

A step toward sustainable development through renewable energy solutions: A case of Italy

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ARTICLE INFO	ABSTRACT
<p>Original Research Article Received on April 30, 2024 Revised on May 02, 2024 Accepted on May 23, 2024 Published on June 03, 2024</p> <p>Article Authors Vinod K. Sharma, D. Buddhi, M. Carbone, Joginder Singh</p> <p>Corresponding Author Email vinodkumar.sharma@enea.it</p>	<p>From the sustainable development viewpoint, renewable energy conversion technologies play a crucial role in ensuring energy security, limiting the rising global atmospheric temperature, energy access to all, food security, and economic development of the society. This study presents the case of Italy that utilizes renewable energy technologies for its sustainability. A few technologies were developed and demonstrated in different regions of the county to explore the available renewable energy sources' potential in an economical manner. Advancements in RE technologies favorable policy initiatives led the country to be among the top renewable energy-driven countries in the world. Presently, renewable energy sources contribute approximately 37% in the overall energy consumption of Italy. Decentralized renewable energy conversion technologies were identified based on the available potential of the renewable energy sources and demonstration systems were installed. Implementation of an energy mix of solar PV of 135 kW; a mini-hydro plant of 400 kW and garbage driven biogas system was proposed that expected to lead to the production of 200 million kWh of electricity, savings of 8 million cubic meters of methane in a period of 10 years. Eventually, the reduction in CO₂ was expected to be around 168 million cubic meters per year. There are a few other demonstrations presented in this paper, which reduced dependency on fossil fuel significantly by utilizing the region-specific renewable energy resources. Such initiatives may assist in ensuring sustainable development not only in countries like Italy but in many other countries around the globe.</p>
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In the midst of accelerated global warming, economic insecurity, and finite resources, it is critical to identify measures, which better quantify territorial units' sustainable development. In the twenty-first century, the idea of sustainable development is important. As per the World Conservation Strategy, released in the year 1980 (World Conservation Strategy, 1980), the process of modifying the biosphere and applying human, financial, and natural resource capital to meet or exceed human demands and improve the quality of life for all people.

As stated in the document, Sustainable development takes into account the long-term and short-term benefits and drawbacks of different measures. It is worth noting that there are more notions of sustainable development (Alaimo *et al.*, 2020; Mendonca *et al.*, 2017; Holden *et al.*, 2017; Robert *et al.*, 2005 and Parris *et al.*, 2003). Alternatively, the sustainable development (SD) is defined as development that fulfils present demands without jeopardizing the ability of future generation to satisfy their own needs (WCED, 1987). This term is linked to two major ideas.

The first is needs particularly the most basic requirements of the world's poorest people, which should be given first priority. The latter is referred to as limitations and it refers to the environment's imposed ability to fulfil current and future needs based on the degree of technological development and social structure. Management of the environment, society and economy are recommended in order to preserve the current level of civilization (Sztangret, 2020). In 1992, the UN criticized decision making processes that separated environmental, social, and economic issues. Further, a method that integrates environmental, social, and economic concerns was outlined by the UN's Agenda 21 (UN, Agenda 21, 1992). It has, however, been difficult to put Agenda 21 into action. The 2030 Agenda for sustainable development, which was just released, outlines a new vision of development. It focuses on five major transformational shifts, which are characterized by the 5P concept (people, planet, prosperity, peace, partnership).

The sustainable development goals (SDGs) include eradication of poverty and hunger, ensuring healthy life style and wellbeing, great higher learning, gender equality and pollution free energy (UN, 2015). Sustainability was summarized in an intriguing way by (Alaimo, 2018). He claimed that the SD may be regarded a three-way comprehensive frameworks, encompassing the complex systems i.e. economic, social, and environmental interact with each other. Contrary to popular belief, many researchers have identified quantifiable indices of sustainable development.

