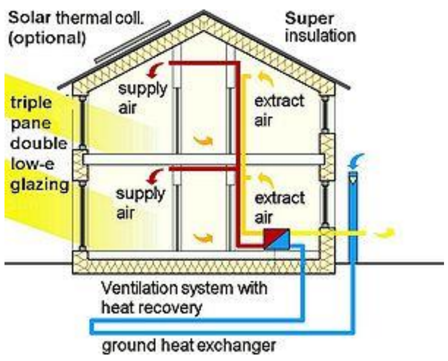
Modeling energy and GHG flows from ageing dwelling stocks towards 2050



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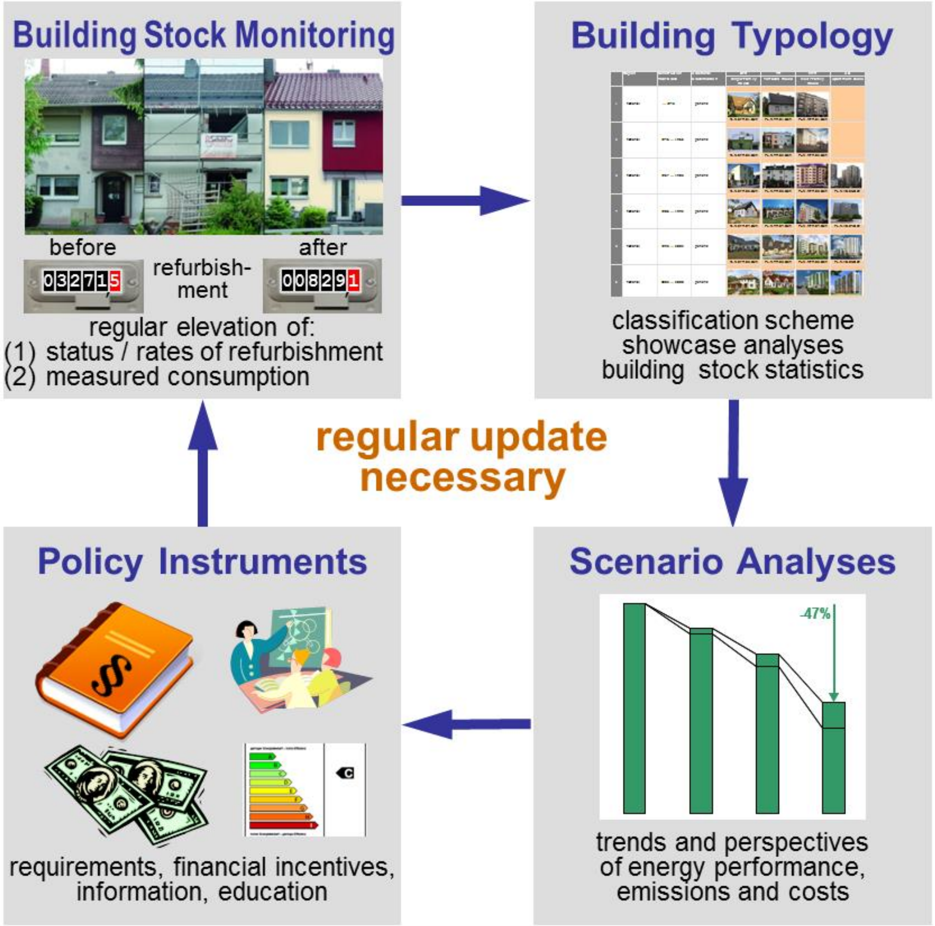
Intelligent Energy Europe – EPISCOPE project

Energy Performance Indicator Tracking Schemes for the Continuous Optimisation of Refurbishment Processes in European Housing Stocks (http://episcope.eu)

- National building typologies for 20 countries (TABULA)
- Energy balance for each stock type/age segment at 3 energy levels
  - Existing buildings
    - Original state
    - Standard renovation
    - Ambitious renovation
  - Future new built
    - Current energy standard
    - Passive house (PH) standard
    - NZEB standard
- Scenario analyses as input for policy and building stock monitoring
  - Energy demand
  - Delivered energy
  - CO_2-emissions
  - Energy costs



