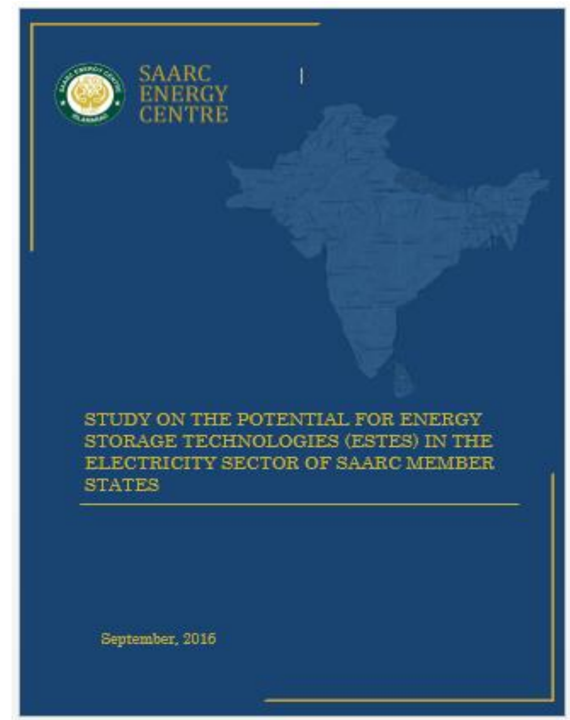
SAARC Dissemination Seminar

Potential for Energy Storage Technologies in Electricity Sector of SAARC Member States

Monday, 13th November 2017



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Why are we here today?

Share, discuss and add value to the draft report on the short term SAARC Study "Potential for Energy Storage Technologies in Electricity Sector (ESTES) of SAARC Member States" for moving ahead on the way to ensure sustainable energy access in South Asia.

Presentation Sequence

1. Study Team
2. Salient Features of the Study
3. Design of the Study Report
4. Chapters of the Report
    a. Introduction
    b. Setting the Perspective
    c. Electrical Energy Storage Technologies
    d. ESTES in the SAARC Region
    e. ESTES in India
    f. International Perspective
    g. Plan of Action
5. Questions and Answers

1. Study Team

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2. Salient Features of the Study

1. **Study rationale:** Energy storage globally emerging as a potential means to support existing electricity networks, facilitate the efficient operation of electricity markets, improving grid stability and meeting energy requirements of residential and commercial customers.
2. Several different energy storage technology types have been identified, investigated and discussed in the study including Pumped-Hydro, Flywheels, and battery based storage etc.

2. Salient Features of the Study

3. For each of the SAARC Member States, a sector assessment summary, based on research, was performed to highlight the important enablers and gaps for energy storage technologies.
4. In the overall SAARC Region, the need for storage is driven by factors such as <u>increasing renewable energy integration</u>, <u>low reserve margins</u>, <u>rural-electrification plans</u>, <u>stress on transmission</u> & <u>distribution networks</u> etc.
5. Globally, Energy Storage Applications are positioning themselves as one of the most important technologies for more reliable and sustainable energy systems.

2. Salient Features of the Study

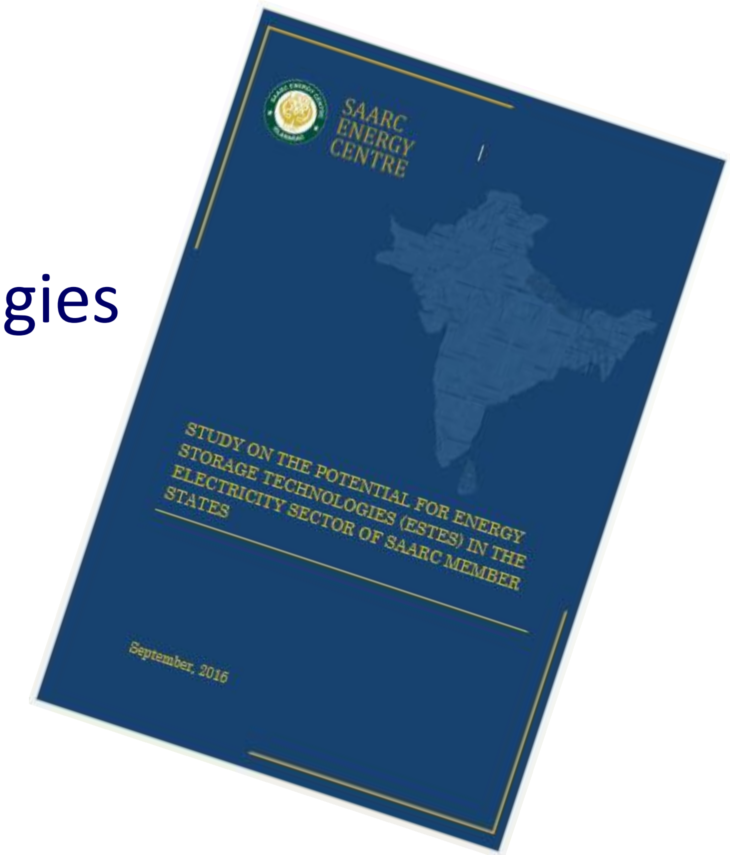
6. An assessment on the main global players was also performed. This assessment debriefs the key takeaways and describes specific efforts as positive lessons for the growth of ESTES.
7. Among the country profiles reviewed, the United States, China, and Japan are included.
8. These three nations have been in the loop of energy storage deployment as well as with many other services within the industry since the late 90s.
9. Three, together, account for more than 70% of this profitable global market

2. Salient Features of the Study

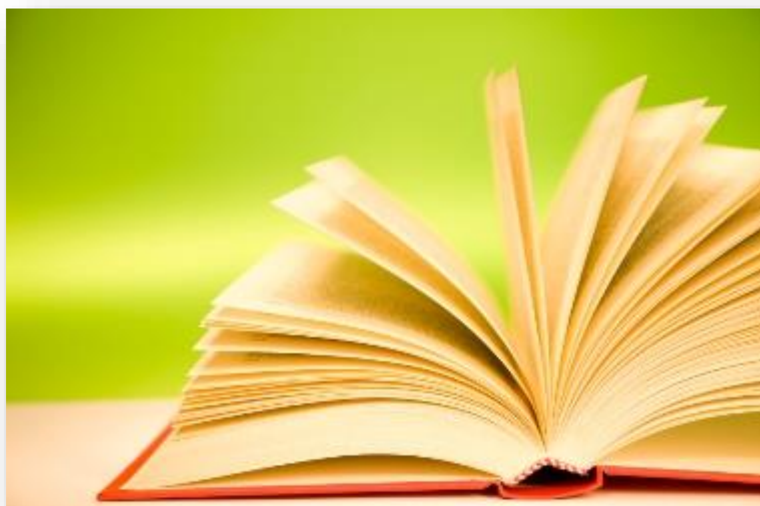
10. **Findings:** As SAARC Member States consider developing their power systems, energy storage options show potential of benefitting the region based on i) learning from international experiences; and ii) an assessment of local conditions and requirements.

3. Design of the Study Report

1. Introduction
2. Setting the Perspective
3. Electrical Energy Storage Technologies
4. ESTES in the SAARC Region
5. ESTES in India
6. International Perspective
7. Plan of Action



4. Chapters of the Study



a. Introduction

Scope of the Study

1. Assess energy storage market for applicable areas in Region
2. Review best ESS practices deployed on utility and commercial scale outside the Region
3. Identify barriers and suggest measures for promotion and adoption of EST in the Region
4. Explore financial aspects of energy storage options in electricity sector of the Region
5. Suggest measures for creating the enabling environment for EST applications in electricity sector of Member States
6. Suggest facilitation for relevant regional cooperation and institutional partnerships in capacity building

Scope of the Study

7. Explore commercial application potentials of electricity storage in remote electricity systems, distribution utility support, grid stability, residential and commercial storage systems using storage technologies such as batteries, flywheels, compressed gas, pumped hydro etc.

8. Propose a brief action plan for successful implementation of Energy Storage Policy and market development in the Region

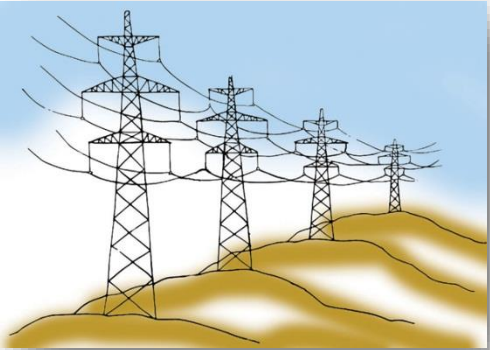
Study Methodology

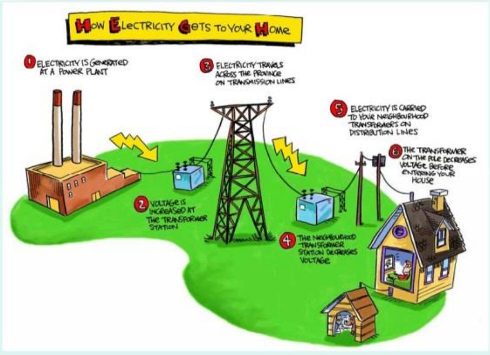
1. Developing an understanding of the Energy Storage Technologies for the Electricity Sector (ESTES)
2. Creating an international perspective to evaluate where ESTs are being deployed
3. Deeper understanding of the ESTES application areas
4. Generating a SAARC Member State power sector assessment profile to understand the extent to which each application area is relevant to a Member State
5. Assessing the gaps with respect to each assessment profile
6. Formulating recommendations for the SAARC Region in the light of the findings for ESTES Potential

b. Setting the Perspective

Elements of Power System

1. Generation
2. Transmission
3. Distribution
4. Customers





Introduction to ESTES

1. Energy and environment are two of the most challenging and major global issues. Energy storage thus becomes key element in achieving goals of energy sustainability that lead to energy and cost savings.
2. Electrical Energy Storage (EES) is a process of converting electrical energy into a form that can be stored for converting back to electrical energy when needed.
3. Such a process enables electricity to be produced at times of either low demand, low generation cost or from intermittent energy sources and to be used at times of high demand, high generation cost or when no other generation means is available.

