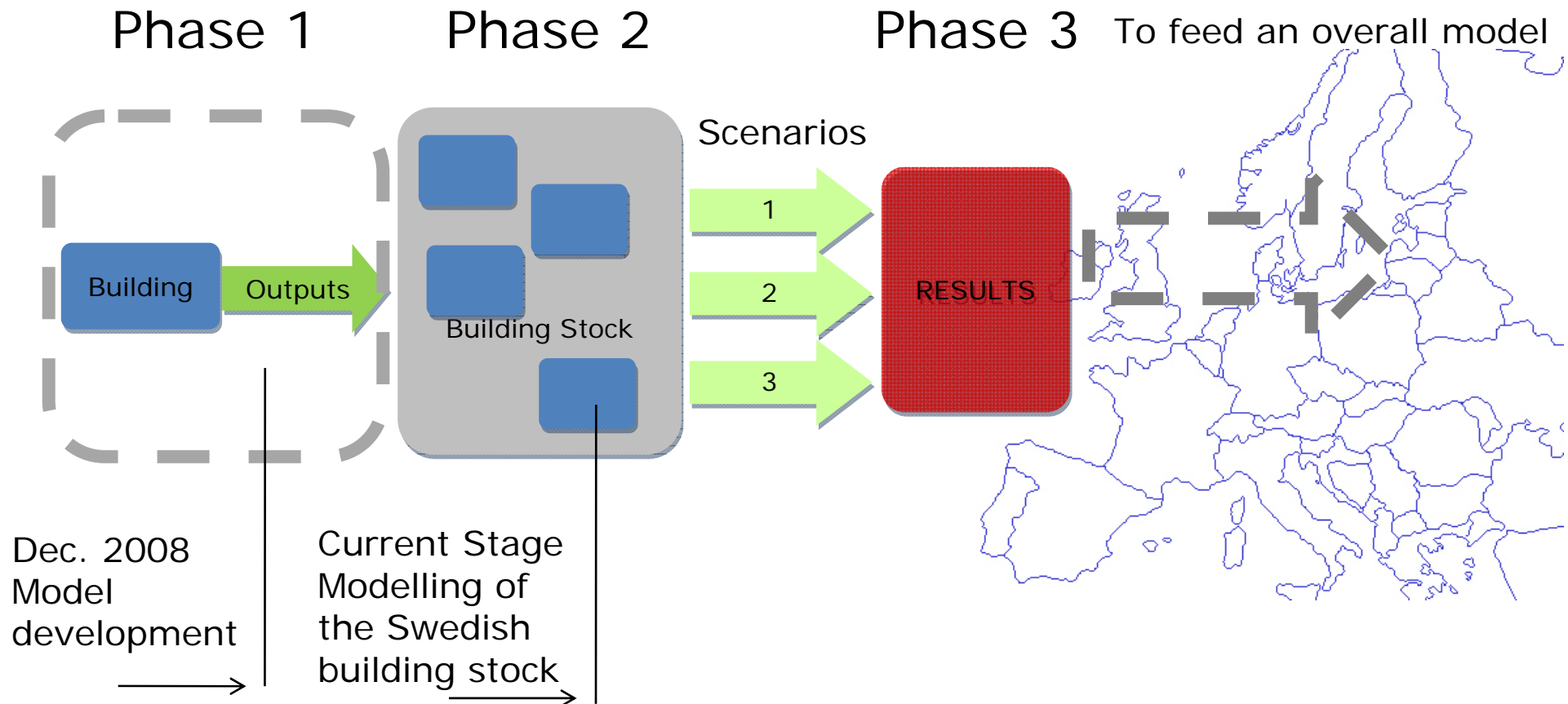


Modelling energy efficiency scenarios for European building stock



Results for the Swedish building stock (project commissioned by Boverket)

Aim

Evaluation of the measures for the reduction of specific energy use (in kWh/m²/year) in the existing Swedish building

Current goal, based on the programme of *Miljömålsrådet* (Environmental Objectives Council):

- 20 % less specific energy use by year 2020, and
- 50 % less by year 2050 (reference year 1995).

Energy saving potential and cost

Boverket's methodology

1. Selection of representative buildings
2. Data gathering in the field survey
3. Building energy simulations
4. List of measures for energy reduction
5. Cost-effectiveness of the measures
6. Scaling up of the results for whole Sweden

1-2 Representative building and data gathering

Field study - **BETSI**
Byggnaders energi, teknisk status och innemiljö.

- 1800 buildings (1384 residential)
- 29 Locations
- 5 Activities
- 5 Ventilation systems
- 5 Energy sources



3 Numerical modelling

- Building energy simulation programme
- Original code written in Matlab / Simulink
- Simplified model of a building model
(based on thermal time constant)
- Model testing and validation:
 - Phase 1 - on a single building
 - Phase 2 - on app. 1400 Swedish buildings

Baseline results

E0 with the inputs from the field survey
(ventilation flow rate below recommended in single family houses)

92,28 TWh/y

E035 with increased sanitary ventilation to 0,35 l/s/m²

97,68 TWh/y.

