

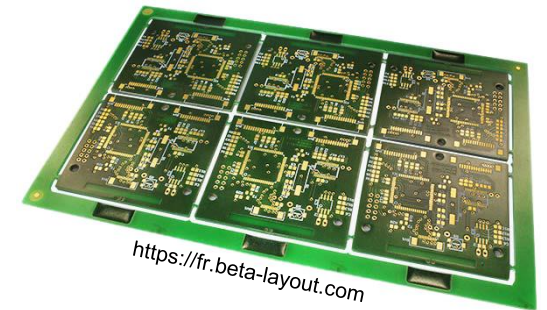


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électronique & numérique durables

PCBnCO: A Carbon Intensity Model of FR-4 Printed Circuit Boards Based on Company Data

Implemented on 



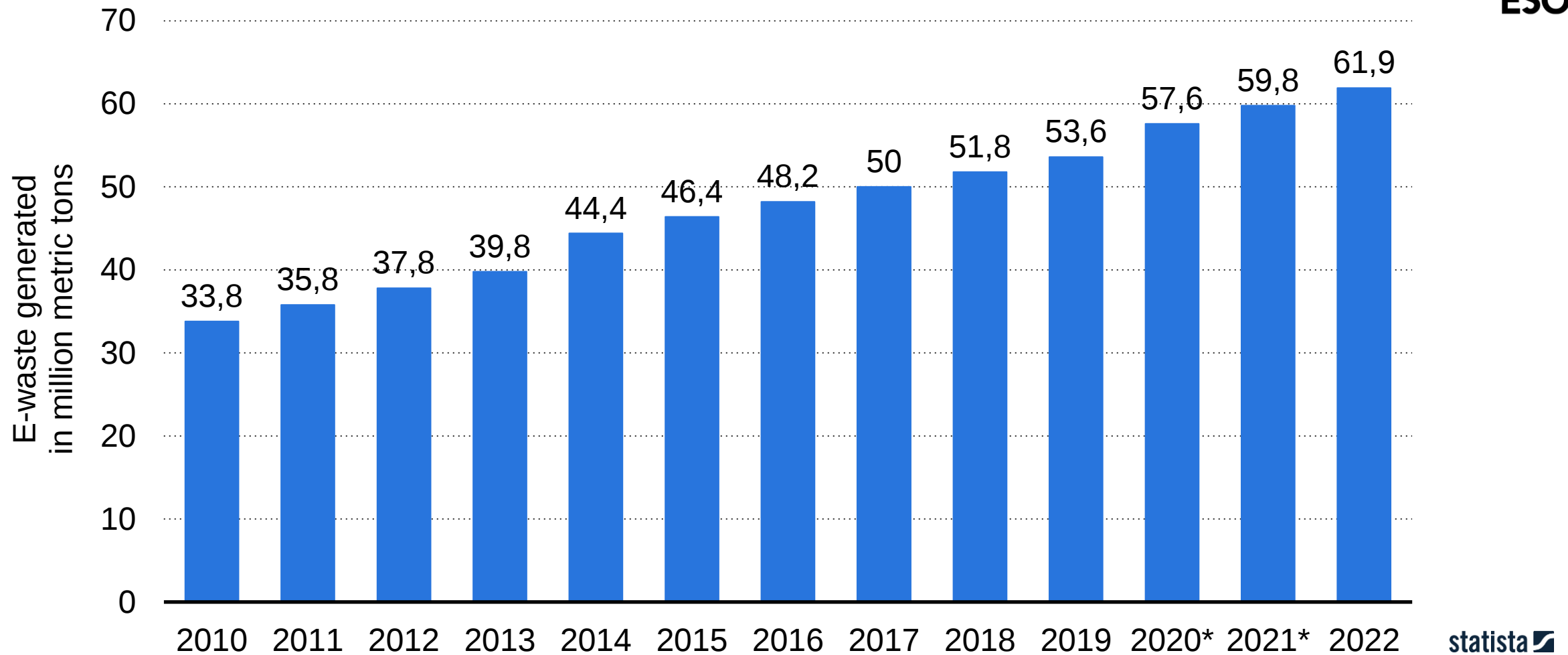
Pierre Le Gargasson

Univ. Rennes, INSA Rennes, CNRS, IETR - UMR 6164, F-35000 Rennes, France

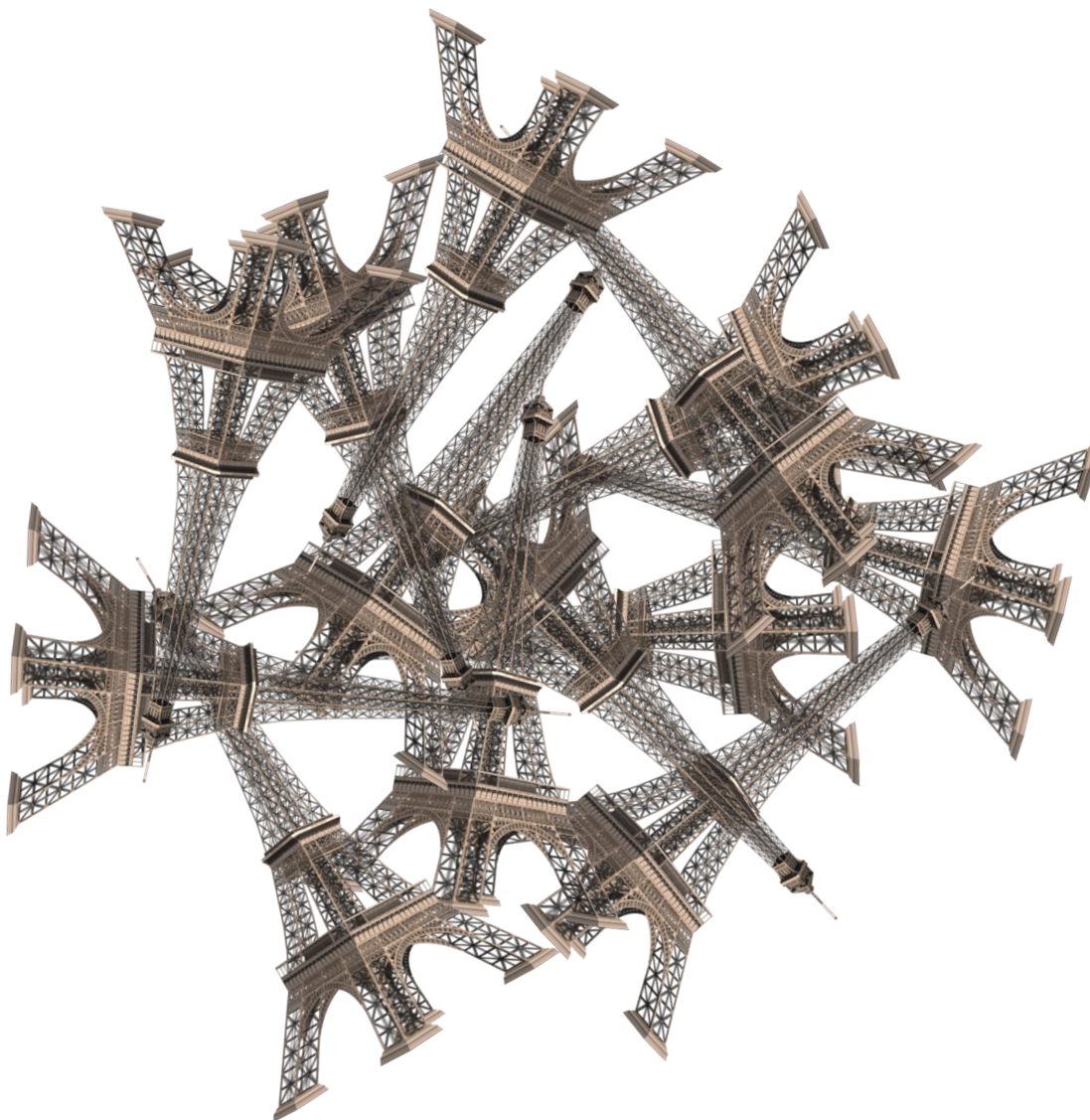
Alyzée Corre

Étudiante INSA Rennes

Global e-waste generation 2010-2022

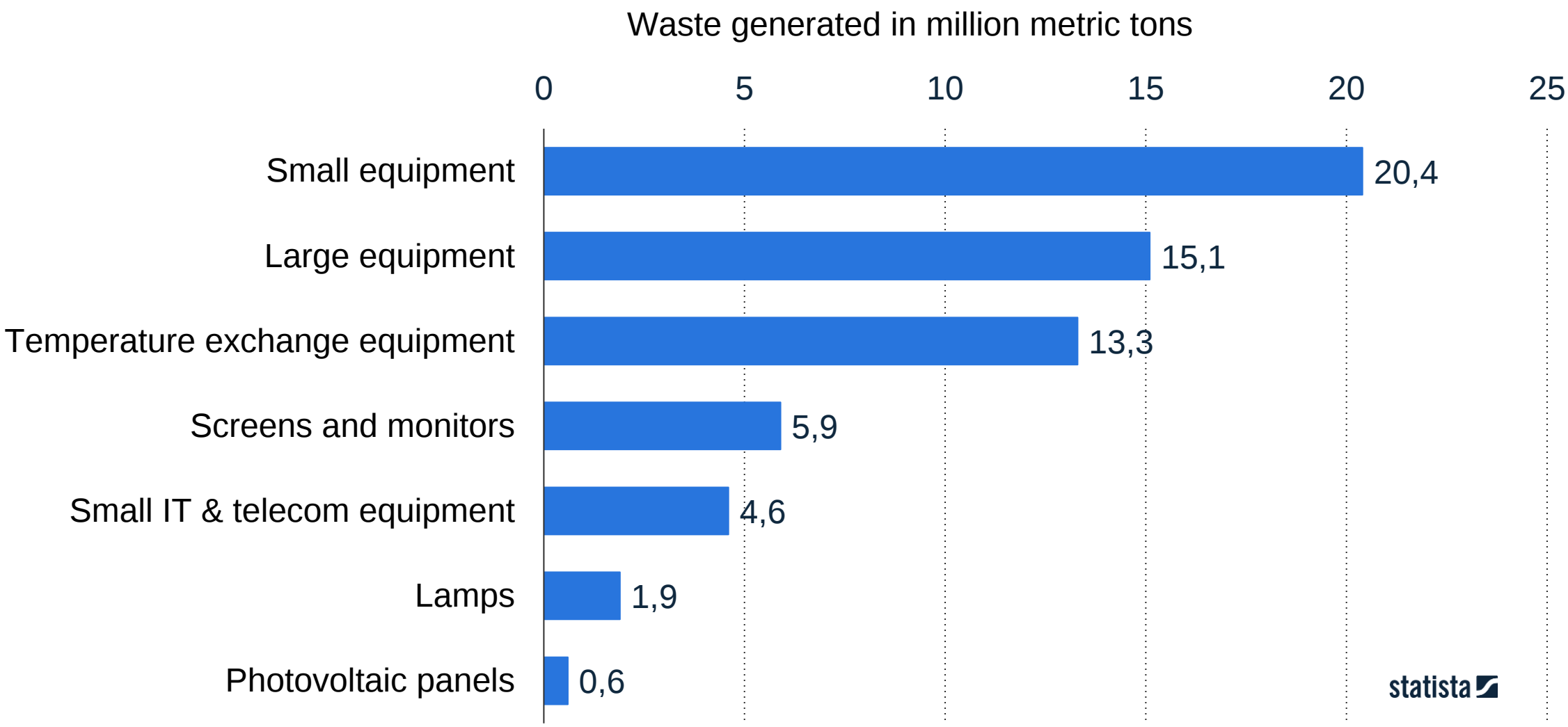


E-waste - Ordre de grandeur 61,9 Mt

