

# Renewable Energy and Implications on Energy Security: Case of CAREC Countries

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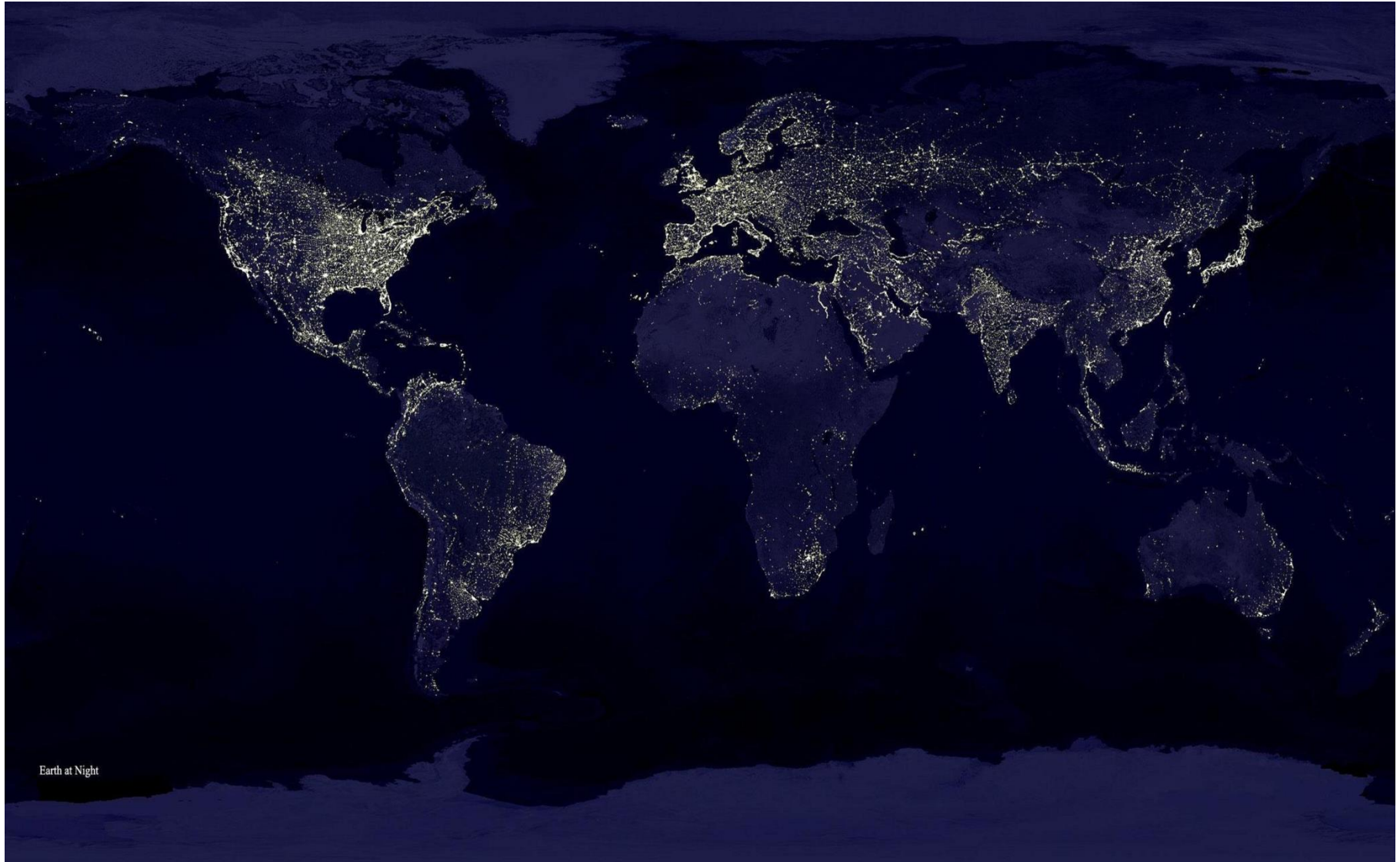
Achieving Energy Security in Asia: Role of Renewable Energy

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# Outline

- Introduction
- Definitions of Energy Security
- Analytical Frameworks
  - Diversity
  - 4-A Framework
- Applications
  - Diversity
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  - Individual Country Analyses: Azerbaijan and Kazakhstan
  - CAREC Countries as a whole
- Evaluations and Interpretations
- Policy Implications and Suggestions
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# World at Night from Satellite



# What is Energy Security?

- Availability of energy in a broader sense
  - How much energy resources each country or the world has
    - Proven reserves
    - Reserve-production ratio (R/P)
  - R/P for world fossil fuels (at the end of 2016)

	Oil	Coal	NG
Proven Reserves	1,706.7 thousand million barrels	1,139,331 million tons	6,588.8 trillion cubic feet
R/P (years)	50.6	153	14.2

Source: BP Statistical Review of World Energy (2017)

# CAREC Countries' Energy Endowment

	Oil	NG	Coal	Hydro	Renewables
Proven Reserves (With China)	63.9 thousand million barrels	935.7 trillion cubic meters	276,574 million tons*	276 million tons oil equivalent (toe)**	86.6 million toe***
Without China	38.2	746.2	32,564	2.9	0.5
R/P (years)	11.4	40.3	67.5	N/A	N/A
Remarks (share of world total)	3.74%	0.6%	24.28%	30.32%	20.64%

Note: Renewables: other than biofuels

\*: China (244,010), \*\*: China (263.1), \*\*\* China (86.1)

Source: BP Statistical Review of World Energy (2017)

# Definition of Energy Security:

## Diversity or Diversification

- In fuel sources
  - Various fossil fuels and renewable energy sources
- In the sources of supply or supplier
  - Piped natural gas vs LNG
- Concepts and Corresponding Indicators (e.g., Stirling, 2010)
  - Variety: The number of options
  - Balance: The share of the most dominant option
  - Disparity: Differences in various options

# Diversity of the Malaysia's Energy Sector: Measures and Implications

- Variety
  - The number of energy resources utilized ( $1/N$ )
  - The lower, the better (i.e., higher  $N$  is better)
- Balance
  - The share of the most utilized energy resource (%),
  - The lower, the better (i.e., less dominant is better)
- Disparity
  - The share of fossil fuels utilized (%)
  - The lower, the better (i.e., high difference is better)

Source: Chang and Yao (2012)

# Diversity of CAREC Countries' Energy Sector: Measures

	Variety	Balance	Disparity
Measures	1 / Number of energy resources utilized (1/N)	Share of the most utilized fuel (could be oil or natural gas)	Share of fossil fuels utilized
Values			
Interpretations	Options are pretty diversified	The single option is slightly dominant	Options are highly similar, little different

Possible Policy Implications:

1. To reduce the dominance of a single fuel
2. To develop renewable energy resources and expand their usage





Jeju Island, Korea





Hoover Dam on Colorado River  
Arizona and Nevada, U.S.A.