Features of the ESTES

1. Meet short-term, random fluctuations in demand: avoid need for frequency regulation by the main plant. Can also provide ‘ride through’ for momentary power outages, reduce harmonic distortions, and eliminate voltage sags, surges.
2. Accommodate minute/ hour peaks in daily demand curve
3. Store the surplus electricity, generate overnight (during off-peak hours) to meet increased demand during the day
4. Store the electricity generated by renewable so as to match the fluctuating supply to the changing demand

ESTES Drivers

1. Ensuring optimal utilization of the energy system resource
2. Increasing use of variable renewable resources
3. Increasing energy access (e.g. via off-grid electrification using solar photovoltaic-(PV technologies)
4. Growing emphasis on electricity grid stability, reliability and resilience
5. Increasing end-use sector electrification (e.g. electrification of transport sector).

Energy Storage as a Structural Unit of a Power System

1. Power system planning becomes complex due to the diversity of electricity usage and particularly the fact that some of its uses, such as lighting and space cooling/ heating, are subject to substantial seasonal variation.
2. Generation itself, in any case, cannot be constant because of fluctuations mainly in hydroelectric generation and intermittency of renewable sources.
3. There should, therefore, be an intermediate unit between producer and customer that can coordinate them.

Parts of the Energy Storage Unit

Energy storage may be used in a power system in three different regimes:

1. Charge
2. Store
3. Discharge

An energy storage unit contains three parts:

1. Power transformation system (PTS)
2. Central store (CS)
3. Charge-discharge control system (CDCS)

Key Parameters for EST Comparison

1. Energy density per mass and volume
2. Cycle efficiency
3. Permissible number of charge–discharge cycles
4. Lifetime
5. Time of reverse and response time level
6. Optimal power output
7. Optimal stored energy
8. Siting requirements

Rationale for Energy Storage

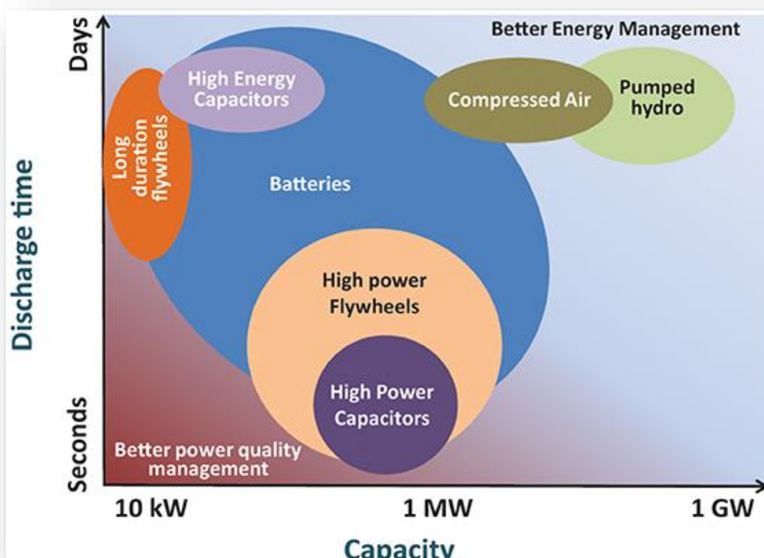
Before installing any device in a power system, a planning engineer should decide in what way the utility is going to use it. Energy storage could be deployed for one or more of the following reasons:

1. Secure power system generating capacities optimal remix
2. Improve the efficiency of a power system operation
3. Reduce primary fuel use by energy conservation
4. No alternative energy source available
5. Provide security of energy supply

Various Types of ESTES

1. Mechanical Energy Storage
2. Compressed Air Energy Storage (CAES)
3. Flywheel Energy Storage (FES)
4. Pumped Hydro Storage (PHS)
5. Electrical Energy Storage
6. Battery Energy Storage (BES)
7. Lead Acid Battery
8. Nickel Battery
9. Sodium-Sulfur Battery
10. Lithium Battery
11. Metal Air Battery
12. Flow Battery Energy Storage (FBS)
13. Superconducting Magnetic Energy Storage (SMES)
14. Super capacitor Energy Storage (SCES)
15. Chemical Energy Storage
16. Thermal Energy Storage
17. Sensible Heat Storage (SHS)
18. Latent Heat Storage (LHS)
19. Thermo-Chemical Energy Storage (TCES)

c. Electrical Energy Storage Technologies

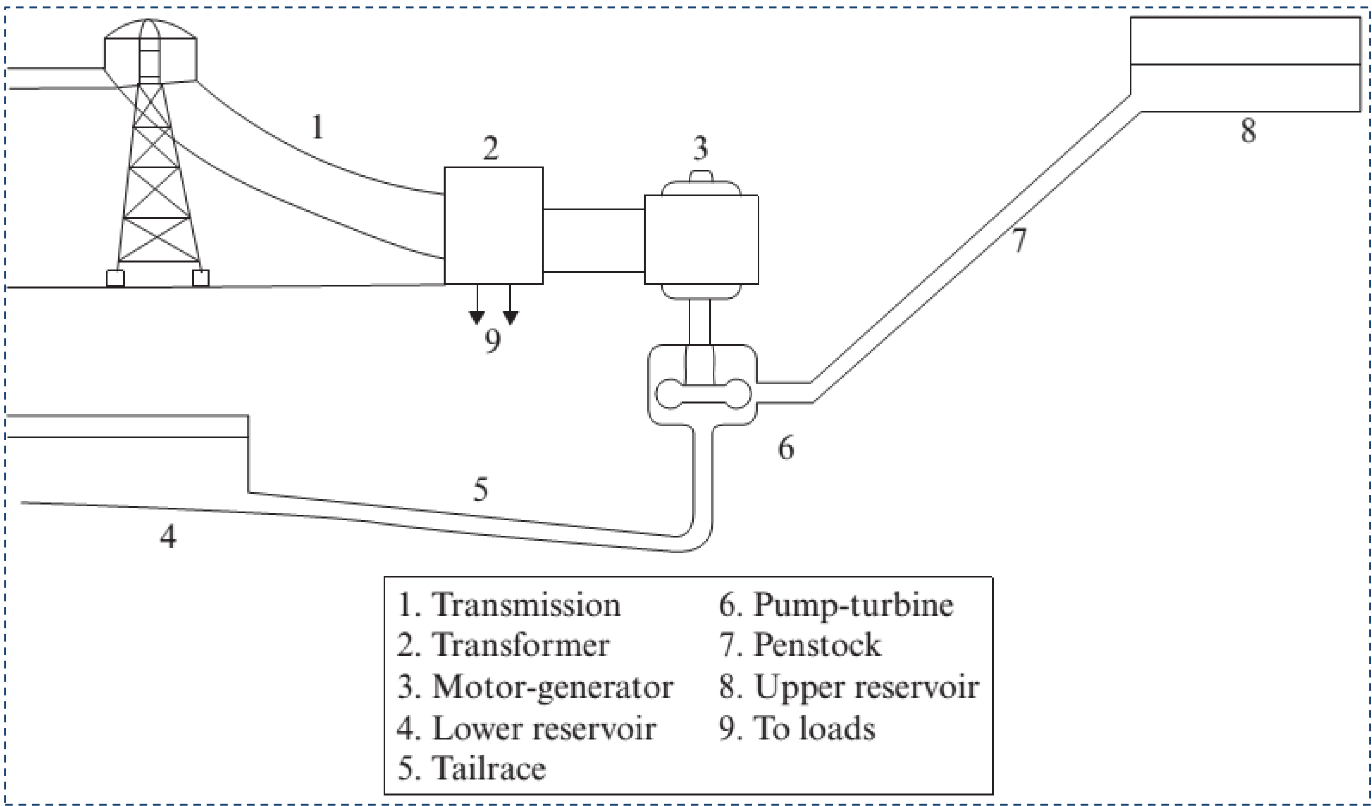


Pumped Hydro Storage

1. Hydro power became cheaper than gas for public lighting as early as 1881.
2. Hydroelectric power systems became widespread, associated developments for energy storage, using pumping water, followed in Italy & Switzerland in 1890s.
3. We have more than a century of experience in the storage of natural inflows as an essential feature of the exploitation of potential hydraulic energy.
4. Pumped hydro storage usually comprises the parts such as **an upper reservoir**, **waterways**, **a pump**, **a turbine**, **a motor**, **a generator** and a **lower reservoir**.

