CAREC HIGH TECHNOLOGY ROADMAP

A sub-project under the Technical Assistance (TA 9299):

Leapfrogging Clean Technologies in Central Asia Regional Economic Cooperation Countries through Market Transformation

ASIAN DEVELOPMENT BANK

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I. EXECUTIVE SUMMARY

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II. INTRODUCTION

1. The Central Asia Regional Economic Cooperation (CAREC) Program member countries are committed to a shared vision for the region's energy sector. This vision is to have access to adequate volumes of reliable, affordable, financially sustainable, and environmentally sound commercial energy for all. The vision requires the implementation of consistent policies to ensure:

    a. energy security through balanced development of the region's energy resources, infrastructure, and institutions;

    b. stronger integration of the region's energy markets and supply chain for emerging high technologies; and

    c. economic growth through energy trade.

2. Major changes in the energy sector and rapid advances in technology are creating new opportunities for CAREC member countries. This is embodied in the idea of 'leapfrogging' – jumping from yesterday's technology to tomorrow's and in doing so, missing out a transition to the mature and soon to be obsolete technologies of today. This follows examples in rural Afghanistan, India and Pakistan, where many people jumped from old analog landlines (or no telephones) to smartphones—leapfrogging digital landlines and analog mobile networks.

3. This roadmap analyses four pillars of the high technology world that present such opportunities: solar power, battery storage, energy efficiency and electric vehicles. Insights on these technologies are drawn from an international team of experts and from consultations with a wide range of stakeholders. These cover the necessary policy targets, regulatory changes, and capacity needed for the region to accelerate adoption of high technology and to create a market to attract investment.

4. The purpose of this roadmap is to create awareness among policy makers, investors and others about these emerging technologies. It provides a framework for CAREC member countries to identify relevant technologies, demonstration projects, policies and enabling actions. It is intended to be a living document that is updated by the CAREC Energy Sector Steering Committee every year until 2020. This will ensure that actions taken by CAREC countries keep pace with the rapid advances in these technologies and are ideally positioned to realize transformational opportunities.

III. SOLAR POWER

A. Introduction

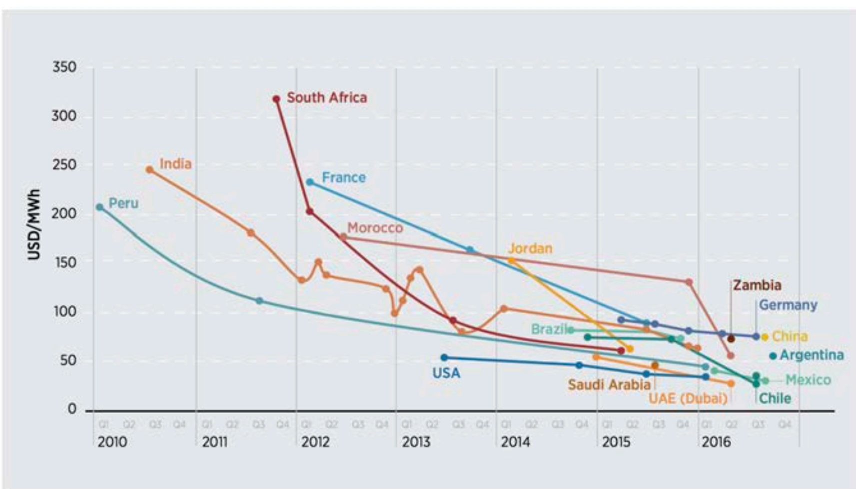
1. Solar energy has been one of the fastest growing electricity technologies in recent years. In 2017, new solar photovoltaic (PV) capacity around the world grew by 50%, reaching over 74 GW. The majority of this growth has been driven by emerging markets, with China accounting for almost half of this expansion and India having the seventh largest installed solar capacity of any country, larger than France, Spain and Australia[1].

2. This spectacular growth has been driven mainly by economies of scale, severe competition among suppliers for markets, and government's policy support. These changes will impact the energy mix of the CAREC member countries and enable countries to meet their commitment under the Paris Agreement.

3. The price of solar panels has come down by 73% between 2010 and 2017 and Bloomberg New Energy Finance expects another 66% price reduction in the next 20 years. The U.S. Department of Energy achieved its 2020 cost target of grid parity in 2017, and the average price of utility-scale solar is now 6 cents per kilowatt-hour (kWh). In 2017, renewable energy auction prices have been breaking records continuously, with the lowest auction price of 1.79 cents per kWh for a 300 MW plant in Saudi Arabia.

4. The following chart from IRENA summarizes the price trends for the last 6 years.

Figure 3 Evolution of average solar prices in auctions, January 2010-September 2016



[1] Bloomberg New Energy Finance, Climate Scope. 2017. Which emerging market is most attractive for clean energy investment? http://global-climatescope.org/en/

B. The case for investment

5. **Huge generation potential**: CAREC countries have greater solar radiation, more rapidly growing electricity demand, and more availability of land than many developed countries. Central Asia is comprised of inland countries with mostly sunny days and little precipitation. For example, Uzbekistan sees 2,650 – 3,050 sunny hours per year, with a potential of 525 – 760 billion kWh. Based on the evaluation of European companies, wind power plant with an installed capacity of over 520 GW has forecasted potential to generate over 1 trillion kWh a year. Apart from electricity from solar, solar thermal can reduce the winter heating load and rooftop solar can reduce summer cooling load, both of which will enable exporter to export more and the energy importer to flatten their energy demand curve.

6. **Access to electricity and development in off-grid**: More than 400 million people in Asia and the Pacific have no access to electricity, and many of them are in two CAREC member countries: Afghanistan and Pakistan. An International Finance Corporation study notes that about 144 million people have no access to reliable electricity in Pakistan alone. People in the remote mountainous areas of other CAREC countries also have poor access to reliable electrical power. Many argue, that only about 30% people can be connected through grid connected electricity and alternative technology with solar may be the only way to connect the remaining in the next 5-10 years.

7. Developments in lithium-ion batteries, solar power, and energy-efficient appliances have made larger off-grid solar systems economically more viable than extending the main transmission and distribution networks, especially in the case of expensive diesel generation-supplied grids. With this new technology, millions of people may be able to stop using kerosene lamps and start producing their own electricity, leapfrogging the long wait for connection to the electricity grid

8. **Energy poverty**: An International Finance Corporation study notes that about 144 million people in Pakistan have no access to reliable electricity and spend about $2.3 billion annually on candles, kerosene lamps, and battery-powered flashlights. Kerosene lamps cost up to 30 times more than the inefficient incandescent bulb and 100 times more than compact fluorescent and light-emitting diode (LED) lamps. In some poor households, kerosene costs may account for up to 25% of their family’s monthly income. Solar power is key to solving the energy poverty.

9. **Economic opportunities**: The expectation of a significant local demand in Central Asia means that CAREC member countries have the potential to become global and regional manufacturing hubs for solar technology goods and equipment.

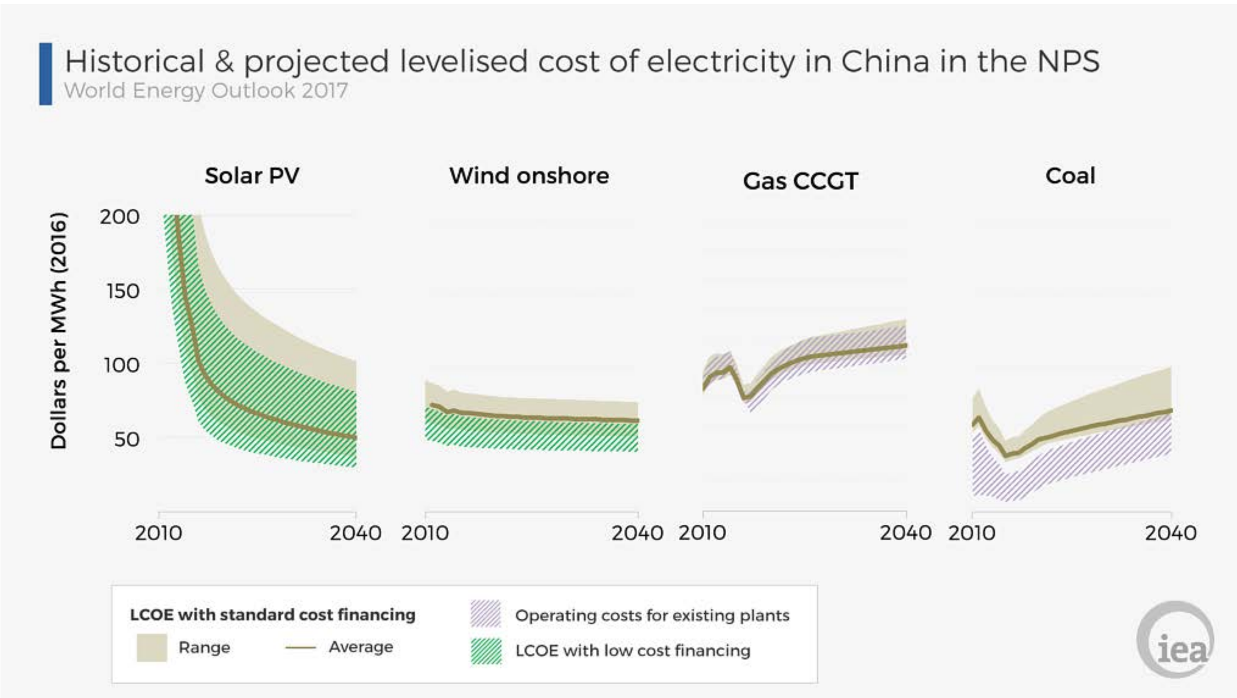
C. Trends and opportunities

10. **Global shift to renewables**: In 2017, Solar PV additions rose faster than any other fuel, surpassing the net growth in coal. Between 2017 and 2022, global renewable electricity capacity is expected to expand by over 920 GW, an increase of 43%. For the next five years, solar PV represents the largest annual capacity additions for renewables, well above wind and hydro.

11. **Increasing efficiencies**: In the last 10 years, the efficiency of average commercial water-based silicon modules has increased from about 12% to 17% (Super-mono 21%).

At the same time, CdTe module efficiency increased from 9% to 16%. In the laboratory, best performing modules are monocrystalline silicon with an efficiency of approximately 24.4% and for high concentration multi-junction solar cells an efficiency has been achieved for up to an estimated 46.0%[2].

