Pearson BTEC Levels 4 and 5 Higher Nationals in Engineering (RQF)

Unit 44: Industrial Power, Electronics and Storage

Unit Workbook 2

in a series of 4 for this unit

Learning Outcome 2

Technology and Policies of Energy Efficiency in Building and Transportation

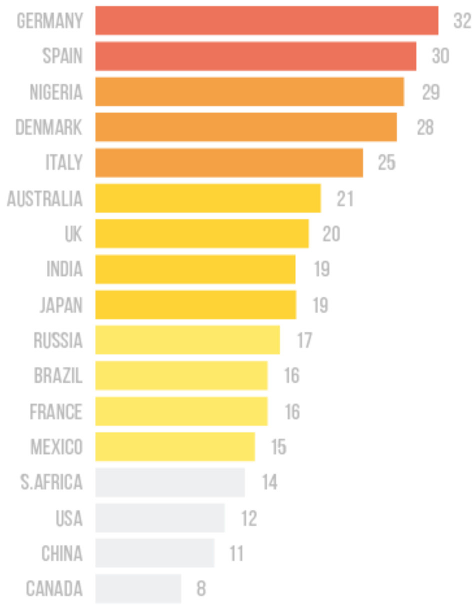

Fig.2.1: Average Electricity Costs Around the World

Germany and Spain have expensive electricity. Canadian electricity is cheap at 8 US cents per kilowatt hour, and this is reflected in their high average electricity usage. US electricity prices at 0.12 $/kWh are also quite cheap internationally. In India and China, they are very cheap. The UK is in the middle at 20 cents/KWh. It's relatively expensive globally but not too bad for Europe, where most countries pay a high share of tax on their power.

In the UK in the last ten years the real price of electricity has risen by 63%, while for gas it has gone up a staggering 115%. These are real prices, so these are the changes after having adjusted for inflation. If you were to look at it nominal prices you'd understand how energy prices became such a hot issue. Ten years ago, a unit of electricity used to cost 7 pence, but today it might be in the region 15p. Likewise, gas went from 2p to 5p. What this meant that was the average dual fuel bill rocketed from £600 to £1,300 over the course of a decade. As our demand for energy grows, so, in all likelihood, will the cost.

Fig.2.1 includes the cost of electricity provided by both renewable and conventional power generating technologies. However, the cost range across the renewable energy technologies is wide, considerably wider compared with conventional energies. The most mature and widely deployed clean energy technologies such as hydro and onshore wind are today close to reaching parity with traditional sources, while emerging technologies such as marine tidal and wave are still at the early phases of cost discovery.

For technologies that are widely deployed across the globe, such as onshore wind, crystalline silicon PV and hydropower, there are significant cost variations between the regions. The costs in Western Europe, the US and most notably Japan are typically several times larger than those in China and India due to limited access to cheap components and higher O&M costs.

Many of the other technologies are currently only deployed in specific regions, depending on the characteristics of the technology and local policy support. However, in line with the continued growth in clean energy investment, the geographic spread of the technologies is likely to increase in the future into countries such as Brazil and South Africa.

2.5 Energy Requirements

According to the International Energy Outlook 2017 (IEO2017) Reference case, total world energy consumption is set to rise from 575 quadrillion British thermal units (Btu) in 2015 to 736 quadrillion Btu in 2040, an increase of 28%. Most of the world's energy growth will occur in countries outside of the Organization for Economic Cooperation and Development (OECD), where strong, long-term economic growth drives increasing demand for energy. Non-OECD Asia (including China and India) alone accounts for more than half of the world's total increase in energy consumption over the 2015 to 2040 projection period. By 2040, energy use in non-OECD Asia exceeds that of the entire OECD by 41 quadrillion Btu in the IEO2017 Reference case (Fig.2.2).

