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Climate impact of housing companies

- a hybrid LCA approach

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Abstract—**The study estimates greenhouse gases generated by suburban housing companies with the use of a hybrid LCA model where IO-LCA methodology is used together with process data. The aim of the research was to learn which activities associated with housing companies generate most greenhouse gases, as well as by whom the emissions could be diminished. In addition, the applicability of hybrid life cycle assessment approach to the housing company context is tested in the study. A case residential area from suburban Helsinki is studied. All housing companies within the residential area share the same property manager and energy provider. Consequently, comparable consumption data (both economic and metric) was available for analysis. The first phase of the analysis utilizes an economic input-output (EIO)-LCA model developed by the Carnegie Mellon University (CMU). With the model, relationships between the different activities can be established, which allows the activities with the most climate effect to be taken into more detailed review. This combined method, where IO-LCA is expanded with process data, can be described as a tiered hybrid LCA approach. The research confirms that heating energy is the most significant contributor to greenhouse gases derived from housing. Furthermore, the study infers that a significant portion of the climate impact of residents derive from activities associated with the housing companies, limiting the potential of the individual residents to affect the impact.**

Keywords-climate impact, EIO-LCA, hybrid LCA, suburban housing, housing companies

I. INTRODUCTION

The building sector is known to be responsible for approximately 40% of global annual energy use. Moreover, the residential sector alone accounts for nearly 30% of the same [1]. Consequently, the built environment is a major generator of anthropogenic greenhouse gases. As a countermeasure, the European Union has set a common carbon dioxide (CO2) reduction target of 20% (compared to 1990 levels) by 2020 for all its member states. In Finland, CO2 even more stringent reduction targets were recently set for the built environment: the 20% reduction is to be achieved as early as 2017 in the building sector. This creates a great need to study the climate effects of the built environment in general, and of residential housing in particular.

Comparative studies between residential areas of high and low density have been conducted to gain knowledge on the climate effects housing [2], [3]. These studies have revealed low-density housing to be more carbon intensive than urban housing. Furthermore, previous studies [3], [4] suggest that the most significant climate effects of housing derive from building operations (incl. operational energy) and transportation. However, previous studies have focused on the role of either urban planning or individual consumption patterns.

This research focuses on the operational phase climate impact of suburban housing companies. The first aim of the research is to provide information on which activities associated with housing companies have the largest climate effect. Another focus is to evaluate the potential of different actors (housing companies, property management, and residents) to influence the said effect. An additional motivation is to test the applicability of a hybrid life-cycle-assessment approach in the housing company context.

A 1960's residential area with multi-family housing from the suburbs of the Finnish capital Helsinki is studied. The significance of different activities associated with housing is studied using both economic and physical consumption data from the case area. Since the study seeks to assess the role of housing companies and property management in the fight against climate change, private transportation, which is known to be a significant housing related contributor to greenhouse gases, is excluded from the study.

As anticipated, heating energy was identified as the dominant activity with regard to carbon emissions from housing companies, electricity use being the second most significant. Consequently, efforts aimed at minimizing the carbon effect and achieving national targets should focus on energy use. An important finding is that a significant portion of an individual's carbon footprint is generated from housing alone. Another main finding related to the results is that individual residents of multi-family apartment buildings have relatively little control over the carbon emissions of their housing unit. It can be concluded that in suburban areas with multi-family apartment buildings, the role of housing companies and property management is crucial in minimizing the environmental impact of housing.

The remainder of the paper is structured as follows. The next chapter discusses the LCA methodology used in the research. Chapter III explains how the study is constructed.

Results are then presented in Chapter IV. Chapter V discusses study limitations and reliability. Finally, the last chapter draws conclusions and evaluates the potential applicability of the findings.

II. METHODOLOGY

The research uses life-cycle assessment (LCA) methodology. Generally three different LCA approaches can be utilized: process LCA, input-output LCA and a hybrid of the two. The traditional, process-based LCA quantifies the environmental impact along a life-cycle using process-level data, whereas the input-output (IO) technique uses data on monetary transactions to assess the life-cycle impact based on sector averages. The weaknesses and strengths of process and IO based approaches tend to complement each other. For example, the former mainly assesses producer, the latter consumer responsibility; the former is better suited for heavy industry and the latter for the service sector [5], [6]. The use of process LCA entails high labor and data requirements, while the IO-LCA is relatively quick and easy to use [5], [7], [8]. Partly due to this, a common problem with process based LCAs is the truncation error caused by system boundary selection [7]. The truncation error inevitably underestimates the environmental impacts as some components have to be omitted.

