

# Contents

<b>Part I</b>	<b>Frame of Reference .....</b>	<b>1</b>
<b>1</b>	<b>Sustainability and Discontinuity.....</b>	<b>3</b>
1.1	Introduction .....	3
1.2	Sustainable Development and Environmental Sustainability .....	4
1.2.1	Preconditions of Environmental Sustainability .....	6
1.2.2	Ten Times More Eco-efficient Production System .....	6
1.3	Bio- and Technocycles .....	8
1.3.1	Biocompatibility and Biocycles .....	9
1.3.2	Non-interference and Technocycles.....	9
1.3.3	Industrial Ecology and Dematerialisation .....	10
1.4	Transition Scenarios .....	11
1.4.1	Strategy of Efficiency: A Radical Way of Doing Things Better .....	12
1.4.2	Strategy of Sufficiency: A Radical Way of Doing Less...	12
1.4.3	Compound Strategy.....	13
<b>2</b>	<b>Products, Contexts and Capacities.....</b>	<b>15</b>
2.1	Introduction .....	15
2.2	Product-based Well-being .....	16
2.2.1	The World as a Supermarket.....	16
2.2.2	The Paradox of “Light Products” .....	17
2.2.3	Lightness as a Non-sufficient but Necessary Condition...	18
2.3	Access-based Well-being .....	19
2.3.1	The World Is Like a Theme Park .....	19
2.3.2	The Material Ballast of Information.....	20
2.3.3	Service Orientation as a Pre-requisite of Sustainability ...	21
2.4	Crisis of Local Common Goods .....	22
2.4.1	The Role of Common Goods .....	22
2.4.2	The Sprawl of Remedial Goods .....	23

2.5	Context-based Well-being .....	24
2.6	Well-being as a Development of Capacity .....	25
2.6.1	Unsustainable Comfort .....	25
2.6.2	Disabling and Enabling Solutions .....	26
2.7	The Forces Behind Changes .....	27
<b>3</b>	<b>A Social Learning Process.....</b>	<b>29</b>
3.1	Introduction .....	29
3.2	The Production–Consumption System .....	29
3.3	Consumers/Users and Co-producers.....	30
3.3.1	The (Potential) Strength of Consumers.....	31
3.3.2	Critical Consumption .....	32
3.4	People as Co-producers .....	32
3.5	Active Minorities and Auspicious Cases .....	33
3.6	Enterprises and New Forms of Partnership .....	35
3.6.1	Producing Value by Reducing Consumption .....	35
3.6.2	New Methods of Running Business .....	36
3.6.3	Eco-efficient Businesses .....	37
3.6.4	From Product to System Eco-efficiency .....	38
3.6.5	Looking for New Solutions.....	38
3.6.6	Starting from the Results.....	39
3.6.7	Business and Social Innovation .....	39
3.7	The Public Sector (and the Rules of the Game).....	41
3.7.1	Facilitate the Social Process of Learning .....	41
3.7.2	Amplifying the Feedback.....	42
3.7.3	Supporting the Offer of Alternative Solutions .....	43
3.7.4	Promoting Adequate Communication.....	44
3.7.5	Designating Adequate Economical Costs to Natural Resources .....	45
3.7.6	Extended Producer Responsibility .....	45
3.8	Designers and Co-designers .....	46
3.8.1	Limits and Opportunities of the Designer’s Role.....	46
3.8.2	Operative Fields for Design for Sustainability.....	47
<b>Part II</b>	<b>Design for Environmental Sustainability .....</b>	<b>51</b>
<b>4</b>	<b>Life Cycle Design .....</b>	<b>53</b>
4.1	Introduction .....	53
4.2	Environmental Requirements of Industrial Products.....	53
4.3	Product Life Cycle.....	55
4.3.1	Introduction.....	55
4.3.2	Pre-production.....	56
4.3.3	Production .....	57

4.3.4	DSollribution.....	58
4.3.5	Use .....	58
4.3.6	Disposal .....	58
4.4	Additional Life Cycles.....	59
4.5	Functional Approach .....	60
4.6	Life Cycle Design.....	61
4.7	Life Cycle Design Objectives.....	62
4.8	Implications of Life Cycle Design.....	62
4.9	The Design Approach.....	63
4.10	Strategies of Life Cycle Design.....	64
4.11	Interrelations Between the Strategies .....	65
4.12	Priorities Among the Strategies .....	66
4.13	Design for Disposal .....	69
4.14	Environmental Priorities and Disposal Costs .....	69
4.15	Current State of Life Cycle Design .....	70
<b>5</b>	<b>Minimising Resource Consumption .....</b>	<b>73</b>
5.1	Introduction .....	73
5.2	Minimising Material Consumption.....	74
5.2.1	Minimising Material Content.....	74
5.2.2	Minimising Scraps and Discards.....	79
5.2.3	Minimising Packaging .....	80
5.2.4	Minimising Materials Consumption During Usage .....	84
5.2.5	Minimising Materials Consumption During the Product Development Phase .....	89
5.2.6	Minimising Energy Consumption .....	90
<b>6</b>	<b>Selecting Low Impact Resources and Processes.....</b>	<b>105</b>
6.1	Introduction .....	105
6.2	Selection of Non-toxic and Harmless Resources.....	106
6.2.1	Select Non-toxic and Harmless Materials.....	106
6.2.2	Selecting Non-toxic and Harmless Energy Resources .....	112
6.3	Renewable and Bio-compatible Resources.....	117
6.3.1	Select Renewable and Bio-compatible Materials.....	118
6.3.2	Select Renewable and Bio-compatible Energy Resources.....	125
<b>7</b>	<b>Product Lifetime Optimisation.....</b>	<b>131</b>
7.1	Useful Lifetime.....	131
7.2	Why Design Long-lasting Goods?.....	132
7.3	Why Design Intensely Utilised Goods?.....	135
7.4	Social and Economic Dimensions of Changes .....	137
7.5	Optimisation Services.....	138