The SD is a complex phenomenon with many facets. Finding acceptable indices to quantify a region's development level using multiple sustainable development dimensions is a challenge. Numerous municipal governments across the world have already begun moving toward long-term social development that is sustainable. There are several small to big scale initiatives addressing issues such as improving energy performance of systems, processes and technologies, offering incentives for using renewable energy sources and emphasizing on organic farming. Many worldwide best practices can be reproduced in small to medium sized cities, based on accessible data.

As an example, photovoltaic systems might be used to power the household and thermal collectors can be used for water heating in India, China, and many European nations. Comprehensive community planning, based on world- wide best practices, should encourage energy diversification, efficient fossil fuel use and the stimulating connections between the energy, environment, and SD. The energy efficiency and optimum utilization of the renewable resources (commonly referred to as sustainable energy sources) are better choices to help improve and increase sustainable development skills (Patel *et al.*, 2022; Jaral *et al.*, 2021; Kumar, 2021 Singh *et al.*, 2020). This paper's goal is to highlight sustainable development techniques used in various Italian areas and their effects on the environment and society as a whole. In addition, the projects chosen in this assessment are based on the dependability and possibility for replication in other parts of the world.

Description of the Case Study Location

Italy is a country made up of a peninsula surrounded by mountains and islands. The nation is in Southern Europe, near the Mediterranean Sea, and is frequently referred to as Western Europe because of its location in the region. Rome is the biggest city in Italy and is capital of the unitary parliamentary republic. The nation is 301,340 km² in size and share borders with Switzerland, France, Slovenia, Austria, San Marino and the Vatican City. The country possesses a territorial exclave in Switzerland, as well as a marine exclave in Tunisian seas. The country is the third most populated member of the European Union (EU), behind Germany and France. Following its rapid industrialization, Italy was slow to address environmental issues. It is presently ranked 84th in the world for environmental sustainability, following significant upgrades. Approx. 5% of total land in the Italy is covered by national parks (Italy Environment, 2009 and National Parks in Italy 1995–2010). The county has a varied climate. Mainly, central interior and northern regions fall in humid sub-tropical to humid continental and oceanic climates. The climate of the Po Valley area, in particular, is predominantly influenced by hard winters and scorching summer (Adriana Rigutti, 2009 and Thomas A. Blair).

A typical Mediterranean climate may be found along Liguria's coast, in Tuscany's hills, and throughout much of the rest of the southern Italian peninsula. The climatic classification of the country is shown in fig 1. During the winter months, conditions in the interior's higher hills and valleys can be considerably different from those found on the peninsula's coastal sections, which are often colder, wetter and more likely to be covered in snow. Winters are pleasant along the shore, while summers are warm and mostly dry, but the low land valleys may get extremely hot during the summer months. Ambient air temperature in summer ranges from 20 °C to above 25 °C while the temperature in typical winter ranges 0 °C in the Alps to 12 °C in Sicily. The winter season can vary greatly throughout the nation, with chilly, hazy, and snowy times in the northern region and warmer, sunny temperatures in the southern region of the country. Summers may be hot and humid in the south, while spring and autumn can bring severe thunderstorms to the north and central (Climate Atlas of Italy). The meteorological conditions imply a substantial need for room heating, which solar energy may provide.

Environmental Issues and Renewable Energy Utilization in Italy

Air pollution persists, notably in the industrialized north, where industrial carbon dioxide emissions ranked tenth globally in the 1990s (Italy Environment, 2011). Cities with high concentrations of people continue to have serious environmental and health problems as a result of traffic congestion. In spite of the fact that smog levels have plummeted during the 1970s and 1980s, and Sulphur dioxide levels have also plummeted (WHO, 2010). According to a World Health Organization research from 2006, air pollution levels in Italian cities varied from 26.3 to 61.1 milligrams per cubic meter (PM10), indicating severe levels of pollution. The WHO sets the threshold at 20 µg per cubic meter, whereas the EU put it at 40µg per cubic meter (daily limit value). Over 66000 people die prematurely from particle air pollution, according to the European Environment Agency (EEA). Because of the Italy's high levels of air pollution, the country has taken strong measures to move away from its fossil fuel-based economy and toward one powered by renewable energy.

