Technology Development and Advancing it to the Market – Case Study

Innovation is not linear. Instead it is a continuous conversation between the facets of successful business: A customer / market need – an end user trying to solve a specific problem.

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Workshop on "How to take ideas from academia to market"
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Innovation – Innovator (Dictionary meaning)

- ✓ Novel / intelligence / disruptive creation
- ✓ A person or group that introduces something new and does something for the first time – a true pioneer and innovator who always pushes the boundaries and follows his vision.

- DNA of innovator (by Jeffrey H. Dyer, Hal Gregersen and Clayton M. Christensen): (https://hbr.org/2009/12/the-innovators-dna)

  (1) Associating,

  (2) Questioning,

  (3) Observing,

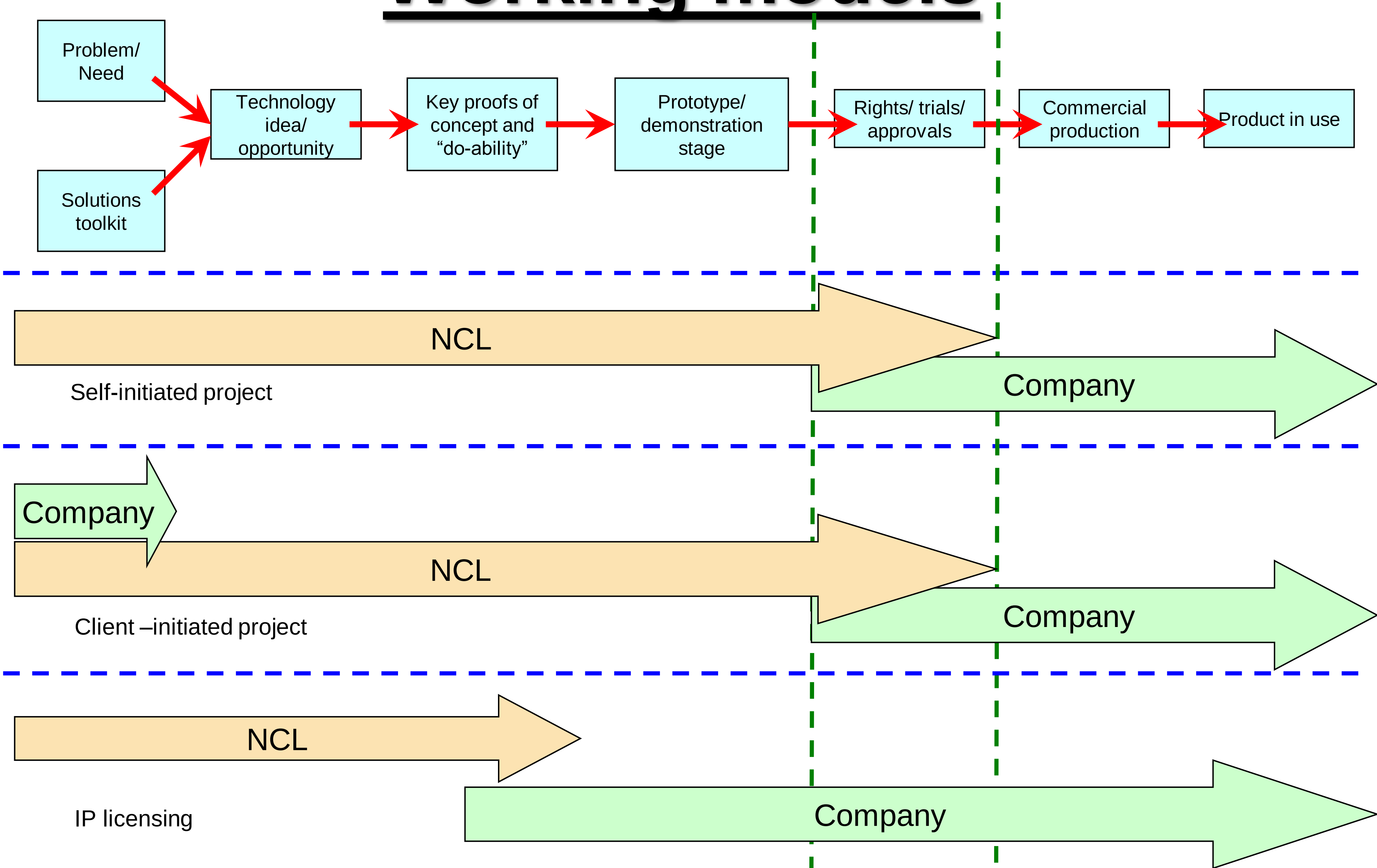
  (4) Experimenting and

  (5) Networking

Why does one more creative than the other : Qualities of innovators –

(1) Continuous reflection
(2) Unattended exploration
(3) Iterating between abstract and concrete thinking
(4) Action oriented
(5) Opportunity focused
(6) Mental resilience
(7) Intellectual humility
(8) Courage
(9) Sensitivity towards uncertainties
(10) Designing valuable experiments
(11) Extracting learning
(12) Implementing learning and idea adaptation

