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Potential for Fluid power to Contribute to EU climate Goal 2030

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Abstract Fluid power drives and systems are an important technology for industrial and mobile applications. Therefore, attention must be drawn to the consequences of worldwide and particular EU climate goals. The chancing climate affects all humans and to reduce serious dangers for our and the next generations greenhouse gas emissions must be dramatically reduced in the next years. In this paper, the EU climate goals are introduced and measures are outlined on how fluid power can contribute to the achievement of the targets. There is still a long way in all industries to go to achieve the goal of zero greenhouse gas emissions, but we need now to think and talk about consequences and challenges for fluid power community.

Keywords: • sustainability • mobile machinery • digitisation • carbon footprint • energy efficiency •

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1 Introduction

Climate change has become one of the greatest risk factors for humanity in recent decades. Extreme weather and natural disasters have forced societal attitudes to change. Additionally, Regulations of the UN and the federal government provide motivation for all sectors to further develop their current practices not only in terms of economic but also ecological aspects to combat climate change.

Fluid power is an important drive technology when a good controllability of high forces or high torques is required. In general, fluid power can be a very sustainable future technology. But, there are some aspects that need to be solved to contribute to worldwide climate goals and to satisfy sustainability demands.

2 EU Climate Goal 2030

With the Climate Goal 2030 member countries of the EU defined a more detailed, ambitious but also necessary plan to achieve the goals of the Paris Agreement of 2015. The Agreement itself is derived from the Kyoto Protocol, which was first drafted by the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and adopted in 2005 with the purpose to stabilize the concentration of greenhouse gases in the atmosphere in order to prevent dangerous human-induced disruption of the climate system [1].

2.1 Kyoto protocol and Paris Agreement

Three economic mechanisms were designed in the Kyoto Protocol to help industrialized countries meet their reduction targets: Emissions Trading, Joint Implementation and the Clean Development Mechanism, which are still relevant today. The Clean Development Mechanism allowed well developed countries to help developing countries in implementing climate saving mechanism with the benefit that the emission reductions are credited to themselves. The Emission Trading enabled all countries to trade emission certificates. By achieving and overshooting the set reduction goal of a country, additional certificates could be sold. This was often criticized, as wealthy countries bought certificates to reach their target instead of advancing their reduction efforts, as well as that some of countries with the most emissions and therefore the greatest impact withdrew from the Protocol after the first commitment period.

