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Editorial: SDEWES science - the path to a sustainable carbon neutral world

In 2021, the 16th SDEWES (Sustainable Development of Energy, Water and Environment Systems) Conference was held in Dubrovnik (Croatia), October 10th – 15th and delivered more than 690 contributions, presented in regular and 13 special sessions, with 7 invited lectures devoted to various sustainability topics.

The Energy journal has continued its cooperation with SDEWES launching a special issue dedicated to this SDEWES Conference. The 29 selected papers cover a wide variety of issues in the fields of energy, water and environment, and all of them propose novel approaches or remarkable advances in well established research lines already explored in past SDEWES Conferences.

Energy planning and modelling as pathway to smart energy systems are among the most investigated topics in SDEWES Conferences. Many countries are replacing conventional means of power generation with RES (Renewable Energy Sources), often wind power and solar photovoltaics. Moreover, the broad spatial distribution of wind and solar resources presents an engineering problem, as physical electricity networks are historically designed to transmit electricity which has been generated in a centralised grid topology [1]. The retail energy market is one of the financial entities which is somewhat embedded into smart grid architectures for the efficient exchange of electricity and natural gas commodities. In liberalised electricity markets, retailers aim to provide a reliable connection, maintain high consumer satisfaction levels and make a profit. To acquire healthy profits, retailers are challenged with formulating optimal decisions on both the supply and demand sides [2]. Retailers procure electricity from the wholesale market via trading agreements, along with a degree of price volatility risk and then sell the electricity to their consumer base at a specified tariff which shields the end-user from wholesale price volatility [3]. To support the modernisation of the energy system, the paper by Hampton et al. [4] reviewed existing modelling techniques and tools related to the retail energy market. The cross-linking of modelling techniques will help progress to an optimally functioning retail market, narrow the knowledge gap and address increasing customer engagement, Figure 1.

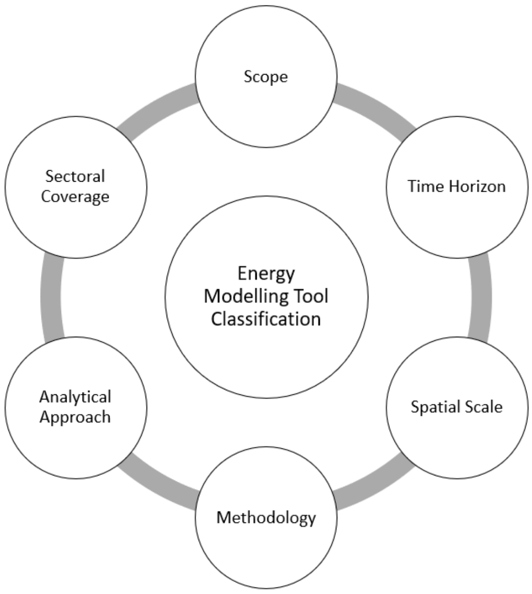


Fig. 1. Energy modelling tool classification [4]

In recent years, there has been a growing interest in enabling prosumers to mutually exchange energy [5]. Globally, many companies, initiatives and projects are moving towards this emerging trend [6] making consumer-centric markets ever more present [7]. In the most general sense, consumer-centric markets can be classified as: (i) fully P2P (Peer to Peer), (ii) community-based or (iii) a combination of both [8]. In a P2P market, the actors bilaterally negotiate the amounts and prices of the exchanged energy and use smart contracts to enforce the settlements [9]. Community-based markets, on the other hand, bring all community members together and generate a benefit by aggregating their generation and demand profiles. These markets require a community manager to: (i) oversee the energy exchanges in the community, (ii) maximize the social welfare of the community members and (iii) ensures a fair distribution of the benefits generated from their joint effort [10]. There are different methods of organising community-based markets. One method is by setting up community markets, where the community manager influences participants to buy or sell energy using pricing mechanisms which reflect the energy balance in the community [6]. The prices can be constant throughout a billing period [11], vary from one time-step to another [12, 13] or can be determined using single and double auctions [14]. An interesting paper by Gjorgievski et al. [15] proposes VNB (Virtual Net Billing) - a new energy sharing method that extends individual net-billing to a community level. VNB can be coupled with any benefit distribution concept, such the SV (Shapley Value) and MV (Min Var). While both are used in this paper, the combination VNB-MV serves as a benchmark for fairness. To overcome the computation complexity of the VNB-SV and VNB-MV, the PFS (Proportional Fair Sharing) key is proposed. Unlike the former methods, VNB-PFS distributes the economic savings generated by VNB in real-time, thus significantly reducing computation complexity at only a slight compromise to the fairness of the payoff distribution. The results show that, based on three metrics, VNB-PFS notably outperforms BS (Bill Sharing), MMR (Mid Market Rate), SDR (Supply and Demand Ratio and VNB-SV in terms of fairness. Several countries have recently published their respective national plans of energy and climate to having an economy partially decarbonized in 2030, leading the worldwide task of climate change mitigation towards a net zero-carbon economy by 2050. A recent research carried out for Spanish by Parrado-Hernando et al. [16] aims to contribute in the discussion by providing a detailed method based on data analysis helped by an energy model. Results evince positive conclusions regarding renewables. Commitment of 74% is fulfilled facing 2030, and Spanish economy could run with a 100% renewable energy system by 2050, Figure 2.

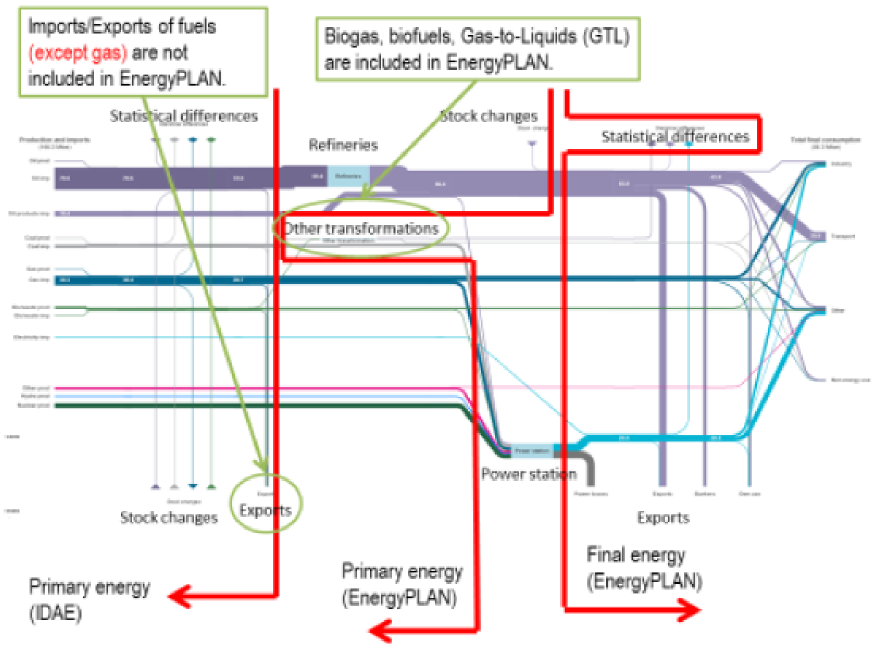


Fig. 2. Sankey diagram of the Spanish energy flows in 2018 [16]

IES (Isolated Energy System) as energy system of an island, is facing numerous energy challenges, such as lack of access to the utility grids, high dependence on imported fossil fuels and inconvenient fuel supply across such inaccessible areas. Since global energy demand is foreseen to increase by more than 25% [17] and the fossil fuels have damaging impact on the environment ranging from climate change issues to increased air pollution [18], the IES requires decarbonization of different energy sectors to set off towards sustainable development. The objective of research carried out by Frković et al. [19] is to explore batteries integration in ships as part of renewable-based isolated smart energy systems by means of the EnergyPLAN program, Figure 3. Case study results confirm that ship electrification can lead to significant reductions in operation costs and life-cycle emissions.

