SOLVENTS ENVIRONMENTAL IMPACT AND PHARMACEUTICAL SOLVENT RECOVERY

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ABSTRACT

Industrial and manufacturing firms commonly rely on solvents for a multitude of tasks: making products, cleaning and degreasing machinery and surfaces, working with materials such as coatings and paints and facilitating chemical reactions. Many corporate sustainability programs are seeking eco-friendly solutions around the employment of organic solvents, which are volatile organic compounds (VOCs) that have environmental and health effects. Many organic solvents are carcinogenic or toxic. According to the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor, millions of U.S. workers are exposed to solvents on a daily basis. Solvents present health hazards, the agency says, including "toxicity to the nervous system, reproductive damage, liver and kidney damage, respiratory impairment, cancer and dermatitis

Due to the fact that solvent regeneration is the most energy-intensive step in this type of cleaning process, modern solvent systems are equipped with heat recovery devices. These devices are being continuously improved. Today’s systems also are equipped with automatic distillation power adjustment to adapt to actual conditioning requirements, thus further reducing energy consumption and operating costs.

This paper describes the use and waste of organic solvents in pharmaceutical manufacturing and the possible impact that greenhouse gas legislation, in the form of a carbon tax, may have on solvent usage and pharmaceutical manufacturing costs. It also will review a financial model for solvent recovery in light of the appropriate rate of return on capital and sensitivity to greenhouse gas legislation, as well as the implications on state Pollution control board (PCB) and Central Drugs Standard Control Organization (CDSCO) administration validation.

Key words: Solvents; environment; Pharmaceutical Solvent Recovery

EXECUTIVE SUMMARY

Pharmaceutical manufacturing is the most solvent-intensive of all chemical processes. Instead of recycling spent solvents, manufacturers incinerate a vast majority of the solvents on-site as a means to generate energy. The decision to burn rather than recycle has been driven by simple financial analysis and return on investment (ROI). At current prices, the cost difference between the heat energy value of burning spent solvents and the replacement cost of those solvents with virgin material has not been sufficient to meet the industry’s required rate of return. At closer look, however, these calculations are flawed. Applying the same ROI rules for production capital expenditures to investments in solvent recovery can be overly simplistic and inconsistent with financial theory.

As the U.S. government looks to establish mandates for greenhouse gas emissions, companies may change their approach to how they use spent solvents. Because pending legislation could dramatically increase the cost of spent solvent incineration, manufacturers may determine that recovering these solvents may have the best impact on the company’s bottom line. As time progresses, solvent recovery will likely become a “must-invest” decision for the majority of pharmaceutical manufacturers

VALIDATION

Changing from virgin to recovered solvents will likely require revalidation. How extensive this effort will be depends on the exact wording of the original validation documentation. In general, validation batches will need to be completed to demonstrate that the quality of product can be maintained using recovered solvents. Many firms use the material data sheets provided by the solvent manufacturer to document validation purity levels, even if those purity levels are not required. This can make solvent recovery needlessly more expensive. It is important therefore that during R&D and process scale up, solvent specifications are kept as broad as possible and the term “recovered” or “recycled” is used in the documentation.

VALUE EQUATION

In today’s sustainability-focused environment, it’s important to keep in mind that pharmaceutical processes are developed on sound economic principals. These processes may appear wasteful and unsustainable when one takes too narrow of a view of the value equation. Economic decisions are based on maximizing the return on invested capital, which requires manufacturers to optimize valuable process resources. In the case of pharmaceuticals, the scarcest resources are not solvents, but rather investment capital and cash flow.

Pharmaceutical business models are dominated by three primary factors:

- Price or value the product creates in improving the health of the patient
- Market or size of the reachable patient population
- Cost of development and certification of the product

Investment capital and cash flow are the scarcest resources due to the length of time and level of
risk that occurs between the investment period (new drug discovery and validation) and market sales. Therefore, alternative uses of capital, such as manufacturing projects, must earn the required rate of return demanded of drug discovery, according to traditional economic theory.

During the patent period, drug prices are high and manufacturing margins are robust. So even though pharmaceutical manufacturing costs and operations are dominated by solvents, the high margins and alternative capital demands reduce the incentive for recovery and recycle investments. In general, solvent recovery investments have failed to meet the ROI hurdle.

