Energy Flows and Energy Cycle _
From Resources to End Users

Mirjana Miletić[1*] and Nebojša Arsić[2]

* Corresponding Author
1 Faculty of Technical Sciences, University in Kosovska Mitrovica, Kosovo*, mirjana.miletic@pr.ac.rs
2 Faculty of Technical Sciences, University in Kosovska Mitrovica, Kosovo*, nebojsa.arsic@pr.ac.rs

ABSTRACT **Energy resources are classified as renewable and non-renewable. Renewable energy sources include wind, solar, and hydro energy; while Non-renewable energies include nuclear fission materials and fossil fuels. Renewable and Non-renewable energies are regarded as primary energy sources that supply energy straight from raw fuels. The increasing price of oil constantly reminds us of the fact that all resources, except renewable ones, are depleting. Prices of energy will constantly increase, while energy reserves will weaken. It is well known that the efficient use of energy and resources is a fast and painless way of reducing energy costs and decreasing adverse impacts on the environment. There is huge pressure from the public and governments to act in a socially responsible way and to use resources efficiently. Special attention should be paid to energy use in buildings, keeping in mind that these man-made structures are one of the biggest energy consumers. The building sector uses 40% of all primary energy worldwide. Because of that, and the emphasis on efficient energy use there must be changes in this energy sector, by implementation of various energy efficiency strategies. This paper, basically divided in two parts, gives an overview about all forms of energies based on level of transformation, energy cycle from resources to end users, and basics of the energy balance of buildings.**

KEYWORDS resources, energy flow, transformation, energy balance of buildings

1 Introduction

The introduction gives an overview of forms of energies based on the level of transformation and the definitions, with the aim to better understand the whole process of energy flow from resources to end users.

Energy, as generally understood, is a system's capacity to work. Energies exist in various forms like heat, motion, or light. All of these forms of energy can be divided in two categories: kinetic energy or energy of motion, and potential energy or energy stored in mass.

Energy holds the capacity of changing from one form to another. Potential energy has the ability to transform into energy of motion or kinetic energy, while kinetic energy goes to sound or sonic energy.

All of these energy transformations are necessary to create commercial energy.

In order to explain the forms of transformation, we consider a coal-fired power plant. Chemical energy is stored in the coal, which is transformed into heat energy by combustion. Heat transforms water into steam and creates energy of motion. Flowing steam spins a generator's turbine, which changes mechanical into electrical energy. The power system transforms energy to useful work. Some of the energy is wasted during the process. With regard to energy efficiency, the value goes from 0% to 100%. Besides the useful energy, part of the energy that is supplied to a used system is lost: this is non-useful energy (Fanchi, 2011).

An overview of mentioned energies and their hierarchy is given in the diagram below.

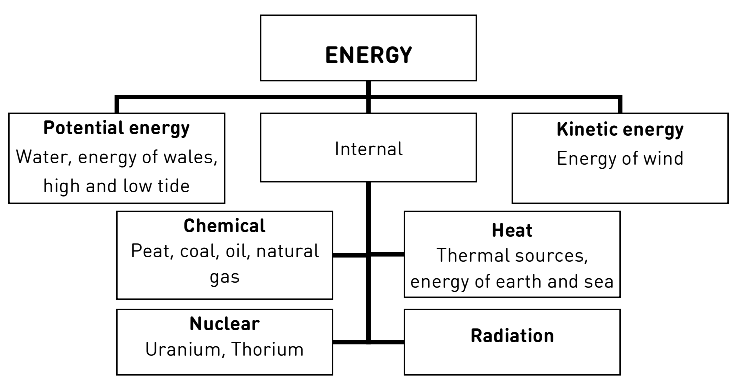

FIG. 1.1 Energies *(Todorovic, 2014)* *(Image by Authors)*

Embodied energy, generally referred to by the term primary energy, represents all of the energy needed to produce a product, which may or may not include the feedstock energy, as heat of burning of raw material inputs to a system. "Operating energy is the energy used in buildings during their operational phase, as for: heating, cooling, ventilation, hot water, lighting and other electrical appliances. It might be expressed either in terms of end-use or primary energy" (Sartori & Hestnes, 2007, p.249). Total energy is represented as the sum of all of the energy that a building use in its lifetime, which means the sum of embodied and operating energy, multiplied by lifecycle. Different user groups like households or industries are using various energy products. That final, useful energy is the energy that consumers are buying for their activities. Industry as well as households uses final energy for heat, lighting, cooling or transport.

In the aim of understanding the life cycle of energy there is a need to define energy flow. The term "energy flow refers to the production, import, export, bunkering, stock changes, transformation, and energy use by energy industries, losses during the transformation, and final consumption of energy products" (IRES, 2016, p.68). When the energy is produced transformed products can be exported, stored for later use, consumed by industries or delivered for final consumption, to different users for heating, cooling, transportation or electricity.

2 Energies Based on Level of Transformation

Two types of energy production exist; primary and secondary. Primary energy sources are "sources found in their natural state" (IRES, 2016, p.21). Primary energy is the energy from renewable and non-renewable sources that has not undergone any transformation process. Secondary energy is obtained from primary energy through transformation process and represents primary energy reduced due to conversion losses (e.g. electrical energy produced in thermal power plants by fuel combustion) (Stojiljkovic, 2014).

Basically, all energy sources can be divided in two categories as renewable and non-renewable. Non-renewable energy sources are fossil fuels and nuclear fission materials; these are sources which are not replenishing like renewable energies, like solar or wind energy, sources that are constantly renewing (Fanchi, 2013).

An overview of forms of energies based on the level of transformation is shown in Fig. 2.1.

The constant increase of energy consumption in all its forms, and the level of transformation, from primary to final energy, raised concern about energy supply, exhaustion of its resources, and the unavoidable environmental impacts like ozone layer depletion, climate change or global warming.

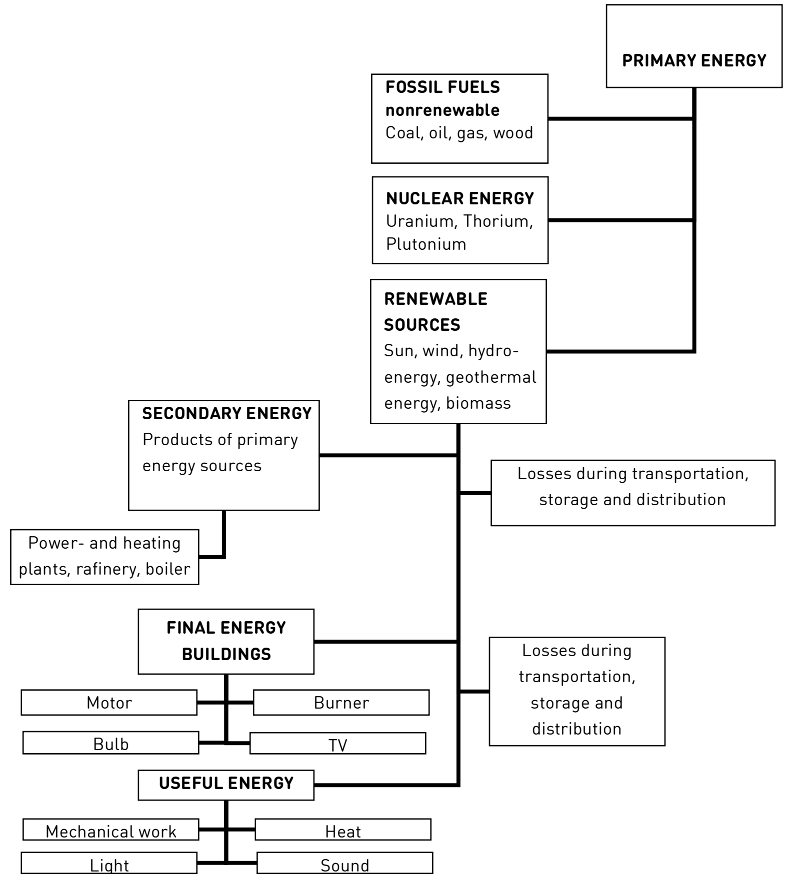

FIG. 2.1 Energy from resources to end users, based on lecturing of professor Milos Banjac, Mechanical Faculty, Belgrade *(Image by Authors)*

