

**NexantThinking™**

**Special Reports**

**Municipal Solid Waste:  
Using Our Refuse**

Brochure  
April 2014



 **Nexant**



## Special Reports

# Municipal Solid Waste: Using Our Refuse

Brochure  
April 2014



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## 1.1 THE OPPORTUNITY TO RECOVER AND RECYCLE WASTES

Disposal of Municipal Solid Waste (MSW) is a pressing economic and political issue in many jurisdictions around the world. It is logistically challenging due to its distributed generation (door-to-door) at a relatively low solids density. Additional challenges include geographic/seasonal variability, odor, vermin, health risks, and other problematic properties. MSW is comprised of the total of materials thrown away by individuals and small businesses (that is, “post-consumer” waste, trash, refuse, or garbage). MSW is generally collected by local governments or private carters, and is different from hazardous waste and nonhazardous industrial/commercial waste, (e.g., construction and demolition debris, automotive shredder fluff, waste treatment sludge, etc.).

This analysis only deals with MSW, which globally poses a massive challenge for local governments and society at large. However, it also represents a great potential resource for the conventional and renewable energy, fuels, materials and chemicals sectors. For example, according to U.S. EPA, U.S. DOE, and USDA statistics, the total volume of organic wastes (paper, food, yard wastes, and wood) that potentially could be used for feeding bio-renewable processes is comparable to the volume of urban tree trimmings. The total of these MSW fractions equals about one-quarter of the United States’ estimated “billion ton” biomass waste resource<sup>(1)</sup>. An important attraction of MSW is that users are paid to take ownership of it, while agricultural and forest “wastes” can have costs up to \$80 per ton.

The MSW stream has long been “mined” for energy to generate power and to recycle aluminum, steel, paper fiber, and some plastic containers. However, the option of using the paper fraction as biomass feed for renewable chemicals and liquid fuels production has been much less practiced. In addition, the options of using mixed plastics as pyrolysis or gasification feedstock for fuels or chemicals, or as a source of materials for plastic lumber, are only now being developed at commercial scale.

A report prepared by the Tellus Institute for the Natural Resources Defense Council and other groups entitled, “More Jobs, Less Pollution”, estimates that the impact of raising the country’s recycling rate to 75 percent from the current roughly 35 level could create 1.5 million new jobs and reduce carbon emissions equal to taking 50 million cars off the road. The report points out that it could also cut dependence on foreign oil, increase exports, save water, improve air quality, and reduce toxic waste. It could also help mitigate the depletion of mineral resources and fossil fuels and feedstocks.

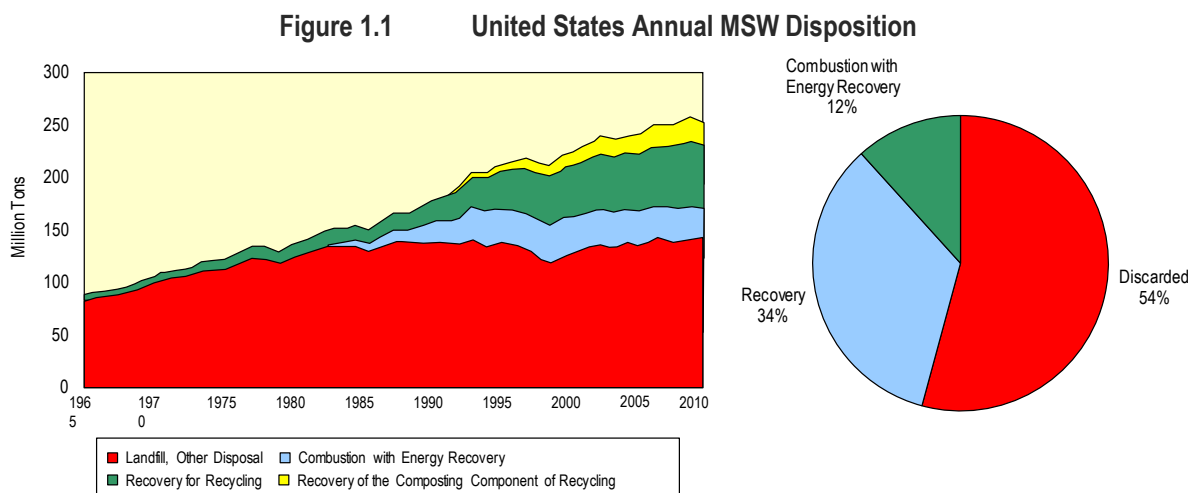
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<sup>1</sup> U.S. DOE

