Institution: Aston University		
Unit of Assessment: 12 Engineering		
Title of case study: Energy Harvest – reducing pollution from open field burning of rice straw		
Period when the underpinning research was undertaken: 2009-present		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Professor R Berry	Dean of Engineering Part time Professor	09/2008-09/2015 09/2015-08/2018
Professor A Bridgwater	Professor, Chemical Engineering	06/1996-present
Professor A Hornung	Former Head of EBRI	10/2007-04/2014
Dr P Davies	Reader	08/2008-10/2018
Dr J G Brammer	Lecturer Senior Lecturer	10/2006-07/2013 08/2013-12/2015
Professor P K Dey	Professor Reader Senior Lecturer	08/2011-present 08/2008-07/2011 12/2004-07/2008
Period when the claimed impact occurred: 2016-present		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Aston research has led to five key impacts:

- Development of a new business model to enable communities to shift from straw burning to straw pellet production.
- Formation of a new business in India – award-winning A2P- that has a commercial demonstrator, contracts to process rice straw, and partnerships with Larsen and Toubro (L&T), IKEA, Pepsi, Jawandsons and WWF.
- Reduction of carbon footprint and associated pollution. Since 2017, 700-2000 tons/year of rice straw, across 300-1000 acres and 40-100 farms, were turned into rice pellets not burned.
- Demonstrated crop yields increase of 7-15% through bio-char application, leading to growing interest from farming communities and reducing commercial fertiliser reliance.
- Raised awareness and engagement in government, business and communities.

2. Underpinning research

This impact built on the following research:

Identification of pyrolysis as key approach to gain value from waste agricultural material

Bridgwater pioneered bioenergy at Aston, researching thermochemical conversion of biomass and developing chemical engineering processes for generating chemicals, fuels and energy [**R1**]. Pyrolysis reactors were designed and built for different biomass feedstocks.

Development of enhanced technology for high value extraction
Specific crops were assessed for the quality of bio-oil produced, including commercially important stability and yield [e.g. **R2**]. Using agricultural land for food and energy crop production can cause conflict, so various high-volume agricultural wastes and residues were evaluated including from paper mills, breweries and sewage works gaining substantial experience in processing a wide range of waste.

Application of Pyroformer™
Aston patented [**R3**] an intermediate pyrolysis reactor where condensed vapours produce pyrolysis oil that, when blended with biodiesel, drives liquid-fuelled combined heat and power engines. Pyroformer™ won Best Technological Breakthrough at the 2013 National Climate Week Awards.

India was a potential volume user for this technology. It produces large amounts of waste rice straw, traditionally burnt to create a significant carbon footprint and associated pollution [**S6**]. Joint research projects with IIT ROPAR (IITR), Punjab Agricultural University (PAU), and the Institute of Petroleum (IIP) made a solution viable. [**G1**].

With IITR, a Pyroformer™ was installed in a community to understand the economic and environmental drivers that would enable adoption. Paddy straw was pelletised and processed to produce biochar and vapour. Condensable vapour was blended with diesel; non-condensable vapour fed a dual fuel engine and powered a school [**S1**].

Project workstream (1) focused on pellet production as a viable business model [**R4**]; workstream (2) established a pyrolysis system at PAU for studies of bio-char [**R5**]; workstream (3) moved to IIP to explore improved liquid products (or applications of existing products), this ongoing work is now replicating PAU's installation in Orissa state, with government support.

In-country supply chain analysis
A financially sustainable supply chain was required that removed straw and delivered value to farmers. Techno-economic evaluations demonstrated the locations and scale where bioenergy generation has greatest potential by minimising costs and maximising performance. Initial studies [**R2**] have been followed by detailed analyses [e.g. R4&R6, Science Bridge project] providing information that is vital to stakeholders.

Challenges include: timing (21 days from rice harvest to wheat sowing); the availability of equipment (straw harvesting requires special equipment and know-how); proximity (raw materials shouldn't be transported far); and storage (straw is collected in a 6-8 week period, and must then be processed). Pellets are a natural intermediate product: dense, low water content, transportable and feed the downstream pyrolysis processes [**S1**].

For pyrolysis, the techno-economic research shows that vapours produced alongside the biochar are better burnt immediately on-site rather than condensing into oil. The plant at PAU utilised this result [**S1**].

