Preliminary analysis of the production of traditional and alternative wall-building materials in Vietnam

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Abstract. Vietnam is undergoing a continuing construction boom. This enormous volume of new constructions is characterized by simple building techniques and large consumption of materials. The Vietnamese government would like to reduce the use of traditional fired clay bricks to avoid inefficient brick production with high energy use, significant CO2 emissions, and the accompanying destruction of valuable agricultural land due to clay mining. The strategy is to switch to alternative wall-building materials in efficient industrial production methods. To support this development, the BMBF-funded project "CAMaRSEC" is developing a study on life-cycle assessment of building materials that provides the basis for sustainable resource management and avoiding hazards to the local environment. A key focus is the holistic investigation of the Production Stage of traditionally fired clay bricks as well as currently existing alternative wall-building materials (non-fired bricks). At present available data sets are mainly for developed countries and cannot be applied to the production methods in Vietnam. Therefore, there is an urgent need for local data sets generated within this project.

1 Introduction

The construction industry makes a significant contribution to global CO_2 emissions and final energy consumption. If the focus is on building materials and construction, we talk about embodied carbon and grey energy. They represent how much CO_2 emissions and energy are already released and consumed before a building is used. Globally, embodied carbon contributes around 10% and grey energy 5% when comparing all sectors [1]. These figures show that materials already make a decisive contribution and must not be neglected.

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Vietnam is undergoing a sustained construction boom. This new construction volume is creating an enormous demand for building materials. A traditional building material, which is still mainly used today, is fired clay bricks with a market share of about 70% [2]. However, fired clay bricks consume valuable agricultural land through clay mining, and due to inefficient kilns, much energy is needed, and harmful emissions are released. Therefore, to reduce resources and energy consumption, the government promotes more sustainable building materials such as non-fired bricks [2].

To evaluate and classify materials according to their sustainability, Life Cycle Assessment (LCA) data on manufacturing processes are necessary. In countries of the global south, the partially available data from developed countries cannot be readily adopted. The structures, machines, transportation means, and electricity mixes in these countries differ significantly from each other. This is also noted by Schneider et al. [3] in their analysis of mining processes in Vietnam. The majority of mining operators cannot reach best practices in mining technology or preparation work. In addition, expert interviews accompanied by photographs conducted as part of this study confirmed that manufacturing processes, especially of fired clay bricks, are far from being as advanced as in, for example, Germany or comparable countries.

To support the development of sustainable materials and enable the classification of building materials, the project "Climate Adapted Material Research for the Socio-Economic Context of Vietnam" (CAMaRSEC) analyses the life cycle of different building materials. Up to now, there is no available LCA database on the production of building materials in Vietnam. However, these data are necessary to obtain information about building materials' environmental impact and sustainability, like fired clay bricks and non-fired bricks. Thus, building materials can be compared, and ecological and resource-saving products can be promoted in a targeted manner. Also, production processes can be improved and benchmarked with good international practice.

2 Methodology

In the following, the framework for the LCA of different wall-forming materials according to the standards DIN EN 15804:2019 [4], ISO 14040:2020 [5] and ISO 14044:2020 [6] is presented. Fig. 1 shows an overview of the workflow.

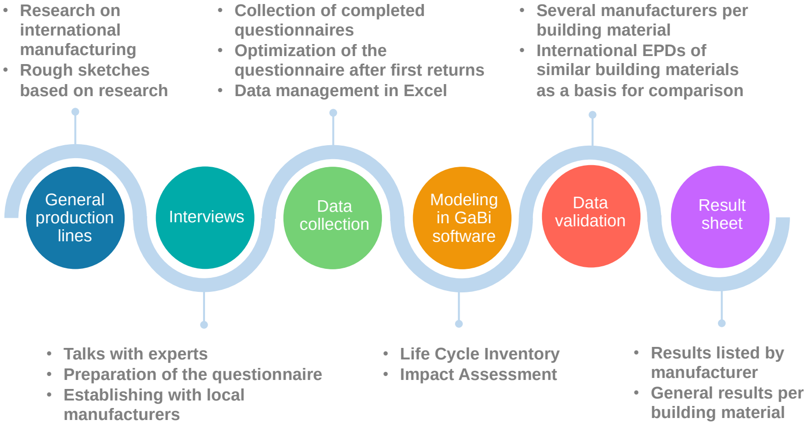

Fig. 1: Workflow for an LCA study for building materials in Vietnam.

