Beyond Sustainability

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Natural resources and challenges

The sustainability challenges we are confronted within the built environment are all related to the physical consumption of natural resources: energy, water, materials and top soil[i]. Extraction and conversion processes lead to depletion and harmful emissions, and as such to challenges in terms of ecology, economy and equity[ii].

The Matrix of Figure 1 depicts biodiversity, health effects and climate change as the most relevant *ecological* challenges we are confronted with, whereas scarcity of materials and natural resources is seen as primary *economic* challenges. In terms of *equity*, the unfair distribution of resources or the deliberate dumping of our toxic waste in countries with little regulations, stand out.

Values / Re-cources	Ecology			Economy			Equity		
	Biodiversity	Health Effects	Climate Change	Scarcity	Cost / Benefits	PR Metaphor	Social Responsibility	Fairness	
Energy	SO2, Acid rain	NOx, PM 2.5	CO2	Fossil fuels	Pay Back Time ******* Life Cycle Analysis ******* Total Cost of Ownership ******* Life Cycle Costing ******* Hard & Soft Costs and Benefits	'Net Positive'	Energy Positive Buildings	'Supergrid'	Coal Powered Electricity ************ Child Labor *********** Resource Depletion ************* 'Externalising' Costs ************* Rampant Environmental Pollution
	Solar-, Wind-, Environmental-, Geothermal Energy and Highly Productive Biofuels (Algae)								
Water	Contaminated Water	Hormones & Medicines	Rising Sea Level	Fresh Water		'Clean'	Cleaner Discharge as Intake	Geo-Political Governance (lack of)	
	Local Cleaning (Reed filters), use of Algae, Nutrition Regeneration								
Materials	Waste *)	Hazardous Emissions	Chlorofluorocarbons	Virgin Materials		'Healthy'	Actively Cleaning Buildings	'Securing' Resources	
	Non-Toxic, -Carcinogenic or –Mutagenic Substances, From Down- to Re- and UpCycling								
Top Soil	Loss & Degradation	Contamination	CH4 - Emissions	Phosphate		'Fertile'	Positive Contribution to Top Soil Production	Displacing Arable Land by BioFuels	
	Apply Green Roofs & Walls, Close Cycles, Recovery of Nutrients, Large Scale Eco-Rehabilitation Projects								
*) Toxic-, Carcinogenic-, Mutagenic, etc.			Environmental Challenges / Solutions / model v11, PG Luscuere , December 2015						

Figure 1: Matrix Resources-Values[iii]

Nearly Zero Energy?

Energy has been the most popular studied resource, as we were – and are – confronted with the limitations of our fossil fuel dependency as well as its related sensitivity to price fluctuations and geo-political interests. Subsequently, we are unpleasantly surprised by global climate change as a – highly likely – consequence of our large-scale fossil fuel driven economy. Thus far, solutions were sought in terms of: reduction of consumption, replacement by renewable sources and improvement of efficiencies i.e. steps we know as the ‘Trias Energetica’. The focus has gradually evolved from energy reduction via low energy buildings to ‘nearly zero energy buildings’. This approach aims at minimizing the negative aspects of building and living, instead of maximizing its potential positive aspects, and is as such hardly sustainable.

i Top Soil being the top few centimeters of fertile soil of which most of our food production depends.

ii Equity in social context, like fairness.

iii This matrix relates four natural resources to three value areas in our society: Ecology, Economy and Equity. Examples of non-sustainable developments are given as well as possible solutions. It can be used to structure discussions on sustainability ambitions.

Energy Transition

At this moment (January 2016) the world population is reaching 7.4 billion: more than seven times the number of people at the start of the industrial revolution[1,2]. During the same timeframe the primary energy consumption per capita has nearly tripled[3,4] whereby the pressure on our, nearly entirely fossil based, energy supply has risen 23-fold. This leads to the present 70 GJ per year per person[3], the equivalent of 2.2 kW or 3 hp. Fossil fuels are being depleted, peak-oil has passed[5] and the oil-addicted industry and governments are trying all they can to exploit their investments for yet a little longer or to savor the extra time of non-dependency from foreign nations.

