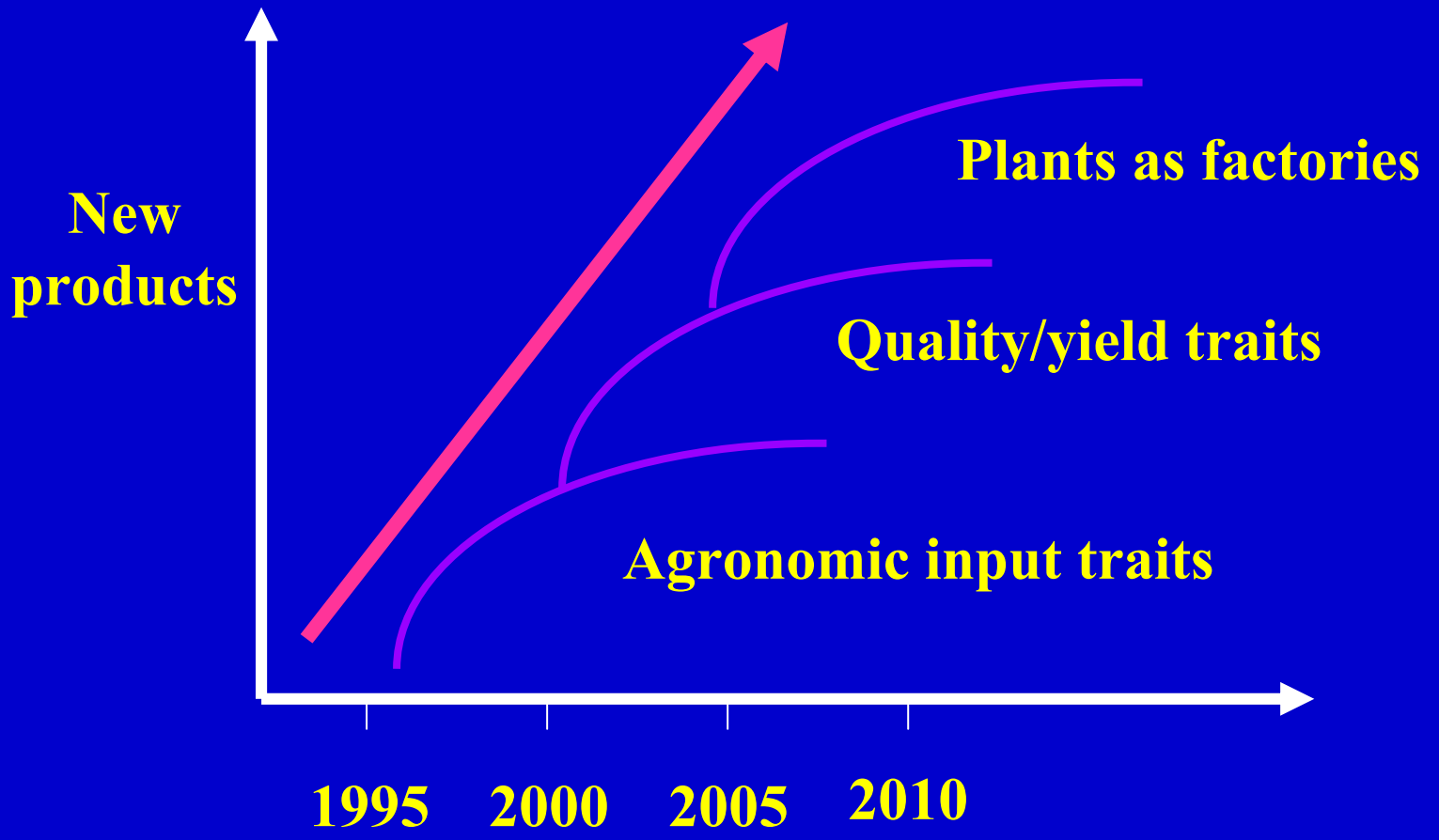
Trevor Stevenson,
Associate Professor of Plant Biotechnology,
RMIT University

