THE ROLE OF ALGAE IN SUSTAINABLE CITIES

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Content

- A bit about CPI
- The Challenge of Sustainable Cities
- One way of looking at it
- Actions that Could Bring it Closer to Reality

A BIT ABOUT THE CENTRE FOR PROCESS INNOVATION

CPI's Vision

Vision

- A World Class Innovation Centre supporting the Process Industries

CPI Moves to this Vision by:

- Build Physical Assets that bring together Companies, Universities, Public Sector Funds and Technology Expertise to develop new products and processes for the Process Industries

Process Development, Proving and Scale Up

Innovation: Technology Readiness Levels (NASA)

ECONOMIC SUPPORT

BUSINESS DEVELOPMENT (Enterprise)

TECHNOLOGY DEVELOPMENT (CPI)

RESEARCH (Universities)

System Test, Launch and Operation — TRL 9, TRL 8

System/Sub-System Development — TRL 8, TRL 7, TRL 6

Technology Demonstration — TRL 7, TRL 6, TRL 5

Technology Development — TRL 6, TRL 5, TRL 4

Research to Prove Feasibility — TRL 4, TRL 3, TRL 2

Basic Technology Research — TRL 3, TRL 2, TRL 1

CPI Works at Technology Readiness Level 4 Up

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CPI Technology Development

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Sustainable Processing (Industrial Biotech and Low Carbon)	**Printable Electronics**
• **High Value Speciality Chemicals** – Pharma intermediates – Agrochemicals – Flavours and fragrances – Resins and glues – Enzymes • **Sustainable Energy** – Industrial carbon capture – Sustainable fuels – Anaerobic digestion – Low carbon energy • **Metals Recovery / Extraction** • **Oil, Gas and Petrochemicals**	• **Organic Displays** – Rigid and Flexible • **Solid State Lighting** • **Organic PV** • **Electronic Packaging** • **Barrier Films** – LCDs – Organic PV – Fuel Cells • **Materials** – Printable electronic formulations

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Located at Wilton Centre

Semi technical area
- pilot manufacture

World class
analytical facilities

Modern laboratory
space

Office
accommodation

Land & infrastructure
for manufacturing

32 companies on site

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Some of the CPI Assets

Bioprocess Lab

Marine Fermentation

Process Intensification

National Industrial Biotechnology Facility

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WHY SUSTAINABLE COMMUNITIES ARE IMPORTANT

The Definition of Sustainability

Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs […]. In essence Sustainable Development is a process of change in which exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance current and future potential to meet human needs and aspirations.

(WCED, Brundtland Commission ,1987)

