行政院及所屬各機關出國報告
（出國類別：考察）

德國畜牧沼氣資源回收及再利用考察

服務機關：行政院農業委員會畜產試驗所

姓名：鄭閔謙

職稱：助理研究員

派赴國家：德國

出國期間：105年2月13日至105年2月21日

報告日期：105年4月19日

摘　要

台灣為海島型國家，天然資源缺乏，又受全球溫室效應、空氣污染及核能安全等因素影響，發展綠色再生能源為當務之急。德國於 2000 年通過再生能源優先法案，且宣示 2022 年全面停止核能發電，因此大力發展綠色再生能源，根據統計 2012 年德國境內約有 8000 多座生質沼氣發電廠，發電量占全國總發電量之 4%。本次前往德國考察之目的為研習其畜牧沼氣資源生產、利用及後續沼液沼渣利用模式與技術。

在參加 2016 年於德國紐倫堡舉辦之國際沼氣會議及參訪三間沼氣工廠並收集相關法規等資料後。提出以下建議：一、台灣需建立沼氣生產利用之友善法規，包括訂定沼氣發電量目標、提高沼氣發電之躉購電價、規劃沼氣工廠設置專區、補助與低利貸款鼓勵業者設置專業沼氣生產工廠、補助沼液沼渣使用、逐年減少化學肥料補助及設立專責單位負責沼氣、沼渣及沼液利用事宜，此專責單位可輔導沼氣生產利用、農地規劃、肥分利用及污染監測（可統合農糧、畜牧、環保及水利等人力）。二、由於德國之沼氣生產採混合發酵，其原料來源包括畜禽糞尿、農業廢棄物（稻麥稈、植物植體、廢棄木頭...等）、生活垃圾等，但於台灣可先朝農業廢棄物與畜禽糞尿混合發酵，亦可解決農業廢棄物燃燒而產生之空氣污染問題。三、引進良心企業資金設立專業沼氣生產工廠，其所產生的電亦可自行利用，並解決其缺電風險。

台灣為能源進口國，急需開發替代能源，然台灣地區豬隻、牛隻與雞隻在養頭數約 550 萬頭、14 萬頭及 1 億隻，每日產生糞尿量極其可觀，畜禽糞尿因含有豐富的有機質成分，為生產沼氣能源良好的基質來源，且發酵過後之沼液沼渣亦為良好的肥料來源。開發利用畜牧與農業廢棄物生產之沼氣為可永續使用之綠色能源，可達到廢棄物資源化目標，亦可真正解決畜牧與農業事業廢棄物處理之問題。

目 錄

德國畜牧沼氣資源回收及再利用考察

出國報告

壹、緣起

台灣為能源進口國，急需開發替代能源，然台灣地區豬隻、牛隻與雞隻在養頭數約 550 萬頭、14 萬頭及 1 億隻，每日產生糞尿量極其可觀，畜禽糞尿因含有豐富的有機質成分，為生產沼氣能源良好的基質來源，且發酵過後之沼液沼渣亦為良好的肥料來源。開發利用畜牧與農業廢棄物生產之沼氣為可永續使用之綠色能源，可達到廢棄物資源化目標，亦可真正解決畜牧與農業事業廢棄物處理之問題。但台灣因缺乏規模化之沼氣工廠，因此沼氣發電仍屬畜牧業自場小規模利用，但台灣畜牧場之沼氣生產係屬廢水處理過程之副產物，其目的為廢水處理而非專業沼氣生產，因此沼氣生產效率較低。如何妥善規劃專業沼氣生產中心營運模式與技術實為台灣日後重要之課題。德國於 2000 年通過再生能源優先法案，且宣示 2022 年全面停止核能發電，因此其大力發展綠色再生能源，根據統計 2012 年德國境內約有 8,000 多座生質沼氣發電廠。發電量占全國總發電量之 4%。本次前往德國考察之目的為研習其畜牧沼氣資源生產、利用及後續沼液沼渣利用模式與技術。

貳、目的

了解德國畜牧沼氣資源回收及再利用技術，引進可用之德國沼氣生產、收集、利用及沼渣利用處理技術，改善本國畜牧沼氣收集與利用技術模式與營運模式。.

參、過程

本次參訪行程安排如下表：

	起迄地點	參訪單位	參訪項目
2/13（六）	桃園機場至法蘭克福機場		
2/14（日）	法蘭克福機場至紐倫堡機場		
2/15（一）	紐倫堡	Bio-Energy-Center Furth	
2/15（二）	紐倫堡	Nürnberg Convention Centre	參加 2016 年國際沼氣研討會
2/15（三）	紐倫堡	Nürnberg Convention Centre	參加 2016 年國際沼氣研討會
2/15（四）	紐倫堡	Natura GmbH ＆ Co. KG	
2/15（五）	紐倫堡	Ruck Biogas GmbH ＆ Co. KG	
2/13（六）	紐倫堡機場至法蘭克福機場		
2/14（日）	法蘭克福機場至桃園機場		

肆、 人員

服務單位	職稱	姓名
畜產試驗所	助理研究員	鄭閔謙

伍、 內容與心得

本次行程分為參加國際沼氣會議及沼氣工廠參訪兩部分。

一、國際沼氣會議

德國國際沼氣會議(如圖 1)為一年一次由德國農業協會(Deutsche Landwirtschafts-Gesellschaft, DLG)與德國沼氣協會(Fachverband Biogas e.V.)聯合舉辦，本次會議主要討論的重點為德國新的液肥修法重點、沼氣廠營運安全及營運效率的改善（包括沼氣生產與發電效率）。

以下僅摘要探討本次會議重要資訊

（一）沼氣廠安全管理

德國目前約有 8,000 多座沼氣廠，發電量為 41 萬瓩，年發電量為 290 億度，大規模沼氣工廠不在少數發電廠，因此需具有專業化管理避免危險發生，因此有需多沼氣工廠會去取得如 ISO 等認證，且德國政府都有定時或不定時的工廠查核制度，表 1 列舉沼氣工廠可因應作業環境安全與人員防護等需求而取得不同認證。

德國的沼氣工廠安全管理措施，簡稱 TSM（Technical Safety Management），可提供沼氣工廠日常操作與維護之自我檢核表，包括人員資格審查、是否符合法律規定，健康和安全維護，環境保護，措施改善等。也有相關的緊急應變措施，例如現場管理部分需要配置沼氣及電工專業人員，如發生事情人員必須於 30 分鐘內抵達現場，並具備由遠端控制電腦能力。具有連續測定 CH_4、H_2S、CO_2、O_2等測定儀器並有警報功能。最少每周需檢查沼氣工廠功能運作狀況。

