**Module 2: Oil-Based Fuels in International Transport**

**Prompt** (8 November 2023): Expand on module 2 concerning the use of oil-based fuels in transport.

ChatGPT

**Module 2: Oil-based Fuels in International Transport: A Sectorial Overview** (2 hours)

**2.1 The Primacy of Oil-based Fuels in Transport**

* Historical context of oil in transport: Evolution from coal to oil
* Global dependence on oil: Current statistics and trends
* The economics of oil: Pricing, market dynamics, and geopolitical influences

**2.2 Characteristics of Oil-based Fuels**

* Composition and types: From crude oil to refined products like gasoline, diesel, jet fuel, and bunker fuel
* Calorific value and efficiency in different modes of transport
* Environmental impact: Emissions profile of each fuel type

**2.3 Oil Use in Different Modes of Transport**

* Maritime: Bunker fuel characteristics, consumption patterns, and the sector's overall contribution to global oil demand
* Air Transport: Jet fuels' properties, efficiency, and challenges in alternative fuel adoption
* Road Haulage: Diesel's dominance, challenges of electrification, and the transition to lower-carbon alternatives
* Rail Freight: Comparative analysis of diesel versus electric trains and the role of oil in the current infrastructure

**2.4 Environmental Impacts**

* CO2 Emissions: Analysis of each mode's contribution to global CO2 emissions
* Local pollutants: NOx, SOx, particulate matter, and their impact on air quality and public health
* Oil spills and leaks: Environmental hazards associated with the transportation and storage of oil

**2.5 Fuel Consumption Patterns**

* Data analysis: Global and regional consumption trends in the transport sector
* Efficiency standards and their influence on consumption patterns
* Projected demand: Forecasts in the context of the energy transition

**2.6 Oil-based Fuels and Climate Policy**

* Regulatory frameworks: IMO 2020 Sulphur Cap, EU Emission Trading System (ETS), and others
* Fuel taxation and incentives for low-carbon alternatives
* The role of international agreements in shaping fuel use, such as the Paris Agreement

**2.7 The Future of Oil-based Fuels in Transport**

* Peak oil demand scenarios and the implications for transport
* The role of technology in fuel substitution and efficiency improvements
* Case studies on industry adaptation: Shipping companies, airlines, and logistics firms transitioning towards sustainability

**Teaching Aids and Materials**:

* Graphs illustrating historical and projected oil consumption by transport mode
* Documentary footage of oil extraction, refinement, and usage in different transport sectors
* Simulation tools for understanding the combustion and emission profiles of different oil-based fuels

**Assessment Methods**:

* Interactive discussions and group activities based on real-world scenarios
* Case study analysis on the impact of regulations on fuel usage in a specific transport sector
* Research assignments or presentations on alternative fuels and the potential for reducing oil dependency in a chosen mode of transport

This module would provide master's degree students with a detailed understanding of how oil-based fuels are ingrained in the international transport system, their environmental impact, and the emerging shifts towards sustainable alternatives.

**THE RESULTS OF THE GROUP WORK**

**2.2 Characteristics of Oil-based Fuels**

Composition and Types:
Crude Oil: The raw material for oil-based fuels is crude oil, a complex mixture of hydrocarbons. Crude oil can vary in composition, with different deposits containing varying proportions of hydrocarbons and impurities.
Refined Products: Crude oil is processed in refineries to produce a range of refined products, including gasoline, diesel fuel, jet fuel (aviation fuel), and bunker fuel (used in ships). The composition of these refined products is tailored to meet specific requirements for different applications.