One of the most logical alternatives is solar energy: it is abundantly available and it provides us with 5,000-10,000 times our current need[4]. Moreover, it is clean, free, and everlasting (at least for the foreseeable future). In approximately 10 years' time Germany has installed a staggering 50 GWp of Photo Voltaic Power[6], the peak equivalent of some 50 nuclear power plants, predominantly by (groups of) individual citizens. This is a substantial contribution of roughly one fourth of the required transition towards 76% renewable energy in 2030, and a fine example of the power of democratization of renewable energy generation as described by J.Rifkin[7].

Positive Footprint: energy

If we were able to realize buildings that generate more renewable energy than they consume, including the initially invested 'embodied energy' in production, transport and construction, one could speak of a positive footprint (regarding energy). This is a real paradigm shift; the (group of) building(s) couldn't be big enough from an energy point of view. It would be energetically beneficial to its environment and to society.

Improvement Potential using Exergy

To generate an energetic positive footprint we need to use the full potential of the available energy sources. At this moment that is not yet the case; the improvement potential of our energy conversions is still very big.

The focus up until this moment was on reduction of the demand and on production from renewable sources. At a systems level the focus was aimed at energy efficiencies, only taking into account the first law of thermodynamics. This approach does not consider the quality of different forms of energy. It thereby fails to identify the true effectiveness of the used energy carrier in different energy systems, as well as its improvement potential. Exergy on the other hand , which is based on the second law of thermodynamics, takes into account the ideal conversion of one form of energy into another. Hence, exergy identifies the real thermodynamic performance and improvement potential. Burning high-value fossil fuels for low temperature heating is energetically highly efficient but exergetically disastrous. Simply analyzing energy flows can be very misleading indeed.

Resource Depletion

Our fossil energy sources are exploited to the point of depletion while at the same time causing potential climate change. The other resources: water, materials and top soil face similar challenges. Water gets contaminated in different ways, sometimes to the point it can hardly be cleaned, several materials are expected to be depleted in the coming decades[8,12,13], and of all available top-soil approximately 50% has been lost during the last 150 years[9]. Such linear processes – referred to as 'Take, Make, Waste' by Michael Braungart and William McDonough in their book on Cradle to Cradle®[10] – does not relate well to a finite planet, as illustrated in a striking manner by Annie Leonard in her video-animation 'The Story of Stuff'[11]. That is why circularity is key; we must be able to endlessly renew all our natural resources. Energy, water, materials and top soil should all be renewable or from renewable sources.

Renewable energy is abundantly available in the form of solar energy. Some material resources are also renewable, but most resources used in industry and the built environment are non-renewable. The amount of those resources at our disposal is limited and we are consuming them in an irresponsible rate, like we have done with our fossil fuels. For example, at the current rate – taking into account a 3.1 % per annum increase – the existing world mineral reserves[iv] of Copper will be depleted by as early as 2035[12]. Based on recent sources[9,13], and given a general 2 % increase per year, one can calculate the depletion of about 12 elements, among which quite common ones such as: Lead, Tin, Chromium, Zinc and Copper, in the coming 20 years.

