Fr	B	C	NY	S	T	Total
4	3	6	4	3	5	25

Example:
As part of the „Climate Neutral City 2050" plan, the Öko-Institut drew up a study in 2011 regarding the plan to reduce energy consumption and to convert the power supply to virtually only renewable energy sources in the city of Freiburg. The institute contrasted the greenhouse gas emissions (Fig. 1) for the Vauban district with those of a defined reference scenario (hypothetical newly built neighbourhood – it is thereby assumed that all infrastructure such as roads and utilities and waste disposal services as well as all the buildings of the district need to be rebuilt) and used them later as an assessment tool. A direct comparison clearly shows how much the lower greenhouse gas emissions in a district of Freiburg (e.g. Vauban) are. Greenhouse gas emissions are determined by means of a material flow analysis.

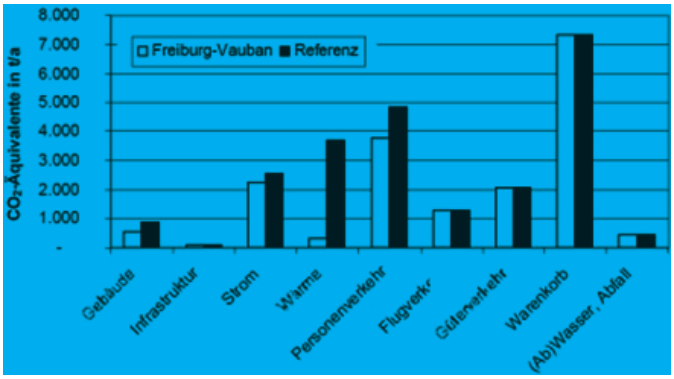

Figure: Material flow analysis as an assessment tool – greenhouse gas emissions for the overall scenario of Freiburg-Vauban compared to the reference scenario ({Öko-Institut 2000 # 23}).
For both scenarios studied here, the greenhouse gases are caused mainly by the so-called „shopping basket" (mainly food production) and traffic. Compared to the reference scenario, however, significantly reduced emissions in the field of heat supply are achieved in the district Vauban.

1. Differentiated description of the key field

The material flow is the pathway of a substance, starting with its production as a commodity through various stages of processing to the final stage, i.e. its intended use and, if necessary, its re-use (recycling) right through to its disposal. Direct material movements are, for example, the transportation of building materials or food purchases; an example of an indirect material flow is the supply of coal for power generation, which is behind the operation of a light switch.

The material flow analysis starts with demand: human needs generate impulses that impact on the resources. Material flows and environmental impacts are triggered in the opposite direction. With the help of material flow analysis, one can determine which material flows and environmental impacts are caused by the demand for products and services. This in turn is the done by having knowledge of the process chains in which all the relevant production costs are quantitatively traced back to their source.
({Öko-Institut 2000 #23})

Thus, the material flow analysis also examines the actual trigger of the material flows and begins, for example, with the needs of the residents of the city. If residents have a need for housing in a certain district, the question of which materials have to be provided for the provision of housing – either through new construction or the refurbishment of old barracks buildings – arises. This means that the residents themselves, their number as well as their behaviour, their way of living and residing in the district will determine the flows. Thus the material flow analysis also considers the demand side and is open to change.

2. Reference to sustainability:

The material flow is the movement of goods. The movement is initially only interesting when it is combined with ecological, economic and social factors. The material flow approach primarily addresses environmental objectives but should be supplemented by economically oriented aspects from a regional point of view. The social dimension is covered by the stakeholder analysis.
The assessment of material flows can, for example, be carried out according to the following criteria:

Ecological:
- Fuel consumption during transportation
- Sustainability of the raw material
- Fuel consumption during extraction
- Environmentally friendly extraction methods
- Exhaustion of finite resources
- Recyclability of the material

Economic:
- Cost of transportation
- Cost of extraction
- Cost of decommissioning
- Costs of processing
- Costs for processing and operation

Social:
- Improvement of working conditions in production and extraction sectors by reducing noise and other emissi-

ons
- Fair wages for all workers involved in the cycle
- Improvement of the living environment

It would be of interest to the city to create an additional related profile of the materials and to use it to optimise the cycles of, for example, energy, materials and transport. This demands the accurate collection of data (technical data: efficiency, performance; environmental data: emissions, land, waste, etc.), from the origin, processing and transportation of the raw materials to the final product. Knowledge of the ecological, economic and social footprint of the used goods and a corresponding evaluation enable the optimisation of the material flows and the deliberate pursuance of a sustainability strategy. Concrete measures to optimise material flows are the decentralisation of the raw materials used and the energy cycles. This reduces transport costs and emissions while also increasing the security of the regional supply.
Key objectives within the material flow analysis in relation to sustainable urban development are:
- The increase in resource productivity.
- The absolute reduction in the consumption of resources.
- The avoidance of and reduction in emissions and waste.
- The avoidance of and reduction in the use of ecologically harmful substances.
- The increase in the use of secondary materials.
- The increase in the recyclability of products and waste materials.

