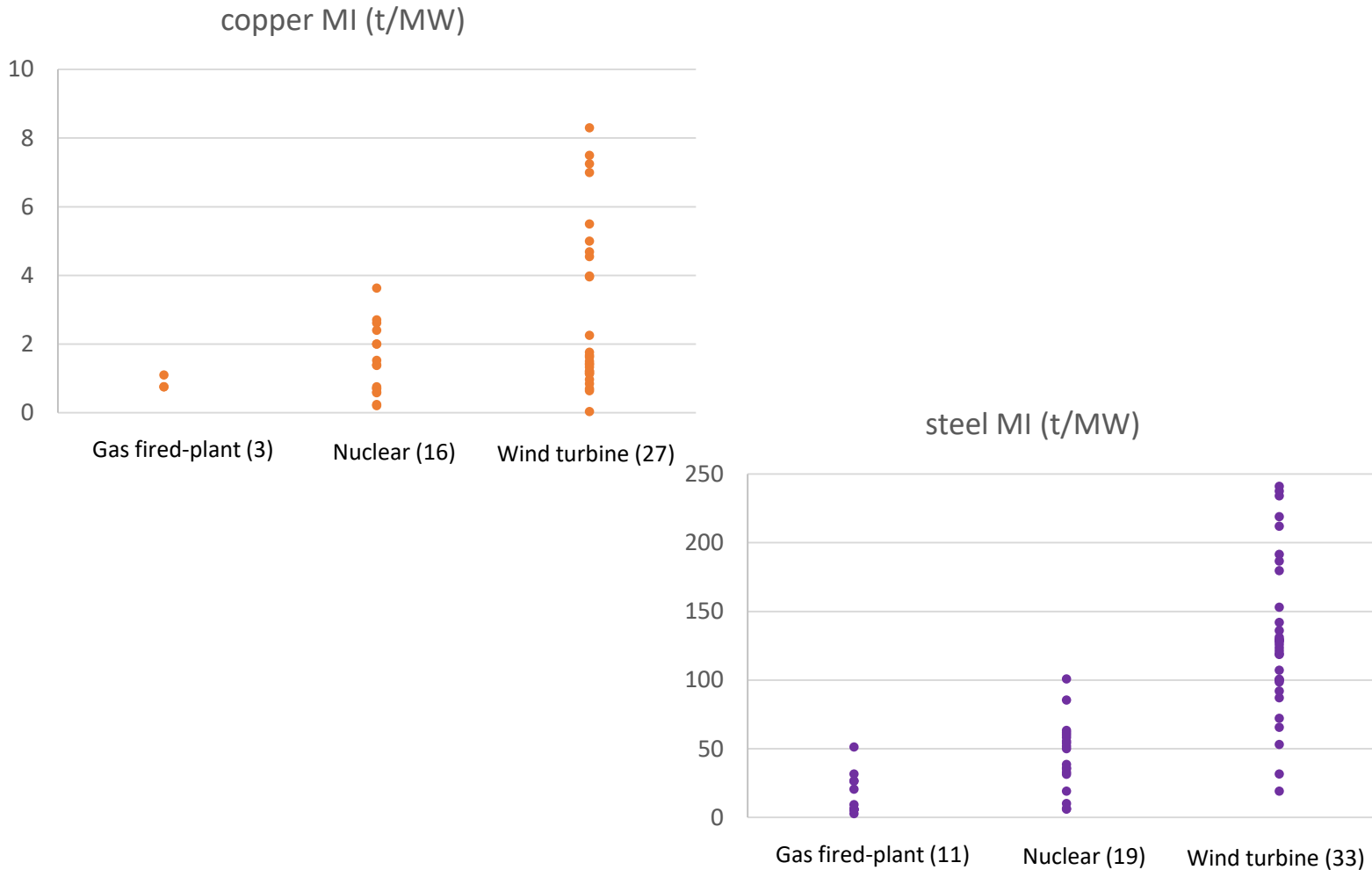
2. Material intensities (MI) calculation

