华北电力大学
North China Electric Power University

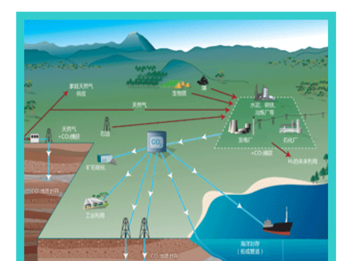
The Role and Prospects of Solar Energy in Future Carbon Mitigation
太阳能辅助碳减排的作用与前景

Dr. Zhai Rongrong
翟融融 博士

North China Electric Power University, Beijing, China
华北电力大学, 北京, 中国







Contents/汇报提纲

1
- The characteristics of solar energy and why it can be used in carbon mitigation
- 太阳能的特性以及它能辅助碳减排的原因

2
- How to use solar energy to realize carbon mitigation
- 如何利用太阳能来实现碳减排

3
- Case study: Solar aided thermal power generation
- 案例分析：太阳能辅助传统燃煤电站

4
- The prospects of solar energy in future carbon mitigation
- 太阳能辅助碳减排的前景

The characteristics of solar energy and why it can be used in carbon mitigation/太阳能的特性以及它能辅助碳减排的原因

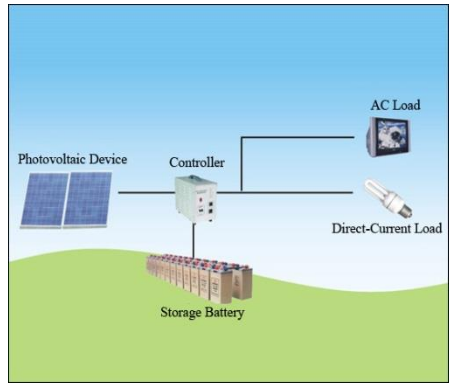
Characteristics 特性

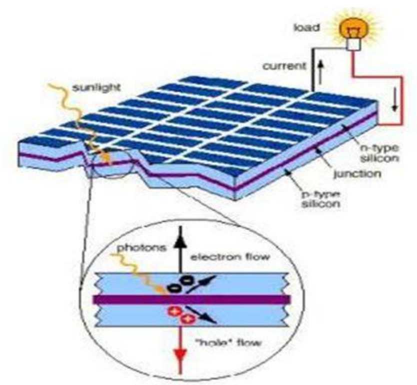
- Huge source of energy to the planet
  能源充足而且免费
- Low power density
  单独发电功率低
- Occupying an enormous area for utilization
  单独发电集热场占地面积大
- CCS: an energy consuming process
  CCS: 消耗汽轮机抽汽，降低机组功率

How to use solar energy to realize carbon mitigation
如何利用太阳能来实现碳减排

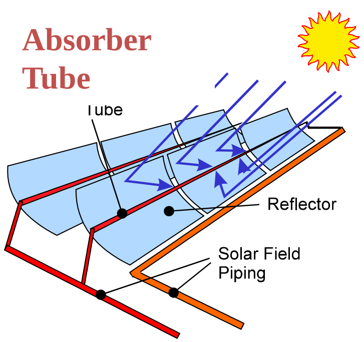
- Two ways of solar energy utilization/太阳能利用的两种方式

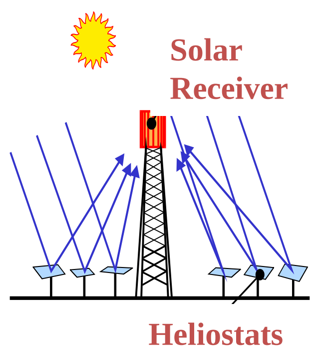
Photovoltaic/光伏发电

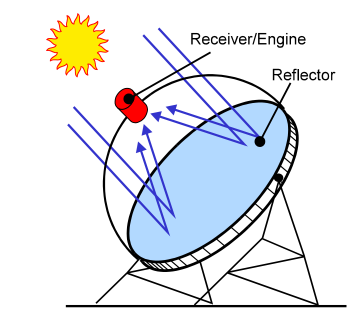




Thermal utilization/光热利用







Case study: Solar aided thermal power generation
案例分析：太阳能辅助传统燃煤电站

- Direct and indirect utilizations of solar energy in carbon mitigation
- 太阳能辅助碳减排的直接和间接利用方式

