How biomass gasification is securing our food, water, forests, and health

When communities make the case for a biomass gasification plant, the conversation almost always centres on energy: kilowatt-hours generated and carbon targets met. But a growing body of evidence assembled by IEA Bioenergy Task 33 suggests that the energy question, compelling as it is, may actually be the least interesting reason to deploy gasification. The deeper argument cuts across food systems, forest management, public health, and water quality – and it is only now coming into focus.

A morning in the Alpine foothills

It is early spring in the Inn valley of Tyrol. A forestry crew is clearing stands of spruce that have been killed by bark beetles – insects that have spread explosively as warming winters eliminated the cold snaps that once kept their populations in check. Dead timber of this kind is dry, abundant, and a fire hazard. A decade ago it would have been burned on-site or left to rot. Today it is chipped, trucked a few kilometres, and fed into a gasification plant built on technology from an Austrian company called SynCraft.

The plant converts the wood into a combustible gas mixture, which is efficiently turned into electricity and heat for the surrounding municipality. What comes out the other end of the reactor, alongside the energy, is a fine black powder known as biochar. Some of it will be applied to nearby fields, some will be tested as a filter medium in a local water treatment facility, a small certified fraction will be added to animal feed, and some will replace fossil coal in steelmaking – in this case through a cooperation with another company called Voestalpine. So a morning's worth of bark-beetle timber serves the energy grid, the soil, the water system, carbon-intensive industry and the food chain simultaneously.

Not all gasifiers produce biochar, but there is a number of other companies like SynCraft, which do not let the char gasify fully, removing it from gasifier before the process is finished. This is not a unique example: researchers with IEA Bioenergy Task 33 have documented this process across Europe and beyond.

Five security needs – and why energy is only one of them

The IEA Bioenergy BioSyn project began from an unusual premise: that the reason to deploy bioenergy technologies should be derived not from energy policy alone, but from a broader audit of what societies actually need to be secure. Working across several IEA Bioenergy Tasks, researchers settled on five fundamental security domains and corresponding services that bioenergy offers: food, resources, home, health, and community.

> *"What we are only now beginning to systematically document is how the same process, in the same installation, simultaneously supports food systems through nutrient return, protects forests through waste biomass removal, filters water through biochar, and manages contaminants through thermal treatment. Technology hasn't changed, but the way we account for its value is starting to catch up. The challenge now is building the regulatory and economic frameworks that let all those co-benefits be recognized and rewarded at once."*
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> **– Jitka Hrbek, IEA Bioenergy Task 33 (Gasification)**

For gasification, the analysis that follows maps each of these services systematically. As the thermochemical conversion of organic material into a gas through controlled heating in a limited-oxygen environment, gasification produces syngas: a mixture mainly of carbon monoxide and hydrogen that can fuel heat and power or serve as a building block for fuels and chemicals. It could also offer biochar as a byproduct, ash, which is rich in nutrients, by employing clean biomass, and streams of heavy metals, concentrated mostly in ash, when industrial waste is used as a feedstock. Each of these outputs has applications that extend far beyond the energy sector.

Food: back to the field

Food and feed processing generates enormous volumes of organic residue: fruit pomace, spent grain, nut shells, crop husks. These are expensive to dispose of and, if left in landfills, release greenhouse gases and cause other environmental problems. Gasification can convert dried food-processing residues into gas for heat and power, while ash and biochar byproducts return to agricultural soils nutrients, such as phosphorus, potassium, and trace minerals.

For example, EQTEC in Spain operates commercial gasification plants processing agricultural residues, including olive pomace. The Bioliq process developed at the Karlsruhe Institute of Technology demonstrated straw gasification at pilot scale, establishing the technical feasibility of converting cereal residues – one of the most abundant agricultural waste streams on Earth – into liquid fuels or chemicals. This way, the mineral fraction doesn't need to leave the loop: whatever the gas becomes, the phosphorus and potassium in the residue can be returned to the field.

Resources: keeping wood in the loop

Wood and its processing residues, such as wood chips and wood pellets, are the most established feedstocks for biomass gasification globally. In Europe alone, there are more than 1,700 operational small-scale gasifiers producing heat and power (CHP). IEA Bioenergy Task 33 monitors the gasification status globally, maintaining a database of approximately 200 reference small- and large-scale gasification plants.

Nowadays, also black liquor from pulp mills is considered a very suitable feedstock for gasification. The integration logic for securing supply of biobased material is simple: a sawmill or pulp mill generates residue streams as a byproduct of its core business; a gasifier converts those streams into the heat and power needed to run the mill. The planned project, Östrand Biorefinery in Sweden, is extending this model further, combining gasification with electrolysis to explore the production of sustainable aviation fuel from forestry residues. Not far from it, the ESKA gasifier in the Netherlands converts paper reject (the fibrous waste of paper manufacture that cannot be reused) into gas, displacing natural gas for generating high temperature heat in an adjacent production facility. Beyond energy security, these biobased solutions help advance waste management and circular economy sectors by offering valuable resources.

Home: ecosystem resilience

The connection between forest management and gasification may be the most immediately legible of all the synergies. When forests are thinned to reduce wildfire fuel loads, when dead timber from pest infestations is removed, or when riparian vegetation is cleared – the resulting biomass needs to go somewhere. Without a market for it, clearing operations are expensive and chronically underfunded. Gasification creates that market. In the Czech Republic, the bark beetle crisis of 2015-2020 produced millions of cubic metres of damaged timber that local mills could not absorb. As a result, arrangements were made to export beetle-killed wood to Austria, where it was processed by biomass gasification plants.

