出國報告（出國類別：考察）

考察美國畜牧場沼氣回收能源化及推動畜牧糞尿資源化

服務機關：行政院環境保護署
姓名職稱：劉峯秀技士、呂郁雯稽查督察員
派赴國家：美國
出國期間：民國 105 年 10 月 12 日至 10 月 22 日
報告日期：民國 105 年 1 月 20 日

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出國計畫名稱：考察美國畜牧場沼氣回收能源化及推動畜牧糞尿資源化

出國人姓名/職稱/服務單位：

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出國日期：105 年 10 月 12 日至 105 年 10 月 22 日

出國期間概況紀要：

本署自 104 年 11 月 24 日修正發布水污染防治措施及檢測申報管理辦法，積極推動畜牧糞尿資源化，現行已有 22 家畜牧業沼液沼渣農地肥分使用計畫審核通過，已達 105 年目標有 15 家畜牧業配合執行，惟全國畜牧業總家數 7726 家，其排放污染量大，仍未能有效改善水體水質，故本處針對畜牧業積極推動沼液沼渣農地肥分使用政策，希冀有效改善水體水質及保護環境。本次考察美國 RCM 厭氧發酵設施製造商，於賓州 Sensenig Dairy、Brubaker Farms、Yippee Farm 厭氧發酵實例，透過畜牧業集資或獨資設置大型消化槽，沼液可作為農地肥分使用，沼渣可作為牛隻畜舍墊料，純化厭氧消化後之沼氣，可發電自用或售電獲益，其執行方式與本署刻正推動沼液沼渣農地肥分使用政策不謀而合，另美國沼氣協會舉辦之 BIOCYCLE 16th Annual Conference，除有厭氧發酵設施製造公司、顧問公司或專家學者發表最新技術與實例外，美國環保署 Ag & Wasteater Biogas 領導人 Chris Voell 與與會者進行法規面及執行面意見交流，未來應可相互交流及分享法令訂定及政策推動執行成果。

活動日期	活動內容	活動地點
10 月 12 日	啟程，由桃園前往美國紐約	桃園-美國紐約
10 月 13 日	拜訪美國厭氧消化(Anaerobic digestion, AD)設備商 RCM 公司人員	美國紐約-賓州
10 月 14 日	參訪賓州 Sensenig Dairy、	美國紐約-賓州

	Brubaker Farms 及 Yippee Farm 等畜牧場參訪 Pôle Mer Bretagne Atlantique	
10 月 15 日	整理考察相關資料	美國紐約
10 月 16 日	紐約前往奧蘭多	美國紐約-奧蘭多
10 月 17 日	整理考察相關資料	美國奧蘭多
10 月 18 日	參加 Biocycle REFOR16 研討會	美國奧蘭多
10 月 19 日	參加 Biocycle REFOR16 研討會	美國奧蘭多
10 月 20 日	參訪 Alliance Dairies	美國奧蘭多
10 月 21 日	返程，由美國奧蘭多前往舊金山	美國奧蘭多-舊金山
10 月 22 日	返程，由美國舊金山前往桃園	美國舊金山-桃園

行程成果評估及心得建議：

美國畜牧場多以沼氣產量最大化為主要考量因素，故本次參訪畜牧場之厭氧消化設備皆採畜牧糞尿混合廚餘進行共消化之方式。為使厭氧消化後產物成分品質穩定以用於農地施灌，國內畜牧糞尿沼液沼渣作為農地肥分政策，目前尚未開放厭氧共消化後產物作為肥分施灌。建議未來可針對畜牧糞尿資源化之目標樣態進行評估分析，研究分析厭氧消化進料源成分對沼氣產量及操作成本之影響，以達生質沼氣產量與沼液沼渣肥分再利用之最佳化條件，促進綠色畜牧產業及循環經濟發展。

美國畜牧場採畜牧資源化經營模式，除了可降低溫室氣體排放、節省畜舍墊料及作物肥料之成本外，同時亦創造其他收入來源，包含碳權交易、販售沼液沼渣肥分與再利用墊料等。為增加畜牧業者及農民參與畜牧資源化之意願，以及順應國際環保趨勢，我國未來應推動建立畜牧業碳權交易制度及交易平台，並促進企業投資畜牧場或畜牧場企業化經營，促進國內轉型為綠色畜牧業，並提升國際競爭力。

摘要

本次出國人員為本處劉峯秀技士、呂郁雯稽查督察員，於 104 年 10 月 12 日出發，參訪行程共計 11 日（含交通），參訪地點為美國西部，主要參訪行程涵蓋紐約、賓州、佛羅里達州奧蘭多等城市。本次主要考察內容包括美國賓州及佛羅里達推動沼液沼渣農地肥分使用及實例參訪，參訪 Sensenig Dairy、Brubaker Farms、Yippee Farm 及 Alliance Dairies 等畜牧場；參與美國沼氣協會舉辦之 BIOCYCLE 16th Annual Conference，瞭解其畜牧糞尿資源化及沼氣回收發電效益，並與 RCM、GTI 厭氧消化設備製造商及 DIGESTER DOC 顧問公司討論及交換意見。

本次考察美國厭氧發酵設施製造商 RCM，於賓州 Sensenig Dairy、Brubaker Farms、Yippee Farm 等畜牧場設置厭氧消化設備之實例，透過畜牧業者集資或獨資設置大型消化槽，沼液可作為肥分於農地施灌使用，沼渣可作為牛隻畜舍墊料，厭氧消化產生之沼氣經純化後，可發電自用或售電獲益。

美國沼氣協會舉辦之 BIOCYCLE 16th Annual Conference，除有厭氧消化設備製造公司、顧問公司或專家學者發表最新技術與實例外，美國環保署 Ag & Wasteater Biogas 領導人 Chris Voell 與與會者進行法規面及執行面意見交流，未來台美雙方應可相互交流分享法令訂定與政策推動等執行成果。

美國 AgStar 計畫政策之目的係為沼氣回收能源化，提升環境、農業與經濟效益。本次考察內容與本處刻正推動畜牧糞尿沼液沼渣作為農地肥分使用政策目的—畜牧糞尿作為農地肥分，以降低畜牧廢水排入河川，促進河川水體清潔，雖略有差異，但美國推動 AgStar 計畫多年，執行方式已十分成熟，相關推動經驗、政策法令及執行細節，值得作為本署爾後推動執行工作之參考。

壹、緣起

我國河川污染的三大來源為畜牧廢水、工業廢水及生活污水，畜牧廢水污染產生量占 26.6%，影響水體清淨與河川環境品質。

水污染防治法 104 年 2 月 4 日修正公布，畜牧業者違反放流水標準或廢（污）處理設施所產生之污泥未妥善處理，罰鍰上限由新臺幣 12 萬元提升到到 60 萬元；若繞流排放，最高可處 2,000 萬元以下罰鍰，罰鍰額度大幅增加。另水污染防治費預算 103 年底已通過立法院審議，畜牧業之水污染防治費自 106 年起開始徵收。

為解決畜牧廢水污染河川之問題，且因應水污染防治法修正大幅提高罰則及 106 年起開徵畜牧業水污染防治費的配套誘因下，本署積極推動畜牧糞尿資源化，自 104 年 11 月 24 日修正發布水污染防治措施及檢測申報管理辦法，現行已有 22 家畜牧業沼液沼渣農地肥分使用計畫審核通過，已達 105 年目標有 15 家畜牧業配合執行，希冀有效改善水體水質及保護環境，以達成循環經濟之目的。

美國自 1993 年起推動農業銀星計畫 AgStar，鼓勵豬隻及牛隻飼養業者，畜牧糞尿採厭氧發酵方式處理，並將產生沼氣予以回收作為發電之用，同時將沼液沼渣作為施灌於農地作為肥分使用，為推動畜牧糞尿資源化先驅，相關法令及制度完備，值得借鏡。

貳、目的

考察美國採厭氧消化處理及回收沼氣再利用之畜牧業，了解美國推動畜牧糞尿資源再利用及沼氣回收能源化之技術、執行實例經驗，並進行意見交流與討論，以作為我國推動執行之參考。

參、考察行程

本次考察自 105 年 10 月 12 日至 105 年 10 月 22 日，共計 11 天，出國行程與內容概要如下表所述：

時間	主要內容
105.10.12(三)	啟程，出發至美國紐約
105.10.13(四)	拜訪美國厭氧消化(Anaerobic digestion, AD)設備商 RCM 公司人員
105.10.14(五)	參訪賓州 Sensenig Dairy、Brubaker Farms 及 Yippee Farm 等畜牧場
105.10.15(六)	整理考察相關資料
105.10.16(日)	紐約前往奧蘭多
105.10.17(一)	整理考察相關資料
105.10.18(二)	參加 Biocycle REFOR16 研討會
105.10.19(三)	參加 Biocycle REFOR16 研討會
105.10.20(四)	參加 Biocycle REFOR16 研討會之現訪行程
105.10.21(五)	返程
105.10.22(六)	返程

肆、 考察工作內容

本次考察行程分為美國畜牧場實場參訪及參加 BIOCYCLE 16th Annual Conference 兩部分，說明如下：

一、參訪美國畜牧場推動畜牧糞尿資源化及沼氣回收能源化

（一）賓州畜牧場實際案例參訪

RCM 成立於 1982 年，為美國厭氧消化設備廠商之一，本次畜牧場參訪係由美國 RCM 業務發展總監 Jim Muir 及採購服務經理 Ben Yoder 協助安排至賓州參訪該公司設備實例之 Sensenig Dairy、Brubaker Farms 及 Yippee Farm 等畜牧場。

1. Sensenig Dairy

（1） Sensenig Diary 位於蘭開斯特(Lancaster County)，農場畜養約 100 頭奶牛，附近區域包含該農場主人親戚的數個農場，區域內畜養總頭數約為 100 頭奶牛、2,000 頭豬和 30,000 隻雞，農場同時種植牧草供牛隻食用。農場主人(Cliff Sensenig)為落實環境保護的理念，決定投資建設沼氣發電設備，並說服鄰近親戚農場的農業廢棄物可以一併集中處理。

（2） 經過 3 年的規劃、資助、許可、建造及安裝，於 2012 年農場始完成厭氧消化及沼氣發電系統之設置，收集鄰近農場之牛糞、豬糞及雞糞，併同當地商店產生之廚餘進行處理，使用厭氧消化槽共消化產生沼氣，消化槽為地下化設置之完全混合式(CSTR)消化槽，可減少熱能損失，亦可節省地面上空間。畜牧糞尿之運送皆透過地下管線運送至消化槽，可有效降低臭味逸散，厭氧消化產物亦無異味。

（3） 厭氧消化產生之沼氣經過脫硫純化程序後，進行熱電聯產，產生清潔電能，併入公共電網，產電量約 200kW；發電餘熱煙氣導入鍋爐產生蒸氣，發電餘熱冷凝水回收熱水貯存利用，回收的熱量用於加熱消化池，農場建築物保暖或冬季預加熱用。

（4） 消化產物經固液分離後，沼渣待乾燥後，與新鮮墊料混拌，再利用於牛舍；沼液於沼液塘中穩定後，作為農場周邊牧草及蔬菜種植所需之有機肥料。

（5） 據農場主人表示，設置厭氧消化及沼氣發電設備後，所帶來的效益如下:

I.　減少異味改善社區關係。

II.　厭氧消化後之沼液沼渣幾乎無臭，且因消化料源來自牛、豬及雞糞，其內所含之營養鹽更高。

III. 除了產電銷售外，從發電機組回收的熱量加熱消化池和熱水儲備，節省燃料費用；另廚餘代處理費也為農場增加額外收入。

IV.　厭氧消化槽產物可用作農場肥料使用和畜舍墊料，節省支出。

V.　將堆肥出售給社區和其他農場作為土壤改良劑。

（6） 該農場推動建設相關現代化技術設備之過程中，所需申請核發之許可證達 21 個，來自 12 個不同的機關單位，相關許可包含區域開發、污染排放管理、能源生產及援助資金等。申請許可所需總費用為 65,000 美元。該農場推動畜牧資源化之努力，使其獲得 2014 年美國酪農業永續發展獎(U.S. Dairy Sustainability Awards)。

圖 1 Sensenig Dairy 農場俯視圖

(來源：Sensenig Dairy: Outstanding dairy farm sustainability,
https://www.youtube.com/watch?v=UHlq8jTUBHY)

圖 2 收集畜牧糞尿原水池

圖 3 收集畜牧糞尿原水池(全貌)

圖 4 沼氣收集設備

圖 5 沼氣純化設備


圖 6 沼液貯存塘


圖 7 施灌車吸取沼液


圖 8 施灌沼液槽車

圖 9 乾燥沼渣出口

圖 10 乾燥沼渣

圖 11 沼氣發電機控制盤

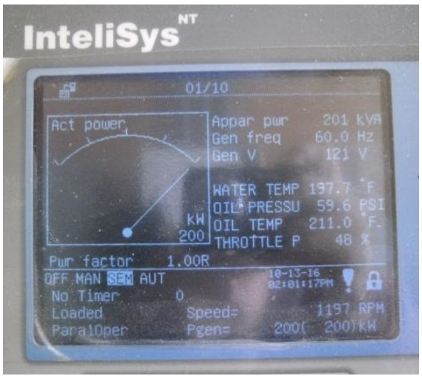

圖 12 沼氣發電機儀表盤

圖 13 厭氧消化設備控制盤

圖 14 沼氣發電設備

圖 15 沼渣作為牛隻畜舍墊料

圖 16 厭氧消化槽設置於農場小山丘之下

圖 17 場內之廚餘破碎機

圖 18 與 Jim Muir、Ben Yoder 及 Cliff Sensenig(由右至左)等人合影

2.Brubaker Farms

（1） Brubaker Farms 位於賓州 Mount Joy，占地約 1,500 英畝，目前畜養約 900 頭牛，農場中同時種植牧草供牛隻食用，農場設置一沼氣發電系統，產電量 225kW。透過每天收集牛舍中之牛糞，併同處理廚餘，使用厭氧消化槽共消化產生沼氣，消化槽採地下化設置，可減少熱能損失，沼氣經過脫硫後，進行熱電聯產、產生清潔電能，約 97%併入公共電網，約 3%為系統自用，發電餘熱用於沼渣乾燥、導入鍋爐產生蒸氣、發電餘熱冷凝水回收熱水貯存利用，回收的熱量用於加熱消化池，農場建築物、農場經營之民宿或冬季預加熱用。

（2） 消化產物經固液分離後，沼渣待乾燥後，與新鮮墊料混拌，再利用於牛舍，沼液於沼液塘中穩定後，用於周邊牧草及蔬菜種植所需之有機肥料。

（3） 據農場主人表示，設置沼氣發電設備後，所帶來的效益如下：

I. 減少氣味改善社區關係。
II. 幾乎無臭的液體流出物直接施用於作物，大量減少肥料使用費用。
III. 除了產生電外，從發電機組回收的熱量加熱消化池和熱水儲備，節省燃料費用。
IV. 厭氧消化槽產物可用作農場肥料使用和動物墊料。
V. 將堆肥出售給社區和其他農場作為土壤改良劑。

（4） 該農場於畜牧產業及環境保護雙方面的努力，使其成為最早獲得賓州環境農業保護優秀認證之畜牧場之一，並於 2011 年獲國際乳業食品協會與今日乳業雜誌評為「年度創新酪農」。

圖 19 牛糞刮除設備

圖 20 牛糞刮除設備

圖 21 施灌車吸取沼液

(來源：2011 Dairy Farmer of the Year: Brubaker Farms,

https://www.youtube.com/watch?v=_vmFCE7EfKI)

圖 22 沼渣分離設備

圖 23 Brubaker Farms 厭氧消化槽建設過程

圖 24 沼氣發電機設備機房

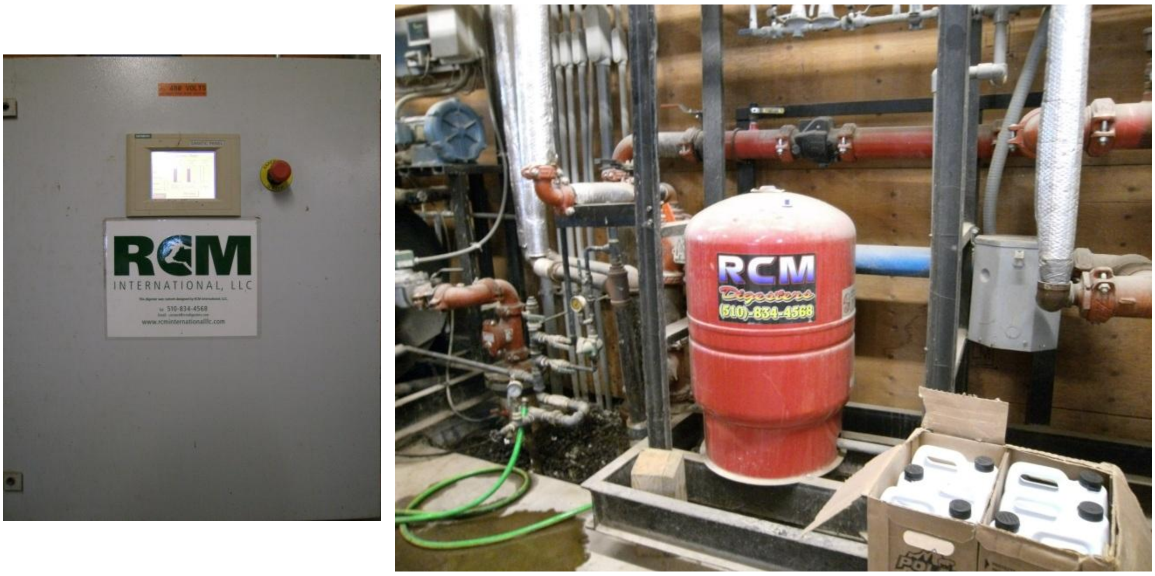

圖 24 機房內部之 RCM 相關設備

3. Yippee Farm

（1） Yippee Farm亦位於賓州Mount Joy，農場包含3座奶牛場，各自獨立及自用土地，從1990年僅100頭乳牛到目前(2016年)3個場共計有約 1,100 頭乳牛及 500 頭小母牛，有鑒於環境保護、法規要求及投資效益，於 2011 年開始建造，並於 2012 年始開始進行產電，產電量500kW，農場中同時種植牧草供牛隻食用。

（2） 各場產生之牛糞皆透過管線傳送至集中式的厭氧消化槽，透過每天收集牛舍中之牛糞，併同處理廚餘，使用厭氧消化槽共消化產生沼氣，消化槽採地下化設置，可減少熱能損失，沼氣經過脫硫後，進行熱電聯產、產生清潔電能，約 96%併入公共電網，約 4%為系統自用，發電餘熱煙氣導入鍋爐產生蒸氣、發電餘熱冷凝水回收熱水貯存利用，回收的熱量用於加熱消化池，農場建築物、農場經營之民宿或冬季預加熱用。

（3） 消化產物經固液分離後，沼渣待乾燥後，與新鮮墊料混拌，再利用於牛舍，沼液於沼液塘中穩定後，用於周邊牧草及蔬菜種植所需之有機肥料。

（4） 據農場主人表示，設置沼氣發電設備後，所帶來的效益如下：

I. 減少異味改善社區關係。

II. 幾乎無臭的液體流出物直接施用於作物，大量減少肥料使用費用。

III. 除了產生電外，從發電機組回收的熱量加熱消化池和熱水儲備，節省燃料費用。

IV. 厭氧消化槽產物可用作農場肥料使用和動物墊料。

V. 將堆肥出售給社區和其他農場作為土壤改良劑。

圖 25 沼氣收集袋(地下為厭氧消化槽)

