



Sustainable chemical manufacture and economic prosperity flowing as One

7th Regional 3R Forum in Asia and the Pacific, Advancing 3R and Resource Efficiency for the 2030 Agenda for Sustainable Development

Dr Oliver E. Hutt | Research Group Leader

4 November 2016

Australia

MANUFACTURING

www.csiro.au



Alignment of Sustainable Chemical Manufacturing (SCM) with the UN Sustainable Development Goals

SDG Goal	Focus	Relevance of Chemistry to SDG
#1	Poverty	SCM of <i>medicines</i> and <i>quality job creation</i> .
#2	Food and Ag	SCM of <i>fertilisers</i> and <i>pesticides</i> to ensure the widespread accessibility of efficient agricultural practices and production of food.
#3	Health	SCM of <i>medicines, insecticides, repellents, larvacides</i> .
#6	Water	SCM to <i>reduce waste pollution</i> and also to develop new chemistries and <i>processes for waste water treatment</i> .
#9	Industrialisation and Innovation	SCM for greening industry through <i>cleaner production</i> approaches.
#11	Cities	SCM to make cities <i>cleaner</i> and <i>safer</i> .
#12	Sustainable Production and Consumption	SCM that delivers the chemicals required to meet <i>human needs</i> , but that reduces the consumption of natural resources.
#13	Climate Change	SCM that <i>reduces emissions</i> through more efficient chemical reaction processes.
#14	Conserve the Ocean	SCM that <i>reduces</i> the production of <i>hazardous wastes</i> that can have a negative impact on ocean ecology.
#15	Conserve the Land	SCM that <i>reduces</i> the production of <i>hazardous wastes</i> that can have a negative impact on terrestrial ecology.

Chemistry in Australia

Supplying inputs to 109 for Australia's 111 Industries



The Chemical Industry in Australia is a Critical Enabler of Manufacturing (PACIA 2014) (reproduced with permission from PACIA)

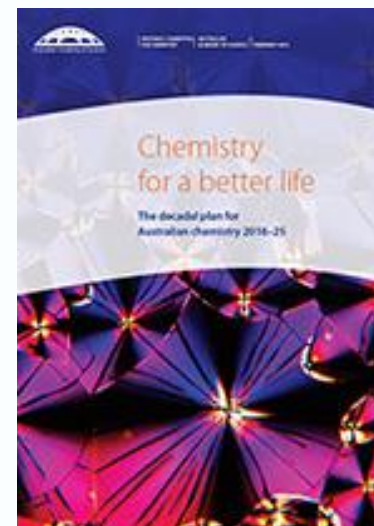
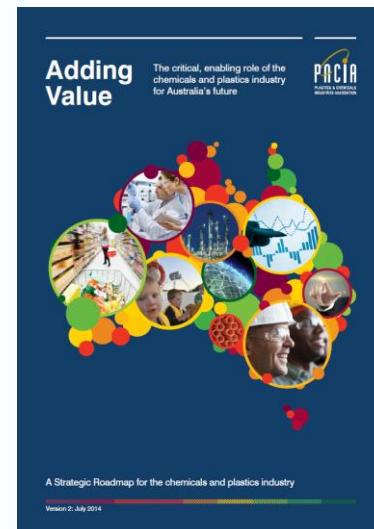
Chemistry in Australia

- **Strategic Framework Development**

- Plastics and Chemicals Industry Association (PACIA) (2014) *Adding Value: A Strategic Roadmap for the chemicals and plastics industry*.
- Australian Academy of Science (AAS) (2016) *Chemistry for a better life. The decadal plan for Australian Chemistry*.

- **Green chemistry in sustainable chemical manufacture**

- Satterfield *et al.* (2009) suggest 'reframing sustainability as an opportunity, investment, and pathway to innovation'.



*Satterfield MB, *et al* (2009) Overcoming nontechnical barriers to the implementation of sustainable solutions in industry, *Environmental Science and Technology* **43**(12), 4221–4226. DOI: 10.1021/es802980j