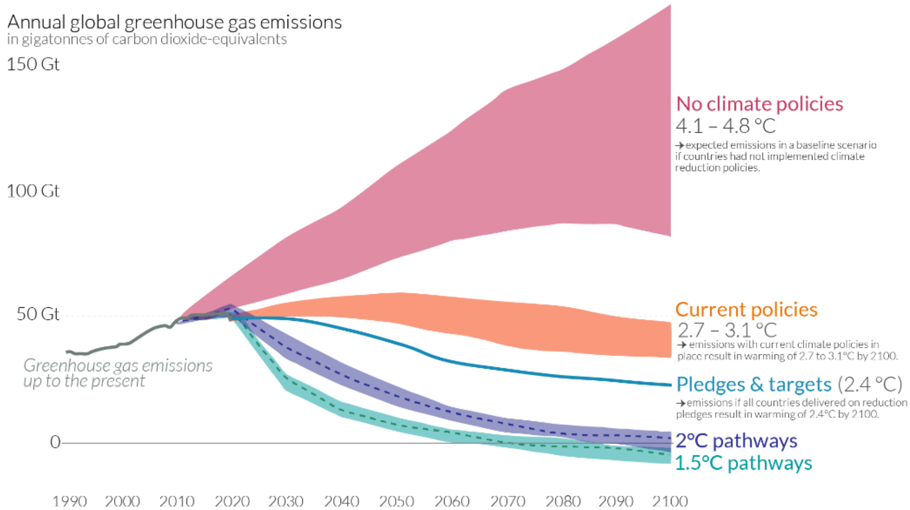

Figure 1: Annual global greenhouse gas emissions [2]**.**

Following the Kyoto Protocol, the Paris Agreement of 2015 was signed by members of the UN Climate Convention with the target to limit the global temperature increase to 1.5 °C over the next 35 years by reduction of climate-damaging emissions such as greenhouse gases like carbon dioxide and nitrogen oxide [3]. In the second half of the century further advances should achieve climate neutrality by reaching an equilibrium between emitted and bound greenhouse gases. Instead of just one common goal for all members like in the Kyoto Protocol, the Paris Agreement also demand for individual intended national determined contribution (NDC) to be included into the international agreement. To ensure transparency, each country reports on its progression every 5 years including newly set ambitious goals to an established committee starting in 2020. As an example Figure 2 displays the graph of the historic and projected emissions under the 2030 emission target for the United States of America [4].

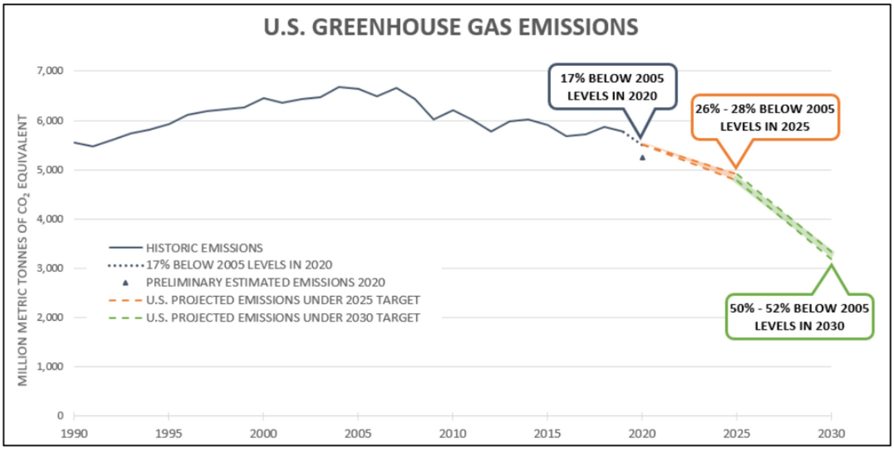

Figure 2: Historic and projected emissions under the 2030 climate target of the United States of America [4]**.**

Additionally the agreement encourages all members to conserve and enhance sinks and reservoirs of greenhouse gases such as forests [3]. Other main objectives worth mentioning are the enhancement of resilience to climate impacts, many of which are unavoidable due to already emitted greenhouse gases and to align financial flows in the wold with the aforementioned objectives [3].

2.2 European Green Deal

Following the Paris Agreement, the European Green Deal aims to make Europe the first climate neutral continent in the world. It is derived from the Paris Agreement, but sets more ambitious goals for its members in a fair, cost effective and competitive way. While still keeping the distant goal of the Paris Agreement to reach global emission neutrality by 2050, all 27 EU members committed to the green new deal, which sets an intermediate target of reducing the greenhouse gas emissions by 55% by 2030 compared to the levels of 1990. Achieving this goal is only possible by simultaneously tackling and investing in sectors like energy, transport, agriculture, finance and regional development, industry as well as research and innovation. All with the greater good of improving the climate, environment and oceans. An overview of the green new deal is given in Figure 3.

