Form and Energy Optimization of Plus Energy Office Buildings

- Learnings from Powerhouse One

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The Research Center on Zero Emission Buildings WP-5 - NTNU Trondheim

Form and Energy Optimization of Plus Energy Office Buildings

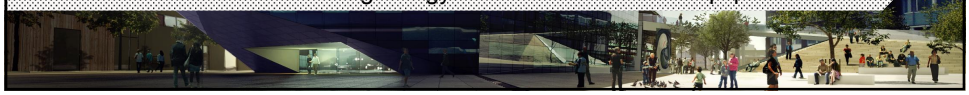
1. Conclusions
2. Project description Powerhouse One
3. BIM based bioclimatic design process
4. Further research

Illustration Snøhetta/MIR

Conclusions

- Plus energy balance over a life cycle of 60 years including embodied energy, construction, operation*, and demolition demands a BIM based integrated bioclimatic design process to achieve optimal utilization of local renewable energy production.
- Tools and processes needs to be developed to ease evaluation of embodied energy as design parameter in the operative dialogue of the design team.

* not inculding energy demand for technical equipment



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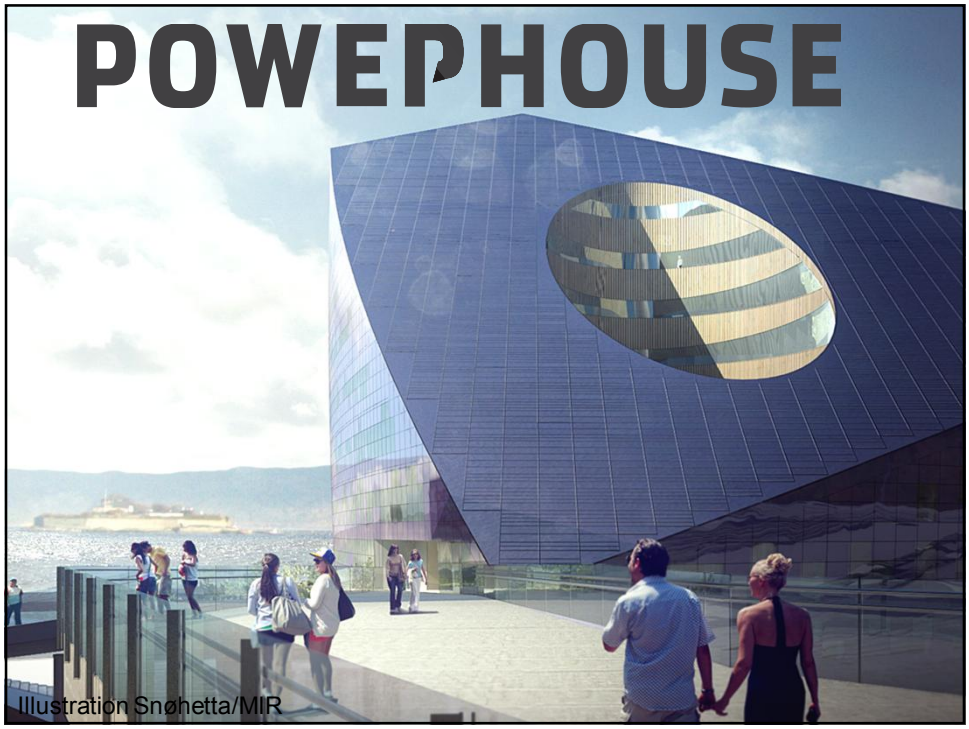
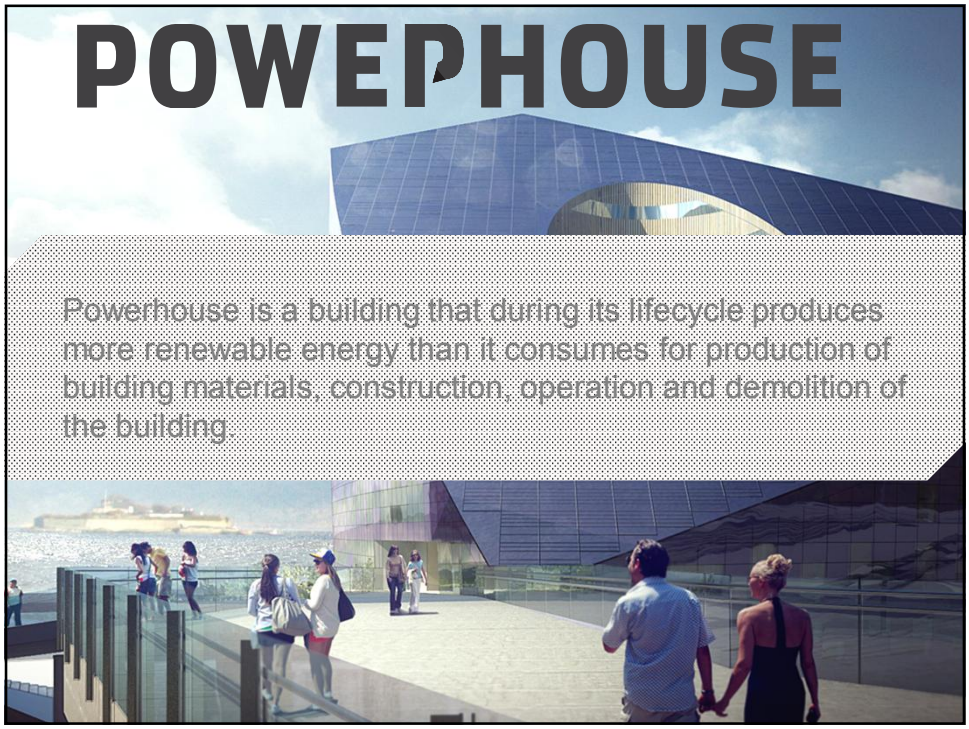
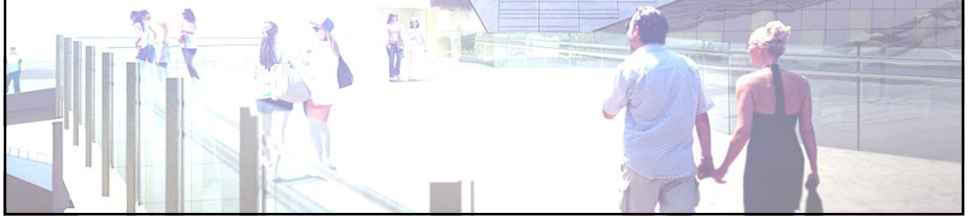

