

Overview of Algal Biofuel Technology Development in Taiwan

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Industrial Technological Research Institute (ITRI)

Founded in 1973. A not-for-profit R&D organization that serves to strengthen the technological competitiveness of Taiwan.

What We Do

Advanced Tech R&D + Industrial Services + IP Business & New Ventures

ITRI's missions

- An innovative world-class institution that creates technological value
- Bedrock for every technological entrepreneur start-up
- Welcoming work environment that all employees are proud of

Focus Area

- Information and Communications
- Electronics and Optoelectronics
- Nanotechnology, Material & Chemical
- Energy and Environment
- Advanced Manufacturing and Systems
- Biomedical Technology



Where Taiwan's High-tech Began



Total Staff: 5,724
R&D Staff : 4,931
Ph.D. : 1,212

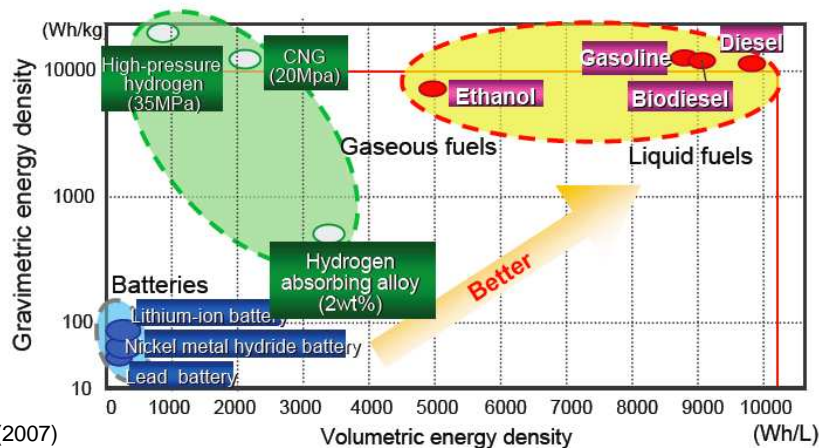
Total Patents: 15,040
Spin-offs : 165

Update: March 4, 2011

Pros & Cons of Biofuel

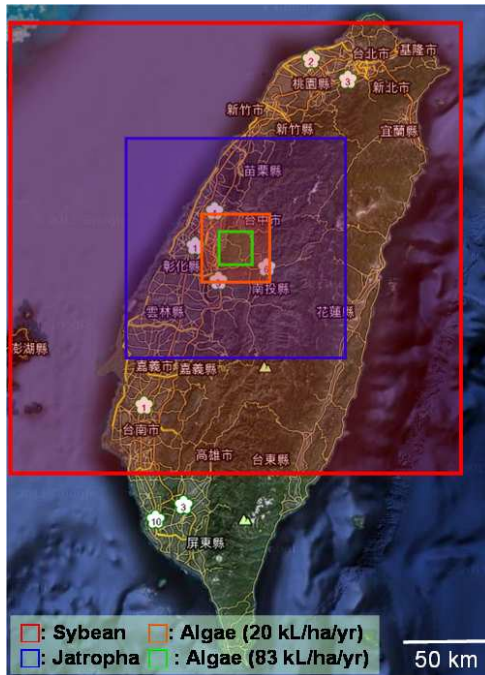
- ✓ Reduce oil dependence
- ✓ Easy to store
- ✓ High energy density
- ✓ Cascade production

- ✗ Low energy efficiency
 - PV : 10-15%
 - Light – cane (3.7%) – ethanol (~0.3%)
- ✗ Fuel vs. Food issue
- ✗ Net carbon reduction



Ref.: Morimitsu (2007)