Model layer 1: Dynamic building stock model

Explained in presentation by Nina Sandberg

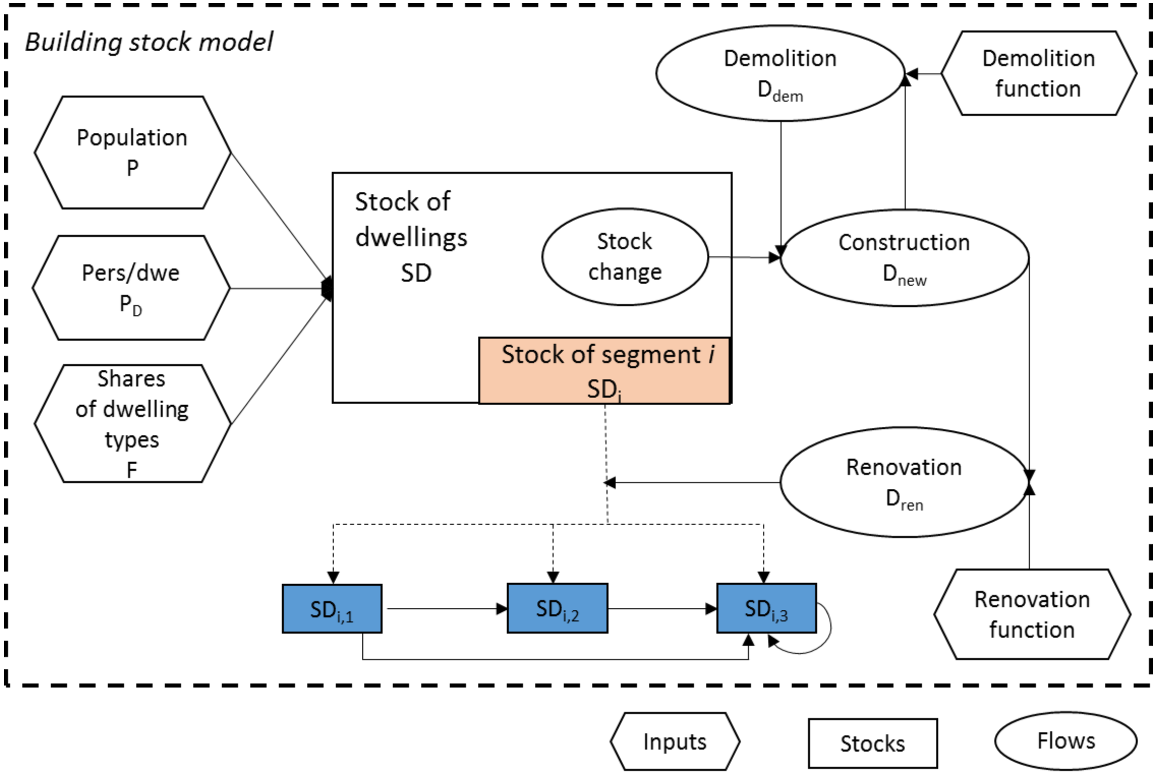
Stock and flows of dwellings

Model based on mass balance equations and probability functions

Segments defined by dwelling type and construction period (cohort)

Archetypes defined by segment and renovation state

Dwellings can move between archetypes within the same segment when renovated



Renovation activity is an output from the model, estimated as the need for maintenance of previous construction