12. **Decreasing costs**: The following price forecast from IEA for different technology indicates (using People's Republic of China as a proxy for the world) that solar PV will continue to achieve cost reductions against mainstream technologies in the coming years.



13. **Competitive auctions**: The growth in solar PV in 2017 was accompanied by the announcement of record-low auction prices of USD 30/megawatts per hour (MWh). Competitive auctions drive costs and price discovery down, which effectively reduce costs along the entire value chain. Auctions with long-term contracts will drive almost half of new capacity growth over 2017-2022.

14. **Going off-grid**: The off-grid solar approach may soon be the preferred choice over grid-connected electricity, even in countries with 100% electrification. For example, a typical new connection in rural Afghanistan is estimated to cost about $1,200 (plus regular

[2] Solar Cell Efficiency Tables (Versions 1-50), Progress in Photovoltaics: Research and Applications, 1993-2017. Graph: Fraunhofer ISE 2017

payments for energy consumed), compared with a $1,500 kit that includes power generation and basic appliances with no additional payment other than basic maintenance for 5 years. According to a recent World Bank report,[3] the market for off-grid electricity will be about $3.1 billion by 2020, reaching about 100 million households. This is leading to a huge paradigm shift: off-grid electrification and micro-grids may no longer be a stopgap measure and may even be the least-cost option in many developing countries. In addition to lighting, modern life requires the use of mobile phone chargers, a mechanical fan, a television, and a small refrigerator. In off-grid areas, these appliances can only be operated with either electricity generated by diesel generators or a larger off-grid solar system with lead acid batteries. As larger solar panels have become cheaper and suppliers of lithium-ion batteries are ready to provide more than 5 years of guarantee, it is possible to design a system that can power lights, a television, and a small refrigerator; and charge mobile phones for off-grid communities.

15. **Tipping point for solar:** The first tipping point will be when off-grid solar generation reaches cost and performance parity with the on-grid electricity, this has been achieved in many remote areas. Soon it is expected to be the norm in all areas. The second tipping point, which may be reached before 2020, is when the cost of transporting long distances becomes more than the cost of local solar power generation plus storage. These tipping points will create phenomenal disruptive changes in the power industry.

D. Best available technology

16. **Rooftop solar**: PV modules can be mounted on the roof or used as roofing material in Building Integrated PV (BIPV) installations. Rooftop solar installation is commonly done in houses with capacities of a few kilowatts and in commercial buildings for a few hundred kilowatts to a few megawatts in large warehouses and malls.

17. The ADB Headquarters in Manila hosted an initial 500kWp solar rooftop that was later expanded for another 100kWp with the construction of its Annex building. These projects were implemented more than 5 years ago. In recent years, with low solar prices, the scale of roof top installation has changed: with the largest one (70 MW) currently being built on the roof of Tesla’s giga factory in Nevada. In 2018, Australia has the largest penetration of rooftop solar in the world with about 7,000 MW solar generation capacity and more than 30% households in Queensland with rooftop solar installations.

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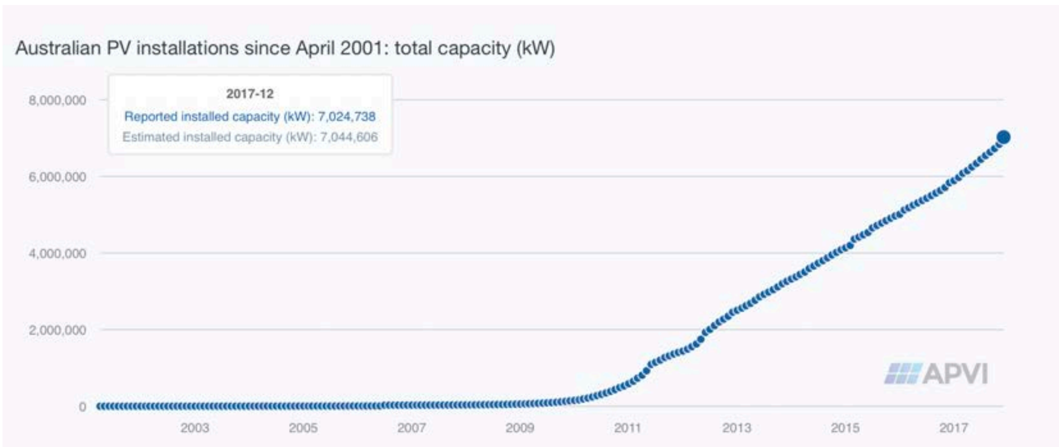
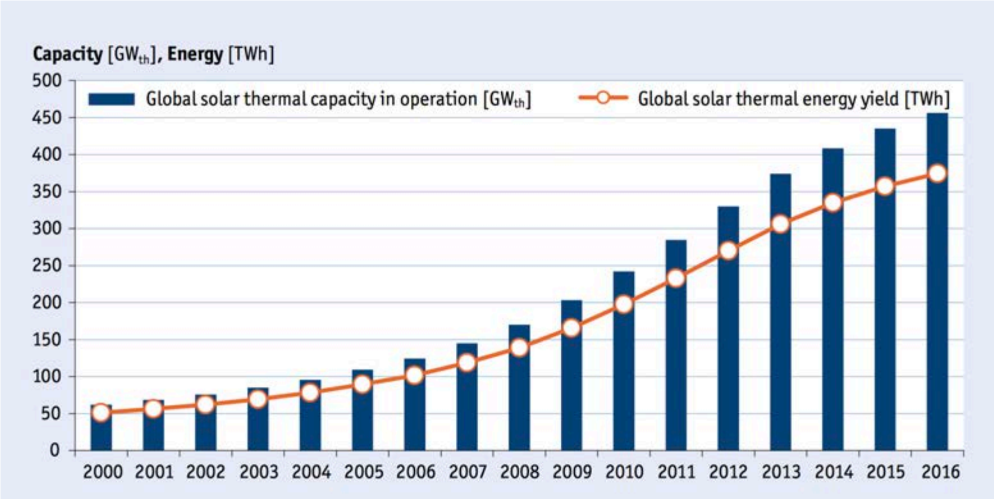
[3] *Lighting Global*. 2016. Launch of 2016 World Bank Group/Bloomberg Off-Grid Solar Market Trends Report. 3 March. https://www.lightingglobal.org/launch-of-off-grid-solar-market-trends-report-2016/.



18. Solar thermal: Rather than using sun's energy to generate electricity, the energy is used to heat water or other fluids, and can also power solar cooling systems. These are different from solar photovoltaic (PV) systems that generate electricity. According to IEA, the global installed capacity by 2016 was 456 GWth, corresponding to 652 million square meters of solar collectors. The main markets are PRC, and Europe. The solar thermal has installation has also grown significantly in the last 10 years, as shown below.



Global solar thermal capacity in operation and annual energy yields 2000 – 2016

19. **Floating solar:** Large scale solar installation can be done with floating platforms on lakes and reservoirs to utilize this open space for power generation. Unlike land-based solar farms, floating solar does not occupy land that can be used for agriculture or for other purposes nor does it require civil works and ground preparations.

Singapore university is running the world's largest testing center for floating solar PV systems.

20. As of 2017, the largest floating solar plant in PRC, in Suixi. The installation consists of two "islands" in two adjacent ponds, 200 meters apart. The associated equipment—inverters, switchgear and transformers—are in a container mounted on one of the floating platforms. Power cables are on floats above the waterline and floats along the panels mounted on high-density polyethylene floats.

21. In the Yanhe plant in PRC, solar modules are placed over concrete columns, keeping the module about 1.5 meters above the water surface. For the time being, the technology is evolving and both the Suixi and Yanhe projects exhibit higher costs than ground-mounted plants, and benefits from the off-take tariffs.

Table 1: Description of Suixi and YanHe Plants

Parameter	Suixi	YanHe
Installed capacity	40 MW	8 MW
Energy output	43.6 GWh / year	10.9 GWh / year
Grid connection	35 kV	20 kV
Installed cost	$48.45 million ($1.21 / Watt)	$9.12 million ($1.14 / Watt)
Off-take price	CNY 0.8 / kWh ($0.12 / kWh)	CNY 1 / kWh ($0.15/ kWh)
Area	~ 100 ha of 134 ha	20 ha
Construction period	~ 12 months	~ 4 months
Surface access fee	None	$34,000 / year
Mounting / anchoring system	HDPE floats (proprietary)	Concrete piles
Prior land use	Flooded due to subsurface mining-induced subsidence Water depth ~ 4 - 5 meters	Inactive aquaculture facility (superfamily *Astacoidea* and *Parastacoidea*, a.k.a., crawfish)

22. A 40MW floating solar plant was installed in a former coal-mining region in Anhui, China while 2MW was installed at the Boryeong dam reservoir in South Korea.

23. **Off-grid solar:** Standard home appliances running on 12V DC such as 32 inches TV, electric fans, and freezers are now packaged as Electricity-in-a-box with solar modules and lithium batteries as a plug-and-play kit. This can be installed in off-grid households or even in electrified areas as stand-alone systems providing similar benefits offered by their AC counterparts but without the monthly electric bills.

E. Policy issues

24. **Installation targets**: From off-grid electrification, solar energy became a mainstream power source and investment in Southeast Asian region was driven by renewable energy policies. Thailand spearheaded solar development with a 6GW target by 2036. Solar installation ramped up in 2010 from 49MW to 243MW in 2011 reaching 2.75GW in 2016[4].

25. **Feed-in tariffs and incentives**: The Philippines passed its Renewable Energy Law in 2008 but had its first batch of 131MW solar installation in 2015 under a Feed in Tariff scheme for a target of 500MW by 2016 at 17.38 US cents per kWh. A total of 20 projects with a capacity of 525MW were awarded with FIT contract from 700MW installations in 27 projects out of a total 4.4GW solar development applications approved by the Department of Energy (DOE)[5]. With the current competitive selection process after the FIT was discontinued, an offer from a solar developer to MERALCO was only 5.98 US cents per kWh in September 2017[6].

26. The Kazakhstan, Kyrgyz Republic and Uzbekistan governments have started the implementation of various incentive policies. For example, in Kazakhstan, Settlement and Financing Center guarantees buying all generated RE for the period of 15 years; the government has set fixed feed-in-tariff rates and exempted RE producers from energy

[4] IRENA Outlook Thailand 2017
[5] Philippine DOE 2016
[6] Manila Bulletin September 20, 2017

transmission tax. There are five operating solar plants with total installed capacity of 57.3 MW. Eight more plants are under construction with total installed capacity of 865 MW.

