Engineering Data Sheet

6018

Application: Oil Sands Tailings Treatment and Site Redevelopment Waste-To-Energy Technology

Tar Sands refer to worldwide **crude bitumen** (bitumen) deposits that occur in more than 70 countries. For marketing reasons, those engaged in bitumen mining activities have changed the somewhat dirty "tar sands" designation to wealthy sounding "**Oil Sands"**. The largest bitumen deposits are in Canada followed by Venezuela. Bitumen is processed into synthetic crude oils. The synthetic crude oils, in turn, are pipeline transferred to refineries where they are processed into gasoline, diesel fuel, jet fuel, natural gas liquids, and other refined products of commercial value in the same manner as naturally occurring crude oils are refined.

Municipalities, pulp & paper mills, sugarcane factories, coal mining, and phosphate fertilizer production are well known to produce significant waste volumes. The waste volumes generated by oil sands bitumen production likely exceed the **combined wastes** of municipalities, pulp & paper mills, sugarcane factories, coal mining, and phosphate fertilizer production by a **factor of 10** to place a perspective on the volume of massive oil sands wastes.

Oil Sands Strip or Surface Mining Operation

Canadian oil sands can be mined using both surface (strip mining) and below surface (in situ) technologies. About 80% of Canadian oil sands are too deep for surface mining and therefore the bitumen must be extracted in situ. In every other country 100% of the oil sands are too deep for surface mining. The bitumen extraction process uses hot water flotation to remove a thin coating of oil from grains of sand. Naphtha is then added to thin the bitumen so that it can be pumped. About two tons of oil sand must be mined in order to yield one barrel of oil. The Canadian oil sands have a bitumen content of 10-12%. For each barrel of oil recovered, 2.5 barrels of liquid waste are pumped into huge tailings ponds. The liquid wastes consist of sand, silt, clay, and unrecovered oil. In these ponds, the sand, silt, and fine clays slowly settle to the bottom. Then as much water as possible is pumped back to the extraction plant and reused in the extraction process. Because of the bitumen that remains in the tailings, the ponds pose a number of environmental risks including the migration of pollutants into the groundwater system and leakage into the surrounding soil and surface waters. Approximately six cubic meters of tailings are created for every cubic meter of bitumen produced. The tailings are comprised of 3-5 cubic meters of water and approximately 1.5 cubic meters of fluid fine tailings. Fluid fine tailings can take anywhere from a few decades to 150 years to settle out.

**Overburden Waste Pile Sits Atop
An Oil Sands Open Pit Surface Mine**

Producing the final synthetic crude oil from bitumen requires two stages of upgrading. The first stage cracks the large bitumen hydrocarbons into smaller molecules. This is done using either coking or hydrocracking, or both. In the coking process, excess carbon is removed when high temperatures (around 500ºC) crack the bitumen molecules by vaporizing them. The excess carbon forms a solid residue called coke. The coke, which resembles coal, is then stockpiled as a waste by-product. Hydrocracking involves the addition of hydrogen to bitumen molecules that are cracked using a catalyst, such as platinum. The second stage of upgrading is called hydrotreating whereby high pressure and temperatures (300-400ºC) are used to remove nitrogen and sulphur. In hydrotreating, metals, sulphur, and nitrogen are removed using a catalyst in a hydrogen environment. The nitrogen is removed as ammonia and is usually used as a source of fuel, while the sulphur by-product is converted to elemental sulphur and either transported for use in other industrial processes (e.g., production of fertilizers) or stored in massive sulphur blocks.

Typical Oil Sands Tailings Ponds

Natural gas is used both to generate the heat necessary to extract the bitumen from the oil sands and as a source of hydrogen to upgrade the bitumen into synthetic crude oil. For surface mining and upgrading, about 250 cubic feet of natural gas are used for extracting and another 500 for upgrading. For in situ production, about 1000 cubic feet are used for extracting and another 500 for upgrading. These natural gas costs amount to 15% and 60% respectively of the total operating costs of surface and in situ mining operations. The energy intensive production methods translate into the requirement to use the energy equivalent of one barrel of oil to produce three barrels of synthetic crude. Production of conventional oil requires much less energy.

