655: Towards closed cycles - New strategy steps inspired by the Cradle to Cradle approach

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Abstract

The three steps strategy or Trias Ecologica has been a commonly accepted guideline for sustainable building. Despite 20 years of use, the Trias has not brought the built environment to the desired sustainable state. Time for an update?
Although not original in all of its contents, 'Cradle to Cradle' (C2C) is a fresh wind blowing through the building industry in various countries. The C2C philosophy can be converted most clearly to materials and products. Nevertheless and more importantly, it can also be good basis for sustainable projects on a larger scale, such as buildings and districts. In these cases energy, water and material cycles can be closed through interconnected loops.
The paper discusses a new strategy of steps inspired by Cradle to Cradle, which will replace the Trias Ecologica as a more effective means toward sustainability. This will be exemplified through discussion of the approach and solutions for the C2C project of Park2020, Hoofddorp, the Netherlands.

Keywords: Trias Ecologica, Trias Energetica, Cradle to Cradle, New Steps Strategy, closing cycles, living machine

1. Introduction

1.1 End of the Trias Ecologica

Since the late 1980s the three steps strategy or Trias Ecologica has been the commonly accepted guideline for sustainable building. It was introduced for a step-by-step approach to sustainable building: 1: reduce the demand, 2: use renewable resources, 3: solve the resuming demand efficiently and clean. The Trias has a few versions, of which the Trias Energetica is best known [1].
Although straightforward in its intention, the first and third step of this strategy are often mixed up in practice. Moreover, it has not brought the built environment to the desired sustainable state: by 2002, the environmental performance of office buildings was still lagging for sustainable development [2]. In particular the penetration of sustainable energy is dissatisfying. A possible cause is an early introduction of expensive sustainable resources in the Trias, when the demand may still be reduced by other interventions.
Therefore, after 20 years of useful service it seems necessary to rephrase the Trias Ecologica. However, until recently there was no real incentive to do so.

1.2 Cradle to Cradle

It was in 2002 that William McDonough and Michael Braungart introduced their theory through the book 'Cradle to Cradle' (figure 1) based on closing material cycles and leaving nothing but food in the final stage of a lifetime [3]. The Cradle to Cradle (C2C) message is a fresh wind blowing through the building industry in various countries. It has renewed the green ambitions of commercial parties, whereas the 1990s can be characterised as a government-directed era of sustainable building.

Fig 1. Sleeve of the Cradle to Cradle book

The C2C theory can be exemplified most clearly by materials and products. The examples given by the authors of buildings, districts and urban plans seem to be a summary of incorporated C2C products rather than the use of these scales as entities of their own, with additional potential to become more than sustainable. Cradle to Cradle lacks a systematic approach to other issues.

1.3 A new strategy

Although mainly inspiring by its examples of products, the C2C philosophy can be a challenging basis for sustainable projects on a larger scale than products and for other aspects than just materials. Meanwhile, it can provide the ingredients for an enhanced step-by-step strategy for a more profound way of sustainable building. The key lies in supply of renewable resources better closed technical cycles, and output of digestible waste.

1.4 Opportunities at a larger scale

The first projects with a C2C intention on the district and urban level, and even higher, are in preparation or under development. As a whole, they are much more complex than materials or products alone, but due to this complexity they also enable to close energy, water and material cycles through interconnected loops. This provides the opportunity to translate Cradle to Cradle to a large-scale strategy.

2. Toward a new strategy

2.1 "Less bad is not good enough"

One of the provoking quotes from Braungart and McDonough is "less bad is not good enough", attacking the current approach of mitigation. Figure 2 is a schematic illustration of the idea. Buildings on the one hand use energy, water and materials and on the other hand produce different flows of waste: waste heat, waste water and waste material. These are usually dumped, incinerated or re-used in lower-graded functions. In the case of 'less bad' these flows are reduced to smaller amounts, but in time this will inevitably also lead to heaps of waste.
The mitigating step of figure 2 is worthwhile and even essential, but it is not enough.

