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Potentials for emission reduction and value creation in the rehabilitation of existing building stock using input-output analysis

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Abstract. Given that most of the world's building stock for the next 30 years already exists today, renovation of existing buildings and infrastructure represent an important pathway towards a more sustainable future. The aim of this paper was twofold: 1) to evaluate potentials for waste reduction, efficient resource utilization, economic advantages and GHG emission reduction in rehabilitation in comparison with building new, 2) demonstrate the usefulness of input-output analysis in evaluation of value creation and employment potential, and environmental effects of changes in the building stock. A macroeconomic, input-output model developed by SINTEF is used in a methodology to make comparative assessments on future scenarios on building and renovation strategies. Preliminary results show how the strategies analysed provide pros and cons when different macroeconomic indicators (value added, GHG emissions, energy efficiency) are considered. Future works will improve technical data and macroeconomic assumptions, as integrate policy analysis into the methodology.

1 Introduction

The buildings construction sector is responsible for 35% of global energy consumption and 38% of energy related total global GHG emissions in 2019 [1]. Of these emissions, 19% is indirect energy related emissions from buildings (11% from residential building and 8% from non-residential building), 10% from building construction industry (manufacturing, transportation and use of construction materials) and the remaining 9% from direct energy related emissions (6% from residential and 3% from non-residential). Emissions from production of building materials and their constructions shows the significance of embodied emissions and the need to focus on extending the service life of buildings and reducing replacing them [1].

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Even if 85-95% of EU's building stock is expected to stand in 2050, around 75% of those buildings are energy inefficient and the annual renovation rate is below 1% [2]. The Norwegian building stock is also expected to follow the same trend. The EU green deal has started a new renovation initiative in 2020 "renovation wave" with a target to doubling the current public and private renovation rate in the next 10 years [3]. The industry is seen as essential to the transition to circular economy as it generated ca. 25-30% of the total waste generated in EU, which is equivalent to around 40% of raw material extraction. To achieve the 55% emission reduction target by 2030 compared to 1990 levels, a reduction of 60% GHG emissions, 14% final energy consumptions and 18% energy consumption for heating and cooling from buildings in EU by 2030 [2] is estimated to be needed. Given the larger proportion of existing buildings compared to the number of new buildings, and that majority of existing buildings are energy-inefficient, there is a need to assess the potential of energy-efficient measures in the existing building stock [4]. Shifting from a linear to circular built environment and investigate potential environmental, economic, and social impacts, benefits and trade-offs using a dynamic input-output analysis method at different scales (at building, neighbourhood, city, region, country, global) over the entire life cycle is essential.

The aim of this paper was to evaluate potentials for waste reduction, efficient resource utilization, economic and GHG emission reduction in rehabilitation in comparison with building new. Further, it will show the usefulness of input-output analysis in evaluation of value creation and employment potential, and environmental effects of changes in the building stock. The paper starts by giving a background, followed by a description of the methodology and used background data. The main findings are then presented, followed by discussions and future research aspects. The paper draws final remarks in the conclusion.

2 Methodology

In this study, the IO model MEIONorway is applied. MEIONorway has been developed by SINTEF [5]. MEIONorway uses macro-econometric regressions to project future developments, making it a Dynamic Input-Output model [6]. The econometric parameters used to direct the future state of the Norwegian economy are taken from the United Nations System of National Accounts. These include expectations on population and GDP developments, labour potential and investment data.

The IO tables used in the methodology are sourced from the openly available Statistics Norway (SSB) data. SSB is also used to source waste from building data [7].

Changes in industrial composition, such as new technologies, efficiency changes, and tax instruments, are exogenous. They correspond to radical developments in one or more production process, and characterise the scenarios used in the numerical simulations. In this work, a scenario models a building stock strategy, either economy-driven, or because of a governmental policy. When a scenario change is introduced and the model's simulation is completed, an economic equilibrium has been achieved, and the values of response variables are reported.

Since the IO model requires cost element at an aggregated level, the top-down approach is followed, using the building data from the Norwegian price book [8], which gives the costs of several different building construction types in Norwegian kroner (NOK). It also gives a detailed overview of the materials and work being performed for the construction of the buildings. The background data from the building project type apartment blocks 3 and 4 storeys named "*1322 Boligblokk prefab betong i 3 etasjer over lukket parkeringskjeller*" in the Norwegian price book. No other building typology was considered for this study as of now. Due to the difficulty of accounting for labour costs in each component in the sources, a flat rate of 10 % was assigned to labour costs, to be refined in future works. To account for this simplification, Scenario 5, based on Scenario 1, is included. Scenario 5 provides a sensitivity analysis on the labour cost simplification.