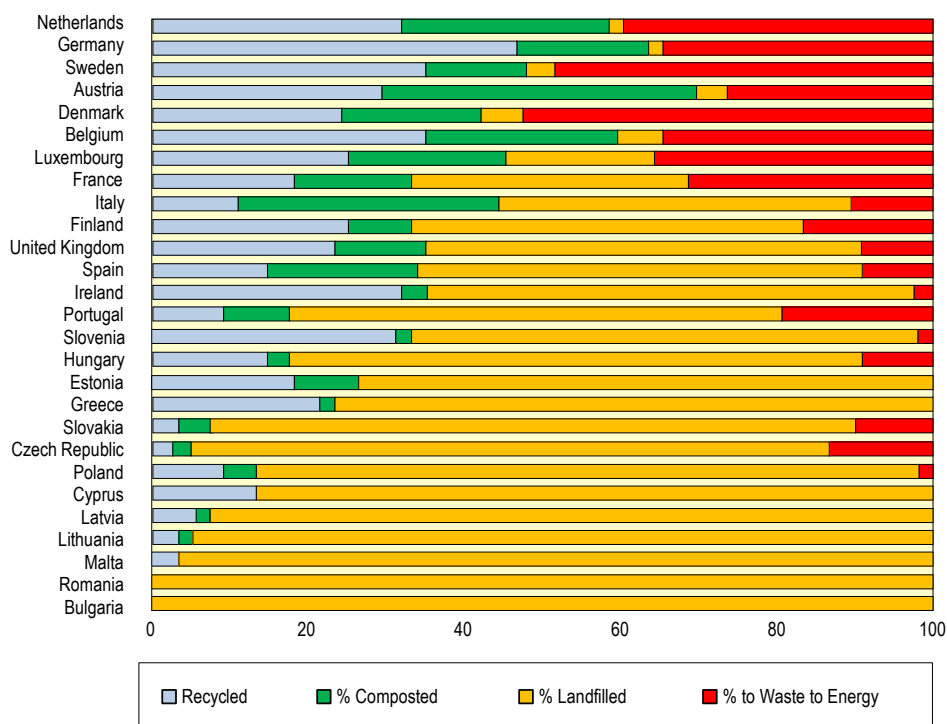
## 1.2 CURRENT DISPOSITION OF MSW

### 1.2.1 Landfilling is Still Significant

Despite all that has been learned about materials recovery and recycling and much effort expended towards developing better alternatives, progress has been spotty, leaving the total recycling rate in the United States at only about 35 percent. As shown in Figure 1.1, landfilling is still the dominant disposal mode in the United States although the absolute amount sent to landfills has stabilized since the early 1980s. Figure 1.2 illustrates the wide spectrum of disposition modes of Western and Central European regional countries.



**Figure 1.2 Spectrum of European Regional National MSW Disposition**



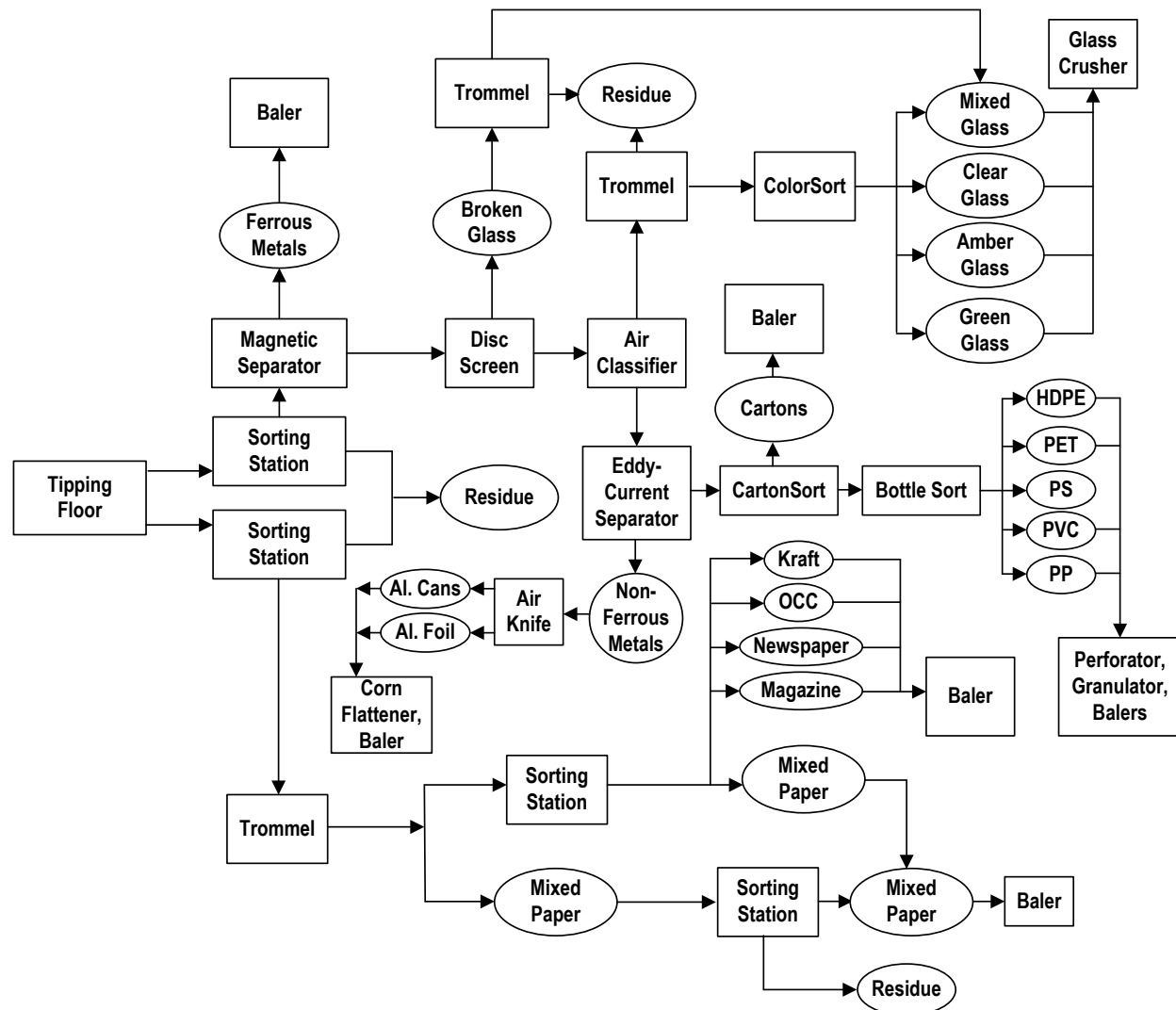
Earth Engineering Center, Columbia University (based on Eurostat 2008 data)

