A 100% Renewable Energy Scenario for Finiq Municipality

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Abstract- *The municipality of Finiq, located in southern Albania, is facing several challenges, such as population shrinkage, isolation, and loss of community identity.*
One of the main issues is related to a non-efficient supply of energy. In this regard, Finiq municipality is affected by frequent blackout of electricity. This is a dramatic issue both for households and companies.
Such issue is a paradox since two big hydropower plants are present within the municipality. However, most of the electricity produced by the hydropower plants is supplied outside the municipality.
The study is focused on the identification of the most suitable renewable energy sources as well as of their location within the municipality in order to transform Finiq in a 100% renewable municipality.
In addition to offering an affordable source of energy, renewable energy sources provide a wide range of socioeconomic and environmental benefits. The transformation to a 100% renewable energy system in all end-uses would generate new jobs, improve health due to cleaner air and water, as well as increase energy independence and economic growth. Furthermore, a 100% renewable scenario would allow to meet the European requirements in terms of energy efficiency and decarbonization of energy, that can help Albania to make a further step towards the entrance into European Union.
Due to agricultural character of the municipality, agrivoltaics (i.e. the simultaneous use of areas of land for both solar photovoltaic power generation and agriculture) can be a valuable option as many crops are suitable to be planted below the photovoltaic panels.
Forest heritage is very huge in Finiq municipality, especially in the mountain area.
A sustainable management of the forest heritage would allow to create a large amount of biomass that can be exploited for heating purpose, mostly in the area with higher heating demands.

Introduction - In recent years, there has been a growing global recognition of the urgent need to confront climate change and reduce greenhouse gas (GHG) emissions to mitigate its catastrophic effects (IEA, 2015).
This ambitious target recognizes the severe consequences of exceeding the 2°C threshold, including more frequent and severe weather events, rising sea levels, and disruptions to ecosystems.
Several scenarios of climate evolution explored by the IPCC (2013) show an increase of summer temperatures up to 4 or 5 °C combined with a decrease of 20% of rain amounts during spring and summer, in the Mediterranean regions, at the 2100 horizon.
The Paris Agreement commits its signatories to take action to ensure that the global average temperature increase is kept well below 2°C and to pursue efforts towards limiting global warming to 1.5°C.
The consumption of non-renewable energy is responsible for carbon emissions with disastrous consequences, normally referred to as global warming, for the planet Earth, and humanity.
Achieving climate neutrality by 2050 means making far-reaching changes to the way we live today, which is why the Commission is proposing to cut greenhouse gas emissions 55% by 2030 (European Commission, 2022). This increased level of ambition for the next decade will put the EU on a balanced pathway to climate neutrality by 2050.
Climate change will continue to create significant stress in Albania in spite of mitigation efforts. Strengthening the efforts on climate proofing, resilience building, prevention and preparedness in the region is therefore crucial (National Agency of Natural Resources, 2021). In line with the European Climate Law, climate neutrality will be reflected in the EU's bilateral relations and accession negotiations with Albania. One critical component of Albania's strategy to achieve its GHG emission reduction goals is the promotion and utilization of renewable energy sources, particularly in rural areas. Renewable energy deployment can provide hosting communities with some benefits (OECD, 2011). Renewable energy increases the tax base for improving service provision in rural communities. It can also generate extra income for landowners and land-based activities. For example, farmers and forest owners who integrating renewable energy production into their activities have diversified, increased, and stabilised their income sources.
Renewable energy provides remote rural regions with the opportunity to produce their own energy (electricity and heat in particular), rather than importing conventional energy from outside. Being able to generate reliable and cheap energy can trigger economic development.
Agrivoltaic and the utilization of biomass from forest residues stand out as particularly suitable renewable energy sources, combining environmental responsibility with economic benefits, for Finiq municipality. Such sources can perfectly match with the agricultural nature of the municipality.

