November 15, 2005 in Beijing, China

Part I: Current Research Activities on Biomass-based Energy in China

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Why bioenergy so important for China?

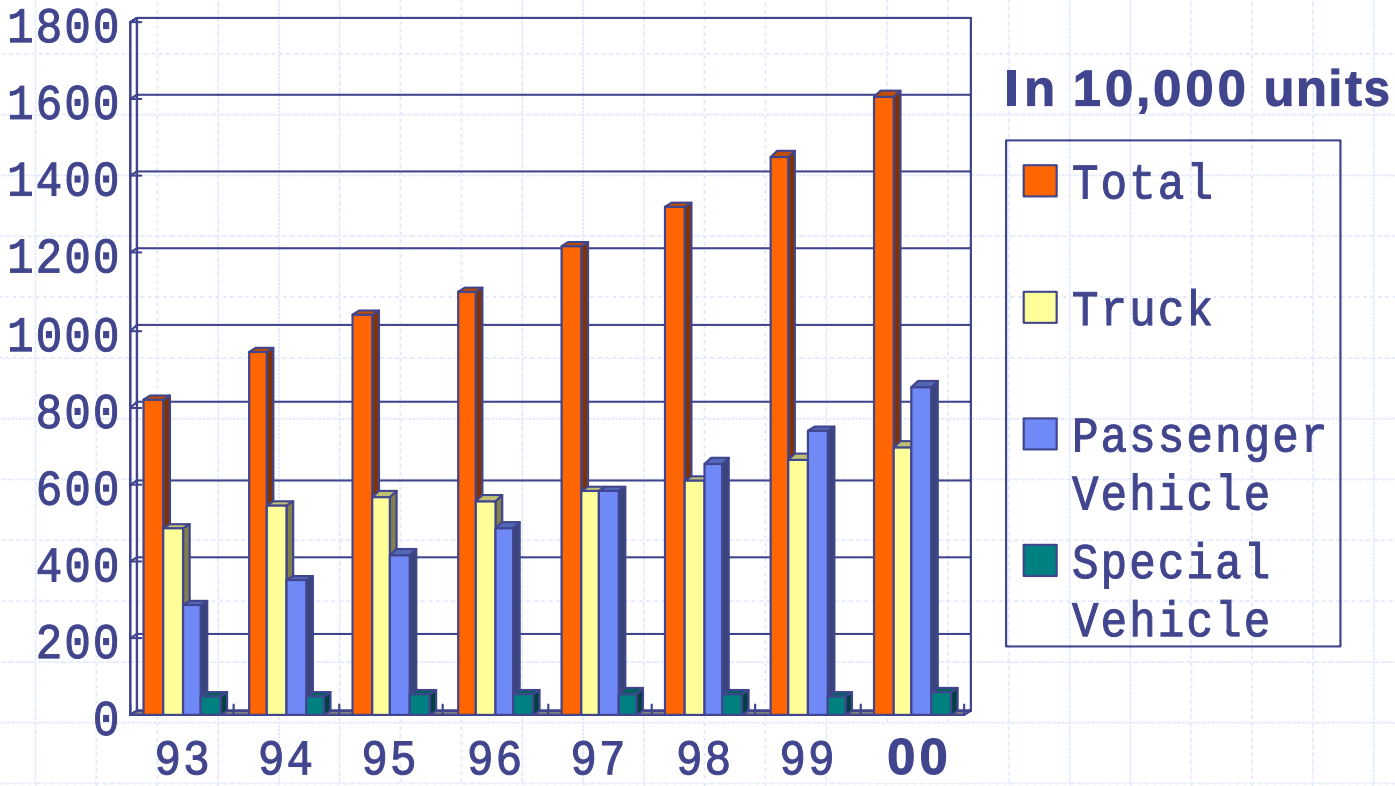
1. Large amount of fossil resources used resulting in serious environmental pollution (67% coal in total energy in 2001)

2. Fossil/Oil used from export to import in 1993, and over 30% of the total oil import in 2000; about 45% expected in 2010

