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The Great Energy Transition: Challenges and opportunities for transformation

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Great energy transition – 9 key takeaways

1. Climate change, energy security, and cost considerations are driving the current energy transition which aims to transform the global energy sector from **fossil-based to zero-carbon**

2. To keep global temperature increase to under 1.5^{O}C this century, **renewable energy penetration must rise to 70-85%** of global energy mix – up from 25% today

3. **Singapore's triple challenge**: i) pledge to reduce emission intensity by 36% from 2005 levels by 2030; ii) natural gas imports ~95% of fuel mix; iii) rising energy costs to firms & low-income households

4. The business opportunity from new energy innovations could be worth **US$4.3 trillion globally** and **US$1.9 trillion in Asia** by 2030

5. **Solar and wind energy hold the largest potential** across renewable technologies – largely cost competitive with fossil fuels and could each account for 24% of global energy mix by 2050

6. Carbon capture, storage & utilisation (CCSU) technologies could contribute **~13% of carbon emissions reduction** by 2050; the cost of restricting global warming to below 2^{O}C could **double without CCSU**

7. There is a **convergence of industries**, where non-traditional players from the finance, automotive, waste management and ICT sectors are now key components of the new global energy value chain

8. A **supportive regulatory landscape is crucial** to support the energy transition – and key to attracting private investments. Common policies include Renewable Portfolio Standards, financial incentives and Public-Private Partnerships, and regulatory sandboxes

9. The energy transition has **significant implications for the labour market** - reskilling the workforce in traditional energy sectors is critical to ensuring a smooth transition for all stakeholders

The Great Energy Transition:
Challenges and opportunities for transformation

On 5 October 2018, Temasek organised a discussion by management consultancy AT Kearney on the future energy value chain, as part of the Ecosperity Conversations series. Change has always been the only constant when it comes to the energy landscape; however, in response to a range of challenges, from combatting climate change through to tackling energy security, today's energy landscape is set for a fundamental transformation. The good news is that there are a range of new technologies available that can address these challenges. The session discussed the regulatory requirements to support this shift in the energy landscape, the potential new business models, and the implications both globally and for Singapore. This summary report covers the key topics discussed during the session and includes additional insights to complement the discussion on the potential implications for Singapore.

The current energy landscape is undergoing a fundamental transformation in response to various challenges

The energy landscape has a long record of innovation. In the early to mid-19th century, whale oil was the principal source of fuel for lighting. Growth in demand led to the rapid depletion of whales, and the price increased two-fold from 1823 to 1855.[1] Experiments with alternative fuel sources eventually led to the development of kerosene. What makes the situation today different is that the energy landscape is faced with a much broader and different set of challenges than the past. While there is no absolute shortage of energy, the world faces challenges with climate change, energy security, and the cost of energy.

Climate change

A recent report by the Intergovernmental Panel on Climate Change (IPCC) warns of the catastrophic impact that climate change could have on the world's ecosystems, economies, and society.[2] This includes increased risk of droughts, sea level rise, flooding, tropical cyclones, ocean acidity, and threats to food security, water supply, and economic growth.

In 2013, energy production accounted for 72 percent of all anthropogenic greenhouse gas (GHG) emissions.[3] The current global energy transition aims for the transformation of the global energy sector from fossil-based to zero-carbon. This is underpinned by the Paris

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[1] Ugo Bardi (2004), *Prices and production over a complete Hubbert cycle: The case of the American whale fisheries in 19th century*, Association for the Study of Peak Oil and Gas.
[2] This special report has received extensive coverage in the press. See Intergovernmental Panel on Climate change [IPCC] (2018), *Global Warming of 1.5 ºC – Summary for Policymakers*. Available at: http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf
[3] World Resources Institute (2017), *CAIT Climate Data Explorer.* Available at: http://cait.wri.org/

Climate Change Agreement, a global pact where countries agreed to put forward their best efforts to mitigate global warming to keep global temperature rise this century well below two degrees Celsius (compared to pre-industrial levels), and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.[4] To achieve a 1.5 degree pathway, the IPCC suggests that renewables will need to account for 70-85 percent of electricity generation by 2050 (up from 25 percent today).[5]

By 2050, renewables will need to account for **70-85%** of electricity generation to achieve a 1.5-degree pathway

In 2007, Singapore's former Prime Minister Lee Kuan Yew called global warming and climate change the "ultimate threat to human survival."[6] As a low-lying city with at least 30 percent of land area less than five metres above sea level, Singapore is prone to flooding from rising seas and vulnerable to the consequences of climate change.[7] While it contributes only around 0.1 percent of global emissions, Singapore ranks 26th out of 142 countries in terms of emissions per capita.[8] As part of its commitment to the Paris agreement, Singapore has pledged to reduce its emission intensity by 36 percent from 2005 levels by 2030.[9] Natural gas, the lowest carbon-emitting fossil fuel, now accounts for 95 percent of Singapore's fuel mix, while renewables capacity including solar power rose 13 times between 2012 and 2016.[10]

Energy security

Energy security is another driver of the current energy transition for some countries. Resource constraints compel countries to consider both longer-term options to supply energy in line with their economic development and environmental needs, as well as shorter-term ability to react promptly to sudden supply-demand imbalances.[11] Global energy usage is projected to increase by 28 percent by 2040, compared with 2015 levels, and research shows that up to 80 percent of oil demand in Asia-Pacific and Europe would come from imported sources in 2030.[12] Volatile oil prices in recent years as a result of geopolitical tensions have also

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[4] United Nations Framework Convention on Climate Change [UNFCCC] (2018), *The Paris Agreement.* Available at: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[5] Intergovernmental Panel on Climate change [IPCC] (2018), *Global Warming of 1.5 ºC – Summary for Policymakers*. Available at: http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf. Data on current renewable energy generation is derived from the International Energy Agency, available at: https://www.iea.org/geco/renewables/.
[6] Forbes (2015), "Thoughts from Lee Kuan Yew in Forbes" Available at: https://www.forbes.com/sites/forbesasia/2015/03/23/thoughts-from-lee-kuan-yew-in-forbes/#2d170e6c1848
[7] National Climate Change Secretariat [NCCS] (2018), *Impact of climate change on Singapore.* Available at: https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/impact-of-climate-change-on-singapore
[8] Based on 2015 data from the International Energy Agency (IEA).
[9] Channel NewsAsia (2017). "Singapore reaffirms commitment to Paris climate agreement after US pullout." Available at: https://www.channelnewsasia.com/news/singapore/singapore-reaffirms-commitment-to-paris-climate-agreement-after-8905862:
[10] Energy Market Authority (2018), *Singapore Energy Statistics 2018.* Available at: https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/SES18/Publication_Singapore_Energy_Statistics_2018.pdf
[11] International Energy Agency [IEA] (2018), *Energy security.* Available at: https://www.iea.org/topics/energysecurity/
[12] US Energy Information Administration [EIA] (2017), *International Energy Outlook.* Available at: https://www.eia.gov/todayinenergy/detail.php?id=32912; and John V. Mitchell/Chatham House (2010), More for Asia: Rebalancing world oil and gas. Available at: https://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/1210pr_mitchell.pdf

encouraged some countries, particularly net energy importers, to diversify their supply base and hedge against increased price uncertainties.