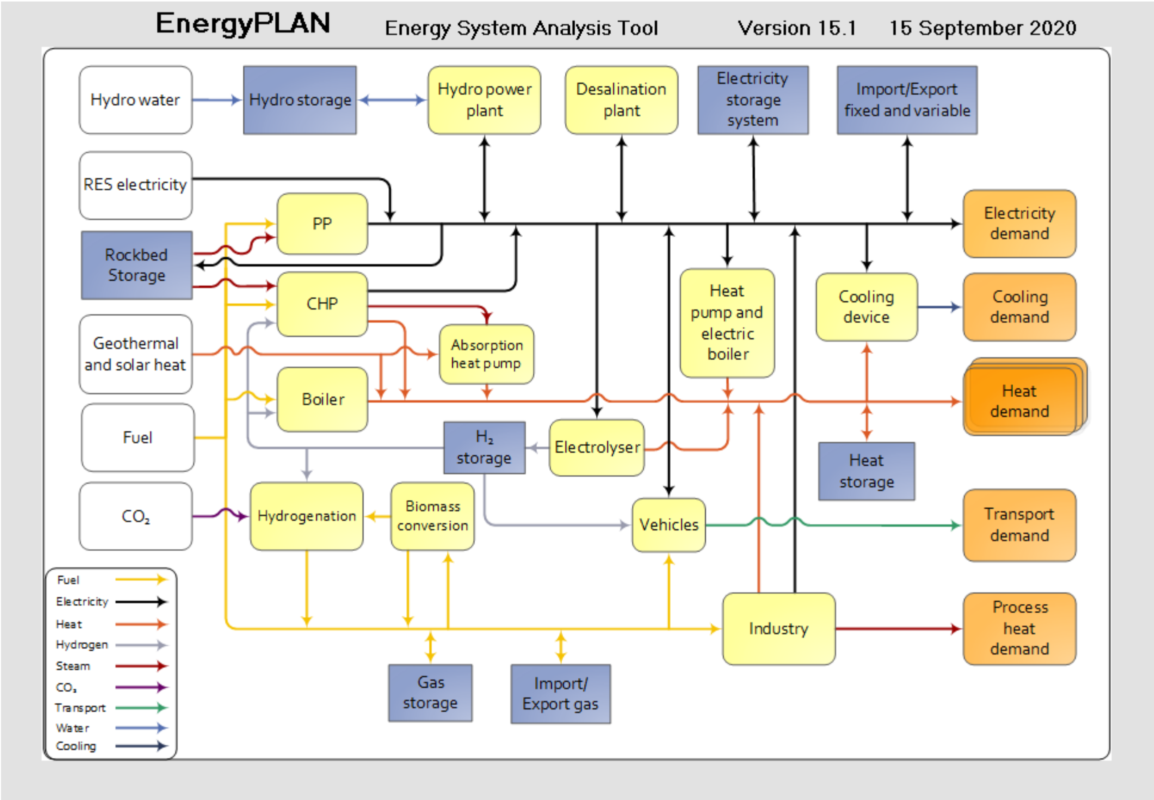


Fig. 3. The EnergyPLAN program analysis model [19]

The energy transition towards a clean and digitalised energy system is proceeding as fast as ever [20, 21]. Islands have been identified as lighthouses to test and validate innovative solutions with high RESs penetration that might then be replicated on the mainland [22]. Small islands represent unique systems, and they all have to face similar challenges such as high energy costs, CO_2 emissions, security of energy supply and system stability due to small grids and thus low inertia [23]. Most of these challenges could be cope with a RESs based and highly digitalised energy system and by taking full advantage of the possibilities offered by SESs (Smart Energy Systems). In research by Groppi et al. [24], a MAC (Marginal Abatement Cost) curve method is applied to optimally select the energy mix of the energy system of the island of Favignana, Italy, Figure 4. The technologies that are taken into consideration are photovoltaic, energy storage and demand response strategies including the maritime transport and heating sectors. The decarbonisation of the maritime transport sector is of utmost importance since it contributes to almost 50% of the energy consumption and GHG emissions of the whole island.

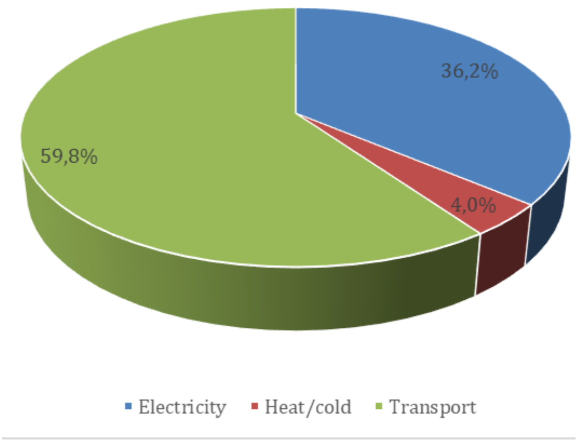


Fig. 4. Energy consumption per sector [24]

District regeneration plans introduce demographic and land use changes that influence their energy balance, modifying electricity and heating/cooling demand profiles. Smart energy district and energy community approaches allow to better solutions from the thermodynamic and economic point of view than traditional and integrated approaches. They integrate RESs with the energy demands using a data centre to menage the energy flows. To evaluate the benefits that a district could obtain when integrating energy planning in regeneration plans, Battaglia et al. [25] analysed the effects of a different approach to the urban design. The authors implement different scenarios, evaluating the most suitable technologies that can be integrated in the former industrial area in the city of Naples, Figure 5, through retrofit and re-use of existing buildings, the construction of new ones and the implementation of smart infrastructures.

Fig. 5. Overview of the area [25]

One way to optimize energy systems is via mathematical optimization, where a mathematical model is developed to mimic the operational behavior of the energy system and it is optimized based on a given objective (i.e., response time, cost etc.) [26]. Several studies have used mathematical models to optimize energy systems [27-30]. Andiappan in work [31] presents an optimization model to optimise the energy system operations in a smart grid based on response time and cost, Figure 6. The developed model can determine optimized load distributions based on the expected response time and cost.

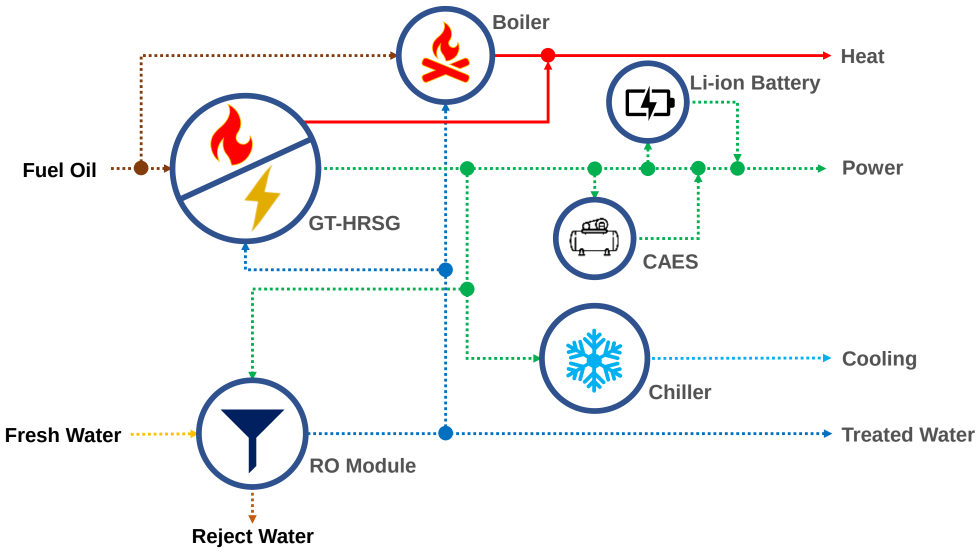


Fig. 6. Possible technologies and connections for poly-generation system [31]

Another extremely hot topic along the 20-years history of SDEWES Conferences is obviously related to RES and the technologies for their exploitation. Contributions in this field may be divided into two main groups, depending on whether they are focused on a systemic level, i.e. they investigate the feasibility and potential of RES-based plants and their integration with the overall energy system, or on a technological level, discussing advances in the state of art with particular regard to novel technologies. The main concern related to climate change deals with the GHG (Greenhouse Gas) emissions which include CO_2 and other CO_2-equivalent gases that are polluting for the atmosphere [32]. As a matter of fact, a huge effort has been performed to detect alternative technologies to produce energy with the aim of reducing GHG emissions [33]. EU countries established a series of steps in order to reach the final goal of zero emissions by 2050 [34]. In 2020 a first great result was achieved thanks to the 20-20-20 policy which obliged many EU countries to reduce their GHG emissions by 20% with respect to 1990s levels. The next significant step is the achievement of 55% GHG reduction within 2030, which implies an even more widespread use of RES to produce the so called "clean energy" [35]. The purpose of employing renewables (wind, solar, geothermal, small hydro, biomass, biofuels, hydrogen, ocean) for electricity production is due to the will of replacing fossil fuels both for transport sector and for industrial and residential sector [36, 37]. Wind energy has developed rapidly in recent years as a result of the energy crisis, and more importantly the inexhaustible nature of wind energy and the mature technology of wind turbines [38]. However, blade icing is a critical factor limiting the performance of wind turbines. In severe cases, almost 30% of the annual power generation is lost due to blade icing [39]. More seriously, blade icing can to some extent cause casualties and production losses. Traditionally, human observation, passive methods, and active methods are the main solutions for the blade icing detection of wind turbines. The human observation is too subjective, and the observations heavily rely on the experience of observers. Passive methods use special materials such as black paint and coating, to anti-icing [40, 41]. Low cost and easy blade maintenance are the main advantages, but icing prevention only by coating alone is not realistic. The active method was proposed in [42] as an effective anti-icing method, but requires additional power and mechanical replacement, which could damage wind turbines. To compensate for these traditional methods, model-based approaches, including mathematical and data-driven methods, have received increasing attention in blade icing detection of wind turbines. Mathematical methods make predictions about wind turbine blade icing by the development of mathematical or numerical models, but the disadvantages are obvious [43, 44]. In recent years, data-driven models detect icing based on mining information hidden in historical measurements [45]. In paper by Cheng et al. [46] proposes a FL (Federated Learning) based model for blade icing detection. The experiment demonstrates the superior performance of the proposed model for online detection with an accuracy of almost 100%, Figure 7.