POWERHOUSE
Illustration Snøhetta/MIR


POWERHOUSE
Powerhouse is a building that during its lifecycle produces more renewable energy than it consumes for production of building materials, construction, operation and demolition of the building.

POWERHOUSE

- 16 400 m2 office and contemporary art museum
- Planned building start 2015
- Ambition BREEAM Outstanding
- Energy Positive Building
- Technology of today (€)



Powerhouse alliance

HYDRO entra SKANSKA

SNØHETTA ZERO MULTICONSULT

ZEB

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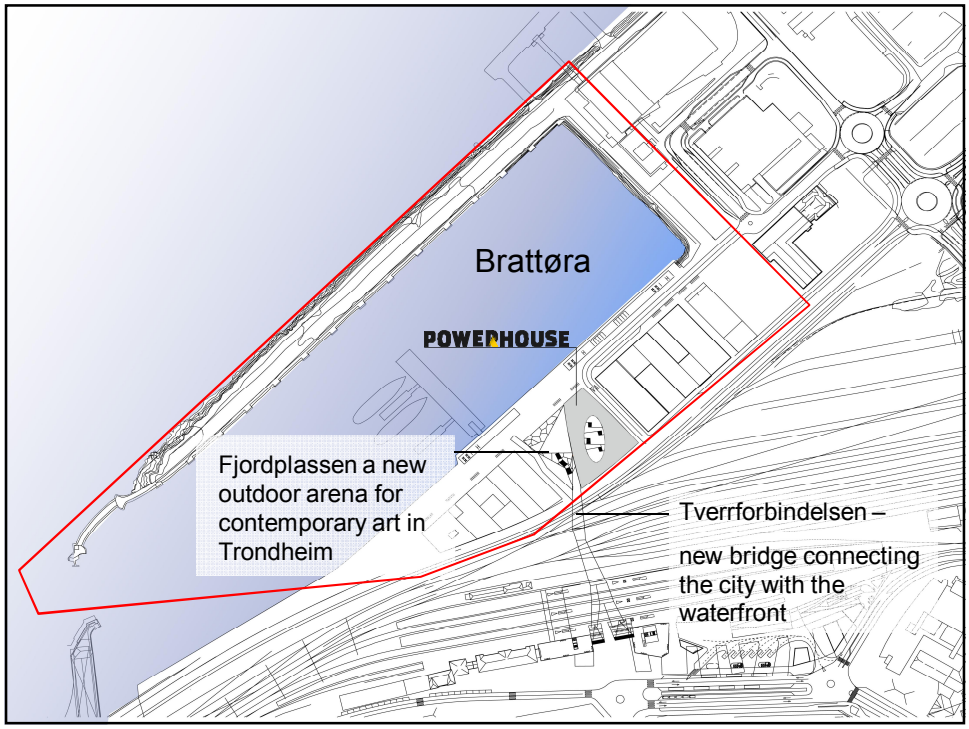
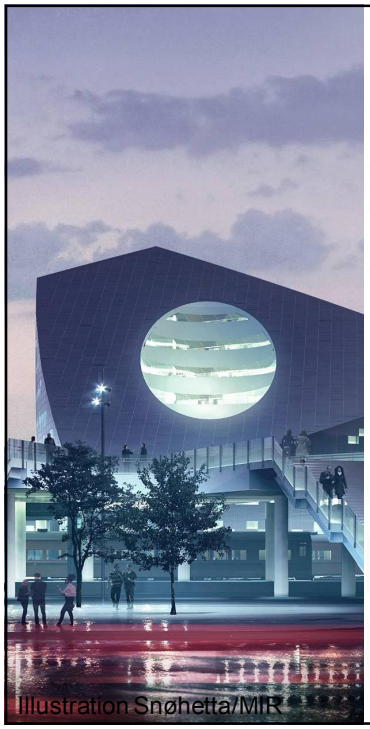
Nullutslippsbygg – fra forskning til praksis


