CARD International Journal of Science and Advanced Innovative Research (IJSAIR)
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 1, Number 2, September 2016
http://www.casirmediapublishing.com

Cracking the Renewal Energy Potential in Nigeria: Solar Energy in Perspective

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ABSTRACT

The supply and demand of energy determine the course of global development in every sphere of human activity. Solar radiation from the Sun is capable of producing heat, causing chemical reactions, or generating electricity. The Sun is an extremely powerful energy source, and sunlight is by far the largest source of energy received by the Earth, but its intensity at the Earth's surface is actually quite low. The sunlight that reaches the ground consists of nearly 50 percent visible light, 45 percent infrared radiation, and smaller amounts of ultraviolet and other forms of electromagnetic radiation. This radiation can be converted either into thermal energy (heat) or into electrical energy. Two main types of devices are used to capture solar energy and convert it to thermal energy: flat-plate collectors and concentrating collectors. Solar radiation may be converted directly into electricity by solar cells (photovoltaic cells). Sunlight provides by far the largest of all carbon-neutral energy sources. More energy from sunlight strikes the Earth in one hour (4.3×10^{20} J) than all the energy consumed on the planet in a year (4.1×10^{20} J). Yet, in Nigeria, solar radiation provided less than 0.1% of the country's energy needs. The importance of this pervasive problem and the perplexing technical difficulty of solving it require a concerted national effort marshalling our most advanced scientific and technological capabilities. All routes for utilizing solar energy exploit the functional steps of capture, conversion, and storage. This research work on Solar Energy Utilization in Nigeria identifies the key scientific challenges and research directions that will enable efficient and economic use of the solar resource to provide a significant fraction of primary energy in the country by the mid 21st century.

Key words: Radiation, Technology, Renewal, Application, Solar, Thermal.

INTRODUCTION

Growing concern over the world's ever-increasing energy needs and the prospect of rapidly dwindling reserves of oil, natural gas have prompted efforts to develop viable alternative energy sources. The volatility and uncertainty of the petroleum fuel supply were dramatically brought to the fore during the energy crisis of the 1970s caused by the abrupt curtailment of oil shipments from the Middle East to many of the highly industrialized nations of the world. It also has been recognized that the heavy reliance on fossil fuels has had an adverse impact on the environment. Gasoline engines and steam-turbine power plants that burn coal or natural gas emit substantial amounts of sulfur dioxide and nitrogen oxides into the atmosphere. When these gases combine with atmospheric water vapor, they form sulfuric acid and nitric acids, giving rise to highly acidic precipitation. The combustion of fossil fuels also releases carbon dioxide. The amount of this gas in the atmosphere has steadily risen since the mid-1800s largely as a result of the growing consumption of coal, oil, and natural gas.

Many countries have initiated programs to develop renewable energy technologies that would enable them to reduce fossil-fuel consumption and its attendant problems. Technologies that are being actively pursued are those designed to make wider and more efficient use of the energy in sunlight, wind, moving water, and terrestrial heat (i.e., geothermal energy). The amount of energy in such renewable and virtually pollution-free sources is large in relation to world energy needs, yet at the present time only a small portion of it can be converted to electric power at reasonable cost.

Creating renewal energy reservoirs will give Nigeria energy systems greater sitting flexibility and will open up the country to the possibilities of competition in the global energy market not only making a significant contribution to the energy mix, but also contributing to system stability.

And Nigeria is generally considered to have a rich renewable energy sources

Solar technology is at the heart of the renewable energy market and has been a key source of new electricity generation in various parts of the world for the last few years. Private households and businesses are looking at ways to take more control over energy production for several reasons. For homeowners, there is a sense of environmental responsibility. For businesses, there is a real need to mitigate the risk of relying entirely upon external energy providers. And both residential and industrial energy consumers want to invest in solar to have more control over their future energy bill.

While there is clear evidence that solar technology is gaining both investors support and commercial operating experience, some challenges remain to be overcome before it can become widespread and economically attractive renewable energy resources.

Energy efficiency provides significant non-energy benefits for economies and societies through broad gains to welfare. For instance, improved efficiency has been associated with higher GDP, huge public health benefits, better public budget balance, increased productivity, job creation, and a rise in consumer surplus, in addition to its role in reducing greenhouse gas and pollutant emissions and improving energy security.