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Model layer 2: Energy model

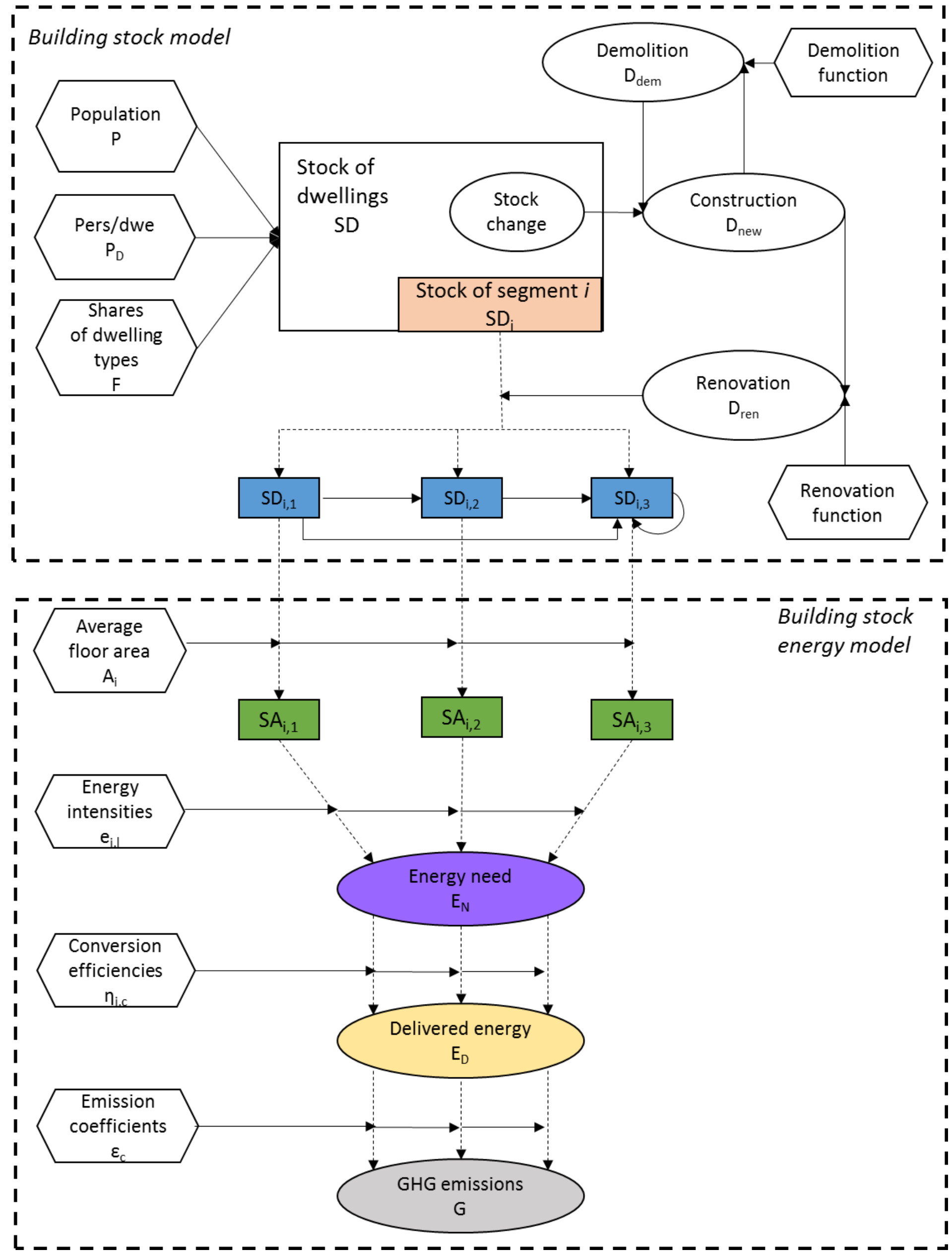
Scenario analyses towards 2050

Inputs:

- Number of dwellings ($SD_{i,l}$) in each archetype and year of the time horizon (output from the Model layer 1)
- Average floor area (A_i) per segment
- Energy intensity ($e_{i,l}$) per archetype (scenario specific, according to assumed progress in energy renovation)
- Conversion efficiency ($\eta_{i,l}$) and GHG emission coefficient ($\varepsilon_{i,l}$) per energy carrier

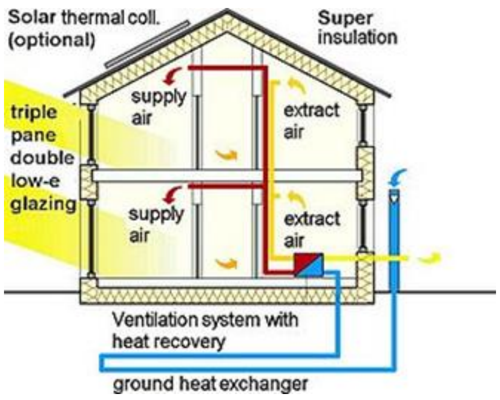
Outputs:

- Stock of floor area ($SA_{i,l}$) per archetype and year
- Energy need (E_N) and Delivered energy (E_D) each year per archetype, segment or total stock
- GHG emissions (G) each year per archetype, segment or total stock



Energy balance calculations

Annual energy balance per dwelling type, cohort and energy level



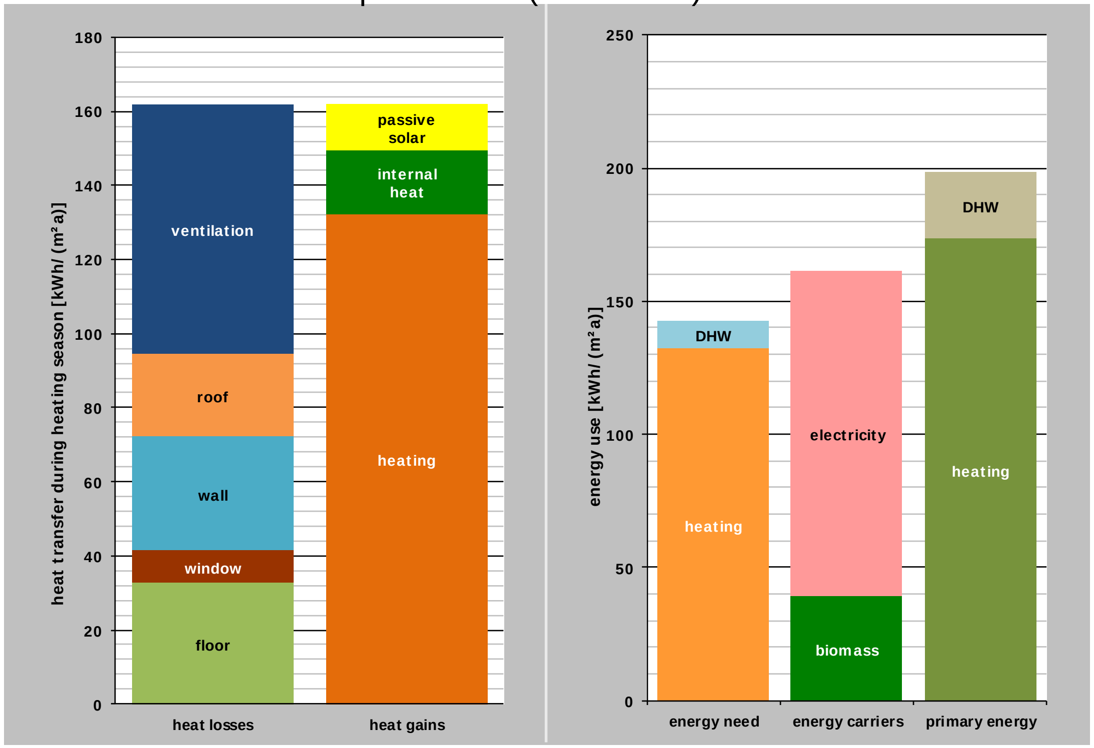
Input:

- Specific input data for each dwelling type, cohort and renovation level
- Average building technologies with corresponding heat performance
  - Building envelope components (roof, walls, windows, floor, doors)
  - Ventilation system
  - Domestic hot water
- Onsite generation (optional)
  - Heat pumps (different types)
  - Solar (photovoltaic or thermal)

Output:

