Good engineering practices in water and waste sectors;
past and current bad practices and solutions

MOVING TO UTILITY OF THE FUTURE

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Cordell Samuels is the O&M Consulting Business Unit Manager for Cole Engineering. He has 38 years of experience in the operations and maintenance of large wastewater treatment plants and other large industrial facilities. He has managed all aspects of some of Canada's largest wastewater treatment facilities including Duffin Creek and Ashbridges Bay. Mr. Samuels has been the President of the Water Environment Federation (WEF) and has helped produce the first Ontario Utility Management Forum in 2015. A resourceful, detail-oriented professional, Mr. Samuels has experience in management, operations and training of facility personnel. He is genuinely intent in developing others to foster their long-term success and growth, uses initiative to deal with issues proactively, and acts independently in decision-making. Mr. Samuels displays adaptability in responding to a changing work environment. He uses innovation to enhance performance by being creative, promoting new ideas, and introducing new solutions and procedures. He also displays leadership to create and communicate a vision and engage others in its achievement.

Abstract

Conventional treatment of water for human consumption and treatment of wastewater for protection of the receiving water bodies and the environment has been credited with being the most important contribution to public health in the last 100 years. While this is undoubtedly true, many of the processes and final disposal of used water have been in need of changes in order to improve efficiency and cost. The disposal of treated water usually at a great cost, and their discharge back to the water courses and the environment has been determined to be less than cost effective. In addition, the discharging of methane from digesters, or the burning of the methane gas has proven to be wasteful and contributes to the proliferation of greenhouse gases. The building of large facilities to treat waste from very large communities of thousands or even millions of people is becoming more difficult as financing is costly and difficult to obtain. New initiatives to address these issues include water reuse from wastewater facilities, and energy recovery to make facilities energy neutral or even energy positive. Recovery of nutrients such as phosphorus and nitrates are also objectives that add to efficiency. This paper focuses on new initiatives in facilities design that are modular, and which can be built to serve small groups or communities, complimented by investigating new treatment technologies, in order to enhance benefits from these more compact treatment units and facilities.

Introduction

Urban sanitation has evolved from the 18th century norm of dumping human waste into the streets, through the era of sewage collection but little treatment from the mid-1800s through the early 1900s, to early treatment efforts of the early to mid-1900s, to the Clean Water Act era of federal intervention requiring secondary or additional treatment following the Act's passing in 1972. According to a recent poll involving 11,341 readers conducted by the British Medical Journal, the advent of modern sanitation, collection and treatment of human wastewater prior to discharge was the single most important public health advance of the last two centuries.

While this is undoubtedly true, many of the processes and final disposal of used water has been in need of change in order to improve efficiency and cost. The disposal of treated water back to the liquid environment is usually at a significant cost. In addition, the discharging of methane from digesters into the atmosphere, or the burning of methane gas, is wasteful and contributes to the proliferation of greenhouse gases. The building of large facilities to treat waste from large communities of thousands or even millions of people is becoming more difficult as financing is costly and difficult to obtain.

New initiatives to be discussed include water reuse from wastewater facilities, energy recovery to make facilities energy neutral or even energy positive, and recovery of nutrients such as phosphorus and nitrates. New initiatives in facilities design that are modular and which can be built to serve small groups or communities will be discussed. Effective disposal of water will also involve investigating new treatment technologies, which will allow for the above-mentioned more compact treatment units and facilities.

Wastewater and Public Health

Wastewater is any water that has been adversely affected in quality by human activity. This can cause disease to spread in the community if the water is not treated properly. Wastewater can originate from a combination of domestic, industrial, commercial or agricultural activities, surface runoff or stormwater, and from sewer inflow or infiltration.

Nutrient Recovery

The Nutrient Recovery Facility recovers phosphorus and nitrogen from the wastewater and transforms them into a highly pure, slow release, environmentally friendly fertilizer which can become an annual revenue stream. According to the Water Environment Federation (WEF), *"the next generation of wastewater treatment has zero net impact with regard to energy use, greenhouse gas emissions and nutrient discharge by 2040. Achieving this goal will require a dedication to overcoming the technical barriers, financial constraints, and regulatory disincentives limiting nutrient removal, greenhouse gas emission reduction, and energy neutrality in the treatment of wastewater".*

Nutrients, commonly nitrogen and phosphorus, are found in agricultural and home fertilizers and also are generated by livestock, industrial, and municipal systems. Specific sources include confined animal feeding operations, row crop farming, industrial pre-treatment facilities, septic systems, municipal and industrial stormwater, and Water