### 1.2.2 MSW Recycling and Disposal

A number of types of policies and regulations affect MSW component generation and/or recycling at the source. These include container recycling deposit laws, which result in highly segregated PET bottle and aluminum can streams (when returns are by machines reading bar codes). Such recycle streams have relatively high prices. Curbside recycling laws and collection programs, in contrast, can result in streams of mixed plastic containers plus metal containers, or the plastics and metals may be separated, plus a paper/paperboard stream. HDPE also has a relatively high recycle rate among plastics because its common use in large milk, juice, and household cleaner and liquid laundry detergent containers makes it easily hand-sorted. Some municipalities have enacted bans on disposable plastic retail bags or certain types of polystyrene food service containers, while many stores provide for recycling plastic bags. Otherwise, plastic recycling has been disappointing compared to the high rates for aluminum and steel cans. Aluminum has very high recycling rates, as does steel, including scrapped automobiles, other vehicles, aircraft, and other large durable structures and scrap from OEM processes.

In many parts of the world the combustible components of garbage are burned in various ways to produce power and heat for sale, in a strategy called waste-to-energy (WTE). Other venues aerobically compost the biodegradable, or “putrescible”, fractions, including food, yard, and some paper wastes to reduce the volume and produce useful soil amendments. Others anaerobically digest slurries of the same fractions, sometimes together with sewage sludge or manure, to produce biogas for heat and power production. In many jurisdictions, Material Recovery Facilities (MRFs) are used to separate recyclable plastics and metals (steel and aluminum) and glass, mostly as discarded containers, to produce organic “Refuse-Derived Fuel”, or RDF. Figure 1.3 illustrates a block diagram of a typical MRF. Often pelletized, RDF is mostly paper, but may also contain some polymer films and resin coatings. This material can be gasified, pyrolyzed, digested chemically, or even fermented in various established and emerging biobased processes.

Figure 1.3 Block Diagram of a Typical MRF System



Note: System Layout of New York City 150 TPH MRF

### 1.2.3 Landfill Pollution

The streams of MSW that are not handled in any of these ways, along with the residuals of these processes (ash, sludge, and other unfermentable or unrecoverable components, etc.) are disposed of in so-called "sanitary landfills". These are distinguished from hazardous landfills and those handling certain commercial, industrial, or construction and demolition debris. Anaerobic digestion of the putrescible paper, food, and yard waste contained in landfills normally produces landfill gas (LFG), a highly contaminated mixture of methane and CO<sub>2</sub>, as well as contaminated leachate, both of which need to be managed. Vented LFG comprises an unacceptable fugitive emission of methane, which is a greenhouse gas 23 times as potent as CO<sub>2</sub>. Although many landfills worldwide still have uncontrolled methane emissions, many flare much of this gas to produce a much less problematic emission of CO<sub>2</sub>, or they clean and utilize it in various ways for its energy content. In the United States, between 20 to 80 percent capture of LFG for destruction or use is estimated over the life of landfills. LFG emissions are being addressed by the UN CDM initiative, which monetizes credits for controlling these emissions in certain

developing economies to provide set-asides for Western European countries that are committed to reducing global carbon emissions.