Pumped Hydro Storage

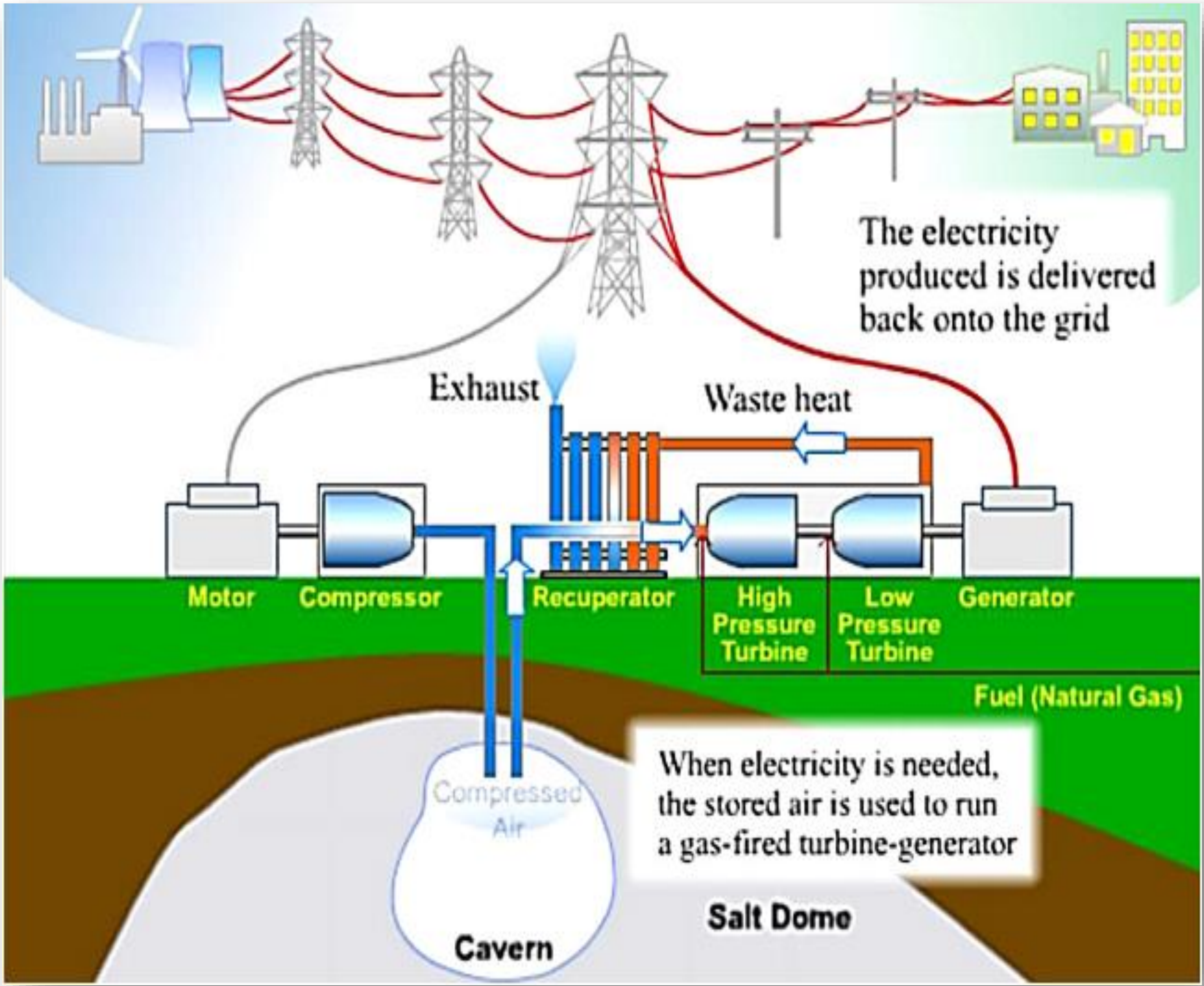
Typical efficiency of this process is about 70%, with 30% used in the pumping–generating cycle. More than 20,000 MW of pumped storage capacity exists in the United States.



Compressed Air Energy Storage

- Compressed gas allows using mechanical energy storage. When a piston is used to compress a gas, energy is stored which can be released when req'd by reversing piston movement.
- Sweden, Finland, Denmark, Yugoslavia, France, and the US have intervene. However, only 2 commercial units have been built: a 220 MW unit in 1977 in Germany and 110 MW unit with a 28-hour discharge capability in Alabama in 1991.
- Further research is required: (a) geological conditions for underground storage, (b) new approaches to underground cavern construction, (c) energy losses storing and moving air, (d) alternative concepts of air storage, and (e) corrosion effects on turbines from air contamination.

Compressed Air Energy Storage



Flywheel Energy Storage

- Storing energy in the form of mechanical kinetic energy (for comparatively short periods of time) in flywheels has been known for centuries. In inertial energy storage systems, energy is stored in the rotating mass of a flywheel.
- The application of flywheels for longer storage times is much more recent and has been made possible by developments in materials science and bearing technology.
- Energy capacity of flywheels, with respect to their weight and cost, has to date been very low
- Utilization has been was mainly linked to the unique possibility to deliver very high power for very short periods (mainly for special machine tools).

Battery Energy Storage

- Conversion from electrical to chemical energy (charging) and the reverse process (discharging) are per-formed by electrochemical reactions.
- Different electrochemical systems have been developed.
- For more than thirty years, efforts have been underway to develop and commercialize various battery systems for use by electric utilities at the scale of distributed energy storage in the size range of megawatts to tens of megawatts.
- Important Types include Lead Acid Battery, Nickel Battery, Sodium Sulphur Battery, Lithium Battery.

d. ESTES in the SAARC Region

SAARC

ESTES Requirement in South Asia

1. Power Sector of SAARC Region was investigated to assess potential for Energy Storage Technologies particularly with reference to increasing renewable potential, the state of the transmission and distribution sector and the underlying investment needs, the degree of electrification of a country and the need for micro-grids.
2. Power sector assessment also looked at factors such as the institutional strength of the power sector, regulatory and tariff regimes as well as their impact on the financial health of the sector.

ESTES Requirement in South Asia

3. The study results show that as the SAARC countries attempt to meet their energy sector targets, energy storage technologies may offer unique opportunities in several application areas.
4. The assessment methodology for potential is to look at application areas and how each technology would map onto these application areas e.g. what is the suitability of different energy storage technologies for an application such as ancillary services provision.
5. Then the assessment is made for the potential for each application area for all the SAARC Member States.

Assessment Methodology for ESTES Requirement in South Asia

1. Assess application areas for ESTES
2. Map suitability of the technology types to application areas
3. Assess suitability of application areas for each SAARC Country
4. Flexibility for SAARC Member States to choose Technology Type

ESTES Application Areas

Application Group	Potential Applications
Bulk Energy Services	Energy Arbitrage by utilizing demand shift properties of storage
	Electric Supply Capacity
Ancillary Services	Frequency Regulation
	Reserve Services (Spinning, non-spinning & supplemental)
	Voltage Support
	Black Start Support
	Other potential support services
Transmission Infrastructure	Infrastructure investment deferral by peak-levelling
	Transmission Congestion Relief

ESTES Application Areas

Application Group	Potential Applications
Distribution Infrastructure	Distribution infrastructure investment deferral peak-levelling allowing asset investment to be deferred
	Providing voltage support at distribution end
Customer-End Services	Power Quality adjustment
	Improving reliability including SAIDI/SAIFI Metrics
	Time of use energy shifting
	Demand side management

Mapping: Technologies vs Applications

Technology	Primary Application	Challenges
CAES	• Energy management • Backup and seasonal reserves • Renewable integration	• Geographically limited • Lower efficiency due to roundtrip conversion • Slower response time than flywheels or batteries • Environmental impact
Pumped Hydro	• Energy management • Backup and seasonal reserves • Regulation service also available through variable speed pumps	• Geographically limited • Plant site • Environmental impacts • High overall project cost

Mapping: Technologies vs Applications

Technology	Primary Application	Challenges
Fly Wheels	• Load leveling • Frequency regulation • Peak shaving and off peak storage • Transient stability	• Rotor tensile strength limitations • Limited energy storage time due to high frictional losses
Advanced Lead-Acid	• Load leveling and regulation • Grid stabilization	• Limited depth of discharge • Low energy density • Large footprint • Electrode corrosion limits useful life

Mapping: Technologies vs Applications

Technology	Primary Application	Challenges
NaS	• Power quality • Congestion relief • Renewable source integration	• Operating temperature required between 250° and 300° C • Liquid containment issues (corrosion and brittle glass seals)
Li-ion	• Power quality • Frequency regulation	• High production cost scalability • Extremely sensitive to over temperature, overcharge and internal pressure build-up • Intolerance to deep discharges

Mapping: Technologies vs Applications

Technology	Primary Application	Challenges
Flow Batteries	• Ramping • Peak shaving • Time shifting • Frequency regulation • Power quality	• Technology, not mature for commercial scale development • Complicated design • Lower energy density
SMES	• Power quality • Frequency regulation	• Low energy density • Material & manufacturing cost prohibitive
Electrochemical capacitors	• Power quality • Frequency regulation	• Currently cost prohibitive
Thermochemical energy storage	• Load leveling and regulation • Grid stabilization	• Currently cost prohibitive

Application Areas & Technology Suitability

Application	Description	CAES	Pumped Hydro	Fly wheels	Lead-Acid	NaS	Li-ion	Flow Batteries
Off-to-on peak intermittent shifting and firming	Charge at the sites of off peak renewable and/or intermittent energy sources; discharge energy into the grid during on peak periods	◐	◐	○	●	●	●	●
On-peak intermittent energy smoothing and shaping	Charge/discharge seconds to minutes to smooth intermittent generation and/or charge/discharge minutes to hours to shape energy profile	○	◐	◐	●	●	●	●
Ancillary service provision	Provide ancillary service capability in day ahead markets and respond to ISO signaling in real time	◐	◐	◐	◐	◐	◐	◐
Black start provision	Units sites fully charged, discharging when black start capability is required	◐	◐	○	●	●	●	●
Transmission infrastructure	Use an energy storage device to defer upgrades in transmission	○	○	○	●	●	●	●
Distribution infrastructure	Use an energy storage device to defer upgrades in distribution	○	○	○	●	●	●	●

Application Areas & Technology Suitability

Transportable distribution level outage mitigation	Use a transportable storage unit to provide supplemental power to end users during outages due to short term distribution overload situations	○	○	○	◐	●	●	●
Peak shifting downstream of distribution system	Charge device during off peak downstream of the distribution system (below secondary transformer); discharge during 2-4 hour daily peak	○	○	○	●	●	●	●
Intermittent distributed generation integration	Charge/discharge device to balance local energy use with generation. Sites between the distributed and generation and distribution grid to defer otherwise necessary distribution infrastructure upgrades	○	○	○	●	◐	◐	◐
End-user time-of-use rate optimization	Charge device when retail TOU prices are low and discharge when prices are high	◐	◐	○	◐	◐	◐	◐
Uninterruptible power supply	End user deploys energy storage to improve power quality and/or provide backup power during outages	○	○	◐	●	●	●	●
Micro grid formation	Energy storage is deployed in conjunction with local generation to separate from the grid, creating an islanded micro-grid	○	○	○	●	●	●	●

Definite suitability for application ●

Possible use for application ◐

Unsuitable for application ○

Assessed Gap Areas

1. Political Will
2. Policy Framework
3. Favourable Deployment Scenario
4. Institutional Arrangement
5. Infrastructure
6. Human Resource and Expertise
7. Market Conditions

Afghanistan - ESTES Potential Evaluation

Application	Potential	Explanatory Factors
Off-to-on peak intermittent shifting and firming	Medium	As renewable energy is still growing, this is not identified to be a high potential area
On-peak intermittent Energy smoothing and Shaping	Medium	Islanded networks mean that storage can give load-following support during that would have otherwise been provided by other generation in the system
Ancillary service provision	High	Requirement for frequency regulation in the islanded networks of Afghanistan is likely to be higher than for completely synchronised networks . ESTES benefits may also include potential voltage regulation and voltage stability provided by these technologies in the islanded networks
Black start provision	Low	Afghanistan is already operating several islanded networks – this suggests that there is sufficient black start capability in the overall power sector

Afghanistan - ESTES Potential Evaluation

Transmission Infrastructure	High	The islanded network nature of Afghanistan means that significant investment would be needed to build infrastructure – any application for deferring investment could be potentially high impact
Distribution Infrastructure	High	The same assessment for transmission infrastructure in Afghanistan applies to distribution infrastructure – the potential is higher because the capacities could be more distributed and the cost is easier to share with the consumer
Transportable Distribution level outage mitigation	Low	The sector needs other investments before this category is considered
Peak load shifting downstream of distribution system	High	By shifting load downstream, infrastructure can be more effectively utilized to provide higher effective capacities

Afghanistan - ESTES Potential Evaluation

Intermittent distributed Generation integration	High	Distributed generation has significant potential in Afghanistan especially given the renewable resources of Afghanistan leading to high application with storage systems
End-user time of-Use (ToU) rate optimization	Low	Already low energy tariffs mean low incentive for ToU optimization
Uninterruptible power supply (UPS)	High	Frequent outages mean that local population requires UPS support
Micro grid formation	High	As it may take significant time for the electrification of rural areas within Afghanistan, micro-grids can lead to acceleration of rural electrification. This can be coupled with the micro-hydro and small scale solar potential in Afghanistan.