Not suffering from the truncation error, input-output based LCAs are more comprehensive by nature. On the other hand, the unavoidable aggregation of industry sectors in the IO-LCA models contribute to the inaccuracy of the approach [5], [9]. Another inherent problem with IO-LCA models is that the included and excluded components are often impossible to identify [9]. Consequently, no assessment of the significance of the exclusions can be made. As an example, the application of IO-LCA utilized in this study, the economic input-put (EIO)-LCA model, potentially underestimates the greenhouse gas emissions associated with waste management if methane gases derived from landfills are not included to full extent. However, according to [5] Lenzen, the comprehensiveness of the IO-LCA outweighs the uncertainties; in other words, the truncation errors associated with process LCAs are greater than the inaccuracy problems of IO-LCA models.

The hybrid LCA approach aims at diminishing the typical errors associated with process- and IO-LCA, while accentuating the respective advantages. To overcome the barriers associated with the two traditional types of LCA, a hybrid model for estimating the life-cycle effects of the built environment, combining input-output models and process-based approaches has been proposed [5], [9], [10]. An input-output based application of the hybrid LCA was chosen for this study as well. The basis of the analysis is formed with an economic IO-LCA model using monetary values to calculate the respective carbon dioxide equivalent (CO2e) impacts. The initial model is then enhanced with process specific data.

III. STUDY DESIGN

A 1960's residential area with multi-family housing from the suburbs of the Finnish capital Helsinki was used as a case study. The case area comprises 55 buildings and 7 different housing companies with altogether 981 apartments and 1,654 inhabitants. The average living space per resident within the case area is 38.8 square meters (sqm), a little over the average living space of 34 sqm in the city of Helsinki.

All housing companies within the residential area share the same property manager and energy provider. Consequently, comparable consumption data (both economic and metric) was available for analysis. Data used for the economic input-output model comprised financial statements of all housing companies from a period of one year (2009). The financial statements included data on energy and electricity consumption, water, wastewater, waste, maintenance and repair, as well as administrative costs. For the purpose of data analysis, economic inputs retrieved from the financial statements were allocated into the following eight categories:

1. Administration
2. Cleaning and property maintenance
3. Repair
4. Water and wastewater
5. Heating
6. Electricity
7. Waste Management
8. Insurance
9. Real Estate Taxes

The first phase of the analysis utilizes an EIO-LCA model developed by the Carnegie Mellon University (CMU) [11]. The model calculates CO2e emissions (CO2, CH4, N2O, CFC/PFC) per monetary input, using US producer prices from 2002. The model is considered the most comprehensive available with altogether 428 industry sectors, reducing the aggregation error in the model. The use of a foreign model is justifiable since the Finnish economy is a small and open economy with a high volume of imports. Furthermore, to reduce inaccuracy related to inflation and currency rates, purchasing power parity was applied to the prices, similar to a study by Weber and Matthews [12] on the carbon footprint of American households.

The first phase of the life-cycle analysis established relationships between the different activities associated with housing companies. Based on the initial analysis, activities that appeared to generate the most CO2e emissions (heating energy and electricity use) were taken into more detailed review. The less significant activities were left in the EIO-LCA model as they were. This method has been described as a screening LCA by Junnila [6]. The purpose of the second phase of the analysis was to enhance the model with regard to the most significant activities, namely heating energy and electricity use. Due to differences in the coal intensity of US and Finnish energy production, CO2e emission levels of energy production retrieved from the US model tend to be exaggerated. Therefore the production phase emissions of energy and electricity output matrices were replaced with process specific data. The required data included metric consumption data retained from property management, as well as emission data (g CO2e/kWh, hereinafter referred to as "carbon intensity") from the local energy provider. The energy production mode in the case area is a coal based, combined (heat and electricity) district heating system, with the carbon intensity of 286 g/kWh for heating and 284 g/kWh for electricity [13]. Except for the first tier process data enhancement, the rest of the output matrices were left untouched to maintain the full coverage of the model.

IV. RESULTS

The study shows, that the seven housing companies within the case area generate a total of 7,180 tons of CO2e emissions on an annual basis. When dividing the total carbon load of all housing company related activities by the number of residents (1,654 in March 2010) the study gives a "housing carbon footprint" of 4.3 ton CO2e per resident. The analysis reveals that heating is the single most important contributor to greenhouse gases with approximately 76% of the total impact (Table 1). Moreover, as electricity is the second largest contributor with approximately 6%, heating and electricity combined account for almost 82% of the total impact. It should be noted that only the communal electricity used by the housing company is considered in the study, the electricity consumption of households is excluded. If the household electricity consumption were included, the share of heating and electricity together would be even greater. The CO2e emissions from maintenance, repair, water and wastewater fall between 3.5% and 5.3% of the total impact, while waste management generates only 2.5% of the total impact. Furthermore, administrative activities, insurance and taxes comprise a negligible portion (less than 1% each) of the total impact.

