

# Green ICT & Energy

## From smart to wise strategies

Jaco Appelman

*Assistant Professor Systems Engineering, Delft University of Technology  
and Sustainability Innovator at FastFact.nl, Delft, The Netherlands*

Anwar Osseyran

*CEO SURFsara, the Dutch national HPC Center and Chairman of the Green IT Consortium  
Amsterdam, The Netherlands*

Martijn Warnier

*Assistant Professor Systems Engineering, Delft University of Technology,  
Delft, The Netherlands*

**CRC Press**

Taylor & Francis Group

Boca Raton London New York Leiden

CRC Press is an imprint of the  
Taylor & Francis Group, an **informa** business

A BALKEMA BOOK

# Table of contents

About the book series	vii
Editorial board	ix
List of contributors	xxv
Foreword	xxvii
Preface by Prof. W. Vermeend	xxix
About the editors	xxxix
1. Editorial introduction: A strategic view on changing an industry	1
<i>Jaco Appelman, Anwar Osseyran &amp; Martijn Warmer</i>	
1.1 Introduction	1
1.2 State of the art: The ICT sector	2
1.3 Standards	5
1.4 Discussion: Efficiency and effectiveness presuppose each other	6
2. Creating synergies between approaches and tools for sustainable ICT development	9
<i>Jaco Appelman, Freek Bomhof &amp; Reinier de Nooij</i>	
2.1 Introduction	9
2.2 Selection of approaches	10
2.2.1 Description of approaches selected	11
2.3 Creation of frame of reference	12
2.3.1 Requirements for sustainability transitions	12
2.3.2 Expert meeting	15
2.4 Analysis and comparison of TNS, CtoC, and EF	16
2.4.1 Analysis overview	16
2.4.2 The natural step	17
2.4.3 Cradle to cradle	18
2.4.3.1 CtoC case: Almere	19
2.4.4 Ecological footprint	20
2.4.4.1 EF case: Dutch municipalities	20
2.5 Combining approaches: Discussion	21
2.6 Consequences for the ICT sector	23
2.6.1 Translation of TNS, CtoC, and EF to the ICT sector	24
2.6.2 Scope of the approaches	24
2.6.3 Implications	25
2.7 Discussion: Ways forward	25
3. Green IT current developments—A strategic view on ICT changing the global warming trend	29
<i>Anwar Osseyran</i>	
3.1 Introduction: Green IT and sense of urgency	29
3.2 Green IT framework	31
3.3 Greening the datacenter: The power loss chain	32

3.4	Green IT and smart grids (Stage I)	33
3.5	Greening datacenters (Stage II)	34
3.6	Sustainability through virtualization and cloud computing (Stage III)	36
3.7	Green software and data life cycle management	37
3.8	Big data and sustainability	37
3.9	Sustainability as motor of the <i>new</i> economy	38
3.10	ICT as an enabler for the low-carbon economy	38
3.11	Transport sector	39
3.12	Smart buildings	40
3.13	Smart industry	40
3.14	ICT for dematerialization	41
3.15	Finally, a word about the necessity of avoiding the re-bounce effect	42
3.16	Conclusions	42
4.	Higher-order sustainability impacts of information and communication technologies	43
	<i>Karel F. Mulder &amp; Dirk-Jan Peet</i>	
4.1	Introduction	43
4.2	The dynamics of information and communications technologies	44
4.2.1	Higher-order effects of ICTs	46
4.2.2	Second and higher-order effects on sustainability	46
4.2.2.1	Dematerialized products	48
4.2.3	How to deal with higher-order sustainability impacts of ICTs?	50
4.3	Conclusions	50
5.	Standardization as ecodesign at sector level	53
	<i>Tineke Egyedi &amp; Sachiko Muto</i>	
5.1	Introduction	53
5.2	The challenge of sustainable ICT	53
5.2.1	Energy use	54
5.2.2	E-waste	54
5.3	Economics of standards	55
5.4	Standards for sustainability	57
5.4.1	Environmental standards	57
5.4.2	Sustainability effects of compatibility standards	57
5.5	Example: A standardized charger for mobile phones	60
5.5.1	European Commission's initiative to standardize	60
5.5.2	Environmental effects of a standard for mobile chargers	60
5.6	Conclusion: Compatibility standards—a green strategy in a gray sector	61
6.	Increasing green energy market efficiency using micro agreements	65
	<i>Kassidy Clark, Martijn Warnier &amp; Frances Brazier</i>	
6.1	Introduction	65
6.2	Future energy markets	66
6.2.1	Intermittent and distributed generation	66
6.2.2	Demand side management	67
6.2.3	Real-time pricing	68
6.3	Market automation	68
6.3.1	Automated agent-based negotiation	69
6.3.2	Automated energy market	69

6.4	Micro agreements	70
6.4.1	Service level agreements	70
6.4.2	Benefits to the consumer	72
6.4.3	Benefits to the producer	72
6.5	Conclusion	73
7.	Framework for measuring the environmental efficiency of IT and setting strategies for green IT: A case study providing guidance to chief information officers	77
	<i>Johanne Punte Kalsheim &amp; Erik Beulen</i>	
7.1	Introduction	77
7.2	Green IT	77
7.2.1	Green IT definitions	78
7.2.2	Green IT as a step towards corporate responsibility	78
7.3	Measuring Green IT	80
7.3.1	Performance assessment	80
7.3.2	Performance indicators	81
7.4	Design requirements	83
7.5	Framework design	84
7.5.1	Framework entity	84
7.5.2	Framework design	85
7.6	Case study	85
7.6.1	Research scope	85
7.6.2	Data sources and data collection procedure	86
7.6.3	Data analysis and evaluation	87
7.7	Evaluation and reflection	88
7.7.1	Evaluation of the framework	88
7.7.2	Reflection on the framework	89
7.8	Practical recommendations on implementation	90
7.8.1	Applied principles of functional design	90
7.8.2	Vision on management process	91
7.9	Conclusion and further research	93
8.	Micro-training to support sustainable innovations in organizations	97
	<i>Mariette Overschie, Heide Lukosch, Karel Mulder &amp; Pieter de Vries</i>	
8.1	Introduction	97
8.2	Learning in sustainable innovations	97
8.3	The challenge for sustainable innovations	98
8.4	Micro-training to support learning in organizations	100
8.4.1	Case 1: Micro-training in a mechatronics company	102
8.4.2	Case 2: Micro-training in a service company for computers	102
8.5	Conclusions and reflection	103
9.	Integration of green IT knowledge in education	107
	<i>Henk Plessius</i>	
9.1	Introduction	107
9.2	The green IT framework	109
9.3	Competencies in green IT	110
9.4	Greening of IT curricula	111
9.5	Examples of green IT in education	113
9.5.1	Measuring and reducing power consumption	113
9.5.2	Green IT in information management	114
9.5.3	IT as enabler for sustainability	115
9.6	Discussion	115

10. Biomimicry: Design and innovation that help reach eco-effective solutions	117
<i>Saskia Muisenberg, Jaco Appelman &amp; Dayna Baumeister</i>	
10.1 Introduction	117
10.1.1 What is it?	117
10.2 Biomimicry is the conscious emulation of life's genius	118
10.3 Three levels of biomimicry	118
10.4 Life's principles	119
10.4.1 Biomimicry case study: How can IT support sustainable communities?	121
10.5 Biomimicry and greening by IT	123
10.6 Conclusion	125
11. Conclusions: Exploring synergies between efficiency and effectiveness	127
<i>Anwar Osseyran, Jaco Appelman &amp; Martijn Warnier</i>	
Subject index	133
Book series page	137