Afghanistan – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Political Will	• Although the power sector is a priority for policy makers, specific support for ESTES has not been exhibited (↓)
Policy Framework	• Weak sector regulation historically (↓) • Recent improvements to regulatory environment have taken place (↑)
Institutional Arrangement	• Weak institutional capability (↓) • Institution building in progress through support of international development organizations (↑)
Infrastructure	• Significant war-periods have meant that infrastructure for supply chain development for ESTES has remained severely under-developed especially in rural areas where ESTES based micro-grids etc. have significant potential (↓)

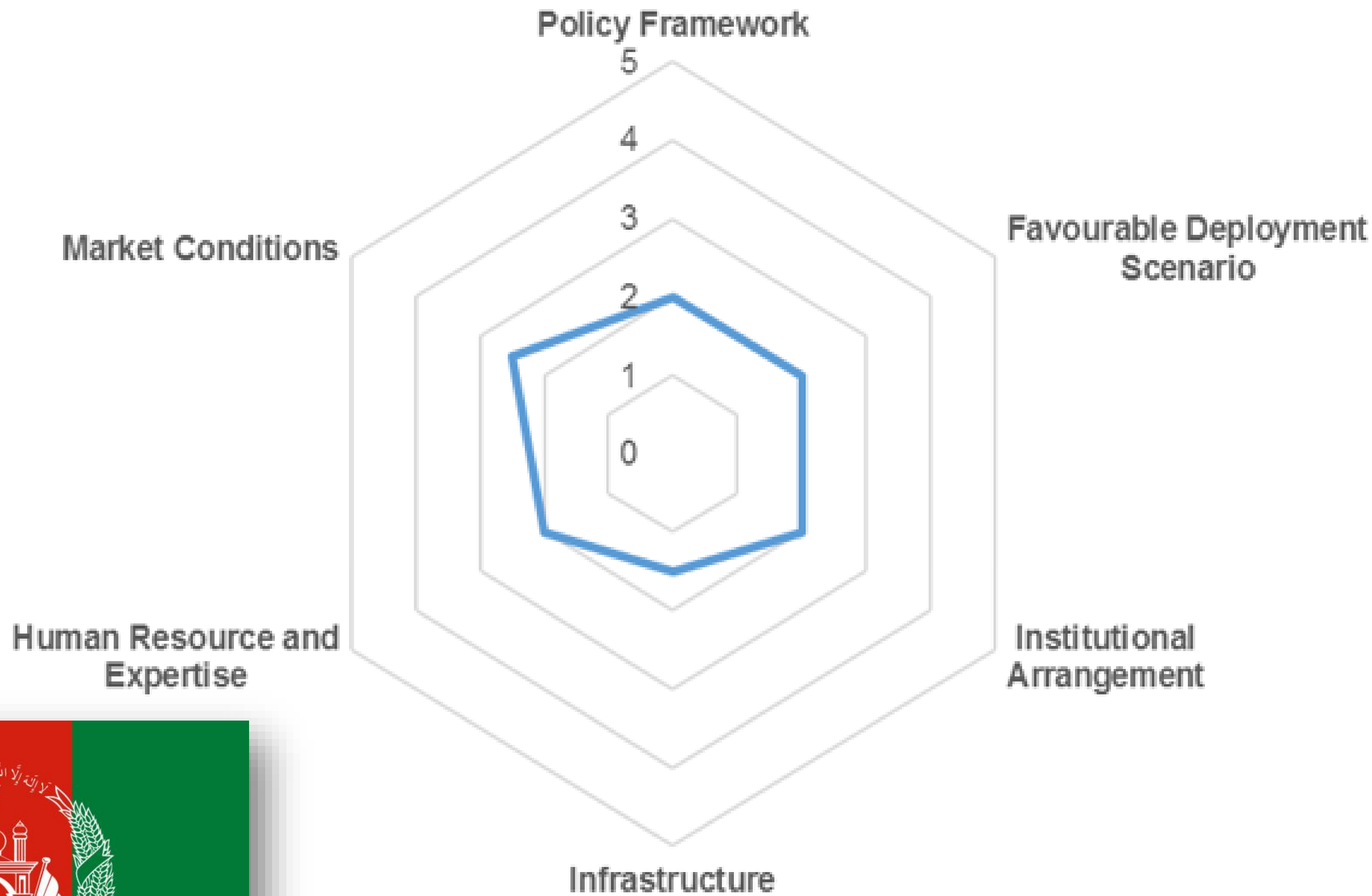
Afghanistan – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Human Resource and Expertise	• Limited expertise available which is local (↓) • ADB has identified lack of expert HR as an overall sector issue (↓) • ESTES international expertise difficult to bring to the country due to security situation (↓)
Market Conditions	• Non-liberalized market with fewer incentives available for private sector profitability through energy arbitrage and other revenue making (↓) • Low tariffs and overall sector financial sustainability low (↓) • Large non-grid connected areas and significant need for investment deferral means that there could be significant potential demand (↑)

Afghanistan – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Favourable Development Scenario	• As the sector's financials, regulation, capacity and renewable penetration increases so will the outlook for ESTES, however given that the rebuilding effort in Afghanistan will take significant time and the security situation remains uncertain, the score for the future development scenario also remains lower than determined by market factors alone

Afghanistan – Radar Map



Bangladesh - ESTES Potential Evaluation

Application	Potential	Explanatory Factors
Off-to-on peak intermittent shifting and firming	Medium	The low reliability of the generation sector in the country means that the during peak scenarios storage can be used to increase reliability
On-peak intermittent Energy smoothing and Shaping	Low	Very low renewable penetration for this to be relevant at this stage
Ancillary service provision	Low	Frequency regulation can be provided by the high amount of thermal power plants in the system which have very fast response rate especially for the gas fired plants
Black start provision	Low	Evidence suggest that there is sufficient black start capability in the overall power sector
Transmission Infrastructure	Medium	The sector assessment showed that significant future investment may be required in the Transmission infrastructure of the country increasing the Investment deferral value of ESTES technologies

Bangladesh - ESTES Potential Evaluation

Distribution Infrastructure	Medium	The same assessment for transmission infrastructure in Bangladesh applies to distribution infrastructure – the potential is higher because the capacities could be more distributed and the cost is easier to share with the consumer
Transportable Distribution level outage mitigation	Low	The sector needs other investments before this category is considered
Peak load shifting downstream of distribution system	High	By shifting load downstream, infrastructure can be more effectively utilized to provide higher effective capacities
Intermittent distributed Generation integration	High	Distributed generation based storage has significant potential in Bangladesh as evidenced by deployment of domestic level solar systems

Bangladesh - ESTES Potential Evaluation

Intermittent distributed Generation integration	High	Distributed generation based storage has significant potential in Bangladesh as evidenced by deployment of domestic level solar systems
End-user time of-Use (ToU) rate optimization	Low	Already low energy tariffs mean low incentive for ToU optimization. The difference between the peak and off-peak tariffs is very low
Uninterruptible power supply (UPS)	High	Chronic outages mean that local population requires UPS support
Micro grid formation	High	With 30% of the country remaining to be electrified, micro-grids can lead to acceleration of electricity to areas in conjunction with solar power deployment

Bangladesh – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Political Will	• Political will in the country is likely to be linked to keeping tariffs affordable which would mean insufficient cost recovery (↓)
Policy Framework	• Evidence found that correct policy making direction being taken with regards to storage as found in the battery storage disposal formulation (↑)
Institutional Arrangement	• Weak institutional capability including slow regulatory reform (↓)
Infrastructure	• Local supply chain for storage especially in the form of battery storage exists (↑)