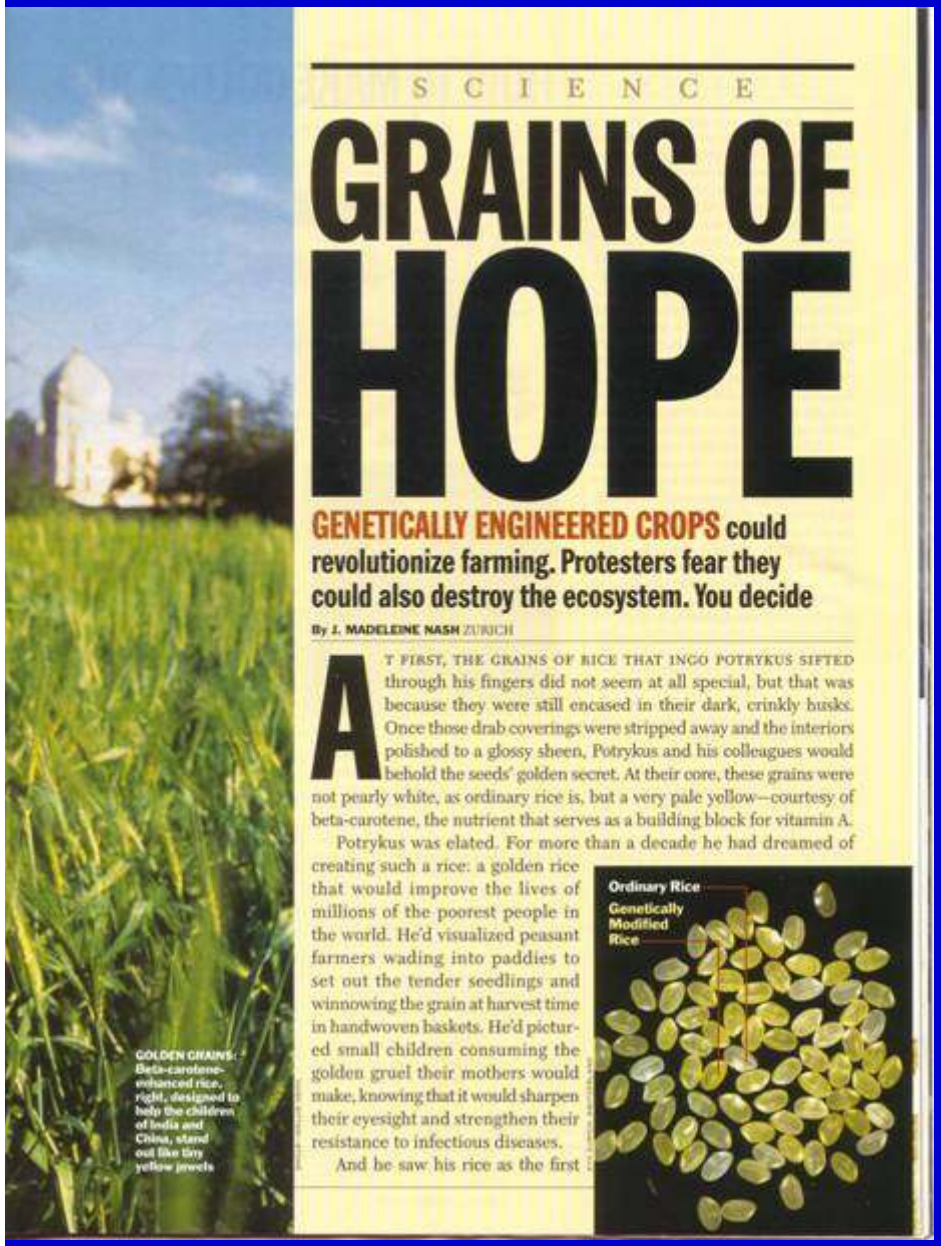
- *Trevor Stevenson will be presenting his view on the importance of using ethanol fuel as part of a bundle of new and emerging technologies to move agriculture through the next 25-30 years.*

