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

Daniel Monfort, Faustine Laurent, B Rodriguez, Frédéric Lai, Stéphanie Muller, Jacques Villeneuve

Congrès international [avniR] 2019

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

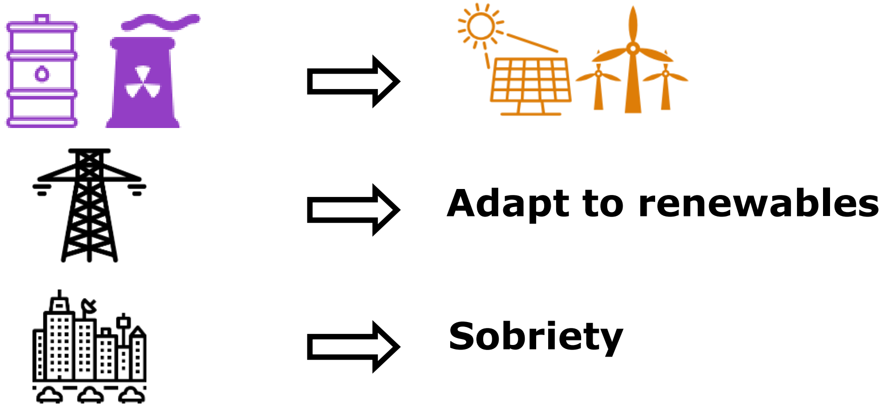
INSTITUT CARNOT brgm

brgm Geoscience for a sustainable Earth

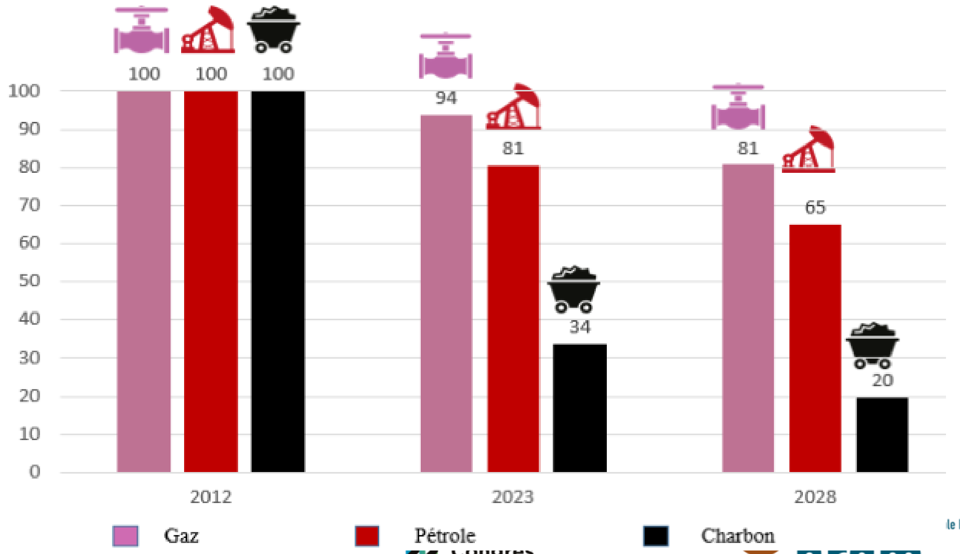
Context: Energetic transition – A needed step to tackle climate change

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%)

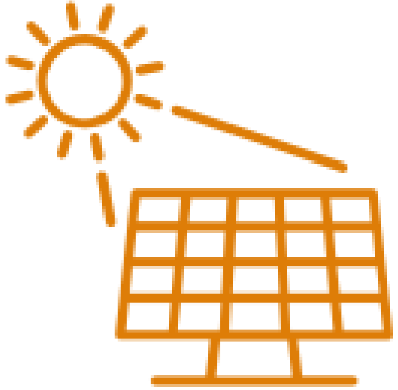


Source: https://www.ecologique-solidaire.gouv.fr/sites/default/files/Synth%C3%A8se%20finale%20Projet%20de%20PPE.pdf