Engineers and Engineering Have Much to Contribute

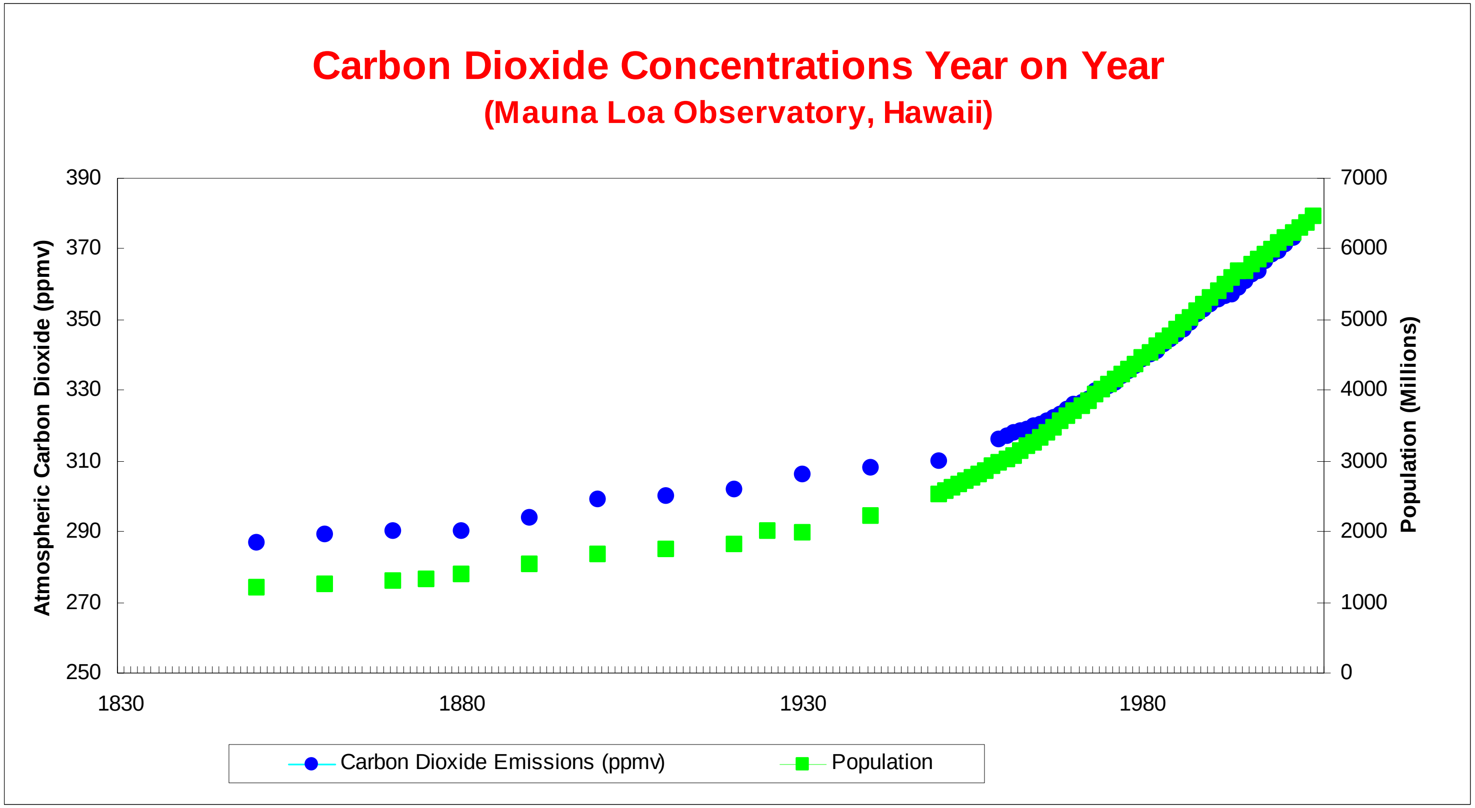
The Challenge of Sustainability

Dealing with:

- **Growing Population**
  - Inexorably increasing the need for food and shelter
- **Growing Affluence**
  - The amount of emissions rise with affluence and we use more
- **Resource Consumption**
  - There is only a finite resource it will not last for ever

This Puts Immense Stress on a Finite System

Carbon Dioxide in the Atmosphere Rises with Population



Source: Mauna Loa Observatory plus historic data from ice cores

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Population Growth Alone Will Increase Atmospheric Carbon Dioxide Concentration Significantly

Case	Population (billion)	Average CO_2 Emissions per Person (t/yr)	Total Annual Human CO_2 Emissions (bn t / yr)	Increase over 2005 Base Case (bn t/yr)
Base Case 2005	6.6	3.6	24	
Rich World 2005 Population	6.6	7.5	50	26 (108%)
Base Case 2050 Population	9	3.6	33	9 (38%)
Rich World 2050 Population	9	7.5	67.5	43.5 (180%)

Dealing with this Much Carbon Dioxide is a Challenge

So What Do We As Engineers Have to Do..

- Develop more sustainable processes
- Use resources more efficiency
- Improve the efficiency of our processes
- Look at the efficiency of integrated systems
- Convert wastes to products
- Convert batch processes to continuous ones

There is a Lot We Can Do

ENGINEERING FOR SUSTAINABILITY REQUIRES A BEHAVIOUR CHANGE

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Big Challenges to Adopting Sustainable Cities

- Global drivers and trends in resource availability favour this approach but we must:
  - Look at engineering problems differently;
  - Make sure policy makers, business leaders and engineers understand change is needed and is possible;
  - Aspire to deliver the benefits;
  - Work collaboratively across technical and social disciplinary boundaries;
  - Create a favourable legislative and regulatory environment
  - Take account of the value of finite resources in our economics;
  - Make attractive, reliable and useable products and demonstrate there are benefits.

Large Opportunity for Economic, Social and Environmental Benefit
We need to Change Our Behaviour and Do Something

What Could We do?

