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CO2-Free Smart Mobility Hub: MORE Industrial Park

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ABSTRACT

A Smart Mobility Hub (SMH) is a transport node that provides smart transportation and logistics services for a specified area (such as a city, city block, or municipality), depending on its intended mission. Utilization of the latest digital and communication technologies makes a mobility hub (MH) smart. Smart mobility services benefit from technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and Big Data, as well as wireless communication such as 5G mobile technology. The aim of SMHs is to make transportation of people and goods more efficient, cost-effective, accessible and, above all, convenient and easy. However, perhaps the most important mission of the SMH is to address the increased CO2 emissions generated by urban transport nodes. To this end, SMH aims to provide new tools and solutions that can help cities and municipalities to achieve zero CO2 mobility emissions transition locally. The key challenge for SMHs is to facilitate the achievement of the carbon neutrality goal set by the European Union for urban mobility and trips under 500 km by the end of 2030. The most critical challenge for the Finnish transport sector is to significantly reduce its emissions and become carbon-neutral by 2035. The aim of this paper is to analyze the kinds of facilities and capabilities MORE Industrial Park, located in Finland, should have and the kinds of services it should provide in order to become an SMH. The paper also explores potential key drivers that can positively differentiate MORE industrial park from competing industrial parks in Southern Finland.

Keywords: Smart mobility hub, Zero emission, IoT, New fuels, Heavy-duty vehicles

INTRODUCTION

Mobility hubs (MHs) are becoming important enablers for CO2-free smart transportation systems. In the past, the hubs caused significant pollution, including CO2 emissions, which is a primary cause of aggressive climate change. The CO2-free smart mobility hub (SMH) is a new concept that aims to address this issue by promoting sustainable transportation options.

Located in Finland, MORE industrial park, which encompasses two industrial parks—Rastikangas in the Municipality of Janakkala and Moreeni in the City of Hämeenlinna—is the Eco Industrial Park designed for an emission-free future. It is also a key MH for the Hämeenlinna economic area, serving the transportation needs of local industry. As part of a development strategy to gain a competitive edge over other similar industrial parks in Southern Finland, there are long-term plans to make MORE Industrial

Park a significant SMH that serves not just the city of Hämeenlinna and Janakkala municipality but also the economic areas of Helsinki and Turku.

The aim is to make MORE Industrial Park a certified sustainable industrial park with all of the latest mobility services for people and companies. To reach that goal, companies and organizations in the MORE industrial park must integrate circular economy principles into their operations, as well as using green energy and CO2-free logistics. There are many issues to be considered in seeking to achieve truly CO2-free smart mobility. The main building blocks of the hub are CO2-free vehicles (such as electric cars), renewable energy sources, charging and fueling stations, and a smart multimodal transportation system.

This paper sought to analyze the kinds of facilities and capabilities MORE Industrial Park should have and the kinds of services it should provide in order to become an SMH. The paper also explores potential key drivers that can positively differentiate MORE industrial park from competing industrial parks in Southern Finland. The specific focus of this paper encompasses potential energy sources for CO2-free heavy-duty vehicles and technology requirements for smart multimodal transportation system for CO2-free SMH.

MORE Industrial Park will have the infrastructure for high-capacity transport (HCT) trucks in place around 2026, and the paper examines the capabilities and services required by these HCT trucks for efficient and sustainable operations. Zero-emission and just-in-time first- and last-mile transportation services for the local economy will also be discussed. As SMH services are produced mainly by utilizing modern digital technologies, the paper introduces the MORE platform, which enables the transition toward efficient, resilient, and sustainable transportation services as one of the key enablers of zero-emission mobility of goods and people.