Rooftop Solar Panel  
Kunming, Yunnan  
China







Ala Moana Shopping Center, Honolulu, Hawaii, U.S.A.

# The Economic Definition of Energy Security

- Definition
  - The adequate and reliable supply of energy resources at a reasonable price (e.g., Bielecki, 2002, Energy Commission Annual Report 2013)
- Adequacy
  - Endowment of (energy) resources
- Reliability
  - Delivery of (energy) resources
- Reasonable price
  - Balance between efficiency and fairness

# Four Perspectives on Energy Security

- Scientific aspect
  - Availability of (energy) resources
- Engineering or technological aspect
  - Applicability of (energy) technologies
- Environmental aspect
  - Acceptability of (energy) resources or technologies by society
- Economic aspect
  - Affordability of (energy) resources

# Energy Security: Definition and Concepts

- Adequate and reliable supply of energy resources at a reasonable price
- Availability
  - Fossil fuels and nuclear energy: Proven reserves
  - Renewable energy resources: Potential
- Applicability
  - Technologies to harness useful energy from the proven reserves and the potential
- Acceptability
  - How a society or an economy is willing to use an energy resource
- Affordability
  - How affordable the cost of using an energy resource (i.e., useful energy) is

# Workings of the 4-A Framework

- No proven reserve or renewable potential, no delivery of energy resources
- Lack of applicable technologies makes the available reserves or the renewable potential untapped
  - Solar energy
- If a society or an economy shuns using the available reserves or the renewable potential, then the applicable technologies will not be utilized and the installed capacity will be stranded
  - Coal
  - Nuclear energy
- If the cost of delivering energy to the end-user is not affordable, then no delivery of energy resource is made



# The 4-A Framework of Energy Security: Possible Indicators

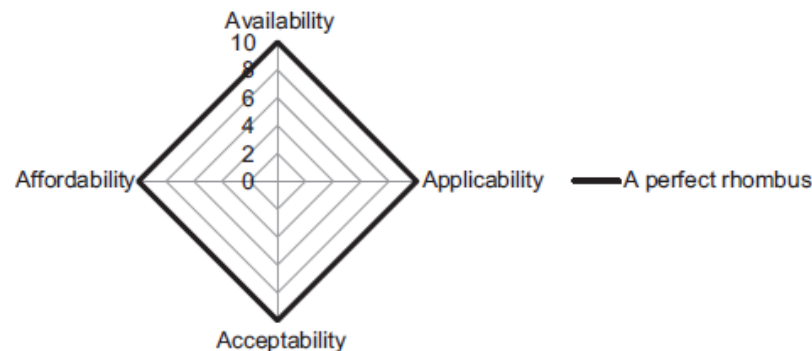
- There could be many indicators. Here are some examples

	Availability	Applicability	Affordability	Acceptability
IAEA	<ul style="list-style-type: none"> <li>Share of households without electricity</li> <li>Reserves to production ratio</li> <li>Diversification of Primary Energy Demand</li> <li>Dependence on imports (mtoe)</li> </ul>	<ul style="list-style-type: none"> <li>Share of households without electricity</li> <li>R&amp;D</li> <li>Energy use per unit GDP</li> <li>commercial and transport energy intensity</li> <li>energy efficiency measures</li> </ul>	<ul style="list-style-type: none"> <li>Share of household income spent on fuel and electricity</li> <li>Energy use per capita</li> </ul>	<ul style="list-style-type: none"> <li>GHG emissions per capita</li> <li>GHG emissions per unit GDP</li> <li>Ambient air pollutant concentrations</li> </ul>
APERC	<ul style="list-style-type: none"> <li>Reserves to production ratio (R/P ratio)</li> </ul>	<ul style="list-style-type: none"> <li>Energy use per unit GDP</li> <li>Industrial, household, agricultural, commercial and transport energy intensity</li> </ul>	<ul style="list-style-type: none"> <li>Energy use per capita</li> </ul>	<ul style="list-style-type: none"> <li>GHG emissions per capita</li> <li>GHG emissions per unit GDP</li> </ul>
IEEJ and ASEAN Center for Energy		<ul style="list-style-type: none"> <li>Energy use per unit GDP</li> <li>Industrial, household, agricultural, commercial and transport energy intensity</li> </ul>	<ul style="list-style-type: none"> <li>Energy use per capita</li> </ul>	

Source: Tongsopit, Kittner, Chang, Aksornkij and Wangjinariran (2016)

# Energy Security in CAREC Countries

- The 4-A framework is applied to all CAREC countries to examine the status of energy security
- Time span: 2011 to 2015
- Values of individual indicators are normalized
- The inside area of the rhombus indicates the overall status of energy security



- A collective analysis, not an individual country analysis

# Energy Security in CAREC Countries: Selected Indicators

The 4-A Framework is applied to CAREC countries (4x2 matrix)

Dimension		Indicators
Availability (Endowment)	AV1	Reserve-Production (R/P) ratio of oil (years)
	AV2	Share of renewable electricity output (%)
Applicability (Efficiency)	AP1	CAREC countries' energy intensity (MJ/\$2011 PPP GDP)
	AP2	CAREC countries' carbon intensity (t CO <sub>2</sub> /toe)
Acceptability (Preference)	AC1	CO <sub>2</sub> emissions per capita (t CO <sub>2</sub> /person)
	AC2	Share of renewable energy consumption (%)
Affordability (Capability)	AF1	Energy consumption per capita (toe/person)
	AF2	Access to electricity (%)