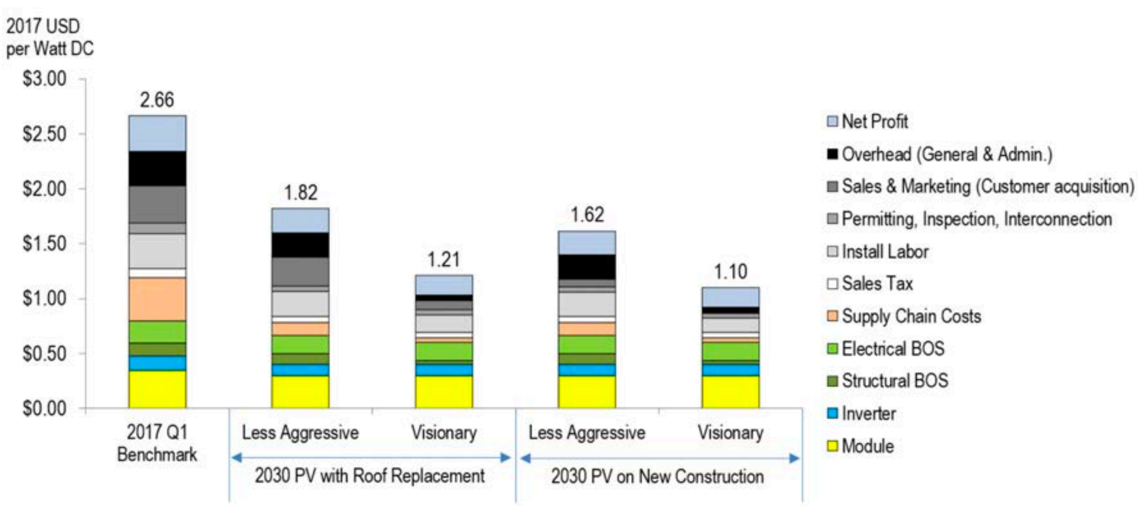
27. **Tax exemptions:** In Kyrgyz Republic, the import/export of RE installation materials is tax-exempted; a distribution company is obliged to buy RE; during the payback period solar tariff is six times the end customer price. Nineteen PV stations, each 1.5-3 kW, installed for "Reliable Energy Supply for Rural Midwifery Points (FAP)"; 0.518 MW installed at Bishkekteploenergo site, saving the equivalent of 124.8 thousand cubic meters of natural gas per year, which is 2.2 million som at the current tariff (project cost 14.8 million som). Provided and financed by German companies "R.I.D.GmbH" and "Dena" 15 kW is installed at the rehabilitation center for street children, the cost of the project is €80 000.

28. In Uzbekistan, the government has implemented conditional tax exemption for RE equipment manufacturers and import of RE parts. The first in the country 100MW solar plant is under construction in Samarkand region, with the help of ADB; 130 kW testing solar plant was implemented in 2015 in Namangan region, generating 500-600 kWh daily (done by Uzbekenergo together with Korean partner); 1.2MW mobile solar station started operating in April 2016 in Bukhar region, supplying energy to the Russian company “Lukoil”. The International Institute of Solar Energy was founded in 2012 in Uzbekistan.

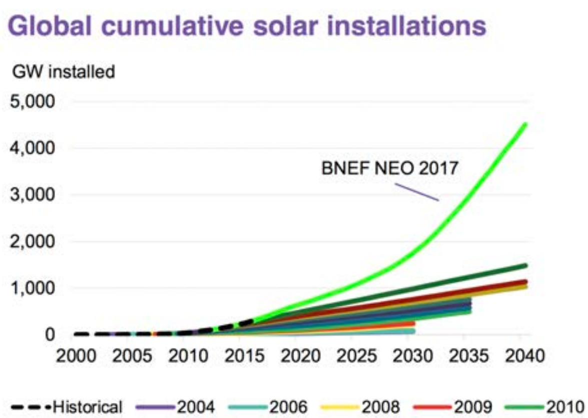
29. **Industrial strategy**: CAREC member countries are slowly adapting to the world trends of renewable energy and the first renewable energy businesses have emerged. Kazakhstan is using its selenium to produce solar PV modules in “AstanaSolar Llp”. Kyrgyz Republic also has a solar panel manufacturing plant “NewTek LLC”.

F. Potentials

30. According to National Renewable Energy Lab, NREL, the solar cost savings are going to continue in the future, bringing the overall leveled cost of roof top solar from 15 cents per kWh in 2017 to about 5-8 cents per kWh by 2030. This will create huge opportunity for the CAREC region.



31. With the revision of its recent forecast for solar power the IEA has confirmed the continuing record performance and sustained strong growth. Until 2022, solar PV represents the largest annual capacity additions for renewables, well above wind and hydro. The IEA has revised its forecast for solar growth every year, and Bloomberg New Energy Finance has even a more aggressive forecast for solar power growth. Solar power is going to bring significant opportunities to the CAREC region, the growth in CAREC may follow and aggressive path as well compared with the 2017 global forecast



IV. ELECTRIC VEHICLES

A. Introduction

1. The global electric vehicle (EV) market grew by more than 60% in 2016 to more than 2 million.[7] As shown in Figure 1, this trend has continued, with new EV sales expected to surpass 1.5 million in 2018.

2. China is by far the largest electric car market but Norway leads the way in terms of market share, with EVs representing 52% of all sales in 2017.[8] The Norwegian government has set a goal of 100% of new car sales to be zero-emission by 2025 and has created a highly favorable policy environment, comprising a large range of incentives, from tax breaks and exemptions to waivers on road tolls and ferry fees.

3. The Paris Declaration on Electro-Mobility and Climate Change and Call to Action, announced at COP21, expresses the ambition to exceed globally the threshold of 100

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[7] IEA (2017) Global EV Outlook 2017: Two million and counting
[8] https://www.reuters.com/article/us-environment-norway-autos/norway-powers-ahead-over-half-new-car-sales-now-electric-or-hybrid-idUSKBN1ES0WC

million electric cars and 400 million electric two-wheelers by 2030.[9] HSBC Global Research identifies EVs as one of its investment themes for the next decade, citing that EVs could make up 35% of new car sales in Asia by 2040[10].

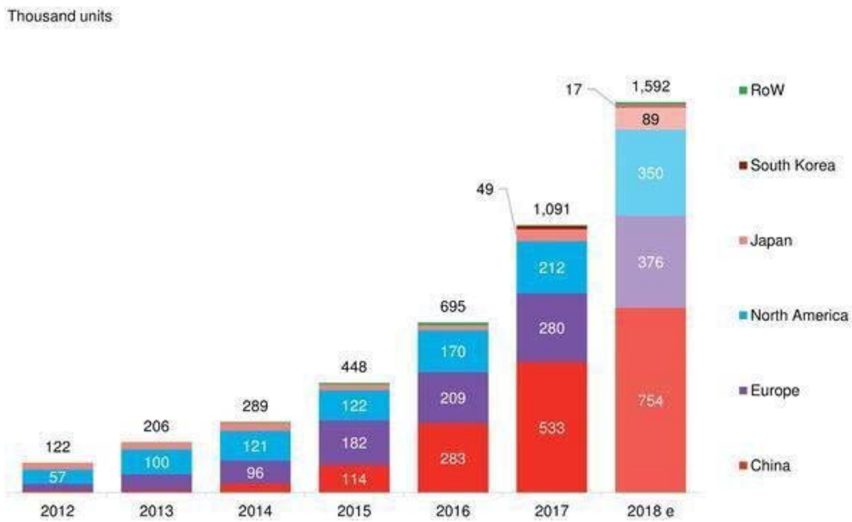

Figure 1: Global EV sales (Source: Bloomberg New Energy Finance, 2018)

B. The case for investment

4. **Emissions reduction:** Asia's motorized transport emissions are responsible for 23% of global aggregate emissions and are set to rise to 31% by 2030. Widespread vehicle electrification could dramatically reduce carbon pollution from transportation. In a base scenario developed by EPRI[11], carbon pollution could be reduced by 430 million metric tons annually in 2050. This is equivalent to the emissions from 80 million of today's passenger cars and represents a 48% reduction on 2015 levels.

5. **Air quality:** Nearly 90% of deaths linked to air quality occur in low- and middle-income countries.[12] The OECD has estimated the economic consequences of air pollution could be as high as USD$2.6tn, or 1% of global GDP by 2060.[13] The biggest rises in mortality rates, and therefore cost, from air pollution are forecast in India, China, Korea and Central Asian countries, where rising populations and congested cities mean more people are exposed to emissions. All CAREC member countries have reported air quality problems, with road transport being a dominant source of emissions. For

[9] UNFCCC (United Nations Framework Convention on Climate Change) (2015a), "Paris declaration on electro-mobility and climate change & call to action", http://newsroom.unfccc.int/media/521376/paris-electro-mobility-declaration.pdf.

[10] https://cleantechnica.com/2016/07/07/evs-account-35-new-car-sales-asia-2040/

example, particulate matter pollution in Kazakhstan was estimated to have caused approximately 2,800 premature deaths and cost the economy over US$1.3 billion annually (or 0.9% of GDP) in increased health care costs[14]. Automobiles account for more than 60% of total emissions in most of Kazakhstan's large cities and 90% in Almaty.

6. **Noise pollution:** Fossil fuelled road transport is a key emitter of noise pollution[15] which has been recognized by the World Health Organization as the second most harmful environmental stressor in Europe, behind air pollution. Asian cities rank among some of the worst for noise pollution according to the Worldwide Hearing Index[16]. The quiet and smooth operation of EVs offers a compelling opportunity to reduce noise pollution in CAREC member countries.

7. **Reducing oil imports:** Asian reliance on oil continues to grow[17], particularly among emerging economies[18]. A 2016 report from Bloomberg New Energy Finance sees EVs displacing 2 million barrels per day (mb/d) of global oil demand by 2023 and 13 mb/d by 2040.[19] Reduced oil imports from a 10% EV fleet would be lead to annual savings of approximately US$80 million in Pakistan, US$50 million in Afghanistan, US$40 million in Kyrgyzstan and US$20 million in Georgia[20].