3. Energy consumption estimated: 2.7%/year increase up to 2030

Energy Status in China

Automobiles in Use in Selected Years

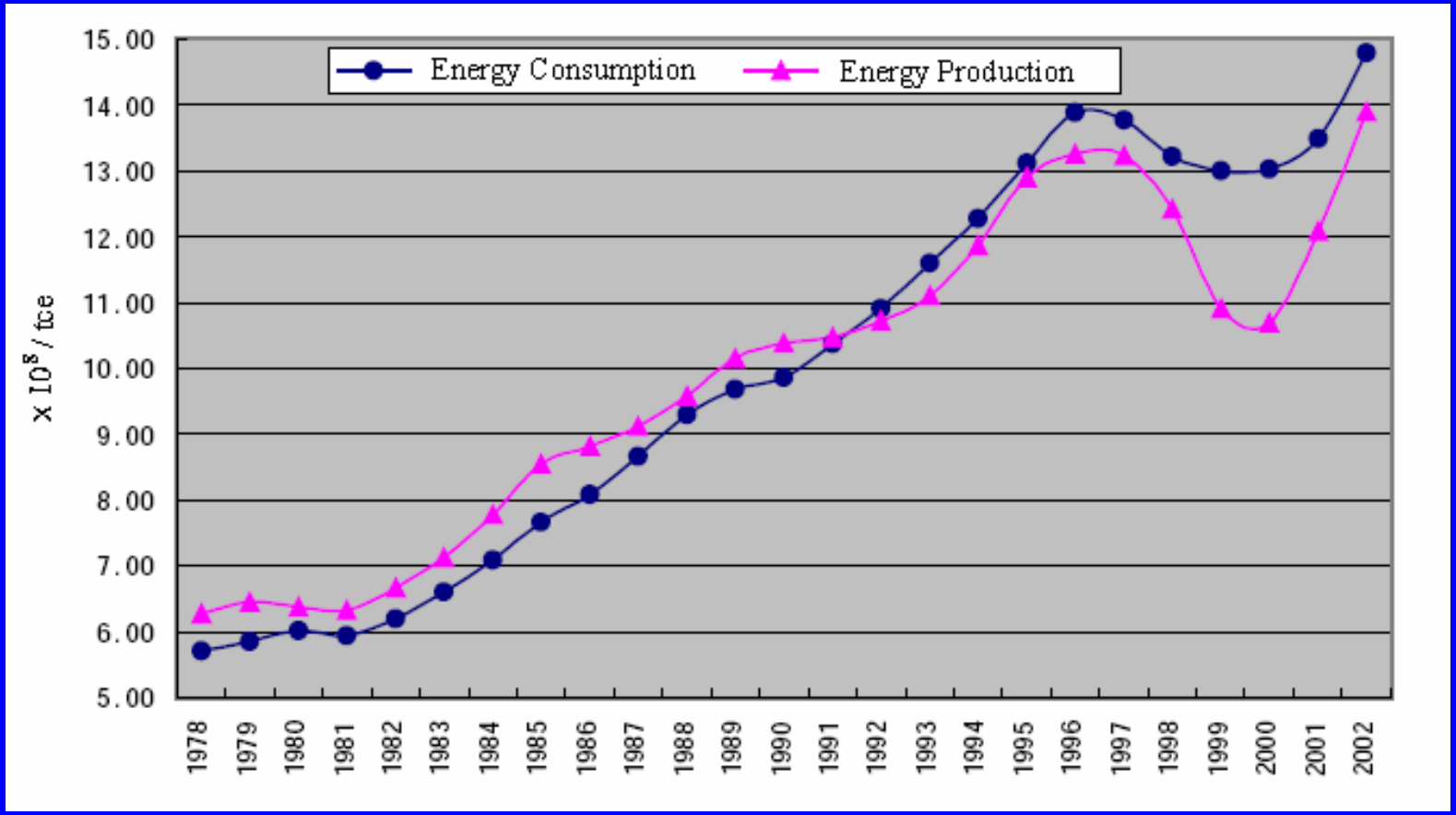


Petroleum Shortage

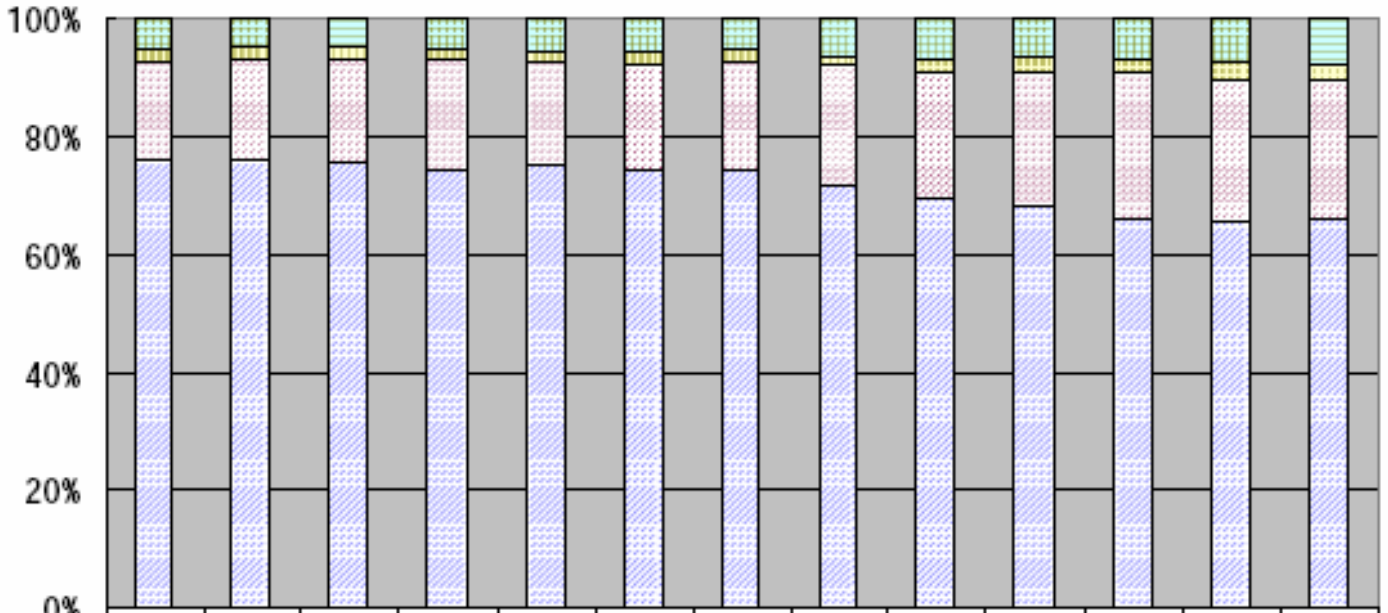
1. During 1990-1999, Chinese GDP increased averagely by 10.35% per year, while gasoline consumption increased from 400 to 950 thousand b/d.
2. In 2001-2010, GDP is expected to increase at an average rate, 7.0-7.5% per year and gasoline consumption will increase from 1300 to 4600 thousand b/d.
3. In2010-2020, Chinese petroleum **deficit** will reach about 8500 thousand b/d.