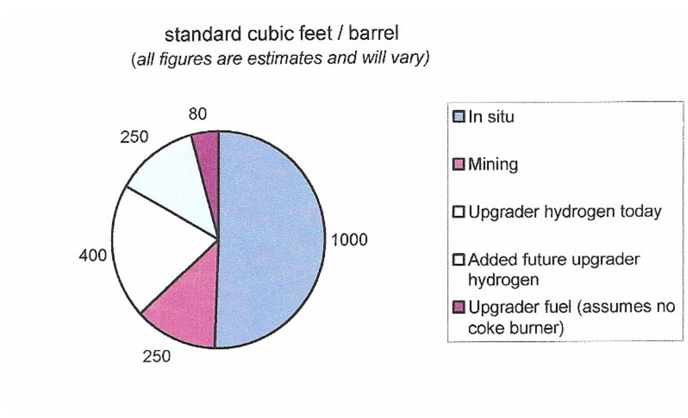
Bitumen production continues around-the-clock. Trucks take the tar sand to crushers, where it is broken down into cantaloupe-size chunks. From the crushers, warm water is added to the sands which are piped to rotating drums where the sands and water are mixed further to reduce the chunks to golf-ball size. At the end of 2003, 32 companies representing 59 projects were operating in the Canadian oil sands according to the Alberta Department of Energy. Combined, these companies produced 938,000 barrels per day of bitumen with production on the increase. The production companies are emoting their confidence in continuing marketplace success. According to Suncor's Rick George, "*A large part of the rest of this industry is chasing the world for reserves…We have reserves…We have no exploration risk and also have no decline curve, so we have a completely different business model from the conventional crude oil producer*" (Moritis, Guntis, Suncor's George: "Oil Sands a long-life, low-risk resource", OGJ 102.11, March 15, 2004, pp. 37-38.) The massive bitumen black gold rush appears unstoppable. **Such is not the case**, however, as *all that glitters (glisters) is not gold*.

Immense problems on the immediate horizon consist of:

1. **Dwindling supplies** of natural gas for extraction and upgrading,
2. **Dwindling supplies** of natural gas condensates to dilute bitumen for pipeline transport,
3. **Continuing increase** in the cost of natural gas,
4. The necessity to use **additional natural gas** for higher quality upgrading to satisfy marketplace demands,
5. The **increasing salinity** (decreasing effectiveness) of recycled extraction water,
6. The **increasing release of methane gas** from the tailings ponds, and
7. The **increasing improbability of future cost effective extraction of in-situ bitumen** representing 80% of the gold rush.

Not to worry as a total scientific solution is now being proposed.

Naphthenic acids are natural constituents of petroleum, where they evolve through the oxidation of naphthenes (cycloalkanes). This diverse group of saturated mono and polycyclic carboxylic acids can account for as much as 4% of raw petroleum by weight (Brient *et al*., 1995), and represents an important component of the waste generated during petroleum processing in some situations. For example, in the Athabasca oil sands industry near Fort McMurray, Alberta, Canada, naphthenic acids become dissolved and concentrated in tailings water as a result of the hot-water process used to extract bitumen from mined oil sands. These tailings are then amassed in large holding ponds in



Oil Sands Natural Gas Demand

Source: Alberta Chamber of Resources (2004) the immediate area. The Athabasca oil sands (AOS) deposit covers about 42,000 km^2 surrounding Fort McMurray (57° 3.07` N, 111° 36.02` W), approximately 440 km northeast of Edmonton, Alberta. It is the largest of 4 major oil sands deposits in the province and contains over 200 billion cubic meters of petroleum, making it the world's largest single oil deposit (AOSTRA, 1990). Oil sands are a mixture of bitumen (crude petroleum), sand, and water. Separation of bitumen from other components is accomplished by the Clarke Hot Water Extraction process, where mined oil sands are mixed with hot (79–93°C) water and caustic soda (sodium hydroxide). After the bitumen is removed, residual sand, clay, and water, along with other inorganic and organic contaminants, are diverted to settling ponds. By 2025, an estimated 1 billion m^3 of tailings pond water (TPW) will have accumulated as a result of mining the AOS (Herman *et al*., 1994). A consequence of the hot water extraction process is that the alkalinity (pH = 8) promotes solubilization of naphthenic acids thereby concentrating them as mixtures of sodium salts in aqueous tailings. The actual amounts of naphthenic acids in the holding ponds of the two major companies operating in the AOS, Syncrude Canada Ltd. (Syncrude) and Suncor Energy Inc. (Suncor), are typically between 80 and 110 mg/l (FTFC, 1995). The bioavailability and persistence of naphthenic acids in contaminated waters are believed to be high. These compounds are highly soluble and have an extremely low volatility (Henry's constant = 8.56×10^{-6} atm x m^3/mol). Sorption to dissolved and particulate organic matter is limited by the polarity of dissolved naphthenates. Large amounts of process-affected water are generated from the extraction of bitumen from the oil sands in Alberta. The tailings are placed into settling basins prior to reclamation and consist of sand, clay, unrecovered bitumen, naphthenic acids (NAs) and polycyclic aromatic hydrocarbons (PAHs). All of the organic constituents can be anaerobically digested to produce methane gas. Methane gas is a near equivalent to natural gas.