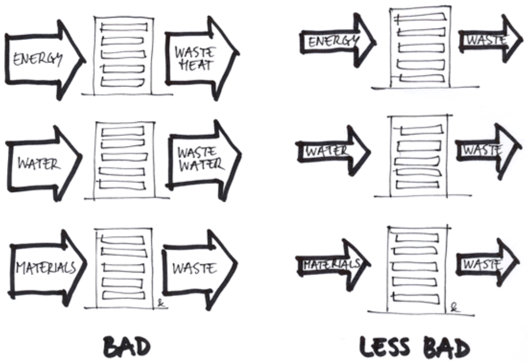

Fig 2. Schematic illustration of the starting condition of a non-sustainable building (left) and the current approach to sustainability by making these flows smaller (right)

2.2 Good

The problem of significant resuming input demands and dysfunctional output flows can only be tackled by means of recycling. Recycling and reuse is usually considered in the same cycle:

- waste heat to be used in the energy cycle
- waste water to be used for the water demand
- waste material to be used in new materials

However, the recycling principle can also apply to other cycles:

- waste heat to water
- waste heat to materials
- waste water to energy
- waste water to materials
- waste material to energy
- waste material to water

Figure 3 illustrates this idea. Each of the arrows can be exemplified by technical measures that enable the recycling into another cycle.

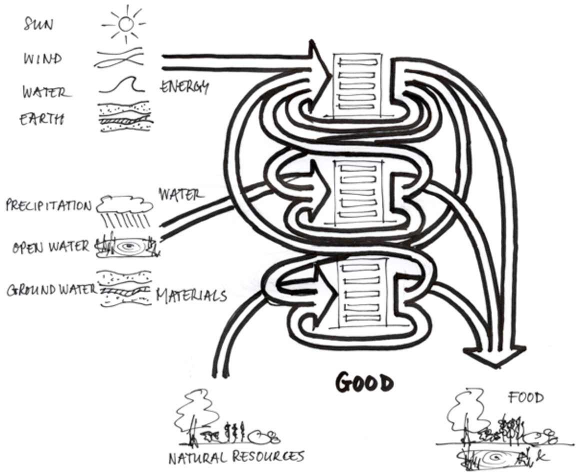

Fig 3. A system where energy, water and material cycles are closed are knotted together.

The combined arrows of figure 3 going in and out of the building seem thick but they actually are equal to what resumes from the mitigation step (figure 2) that led to thinner arrows in the first place. The key message of figure 3 is that an even smaller demand for resources remains on the left hand side and an equally smaller produce of waste to the right.
The consequence is that the resulting demand can be solved by sustainable resources for smaller costs, hence much easier. In addition, if the resulting waste flow is 100% clean and 'food' to the environment, a closed cycle will have been established of natural resources into the technical sphere and back to nature.

2.3 The New Steps Strategy

A step-by-step approach can be proposed based on the previous deduction. From a traditional building this New Steps Strategy commences with the reduction of the demand by smart design of the building (which is more than just insulating well), followed by the recycling of waste flows (internally and externally) and finally by supplying renewable resources and letting only clean and nutritious waste to nature (see figure 4).

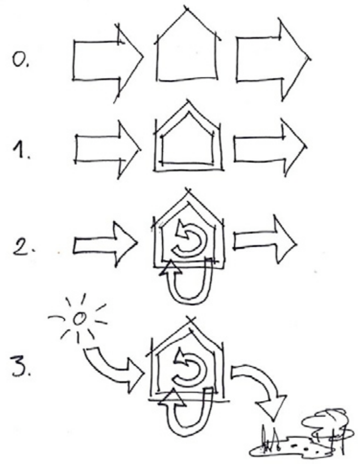

Fig 4. The New Steps Strategy: 1. reduce the demand, 2. reuse and recycle, 3a. supply the resulting demand sustainably and 3b. let waste be food.

Whilst step 3 is divided between the in- and out-flow, step 2 can be divided into potentially six sub-steps, when taking into account energy, water and materials.

2.4 Systematic approach

The steps of the New Steps Strategy can be converted to seven main stages in the cycle, of which figure 5 depicts five:

2. recycle internally
3. collect waste water and waste material
4. process waste water and waste material in a central treatment plant
5. re-use the effluent of this in the building
6. supply the resuming demand

This is without the first and last stage: reduce the demand by smart design and let waste be food.