Diversifying energy supply is key to maintaining Singapore's energy security. Natural gas imports account for around 95 percent of Singapore's fuel mix.[13] Imports of natural gas are predominantly piped from Malaysia and Indonesia, and liquefied natural gas (LNG) is imported from the United States (US), Qatar and Australia.[14] Given that energy demand is expected to continue growing, it is imperative for Singapore to ensure energy security by reducing external dependency and diversifying the fuel mix through renewables such as solar power.[15]

> Natural gas **imports** account for **95 percent** of Singapore's fuel mix

Costs

Lower-income households typically spend a larger share of their income on energy (than higher income households), and this is exacerbated by stagnating incomes for lower-income families in many economies. For instance, households from the lowest income decile in the United Kingdom (UK) spent 8.4 percent of their income on energy in 2016, in comparison with the highest decile, which spent 2.6 percent.[16] Similarly, in Singapore, latest data shows that households from the lowest income decile spent 4.1 percent of total expenditure on electricity, gas and other utility fuels – more than double of what the top decile spends.[17]

> Lower-income households in Singapore spend over **4%** of their total expenditure on meeting their energy needs

Energy costs also matter for businesses. The Singapore government announced during the 2018 Budget that from the following year, a tax of S$5 per tonne of GHG emissions will be levied on companies that emit 25,000 tonnes or more of GHG annually. This carbon tax rate will be reviewed and could increase to between S$10 and S$15 by 2030.[18] Estimates show that the tax amounts to an increase of S$5 to S$9 to the cost of processing a barrel of crude into refined oil products such as diesel or gasoline (based on S$76 per barrel price of oil).[19] Energy Market Authority (EMA) data shows that the chemicals and petroleum refining sectors were responsible for more than 60 percent of the country's carbon dioxide (CO_2) emissions in

[13] Energy Market Authority (2018), *Singapore Energy Statistics 2018.* Available at: https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/SES18/Publication_Singapore_Energy_Statistics_2018.pdf
[14] Channel NewsAsia (2018), "Stepping on the gas to keep Singapore's lights burning" Available at: https://www.channelnewsasia.com/news/cnainsider/lng-natural-gas-electricity-singapore-energy-security-tank-10088910
[15] Peak demand is projected to grow at a compound annual growth rate (CAGR) of up to 1.9 percent from 2018 to 2028, compared with a CAGR of 2.4 percent over 2006-16. Energy Market Authority (2017), *Singapore Electricity Market Outlook (SEMO) 2017.* Available at: https://www.ema.gov.sg/cmsmedia/Singapore%20Electricity%20Market%20Outlook%20%23final%20v2.pdf
[16] Ofgem (2018), *Energy spend as a percentage of total household expenditure (UK).* Available at: https://www.ofgem.gov.uk/data-portal/energy-spend-percentage-total-household-expenditure-uk
[17] Singapore's household expenditure survey is conducted once every five years. Department of Statistics Singapore (2013), *Report on the Household Expenditure Survey 2012/13.* Available at: https://www.singstat.gov.sg/-/media/files/publications/households/hes1213.pdf
[18] The Straits Times (2018). "Singapore Budget 2018: Carbon tax of SG$5 per tonne of greenhouse gas emissions to be levied". Available at: https://www.straitstimes.com/singapore/singapore-budget-2018-carbon-tax-of-5-per-tonne-of-greenhouse-gas-emissions-to-be-levied
[19] The Straits Times (2017). "Carbon tax likely to impact oil refineries, wholesale electricity prices". Available at: https://www.straitstimes.com/business/economy/carbon-tax-likely-to-impact-oil-refineries-wholesale-electricity-prices

2010, suggesting that a key pillar of Singapore's economy could face economic competitiveness challenges given these changes.[20]

A range of technologies are providing opportunities to address these challenges

A range of technologies in different stages of maturity and commercial viability are driving the current energy transition globally. AlphaBeta's past work with the Business & Sustainable Development Commission (BSDC) and Temasek identified technologies ranging from battery storage to promoting energy efficiency that could be worth US$4.3 trillion globally by 2030, including US$1.9 trillion (44 percent) worth of opportunities in Asia.[21] This section focuses on four particular opportunities: clean energy; energy storage; carbon capture, storage and utilisation; and smart grids.

Clean energy

Solar and wind energy could each account for **24 percent** of the global power mix by 2050

A key trend in energy transition is the rapid growth in adoption of clean and renewable energies. In 2016, two-thirds of global net capacity additions to the power grid came from renewables.[22] The International Energy Agency (IEA) increased its 2022 forecast of renewable electricity capacity by 12 percent, primarily due to upward revisions in the take-up of solar photovoltaic (PV) in China and India.[23] By 2050, solar and wind could each account for 24 percent of the global power generation mix, up from just two percent and five percent respectively in 2017.[24] Commercialised renewables at current costs are cost-competitive with traditional hydrocarbon sources (Exhibit 1). Solar energy without subsidies matches fossil fuel costs in over 30 countries, including Singapore, and could be cheaper than coal in China and India by 2021.[25] Solar photovoltaic (PV) plants and onshore wind have already seen their levelised cost of electricity (LCOE) decline by 77 percent and 41 percent respectively between 2009 and 2018, with further forecasted declines of 71 percent and 58 percent by 2050.[26]

[20] Energy Market Authority [EMA] (2012). *Energising our Nation – Singapore Energy Statistics 2012*. Available at: www.ema.gov.sg/media/files/publications/EMA_SES_2012_Final.pdf and National Climate Change Secretariat (2013). *Industry Energy Efficiency. Technology Roadmap*. Available at: https://www.nccs.gov.sg/docs/default-source/default-document-library/industry-energy-efficiency-technology-roadmap.pdf

[21] BSDC, Temasek and AlphaBeta (2017), *Better Business Better World Asia*. Available at: http://report.businesscommission.org/reports/better-business-better-world-asia

[22] International Energy Agency [IEA] (2017), *Renewables 2017 – Analysis and Forecasts to 2022.*

[23] Solar photovoltaic (PV) is one of four main direct solar-energy technologies, the other three being concentrating solar power (CSP), solar thermal and solar fuels. Electricity is generated via the direct conversion of sunlight into electricity in PV cells. See International Energy Agency [IEA] (2017), "Solar PV grew faster than any other fuel in 2016, opening a new era for solar power" Available at: https://www.iea.org/newsroom/news/2017/october/solar-pv-grew-faster-than-any-other-fuel-in-2016-opening-a-new-era-for-solar-pow.html

[24] AT Kearney Energy Transition Institute (2018), *Temasek – Energy Transition, major trends and opportunities.*