- Aggregation of kg per substance and per component
- Divide by a reference value (e.g. capacity)
- Return MI (in kg/MW)

Assessing the direct material requirements – Material intensity

From the SURFER database... to THE material intensity

Multiple sources of data imply **variability** within the harmonized MI



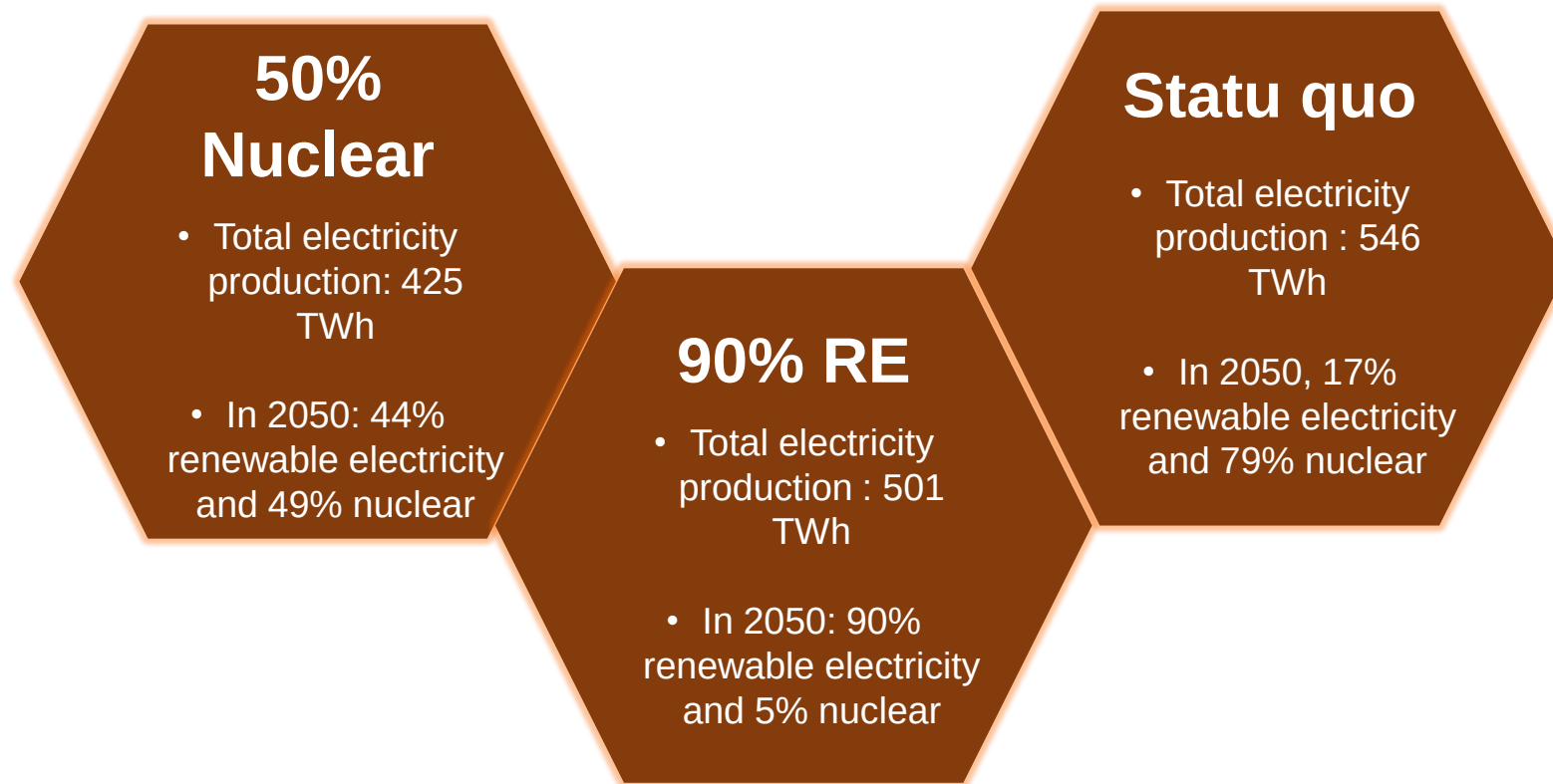
Procedure

- Elimination of outliers
- Comparison with industrial data
- Validation by experts