Microalgae – a potential feedstock



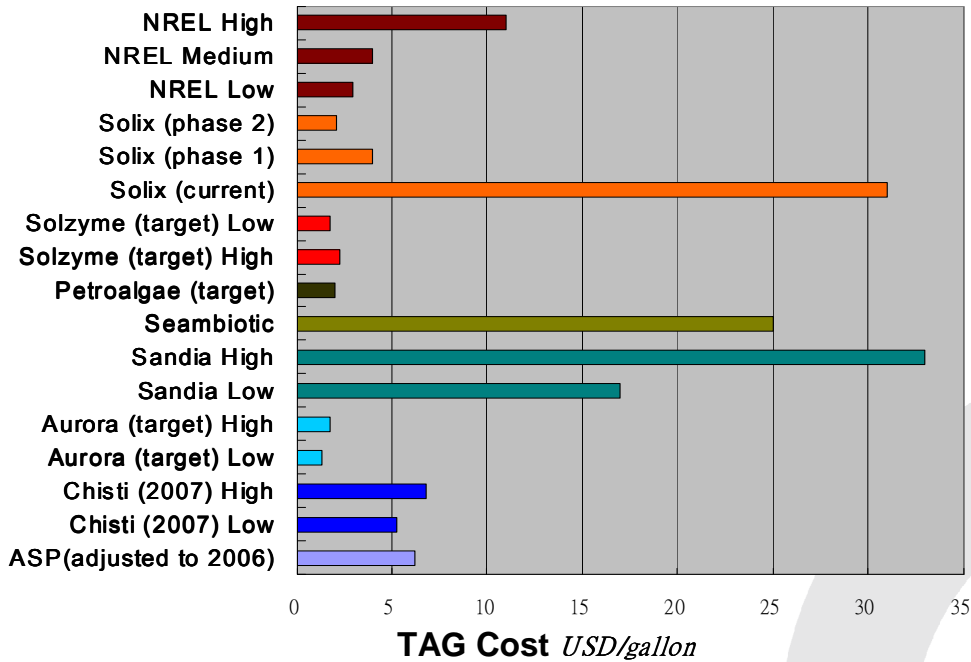
Land required to replace 50% of the usage using soybean, jatropha and algae

- Mandatory B2 program
~ 100 million liters per year mainly produced from recycled cooking oil
- Future plan:
 - Mandatory B5 in 2016 (under review)
 - What will be next generation feedstock?
- Land required for replacing 50% of diesel consumption in Taiwan
 - Microalgae (20 g/m²/day @ 30% TAG) 151,515 ha
 - Microalgae (50 g/m²/day @ 50% TAG) 36,364 ha
 - Soybean (450 L/ha/yr) 6,666,667 ha
 - Jatropha (1,900 L/ha/yr) 1,578,947 ha

Technological Challenges

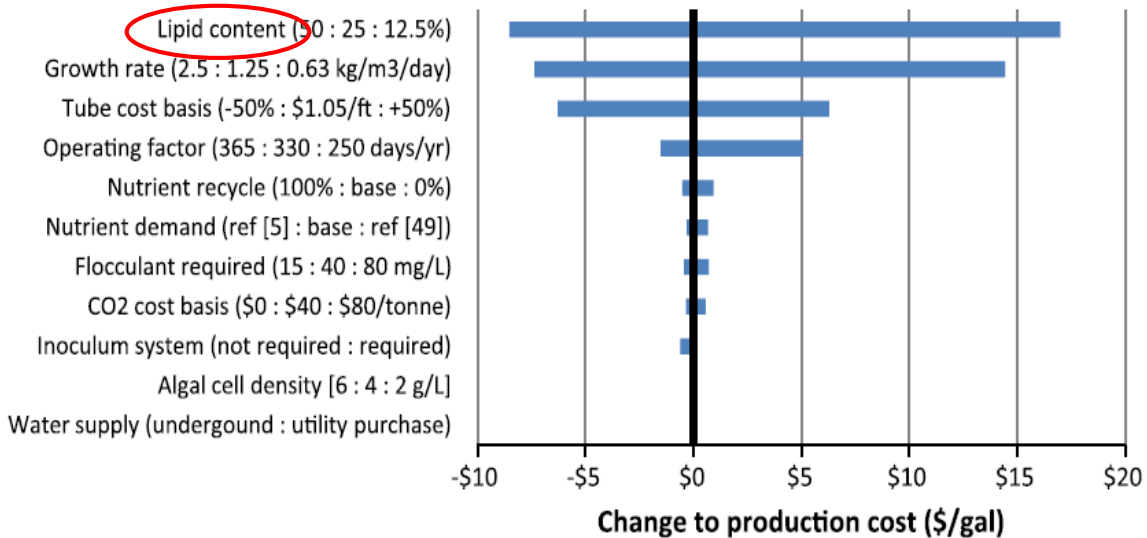
- **Biology**
 - Algae strain for high yield
 - Systems biology for lipid production
 - Crop protection
 - ✓ resistance to chytrid fungi or virus
- **Engineering**
 - Optimizing sustainable cultivation and production systems in large scale field
 - Water treatment
 - ✓ Biomass concentrated/dewatering
 - ✓ Nutrient/water recycling
 - Energy consumption
 - Site selection
- **Economics**
 - viable fuels and coproducts

