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Biodiesel@MIT

On May 13, 2008, the MIT student newspaper, *The Tech*, ran a cover story describing how the student run Biodiesel@MIT project, which aimed to reprocess used vegetable oil from campus dining facilities into eco-friendly biodiesel fuel to power campus shuttle buses, was about to close shop. A year earlier, Biodiesel@MIT had won a prestigious $25,000 prize from the mtvU/General Electric Ecomagination Challenge. The project team members had planned to use the prize funds to purchase a biodiesel fuel processor and to retrofit space on campus to house the equipment. Joseph D. Roy-Mayhew '08 originally came up with the project in 2006 as part of an IAP (Independent Activities Period) seminar, and had "hoped to have the project fueling MIT's shuttles by the start of the 2007 academic year." Unfortunately, things hadn't gone quite as planned. Fifteen months after securing the capital and garnering national notice for their innovative proposal, Biodiesel@MIT was no more. So it seemed when this story ran in the May 13, 2008, *The Tech*.

What went wrong? What can we learn about organizational decision-making by looking more closely at the fate of this energy conservation project at an organization of close to 20,000 members arrayed in four basic population groups: students, faculty, administration, and support staff for the physical plant?

The Energy Issue

In 2006, MIT estimated that it used over 800 gallons of diesel and 2,300 gallons of gasoline yearly to run shuttle buses around campus. In July 2007, the Institute began replacing aging gasoline vehicles with diesel vehicles, reversing the fuel consumption balance to 2,400 gallons of diesel and 700 gallons of gasoline. In addition, MIT uses approximately 150 gallons of diesel and 1,700 gallons of gasoline per month to run maintenance and landscaping vehicles and equipment. Cumulatively across all uses, MIT estimated in 2007 that it would be using approximately 30,000 gallons of diesel annually for fueling purposes.[1]

Although diesel is a more efficient fuel (with more energy per gallon available for powering a vehicle), its lack of availability relative to gasoline, higher purchase cost and poor performance for early diesel vehicles had prevented widespread adoption in the US during the 20th century. European tax systems favored diesel because of the better mileage and over time improved the engines considerably for automobiles as well as railroads, making them more readily available.

"A diesel engine gets more miles-per-gallon than an equivalent gasoline engine…

[1] The biodiesel proposal was confusing with regard to annual v monthly consumption. Can we get this checked?

because diesel fuel has a higher energy density – on average, a gallon of gasoline contains 85 to 87 percent of the BTUs (British Thermal Units) of energy of a gallon of diesel fuel. Diesel engines are also more efficient than their gasoline counterparts because more power is produced as a result of the higher compression of the air/fuel mixture. Today's gasoline engines have compression ratios of about 10:1 to 11:1, while the compression ratios in diesels can be as high as 25:1. The higher the compression ratio, the more power generated. The much higher compression ratio means diesel engines have to be heavier and more robust. This means they are more expensive to build, but the higher cost is offset by much longer lifetimes. For instance, we've seen Mercedes-Benz diesels with 350,000 or more miles on the odometer running great on the original engine. Because of higher component weight and high compression ratios, diesels operate at lower rpms, producing lots of low end torque but less horsepower. "[2]

Why bio-diesel?

Recycled biodiesel is produced by coverting used vegetable oil from cooking into fuel for engines. When burned in internal combustion engineers, it has significantly lower CO2 emissions than standard diesel fuels. It is currently the only alternative fuel to have completed the EPA-required Tier I and Tier II health effects testing under the Clean Air Act.[3] Over its life cycle, commercial – rather than recycled - biodiesel is less greenhouse gas intensive than petroleum-based diesel, although biodiesel created from virgin vegetable oil emits more pollutants from agricultural and electricity generation than when produced from recycled oils. Importantly, recycled biodiesel has significantly lower Co2 and life cycle emissions than commercial biodiesel because the input is local used vegetable oils left over from cooking. Thus, the agriculture, transport, and crushing steps of the commercial biodiesel generation process are bypassed. When used vegetable oil is recycled at a small scale, the electricity consumed during production of biodiesel is greater per metric ton; however, even with the increased emissions from this electricity consumption the result in lower overall emissions when compared to petro-diesel production and the initial processes in commercial biodiesel production.

Biodiesel is made through a chemical process called transesterification whereby the glycerin is separated from the fat or vegetable oil. The process leaves behind two products -- methyl esters (the chemical name for biodiesel) and glycerin (a valuable byproduct usually sold to be used in soaps and other products). Biodiesel (meeting ASTM D6751 standards) refers to the pure fuel before blending with diesel fuel. Biodiesel blends are denoted as, "BXX" with "XX" representing the percentage of biodiesel contained in the blend (ie: B20 is 20%

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[2] http://www.greencar.com/articles/difference-between-diesel-gasoline-engines.php, 1/22/2011.