The International Energy Agency (IEA) is gathering data about energy consumption worldwide. The observed trend is quite frightening and shows that in the period from 1984 to 2000 primary energy grew by almost 50% and CO_2 emissions by 45%, with an increase of 2% per year respectively. Current predictions show that this trend will continue growing. Basic indicators of the mentioned trend are shown in Table 1.1.

PARAMETER	1973	2004	RATIO %
Population (millions)	3938	6352	61,3
Primary Energy (Mtoe)	6034	11059	83,3
Final energy (Mtoe)	4606	7644	66,0
Electrical energy (Mtoe)	525	1374	161,8

TABLE 2.1 Evaluation of global energy growth from 1973 up to the end of the twentieth century (Lombard, Ortiz, & Pout, 2008)

The primary energy unit is 'toe' (tonnes of oil equivalent). Based on conversion factor 'toe' can be turned into 1 toe= 41868MJ= 11630kWh= 11,63MWh

Primary energy consumption grows at a higher level than population growth. It is noticeable that electricity consumption has drastically risen, more than two and a half times with 18% by 2000 in the final energy consumption (Lombard, Ortiz & Pout, 2008).

Primary energy

As mentioned, primary energy sources are sources found in their natural state and can be divided in two categories: Non-renewable and renewable.

Non-renewable energy sources

Non-renewable energy sources supply almost 85% of the total energy demand. They include fossil fuels, coal and peat, natural gas, and petroleum (US EIA, 2012).

Fossil energy- coal and peat

Coal is a solid fossil fuel that can be created by algae, phytoplankton, and zooplankton in the process of coalification. It can be also formed by plants and animals. Coal is classified by ranking, which presents the degree of coalification of carbonaceous material. The lowest rank is lignite, followed by bituminous coal, anthracite and graphite (Fanchi, 2013).

There exist two categories of primary coal: hard coal and brown coal. The table shows coal categories, subcategories, and their utilisation.

<table>
<tr><th colspan="5">FOSSIL FUEL- COAL</th></tr>
<tr><th colspan="3">Hard coal
(GCV less 24MJ/kg, Rr greater than 0.6)</th><th colspan="2">Brown coal
(GCV less 24MJ/kg, Rr less than 0.6)</th></tr>
<tr><td rowspan="2">Anthracite
Can be used for industrial and household heat boost</td><td colspan="2">Bituminous coal
industrial coking
household heat raising</td><td rowspan="2">Sub bituminous coal
used primarily as fuel for steam-electric power generation.</td><td rowspan="2">Lignite
used exclusively as a fuel for steam-electric power generation</td></tr>
<tr><td>Coking coal
the production of a coke for support a blast furnace charge.</td><td>Steam coal</td></tr>
</table>

TABLE 2.2 Coal categories and utilisation *(IRES, 2016)*

GCV Gross Caloric Value / Rr Vitrinite mean Random Reflectance per cent

Consumption of coal as primary energy by sector and source is presented in the figure below.

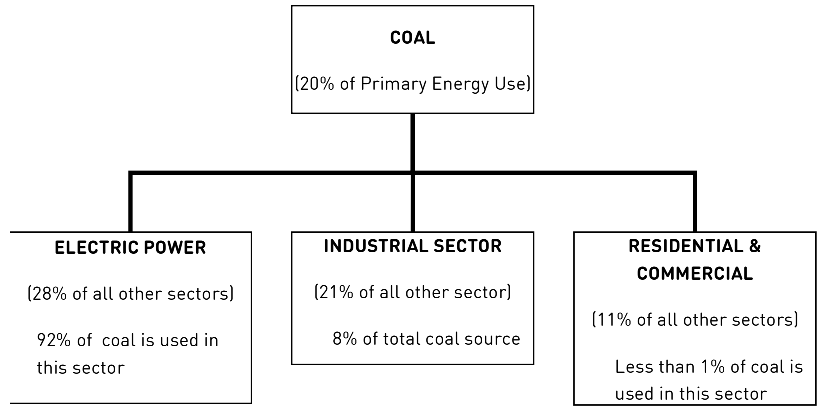

FIG. 2.2 Primary Energy Consumption: Coal, by Source and Sector, 2011, based on data retrieved from https://www.eia.gov/totalenergy/data/annual/pdf/sec2_3.pdf *(Image by Authors)*

Partial decomposition of dead vegetation in high humidity, at the early stage of coalification creates a solid form of peat. The reason why peat is not considered as a renewable source is that its regeneration period is very long. Milled peat and sod peat are two forms of peat available to be used as a fuel.Milled peat can be used in power stations and for manufacture of briquette (IRES, 2016).

Fossil energy- oil and gas

"Oil and gas are terms that refer to mixtures of hydrocarbon molecules in the liquid phase and gas phase, respectively. Crude oil is a mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through facilities on the surface that separate gas and liquid" (Fanchi, 2013, p. 49).

Crude oil, after refining, is used in the transportation sector as fuel for generation of electric power, and as a fuel in the commercial, industrial, and residential sectors. There are conventional and unconventional oils and gas. Unconventional oil refers to hydrocarbon production from shale oil and tar sands, while unconventional gas refers to coal gas, tight gas, and shale gas. The main difference between the two is the ability of the fluid to flow through rock (US EIA, 2012).

Oil shale or oil sand is a sedimentary rock that contains kerogen, waxy hydrocarbon material regarded as a predecessor to petroleum. Petroleum is a naturally occurring mixture that consists of hydrocarbons in the gaseous, liquid, or solid phase (UNECE, 2004).

An overview of petroleum use in different sectors is given in the diagram below with the remark that this primary energy source, as accounted for in the statistical energy balance, is given before any transformation to secondary or tertiary forms of energy.