Based on initial literature research and expert interviews on manufacturing processes of building materials, surveys are created and conducted, which serve as a basis for the process modelling in the GaBi software [7]. For each building material, data from various manufacturers and Environmental Product Declarations (EPD) are included. The results are presented on the one hand depending on one manufacturer and, the other hand, summarized of several manufacturers.

2.1 Goal and Scope

The study's goals, to compare alternative wall building materials to support decision-making at the design and policy level and to identify inefficiencies and ecological impacts of the materials. Another aim, to identify optimization potentials in production.

Four wall-forming materials, i.e. fired clay bricks, autoclaved aerated concrete, foam concrete bricks, and concrete brick blocks that perform non-loadbearing functions of the exterior wall, are chosen for this LCA study. For these materials, the thermal conductivity of building materials is measured in another work package within the project. These data are relevant for the characterization of building physical performance and for defining comparable functional units in the LCA. The measured data then compiled with the generated LCA data in datasheets for the building materials.

The masses of the different building materials are related to a uniformly defined heat transfer coefficient of a 1 m^2 wall to generate meaningful results in the LCA study. For example, this could be set at 1,79 W/m^2K following the required heat conduction performance in the Vietnamese building energy standard [8]. The life cycle phases considered are based on the cradle-to-gate system boundary for Modules A1 to A3 (raw material extraction, transport, and production) [4], for autoclaved aerated concrete as shown as an example in Fig. 2. The environmental impacts are calculated by EN 15804:2019 [4]. Data requirements are ranked with a preference for Vietnamese data, followed by data from countries with similar levels of technology, and finally, global data. If none of these data, available for the specific case, European or German data sets, for example, should also be used in the last place.

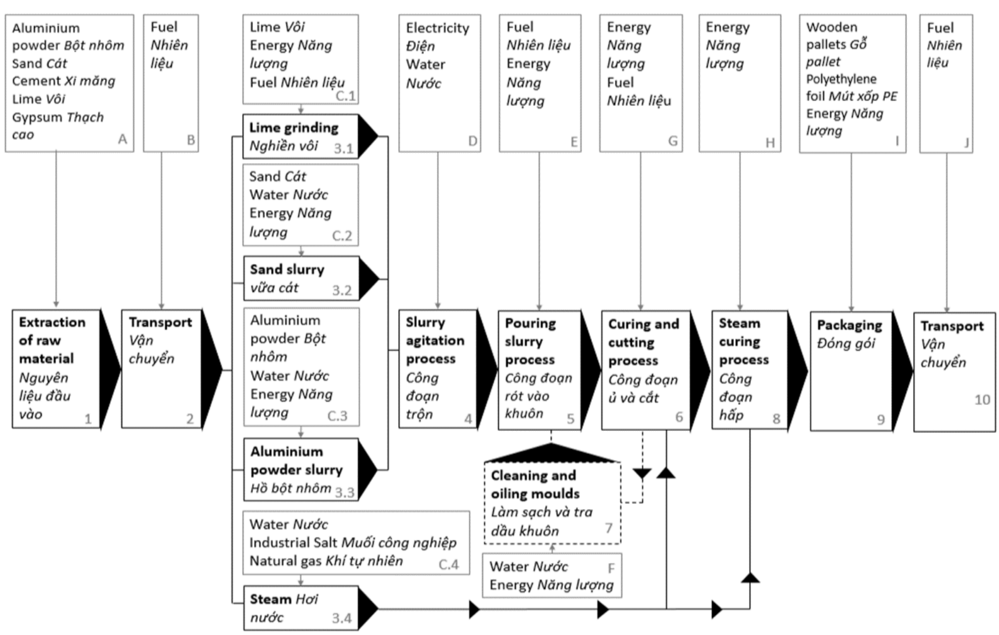

Fig. 2. Example for Modules A1 to A3 for autoclaved aerated concrete.