Applying these material intensities to the deployment of energetic scenarios

Different energetic scenarios

- Scenarios based on « Visions 2035-2050 » from ADEME



Applying these material intensities to the deployment of energetic scenarios

Example for the deployment of wind turbines

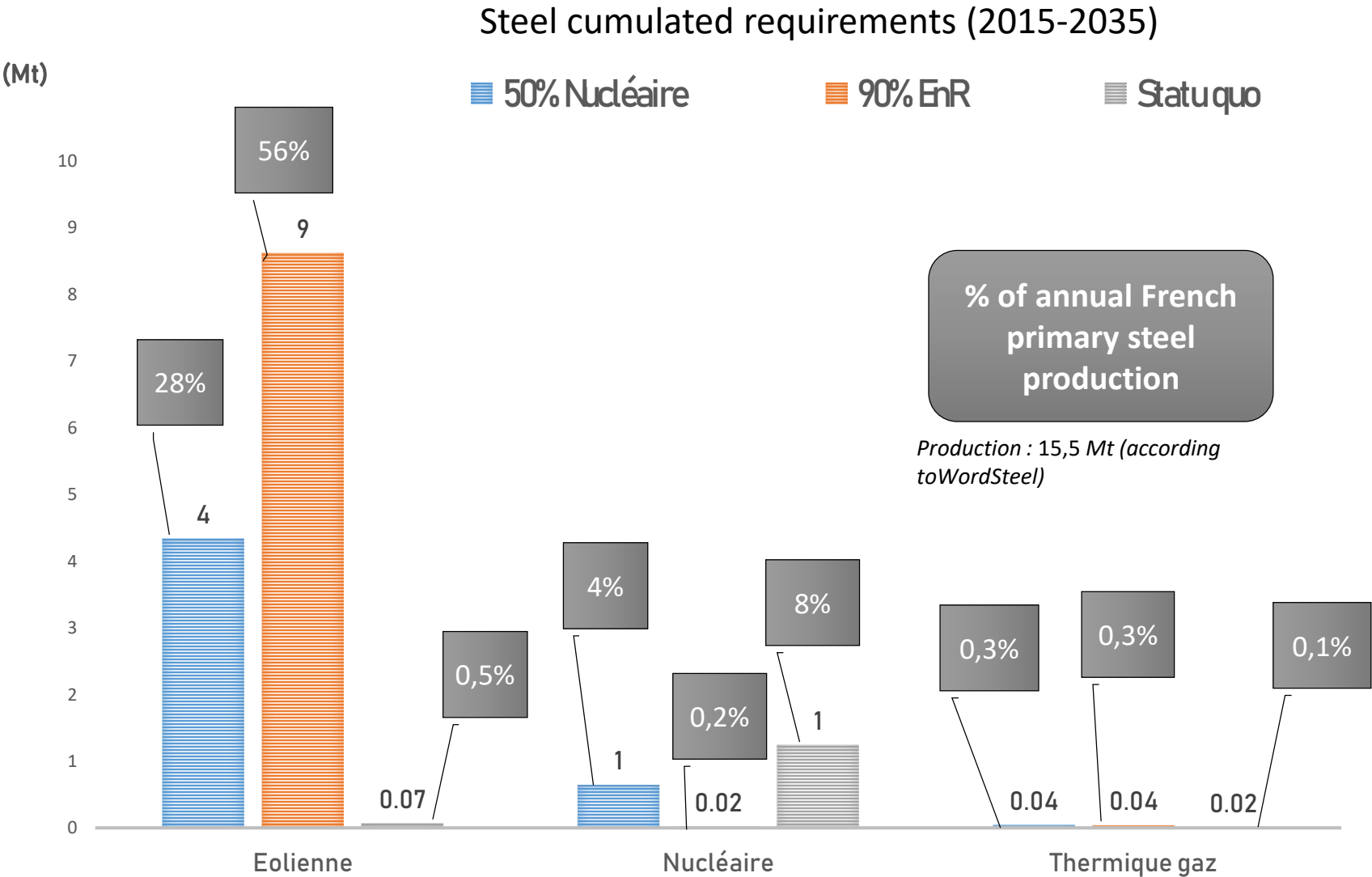
- Definition of three types of windmill parks

