Electricity Market Deregulation and Energy Security:
A Study of Malaysia, the UK, Singapore, ASEAN and China

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Outline

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- Definitions of Energy Security
- Analytical Frameworks
  - Diversity
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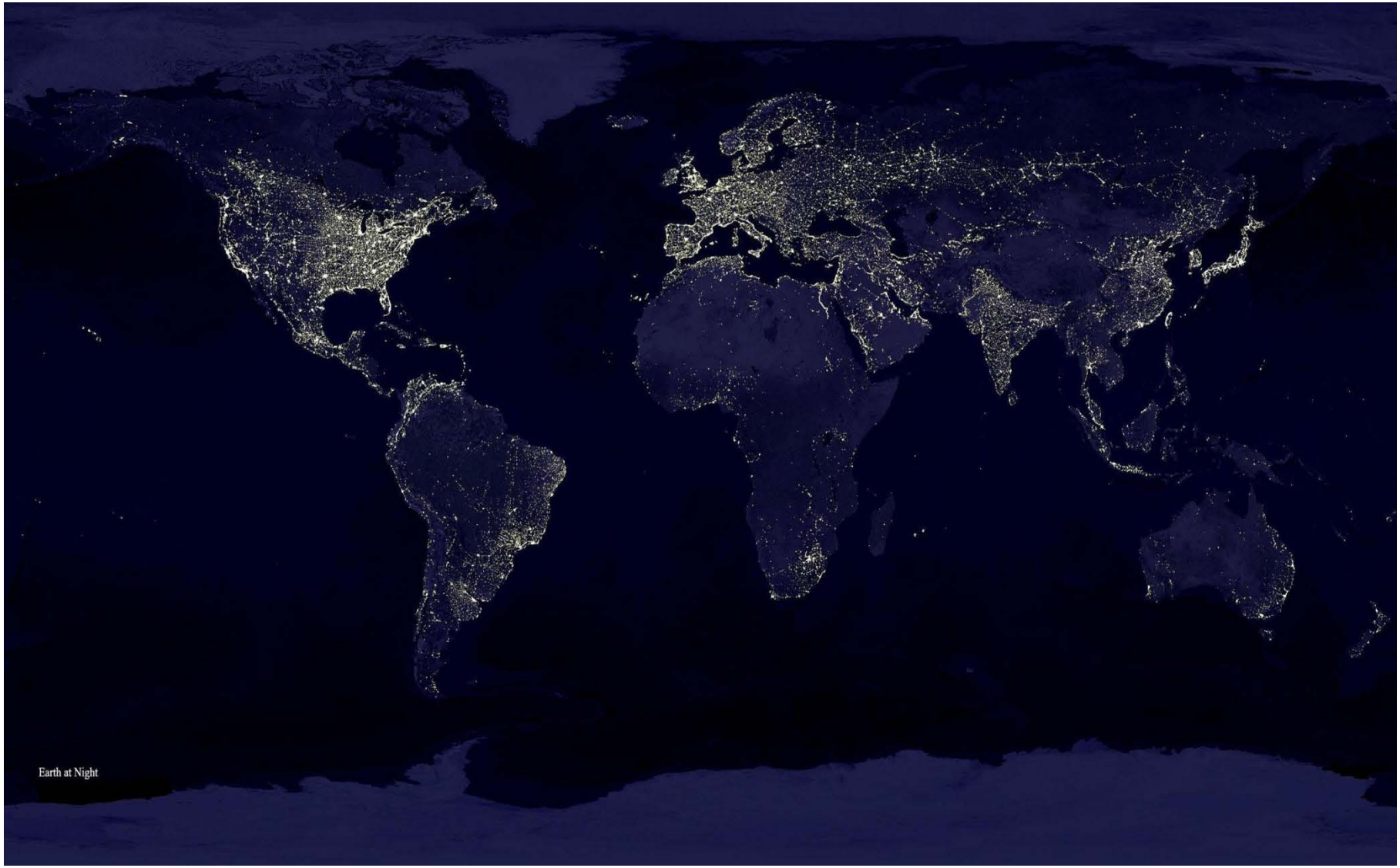
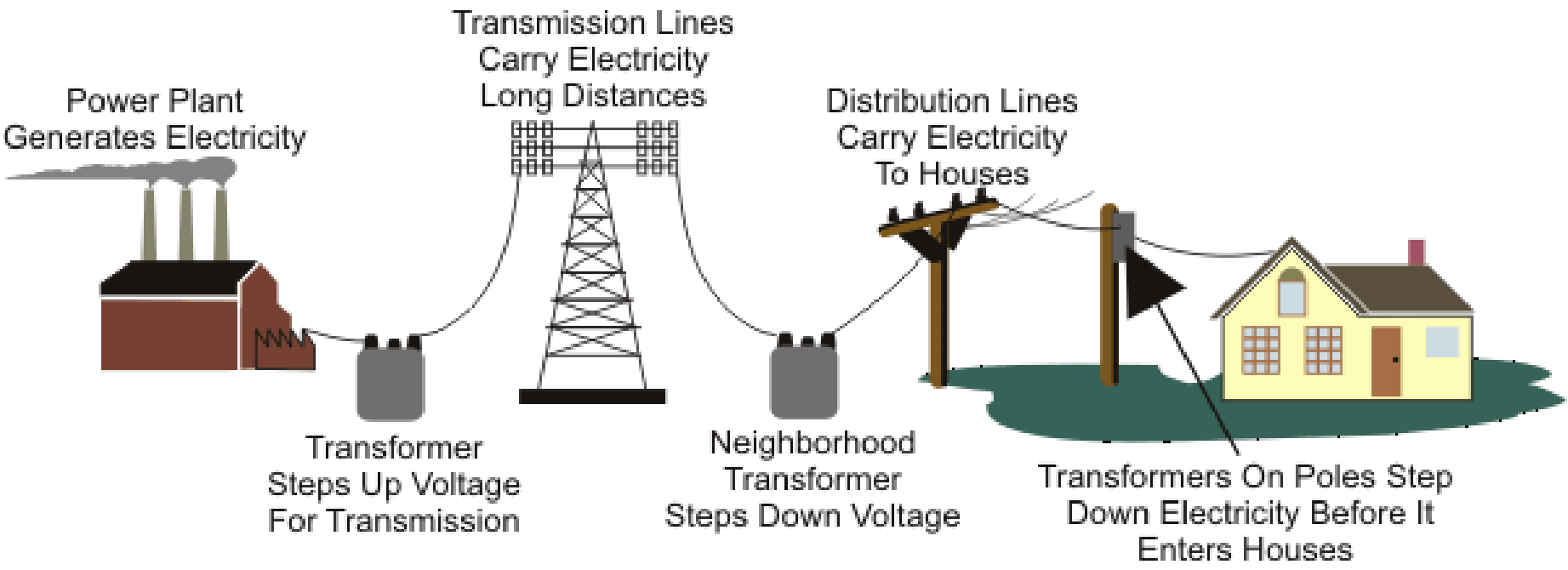
  - Diversity: Malaysia and ASEAN
  - The U.K., Singapore, ASEAN and China
- Malaysia Electricity Market and Energy Security
  - Evaluations and Policy Implications
- Concluding Remarks

