

MAGIC Processes & Plants

Transform Manufacturing of Specialty Chemicals

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Create Innovations & Knowledgebase to Solve Relevant Problems

Outline

- Specialty chemicals
 - Key requirements/ drivers
 - Challenges/ technology platforms
- MAGIC processes and plants
 - Key attributes
 - Realizing MAGIC in practice
- Summary & path forward

Specialty Chemicals

- Characterized by low volumes, niche applications, high price, sold on performance specifications
- Key sub-sectors
 - Catalysts
 - Textile chemicals
 - Water treatment chemicals
 - Adhesives and sealants
 - Leather chemicals
 - Detergents & surfactants
 - Paper chemicals
 - Electronic chemicals
 - Biomarkers
 - API
 - Paints, pigments and colorants
 - Flavors and fragrances
 - Foundry chemicals
 - Rubber chemicals
 - Photographic/reprographic chemicals
 - Printing inks
 - Additives for polymers
 - Construction chemicals
 - Oil field chemicals
 - Cosmetics

Indian Specialty Chemicals Sector

- Current turnover: ~ ₹ 150000 Crores
 - Expected to grow at double the rate of GDP in emerging economy like India
- Turnover will cross ₹ 750000 Crores by 2022
- Need significant technology inputs to create addition turnover of ₹ 600000 Crores!

Growth Potential

- Globalization of business
- Shifting manufacturing geographies
- Growing concerns for sustainability
 - Catch up with and exceed the global benchmarks on sustainability
- Changing customer expectations driven by new demographics
 - Address unmet needs & newer demands of rapidly developing nation (capacity/ quality)
- Rapid market fluctuations/ cycles
- Industry consolidation

Key Drivers for Growth

- Low cost operation/ manufacturing
- Develop better process technologies/ product quality
- Provide systems solutions
- Develop new applications for existing products
- Develop new products to create new market based on unmet needs of customer

Indian Specialty Chemicals: Challenges

- Business issues

- Fragmented capacity; low capital/ technology intensity
- Threat of horizontal transfer of technology/ quicker erosion of margins due to commoditization of products
- Difficulties in identifying new growth platforms
- Lack of deep pockets to sustain business cycles; branded as low cost supplier/ manufacturing entity; managing supply chain of raw materials

- Technological issues

- Cost of new product introductions/ cost of raw materials & energy
- Relative unfamiliarity with catalytic processes/ different reactors; conventional engineering practices
- Limited in house technology development strength
- Innovation deficit; few processes based on proprietary knowledge/ IP; serious issues of talent retention/ flight
- Increasing regulatory (environment, health and safety) frameworks

Possible Ways to Overcome Challenges

- Improve productivity and develop innovative products; Adjust with rapid market fluctuations/cycles; Reduce time to market
 - Multiple products from the same facilities
 - Improve functionalities – new markets
 - Flexible & multi-purpose plants
 - Focus on formulated products
 - Products with unique raw material advantages
 - Process intensification & compact plants
 - Use continuous processes
 - Computational modeling for faster lab to market

Science, Technology & Innovation

Some Key Principles

- Use catalysts, not stoichiometric reagents
- Use better (& safer) solvents and reaction conditions
- Design syntheses so that the final product contains maximum proportion of the starting materials
- Prevent waste, leave no waste to treat or clean up
- Design safer (non-toxic) chemicals and products
- Maximize energy efficiency & effectiveness
- Use multi-functional & intensified process equipment
- Real-time monitoring and process control