({Lohmann 2011 #24})

3. Relevance to industrial sectors?

Mobility:	Medium
Energy:	High
Production & logistics:	High
Security:	Low
ICT:	Medium
Water infrastructure:	High
Buildings:	High
Governance:	Medium

Brief description of the high level of importance:
Material flows play a major role firstly in production and logistics. Here, the collection, use and recovery of raw materials in products can be measured and optimised. The logistical costs of production (e.g. by the purchasing of local goods) can be reduced in order to simultaneously reduce the consumption of gasoline and other fuels.
Material flows can be directly transferred to energy flows, the water cycle and the life cycle of buildings. In the field of energy, the use of waste heat and other by-products offers great potential. In the water sector, the use of rainwater and recycled water can be extended. Material flows play a significant role within the framework of a life cycle analysis, especially with regard to buildings. Rather than simply being disposed of, for example, valuable raw materials can be reused by being dismantled and recycled.

4. Impact:

• A material flow analysis allows an accurate assessment of the sustainability of raw materials and goods.
• A material flow analysis is ecologically and economically profitable because by disclosing the ways and environmental impacts, an assessment and optimisation can be carried out simultaneously.
• A material flow analysis requires concerted cooperation and a flow of information from one project step to the next, since, in all neighbourhoods, the interfaces, etc. between transport and buildings above all must not to be neglected.

5. Implementation measures:

1.) General definition and prioritisation of the material flows to be examined as well as the formulation of targets for the „analysis“
2.) Promote training courses and knowledge base for material flow analysis in the industry and with raw material suppliers
3.) Demand details from the material flow analysis for buildings, energy and water
4.) Definition of a rating scale
5.) Promotion of projects with good material flow analysis values

6. Actors: Who can shape things? With whom?

Construction companies/materials manufacturers: They can provide information relating to the purchase of raw materials and their previous life cycle
Politicians, citizens, city administration: They can demand a life cycle analysis for all new buildings
Companies: They can increase their cost effectiveness by using material flow rating systems, or enhance their profile by specifying the material flow values for their products.
Research facilities: They can develop, in cooperation with public institutions, stronger rules for the production and use of environmentally harmful substances

7. Prerequisites:

- Data collection and monitoring of material flows
- Regulation regarding the publishing of the data from the raw material flow analysis
- Clear rules for the collection and processing of data for

the analysis (e.g. in an ecological profile)

8. Obstacles/barriers:

Analysis of whole neighbourhoods: The occurrence of material flows, their whereabouts and the challenges associated with them must always be considered. One must also be aware that a holistic approach to material flows in urban areas is only possible where, in principle, the entire life cycle of a neighbourhood and its components is considered. The method of material flow analysis (MFA) serves to analyse material flows; the LCA method is suitable for the further consideration of ecological consequences. Data acquisition often represents a further challenge due to a lack of data or sources. Furthermore, concepts relating to the economic use of material flow analysis are required in order to be able to assess the weaknesses and the potential for the optimisation of a neighbourhood, for example.

9. Indicators:

Products and materials (e.g. water, building materials, food, etc.) of the city involve many material flows. A city's material flows can be assigned to the following superordinate groups: building, transport infrastructure, infrastructure services, supply and disposal services including water, energy and waste. In an ideal world, material flows make complete cycles of interlocking technical and natural cycles.

Specific information that must be collected and represent, above all, qualitative statements are:

- Is there a life cycle analysis for new construction projects?
- Do dismantling concepts for old buildings exist?
- Is rainwater and recycled and reclaimed water used?
- Are energy-related by-products from industry or in buildings re-used?
- Where do the individual commodities come from?

10. Special features/remarks:

Despite the clear advantages and benefits that can be achieved by analysing material flows, life cycle analyses, for example, are not very widespread. Overall, there is often a lack of expertise and experience to integrate material flow analysis into the project at the right time. Clear process models and targeted training could result in decisive progress in the future.