# Data Sources

- BP Statistical Review of World Energy, various years
- World Bank, World Development Indicators
- International Energy Agency (IEA), Statistics/Indicators

# Energy Security in CAREC Countries: Data Normalization

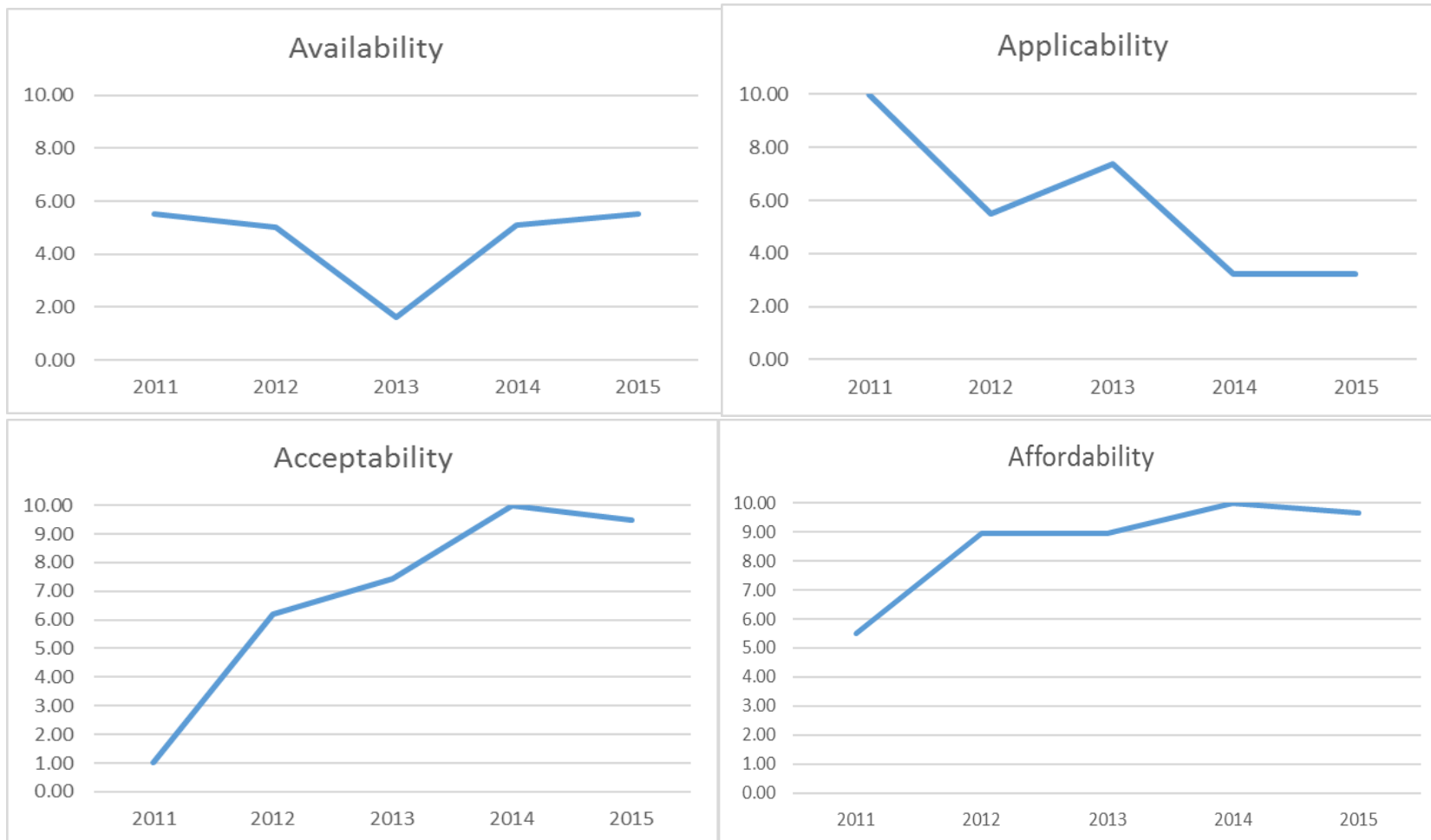
- For each A, the maximum and the minimum values are identified
- The cardinal value of each indicator is normalized by the following formula
  - For the indicator, “the higher, the better”
    - $1 + \frac{\text{Actual value} - \text{Minimum}_A}{\text{Maximum}_A - \text{Minimum}_A} * (10 - 1)$
  - For the indicator, “the lower, the better”
    - $1 + \frac{\text{Actual value} - \text{Maximum}_A}{\text{Minimum}_A - \text{Maximum}_A} * (10 - 1)$

# Normalized Values of 4A's: Azerbaijan

	2011	2012	2013	2014	2015			2011	2012	2013	2014	2015
AV1	1.00	6.32	1.00	9.18	10.0		AP1	10.0	1.00	7.03	5.42	5.42
AV2	10.0	3.73	2.24	1.00	1.00		AP2	10.0	10.0	7.75	1.00	1.00
<b>AV</b>	<b>5.50</b>	<b>5.02</b>	<b>1.62</b>	<b>5.09</b>	<b>5.50</b>		<b>AP</b>	<b>10.0</b>	<b>5.50</b>	<b>7.39</b>	<b>3.21</b>	<b>3.21</b>
AC1	1.00	6.91	7.43	10.0	8.97		AF1	1.00	7.92	7.92	10.0	9.31
AC2	1.00	5.44	7.44	10.0	10.0		AF2	10.0	10.0	10.0	10.0	10.0
<b>AC</b>	<b>1.00</b>	<b>6.18</b>	<b>7.43</b>	<b>10.0</b>	<b>9.49</b>		<b>AF</b>	<b>5.50</b>	<b>8.96</b>	<b>8.96</b>	<b>10.0</b>	<b>9.65</b>

Notes: **Values in red** are assumed to be the same as the one in the preceding year as the data for the year was not available