TRONDHEIM


POWERHOUSE





Energy concept

- Energy effective form and building envelope
- Demand control
- Daylight optimization
- Reduction of embodied energy
- Hybrid ventilation
- Heat exchange with the fjord
- Local energy production PV

Calculated energy consumption

Table 1: The "best case" net energy demand, and demand for delivered energy for Powerhouse Brattørkaia 17 a. Embodied energy and electricity production is not included.

	Net specific demand kWh/m2/y	Spesific demand for delivered energy kWh/m2/y
Space heating	9,9	2,8
Ventilation heating	5,5	1,6
Tap water heating	5,0	3,7
Fans	3,0	3,0
Pumps	0,4	0,4
Lighting	9,4	9,4
Equipment	12,5	12,5
Space cooling	0,0	0,0
Ventilation cooling	0,0	0,0
Total	45,7	33,4
Total excluding equipment	33,2	20,9

Bjørn Wachenfeldt Jensen, Skanska Schematic design report, 2011

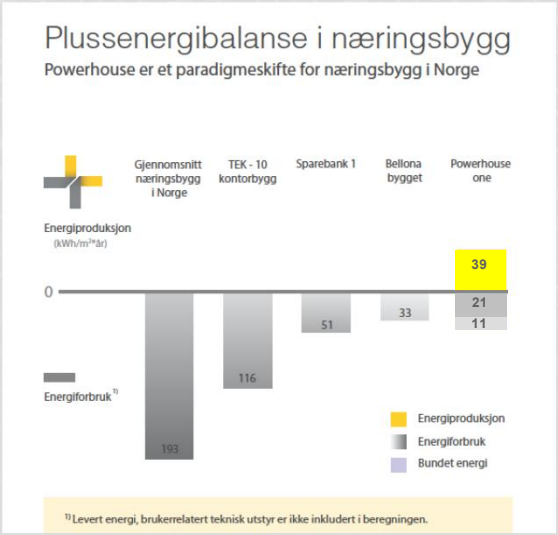
Calculated energy production

Table 2: Best Case estimate of total electricity production.

	Total kWh/y	Per m^2 heated floor area kWh/m2/y
Need for delivered energy (best case, excluded equipment)	308.543	20,9
Calculated maximum electricity production - PV		
Alternative A: Roof only	370.000	25,0
Alternative B: Roof + south-east facade	481.000	32,6
Alternative C: Roof + south-east and south-west facade	585.000	39,6

