The Global Grid: Cooperation for Sustainable Development

Kanika Khanna, M.Eng, Massachusetts Institute of Technology
Sunkalp Energy, M/S BD Khanna Estates Pvt. Ltd.
New Delhi, India
kanika@sunkalp.com

Abstract:
The world today faces four faceted energy challenges of supply, security, access and de-carbonization. In a highly interdependent world where renewable energy is becoming an increasing part of the global energy mix, this paper proposes global energy connectivity as an important part of the solution. We analyse the technical and political aspects of energy connectivity and present several case studies to be referred to by policy makers as they prepare for global energy connectivity.

The key energy related challenges faced by our world today are to i) increase energy supply to keep up with our growing demands even as we reduce energy intensity, ii) achieve energy security, iii) provide energy access to ensure that no one is left behind and iv) transition to low-carbon sources in keeping with our global commitment to mitigate climate change.

The Interconnected Nature of our Energy Challenges

i) *GDP and energy consumption*: Even though energy intensity is reducing the world over as we become more efficient, the GDP of any country is tightly coupled with its total energy consumption. Given that the GDP of developing nations will increase at a higher rate than that of developed nations (at ~7% for Asia-Pacific from 2017-19), these countries will demand an increasing amount of energy over time.

ii) *Disproportionately increasing energy consumption*: An example of a trend that will result in increased energy consumption in Asia-Pacific is the dramatic growth of the middle class. The region will account for 60% of the world's total middle-class energy consumption by 2030 as compared to merely 23% today (Pezzini, 2012). Similar patterns are visible across the world and we should prepare for major energy load centres to shift geographically, even while it is difficult to physically move the generating stations.

iii) *Impact of variation of energy cost on economies*: The Pacific island nations spend up to 20% of their GDP on energy imports, a large part of the expense being on diesel. These countries have little or no energy security and are highly susceptible to even small cost variations. Further, even though countries like India and China export energy, their energy self-sufficiency ratio is less than 1- 0.85 for China, 0.66 for India and only 0.5 for Sri Lanka; whereas countries like Indonesia have a self-sufficiency ratio of 2.0 (UNESCAP, n.d.)

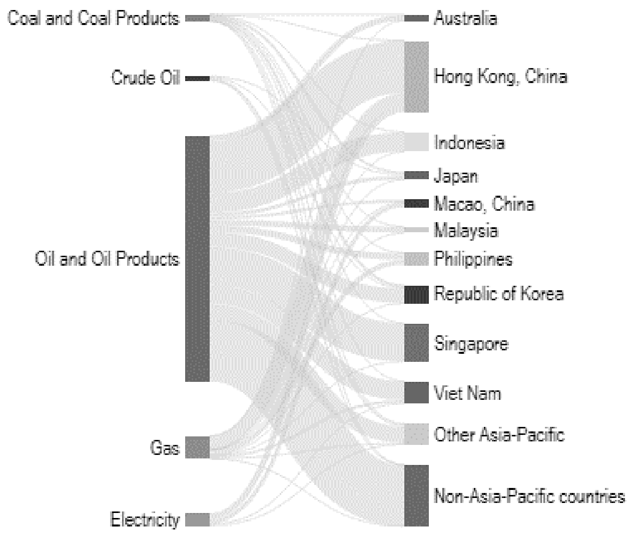

Figure 1: China's Energy Exports

iv) *Energy access*: Just in Asia-Pacific itself, more than 400 million people, or 10% of the population, do not have access to energy. Without energy access there is neither social equality, nor is there productivity and growth.

v) *Climate Change*: 13 of the 30 countries most vulnerable to damage from climate change are in the Asia-Pacific region. 70 per cent of the world's natural disasters, 50 per cent of the damages caused by those disasters, and 90 percent of the resulting fatalities in the last century occurred in Asia-Pacific countries. However, Asia-Pacific only consumes a quarter of the world's energy. As an example, Bhutan is the only carbon *negative* country in the World- which means that it absorbs more carbon dioxide that it produces due to its purposefully maintained dense forest cover. However, Bhutan is still susceptible to the consequences of climate change through natural disasters like glacial lake outbursts and flash floods. This proves that no country is an island in the fight against climate change.