Consequently, the country became one of the major renewable energy producers in the world in 2010 and secured 4th rank in the highest solar power system installation and 6th rank among the highest wind power system installation (REN21, 2010; World Wind Energy Association, 2010 and Photovoltaic Energy Barometer, 2010). The mean of yearly values of PM10 in the Italy between 2012-2015 was estimated, by the EEA, below threshold level (Brett Smith, 2015). The proportion of renewable and nonrenewable energy sources to overall power generation is depicted in fig 1. Since 1990, the proportion of renewable energy used for electricity generation has been steadily rising. In 2020, approximately 37% of the total energy usages in the country were fulfilled by the renewable sources of energy (Redazione ANSA, 2021).

Best Renewable Energy Practices for the Sustainable Development

For minimizing the country's air pollution being produced by the combustion of conventional sources of energy, maximizing the usage of renewable energy appears to be a good alternative to consider. Decentralized renewable energy conversion technologies for heat and power applications, in addition, have the potential to enable the efficient and cost-effective utilization of renewable energy sources in various regions of the nation. Thus, the generation and use of Bio oil in Caorle (Veneto); generation of electricity and biomethane for power supply and other services in the Lucanian Dolomites (Basilicata); installation of solar collector - storage heating system for heating a school in Caviglio (CO), etc., were accomplished in Italy.

Biofuel Farm Chain to Supply Pure Vegetable Oil for Tractor Engines

Dossetto Vallevecchia it is 400 acres agriculture farm using a tractor fleet of 13 machines was established in a short and closed chain for producing bio-oil for fueling the tractors (Agostinetti *et al.*, 2013). An all-in-one manufacturing and filtering system for pure vegetable oil has been set up on-site. The machine is very efficient and manageable due to its total automation and electronic starter and control system.

Cold mechanical pressing is used to extract the oil, with no chemical solvents used. The oil yield is around 37% to 40%, and the seed processing capacity is about 120 kg per hour. The machine yields around 40 kg of pure vegetable oil every hour (about one-third of the seed's original weight) and about 80 kilograms of a by-product (about two-thirds of the seed's starting weight). The machine is fed rapeseed grown on farm agricultural land (which yields 3 tons of seed per hectare). Two commercial tractors are run on 100% bio-oil (Lamborghini Victory plus 230 and Fendt 820 Vario Greentec). The establishment of the farm chain creates new economic prospects in the field of renewable energy generation. Unlike the fuels (i.e. diesel, bio-diesel), a single farm or group of small farms can be used to produce pure bio-oil. It is environmentally good to use vegetable oil as a fuel. Emissions are reduced and improved because it is biodegradable and renewable. The selling of expeller cake for animal feed is a significant economic source that enhances agricultural revenue.

Bio-electricity from Biomass

Fig 4 shows the machination plants for biomass energy generation, developed by ENEA. The activity was sponsored by a total budget of 500000 Euro. A biomethane-to-electricity plant was also developed based on the concept, and it was proven that it could be utilized to provide services in the protected Lucanian Dolomites of Basilicata. The wood debris collected from forest cultivation was effectively used. Gasification produces electricity and heat and may be incorporated into the national energy production system. The incentive strategy adopted by the Decree of Law on July 6, 2012, certainly makes it convenient and feasible to be integrated. Plants that burn or gasify woody biomass to produce heat and power have proliferated across the country in the last few years. For the most part, these facilities are modest to medium-sized and able to employ local biomass as feedstock (such as pruning from vineyards and olive groves, wood from forest care, and so on).