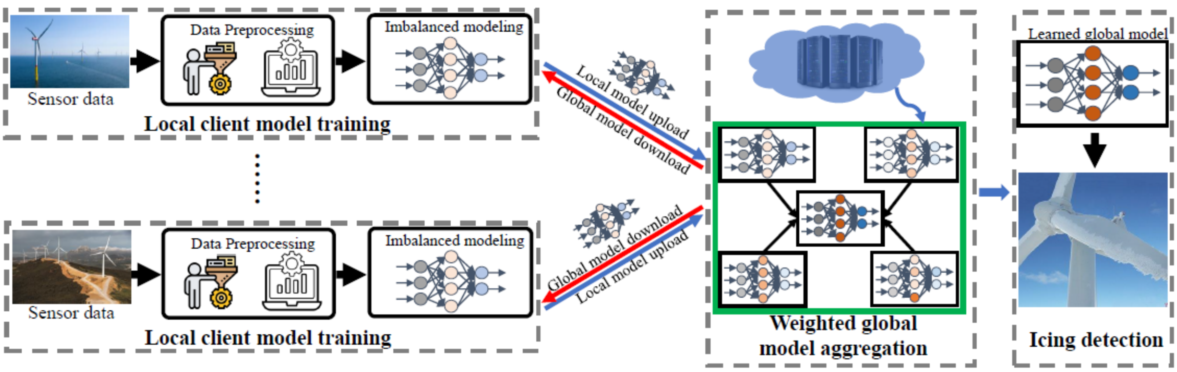


Fig. 7. Overview of Icing FL for blade icing detection of wind turbines [46]

Among RES, ocean wave energy holds great promise as a reliable and sustainable source of energy [47], with an expected potential of around 337 GW worldwide [48]. The main reason for this popularity is that wave energy is highly available in a number of regions, and carries higher energy density (per square metre) than wind energy [49]. A study [50] indicates that Indonesia has 1.2 GW ocean wave potential and implementation of ocean WEC (Wave Energy Converter) technology seems to be the solution for the rural islands. In [51] on the basis of diagrams for bivariate distributions of the sea states occurrences, defined by the significant wave height and the energy period, the output of nine different technologies for the conversion of wave energy is assessed in the reference locations in the bay of Cádiz-Spain. According to the results obtained, it can be said that the bay of Cádiz is a suitable place for wave energy extraction. In paper [52], a numerical model of typhoon waves in the Taiwan Strait is established based on the third-generation ocean wave model SWAN and then calculated by the wave energy empirical equation. The results show that most concentrated wave energy values are more than 300 kW/m for typhoon and more than 900 kW/m for strong typhoons, over 60 times and 180 times the annual average (5 kW/m) in the Chinese sea area, respectively. Therefore, there is a growing body of research on the design of WECs and diverse designs of WECs have been proposed in the last decade [53-55]. Neshat et al. in work [56] propose a novel multi-step forecasting model, consisting of an adaptive decomposition-based method and Bi-directional long short-term memory model to forecast the wave energy. The obtained results show that the proposed model significantly outperforms others over extended time periods.

The development of suitable electric energy storage system is crucial in order to handle the unpredictability and the fluctuations typical of renewables. One of the most attractive technologies is represented by hydrogen, considered as the ultimate solution to produce and store electric energy, when coupled with electrolyzers, fuel cells and hydrogen storage technologies [57]. The basic principle of this technology lies in the use of the excess renewable electricity to produce hydrogen, using electrolyzers, which can be stored in suitable systems and subsequently supplied to a fuel cell to produce electricity, when the user demand is higher than the renewable production. The large interest is demonstrated by the EU Hydrogen Strategy [58]. The main objective of work by Calise et al. [59] is the development of a specific dynamic model simulation of a reversible solid oxide fuel cell, allowing one to evaluate the system operating parameters, such as: cell temperature, cell efficiency and power, hydrogen production and consumption. Results showed that this system exhibits a very good storage capacity, but its capital cost is still too high for a good economic profitability.

As a promising RES, the utilisation of biogas is growing [60] at the rate of 11.5%/y [61], mainly because of its clean energy characteristics [62]. Biogas transportation is a matter of concern because of its production at atmospheric pressure. At this pressure, biogas has a very low energy density which makes its transportation uneconomical. For economical transportation, biogas is upgraded (known as biomethane) and liquefied (known as LBM) to enhance its energy density. Biomethane liquefaction is an energy-intensive process because of its low temperature (cryogenic) operation, mainly attributed to high compression energy required in refrigeration cycle. Any enhancement in liquefaction process either in terms of cycle modification or in refrigerant selection will be useful in energy saving [63, 64]. The study [65] presents an innovative biomethane liquefaction process that utilises CO_2 as a precooling refrigerant. This CO_2 precooling provides dual benefit; one is to overcome load on the main refrigeration cycle, and the other is its utilisation in a close loop that will contribute to manage CO_2 in a safe and economical way.

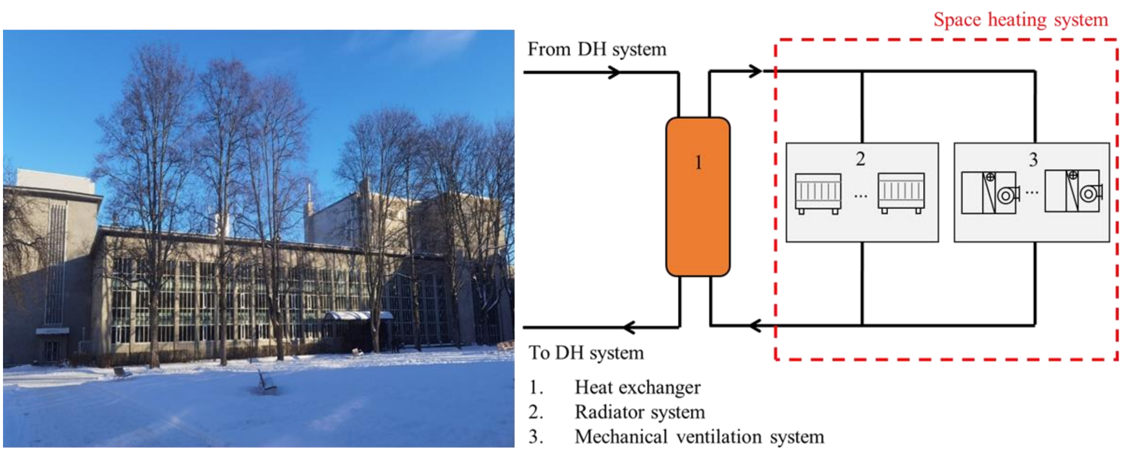
Small islands potentially have a great amount of RES which is often unexploited [66]. Indeed, in Italy, the maximum percentage of electricity produced by RES in islands is much smaller than the National average value equal to 33,9% [67, 68]. Moreover, transport, communication and energy costs are bigger respect to continental regions [69]. Processing the organic fraction of municipal solid waste through an anaerobic digester [70] directly on islands can be a solution to reduce the dependence from mainland in the waste management and to efficiently exploit local RES, producing clean biofuel and reducing costs. Masala et al. in the paper [71] investigate the economic, energy and environmental benefits given by the installation of an anaerobic digester in reducing costs, greenhouse emissions and primary energy imports in small islands. Three scenarios are hypothesized for the use of producible biogas. The results for island of Procida, Figure 8, show reasonable payback time, mainly due to the significant savings in the maritime transport and to the partial avoidance of the waste disposal on the mainland.

Fig. 8. Map of Procida [71]

Distillation columns are widely spread in the world industry. In review papers [72, 73] recently state-of-the-art literature review on HIDiC (Heat Integrated Distillation Columns) is presented. In study by Markowski et al. [74] a dynamic model of the apparatus, based on a new technology and used for thermal rectification of mixtures was developed. The channel-type exchanger is accompanied by diaphragm heat exchange. Their application in HIDiCs would allow reducing heat consumption by 40-60% compared to the existing industrial solutions.