圖 26 沼液貯存塘

圖 27 沼氣純化槽

圖 28 供電網及燃燒多餘沼氣

圖 29 沼氣發電機設備機房

（二）與 RCM 厭氧消化設施製造商討論及交換意見

1. 3 場畜牧場均畜養牛隻，採用地下化設置之完全混合式(CSTR)厭氧消化槽，可降低熱能損失，亦可節省地面上空間；畜牧糞尿之運送皆透過地下管線運送至消化槽，可有效降低臭味逸散，厭氧消化產物亦無異味。

2. 為提升沼氣產量，3 場畜牧場皆以畜牧糞尿混合廚餘進行共消化，厭氧消化產物(digestate)經固液分離程序，沼液於沼液塘穩定後用於農地施灌，現場亦有大型槽車吸取沼液，準備運至鄰近農地施灌；沼渣則靜置乾燥後與新鮮墊料混合再利用於畜舍。產生沼氣經純化後，經由熱電聯產產生電能，部分併入電網，部分自用，餘熱用於畜牧場建築物或熱水加熱用。

3. 本次參訪之畜牧場占地規模大，相關設備系統均自動化操作，現場多半未見畜牧場人員在場。經與畜牧業者交換有關厭氧消化及沼氣發電設備之意見，其對於相關設施操作具有基本認知。RCM 工作人員則定期經由畜牧場設備監控儀表板進行維護管理，以維持厭氧消化及沼氣發電之穩定操作。

4. 政府部門替代及清潔能源計畫與再生能源計畫所提供的補助款及貸款，為這些畜牧場建造厭氧消化槽及沼氣發電機等現代化設備提供了資金援助，加速推動畜牧糞尿資源化。

二、 參加美國沼氣協會所辦之 BIOCYCLE 16th Annual Conference

（一）105 年 10 月 18 日及 10 月 19 日研討會

本研討會係由美國沼氣協會(American Biogas Council, ABC)主辦，ABC 的主要目標為為美國沼氣工業創造就業，環境永續和能源自主而努力，議程包含 2 天討論會與廠商展示會，以及 1 天現場參訪活動。討論會包含厭氧消化、電力生產、沼氣燃料、土壤改良、廚餘管理與堆肥等議題。以下摘述本次會議重點資息：

1. 與來自紐約衛生局人員 Sakura Suzuki 交流意見：(1)美國禁止畜牧糞尿排放於地面水體，促進畜牧糞尿沼液沼渣再利用作為農地肥分使用；(2)國家肉品市場開放政策，亦為影響畜牧業者投資厭氧消化設施意願之因素，提升國家畜牧業競爭力方為最佳方法。

2. 展示會有多家設備廠商公司參展，其中 DIGESTET DOC 為專門提供科學檢測分析服務（包含甲烷潛能試驗、微生物最佳化分析、沼液沼渣品質分析等）。該公司人員 Will Charlton 說明為提高客戶厭氧消化設備沼氣產量，依據厭氧消化系統內微生物菌相、有機酸組成與重金屬等檢測分析結果，提供客戶調整厭氧消化系統操作條件之專業建議，並額外提供沼氣產量保證提升之服務。

3. 研討會上美國環保署 Ag & Wasteater Biogas 領導人 Chris Voell 與與會者進行法規面及執行面意見交流。會後與 Chris Voell 進行意見交換，說明國內推動畜牧糞尿沼液沼渣作為農地肥分使用，不再將畜牧糞尿視為需要處理之廢水，而是作為農地肥分使用之資源。Voell 表示明年如我國仍有現勘美國畜牧場之需要，可予以協助。

圖 30 研討會開幕及 ABC 主席 Bernard Sheff 致詞

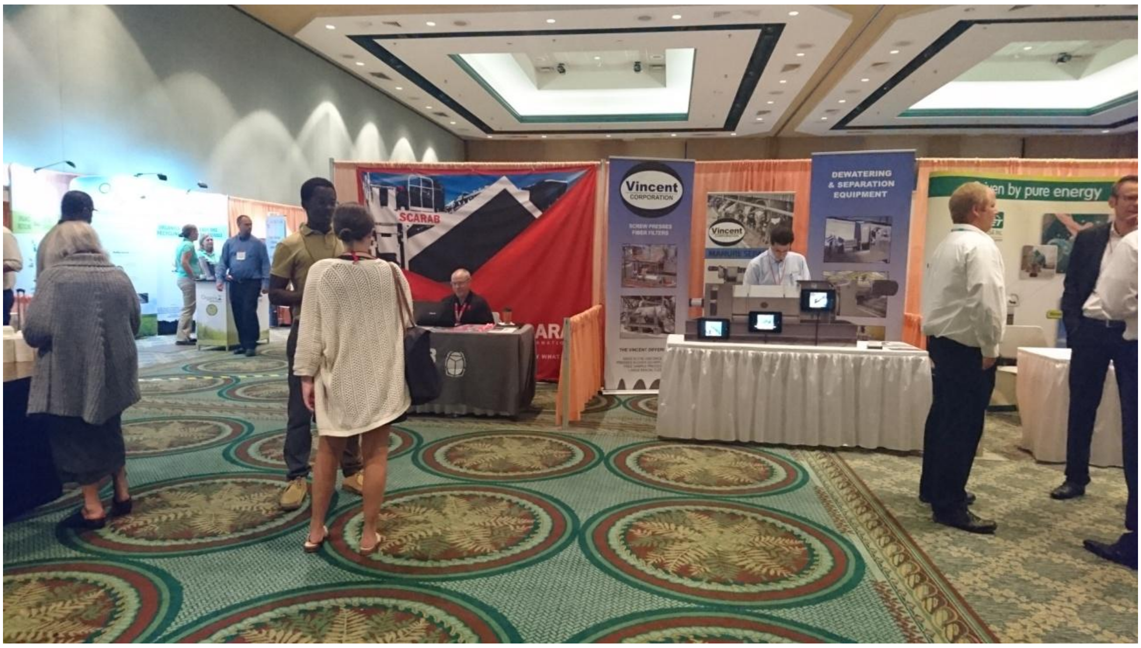

圖 31 研討會相關廠商展覽

圖 32 Digester Doc 公司人員說明提供客戶厭氧發酵操作條件之專業建議

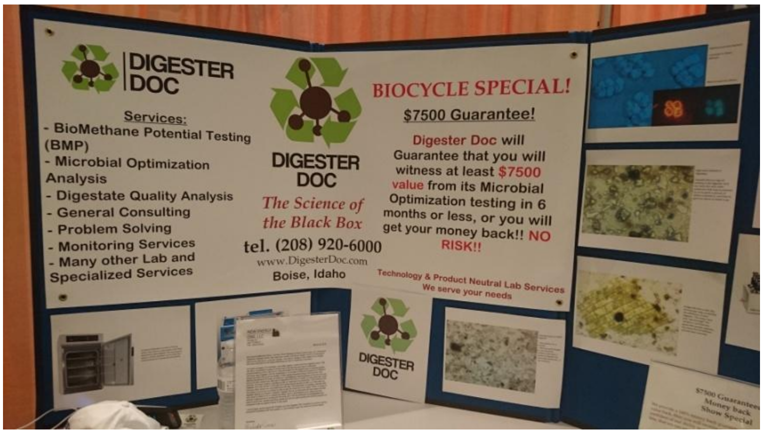

圖 33 Digester Doc 公司展示版

圖 34 GTI 公司展示版

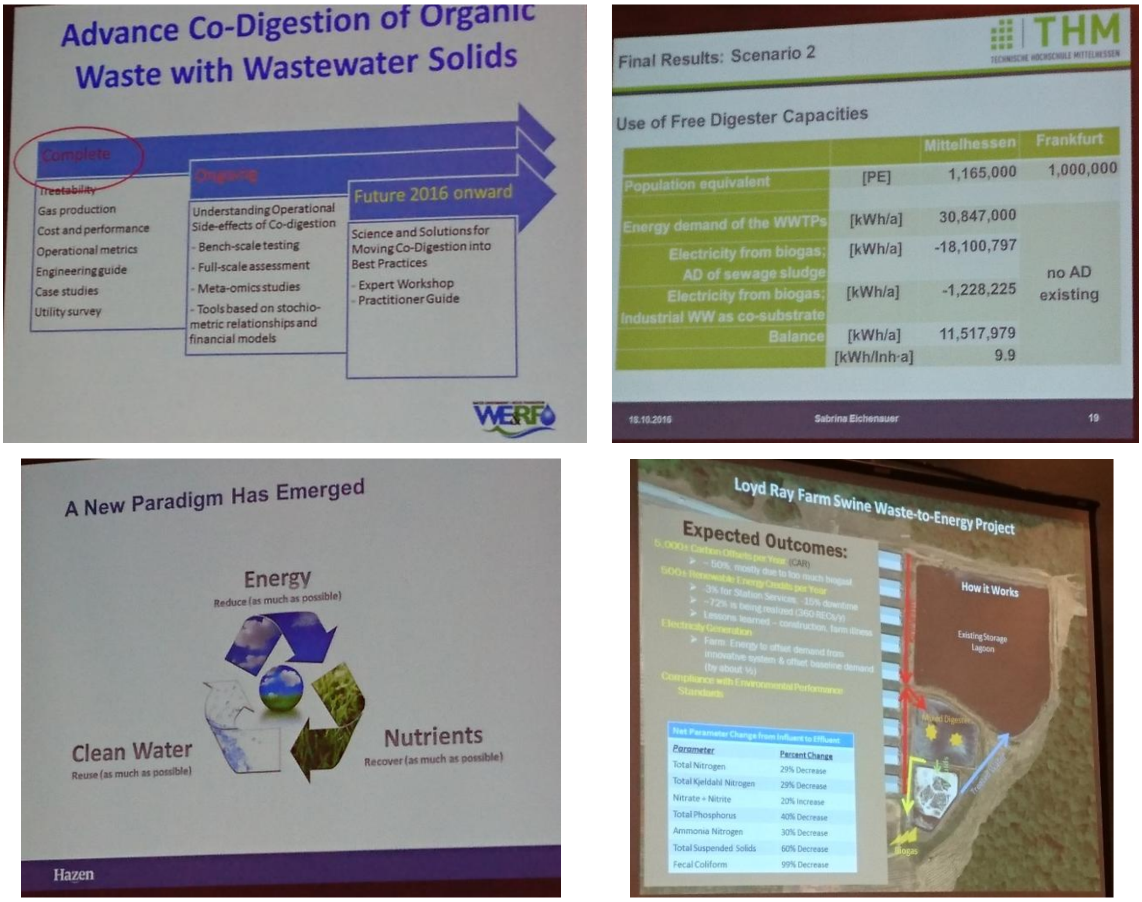

圖 35 研討會相關簡報

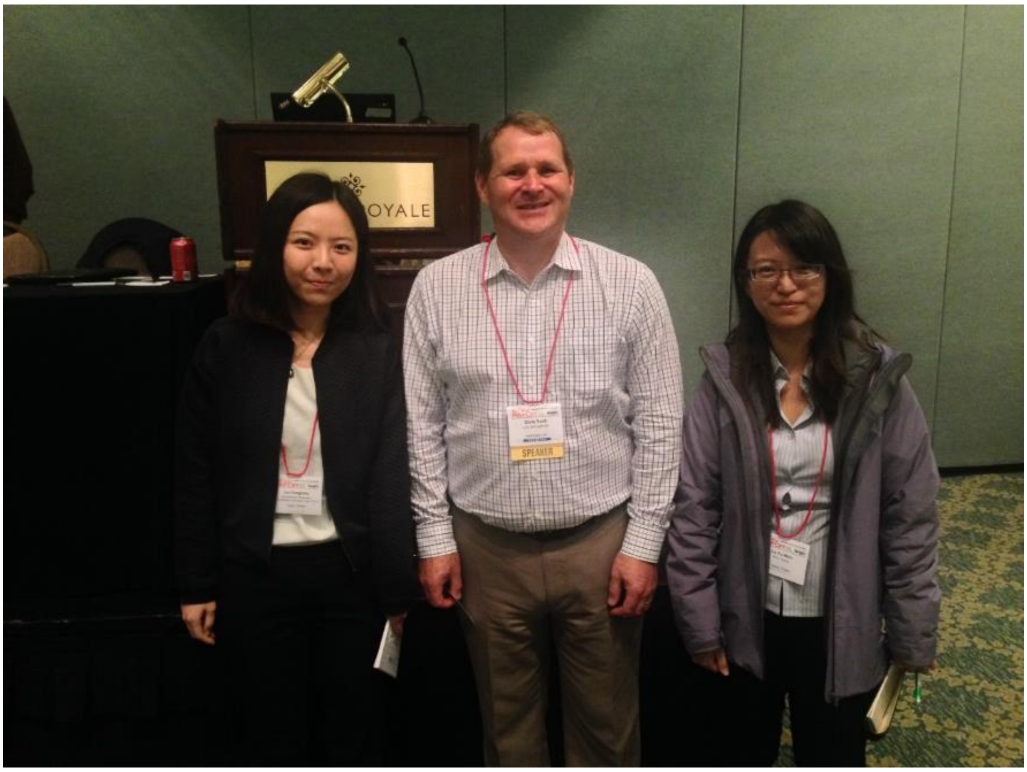

圖 36 拜會美國 ENVIROMENTAL PROTECTION AGENCY Lead Chris Voell

（二）105 年 10 月 20 日現場參訪

BIOCYCLE 16th Annual Conference - Site tour 現場參訪行程包含 Anuvia Plant 及 Alliance Dairies，說明如下：

1. Anuvia 為 1 家在奧蘭多附近開設的第一個環保肥料生產廠，總投資額為 9,800 萬美元，能夠生產超過 200 噸/天的高效、營養成分高、緩釋的專用商業肥料產品，其原料包括市政有機固體廢棄物，食品有機廢物和來自厭氧消化槽後的消化物等有機廢棄物。處理流程包括有機物接收區、氣味控制、肥料生產製程、暫儲存區、環境控制和配送倉庫等。

圖 37 控制室儀表板監控場內肥料製造過程

圖 38 肥料產品貯存區

圖 39 廠內肥料製程實驗室

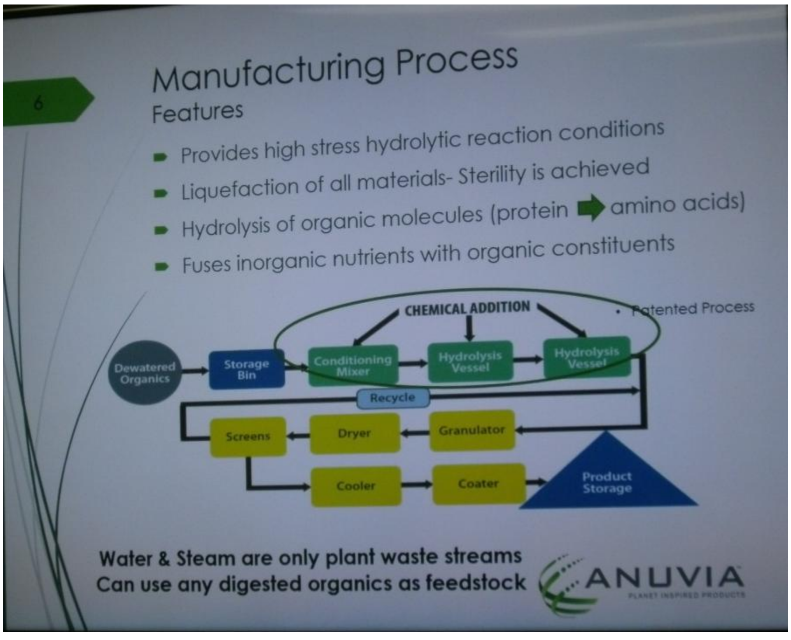

圖 40 Anuvia Plant 環保肥料製程說明

2. Alliance Dairies 為一牛乳生產廠，2010 年安裝由 DVO 公司設計及施工的混合柱塞流式(Plug Flow)厭氧消化槽及發電系統，用於處理畜舍沖洗水及牛糞，除降低糞便異味外，還為乳品生產製程提供動力。消化後產物經分離後，沼渣用於墊料再利用及土壤改良劑。Alliance Dairies 是佛羅里達州北部第 1 家獲得佛羅里達州環境保護部頒發的永續廢水管理實踐許可證的乳製品公司。

圖 41 畜牧場牛隻畜舍

圖 42 畜牧場工作人員解說場內設備

圖 43 畜牧糞尿固液分離設施

圖 44 沼氣發電設備

圖 45 沼液穩定塘

伍、 結論與心得建議

一、結論

（一） 賓州或佛羅里達州之畜牧業者，對於畜牧糞尿均非視為需要處理之廢水，而是資源。經厭氧消化後之沼液沼渣，沼液可用於牧草種植，或販售給附近農民作為肥料，沼渣可作為牛隻畜舍墊料，以促進牛隻泌乳量。厭氧消化後產生沼氣經脫硫後可發電自用，有餘裕量亦可賣電。

（二） 賓州或佛羅里達州對於畜牧糞尿係禁止排放到地面水體，畜牧糞尿均作為農地肥分使用，並著重於提高沼氣產量。畜牧場作為厭氧消化料源之畜牧糞尿來源多元，除了牛隻外，亦有豬隻、雞隻等。且為提高沼氣發電效益，厭氧消化料源多非單一來自畜牧糞尿，亦混合廚餘進行共消化，以提高厭氧消化沼氣產量。

（三） 政府機關簡化施灌前相關行政作業，賓州畜牧業者如要施灌沼液作為農地肥分使用，事前免申請許可證（文件），但仍應於施灌前進行氮磷鉀含量檢測，確認是否符合標準始得施灌。

（四） 賓州畜牧業者設置厭氧消化設施成本雖高，但因畜牧糞尿資源化效益遠高於化學肥料成本，畜牧業者仍願意投資厭氧消化設施。如區域內畜牧場集中分布，規模較大之畜牧場設置之厭氧消化設施，可共同處理鄰近畜牧場之畜牧糞尿，共同分擔設置及操作維護成本，亦共同分享沼液沼渣再利用及沼氣回收發電之效益。

二、建議

（一） 為降低畜牧污染排入河川，且基於畜牧糞尿含有豐富高養分及肥分應視為資源，本處刻正積極推動畜牧糞尿資源化。美國推動畜牧沼氣能源化經驗豐富，並有跨部會執行之 AgSTAR 計畫。拜會美國厭氧消化設備商及參訪已推動沼氣能源回收之畜牧場，瞭解美國厭氧消化技術及畜牧場運作方式與實務經驗，可作為本署未來推動執行之參考。

（二） 美國厭氧消化設備商 RCM 推動厭氧消化技術超過 30 年，為美國頗具規模的厭氧消化設備商，其除了專門提供厭氧消化槽設置及輔導操作外，也與沼氣發電、管線設置等相關設備商合作，可為客戶提供一系列設備配置服務。其沼氣能源產業已形成一產業鏈，能提升農民推動意願，故能提升推動成效。國內未來可透過輔導業者及扶植市場機制，促進畜牧糞尿資源化產業鏈之形成。

（三） 畜牧糞尿資源化包含肥分再利用、沼氣回收再利用（生質能源）、溫室氣體減量、降低畜牧業水污染與臭味防制等面向，屬於跨部會綜合性業務。美國有 AgSTAR 計畫整合美國環保署、農業部及能源部相關資源共同推動；另有業者專門提供厭氧消化設備操作與沼氣發電潛力評估及輔導等相關服務。未來我國應可師法美國推動模式，強化各部會之橫向業務聯繫，或成立跨部會專案小組與技術輔導團隊，除整合各項推動補助資源外，亦可統整國內畜牧業、施灌農地、作物施灌量

等調查研究資料，建立國內畜牧資源化資料庫，並可另就技術面提供專業諮詢輔導。

（四）美國畜牧場多以沼氣產量最大化為主要考量因素，故本次參訪畜牧場之厭氧消化設備皆採畜牧糞尿混合廚餘進行共消化之方式。為使厭氧消化後產物成分品質穩定以用於農地施灌，國內畜牧糞尿沼液沼渣作為農地肥分政策，目前尚未開放厭氧共消化後產物作為肥分施灌。建議未來可針對畜牧糞尿資源化之目標樣態進行評估分析，研究分析厭氧消化進料源成分對沼氣產量及操作成本之影響，以達生質沼氣產量與沼液沼渣肥分再利用之最佳化條件，促進綠色畜牧產業及循環經濟發展。

（五）美國畜牧場採畜牧資源化經營模式，除了可降低溫室氣體排放、節省畜舍墊料及作物肥料之成本外，同時亦創造其他收入來源，包含碳權交易、販售沼液沼渣肥分與再利用墊料等。為增加畜牧業者及農民參與畜牧資源化之意願，以及順應國際環保趨勢，我國未來應推動建立畜牧業碳權交易制度及交易平台，並促進企業投資畜牧場或畜牧場企業化經營，促進國內轉型為綠色畜牧業，並提升國際競爭力。

（六）由美國畜牧場推動畜牧資源化之過程，可能需經過多項許可證之審核及核發，申請、審核及核發時間及所需經費對小型畜牧業者而言是一大負擔，考量國內畜牧、能源及環保等業務分屬不同機關及層級，建議未來可整合、簡化畜牧場相關申請或變更許可證之流程，或成立專責輔導、協助代辦單位機關，以提升畜牧業者推動執行之意願。

陸、附件

- RCM 公司簡介及厭氧消化槽實績
- Sensenig Dairy 簡介
- RCM 公司說明文件-將農場廢棄物轉化為能源
- 厭氧消化沼液沼渣說明文件(Digestate Q&A)
- BIOCYCLE 16th Annual Conference 議程及展示廠商
- 美國農業部(USDA)、環保署(USEPA)及能源部(USDE)之 Biogas Opportunities Roadmap

RCM's Mark Moser Helped Shape Anaerobic Digestion Industry

RCM Digesters, Headquarters: Oakland, CA

Overview

When Mark Moser founded RCM Digesters in 1982, anaerobic digestion was still in its commercial infancy. Digester technology has been around since ancient times. Although the science had been proven in academic lab settings and was used by some municipalities, there weren't easy options available for farms or factories. His leadership has transformed - and largely created - the anaerobic digester industry.

