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Some Considerations of Comprehensive Energy Conservation

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- If today's trend of utilization of fossil fuel continues (BAU technology), we are running out of atmosphere **faster** than we're running out of fossil fuels.
- Terrorism **doesn't** threaten the viability of the heart of our high technology life-style, but energy really **does**.
- Human-induced climate change could **overshadow** all our other efforts to cure diseases, reduce poverty, prevent warfare and preserve biodiversity.

General Conclusions

- According to the projection of energy demand and supply, coal will still play the dominant role (50~60% in 2050).
- Coal utilization will contribute about 70~75% of CO₂ emission in China (at present 76.8%), and SO₂, NO_x, PM₅, Hg as well.
- Coal mainly will be used for power generation in future (up to 80%, at present about 45~50%). It means the coal fired power plants will contribute 60% or more CO₂ emission of the total.

General Conclusions *(Cont.)*

- Large scale mitigation of the shortage of liquid fuels could be realized only by coal-derived alternatives (F-T synthetic fuel, Methanol, DME), Biodiesel and ethanol from corn and cellulose could only solve small part of the shortage problem.
- Capturing CO₂ from the flue gas of power plants is investment-intensive with unaffordable large (per unit CO₂) energy consumption.
- “Hydrogen Economy” with renewable-derived hydrogen still has a long way to go (20~30 years).

The focus: improvement of energy efficiency & energy conservation

- There are a lot of studies concerning the future scenarios by 2020, 2030 and 2050. **Improvements of energy efficiency and energy conservation are the focus.**

- Power generation

	$\eta(\%)$
Subcritical	35~37
Supercritical	42
Ultra-supercritical	44~45
NG fired CC	58

1% of efficiency improvement
→ 2~3% CO₂ reduction

- Advanced vehicle engines

	$\eta(\%)$
Diesel	20~25 (tank to wheel)
Hybrid	30~35 (TTW)
Electricity	85

- Industrial Boiler: $\eta=65\sim70\%$

Total consumption → about
300~400 mil t coal

From consumption side

- China is still in the condition of higher energy consumption per unit products (20~30% higher).
 - Reduce the energy consumption for iron, steel, fertilizers, cement, AI, different chemicals etc..
 - Improve the efficiency of electrical motors (variable speed control...) and huge amounts of different pumps.

From consumption side *(Cont.)*

- All the above mentioned are the efficiency in a *narrow* sense, China has spent and been spending continuous efforts for decades. It is extremely important, but only part of the problem.
- Efficiency in *broad* sense (or *comprehensive*) is more important and has more potential.
- Irrational allocation and utilization of different energy resources are causing a huge waste of energy.

Several examples

- When **USC power plant** operates on off-design performance, the efficiency merits will be greatly diminished;
- Using high temperature fossil fuel combustion (1400°C or more), heat transfer, electricity generation and long distance transmission to solve the problem of **raising the room temperature** about 20 °C(winter) and **lowering** down 5~10°C (summer) in comparison with ambient temperature;
- Use stalks and straws for **power generation** – highly scattered, small land per capita (1/15 hectare), large diameter of collection (about 50~100 km), waste of valuable liquid fuels and labors. In contrast, farmers have to use coal for cooking and heating with low efficiency and severe pollution.

Several examples *(Cont.)*

- Power generation, chemicals production, iron and steel make the total utilization of coal as primary energy, and every sector has its own process. Local process optimization does not mean the optimization of coal utilization in general. The potential efficiency improvement of coupling these processes is 15~20%;
- Directly end-user oriented distributed energy system (combined cooling, heat and power CCHP) could lower the loss of energy for circuitous transportation and transmission.