Another topic widely investigated by contributors at SDEWES Conferences is the energy use in buildings, energy performance of buildings and the analysis of energy saving strategies in this sector. Some papers have been focused in particular on studying building envelope, passive strategies to reduce energy loads and solutions for renovation of buildings. The energy use in buildings accounts for a large share of total energy use and contributes to global warming considerably. In the EU, buildings are responsible for approximately 40% of the total energy use and 36% of the GHG emissions [75]. Among buildings' energy use, about

80% is for heating purpose including SH (Space Heating) and domestic hot water [76]. These numbers hint that small individual energy savings in the heating sector might have great impacts at a country level. It is critical to increasing the energy efficiency of the existing heating system in buildings, i.e. to reduce site energy use and energy cost while guaranteeing thermal comfort for the building's occupants. The application of predictive control techniques for the SH system to realize the optimal operation of the SH may be one way to achieve the above goals [77, 78]. MPC (Model Predictive Control) may be focused on the reduction of energy use, energy cost, and associated GHG emissions while maintaining and potentially enhancing occupant comfort [79]. The suitability of MPC to tackle the optimal operation of the SH system has been proven both by theory and real-life experiments [80-82]. A study carried out by Hou et al. [83] aimed to increase the energy efficiency of SH system by optimizing the operation of the SH system, while guaranteeing thermal comfort for the building's occupants. The proposed method was tested by simulation on a university building located in Norway, Figure 9. Results showed that the proposed MPC control strategy shaved the peak load by 7.8% and saved the heat use by 3.3% during one week, compared to the current rule-based control.



a) The university building b) Space heating system in the building

Fig. 9. The university used as the case study [83]

Future energy systems rely on the integration of RES in order to decarbonise the heating and cooling sectors and contribute to global net zero targets. Research has shown that conserving energy and producing green energy are the most effective methods of reducing GHG emissions [84]. In building applications conservation energy with aim to reducing GHG emissions involves retrofitting and installing high efficiency HVAC (Heating, Ventilation and Air-Conditioning) systems as well as introducing renewable technologies such as solar panels and absorption heat pumps. HCN (Heating and Cooling Networks) are a sustainable, flexible, and cost-effective engineering solution which will be a key player in the decarbonisation of this sector [85]. The fundamentals of this technology is to generate heating and cooling in a centralised location and distribute to a network of residential, commercial, and industrial consumers. Figure 10 shows the European fuel mix in building heating and cooling according to a publication by the Heat Roadmap Europe in 2017 [86]. Brown et al. [87] evaluated the current tools and techniques used to model heating and cooling networks and then proposes a more up to date hybrid approach which utilises recent technological advancements. The review concludes that energy models must evolve to become interdisciplinary and multi-objective, in order to simulate a smart energy system.

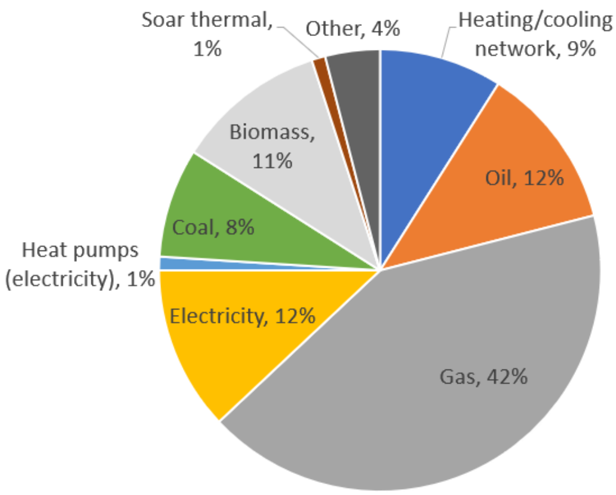


Fig. 10. Distribution of fuels in building heating and cooling in Europe [86]

The increase of the energy demands of residential neighborhoods constitutes a huge challenge to be faced. A viable option lies in the insertion of both renewable energy production systems and cogeneration units within urban territories. It is widely recognized that CHP (Combined Heat and Power) production allows achieving not only promising energy saving compared to separate systems but also to reduce the environmental impacts burdening the energy production [88]. Although CHP plants are commonly used in industries, some barriers have hindered the wide adoption in the residential and tertiary sectors. In particular, the most important problem to be faced when designing and operating CHP systems for these sectors is the variability of users' demand during the day. To address this issue, both deterministic [89] and stochastic approaches [90] were proposed. It is possible to enhance the sustainability of CHP plants by hybridizing them with RES [91]. Published papers have highlighted the increasing interest in combing fossil fuels with RES in polygeneration systems [92].

In a paper Volpe et al. [93] have developed a tool aimed at modeling heating and electricity networks integrated with cogeneration units installed in urban areas, Figure 11, tested on a densely populated area in Southern Italy. The tool accounts for the following possibilities: (i) variation of topology and sizes of both heating and electric networks, and (ii) evaluation of the electricity sharing configurations arising among end-users.

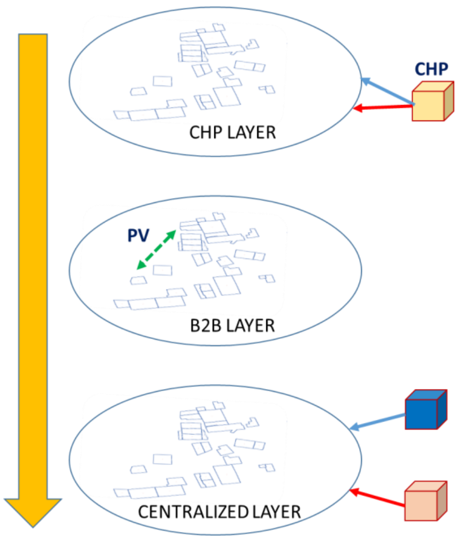


Fig. 11. Holistic overview of the thermal and electrical layers [93]

Renewable technologies are not recommended for large-scale production plants or centralized plants, leading to the introduction of the concept of decentralized plants based entirely on distributed production. This concept is directly related to integrated technologies, such as BIPVT (Building Integrated Photovoltaics Thermal), which exploits the solar radiation to produce electricity and thermal energy. The first experimental studies on PVT (Thermal Photovoltaics) were made by [94], and have completely revolutionized the way of approaching PV (Photovoltaic), making them useful for both electrical and thermal production. Moreover, if temperature values are not controlled, this leads to low efficiencies, making the use of PVs not productive. So, the introduction of air channels at the bottom of the PV panels for cooling aims produces a twofold benefit: increase of electrical production and use of waste heat recovery to balance the building thermal needs. In reference [95], the possibility of using air or water as cooling fluid is introduced, and results showed that PVT can cope with a large part of the load, given their high electrical and thermal production. In this way the economic feasibility of the technology is improved.

The present study by Maturo et al. [96] investigates the use and implementation of energy efficient measures and strategies for building applications, toward the NZEB (Near Zero Energy Buildings) target. Specifically, objective of the study is to implement BIPVT devices coupled with PCM (Phase Change Materials) and thermal storage building components, increasing building flexibility while still maintaining the indoor comfort level of occupants. The a multi-zone grey-box whole simulation model, including both thermophysical building, PVT, PCM and control features, is developed to capture the thermal dynamics of a building and for the use with a control strategy for energy management, Figure 12. Preliminary simulation results show that the proposed management strategy achieves load shifting, peak shaving, and grid interaction reduction, by optimally exploiting building thermal inertia and solar conversion toward the increase of building flexibility.

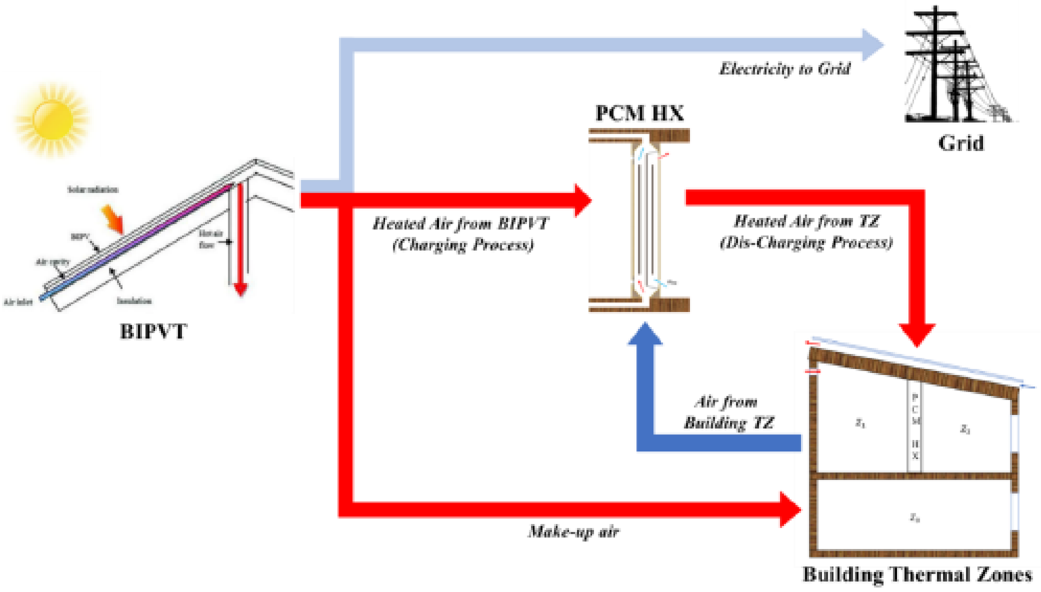


Fig. 12. Energy flows scheme [96]