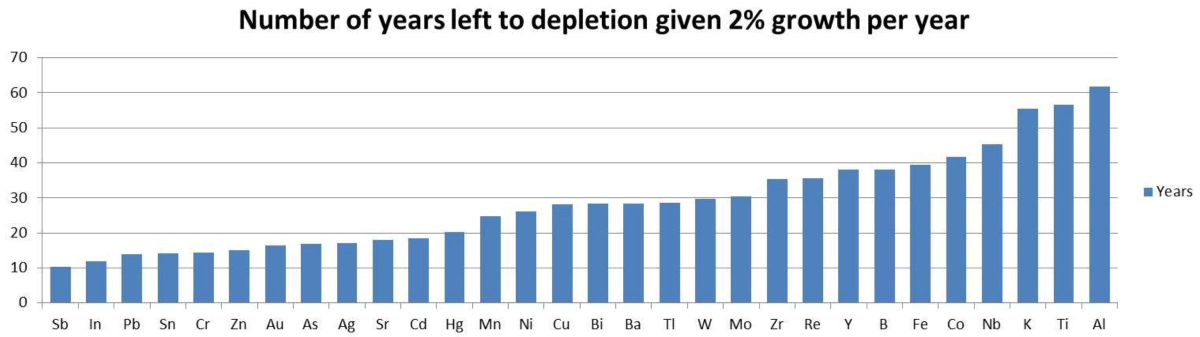

Figure 2: Number of years left to depletion of mineral reserves (Luscuere after USGS[8] and Diederen[13].

The depletion of resources is more imminent and potentially more disruptive than the fossil energy depletion alone. In this context circularity is a means to achieve renewability, whether it concerns water, top soil, materials or energy.

iv A mineral reserve is defined as that part of a known mineral deposit that can be extracted legally and economically.

A growing economy, or rather: a growing production of goods requires materials to answer to the increased demand. As most technological materials are finite, or only renewable in extremely long cycles, we have to find new abundant renewable alternatives alongside the extraction of materials from our waste. Furthermore, it is imperative that either the regenerative capacity of the earth allows for sufficient food production or that the production of renewable materials does not compromise food production. In a way, technological materials that are fully recyclable and capable of functioning in continuing cycles, can be considered renewable. Besides this, rare technological materials for which no substitutes exist, need to be reserved for specific essential processes. Harmful materials and recycling processes must be avoided, just as hybrid materials that thwart the continuation of pure – biological or technological – flows ('monstrous hybrids' as they are called by Braungart en McDonough).

The relation between resources

It is essential to consider the interrelationship of all resources. Systems for the production of energy from renewable sources also require materials, many of which are finite. Well-known examples are the so-called 'Rare Earth Metals'. Water may be a carrier of materials as well, in the form of impurities or salt for example. All these materials can be 'nutrients' for a material's cycle. For the biological material cycle a relation exists with top soil: the amount of renewable materials to be produced depends on the ecological capacity of the earth to (re)generate top soil. This underlines the importance to study the flows of energy, water, materials and top soil in an integrated way.