Bjørn Wachenfeldt Jensen, Skanska Schematic design report 2011

Energy balance



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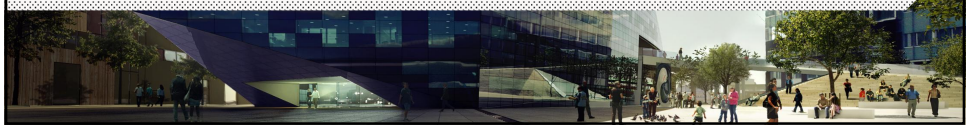
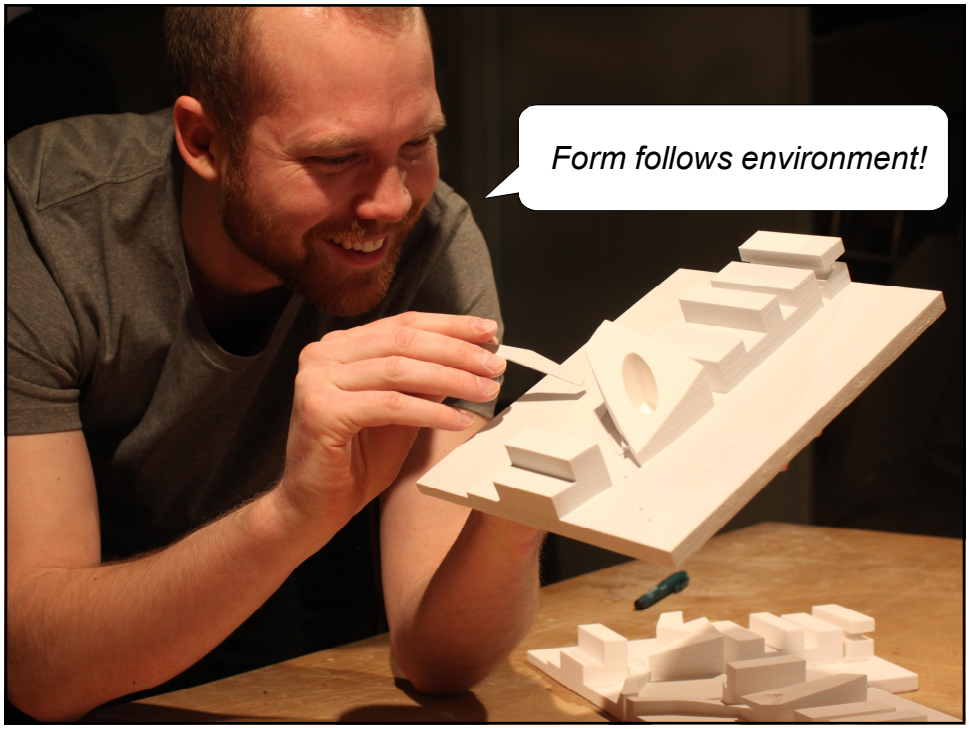
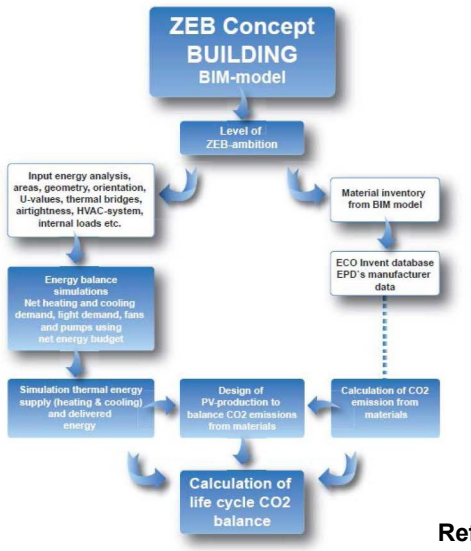




ZEB-Design



Ref. Dokka et al, 2013

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Nullutslippsbygg – fra forskning til praksis

BIM based bioclimatic design tools

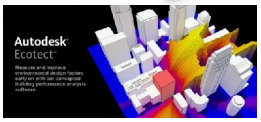
1 Rhinoceros® NURBS modeling for Windows

2 geco

GH2ECO AND VICE VERSA

- component EcoLink
- component EcoMeshExport
- component EcoSolCal
- component EcoSolRequest
- component EcoGridRequest
- component EcoLua
- component EcoDayOfYear

3 Autodesk® Ecotect®



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Nullutslippsbygg – fra forskning til praksis

FME Forskningssenter for miljøvennlig energi

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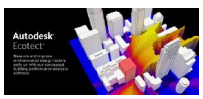

4 PVSYST

Results verified in PVsyst

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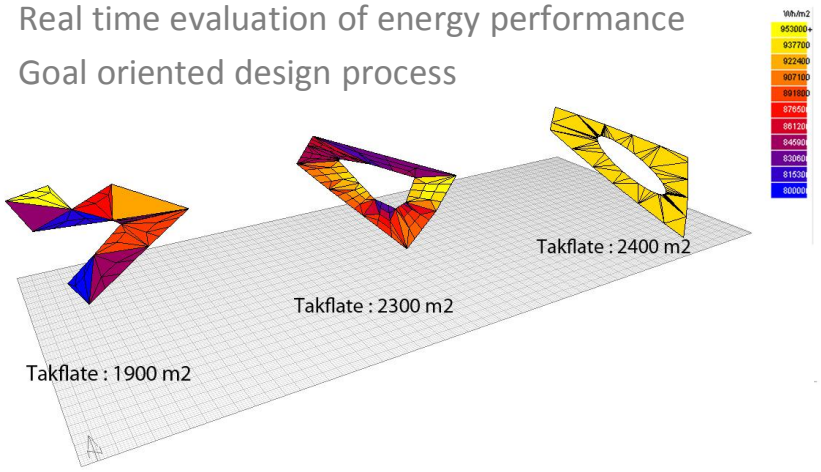
Nullutslippsbygg – fra forskning til praksis