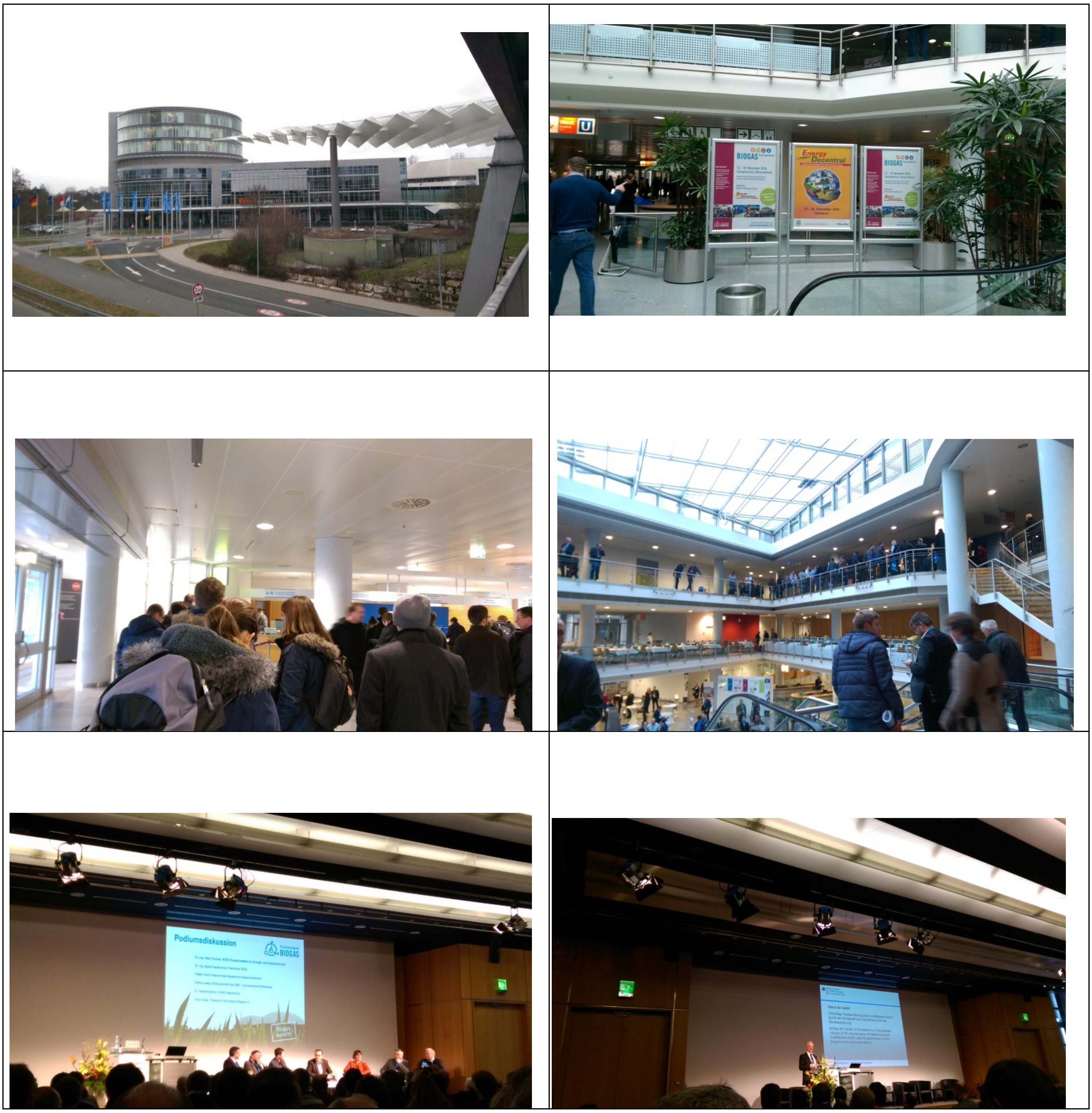


圖 1. 沼氣會議

表 1. 德國沼氣工廠建議取得認證項目

認證項目	安全管理項目
ISO 9001	Quality management according
ISO 14001	Environment management
OHSAS 18001	Health and safety management according

（二）法律

德國為了管理沼液沼渣應用，防止環境污染而備有數種相關的管理辦法，以下列舉幾項較重要的規定

1. 沼液沼渣需儲存 9 個月以上方能利用。
2. 高地下水水位區之沼液沼渣儲存設施需使用更堅固的防漏設施，例如雙牆面設計
3. 盆地地區不可設置沼液沼渣儲存設施
4. 依照 91/676/EEC 硝酸鹽指令 (Nitrate Directive)，需劃設境內之硝酸鹽脆弱區 (Nitrate Vulnerable Zones, NVZs)，以減低硝酸鹽對水源造成的污染，硝酸鹽脆弱區內每年每公頃可施用之總氮量不得超過 170 公斤（蘇銘千。2010）。
5. 載運機具規格需符合法令規定及駕駛需具備職業駕駛執照。
6. 各項營業需注意是否符合相關稅法規定。
7. 肥料販售需明確標示成分、警語、施用時期等內容。
8. 行駛於道路需符合相關交通法規，避免載運物散落地面而造成交通事故。

台灣雖有類似的規定，但台灣所缺乏的是對全國農業廢棄物、農地與地下水的統整，雖有一些調查數據，但可能都零散分布於不同單位做為不同用途使用，應該設立權責部門將資料集中統整，補齊缺乏部分並定期更新。如此方能釐清台灣農地與農產廢棄物特性，例如台灣有多少種類之農業廢棄物及其數量可作為沼氣發酵料源、劃定台灣沼液沼渣可利用區域並計算面積，統一規劃、管理及監控，使台灣沼氣綠能產業步上軌道。

（三）沼液沼渣產品利用

畜牧糞肥中含有許多的微生物，亦可能含有動物治療後殘留之抗生素甚至有抗藥性基因的微生物存在。因此確認沼液沼渣安全性為首要工作。德國學者調查當地以各類動物糞肥作為料源之沼氣工廠後發

現，雖然沼液沼渣含有豐富的微生物族群，但無含有動物或人類之病原性微生物、抗生素殘留及抗藥性基因的發現。

德國當地沼氣工廠會利用乾燥、濃縮等方式提高沼液沼渣之營養濃度，降低運輸管銷成本，製成各種商品販售（如圖 2-1、2-2）。乾燥熱能來源有電熱、發電餘熱、日光能等。沼渣商品需具有持續性、高有機質含量、方便使用、包裝精美、肥料用途廣、即時取得、營養成分穩定（可以適當加入單獨營養素）等特點。另外有一些研究為將沼渣開發成合成氣體、合成油或生物碳等較高價值之商品。但尚未達經濟規模價值。

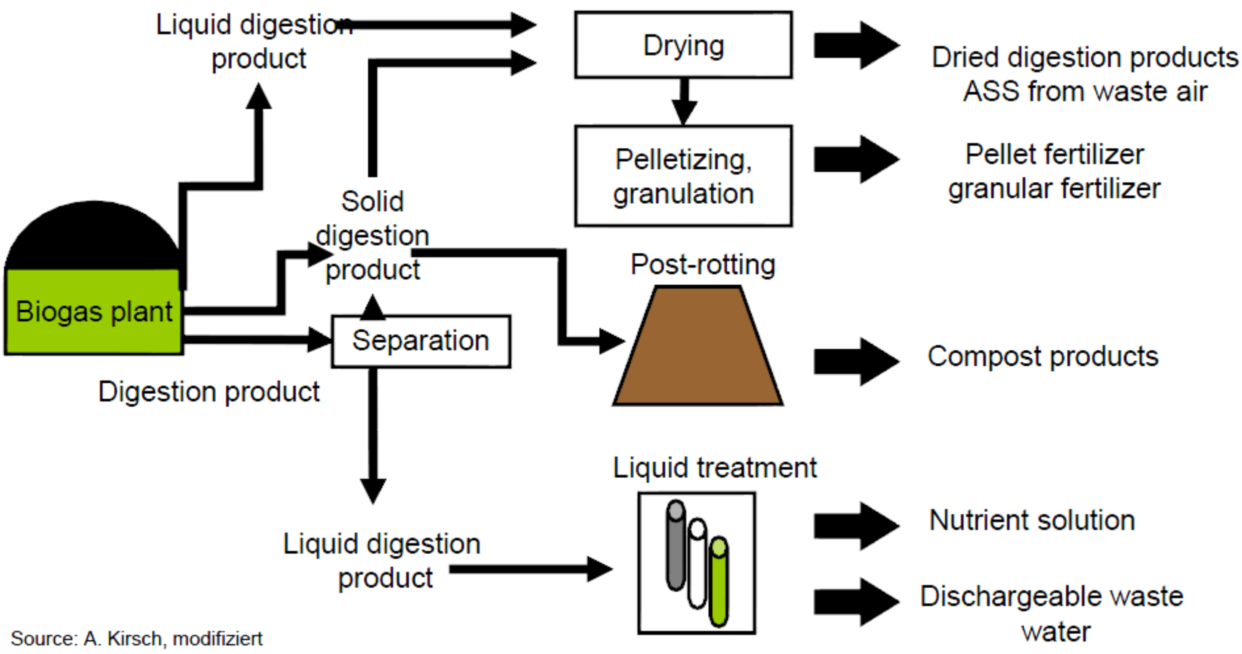


圖 2-1. 德國沼液沼渣處理流程

(資料來源 Thomas karle)

圖 2-2. 沼液沼渣產品化

（四）改善沼氣發酵效率

1. 建立沼氣發酵料源基本成分資料

每種沼氣發酵材料之成分特性皆不同，德國已有系統性的建立每種沼氣發酵材料之成分分析，並研究各項成分（例如澱粉、醣類、蛋白質、纖維素）對沼氣產量之影響。據此以電腦模式推估各項材料組合混合發酵後其沼氣產量與成本收益分析。台灣應可參考其模式，建立本土性發酵料源成分特性評估，作為台灣沼氣綠能發展之基礎。

2. 預處理

使用不同料源進行沼氣發酵皆會影響沼氣產量，尤其是富含纖維性高之原料，其分解效率較差，因此可先作預處理，例如細切、粉碎、攪拌等（圖 3)、熱分解（熱水、熱氣）及化學處理（酸或鹼）可提高沼氣發酵效率，增加沼氣產量。