- TABULA energy balance results (kWh/m^2/year)
  - Left side of figure:
    - Heat losses
    - Heat gains
  - Right side of figure:
    - Energy need
    - Energy carriers (delivered energy)
    - Primary energy

Example: SFH04 (1981-1990) level 1



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Energy need improvements

Annual energy need intensities per dwelling type, cohort and energy level

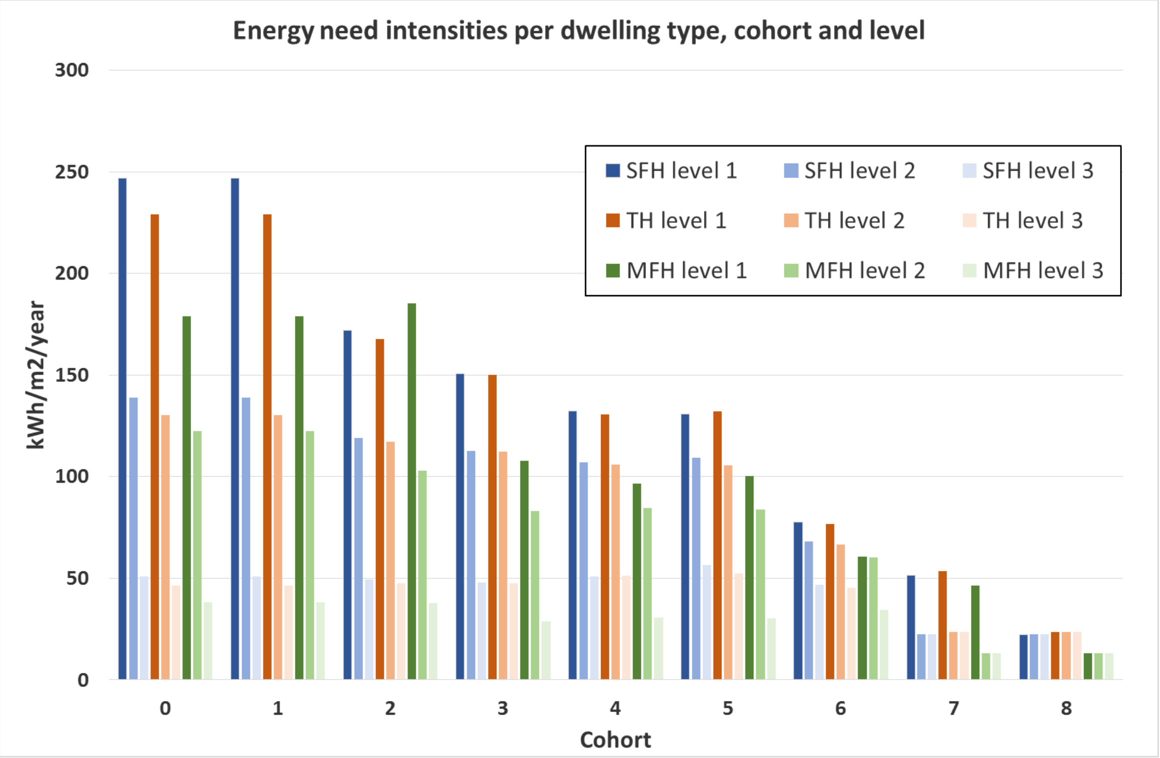
Input:

- Building technologies used
  - Building envelope components
  - Ventilation system
  - Domestic hot water
  - Onsite heat pump and solar generation (PV or thermal)
- Specific for each dwelling type, cohort and level

Output:

- TABULA energy balance results
- Energy need intensities (kWh/m²/year), for all archetypes
  - SFH, TH and MFH
  - Level 1, 2 and 3

    1 = Original state
    2 = Standard renovation (common current renovation)
    3 = Advanced renovation (ambitious future renovation)
  - Cohort 0 – 8



