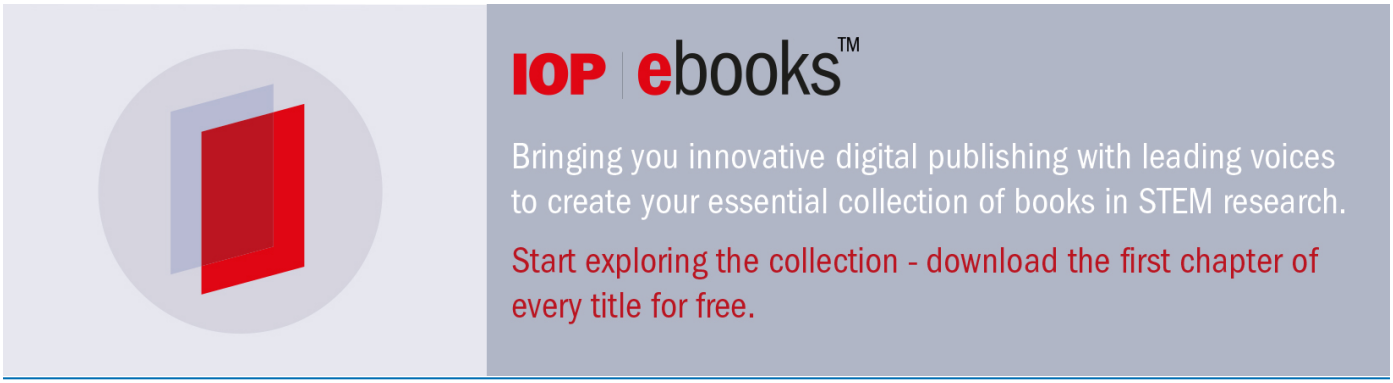
Integrated evaluation of energy and emission reduction potential and management strategies for urban road systems



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Integrated evaluation of energy and emission reduction potential and management strategies for urban road systems

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Abstract. Solving the problems of high energy consumption and high emissions generated by the urban road systems is of great importance for the construction of low-carbon cities. Several tools have been developed to establish a method to evaluate the carbon emission related to the life cycle of road pavements. However, the lack of key basic data such as energy consumption, pollutants and carbon emissions, and accurate management policies have hindered the transition of urban roads to clean, low-carbon systems. The HERMES project aims to compile long-term dynamic inventory of urban road energy consumption and environmental emissions and build a life cycle model. The Data Envelopment Analysis model will be used to predict the energy saving and emission reduction potential of urban roads depending on the technological solution, establish a multi-criteria evaluation system that includes energy, environment, and economic parameters, identify the best available technological solution in different cities, and propose a more targeted and effective clean low-carbon management policies. The study will provide an accurate understanding of the environmental impact of urban roads in China and Europe, evaluate the potential for energy saving and emission reduction, and provide theoretical data and decision-making reference for a clean, low-carbon transition.

1. Introduction

More than 275 million tons of asphalt are produced every year in Europe alone for maintenance and rehabilitation of roads (1). This consumes large amounts of resources and contributes to the emission of greenhouse gases (GHG). This equals approximately 30 million tons of CO_{2eq} emissions from the production of asphalt for maintenance and rehabilitation alone (EPD Norway). However, roads are heterogeneous in their design and construction; the global warming potential (GWP) associated to these operations shows a large variation, depending on the material composition, procedures and

maintenance. Typical values vary from almost neglectable to 60 000 tons of CO_{2eq} per lane km over a 50 year time period (2). In order to reduce the negative impact related to maintenance and rehabilitation of urban roads, the goal of HERMES project is to provide a methodology enabling the selection of the best available technology and strategy with the lowest cost for the environment and society.

The final output of the project would therefore be a matrix usable by road owners and contractors to define, based on the local conditions, regulations, restrictions and technology availability the best solution for the construction or maintenance of the road in terms of environmental factors, financial investment and local boundary conditions.

2. Objectives and targets

Targets for a greener future are being set worldwide. To achieve these goals, a shift towards more sustainable technologies is required in all fields including road construction, maintenance and rehabilitation. Better asphalt mixtures and technologies have a great potential to contribute to the reduction of greenhouse gases, pollution and energy consumption (3). The introduction of a procurement system based on sustainability criteria could encourage the development of more efficient and durable solutions. Several methodologies (LICCER, CEREAL, EDGAR (4, 5)) have already been developed and EPDs are becoming a standard procedure: the general trend highlights the shift towards more environmentally friendly technologies. The limited success, in terms of direct use by others, of the previous projects was due to several factors such as the extend of the life cycle considered, the flexibility in considering additional new technologies, the possibility to adapt the tool to local conditions and requirements and most important user friendliness and practicality. It has therefore been of crucial importance to consider all those factors already from the conception of the project.