In the building sector research is actively investigating innovative envelope configurations to limit thermal exchanges with the outdoor environment, provide thermal comfort to the occupants and exploit RESs. Several passive systems have been recently contemplated by the literature, and among them, solar walls are being rediscovered, since they allow rational use of solar radiation. Trombe walls fall in this category and they are an interesting solution that, although initially conceived for sole winter heating, can be used, if properly managed, also in a Mediterranean climate where the risk of summer overheating is high. Initially designed exclusively for passive heating of buildings in continental climates, they have recently received attention due to their low cost, simple implementation geometry, low running costs, and operational reliability also in other climates [97]. In **a** study carried by Bevilacqua et al. [98] an innovative configuration of a modular trombe wall for a residential application was presented, Figure 13. It can be easily integrated into existing buildings or new constructions providing benefits in both the winter and summer seasons. Results demonstrated the validity of the proposed solution indicating how a well-managed trombe wall can be regarded as an interesting solution to achieve energy savings in summer and winter.

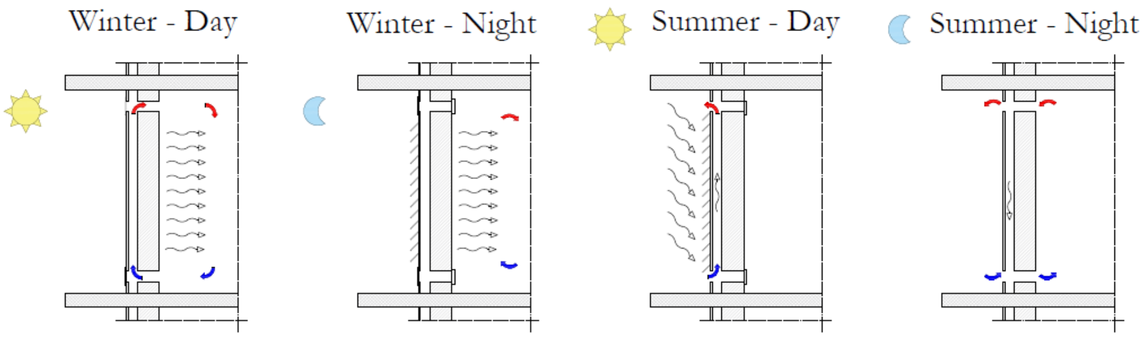


Fig. 13. Schematic operation of the Trombe wall in winter and summer [98]

Transmission losses in opaque components are influenced by mass transportation phenomena, the latter depending on built-in humidity level, material hygrometric properties and climatic conditions. Therefore, identical opaque components could offer different transmission losses as function of exposition and location. In order to limit as much as possible the thermal energy requirements, dispersing components have to be designed with proper U-value [99]. Indeed, the limitation of heating needs are achieved mainly by limiting the transmission thermal losses through the dispersing components [100]. Nevertheless, the evaluation of the transmission thermal losses in the common simulation tools are conducted in simplified manner [101]. Currently, it is determined as function of the thermal resistance of surfaces and layers in accordance to the standard EN ISO 6946 [102]. However many calculation simplifications are adopted (the hypothesis to consider an isothermal surface and neglecting the effects connected with the mass transport).

In a subsequent study by Bruno and Bevilacqua [103] by means of the dynamic procedure of the EN ISO 15026 implemented in the WUFI software, the effects on the thermal losses due to the combined effect of heat and mass transport in different wall solutions, were investigated for two opposite climatic conditions of the Mediterranean area. By referring to the steady U-value, results showed that deviances up to 15% were detected for walls North facing, whereas heating requirements of a reference building have showed increase of 5 - 9%. Nowadays, there are many technologies to supply buildings with heat, cooling and electricity as well as technologies for energy storage. With regard to the energy transition, it is needed to switch the energy supply to RES, to apply energy storage to balance the volatile resources available and to link the different energy sectors with each other. However, the current structure of taxes and levies does not lead to the application of corresponding energy systems. There are a lot of possible energy supply concepts for individual buildings as a result of the combination of GB (Gas Boiler), direct EH (Electrical Heating, PV, CHP, HPs (Heat Pump), SC (Solar Thermal Heat Generation) and energy storage technologies as HWT (Hot Water Tank) and BATs (Batterie), Figure 14 [104]. Which combination makes best sense depends strongly on the economic conditions and the energy market rules.

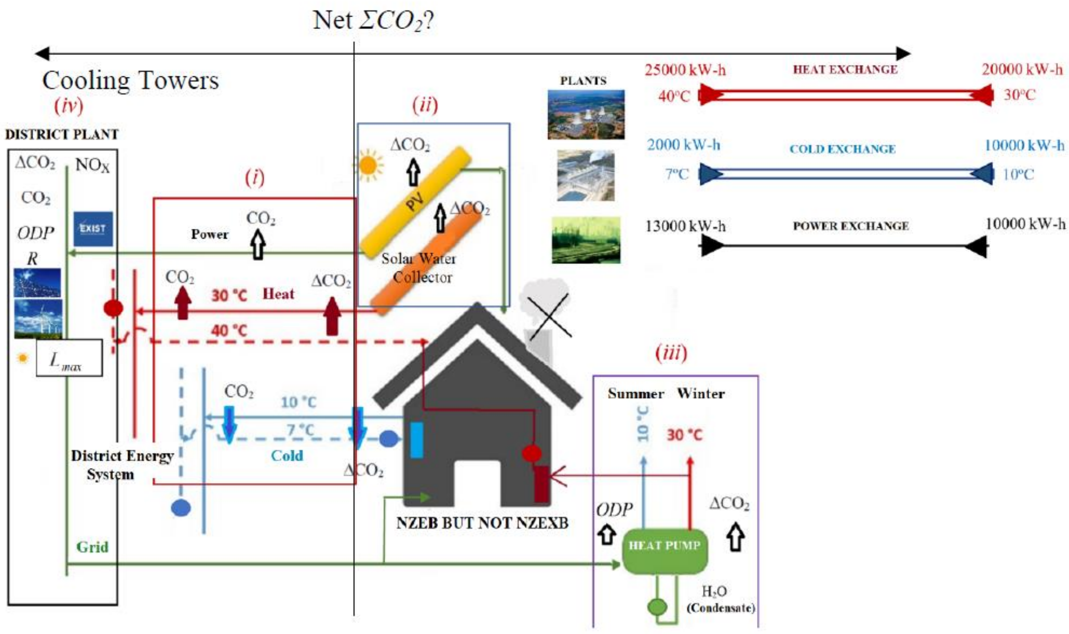


Fig. 14. A „Net-Zero Energy“ Prosumer Exchanging Heat, Cold, and Power [104]

A recent paper by Kilkis B. [104] discusses that the present net-zero building definitions are not comprehensive enough to achieve sustained goals for decarbonization and total electrification by showing that exergy destructions play an important role, especially in solar buildings in focus. The paper is also concerned with the efforts of transitioning to low-temperature district energy systems and argues that low-exergy renewable and waste energy sources may be utilized widely only with low-exergy buildings by using new hydronic heating equipment with heat pipes. It has also been concluded that a NZEB may neither be a net-zero exergy building nor a zero-carbon building due to unavoidable exergy destructions. The motivation of research work carried out by Baum et al. [105] is on the one hand to investigate the influence of current German regulation, taxes and charges on energy carriers on building energy systems. Furthermore, the aim is to show which regulatory approaches represent the most cost-effective solutions for energy supply that lead to CO_2 neutrality and also to the use of energy storage systems. A new method for the estimation of investment costs between 2015 and 2050 is developed and applied, Figure 15. The paper shows how an optimal building energy supply would look like under changed legal framework conditions as well as different tax burdens and reliefs.

