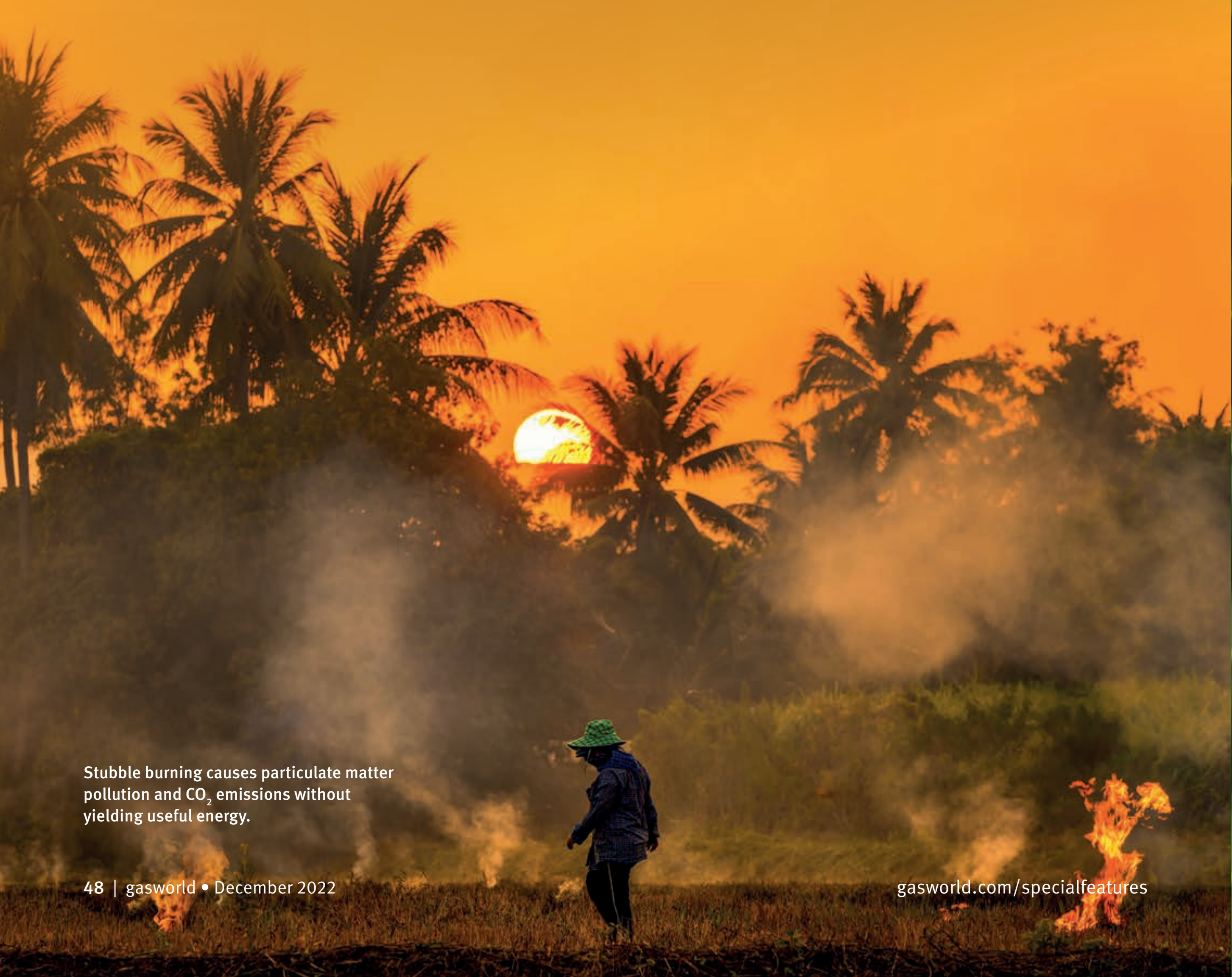
Crop-waste conversion

Creating green hydrogen, bio-CO_2 and bio-LNG

By Stephen B. Harrison



Stubble burning causes particulate matter pollution and CO_2 emissions without yielding useful energy.