# Energy Security in Azerbaijan: Trend of Each Dimension

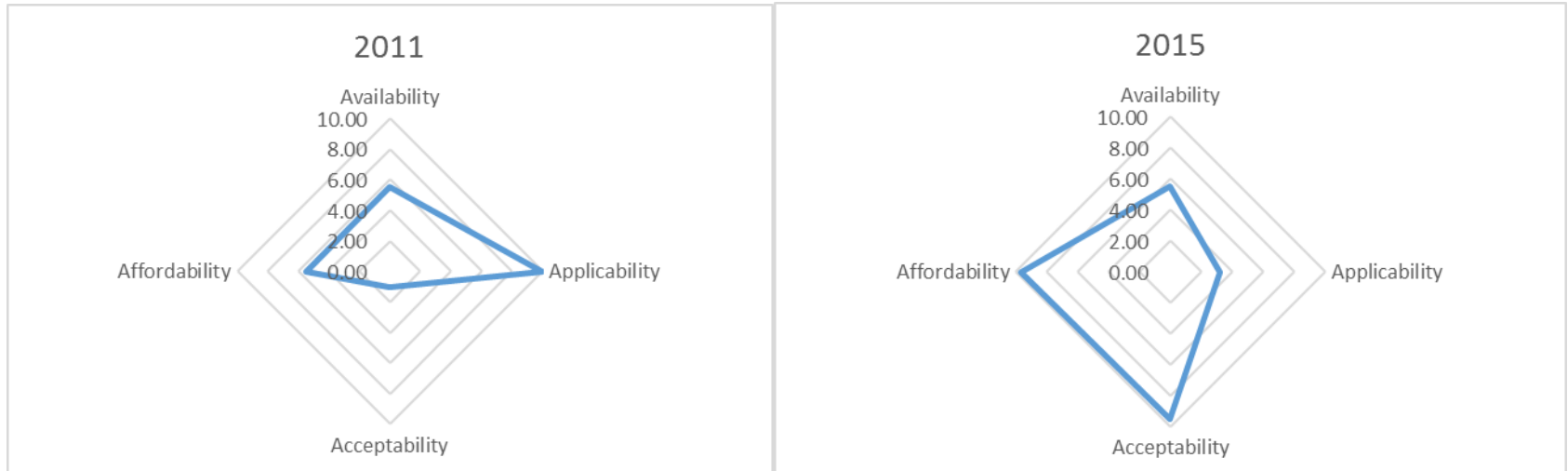


# Energy Security Status in Azerbaijan





# Energy Security Status in Azerbaijan 2011 vs 2015



For the 4-A perspectives, between 2011 and 2015, Acceptability and Affordability appear to have improved while Applicability appears to shrink considerably and Availability remains to be the same.

