Symposium pour l'électronique & le numérique durables

Le 12 décembre 2024, Grenoble

AVEC tech & fest

NANOELEC. Univ. Grenoble Alpes Labex µElec FRANCE 2030 PROGRAMME DE RECHERCHE ÉLECTRONIQUE

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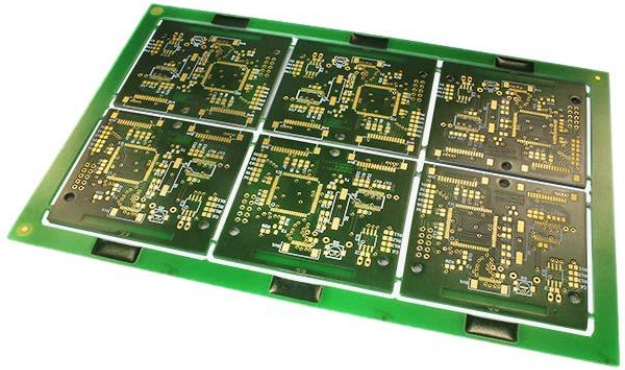
Carbon Impact of Printed Circuit Boards

Grenoble – 12 décembre 2024

Pierre Le Gargasson



https://fr.beta-layout.com/images/spec/multipanneau_PCB__Beta_LAYOUT.jpg

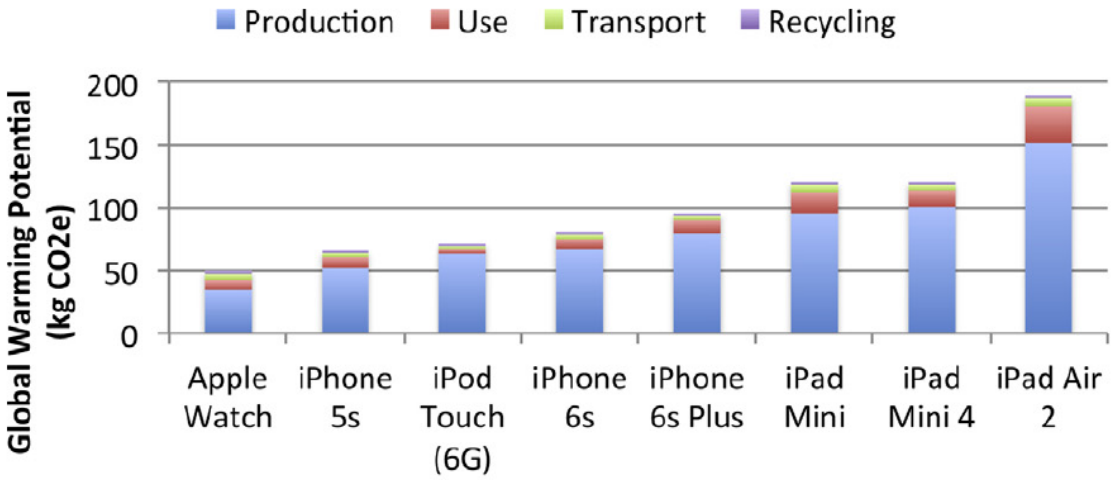
Authors : Olivier Weppe, Pierre Le Gargasson

LCA of electronics

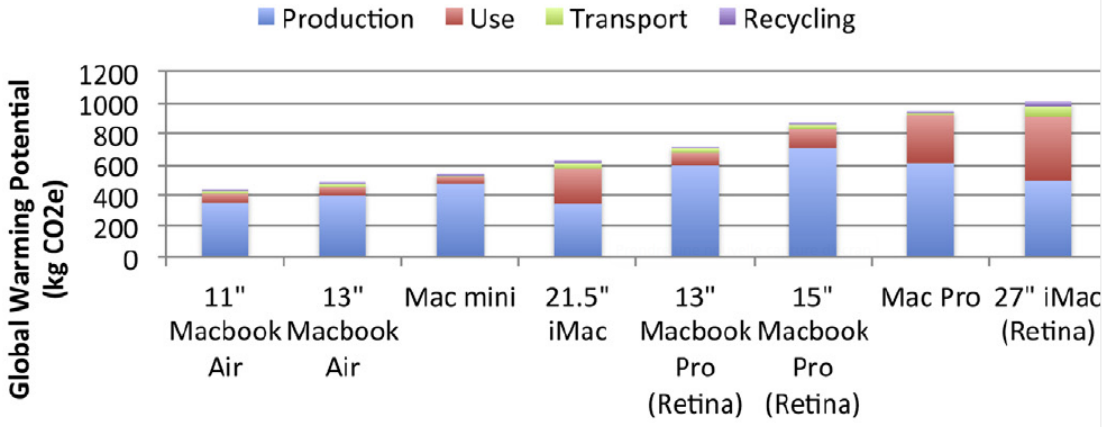
Authors : Olivier Weppe, Pierre Le Gargasson