Technology development & transfer: Working models



Case Study of Industry Projects

- **Example 1: Technology Licensing + Co-development** (Titanosilicate with Süd Chemie and DMC with RIL)
- **Example 2: Research + Technology Licensing** (Biodiesel/Lubricants – Benefuel Inc.)
- **Example 3: Developing in-depth understanding** (Drug intermediates – Emcure; Industrial catalysts – Indian Industries; R&D/Tech. Service)
- **Example 4: Information analysis and advisory** (Zeolites in industrial applications – consultancy)

Problem/Need – Solutions toolkit

- **Presently, most of our energy is derived from fossil resources** (Coal, Natural gas & Oil).
- Transport fuels form a major part of the Energy requirement.
- **Fossil resources are limited. They impart adverse effects on the Environment.**
- Thus, clean energy is the need of the day.
- **Sustainable Development requires Energy Security and Protection of the Environment.**
- Renewable / Clean Energy leads to Sustainable Development. It can bring down our oil import bill.
- **Transport Fuels from biomass, water & CO_2 can form Clean Energy**.

India's Clean Energy Transition

- ✓ To reach net-zero emissions by 2070.
- ✓ To meet 50% of its electricity requirement from renewable energy sources by 2030 - installing 500 gigawatts of renewable energy capacity, reducing the emissions intensity of its economy by 45%, and reducing a billion tonnes of CO_2.
- ✓ India aims to become a global hub for green hydrogen production and exports.
- ✓ India brought in National Policy on Biofuels

Bio-fuels

- Fuels derived from Biomass
- Renewable, C-neutral, create additional employment, rural revitalization, decentralized energy
- Excess available biomass in India is ~ 200 MMTPA
- At 10% substitution, biofuels will bring in Rs. 75,000 crores in rural economy.
- Efficient conversion technologies are needed.
- Bio-fuels: bioethanol, **biodiesel**, bio-JET fuels, biobutanol, biohydrogen, etc.

Inedible Oil Feedstock for Fuels

- Avoid food *vs* fuel controversy.
- Could be grown even on arid lands (with little water/nutrients).
- Algae cultivation helps controlling atmospheric CO_2 levels.
- Other than TG, inedible oils contain mono and diglycerides, fatty acid (FFA), water, phospholipids (which are impediment to the conventional alkali-based biodiesel process).
- Example: Jatropha, Karanja, Animal Fat, Algae, etc.

BIOFUELS FROM VEGETABLE OILS

- Biodiesel (1ST Generation)

Fatty Acid methyl esters - methyl esters of C_{16} - C_{18} acids: Fuel boiling in the petro-diesel boiling point range obtained by TransEsterification of triglycerides present in vegetable and algae oils with methanol.

- Green Diesel (2nd Generation)

Hydrocarbons; C_{16} - C_{18} saturated, branched Hydrocarbons similar to those in petrodiesel; High cetane number (70 – 80). Good stability

CATALYTIC PROCESSES FOR BIODIESEL MANUFACTURE

- Homogeneous: COMMERCIAL. NaOH; 65°C; large quantities of **water and acid washes**; yields **low quality glycerol**; feedstock limitations; salt **byproducts**.

  Enzymatic: Lipase; **cost of enzyme is a major barrier. Enzyme denatures in the presence of methanol; requires additional solvent THF or hexane.**

- Heterogeneous: Zn aluminates (IFP), Ca-carbonate, ETS-4/10, sulfated/tungstated zirconia.

Technology / Idea, Opportunity

- **Use of inedible oils** instead of edible oils; inedible oils contain significant amount of FFAs.
- Simultaneous esterification of FFA & transesterification of glycerides; **one-pot process**
- **Catalyst tolerance towards water** produced in esterification reaction.
- **Catalyst life** - stability of catalyst towards impurities in inedible oils and products generated during reactions.
- **Glycerin yield and purity** – important for economic viability of biodiesel plant

What should be the characteristics of a stable, high performance catalyst ?