	2011	2012	2013	2014	2015
Rhombus	50.38	81.01	74.02	99.67	96.39

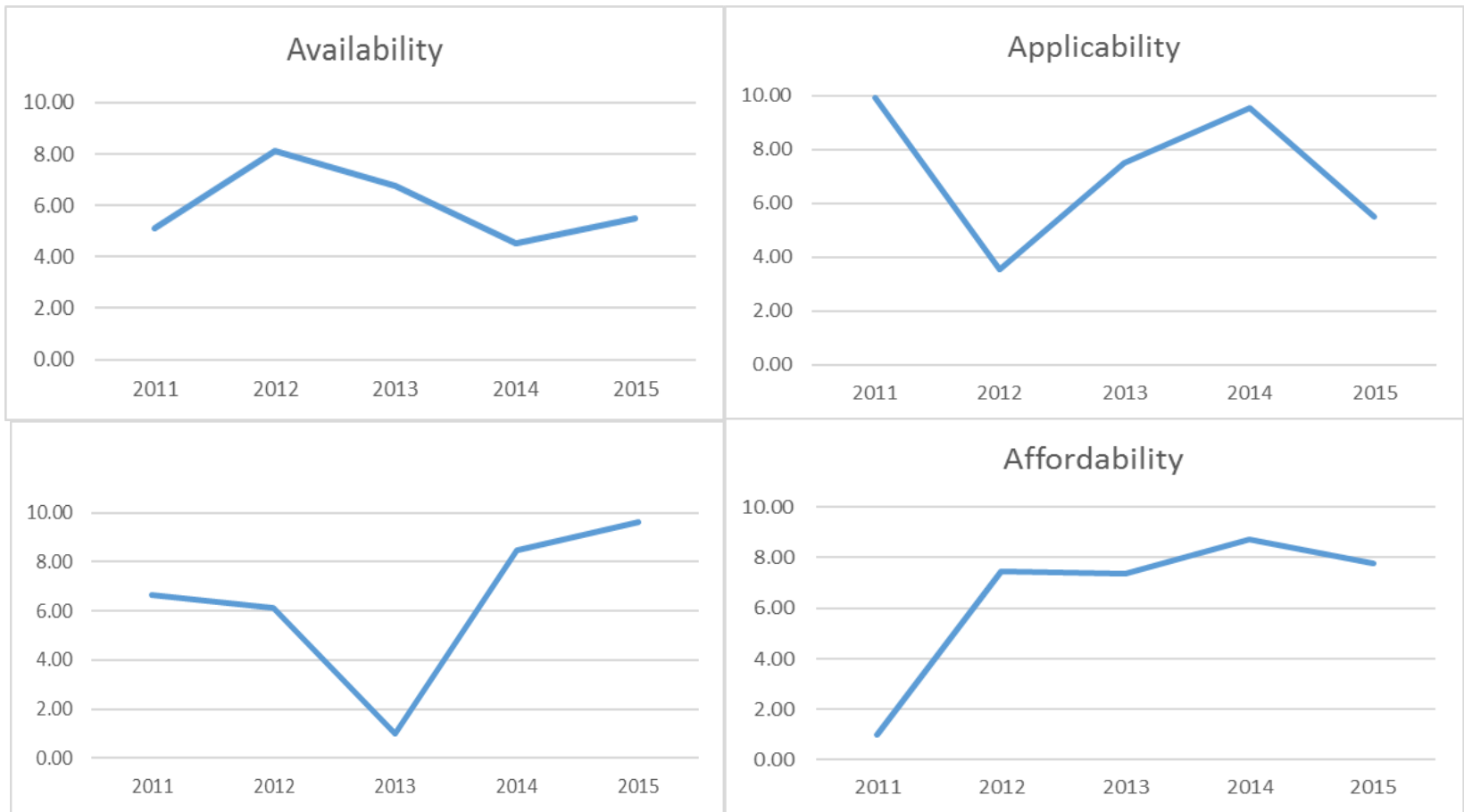
# Normalized Values of 4A's: Kazakhstan

	2011	2012	2013	2014	2015			2011	2012	2013	2014	2015
AV1	1.00	6.28	3.54	8.04	10.0		AP1	9.81	1.00	7.12	10.0	10.0
AV2	9.18	10.0	9.99	1.00	1.00		AP2	10.0	6.10	7.90	9.10	1.00
<b>AV</b>	<b>5.09</b>	<b>8.14</b>	<b>6.77</b>	<b>4.52</b>	<b>5.50</b>		<b>AP</b>	9.90	<b>3.55</b>	<b>7.51</b>	<b>9.55</b>	<b>5.50</b>
AC1	3.25	4.50	1.00	7.70	10.0		AF1	1.00	10.0	6.79	7.43	5.50
AC2	10.0	7.75	1.00	9.20	9.20		AF2	1.00	4.95	7.96	10.0	10.0
<b>AC</b>	<b>6.63</b>	<b>6.13</b>	<b>1.00</b>	<b>8.45</b>	<b>9.60</b>		<b>AF</b>	1.00	<b>7.47</b>	<b>7.37</b>	<b>8.71</b>	<b>7.75</b>

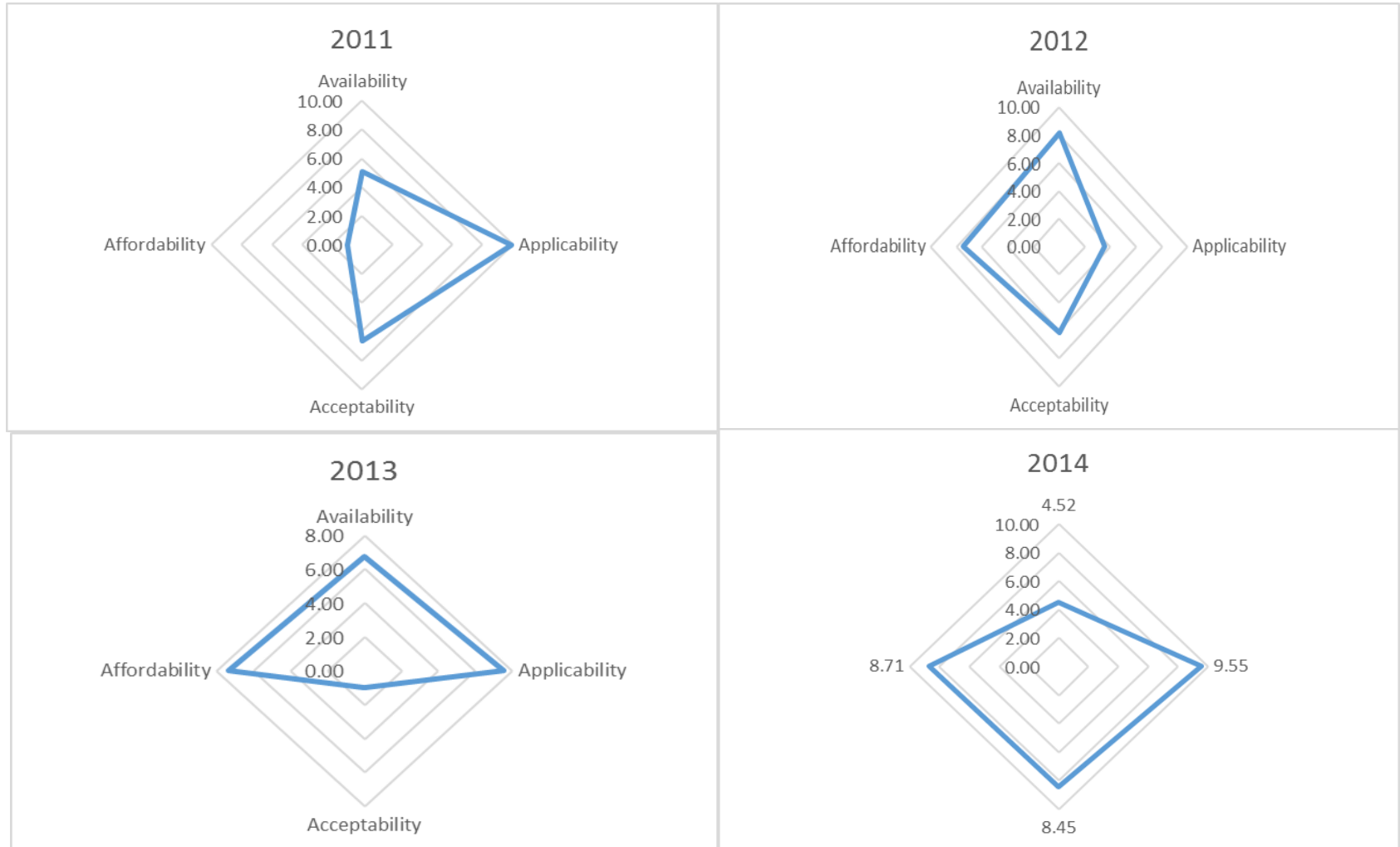
Notes: **Values in red** are assumed to be the same as the one in the preceding year as the data for the year was not available

# Energy Security in Kazakhstan:

## Trend of Each Dimension



# Energy Security Status in Kazakhstan



# Energy Security Status in Kazakhstan 2011 vs 2015



For the 4-A perspectives, between 2011 and 2015, Acceptability and Affordability appear to have improved while Applicability appears to shrink considerably and Availability seems to be more likely the same.