Thermally accelerated Anaerobic Digestion (TAD) is a system that converts organic waste into high energy fuels, such as bio-hydrogen and biomethane, achieving up to 50% biomass to fuel conversion efficiency.

According to one team behind this innovative technology, Biezel Green Energy, this energy conversion yield is significantly better than any current biomass gasification and digestion technique. The company was founded in 2018 by Dr. Preetam Singh in Uttar Pradesh, India. He works alongside co-founder, Dr. Konda Shiva, and is mentored by Professor John B. Goodenough, the inventor of the current generation of rechargeable Li-ion batteries and recipient of the Nobel prize in chemistry 2019 for his work in that field.

"TAD reactors can process any kind of biomass and biomass wastes," says Dr. Singh. "However, green ligneous wastes, such as banana leaves, rubber plantation waste, palm fronds and coconut husks are preferred." Rice husks, wheat straw, sugar cane, flowers and ligneous paper waste are also highly suitable. These feedstocks are ideal because the lignin has high hydrogen to carbon ratio in the natural molecules and they respond well to the chemical processes and catalyst that are used in the TAD reactor.

Fresh green feedstocks with a moisture content of around 20-25% are ideal for the process because hydrogen contained in the water molecules is converted to hydrogen gas by the catalysts in the reactor. The hydrogen yield of green crops therefore exceeds that of dried feedstock.

The process of waste crop conversion

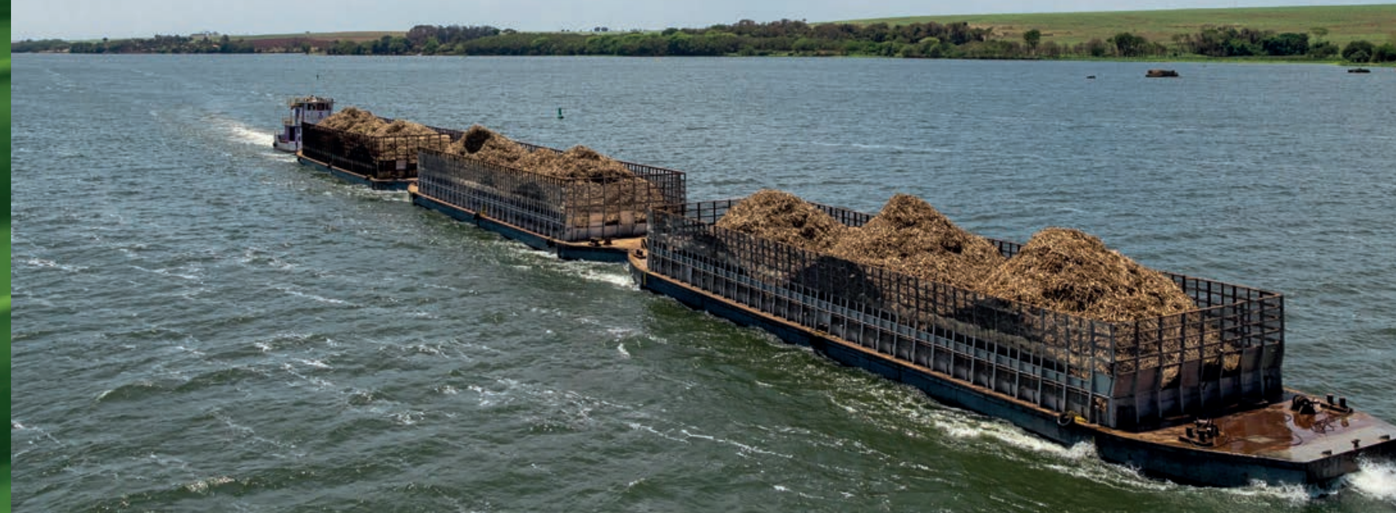
Beyond India, rural economies in tropical and sub-tropical countries, such as Bangladesh, Vietnam and Indonesia, would be ideal target locations for this process.

The flexibility of the TAD to process a broad range of feedstocks means that the seasonal availability of various crops throughout the year can ensure operation for up to nine months out of 12. During the remaining three months, the process can be fed with food scraps or crop wastes that have been stored from the growing and harvesting seasons.

