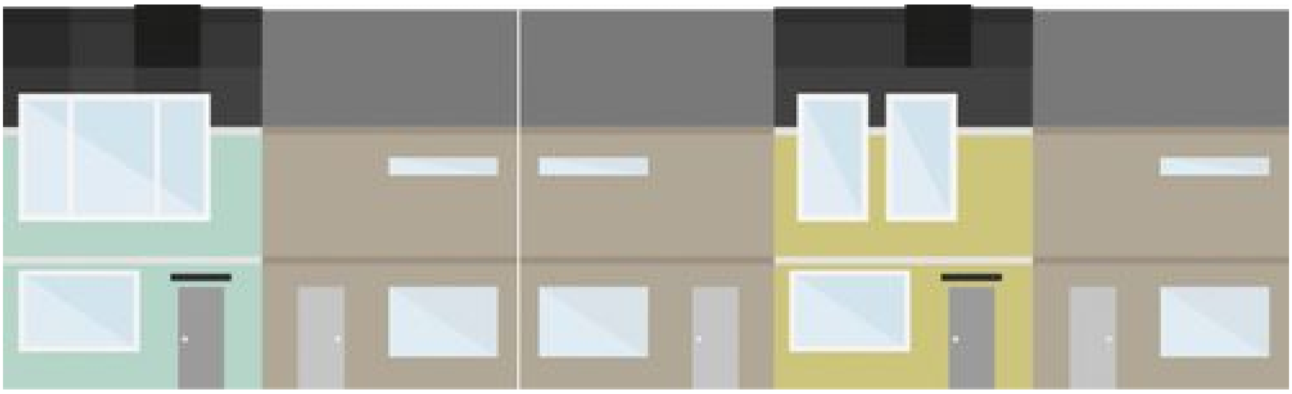


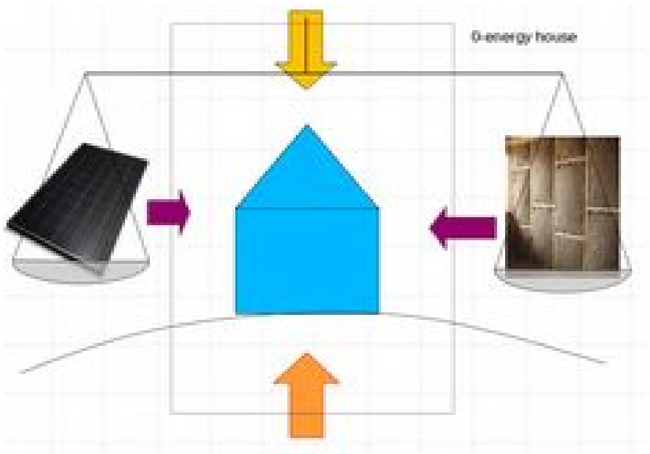
Rapport More-Connect

Deliverable 3.2: Tool to optimize the combined energy and materials performance of the alternative configurations in relation to local typologies

(WP 3.4)

CO2 emissions reduction, 0-energy and embodied energy indicators.
Version 1.0

R.Rovers January 2017
Huygen Adviseurs & RiBuilT, by SBScentre

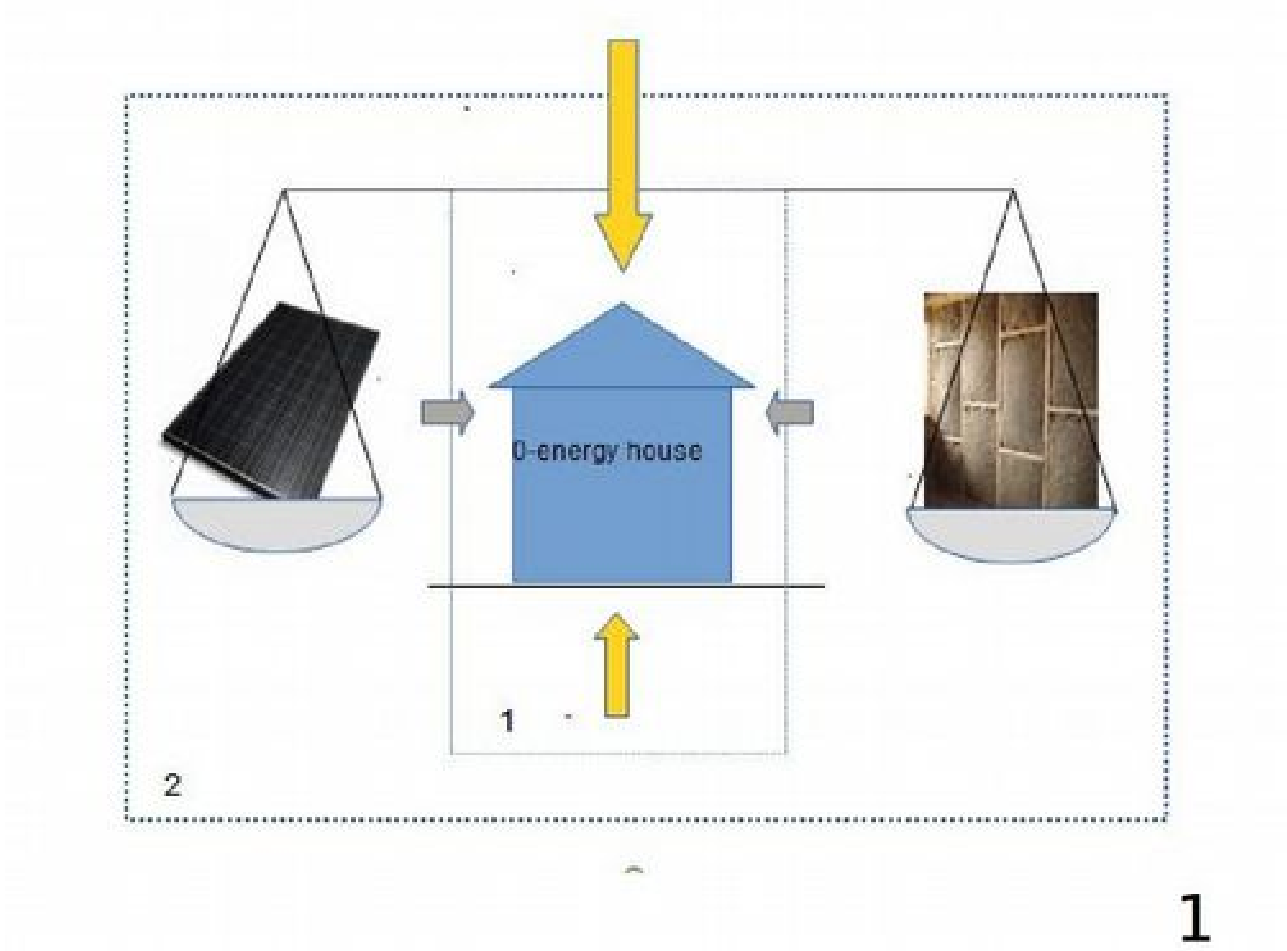


This project has received funding from the European Union’s H2020 framework programme for research and innovation under grant agreement no 633477

Introduction

Designing and Constructing a house is a optimization task: many properties have to be combined in 1 design. A special case is regarding energy: there are materials invested to reduce energy demand, and nowadays materials to generate on site renewable energy are invested as well, related to create NZEB or ZEB buildings on location .
With retrofit or refurbishment with CO2 reduction in mind, this optimization is even the major task: : a decision has to be made between how much insulation will be added, which in many cases directly relates to the amount of PV elements that have to installed to generate the remaining operational energy demand . In the end this is a trade-of between investing materials: for more insulation or in more panels. [1]

This is even more clear when we arrive at a 0-energy buildings target, or even energy plus buildings: actually in that case there is no impact anymore from the operational energy, other then materials invested: The PV panels are a materials investment that comes inclusive with energy (-generation) .



This balance between materials invested in reduction, and materials invested in production, [ill 1: balance] can be established at different levels: more insulation, leads to less panels required, less insulation requires more energy generating panels : In all cases the end situation is a 0-energy building, but the question comes down to which balance of alternatives has the least materials impact,, since that is now the real fossil fuel and CO2 related impact.
Its of course obvious that when end-use demand is reduced (by inhabitants behavior and way of using the house -think of heating less rooms) , combined material investments for reduction and production will be lower , leading to lower CO2 emissions required to become 0-operational energy.

Therefor its of utmost importance to evaluate different combinations to find out what is the optimal balance with the least CO2 emissions with a given end use demand. There are many tools in which the environmental impact can be calculated, but if only one house configuration is calculated, for instance the renovation of an old house, the new situation will always score better as the old situation. However, this might not be the optimal solution. This is unknown and not visible with only one checkpoint.

This is of importance also for NZEB or 80% CO2 reduction concepts. Since these do not aim at first on a 0-energy situation, the concept usually starts from concentrating on extreme energy demand reduction. Understandable, but these houses will undoubtedly in future make a next step towards 0-energy or energy-plus buildings, by adding PV panels and other technologies. Therefor any intermediate result may not be the best result from fossil fuels /CO2 point of view, since it was not optimized with that in mind: only extreme energy *reduction* was a criterion.

That is one of the reasons in the More Connect project some explorations are made with the 0-energy or ZEB situation as a reference case for this part of the project. It has a few advantages: It makes concepts comparable over several climate zones, since 0 is 0 everywhere, and it avoids the sub optimization of partial reduction. Besides, when the optimal concept is found, its alway possible to scale down the optimal solution to a 80 pct situation, for instance by installing less PV panels, and have investments reduced. In case in future PV panels are installed, its clear that the end result is the optimum from both energy as well as materials impact point of view.