World at Night from Satellite



Electricity Generation, Transmission and Distribution: A Schematic Diagram



Structures of Electricity Market

- Under regulation
  - Vertically integrated, mostly government owned, natural monopoly
  - Instruments for regulation
    - Price and quantity
- Under deregulation
  - Separation of industry by ownership
  - Horizontally unbundled
    - Full competition in generation and wholesale/retail
    - Still monopoly in transmission and distribution (T&D)
- Motivations for unbundling
  - Lower electricity price?

In a Deregulated Electricity Market

- Market becomes competitive
  - Non-existence (or little abuse) of market power
  - Easy entry and exit of players
  - Efficiency of allocation and lower and/or stable prices
- Market functions properly
  - Informed decisions
  - Allocation of risk
  - Transactions at minimal cost and lower production costs
- Market leads close to marginal-cost pricing
  - Prices would be close to the marginal cost under workable competition and a reasonably well-functioning market environment
- What do we expect?
  - Right and Stable Prices
  - Competition and Reliability

Models for the Electricity Sector

- Model 1
  - No competition, vertically integrated, publicly or privately owned
- Model 2
  - Model 1 but with competition in generation. A single buyer (a distribution company) may buy from a number of different producers
- Model 3
  - Model 2 but with common or contract carriage of high voltage transmission lines offered to all wholesale sellers and buyers
- Model 4
  - Model 3 but retail customers also choose their suppliers in full retail competition

Model 4 is the Most Economically Efficient

- If there are
  - A well-established electricity retailing system
  - Mature market institutions
  - Constant vigilance against market power
  - Appropriate methods of dispatch

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 2015)

	Oil	Coal	NG
Proven Reserves	1,697.6 thousand million barrels	891,531 million tons	186.9 trillion cubic meters
R/P (years)	50.7	114	52.8

Source: BP Statistical Review of World Energy (2016)

Malaysia's Energy Endowment

	Oil	NG	Coal	Hydro	Renewables
Proven Reserves	3.6 thousand million barrels	1.2 trillion cubic meters	N/A	3.3 million tons oil equivalent (toe)	0.2 million toe
R/P (years)	14.2	17.1		N/A	N/A
Remarks (share of world total)	0.2%	0.6%		0.4%	0.1%

Note: Renewables: other than biofuels
Source: BP Statistical Review of World Energy (2016)

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
- Balance
  - The share of the most utilized energy resource (%),
  - The lower, the better
- Disparity
  - The share of fossil fuels utilized (%)
  - The lower, the better

Source: Chang and Yao (2012)

Diversity of the Malaysia's Energy Sector:
Results and Evaluations

	Variety	Balance	Disparity
Measures	Number of energy resources utilized	Share of the most utilized fuel (natural gas)	Share of fossil fuels utilized
Values	0.13	51%	97.5%
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