馬糞墊料

沼氣發酵料源前處理設備

(資料來源：Hans Oechsner)

圖 3. 沼氣發酵料源前處理設備

（五）二段式發酵

使用二段式發酵方式，增加停留時間，可使發酵物質充分被分解利用。

（六）添加微量營養素或氫

於甲烷化階段提供 Ni、Co、Mo、Se 及 Fe 等甲烷菌所需之微量營養源或氫可促進沼氣生產。

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$。

（七）降低沼氣廠設備之故障率與提高沼氣利用率

透過良好的管理，降低沼氣廠發電機之故障率，可減少因發電機故障無法發電而損失之成本。另一方面，有效控管料源投入、沼氣貯量與發電消耗量之彼此關係，避免因沼氣生產過多而透過洩壓閥溢散至大氣造成沼氣浪費與環境污染。

（八）優良料源管理

青貯玉米為生產沼氣之優良料源，因此做好玉米青貯管理，避免於青貯過程中因劣質發酵而產生不必要的乾物質損失。根據數據指出，青貯玉米經劣質青貯過程，最高可造成 40%之乾物質損失，進而造成 720 歐元/公頃金額損失。

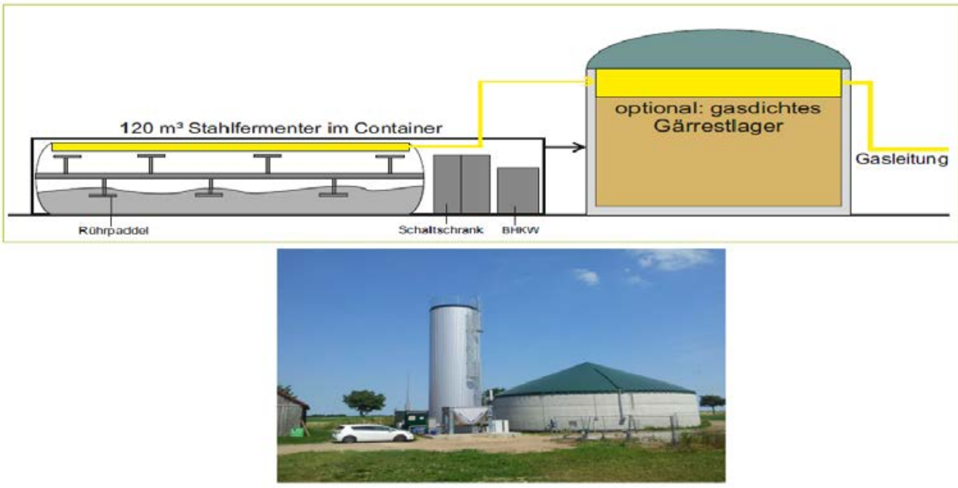
（九）減少沼氣工廠污染排放

沼氣工廠主要的污染排放為一氧化氮（NOx）、二氧化硫（SO_2）及顆粒性物質（PM），可以適當的選用過濾系統，減少空氣污染源之排放。

（十）鼓勵小型畜牧糞肥沼氣工廠設置

由於德國糞肥利用於沼氣工廠的比例不到 30%，加上德國東部農業結構的改變及政府躉購費率優惠政策支持下，促使小型沼氣工廠（<75KWH，<300 頭成年乳牛）逐漸受到大家歡迎。且在各項綠能發電補助逐年縮減狀況下，以禽畜糞為原料之 75 KW 以下之沼氣工廠，2012 年之保證收購電價為 新台幣 10.78 元/度（維持 20 年），較原價格提高 20%，同時德國政府亦提供生質沼氣設施與熱電共生系統 10 至 20 年的全額優惠貸款，以全面促進該產業之發展（蘇銘千。2010）。

小型沼氣工廠可以由一座預混攪拌槽、一座厭氧發酵槽（含攪拌設備）、一座沼氣貯槽、一座沼渣貯槽、純化系統及發電機組設備組成（如圖 4）。雖然小型沼氣工廠之投資建造成本較低，但需注意於衛生管理、沼渣利用規定及利潤成本控制等方面。台灣地狹人稠，應可通盤檢討台灣適合設立大型或小型沼氣工廠之地點，儘量降低運輸成本。



（資料來源：Dr. Walter Stinner）

圖 4. 小型沼氣工廠

二、沼氣工廠參訪

Bio-Energy Furth 沼氣工廠位於德國紐倫堡，於 2011 年正式商轉（如圖 5）。總投資金額大約 2,300 萬歐元。每日約投入 110 公噸之發酵料源（如圖 6 與圖 7），主要材料為玉米青貯（85%）再加上一些禽畜糞肥或其他發酵原料。沼氣產量為 700 m^3/hour 年。發電機組設置 250 KW，年運轉 8,300 小時，換算一年發電量為 200 萬度。沼氣工廠由原料貯存區、發酵料源前處理系統、料源輸送系統、數個厭氣發酵槽體（如圖 8）、沼氣純化系統及發電機系統（如圖 10）組成。其中純化系統利用鹼水洗方式將沼氣純化至含 99%之甲烷，目前全部作為發電使用，未來可發展為汽車燃料。該廠之沼液沼渣利用為以槽車行駛至貯槽旁經由管道自動填裝（如圖 8 與圖 9），然後載運至附近農地施灌。由於該廠因發酵料源關係，因此較無明顯之臭味產生。

圖 5. Bio-Energy Furth 沼氣工廠

圖 6.發酵料源-玉米青貯

圖 7.發酵料源-廢棄木屑

圖 8. 厭氧發酵槽

圖 9. 施灌槽車

圖 10. 純化系統與發電機室

Natura GmbH & Co. KG 沼氣工廠於 2004 年開始商轉（如圖 11）。主要發酵材料為食品垃圾（賣場過期品、市場農場品、工廠不良品）、廢棄木頭、廄肥墊料（如圖 12）。沼氣產量為 780 m^3/hour，沼氣發電機組有 844 KW 一台與 526KW 二台，輪流運轉。一年共運轉 8,650 小時，年發電量約 500 萬度。由於食品垃圾來源複雜，且大部分含有包裝物，因此該廠備有垃圾破碎分選裝置，去除無法被微生物分解之物質。該廠因發酵料源關係，廠區部分垃圾分選空間較有異味產生，因此亦備有除臭設備。

圖 11. Natura GmbH & Co. KG 沼氣工廠　　　　圖 12. 發酵料源-廄肥墊料

Ruck Biogas GmbH & Co. KG 沼氣工廠於 1995 年正式商轉（如圖 13）。總投資金額大約 80 萬歐元。廠區備有 2 座 900 公噸一次發酵槽及一座 2,700 公噸之二次發酵槽（如圖 14）。每年發酵基質大約 15,000 公噸，由畜牧糞肥、屠宰場血液、餐飲廢棄物、青芻玉米組成（如圖 15），發酵料源皆使用自動送料系統進入厭氣發酵槽（如圖 16）。沼氣產量為 150 m^3/hour。發電機組設置 350 與 250 KW 各一台，輪流運轉。該廠沼渣貯存空間為開放式，槽車抽取時再以一輛攪拌車於池邊進行沼渣攪拌（如圖 17）。施灌槽車行駛至池邊，以自動對接管道方式抽取沼渣（如圖 18）。槽車未進行施灌時，施灌管路收縮至槽體兩旁（如圖 19），當進行施灌時，施灌管路則展開，可進行大面積施灌（如圖 20）。沼渣貯存池周圍與施灌全程之異味濃度尚可接受，可能因為沼渣已經長時間厭氣發酵所致。

圖 13. Ruck Biogas GmbH & Co. KG 沼氣工廠

圖 14. 厭氧發酵槽

圖 15. 發酵料源-青芻玉米

圖 16. 自動送料系統

圖 17. 開放式沼渣貯存池

圖 18. 施灌槽車抽取沼渣

圖 19. 槽車行駛中

圖 20. 槽車施灌中

陸、 建議事項

一、建立台灣可施灌農地與畜牧飼養分布資料

農委會每年皆有農情調查，其中有許多資料可供應用，因此統整現有調查資料，包括台灣現有可施灌地面積、土壤特性、地形地貌、地下水水位、水質、畜牧飼養動物種類、分布地區、數量、農業種植作物種類、數量、分布地區，如此可歸列出台灣沼氣工廠可設置地點與規模、可作為發酵潛力料源種類、數量及計算出後續沼液沼渣需多少農地面積去化等。台灣有豐富的調查資料，如能妥善運用，再參考國外相關文獻資料，相信應能快速釐清相關問題，並發現問題進而解決問題。