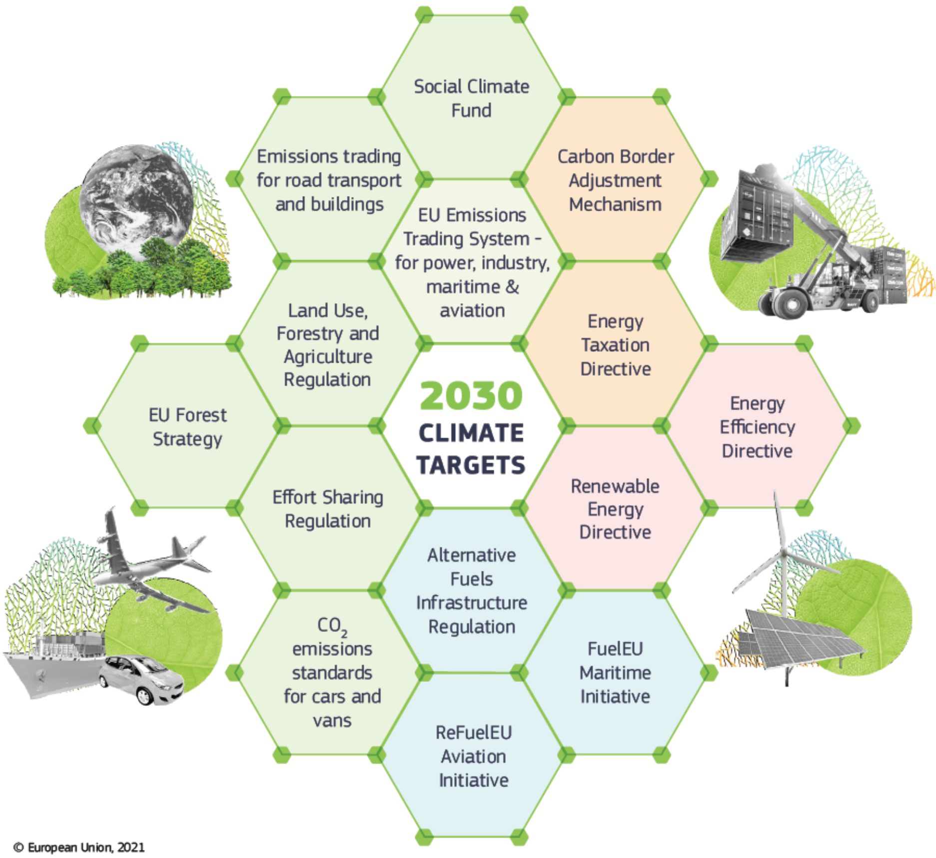

Figure 3: 2030 Climate targets of the European Green Deal [5].

2.3 Emission sources

When trying to reduce the greenhouse gas emissions, it is essential to identify the sectors with the highest impact. Looking at Figure 4 it is clear to see, that the energy sector accounts for the largest share next to agriculture, forestry and land use. Interesting for the scope of this paper is the energy used for operation as well as the energy for manufacturing products and components including the extraction and processing of raw materials such as steel and other metals.