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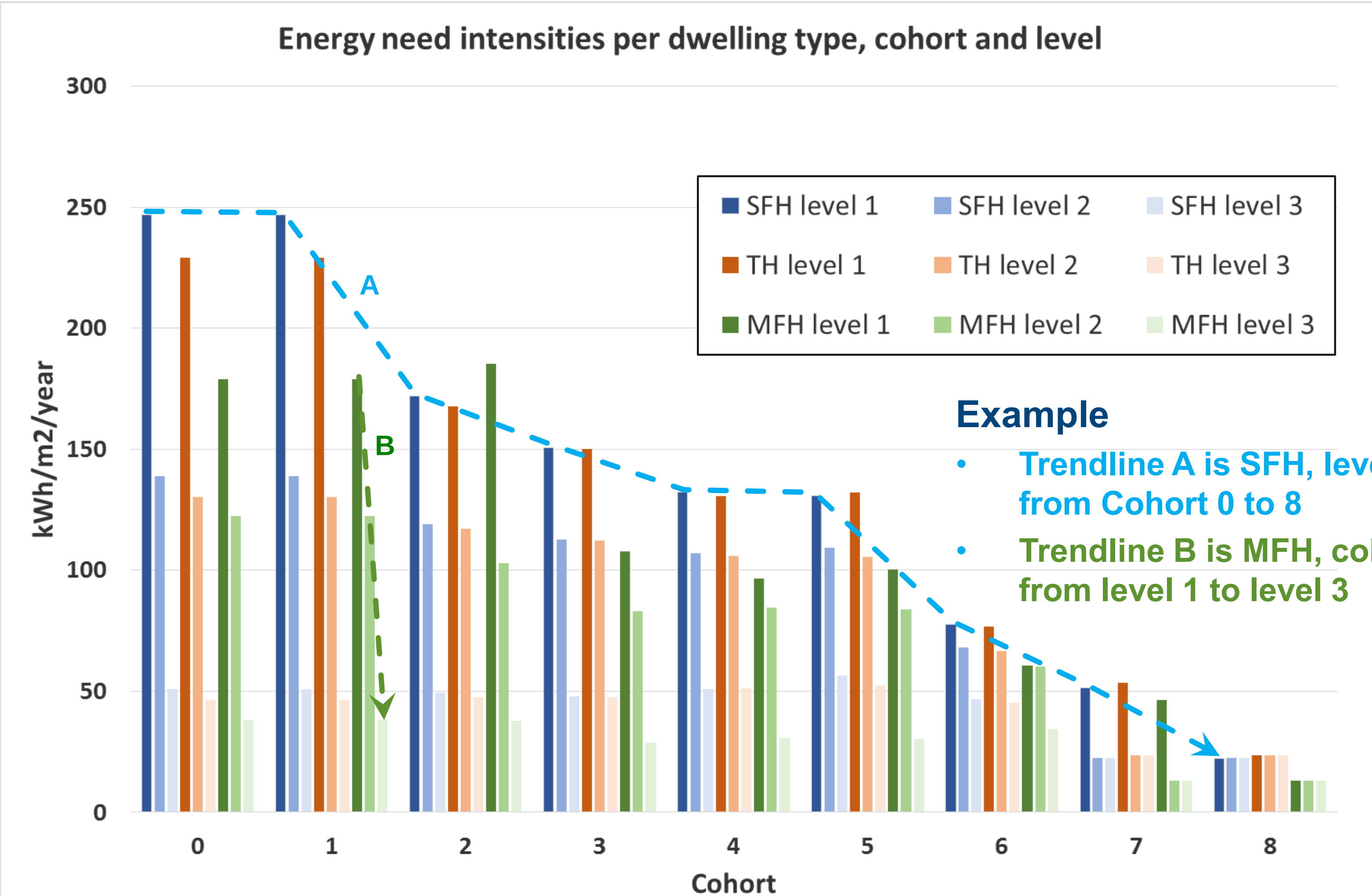
Energy improvement trendlines

Energy need for heating



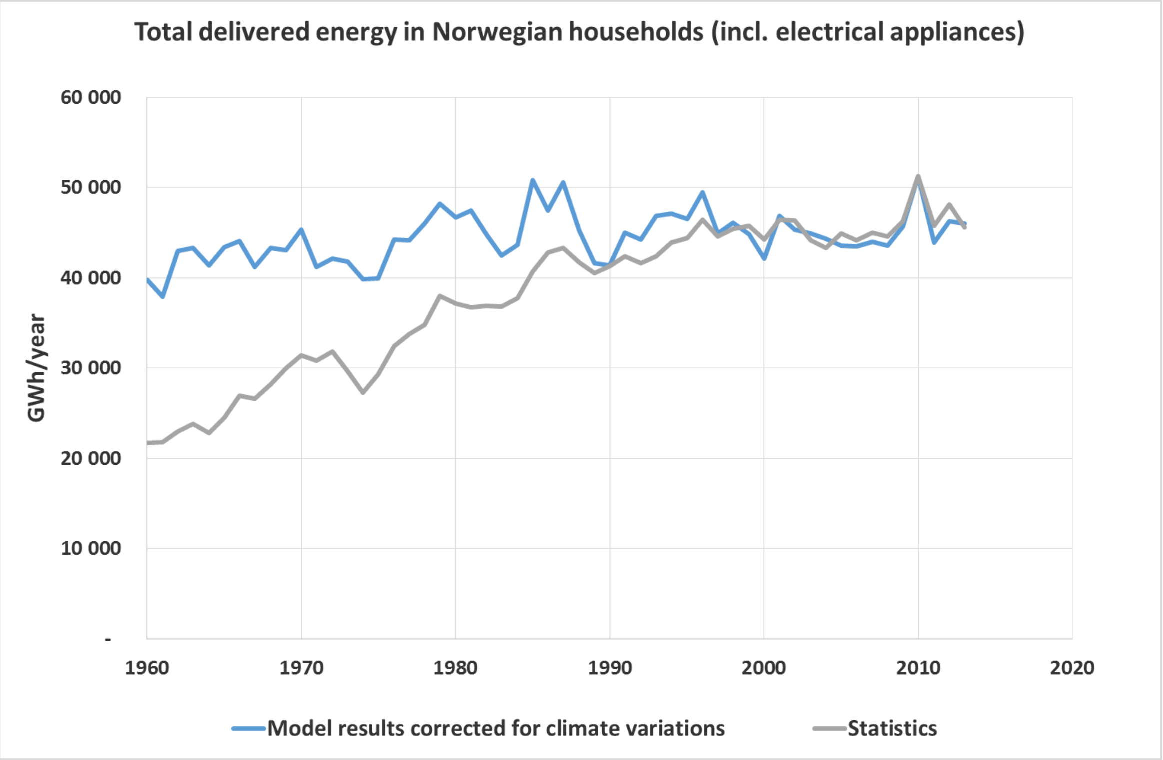
Example

- **Trendline A is SFH, level 1 from Cohort 0 to 8**
- **Trendline B is MFH, cohort 1 from level 1 to level 3**