TABLE I. CO2E (T) EMISSIONS FROM HOUSING COMPANY ACTIVITIES

Category	*Industry Sector in EIO-LCA*	*CO2e (t)*	*% CO2e (t)*
Heating	Power generation and supply	5,478.2	76.29
Electricity	Power generation and supply	432.1	6.02
Water and wastewater	Water, sewage and other systems	382.3	5.32
Cleaning and property maintenance	Residential maintenance and repair	351.4	4.89
Repair	Residential maintenance and repair	252.3	3.51
Waste Management	Waste management and remediation systems	180.3	2.51
Real Estate Taxes	General state and local government services	57.0	0.79
Porpery management and administration	Real estate	42.9	0.60
Insurance	Insurance carriers	4.2	0.06
Total	All	7,180.1	100.00

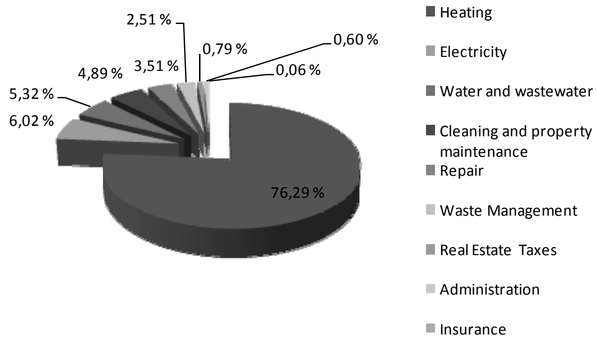

Figure 1. Percentage of CO2e emissions by housing company activity.

As stated earlier, the annual housing carbon footprint in the case area is 4.3 ton CO2e per resident. Previous studies in Finland suggest an annual total carbon footprint of 10.1 ton CO2e in the country [14] and 12.5 ton CO2e in the Helsinki Metropolitan area [4]. Against these reference values, the housing company related activities of the residents in the case area account for 42.5% of the annual carbon footprint of an average Finn, and 35% of the carbon footprint of an average Helsinki inhabitant. Furthermore, heating and electricity alone make up 3.6 tons CO2e, almost a third of the total footprint. This result is in line with a reference study [15] from the Helsinki metropolitan area, where the category "Energy related to housing" dominated the carbon footprint with 3.7 tons CO2e. However, unlike the case study, the reference study included the household electricity consumption. Excluding household electricity from the reference study would likely reduce the energy related carbon load below the 3.6 tons CO2e determined in this study. One plausible explanation for the high carbon load per resident is the larger than average apartment size in the case area.

V. DISCUSSION

One of the aims of the study was to test to usability of the input-output-based LCA method in estimating the carbon effect of housing. It seems that the results are in line with earlier studies. A recent reference study using the same methodology in the same region [15] shows that the results of the hybrid LCA technique are consistent. An economic input-output based methodology which is quick and relatively simple to use could be utilized by housing companies, in co-operation with property management, to estimate their annual environmental impact. Housing companies readily hold the financial information of their own activities, while property management should be able to provide data on physical consumption.

The methodology of the research entails some inherent limitations. The aggregation of sectors is inevitable in all input-output models, however the EIO-LCA model used in this study can be considered one of the least aggregated with altogether 428 industry sectors. Another problem with EIO-LCA is that the components are hidden, in other words, it is difficult to determine whether all significant activities are factored in. As an example, the methane emissions from landfills may not be included to full scale. However, looking into the CO2e emissions of the industry sector "Waste Management" it can be seen that the methane (CH4) emissions well exceed the other CO2e emissions, unlike in most of the other sectors. This would indicate that the methane gases derived from landfill operations are in fact included. Other uncertainties generally associated with the methodology include temporal and currency fluctuations. In this study, purchasing power parity (PPP) was applied to the prices to diminish the inaccuracy.

The data quality in the study is considered relatively high. All housing companies in the area are managed by the same property manager, allowing for comparable financial and physical data. The coverage of the data is lacking on one activity, namely the household electricity consumption. However, as one major motivation for the study was to emphasize the role of the housing companies and property management, the communal commodities are considered to be of greater importance than the household specific.