Resource Recovery Facilities (WRRFs). According to the U.S. Environmental Protection Agency (EPA), more than 100,000 miles of rivers and streams, close to 2.5 million acres of lakes and ponds, and more than 800 square miles of bays and estuaries are affected by nitrogen and phosphorus pollution in the US. Nutrients in excess can be harmful water pollutants. Excess nutrients can lead to algal blooms, which can result in hypoxic zones and can turn to harmful algal blooms (HAB), which produce toxins. HABs received national attention in summer 2014 after a cyanobacteria bloom in Lake Erie caused Toledo, Ohio, to issue notices to nearly half a million people to not drink, cook, or bathe with city water.

WRRFs too are part of the solution. With advanced biological and chemical methods, facilities already can achieve significant nutrient reductions. The WEF roadmap lays out a strategy for facilities to achieve zero net impacts from nutrient discharges by 2040. WRRFs also can reclaim nutrients. Biosolids are a source of nitrogen and phosphorus. Fertilizers can be energy-intensive to manufacture, and the supply of some nutrients, such as phosphorus, is limited. Recovery not only prevents nutrients from entering waterbodies as point source discharges but provides a supply of these essential resources.

In 2013, NACWA, the WEF and the Water Environment Research Foundation (WERF), released the *Water Resources Utility of the Future: A Blueprint for Action* to capture the ground-breaking transformation happening at wastewater utilities as they progressed beyond simply complying with the Clean Water Act.

Clean water agencies have been increasingly embracing and implementing innovative approaches and technologies related to energy production, water reuse, green infrastructure, non-traditional partnerships, and moreover, to improve environmental performance while lowering costs, increasing revenue and helping boost the local economy. This triple-bottom-line approach is at the heart of the Utility of the Future (UOTF) initiative and is rapidly spreading throughout utilities of all sizes.

There are a variety of processes that can be used to clean up wastewaters depending on the type and extent of contamination. Most wastewater is treated in industrial-scale wastewater treatment plants (WWTPs) which may include physical, chemical and biological treatment processes. Most wastewater treatment systems typically have three distinct stages of operation. The treatment plants have a primary treatment stage to reduce the Biological Oxygen Demand (BOD) (the amount of oxygen required by aerobic microorganisms to decompose the organic matter in a sample of water) and amount of settleable solids in the wastewater. The secondary treatment achieves further biological removal of BOD, solids, and other pollutants. Pathogens and other toxic pollutants are removed in the tertiary stage through the use of disinfectants. The typical stages of a wastewater treatment system are illustrated in **Figure 1** below.

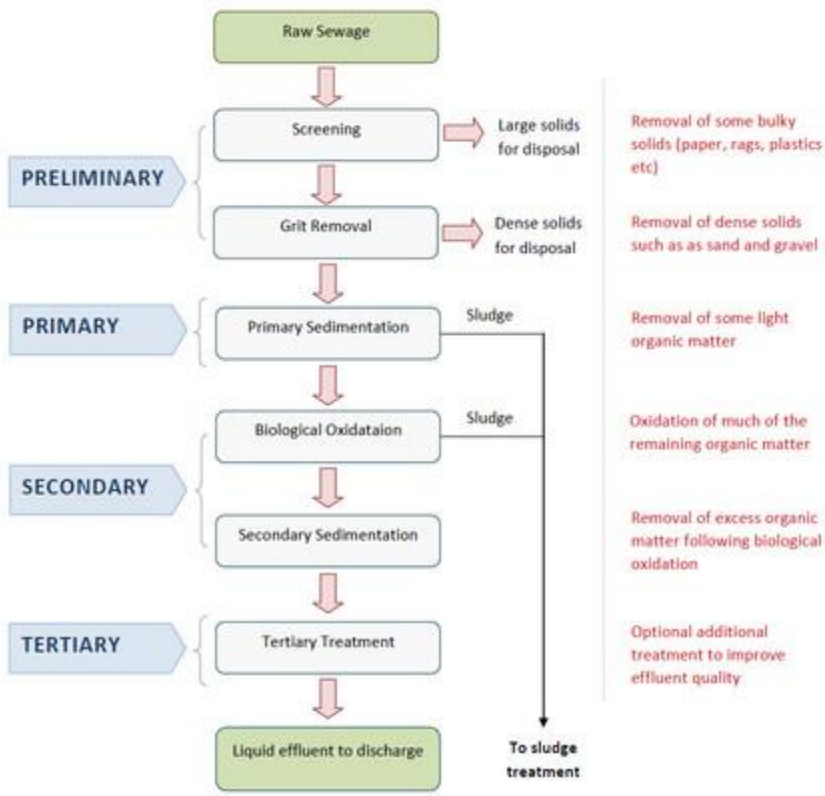

Figure 1: Typical Stages in a Conventional Wastewater Treatment Operation

(Source: http://www.lboro.ac.uk/well/resources/technical-briefs/64-wastewater-treatment-options.pdf)