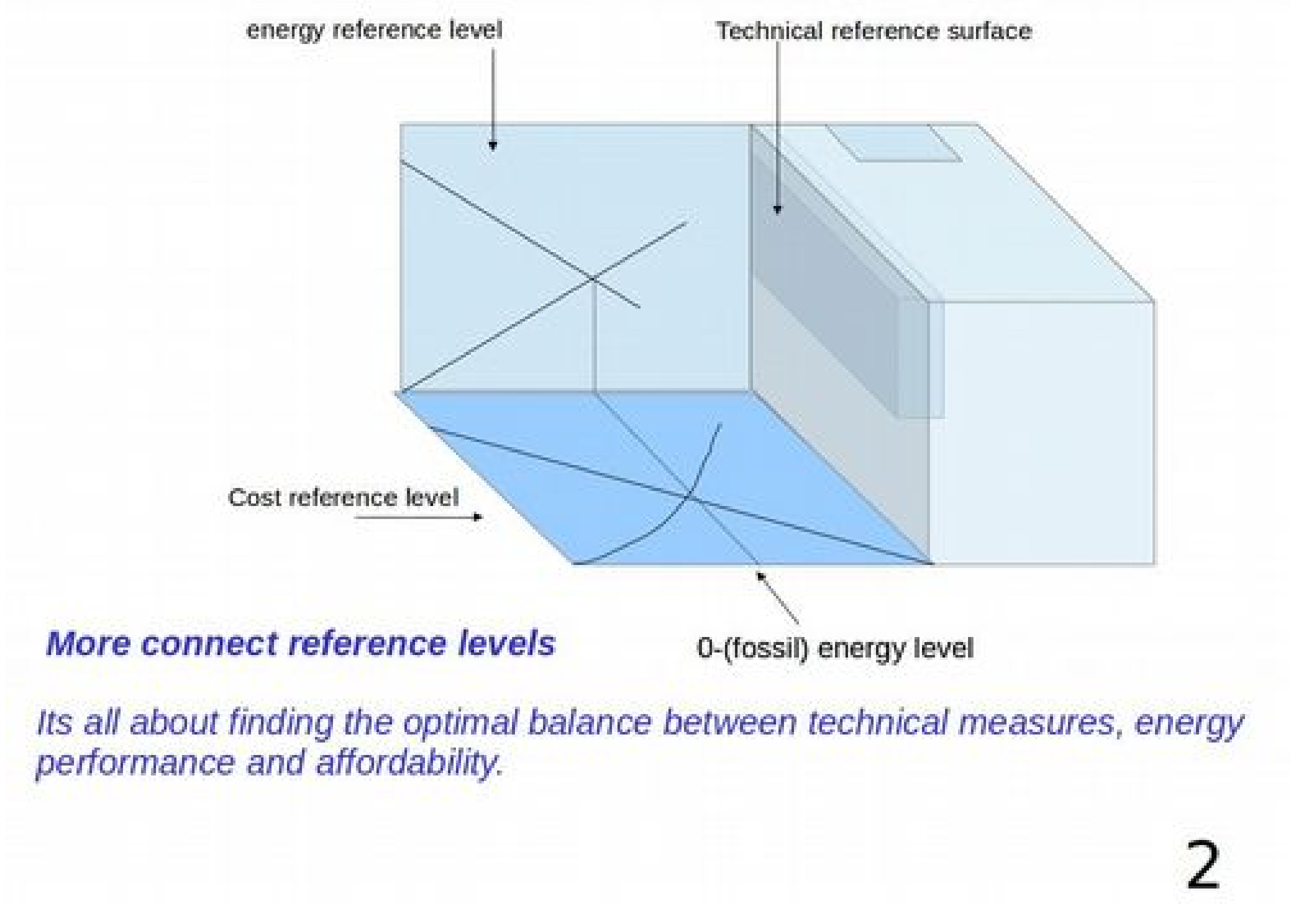
This report describes the indicators involved in such approach, as well as explores the process to come to optimization in Embodied energy/CO2 emissions in a 0-balance design or retrofit case. A basic decision tool/approach is developed, and -in joint More Connect workshops- relations are explored with technical aspects, investment consequences, comfort and behavioral adaptations.

- to explore more in depth the material related CO2 consequences of retrofitting the EU housing stock, the author took part in a joint international initiative to explore the real impact of the climate change agreement: How much CO2 can be released before the 2 degree threshold is passed, and what are the consequences for CO2 investment in the European housing stock retrofit? This will shortly be explained at the en, since it can have influence on what level of balance Is compliable with the 2 degree scenario.

The project has been developed within subtask 3.4, discussed in several meetings and tested in a workshop. January 2017

Chapter 1
The More Connect approach- base cases

The More Connect project aims to develop guidelines for retrofit of houses, in a combination of technical , environmental and economical optimizations. These three are interrelated. This is illustrated with the drawing in ill 2, the base case : There is a building, that will be adapted, and has technical possibilities and constraints. Which an be similar throughout Europe, or differ according to construction style or climate. These geo-cluster casetypes are defined in project 3.1 , and provide insight in which parts countries can profit from each others knowledge, as well a provide common starting points for a EU wide retrofit program. This will be detailed in several deliverables.
Within technical possibilities, its the ultimate goal to establish a energetic optimization, which is the main reason for the More project, to provide guidelines for a large scale housing retrofit program in Europe.



To create real reduction in fossil fuel dependence, and limit CO2 emissions globally, as is the ultimate goal of the Paris climate change agreement, measures are required at three scale levels

1 at macro level: global CO2 levels: since local solutions, when extrapolated to the global level need not by definition lead to global reduction.
2 at meso level: retrofitting housing stock , by countries for instance, characterization of stock, indicators for decision making.
3 at microlevel: technical execution , financing constructions, inhabitants behavior regarding needs and wants

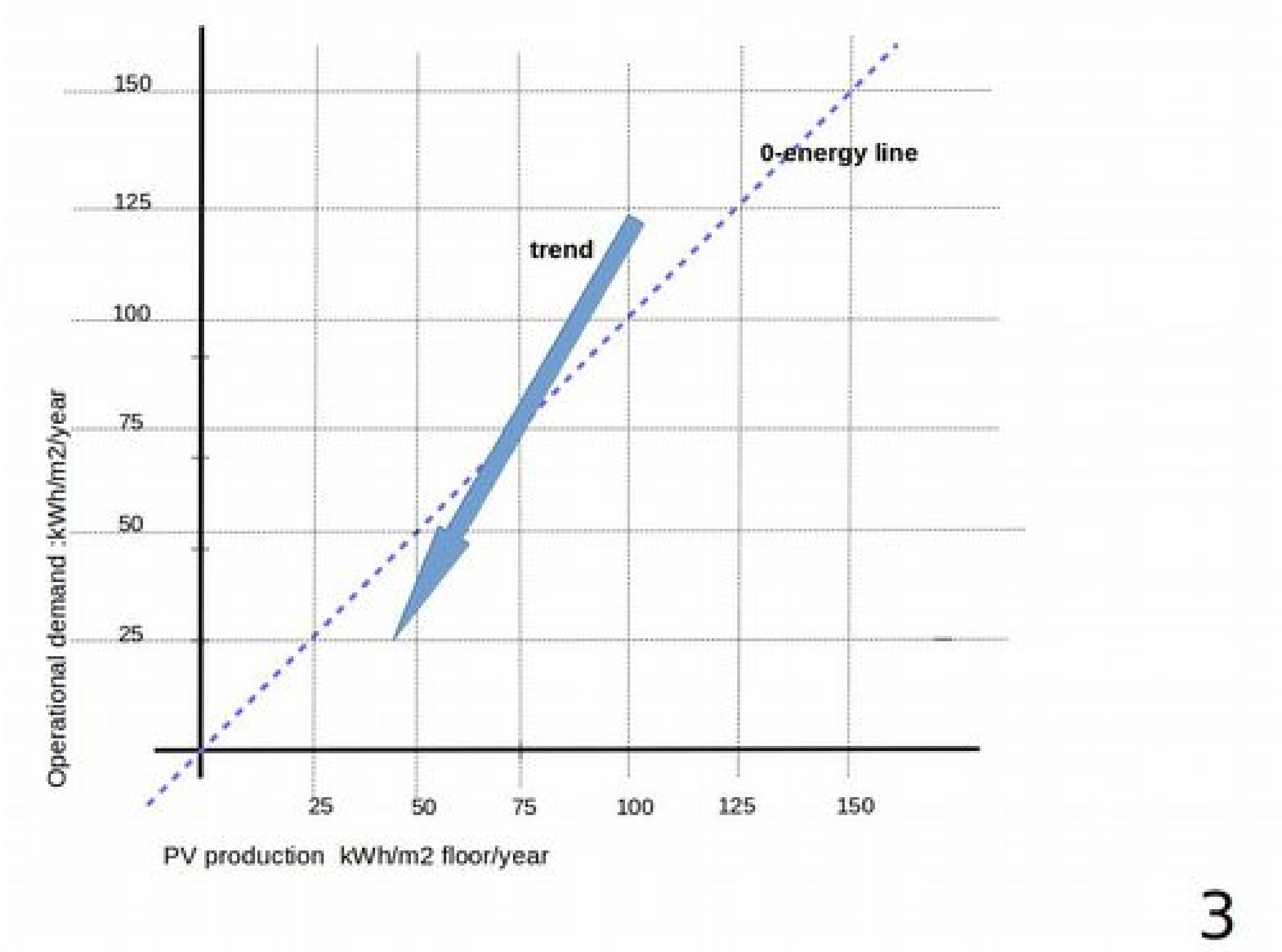
More connect is about 2 and 3, while subtask 3,4 is mainly focussing at the meso level, with explorations and input from both macro and micro level.
The macro level is explored in a spin of project, which will be described later.

