NEO WP3 Energy efficiency and conservation
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Research Questions and Findings

- RQ1: What is the existing knowledge on key aspects of *Efficiency and Conservation of Energy and Materials* (*ECEM*) in the Nordic area, from different methodological perspectives?
- RQ2: To what extent do the most recent energy development scenarios in the Nordic countries explore the role of ECME?
- RQ4: How can existing energy system models be improved to assess the role, and potentials for, ECEM in the Nordic context?

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Efficiency and Conservation of Energy and Materials (ECEM)

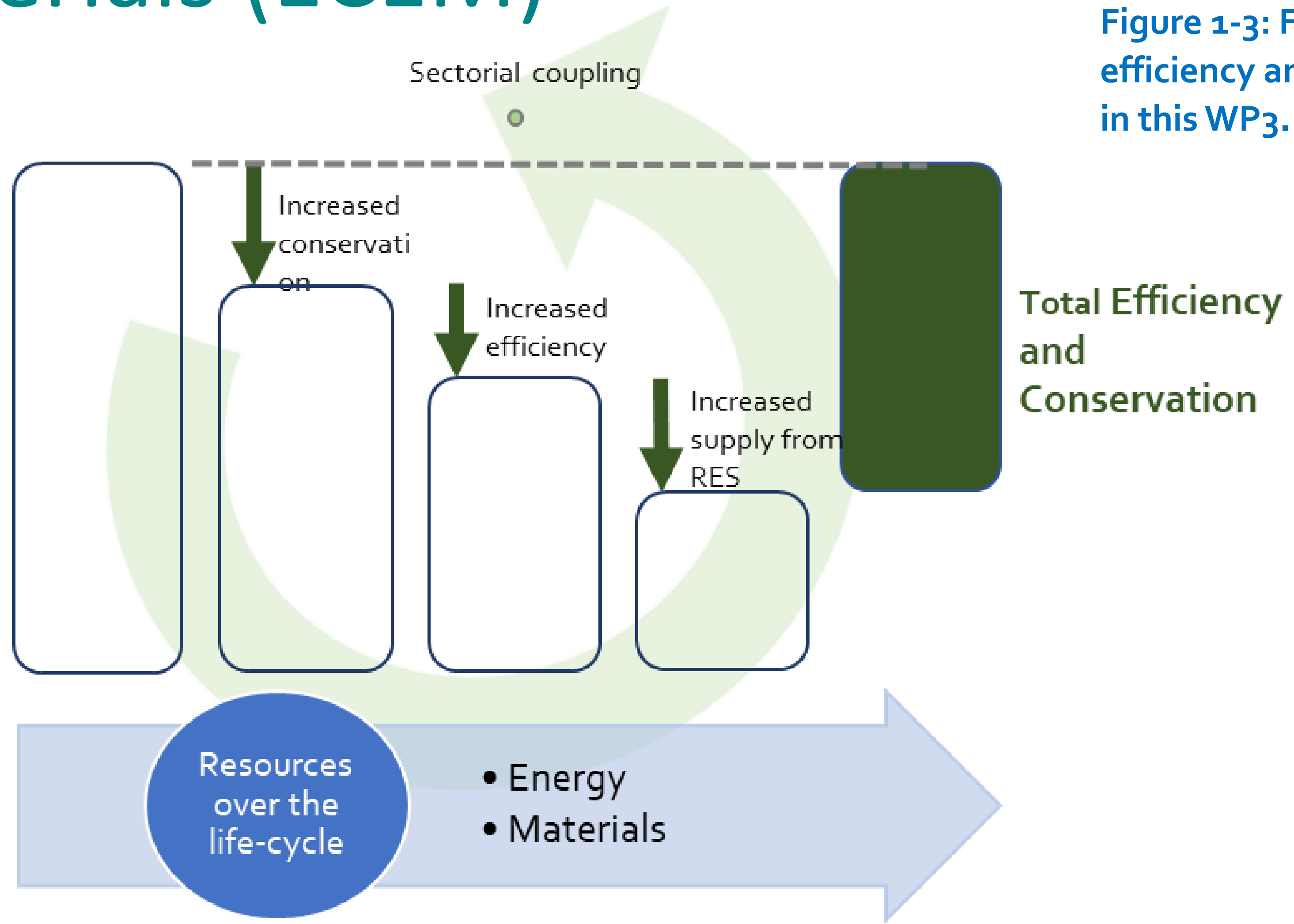

Figure 1-3: Framework for energy efficiency and conservation adopted in this WP3.