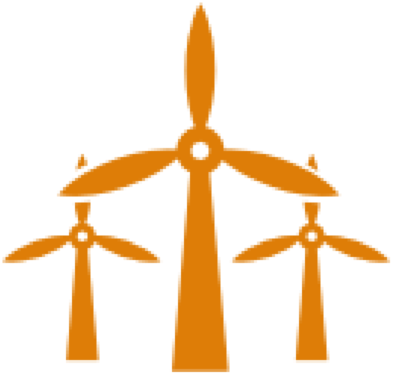
Context: Energetic transition – A needed step to tackle climate change but requires new infrastructures

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?

Congrès international [avniR] 2019

Geoscience for a sustainable Earth brgm

(*) 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!

Congrès international [avniR] 2019

Geoscience for a sustainable Earth
brgm

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

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

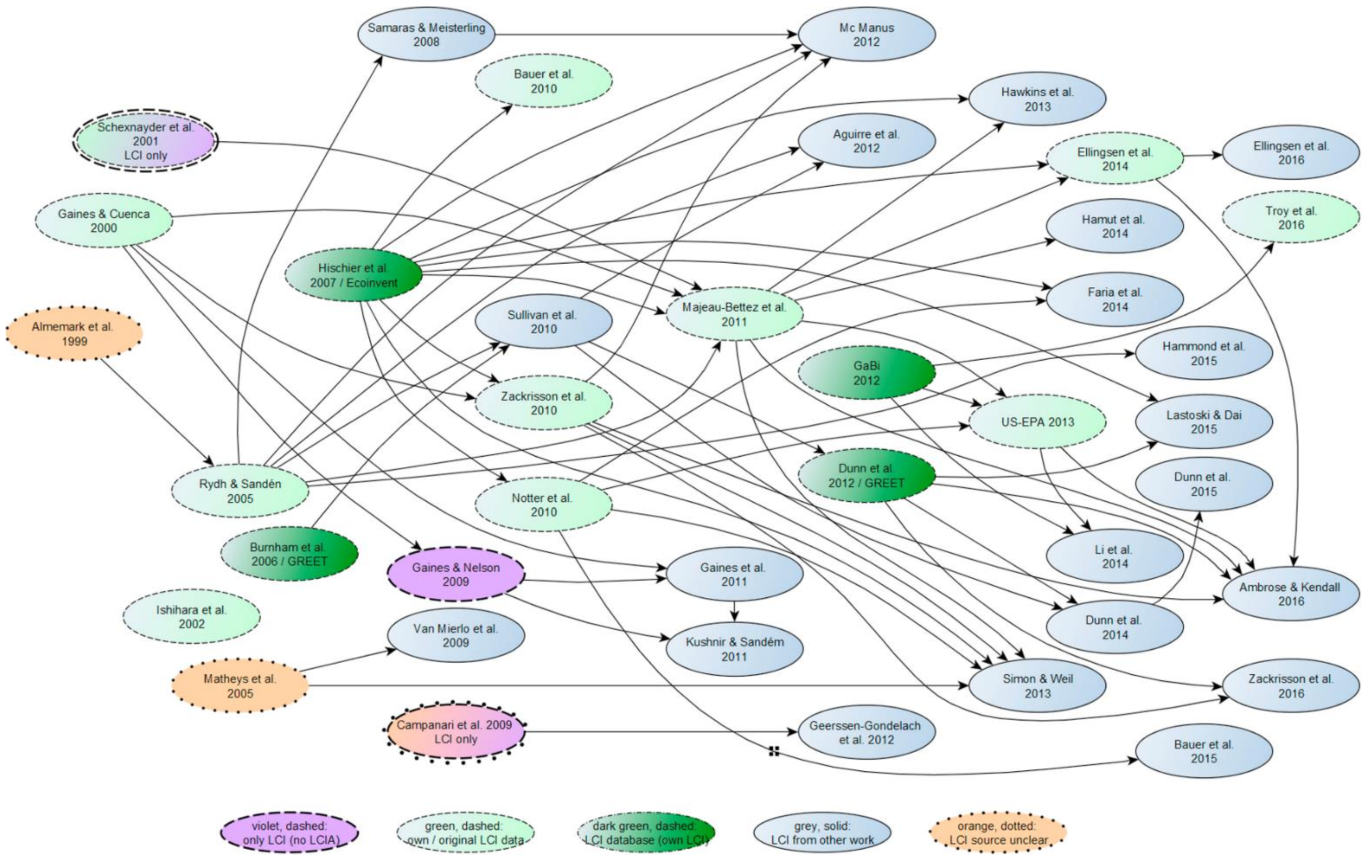
➔ *e.g. kg of uranium for producing 1 kWh*