LCA in electronics

- Carbon footprint by lifecycle step



(a) Tablets



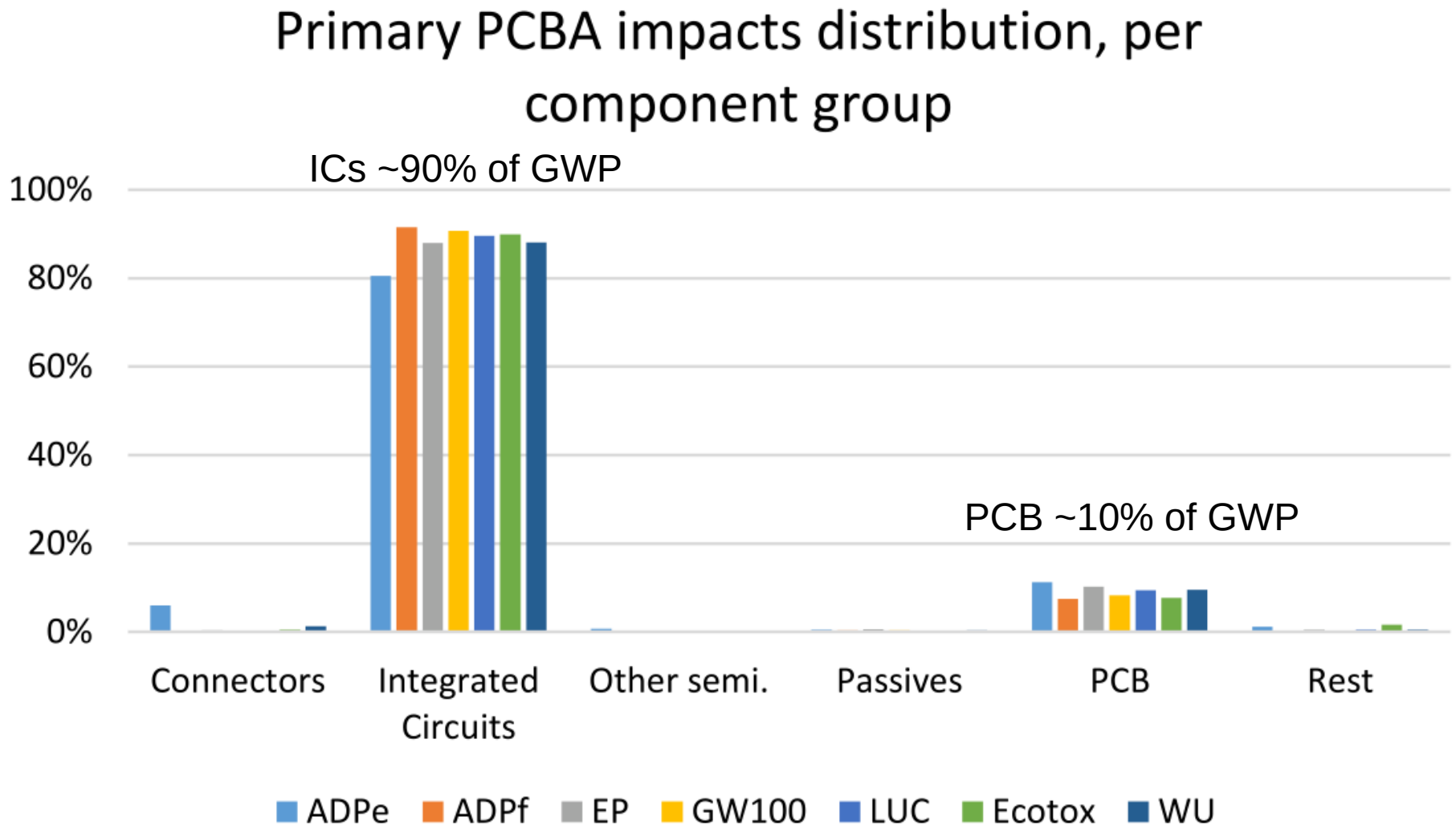
(b) Computers

Source : Donald Kline Jr. (2019)