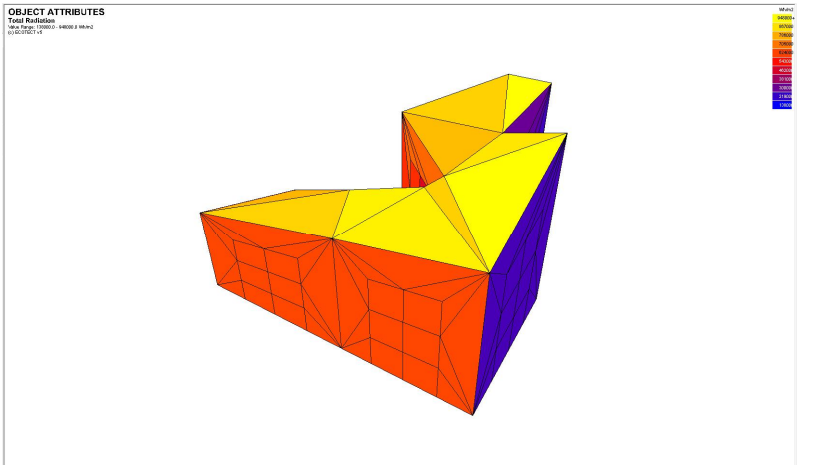
FME Forskningssenter for miljøvennlig energi

BIM based bioclimatic design

- Dynamic simulations
- Real time evaluation of energy performance
- Goal oriented design process