8. **Supporting an increase in renewables:** Intermittency remains a challenge to the further expansion of renewable energy in Asia.[21] The increased flexible storage potential of EVs can help to accommodate additional wind and solar energy, preventing the ramping up or down of fossil fueled combustion sources that would otherwise be used to balance the variability of renewable resources.[22] Replacing fossil fueled vehicles with EVs also increases the demand for electricity, making it more lucrative for energy suppliers to invest in new generation capacity.[23]

9. **Connectivity:** Affordable transport plays a vital role in connecting people to employment, education, healthcare and other essential services. Policies that succeed in making public and private transport more accessible and affordable will make a large difference to CAREC member countries. The lower operating costs of EVs compared to

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[11] https://www.epri.com/#/pages/product/3002006881/
[12] http://www.un.org/apps/news/story.asp?NewsID=55138#.WR61aMa1vhY
[13] http://www.oecd.org/env/air-pollution-to-cause-6-9-million-premature-deaths-and-cost-1-gdp-by-2060.htm
[14] World Bank (2013) Towards Cleaner Industry and Improved Air Quality Monitoring in Kazakhstan
[15] http://ec.europa.eu/environment/integration/research/newsalert/pdf/air_noise_pollution_socioeconomic_status_links_IR13_en.pdf
[16] https://www.weforum.org/agenda/2017/03/these-are-the-cities-with-the-worst-noise-pollution/
[17] http://fuelfix.com/blog/2017/01/16/market-currents-asian-oil-reliance-continues-to-grow/
[18] http://thediplomat.com/2016/08/central-asias-oil-and-gas-now-flows-to-the-east/
[19] https://about.bnef.com/blog/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040/
[20] Analysis undertaken for this roadmap based on import price of US$1.55/gallon.
[21] https://www.adb.org/news/speeches/solar-energy-potential-asia-and-pacific-takehiko-nakao
[22] http://www.calmac.org/publications/7-18-12_Final_White_Paper_on_Use_of_DR_for_Renewable_Energy_Integration.pdf
[23] http://theconversation.com/how-electric-cars-can-help-save-the-grid-73914

fossil fueled vehicles can help to break the transport poverty cycle and provide affordable transport for deprived urban and rural communities.

10. **Automotive manufacturing:** The rise of EVs means long-established automotive players are experiencing profound and prolonged challenges such as new technologies and products, new competitors and new regulations. Embracing EVs and encouraging automotive supply chains to develop and transition will help to safeguard and create jobs in CAREC member countries. For example, in 2012, 3.5 million workers were employed in Pakistan's automotive sector, which represented 2.8% of GDP with a turnover $2.8 billion. Pakistan is the world's 6th largest motorcycle market producing 1.8 million motorcycles annually; a 5% global market share of electric motorcycle market would be equivalent to $2.75 billion by 2024.

11. **Battery manufacturing:** Asian battery makers currently have around 50 GWh of production capacity, equivalent to 50% or more of global output (consumer electronics/automotive battery capacity combined) and have monopolistic shares of 50%-80% of core component materials, such as cathode materials and separators.[24] There is an estimated US$1 trillion in untapped lithium mineral deposits in Afghanistan, meaning the country could substantially benefit from increased EV uptake.

12. **Sustainable tourism:** EVs are an opportunity for the tourism industry to benefit from sustainable practices.[25] For example, poor air quality has been blamed for driving tourists away from China[26] and Thailand[27] in recent years.

C. Trends and opportunities

13. **Shifting consumer demand:** Demand is starting to shift in favor of EVs and has strong disruption potential. As an example, between the start of pre-ordering on March 31, 2016, and year-end, consumers globally placed more than 380,000 orders for the Tesla Model 3 – the largest number of pre-orders for any car in history.[29] Between 2011 and 2016, a threefold increase in consumer interest in EVs was reported in China, with 30 and 45% of vehicle buyers in the US and Germany respectively considering an EV purchase in 2016.[29] As a result, all major vehicle manufacturers have invested in EVs and will be offering increasing numbers of vehicles to the market in coming years.

14. **Advances in battery technology:** Battery costs have decreased from $800 in 2011 to $227 per kWh in 2016.[28] An assessment by the U.S. Department of Energy identifies that technologies currently in the R&D stage have better performance than those

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[24] http://www.automotivenl.com/images/November_2016/Goldman_Sachs_On_Batteries_-_2016.pdf
[25] https://2lwej44565rn2mmjlk31pmwq-wpengine.netdna-ssl.com/wp-content/uploads/2014/08/White-Paper-EV-Tourism-2014.pdf
[26] https://qz.com/333787/chinas-air-pollution-is-driving-away-international-tourists/
[27] http://www.dw.com/en/haze-affecting-thai-tourism-industry/a-18801663
[28] https://www.scribd.com/document/337911353/How-Automakers-Can-Drive-Electrified-Vehicle-Sales-and-Profitability-McK#download&from_embed

currently available on the market. These improvements in energy density suggest that driving ranges will continue to increase and battery costs will continue to decline. Current projections put EV battery pack prices below $190/kWh by the end of the decade and suggest the potential for pack prices to fall below $100/kWh by 2030[29] reaching price parity with combustion engine models by 2025.

15. **Fast charging:** Global charging outlets surpassed 2 million in 2016. Much of this growth has been in the number of fast chargers (>22kW) and is largely attributable to China where fast chargers grew sevenfold to nearly 90,000 units. Even when China is not considered, the growth rate for publicly accessible fast chargers in 2016 was still greater than publicly available slow chargers (≤22kW).[7]

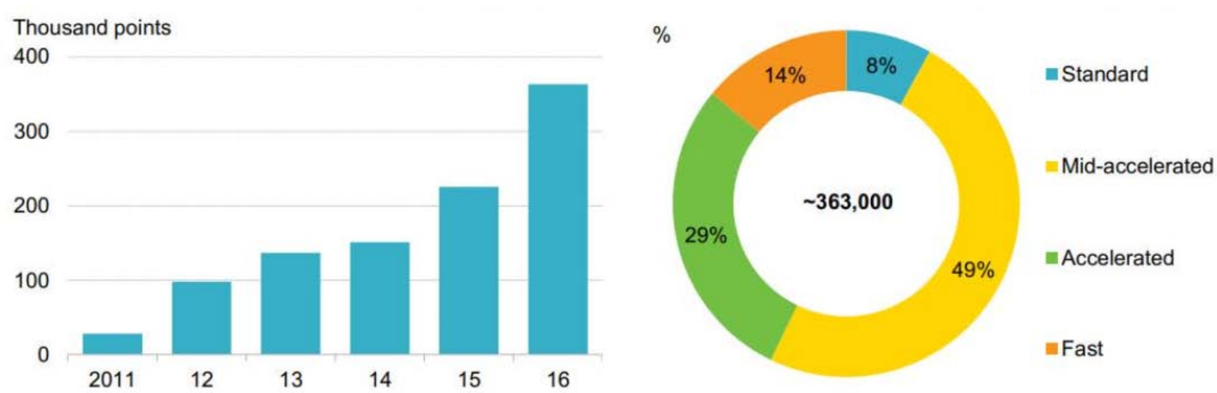

Figure 2: Global number of EV charging points and level of charging (Source: Bloomberg New Energy Finance, 2017)

16. **Importing used EVs:** Ukraine has become one of the fastest developing markets for EVs, with reports of over 4,000 EVs in the country.[30] The majority of EVs in Ukraine are second-hand Nissan LEAFs from the USA with an average price of €15,000.[31]

17. **EV conversions:** An EV conversion is the modification of a conventional internal combustion engine driven vehicle to electric propulsion. In 2016, the Road Transport and Highway Ministry in India issued a notification to allow retrofitting of old vehicles into hybrid EVs and started certifying the manufacturers of conversion kits. The government also asked key automotive suppliers such as Bosch and Cummins to offer retrofitting technology for Indian customers.[32]

18. **Second-life batteries:** The second life potential of EV batteries could have significant impacts on electrification in the developing world, supporting a shift to renewables and

[29] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/electrifying-insights-how-automakers-can-drive-electrified-vehicle-sales-and-profitability

providing energy access to some of those least likely to obtain it.[33] Comparable experience of a large-scale recycling program used lead-acid batteries in Bangladesh has been particularly successful, with more than 2 million solar home systems installed.[33] Major EV manufacturers such as BMW, GM, Nissan and Toyota are examining the potential value of second-life batteries for storage.[34] For example, 2,600 used battery modules from over 100 EVs were used to form a large electricity storage facility in Hamburg.

19. **Battery recycling:** The automotive industry is the largest source of spent batteries.[35] The global battery recycling market is projected to reach USD$19.9bn by 2024. The recycling/processing infrastructure for EV batteries is in its infancy, but large players are already in the market and are assessing options for future expansion. Support from environmental institutions and governments is also enabling smaller companies to emerge in this sector.[35]

D. Best available technology

1. Cars and vans

20. Bloomberg New Energy Finance (BNEF) forecast that by 2040, 54% of new car sales and 33% of the global car fleet will be electric. This will be driven by falling lithium-ion battery costs, which will bring price-competitive EVs to all major light-duty vehicle segments before 2030. While EV sales to 2025 will remain relatively low, an inflection point in adoption is expected between 2025 and 2030, as EVs become economical on an unsubsidized total cost of ownership basis across mass-market vehicle classes.

21. BNEF expect that much of this growth will come from the medium car segment, which includes high-selling models like the Toyota Camry and Honda Accord. It also forecasts that while plug-in hybrid EV (PHEV) sales will play a role in EV adoption to 2025, after this battery EVs (BEVs) take over and account for the vast majority of EV sales. The engineering complexity of PHEV vehicle platforms, their cost and dual powertrains make BEVs more attractive over the long-run.

