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RAIL DECARBONIZATION: A GLOBAL COLLABORATIVE RESEARCH ENDEAVOR

SUMMARY

This report summarizes a series of three workshops on rail decarbonization hosted by the Federal Railroad Administration (FRA). These internationally attended workshops laid the foundation for future decarbonization research topics, funded through FRA's Research, Development, and Technology (RD&T) Program's Broad Agency Announcement (BAA; FRA, BAA Web Page, 2023). The BAA's Energy and Emissions topic statement within the Rail Energy, Emissions and Engine (Rail E3) Technology Research Program is a direct result of the first two workshops. This program prioritizes research into the safety and efficacy of emissions reduction and energy efficiency improving technologies.

FRA-sponsored decarbonization research projects supported the development of standards for alternative fuel locomotive fuel tenders, development of a dual fuel hydrogen internal combustion engine, testing of blends of biodiesel and diesel fuel in a Tier 4 single cylinder test engine, development of the Locomotive Waste Heat Recovery System, and reduction of Greenhouse Gas emissions, Regulated Emissions and Energy Use in Technologies (GREET) model. Achieving the Administration's goal of attaining Net-zero emissions by 2050 requires rail industry-wide collaboration in R&D and implementation of technologies. Therefore, FRA intends to continue its collaborative research efforts to these ends.

BACKGROUND

FRA recognizes the urgent need to decarbonize rail, and the global scale of this problem and its solutions. FRA plays a key role in supporting innovation and experimentation. To these ends, FRA met with the Transport Canada (TC) Center for Innovation in 2021 to brainstorm how to exchange data and streamline research efforts for their mutual clean energy research projects. This meeting highlighted the opportunities for decarbonization and the need for global collaboration. It was concluded that one or more workshops discussing common problems of technology and research, with international participation could foster united research efforts, reduce duplications and define best practices for safe deployment of these new technologies. To capitalize on these opportunities, FRA hosted a series of three decarbonization workshops.

The first workshop assessed the state of affairs of rail transportation in Europe, Mexico, and the US, and outlined the necessary actions for decarbonization within US policy goals. FRA hosted a follow-up workshop with the US Department of Energy and TC in 2022, which reviewed research progress and safety concerns around decarbonization technologies.

RAIL: GETTING ON TRACK FOR DECARBONIZATION WORKSHOP

The first two workshops, held virtually, set the stage for a third, in person, workshop in Denver, CO in May 2023, which brought together over 150 experts in rail rolling stock, clean energy, emissions reduction, rail operations, and regulators. Technical discussions between US and international experts covered advanced

energy storage and rail propulsion systems, hydrogen fuel, and bioenergy technologies. Participants also toured the National Renewable Energy Laboratory and Transportation Technology Center (TTC; Figure 1).

These workshops highlighted common problems in global rail decarbonization, including a rapid timeline, infrastructure development for electric battery recharging, green energy generation and distribution, limitations of new technology to provide comparable performance to diesel fuel, understanding the reliability of new technology options, and safety.

Figure 1. Decarbonization workshop tour of TTC in Pueblo, CO, showing dump truck impacts on a tank car natural gas fuel tender

Both domestic and international workshop participants identified two primary technologies needed to achieve net-zero by 2050: battery energy storage systems (BESS) and hydrogen fuel used in fuel cells or in internal combustion engines. Though the performance characteristics of these two technologies have been studied, no data are available on BESS and hydrogen fuel safety performance under normal and exceptional rail operations (i.e., accidents and collisions). Understanding the risks associated with using these new technologies to power rail transportation is a priority for FRA, as safety is FRA's primary mission. Additionally, FRA and the US rail sector recognize the current limitations of these technologies for long distance movement of people and goods.

FRA'S ROLE IN FOSTERING NEW TECHNOLOGY DEVELOPMENT

RD&T oversees the BAA, their most powerful tool for developing and implementing decarbonization technologies. The 2022 BAA included the Energy and Emissions topic statement, which integrated ideas from discussions held during the first two workshops and collaboration with the Office of Railroad Safety. This topic seeks research concept ideas to investigate the efficacy, safety, workforce development, and environmental justice impacts of these technologies (FRA, 2023).

Funded Energy and Emissions and related research topics are housed in the Rail E3 Technology Research Program, launched unofficially in 2008 as part of the Rolling Stock Research Division of RD&T. The program objectives are to: (1) promote and support the development of safe, efficient, and reliable alternative fuels and motive power for rail transportation, (2) develop and demonstrate safe and reliable technologies that reduce emissions of rail transportation, and (3) develop knowledge and tools to address climate change and rail infrastructure resiliency.