NEW ENERGY SOURCES FOR HEAVY-DUTY ROAD TRANSPORT

For decades, diesel has been the de facto fuel for trucks of every kind, because it is more energy-dense than gasoline. Diesel engines are also more efficient than gasoline engines, resulting in lower fuel costs. Because they are built specifically for heavy-duty use, diesel engines are well suited for heavy vehicles like trucks. However, diesel engines emit high levels of nitrogen oxides (NOx), particulate matter (PM), and carbon dioxide (CO2) (Reşitoğlu, 2015). NOx emissions contribute to the formation of smog and acid rain and aggravate respiratory conditions such as asthma. NOx emissions are also major contributors to eutrophication, a process that occurs in bodies of water that are over-enriched with nutrients. Eventually, this leads to excessive growth of plants and algae, which reduce oxygen levels in the water (EPA, 1999). When PM particles are inhaled into the lungs, they cause respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD). Long-term exposure to PM can increase risk for heart disease and lung cancer (Sydbom, 2001). The main source of emissions of CO2 (the primary greenhouse gas) is fossil fuel combustion in engines.

Clearly, then, new environmentally friendly fuels for trucks are important for the transportation sector in addressing the sector's environmental, economic, and energy challenges. The potential energy solutions for next-generation heavy-duty vehicles include battery-electric, hydrogen, natural gas and biodiesel fuel alternatives.

Battery-Electric

Lithium-ion batteries are the most widely used technology in electric vehicles (EVs) because of their high energy density and long cycle life, and research is ongoing to improve the energy density and safety of these batteries. By the end of 2022, the best lithium-ion batteries had an energy density of about 500–700Wh/liter (Sakuu, 2022).

Solid-state batteries are considered a promising technology for the next generation of EV batteries. Rather than the liquid electrolyte found in traditional lithium-ion batteries, they use a solid electrolyte, which can increase the battery's energy density and safety. Solid-state batteries are also expected to have a longer lifespan and better performance at high and low temperatures. Sakuu, a California-based company, has successfully tested an 800Wh/liter solid state battery, which was expected to be available for commercial applications by the end of 2022. The company also plans to introduce a fully 3D-printable solid-state battery capable of exceeding 1200 Wh/liter during 2023 (Sakuu, 2022).

Lithium-sulphur batteries have a high theoretical energy density that is about five times higher than traditional lithium-ion batteries. This high energy density can potentially increase EV range while reducing battery weight and size. However, current lithium-sulphur batteries cannot sustain many recharging cycles (Merrifield, 2022).

Hydrogen

Heavy-duty vehicles that run on hydrogen fuel emit only water vapor as exhaust. Hydrogen fuel is created by extracting hydrogen from sources that include natural gas and water. There are several methods for extracting hydrogen, and these have very different environmental impacts.

In the steam methane reforming (SMR) method, methane (CH_4) reacts with steam (H_2O) to produce carbon monoxide and hydrogen (H_2). This is currently the most common method of large-scale hydrogen fuel production because of its high efficiency, relatively low cost, and well-established technology. Unfortunately, it also has some drawbacks, including emissions of CO_2, a greenhouse gas produced during the process (Naterer, 2010).

The electrolysis method uses electricity to split water (H_2O) into hydrogen and oxygen (O_2). This is considered a clean and renewable way of producing hydrogen fuel if the electricity is produced by windmills or solar panels. However, this method of hydrogen production is energy-thirsty and can be relatively expensive (EERE, n.d.).

The gasification method converts carbon-containing materials at high temperatures into carbon monoxide (CO), hydrogen, and carbon dioxide (CO_2). One of the main benefits of gasification is that it can be used to convert a wide range of carbon-containing materials into useful products. It is considered a clean and sustainable method of producing hydrogen fuel because it uses biomass as a feedstock; this is a renewable resource, and carbon dioxide (CO2) is consumed by plants as part of their natural growth process. Gasification technology is still in development and must resolve challenges that include high capital costs and low efficiency (EERE, n.d.).

The photoelectrochemical method uses sunlight to split water into hydrogen and oxygen. This is a promising way of producing hydrogen fuel, but it is still in the research and development stage. The biological processes method utilizes certain microorganisms to produce hydrogen. This method is still in the early stages of development but has the potential to become a sustainable way of producing hydrogen fuel (EERE, n.d.).