As we tackle the energy challenges that our world faces, we need to completely rethink the way we generate, finance, consume, store and transmit energy. Given the multi-fold nature of these challenges- technological, financial, political and environmental- no one organization or country can tackle them alone.

These challenges can be tackled by i) increasing energy efficiency, ii) increasing energy access, iii) increasing renewable energy in the mix and iv) increasing energy connectivity (Akhtar, 2017). While the first three themes are attracting a lot of attention, action and investment, energy connectivity which is the clearest expression of global cooperation is still not at the forefront for policy makers- for this reason it is being highlighted through this forum.

Increasing Energy Connectivity

"Interconnection allows for balancing of electricity demands across larger areas: linking winter peak demand regions with summer peak demand regions and different time zones yields large benefits by smoothing daily peak/valley and seasonal loads. Similarly, there is a regional disparity between renewable production patterns and resource endowment." (Yinbiao Shu, 2016) At domestic or regional levels efforts after already underway, with the example of India's nationalized grid.

A greater level of connectivity in the form of inter-country power grids and gas pipelines will allow us to leverage geographically unevenly distributed resources and diversify our energy sources. Further as an increasing percentage of renewable energy is introduced into the mix, energy connectivity will be critical to absorb the increased temporal variations.

In the early part of this century, cross country gas transport had seemed a pipe dream, quite literally, but today gas pipelines 1000 km or longer are commonplace with a global total of 3.5 mn kms already installed. Prime examples of pipelines are the 2,475 km long Trans-Mediterranean natural gas pipeline which transports gas from Algeria to Italy via Tunisia and Sicily, built as far back as 1983 and with a massive capacity of 30 bn cum of gas annually. Closer home, the Iran-Pakistan-India pipeline is a 2,775 km long project.

As these examples demonstrate, multi-lateral energy connectivity is not a new concept and has been already exploited in the form of pipeline transport. Further electrical grid connectivity efforts are underway at a regional level. Through this paper we hope to incite discussion at the next level with global energy connectivity.

Global Energy connectivity will also ensure greater energy security as it will allow the use of diversified energy sources which will protect economies from shortages and prices volatilities. Through energy connectivity, we can ensure that we do not leave behind countries or sections of society that are unable to invest large capital resources upfront; and hence further the United Nations' goal of sustainable development for all.

Increased opportunities of power trade between countries and energy connectivity will need i) transformative technology for efficient transmission of power across large distances, ii) strong policies and systems for ensuring fair trade, iii) considerable capital investment and most importantly, iv) trust between nations.

Political Aspects of Energy Connectivity (UN, 2006)

There are multiple benefits of grid connectivity between nations. As a first, establishing energy connectivity opens up the channels of communication between nations which heralds further cooperation in other areas of trade, investment and cultural exchange. Once energy connectivity is established, there is increased incentive for the nations involved to resolve any conflict amicably in a non-military manner because of their economic interdependence. And finally, by establishing grid connectivity between nations, there is potential to provide energy to previously underserved geographies which can result in development and political stability.

On the flip side, there are some liabilities associated with establishing grid connection and energy trade between nations, which need to be considered before entering into such agreements. Where cross-border transmission lines are laid in remote locations, there is a security risk to the resource being held 'captive' by militants who may extort the countries involved. The connected grid may also be used as political leverage by one country over another where there is disproportionate dependence.

Further, multiple decisions need to be taken in the execution of large value grid interconnection projects including the selection of contractors, routing of power lines and the sharing of costs and benefits. Due considerations need to be made to transparently engage all involved stakeholders early on in the negotiation and formulation stages to ensure consensus and fair distribution of returns. Project longevity and success should be secured by establishing methods for collecting and disseminating data regularly to stakeholders.

Grid interconnection projects will take shape only when there is political will to engage and cooperate in addition to political stability and a culture of honouring long term contracts. Finally, even after all the policies and contracts are established amongst willing players, grid connectivity projects will take off only when there is a competitive atmosphere in the off-taking market and existing utilities are not threatened by cheaper imported power. As an example, the European Union is fecund with opportunity, given their financial and political allegiance. After a common currency, it is high time that the EU take action for an integrated European market for electricity which is a stated long-term goal of the European Union's European Electricity Directive of 1997.