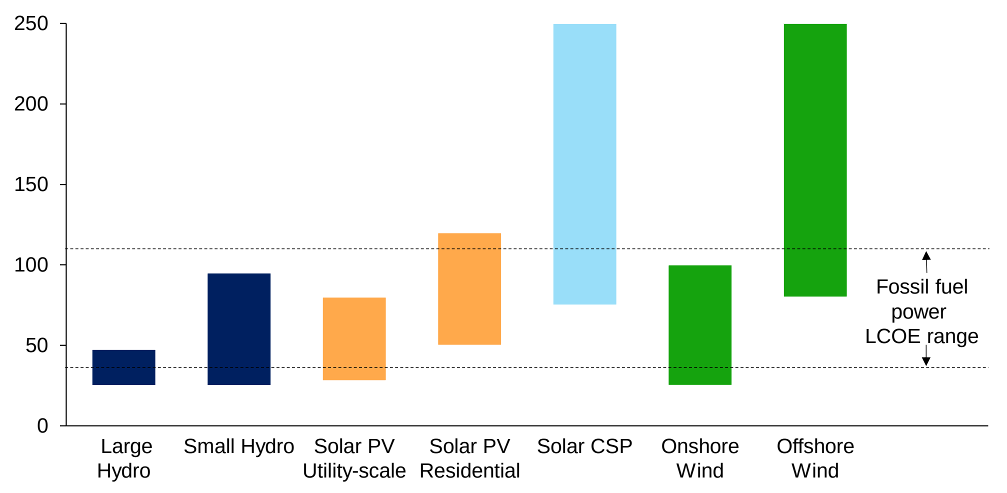
25 International Energy Agency [IEA] (2016), *World Energy Outlook 2016.* Available at: https://www.iea.org/media/publications/weo/WEO2016Chapter1.pdf

[26] The levelised cost of electricity (LCOE) is the net present value of the unit-cost of electricity over the lifetime of an energy generating asset. It is often taken as a proxy for the average price that the generating asset must receive in a market to break even over its lifetime.

EXHIBIT 1

Renewables are becoming cost competitive with hydrocarbon power sources

Levelised Cost of Electricity (LCOE) range for renewable operating facilities
(Euros/MWh, 2017)



SOURCE: A.T. Kearney (2018); IRENA (2017); IEA (2017)

Newer technologies at the research and development stage hold immense potential. In the UK, scientists are testing the use of the atomically thin semiconductor hafnium disulphide (HfS2) in solar cells, which could potentially raise the electrical conversion rate from the current 20 percent to around 60 percent.[27]

Singapore set solar generation target at **1 GWp** beyond 2020

Solar energy holds the most potential for driving renewable energy generation in Singapore, due to conducive conditions to harness solar energy and also in part owing to the low potential of other renewable sources. For instance, Singapore has a high annual average solar irradiance i.e. solar power capacity per unit of area – in fact, it receives 50 percent more solar radiation than countries in temperate climate zones.[28] In contrast, it is difficult for Singapore to tap on wind energy – as onshore infrastructure requires space that land constraints and high-rise buildings do not allow for, and offshore installations would cross shipping routes and international waters. Land constraints similarly restrict geothermal energy, and low or weak tidal range curbs the potential for tidal energy.

[27] The Next Big Future (2018), "Breakthrough could triple the energy collected by solar to 60% efficiency" Available at: https://www.nextbigfuture.com/2018/07/breakthrough-could-triple-the-energy-collected-by-solar-to-60-efficiency.html
[28] Energy Market Authority [EMA] (2018), *Solar Photovoltaic Systems.* Available at: https://www.ema.gov.sg/solar_photovoltaic_systems.aspx

Singapore has set a target to raise solar generation to 350 megawatt-peak (MWp) by 2020 from 140 MWp today, and to 1 gigawatt-peak (GWp) beyond 2020.[29] Put differently, Singapore's long-term goal is to draw 20 percent of its electricity from solar energy by 2050, up tenfold from around two percent today.[30] Under the SolarNova programme, Singapore is installing solar panels on rooftops of Housing and Development Board (HDB) blocks and government sites.[31] Singapore is also adopting innovative ways to navigate land constraints, including floating solar panels at Tengeh Reservoir. Other solar-related innovations that are gaining traction include microgrid storage systems and Building Integrated Photovoltaics (BIPV) – incorporation of solar generation capabilities into vertical building design elements such as windows.[32] Singapore's Building and Construction Authority is encouraging development of BIPV technologies including for glass facades as a part of the Green Mark scheme. Such windows have been deployed at facilities such as Biopolis.[33]

Energy storage

Progress is apparent not only in power generation but also in distribution and storage. Energy storage is a key element of a stable, decarbonised grid, navigating intermittency issues with large-scale generation of renewable energy.[34] It can also reduce the need for increased peak capacity by storing excess power generated during off-peak periods. IRENA estimates an additional 150 GW of battery storage may be required by 2030 to support a doubling of global renewable energy generation.[35]

150 GW of battery storage required by 2030 to support 2x global renewable energy generation

As of 2017, over 95 percent of the world's storage capacity is in pumped-storage hydroelectricity.[36] However, a number of battery and other storage technologies are developing quickly, and are expected to become cost-competitive with hydroelectricity on a levelised basis by 2030.[37] Deployments of lithium-ion batteries are forecasted to grow at a compound annual growth rate (CAGR) of 55 percent through 2022.[38] Increasing scale of

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[29] Energy Market Authority [EMA] (2018), *Solar Photovoltaic Systems.* Available at: https://www.ema.gov.sg/solar_photovoltaic_systems.aspx; and Channel NewsAsia (2018), "From floating solar farms, to HDB rooftops: Where Singapore's sun-powered future lies" Available at: https://www.channelnewsasia.com/news/cnainsider/floating-solar-farm-hdb-singapore-testbed-energy-photovoltaic-10064656
30 Channel NewsAsia (2015), "Solar power taking off as alternative energy source in Singapore" Available at: https://www.channelnewsasia.com/news/singapore/solar-power-taking-off-as-alternative-energy-source-in-singapore-8244354
31 Channel NewsAsia (2017), "HDB calls 'largest tender' to install solar panels across government agencies" Available at: https://www.channelnewsasia.com/news/singapore/hdb-calls-largest-tender-to-install-solar-panels-across-9365000
[32] IPI Singapore (2018), "Beyond a building material – clear glass solar windows provide a renewable source of energy" Available at: https://www.ipi-singapore.org/success-stories/beyond-building-material-clear-glass-solar-windows-provide-renewable-source-energy
[33] Building and Construction Authority [BCA] (2018), *Green Handbook – Photovoltaic (PV) systems in buildings.* Available at: https://www.bca.gov.sg/GreenMark/others/pv_guide.pdf
[34] Intermittency issues refer to the fact that timing of renewable energy generation and electricity demand are poorly correlated as generation is contingent on weather conditions. For instance, energy demand for air conditioners can be high at night when there is no solar energy.
[35] International Renewable Energy Agency [IRENA] (2015), R*enewables and electricity storage: A technology roadmap for REmap 2030*. Available at: http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_REmap_Electricity_Storage_2015.pdf
[36] US Department of Energy (2018), *DOE Global Energy Storage Database.* Available at: http://www.energystorageexchange.org/
[37] World Energy Council (2016), *E-storage: Shifting from cost to value, Wind and solar applications*, Available at: https://www.worldenergy.org/wp-content/uploads/2016/01/World-Energy-Resources-E-storage-wind-and-solar-presentation-World-Energy-Council.pdf
[38] Renewables Now (2017), "Lithium0ion battery deployments to grow 55% annually through 2022" Available at: https://renewablesnow.com/news/lithium-ion-battery-deployments-to-grow-55-annually-through-2022-624440/

production is a significant driver for cost reduction. Hydrogen fuel-cells are another developing storage option that could power the next generation of carbon-neutral vehicles.[39] Further investment in innovation will be required to capture this opportunity, particularly for nascent and non-commercialised technologies such as fuel cells and metal-oxide batteries.