Agrivoltaic

The process of co-developing of PV electricity generation and crop cultivation on the same land is called 'agrivoltaic'. The prefix 'agri' refers to the science and technology of producing crops in agriculture, and 'voltaic' refers to PV power generation. An agrivoltaic system emerges as a promising and harmonious solution for addressing the energy needs of rural villages steeped in agricultural traditions.
This innovative approach blends with the agricultural culture that defines such communities and offers a multitude of benefits that extend far beyond just meeting energy requirements. The integration of an agrivoltaic system within the fabric of a village exemplifies

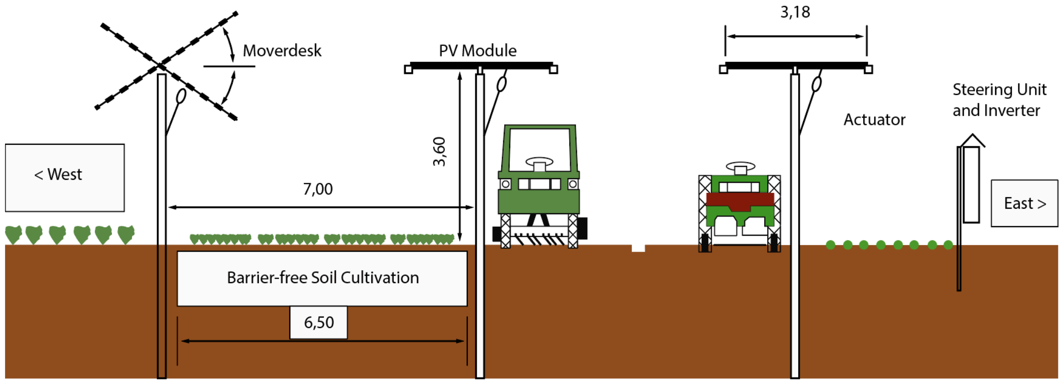

Fig1 / Cross-section of a typical agrivoltaic system installed on an open field
source / Fraunhofer ISE, Agri-Photovoltaik. Chance für Landwirtschaft und Energiewende. 2020
https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/APV-Leitfaden.pdf

the perfect marriage between sustainable energy generation and the rural, agrarian way of life. Agriculture has been the lifeblood of these communities for generations, and by harnessing solar energy while maintaining farming operations, agrivoltaic systems honour this legacy.
Schematic of a typical agrivoltaic system installed on an open field is shown in Fig1 (Gorjian et al., 2022). As depicted in this figure, different distances between the modules on the module rows should help to determine the influences of different degrees of shade on the yield of the plants, and therefore, identifying the best coverage.
Agrivoltaic systems are broadly classified according to various measures, including the type of the system (being closed or open), type of the structure (interspace PV, overhead PV, PV integrated greenhouses), the tilt of modules (fixed, one-axis tracking, two-axis tracking), and type of the application (grassland farming, arable farming, horticulture, and aquaculture. Moreover, the application of animal husbandry under closed opaque buildings is presented, although they are not typically considered as agrivoltaics.
Agrivoltaic bears the chance to enhance the resilience of farming systems against future drought (Trommsdorff et al., 2021). Agrivoltaic might reduce evapotranspiration and, hence, decrease irrigation needs, drought stress, and soil degradation. Combining agrivoltaic systems with water pumping, water treatment and irrigation systems, agrivoltaic might be an eligible technology to restore degraded land or to revegetate desert areas.
As already established by the FAO (Turral et al., 2011), the alarming consequences on the agricultural world consist in an increase of water demands by the plants, a decrease or a capping of crop yields and a decrease of water availability in regions where irrigation would be necessary or currently allows considerable benefits.
Model simulations have been able to reproduce the expected benefits from agrivoltaic installations, for example showing that it is possible to improve land use efficiency and water productivity at once, by reducing irrigation amounts by 20%, when tolerating a decrease of 10% in yield or, alternatively, a slight extension of the cropping cycle (Elamri et al., 2018).
Agrivoltaic appears a solution for the future when facing climate change and the food and energy challenges, typically in the rural areas especially if the procedure presented here proves relevant for other crops and contexts. A well-designed agrivoltaic facility can solve several issues of land use competition while providing income and employment opportunities in rural areas and in fragile ecosystems. It produces a diversified income stream from sales of farm produce and electricity as joint products. Financially, the combined crop and energy output from an agrivoltaic system can enhance land productivity by up to 70% (Al Mamun et al., 2022). Significant social benefits from agrivoltaic farms arise from new jobs, community income and potential tax revenues. Micro-entrepreneurship was encouraged as market networks for processed food were expanded. All these factors combine to reduce migration of the rural community to urban areas.

