Renewable Energies – Part I
可再生能源 – 第一二部分

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创新领先 奉献能源

用再生资源替代石油资源

长春大成集团

创新领先 奉献能源

大成集团基本情况

- 大成集团是以玉米作原料，利用生物技术、化工技术精深加工的企业集团，年处理玉米300万吨，主要产品:年产氨基酸60万吨；淀粉糖160万吨；变性淀粉15万吨；生物化工醇22万吨等。赖氨酸产能世界第一，生物化工醇工业化大生产世界首例。

大成多元醇的开发

创新领先 奉献能源

- 随着全球经济发展，石油的需求日益增加，而石油资源却日渐递减；石油供需矛盾日益加剧。
- 我国每年大量进口石油，石油资源的安全压力及能源压力明显加大。
- 利用地球上取之不尽、用之不竭的生物质资源，发展生物质化工产业，替代石油化工产品，向生物质要能源、资源和材料，是解决资源和能源的必由之路，是可持续发展的重要途径，也是当务之急。

大成多元醇的开发

创新领先 奉献能源

- 中国改革开放以来，随着农业生产技术进步，粮食产量大幅增加，玉米用于食用已很少，绝大部分用于饲料和工业加工，而且全球粮食价格相对稳定。
- 所以用玉米淀粉作原料，利用生物技术和化工技术发展替代石油的化工产品面临着重大发展机遇（用其他生物质也可以生产）。

大成多元醇的开发

创新领先 奉献能源

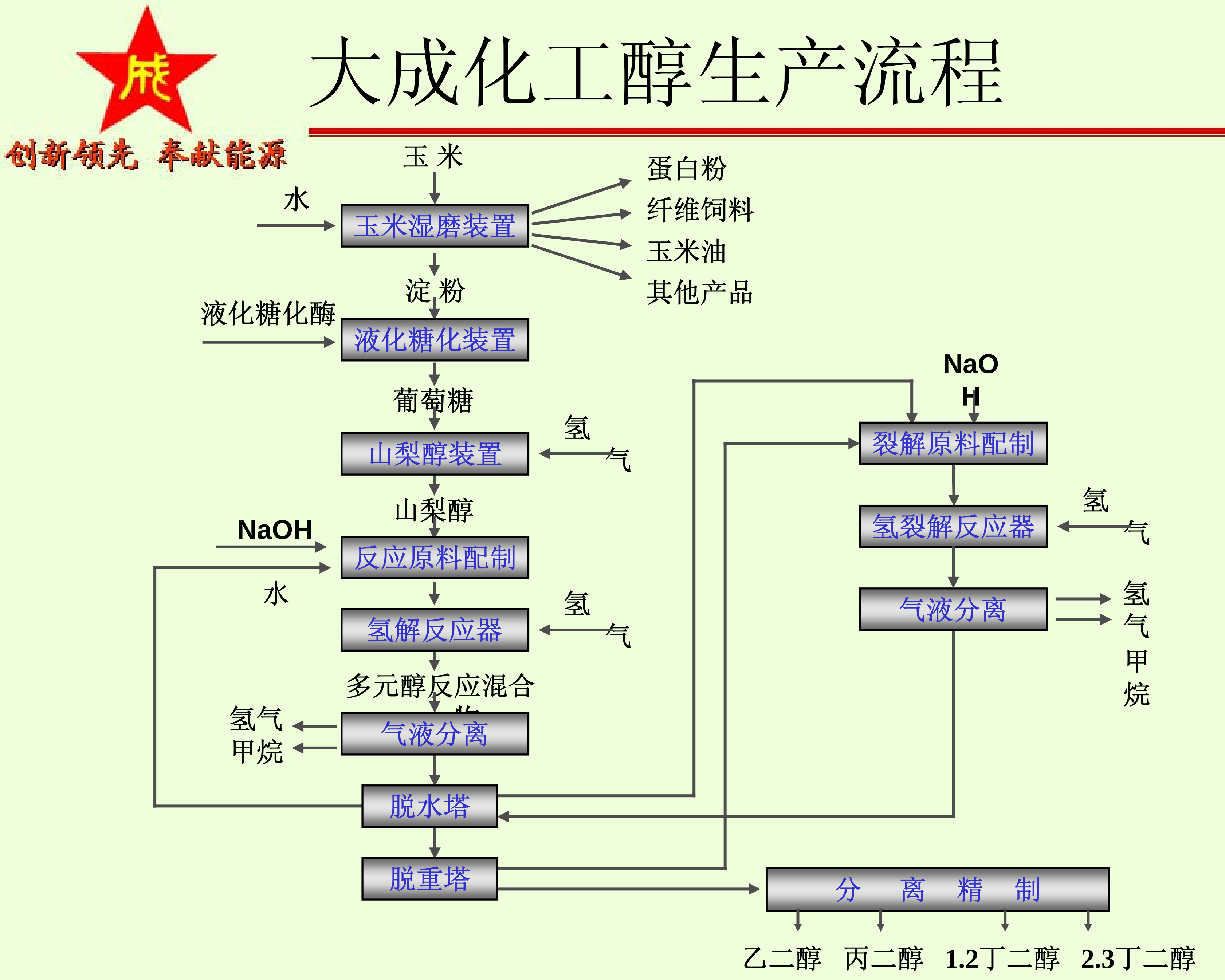
- 在2004年前，以石油为原料生产有机化工醇的技术很成熟。但是，以生物质为原料除了可以生产乙醇和山梨醇外，用其规模化生产其他化工醇产品在全球尚无成功先例。
- 大成集团集中了一批专家，经过多年研究开发，在2004年成功的建设一座年产2万吨，以玉米淀粉为原料生产多元化工醇的生产工厂，实现了规模化工业生产。产品有乙二醇、丙二醇、1,2丁二醇、树指醇等。