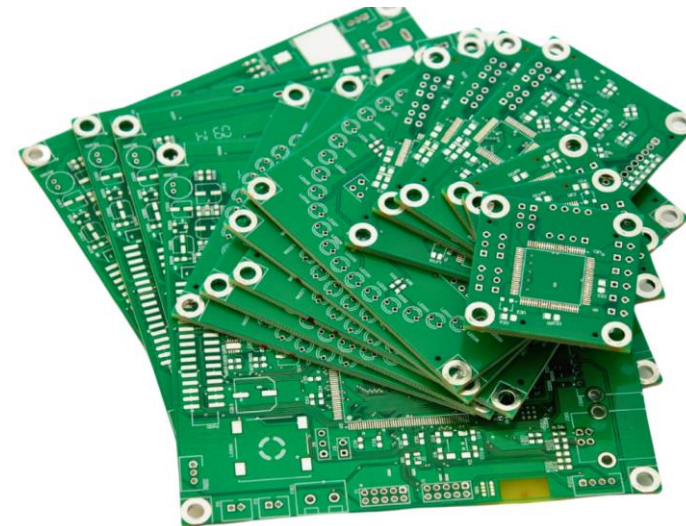
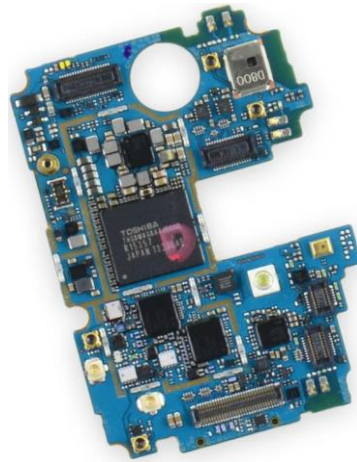
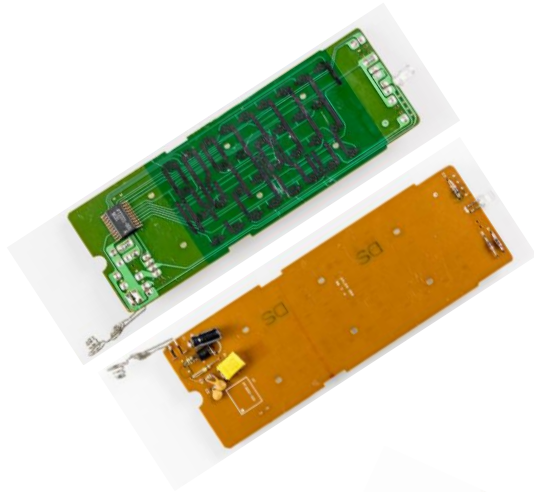


x 6 129

Global e-waste generation 2022, by type



Carte et circuit imprimé



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<https://www.ifixit.com/products/lg-refrigerator-main-control-board-eb74796401>
<https://www.ifixit.com/products/lg-g2-motherboard-at-and-t>
<https://www.ifixit.com/products/surface-studio-2-plus-motherboard-genuine>
<https://www.viasion.com/fr/blog/comment-sont-fabriqu%C3%A9s-les-circuits-imprim%C3%A9s/>