RCM developed many of the business models that have emerged to form successful digester companies, even entirely new market segments.

Over the past 30 years, RCM has been a pioneer in many leading agricultural and renewable energy sectors. We have integrated the knowledge and cultural bases of farming, agricultural science and renewable energy policy making. Nationally and internationally, RCM's work has enabled the company to provide true global perspectives for clients with business interests that transcend countries and regions. In addition to working in more than a dozen states in the U.S., RCM has provided consulting services in Armenia, Australia, Belize, Canada, Chile, China, Colombia, Costa Rica, Ecuador, Ireland, Italy, Japan, Korea, Mexico, Philippines, Spain and Taiwan.

Milestones

1982 - 1985 - RCM Digesters founded, based on the name Resource Conservation Management. First codigestion system built at Langerwerf Dairy in Durham, CA, for 500 cows and food waste. Thirty years later, the Plug Flow digester is still in successful operation. Within a year, RCM has built a Plug Flow digester at Frey Dairy in Conestoga, PA, for its 600 cows. Two more systems begin operation in Lodi, CA, and Gonzales, CA, in 1985.

1986 -1989 - RCM's Complete Mix system debuts at DJ Acres in Seven Valleys, PA. The ground-breaking design was designed to optimize energy production. At DJ Acres, the 150 kilowatt system was used to heat farm buildings by handling the waste of up to 18,000 hogs. RCM's first international projects began with Complete Mix systems installed in Ireland (1988) and two locations in Japan (1989).

1990s - Complete Mix, Covered Lagoon and Plug Flow systems are built by RCM across the US, including locations in California, Colorado, Connecticut, Iowa, Minnesota, New York and Oregon. A Complete Mix digester is designed and constructed at Seoul National Technical University for research purposes. During this time, RCM began its long-standing partnership with the farm credit association AgStar.

2000-present - RCM's projects include a growing number of regional centers, including Port of Tillamook Bay in Oregon and Santiago, Chile. Codigestion plants that handle a variety of waste materials become increasingly popular, particularly in dairy businesses in Pennsylvania and New York.

RCM DIGESTERS

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A Long History of Successful Digesters

International Experience

Armenia, Australia, Belize, Bulgaria, Canada, Chile, China, Colombia, Costa Rica, Ecuador, El Salvador, Estonia, Greece, Ireland, Italy, Japan, Korea, Mexico, Mongolia, the Philippines, Poland, South Africa, Spain, Ukraine, Taiwan and Uruguay.

Digester Systems

Digesters for Dairy Cows

Complete Mix Tank Digesters for dairy cows

- December 2015 - Woodcrest Dairy, Ogdensburg, NY, 2,000 cows, 450 kW, digested solids separation and reuse, digested solids separation and reuse
- February 2014 - Greenwood Dairy, Canton, NY 1,500 cows, 410 kW, digested solids separation and reuse
- December 2013 - **CODIGESTION** Longview Dairy, Hadley, MA, 350 cows, substrates, 300 kW
- October 2013 - Diamond K Dairy, Altura, MN, 1300 cows, 300 kW, digested solids separation and reuse
- March 2013 - **CODIGESTION** Keefer Dairy, Chambersburg, PA 500 cows, substrates, 225 kW, digested solids separation and reuse
- January 2013 - **CODIGESTION** Yippee Farms, Mt Joy, PA, 1,100 cows, substrates 500 kW, digested solids separation and reuse
- December 2012 - **CODIGESTION** Reinford-Frymoyer, Mifflintown, PA 400 heifers, substrates, 225 kW, digested solids separation and reuse
- Sept 2012 - **CODIGESTION** Sensenig Farms, Lancaster County, PA, 250 cows, 2200 finisher pigs, 33,000 hens, substrates, 200 kW, digested solids separation and reuse
- July 2012 - **CODIGESTION** Maplehurst Farms, Greensboro, VT, 400 cows, 150 kW, digested solids separation and reuse
- April 2012- **CODIGESTION** Mill Creek Dairy, OH, 2000 heifers, 450 kW, digested solids separation and reuse
- Feb 2012 – **CODIGESTION** Walker Farms, Fort Ann, NY, 1200 cows, 300 kW, digested solids separation and reuse
- Dec 2011 – **CODIGESTION** Oak Hill Farm, Nottingham, PA, 100 cows & 4,500 pigs, 40 KW
- April 2011 – Pennwood Dairy, Berlin, PA, 600 cows, 180 kW, digested solids separation and reuse
- Feb 2011 – **CODIGESTION** Kish View Farms, Belleville, PA, 400 cows, 130 KW, digested solids separation and reuse
- Nov 2010 – **CODIGESTION** S&A Kreider Farms, Quarryville, PA, 1,100 cows, 225 kW, digested solids separation and reuse
- Oct 2010– **CODIGESTION** Landyshade Farms, Lancaster, PA, 500 cows, 180 KW, digested solids separation and reuse
- July 2010– **CODIGESTION** Chaput Family Farms, North Troy, VT, 1600 cows, 300 KW, digested solids separation and reuse

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- July 2010 – Roach Dairy, Venice Center, NY, 2500 cows, 450 KW, digested solids separation and reuse
- Dec 2009 – **CODIGESTION,** Zuber Farms, Byron, NY, 1800 cows, 399 KW, digested solids separation and reuse
- May 2008 – **CODIGESTION,** Reinford Dairy, Mifflintown, PA, 450 cows, substrates,130 KW, digested solids separation and reuse
- December 2007 – **CODIGESTION** Brubaker Dairy, Mt. Joy, PA, 700 cows, substrates, 225 KW, digested solids separation and reuse
- July 2007 – Wanner's Pride-n-Joy, Lancaster PA, 600 cows, 120 KW, generator, digested solids separation and reuse
- August 2006 – Penn England, Williamsburg, PA, 800 cows, 120 KW, generator, digested solids separation and reuse
- October 2005 – **CODIGESTION** Patterson Dairy, Auburn, NY, 1,200 cows, substrates, 450 KW, building heat, digested solids separation and reuse.
- November 2001– **CODIGESTION** Ridgeline Dairy (formerly Matlink Dairy), Clymer, NY, 400 cows, organic wastes, 165 KW, building heat, digested solids separation and reuse

Heated Mixed Lagoon Digesters for dairy cows

- April 2009 – Tollenaar Holsteins, Elk Grove CA, 1,000 cows, 225 KW.

Ambient Mixed Lagoon Digesters for dairy cows

- October 2009 – Agricola Ganadera Los Lujan, Delicias, Mexico, 7,000 cows, 600 KW
- August 2008 – Bullfrog Dairy, Imperial, CA, 3,300 cows 300 KW generator
- May 2008 – Cal-Denier Dairy, Galt, CA, 600 cows 60 KW generator
- August 2004 – Castelanelli Dairy, Lodi, CA, 1,600 cows plus replacements, 300 KW generator
- July 1995 – 1998- Cal Poly Dairy, San Luis Obispo, CA – Process design, 400 cow capacity

Plug Flow Digesters for dairy cows

- October 2006 - Dovan Farms, Berlin, PA, 500 cows, 135 KW, generator, digested solids separation and reuse
- July 2006 – Schrack Farms, Loganton, PA, 1,000 cows, 230 KW, generator, digested solids separation and reuse
- July 2006 – Sunny Knoll Farm, Perry NY, 1,500 cows, 230 KW, generator, digested solids separation and reuse
- July 2006 – Four Winds Dairy, Ulysses, PA, 700 cows, 120 KW, generator, digested solids separation and reuse
- May 2006 – Emerling Dairy, Perry, NY, 1,200 cows, 230 KW, generator, digested solids separation and reuse
- January 2006 – Eden Vale Dairy, Lemoore, CA, 1,000 cows, 140 KW, generator, digested solids separation and reuse
- February 2005 –Van Ommering Dairy, Lakeside, CA, 600 cows, 85 KW generator, digested solids separation and reuse
- June 2004 – Meadowbrook Dairy, El Mirage, CA, 1,400 cows digester, 180 KW generator, digested solids separation and reuse

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- October 2003 – **REGIONAL,** Port of Tillamook Bay, Tillamook, OR, 8 farms combined at 2,000 cow regional site with 4 digesters, 240 KW, building heat, digested solids separation and reuses
- September 2003 – Northern Plains Dairy, Saint Peter, MN, 3,000 Jersey cows, 2 digesters, 270 KW, building heat, digested solids separation and reuses
- October 2002 – Hillcrest Dairy (formerly New Horizons Dairy), Elmwood, IL, 2,000 cows, 2 digesters, 240 KW, building heat, digested solids separation and reuses
- May 2002– Stencil Dairy, Denmark, WI, 1200 cows, 160 KW, building heat, digested solids separation and reuse
- January 2002 – Rebuild, update and expand non-RCM digester, Koetsier Dairy, Visalia, CA 1500 cows, 210 KW, building heat, digested solids separation and reuse
- October 2001 **–** New Hope View Farm (formerly DDI), Homer, NY, 1000 cows, boiler, experimental gas turbine, building heat, digested solids separation and reuse
- September 1999 – ICF, Inc./AgSTAR, Haubenschild Dairy, Princeton, MN - 1000 cows, 135 KW engine, building heat, digested solids separation and reuse
- September 1997 – ICF, Inc./AgSTAR, Freund Dairy, E. Canaan, CT, - 250 cows, boiler, building heat, digested solids separation and reuse
- September 1997 – ICF, Inc./AgSTAR, AA Dairy, Candor, NY - 1000 cows, 120 KW engine, boiler, building heat, digested solids separation and reuse
- December 1996 – Craven Dairy, Cloverdale, OR - 1000 cows, 120 KW, digested solids separation and reuse
- December 1985 – Luiz Dairy, Lodi, CA - Rebuild non-RCM 900 cows, 140 KW,
- February, 1985 – M&M Dairy, Gonzales, CA - 400 cows, 60 KW, digested solids separation and reuse
- June, 1983 – Frey Dairy, Conestoga, PA - 600 cows, 100 KW, digested solids separation and reuse
- December, 1982 – **CODIGESTION** Langerwerf Dairy, Durham, CA - 500 cows, 85 KW, building heat, digested solids separation and reuse

Digesters for Beef Cattle and Substrate

Complete Mix

- November 2014 **CODIGESTION,** Alten, Mead, NE, 28,000 beef, ethanol stillage, steam production for distillation plant

Digesters for Chickens

Complete Mix digester for chickens

- November 2014 – Darling Downs Fresh Eggs, Qld, Australia, 300,000 layers, 250 kW
- October 1999 – Yerman Egg Ranch, CA, 140,000 layers, 110 kW

Digesters for Pigs

Heated Mixed Lagoon Digesters for pigs

- September 2015, CEFN, Clifton, QLD, Australia, 30,000 finishers, 400 kW
- December 2014, Tong Park, Dalby, Qld, Australia, 46,000 finishers, 500 kW capacity

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- September 2013, Cameron Pastoral, (Limebush) Gundiwindi, QLD, Australia,12,000 finishers, 170 kW,
- April 2011, Blue Mountain, Utah, 225,000 finishers, 2 digesters, 2,000 kW installed capacity
- March 2003 **–** Agricola Super Ltda., (La Estrella), Agricola Ltda., Santiago, Chile, 120,000 finish hogs, boiler
- February 2003 – Agricola Super Ltda., (Pocillias), Agricola Ltda., Santiago, Chile, 238,000 finish hogs, boiler
- December 2000 – Agricola Super Ltda., (Peralillo), Agricola Ltda., Santiago, Chile, 120,000 finish hogs, boiler
- June 1998 – Apex Pork, Rio, IL, 8,900 finish hogs, boiler

Ambient Mixed Lagoon Digesters for pigs

- September 2013 - Cameron Pastoral (Lapunyah) Gundiwindi, QLD, Australia, 1200 sow farrow to finish, 170 kW,
- November 2012 – Pronaca (Campo Lindo), Eucador, 200 sow farrow to finish, flare
- September 2009-Pronaca (Tropicales), Ecuador, 11,200 finishers, flare
- February 2009- Pronaca (Colorados), Ecuador, 10,000 nursery, flare
- Nov 2008 – Pronaca (Zaracay), Ecuador, 10,500 nursery, flare
- July 2008 - Pronaca (Toachi) , Ecuador, 8,000 sows and 24,000 nursery, flare
- May 2008 - Pronaca (Oro), Ecuador, 11,200 finishers, flare
- March 2008 - Pronaca (Socorro), Ecuador, 7,200 finishers, flare
- Winter 2005 – Agricola Super Ltda., Santiago, Chile, 22,000 sows farrow to wean flare
- Winter 2004 – Agricola Super Ltda., (Tantehue) Santiago, Chile, 13,500 sows, flare
- Winter 2004 – Agricola Super Ltda., (La Ramirana), Chile, 18,000 sows farrow to wean, 22,000 nursery hogs, flare
- April 2003 – Agricola Super Ltda., (Santa Rosa), Chile, 22,000 sows farrow to feeder, flare
- July 2002 **–** Agricola Super Ltda., (Corneche), Chile, 90,000 finish hogs, flare
- September 1998 – ICF, Inc./AgSTAR, Piney Woods School, Rankin County, MS, 120 pigs, flare
- June 1998 – ICF, Inc./AgSTAR, Boland Farm, Williamsburg, IA, 2,700 nursery pigs, flare
- April 1997 – Martin Hog Farm, S. Boston, VA - 600 sow, farrow to feeder, flare
- December 1996 – ICF, Inc./ AgSTAR, Barham Farm, Zebulon, NC - 4000 sows, farrow-wean, 120 KW, building heat
- October 1992 – Palmer Farm, Yell County, AR - 300 sow, farrow to feeder, flare

Complete Mix Concrete Tank Digesters for Pigs

- July 2011 – **CODIGESTION,** Ideal Family farms, 11,000 finishers, substrates, 180 kW
- March 2008 – Ballard Hog Farm, Provo, UT, 400 sows farrow to finish, 60 kW
- October 2005 – **CODIGESTION,** Dodge, NE, Kluthe Hog Farm – 8,000 Finishers, 95 KW
- September 2004 – Wheatland, WY, Wyoming Premium Farms - 16,000 finishers, 180 KW
- December 2003 – Wheatland, WY, Wyoming Premium Farms - 5,000 sow farrow to wean, 80 KW
- October 2000 **– CODIGESTION,** Rebuild, update and expand non-RCM digester, Rocky Knoll Farms, Lancaster, PA, 4,000 pigs and organic waste, 120 KW generator
- September 1999 – ICF, Inc./AgSTAR, Colorado Pork, Lamar, CO - 5,000 sow farrow to wean, 80 KW generator
- July 1999 – ICF, Inc./AgSTAR SWUSA, Thayer, IA, - 5,000 sow farrow to wean, 80 KW generator
- October 1997 – Seoul National Technical University, 5 m^3 - research digester

- October 1989 – NMP, Tokyo, Japan - Kazuno Farm - 2 digesters - 925 sow farrow to finish (21,000 hogs), 80 KW
- January 1989 – NMP, Tokyo, Japan, Yokohama Farm, Aomori - 2 digesters, 1250 sow farrow to finish (30,000 hogs), 120 KW, building heat
- November 1988 – Sugar Creek Hog Farm, Crawfordsville, IN - 3000 sow farrow to finish (36,000 hogs), 2 digesters, 400 KW
- August 1988 – Ireland, Private Client - Complete mix digester, 250 sow farrow to finish
- March 1986 – DJ Acres, Seven Valleys, PA - 1800 sow farrow to finish (18,000 hogs), 150 KW, building heat

Representative Non-Farm Clients

Electrical Generation Service
Salinas STP #1 Monterey Co., CA - 150 KW generator with heat recovery

Government
USEPA, USDA-NRCS- AgSTAR Program
Mojave Tribe – Arizona
Ak-Chin Tribal Utility – Arizona
Tulalip Tribe – Washington
California Energy Commission
Minnesota Department of Agriculture
Sonoma County, CA

University
Washington State University
California State University, San Luis Obispo
State University of New York, Morrisville
E. Kentucky State University
South Dakota State University
Cornell University Vet School

Commercial - Industrial
MEAD Project, Tillamook Co., OR
Alliant Energy WI
Saphire Energy (algae), NM
North State Rendering, CA
Recology (Solid waste), CA

International
Methane to Markets –
Hog Farm – Mexico,
Meat Packer – Colombia,
Meat Packer – Mongolia,
Hog Farm – China
Dairy - Argentina
Delicias Juices SA, Guatemala City
Poricultores de Jalisco, Mexico
Poricicultores de Colombia, Bogota
Consejo Mexicano de Porcicultora - Mexico
Eloka – Regional digester Cyprus
Carandini Dairy, Torre im Pietra, Rome, Italy
Ainia, Valencia, Spain
Sustainable Energy, Victoria, Australia
Ontario Hydro, Toronto, Canada
Canadian Pork Council, Ottawa, Canada
Nippon Meat Packers, Japan
Silk Roads, Ltd. Philippines
Del Sur Hog Farm, Lipa City, Philippines
Private Client – Chicken producer, Romania
Danone Milk Products, Mexico
Ovobrand Egg Producers, Argentina
Adecoagro Dairy, Argentina
Private Ethanol Producer, Poland

U.S. Dairy Sustainability Awards
Innovation Center for U.S. Dairy®

Sensenig Dairy

Kirkwood, Pennsylvania

Winner: Outstanding Dairy Farm Sustainability

Dairy perseveres with creative solutions and collaborations

Traditionally, anaerobic digester systems have not been practical on small dairy farms, but this didn't stop Sensenig Dairy, a 100-cow farm, from pursuing its goal of being both financially successful now and in the future. In order to do so, Sensenig Dairy needed a way to collect enough manure to fuel a digester. With the help of a team of consultants and nearby relatives who own hog and poultry farms, the farm surged forward with the implementation of a digester to reduce costs and create a new revenue stream.

