BIM based deep building renovation optimisation for sustainability

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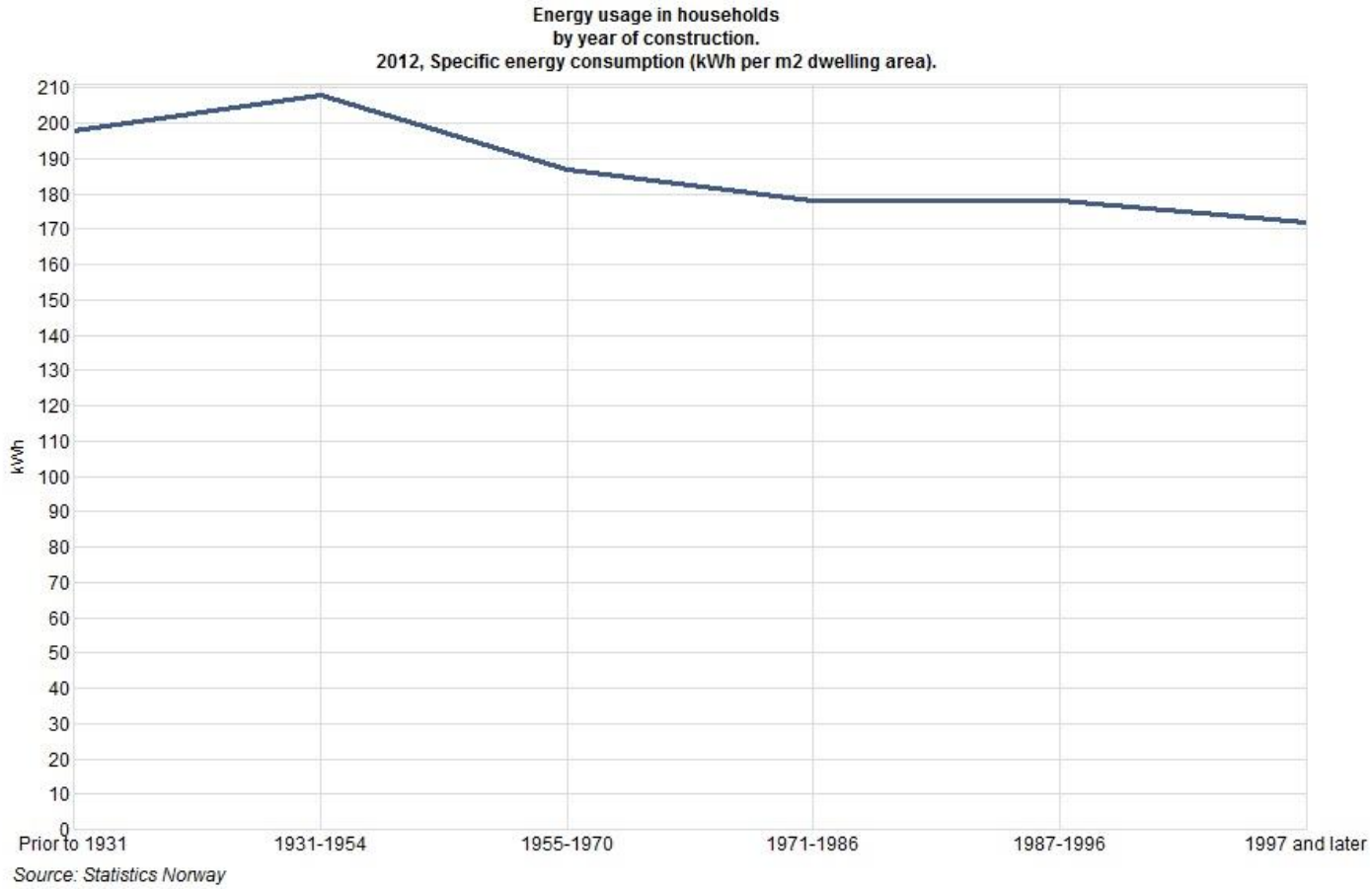
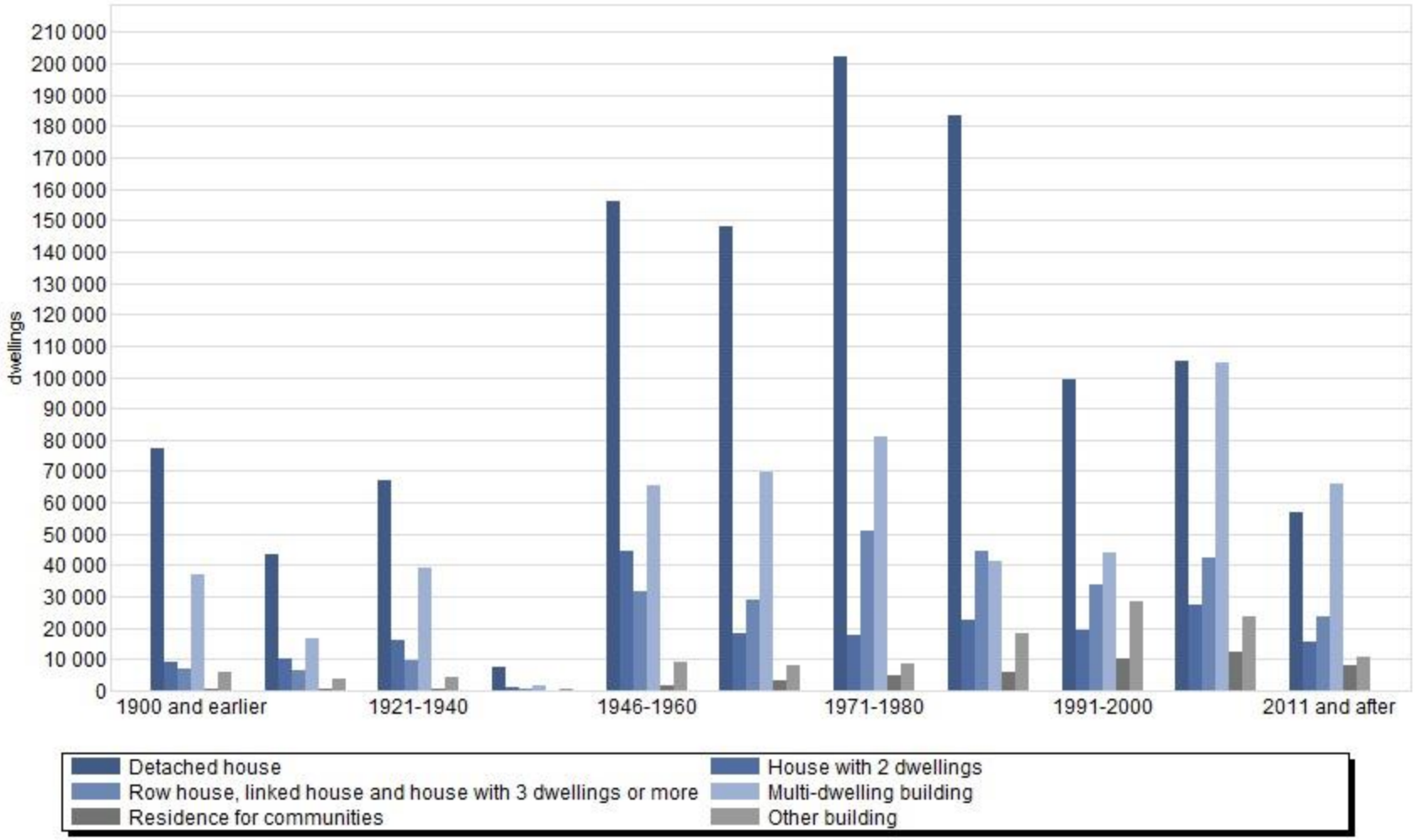
Introduction



