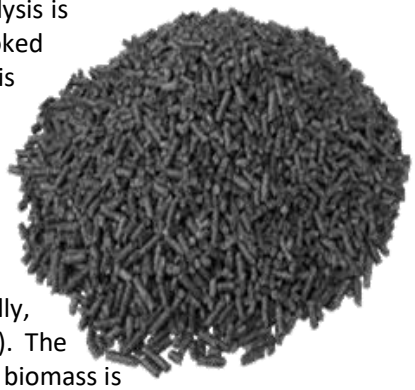
Commercial Methods to Produce a Water Repellent Biomass Pellet

More than 25,000,000T of wood pellets are manufactured today for both industrial and domestic use. The 500+ manufacturers in 25 countries use an identical no-tech process developed 40 years ago that combines of wet grinding, hot air drying and densification. The pellet press is the same as was originally developed for cattle feed in the 1930's. While pelletized cattle feed can be exposed to moisture, when biomass is extruded into a pellet for fuel, it must be carefully stored and transported without any exposure to water until it is burned in a boiler or it will fall apart and become useless.

To overcome the water-solubility issue over the past 20 years, several companies have developed various approaches to manufacture a water repellant biomass pellet. Two of most common are:

Torrefaction - This process has been proven technically by several companies in Europe and the US over the past 25+ years. Biomass is ground to a small micro-chip size, then 'slow-roasted' in a low oxygen environment at temperatures typically between 200°C and 320 °C. Pyrolysis is similar to roasting or baking where the biomass constituents are "cooked off" and the remaining biomass becomes denser. The finished material is then ground and densified in a pellet press just like a white pellet. The final form of torrefied pellet is hydrophobic and with a higher energy content than a white pellet.



Steam Explosion - This method of biomass processing is a pre-treatment that opens up the fibres and makes the biomass polymers more accessible for subsequent processes or densification processes. Typically, wood chips are heated to ~280°C at a pressure of 3.5 MPa (500 psi). The pressure is then raised to 7.0 MPa (1,000 psi) for a few seconds and the biomass is discharged through restricted ports where it "explodes" and opens up the fibre. Pellets from steam explosion processes are dark brown in color, and stiffer than conventional wood pellets. They are less abrasive and are distinctly hydrophobic. The bulk density of steam exploded pellets is relatively high in comparison to conventional wood pellets, but the finished product typically does not have an energy content much greater than a white pellet fuel. Hence the commercial case for selling a steam-exploded pellet is that it is waterproof and is accepted as a proven manufacturing method.

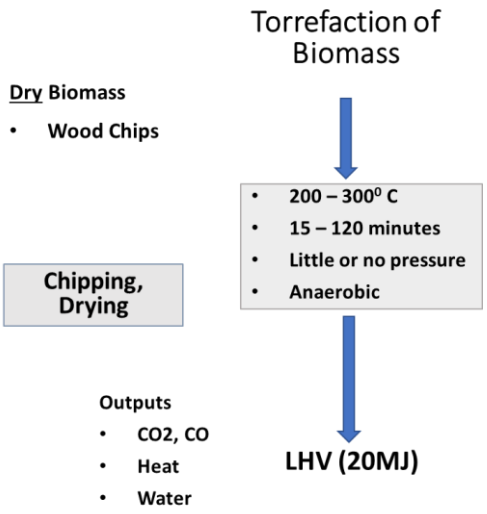
Thermo-Catalytic Conversion (TCC) is process developed and third-party validated by Arterran. The TCC technology homogenizes lignocellulosic biomass at much lower process temperature and pressure than that required for torrefaction or steam explosion. The blend of biomass at normal moisture content with proprietary catalysts inside a commercial reactor vessel results in a slurry which is then mechanically separated. The solid portion then immediately densified into a pellet fuel which is both water resistant and has an energy density equal to bituminous coal.

The Mechanics of Converting Biomass into a Water Repellent Pellet Fuel

The key to the manufacture of a water-resistant pellet is to process the raw biomass in a manner that will cause it to shed as much water as possible. A water-resistant or hydrophobic pellet is commonly referred to as a 'black' pellet – a photo of which is shown above.

The process description of the three currently available conversion methods are described on the following pages.

Torrefaction - Application of Heat - The primary technique for all three processes is to apply heat (200^0C-320^0C) which causes the trapped moisture to "boil" and escape from the porous structure of woody biomass. As the heated water transitions from liquid to gas, it ruptures the structure that held the moisture. This, in turn, creates voids that, when densified in a pellet press, will allow the biomass to resist future re-entry of water (which equates to water resistance). Unique to the torrefaction process is the requirement to heat the biomass in a low oxygen environment. This has inherent manufacturing process risks in that the fully torrefied biomass must be brought back into a normal oxygen-content atmosphere before it can be densified.