大成多元醇的开发

创新领先 奉献能源

- 大成多元醇的生产技术是完全享有自主知识产权的，目前为世界首创，产品不但完全可以替代石油基化工产品。而且，有很多性能优于石油产品，是全新的生物化工产品，有许多石化产品不具备的特性。

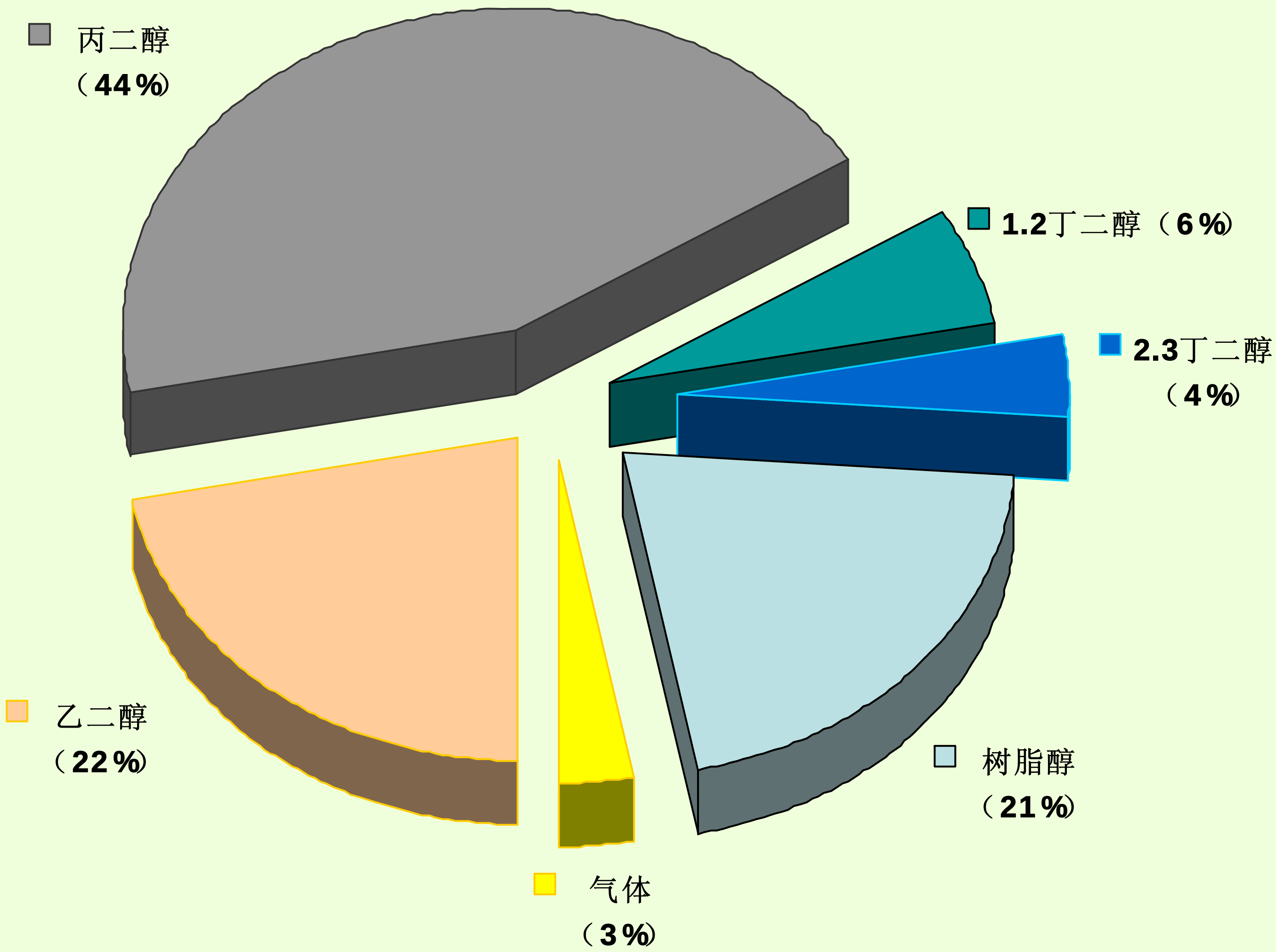
大成化工醇生产流程



创新领先 奉献能源
玉 米
水
玉米湿磨装置
蛋白粉
纤维饲料
玉米油
其他产品
淀 粉
液化糖化酶
液化糖化装置
葡萄糖
山梨醇装置
氢气
山梨醇
NaOH
反应原料配制
水
氢解反应器
氢气
多元醇反应混合物
气液分离
氢气
甲烷
脱水塔
脱重塔
NaOH
裂解原料配制
氢裂解反应器
氢气
气液分离
氢气
甲烷
分 离 精 制
乙二醇
丙二醇
1.2丁二醇
2.3丁二醇

创新领先 奉献能源

大成多元醇的产品结构



大成多元醇性能优良

创新领先 奉献能源

- 大成集团生产的生物化工多元醇是一种全新的生物化工产品，经两年多几十家用户使用，生产的产品性能良好，表现出许多石化产品不具备的优点和特性。
- 目前，大成生产的各种产品均已申报国家标准和相关专利。

大成乙二醇的应用

创新领先 奉献能源

- 用大成乙二醇与对苯二甲酸（PTA）共聚，可制得低成本、高性能的新型聚酯切片，我们命名为“PDT”即“大成纤维聚酯”；用“PDT”聚酯切片生产的纱，所织布料等织物，其光泽、垂度、揉性、透度、手感都非常好，特别在染色过程中易着色、鲜艳、温度低10度左右。用“PDT”纺的纱，我们命名“康宜”纤维。均已注册。产品深受用户欢迎。

创新领先 奉献能源

大成丙二醇的应用

- 大成丙二醇已被多家企业应用于制药、高级化妆品、清洗剂、树脂、不饱和树脂等产品使用，性能提高20%以上。

创新领先 奉献能源

大成树脂醇的应用

- 用树酯醇生产出的不饱和树脂，生产出来的产品，经严格检验，F191试验，其拉申强度、抗伸弹性模量、断裂延伸率和弯曲强度等12项指标均高于同类石油基不饱和树脂产品的30%。

大成树脂醇的应用

创新领先 奉献能源

- 用树酯醇生产出的不饱和树脂，生产出来的产品，经严格检验，F191试验，其拉申强度、抗伸弹性模量、断裂延伸率和弯曲强度等12项指标均高于同类石油基不饱和树脂产品的30%。
- 大成树脂醇与谷氨酸聚合可生产出高档树脂。大成生物化工醇及其产品应用的成功开发，为树脂革命和纤维革命提供新材料，为替代石油资源将做出巨大贡献。

经济可行性