Potential: Drivers and Benefits

The National Energy Policy Document states that "Nigeria lies within a high sunshine belt and, within the country; solar radiation is fairly well distributed. The annual average of total solar radiation is varies from about 12.6 MJ/m^2-day (3.5 kWh/ m^2-day) in the coastal latitudes to about 25.2 MJ/ m^2-day (7.0 kWh/ m^2-day) in the far north." Assuming an arithmetic average of 18.9MJ/ m^2-day (5.3 kWh/ m^2-day), Nigeria therefore has an estimated 17,459,215.2 million MJ/day (17.439 TJ/day) of solar energy falling on its 923,768 km^2 land area. The above arithmetic average may be interpreted as the application of each of the above radiation values to approximately half the area of the country, thus giving a total of (12.6 + 25.2) x (923,768/2) which gives the same value as before. Annually, the above average solar intensity is 6898.5 MJ/m^2-year or 1934.5 kWh/m^2-year: a value that can be used to calculate the available solar energy.

With this abundance of solar energy resources in the country, it therefore becomes imperative to deploy the technology for the following reasons:

To Improve Energy Security:Energy security involves the provision of su fficient and reliable energy supplies to satisfy demand at all times and at affordable prices, while also avoiding environmental impacts. A conventional view of energy security emphasizes availability and affordability; more recent definitions have a longer-term perspective and recognize the need to take into account additional factors. In the long term, only energy sources that reconcile economic factors with sustainability will be able to guarantee secure energy supplies. Availability, affordability and sustainability of energy supply are interlinked facets of overall energy security. The importance that countries assign to each facet will vary depending on aspects such as natural resource endowment, stage of economic development and local environmental priorities.

To Encourage Economic Development, particularly associated with rural and agricultural sectors, or with innovation and high-tech manufacturing. solar technologies are able to contribute to sustainable economic development by allowing exploitation of natural but replenishing resources, providing new sources of natural capital. The technologies will allow the country with good solar source, for example, to exploit these resources as "new" assets to support their own energy needs. This technology may even allow the country to exploit renewable energy resources with long-term export potential, by producing biofuels sustainably, or by using high levels of solar radiation to generate exportable electricity via concentrating solar power.

To Protect the Climate and the Wider Environment from impacts of fossil fuels use. Solar energy can play a key role in combating climate change; they already deliver important CO_2 emission reductions. In fact, solar energy will be the central element of any energy system that is secure in both the short and long term.

To Create Job Opportunities for the teaming population of the country youths as this will necessitate massive increase in both small and large businesses.

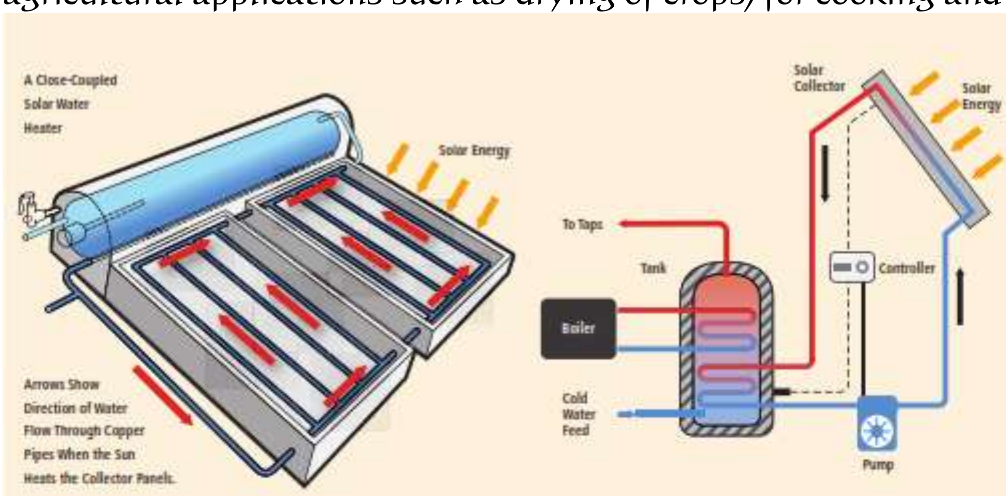
For these reasons, it is important to take both short-term and long-term view when developing policy and to consider adequately the interactions between policies designed to improve energy security, support economic development and address climate change and environ mental concerns.

