Once deemed a ‘phantom’ or ‘fantasy’ fuel by detractors, cellulosic ethanol now is ready for prime time use by billions of consumers around the world.

Ready for the spotlight

Fossil-fuel dependence presents several problems, two of which appear inescapable: fossil fuels are a finite resource that are increasingly expensive to extract and process, and their carbon-rich nature is poisoning our environment and driving global climate change – actually harming the health of the very people who use these energy sources to better their lives.

Governments worldwide are choosing bio-based sources as they industrialise and seek to become economically competitive. As Stephan Tanda, DSM’s managing board member, has said: ‘The shortcut that oil provided for a century or so is ending, and we will have to go back to living off the land.’

Global motor fuel choice

One of the earliest biofuels is ethanol. In its traditional form, it has been produced in volume from sugarcane in tropical regions such as Brazil, as well as from the starch component of corn in the US and other countries. It has become the most widely used biofuel for transportation use globally.

Since about 38% of the fossil fuels used in the US, for example, are used for transportation, finding non-petroleum replacements is crucial to reducing the large carbon footprint being generated. Ethanol is a viable replacement for petrol, the most widely used fossil fuel in the transportation mix. Because it is relatively easy to produce and inexpensive, ethanol has proven itself to be a mainstream fuel with established success in the US, where a 10% blend currently is the standard, and in Brazil, where ethanol provides more than 40% of the country’s transportation fuel. With many large previously underdeveloped countries now finding their stride in the world economy, this volume is just the tip of the iceberg.

Due to its government-supported production of ethanol from sugarcane and its embrace by the country’s population, Brazil has been called the world’s first sustainable biofuels economy. Its regular petrol has an ethanol concentration of between 18-25% (E18-25). It also sells E100 hydrated ethanol for flex-fuel vehicles, which can run on any concentration of petrol and ethanol. Brazil continues to invest in ethanol technology, with two cellulosic projects coming on stream this year that use bagasse.

China, which is a significant energy importer, also has serious air-quality issues in populous areas, due to its heavy use of coal and fossil fuels. It is seeking to utilise biofuels, such as ethanol, to help reduce its problem in five cities in its central/northeastern region. It will use its significant biomass resources and some surplus grain to produce cellulosic ethanol for both transportation fuel and for electric power generation. This is expected to also help stabilise grain prices and raise income for area farmers. Until China’s cellulosic ethanol industry can reach commercialisation, it will import as much ethanol as possible to deal with its smog sickness, which is said to override even its GDP economic drivers.

Thailand is a forward-thinking country regarding biofuels, where a 10% ethanol blend motor fuel has been standard for years. The country adopted E20 in 2008 due to strong demand and sells flex-fuel vehicles capable of using E85, though infrastructure for such a high volume is a limiting factor. It domestically produces ethanol from sugar, starch and biomass based on the country’s large sugar cane, sugar beet and tapioca crops. Thailand is in the middle of a 15-year National Development Plan for Alternative Energy that has aggressive goals
for the increased use of ethanol, biodiesel and natural gas vehicle gas.

**Biomass harvesting management**

To replace the energy and materials feedstocks which coal and petroleum have provided, nature offers a readily available resource in biomass. Because it is renewed every year and often is a minimally used by-product of the harvest, it is readily available and is a sustainable resource. Key advancements in today’s biotechnology world have made such a shift feasible and very desirable.

Poet-DSM Advanced Biofuels has been a leader in biomass research and management, and has been working closely with farmers and agronomists who are key stakeholders in supplying this critical feedstock, since 2008 through parent company Poet. The company’s four-year study of corn stover harvesting methods and practices with Iowa State University and the US Department of Agriculture (Emmetsburg Soil Study: Evaluation of corn cob and stover removal levels on crop production, soil quality and nutrient levels, 2008-2011) included replicated field trials of seven different stover harvest methods. It evaluated the effect of stover harvest and removal on soil quality, soil fertility, and soil organic matter, as well as on subsequent crop yields. During the course of the four years, in addition to the stover research, the company harvested more than 192,000 tonnes of corn stover. That research is ongoing, with six years of site data now on hand.

The commissioned study determined that grain yield was not significantly affected by stover harvest treatments. Spatial and temporal variation in soil nutrients and overall crop management can have a much greater effect on crop yields and sustainable production than the effect of different stover harvest removal rates. The researchers recommend a removal rate of approximately 2 tonnes per acre on fields with greater than a 180 bushel per acre yield. However, the company fixed its initial stover harvesting threshold at a very conservative 1 bone-dry tonne per acre.

As part of the research and experience with corn stover biomass harvesting, the company has developed biomass standards and specific processes to reduce biomass contamination by dirt and other non-organic elements. To maximise convenience, farmers are offered the option to self-collect and supply their own stover or have the collection conducted for them through Poet-DSM.

**The Renewable Fuel Standard**

When the Renewable Fuel Standard (RFS) was established in 2005, the ethanol industry understood that cellulosic ethanol, required in increasing volumes by the standard, was achievable, though not commercially available. As the industry prepared to build cellulosic biorefineries to meet RFS production targets, the Great Recession sidelined major institutional investors, who were needed to capitalise the complex facilities, which significantly pushed back timetables for commercial production, which was specified by the standard.