- 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...



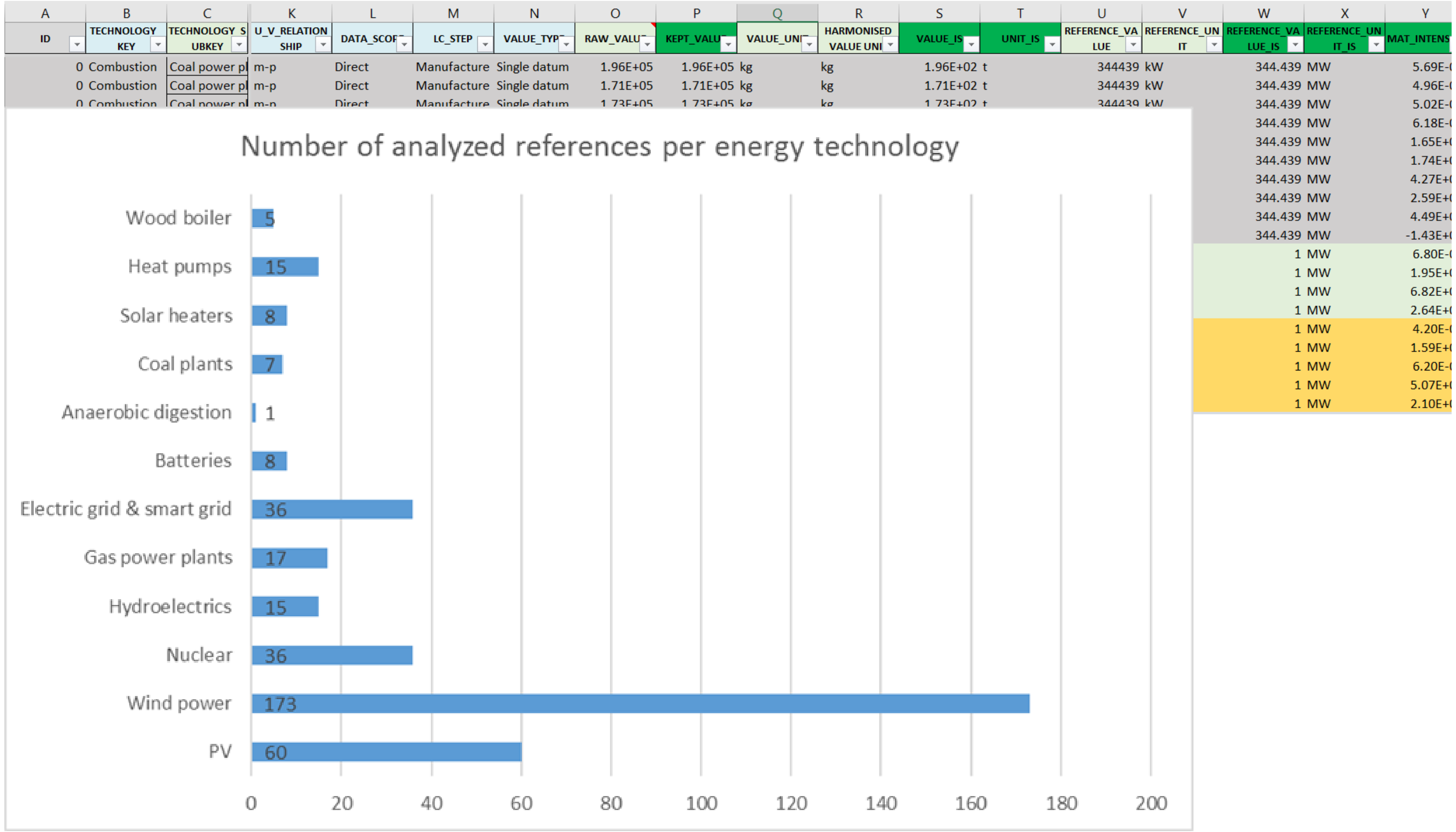
Peters et al., 2017, The environmental impact of Li-Ion batteries and the role of key parameters – A review