Calorific Value:
Calorific value, also known as heating value or energy content, represents the amount of energy released when a fuel is burned. Oil-based fuels generally have high calorific values, making them efficient energy sources.
Gasoline, diesel, and jet fuel have similar calorific values, typically ranging from 43 to 47 megajoules per kilogram (MJ/kg).
Bunker fuel, used in maritime shipping, has a slightly lower calorific value, often around 42 MJ/kg.
Efficiency in Different Modes of Transport:
Gasoline: Commonly used in light-duty vehicles such as cars, gasoline engines are known for their high efficiency and power output. They are relatively efficient for shorter-distance travel.
Diesel: Diesel engines are widely used in heavy-duty vehicles like trucks, buses, and trains. They offer better fuel efficiency and torque, making them suitable for long-haul transportation.
Jet Fuel: Jet engines are highly efficient and are designed for aviation, where weight and thrust are critical. They provide high energy output for aircraft propulsion.
Bunker Fuel: Used in large ships, bunker fuel engines are less fuel-efficient than some other transportation modes, but they are capable of carrying massive cargo loads.
Environmental Impact:
Emissions Profile: Oil-based fuels release carbon dioxide (CO2), a greenhouse gas, and other pollutants when burned. Diesel and bunker fuel, in particular, produce higher levels of particulate matter and nitrogen oxides (NOx), which have adverse environmental and health effects.
Carbon Footprint: The carbon footprint of oil-based fuels is significant, contributing to global warming and climate change. Efforts are ongoing to reduce these emissions through the use of cleaner fuels and advanced engine technologies.
Spills and Environmental Incidents: Oil-based fuels are associated with the risk of oil spills during transport and storage, which can lead to devastating ecological damage in case of accidents.
Efforts are being made to develop alternative and cleaner energy sources to reduce the environmental impact of oil-based fuels. This includes the promotion of electric vehicles, the use of biofuels, and the development of more fuel-efficient and cleaner-burning engine technologies. However, oil-based fuels continue to be a major source of energy for transportation, and their environmental impact remains a significant concern.

**2.3 Oil Use in Different Modes of Transport**

* Maritime

Bunker Fuel has many characteristics that depend on: The types of Bunker Fuel: Bunker fuel typically refers to heavy fuel oils used in ships, and it comes in various grades and specifications. The most common types are IFO (Intermediate Fuel Oil) and HFO (Heavy Fuel Oil). These fuels have higher viscosity and are generally less refined compared to other petroleum products. The Viscosity and Sulphur Content: Bunker fuels have high viscosity, making them suitable for large marine engines. They also tend to have a relatively high sulphur content, which can contribute to air pollution and environmental concerns.

And the Energy Density: Bunker fuel has a high energy density, which is important for powering large ocean-going vessels that need to travel long distances and carry heavy cargoes.

In term of Consumption Patterns:

The maritime industry is one of the largest consumers of oil, accounting for a significant portion of global oil demand. The exact share can vary, but it's estimated to be around 5-10% of total oil consumption. Different types of vessels consume bunker fuel, including container ships, bulk carriers, tankers, and cruise ships. The fuel consumption of these vessels can vary widely based on their size, engine efficiency, and the distances they travel. The consumption of bunker fuel also depends on the length of the shipping routes and the volume of cargo being transported. Longer routes and heavier cargoes require more fuel.

*Sector's Overall Contribution to Global Oil Demand:* The maritime sector significantly contributes to global oil demand, and its importance is underscored by the following points: The volume of Oil Consumed: The maritime sectors is one of the largest consumers of oil, the maritime sector's demand for bunker fuel is substantial. This demand is driven by the need to power a vast fleet of ships responsible for global trade and transportation. The economic Impact: The shipping industry is crucial to the global economy as it facilitates the transportation of goods across the world. A substantial portion of global trade relies on maritime shipping, and the sector's demand for oil is intrinsic to this process. And the environmental Considerations: The environmental impact of bunker fuel consumption, particularly in terms of air pollution and greenhouse gas emissions, has led to regulatory changes and increased scrutiny. As a result, the sector's contribution to oil demand is evolving as cleaner fuels and technologies are being adopted.

**Air transport**

Jet fuels’ properties: Jet fuel is a type of kerosene that has a high energy density, low freezing point, and good stability. Jet fuel is mainly composed of hydrocarbons, but it also contains additives to improve its performance and safety. Jet fuel is classified into different grades. Jet A and Jet A-1 are the most commonly used for commercial aviation and Jet B is used for its enhanced cold-enhanced cold-weather performance

Efficiency: The efficiency of jet fuel depends on several factors, such as the engine type, the flight speed, the altitude, the weather, and the aircraft design. According to the International Energy Agency (IEA), the average fuel efficiency of commercial aviation in 2018 was 37 passenger-kilometres per litre, which means that one litre of jet fuel can transport one passenger for 37 kilometres.

