wholeSEM 3rd Annual Conference

Site-level resource efficiency analysis

Ana Gonzalez Hernandez
Jonathan Cullen

EMERSON

UNIVERSITY OF CAMBRIDGE

As awareness about climate change increases and concern grows, manufacturing companies are increasingly being demanded environmental accountability. However, current process control does not consider environmental impacts, and is instead focused on maintaining process equilibrium, product quality, isolated optimisations and safety. At the same time, resource efficiency analyses typically focus on materials or energy flows alone, without considering the interactions between them. This makes it impossible to characterise the efficiency of material-converting processes and to compare across processes producing different materials and across sectors. This project seeks to help companies understand their resource flows, the impact of these on the firm's environmental performance and the opportunities available to improve resource efficiency. This poster outlines the steps to analyse resource efficiency at a plant level.

1 Collecting resource use data at a plant-level

In this study we assume that metered energy data at individual process level from an installed control system is available, and that material flow data is either metered or at least collected in financial reports. Fig 01 depicts the data collection process. This project will use control data to construct maps of resource use at a plant level. In order to do this, we need to investigate the amount of data points required, the level of detail (i.e. readings from every device, or every process or process line) and the time resolution (i.e. readings every second, every minute, hour or day) needed to reveal improvement opportunities.

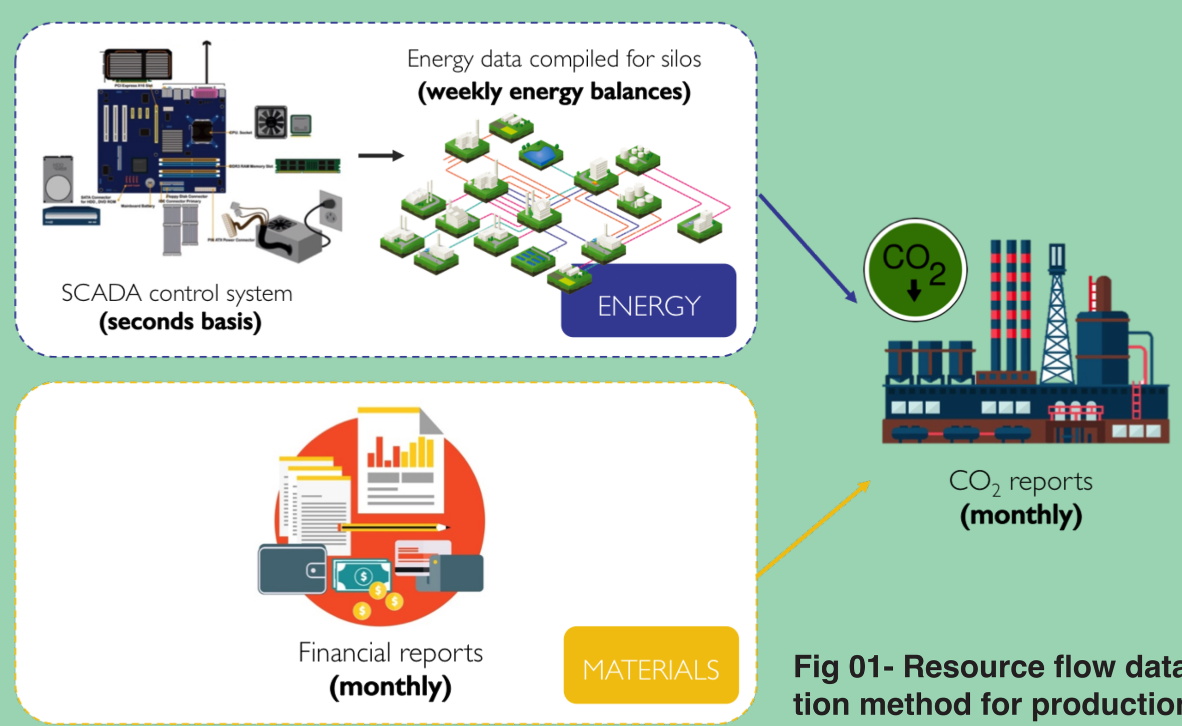

Fig 01- Resource flow data collection method for production plants

2 Analysing resource flow data

Before the data can be used to inform decisions on how to improve resource use, the resource flows need to be balanced and further processed into the appropriate level of aggregation and unit of measurement. Resource efficiency improvements are available at various system levels, from efficiency improvements of individual devices to the integration of steam, compressed air or heat at a system level. This means that it is crucial to understand the interactions of improvement measures both vertically and horizontally along the supply chain.