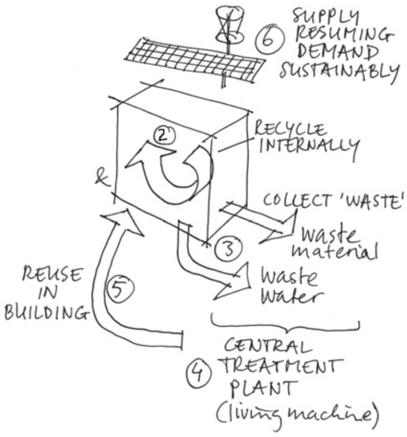

Fig 5. Illustration of stages 2 to 6 of seven in total (not shown: 1. reduce the demand + 7. waste = food).

2.5 Smart planning and design first

Before we skip it, the first step of all strategies mentioned is the most important one. It relates to buildings as well as urban plans and refers mainly to passive design measures that do not require auxiliary energy for operation.

Essential definition in this case is smart & bioclimatic design. The meaning of smart design and specifically smart architecture has shifted towards sustainable designs that intelligently interact with the environment [4]. Bioclimatic design was defined by the Malaysian architect Ken Yeang [5]: "the passive low-energy design approach that makes use of the ambient energies of the climate of the locality (including the latitude and the ecosystem, through siting, orientation, layout and construction) to create conditions of comfort for the users of the building". The combination of both terms – smart and bioclimatic design – is defined as "a design approach that deploys local characteristics intelligently into the sustainable design of buildings and urban plans" [6].

Smart & bioclimatic design commences with a profound analysis of local circumstances (the climate, seasonal changes, variety of the weather, diurnal differences, geomorphology, etc. – figure 6) yet also to man-made interventions (the landscape, cultural, historical and technical features, and the built surroundings).

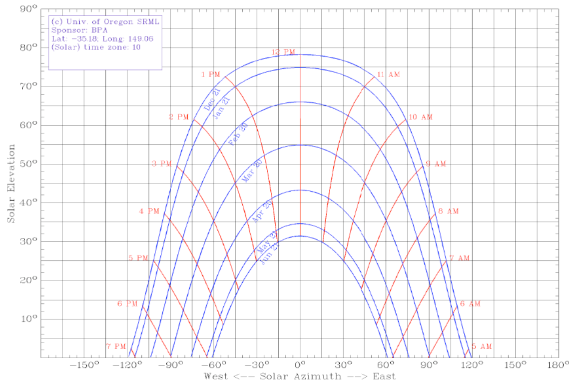

Fig 6. Solar chart for Canberra, Australia, showing the solar azimuth and elevation through the months [7].

When done thoroughly, this leads to clear boundary conditions for the building site (figure 7) and an optimally sited, oriented and shaped building through which the initial demand for resources has been reduced to a minimum.

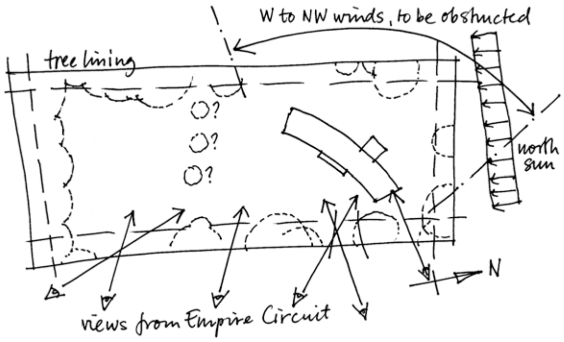

Fig 7. Urban boundary conditions for the new Dutch embassy in Canberra, Australia [9].

Specific measures can be taken to the building skin, depending on temperatures, solar properties and the orientation (figure 8).

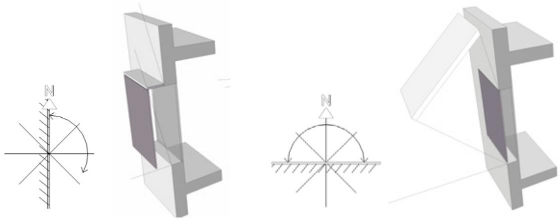

Fig 8. Orientation-bound façade concepts based on obstruction of direct solar radiation in Australia [8].

