Embodied Land

to measure Maximum energy + materials performance

The District of Tomorrow.

A “District of Tomorrow” is constructed in the science and business park Avantis, on the German-Dutch border near Heerlen – Aachen.
Four buildings, each year one and each more ambitious than the previous one : energy producing, and up to 100% made of renewable and recycled materials, partly grown in the garden.
The (small) district itself, should be 0-energy as well, and produce and clean its own water. Together with developing a 0-impact district, and a learning and research environment for the students, market stakeholders and the region together.
Its a project initiated by Zuyd University and coordinated by RiBuilT, the Research Institute Built environment of Tomorrow. Its part of a Transition program for the region, to cope with climate change, fossil fuels depletion and resource scarcity. It becomes very special due to the fact that Students design the projects (the winning design form the University graduation projects) and is constructed by pupils of construction schools.

Existing District of Tomorrow

A sister project is a district for ambitious re-development of existing districts. A first pilot was the 0-energy renovation of 150 row houses. With prefabricated wooden façade and roof elements. In 10 days per house, inhabitants stayed at home during the work. The façade and roof elements are now studied within the IMDEP research project, for optimization using MAXergy to detail the elements: calculated for instance is the optimum between amount of insulation, versus amount of PV panels, by Embodied Land.

0-materials house

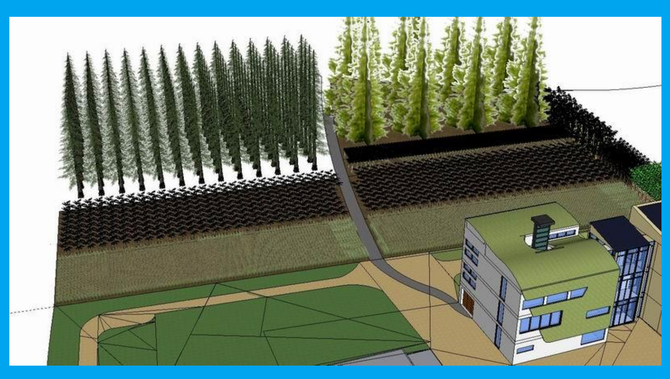
The 4th house in the new district has the ambition to be fully constructed from renewable materials. That will be re-grown in the garden behind the house. The house will produce it own materials over its life time, which is similar to a 0-energy house, that produced its own energy during the operation. This way we will have the 1st 0-materials house in the Netherlands and probably Europe.

100% biobased house

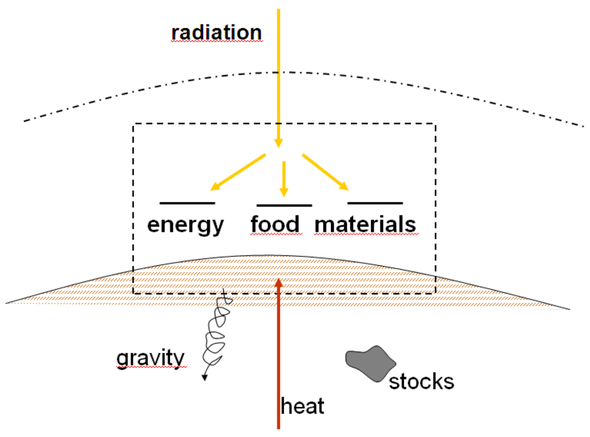
In fact renewable materials, and sometimes produced via industrial process like in the biobased industry, is also a 100% biobased house: we aim at producing alternatives for every element form biobased resources, also light switches, sanitary equipement etc. It is therefore a 100% biobased house, a showcase for the biobased economy.

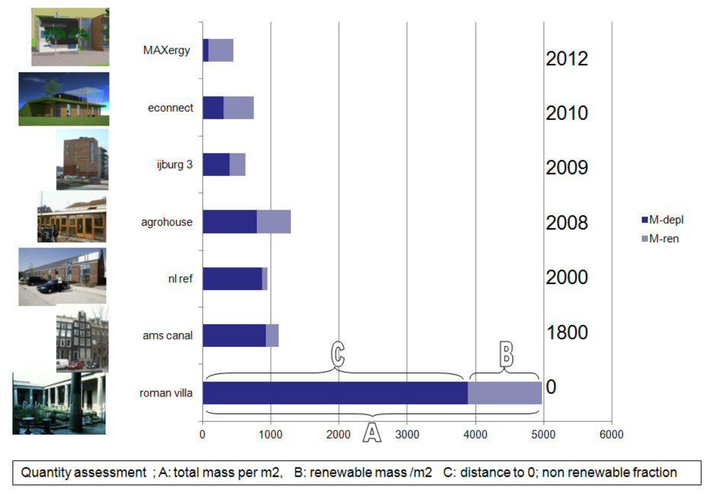
0-exergy house

if we not only would add a materials garden, but also enough solar pv panels to compensate for all energy production capacity involved in materials fabrication and restoring of metals and minerals, it would be a 0-exergy building: one that does not increase the entropy within its borders. However for the moment this is not foreseen.