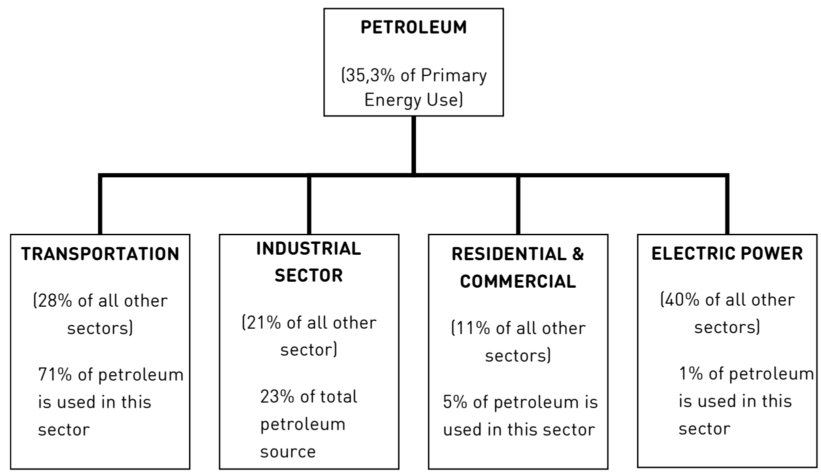

FIG. 2.3 Primary Energy Consumption: Petroleum, by Source and Sector, 2011, based on data retrieved from https://www.eia.gov/totalenergy/data/annual/pdf/sec2_3.pdf *(Image by Authors)*

Natural gas represents a mixture of gaseous hydrocarbons; methane, ethane, propane and nitrogen and carbon dioxide as non-combustible gases (IRES, 2016).

Conventional crude oil, in liquid phase, exists under normal surface pressure and temperature and usually flows to the surface under pressure from the natural reservoir.

An overview of the use of natural gas in different sectors is given in the diagram below.

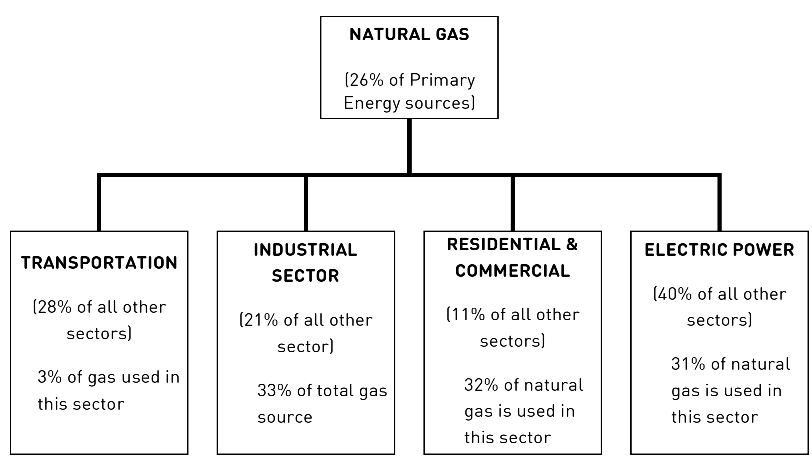

FIG. 2.4 Primary Energy Consumption: Natural Gas, by Source and Sector, 2011, based on data retrieved from US EIA 2011, https://www.eia.gov/totalenergy/data/annual/pdf/sec2_3.pdf *(Image by Authors)*

Nuclear energy

The dominant energy source in the 20th century was fossil fuels. Considering the fact that the supply of fossil fuels is limited, and the fact that the combustion of these fuels is creating greenhouse gases, there is a motive to search for and use other sources of energy. The energy source that is interesting for researchers in this context is nuclear fission energy. Energy is obtained from two types of reaction: fission and fusion.[1] Nuclear fusion is considered to be the technology of the future.

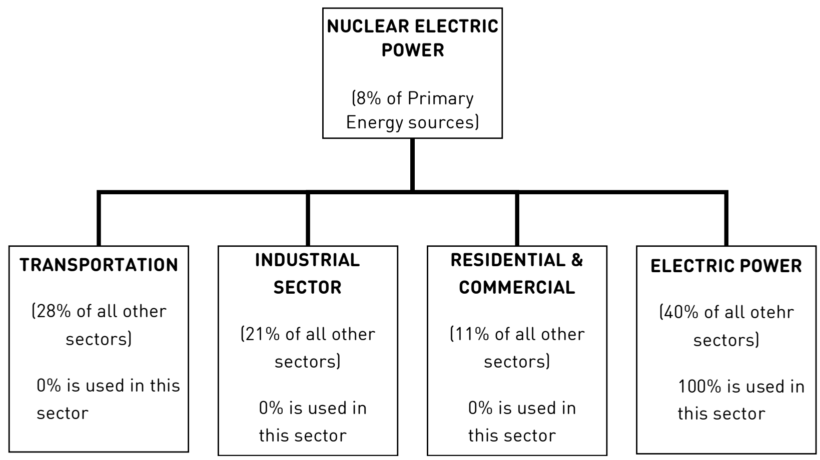

FIG. 2.5 Primary Energy Consumption: Nuclear Energy, by Source and Sector, 2011, based on data retrieved from US EIA, 2011, https://www.eia.gov/totalenergy/data/annual/pdf/sec2_3.pdf *(Image by Authors)*

Uranium is the most plentiful fuel for nuclear fission. In the earth it exists as mineral uraninite or uranium oxide (U_3O_8), that can be found in sedimentary rocks. Uranium is obtained from the mineral uraninite in the mining process. Uranium is considered as a non-renewable energy resource as it exists in a limited volume in the earth. Other fuels that can be used are plutonium and thorium. All three can be used in nuclear reactors, as sources to produce heat and electricity (Fanchi, 2013).

Nuclear energy consumption by source and sectors is shown in Fig. 2.5.

1 Fission is the splitting of one large nucleus into two smaller nuclei; fusion is the joining of two small nuclei into one larger nucleus.

Renewable energy sources (RES)

Renewable energy sources (RES) supply almost 14% of total energy demand. RES includes hydropower, geothermal, biomass, solar, wind, and marine energies. "Renewable energy sources are those resources which can be used to produce energy again and again, e.g. solar energy, wind energy, biomass energy, geothermal energy, etc. and are also often called alternative sources of energy. Renewable energy sources that meet domestic energy requirements have the potential to provide energy services with zero or almost zero emissions of both air pollutants and greenhouse gases." (Panwar, Kaushik, & Kothari, 2011, p.1514.)

An overview of RES use by sectors is given in the diagram below.

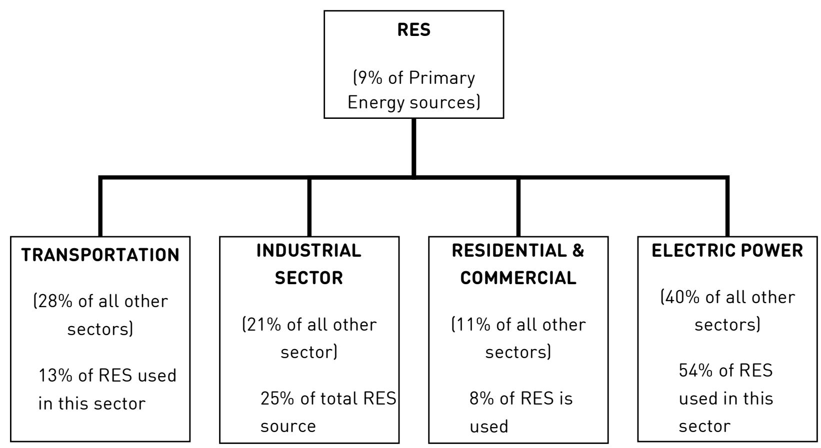

FIG. 2.6 Primary Energy Consumption, RES, by Source and Sector, 2011, based on data retrieved from US EIA 2011, https://www.eia.gov/totalenergy/data/annual/pdf/sec2_3.pdf *(Image by Authors)*

Solar energy

"Renewable is a misnomer when talking about solar energy. Solar energy is provided by the Sun from nuclear fusion reaction. The nuclear fusion process in the Sun consumes isotopes of hydrogen to form helium and release energy" (Fanchi, 2013, p.133). In some time, the fuel for nuclear fusion will be exhausted. However, the remaining time of the Sun is expected to be billions of years and therefore many people consider solar energy to be inexhaustible. The fact is that solar energy is limited but available for many future generations. In spite of the nature of solar energy, without the Sun there is no life on Earth and that is why the general comprehension is that solar energy is renewable.