3. Case study

3.1 The C2C boost

For the Netherlands, as an English book with no pictures, Cradle to Cradle led a submersed life until a Dutch documentary was made with the title of 'Waste=food' [9]. This was the catalyst for an unprecedented uprise of ambitions exceeding the government-triggered sustainable projects of the 1990s. Every municipality, developer or principal with the desire to be considered green wanted their projects to become 'cradle to cradle', an acronym with no clear definition. Playing at a larger scale than the examples from the book these C2C projects encountered complications and challenges. One of these projects will be discussed below.

3.2 Park 20|20

For one of the commercial district-scale projects in the Netherlands, Park2020 in Hoofddorp (the Netherlands), Cradle to Cradle was a rudimentary requirement by the municipality. The programme predominantly contains offices yet also involves a hotel and conference centre. William McDonough + Partners drew a crude urban plan (figure 9). Delta was invited to develop the project. A consulting company was asked for the technical concept, and they hired experts to help them.

Fig 9. Artist's impression of McDonough's Park 20|20 [source: Delta Project Development].

This could have been a tricky business, for there was no experience with Cradle to Cradle, let alone with the use of the C2C vision on a district scale, but as it turned out, the experts came up with a promising plan that potentially goes beyond the C2C examples limited to materials.

3.3 Approach

For Park20|20 the New Steps Strategy was used to close energy, water and material cycles. Since the urban plan was already fixed, which meant a restriction for an optimal plan, the proposals started with general recommendations and design ideas for the buildings.

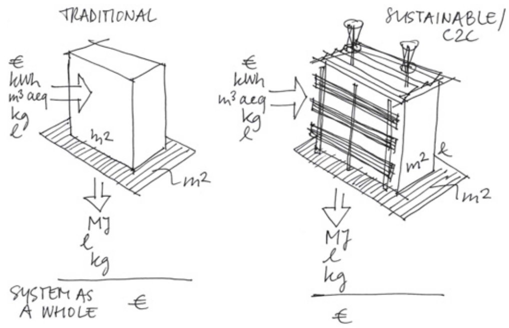

Fig 10. A traditional and sustainable/C2C building compared financially as a system rather than on the basis of separate measures

As with all commercial projects, the financial side to this ambitious project was kept in view from the very beginning. An important shift in mindset was achieved by the recognition of a holistic view on investments and returns. This implies that measures cannot be considered separately, yet should be taken into account all together and compared to traditional plans only in the end, when all benefits and costs are in focus (figure 10). This is the only way that communal facilities, which are needed when striving for an affordable cradle to cradle plan, can be seriously considered.