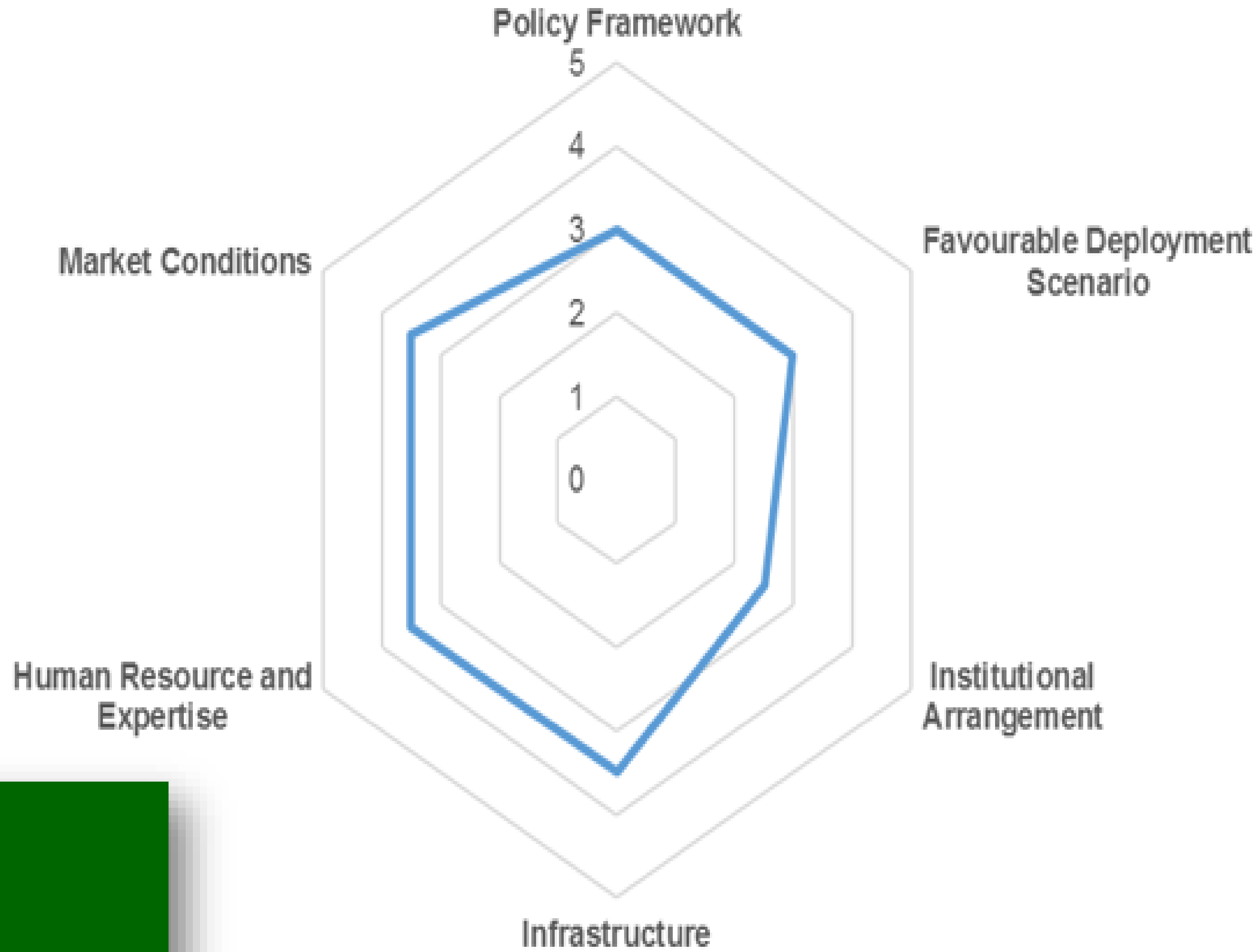
Bangladesh – Gap Assessment

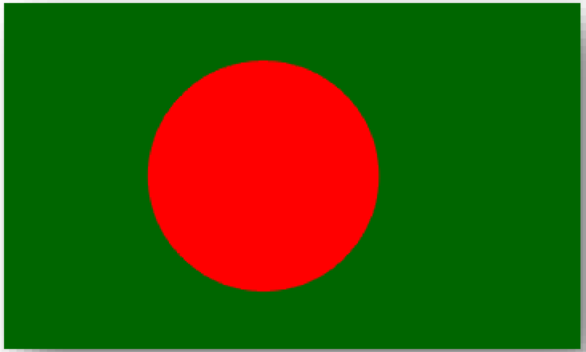
Issue Area	Summary of Explanatory Factors and Trends
Human Resource and Expertise	• Local industry has expertise available which is also local (↑) • Presence of academic and research institutions (↑)
Market Conditions	• Non-liberalized market with fewer incentives available for private sector profitability through energy arbitrage and other revenue making (↓) • Low tariffs and overall sector financial sustainability low (↓) • Large non-grid connected areas and significant need for investment deferral means that there could be significant potential demand (↑) • Incentivized house-hold solar schemes (↑)

Bangladesh – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Favourable Development Scenario	• As the sector's financials, regulation, capacity and renewable penetration increases so will the outlook for ESTES (↑)

Bangladesh – Radar Map





Bhutan - ESTES Potential Evaluation

Application	Potential	Explanatory Factors
Off-to-on peak intermittent shifting and firming	High	The ability to shift storage patterns combined with potential renewable deployment will prove helpful as it has the ability to increase the export potential for Bhutan – however the final ability would depend on the degree of co-relation between the consumption patterns of India and Bhutan
On-peak intermittent Energy smoothing and Shaping	Medium	The low size of the network in winter when hydro power is limited and reliance would be on other resources especially renewables, storage would help smooth the intermittency of the generation
Ancillary service provision	High	Requirement for frequency regulation in the very small network of Bhutan would likely be high given lower spinning reserves and inertia in the system This also means that ancillary services such as reserve etc. are likely to be valued highly from a system security perspective as the system has lower capacity to deal with shocks

Bhutan - ESTES Potential Evaluation

Black start provision	Low	Evidence suggests that there is sufficient black start capability in the overall power sector
Transmission Infrastructure	Medium	Considerable need has been identified for transmission investment – part of this may be offset by storage which allows for peak-shaving
Distribution Infrastructure	Medium	The same assessment for transmission infrastructure in Bhutan applies to distribution infrastructure
Transportable Distribution level outage mitigation	Low	The sector needs other investments before this category is considered
Peak load shifting downstream of distribution system	Medium	Can lead to investment deferral

Bhutan - ESTES Potential Evaluation

Intermittent distributed Generation integration	Medium	Distributed generation has potential in Bhutan especially given the renewable resources of Bhutan leading to application with storage systems
End-user time of-Use (ToU) rate optimization	Low	Already low energy tariffs mean low incentive for ToU optimization
Uninterruptible power supply (UPS)	Medium	UPS support is likely to be needed in winter when hydro resources
Micro grid formation	Medium	As it may take significant time for the electrification of rural areas within Bhutan, micro-grids can lead to off-grid electrification – however the potential is limited by the relatively high electrification rate achieved by Bhutan

Bhutan – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Political Will	• Bhutan displays a strong focus on improving the state of the electricity sector(↑)
Policy Framework	• Recent improvements to regulatory environment have taken place like tariff development for cost recoveries (↑) • Overall the policies of the power sector have been identified as inadequate (↓)
Institutional Arrangement	• Institutional capability has been improving through corporatization of the sector and delivery of results has been successful (↑ • Government has limited experience of project formulation
Infrastructure	• Infrastructure levels required for supply chain development of ESTES locally e.g. manufacturing etc. are not present to a high degree in Bhutan (↓)

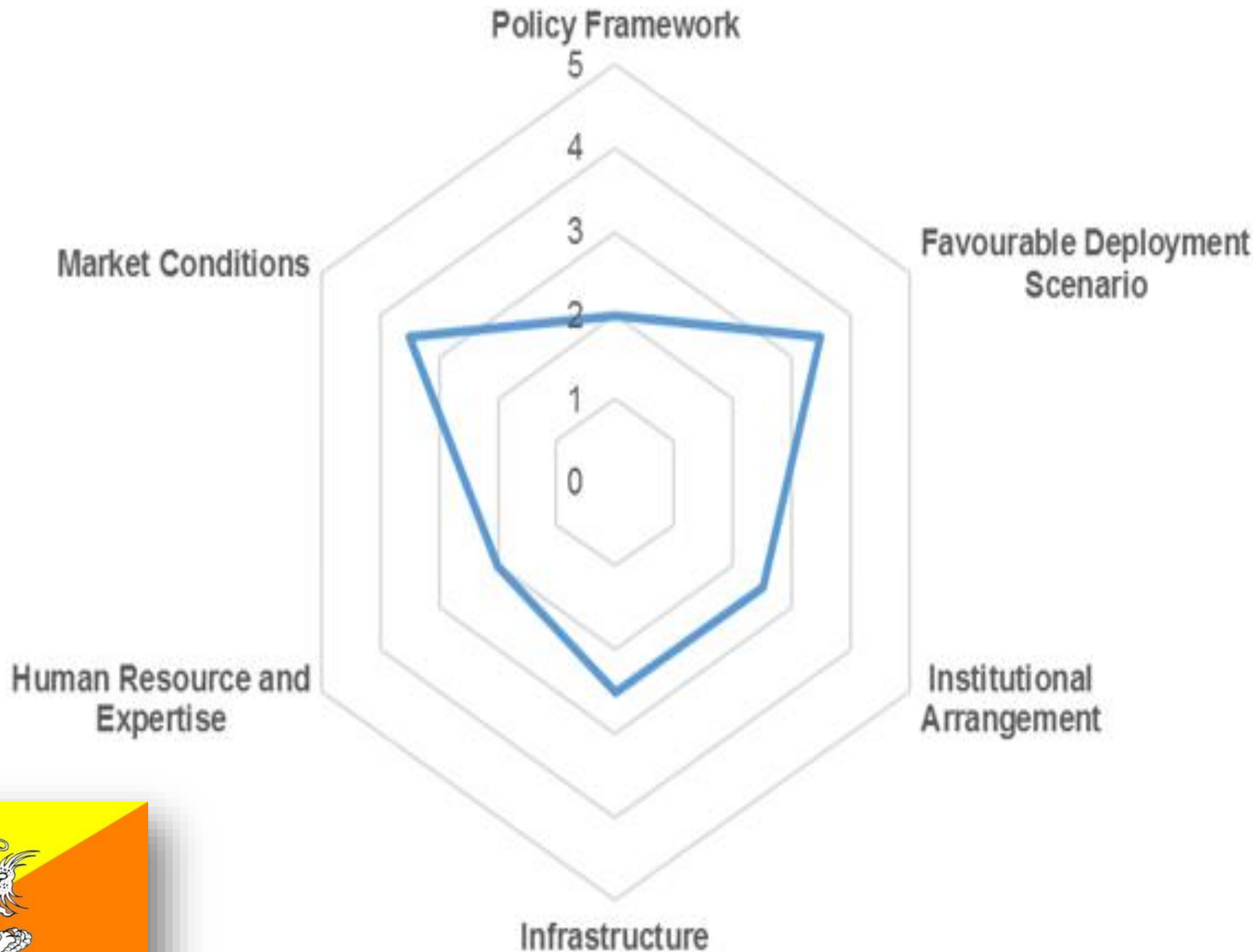
Bhutan – Gap Assessment

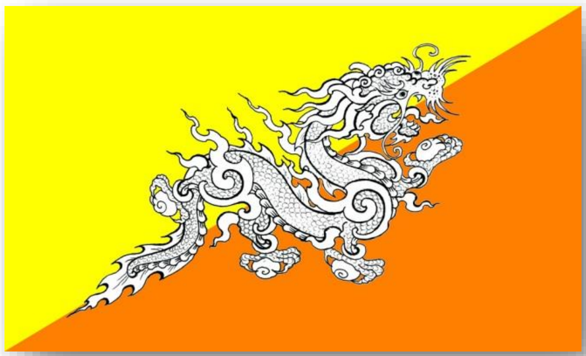
Issue Area	Summary of Explanatory Factors and Trends
Human Resource and Expertise	• Limited academic or professional expertise available which is local (↓) • ADB has identified lack of expert human resource as an overall sector issue (↓)
Market Conditions	• Non-liberalized market with fewer incentives available for private sector profitability through energy arbitrage and other revenue making (↓) • Potential for export exists (↑) • Profit making power sector (↑) • However, lack of commercial business practices still exists (↓)