NCL’s Catalyst Characteristics

- Solid reusable catalyst
- Hydrophobic surface
- Acid functional groups

Proof of concept: Feedstock Flexibility

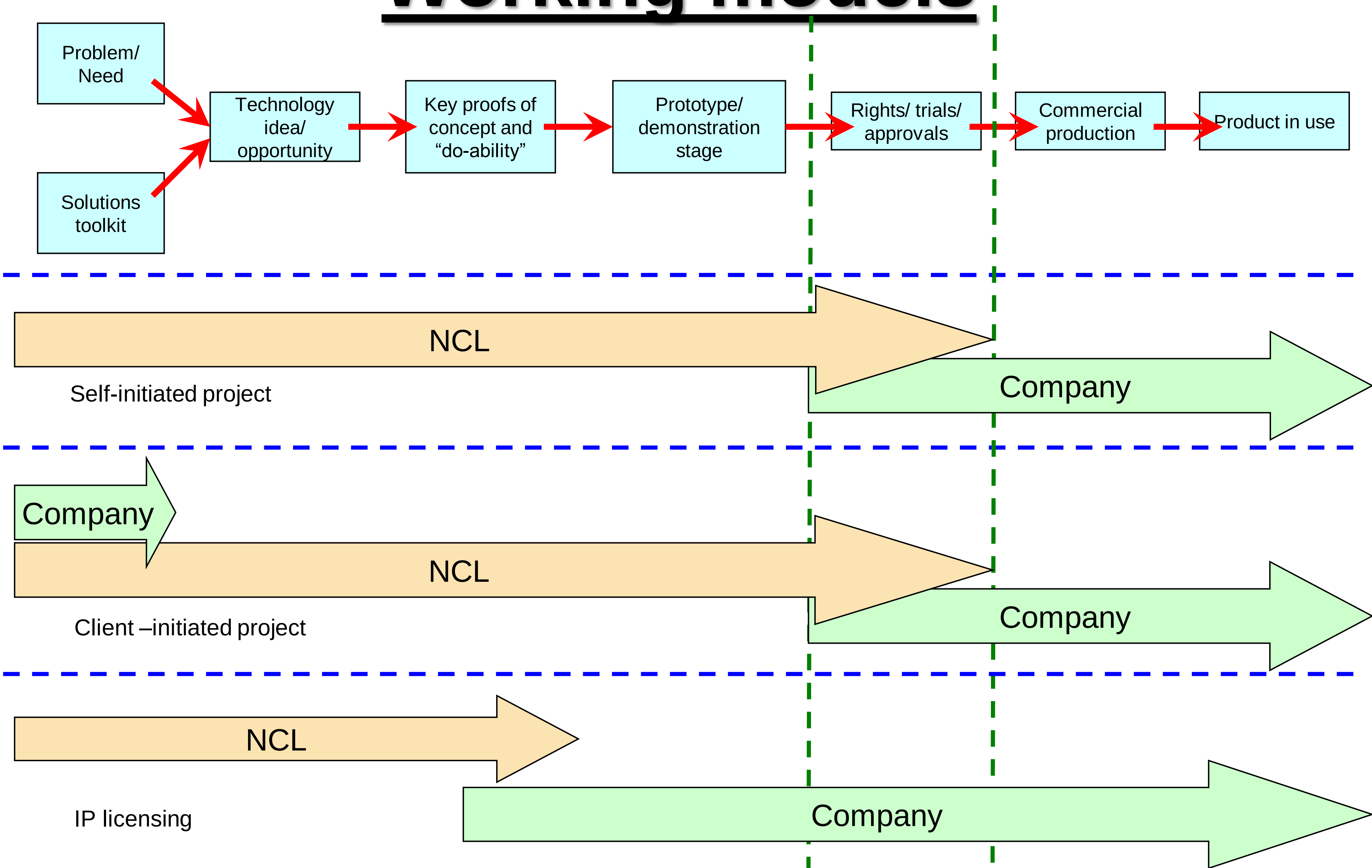
FEEDSTOCK	% FFA CONTENT
Plant/vegetable oil	0.05-20
Waste cooking oil	4-50
Animal fat/tallow	5-30
Brown Grease	5-100

Traditional biodiesel technology turns FFA into soap.

With traditional biodiesel processing there is a 2% yield loss for every 1% of FFA removed.

NCL catalyst turns FFA into biodiesel and enables higher yield of product biodiesel.