The major disadvantages associated with current wastewater treatment practices are:

- Many wastewater treatment processes generate large amounts of sludge (solid waste material) that must be sent off-site for disposal. Handling and disposal of this sludge is typically the largest single cost component in the operation of a wastewater treatment plant.
- Most wastewater treatment processes cannot effectively respond to diurnal, seasonal, or long-term variations in the composition of wastewater. A treatment process that may be effective in treating wastewater during one time of the year may not be as effective at treating wastewater during another time of the year.

- High energy requirements will make many wastewater treatment methods unsuitable for low per-capita energy consumption countries.
- High operation and maintenance requirements, including production of large volumes of sludge, make them economically unviable for many regions.

Sludge is a mixture of solid wastes and water, and hence it is usually treated by filtration or sedimentation. Biological methods of sludge removal include processes such as coagulation, agglomeration with the help of microbes, etc.

Current Wastewater Treatment Process: Sludge Removal

The sludge accumulated in a wastewater treatment process must be treated and disposed of in a safe and effective manner. The purpose of digestion is to reduce the amount of organic matter and the number of disease-causing microorganisms present in the solids.

The most common treatment options include anaerobic digestion, aerobic digestion, and composting. Incineration is also used albeit to a much lesser degree. Choice of a wastewater solid treatment method depends on the amount of solids generated and other site-specific conditions. However, in general, composting is most often applied to smaller-scale applications followed by aerobic digestion and then lastly anaerobic digestion for the larger-scale municipal applications.

New Technologies for Sludge Removal from Wastewater

The Innovative Concept: Automated Chemostat Treatment™ (ACT)

The process is flexible and easy to integrate, fully automated, controllable and significantly more efficient than current practices. The results are a virtually sludge-free output of water which can be returned directly into the environment or processed further.

The scientific concepts behind ACT are the application of an appropriate bacterial cocktail for a given type of polluted water, and an innovative chemostate.

The process is maintained in a balanced state of bacterial growth and organic compound degradation. Because of the low concentration of bacterial cells, no aggregates are formed, and each bacterium acts as a single cell which increases the surface available for the process and enables biodegradation at a much higher efficiency. The BPC-ACT™ operates as a continuous flow reactor without using activated sludge. The bioreactor can thus be applied on site while using available infrastructure with high flexibility for modulation of the process saving dramatically in operational and maintenance costs. ACT simplifies the process by reducing bio-sludge and chemical usage as well as reducing black sludge creation. In addition, ACT's flexibility and modularity enables to handle low and high capacities and contamination, to be used for fresh and salt water as well as to be easy modify and Increase capacities. ACT's output is virtually sludge-free, meeting strictest disposal standards. This trailblazing "green" process is easy to modify and can be used in various sites, including oil refineries, oil storage farms, drilling sites, marine ports, contaminated reservoirs and storage tanks.

KemiCond Process

The KemiCond® process can be divided into three steps: acidification, oxidation and flocculation. The basic idea is to improve dewatering by breaking down the water - retaining structures which are formed in sludge.

Acidification is achieved just before dewatering by treating the sewage sludge with sulphuric acid at a pH below 5. This causes inorganic salts, such as iron phosphates and calcium carbonates to dissolve. The dissolution of salts contributes to a sludge volume reduction. Oxidation is achieved by adding hydrogen peroxide, H_2O_2; a strong oxidizing agent.

In the presence of various transition metals hydrogen peroxide decomposes into hydroxyl radicals. This facilitates dewatering and prevents phosphorus from reaching the recipients. The dissolved calcium is removed from the sludge with the filtrate and thus the ash content in the sludge is decreased. Addition of hydrogen peroxide assists in reducing odours, as it oxidizes organic matter such as mercaptans and sulphides.