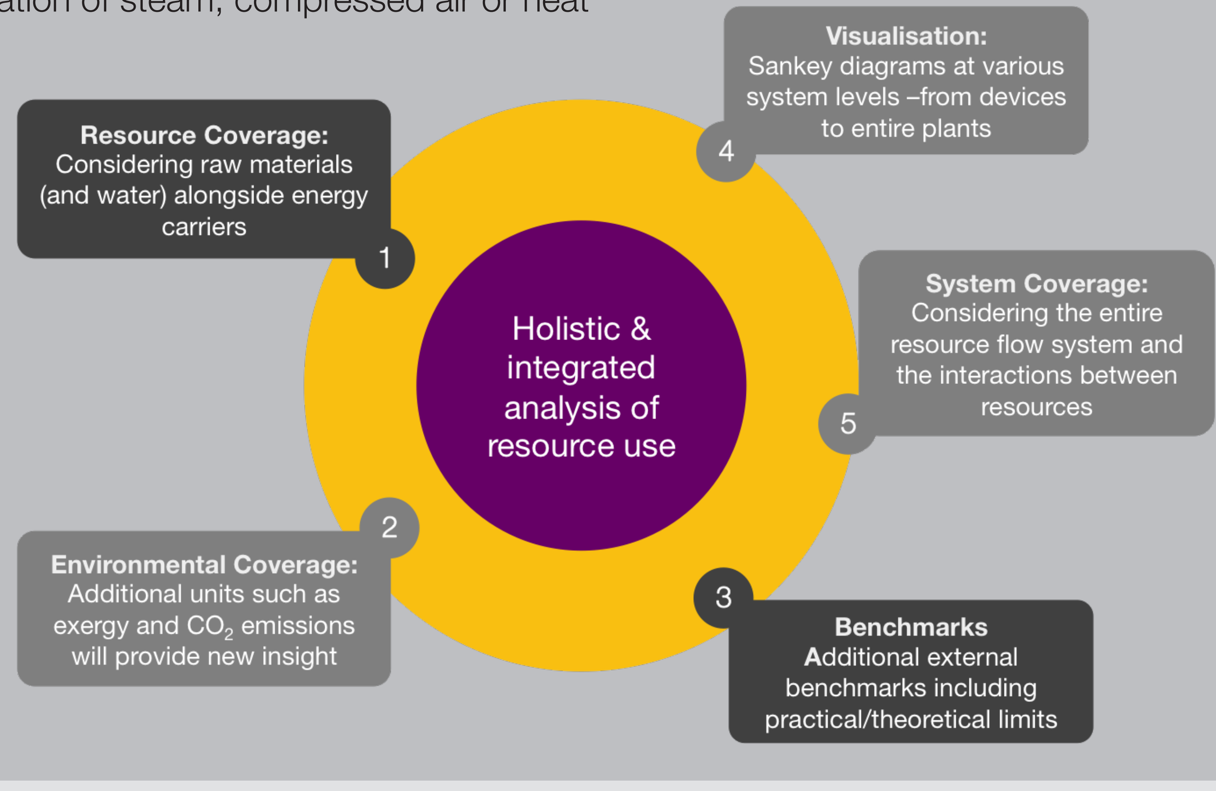

Fig 02- What does a holistic resource flow picture at a plant level entail?

3 Benchmarking resource flow data at a plant-level: resource efficiency metrics

Tracking progress requires the ability to quantify the performance of energy converting (e.g. electric motors), and material-converting devices (e.g. blast furnaces). Currently, the performance of the former is measured using dimensionless values of energy efficiency. However, for the latter, energy intensity values (in GJ/t) are commonly quoted. To compare performance across all proceses, we need to define the conversion of material-converting processes in a similarly dimensionless way. The tool used to do this is **exergy:** it facilitates the integration of energy and materials into a single common metric. We denote this exergetic efficiency as **resource efficiency**:

$$\text{RE (\%)} = \frac{\text{Embedded exergy}}{\text{Embodied exergy}}$$

Equation 01- Definition of resource efficiency, portrayed diagrammatically in Fig 05.