Bhutan – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Favourable Development Scenario	• As the sector's financials, regulation, capacity and renewable penetration increases so will the outlook for ESTES, however given that the volume of ESTES deployment is dependent on the size of the power sector of Bhutan, which is relatively small, the score for the future development scenario also remains lower than determined by market factors alone

Bhutan – Radar Map





Maldives - ESTES Potential Evaluation

Application	Potential	Explanatory Factors
Off-to-on peak intermittent shifting and firming	High	The ability to shift storage patterns combined with potential renewable deployment will prove helpful as it has the ability to lower the fuel usage of Maldives which heavily impacts the economy
On-peak intermittent Energy smoothing and Shaping	Medium	In the future as renewables resources grow, storage would help smooth the intermittency of the generation
Ancillary service provision	High	Requirement for frequency regulation in the very small island networks of Maldives would likely be high given lower spinning reserves and inertia in the system This also means that ancillary services such as reserve etc. are likely to be valued highly from a system security perspective as the system has lower capacity to deal with shocks
Black start provision	Low	Sufficient black start capability expected in the islanded networks in the form of the diesel generation deployed

Maldives - ESTES Potential Evaluation

Transmission Infrastructure	Medium	Considerable need has been identified for transmission investment – part of this may be offset by storage which allows for peak-shaving
Distribution Infrastructure	Medium	The same assessment for transmission infrastructure in Maldives applies to distribution infrastructure
Transportable Distribution level outage mitigation	Low	The sector needs other investments before this category is considered
Peak load shifting downstream of distribution system	Medium	Potential for investment deferral exists in the small islanded networks by shifting load downstream

Maldives - ESTES Potential Evaluation

Intermittent distributed Generation integration	Medium	Storage with distributed generation has significant potential for Maldives given its explicit policy aims of low carbon development and renewable energy deployment
End-user time of-Use (ToU) rate optimization	Low	Already low energy tariffs mean low incentive for ToU optimization
Uninterruptible power supply (UPS)	Medium	UPS support although needed is not projected to be extremely significant as the generation mix yields more towards utilizing generators
Micro grid formation	High	The islanded nature of the Maldives grid yields particular applications for storage deployment in the grid of Maldives

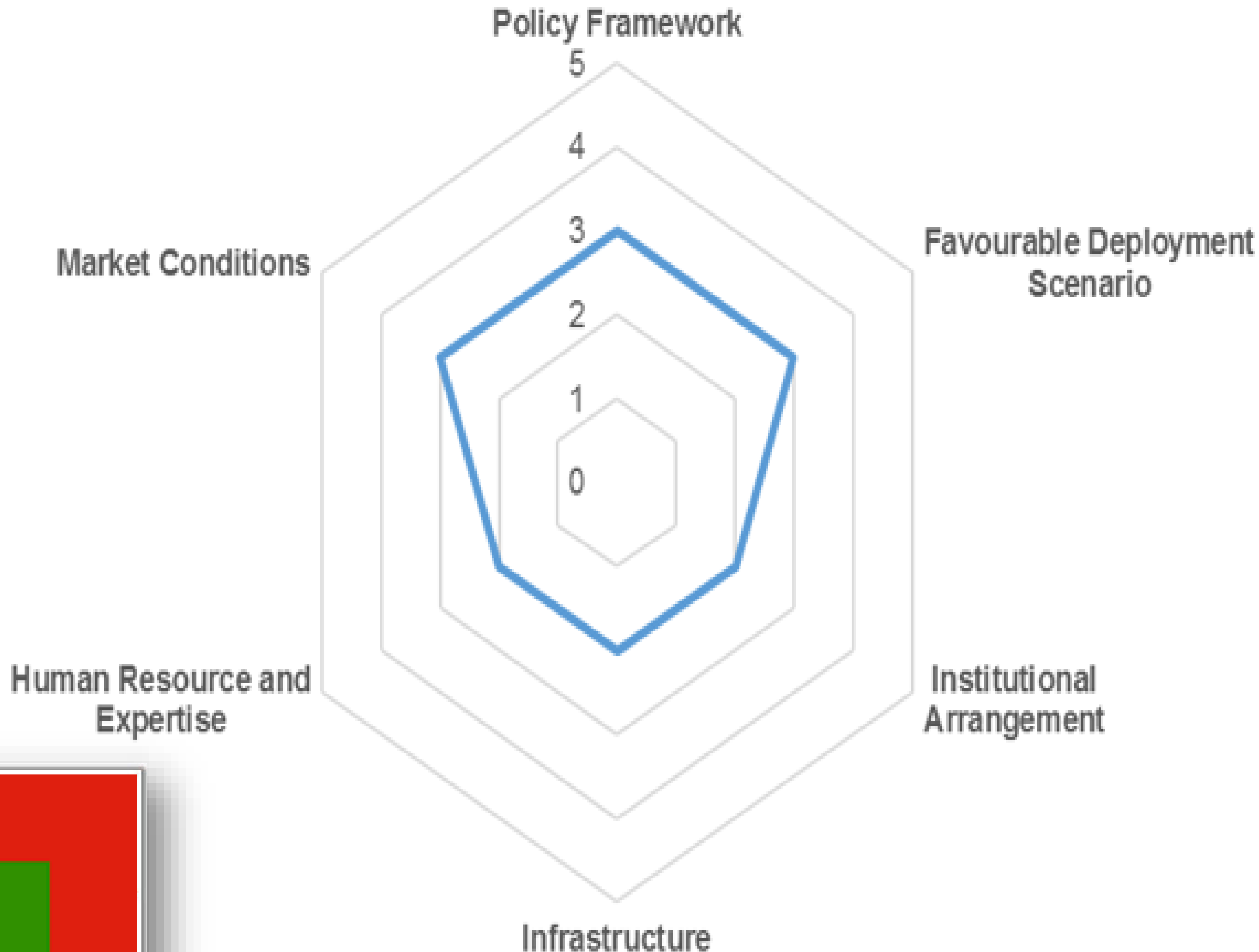
Maldives – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Political Will	• Maldives set to improve power sector with reforms (↑)
Policy Framework	• Clearly defined but very high-level policy (↑) • Policy development underway includes evaluating new technologies (↑)
Institutional Arrangement	• Institutional capability requires significant improvement with limited evidence of sector level planning (↓) • Utility capacity has been identified to be limited to deploy project based on new technologies (↓) • Commercial contracts capacity underdeveloped (↓) • Limited independence of the regulator (↓)
Infrastructure	• Infrastructure levels required for ESTES supply chain development locally e.g. manufacturing not present to a high degree – significant import would be required (↓)

Maldives – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Human Resource & Expertise	• Lack of expert human resource as an overall sector issue (↓)
Market Conditions	• Non-liberalized market with fewer incentives available for private sector profitability through energy arbitrage and other revenue making (↓) • Potential for lowering fuel import (↑) • Lack of commercial arrangement and instruments (↓) • High risk perception of investors (↓)
Favourable Development Scenario	• Volume of ESTES deployment is dependent on the size of the power sector of Maldives, which is relatively small, the score for the future development scenario also remains lower than determined by market factors alone

Maldives – Radar Map



Nepal - ESTES Potential Evaluation

Application	Potential	Explanatory Factors
Off-to-on peak intermittent shifting and firming	Medium	The ability to shift storage patterns combined with increased generation deployment will prove helpful as it provides the ability to utilize generation using off-peak times to increase supply during peak times – Potential achievable is limited by the low hydro production in winter
On-peak intermittent Energy smoothing and Shaping	Medium	In the future as renewables resources grow, storage would help smooth the intermittency of the generation
Ancillary service provision	High	Requirement for frequency regulation in the smaller network of Nepal would likely be high given lower spinning reserves and inertia in the system
Black start provision	Low	Sufficient black start capability expected in the networks

Nepal - ESTES Potential Evaluation

Black start provision	Low	Sufficient black start capability expected in the networks
Transmission Infrastructure	High	Considerable need has been identified for transmission investment – part of this may be offset by storage which allows for peak-shaving
Distribution Infrastructure	Medium	The same assessment for transmission infrastructure in Nepal applies to distribution infrastructure
Transportable Distribution level outage mitigation	Low	The sector needs other investments before this category is considered

Nepal - ESTES Potential Evaluation

Peak load shifting downstream of distribution system	High	By shifting peak loads downstream, the delivery capability of the system can be enhanced which can lower bottlenecks of the system
Intermittent distributed Generation integration	Medium	Storage with distributed generation has significant potential for Nepal given its renewable potential
End-user time of-Use (ToU) rate optimization	Low	Already low energy tariffs mean low incentive for ToU optimization
Uninterruptible power supply (UPS)	Medium	UPS support needed to lower impact of electricity cuts
Micro grid formation	High	With presence of certain electrified areas, micro-grids with renewable generation can accelerate reliable supply of power