Circuit imprimé – Ordre de grandeur



2021 PCB PRODUCTION ESTIMATION (AREA)												
(M m ²)	Multilayer								HDI	Package Substrate	Flex	Total
	Paper	Composite	Rigid DS	4 Layer	6 Layer	8 – 16 Layer	18+ Layers					
Americas	0.1	0.2	1.0	0.7	0.5	0.6	0.1	0.2	0.0	0.9	4.3	
Europe	0.1	0.9	2.4	1.1	0.5	0.1	0.0	0.2	0.0	0.5	5.9	
Japan	0.6	3.7	0.6	1.6	1.1	0.6	0.1	0.7	1.8	3.4	14.2	
China	42.2	44.6	66.3	88.8	41.1	17.2	0.7	12.9	3.0	33.3	350.2	
Asia (xJP/CN)	9.9	9.6	9.8	10.1	8.0	5.0	0.3	5.5	7.5	23.8	89.4	
Total	52.9	59.0	80.2	102.2	51.2	23.5	1.1	19.4	12.4	62.1	464.1	

<https://www.prismark.com/pcb-sample-report, p21>, accessed 2025-12-08



géoportail

PCBnCO: A Carbon Intensity Model of FR-4 Printed Circuit Boards Based on Company Data

IEEE SusTech2025

Los Angeles – April 2025

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Questions initiales

- ☐ Quel est le GWP de la fabrication des circuits imprimés ?
- ☐ Quel est l'impact du nombre de couches sur le GWP ?
- ☐ Quel est le meilleur compromis entre la surface et le nombre de couches ?
- ☐ Peut-on le modéliser ?