Singapore's EMA and SP Group recently awarded the CW Group and Red Dot Power S$17.8 million to develop the country's first utility-scale energy storage system (ESS) using lithium-ion batteries.[40] This test-bed is expected to be in operation for three years at two substation locations in north and north-eastern Singapore – providing up to 4.4 MWh of reserves generated by solar power to reduce peak demand. This facility will help establish technical guidelines for future ESS deployment.

Carbon capture, storage and utilisation (CCSU)

Demand for CO_2-based products to reach **5 Gt by 2050**

Carbon capture, storage and utilisation (CCSU) refers to the capture of CO_2 at the point of emissions and storage of this input for further utilisation. CCSU is considered a major potential driver of decarbonisation, given that it directly deals with current GHG emissions from power generation. The International Energy Agency (IEA) estimates that CCSU could contribute to 13 percent of carbon emissions reduction by 2050, while the IPCC estimates that restricting global warming to below two degrees Celsius would be twice as expensive or even unfeasible without CCSU.[41] The Shell Sky Scenario anticipates that by 2050, the world might be storing 5 Gt of CO_2 per annum and using another 5.1 Gt in CO_2-based products.[42]

CCSU holds significant potential for Singapore for two reasons – a lack of viable alternative energy sources beyond solar power, and the potential to reduce emissions from heavy manufacturing industries (e.g. petrochemicals). These high-footprint industries are a pillar of the country's economy – accounting for 19 percent of nominal value added to the economy in 2017.[43] Recent developments in this space have been positive. For instance, French

[39] McKinsey (2017), "Hydrogen: The next wave for electric vehicles?" Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/hydrogen-the-next-wave-for-electric-vehicles
[40] EMA (2017), "Launch of Singapore's first utility-scale energy storage system" Available at: https://www.ema.gov.sg/media_release.aspx?news_sid=20171023Q2Ay3V8ycW9P
[41] AT Kearney Energy Transition Institute (2016), *Carbon Capture and Storage: At a crossroads.* Available at: http://www.energy-transition-institute.com/_/media/Files/ETI/SummariesCCS/SBC%20Energy%20Institute_CCS%20FactBook%20Summary_2016%20update.pdf
[42] S. Paltsev, A. Sokolov, X. Gao and M. Haigh (2018), *Meeting the gaols of the Paris Agreement: Temperature implications of the Shell Sky Scenario.* Joint Program Report Series, Match, pp.10. Available at: https://globalchange.mit.edu/publication/16995
[43] See SingStat (2018), *Gross Domestic Product.* Available at: https://www.singstat.gov.sg/find-data/search-by-theme/economy/national-accounts/visualising-data/gross-domestic-product;
Chemicals sector contributed to 28.6 percent of total manufacturing output in 2015, the latest available year of assessment. See Economic Development Board [EDB] (2015), *Economic Survey of Singapore 2015.* Available at: https://www.mti.gov.sg/ResearchRoom/SiteAssets/Pages/Economic-Survey-of-Singapore-2015/FullReport_AES2015.pdf

chemicals group Novabay opened a sodium bicarbonate manufacturing plant in Jurong in 2017, which will use carbon captured from industry emissions as an input.[44]

However, there are several challenges to CCSU in Singapore. First, given the lack of suitable storage sites in Singapore, there is likely going to be more focus on CO_2 utilisation (as opposed to storage). R&D to facilitate the long-range cost-effective transport of concentrated CO_2 to off-shore or regional sites could therefore be essential. Second, around 84 percent of Singapore's CO_2 emissions are from stationary sources, with majority of these emissions having CO_2 concentration of three percent due to the ubiquitous usage of natural gas for power generation.[45] Hence, there needs to be a strong focus on technologies that lower the energy penalty (i.e. the energy efficiency loss) for capturing these CO_2 streams. Third, given the extent of existing infrastructure, greater focus may be needed to be put on technologies that can be easier to retrofit on existing power generation plants (e.g. post-combustion and oxy-combustion technologies).

Smart grid technologies

Smart grid benefits **outweigh costs by up to 6x**

A smart grid is an electricity network that monitors, protects and optimises power transmission while allowing bi-directional flow of power.[46] In contrast to traditional unidirectional grids, a smart grid allows decentralised generation and storage of electricity via smaller units installed at end-user locations (e.g. solar panels, storage batteries, electric vehicles), and flow of excess power back to the transmission stations. Effectively, customers become producers and can "sell" excess energy back to the grid. Real-time monitoring of energy consumption data from a wide range of regions makes electricity transmission more balanced, reliable, and energy-efficient.[47] Global investments in smart grid technologies amounted to US$44 billion in 2014.[48] Studies in the US and China have shown that economic and environmental benefits of smart grid deployments could outweigh setup costs by up to a factor of six. The IEA estimates that widespread global use of smart grids alone could contribute up to four percent of the cumulative global reduction in CO_2 emissions needed by 2030 in pursuit of the two degrees Celsius target.

Singapore's trials with smart grids began with the Intelligent Energy System (IES) pilot in 2010; smart meters and consumer applications were tested with industry partners and participating