Source: LI Wen. World Energy Outlook 2000. International Energy Agency,2001(10):31

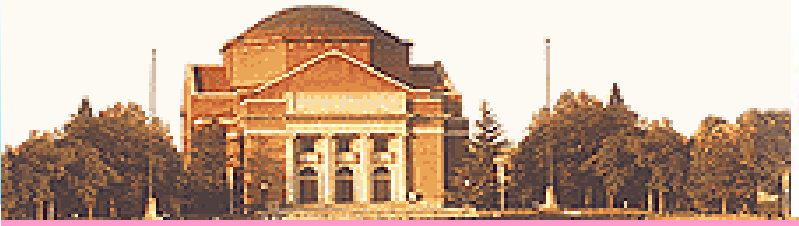
Energy consumption and production in China (1978 to 2002)



Energy sources in China from 1990 to 2002



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Water	5.1	4.8	4.9	5.2	5.7	6.1	5.5	6.2	6.7	6.6	6.8	7.7	7.8
Gas	2.1	2.0	1.9	1.9	1.9	1.8	1.8	1.7	2.2	2.2	2.5	2.7	2.7
Petroleum	16.6	17.1	17.5	18.2	17.4	17.5	18.0	20.4	21.5	23.2	24.6	24.3	23.4
Coal	76.2	76.1	75.7	74.7	75.0	74.6	74.7	71.5	69.6	68.0	66.1	65.3	66.1



Environment Status in China

Air Pollution

Among world wide great cities:

TSP content : Beijing ranks second

NO_2 content: Beijing ranks second

SO_2 content: Beijing ranks third

Great efforts are being made by the local government to improve the environments quality

Water Pollution and Its Control

Changes in wastewater amount of China

1997: 36.5 billion ton

2000: 41.5 billion ton

2002: 43.95 billion ton

2004: 48.24 billion ton (45.8% of industrial wastewater)

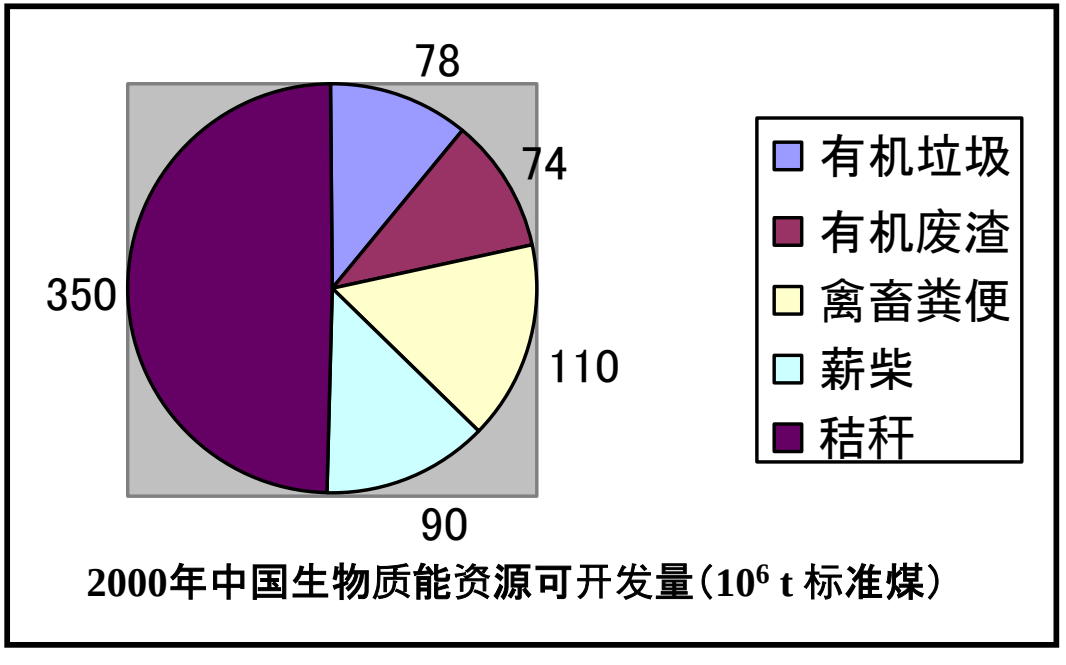
§ Large amount of wastewater
Serious pollution of waters in cities

