Guiding safe and sustainable technological innovation under uncertainty: a case study of III-V/silicon photovoltaics

Blanco Rocha, C.F.

Acknowledgements

Devoting four years of one's life to the study of one specific topic is a very big commitment. It is a decision to embark on a long journey full of challenges, gratifications, unexpected detours, surprising outcomes, many questions and some answers. In this journey, it would have been very easy to lose my course were it not for the many people willing to share a vision, an insight, an idea, an opinion, or simply lend an ear.

First and foremost, I would like to express my deepest gratitude to my promotors and mentors: Martina Vijver, Stefano Cucurachi and Willie Peijnenburg. I was very lucky to count on their experience and different backgrounds, as well as their keen interest in my development as a PhD student and an academic. I will never forget their support, generosity and openness to share guidance in technical aspects but also towards my personal career development.

Throughout the past 4 years I also had the pleasure and honour to collaborate with highly esteemed colleagues from Leiden University's Institute of Environmental Sciences (CML) and Leiden University College (LUC) on several publications: Paul Behrens, Jeroen Guinée, Reinout Heijungs, Bernhard Steubing, Maarten Koese, Gerard Breeman, Vrishali Subramanian, Joao Rodrigues, Peter van Bodegom and Alexandra Marques. At CML I also encountered a brilliant and inspiring group of colleagues and friends. A special thanks to those who joined me in the Ex-ante LCA Working Group for their wonderful insights and validation of the important work we are doing. And to my students from the Industrial Ecology, Governance of Sustainability and LUC programmes, who trusted me with supervision of their projects from which I also learned a lot. All the above was made possible thanks to the ever-growing and high-visibility platform that our institute director, Arnold Tukker, and the management team at CML have shaped. To them I also owe enormous gratitude for supporting my transition to a new role as Assistant Professor where I will be able to continue this exciting and promising research line.

I owe much of the valuable data and technological insights in this work to the generosity of the SiTaSol project consortium partners, where I would especially like to thank Frank Dimroth, Thomas Bergunde, Jan Bennick, Dietmar Schmitz, Sebastian Nold, Matthew Hull, Roman Trattnig, Nastaran Hayatiroodbari, Mirella El-Gemayel and Leif Jensen. I also benefited greatly from our collaboration with Caterin Salas-Redondo and Lars Oberbeck at L'Institut Photovoltaïque d'Île-de-France (IPVF). The most challenging chapters of this thesis would have been impossible to write without the technical input and insights of Joris Quik and Matthias Hof at the Netherlands Institute for Public Health and the Environment (RIVM).

To my mother, Maria Victoria, thank you for working so hard and against all forces of nature to instil in me the discipline required for this type of work. To my father, Alberto, for imbuing me with admiration for science, philosophy and beauty. To Niall, for the endless supply of extra mental power whenever reserves were running low. To Sammy, for making everything so unbelievably easy.

List of publications

Papers in this thesis

- Blanco, C.F., Cucurachi, S., Dimroth, F., Guinée, J.B., Peijnenburg, W.J.G.M. & Vijver, M.G. (2020), Environmental impacts of III–V/silicon photovoltaics: life cycle assessment and guidance for sustainable manufacturing, *Energy and Environmental Science* 13(11): 4280-4290.
- Blanco, C.F., Cucurachi, S., Guinee, J.B., Vijver, M.G., Peijnenburg, W.J.G.M., Trattnig, R. & Heijungs, R. (2020), Assessing the sustainability of emerging technologies: A probabilistic LCA method applied to advanced photovoltaics, *Journal of Cleaner Production* 259: 120968.
- Blanco ,C.F., Cucurachi, S., Peijnenburg, W.J.G.M., Beames, A. & Vijver, M.G. (2020), Are Technological Developments Improving the Environmental Sustainability of Photovoltaic Electricity? *Energy Technology* 8(11): 1901064.

Related publications

- Koese, M., Blanco, C.F., Breeman, G.E., Vijver, M.G. (2022) Towards a more resource-efficient solar future in the EU: an actor-centered approach, *Environ. Innov. Soc. Transit.* (in review).
- Cucurachi, S., Blanco, C.F., Steubing, B.R.P. & Heijungs, R. (2022), Implementation of uncertainty analysis and moment-independent global sensitivity analysis for full-scale life cycle assessment models, *Journal of Industrial Ecology*: 13194.
- Adrianto, L.R., van der Hulst, M.K., Tokaya, J.P., Arvidsson, R., Blanco, C.F., Caldeira, C., Guillén-Gonsálbez, G., Sala, S., Steubing, B.R.P., Buyle, M., Kaddoura, M., Navarre, N.H., Pedneault, J., Pizzol, M., Salieri, B., van Harmelen, T. & Hauck, M. (2021), How can LCA include prospective elements to assess emerging technologies and system transitions? The 76th LCA discussion forum on life cycle assessment, 19 November 2020, *The International Journal of Life Cycle Assessment* 26(8): 1541-1544.
- Cucurachi, S. & Blanco, C.F. (2019), 31 - Life-cycle assessment of engineered nanomaterials. In: Cucurachi S. & Blanco Rocha C.F. (Eds.) *Nanotechnology in Eco-efficient Construction*. Nanotechnology in Eco-efficient Construction: Woodhead Publishing. 815-846.
- Blanco, C.F., Penedo De Sousa Marques, A. & van Bodegom, P.M. (2018), An integrated framework to assess impacts on ecosystem services in LCA demonstrated by a case study of mining in Chile, *Ecosystem Services* 30(Part B): 211-219.

Curriculum Vitae

Carlos Felipe Blanco was born in Barranquilla Colombia, where he obtained a dual Colombian Bachillerato and U.S. High School degree from Karl C. Parrish School in 1998. Carlos Felipe graduated amongst the top of his class and was awarded with the prestigious *Andres Bello* award from the Colombian Ministry of Education for achieving the highest regional score in the ICFES state examinations.

In 2004, Carlos Felipe obtained his bachelor's degree in Environmental Engineering from Universidad de Los Andes in Bogota, Colombia. Here he was again awarded by the Ministry of Education for ranking amongst the top 10 national scores in the ECAES examinations for the quality of higher education. His thesis project "*Aquamod: An Educational Software Tool to Model Transport of Pollutants in Surface Water*s" was graded with a perfect score.

Carlos Felipe went on to work for 8 years in the mining industry as a Health, Safety, Environment and Community Relations (HSEC) manager in various countries in Latin America including Chile, Argentina, Guyana, Peru, Colombia and Brazil. In this role, Carlos Felipe led social and environmental impact studies for large-scale mining and minerals exploration projects, developed mine closure plans and led several critical incident investigations. He was also tasked with environmental auditing and implementing ISO14001 and OHSAS18001 health and safety standards.

In 2014, Carlos Felipe moved to the Netherlands to pursue a M.Sc. degree in Industrial Ecology at the Institute of Environmental Sciences (CML). In his M.Sc. thesis, Carlos Felipe developed a framework to assess ecosystem services in Life Cycle Assessment (LCA), which was demonstrated by a case study of water supply for the mining industry in the north of Chile. The thesis was awarded the Stans prize by CML in 2016 and later published in the journal *Ecosystem Services*.

Throughout the period 2014-2020, Carlos Felipe also worked part-time as a sustainability consultant for the energy and forestry industries and developed software solutions for stakeholder engagement programs in several large-scale mining projects.

In his free time, Carlos Felipe is an avid reader of geopolitics and philosophy and devotes considerable time to music composition and production. His artistic work can be found in Spotify under the artist name *Galactic Desperates* and the soon-to-be-released collaboration *Chaos, Order and the Lines*.