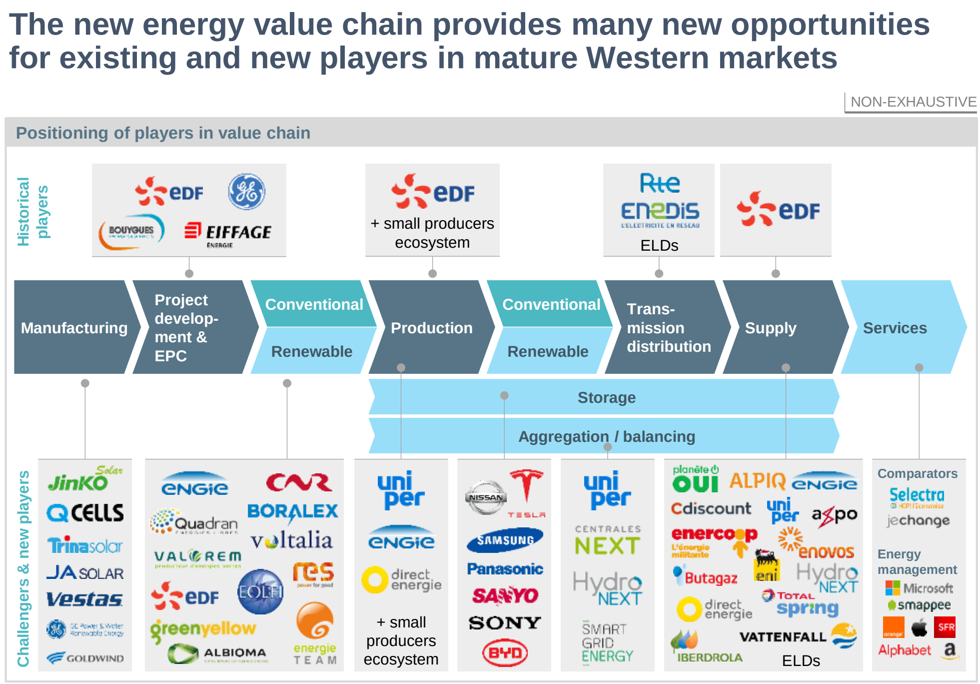
[44] Enterprise Singapore (2016), "New chemical plant on Jurong Island to use adjacent factories' carbon emissions" Available at: https://ie.enterprisesg.gov.sg/Media-Centre/News/2016/6/New-chemical-plant-on-Jurong-Island-to-use-adjacent-factories--carbon-emissions
[45] National Climate Change Secretariat [NCCS] (2013), *Carbon Capture and Storage/Utilisation: Singapore Perspectives.* Available at: https://www.nccs.gov.sg/docs/default-source/default-document-library/carbon-capture-and-storage-utilisation-singapore-perspectives.pdf
[46] AT Kearney Energy Transition Institute (2018), *Smart Grids (Introduction).* Available at: http://www.energy-transition-institute.com/Insights/SmartGrids.html
[47] SmartGrid.gov (2018), *What is the Smart Grid?* Available at: https://www.smartgrid.gov/the_smart_grid/smart_grid.html
[48] AT Kearney Energy Transition Institute (2018), *Smart Grids (Introduction).* Available at: http://www.energy-transition-institute.com/Insights/SmartGrids.html

households in the Punggol area.[49] Following its success, the Singapore Power (SP) Centre of Excellence was launched in 2015 with a S$30 million budget to further develop commercialisation of smart grid technologies.[50] The Centre, which has the support of the Economic Development Board (EDB), signed five partnerships in 2016 – including with General Electric's (GE) Grid Solutions on substation digitalisation and with 3M on grid sensing solutions. The SP Group is also collaborating with seven international utility companies to launch a global energy accelerator programme for start-ups developing smart grid solutions.[51]

A convergence of industries in the energy sector is leading to new business models

A range of new players is participating in the energy transition, leading to a convergence of activities across industries such as finance, automotive, waste management and ICT. This has redefined the makeup of the traditional energy value chain (Exhibit 2).

EXHIBIT 2



SOURCE: A.T. Kearney (2018)

[49] Energy Market Authority [EMA] (2012), *Smart Grids – The Intelligent Energy System (IES) Pilot.* Available at: https://www.ema.gov.sg/cmsmedia/newsletter/2012/04/eyeon-emaies.html

[50] Singapore Power [SP] Group (2016), *News Release: Singapore Power Centre of Excellence commences collaboration with 5 industry partners.* Available at: https://www.spgroup.com.sg/wcm/connect/spgrp/539bb3ae-3b0c-49d8-888e-91908c3e316b/%5B20160812%5D+Media+Release+-+Singapore+Power+Centre+Of+Excellence+Commences+Collaboration+With+5+Industry+Partners.pdf?MOD=AJPERES&CVID=

[51] Singapore Power [SP] Group (2017), *SP Group: Year in Review 2017.* Available at: https://www.spgroup.com.sg/poweringthenation/next-generation-solutions-for-your-future-needs.html

Examples of non-traditional industries that are most active in the energy transition include:

Financial institutions

ASEAN will need **US$200 billion annually in green investments** through 2030

Commercial banks, investors and international financial institutions are increasingly enabling the transition to low-carbon energy systems. Many leading institutions such as the World Bank, ING Bank and AXA recently announced plans to divest in "stranded assets" in fossil fuels such as coal, oil and gas, owing to the shift towards renewables and growing carbon consciousness.[52] Green energy finance is gaining traction, particularly in emerging markets setting ambitious targets. A key example is India, which aims to produce 175 gigawatts of renewable energy by 2022 – three times higher than in 2017.[53] Reportedly, ASEAN alone will need US$200 billion in green investment annually from 2016 to 2030.[54] In June 2018, the Monetary Authority of Singapore (MAS) signed a memorandum of understanding with the World Bank to boost the growth of the Asian green bond market.[55] In 2017, DBS became the first commercial bank to launch a green bond in Singapore.[56] The bank also provided real estate developer CapitaLand with a S$300 million loan with interest rates linked to performance against a range of sustainability indicators such as carbon emissions, energy efficiency and water usage – reportedly the largest credit of its kind in Asia.[57]

There are a range of investible opportunities for financial institutions. Investors with higher risk profiles such as venture capital firms may be attracted by the scaling potential of emerging technologies. For instance, the Clean Energy Finance Corporation in Australia created the A$200 million Clean Energy Innovation Fund to invest in early-stage clean energy companies.[58] Clearly, investment opportunities extend beyond early stage technologies. For example, international financial institutions such as the Asian Development Bank (ADB) and the World Bank have invested heavily in proven renewable technologies across solar and

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[52] "Stranded assets" refer to increasingly unattractive investments in traditional hydrocarbon energy as a result of regulations limiting the use of fossil fuels (e.g. carbon pricing), a change in demand (e.g. shift to renewables due to lower costs), or legal action. See LSE (2018), "What are stranded assets?" Available at: http://www.lse.ac.uk/GranthamInstitute/faqs/what-are-stranded-assets/; and Clean Technica (2017), "World Bank, ING and AXA announce fossil fuel divestment worth billions" Available at: https://cleantechnica.com/2017/12/13/world-bank-ing-axa-announce-fossil-fuel-divestment-worth-billions/

[53] Asian Development Bank [ADB] (2018), *Green energy finance in India: Challenges and solutions.* Available at: https://www.adb.org/sites/default/files/publication/446536/adbi-wp863.pdf

[54] The Straits Times (2018), "MAS partners IFC to spur green bond market in Asia" Available at: https://www.straitstimes.com/business/invest/mas-partners-world-bank-member-to-spur-green-bond-market-in-asia

[55] The Straits Times (2018), "MAS partners IFC to spur green bond market in Asia" Available at: https://www.straitstimes.com/business/invest/mas-partners-world-bank-member-to-spur-green-bond-market-in-asia

[56] DBS Newsroom (2017), "DBS Group Holdings Ltd's first green bond offering attracts strong interest" Available at: https://www.dbs.com/newsroom/DBS_Group_Holdings_Ltds_first_green_bond_offering_attracts_strong_interest

