Biomass or batteries

Miedema, Jan Hessels

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The role of three technological innovations in the energy transition

Jan Hessels Miedema

Colophon

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The role of three technological innovations in the energy transition

PhD thesis

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by

Jan Hessels Miedema

Born on 12 September 1985
in Leeuwarden

Supervisor
Prof. H.C. Moll

Co-supervisor
Dr. H.J. van der Windt

Assessment Committee
Prof. M.A. Herber
Prof. F.M.D. Vanclay
Prof. E. Worrell

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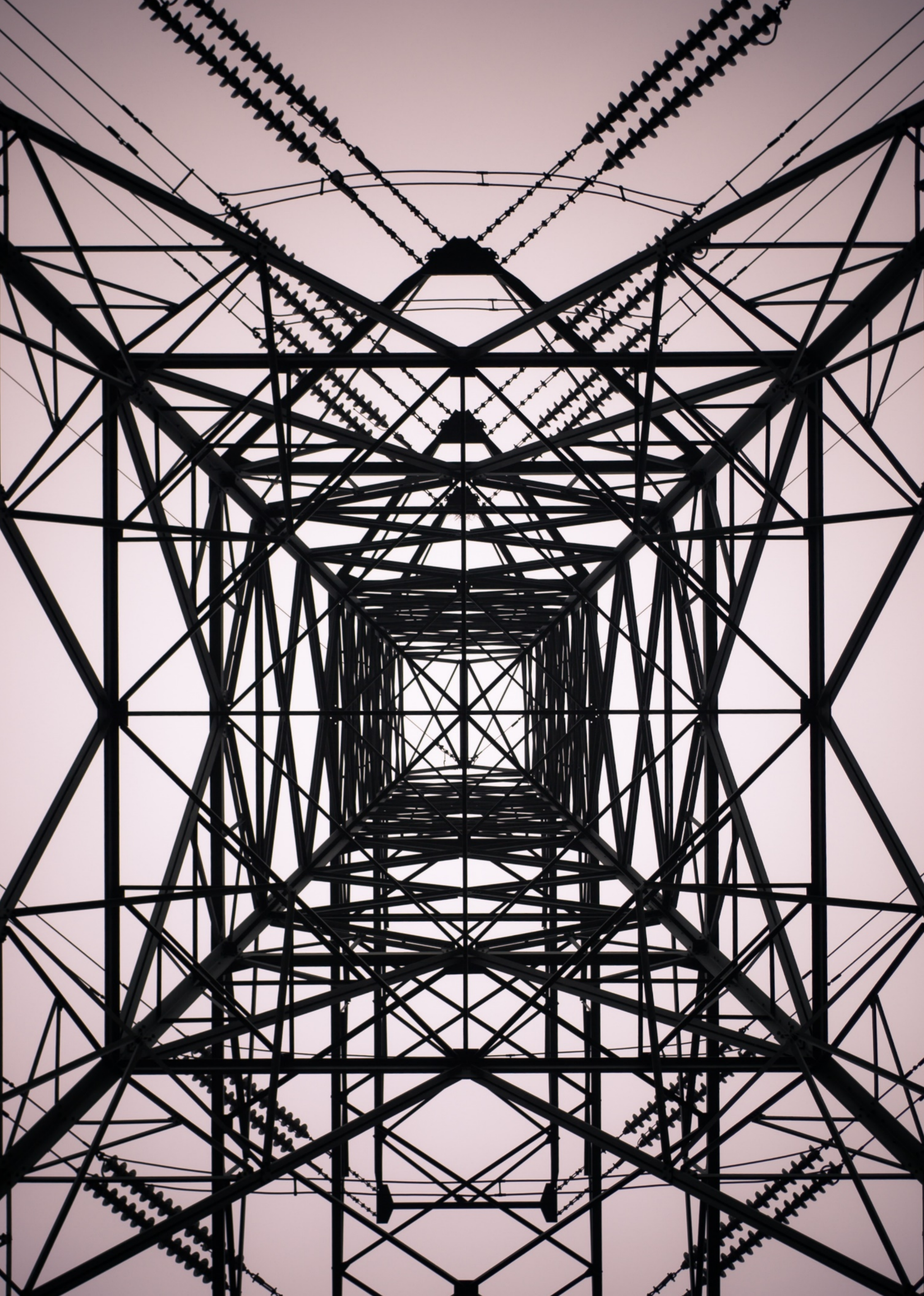
Preface