4. Measures for reduction of energy use in buildings

Measure 1	Change of U-value of crawl space floor
Measure 2	Change of U-value of slab on grade in cellar/basement
Measure 3	Change of U-value of floor above unheated cellar/basement
Measure 4	Change of U-value of of basement walls above ground
Measure 5	Change of U-value of of basement walls below ground
Measure 6	Change of U-value of facades (different types)
Measure 7	Change of U-value of facades (different types)
Measure 8	Change of U-value of facades (different types)
Measure 9	Change of U-value of attic floor (different types)
Measure 10	Change of U-value of attic floor (different types)
Measure 11	Change of U-value of attic floor (different types)
Measure 12	Change of U-value of attic floor (different types)
Measure 13	Change of U-value of knee-walls
Measure 14	Change of U-value of insulated slooping roof
Measure 15	Change of U-value of windows
Measure 16	For the single family houses (byggnadstyp = S) Change of ventilation systems S, F, FT and upgrading of FTX to FTX systems with heat recovery efficiency of 0.75. Also the SFP value is changed.
Measure 17	For the larger residential buildings (byggnadstyp = F) Change of ventilation systems S, F, FT and upgrading of FTX to FTX systems with heat recovery efficiency of 0.75. Also the SFP value is changed.
Measure 18	Reduction of power for lighting (50 %)
Measure 19	Reduction of power for appliances (50 %)
Measure 20	For the single family houses; Change of use of hot water. Reductions to 0.80 W/m ²
Measure 21	For the larger residential buildings; Change of use of hot water. Reductions to 1.10 W/m ³
Measure 22	Change of electrical power to hydro pumps
Measure 23	Change of indoor air temperature down to 20 centigrade

How are measures applied:

- Total number of simulations:
23 measures x 1384 buildings = 31 832 results
- All measures cannot be applied to all buildings *
10491 results
- Results are ranked according to the COST EFFICIENCY only

* Example: changes in U-value of knee-walls, changes in ventilation rate of single family houses

Results - energy reduction by a single measure

The potential savings for the 23 measures studied are between 0,03 and 13,60 TWh/y.

The measures that would produce more savings :

- 6 U-value of facades
- 15 Window replacement
- 16-17 Heat Recovery
- 23 Tint 20C

Energy demand TWh/y		
BASELINE	92,28	
BASELINE 0,35	97,68	
Measure 1	0,26	0,3 %
Measure 2	1,72	1,8 %
Measure 3	0,34	0,4 %
Measure 4	1,80	1,8 %
Measure 5	3,26	3,3 %
Measure 6	7,18	7,4 %
Measure 7	0,09	0,1 %
Measure 8	0,03	0,0 %
Measure 9	0,77	0,8 %
Measure 10	0,01	0,0 %
Measure 11	0,19	0,2 %
Measure 12	1,78	1,8 %
Measure 13	0,31	0,3 %
Measure 14	0,44	0,5 %
Measure 15	6,51	6,7 %
Measure 16	11,95	12,2 %
Measure 17	9,61	9,8 %
Measure 18	0,34	0,3 %
Measure 19	0,96	1,0 %
Measure 20	2,61	2,7 %
Measure 21	2,11	2,2 %
Measure 22	0,60	0,6 %
Measure 23	13,60	13,9 %

Results - energy reduction by aggregating measures

Criteria for measures aggregation

Cost-efficiency
(material and labour)

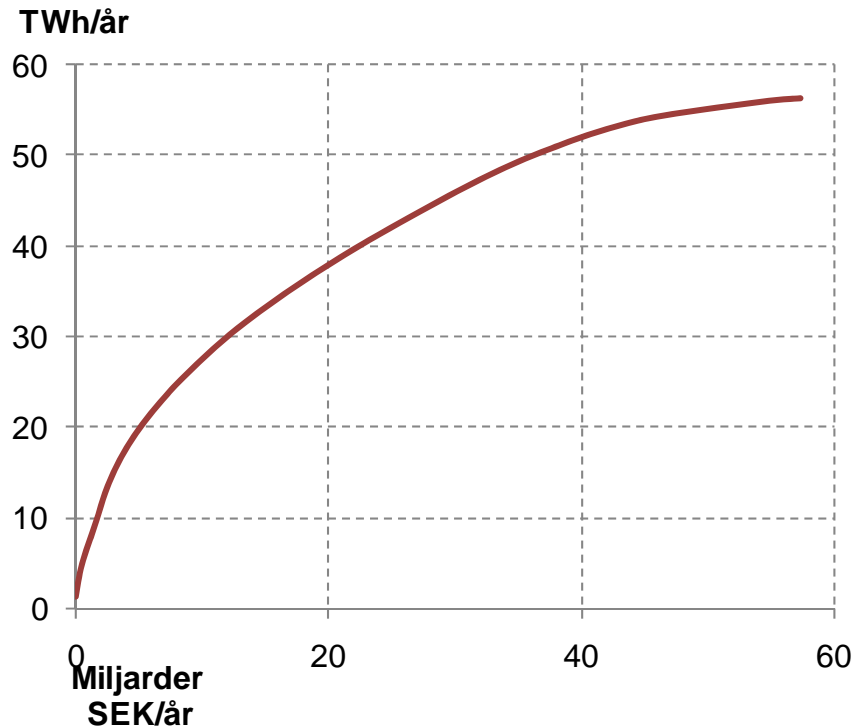
Maximum energy saving according to
their cost-efficiency

