ATLANTIS PRESS

Advances in Social Science, Education and Humanities Research, volume 89

4th International Symposium on Social Science (ISSS 2018)

Entrepreneurship & Innovation

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Keywords: solar roofs, energy consumption, cost efficient.

Abstract. Over the last decades the global population has grown from 5.3 billion in 1990 to almost 7.5 billion in 2016, while, because the higher population densities tend to associate with lower levels of energy consumption, but the total population growth and the increasing wealth and economic income level of the population cause the total energy consumption to rise dramatically, which becomes an urgent challenge need to be addressed. This report firstly proposed three potential solutions, namely, constructing higher buildings, making use of industrial exhaust heat, and applying solar roofs. Then, these three solutions were compared with regards to the technical aspects, market aspects as well as return on investments aspects. Further, solar roof has been selected as so far the best solution in respond to the housing challenge, and the feasibility and benefits of solar roof, as well as factors that can influence the viability of this solution were illustrated afterwards.

1. Introduction

Over the last decades, the global population has grown from 5.3 billion in 1990 to almost 7.5 billion in 2016. However, the growth of the world population over the same period has declined from 1.82% to 1.13%, it is still a substantial growth and is expected to continue. At the same time the urbanisation rate, as stated by the United Nations report, will also increase dramatically.

The aforementioned developments also incline a substantial increase of carbon generated energy. However a direct relationship between urbanization and increase in carbon emissions is not clear (Liddle, 2014), because higher population densities tend to associate with lower levels of energy consumption. The total population growth and the increasing wealth and economic income level of the population causes the total energy consumption to rise dramatically.

Seeing the circumstances, it is not likely that the energy consumption will differ much from abovementioned scenario. However, the source of the energy does not have to be carbon based and can be more sustainable generated than is done now. We asked to look on how house building and house building technics can be more sustainable and contribute to a lesser carbon footprint so that the total energy consumption as a whole is more sustainable.

Since the general question is too broad to answer in the time span of this consultancy assignment, our main focus will be on residential housing solutions in the USA and the influence on sustainability. We will first look at potential solutions which are already on the market or can be implemented directly or in the near future. Further on we will look at the feasibility of the suggested solutions and whether they contribute to a more sustainable house building technic and a more sustainable way of living in these houses. After that we will summarize and compare on the solutions, to come up with final recommendations for a more sustainable housing/living industry.

2. Potential Solutions

2.1 Constructing Higher Buildings.

Firstly, in order to meet the ever-increasing demand for housing problems, constructing higher buildings would be a proper option. By increasing the floors of the building, people will find their residences within limited surface areas. A 100 square meters' area could now inhabitant with 30 or more families instead of only one family in the past.

2.2 Making Use of Industrial Exhaust Heat.

Secondly, industrial exhaust heat roused increasing public attentions nowadays. The idea of connecting the household heating system with the industrial exhaust heat seems making sense, however, people argue that the initial investment would be too much to afford, the technical problem would set back the whole process as well. Meanwhile, the ultimate aim for industries is to reduce the emission of all kinds of pollutions, instead of just making use of the exhaust heat, leave the polluted gas and water still be serious problems.

2.3 Solar Roof

Another idea noticeable is the solar roof, which achieved considerable breakthrough recently. On 31st of October, Elon Musk, CEO, and product architect of Tesla Motors; co-founder and chairman of SolarCity, announced the "future of solar" finally comes. Hundreds of people were invited to the conference sit, and then been asked whether have noticed the house they are currently in is a "solar house", the answer is obviously, in short, no. Although everyone was invited to see the press conference for solar houses, nobody could find out anything different with an ordinary house. Indeed, the appearance of the roof tiles are exactly same with any other shingles, but it actually made of textured glass (Bloomberg Technology), which could allow light to pass through from above onto a standard flat solar cell. Moreover, according to Musk, this kind of material is just "tough as steel" and has a "quasi-infinite lifetime".

Of all these three ideas, the idea of solar roof, with its ability to generate renewable energy with hardly any pollution for its dwellers, has been selected as so far the best solution responds to the housing challenge, and the feasibility as well as economic gains and defects will be further illustrated afterwards.

3. Feasibility Analysis

3.1 Technical Aspects.

Roof techniques have long been hot research topics; however, traditional studies mainly concentrate on the following two functions:

To prevent rain and snow infiltration

To provide good thermal insulation

There are certain roofs already on market that meet the above-mentioned demands, but the application of those roofs usually limited due to their unaffordable costs (Juanicó, L. E. 2010). In addition, none of the pre-existing roofs focus on collecting the solar energy, which is a totally renewable and clean energy that could be transferred into electric power for not only household electricity consumptions, but also electrical cars' energy charging problems.

It is noteworthy that on October 2016, Musk proposed Tesla's new combination of electrical cars together with its self-designed supporting solar roofs. With this amazing combination, not only vehicles' greenhouse gas emission problem could be solved, but also the charging problem for electrical cars becomes much more convenient and affordable. Moreover, even the demand for household heating system as well as other electricity consumption could be met or at least partially satisfied by making use of the energy collected by the solar roof. The techniques of solar roof now become relative mature and keeps improving.