Technology development & transfer: Working models



Lab to Demonstration Scale & Commercialization

(100 ml)

Batch Process

(20 liters)

(0.8 lit/day)

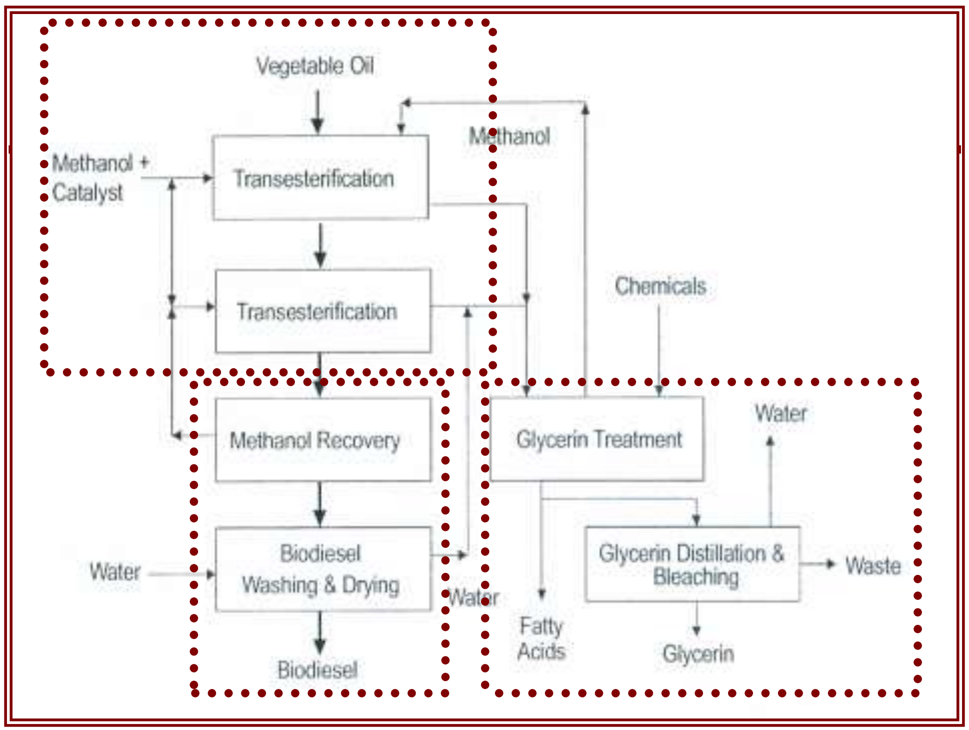
(1 ton/day)

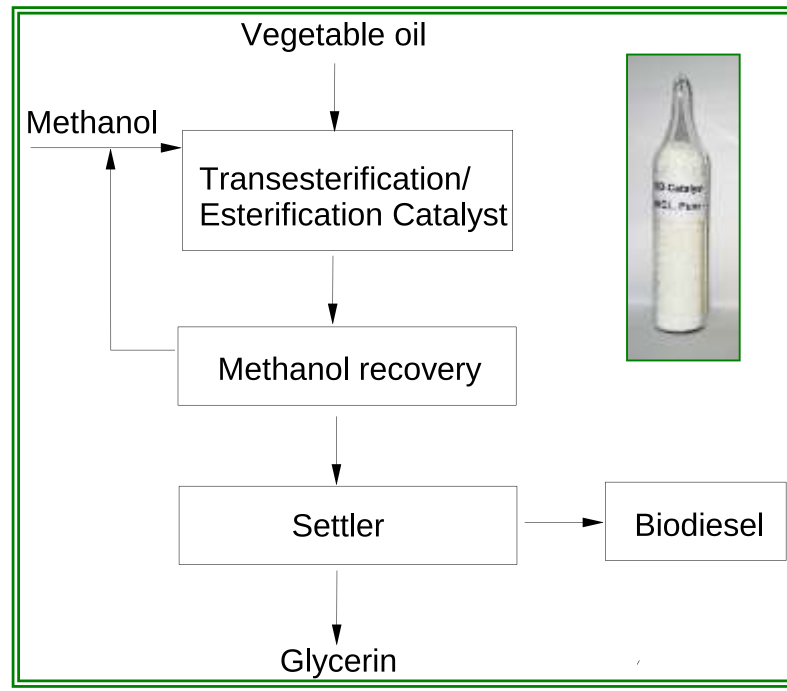
(160,000 tons/yr)

Solid Catalyst and Continuous Process for BIODIESEL

Conventional Technology
Homogeneous Catalyst

ENSEL™ Technology
Heterogenous Catalyst





ENSEL Technology for Biodiesel

- Solid catalyst & continuous process for biodiesel from non-edible oils.
- IP was licensed to Benefuel Inc., USA. A commercial facility (160,000 tons/year) was established at Beatrice, Nebraska, USA.
- Sud-Chemie India Pvt. Ltd., Vadodara manufactured and supplied catalyst.
- Biodiesel - renewable fuel derived from biomass; carbon-neutral; environmentally & economically benificial; energy independence.