Around 35% of the light from the Sun doesn't reach Earth because of the clouds, atmosphere and reflection from the Earth's surface.

Whilst fossil and nuclear energy provide energy on demand, RES, like wind and solar, are considered as intermittent energy sources because of their availability. Solar energy relies on access to sunlight, which is not always available and never available during the night, just as wind energy also depends on weather conditions.

FIG. 2.7 Solar power plant *(Photograph by MTI, retrieved from https://dailynewshungary.com/hungary-solar-power-capacity-reach-2100-mw-end-2018/*

FIG. 2.8 Wind turbine *(Image retrieved from https://cleantechnica.com/2014/04/21/real-innovation-wind-energy/)*

Solar power plants

Solar power plants are designed to provide electrical power in the same way as plants that rely on nuclear or fossil fuel. They use reflective materials like mirrors to concentrate solar energy.

Wind energy

Air motion, wind, is caused by a difference in air pressure. The kinetic energy of moving air is considered to be renewable. Wind turbines convert the mechanical energy of rotating blades into electrical energy with a generator. Converted energy is transmitted through a line that connects the wind turbines to the electric grid with a generator that produces electricity directed to an electric grid.

Energy from water

Water as a renewable energy source makes an important contribution to worldwide energy consumption. "The water cycle is a global cycle of moving water. Water evaporates from lakes and oceans and rises into the atmosphere, where it coalesces into clouds. Clouds can move over all parts of the earth until atmospheric pressure and temperature changes lead to water precipitation in the form of rain or snow. Some of the precipitated water seeps into the earth as groundwater, and some flows along rivers and streams back to lakes and oceans, where the water cycle begins again. The hydrosphere includes groundwater and water found in oceans, glaciers, surface waters such as rivers and lakes, and atmospheric moisture" (Fanchi, 2013, p.183).

Hydroelectric power is an example of the creation of energy from moving water. The movement of water and its temperature gradients are used for providing energy.

A scheme of work of a hydroelectric power plant is presented in Fig 2.9.

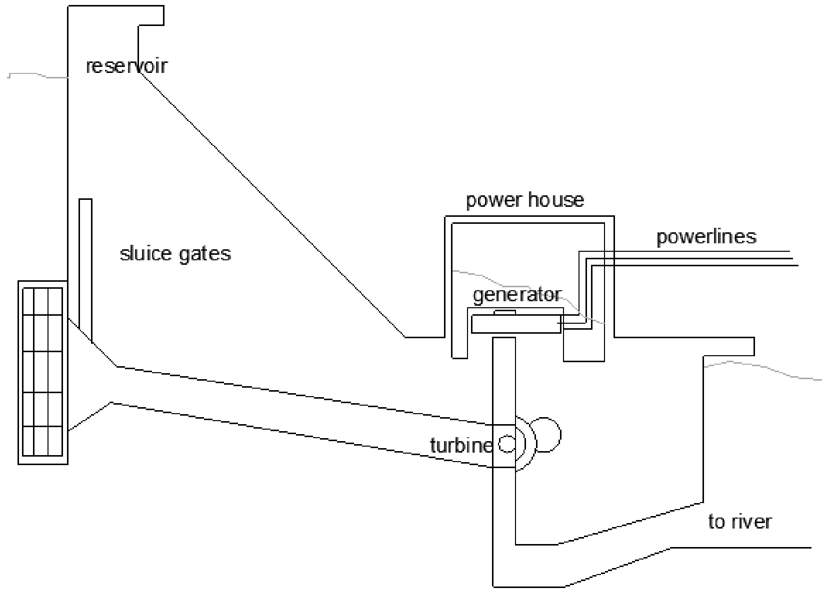

FIG. 2.9 Hydroelectric power plant, based on data retrieved from http://www.tutorvista.com/content/science/science-ii/sources-energy/hydro-electric-power.php *(Image by Authors)*

Energy from waves and tides

While renewable energy research is focused on the development of solar, wind, and biomass sources, it is important to keep in mind the massive energy stored in oceans. The benefit of the creation of a system of energy consumption from the waves or tides derives from the fact that much of the infrastructure already exists due to the role of the oil industry. The process of energy transformation in the oceans is as follows: "Ocean thermal energy conversion produces electricity from the natural thermal gradient of the ocean, using the heat stored in warm surface water to create steam to drive a turbine, while pumping cold, deep water to the surface to re-condense the steam. In closed-cycle warm seawater heats a working fluid with a low boiling point, such as ammonia, and the ammonia vapor turns a turbine, which drives a generator" (Pelc & Fujita, 2002, p. 473.).

In total, it is estimated that about 10 TW (10 trillion W or 10 billion kW) of power, can be provided by the conversion of ocean thermal energy without affecting the thermal structure of the ocean (Pelc & Fujita, 2002).

Bioenergy and synfuels

Biomass includes wood and other plants or animal substances, that can be burned directly or converted to fuels. During combustion, biomass is transformed into useful energy. There are technologies that convert animal dung, plant garbage, and municipal solid waste into natural gas. An example of energy conversion from biomass is the production of gas from organic waste in landfills.

Biofuels are derived directly from biomass. The table shows the current categories and utilisation of biofuels.

TOC

BIOFUELS

Solid biofuels				
Wood- fuel Wood pellets used as fuel	**Bagasse** From fibre after juice extraction	**Animal waste** When dry used directly as a fuel	**Black liquor** For pulping process	**Charcoal** As fuel for transport, electricity or stationary engines
Liquid biofuels				
Bio gasoline Blended with petroleum and used directly in engines		**Biodiesels** Used for diesel engines		**Biojet kerosene** Replacing jet kerosene
Bio gasses				
From anaerobic fermentation To be processed to remove carbon dioxide		**From thermal processes** Produce substitute natural gas		

TABLE 2.3 Biofuels and their uses, based on IRES, 2016*(Image by Authors)*

Geothermal energy

Heat from the earth is geothermal energy. Sources of geothermal energy can be from shallow ground to hot rock and water found miles under the Earth's surface and even deeper to magma (molten rock). Hot dry rock resources occur at the depth of 3 to 5 miles beneath the Earth's surface. Shallow ground maintains a constant temperature of 10°C to 16°C. Geothermal pumps can tap into the source to heat and cool buildings. "A geothermal heat pump system consists of a heat pump, an air delivery system (ductwork), and a heat exchanger- a system of pipes buried in the shallow ground near the building. In the winter, the heat pump removes heat from the heat exchanger and pumps it into the indoor air delivery system. In the summer, the process is reversed, and the heat pump moves heat from the indoor air into the heat exchanger. The heat removed from the indoor air during the summer can also be used to provide a free source of hot water" (Geothermal Energy Association, 2016).

Geothermal electricity production that generates electricity from the Earth's heat is one of the existing geothermal energy technologies. Besides this, there is geothermal direct use, which takes heat directly from the hot water in the earth. A final existing geothermal energy technology is the geothermal heat pump that uses heat from shallow ground for heating and cooling buildings.

