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Communication

CO_2 Capture by Virgin Ivy Plants Growing Up on the External Covers of Houses as a Rapid Complementary Route to Achieve Global GHG Reduction Targets

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Abstract: Global CO_2 concentration level in the air is unprecedently high and should be rapidly and significantly reduced to avoid a global climate catastrophe. The work indicates the possibility of quickly lowering the impact of changes that have already happened and those we know will happen, especially in terms of the CO_2 emitted and stored in the atmosphere, by implanting a virgin ivy plant on the available area of walls and roofs of the houses. The proposed concept of reducing CO_2 from the atmosphere is one of the technologies with significant potential for implementation entirely and successfully. For the first time, we showed that the proposed concept allows over 3.5 billion tons of CO_2 to be captured annually directly from the atmosphere, which makes even up 6.9% of global greenhouse gas emissions. The value constitutes enough high CO_2 reduction to consider the concept as one of the applicable technologies allowing to decelerate global warming. Additional advantages of the presented concept are its global nature, it allows for the reduction of CO_2 from all emission sources, regardless of its type and location on earth, and the fact that it will simultaneously lower the air temperature, contribute to oxygen production, and reduce dust in the environment.

Keywords: carbon footprint; carbon capture and storage; zero/low emission building; greenhous effect; environmental protection

Citation: Krzywanski, J.; Ashraf, W.M.; Czakiert, T.; Sosnowski, M.; Grabowska, K.; Zylka, A.; Kulakowska, A.; Skrobek, D.; Mistal, S.; Gao, Y. CO_2 Capture by Virgin Ivy Plants Growing Up on the External Covers of Houses as a Rapid Complementary Route to Achieve Global GHG Reduction Targets. *Energies* **2022**, *15*, 1683. https://doi.org/10.3390/en15051683

Academic Editors: Marta González Plaza and Rui P. P. L. Ribeiro

Received: 23 January 2022
Accepted: 22 February 2022
Published: 24 February 2022

1. Introduction

Progressing climate change has nowadays become a fact [1,2]. The carbon dioxide (CO_2) concentration level in the atmosphere is unprecedentedly high and is a crucial driver of catastrophic global warming and climate change calamities. It is required to reduce CO_2 emission under the joint efforts and commitments made by the researchers, governments, and society for humanity's sustainable environment and well-being [3]. The primary factor responsible for global warming is greenhouse gases produced by human activity, mainly carbon dioxide. The above-mentioned activities can be expressed in deforestation for urban living, large-scale industrialization, rapid economic development, and lifestyle [4]. Meeting the energy demands to sustain the growth of human societies is imperative, which is effectively met by the naturally available energy sources. In this regard, it is essential to mention that coal and oil-based energy systems have remained the key technologies for meeting the energy needs of the societies and are still in use across the under-developed and some of the developed nations such as China and the USA [4].

Based on the latest research results, the world emits 51 billion tons of greenhouse gases per year, mainly carbon dioxide, into the atmosphere [5,6]. About 81% of the totally emitted greenhouse gases are carbon dioxide, 10% methane, 7% nitrous oxide [7], and 2% constitute other greenhouse gasses. That is why most scenarios that limit global warming to two degrees Celsius rely on CO_2 removal and storage. Therefore, looking for an effective solution to eliminating CO_2 from the atmosphere is an urgent task, avoiding global warming and climate collapse [8].

In its latest report, the international energy agency (IEA) has presented the levels and sources of CO_2 emissions from various energy resources and industrial sectors [9]. The contribution of various energy resources like renewables, nuclear, natural gas, oil, and gas on the energy production in TWH as well as gigaton of CO_2 (Gt. CO_2) emissions from the electricity production, industrial systems, transport, buildings and other sectors from 2020 to 2050 for the advanced and emerging economies are presented in Figure 1. Increasing penetration of renewables and the associated reduction in CO_2 emissions is projected for the developed economies. At the same time, the demand for coal and gas appears to be nearly constant for energy production for emerging economies. Large volumes of CO_2 emissions are expected to be discharged into the atmosphere.