- Solid catalyst
- Feedstock flexibility
- Water-free & zero waste process
- High yield of biodiesel
- High quality glycerin
- Product with ASTM & EN specifications
- Economic process

Contributors for Lab to Market

- Students (Ph.D., M.Tech., M.Sc., BE/B.Tech, PAs)
- Divisional Colleagues
- Directors / Deputy Directors / Leadership
- BD Division team
- IP team
- Support staff
- The Organization
- Benefuel Inc.

Output / Outcome

- Technology development, licensing (Benefuel Inc., USA) and advancing it to the market
- Monitory realization
- Publications: 15 (International peer reviewed journals)
- Patents: 5 (India & PCT)
- Ph.D thesis.: 5
- Trained students: 35
- New Project Initiations: 2 (CSIR-Network ; Industry)
- National Awards / Recognitions
- **Economic :** Duonix produces 5% biodiesel of US requirement.
- **Societal** : New Jobs, Green Fuel, cut on CO_2 emissions, energy independence
- **Strategic** : 1^{st} Solid catalyst based BD process, Eco-friendly zero-waste process

Factors that make technology transfer successful

- Maturity and Communication of the Teams
- Innovativeness
- Knowledge
- Quality of the product
- Motivation
- Commitment by all the parties
- A documented, planned approach using trained and knowledgeable personnel with good ethics working within a quality system
- Speed of technology transfer

Characteristics of Successful Technology Transfer

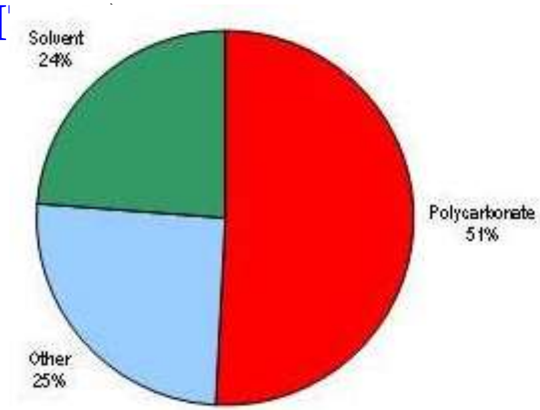
https://nap.nationalacademies.org/read/10321/chapter/1

- ✓ The technology must be appropriate for the proposed application.
- ✓ The technology must be at an appropriate level of maturity.
- ✓ The recipient must be at an appropriate level to apply the technology.
- ✓ The technology must meet the organizational needs of the recipient.
- ✓ The technology must be economically viable.
- ✓ Innovation is a continuous conversation between the facets of successful business: A customer / market need – an end user trying to solve a specific problem.

Dimethyl Carbonate (DMC):
Market Demand & Applications

1. Solvent - Paints, Inks, Coatings, etc.
2. Electrolyte – Lithium ion batteries
3. Versatile Chemical / Intermediate (instead of phosgene, dimethyl sulfate, etc): Polymers (eg., polycarbonates, polyurethanes), pharmaceuticals, pesticides, anti-oxidants, high performance resins etc.
4. **Fuel Additive / Gasoline Blending Component (Future application):**

Very high oxygen content (53 wt% vs 18 wt% in M carbon-carbon chemical bonds



Good blending octane

(RON = 109, MON = 102, R+M/2 = 105)