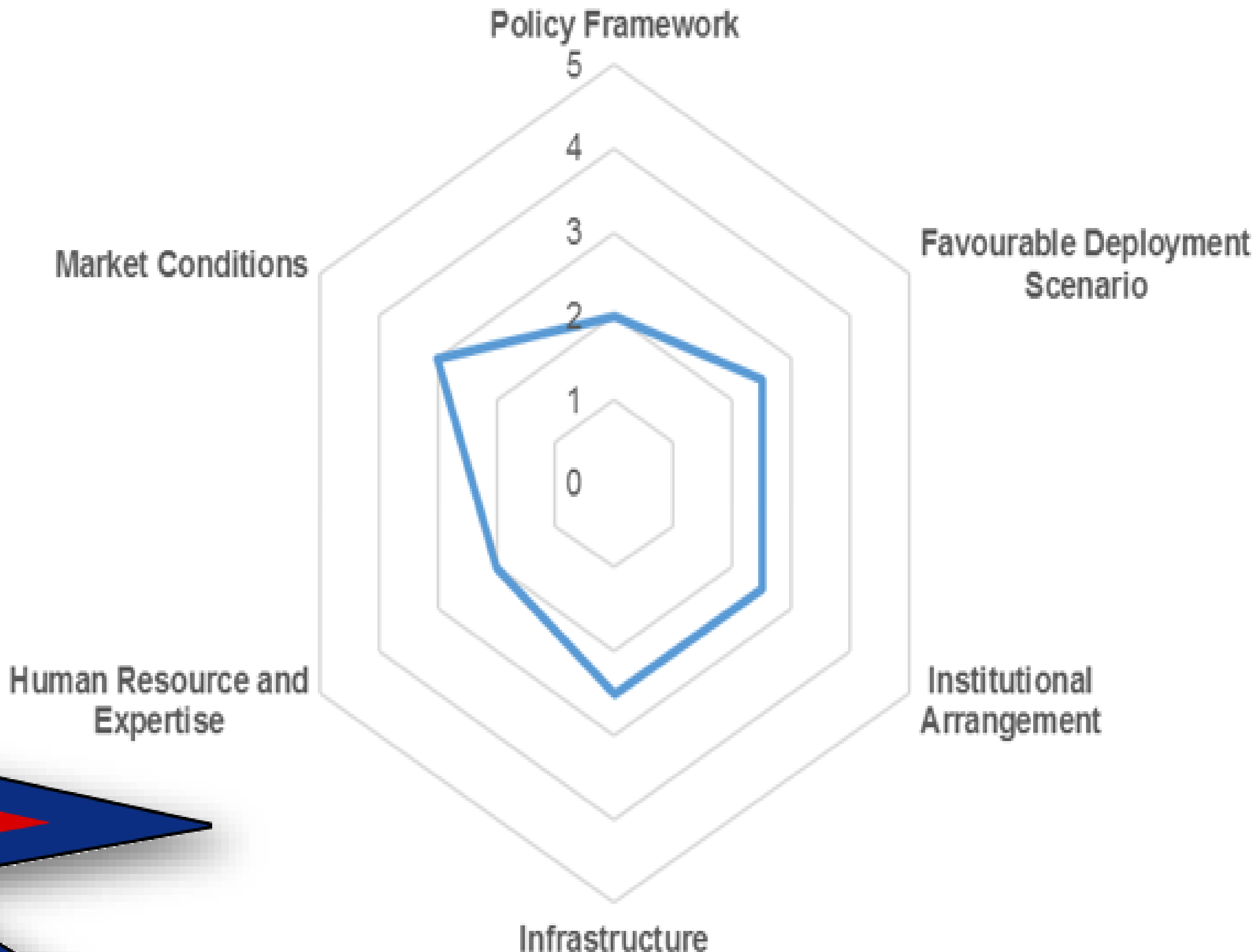
Nepal – Gap Assessment

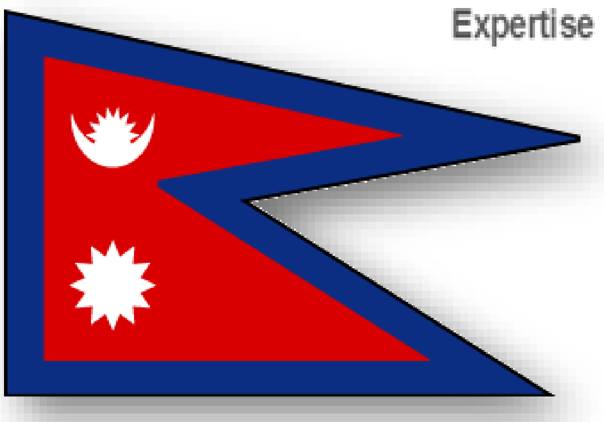
Issue Area	Summary of Explanatory Factors and Trends
Political Will	• Evidence found suggested focus on political with regards to tariff levels (↓)
Policy Framework	• Power Sector Policies are currently developing and have been inconsistent historically (↓)
Institutional Arrangement	• Institutional capability requires significant improvement with limited evidence of sector level planning (↓) • Some recent improvement in terms of developing institutions and legal measures for tacking issues such as electricity loss (↑)
Infrastructure	• Infrastructure levels required for supply chain development of ESTES locally e.g. manufacturing etc. are not present to a high degree in Maldives – significant import would be required (↓)

Nepal – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Human Resource & Expertise	• Lack of expert human resource as an overall sector issue (↓)
Market Conditions	• Non-liberalized market with fewer incentives available for private sector profitability through energy arbitrage and other revenue making (↓) • Lack of commercial arrangement and instruments (↓) • High risk perception of investors due to financial situation of the sector (↓)
Favourable Development Scenario	• Given political will rises, organizations such as the IFC, World Bank and the ADB can provide significant assistance in development of the sector which will have spill overs for storage technology deployment

Nepal – Radar Map





Pakistan - ESTES Potential Evaluation

Application	Potential	Explanatory Factors
Off-to-on peak intermittent shifting and firming	Medium	The ability to shift storage patterns combined with potential renewable deployment will prove helpful as lack of reserves in the system means storage can be utilized to store excess energy from solar power plants at day or wind during night and re-supply to the grid during peak times. This is limited by the quantity of renewables that will eventually be deployed
On-peak intermittent Energy smoothing and Shaping	Medium	The ability to shift storage patterns combined with potential renewable deployment will prove helpful as lack of reserves in the system means storage can assist in lowering the impact of renewable intermittency

Pakistan - ESTES Potential Evaluation

Ancillary service provision	High	In case of insufficient reserves in the system, storage based systems can provide temporary frequency support during a large-unit trip giving enough time for load-shedding to be done and add to system security. This can provide protection from system wide blackouts for which media evidence was found
Black start provision	Low	Sufficient black start capability expected in the network with generation being distributed across the different regions of the country
Transmission Infrastructure	Medium	Considerable need has been identified for transmission investment – part of this may be offset by storage which allows for peak-shaving
Distribution Infrastructure	High	The study team assessment suggests that the distribution infrastructure in Pakistan is significantly overloaded – utilizing storage to

Pakistan - ESTES Potential Evaluation

		shift load between peak and off-peak times can increase utilization
Transportable Distribution level outage mitigation	Low	The sector needs other investments before this category is considered
Peak load shifting downstream of distribution system	High	System capacity can be enhanced if peak loads can be shifted downstream and saved off using storage during peak times
Intermittent distributed Generation integration	Low	Storage with distributed generation has shown slow pick-up in Pakistan although recent Grid Code developments seem supportive

Pakistan - ESTES Potential Evaluation

Intermittent distributed Generation integration	Low	Storage with distributed generation has shown slow pick-up in Pakistan although recent Grid Code developments seem supportive
End-user time of-Use (ToU) rate optimization	Low	Already low energy tariffs mean low incentive for ToU optimization
Uninterruptible power supply (UPS)	High	High level of power outages suggests that UPS support is needed by most households in the country
Micro grid formation	Low	Relatively high level of electrification in the country suggests the micro-girds would only be necessary in the few distant areas without electricity

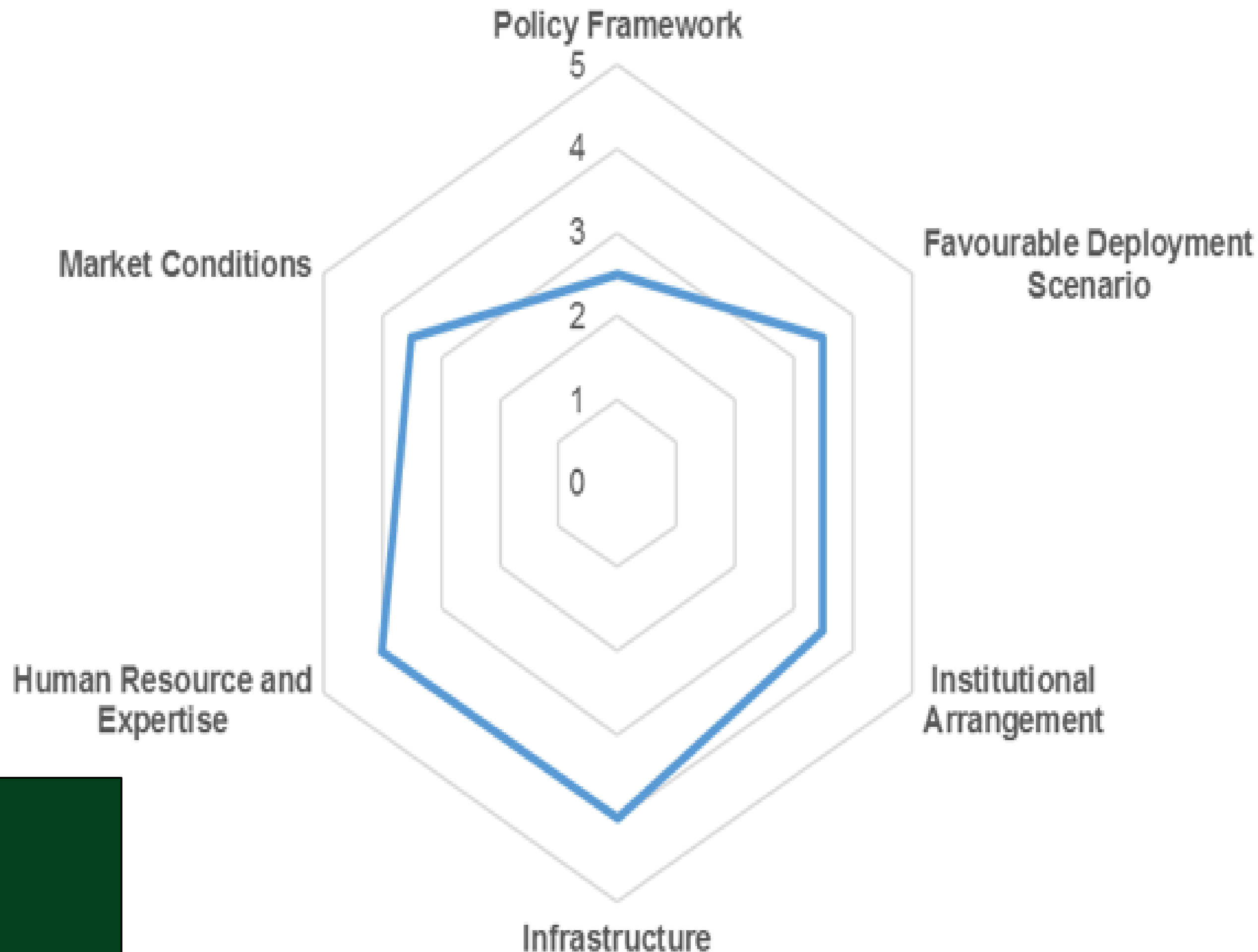
Pakistan – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Political Will	Power sector issues are politically crucial – hence high level of political will is expected to be present (↑)
Policy Framework	Historical evidence of frequent policy changes linked to government changes lead in sector wide uncertainty (↓)
Institutional Arrangement	• Although Transmission Utility capacity and capability is well developed in some areas, capacity is much more reduced at a distribution company level • Commercial contracts capacity underdeveloped (↓) • Increasing independence of the regulator needed (↓) • Formation of new CPPA agency step in strengthening institutions (↑)
Infrastructure	Infrastructure levels required for ESTES supply chain development. Can be developed with relative ease (↑)

