

Preliminary Theoretical Research on the Development of a New Plastic Heat Exchanger Concept for Geothermal Heat Pumps

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Abstract - The increase in global energy demand and greenhouse gas emissions have led to an already existing and continuously growing problem: climate change. Along with pollution reduction, the problem is the centre of interest of many research worldwide, becoming one of the priorities of many countries and of various entities from the private sector. There are numerous strategies on this topic aimed at maximizing the use of renewable energy, but none focus on the production of cost- and energy-efficient heat exchangers in the form of extruded plastic plates. Therefore, the paper presents some preliminary theoretical aspects and challenges concerning the complete replacement of traditional heat exchangers (made of stainless steel or plastic pipes), for new and modern geothermal heat pump systems, with recyclable composite polymer plates. The inherently low thermal conductivity of such materials (emphasising on those based on polyethylene) must be increased to achieve the highest possible heat extraction performance. Further discussed aspects include, environmental factors affecting thermal conductivity and the “double-edged sword effect” of plastic recyclability and degradation.

Keywords: heat exchanger, geothermal energy, heat pumps, renewable energy, polyethylene-based composites, thermal conductivity, polymers degradation, recycling

1. Introduction

The role of energy in human evolution, progress and continuous modernisation (e.g. electrification of means of transportation and the expansion of the data centre sector) and industrialisation, along with increasing population growth rates, urbanisation (increasing cooling demand especially in these areas) and people's desire for consumerism are some of the causes leading to a significant increase in global energy demand and consumption. Global electricity consumption grew by nearly 1100 terawatt-hours TWh [1] in 2024, more than twice the annual average increase over the previous ten years. This can be correlated with an increase in global energy demand by 2,2 % [1] than the average pace over the same period. In 2024, 32 % of the growth in global electricity generation was provided by renewable sources and 48% by nuclear power which has prevented (along with the increased use of electric cars) the formation of up to 2,6 billion tonnes of CO₂ [1].

Throughout the year, heat pumps continued to gain market share over heating systems powered by fossil fuels and by 2024, they outsold natural gas furnaces by 30 % [1]. Therefore, heat pumps are a sustainable means of transitioning towards renewable-cleaner technology to limit anthropogenically induced climate change, energy shortage and pollution.

Regardless of their type, an important part of the modern heat pump system that affects its efficiency and cost is the heat exchanger HE. The aim of this paper is to present some preliminary theoretical research on the development of an energy-efficient and economical plastic-based heat exchangers that can be used in modern ground-source heat pumps systems GSHP's. Such plastic HE have a much lower CO₂ footprint, are cheaper to manufacture, transport and install and can be easily recycled afterwards.

The development of such a new concept is a complex technical problem and includes the investigation and targeted control of all relevant composite material properties, design and construction of heat exchanger plates as well as the construction of tools for extrusion and other custom devices for manufacturing, assembling and testing of the final product. In addition, the inherently low thermal conductivity of polymers (emphasising on polyethylene-based ones) must be increased to achieve the highest possible heat extraction performance. Special attention was also given to the identification of working conditions (environmental factors, polymer aging and degradation) that influence the effectiveness of our proposed approach.

2. Heat Pump Systems

2.1. Types of Heat Pumps

An ideal heat pump HP is a thermal system that transfer heat flow from a cold area to a warmer one using the refrigeration cycle [2], to which some losses should be added [3]. They are highly efficient devices because most of the heat is transferred rather than generated or transformed, like conventional heating systems do. HP are also used to reduce a building energy consumption (heating/cooling account for up to 50 % of the electricity consumption [1] throughout the year) because they require a little to no electric power input (especially when combined with another renewable energy source, e.g. solar panels).

A first categorisation can be made according to their heat source and two most common types are air source heat pump ASHPs and ground source GSHPs respectively. Therefore, they can be designed using a traditional Vapor Compression Refrigeration System VCRS (with mechanical compressor) or using a Gas Absorption System GASHP (with thermal compressor) [2]. Other types use nearby water sources, heat waste from factories [4] or can be combined with other heating systems, commonly natural gas or coal, in hybrid configurations. The underground ones use the more stable ground temperature as the energy source or sink and are the starting point of this paper.