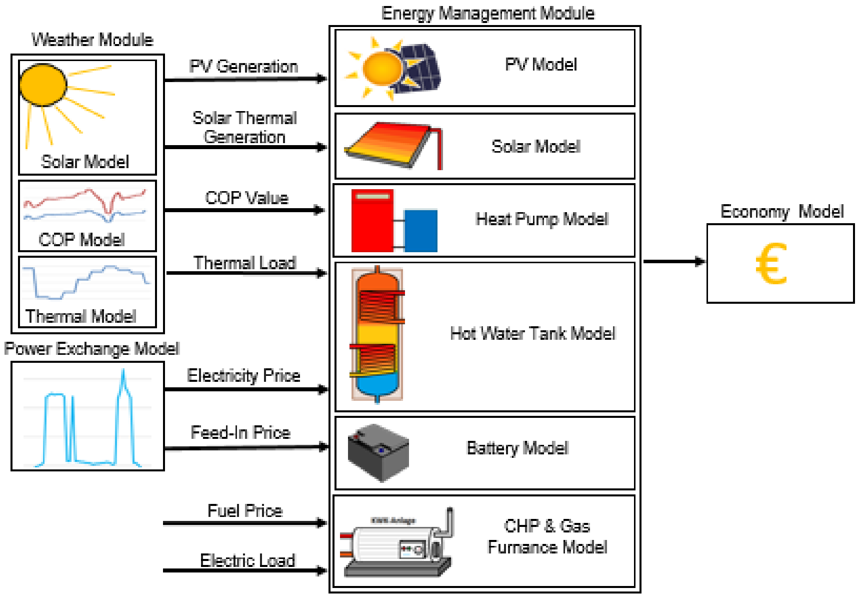


Fig. 15. Design of the simulation environment [105]

One of the major factors affecting the energy performance of HVAC systems is the occurrences of faults during their lifecycle. The occurrences of faults in HVAC systems have increased dramatically over the past few decades [106]. The large number of operational faults existing in HVAC systems leads to reduced performances for HVAC equipment, causing an additional 20% or more of HVAC energy consumption [107] and cost. Meanwhile, the degraded HVAC equipment also influences the indoor occupant thermal comfort and thus reduce the productivity of occupants in workplaces, such as offices. As a result, increasing demand for the development of robust FDD (Fault Detection and Diagnostics) methods. By introduction of FDD methods, HVAC energy consumption has reduced by 10-40% [108]. The presented study by Zhong et al. [109] assesses the impacts of operational faults on a VAV (Variable Air Volume) system from a medium office building under the current and 2030s weather conditions and investigates the influence of climate change on the fault impacts of VAV system in terms of system energy consumptions and occupant thermal comfort, Figure 16. The energy and thermal comfort impact indicators were proposed and calculated, and the faults were ranked in system energy consumption and occupant thermal comfort based on these indicators. The results demonstrate the importance of considering the effect of climate change on the development of FDD methods.

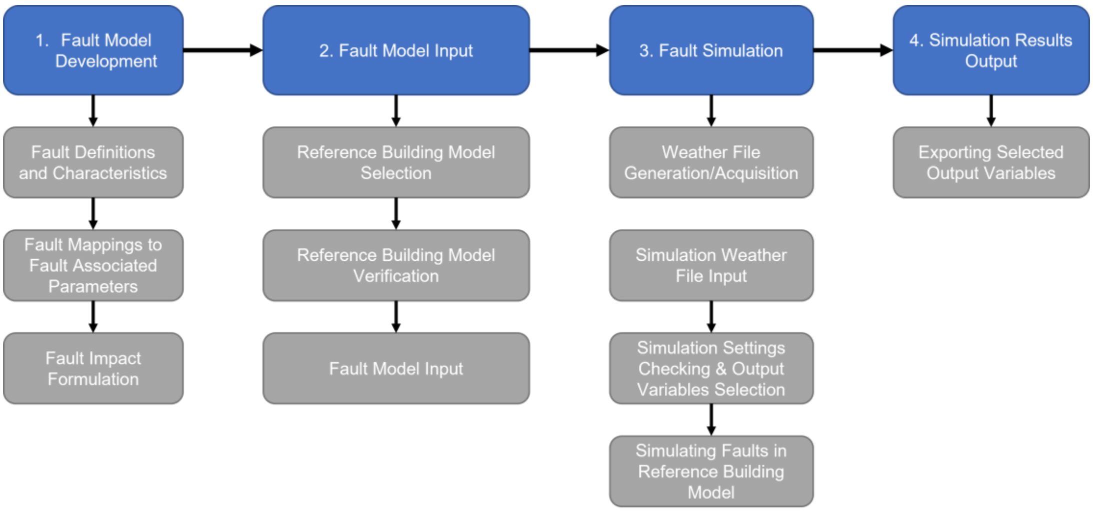


Fig. 16. Fault modeling and simulation processes [109]

Shopping malls have great potential to become crucial players in providing flexibility to the grid by regulating their energy demand. The HVAC system constitutes up to 40% of the total load, therefore it has a high potential to provide flexibility to the grid according to the required occupants comfort. In the most recent demand participation programs, referred to as DR (Demand Response), the consumers themselves are the protagonists, who can make their energy demand flexible as the economic conditions change in accordance with market logics [110]. By participating in DR programs, the user can actively contribute to solving any problems present in the network [111-113]. In particular, the user, following the declaration of a load profile for the following day, can offer the TSO (Transmission System Operator) a flexibility to go up or down in exchange for remuneration. A study carried out by Marco Tina et al. [114] was focused on a shopping centre heated and cooled through an HVAC system. The results show that shopping centers have good potential for participation in DR services, however during the summer season, the introduction of a DR event can compromise the thermal comfort of the occupants.

In the last years, the Covid-19 outbreak raised great awareness concerning IAQ (Indoor Air Quality) in confined spaces. Specifically, HVAC system design and operating parameters, such as ACH (Air Change per Hours), air recirculation ratio, and vents location, play a crucial role in ensuring indoor spaces air safety and in reducing the spread of viruses, mold, bacteria, and general pollutants. Concerning the transport sector, due to the impracticability of social distancing and to the low IAQ standards, the SARS-COV-19 outbreak brought a reduction of payload (up to 50%) for different carriers. Specifically, the payload reduction has been particularly severe for the railway sector, where carriages are typically characterized by a high recirculation ratio and low air changes per hour. Since the spread of the SARS-COV-2 (severe acute respiratory syndrome coronavirus 2) at the end of 2019 and the consequent outbreak of the Covid-19 (COronaVIrus Disease-2019) [115], the topic of IAQ has gained increasing interest [116]. Previously, the compromise between energy-saving and good air quality always saw the latter overwhelmed, excepting for some explicit applications (for example hospitals, specific industrial contexts, etc.). Conversely, ensuring excellent indoor air quality has become extremely vital [117], especially in the case of small and crowded indoor spaces. In this regard, diverse works exist in the literature assessing the Covid-19 contagion risk in indoor environments under diverse conditions: the small spaces, the high occupancy rate, and the adoption of ventilation systems with high recirculation rate makes busses, trains, metros, etc., places where the contagion risk is quite high [118-122] proving this to be a very actual matter [123]. However, most of the existing literature regarding this topic is focused on buildings neglecting other sectors. Specifically, Covid-19 risk represents a big issue for the public transport sector [124, 125]. A recent study by Barone et al. [126] aims at studying the feasibility and the convenience in adopting different solutions for indoor air quality enhancement in railway carriages (Figure 17 and Table 1), such as increasing ACH and reducing air recirculation ratio. It is possible to conclude that, to reduce the Covid-19 risk in railways coaches, revamping actions focused on the ventilation system could be feasible from the energy, economic and environmental points of view.

Fig. 17. Train 3D model [126]

Table 1: Train data [126]

Length	**27.2**	**m**
Width	2.80	m
Height	4.30	m
Floor area	87.48	m^2
Volume	169.75	m^3
Lower floor height	0.38	m
Intermediate floor height	1.20	m
Upper floor height	2.35	m
Fixed seats	129	-
Folding seats	6	-

Some contributions presented at SDEWES Conferences, which related to the previous two topics, have been focused on the energy storage. The development of new types of energy storage systems is crucial for the massive deployment of renewable energy on a large scale. Energy storage systems continue to grow in importance with the steady increase in RES within the framework of the global energy transition. Mechanical energy systems, as PHS (Pumped Hydro Storage) and CAES (Compressed Air Energy Storage), with a discharge capacity that can reach the order of GW [127-129], together with thermal systems (sensitive and latent), with a lower discharge capacity (0.1-300 MW) [130, 131] compared to mechanical systems, have been successfully tested in real operations so that they have a very high level of development, with TRL (Technology Readiness Level) equal 9. This is followed by electrochemical energy systems, batteries, with a discharge capacity limited to about 40 MW [132, 133], at a development level ranging from TRL 9 to systems whose prototype or components have been tested in relevant environments (TRL 5). At a lower level of development but with a discharge capacity similar to that of thermal systems [134, 135], are thermochemical systems, where the technology components have only been tested at the laboratory level (TRL 3-4). In terms of efficiency, mechanical systems would range from 60-80% [136, 137], followed by 50-90% for thermal systems [138]. Batteries would reach maximum efficiency of 95% (70-95%), while thermochemical systems offer a range of 75-99% [139]. In terms of initial investment, thermochemical systems are around 2000 USD/kW, which according to [140], is only surpassed by CAES systems. In the field of thermal energy, there are power and industrial facilities of high impact operating at temperatures in the range of 300-500 ºC, as the parabolic trough CSP (Concentrating Solar Power). Low-cost, low impact sustainable energy storage systems are required and adapted to different needs. There is a need for thermal energy storage systems to provide them with dispatchability. Current options are molten salt systems, with an LCOE (Levelized Cost of Energy) of 10-13