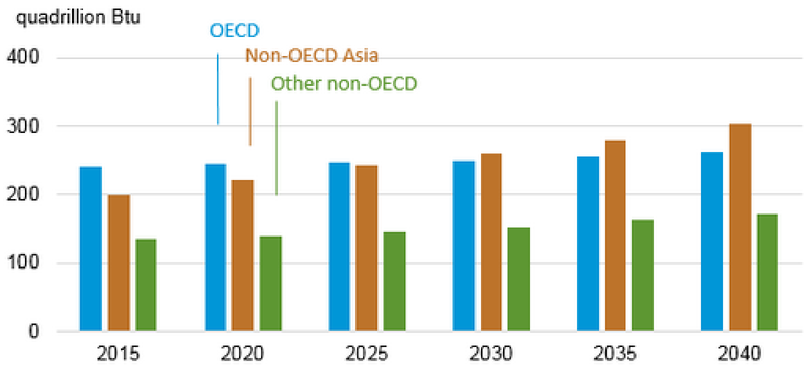

Fig.2.1: World Energy Consumption by country grouping

Economic growth, as measured by gross domestic product (GDP), is a key determinant in the growth of energy demand. The world's GDP (expressed in purchasing power parity terms) rises by 3.0%/year from 2015 to 2040. The fastest rates of growth are projected for the emerging, non-OECD regions, where combined GDP increases by 3.8%/year, driving the fast-paced growth in future energy consumption among those nations. In the OECD regions, GDP grows at a much slower rate of 1.7%/year between 2015 and 2040, at least in part, because of slow or declining population growth in those regions. Economic growth, as measured in GDP, is also a key determinant in the growth of energy demand. The world's GDP (expressed in purchasing power parity terms) rises by 3.3%/year from 2012 to 2040. The fastest rates of growth are projected for the emerging, non-OECD countries, where combined GDP increases by 4.2%/year. In OECD countries, GDP grows at a much slower rate of 2.0%/year over the projection as a result of their more mature economies and slow or declining population growth trends. The strong projected economic growth rates in the non-OECD drive the fast-paced growth in future energy consumption among those nations.

2.5.1 World energy markets by fuel type

In the long term, the IEO2017 Reference case projects increased world consumption of marketed energy from all fuel sources (except coal, where demand is essentially flat) through 2040 (Fig.2.3). Renewables are the world's fastest-growing energy source, with consumption increasing by an average 2.3%/year. The

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world's second fastest-growing source of energy is nuclear power, with consumption increasing by 1.5%/year over that period.

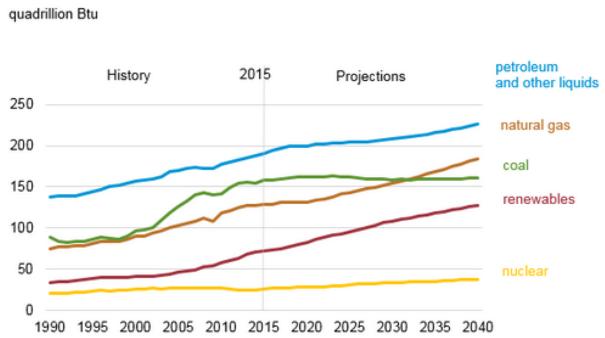

Fig.2.2: World Energy Consumption by Energy Source

Although consumption of non-fossil fuels is expected to grow faster than fossil fuels, fossil fuels still account for 77% of energy use in 2040. Natural gas is the fastest-growing fossil fuel in the projections. Global natural gas consumption increases by 1.4%/year. Abundant natural gas resources and rising production (tight gas, shale gas, and coalbed methane) contribute to the strong competitive position of natural gas. Liquid fuels (mostly petroleum-based) remain the largest source of world energy consumption. However, the liquids share of world marketed energy consumption falls from 33% in 2015 to 31% in 2040, as oil prices rise steadily, causing users to adopt more energy-efficient technologies and to switch away from liquid fuels when feasible.

Compared with the strong growth in coal use in the 2000s, worldwide coal use remains flat in the IEO2017 Reference case. Coal is increasingly replaced by natural gas, renewables, and nuclear power (in the case of China) for electric power generation, and demand for coal also weakens for industrial processes. China is the world's largest consumer of coal, but coal use is projected to decline in China by 0.6%/year, and also in the combined OECD countries by 0.6%/year. With coal consumption in India and other nations in non-OECD Asia growing over the projection period, worldwide coal consumption is not as low as it would otherwise be in 2040. The coal share of total world energy consumption declines significantly over the projection period, from 27% in 2015 to 22% in 2040.

2.5.2 Electricity

In the IEO2017 Reference case, world net electricity generation increases by 45%, rising from 23.4 trillion kWh in 2015 to 34.0 trillion kWh in 2040. Electricity is the world's fastest-growing form of end-use energy consumption, as it has been for many decades. Power systems continue to evolve from isolated, non-competitive grids to integrated national and international markets.