Challenges in alternative fuel adoption: Alternative fuels, such as sustainable aviation fuels (SAF), hydrogen, and electricity, have the potential to reduce the carbon footprint and environmental impact of aviation. However, there are also significant challenges and barriers to their adoption, such as the availability, cost. Green fuels currently account for less than 0.1% of total jet fuel consumption. Hydrogen and electricity, on the other hand, require major changes in the aircraft design, infrastructure, and regulation, and they face technical and safety issues. For example, Airbus plans to bring a hydrogen-powered aircraft into service in 2035.

**Road Haulage**

Oil use in road haulage, particularly diesel, has been a dominant fuel source for decades. Road transport consumed more than 40% of all oil demand. Oil-based fuels, such as diesel and gasoline, have a high energy density, which means they contain a substantial amount of energy in a relatively small volume. Diesel fuel has long been the primary choice for road haulage due to its energy density, efficiency, and availability. Diesel engines are well-suited for long-haul transport and heavy-duty applications.

Electrification, especially battery-electric vehicles, is seen as a promising solution to reduce emissions in road haulage. Challenges include the limited range of electric trucks compared to their diesel counterparts, the need for extensive charging infrastructure, and the high upfront cost of electric vehicles. Battery weight and charging time can also be significant issues for long-haul transportation, as it may require frequent recharging stops.

**Transition to Lower-Carbon Alternatives:**

To address these challenges, the road haulage industry is exploring various lower-carbon alternatives:

- Like Hydrogen Fuel Cell Vehicles: Hydrogen fuel cell trucks are being developed to offer longer ranges and faster refuelling compared to battery-electric trucks. However, hydrogen production and infrastructure challenges need to be addressed.

- Natural Gas: Compressed natural gas and liquefied natural gas are considered transitional fuels that can reduce GHG emissions compared to diesel. They are particularly popular for regional haulage.

- Biofuels: Biofuels derived from renewable sources, such as biodiesel or biomethane, offer a way to reduce carbon emissions in existing diesel engines.

**Rail Freight**

Rail freight is the least emissions-intensive mode of transport – its expansion help reduce overall emissions. In last 13 years, the emission of CO2 for rail transportation, except 2018-2019, is always lower than 100 million tons in Europe.

The rail transportation uses mainly two types of energies: diesel and electricity, coal is only used in limited lines and areas.

According to an energy consumption chart for rail by fuel in Europe generated by the International Energy Agency (IEA), the use of electricity is gradually increasing from 2010-2022, from 0.74ej to 1.08ej, and predictably would increase to 1,44ej in 2030. For diesels, the consumption remains at the same level at around 1.2ej to 1.3 ej, but predicting a decrease for 2030 to less than 1ej, at the same time, the use of biodiesel is increasing slightly as well

In Europe, electric rail, which accounts for over 85% of passenger rail activity and 55% of freight movements, does not emit any direct CO2 emissions. However, worldwide speaking, diesel, in particular, plays a much more prominent role in freight rail, accounting for 75% of its total energy consumption worldwide in 2022.

**2.4 Environmental Impacts**

1. **CO2 Emissions: Analysis of each mode's contribution to global CO2 emissions**

According to statistics about the global emissions in 2018 for the different modes of transport, the total amount of emissions were 8 million tons with 24 % of them coming from energy. About Europe, the Transport was responsible for about a quarter of the EU’s total CO2 emissions in 2019, of which 71.7% came from road transportation.

 The most emissive one in the passenger road transport which accounts for 45.1 %, following by the fret road transport which accounts for 29.4%, then the aviation was 11.6% where 60% coming from international flights and 40% from domestic flights, and the rail sector accounted for only 1%.

*If we are looking at the quantity of emissions by the type of vehicles between 2000-2020:*

* We found that the quantity of emission of passenger cars varies between 2.2 and 2.9 million tons globally and it reaches its peak in 2019 with 3,2 million tons, then it started to decrease during the pandemic which put a lot of restrictions on mobility so that it reached 2.9 million tons. In the coming years it’s expected to decrease until reach less than 0.5 million ton by 2050,
* For the medium and heavy trucks their emissions vary between 1.1 and 1.9 million tons. The peak was in 2019 with 1.9 million tons. It’s expected to decrease but is less important than passenger cars.
* for buses and light commercial vehicles, they have small amounts which vary between 0.4 and 0.5 million tons. Like the other types of the peak was in 2019 with 0.5 million tons.