PCB overview

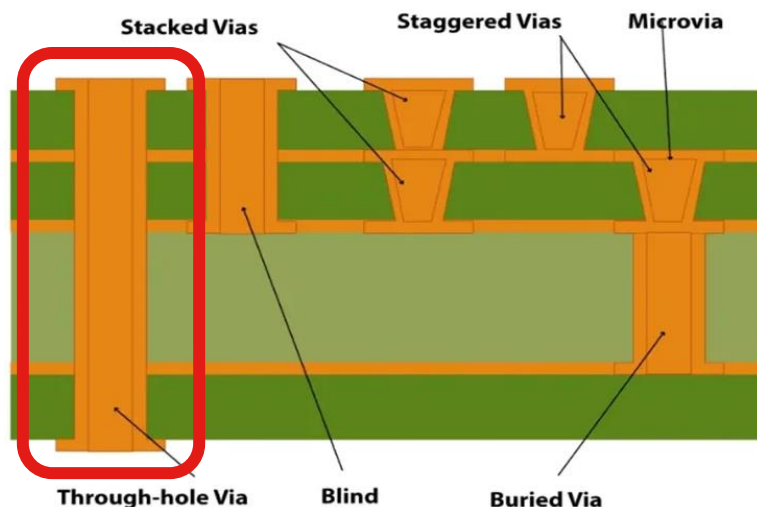
□ FR-4

□ Epoxy resin

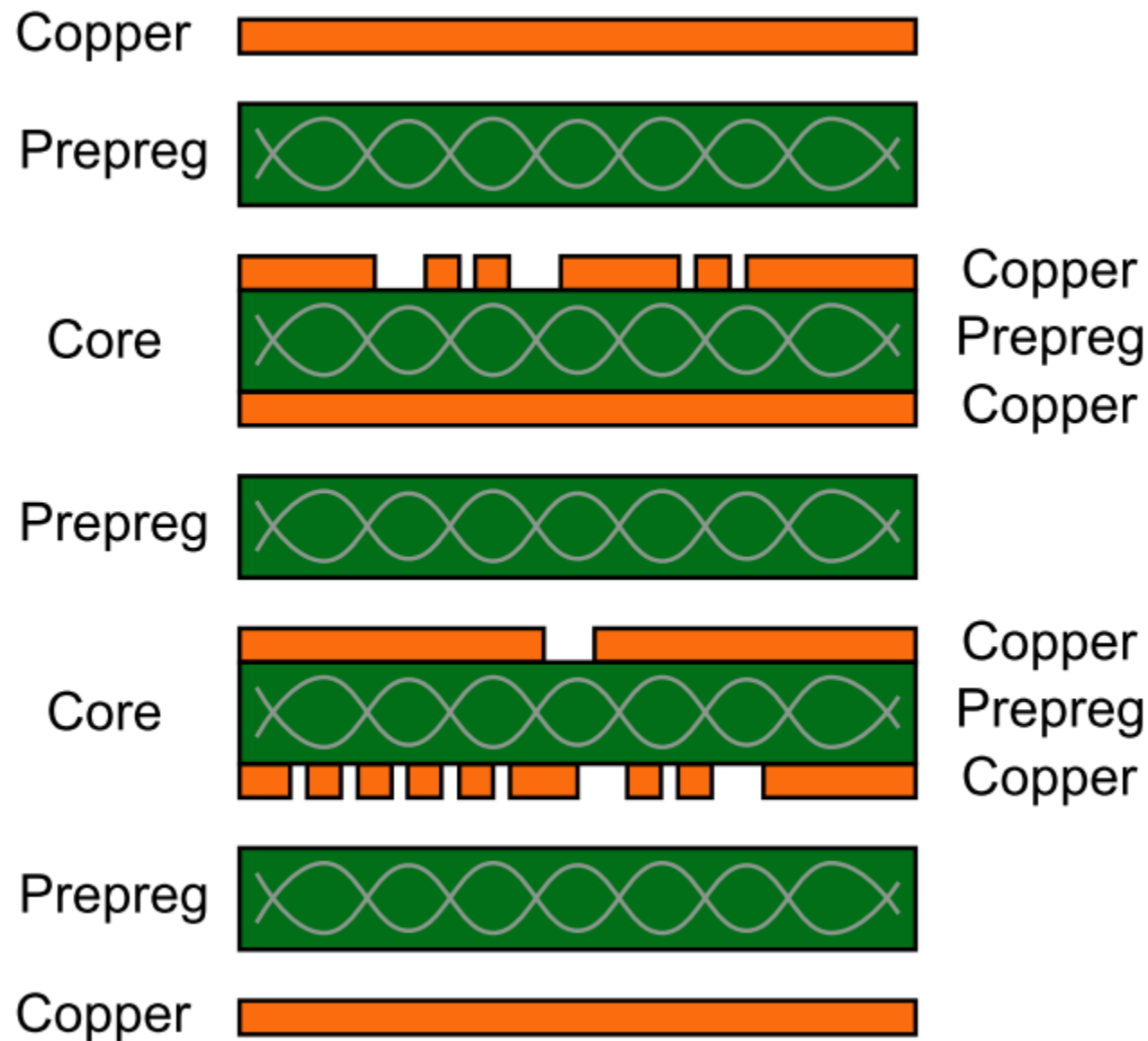
□ Fiberglass

□ Copper

□ Plated Through-Hole

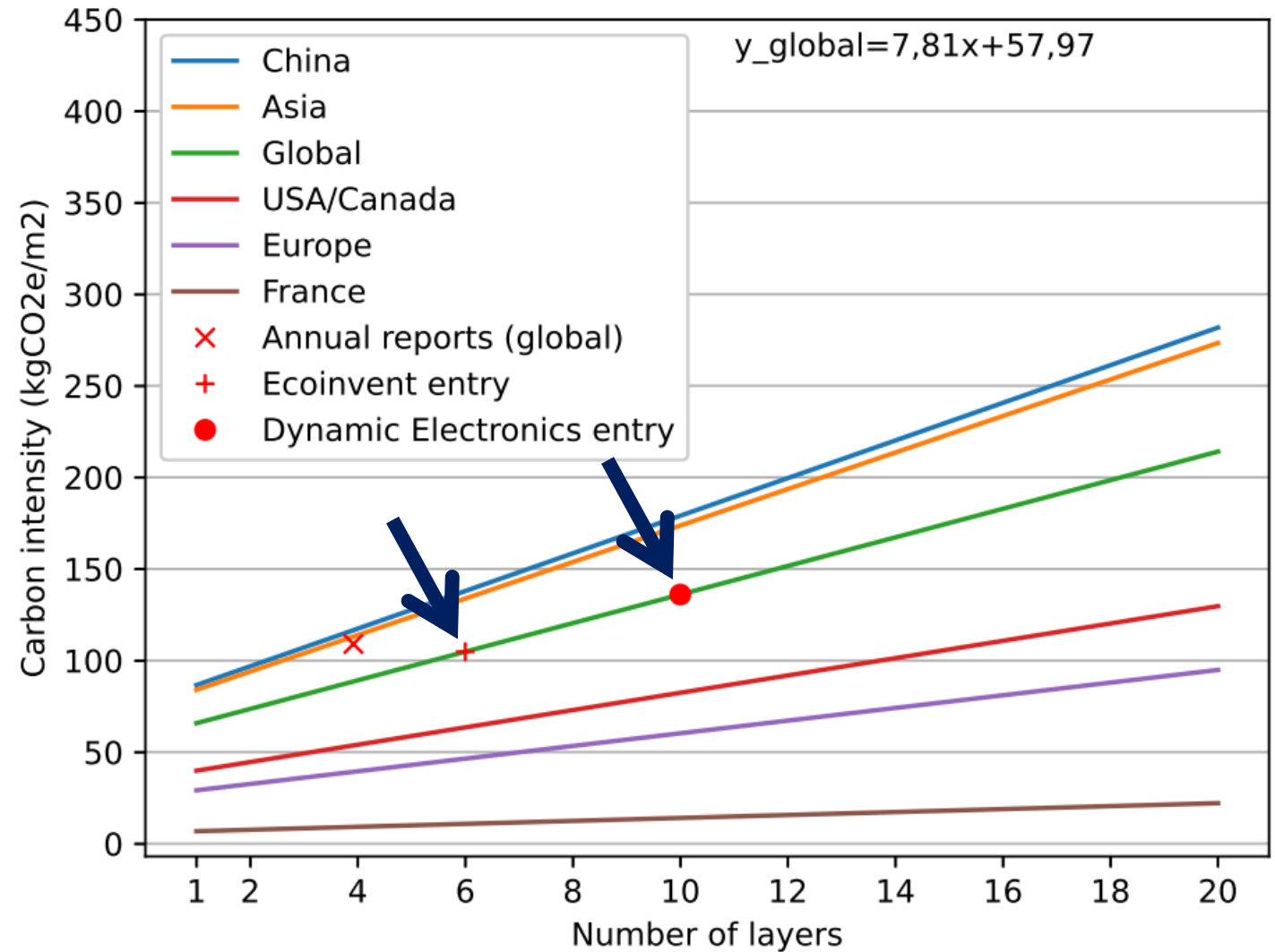


<https://www.viasion.com/blog/what-are-blind-via-buried-via-and-ptv-via/>



Stackup model

- ❑ Bottom-up method
 - ❑ Accurate inventory
 - ❑ Ecoinvent 6L
 - ❑ Dynamic Electronics 10L
- ❑ Affine function
- ❑ Normalized locations
- ❑ Still need data
 - ❑ Expansion to other impacts



Stackup model application

❑ Compare GWP

❑ Layers

❑ Area

❑ Color = value range

❑ CAD software

❑ Informed decision

		Layers							
		1	2	4	6	8	10		12
PCB area (cm²)	20	0,13	0,15	0,18	0,21	0,24	0,27	0,30	Global Warming Potential (kgCO2e)
	40	0,26	0,29	0,36	0,42	0,48	0,54	0,61	
	60	0,39	0,44	0,54	0,63	0,72	0,82	0,91	
	80	0,53	0,59	0,71	0,84	0,96	1,09	1,21	
	100	0,66	0,74	0,89	1,05	1,20	1,36	1,52	
	120	0,79	0,88	1,07	1,26	1,44	1,63	1,82	
	140	0,92	1,03	1,25	1,47	1,69	1,90	2,12	
	160	1,05	1,18	1,43	1,68	1,93	2,18	2,43	
	180	1,18	1,32	1,61	1,89	2,17	2,45	2,73	
	200	1,32	1,47	1,78	2,10	2,41	2,72	3,03	
	220	1,45	1,62	1,96	2,31	2,65	2,99	3,34	
	240	1,58	1,77	2,14	2,52	2,89	3,26	3,64	
	260	1,71	1,91	2,32	2,72	3,13	3,54	3,94	
	280	1,84	2,06	2,50	2,93	3,37	3,81	4,25	
	300	1,97	2,21	2,68	3,14	3,61	4,08	4,55	
	320	2,10	2,35	2,85	3,35	3,85	4,35	4,85	
	340	2,24	2,50	3,03	3,56	4,09	4,62	5,16	
360	2,37	2,65	3,21	3,77	4,33	4,90	5,46		
380	2,50	2,80	3,39	3,98	4,58	5,17	5,76		
400	2,63	2,94	3,57	4,19	4,82	5,44	6,07		
		Global							

Global Warming Potential (kgCO₂e)

KiCad plugin

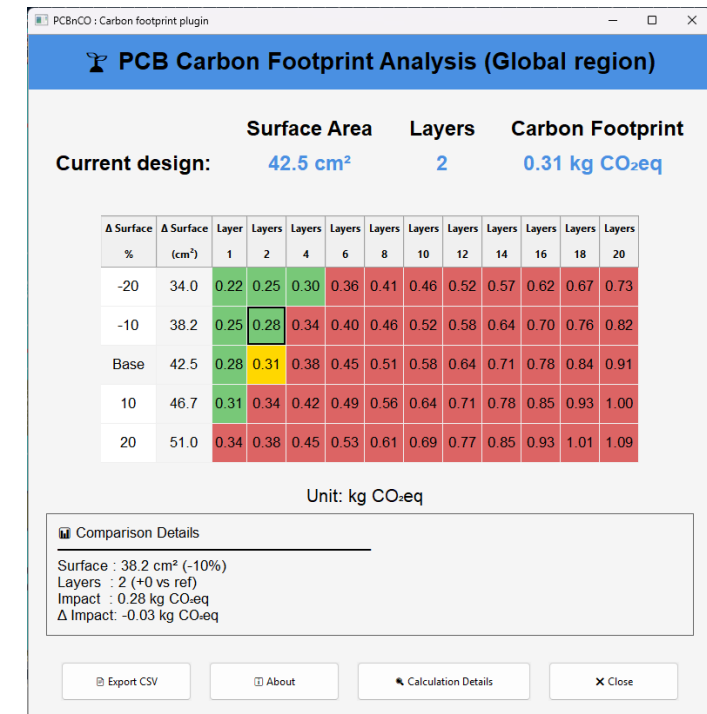


❑ KiCad

- ❑ Schéma et routage de cartes électroniques
- ❑ Démarré en 1992 à l'IUT Grenoble par Jean-Pierre Charras
- ❑ Open source
- ❑ Fichiers en clair, version Git
- ❑ Supporte les scripts Python