二、成立任務團隊或專責單位輔導沼液沼渣利用

行政院農業委員會自民國 99 年依據農業事業再利用管理辦法，開放畜牧廢水以槽車載運方式至農田進行施灌之再利用申請，畜牧廢水始能做為肥料來源合法施用於農地，接著環保署於民國 104 年 11 月通過修正水污染防治措施及檢測申報管理辦法，設立沼液沼渣農地肥分使用專章，沼液沼渣才可依法使用管線進入農地作為肥份使用。但農民舊有使用習慣早已養成，建議應成立任務團隊或專責單位負責輔導農民沼液沼渣再利用事宜，例如宣導飼料中銅鋅減量觀念與畜舍節水提高廢水濃度、負責農地沼液沼渣利用規劃、全國農地與地下水統一污染監測；並每年檢討、建立各種類作物、地形地貌、土壤特性之沼液沼渣利用準則（可統合農糧、畜牧、環保及水利等人力）。

三、專業沼氣工廠設置並輔導第三方業者協助載運沼液沼渣與農地利用事宜。

目前台灣之沼氣生產方式尚屬於廢水處理過程中所產生之副產物進行利用，而非以生產沼氣為目的而去產生沼氣，兩者之效益差距甚大，然最大瓶頸尚在沼渣去化困難。實務上農民想提高進料濃度，增加沼氣產量，但怕放流水標準超標。因此需設置專業沼氣工廠於畜牧場集中區附近，或輔導第三方業者協助載運沼液沼渣與農地利用事宜，並輔導畜牧場升級厭氣發酵設備，產生沼氣供自場利用。

台灣電力公司目前於台灣有 5 座天然氣發電廠，建議沼氣工廠可優先考慮設置於這幾座天然氣發電廠周邊，因為隨著民眾要求乾淨能源使用，日後天然氣佔台灣發電比率勢必提高，但台灣天然氣全部自國外進口，價格起伏易受油價波動。沼氣中含 55-75%之甲烷，如經過適當純化，可將甲烷提高至 99%，成分已非常近似於天然氣，可直接以現有設備進行利用，減少購地、人員與設備設置成本與時間。

四、鼓勵台灣大型畜牧場設置小規模發電設備並應提供全額優惠貸款及協助

鼓勵台灣大型畜牧場設置小規模發電設備，並應提供全額優惠貸款及協助。經濟部能源局 102 年公告沼氣發電系統推廣計畫補助作業要點，公告沼氣發電系統設置費補助金額，以發電機組裝置容量核計，每瓩補助金額度以新臺幣三萬五千元為上限；補助總額不得超過沼氣發電系統設置費之百分之五十，然小規模發電機組（75 KW）加上純化設備之設置成本少則百萬多則上千萬元，有意願裝設小型機組發電機之業者大部分為農民，因此大部分應於補助之外再給予 10 至 20 年之全額優惠貸款，減輕初期設置成本壓力。

五、提高沼氣發電躉購費率

依據經濟部能源局頒布中華民國 104 年度再生能源電能躉購費率及其計算公式中沼氣發電之躉購費率為 3.3803 元，雖然台灣每年檢討躉購費率之合理性並做適度調整，但目前成本探討僅討論台灣現行沼氣生產成本，然台灣目前之沼氣生產為畜牧廢水處理之副產物再利用，非如國外以專業沼氣生產工廠成本探討，包括發酵料源成本、沼渣去化成本及管銷成本皆未能明確計算。反觀德國較類似台灣以糞肥為主原料（>80%）之小型沼氣工廠（≤75KW），20 年躉購費率為新台幣 10.127 元（0.2767 歐元/ kWh）。兩者相差甚遠，台灣相對較低的躉購電費較難產生政策誘因。另一方面，台灣住宅與工業用電全球第 3（2.8530 元）與第 4 低（2.927 元），如此低的電價實乃政府德政，但較不利於各項再生能源發展。2014 年德國每度電費平均為新台幣為 8.51 元（0.23 歐元）。但大部分民眾卻可以接受因使用較乾淨再生能源而電價必須漲價的事實，台灣電價大漲可能有其困難，不妨可以建立一套公式，該公式以台灣每年再生能源的比率做為電費計算的基礎，再加上做好良好的政策溝通，為台灣奠定綠色能源良好的發展基礎。

六、引進良心企業資金設立專業沼氣工廠

經濟部擬修正電業法讓民間可自由銷售電力，如通過後可鼓勵民間資金投入電力開發。另一方面，溫室氣體減量法正式於民國 104 年 6 月通過，並將我國減碳目標入法，且未來還能衍生碳交易等，如此可鼓勵企業投入綠色能源開發。透過以上政策誘因，引進良心企業資金設立專業沼氣工廠，不僅可穩定本身企業供電品質、提升企業形象、增進產品出口競爭力及減輕政府負擔，一舉數得。

柒、附件

What is the focus of the different systems?

• ISO 9001	Product quality, service sector, customer benefit
• ISO 14001, EMAS	Emissions, resource consumption
• OHSAS 18001	Health protection
• TSM	Prevention of organizational fault

ISO 9001, ISO 14001, EMAS, OHSAS 18001 define general requirements which the company must translate into concrete action.

TSM is based on compliance with laws, regulations and the generally accepted rules of technology which apply throughout the industry and are the same for all companies.

Principle of management systems

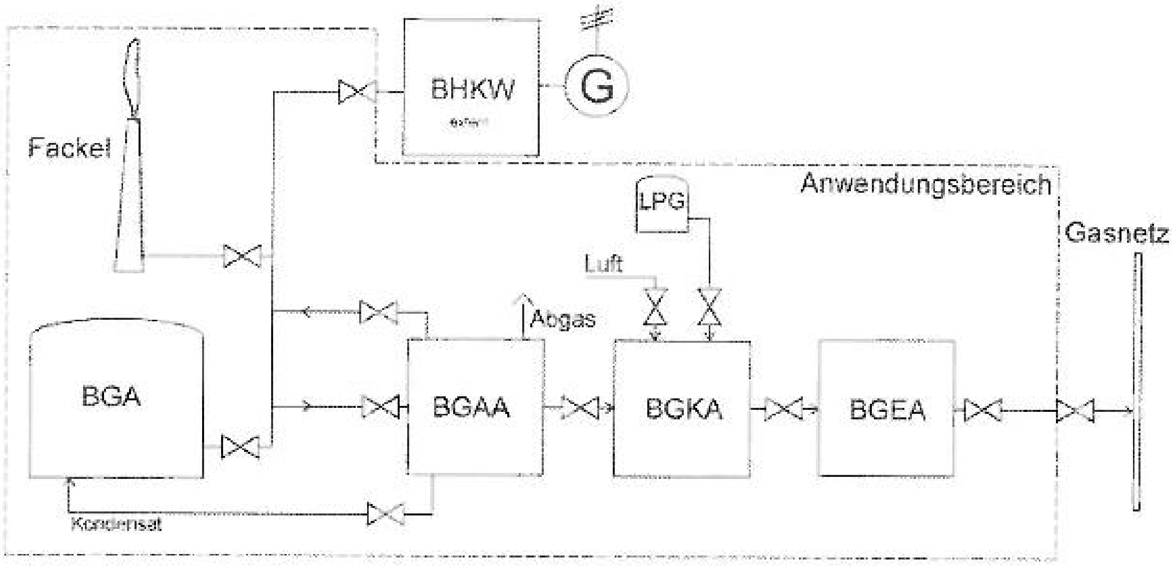
9001, 14001, 18001 … and TSM operate on the principle: **PDCA**

- Plan
- Do
- Check
- Act.