Hydrogen fuel is more difficult to store than diesel and must be compressed, liquefied, or solidified for storage and transport to the point of use. As hydrogen is a highly compressible gas, it occupies a large volume at low pressures, making it challenging to store in large quantities. Compared to diesel, hydrogen fuel has a relatively high energy content. However, because of its low energy density, it takes a much larger volume of hydrogen to store the same amount of energy as diesel or natural gas. This makes it less cost-effective and more challenging to store and transport hydrogen in large quantities. Additionally, hydrogen is extremely flammable. Hydrogen storage requires expensive specialized infrastructure, such as high-pressure or cryogenic tanks. For these reasons, hydrogen cannot easily be used in small portable containers (Andersson, 2019).

Gas

Liquified natural gas (LNG) and compressed natural gas (CNG) are cleaner-burning alternatives to diesel, and gas trucks are often less expensive to operate than diesel trucks. However, they require special storage and dispensing equipment, and the infrastructure for fueling gas vehicles is less widely available. While natural gas is considered cleaner than diesel because it emits less carbon dioxide (CO2) when burned, it is still a fossil fuel, and its extraction and transportation cause negative environmental impacts. The process of natural gas extraction releases methane, which is very powerful greenhouse gas that has a much greater atmospheric warming effect than CO2 (EIA, 2022).

Biodiesel

Biodiesel is a type of diesel fuel made from renewable biomass sources such as vegetable oils and animal fats. It is considered more environmentally friendly than traditional diesel fuel, which is made from non-renewable fossil resources. Biodiesel can be used in diesel engines without any modification; it can also be blended with traditional diesel fuel to create a lower-emissions blend. Biodiesel generally emits less particulate matter, sulphur oxides, or hydrocarbons than traditional diesel. It also has a lower carbon footprint than traditional diesel because the carbon dioxide it releases is absorbed by the biomass used to make it. However, biodiesel also contributes to environmental issues; for example, feedstock cultivation for biodiesel production contributes to deforestation and loss of wild life habitats and can release pollutants into the air and water courses. Biodiesel's environmental impact depends on how it is produced and used (EIA, 2022).

MOBILITY HUB PLATFORM

The MORE platform is an enabler of environmentally friendly smart mobility services for companies and organizations in the MORE Industrial Park. The platform will provide a set of technologies that enable desired new mobility services as well as essential infrastructure and equipment. As the key enabler for fast and reliable modern communication solutions, fiber-optic technology is one of the MORE platform's key infrastructures. This forms the backbone of current mobile network technologies like 4G and 5G, as well as the emerging sixth generation. In addition to modern digital technologies, the platform must be able to support the latest logistics services and infrastructure for efficient heavy-duty vehicle operations. In simple terms, the MORE platform's capabilities must encompass virtual and physical environments to support modern environmental mobility services.

Communication

Fast and reliable communication technologies and high-quality data security solutions are key features of the MORE platform. To be able to adapt quickly to emerging 6G technology, the platform must have the long-range communication capabilities offered by 5G mobile networking technologies, including the Internet of Things (IoT), virtual reality (VR), and augmented reality (AR). The sixth generation of mobile communication technology is still in development and is expected be available for commercial use by about 2030. This will facilitate smart mobility solutions such as terabit-per-second (Tbps) data transfer speeds, extremely low latencies of 1 millisecond or less, much greater capacity to support billions of connected devices, more efficient use of the spectrum and network resources, enhanced security and privacy features, and improved support for emerging technologies like quantum computing, holographic communications, and satellite-based communications (Alliance for Telecommunications Industry Solutions, 2022).