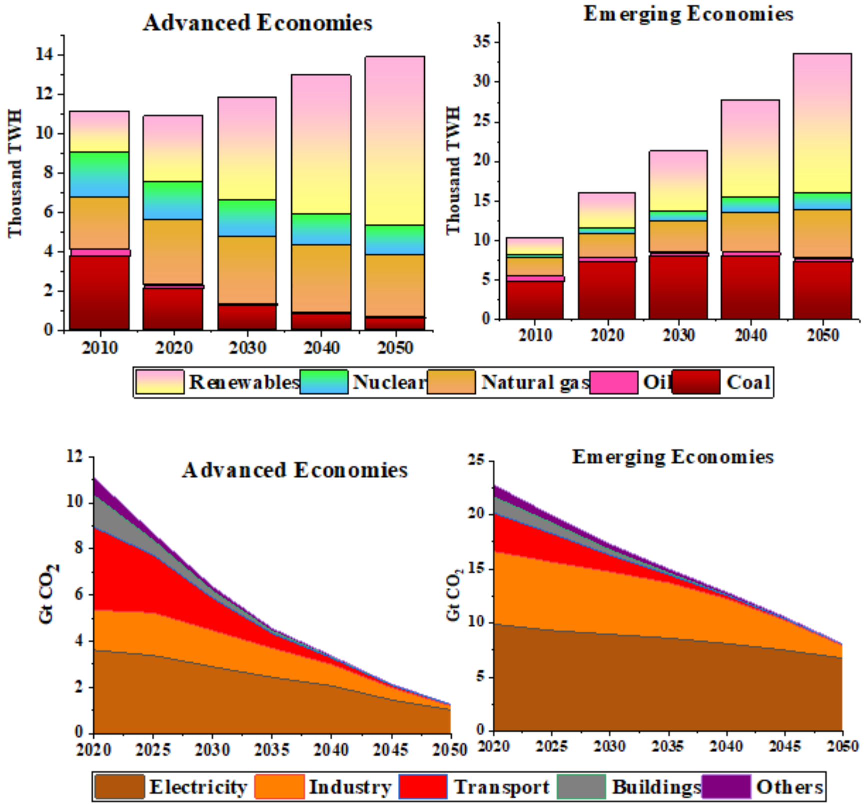

Figure 1. Energy demand and CO_2 emissions trend from the advanced and emerging economies until 2050 [10].

The report highlights that 63.1% of the global energy supply is met by fossil fuels, out of which coal contributes to about 36.7% for power production in 2019. Furthermore, the global energy demand is expected to rise above 80% by 2050. Interestingly, under-developed countries would share 85% of the projected energy needs mainly by the oil and coal-based energy conversion technologies [10]. Therefore, the mitigation of hazardous and greenhouse gas emissions is a significant challenge across the globe. Although, IEA has presented the key technologies such as carbon capture and storage, electrification of the industrial systems, biofuels, etc., as an alternative energy source for decarbonizing the energy sector [9,11]. However, the technologies are under the development stage. In this regard, various global commitments and agreements like Paris Accord and net-zero emissions targets are signed to control the CO_2 emissions from the diverse industrial sectors and seek the timeframe from the nations for reaching the net-zero emissions targets and limiting the global atmospheric temperature rise lower than 1.5 degrees.

Two strategies for reducing atmospheric concentrations of CO_2 can be distinguished. The first one covers most efforts and is focused on reducing emissions of CO_2 to the atmosphere, including increasing energy efficiency or switching to low- or zero-carbon fuel sources. Another approach is to deploy negative emissions technologies (NETs) to remove carbon from the atmosphere and sequester it reliably [8].

The CO_2 capture technologies for energy systems are classified into four groups: pre-combustion capture, oxy-fuel combustion, chemical looping combustion, post-combustion capture [12–16]. Pre-combustion capture is a fuel-reforming system for H_2 production from carbonaceous fuels via gasification and CO_2 separation. In oxy-fuel combustion, N_2 in the air is removed before combustion so that the flue gas consists mainly of CO_2 and H_2O [17]. Chemical looping combustion is based on the reduction and oxidation of metal oxides (oxygen carriers) using fuel (in fuel reactor) and air (in air reactor), respectively, in separate gas streams [18]. Post-combustion capture technologies are gas separation processes to separate CO_2 from flue gas, mainly in air-blown combustors. However, the capacity of all methods is not sufficient, and there is currently no satisfactory method of carbon sequestration [19]. For example, the carbon capture and storage (CCS) technology significantly increases investment costs.

On the other hand, oxy-fuel combustion and chemical looping combustion technologies increase the CO_2 content in flue gas, lowering the nominal cost of CO_2 sequestration. However, they are still suitable only for the CO_2 capture at the gas supply point [19]. Finally, many forms of renewable energy are considered safe, abundant, and clean to use compared to fossil fuels, but location-specific and require storage capabilities [20].

Therefore, this work presents the concept of direct CO_2 capture from the atmosphere through walls and roofs covered with vegetation.