§ Low treatment ratio (<20%)

§ Treatment Technology
Traditional biological process
(Simplified environmental conditions)

The Status of Biomass Resource

- **Potential of biomass energy: 5 billion ton standard coal**
- **4 times of the present energy consumption**
- **Collectable biomass: agricultural biomass, firewood, animal soils, organic garbage, industrial wastes and wastewater.**



2000年中国生物质能资源可开发量(10^6 t 标准煤)

- **Available biomass resource: 0.7 billion t,**
- **Agricultural biomass: 50%**

孙振钧. 中国生物质产业及发展取向. 农业工程学报,2004, 20(5):1-5

Legislation of Renewable Energy

- approved on February 28, 2005
- will be put in force from January 1, 2006.
- 8 chapters: including general rules, resource survey and development plan, industry guideline and support to technology development and application, market management, legal duty and supplementary articles

Renewable energy:
- Wind power,
- Solar energy,
- Water energy,
- Biomass energy,
- Terrestrial heat,
- Tide energy

http://www.legalinfo.gov.cn/lfqy/2005-03/02/content_191503.htm

Domestic Conferences on Biomass Energy

Conference on Biomass Energy Technology and Sustainable Development of China

- Held in Aug 27-31, 2004
- Topics: Biodiesel, BioH2 from biomass, biomass gasification etc.
- Progress Report of National Projects: "863" projects, "10th Five Years" projects
- Mid- and Long-term Plan: R & D Strategy for biomass energy

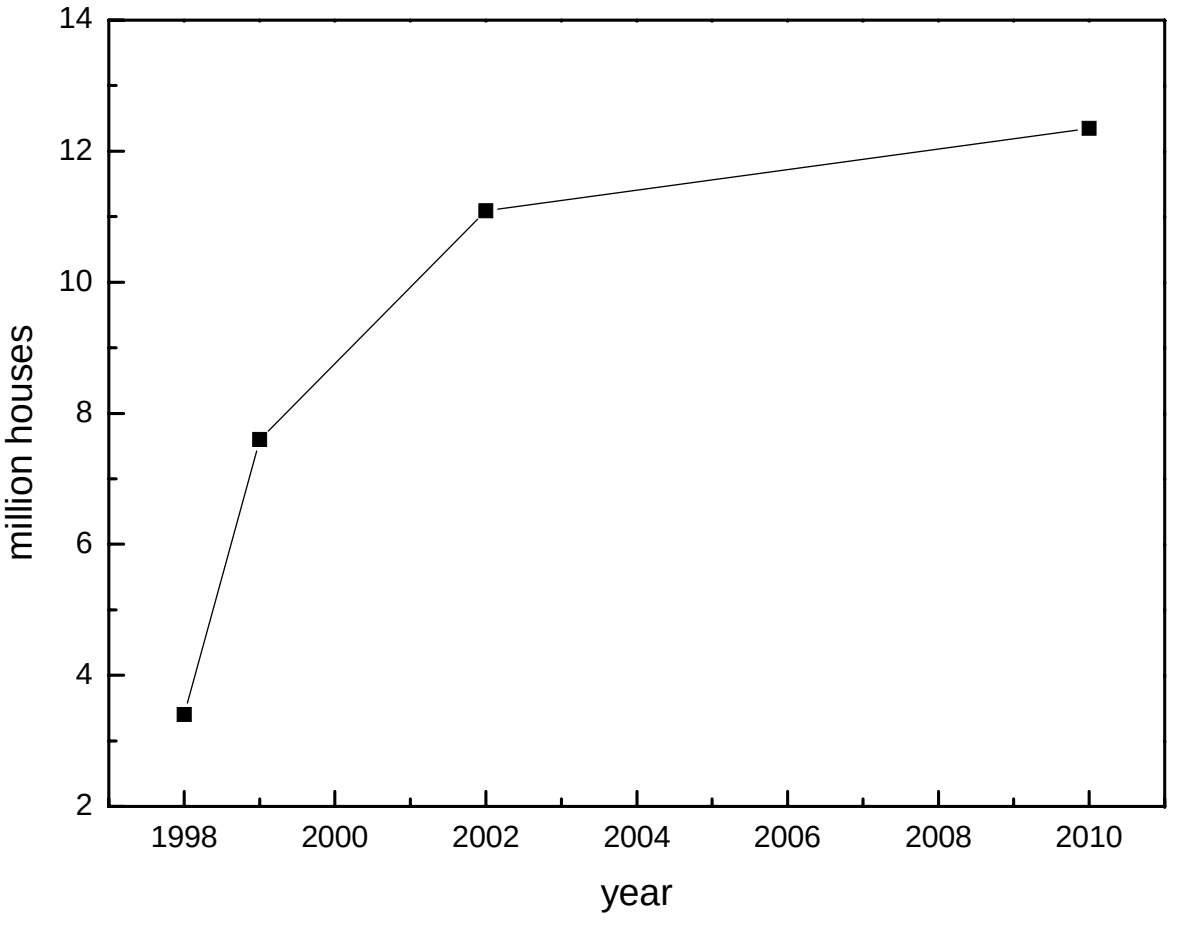
http://www.hnskxy.com/kynews/2004-08-28.htm