In addition to the tailings, other area wastes consist of municipal solid wastes (MSW), sewage, cooling water, dyke (dike) seepage, site drainage, muskeg, overburden, mine runoff, and mine depressurization water, coke, and sulfur. A fine slurry mixture of the solid wastes with the liquid wastes can be anaerobically digested to produce methane gas. The liquid effluent from the digester can be separated into liquid fertilizer concentrate and reverse osmosis (RO) water. The saline free RO water can be used for high quality extraction water and steam production with excess going to the river. The methane gas can be used to augment or even replace the dwindling supplies of natural gas. Since the digester solids (digestate) still contain valuable minerals they can be processed to yield their Titanium and Zirconium minerals for sure, and possibly Tourmaline and Pyrite as well. After mineral recovery, the digestate will still contain clays. The clay constituent of the digestate as well as coke and sulfur wastes may be added to Alberta area phosphogypsum stacks from the phosphate fertilizer industry to produce cement.

Typical Alberta Phosphogypsum Stacks

The non-clay constituents of the digestate may be used to produce concrete wall panels for the building industry. The concrete wall panels may be used in the construction of a large building to house the anaerobic digester, a photobioreactor to grow microalgae, process equipment to produce biodiesel from microalgae, and all associated processing operations. The biodiesel will be further refined through distillation to produce SuperBiodiesel™ and BioLubricants™. The SuperBiodiesel™ can likely be used for modern jet fuel as well as all other diesel powered transportation and equipment without regard for cold weather limitations. The biodiesel based biolubricants can possibly be used as a direct replacement for high quality synthetic lubricants. The superbiodiesel can be used at the project site to replace petroleum diesel with excess to the marketplace. The superbiodiesel can also be used to replace the dwindling supply of condensates for bitumen dilution.

The ammonia produced during hydrotreating can be used to generate electricity by adding it to the methane fuel. The associated combustion reactions are:

$$CH_4 = 2O_2 \rightarrow CO_2 + 2H_2O + 890 \text{ kJ}$$

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O + 905 \text{ kJ}$$

All oxides of nitrogen formed during combustion are beneficially used by the microalgae within the enclosed photobioreactor. The proportion of ammonia gas added to methane gas can vary from 0 – 100% without adverse impact on power generation because the associated heats of combustion of the two gasses are quite similar.