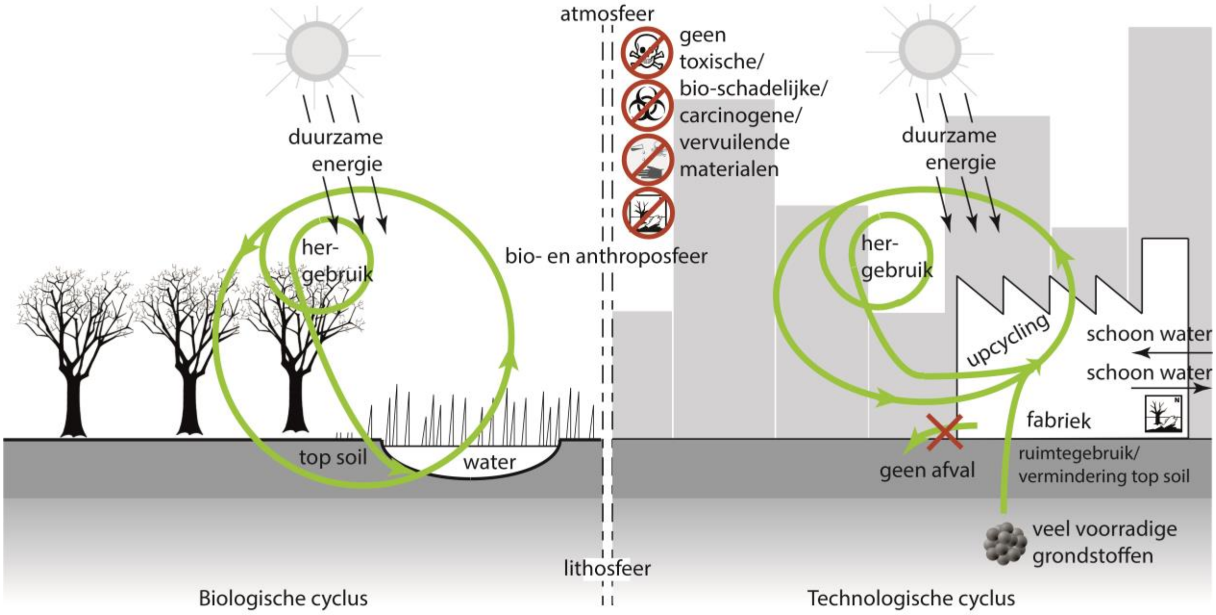

Figure 3: Biological and technological material cycles in our society

From Recycling to Upcycling

In the traditional linear economy minerals are mined, processed to products and finally wasted in landfills or burnt in incinerators. In order to safeguard the availability of these materials, not only for the coming decades but surely also for our progeny, we will have to come up with more effective ways to recycle or even upcycle materials. And there is plenty available: not in our mines but in our present and historic waste.

The term 'upcycling' often gives rise to confusion. People argue this contradicts the second law of thermodynamics, in which entropy is ever increasing. The flaw in this reasoning is that it is not forbidden to feed energy to the system. In this way it is for instance possible to combine Carbon dioxide (mostly seen as a nasty climate change propelling waste product) with Hydrogen (originating from renewably powered electrolysis) to produce Methane. The latter is better known as natural gas, but now acquired through a very short-cycled renewable process as opposed to the fossil version.

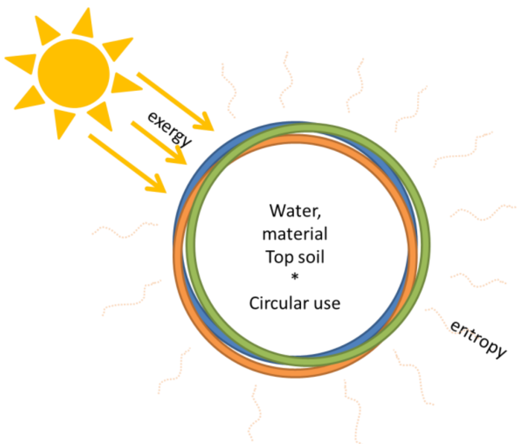

Figure 4: Sustainable energy powering the circular use of natural resources.

Waste as a resource

Waste does not exist in nature. As in the C2C® principle of Waste = Food[10], all biological materials end up as intake for other processes. It is challenging to consider CO_2 as a resource instead of a harmful greenhouse gas. Multiple applications can be found for CO_2. In The Netherlands for example, where 'waste' CO_2 from industrial processes is captured and used to fertilize greenhouse agriculture.

The word 'waste' is thus an abomination; it disregards the value of the constituent elements and components. In order to understand the true value of this we should approach waste as a resource. One kilogram of gold can be obtained from 200-1,000 ton of ore, depending on the richness of the mine. In 2009 one could find one kg of gold in 3.3 ton of used mobile phones, alongside 471 kg of Copper, 10 kg Silver, 0.4 kg Palladium and 10 grams of Platinum[14]. This richness in our 'waste' can best be described by using Exergy as a metaphor: the Exergy of waste or '*Ex Waste*'.

Ex Waste

Following the mobile phone example: the constituent substances of a mobile phone represent more value than the caloric value of the device when burning it. The ways in which the substances are mixed, however, often withhold us from harvesting them in a clean and reusable state. For this we are dependent on logistics and technologies that may or may not be developed yet and will be continuously improved in the future. In the *Ex Waste* concept such contextual elements are taken into account. *Ex Waste* integrates different 'embodied values', depending on the inextricable preconditions surrounding the given waste stream. The Netherlands, for example, has an intensive livestock industry, producing more manure than can be processed naturally. Therefore manure is often seen in The Netherlands as an environmental burden or even a liability, whereas in neighbouring countries this manure is highly valued (in original or processed conditions). *Ex Waste* thus uses Exergy as a metaphor rather than an analogy, stressing the *quality capacity*, including thermodynamic principles but not solely depending on them.