It has to be mentioned, that the only organisms capable of carrying out the photosynthetic process are plants, algae, and a group of bacteria called cyanobacteria [21–23].

The photosynthesis process consists of a light and a dark phase. In the light phase, water is split using light into oxygen, protons and electrons. Then in the dark phase, the protons and electrons are used to reduce CO_2 to carbohydrate. Photosynthesis is a biochemical process that sustains the biosphere as the basis for the food chain. Therefore, plants are the basis of food for most living organisms. Other important roles of plants are the production of oxygen and the reduction of carbon dioxide from the atmosphere [21,24,25].

The amount of carbon sequestrated by plants during photosynthesis is strictly dependent on the area of greenery and plant type [26]. There are many applications of plants known in the literature for the purpose of CO_2 sequestration [27–29]. However, ivy exhibits the best qualities, such as high frost resistance and resistance to air pollution, does not require fertile soil, and grows both in sunny and shaded positions. Its low requirements and high adaptability allow it to occur in various climatic zones [30,31].

The above-mentioned excellent properties of ivy contributed to its selection for the presented analysis concerning CO_2 capture from the atmosphere through walls and roofs covered with ivy plants.

Moreover, it has to be mentioned, that there are many species of climbing plants that can cover walls and roofs of buildings. Each species is characterised by a different strategy of permanent attachment to vertical or horizontal surfaces. In order to exclude the negative influence of plants on the building, it is necessary to analyse the characteristics of individual species.

The attachment pads of Boston ivy (Parthenocissus tricuspidata), the attachment roots of ivy (Hedera helix) and the clustered attachment roots of trumpet creeper (Campsis radicans) can have a negative effect on wall surfaces. However, tendrils tipped with small strongly adhesive pads of five-leaved ivy named as Virginia creeper (Parthenocissus quinquefolia), which rhizomes do not disturb the continuity of the walls, do not have a negative effect on the building structure [32,33].

In addition, ivies belong to plants that rarely suffer from parasitic diseases and are rarely attacked by pests [34]. They can also have a positive impact on the energy efficiency of the building because they provide insulation. During summer they protect against overheating and provide coolness, and in winter they can additionally shield the house from strong winds and frost.

Although the proposed idea belongs to so-called direct-air capture (DAC) technologies, the material's outstanding novelty and broad impact lie in the presented method's designated potential and distinct advantages. The proposed concept further integrates with the global efforts made by the communal populations in the context of mitigation of CO_2 from the atmosphere. The communication of the potential idea to the more significant segments of the population is a crucial step to inclusively contribute to environmental protection with the adoption of green and feasible methods for CO_2 absorption. The obtained results for the first time demonstrate the significant ability of the proposed idea of rapidly globally reducing CO_2 emissions in a relatively shorter time perspective from all emission sources, regardless of its type and location on earth.

2. Methods and Discussion

The proposed concept of removing carbon dioxide directly from the atmosphere through large-scale utilization of green vegetation plants, such as virgin ivy, is shown in Figure 2. It is proposed that the walls and roofs of the houses can be covered with the widely available virgin ivy plants, which would act as the CO_2 capture system. CO_2 in the air is captured by the plant and undergoes the photosynthesis process for converting it into glucose, an energy source for the plants. Moreover, O_2 is released into the air as the by-product of the photosynthesis reaction. Therefore, covering the houses with the virgin ivy plant has several benefits: CO_2 removal from the atmosphere, O_2 release in the air for improving the air quality conditions for breathing purposes and reduction of the hot weather conditions impact on the houses thereby reducing the cooling load in the summer season.