Three Phases of Plant Biotechnology



RMIT UNIVERSITY


AUGUST 7, 2000 $4.50 (INCL. GST)
TIME
THIS RICE COULD SAVE A MILLION KIDS A YEAR
...but protesters believe such genetically modified foods are bad for us and our planet. Who's right?
Swiss Professor Ingo Potrykus with his beta-carotene-enriched rice



SCIENCE

GRAINS OF HOPE

GENETICALLY ENGINEERED CROPS could revolutionize farming. Protesters fear they could also destroy the ecosystem. You decide

By J. MADELEINE NASH ZURICH

AT FIRST, THE GRAINS OF RICE THAT INGO POTRYKUS SIFTED through his fingers did not seem at all special, but that was because they were still encased in their dark, crinkly husks. Once those drab coverings were stripped away and the interiors polished to a glossy sheen, Potrykus and his colleagues would behold the seeds' golden secret. At their core, these grains were not pearly white, as ordinary rice is, but a very pale yellow—courtesy of beta-carotene, the nutrient that serves as a building block for vitamin A.

Potrykus was elated. For more than a decade he had dreamed of creating such a rice: a golden rice that would improve the lives of millions of the poorest people in the world. He'd visualized peasant farmers wading into paddies to set out the tender seedlings and winnowing the grain at harvest time in handwoven baskets. He'd pictured small children consuming the golden gruel their mothers would make, knowing that it would sharpen their eyesight and strengthen their resistance to infectious diseases.

And he saw his rice as the first

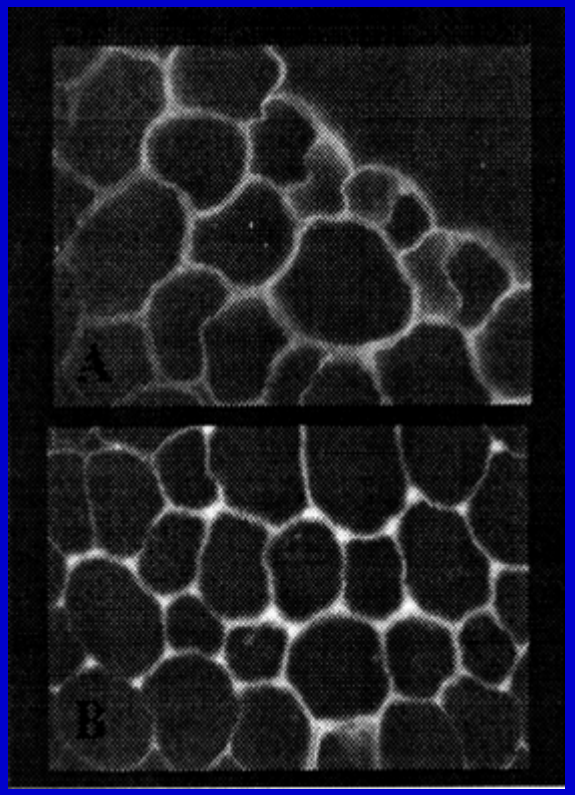
GOLDEN GRAINS: Beta-carotene-enhanced rice, right, designed to help the children of India and China, stand out like tiny yellow pixels

- "Golden Rice"
- Iron fortification
- Vaccines
- Antibodies
- Pharmaceutical proteins
- Disease resistance
- Marginal land
- Drought resistance
- Decreased allergens
- Functional foods
- Nutraceuticals
- Secondary metabolites
- Plant architecture & partitioning