- 根据年产2万吨化工醇工厂，两年半运行状况的总结和年产20万吨化工醇项目的运行和投资予决算，投资分析和生产成本分析结论如下（石化工厂的相关资料，为有关部门两年前提供的数据，仅供参考）：

1. 建厂投资比例：
   – 建设1万吨石油基乙二醇生产厂投资与建设1万吨玉米基化工醇厂投资对比为16,300万元比3,900万元，即4比1。

经济可行性

创新领先 奉献能源

2. 消耗原料比例

- 生产1吨石油基乙二醇消耗石油5.6吨。
- 1.42吨玉米可生产1吨淀粉。
- 1吨淀粉可生产1吨化工醇。

- 生产1吨乙醇需要玉米3.3吨。

经济可行性

3. 生产成本对比：
   – 目前用乙烯做原料生产1吨乙二醇成本在8,000元左右。新建年产20万吨玉米基化工醇平均成本每吨4,580元。按市场价计算，在由本公司提供糖和氢气的基础上，成本结构为（全部以干基计价）：
     - ◆结晶糖：1.09吨=3,000元
     - ◆氢气：两次加氢数量600m3=480元
     - ◆每吨加工费为1,100元
     - ◆合计成本4,580元
   - 乙二醇成本比:石油的8,000元比玉米的4,580元；
   - 丙二醇成本比:石油的12,000元比玉米的4,580元；
   - 06年12月份原料玉米价为1400元/吨，由于大成工艺技术进步，耗能大幅度下降，影响成本很小，经济效益可观。

创新领先 奉献能源

国家支持，统一规划，分期发展

- 国家发改委给予大成集团生物再生资源替代石油的项目极大支持。
- 大成集团已按照国家发展的需要，遵照国家发改委的统一规划，在原料产区和资源、能源充足的地区布点，已规划在吉林省长春市和河南省郑州市分期建设两个100万吨生物化工醇、100万吨聚酯和100万吨树脂的生物化工基地，以解决国内需求，缓解石油资源的压力。

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The Development of biofuels in China

Dehua Liu
Department of Chemical Engineering
Tsinghua University

Development status of biofuels - fuel ethanol

Exited Fuel Ethanol Plants

COFCO Inc., Heilongjiang Province in North-east China (100,000 t/y)