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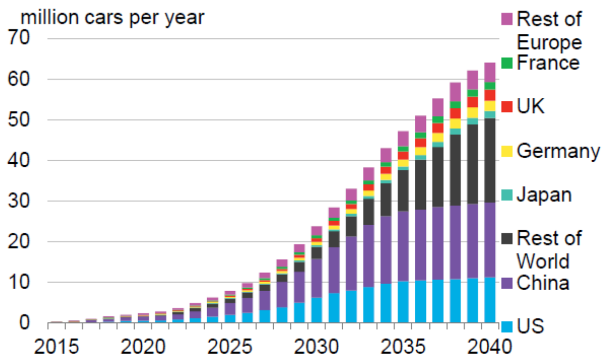
[30] https://www.kyivpost.com/technology/electric-car-sales-ukraine-increase-3-2-fold-january-october.html
[31] https://cleantechnica.com/2017/10/25/u-ev-charging-leadership-fast-changing-electric-vehicle-world/
[32] https://economictimes.indiatimes.com/industry/auto/news/government-to-allow-conversion-of-old-vehicles-into-hybrid-electric-vehicles-through-retrofitting/articleshow/53201038.cms
[33] http://iopscience.iop.org/article/10.1088/1748-9326/9/9/094004
[34] https://thinkprogress.org/why-used-electric-car-batteries-could-be-crucial-to-a-clean-energy-future-6ab9a2308cdb
[35] http://www.prnewswire.com/news-releases/battery-recycling-market-to-reach-us199-billion-by-2024-global-industry-analysis-size-share-growth-trends-and-forecast-2016---2024-tmr-586947891.html



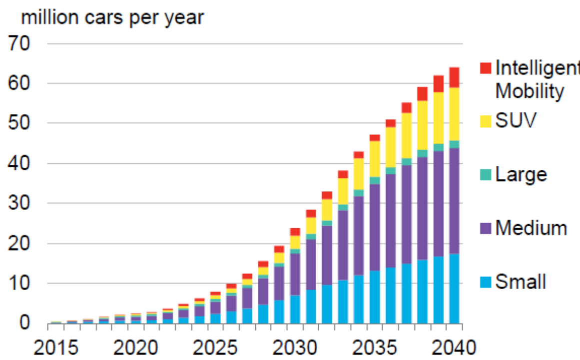


Figure 3: Forecasts of annual global EV sales by market and vehicle class (Source: Bloomberg New Energy Finance, 2017).

2. Motorcycles

22. The global market for electric motorcycles and scooters was valued at over US$25 billion in 2015 and forecast to grow at more than 10% CAGR from 2016 to 2024. Global shipments are projected to surpass 60 million units by 2024 with a value of US$55 billion.[36]

23. Lithium-ion battery-equipped electric motorcycles and scooters are expected to grow with the highest CAGR. These batteries are preferred in due to low weight compared to lead acid alternatives. The batteries can be recharged from any external source of electricity and frequent charging is required as these vehicles have shorter driving range.

24. China’s electric motorcycles and scooters market is expected to remain the leading industry, with over 80% of the global shipments in 2015.

3. Tricycles

25. Electric tricycles are lightweight vehicles that offer car-like features, with cargo or passenger capacity. Advances in lithium ion batteries have helped the electric tricycle manufacturers to reduce the overall weight of the vehicle and have a longer lifespan compared to conventional VRLA and lead acid batteries.

26. The global electric tricycle market is dominated by the Western European Region, which represents about half of the market share.

[36] https://www.gminsights.com/industry-analysis/electric-motorcycles-and-scooters-market

4. Taxis

27. Although taxis represent a relatively small percentage of urban vehicles, their high mileage makes them disproportionately large contributors to problems of climate change and air quality in cities across the globe. High mileage also means high maintenance and fuel expenditures, making it possible for taxi operators and drivers to enjoy considerable savings through electrification. As a result, electric taxis are becoming a feature in cities around the world.

28. For example, it was reported in 2017 that all newly added or replaced taxis in the city of Beijing would be EVs, according to a draft work program on air pollution control for Beijing, Tianjin, Hebei, and surrounding areas. This is expected to create a market worth nine billion yuan (US$1.3 billion).[37]

29. The high demand for low-cost electric taxis, primarily in emerging countries points to an opportunity for micro electric taxis in the form of electric rickshaws or trikes. These electric taxis cost much less than electric cars, making them a more viable option for many buyers.

5. Buses

30. The global electric bus market is forecast to witness a CAGR of 33.5% between 2017 and 2025.38 This is driven by supportive public policy, a desire to replace diesel and natural gas based public transit and the lower operating costs of electric buses. An electric bus saves around US$365,000 of fuel over its operational life when compared to diesel buses; and US$225,000 compared to natural gas (CNG) buses.[38] Electric buses are also less noisy and require less maintenance than internal combustion engine vehicles.

31. Led by China, Asia-Pacific accounted for the highest number of shipments in the global electric bus market in 2016.[38] The Chinese electric bus market is expected to grow significantly, with companies such as BYD and Yutong being major global players. The Indian government has set a target has set a target to deploy over 10,000 electric buses in the near term[39], with leading India's bus manufacturers such as Ashok Leyland and Tata developing EVs.

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[37] http://www.nbdpress.com/articles/2017-02-23/1613.html
[38] https://www.reportbuyer.com/product/5038468/global-electric-bus-market-size-share-development-growth-and-demand-forecast-to-2025-industry-insights-by-technology-by-size.html
[39] http://www.india.uitp.org/articles/electric-bus-market-in-india

6. Boats

32. Hybrid and pure electric marine vessels, with electric propulsion some or all of the time, have been around for over 100 years. There are over 100 manufacturers of electric and hybrid watercraft, but the market for these vessels is still low with about 1-2% of the addressable market.[40]

33. The market for hybrid and pure electric boats and ships will rise rapidly to over $20 billion worldwide in 2027 for non-military versions. Recreational boats are the largest and fastest growing electric marine market in sales number.[40]

34. Beyond new electric craft, there is already a substantial and growing business in retrofit of hybrid electric ferries and other ships with pure electric or hybrid electric powertrains. There is also potential to sell pure electric motors as they become more affordable and more energy harvesting is provided on the craft to charge the batteries, improving range.

7. Charging infrastructure

35. Charging infrastructure exists in all forms and sizes: from a simple socket to high power chargers. The sockets have been standardized to a certain number of sockets, mainly per continent.

36. In terms of location and use, a distinction can be made between home, semi-public and public charging. Home and workplace (semi-public) charging are currently the most commonly used types of charging for electric vehicle drivers. In addition, public chargers can accommodate for residential charging (charging at home where off-street parking limited), destination charging (charging at any destination such as work, town or shopping centre) and corridor charging (charging on-route such as next to the highway).

37. The global EV charging infrastructure market is expected to reach US$45.59 billion by 2025. The fast chargers segment is expected to exhibit the fastest growth, with an estimated CAGR of around 47.9% from 2017 to 2025. In 2016, CHAdeMO possessed the largest market share in the connector segment, however, it is predicted to be surpassed by the Combined Charging System (CCS) connectors segment, which is a combination of SAE J1772 (IEC Type 1) and IEC Type 2 connectors.[41]

E. Policy issues

38. **Joined-up commitments:** As the benefits of EVs span a number of different policy areas, all responsible government departments and agencies should be encouraged to

[40] https://www.researchandmarkets.com/research/hgpc77/electric_boats
[41] https://www.grandviewresearch.com/press-release/global-electric-vehicle-ev-charging-infrastructure-market

embed relevant commitments in their respective policy instruments and strategies. This includes, but is not limited to: transport, climate change, air quality, environmental protection, health, education, planning, taxation, economic development, renewables and energy security. This approach can unlock new sources of funding, promote awareness and build compelling business cases for investment.

39. **Financial incentives:** There are four major incentive types implemented around the world: income tax credit, vehicle purchase rebate, one-time vehicle tax reduction, and annual vehicle tax reduction. These EV incentives generally fall into two broad categories: subsidies (including income tax credits and vehicle purchase rebates) and vehicle tax reductions (including the one-time vehicle tax reduction and annual vehicle tax reduction). Subsidies typically tend to be relatively transparent and direct, generally with a vehicle-specific dollar value attached. Vehicle tax reductions can be much more variable, opaque, and are dependent on both the tax system and typically the vehicle specs.[42]

40. **Local incentives:** Advantages can also be offered to EV drivers in the form of reduced fees, privileged access and time savings. These targeted policies are best developed at the municipal level and adapted to the unique, local mobility conditions of each urban area. This includes: waivers on regulations that limit the availability of license plates for ICE vehicles; exemptions from access restrictions to urban areas; exemptions from usage fees for specific portions of the road network (e.g. parking fees, road tolls and other fees incurred from vehicle use); dedicated parking and access to publicly available charging infrastructure; and allowances to access bus lanes and high-occupancy vehicle (HOV) lanes.

41. **Charging infrastructure:** Installing charging infrastructure should go hand in hand with grid reconstruction, as well as modernization and transformation for the inclusion of renewable energy sources into the electrical mix. This is an opportunity for governments and institutional investors to back large scale and long-term investments in EV infrastructure.

42. **Communications:** Increasing awareness and confidence in EVs is a key factor in encouraging uptake. This includes promoting the imperatives for EV uptake and helping fleets and individuals to better understand how EVs can meet their needs. There are a range of ways to deliver these messages, including: specialized forums such as workshops between policy-makers and industry groups and detailed information for consumers on the life cycle costs and environmental benefits of EVs.

43. **Procurement:** Fleet operators, both in public authorities and the private sector, can contribute significantly to the deployment of EVs: first through the demand signals that

[42] https://www.theicct.org/sites/default/files/publications/ICCT_IZEV-incentives-comp_201606.pdf

they can send to the market, and second thanks to their broader role as amplifiers in promoting and facilitating the uptake of electric cars by their staff and customers.

44. **Skills:** Provisions need to made for the necessary skills to support the growing market for EVs and to adapt to the new challenges that this will bring. Technical professionals will need to be equipped with the necessary knowledge to repair and maintain EVs. Technical skills will also be required by personnel responsible for the installation, maintenance, servicing and inspection of different recharging technologies. It is also essential that vehicle dealerships and sales personnel are sufficiently knowledgeable to promote plug-in vehicles as a viable option to prospective customers. Another important area is first responders, such as police, paramedics, fire fighters and hazard response teams. It is important that these professions are trained in how to safely respond to road traffic accidents or other incidents involving electric vehicles and related infrastructure.

V. ENERGY EFFICIENCY AND ENERGY CONSERVATION

A. Introduction

1. Continued secured energy supply and access to reliable energy by the population remains a key development challenge for most countries in the CAREC region. With the development of new technologies, the energy savings potential in all aspects of modern life has grown significantly in recent years, whether it is for transportation, cooking, heating, cooling, lighting, entertainment, manufacturing and many other processes. Energy conservation or "switch the light bulb when not in use" and energy efficiency "use best technology light bulb that gives maximum for a given energy input" are important elements in securing future supply and tackling climate change.

