Relative Contribution of the Transportation Sector to the Carbon Footprint of a Medium-Sized Municipality

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Introduction

In the specific study the relative contribution of the transportation sector in the medium sized Greek municipality of Kavala, was examined (Figure 1). Kavala is situated in Northeastern Greece and according to the latest census has a population of approximately 70.000 citizens. The main specific characteristics of the municipality are its proximity to both coastal and mountainous areas, its mild Mediterranean climate and its service sector based economy.

The municipality of Kavala participates in the Covenant of Mayors (CoM), an EU-scale initiative involving a significant number of municipalities within EU. The participating municipalities are voluntarily committed to increase energy efficiency within their jurisdiction and the basic quantitative objective of the specific initiative is a 20% reduction of CO_2 emissions from their municipal activities by 2020 (Covenant of Mayors, 2012). In that aspect, it is important to identify the sectors that highly contribute to the carbon footprint of the municipality so that efficient strategies and policies can be applied.

Figure 1: The municipality of Kavala.

Methods

In order to estimate the relative contribution of the transportation sector to the carbon footprint of the city, the total carbon footprint had to be estimated. Analytical data regarding energy and fuel consumption of various activities and sectors (housing, services, lighting etc.) were estimated for the year 2011 (baseline year). The specific data were acquired from local providers, city authorities and energy audits performed by the authors. Issues such as local energy mix, renewable energy utilization and fuel type were also taken into account.

All factors were translated to equivalent CO_2 emissions with the application of the Intergovernmental Panel on Climate Change (IPCC) guidelines and the adoption of IPCC 2006 emission factors (IPCC, 2006). The specific guidelines were chosen due to the wide applicability of the method and the compatibility with the Covenant of Mayors (CoM) proposals (European Commission, 2010).

The private and public transport CO_2 emissions were estimated according to the total distance (in km) traveled during 2011 and the corresponding average emissions per type of vehicle (heavy-light duty, two wheels, passenger cars). Data were acquired from various sources (Egnatia Odos S.A., Hellenic Office of Statistics, local transportation union, i.e.KTEL etc.). The

formula applied to estimate the carbon footprint for every vehicle type is presented below (Figure 2).

$$\text{CO2 emissions per type of vehicle} = \underbrace{\left[\text{No. of vehicles in circulation} \times \text{Annual distance covered per vehicle (in km)} \times \text{Avg. consumption (in L/km)} \times \text{Energy conversion factor (in KWh/L)}\right]}_{\textit{Total energy consumption per type of vehicle}} \times \text{Emission factor (in t CO2/KWh)}$$

Figure 2: Formula applied to estimate the carbon footprint for every vehicle type.

Additionally, the energy/fuel flows were modeled and assessed with the application of Life Cycle Assessment (LCA) software (SimaPro 7.2) in order to further strengthen the results of the study and examine CO_2 emissions alterations due to the life cycle approach.

Results

The total CO_2 emissions inventory for the municipality of Kavala, is presented in Table 1. The carbon footprint was estimated to be 511,799 tons CO_2 or 6.9 tons CO_2 per capita. 77% of the total carbon footprint is attributable to the building sector whereas the private and commercial transport is accountable for approximately 23% of the total carbon footprint of the municipality or 115,535 tons CO_2 (see Table 1 and Figure 3).

Table 1: Carbon footprint inventory of the municipality of Kavala in 2011.