BIM based bioclimatic design



Solar optimization

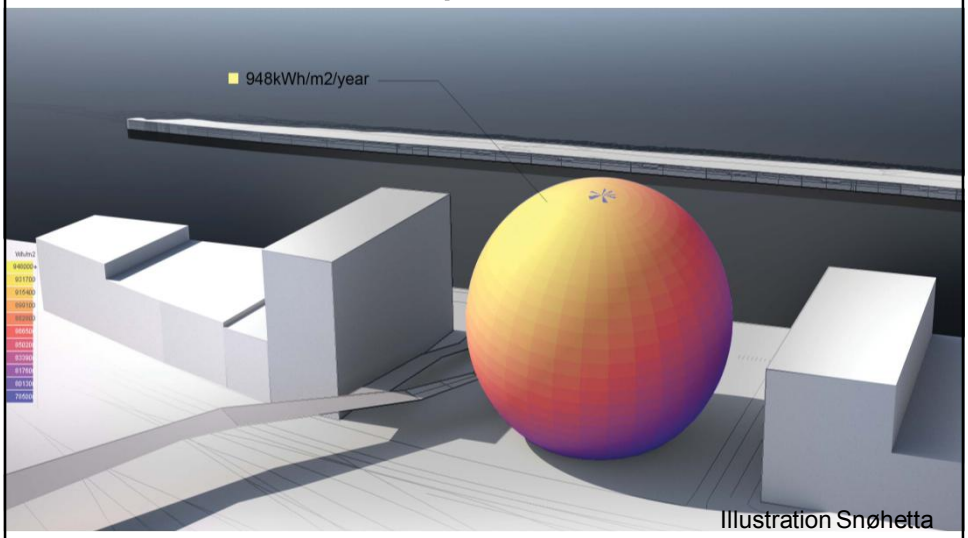


Illustration Snøhetta

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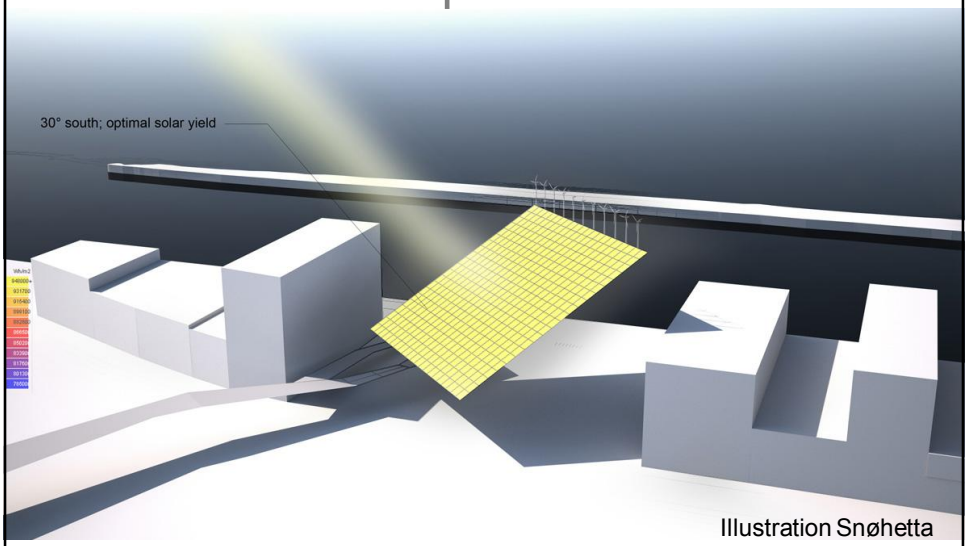
Solar optimization



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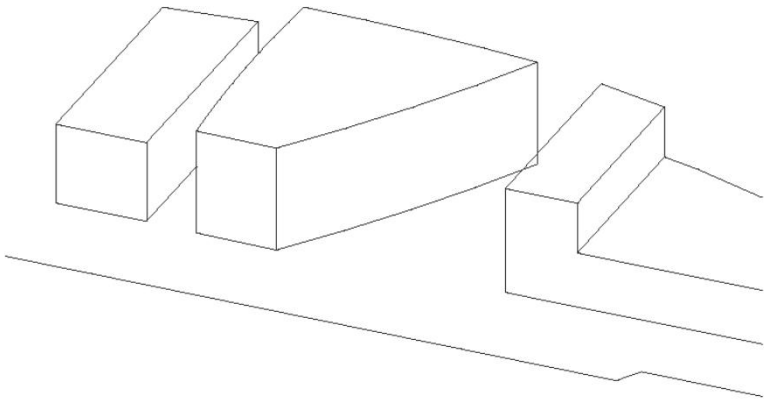
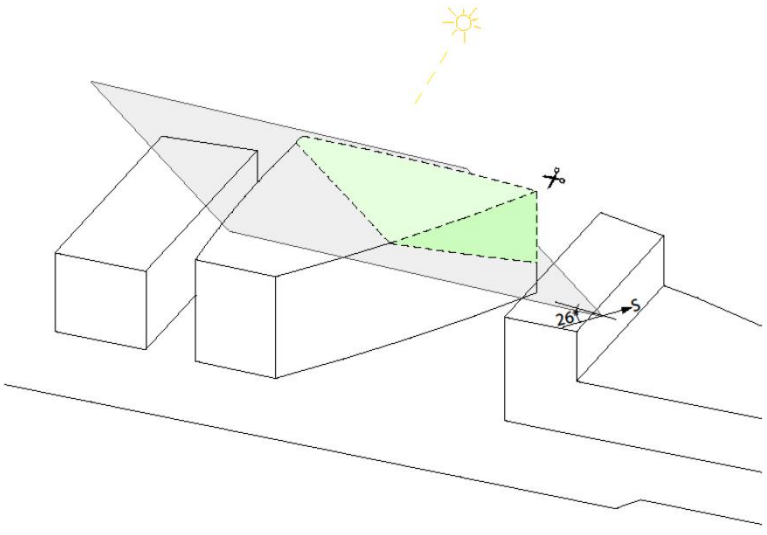
Nullutslippsbygg – fra forskning til praksis