Redirecting Plant Carbon

Transgenic poplars expressing CBD gene from *Clostridium cellulovorans*

Increased growth rate and biomass



Increased cellulose content in plant trachery walls

Commercial Milestones for Agricultural Biotechnology

- **First GM plant field trial – 1987** (Calgene)
- **Initial regulatory approval for GM whole food – 1994** (Calgene; Flavr Savr tomato)
- **First commercial sale of GM whole food product – 1994** (Calgene; Flavr Savr tomato)
- **First commercial sale of GM seeds – 1995** (Calgene - BXN cotton: Monsanto – RR soybeans)

Current Ag Biotech Status

- All major & minor dicot and monocot species can be genetically transformed
- GM crops grown on 222 million acres in 2006
- Over 1 billion acres
- Some small scale minor crop launches for disease resistance (pepper, melon, papaya)
- GM flowers sold on 4 continents
- European opposition on the decline? Yes!

Broad acre agriculture biotech outcomes

- ~ $5-6 billion spent on broad acre ag biotech R&D
- only Monsanto derives revenue!!!
- only four genes (herbicide resistance and Bt) effectively commercialized on a large scale
- industry consolidation occurred; small (& large) companies swallowed to a great degree
- current products not consumer friendly
- badly beaten up by environment (anti GM) groups
- lack of understanding by investors
  - Breeding and seed increase take time

Ag Biotech Outcomes (cont)

- Difficult regulatory path to commercialization
- Product values (NPVs) "not big enough"
- An over-focus ($$$) on genomics
- Patent situation 'messy'
  - broad enabling patents
  - held by a few major ag chem players
  - license terms not easily obtained

The Next Generation- today's topic?

- Driven by $ benefits in the chain, farmer, end user
- Impact. Is it big enough to make a difference and make worthwhile?
- “futuristic” traits-
  - “Blue ocean innovations”
  - Like Roundup Ready and *Bt*
  - New market spaces
- New industries
  - Biofuels
  - Ethanol
- Funding and philosophy

Fuel ethanol

- Checkered past
- Political football
- Parallel with GM crops with regard to public perception uncanny!

BioEthanol – the Facts

- Benefits of Bioethanol
  - Provides new income source for growers
  - Renewable, clean and green resource
  - Greenhouse gas benefits
  - Replacement for toxic additives
  - Suitable for virtually all vehicles
- However the Reality!
  - Using current technology, Bioethanol not cost competitive with petrochemical-based fuels
    - but at > US$ 70 per barrel?

Another fact!- Feedstock Limitations to a Viable Ethanol Industry

- Current ethanol production relies solely on grain/starch or sugar as the fermentation feedstock.
- Reliance on grain/starch and sugar as feedstocks is unsustainable
- Feedstock production costs and competing demand
  - animal feed and human food.

Forecast Demand in Australia

- Govt mandate - by 2010 biofuels will contribute at least 350 ML to the total fuel supply.
- If E10 blend total annual requirement for fuel ethanol in Australia by 2016 is projected to increase to **~4 BL (Billion Litres)**.
- Requires a **30-50-fold** increase over current production levels (~70 million litres per year).
- Consistent with the US experience from 10 BL in 1996 to 20 BL in 2005, forecast 60-80 BL in 2012.
- Where is the feedstock coming from?????
- Only one source of renewable carbon large enough to meet the demand!

