SUSTAINABILITY AND ENERGY EFFICIENCY IN FLUID POWER - RECENT ADVANCEMENTS IN RESEARCH AND INDUSTRY

DOI
https://doi.org/10.18690/um.fs.7.2025.1

ISBN
978-961-299-049-7

KATHARINA SCHMITZ

RWTH Aachen University, Institute for Fluid Power Drives and Systems, Aachen, Germany
Katharina.Schmitz@ifas.rwth-aachen.de

Sustainability in all its three dimensions is a major driver for recent advancements in many sectors. In fluid power applications, sustainability and decarbonization are often linked to energy efficiency and reducing energy losses. Therefore, different new approaches and examples exist in research and in industry. Digital tools enable new advancements and additional methodology for developments. The paper gives an example of recent advancements and discusses the need for further developments in research and industrial development.

Keywords:
sustainability,
decarbonization,
energy efficiency,
research,
industrial development

University of Maribor Press

1 Introduction

Fluid power systems are widely used in industrial and mobile applications. Since decades, it is a well-developed and mature technology with a high-power density, high forces and torques, good controllability, as well as a good reliability and robustness [1]. Nevertheless, energy consumption is rather high, compared to other technologies. However, in last years and decades the focus of industrial development mainly lied on cost issues rather than energy efficiency, where still a lot of potential can be found. Research institutions worldwide have shown several approaches for more energy efficiency and have a profound record of research on making systems and components better controllable and more efficient.

The importance of advancement and further development now comes to a new stage when discussion sustainability with its three dimensions: Society, Economy and Environment. Since its launch in 2019, the Green-Deal of European Commission sets a new target to transform Europe's economy, energy, transport, and industries for a more sustainable future [2]. It sets the clear goal of reaching climate neutrality in Europe in 2050 and a pathway towards it. This action plan relates to greenhouse gas (GHG) emissions and other climate merits but also means introducing new legislation on the circular economy, building renovation, biodiversity, farming and reporting obligation of companies. Therefore, many companies have started in including sustainability goals to their agenda and future development plans, including environmental footprint, economical numbers and considering the human factor.

To achieve Europe's climate goals, all industrial sectors need to contribute and to transform. Therefore, also fluid power researcher and companies need to answer the question, how a transformation into sustainable motion technology can be achieved.

2 Sustainable fluid power systems throughout the life cycle

The transformation towards climate neutral and decarbonized fluid power components and systems will be mainly driven by three key-enabler:

1. Electrification

   To achieve emission-free mobile machines, electrification (battery electric or hydrogen fuel cell electric) will be one of the most probable solutions to drive heavy duty machines in the future. This means, on the one hand, new boundary conditions for the fluid power system and on the other hand, a larger attention towards energy consumption of the system itself.

2. Digitalization (connectivity, "smart systems" and data algorithmic (AI))

   New digital solutions and the smart use of data are evolving rapidly in all fields of technology. For fluid power systems, data algorithmic and increasing connectivity will enable new system architectures, better controllability, energy savings, increasing robustness and higher productivity.

3. New paradigm: Circular Economy & Holistic Approach

   Starting with the Green-Deal, the topic circular economy is increasingly present nowadays. It requires awareness of the whole product life cycle from development, manufacturing, commissioning, usage, recycling / reconfiguration / reuse. In combination with a more holistic approach, this new paradigm will change the perspective of products and product development.

Right now, fluid power research and industry have started the transformation towards sustainable motion technology and fulfilling EUs goals [3], but there is still a long way to go until 2050. Selected recent advancements are discussed below, considering the various phases of the product life cycle.

2.1 Design and manufacturing

In the design process of fluid power components and systems, more digital tools help development and design engineers. Starting with standard tools like simulations and computer-aided calculations, artificial intelligence (AI-) or machine learning (ML-) based tools are now evolving and soon to be used in the development and designing process of technical systems as well as fluid power components and systems [4].

New manufacturing technologies are emerging and the concept of Industry 4.0 promises further improvements in manufacturing. Additive manufacturing might become increasingly important for fluid power components as it can save a lot of material during manufacturing, components can be lightweight and energy consumption during usage phase can be reduced due to smoother fluid flow through e.g. valve blocks [5], [6].

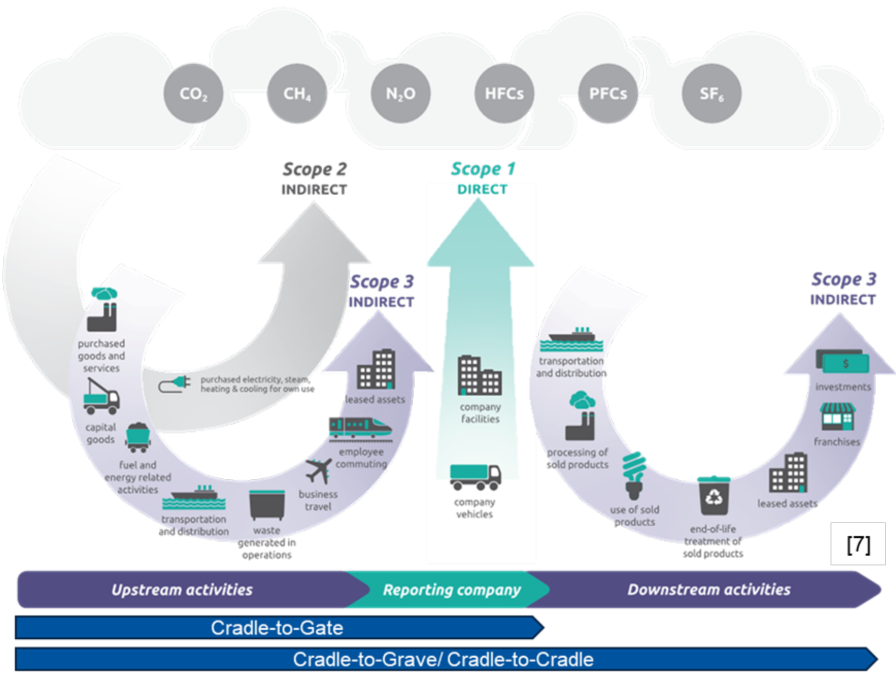

Figure 1: Greenhouse Gas Protocol: Scope 1, Scope 2 and Scope 3
Source: ifas & [7]