Bio-hydrogen 3.5 to 4% by mass	High purity to ultra-high purity (UHP) grades can be achieved through purification of the TAD reactor gases
Biomethane 12 to 14% by mass	Can be used as CNG or high purity laboratory grade to UHP-grade is achievable through purification and liquefaction of the TAD reactor gases
Bio-coal 25 to 30% by mass	Graphitic oxide coal with an energy density of circa 30MJ/kg and ash content of 4.5%
Bio-tar 1 to 2% by mass	Can be used in a similar way to heavy fuel oil as a transportable energy vector

© Biezel Green Energy | **Products from the Biezel Green Energy process**

Agro-waste transportation



During the process, moist biomass is converted into hydrogen, methane, bio-coal, and bio-tar. Bio-CO_2 is also released, and this may be recovered and utilised, if required. Its release to atmosphere would be carbon-neutral since it was derived from biomass.

This process of converting biomass into fuel replicates the generation of fossil fuels from plants that has taken millions of years inside the earth's crust, however in TAD reactors, which work at 400-600°C, the same process can be completed in one single day. Carbon-neutrality can be achieved in one cropping season because the plants capture carbon dioxide from the air during their growth. When the fuels that are derived from the biomass are subsequently burned to release carbon dioxide, there is no long-term increase in the CO_2 in the air.

The TAD process has high raw material to fuel conversion rates and could potentially provide clean energy at affordable prices. Moreover, it has the potential to empower rural India and other tropical regions around the world with local, low-cost energy production from crop wastes.

According to Dr. Singh, "We propose stubble management to yield usable energy vectors instead of stubble burning which simply releases carbon dioxide and particulate emissions to the air. Our TAD process is highly effective and uses agro-waste and crop residues." One acre of land generates about two tonnes of crop residue, which can create 60kg of hydrogen, in addition to biomethane and bio-coal.

"TAD reactors can be run on residues of all the crops grown in the Uttar Pradesh state where Biezel is based," adds Dr. Singh. "These include wheat, rice, cotton, sugarcane, pearl millet, maize, barley and fruits. The biomass to fuel conversion rate can be up to 55% with some crop residues."

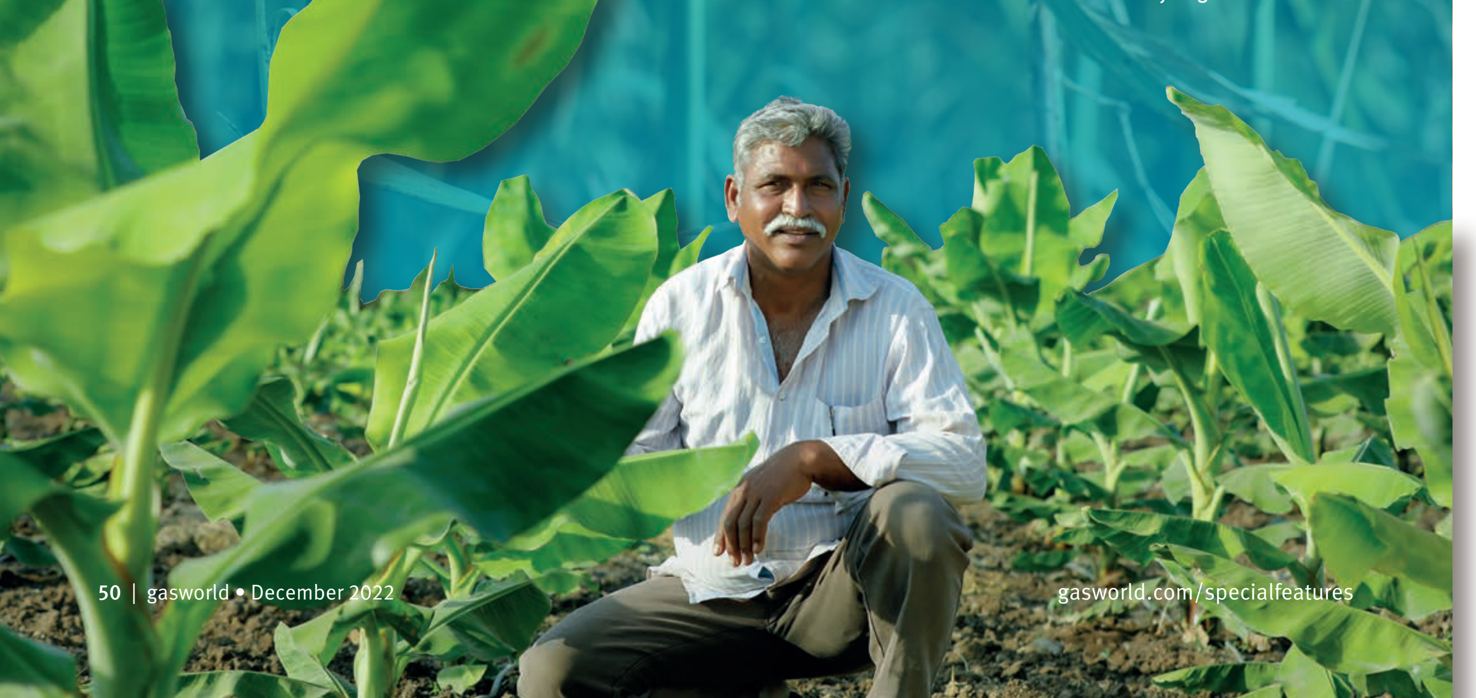
The heart of the process: the TAD reactor