The strongest growth in electricity generation is projected to occur among the developing, non-OECD nations. Increases in electricity generation in non-OECD countries average 1.9%/year as rising living standards increase demand for home appliances and electronic devices, and for commercial services, including hospitals, schools, office buildings, and shopping malls. In OECD nations, where infrastructures are more mature and population growth is relatively slow or declining, electric power generation increases by an average of 1.0%/year from 2015 to 2040 in the IEO2017 Reference case.

Long-term global prospects continue to improve for generation from renewable sources and natural gas (Fig.2.4). Renewables are the fastest-growing source for electricity generation, with average increases of 2.8%/year. Non-hydropower renewable resources are the fastest-growing energy sources for new generation capacity in both the OECD and non-OECD regions. Non-hydropower renewables accounted for 7% of total world generation in 2015; their share in 2040 is 15% in the IEO2017 Reference case, with more than half of the growth coming from wind power. After renewable energy sources, natural gas and nuclear power are the next fastest-growing sources of energy used to generate electricity.

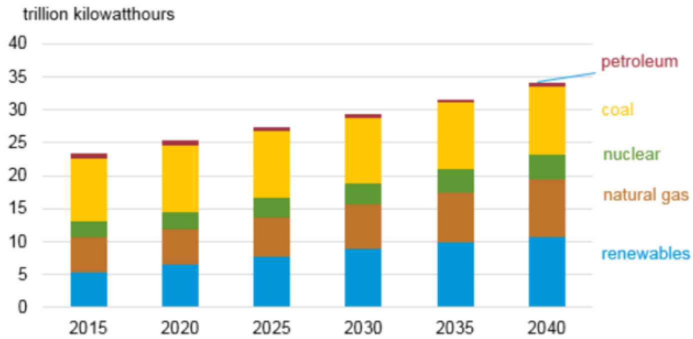

Fig.2.3: World net electricity generation by energy source

Many countries, particularly those in the OECD, have enacted environmental policies and regulations intended to increase the pressure on electric power generators to reduce greenhouse gas emissions from electric power plants by decreasing the use of fossil fuels. As a result, the consistent role of coal as the least expensive fuel for electric power plants will change. Coal-fired net generation increases by 0.4%/year, compared to the 2.8%/year increase in projected renewable generation. By 2040, generation from renewable energy sources surpasses generation from coal on a worldwide basis.

Electricity generation from nuclear power worldwide increases from 2.5 trillion kWh in 2015 to 3.2 trillion kWh in 2030 and to 3.7 trillion kWh in 2040 in the IEO2017 Reference case. Concerns about energy security and greenhouse gas emissions support the development of new nuclear generating capacity, but reactor retirements and opposition from local populations keep nuclear from expanding in many parts of the world. Virtually all of the projected net expansion in world installed nuclear power capacity occurs in non-OECD countries, led by China's addition of 111 gigawatts (GW) of nuclear capacity from 2015 to 2040.

The combined capacity of all OECD nuclear power plants drops by a net 14 GW from 2015 to 2040. Among the OECD regions, only South Korea has a sizable (16 GW) increase in nuclear capacity. Capacity reductions in the United States, Canada, OECD Europe, and Japan (where nuclear capacity in 2040 in the Reference case remains below the total before the March 2011 Fukushima Daiichi nuclear disaster) more than offset the increase in South Korea's nuclear capacity.

2.5.3 World carbon dioxide emissions

World energy-related carbon dioxide (CO_2) emissions rise from 33.9 billion metric tons in 2015 to 36.4 billion metric tons in 2030 and to 39.3 billion metric tons in 2040 in the IEO2017 Reference case (an increase of 16% over that period). Much of the growth in emissions is attributed to developing non-OECD nations, many of which continue to rely on fossil fuels to meet the growth in energy demand. In the IEO2017 Reference case, non-OECD emissions in 2040 total 26.9 billion metric tons, or about 25% higher than the 2015 level. In comparison, OECD emissions remain at about the same level of 12.4 billion metric tons throughout the projection period.