Key Technology Platforms

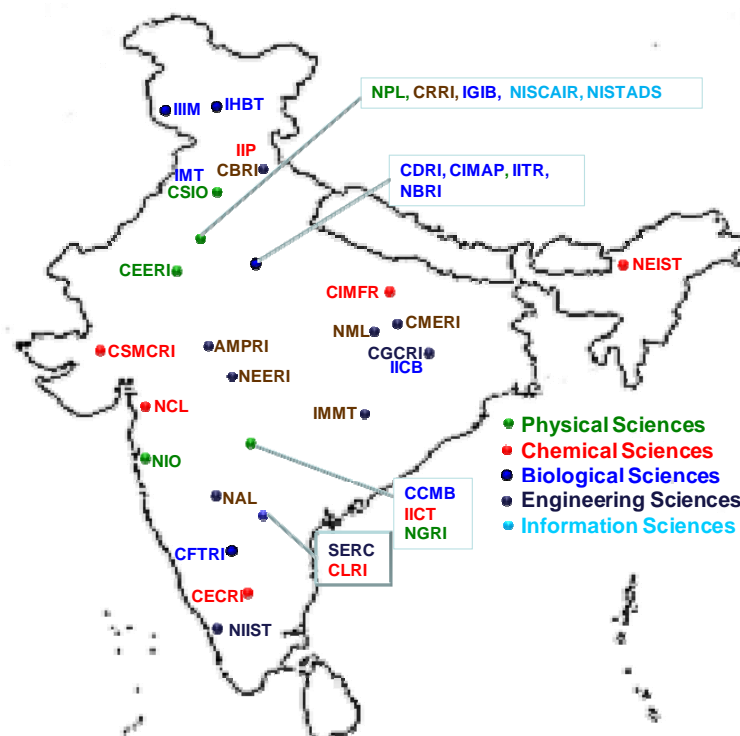
- **Chemistry**
 - Catalysis (replace reagent based processes)
 - Improved solvents (supercritical media, ionic liquids)
 - Other tools like chiral switches / single enantiomers, micro-encapsulation, Suzuki coupling, metathesis, click chemistry and so on
- **Chemical engineering & process intensification**
 - Batch to continuous, multifunctional reactors
 - Micro-reactors, new reactors and mixers
 - Novel separation platforms
 - Computational modeling, simulation & visualization

