ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/01.3001.0012.4821

PLANNING AND BUILDING 100% RENEWABLE ENERGY INFRASTRUCTURE WITH THE TECHNOLOGIES OF THE FUTURE

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Abstract

When and why humanity faced the Energy Problem, it is a question. What was the problem? How are we trying to handle it since the beginning? Do we have enough resources of renewable energy? Which technologies are mature enough to contribute and take part in the solution? Are they available in the market with compatible prices? What is the role of storage for dealing with the intermittent nature of renewable energy resources? Why do we need to build, operate, integrate and manage energy efficiency, storage and renewable energy in harmony with nature by smart grids in sustainable cities of the future? Is transition to 100% Renewable Energy the solution? If so what else is required to reach this target? What are we going to do with the existing system? Which methodologies and techniques we need to use to realize this transition with minimum costs and externalities? How are we going to justify this transition? Is it only a technology problem? What parameters we need to consider when we are trying to live in harmony with nature? How are we going to readapt human beings to be satisfied with minimum ecological footprint societies? Can human beings build democratic societies where energy efficiency and 100% renewable energy is respected and beneficial for each individual of the communities? Transition to 100% renewables requires planning the future with the information of the future. For reaching this target we need to carry on a multidisciplinary approach to understand and take into consideration the basic constraints and requirements of the living space we are sharing all together in the atmosphere. How to Speed-up the Global Transition to 100% Renewable Energy?

Keywords: *energy, efficiency, transition to 100% renewable energy, energy storage, smart grids, planning future, future technologies*

1. Introduction

Scientists believe that the Earth was formed about 4.5 billion years ago. [1] Its early atmosphere was probably formed from the gases given out by volcanoes. It is believed that there was intense volcanic activity for the first billion years of the Earth's existence. The early atmosphere was probably mostly carbon dioxide, with little or no oxygen. There were small quantities of water vapour, ammonia and methane. As the Earth cooled down, most of the water vapour condensed and formed the oceans. The proportion of carbon dioxide in the atmosphere went down, and the proportion of oxygen went up because of photosynthesis by plants. The proportion of carbon dioxide went down because:

- it was locked up in sedimentary rocks, such as limestone, and in fossil fuels,
- it was absorbed by plants for photosynthesis,
- it dissolved in the oceans.

As a result, the existing living space energized totally by sun became available for the life to continue on earth. As shown in Fig. 1, The Greenhouse gasses act like blanket to stabilize the average temperature of the atmosphere. The average annual temperature for the globe between 1951 and 1980 was around 14ºC [2].

Since 1850s, beginning with the industrial revolution, burning fossil fuels is adding carbon dioxide to the atmosphere faster than it can be removed. This means that the level of carbon dioxide in the atmosphere is increasing. Together with Industrial Revolution, human beings faced and even created first time energy problem on earth. Using coal as an energy source in the atmosphere ended up with disasters like The Great Smog of London, also called The Killer Fog of 1952, (Dec. 5-9, 1952), major environmental disaster in which a combination of smoke mixed with cold fog hovered over London, England. The resulting smog caused the deaths of an estimated 4,000 to 12,000 people [3]. Swithcing to petroleum ended up with petroleum crisis in 1970 and related wars.