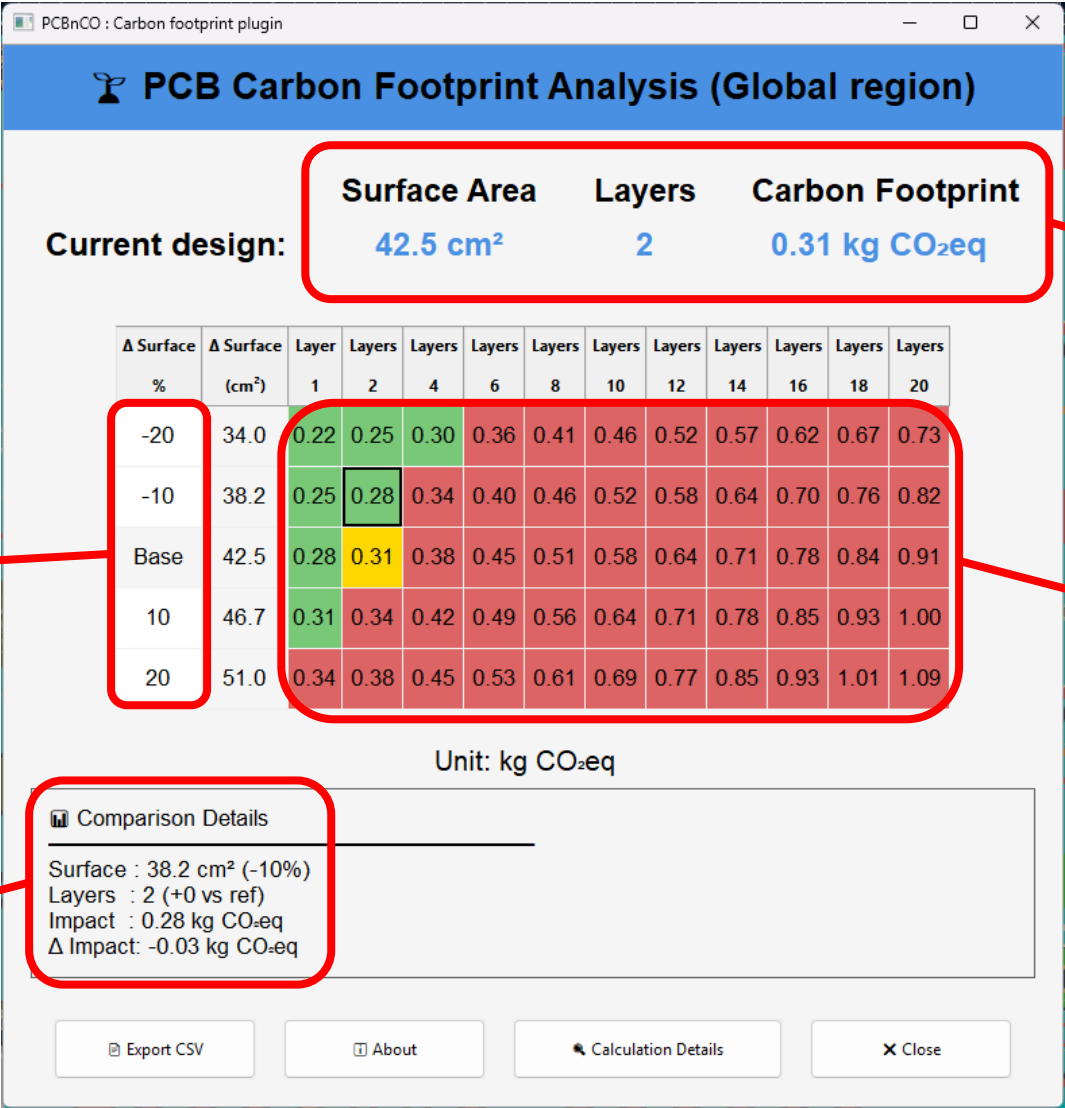
❑ KiCad plugin

- ❑ Input : surface + nb couches
- ❑ Output : GWP (conception en cours)
- ❑ Alyzée Corre, stage M1 INSA Rennes



❑ <https://gitlab.insa-rennes.fr/esos/pcbnc0-kicad-plugin>

KiCad plugin



Données PCB en cours (fixe)

Ajout ou retrait de surface % (éditable)

GWP(dynamique)
- Nb couches
- Surface
Rouge si GWP ↑
Vert si GWP ↓

Comparaison par rapport au PCB en cours

Demo

<https://gitlab.insa-rennes.fr/esos/pcbnc0-kicad-plugin>

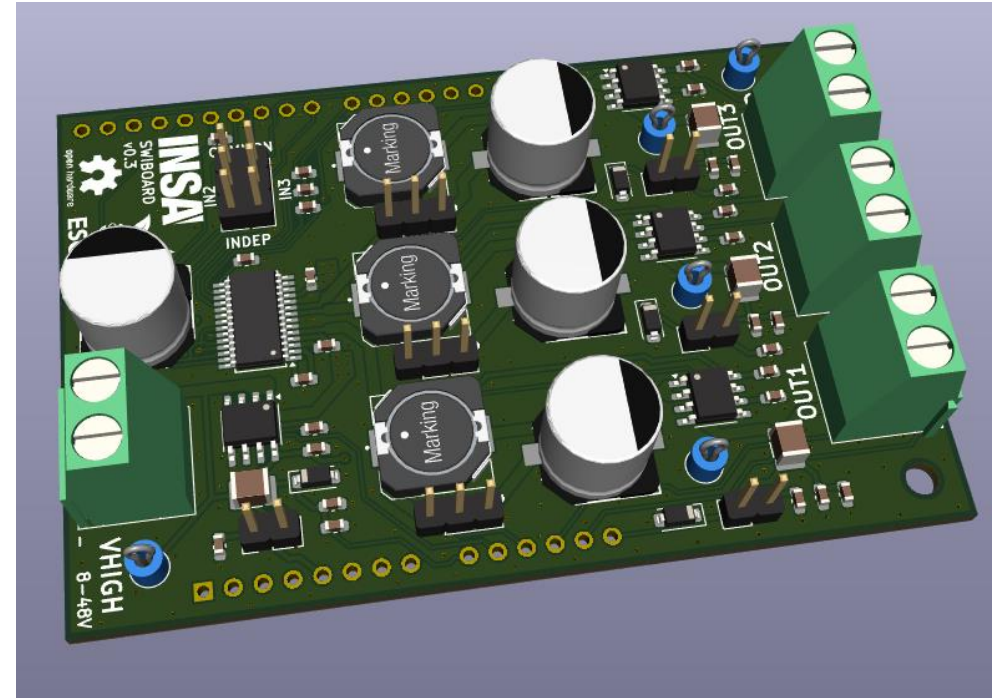
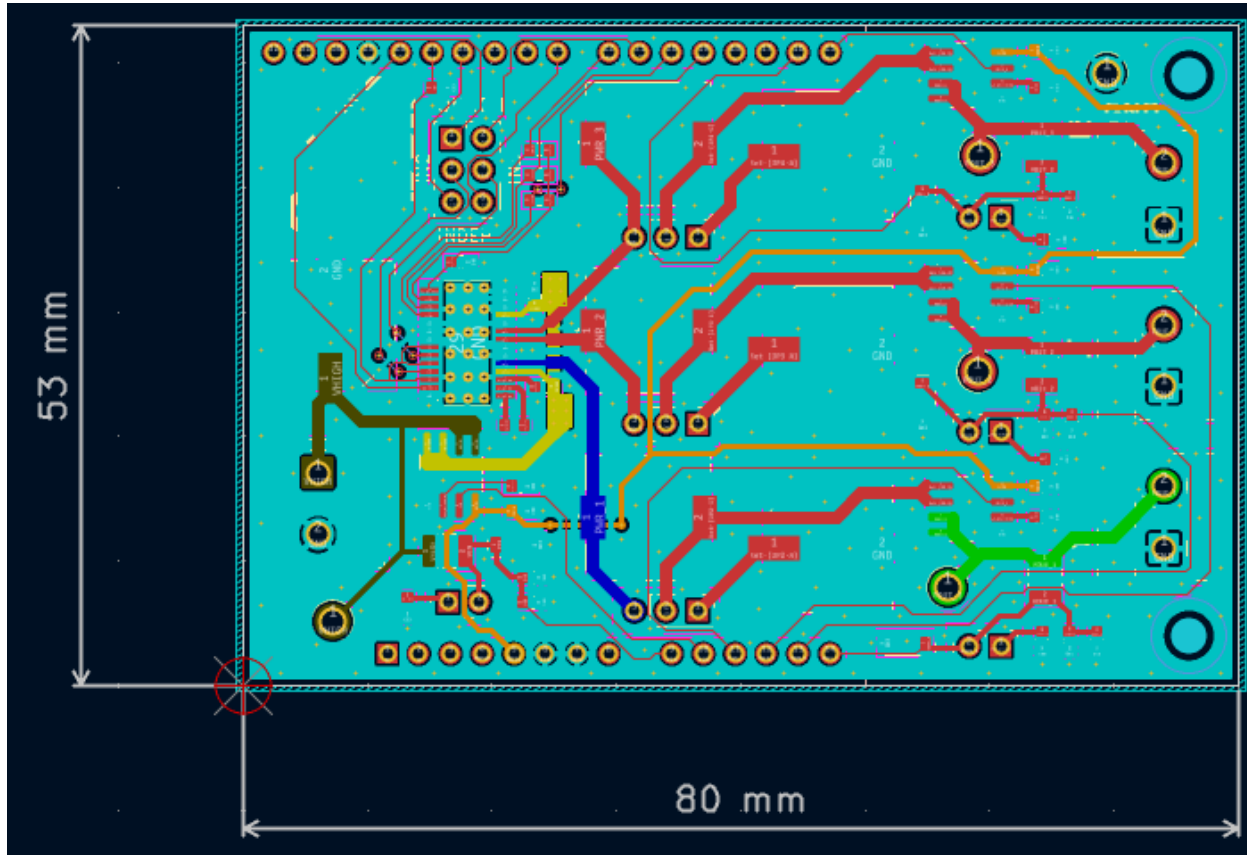
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Implemented on **KiCad**