As argued in the introduction, the starting point is a ZEB retrofit, as reference , and since the CO2 impact in a ZEB approach is shifted from operational energy to embodied energy, the energy in producing materials, the aim is to evaluate both together to explore the lowest CO2/energy option overall. (Ill. 3 , next page)

The third element in the base case are costs or investments: with each for each materialized retrofit concept comes a a cost calculation, which should be optimized as well.
Its against these three backgrounds that More connect seeks to find optimal solutions amd abstract guidelines for practice. This report starts from the energetic analyses, to provide input for the search for the optimal technical outfit with optimized cost implications.

Chapter 2
The energy base case

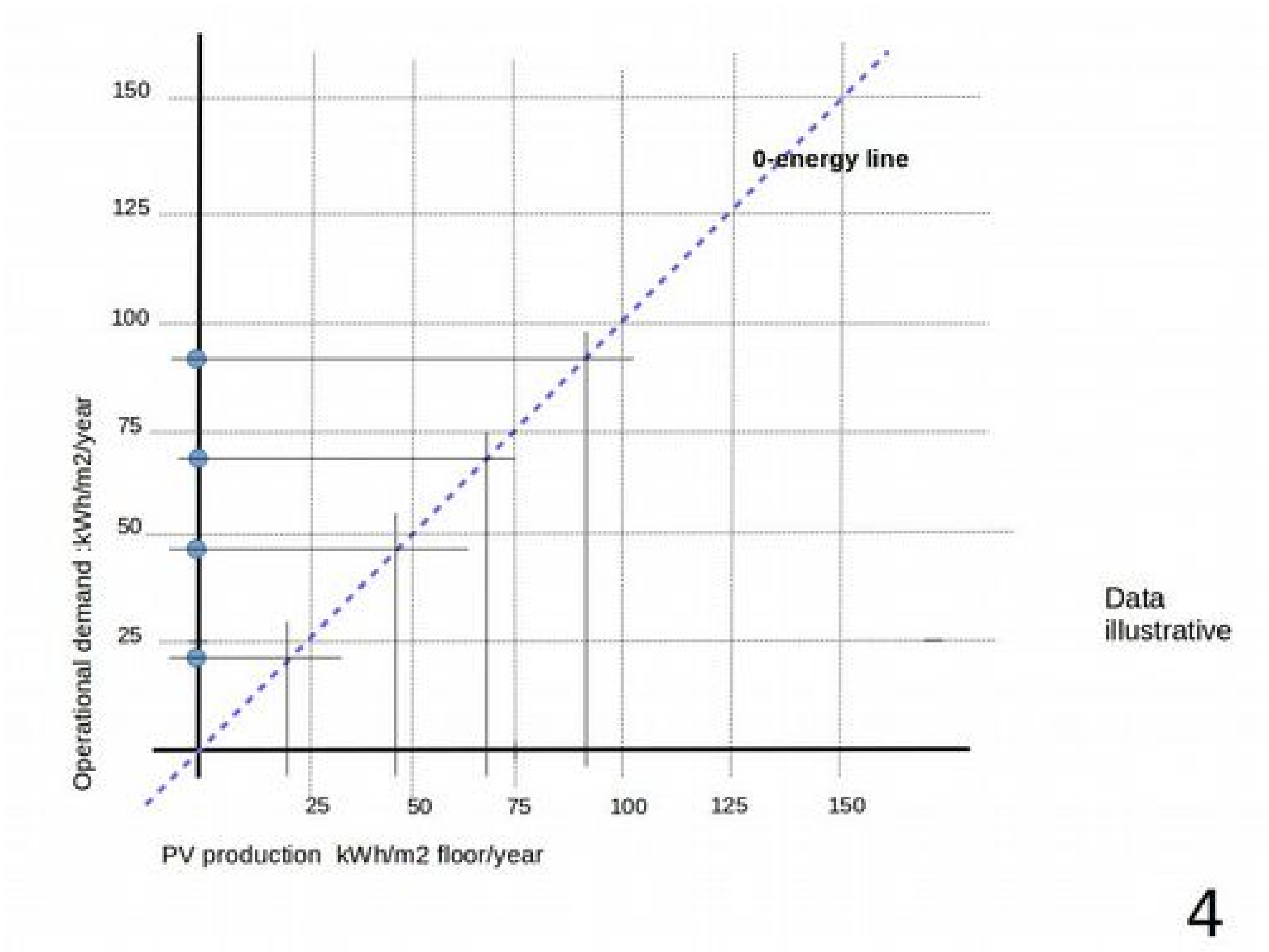
Energy wise a building can be described by its operational energy demand, and the on site generated renewable energy. Which are the two indicators that decide for NZEB or ZEB buildings. The illustration shows the X- axis and Y-axis representing these two variables. Left from the dotted diagonal, the building consumes energy, right it produces net energy. The diagonal line is where the two are equal and a 0-energy/ZEB situation is established.



Further for detailing of the method below, and good understanding of the approach, its assumed that in all cases the situation is all electric (installed devices) , and that this electricity is generated with PV panels. Other configurations will be addressed separately. This is one concept for explanation of the method. Its also assumed that demand is addressed “as is”, in other words, we start from the original situation, without adaptations in comfort or behavior.

In a combined research project with PhD work at Zuyd university, a study was made how the insulation measures in combination with PV panels would interact in terms of CO2 emissions, for different combinations and using embodied energy as the indicator. [2] The outcomes of this study are used in this report to work out the conceptual approach.

ill 4 shows 4 possible combinations for a imaginary case : different levels of energy demand (due to increased insulation levels blue dots on the y-axis) and accordingly different amount of PV power installed, to create a ZEB balance
3a: no insulation is applied in the renovation, and the whole original demand is covered by installed PV power: indoor climate is the same before and after, with still a 0-energy balance. Of course this requires significant amount of PV panels .
3b: basic measures for energy reduction have been taken, (such as double glazing and cavity wall insulation) and accordingly lower amount of PV installed capacity is needed.
3c: 3b plus extr level of insulation (thin outside layer) , with reduced PV panels power
3d: extreme insulation, passive house style, with low amount of PV power installed.



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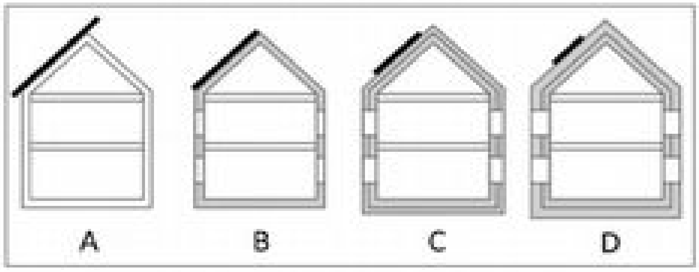
Chapter 3

the research case

The cases in ill 3 have been detailed in a research combined with a PhD work in energy optimization of facades. The research is recently published and the data are used here [2] . 4 cases of retrofit are explored , assuming the same installations in all cases, all retrofitted for 0-energy performance (without behavior change),((ill 5) .



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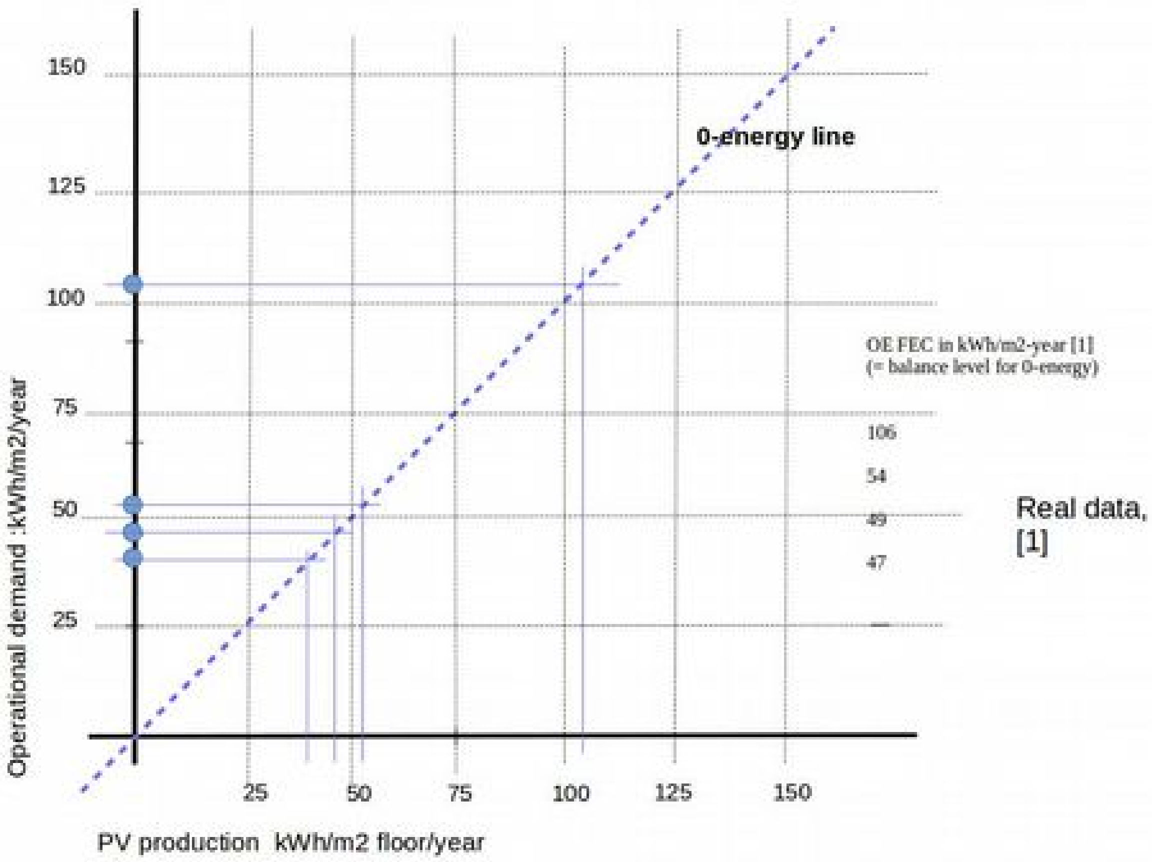
Ill. 6 shows the calculated data in the MC base case graph, together with the remaining required amount of PV power to become ZEB (in kWh/m2-year to be generated.)



