Study on Hybridization of Existing Thermal Power Stations with Solar Collection Fields and Local Manufacturing of CSP Components

at Cairo University Faculty of Engineering April 1st 2014

Study on Hybridization of Existing Thermal Power Stations with Solar Collection Fields

Main Objective

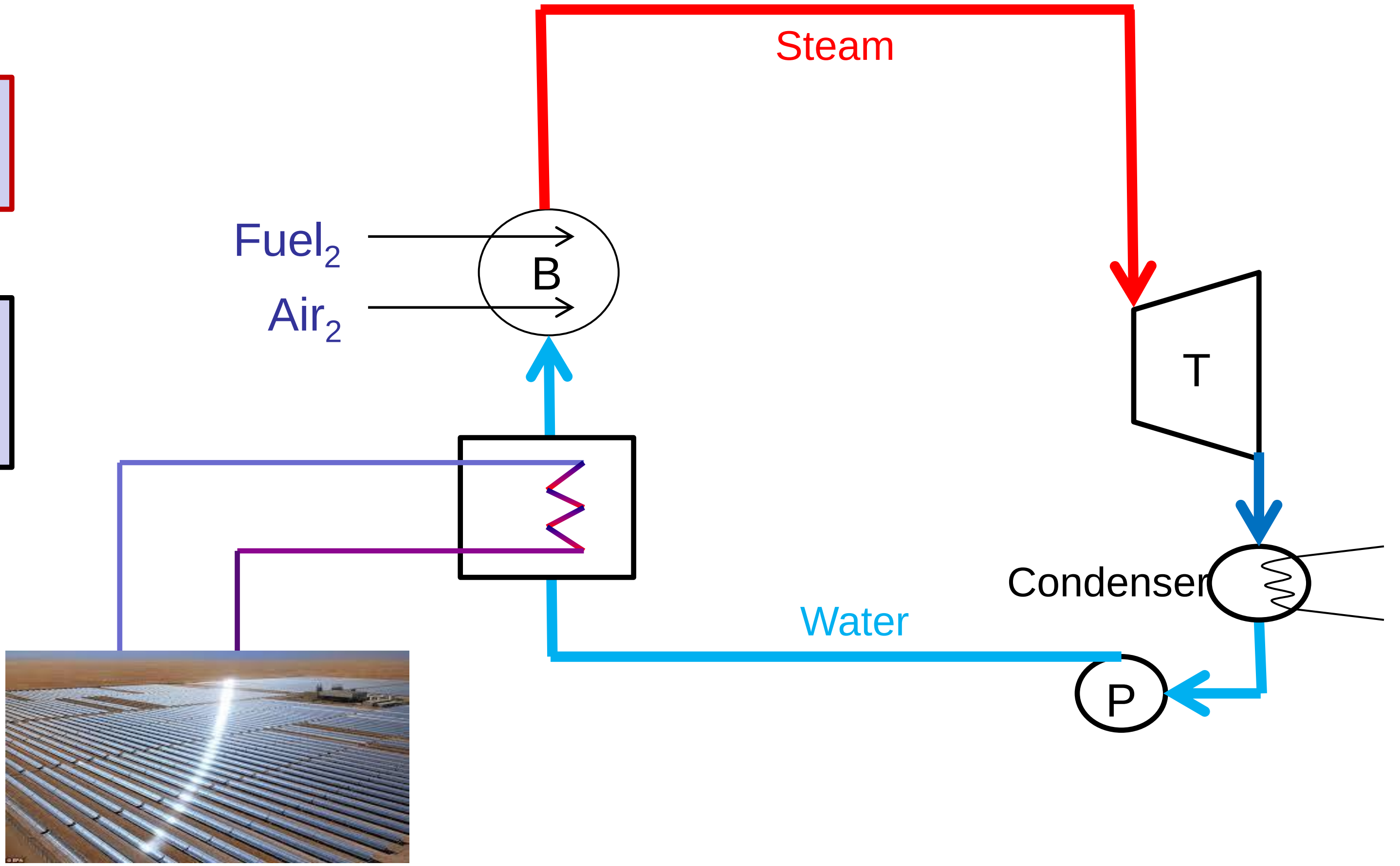
Investigating the development of electricity generation with less fuel by integrating solar fields into existing conventional thermal power plants.