Several examples *(Cont.)*

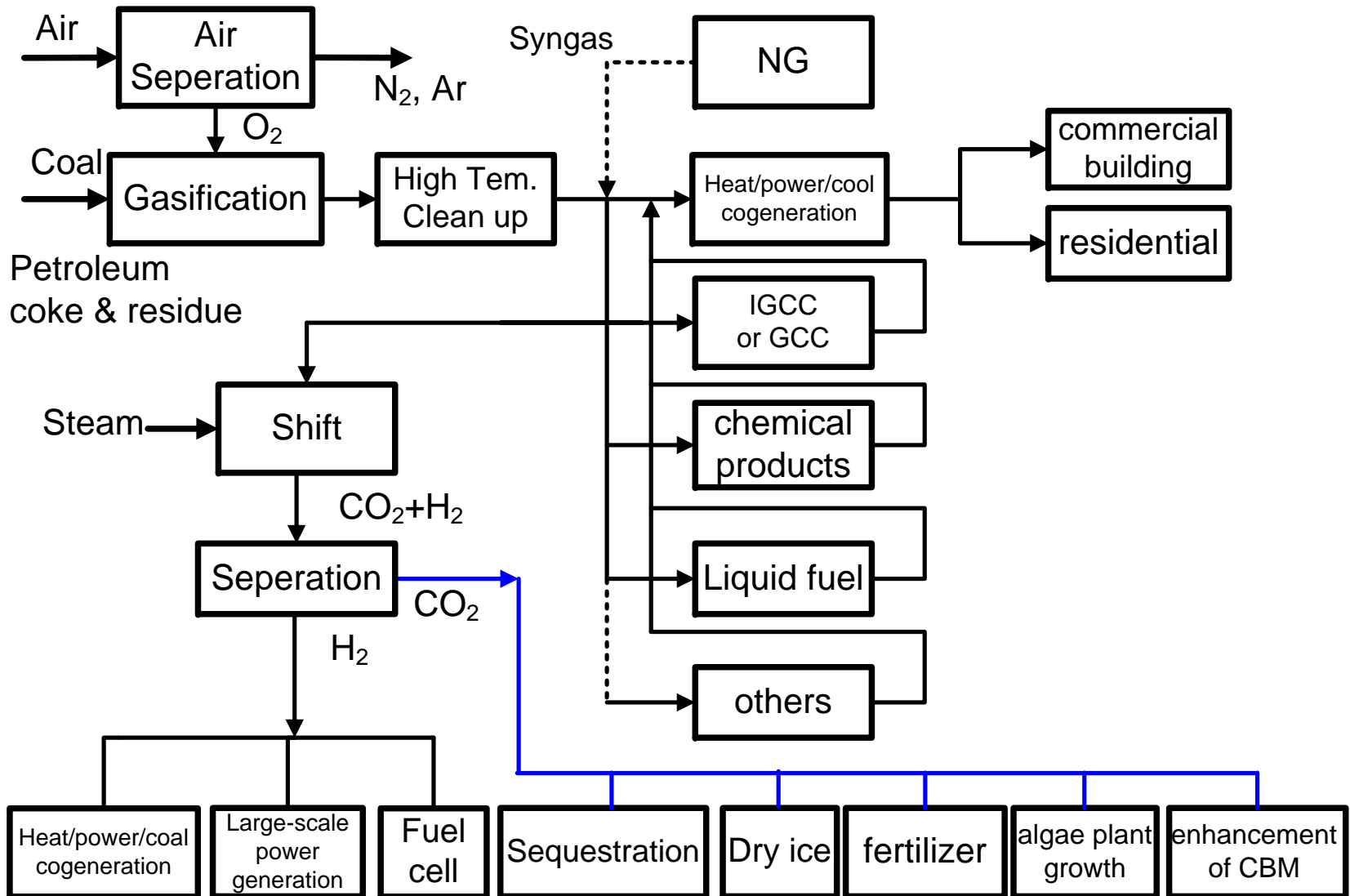
- The current energy system should be gradually reorganized to the more sustainable one. In addition to continuously improving the efficiency of concrete technology, more attention should be paid to improve the comprehensive efficiency.
- In practice, some technologies in themselves have already reached their limits:
 - The efficiency of large compressor → 88~90%
 - The working fluid temperature of gas turbine → 1400~1500°C
 - Conversion NG to methanol → 29GJ NG/t
 - Further efficiency enhancement of 1 point percentage is already quite difficult.