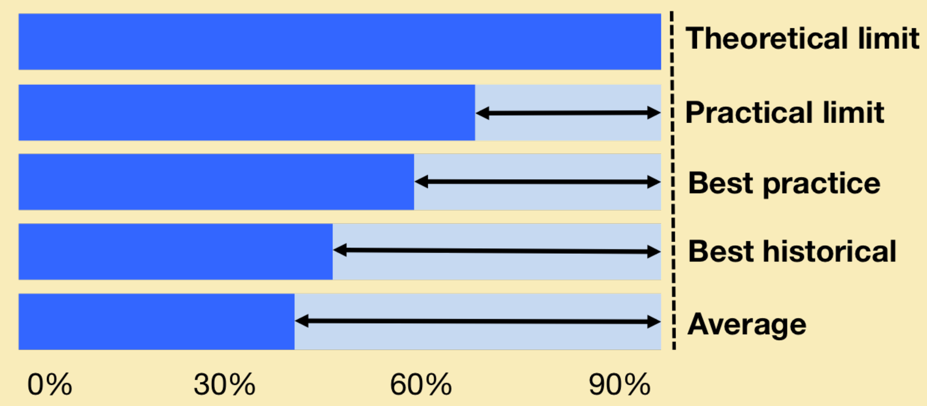

Fig 03- Current benchmarks are often limited to best historical or best practice values, ignoring practical and theoretical limits.

4 System-effects: levels of aggregation

Making an improvement in the efficiency of a specific process has an effect on its own performance but also affects that of the overall system. It is therefore important to be able to understand the interactions between different improvement actions in order to appropriately characterise the headroom for improvement available. Understanding these interactions involves developing a system model.

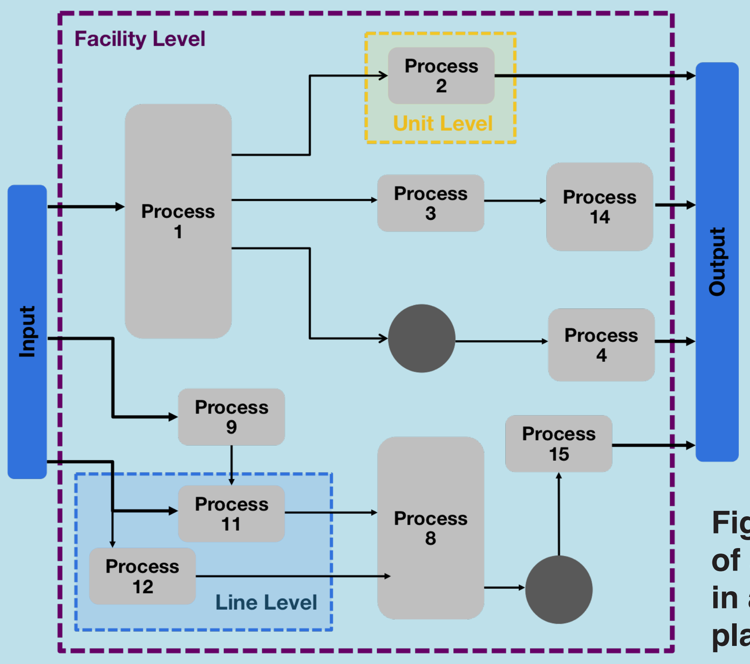

Fig 04- Flowchart of a system levels in a production plant.

5 Visualising resource flow data at a plant-level: Sankey diagrams

In this project we use Sankey diagrams (see Fig 05), where the arrow width represents the magnitude of the flow. Sankey diagrams immediately reveal what flows are most relevant in reducing environmental impact, and portray the flow structure in a format that is appropriate for the task of accounting and managing resources. In this project, our visuals will integrate the flows of multiple resources and will aim to convey additional factors, such as for example, variability.