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These 4 cases are compared for the impact of materials and products introduced in terms of Embodied energy: the (fossil) energy that has been invested in harvesting/mining, transport and processing the materials. The case is a row house. The results are in the left of ill 7 (from [2]) : the combined embodied energy of insulation measures and PV panels, is what is actually invested to eliminate operational energy. This is averaged over 50 years , (including replacing pv panels after 25 years).

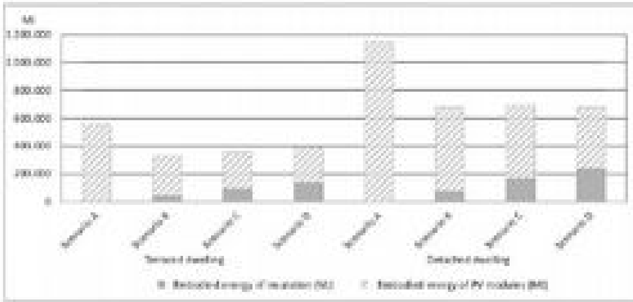


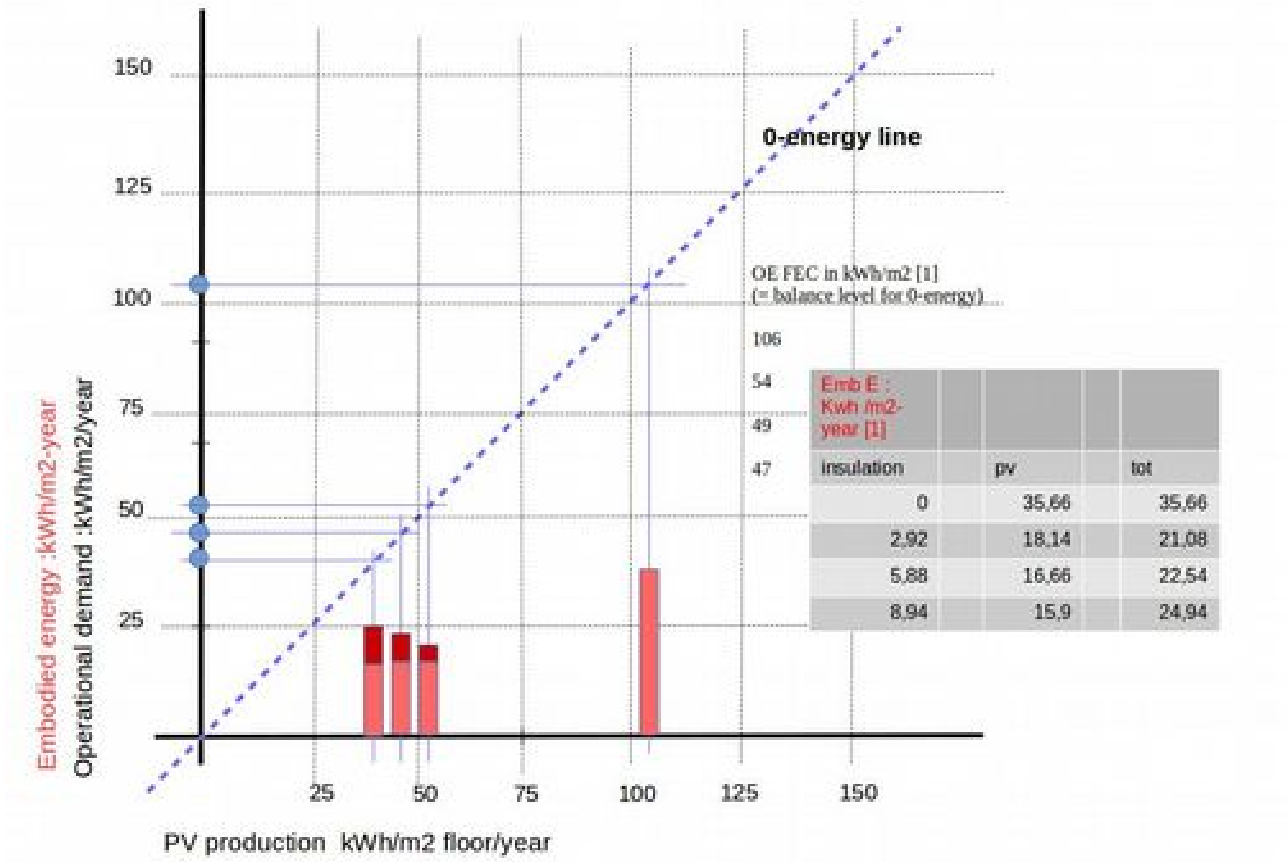
Fig. 10. Embodied energy (MJ) of the different scenarios in the two dwelling types.

From [1] : the left part, Terraced dwelling, is used here.

7

All 4 cases lead to a lower yearly fossil energy/ CO2 impact, but CO2 is not 0 of course, the burden has shifted from operational to embodied energy. But although all 4 cases have improved the situation there is a clear situation what has overall the best situation: case 2 , with partial and basic reduction measures. (double glazing cavity-wall insulation, etc , see the paper for a full description.

This outcome is transposed into the More-Connect base-case-graph, ill.8 using the Y-axis now also for " embodied energy" (also in kWh/m2-year). The columns are placed below the corresponding 0-operational energy balance point .



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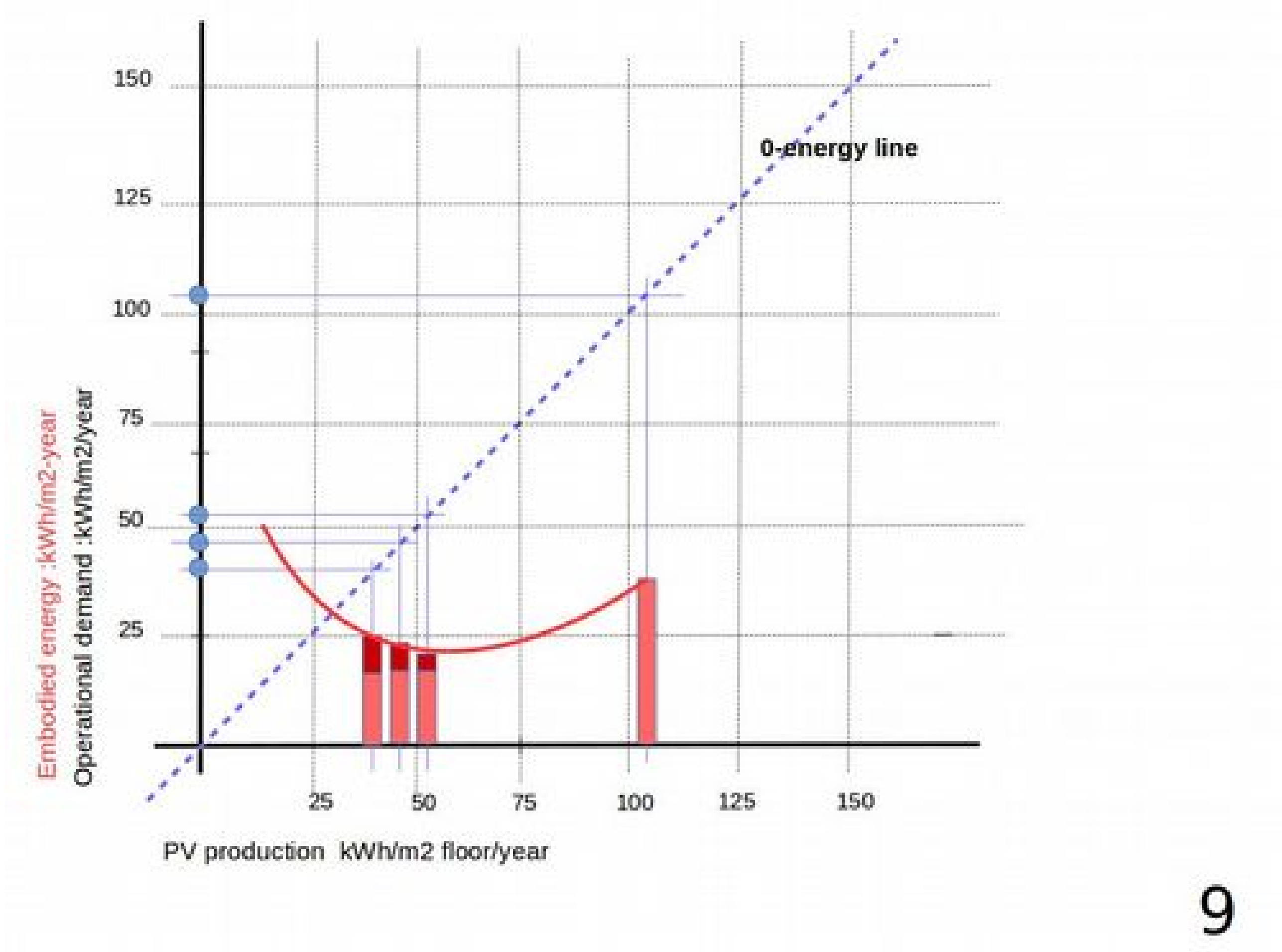
And from these 4 points a continuous graph has been drawn to show the the trends. (Ill 9)



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This is the base graph for further analyses. *Be aware that the graph for finding the optimum only becomes visible with multiple variations in balance calculated. With the use of a generic calculation method and only one case/concept/configuration, the result will always be lower as the non retrofitted starting case, but it will be unknown if that is the best case overall.*

The extreme reduction case will lead to higher overall CO_2 emissions in this example.