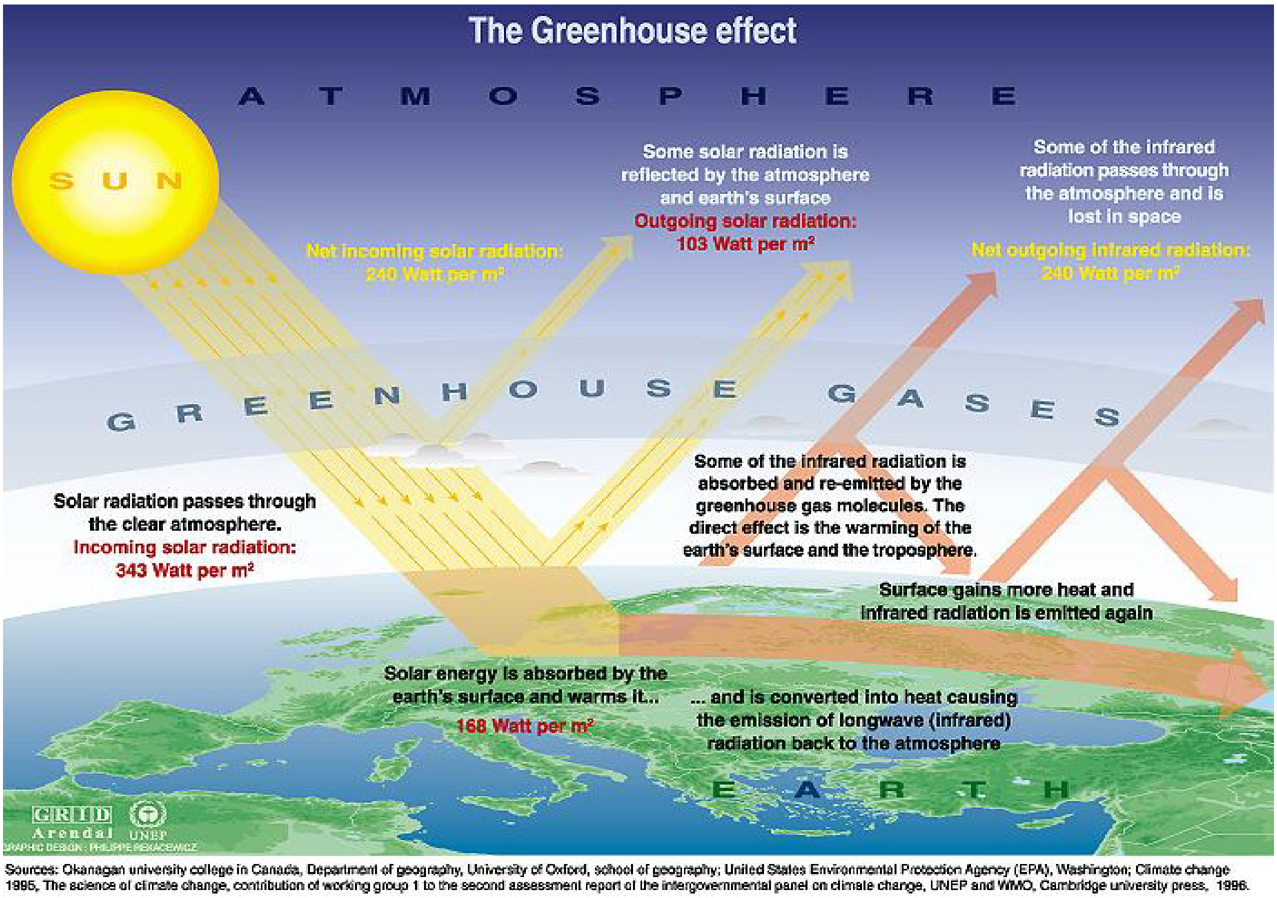

Fig. 1. Greenhouse Effect providing a living space in the atmosphere

Nuclear waste heat power plants installed between 1973 and 1978 could not also provide a permanent solution to the energy problem. With a solution-oriented approach, OECD Countries initiated Energy Technology Agreements between members of International Energy Agency to develop clean coal, safe nuclear and renewable energy technologies; energy efficiency and energy decision support tools. Clean coal and safe nuclear technologies did not work. Global efforts designed by UNFCCC (United Nations Framework for Climate Change Convention) COP (Conference of Parties) meetings organized since 1994 and studies for internalisation of external costs since 1993 convinced all stakeholders those fossil fuels should stay underground to contribute to the good quality of the living space on earth.

Today, many countries are engaging for the first time in discussions about a deliberate and fundamental transformation of energy. The two main goals are to reduce CO_2 emissions and to reduce dependence on foreign energy sources from other parts of the World. These goals are to be accomplished through decarbonisation of the economy and, ultimately, the active transition to renewable energies [4].

This work will try to suggest a road map to accelerate community power based transition to 100% renewable energy societies of Future.

2. Climate Change Mitigation

Human activities on earth such as fossil fuel combustion for transportation, industry, agricultural and building sectors are mainly responsible for climate change. Priority in energy solution is climate change mitigation. As can be seen from Fig. 2 based on the comparison of atmospheric samples contained in ice cores and more recent direct measurements, provides evidence that atmospheric CO_2 has increased since the Industrial Revolution. (Credit: Vostok ice core data/J. R. Petit et al.; NOAA Mauna Loa CO_2 record.) [5].