2.2. Heat Pumps Performance

Heat pump efficiency can be defined using a Coefficient of Performance COP, which is the ratio between the used energy (e.g. in form of heat released in the condenser for heating mode and pumped at the evaporator- cooling mode) and the amount of input driving energy (electricity) given at the compressor. For both cooling and heating, the COP coefficient can be expressed mathematically [3] using Eqs. (1) and (2).

$$COP_{heating} = \frac{q_{out}}{W} = \frac{q_{out}}{q_{out} - q_{in}} = \frac{1}{1 - q_{out}/q_{in}} \quad (1)$$

$$COP_{cooling} = \frac{q_{in}}{W} = \frac{q_{in}}{q_{out} - q_{in}} = \frac{1}{1 - q_{in}/q_{out}} \quad (2)$$

According to the first law of thermodynamics, the absolute efficiency of a system cannot exceed 100%. In the case of heat pumps, the coefficient of performance (COP) for a typical household heat pump is around four, which means that energy output (in forms of heat moved to the hot space) is four times greater than the electrical energy used to run it. This makes current models 3-5 times more energy efficient than gas boilers [4]. Reports [5] have indicated the ability to reach efficiencies as high as 600% (COP of 6).

Depending on the heat pump classification, performance rates of various systems, under real working conditions can be initially supported by some performance tests in accordance with and regulated by the applicable norms: ISO 13256-2:2021, ISO 13256-2:2021, VDI 4640 Part 1:2021, VDI 4640 Part 2:2021, ANSI/CSA/IGSHPA C448 Series-16 (R2021), ISO 5151:2017, ISO 13253:2017, ISO 15042:2017 and AHRI 210/240:2023.

3. Ground Source Heat Pumps

3.1. Open, Closed and Hybrid Loop Systems

Geothermal source heat pump (GSHP), also commonly known as geoexchange heat pump, ground-source heat pumps or earth-coupled heat pump, can maintain a cool environment during the warm days by transferring the heat from the building to the ground, or from the earth to the building in winter, acting as a heating system [6]. This can be attributed to the fact that after certain depth, the ground maintains a relative constant temperature throughout the year (below the frost line). GHPS can be classified into two (closed and open systems) groups, based on their main loop types. For open loop configurations, usually, copper pipes [6] or plate-and-frame heat exchanger PHEX [7] are used to transfer the heat directly to/from a building. Those systems use an underground aquifer or surface water as the direct heat carrier. After usage, used water can be reinjected back to the same source, into another pond/lake, or it can be further used in other applications such as irrigation.

On the other hand, as the name might suggest, closed loop systems circulate the heat carrier fluid (mixture of antifreeze solution, water, saline, ethylene glycol solutions, refrigerant substance or mixture, brim mixtures) through a closed circuit of pipes to transport ground heat to the heat pump or the opposite. One component for those systems consists of high-density

plastics pipes (e.g. polyethylene HDPE, polypropylene HDPP or polybutylene PB) which represent the primary unit or system heat exchanger. Furthermore, the closed systems can be divided into several types, depending on the orientation and configuration of the pipes [6,7]: horizontal closed loop systems (further classified in series, parallel, helical or spiral coil, slinky pipe, foundation heat exchangers and trench collectors), vertical loops or borehole heat exchangers (with various configurations: slinky loop, slanting, thermos-active foundation pile or commonly known as energy piles, with U, W, helical, elliptical, offset or co-axial pipes arrangement), pond/lake (exchange heat with a body water instead of the ground) and hybrid systems (combination of different geothermal resources or geothermal resource with outdoor air).