Four directions for increasing comprehensive (or system) efficiency – **IDDDN**

I Integration

- Break the boundaries of different industrial sectors
- The target-optimized utilization of resources / energy of raw feedstock
- Change the traditional technological processes
- Polygeneration based on coal gasification
- Coproduction of power, liquid fuels and chemicals
- Potential of efficiency increase 10 ~15%

Polygeneration system scheme



I Integration

- Coal gasification + NG reforming
 - “Chemical” cooling of high temperature syngas at the exit of gasifier
 - More appropriate syngas H_2/CO ratio
- Coal gasification + Coke-oven gas, more appropriate H_2/CO ratio, diminish the shift process with energy loss
- Iron ore reduction + coal gasification to eliminate coal coking process (high pollution process)
- Large scale (300MW per unit) steam extract district heating, though utilization of the heat which is usually go to the cooling tower.
- Combined cooling, Heating and Power (CCHP)

I Integration – renewable energy with fossil fuels

- How to use the renewable energy appropriately is an important issue.
- The strategic position of different renewable energy in the whole energy system should be carefully defined according to their features.
- We must consider the utilization of the renewable energy in combination with fossil fuels.
 - Solar heat collector + heat pump + NG (building energy supply)
 - Solar heat for feed water heating
 - Solar heat for CCS
 - Cofiring of biomass with coal for power generation

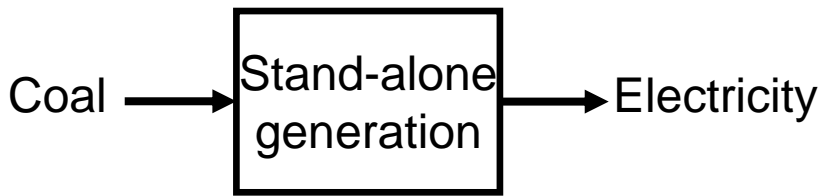
I Integration – renewable energy with fossil fuels

- Large wind farm + gas turbine or compressed air storage
- Wind power integrated with coal chemical industry
 - Large wind farm off grid operation, electrolyzing the water for H_2 and O_2 production with combination of coal chemical industry
 - Utilization of the uncontrollable wind power, off-grid operation, and elimination of its negative influences on the grid
 - Thoroughly utilize all chemical elements, so the CO_2 emission during methanol/DME production will be greatly reduced

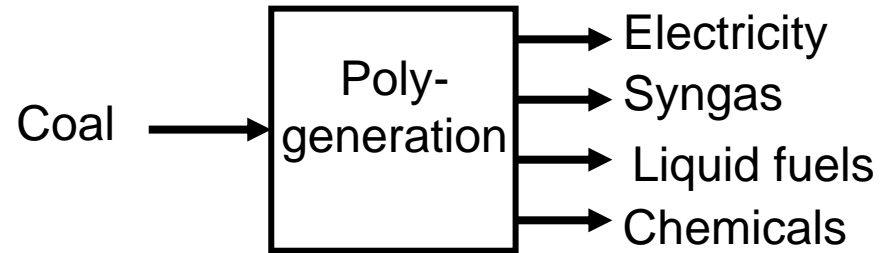
Integration of energy systems

Electricity, liquid fuels, chemicals, iron & steel...