Cost Issue



Ref.: adapted from National Algal Biofuels Technology Roadmap (Draft), USDOE, 2009 and publically available estimates

Production Cost: Sensitivity Analysis

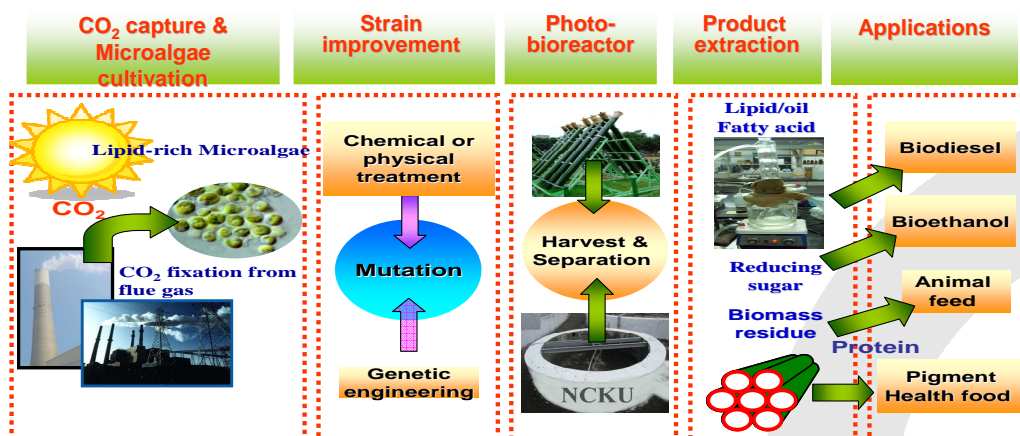


Ref. 2010, NREL, A REPORT TO IEA BIOENERGY TASK 39

- **Funding agencies**
 - Bureau of Energy, MOEA
 - National Science Council
- **Research organizations: ITRI, Fisheries Research Institute**
- **Academic**
 - Academia Sinica
 - Universities
- **Industry**
 - CPC, Taiwan
 - China Steel Corp.
 - Taiwan Power
 - Biodiesel producers
- **Others**

Research Focus in NEP

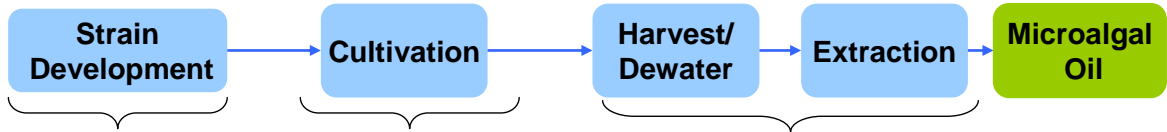
- **Strain screening**
 - High oil content
 - Resistance to the impurities in flue gas and high CO₂ conc.
- **Microalgal oil production**
 - *Chlorella vulgaris* ESP-31
 - 150 L (50 L x 3) outdoors
 - Lipid productivity: 50 mg/L/d
- **Biofixation of flue gas CO₂**
 - Co-operated with China Steel Co.
 - Thermophilic (> 70°C) and alkaliphilic (pH > 8.5) strains (cyanobacteria) were isolated
- **Biodiesel production**
 - Development of heterogeneous catalysis