Calculated versus observed delivered energy

Historical modeling results compared to statistics

- **Model fit to reality?**
  - **Systematic overshoot before 1990**
    - Model is not adjusted for differences in occupancy behaviour over time
    - Likely important factors are No. of rooms heated, hot water consumption, indoor temperature and use of electrical appliances
  - **Good fit since 1990**
    - Model is able to predict level and fluctuations
- **Model OK for use in scenarios towards 2050**



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Estimated change in delivered energy intensity

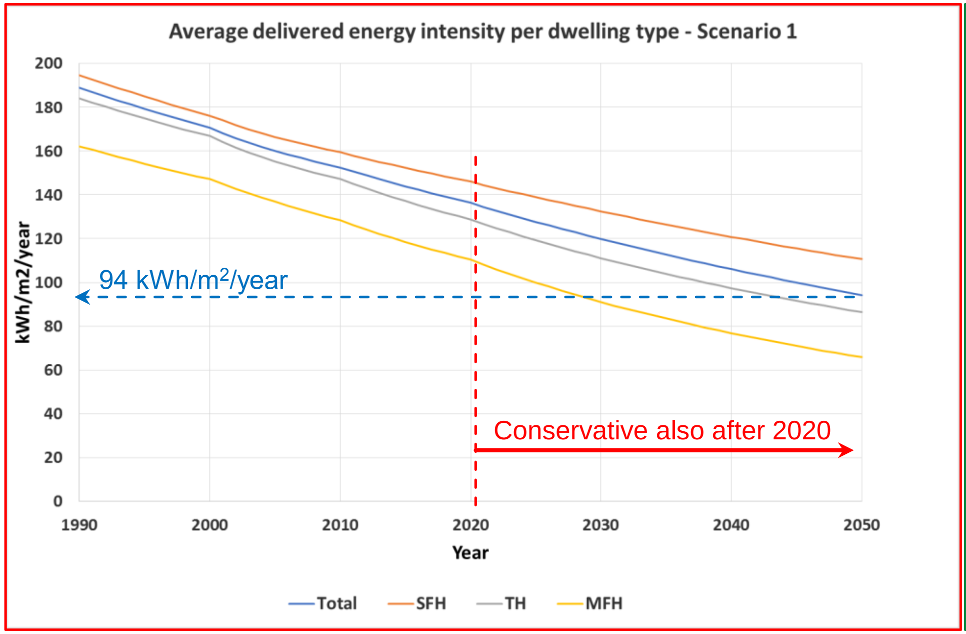
Construction, renovation and demolition activities taken from Building Stock Model. Energy levels (energy need intensities) after renovation are defined in scenarios.

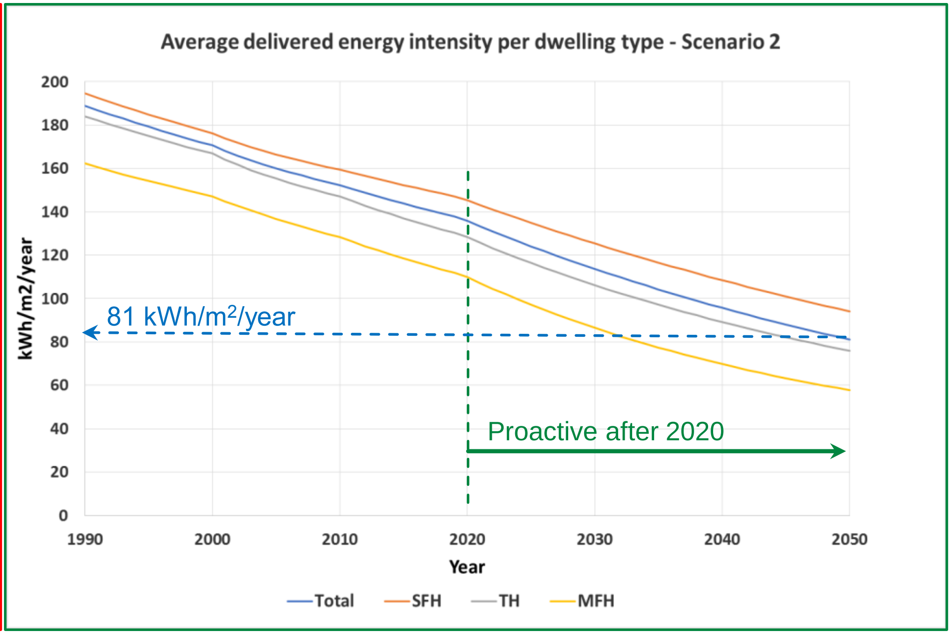
Scenario 1: "Conservative"

- **Existing buildings renovated to Level 2 (common current renovation) all the way to 2050**

Scenario 2: "Proactive"

- **Existing buildings renovated to Level 3 (ambitious future renovation) from 2020 to 2050**





Here is accounted for effects of measures in the building envelope only, with no onsite energy generation! Renovation cycle is 40 years. New built after 2020 is by PH standard.