Solar Technology and Applications

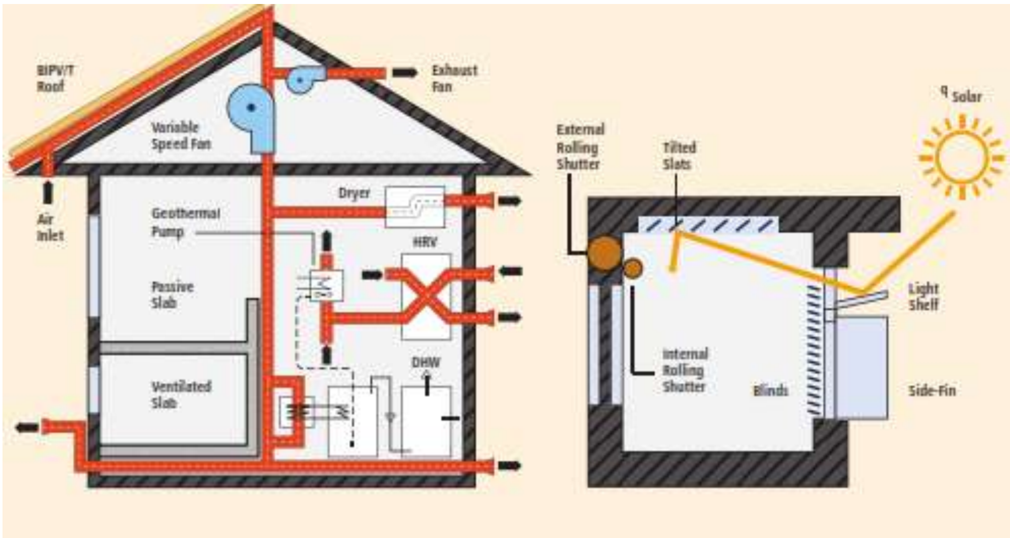
Solar technology is applicable in various aspect of life ranging from cooling, heating, drying and electric generation. The technology and application is discussed under the headings below.

Solar Thermal: This is application of blackened flat plate solar collector with attached conduits, through which passes a fluid to be heated. Flat-plate collectors may be classified as follows: unglazed, which are suitable for delivering heat at temperatures a few degrees above ambient temperature; glazed, which have a sheet of glass or other transparent material placed parallel to the plate and spaced a few centimeters above it, making it suitable for delivering heat at temperatures of about 30°C to 60°C; or evacuated, which are similar to glazed, but the space between the plate and the glass cover is evacuated, making this type of collector suitable for delivering heat at temperatures of about 50°C to 120°C. To withstand the vacuum, the plates of an evacuated collector are usually put inside glass tubes, which constitute both the collector's glazing and its container. In the evacuated type, a special black coating called a 'selective surface' is put on the plate to help prevent re-emission of the absorbed heat; such coatings are often used on the non-evacuated glazed type as well. Typical efficiencies of solar collectors used in their proper temperature range extend from about 40 to 70% at full sun.

They are commonly used to heat water for domestic and commercial use, but they can also be used in active solar heating to provide comfort heat for buildings. Solar cooling can be obtained by using solar collectors to provide heat to drive an absorption refrigeration cycle. Other applications for solar-derived heat are industrial process heat, agricultural applications such as drying of crops, for cooking and so on.



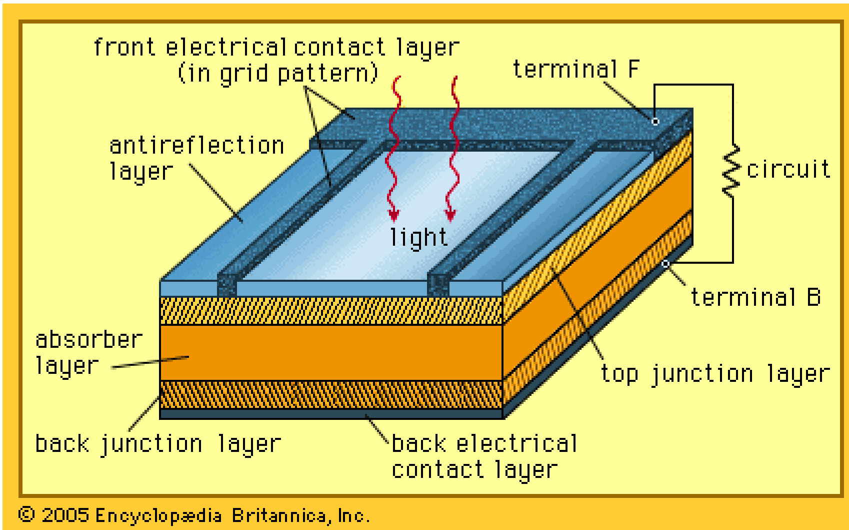
Generic schematics of thermal solar systems
Left: Passive (thermosyphon). Right: Active system.