No. 256 Xiangsan Academic Meeting: Potential and Perspectives of Biomass Energy

- **Held in May 31 to June 2, 2005**

- **Topics: 1) position of biomass energy in national energy structure**
  - **2) Physiology and ecology of energy plants**
  - **3) Breeding and genetic engineering of energy plants**
  - **4) Biomass collection system**
  - **5) Biomass liquefaction and gasfication**
  - **6) Oils from biomass**
  - **7) BioH2 production**

http://www.xssc.ac.cn/Web/ListConfs/ConfBrief.asp?rno=694



Annual change in users of methane fermentation in China

Technological problems for biomass energy

1. Environmental issue pertaining to biomass energy use

- **Wastewater from biomass gasfication**
- **Biomass waste after processing and its use as fertilizers**

2. Biomass structures

- **Pretrement of biomass**
- **Alkali metals and trace elements in biomass**
- **Characteristics of minerals in biomass ashes**

3. Burning technology of biomass

4. Biomass gasfication technology

5. Biomass liquefaction technology

- **Thermal**
- **Biological**

National Fundamental Research Projects ("973") Leader: Dr. Hongzhang Chen
National R&D Projects: "863" "Bioenergy"

6. Biomass-based chemical products

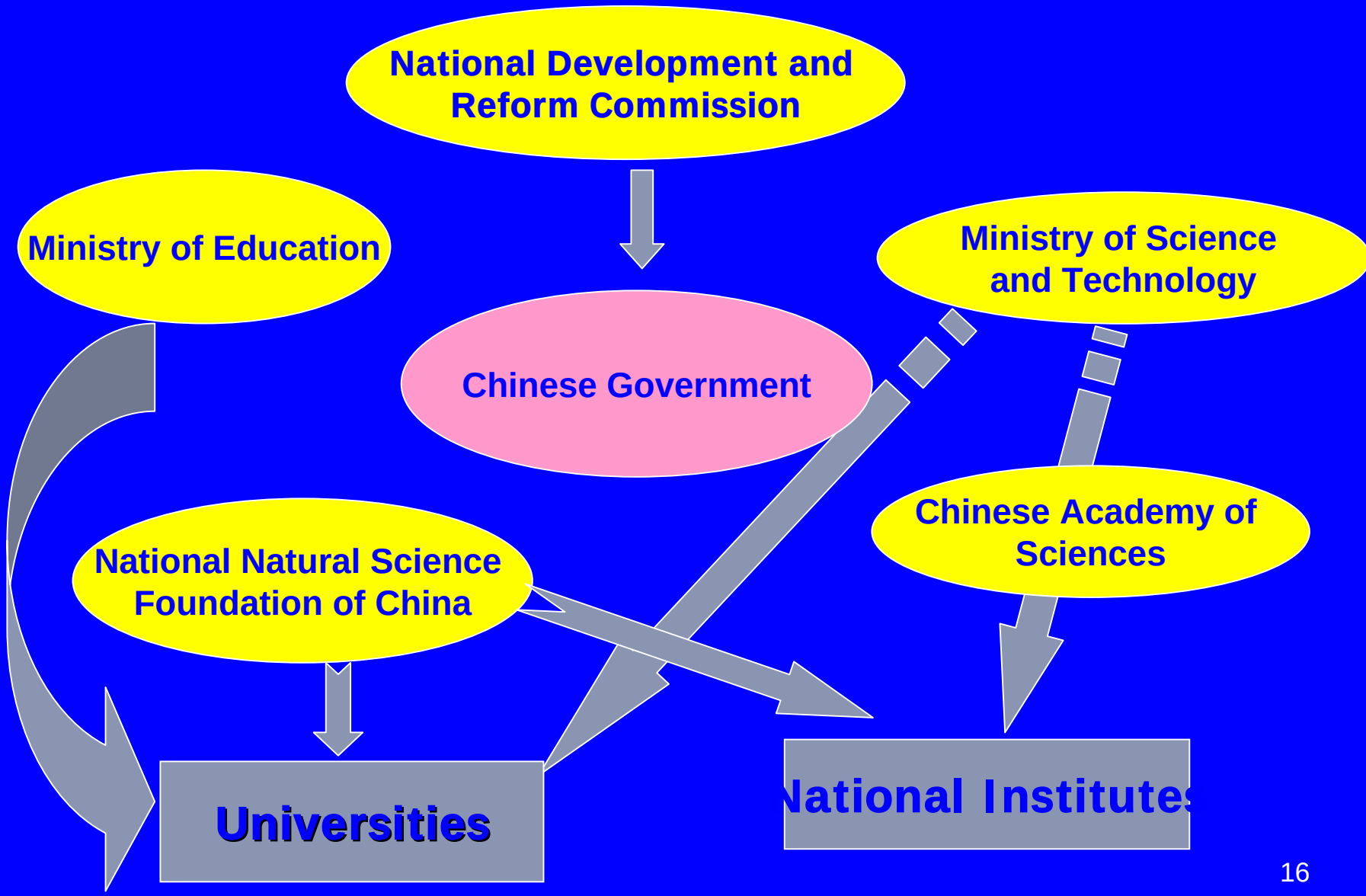
7. System engineering of biomass energy

An Outline of Hydrogen/BioHydrogen Researches in China

1. Started from 1960s; liquid hydrogen for rockets

2. New energy study from 1970s

3. Studies on bio-Hydrogen energy with respect to environment issue from 1990s


National Development and Reform Commission
Ministry of Education
Ministry of Science and Technology