Congrès international [avniR] 2019

Geoscience for a sustainable Earth brgm

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

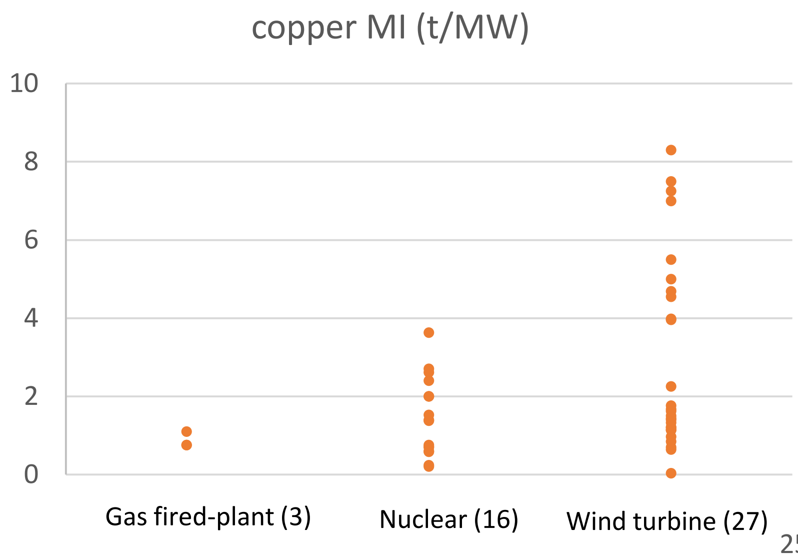
2. Material intensities (MI) calculation

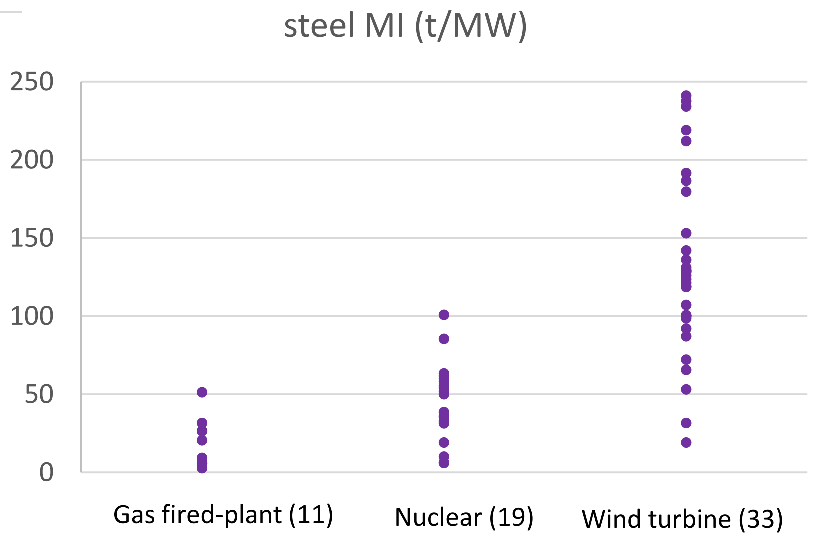
- Aggregation of kg per substance and per component
- Divide by a reference value (e.g. capacity)
- Return MI (in kg/MW)