Conventional chemical manufacture

The mainstay of fine chemical & pharmaceutical industries



Development



Pilot scale



Batch manufacturing scale

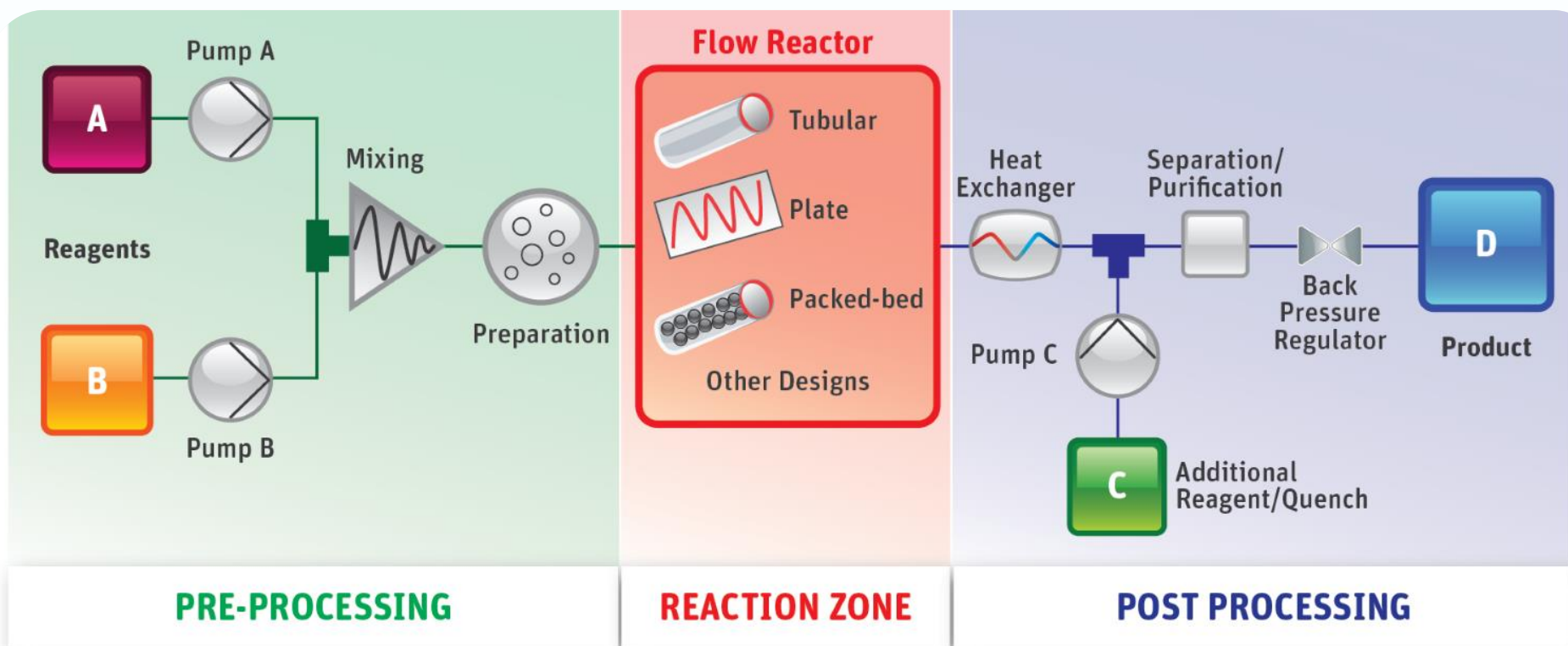
So how do we do it better?

- Develop better chemical processes
 - Simpler, more robust processes
 - Shorter processing times
 - Higher yields
 - Fewer by-products
 - Less waste
 - Safe
- Smaller manufacturing plants
- Lower plant & maintenance costs
- Reduced operating costs



Continuous Flow Chemistry

Use of intensive reactor technologies (hotter, more concentrated, faster) to transition from batch to continuous processing.



Fine chemical synthesis

Photochromic dyes



Step	Batch		Flow		Benefits of Flow Chemistry
	Yield	PMI	Yield	PMI ^a	
1	85%	119	98%	7	Operationally complex 2-step batch process reduced to simple, solvent-free 1-step flow process
2					
3	70%	173	85%	19	Reduced energy consumption – batch process requires cooling whereas in flow this is performed at room temperature
4	85%	119	98%	5	Solvent-free process used
5	76%	55	81%	31	Hazardous reagent can be replaced with safer and cheaper alternative
6	75%	64	71%	11	No need for chromatographic purification. Hazardous solvent can be replaced with more environmentally friendly alternative

^a Process Mass Intensity (PMI) is the amount of material required (reagents, solvents, etc. in kg) to produce 1kg of product.