56,3 TWh/y (58 %)

Measures	Energy saving TWh/y	
Aggregated 1	1,3	1,3%
Aggregated 2	4,8	4,9%
Aggregated 3	8,7	8,9%
Aggregated 4	14,1	14,4%
Aggregated 5	19,0	19,5%
Aggregated 6	23,9	24,5%
Aggregated 7	27,5	28,1%
Aggregated 8	30,6	31,4%
Aggregated 9	34,8	35,6%
Aggregated 10	39,4	40,3%
Aggregated 11	44,4	45,5%
Aggregated 12	48,5	49,6%
Aggregated 13	51,4	52,6%
Aggregated 14	53,0	54,3%
Aggregated 15	54,3	55,6%
Aggregated 16	56,0	57,3%
Aggregated 17	56,3	57,6%

Published results – September 2009

(Report: *Så mår våra hus*)



Cost of reaching the targets:

20% less in 2020 would cost
7 billion SEK

50% less in 2050 would cost
57 billion SEK

Data provided by Boverket.

Further work:

1. With what we have

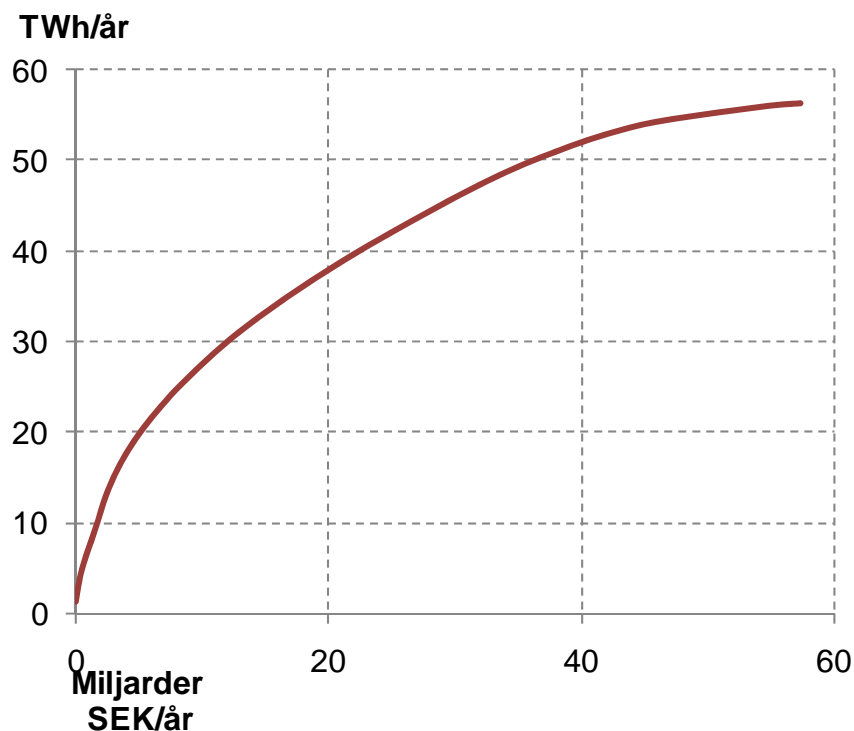
- Detail a strategy for specific buildings, for instance: for S the best is to...
- Plot reference values for type buildings

2. With new work/data

- Analyze more issues than cost-efficiency: technology, transaction cost, competitiveness, security of supply, etc.
- Apply the model to another building stock with available data (p.eg. French residential or Spanish non-residential)