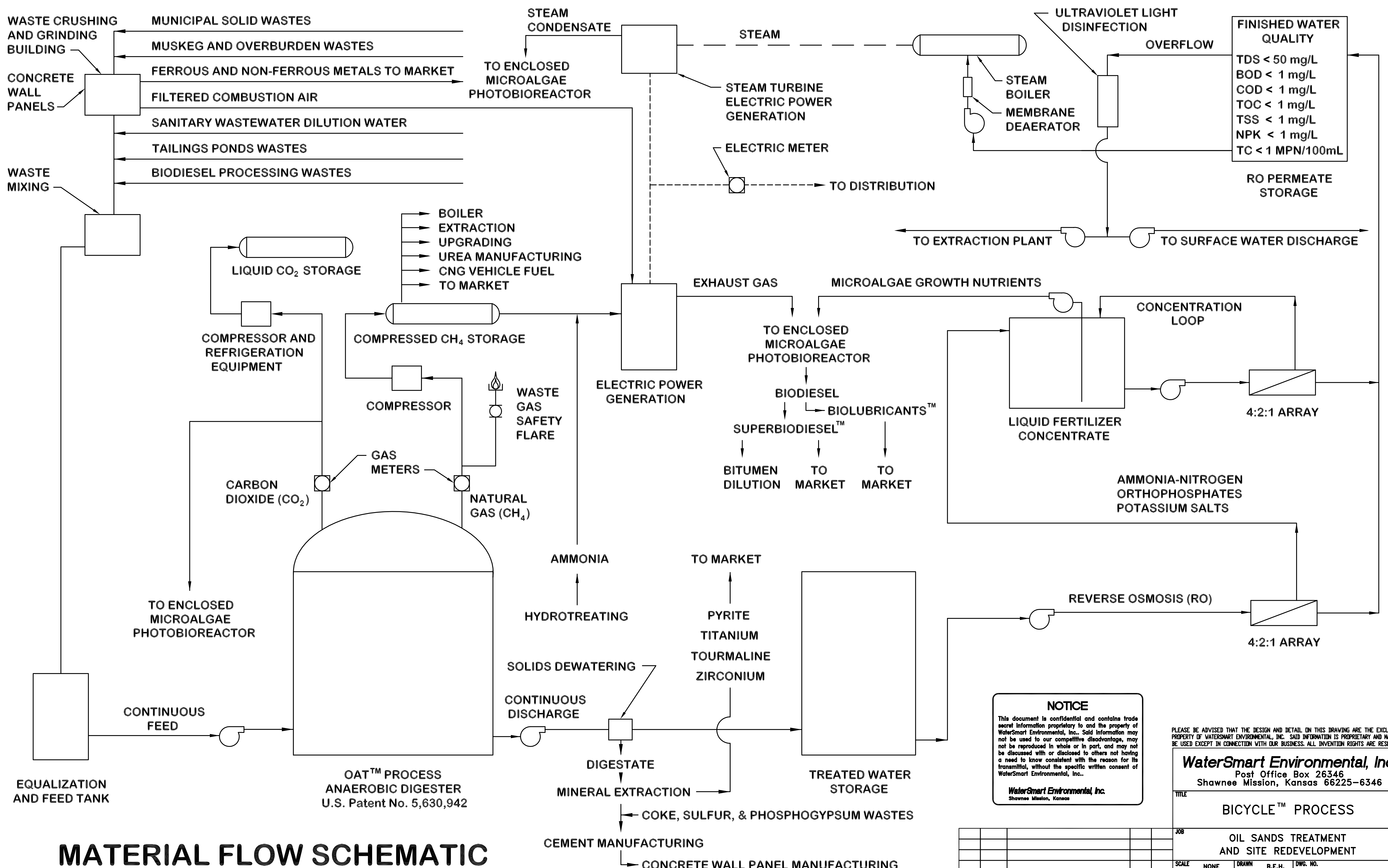
The inexpensive methane gas produced can be used at the project site for extraction, upgrading, and to power generation equipment. The inexpensive methane gas may also be used to revitalize the local phosphate and urea fertilizer industries. At the end of the day phosphogypsum stacks, tailings ponds, methane gas emissions, carbon dioxide gas emissions, MSW piles, coke piles, sulfur piles, and overburden waste piles begin to disappear while additional energy supplies are being produced.

The inexpensive anaerobic digestion produced methane would likely enable the full realization of in-situ oil sands making the entire Canadian crude bitumen production fully sustainable over the life of the entire bitumen deposits. As the microalgae photobioreactor continues to grow in size and capacity the production of SuperBiodiesel™ will gradually replace the production of bitumen thus making the energy production facility permanently sustainable. The proposed total solution for site redevelopment fully complies with all Kyoto Protocols thus tending to reverse global warming. WSE Drawing No. S-5099 identifies the Material Flow Schematic of the proposed total solution technology.

The Engineers, Chemists, and Scientists at ***WaterSmart Environmental, Inc.*** welcome your inquiries with enthusiasm.

Plot Date 1-9-06/1500 Plot Scale 1=1 Produced On AutoCAD Release 2000i

MATERIAL FLOW SCHEMATIC



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REV.	DATE	DESCRIPTION	BY	CHK

DO NOT SCALE DRAWING. USE DIMENSIONS ONLY.

TITLE: BICYCLE™ PROCESS

JOB: OIL SANDS TREATMENT AND SITE REDEVELOPMENT

SCALE	NONE	DRAWN	B.E.H.	DWG. NO.
DATE	1/9/06	CHECKED	C.G.S.	S-5099