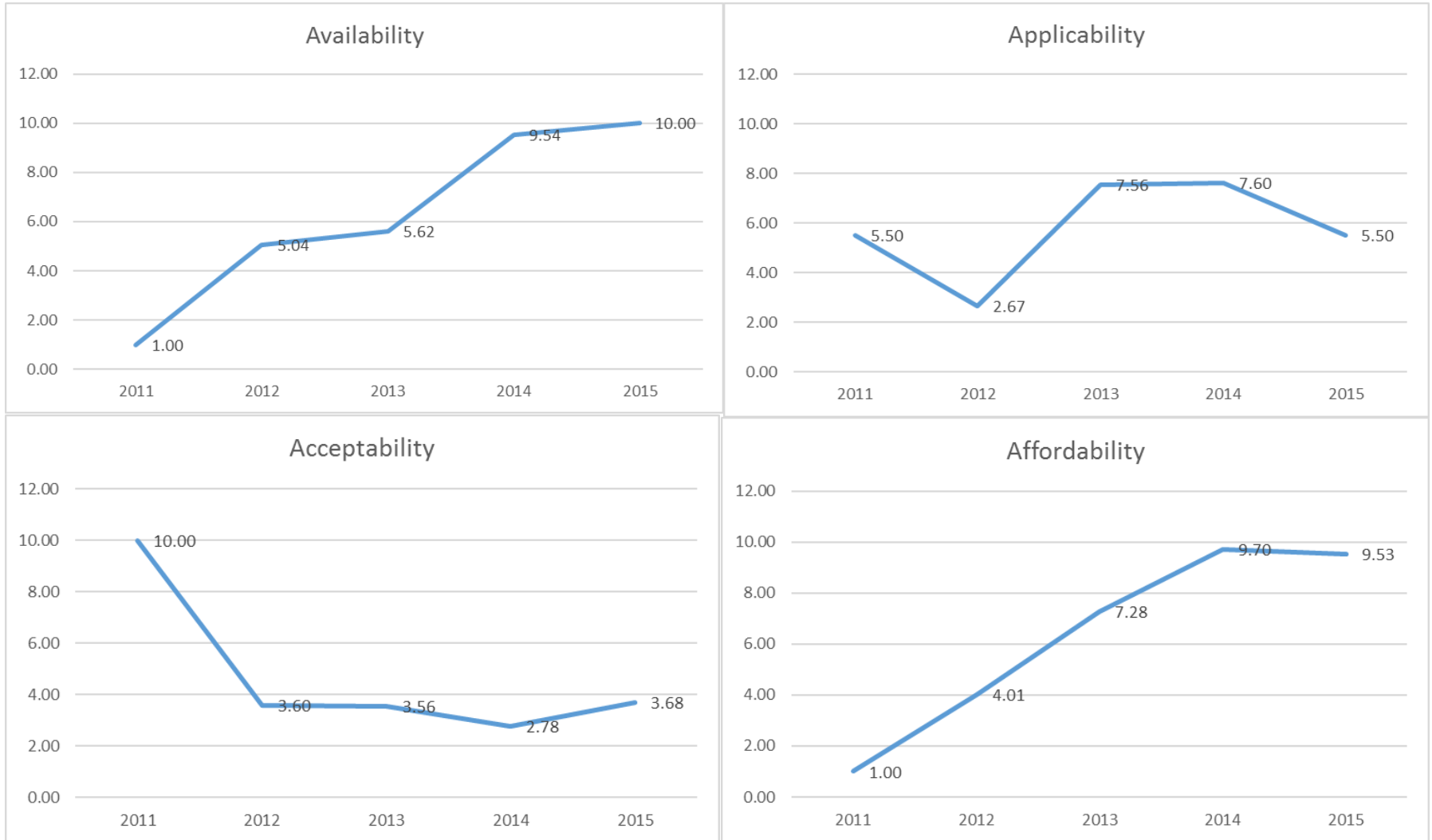
	2011	2012	2013	2014	2015
Rhombus	63.88	78.63	57.78	118.45	100.03