Direct method/直接利用方式

OR

- solar aided direct carbon reduction system;
- solar aided CCS

Indirect method/间接利用方式

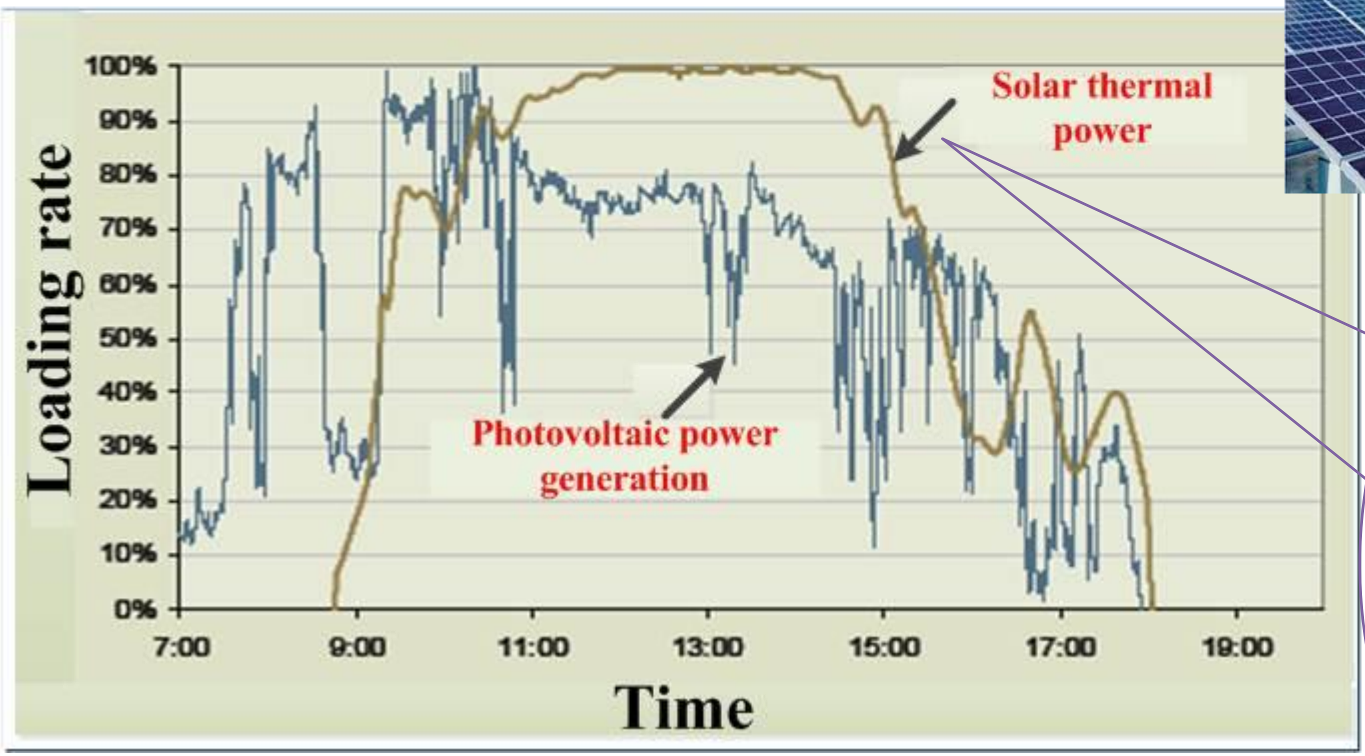
- direct solar thermal power generation;
- direct photovoltaic power generation;
- solar aided fossil fuel power generation