The Biezel Green Energy TAD reactor is a batch process. Each batch uses 1,500kg of biomass in an operational cycle of approximately 36 hours. When the reaction is complete, the TAD reactor is cooled, cleaned and the bio-coal is removed, and the reactor is recharged with biomass. The reactor needs 25 kWh of electrical power to operate, and the final gas production is BBH (Biezel Bio-Hydrogen), which is 60-75% bio-hydrogen by volume, with the residual gas content being biomethane.

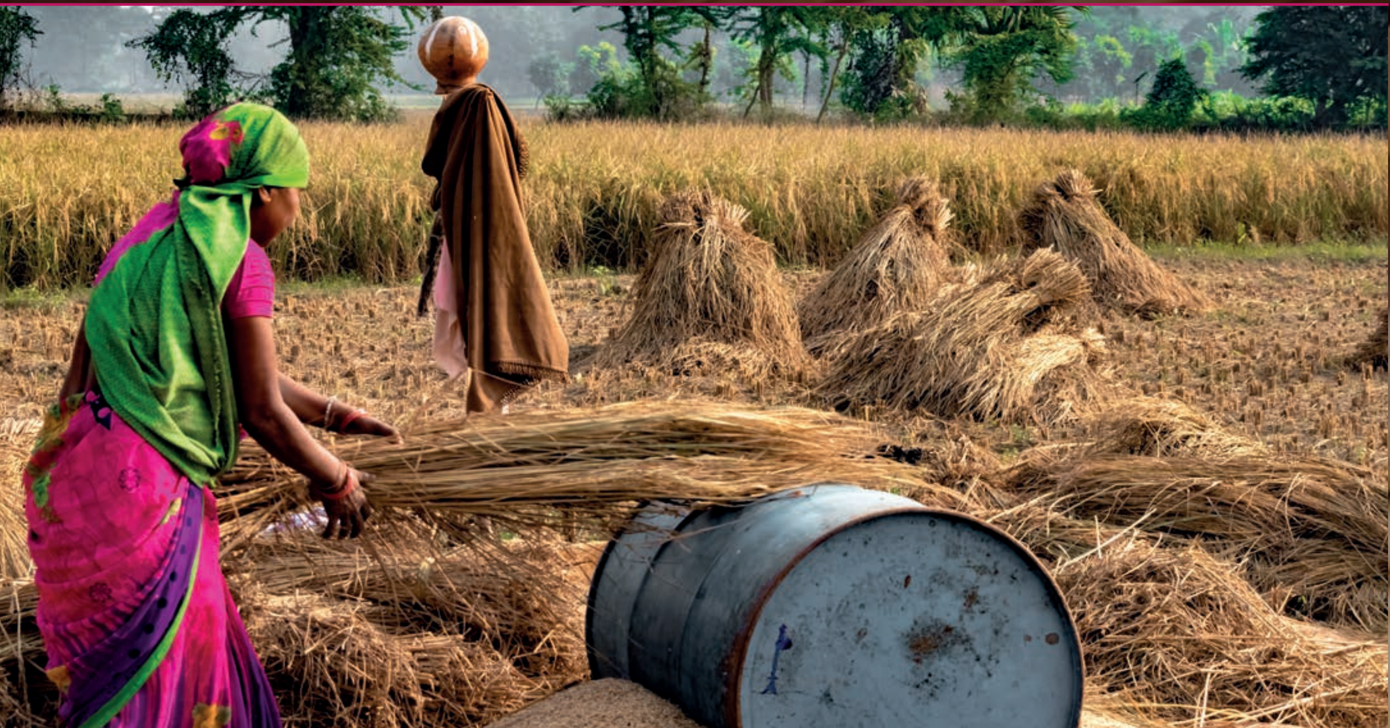
> "The TAD process has high raw material to fuel conversion rates and could potentially provide clean energy at affordable prices"