Chapter 4

variations in the energy base case

4.1 80 pct scenarios

The More Connect initial project proposal started form the requirement of 80% CO_2 reduction from operational energy demand. It has been agreed among partners to take 0-energy as virtual starting point, and from there optimize, thats is: if required the ambition can afterwards be reduced to 80 %. This has two advantages: first, data become more comparable between countries and climates. Comparing at 80% levels would introduce many insecurities in the calculation, due to starting point levels, and subsequently different absolute 80 % levels, as well as differences in local climate and geography. 0-energy provides at least from energy point of view a comparable and understandable

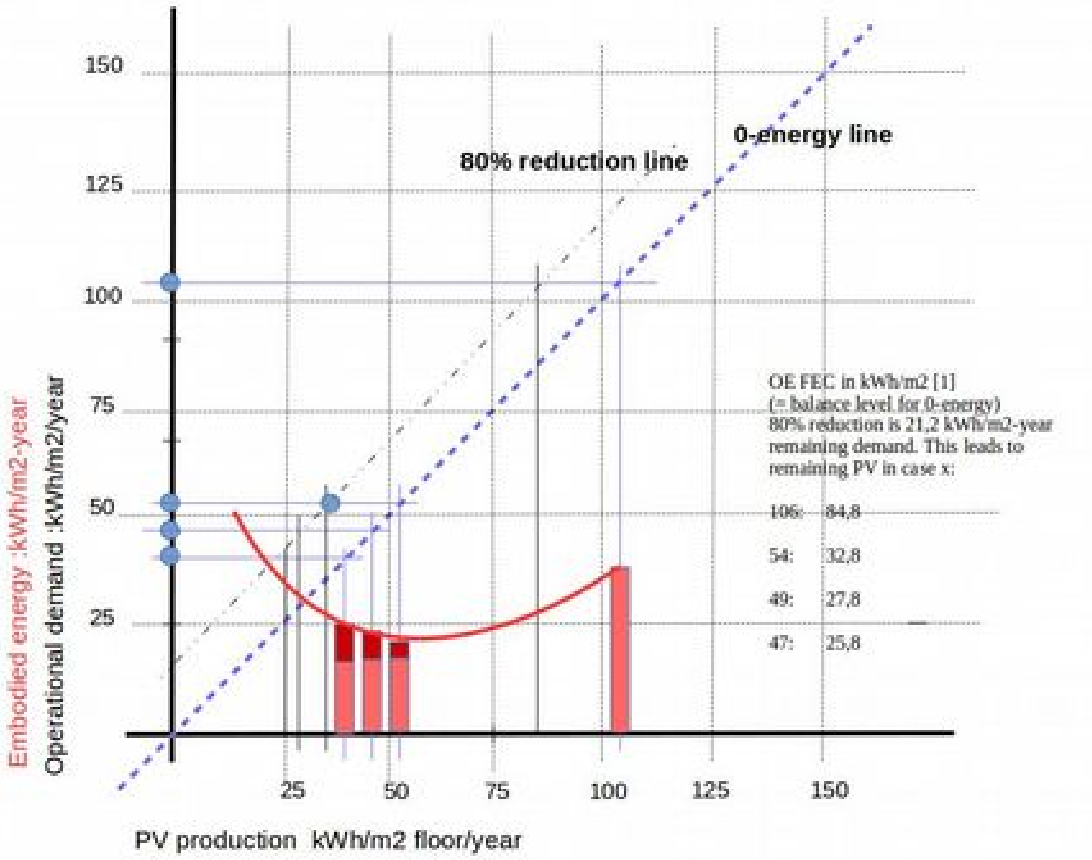
level.
Secondly, As the previous analyses shows, the 80 % condition will not lead to the optimal choices from operational and embodied energy combined: Its not required to apply extreme reduction, once 0-energy comes in sight. Its better to explore the 0-energy case and from there work backwards to 80% , at least the right balance has been found, in case at some future moment the step from 80% to 0-energy will be made. The 80% (OE reduction) options are here explored.

There is two ways to handle this:

A to start from a 0-energy option analyses as in the cases above , and work backwards to find out what a 80% of the optimal concept would imply.
B to start from the original situation and explore which options there are to create 80% reduction,

A: 80 pct from 0-energy cases
Since the aim in future remains is to become 0-energy anyway, it is assumed that in the 80 % scenario its not the optimal insulation level that will be adapted, but the installed amount of PV.

To arrive at 80% reduction of original operational energy, (106 kWh/m2 year), implies a remaining max demand of 21,2 kWh/m2-year. The amount of PV can be reduced with that amount, leading to the data in ill 10 , horizontally shifted to the left. Graphically this produces a 80% line : the line where PV installed is adapted, but not end-use-demand/insulation levels. Since that would lead to suboptimal levels form a embodied energy point of view, in the future end state of 0-energy.
This way the optimal approach has been found, in a two step approach via 80% towards 0-energy.



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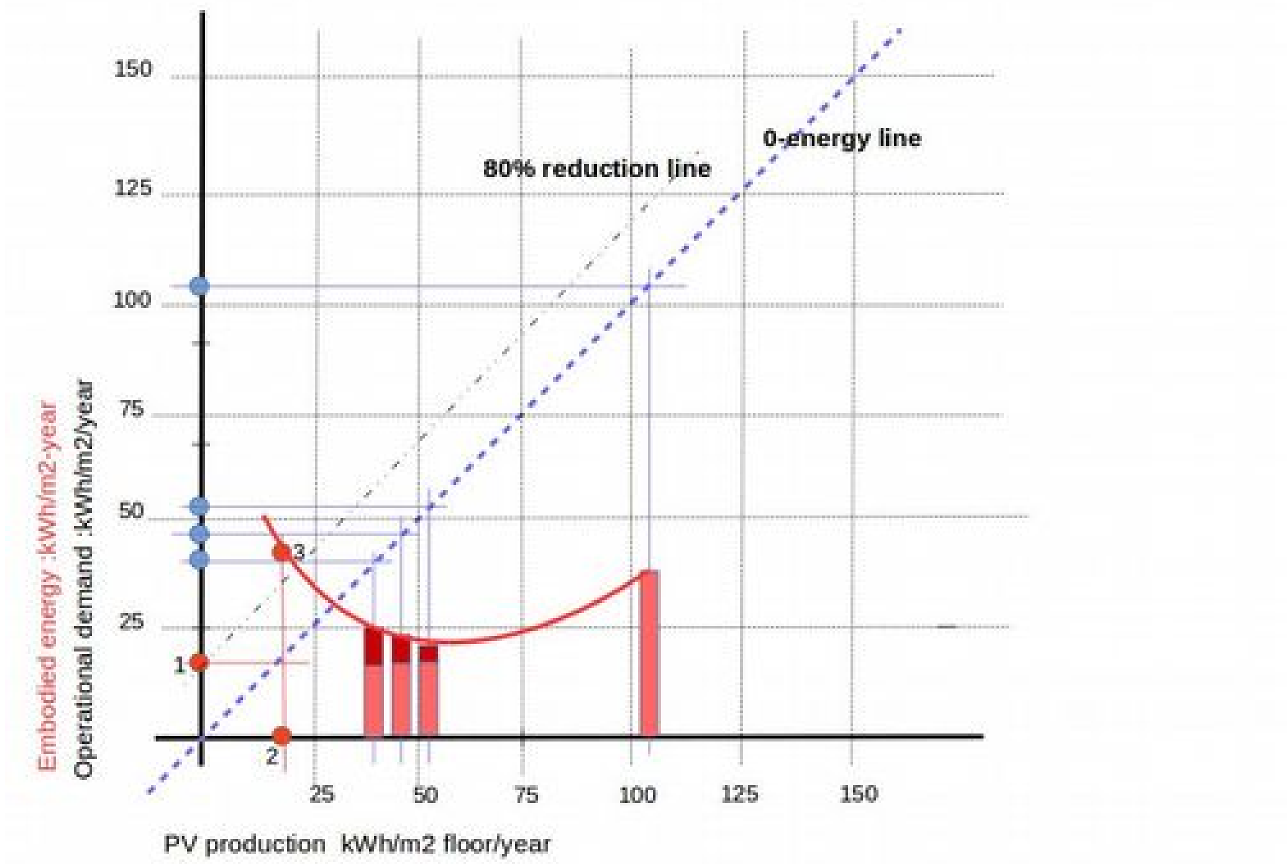
B The usual approach when aiming at 80 % reduction is extreme insulation (like Passive haus) This is illustrated in ill 11, the red dots. The extreme insulation package leads to a remaining demand illustrated with the red dot 1 on the Y-axis. In case in future the step towards 0-energy will be made, this corresponds with the amount of PV as in the red dot 2 on the x-axis . Now we have 0- impact from operational energy. To see the impact from materials Embodied energy, the line can be followed vertical, to the point where it crosses the previously created EE graph, the red dot 3. Which shows that in this approach, ultimately much more impact has been created for the same end result, nearly twice as much as in the optimal original case.