### 1.2.4 Recycling has Enormous Benefits

The strategy of environmentalists and of many practical political and business leaders to more economically manage generation of MSW is to “Reduce, Reuse, and Recycle”.

- **Reduction** in either disposable or durable items or systems means providing the same or similar function with less material. This strategy is manifest for instance in the reduction that has occurred of disposable PET water bottles to paper-thinness and in the shortening of their cap and seal threads, and also in the introduction of concentrated liquid laundry detergents
- **Reuse** in industry is manifest in reusable shipping containers, as with tote bags, ISO containers, and pallets
- **Recycling** rates of aluminum, steel, and copper metals are very high, and PET and HDPE have relatively high rates among the commodity polymers

As these strategies are implemented, the volume and composition of the MSW stream will change, but other forces, such as population and GDP growth, rising incomes in developing countries, and social trends such as increased popularity of prepared foods, curbside recycling, bans on or market de-selection of certain materials, etc. also will impact the waste stream. In the title of the proposed report, we are including in the term “reuse”, the use of RDF as feedstock for bio-renewables and WTE, which is not exactly the same as reusing a manufactured container or durable item.

## 1.3 ECONOMICS OF RDF RECOVERY FOR BIO-RENEWABLES

Currently, the composition of MSW among industrialized and developing economies varies drastically. While paper and plastics used in packaging and publications dominates the waste stream in industrialized countries, in developing countries it tends to be dominated by wet wastes such as putrescible wastes from food preparation and post-dining, as well as by plant debris.

Table 1.2 presents a summary of a Nexant model of the economics of a typical MRF designed to separate and prepare the paper (cellulosic) fraction of MSW in pelletized form as RDF. These pellets are easily handled, shipped, and stored. They may be:

- Co-fired with coal or with other biomass to make power and heat
- Gasified to obtain syngas
- Pyrolyzed to make bio-oils and char
- Hydrolyzed and fermented or chemically reacted to produce renewable chemicals or liquid fuels

In this example the producer receives a credit of \$50/ton for the MSW as well as credits for recovered metals, so that the production cost for RDF is \$19.4/ton. If a higher credit of \$70/ton is assumed for MSW, which is still a substantial discount to what New York City pays, the overall credits will exceed the costs of producing RDF, and it will have a “cost” of minus \$55/ton.



**Table 1.1 Model Cost of Production of Refuse-Derived Fuel (RDF)**  
*(negative indicates a credit to RDF producer)*

	<b>\$/ton</b>
MSW (cost of \$50/ton)	(186.00)
Recover Metals	(56.00)
MSW Rejects	136.00
Variable Costs	11.40
Fixed Costs	114.00
Cost of RDF	<b>19.40</b>

#### 1.4 WHO SHOULD SUBSCRIBE?

Many of the aspects of MSW have been covered in earlier Nexant multiclient reports, including those on:

- Plastics recycling
- Biomass gasification
- Commodity biomass feedstocks, including MSW
- Liquid biofuels production from MSW by various routes
- Waste fats oils and greases (FOGs) use in oleochemicals and biodiesel production
- Many Waste-to-Energy engagements, and other relevant single client engagements

This study is the first comprehensive, integrated treatment of MSW by Nexant. This report describes and analyzes the technologies and model and analyze the economics of recovering various material and energy resources from MSW. It also looks at utilizing MSW's organic fractions as biomass resources for producing energy, biofuels, and renewable chemicals in a variety of key ways. Nexant also reviews policy and market trends that are affecting the composition of the waste stream.

Any organization that produces or sells products that significantly impact the volume of MSW or its composition should subscribe to this report. This report is also of value to firms that wish to understand the potential for utilizing this resource for recovered industrial materials and/or biomass. Such recovery can offer lower feedstock costs and a better life cycle profile than practically any virgin resource, along with other benefits. Political jurisdictions and agencies, NGOs that are highly incentivized to mitigate the costs of MSW management burdening society may also be interested in subscribing.

The study was completed in April 2014.

### 2.1 OBJECTIVE

The objective of this study is to evaluate MSW as a resource for energy and chemicals production. To meet this objective, the relevant market, policy, technical, and economic aspects of MSW are evaluated, with the objective to identify the most economically and socially attractive technical options for its processing and use.