Pakistan – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Human Resource & Expertise	• Although in some areas sector level specialists are missing but on the whole, the country has good human resource potential with quality academic institutions and research capabilities compared to peers (↑)
Market Conditions	• Non-liberalized market with fewer incentives available for private sector profitability through energy arbitrage and other revenue making (↓) • Lack of commercial arrangement and instruments (↓) • High risk perception of investors (↓) • Very high need for some areas such as UPS deployment (↑)
Favourable Development Scenario	Depends on the level of institutional and policy reform that can be achieved by the sector however, the country has good potential for storage deployment. The current needs however are likely to be focused on enhancing generation capability

Pakistan – Radar Map



Sri Lanka - ESTES Potential Evaluation

Application	Potential	Explanatory Factors
Off-to-on peak intermittent shifting and firming	High	40% difference between peak and off peak consumption patterns makes this a high potential application as there is sufficient generation available during off-peak times to be able to charge storage
On-peak intermittent Energy smoothing and Shaping	Low	Sufficient generation in the system available for this to be graded low
Ancillary service provision	Medium	Currently low penetration of renewables with good generation reserve. In the future as renewables grow, this may grow as well
Black start provision	Low	Sufficient black start capability expected in the network
Transmission Infrastructure	High	Transmission infrastructure has been identified to be stressed due high peak-to-off-peak load differences coupled with historic underinvestment in infrastructure. Using

Sri Lanka - ESTES Potential Evaluation

Distribution Infrastructure	High	The same assessment for transmission infrastructure in Sri Lanka applies to distribution infrastructure
Transportable Distribution level outage mitigation	Low	The sector needs other investments before this category is considered
Peak load shifting downstream of distribution system	High	40% difference between peak and off peak consumption patterns makes this a high potential application
Intermittent distributed Generation integration	Medium	Storage with distributed generation has significant potential for Sri Lanka given its

Sri Lanka - ESTES Potential Evaluation

		explicit policy aims of high renewable energy deployment in the future
End-user time of-Use (ToU) rate optimization	High	Recent ToU approved tariffs mean high cost of electricity during peak times which is 4 times as expensive as during peak times. This creates financial incentive for storage
Uninterruptible power supply (UPS)	Low	Sufficient generation in system - however low grid reliability means that sometimes UPS are needed
Micro grid formation	Low	Very high degree of electrification (98%) in Sri Lanka means that there is limited rationale to deploy micro-grids

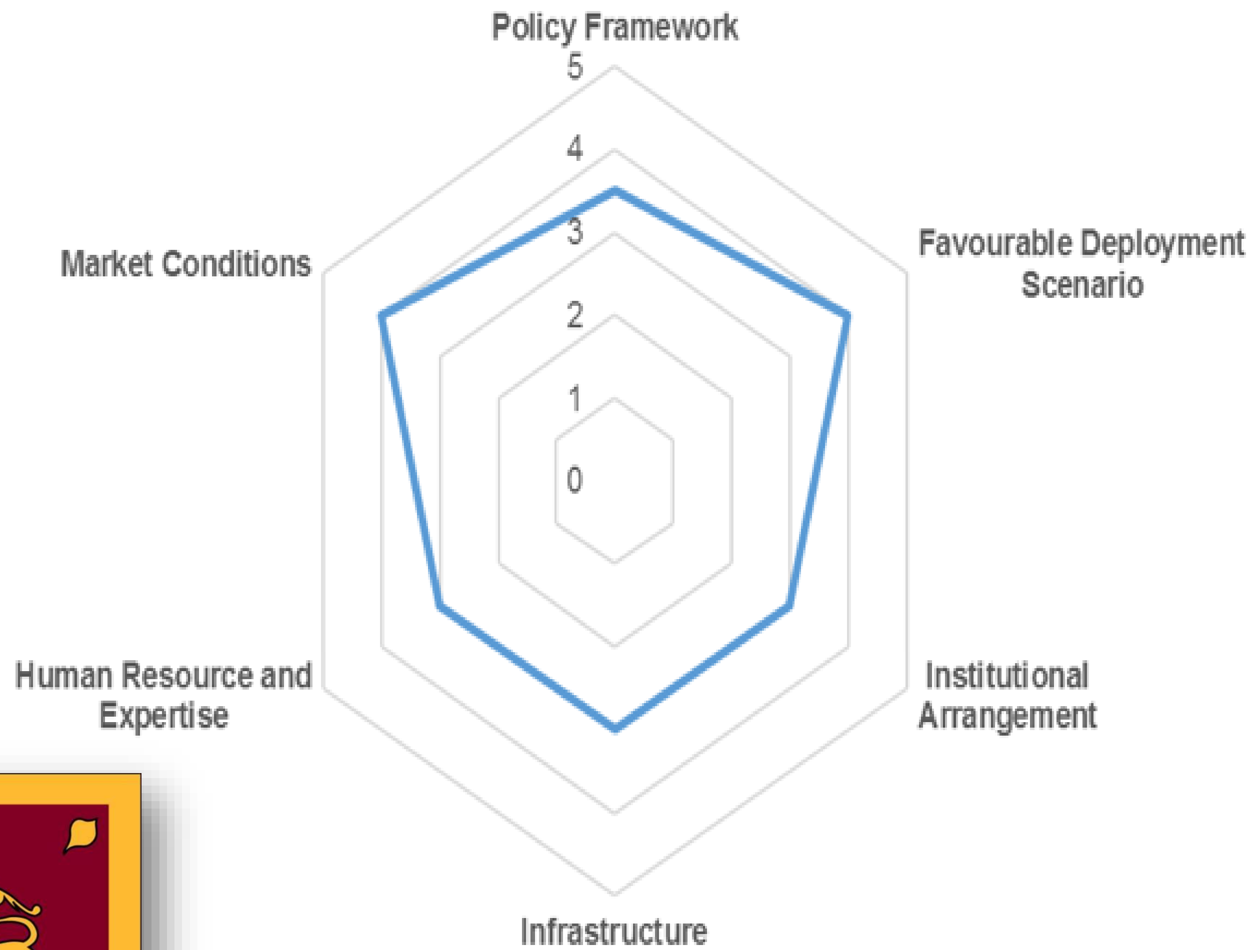
Sri Lanka – Gap Assessment

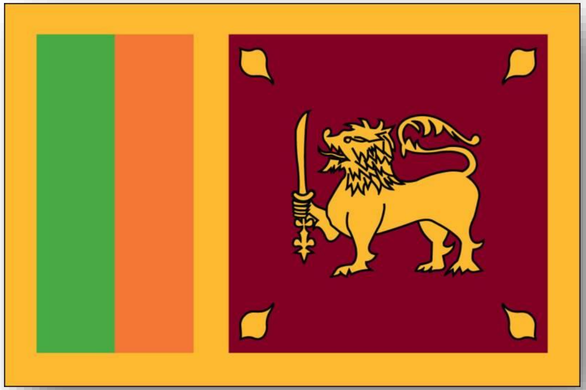
Issue Area	Summary of Explanatory Factors and Trends
Political Will	Although political will is hard to assess but the overall direction of the power sector in Sri Lanka shows that there is political will to rectify the sector situation (↑)
Policy Framework	• Clearly defined but very high-level policy (↑) • Overall the policies of the power sector have been identified as adequately forward looking (↑)
Institutional Arrangement	Institutional capability require improvement especially on technical and commercial frameworks (↓)
Infrastructure	Infrastructure levels required for supply chain development of ESTES locally e.g. manufacturing etc. are not present to a high degree in Sri Lanka – significant import would be required (↓)

Sri Lanka – Gap Assessment

Issue Area	Summary of Explanatory Factors and Trends
Human Resource & Expertise	The human resource within the sector and expertise can be regarded as relatively better compared to several other South Asian peers (↑)
Market Conditions	• Non-liberalized market with fewer incentives available for private sector profitability through energy arbitrage and other revenue making (↓) • ToU regime makes it possible to • Potential for lowering fuel import (↑) • Lack of commercial arrangement and instruments (↓) • High risk perception of investors (↓)
Favourable Development Scenario	Given that the volume of ESTES deployment can be positively co-related with renewable energy deployment due to

Sri Lanka – Radar Map





e. ESTES in India

f. International Perspective

g. Plan of Action

Suggested Plan of Action

1. Managing political and institutional pre-conditions;
2. Sensitizing decision makers on Legislation & Policy Regime;
3. Facilitating human resource and academia involvement;
4. Governments to provide relevant infrastructure and creating mass awareness for broader acceptance; and
5. Materializing regional cooperation and institutional partnerships with respect to capacity building

5. Questions and Answers


THANK
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