3.2 Market Aspects.

The US home builder industry has witnessed a rapid growth recently. Over the past five years to 2016, the US newly built housing generated 87 billion revenues and enjoyed a 10.7% annual growth rate. And according to 2015 American Housing survey, about 22 % housing units have a purchase price equal to or more than $250,000, making the initial investment of solar roof relatively not as expensive as comparing to the housing price. Besides, above 56% U.S. house owners are younger than 55, demonstrating a high potential of getting the initial investment into solar roof back, given the life expectancy at birth is 76.9 years. According to 2015 American Community Survey, among occupied housing units, only 0.1% has used solar energy as house heating fuel, and the percentage of

houses using fuel oil, wood, coal or coke far surpasses the percentage of houses using solar energy. Bare use of solar system exhibits great market potential.

3.3 Financial Aspects.

For residents, return generated from power bills savings needs a relatively long time to justify, but users can expect greater returns in the long run. Cost for about 3,000 square feet of roofing needed to cover an average size home in the U.S. is $27,000 for Clay tile, and $46,500 for Slate respectively. Assume cost of the solar roof is about $73,500, which has an estimated life expectancy of 30 years; and the solar roof needs to be used with a $6,500 worth battery storage device, which has a warranty of only 10 years. According to 2015 American Housing survey, 22% households have a monthly cost paid for electricity of more than 150 dollars (median 104 dollars), assuming the solar roof package can generate 100% renewable energy for the household, then it means 1800-dollar savings per year. For the 30-year life expectancy of solar roof, it means 54,000-dollar savings, which can cover the cost difference between solar roof and many other roofing materials, without taking the time value of money, life expectancy of the battery into account. Considering the possibility of using solar generated electricity to charge electric cars, cost savings can be further increased.

There are also various methods for solar roof provider to generate revenue, making the solution financially attractive. Except the huge potential market demand and profit margin, 30-year life expectancy of solar roof and 10-year warranty of battery storage device means recurring income, and maintenance service can also be a complementary revenue stream.

3.4 Potential Benefits.

There are basically 3 major benefits of using solar roofs. Firstly, solar roof saves users' electricity bills. By upfront investment, household user can expect greater returns in the long-run, as solar costs less than traditional way generated electricity. Secondly, solar roofs provide users with energy independence. As long as the sun rises, solar energy will never be exhausted. Solar roof provides users with endless source of energy comparing to fossil fuels, which is limited in reserve, and help to conserve energy for future generations. Last but not least, solar roofs are environmentally friendly. Solar creates significantly less pollution than natural gas and coal, helping to create a sustainable environment.

3.5 Others Criteria That Would Increase the Viability of the Solution.

Increasing electricity price: US average residential electricity price has been climbing and has always been more expensive than commercial and industrial electricity price during past decade, this trend might continue in the short-term as natural gas price is unlikely to decrease and EPA restrict coal-fired electricity generation. According to British national grid, the price of electricity could double over the next two decades. As long as the cost of electricity keeps increasing before the price of solar roof drops, the electricity bill savings should raise, thus increasing return rate of initial investment and making solar roof financially more attractive for the customers (Chaoqing Yuan, Sifeng Liu, Junlong Wu, 2010).

Financial support: Financial support from government to solar roof providers and end users, for example, subsidies and tax reduction; or payment alternatives from solar roof providers to end users, e.g. load, lease would both help to provide incentives for companies and end-users.

Legislation support: As the initial investment of both solar roof providers and end users are high, legislation enforcement might be a good supplement to economic incentives, guaranteeing the implementation of proposed solution.

Technological innovation: Relevant technological breakthroughs that either reduce the cost or increase the power generation efficiency would make this solution more attractive for both investors and end-users.

Organizational competency: A good idea never accomplishes it value unless been executed properly. Thus, the management prowess of the solar roof provider and access to sufficient, cheap but high-quality supplies and up-to-date technological innovations are also important for the viability solution.

4. Conclusion

4.1 Final Recommendation.

Our research has shown that the global population and the fuel consumption thereof will rise substantially over the coming decades. This energy consumption cannot be stopped or decreased due to demographic influences. However, we have shown that the carbon footprint of this consumption can be changed by implementing some solutions in the housing industry.

As examined one of the solutions, excess industrial exhaust waste, is feasible and desirable but requires governmental commitment and coordination. Above that it also requires a lot of legislation. This is beyond the scope of our consultancy.

However solar roofs provide us with an easy to implement solution to reducing the carbon footprint of our increasing energy consumption. When solar roofs are taken into account in new to build houses, the relative increase in costs is foreseeable and will be less than 10% of the building price (over $ 300.000). This can easily be financed within a mortgage, since the monthly costs of living decrease since there are hardly any energy bills. For existing houses, the solar roofs could be installed over the coming years when roofs are being replaced.

Although solar roofs are easily available and cost efficient, the installment of solar roofs depends on the willingness of housebuilders. Legislation from the government on this part would help greatly, a public awareness campaign would also help to convince housebuilders and –owners to implement the solar roofs.

4.2 Limitations of the Report.

Our research, to make housebuilding more sustainable, has shown that there are already ready to use solutions on the market. However, some require more governmental influence and legislation or regulation than others. This governmental legislation and regulation is beyond the scope and influence of our research. For instance, powering house by excess industrial exhaust heat requires huge governmental influence. As a consulting group it is beyond our scope to have any influence on this.

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