A suitable tool to analyse the operations connected to road construction, maintenance and dismantlement thoroughly is represented by Life Cycle Assessment (LCA) . Previous researches have highlighted the most important inputs, system boundaries, functional units and limitations connected to the LCA of pavement infrastructure (6, 7); furthermore, LCA is a holistic tool that can be used to assess the impact of using both traditional and alternative materials (8). LCA is a data-intensive methodology strongly dependent a variety of inputs connected to various scientific fields; acknowledging the deficiencies of the LCA conducted so far can allow HERMES study to define a more transparent assessment framework, thus contributing in synergistic fashion the literature and previous researches (9, 10).

The overall objective of the HERMES project is to establish a long-term dynamic inventory of carbon emissions deriving from the analysis of a variety of urban roads, based on best practices is Europe and China. The main research tasks are connected to the following areas:

1. Energy consumption and emission patterns throughout the life cycle,
2. Best available technologies for road pavements,
3. Clean and low-carbon construction and maintenance operations.

The project aims to improve emission reduction management policies that can be adopted to promote the sustainable development of urban road systems in China and Europe. Currently there is no cross-national comprehensive comparison regarding the different road design methods and their environmental impacts on the service-life in different urban settings and climate zones.

The development of HERMES project will be based on the following criteria:

- User-friendly and global
- Comprehensive
- Sustainability oriented
- Performance oriented
- Tested in collaboration third parties.

To achieve the main objective, the following targets have been identified (refer to figure 1 for short work package (WP) description):

1. Review of the available methodologies and technologies for the assessment of green asphalt (and other construction materials) (WP3)
2. Analyse the procurement processes including a sustainability assessment (WP3)
3. Broaden and improve the data inventory by including information about pavement life time prediction (WP3 and 4).
4. Assess the effects of maintenance schedule on emissions (WP5).
5. Test the validity and usability of the HERMES tool (WP6)
6. Establish the bases for further implementation and cooperation (WP2, 3 and 6).

In order to avoid a strictly national approach, the project acknowledges that road construction operations are influenced by climate mitigation policies that contribute to different SDGs (Sustainable Development Goals). Thus, a more integrated approach can allow for a broader understanding of mutual dependencies in the development of road construction. This will provide a more detailed insight into the actual design and operating of road constructions.

Moreover, the project is especially aimed at creating a management system able to take into account the pavement life cycle, environmental, social and economic issues. Special emphasis is put on how the management and monitoring operations are performed when it comes to evaluate climate change policies. For a better mutual understanding and implementation, the methodologies will be applied in trial road sections in both Europe and China.

The project involves trans-national cooperation between Norway, Austria and China, and is meaningful for both research institutes and stakeholders of road construction projects. The collaboration also addresses how road constructions in Norway, Austria and China approach sustainability assessment in their strategies. Therefore, HERMES project entails the exchange of knowledge, analysis of policy making strategies and identification of differences in planning frameworks at an international level.

The LCAs connected to HERMES project take the first steps considering the limited amount of literature currently available regarding pavement infrastructure. These investigations have been carried out on countries that are geographically close to the nations involved in the HERMES project: Sweden (11), Finland (12), Switzerland (13), South Korea (14) and Taiwan (15).

The project contributes to ongoing scientific discussion by adopting different interdisciplinary insights. On one hand, the project provides a more practice-oriented research perspective to sustainability assessments, at road constructions which enables to discuss how the context of urban processes and subsystems is conceptualized in these assessment methodologies. Rather, this project aims at developing ways to contextualize assessment methodologies from the perspective of stakeholders' practices. On the other hand, the project provides a more assessment-oriented research perspective to practice and transition studies in relation to sustainable development.