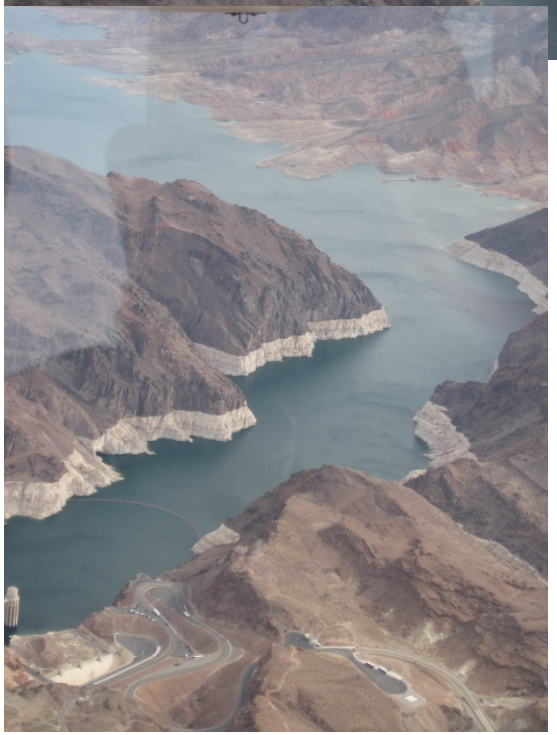
Energy Diversity of Malaysia and ASEAN

Country	Number of resources (inverse of the number of energy resources [1/n])	Most utilised resource (share of the most utilised resource [%])	Share of fossil fuels used (%)	Share of top five most utilised resources (%)
Brunei	0.5 (2)	Natural gas (73)	100.0	100.0
Cambodia	1.0 (1)	Oil (100)	100.0	100.0
Indonesia	0.11 (9)	Oil (47)	97.7	99.6
Laos	0.33 (3)	Oil (100)	100.0	100.0
Malaysia	0.13 (8)	Natural gas (51)	97.5	100.0
Myanmar	0.5 (2)	Natural gas (56)	100.0	100.0
Philippines	0.13 (8)	Oil (58)	92.5	100.0
Singapore	0.33 (3)	Oil (88)	100.0	100.0
Thailand	0.13 (8)	Oil (52)	96.6	98.1
Vietnam	0.17 (6)	Oil (37)	100.0	100.0

Abbreviations ASEAN = Association of Southeast Asian Nations; *n* = number of resources
Changes of values after 2009 are very small or nil

Source: Chang and Yao (2012)

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

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

Deregulation of Electricity Market and Energy Security

- Deregulation of Electricity Market
  - Brings competition into the electricity market
  - Real-time pricing or Time-of-Use (TOU) charges
- Application to the Electricity Sector
  - Adequacy
    - Sufficient amount of installed capacity and generation
  - Reliability
    - Dependable Transmission and Distribution (T&D) network
  - Reasonable Price
    - Stable price
    - Right price – price = marginal cost of generation

Applications: The U.K. and Singapore

- The economic definition of energy security is adopted
- A 3x3 matrix of questions are established

	Adequacy	Reliability	Reasonable Price
Present (Normal)			
Present (Emergency)			
Future			

- Corresponding indicators that can answer the questions best are selected

Energy Security Framework:
Questions and Indicators

	Adequacy	*Reliability*	*Reasonable price*
Present (normal)	Is there enough generation capacity to meet current demand?	Is the grid reliable now?	Is price reasonable now?
	Measure: Reserve margin	Measure: SAIDI and SAIFI	Measure: Lerner Index
Present (emergency)	Is there enough generation surplus to deal with emergency shutdown of a plant?	Is the system robust enough to handle an emergency?	Are there effective guards against high prices in an emergency?
	Measure: Supply marginal assessment	Measure: Feature checklist	Measure: Residual supply index
Future	Is there sufficient investment to ensure enough capacity in the future?	Is there sufficient investment to ensure continued grid reliability in the future?	Are there efforts to ensure reasonable prices continue in the future?
	Measure: % Growth investment	Measure: % Growth investment	Measure: Policy checklist

Source: Chang and Lee (2008)

Summary of Selected Indicators

	Adequacy	Reliability	Reasonable Price
Present (Normal)	Reserve Margin	SAIDI SAIFI	Lerner Index
Present (Emergency)	Supply Margin Assessment (SMA)	Feature Checklist	Residual Supply Index (RSI)
Future	Growth in Investment	Growth in Investment	Policy Checklist

Source: Chang and Lee (2008)

Summary of Benchmark Levels

	Adequacy	*Reliability*	*Reasonable price*
Present (normal)	>20%	SAIDI: 0.89 – 1.16 hour SAIFI: 0.90 – 0.92 incidents	<10%
Present (emergency)	Non-pivotal	Feature present?	Non-pivotal
Future	Investment levels result in healthy reserve margin (>20%)	Investment growth > demand growth	Policy present?

Source: Chang and Lee (2008)

Summary of Evaluations

Singapore

	Adequacy	*Reliability*	*Reasonable price*
Present (normal)	P	P	P
Present (emergency)	P	P	P
Future	P	?	P

The U.K.

	Adequacy	*Reliability*	*Reasonable Price*
Present (normal)	P	P	P
Present (emergency)	P	P	P
Future	P	?†	P

*P = Pass; F = Fail; ? = Inconclusive.