CSIR - National Chemical Laboratory

CSIR

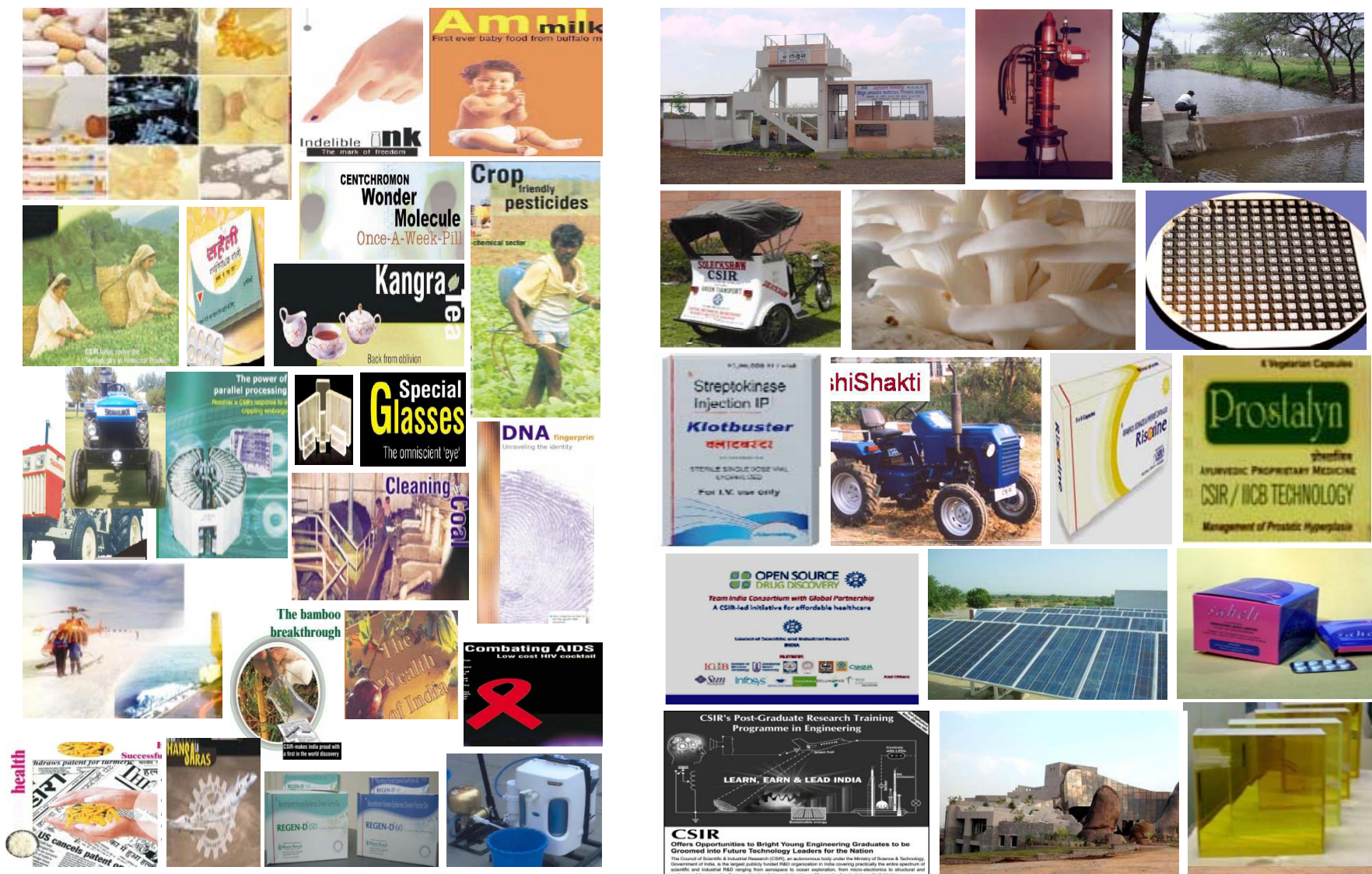
- CSIR's mission

- To provide scientific industrial R&D that maximizes the economic, environmental and societal benefits for the people of India.



Total No. of Laboratories/Institutes: 37 Outreach Centres: 39

CSIR Today: Played Key Role



CSIR's Post-Graduate Research Training Programme in Engineering

LEARN, EARN & LEAD INDIA

CSIR
Offers Opportunities to Bright Young Engineering Graduates to be Groomed into Future Technology Leaders for the Nation

The Council of Scientific & Industrial Research (CSIR), an autonomous body under the Ministry of Science & Technology, Government of India, is the largest publicly funded R&D organization in India covering practically the entire spectrum of scientific and industrial R&D ranging from aerospace to ocean exploration, from micro-electronics to structural and environmental engineering, from smart materials to nanotechnology, and from environmental to synthetic biology.

CSIR Vision: New CSIR for New India

- Pursue science which strives for global impact, technology that enables innovation-driven industry and nurture trans-disciplinary leadership thereby catalyzing inclusive economic development for the people of India
 - Establish science & engineering leadership
 - Provide innovative technology solutions
 - Harness open innovation and crowd sourcing
 - Encourage science based entrepreneurship
 - Realize socio-economic transformation through S&T intervention

**New CSIR for
New India**



National Chemical Laboratory

- NCL's mission

- To further knowledge in the chemical sciences and apply it for the benefit of the people.



- Knowledge creation, capability building, PhD research
- Knowhow, technology, innovations
- Research services, consulting, technical support
- Establish & nurture resource centers

NCL Eras: Lab to Market

Basic chemicals; Dye stuffs (1950s)



Agrochemicals; Organic chemicals (1960s)

Pharmaceuticals; Fine chemicals (1970s)



Import subs; Catalysis; Tissue culture (1980s)



Research services; India - Global R&D hub;
Patenting; Global tech transfer (1990s/early 2000s)



Partnership models; Entrepreneurship;
Innovation networks (mid/late 2000s/ 2010s)

National Chemical Laboratory

- Create innovations and knowledge base to enhance quality of life via contributions to key industry sectors
 - Create value through innovations, IP, development of non-infringing processes and science based understanding of complex processes
- Capabilities
 - Strong process chemistry/ process design and engineering skills
 - Competence in homogeneous and heterogeneous catalysis
 - Process intensification, reactor engineering & scale-up
 - Separation sciences
 - Strong domain knowledge in process modeling, simulation, advanced process control strategies and flow modeling

Close association with industry/ a credible partner

Process Intensification at NCL

- First in initiating research on micro-reactors in India
 - Established first of its kind industry consortium on 'micro reactors' at NCL
 - Equipment manufactures to users
- Complemented consortium with CSIR funded center of excellence (CoE) on micro reactors
 - Development of new process equipment/ multifunctional devices
 - Convert batch processes to continuous ones
 - Intensify processes to achieve compact & multi-purpose plants

MAGIC Plants & Processes



Modular

AGile

Intensified

Continuous

M for Modular

- **Modular plants**

- Designed as interchangeable modules containing groups of equipment with pre-defined interfaces to utilities etc.
- Reduce field work/ reduce time from lab to practice
- Facilitate shorter schedules, compact design & rigorous testing
- Enhance flexibility/ relocation