Technologies for the Global Grid

The enabling technologies for the Global Grid can be broadly categorized as hardware and software. The hardware are primarily technologies for collection, delivery and point to point transfer of power. Whereas the relevant software are used for monitoring, dynamic control and metering of power or technologies that would make the grid smart. Here we take a look at some of the hardware tech available.

Transmission

UHVAC or Ultra High Voltage AC Transmission is one of the key options for long distance transmission. It refers to AC transmission with rated voltage of 1000 kV and above. The technology was first implemented in 1985 in the Soviet Union and is now well established. China is currently building a 640 km long UHVAC grid connecting North China to Central China.

UHVDC refers to DC transmission with rated voltage of +/- 800 kV or more. It is a fairly mature technology that first came into use in 1954. In January 2016, the State Grid Corporation of China, SGCC began construction of the world's first ±1100 kV UHVDC project, with a transmission distance of 3,324 km and rated power of 12 GW

Each of these two technologies has their own applications. While UHVAC grids would preferably be used to collect power on the supply side, or to deliver power on the demand side, UHVDC could be used for point-to-point power transmission.

Table 1: Comparison of Various Transmission Technologies for the Global Grid

Type of Technology	500 kV AC	UHVAC 1000 kV AC	UHVDC +/- 800 kV DC	UHVDC +/- 1000 kV DC	UHVDC +/- 1500 kV DC
Transmission Capacity (GW)	2 ~ 2.4	8 ~ 9	~8	~12	-
Economical Transmission Distance (km)	250 ~ 800	500 ~ 2000	1100 ~ 2500	2300 ~ 5000	>5000 km
Line Loss Rate (% / 100 km)	0.46 ~ 0.69	0.17 ~ 0.21	0.16	0.09	-
Costs (USD/ MW * km)	290	201	99	94	-
Status	Norm	Established	Established	Established	Experimental

Flexible AC Transmission

Using advanced power electronics, flexible AC transmission systems, or FACTS, are helpful in variable renewable energy integration for voltage and power flow control.

VSC HVDC and HVDC grids

Voltage-source converter-based HVDC permits quick control of both active and reactive power independently, and even black starts as they use fully controllable valves. Power flows are easy to reverse, and they are not susceptible to commutation failures. This makes the technology suitable for forming multi-terminal HVDC (Yinbiao Shu, 2016).

Table 2: Distance from Major Renewable Resources to Load Centres

From	To	Distance (km)
Arctic Kara Sea (wind power)	North China	4,400
Bering Strait (wind power)	N. China, Japan, S. Korea	5,000
Bering Strait (wind power)	West US	4,000
Arctic Greenland (wind power)	North UK	2,100
Arctic Greenland (wind power)	Quebec Canada	2,000
North Africa (solar power)	Europe	<2,000

A review of Table 1 and Table 2 shows that in terms of distances to be covered for the Global Grid, the existing transmission technologies are ready and capable.

Apart from transmission, various technologies for simulation, operation, planning, control and maintenance are required to enable the Global Grid and to make it smart. These include SCADA for monitoring, Information and communication technologies, hybrid analog and digital simulation protocols and GIS for networks information systems. Asset intelligence networks for advanced planning, operations and maintenance of grids also need to be developed.

Case Studies of Energy Connectivity

There is much to be learned from regional level connectivity projects and the existing attempts at connectivity policy. Here we examine a few interesting cases:

TransÉnergie's Cross Sound Cable- Technological Triumph turns Political Fiasco

In 1999, a permit was awarded to TransÉnergie, a Canadian company to build at its own cost, a 40 km underwater transmission line to strengthen the connectivity between Connecticut and Long Island Sound, United States. The Canadian entrepreneur was set to install the first 'merchant' line in the United States. From a technological standpoint the Cross Sound Cable was going to be a cutting edge HVDC transmission with digital control, which would have allowed the company to lease space on its line, precisely control electrical flows while simultaneously filtering out dangerous spikes and sags (Fairly, 2005); and hence monetize and get a return on its capital investment- much like a toll road.