Mark York

Waste Reduction



	Batch	Flow
Chlorinated waste	218 L	0 L
Non-chlorinated organic waste	612 L	73.5 L
Contaminated aqueous waste	418 L	32.5 L
Liquid waste	1,248 L	106 L (>90% reduction)
Energy	18.5 kWh	1.6 kWh (>90% reduction)

**Flow Chemistry processes provide a
competitive advantage for industry.....**

Obstacles

Collaboration	Challenges bringing together the capabilities embedded in <i>industry, academia, and regulators</i> that are needed to develop new green chemistry approaches.
Business Incentives	Benefits of new sustainable green chemical manufacturing may flow to society, they don't necessarily flow to the company or individual.
Funding	Governmental research agencies who typically view industrial research has something that should be funded by companies.
Culture	Green chemistry as a field is ' competence destroying ', making obsolete the existing processes and incumbents.

Present & Future Challenges

Present	Challenges for sustainable chemical manufacturing are substantial, multifaceted, and ongoing.
Future	The industry of the future will be based on chemistry providing solutions to the problems that society faces.

The current problems we face are:

- How can we provide improved benefit with less chemical load on the environment?
- How can we reduce the potential for harm from, for example, waste production or the risk of catastrophic plant failure?

The path forward.....

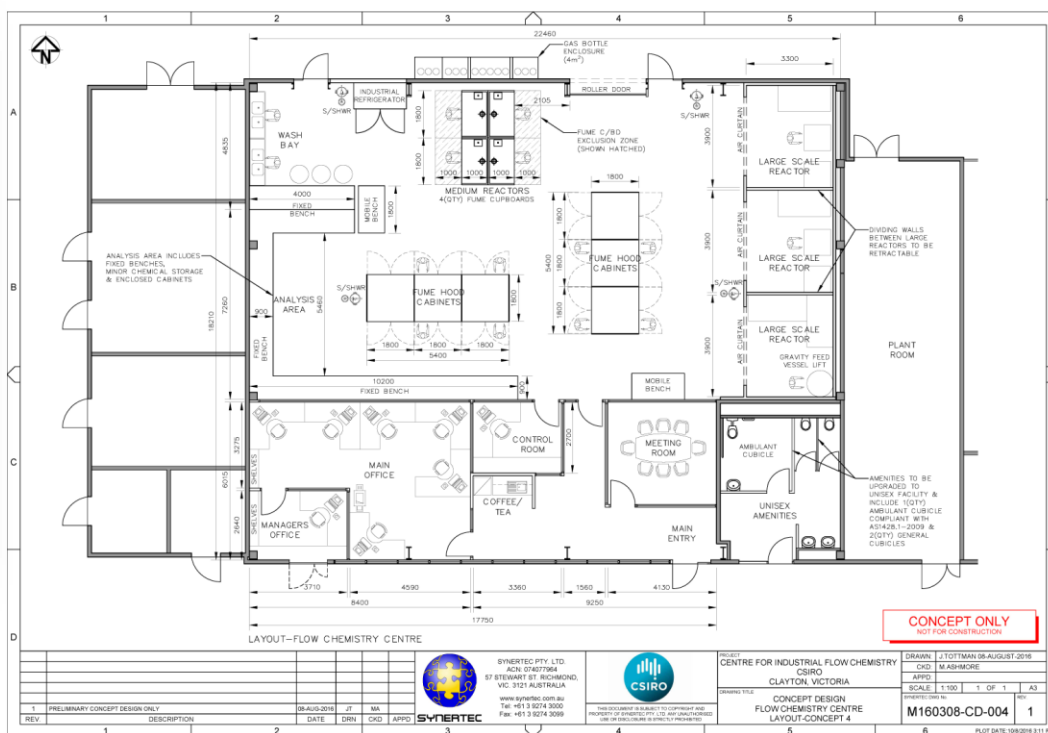
Regulation	Harmonisation of regulation – across state boundaries inside Australia and across nation states in the region.
Education	Education and training is a key driver of increased collaboration. Currently in Australia, chemistry business pathways are siloed into academic, industry or government agency frameworks. We now have industry and science roadmaps in hand to guide the skills necessary and Australia is now in a position to craft new courses and qualifications.
Policy Makers	More focus on those scientists who will become the collaborators and policy makers of the future.

CSIRO Flow Chemistry Centre

- Access to cutting-edge research into industrial flow chemistry
- The centre houses a state-of-the-art flow chemistry reactors for the sustainable and cost-efficient chemical processes.



Temperatures: up to 250 °C
 Pressures: 25bar
 Output: tonnes/day



Thank you

Manufacturing

Oliver Hutt
Research Group Leader

t +61 3 9545 2580
e oliver.hutt@csiro.au
w people.csiro.au/H/O/Oliver-Hutt

Manufacturing

Tim Head
Business Development

t +61 3 5246 4130
e tim.head@csiro.au