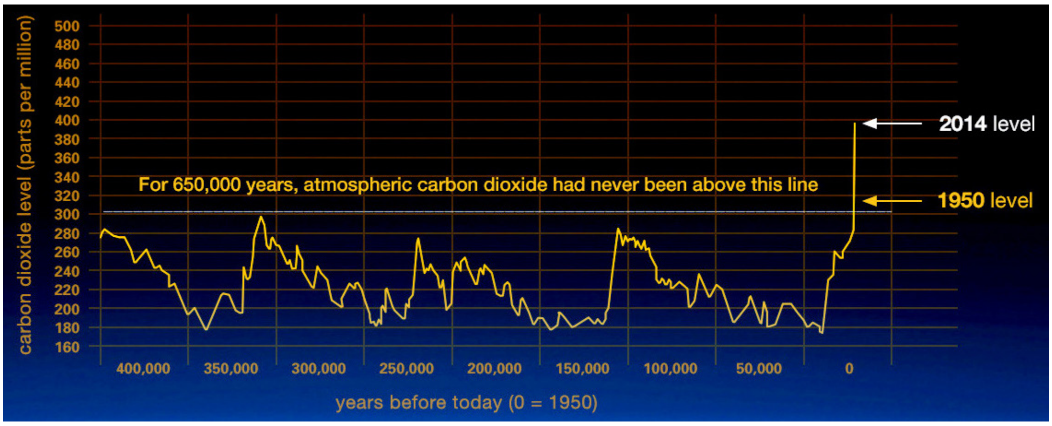

Fig. 2. NASA analysis of CO_2 levels, now higher than at any time in the previous 650,000 years

3. Internalisation of the Externalities

Transition to 100% Renewable Energy is possible only as a part of an overall transition of Societies. Utilities should understand that they need to adapt their services accordingly. Medical doctors must believe in preventive medicine. Harmful subsidies provided to fossil and nuclear energy should be stopped. External costs or social costs of energy production and consumption must be internalised. Today, wind and solar electricity is cheaper than fossil and nuclear electricity even without considering the externalities. General tendency today is to decommission coal and nuclear power plants and invest more on cheap, clean climate friendly renewable energy technologies. We need to get rid of as many problems as we can define if we want to accelerate the transition to 100% renewable energy societies.

4. Synergy between energy efficiency and renewable energy

After the Petroleum Crisis, reducing the amount of energy consumption became a priority. However, beginning with 1980s, energy end use efficiency became more popular for providing unit services required by minimum consumption of energy carriers such as electricity, hydrogen and process heat. Priority in finding a solution for energy problems always lies in energy end use efficiency. When possible using less renewable energy to reach the solution should be preferred. IRENA working paper [6] considers how renewables and energy efficiency can work together to contribute to global energy decarbonisation by 2050. It also looks and how this synergy affects energy system and technology cost, and the effect it has on air pollution and avoidance of adverse health effects caused by these pollutants.

5. How can we define energy solution?

For any energy type to be named as a solution, there are some requirements: The resource of the primary energy must be enough and available, the technologies to convert the resource to energy carriers like electricity, hydrogen and process heat must be available commercially in the market and the cost of production of the energy carrier must be cheapest when compared with the competitors.

As can be seen in Fig. 3 global renewable energy potential is enough to fuel all energy requirements of humankind on earth [7].