### 2.2 SCOPE

To meet the study objective, Nexant undertakes the following tasks:

- Overview of MSW generation, composition, and economics, including logistics and tipping fees
- Identification of drivers to avoid landfilling – considering factors such as the UN CDM program, fugitive methane in LFG, groundwater pollution
- Overview of materials separation and recovery in MRFs (material recovery facilities)
- Technology overview of metals recycling
- Technology overview of plastics recycling (physical and chemical, at a high level)
- Assessment of technology and economics of RDF production in an MRF
- Assessment of technology and economics for Waste-to-Energy (WTE)
- Feeding organic fractions to various bio-renewable fuel and chemical processes (gasification, pyrolysis, fermentation, chemical treatment/catalytic, and hybrid processes (e.g., Fulcrum, TRI, Micromidas, KiOR, etc.))
- Relevant example of technology and economics of composting/fermenting putrescibles to produce bio-gas (methane plus CO<sub>2</sub> for power generation, or production of chemicals) and/or with production of soil fertility amendments
- Screening and ranking of various routes to MSW processing

The geographic emphasis of the study is on the United States, with parallels or contrasts provided to other regions and developing economies.

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The evaluation of conventional technology is based on Nexant's in-house information regarding process technology, augmented by contacts with government regulators, licensors, engineering contractors, and other experts. Analyses of emerging technologies are built up from reviews of patents, public domain information, and discussions with technology development companies and engineering contractors.

Nexant utilizes proprietary and commercial state-of-the-art software tools to develop its technical and economic evaluations. These tools are well-established in the chemical process and bio-renewables sectors and a number are employed by major engineering contractors.

Commercial information and forecasts are developed from Nexant's extensive in-house databases and models, augmented with selected regional fieldwork. Market projections also consider relevant government regulations.

While this report will represent an original effort by Nexant based on its own research, it is understood that portions of the report will involve the collection of information from third parties, both published and unpublished, but none falling under secrecy agreements. Therefore, Nexant does not believe that the report will contain any confidential technical information of third parties.

### 4.1 BACKGROUND

Nexant was established on January 1, 2000 and prior to that date, the staff of Nexant operated as a separate consulting group within a major engineering company. Nexant is now an independent company owned by a number of investors. Nexant acquired Chem Systems, Inc. in 2001, and the combined entity ("**Nexant**") now has access to even more enriched and extensive experience and resources, offering services that include:

- Master planning/feasibility studies
- Technology evaluation
- Techno-economic and commercial analyses
- Financial evaluation (cashflow modeling, etc.)
- Benchmarking
- Monitoring project implementation

Nexant is very well qualified to undertake the technical, commercial, economic and financial evaluations, from its own offices, without the need to subcontract. Owing to its extensive experience, and known for its "out-of-the-box" thinking, Nexant has also received the honorable award of "Best Large Consultancy" by the British Consultants and Construction Bureau. . Nexant was judged the winner for its outstanding contribution in developing a real-time, on-line chemical industry simulator.

### 4.2 DESCRIPTION OF SERVICES

Nexant is a specialist, not a generalist company. Our area of expertise is the energy and process industries, including oil refining, natural gas, petrochemicals, polymers, chemicals, pharmaceuticals, and fertilizers. Our business has been built upon providing broad management consultancy services to leading companies active in these industries, and also to banks, suppliers, governments and others interested in these sectors. Nexant's strengths lie in its combination of techno-economic, commercial, and strategic capabilities. These core competencies are described below.

### 4.2.1 Technology/Economics

From its foundation in chemical engineering and industrial chemistry, Nexant offers distinctive expertise in process technology and economic analysis. Assignments may be performed on a separate, stand-alone basis or as input to broader consulting engagements.

Services include:

- Economic and financial analyses of projects or businesses
- Valuation of assets or businesses
- Technical audit of existing facilities
- Project feasibility/planning
- Technology innovation and assessment
- Comparative/competitive technology audit and appraisal
- Process design and cost estimation
- Technology availability, screening, licensing arrangements
- Contractor pre-qualification, evaluation and selection
- Project management, including resident advisory services
- Price, margin and profitability forecasting

This discipline is supported by comprehensive economics, cost and price databases.

### 4.2.2 Commercial

Based upon a technical and commercial understanding of the industries we serve, Nexant supports clients through a variety of market and commercial activities. As with our techno-economic work, these commercial assignments may be performed on a stand-alone basis but are more normally an input to broader consulting engagements.

Services include:

- Feedstock and product market analysis
- Marketing and market research
- Supply/demand analysis and forecasting
- Studies of trends and future markets
- "Benchmarking" of costs and competitiveness
- Medium- and long-range planning

The commercial discipline is supported by databases of global supply, demand and capacity developments in all major petrochemicals.