# Normalized Values of 4A's: CAREC Countries

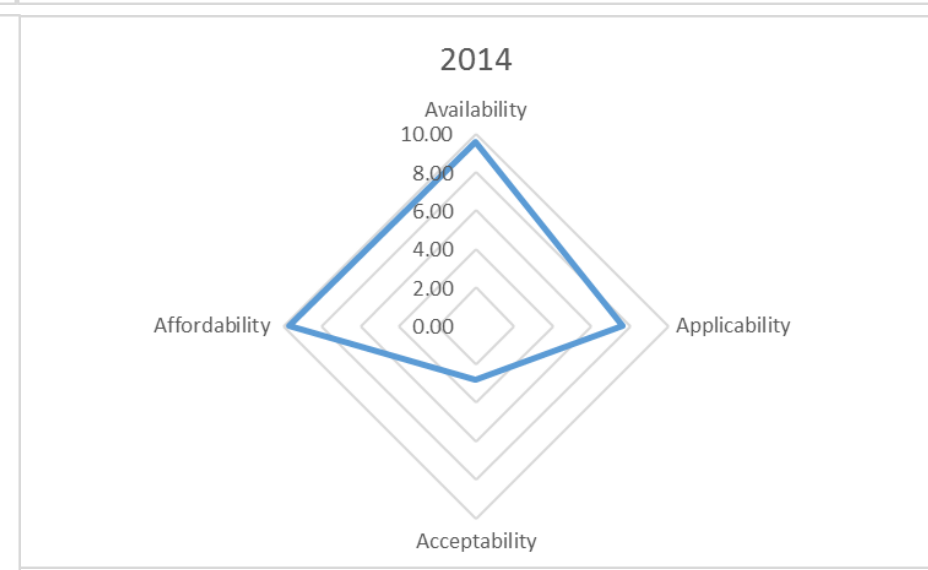
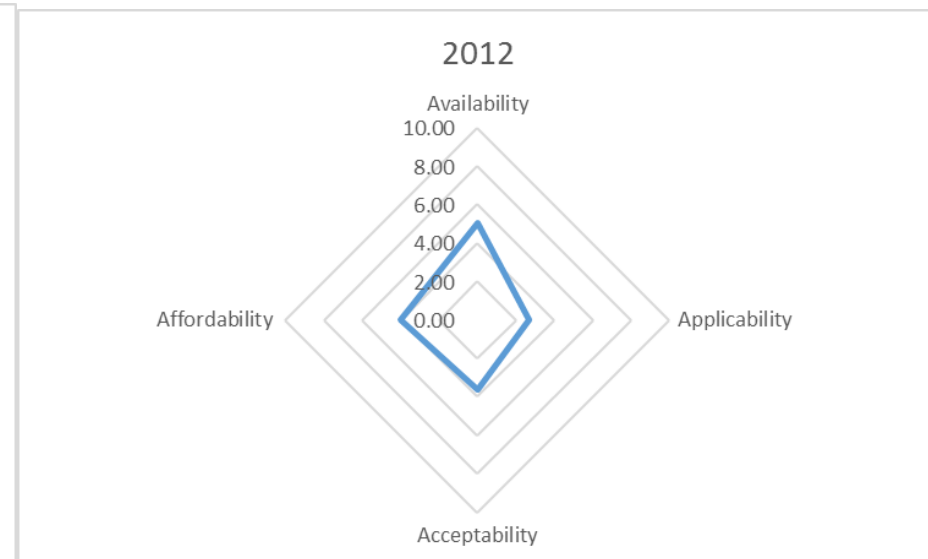
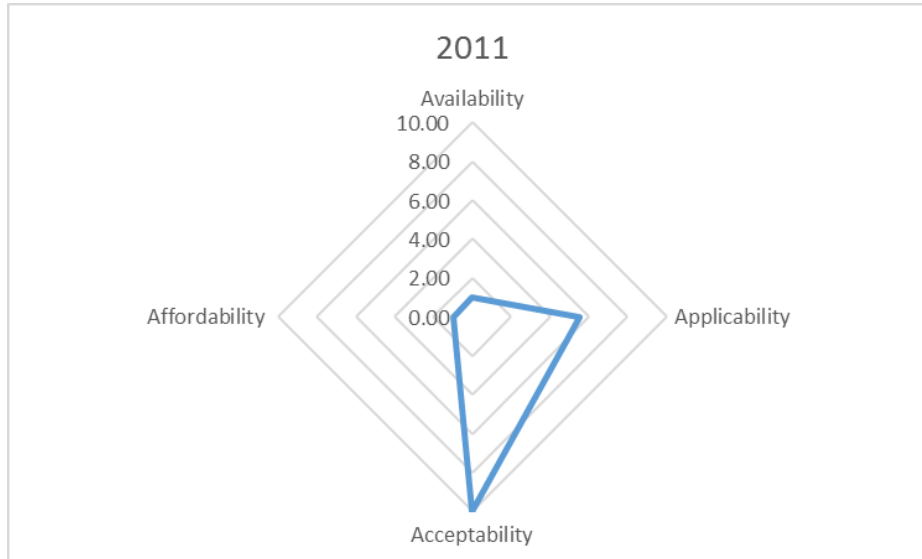
	2011	2012	2013	2014	2015			2011	2012	2013	2014	2015
AV1	1.00	7.83	7.44	9.08	10.0		AP1	1.00	2.46	6.86	10.0	10.0
AV2	1.00	2.25	3.81	10.0	10.0		AP2	10.0	2.89	8.26	5.21	1.00
<b>AV</b>	<b>1.00</b>	<b>5.04</b>	<b>5.62</b>	<b>9.54</b>	<b>10.0</b>		<b>AP</b>	<b>5.50</b>	<b>2.67</b>	<b>7.56</b>	<b>7.60</b>	<b>5.50</b>
AC1	10.0	4.23	1.00	4.55	6.37		AF1	1.00	4.32	10.0	9.41	9.05
AC2	10.0	3.00	6.10	1.00	1.00		AF2	1.00	3.70	4.60	10.0	10.0
<b>AC</b>	<b>10.0</b>	<b>3.60</b>	<b>3.56</b>	<b>2.78</b>	<b>3.68</b>		<b>AF</b>	<b>1.00</b>	<b>4.01</b>	<b>7.28</b>	<b>9.70</b>	<b>9.53</b>

Notes: **Values in red** are assumed to be the same as the one in the preceding year as the data for the year was not available