Biomass from forest residues

Forest residues encompass the organic remnants left in the wake of logging and other forest management activities. These residues include a variety of woody materials, including branches, treetops, bark, and smaller trees that typically do not find use as primary timber products. Additionally, forest residues can encompass non-woody elements such as leaves, needles, and other vegetative debris. As a source of energy, forest residues are a reliable alternative, with distinct advantages. Unlike some second-generation bioenergy sources, they do not compete with food production, are cost-effective, abundant in forest-rich regions, and exhibit an energy balance close to neutrality. Biomass heating can be considered carbon-neutral when managed sustainably. This means that the carbon dioxide released during combustion is balanced by the carbon dioxide absorbed by growing trees, making it a net-zero carbon source of heat.
These biomass estimates provide valuable insights for shaping energy strategies that reduce reliance on fossil fuels (Carrasco-Diaz, 2019).
Depending on the tree species, forest residues can constitute between 10% and 22% of a tree's biomass (Vargas-Larreta et al., 2017). Leveraging these residues for bioenergy not only opens up market opportunities but also generates employment in rural areas, fostering economic growth, and gradually diminishing our reliance on fossil fuels.
It is worth noting that while large wood logs hold substantial value in wood-based materials production, forest residues, often neglected due to their low value, can contribute to the ignition of forest fires (Madrigal et al., 2017). Consequently, integrating forest biomass into energy production serves not only as a renewable energy source but also as a tool for effective forest management to curtail fire incidence and promote a more circular economy.
However, the utilization of forest residues must be conducted with care and sustainability to mitigate adverse environmental impacts such as soil erosion, habitat disruption, and carbon emissions. Sustainable forest management practices, guided by certifications like PEFC and FSC, provide essential guidelines for residue removal and reforestation efforts, ensuring the long-term vitality of forests while reducing their ecological footprint.

Application to Finiq municipality

Application of agrivoltaic

The identification of the most suitable areas for agrivoltaic installations and the calculation of the potential photovoltaic capacity are critical steps in harnessing renewable energy sources while optimizing land use and promoting sustainable agriculture. This integrated approach aims to maximize the benefits of both solar energy production and agricultural activities.
Plain lands have emerged as the most suitable areas for the installation of agrivoltaic systems. Plain lands typically receive ample sunlight throughout the day, making them ideal for efficient solar energy generation. Unlike areas with hills or forests, plains generally have fewer obstructions that can cast shadows on solar panels. This minimizes the loss of energy production due to shading.
Plains often offer more available land for both solar panels and agriculture. This synergy allows for the coexistence of crop cultivation and energy generation without compromising either activity significantly.
The relatively flat terrain of plain lands simplifies the installation of solar panel arrays, reducing construction costs and time.
Three areas of Finiq municipality were identified as suitable for the installation of agrivoltaic system (Fig2):
1) a 21.63 km2 flat area approximately positioned between Vrion and Butrint Lake;
2) a 6.36 km2 flat area close to Finiq village;
3) a 5 km2 flat area between the villages of Finiq, Fitore and Rahulle.
Determining the potential photovoltaic capacity involves assessing the electricity demand of the municipality and aligning it with the available solar resources.
The electricity demand of the municipality is calculated by multiplying the per capita demand of Albania by the number of inhabitants in the municipality. This accounts for the total energy needs of the community (Tab1).
To estimate the potential photovoltaic capacity, a solar resource assessment is performed. This assessment considers factors such as the annual average solar

Fig2 / Map of Finiq Municipality: potential areas devoted to agrivoltaics are highlighted in yellow
source / the author

irradiance in the region, panel efficiency, and system losses. Based on the solar resource assessment, the photovoltaic system can be sized to meet the municipality electricity demand. This sizing includes determining the number of solar panels, their orientation, and the overall system capacity.
Depending on the municipality's energy needs and grid connectivity, energy storage solutions like batteries may be incorporated to ensure a continuous power supply, especially during non-sunlight hours.
The energy output of a photovoltaic system can be determined from the equation:

$$E = A * r * H * PR$$

where:
- E is the energy output;
- A is the total solar panel area;
- r is the solar panel efficiency. State-of-the-art efficiency photovoltaic panels is equal to 20%;
- H is the annual average solar radiation, equal to 1690 kWh/m2 (Hida et al., 2017);
- PR is the performance ratio, equal to 0.75.