Best Practices

1 Community digester

Summary

The community digester at Sensenig Dairy is fed six times a day by manure from 200 dairy animals, 2,000 hogs and 30,000 chickens. The community also contributes to the digester by adding food waste. The project has reduced greenhouse gas emissions, taxes, bedding and fertilizer costs, while also creating new revenue streams including the sale of carbon credits, fertilizer and bedding. Because the digester produces three times the amount of energy the dairy needs, the dairy also generates revenue by selling energy back to the grid.

Key benefits

The digester produces 1,401,600 kilowatt hours of electricity per year. It also offsets 989 metric tons of greenhouse gas emissions per year, which is equivalent to removing 206 cars from the road. In addition, an underground pipeline has alleviated the need for trucking, reduced the possibility of manure spills and improved air quality by reducing odor by 80 percent.

2 Community relations/involvement

Summary

The Sensenigs worked with the community for one year and then secured final approval from their neighbors. The entire project was community-oriented and required collaboration from many different parties, including one neighbor in particular who was impacted because the pipeline ran through his property. Cliff and Andrea worked with that neighbor to ensure the pipeline would remain part of the digester if the farmer ever sold his property. They also worked with their county to ensure the 1.1-acre digester site would be classified as a rural enterprise, but the dairy could keep its status as a farm. Finally, in an effort to show their support for the local economy, the Sensenigs chose to purchase many of the supplies for the digester and nearly all of the farm inputs from local vendors.

Key benefits

Due to their efforts to involve the community early in the planning process, Cliff and Andrea received early buy-in and continued interest in the project. They truly paved the way for similar community digester projects by exploring uncharted territory and setting a precedent in several areas. In an effort to share that knowledge and experience with others, they have hosted two educational events focused on teaching farmers about the feasibility of implementing digesters on small dairies.

The Sensenigs continue to explore innovative management practices to make their dairy more lucrative and sustainable for their young children. While digesters are generally seen as feasible only for large dairies, Cliff and Andrea have proven that creative solutions can work for small dairies, too.

The Sustainability Awards are part of the U.S. Dairy Sustainability Commitment, an industrywide effort to measure and improve the economic, environmental and social sustainability of the dairy industry. The award program recognizes dairy farms, businesses and collaborative partnerships for their contributions to healthy people, healthy products and a healthy planet and showcases that sustainability makes good business sense. An independent panel of judges evaluates all nominations based on the program's or project's results as measured by triple-bottom-line success – economic, environmental and social. For more information, please visit USDairy.com/Sustainability/Awards.

Email: InnovationCenter@USDairy.com
USDairy.com/Sustainability/Awards

Converting Farm Waste into Energy with America's Most Experienced and Flexible Anaerobic Digesting (Biogas) Company

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I. Return on Investment to Farms

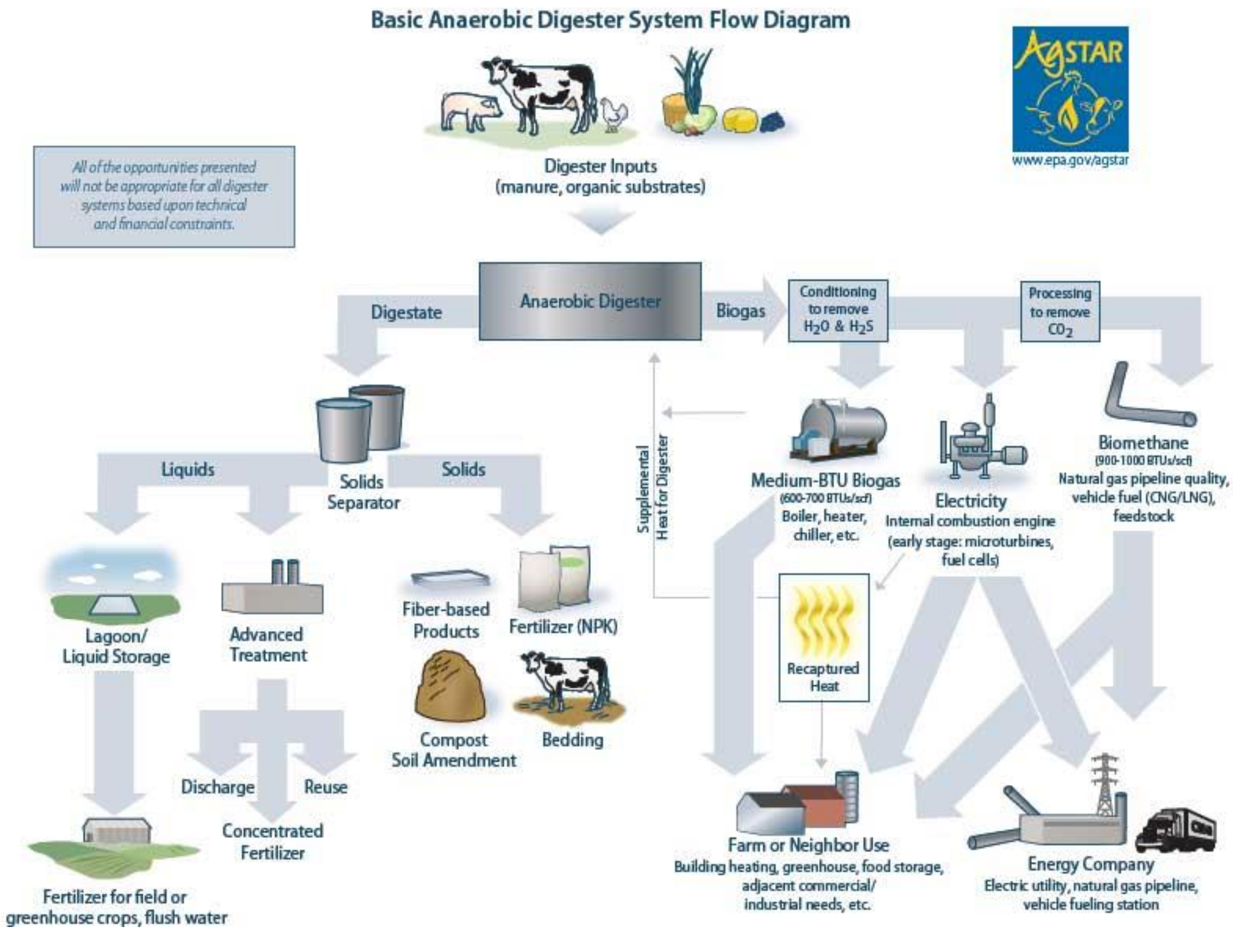
All renewable technologies produce energy and some improve the environment - but farms exist in the real business world and must produce positive return on investment. That return can be seen in today's bottom line or in the avoidance of future fines by complying with strict new governmental standards now. Either way, anaerobic digesters succeed based on how they are built and operated - so agricultural entities must carefully consider all variables. RCM is committed to providing accurate biogas and electricity projections as well as "after sale" assistance in the form of technical training for optimal digester operations and maintenance.

Anaerobic digesting has been around a long time and the technical differences between leading manufacturers, both European and RCM, are minor. Currently however, RCM is less costly. That said, careful research, accurate financial projections and manufacturer motivation remain key to success. Uniquely, RCM avoids the temptation to provide "optimistic" energy production estimates in order to win a sale. Instead they offer realistic figures to both owners and investors. RCM also "talks straight" about what expenses should be anticipated in the future. No surprises.

In recent years international farms have become aware of the hidden value of their waste (e.g. manure) and are seeking to develop this new revenue stream. RCM, founded in 1982, is America's oldest agricultural digesting company and has designed and built approximately 45% of the digesters produced American based digester companies (in the USA and overseas). Included are systems for dairies, swine, poultry, cattle, meat packers and food processors. Anaerobic digesting can also be used for sewage treatment and conversion of landfill gas into energy.

II. Anaerobic Digesting Technology from RCM

The anaerobic digesting process stores waste without oxygen in a large, sealed container at a constant temperature of 38 C. Biogas is then created by organisms, including bacteria, breaking down the waste. The biogas created can drive a co-generator or boiler which produces electricity or heat. In some cases biogas can also be converted to commercial quality natural gas (CNG).



With its 34 years' experience and over 100 successful projects in operation worldwide, RCM is known as the company that offers farmers a choice. Rather than promoting one style, such as "plug flow", RCM offers four different digester systems. They do this because maximum ROI occurs when a project is customized for the logistics, climate, budget and goals of the customer.

Instead of simply selling *a digester* they want to sell customers the *right digester*.

Along with choosing the most cost effective digester style, capital expense can be minimized via labor or general contracting services expertise provided by the customer. RCM's mission is to provide honesty, straight talk and intelligent options.

III. Description of RCM's Four Digester Options

With RCM Digesters, owners turn manure into clean energy and profitable byproducts. RCM works with managers to find the best options for their sites by looking at factors such as:

- climate conditions
- method of manure collection
- total solids content (the weight of manure without water)
- cost efficient energy use

Due to the large number of variables, RCM favors reviewing the site prior to recommending a digester type. Farms can choose from four types of RCM digesters, including:

- **Complete Mix -** A good option for colder climates, Complete Mix systems can also digest food waste which increases energy yields.
- **Smart Heated, Stirred Lagoon** - This digester adds the functionality of heating and mixing to the cost savings of a lagoon set up.
- **Smart Ambient Lagoon** - Favored in climates that are warm year round and for flush-collected manure. This simple technology can be highly cost-effective.
- **Plug Flow** – An older technology used at some RCM dairies prior to 2007.

IV. RCM Services for Anaerobic Digester Systems

- Expert guidance from early feasibility studies to final energy production
- Planning level cost estimates
- Financing level studies with bankable estimates of costs and benefits
- Turnkey design/build services for complete project installation
- Construction services, including construction oversight, start-up and troubleshooting
- Equipment manufacturing and supply

- *Cooperation with your bank to help arrange for a Letter of Credit (LOC) which can be guaranteed by a respected American bank acceptable to RCM*

V. *Description of potential feedstocks*

RCM has become the industry leader in anaerobic digestion due to its proven ability to make systems that work. With the largest range of digester options, RCM systems are tailored to the unique site and business of each client. This maximizes energy production and waste management, while minimizing cost. With more than 100 installations throughout the U.S. and internationally, RCM uses proven technology that completes systems on time and on budget. Here is a link to descriptions of just some of RCM's international projects including one for 238,000(!) finish hogs in Chile, South America:

RCM Digesters aren't just for individual farms. Multi-waste codigesters combining farm and non-farm waste are common as are regional digesters taking in waste from multiple locations.

In addition to energy, RCM's digesters produce high-quality bedding that increases cow comfort and can be sold to nearby dairies as well.

RCM has completed more digester projects for pig farmers than any other American company.

With an RCM Complete Mix digester, food wastes from nearby farms or food factories can be added to poultry manure to increase energy profitability.

With a Complete Mix digester, ranches can process manure and food waste to maximize biofuel production.

Co-digesting food wastes provides extra income to farmers using RCM digester systems to process their manure.

Removal of sugar beet waste is a costly problem. Now an RCM digester can turn this "problem" into renewable energy profits.

Brewery waste can be a highly reliable feedstock for anaerobic digesting.

Organic waste from vineyards can be a primary feedstock or co-digested with manure

Meat packing waste has more energy than manure, and slaughter houses will happily deliver their waste, and pay tipping fees to digester owners.

Unhealthy methane, building up for years inside city landfills, can be easily drawn out and converted into electricity or natural gas using RCM technology.

VI. Optimizing return on investment (ROI)

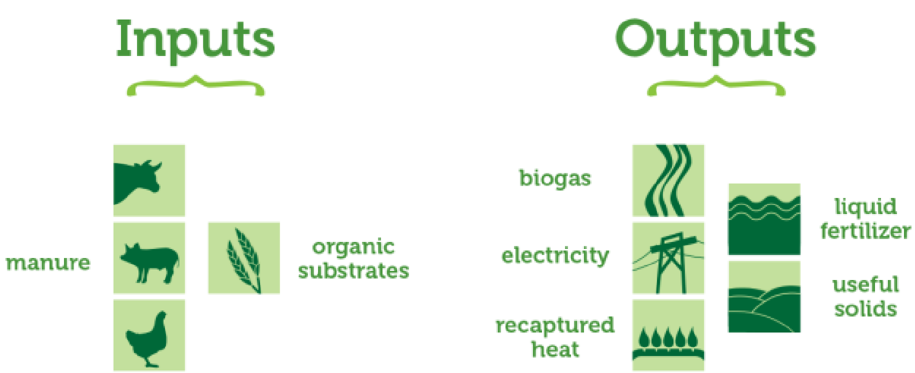
Owners of anaerobic digesters should be open minded and creative! There are:

- various feedstocks and combinations of feedstocks that can be used. For example manure plus local food processing waste
- international, national and regional government incentives that reduce cost
- a variety of valuable byproducts that must be calculated when determining actual ROI

A properly run digester provides maximum return. A digester that does not operate at top efficiency can become a bad investment. That makes experience and manufacturer support extremely important. With over 33 years and 100 American and International projects to its credit, RCM does not need to guess - they have seen it all before.

What saleable products can a digester produce? Depending on the project site the possibilities include steady and reliable:

- electricity
- compressed natural gas
- steam heat or hot water
- high quality, liquid fertilizer that can be stored and applied when desired
- high quality, clean animal bedding that reduces costly infections
- high energy soil supplements for nurseries
- tipping fees from area businesses (e.g. food processing, sugar beet, slaughter houses and restaurants) who pay to bring their waste to the digester for clean disposal



Each site is unique and the key to a successful project is choosing the smartest option from the many offered by RCM

What non-saleable, but still valuable, benefits result from digesters?

- odor reduction at the farm, field application site and surrounding area
- avoiding current and future government fines for generating water and air pollution
- positive public relations value for improving the environment and health of employees and the local population. This can be mentioned in product labeling, advertising, billboards, websites and articles

RCM equipment was designed to be profitable at American farms where the average cost paid for electricity is very low. What financial incentives might be available is difficult to say but the following might be obtained by foreign companies:

- if the green tariff is available, electricity can be sold to the grid at the highest price.
- carbon credits (Kyoto protocol) currently have little value due to lower global energy demand, but the European Commission is working to change this in the near future.
- international financial organizations (EBRD, IFC, OPIC, USAid etc.) prioritize renewable projects.
- private investment companies also seek renewable energy projects. Some dedicate a percentage of their total investment fund to this.
- there is an international methane reduction fund that might provide partial funding.
- construction services such as excavation, trenching for piping, concrete work, building construction and electrical work may be provided by the client, thus reducing cost.

Conclusion

There are many paths to follow to create an anaerobic digesting project with a healthy ROI. To determine what is possible for each customer requires the full attention and interest of the farmer as well as the manufacturer. The RCM team enjoys this process and looks forward to working with you.

Jim Muir (right), Director of Business Development for RCM in Eurasia, speaks conversational Russian, a language used throughout the 15 former Soviet Republics. Pictured with renewable energy legal specialists in Kyiv, Ukraine.

Soil management and fertilizer.

1，How much chemical fertilizer can be replaced by organic digestate?

If the farm plans to digest the manure and directly land apply it without separating it then the can expect the following range of nutrient content

N	20-30lbs/1000gal
P2O5	10-15lbs/1000gal
K2O	15-25lbs/1000gal

2，Can chemical fertilizer be completely replaced by organic fertilizer (digested liquid and solid)? We wat to know what proportion of organic fertilizer (digested liquid and solid) can achieve the same fertilizer efficiency of chemical fertilizer.

We would not recommend relying totally on digested manure to supply all of the nutrients for crop production due to the fact that the proportions of the nutrients do not precisely match the needs of the crops and if you apply at a rate to meet the nitrogen needs of the crop almost universally you will greatly over apply phosphorus and potassium

3，Everyone knows that the digested liquid can be used as organic fertilizer in the field, it is good for crops and vegetables. But farmers at RCM digester farms have said that while the liquid and solid are good to the soil, it does not seem to increase yield, the digestate does not reduce the usage of chemical fertilizer.

We know, digested liquid and solids are good organic fertilizers on the crops, we just want to know how what percentage of chemical fertilizers can be reduced if we use digested liquid or solid. This very important to us. We have a lot of clients who hope to replace the usage of chemical fertilizer with digested liquid or solid.

In reference to the examples above let's look at a typical corn crop

Let's say we have a corn grain crop that we expect to get 200bu/ac yield. The nutrient recommendation for this crop would be:

200lbs/ac Nitrogen
80lbs/ac P2O5
60lbs/ac K2O

And let's assume that the digested liquid manure has a nutrient content of:

28lbs/1000gal N
13lbs/1000gal P2O5
21lbs/1000gal K2O

And is spring applied in a no-till situation where the manure is not incorporated, in these situation perhaps only 30% of the nitrogen is retained due to volitilzation/leaching so if we apply a rate of 6,000gal/ac of the digested liquid manure it would provide:

50lbs/ac N
78lbs/ac P2O5
126lbs/ac K2O

So all of the crops P & K needs are met but we still need to apply 150lbs/ac commercial N to meet the crops needs. Yes K2O was over applied but it is considered environmentally neutral and does not cause eutrophication like N & P does.

If you apply to meet N needs you would need to apply 14,000gal/ac which will over apply P by 100lbs/ac which over time will cause a real problem environmentally.

I think what the farmer is getting at is that strictly looking at it from a fertility standpoint there really is no big difference between digested and non-digested manure.

4， "All the information I have read seem to identify digested manure as soil amendment. Does that mean it will not replace fertilizer? In our case, does that mean it is only used prior to planting and after harvest to replenish the soil? This is very important because we need to understand whether it can replace our existing fertilizer (used while the plant is growing) or not"

Typically here in the USA the manures are applied before planting or after harvest, however some of our clients that have digesters and separators do fertigate with separated liquids during the growing season. I would still recommend that the manure be used to offset a large portion of the nutrients but not replace commercial fertilizers 100%

5，FDA seems to treat raw manure and compost very differently. Raw manure carries a much greater health risk and has a rather long plant/harvest interval whereas the compost does not. Does the manure that goes through your digester qualify the finished product as a compost?

If so, can it be validated scientifically? And I'm mainly concerned about the Listeria Monocytogenes, Salmonella species and E. coli.

In the USA regulation specifies that fresh, aerated, anaerobic, or "sheet composted" manures may only be applied on perennials or crops not for human consumption, or such uncomposted manures must be incorporated at least 120 days before harvest of a crop for human consumption, if the crop contacts the soil or soil particles (especially important for nitrate accumulators, such as spinach). If the crop for human consumption does not contact the soil or soil particles (e.g. sweet corn), raw manure can be incorporated up to 90 days prior to harvest. Biosolids, sewage sludge, and other human wastes are prohibited. Septic wastes are prohibited, as well as anything containing human waste.