Assessing the direct material requirements – Material intensity

From the SUPFER 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

Congrès international [avniR] 2019

Geoscience for a sustainable Earth brgm

Applying these material intensities to the deployment of energetic scenarios

Different energetic scenarios

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

50% Nuclear

- Total electricity production: 425 TWh
- In 2050: 44% renewable electricity and 49% nuclear

90% RE

- Total electricity production : 501 TWh
- In 2050: 90% renewable electricity and 5% nuclear

Statu quo

- Total electricity production : 546 TWh
- In 2050, 17% renewable electricity and 79% nuclear

Applying these material intensities to the deployment of energetic scenarios

Example for the deployment of wind turbines

- **Definition of three types of windmill parks**

MODEL 1			
Parameter			Unit
Grid connection			m per far
Wind farm	Power		MW
	Number of wind turbines		
	Number of substations		
	Wind turbine spacing		
	Lifespan		y
Wind turbine	Power		
	Height		
	Transformer distance		m per
	Rotor diameter		
	Internal cables	Copper	
		Aluminium	
	External cables	Copper	
		Aluminium	
	Foundations	Gravity base	
	Tower	Concrete	
		Steel	

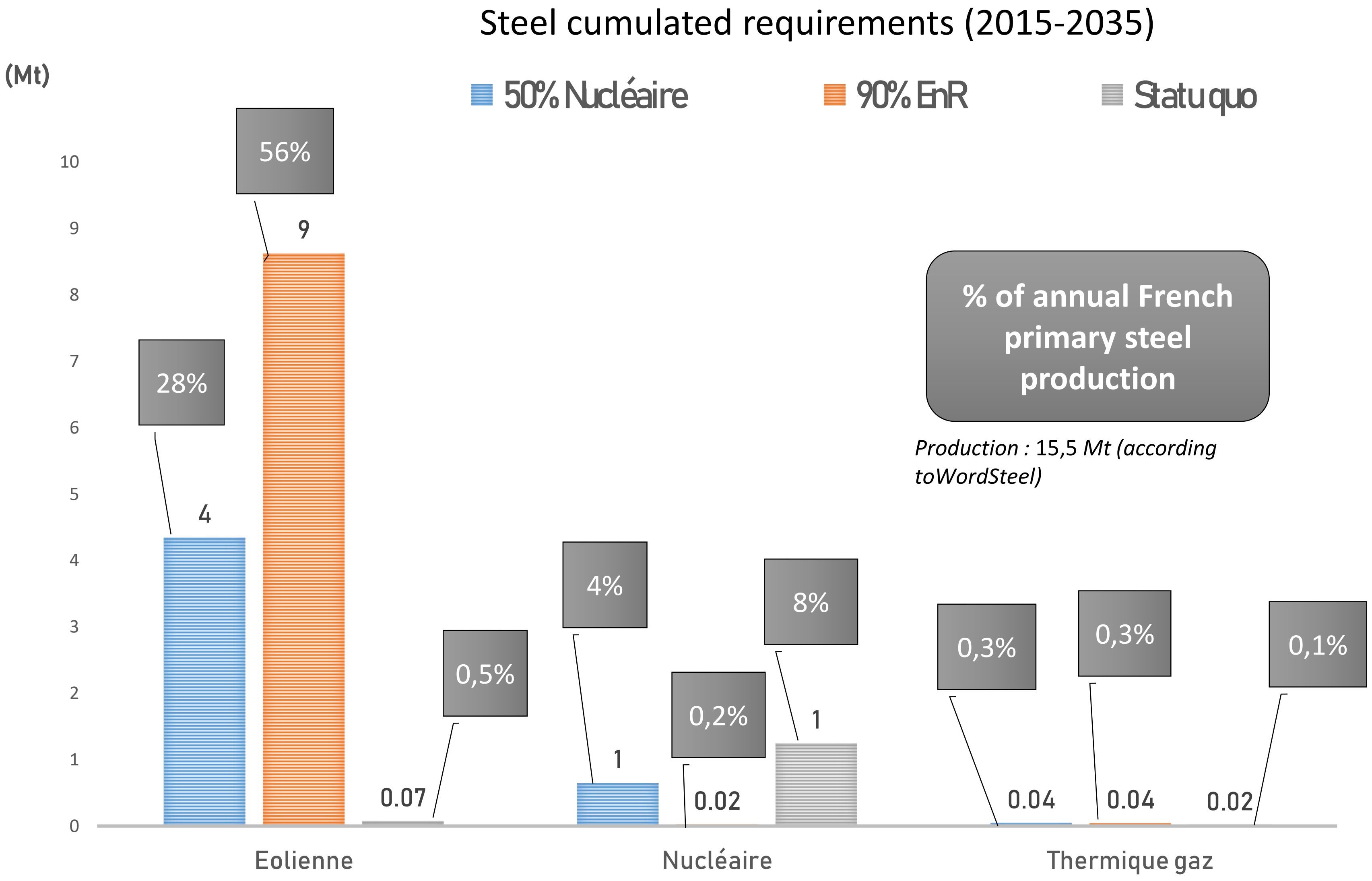
MO			
Parameter			
Grid connection			m pe
Wind farm	Power		
	Number of wind turbines		
	Number of substations		
	Wind turbine spacing		
	Lifespan		y
Wind turbine	Power		
	Height		
	Transformer distance		m per
	Rotor diameter		
	Internal cables	Copper	
		Aluminium	
	External cables	Copper	
		Aluminium	
	Foundations	Gravity base	
	Tower	Concrete	
		Steel	