[3] Clean Air act

biodiesel, 80% petroleum diesel).

Biodiesel contains no sulfur or aromatics, and use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide and particulate matter. A U.S. Department of Energy study showed that the production and use of biodiesel, compared to petroleum diesel, resulted in a 78.5% reduction in carbon dioxide emissions. Moreover, biodiesel has a positive energy balance. For every unit of energy needed to produce a gallon of biodiesel, 3.24 units of energy are gained.[4] Although recycled biodiesel requires more electricity, it is the most renewable and efficient fuel over its life cycle.[5]

- Petroleum-based diesel requires 1.1995 fossil fuel units for 1 unit of fuel. Commercial biodiesel requires 0.31; recycled biodiesel, 0.2090.
- Over its life cycle, petroleum-based diesel emits 633.28gCO2/g/bhp-hr.[6] Commercial biodiesel emits 21.55% of this amount and recycled biodiesel emits 2.42% of this amount.
- The life cycle energy efficiency (fuel energy divided by total energy needed to produce fuel, including the fuel itself) of petroleum-based diesel is 83.28%. Commercial biodiesel is 80.55% and recycled biodiesel is 99.1%.
- Tailpipe NOx emissions are, however, 8.89% greater for biodiesel than for petroleum-based diesel.[7]
- Life cycle NOx emissions are 13.35% greater for commercial biodiesel than for petroleum-based diesel, and 4.36% greater for recycled biodiesel than for petroleum-based diesel.

However,

- Tailpipe CO emissions are 68% lower for biodiesel than for petroleum-based diesel.

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[4] National Biodiesel Board – www.nbb.org

[5] Biodiesel@MIT, March 2007 Proposal.

[6] EPA Tier 1-3 Nonroad Diesel Engine Emission Standards g/kWH (g/bhp.hr)

[7] Nitrogen oxides (NOx) are formed when nitrogen (N2) and oxygen (O2) are combined at high temperatures and pressure during the combustion of fuel. All fuels, such as gasoline, diesel, biodiesel, propane, coal, and ethanol, emit NOx when burned.The EPA estimates that 49% of NOx emissions come from on-road and off-road vehicles, 27% from power generation (electric utilities) and the remaining 24% from industrial, commercial and residential sources. Since the passage of the Clean Air Act in 1970, all primary air pollutants have decreased - except NOx, which has increased by 10%. NOx is an odorless gas when combined with particulate matter appears reddish-brown (smog). It is known to contribute to asthma, emphysema and bronchitis, aggravates existing heart disease, damages lungs. It is a component in ground-level ozeon and smog, contributes to acid rain and leads to oxygen depletion in bodies of water, upsetting the chemical balance to aquatic environments, contributes to global warming and climate change. It may also contribute to biological mutations.

- Tailpipe SOx emissions are eliminated in biodiesel.
- Life cycle SOx emissions are 8% less for commercial biodiesel, and 93% less for recycled biodiesel than diesel.

Because biodiesel can be manufactured using existing industrial production capacity, and used with conventional equipment, it provides opportunity to provide energy domestically, thus addressing issues concerning energy security as well as deficit reduction. "For instance, in 1996, it was estimated that the military costs of securing foreign oil was $57 billion annually. Foreign tax credits accounted for another estimated $4 billion annually and environmental costs were estimated at $45 per barrel. For every billion dollars spent on foreign oil, America lost 10,000 – 25,000 jobs."[8]

Why Biodiesel@MIT?[9]

In its March 2007 submission to the Ecomagination Challenge, Biodiesel@MIT proposed to supply 25,000 gallons of B20 to cover MIT's annual diesel usage, replacing 5,000 gallons of petro-diesel with biodiesel at a ratio of 1 part biodiesel to 4 parts petro-diesel.[10] Biodiesel would supply approximately 20% of MIT's diesel needs by recycling used cooking oils from campus kitchens. The plan would be environmentally and economically beneficial.

If implemented, the recycled biodiesel produced from used vegetable oil would, over its life cycle, reduce CO_2 emissions by a factor of 40,[11] by over 108.1 tons a year, the equivalent of taking 9.3 fossil-fuel powered cars off the road.[12] In addition to reducing emissions, the proposed biodiesel system would turn waste into a usable resource by reducing costs associating with disposing cooking oils as well as the pollution from transporting the disposed oils. By recycling used vegetable oil on associated pollution from its transport. MIT would resemble more of a closed looped sustainable system and start to "walk the talk" of sustainability.

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[8] National Biodiesel Board – www.nbb.org

[9] This text borrows from Biodiesel@MIT, March 2007.