#### 4.2.2.1 Strategic Planning

Industry specific expertise and an understanding of world market forces distinguish Nexant's work in Strategic Planning. Various innovative tools and methodologies tailored to the energy and process areas are used to challenge conventional thinking. Nexant extends its traditional project team approach to engaging clients directly in the Strategic Planning process. Interactive client consultant relationships promote consensus, a critical factor for successfully developing pragmatic, implementable solutions.

Services include:

- Definition of corporate and business visions
- Portfolio planning
- Entry strategy evaluation
- Diversification, acquisition, divestment studies
- Competitive analysis and business positioning
- Global competitiveness
- Trade flow and impact studies
- Strategic options, selection, and implementation

### 4.3 ASSIGNMENTS UNDERTAKEN COVERING WASTES UTILIZATION AND BIO-RENEWABLE FUELS AND CHEMICALS

#### 4.3.1 Single Client Studies

Selected single client studies that include coverage of utilization of waste and recycled materials:

- **Bio-Feedstock Study** – For a (confidential) client developing a fermentation platform for bio-renewable chemicals production, Nexant provided model economics for range of renewable feedstocks, including commodity crop-derived, wood waste-derived, and RDF from a MRF separating MSW
- **Waste Paperboard Feedstocks to Chemicals** – For a start-up developing a multi-step chemical catalytic route starting with cellulosic wastes such as kraft paperboard to make a bio-based drop-in replacement for a key petrochemical polymer intermediate, Nexant provided technical and market due diligence for a syndicate of private equity investors. The same company is developing a route to utilize sewage sludge and manure as process feed to produce a family of other drop-in chemicals
- **MSW Gasification Process Due Diligence** – For a developer of a process for MSW gasification to synthesize higher alcohols, which was also developing a project to utilize this technology to make next generation fuel ethanol, Nexant provided finance technical due diligence to a syndicate of banks towards filing for an IPO
- **MSW Gasification Location Studies – Alcohols Markets** - For developers of an MSW gasification technology with the intent of locating projects to make either methanol or fuel ethanol, Nexant provided market and logistics studies for proposed sites
- **Pegasus Project Development, Little Rock, AR** – Nexant analyzed all North American hazwaste and industrial waste generation; performed a project feasibility for the sponsor, Rineco, using Thermoselect Process (formerly only used in Europe for MSW gasification) – analyzed competitive economics and technologies, assessed opportunities for adding value in disposal of industrial hazardous wastes and other industrial, special solid wastes; also assessed drivers for reduction of hazardous waste generation, including industrial pollution prevention and waste destruction in cement kilns
- **Arkenol Process-Ethanol-Citric Acid** – Assisted in a due diligence feasibility study for a private client of adapting a biomass (wastepaper) acid hydrolysis/fermentation process intended originally for fuel ethanol production to producing citric acid
- **Food & Ag Waste Fermentation: Boubyan Petrochemical / MOM-ECAP / COINC** – Initially engaged in a series of three assignments by Boubyan (Kuwait) for technical and market due diligence on the IBRC (Vancouver, BC) EATAD process to digest putrescible MSW fraction (food



waste, etc.) to produce liquid and solid fertilizer/fungicide products for potential application in Kuwait. Nexant later performed similar feasibility analyses, market research, and project development assistance for MOM-ECAP to use the process in the NYC – Bronx Harlem Yards; Nexant assisted MOM in presentations to NY City Council for the project in which a broad range of MSW solutions were benchmarked; For the project as later moved to Woodbridge, NJ; Nexant led a bankable due diligence report on the final design and location of the project, which was built and is operating. This was followed up with a global market study for a potential investor in Indonesia.