Table 1 shows scenarios with parametrised changes along three dimensions: build mix (new, rehabilitated), Energy Efficiency per building type, and labour costs.

Table 1. Scenario Design; A scenario Combines one Building Strategy, one Energy Efficiency Strategy (based on standards by the Building Quality directorakte, dibk.no), and one Labour Estimation Strategy

Scen	Building Strategy	Energy Efficiency Strategy	Labour Cost
BAU	**BAU** (98.8 % new buildings, built from scratch; 1.2 % partially rehabilitated buildings)	**BAU:** New buildings: AB_TEK17; Part. Rehab Buildings: Standard upgrade.	10 %
1	**Ambitious rehabilitation** (96 % new; 2.4 % partially, and 1.2 fully rehabilitated buildings)	BAU	10 %
2	**Extreme rehabilitation** (92 % new; 5 % partially and 2.4 % fully rehabilitated buildings)	BAU	10 %
3	Ambitious rehabilitation	**EE1** New buildings: AB_PH Partially. rehab. buildings: Standard Upgrade Fully rehab buildings: Ambitious Upgrade.	10 %
4	Ambitious rehabilitation	**EE2** New buildings: AB_PH Partially rehab. buildings: Ambitious Upgrade. Fully rehab buildings: AB_TEK17	10 %
5	Ambitious rehabilitation	BAU	20 %
6	Extreme rehabilitation	EE1	10 %
7	Extreme rehabilitation	EE2	10 %

3 Results

Value Added, for most sectors, represents the total wages, salaries, taxes, and capital returns of the sector. Value creation can be understood as the relative increase (with respect to the BAU scenario) in value added in any or all sectors. Summarising value creation we focus on the Construction, Power Generation, and Waste-management-and-Reuse sectors, which are the ones more closely linked to the building and rehabilitation activities.

In general, all scenarios see a positive effect in value creation with respect to the baseline scenario, with the Extreme rehabilitation scenario delivering a high 0.1495 % increase, followed by ExtremeEE1 and Extreme EE2 (**FIG. 1**, left). Notice that, we have allocated spending saved from new buildings to leisure activities, which overall have a high VA potential compared to other industries and this affects the results accordingly. The construction sector sees a decrease in VA in the first few years, regardless of scenario. Here, the largest loss of VA is observed in the Extreme scenarios (**FIG. 1**, right).

The electricity sector shows a decrease in the first few years, only to recuperate its steady growth in the following years. Expectedly, the Energy Efficiency 1 and 2 scenarios contribute more to this trend than their counterparts, The Waste treatment, Sewage and (emphasizing) Recovery sector, shows the opposite behaviour. This sector increases its value added as its economic activity is boosted by providing recovery materials to the economy, which we see appears to be able to create more value than disposal.

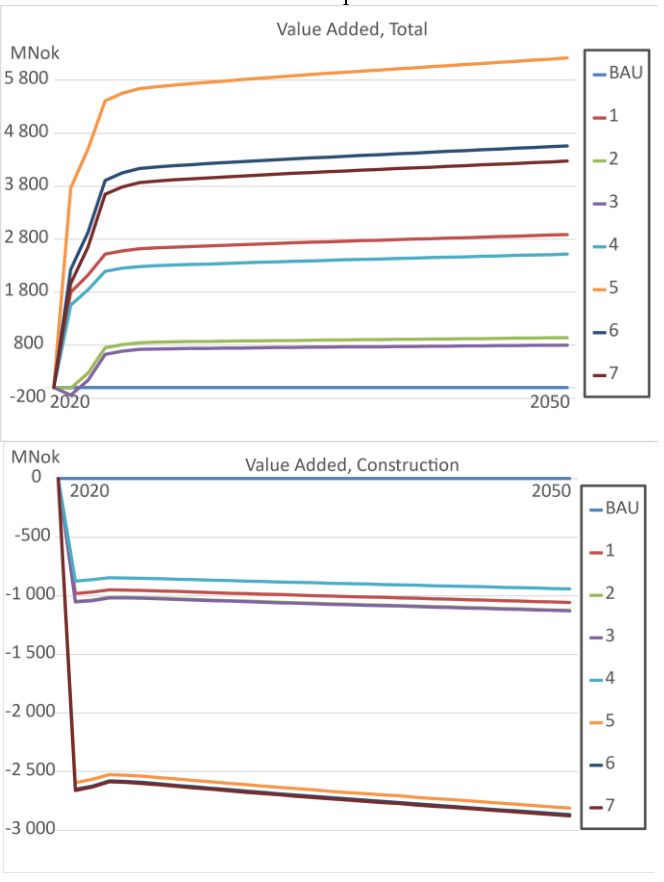

Fig. 1. Above: Value Creation Total; below: VA for the Construction sector, MNok. Values are relative to the BAU scenario.