Chinese Government
National Natural Science Foundation of China
Chinese Academy of Sciences
Universities
National Institutes

Government Funds on Energy

1、973 Projects

2、Key-Tech-Solving Projects (Gongguan)

3、863Projects

4、National Natural Science Funding of China

5、Chinese Academy of Sciences

Financial funds by Company

China Petroleum & Chemical Corporation

Key-Tech-Solving Projects in Energy Field

1、可再生能源技术（2800万RMB）
Renewable Energy Technology

2、清洁能源行动（7000万RMB ）

Clean Energy Action

3、燃料电池技术（3000万RMB ）

Fuel Cell Technology

4、节能技术（1000万RMB ）

Energy-Saving Technology

H2 energy R&D
Industrial-scale production, storage and application (fuel cell)

R & D for BioH_2 in China

- Bio-Hydrogen energy studies from 1990s
- First Bio-Hydrogen pilot plant in Harbin, Heilongjiang province
  (600 m^3/day, 2003; 1200**m^3**/d in 2005 with the investment of 120 million Yuan)
  Dark fermentation from wastewater
  production rate of **5.7m^3/m^3/d**
- Fund: Ministry of Science and Technology, Natural Science Fundation of China
- Research groups: 15 groups in universities, 3 groups in Institutes of Chinese Academy of Sciences
- Research fields for BioH_2: dark fermentation, photosynthetic bacteria, algae, in vitro bioproduction system, microbial fuel cells, hydrogenase genes, bioprocess technology, genetic engineering, metabolic engineering, protein engineering, bioinformatics
- Present status: research groups dispersed and small researcher population
  few funds specialized for BioH2 research

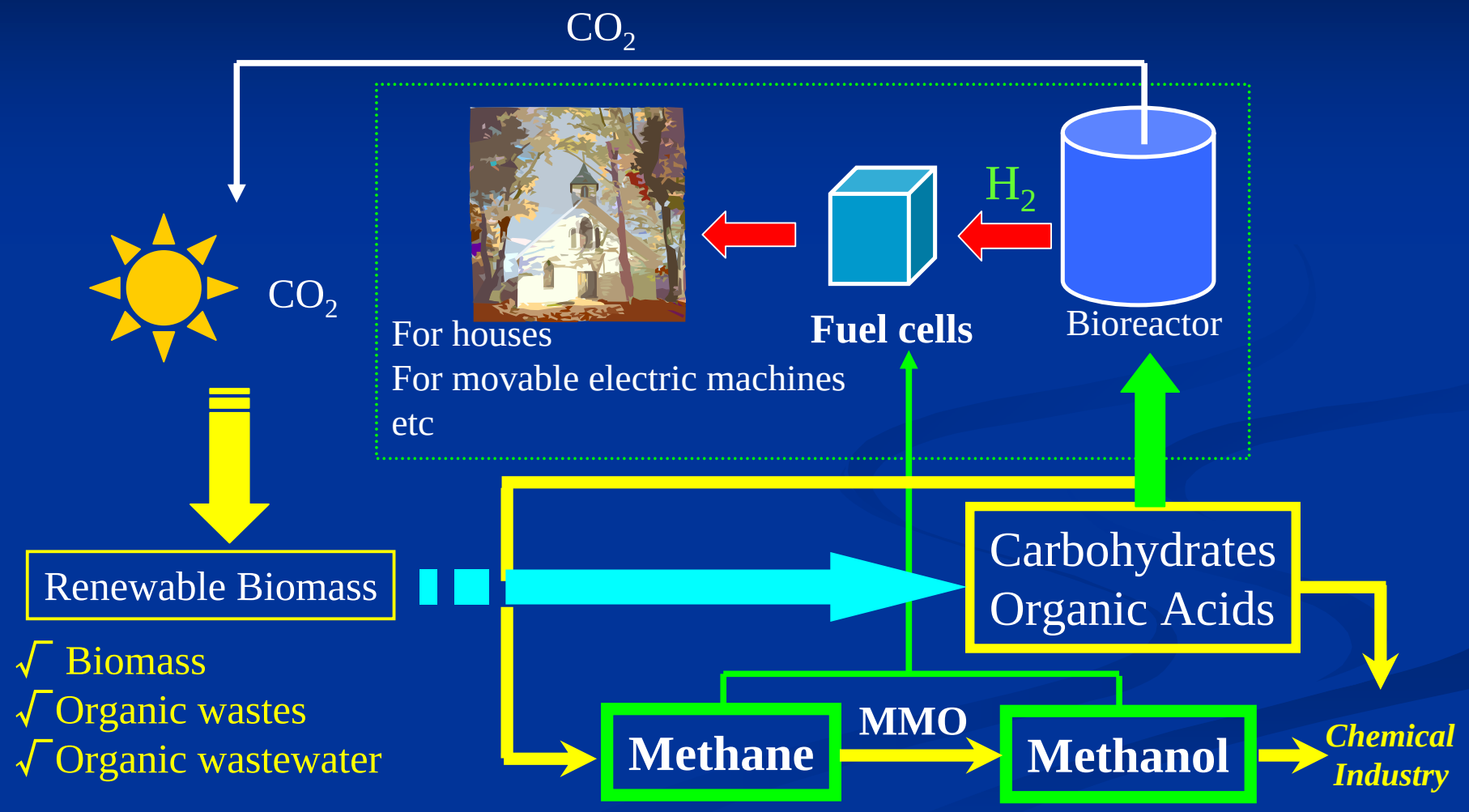
Research Activities on Bioenergy in China