Source: Prof. Jo-Shu Chang, NCKU

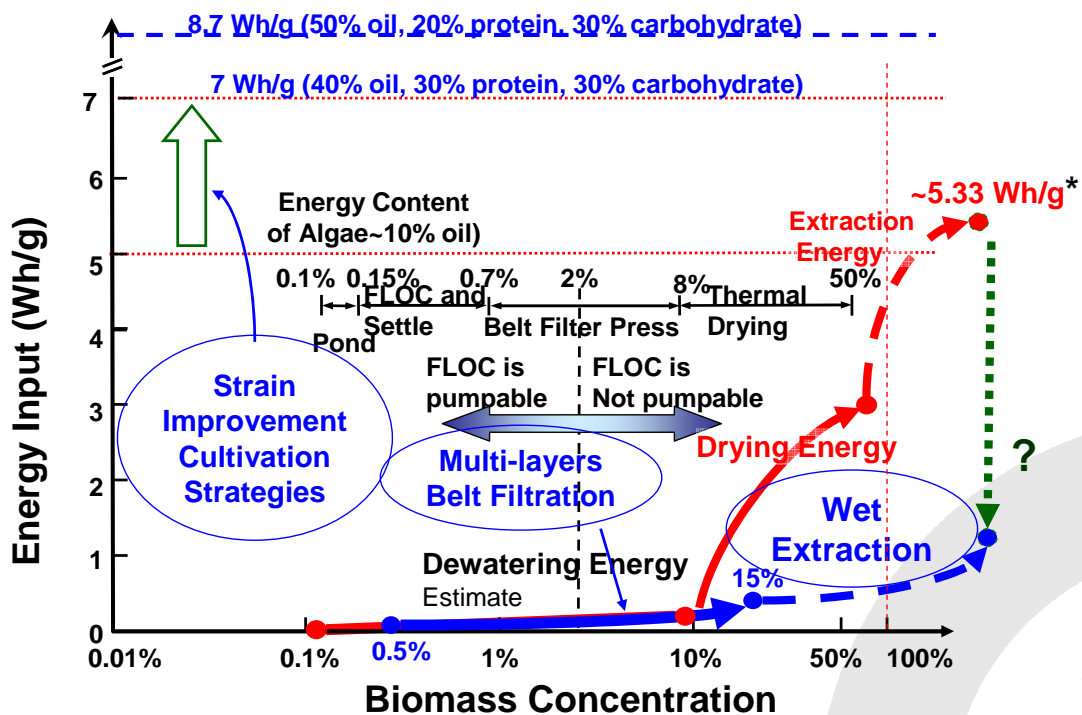
Microalgal Biofuel Project in ITRI

Team Work and Collaboration



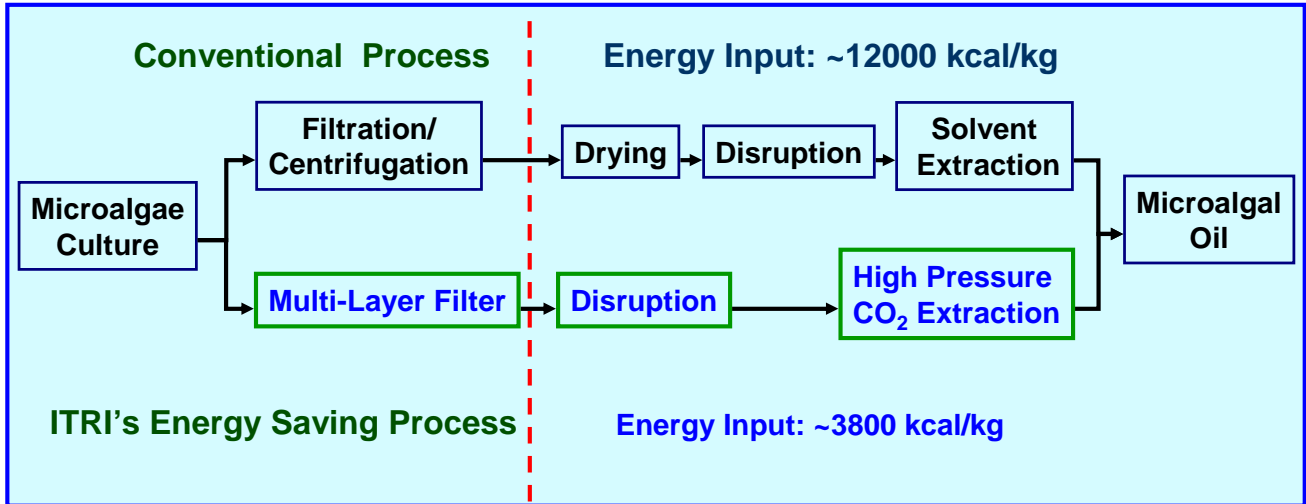
<ul style="list-style-type: none"> • Strains Isolation • Molecular Biology in Cyanobacteria • Molecular Biology in Chlorella 	<ul style="list-style-type: none"> • Cultivation Strategies • PBR Development • Raceway system Development 	<ul style="list-style-type: none"> • Harvest/Cell Disruption/Oil Extraction Technologies • System Integration • System Simulation
<ul style="list-style-type: none"> • ITRI -GEL/MCL • Academia Sinica • NCU(中央大學) • NREL • DYU(大葉大學) • MCUT(明志科大) 	<ul style="list-style-type: none"> • ITRI/GEL • FRI/TBRC(水試所東港生技中心) • NTU(台灣大學) 	<ul style="list-style-type: none"> • ITRI -GEL/MCL/MSL • NCKU(成功大學)