When I aimed to finish my master degree in Energy and Environmental Sciences at the University of Groningen at the end of 2011, I ended up having the same discussion with my wife as roughly two and a half years before, when I finished my bachelor degree in Environmental Science at the Van Hall Larenstein. “What are you gonna do with your life?”. Whilst I studied systems and scenarios, I found out that in life only one scenario can be lived; thus, at a certain point one has to choose a direction. After the “unilateral” agreement, with my wife, that I wasn’t welcome home if I didn’t make sure that, Henk Moll, my supervisor during my master thesis, knew I wanted a PhD position, I made sure he did. Sadly, the few positions available were already given out. However, about two months later a position became available and, partially due to the interest I had shown before, I ended up as a PhD student in April 2012.

Almost seven years later my thesis lies before you. It was a bumpy road, with ecstatic highs and incredible lows, challenging my intellectual abilities and mental perseverance. I owe a number of people my gratitude for their support during those seven years; there is, however, not enough space in this preface to name all the people who helped me, in every way possible. Still, there are a few people that I specifically want to thank. First of all, my promotor Henk Moll, for being bold enough to give me this position, whilst knowing that I had gone and was still going through the most challenging years of my life together with my wife, who was, at that time, recently diagnosed with a diffuse astrocytoma. Thank you for giving me the space I needed, and for having confidence in me bringing this journey to a successful end. Aside from this, I’m grateful that you continuously challenged my intellectual abilities and gave me the opportunity to further develop myself. Second, my co-promotor Henny van der Windt, who showed vast quantities of patience, over the years, in widening my technical perspectives towards a more general understanding of the importance of, among other factors, our society when thinking about system change. Third, René Benders, for developing similar models as I did in order to confirm my results, especially in the first years of my PhD trajectory. Your critical notions related to my results and subsequent interpretation have substantially contributed to this thesis.

In addition, to my supervisors there are a few others that I want to mention. Once in a while, during my PhD trajectory, I tended to joke about my “traditional” marriage, since my wife always makes me the best sandwiches one can imagine for lunch. Sanderine Nonhebel was the only one connecting the dots when she asked me if everything was all right, at the moment she noticed me buying lunch in the canteen, instead of bringing my own. In addition, thank you Sanderine, for always taking the time to have some coffee and provide me with motivating words in my times of need and pointing out the opportunity to participate in the best international conference ever. Against my expectations, I made two friends for life at this conference, David Alejandro Zambrana Vasquez and René Buffat. Anyone who sends me roughly two kilograms of Swiss chocolate (where weight and shipping cost are optimised) has my loyalty. Furthermore, I want to thank Ton Schoot Uiterkamp, especially during the last few years, where we shared a room in the Energy Academy Building. I’m grateful for the talks that we had about science and the future of our planet, but I am even more grateful for you sharing some of your life experience with me when this was appropriate or needed. Additionally, I would like to thank Annemiek Huizinga for helping me out with a lot of organisational questions and obviously for extending my rights as a staff member after my contract had finished. Even though some doors literally got locked for me, at least I could always get free coffee. Furthermore, I would like to thank my paranymphs, Ron de Vrieze and Gideon Laugs. Ron and I found that we had more in common than I initially thought, given our age difference and educational background. Thank you for our conversations, for me it contributed to determining what is actually important in life. Gideon, my officemate for several years. Thank you for listening to obscure music with me for about five years in a row; what a relief that we ended up with each other! Our musical preference has often resulted in strange looks and remarks from people questioning whether we were able to work productively whilst listening to the genius of, for example, Devin Townsend. One of the highlights for me was that you were willing to "neglect" your children by picking them up late from kindergarten, since you helped me jumpstart my car (more than once), in order to get home safely. Besides that, I want to thank everyone at IVEM for always making me feel at home and giving me the opportunity and trust to start a new job as a lecturer in Environmental Physics at the Van Hall Larenstein, University of Applied Sciences in Leeuwarden before the end of my PhD. Sometimes one has to grab opportunities when they present themselves. Therefore, I also want to express my gratitude towards my colleagues in Leeuwarden for giving me the time and space to finish my PhD thesis. Thank you for letting me be a part of your team at the Environmental Science department. I'm looking forward to many more years. As well as my colleagues, I want to thank the third year students of the module "Adviesbureau voor duurzame oplossingen" in 2017-2018, for thinking with me about possible sustainable solutions for the energy transition. In addition, I want to thank Cor Herder for reading parts of this manuscript and for providing useful advice on grammar and spelling.