USD/MWh$_e$ in economic terms, and major limitations and drawbacks in operation and maintenance, batteries, with an LCOE of 100-1000 USD/MWh$_e$, pumped hydro and CAES, with LCOE of 120-210 and 350-400 USD/MWh$_e$, respectively, which have significant geographical limitations and location impacts, and flywheels, with 350-400 USD/MWh$_e$ [141]. Paper by Carro et al. [142] presents the analysis of a system for the storage of solar thermal energy in the form of thermochemical energy, on a large scale, based on the reversible reaction of calcium hydroxide formation, Figure 18 a,b. The CaO/Ca(OH)$_2$ system is based on the hydration/dehydration reactions of CaO, heating to decompose reactive calcium hydroxide into calcium oxide and steam and releasing heat through the reaction of steam with the calcium oxide, in the range of 410-550 ºC. CaO-based material is one of the most promising storage media due to its abundant and cheap resources, the possibility to store at ambient temperature and pressure, its high energy density or its easy operation in industrial applications. The analysis shows that the technology can be the basis for competitive energy storage, achieving overall efficiency of 35% and LCOE values below 60 USD/MWh$_e$ in economic terms, addressing the problem of renewable storage without the limitations that other storage technologies incorporate.

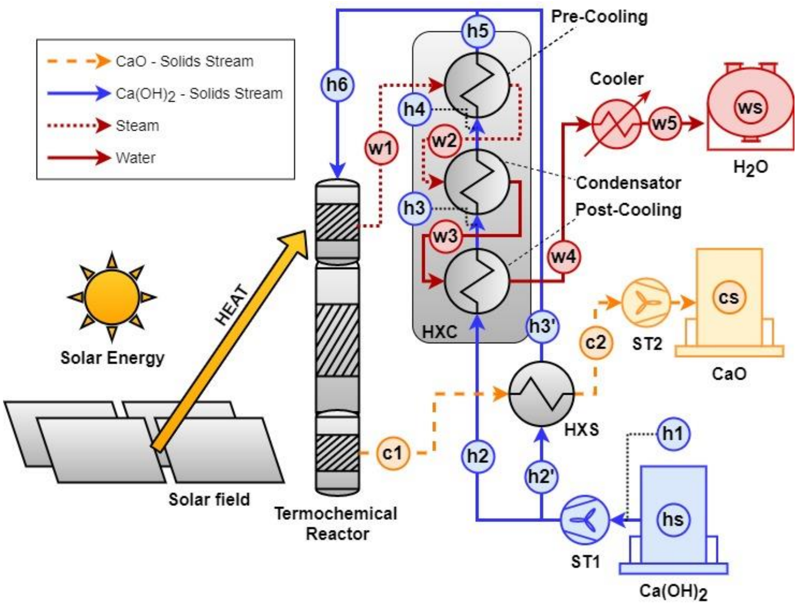


Fig. 18.a. System configuration in charging phase [142]

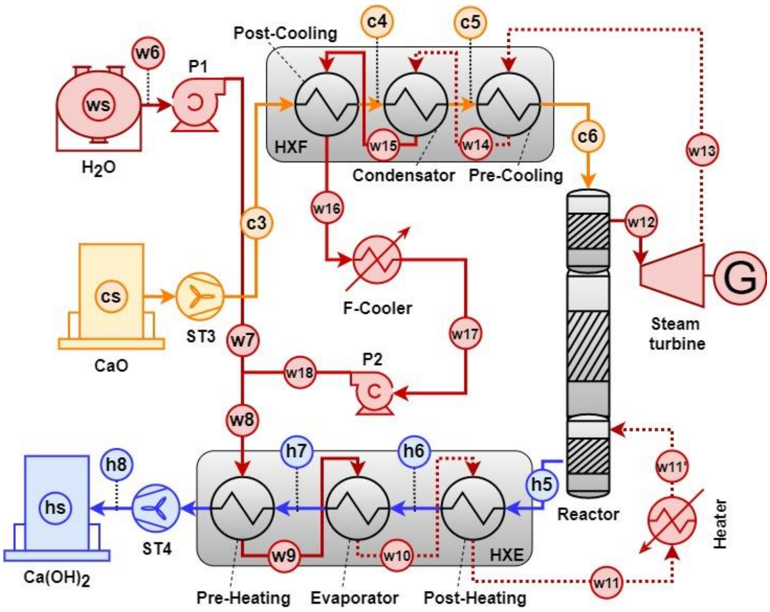


Fig 18.b. System configuration in discharging phase [142]

TES (Thermal Energy Storage) is a cost-effective and easy way to address the gap among energy demand and supply in various energy sectors [143], such as CSP plants [144]. To date, most scientific and economic research into energy storage at any scale has relied on the incorporation of energy storage techniques, for instance sensible, latent, or thermochemical [145]. Owing to the significant cost of its materials, the unit cost of storing thermal energy is currently higher [146, 147]. The capital and operating costs of the storage modules, as well as the system's life cycles, are used to calculate the capacity cost of a TES system [148]. In a paper Elfeky et al. [149] suggest the CSLHS (Combined Sensible-Latent Heat Storage) device as a replacement for the existing two-tank storage systems, with a solid structure layer of low-cost material and different thickness of the PCM layer, Figure 19. On the basis of two-phase dispersion-concentric equations, a detailed transient numerical analysis is developed. Numerical investigations are used to compare the proposed CSLHS system to the SHS (Sensible Heat Storage) system in the context of cost and efficiency. The impact of various performance evaluation indexes including axial temperature allocation, thermocline layer degradation, charging time, discharging time, and overall efficiency is investigated. Due to its optimized efficiency, reduced thermocline area, and comparatively low cost, the CSLHS (15% PCM-70% SHS-15% PCM) configuration demonstrates that it is a more viable choice among the considered cases.

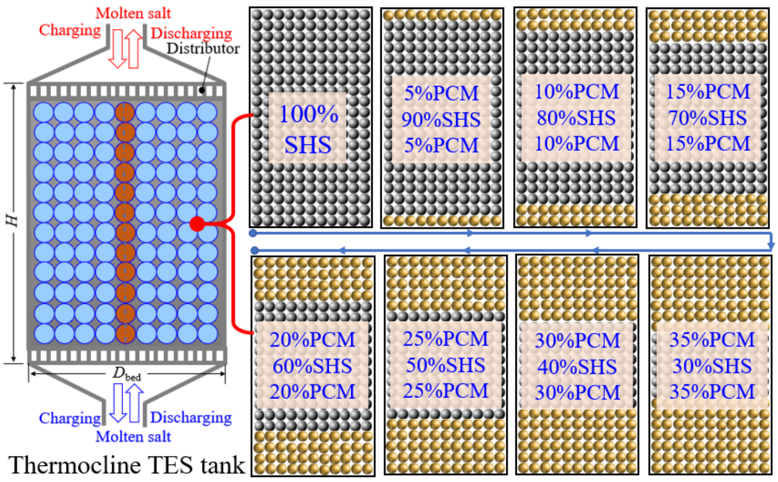


Fig. 19. Schematic of TES device systems [149]

Now the heating and water heating sector in households is responsible for approximately 20.5% of final energy consumption in Europe, with 56% still based on fossil fuels [150].The most promising solution towards a future low-carbon heating sector would be a combination of energy-efficient buildings with TES solutions linked to local low-carbon renewable technologies, such as efficient renewable DHC (District Heating and Cooling) networks and efficient HPs, involving the decarbonisation of the electricity grid [151, 152]. However, the electrification of heat is expected to be a difficult task [151]. It could cause a significant increase in electricity peak demand, above all in highly gas-dependent regions, which could have adverse consequences on the electricity system, particularly on the low-voltage distribution networks [153]. Moreover, this could be worsened by the deployment of electric vehicles [154]. The opportunity of the flexible electricity system to support heating, electrification and decarbonisation is moving rapidly through global energy policy discourse [155-160]. Lizana et al. in research [161] evaluated the heat storage potential in buildings during the next decade to foster heating electrification and decarbonisation, Figure 20. First, the implication of the heating sector in the European environmental targets is evaluated using the data provided by EUROSTAT [162], Figure 21. Second, the potential impact of heat storage for heating electrification is evaluated using Spain as a case study. The results highlight the implications of heat storage in buildings to promote European targets, which should be considered in future building regulations to help transform the power system.