However, the project ran into political trouble in 2002, when the Connecticut attorney general, Richard Blumenthal lobbied against the underwater transmission cable, citing it as an environmental hazard and bad for Connecticut's economy. He made a case that the Cable would siphon off Connecticut's cheap power to other cities, resulting in electricity prices hikes for the state. TransÉnergie's troubles worsened when there were some technical errors in laying the cable underwater and the Cable was not allowed to operate until further notice.

This moratorium was lifted only in August 2003, when in response to nationwide power outages in the United States, emergency legislation was passed to allow the Cable to transmit power to electrify Long Island. However by that time, the operational delays, lobbying and legal battle resulted in a 20% increase in Cross Sound Cable's project cost. TransÉnergie's CEO, Donahue, regrets not having educated Connecticut's politicians about the Cable's benefits early on.

Harvesting the Deserts

"Within six hours, deserts receive more energy from the sun than humankind consumes within a year", states Desertec's website. The foundation envisions tackling climate change, energy demand and migration with one clean sweep. Their master plan is to generate clean energy in the desert areas of the MENA region and export it to affluent European countries over 3000 kms away using high voltage transmission lines. They argue that clean energy generated in the Sahara desert will create employment, energy supply and prosperity in the poorest parts of the world.

Desertec's poster child is Morocco's 160 MW concentrating solar power project- Noor Ouarzazate I (Noor 1, 2017)- which supplies energy well over three hours after sun-down, thanks to its molten salt based storage capacity. The project sells electricity at USD 0.189/ kWh. The latest addition to Noor is Ouarzazate IV- a 70 MW solar photovoltaic power plant with a PPA rate of merely USD 0.048/kWh. Desertec's focus is now on garnering political consensus for building the 3000 km transmission line for intercontinental energy connectivity.

The Chinese Lead with Ambitious Plans

In March 2016, the State Grid Corporation of China announced ambitious plans (Baculinao, 2016) to build a super grid linking new and existing solar generating plants and wind turbines across the continents of Asia, Europe, Africa and the Americas. The plan will, if it goes through, will be the world's largest infrastructure project requiring a $50 trillion investment and could connect the world by 2050.

With such ambitious plans, the Chinese are unequivocally announcing their global leadership, and in this case, energy may literally translate to power.

The SAARC Energy Ring and CASA 1000

A truly multi-lateral energy connectivity project is the Central Asia South Asia energy grid- CASA 1000- which will allow for the export of surplus hydroelectricity from Tajikistan and Kyrgyzstan to Pakistan and Afghanistan. The $1.6 bn project which is under construction, is slated for completion by end of 2018.

Technologically, the CASA 1000 will include a 477 km long 500 kV AC line; a 1300 megawatt AC-DC Convertor Station; a 750 km High Voltage DC line and a 1300 megawatt DC-AC Convertor Station. The project has an impressive donor list which includes the World Bank Group, Islamic Development Bank and USAID among others.

Figure 2: Map of CASA 1000

Summary

As the world takes small steps towards the Global Grid, we need to learn from the experiences of past attempts at Grid Connectivity. Wildly varying state and national level policies and interests expose connectivity projects, investors and entrepreneurs to political attacks and cost and schedule unpredictability.

Associations of countries and platforms such as ESCAP and ASEAN need to lay down protocols around how transmission services and energy will be traded. A stable political environment needs to be established along with a joint commitment towards energy connectivity

The Global Grid, if taken seriously by policy makers can become a worthy competitor for the considerable investments being made currently in large scale energy storage, as a solution to demand and supply variability.

Given India's leadership in the Indian subcontinent and its commitment to renewable energy and to mitigating climate change, we are confident that India will take a leadership position in an endeavour towards building The Global Grid.

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About Sunkalp Energy

Sunkalp Energy is a leading solar power company, headed by a technologist, ex-bureaucrats and serial entrepreneurs. It is a unit of the diversified Bhagwan Dass Khanna Group that has presence in 7 states. We have over 100 clients in North India and are proud to install the largest roof-top solar power plant of Rajasthan, in Jaipur. Sunkalp Energy works closely with DISCOMs for streamlining Net Metering policies and procedures. Sunkalp Energy aims to set quality benchmarks and influence the solar industry in India through thought leadership.

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