Finally, I owe a lot to my family. My father, for passing the same "defects" on to me, as he inherited from his father, which contributed to me becoming a lecturer. Besides that, he motivated me to work harder by arguing that he did think I would get my high school degree, but probably not in the regular time. At that time he wasn't right, since I did graduate without delay, but these words still echoed in my mind when my discipline and perseverance were tested during this PhD journey. My mother, for knowing me without words being spoken, and for knowing me when words were being spoken on the phone, sometimes for hours during the good and the bad times of this whole experience. To my sister, who is living in Bolivia: I'm proud of what you achieved so far and I know the same holds for you, when it comes to me. "Los dos estamos tratando de contribuir a un mundo mejor a nuestra manera." Both my parents in law, for always showing their interest in what I was doing and, for being there for me and my wife in our times of need. My father in law for providing me with the famous words "it komt dochs altyd oars dan asto tinkst", when things didn't go as planned. Furthermore, I want to thank my brother in law Danny Boonstra for designing the cover art for this dissertation.

Most of all I owe my wife, who I cherish and adore, a lot. In order to express this in the best way I can, I will finalise this preface in Frisian.

Ik draach dit boek op aon myn frau Marjet, myn foarbyld, om't ik nea ien sjoen ha mei sa'n bjusterbaarliik trochsettingsfermogen. Nettsjinsteande dat hja dat sels lang net altyd sa sjocht, wit ik fêst dat ik nea safier kommen wie as sy net altyd foar my klear stie; mei ynspiraasje, in harkjend ear, wurden fan motivaasje, bôle foar wilens it skoft, of in skop foar myn bealch. Do bist myn alles.

Sincerely,

Jan Hessels Miedema

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List of abbreviations

AD	Anaerobic digestion
BAU	Business as usual
BC	Best case
BEV	Battery electric vehicle
BFB	Bubbling fluidised bed
CHP	Combined heat and power
$CO_{2\ eq.}$	Carbon dioxide equivalent
CO_2	Carbon dioxide
db	Dry basis
DSO	Distribution system operator
EBN	Energiebeheer Nederland
ECN	Energy research centre of the Netherlands
EE	Energy efficiency
EJ	Exajoule
EPBD	Energy performance of buildings directive
ER	Energy ratio
EU	European union
GHG	Greenhouse gas
GJ	Gigajoule
Gt	Gigaton
GTS	Gasunie transport services
GW	Gigawatt
ha	Hectare
HEV	Hybrid electric vehicle
HFO	Heavy fuel oil
ICE	Internal combustion engine
ILUC	Indirect land use change
km	Kilometre
kt	Kiloton
kWh	Kilowatt-hour
LCA	Life cycle analysis
Li_2CO_3	Lithium carbonate
Li-Ion	Lithium-ion
Mha	Million hectare
MILENA	Biomass gasification technology developed by ECN optimized for SNG
MJ	Megajoule
MLP	Multi-level perspective
Mt	Megaton
Mtoe	Megaton oil equivalent
MW	Megawatt
MW_e	Megawatt electric
NAM	Nederlandse Aardolie Maatschappij
NLs	Netherlands

NO_x	Nitrogen oxides
PHEV	Plug-in hybrid electric vehicle
PJ	Petajoule
ppm	Parts per million
R&D	Research and development
RED	Renewable energy directive
SNG	Synthetic natural gas
SO_x	Sulphur oxides
t	Ton (i.e. 10^3 kg)
TIS	Technological innovation system
tkm	Ton kilometre
TOP	Torrefaction and pelleting
TSO	Transmission system operator
US	United States
wb	Wet basis