2.2 Data collection

As little information on the manufacturing processes of building materials in Vietnam is available so far, this study collects data on energy and raw material inputs. Data collection is done in close cooperation with local material producers to obtain current and valid data. Unfortunately, no personal visits and meetings were possible due to restrictions under Covid conditions. Therefore, data collected via telephone calls, online meetings, and digital questionnaires to enable data acquisition under these conditions. The bilingual (English and Vietnamese) questionnaire collects general data about the company and the respective product and detailed data about the individual process steps. Data on input, quantities, machines, or energy consumption are requested to understand the respective process steps, Fig. 3 shows an extract from the bilingual questionnaire and indicates the depth of detail asked. Generated data processed in Excel to model the manufacturing processes in the GaBi software [7].

Process number and **name** *Số thứ tự và Tên của quy trình*	**Inputs** (rough quantity) **per month** *Nguyên liệu đầu vào (Khối lượng sơ bộ) mỗi tháng*	**Machines or vehicles used** *Máy móc hoặc phương tiện vận chuyển*				**Process description** in short words If truck transport: please always complete which type of road (highway, urban, rural) is mainly used. ***Mô tả quy trình*** *(ngắn gọn)* *Nếu dùng xe tải, vui lòng ghi chú loại đường sử dụng chính là cao tốc, hay đường đô thị, hay đường nông thôn*
		Name of machine *Tên máy*	**Usage** time **(time during which the machine works) [h] or** distance **[km] per month** *Thời gian sử dụng (tính trong lúc hoạt động) hoặc khoảng cách vận chuyển [km] mỗi tháng*	**Power** [kW] *Công suất [kW]*	**Fuel consumption** [l/h] or [l/km] *Nhiên liệu tiêu thụ [lít/h] hoặc [lít/km]*	

Fig. 3. Extract of the bilingual questionnaire.

2.3 Life Cycle Inventory analysis

The life cycle inventory is carried out, GaBi software [7]. The processes for raw material extraction and transport are modelled from the data sets available in GaBi software [7]. The data are compiled according to data requirements introduced in paragraph 2.1. For modelling, the extension databases IXa (end of life), II (energy) and XIV (construction materials) were used together with the professional database and the Electricity mix for Vietnam (data on demand). The processes within the production are built up according to the data collected from the questionnaire. For this purpose, own processes are modelled and supplemented with already existing data from databases.

2.4 Data validation

Data from several manufacturers are processed for each building material to obtain generally valid and manufacturer-independent data. The distribution of manufacturing factories varies in number and location for different materials so that no uniform distribution can be set. As a lower limit, it is the objective to include two manufacturers per building material. Data of the manufacturers are compared and checked for reasonableness. Finally, the manufacturer-dependent data per material are combined into a conglomerate model. In addition, international EPDs are used as a basis for comparison to examine the comprehensibility of the collected data and generated results.

3 Results and discussion

The study is currently in the work steps "data collection" and "modelling, the GaBi software" (see Fig. 1). Data acquisition is a time-consuming process. This may be due to the current lockdown in Vietnam and the fact that data, sensitive for the manufacturers.

So far, modelling has been completed for autoclaved aerated concrete bricks from one manufacturer. These initial data sets are evaluated qualitatively and discussed below. The results serve as an assessment for further investigation and are intended to provide a baseline of existing LCA data for all other modellings. Fig. 4 and Fig. 5 show an example of the Global Warming Potential and Primary Energy Non-renewable Total, divided into raw material extraction versus transportation and manufacturing processes. This illustrates the relevant influence of resource extraction on, for example, GWP and PENRT compared to transport and manufacturing.