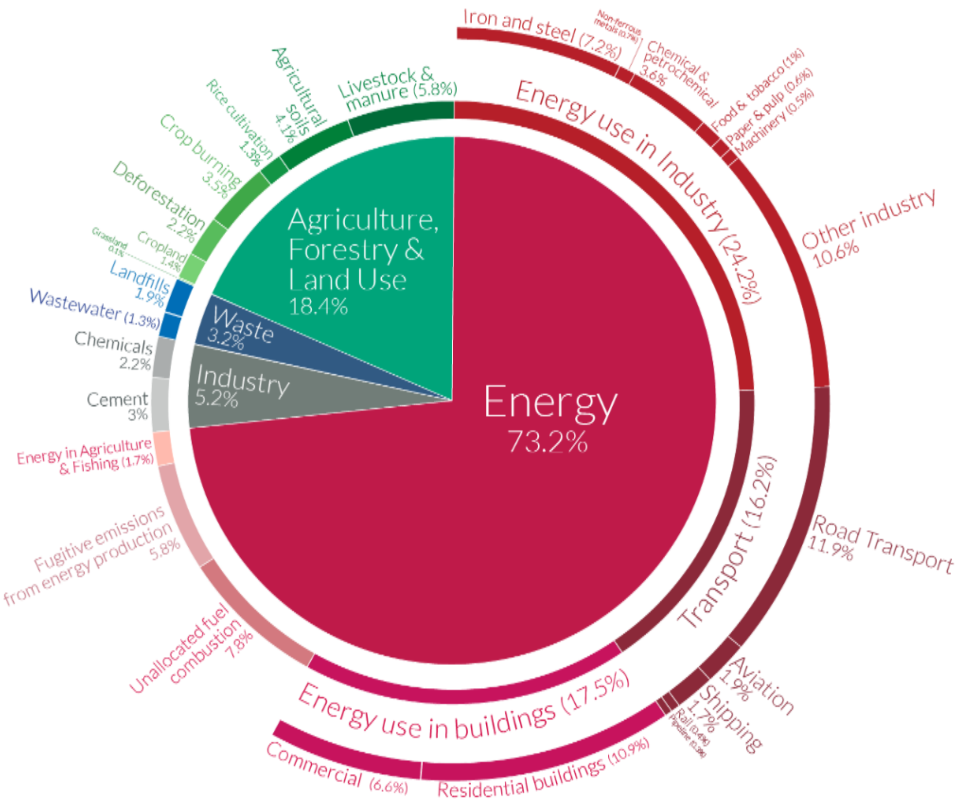

Figure 4: Global greenhouse gas emissions by sector [6].

3 Contribution Potential by Fluid Power

In fluid power industry, three key aspects are of special relevance: 1. Energy consumption of hydraulic and pneumatic systems, 2. Energy and resources needed for manufacturing these components and 3. Overall energy consumption of machines using fluid power drives.

In fact, the emissions linked to the production of hydraulic and pneumatic components only makes up a minor impact as the operation of these components add up to significant greater amounts of greenhouse gas emissions. Previous investigation of a pneumatic drives showed that 99 % of all the entire life cycle emission are due to the energy consumption [7]. Nevertheless, in the future the manufacturing of the products and materials will increase in importance in fighting climate change as the operation emission will decrease due to the use of electricity from more and more renewable energy sources.

3.1 Sustainable Components & Fluids

When talking about sustainable components, the production of steel and aluminium is a mayor challenge. But, fluid power components have not yet reached the state to only consist of one material that is uncritical to produce. In hydraulics more effort must be set to find better materials for tribological contacts in hydrostatic pumps and motors in order to avoid problematic materials like lead. In previous investigations at ifas, different special alloys were tested to their operation capability in hydrostatic pumps as an alternative to lead. The tribological tests show good behaviour, long endurances and a reduced coefficient of friction [8].

In addition to manufacturing, energy losses in components during operation should be pressed to a minimum. Therefore, new technologies in manufacturing can be useful. One approach is the use of additive manufacturing for the production of fluid power components. This allows the design of smooth flow channels with the benefit of a rigid reduction of pressure losses due to fluid friction. In addition, this allows a more compact design leading to an increase in power density and a reduction of installation space demands. In consequence, this space can then be used in a machine or systems for other components to increase energy saving measures. In Figure 5 an example for an additive manufactured gear pump housing designed at ifas can be seen.

Figure 5: Additive Manufactured Gear Pump [9].

In hydraulics, not only the components such as pumps, motors and valves must be considered but also the pressure media. Standard mineral oil has a CO2 equivalent of about 3.56 kg for 1 kg oil [10]. In comparison with the overall energy consumption of a fluid power system this can often be neglected, but for the overall goal to reach complete sustainability this aspect needs to be considered in the future.

3.2 Energy efficiency in fluid power systems

The sustainability of fluid power systems and our contribution to worldwide climate goals mainly is a question of energy consumption. In the last decades fluid power community has worked on different measures to decrease energy consumption and to increase energy efficiency. In research, many measures were developed and presented but higher investment costs restricted the extensive use in industry. Nevertheless, the question of energy efficiency will rise in the next years. Special attention should be paid to the overall performance and energy consumption of complete machines and systems. Especially when interacting with other drive technologies like electric motors or diesel engines the overall efficiency is of importance and not only the energy consumption of the fluid power system.

One impressive example for the benefit of a holistic approach is the STEAM project at ifas. There, the hydraulic system of a mobile excavator was optimised in a holistic consideration together with the diesel engine. By using a multipressure hydraulic system and storing some hydraulic energy in accumulators, it was possible to reduce the diesel engine speed from 1800 rpm to 1200 rpm and most power was withdrawal at the optimum operation point of the engine.