- **Need to develop**

- New & better connectors
- Intensified & compact reactors
- New concepts in modularizing
- Standardization and interoperability policies



AG for Agile

- **Agility**

- Ability to change process plants quickly in response to market needs and to manufacture new products
- Demands re-configurable process and plant designs
 - Dynamic plant layout

- **Need to develop**

- New & multifunctional process equipment
- New design paradigms: ranges of the values of the design parameters instead of point values as input parameters; Combinatorial methods to scan the domain consisting of design variables and process functions
- Use of wireless technologies as enabler in plants

I for Intensified

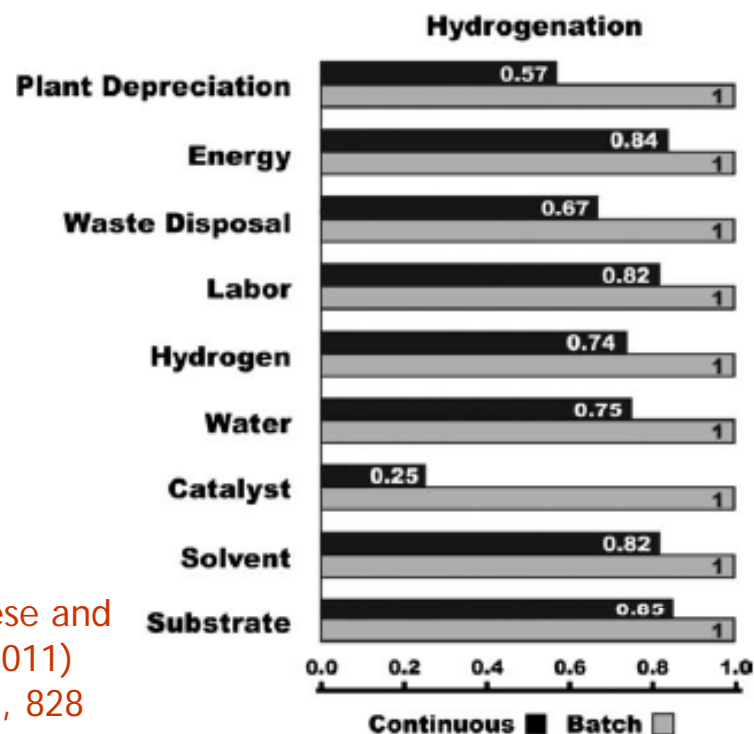
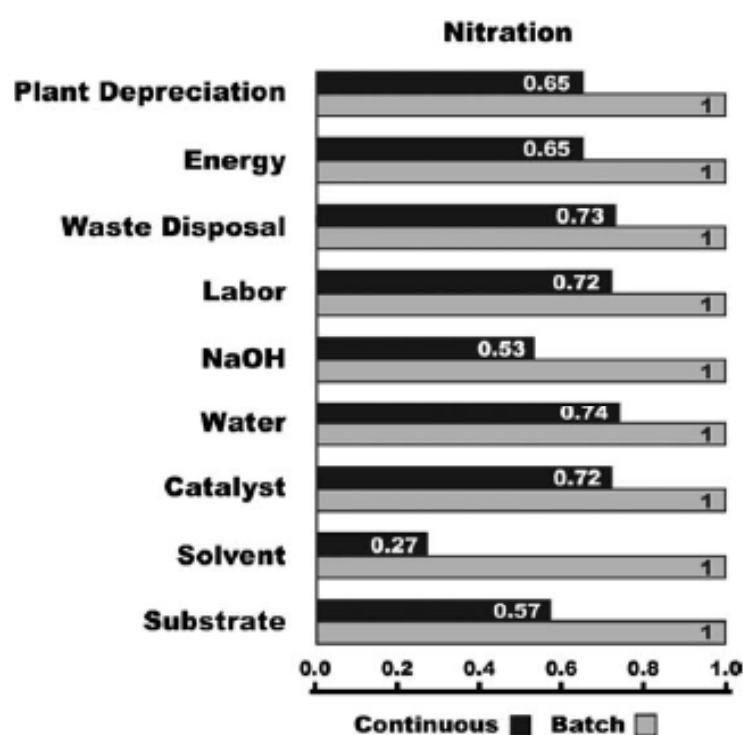
- Enhanced transport rates
 - Very large surface area to volume ratio/ interfacial interactions
 - Fast mixing/ heat transfer/ mass transfer
 - Precise control on residence time distribution
- Small reaction volumes
 - Low inventories/ safer operations
 - Ability to withstand extreme conditions
- Possibility of integrating multiple reactions/ separations on single platform