Category	CO_2 Emissions [%]					
	Electricity	Oil(heat)	Diesel	Gasoline	Wood	Total
Buildings/Facilities						
Municipal buildings/facilities	3.8%	0.4%				4.2%
Tertiary buildings	29.3%	0.9%				30.2%
Residential buildings	29.5%	8.4%			2.8%	40.7%
Municipal public lighting	2.3%	-				2.3%
Subtotal Buildings/Facilities	64.9%	9.8%			2.8%	77.4%
Transport						
Municipal fleet			0.1%	>0.1%		0.2%
Public transport			0.4%	-		0.4%
Private transport			12.2%	9.9%		22.1%
Subtotal transport			12.7%	9.9%		22.6%
Total						(511,799 t CO_2) 100%

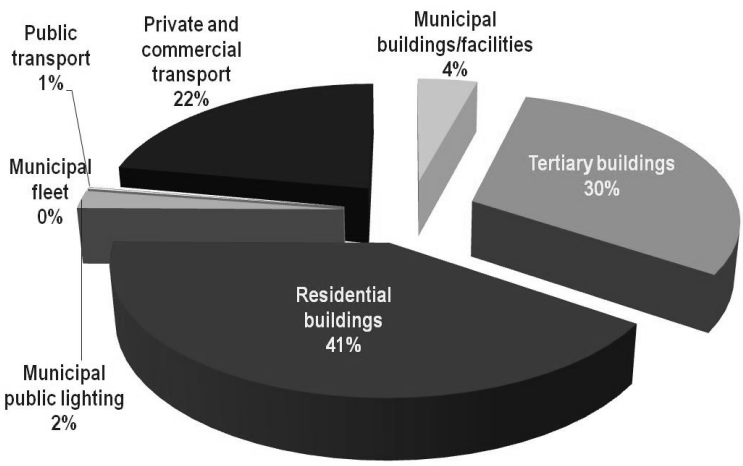

Figure 3: Relative contribution of various sectors to the carbon footprint of Kavala.

Private and commercial transport is the predominant subsector compared to public and municipal transportation activities in terms of CO_2 emissions contribution. The relative contribution of CO_2 emissions per fuel and per sector is presented below (Figure 4). Diesel is the predominant fuel for public and municipal subsector in accordance with the current fuel consumption scheme in Greece.

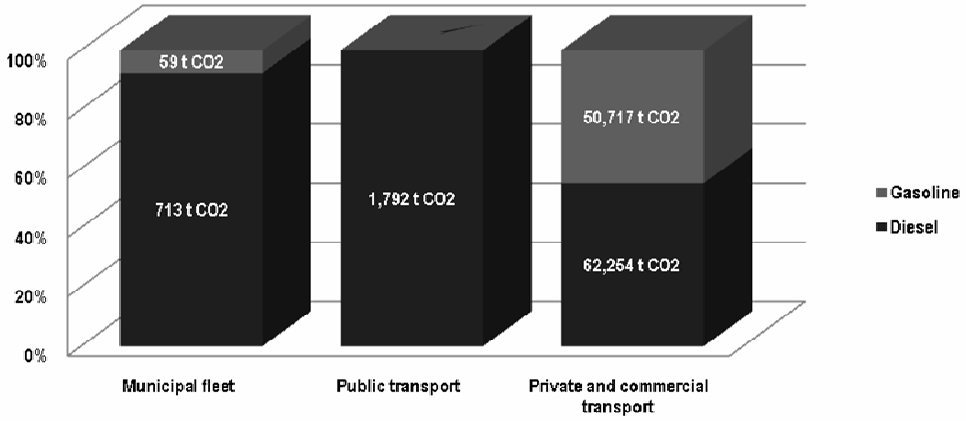

Figure 4: Relative contribution of CO_2 emissions per fuel and per sector.

The various fragments of the transportation sector were individually quantified and assessed.

Private and Public transport

A total of 112,971 tons CO_2 were emitted from private and commercial transport. The traffic could be distributed into two main components; the approximately 20 Km of Egnatia Odos (a highway that connects northeast and northwest Greece) that fall within the boundaries of the municipality and the rest of the existing national road network (Figure 5).