Basic Concept

Steam Power Plant

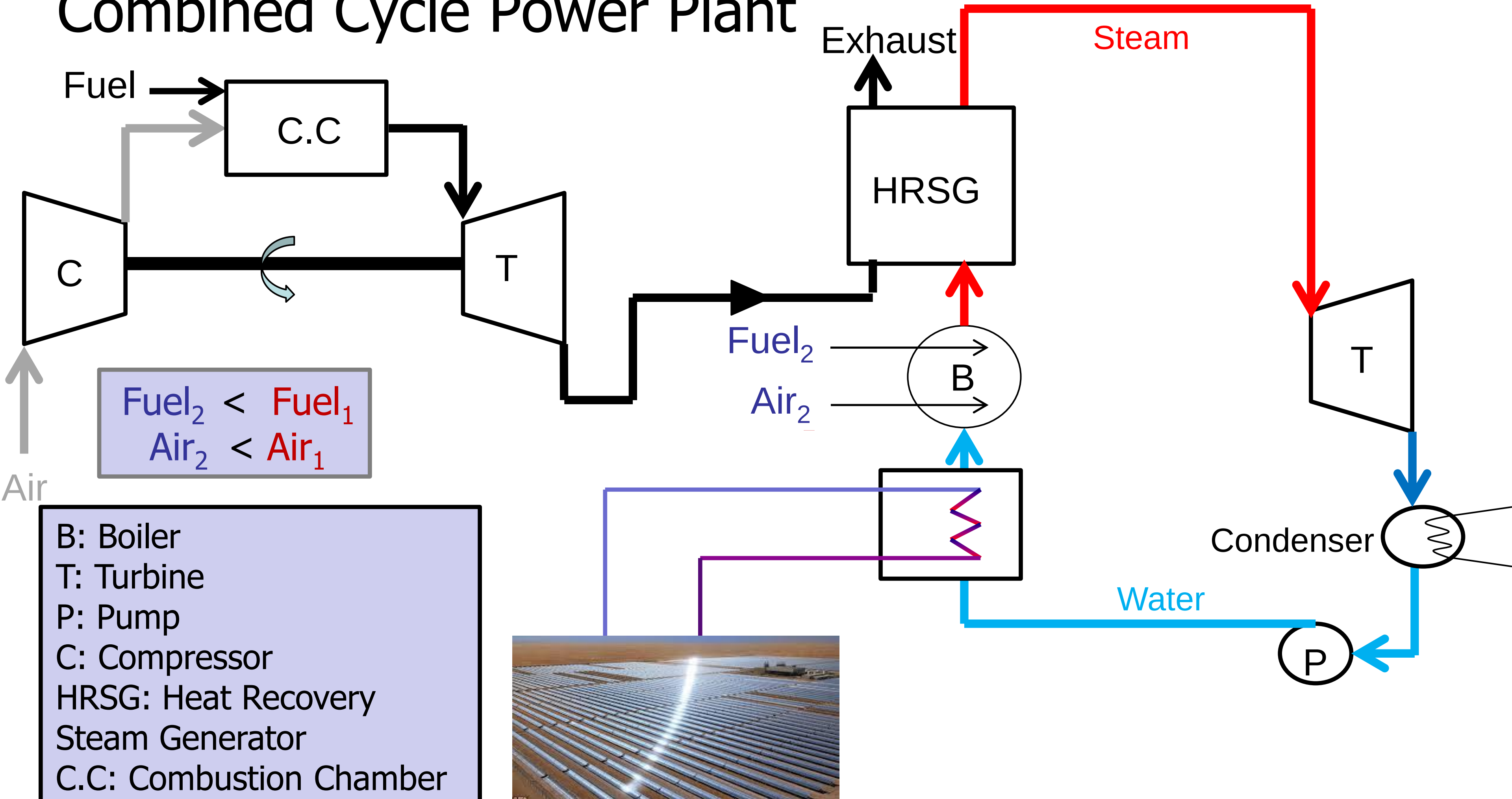
$Fuel_2 < Fuel_1$
$Air_2 < Air_1$

B: Boiler
T: Turbine
P: Pump



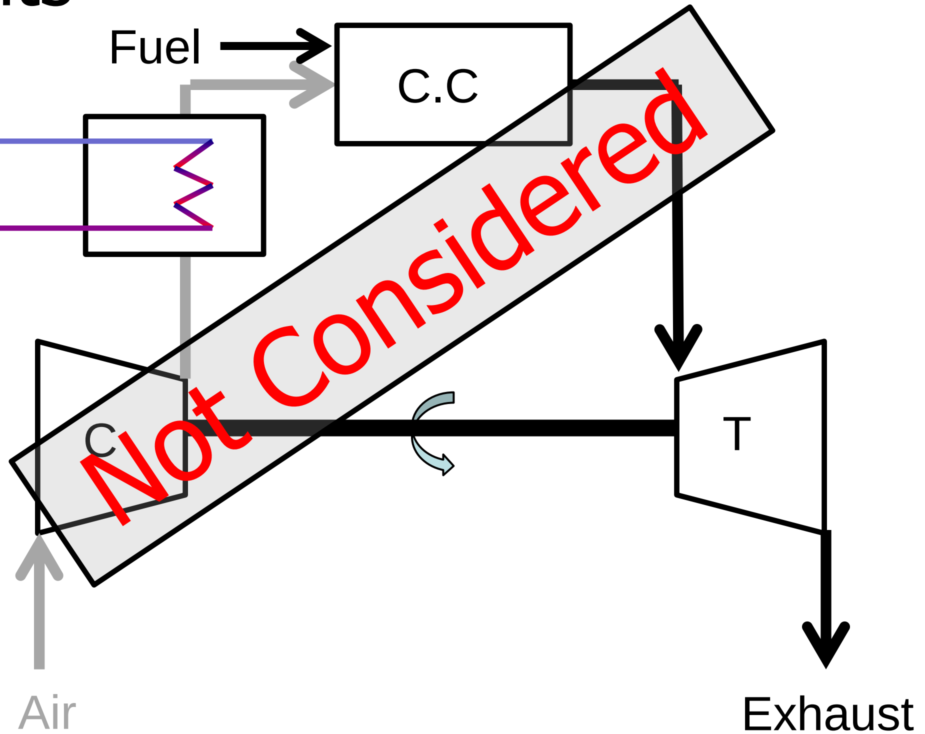
Basic Concept

Combined Cycle Power Plant



Basic Concept

Gas Power Plants

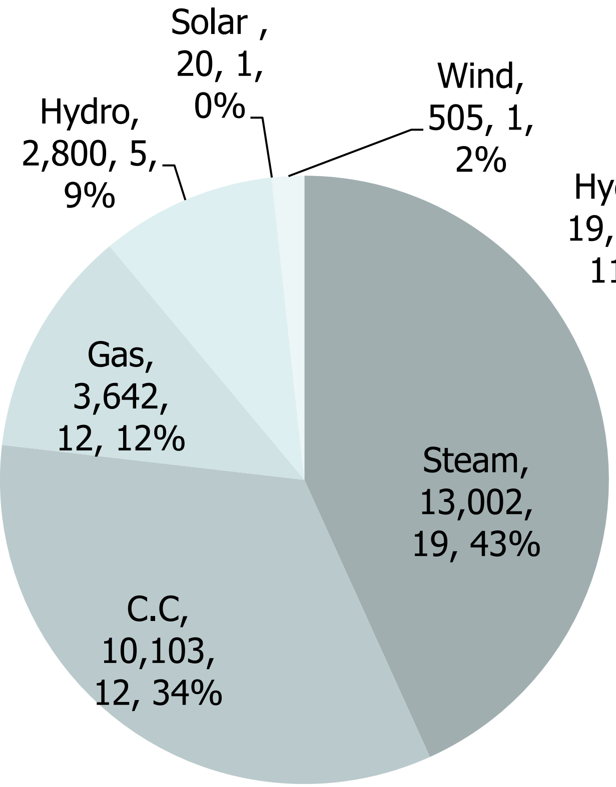


- **Inefficient**
- **Needs large heat exchanger surface area**

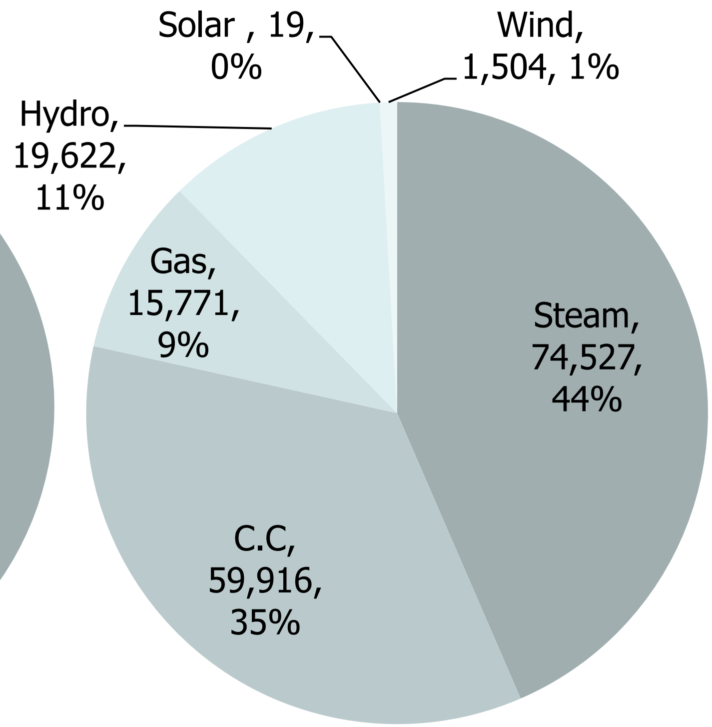
T: Turbine
C: Compressor
C.C: Combustion Chamber