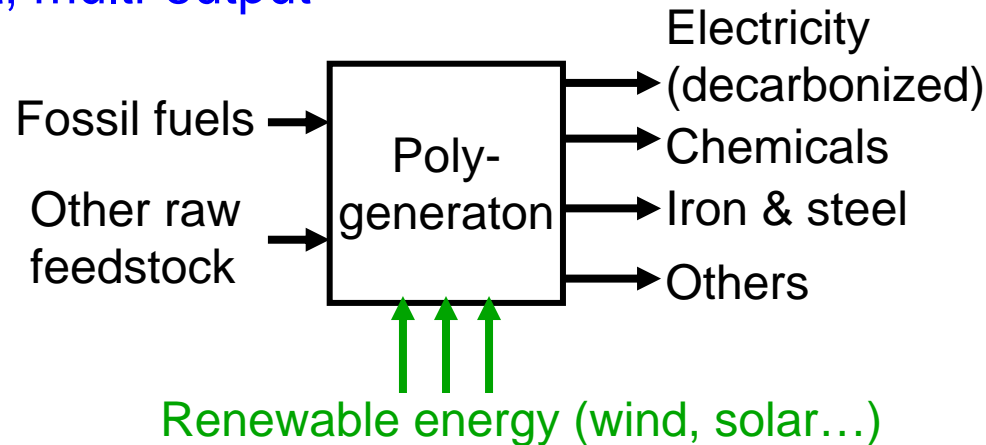
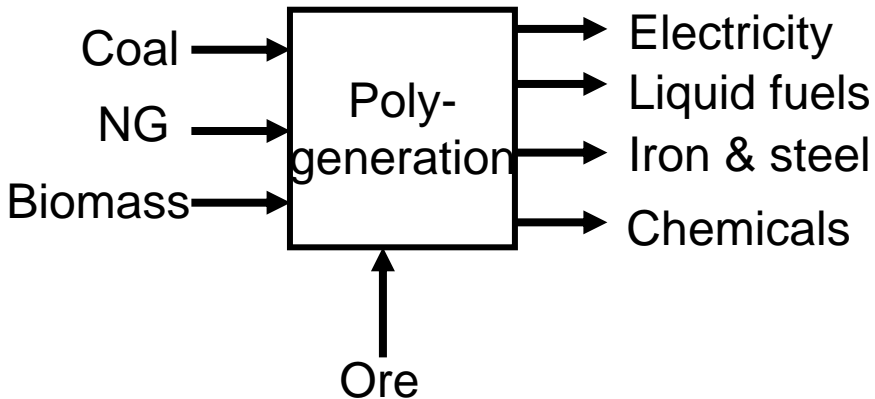
Single input, single output



Single input, multi-output

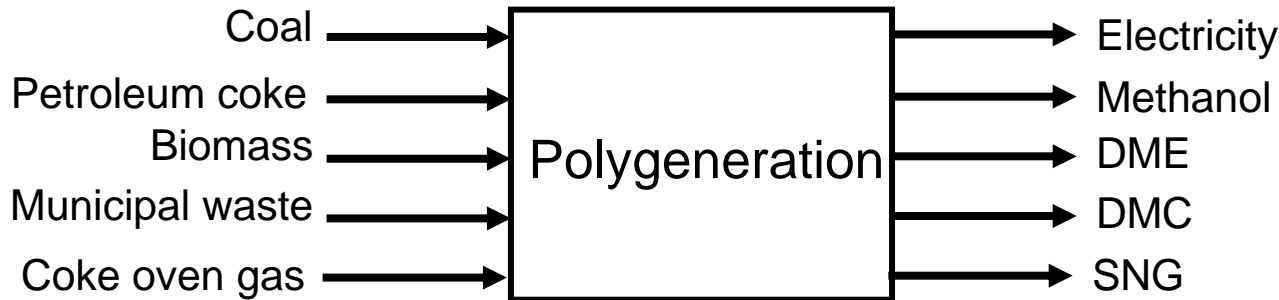


Multi-input, multi-output



Every kind of energy could play its specific role in the multi-input and multi-output system.

Comprehensive total energy system



- Cascade utilization of **H₂/CO ratio**
- Cascade utilization of **pressure**
- Cascade utilization of **materials**
- Cascade utilization of **temperature**
- Total energy system: **temperature matching, appropriate components matching, cascade and optimized utilization of physical and chemical energy.**

II Differentiation of end user's demand

- **High temperature** – different kinds of industrial use
- **Low temperature** – building's cooling and heating supply. Renewables and cascade utilization of energy
- **Stable supply** – industrial processes
- **Supply with tolerant fluctuation**
 - Electrolysis of Al or H₂O
 - Desalination of water
 - Other chemical processes
 - ...