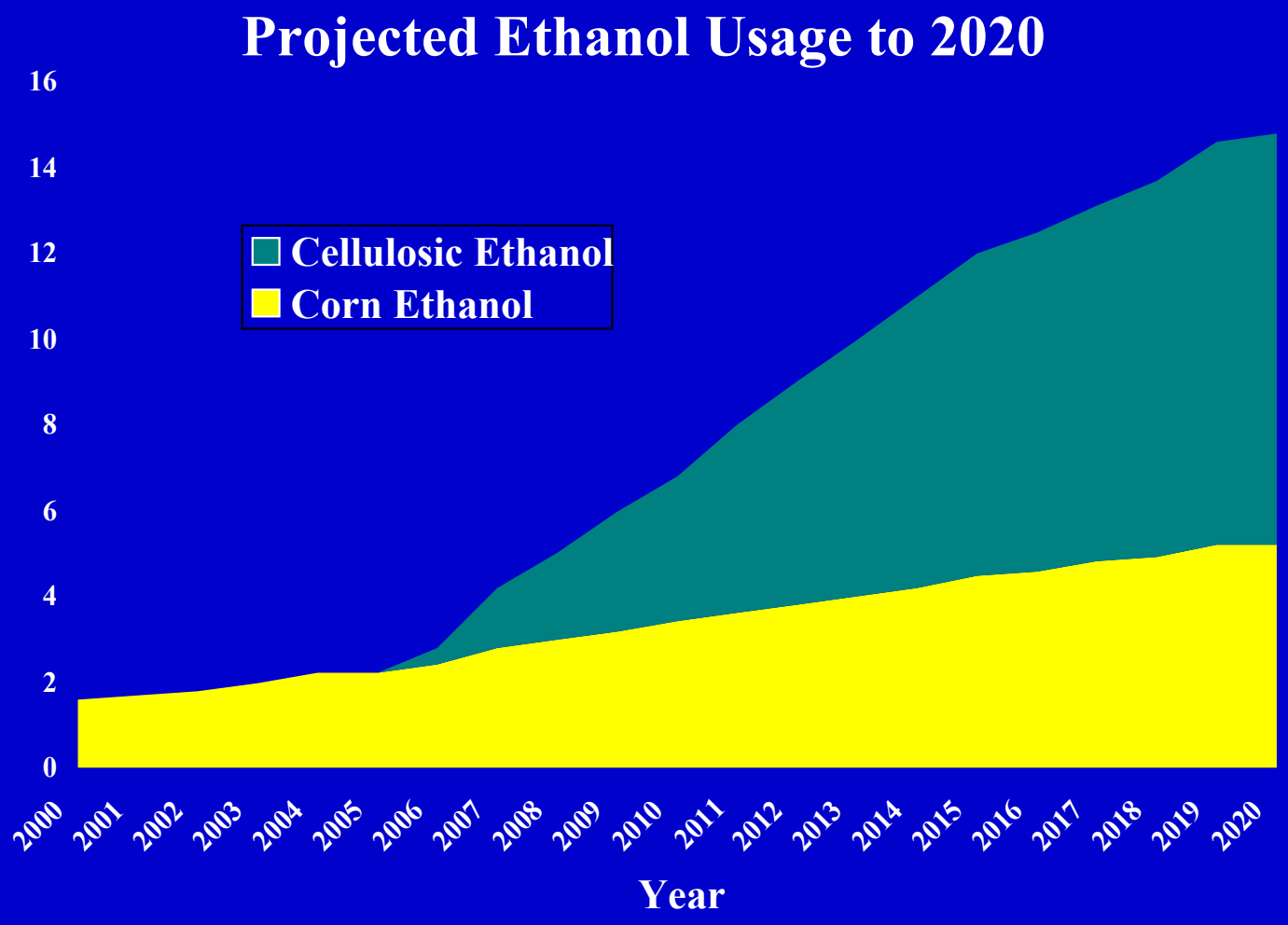
Rationale for Use of Crop Residues

- The only large-scale and sustainable feedstock that can satisfy the demand required to meet an E10 target is lignocellulose from crop residues, especially from grain crops such as wheat, barley and sorghum.
- Worldwide, ligno-cellulosic crop residues (wheat, maize, rice, barley and sorghum) approaches 1.5 B tonne/yr.
- Assuming a 500 L ethanol/tonne of feedstock output, conversion of 25% of this available feedstock could provide about 1900 BL/year on a worldwide basis.
- Australia could generate ~40 M tonne of crop residue feedstock/yr from wheat and barley that could eventually produce upwards of 20 BL of ethanol annually. Note E10 requires 4 BL.