Published results – Sept. 2008

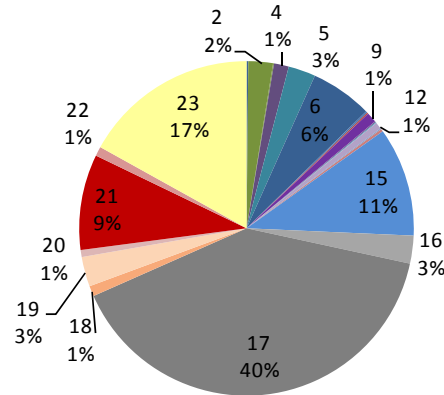
(Report: Så mår våra hus)



Steg	Besparing i steget	Aggregerad besparing	Kostnad i steget [MdSEK]	Aggregerad kostnad [SEK/år]	Total energianvändning [TWh/år]	Kostnad per sparad kWh	Aggregerad kostnad/aggregerad besparing
E0.0.23					92,3		
E0.0.35					97,7		
1	1,3	1,3	0	0	96,4	0	0,00
2	3,5	4,8	0,5	0,47	92,9	0,13	0,10
3	3,9	8,7	0,9	1,4	89,0	0,24	0,16
4	5,4	14,1	1,3	2,7	83,6	0,24	0,19
5	4,9	19	1,9	4,6	78,7	0,39	0,24
6	4,9	23,9	2,8	7,4	73,8	0,57	0,31
7	3,6	27,5	2,6	10	70,2	0,72	0,36
8	3,2	30,7	2,6	12,6	67,0	0,81	0,41
9	4,1	34,8	4,0	16,6	62,9	0,98	0,48
10	4,6	39,4	5,1	21,7	58,3	1,11	0,55
11	5,0	44,4	6,3	28	53,3	1,26	0,63
12	4,1	48,5	5,7	33,7	49,2	1,39	0,69
13	2,9	51,4	5,1	38,8	46,3	1,76	0,75
14	1,7	53,1	3,7	42,5	44,6	2,18	0,80
15	1,3	54,4	4,0	46,5	43,3	3,08	0,85
16	1,6	56	8,2	54,7	41,7	5,13	0,98
17	0,3	56,3	2,6	57,3	41,4	8,67	1,02

Data provided by Boverket.

Percentage of total energy saving due to each measure



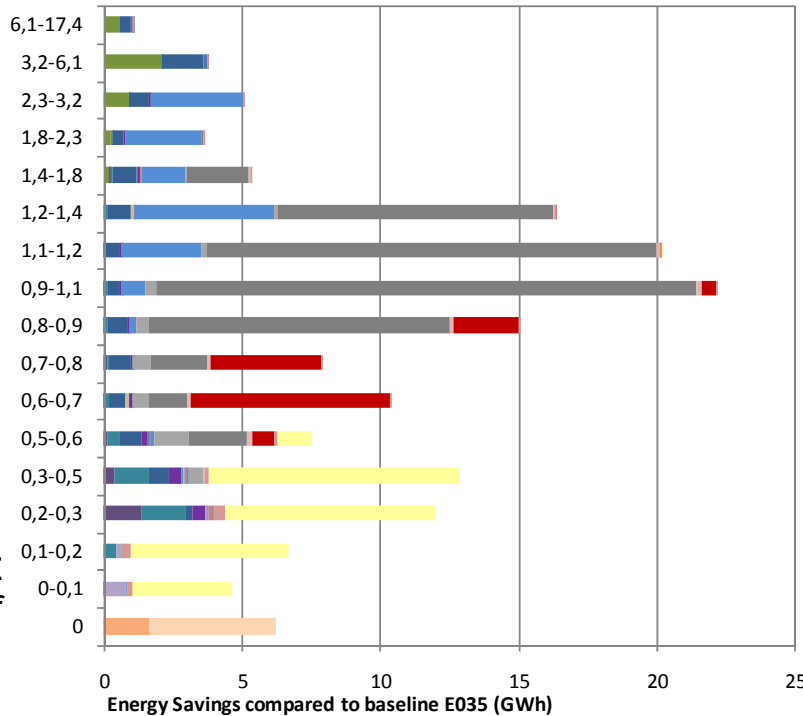
Detailed Results

Issues represented:

Measure, Energy saving, Cost-efficiency

LESS
cost-eff

Stages of cost-efficiency (SEK/kWh)



MORE
cost-eff

- 1 Change of U-value of crawl space floor
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- 15 Change of U-value of windows
- 16 (byggnadstyp S) Change of ventilation systems to FTX systems with heat recovery eff 0.75
- 17 (byggnadstyp F) Change of ventilation systems to FTX systems with heat recovery eff 0.75
- 18 Reduction of power for lighting (50 %)
- 19 Reduction of power for appliances (50 %)
- 20 (byggnadstyp S) Change of use of hot water. Reductions to 0.80 W/m2
- 21 (byggnadstyp F) Change of use of hot water. Reductions to 1.10 W/m3
- 22 Change of electrical power to hydro pumps
- 23 Change of indoor air temperature down to 20 cen tigrade