RQ1: What is the existing knowledge on key aspects of Efficiency and Conservation of Energy and Materials (ECEM) in the Nordic area, from different methodological perspectives?

- Representation of ECEM
- Key ECEM measures
- Conclusions

Table 4 1. Non-exhaustive summary of ECEM measures considered in the modelling works reviewed.

	Cross- sectorial	Buildings	Industry
EC: Reduced energy demand		Reduced indoor temperature (TIMES-IFE); Shared office spaces; More efficient new buildings, exogeneous (ON-TIMES, TIMES-IFE)	
MC: Reduced demand of materials		Shared office spaces	
EE: Reduced final energy consumption		Energy saving measures, undetermined (ON-TIMES); Insulation (individually: walls, roof, floor)(TIMES-IFE); New windows and doors (TIMES-IFE); Improved power efficiency (TIMES-IFE); Improved ventilation regulation (TIMES-IFE); Lighting regulation (TIMES-IFE) Energy efficient lighting (TIMES-IFE) Automatic sun protection (TIMES-IFE) Demand controlled ventilation (DCV) (TIMES-IFE) Energy management systems (TIMES-IFE) More efficient new buildings, exogeneous (ON-TIMES, TIMES-IFE); Switch to on-site HP Increased efficiency of on-site HP	Use of excess-heat sources; Heat pumps (at disaggregated temperature levels) (GENeSYS-MOD; NO); Heat-to-power technologies.
ME: Increased material efficiency			Material recyling
EE: Reduced primary energy consumption	High temperature heat pumps (OSeMOSYS); New resources such as industrial waste heat (OSeMOSYS)	Switch to DH Reduction of direct electric heating (GENeSYS-MOD; NO); Installation ground HP (GENeSYS-MOD; NO); Hygrogen boilers (GENeSYS-MOD; NO); Reduced use of gas boilers (GENeSYS-MOD; NO) Reduced use of biomass boilers (GENeSYS-MOD; NO) Installation of PV	

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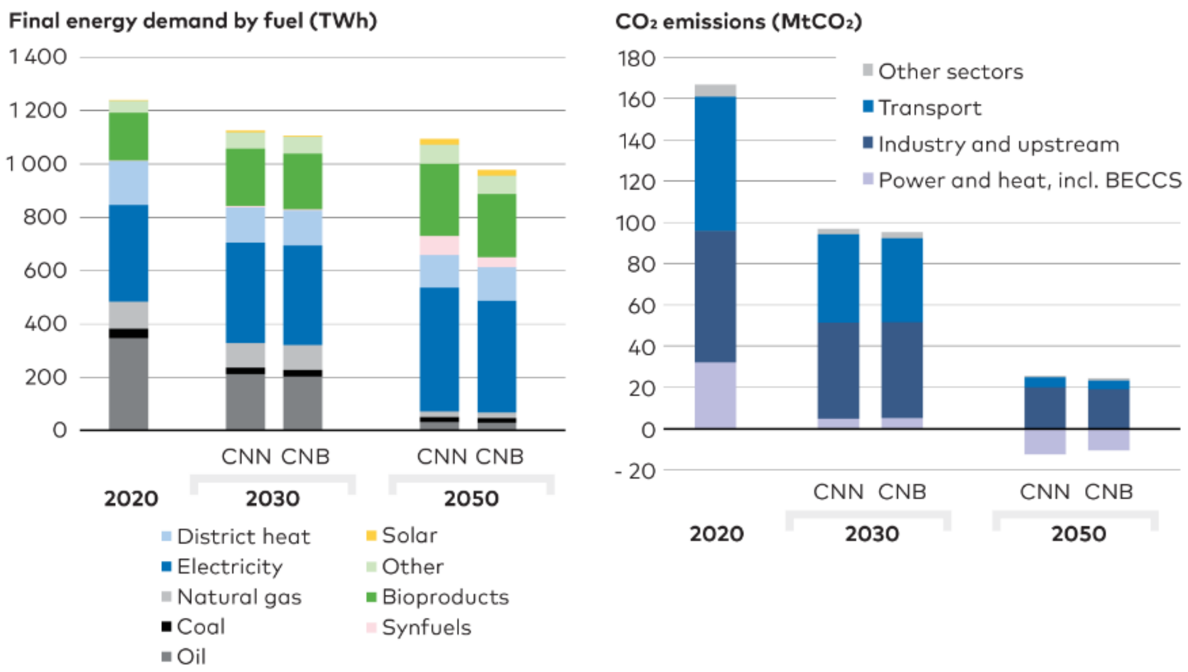
1 Representation of ECEM