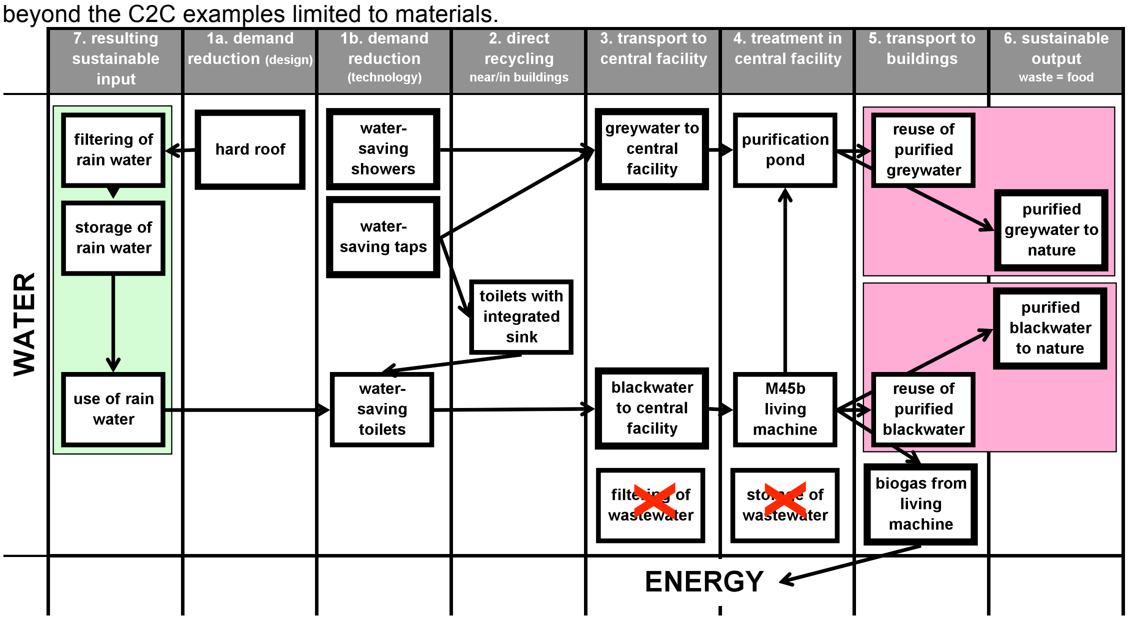

Fig 11. Measures; in this case for water, organised by stage of approach and logically connected.

According to figure 5 the different stages of energy, water and material flows were made explicit by extensive lists of measures, organised by their place in the approach stages (figure 11). These measures were analysed in terms of environmental and financial costs and benefits and schematised to a scheme of largely inter-connected chains (figure 12, next page). These chains formed the basis for the calculation of effects in terms of energy and finances.

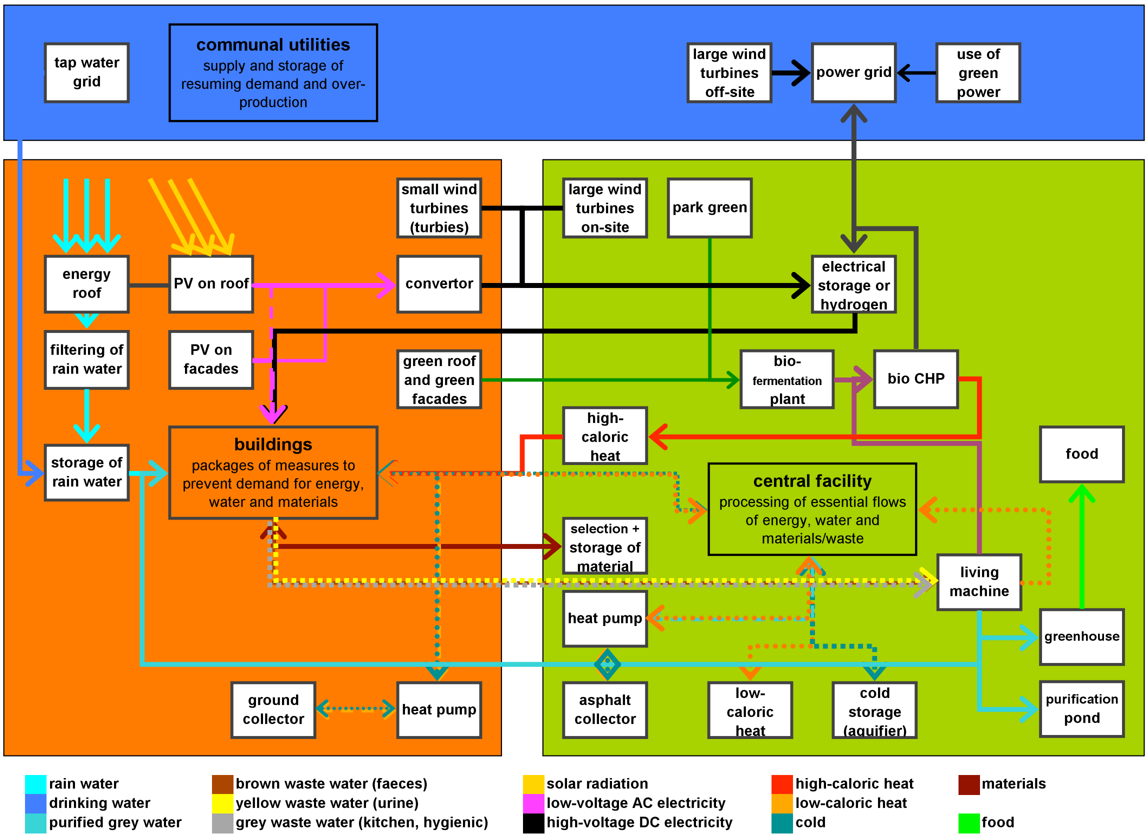

Fig 12. Chains of measures for Park 20|20; external (above blue), buildings (left, red), central facility (right, green)