Development Strategies in ITRI

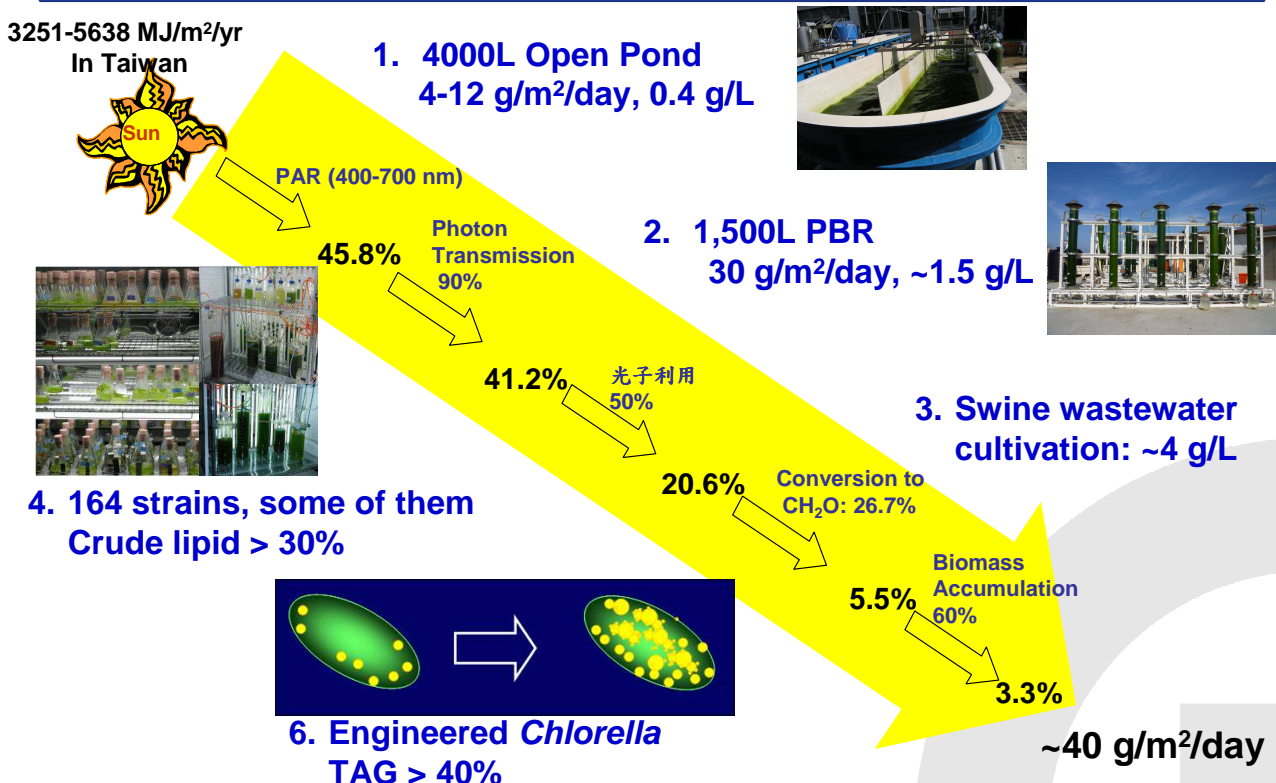


Overview of Downstream Processes in ITRI

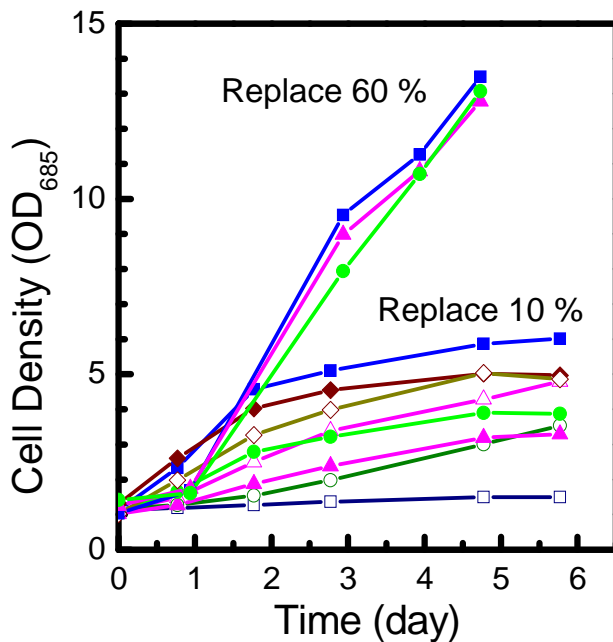
- Focus on energy saving, water recovery, high-value chemical extraction and cost competitiveness
- Key components need further development



Overview of Microalgae Cultivation in ITRI



Swine Wastewater Cultivation



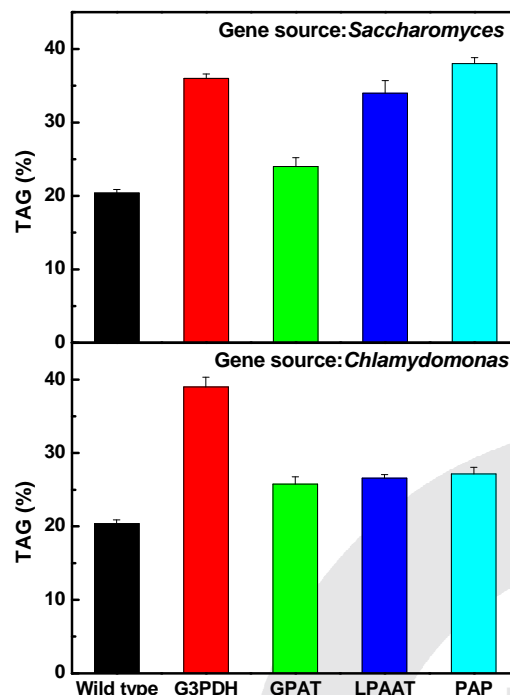
- **Replace 10% of medium**
 - Most of the strains tested grow well.
 - *N. oculata* and *Chlorella* G2-1 can grow better, crude lipid are 60 wt.% and 36 wt.%, respectively.
- **Replace 60% of medium**
 - Biomass conc. ~ 4g/L

	<i>N. oculata</i>	<i>Chlorella</i> sp.	<i>C. minutissima</i>
Growth rate	0.8 g L ⁻¹ day ⁻¹	0.92 g L ⁻¹ day ⁻¹	0.85 g L ⁻¹ day ⁻¹
Lipid content	38 wt.%	36 wt.%	33 wt.%

△ : ITRI 01 □ : ITRI 03 ○ : ITRI 05 ■ : *N. oculata*
 ▲ : *Chlorella* sp. ● : *C. minutissima* ◆ : *Chlorella* G2-1 ◇ : *Chlorella* Y8-1

Development of Genetic platform

- **Increasing TAG Synthesis Efficiency**
 - A transformation tool has been Constructed
 - TAG content can be increased from 20% to 40% by cloning TAG synthesis related gene
- **Other Focuses**
 - Develop *Chlorella*-based genetic platform
 - Establish algal lipid secretion machinery



Effect of single gene overexpression on TAG synthesis

Concluding Remarks

- Microalgae possesses great potential in replacing fossil fuel, but
 - cost higher than vegetable oil or diesel
 - Need intensive R&D
- International collaboration on capacity building and technology transfer
- Alignment of biofuel and other related sectors

Thank you for your attention

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