[57] ESG performance will be assessed using RobecoSAM's Corporate Sustainability Assessment (CSA) tool. See The Straits Times (2018), "CapitaLand gets $300m sustainability-linked loan from DBS" Available at: https://www.straitstimes.com/business/companies-markets/capitaland-gets-300m-sustainability-linked-loan-from-dbs; and RobecoSAM (2018), *The Corporate Sustainability Assessment at a glance.* Available at: http://www.robecosam.com/en/sustainability-insights/about-sustainability/corporate-sustainability-assessment/index.jsp

[58] Clean Energy Finance Corp (2018), *Innovation Fund.* Available at: https://www.cefc.com.au/where-we-invest/innovation-fund/

wind, with the ADB planning to support 19 projects worth US$1 billion in clean energy in the Pacific region alone through 2021.[59]

Automotive

The increased penetration of electric vehicles (EVs) means that the automotive sector is now a key driver of the energy transition. This has three important implications. First, EVs are carbon-neutral in emissions in contrast to traditional vehicles that emit varying levels of carbon into the atmosphere. Second, when coupled with the increased penetration of renewable energy for electricity generation; the source of energy itself can be carbon-neutral versus traditional fuels that are carbon-intensive to produce and transport. Third, advancements in EV battery storage and smart grids have enabled consumers to “sell” excess stored energy back to the main electricity grid – an important mechanism through which EVs can aid with load management during peak periods of energy demand.

Porsche plans for EVs to account for **100 percent** of production by 2030

There are a range of development in this sector worth noting. Many automakers have ambitious EV production targets. For instance, Porsche plans for EVs to account for 50 percent of production by 2024 and 100 percent by 2030.[60] Parent company Volkswagen has planned a 100,000 EV capacity facility for 2020. Sono Motors, a German startup, is set to launch a vehicle with in-built solar panels to provide charge to batteries in 2019.[61] Kinetic energy regeneration systems (KERS) are now being used on commercial and race cars to harness energy released from braking.[62] Companies such as Nissan and Tesla have produced leading energy storage solutions, increasing the range of the electric cars by many hundreds of miles.[63]

Technologies to harness energy stored in EV batteries are also gaining ground. For instance, EV8 Technologies is a joint venture between Cenex (hydrogen-enabled transport experts), Brixworth (a data analytics firm) and AT Kearney that has built an EV battery storage management system together with a smartphone-enabled app. The app monitors stored energy usage patterns, analyses consumption and energy demand data, and then provides owners with options to sell their excess energy back to the grid. [64]

[59] Asian Development Bank [ADB] (2018), *Pacific Energy Update 2018.* Available at: https://www.adb.org/documents/pacific-energy-update-2018
[60] Electrek (2018), “Porsche CEO expects German automaker to only sell electric vehicles starting in 2030” Available at: https://electrek.co/2018/04/09/porsche-ceo-only-electric-vehicles-2030/; and Electrek (2018), “VW is planning a capacity of 100,000 electric cars per year for first plant to go electric” Available at: https://electrek.co/2018/09/10/vw-electric-cars-production-capacity-first-plant-go-electric/
[61] Express (2018), “Solar-powered electric car set to launch in 2019 – and it’ll be cheaper than you think” Available at: https://www.express.co.uk/life-style/cars/1000135/electric-car-solar-powered-Sono-Motors-Sion-price-2019
[62] Electrek (2018), “Regenerative braking: how it works and is it worth it in small EVs?” Available at: https://electrek.co/2018/04/24/regenerative-braking-how-it-works/
[63] Consultancy.org (2017), “The race for electrification in the automotive industry has begun” Available at: https://www.consultancy.uk/news/14039/the-race-for-electrification-in-the-automotive-industry-has-begun; and Interesting Engineering (2018), “Tesla taps into “breakthrough’ battery innovations” Available at: https://interestingengineering.com/tesla-taps-into-breakthrough-battery-innovations
[64] AT Kearney Energy Transition Institute (2018), *Temasek – Energy Transition, major trends and opportunities.*

Partnerships are also being formed between traditional power and automotive players. The SP Group in Singapore will build a network of 500 fast-charging stations around the island by 2020 to support Grab's plan to introduce 200 new electric vehicles to its fleet in 2019.[65] Under Singapore's first large-scale EV car-sharing programme, which aims to have a fleet of 1,000 EVs, the Land Transport Authority (LTA) and EDB worked closely with tech firm BlueSG to progressively roll out 30 new charging stations starting in December 2017.[66]

Waste management

The push towards decarbonisation has led to increased emphasis on second-generation biofuels (manufactured from non-food biomass) and waste-to-energy production, creating the opportunity for waste management companies to play an increased role in the energy transition. The organic matter in solid waste such as food, paper and wood chips acts as feedstock for biofuels. Singapore is home to four waste-to-energy incineration plants, where heat from combustion of waste produces electricity.[67] Incineration also helps reduce the amount of solid waste requiring disposal by up to 90 percent.

In 2016, Sembcorp unveiled a S$250 million energy-from-waste (EfW) facility on Jurong Island, capable of converting 1,000 tonnes of industrial and commercial waste collected by its waste management operations into energy.[68] The company has another facility for woodchip-based biomass steam production on Jurong Island as well.[69] Other companies in Singapore, such as Biofuels Industries, extract suitable feedstock from waste that can be either domestically converted into biomass or exported to biofuel producers overseas.[70]

Waste-to-Energy technology turns organic waste into biofuel

Information and Communications Technology (ICT)

The development of smart grids, decentralised energy generation and storage has led to the ICT industry becoming an integral new player in the energy ecosystem.[71] Energy management service providers, telecom operators and tech start-ups have developed data-driven solutions

[65] The Straits Times (2018), "Grab to introduce 200 electric vehicles from next year under SP Group partnership" Available at: https://www.straitstimes.com/singapore/transport/grab-to-introduce-200-electric-vehicles-from-next-year-under-sp-group
[66] Land Transport Authority [LTA] (2017), "Singapore's first large-scale electric vehicle car-sharing programme to hit the roads in December" Available at: https://www.lta.gov.sg/apps/news/page.aspx?c=2&id=48509d3b-e74d-459b-b84e-5c1b79db4c76
[67] National Environment Agency [NEA] (2018), *Waste Management Infrastructure*. Available at: https://www.nea.gov.sg/our-services/waste-management/waste-management-infrastructure/solid-waste-management-infrastructure; and NEA (2018), *Waste-to-Energy Incineration Plants.* Available at: https://www.nea.gov.sg/our-services/waste-management/waste-management-infrastructure/waste-to-energy-and-incineration-plants
[68] Sembcorp (2014), "Sembcorp begins construction of its largest Energy-from-Waste project in Singapore" Available at: http://www.sembcorp.com/en/media/media-releases/utilities/2014/march/sembcorp-begins-construction-of-its-largest-energy-from-waste-project-in-singapore/
[69] Sembcorp (2012), "Energy-from-Waste plans steam ahead with new woodchip boiler plant on Jurong Island." Available at: http://www.sembcorp.com.sg/internal_enewsletter/mayjun12/bu_Jurong_Island.htm
[70] Alpha Biofuels (2018), *About us.* Available at: http://alphabiofuels.sg/pages/general/about.html; and BioFuel Industries (2018), *Biomass export.* Available at: http://www.biofuelindustries.sg/our-process/biomass-export.html
[71] IBM (2016), *The modern era energy grid and the role of energy integrator*. Available at: https://public.dhe.ibm.com/common/ssi/ecm/eu/en/euw03083usen/industry-energy-and-utilities-eu-white-paper-external-euw03083usen-20180205.pdf

for grid operators and consumers.[72] For instance, IBM has developed a suite of products from "plant to plug" to help transmission and distribution companies around the world improve network operations, reduce outages, optimise response times, automate distribution to areas with high demand, and streamline reporting.[73] IBM also partnered Siemens to help consumers monitor their consumption with smart meter technologies and efficiently manage their excess capacity.[74]