The long-term power and heating consumption is of particular interest. The Energy Efficiency dimension of the analysis was expected to show an offsetting of costs. This was indeed observed. The Ambitious and Extreme rehabilitation scenarios increase energy consumption, potential energy gains in their respective EE1 and EE2 variants compensate for this (**Fig. 2**). Total consumption, however, is a net increase after the first few years, meaning households spend more overall, increasing their welfare measure.

The IO model can quantify different types of GHG emissions produced by each industrial sectors' operation, in CO2 equivalent. Emissions per sector are calculated using SSB estimations [9], and the conversion of other emissions to CO2 equivalent was made using the IPCC report [10]. There is a visible effect being driven by both the push for refurbishing, and the energy efficiency measures implemented. When we look *solely* at power generation, the EE1 and EE2 cases do manage to offset the additional emissions from the ambitious and extreme refurbishing strategies. In the construction sector GHG emissions fall at a similar rate as the loss in VA for the sector. The Waste treatment sector, which sees increased VA due to its role as recovery and recycling activities, sees increased emissions accordingly.

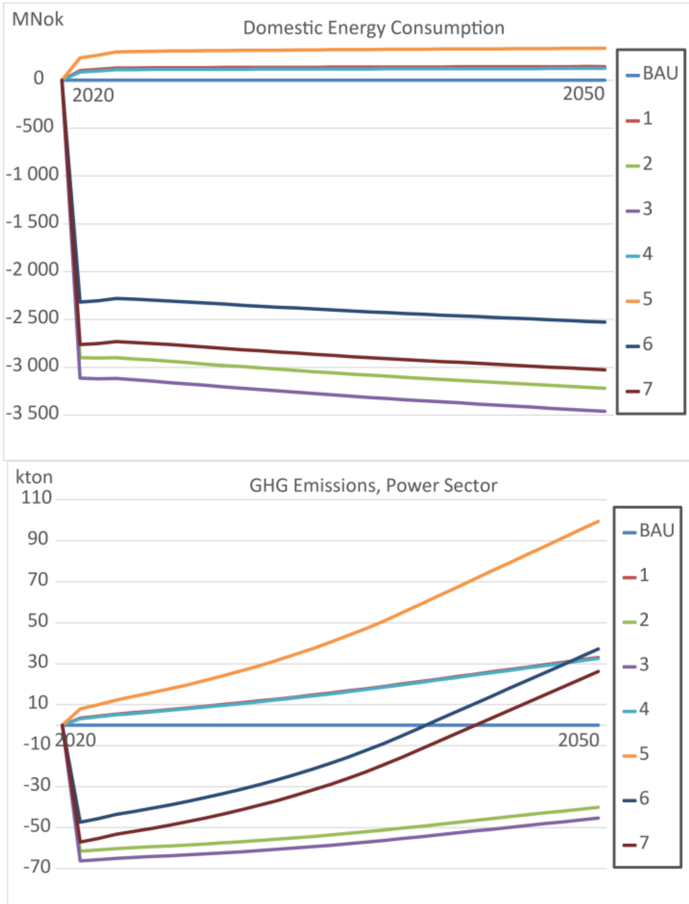

Fig. 2 Above: Household Energy Consumption; below: GHG emissions for the Power sector; values are given as relative to the BAU scenario.

The model shows an *overall increase* in emissions, of about 2.5 % in the Extreme case. This can be expected as emissions increase with the increase in GDP. The increase is due to MH4 and N2O, and it comes from the agricultural sector. This in an inevitable consequence of the assumption that the money *not spent* in construction activities due to the cheaper refurbishing is spent in other sectors which provide higher VA, thus increasing GDP and therefore driving higher food consumption.

Social sustainability can be measured in part by the estimated employee numbers provided by the model. As it can be seen, employment effects are positive, even more so in the *Extreme* scenarios. This assumes that those jobs not required in the building sector instead to go renovation, waste recovery, and leisure activities, which are paid better. If we assume the effects can be extrapolated to larger areas, employment itself can become a driver for building policy in the medium term.

4 Discussions and further work

The findings from the study show that, apart from the material flow involved in waste reduction, efficient resource utilization, economic advantages and GHG emission reduction potential of rehabilitation is better than building new (objective 1). Increased refurbishing increases value added/GDP in the country, though not necessarily in every sector equally. In particular, the construction sector experiences a fall in VA with more refurbishing, and the power sector sees less VA when efficiency measures are implemented. These results assume a redistribution of spending, and limited effects on exports of energy; the first are assumed as given, whereas the second imply assumptions non-related to the construction/rehabilitation questions and were thus not considered for the moment.