Widening the Concept of a Positive Footprint

The positive footprint concept can be applied to all four resources in the Built Environment:

1. Energy: Produce more renewable energy than the building consumes, including the embodied energy.
2. Water: Install water treatment that allows for better quality water out as in.
3. Top Soil: Take measures to produce more top soil during the anticipated life time of the building as what is destroyed during construction.
4. Materials: Bring materials in a biological or technological cycle so that they can be reused indefinitely.

Several energy positive buildings have already been realized[15], albeit without taking the embodied energy thoroughly into account. Biological water purification techniques are applied successfully in modern office buildings[16] and impressive results are achieved with regard to decentralized water purification in places with high concentrations of contaminants, such as hospitals[17]. Urban greening can help to form top soil, and phytoremediation interventions can help restore contaminated top soil[18]. At multiple continents large-scale eco-remediation operations are successful[19]. Biological materials are renewable by definition: they grow. Unfortunately this quality is sometimes undermined: trees are being cut down for wood at a far greater rate than they are replanted[20]. Furthermore, dramatic efficiency improvements can be achieved in the cultivation of biological materials by choice of different crops[21] and harvesting techniques. Technological materials are presenting us with far more serious challenges. For several chemical elements the depletion of their mineral reserves will be reached in the two decades to come (see Figure 2). Without a doubt prices will rise significantly on the mid to long term, whilst showing large fluctuations due to uncertainties. The only sustainable way forward is developing improved recycling and upcycling techniques.

For each of the resources the question is if, and if so, how the objective of a positive footprint can be met. This provides us with some challenging research questions. The research projects proposed in the last part address some of the most urgent ones.

New Business models

As a result of the abovementioned developments new business is emerging: design and development of new materials, components and products – that can be restored in the original constituent parts – as well as processes and services that enable full recyclability. The associated investments lead to new business models in which the ownership of renewable materials remains with the producers. The materials are provided for a defined period of time in what is -in fact- a material lease construction. At this moment track and trace systems and 'circularity passports' are being developed to safeguard the value of materials now and in the future, for example in the Horizon 2020 project: 'Buildings as Material Banks'.

Social values and health effects

A positive footprint for energy, water, materials and top soil relates to the users of these resources: all of us, here and there, now and later. Therewith it is first and foremost a *social* transition. But what this entails exactly, and how to anticipate it, is not immediately clear. In any case, the social aspects will have to be better integrated in the business – or: value – models of the construction sector. An instrument such as 'social return on investment' can be of assistance to secure the social added value of propositions and interventions. This ranges from e.g. stakeholder involvement, procurement policy and transparency to health, comfort and environmental effects. Traditional market mechanisms and earning models fall hopelessly short in this respect.

A lot is going on in this area, at various levels of interest. An example is the immense increase of decentralized generation of renewable energy, as described by Rifkin[7], which is in fact a democratization of energy generation. While existing structures are based on centralized generation and decentralized consumption, the emerging trend is decentralized generation of a substantial part. This transition increasingly takes shape through local cooperatives, which simultaneously promotes the social coherence in a neighborhood.

The fossil fuel industry encounters problems in terms of overcapacity, net problems and reserve capacity. Criticism from this industry regarding the 'subsidization' of renewable energy sources ignores the externalized hidden costs that the fossil fuel industry has forced upon society during its entire existence. An estimation of these costs can be found in a working paper from the International Monetary Fund: it amounts to 5.3 E12 $/y[22,23,24]. This equals 9 Million € per minute.