The digestion process effectively sterilizes the manure so all major disease causing microbes are typically eradicated through the digestion process. I don’t see why this would qualify the same as composted manure.

6，The application interval is significantly different for covered and non-covered produce (those that are for human consumption). Many of our crops are root crops. Are root crops considered covered or non-covered?

See above

7，Benefits of organic digested fertilizer to crops.

Pathogen free, reduced odor, mineralized N fraction, offsets most of the commercial fertilizer needs

8，How much is the moisture content of the biogas residue?

86-93-% for non-separated
95-97% for separated liquids

9，How much/high is the organic matter concentration of the biogas slurry？

7-14% for non-separated
3-5% for separated liquids

10，In US, How many kinds of organic constituent or ingredient are in digested liquid and solid? What are the contents of each organic ingredient?

We typically only test for the 3 macronutrients N, P and K but there would be many secondary nutrients and many, many more micronutrients in the material.

11，What is the separate content standard of digested liquid and solid in the United States?

There are no set standards required by any laws here.

12, Usually, will the content of heavy metal in digestate exceed standard? How can the heavy metal can be removed if it exceeds the standard?

Ideally non-detectable… this would be directly linked to what the animals producing the manure are being fed and we have very strict guidelines regarding heavy metals in livestock feed

12， How much digestate can be borne or fertilized at maximum by per acre/hectare, every year?

This is dependent on the nutrient content of the digestate, the background soil fertility based on soil testing and the type of crop grown and is typically outlined in a farm specific Nutrient Management Plan. The requirements of the nutrient management regulation differ from state to state here in the USA

13， How can the liquid irrigate the field and what is professional equipment is necessary? How many times should the liquid should be used for irrigation every year and when? What is the effect of the concentration of liquid on the soil and crops.

Most of our clients either use a “Traveling Gun” or drag line irrigation. There are a few that use center pivots.

Tuesday October 18, 2016

TUESDAY OPENING PLENARY

Caribbean Ballroom 1, 2

9:00 AM – 10:15 AM

Welcome

Nora Goldstein, BioCycle
Bernard Sheff, Chair, American Biogas Council
Honorable Sherrod Brown, U.S. Senator, Ohio (video)

The Power Of Organics

Moderator: Nora Goldstein, BioCycle

Florida's Organics Recycling Strategic Plan
F. Joseph Ullo, Jr.
Division Director, Florida Department of Environmental Protection, Division of Waste Management

Coffee • Caribbean Ballroom 3, 4, 5 • 10:15 AM–11:00 AM

TRACK 1

Caribbean Ballroom 1

TRACK 2

Caribbean Ballroom 2

Organized By American biogas Council

11:00 AM – 12:15 PM

Organics Ban Implementation And Assessment

Moderator: Nora Goldstein, BioCycle

Organics Disposal Ban Implementation And Analysis
Paul Henderson, Metro Vancouver, BC

Organics Ban Compliance, Catalyzing Wasted Food Reduction
Lorenzo Macaluso, Center for EcoTechnology

Assessing Organics Bans
Panel Discussion

Federal Biogas Policy — Analyses And Predictions

Moderator: Amy McCrae Kessler, Turning Earth, LLC

Biogas federal policy hot topics, presidential candidates' positions on biogas and related industries, outlook for Lame Duck Session, likelihood of biogas tax credits extensions, and why you should care about the 2019 Farm Bill now.
Maureen Walsh, American Biogas Council
Paul Bleiberg, National Milk Producers Federation
Marcus Gillette, Coalition for Renewable Natural Gas

Buffet Lunch • Caribbean Ballroom 3, 4, 5 • 12:15 PM–1:45 PM

1:45 PM – 3:30 PM

Contaminant Management, Depackaging

Moderator: Craig Coker, BioCycle

Composter Invests In Depackaging To Service Food Waste Generators
Jay Fischer, Ag Choice

Processing SSO For WWTP Digesters
Daniel Hagen, Waste Management

Food Waste Preparation For Composting And AD
William Kish, Ecoverse

Feedstock Separation: Organics Versus Inorganics
Scott Nally, quasar energy group

Impact Investors In The Biogas Market

Moderator: William Jorgenson, Vanguard Renewables

Impact investing, the allocation of the institutional capital pool, is directed to a "cause" that is usually consistent with the main focus of the fund. Impact investors for the biogas industry focus on renewables or climate change. Panelists lay out their impact investing strategies and expectations.
Jeff Possick, MissionPoint Partners
John Dannan, Generate Capital, Inc.
Ben Vitale, Wastewater Capital Management, LLC
Mike Land, Baker Tilly

Refreshments • Caribbean Ballroom 3, 4, 5 • 3:30 PM–4:15 PM

4:15 PM – 6:00 PM

Expanding Biogas Markets

Moderator: Ned Beecher, North East Biosolids & Residuals Assoc.

Biogas Developments in Ontario — Innovations To Tap New Opportunities
Chris Duke, Ontario Ministry of Agriculture, Food, and Rural Affairs

Pipeline Interconnection And Impact Of Gas Quality Requirements
Jeremy Holland, HDR Inc.

CHP Project Development Model To Secure PPAs
Lauren Barbir, GE Power

Dairy Biogas Electricity And Fuels Cluster
N. Ross Buckenham, California Bioenergy LLC

How To Keep Digesters Successful — Overcoming Inevitable Challenges

Moderator: Norma McDonald, OWS, Inc.

Green Cow Power, 2015 ABC Awardee
Melissa VanOrnum, DVO, Inc.

UW Oshkosh Foundation Rosendale Biodigester, 2014 ABC Awardee
Brian Langolf, University of Wisconsin, Oshkosh

Chino, California Biogas Plant
Ben Sheff, ES Engineering

Fennville And Freeport, Michigan Biogas Plants
Andy Austin, Scenic View and Brook View Dairy

Hometown Bioenergy, 2015 ABC Awardee
Brian Meek, Avant Energy
Plus … 6 Project Videos

TUESDAY OPENING PLENARY

Caribbean Ballroom 1, 2

9:00 AM – 10:15 AM

NOTE: Keynote speaker biographies appear on page 9. Speaker biographies are listed alphabetically beginning on page 25.

The Power Of Organics

Moderator: Nora Goldstein, BioCycle

Roadmap To 50% Food Waste Reduction By 2030
Cheryl T. Coleman
Director, Resource Conservation And Sustainability Division, U.S. EPA

Moving The Needle On Microgrids
John Farrell
Director Of Democratic Energy, Institute for Local Self-Reliance

Coffee • Caribbean Ballroom 3, 4, 5 • 10:15 AM–11:00 AM

Tuesday October 18, 2016

TRACK 3
Caribbean Ballroom 6

TRACK 4
Caribbean Ballroom 7

11:00 AM – 12:15 PM

Track 3: Biogas To Vehicle Fuel

Moderator: Jay Bassett, U.S. EPA Region 4

Trends In Growth Of U.S. Biogas To Vehicle Fuel Industry
Joanna Underwood, Energy Vision

Selling RINs In RFS Marketplace — Logistics And Insights
Susan Olson, Genscape

Biogas To Fleet Fuel — Case Studies
Eric Wilgenbusch, Unison Solutions

Track 4: Digestate Management

Moderator: Melissa Pennington, U.S. EPA Region 3

Fertilizer Production From Digester Effluent
Josh Rapport, CleanWorld

Converting Digestate To Biochar For Gas Cleaning, Nutrient Recovery
Andrew White, CHAR Technologies

Commercial Grade Fertilizer Production Utilizing Recycled Organics
Jeffery Burnham, Anuvia Plant Nutrients

Buffet Lunch • Caribbean Ballroom 3, 4, 5 • 12:15 PM–1:45 PM

1:45 PM – 3:30 PM

Track 3: Codigestion With Biosolids

Moderator: Ned Beecher, North East Biosolids & Residuals Assoc.

Advancing Codigestion Of Food Waste And Wastewater Solids
Allison Deines and **Lauren Fillmore**, Water Environment & Reuse Foundation

Using AD To Increase Efficiency Of Municipal Wastewater Treatment
Sabrina Eichenauer, University of Applied Sciences

You Have Codigestion, Now What? Researching Operational Impacts
Micah Blate, Hazen and Sawyer

Biological Hydrolysis And Codigestion
Michael Theodoulou, GE Water & Process Technologies

Track 4: Wasted Food Prevention And Rescue

Moderator: Heather Billings, Center for EcoTechnology

Waste Not Orange County: Feed The Need
Eric Handler, OCHCA and Waste Not Orange County

Scaling Food Waste Reduction
Steven Finn, ResponsEcology

Winning the Race To End Wasted Food
Heide Hart, Sustainable America, Inc.

Refreshments • Caribbean Ballroom 3, 4, 5 • 3:30 PM–4:15 PM

4:15 PM – 6:00 PM

Track 3: WRRF Codigestion — Planning And Operations

Moderator: Melissa Pennington, U.S. EPA Region 3

Process Hazards Analysis — Preparing For What-Ifs At Codigestion Sites
Paul Greene, CDM Smith

Food Waste Digestion Results In Net Energy Producer
John Hake, East Bay Municipal Utilities District, Oakland, CA

Codigestion And Biosolids–To–Energy Enhancement Project
Jim Meehan and **John Buonocore**, Rahway Valley Sewerage Authority, NJ and **Rick Sapir**, Hawkins Delafield & Wood LLP

Upgrading Biosolids AD Facility In Preparation For Food Waste Codigestion
Christine McKiernan, BIOFerm Energy Systems

Track 4: Integrating Anaerobic Digestion And Composting

Moderator: Amy McCrae Kessler, Turning Earth, LLC

Sequential AD And Composting Decision Making Based On LCA Modeling
Sara Pace, University of California, Davis

Practical Considerations Of Combining AD And Composting
David Border, DBCC

Composting Treatment Of Anaerobic Digestion Residuals
Brian Fuchs, W. L. Gore & Associates

Can Composting Of Liquid Manure Or Digestate Complete The N Cycle?
Alessandro Chiumenti, University of Udine, Italy

Wednesday October 19, 2016

TRACK 1
Caribbean Ballroom 1

TRACK 2
Caribbean Ballroom 2

Organized By American Biogas Council

8:30 AM – 10:15 AM

Track 1

Business Of Biogas
Moderator: Nora Goldstein, BioCycle

Rolling the Dice: Using Risk Tolerance To Define Commissioning Scope
Wayne Dunn, E. W. Dunn

ReFED Roadmap: Exploring Economic Analysis Of Centralized AD
David Stead, Resource Recycling Systems

Utilizing PPPs To Maximize Value Of Existing WWTP AD Infrastructure
Richard H. Cisterna, Renewable Organics Infrastructure

What's New In Tax Laws For Biogas Industry?
Kathy Parker, Rodman CPAs

Track 2

Streamlining AD Project Development — Critical Components
Moderator: Craig Frear, Regenis

Financing: Complexities, Nuances of Capital Markets
Ben Vitale, Wastewater Capital Management, LLC

Evaluation And Assessment: Feasibility Analysis, Technical Review, Feedstock Supply
Charles Opferman, Greenfire Management Services, LLC

Coproducts: Value-Added Sales, Product Development
Robert Joblin, Magic Dirt

Technology Response: Meeting Regulatory And Market Demands
Steve Dvorak, DVO, Inc.

EPC Contracting: Operations/Maintenance, Project Development
Craig Frear, Regenis

Coffee • Caribbean Ballroom 3, 4, 5 • 10:15 AM–11:00 AM

11:00 AM – 12:15 PM

Track 1

Food Recovery, Organics Recycling Infrastructure
Moderator: Lorenzo Macaluso, Center for EcoTechnology

Food Recovery, Organics Management Trends In North Carolina
Jorge Montezuma, North Carolina Department of Environmental Quality

Building Anaerobic Digestion Capacity: Why Data is Critical
Melissa Pennington, U.S. EPA Region 3

Don't Waste Food SC Campaign
Richard Chesley, South Carolina DHEC

Track 2

American Biogas Council All-Member Meeting
Moderator: Patrick Serfass, American Biogas Council

2016 Year In Review

ABC Activities, Strategies For 2017 — Member Input, Planning

Buffet Lunch • Caribbean Ballroom 3, 4, 5 • 12:15 PM–1:45 PM

1:45 PM – 3:30 PM

Track 1

AD Facility Development
Moderator: Craig Bartlett, Region of Durham, Ontario

Public-Private Partnership for AD + Composting Project In Prince William County, VA
Ljupka Arsova, Gershman, Brickner & Bratton, Inc.

Matching AD Technology To Site Realities In Hawaii
Andy Naden, BioEnergy Hawaii and **Michael Krismer**, Thöni

Planning Food And Green Waste Facility In California — Lessons Learned
Thomas Gratz, Hitachi Zosen Inova USA, LLC

Biogas Project Development in Argentina: Opportunities, Case Study
Franco Borrello, Cleanergy Renovables S.A.

Track 2

Carbon Benefits Of Anaerobic Digestion
Moderator: Tony Callendrello, NEO Energy

AD Project Eligibility And Revenue Opportunities In The Carbon Markets
Brian KillKelley, NativeEnergy, Inc.

Carbon Profile Of AD Compared To Other Waste Management Options
Swarupa Ganguli, U.S. EPA Office of Resource Conservation and Recovery

Digesters And GHG Reductions
Mark Stoermann, Newtrient, LLC

A Carbon Case For AD In A Warming World
David Babson, U.S. Department of Energy

Refreshments • Caribbean Ballroom 3, 4, 5 • 3:30 PM–4:00 PM

4:00 PM – 5:45 PM

Track 1

The Biogas Roadmap — Where Has It Led?
Moderator: Chris Voell, U.S. EPA AgSTAR

Hard look at goals of U.S. government's August 2014 Biogas Opportunities Roadmap and where stakeholders stand in addressing identified barriers to further deployment of AD and biogas systems across the U.S. Panelists from across the industry will share opinions and address audience questions.

Robert Joblin, Magic Dirt
Christopher Maloney, Digested Organics
Norma McDonald, OWS, Inc.
Chris Voell, U.S. EPA AgSTAR

Organized By AgSTAR

Track 2

12 Ways to Kill a Digester
Moderator: Paul Greene, CDM Smith

Maintaining Operations Excellence At High Profile Digester
Mark Stoermann, Newtrient, LLC

Lessons Learned At Challenging Project Locations
Bernard Sheff, ES Engineering Services

Contamination Control And Best Practices At Farm Based Codigestion Sites
Derek Hundert, PlanET Biogas USA Inc.

TRACK 3
Caribbean Ballroom 6

TRACK 4
Caribbean Ballroom 7

8:30 AM – 10:15 AM

Agricultural Digestion
Moderator: Ned Beecher, North East Biosolids & Residuals Assoc.

Small-Scale AD To Manage Agricultural Wastes: Final Case Study Report
Sabrina Eichenauer, Technische Hochschule Mittelhessen (University of Applied Sciences)

100% Chicken Litter-To-Biogas Facility With Nitrogen Recycling
Ikka Virkajärvi, Ductor Oy

Swine Waste Project Connects To Natural Gas Pipeline
Gus Simmons, Cavanaugh & Associates, P.E.

Poultry Power: Northern Ireland Case Study
Anders Peter Jensen, Xergi A/S

Organics Collection And Processing
Moderator: Craig Coker, BioCycle

Rockin' Rural Food Scrap Commercial Collection
Elisa Seltzer, Emmet County DPW

City-Sponsored Food Scraps Drop Off At Farmers Markets
Michelle Minstrell, Waste Knowledge LLC

Cocollection Of Organics With MSW: Project Economics, GHG Benefits
Jim Wollschlager, Organix Solutions

Optimizing Codigestion Of Urban Organic Waste
Temesgen Fitamo, Technical University Of Denmark

Coffee • Caribbean Ballroom 3, 4, 5 • 10:15 AM–11:00 AM

11:00 AM – 12:15 PM

Compost, Biosolids And Digestate Utilization
Moderator: Craig Coker, BioCycle

Research Update: Citrus Greening And Compost Utilization
Monica Ozores-Hampton, University of Florida/IFAS/SWFREC

Biosolids And Compost As Site Amendments For Tree Plantations
Donald Rockwood, Florida FGT LLC/University of Florida

Regulatory Restrictions On Phosphorus: Market Impacts For Recycled Organics
Ned Beecher, North East Biosolids & Residuals Association

Optimizing Digester Operations
Moderator: Nora Goldstein, BioCycle

Evaluating Air Quality, Climate And Economic Impacts Of Biogas Management Technologies
Michael Kosusko, U.S. Environmental Protection Agency

Deploying Innovative Odor Reduction Technologies
Alan Johson, quasar energy group

Combining Technologies To Improve Digestion Efficiencies, Recover Nutrients
Robert Lems, DMT Clear Gas Solutions

Buffet Lunch • Caribbean Ballroom 3, 4, 5 • 12:15 PM–1:45 PM

1:45 PM – 3:30 PM

Anaerobic Digestion Research
Moderator: Craig Coker, BioCycle

Micro-Aeration To Reduce Hydrogen Sulfide In Dairy Manure Digesters
Walter Mulbry, USDA/ARS

Hydrothermal Post-Treatment Of Solid Digestate To Maximize Methane Yield
Serge Guiot, National Research Council Canada

Dry AD Pilot Measures Methane Production Using Unsorted Food Waste, Bioenergy Crop Residues
Kimberley E. Miller, Ohio University

Biodegradation And Subsequent Biomethane Production From Anaerobically Digested Biopolymers
Anne Schauer-Gimenez, Mango Materials

Commercial Organics Diversion In Florida
Moderator: Keyna Cory, Florida Recycling Partnership

Infrastructure Realities For Supermarket Organics
Kim Brunson, Publix

Commercial Food Waste Collection Initiative
Ian M. Jurgensen, Orlando Office of Sustainability & Energy

Food Scraps Separation And Collection Strategies
Frank Santelli, Walt Disney World

Commercial Organics Processing
Panel Discussion

Refreshments • Caribbean Ballroom 3, 4, 5 • 3:30 PM–4:00 PM

16TH ANNUAL CONFERENCE
REFOR16
RENEWABLE ENERGY FROM ORGANICS RECYCLING

Oct. 17, 18, 19, 20, 2016
Orlando, Florida
Caribe Royale Hotel

Official Conference Of The American Biogas Council

ANAEROBIC DIGESTION • COMPOSTING • BIOGAS MARKETS • FOOD WASTE • MANURE • DISTRIBUTED ENERGY

BIOCYCLE REFOR16 Exhibits

2G	Anuvia Plant Nutrients Corporation	BA Valves	Bio-Organic Catalyst, Inc.	BioBag
BIOFERM Energy Systems, Viessmann Group	Bioprocess Control Sweden AB	Boerger, LLC	Brugg Pipesystems	Cabot Norit Activated Carbon
Caterpillar Inc.	CST Storage	Delta Instrument	Diamond Z / Rule Steel	Digester Doc
dmt Clear Gas Solutions	Doda USA, Inc.	Dorset Green Machines BV	DTEnvironmental	Ductor Oy
DVO Anaerobic Digesters	E&R Sales, LLC	Ecoverse	EISENMANN Corporation	GE Water & Process Technologies
Geomembrane Technologies Inc. (GTI)	Gershman, Brickner & Bratton, Inc.	Haarslev Industries	Harvest Power	Hitachi Zosen Inova USA LLC
Komptech Americas	Martin Energy Group Services, LLC	Methuen Construction	MTU Onsite Energy	MV Technologies, LLC

ORBIS Corporation

Orbital Gas Systems

Organix Solutions

OWS, Inc.