Data-driven energy management has further enabled smaller communities to become energy efficient and reduce energy dependence on the national grid. For instance, the Nottingham Trent Basin project under Project SCENe (Sustainable Community Energy Networks) brings together over 120 home owners and a range of energy players with a system of decentralised renewable energy production. Under this arrangement, smart meters are used to drive energy efficiency and are combined with community energy storage systems to enable centralised load balancing.[75] The goal is to reduce household costs by 35 percent, demand by over a third and build a scalable model to replicate across communities.[76]

Google's **DeepMind** AI teamed up with UK National Grid to reduce energy consumption by **10 percent**

The broader role of artificial intelligence (AI) in energy was also discussed during the session, particularly its potential deployment in the utilities sector. For instance, machine learning could be used to forecast supply and demand of energy in order to optimise transmission. Google's DeepMind is partnering with the UK's National Grid on such a project which targets reduction of energy usage by 10 percent.[77] AI can also help reduce leakages in energy production through real-time monitoring and adjustment of equipment. GE Renewable Energy's "Digital Wind Farm" concept is a prime example, where software monitors and optimises wind turbines, increasing production by up to 20 percent.[78]

The telecom sector has also worked with green energy partners to reduce the carbon footprint of their networks of cell towers and data centres. For instance, Schneider Electric has developed solar-powered telecom towers for regions with unreliable grid supply and high costs of energy – allowing for retrofitted solutions.[79] This technology enabled Indogreen in Indonesia

[72] AT Kearney Energy Transition Institute (2018), *Temasek – Energy Transition, major trends and opportunities.*
[73] IBM (2018), *Grid operations*. Available at: https://www.ibm.com/industries/energy/solutions/grid-operations
[74] Siemens (2018), *Grid application platform partners – IBM.* Available at: https://w3.siemens.com/smartgrid/global/en/products-systems-solutions/smart-metering/emeter/partners/pages/ibm.aspx
[75] University of Nottingham (2018), *Project SCENe*. Available at: https://www.projectscene.uk/
[76] AT Kearney Energy Transition Institute (2018), *Temasek – Energy Transition, major trends and opportunities.*
[77] Financial Times (2017), "DeepMind and National Grid in AI talks to balance energy supply" Available at: https://www.ft.com/content/27c8aea0-06a9-11e7-97d1-5e720a26771b
[78] GE Renewable Energy (2018), *Meet the Digital Wind Farm.* Available at: https://www.ge.com/renewableenergy/stories/meet-the-digital-wind-farm
[79] Solar Schneider Electric (2018), *Telecom Towers.* Available at: https://solar.schneider-electric.com/solution/telecom-tower/

to cut consumption diesel consumption of its tower sites by 50 percent.[80] Keppel and Singtel have developed next-gen high-rise data centres in Singapore that reduce energy usage and emissions by up to 15 percent using improved building and rack designs, intelligent controls and cooling mechanisms.[81]

While the specific operations of companies participating in the energy transition differ, there are some common themes emerging across all players in the energy value chain:

- **Capturing value from complementary services.** Finding complementary services to create additional value from energy activities (also known as "hybridisation") can help transform the cost competitiveness of new technologies. For instance, excess solar PV generation in the Middle East has been stored as desalinated water – sales of which have helped reduced operation costs.[82] Another example is in energy storage, where EV charging stations are being established near shopping centres to attract consumers.
- **Consumerisation**. The new energy value chain places large emphasis on end-users such as households and businesses to be active participants. As mentioned previously, renewable energy generation in homes and smart grids allow consumers to essentially become power retailers. Liberalisation of energy markets further empowers consumers to select plans that suit them the most. This empowering of consumers is likely to lead to innovations in business models targeting different segments. For example, SP Group announced that from 2019, households in Singapore can ensure that their energy is derived from green sources by buying "green credits" through a blockchain enabled online platform.[83]
- **Digitisation.** Digitisation of key activities is increasing throughout the current energy value chain, and this is a critical enabler of non-traditional industries' participation. There are four main areas of opportunity. First, digital sensors and automated response systems can be combined to optimise the mechanical components of energy production. Second, predictive analytics and real-time consumption data monitoring can optimise power transmission and load balancing. Third, smart meters and consumer applications can enable users to monitor their consumption and opt for energy efficient practices. Fourth, data from smart grids can support consumer decisions to sell their excess energy to the national grid in times of peak demand.

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[80] Schneider Electric (2014), *Schneider Electric solution enables Indogreen to cut diesel consumption of Telecom Tower sites by ~50%*. Available at: https://41j5tc3akbrn3uezx5av0jj1bgm-wpengine.netdna-ssl.com/wp-content/uploads/2014/11/solution-for-indogreen-telecom-towers-case-study_eng.pdf
[81] As quoted by Deputy Prime Minister Teo Chee Hean. See Prime Minister's Office [PMO] (2018), *DPM Teo Chee Hean at the 10th Singapore International Energy Week*. Available at: https://www.pmo.gov.sg/newsroom/dpm-teo-chee-hean-10th-singapore-international-energy-week
[82] AT Kearney Energy Transition Institute (2018), *Factbook: Solar Photovoltaic.* Available at: http://www.energy-transition-institute.com/Insights/SolarPhotovoltaic.html
[83] The Straits Times (2018), "SP launches platform for households, small producers of solar energy to sell 'green credits'" Available at: https://www.straitstimes.com/singapore/environment/sp-launches-platform-for-households-small-producers-of-solar-energy-to-sell?xtor=CS3-18

A supportive regulatory landscape is crucial to support the transition

Support for decarbonisation is extensive around the globe. While measures vary between regions, participants discussed five regulatory approaches that are essential to the energy transition: mandatory targets, financial incentives, flexible regulations, pro-competition measures, and a workforce transition framework.