C for Continuous

- Compact & low inventory
 - Safer operations, lower foot print
- Consistency in product quality
 - Better control on selectivity
 - Better atom efficiency
- Optimal use of utilities
 - More efficient
- Better process control

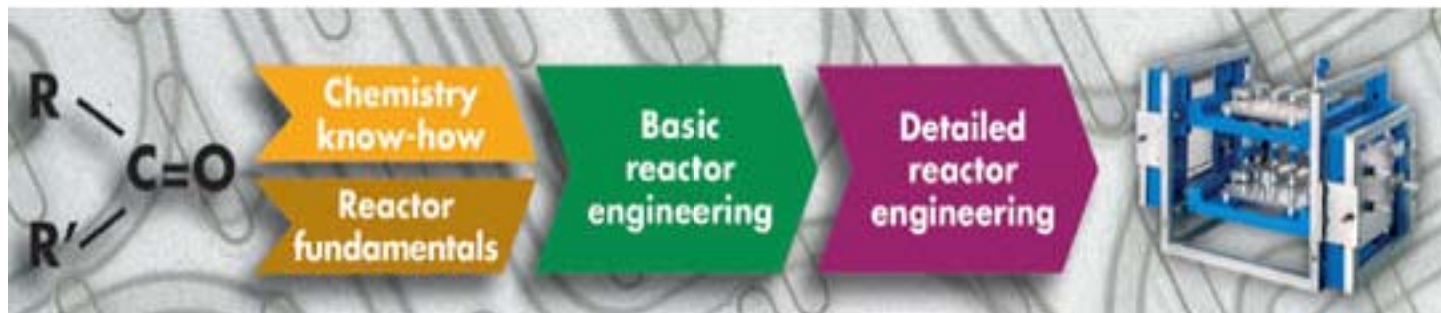
Drivers for MAGIC

- Enhanced quality and safety at reduced cost and environmental impact
 - Modular and agile (ability to conduct several product campaigns with minimum down time & off spec products)
 - Lower E factor, carbon & water footprints, hazards (green)