- Scenarios

MODEL 1		Power (MW)	2000	2001	2002	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Parameter		Unit																		
Wind farm	Grid connection	m per farm	Installed capacity (new)	94	35	1 360	1 360	1 360	1 360	1 360	743	743	743	743	743	743	743	200	200	200
	Power	MW	Installed capacity (repowering)					94	35	90	174	359	750	748	1 077	1 247	1 190	950	822	3,68
	Number of wind turbines		Total installed capacity	94	35	1 360	1 360	1 454	1 395	1 450	917	1 102	1 493	1 491	1 820	1 990	1 933	750	622	1,97
	Number of substations		Accumulated installed capacity	0	94	129	16 360	17 720	19 080	20 440	21 800	22 543	23 286	24 029	24 771	25 514	26 257	27 000	26 800	26 600
	Wind turbine spacing		Number of wind farm	*change only the percentage*																
Wind turbine	Lifespan	y	Model 1																	
	Power		Total installed capacity per farm model	90%	90%	80%	80%	80%	80%	80%	70%	70%	70%	70%	70%	50%	50%	50%	50%	50%
	Height		Model 2	77	77	73	70	73	40	48	65	65	80	62	60	23	19			
	Transformer distance	m per	Total installed capacity per farm model	10%	10%	10%	10%	10%	10%	15%	15%	15%	15%	15%	15%	30%	30%	30%	30%	30%
	Rotor diameter		Model 3	4	4	4	4	4	4	5	6	6	8	17	16	6	5			
	Internal cables	Copper	Total installed capacity per farm model	0%	0%	10%	10%	10%	10%	15%	15%	15%	15%	15%	20%	20%	20%	20%	20%	20%
	Aluminium		Total material consumption/year	0	0	3	3	3	3	3	5	5	6	8	8	3	3			
	External cables	Copper	IM*total installed capacity (t)																	
	Aluminium		Concrete																	
	Foundations	Gravity base	Steel and Iron	6,26E+05	6,26E+05	6,66E+05	6,39E+05	6,64E+05	4,14E+05	4,98E+05	6,75E+05	6,74E+05	8,23E+05	8,68E+05	8,43E+05	3,27E+05	2,71E+05	1,84		
Wind turbine	Tower	Concrete	Copper	1,34E+05	1,34E+05	1,38E+05	1,32E+05	1,37E+05	8,43E+04	1,01E+05	1,37E+05	1,37E+05	1,67E+05	1,74E+05	1,69E+05	6,56E+04	5,44E+04	3,68		
	Aluminium		Aluminium	4,35E+03	4,35E+03	4,65E+03	4,46E+03	4,64E+03	2,93E+03	3,53E+03	4,78E+03	4,77E+03	5,82E+03	6,37E+03	6,19E+03	2,40E+03	1,99E+03	1,35		
	Internal cables	Copper	Aluminium	3,26E+03	3,26E+03	3,49E+03	3,35E+03	3,48E+03	2,20E+03	2,64E+03	3,58E+03	3,58E+03	4,37E+03	4,78E+03	4,64E+03	1,80E+03	1,49E+03	1,01		
	External cables	Copper																		
	Aluminium																			
	Foundations	Gravity base																		
	Tower	Concrete																		