Mandatory targets

Mandatory targets have been important for spurring the growth of renewables and supporting energy efficiency. One example is Renewable Portfolio Standards (RPS), which require energy providers to allocate a minimum specified proportion of their electricity mix to renewables. South Korea uses RPS to good effect – requiring some power companies to produce three percent of their power from renewable sources in 2015, rising gradually to 10 percent by 2024.[84] Japan put in place a system of progressive increases in energy-efficiency standards based on the most efficient in the market—the top runner—and gives companies a set period within which they must ensure that the weighted average of their products meets each new standard. The scheme has demonstrated the potential for rapid technological innovation: the energy efficiency of television receivers improved by 26 percent, refrigerators by 55 percent, and videocassette recorders (VCRs) by 74 percent compared with expectations of 16 percent, 31 percent, and 59 percent respectively.[85]

Financial incentives

Governments have a key role in providing financial incentives to key stakeholders to accelerate development, commercialisation and production of new technologies for energy transition. Generous subsidies to green energy producers in Germany in the early 2000s propelled renewables' participation in the electricity mix from nine percent in 2004 to 32 percent in 2016.[86] The US offers the Solar Investment Tax Credit (SITC) amounting to 30 percent for solar installations on residential and commercial properties – propelling the CAGR of solar deployments to 59 percent annually since 2015.[87] Singapore's EMA has awarded a total of S$15 million in research grants to the National University of Singapore (NUS) and Nanyang Technological University (NTU) to develop innovations in energy storage.[88] The latter is developing next-generation metal oxide-based batteries that would have five times the life cycle of existing lithium-ion batteries, charge faster, be more cost-efficient to maintain and

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[84] Obtained from a scan of individual country regulations, and Center for Climate and Energy Solutions (2018), "Renewable and Alternate Energy Portfolio Standards" Available at: https://www.c2es.org/document/renewable-and-alternate-energy-portfolio-standards/

[85] Kimura Osamu (2012), *The role of standards: The Japanese top runner program for end-use efficiency*. Available at: http://www.iiasa.ac.at/web/home/research/researchPrograms/TransitionstoNewTechnologies/12_Kimura_Japan_TopRunner_WEB.pdf

[86] Financial Times (2017), "The Big Green Bang: how renewable energy became unstoppable" Available at: https://www.ft.com/content/44ed7e90-3960-11e7-ac89-b01cc67cfeec

[87] Solar Energy Industries Association [SEIA] (2018), *Solar Investment Tax Credit.* Available at: https://www.seia.org/initiatives/solar-investment-tax-credit-itc

[88] EMA (2016), "$15 million awarded to innovations in energy storage" Available at: https://www.ema.gov.sg/media_release.aspx?news_sid=201606019cO74GHYKuLg

also be better suited to Singapore's tropical climate. However, financial incentives need to be used carefully. As the experience with feed-in tariffs in Europe showed, if designed poorly, they can lead to a high taxpayer burden, over-capacity, and eventual unsustainable costs for consumers when phased out.[89]

Flexible regulations

Flexible regulations play a pivotal role in encouraging energy innovation. For instance, policies such as "regulatory sandboxes" create safe spaces for stakeholders in energy innovation to test their solutions in a live (but controlled) environment without being subject to normal regulatory requirements. Singapore's EMA introduced such a sandbox for energy sector innovations in 2017 to encourage Singapore-specific solutions to support its energy transition.[90]

Pro-competition measures

1.4 million households will be added to Singapore's contestable retail energy market over 2018-19

Pro-competitive measures are gradually replacing subsidies as commercialisation levels now favour contestable markets. For example, auctioned renewable electricity globally in 2016 was three times that in 2015.[91] In April 2018, EMA announced the soft launch of the Open Electricity Market (OEM), where eligible households and businesses in Jurong were given the option of picking retailers and price plans. From November 2018, the OEM will be extended to all Singaporean households and businesses and rolled out progressively by geographical zones through May 2019, adding 1.4 million new consumers to the contestable market.[92] The liberalisation of retail energy is expected to bring cost reductions – with households able to choose (including choice of renewable energy sources) from 12 licensed players.

Workforce transition framework

Labour market policies in reskilling will play a pivotal role in the energy transition. As the use of fossil fuels declines in pursuit of renewables, there will be a number of structural changes to employment within the energy sector. A recent report by the International Labour Organisation (ILO) highlighted that 24 million jobs are expected to open up in the "green" economy, while 6 million are expected to be lost in more traditional sectors, with petroleum extraction and refining the hardest hit. In fact, while 2.5 million jobs will be created in renewable

[89] EMA (2018), *Top 10 most popular FAQs.* Available at: http://www.ifaq.gov.sg/ema/apps/fcd_faqmain.aspx?FAQ=161690
[90] EMA (2018), "Launch of regulatory sandbox to encourage energy sector innovations" Available at: https://www.ema.gov.sg/media_release.aspx?news_sid=20171020Wab84AqS9NXY
[91] Financial Times (2017), "The Big Green Bang: how renewable energy became unstoppable" Available at: https://www.ft.com/content/44ed7e90-3960-11e7-ac89-b01cc67cfeec
[92] EMA (2018), *Liberalization of Retail Energy Market.* Available at: https://www.ema.gov.sg/electricity_market_liberalisation.aspx; and for a full list of retailers, see EMA (2018), *Open Electricity Market Retailers.* Available at: https://www.ema.gov.sg/retailers.aspx

energy generation, 1.5 million jobs will be lost in oil and gas together with conventional electricity generation.[93] Managing this skills transition in the energy sector will require significant investment in enhancing the readiness and adaptability of the workforce.[94]

Despite net job creation in the long-term, there could be net loss of jobs in the near-term in the absence of effective policies to support the skill transition of energy workers. The management of this transition was a key subject of debate among participants in this session, where the Union of Power and Gas Employees (UPAGE) stressed the importance of reskilling affected workers.[95] To this end, the Singapore government has placed strong emphasis on retraining workers in the energy sector through the Skills Framework for Energy and Power under the Skills Future initiative. This framework brings together relevant government agencies in energy and manpower, industry associations, training providers, organisations and unions to develop future career pathways and necessary steps for progression, covering 11 tracks and 122 key jobs.[96]

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The energy sector faces severe challenges from climate change, energy security, and managing costs. These challenges however are transforming the energy landscape, creating innovative new business models, often supported by equally innovative regulatory approaches.

[93] International Labour Organisation [ILO] (2018), *Greening with jobs.* Available at: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_628654.pdf
[94] World Economic Forum (2018), *Fostering effective energy transition: A fact-based framework to support decision-making.* Available at: http://www3.weforum.org/docs/WEF_Fostering_Effective_Energy_Transition_report_2018.pdf
[95] Singapore Bank Employees' Union (2018), "Face to Face with Mohamed Nazir Sami" Available at: http://www.ntuc.org.sg/wps/portal/sbeu/home/workingforu/workingforudetails?WCM_GLOBAL_CONTEXT=/content_library/ntuc/home/working+for+u/a387723b-ea18-417e-88cd-f5c05ef6e7be
[96] Skills Future (2018), *Skills Framework for Energy and Power.* Available at: http://www.skillsfuture.sg/skills-framework/energyandpower