The Utility of the Future

Today's utilities have evolved and matured over decades. Technical engineering entities and utility managers now embrace sophisticated management approaches and have developed innovative finance capabilities. These institutions have accomplished many of their goals: they are operationally efficient collectors, managers of household and industrial wastewaters and protectors of the quality of the waterways. In recognition of these achievements, these utilities are increasingly renaming themselves "Water Resources Recovery Facilities" or "Clean Water Agencies."

The most progressive of today's clean water agencies are defining the UOTF. Instead of solely collecting and transporting wastewaters as far downstream as possible to central treatment plants where wastes are cleansed to meet permit limits prior to discharge to waterways, the UOTF transforms itself into a manager of valuable resources, a partner in local economic development, and a member of the watershed community seeking to deliver maximum environmental benefits at the least cost to society. It achieves this by reclaiming and reusing water, extracting and finding commercial uses for nutrients and other constituents, capturing waste heat and latent energy in biosolids and liquid streams, generating renewable energy using its land and other horizontal assets, and using green infrastructure to manage stormwater but also to improve urban quality of life more broadly. These actions benefit the utility in the form of reduced costs and increased revenues. However, they also deliver environmental, economic, and social benefits both locally and nationally.

Resistance to change is strong, reinforced by regulatory pressures, strained utility budgets, political reluctance to raise rates, customer confusion about the benefits of innovation, skyrocketing demands for capital competing for every dollar, risk and regret associated with technology failure, and venture capital looking elsewhere for faster and safer returns.

Defining the Utility of the Future: A New Model Is Emerging

While traditional public health and environmental protection will always be central, the model for the UOTF is evolving in new directions. It contemplates a new business approach where instead of simply collecting, treating, and disposing of municipal and industrial wastewater, the UOTF recognizes that its inputs are valuable resources. As such, its objectives are to separate, extract, reuse, or convert valuable water, energy and commodities from wastewater while using utility assets in innovative ways to reduce costs, increase revenues, and strengthen the local economy.

The UOTF also seeks to engage more fully with others that share the water resource through watershed-based approaches, innovative partnerships and adaptive management techniques to ensure that actions maximize environmental benefits.

This is no longer an aspiration. With the help of technology developers, innovative clean water agencies are beginning to take these steps today. Clean water agencies are becoming more energy and operationally efficient, recovering energy from biosolids, reusing effluent and biosolids, recovering nutrient and other constituents, transforming waste streams into valuable new commodities, taking steps to support economic expansion by setting capital investment priorities to meet the needs of industry, and working collaboratively with other water quality interests within their watersheds.

Non-potable wastewater reuse (for industrial cooling, toilet flushing, landscape irrigation, fire fighting, and ecological enhancement), while still in its infancy, is increasing rapidly and offers cost-effective solutions to stressed water supplies and in rapidly growing regions. Water reuse builds on the success of water conservation programs, which have allowed utilities to better manage infrastructure expansion needs. While non-potable wastewater reuse has doubled over the last decade to about 2 billion gallons a day in the US, this represents only about 5% of total municipal wastewater discharged, according to the WaterReuse Association. Where water scarcity threatens local economies or community stability, reuse offers "water independence" and greater local control of future economic growth.

The UOTF will be more distributed, automated, and circular. Reuse facilities, for example, are likely to be distributed because it will make little economic sense to reuse wastewater after it is transported long distances downstream to centralized facilities and pumped back upstream to points of application.

Significant savings in energy, infrastructure replacement, and maintenance are possible with distributed, local reuse for cooling or landscape irrigation. Automation and controls, web-enabled mobile devices, and cloud computing will help drive this transition and, more generally, enable unattended operations linked to central control rooms that monitor operations, adjust processes in real time, communicate with customers, and manage the entire commercial process.

UOTF processes will be circular in the sense that water, nutrients, solids, heat, energy, and other constituents will be reused and not discarded.

The UOTF will be more involved with others within its watershed and greener as a result of energy efficiency and generation of renewable energy as well as in terms of the design of facilities and the choices of solutions, particularly green infrastructure, natural land-based solutions in place of concrete and steel containment and treatment structures to manage stormwater.

Working with others at the watershed scale will enable clean water agencies to implement water quality solutions that save them and their communities' money while preserving valuable resources for their most productive uses, including for example, partnering with drinking water utilities on conservation to reduce sanitary wastewater and expand wastewater infrastructure.