Existing Plants (EEHC 2011/2012)

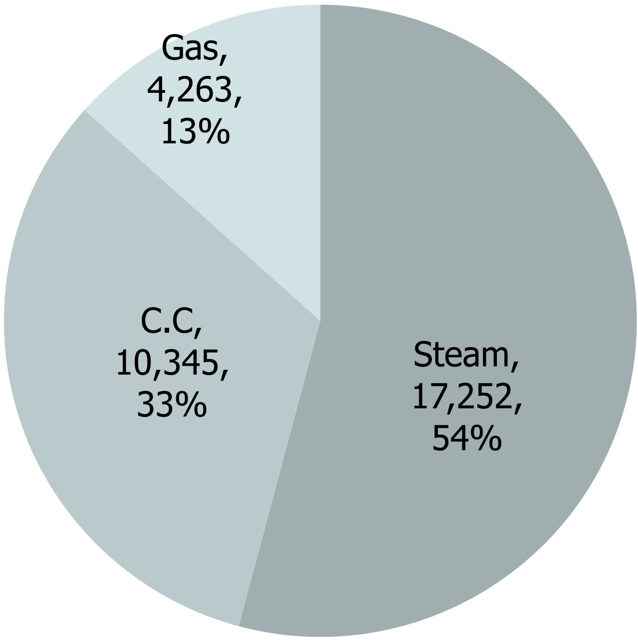
Capacity (MW, #, %)



Energy (GWh, %)

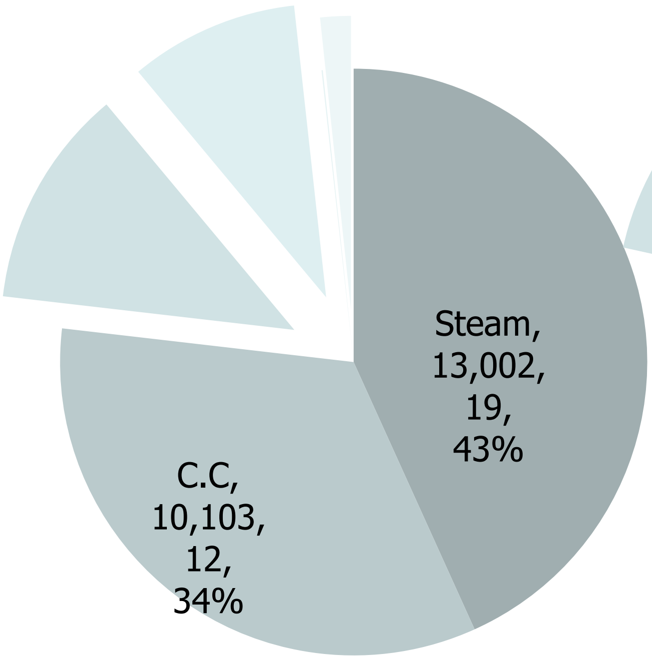


Fuel Use (ktoe, %)

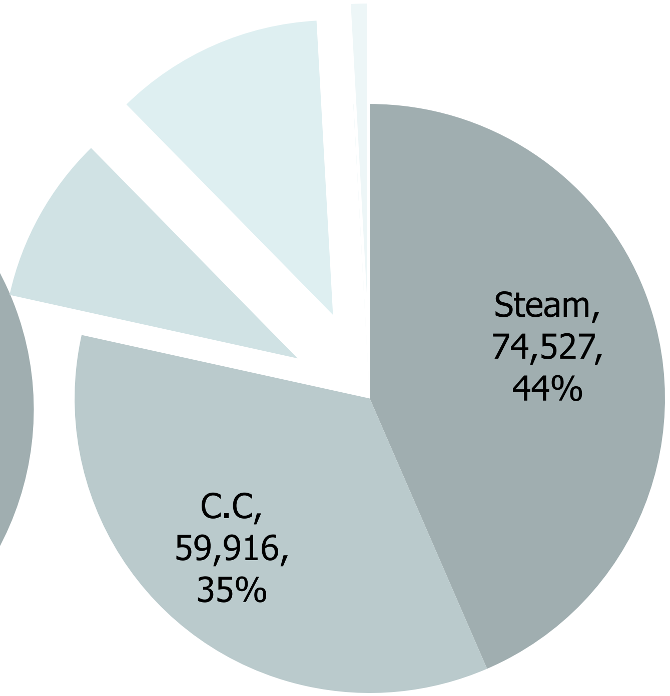


Plant types under consideration

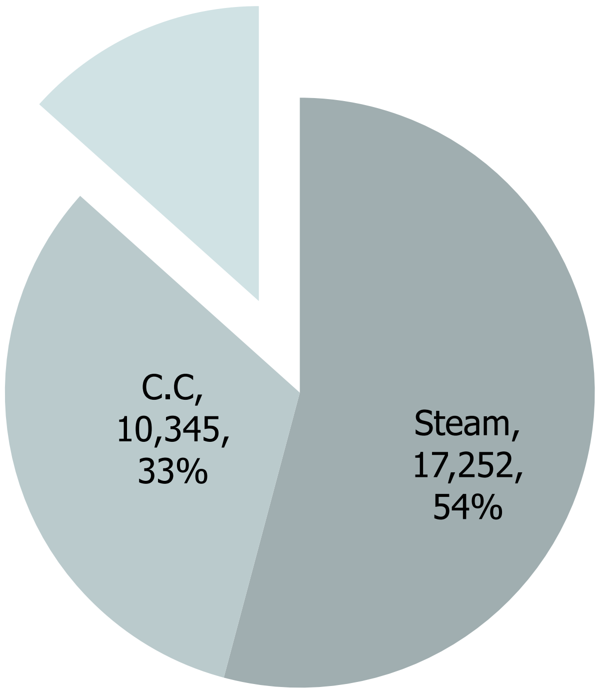
Capacity (MW, #, %)



Energy (GWh, %)



Fuel Use (ktoe, %)



Exclusion Criteria

1. Capacity Factor
2. Plants Age
3. Topography of the Land
4. Direct Normal Irradiance DNI at the plants locations
5. Available Land Area

Exclusion Criteria

1- Capacity Factor

The ratio of the plant's annual actual electrical output, to its annual potential if it operated at full capacity.

- **Plants that have capacity factor less than 15% are excluded.**
- No plants are excluded based on this criteria.