Authors : Olivier Weppe, Pierre Le Gargasson

Global Warming Potential example

- Fairphone 5



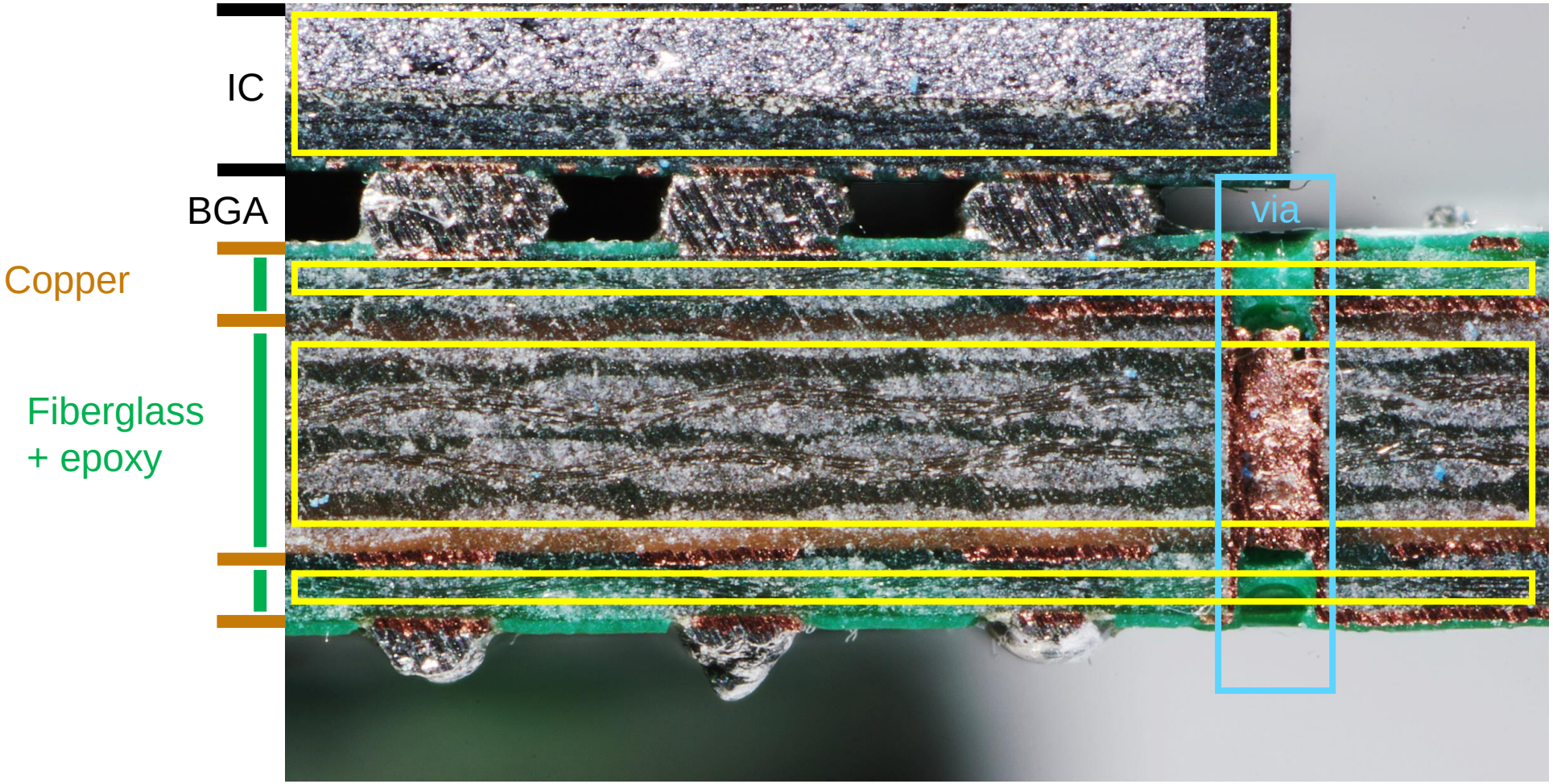
Authors : Olivier Weppe, Pierre Le Gargasson
https://www.fairphone.com/wp-content/uploads/2024/09/Fairphone5_LCA_Report_2024.pdf