In sum, deregulation of electricity market appears to help ensure energy security in the U.K. and Singapore

Source: Chang and Lee (2008)

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

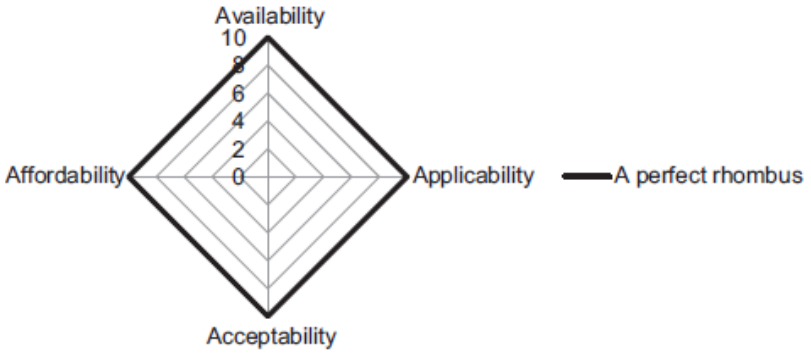
The 4-A Framework of Energy Security:
Possible Indicators

	Availability	Applicability	Affordability	Acceptability
IAEA	• Share of households without electricity • Reserves to production ratio • Diversification of Primary Energy Demand • Dependence on imports (mtoe)	• Share of households without electricity • R&D • Energy use per unit GDP • commercial and transport energy intensity • energy efficiency measures	• Share of household income spent on fuel and electricity • Energy use per capita	• GHG emissions per capita • GHG emissions per unit GDP • Ambient air pollutant concentrations
APERC	• Reserves to production ratio (R/P ratio)	• Energy use per unit GDP • Industrial, household, agricultural, commercial and transport energy intensity	• Energy use per capita	• GHG emissions per capita • GHG emissions per unit GDP
IEEJ and ASEAN Center for Energy		• Energy use per unit GDP • Industrial, household, agricultural, commercial and transport energy intensity	• Energy use per capita	

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

Energy Security in ASEAN (Tongsopit et al, 2016)

- The 4-A framework is applied to all ASEAN countries to examine the status of energy security
- Time span: 2005 to 2010
- 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 ASEAN:
Selected Indicators

Availability (AV)	**Applicability** (AP)
AV1: R/P Ratio of Oil	**AP1**: ASEAN Energy Intensity
AV2: R/P Ratio of NG	**AP2**: Industrial Energy Intensity
AV3: R/P Ratio of Coal	**AP3**: Services Energy Intensity
AV4: Renewables Consumption (TWh)	**AP4**: RE generation status excluding large hydro (MW production capacity)
Affordability (AF)	**Acceptability** (AC)
AF1: Share of population without electricity	**AC1**: CO_2 emission per capita
AF2: Energy per capita	**AC2**: Total estimated SO_2 emissions
AF3: Gasoline Volatility	**AC3**: ASEAN share of global CO_2 emissions
AF4: Retail electricity tariffs (USD/kWh)	**AC4**: Share of RE in total generating capacity (excluding large hydro) (%)

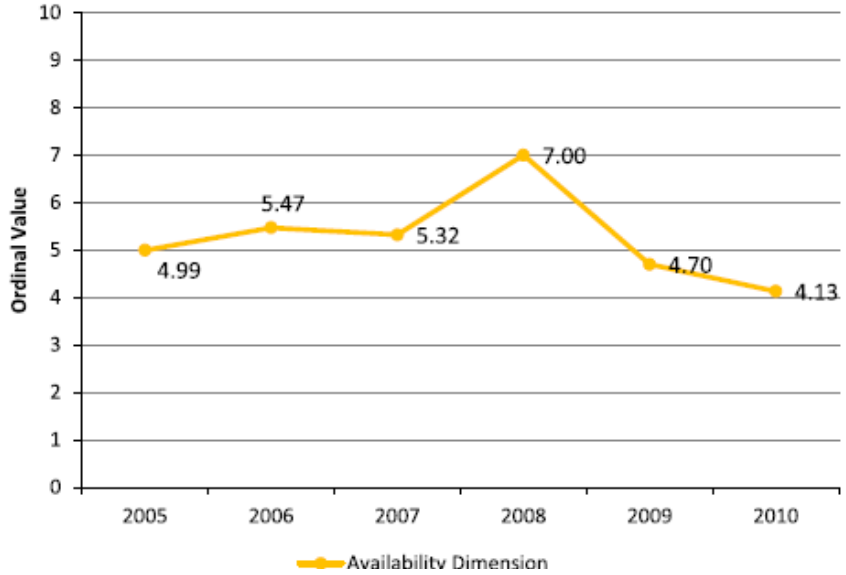
Source: Tongsopit et al (2016)

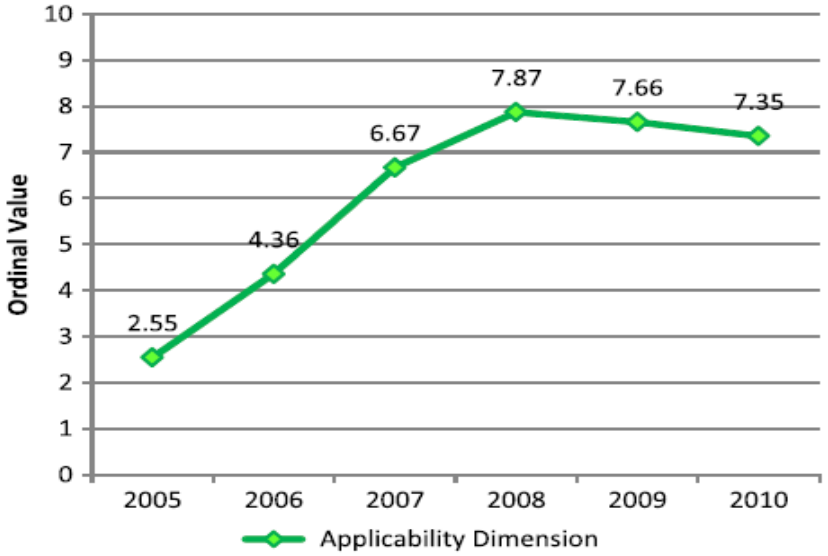
Energy Security in ASEAN:
Data Normalization