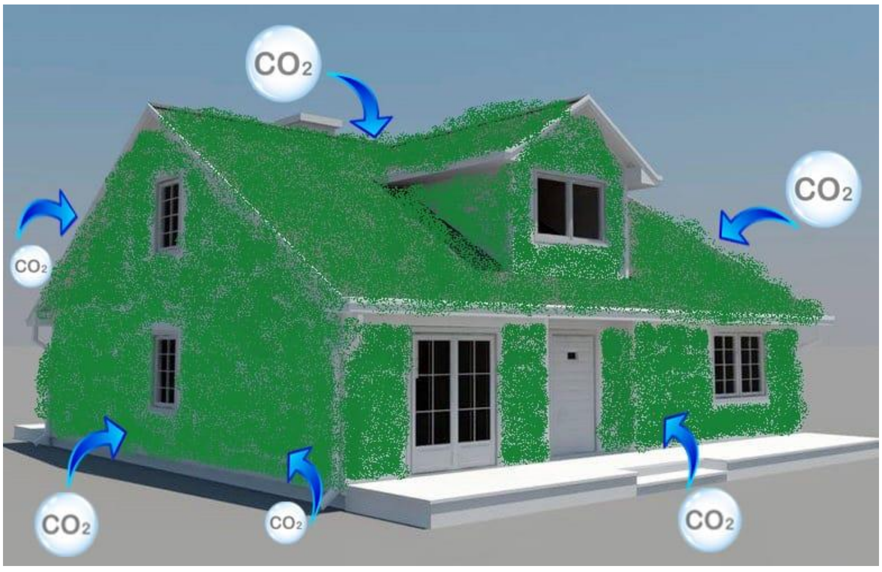

Figure 2. CO_2 absorption concept by virgin ivy plant.

The calculations are based on accessible data reported in the literature. Many parameters are included to estimate the CO_2 capture level from the atmosphere by the virgin ivy plants. Some of the critical parameters mentioned here are the total amount of CO_2 emitted from 1–2 car tank fillings, the average size of oil tanks for cars, the average CO_2 emissions for gasoline and diesel-based engine fuels, the average number of people living in the houses and the world population. The systematic and step-by-step approach incorporating all relevant performance parameters is adopted, and the detailed calculation procedure is shown in Table 1.

Table 1. Calculating procedure of percentage reduction in the CO_2 emissions to the atmosphere.

No.	Parameter	Value		
1.	The average size of oil tanks			
	The average size of fuel tanks for smaller cars (gallons)		12	
	The average size of fuel tanks for larger cars (gallons)		15–16	
	The average size of oil tanks for cars (gallons)		14	
2.	The average CO_2 emissions from a gallon of gasoline			
	The CO_2 emissions from a gallon of gasoline (g/gallon/year)		8887	
	The CO_2 emissions from a gallon of diesel (g/gallon/year)		10,180	
	The average of the CO_2 emissions for two fuels (g/gallon/year)		9533.5	
3.	The CO_2 emissions for the average tank size of 14 gallons		133,469	
4.	Since 1–2 car tank fillings worth of CO_2 will have been absorbed by the plants from the air, per house wall, let us consider three cases with the lowest, average, and maximum number of cars equivalent for CO_2 capture, i.e., 1.0, 1.5 and 2.0	1.0	1.5	2.0
5.	CO_2 emissions absorbed (ton/gallon/year) by a house	0.200193	1.001018	1.334690
6.	Average Number of people living in houses		3	
7.	World Population (billion)		7.9	
8.	The average number of houses (billion)		2.633333	
9.	CO_2 captured (billion ton/year)	0.527175	2.636013	3.514684
10.	Global CO_2 absorbed by ivy plant per year (%)	1.03	5.17	6.89

Because the total amount of CO_2 emitted from 1–2 car tank fillings will have been absorbed by the virgin ivy plants, which have been covered on average-sized plants from the air per average house wall considering the geographical climatic conditions and the phenomena like convective mixing of the atmosphere, wind force and diffusion of CO_2 [18], let us consider three cases with the lowest, average and the maximum number of cars equivalent for CO_2 capture, i.e., 1.0, 1.5 and 2.0. The average size of oil tanks for vehicles equals 14 gallons (as an average of 12 gallons for smaller cars and 15–16 gallons for larger cars) [35]. The average size of the fuel tanks is taken to estimate the vehicles' oil filling capacity. It is found that the average CO_2 emissions for gasoline and diesel-based fuels are 9533.5 g/gallon/year, which is calculated by averaging CO_2 emissions from a gallon of gasoline (8887 g/gallon/year) and diesel (10180 g/gallon/year) [36]. Therefore, the minimum, average and maximum CO_2 capture per house walls and roof can contribute will equal the 0.200193, 1.001018 and 1.334690 ton/gallon/year, respectively. The presented results consider global CO_2 emissions, from all possible sources.

It is quite an overwhelming number for the CO_2 reduction for a single house. Therefore, joint and integrated efforts made by the global human community can significantly synergise the efforts for removing CO_2 from the atmosphere. For this, the CO_2 abatement by the human housing structures in the world covered with virgin ivy plants is also investigated.

Assuming the number of people living in a family in various regions of the world is equal to three [37], and a world population by the end of 2021 is estimated to be equal to 7.9 billion [38], the average number of houses in the world will be equal to 2.633333 billion.