Open-loops systems are more sustainable, maintenance cost less and provide better heat exchange since the water exchanges the heat directly with the heat pump without any further heat exchangers. The major disadvantage [6-7] is that it requires a stable and “relatively clean” water source (high amount of minerals, salts and hydrogen sulphide can cause system clogging and corrosion). Despite all the advantages, the horizontal closed loop system is by far the most widely adopted [8] because it has the advantage to accommodate large-scale applications in urban and highly densely populated area (residential and commercial building). Recently, some hybrid systems [7] (solar-assisted GSHP, cooling tower or sewer heat exchange system) emerged to address the challenges associated with using conventional systems.

3.2. Economic Feasibility and Environmental Impact

Looking at the GSHP units per inhabitants, the Scandinavian and Baltic countries are on top 10, with Sweden (installation ratio of 52,43 per 1000 people) and Netherland (5,93 installations per 1000 people) taking first places. Switzerland and Austria are ranking 4'th and 6'th place, respectively, and Germany with its population of over 83 million just makes it to rank 10, despite being second in total numbers of installed systems [9].

In 2023, the European heat pump market was valued at 15,9 billion € and is expected to grow at a compound annual growth rate CAGR of 18 % between 2024 and 2032 [8]. Government incentives play a critical role in the market, with various forms of possible financial support (e.g. subsidies, tax credits, and low-interest loans), making GSHP installations more accessible and appealing to a broader range of users and in different residential areas.

In terms of environmental impact, Kimiaei et. al. [7] reported that after 30 years of operation, the electricity consumption of the GSHP was up to 75 % when compared to traditional air conditioning systems. With a lower energy footprint and greenhouse gas emissions than the usual heating systems, heat pump system are considered environment-friendly with only the refrigerant (e.g. water, isobutane, R-744 CO₂, propane R-290, hydrofluorocarbon R-410A, R32/125/134A, tetrafluoroethane, dichlorofluoromethane, propylene glycol water solution, ethyl alcohol water solution etc.) potential leak [3, 6, 8] being the major concern. Environmental potential impact can be evaluated using Eq. (3), also known as TEWI (Total Equivalent Warning Impact):

$$TEWI = DGWP + IDGWP = GWP * \left(L * \frac{n}{DGWP} + m * (1 - \alpha) + n * \frac{E * \beta}{IDGWP} \right) \quad (3)$$

where: GWP- Global Warning Potential Index, L [kg/y]- annual quantity of refrigerant leak during a year, n [y]- life cycle of the equipment, m [kg]- quantity of refrigerant in the heat pump at installation, α (0-1)- recovery rate of refrigerant at the end of its working life, E [kWh/y]- annual energy consumption, β [kg CO₂/kWh]- carbon factor associated with electricity generation.

Economic feasibility and environmental impact as described above, are just some of the reasons why the current approach focuses on the development of an extruded plastic heat exchanger for the GSHP. This new HE is a combination between the vertical and horizontal closed loop systems. Major advantages of our approach are the dimension of the heat exchanger (one meter high and up to 6 m long), depth to be excavated for installation (bellow the frost line but not as deep as vertical systems that require drilling depth between 60 m and 200 m) and significantly less excavated surface (major drawback of the spiral horizontal type GSHPs). By burying at a greater depth, the impact of environmental factors on the ground surface is limited, thus avoiding temperature fluctuations not only during the year (seasons) or changes caused by climatic conditions (wind, rain, sun, floods), but also when it comes to temperature fluctuations during the day and night. This will ensure lower initial cost (for manufacturing as well as handling, storage and transportation), easy maintenance and of course the possibility of recycling the composite material from which the plates are made.

4. Impact of Different Reinforcements Incorporation on Polyethylene PE-Based Composites

Most commodity thermoplastics in their virgin form exhibit lower thermal conductivity, in the range of 0,1-0,5 W/mK [10,12] when compared to metals (<81 W/mK for steel, 290 W/mK Al, <400 W/m²K Cu) which makes them not ideal for heat exchanger application. Polymers are characterised by having low atomic density, covalent chemical bond structures, inharmonic vibration of the molecule chains and crystal lattice, structural inhomogeneity, and mismatch in molecular chains. Thermal conductivity (λ or k_t) of polymers is promoted by phonon transport, which is the quantised vibrational modes that propagate through a material [10]. Thus, polymer properties inhibit phonon transport (causing phonon scattering) resulting in an inherently low thermal conductivity (e.g. 0,1-0,22 W/mK for PP, < 0,22 W/mK PC, 0,35 W/mK PE and <0,45 W/mK HDPE) [11,12].