Solar thermal, both passive and active integrated into a building

A solar collector can incorporate many different materials and be manufactured using a variety of techniques. Its design is influenced by the system in which it will operate and by the climatic conditions of the installation location.

Photovoltaic Electricity Generation: This is a process of generating electric current using a device called photovoltaic or solar cell. Photovoltaic cell is device that directly converts the energy in light into electrical energy through the photovoltaic effect. The overwhelming majority of solar cells are fabricated from silicon—with increasing efficiency and lowering cost as the materials range from amorphous (noncrystalline) to polycrystalline to crystalline (single crystal) silicon forms. Unlike batteries or fuel cells, solar cells do not utilize chemical reactions or require fuel to produce electric power, and, unlike electric generators, they do not have any moving parts. Solar cells can be arranged into large groupings called arrays. These arrays, composed of many thousands of individual cells, can function as central electric power stations, converting sunlight into electrical energy for distribution to industrial, commercial, and residential users.

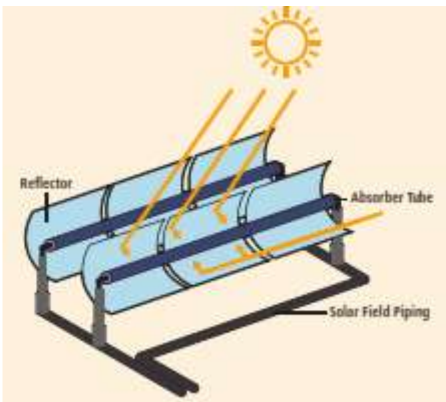


A commonly used solar cell structure. In many such cells, the absorber layer and the back junction layer are both made of the same material.
The application of PV for useful power involves more than just the cells and modules; the PV system, for example, will often include an inverter to convert the DC power from the cells to AC power to be compatible with common networks and devices. For off-grid applications, the system may include storage devices such as batteries. Work is ongoing to make these devices more reliable, reduce their cost, and extend their lifetime.

Concentrating Solar Power Electricity Generation (CSP): This includes technologies used to produce electricity by concentrating the Sun's rays to heat a medium (liquids or gases) that is then used (either directly or indirectly) in a heat engine process (e.g., a steam turbine) to drive an electrical generator. Any concentrating solar system depends on direct-beam irradiation as opposed to global horizontal irradiation as for fl at-plate systems.

Some of the key advantages of this system include the following:

1) It can be installed in a range of capacities to suit varying applications and conditions, from tens of kW (dish/Stirling systems) to multiple MWs (tower and trough systems);
2) it can integrate thermal storage for peaking loads (less than one hour) and intermediate loads (three to six hours);
3) it has modular and scalable components; and
4) it does not require exotic materials



A common type of concentrating solar power technology, a trough collector.

Solar Fuel

Solar fuel technologies are applied in conversion of solar energy into chemical fuels. It is a desirable method of storing and transporting solar energy. Solar fuels can be processed into liquid transportation fuels or used directly to generate electricity in fuel cells; they can be employed as fuels for high-efficiency gas-turbine cycles or internal combustion engines; and they can serve for upgrading fossil fuels, CO synthesis, or for producing industrial or domestic heat. The challenge is to produce large amounts of chemical fuels directly from sunlight in cost-effective ways and to minimize adverse effects on the environment (Steinfeld and Meier, 2004).