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This is why a 0-energy balance calculation is preferred as a start before a energy demand reduction approach, even in case of 80% requirement.

4.2 100% / 80% including embodied energy

the 80% energy/CO_2 reduction, is usually interpreted as reduction in final demand. But if final demand reduction is replaced with additional embodied energy, the question is justifiable if the 80% pct should be overall, including embodied energy. Otherwise the 80% is relative, not absolute.

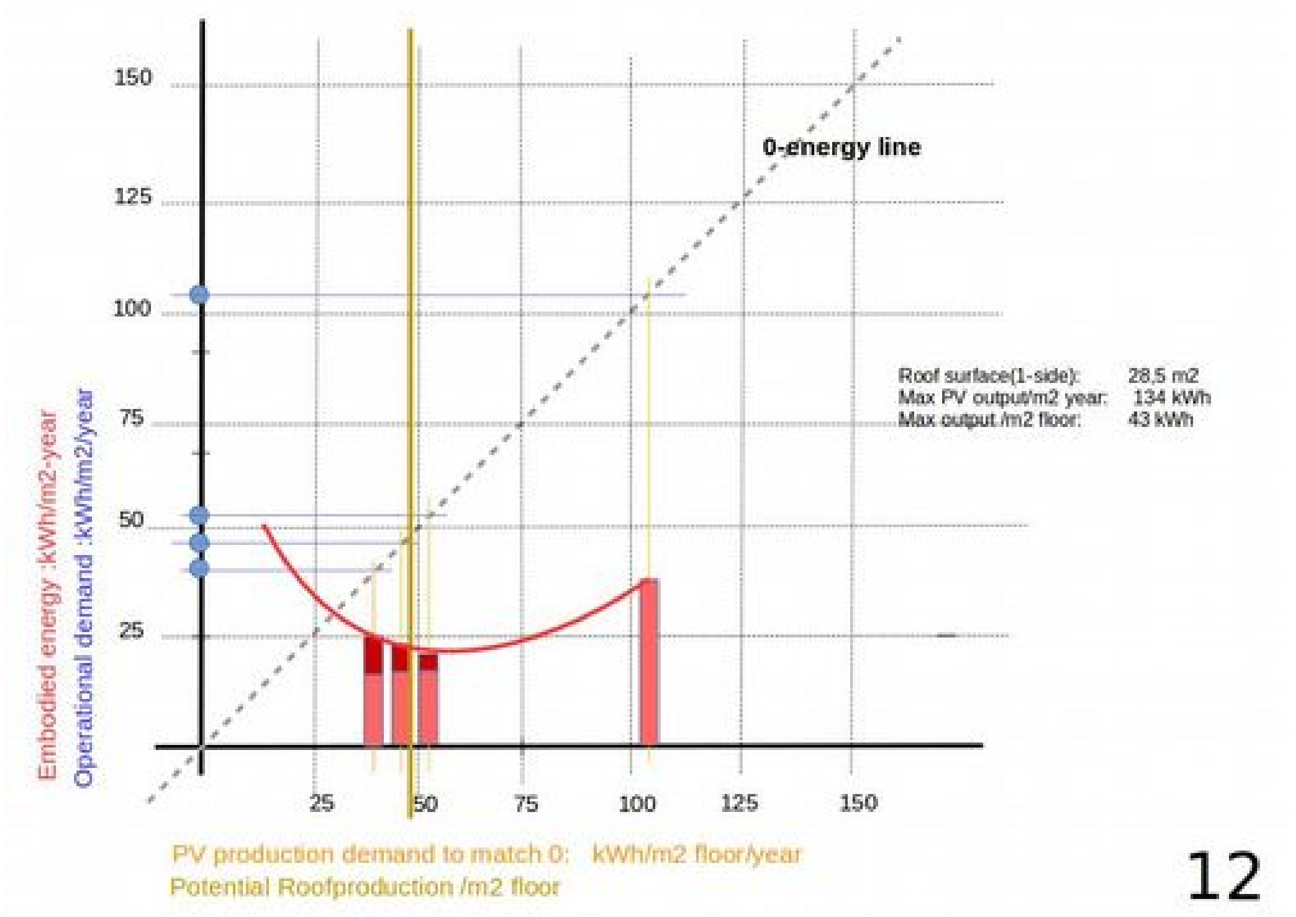
In our case the original demand was 106 kWh/m2. And the best 0-energy case required 21 kWh/m2-year in embodied energy. Which is 19,8 % of original demand. As such, this solution , in fact a 0-energy solution with 100% demand reduction, stays just within the 80% limit, and with OE and EE combined is in fact a 80% solution.

in Summary: 0 incl + embodied energy:

Bringing operational energy to 0, gives in return a impact from Embodied energy. Therefor, operational 0 is not overall 0, as follows for these 4 cases: (based on 50 years exploitation time)

case A from 106 kWh/j OE to 0-OE : + **35,5 kWh**/m2-j EE , tot result is reduction by **67 %**
case B from 106 kWh/j OE to 0 OE : + **21 kWh**/m2-j EE , tot result is reduction by **80 %**
case C from 106 kWh/j OE to 0 OE : + **22,5 kWh**/m2-j EE , tot result is reduction by **79 %**
case D from 106 kWh/j OE to 0 OE : + **25 kWh**/m2-j EE , tot result is reduction by **76.5%**
This implies that to become overall 0 , for OE+EE combined , requires additional production compensation from renewable energy, ie additional PV panels(including again the EE compensation).

4.3 relation with technical references
More Connect has defined three reference levels: energy, technical and cost reference levels. One of the decisive technical references is the available roof surface for on site generation of solar energy. To create a direct link from the energy reference exploration to the to this roof surface technical reference in the More connect approach, its possible to change the X-axis from PV power to m2 PV output (from the roof) per m2 floor, for the specific climate zone and PV efficiency. This way its directly visible how much m2 PV will be needed to cover demand. In the cases studied the south oriented roof surface available is 28,5 m2 . In the Netherlands the max output per m2 PV is 134 kWh/year, which leads to a max output for the whole roof of 43 kWh *per m2 floor.* This maximum available roof surface output (for instance) can be expressed via a vertical line in the MS base graph.
Any conceptual solution in case of a 0-energy house will have to be on the left of the bar, since there is no more roof surface available to produce for a higher level balance. (For a row house its the entire roof expressed, for a apartment block it can be a equal share of the available joint roof surface).
Ill 12 shows our case study: the brown line is the max output from the south facing roof parts: case C and D fit, case B , the ideal from EE point of view, does not, or requires additional PV on the North facing roof part, or maybe even facade panels. The difference is not that big, and case C could be acceptable.