Case study: Solar aided thermal power generation
案例分析：太阳能辅助传统燃煤电站

- Direct solar thermal power generation (DSTG)/直接太阳能热发电

Case study: Solar aided thermal power generation
案例分析：太阳能辅助传统燃煤电站

- Compared with Direct Photovoltaic (PV) Power generation
- 与直接太阳能光伏发电的对比



The actual measurement comparison between 50MW thermal power generation and 50MW photovoltaic (California, USA)

50MW 光热电站和50MW 光伏电站 实测值对比（加利福尼亚，美国）

Disadvantages of the solar power station:

✓Changes in radiation intensity makes it harmful to the grid

✓Solar thermal power generation is more stable than the PV

✓太阳能发电站的特点:

✓辐照条件的多变性对电网稳定性有影响

✓太阳能光热发电比光伏发电稳定

Case study: Solar aided thermal power generation
案例分析：太阳能辅助传统燃煤电站

➢ Shortcomings of DSTG/DSTG的缺点

Instability of the solar irradiance
太阳辐照的不稳定性

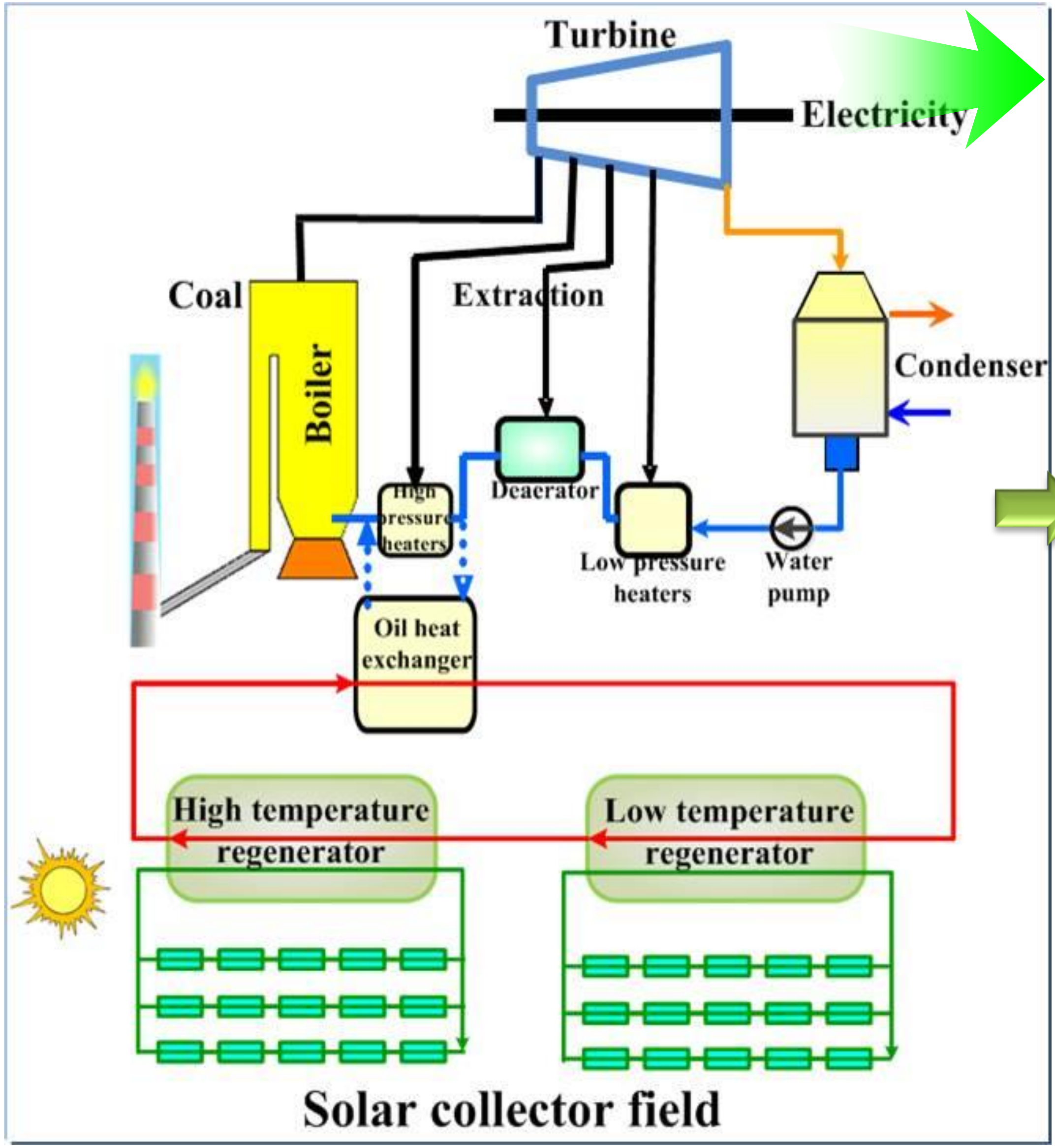
Large scale heat storage system
庞大的蓄热系统

High cost/
成本高

Solution: Coupling with other energy hybrid power generation

解决方案:与其他能源互补发电

Case study: Solar aided thermal power generation
案例分析：太阳能辅助传统燃煤电站



Present: Feed water is heated by extracted steam from turbine

现状：用汽轮机抽汽加热给水

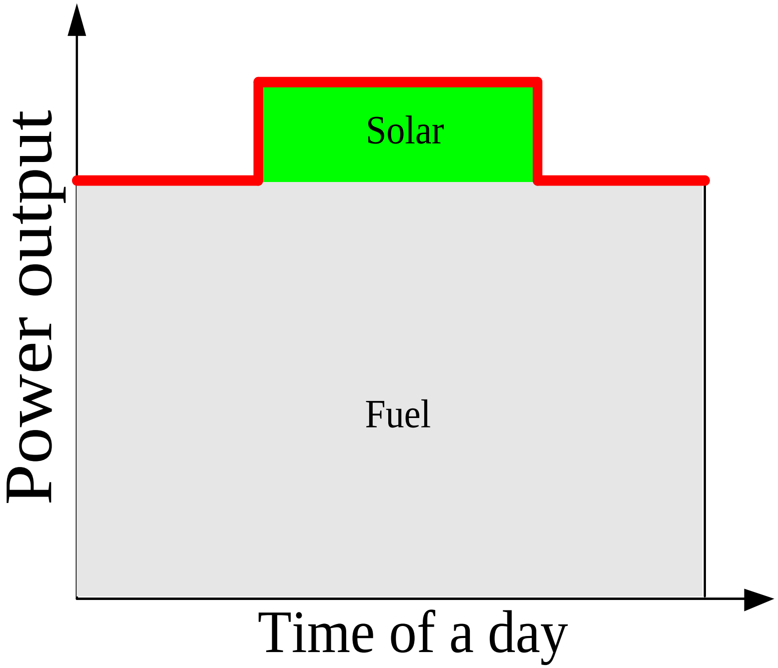
- Reduce heat storage requirements
- Shared turbine system
- Cascade employment of energy grade
- 共享汽轮机系统
- 减少蓄热需求
- 能量分级利用