Knowing E, r, H, PR, the solar panel surface that meets the electricity demand of Finiq municipality can be calculated from equation 1, resulting equal to 104852 m2. Therefore, 0.3% of the overall agricultural area of the municipality can satisfy the electricity demand of the municipality.

Application of biomass from forest residues

Generating heating from forest residues is a sustainable and efficient way to utilize biomass resources and reduce reliance on fossil fuels for heating purposes.
Heating from forest residues offers a renewable and sustainable energy source while supporting responsible forest management practices. It can be an environmentally friendly and cost-effective alternative to traditional heating methods, especially in areas with abundant forest resources, such as Finiq municipality. Figure 3 shows the potential areas devoted to forest residues exploitation for heating purpose. An overall area equal to approximately 40 km2 (or 4000 ha) was identified. The surface area of 4000 hectares harbours a substantial natural resource in the form of forest residues. With a specific forest residue yield of 0.5 tons per hectare

Electricity demand of the municipality	
Per capita electricity consumption - Albania	2280 kWh (EIA,2019)
Finiq population	11635 inhabitants (Rembeci, 2023)
Electricity demand – Finiq municipality	26257.8 MWh

Tab1 / Electricity demand of the municipality

Fig3 / Map of Finiq Municipality: potential areas devoted to forest residues exploitation are highlighted in green
source / the author

(Fernandes et al., 2010), this expansive forested area generates 2000 tons of overall forest residues annually. These residues are a valuable source of energy, given their Lower Heating Value (LHV), of 15 GJ per ton (Fernandes et al., 2010).
An overall heating production of 30000 GJ/year (equal to 8333 MWh/year) might be potentially produced from forest residuals. Such energy amount is approximately half of the Albanian energy production in 2020 (source IEA).

Conclusions

The scenario presented in this paper for the exploitation of renewable energy sources in Finiq municipality exemplifies a forward-thinking approach to meeting the local electricity demand while simultaneously promoting sustainability and environmental responsibility.
One noteworthy aspect of this scenario is the efficient use of land resources. By dedicating only a small fraction, approximately 0.3%, of the agricultural land for renewable energy production, Finiq municipality can meet its electricity demand. This approach minimizes the competition between energy production and food cultivation, ensuring that local agriculture can continue to thrive while contributing to the region's energy transition. This strategy aligns with the broader trend in sustainable energy development, which emphasizes land use optimization and minimization of environmental impact. By prioritizing non-arable or underutilized land for renewable energy projects, municipalities like Finiq can reduce the pressure on valuable agricultural land and preserve its use for food production. Furthermore, the incorporation of sustainable forest management practices for biomass heating is another commendable aspect of this scenario. Forest residues, often overlooked and left to decompose or burned inefficiently, can be a valuable source of renewable energy. When managed responsibly, forests can serve as a sustainable source of biomass for heating purposes. Forest residues, such as branches, treetops, and small-diameter trees, are often generated during logging operations or natural forest processes. By collecting and efficiently utilizing these residues for heating, municipalities can reduce waste and create a local, renewable energy source. Sustainable forest management practices ensure that residue collection does not harm forest ecosystems. These practices may include selective harvesting, reforestation efforts, and monitoring to maintain biodiversity and soil health.
Biomass heating can also provide economic benefits to the community by creating jobs in the forestry and biomass supply chain. In summary, the scenario outlined in this paper demonstrates the potential for integrating renewable energy sources into the energy mix of Finiq municipality in a sustainable and responsible manner. By balancing the use of minimal agricultural land for renewable electricity generation and implementing sustainable forest management practices for biomass heating, the municipality can take significant steps toward a greener and more resilient energy future.

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