Exclusion Criteria

2- Plants Age

- **Plants that are older than 25 years are excluded.**
- 7 plants are excluded:

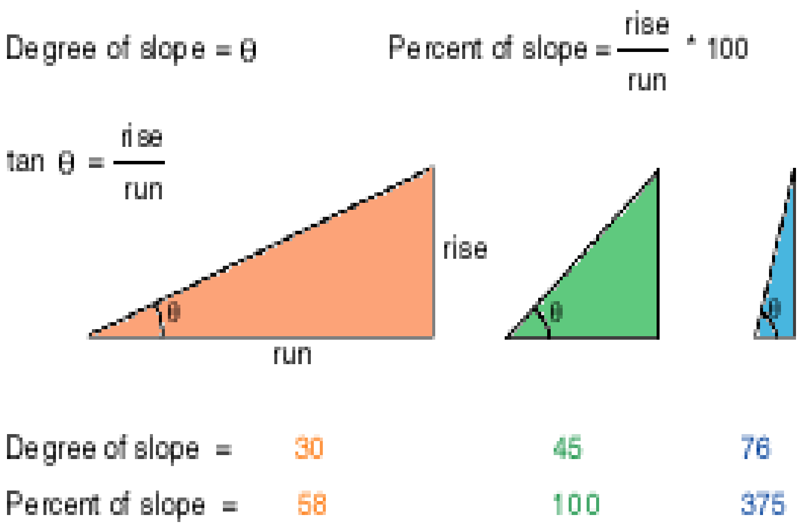
Plant	Type	Age in 2013 (years)
Shoubra El-Kheima	ST	26
Cairo West	ST	34
Ataka	ST	26
Abu Sultan	ST	27
Kafr El-Dawar	ST	27
Damanhour Steam	ST	27
Assiut	ST	46

Exclusion Criteria

3- Topography of the land

The slope of the power plant's land.

- **Any plant with surrounding land that has a slope greater than 5% is excluded.**
- No plants are excluded based on this criteria.



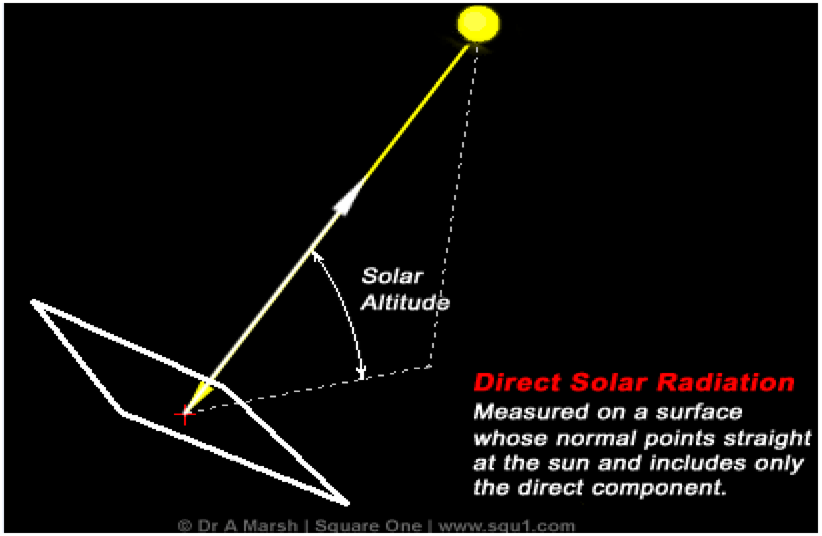
Exclusion Criteria

4- Direct Normal Irradiance DNI at the plants locations

The amount of solar radiation received per unit area by a surface that is always held perpendicular to the rays that come in a straight line from the direction of the sun.

Plants that have DNI less than 4 $kWh/m^2/day$ are excluded.

No plants are excluded based on this criteria.



Exclusion Criteria

5- Available Land Area

- **Plants that do not have excess land area inside or outside their borders are excluded.**
- 10 plants are excluded:

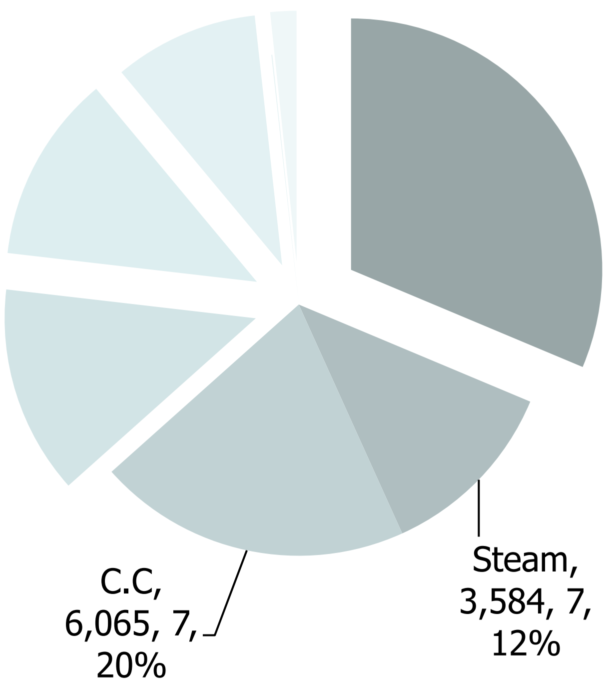
Plant	Type	Comment
Cairo West Ext.	ST	Surrounded by residential and agricultural area
Cairo North	C.C	Surrounded by residential area
Tebbin	ST	Surrounded by industrial and residential area
Talkha	C.C	Surrounded by residential and agricultural area
Talkha steam (210)	ST	Surrounded by residential and agricultural area
Talkha (750)	C.C	Surrounded by residential and agricultural area
Mahmoudia	C.C	Surrounded by agricultural area
El-Atf	C.C	Surrounded by agricultural area
Damanhour C.C	C.C	Surrounded by agricultural area
Abu Kir 150	ST	Surrounded by agricultural area

Excluded Plants

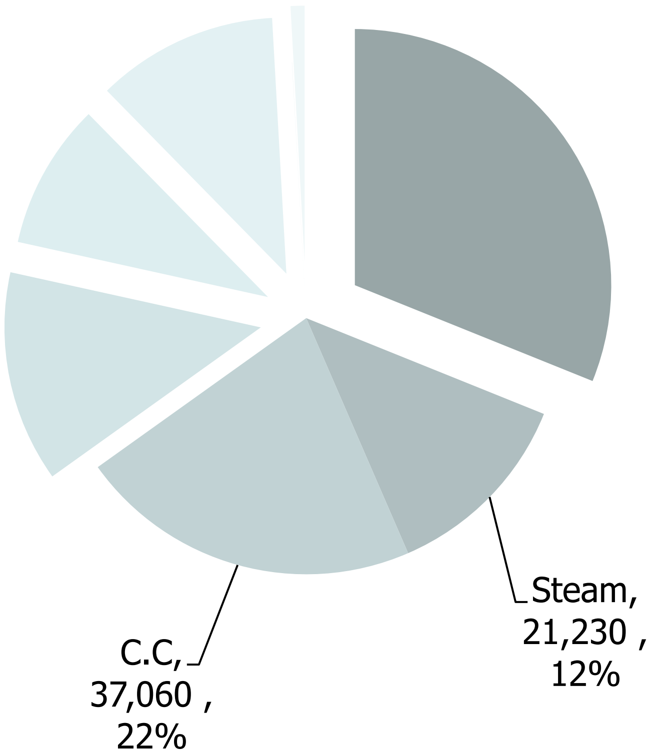
#	Criteria	Number of excluded plants
1	Capacity Factor	0
2	Plants Age	7
3	Topography of the Land	0
4	Direct Normal Irradiance DNI at the plants locations	0
5	Available Land Area	10