2. Today, energy efficiency and conservation (abbreviated as EE) is the main driver for a future with safe, reliable, affordable and sustainable energy system. While many countries, have active energy efficiency policies in place, vast amounts of untapped EE potential are everywhere, especially in the CAREC countries. For example, if one million customers can be convinced to replace one incandescent light bulb with an LED, the electricity demand will be 50 MW less—the power company will not need to build a 50 MW power station costing more than $50 million and avoid other associated operation and maintenance costs. Convincing one million customers will need improved consumer understanding of the technology and access to LEDs at reasonable costs. Consumers will also benefit from reduced electricity costs. Once consumers make the switch, society will permanently save "50 MW" without any incremental cost.

B. The case for investment

3. Studies have reported that, on average, residential buildings in Kazakhstan use 3 times more energy for heating than residential in Northern Europe because of outdated equipment and lack of maintenance. Kazakhstan has a program "Energy saving 2020" with targets to reduce the energy intensity of its GDP: 10% by 2015, 25% by 2020, 30% by 2030 (from 2008 baseline level). Energy saving and energy efficiency have become one of the top priorities of state policy.

4. In Kyrgyz Republic, some reports suggest very high average energy consumption in households compared with the lifestyle, size of buildings and equipment use. The government is working on projects to improve energy efficiency by modernizing individual heating points in residential buildings, and installing smart meters. The government also plans additional industrial energy efficiency projects.

5. The objective of this energy efficiency roadmap is to bring a common energy efficiency target for the region and gain from economies of scale and scope.

Table 7.1 ▷ Selected energy efficiency policies announced or introduced in 2015 to mid-2016

Region	Sector	New policy measure
China	General	Improve energy intensity by 15% by 2020 compared with 2015 (13th Five-Year Plan). Circular Economy Promotion Plan supporting industrial parks and waste recycling.
	Industry	Planned closure of 100-150 Mt of inefficient steel capacity within five years.
United States	Buildings	Energy conservation standards for air conditioners, heat pumps, walk-in coolers and freezers, residential boilers, battery chargers and dehumidifiers.
	Industry	Introduction of energy conservation standards for clean-water pumps.
European Union	General	Germany: Competitive tenders for electricity saving projects, support for efficient cross-cutting technologies and waste-heat recovery. Poland: New act on energy efficiency including obligatory energy audits and a modification of the efficiency certificates system.
	Buildings	Proposal to revise the EU Directive on energy labelling of consumer appliances.
India	Transport	Plans to implement a "green tax" of 1% on small petrol, LPG and CNG cars, 2.5% on certain diesel cars and 4% on larger cars and SUVs.
	Buildings	National Energy Efficient Fan Programme to distribute efficient ceiling fans.
Middle East	Buildings	United Arab Emirates (Dubai): Plan to introduce energy efficiency ranking of buildings and MEPS for retrofits.
Latin America	General	Mexico: Energy transition law to establish an efficiency goal and a roadmap. Brazil: Increased funding for the National Electricity Conservation Programme. Uruguay: Implementation of the National Plan for Energy Efficiency 2015-2024 with the goal of saving a cumulative 1.69 Mtoe.
	Buildings	Mexico: MEPS on split-type air conditioners. Brazil: Installation of LED street lights in Rio de Janeiro for the Olympic Games.
Southeast Asia	General	Philippines: Energy Efficiency and Conservation Action Plan 2016-2020 to reduce energy intensity by 40% by 2030 from 2005. Thailand: Drafting of the Energy Efficiency Development Plan 2015-2036 with a target to reduce energy intensity by 30% in 2036 compared with 2010.
	Buildings	Philippines: Approval of energy labelling and efficiency standards for refrigerators and air conditioners.
Japan	Buildings	Mandatory energy efficiency standards for new non-residential buildings from 2017 and a labelling system from 2016. Phase out incandescent light bulbs and fluorescent tubes by 2020. Top Runner Program requirements strengthened for refrigerators and freezers. Update of mandatory efficiency benchmarking to include the services sector, with the aim to cover 70% of energy demand in services and industry by 2018.
Canada	Buildings	Update and strengthen the national energy codes for buildings, including lighting and HVAC systems.
Australia	General	Release of the National Energy Productivity Plan aiming to improve energy productivity by 40% between 2015 and 2030.
International	Transport	Announcement of CO_2 limits for new aircraft from 2028 by the ICAO.
	General	Almost nine out of ten of all national submitted NDCs mention energy efficiency. One of the UN's SDGs is to double the global rate of improvement in energy efficiency.

Notes: LPG = liquefied petroleum gas; CNG = compressed natural gas; HVAC = heating, ventilating and air conditioning systems.

C. Trends and opportunities

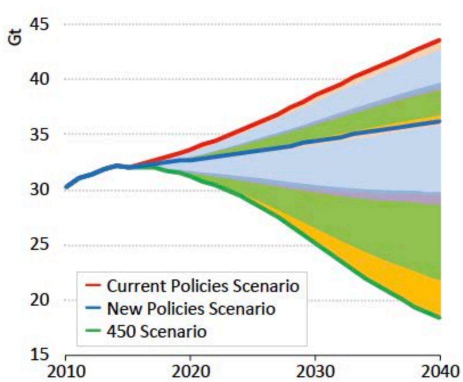
6. **Cost of savings**: A kWh through energy efficiency costs much less than producing an extra kWh. Often for a consumer, the benefit is net gain or the cost is negative cost per kWh.

7. **Efficient buildings**: It is well established that about 70% of electricity produced is consumed by buildings and energy efficiency in buildings can significantly reduce need for electricity generation and hence climate change. Within the buildings sector, about 75% energy is consumed in households, and the balance is distributed in the services sector—public buildings, offices, shops, restaurants and water treatment and pumping.

8. **Efficient motors**: Based on 2016 data, more than 50% global electricity was used in electric motor systems and 30% (6,000 TWh) of global electricity consumption came from industrial electric motor-driven systems. In the industry sector, new motor systems consume 40% less energy than the ones currently in operation, and there are huge savings potential through coordinated policy measures, and stricter regulation on motors and motor-driven equipment. Just by promoting variable speed drives and other system-wide efficiencies, according to IEA's 2016 Energy Efficiency Outlook, overall, about $450 billion investment in power generation can be avoided by investing about $300 billion in the industry on efficiency. A summary of global policy measures is in Table 7.1 (from IEA, World Energy Outlook 2016).

9. **National commitments**: According to IEA's analysis, nine out of ten of the Nationally Determined Contributions (NDCs) submitted to the 2015 climate summit in Paris plan to use energy efficiency to deliver those commitments. All countries in the Central Asian region have made commitment to the Paris Agreement in 2015, and investment in energy efficiency is one main opportunities to deliver those NDC commitments. As shown in the Figure 7.8 (quoted form IEA Publication), energy efficiency would provide 35% to 45% of the CO_2 abatement by 2040 for the world, considering the legacy systems and age of assets, the contribution of energy efficiency for the CAREC countries to meet their NDC commitments will be much higher.

Figure 7.8 ▷ **World energy-related CO_2 emissions abatement by scenario**



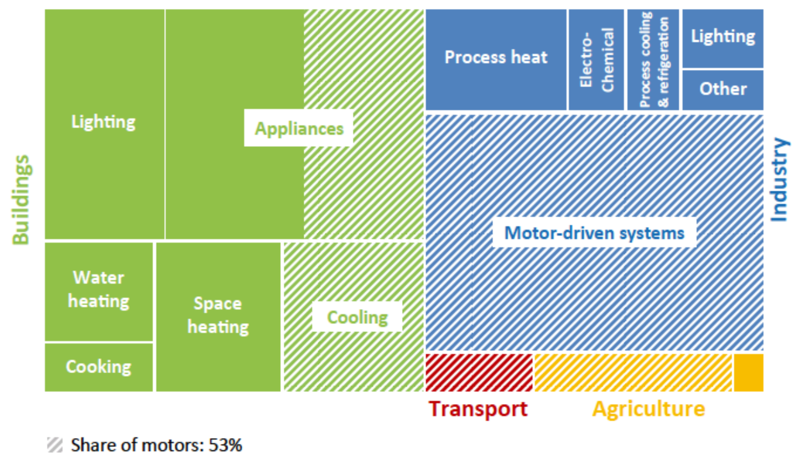
CO_2 abatement in 2040	CPS to NPS	NPS to 450
Activity effect	12%	2%
End-use efficiency	39%	33%
Supply efficiency	6%	2%
Fuel and technology switching	3%	4%
Renewables	32%	39%
Nuclear and CCS	9%	19%
Total (Gt CO_2)	**7.4**	**17.9**

Energy efficiency is a key abatement measure in the New Policies and the 450 Scenario

Notes: CPS = Current Policies Scenario; NPS = New Policies Scenario; CCS = carbon capture and storage.

10. The priority areas for the CAREC region for energy efficiency are energy used in buildings, public lighting, and industrial systems. This fits well with the overall energy consumption as mapped out by IEA in their Figure 7.9, below.

Figure 7.9 ▷ Global total final electricity consumption by end-uses, 2014



Motors account for more than half of today's electricity consumption

Source: IEA analysis.

11. The following text summarizes the technologies for energy efficiency in the building systems and lighting:

1. Efficient Building Systems and Technologies

12. Energy consumed by buildings represent a large part of an electric utilities power demand, efficient operation of buildings can allow utilities to shift energy demand away from peak periods—especially during cold winter evening or hot summer afternoons.

13. In the CAREC region, many commercial and residential buildings in operation today were built in the 70s, so it's important to use leapfrogging technologies to retrofit these existing buildings as well the new ones to be built. As a large amount of the existing stock is of poor efficiency, technologies for retrofit will have an important role, including: low-cost solutions (thin, easily-installed insulation, leak detectors), systems problems (optimum refrigerants on air conditioners), and capacity building for energy conservation. For new buildings, there are opportunities to promote modern architecture, best practice energy systems design, and train occupants and building managers on effective operations and maintenance.