2.1 Secondary Energy

The first law of thermodynamics states that "Energy can neither be created nor destroyed." In other words, it just changes from one form to another.

"Energy transformation is any process of transforming energy. Energy of fossil fuels, solar radiation, or nuclear fuels, which are all primary, can be converted into other energy forms such as electricity and heat that are more useful to us. All energy that has been subjected to human-made transformation is secondary energy" (Overgaard, 2008, p.5.).

The classification of primary energies and their conversion into secondary energies is provided in Table 2.4.

	Primary	Secondary
NON-RENEWABLE	– Hard coal – Brown coal	– Coal products
	– Peat	– Peat products
	– Oil shale – Natural gas	– Manufactured solid fuels and gases
	– Conventional crude oil – NGL – Additives and oxygenates	– Refinery feedstock – Petroleum products
	– Industrial and municipal waste – Nuclear and Heat from chemical processes	– Electricity and heat from combusted fuels of fossil origin – Electricity from nuclear heat, chemical processes – Any other product derived from primary/secondary non-renewable products
RENEWABLE	– Biofuels (except charcoal) – Municipal waste – Heat from renewable sources, except from combusted biofuels – Electricity from renewable sources, but not from geothermal, solar thermal or combusted biofuels	– Charcoal – Electricity and heat from combusted biofuels – Electricity from geothermal and solar thermal

TABLE 2.4 Classification of energy products, primary energy and their conversion in secondary energy *(IRES, 2016, p.178)*

Coal products

Coal products are derived either directly or indirectly from different classes of coal, through carbonisation or pyrolysis processes. All of the coal products and their uses are given in Table 2.5.

	Coal product	Products of the product	Use
COAL PRODUCTS	**Coal coke**	Coke oven coke	Heat source in Iron and steel industry
		Gas coke	For heating purposes
		Coke breeze	Residue from screening coke
		Semi cokes	Used as heating fuel
	Patent fuel	Hard coal briquettes	Possible substitute for wood fuel
	Brown coal briquette (BKB)		Composition fuel
	Coal Tar, LCD		Medical and industrial
	Coke oven gas		To produce coal coke
	Gas works gas		
	Recovered gas	Blast furnace gas	As fuel and to heat blast air
		Oxygen steel furnace gas	Industry
		Other recovered gases	

TABLE 2.5 Coal products and their use *(IRES, 2016, p.35-38)*

Peat products

Peat products are derived from sod peat and milled peat. Peat products comprise peat briquettes that are used mainly as household fuel and other peat products such as peat pellets.

Oil products

Oil products are obtained from crude oil, gases from oil, or gas fields. Production is done through the refining of crude oil or during separation process of natural gas (IRES, 2016, p. 39-45.).

An overview of oil products and their use is shown in the Table 2.6.

	Oil product	Products of the oil product	Use
OIL PRODUCTS	**Refinery gas**		Mainly use as a fuel in refinery
	Ethane		Feedstock for petrochemical manufacture
	Liquid petroleum gases LPG		Used for heating and as vehicle fuel
	Naphtha		Manufacture of olefins in petrochemical industry
	Gasolines	Aviation	For aviation piston engines
		Motor gasoline	For motors
		Gasoline type jet fuel	Aviation turbine fuel
	Kerosines	Type jet fuel	As jet fuels
	Gas oil	Diesel oil	For diesel engines
		Heavy gas oil	Gas oil and fuel
		Fuel oil	Industrial fuel oil
	Other oil products	Lubricants, paraffin waxes, bitumen…	

TABLE 2.6 Oil products and their use *(IRES, 2016)*

Waste

Waste means material that is no longer required by its holders, and, in general comprises municipal and industrial waste. Industrial waste often consists of used tires or special residues from chemical industry, while municipal waste is collected at facilities for waste disposal with a system of recovery for liquids, gases, or heat.

Nuclear fuels

Nuclear fuels like uranium, thorium, plutonium, and their products, can be used in nuclear reactors for electricity and heat production.

Other than the afore mentioned non-renewable primary energies and their transformation to secondary energies, there also exist renewable primary energy sources whose conversions are given in the following chapter.

Biofuels

Biofuels are derived directly or indirectly from biomass.

	Biofuels	Categories	Subcategories	Use
BIOFUELS	**Solid biofuels**	Wood fuel	Wood pellets	As fuel
			Wood residues and by products	As fuel
		Bagasse		Fuel
		Animal waste		Directly as fuel
		Black liquor		Fuel in pulping process
		Charcoal		Fuel
	Liquid biofuels	Biogasoline	For transport and electricity	
		Biodiesel		
		Biojet kerosine		
	Biogases	Biogases from anaerobic fermentation	As fuel	
		Landfill gas		
		Sewage sludge gas		

TABLE 2.7 Biofuels, products of biomass *(IRES, 2016)*

TOC

There are three categories of biofuels defined based on physical state of the material: solid, liquid biofuels, and biogases. Biofuels are presented in Table 2.7.

2.2 Concept of Energy Flow

The term "energy flow" refers to the production, bunkering, transformation, import, export, use of energy by industries, and losses during the transformation processes, to the final consumption of energy products.

Energy production is of major importance in the energy flow process, and can be primary and secondary. Primary refers to the extraction of energy from natural energy flows whilst secondary refers to the manufacture of energy products through the process of transformation of other energies.

ENERGY INDUSTRY	MANUFACTURE PROCESS
Electricity, CHP and heat plants	Electricity, steam and air conditioning supply
Pumped storage plants	
Coal mines	Coal and lignite
Coke ovens	Coke oven products
Coal liquefaction plants	Refined petroleum products
Patent fuel plants	Refined petroleum products
Brown coal briquette plants	Refined petroleum products
Gas works	Gas, distribution of gaseous fuels
Gas separation plants	Crude petroleum and natural gas
Gas to liquid plants GTL	Refined petroleum products
LNG plants	Support of petroleum and natural gas extraction
Blast furnaces	Of basic iron and steel
Oil and gas extraction	Crude petroleum and natural gas
Oil refineries	Refined petroleum products
Charcoal plants	Manufacture of basic chemicals
Biogas production	Gas
Nuclear fuel extraction and fuel processing	Uranium and thorium ores
Other energy industry	Extraction of peat

TABLE 2.8 Energy industries with their main activities *(IRES, 2016)*

After production, energy, or part of it moves to one or more different energy products (like heavy fuel oil to electricity). The process is called transformation of energy, and is identified by the plants in which it occurs: electricity plants, CHP plants, heat plants, coke ovens etc. Besides transformation, there is a need to define losses as a very important part of the energy flow concept. Losses merge during the distribution, transmission, and transport of fuels, heat, and electricity. The energy that is extracted, produced, transformed and distributed with the losses in the process of the flow results in what is called final consumption, or- useful energy.

TOC

Final consumption refers to all fuels and energy that is delivered to the final consumers, or end users.

Energy industries are involved in primary production, distribution, and transformation of energy products. Industries and their basic activities are listed in the Table 2.8.

Electricity and heat

Electricity is defined as "transfer of energy through the physical phenomena involving electric charges and their effects when at rest and in motion" (IRES, 2016, p.49). It can be generated within the generating plants in different processes like conversion of energy of falling water, wind or waves, by combustion of fuels or through photovoltaic process.