# Energy Security in CAREC Countries: Trend of Each Dimension

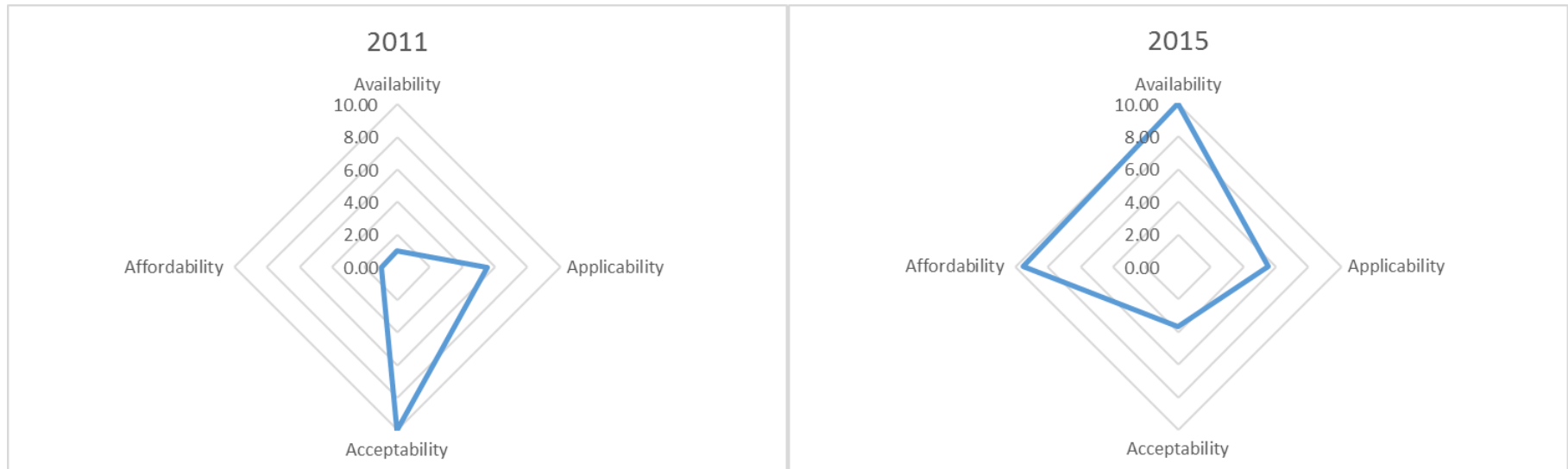


# Energy Security Status in CAREC Countries





# Energy Security Status in CAREC Countries 2011 vs 2015

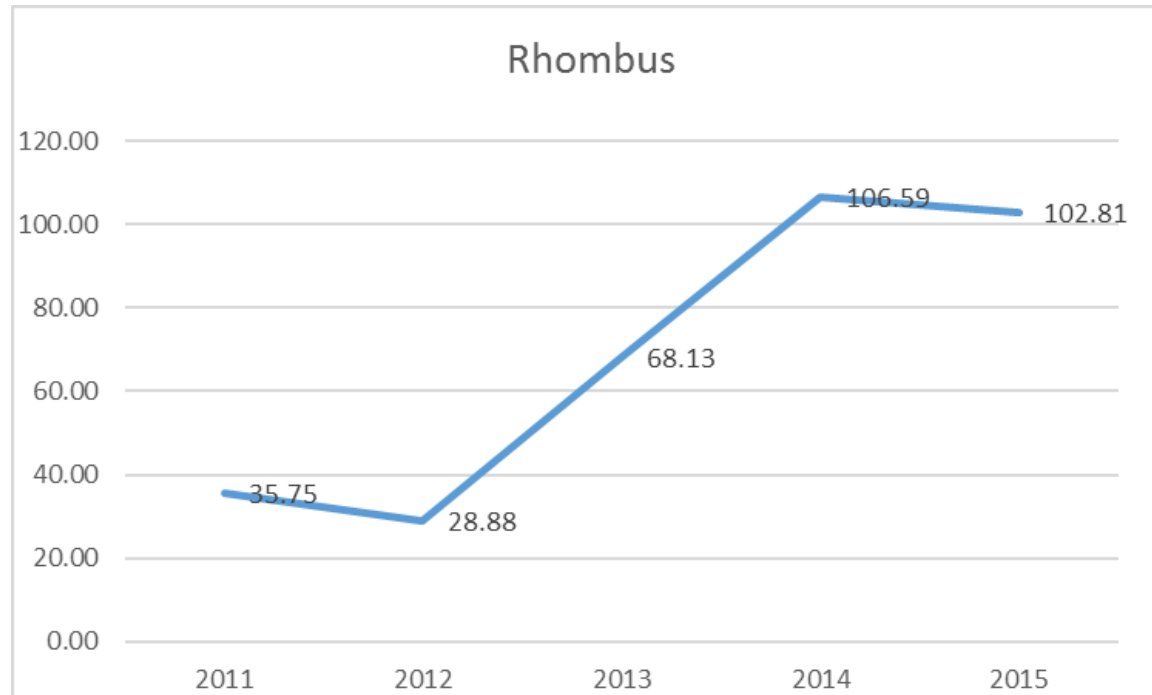


For the 4-A perspectives, between 2011 and 2015, Availability and Affordability appear to have improved while Acceptability appears to shrink considerably and Applicability seems to be more likely the same.

	2011	2012	2013	2014	2015
Rhombus	35.75	28.88	68.13	106.59	102.81

# Energy Security Status in CAREC Countries

	2011	2012	2013	2014	2015
Rhombus	35.75	28.88	68.13	106.59	102.81



# Energy Security in CAREC Countries: Evaluations and Interpretations

- Overall
  - The area of the rhombus shows that the overall status of energy security in CAREC countries is improving though 2015 is slightly worse than 2014
- The Availability
  - It shows improvements over the period due to slight increases in the proven reserves of oil and the share of renewable electricity output
- The Applicability
  - It dropped in 2012 but increased in 2013 and remained the same in 2014 but decreased again in 2015.
  - The main cause of decrease is worsening carbon intensity

# Energy Security in CAREC Countries: Evaluations and Interpretations

- The Acceptability
  - It is the highest in 2011 and since then it is decreasing.
  - The main cause of the decline is increases in CO<sub>2</sub> emissions per capita and the declining shares of renewable energy consumption
  - It seemed to improve a little bit in 2015
- The Affordability
  - It showed an increasing trend though it decreased a bit in 2015
  - The main drivers of the increase are increases in primary energy consumption per capita and in the rates of access to electricity

# Policy Implications of Renewable Energy on Energy Security in CAREC Countries

- Availability
  - The higher share of renewable electricity output will help the availability increase and the overall status of energy security in CAREC countries
  - Identifying and developing renewable energy potential is recommended
- Applicability
  - The higher level of renewable energy production will decrease carbon emissions and carbon intensity
  - More adoption of renewable electricity technologies is recommended, which will lower carbon intensity and improve the level of energy security in CAREC countries

# Policy Implications of Renewable Energy on Energy Security in CAREC Countries

- Acceptability
  - The development and utilization of renewable energy will lower carbon emissions per capita and increase the share of renewable energy consumption, which in turn enhances the level of energy security in CAREC countries
  - Utilizing a little or no carbon emitting fossil fuels is recommended
- Affordability
  - Improving access to electricity through renewable electricity (and distributed generation) will improve the level of energy security in CAREC countries
  - Policies that promote distributed generation are recommended
  - Infrastructure development such as transmission network is recommended

# Concluding Remarks

- The 4A framework of energy security presents the level of energy security in CAREC countries as a whole appears to have improved from 2011 to 2015
  - Availability appears to improve
  - Applicability is fluctuating but a slightly decreasing in 2015
  - Acceptability appears to worsen
  - Affordability appears to improve
- The harnessing renewable energy is expected to improve the level of energy security in CAREC countries
- To implement policies to identify renewable energy potential in the region and develop them is suggested
- To develop transmission network and other infrastructure is also suggested

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# Thank you for your attention!

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