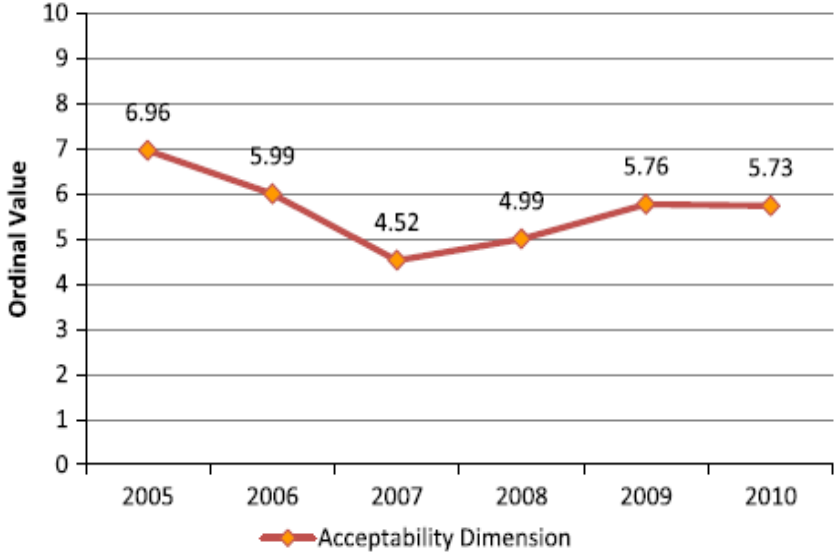
- For each A, the maximum and the minimum values are identified
- The value of each indicator is normalized by the following formula

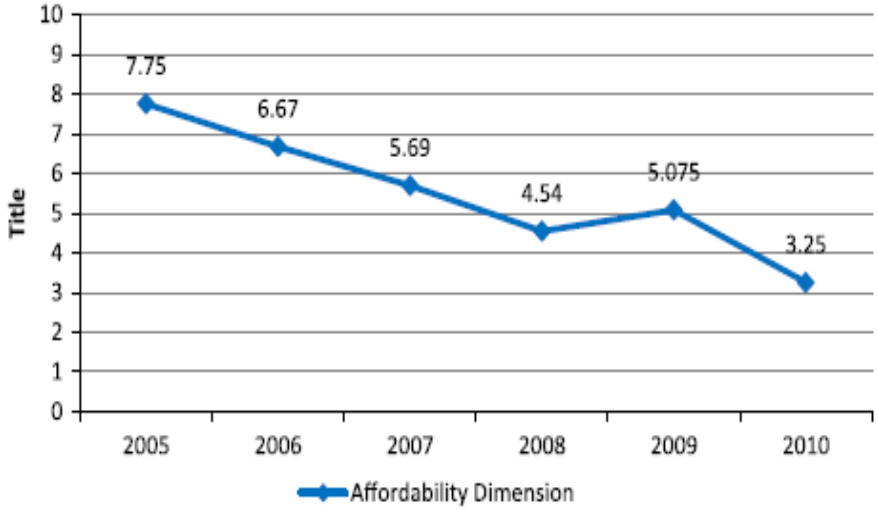
$$\text{Normalized value} = 1 + \frac{Actuial\ Value - Minimum}{Maximum - Minimum} * \quad (10\text{-}1)$$