- Long-term energy system optimization models (i.e. ON-TIMES, IFE-TIMES and GENeSYS-MOD) generally use demand from various sectors as a constraint/input, and the total discounted cost is minimized to meet the demand. >
  - Typically allow representation of EE measures, not EC and MC measures.
- OSeMOSYS considers the techno-economic feasibility of extending existing thermal grids to integrate excess heat, then soft linked with the short-term energy system optimization tool EnergyPlan to consider the intra-annual operation of the heating technologies.
  - Investigate new EE measures, e.g. high temperature HPs and new industrial waste heat.
- GAINS model allows to evaluate non-energy consequences of ECEM, in terms of impacts of pollutants such as short-Lived climate forcers (SLCFs), specifically Black carbon (BC), Organic carbon (OC), CO2 and O3-precursors. Focus on EE measures:
  - Decrease of BC emissions from power production
  - Renovation of domestic fuel wood boilers
  - Installation of domestic HP, combined with solar thermal or PV

1 Representation of ECEM

- Buildings sector in ON-TIMES:
  - EC measures are only represented by allowing all the buildings in Sweden constructed before 2012 invest in energy saving measures corresponding to different cost levels, although the extent of these measures is not described
  - All buildings also have the possibility to invest in EE individual heat devices (e.g., HPs, boilers) if it is cost-effective from a system perspective;
  - Some buildings can invest in a connection to DH, due to their location;
  - Simultaneously, some existing buildings are demolished and replaced with new and more efficient buildings, implying a change in overall building performance that includes an unspecified combination of EC and EE.
- Industry in ON-TIMES:
  - Focus on EE via existing technologies gradually being replaced with new technologies (due to either reaching their lifetime or constraints on CO_2 emissions) given as new investment options in the model.

2 Key ECEM measures ON-TIMES NCES (all sectors)



Final energy demand (left) and CO2 emissions (right) in CNN and CNB scenarios. (Source: Figure E7.1, Nordic Clean Energy Scenarios 2021).

CNB scenario (compared to CNN)

- Power demand in Nordic countries 5% lower in 2050
- Final energy demand 17% lower in 2050
- Total system costs would also decrease by about 10% over the period
- Electrification (HPs to other technologies, and switching to electric heating, engines; flexibility) and heat waste utilization

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2 Key ECEM measures RePowerEU scenario

Litle impacts on the chosen ECME parameters in 2030 are very little.

The reason is that similarto the base scenario (i.e., CNB), in the RePowerEU scenario, ECME measures in the industry sector are considered after 2030.