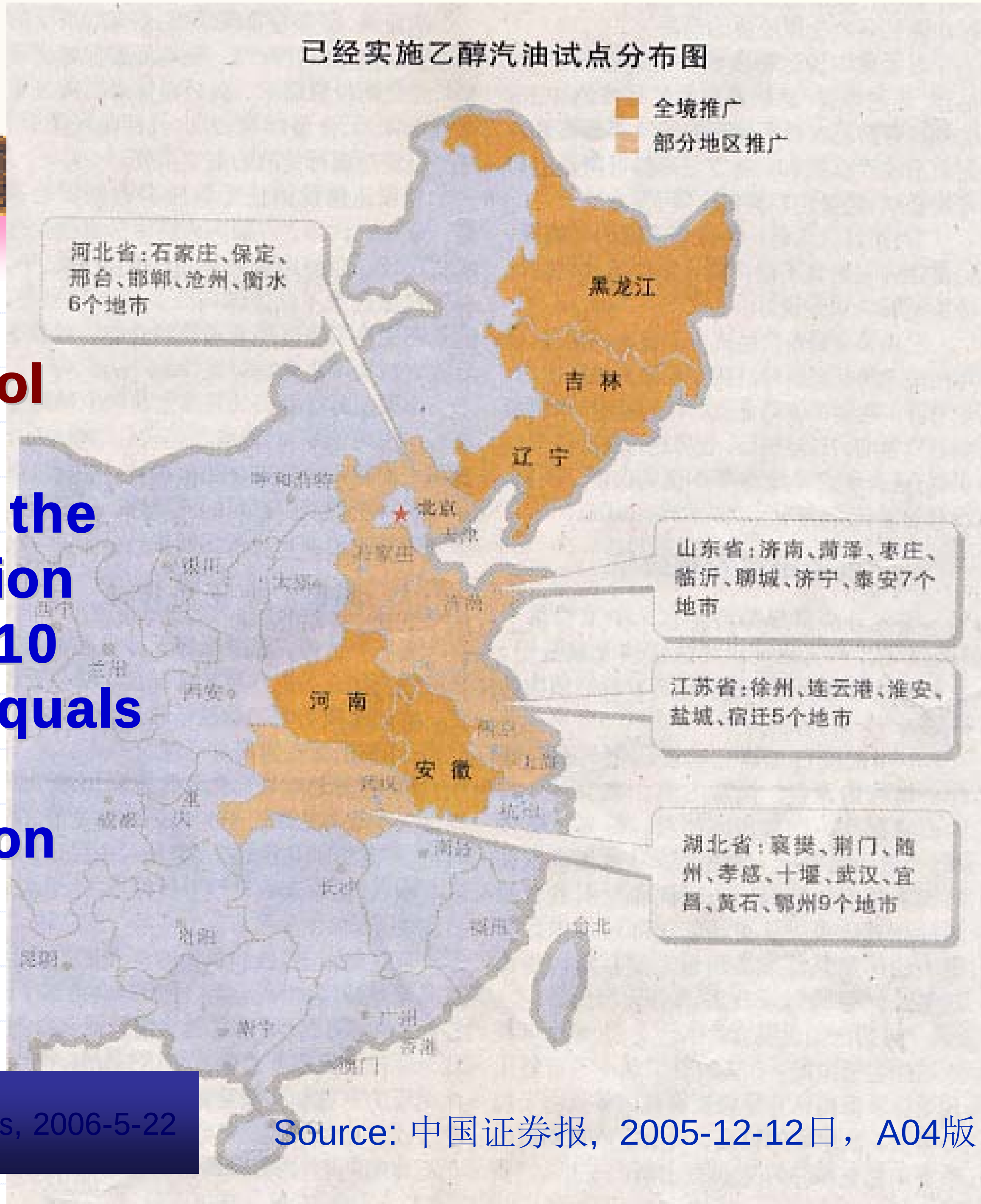
Jilin Province in North-east China (600,000 t/y)

Fengyuan Group, Anhui Province in East China (320,000 t/y)

Tianguang Group in Henan Province (300,000 t/y)

Expansion of Gasohol application

By the end of 2005, the total E10 consumption reached more than 10 million ton, which equals about 1/4 of total gasoline consumption