pierre.le-gargasson@insa-rennes.fr

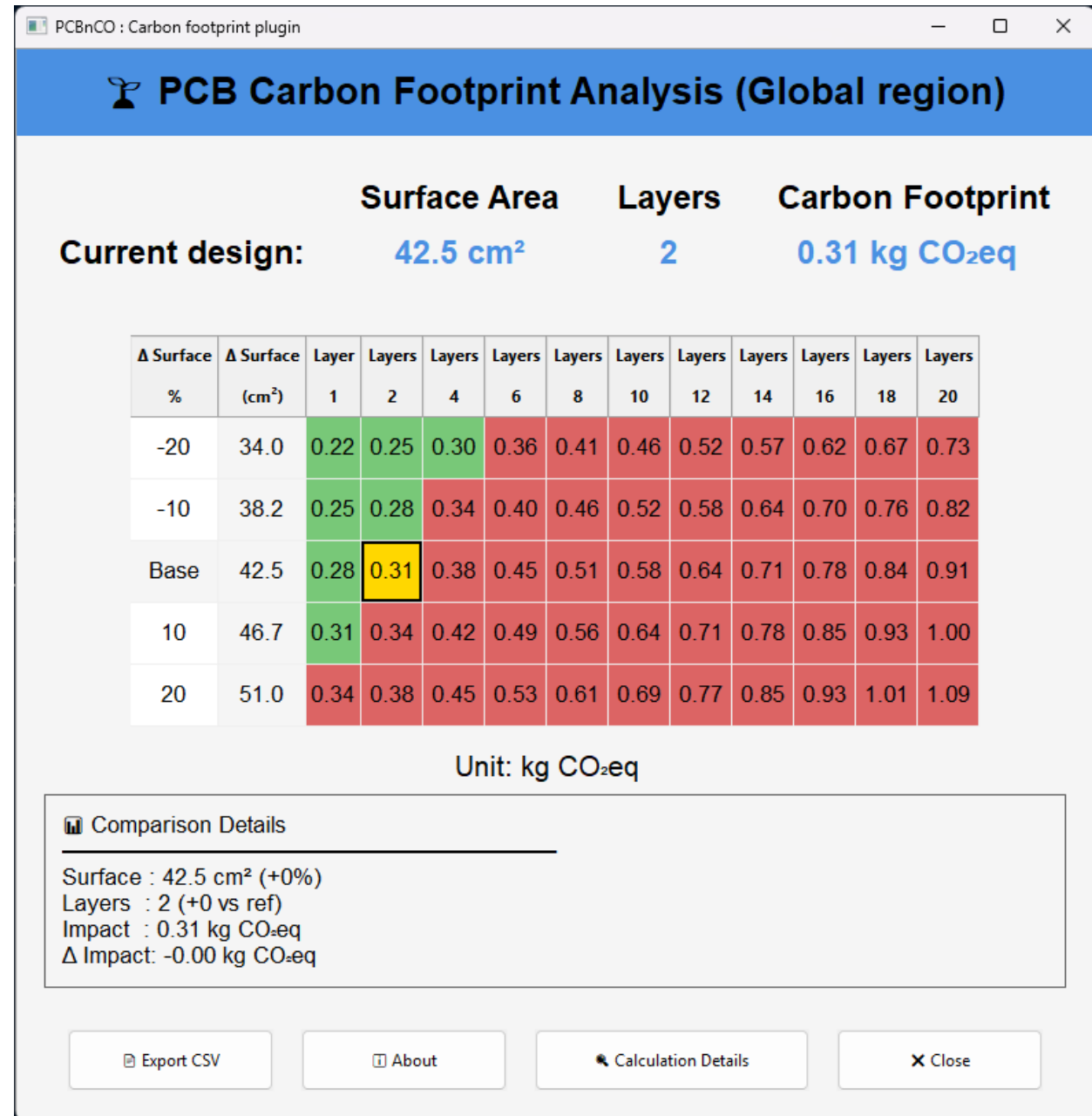
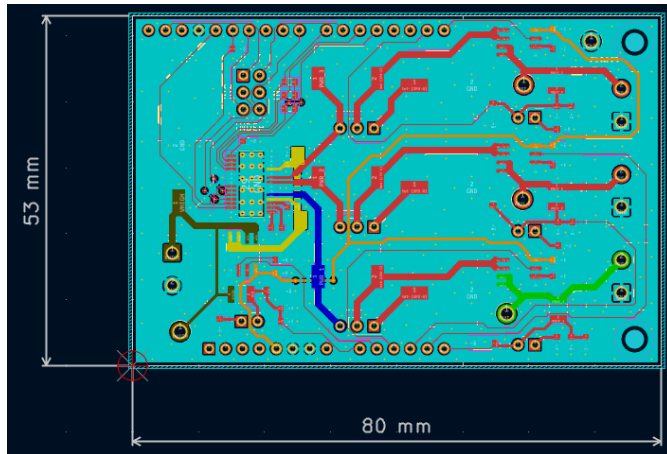
KiCad plugin