Estimated Availability of Nonwood Fibers (million bone dry metric tons)

Agricultural Residue	U.S.	World
Wheat Straw	76.0	600.0
Rice Straw	3.0	195.0
Seed Flax Straw	0.5	2.0
Corn Stover	250.0	550.0
Cotton Stems	4.6	68.0
Sorghum Stems	28.0	252.0
Sugar Cane Bagasse	4.4	102.2

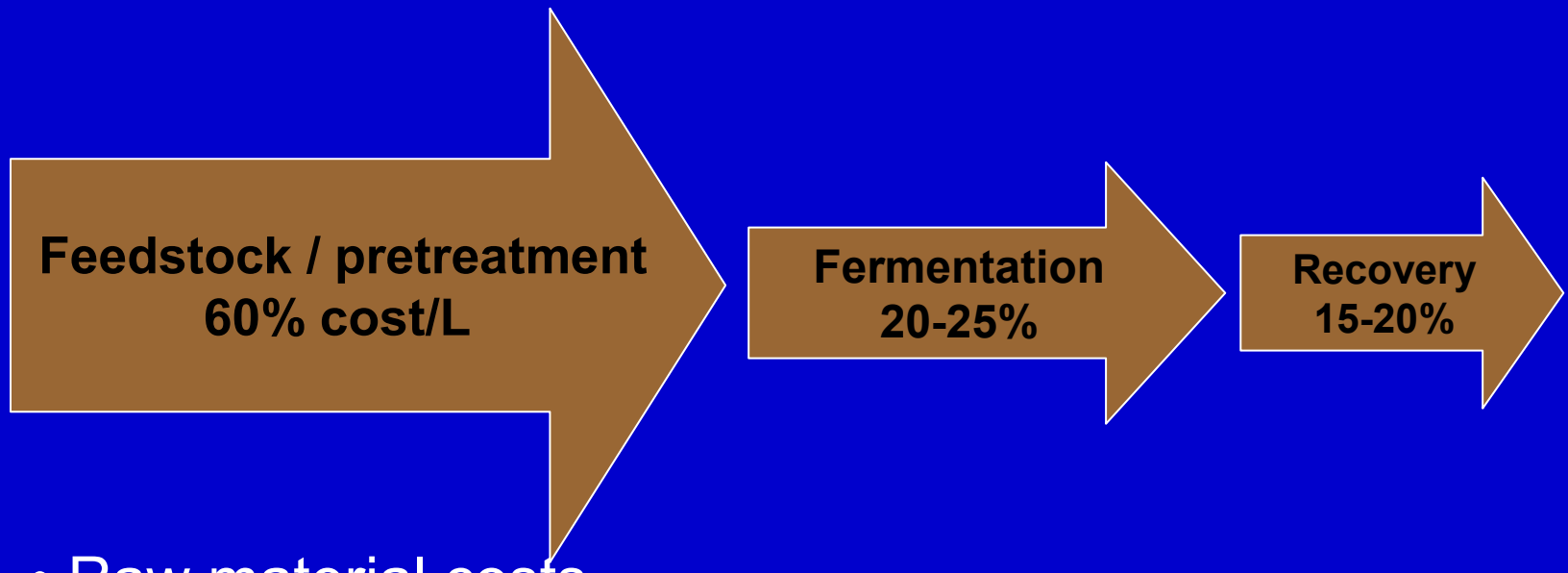
Lignocellulosic Potential



Processing Just 30% of Corn Stover has the following impact:

- **Adds 20 to 35 billion liters of ethanol for fuels with no increased land use**
- **Increases direct farm income $2.3 billion from feedstock sale of 30% of total**
- **Improves soil quality (no till farming)**
- **Mitigates GHGs by more than 60- 97 M metric tons C/year, 12% - 20% Kyoto Commitment**

Production Costs – Lignocellulosic Ethanol



- Raw material costs
- Transport & storage
- 1st pretreatment
- Cellulase enzyme(s)