Selected Plants

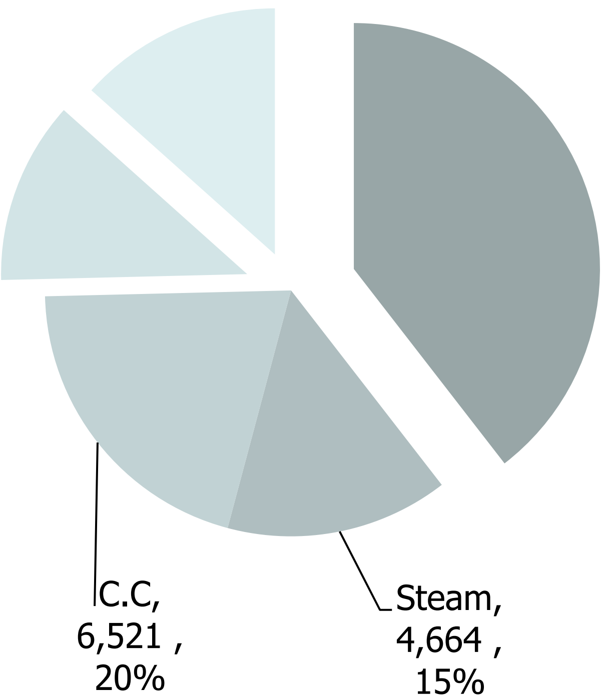
Capacity (MW, #, %)



Energy (GWh, %)



Fuel Use (ktoe, %)



Selected Plants

#	Power Plant	Plant Type	Plant Capacity (MW)
1	Cairo South I	C.C	450
2	Cairo South II	C.C	165
3	Damietta	C.C	1,200
4	Arish	ST	66
5	Oyoun Mousa	ST	640
6	Nubaria (1,2,3)	C.C	2,250
7	Damanhour Ext.	ST	300
8	Sidi Krir 1,2	ST	640
9	Sidi Krir (C.C)	C.C	750
10	Matrouh	ST	60
11	Walidia	ST	624
12	Kuraymat steam	ST	1,254
13	Kuraymat 1 (C.C)	C.C	750
14	Kuraymat 2 (C.C)	C.C	500

Technology Assessment

Parabolic Trough

Advantages:

1. the most cost effective concentrating solar power technology.
2. Hybrid operation is already a commercially proven concept.

Power Tower

Advantages:

1. It utilizes the cheapest flat mirrors.
2. It is suitable for operation with all power cycles.
3. Higher temperatures lead to better efficiency of turbines at a conventional Rankine cycle.

Technology Assessment

Parabolic Trough

Disadvantages:

1. The temperature limits of 400-500^{0}C leads to the production of steam suitable only for conventional Rankine cycles.
2. Lower temperatures obtained from these systems leads to efficiencies less than power tower and dish systems.

Power Tower

Disadvantages:

1. The technology is less mature than trough ones.
2. Land use efficiency is less than that of linear systems.

Technology Assessment

Input

	Parabolic Trough	Power Tower
Land Use Factor	40%	25%
Optical Efficiency	70%	63%

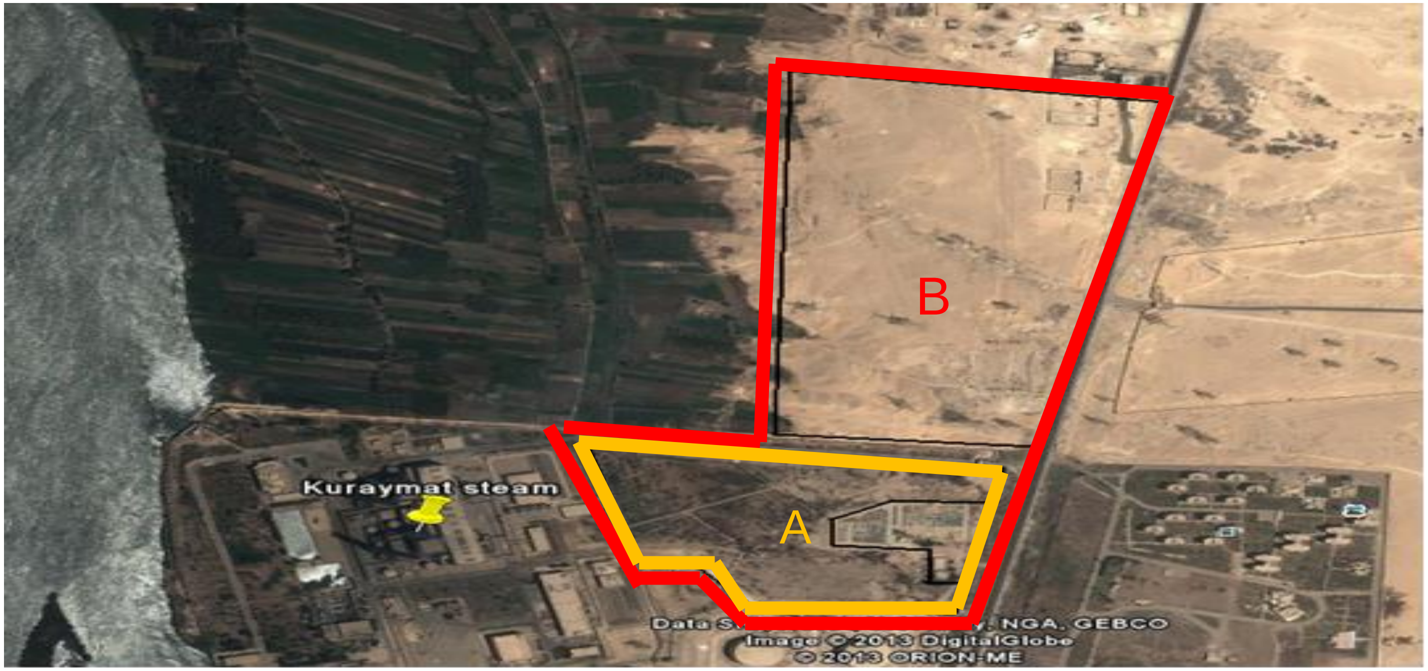
Output

	Parabolic Trough	Power Tower
Energy (GWh)	189	107
Capacity (MW)	51.9	29.2

Not Selected

Implementation Scenarios

- **Scenario A:** Only available land within the plants borders are used.



- **Scenario B:** Available land within and outside the plants borders are used.