Model	Unit	ON-TIMES				
		Nordic area	Denmark	Finland	Norway	Sweden
Industrial excess (waste) heat use in district heating	TWh/yr	0	0	0	0	0
Urban excess (waste) heat* use in district heating	TWh/yr	0	0	0	0	0
Final energy consumption in the residential sector	TWh/yr	+0.8	+0.25	0	0	+0.5
Share of district heating of total fuel/ energy consumption in the residential sector	%	0	0	0	0	0
Energy saving in the residential sector	TWh/yr	0	0	0	0	0
Final energy consumption in the industry sector	TWh/yr	-0.3	+0.5	-0.5	-0.3	-0.5
Energy saving in the industry sector	TWh/yr	0	0	0	0	0

Impact of RePowerEU scenario for the Nordic area, 2030 (delta values +/-, not absolute values).

2 Key ECEM measures Industry sector

Model	Unit	ON-TIMES				
		Nordic area	Denmark	Finland	Norway	Sweden
Total energy demand in 2050	TWh/yr	531	51	175	116	188
Change in energy demand from 2020 values	%	1	-9	-4	10	-3

Table 8. CNB Scenario, industry final energy consumption

The energy demand from the industry sector does not necessarily follow the overall trend (in other sectors) of decreasing energy demand/consumption.

CNB scenario (Nordic area +1%, Norway increase 10%, Denmark, Finland, Sweden decrease -9%, -4% and -3% respectively)

Comparing with the CNN scenario it seems that the climate neutral behavior adopted in this scenario does not imply large differences for the energy demand in industry.

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2 Key ECEM measures Buildings sector

Table 6. Residential fuel consumption in 2020 and 2050 for Nordic area and the Nordic countries, from CNB scenario.

Model	Unit	ON-TIMES				
		Nordic area	Denmark	Finland	Norway	Sweden
Residential fuel consumption 2020	TWh/yr	226	46	59	49	71
Residential fuel consumption 2050	TWh/yr	197	36	40	50	71
Change in fuel consumption from 2020 values	%	-13	-21	-33	2	0

- Overall decrease in residential fuel consumption in CNB scenario

  Nordic area -13% (Denmark and Finland decrease -21% and -33% respectively, Norway +2%, Sweden no change)

- Factors influencing the results

  New investment options available for the existing buildings (heat-saving measures, new heat devices and connection to the DH systems etc.)

  Some existing buildings are demolished and replaced with new and more efficient buildings.

  Area demand projections for countries (increasing area demand can counteract efficiency)

  Missing KPI for efficiency in buildings

- RePowerEU: No change in energy saving for the residential sector.

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2 Key ECEM measures from GAINS model

- According to the Swedish emission projections, the national total emissions of all short-lived climate pollutants (SLCP) will be lower in 2030 compared to today.
- Emissions from residential combustion of biomass are expected to remain at about the same level as at present.
- The most cost-effective measures in the analysis were an increased proportion of pellets as biomass fuel replacing wood logs in residential combustion.
- As a result of reduced emissions of air pollutants, efficiency has additional benefits in resulting from reductions of adverse health effects.

Conclusions

- The reviewed energy system models of the Nordic countries have a simplified representation of ECME, which could be relatively easily improved based on existing knowledge from bottom up and sectorial models. More specific suggestions are given under RQ4-6.
- The reviewed sectorial models provide valuable insights in EC and EE measures, and have started being used to also address MC and ME.
- Gains model provides additional knowledge on key themes (pollution, health impacts and their economic evaluation) for which the integration in energy system models is not apparently straight forward. Although the model could be used to investigate EC, MC and ME measures, existing studies focus on EE.

RQ2: To what extent do the most recent energy development scenarios in the Nordic countries explore the role of ECEM?

Review of 25 existing scenarios and 12 new

- Scope
- NCES
- Gaps
- Conclusions

<table>
<tr><th></th><th>Energy system</th><th>Buildings</th><th>Industry</th><th>Sector-coupling</th></tr>
<tr><td>Nordic countries</td><td rowspan="4">4</td><td>4</td><td>4</td><td>-</td></tr>
<tr><td>Sweden</td><td>16</td><td>-</td><td>2</td></tr>
<tr><td>Norway</td><td>5</td><td>-</td><td>-</td></tr>
<tr><td>Denmark</td><td>-</td><td>-</td><td>-</td></tr>
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Four Nordic scenarios for energy system development from ON-TIMES

CNN - Carbon Neutral Nordic, seeks the least-cost pathway, taking into account current national plans, strategies, and targets.