With 2014’s mass commercialisation of cellulosic ethanol, which uses biomass from sugarcane bagasse, corn stover, energy grasses grown on substandard land, and eventually from wood pulp and municipal solid waste, a more widespread use of ethanol in petrol is expected and has been required by the RFS since 2005. Though some point to a 10% concentration level in today’s regular petrol as a limit, the requirements and intent of the RFS are to push ethanol use beyond this point to eventually blend 36-billion gallons of grain-based and cellulosic ethanol into the nation’s fuel supply.

Other countries also are working to expand use of these types of non-grain-based ethanol because they:

- Reduce CO2 emissions, improving air quality (grain-based ethanol has good CO2/greenhouse gas reductions above 25%; cellulosic ethanol reduces these elements by more than 80%, versus petrol)
- Provide a home-grown energy solution that creates local jobs and contributes to local economies, since the feedstock must be grown locally by farmers or collected as waste
- Ensure energy security in politically unstable regions of the world, where oil supplies are threatened
- Hedge transportation fuel costs against a volatile, rising worldwide crude oil price.

**Growth strategy for producers**

Becoming a cellulosic ethanol producer is the ethanol growth strategy for US biorefineries that want to sell their products in the country. With feedstock sensitivity being a primary concern in Europe, Asia...
the broad range of sugars unlocked in saccharification, specialty yeasts are required that can convert multiple C6 and C5 sugars, such as sucrose and xylose, into ethanol

- Co-product processes: Taking a page from the grain-ethanol playbook, the cellulosic process capitalises on co-product processes to maximise conversion of the end streams of residual organics and lignin and convert them to energy or other valuable co-products. This allows optimum greenhouse gas reduction and maximum revenue generation.

The combination of lack of capital investment due to the recent Great Recession and heavy refiner opposition to ethanol blending above the 10% level, have pushed back the reality of cellulosic ethanol availability a few years from the Environmental Protection Agency’s (EPA) original forecast. Despite the many factors that combined against the cellulosic industry soon after the RFS was enacted, many ethanol pioneers, such as Poet, DuPont and Abengoa Bioenergy, saw the vision of advancing the use of ethanol in the transportation industry. Through internal financing of partnerships, these companies worked diligently to overcome the roadblocks and planned and broke ground for cellulosic facilities in the 2012 timeframe.

**Project Liberty**

Projected Liberty, named to share the vision of freedom from fossil-based transportation fuels for America, is the product of a joint venture between Poet, based in Sioux Falls in the US state of South Dakota, and Royal DSM, a 100-year-old Dutch company with expertise in enzymatic and yeast processes in the consumer and industrial markets. The two companies formed the joint venture because of their shared goals for sustainability and a focus on contributing to a bio-based global economy.

Project Liberty is nestled in the agricultural area of Emmetsburg, Iowa, about 60 miles from the state’s northern border with Minnesota. Emmetsburg is in the heart of corn country, making it an ideal location for a cellulosic ethanol demonstration biorefinery.

The facility is located directly adjacent to Poet Biorefining, a 55-million-gallon grain-ethanol plant. Co-location was important to allow the project to share excess energy from the cellulosic production process with the grain-based facility to maximise greenhouse gas reductions. The plants will also share workforce and infrastructure, such as rail access and ethanol storage.

Project Liberty uses enzymatic hydrolysis and advanced fermentation to produce ethanol from biomass. The cellulosic process requires a combination of dry grinding of the stover, as well as high temperatures and pressures to help break down the lignin in the biomass. In the saccharification process, an enzymatic cocktail is required to break down the cobs, stalks and leaves in the feed stream to release the C6 and C5 sugars, which are used in fermentation to produce ethanol. Because the C6 and C5 sugars are unique, fermentation requires specialty yeasts, developed by DSM’s highly seasoned chemical engineers, which allow their complete conversion to ethanol.

Once fermentation is complete, the remaining liquid stream is sent to the biorefinery’s anaerobic digester to create biogas and to its solid-fuel boiler to produce energy from the remaining lignin. These processes allow Liberty to reduce the overall GHGs of the cellulosic ethanol to more than the 80-percent level. Excess energy from the cellulosic process is exported to the adjacent grain ethanol plant for further greenhouse gas capture.

As of May 2014, 95% of the plant’s construction is complete, with finishing work being done on the biorefinery’s anaerobic digestion and solid-fuel boiler areas. Commissioning of plant systems is concurrently being conducted to ensure operational performance. Construction on Liberty is expected to be complete in the second quarter of 2014.

**Poised for production**

In 2014, a number of other cellulosic ethanol pioneers are scheduled to bring commercial-scale biorefineries online, moving the volume of ethanol produced from non-grain sources from a few hundred thousand gallons to upward of 17 million gallons for the year. All told, when the three major biorefineries (Poet-DSM, DuPont and Abengoa) are running at capacity, they will add 85 million gallons of cellulosic ethanol to the biofuels mix.

**Coming soon to a fuel station near you**

Cellulosic ethanol is an environmentally sustainable energy source that is an ideal replacement for petroleum-based petrol. Technological and capitalization hurdles that had to be conquered have been overcome, and the cellulosic process is ready for prime time. Three producers will begin manufacturing ethanol using the cellulosic process in 2014. The industry is ready; the future is now!