1. As with kWh for energy, you can indicate materials quantities by kilograms , and compare for instance buildings. But what about the quality of materials? And how to evaluate energy performance with their materials impacts? The Questions is how to overcome imperfections of current ways of assessment:
A By avoiding use of weighting factors, to combine different resource impacts
B Not to relate to a (bad) benchmark, but by indicating the (distance to the) ideal situation where both energy and materials impacts are compensated within the time of use
C to evaluate the whole resource chain, not starting from accidently availability of resource stocks, like fossil fuels.



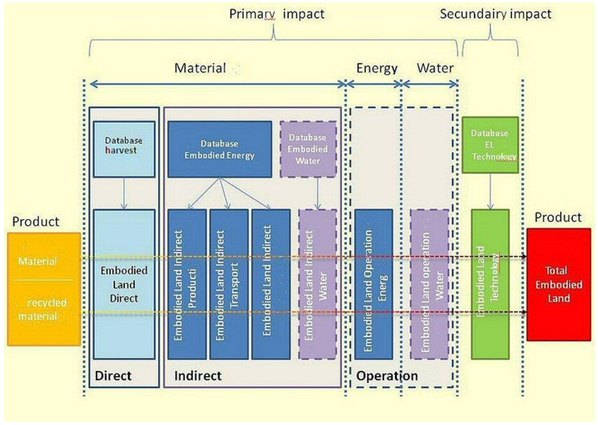


Quantity assessment ; A: total mass per m2, B: renewable mass /m2 C: distance to 0; non renewable fraction

2. Where do the resources come from in any system? If they come from inside the system, eventually you will run out of resources. If you get them from your neighbors, they will run out faster. The only free resource outside of the system is the sun, sending out radiation into the system that can be captured and converted into food, energy and materials. In order to do this, you need land area to produce a certain quantity and quality over a period of time. That’s the basis for the MAXergy approach and the Embodied Land calculation model.*

“There is no difference between non renewable and renewable: all resources are renewable, only the route along which they are regenerated differs: by nature or by mankind

3. The principle of MAXergy is to relate all the resources to the amount of solar input needed to generate these resources via the land area needed to capture and convert the solar radiation into useful resources. In other words, to maximize exergy in a system and to prevent the loss of exergy (increasing entropy). The resources used from within the system are therefore required to be restored again within the lifetime of their use. To do this, land area needs to be reserved so that the future availability of the resources is guaranteed. The amount of land area involved is referred to as Embodied Land.



flax fibres (vlas) for insulation material	2.000	kg/ha-year
flax shives for partile board / flax board	3.000	
flax linseed for linoleum	1.500	
straw	4.000	
roof reed (dry)	6.500	
sheep wool	29	
hemp	3.500	
wood	10.800	
bamboo	36.000	
cork	125	
shells	245	
loam	1.000	
sand	1.000	

Table 1 Energy-input for extraction of metals from . Authors, re-calculated from Bardi (2010)

Element	Total mass in oceans (tons)	Mass of sea water to be processed (tons) for 1 kg	Energy input (MJ/kg)
Lithium	$2.31x10^{11}$	5.600	50.400
Molybdeen	$1.30x10^{10}$	100.000	900.000
Uranium	$4.29x10^{9}$	303.759	2.733.835
Vanadium	$2.47x10^{9}$	525.597	4.730.375
Cadmium	$1.43x10^{8}$	9.095.477	81.859.296
Gold	$1.43x10^{7}$	90.800.000	817.200.000
Tin	$3.64x10^{8}$	3.566.667	32.100.000
Nickel	$8.58x10^{8}$	1.511.236	13.601.124
Copper	$1.17x10^{9}$	1.108.974	9.980.769
Manganese	$5.20x10^{8}$	2.500.000	22.500.000
Zinc	$6.50x10^{8}$	200.000	1.800.000
Aluminium	$1.30x10^{9}$	1.000.000	9.000.000
Chromium	$2.60x10^{8}$	5.000.000	45.000.000
Lead	$3.90x10^{7}$	33.239.437	299.154.930
Iron	$4.42x10^{9}$	294.248	2.648.230
Titanium	$1.30x10^{8}$	45.409.836	408.688.525
Cobalt	$5.07x10^{8}$	2.552.167	22.969.502

4. For a building it adds up to:
- The amount of land occupied over a certain period of time needed to install solar panels that generate the required energy (x m^2 year)
- The amount of land used for growing crops that are used in building materials like wood, hemp, flax, bamboo, etc (y m^2-year)
- The Embodied Energy to process the materials and the land area to generate this required energy.
- The use of minerals and metals are compensated by calculating the energy, in land and time, to reproduce/restore the mineral/metal from a dispersed sink like seawater

“Materials (and energy resources) are not sustainable or un-sustainable: Its their use, , and their impact in time and space, that decides if their use is sustainable or not .”