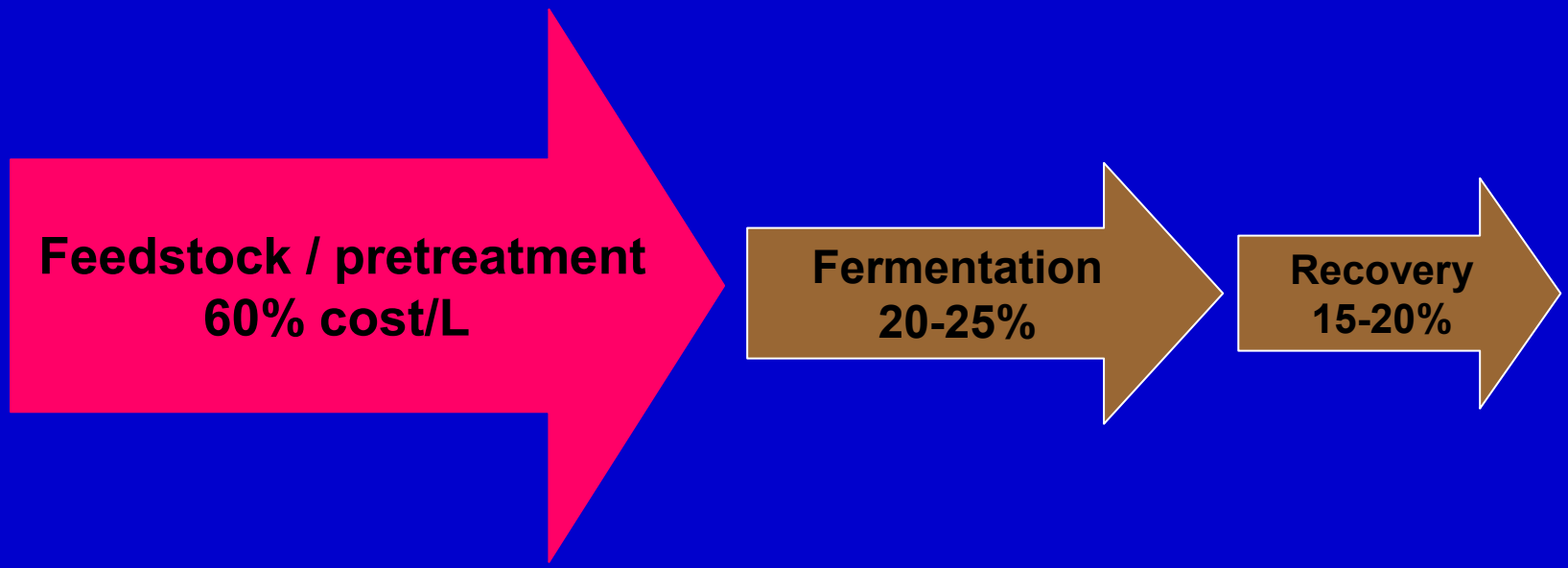
- 2nd pretreatment
- Saccharification
- Fermentation

- Distillation
- Purification

The Technical Challenge

- Ligno-cellulosic biomasses are non-starch polysaccharides are about 50% of the solar energy transformed by plants into chemical energy.
- Efficient ligno-cellulose degrading enzymes are currently not commercially available.
- Cost, production- fermentation?
- A secondary consideration is the need for very large scale fermentation to produce the enzymes.
- Can GM technology bring anything to help?