Cost reduction of solar thermal power generation
降低太阳能热发电的成本

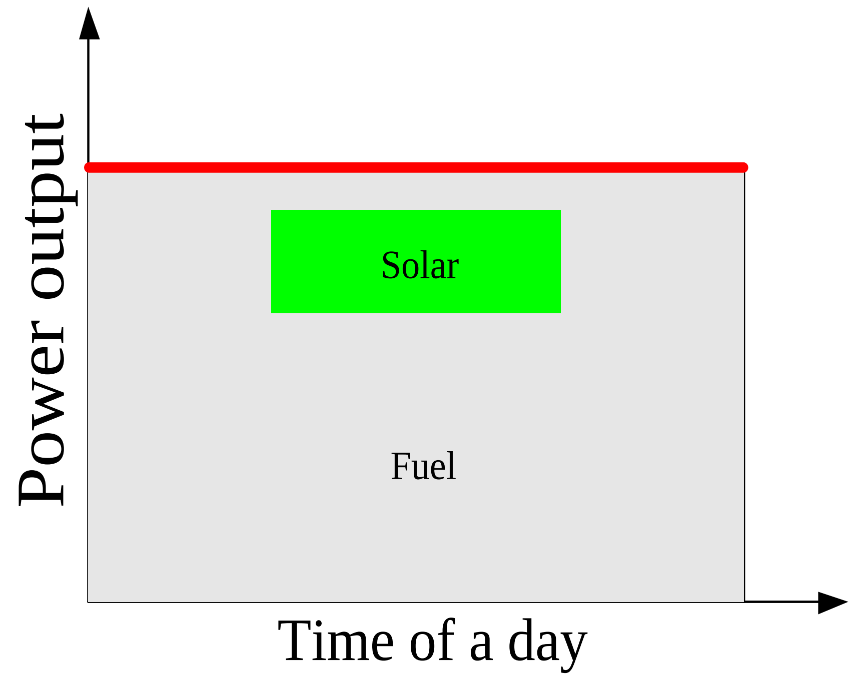
Deeply energy saving and emission reduction for a coal-fired power station
实现燃煤电站的深度节能减排