Create a 'Low Carbon Resource Efficient Community'
Based on an integrated set of projects
that
Combine industrial, residential, agricultural and transport applications
to
Exploit the inherent strengths of the Communities and Regions
And
Deliver Economic Well Being

To do this we need to:

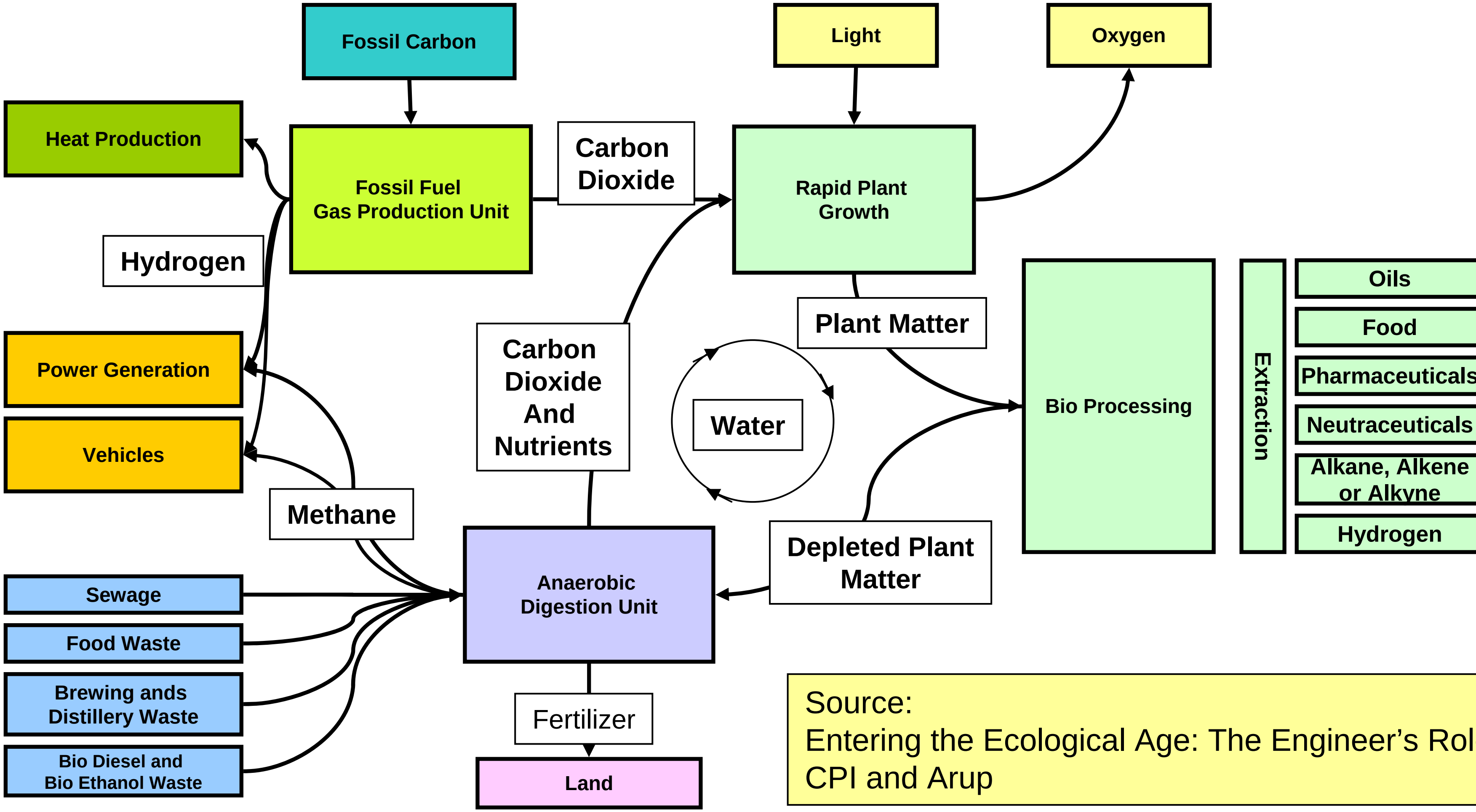
- Facilitate links between research, development and commercial interests to create value through application development.
- Create a range of supply partnerships appropriate to end users to increase adoption.
- Build supply chain networks that develop the UK industry base.
- Utilise a range of funding sources.

SHORT CARBON CYCLE COMMUNITIES

Notes on the Short Carbon Cycle System

- Close the loop from power plants to make use of the carbon dioxide.
- Need fossil fuel inputs but close and shorten the carbon and nutrient cycle to a sustainable level.
- The system is idealised.
- Further work is required to understand the operating units and to balance the inputs and outputs to make an integrated system.
- Need to:
  - Co locate units.
  - Size integrated systems to the local communities.
  - All operating units will need to be more efficient.
  - Research on algae and rapid plant growth must be accelerated and viable production units developed.
  - Anaerobic digesters will need to be further intensified: Smaller with higher yield.