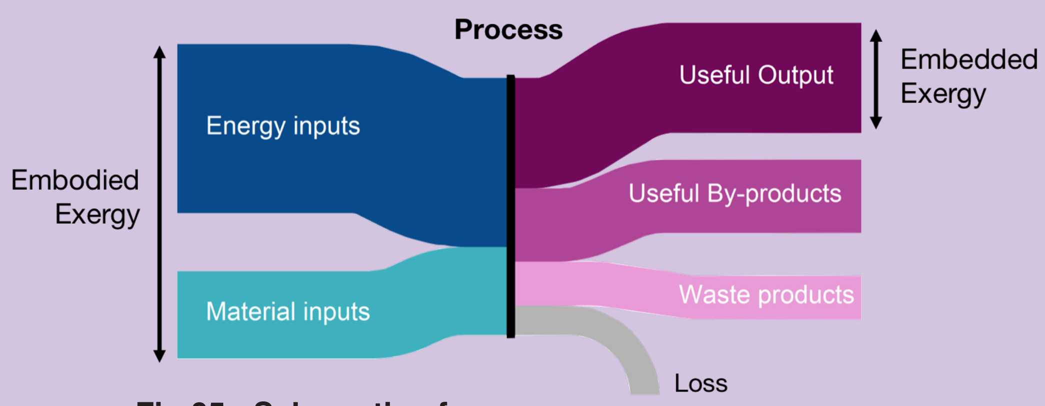

Fig 05- Schematic of a Sankey diagram (using exergy)

6 Prioritising resource efficiency interventions

The efficiency of a process provides a relative measure of the headroom for improvement, but it does not reflect an absolute scale of resource saving and is therefore insufficient to determine which processes should be tackled first. Different tools that can guide plant managers through the decision-making process of prioritising improvement interventions will be explored. The development of prioritisation indices or marginal abatement cost curves (MACCs) are examples of useful tools that can trigger well-founded discussions about the implementation strategies.

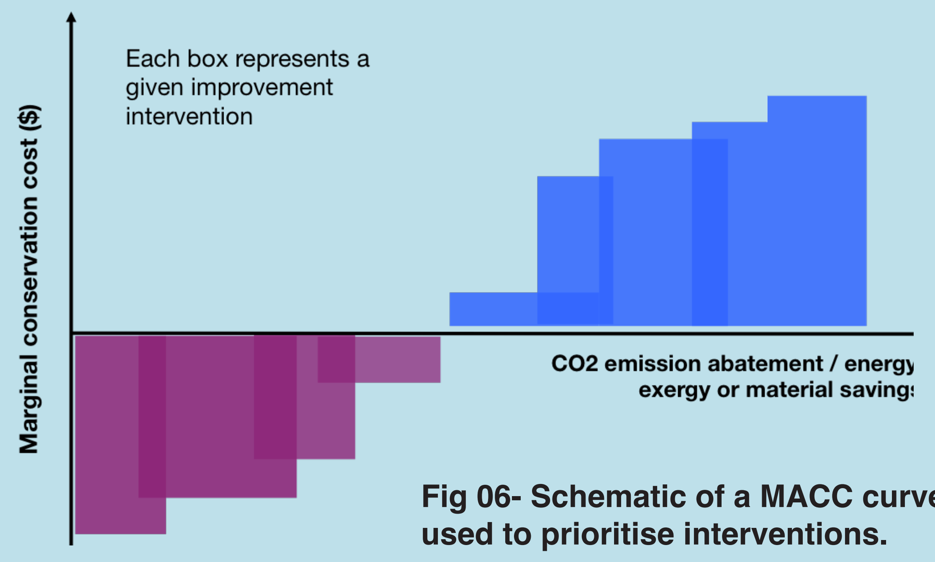

Fig 06- Schematic of a MACC curve used to prioritise interventions.

Case studies: steel and ammonia production

Fig 07 shows the preliminary results obtained for the case study of the steelmaking. Resource flow data was obtained by worldsteel from company surveys. This raw data was processed into flows of exergy and depicted as a Sankey diagram, which tracks the resource flows from coking to hot rolling. Using Equation 01, we characterised the resource efficiencies of processes and entire production routes.