VI. CONCLUSIONS

Heating energy was identified as the dominant activity with regard to carbon emissions from housing, electricity use being the second most significant. Based on this study, activities associated with for example water and wastewater or waste management have only a minor effect on the carbon load of housing. Consequently, efforts aimed at minimizing the carbon effect and achieving national targets should focus on energy use. At the same time, it is important to note that only greenhouse gas emissions were considered in the study, and that poor water or waste management will have other negative environmental implications.

An important finding is that a significant portion of an individual's "carbon footprint" is generated from housing alone. Another main finding related to the results is that individual residents of multi-family apartment buildings have relatively little control over carbon emissions of their housing unit, since the heating energy consumption of the unit is usually adjusted by property management based on weather conditions. Moreover, individual residents have even less influence on the choice of energy production mode, the carbon intensity of which has a major effect on the emissions. It can be concluded, that in suburban areas with multi-family apartment buildings, the role of housing companies and property management is crucial in minimizing the carbon impacts of existing buildings. That is not to say residents have no power over decision making of the housing companies; particularly in owner-occupied buildings they do. The housing companies in turn mandate the activities of property management. The use of a simple, easy-to-use EIO-LCA based tool could be one way to support and advice in the decision making. Naturally, major structural changes such as the choice of energy production mode are also influenced by other factors such as existing infrastructure or public policies.

REFERENCES

[1] UNEP, Buildings and Climate Change - Status, Challenges and Opportunities. Paris: UNEP, 2007.

[2] D. Dodman, "Blaming cities for climate change? An analysis of urban greenhouse gas emissions inventories," Environment and Urbanization, vol. 21, no. 1, pp. 185-201, Apr. 2009.

[3] J. Norman, H. L. MacLean, and C. A. Kennedy, "Comparing High and Low Residential Density: Life-Cycle Analysis of Energy Use and Greenhouse Gas Emissions," Journal of Urban Planning and Development, vol. 132, no. 1, pp. 10-21, Mar. 2006.

[4] J. Heinonen and S. Junnila, Matalahiiliasumisen lähtökohdat (Preconditions for low-carbon living). Sitra, 2010.

[5] M. Lenzen, "Errors in Conventional and Input-Output—based Life—Cycle Inventories," Journal of Industrial Ecology, vol. 4, no. 4, pp. 127-148, 2000.

[6] S. Junnila, "Environmental Impact and Intensity of Processes in Selected Services Companies," Journal of Industrial Ecology, vol. 13, no. 3, pp. 422-437, 2009.

[7] S. Suh et al., "System Boundary Selection in Life-Cycle Inventories Using Hybrid Approaches," Environmental Science & Technology, vol. 38, no. 3, pp. 657-664, Feb. 2004.

[8] C. Hendrickson, A. Horvath, S. Joshi, and L. Lave, "Economic input-output models for environmental life-cycle assessment," Environmental Science & Technology., vol. 32, no. 7, p. 184, 1998.

[9] G. J. Treloar, P. E. D. Love, O. O. Faniran, and U. Iyer-Raniga, "A hybrid life cycle assessment method for construction.," Construction Management & Economics, vol. 18, no. 1, pp. 5-9, Jan. 2000.

[10] H. A. U. Haes, R. Heijungs, S. Suh, and G. Huppes, "Three Strategies to Overcome the Limitations of Life-Cycle Assessment," Journal of Industrial Ecology, vol. 8, no. 3, pp. 19-32, 2004.

[11] Carnegie Mellon University Green Design Institute, "Economic Input-Ouput Life Cycle Assessment (EIO-LCA). US 2002 Industry Benhmark Model.," 2008. [Online]. Available: http://www.eiolca.net. [Accessed: 25-Oct-2010].

[12] C. L. Weber and H. S. Matthews, "Quantifying the global and distributional aspects of American household carbon footprint," Ecological Economics, vol. 66, no. 2, pp. 379-391, Jun. 2008.

[13] Energiateollisuus ry, "Energiatilasto," 2008. [Online]. .Available: http://www.energia.fi/FI. [Accessed 20-Jan-2010].

[14] J. Seppälä et al., Suomen kansantalouden materiaalivirtojen ympärisötvaikutusten arviointi ENVIMAT-mallilla (Assessment of the environmental impacts of material flows caused by the Finnish economy with the ENVIMAT model). Suomen ympäristökeskus, 2009.

[15] J. Heinonen and S. Junnila, "Comparing climate change effects of rural and metropolitan lifestyles, a hybrid-LCA approach," Proc. Pacific Rim Real Estate Society (PRRES) Conference Jan. 2011.