ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

HVDC pricks the hydrogen bubble

Andrew Blakers

Research School of Electrical, Energy and Materials Engineering, Australian National University, Canberra, Australia
E-mail: Andrew.Blakers@anu.edu.au

Summary

There is much talk of a renewable hydrogen boom in Australia.

However, transmission of renewable energy via high voltage DC cables (HVDC) is much cheaper than transmission via hydrogen because of 3-fold higher losses via hydrogen.

Because of HVDC, Australia's export market for hydrogen is small. Australia's internal hydrogen market is also small except perhaps for reduction of iron ore in the Pilbara.

Energy transmission

Electricity transmission by high voltage DC (HVDC) and AC (HVAC) cables is a mature, low cost and highly efficient way of transmitting large-scale renewable energy over large distances. State of the art is a cable operating at 1.1 Megavolts over a distance of 3,000 km and transmitting 12 Gigawatts with 10% loss.

100% of net new electricity deployment in Australia (and two thirds world-wide) is PV and wind. Asia has vast solar and wind resources, similar in quality to Australia (see maps below). Most Asian countries have ample solar and wind resources. All of Asia west to Europe, east to Japan and south to Sri Lanka is within HVDC range of excellent Asian wind and solar regions (Figure 1). In contrast, only Indonesia, PNG and Singapore are within 3000 km of Australia.

Australia is at a disadvantage relative to China, Mongolia, the Middle East and other superbly endowed Asian nations for supply of renewable energy to Asia.

Hydrogen transport

1. Hydrogen has low (~30%) round trip efficiency for renewable energy transport:
    a. First, we produce electricity via PV and wind
    b. Then we produce hydrogen via electrolysis of water, with 50-70% efficiency
    c. Then we ship a hydrogen-rich liquid chemical (hydrogen, ammonia, methane etc)
    d. Then we use the hydrogen-rich chemical as a fuel for electricity generation or motive power with 30-50% efficiency
    e. Round trip efficiency to electricity or motion is low: (50-70%) * (30-50%) ~ 30%
    f. In contrast, the transmission efficiency of HVDC electricity over long distance is ~90%. It will thus be necessary to generate three times more renewable electricity for hydrogen than HVDC which triples the cost
    g. This triple cost is a critical shortcoming of hydrogen in competition with HVDC
2. Hydrogen for heating has tough competition from heat-pumps and direct electrical heating

3. Hydrogen is an important pre-cursor chemical for industry. However:
    a. Hydrogen from methane is much cheaper than from renewable electrolysis and will remain so for many years - long after PV & wind have pushed methane out of industrial heating
    b. Electrolysis of water in Asia (including via HVDC) allows direct hydrogen production on site.

East Asia offers lukewarm prospects for hydrogen exports from Australia

A prospect for significant Australian hydrogen exports is to Japan, Korea and Taiwan, if these countries are unwilling to accept renewable electricity via HVDC cable from China, Mongolia or Russia. However:

1. The cost differential between HVDC and hydrogen is large (factor of 3) due to the low efficiency of energy delivery via hydrogen. This would make the economies of these countries less competitive.
2. Unlike natural gas, anyone can make hydrogen via renewable electricity. Many countries can supply renewable hydrogen to East Asia using local or HVDC-delivered renewable energy.
3. East Asia is quite well endowed with wind and solar (Tokyo and Seoul have similar latitudes to Canberra). An East-Asian undersea HVDC grid (Korea, Taiwan, Philippines and Japan) could supply a large fraction or all of the local energy needs, particularly if competing with expensive Australian renewable hydrogen.

Australia's internal hydrogen market is small (except perhaps for the Pilbara)

1. The only real prospects for an export competitive advantage is hydrogen-assisted, non-electrolytic reduction of metal oxides - overwhelmingly iron oxide ore in the Pilbara because here, iron ore deposits coincide with excellent wind and solar resources.
2. Australia has a small chemical industry that might need hydrogen (eg ammonia).
3. Hydrogen as a fuel for electricity production or vehicles or heating is not and will not be competitive with direct use of renewable electricity because of low round-trip efficiency
4. Hydrogen as energy storage is and will remain far more expensive than pumped hydro or batteries because of low round-trip efficiency

Production of hydrogen

It is very likely that renewable hydrogen production will entail generation of renewable electricity via grid-connected PV and wind farms, and direct electrolysis of water on site. This allows hydrogen production to utilize electricity at the price available in a large and mature market.

Photo electrochemistry and other specialized methods of hydrogen production are also available. However, these are likely to be much more expensive because (i) they are technically immature (ii) are unavailable in the market place (iii) are unlikely to be more efficient than ordinary PV coupled with an electrolyser and (iv) require vast networks of hydrogen pipes over thousands of km^2 to collect hydrogen from vast numbers of water-filled photo electrochemical cells. The construction, operations and maintenance of such a system is likely to be rather expensive.