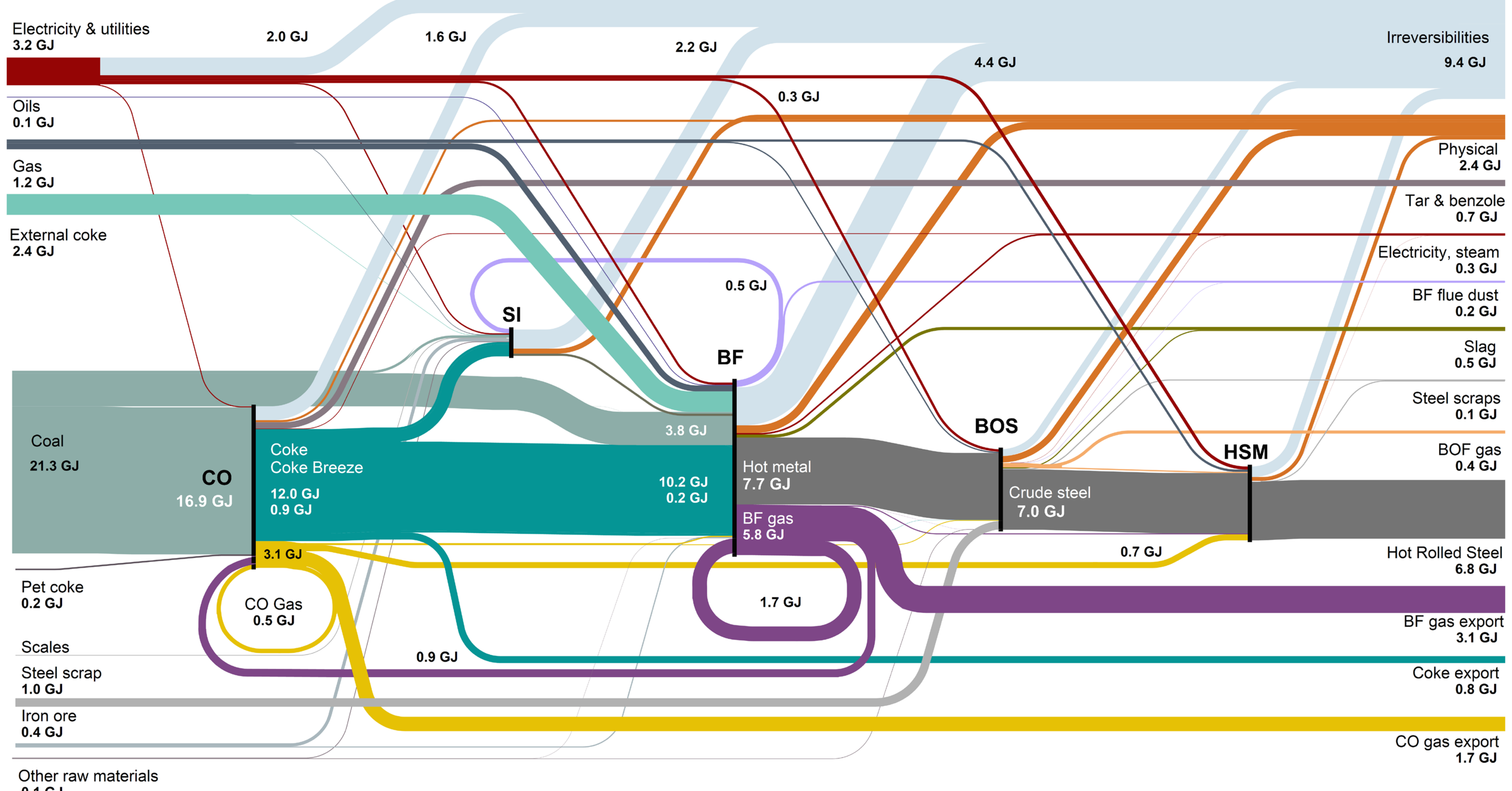

Fig 07 - Average exergy flows in the Blast Furnace (BF)-Basic Oxygen Furnace (BOF) route (in exergy per tonne of rolled steel) for 2010. CO: coke oven; SI: sinter plant; HSM: hot strip mill.