Logistics Services

Logistics services coordinate and manage the movement of goods, information, and resources from their point of origin to the point of consumption. This may include transportation, warehousing, inventory management, packaging, and other activities related to the supply chain. Logistics services are critical for businesses of all sizes; they allow companies to manage the movement of goods and materials efficiently and ensure that products are delivered to customers in a timely and cost-effective manner. Companies use logistics services to improve efficiency, reduce costs, and increase customer satisfaction. In addition to traditional logistics services, digitalization and automation have driven the emergence of new services such as e-commerce logistics, last-mile delivery, and real-time tracking and monitoring. These services are supported by technologies like IoT, wireless communication, and AI (Agatic, 2020).

Infrastructure

Heavy-duty vehicles depend on appropriate physical infrastructure and systems to support their operation. This includes highways, bridges, rest areas, weigh stations, and other facilities designed to meet the unique needs of these large vehicles. Heavy-duty trucks rely on well-maintained roads and highways to travel safely and efficiently over long distances, including dedicated truck lanes and bypasses designed specifically to accommodate these large vehicles. Heavy-duty trucks also require bridges that are strong enough to support their weight and size; special reinforcement techniques and load-bearing capacity are needed to ensure the safety of the vehicles and of the bridges themselves. Rest areas and other facilities allow drivers to take breaks, rest, and refuel, and weight stations ensure compliance with weight limits and regulations. Heavy-duty electric trucks need charging hubs along core routes, including both fast-charging and overnight charging hubs. Hydrogen- and gas-powered heavy-duty vehicles would need their own fueling stations, as well as specific transportation and storage facilities required by the nature of these fuels (Sperka, 2021).

CONCLUSION

The CO2-free SMH has the potential to revolutionize transportation systems. By enabling smart sustainable mobility services and providing the necessary infrastructure, these hubs can significantly reduce pollution and promote green mobility. The use of environmentally friendly fuels will be crucial in minimizing the pollution caused by mobility hubs.

At present, battery-electric energy is the most promising zero-emission solution for heavy-duty vehicles in countries with well-stablished electric power grids. It is relatively easy to install charging stations for electric vehicles once the grid can be accessed from any suitable location. With the rapid increase in electric passenger vehicles, battery technology has developed rapidly in recent years. Today, heavy-duty vehicles like the Tesla Semi have a maximum range of 800 km on a single charge. Next-generation technologies like solid-state batteries have between two and five times higher energy density and can sustain up to 10,000 recharging cycles (Maisch, 2022). This means that battery packs in heavy-duty EVs are getting lighter, enabling payload and battery life cycle improvements similar to or greater than other vehicles across the life cycle. Electricity produced by windmills or solar panels will ensure that EV emissions are as close as possible to zero.

Hydrogen and gas fuels present similar challenges, including low energy volume, complex and expensive storage requirements, and distribution networks that have yet to be developed. Building the extensive hydrogen or gas distribution networks required by the logistics industry would be expensive. These issues probably explain why gas-powered heavy-duty vehicles have not become popular and are used only for very specific purposes—for example, gas buses that operate within the city and require only one fueling station. Nevertheless, cities in Finland are renewing their fleets with electric buses. Hydrogen- and gas-powered vehicles are not considered zero-emission unless the fuel is produced using wind or solar energy.

As biodiesel is produced from renewable sources, it reduces dependence on fossil fuels. Because it emits fewer pollutants and greenhouse gases than conventional fuels, biodiesel is a cleaner and more sustainable option. It can also be mixed with fossil diesel, and existing fuel station networks can be used for distribution. Above all, biodiesel can be used directly by existing diesel engines. This makes it a great solution for reducing mobility-related CO2 emissions in less developed countries or in areas that lack a well-developed electric power grid. In developed countries, biodiesel can offer an excellent solution during the transition to electrified mobility and logistics services.

As well as contributing to significant reductions in CO2 emissions, mobility hubs must provide the necessary infrastructure and services to ensure seamless and efficient logistics. Modern mobility services utilize the latest digital technologies to ensure the best possible experience, and the infrastructure must support heavy-duty vehicles, public transportation, private automobiles, and new mobility equipment that includes city bikes and scooters.

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