- **Scenarios**

Power (MW)	2000	2001	2002	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	20
Installed capacity (new)		94	35	1 360	1 360	1 360	1 360	1 360	743	743	743	743	743	743	743	- 200	- 200	-
Installed capacity (repowering)					-	94	35	90	174	359	750	748	1 077	1 247	1 190	950	822	
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	
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	26
Number of wind farm	**change only the percentage**																	
Model 1				*90%*	*90%*	*80%*	*80%*	*80%*	*70%*	*70%*	*70%*	*70%*	*70%*	*50%*	*50%*	*50%*	*50%*	*50*
Total installed capacity per farm model				77	77	73	70	73	40	48	65	65	80	62	60	23	19	1
Model 2				*10%*	*10%*	*10%*	*10%*	*10%*	*15%*	*15%*	*15%*	*15%*	*15%*	*30%*	*30%*	*30%*	*30%*	*30*
Total installed capacity per farm model				4	4	4	4	4	4	5	6	6	8	17	16	6	5	
Model 3				*0%*	*0%*	*10%*	*10%*	*10%*	*15%*	*15%*	*15%*	*15%*	*15%*	*20%*	*20%*	*20%*	*20%*	*20*
Total installed capacity per farm model				0	0	3	3	3	3	3	5	5	6	8	8	3	3	
Total material consumption/year	input																	
IM*total installed capacity (t)																		
Concrete				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
Steel and Iron				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
Copper				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
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
Number of wind farm																		
Model 1				920	997	954	1022	1090	986	1019	1051	1084	1116	821	844	838	831	8
Model 2				45	49	53	57	61	94	97	100	103	106	219	225	223	222	2
Model 3				0	0	40	43	45	70	73	75	77	80	109	113	112	111	1
Total material consumption/year	stock																	
IM*Accumulated installed capacity (t)																		
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
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
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
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
Number of wind farm																		
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
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
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
Total material from dismantling/year	output																	
IM*Installed capacity (repowering) (t)																		
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
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	
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+0	
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	1,9	