Building volume based on plan of regulations





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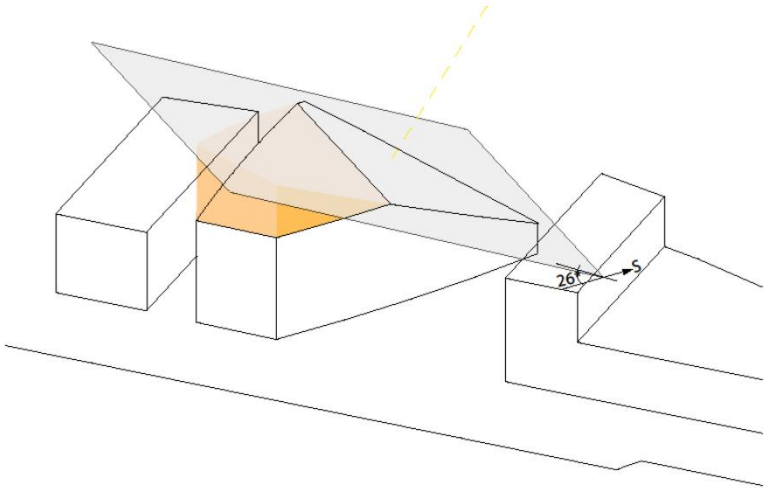
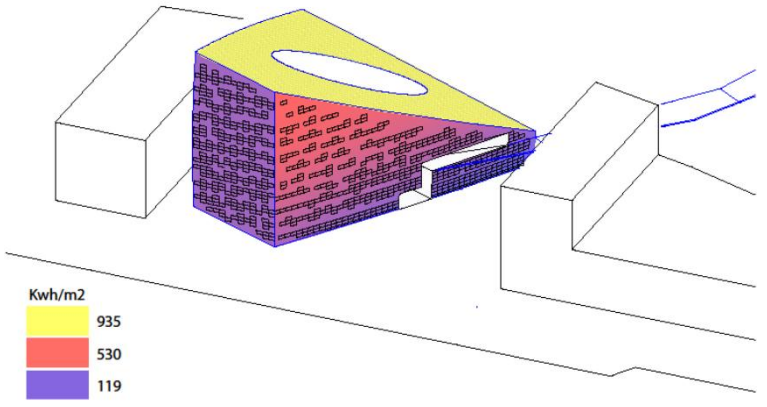


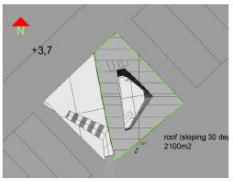
Optimization of window and PV distribution



Building integrated PV

- Efficient solar cell module with 20% efficiency
- 26 degree angle towards south
- Minimal frame area

Simulations for Powerhouse#1



	Tilt	Azimut	m2	Total kWp	MWh/y	kWh/kWp	PR	kWh/m2/y
Roof Sunpower 333 Wp	26	0	2100	429	390	910	86 %	186
Roof REC 245 Wp	26	0	2100	309	277	898	84 %	132
Roof ITS 230 Wp	26	0	2100	250	253	873	82 %	120
Facade North West	90	140	64	13	5	347	83 %	70
Facade North East	90	-135	490	100	36	358	82 %	73
Facade South East	90	-40	490	100	71	709	85 %	144
Facade South West	90	78	490	100	58	584	84 %	118

Ref. Bjørn Thorud, Multiconsult Schematic design report 2012

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Nullutslippsbygg – fra forskning til praksis

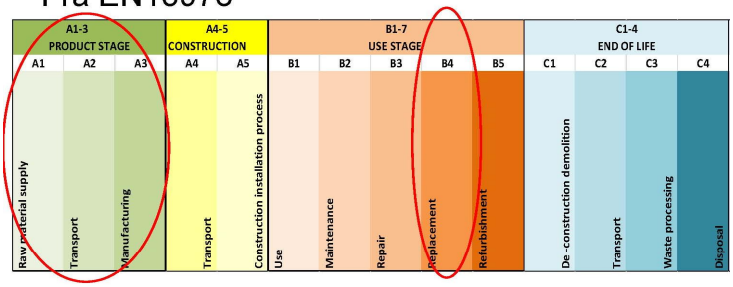
Simplified energy budget in excel

	A	B	C	D	E	F	G	H	I	J	K
1							**Best case electricity demand (taking into account system COPs)**				
2	Treated floor area		16200	m2	*Estimert*		Heating		5,00		
3	Electricity demand		17	kWh/m2år			Domestic Hot Water (Half covered by solar thermal)		2,50		
4	Embodied energy		10	kWh/m2år			Fans and pumps (assuming mixed mode ventilation and SFP below 0,5 (!) in mechanical mode)		2,00		
5	SUM el&em		27	kWh/m2år			Lighting		9,00		
6							Cooling		0,00		
7	Electricity demand		400000	kWh/a			**SUM**		**18,50**		
8	PV best case average effciency		15,00 %								
9	Solar production		Peak radiation [W/m2]	Average radiation [W/m2]	kWh/m2 a	PV yield					
10	South, 30 degress		1000	123	1077	186					
11	Flat			99	867	130					
12	East/West, 30 degrres			93	815	122					
13	South west, 90 degrees		887	77,5	679	118					
14	South east, 90 degrees		887	77,5	679	144					
15											
16		Max PV area	Peak power output [kW]			PV yield	Percent of demand				
17	Are south, 30 degrees	2100	420			390600	98 %				
18	Area flat	0				0	0				
19	Area east/west, 30 degrees	0				0	0 %				
20	Area south west, 90 degrees	800	141,92			94400	24 %				
21	Area south east, 90 degrees	0	0			0	0 %				
22	**SUM**	**2900**	**561,92**			**485000**	**121** %				
23	Pris	4500				29,9	KWh/m2år				