Next to new manufacturing technologies, current scope of interest for larger companies that contribute to ESG reporting is the reporting of their GHG emissions, e.g. according to the Greenhouse Gas Protocol [7], (Figure 1). Several companies report their emissions from Scope 1 (direct emissions of the reporting company) and Scope 2 (indirect emissions, mainly from purchased electricity, steam, heating and cooling) and set goals for reaching emission neutrality in Scope 1 and 2 within the next years. Next to the emissions on a company level, the product carbon footprint of single components and systems is of interest considering not only the upstream activities, but also the downstream activities including end of live consideration as well as the usage phase. The balancing of upstream activities for fluid power components is challenging [8], but especially for fluid power components that are widely used in many different applications and systems, the accounting of emissions during usage phase is an even more challenging task and not easy to calculate. Therefore, the basis of calculations for a product carbon footprint during usage phase is currently topic of discussion within a joint research project of a group of companies and universities [9].

One disadvantage of GHG emission monitoring is that ecological aspects are not covered in this reporting. Therefore, it is important to additionally consider environmental aspects. Legislation exists (e.g. REACH and possible future PFAS regulation), but companies and research need to further develop alternatives to environmental risky materials. However, this is a complex field of advancements. The reduction of environmental critical materials needs to be achieved by maintaining or improving current state of energy efficiency, robustness and should additionally consider recyclability or reparability.

Current research on different research facilities focuses, e.g., on new design of piston slippers of axial piston machines [10], [11] to enable lead-free slippers.

2.2 Commissioning

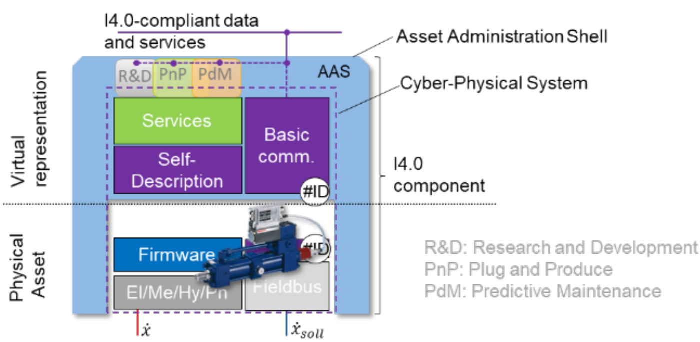

Figure 2: Asset Administration Shell (AAS).

Source: ifas & [12]

The commissioning of fluid power systems is a complex task due to a high number of different components, sometimes even from different suppliers by often an OEM and not the end customer. To facilitate the process, the interoperability of components and the consistent deposition of data plays an important role. The asset administration shell offers a tool to address this need during commissioning phase [12], and throughout the whole product life cycle [9], [13].

2.3 Usage

Main driver for emissions related to fluid power components is the usage phase. During power transmission, energy losses are unavoidable. But it is increasingly important to 1. decrease energy consumption (as it is directly linked to GHG emissions. In addition, total cost of ownership in electrified machines is highly dependent on energy consumption.) and to 2. increase productivity of machines using fluid power systems to decrease energy consumption per work cycle.

Several new approaches exist in research and industry to decrease energy consumption of fluid power components and systems during the usage phase. Especially, the collaborative research and development between universities and companies shows promising results, e.g. [14], [15], [16].

Figure 3: Examples of energy efficiency increase and increased productivity from bauma innovation awards 2025 in Munich, Germany

Source: ifas & [17]

An important field of current advancements lies in the increase of productivity of fluid power driven machines. Especially the construction sector develops further quickly in adapting automation technologies to their field of technology. Here, digital technologies and data algorithms will contribute to further advances in this area.

Three industrial examples in decreasing energy consumption and increasing productivity are shown in Figure 3 from 2025 Bauma Innovation Award [17].

2.4 End of life and repair

When discussion about the complete product life cycle, the end of life, repair and recycling need to be considered. Here, one advantage of fluid power components and systems comes into effect. The systems are modularly composed of different components and can be rearranged easily to new motion duties. In addition, most components are long lasting and robust and the steel base easy to repair. It is important to maintain this advantage even with improvements regarding new materials or new manufacturing technologies and with increasing use of digital technologies (especially integrated sensors). In addition, this advantage should be more clearly communicated in marketing and advertisement for fluid power technology.

3 Conclusion and Outlook

The transformation of our industry and society is unstoppable. Fluid power technology needs to further develop and is further developing with the help of new digital tools, the increased awareness of energy efficiency and the new paradigm of circular economy. Only by looking at the overall picture and considering all aspects, can an optimal solution for each individual case and task be found. A holistic approach is indispensable and requires involvement of all stakeholders, from component manufacturers to end users and common effort from industry and research institutions.

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