Crystalline polymers have inherently higher k_t , as their higher density and order chain alignment improve phonon transport, compared to amorphous ones which exhibit small mean free path due to phonon scattering [10]. Aligned of the polymer molecules increase thermal conductivity and can be also achieved during processes such as drawing and extrusion (resulting also in an increased degree of crystallinity).

Polyethylene PE has been widely used for pipe materials of drinking water and gas while high density HDPE has corrosion resistance in soil and good economic performance due to its low price and large spreading [13]. Throughout the years, developments in the field of materials and engineering have proved successful in avoiding and overcoming the complications associated with the use of thermoplastics in the construction of heat exchangers. By adding various fillers (fibres, powders or mixtures) that possess high thermal conductivity can increase the overall thermal conductivity of the composite by forming percolating network for thermal transport.

4.1. Morphology of PE Composites

Some aspects that can be considered and modified [10] to a certain degree, to increase the conductivity of the base material, are: polymer degree of crystallinity (by adding nucleation agents that promote the formation of crystals or by thermal post-processing: annealing or tempering), chemical structure (e.g. phenylene structures in the polymer backbone provides a percolation path), bond strength (promoting hydrogen bonds at the expense of weaker Van der Waals forces) of side chains (preventing their presence to reduce phonon scattering and reduce axial conductivity), molecular weight, glass transition temperature and melting temperature.

However, one of the most practiced and studied methods of enhancing the k_t of polymers is by adding filler materials, resulting in polymer composites. For composites, the heat flux is transferred along thermally conductive fillers paths or networks with lower thermal resistance. In addition to increasing the k_t of the base polymer, research in this area has focused on finding compatible conductive fillers with extremely high k_t and improving the interface between the base polymer matrix and conductive fillers.

The most well-known and studied [10, 12] factors influencing the properties of PE composite include:

- type: metals (Al, Ag, Cu, nickel), ceramics (aluminium nitride, boron nitride, silicon carbide, beryllium oxide) and carbon (carbon black CB, carbon fibre CF, graphite, graphene, single- SWCNT and multiwall carbon nanotubes MWCNT and nanosheets);
- surface treatment/functionalization and interfacial structure: introduction of thermally conductive fillers form contacts interfaces with polymer matrix and between them (spherical fillers form point contact among fillers, linear one form line contact and laminar fillers form surface contact). Reducing the interface or improving the interfacial performance minimize the phonon scattering effect at the interface level and greatly increase the efficiency of thermal conduction. Different surface functionalization methods include mechanochemical method, chemical modification, acid-base treatment (e.g. purification), and surface coating (implementing mechanism such as Coulomb electrostatic interaction, chemical bonding and supersaturation). Besides improving the thermal properties, filler treatment increases lifetime, mechanical and morphology stability of the final composite, and protects the filler from external factors (e.g. humidity);
- aspect ratio: 0D (spherical), 1D (rod, wires, tubes or fibres), 2D (platelets or flakes), 3D isotropic (cubic, sponge). When aspects ratio increases, the probability that two adjacent particles are close enough for phonon transport increase resulting in lower percolation threshold. Therefore, as a rule of thumb fibres are better than flakes (form thicker conductive paths) and

flakes are better than spheres, but fibres tend to arrange/align and form better conductivity in-plane compared to thru-plane k_t . It is generally acknowledged that small size thermally conductive fillers form more efficient thermally conductive paths and networks when fillers loading is appropriate. Nanoscale filler tends to aggregate more often. To overcome these problems, strategies such as solution dispersion, high shear extrusion and filler functionalization can be adopted;