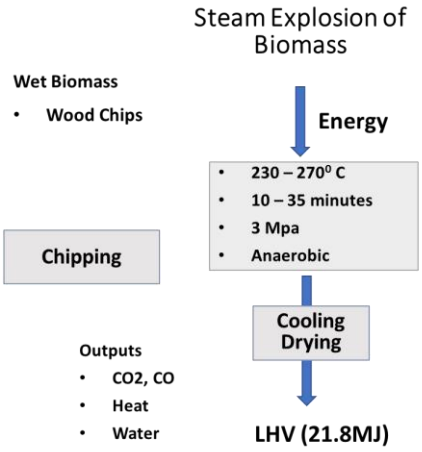


Steam Explosion - Application of Pressure - The second technique common to these processes is the further application energy in the form of pressure. From industry literature and reports we know that the amount of pressure can vary from 2MPa (290 psi) to as high as 27MPa (3,900 psi) depending on process, feedstock, chip size etc.

The loss of moisture and the resultant loss of structural integrity allows the pressure to "crush" and or "explode" the biomass thereby eliminating the void water once occupied. A secondary effect at this stage is the creating of frangibility. The biomass has lost its original structural integrity and is now somewhat brittle and easily ground.

The end product from each the three processes is a densified, truly water-resistant biomass pellet fuel.

The three main components of biomass are cellulose, hemicellulose and lignin. High temperature and high pressure will reduce the mass by 30-50% due to the fact that portions of the biomass are consumed, gasified or become soluble in the process.



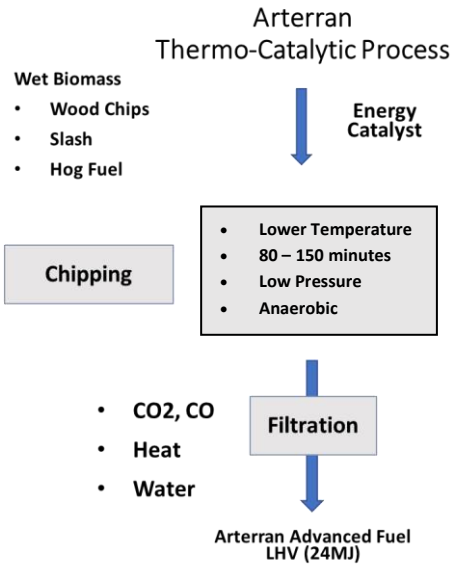
Depending on which conversion process is selected, the use of higher temperatures can decrease the amount of lignin available in the final product. This factor is important because lignin has the highest energy density of the three fractions and any loss will directly reduce its energy density. This is why torrefaction and thermos-catalytic conversion methods will yield much higher energy density than pellets resulting from steam explosion.

Thermo-Catalytic Conversion (TCC) – The Arterran proprietary conversion method differs substantially from the other two hydrophobic processes by fracturing the cellular walls of the biomass material at a lower heat and pressure

Compared to torrefaction and steam-explosion fuels, the Arterran process requires significantly less heat energy and pressure to create a densified, high energy hydrophobic fuel.

Less energy during the conversion process equates to lower operating overheads. From a capital cost standpoint, Arterran's process requires less expensive equipment and there is virtually no risk of fire or explosion.

Unlike all other methods of manufacturing wood pellets, a feature of the TCC process is that no biomass drying is required to make the finished product.



Comparison of Currently Available Water-Resistant Biomass Fuels

As of January 2020

	Coal	Torrefied Pellets	Steam Exploded	Wood Pellets	Arterran Advanced Fuel
Energy Density GJ/t	17-30	**20-21**	**20-22**	16-20	**24-29**
Moisture wt.%	10 to 15	**1 to 5**	**2 to 5**	16 to 20	**2 to 4**
Ash%	3-50	1 to 2	1.3 to 2	.5-2.0	1.5 to 2
Fixed Carbon%	50-55	**28-35**	**28-36**	20-25	**45-46**
Volatiles%	15-30	**55-65**	**55-66**	70-75	**50-51**
Bulk Density Volumetric kg/m3	800-850	**700-850**	**700-850**	550-750	**775-850**
Hydrophobicity	Yes	**Yes**	**Yes**	No	**Yes**
Biological Degradation	No	**No**	**No**	Yes	**No**
Self-Heating	No	**No**	**No**	Yes	**No**
Oxygen Depletion	High	**No**	**No**	Extreme	**No**