3.4 The central facility

The central facility plant of technical and natural utilities is essential to the success of a plan such as Park 20|20 is, as it enables the treatment and reprocessing of waste flows. It is financially not feasible to establish this on the scale of a separate building, whereas the city as a whole is too big a size for transport of multiple resources and waste. For cities as a whole, the solution of centralised supply and treatment of waste may be most appropriate under current conditions. The ideal scale for local self-processing of energy, water and material cycles seems to be the district, where communal investments can be tackled but distances are still relatively short. This is supported by findings by Timmeren [10].

For Park 20|20, the central facility performs a number of communal purposes:

- heart of the sustainable infrastructure
- collection of waste materials that can still be reused
- treatment of waste water ('Living Machine')
- digestion of green waste from the buildings and park, production of biogas
- generation of heat and power from biogas
- storage of hot and cold in aquifers
- heat exchange with the shallow underground
- storage of heat in insulated containers
- management of energy, water and material flows (including a hot and cold water circuit)

In particular, although existing as a concept since the 1970s, the Living Machine is a new asset to the Dutch sustainable building market, as would be the central management of different flows in the area.

3.5 Performance

In April 2008 the entire team of developer, architects, consultants and treasurers gathered to elaborate on the crude plans that had been made so far. In a two-day session the C2C system to be applied in Hoofddorp was further improved and the list of measures was calculated on various effects. The scheme of figure 12 was used to calculate energy and financial performance of the system proposed. I will only discuss the energy part of it.

The energy potential from heat and cold storage in aquifers, in addition to an underground heat pump system, could be determined relatively conventionally by energy utility specialists. However, key to the project was the yield of energy from the central facility plant with its Living Machine. This plant treats the following types of organic waste:

- Toilet flush water from the offices and hotel
- Vegetable and fruit waste from the restaurant kitchens and the hotel
- Organic waste from the park and gardens.

For each flow the expected input was calculated on the basis of projected future usage figures.

These were consequently converted to methane quantities from biogas through the fermentation process.

All in all, the central plant could produce 53,600 m^3 of methane, on the basis of which a combined heat and power plant would produce 210 MWh electric and 1132 GJ heat. The heat accounted for approximately 10% of the initial unsustainable demand, but the remaining heat could be easily solved by means of heat recovery systems and heat exchange with the underground. The electricity yield equalled around 20% of the expected demand. In this case, however, additional power-producing devices such as PV panels and small wind turbines could not add up to the full demand. Approximately a quarter of the demand remained unsupplied. If this demand were to be solved sustainably it would need to be covered by green power from elsewhere.
This is a general problem: decentralised provision of electricity becomes difficult in the case of high densities, since energy from sun, wind and biomass require space (especially roof or ground surface). Therefore intensive urban plans will always need some extent of centralised power usage under the present luxury demand for electricity in the western world.

4. Conclusion and discussion

Cradle to Cradle (C2C) projects require different development processes than traditional ones. This is due to the novelties to be incorporated yet also to the collaboration which is necessary to make ends meet.
Reinventing the wheel seems a useless exercise but sometimes old ideas (as of the 1970s) may be given a new jacket to become attractive to a yet unwilling audience. Although C2C offers more than just old ideas, this is approximately what happened when referring to the ideas of closing cycles and procuring clean manufacturing processes.
The philosophy is particularly valuable as a means to refresh the old Trias Ecologica approach to sustainable building. The New Steps Strategy as presented in this paper does not offer completely new ideas but rephrases and reorders them, enabling better coverage of demands by sustainable resources and complying with the "waste equals food" principle. When using this strategy, the C2C philosophy can be extended to a larger scale than just the product and involve other flows than just materials. The final picture of such a system is more complex, but the underlying methodology is transparent.
The first projects that intend to tackle large-scale developments in accordance with C2C are promising, although they are still under development and need to live up to the expectations. Open-mindedness and honest monitoring of these forerunner projects would be the essential to future projects. On the other hand, a preliminary negative verdict should also be discouraged, in order to give way to new ambitious developments. After all, old methods have not led to the desired result.

5. References

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