- volume ratio/fraction or filler loading: high volume ratio (above 30 vol%), up to a certain point, enhances thermal conductivity but can also create filler agglomeration which leads to mechanical instability (decrease of some mechanical properties), costs increase, and processing issues (poorly melt flow and apparition of melt fracture or disruption) due to composites increased viscosity and yield stress, friction and wear properties. Generally, percolation theory or scaling law (eq. 2) provides a framework for understanding the effects of loading on energy transfer within composites. The theoretical maximum addition volume fraction, of spherical rigid fillers, is 0,637;

$$k_{tc} \propto k_{tf}^* (f - f_c)^t \quad (4)$$

Where: k_{tc} and k_{tf} [W/m K]- thermal conductivity of composite and filler, f [%]- filler volume fraction, f_c - percolation threshold and t - percolation exponent

- processing technologies: moulding processes (e.g. injection, press moulding, 3D-printing and extrusion) will cause anisotropic fillers to align along the flow direction resulting in lower values for the perpendicular/transverse thermal conductivity (thru-plane k_t), that being the critical one in our case. Studies showed that the orientation of the fillers can be controlled using electric or magnetic field and in situ-polymerization. Adding filler can also affect the processing parameters (increase in shear mixing and prolonged residence time undergo thermal and mechanical stress) which can further result in polymer matrix/molecular weight degradation caused by excessive temperature and shear from chain scission.

Hybrid composites with fillers of different types, shapes and sizes incorporate properties of all fillers and form better conductive pathways (especially when thru-plane paths are needed). Composites processing presents problems such as achieving proper dispersion and interfacial flaws (voids/ air gaps). Generally, methods for preparing hybrid composites include direct or chemical blending and physical absorption (e.g. electrostatic absorption or π - π interaction).

External conditions (environmental factors such as operating temperature, humidity and heat flux) also have influences on the k_t values of our polymer composites. Higher operating temperature will result in higher values for k_t because of the increased thermal motion of molecules but the effect is dependent on the composite glass transition temperature T_g . Polymers and filler materials absorb water, which can be a positive thing as moisture has been shown to increase the k_t -value of the composite.

4.2. Enhancement of Thermal, Mechanical and Rheological Properties

Mechanical properties such as modulus, Vicat softening point and stress at break typically increase when polymers are filled with metallic inclusions [10]. Furthermore, values up to 1.99 [W/m*K], 1.7 [W/m*K] and increase by a factor of two for k_t of various HDPE composites (with 30 vol% nickel, 20 vol% zinc powder and 24 vol% Cu respectively) can be obtained.

Problems such as increase in density, surface oxidization, corrosion and abrasion of processing equipment are often encountered. Despite the considerable increase in k_t of the composite, due to the disadvantages and the fact that in our case it might be necessary to treat the filling or the final GHE (protect it against corrosion and oxidation), metallics filler will be further avoided.

Compared to previous one, carbon filler have relatively low bulk density, higher thermal conductivity coefficient (e.g. graphene: 5000-6000 W/mK [10]), lower coefficient of thermal expansion, are resistant to corrosion and chemical decomposition but come at a higher price and is more difficult to obtain a uniformly dispersed mixture.

Ceramic based fillers offer to the thermoplastic matrix higher thermal stability, lower shrinkage and dimensional stability, have lower density compared to metals and can endure higher service temperatures ranges. Using a PE-hybrid ceramic composites (AlN, SiC and BN) rapid increase in k_t (up to 3,66 W/mK) at filler volume fraction between 50 and 60 % can be obtained [10]. Thermoplastics resins with ceramic and carbon-based fillers must be processed at higher temperatures compared to the neat resin, which can lead to matrix degradation, parts with defects and inferior properties.

5. Working Conditions Influence on Proposed Approach Efficiency

The performance of ground heat pumps is influenced not only by their type, but also by the temperature of the medium (soil or water) and its thermal conductivity. In this sub-chapter the environmental factors affecting the performance of the proposed solution are analysed, thus excluding open and some closed loop systems. These together with the characteristics of the newly developed polymer material, recyclability, degradation and aging of plastics, are factors which will be considered in the design stage of the new innovative plastic heat exchanger.