Technical Safety Management (TSM)

Technical Rule – bulletin DVGW G 1030

Requirements on the qualification and the organization of owners of plants for generation, conveyance, treatment, conditioning or feeding of biogas



BGA → Biogas plant

BGAA → Biogas treatment plant

BHKW → Cogeneration unit

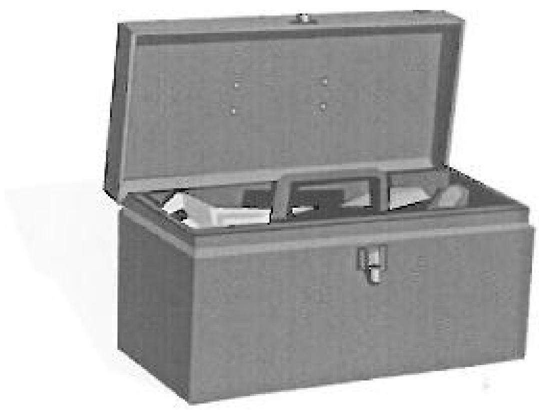
BGKA → Biogas conditioning unit

BGEA → Biogas feeding unit

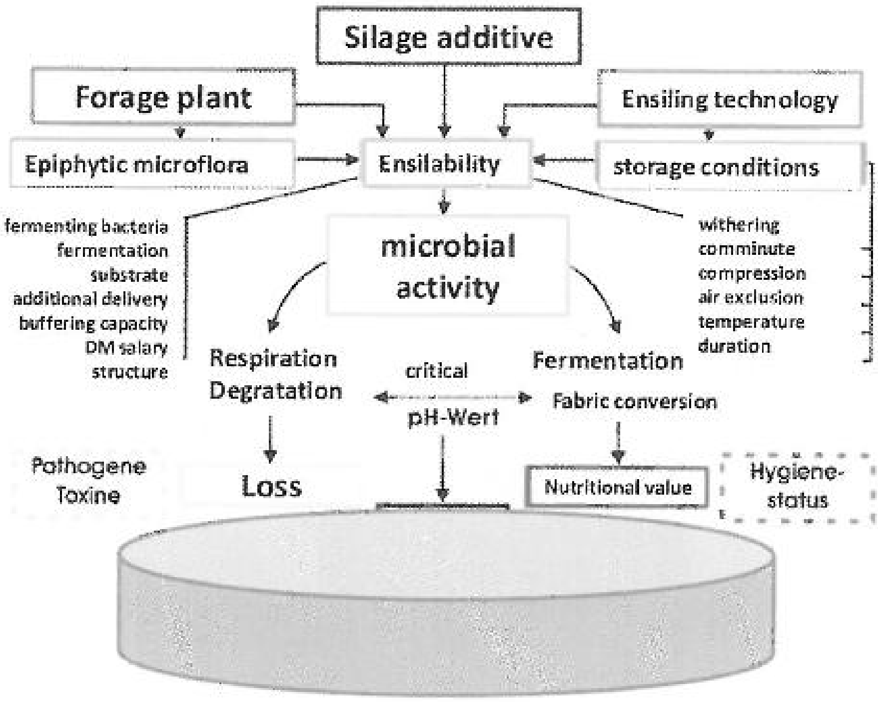
Guidelines as tools of the TSM

Guideline as an instrument / tool for the following segmentts:

- Gas,
- Water,
- Waste water,
- Electricity,
- District heating,
- Industry gas,
- LPG (networks)
- **Biogas,**
- …



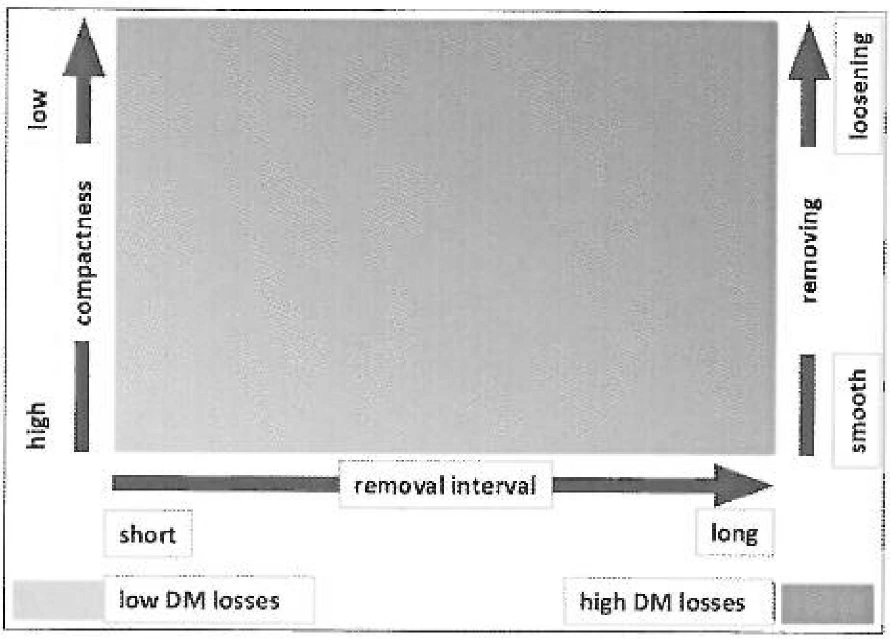
Influence on yield



System silage - Zimmer 1969

Influence on yield

Schematic representation of the DM losses



Source > KWS

Example Hazard evaluation / PLT

Steuerung allgemein	Mangelnde Funktionssicherheit	☑ 1. Die Prozessleittechnik ist gemäß Risikoanalyse fehlersicher ausgeführt	ok.	
		auf Methan (Gassensor) ☐ 2.5. Strömungswächter technischen Lüftung ☐ 2.6. Feuchtesensor ☐ 2.7. Drucksensor an der Substratpumpe ☐ 2.8. Druckluftüberwachung		

…n an die …e umfassende detaillierte anderen …nteilung nach zur Verwendung …auteilen führt. …ahteten, unabhängigen, zusätzlichen Überwachungseinrichtungen, welche die Anlage bei Fehlfunktionen in einen sicheren Betriebszustand überführen, ist auf Biogasanlagen die gängige Alternative.

Specialist knowledge is still required.

Safetydocx cannot replace the knowledge communicated in technical training and instruction sessions.

Efficient: *Safetydocx*

Safety folder

- Contents
- Risk evaluation
- Explosion protection document
- Emergency plan
- Organigram
- Operating instructions
  - Start-up
  - Action in case of power outage
  - Action in case of gas alarm
  - Work in potentially explosive atmosphere
  - Handling process aids (TRGS 529)
  - Inspection of pits and shafts
  - Activated charcoal change
  - Electrical work
  - Other
- Maintenance schedule
- Hygiene plan
- Instruction protocols for personnel
- Instruction protocol for visitors
- Other

ARGE Biogas SAFETY FIRST

Efficient: *Safetydocx*

Library

- Rules and regulations
- Publications by FvB
- Safety labels
- Typical fire brigade plan acc. to DIN 14095
- Typical process control matrix
- Typical hygiene plan
- Typical explosion protection document "Dust"
- Workplace exposure limts
- Other

ARGE Biogas SAFETY FIRST

Efficient: *Safetydocx*

Advisor Worth knowing

- Damage management / trouble shooting
- Authority compliant behavior
- Insurer compliant behavior
- Fire protection concept
- Lightning stroke risk analysis
- New hazard symbols
- Practical examples
- Other

Water legislation

§ 62/63 WHG: Duty of care principle – reference to building authority permission

AwSV (VAwS)
Requirements on plants

TRwS
Unanimity among experts

Proof of suitability for plants specified in the AwSV

Water authorities

Simplified building laws

Art. 17 MBO: Proof of suitability also for other legal areas

WasBauPVO
Identif. of concrete building projects

abZ for building products as parts of AwSV plants

Changed by ECJ judgment

Building supervisory authorities

Bundesministerium
für Umwelt, Naturschutz,
Bau und Reaktorsicherheit

Link to building law

Following the ECJ judgment of 15 October 2014, member states must not make national requirements on building products harmonized on European level. This relates to permissions by the building supervisory authority and other procedures or markings.
As a consequence of this, the building law and to some extent the water law are being reviewed.

BIOGAS-Tagung 16. – 18. Februar 2016 Nürnberg

What is the essence of the amended laws ? ? ?