14. The following approaches are universally used for building efficiency, some of which would be highly relevant for the CAREC region.

   a. **Energy efficient enclosure:** A rational and effective way to increase the thermal protection of operated buildings is additional external insulation of the enclosing structures—exterior wall structures, roofing, ceilings and partitions. Usually the following insulation materials are used: (i) mineral wool heat insulation boards; (ii) envelop building with extruded polyethylene foam as insulation; (iii) thermal insulation panels made of basalt rocks; and slabs (blocks) of foam glass, etc.

b. **Heating loss reduction:** Up to 40% to 50% can be achieved through better insulation and better technology and behavioral change of occupants. Heat losses through windows can be reduced by installing double and triple glass panes (including low-emission coating).

c. **Sealing (closing) the entrances:** Direct insulation and sealing of the previously installed windows and entrance doors, installation of new metal single entrance doors with intercoms and door closers, installation of the second door, thus creating a heat-insulating vestibule. This can save up to 5% of all heat energy entering the building heating system.

d. **Installation of radiator thermostats:** The radiator thermostat can eliminate the need to open windows to regulate the temperature in the rooms, as it will constantly maintain the temperature at the desired level with an accuracy of 1°C, reducing heating consumption by 10%-20%.

e. **Slab Heating or "Warm floors":** The use of special collectors allows the system of warm floors to be divided into several circuits allowing separate control of different zones. Warm floors most effectively work with heat pumps. The high thermal inertia, with a system of warm water floors, even allows to maintain a comfortable temperature in the rooms even when the heating is turned off, effectively making warm floors a thermal battery. The use of warm floors in comparison with radiators allows to save up to 30% of thermal energy.

f. **Installation of heat metering devices:** Appropriate metering provides incentive to save energy and benchmark consumption to identify areas of high inefficiencies and losses

g. **Use of automated and independent schemes:** Automated heat points allow individual regulation and can generate about 40% savings. Independent heat supply schemes with heat exchangers can radically change the requirements for the design of the internal heating system of the building, saving between 10-40% of costs for water treatment

h. **Transfer of open heat supply systems to closed ones (District Heating networks and hot water supply systems):** This will reduce the supply of cold water to the CHP plant or boiler house, reducing chemical treatment cost, savings of network water and heat, improve quality and reliability of heat supply system, and overall reduction of fuel consumption.

i. **Use of heat pumps rather than boiler houses:** Heat pumps can use any running water with a temperature of +5 to + 40°C and artesian wells, industrial discharges, cooling towers, and non-freezing water bodies are used as a source. Heat pump spends energy not on heat generation, like an electric heater, but only on moving Freon through the system. The overall configuration transfers heat to the consumer from the source, which makes them cheaper than boiler houses. Heat pumps can save electricity and improved reliability than many centralized heating facilities in housing and in utilities. These investments have a pay-back period of about 2 years, will also save transmission losses and maintenance costs from long-distance heating sources to consumption points. This leads to reduced losses and costs for their maintenance and increased reliability of heat supply.

j. **Heat recovery from ventilation schemes:** Ventilation schemes usually increase heat consumption, as heated air leaves through the exhaust openings. Technology will allow recovery of heat from the combined inflow and exhaust air in one unit, capturing heat losses.

k. **Infrared motion and presence sensors:** Energy consumption in public facilities can be reduced by 50-60% (room with large flow of people), 50%(classrooms), 85% (rooms with permanent occupants) and about 95% (room with small stream of people) by using sensors and target lighting. The system usually detects presence of occupants using thermal (infrared) sensors and motion sensors. Proximity sensors—to detect small movements of people, including those sitting or standing—are used to increase the accuracy of the system. The sensors can delay switching off the light after the last recorded motion. Other sensors can monitor natural light and switches off light (or turns off - for presence sensors) when natural illumination exceeds a predetermined threshold even if people are in the field of view of the sensor.

2. Public lighting and lighting efficiency

15. Modern LED technology allows, without loss in the level of illumination of the premises, to replace traditional light sources with energy savings from 40 to 90%. LED is the perfect light source since it is easy to dim, scalable, and easily addressable. As LED coverts electric current into light, LEDs consume a fraction of the electricity of other technologies—about 20% of an incandescent lamp, and about 50% of a fluorescent lamp. Despite the high price of LED lamps, the investment is usually paid back within 2.5 to 5 years, while the benefit of low cost maintenance operation continues for the entire life of the LED.

D. Best available technology

16. In this world of abundant technology and innovation, identifying appropriate technology that can be trusted is a huge challenge in the CAREC region. The following section presents a short-list of technologies that are available and proven, based on the long list 160 technologies identified by the Energy Conservation Centre of Japan.

1. Insulation

17. **Heat Shielding and Heat Insulation Glass Units:** Reduces cooling and heating costs. Heat shielding capacity is 2 times higher than of ordinary double-glazed window.

18. **Low-E glass applicable to Existing Window Panes on the site**: Effective in heat shielding and insulation, prevention of dew condensation; potential savings up to 32% energy per year

19. **Low-contamination High Thermal Energy Reflectance Fluoropolymer Coating (High Solar Reflectance Paint):** Reflects sunlight and suppress increase in surface

temperature. A study showed reduction of temperature raise by 12C. Application: building roof (factory, warehouse, other buildings).

2. Combined Heating and Cooling

20. **Commercial Heat Pump Air Conditioning System** (Multisystem Air Conditioner for Highly-Efficient Buildings): Comprises of a single external unit connected to multiple internal units. Application: large office buildings, hotels, public facilities. Power consumption reduced by: 60% compared to an inverter unit released year 2003, 20% compared to conventional units

21. **Radiant Air-conditioning system:** Use far infrared rays for heating and cooling. Approximately 31% energy saving compared to convection air-conditioning.

3. Heating

22. **Heat Pump with waste heat recovery:** Heat pump for simultaneous supply of hot and cold water [streamlining of cooling and heating].

23. **Far Infrared Heating:** 45% energy saving.

24. **Commercial Heat Pump Water Heater:** Uses energy abundantly available, such as ambient heat, underground heat, waste heat. 60% reduction of CO_2, 61% reduction of running cost.

25. **Solar Absorption Chiller-Heater:** Provide chilled water by using renewable energy or natural gas combustion. Solar collectors heat water, then chiller-heater thermally recovers heat from hot water and exchanges it to lithium bromide solution in the machine, then the natural gas combustion is reduced. Waste heat from Gas Engine or Gas Turbine is also applicable. 32% natural gas combustion savings. Application: large buildings.

26. **Heat Pump (general purpose):** Uses energy from air and water. Reduces energy consumption and CO_2. Application: commercial buildings, district cooling systems.

27. **Far Infrared Heater**: In compare to silica glass tube heater, heats 20% faster and 10% higher temperature.

28. **Underground heat:** Underground temperatures (from 10m below the ground surface) are almost constant throughout the year regardless of seasons and the temperature varies about 10°C to 15°C, for example in Japan, between the above ground and underground in winter and summer. The use of underground heat means taking out the thermal energy with stable temperature from underground and use the temperature differential as a source for cooling, heating, water heating and snow melting.

4. Lighting

29. **Sophisticated Green Building Design:** The use of light shelves that block and diffuse direct sunlight and cast an abundance of indirect natural light inside, vertical louvers for western sun screening, natural ventilation to draw outside air inside, airflow windows to reduce the amount of radiant heat transfer through windows, an atrium to provide natural

air circulation through the entire building, other devices such as NaS batteries, micro-gas turbines and PV cells. Lowers life cycle CO_2 emission by 40%, life cycle costs by 50%. Example: Islamic Development Bank Headquarters.

30. **Mirror Duct System to Use Natural Light:** Provides natural light, requires no power. Can provide natural light to windowless rooms. Reduces annual power consumption by 65% in office buildings.

5. Pumps and Motors

31. **Gold Motor:** 30-40% energy loss reduction compared to an induction motor.

32. **Permanent Magnet Motor:** 57% loss reduction compared to an induction motor.

6. Renewable Energy

33. **Micro Tubular Turbine:** Uses a tubular hydraulic turbine designed for large flow rate points. At a point when where the flow rate will vary, a motor-driven adjustable-vane hydraulic turbine maximize the use of energy. Application: waterworks, sewage systems, irrigation canals and rivers, factory utility.

34. **Glass Integrated Photovoltaics:** Laminated safety glass embedded solar cells. See-through with high efficiency.

7. Large Scale Energy Efficiency

35. **Waste Heat Recovery Power Plant:** 30% reduction in energy use in cement plants.

36. **AC inverter:** Application: manufacturing plants. 50% energy saving.

37. **Pump Speed Control Type Electro-Hydraulic Hybrid System:** Controls rotational speed of hydraulic pumps in accordance with the required power. Application: manufacturing (steel plants, molding machines, press machines, etc.). Energy saving: 40-60%.

38. **Exhaust Heat Recovery System for Hot Air Stoves:** Uses the heat energy in the combustion exhaust from a hot stove to preheat fuel gas and combustion air. Approx.10% reduction of fuel gas/energy consumption in a hot stove. Application: steel plants.

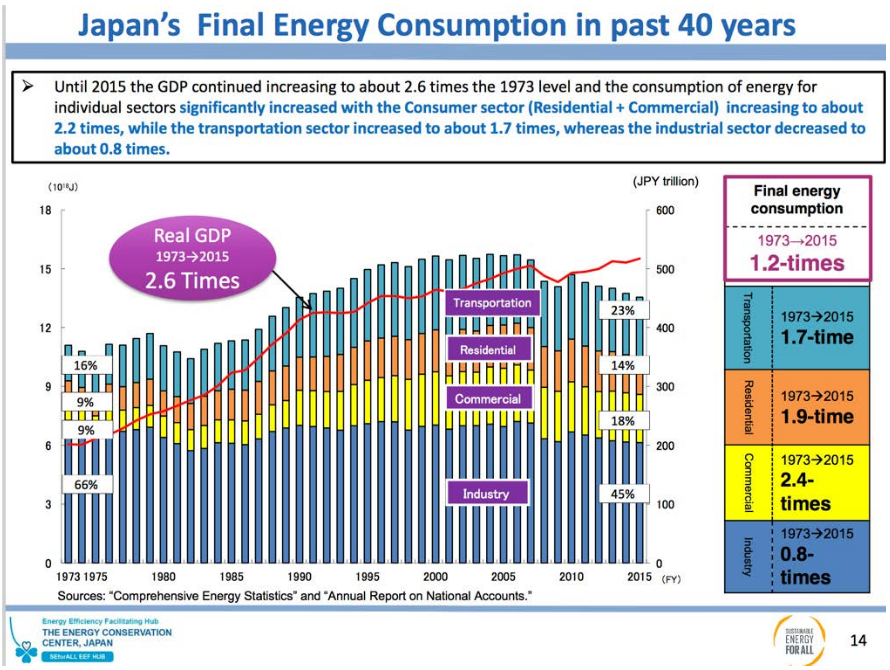
39. **Machine-Room-Less Elevator:** Standby power reduction, regenerative converter. Up to 36% energy saving.