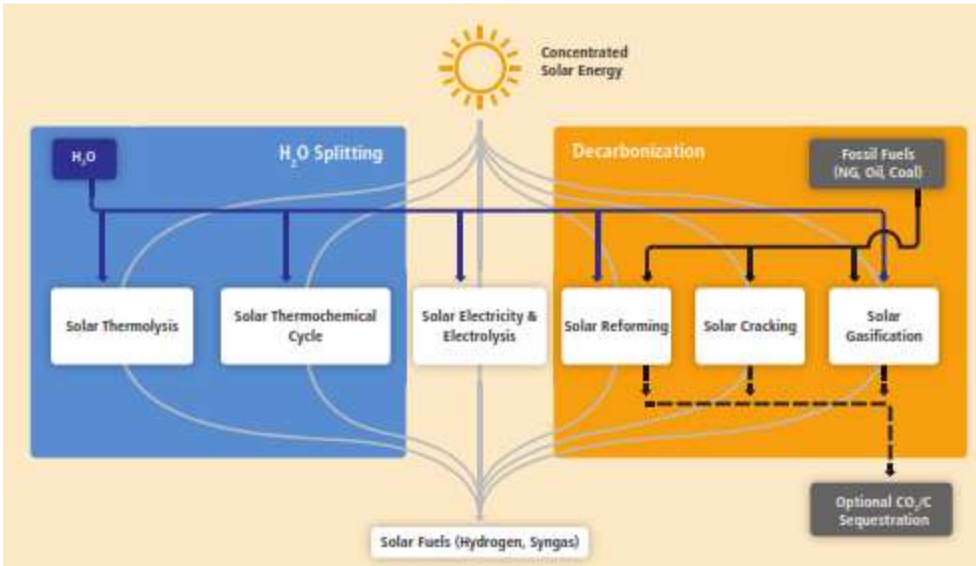
Solar fuels that can be produced include

1. synthesis gas (syngas) which is a mixed gases of carbon monoxide and hydrogen),
2. pure hydrogen (H_2) gas,
3. dimethyl ether (DME) and
4. Liquids such as methanol and diesel.

The Technology

There are three basic methods, alone or in combination, for producing storable and transportable fuels from solar energy:

1. The electrochemical method uses solar electricity from PV or CSP systems followed by an electrolytic process. This is the Electrolysis of water where solar electricity generated by PV or CSP technology in a conventional (alkaline) electrolyzer, considered a benchmark for producing solar hydrogen.
2. The photochemical/photobiological method makes direct use of solar photon energy for photochemical and photobiological processes.
3. The thermochemical method uses solar heat at moderate and/or high temperatures followed by an endothermic thermochemical process (Steinfeld and Meier, 2004). Thermolysis and thermochemical cycles are a long-term sustainable and carbon-neutral approach for hydrogen production from water. This route involves energy-consuming (endothermic) reactions that make use of concentrated solar irradiance as the energy source for high temperature process heat (Abanades et al., 2006).



Thermochemical routes for solar fuels production, indicating the chemical source of H2 : water (H2O) for solar thermolysis and solar thermochemical cycles to produce H only; fossil or biomass fuels as feedstock for solar cracking to produce H2 and carbon (C); or a combination of fossil/biomass fuels and H2O/CO_2 for solar reforming and gasification to produce syngas, H2 and carbon monoxide (CO). For the solar decarbonization processes, sequestration of the CO2/C may be considered (from Steinfeld and Meier, 2004; Steinfeld, 2005).

Achieving Sustainable Solar Energy Deployment in Nigeria through a Sustainable support Mechanisms and Financing

Solar energy deployment in Nigeria have the potential to help achieve the most important energy challenges in the country: extending access to affordable, reliable and clean energy to more than 60 million people in rural areas who do not have grid access; enabling energy independence and security; and reducing specific CO_2 emissions. Domestic financial and technological resources and capacity however, are generally lacking, and, even where solar energy might be cost-competitive with conventional alternatives, significant economic and noneconomic barriers to deployment and investment are present.

Well designed and coordinated support is, therefore, needed to address the non-economic barriers, strengthen local technological capabilities and capacity-building, and boost the interplay of official development assistance to create enabling conditions for deployment and to allow the populace to exploit their solar potential.