There are three types of generating plants:

- Electricity plants that only produce electricity that can be obtained from geothermal, wind, hydro, tidal, solar energy, or from nuclear reactions.
- Combined Heat and Power (CHP) plants that produce heat and electricity.
- Heat plants that produce heat only.

Heat is "energy obtained from the transitional, rotational and vibrational motion of the constituents matter, as well as changes in its physical state. Heat can be produced by different production processes" (IRES, 2016, p. 50).

An overview of the electricity and heat that can be generated through different technologies is given in Table 2.9.

PRODUCTION	
Electricity	
Solar PV electricity	from solar photovoltaics
Solar thermal electricity	from solar heat
Wind electricity	from devices propelled by wind
Hydro electricity	by devices propelled by falling water
Wave electricity	by devises driven by motion of waves
Tidal electricity	by devices driven by tidal motion
Geothermal electricity	Generated from the heat from geothermal sources
Nuclear electricity	Generated from nuclear heat
Heat	
Solar heat	Generation of heat from solar thermal
Geothermal heat	Heat extracted from earth
Nuclear heat	Obtained from the nuclear reactor fluid
Heat from combustible fuels	Combustion of fuels, same for electricity
Heat from chemical processes	Generated in Chemical Industry

TABLE 2.9 Types of technologies for generation of heat and electricity

2.3 Final Energy

The term itself refers to the use of services and goods by individual households in order to satisfy individual and collective needs.

Final energy use is divided into three categories: industry, transport, and other. The *other* category includes agriculture, services, and residential buildings. Services refers to all commercial buildings and energy services within them, including HVAC, and food preparation. Buildings, both domestic and nondomestic, account for up to 40% of the total energy consumption. "Growth in population, enhancement of building services and comfort levels, together with the increment of time spent inside buildings, has raised building energy consumption to the levels of transport and industry." Industry accounted for 39% of total energy use at the end of twentieth century, transport 25%, and other sectors for 36% of total energy use. The situation is different nowadays (Table 2.10.). The growth in population caused an increased demand of services like health, education, culture, and the energy consumption within them, at the rate of 2% per annum worldwide (Lombard, Ortiz, & Pout, 2008, p. 395.).

SECTOR	FINAL ENERGY CONSUMPTION %
Industry	30
Transport	28
Other sectors	42

TABLE 2.10 Final energy consumption by sectors worldwide *(Lombard, Ortiz, & Pout, 2008)*

3 Basics of Energy Balance of Buildings

The building sector is responsible for 16–50% of the energy consumption in the world, compared to the consumption by all other sectors, which averages approximately 40% worldwide (Swan & Ugursal, 2009). Energy consumption in buildings significantly differs based on location, area, and applied structural materials. It consists of thermal energy used for space heating and hot water, and electrical energy for air conditioning, cooling, ventilation, equipment, and lighting.

Conventional buildings are those that are built according to the common practice of a specific country in a specific period. These buildings use 200-300 kWh/m^2 of heating energy while low energy houses consume 40 kWh/m^2 and passive houses 15 kWh/m^2 or less (Sartori & Hestnes, 2007). In developed countries, energy saving is of very high priority. In the process of design and construction, the adaptation of suitable parameters such as building orientation, shape, envelope system, mechanisms of passive heating and cooling, as well as shading and glazing, are vital in energy saving. However, in existing buildings where it is impossible to change the most important parameters,

TOC

energy efficient retrofitting measures should be highly implemented (Pacheco, Ordonez, & Martinez, 2012).

The focus is placed on the thermal envelope of the buildings where different passive and active features can be applied. The structure's thermal envelope refers to its elements that are in contact with the outside air – these are the elements by which the heated and the unheated spaces are separated: transparent and non-transparent parts. The transparent elements are the windows, patio doors, front doors, and storefronts, while the exterior walls are considered the non-transparent parts of the facade assembly. The transparent elements account for the highest percentage of heat energy losses; 40% of energy is lost through standard façade doors and windows, which, therefore, need to receive special attention (Miletic, 2014).

In one conventional residential house, ventilation and transition losses through transparent parts of the building are up to 51%, internal gains account for 6%, and solar gains 12% while losses through the heating system are 12% (Stojiljkovic, 2014). Such losses show the potentials for energy saving, and for the implementation of energy efficiency measures. It is known that 40% of all primary energy is used for buildings, and in adition, that through architectural retrofitting it is possible to achieve a 60% saving in heating energy (Asif, Muneer, & Kelley, 2007).

Heat losses during the heating period for the conventional residential house are shown in Fig. 3.1.

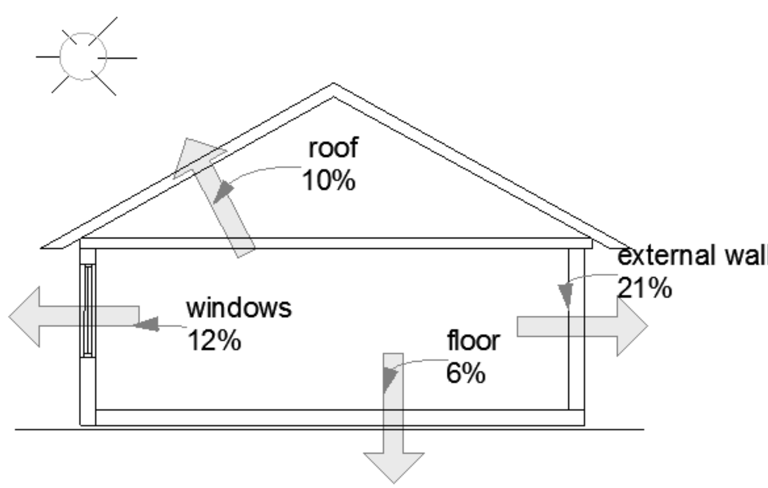

FIG. 3.1 Heat losses during the heating period of residential house *(Image by Authors)*

3.1 Passive Retrofitting Interventions

Some of the technologies that enable the capture of solar energy are passive features. Passive technologies do not use mechanical devices. Simple passive systems are roof overhangs (shades) and thermal insulation. One of the ways of controlling direct solar heating in buildings with transparent sections of the façade is the construction of roof overhangs.

Thermal insulation installed in walls can keep heat out of a structure during the summer and keep heat inside the room during the winter period, thus demonstrating another passive technology. This strategy reduces the demand of total energy use in the observed structure.

This passive measure of energy saving applies of thermal insulation to the non-transparent parts of the thermal envelope. The thermal insulation can be found in different physical forms, such as (Sadineni, Madala, & Boehmn, 2011):

- Mineral fibre blankets (such as fiberglass and rock wool);
- Poured-in with concrete (cellulose, perlite, vermiculite);
- Loose fill, which can be blown-in (fiberglass, rock wool);
- Rigid boards (polyisocyanurate, polystyrene, polyurethane and fiberglass);
- Boards or blocks (vermiculite and perlite);
- Foamed (polyisocyanurate and polyurethane);
- Reflective materials (aluminium foil, ceramic coatings);
- Insulated concrete blocks.

The strategy of initial improvement by passive retrofitting interventions implies the upgrading of thermal insulation, both in fabrics and thickness, which can be applied internally or externally. One of the ultimate achievements should be that the value of thermal transmittance, or U- value (W/m^{2}K) is reached by retrofitting actions on different parts of the thermal envelope thus reducing energy consumption. Values are given by Passive House Regulation (EnerPHit/EnerPHit^{+i} for retrofitting of existing buildings) in the table below.