Freistaat Thüringen

DVO – Fertilizer Ordinance

- Digestion products are charged to the farm's upper limit longer blocked periods / restrictions on crop types
- Nutritional balance / budget per holding
- Provision of 6 months' storage space for all liquid types of farm manure

AwSV

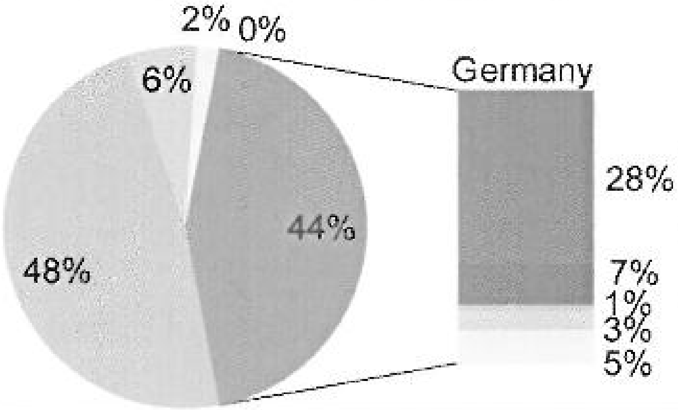
- 9 months storage volume for liquid digestion products
- No store of digestion products in earth basins
- Service the biogas plant with wall
- Leak test (every 5 years with empty tank)

→More storage capacity, more efficiency in application needed,
→Scarcity of area, transport and treatment of digestion product

Use of substrates in biogas plants

Freistaat Thüringen

Source: DBFZ owner opinion poll in 2014



Biogas plant stock in Germany: 0.24 kW/ha

Size depends on farm manure use

Inst. capacity kW	Renewables %	Farm manure %
< 70	16	83
71 – 150	34	65
151 – 500	45	53
501 – 1000	51	40
> 1000	50	32

Farm manure use depends strongly on stable size, not on stocking rate

→ Low level of slurry use refining regions

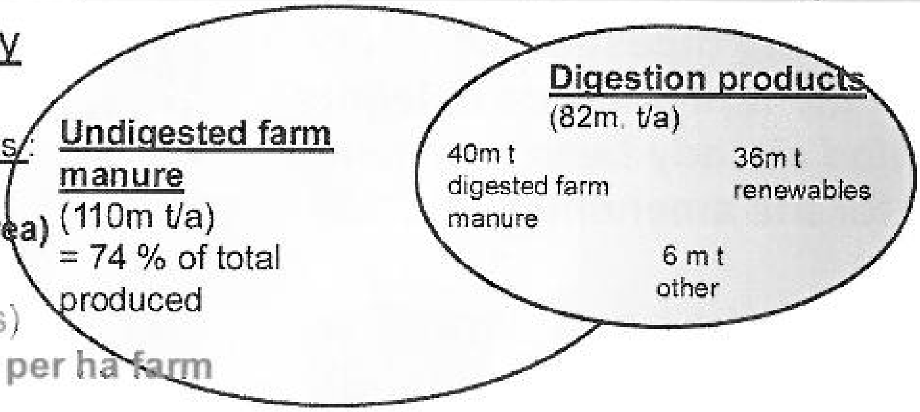
→ High rate of slurry use in Central Germany

Farm manure and digestion products

Quantity in Germany

192 million t/a

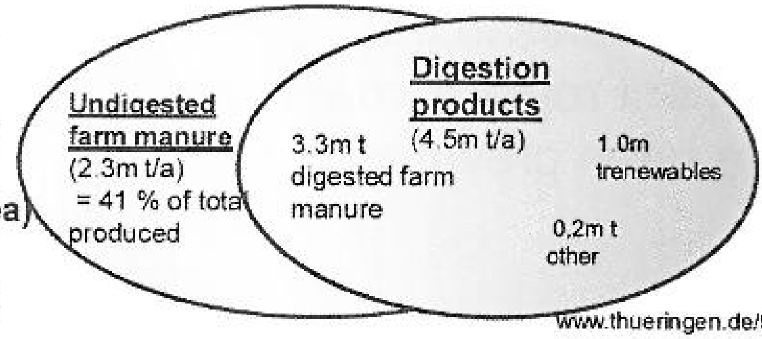
Higher due to biogas plants :
from 152m to 192m t/a
to 126 % **(16 t/ha farm area)**
(of that
43 % digestion products)
abt. 80 kg N & 16 kg P per ha farm area



Quantity in Thuringia

6.8 million t/a

Higher due to biogas plants :
from 5,6m to 6.8m t/a
to 121 % **(8.5 t/ha farm area)**
(of that
66 % digestion products))

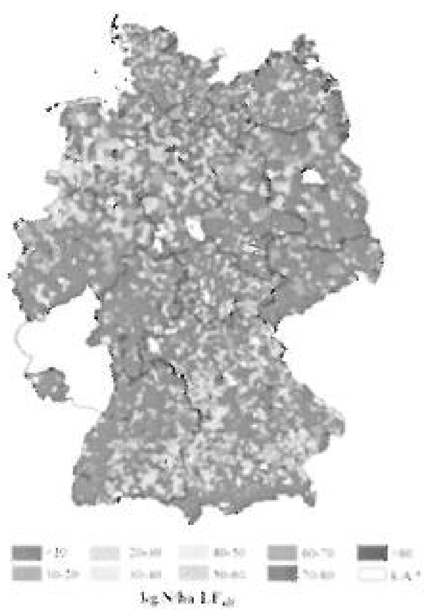


N produced by municipalities

Date: 2010 Source: Wüstholz, et.al. 2014, Berichte über Landwirtschaft Band 92, Heft 3

Due to animal stocks

Due to biogas



Animal husbandry had little influence in the selection of biogas plant sites

Excursion: Amendment of the DVO 2006

Putting digestion products in the farm manure category had already been a demand for the amendment in 2006

Had this been done, the absurd construction of biogas plants feeding on renewables in the refinement regions could have been prevented


Thüringer Landesanstalt für Landwirtschaft

Standpunkt

zur

Ermittlung der Nährstoffgehalte und zur Nährstoffbilanzierung bei Einsatz von Biogasgülle

FREISTAAT THÜRINGEN

Solution: **Refinement stock =** (animal stock plus biogas plant stock per ha) **as yardstick**

- *Effect of biogas plant is that of livestock keeping*
- *1 kW biogas = 1 livestock unit (LU) as regards forage area and fertilizer area*

Refinement stock:

$$\frac{LU + kW}{ha}$$

Dairy cow (1 LU)	Parameter	Biogas plant - corn (1 kW)
0,5 ha/LU staple fodder	Area needed	0.5...0.55 ha/$kW_{inst.}$
Energy concentration	Feed requirement	Digestibility
80 - 90 kg/LU net	N produced	86 - 95 kg/kW
14 - 16 kg/LU	P excreted	16 – 18 kg/kW
100 - 110 kg/LU	K excreted	85 - 95 kg/kW