5.1. Environmental Factors

For shallow horizontal GSHPs, it is crucial to consider soil temperature variations as a main environmental affecting factor. The current approach, however, refers to a vertical positioning of the heat exchanger but at comparably greater depths than horizontal closed systems (soil temperature remains relatively constant throughout the year). Therefore, failure to balance the cooling and heating cycles can affect soil ability to maintain its thermal equilibrium or to recover short-term localized heat losses (warmth is extracted by the system- cold seasons) and thermal accumulation (during warm seasons). All these issues lead to a gradual decrease in the efficiency of the heat pump, both in the case of the proposed method and in the case of conventional systems.

In their comprehensive review, Adebayo et. al. [7], presents a series of methods to enhance heat pump performance: by using phase change materials PCM or secondary soils (with increased thermal conductivity and volumetric heat capacity) around the ground heat exchangers. In the case of energy piles and steel energy piles (VGHE- 20 to 40 m deep), an increase in system performance [7] can be achieved by filling/surrounding them with thermally enhanced cement (graphTHERM and cement mix, or steel fibres), additives (e.g. water, saturated sand, grout, grout and fibre mix) or by welding a steel helix.

By moisturizing the soil sandwiched between two plastic sheets, Habibi and Hakkaki-Fard [7] obtained a saturated secondary soil which not only increased performance but also reduced the GHE's installation costs by up to 40%. Using an experimental approach, it was demonstrated that by implementing intermittent cycling and increasing soil moisture, the soil's ability to recover temperature can be improved. Similar intermittent operation allows 24,1 % more heat extraction than continuous operations [7]. More overall improvements in GHE efficiency and system performance due to the increase in soil moisture were described in Adebayo et. al. review.

5.2. Polymer aging and degradation

In addition to environmental effects on thermal performance, effects on mechanical behaviour and long-term stability/integrity of GHE's must also be considered. Thermally induced stresses (thermal expansion and contraction over the usage temperature range) as well as the earth pressure generated by the plastic heat exchanger plate must be considered during the design stage. Another concern is the differences in thermal expansion and contraction of GHE components. This new additional challenge occurs not only between thermoplastic components of the same type (especially at the joint regions) but especially between thermoplastic and fillers.

Polymers aging and degradation is unfavourable for predicting service lifetimes and favourable for predicting end-of-life of materials or products. Due to current concern regarding management of plastic, reuse and recycling of plastics in accord with the EU plan for 2030 it is important to establish how the environment impacts materials properties or how the material impacts the environment. Generally speaking, results two types of products, short-term ones where biodegradable polymers composites (short end-of-life and climate neutrality) are favoured over high performance composites (durable but less environmentally friendly) used in long-term structural applications. Which is why some researchers have proposed the idea that environmental degradation has is "two-edged sword" [14].

In our case, for this long-term structural application, the key factor is durability and long service lifetime of the GHE. At the end lifetime of the GHE it is proposed an appropriate route to handle the used composites "waste" throughout the mean of two stage recycling, which will be explain in future works. Similar to other reinforced polymers used in continuous applications (e.g. wind energy sector, oil and gas, offshore and marine, aircraft and transportation industries) is important to determine and designed the GHE for a lifetime of several years or decades and to ensure system efficiency throughout this time. To do this it is necessary to identify which mechanisms cause the degradation and how they affect the material, how these mechanisms can be approximated and consequently predicted, without the need for testing under real conditions over very long periods of years.