Paques Inc.

Peninsula Plastics Ltd

Pentair

Perennial Energy

Pioneer Air Systems

PlanET Biogas USA Inc.

quasar energy group partners and collaborators

quasar energy group

The Alpha Group

Greenlane Biogas

Grind2Energy™

Tank Connection

QED Environmental Systems, Inc.

Rodman CPAs

Sage Metering, Inc.

SCARAB International LLLP

Schumann Tanks

Scott Equipment Company

SUMA America Inc.

Sustainable Generation / GORE Cover

Thoeni Industriebetriebe, GmbH

TORXX Kinetic Pulverizer

Trident Processes LLC

TTcogen

U.S. EPA AgSTAR

Unison Solutions, Inc.

Vaughan Company, Inc.

VERDEK LLC

Vincent Corporation

Vogelsang

Wangen America Inc.

WesTech

Xergi A/S

Yield Energy Inc.

Biogas Opportunities Roadmap

Voluntary Actions to Reduce Methane Emissions and Increase Energy Independence

U.S. Department of Agriculture, U.S. Environmental Protection Agency, U.S. Department of Energy

August 2014

Biogas Opportunities Roadmap

Table of Contents

Table of Figures

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Executive Summary

Methane is both a potent greenhouse gas and a valuable source of energy. In the Climate Action Plan, President Obama directed the Administration to develop a comprehensive, interagency strategy to reduce methane emissions. In March 2014, the White House released the *Climate Action Plan - Strategy to Reduce Methane Emissions*. As part of the Strategy, the U.S. Department of Agriculture (USDA), the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) committed to work with industry leaders to formulate a biogas roadmap.

This *Biogas Opportunities Roadmap* builds on progress made to date to identify voluntary actions that can be taken to reduce methane emissions through the use of biogas systems and outlines strategies to overcome barriers to a robust biogas industry in the United States. It supports the U.S. dairy industry's voluntary 2008 goal to reduce its greenhouse gas emissions by 25% by 2020. This goal was a driver behind a partnership forged between the Dairy Industry and USDA in December 2009 and renewed in May 2013. As part of the 2013 renewal, the dairy industry also requested that USDA create a voluntary biogas roadmap to support this goal.

Biogas is a proven source of energy used in the United States and around the world for decades. The United States currently has more than 2,000 sites producing biogas. The Roadmap found that with the proper support, more than 11,000 additional biogas systems could be deployed in the United States. If fully realized, these biogas systems could produce enough energy to power more than 3 million American homes and reduce methane emissions equivalent to 4 to 54 million metric tons of greenhouse gas emissions in 2030, the annual emissions of between 800,000 and 11 million passenger vehicles.

In order to realize these opportunities, the Roadmap identifies actions the Federal government will take to increase the use of biogas to meet our renewable energy goals, strengthen the economy, and reduce methane emissions exclusively through voluntary actions. These include:

- **Promoting Biogas Utilization through Existing Agency Programs**: USDA, DOE, and EPA will use their existing programs as a vehicle to enhance the utilization of biogas systems in the U.S by ensuring that existing criteria for technical and financial assistance considers the benefits of biogas systems, leveraging over $10 million in research funding to enhance the economic viability and benefits of biogas systems and co-products, and strengthening programs that support the use of biogas for clean energy, transportation fuel, renewable chemicals and biobased products.

- **Fostering Investment in Biogas Systems**: To help overcome financial barriers to the widespread investment in biogas systems, USDA will lead efforts to improve the collection and analysis of industry financial and technical data needed to track the performance of anaerobic digesters, evaluate current loan and grant programs for opportunities to broaden the financing options available for biogas systems, and review Federal procurement guidelines to ensure that products of biogas systems are eligible for and promoted by applicable government procurement programs.

- **Strengthening Markets for Biogas Systems and System Products:** To strengthen U.S. markets for renewable energy and value-added non-energy products from biogas systems, USDA, DOE, and EPA will review opportunities to overcome barriers to integrating biogas into electricity and renewable natural gas markets, for example, though modernizing existing Federal incentives provided for renewable energy generation. USDA, EPA, and DOE will also drive the creation of tools to help industry broaden the market development for energy and non-energy biogas systems products.

- **Improving Communication and Coordination:** In order to implement the strategies laid out in this document and promote strong coordination and messaging across Federal agencies, USDA will establish a Biogas Opportunities Roadmap Working Group that will include participation from DOE and EPA, as well as the dairy and biogas industries. The Working Group will collaborate with industry to publish a progress report in August 2015, which identifies and prioritizes policies and technology opportunities to expand the biogas industry and reduce greenhouse gas emissions.

The emissions intensity of the production of meat and milk in the United States is already much lower today than it was even a few decades ago[i]. Due to improvements in production efficiency, it's amongst the lowest in the world[ii]. Enhancing the deployment of cost-effective technology to utilize biogas can increase revenues and reduce emissions, providing another "win-win" for farmers, communities, and the nation.

I. Biogas and Biogas Systems

Biogas is primarily a mixture of methane and carbon dioxide produced by the bacterial decomposition of organic materials in the absence of oxygen. Depending on the source of organic matter, biogas typically contains 50-70% methane, 30-40% carbon dioxide, and trace amounts of other constituents, such as hydrogen sulfide, hydrogen, nitrogen, and siloxanes.

Today, methane accounts for nearly 9% of domestic greenhouse gas emissions. Thirty six percent of these emissions come from the agricultural sector, equivalent to over 200 million tons of carbon pollution. While methane's lifetime in the atmosphere is much shorter than carbon dioxide, it is more efficient at trapping radiation. Pound for pound, the comparative impact of methane on climate change is over 20 times greater than carbon dioxide over a 100-year period. Although U.S. methane emissions have decreased by 11 percent since 1990, they are projected to increase through 2030 if additional action is not taken.

Biogas systems have the potential to capture methane that would escape into the atmosphere and utilize it to create energy (e.g., electricity, heat, vehicle fuel). Other byproducts of biogas systems include non-energy products such as nutrient rich soil amendments, pelletized and pumpable fertilizers, and even feedstock for plastics and chemicals. Successful biogas systems capture and use gas from landfills and/or the anaerobic digestion of wastewater biosolids, animal manure, and other organics for energy. Each system includes both the infrastructure to manage the organic wastes as well as the equipment to generate energy from the resulting biogas. These systems have been used on a commercial scale in the United States since the late 1970s, when concerns over energy prices and U.S. dependence on oil spurred interest in the use of recovered biogas as a source of energy.

While the landfill gas energy industry has matured over the last 40 years due to third-party private investment, a strong project development community, and federal incentives, the biogas industry as a whole has not advanced at the same rate. There are currently more than 630 landfill gas energy projects in place across the United States, with more than 2,000 MW of installed capacity for electricity generation and more than 310 million cubic feet per day of gas delivered for industrial purposes.[iii] Meanwhile, only 239 manure-based digesters are in operation across the United States. The landfill gas energy sector offers many lessons that could be applied to the biogas industry as a whole due to the similarities in project development and the technologies for processing and using the resultant biogas.

Differences between landfills and anaerobic digesters are clear; however, divisions based on feedstock sources are becoming blurred. While older biogas systems typically were designed to process one feedstock, new systems usually can accept a variety of organic materials. Traditional waste management systems and recycling or alternative processing options are now converging. Lines drawn between landfills, water resource recovery facilities, manure management, source-separated organics, and industrial waste streams are becoming harder to discern. Anaerobic digesters and biogas systems have become a hot topic for many local, state, and national discussions as policymakers recognize organic waste as a resource to use rather than a problem to manage.

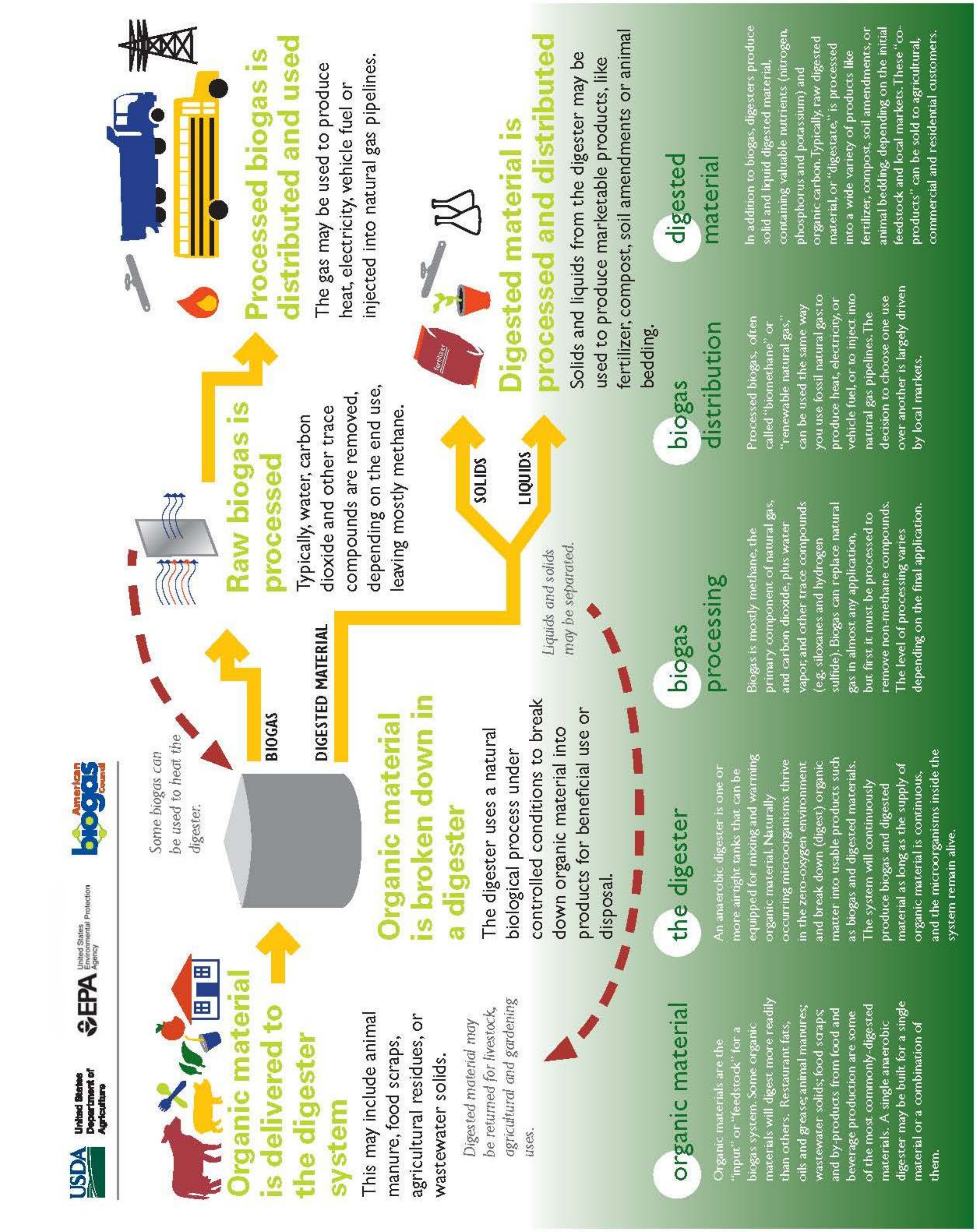

Figure 1 - Overview of Anaerobic Digester Systems

Biogas Feedstocks

A growing awareness of the resource potential of organic material discarded each day in the U.S. is inspiring interest in using organic waste as biogas system feedstocks. Historically, the feedstocks for most biogas systems have been livestock manure, wastewater sludge and, in the case of landfills, municipal solid waste. While new projects continue to use these traditional feedstocks, many projects are also using source-separated and industrial organics as either a primary or supplemental feedstock. The primary biogas system feedstocks include:

- Livestock manure – dairy, swine, poultry, and beef.
- Municipal solid waste – mixed MSW delivered to landfill (~30% organics).
- Wastewater biosolids and primary sludge – by-product of water recovery treatment process.
- Food loss and waste – the amount of edible food, postharvest, that is available for human consumption but is not consumed for any reason.
- Food production residuals – by-products of the food production and processing industry.

Blending Feedstock for Biogas Systems: A Growing Trend in America

A growing number of existing and planned projects combine multiple feedstocks within a given biogas system. Some examples of this exciting new trend include:

- In Ithaca, New York, the local municipal water resource recovery facility is co-digesting food waste with wastewater biosolids to provide an alternate waste management option and boost biogas production.
- In Rutland, Massachusetts, a digester accepts manure from 300 cows as well as residuals from ice cream and salad dressing production to increase tipping fee revenue and biogas output.
- In Arlington, Texas, a biogas system blends landfill gas and wastewater digester gas to fuel an energy plant that powers the facility and supplies energy to the grid.
- In Janesville, Wisconsin, the local wastewater treatment facility digests biosolids and food wastes, using the biogas to both power microturbines for electricity production and a unit to produce vehicle fuel.

Figure 2 - Harvest Energy Garden

- At the Harvest Energy Garden in Lake Buena Vista, Florida, wastewater biosolids, fats, oils, grease, and food waste from Walt Disney World and surrounding communities are fed into the digester to recover energy and nutrients, manage odors, process biosolids, and produce a high-quality organic fertilizer.

As the biogas industry deploys more digester facilities across the country, the potential for blending feedstocks from various sources will increase due primarily to decreased hauling distances.

II. Benefits of Biogas Systems

Biogas systems provide economic, energy, and environmental benefits for farms, businesses, and communities. These systems enable the capture and use of methane while also addressing waste management and nutrient recovery needs.

Biogas system products vary from energy (electricity, heat, fuel) to nutrient-rich soil amendments, pelletized and pumpable fertilizers, a renewable replacement for natural gas, and even feedstocks for renewable chemicals and bioplastics. The energy products typically come from the biogas, while the other products are made from the digested solid and liquid materials a biogas system produces.

Provide a Renewable Source of Energy

There are several different options for converting biogas to energy. Numerous factors such as project goals, local energy policies, infrastructure availability, and markets for renewable energy products will dictate what end use best fits the project. Unlike intermittent renewable energy alternatives such as wind and solar power, biogas delivers a continuous source of energy with a very high capacity factor. The flexibility and reliability of biogas systems are very important assets. Currently 37 states recognize biogas in their state renewable energy goals, and the U.S. government has set a target for 20 percent of the electricity consumed by Federal agencies to be from renewable energy by 2020. Biogas can assist in achieving these goals and provide many energy benefits. Specific commercially proven energy uses for biogas include:

Figure 3 - The Los Angeles County Sanitation District (LACSD) in California has operated a 50 megawatt (MW) landfill gas energy project at its Puente Hills Landfill since 1985, producing electricity for customers throughout Los Angeles.

Thermal applications: Biogas is used directly on-site to heat digesters and buildings/maintenance shops, to fuel boilers or kilns, and to generate heat or steam.

Power generation: Electricity is produced through an internal combustion engine, gas turbine, or microturbine technologies for on-site use or sale to the electric grid. Combined heat and power (CHP) systems increase overall energy efficiency of electricity systems by producing heat and electricity at the same time, which can be used for heating, cooling, dehumidification or other process applications. Unlike intermittent renewable energy sources, biogas systems are providing continuous dispatchable electricity onto the grid.

Industrial applications: Biogas can be used in industrial applications to offset use of natural gas, propane, fuel oil, or other fossil fuels. Many industries such as sugar refineries, distilleries, dairies, and paper mills generate processing and waste water that can be digested directly on site. The resulting biogas can then be used for fuel in equipment such as boilers, kilns (e.g., cement, pottery, brick), sludge dryers, infrared heaters, paint shop oven burners, tunnel furnaces, process heaters, and blacksmithing forges or for other direct thermal applications.

Biomethane injection: Upgraded and refined biogas, also called renewable natural gas (RNG), can be injected into existing natural gas networks.

Vehicle fuels: Upgraded biogas can be converted to various vehicle fuels including compressed natural gas, liquefied natural gas, hydrogen, and liquid transportation fuels.

Biogas may also be used for fuel cells, which, with appropriate cleanup to remove trace contaminants, chemically convert biogas directly into electricity. Like engine systems, fuel cell systems can be configured to produce heat as well as power. Certain fuel cell systems can also be configured to produce pure hydrogen, in addition to heat and power, known as trigeneration.

Benefits of Combined Heat and Power:
Vander Haak Dairy was the first Washington State dairy to install an anaerobic digester. The dairy utilizes on-farm waste and manure from two neighboring operations. Biogas generated is burned in a reciprocating engine. Thirty to sixty percent of the engine heat is used to heat the digester and the rest is used to dry bedding fiber and heat a house. Excess heat is available to meet additional needs of the dairy.

Currently in the United States, biogas fuels milk and recycling trucks, produces electricity for on-site and grid use, chills milk, heats greenhouses, produces steam, fires pottery and brick kilns, supplies pipeline quality gas, and provides fuel to local industrial plants. Projects range from small scale farm or community driven initiatives to multimillion-dollar private investments. Nearly 11,000 additional projects like these could be developed with the sources of biogas currently available in the United States.

Biogas Systems as 'BioRefineries'
There is a growing trend towards integrated biorefineries (biogas systems as sophisticated manufacturing centers) that are built to produce energy and high-value products as opposed to constructed as an add-on waste management process. These can involve a suite of technologies and processes to more efficiently and effectively process approved feedstocks to produce renewable fuels as well as marketable and valuable commodities and products, while potentially reducing environmental impacts. Primarily being developed by third-party private investors, these systems can be municipally owned, offering a good opportunity for public-private partnerships, or privately owned. As project developers look to more comprehensive solutions related to organic feedstocks, additional opportunities for biogas and co-product use are emerging. Some examples include:

- Biogas that is used to produce renewable hydrogen fuel for use in fuel cell applications.
- Biogas that is used as a feedstock for biodegradable plastics and intermediates for other bio-based product manufacturing.

- Anaerobic digester systems that enable algal biomass and advanced biofuel production. This could include biogas to generate electrical power to run algae production and biorefinery systems; excess heat offtake to stabilize and regulate water temperature systems for open raceway pond and photobioreactors; generator set exhaust that serves as the necessary CO_2 source for algae production; and recycled digester effluent that provides a needed nutrient source to promote algae biomass and lipid production.

Using Food Waste for Energy

USDA estimates that in 2010, approximately 133 billion pounds of food from U.S. retail food stores, restaurants, and homes went uneaten.[1] This represents 31% of the 430 billion pounds of the available food supply at the retail and consumer levels in 2010, with retail-level losses accounting for 10% (43 billion pounds) and consumer-level losses for 21% (90 billion pounds) of the available food supply.

With the U.S. Food Waste Challenge, the U.S. Department of Agriculture (USDA) and the U.S. Environmental Protection Agency (EPA) have joined efforts to:

- Reduce food loss and waste,
- Recover wholesome food for human consumption, and
- Recycle food waste to other uses including animal feed, composting, and energy generation.

One objective of the U.S. Food Waste Challenge is to reduce the amount of food discarded to landfills. The EPA estimates that food waste is the single largest component of municipal solid waste going to landfills and that landfills are the third largest source of methane in the United States.