PCB

Authors : Olivier Weppe, Pierre Le Gargasson

Inside PCB

- Plated Through-Hole (PTH) FR-4 PCB

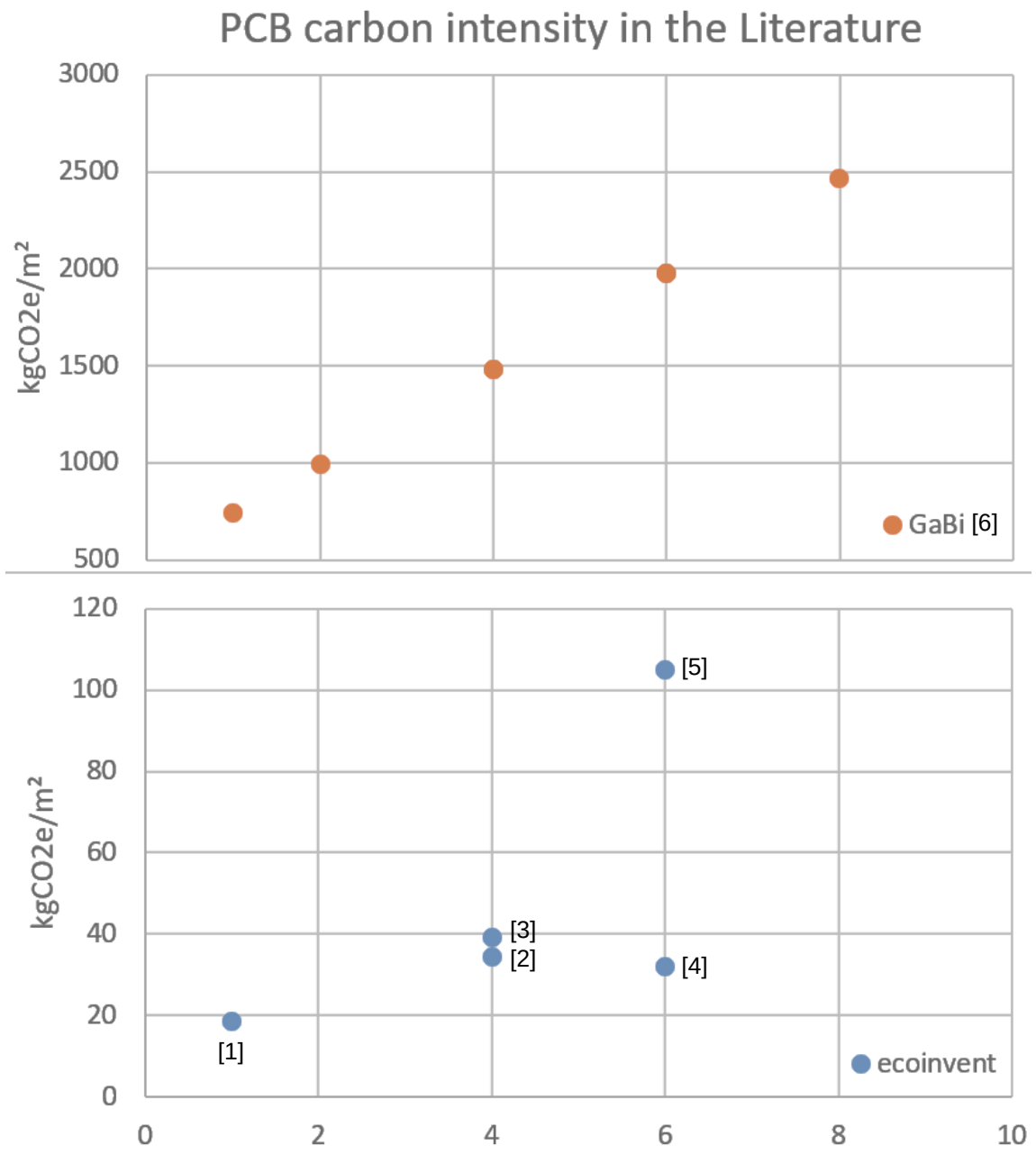


By Smial - Own work, FAL, https://commons.wikimedia.org/w/index.php?curid=3893168