CO₂ Savings by Renewable Energy Mix in Marche

As part of its General Plan for the Development 2012-2014, to take maximum

advantages of locally available renewable energy resources, Maiolati Spontini Municipality had installed a 135 kW solar PV plant, a mini hydro power plant of 400 kW and a trash dump based biogas digester (Photovoltaic Solar Panels). The fact that it is made up of two 4.130 kW plants and produces approximately 17 million units annually, which eventually accomplishes annual energy usage of around 4000 households is quite intriguing. Moreover, the strategy was backed by incentives for the removal of existing asbestos containing buildings and structures, programmes for environmental conservation and preservation, the progressive replacement of conventional lighting systems with most energy-efficient luminaries, the use of non-conventional sources of energy and verification of the contribution from renewable energy conversion technologies (i.e. solar PV, solar thermal, bio-digesters, wind power systems etc.) and financial support for projects involving renewable energy sources as well as incentives for bio-construction. The reduction of reliance on fossil fuels and the enhancement of environmental quality (i.e. daily collection of about 40000 cubic meters of waste gas that is characterized by toxic chemicals such as methane (55 percent), CO₂ (35 percent), and nitrogen (6 percent) a) were anticipated.

According to initial estimates, 200 million kWh of energy will be generated over the next decade, and 8 million cubic meters of methane will be avoided. This would reduce CO₂ emissions by 168 million cubic meters per year. This good practice was just formed out of the voluntary efforts of the Energy Community, an association of residents in Energy towns. This organization's mission is promoting renewable energy conversion technologies installations in the town. To promote citizen participation in a communal investment to build a renewable energy production facility in San Lazzaro di Savena, this organization made an announcement with the municipality (L. Barbieri). The local government, the township Association (Energy Community), and the residents are the partners. Citizens from San Lazzaro di Savena and neighboring towns are welcome to join in the project. Citizens who opted to engage in the venture formed an association and funded the investment by purchasing finite and upto 250 Euro's shares in the total investments.

For executing the plan, local government arranged the rooftop of a public school the installation of solar plant. The association was in charge of the solar plant's design and construction. The local government assumed control of the plant once it was installed. The citizens' association gets the economic return on investments, which are associated with the benefits and incentives earned by selling of generated power, for 20 years period, from the installed renewable energy power plants in the country. The associations dis tributes the monetary benefits to the participants in the investment in proportion to their ownership of the shares. The power generated by solar energy is used by the school. The major projected results are a 20% reduction in final energy consumption compared to 2005, as well as the development of the renewable energy generation systems and the promotion of energy efficient technology; allowing people to become producers and sellers of renewable power while receiving all advantages offered currently by the government as financial incentives, lowering school energy expenses and producing energy from renewable resources, and so on.

Creating Thermal Comfort Local District School at Vicenza using Wood Chips Boiler

When the City Council and the residents of Valli del Pasubio commissioned a feasibility study, they found out that the local biomass could be utilized as fuel in the school's wood boiler (local district school, 2004). In the valley, wood chips are mostly generated via the up- keep of local trees. At the middle school, the heating plant is housed in a building that was formerly used for the boiler. Wood chips are stored in a silo that is entirely underground. The boiler is a UNICONFORT moving grate type designed to heat water at 95°C and supplying it. The chips are exposed to two stages i.e. first gasification and thereafter oxidation of produced gases. The heated gases, which are at around 900°C, are used to heat the water in the range of 80-90°C by passed through a heat exchanger. Then, the heated water is supplied to the two schools by a hot water distribution system to accomplish their hot water requirements. Prior to entering the flue, combustion gases travel through a multi-cyclone system that ensures emission levels are fewer than permissible.

The entire heated volume is roughly 23,000 square feet, with an annual wood chip usage of around 200 tonnes. By using wood instead of fossil fuel, the City Council and the surrounding Mountain Community have saved a substantial amount of money.

Solar Heating of School Building at Caviglio in COMO

A system is made up of a solar collector, which is connected to an 8 cubic meter tall storage tank. It was planned to operate the system in the solar conversion efficiency in the range of about 55-60% (Giorgi, 1991). A solar air collector with a gross area of 50 m² (2.5m high and 20m in length) was installed to charge the storage tank and supply warm air to the building. The storage system was divided into two compartments, A and B each of them had an effective storage volume of 4.8 x 2.2 x 0.84 m³, respectively. The storage compartments utilized the bricks for sensible heat storage. The entire system is housed in a cubic shape with dimensions of 5.85 x 2.80 x 0.84 m³. A 30 cm thick polyurethane layer is applied around the perimeter and at the back to prevent heat loss.