	Steel																			
MODEL 2			Number of wind farm																	
Wind farm	Grid connection	m per	Model 1	920	997	954	1022	1090	986	1019	1051	1084	1116	821	844	838	831	8		
	Power		Model 2	45	49	53	57	61	94	97	100	103	106	219	225	223	222	2		
	Number of wind turbines		Model 3	0	0	40	43	45	70	73	75	77	80	109	113	112	111	1		
	Number of substations		Total material consumption/year	stock																
	Wind turbine spacing		IM*Accumulated installed capacity (t)																	
Wind turbine	Lifespan	y	Concrete	7,53E+06	8,15E+06	8,74E+06	9,36E+06	9,98E+06	1,02E+07	1,05E+07	1,09E+07	1,12E+07	1,15E+07	1,14E+07	1,18E+07	1,17E+07	1,16E+07	1,15		
	Power		Steel and Iron	1,61E+06	1,74E+06	1,80E+06	1,93E+06	2,06E+06	2,07E+06	2,14E+06	2,21E+06	2,28E+06	2,34E+06	2,29E+06	2,36E+06	2,34E+06	2,32E+06	2,31		
	Height		Copper	5,24E+04	5,67E+04	6,11E+04	6,54E+04	6,98E+04	7,21E+04	7,45E+04	7,69E+04	7,93E+04	8,16E+04	8,40E+04	8,64E+04	8,58E+04	8,51E+04	8,45		
	Transformer distance	m per	Aluminium	3,93E+04	4,25E+04	4,58E+04	4,91E+04	5,23E+04	5,41E+04	5,59E+04	5,77E+04	5,95E+04	6,12E+04	6,30E+04	6,48E+04	6,43E+04	6,38E+04	6,34		
	Rotor diameter																			
	Internal cables	Copper	Number of wind farm																	
	Aluminium		Model 1	0,0	0,0	4,7	1,8	4,5	7,6	15,7	32,8	32,7	47,1	39,0	37,2	29,7	25,7	1		
	External cables	Copper	Model 2	0,0	0,0	0,3	0,1	0,3	0,7	1,5	3,1	3,1	4,5	10,4	9,9	7,9	6,9	5		
	Aluminium		Model 3	0,0	0,0	0,2	0,1	0,2	0,5	1,1	2,3	2,3	3,4	5,2	5,0	4,0	3,4	2		
	Foundations	Gravity base	Total material from dismantling/year	output																
Wind turbine	Tower	Concrete	IM*Installed capacity (repowering) (t)																	
	Steel		Concrete	0,00E+00	0,00E+00	4,31E+04	1,60E+04	4,12E+04	7,86E+04	1,62E+05	3,39E+05	3,38E+05	4,87E+05	5,44E+05	5,19E+05	4,14E+05	3,58E+05	2		
	Internal cables	Copper	Steel and Iron	0,00E+00	0,00E+00	8,89E+03	3,31E+03	8,51E+03	1,60E+04	3,30E+04	6,89E+04	6,87E+04	9,90E+04	1,09E+05	1,04E+05	8,30E+04	7,18E+04			
	Aluminium		Copper	0,00E+00	0,00E+00	3,01E+02	1,12E+02	2,88E+02	5,57E+02	1,15E+03	2,40E+03	2,39E+03	3,45E+03	3,99E+03	3,81E+03	3,04E+03	2,63E+03			
	Foundations	Gravity base	Aluminium	0,00E+00	0,00E+00	2,26E+02	8,40E+01	2,16E+02	4,18E+02	8,62E+02	1,80E+03	1,80E+03	2,58E+03	2,99E+03	2,86E+03	2,28E+03	1,97E+03			