Case study: Solar aided thermal power generation
案例分析：太阳能辅助传统燃煤电站

- Two operation modes: power boosting and fuel saving modes
- 两种运行模式：功率增加型和燃料节省型



Power boosting mode



Fuel saving mode

Power output increased

Coal consumption rate unchanged

输出功率增加、煤耗率不变

Power output unchanged

Coal consumption rate reduced

输出功率不变、煤耗率降低

Case study: Solar aided thermal power generation
案例分析：太阳能辅助传统燃煤电站

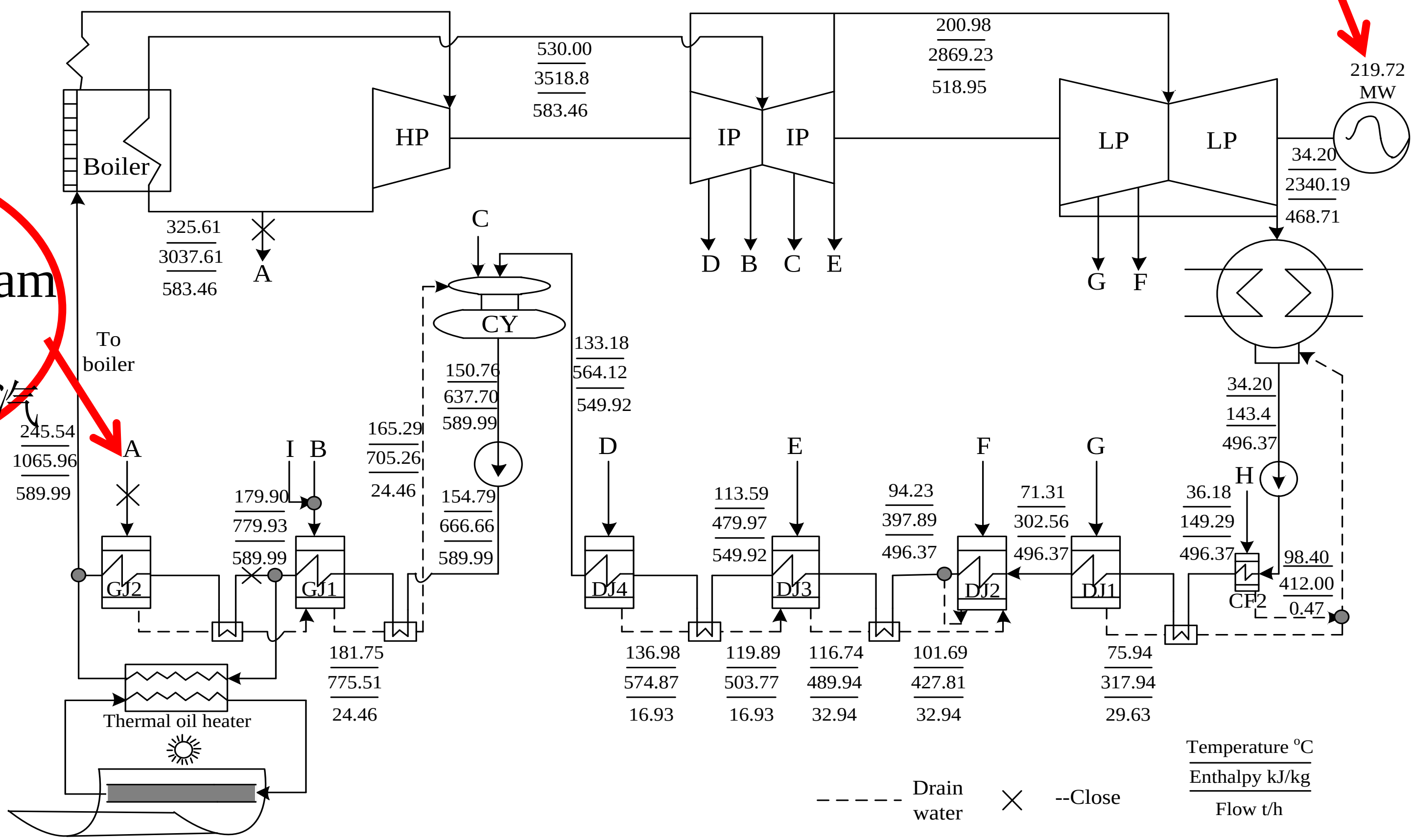
- 200MW subcritical unit: Thermal performance/200MW 亚临界机组: 热力性能

260ºC Thermal Oil 导热油

Oil: Power boosting mode
导热油：功率增加型

Power boosting
功率增加
(from 200 to 219.72MW)