Applying these material intensities to the deployment of energetic scenarios

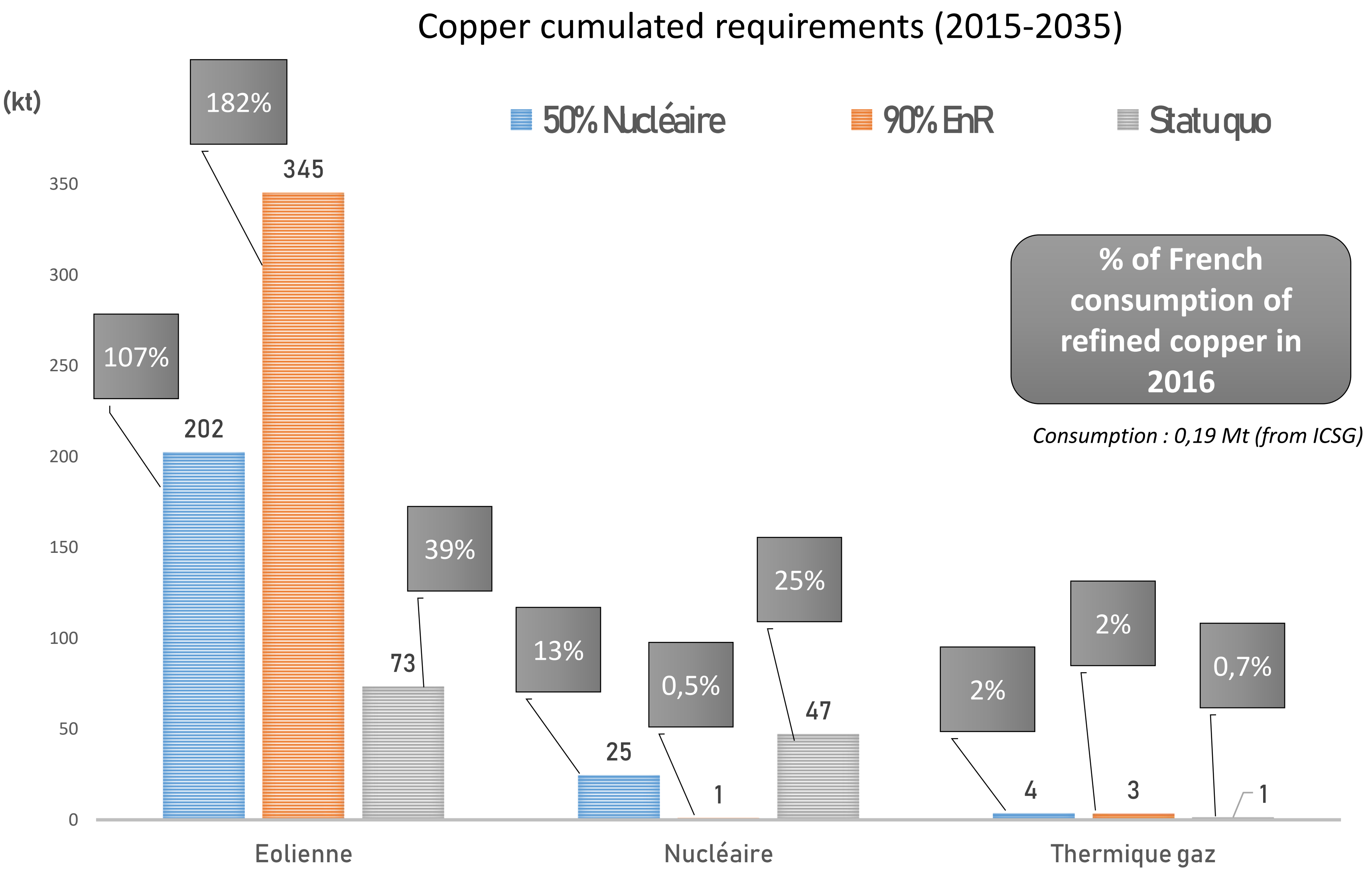
Some results for wind turbines, gas-fired plants and nuclear plants



Production : 15,5 Mt (according toWordSteel)

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)