States, counties, and municipalities are helping to lead the way in reducing the amount of food waste discarded into landfills. Some are starting to mandate diversion of primarily commercial organics from landfills. Thus, more source-separated organics (SSO) are becoming available as feedstocks for biogas systems. Food production plants, universities, restaurants, hotels, and hospitals generate considerable volumes of organic wastes. Biogas systems can be designed and built specifically to process organic wastes on-site at these commercial facilities, or wastes from these sites can be transferred to serve as the feedstock for digesters at agricultural sites for improved food system resiliency. Some generators produce waste streams that are an economic liability to their operations but would be welcome financial additions to a biogas project, such as whey, residuals from bakery/brewery/winery, fats, oils and greases (FOG), due to the fact that these wastes produce high amounts of biogas.

The community digester at Sensenig Dairy in Kirkwood, Pennsylvania is fed six times a day with manure from cows, hogs and chickens, and community food waste. The project has reduced emissions and operational costs, while creating additional revenue from the sale of carbon credits, fertilizer, and bedding.

Drive Economic Growth

Biogas systems offer a wide range of potential revenue streams, growing jobs and boosting economic development in the community. These systems can also improve rural infrastructure for waste management and distributed energy delivery improving community health, resiliency, and viability. Biogas systems can produce high-quality, concentrated liquid organic fertilizer for improved land management and increased crop yield, building and maintaining healthy and productive soils needed for sustainable food production. Along with generating revenues from the sale of renewable energy products, outputs from biogas systems can offer avoided costs of on-site electricity, heat, and transportation fuel. Renewable electricity can be sold into the power grid, and is often the primary driver for many biogas project investments. However, energy off-take contracts are often insufficient to fully finance a biogas system, and to be feasible many projects must realize the broader value of co-products, such as separated nutrients, marketable fertilizers and soil amendments. Separated fibers from the effluent stream can also reduce operational expenses or increase revenue through the production and sale of animal bedding. While niche markets exist for these products locally, developing more reliable national markets would reduce time for system payback, making project financing more attractive.

Low-Emission Fuel for Vehicles

On a well-to-wheel (WTW) basis, a truck fueled with fossil natural gas (NG) produces only slightly less CO_2 equivalent (CO_2e) emissions per mile traveled than one fueled with gasoline (Argonne National Lab, GREET 2013, http://GREET.es.anl.gov). If that same compressed natural gas vehicle (CNGV) were fueled with RNG produced from the anaerobic digestion of manure or at a wastewater treatment plant (WWTP), there would also be a significant reduction in CO_2e emissions from currently uncaptured and/or flared biogas, thereby resulting in negative CO_2e emissions.

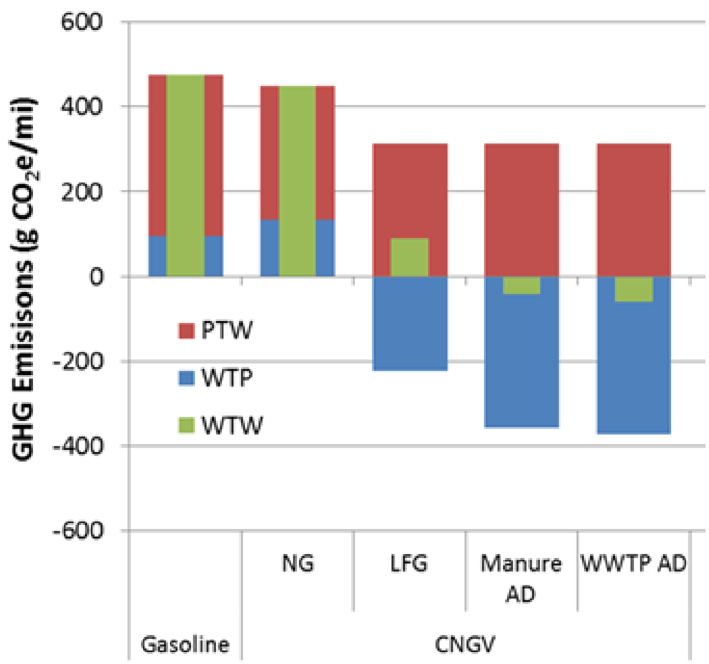

Figure 4 -Well to Wheel Emissions, Biogas v. Fossil Fuel Sources (PTW- Pump to Wheels, WTP- Well to Pump, LFG-

Additional opportunities exist for revenue generation from environmental attributes of the system, such as Renewable Energy Certificates (RECs) for electricity generation or Renewable Identification Number (RIN) credits under the Renewable Fuel Standard for the generation and use of biogas as vehicle fuel. There are also developing markets for carbon emission and nutrient offset credits, like that in California and the Chesapeake Bay watershed[iv], which provide opportunities to offset regulatory compliance costs with voluntary installation of biogas systems

All these potential financial returns can benefit project stakeholders and others involved in the biogas system. In addition, the federal government can provide environmental incentives to help defray infrastructure costs for systems which support conservation. For example, if a dairy farm installs a biogas system for enhanced manure management and renewable energy generation, cost-share funding from USDA's Environmental Quality Incentives Program (EQIP) could be combined with grant funding under USDA's Rural Energy for America Program (REAP) to help offset the investment.

Businesses and other organizations, such as universities and government facilities, can save on energy costs and achieve sustainability goals by choosing biogas as a direct fuel source in place of fossil fuels. Some end-users have saved millions of dollars over the duration of their biogas energy projects. Farmers and other companies who are recognized as leaders in sustainability and use of renewable energy may achieve indirect economic benefits through publicity of these accomplishments.

As with development of any energy project, biogas projects can benefit the local economy. Temporary jobs are created for the construction phase, while design and operation of the collection and energy recovery systems produce long-term jobs. Biogas energy projects involve engineers, construction firms, equipment vendors, and utilities or end users of the power produced. Some materials for the overall project may be purchased locally, and often local firms handle construction, electrical, plumbing, and other services.

Create Additional Revenue from Non-Energy Digester Products

In addition to energy, other potential revenue streams include nutrient recovery and management, tipping fees, thermal usage, bedding savings for farms, and carbon offsets, where available. Digestate liquids and solids (what remains after digestion) can produce additional economic benefits. The digestate has soil enhancement qualities and can be applied to growing crops, making it a marketable and valuable soil amendment. Reducing the need for synthetic fertilizers, the digestate delivers nutrients in a form that is more consistent, more readily absorbed, and more concentrated than raw manure. The use of digestate could provide a cost-savings to the farmer when compared to the purchase of synthetic fertilizers. Storage, mixing, pumping, and spreading digestate are easier than handling undigested organic materials, which can reduce energy demand and handling costs. Biogas production facilities designed to process landfill gas or source-separated organics (SSOs) provide economic benefits to the municipalities or waste management companies that own these facilities, as well as the broader community. Direct revenue sources include commercial tipping fees for SSOs.

An emerging benefit associated with biogas systems that use anaerobic digesters is the extraction of valuable nutrients, which supports environmentally and economically sound waste management. A number of systems, technologies, and procedures are available for nutrient recovery. The degree to which nutrients are removed depends on the value of the recovered nutrients, the need to produce clean water, and the economics of the technology used. Recovered nutrients offer an opportunity to create a "value-added" product that can be sold off-site as an organic amendment or as an organic fertilizer.

Cut Methane Emissions

Methane emissions in agricultural systems primarily come from three sources: livestock enteric fermentation, livestock manure waste, and rice cultivation. Manure management from dairy cattle, swine, and beef cattle operations in the United States accounts for 26% of all greenhouse gas emissions related to livestock sources.

Biogas systems can be used to capture methane that would escape into the atmosphere and contribute to climate change, and use it to create energy instead. The 239 livestock biogas systems currently operating in the U.S, reduce methane emissions by approximately 2 million metric tons of carbon dioxide equivalent annually. These projects provide enough renewable energy to power the equivalent of almost 70,000 average American homes.

The diversion of organics from landfills, collection of landfill gas and anaerobic digestion at waste water treatment plants can also decreases methane production and release.

Anaerobic digestion of livestock manure has been adopted by the State of California as an eligible project type for the generation of offsets under its statewide cap-and-trade program. This means that there is potentially a developing market demand for offsets from dairy and swine manure digester projects.

Protect the Environment
In addition to reducing methane emissions, some of the many environmental benefits of biogas systems include:

- Stabilization of nutrients for reduced water contamination risks, including substantial reduction of pathogens in manures and food wastes.
- Nutrient recovery and recycling.
- Reduction of odors during storage and decomposition.
- Providing a natural waste treatment process.
- Smaller physical footprint for organics waste processing versus composting.
- Reduced volume of waste for transport and land application.
- Efficient organic decomposition.

Digester systems protect America's waters by providing a step in broader biosolids treatment and nutrient management programs. The anaerobic digestion of manure and biosolids plays an important role in cost-effective wastewater treatment at thousands of facilities. Anaerobic digestion concentrates nutrients such as nitrogen and phosphorus, which can then be managed and diverted from water bodies to beneficial uses. With proper post-digestion nutrient management, biogas systems can thus improve water quality. Using an anaerobic digester to process organic wastes can help protect water quality. Pathogen levels can be reduced up to 99% compared to undigested manure. Anaerobic digestion is also an essential precursor to many advanced phosphorus and nitrogen separation technologies.

Biogas systems can offer significant improvements over traditional waste practices for organic material. While most organics other than manure find their way into landfills, companies and municipalities are looking to digesters for numerous environmental improvements.

Biogas systems must be properly designed and managed to operate effectively and avoid creating new environmental problems. Anaerobic digestion systems do not reduce the total amount of nutrients in the system or eliminate all organic wastes. For example, some of the organic nitrogen in the waste streams is converted to ammonium salts, which is easier for crops to utilize when incorporated into farmland. However, if not incorporated into the soil, ammonium salts can be converted to ammonia gas which is released, potentially at two to three times the rate of ammonia emissions from aerobic storage of organic waste streams. Similarly, some combustion equipment used to generate energy from biogas can increase air emissions as well. Therefore, it is important to evaluate the entire system holistically to determine impacts from pollutants of concern, including particulate matter, volatile organic compounds, nitrogen oxides (NO_x), ammonia, hydrogen sulfide, and greenhouse gases. In some instances the installation of a biogas system can necessitate additional controls and permitting requirements, which the project developers and stakeholders must be aware of and able to meet.

Overall, employing innovative digester systems with appropriate control of the nutrients, digestate solids and liquids, and air emissions could be a "win-win" for farmers, communities, the environment, and project investors. These efforts may lead to voluntary reductions in greenhouse gases and other air pollutants, pathogen load in runoff from farms, and the amount of organic wastes going to landfills. Communities that take appropriate actions to improve environmental quality, including the installation of biogas systems, can lower pollution control costs and extend the life of landfills. Economies of scale can be achieved by combining wastes from several sources.

Enhance Resilient Communities

Biogas systems can support sustainable communities by reducing methane emissions, improving water quality, producing a local source of renewable heat, electricity and fuel, and strengthening the local economy by reducing energy costs and generating revenue. They can also play a vital role in helping communities adapt and become more resilient to the effects of climate change. For example, the distributed nature of the biogas systems can increase the reliability of critical services – food, energy, waste management, wastewater treatment, and transportation – during and after disasters. Biogas systems are potentially less vulnerable to grid failures that can halt vital services. For example, a wastewater treatment or food production that is powered by onsite biogas could continue operation during a grid-wide power outage. Biogas system products could also be used to produce a renewable transportation fuel for routine use or should traditional sources be temporarily cut off.

Today's clean water agencies are increasingly considering how they can improve environmental performance, benefit their communities and improve their financial picture. The Water Resources Utility of the Future (UOTF) initiative encourages water utility leaders who are using innovative technologies and cutting-edge practices to focus on resource recovery including energy production, water reuse, green infrastructure or watershed-based approaches. The National Association of Clean Water Agencies, the Water Environment Research Foundation (WERF), and the Water Environment Federation (WEF) released the *Water Resources Utility of the Future . . . Blueprint for Action* to define relevant issues, analyze key data, and offer recommendations for critical actions for the future. Currently more than 1,200 water resource recovery facilities have anaerobic digester systems, and more than 2,400 additional facilities could install an anaerobic digester on site. Working closely with the water resource utilities is one important way to help grow the biogas industry and enhance wastewater resiliency.[v]

Furthermore, putting food waste in digesters helps close the food system loop. Connecting food waste and nutrients back to the farm creates synergies and resiliency for agriculture's adaptation needs.

The Columbus, Ohio, Merchant Digester produces biogas from municipal wastewater biosolids, food and beverage wastes, and fats-oils-and greases. The biogas is converted to CNG and electricity to supply community needs for transportation, fuel, and power. The effluent is a high-value liquid fertilizer for use on farms and community landscapes.

As an example, public and private partners in Columbus, Ohio added anaerobic digesters to the municipal wastewater treatment plant to process 300 tons per day of organic waste. The plant now produces enough biogas to generate one megawatt (MW) of electricity and 1,200 gasoline gallon equivalents (GGE) per day of CNG transportation fuel plus 90,000 gallons per day of nutrient-rich fertilizer for agricultural and landscape uses.

III. Biogas Potential in the United States

There are vast organic resources available to feed biogas systems in the United States, with the primary feedstock sources being livestock manure, food waste, landfill gas, water resource recovery facility biosolids, and food production residuals. The decomposition of these organic materials can release methane, a potent greenhouse gas that has an effect on global temperatures that is over 20 times greater than carbon dioxide over a 100-year period. Already:

- Thirty-six percent of human-related methane emissions come from the agricultural sector in the United States, equivalent to more than 200 million tons of carbon dioxide pollution.[vi]
- Municipal solid waste landfills account for approximately 100 million metric tons of carbon dioxide equivalent pollution.[vii] While more than 600 landfills currently capture and use landfill gas for energy, hundreds of additional landfills are capturing their gas for compliance and safety but flare it without producing energy.
- In 2010, more than 130 billion pounds of food meant for human consumption at the retail and consumer levels was not consumed; this is the equivalent of approximately $160 billion worth of food.[viii]
- In 2011, more than 34 million tons of food waste was landfilled or otherwise disposed of in ways that do not allow for nutrient recovery.
- More than 1,200 water resource recovery facilities across the United States use anaerobic digestion for biosolids management, thereby producing biogas that could be captured[ix]
- Food production and processing facilities (e.g., milk processing, breweries, wineries, juice plants) produce large volumes of industrial organics as a by-product of their processes. While a number of these facilities have installed on-site digesters to manage these wastes, many more processors could produce biogas by installing digesters.

If captured and managed in a biogas system, these resources could yield substantial energy and bio-based product resources while providing environmentally sound management. According to U.S. Federal government and industry sources, the United States has more than 2,000 operational biogas systems out of more than 13,000 potential sites that could host a biogas system with manure, landfill gas and water recovery facility biosolids as feedstocks[x]. The potential for these systems to generate energy and reduce greenhouse gases is summarized in the following tables.

Currently Operational and Potential Biogas Systems in the United States				
	Livestock Manure	Landfill Gas	Water Resource Recovery Facilities	Total
Currently Operational Biogas Systems	239[xi]	636[xii]	1,241[xiii]	2,116
Total Potential Number of Biogas Systems	8,241[xiv]	1,086[xv]	3,681[xvi]	13,008

Figure 5 - Currently Operational and Potential Biogas Systems in the United States Creating Energy

If the potential projects outlined in Figure 5 were fully realized, biogas could become a significant reliable renewable energy source. When taken together, these biogas sources could provide 41 billion kWh/year of electricity from 654 billion cubic feet of biogas/year. This is enough energy to power more than 3 million U.S. homes for one year or to produce the equivalent of 2.5 billion gallons of gasoline for vehicles.

Estimated Energy Potential from Biogas Sources in the United States[xvii]				
	Livestock Manure	Landfill Gas	Water Resource Recovery Facilities	Total
Biogas Production Potential (billion cubic feet/year)	257[xviii]	284[xix]	113[xx]	654
Annual Energy Production Potential (MMBTU/year)	142,000,000[xxi]	142,000,000[xxii]	67,000,000[xxiii]	351,000,000
Annual Electricity Potential (billion kWh/year)	13.1[xxiv]	22.5[xxv]	5.6[xxvi]	41.2
Equivalent Residential Electricity Use (1000 homes/year)[xxvii]	1,089	1,864	539	3,492
Potential Vehicle Fuel Gallons Displaced (million GGE)[xxviii]	1,031	1,028	441	2,499

Figure 6 - Energy Potential from Biogas Sources in the United States

Cutting Carbon Pollution

Biogas capture from landfills, livestock operations and water resource recovery facilities can lead to significant reductions in U.S. greenhouse gas emissions. According to the *Global Mitigation of Non-CO_2 Greenhouse Gases: 2010-2030*, annual methane reductions from the landfill, livestock and wastewater sectors could range from almost 4 to 54 million metric tons of greenhouse gas emissions in 2030, depending on the cost-effectiveness of various abatement options[xxix]. These reductions are equivalent to the annual greenhouse gas emissions of between 800,000 and 11 million passenger vehicles.

Boosting the Economy

In estimating the market potential for full deployment, a lack of consolidated financial and technical data for the biogas industry limited analysis which could be done by federal agencies. Based on a survey with the industry and project developers reflecting current deployment, building those 11,000 potential systems would result in an estimated $33 billion in capital deployment for construction activity which would result in approximately 275,000 short-term construction jobs and 18,000 permanent jobs to build and run the digesters.[xxx] This number does not reflect the full market impact of biogas, which would also include energy and product sales and potential environmental credits. A complete economic analysis of the benefits of expanding biogas systems is not available; however, a study[xxxi] examining the market potential from installing digesters on 2,647 dairy operations provides insight into the potential value.

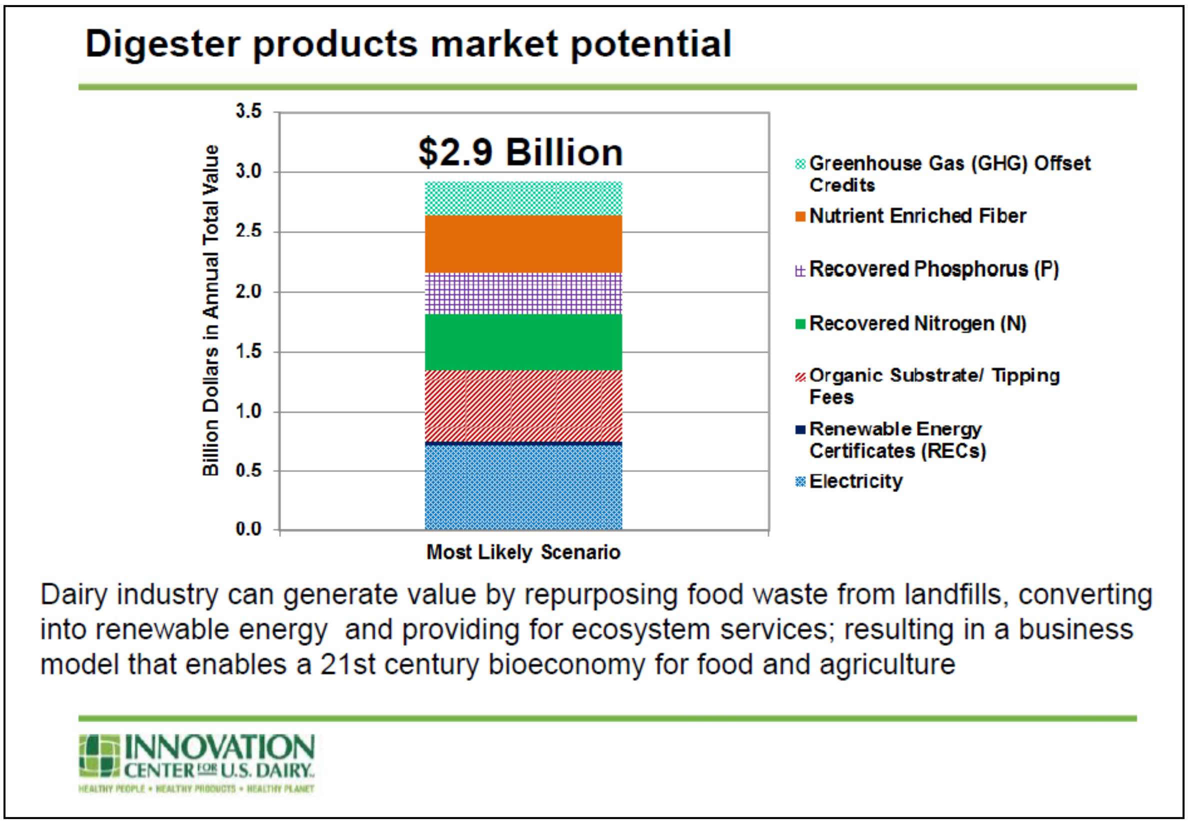

Figure 7 – Dairy digester products market potential based on Informa Economics analysis

Realizing the Potential of Biogas Systems

Fully realizing the market potential of biogas systems will take significant investment by livestock producers, municipalities, food producers, the private waste sector, and project developers. An integrated approach will be necessary to overcome the barriers limiting growth of the biogas industry. Critical efforts to promote development of biogas include:

- Support from federal agencies, including modifications or expansions of programs that advance biogas systems.
- Greater private investment in biogas systems.
- Development of broader markets for biogas and biogas system products.
- Increased emphasis on research and development to optimize systems.