- **Biodiesel Technology and Business Finance Due Diligence** - For a financial syndicate, assessed the quality and uniqueness of patents and other intellectual assets of a company and its business plan that are based on a modular plant design, systematic acquisition of waste oil and crude oils and fats resources, unique market positioning, and roll-out of a large new fleet of plants.
- **UNDP/World Bank Philippine Industrial Energy Efficiency/ESCO Workshop** – In a two-week mission to the Philippines as part of a multi-national team, Nexant audited the energy efficiency of facilities in the petroleum refining, Portland cement, pulp and paper (**recycle fiber**), and **recycle steel** sectors, compared to international benchmarks; participated in a workshop among stakeholders in the ESCO sector, employing interviews and focus groups, to determine why indigenous ESCOs were having limited success versus foreign consultants in providing their services and recommend solutions
- **U.S. AID – Methane-to-Market (M2M) Opportunities for Emerging Economies** - Driven by goals of greenhouse gas emissions reductions and economic improvement, screened and evaluated strategies and technologies for commercial use of fugitive methane (flare and leaks) from gas production, processing and pipelines, coal seams and mining, **landfills, and anaerobic decomposition** of agricultural and other biomass.
- **Multiple Technoeconomic Due Diligences** – In advance of IPOs, Nexant performed comprehensive technoeconomic analysis, including technology and markets. In such capacities, Nexant has investigated and evaluated multiple conversion technologies, including cellulose hydrolysis as well as thermochemical platforms for products from biomass
- **“Forest Refinery” Industry Evaluation** - A U.S. national laboratory retained Nexant to assess the technical and economic feasibility of a forest refinery designed to manufacture chemical products from trees and forest waste. The analysis screened a variety of biomass conversion technologies and compared the production costs and energy consumption levels of each route to conventional routes. Processes evaluated included fermentation, lignocellulose separation, lignin conversion and gasification
- **Hunest Biorefinery Market Study** - A project to revitalize a former Nitrokemia site in Hungary to convert circa 200,000 tons per year of biomass into biopolymers, green solvents, and intermediates. Nexant was engaged to undertake a market study of the commercial opportunities for the project covering mainly pricing and the European market in order to guide the company in developing its marketing strategy for the project
- **Biochemical Opportunities in the United Kingdom** - The National Non Foods Crops Center (NNFCC) engaged Nexant to provide a focused analysis of renewable chemical opportunities in the United Kingdom. The project was in part undertaken to gain a better understanding of the opportunities for the United Kingdom to integrate renewable feedstocks into its chemical manufacturing base. Nexant's analysis was used to support the development of research and development programs in both academia and industry organizations
- **Fermentation Routes to Adipic Acid: Petrochemical Competitive Benchmarking** - For a developer of fermentation routes to adipic acid (nylon intermediate), this study was to provide

- analyses of conventional petrochemical routes, issues over nitric oxide emissions, and other critical factors
- **Financial Due Diligence** - Analysis of Myriant Technologies' renewable route to succinic acid and potentially to adipic acid and other valuable green chemical intermediates. Examines technology, intellectual property position, market potential, and competitor positioning
  - **Sustainability and Plastics** - Client was interested in understanding how increased awareness of environmental issues and of the related initiatives might impact the polyolefins business in the future and asked Nexant to provide a high level review of the following conventional polymer displacement threats to conventional polymers: biodegradable polymers, bio-based polymers, and recycling. The main focus was on polypropylene in North America, but wider issues were also considered
  - **Fermentation Routes to Bio-Succinic Acid/BDO** – In a series of studies for a number of different stakeholders, Nexant evaluated technologies, markets, and competition for fermentation routes being developed for this potential raw material for polybutylsuccinate, 1,4-butanediol, and other chemicals derivatives, and compared to petrochemical routes
  - **PLA** – For this key renewable, biodegradable commodity polymer, polylactic acid, or polylactide (PLA) made from corn or sugar substrates, Nexant evaluated production technologies and markets for a number of different stakeholders
  - **Chemicals by Depolymerization of PHAs: Petrochemical Competitive Benchmarking** – For a developer of fermentation and crop-based PHA (polyhydroxyalkanoates) production that exploring the feasibility of depolymerizing these natural polyesters to make commercial chemicals (monomers, intermediates, solvents, etc.), Nexant provided analysis of the same C<sub>3</sub> and C<sub>4</sub> chemicals production via petrochemical routes, and assisted in developing process and cost models of the speculative depolymerization routes
  - **Hydrocarbon Fuels and Chemicals via Sugar Fermentation: Process Development Assistance** – For a biotech developer of sugar fermentation routes to C<sub>5</sub> hydrocarbon-based (isoprene homologues) for vehicle fuels, chemical intermediates and specialty chemicals, this was a series of three projects to provide assistance, including process flowsheet and capex review, troubleshooting, and cost reduction strategies, product recovery studies, and process safety analyses
  - **Advanced Biobutanol Process Technology, Economic, and Market Due Diligence** - For a prospective investor in this technology development, Nexant performed a broad-based feasibility study/due diligence with the full cooperation of the developer providing R&D data and existing business models for critique. Butanol was examined for its proposed fuel potential as well as for its large existing market as a solvent and chemical feedstock. The economics of the incumbent petrochemical route was compared
  - **Biopolymers for Beverage and Food Packaging** – For a U.S.-based, leading, multinational beverage and food company, Nexant performed a study of the technical and economic feasibility of using, and issues around, selected bio-based polymers for packaging in the future, including PLAs, PHAs, green polyethylene, and others. For this, Nexant evaluated and compared three radically different emerging routes to green *p*-xylene production for feeding drop-in production of green PTA to react with green MEG to make 100 percent green PET bottle (and fiber) resin
  - **Bioethylene for Beverage and Food Packaging** – For another U.S.-based, leading, multinational beverage and food company, Nexant performed a study of the technical and economic feasibility of using, and issues around, green polyethylene. For this, Nexant evaluated and compared green MEG production for PET bottle (and fiber) resin
  - **Biopolymer Value Chain** – Investigate renewable feedstocks for biopolymers, biopolymer compounding and polylactide