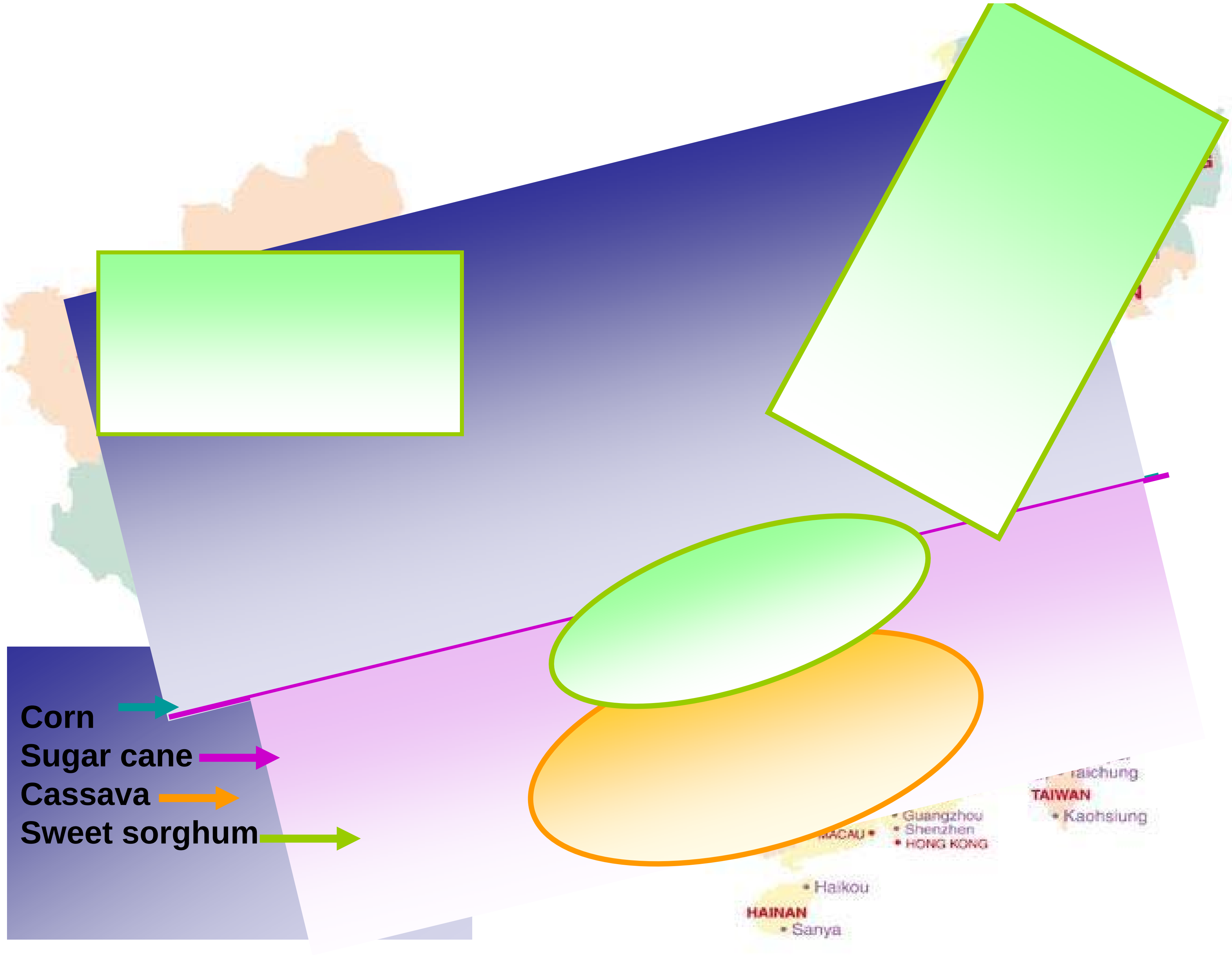
Source: China Chemical Industry News, 2006-5-22

Source: 中国证券报，2005-12-12日，A04版

Development status of biofuels - fuel ethanol

Feedstocks for fuel ethanol

- **In 2001 – 2004, about 500 M tons of grain was averagely produced in a year**
- **During the same period, about 30 – 35 M tons of potato-typed products was produced averagely in a year**
- **Sugar cane: average annual production during 2000 – 2004 was 75 M tons.**
- **Sweet sorghum: mainly trial plantation at present, but more attractive.**


Corn
Sugar cane
Cassava
Sweet sorghum
TAIWAN
Kaohsiung
Guangzhou
Shenzhen
HONG KONG
Haikou
HAINAN
Sanya

Development status of biofuels – fuel ethanol

Ethanol production from non-grain crops

- It has been estimated that in China the cost of ethanol is 4400-4500 RMB/t when produced from corn or aging wheat, and 3300 RMB/t from sugarcane or fresh cassava, 2600 RMB/t from sweet sorghum.

(Source: Web of National Development and Reform Commission, http://www.ndrc.gov.cn/)

- It was reported that a new kind of sweet sorghum bred in satellite in the airspace contains 2.3% more sugar than sugarcane. What's more, it can be stored more than 8 months.

