



Universiteit
Leiden
The Netherlands

Software and data for circular economy assessment

Donati, F.

Citation

Donati, F. (2023, April 26). *Software and data for circular economy assessment*. Retrieved from <https://hdl.handle.net/1887/3594655>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/3594655>

Note: To cite this publication please use the final published version (if applicable).

Software and Data for Circular Economy Assessment

Franco Donati

© **Franco Donati (2023)**

Software and Data for Circular Economy Assessment

ISBN/EAN: 9789051912043

Cover design and layout: Franco Donati

Art design made with Python Samila and exiobase 3.8 IOT pxp 2017

Software and Data for Circular Economy Assessment

Proefschrift

ter verkrijging van
de graad van doctor aan de Universiteit Leiden,
op gezag van rector magnificus prof.dr.ir. H. Bijl,
volgens besluit van het college voor promoties
te verdedigen op woensdag 26 april 2023
klokke 11:15 uur

door

Franco Donati
geboren te Sassari, Italië
in 1987

Promotor: Prof. dr. A. Tukker

Promotiecommissie: Prof. dr. H. Lin
Prof. dr. ing. J.W. Erisman
Prof. Dr. K. Hubacek (Rijksuniversiteit Groningen)
Dr. R. Wang
Dr. O. Ivanova (Planbureau voor de Leefomgeving)

TABLE OF CONTENTS

1	Introduction	1
1.1	Circular economy	1
1.2	Models for circular economy assessment	5
1.3	Software and data for Circular Economy assessment	11
1.4	Problem statement and research questions	13
1.5	Structure of the thesis	14
2	Environmental Pressures and Value Added Related to Imports and Exports of the Dutch Agricultural Sector	21
2.1	Introduction	22
2.2	Materials and Methods	23
2.2.1	General Methods and Data	23
2.2.2	Data	24
2.2.3	Contribution Analysis	25
2.3	Results	25
2.3.1	Greenhouse Gas Emissions	26
2.3.2	Land Use	29
2.3.3	Water Consumption	31
2.4	Discussion	34
2.5	Conclusions	35
3	Modeling the circular economy in environmentally extended input-output tables: Methods, software and case study	43
3.1	Introduction	44
3.2	Methods	47
3.2.1	CE policy modelling framework	47
3.2.2	Environmentally Extended Input-Output (EEIO) analysis	48
3.2.3	Baseline and counterfactual scenario	49

3.2.4	Change coefficients and substitution	50
3.2.5	Modeling CE interventions in EEIO	51
3.3	Data, software and case study settings	55
3.3.1	Data	55
3.3.2	Software	55
3.3.3	Case study settings	56
3.4	Results	60
3.4.1	Impact of the strategies	60
3.4.2	Impact of individual interventions	63
3.5	Discussion	66
3.5.1	Methods and framework	66
3.5.2	Software and Data	67
3.5.3	Case study	67
3.5.4	Future work	69
3.6	Conclusions	69
4	Modeling the Circular Economy in Environmentally Extended Input-Output: A web-application	77
4.1	Introduction	78
4.2	Requirements, review of existing software, and design choices for Rama Scene	79
4.2.1	Review of existing software	79
4.2.2	Implications and design choices for the RaMa-Scene platform	82
4.3	Data, Methods and User Interface	83
4.3.1	Data	83
4.3.2	Methods	84
4.3.3	Baseline and Counterfactual scenarios	89
4.3.4	The Rama-Scene user interface	91
4.4	Use cases	93
4.4.1	Which country is responsible for the highest amount of material extraction due to their consumption?	93

4.4.2	Which sub-sectors are the top CO ₂ -eq emitters in Italy?	95
4.4.3	What global effects does the increase in secondary steel content in “Electrical machinery and apparatus n.e.c.” (EMA) have on total Greenhouse Gas Emissions (GHGs)?	96
4.5	Discussion and conclusions	99
5	LCI data from Computer-Aided Technologies and Artificial Intelligence: a systematic review	107
5.1	Introduction	108
5.2	Background	109
5.2.1	Life Cycle Inventories (LCIs)	110
5.2.2	Computer-Aided Technologies (CAx)	111
5.2.3	Artificial intelligence (AI)	112
5.3	Approach to the literature review	113
5.4	Results	114
5.4.1	Overview of literature findings	114
5.4.2	How CAx can be used to estimate data for LCIs	119
5.4.3	How AI methods can be used to estimate data for LCIs	125
5.4.4	Integration: how the combination of CAx and AI methods can be used to obtain data for LCIs	129
5.5	Discussions and conclusions	131
6	The future of artificial intelligence in the context of industrial ecology	147
6.1	Introduction	148
6.2	Envisioning the role of AI in IE	150
6.3	Challenges	153
6.3.1	Resource requirements	153
6.3.2	Data accessibility and governance	154
6.3.3	Explainability, interpretability and causality	156
6.4	Recommendations	156

7	Discussions and Conclusions	165
7.1	Introduction	165
7.2	Conclusions	166
7.2.1	Introduction	166
7.2.2	How can MR EEIO be used for priority setting for CE interventions?	166
7.2.3	How can CE strategies be modelled in MR EEIO?	167
7.2.4	How can we create a user-friendly interface for modelling CE strategies with MR EEIO, easily accessible for non-specialists?	168
7.2.5	How can we use Computer-Aided Technologies (CAx) and Artificial Intelligence (AI) methods to increase data availability for the analysis of CE?	169
7.2.6	How can the IE community position itself with regards to AI and digital technologies to better support sustainability and CE assessment?	170
7.2.7	Answer to the main research question	171
7.3	Limitations and suggestions for further research	172
7.4	Implications and reflections	176
	Summary	183
	Samenvatting	189
	Curriculum vitae	195
	List of publications	196
	Acknowledgements	197