Example 1 MAXergy house

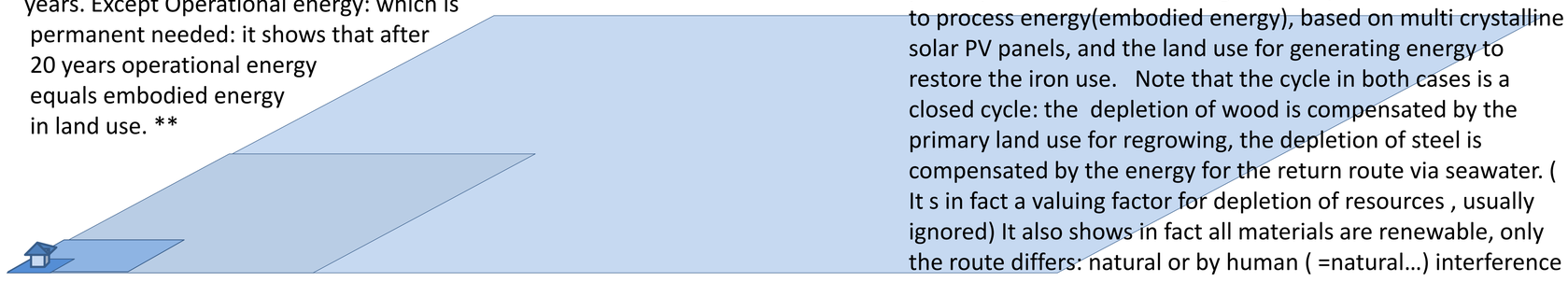
The 4th house to be constructed in the District of Tomorrow, will be optimized by MAXergy and Embodied Land calculations. The total embodied land for this building, per m2 floor , is 5,62 ha-year. If we take only the fraction of renewable materials (82% of the building) the EL per m2 floor is 0,08 ha-year . The Embodied Land for the embodied energy in the materials, per m2 floor, is 0,000929 ha-year or, 9,29 **m2**-year . The operational energy is 0,000053 ha-year , or 0,53 **m2**-year (half a m2 solar panel per m2 floor) : If the lifetime of the building is 50 year, it could be divided by 50, to be reproduced over 50 years. Except Operational energy: which is permanent needed: it shows that after 20 years operational energy equals embodied energy in land use. **

Example 2 beams compared

met versie 1.0
steel and wood beam adapted for comparable load (carry floor section)

m2 (-year)		Emb Land, Ren. Energy based				without return or prim. harvest EL is only EL from EE	Embodied energy in MJ
	kg	EL-harvest	EL -emb.energy	EL-return energy	TOTAL EL-RE		
steel beam	18	0,002	255	19130681,00	**19130936,0**	255	630
wood beam	11,3	23,8	33,4	0	**57,2**	33,4	83,25

A basic way to use Maxergy is to compare for instance the use of a wooden beam versus a steel beam (this way only materials impact are evaluated, no operational energy). The table shows: primary land use for harvesting material , the land use related to process energy(embodied energy), based on multi crystalline solar PV panels, and the land use for generating energy to restore the iron use. Note that the cycle in both cases is a closed cycle: the depletion of wood is compensated by the primary land use for regrowing, the depletion of steel is compensated by the energy for the return route via seawater. (It s in fact a valuing factor for depletion of resources , usually ignored) It also shows in fact all materials are renewable, only the route differs: natural or by human (=natural…) interference



- there is also a little bit of gravity you can use sometimes in hilly areas).

** these calculations are made by version 0.9. Which had not included the impact of PV panel production, both for operational energy as for embodied energy in construction materials, this is added in version 1.0 and increases the outcomes.

More background in:
Rovers R. 2009, Material-neutral building: Closed Cycle Accounting for building Construction, paper SASBE conference, Delft, The Netherlands 2009
Rovers R. Et all, 2010, 0-material building: space time analyses, Sustainable Building 2010 conference Maastricht
Rovers R. et all, 2011 , Designing for only energy: suboptimisation. PLEA conference 2011 Louvain la neuve, Belgium
Rovers R. , 2012 , Evaluation of 0-materials house design , PLEA conference 2012, Lima, Peru.

RiBuilT THE CONCEPT OF ZERO

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