Carbon impact of PCBs in the Literature

Authors : Olivier Weppe, Pierre Le Gargasson

Literature review



- PCB LCAs scaled to a reference unit

- [1] E. Ozkan, N. Elginoz, and F. Germirli Babuna, “Life cycle assessment of a printed circuit board manufacturing plant in Turkey,” Environmental Science and Pollution Research, vol. 25, no. 27, pp. 26 801–26 808, Sep. 2018. [Online]. Available: http://link.springer.com/10.1007/s11356-017-0280-z
- [2] M. N. Nassajfar, I. Deviatkin, V. Leminen, and M. Horttanainen, “Alternative Materials for Printed Circuit Board Production: An Environmental Perspective,” Sustainability, vol. 13, no. 21, p. 12126, Nov. 2021. [Online]. Available: https://www.mdpi.com/2071-1050/13/21/12126
- [3] J. Liu, C. Yang, H. Wu, Z. Lin, Z. Zhang, R. Wang, B. Li, F. Kang, L. Shi, and C. P. Wong, “Future paper based printed circuit boards for green electronics: fabrication and life cycle assessment,” Energy Environ. Sci., vol. 7, no. 11, pp. 3674–3682, 2014. [Online]. Available: http://xlink.rsc.org/?DOI=C4EE01995D
- [4] Y. Deng, D. Paraskevas, Y. Tian, K. Van Acker, W. Dewulf, and J. R. Dufl ou, “Life cycle assessment of fl ax-fi bre reinforced epoxidized linseed oil composite with a fl ame retardant for electronic applications,” Journal of Cleaner Production, vol. 133, pp. 427–438, Oct. 2016. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0959652616306515
- [5] https://ecoquery.ecoinvent.org/3.10/cutoff/dataset/9764/documentation, accessed 2024-10-01
- [6] K. Grant, S. Zhang, and J. Kettle, “Improving the sustainability of printed circuit boards through additive printing,” in 2023 IEEE Conference on Technologies for Sustainability (SusTech), 2023, pp. 86–90. [Online]. Available: https://ieeexplore.ieee.org/document/10129587

Authors : Olivier Weppe, Pierre Le Gargasson

Carbon impact of PCBs from manufacturers

Authors : Pierre Le Gargasson, Nicolas Beuve, Maxime Pelcat

Annual reports

- Gate-to-gate scope
- Energy
- GHG emissions
  - Scope 1 : direct
  - Scope 2 : indirect (energy)

- Analyze 25 manufacturers

TOP 25 PCB SUPPLIERS MANUFACTURING LOCATIONS

FACTORY LOCATIONS

Company	Americas	Europe	Japan	China	Taiwan	Korea	Thailand	Vietnam	Malaysia	Philip-pines	India
Zhen Ding				√	√		•				√
Unimicron				√	√		•				
Dongshan Precision				√			•				
Nippon Mektron			√	√	√		√	√			
Ccmpeq				√	√		•				
TTM	√			√					•		
Tripod				√	√			•			
Nan Ya PCB				√	√						
AT&S		√		√		√			•		√
Ibiden			√	√					√	√	
Young Poong Group				√		√		√			
Shennan Circuit				√			•				
Kingboard Group				√			√				
SEMCO						√		√•			
Shinko			√								
Kinwoog				√			•				
FLEXium				√	√						
WUS Group				√	√		•				
HannStar				√	√				√•		
Simmtech			√	√					√		
BH Co				√		√		√•			
Maiko			√	√				√•			
Kinsus				√	√				•		
Victory Giant				√			•	•			
Gold circuit			√	√			•				