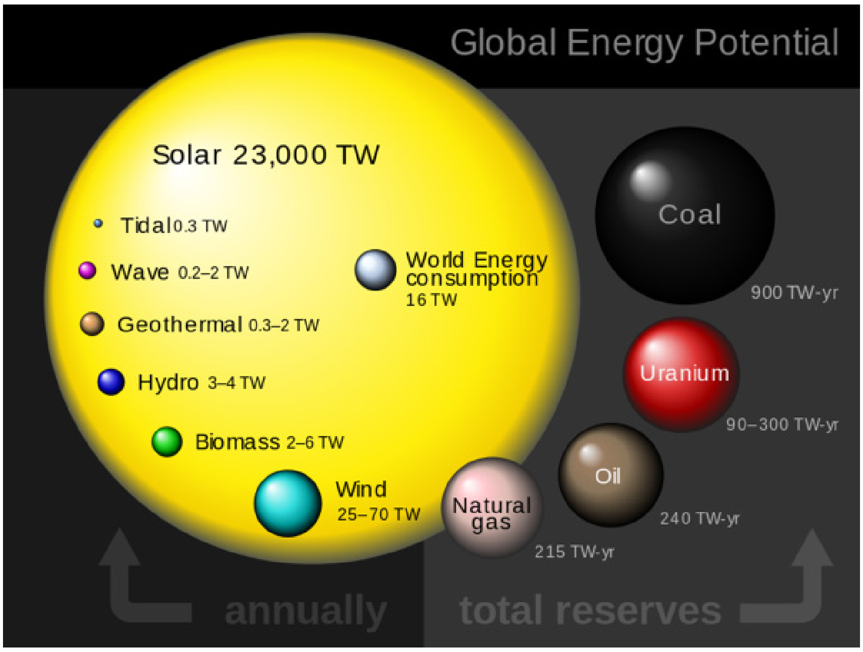

Fig. 3. 2009 Estimate of finite and renewable planetary energy reserves (Terawatt-years); total recoverable reserves are shown for the finite resources; yearly potential is shown for the renewables

Regarding the technology, we understand from the working paper produced at IIASA Austria [8] and EPRI studies [9, 10] that the renewable energy technologies are getting more competitive each year since 1976 and today is cheaper than fossil and nuclear power plants (Fig. 4).

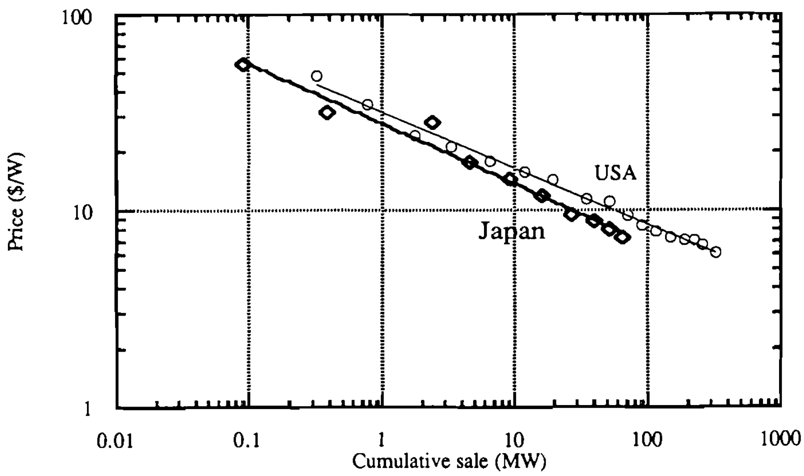

Fig. 4. Experience curves of PV cells in the US 1976-1992 and in Japan 1979-1988

Evolution of wind turbine heights and output since 1990 and best PV research-cell efficiencies recorded since 1975 can be seen in Fig. 5 and 6, respectively.

Together with these technological developments and support policies global installed capacities of wind and solar power plants reached to 402 and 536 GW respectively by the end of 2017 as can be seen from the Fig. 7 and 8 [11].