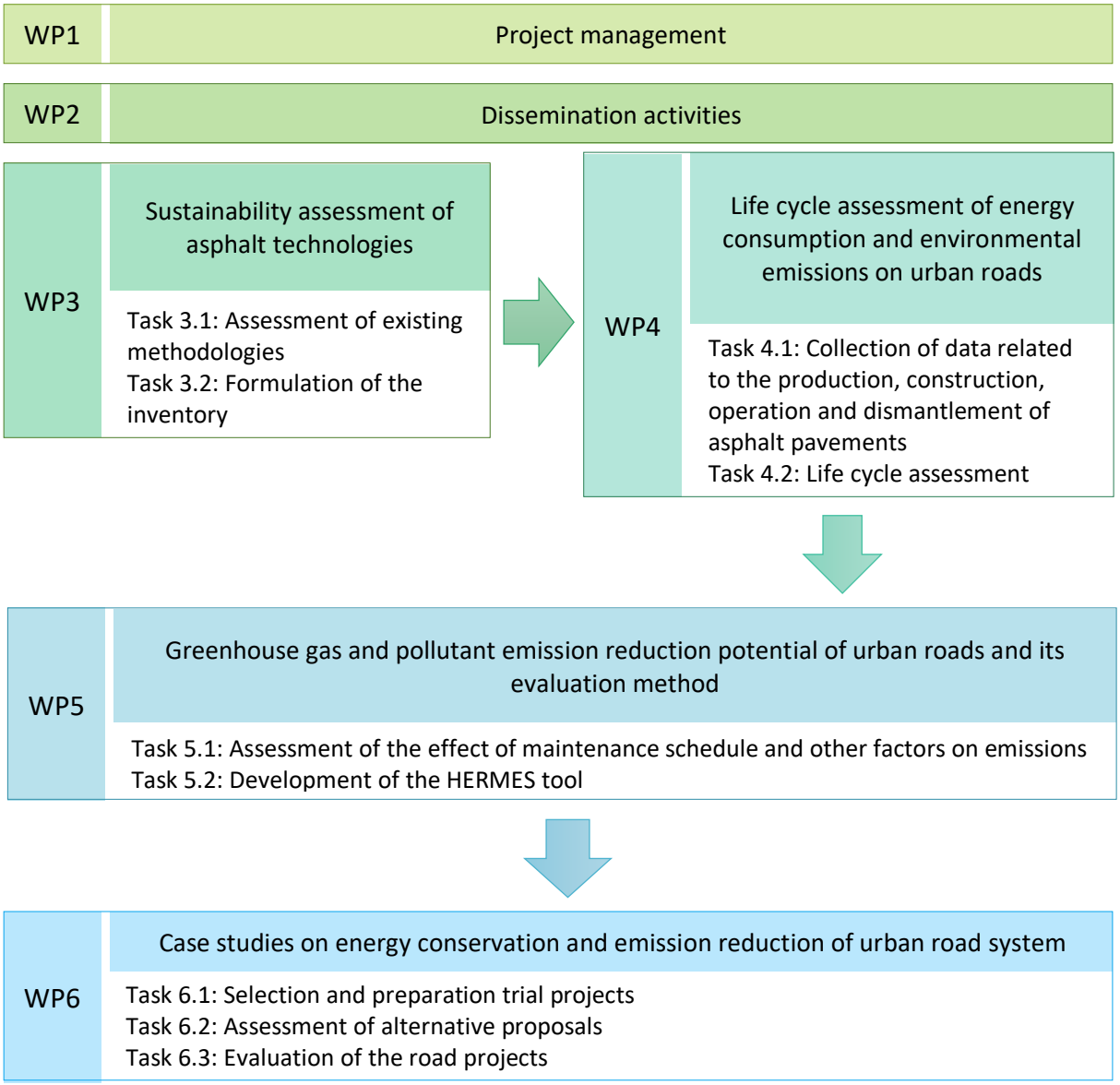

Figure 1: Work package description

3. Key activities

The overall objective of the project is to create a tool able to help both stakeholders and contractors reducing the impact of pavement maintenance and rehabilitation on the urban environment in terms of both energy consumption, emission and pollution production, efficiency and cost-effectiveness through a more efficient and effective planning. At the end of the project, the existing gaps will be filled, and a functional methodology will be available, rising the technology readiness level from 5 to 8. Therefore, the project will start from an analysis of previously developed tools and procurement processes based on sustainability criteria leading to the formulation on the basic framework of the HERMES project (WP3). At the same time a high resolution dynamic inventory of emissions from urban roads construction and maintenance will be created (WP3).

Once the energy consumption and emission sources have been identified and analysed, an appropriate life cycle analysis method (Simapro and Ecobalance) will be used to quantify the effects of urban road systems on resources, energy and environment in both the Chinese and European case (WP4). Great importance will be put in the uncertainty/variability assessment of the different indices used in the analysis.

The next step (WP5) is focused on the development on the HERMES tool based on considerations on how other factors, such as pavement service life, maintenance schedule, and innovative technologies influence the computation of the technical indices. In this step it will be important to emphasize user-friendliness and flexibility of the tool. The tool shall be able to integrate the evolution of energy saving and emission reduction potential with management strategies for the urban road systems. Collaboration and cooperation between the partners and dialogue between the work-packages will be central enabling factors to facilitate and make the success of the project possible.