On November 4, 2016, the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement became effective, with signatory parties committing to take actions to keep the rise in the global temperature to less than 2 degrees Celsius above preindustrial levels when fully implemented. Parties to the agreement were asked to submit their first nationally determined contributions (NDCs) that listed the actions they would take to achieve the Paris Agreement goals. NDCs can be adjusted if they are expected to be (in aggregate) insufficient to meet the agreed-upon 2-degree long-term goal. As of September 2017, 155 parties have submitted their NDCs to the UNFCCC.

EIA tried to incorporate some specific details of the NDCs into the IEO2017 Reference case, such as renewable energy and other lower-emitting generation mix goals. However, a great deal of uncertainty remains about the full implementation of policies to meet the stated goals, because most commitments have been made only through 2030, and it is uncertain how they will ultimately achieve these goals. In addition, beyond energy-related CO_2, other gases (e.g., methane) and sources (e.g., deforestation) that contribute to net greenhouse gas (GHG) emissions but are not considered in IEO2017 projections could have significant effects on national or regional shares of total GHG emissions and the achievement of NDCs. In the future, EIA's projections for CO_2 emissions may change significantly as laws and policies aimed at reducing GHG emissions are implemented and enforced, or if existing laws are enhanced.

On June 1, 2017, the United States announced that it would withdraw from the Paris Agreement. However, the primary mechanism for U.S. participation is the Clean Power Plan (CPP), which is still in place, but currently being challenged in court. Even with the CPP, the United States does not meet its NDC targets based on reductions projected from compliance with the CPP alone in the Reference case.

World energy-related CO_2 emissions from the use of liquid fuels and natural gas increase in the IEO2017 Reference case, while coal-related emissions remain largely flat through 2040 (Fig.2.5). CO2 emissions related to the combustion of liquids grow at an annual rate of 0.7% from 2015 to 2040. With the exception of some penetration of electric- and natural gas-powered vehicles, no ready substitutes are available for liquids in the transportation sector, which drives up the demand for liquids. By 2040, the global emissions from liquid fuels are almost the same as those from coal. CO2 emissions from natural gas rises by 1.4%/year from 2015 to 2040, as natural gas increasingly displaces coal for electricity generation.

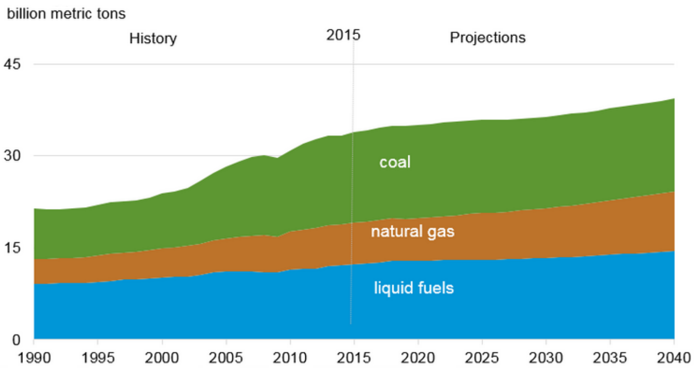

Fig.2.4: World energy-related carbon dioxide emissions by fuel type

2.8 Energy and Buildings

The following information is taken from Ref. 3, Joint Research Centre - the European Commission's in-house science service and Ref. 4, Energy and Buildings - An international journal devoted to investigations of energy use and efficiency in buildings. You are also advised to undertake your own research on this topic.

2.8.1 Energy consumption

About 37% of final energy consumption is taken by the building sector (households and services). A gradual shift over the last five years is observed from fossil fuels to renewable energy sources, such as solar energy, wind power and bio-energy. By means of Directives, Recommendations and Regulations the European Commission is giving direction to the future of sustainable energy use and supporting the low carbon energy policy.

Energy performance of buildings and efficient energy end-use are the important topics of interest. European standardisation facilitates exchange of goods, information and services to ensure a competition in a single European market.

The Energy Performance of Buildings Directive (EPBD 2010/31/EU) concerns the residential and the tertiary sector (offices, public buildings, etc.).

Member states must apply minimum requirements as regards the energy performance of new and existing buildings. A common calculation methodology should include all the aspects which determine the final and primary energy consumption of the building. This integrated approach should consider aspects such as heating and cooling installations, lighting, the position and orientation of the building, heat recovery and the application of renewable energy. The member states are responsible for setting the minimum standards for buildings that are calculated on the basis of the above methodology.