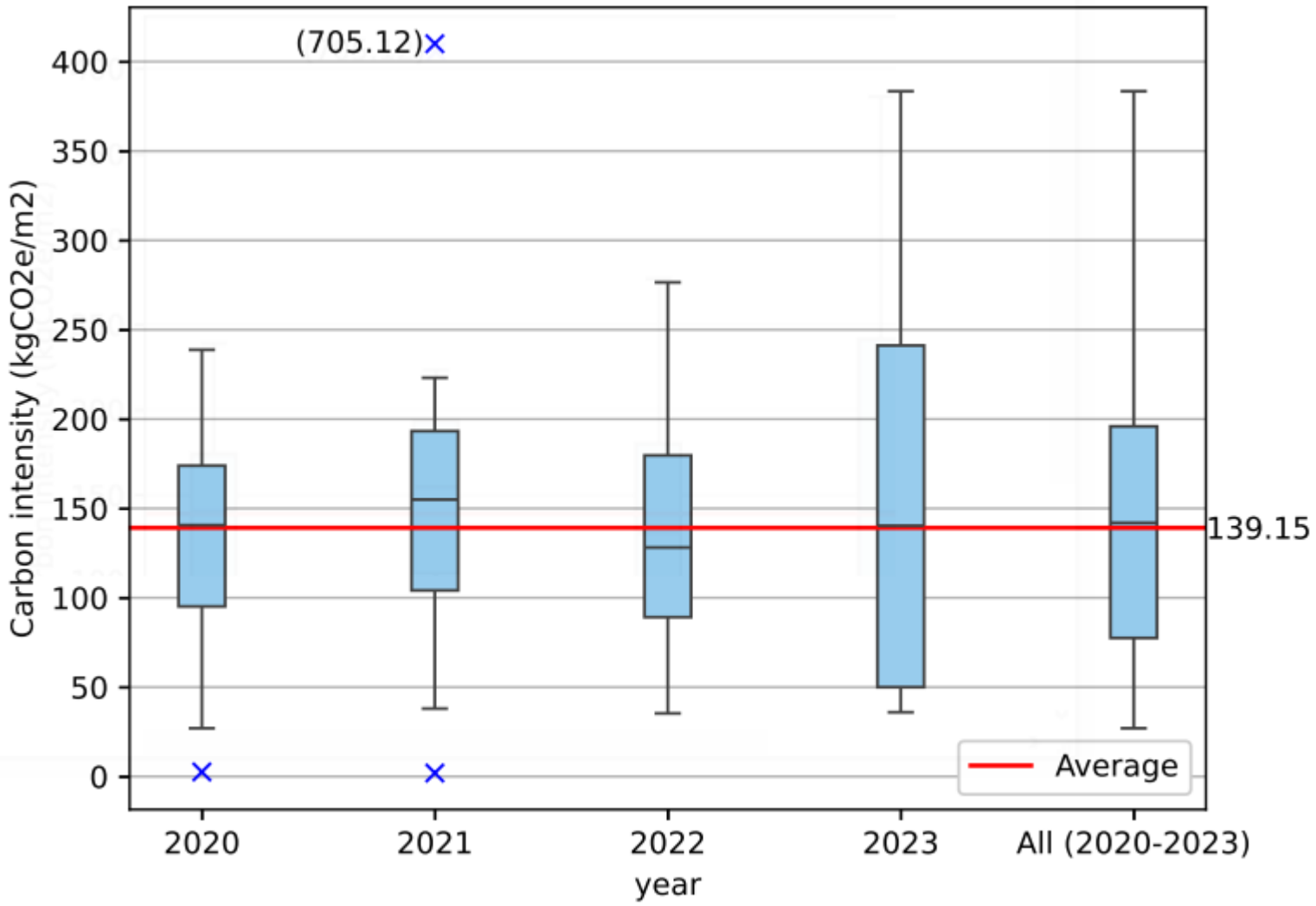
• New facility / investment either announced recently or still in construction
√ Existing factory that can pivot production or volume production
Source : PRISMARK PARTNERS LLC : The Printed Circuit Report, Third Quarter, November 2023

https://investor.kce.co.th/en/download/one-reports

Authors : Olivier Weppe, Pierre Le Gargasson

Carbon intensity

- 11 companies
- 35 samples over 4 years
- Large variance
  - 27 kgCO2e/m²
  - 383.41 kgCO2e/m²
- Average
  - 11.8 million tCO2e (4y)
  - 84.7 million m² (4y)
  - 139 kgCO2e/m²