Source: Statistics Norway

Dwellings,
by type of building and year of construction of the building.
2016, Dwellings (occupied and vacant), The whole country.



Source: Statistics Norway

Småhus	Levert energi pr m^2 oppvarmet BRA (kWh/m^2)						
	A	B	C	D	E	F	G
Oppvarmet BRA (m^2)	Lavere enn eller lik	Lavere enn eller lik	Lavere enn eller lik	Lavere enn eller lik	Lavere enn eller lik	Lavere enn eller lik	Ingen grense
50	111,00	152,00	195,00	257,00	321,00	410,00	> F
75	105,67	141,33	178,33	229,67	282,33	356,67	> F
100	103,00	136,00	170,00	216,00	263,00	330,00	> F
125	101,40	132,80	165,00	207,80	251,40	314,00	> F
150	100,33	130,67	161,67	202,33	243,67	303,33	> F
200	99,00	128,00	157,50	195,50	234,00	290,00	> F
300	97,67	125,33	153,33	188,67	224,33	276,67	> F
400	97,00	124,00	151,25	185,25	219,50	270,00	> F
500	96,60	123,20	150,00	183,20	216,60	266,00	> F

Øvre grense for karakter C er basert på nivå for TEK 2010.

Method

- BIM: On-site survey, Terrestrial Laser Scanning or Data Capture with Drone
- Life cycle analysis
  - FU:the off-site preparation, on-site renovation, use and demolition of one building over the lifetime of 50 years
  - Data: On-site data, simulation results, EPD Norge and Ecoinvent database, the cost database in Holte (following the Norwegian standard NS3450) Impacts:Climate change (GWP) and Particulate matter formation (PMFP)

- Life cycle environmental impacts

- $E_{i_{tot}} = \sum_{E_i}\left(E_{i_{ot}} + E_{i_r} + E_{i_o} + E_{i_d} + E_{i_e}\right)$

- Life cycle cost

$$C_{i_{tot}} = \sum_{E_i}\left(C_{i_{ot}} + C_{i_r} + C_{i_o} + C_{i_d} + C_{i_e}\right)$$

- Optimization

$$MinLCC, MinLCEI, MinLCE_c, \& MaxLCE_p$$

Subject to:

$$0 \le LCC \le C_c$$

$$0 \le LCEI \le C_{EI}$$

$$0 \le LCE_C \le C_E \,/\, LCE_P$$

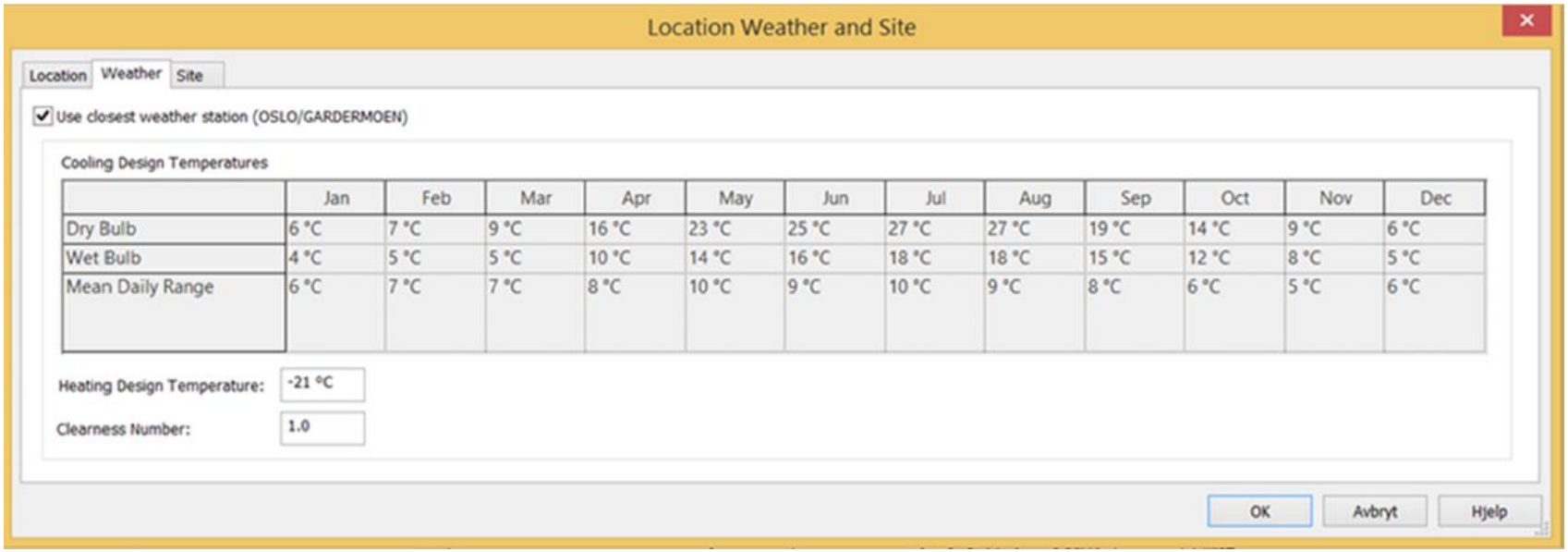
Level 1	Level 2	Level 3	Leve4
Deep renovation optimization solutions	Theme	Criteria	Indicators
	Environmental impacts (life cycle perspective)	Local impacts	PM10 Emissions
		Global impacts	GHGs emissions
	Resource	Energy	Energy production
			Energy consumption
	Cost	Life cycle cost	Life cycle cost