研究单位	代表作者	主要研究方向	研究特色及主要成果
哈尔滨工业大学	任南琪	有机废水厌氧发酵制氢	厌氧活性污泥发酵类型的控制、反应器运行特性研究，达到中试水平，COD去除率20%，产氢5.7m^3/m^3d
河南农业大学	张全国	太阳能光合生物制氢技术研究	2004年863立项，尚未见成果报道 太阳能光合生物制氢光转化效率的影响因素研究
郑州大学化学系	樊耀亭	有机物厌氧发酵制氢	堆肥中产氢芽孢细菌的条件控制
中科院生态中心	刘俊新	剩余污泥资源化制氢	碱预处理剩余污泥进一步厌氧发酵制氢
中国科技大学	俞汉青	以有机废弃物为原料的两步生物产氢技术、以生物质为原料的的人工瘤胃产氢技术、高效产氢菌种的选育和生物产氢系统中微生物种群的优化调控	在上流厌氧反应其中获得产氢效率9:33 l H2/g VSS d，转化率1.37–2:14 mol=mol-hexose.
香港城市大学	Fang H.H.P. Longan, B.E.	有机物厌氧发酵制氢，产氢菌群分析	嗜热条件下转化淀粉制氢，最大转化率92 ml/g starch，最大产氢速度365 ml/(g-VSS.d)，分析菌群分布；研究了菌群自固定化特性
中科院化学所	Liu G Z	有机物厌氧发酵制氢	混合菌，淀粉为底物，最大转化率为194 ml/g-starch，最大产氢速度为237 ml/g-VSS d
厦门大学	龙敏南.	产氢菌种的分离鉴定	分离出来自于温泉的高效产氢菌Klebsiella oxytoca HP1，连续培养转化率达到3.6 mol/mol sucrose
清华大学	√邢新会 √林章凛	√产气肠杆菌氢酶基因的克隆、表达；以NADH为媒介的还原反应控制实现高效产氢 √氢酶基因向耐氧方向定向进化	√以基因工程、代谢工程，新型多细胞耦合方法解决生物制氢低转化率瓶颈问题，如能突破，将会极大推动发酵生物制氢的应用进程。 √藻类氢酶的定向进化
中科院大连化物所	张 伟	藻类制氢	海水中筛选高效藻类、工艺条件优化

Part II:
-Our Research Introduction-

1. Biological Engineering Approach for Construction of *Enterobacter aerogenes* with high BioH_2 Productivity

Recycle of Renewable Resources and Production of Bioenergy and Chemicals



Biohydrogen

Low solar conversion efficiency

Low Hydrogen yield

DIRECT BIOPHOTOLYSIS	•H_2 is produced from H_2O and sunlight, the most abundant renewable sources on earth
INDIRECT BIOPHOTOLYSIS	•No O_2 inhibition •Improved economics in two-reactor processes
PHOTO-FERMENTATIONS	•High H_2 yields from organic substrates and wastes (~ stoichiometric) •Use a wide range of wastes (effluents and solids) from different origins (industrial, agricultural and municipal) • Do not produce O_2, no O_2 inhibition • Produce valuable co-products
DARK FERMENTATIONS	•High rate of H_2 evolution •Hase requires no direct ATP supply •Convert organic substrates and sugar wastes •Produce valuable co-products •Fermentation technology is cheap and already used commercially

First ferment wastes in the dark we must do
Second, water split
with algae that sit
in the sun in ponds and tubes, it's true.