It is further estimated that covering the roofs and walls of all the houses of the world with the virgin ivy plants can mitigate the 0.527175, 2.636013 and 3.514684 billion ton/year for the case corresponding to a minimum, average and maximum of carbon capture, which constitutes about 1.3, 5.2 and 6.89% of global annual carbon dioxide emissions.

Thus, the calculations and analyses showed that the global annual carbon dioxide capture by the proposed concept is much more than the 500 million tons a year, i.e., roughly above 1% of global emissions and above the threshold below which technologies should not compete for the limited resources we have [6]. The general expression for the CO_2 absorption adopted is expressed as:

$$\% \text{ global } CO_2 \text{ absorbed by ivy plant/year} = \frac{\text{Avg. } CO_2 \text{ capacity } \left(\frac{\text{ton}}{\text{year}}\right) * (\text{no. of walls} + \text{roof}) * \text{no. of houses}}{\text{global } CO_2 \text{ load (ton)} * 10000} \quad (1)$$

where the average CO_2 capacity refers to the annually averaged CO_2 absorbed by the virgin ivy plant.

Moreover, it is worth noting that in the case of the minimum CO_2 adsorption capacity, the obtained value of global adsorption exceeds this profitability threshold.

Besides capturing a significant amount of CO_2, the discussed concept also allows lowering the air temperature, contributes to oxygen production and reduces dust in the built-up environment [39].

The significant potential of the virgin ivy plants in removing the CO_2 from the atmosphere can result in the integrated and joint efforts made by the communities around the globe. There is a need to communicate this much potential of the green plants in removing the CO_2 from the air, which directly contributes to the global net-zero emissions targets of the nations to limit the global atmospheric temperature rise to 1.5 degrees. The proposed idea and the advanced carbon capture technologies can collectively work on the single objective to reduce the greenhouse gas emissions level and, therefore, ensure environmental sustainability and the existence of life on the planet.

3. Conclusions

An idea of direct CO_2 capture from the air is presented. It is proposed that the green virgin ivy plants naturally available in the environment can be covered along the roofs and walls of the houses of the world. The discussed idea demonstrates the significant potential of the proposed concept of rapidly reducing CO_2 emissions in a relatively shorter time perspective and with relatively lower investment costs, compared to existing other methods. It is estimated that up to 6.89% of the global CO_2 emissions level can be directly reduced by covering the walls and roofs of all houses of the world. Additional advantages of the presented concept are its global nature, as it allows for reduction of CO_2 from all emission sources, regardless of its type and location on earth.

Thus, the proposed idea constitutes one of the applicable technologies allowing to slow down dangerous global warming via dropping global carbon dioxide emissions to zero. Furthermore, it also integrates the efforts of the world population especially from the emerging economies struggling to fulfil their energy needs from fossil fuel-based energy systems with the governments, industrial and scientific communities working on lowering the CO_2 levels in the atmosphere, limiting the global atmospheric temperature rise to 1.5 degrees and fulfilling the global net-zero emissions targets. Therefore, the lowering of the greenhouse gas concentration by covering the walls and roofs of the houses can contribute to the environmental sustainability for future generations, especially in the emerging economies which are struggling with the higher CO_2 emissions levels and the deployment of costly carbon capture technologies could be a challenge for the governments for decarbonizing the industrial sectors.

The technology presented in the paper is particularly valuable for developing countries, as their economies are particularly dependent on fossil fuels, and this technology is simple and inexpensive to implement and allows a rapid reduction in CO_2. However, the presented solutions can be applied in all countries, regardless of their level of development or geographical location.

Future research on the presented technology will be focused on the study of the dynamics of CO_2 adsorption, taking into account various factors affecting the performance of the proposed technology.

Author Contributions: Conceptualisation, J.K.; methodology, J.K. and W.M.A.; software, J.K. and W.M.A.; validation, J.K. and W.M.A.; formal analysis, J.K., W.M.A., T.C., M.S., K.G., A.Z., A.K., D.S., S.M. and Y.G.; investigation, J.K. and W.M.A.; resources, J.K. and W.M.A.; data curation, J.K. and W.M.A.; writing—original draft preparation, J.K. and W.M.A.; writing—review and editing, J.K., W.M.A., T.C., M.S., K.G., A.Z., A.K., D.S., S.M. and Y.G.; visualization, J.K.; supervision, J.K. All authors have read and agreed to the published version of the manuscript.

Funding: The work was performed within the subsidies of the Faculty of Science and Technology, Jan Dlugosz University in Czestochowa, Poland. The support is gratefully acknowledged.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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