No phase separation; Low toxicity

Rapid biodegradability

Reduces harmful particulate matter (PM) emissions

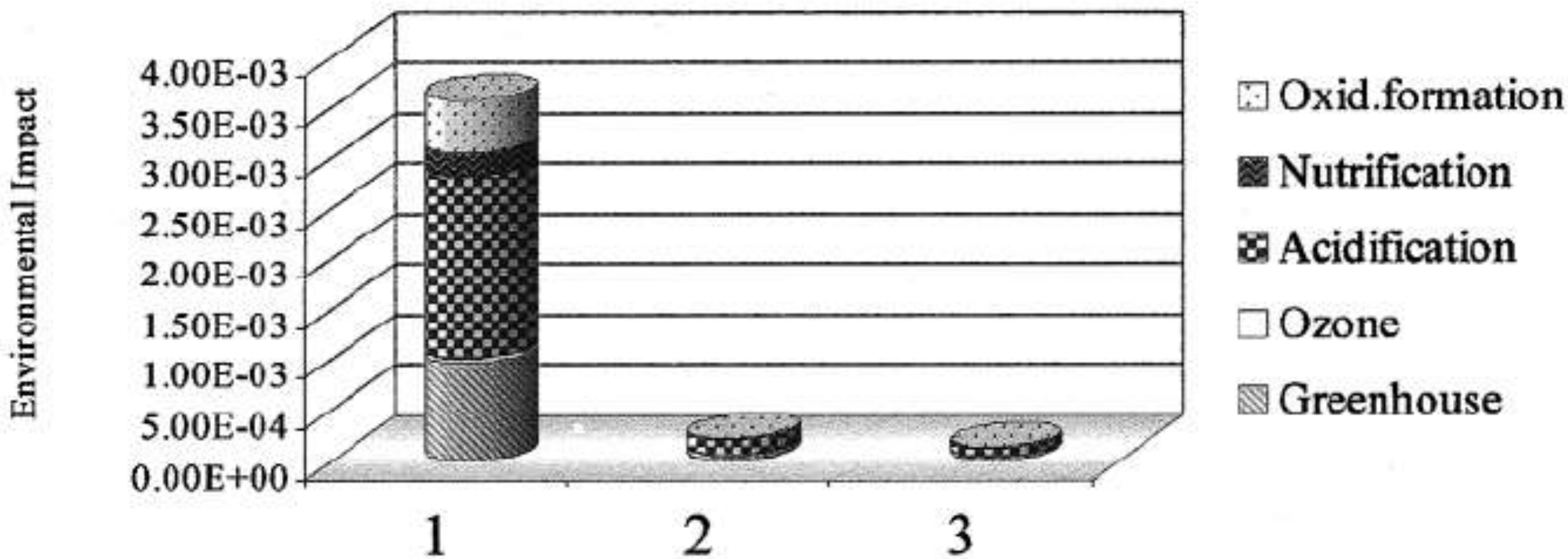
Increases thermal efficiency of diesel engines

At the same wt% oxygen in the fuel, DMC reduces total HC, CO and formaldehyde more than MTBE (Amoco emission tests)

International Capacity of DMC (2002) ≈ 170,000 t/a; output and consumption ≈ 90,000 t/a (China Chemical Reporter Oct 16, 2004)

Life Cycle Assessment of DMC Synthetic Pathways

Aresta et al., Energy & Fuels 15 (2001) 269-273



1: DMC from phosgene and methanol; 2: DMC from urea and methanol;
3: DMC from methanol and CO_2.

Recycling CO_2 into Fuels Pool

- CO_2 emissions from top 10 emitting countries amount of 30 GTPA. India emits ~ 2.5 GTPA and occupies the 4^{th} position in the list.
- COP-21 resolution: CO_2 emissions to be reduced by 30 – 35% of 2015 levels by 2025.
- Recycling of CO_2 into Fuels is a possible solution to achieve this task.
- CO_2 is thermodynamically stable and kinetically inert molecule.
- It requires addition of H_2 for activation and conversion into fuels.
- Sources of H_2: Impure hydrogen, eletrolysis/photolysis of water ??

Direct Synthesis of DMC from MeOH & CO_2

$$2\ CH_3OH + CO_2 \leftrightarrow CH_3OC(O)OCH_3 + H_2O$$

Advantages:

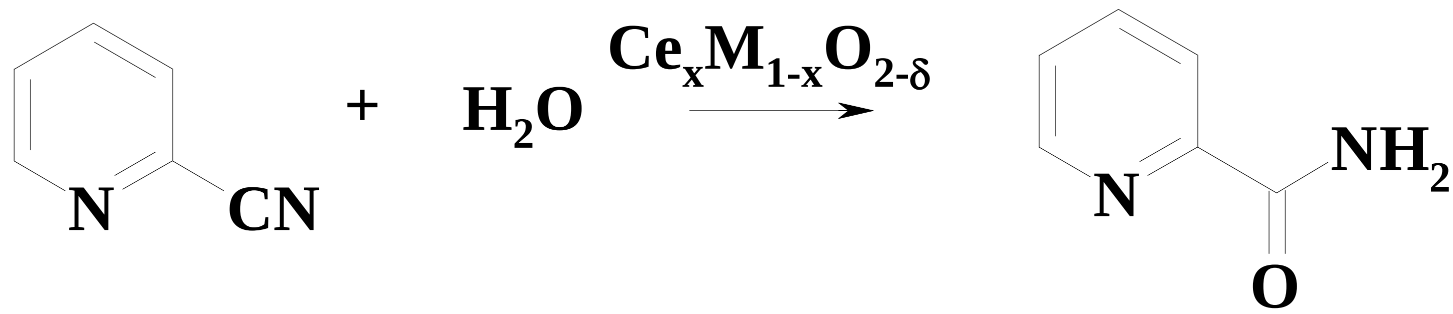
1. High atom efficiency
2. Environment benefits / Carbon credit
3. Byproduct is water
4. CH_3OH is also produced from CO_2 by hydrogenation.

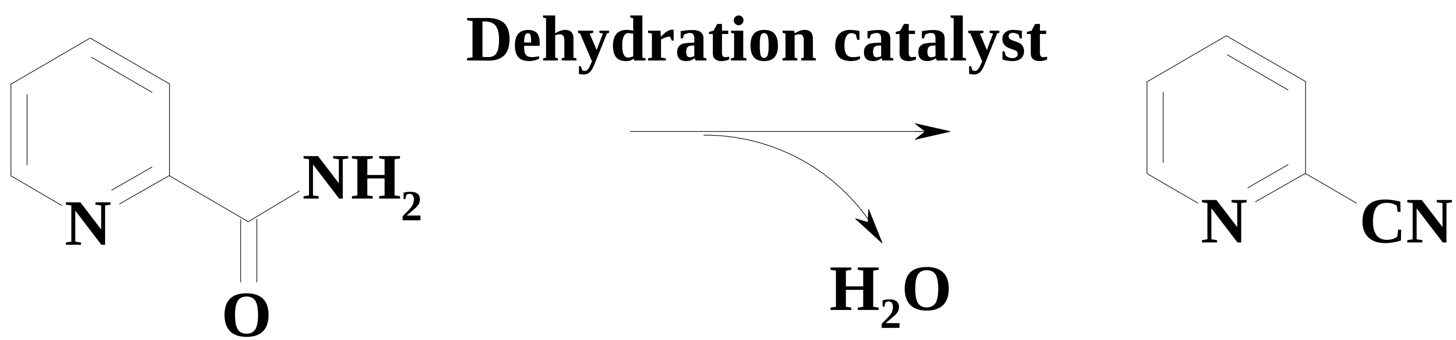
Drawbacks:

1. Limited by thermodynamics ($\Delta G = +\ 26.21$ kJ/mol)
2. Low DMC yield
3. Catalyst deactivation in presence of water

Strategy to enhance DME yield

$$2\ CH_3OH + CO_2 \xrightleftharpoons{Ce_xM_{1-x}O_{2-\delta}} CH_3OC(=O)OCH_3 + H_2O$$





CONCLUSIONS

- Clean energy is essential for Sustainable Development.
- Biofuels from inedible oils offer clean transport fuels.
- The ENSEL® technology (commercialized at Beatrice, Nebraska; 160,000 TPA) converts a range of inedible oils to biodiesel.
- NCL's catalyst process for direct synthesis of dimethyl carbonate (Reliance Inc) is high yielding and has low environmental impact.

Barriers to Tech. Transfer - 1

- **Organizational or Economic Barriers:**
  - ✓Different orientations exist between the technology provider (R&D organization) and its user (business) concerning the aspect of time (long vs. short term), goal (scientific vs. techno-economic market) and risk (high risk vs. low risk expectance).
  - ✓Large asymmetries exist between the provider and the recipient in terms of having different characteristics, e.g., skills, prices, endowments, internal structure, size, and experience, etc.
  - ✓Different approaches are taken by the technology provider and recipient towards the desired results. Usually, these approaches include innovation-oriented vs. market-oriented approaches or focus on superior technologies vs. easily implemented

Barriers to Tech. Transfer - 2

- **Organizational or Economic Barriers (contd..)**:
  - ✓Imperfect technical information transmission and insufficient co-operation between the R&D organization and the technology user at the stage of technology development are often evident.
  - ✓Unsatisfactory or poor business management and negotiation skills exist on both sides (the technology provider and recipient); however, this problem is usually mostly on the provider’s side.
  - ✓There are often problems with selecting the most appropriate technology transfer mechanisms.
  - ✓The lack of an accurate assessment of technology transfer frequently exist.