- 7.6 Guidelines..... 138
  - 7.6.1 Designing for Appropriate Lifespan ..... 139
  - 7.6.2 Designing for Reliability..... 141
  - 7.6.3 Facilitating Upgrading and Adaptability..... 141
  - 7.6.4 Facilitating Maintenance..... 145
  - 7.6.5 Facilitating Repairs ..... 148
  - 7.6.6 Facilitating Re-use ..... 150
  - 7.6.7 Facilitating Re-manufacturing ..... 154
  - 7.6.8 Intensifying Use ..... 155
  
- 8 Extending the Lifespan of Materials..... 159**
  - 8.1 Introduction ..... 159
  - 8.2 Guidelines..... 165
    - 8.2.1 Adopting the Cascade Approach..... 166
    - 8.2.2 Selecting Materials with the Most Efficient Recycling Technologies..... 168
    - 8.2.3 Facilitating End-of-life Collection and Transportation .... 170
    - 8.2.4 Identifying Materials..... 172
    - 8.2.5 Minimising the Overall Number of Different Incompatible Materials ..... 173
    - 8.2.6 Facilitating Cleaning ..... 176
    - 8.2.7 Facilitating Composting ..... 177
    - 8.2.8 Facilitating Combustion..... 178
  
- 9 Facilitating Disassembly..... 181**
  - 9.1 Introduction ..... 181
  - 9.2 Guidelines..... 187
    - 9.2.1 Reducing and Facilitating Operations of Disassembly and Separation..... 188
    - 9.2.2 Engaging Reversible Joining Systems ..... 191
    - 9.2.3 Engaging Permanent Joining Systems that Can Be Easily Opened ..... 193
    - 9.2.4 Co-designing Special Technologies and Features for Crushing Separation ..... 194
    - 9.2.5 Using Materials that Are Easily Separable After Being Crushed ..... 196
    - 9.2.6 Using Additional Parts that Are Easily Separable After the Crushing of Materials ..... 197
  
- 10 System Design for Eco-efficiency..... 199**
  - 10.1 Economic Restrictions in Traditional Supply and Demand System ..... 199
  - 10.2 System Innovation for New Interactions Between Socio-economic Actors..... 202

10.3	The Supply Model of the Product Service System .....	203
10.4	Guidelines.....	204
10.4.1	Services Providing Added Value to the Product’s Life Cycle .....	205
10.4.2	Services Providing “Final Results” for Customers .....	206
10.4.3	Services Providing “Enabling Platforms for Customers” .....	208
10.5	Strategic System Design for Eco-efficiency .....	212
<b>Part III</b>	<b>Methods and Support Tools for Environmental Sustainability Analysis and Design .....</b>	<b>213</b>
<b>11</b>	<b>Environmental Complexity and Designing Activity .....</b>	<b>215</b>
11.1	Introduction .....	215
11.2	Methods and Tools for Design for Environmental Sustainability .....	216
<b>12</b>	<b>Estimating the Environmental Impact of Products: Life Cycle Assessment .....</b>	<b>219</b>
12.1	The Environmental Impact of Our Production–Consumption System .....	219
12.1.1	Exhaustion of Natural Resources .....	220
12.1.2	Global Warming.....	220
12.1.3	Ozone Layer Depletion .....	221
12.1.4	Smog .....	222
12.1.5	Acidification .....	223
12.1.6	Eutrophication.....	223
12.1.7	Toxic Air, Soil and Water Pollution .....	224
12.1.8	Waste .....	225
12.1.9	Other Effects .....	226
12.2	Quantitative Methods for Estimating and Analysing Product Environmental Impact .....	226
12.2.1	Life Cycle Assessment.....	227
12.2.2	Stages of LCA.....	228
12.2.3	LCA and Design: Importance and Limitations .....	236
12.2.4	Power to Choose: Discriminant Power Versus Scientific Reliability .....	237
12.2.5	Incisive Decisions: First Stages of Development Versus LCA Applicability .....	238
12.2.6	Developing LCA.....	239
<b>13</b>	<b>Environmentally Sustainable Design-orienting Tools .....</b>	<b>243</b>
13.1	Introduction .....	243
13.2	Tools Developed for Certain Environmental Goals.....	243

- 13.3 Limitations of Tools that Are Developed  
for Certain Environmental Goals..... 245
- 13.4 Tools for Product LCD ..... 246
- 13.5 Tools for Design for Eco-efficiency ..... 247
  
- Part IV The Roadmap and the State of the Art..... 251**
  
- 14 Evolution of Sustainability in Design Research and Practice ..... 253**
  - 14.1 Introduction ..... 253
  - 14.2 Evolution of Sustainability in Design..... 255
  - 14.3 Low Impact Resources Selection..... 256
  - 14.4 Product Life Cycle Design ..... 257
  - 14.5 System Design for Eco-efficiency ..... 258
  - 14.6 Design for Social Equity and Cohesion..... 260
  - 14.7 State of the Art..... 262
  
- Appendix A Design Criteria and Guidelines..... 263**
  
- Appendix B Diagrams of Environmental Impacts..... 273**
  
- References..... 283**
  
- Index ..... 297**