(Source: China Chemical Industry News, 12 Feb. 2007)

Development status of biofuels – fuel ethanol

Potential ethanol production from non-grain crops

Crop	Plant area ($X10^4$ ha)	Yield (t/ha/y)	Productivity of ethanol (kg/ha/y)	Potential yield of ethanol ($X10^4$ t/y)
Sweet sorghum	300	60	6106	1800
Cassava	150	40	6000	900
Sugar cane	120	70	4900	580
Others	400	40	4800	1920
Total	970			5200

Source: Mr. Qiu, CNCBD

Development status of biofuels - biodiesel

- The specification and incentive policy on biodiesel has not been issued, it is expected to be published soon;
- A few small plants (capacity from 5 to 20 thousand tons per year) had been built, and more bigger ones are in construction and plan;
- The feedstock used for biodiesel production include waste cooking oil, some oil from oily plants;
- Part of biodiesel products were exported abroad;
- A lot of technological researches are being conducted.

The first biodiesel plant (20,000 tons/year) using enzymatic approaches in the world.

Development status of biofuels - biodiesel

Feedstocks for biodiesel

- Oil source
  - Animal: recovery
  - Plant
    - Oil plant
      - Woody
        - Jatropha
        - Pistacia
        - Cornus
      - Grassy
        - Rapeseed
        - Soybean
    - Energy plant: Switch grass
  - Microbe

Welcome to
Tsinghua University !

Thanks!

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Electricity Generation

- Advanced Nuclear Power
- Clean Coal Technologies/Futuregen
- Solar Power (thin film plus advanced battery)
- Wind Power
- Biopower
- Geothermal Power
- HydroPower
- Wave Power
- Distributed Power Generation
- Advanced Electric Grid
- Efficient Building Technologies
- Quadrupling by 2015 to over $100 billion/yr

Transportation

- Biofuels (ethanol, new crops, biorefining)
  - quadrupling to over $75 billion/yr by 2015
- Advanced Vehicle Technologies
- Fuel Cell Vehicles
- Coal-based Fuels

Energy Storage

- Batteries
- Supercapacitors
- Flywheels
- Hydrogen
- Thermal Energy Storage
- Potential Energy Storage

Energy Outlook

- **Most sources are finite and non-renewable**
- **No form of energy is inexpensive and easy to create on scale**
  - Potable water — Digital world
  - Agriculture — Transportation
  - Healthcare — Electricity
- **IEA Future cost of energy infrastructure: $16 trillion to 2030**
  - $10 trillion to power
  - $6 Trillion to oil and gas
- **Peaking of Oil is a fierce debate**
- **Hydrocarbons will continue to dominate transportation**
- **Coal (security) and gas (cleanlininess) will continue to dominate heating and power**
- **Renewables will grow exponentially and have great potential but remain a fraction of total energy**
- **Disruptive technology and geopolitical forces are the wildcards that can lead to dramatic improvements in energy intensity**

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Biofuels Research in the MIT Energy Initiative

- Two examples
  - Engineered strains for better biomass to biofuel conversion
  - More efficient engine design

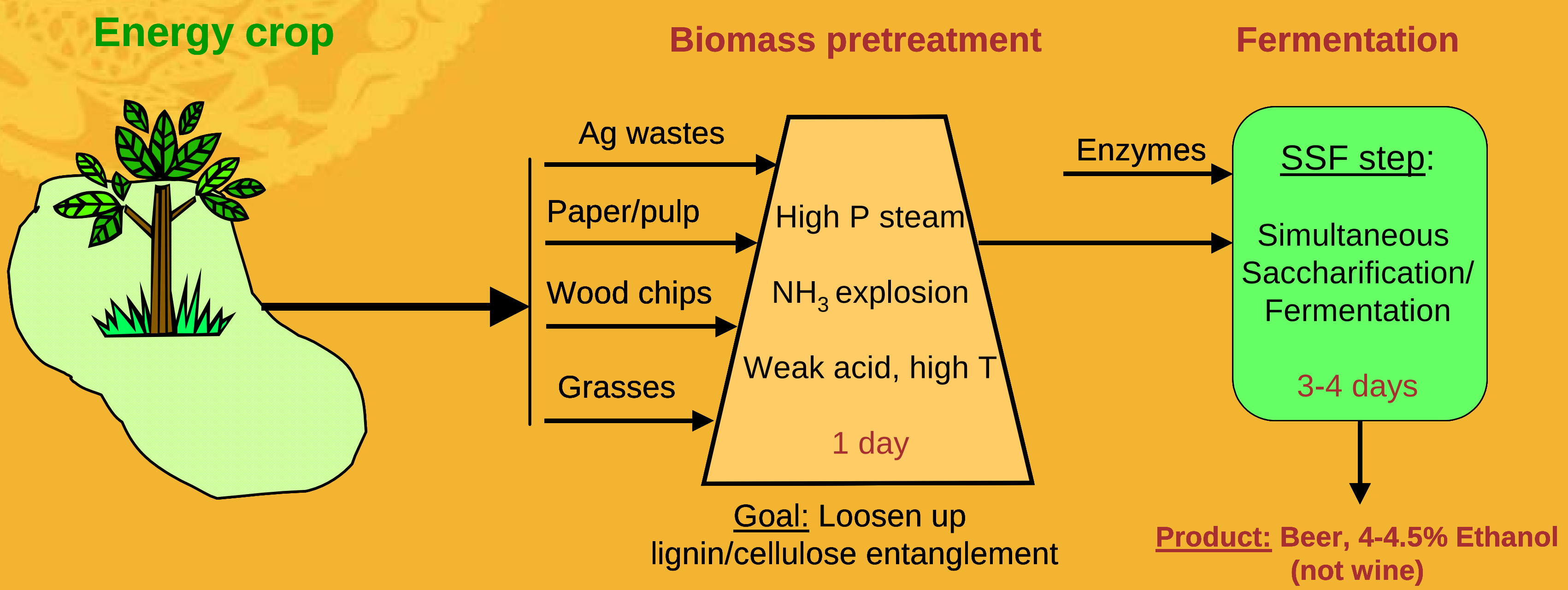
Robert C. Armstrong
Associate Director, MIT Energy Initiative
Chevron Professor, Chemical Engineering
Massachusetts Institute of Technology