Governing Equations

$$Aperture\ Area\ (m^2) = Free\ Area\ (m^2) * Land\ Use\ Factor$$

$$Thermal\ Output\ (kWht) = DNI\ (kWh/m^2\ /year) * \ Aperture\ Area\ (m^2) * Optical\ Efficiency$$

$$Thermal\ Capacity\ (MWt) = \frac{Thermal\ Output\ (kWht)/1000}{8760 * Availability\ Factor}$$

$$Availability\ Factor = \frac{Average\ daily\ sunshine\ hours}{24}$$

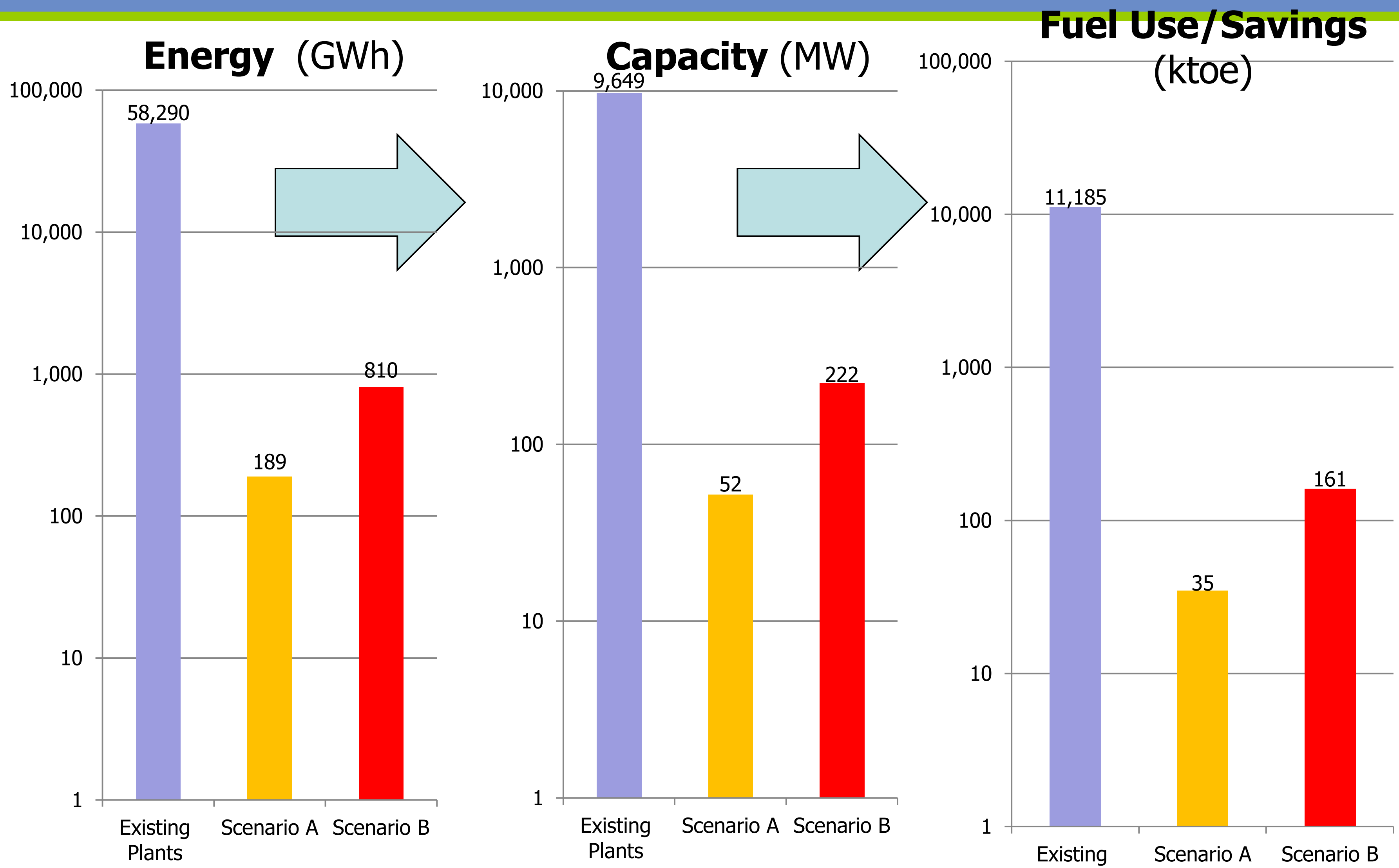
Governing Equations

$$Electrical\ Output\ (kWhe) = Thermal\ Output\ (kWht) * Plant\ Efficiency$$

$$Electrical\ Capacity\ (MWe) = Thermal\ Capacity\ (MWt) * Plant\ Efficiency$$

$$Annual\ Fuel\ Savings\ (ktoe) = \frac{Electrical\ Output\ (kWhe) * Plant\ Specific\ Fuel\ Consumption\ (gm/kWh)}{10^9}$$

Technical Assessment



Economic Assessment (Subsidized Fuel)

Scenario	Investment ($)	Annual Savings ($)	Payback period (Years)
A	100,221,457	2,426,796	41.3
B	469,289,894	11,227,313	41.8

Economic Assessment (Fuel's Market Price)

Scenario	Investment ($)	Annual Savings ($)	Payback period (Years)
A	100,221,457	14,819,977	6.8
B	469,289,894	68,563,034	6.8

Economic Assessment (Subsidized Fuel)

Investments decrease by 20%

Scenario	Investment ($)	Annual Savings ($)	Payback period (Years)
A	80,177,165	2,426,796	33
B	375,431879	11,227,313	33.4

Economic Assessment (Fuel's Market Price)