Furthermore, many materials that are used in our society contain harmful substances for our health. Emissions in our indoor environments and exposure to fine particulate matter by industry, building activities and traffic shorten our statistical life expectancy[25]. Such observations may sound quite technical but are of course based on real life experienced negative effects (health problems, nuisance in smell, noise, visual discomfort etc.). Reduction of these hazardous elements in materials is an important step towards a sustainable society.

Functions and applications in the built environment are often very suitable to contribute positively to our living environment. For example, plants, trees and mosses are able to intercept or even metabolize fine particles, coatings exist with air cleaning properties, and harmful contaminants can be eliminated by positive micro-organisms[26].

Competition between energy and materials cycles on one hand, and the production of food on the other should be prevented at all costs. A well-known example is the production of 1st generation bio-fuels, such as corn. Violent protests broke out in Mexico after the price of tortillas quadrupled in 2007, supposedly as a result of increased demand for corn from the USA for bio-fuel production[27]. Such price increases will first and foremost harm the poorest people on earth, leading to famine and increased poverty. Circularity as a concept can help to avoid an increase in the demand for such bio-fuels, whilst safeguarding sufficient arable land for food production.

Other aspects related to the concept of circularity and renewability are potential positive effects on employment and working conditions on the one hand, and increased flexibility for building owners and occupants on the other.

Beyond Sustainability and Cradle to Cradle®

Some of the ideas in this paper are consistent with or inspired by ideas from Cradle to Cradle ®. Up until now no building can claim a C2C-status, but a building that has positive footprints regarding all four resources, while honoring the mentioned ecological, economic and social challenges will be well on its way.

Necessary Research

Starting points

1. All four resources renewable or from renewable sources.

2. Effects on ecology, economy and equity as a framework to assess the desired developments.

3. Urban development areas as testing grounds.

4. Securing interdisciplinary collaboration.

Research themes/questions

1. Energy, materials and use of space

Generation, conversion, transport and storage of renewable energy in the form of heat, electricity or specific energy carriers cannot be seen detached from the required materials, the invested embodied energy, the desired circular use, as well as the land use for these systems. Various scale levels should reinforce one another.

- What is the relation between energy at building or district level?
- What is the relation with circular use of materials?
- Is the use of space a limiting factor?
- What is the added value of an exergy approach?

2. Water, top soil and food production

Strong links exist between water use, water quality and food production. Urban Agriculture is increasing, for example by means of *Building Integrated Greenhouses,* whether or not in combination with fish farming. Mutually beneficial cycles are applied here, which reinforces surrounding business cases.

- What is the potential of urban agriculture?
- What can be the role of local water treatment systems?
- What are the effects on biodiversity and top soil?
- Does this development contribute to a better air quality?

3. Circular Economy

Circularity, on its own, is not the objective, but renewability of natural resources is. For energy, the source should be renewable, such as: solar energy (including wind, tidal, hydro, and biomass) or geothermal energy. For all other resources renewability should be pursued by approaching all flows (water, materials, nutrients, and waste) as part of ongoing cycles, not as separate consumption flows. Improved recycling or even upcycling will come with added energy input and costs. Processes that reduce value must be phased out or eliminated and process steps that increase value need to be added.

- How can energy, water, food and waste flows work together and reinforce one another in a circular economy?
- How can business models help to prevent future shortage of materials?
- Which techniques/innovations and business models are best suited to facilitate a circular economy? (See also[28]).
- How can we best take the lead in an international context?
- How do the Internet of Things and Building Information Modelling fit in?

4. Society

Sustainable developments are influencing the way society evolves. Individual citizens are increasingly generating their own renewable energy, and technologies like additive manufacturing allow them to become material producers. A shift occurs from ownership to 'usership', promoting a sharing economy. The system of capitalism/socialism might change into one of communality[29], reducing free-market forces and the role of governments, whilst increasingly measuring success through acquired social capital.