The biotech revolution and chemical-fuels industry

- Fuels and chemicals were the initial biotech target
  - Cetus (Chiron), Genex, Biogen
- More challenging technical problem than insulin
  - Switch of emphasis to medical applications
- Changing boundary conditions
  - Emphasis on renewable resources
  - Robust US federal funding $\Rightarrow$ Applied mol. biology
  - Genomics
  - Metabolic Engineering
  - Systems Biology: a new mindframe in biological research
- Exploit applications of biology beyond medicine

Key Challenges for a B2B Biorefinery

We can make biofuels from biomass today…



… but we must do so in a *sustainable* manner and *economically*

Sustainable supply of cellulosic biomass

- For a 500 M gallon/year bio-refinery (investment of $1-2 B),
- We will need 4-8 million tons of dry biomass/year.
- This quantity, multiplied *N*-fold for *N* bio-refineries, must be supplied in a sustainable manner, year after year, without disturbing the nutrient, water, or ecological balance of the region around a bio-refinery.
- *N* = 50 for US is a conservative number if B2B conversion is to make a difference

Technical goals of B2B process

- Double yield of energy crop/acre
  - Plant science, new hybrids, genomics
- Double yield of gallons per ton of biomass
  - Metabolic Engineering, strain improvement to increase yield and productivity of B2B process
- Double productivity: increase microbe
  - tolerance to fuels/other inhibitory compounds
  - Global Transcriptional Machinery Engineering (gTME) successfully used to increase tolerance to glucose and ethanol
- Engineer pathways for other biofuels
- Do so in a sustainable manner

MIT Biofuels Program Features

- Comprehensive program in ethanol and other biofuel research
  - Teams in place at MIT-Purdue-IBM-Whitehead
  - Supported by world-class bioscience and bioengineering infrastructure
  - Exceptional innovation environment along full B2B R&D spectrum and along biofuels value chain to market
- Novel paradigm in biological research that emphasizes Systems Approach to pathway, cell and bioprocess optimization
- Facilities for field tests and pilot studies
- Technology transfer – MIT ranked No. 1 in biotech transfer

What is different now?

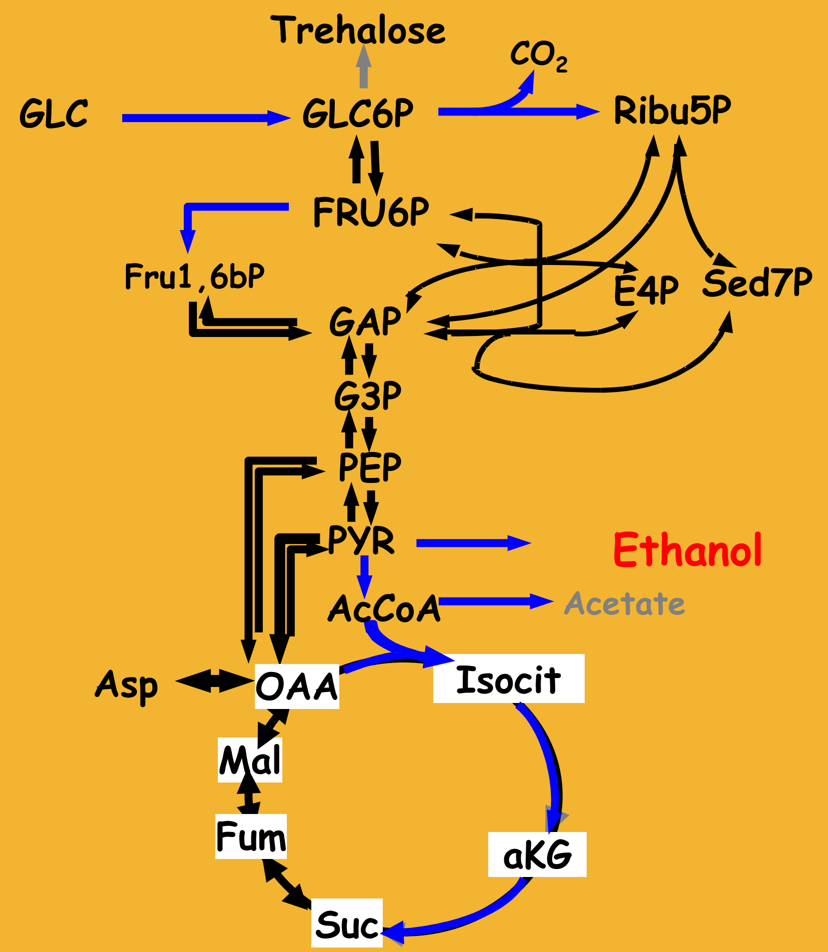
- This is not the first time that B2B conversion is contemplated (experience of 70's)
- Now vs. then:
  - Cheaper enzymes (from ~1.10/gallon to ~30c/gallon- another 3X cost reduction needed)
  - Potential biomass availability (land potential)
  - New Biology
    - Genomics and "omics" technologies
    - Exquisite genetic controls
    - Metabolic Engineering
    - Tools and mind-frame of Systems biology