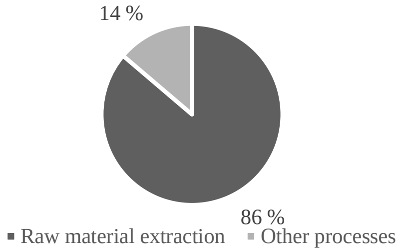

Fig. 4. Percentage share on the Global Warming Potential (GWP)

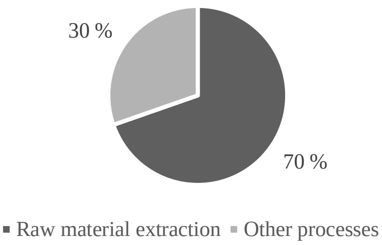

Fig. 5. Percentage share on the Primary Energy Non-Renewable Total (PENRT)

Looking at the geographical origin of the data used for raw material extraction, it is apparent that it consists exclusively of Chinese data. Accordingly, only about 14% and 30% of the impact, GWP and PENRT, respectively, are calculated with local data, mainly for material production. This shows that the information obtained with the help of the manufacturers can be used to map production for the specific situation. For the large share representing material extraction, however, 86% and 70% of the impact, GWP and PENRT, respectively, the calculations are based on Chinese data. This illustrates the need for research on the impact of raw material extraction to generate local data. These data reflect only the result of a single model, but these statements can also be applied to models for other relevant materials. Raw materials such as sand, lime, or cement are also required for other production processes, so the assumptions also apply to further raw material extraction.

To improve the relevance for local conditions in Vietnam, further studies with an extended scope are necessary. Therefore, the following points should be addressed:

- An investigation, the extent to which the raw material extraction in China and Vietnam differ from each other is required to justify assumptions and to qualify the use of foreign data for local LCA studies. It must be considered that the LCA data are also based on assumptions and that China and Vietnam have regional differences, making it difficult to make general statements about an entire country and always involving simplifications.
- Raw material suppliers must be included in the study. In this way, specific data on the local situation can be collected. However, this would require a significant amount of time, which is also dependent on the extent to which raw material suppliers agree to participate. Initial discussions show that establishing contact here is more complicated, and data only passed on to a limited extent.

These possibilities could contribute to closing the data gap in raw material mining. If this is made possible, these data could be merged with local manufacturing data. This would enable holistic modelling of Module A. The balancing of Module A is increasing in relevance in the future, as embodied carbon and grey energy become more and more the focus of sustainable building design. The finite supply of mineral resources also contributes to the interest in raw material origin as well as extraction. Ecologically sustainable and fair supply chains, which can be presented transparently, enable the promotion of these and avoidance of illegal raw material quarries.

4 Conclusion

The framework for conducting an LCA study of various wall-building materials in Vietnam is presented and discussed. The close exchange with local manufacturers is a strength of this study, allowing access to current and relevant data, data used for the modelling of manufacturing (Module A3) and combined with existing data for Modules A1 (raw material extraction) and A2 (transportation) to create a model for the production stage. In the modelling in the GaBi software [7], a data gap becomes apparent, especially for the extraction of raw materials. The first modelling results underline the necessity to close this data gap with local data due to the significant influence of raw material extraction on the environmental impact. So far, insufficient LCA data exist for raw material extraction in Vietnam. Only if this data gap can be closed, holistic life cycle models of the manufacturing phase, be possible.

The presented study is conducted within the CAMaRSEC project, which aims to support the generation of relevant data on building materials, such as building physical characteristics and environmental impact in the life cycle. It is very apparent that before comprehensive building certification systems can be applied in Vietnam, fundamental data on material production and material performance need to be generated to elevate the local construction practice from its current state.

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