Health: water and contaminant management

Biochar, which is the carbon-rich solid residue of gasification, has a highly porous structure and chemically reactive surface that makes it an effective filter material. Research at the Josef Ressel Centre in Innsbruck, operated in partnership with SynCraft Engineering and regional utilities, has developed methods for converting gasification residues from waste wood into powdered activated carbon for wastewater treatment: a locally sourced filter material capable of adsorbing organic micropollutants, pharmaceuticals, and heavy metals from water. Gasification also addresses contaminants through thermal destruction: at the high temperatures reached inside a gasifier, all organic pollutants and pathogens are broken down. Through this process, metals are mostly concentrated and immobilised in the solid ash, allowing controlled management or recovery.

Community: urban water and infrastructure

Sewage sludge is the solid residue of wastewater treatment and one of the most challenging materials in urban waste management. Gasification offers a route to energy recovery, volume reduction of up to 80 percent, and the concentration of phosphorus in ash for potential recovery as fertiliser. A facility in Balingen, Germany, operated by KOPF SynGas, produced gas from sewage sludge and generated electricity for the treatment plant itself, while exploring recovery of the phosphorus-rich ash as a nutrient source.

Emerging frontiers and the questions that remain

Beyond energy, gasification contributes to multiple dimensions of security simultaneously. For **food security**, it converts dry crop and feed residues into useful heat and power while concentrating phosphorus, potassium, and other minerals in the solid residue, such as ash or biochar, that can be returned to farmland wherever regulations and agronomy allow. For **resource security**, it closes loops in the wood sector: residues from sawmills, pulp mills, and paper production are transformed into syngas to power the very facilities that generate them, reducing reliance on fossil natural gas. It also strengthens **home security** through forest thinning and dead-timber clearance, so the biomass killed by bark beetle and therefore prone to fires is removed. These technologies protect **health security** by destroying pathogens and organic pollutants in the heat of the reactor, while locking heavy metals into a solid ash that can be safely managed, and by turning waste wood into activated carbon that filters micropollutants from water. And finally, gasification can reinforce **community security** by making wastewater treatment plants energy self-sufficient and recovering scarce phosphorus from urban sewage sludge, keeping the infrastructure, on which communities depend, running.

But some of the most significant possibilities identified by Task 33 researchers are not yet deployed at commercial scale, and what holds them back is not only the technology, but also that the value they would create is one not yet grasped by the market.

Phosphorus is the clearest case, as a finite, mined resource with no substitute in agriculture. Supercritical water gasification of sewage sludge has achieved recovery rates of up to 95 percent in research settings at the Universities of Twente, Wageningen, and Cracow. The remaining hurdles are partly technical (such as corrosive conditions or co-contaminants), but the bigger issue is that recovered phosphorus has to compete on price with mined phosphate, and a circular bioeconomy system that secures long-term fertiliser supply is not visible to a market that only sees its next tonne.

Biochar in animal feed is an elegant triple benefit: better animal welfare, less ammonia lost from manure, and stable carbon carried into the soil when that manure is spread. Applied to degraded or sandy land, in trials from sub-Saharan Africa to Australia, it improves water retention and nutrient cycling in ways the Amazonian Terra Preta soils have demonstrated over centuries. Whether these effects hold across climates and soils is still open. But the harder question is how to attract the funds today for a soil that will be better at holding water

and carbon a decade from now, so that the long-term security targets are prioritised over immediate profits.

Medical and biohazard waste closes the set with a benefit that is almost pure security. China built out plasma and pyrolysis-gasification for infectious waste at speed during the COVID-19 pandemic. But outside China, the technology remains largely at pilot scale. The interesting question is whether small, mobile gasifiers could sterilize hazardous waste at remote hospitals or in disaster response. Beyond energy or even cost reduction, the value is measured in a contaminant rendered harmless and how effectively disease transmission chains can be broken, which matters especially when systems are under stress.

About this project

IEA Bioenergy Task 33 is the international research collaboration focused on biomass gasification: the thermochemical conversion of organic material into producer gas, which is called syngas after cleaning and conditioning. Syngas is usable for production of electricity, heat, biofuels (such as SNG – substitute natural gas, biodiesel, SAF, hydrogen) and biochemicals (mixed alcohols). The Task coordinates research across member countries, maintains a global plant database, and assesses emerging technologies.

The findings presented in this story were produced as part of the IEA Bioenergy BioSyn Project – a collaborative effort of IEA Bioenergy, coordinated by Task 44 (Systems Analysis and Integration) with participation from Task 33 (Gasification), Task 34 (Pyrolysis and Liquefaction), Task 37 (Anaerobic Digestion and Biogas), and Task 39 (Liquid Biofuels).

The objective of BioSyn is to understand the synergies between bioenergy technologies and fundamental security needs. This societal lens allows moving beyond energy metrics to capture the full scope of value that bioenergy systems contribute to food, resources, home, health, and community security.

The project draws on the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) classification of 'nature's contributions to people,' adapted to a bioeconomy context that accounts for material, regulatory, and non-material contributions of bioenergy systems to society.

For more information: www.task33.ieabioenergy.com

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