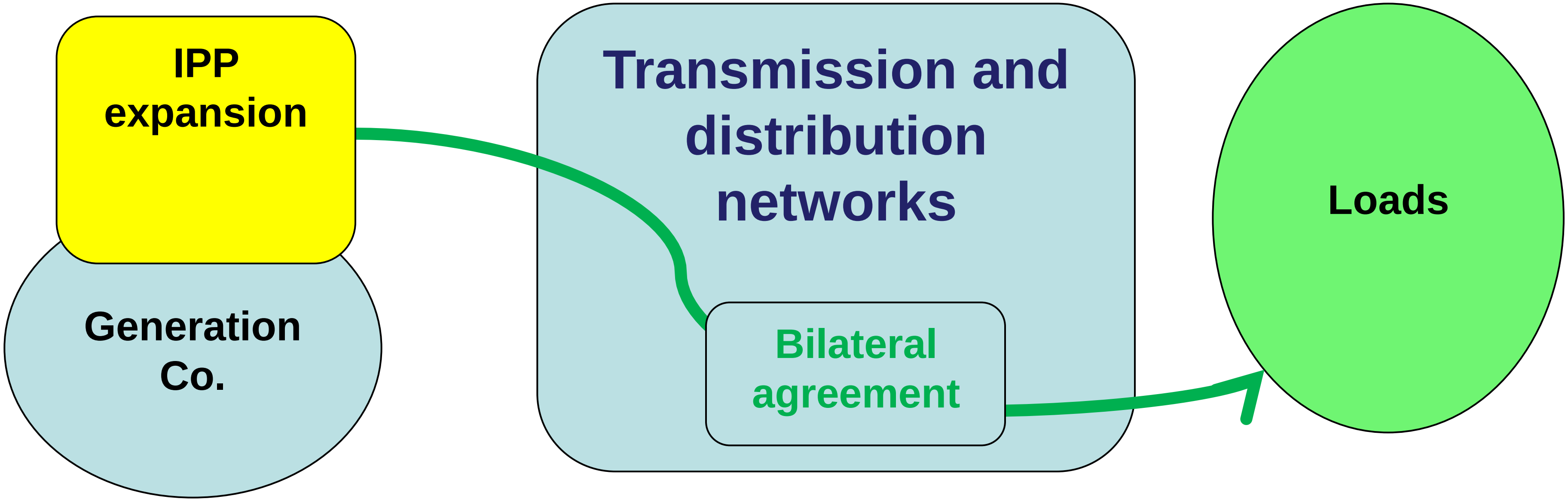
Investments decrease by 20%

Scenario	Investment ($)	Annual Savings ($)	Payback period (Years)
A	80,177,165	14,819,977	5.4
B	375,431915	68,563,034	5.4

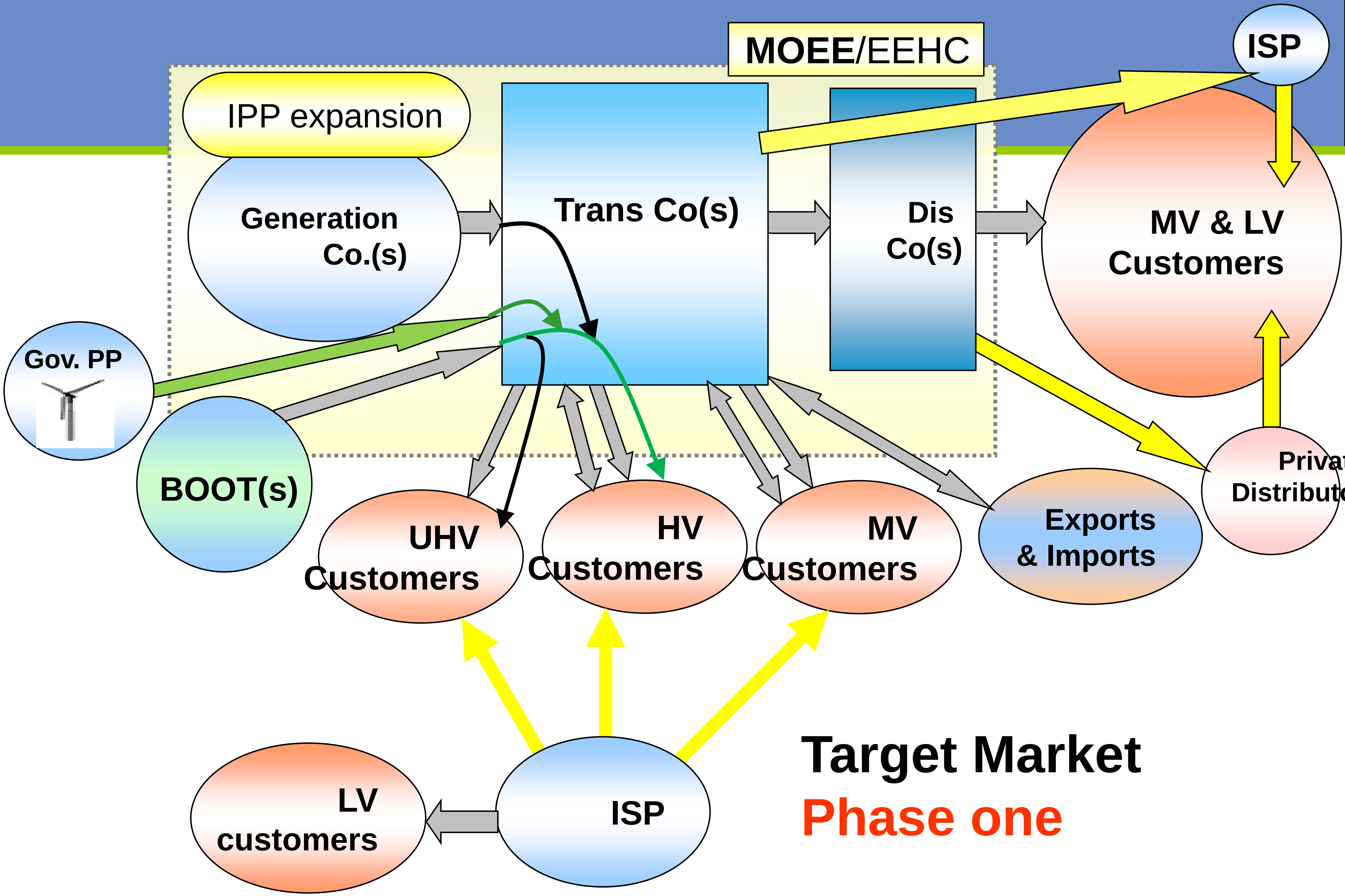
Public Private Partnership (PPP)