1. **Local pollutants: NOx, SOx, particulate matter, and their impact on air quality and public health**

The two main pollutants from ship emissions are **Nitrogen oxides (NOx)** and **Sulfur oxides (SOx)**. These combustible gasses are emitted into the environment in the form of smoke.

Marine fuel in an internal combustion engine is burned inside the combustion chamber by the correct mixture of fuel and air in the presence of heat. Nitrogen reacts with oxygen under certain engine operating conditions to form **Nitrogen oxide (NOx) emissions**.

**Sulfur oxide (SOx) emissions** are main­ly due to the presence of sulfur compounds in the fuel.

Particulates or atmospheric particulate matter are **microscopic particles of solid or liquid matter suspended in the air.**

*What is the impact of NOx and SOx on air quality and public health?*

Nitrogen oxides (NOx) and sulfur oxides (SOx) have negative impacts on air quality and public health. They contribute to the formation of fine particulate matter, smog, and environmental acidification. This can lead to respiratory problems, cardiovascular diseases, respiratory infections, and long-term harmful effects. Reducing NOx and SOx emissions is crucial to improving air quality and protecting public health.

**III. OILS SPILLS AND LEAKS**

Oil spills and leaks pose **significant environmental hazards during the transportation and storage of oil**. These hazards can have devastating effects on ecosystems, wildlife, and local communities.

* **Water Pollution:** Spilled oil can contaminate bodies of water, such as oceans, rivers, and lakes.
* **Impact on Wildlife:** Animals that come into contact with oil suffer.
* **Long-term Environmental Damage and Disruption of Ecosystems:** Even after a cleanup, some oil residues can remain, continuing to harm the environment.
* **Human Health Risks:** People living in areas affected by spills may experience respiratory problems from inhaling oil fumes.
* **Oil Infrastructure and surrounding areas damaged by** leaks or spills
* **Economic Impact:** Oil spills impact industries like fishing, tourism, and local businesses that rely on clean and healthy ecosystems.

**2.6 Oil-based Fuels and Climate Policy**

1. **Regulatory frameworks: IMO 2020 Sulphur Cap, EU Emission Trading System (ETS), and others**
2. ***The IMO 2020 Sulphur Cap***

One of the most significant regulations is the IMO 2020 Sulphur Cap, which aims to reduce the Sulphur oxide and nitrogen oxides emissions from ships by limiting the Sulphur content of their fuel oil to 0.50% or less. This regulation applies to all ships operating outside designated Emission Control Areas (ECAs), where the limit is already 0.10%.

* The IMO 2020 Sulphur Cap is expected to have positive impacts on human health and the climate by reducing air pollution and acid rain.

 Emission control areas include the Baltic Sea, coastal areas of North America, and the Caribbean. The inclusion of the Mediterranean Sea, and by extension of the Suez Canal, will prevent ships from using MGO in a strategic area for international trade starting in May 2025.

According to the International Maritime Organization (IMO), this measure has reduced total sulphur oxide emissions from ships by 70%.

The impact of the IMO 2020 sulphur limit:

* In 2020, global demand for high-sulphur fuel oil (HSFO) fell by 77%, dropping from 3.5 million barrels per day (b/d) to 0.8 million b/d.
* In the first quarter of 2021, the average price of HSFO was about $300 per tonne, compared to about $400 per tonne in the same period of 2020.
* The implementation of the IMO 2020 sulphur limit has led to an increase in demand for low-sulphur fuels, such as marine gas oil (MGO) and very low-sulphur fuel oil (VLSFO) .
* The use of low-sulphur fuels has resulted in a reduction in black carbon emissions from ships, which are a significant contributor to climate change .
1. ***The EU Emission Trading System (ETS)***

The EU Emission Trading System (ETS), is a market-based mechanism that sets a cap on the total amount of greenhouse gasses that can be emitted by certain sectors, including major industrial installations, aviation and maritime transport.

The EU ETS allows participants to buy and sell emission allowances, creating an incentive for them to reduce their emissions and invest in low-carbon technologies. The EU ETS covers about 45% of the EU’s greenhouse gas emissions and is the largest carbon market in the world. To this day, many companies are buying and selling fuels Allowances, which are traded for a value of 100 euros.