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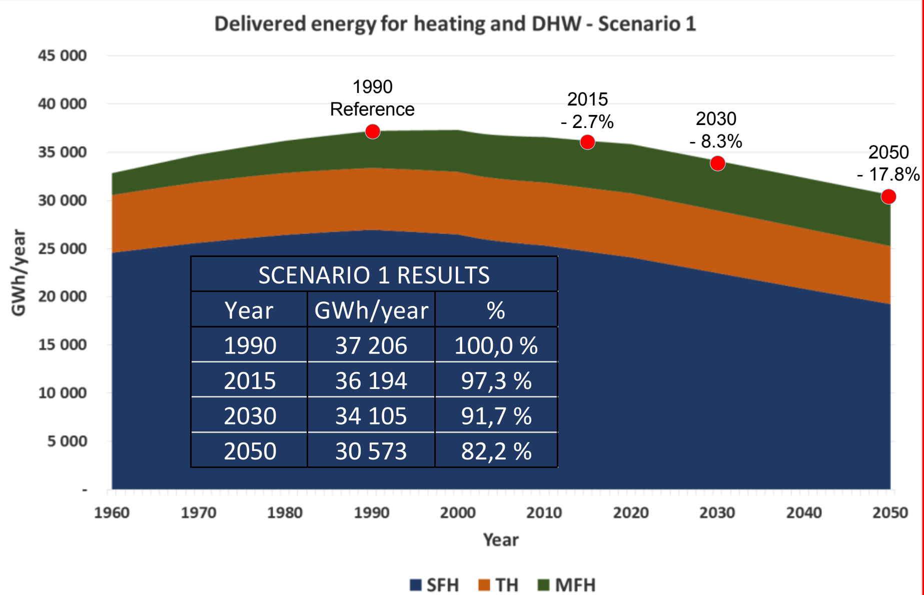
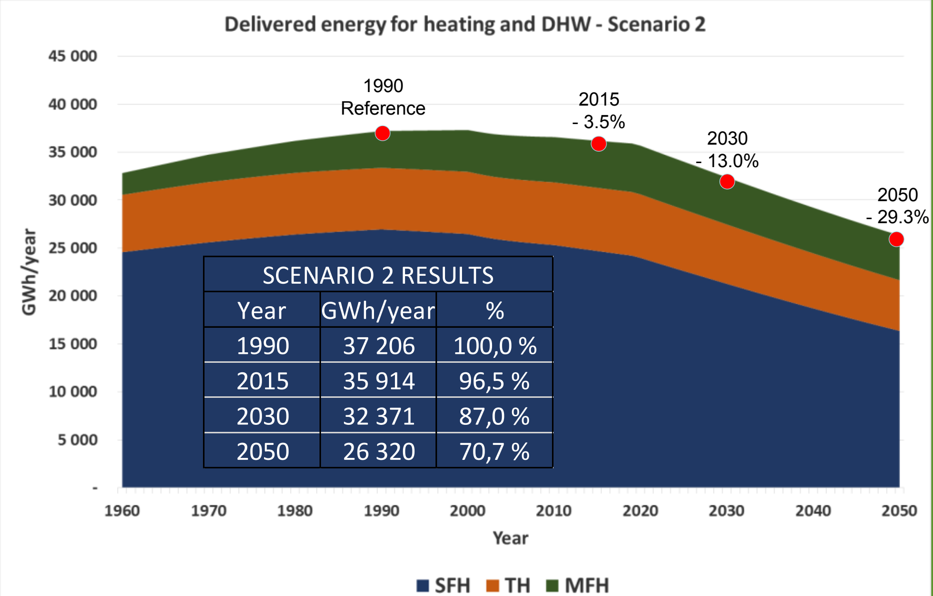
Total stock delivered energy – Scenario 1 and 2

For space heating, ventilation and domestic hot water (excl. electric appliances)

- **Annual model results from 1960 to 2050, using 1990 as reference**
- **The two scenarios show somewhat different results in 2015, 2030 and 2050**
- **However, even in the proactive scenario (S2) delivered energy is reduced by only some 30% compared to 1990.**



SCENARIO 1 RESULTS		
Year	GWh/year	%
1990	37 206	100,0 %
2015	36 194	97,3 %
2030	34 105	91,7 %
2050	30 573	82,2 %



SCENARIO 2 RESULTS		
Year	GWh/year	%
1990	37 206	100,0 %
2015	35 914	96,5 %
2030	32 371	87,0 %
2050	26 320	70,7 %