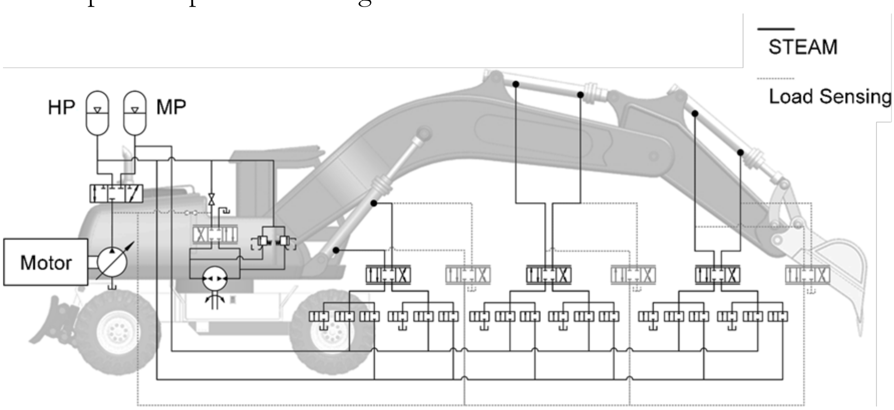

Figure 6: STEAM – Multipressure hydraulic system [11].

In addition, the hydraulic pump was mainly set to a large swivel angle, leading to a higher efficiency of the hydraulic pump. In consequence the measures led to a fuel consumption of -27 % in a standard dig-and-dump cycle [11]. Many more examples like this exist and more effort must be made to decrease energy consumption of fluid power systems and the machines they are used in.

3.3 Smart Fluid Power

The reduction of energy demands in fluid power systems as well as a further increase in operating uptime can be achieved using digital components and approaches. By the use of more sensors inside systems and components, more information of the current state of the system are available. These data can be used for condition monitoring and predictive maintenance approaches leading to reduced downtimes of machines and systems and also allowing longer operation durations with maximal energy efficiency. More research and development is needed here to find efficient and robust ways to extract the required information out of the collected data. Here, machine learning algorithms and artificial intelligence are needed to achieve afore mentioned goals [12], [13].

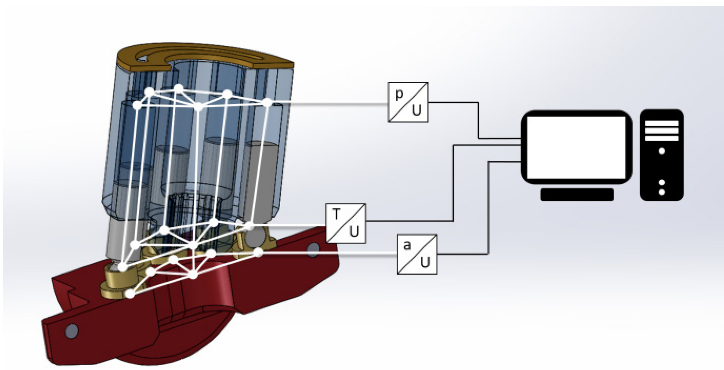

Figure 7: Integrated sensors in a hydraulic pump.

Next to data analysis from components and systems in operation, the further development of virtual representations of both is essential. At ifas, a simulation model was developed that allows for the purely physical modelling of the friction force and the wear of translator seals [14]. Having such simulation tools, the next step could be the implementation of a virtual twin for a component like a rod seal, and the current wear status could be simulated simultaneously to its operation.