NPH - Nordic Powerhouse, explores the opportunity for the Nordics to play a larger role in the broader European energy transition by providing clean electricity, clean fuels, and carbon storage.

CNB - Climate Neutral Behaviour, reflects Nordic societies taking additional energy and material efficiency measures in all sectors.

← Base scenario in this WP

RePowerEU scenario, CNB scenario + 30 TWh of additional net electricity export from the Nordics is assumed in year 2030.

These are, however, exogenous assumptions in which the different components of ECEM are mentioned, and only serve to see the effects of ECEM broadly.

Most of these scenarios have a techno-economic approach to ECEM

- Change in energy demand over time for different sectors.
- Potentials for energy-saving measures in existing buildings (retrofitting measures, efficient appliances etc.) and their cost-effectiveness
- Sensibility to variations in energy prices and interest rates.
- Total increase of energy efficiency if existing buildings are replaced with new more efficient.
- Increased use of excess heat through sector-coupling.
- Measures to increase use of RES (e.g. HP in buildings and industry).
- The potential for overall increase in energy efficiency in industry based on existing technologies gradually being replaced with new technologies given as new investments.
- Potential energy savings from user flexibility/demand response and price mechanisms which can influence the extent to which such measures are taken.
- Price elasticity and macro-economic determinants of buildings' future energy demand.

Scenarios on socio-demographic perspectives, institutional issues or trade-offs and synergies

- Corresponding air pollutant emissions (PM2.5, SO2, NOx, black carbon etc.) from different sectors (transport, buildings, industry) and the health benefits and following financial benefits of lower levels of air pollutants.
  - Such scenarios point that energy efficiency measures in several sectors (e.g. electrification, scrapping of old vehicles and machinery) show important synergies with lower emissions of air pollutants.
- The robustness of building retrofitting measures against climate uncertainties:
  - Such scenarios point that energy conservation is the most resilient measures, such as improvements in the building envelope (insulation, windows) and lowering indoor temperatures.

Gaps and topics for further research

- If new developments for potential new industries should be modelled, such as data centers, battery production, and hydrogen, a market equilibrium model is then required to project the future growth of these industries in the global context as input to GENeSYS-MOD.
- No scenarios were found that include all Nordic countries and focus specifically on ECEM in the buildings and industry sectors, on circularity or on material conservation and efficiency.
- More work is needed to understand implementation issues.

RQ4: How can existing energy system models be improved to assess the role, and potentials for, ECEM in the Nordic context?

Policy relevance and understanding results

Challenging to compare varying aspects of efficiency and conservation between different models and scenarios, need to pursue such selections in a systematic and policy-relevant manner, to better understand the opportunities, risks, synergies, and trade-offs within each modelled scenario if energy systems modelling results are to be used as a basis for decision making. This can be achieved by:

- Key Performance Indicators
- Other visualization tools.
- Of particular interest is the comparison over time
- Disaggregation of inputs
- Extended documentation and descriptions

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Modelling energy conservation, energy demand reductions and materials' use

- Improved description of measures which lead to less floor area (i.e., reduced population growth, increased space sharing) and less new buildings (i.e., increased renovation of existing buildings, or caps on use of virgin materials). Similarly, the industry sector is often represented by energy flows for the industrial process.
- Cross-sectorial effects in energy and material use in the industry sector with a direct impact on less energy and material use for cement and steel production, over time.
- Material recovery processes and their associated energy use are not explicitly represented. Such a representation would require the techno-economic parameters of the recovery processes as well as data assumptions on availability potential of waste materials being recovered in the recovery processes.
- For the assumptions of the amount of waste materials, a linking between energy system model and macro-economic models could be useful.

More detailed suggestions are given below in terms of improvements of the datasets (RQ5), and on how different ECEM measures in industry and buildings can be included in energy system models (RQ6).

Recap Conclusions RQ1, RQ2, RQ4

- Write together

Thanks!