A systems approach to B2B

Ethanol biosynthesis is a property of the the *entire* pathway, not an individual gene or enzyme

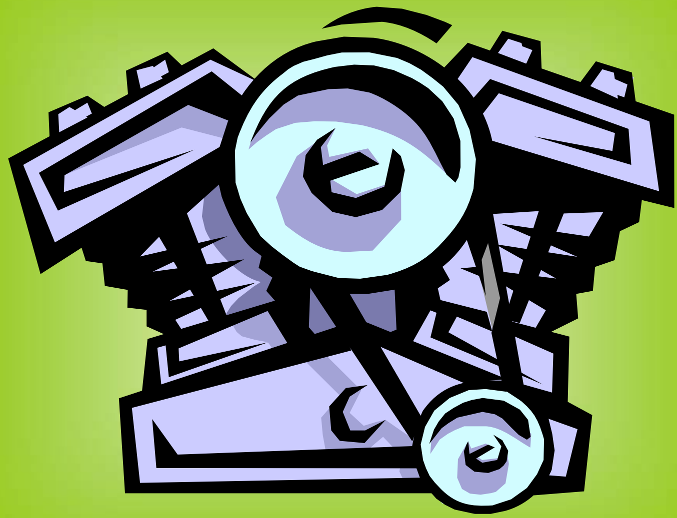
Same is true for other traits like ethanol tolerance, osmotic stress, etc.

This suggests a different approach to classic problems of trait improvement in plants and microbes



High Efficiency Engine

Replacement of a standard gasoline engine…



… with a much smaller, turbocharged engine with same power

High Efficiency, Ethanol Boosted Gasoline Engine

- Use of a small of amount of ethanol (E85) to provide clean, high efficiency operation at low cost
- 20 - 30% efficiency improvement for an incremental cost of ~ $1,000
- Short payback time (2 - 4 years)
- Substantially enhances value of ethanol through leveraged impact on efficiency
- Encourages increased use of ethanol, further increasing gasoline savings

(Bromberg, Cohn and Heywood)

Removing Knock Limit On Engine Power

Gasoline source

Ethanol source

Direct Injection suppresses knock at high torque

Highly turbocharged engine (300 % more power)

Knock Suppression

- Knock (unwanted detonation) limits performance and efficiency of spark ignition engines
- Direct ethanol (E85) injection has very large knock suppression effect (evaporative cooling)
- Equivalent to on-demand octane increase to more than 150 octane number
- 20 -30 % more efficiency in smaller engine with same power or 300% more power in same size engine (or a spectrum of efficiency-performance improvements)

Ethanol Use

- Ethanol use could be limited to < 10 % of gasoline use
- Refuel by E85 pump or containers
- Refuel interval could be as long as four months
- Robustness to
  - Limited ethanol distribution network
  - High ethanol cost relative to gasoline cost
  - Limited ethanol supply

Comparison To Hybrid

	Electric Hybrid	Ethanol Boost
Efficiency Gain	30 – 40%	20– 30%
Extra Cost	$3,000 – $5,000 + battery replacement cost ?	~ $1000
Technology	•Gasoline engine •Electric motor •Batteries •Adds weight	•Turbocharged gasoline engine •Ethanol direct injection •Reduces weight

Other features

- Removes need for high octane gasoline
- Removes ethanol cold start problem
- Non-dewatered ethanol could be used
- Methanol could also be used

Increasing US Ethanol Use

- Present use:
  - in mandated gasoline blends (10 % ethanol)
  - stand alone fuel (E85 in flex fuel vehicles)
- Future use in ethanol boosted gasoline engines
  - High value use of ethanol (E85)
  - 1 gallon of E 85 replaces 4 gallons of gasoline

Path Forward

- MIT spinoff company:
  - Ethanol Boosting Systems, LLC (EBS)
- Tests at Ford consistent with projected large increase in knock resistance
- Production vehicle in 2011