From Calabrese and
Pissavini (2011)
AIChE J, 57, 828

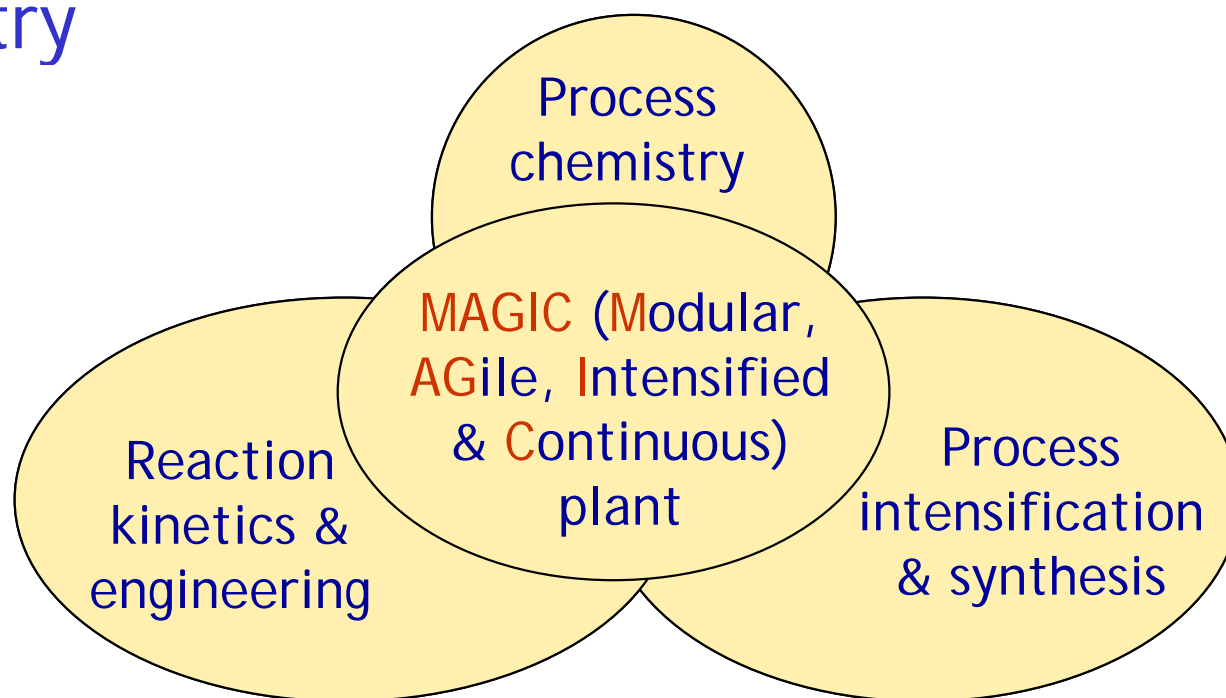
MAGIC Plant: Scientific Challenges



- Early stage reaction engineering analysis:
 - Selected reaction platforms (chemistry/ reaction kinetics)
- New concepts & designs for intensified process equipment/ process control
 - Delivering materials and energy at right time and at right place (manipulate design & process control strategies)
- Understand, quantify & manage other issues:
 - Corrosion/ erosion/ clogging/ maintenance/ cleaning/ switching products/ reconfiguration

Innovate, Develop & Up Scale Modular, Agile, Intensified & Continuous Processes & Plants



- **Magically** transform Indian specialty chemicals industry



- Likely project partners (industry, CSIR, others)
 - ICC, sector specific industry consortiums
 - NCL, IICT, NIIST, CSMCRI, NEIST + CEERI, CMERI

Indus MAGIC

Enhance Productivity & Profitability

Conventional way	Indus MAGIC way
Batch or semi-batch processes	Continuous processes
Stirred reactors	Compact, intensified reactors
Less flexible plants, clumsy cleaning	Modular, agile and reconfigurable plants
Use of stoichiometric reagents	Use of catalysts & catalytic processes
Generate significant waste per unit product	Intensified processes/ operation to maximize atom efficiency
Large water foot print	Reduced water foot print via water recycle and reuse
Use hazardous solvents	Conduct reactions in water/ benign solvents
Reactions limited by transport limitations	Reactions at intrinsic rates without any transport limitations
Separate unit operations: reactors, separations	Integrated processes with multi-functional reactors/ process equipment
Cabled process instrumentation & control	Wireless process instrumentation & control/ new paradigms for process optimization
	

Indus MAGIC Approach

- Establish focused research programs on work packages
 - Continuous reactors & processes, separations, replace reagent based processes by catalytic processes, use benign solvents ...
 - Reduce, reuse & recycle
- Establish industry consortium to involve industries
 - Include industry representatives in the management board of consortium
- Establish 'MAGIC Plant' facility to demonstrate key concepts to specialty chemicals industry
- Associate large number of final year ChE students
 - Formulate final year projects around Indus MAGIC theme
- License technologies, create new entrepreneurs, start-up ventures & globally leading specialty chemical industry

Pre-project of Indus MAGIC

- Initiated pre-project of Indus MAGIC at NCL
 - Reposition research focus on MAGIC concepts

iCPS[©]

Develop Intensified & Continuous
Processes for Specialty Chemicals

- Focus on developing intensified & continuous processes and plants
 - Associated industry consortium
 - Associate large number of BE project students for pre-screening
- Develop multifunctional processes
 - Compact modular reactors: assembled using a few basic devices like helical coils, diodes, mixers

www.indusmagic.org will be launched soon

Realizing MAGIC Processes & Plants

Indus Scholar[®]

Identification of potential candidates
for process development/ initial
screening via Indus Scholar

Just in time/ decentralized
manufacturing

New ways/new
markets

Evaluation of promising
processes/ inputs from
Indus CPI/ ICC/ other
sources

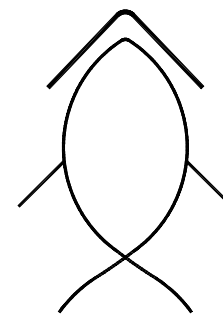
ICC & other industry
contacts

iCPIs[®]

Licensing/
Commercialization/
Spinout companies

Indus CPI[®]