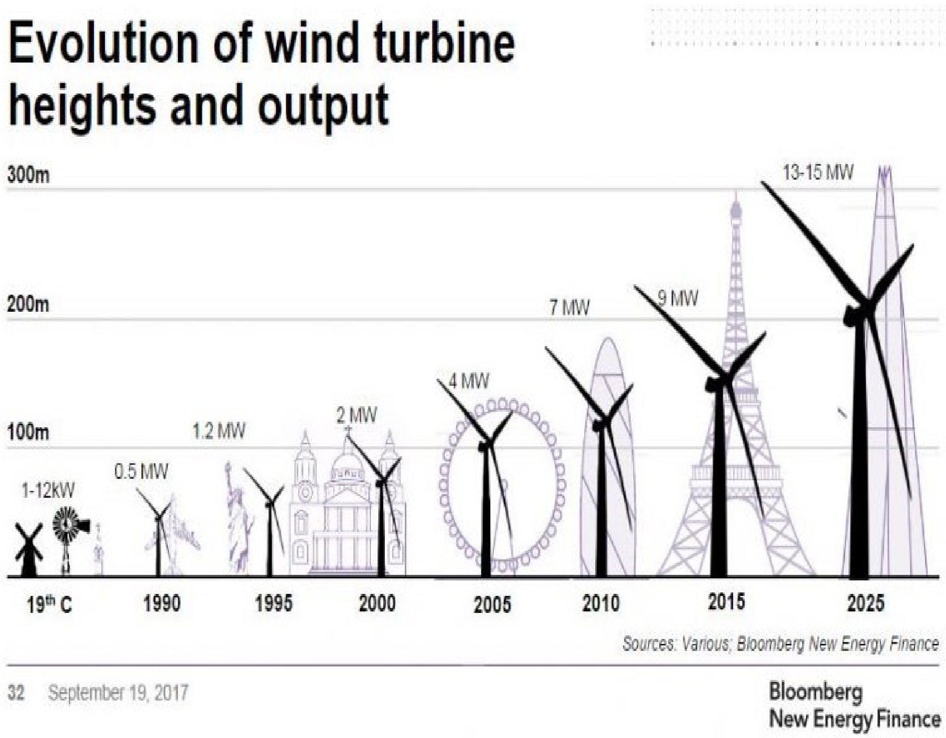

Fig. 5. Evolution of wind turbine heights and output

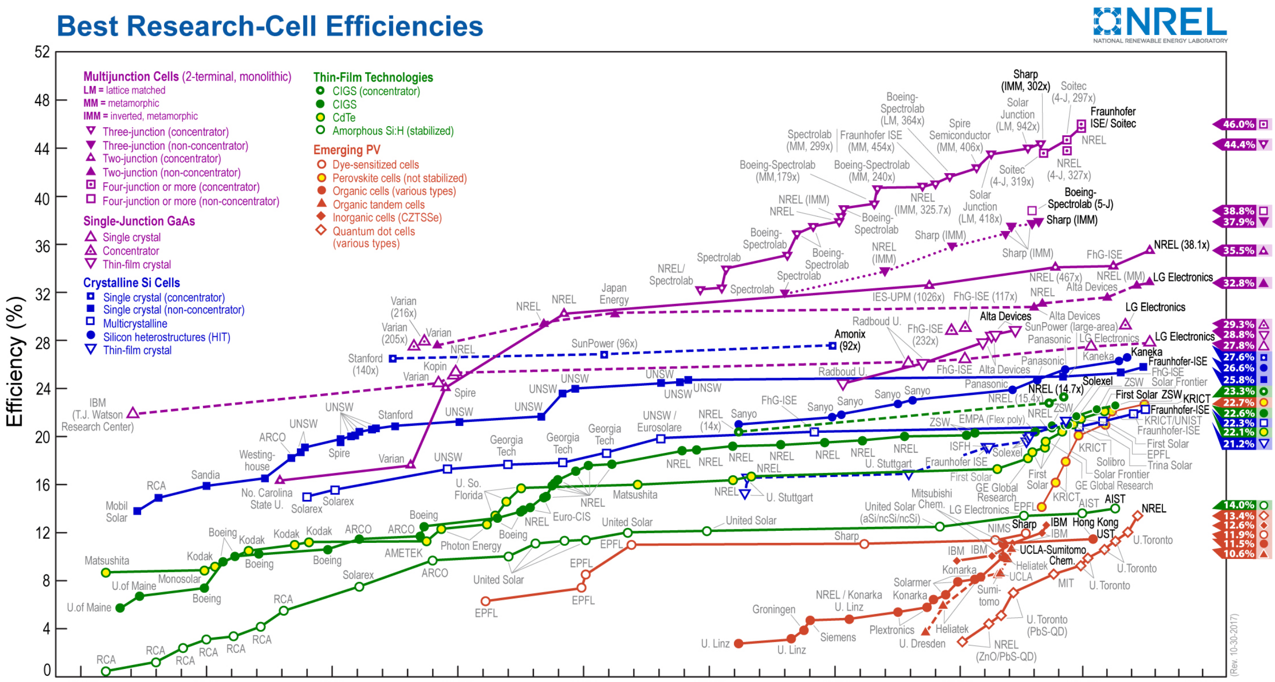

Fig. 6. NREL Best Research Cell Efficiencies

Finally, as given in Fig. 9, at least 67 countries had used auctions for renewable energy contracts by mid-2016. Chile, Mexico, Morocco and the United Arab Emirates achieved record price lows with solar and wind auctions in 2016 [12].