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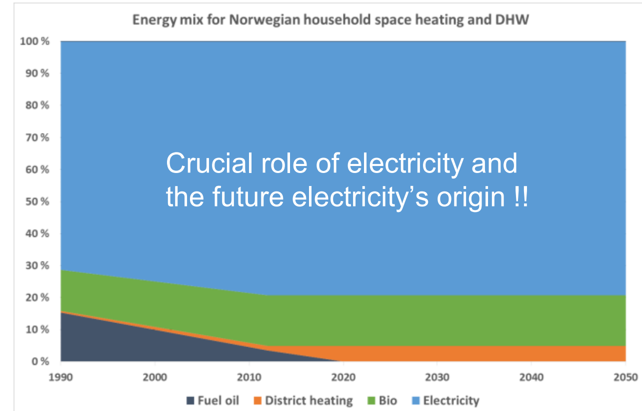
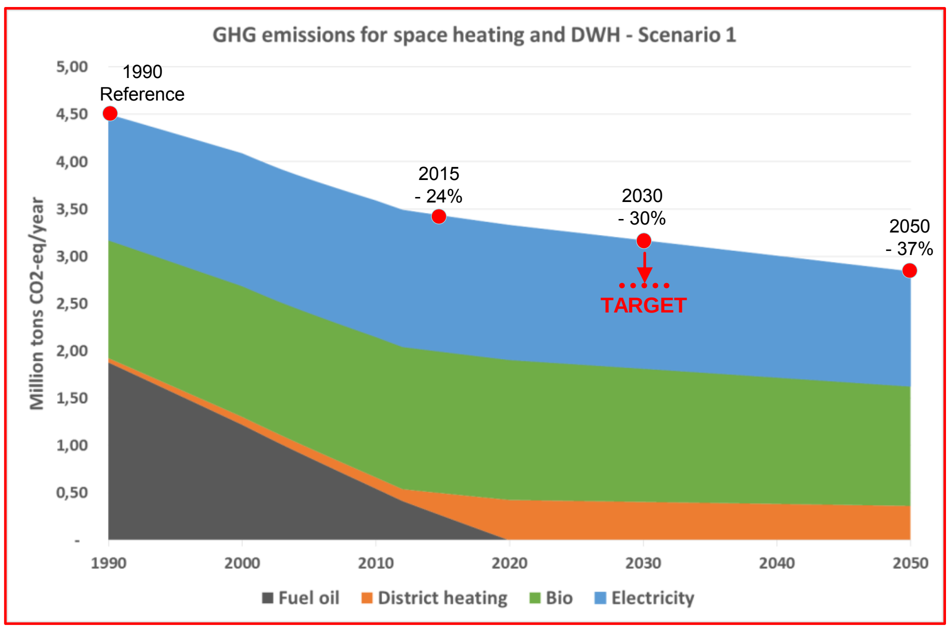
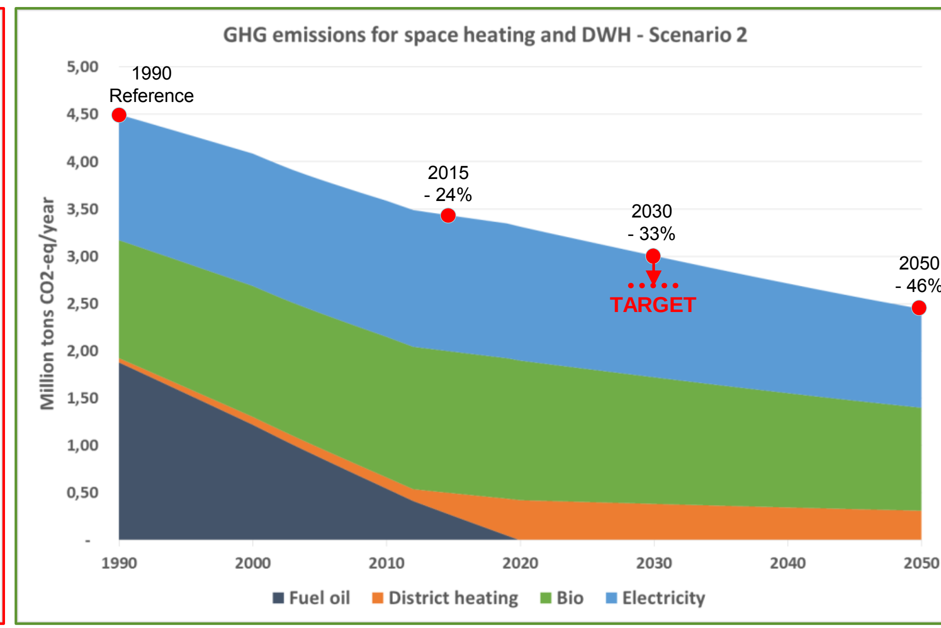
GHG emission trends 1990 – 2015 – 2030 – 2050

- **Assuming moderate change in energy mix**
  - **Phasing out fuel oil by 2020**
  - **Biofuel kept at today's level**
  - **Electricity still by far dominant**
- **GHG emission reduction potentials**
  - **National target is 40% reduction by 2030 for all sectors combined**
  - **Scenario 1 and Scenario 2 potential is significantly below 40%**
  - **Important role of onsite energy generation (heat pumps + solar)!!**







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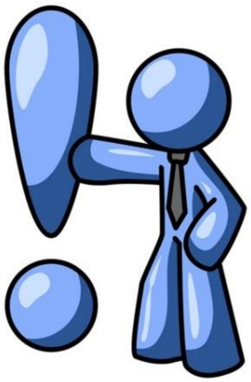
Conclusions



- We demonstrate the usefulness of adding the energy layer to a dynamic segmented building stock model, using bottom-up building energy balance data for different renovation levels per type/age stock segment
- We estimate significant reductions in energy and GHG emissions towards 2030 and 2050, despite an overall growing building stock
- However, such reductions are lower than policy targets, when only considering building envelope improvements, also in a proactive renovation scenario
- This calls for widespread use of onsite energy generation and NZEB concepts, in order to reduce net demand for energy carriers
- However, the Norwegian special case of high electricity dependency indicates a crucial role of the future electricity origin