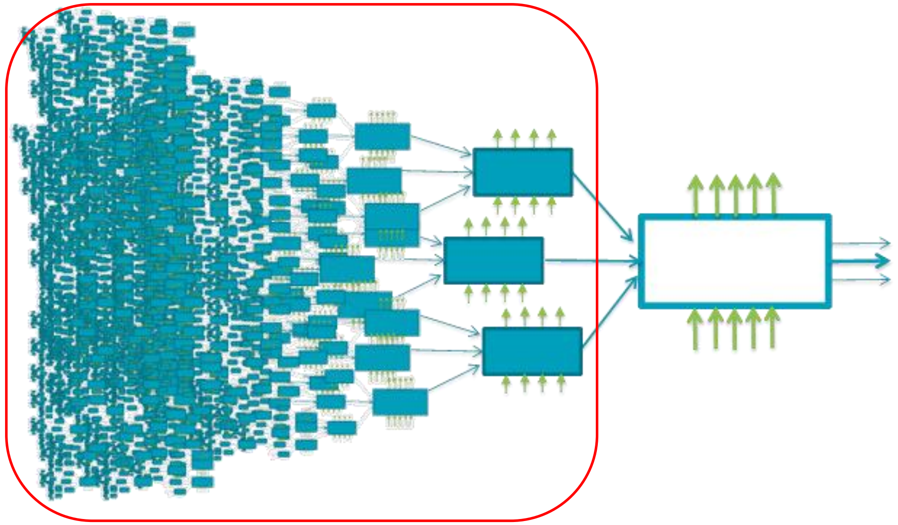
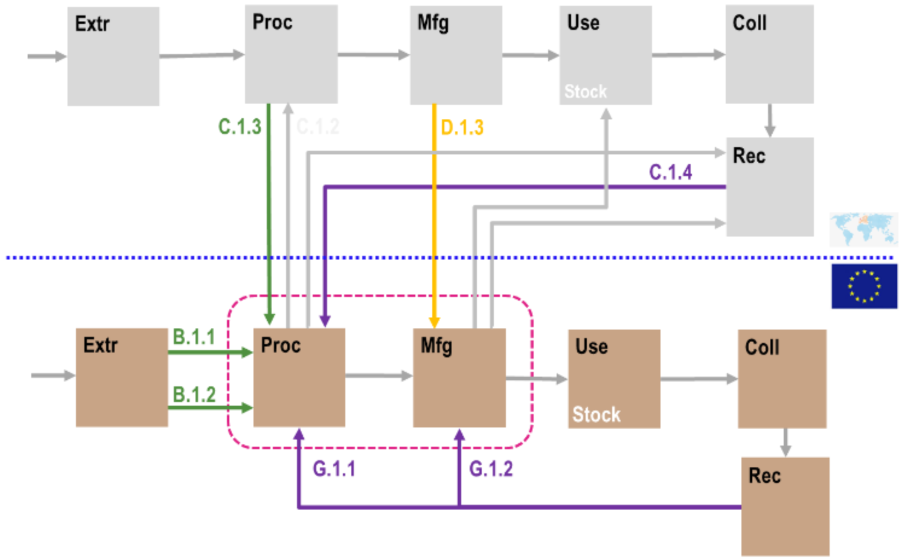


Figure 1 System boundaries and material flows included in the calculation of the EOL-RIR[7].



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

Source: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC112720/kj-na-29435-en-n_recycling_report.pdf

Conclusions

- **Challenges raised by the SURFER project**
  - Data collection and harmonization
  - Assumptions and evolutions to take into account (lifespan, recycling rage,...)
  - 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 criticity assessment

SURFER

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

ADEME Agence de l'Environnement et de la Maîtrise de l'Energie

brgm Géosciences pour une Terre durable

ISTerre Institut des Sciences de la Terre

Congrès international [avniR] 2019

brgm Geoscience for a sustainable Earth

Congrès international [avniR] 2019

Thank you for your attention

Contact: s.muller@brgm.fr – j.villeneuve@brgm.fr

INSTITUT CARNOT brgm

Geoscience for a sustainable Earth brgm