Energy saving measures are a clear defining factor for the consumption of households; without energy efficiency measures, we have a net increase in energy consumption in the scenarios where we build fewer new buildings and instead use refurbished ones. Interpreting GHG results requires more nuance; redistribution of spending and increase in VA lead to increased GHG emissions overall. The hypothesis here is that spill over effects into other sectors could happen; so additional policy tools could be used to address this.

The results from this study also show the usefulness of input-output analysis in evaluation of value creation and employment potential, and environmental effects of changes in the building stock (objective 2). We interpret the capability of the methodology herein presented to provide deeper insights into a) the economy in general, and b) the construction sector in particular, which could not necessarily be obtained without the systemic view provided by the input-output perspective.

There are, admittedly, a number of limitations in this work, due to both unavailability of data, and the time and cost of their implementation. Many of these also present opportunities for further development of the study, and possibly also of the methodology itself.

Labour cost estimation should be improved to include itemised labour cost parameters instead of a flat 10 % rate. As for **background data and statistical projections,** we have used a top-down approach; however, a bottom-up approach would give more detailed and validated background data. A better assumption for future works would have a differentiated per-year expected demand for these and other types of housing options.

The study covers only at **housing blocks**; adding the remaining dwelling options to the analysis would provide a more comprehensive look at the construction sector and closely interlinked sectors.

There are many factors involved in the evaluation of the GHG **emissions** produced. In future works, we hope to add more refined assumptions on emissions for the relevant sectors, as well as introducing measures which address the increase in emissions on indirectly impacted sectors.

While there is a strong link to **circular economy** in the study, we lack a dedicated recycling, repurposing and reuse industrial sector, separate from the sewage, and waste management sector, which we hope to add in the future. Additionally, a **material flow extension** can bring material waste in the model on par with the emission accounting as it is now.

5 Conclusion

The study on input-output techniques applied to rehabilitation of buildings with emphasis on energy efficiency found that in general, there is a good value creation potential when we look at schemes with increased rehabilitation rate of housing blocks instead of building new units. There were also generally positive spill-over effects in employment, reduction in waste and lower energy consumption. However, we also saw increased emission rates in sectors not directly related to the construction and energy ones, though the latter do have a reduction. Thus, this type of methodology combining the macroeconomic perspective of an input-output model with the building-specific parameters as input data gives a holistic perspective not necessarily achieved when we only use one or the other.

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References

1. UNEP, Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector. United Nations Environment Programme. Nairobi (2020)
2. European Commission, A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. COM(2020) 662 final. Brussels, 14.10.2020. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662. (Accessed: May 08, 2021)
3. HJ, "Renovation wave," *Energy - European Commission*, Jun. 04, 2020. Available at: https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en. (Accessed May 08, 2021)
4. S. M. Fufa, C. Flyen, and A.-C. Flyen, How Can Existing Buildings with Historic Values Contribute to Achieving Emission Reduction Ambitions?, *Appl*, 11, no. 13, Art. no. 13, (2021)
5. V. S. Nørstebø *, K. S. Wiebe, T. Andersen, T. Grytli, U. Johansen, F. R. Aponte, G. A. Perez-Valdes, S. Jahren*, Studie av potensialet for verdiskaping og sysselsetting av sirkulærøkonomiske tiltak. Utvalgte tiltak og case. SINTEF Rapport no. 2020:00958. ISBN 978-82-14-06555-8, (2020)
6. K. S. Wiebe, E. L. Bjelle, J. Többen, and R. Wood, Implementing exogenous scenarios in a global MRIO model for the estimation of future environmental footprints, *J. Econ. Struct.*, 7, no. 1, p. 20, (2018)
7. Statistics Norway, Waste from building and construction.. Available at: https://www.ssb.no/en/natur-og-miljo/statistikker/avfbygganl/aar/2021-02-25. (Accessed May 08, 2021)
8. Norconsult, Norsk prisbok. Available at: https://www.norskprisbok.no/Home.aspx (Accessed May 01, 2021)
9. Statistics Norway, "Emissions to air. 09288: Greenhouse gases from Norwegian economic activity, by industry and pollutant 1990 - 2019, *PX-Web SSB*, 2021. Available at: http://www.ssb.no/en/statbanken/statbank/table/09288/ (Accessed May 01, 2021)
10. IPCC, Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp. (2007)