Direct use of the electricity from wind farms without the grid connection

II Differentiation of end user's demand

■ As heat energy

- High temperature, as different industrial uses
- Intermediate temperature
- Low temperature, as building heating (we usually use high temperature energy to satisfy this demand)

■ As electricity

- High voltage, low voltage, Alternative/Direct Current
- Stable supply / tolerant with fluctuations

■ As primary energy for vehicles

- City bus, intercity buses and commute cars - definite routes
- Taxi - relatively short distances
- Private cars – electrical drive, hybrid, plug in
- Alternative fuels (MeOH and DME)...

II Differentiation of end user's demand

- Only on the base of differentiation of end users' demand, the diversification of the supply including RE, could play a more essential role in the energy system
- Different end users should use the appropriate energy (according to the concrete local condition)
- Eliminate the unnecessary steps of energy conversion and transportation (transmission)
- Electricity is the best carrier of energy (from the point of clean, convenience, infrastructure...)

III Diversification of the supply

- Coal, petroleum, NG, nuclear, hydraulic, renewable energy, solar PV, solar heat, wind (small, medium and large scale), biomass...
- According to its nature, every kind of energy should “find” its appropriate position in the energy system.
- How to make diversifying supplies to meet the differentiated demand, **the principles are:**
 - High density energy should be used with centralized conversion (high efficiency and low pollution). Use the existing infrastructure like power grids and gas pipeline network to reach the end users

III Diversification of the supply

- Distributed, low density energy should be used in distributed way (energy supply for rural areas)
- High quality energy → electricity
- Medium and low quality energy → cascade utilization, to avoid the unnecessary steps of conversion
- RE should be tailored to the local concrete conditions

Cheap, simple and convenient method for using highly distributed straw and stalk (palletizing, digester) – **special oven for piecemealed biomass** to meet peasants' demand for cooking and heating.

Relative centralized shrub could be used for district heating and small boilers in the light of urbanization.

III Diversification of the supply

- From thermodynamics analysis, any energy conversion and thermodynamic cycle has the nature of cascade change of physical and chemical exergy.
 - Gas turbine cycle, steam turbine cycle, internal combustion engine cycle, different heat pump cycle, different refrigeration cycle, etc.
- Diversification of the supply implies to match the cascade nature of the energy conversion processes with the differentiated energy demands.

III Diversification of the supply

In principle:

- Higher energy for “higher” utilization
- Lower energy for “lower” utilization with energy loss as little as possible
- Physical energy – suitable temperature matching, cascade utilization
- Chemical energy – suitable components, rational allocation, multi-products, fully utilization of valuable substances of feedstock and raw materials

IV Decentralization of energy supply system (DES)

■ Decentralized energy supply systems

- End-user oriented energy systems of small and medium size
- Local energy production, conversion and supply
- Satisfy the multi-demand of end-users

■ Features:

- Closely linked to the end users in distance and types of energy
- Small and medium size (micro GT, internal combustion engines, heat pumps, wind power, solar PV, solar heat collectors...), in combination with different types of energy storage systems

IV **D**ecentralization of energy supply system (DES)

- Cheap and convenient energy storage systems (electricity, heat...) of large, medium and small size are the most important issue for energy conservation. Technology breakthroughs are extremely needed.
- High efficiency, less energy loss in conversion, transportation and transmission
- Multi-energy sources (NG, LPG, city gas, coke-oven gas, CBM, including renewable energy)
- More convenient for coupling with RE, which are low energy density, and have random characters.

Great potential for efficiency improvement, up to **20~30%**.