In terms of project development as in deployment of solar technology in Nigeria, a lot of barriers may be encountered which can can include a deficient regulatory structure, a lack of clear legal framewor k in the country, and a lack of experience with incentivizing policies. Technical concerns can also be a significant barrier for project developers, such as grid integration constraint, the lack of local technological expertise to install or maintain facilities, and a deficient assessment of available solar resources. Obtaining financing is, of course, decisive for a project developer. This raises the question whether the technology is cost-competitive in the context of the project, and if not, whether adequate, transparent and certain incentives are in place and how these incentives are financed. In Nigeria for example, subsides for fossil fuels distort the market and undermine the cost-competitiveness of solar energy. Existing fossil fuel subsides; therefore, need to be redirected in favour of support for solar and other renewable and energy efficiency.

Support Mechanisms and Financing

Performance-based incentives

Performance-based incentives reduce investment risk and can drive rapid growth of solar energy deployment in the country if designed well and implemented at the right level. The incentives might come as feed-in tariffs (FITs) as practiced in developed economies. The country should also key in to the proposed Global Energy Transfer Feed-In Tariff (GET FiT) programme which advocates a feed-in premium system in regions where the grid is strong enough to integrate renewable energy sources (DB Climate Change Advisors, 2010). In this incentive mechanism utilities commit to purchase the electricity at the market price, and the above market costs are carried by multilateral or bilateral public sector funds and passed through the government and the utilities to the Independent Power Producers (IPPs). In the case of remote areas not included in current grid- expansion plans, performance-based incentives for decentralized energy generation could replace feed-in tariffs.

Risk insurance

Nigeria runs a relatively high risk for political, economic or currency system instability; creditworthiness of project partners is also often doubtful. Therefore, in addition to direct financial support, policy makers need to reduce the various risks of solar energy projects in the country through international private and public insurances in order to improve credit conditions and attract private investment.

Soft Loan and Guarantees

Similarly, loan-softening programmes and loan guarantees, or reassuring of guarantees given by the governments will reduce the costs of private lending and thus improve the project economics in the country.

Technical Assistance and Capacity Building

Technical, administrative, legal or political barriers cannot be fully addressed by policy design only, but require technical assistance and local private and public capacity building to strengthen demand for finance and to create a clear and reliable framework for investment and deployment. This support programme should try to maximise the involvement of local institutions to foster technology and policy learning in the country and thus to foster expertise and capacity building. The governments and utilities of the country should be involved to allow them to gain experience with renewable energy projects and policies. In addition, structures for local private-sector actors such as local companies and banks should be created to allow them to gather experience with financing and operation of solar energy projects. Therefore, technical assistance and capacity building should focus on:

- Policy design for policy makers: e.g feed-in tariff design, price and rate setting, as well as policy review and transitional decreasing of financial support over time;
- development, resources assessment and feasibility studies for governments and local partners;
- Construction, operation and maintenance for local companies;
- Grid expansion, management and integration strategies for utiliti es; an
- Financing and risk mitigation strategies for local financiers.

Technology Transfer

Widespread transfer of sustainable solar energy technologies is required to sufficiently deploy the technology and reduce CO_2 emissions in the country and at the same time allow sustainable paths for development. To enable technology transfer on a larger scale, incentives have to be created for technology developers to cooperate and share the technology knowledge.

Direct Government Financing

The government should also endeavor to directly finance research and development, technology commercialization, manufacturing and deployment solar energy systems in the country. Financing of deployment mostly in the remote areas of the country through the integrated power projects will also be of great benefit.

CONCLUSION

All societies require energy services to meet basic human needs (e.g., lighting, cooking, space comfort, mobility, communication) and to serve productive processes. For development to be sustainable, delivery of energy services needs to be secure and have low environmental impacts. Sustainable social and economic development requires assured and affordable access to the energy resources necessary to provide essential and sustainable energy services. This may mean the application of different strategies at different stages of economic development. To be environmentally benign, energy services must be provided with low environmental impacts and low greenhouse gas (GHG) emissions.

A structural shift towards a world energy system that is mainly based on renewable energy might begin with a prominent role for energy efficiency in combination with renewable energy. Additional policies are required that extend beyond R&D to support technology deployment; the creation of an enabling environment that includes education and awareness raising; and the systematic development of integrative policies with broader sectors, including agriculture, transportation, water management and urban planning. The appropriate and reliable mix of instruments is even more

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