Energy Security in ASEAN: Results

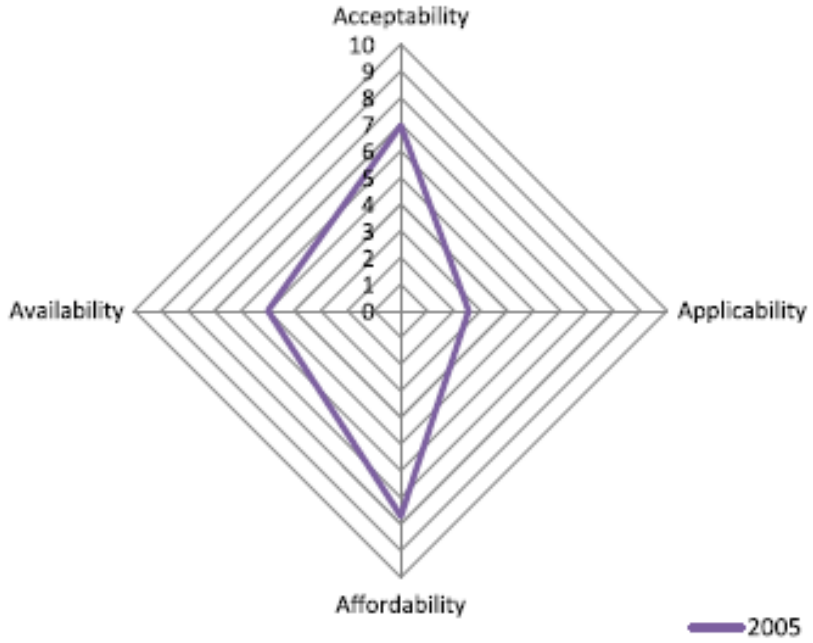


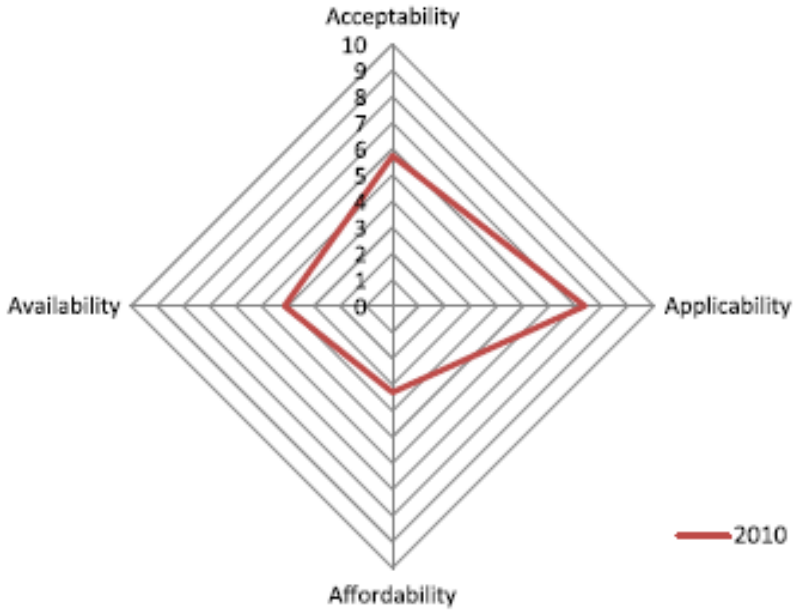






Interpretations and Comparisons: 2005 vs 2010





For the 4-A perspectives, only Applicability appears to have improved. The area of rhombus in 2010 appears to slightly shrink compared to 2005 (from 55.27 to 51.79), which indicates less secured.

Energy Security in ASEAN:
Evaluations and Policy Implications

- For Availability
  - To diversify fuel sources
  - To develop bases of renewable energy
- For Applicability
  - The level of energy intensity has been declining
  - To keep improving overall energy efficiency
- For Acceptability
  - To keep reducing per capita carbon emissions
- For Affordability
  - To decrease the population without access to electricity
  - To reduce the volatility of gasoline price

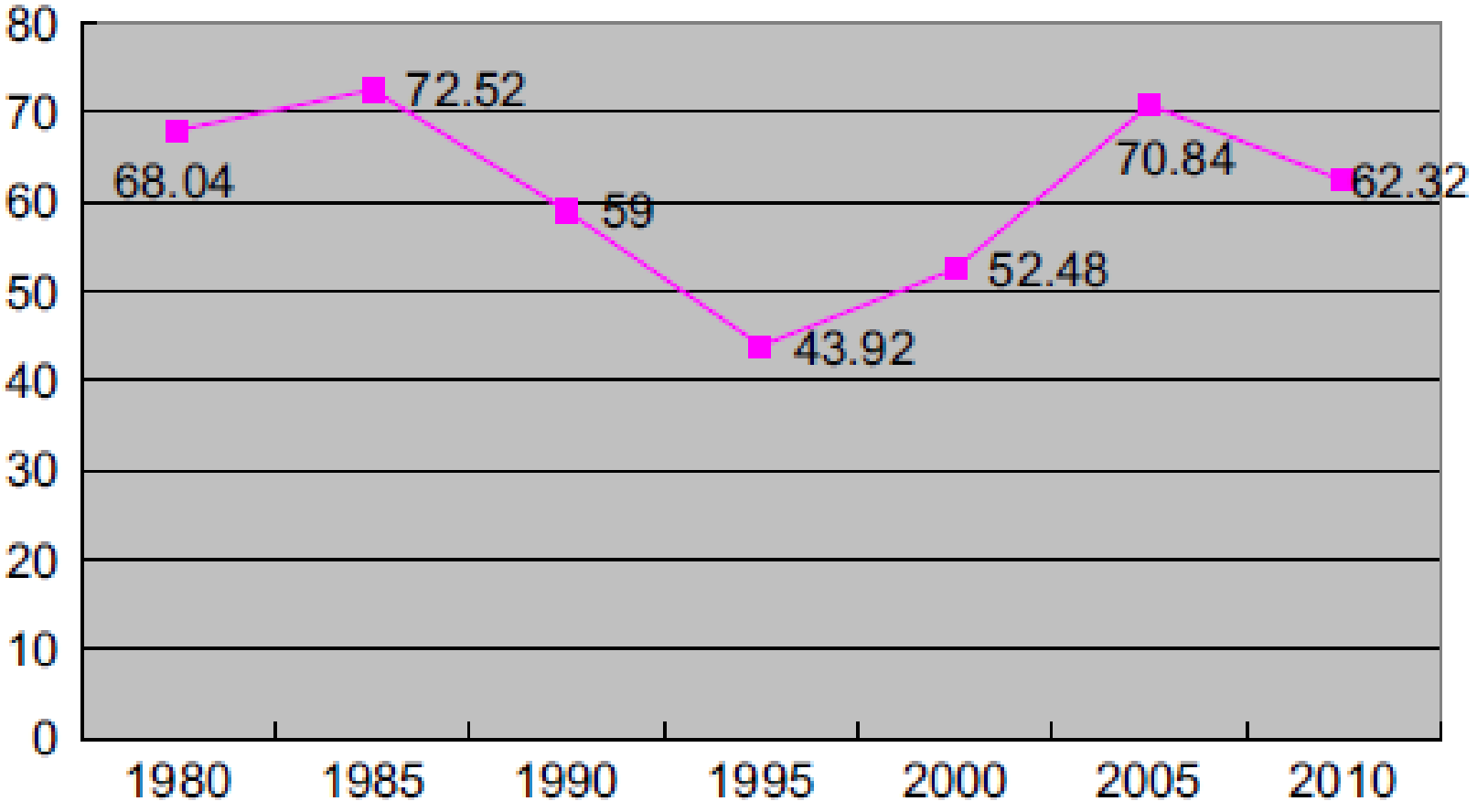
Energy Security in China
(Yao and Chang, 2014)