It was also recognised that producing pellets from rice straw and using them directly as fuel is beneficial, with local pellet production addressing a number of the key challenges above. Identifying a number of local boiler operators, most consuming biomass shipped from hundreds of kilometres away, also highlighted an opportunity [**S1**].

Demonstration of increased crop yields
Joint research with PAU, funded by Coromandel (fertiliser division of India's multinational Murugappa Group), showed an increase in potato, onion and maize crop yield treated with biochar. A new reactor version was also developed that produces biochar but also directly burns resulting vapour to produce hot water. This is fed into a Vapour Absorption Machine (VAM) to produce cold air, which the demonstrator uses to chill a food storage unit. [**S5,R5**]

3. References to the research

R1 Bridgwater, A.V., Toft, A.J. and Brammer J.G., "A technoeconomic comparison of power production by biomass fast pyrolysis with gasification and combustion", Sustainable and Renewable Energy Reviews, 6 (3) pages 181-248, 2002, http://dx.doi.org/10.1016/S1364-0321(01)00010-7

R2 Decentralised off-grid electricity generation in India using intermediate pyrolysis of residue straws, S Sagi, A Patel, A Hornung, H Singh, A Apfelbacher, R Berry, World Renewable Energy Forum (WREF), 2012

R3 International Patent: WO2009/138757 "Thermal treatment of biomass", Publication Date: 19.11.2009, A Hornung and A Apfelbacher, http://www.google.com/patents/WO2009138757A2

R4 Supply chain optimisation of pyrolysis plant deployment using goal programming, JD Nixon, PK Dey, PA Davies, S Sagi, RF Berry, Energy 68, 262-271, 2014, https://doi.org/10.1016/j.energy.2014.02.058

R5 Interactive effects of rice-residue biochar and N-fertilizer on soil functions and crop biomass in contrasting soils. Manpreet Singh Mavi, Gurwinder Singh, Bhupinder Pal Singh, Bharpoo Singh Sekhon, Om Prakash Choudhary, Sudhakar Sagi, & Robert Berry (2018). *Journal of soil science and plant nutrition*, *18*(1), 41-59 https://dx.doi.org/10.4067/S0718-95162018005000201

R6 Trigeneration using biomass energy for sustainable development, P Vasudevan, PK Sen, SN Singh, P Singh, P Davies, PK Dey, R Berry - International Journal of Energy Sector Management, 2013, https://doi.org/10.1108/IJESM-02-2013-0006

Grants

G1 Davies, Technology and Business Solutions for the UK and India, RCUK Science Bridge Programme, 12/2008, £1,465,899

G2 The Oglesby Charitable Trust, donation to Aston University for energy harvest project, 10/2015, £240,000 (see: https://oglesbycharitabletrust.org.uk/inspired-by-nature-run-by-humans-a2p-energy-from-the-lab-to-the-field-to-the-un/)

4. Details of the impact

Each village in the Punjab produces ~1-2,000 tonnes of waste rice straw which must be cleared from fields within 21 days of harvest to plant wheat crops. It is often burnt while damp in open fields, using kerosene, creating a large carbon footprint and significant pollution. 20 million tonnes of rice straw is burnt annually in the Punjab alone.

In 2016, Aston and the Oglesby Charitable Trust created an Indian charitable trust, Energy Harvest Trust (EHT) to address this issue leading to five key impacts.

1. Development of a new business model in India to prevent open field burning (reducing pollution and carbon emissions), create viable supply chains and benefit communities

This required establishing infrastructure for engaging with farmers: harvesting and collecting straw; manufacturing, handling, and storing pellets; and identifying customers for using the pellets as fuel. This supply chain did not exist in the Punjab prior to establishing A2P Energy Solution (A2P) in 2018 (Impact 2) [**S1**]. A key challenge was understanding how it would be used within communities - it needed to be local, reliable, energy efficient and economically viable [**R2**].

In 2017, EHT worked with Nabha Power Ltd (NPL) (a division of L&T) to engage with villagers. A local entrepreneur hosted the plant, and other entrepreneurs began collecting paddy straw. Pellets were manufactured and sold to a local Pepsi plant, fuelling the boiler employed in crisp manufacture. [**S1,S2**]

In 2018, the plant was expanded by A2P, and a new partnership established with Jawandsons, a major textile contributor to IKEA's supply chain, now using paddy straw pellets as boiler fuel for steam production. The WWF is monitoring this project, working with IKEA to move it towards a more sustainable energy supply chain, and to replicate the model elsewhere. [**S1,S3,S4**]

2. Formation of a new business in India
A2P was formed by Berry and Singh in Chandigarh, India. Building on [**R2,R4,R6**], A2P has: a pyrolysis product made by local manufacturers (cost £20,000), a working business model, and several customers.