Currently 8 members

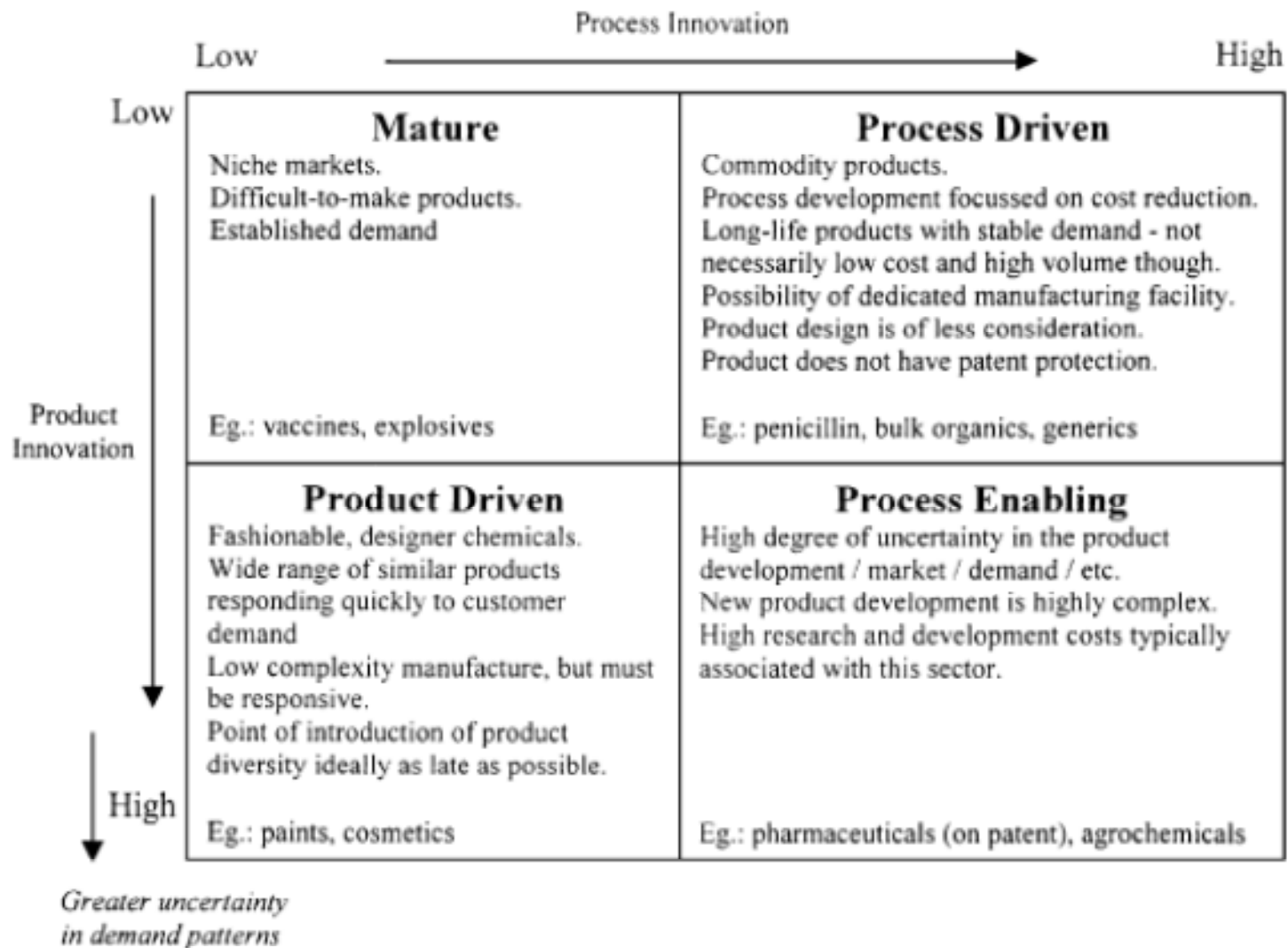


Indus MAGIC will be initiated under 12th five year plan

Summary

- Realizing next phase of growth & leadership in specialty chemicals require
 - Innovations in process intensification & reactor engineering: iCPs/ Indus MAGIC
 - Proactive participation of industry: Indus CPI
 - Harnessing large number of young chemical engineers/ students: Indus Scholar
 - Will be agents of transformation in the coming years
- Significant potential to transform Indian specialty chemical industry by partnering with CSIR – NCL and other CSIR chemical cluster laboratories

Specialty Chemicals Market



From Burgess et al. (2003), European Management Journal, 20(2), 199-212