DESCRIPTION U [W/m^{2}K]		EnerPHit/EnerPHit^{+i} U [W/m^{2}K]
External wall	External insulation	≤ 0,15
	Internal insulation	≤ 0,35
Floor		≤ 0,15/f (f-temperature factor)
Roof		≤ 0,15
Transparent part of facade		≤ 0,85
Air infiltration		max n_{50} ≤ 1,0
ENERGY		*kWh/m^{2}a*
Heating energy		≤ 25
Cooling energy		Defined through Primary energy
Specific Annual Primary Energy		Qp≤ 120+((Qh-15)x1,2)

TABLE 3.1 Maximum U-values and expended energy based on EnerPHit/EnerPHit+ certification *(Passive House Institute, 2016)*

Glass is treated as a special class in the context of materials that are important for the thermal insulation of buildings- because, by its nature it is a poor thermal insulator. One measure of passive retrofitting is the increase of opening sizes and the replacement of existing glazing.

For heat and light energy transfer, glazed surfaces should meet the following requirements (Table 3.2.):

- minimise heat loss (outward heat transfer)
- minimise heat gains (inward heat transfer)
- provide the optimum amount of light (Miletić, 2014).

TYPE OF GLASS	HEAT TRANSFER COEFFICIENT U (W/m² K)	TOTAL SUN ENERGY TRANSFER g	LIGHT PERMEABILITY T
Duplex thermo insulation glass	≥ 1.1	0.55-0.65	0.8
Triplex thermo insulation glass	≥ 0.5	0.5	0.4-0.7
Sun radiation controlling glass	≥ 1.1	0.5-0.65	0.7-0.8

TABLE 3.2 Requirements glass needs to meet, regarding its heat and light energy transfer properties *(Miletić, 2014)*

Besides improvements in the previously mentioned parts of the façade, the roof is considered to be part of the thermal envelope of the building in which increasing the thickness of insulation is one of the verified methods of improvement. As a special intervention, the construction of a green roof is shown to be a successful tool in gaining economic and environmental benefits, reducing energy consumption and costs for end users, and also minimising the environmental impact due to low emissions. "Green roofs could be seen as a design technique which contributes to achieving sustainable development postulates in urban areas. Diverse benefits of green roofs, from environmental, economic and social aspects, have been confirmed by numerous studies worldwide" (Stamenković, Miletić, Kosanović, Vučković, & Glišović, 2017).

3.2 Active Retrofitting Technologies

Active solar energy represents the construction of systems that collect and convert solar energy into other energy forms, like heat and electricity. Solar heat collectors are features of active energy technology.

Solar heat collectors transform radiant energy into heat energy by capturing sunlight. Photovoltaic (PV) systems produce electricity directly from solar radiation. These systems became widespread in domestic buildings, producing lighting and general power (PV installation guide, 2001). A photovoltaic scheme is presented in Fig. 3.2.

TOC

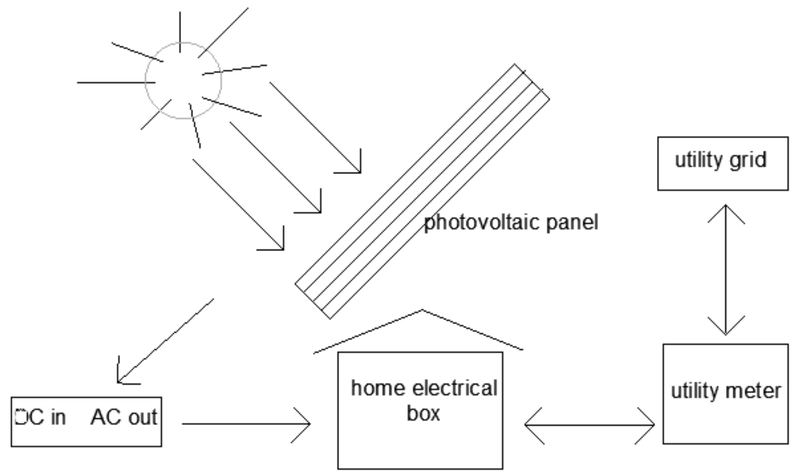

FIG. 3.2 Photovoltic scheme, based on data retrieved from http://www.growbygreen.in/knowledge.php *(Image by Authors)*

3.3 Estimation of Effects of the Implemented Measures

Building energy modelling and dynamic simulations can be used to estimate the energy performance of building, HVAC sizing, lighting requirements, or economic feasibility. All proposed retrofitting measures, and their effects in energy saving, can be evaluated through different software like EnergyPlus, BLAST, DOE-2.1E, ECOTECT, Ener-Win, Energy Express, Energy-10, eQUEST, ESP-r, IDA ICE, Integrated Environmental Solutions IES/VE, HAP, HEED, BSim,DeST, PowerDomus, SUNREL, Tas, TRACE and TRNSYS (Sadineni, Madala, & Boehm, 2011). Basically, these programs have modules to evaluate the application of different individual, or group, energy efficiency measures selected after defining methodology for improvement. These modules can be used by building designers to develop an optimal energy efficient building (Dodoo, Tettey, & Gustavsson, 2017). The accuracy of the building energy simulations depends on user input data such as geographic location, orientation, building geometry, construction details, mechanical equipment, existing parameters of HVAC system, type of building, thermal characteristics etc.

4 Conclusions

The increase of primary energy consumption by almost 50% in the final years of the twentieth century, and the increase of overall CO_2 emissions by 45% with an average increase of 2% per year have raised big concerns for population and governments worldwide.

In the process of energy flow, final consumption refers to the use of fuel, electricity, or heat that is delivered to end users. That final energy use is divided into three categories within different sectors: industry, transport, and a third sector that includes agriculture, and commercial and residential buildings. Industry accounts for 39% of total energy use, transport 25% and other sectors 36%.

Currently, industry uses 8% of total coal resources worldwide, the electrical power sector uses 92%, while other sectors use less than 1%. Transportation uses 71% of the total petroleum sources, while the residential sector 32% of total source of natural gas, and the electric power sector uses 100% of nuclear electric power resources.

A constant increase in energy demand and energy consumption is putting pressure on the finite availability of mentioned fossil fuels.

The trend is moving towards an increase in the use of renewable energy sources, RES, and their systems. At present, the situation is as follows: 13% of total RES is used in the transportation sector, 25% in industrial, 11% in residential and 54% in electric power systems.

One of the predicted scenarios, in the sense of increased use of RES indicates complete replacement of nuclear and fossil fuels with renewable energy only. A very important objective of this scenario is the reduction of greenhouse gas emission to levels that are considered safe. One obstacle to this scenario is that most of the global energy infrastructure is designed to use fossil fuels. A conversion from fossil fuels to forms of renewable energy will require the construction of a completely new infrastructure. An attempt to move too quickly away from fossil energy can disrupt the modern economy, whereas moving too slowly toward energy sustainability can lead to undesirable and irreversible changes to the climate. The transitional rate should be optimised.