- How can we reduce negative health effects?
- How can these developments contribute to livable cities?
- How can we use this to stimulate creativity?
- How to attract and integrate other fields of expertise, such as Psychology, Sociology, and Marketing?
- How to use Big Data to our advantage whilst protecting our privacy (see also[30]).

[1] World Health Organization:
http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/

[2] Worldometers: http://www.worldometers.info/world-population/

[3] http://ourfiniteworld.com/2012/03/12/world-energy-consumption-since-1820-in-charts/

[4] Welt im Wandel, Energiewende zur Nachhaltigkeit. Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen. ISBN 3-540-40160-1.
http://www.wbgu.de/fileadmin/templates/dateien/veroeffentlichungen/hauptgutachten/jg2003/wbgu_jg2003.pdf

[5] http://www.peakoil.net/publications/peer-reviewed-articles

[6] BEE Plattform Systemtransformation 2012 Das BEE Szenario Stromversorgung 2030 Björn Pieprzyk:
http://www.bee-ev.de/fileadmin/Publikationen/Studien/Plattform/BEE-Dialogkonferenz_Szenario-Stromversorgung-2030_BEE-Pieprzyk.pdf

[7] J Rifkin, The Third Industrial Revolution. ISBN: 978-0-230-34197-5

[8] Mineral Commodity Summaries 2015, US Dept. of the Interior, US Geological Survey:
http://minerals.usgs.gov/minerals/pubs/mcs/2015/mcs2015.pdf

[9] WWF: https://www.worldwildlife.org/threats/soil-erosion-and-degradation

[10] M Braungart, W McDonough, Cradle to Cradle: Remaking the Way We Make Things, 2002. ISBN: 0-86547-587-3

[11] Story of Stuff: https://www.youtube.com/watch?v=9GorqroigqM

[12] P Mobbs: http://www.fraw.org.uk/mei/current/ecological_limits.shtml

[13] A Diederen, Global Resource Depletion, Managed Austerity and the Elements of Hope, 2010. ISBN: 978-90-5972-425-9

[14] The Encyclopedia of Earth: http://www.eoearth.org/view/article/150977/

[15] MN Fisch, Energy Plus. Buildings and districts as renewable energy sources. ISBN: 978-3-00-041246-2

[16] http://openbuildings.com/buildings/covent-garden-profile-3744

[17] Pharmafilter: http://www.pharmafilter.nl/en/

[18] http://www.thehenryford.org/rouge/teachers.aspx
(21st Century Ford Rouge Factory –Environmental Innovations at the Rouge)

[19] https://www.youtube.com/watch?v=YBLZmwlPa8A

[20] MF Ashby, Materials and the Environment. ISBN: 978-1-85617-608-8

[21] http://www.bioenergy.wa.gov/oilseed.aspx

[22] International Monetary Fund, WP/15/105, How large are Global Energy Subsidies?

[23] JP van Soest en F Rooijers, Overheid stimuleert het gebruik van fossiele energie. NRC, 2015 05 23, O&D p. 9.

[24] The Guardian: http://www.theguardian.com/environment/2015/may/18/fossil-fuel-companies-getting-10m-a-minute-in-subsidies-says-imf

[25] European Environmental Agency, Loss of statistical life expectancy attributed to anthropogenic contributions to PM2.5, 2000 and 2020.
http://www.eea.europa.eu/data-and-maps/figures/loss-of-statistical-life-expectancy-attributed-to-anthropogenic-contributions-to-pm2-5-2000-and-2020

[26] Bioorg: http://www.bioorg.eu/

[27] L Sherriff (2007), “Bio-fuels trigger tortilla price bubble”, The register, 1 Feb. 2007: http://www.theregister.co.uk/2007/02/01/tortilla_bubble/

[28] Model Behavior, 20 Business Model Innovations for Sustainability. SustainAbility, February 2014.

[29] J Rifkin, The Zero Marginal Cost Society. ISBN: 978-1-137-27864-3

[30] A Pentland, Social Physics. ISBN: 978-1-59420-565-1