Meteorologisk sta
Nummer/Navn
6815 Trondhei

Embodied energy

Livssyklusfaser for en bygning – Fra EN15978*



- Funksjonell enhet: 1 m^2 av BRA over en levetid på 60 år
- BRA – 16200 m^2
- Solcelle-areal – 5728 m^2

*Bærekraftige byggverk - Vurdering av bygningers miljøpåvirkning Beregningsmetode

Ref. Torhildur Kristjansdottir, 2012

Embodied energy

Building elements		No.	Material input	Process used	Inputdata: Density [kg/m3]	Amount	Unit	Amount	Unit	kWh/unit	kg CO2eq/kg (SIMAPRO)	kg CO2 eq/unit
23 Outer walls												
	231 Bearing outer wall	2311	Timber	Plywood, outdoor use, at plant/RER U and Hevellast, EPDnr 84 tot.		15407	kg					
		2311	Timber (Trestendrelwoodwork)									
		2312	Insulation	Glass wool mat, at plant/CH U ZEB and Glava EPD	40	356	m2	62	m3	149		
		2312	Plasterboard	Gypsum plaster board, at plant/CH U ZEB and Norsipa EPD	Not specified	356	m2	3,4	m3			
		2312	Vapour barrier	PE FOIL	Not specified	177	m2	0,36	m3		2,1	
		2311	Vapour barrier retarder	Vindsperre ruil based	2222	177	m2	0,28	m3		??	
	232 Non Bearing outer walls											

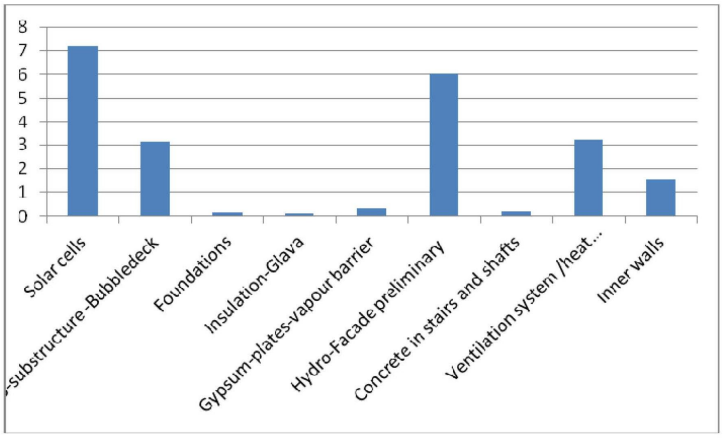
Key Challenge

- Not all materials in ZEB model exist in the SIMAPRO/Ecoinvent database. Until information on emission factors for these materials are available then data from Norwegian EPD's may need to be substituted.
- This is currently under discussion since Norwegian EPD's use Nordel electricity mix which is different to average European factor used in Ecoinvent

Ref. Aoife Houlihan Wiberg, 2013

Embodied energy

Table 24 Preliminary summary of results



Torhildur Kristjansdottir, Schematic design report 2012

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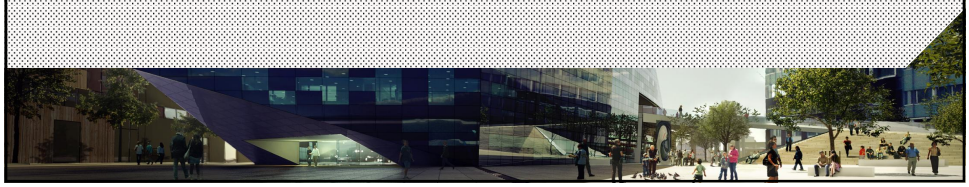

Further research

- Develop a robust BIM based real time evaluation tool for informed Embodied Energy design decisions. The current ZEB process utilize Rhino BIM to retrieve data on the indiviual project, but is highly dependent on manual input and extraction.
- Include wind and ventilation simulations in the optimization process.

ZEB The Research Centre on Zero Emission Buildings

Nullutslippsbygg – fra forskning til praksis

References

- Powerhouse One, Schematic design report 2012
- A Net Zero Concept Analysis of a Norwegian Office building, Dokka et al, 2013
- Torhildur Kristjansdottir – ZEB 2012 conference presentation
- Aoife Houlihan Wiberg – PresentationKlimax seminar, 2013