- The 4-A framework is applied to examine energy security of China from 1980 to 2010 (from the Sixth Five-Year Plan to the Eleventh FYP)
  - 1980 is used as the base year
- Each A has five indicators
- Values of all indicators are normalized
- The trend of each A is analyzed
- The area of the rhombus indicates the overall level of energy security (refer to the ASEAN case)

Energy Security in China: Selected Indicators

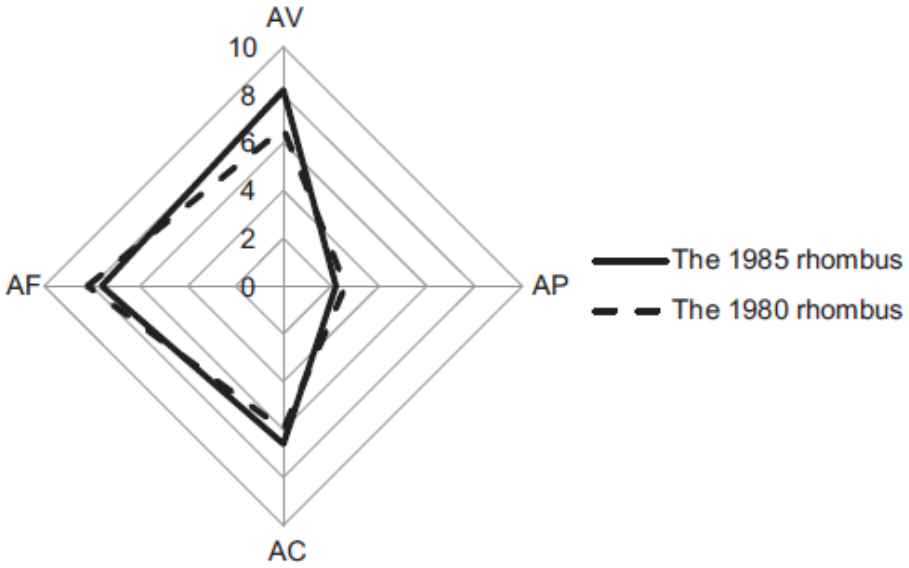
Availability	Applicability	Acceptability	Affordability
Coal R/P ratio	Energy intensity (primary energy/GDP)	Share of China's CO_2 emissions	Growth rate of price of coal
Oil import dependence ratio	Gross generation efficiency of fossil fuel-fired power plants	China's SO_2 emissions	Growth rate of price of petroleum
NG R/P ratio	Crude oil distillation capacity	China's soot emissions	Growth rate of price of electricity
Availability factor of conventional thermal electricity	Power plants owned by LME	Share of renewable energy generation	Volatility of coal price
Availability factor of non-thermal electricity	Energy industry technical updating	Share of nuclear energy generation	Energy consumption per capita

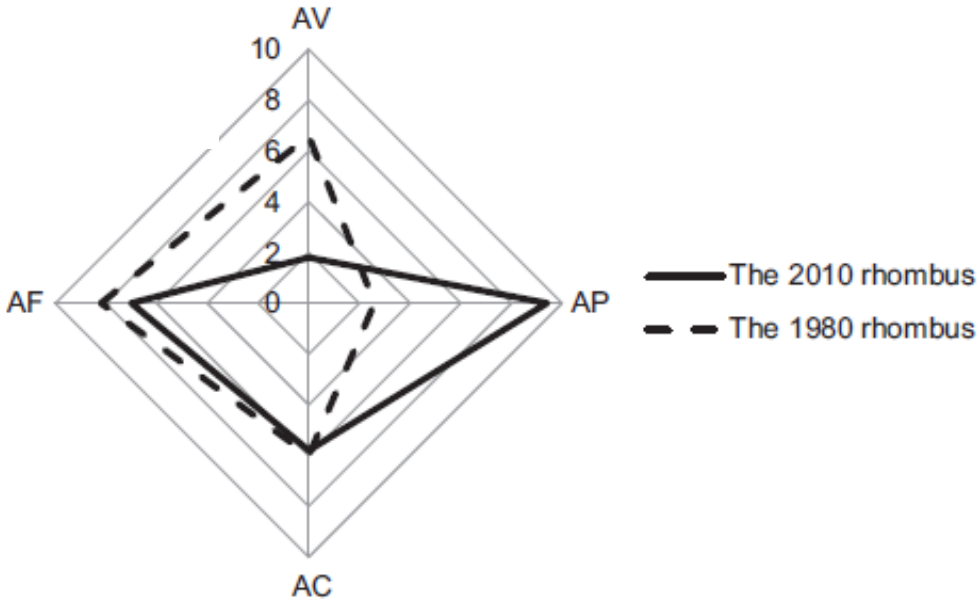
Energy Security in China:
Results: Area of Rhombus



Source: Yao and Chang (2014)