Authors : Olivier Weppe, Pierre Le Gargasson

Average stackup

- Prismark PCB annual report
- Sampled in Thailand + Taiwan + China
- PTH FR-4 PCBs (68% world production)

2021 PCB PRODUCTION ESTIMATION (AREA)

				Multilayer							
(M m^2)	Paper	Composite	Rigid DS	4 Layer	6 Layer	8 – 16 Layer	18+ Layers	HDI	Package Substrate	Flex	Total
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**

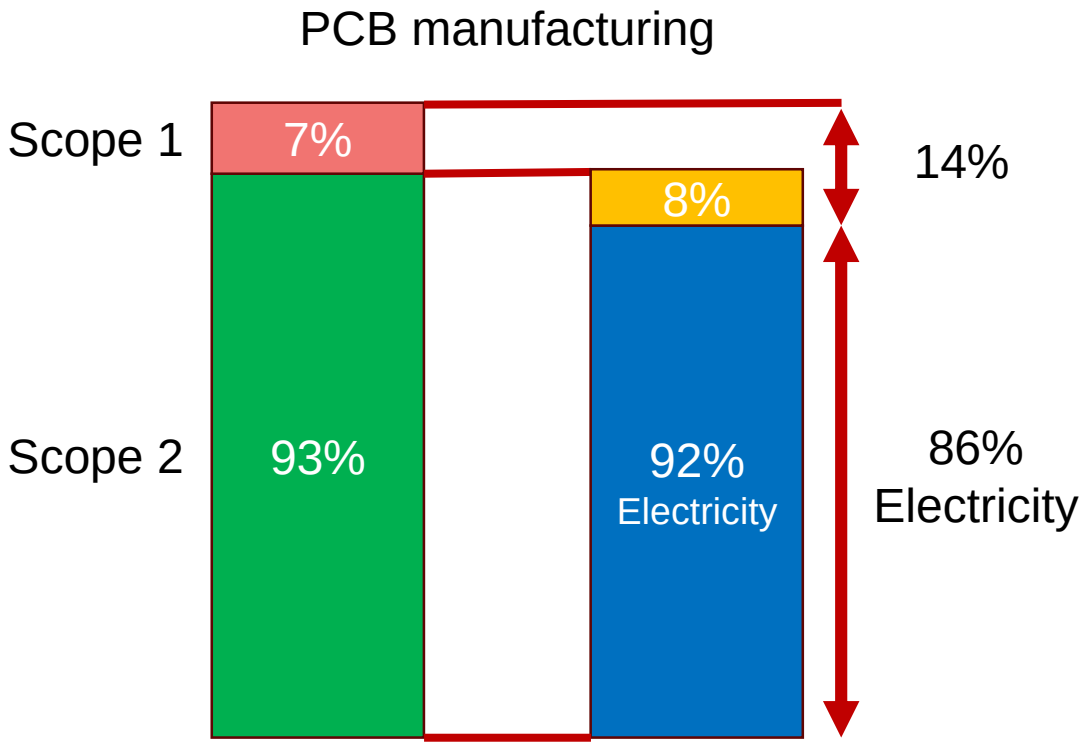
- Average stackup = 3.9 layers

Authors : Olivier Weppe, Pierre Le Gargasson
https://www.prismark.com/pcb-sample-report, p21, accessed 2024-10-31

Production location

- PCB manufacturing : 86% based on electricity
- Location based on electricity mix (ecoinvent v3.10 EF v3.1)

- Average TH + TW + CH
  - 139 kgCO2e/m²
- Average Global
  - 109 kgCO2e/m²
  - 3.9 layers



Authors : Olivier Weppe, Pierre Le Gargasson

Locations examples

- Optimistic / Average / Pessimistic evaluation of PTH FR-4 PCB
- Gate-to-gate scope

Region	25% quantile	Average	75% quantile
	kgCO2e/m²		
Global	60.73	109.03	153.51
Asia	77.54	139.23	196.03
China	79.93	143.52	202.08
Taiwan	65.03	116.76	164.40
Europe	26.91	48.31	68.02
France	6.27	11.26	15.85
Germany	36.20	65.00	91.52
USA/Canada	36.78	66.04	92.99

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