[10] "Since B20 is a blend of 20% biodiesel and 80% petro-diesel, this goal would require the annual production of 6,360 gallons of pure biodiesel (B100). Biodiesel fuel is typically blended with petroleum-based diesel to maintain engine performance, with the blending percentages denoted by Bxx where xx indicates the biodiesel percentage in the blend." Biodiesel@MIT, March 2007.

[11] Roy-Mayhew, Joe. "Comparative Life Cycle Analysis of Diesel, Commercial Biodiesel, and Biodiesel
produced from WVO." <http://web.mit.edu/zepster/Public/Biodiesel/Comparative%20Life%20Cycle%20Analysis%20of%20fuels.doc>. Cited in Biodiesel@MIT, March 2007, p. 5.

[12] Unit Conversion: (5,000gallons/year)*(10.07kg CO2/galdiesel)*(2.2lb/kg)*((1-.0242)percent reduction)
Emission Facts: Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel.
<http://www.etieco.com/content-files/EPA%20emissions%20calc%20420f05001.pdf>. Cited in Biodiesel@MIT, March 2007, p.5.

Furthermore, the biodiesel project had research and teaching components, serving as a model for the MIT Energy Initiative (MITEI), displaying to local and national audiences MIT's commitment. From its outset, Biodiesel@MIT was part of the Institute's educational program, having been initiated through a student workshop and collaboration of 16 students, supported by approximately 20 faculty with whom they consulted. The entire process of converting used vegetable oil to biodiesel could serve as a living classroom for students at MIT and others in the local Cambridge and Boston areas. The processor, its inputs and outputs could be available for study and modeling for various subjects including chemistry, chemical engineering, or systems engineering, as well as a simple logistics problem for entrepreneurship and small business classes, possibly with the economics of the production used as a case study.

Implementing Biodiesel@MIT

To begin, Biodiesel@MIT proposed a two-stage model. In the transition stage, 200 gallons of B100 would be produced per month to test the process and product. This transitory stage would be scaled up to a steady-state stage with production of 5,000 gallons of B100 per year, which would provide 25,000 gallons of usable diesel fuel, 20% of MIT's usage at the time.

To bring this plan to fruition would require capital, space and coordination with service and facilities staff and fuel provision processes.

The project leaders approached Institute administrators before even finalizing the project design, way back in 2006. Basically ignored by the administration, they were advised to find independent sources to fund the project and space to house it. The team considered four different locations, all of which would need modifications to support the processor's water, power, sewage or safety demands. The team projected $3000 for safety purposes.

After winning the GE Ecomagination competition with a $25,000 prize, the team looked for space to house the converter, storage and distribution processes. At the same time, the prize money was delayed in arriving and coordination between finding spaces, ordering the converter and renovating spaces occupied the team for the next year. For over one year, 2007-2008, the team looked for sites on campus, receiving $35,000 estimates from facilities for renovation of two different spaces. The estimates included items the team had not anticipated, especially safety, sewage and related costs.

Although "the $35,000 was beyond the project's prize money (which was also needed to purchase a $15,000 fuel processor), MIT's Committee for Review of Space Planning (CRSP), reporting to the Provost, offered to loan money to support the project" (Tech May 13, 2008). Given what they experienced as stalling and lack of interest, the team was surprised by CRSP's offer to share the expenses. All agreed that the loan would be paid back by the Institute purchasing the biodiesel from the processor.

However, estimates from the Environmental Heath and Safety office and the facilities staff kept rising. Eventually, the recycling area costs increased to $60,000 and then to $137,000. CRSP was on board for the $60,000 but $137,000 was stretching their own budgets.

The increased costs were only partially specified, although safety and fire equipment was a large part.

Team members had no idea that so much renovation would be involved to retrofit a space for the processor, and how much safety protection was going to be necessary. Thus, their original project plan had significantly underestimated the project costs when they submitted their proposals. The team was simply not aware of all the environmental, health and safety issues would be involved in a fuel processor, especially fire suppression and spill mitigation. The Environmental Health and Safety staff identified these issues and began to design responses.

During the 2007-2008 year, the Facilities department was also undergoing leadership and organizational changes, eventually splitting the department into two divisions. The Biodiesel team ended up working with personnel who had been on the job only a few months. "Facilities sort of admitted that they … didn't originally carry out a … robust enough analysis of each location," Sara Barnowski '10, 2008 President of the Biodiesel@MIT team. Nonetheless, CRSP and Facilities managed to bring costs back down near $60,000 and assigned a manager in the Facilities Department to direct renovations of the lower level of the Grounds Garage, where campus maintenance equipment is stored. With this agreement in place, the project team began the legal work to purchase the processor; MIT required them to purchase a commercial bioreactor rather than make their own. With an augmented team including UROPS, the Biodiesel@MIT moved ahead, expecting renovations to the garage to be complete by May 2008.