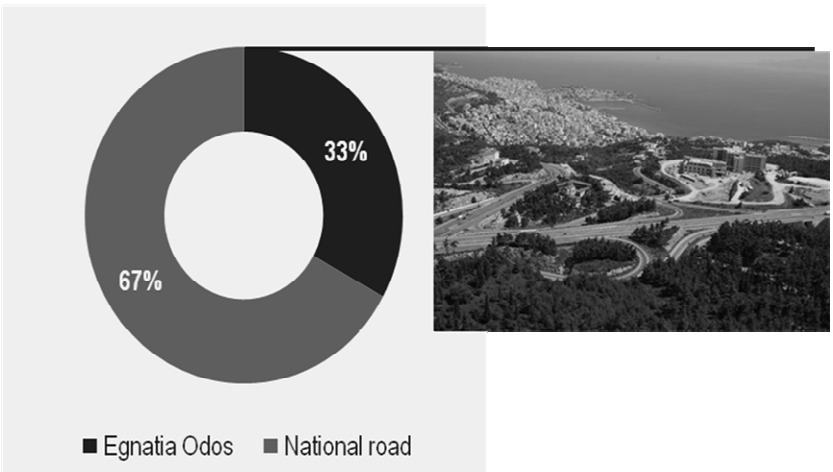

Figure 5: Distribution of traffic of private/commercial vehicles on the two main road networks of the municipality of Kavala.

The total diesel oil consumption for public transport in 2011, was estimated to be 6,711 MWh or 1,792 tons of CO_2 equivalent emissions. The urban transport load was estimated to be approximately 1,326,402 km, responsible for the consumption of 387,309 lt. of diesel oil, whereas the long distance transport within the boundaries of the municipality was estimated to approximately 972,213 km consuming 283,886 lt. of diesel oil.

Municipal fleet

Despite the fact that the contribution of municipal fleet to the total carbon footprint is low (<1%), fuel savings and CO_2 emissions reductions is crucial due to the significant amount of fuel that could be saved. The individual consumption percentage by sector of municipal management is

shown in Figure 6, indicating that the major fuel consuming activities and the corresponding "hot spots" in terms of municipal fleet CO_2 emissions are the activities related with cleaning and waste management.

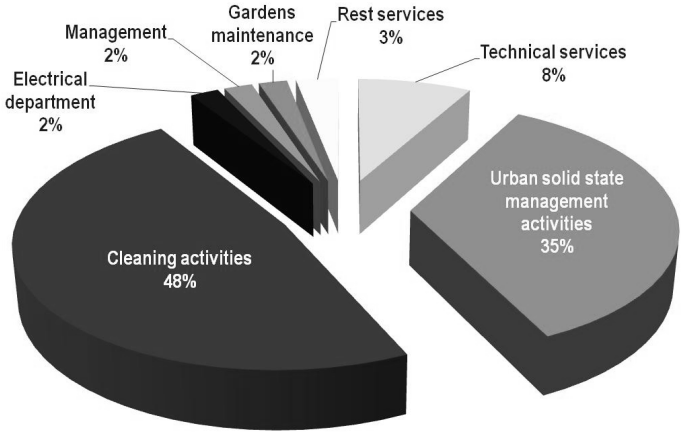

Figure 6: Municipal fleet fuel consumption by department/use.

Life cycle analysis

The energy/fuel flows were modeled and assessed with the application of Life Cycle Assessment (LCA) software (SimaPro 7.2) in order to further strengthen the results of the study and examine CO_2 emissions alterations due to the life cycle approach. LCA is an analytical tool for assessing the environmental impact of a system, taking into account all the stages of its life (manufacturing, use, disposal etc.) (Environmental Protection Agency, 2006). Data gathered during the specific study were modeled and assessed with the ReCiPe method (Goedkoop et al., 2009).

The application of LCA methodology, further confirmed the results quantifying the relative contribution of the transportation sector to the total carbon footprint of the municipality of Kavala to an approximate percentage of 25%. (Figure 7).