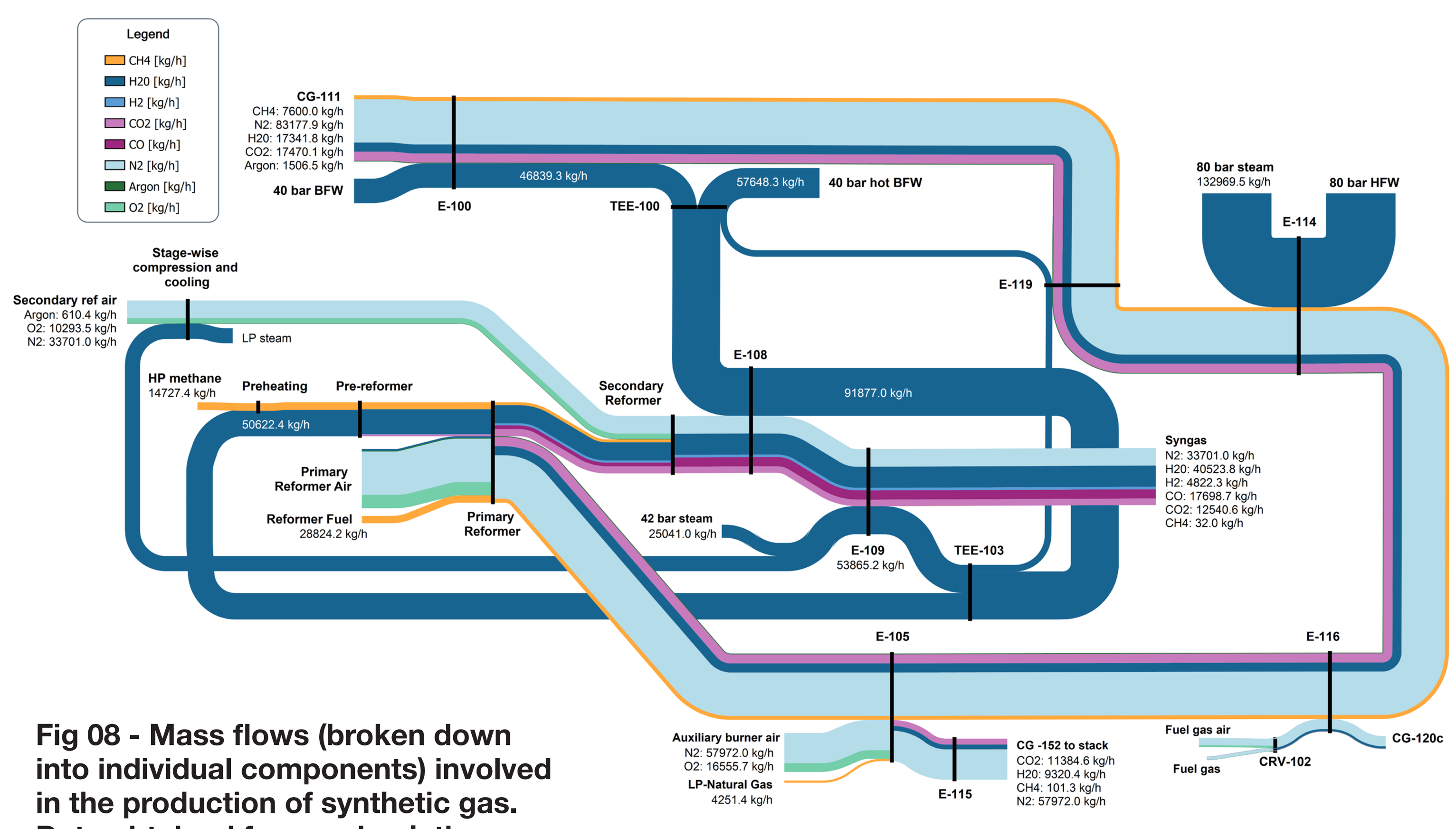

Fig 08 - Mass flows (broken down into individual components) involved in the production of synthetic gas. Data obtained from s simulation.

Our second case study focuses on the production of ammonia. Fig 08 shows the component mass flow rates involved in the production of synthetic gas; a prerequisite for ammonia production. This map was constructed using simulation data, and it represents a static plant-level picture of material flows. The following steps involve the mapping of energy, exergy and carbon dioxide emission flows. Quantifying the exergy flows will then allow us to characterise the resource efficiency of the different production processes.