Case study

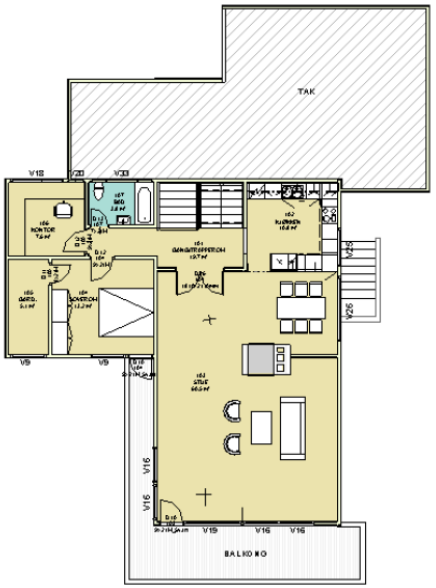
- A detached house (226 m^2) located close to Oslo built in 1966 is selected to be a case study for the project.
- It is supposed to be two part: 1) to renovate it following the existing building code in Norway (TEK10), 2) to install the solar PV panel to produce the enough electricity for the building.


Sweden
Norway
Trondheim
Kristiansund
Molde
Ålesund
Sundsvall
Hudiksvall
Lillehammer
Mora
Bergen
Skrivervegen 5
Oslo
Drammen
Haugesund
Karlstad
Fredrikstad
Stavanger
Kristiansand
Gothenburg
Jönköping

- The average sunlight hours in Oslo area are 1632 hours annually [23].
- The installation of solar PV will got the 10000 NOK (Norwegian kroner) and 1250 NOK per kW (up to 15 kW) subsides from ENOVA.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dry Bulb	6 °C	7 °C	9 °C	16 °C	23 °C	25 °C	27 °C	27 °C	19 °C	14 °C	9 °C	6 °C
Wet Bulb	4 °C	5 °C	5 °C	10 °C	14 °C	16 °C	18 °C	18 °C	15 °C	12 °C	8 °C	5 °C
Mean Daily Range	6 °C	7 °C	7 °C	8 °C	10 °C	9 °C	10 °C	9 °C	8 °C	6 °C	5 °C	6 °C



PLAN 1 ET.

PLAN U-ET.

Solutions	energy saving after renovation (kWh/year)	energy production requirement (kWh/year)	GWP (ton CO_2eq)	PMFP(kg PM10 eq)	LCC(million NOK)
Option 1: Change roof, facade, and window+ install the solar pv	25306	35780	56.13	282.75	1.04
Option 2: Change roof (not increasing the insulation quality) facade, and window+ install the solar pv	20507	40579	62.69	48.59	1.06

Discussion and conclusion

- The saving of energy for the renovated to be current building code on roof, façade and windows will save energy use around 25 MWh annually and 1.3 million NOK energy cost in total life.
- The renovation of housing itself will be more cost-effective than the installation of PV panel. The most cost effective renovation part is the façade.
- The saving of the GWP of the renovation is not as significant as the energy saving and life cost saving.

Thank you