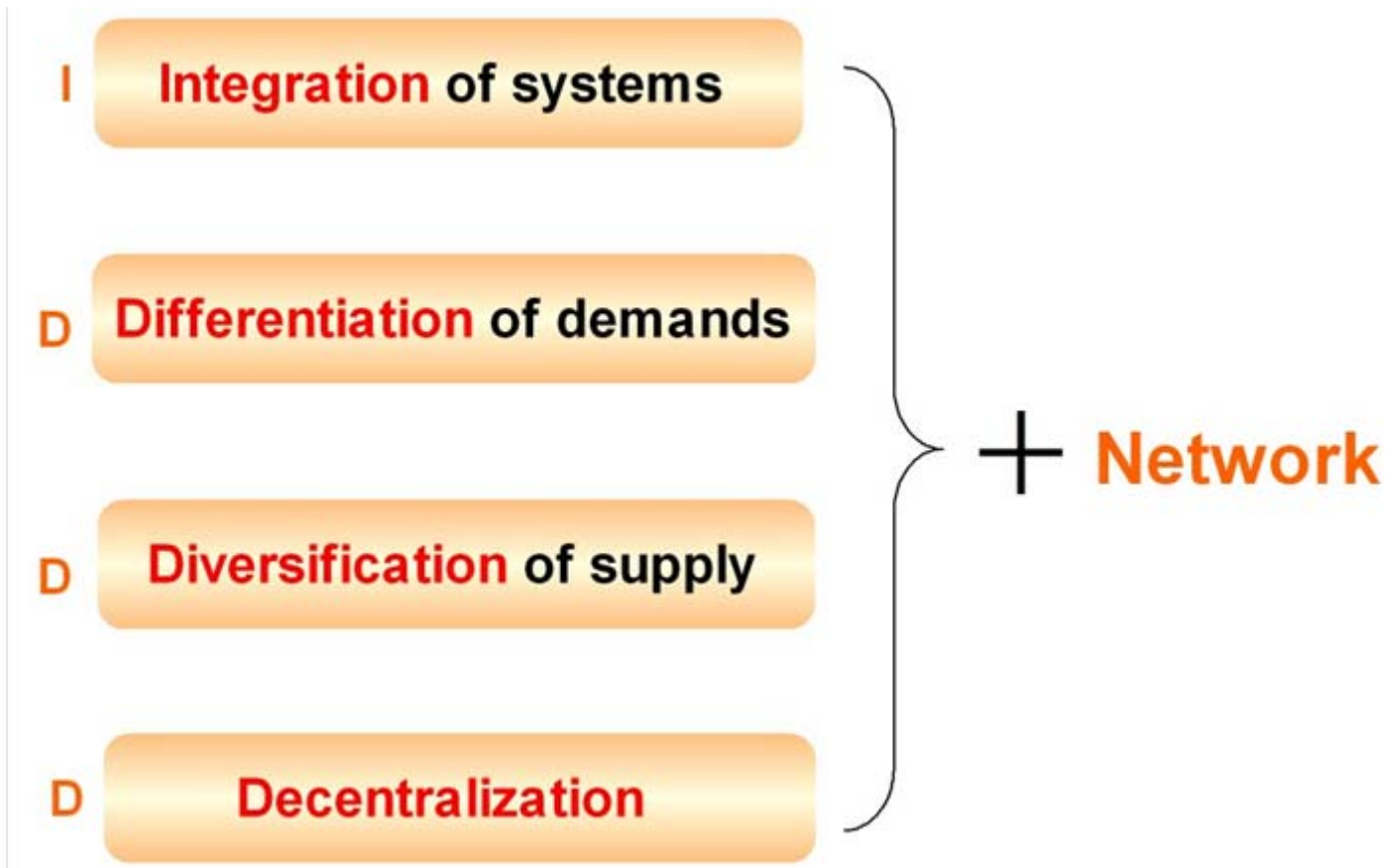
IV **D**ecentralization of energy supply system (DES)

- Combination of centralized electrical grid, distributed electrical grid, off grid operation...
- Different kinds of energy should be used in the way of mutual compensation, and mutual combination.

V Network

- On the base of above mentioned **IDDD**, a sustainable energy system could be established via evolution of existing energy system.
- Flexibility, controllability, reliability, on-line static and dynamic optimization are totally new challenges.
- Fast-developing information technology should be used to promote the establishment of new sustainable energy system, such as:
 - Data collection, sensor network, state-variables detecting, data analysis, data mining, data prediction, forecast technologies (especially for renewable energy)
 - Establishment of energy information platform of broad coverage
 - Establishment of network of hierarchical optimization for different hierarchies (small, medium, large, regional, provincial...)

Summary



Methodology —total life cycle analysis

Philosophy —put the right thing on the right place

I D D D + N

Mode of New Sustainable Energy
System



Thank You!