During the 2023 cycle, FRA received 11 concept papers for research, 7 of which were selected and invited to submit proposals. These proposals are currently under review for possible award in fiscal year 2024. RD&T intends to reissue and expand the Energy and Emissions topic statement, in a future solicitation, to yield further answers needed for decision-making.

In 2022, RD&T funded a collaborative project supporting the development of a dual fuel hydrogen internal combustion engine, partnering with US Department of Energy (DOE) Vehicle Technologies Office (VTO), Wabtec, Oak Ridge National Laboratory, and Argonne National Laboratory. This project will investigate the emissions reduction and energy output of blending small to moderate amounts of hydrogen with diesel.

Similarly, FRA, US DOE VTO, Argonne National Laboratory and Progress Rail are investigating the performance of higher blends of biodiesel in advanced tiered locomotive engines.

RD&T is also sponsoring work with the American Short Line and Regional Railroad Association (ASLRRA) to evaluate the performance of alternative technologies for improving short haul locomotive performance. Through this work, the team aims to assess technologies on the market for Class II and III railroads, such as engine kits and fuel additives that have the claim of reducing emissions.

In 2023 RD&T provided funding for further development of the Locomotive Waste Heat Recovery System (LWHRS), aiming to improve the efficiency of older locomotives. Future research will expand the technology for application to Progress Rail's Electro-Motive Diesel type engines. Past research in partnership with ThermaDynamics Rail, LLC and Norfolk Southern Corporation focused on evaluating the feasibility of the technology in rail application and validation of power generated through rail yard and over the road tests.

The LWHRS prototype system is based on tandem Rankine Cycle using heat exchangers. Water is the working fluid, capturing heat from locomotive exhaust to convert it to electricity that can be used elsewhere on the locomotive. An independent technology assessment by Michigan Technology University found that over 350 kilowatts of energy are available to be captured from locomotive exhaust without adversely impacting the performance of older Wabtec engines.

RD&T and Argonne National Laboratory are working to enhance the GREET model by including a module for evaluation of rail transportation. The Rail Module in GREET provides users with a tool to evaluate the lifecycle energy intensity and emissions of their rail operations. It can be used to compare the energy and emissions associated with extracting, refining, and distributing raw material for fuel/energy needed to make biofuel, diesel or hydrogen fuels, batteries, etc., and their energy use for tractive effort at wheels to move goods and people. GREET can be used by practitioners to make decisions about how to decarbonize the rail sector based on best available resources. R&DT constantly seeks partners willing to share data on their rail operations to make the Rail Module in the GREET Model more robust and reflective of the experience of rail industry.

FRA has a long history of collaborating with the rail industry on advancing technologies that promote rail safety and efficiency. From 2013 - 2019, FRA worked with the Association of American Railroads and Class I railroads in the development of M-1004 Specification for Fuel Tenders for natural gas and other alternate fuels as part of the Natural Gas Fuel Tender Technical Advisory Group. This collaboration focused on developing robust design, operations, and maintenance requirements for natural gas fuel tenders. Research funded by RD&T directly benefitted the development of accident scenarios for evaluating the crashworthiness performance of the tenders and inter-car dynamics between coupled locomotive and tender car connections (needed for fatigue life design of tender hoses and cables). This research can be used as the foundation for research on the requirements and safety of hydrogen fueled locomotives and BESS.

In FY 2024-2025, RD&T plans to conduct bench scale and potential field scale tests at TTC, contingent upon FY 2024 and 2025 budget appropriations. The tests aim to understand the behavior (under normal rail operating conditions as well as in abnormal conditions – accidents) of high-pressure hydrogen tanks, their associated systems, and high energy storage batteries proposed for use in rail vehicles as a part of the conversion to zero emission technology.

CONCLUSIONS AND FUTURE ACTION

Decarbonization requires industry-wide collaboration to meet the goals set forth for

emissions reduction. The need for partnership and collaboration was evident when, in 2022, FRA issued its Climate Challenge to the rail industry, asking owners and operators on the national rail network, and manufacturers of rail equipment, to commit to reach net-zero greenhouse gas emissions by 2050. This was also the core message throughout the in-person workshop: decarbonization requires commitment and collective efforts.

The projects described above represent the strides made by FRA to advance decarbonization technologies and reduce locomotive emissions. The Rail E3 program began with a small project evaluating the feasibility of B20 biodiesel in passenger revenue service 15 years ago. Today biodiesel is the most viable near-term and quickly deployable solution for emissions reduction in rail transportation. However, additional research is still needed, including understanding durability issues of long-term use of biodiesel and engine performance using different feedstock from different regions.

Therefore, FRA intends to continue its collaborative research efforts to advance toward meeting the targeted timeframe of net-zero by 2050. RD&T has proven itself a worthy, viable partner for rail research by building research relationships with the rail industry. The Division will continue to rely on its strong partnerships into the future, working to reduce emissions in the rail sector.

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