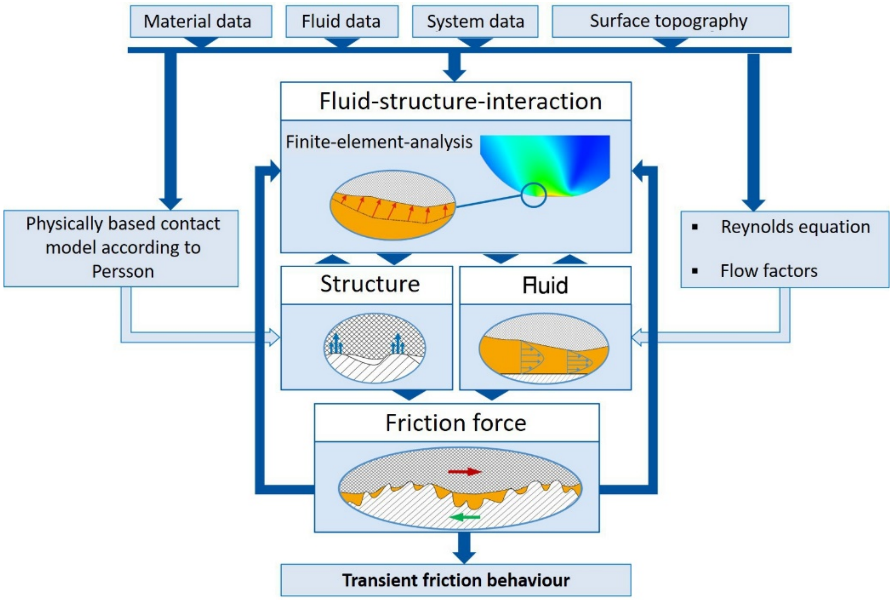

Figure 8: IFAS sealing simulation approach [14].

3.4 Connected Machines

Hydraulic systems are widely used in construction machineries. Therefore it is ineviTable to look at this sector separately. Construction machinery is responsible for a relevant share of global CO2, NOx and particulate matter emissions. In Germany, construction machinery accounts for ~12 % (123.6 kt p. a.) of all NOx emissions and ~7 % (13.5 kt p. a.) of all particulate matter emissions. Nevertheless, extensive construction activities are necessary for the expansion of renewable energies and for the energy-efficient refurbishment of buildings [15], [16].

At the same time, the construction industry is inefficient in terms of labour productivity compared to other industries, which offers great potential for machine adaptation, including the use of new drive technology or more efficient automated machine operation. In the last decades, the productivity in all industrial sectors increased (world GDP +13 % in last 20 years) due to more automation. In contrast, in the construction sector productivity stagnated [17].

In order to reduce emissions, especially in urban areas, smaller battery-powered construction machines are increasingly being used. However, these are still significantly more expensive than diesel-powered machines and have therefore not yet gained widespread acceptance [18].

Still, to gain more productivity and lower the emissions, energy, and resource consumption the automation of construction machines is a necessity. Since the automation of construction machinery is a major challenge, the first step is to locally remove the operator from the machine itself. The operator controls the machine remotely, first from the construction site itself, then remotely from any distance. By controlling the machine from outside the jobsite environment, employees no longer need to be present on site and are no longer exposed to physically stressful environments, no longer have to travel, which results in direct CO2 savings and can thus be deployed regardless of location [19], [20], [21]. If subtasks are now automated step by step, productivity can be significantly increased until the operator becomes the supervisor of several highly automated, highly efficient construction machines.

In recent years manufacturers of construction machinery developed assisting systems like semi-autonomous digging functions, weighting systems or geo-fencing systems to raise productivity and increase safety for operator, machine and environment. Especially the safety increases are essential as the construction industry is one of the sectors with the highest number of occupational accidents [22].

Besides the improvement of digging functions, e.g. by machine learning motion controllers, linking the interoperation between several machines and gathering and distributing the environmental information is in the focus of current researches. This includes the recording and processing of environmental information, e. g. by LIDAR or camera, the derivation of actions, e.g. by AI or decision trees, as well as advanced communication between construction site members [20], [23], [24].

Beside electrification, automation is a key solution, to make machines more efficient. Automation can help reduce the quantity of resources needed and decrease the energy consumption. These areas offer even more potential for improvement in the future when the machines are interoperable connected. Remote control of machines that cannot be fully automated today allow the reduction of workload on operators, resulting in a less stressful work environment and thus higher morale. Nevertheless, more research is needed to cope with these highly complex tasks and to reduce the high greenhouse gas emissions and inefficiencies in the energy intensive construction industry.

4 Conclusion

The contribution to worldwide climate goals and EU climate goal in particular is of high relevance for fluid power development and research. The global greenhouse gas emissions must be drastically reduced in the next years.

In this paper different approaches were detected and shown as a starting point for longer discussions and deepening research and development projects how fluid power community can contribute to this mayor human challenge.

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