The first system was installed in partnership with NPL which had a power plant in the area and was working with 49 villages to provide infrastructure [**S2**]. A2P has focussed on improving efficiencies of this pellet plant at Nabha which can now process 10-12 tons/day and mixes 70% rice straw and 30% sawdust to increase calorific value which can then be burnt in a controlled way to produce power. In 2020 business growth allowed A2P to employ 12 people directly in pellet manufacture, and 34 people seasonally (for collection/baling). [**S1**]

3. Reduced carbon footprint and pollution
A2P has issued contracts for the collection of 600-2,000 tons/year of rice straw to be turned into rice pellets by their first commercial demonstrator. The facility is with local manufacturers and is currently producing 5-10 tons pellets/day. Pellets reduce straw to 40% of the original volume, making it easier to store and transport, and are used for fuel and potentially animal food.

Burnt in the open field, 1 ton of paddy straw releases 3kg particulate matter, 60kg CO, 1,460kg CO2, 199kg ash, and 2kg SO2. In pellet form, straw has a lower moisture content, <5% versus 30% lying in the field. So, burning pellets substantially reduces CO/CO2 emissions, and since commercial boilers in India are mandated to regulate emissions, the 3kg/ton particulate matter is also eliminated directly. The locally produced pellets reduce reliance on transported fuel - Jawandsons now uses ~3 tons/day of pellets instead of groundnut shells transported hundreds of kilometres. [**S1,S4**]

4. Increased crop yields
A second pellet and pyrolysis demonstrate was installed at PAU. This creates biochar, which can be used as a soil additive, and the resulting pyrolysis vapours are burnt directly at source and used to heat water which in turn can be used for refrigeration.

Joint field trials with PAU and Coromandel (2016-2019) showed a 7-15% increase in potato and onion crop yields when biochar is applied. Coromandel has now funded more work (2019-2021) to enable farmer-field trials and test paddy-straw biochar as a commercial product. They are also funding A2P for the development of a commercial grade biochar reactor. [**S1,S5**]

5. Raising government and community awareness
There had been government resistance to ex-situ solutions, but state and national government agencies now seek advice from A2P on new projects, and the government has initiated a number of its own that build on A2P's supply chain establishment and technical approach. [**S1**]

Working with the IKEA supplier has also impacted IKEA's sustainability strategy. Initially focused solely on the use of local and renewable materials in manufacturing, A2P's work with paddy straw has influenced IKEA's direction to include the energy used in production.

WWF also has an initiative to address the paddy straw burning problem, and A2P is assisting with this work to expand their suite of best-practices, and to influence the wider community of textile manufacturers. A new CSR initiative has been established to fund straw collection equipment for farmer entrepreneurs. With a single upfront donation of about £70k the equipment can be purchased to enable 1200 acres/season of straw to be collected. This straw produces a sustainable income of £35k/year for 5-6 years, and results in large reductions in annual emissions (~3.5 Mtons/yr CO2, 7.2 tons/yr particulates). Additionally, >50% of operating costs is invested directly back into the community via employment and services (straw collection). WWF has committed to co-brand this initiative in India, as well as support it through donation. [**S4,S1**]

5. Sources to corroborate the impact

S1 Letter and material from Director of A2P and Energy Harvest Trust, August 2020
S2 Letter from Director of Nabha Power Ltd, (Larsen & Toubro), December 2021
S3 Letter from Head of Procurement, Jawandsons Corporate, IKEA supply chain partner
S4 Letter and annual report from Associate Director of Sustainable Agriculture Programme, WWF-India, October 2020
S5 Letter and material from Executive Vice President – Technology, Coromandel International, September 2020
S6 Gupta, Prabhat K., Shivraj Sahai, Nahar Singh, C. K. Dixit, D. P. Singh, C. Sharma, M. K. Tiwari, Raj K. Gupta, and S. C. Garg. "Residue Burning in Rice–wheat Cropping System: Causes and Implications." Current Science 87, no. 12 (2004): 1713-717. Accessed January 22, 2021. http://www.jstor.org/stable/24109770.