Barriers to Tech. Transfer - 3

- **Organizational or Economic Barriers (contd..)**:
  - ✓There is often the lack of a plan for the implementation of research results and ex-post analysis of implementation outcomes.
  - ✓R&D organizations focus too much on the advancement and dissemination of knowledge, e.g., making results public before their patenting, which deeply collide with the demands of industry.
  - ✓Technology providers frequently have insufficient knowledge about potential markets and consumers.
  - ✓There is frequently insufficient time for testing and the demonstration of new technologies before they can compete with well-established technologies, which hampers the process of the practical application of technology.

Barriers to Tech. Transfer - 4

- **System Barriers** :
  - ✓ The lack of developed infrastructures, market and public incentives exist.
  - ✓ The absence of a technological development plan is observed at a national level, because the public decision making power is not able to create conditions of promotion, support, and a coherent target for public and private R&D and innovation.
  - ✓ Standard-setting groups offer a safeguard against unexpected failure that often deliberate and can delay implementation of innovations.
  - ✓ Lobbies or interest groups effectively impede change and amelioration in the legal system, making technology transfer impossible or inefficient.

Barriers to Tech. Transfer - 5

- **Technical Barriers**:
  - ✓ A high level of tacit knowledge included in technologies makes technology transfer more difficult (especially with regard to the newest solutions).
  - ✓ New technologies need to be tested and demonstrated thoroughly before public agencies will accept them in competition with other, well-established technologies.
  - ✓ Technology is too sophisticated, making it difficult or impossible to change in order to make it suitable for the requesting production/market.
  - ✓ The recipients are not able to discern the level and characteristics of the technology needed.

Barriers to Tech. Transfer - 6

- **Other Barriers** :
  - ✓ Multiplication of solutions: R&D organisations often have the capacity to develop a single professional solution. Since its development is connected with high technical and personnel requirements, problems concerning its acquisition by the potential producer may arise.
  - ✓ A long time is needed for technology development, resulting from the fact that the technologies offered are mainly of a unit character, which may lead to the discouragement of the potential clients who wish the technology to be developed as quickly as possible.

Barriers to Tech. Transfer - 7

- **Other Barriers**:
  - ✓ Innovative technologies represent a short series or unit character, which means that their production is very expensive; therefore, they are less competitive.
  - ✓ Technological concepts are changed in the course or even after the contract execution.
  - ✓ A prototype version of a technology is often not compatible with the demands of mass production – achieved high technical parameters vs. unsatisfactory economic parameters.
  - ✓ The lack of professional marketing as well as the lack of skills and practice in technology transfer resulting in the low effectiveness of such activities.

Barriers to Tech. Transfer - 8

- **Other Barriers** :
  - ✓ Problems concerning Intellectual Property Rights resulting from the joint development of an innovation by the consortium, particularly when one or more partners are from business.
  - ✓ Inspiring industry by ideas revealed or discussed at the early stages of co-operation preceding the signing of a contract, frequently stimulating ideas by industry, which tries to apply them by themselves.

Technology Transfer barriers and challenges faced by R&D Organizations , Adam Mazurkiewicz and Beata Poteralska, Procedia Engineering 182 (2017) 457 – 465

Barriers to Tech. Transfer - 9

- **Other Barriers**:
  - ✓ The existing triad of co-operation extremely profitable only for the industry side: the lowest possible price (without costs of research and development) – complete takeover of property rights by enterprises – R&D organization responsible for possible losses in the course of using the technology.
  - ✓ Organisational changes in industrial enterprises.
  - ✓ Different work organization in business and in science.
  - ✓ The interest of industry in financing the final result, not the research process itself.

References

- M. Nandagopal, K. Gala and V. Premnath, ISB Conf. Paper (2011)
- L.L.J. Meijer et al. Renew. Sust. Energy Rev. 112 (2019) 114-126.
- A. Mazurkiewicz and B. Poteralska, Procedia Engineering 182 (2017) 457 – 465.
- R. Ravi and M.D. Janodia, Journal of the Knowledge Economy 13 (2022) 787-803.
- "Great Mistakes in Technology Commercializa-tion," K. Parker and M. Mainelli, Z/Yen Ltd. The Journal of Strategic Change, Vol. 10, 2001.