Replace the first stage of steam Extraction
替代第一级抽汽



Case study: Solar aided thermal power generation
案例分析：太阳能辅助传统燃煤电站

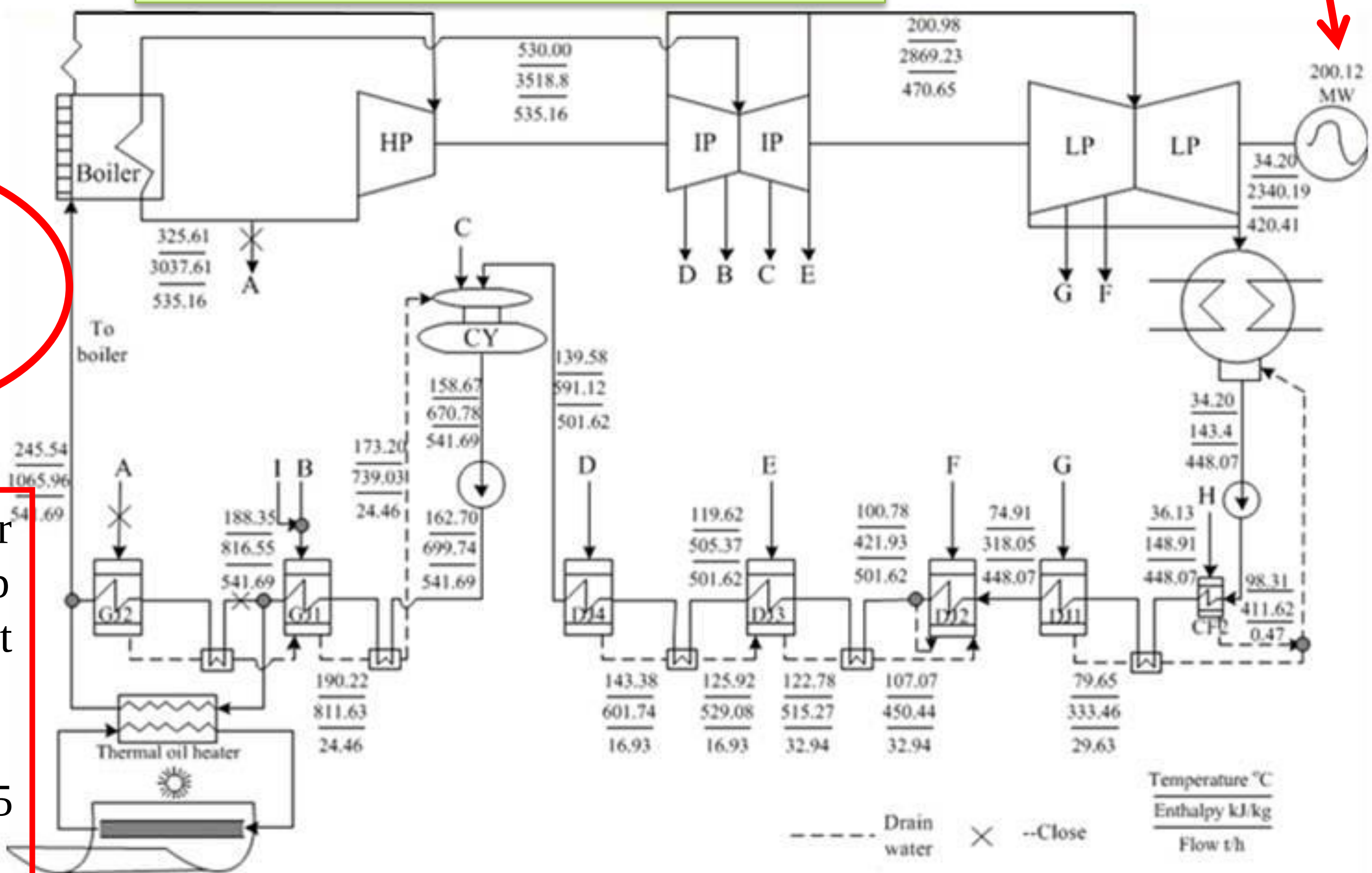
- 200MW subcritical unit: Thermal performance/200MW 亚临界机组: 热力性能

Oil: Fuel saving mode
导热油：燃料节省型

260°C
Thermal Oil
导热油

Obtain发电功率 200 MW

Fuel saving
燃料节省
(From 55.17t/h to 51.58 t/h)



Reduce feed water flow to maintain base load from 590to 541.7t/h
降低给水流量来维持基本负荷从590到541.7t/h