All these developments proved that renewable electricity is a reliable permanent solution for equity, energy independence, peace and local employment so far more than 10 million people globally. Electricity, hydrogen, biofuels produced from renewable energy is the energy carriers ready to serve in zero carbon 100% renewable cities for sustainable transportation.

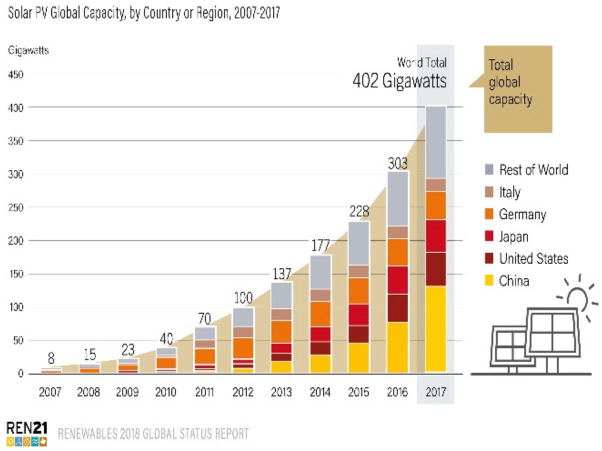

Fig. 7. Solar power global capacity, by country or region, 2007-2017

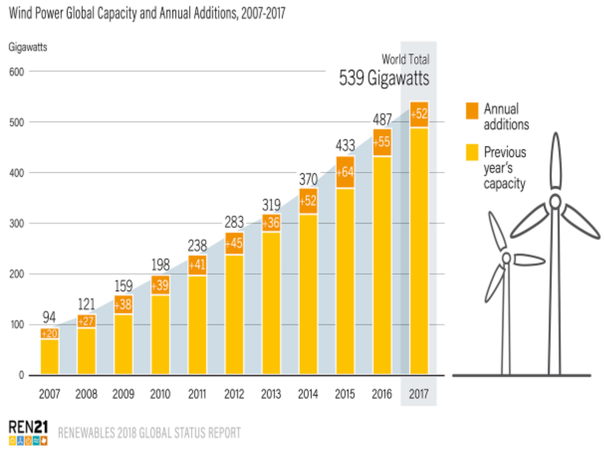

Fig. 8. Wind power global capacity and annual additions, 2007-2017

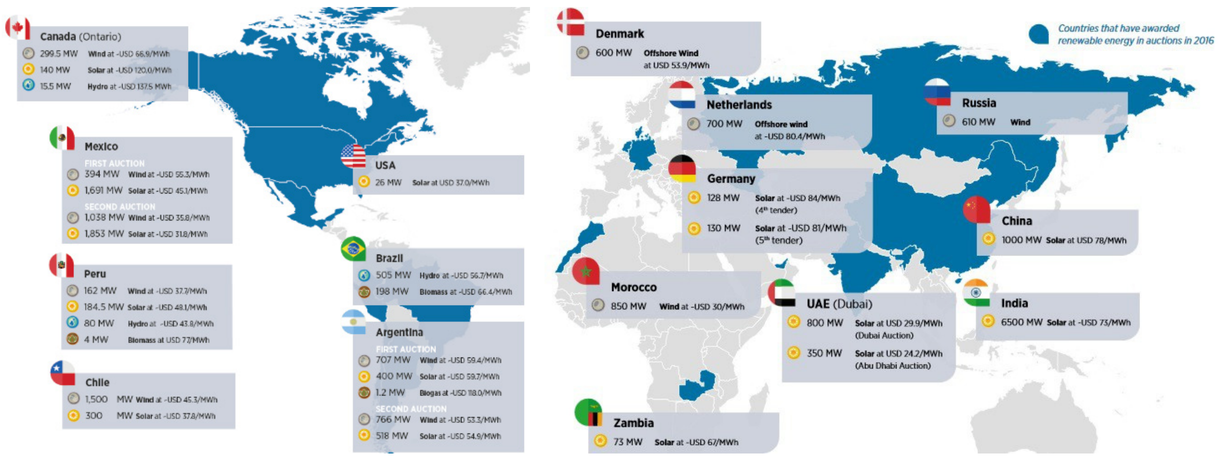

Fig. 9. Countries that have awarded renewables in auctions in 2016: technology, quantity and price