Polymers and polymer composites especially, generally exhibit nonlinear and time-dependent behaviour and combined with their susceptibility to environmental degradation, makes it challenging to model their long-term performance. Since the consequences can be reversible (plasticization) or irreversible, even after, successful use, it is important to approximate the material properties after years of use for its recycling stage and future post-applications. Fortunately, modelling the long-term durability of polymers and polymers composites is common concern and many researches address these problems [13, 14]. Common methods for determining the service life of a structural component or composites include:

- estimation based on short term data or accelerated test (accelerated degradation test) in conjunction with predictive models: rate models (Arrhenius Model, Eyring's Model, Zhurkov's Model) or superposition principles SP based depends on one accelerated factors (time-temperature superposition principles TTSP, time-moisture TMSP, time-stress TSPP) or related to an ageing mechanism (resulting time-physical ageing or time-curing degree, time-plasticization, time-hydrothermal ageing);
- accelerated failure, by means of degradation rate models, superposition principles and parametrisation techniques such as: plasticity-controlled failure (Erp method which is based on the critical strain concept and Eyring thermal activation theory, Zapas-Crisman Model, creep failure time models developed by Spathis and Kontou or Monkman-Grant parametrisation) and parametric methods for creep (Larson-Miller or Monkman-Grant parametrisations methods);
- fatigue models or fatigue prediction methods: construction of Wöhler stress-cycle S-N master curves according to TTSP, accelerated methodology, Larson-Miller parametrisation for fatigue lifetime and construction of the S-N master curves (from data obtained at different temperatures), normalisation of the characteristic stress of the fatigue models, modelling S-N curves and the residual strength and stiffness by applying known models with environmental factors dependent parameters;
- multiscale simulation: Direct Numerical Simulations DNS (model the microstructure explicitly throughout the complete macroscopic domain of interest), analytical homogenization AH (deriving analytical expressions for combining properties coming from different materials at a lower scale towards a homogeneous higher-scale representation), Numerical Homogenization NH (obtains average properties from a numerical model of the material microstructure by using Representative Volume Element RVE/ Representative Unit Cell RUC), Computational Homogenization CH or Concurrent Multiscale CM or FE², accelerating Multiscale Simulations (Model Order Reduction MOR and Machine Learning ML Approaches) or other approaches proposed by various researchers (framework for fully coupled diffusion mechanics, DNS combined with NH hybrid approach, LATIN method etc.);

To take such a complex phenomenon into account, modelling is performed on different scales of the material structure [14]: micro- (composites constituents and their interaction), meso- (representative elements of a composites) and macroscale (GHE as a whole). Usually complex and detailed modelling approaches employing data analysis from micro- to macrolevel of composites (bottom-up approaches) which requires highly detailed knowledge of the implied phenomes. Otherwise, a simplified method (top-down approach) of determining/predicting the service life is by monitoring the evolution of critical parameters used to characterize the system performance or the general characteristics of any plastic or composite material.

6. Conclusion and Future Prospects

The European Climate Law- European Commission has set a target to achieve climate neutrality by 2050, with an intermediate goal of reducing net greenhouse gas emissions by at least 55% by 2030. Heat pumps are a sustainable means of transitioning towards renewable-cleaner technology and are increasingly being used to heat/cool residential or commercial building. Even though GSHPs offer significant benefits in terms of energy efficiency and sustainability, some challenges and disadvantages (high upfront installation cost, lack of space and/or water source, unfavourable government policies, lack of awareness etc.) need to be addressed before they become even more widely adopted. The current paper succinctly presents by theoretical means what implies (advantages, disadvantages and future steps) the development of a new plastic heat exchanger concept for modern geothermal closed loop heat pumps.

In addition to the classification of heat pumps (with an emphasis on geothermal systems), two mathematical models for determining the performance and environmental impact of new approaches were presented. Polymeric material chosen for further test and research is polyethylene and hold several advantages over metal components in heat exchangers such as costing saving (processing, handling, etc.), recyclability, lighter weight and corrosion resistance. Polymer thermal conductivity can be enhanced by modifying the bae structure or through addition of conductive filler.

Several experimental studies are required to find the ideal composite material (type of filler, its volume ratio, filler dimensions, etc.) for our approach. In addition to the material influence on system performance, several environmental factors have been identified, these also influencing polymer composite degradation and ageing.

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