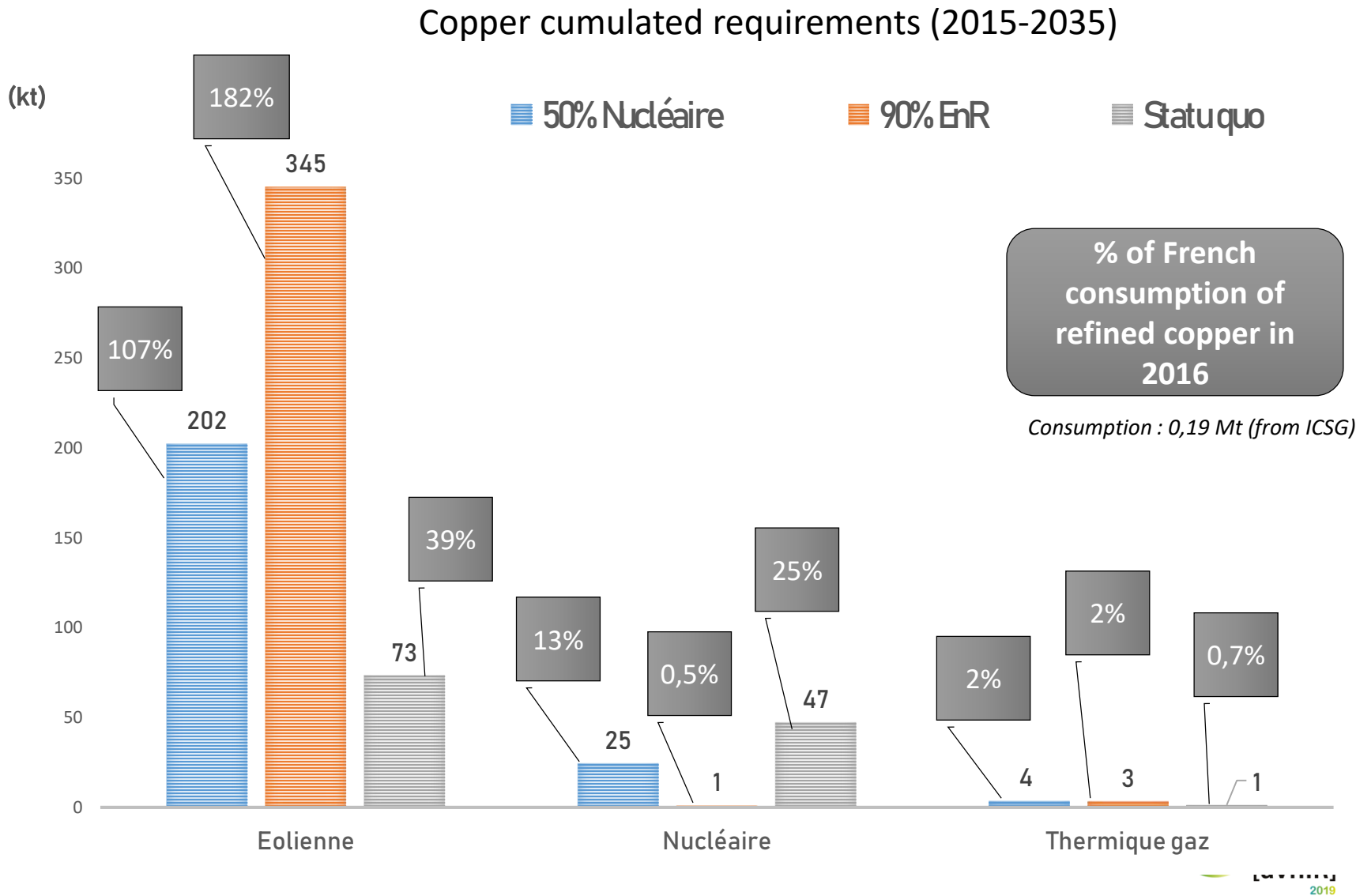
Applying these material intensities to the deployment of energetic scenarios