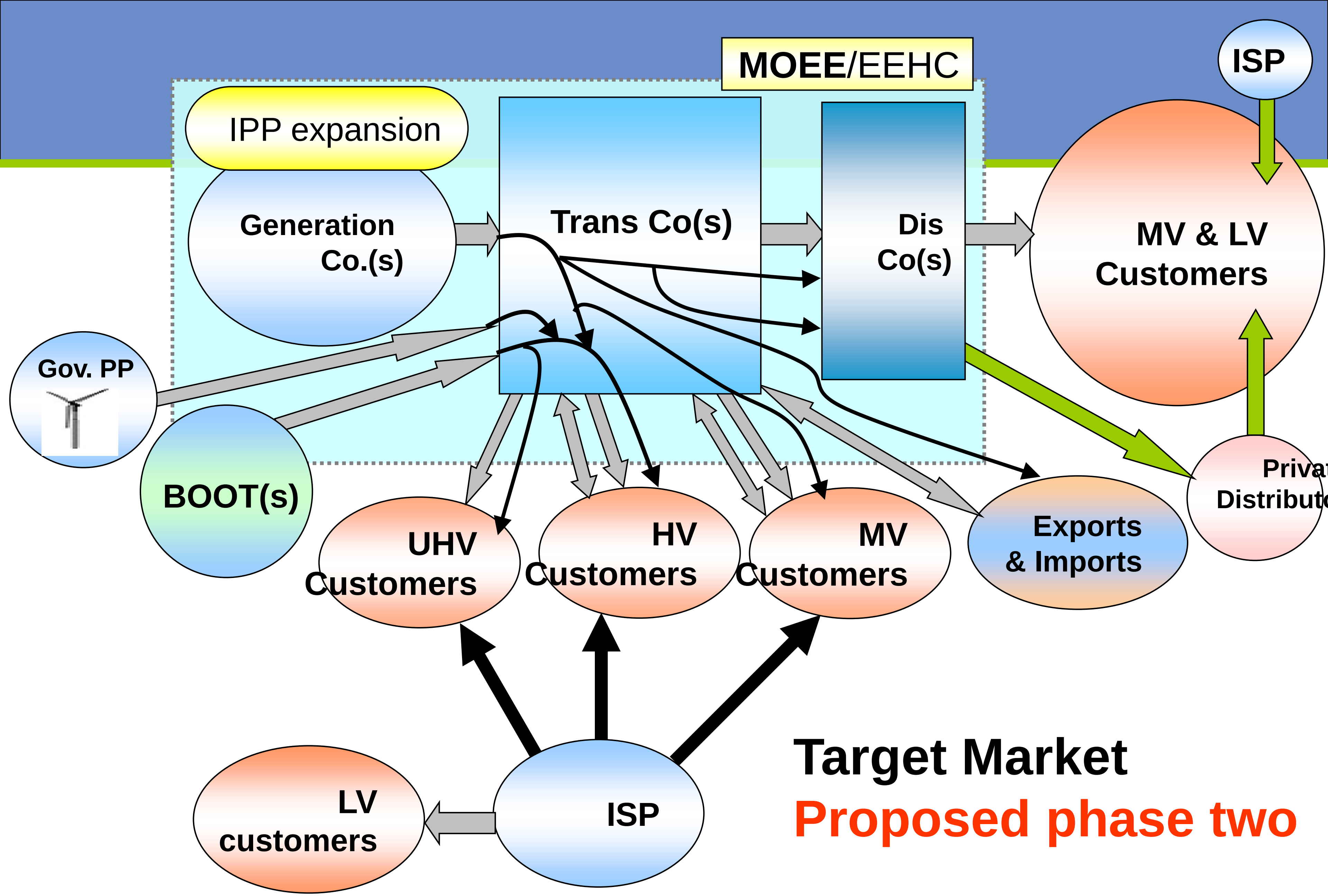
- 1% contribution
- 5% contribution

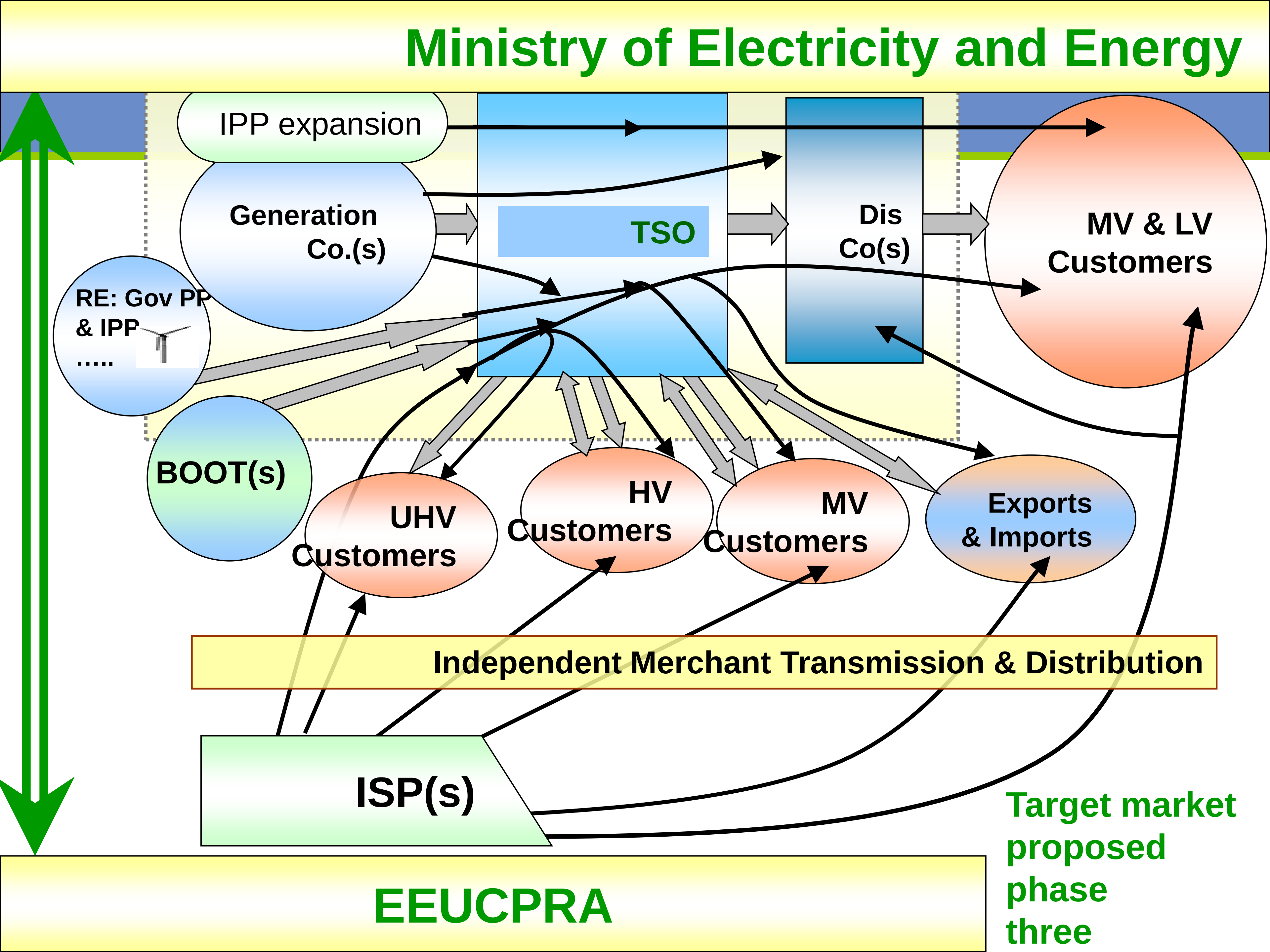
Regulatory framework



Target Market
Phase one




MOEE/EEHC
ISP
IPP expansion
Generation Co.(s)
Trans Co(s)
Dis Co(s)
MV & LV Customers
Gov. PP
BOOT(s)
UHV Customers
HV Customers
MV Customers
Exports & Imports
Privat
Distribut
LV customers
ISP
Target Market
Proposed phase two


Ministry of Electricity and Energy
IPP expansion
Generation Co.(s)
TSO
Dis Co(s)
MV & LV Customers
RE: Gov PP & IPP …..
BOOT(s)
UHV Customers
HV Customers
MV Customers
Exports & Imports
Independent Merchant Transmission & Distribution
ISP(s)
Target market proposed phase three
EEUCPRA

Possible demo implementations

- At current power plants in the industrial sector

Thank you for your attention

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Questions, Clarifications & Comments