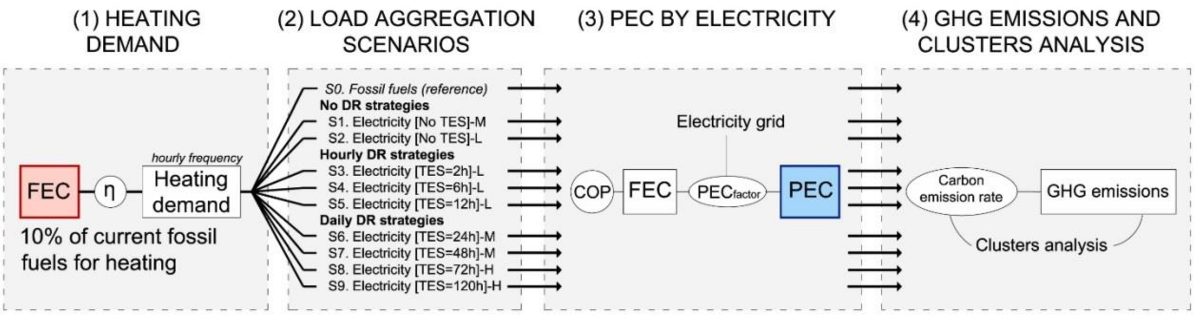


Fig. 20. Methodological steps for evaluating the heat storage impact [161]

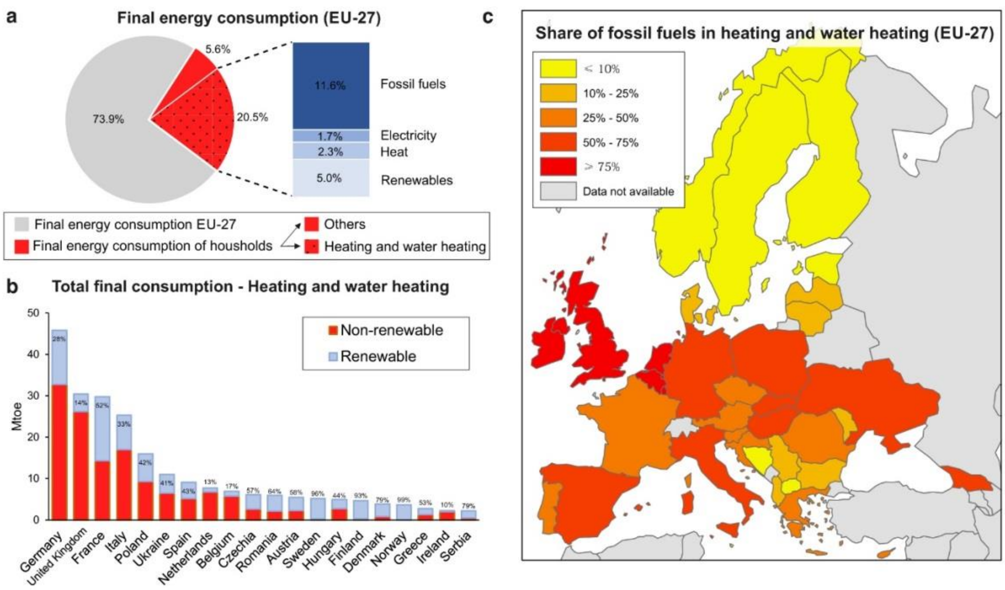


Fig. 21. Heating sector in EU [162]

The aim of study Li et al. [163] is to systematically investigate the charging and discharging processes of the as-synthesised TCM (Thermochemical Material) in a corrugated-shaped HSU (Heat Storage Unit). The results may offer a prediction and regulation strategy of the thermochemical conversion behaviour in a TCES (Thermochemical Energy Storage) system and provide insights into the prediction and improvement of thermochemical conversion behaviours.

Finally, technology that has attracted increasing interest due to its potential to contribute to the ongoing energy transition, and in particular to the environmental pollution, exhaustion of resources, and excessive land use is WtE (Waste to Energy). Along with the world urbanization development, the production of MSW (Municipal Solid Waste) grows rapidly. The annually generation of the MSW in the world will reach 2.2 billion tons in 2025 and 4.2 billion tons in 2050, respectively [164]. The CE (Circular Economy) concept is accommodated worldwide to respond to current negative environmental trends and recently obtained substantial attention from policymakers worldwide [165]. The paper [166] characterizes CE as an approach that can overcome environmental problems and embed sustainability into production processes. The main idea behind this approach is rather simple: perceiving the earth as a closed system with finite resources, where economy and environment should coexist in balance [165]. The aims of CE can be summarized as follows: reduction of virgin inputs, especially natural resources, minimization of waste by recycling or restoring, and closing production cycles [166]. Expectedly, non-recyclable waste may represent a possible complication within CE closed production cycles. However, even this non-recyclable fraction can be utilized. According to [167], practical CE makes point of utilizing non-recyclable waste using WtE technology among other methods. Incineration of MSW presents a promising implementation of WtE technology [168], because of the advantages of efficiently reducing the mass and volume of MSW and the energy recovery [169]. WtE plants prevent entering of dangerous wastes into the environment and minimize GHG emissions, serving as low carbon energy sources [170]. Due to high public attention and continuous development of incineration technology, WtE plants have become and widely implemented environmentally friendly WM practice [171, 172]. However, according to [173], there must be a necessity to significantly increase landfill taxes to promote environmentally friendly waste treatment and to lower GHG emissions. Article by Eryganov et al. [174] provides a review of current applications of game theory to environmental studies and exploits apparatus of distributed dynamic coalition formation games in the Czech Republic WM case study. Results provide a view on the impact of the WtE technology implementation and limited landfilling on the municipal budgets and suggest the most suitable municipal unions for handling waste management tasks. Due to the stability and flexibility, grate-firing technology has been widely used in MSW incineration, in particular for the high moisture or low heating value MSW. Most of WtE plants were designed and operated based on the low heating value (around 7530 kJ/kg) MSW [175]. The moisture of the MSW for incineration is considered to reduce by 13.6%, and the heating value is considered to increase by 16.2% as reported in [176], which will influence the incineration status a lot for the current MSW incinerators. In paper Gu et al. [177] simulate MSW incineration in an industrial grate-firing boiler via Ansys Fluent coupled with an in-house bed model, by the radiation heat flux from the freeboard and the combustibles leaving the fuel bed. After validation by the operation data, the simulation study for a new MSW feedstock incineration has been carried out aiming for the mandatory garbage classification rules implementation in China recently.

Conclusion and acknowledgements

This Special issue, dedicated to the 16th SDEWES Conference held in Dubrovnik, October 10th – 15th, 2021, where recent advances were presented in several fields relevant to the sustainable development of energy, water and environment systems: energy planning and modelling of energy systems, renewable energy sources, energy use in buildings, energy storage and waste to energy. The Guest editors believe that the selected papers published in the five hot topics will considerably contribute to extend the knowledge body published in Energy journal and will be of interest to its readers. The Guest editors would like to thank all the reviewers who have made most valuable and highly appreciated contributions by reviewing, commenting and advising the authors. Special thanks should go to the administrative staff of the Energy journal for their excellent support.

Abbreviations

ACH	Air Change per Hours
BAT	Batteries
BIPVT	Building Integrated Photovoltaic Thermal
BS	Bill Sharing
CAES	Compressed Air Energy Storage
CE	Circular Economy
CHP	Combined Heat and Power
CSLHS	Combined Sensible Latent Heat Storage
CSP	Concentrating Solar Power
DHC	District Heating and Cooling
DR	Demand Respond
EH	Direct Electrical Heating
EU	European Union
FDD	Fault Detection and Diagnostics
FL	Federated Learning
GB	Gas Boiler
GHG	Greenhouse Gas
HCN	Heating and Cooling Networks
HIDiC	Heat Integrated Distillation Columns
HP	Heat Pump
HSU	Heat Storage Unit
HVAC	Heating, Ventilation and Air-Conditioning
HWT	Hot Water Tank
IAQ	Indoor Air Quality
IES	Isolated Energy System
LCOE	Levelized Cost of Energy
MAC	Marginal Abatement Cost
MMR	Mid-Market Rate
MPC	Model Predictive Control
MSW	Municipal Solid Waste
MV	MinVar
NZEB	Near Zero Energy Buildings
PCM	Phase Change Materials
PFS	Proportional Fair Sharing
PHS	Pumped Hydro Storage
P2P	Peer to Peer
PV	Photovoltaic
PVT	Thermal Photovoltaics

RES	Renewable Energy Source
SC	Solar Thermal Heat Generation
SDEWES	Sustainable Development of Energy, Water and Environment Systems
SDR	Supply and Demand Ratio
SES	Smart Energy System
SH	Space Heating
SHS	Sensible Heat Storage
SV	Shapley Value
TCES	Thermochemical Energy Storage
TCM	Thermochemical Material
TES	Thermal Energy Storage
TRL	Technology Readiness Level
TSO	Transmission System Operator
VAV	Variable Air Volume
VNB	Virtual Net Billing
WEC	Wave Energy Converter
WM	Waste Management
WtE	Waste to Energy

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