- ❑ État initial
- ❑ 2 couches



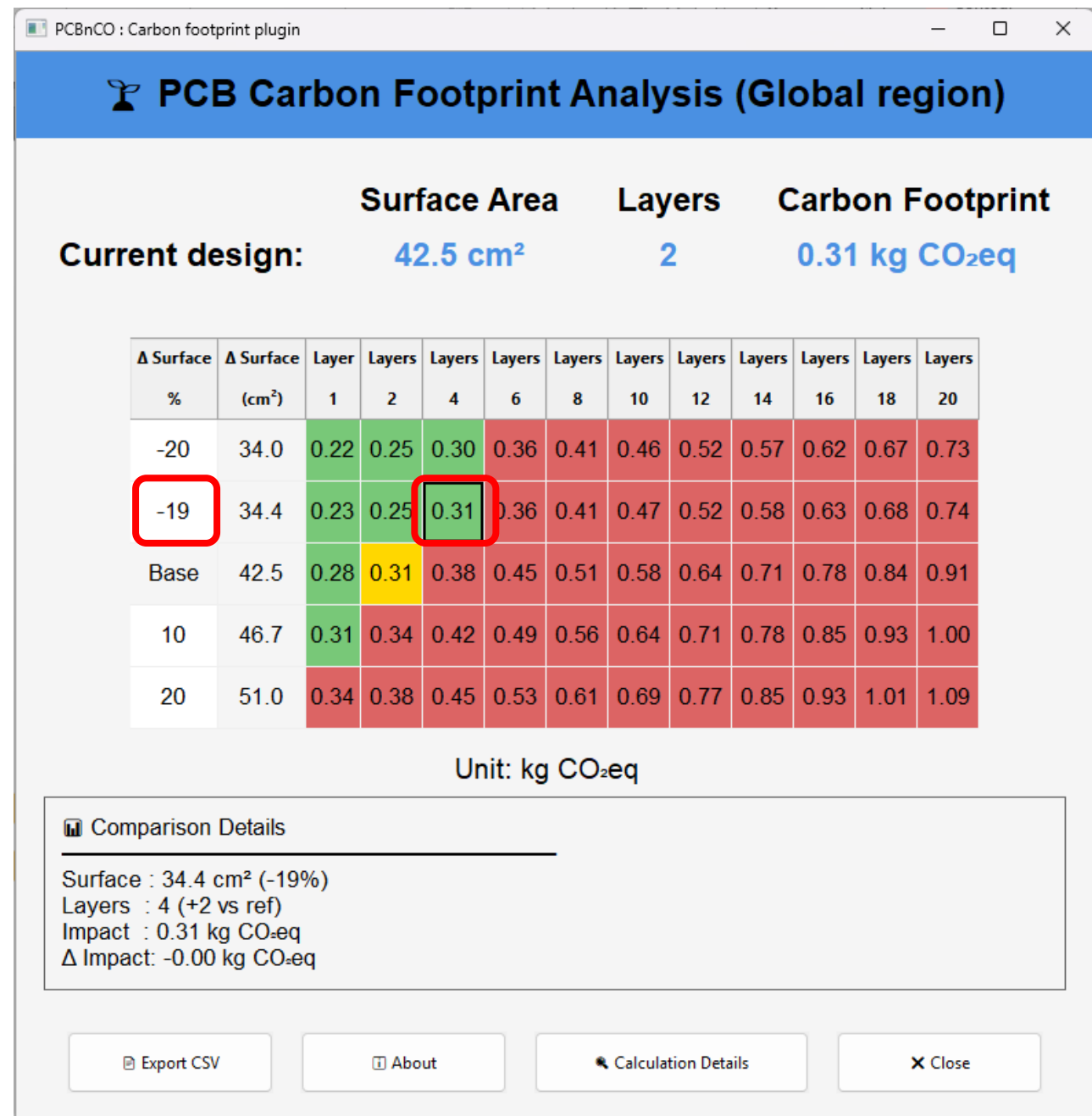
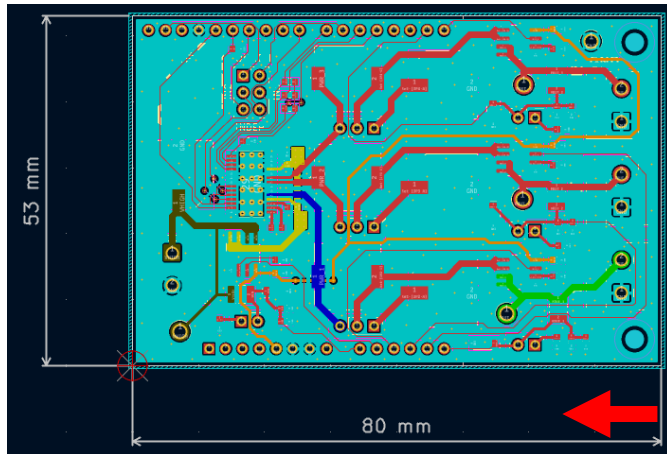
KiCad plugin

- ❑ État initial
- ❑ 2 couches



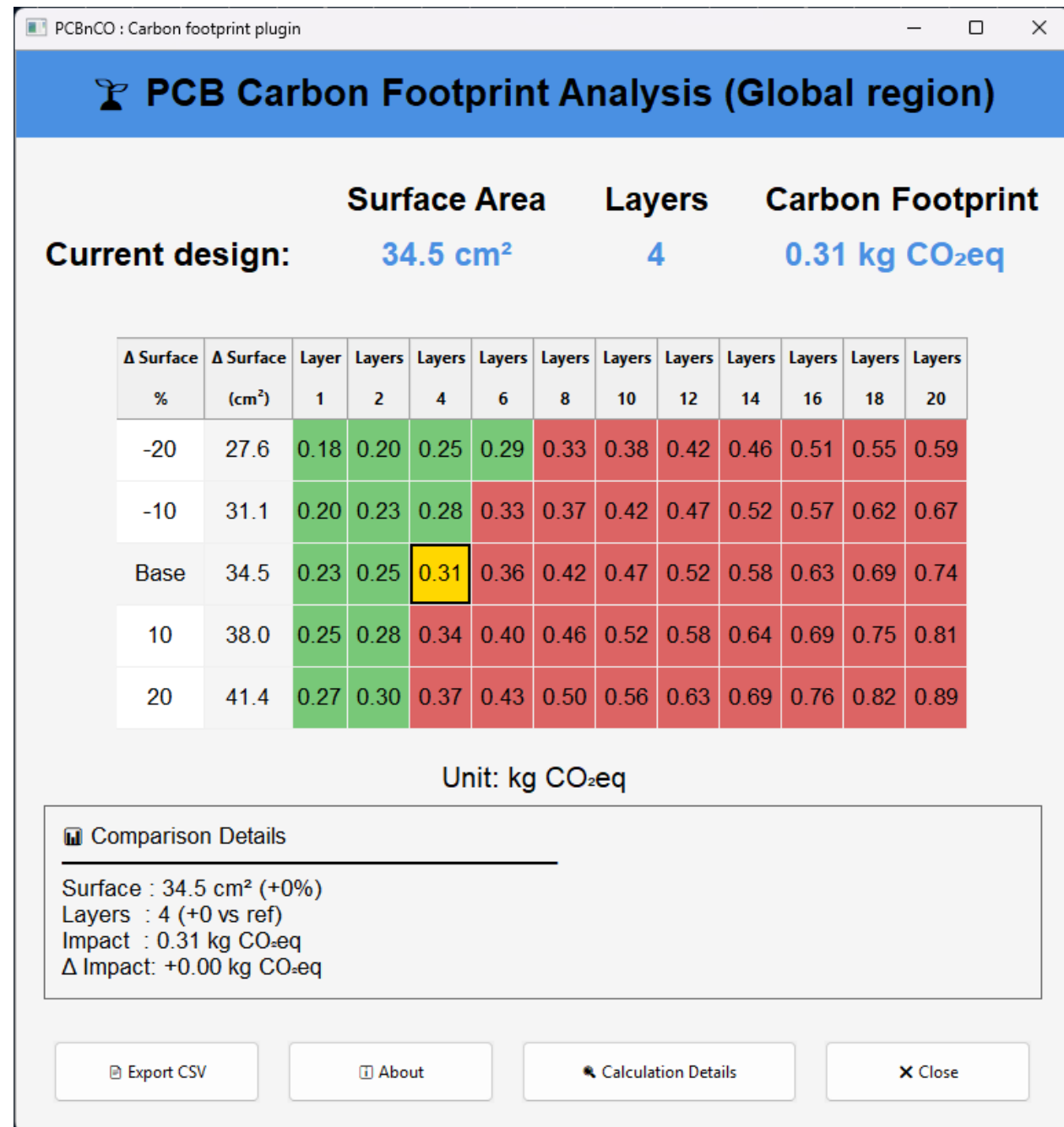
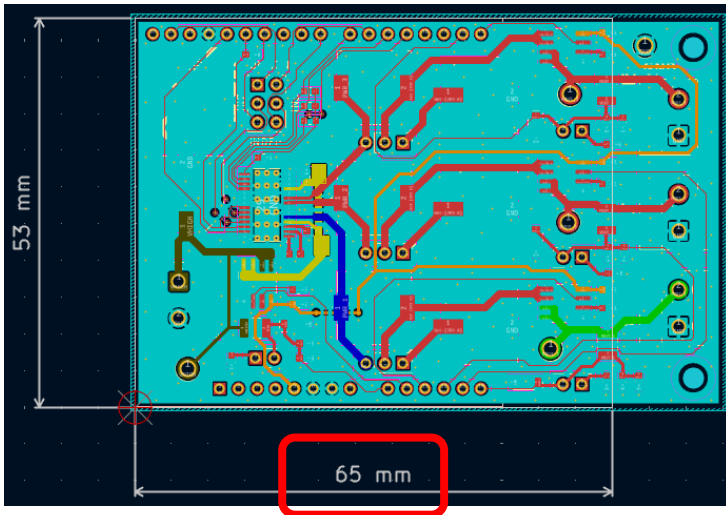
KiCad plugin