An Innovative Systems Approach to Communities



Source:
Entering the Ecological Age: The Engineer's Role
CPI and Arup

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Using Simple Idealised Conversion Efficiencies

Factor	Input / Output	Closed Loop Model	Coal Gasification Alone	Benefit of Closed Loop over Gasification
Coal	In	2.45mt/yr	2.95mt/yr	17% reduction
Carbon Dioxide	**Out**	**845kt/yr**	**7.95mt/yr**	**89% reduction**
Ash	Out	390kt/yr	410kt/yr	5% reduction
Heat and power	Out	2.7GW	2.7GW	Same
Water	In	In balance if sewage water is used	In balance if water is recirculated	Same
Light	**In**	**>City power use**	**0**	**Fundamental Challenge**
Ammonia	In	375kt/yr	0	375kt/yr more nitrogen required
Oxygen	**In**	**50kt/yr**	**5.6mt/yr**	**99% reduction**
Algae for chemicals	Out	80kt/yr	0	Additional effect chemicals produced
Food and human waste	In / Out	109kt/yr as feedstock	109kt/yr to land	
Fertilizer / Biomass	Out	2.8mt/yr	See above	Closed loop produces fertilizer or biomass as carbon has been fixed

Carbon Dioxide Emission Could Theoretically Be Reduced

Notes on Coal Gasification

- Known technology, but not widely used.
- Operating units are large. 800 MW is a viable scale.
- Smaller economic sizes are necessary to match the needs of communities.
- Inputs: Coal and water.
- Outputs: Electricity, carbon dioxide, heat, water and hydrogen. The latter could be used as a vehicle fuel.

Known technology but is emits carbon dioxide.
This idea uses the carbon dioxide as an input to the next process step.

Notes on Algae or Rapid Plant Growing

- Technology not commercially viable:
  - Much research and some demonstration, but no mainstream operating units.
- Photosynthesis with rapidly growing plants, algae and cyanobacteria created the atmosphere.
- Speeding up and commercialising the process may restore a stable position.
- Inputs: Carbon dioxide, light (natural or artificial), heat, water and nutrients.
- Varying sunlight and lack of control makes current processes slow and intermittent.
- Cost and energy consumption of artificial light can be prohibitive.
  - New high efficiency frequency specific light technologies offer opportunities.
- Needs serious process engineering to work effectively.
- Could produce chemical building blocks currently produced from oil.
- A key output is biomass or depleted bio mass that can be used in the next step of the closed loop process.

This element of the model is the key to its success,

But is the greatest challenge

Anaerobic Digesters

- Biomass could be used as a combustion fuel, but better to take through a digestion.
- Can use other organic wastes as feeds.
- Reduce fossil fuel input, thus shortening the carbon cycle further and reducing the size of the coal gasifier. Therefore reduces capital cost.
- Produces methane, nutrients and digestate. All can be reused.
- Needs no external input to operate.
- AD Technology is in widespread use from individual units for single homes to megawatt scale plants.
- Process intensity, speed and yield are the drawbacks. Gas yield is frequently only c.15%.
- Process development to increase efficiency and yield is required.

Speed up and intensify anaerobic digestion

Conclusions

- As population and affluence increase demand on the world's natural resources grows.
- Fossil fuels are being depleted and their use is releasing carbon dioxide and other greenhouse gases into the atmosphere.
- Many wastes have an energy value and could be used as feedstocks.
- Approach could partly reduce fossil fuel use and reduce waste being disposed of.
- Processes that consume carbon dioxide are required.
  - The most effective process is photosynthesis.
  - The fastest growing organisms are algae and cyanobacteria.
- A closed loop that links coal gasification with algae growing and anaerobic digestion plant could reduce carbon dioxide emissions by up to 90%.
- Industrialised algae growing is a concept.
  - Develop in parallel to the other elements of the integrated system.

Next Steps

- Get additional data from real communities on resource flows.
- Assess a range of technologies to find the optimum resource efficient route forward.
- Set-up a co-ordinated research and development programme
  - Develop bioreactors that use carbon dioxide, waste heat and light to rapidly grow plants
  - Move from small scale testing to large scale processes.
  - Develop viable commercial bio-processing.
  - Improve efficiency and intensity of anaerobic digestion.
  - Look at how whole city waste management systems can best be integrated – and on using power station fuel supply lines to bring compost out from the digesters too.
- Government must ensure that new rules and regulations on carbon capture embrace these alternative approaches.

Government and business, working together, to show leadership, ownership and commitment.
Attract investment and build technological capability.

The Centre for Process Innovation

www.uk-cpi.com

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one NORTH EAST Moving Forward: The Northern Way

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BIS Department for Business Innovation & Skills

Technology Strategy Board Driving Innovation

INVESTOR IN PEOPLE

Passionate about business north east england

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