40. **High-efficiency transformers Friendly to Global Environment:** Uses carbon-neutral material (rapeseed oil) as an insulating oil. Lowers loss, achieve energy conservation. Excellent flame resistance performance can extend expected life. Reduces CO_2 by 89% compared to transformers used 30 years ago and 27% compared to Top Runner transformers.

41. **System for Sewage Purification in pipeline:** Sewage can be purified while it simply flows through a purification pipeline with the gravity flow, without electric power. Lowers

construction and maintenance cost. Application: sewage treatment plants, heavily polluted rivers and lakes.

42. The impact of these technologies is demonstrated by the fact that although Japan's GDP grew by more than 260% over the last 40 years, the energy intensity of its sectors has grown at a much lesser pace.



VI. ENERGY STORAGE

A. Introduction

1. The rapid advances in battery energy storage technologies over the past decade have led to stationary energy storage systems becoming one of the most disruptive technologies now available. While the advances in technology were initially driven primarily by demand from the electric vehicle (EV) industry, in recent years the demand for stationary storage has increased dramatically. This has coincided with a significant drop in battery storage pricing.

2. Battery Energy Storage Systems (BESS) are disrupting the way electricity is delivered and consumed. They are accelerating the shift towards more distributed energy supply, delaying traditional network investment and offer a range of grid support services.

B. The case for investment

3. **Economic opportunity:** Battery energy storage offers significant economic potential to the Central Asia Regional Economic Cooperation (CAREC) countries. These countries have the opportunities to benefit from both the application of battery storage into their grids and through the wider battery technology value chain (i.e. through mineral deposits, materials processing and manufacturing).

4. **Modernizing and expanding grids:** The electricity sectors in many of the CAREC countries include a significant proportion of generation assets that are close to the end of their economic life and will require significant refurbishment in the coming years. The replacement of this infrastructure provides an opportunity to embrace emerging technologies such as renewable energy and battery storage and to build electricity systems that are economical, optimized for the present, while also being future proof.

5. **Supporting renewables uptake:** Local electrical grids are typically not designed to handle variable generation output from renewables and are often already strained in delivering the existing electricity. BESS can help to safely integrate variable resources and align supply and demand in order to avoid curtailing renewable energy generation.

6. **Resilience:** BESS technology can also support aging grid infrastructure, providing increased network reliability and better-quality power at a lower cost to communities. Recent natural disasters have also highlighted the fragility of centralized grid architecture and have resulted in many communities opting for more local generation and use of micro-grids to ensure that they still have power during a disaster.[43]

C. Trends and opportunities

7. **Battery energy storage system costs:** The falling price of Li-on is being driven by manufacturing efficiencies, technology improvements from R&D, raw material extraction improvements, competition, and scale of production due to the parallel emergence of EVs. As shown in Figure 4, data from Bloomberg New Energy Finance (BNEF) suggests that battery cell prices reached $200/kWh in 2017. Some authors have forecast that installed costs of battery storage systems will fall by 50-66% by 2030.[44]

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[43] https://www.ifc.org/wps/wcm/connect/ed6f9f7f-f197-4915-8ab6-56b92d50865d/7151-IFC-EnergyStorage-report.pdf?MOD=AJPERES

[44] IRENA, 2017, Electricity Storage and Renewables: Costs and Markets to 2030.

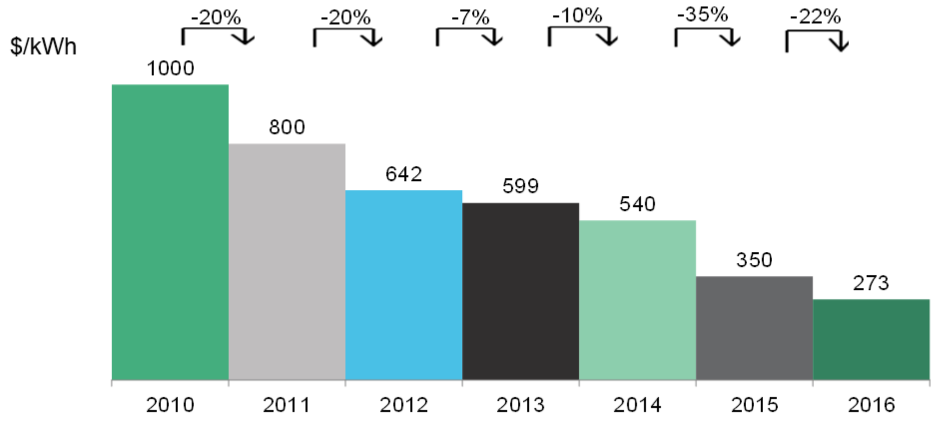

Figure 4: BNEF EV battery price survey[45]

8. **Increasing competition:** A growing list of Li-ion manufacturers is leading to increased competition across market segments, applications, and business models. In 2017 the major cell manufacturers globally include Panasonic (Japan); LG Chem and Samsung SDI (South Korea); Lishen and BYD (China). Chinese production capacity in particular is expanding rapidly (via CATL and Wanxiang). Major battery pack suppliers (i.e. cell integrators) globally include: Tesla (USA), LG Chem, Samsung SDI, Lishen and BYD. Major battery inverter suppliers globally include Tesla, Siemens, ABB, Dynapower and SMA. Major system integrators globally include: AES Energy Storage, ABB and Korea Electric Power.

9. **Increasing deployment:** The uptake of batteries for stationary applications has increased rapidly in the past few years, particularly in markets with high penetrations of solar PV, such as Germany, Australia and California.

10. **Storage capacity:** The cumulative capacity of electro-chemical (battery) storage internationally is expected to reach over 40 gigawatts by 2024.

11. **Supply side opportunities:** For countries with manufacturing capability and capacity, such as mainland China, significant opportunities are being created in the central part of the value chain for the large-scale manufacture of batteries, along with hardware and software associated with electronic energy management and control systems. For countries that have reserves or refining facilities for minerals used in the BESS products, the opportunities are in the upstream activities of mining and processing. For example, Afghanistan has large untapped mineral resources yet to be developed including lithium,

[45] Note that this represents the reported price (in USD per unit of energy capacity) of electric vehicle battery packs to electric vehicle manufacturers. It does not refer to stationary storage battery packs, and does not account for differences in performance, longevity etc. Nevertheless, the chart is indicative of the general rate of capital cost progress over recent years.

cobalt, nickel and graphite.[46] There could also be scope to assess opportunities to participate in repurposing second life batteries from EVs using relatively low cost local labour for sorting of components and materials.

D. Best available technology

12. Lead-acid was the most commonly deployed battery-type throughout the 20th century. However, Li-ion technology is now displacing lead-acid technology in stationary, regular-cycling storage applications. Li-ion accounts for over 80% of new battery storage capacity.[47]

13. Despite the progress made to date by Li-ion, efforts to commercialise a range of other battery technologies and chemistries continues. Each have their own benefits, limitations, and applications.

14. Other battery technologies that are continuing to be developed for stationary applications, include flow batteries (Zinc Bromine and Vanadium Redox), aqueous hybrid ion (‘salt water’) batteries, high temperature liquid metal batteries and sodium batteries. Of these, the most commercially available are flow batteries. These technologies offer some benefits such as increased cycle life but also have limitations in terms of energy/power density, charge/discharge efficiency. On balance, emerging battery technologies are struggling to keep pace with the rapid decline in Li-ion battery pricing.

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[46] US Geological Survey https://minerals.usgs.gov/minerals/pubs/country/2007/myb3-2007-af.pdf
[47] http://www.navigantresearch.com/research/energy-storage-tracker-3q16

E. Policy issues

15. **Targets and mandates:** To date, a handful of governments in the world have adopted targets for energy storage. Some of these governments have also implemented mechanisms to support achievement of these targets in the form of utility mandates for energy storage capacity. California is a forerunner in the US and globally with a target of 1,325 MW of utility battery storage and 500 MW of distributed battery storage by 2020. Oregon passed legislation requiring that the state's main utilities deploy 5 MWh of storage by 2020; Puerto Rican government-owned Autoridad de Energia Electrica introduced a mandate in 2013 that renewable energy project developers must incorporate energy storage into new projects; and China has introduced a pilot program for energy storage to receive payment for peak shaving and frequency regulation in three of the country's northern regions where must-run coal plants and high levels of solar and wind have created a need for services.

16. **Procurement:** Early adoption of storage has primarily occurred through tenders, attracting responses from many suppliers prepared to be loss leaders in order to demonstrate the use of technology. Utilities are testing the capabilities of battery energy storage through programs that explore new business models, shave peak capacity, mitigate local reliability issues, and defer investments. This includes grid level and customer-owned storage. It also includes tenders for renewable energy projects that mandated the inclusion of a storage component or dispatchable capacity.

17. **Financial incentives:** National and state governments around the world are providing a variety of grants, loans and fiscal incentives. This includes: The ACT Government in Australia is providing over $25 million to over 5,000 homes and business to install batteries. The California Self-Generation Incentive Program - $166m annual program to 2020 which provides rebates for battery storage at Small Residential (<10 kW) and Large-Scale Storage (>10 kW, up to 5 MW); In Germany, a distributed storage subsidy program of €30 million provides loans and grants to residences and small business for battery storage installations; Maryland provides a 30% tax credit for energy storage systems, with credit capped at $5,000 for residential and $75,000 for commercial; and the New Jersey Renewable Electric Storage Program offers a per kWh incentive to storage projects coupled with a renewable energy project that is interconnected behind a non-residential customer's meter.

VII. MANAGING INDUSTRY DISRUPTION

VIII. FINDINGS, SUMMARY, CONCLUSION

IX. RECOMMENDATIONS

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Tim van Beek (1976) is co-founder of EVConsult, and has been working as a strategy consultant and project manager in electric mobility and charging infrastructure for more than 10 years. He helped several clients in national and international projects to get thousands of vehicles electrified and some 10,000 charging stations installed in public and private space. His deep knowledge of the market and EV charging value chain includes charging infrastructure IT, asset management, finance and contracting strategies. He enhances action plans and policies through cooperation with experts of different backgrounds and organisations. Tim is regularly asked to speak at events or workshops with national and international EV specialists. He holds degrees of universities at Leiden, Delft, Stellenbosch and Stockholm.

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