Some governments are encouraging or requiring the development of energy saving technologies within the building sector. Energy use in this sector accounts for almost 50% of that consumed by all other sectors, approximately 40% worldwide. Some of the measures to decrease energy consumption and improve energy efficiency are passive and active features that were mentioned earlier. We can expect energy saving to increase in the future as a result of a more widespread adoption of energy efficiency measures and by improvements in energy conversion efficiency. However, we should not expect energy conservation and implementation of the energy saving measures to be enough to satisfy global energy needs. It is essential for the building industry to achieve sustainable development, meaning development with low environmental impact. To achieve this goal, there is a need to adopt a multi-disciplinary approach such as energy saving, energy conservation measures, retrofitting actions, and reuse and recycling of materials with control of greenhouse gas emissions. That should be the overall objective - to start from small actions so as to achieve a remarkable one.

References

Asif, M., Muneer, T., & Kelley, R. (2007). Life cycle assessment: a case study of a dwelling home in Scotland. *Building and Environment, 42*(3), 1391–1394. Retrieved from https://doi.org/10.1016/j.buildenv.2005.11.023

Clean Technica. (2017). *Where Is The Real Innovation In Wind Energy?* Retrieved from https://cleantechnica.com/2014/04/21/real-innovation-wind-energy/)

Dodoo, A., Tettey, U., & Gustavsson, L. (2017). Influence of simulation assumptions and input parameters on energy balance calculations of residential buildings. *Energy, 120,* 718-730. Retrieved from https://doi.org/10.1016/j.energy.2016.11.124

Fanchi, J. R. (2013). *Energy In The 21st Century* (3rd Edition). Singapore: World Scientific.

Geothermal Energy Association. (2016). *2016 Annual U.S. & Global Geothermal Power Production Report* Retrieved from http://geo-energy.org/reports/2016/2016%20Annual%20US%20Global%20Geothermal%20Power%20Production.pdf

Grow by green. (2017). *Photovoltic scheme*. Retrieved from http://www.growbygreen.in/knowledge.php

Hydro-electric Power Plant. (2017). *A schematic view of the hydro power.* Retrieved from http://www.tutorvista.com/content/science/science-ii/sources-energy/hydro-electric-power.php

IRES International Recommendations for Energy Statistics. (2016). *United Nations, Energy Balances and Electric Profiles—Concepts and definitions.* Retrieved from https://unstats.un.org/unsd/energy/ires/IRES_Whitecover.pdf

Kumar Dixit, M., Fernandes- Solis, J., & Lavy, S. (2010). Identification of parameters for embodied energy measurement: A literature review, *Energy and Buildings, 42*, 1238-1247. Retrieved from http://faculty.arch.tamu.edu/media/cms_page_media/2861/Dixitetal_2010.pdf

Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy consumption information. *Energy and Buildings*, *40*, 394-398. Retrieved from https://doi.org/10.1016/j.enbuild.2007.03.007

Market analysis and forecast to 2021. (n.d.) *Energies*. Retrieved from https://www.iea.org/publications/freepublications/publication/MTOMR2016.pdf

Miletić, M. (2014). Use of transparent insulation materials as one of measures of improving energy efficiency of structures, In Dincer et al. (Eds.), *Progress in Exergy, Energy, and the Environment*, (1st ed.) (pp. 487-494). doi: 10.1007/978-3-319-04681-5_44

Miletić, M. (2013). Innovative polymer based materials within the façade envelope assembly of buildings. In A. Mendez-Vilas (Ed.), *Materials and processes for energy: communicating current research and technological developments* (pp.709-718). Retrieved from: http://www.formatex.info/energymaterialsbook

NREL National laboratory of the U.S. Department of Energy Efficiency & Renewable Energy Alliance for Sustainable Energy, LLC. (2015). *Advanced grid technologies Laboratory Workshop Series*. Retrieved from www.nrel.gov/publications.

Overgaard, S. (2008). *Issue paper: Definition of primary and secondary energy,* UNSTATS. Retrieved from https://unstats.un.org/unsd/envaccounting/londongroup/meeting13/LG13_12a.pdf

Pacheco, R., Ordonez, J., & Martinez, G. (2012). Energy efficient design of buildings. A review. *Renewable and Sustainable Energy Reviews, 16*, 3559-3573. Retrieved from https://doi.org/10.1016/j.rser.2012.03.045

Panwar, N. L., Kaushik, S. C., & Kothari, S. (2011). Role of renewable energy sources in environmental protection: A review. *Renewable and Sustainable Energy Reviews, 15*, 1513- 1524. Retrieved from https://doi.org/10.1016/j.rser.2010.11.037

Passive House Institute. (2016). *Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard*. Retrieved from http://www.passiv.de/downloads/03_building_criteria_en.pdf

Pelc, R., & Fujita, R., M. (2002). Renewable energy from the ocean, *Marine Policy*, *26*, 471-479. Retrieved from https://centerforoceansolutions.org/sites/default/files/publications/Pelc%20and%20Fujita%202002.pdf

PV Installation guide. (2001). A guide to Photovoltaic (PV) system design and installation. Retrieved from http://www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF

REN21 Global Futures Report. (2017). *Renewables Global Futures Report (GFR).* Retrieved from http://www.ren21.net/future-of-renewables/global-futures-report/

Renewable Energy World. (2017). *Geothermal energy.* Retrieved from http://www.renewableenergyworld.com/geothermal-energy/tech.html

Sadineni, S., Madala, S., & Boehm, R. (2011). Passive building energy savings: A review of building envelope component. *Renewable and Sustainable Energy Reviews, 15*, 3617-3631. Retrieved from file:///D:/Dokumenta/Downloads/PassivebuildingenergysavingsAreviewofbuildingenvelopecomponents.pdf

Sartori, I., & Hestnes, A, G. (2007). Energy use in the life cycle of conventional and low-energy buildings: A review article, *Energy and Buildings, 39*, 249-257. Retrieved from https://www.sintef.no/globalassets/upload/energi/transes/article_life-cyle-energy_enb.pdf

Sommer, M., & Kratena, K. (2017). The Carbon Footprint of European Households and Income Distribution. *Ecological Economics, 136,* 62-72. Retrieved from http://www.sciencedirect.com/science/article/pii/S0921800916303627?via%3Dihub

Stamenković, M., Miletić, M., Kosanović, S., Vučković, G., & Glišović, S. (2017). The impact of a building shape on space cooling energy performance in the green roof concept implementation, *Thermal Science.* Retrieved from http://www.doiserbia.nb.rs/img/doi/0354-9836/2017%20OnLine-First/0354-98361700205S.pdf

Stojiljkovic, M., & Todorovic, M. (2016, November). *Basics of energy balance of the buildings*, Thematic lecturing no. 8, Engineering Chamber, Belgrade.

Stojiljkovic, M. (2016, November). *Basics of energy balance of buildings*, Engineering Chamber, Energy Efficiency Training, Belgrade.

Sun and Wind Energy, The Platform for Renewable Energies. (2017). *Solar power plant*. Retrieved from http://www.sunwindenergy.com/photovoltaics/hungarys-largest-solar-power-plant-now-operational

Swan, L., & Ugursal, V. (2009). Modeling of End-Use Energy Consumption in the Residential Sector: A Review of Modeling Techniques. *Renewable and Sustainable Energy Reviews, 13*, 1819-1835. Retrieved from https://doi.org/10.1016/j.rser.2008.09.033

UNECE. (2004). *United Nations Framework Classification for Fossil Energy and Mineral Resources*. Retrieved from https://www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/UNFCemr.pdf

US EIA-Energy Information Administration. (2011). *Annual energy review 2011*. Retrieved from https://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf

US EIA-Energy Information Administration. (2012). *Today in Energy*. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=5610