Preconditions for good and regional use of digestion products

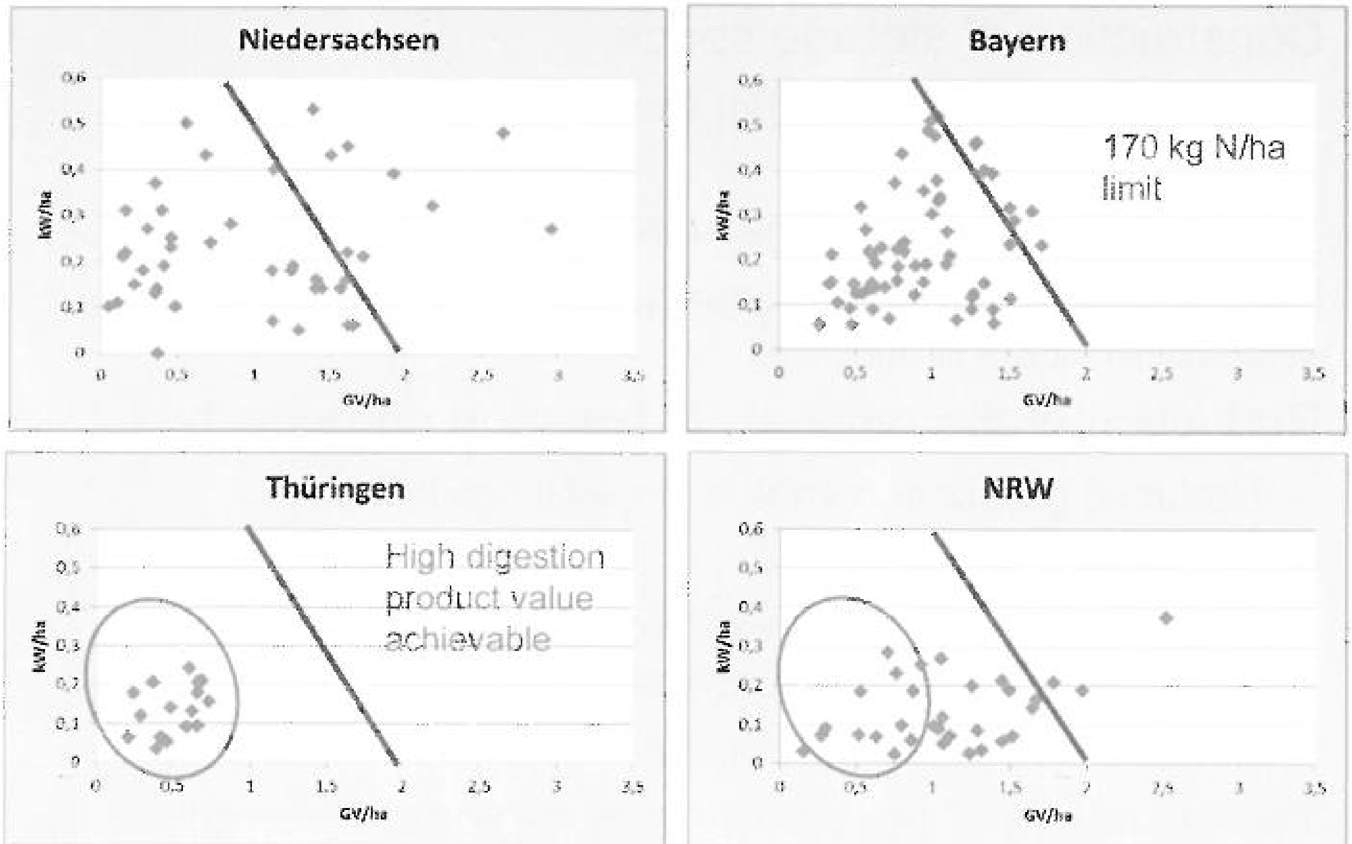
Freistaat Thüringen

- Digestion product ingredients *(mixed fertilizer)*
  → 2/3 of the need by organic fertilizer
- Observe site nutrient demand (supply stages)
  - Animal stock (LU/ha) and biogas plant stock (kW/ha)
  - Soil properties / crop rotation
- Cultivation / crops (depends on animal stock)
- Application period / application type (legal framework)
- Low loss (NH_4-N proportion → N-MDÄ)
- *Loss in transport and cost of application < nutrient value*

Within ready reach in regions with
refinement stocks < 1.5 (LU+kW)/ha

LU and kW stocks on rural district level (date: 2013/14)

Freistaat Thüringen



Interim conclusion

Consequences of the **inclusion of digestion products in the 170 kg limit** for biogas plants:

- Rate of digestion of external slurry declines
- Trend to treatment (of liquid-solid separation to drying and total treatment)
- Necessity of removing nutrients from refinement regions increases
- Higher transport volume (farm manure)
- High economic pressure on biogas plants in refinement regions

Effects felt mainly in refinement regions with refinement rates > 2 (LU+kW)/ha

Adaptation reaction to increasing need for storage capacity (9 months)

- Construction of storage space
  - Gas-tight digestion product store on the site of the biogas plant
  - Not of gas-tight field-edge storage capacity
- Reduction of substrate use (with/without output compensation, with consideration of flexibilization)
- Reduction of the amount of digestion products by
  - Reduced output in combination with flexibilization
  - Substrate change
  - Digestion product treatment (solid-liquid separation, thickening, drying, total treatment)
  - Use of pilot injection machines
- Transport out of the refinement regions

Model plant (site with 10.000 m³ cow slurry, 300 MWh/a heat demand, 200 / 400 kW rated output)

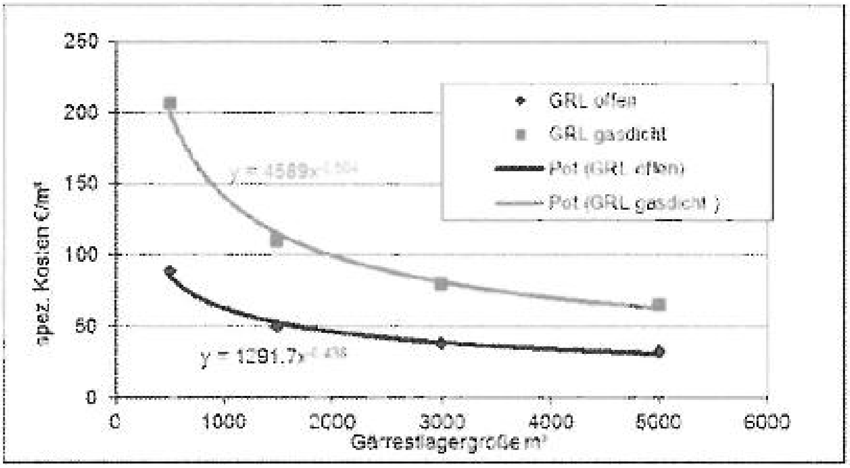
Freistaat Thüringen

Parameter	Unit	Plant A	Plant B
Installed capacity	kW	225	450
Corn input	t/a	2 887	6 950
Slurry	%	78	59
Digestion space volume	m³	2 000	3 500
Dwell time (2.3 kg/m³ d)	d	57	75
Digestion product	m³/a	11 810	14 904

Applies to: EEG 2009, constructed in 2011

Construction of storage space

Freistaat Thüringen



To observe (incomplete):

- Residual filling
- Installation site

  (fire protection/explosion hazard zone)
- Distance to buildings
- Effect on gas flow
- approval? Major Accident Law?

- **Legacy plants**: Vessel stability; wind and snow loads
- Passive corrosion protection of walls and bottom
- Agitator, center pillar, gas cover (pressure holding)
- Gas system (observe pressure differences/ gas flow direction)

Effect of the construction of a digestion product store (DPS)

Freistaat Thüringen

Parameter	Unit	Plant A	Plant B
Constr. DPS for 90 d	m³	2 912	3 675
1. Gas-tight DPS nex to to the biogas plant			
Investment	€/m³	83	74
	K€	241	270
Depreciation (10 a)	K€/a	24	27
Interest (5%/2)	K€/a	6	7
Total cost	K€/a	30	34
	ct/kWh	1.72	0.96
2. Field edge store			
Total cost	K€/a	14	16
	ct/kWh	0.82	0.47

TLL, Reinhold 2016

www.thueringen.de/th9/tll

Effect of the reduction of the slurry proportion

Freistaat Thüringen

Parameter	Unit	Plant A	Plant B
Rated output	kW	170	361
Slurry input / proportion	m³/a	5 904 / 67%	4 831 / 41%
Corn input	t/a	2 887	6 950
Profit reduction	K€/a	- 38,5	- 52.8
Possible earnings (flexibility bonus)	K€/a	9.0	17.9

Generally imaginable when **external slurry** is used:

(loss of slurry bonus, no transport and application cost)