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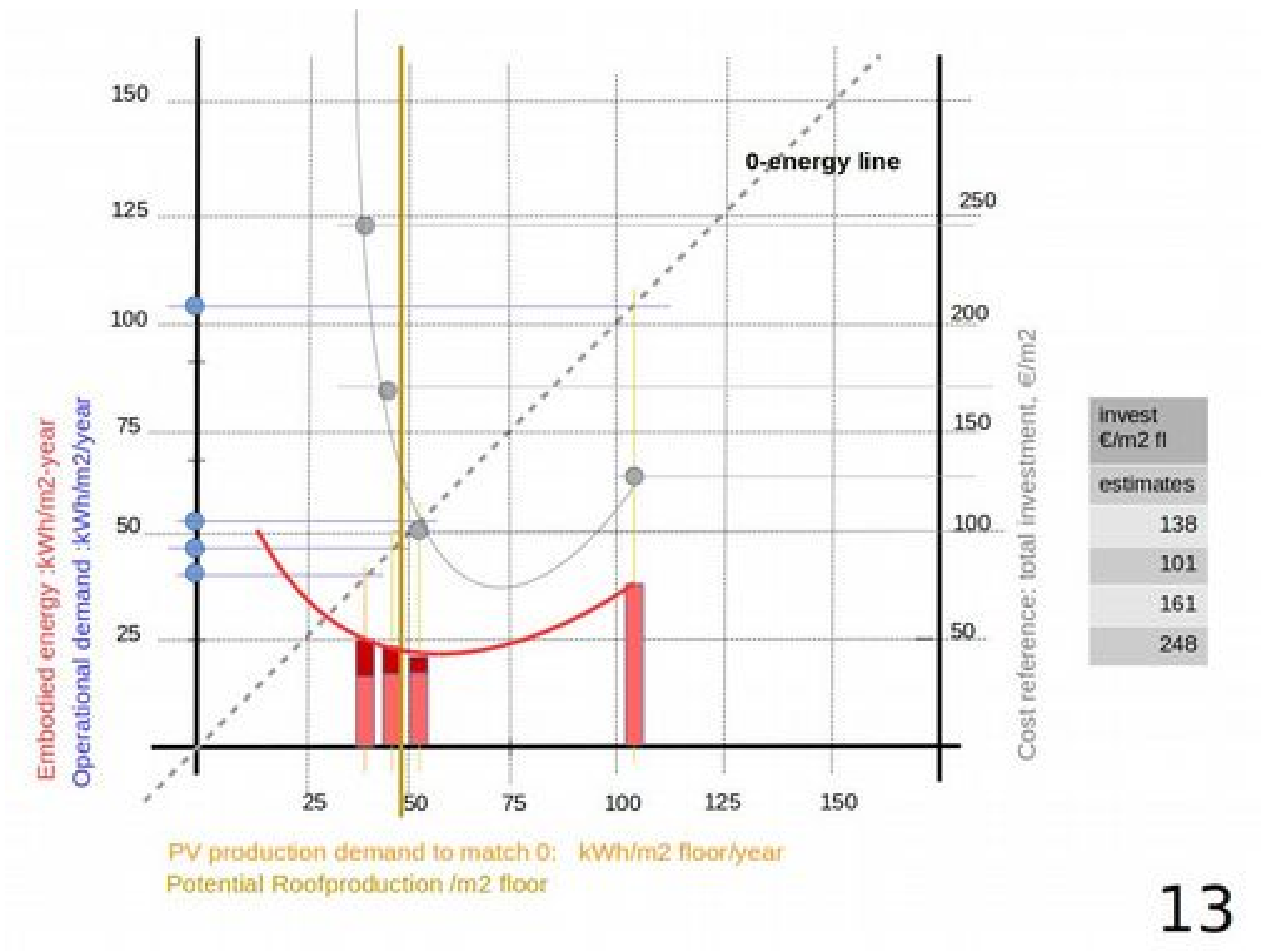
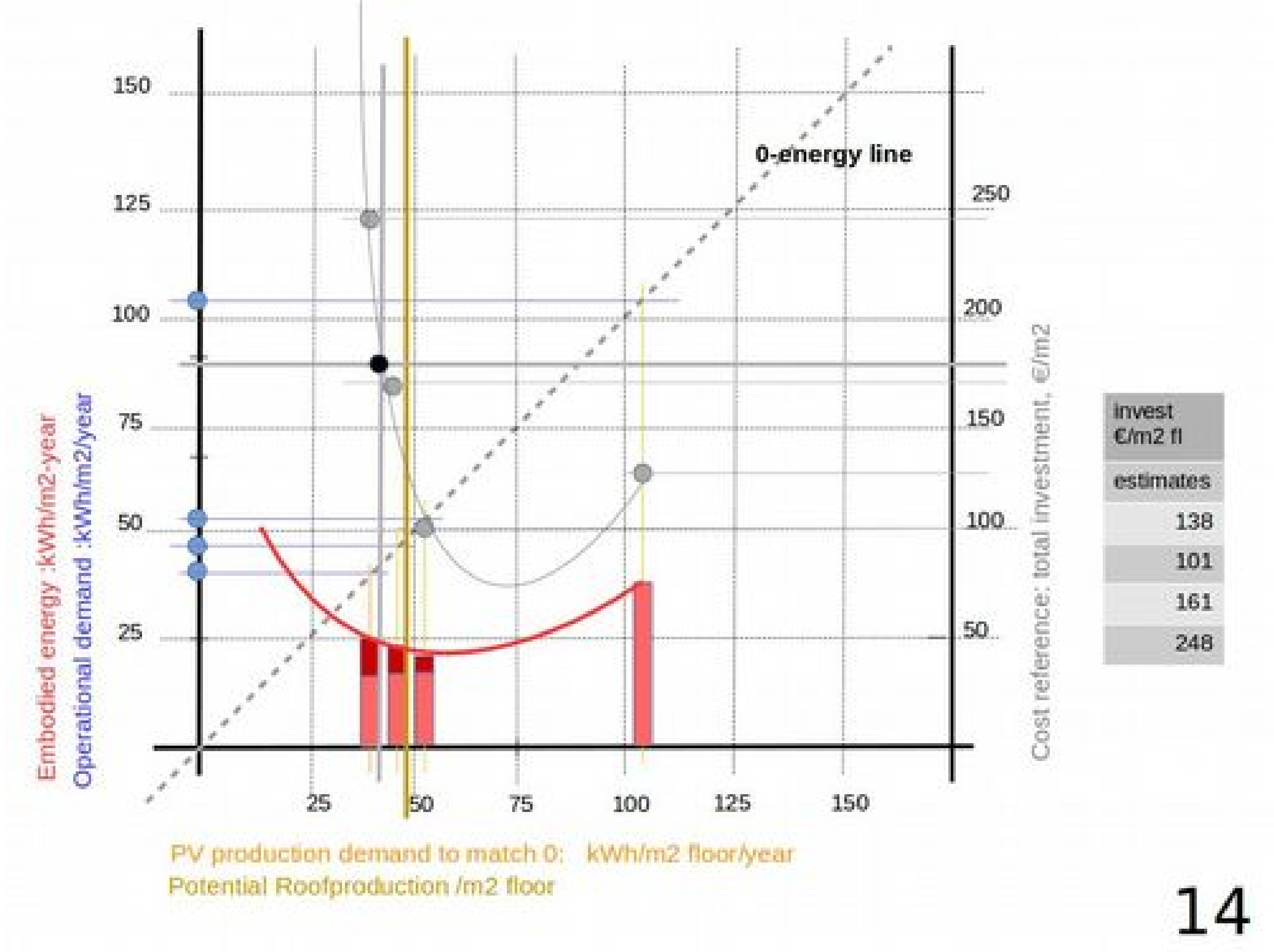
4.4 relation with cost references
To make a connection with the MC cost reference level, similar as with the technical reference, a additional Y-axis on the right side of the graph is created , to indicate costs with each of the concepts. The value can be chosen whats best fits the local situation: total investment , tot. investment per m2 floor, or monthly interest over x years of loan[1] . Here investment/m2 floor is chosen as a example, based on estimated cost (not calculated in detail, only as example)
The cost in the graph appear as grey dots on the vertical case lines for each case. The graph line created shows that also for cost there is a optimum, for insulation measures and PV panels combined.
Illl 13



1 This the indicator used in the Netherlands: the original energy cost per month are taken as the maximum loan and interest to pay for the retrofit (over 30 years of pay-back period) : not only the building is 0 energy wise, but also the cost difference before and after are 0 .

Costs of course have to fit within budgets. Suppose the maximum available budget is 175 Euro/m2 , a horizontal line can be drawn to illustrate this level, showing which options are feasible and which not. Where the cost graph crosses the maximum line (black dot). A vertical line can be drawn, since all options left are are beyond budget. It , marks the lowest possible balance situation within budget, illustrated with another gray line. Ill 14