What are we doing

Known

Enterobacter aerogenes

☐ Less oxygen sensitivity

☐ High yield of hydrogen in theory (12mol H_2 /mol glucose through NADH pathway)

Research background

☐ Research groups: Tanisho, Nisho, Yoki

☐ Research areas: Bacteria and its hydrogen production characteristics, process optimization (pH, CO_2 removal, N_2 sparking, immobilization…)

☐ Maximal yield: 1.5 mol H_2 /mol glucose

Unknown

Hydrogenase

☐ The characteristics…

☐ The purification…

☐ The structure…

☐ The function…

☐ The development…

What are we doing

☐ **Research tool development:** rapid, non-disruption method for hydrogenase detection

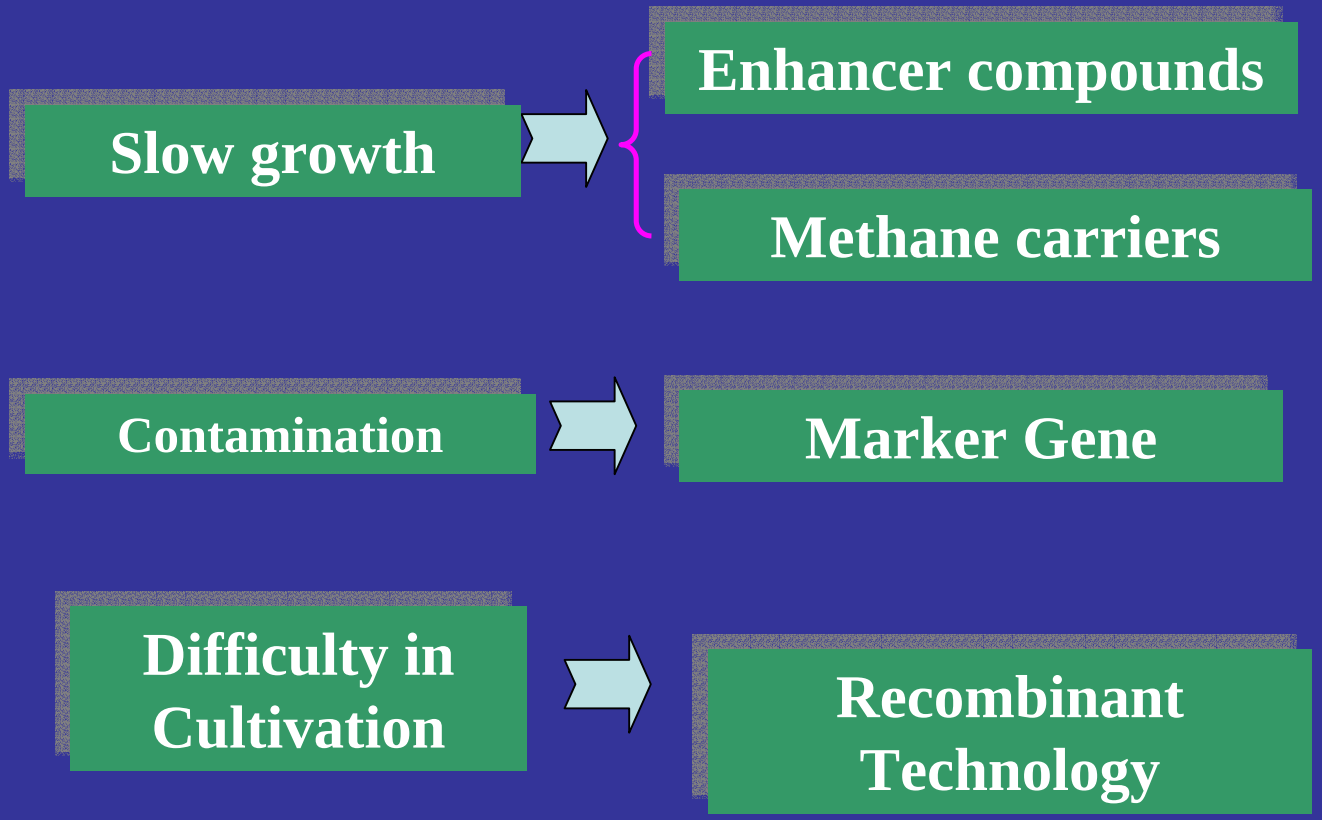
☐ **Characteristic study** of the hydrogenase in *Enterobacter aerogenes*

2. Biological Engineering Approach for Biotransformation of Methane into Methanol

Potential application of MMO in Methanotrophs

- Production of methanol from methane
- Production of bulk chemicals (e.g. propylene oxide)
- Playing an important role in global carbon cycle.
- Bioremediation.

Problems and Strategies



pMMO expression has not been succeeded

Acknowledgements

Prof. Ichiro Okura of Tokyo Institute of Technology

Drs. Zhongxuan Gou, Mingfang Luo, Hongxin Zhao

Graduates: Minsheng Liu, Chong Zhang, Bing Han, Yuan Lu, Hao Wu, Hao Jiang, Yunli Ren, Lei Wang

Supported by Key Projects (No.20336010) of the National Natural Science Foundation of China, and the National Basic Research Program of China (973 Plan) (No.2003CB716003).