UOTF Leadership in the US

The East Bay Municipal Utility District (EBMUD) serving Oakland and surrounding areas east of San Francisco implemented an innovative program to blend community food waste (e.g. fats, oils, and grease from local restaurants and food waste from wineries and farms) with their own biosolids to produce enough methane-generated electricity to meet their own demand and send excess to the local grid. This 55,000 MW-hr/yr, $31 million biogas project saves the utility $3M per year in energy and contributed to EBMUD's reduction of 13,300 metric tons of carbon from its 2010 baseline.

The Hampton Roads Sanitation District (HRSD), serving 1.6 million people in 17 cities in southeast Virginia, employs a unique nutrient recovery process in its Nansemond Treatment plant, one of nine large treatment facilities. In an innovative partnership with Ostara Nutrient Recovery Technologies, Inc., HRSD recovers and converts about 85% of phosphorus and 25% of ammonia from its dewatering process into a slow release fertilizer, Crystal Green™.

Fertilizer revenues offset both capital and operating costs, effectively reducing discharge of nutrients at no cost to HRSD and compared to alternatives, saves ratepayers money. It also increases overall plant efficiency and replaces mined phosphorus fertilizer generating net economic and environmental gains.

Dozens of clean water agencies have installed solar photovoltaic networks and/or erected wind turbines, converting their land and building assets into sources of renewable energy to power their facilities, reduce energy costs, and cut carbon emissions.

UOTF Transformations Worldwide

Similar transformations are occurring around the world. Singapore's Public Utility Board has been treating and reusing municipal wastewater to achieve drinking water quality since 2003. With three "NEWater" plants in operation today, reused wastewater supplies 30% of Singapore's water needs, including supplies for industrial processing and blending with reservoir supplies for potable reuse. By 2060, Singapore estimates that NEWater will meet 50% of the nation's water needs.

Australia has embarked on a $1.5 billion “Water Smart Australia” program to transform the way utilities and other institutions use and manage their water resources with broader and faster uptake of smart technologies. In one example, two private firms, Veolia Water and AquaNet Sydney, acquired the license to supply Sydney Water, the public utility serving Australia’s capital, with about 5 million gallons per day (mgd) of recycled water under a 20-year agreement. In this $100 million project, treated secondary wastewater is diverted from discharge pipes and membrane filtered (ultra filtration and reverse osmosis) prior to storage and pumping to various sites for reuse as industrial cooling and process water, as well as irrigation and fighting fire.

Conclusion

The future of wastewater treatment worldwide is in transition. Similar to Green Energy the pace of change is slow but as has been demonstrated by many companies the objectives are no longer aspirational but achievable. This paper indicates that there are barriers to change, but with will and determination, and a vision of the future that is different to the recent past we will see the desired changes. This is not simply change for change’s sake; the returns to the taxpayer can be substantial both financially and environmentally.