Generic drug manufacturers face a different price and market environment. Their much slimmer manufacturing margins provide stronger incentives for continuously improving manufacturing efficiency. Even here, solvent recovery investments have been timid due to the high fuel value of
the solvents. It is interesting to note that almost all pharmaceutical organic solvents have a thermal energy value (calorific value) greater than coal.

ATOM ECONOMY

The atom economy looks at the overall efficiency of output creation regardless of price abstractions. It is simply an equation of resources in versus resources out. In its simplest form, it is just a counting exercise, counting all the "atoms" that go into making the product as compared to the total number of atoms in the product. This is important because it is believed that over time the value equation and the atom economy will converge as the price of the product falls to its marginal cost to manufacture, when the product becomes generic. Both views are important in determing the sustainability of a process. They simply answer different economic questions. The value equation answers the question, "Does it make money?" while the atom economy asks "Does it make sense?"

The value equation is easy to determine because it is just the difference between cost and sale price while a detailed engineering analysis is required to determine the atom economy. When each process consituent is considered from cradle to use, the average pharmaceutical synthesis often contains thousands of process steps.

Each process step is accompanied by some yield loss resulting in a low cumulative yield propagation. More over, virtually every step creates spent solvent where consumption is many times greater than the cumulative yield losses. Applying industry averages, for each kg of tetralone produced, 200 kg of waste is created. This generates an atom economy index of 0.005 (1/200), which is a measure of efficiency or lack thereof. Contrast that to the average atom efficiency of basic petrochemical production of propane with an atom index of approximately 0.97. This results from high yield in the synthesis, as well as the reuse or selling of all byproduct.

The atom economy of a process is important because proposed carbon tax legislation will be applied to the atom economy and act similar to a value-added tax. Each process step that utilizes energy, vents carbon dioxide or creates organic waste added to the tax on the product. Basically, a carbon tax is a penalty on the inefficient use of carbon.

THE APPROPRIATE ROI

The required rate of return on an investment is typically an average of investment classes ranging from high-risk to moderate- to low- or no-risk investments. In the case of solvent recovery, the typical investment class and context would typically be considered moderate-risk manufacturing equipment. Most manufacturing equipment is considered moderate risk, because its return is a direct function of the demand for the product in the market and can change rapidly due to a variety of factors

A solvent recovery investment actually reduces a company's supply chain, thus revenue and profit risk. Solvent recovery also should be considered an insurance policy against future supply-chain disruptions.

CONCLUSION AND NEXT STEPS

Impending global-warming legislation offers an economic incentive to reduce carbon-dioxide generation. If approved, new cap-and-trade regulations will dramatically improve the ROI in solvent recovery for pharmaceutical companies and, more importantly, change the investment analysis context from one of cost savings to one more directly focused on sustainability and business continuity. Bottom line: solvent recovery offers a simple, low-risk method to reduce your carbon footprint and help shield your company from significant adverse effects of environmental legislation.

Because of their extensive use of solvents and high mass leverage, pharmaceutical companies should determine the impact of a carbon-dioxide tax and start preparing action plans now. In the short run, investing in solvent recovery offers companies an effective profit-protection strategy. In the long term, reducing reliance on solvents with high imputed carbon dioxide will be necessary.

We recommend that pharmaceutical companies consider the following actions:

- Collect data on solvent usage
  - Volume of each solvent used
  - Composition of "waste solvent streams"
  - Volume of each "waste solvent stream"
  - Purity requirement for each solvent (with and without re-validation)
- Establish appropriate rate of return
  - Identify personnel responsible for sustainability and green initiatives
  - Discuss investment with responsible parties, get support and sponsorship
  - Determine "appropriate" rate of return for this type of investment
- Complete funding and tax homework
  - Global warming incentives
  - Tax credits

- Low-interest financing
- Energy credits, rebates (state and local utilities)
- Determine position on carbon tax or cap and trade
- Structure of investment (capital, service contract, outsource)

• Determine life-cycle impact of each solvent
• Work with experienced technology partner like Rockwell Automation for help in calculating ROI (capital investmen requirements, ROI tools and project strategy, planning and implementation)

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