Energy Security in China:
Evaluations and Comparisons



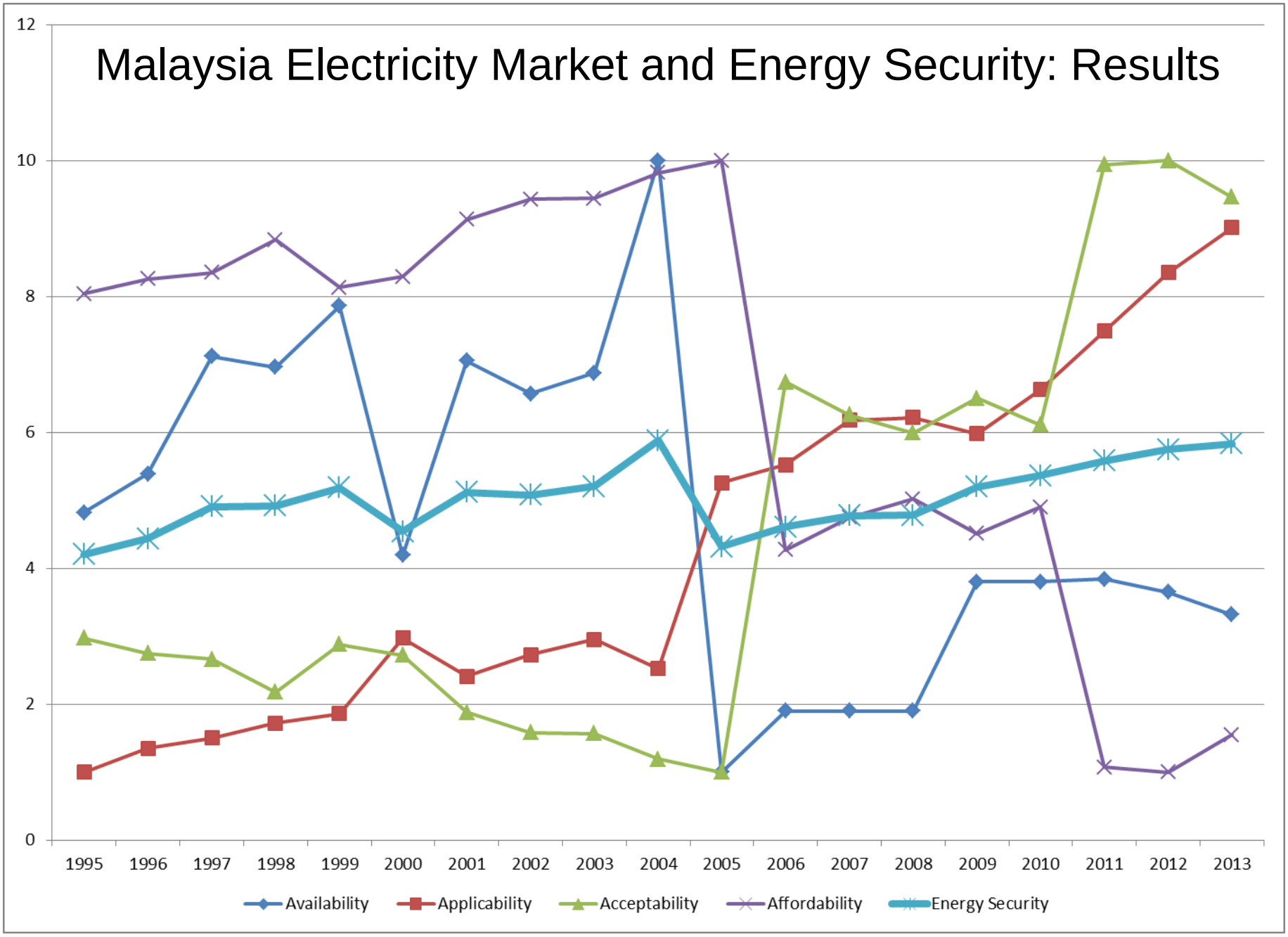


Source: Yao and Chang (2014)

Malaysia Electricity Market and Energy Security

- The 4-A Framework is applied to the electricity sector in Malaysia (4x1 matrix)
- Selected Indicators for each A

	Concepts	Indicators
Availability (AV)	Endowment	Total installed capacity of electricity generation (MW)
Applicability (AP)	Efficiency	A ratio of electricity generation to the installed capacity (%)
Acceptability (AC)	Preference	Carbon emissions per capita (tons)
Affordability (AF)	Capability	Electricity consumption per capita (toe)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Acceptability
Affordability
Energy Security

Malaysia Electricity Market and Energy Security: Interpretations and Policy Implications

- The overall energy security of the Malaysia's electricity sector exhibits an increasing trend after a little drop in 2004
- The Availability
  - The installed capacity dropped in 2000 and 2005
  - To increase the installed capacity, especially renewable sources
- The Applicability
  - The efficiency of electricity generation appears to have improved
  - To increase the load factor
  - To develop renewable energy technologies

Malaysia Electricity Market and Energy Security: Interpretations and Policy Implications

- The Acceptability
  - The CO_2 emissions dropped in 2005 and 2010
  - To develop no or little carbon emitting generation technologies
- The Affordability
  - The electricity consumption per capita shows a declining trend over time
  - To decrease the number of people without access to electricity
  - To decrease the amount of electricity wasted during T&D
  - To introduce real-time pricing or TOU charging

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Thank you for your attention!

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