- ❑ Passage à 4 couches
- ❑ Empreinte carbone constante



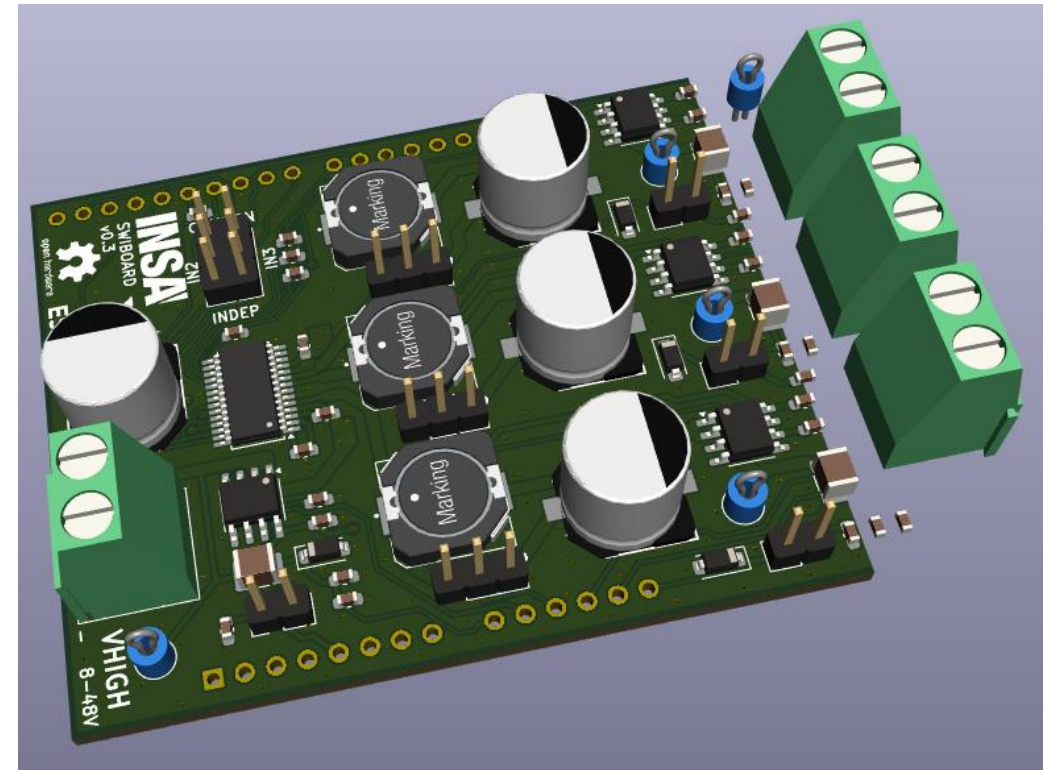
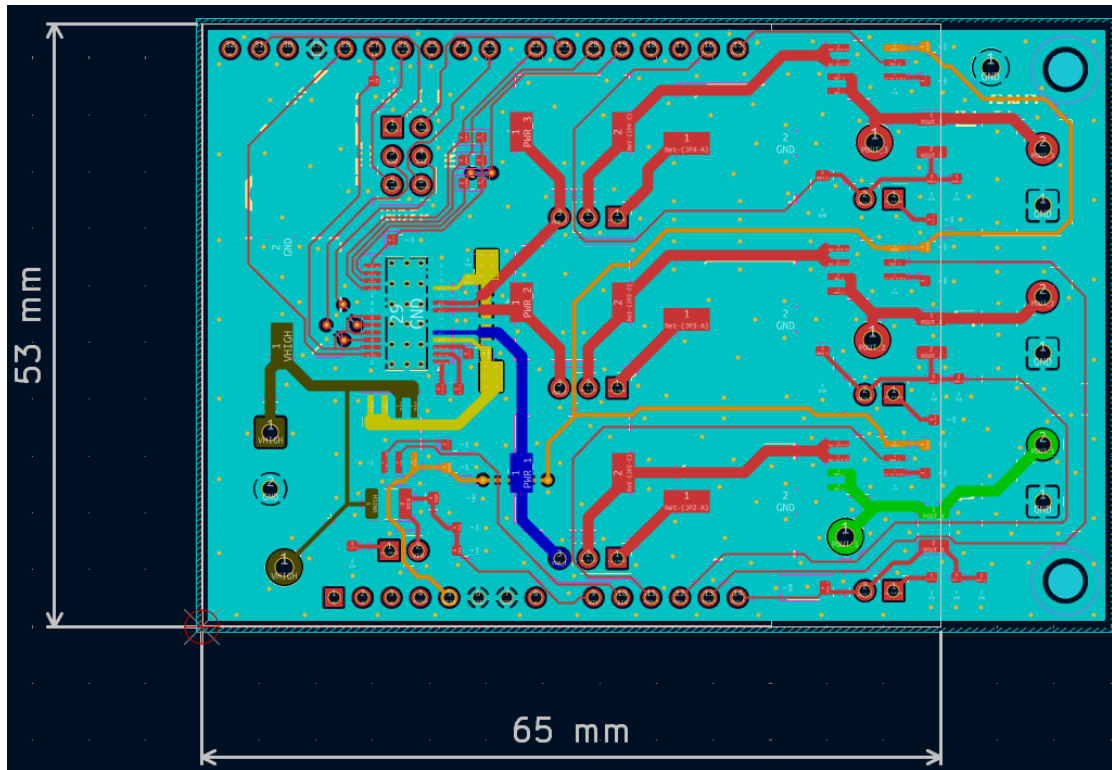
KiCad plugin

- ❑ Passage à 4 couches
 - ❑ -19%
 - ❑ 80 mm => 65 mm
 - ❑ 42,5 cm² => 34,5 cm²



KiCad plugin

- Bilan
- Densification du PCBA
- Couche dessous



Merci

<https://gitlab.insa-rennes.fr/esos/pcbnc0-kicad-plugin>

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