The philosophy that supports the reduction of energy consumption in buildings is presented in three priority steps:

1. Energy saving (improve insulation),

2. Increase energy efficiency (building installations),

3. Use renewable energy resources (solar energy, etc.).

2.8.2 Energy performance of buildings

Energy performance of buildings can be classified in three consumption categories:

Building energy needs (savings): This is directly related to indoor (comfort level of temperature, air quality and light) and outdoor climate conditions (temperature, solar radiation and wind) for working and living in buildings. The heat transfer through the building envelops and the ventilation define importantly the building energy needs. Minimum energy performance requirements are set for insulation levels of walls, roof, floor and windows, etc.

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2.9 Energy and Electric Vehicles

2.9.1 Electrical Vehicles

An electric vehicle (EV), uses one or more electric motors or traction motors for propulsion. An EV may be powered through a collector system by electricity from off-vehicle sources, or may be self-contained with a battery, solar panels or an electric generator to convert fuel to electricity. EVs include road and rail vehicles, surface and underwater vessels, electric aircraft and electric spacecraft.

EVs first came into existence in the mid-19th century, when electricity was among the preferred methods for motor vehicle propulsion, providing a level of comfort and ease of operation that could not be achieved by the petroleum cars of the time. Power, Range, Charging Time and a host of other aspects of EVs, though, were problematic and the internal combustion engine (ICE) has been the dominant propulsion method for motor vehicles for almost 100 years. However, electric power has remained commonplace in other vehicle types, such as trains, trams and smaller vehicles of all types.

In the 21st century, EVs have seen a resurgence due to technological developments and due to climate change forcing an increased focus on renewable energy with governments incentivising adoption.

Electric vehicles do not necessarily reduce the overall amount of energy used, but they do away with onboard generated power from ICEs fitted to vehicles and transfer the problem to the power stations, which can use a wide variety of fuels and where the exhaust emissions can be handled responsibly. Where fossil fuels are burnt for supplying electricity the overall efficiency of supplying energy to the car is not necessarily much better than using a diesel engine or the more modern highly efficient petrol engines. However, there is more flexibility in the choice of fuels at the power stations. Also, some or all the energy can be obtained from alternative energy sources such as hydro, wind or tidal, which would ensure overall zero emission.

2.9.2 Types of Electric Vehicles

Under the basic heading of autonomous wheeled vehicle, there are effectively six basic types of electric vehicle, which may be classed as follows:

- traditional battery electric vehicle (the type that usually springs to mind when people think of electric vehicles.
- the hybrid electric vehicle, which combines a battery and an ICE, is very likely to become the most common type in the years ahead.
- vehicles which use replaceable fuel as the source of energy using either fuel cells or metal air batteries.
- vehicles supplied by power lines.
- electric vehicles which use energy directly from solar radiation.
- vehicles that store energy by alternative means such as flywheels or super capacitors, which are nearly always hybrids using some other source of power as well.

Other vehicles that could be mentioned but don't fall under the banner of "autonomous wheeled vehicle" are railway trains and trams, surface and submarine ships, electric aircraft, and space vehicles.

Battery Electric Vehicles (BEV)

A battery electric vehicle (BEV) is a vehicle that is powered entirely on electric energy, typically a large electric motor and a large battery pack. Based on the type of transmission; the use of a clutch, gearbox, differential, and fixed gearing; and the number of battery packs and motors there are many variations on the BEV design. However, a basic BEV system is shown in Fig.2.6.

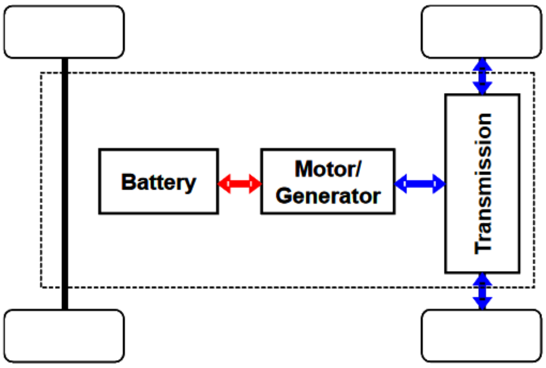

Fig.2.5: Schematic of a battery electric vehicle (BEV) powertrain.