Some results for wind turbines, gas-fired plants and nuclear plants



Applying these material intensities to the deployment of energetic scenarios

Some results for wind turbines, gas-fired plants and nuclear plants



How to consider indirect material requirements and material cycle?

- **Indirect material requirements**
 - Application of life cycle approaches
- **Material cycle – how to consider dismanteling?**
 - Industrial reconversion
 - Two possible approaches for recycling
 - ✓ Closed-loop recycling
 - Recycling without the same product system
 - Recycling without any changes to inherent properties
 - ✓ Open-loop recycling
 - Recycling into different product systems
 - Recycling with changes to inherent properties
 - Two important notions to consider
 - ✓ Recycled content
 - ✓ End-of-life recycling input rate (EOL-RIR)

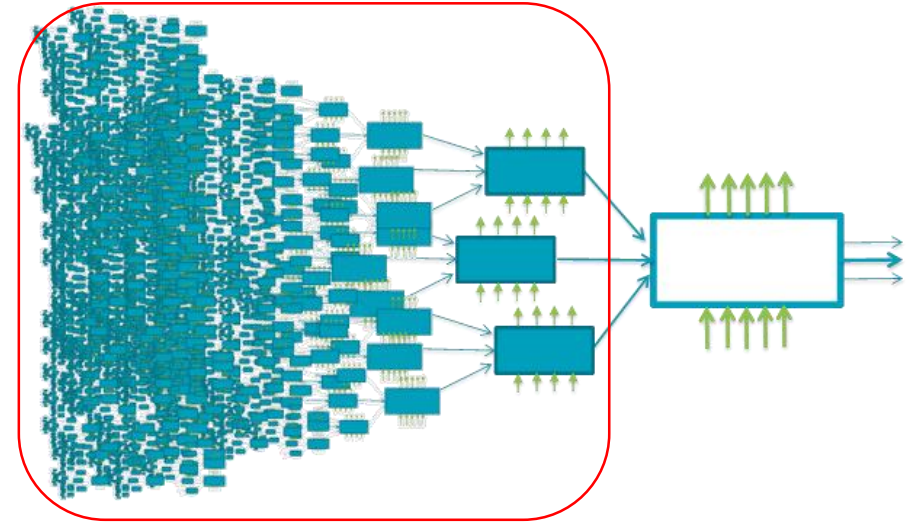
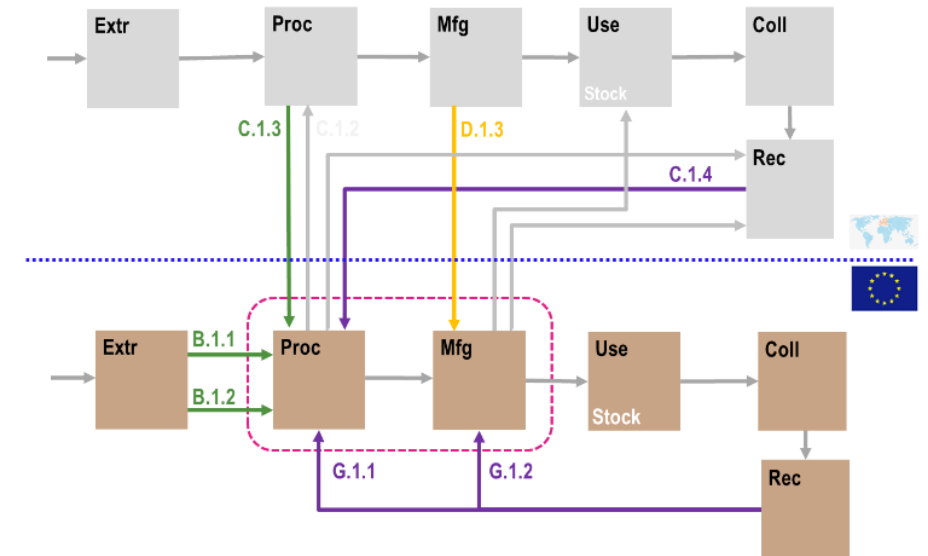


Figure 1 System boundaries and material flows included in the calculation of the EOL-RIR⁷.



Extr: Extraction; Proc: Processing; Mfg: Manufacturing; Coll: Collection; Rec: Recycling

Conclusions

- **Challenges raised by the SURFER project**
 - Data collection and harmonization
 - Assumptions and evolutions to take into account (lifespan, recycling rate,...)
 - Modelling of scenarios
- **Still some work to do**
 - Assessment of the total materials requirements
 - Assessment of the environmental implications of these requirements (energy, water, land)
 - Contextualization to French consumption
 - Materials criticality assessment

SURFER

Analyse de l'impact matières premières, énergies et eau du déploiement des énergies renouvelables sur la période 2015-2050 en France



Thank you for your attention

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