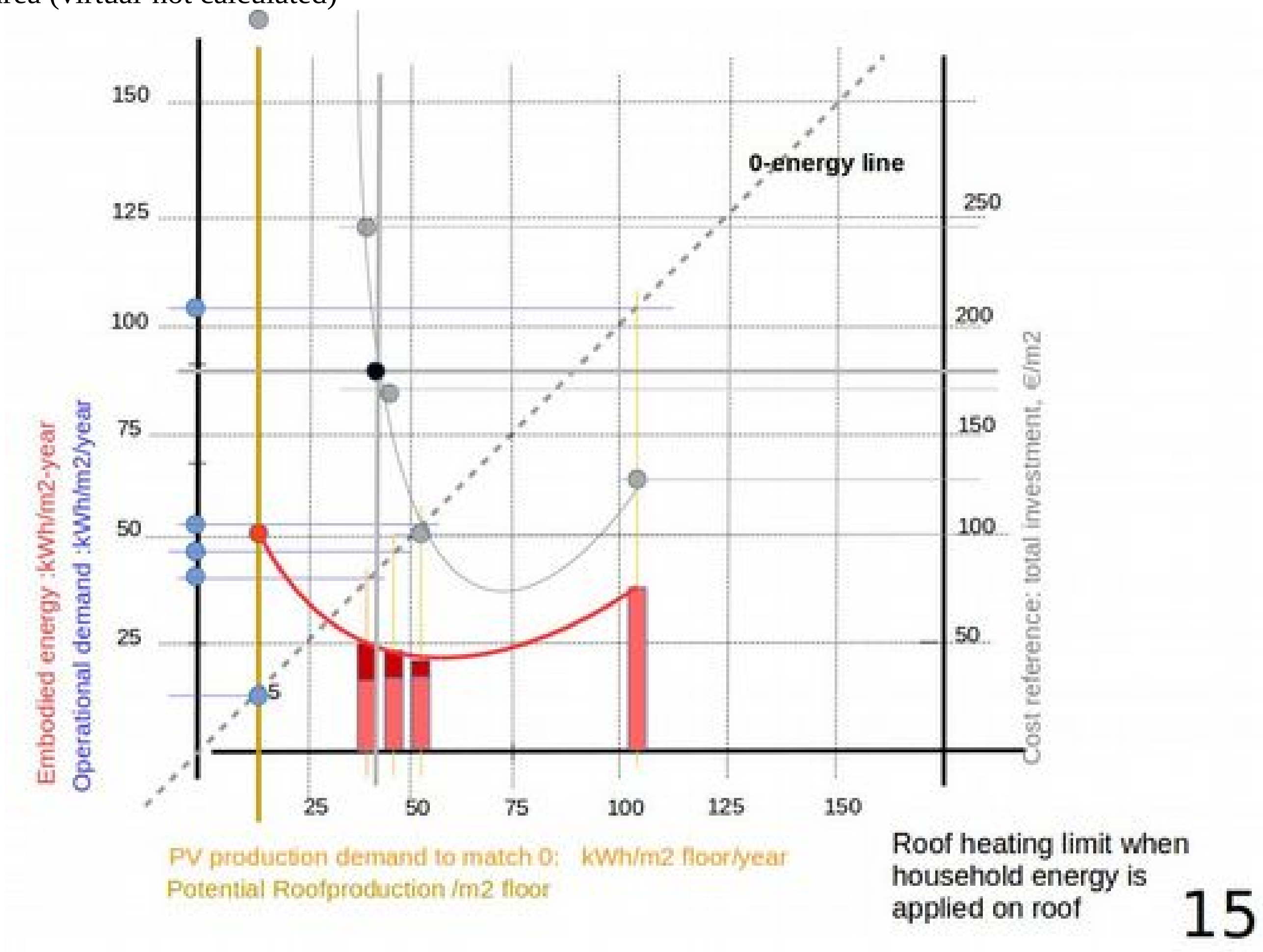
4.5 e+t+c combined reference levels

A combination of three MC reference levels now becomes visible: the energy solution should be left from the technical reference line (yellow), and below and right from the cost reference lines. Though this is an imaginary situation, its is the basis for a decision graph for renovation concepts, integrating energy costs and technical boundaries.

4.6 household energy

In the optimization so far energy generation to cover household energy (energy for living equipment, TV, laundry, cooking etc) has not been incorporated. It will require to increase the amount of PV panels significantly , ie the on site surface to install additional panels.
In the Dutch reference case a average of 2700 kWh per year is included for household use, or additional 30 kWh/m2 floor per year has to be generated.
There was 43 kWh/m2 floor available, minus 30, gives only 13 available for heating.
This in turn, will force the the heating energy-demand to be further reduced , and extreme insulation is among the measures. This is what happens in the Dutch national program for NOM (nillonthemeter) renovations, that include household energy in the cases. (see del 3.8 for decription)
More insulation, creating a case 5 left of case 4, with higher embodied energy for both PV and insulation, and much higher cost.

The last option can be shown in the main graph, ill 15: distract the 30 kWh extra PV need from the available 43 , and move the technical reference line to the left at 13 kWh (is remaining available for building related) . This gives case 5 , with high embodied energy , and pushing cost outside graph area (virtual-not calculated)



4.7 comfort and behavior change

the above examples are all based on equal behavior before and after renovation: people climatize the whole house 24 hours a day. Its obvious that a different behavior could reduce the starting point demand significantly, and create more interesting cases from CO2 point of view: demand will be lower, the installed materials will be less, and remaining CO2 emissions as well.

Still in many countries, without a real winter, people live without heating at all: in the coldest days they put on a sweater and or coat indoors, for the few days that its chilly.

Comfort

Suppose people lower indoor temperature in winter, reducing demand to 80%. (say the thermostat goes to 18 In stead of 20 degrees) That will move all 0-data , following the diagonal to left below. : lower demand, lower amount of PV required.

The EE graph will lower and move left: the embodied energy for insulation will remain the same, (same packages applied, but after user reduction) but EE from PV will be lowered, as well as totals.

The result is that case 2 will be pushed to come within the technical reference border. (ill 14)

Cost of course will be slightly lower, due to less pv panels, but the trend will remain the same

2 Suppose people choose to heat only the ground floor in winter, and the insulation package is applied

only to that area. (same prefab elements on ground floor, but 1st floor level insulated, but not walls and roof.) That will reduce heat demand, reduce materials for insulation and reduce amount of pv panels. Together reducing EE significantly as well as freeing roof surface for household energy.

Chapter 5
other RE devices.

So far the case has been developed for energy production via PV solar panels. There are many other devises possible, like ground source heat exchanger, urban wind turbines, or , coming from outside the house system, district heating. The first two can be implemented similarly, since within the evaluated system (the building site) , The latter is different and will be shortly addressed here.

5.1 district heating

One of the discussions on application of the graph is about introducing **district heating**.
The case developed here is for a house completely running on energy from renewable generated sources, to be CO2 free from the operational point (Though not from materials point)
The heat capacity from a District heating can have two origins: waste /rest heat from other processes, or generated by renewable sources.
In the first case this is of course not CO2 free energy: The waste resources is most likely aa residue from a fossil energy driven process. Sometimes this is regarded as impact free, However, the impact form the original process should be attributed to both uses: the primary process and the secondary process. For the reason that when the primary process becomes more efficient (and industries have targets for this as well) then the reduced wast heat will have to be reproduced with other fossil sources. If it will be reproduced with renewable energy , it could improve the situation, but this is unknown, and for the moment we cant include that. Therefor: this chain of energy supply does not count for a 0-energy housing retrofit process.
The second possibility is different:the heat is generated with a Renewable energy based source, and can be included in the o0energy retrofit concept, as CO2 free produced. Except of course for the Embodied energy of the system, just as with the other devices. (and strictly speaking it will not be 0-energy but energy neutral (since coming from outside the evaluated system, but thats acceptable)
The embodied impact of the renewable energy driven district heating should then be divided over the total amount of users, (households) and implemented in the evaluation similar as above described. Of course, the extra EE from district heating will imply a reduced EE from PV panels, since less are needed.

There is one issue not solved this way: In the cases so far we have not included the embodied energy of the equipment installed, like the heatpump. This was left out since in all cases this was the same and unavoidable. (And therefor not influencing finding the optimum solution, it would have similar effect on all cases) When comparing with district heating, not only less PV panels will be needed , but also the heatpump for heating becomes obsolete . To have this effect included, new research is needed with the same exercise now including heating installations.

chapter 6
Discussions

end use/ primary energy
In the example here evaluated, the operational energy as well as the PV panel production is calculated in final energy. Which makes logic, the output and demand are direct end uses and balanced.
The embodied energy is both for insulation materials as for the PV panels calculated in Primary energy. Which is unavoidable, databases for EE provide inclusive data, always in primary energy. For the general conclusions this makes no difference, the curves remain the same.

However, not included is the grid impact, for exchange of surplus or import of shortage. Since this is assumed to be still provided by fossil fuel driven energy plants , primary energy is usually used to bring everything into one calculation. The problem is that we are in a transition, to a 100% supply by renewable energy: Solar power plants, Windturbine parks will have to take over from fossils. In that case calculating in primary energy might not be the optimal approach anymore , since it stems from a time when only fossil fuels were used, and as such relates everything to a theoretical potential from fossil fuels. The UN statistical committee that introduced primary energy calculation methodology [x] already stated that in time, when enough data would be available, calculating in en use/final energy would make more sense and a better approach. Now 40 years later, with a massive amount of data, and the shift toward a renewable energy supply system, this becomes apparent.
It will require that Embodied Energy data should be recalculated in final energy data, to bring everything under the same approach. This is also relevant for industry: using a generic energy mix to calculate primary energy and compare products, will disadvantage industries that already have invested in a renewable energy based production facility. Having embodied energy data in final energy demand, makes it possible to distinguish products and resource chains from the ones produced with a predominant fossil mix. [3]

It will require serious research, to redevelop calculation methodology, to come to a objective approach , in our case for for introduction of a grid connection into the equation, or other secondary processes involved (like district heating) . The general trend illustrated by this study will not change, however absolute levels might change somewhat. Besides, all databases should also split embodied energy data into production process and transport data separately, and in end use energy, so that data becomes independent from the applied energy mix, which is rapidly changing now, also in transport (-energymix).

installations/ equipment
So far left out of the equation, are heating and ventilation devices itself, since assumed to be similar to any option. Including these would not change the trend, only influence the absolute levels.
Nevertheless, a optimization approach is required here also. If for instance different technical configuration should be compared. Unfortunately, there are so far too little data available to compare equipment by embodied energy investments. This is a general problem in databases, and should be addressed. Since they have significant contribution in Embodied energy. Its recommended to have a specific project to bring these components into the databases.

Chapter 7
conclusions

Some of the conclusions that can be drawn from this tool developed and the case studied .

1) Most important is that ZEB retrofit measures shift burden to material related energy impacts, and that these can not be left out of the equation.

2) that for any retrofit concept its best to develop a ZEB retrofit concept, even if the actual retrofit will not be ZEB, and some measures will be left out of the retrofit project. The ZEB exploration gives information about optimal configurations, and which elements to what level can be implemented or postponed. Which will prevent suboptimal solutions, and lock ins in the case that in a later stadium the 0-energy situation will be anyway introduced.

3) it requires several basic concepts and combination of measures to be studied to find the optimal solution, the solution with the largest overall CO2 reduction: Any operational energy related improvement will lead to a lower CO2 emission level, however, there is an optimum ; only with more configurations explored, this optimum from energy/CO2 point of view can be found .

4) Roof surface is the critical element. To include household energy in a ZEB retrofit will push towards extreme insulation saving roof surface for household related pv production: and as such lead to a far from optimal heating configuration, with higher Embodied energy/CO2 levels, and higher costs . This points to the need to address household reduction related end use first, before developing the technical case..

5) the best ZEB case in our example, is still only 80% energy(CO2) reduction overall.

6) the here developed methodology seems useful to illustrate and compare the consequences of different retrofit concepts for energy and material related consequences combined. It requires more study to perfecting the method, and develop experiences with more divers cases.

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