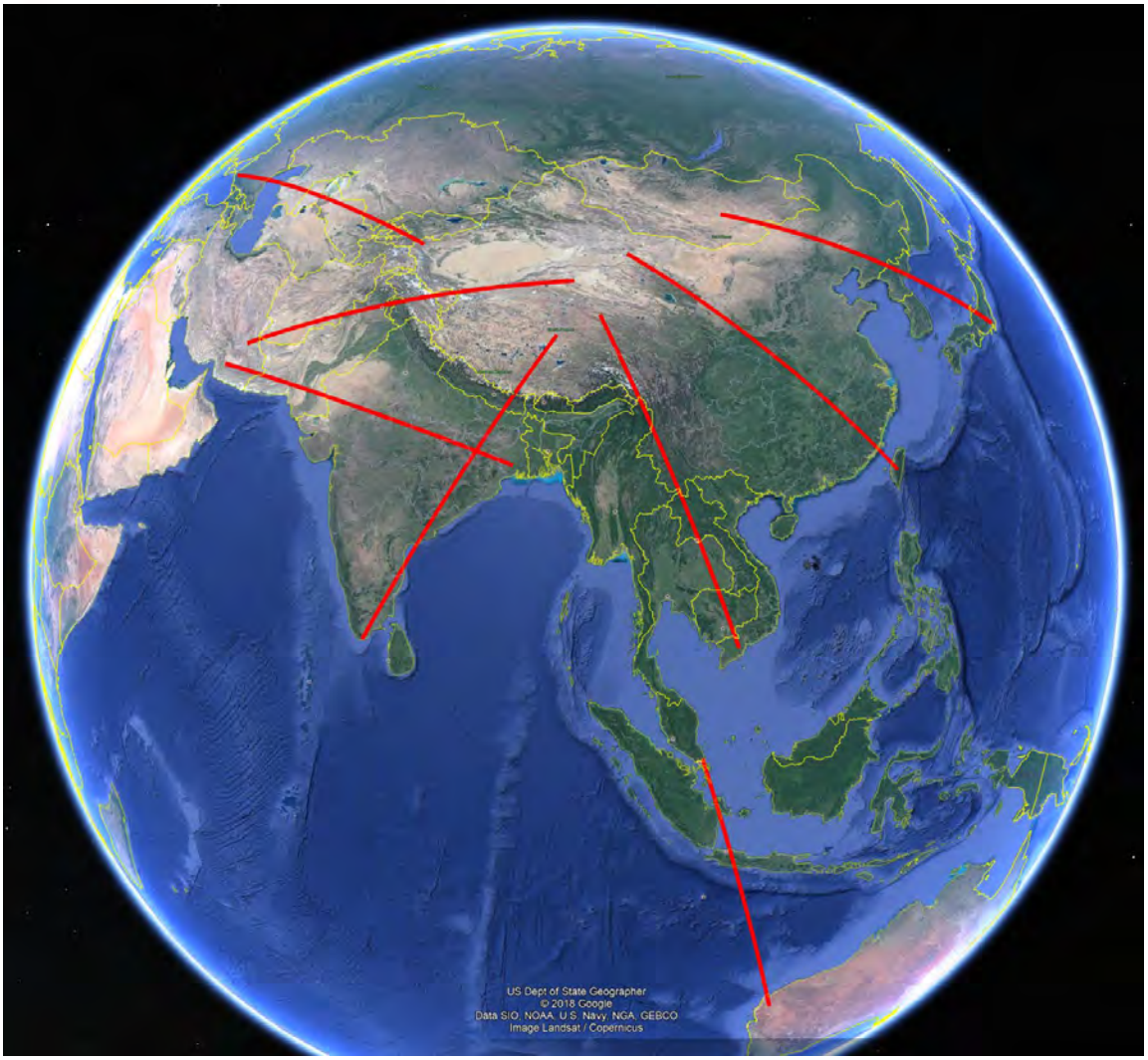

Figure 1: Asia has excellent solar and wind resources (see maps below). Most of the world's population resides within HVDC-range (3000 km) of central Asia, However, Australia is out of HVDC range of global population centres except for Indonesia. The red bars are each 3000km long. Map: Google Earth.

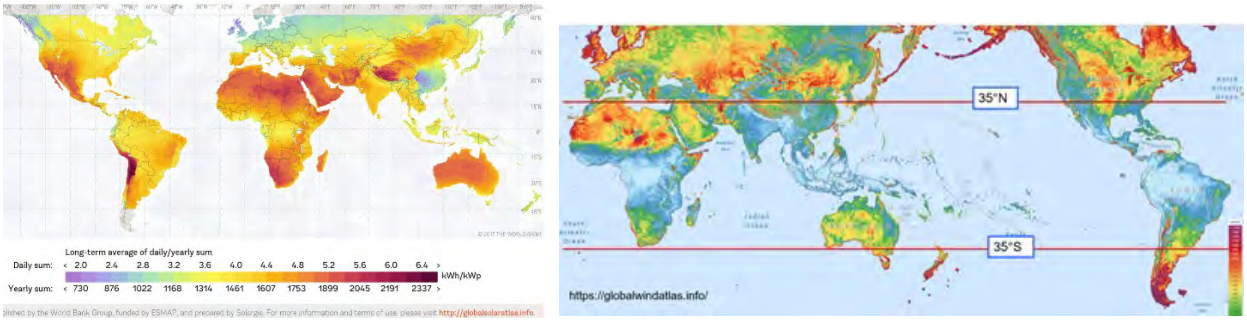

Figure 2: Asia is very well endowed with solar energy (left) and wind (right)