BCT Technology Impacts



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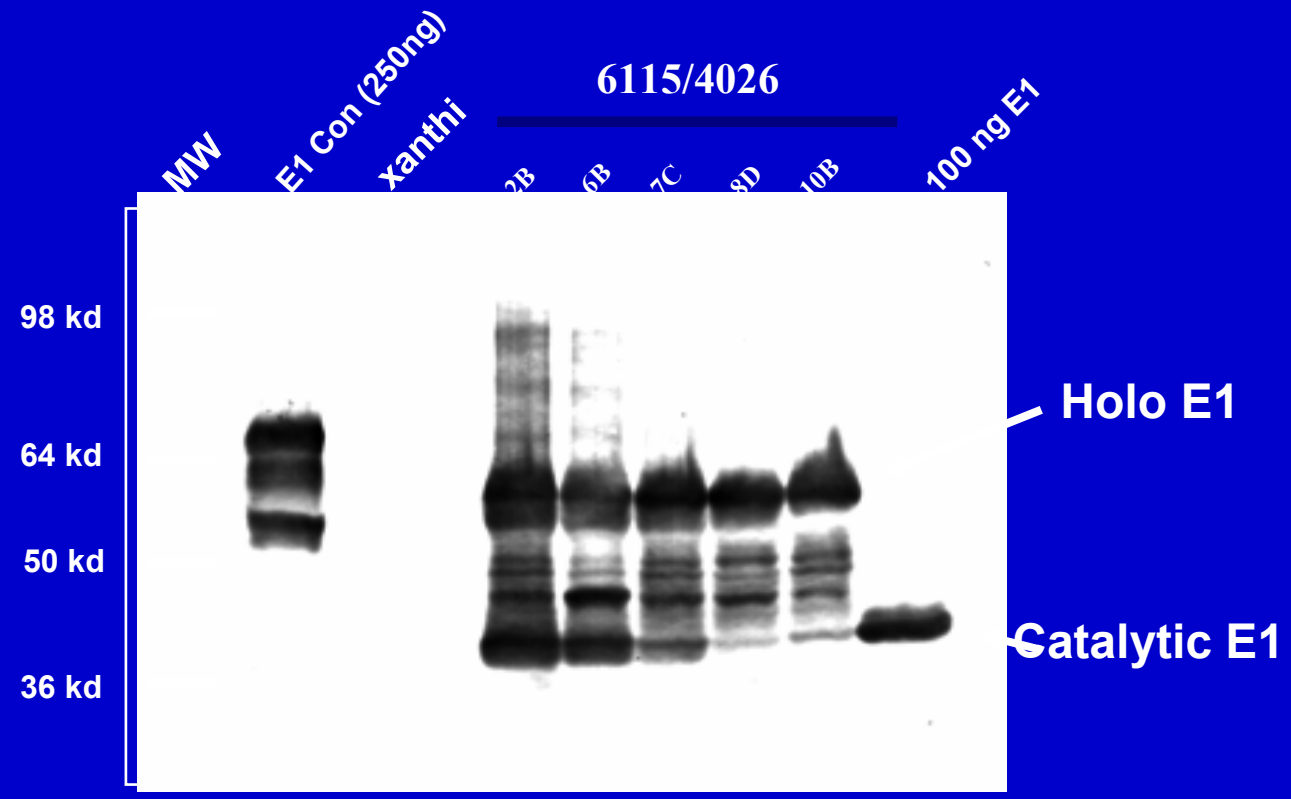
Microbial Cellulase Expression in Plants

Plastid-derived *Acidothermus* E1 cellulase expression in transgenic tobacco



Benefits to Australia

- Revenue source for Australia's cereal growers/farmers from a large agricultural post-harvest waste stream.
- Lessen Australia's dependence on fossil fuels.
- New industry potential, technology innovation for large-scale bioprocessing and rural job creation.
- A cleaner, healthier environment
- More efficient use of waste biomass

It is a long way into the future but:

- Clear consumer and environmental benefits
- It is big enough market to make worthwhile
- Blue ocean? We think so.
- It is GM for major food crops.
  - The last bastion for the opponents.
- It will require ”co- harvesting” with food grain
- If we don’t someone else will.
- We don’t really have a choice this time around!

Funding

- Prepared to risk (and to succeed!)
- How to pick the projects with potential impact
  - Not just scientific papers or "reputations"
- Have/are the Australian granting agencies, companies and corporations good at that?

- **trevor@rmit.edu.au**