6. Renewable Transportation

"The conversion of the present transport system appears to be one of the most difficult aspects of such renewable transition. A 100% renewable transport providing the same service as global transport in 2014 would demand about 18% less energy. The main reduction is expected in road transport (69%), but the shipping and air sectors would notably increase their consumptions: 163% and 149%, respectively. The analysis concludes that a 100% renewable transportation is feasible, but not necessarily compatible with indefinite increase of resources consumption. The major material and energy limitations and obstacles of each transport sector for this transition are shown" [13].

"The main types of infrastructure, technologies and policy measurements which may be useful for urban, regional, marine, and air transport in a future 100% renewable economy are discussed in the following six subsections" [13]:

- electrification of urban and inter-urban transport (hydrogen, fuel cells, electrical vehicles, electrical trains and metro systems),
- light electric vehicles and public transport for urban mobility (electric rickshaws, electric motorbikes, electric scooters and electric light quadricycles powered by rechargeable batteries),
- metropolitan and regional transport (efficient public transport systems powered by renewable electricity),
- demand reduction,
- marine transport,
- air transport.

"Renewable City Strategy" [14] of Canadian city of Vancouver's energy supply is currently 31% renewable, with the remaining fossil fuel portion dominated by natural gas for space heat and hot water, and gasoline for personal and light-duty vehicle use. Vancouver's energy use and resulting greenhouse gas emissions are dominated by buildings and transportation. Fig. 10 shows how Vancouver will get to 100% Renewable Energy by 2050.