The TAD process consumes only 1kW of power to convert 1kg of biomass into the mix of biofuels. Not included in this power requirement are the optional additional electricity requirements to convert the carbon dioxide gas to dry ice and the power that is consumed to generate liquid nitrogen, which can be used to liquefy the biomethane gas to make Bio-LNG.

The main start-up cost is the reactor, ▶



Pictured: **Banana fronds can be converted to RLNG and hydrogen.**



© Biezel Green Energy | Threshing wheat grains from straw – the straw can be converted to hydrogen and biomethane.

which represents 50% of the CAPEX. Of that, approximately one third is related to the proprietary catalyst, which contains small amounts of precious metals.

Gas purification, renewable LNG and bio-hythane

Carbon dioxide, water vapour, hydrogen methane gases and some volatile tars are contained in the gas mixture released by the TAD reactor. To clean up this stream, water condensate is utilised to remove tar and, water vapour and a monoethanolamine (MEA) washing system is used to remove carbon dioxide. If required, pure bio-CO_2 can be extracted from the MEA and converted to dry ice.

The resulting mixture of hydrogen and methane can be further processed to yield liquefied renewable LNG (RLNG), also known as bio-LNG. This is achieved by heat exchange against liquid nitrogen. Since the volume of bio-LNG is 1/600th that of biogas, it is much easier to transport by train or road to the point of application.

As a co-product of the bio-LNG production, a high purity stream of hydrogen is released. This can be used for a range of high purity applications such as fuel cells for mobility or electrical power generation.

As an alternative to separating the biomethane and hydrogen, the mixed energy gas stream can be used as BBH with an energy density of around 79 MJ/ kg. This is a high calorific value green fuel that burns without forming any oxides of sulfur, meaning that it has a very low contribution to air pollution.

Owing to its high energy density and moderate hydrogen content, BBH can also be used as a fuel in natural gas-based furnaces. Due to the high flame temperature which results from the hydrogen in the gas mixture, BBH is especially useful for ceramics production and glass making.

A bright future for green energy

TAD reactors convert biomass wastes that do not have any significant commercial importance into carbon-neutral fuels with unprecedented efficiency. Biezel is currently establishing its first bio-hydrogen plot in Khanwa, Madhyapradesh in India with a production capacity of 0.5 tonnes of hydrogen per day.

Its industrial-scale demonstration centre is situated in Rampur Shakteshgarh, Mirzapur, Uttar Pradesh, India and the company is now also upgrading its demonstration centre to a plant capacity of one tonne of bio-hydrogen per day – consuming 30 tonnes of biomass per day. On average, with 30kg of biomass and using 30 kWh of electricity, the plant can produce 1kg of hydrogen, 3.6-4kg of biogas with more than 98% methane, and 7.5-8kg of smokeless bio-coal with a gross calorific value of more than 7,000 kcal/g.

Beyond this plant, Dr. Singh and the team at Biezel Green Energy are actively seeking additional business partners to achieve their scale up objectives in India and overseas. gw