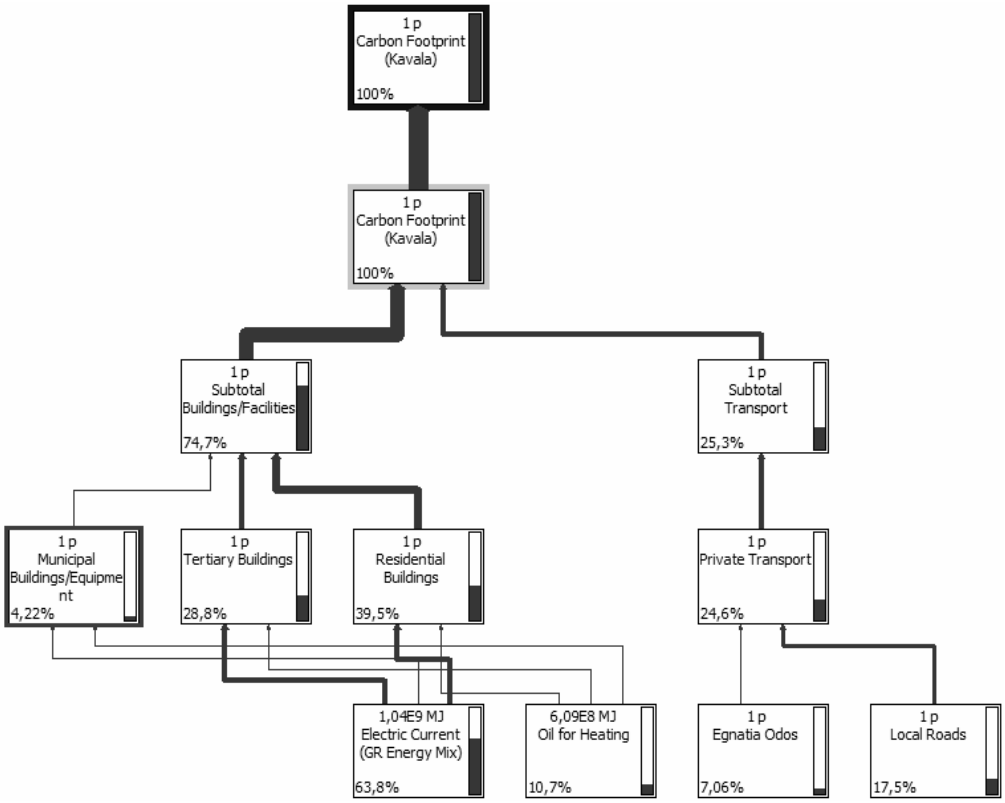

Figure 7: Model developed in LCA software to assess the carbon footprint.

Further analysis of the LCA results indicated that the major environmental impacts of the transportation sector are related with the formation of photochemical oxidants and PM_{10}.

Conclusions

In the specific study, the relative contribution of the transportation sector to the total carbon footprint of a medium sized municipality was analytically quantified and assessed. The basic conclusions derived from specific study are:

- Nearly 1/4 of the total carbon footprint of the municipality examined is attributable to transportation activities.
- Municipal fleet, although contributing to a low percentage of the total carbon footprint, should act as an exemplar for private/commercial transportation sector.
- Almost 1/3 of the total private/commercial CO2 emissions from the transportation sector are due to traffic in Egnatia Highway where the municipal authorities cannot interfere drastically. In that aspect, improvement actions should focus on reducing the utilization of private/commercial cars inside the town of Kavala.
- The transferring of the interurban bus station in the outskirts of Kavala Municipality is estimated to have positive environmental impacts and reduce the total carbon footprint, however this is a proposal that need further elaboration. Moreover, possible scenario examining the railway connection of Kavala with Thessaloniki and Toxotes is also estimated to reduce the total carbon footprint of the Municipality due to anticipated decrease of the transportation load in Egnatia Highway.
- Assessing the energy/fuel consumption and the respective carbon footprint for each sector in a municipality level was found to be especially useful for strategic decision management and energy/fuel savings.

The results of the specific study are expected to be useful for decision makers, local and regional authorities interested in their environmental performance and the reduction of their carbon-environmental footprint.

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