However, the available storage volume was not sufficient to store all the heat supplied by the designed and installed solar collectors. The thermal performance of two similar storage compartments but having unequal air flow channels may vary if the arrangement and materials of the bricks used in the storage are changed. The air supplied to the heat storage compartments from top to extract heat from the storage unit and to hot air exit from the other side and supplied to the space to be heated. The solar conversion efficiency of the solar air heater system was estimated approximately 45% on clear days while the instantaneous efficiency was around 55%. The energy accumulated throughout the day was utilized to heat the building by discharging the storage device at midnight. In addition, the Storage technology may maintain a large amount of energy stored overnight. Passing the air straight through the storage was a small change made to utilize the energy accumulated during the early morning hours, i.e. almost 2 hours before school begins. It is not recommended to send air through the collector since this causes additional cooling, which is especially important on cold, cloudy days.

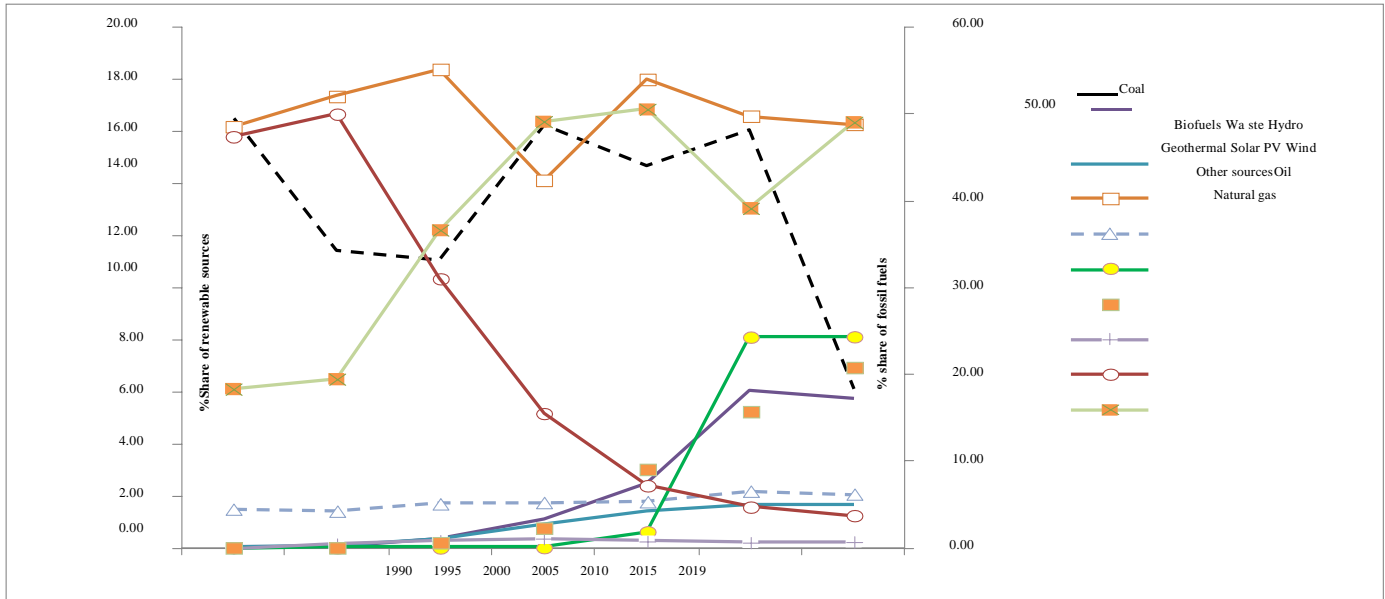


Fig 1. Change in share of different energy sources in Italian total electricity production between 1990-2019 (Data source: IEA)



Fig 2. Good renewable energy practices in Italy (Source: ENEA)



Fig 3. Methanation plant for bio-electricity production installed in Lucanian Dolomites of Basilicata (Source: ENEA)



Fig 4. Wood chip based heating plant installed at School in Valli del Pasubio in Italy

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