After purchasing the $15,000 processor, hiring 3 UROPS, and thinking that they had everything in place, the project team learned from CRSP in early May (May 8, 2008), that installation in the garage was not feasible, but that installation in W92, a building currently housing Student & Administrative Information Systems (SAIS), Information Services & Technology (IS&T), Student Services Information Technology. This seemed a peculiar choice compared to the Grounds Garage. More importantly, this space would need nearly $80,000 renovation, $20,000 more than the garage space. At $80,000 the implementation of Biodiesel@MIT was far in excess of similar projects elsewhere in the U.S. About $50,000 was estimated for the health and safety systems.

Unfortunately, CRSP could not provide more than it has offered when the project was $60,000; "there is a limit to how much we can put into one student project," chair of CRSP explained. "We have lots of requests... at some point in the future, maybe things will change."

The team was left with few options. They considered off campus locations but that did not seem likely. When the May 13, 2008 story ran, the team was considering options to cancel the processor purchase and return the $25,000 prize money. They had already brokered of fuel swap with a shuttle leasing company to avoid non-profit/for-profit issues. "Money or not," the Tech reported, "the failure to bring a biodiesel process to MIT may take away from MIT's educational experience." Barnowski elaborated: "There's definitely a loss of an academic resource. Course 10 has implemented a lot of biodiesel modules for Chemical-Biological Engineering Laboratory 10.28," including "projects to design quality control kits for biodiesel processors, but now students have no place to test their designs or see their real-world applications." She was disappointed that the project would not be implemented. "The people I've talked to feel that is really unfair and hypocritical ... to be pushing new Energy Initiative [when] even this project with so much funding and support couldn't get implemented," she said. "We had a lot of theoretical support from higher up in the administration," but no one seemed to take on the project. "No one was really specifically willing to donate their time, or money, or their space to the project. It sort of got lost in the middle."

September 2008: Biodiesel@MIT Finds a Home

In September 2008, CRSP finally located a space in which to house the biodiesel processor, and requiring little renovation– the same site the team had proposed 2 years earlier. NW14, the Francis Bitter Magnet Lab has a multipurpose room with water, electricity, load dock access and meets MIT Environmental Health and Safety specification, making it a perfect place for the biodiesel processor. Unfortunately, the space was inhabited by a Course XII EAPS – Earth, Atmospheric and Planetary Sciences graduate student doing dissertation research. The push from Biodiesel, Barnowski said, pushed the student to finish faster. The project team renewed their purchase order and planned to move in October 2008 when the minor renovations would be complete.

The teams final preparatory work focused on synchronizing the Student Activities office, Campus Dining, and the Grounds Department (in Facilities) to get used vegetable oil transported to NW14.

September 2009

After 2 years of space frustration, with public dissolution of club in university media, CRSP and Facilities finally found space for a processor – the same site the students had proposed 2 years earlier – and after 1 yr of renovation and reactor installation/testing, fuel is finally being produced.

The team succeeded in making its first batch of biodiesel fuel in August, 30 gallons of slightly cloudy, golden-colored fuel. In September, they finished a second batch. "Before the fuel can actually be poured into the tank of a shuttle bus, though, it has to be tested under standards set by ASTM International (originally known as the American Society for Testing and Materials), an independent safety standards and testing organization, to assure that it's free of contaminants and has the correct "flash point" for ignition. "If it passes that," says Biodiesel@MIT vice president Kyle Gilpin, a graduate student in EECS, "then we will pass it off to facilities to use in their equipment."[13] The initial batches were used for lawn mowing equipment, with later batches passing tests for 20% biodiesel to supply the campus shuttles.

Questions for class discussion:

(1)A campus student movement succeeds after several years in getting MIT President, Susan Hockfield, to commit to reduce MIT carbon footprint but only after other major universities also signed on. Turning waste oil from dining facilities into fuel took 5 years. Why it did it take so long? Does this project fit with MIT values? What are these? Why did the project need reframing to fit better with MIT values? If MIT is an energy leader, why not an environmental leader?

(2) Can the story be seen as three years of frustrating but nonetheless incremental movement?

(3) How is this effort positioned, and not positioned, within recognized university categories?That is, within labs, departments, chains of command, etc.? What more would you need to know to answer this question?

(4) How did biodiesel@MIT work within the bureaucratic hierarchy? How did the team handle the complexity of a 20,000 person organization? Who had the power to make the decisions to move ahead? Where were the incentives and who would benefit?

(5) How does change take place?

[13] "Used frying oil to power MIT Shuttles," physorg.com, 23 September, 2009. www.physorg.com/news172920458.html.

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