- **Fermentation Propanol to Green Propylene – Confidential.** This report identifies and discusses four routes to producing propylene from renewable feedstock (corn, sugarcane and glycerine). Bio-propylene, bio-based chemicals, biological route, biotechnology, genetically modified organism (GMO), and bacteria are included in the study
- **Chemicals from Corn** - This was a broad-based study for the National Corn Growers Association (NCGA) funded by the U.S. DOE, to identify and screen chemicals that could be feasibly produced from corn. The study considered a wide range of potential sugars, and fermentation-derived acids, alcohols, and other building blocks, but emphasized fuel ethanol derivatives, including basic petrochemicals, solvents, intermediates and specialties, and application of the Reactive Distillation technology sponsored by the NCGA. The basic economics of ethanol production and potential improvements, economies of scale, logistics, and other production and value chain issues, are addressed in the study

#### 1.4.1 Multi-Client Work

During the past ten years, Nexant has completed a number of major multisubscriber studies. Selected multisubscriber studies that include coverage of bio-renewable chemicals and bio-feedstocks, many of which also examine the use of waste materials, include:

- **Plastics Recycling Multiclient Study** – Jointly with Franklin Associates, a leading consultant in municipal waste stream analysis and disposition, Nexant performed a milestone study on policy, technical, economic, and practical aspects of plastics recycling.
- **PERP Report 09/10S4, Biobased Commodity Feedstocks** – A study of the technology, and economics of producing commodity biofeedstocks, which presents “costs of production” of agronomic, sylvan, and derivative sugar and oil commodities, including economics of MSW resource separation
- **PERP Report 08/09S9, PET Bottle to Bottle Recycling** - The technologies and economics of PET “bottle to bottle” recycling are presented and compared to the production costs of virgin PET; superclean (physical) and chemical recycling techniques are assessed; regional PET bottle grade supply, demand and trade forecasts are included.
- **PERP Report 05/06S2, Thermoplastic Wood Composites** - The technology and production economics for thermoplastic wood composites are presented for this growing area; polyethylene, polypropylene and PVC based composites are assessed; market outlooks for North America, Western Europe and China are presented.
- **PERP Report 06/07S4, Glycerin Conversion to Propylene Glycol** – A study of the emerging biotechnology, processing technologies and economics of producing and recovering propylene glycol from glycerine, and a comparison to conventional routes
- **PERP Report 08/09S11, Plants as Plants (PHAs)** – A study of the emerging biotechnology, processing technologies and economics of producing and recovering polyhydroxyalkanoates (PHAs), as an alternative to conventional polyesters
- **PERP Report 00/01S3, Biotech Route to Lactic Acid/Polylactic Acid** – A study of emerging biotech routes to lactic acid and polylactic acid. Processing technologies, and economics of producing and recovering lactic acid and polylactic acid are investigated
- **PERP Report 09/10S8, “Green” Glycols and Polyols** – A study of emerging biotech routes to glycols and polyols (e.g., propylene glycol and sorbitol). Processing technologies, and economics of producing and recovering glycols and polyols are investigated
- **Bio-Based Chemicals: Going Commercial** – A survey of the emerging biotechnology, processing technologies, announced project capacities, and a risk adjustment of these

announced capacities. This included coverage of commodity monomers and polymers, as well as emerging polymers (e.g., succinic acid and/or 1,4-butanediol for polybutylene succinate)

- **Plants to Plastics: Can Nature Compete in Commodity Polymers?** – A study of the emerging biotechnology, processing technologies and economics of producing and recovering commodity polymers such as polyethylene, polypropylene, polyethylene terephthalate, and others as well as a comparison to conventional routes
- **Biotransformation Routes to Specialty Chemicals** – Includes consideration of conversions of natural oils, fatty acids, fatty acid esters, fatty alcohols and fatty amines, and fermentation technologies and commercial overviews of many bio-based product markets

Nexant has also completed a number of definitive studies analyzing the business structure and opportunities for many of the recovered commodities covered in this proposed study within the context of a changing economic environment. In addition to these studies, Nexant maintains a global commercial and technoeconomic database covering principal petrochemicals, intermediates, polymers, and other materials markets potentially affected.

### 5.1 CONTACT DETAILS

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