FUEL EU Maritime will set limits on the greenhouse gas intensity of shipping vessels. This is the first legislation that measures emissions from a well to wake basis meaning that emissions from fuels taking into account the production process of the fuel.

Other international agreements include CORSIA carbon offsetting and reduction schemes for international aviation conceived by the International organization of civil aviation. This program is different then trade and cap because instead of simply lowering emisisons it seeks to stimulate investment in carbon offsetting schemes such as planting more trees that can reabsorb carbon.

The EU ETS and FUEL eu are part of the larger fit for 55 eu legislative package which seeks to lower emissions by 55 % by 2030 and reach overall net zero by 2050.

* Fuel taxation and incentives for low-carbon alternatives

Fuel taxation and incentives for low carbon alternatives are policy measures aimed at reducing carbon emissions and promoting sustainable energy practices.

First, let’s talk about fuel taxation. Their purpose is to encourage the reduction of the consumption of fossil fuels hence reducing environmental impact.

To do that, taxes on gasoline, diesel, and other carbon-intensive emissions are put in place. Higher prices will incentivize consumers to use alternatives such as alternative modes of transportation, fuel-efficient vehicles, public transport etc.

Moreover, funds will be generated from this policy and these funds may potentially be reinvested in sustainable projects. Projects such as in the development, the research of renewable energies, installation to capture carbon such as CCS or natural reserves…

Secondly, incentives for low carbon alternatives could be another possible policy.

So, its purpose is to promote the adoption of eco-friendly technologies and renewable energy sources. There are possibly multiple types of incentives for this, subsidies on the use of low carbon alternatives; reducing the tax liability for firms investing in businesses investing in green technologies, or technologies suitable for the ecological transition to reach the zero-emission at term, so it could concerns firms investing in solar panels, wind or sea power installations, electric vehicles, energy-efficient appliances etc.

Another incentive could be subsidies but research, development and deployment of clean energy solutions.

The benefits of these incentives are to encourage innovations, stimulate market demand for green products and accelerate admittedly the transition to a low-carbon economy.

The EU is currently in the process of revising its Taxation directives for energy in order to incentivize the consumption of renewable fuels. The Energy taxation directive is currently in limbo as the 27 states cannot reach an agreement with the commission on how the new taxation directive will favour certain renewable fuels over others. Intense lobbying by the fuel industry is another major barrier.

* The role of international agreements in shaping fuel use, such as the Paris Agreement

The international agreements aim to bring the countries to discuss greenhouse gas emissions and climate change. They bring to the table the negative externalities caused by pollution in order to find solutions for reducing or adapting to climate change. There are several types of meeting of this kind, such as the Paris Agreement, which aims to reduce CO2 emissions by putting in place recommendations that the member countries will then apply. There is also the Climate COP, which is a forum of representatives of the member countries of the United Nations who recognise the existence of global warming and the responsibility of industrialized countries

the main roles of this agreements about climate change:

Setting Emission Reduction Targets: during The Paris Agreement, adopted in 2015, the countries communicate their greenhouse gas (GHG) emission reduction targets. These targets are meant to limit global warming to well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 degrees Celsius. By committing to these targets, countries agree to reduce their reliance on fossil fuels and transition to cleaner energy sources.

Promoting Renewable Energy and Energy Efficiency: International agreements often include provisions and commitments to promote renewable energy sources, improve energy efficiency, and reduce the use of fossil fuels.

Financial and Technological Support: International agreements may provide financial and techMarket Mechanisms: Some international agreements, like the Kyoto Protocol market-based mechanisms, such as emissions trading and the Clean Development Mechanism (CDM), to incentivize emissions reductions and the use of cleaner fuels.

Reporting and Transparency: to report their emissions data, making it easier to identify areas where improvements are needed.

Peer Pressure and Global Norms: By participating in international agreements, countries signal their commitment to addressing climate change and reducing their reliance on fossil fuels

Legal and Political Framework: International agreements provide a legal and political framework for addressing energy and environmental issues on a global scale. They create a platform for negotiations, information sharing, and the development of common policies and strategies to tackle the challenges associated with fuel use.