IV. Primary Barriers to Realizing the Full Potential of a U.S. Biogas Industry

While there is a growing understanding among investors, policymakers, and the public of the value of investing in renewable energy systems, there remain significant barriers toward achieving a robust U.S. biogas industry.

- **Lack of Awareness of Biogas Benefits.** Investors, policy makers, and the public could benefit from gaining a deeper understanding of the value of investing in biogas systems and a biogas industry in the United States. Greater public support for the adoption of biogas systems could result in more opportunity for biogas development.

- **Unpredictable Biogas Market Conditions**. Market unpredictability is a prime barrier toward greater investment in biogas systems. Unpredictability arises from multiple factors, including uncertainty and inconsistency in state and national energy policy, which restricts access to financial markets. Further market uncertainty arises when consumers perceive inconsistency in the quality or quantity of biogas systems or in the safety and quality of solid and liquid end products from digesters.

- **Lack of Market Maturity.** Underdeveloped markets for greenhouse gas reduction benefits pose a significant barrier toward biogas systems adoption. Additionally, immature markets for non-energy products– such as nutrient rich soil amendments, pelletized and pumpable fertilizers and feedstock for plastics – also reduce incentives to invest. Additionally,there is a need for a classification system for the use of digested solid and liquid residuals to encourage consumer confidence in product safety and consistency.

- **Lack of Full Valuation.** It is difficult for small generators to interconnect to the grid and to receive a fair market price that reflects the full environmental value provided. Overall, the high project costs without financial recognition of the non-energy servicescreate a barrier toward widespread investment in biogas systems.

- **Inconsistencies across Federal, State, and Local Governments.** Fragmentation of existing resources, regulatory authorities, and jurisdictions at the Federal, State, and local levels affect biogas system implementation. Additionally, fragmented efforts within and among Federal agencies to inform stakeholders, State and Tribal governments, and the public of the regulations, policies, practices, and potential funding of biogas systems create additional barriers.

- **Lack of Technical and Applied Research & Development**. The United States currently lacks adequate environmental, technical, and economic performance data related to biogas-system production of energy, co-products, greenhouse gas and other emissions, and water quality benefits. Consolidation of this data could help market analysis and underwriting**.** There is also a need for more advanced research in the United States related to renewable energy and biogas co-product benefits, including a better understanding of barriers by sector that prevent full utilization of anaerobic digester capacity and digestion of feedstocks.

V. Solutions to Enhance Biogas Potential

In order to help the private sector voluntarily realize the full potential of biogas systems, the Roadmap identifies near terms voluntary actions the government will take to promote biogas utilization through existing programs, foster investment and strengthen markets for biogas systems and products, and improve coordination and communication. Together, these actions will increase the use of biogas to meet our renewable energy goals, strengthen the economy, and reduce methane emissions.

Promote Biogas Utilization through Existing Agency Programs

A number of programs at USDA, DOE, and EPA are driving the development of biogas systems. AgSTAR and the Landfill Methane Outreach Program (LMOP) are dedicated to promoting biogas utilization from the livestock and landfill sectors in order to reduce greenhouse gas emissions. The Rural Energy for America Program, Environmental Quality Incentives Program, Bioenergy Program for Advanced Biofuel, Biorefinery Assistance Program, and Conservation Innovation Grants provide funding for biogas systems and components. USDA, DOE, and EPA will use existing programs as a vehicle to enhance the utilization of biogas systems in the U.S through:

Promoting Biogas Systems in Federal Tools

- EPA recently released a National Agricultural Anaerobic Digestion Mapping Tool that allows users to view and analyze information about the current status and potential for biogas recovery systems in the agriculture sector.
- EPA is currently updating its Waste Reduction Model, which helps solid waste planners and organizations track and voluntarily report GHG emissions from several different waste management practices, to include anaerobic digestion.
- EPA is preparing updates to the Pacific Southwest region Co-Digestion Economic Analysis Tool, which assesses the initial validity of food waste co-digestion at wastewater treatment plants for the purposes of biogas production.

Technical and Financial Assistance: USDA's Natural Resources Conservation Service (NRCS) provides technical and financial assistance to farmers and ranchers for voluntary conservation practices. The NRCS will conduct a full review of the standards used to determine which conservation practices are eligible to receive technical and financial assistance through the Environmental Quality Incentives Program (EQIP) and other programs to ensure that they recognize the full environmental benefits of modern anaerobic digesters. Accounting for these conservation benefits (e.g., methane destruction, manure separation and nutrient recovery, manure pipelines, and manure application) will enhance the amount of financial and technical assistance available to farmers and ranchers using biogas systems.

Research and New Technology: USDA's Agricultural Research Service and National Institute of Food and Agriculture will leverage over $10 million in research funding for anaerobic digesters to improve research for nutrient recovery, particularly nitrogen and phosphorus, from biodigester effluent and solids and investigate agronomic and economic viability of using captured nutrients as commercial fertilizers and soil amendments. USDA will also continue evaluating the carbon sequestration and soil productivity potential of biochar production from biodigester solids. These results will be communicated to stakeholders (e.g. industry, regulatory agencies, and private carbon market entities) to accelerate the adoption of anaerobic digester systems. In addition, DOE will further integrate biogas and biosolids systems into the Bioenergy

Technologies Office program and develop a research plan to implement the recommendations of the Biomass Research & Development Technical Advisory Committee to accelerate development of bio-based products from biogas systems.

Partnerships: EPA will continue to engage stakeholders to address barriers to deploying biogas systems through existing programs, such as AgSTAR, the Landfill Methane Outreach Program, the Combined Heat and Power Partnership, and the Sustainable Materials Management program, including increasing outreach to state and regional partners on the benefits of biogas systems.

Transportation Fuel: DOE will include renewable natural gas from biogas as a clean energy option for research and development in the Vehicle Technology Office's Fuel and Lubricant Technologies Program to drive additional research on the utilization on biogas as a transportation fuel. DOE will also strengthen programs that support the use of renewable natural gas from biogas to compressed or liquid vehicle fuel directly; as feedstock to develop other renewable vehicle fuels (e.g., hydrogen, DME, etc.) and generate renewable liquid fuels (e.g., gasoline, diesel, jet fuel); and as a tool to increase fuel efficiency of vehicles. DOE will also increase the visibility of their existing commitment to support the use of renewable natural gas as a part of the Clean Cities Program's.

Renewable Energy: DOE will analyze the impact that biogas energy can have on electricity generation and fuel production in the U.S and its potential role as a drop-in biofuel and explore and map ways to integrate biogas with wind and solar for distributed renewable energy.

Biogas under the Renewable Fuel Standard

EPA has recognized the benefits of promoting net low-carbon fuels derived from biogas, and in a recent rulemaking EPA classified many sources of biogas as cellulosic feedstock for transportation fuels as part of the Renewable Fuel Standard (RFS). Cellulosic biofuels are the highest level of advanced biofuels specified in the RFS and achieve greater than 60% greenhouse gas (GHG) reductions as compared to the fossil fuels they replace. Use of biogas derived fuels in the transportation sector can substantially reduce GHG emissions and can serve to promote effective organic waste management, as well as efficient biogas production, recovery and utilization. Further, use of biogas under the RFS can improve anaerobic digester economics by allowing biogas producers to generate Renewable Identification Numbers (RINs).

http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm

Fostering Investment in Biogas Systems

High initial project costs create a barrier for the widespread investment in biogas systems. To begin to overcome this challenge, USDA, DOE, and EPA will take the following actions:

Propose NAICS Codes for Biogas Systems: The lack of NAICS codes for biogas systems has prevented the collection and analysis of industry financial and technical data needed to track the performance of anaerobic digesters. To address this, the Administration will assess the efficacy of developing NAICS codes for biogas systems, and if appropriate, submit a proposal for the development of a NAICS classification for biogas systems for consideration by the Economic Classification Policy Committee and the Office of Management and Budget.

Enhance Federal Financing: USDA and DOE will review applicable current loan and grant programs to enhance the financing options available for biogas systems. This includes exploring unique funding strategies for which biogas could qualify, including the Rural Utility Service's

Energy Efficiency Conservation Loan Program along with the traditional Electric Loan Program, and improving access to capital under the Rural Energy for America Program. USDA will also work with the financial community through its partnership with the dairy industry to help them better understand the risks of biogas projects to encourage additional investment.

Lead by Example: To further the development and deployment of biogas systems, within 90 days, the USDA and partners will review federal procurement guidelines for alternative fuel use and renewable energy procurement and provide recommendations to CEQ and OMB, including the Office of Federal Procurement Policy, for ensuring that products of biogas systems are eligible for and promoted by applicable government procurement programs.

Strengthening Markets for Biogas Systems and Products

According to investors, market unpredictability is a prime barrier to greater investment in biogas systems. Immature markets for biogas energy and products are also limiting development of this technology. To strengthen U.S. markets for biogas systems energy and their value-added, non-energy products, such as recovered nutrients, fiber, and soil amendments, USDA, DOE, and EPA will take the following actions:

Accelerate the Use of Biogas in Clean Energy Markets: Already, 37 states consider biogas a renewable source of energy in their renewable energy targets. USDA, DOE, and EPA will continue to work with the appropriate state and local agencies to recognize biogas' role in supporting local and state environmental and renewable energy goals and ensure that biogas systems' contribution to greenhouse gas reductions, renewable energy generation, environmental improvements and energy security are recognized. USDA, DOE, and EPA will also review opportunities to overcome barriers to integrating biogas into electricity and renewable natural gas markets through the following mechanisms:

- Electric utility and natural gas interconnection standards;
- Interconnection fee structures;
- Natural gas pipeline injection standards;
- Fair market access and right to wheel provisions;
- Net-metering; and
- Current federal incentives provided for renewable energy generation.

Promote Products of Biogas Systems: USDA, EPA, and DOE will drive the creation of tools to broaden the market for non-energy biogas system products. These tools could include best management practices for digestate use and land application, particularly in targeted watersheds with nutrient trading potential.USDA, DOE, and EPA will also provide information on the ability of biogas system products to participate in markets that provide environmental benefits. This includes working to inform decisions that could increase the degree to which biogas receives credit related to renewable electricity, fuel, carbon reductions, and water quality improvements (e.g., RECs, RINs, carbon offsets, nutrient trading credits). USDA, DOE, and EPA will analyze markets for energy and non-energy products of biogas systems and the benefits these will generate. The energy and value-added products include:

- Electricity, heat, renewable natural gas, vehicle fuels.
- Nutrients, fertilizer, fiber, soil amendments.
- Liquid biofuels, renewable chemicals, intermediaries and bio-based products.

Improving Coordination & Communication

Strengthening communication across Federal agencies, state and local levels of government will be imperative to increase the adoption of biogas systems. To overcome this barrier, USDA, DOE, and EPA will:

Establish a Biogas Opportunities Roadmap Working Group: In order to implement the strategies laid out in this document and promote strong coordination and messaging across Federal agencies, USDA will establish a Biogas Opportunities Roadmap Working Group that will include participation from DOE and EPA, as well as the dairy and biogas industry. The working group will commit to collaborating with industry to publish a progress report in August 2015 that identifies and prioritizes policies and technology opportunities to expand the biogas industry and reduce greenhouse gas emissions. A key component of this effort will be to assess existing and potential interagency cooperative structures, specifically EPA's and USDA's AgSTAR Program; DOE's and USDA's Biomass Research & Development Initiative; the EPA, USDA, and DOE "Biodigesters and Biogas" Workgroup; and the EPA, USDA, and USGS integrated nutrient management strategy.

Improve Information Sharing: USDA, DOE, and EPA will work together to improve existing information on biogas systems within government programs. This will include updating biogas data and links to resources that describe the benefits of biogas to reflect current knowledge and state of the industry on Federal websites. The Agencies will also provide guidance on incorporating biogas systems within existing technical assistance and market programs, including anaerobic digestion as a component of relevant project development tools. Agencies will also review current information related to renewable energy and other relevant initiatives to identify where additional coverage of biogas systems can help accelerate biogas system deployment.

Research and Development: USDA, DOE, and EPA will also continue to improve communication and coordination of research and development among government agencies, industry groups, and the public. Better communication of research results will aid industry's efforts to continue making advancements in the biogas sector. To initiate this process, the Biogas Opportunities Roadmap Working Group will identify research gaps in biogas and anaerobic digestion technology, including environmental benefits, market assessment, and performance standards. Examples for possible investigation could include:

- Nutrient capture technology and markets;
- U.S. biogas feedstock and biogas energy markets;
- Advanced biogas technology applications such as biochemical and algae production, carbon black, nano-fibers, biochar, fuel cell, and bio-plastic;
- Potential impact of biogas energy as first mover for other distributed renewable energy resources;
- Standards and testing for digester performance and solid and liquid residuals quality control;
- Biogas systems as infrastructure resiliency in municipal, natural disaster, and military applications;

- Logistics and infrastructure requirements for organic materials diverted from landfills to farms and community waste water treatment; and
- Biogas systems to improve rural and urban water resource recovery and treatment.

USDA, DOE, EPA Programs for Biogas Utilization

USDA, EPA, and DOE have targeted programs aimed at facilitating better communication and coordination. As the actions in the Roadmap are implemented, the agencies will utilize these programs to effectively disseminate new information to interested parties. For example, USDA and EPA will use the Food Waste Challenge to educate target audiences, especially organic waste generators, on the benefits of organics recycling using biogas systems. Additional examples of existing programs include:

USDA has programs from applied research to end use markets and financial and technical assistance programs to assist in deployment and assistance on biogas systems and, since 2009, has worked closely with the Dairy Industry to capture triple-bottom-line benefits with biogas systems. USDA's primary programs for funding biogas systems are the Rural Energy for America Program, the Environmental Quality Incentives Program, Bioenergy Program for Advanced Biofuel, Biorefinery Assistance Program, and Conservation Innovation Grant, among others. Information on these programs, past investments and other tools for project development can be found at www.USDA.gov/Energy.

EPA currently provides a wide range of information related to biogas systems, including educational materials describing biogas systems and their benefits, profiles of biogas facilities, and technical information and tools to help stakeholders evaluate the feasibility of potential biogas projects. More information on these tools can be found at www.epa.gov/agstar.

DOE is developing advanced "drop-in" biofuels, which take advantage of existing infrastructure by providing nearly identical biobased substitutes for derived intermediates gasoline, diesel fuel, jet fuel, and chemicals and other products from crude oil. DOE has also made pioneering advances to reduce costs and establish best practices for harvesting, handling, and preprocessing a variety of crops for energy production. DOE's Bioenergy Technologies Office is focused on forming cost-share partnerships with key stakeholders to develop and demonstrate technologies for advanced biofuels production from lignocellulosic and algal biomass and waste streams. Additional information can be found at:

http://energy.gov/eere/transportation/bioenergy
http://www1.eere.energy.gov/financing/current_opportunities.html

VI. Conclusion

Developing a viable biogas industry in the United States can boost the economy and provide a reliable, distributed source of renewable energy while reducing greenhouse gas emissions. Increasing production of biogas not only supports President Obama's Climate Action Plan goal of cutting methane emissions, but it also increases energy independence and security.

Biogas systems are currently installed primarily to manage wastes, but can also improve profitability for operations through energy and co-product sales, nutrient recovery and avoided energy costs. These new revenue streams come along with the added benefits of reducing greenhouse gas emissions, improving water quality, and limiting odors. Although 2,000 sites operate today, more than 11,000 additional biogas systems could be employed to handle organic waste and produce energy and biogas system co-products. Biogas can play a critical role in the sustainability and viability of communities throughout the U.S.

Realizing the full potential for the biogas industry will require support from federal agencies, greater investment, expanded markets for biogas and biogas products, and increased research and development. The benefits of biogas systems are clear. The task ahead is to reduce barriers and promote financial opportunities to move forward in developing a robust biogas industry.

Endnotes

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[iii] USEPA Landfill Methane Outreach Program
[iv] http://www.wri.org/publication/comparison-tables-state-nutrient-trading-programs-chesapeake-bay-watershed
[v] http://www.nacwa.org/index.php?option=com_content&view=article&id=1604&Itemid=250
[vi] Climate Action Plan: Strategy to Reduce Methane Emissions, March 2014
[vii] ibid
[viii] The Estimated Amount, Value, and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States, USDA Economic Research Service, February 2014
[ix] Water Environment Federation
[x] More biogas systems based on dedicated food production and processing facilities could also be built, although it is more difficult to estimate the full market potential due to a lack of industry data in those sectors.
[xi] http://epa.gov/agstar/projects/index.html
[xii] http://www.epa.gov/lmop/projects-candidates/index.html
[xiii] http://www.wrrfdata.org/biogas/biogasdata.php
[xiv] http://epa.gov/agstar/documents/biogas_recovery_systems_screenres.pdf
[xv] http://www.epa.gov/lmop/projects-candidates/index.html (Added current + potential)
[xvi] Assuming facilities with an average flow > 1 million gallons per day are potential sites. http://www.wrrfdata.org/biogas/ and EPA 2008 Clean Watershed Needs Survey
[xvii] The energy production potential and methane estimates were calculated using two difference mythologies. For further information on the methodology refer to the sources cited in each section.
[xviii] Assuming biogas from livestock manure is 60% methane; http://epa.gov/agstar/documents/biogas_recovery_systems_screenres.pdf
[xix] Adding current + potential biogas production potential from http://www.epa.gov/lmop/projects-candidates/index.html (460 +317 mmscfd * 365 days/year = 283.605 billion ft3/year)
[xx] Utilities of the Future Energy Findings, Steve Tarallo, et. al published by WERF under ENER6C13 estimate fall 2014
[xxi] http://epa.gov/agstar/documents/biogas_recovery_systems_screenres.pdf
[xxii] Using potential biogas production above and a biogas energy content of 500Btu/scf. http://www.epa.gov/lmop/faq/landfill-gas.html
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[xxv] Used current + potential electricity potential from: http://www.epa.gov/lmop/projects-candidates/index.html and converted MW to kWh/year using (MW*24 hrs/day * 365 days/year *.9 time online)
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(based on industry survey of current project developers and assumes $3M capital cost, 25 construction job, 1.66 permanent job per project)1
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