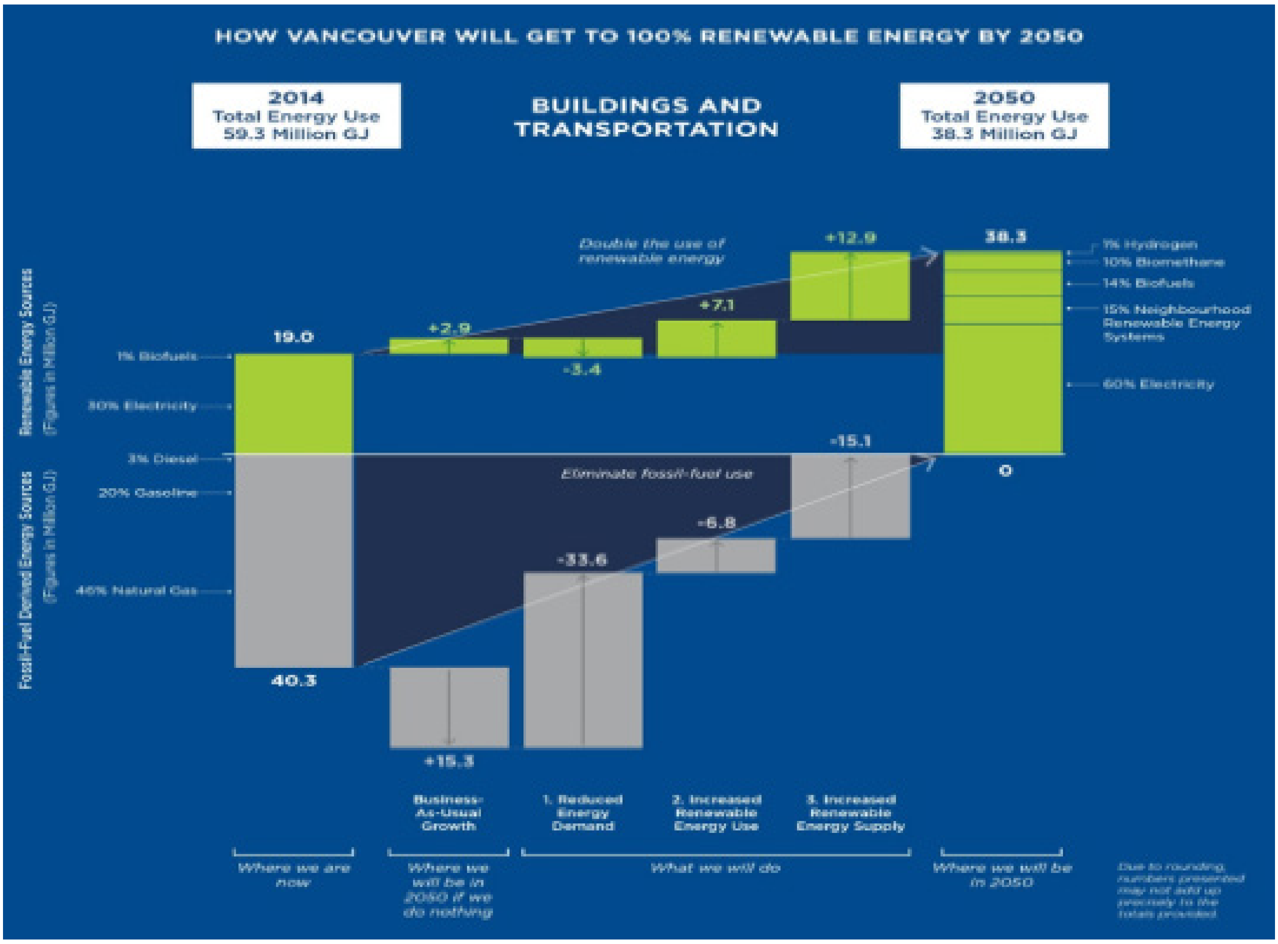

Fig. 10. How Vancouver will get to 100% Renewable Energy by 2050?

Simon Fraser University Faculty of Environment studies and organizes courses on walkable, bikeable cities, public transportation and zero emission vehicle infrastructure [15].

7. Base load as a demand requirement

When compared with the conventional resources, the main critics are coming to the intermittent nature of renewable energy resources. The critics itself is a conventional character. The argument about base load supply requirement in power generation is misleading. Base load is a concept of demand. Conventional power plant owners, due to their non-existing capability to follow the demand, insist that the base load power plants are inevitable. That is not true. As we witness in countries and cities targeting transition to 100% renewable electricity, a symphony of renewables together with the renewable energy storage technologies changes the paradigm. Today renewables are the base load and we are not obliged to use centralized fossil fuel and nuclear waste heat power plants on earth. For example, California's system for producing, moving and using electricity is changing fast. In addition, apparently it no longer has room for a nuclear plant. Nuclear plants of Diablo's generation were designed to ramp up to full throttle and stay there day and night, providing "baseload" power for the grid. However, that, increasingly, is not what

California needs. “We’re transitioning, clearly, to a distributed system where you rely less and less on those big resources and more on distributed resources,” said Stephen Berberich, CEO of the California Independent System Operator, which manages the grid. “You need a flexible fleet that can start and stop quickly,” he said. “The way California is headed, big; baseload power isn’t as valuable as it was.” [16].

8. Storage and mini grids to handle intermittency character of renewables

High entropy nature of renewable energy resources allows users to produce required quantity of energy carrier in necessary qualities. We can store renewable energy as an energy carrier (electricity, hydrogen, process heat etc.) to use when there is no sun, wind or rain. Geothermal and bioenergy resources are naturally stored and can supply any time the energy required by base load demand. Locally produced energy carriers do not need transmission lines and conventional grid capacities. Mini grids with storage require community power solutions with the participation and ownership of local stakeholders.

9. Community Power

We need a community power approach where the decisions are taken by the local people and renewable energy systems are owned by them. We need democratic societies to build energy efficient, minimum ecological footprint communities using 100% renewable energy. If we manage to understand the constraints of the nature, we can organise our societies considering the information, expectation and demands of the individuals in the society. We can design democratic societies if we have ecological societies.

10. Conclusion

Chemical energy stored in biomass and renewable energy stored as process heat or electricity and their conversion to liquid and gases fuels make the transition to 100% renewable energy possible without relying on conventional fossil fuels. This makes renewables independent from fossil fuels, or, the energy solution independent from the energy problem.

Extensive availability of renewable energies locally necessitates the involvement of communities, municipalities and cooperatives as part of the decision making process, and as owners of their renewable energy investments for sustainable energy solutions.

The implementation of renewable energy as community power would mean equity, freedom, peace and local employment. Increasing the number of such applications will result in renewable energy regions and, finally, with 100% Renewable Energy Cities.

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Manuscript received 27 July 2018; approved for printing 29 October 2018