While the other work packages will progress towards the development of the HERMES tool, the WP6, centred on its utilization, will start its activities in large advance to guarantee a smooth cooperation with the local stakeholders and contractors during the preparation of the procurement tender and contract documents. The extended period of time will also allow the contractors to gather data and information to calculate the technical indices to be considered in the procurement process. Once the alternative proposals will be assessed, the partners will evaluate the case studies and how stakeholder and contractors interacted with the HERMES tool.

4. Expected impacts

The expected outcome of the HERMES project is to analyse effective ways of assessing environmental impact of both present and future urban road systems. The project interdisciplinary approach enables a meaningful connection between stakeholders of road construction projects, policy maker practices and sustainability assessments.

A major challenge of the project is to ensure a proper holistic integration of the many perspectives and interests of the involved parties. The non-hierarchical structure of management should facilitate the execution of such an interdisciplinary project.

The potential users of research project are mainly stakeholders of road construction projects, policy makers in municipalities and similar organizations that are responsible for developing strategic plans and project concerning climate mitigation solutions. The project is also intended to challenge the national and international policy making systems (like that of the European Union), since these often play an important role in defining the planning framework for the development and access to strategic plans. There is a general need to recognize the difficulty of bridging between the local complexity of specific plans and projects, and the abstract methodological complexity of sustainability assessments. This challenge can only be addressed through a more thorough understanding how these issues intersect in the practices of policy makers.

Since the project entails a tight Sino-European collaboration, the differences in creating policies are important to be taken into account. Generally, when a study is carried out at a purely national level, the specific social, technical, geographical and organizational norms of the country are often neglected or overlooked. A trans-national project will ensure that these critical differences between different countries involved in the project are surfaced and addressed. Such a trans-national perspective will also contribute to help to address the scaling challenges more specifically, since it will become clear that the three countries operate within similar global contexts, but within different national and local conditions.

5. Expertise of the consortium

The project brings together a unique combination of research knowledge and expertise to underpin the development of the HERMES tool at international level. The consortium is formed by five research institutions (SINTEF, Graz University of Technology – TUG, Norwegian University of Science and Technology – NTNU, Wuhan University of Technology – WUT and Shangdong University) with key knowledge in the project's topics and an enterprise (Zement+Beton Handels- und W. GmbH (Z+B)) who has already widely contributed to the development of sustainable solutions for concrete roads with the implementation of tools and regulation for their construction and maintenance.

This consortium combines environmental, technical and social research competences, hereby representing a truly interdisciplinary consortium that analyses quantitative sustainability assessments and social dynamics of change and practices in relation to technical infrastructures and networks in an urban context. This provides a more holistic basis for developing assessments tools and methods to be more effectively adopted to achieve reductions in GHG emissions through climate mitigation policy

making. The partners have a well-recognized leadership, expertise and skill in the following crucial areas for the project:

- Management and coordination: SINTEF
- Greenhouse gas and pollutant emission: NTNU, TUG, Shangdong University and WUT, Z+B
- Energy consumption: TUG, Shangdong University
- Life cycle analysis: NTNU, TUG, Shangdong University, Z+B
- Road materials: SINTEF, NTNU, WUT
- Life cycle cost assessment: SINTEF, NTNU, Shangdong University, Z+B
- Road pavement construction, maintenance and rehabilitation: SINTEF, NTNU, WUT,
- Z+B
- Communication, dissemination and exploitation of results: SINTEF, NTNU, TUG,
- WUT, Shangdong University, Z+B

For the assessment of existing methodologies, a large effort is expected by all partners. The internationality of the group allows to gather information about projects and procurement processes using sustainability indicators to evaluate road pavements around the globe, giving the opportunity to finally extend the analysis to the Asian context that because of language and cultural barriers has always been difficult to approach. The involvement of other research groups and local stakeholders will be necessary.

Shangdong University and WUT, together with TUG, Z+B and NTNU will also have an extremely important role in the assessment of both emissions (including greenhouse gas and VOCs) and energy consumption due to pavement construction and maintenance. During this phase the partners will gather information also through direct contact with local contractors.

SINTEF, NTNU and WUT are nationally and internationally known for their expertise in pavement design, maintenance and rehabilitation. Their knowledge, previous research projects and local contacts will be used to assess the service life of different pavement technologies. Their impact on emissions and energy consumption will then be assessed by TUG, Shangdong University and Z+B.

A common effort will be put in the development of the HERMES tool and in the case studies.

Acknowledgments

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