Appendix A

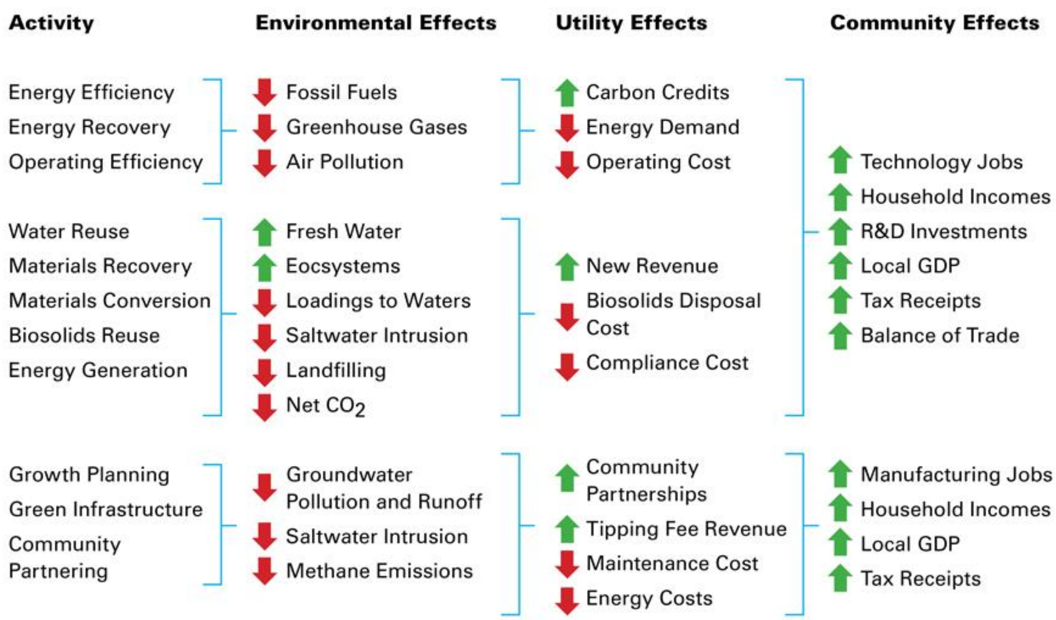

Figure 2: Environmental, Utility and Community Effects of New Initiatives

Motivation	Activity	Innovation
Financial Strengthening (Increased Revenues, Reduced Costs)	Water Reuse Materials Recovery Materials Conversion Biosolids Reuse Energy Generation Energy Recovery Operating Efficiency	• Industrial Cooling, Recharge, landscape, Golf Course Irrigation • NH4, P Compounds, N Compounds, Metals • Bioplastics, Pyrolysis Fuel Oil, Algal Biomass, Solid Fuels, Fertilizers • Liquid / Solid Fertilizer • Photovoltaics, Wind Turbines • Methane, Hydrogen, Heat Recovery • Automation and Smart Operations, Asset Management, Sourcing
Environmental Sustainability	Watershed Processes Energy Efficiency Green Infrastructure Infiltration / Inflow Control	• Alternatives to Point Source Controls • Energy Efficiency Equipment & Networks • Green Roofs, Urban Parks, Porous Pavement, Leak Detection & Repair
Social and Community Well-Being	Growth Planning Green Infrastructure Infiltration / Inflow Control Community Partnering	• Sectoral Expansion, Targeted Upgrades, Managed Package Plants • Urban Runoff Controls • Biowaste Conversion to Methane

Figure 3: Motivation for New Initiatives

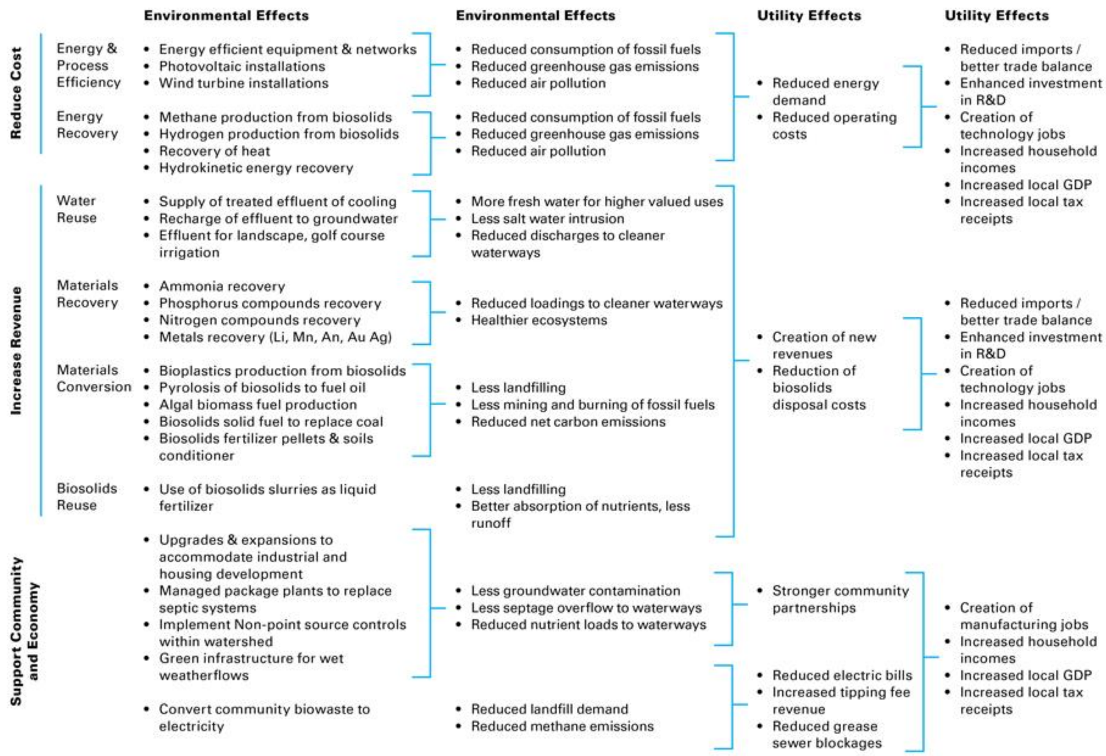

Figure 4: Environmental and Utility Effects of Processes