Mild Hybrid Electric Vehicles

Unlike a BEV, a hybrid electric vehicle (HEV) relies on two energy sources, usually an internal combustion engine and an electric battery and motor/generator. A Mild Hybrid is the least electrified type of HEV. A Mild Hybrid is a conventional internal combustion engine (ICE)vehicle with an oversized starter motor that can also be used as a generator, usually called an integrated starter-generator (ISG) or a belted alternator starter (BAS), and an oversized battery that powers and is recharged by the motor. A simple Mild Hybrid system is shown in Fig.2.7. In a Mild Hybrid, the engine must always be on while the vehicle is moving. However, the motor/generator can be used to enable idle stop in which the engine is turned off while the vehicle is at idle. The motor/generator can be used at high loads to assist the engine and increase vehicle performance. At low loads, it increases load on the engine and recharges the electric battery.

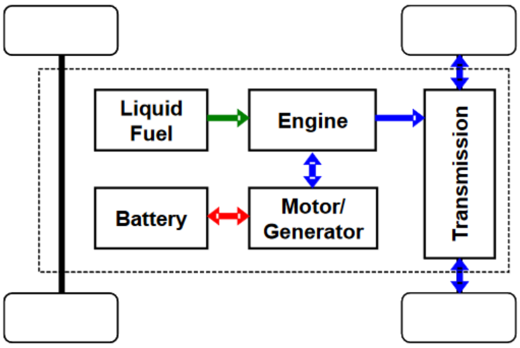

Fig.2.6: Schematic of a Mild Hybrid powertrain

Series Hybrid Electric Vehicles

In a Series Hybrid there is a single path to power the wheels of the vehicle, but two energy sources. As shown in Fig.2.8, the fuel tank feeds an engine which is coupled to a generator to charge the battery which provides electrical energy to a motor/generator to power the wheels through a transmission although a direct coupling can also be used. The motor/generator is also used to recharge the battery during deceleration and braking.

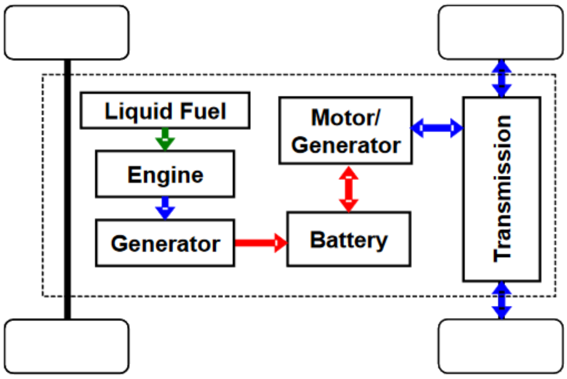

Fig.2.7: Schematic of a Series Hybrid powertrain

The Series Hybrid can operate in the following seven modes:

1. Engine only traction
2. Electric only traction
3. Hybrid traction
4. Engine Traction and Battery Charging
5. Battery Charging and No Traction
6. Regenerative Braking
7. Hybrid Battery Changing

Although most Series Hybrids use an ICE, it is also possible to design a Series Hybrid using a Fuel Cell powered by hydrogen, creating a Fuel Cell Electric Vehicle (FCEV).

Parallel Hybrid Electric Vehicles

In a Parallel Hybrid, there are two parallel paths to power the wheels of the vehicle: an engine path and an electrical path, as shown in Fig.2.9. The transmission couples the motor/generator and the engine, allowing either, or both, to power the wheels. Control of a Parallel Hybrid is much more complex than that for a Series Hybrid because of the need to efficiently couple the motor/generator and engine in a way that maintains driveability and performance.

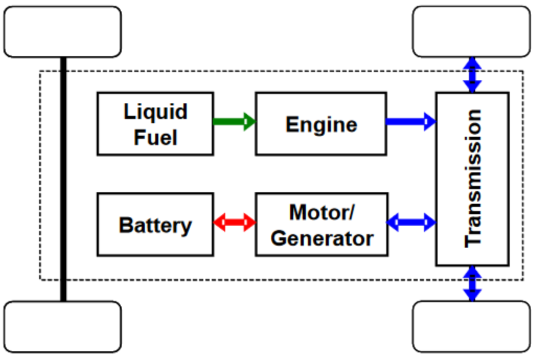

Fig.2.8: Schematic of a parallel hybrid powertrain