Case study: Solar aided thermal power generation
案例分析：太阳能辅助传统燃煤电站

- 200MW subcritical unit: Thermal performance/200MW 亚临界机组: 热力性能

Medium temperature
中温

Scenario No.	Power output	Standard coal consumption	Solar heat/Thermal oil temperature	Boiler steam flow rate	Calculated boiler heat load q	Calculated SSC d	Calculated coal consumption b	η_{se}	Solar collector areas required	Remark
	MW	ton/h	°C	t/h	kJ/kWh	kg/kWh	g/kWh	%	m²	Unit
Base condition	200.24	55.17	0	589.99	8072.04	2.946	275.79	0	0	
Scheme 1 in power boosting mode	219.72 (+9.73%)*	56.19 (+1.85%)	**260**	589.99 (0)	7492.55 (-7.18%)	2.685 (-8.86%)	256.00 (-7.18%)	36.58	112,415	Δt =15°C
Scheme 1 in fuel saving mode	200.12 (-0.06%)	51.58 (-6.51%)	**260**	541.69 (-8.19%)	7551.45 (-6.45%)	2.707 (-8.11%)	258.01 (-6.45%)	---	90,098	Δt = 15°C
Scheme 2 in power boosting mode	205.02 (+2.39%)	54.79 (-0.69)	**215**	589.99 (0)	7829.59 (-3.00%)	2.878 (-2.31%)	267.51 (-3.00%)	25.48	46,891	Δt = 17°C
Scheme 2 in fuel saving mode	200.12 (-0.06%)	53.54 (-2.95)	**215**	577.89 (-2.05%)	7838.07 (-2.90%)	2.888 (-1.97%)	267.80 (-2.90%)	---	42,239	Δt =17°C
Scheme 3 in power boosting mode	207.88 (+3.82%)	54.81 (-0.65%)	**160**	586.61 (-0.57%)	7725.00 (-4.30%)	2.822 (-4.21%)	263.94 (-4.30%)	13.15	151,825	Δt =16°C
Scheme 3 in fuel saving mode	200.02 (-0.11%)	52.65 (-4.57%)	**160**	567.23 (-3.86%)	7711.31 (-4.47%)	2.836 (-3.73%)	263.47 (-4.47%)	---	145,752	Δt =16°C
Scheme 4 in power boosting mode	202.40 (+1.08%)	55.17 (0)	**90**	589.99 (0)	7985.85 (-1.07%)	2.915 (-1.05%)	272.85 (-1.07%)	10.65	50,702	Δt =14°C
Scheme 4 in fuel saving mode	200.21 (-0.03)	54.54 (-1.14%)	**90**	584.60 (-0.91%)	7980.73 (-1.13%)	2.920 (-0.88%)	272.68 (-1.13%)	---	50073	Δt =14°C

*--Percents compared with the base condition

The benefits of solar aided thermal power generation
太阳能辅助燃煤电站的优势

Case study: Solar aided thermal power generation
案例分析：太阳能辅助传统燃煤电站

- 200MW subcritical unit: Economic Analysis/200MW 亚临界机组: 经济性分析

Results of the integration of power generation techno-economic analysis
互补发电站的技术经济分析结果

	Lhasa		Hohhot	
	Replace the first exhaust Fuel saving	Replace the HPHE Fuel saving	Replace the first exhaust Fuel saving	Replace the HPHE Fuel saving
Solar collector field and bracket (10^6 ＄)太阳集热场及支架	24.3	47.3	28.4	55.2
Heat transfer equipment or steam generator (10^6 ＄)换热器或蒸汽发生器	/	1.4	/	1.7
Total investment cost (10^6 ＄)总投资	24.3	48.7	28.4	56.9
Annual operating and maintenance costs (10^6 ＄)年运维费用	0.31	0.61	0.26	0.51
Unit cost of power generation (＄/kW.h)单位发电成本	0.073	0.075	0.101	0.104
Unit cost of power generation (¥/kW.h)单位发电成本	**0.57**	**0.585**	**0.793**	**0.813**

The prospects of solar energy in future carbon mitigation
太阳能辅助碳减排的前景

Renewable energy, especially solar energy, can be applied for substituting conventional fuel
可再生能源，特别是太阳能，可以应用于代替传统的燃料

Thermal storage technologies are key to the development of solar energy utilization
蓄热技术是太阳能利用发展的关键

Suggestions: First stage-Solar aided fossil fuel power generation systems
建议: 太阳能辅助燃煤电站的集成方式

Thanks!
谢谢！

Dr. Zhai Rongrong

North China Electric Power University, Beijing, China