Own farm slurry → **Additional storage space required**

TLL, Reinhold 2016

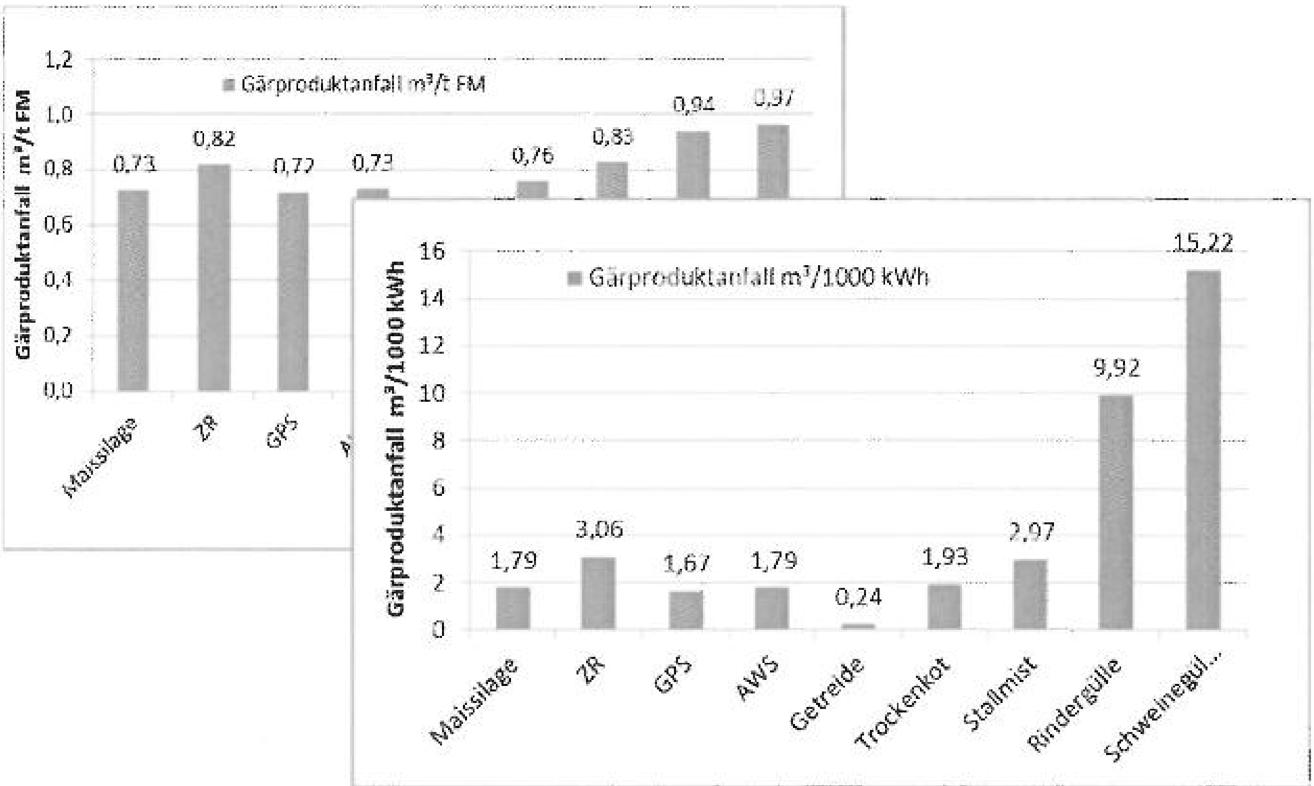
www.thueringen.de/th9/tll

Reduction of the slurry proportion and increase of corn input

Parameter	Unit	Plant A	Plant B
Slurry	%	59	33
Corn raised to	%	127	114
Extra cost	ct/kWh	1.66	1.05
Construction of open slurry store for undigested slurry			
Store size	m³	2 386	3 011
Investment	K€	102	117
Storage cost	ct/kWh	0.73	0.42
Total cost	ct/kWh	2.39	1.47

Own farm slurry → Additional storage space needed because digestion product and slurry must not be stored together

Substrate change to reduce the amount of digestion product



Solid-liquid separation to reduce storage space

Parameter	Unit	Plant A	Plant B
Separation cost (1 €/m³)	ct/kWh	0.67	0.42
Construction of open slurry store for residual storage			
Store size	m³	2 148	3 828
Investment	K€	96	134
Storage cost	K€/a	12	16
	ct/kWh	0.69	0.48
Total cost	ct/kWh	1.36	0.90

Limited effect (abt. 10%) – but reasonable when some nutrients can also be relocated.

Use of ignition oil

- 3 … 5 % ignition oil
- 2… 3 % higher efficiency (compensates the higher cost of pilot ignition equipment)

→Digestion product reduced by about 5 % due to

→Higher efficiency (substrate saving) and

→Substitution of substrate (ignition oil * efficiency)

→Additional storage requirement lower by about 12 %

→Stronger effect with

→Smaller biogas plants (efficiency improves)

→Saving of substrates low in dry matter

Use of pilot injection cogeneration unit (5 % dosage)

Parameter	Unit	Plant A		Plant B	
		GOM	ZüSt	GOM	ZüSt
Efficiency	%	38	42	40	43
Digestion product	m³/a	11 810	11 327	14 904	14 144
	%		96		95
Avail. digestion product store	m³	5 905		7 452	
Add. for 9 months	m³	2 953	2 590	3 726	3 156
Saving	%		12		12

Useful only when cogen unit is changed and other changes are also made at the same time.

Proposed blocking of earth basins digestion products (AwSV)

"Earth basins" are basins built into the ground or constructed by dams ... the bottom and slope consisting of soil sealed to the ground by a membrane

- Construction preferably in the East in large TPA
- Thuringia: medium size
  - Earth basins 6000 m³
  - High-level tanks 2500 m³
- **Non-approval of earth basins**
  - Planned under purely formal legal aspects
  - Aggravates the storage issue, especially for biogas plants with high slurry input (Thuringia, Saxony and Mecklenburg-West Pomerania)

Affected by the amendments

Freistaat Thüringen

Amendment of the DVO has most pronounced effect by **inclusion of digestion products**

- in the refinement regions

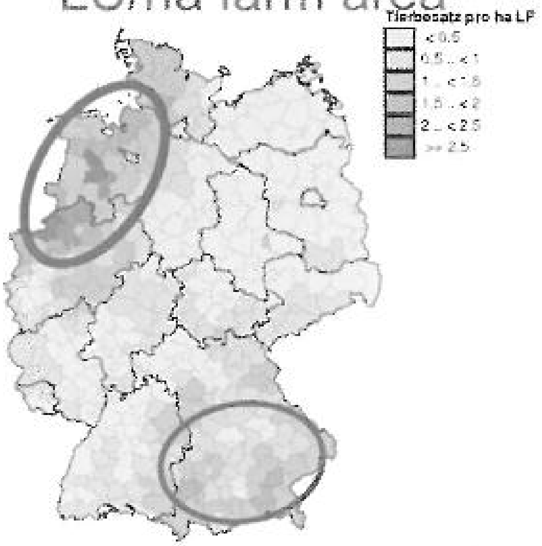
Amendment of the AwSV has effect on all biogas plants through the **9 months storage requirement,** most strongly on:

- Small plants (because of higher slurry input, poorer efficiency)
- Plants with high own slurry input (plants on large livestock farms in eastern Germany)

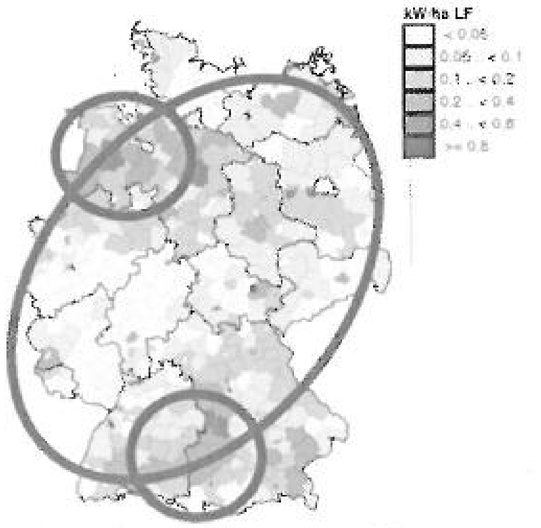
Regional affectedness:

Freistaat Thüringen

Animal husbandry
LU/ha farm area



Biogas
kW/ha farm area



Inclusion of digestion in 170 kg N/ha (DVO) has effect only where refinement stock is high

9 months storage time (AwSV) affects all biogas plants, additionally impairs high slurry input

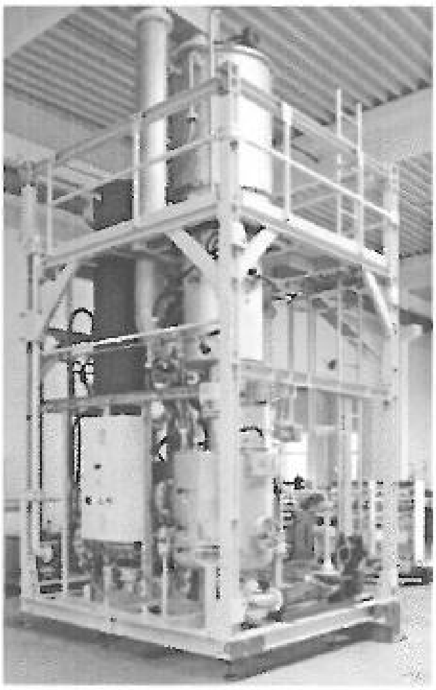
Practice 3, liquid: Vacuum evaporation

Summary:

- Abt. 2/3 volume reduction of liquid DP
- Distillate: abt. 1.3l/kWh th.

+ High evaporation efficiency
+ Low emission level
+ ASS as (potential) product for sale

-/+ Little nutrient loss
-/+ Heat and electricity demand
-/+ Eligible for cogeneration bonus



Source: MKR-Systeme

Conclusion & outlook (1)

Production & marketing:

- Digestion products for the market make high demands
- Digestion products are quality fertilizers
- Product development for single biogas plants almost impossible
- Marketing + sales very laborious and extensive
- Potential solution: Pooling or franchising (see example of composting plants)
- Earn more from sale of digestion products (professionalization)

Cultivation and transport

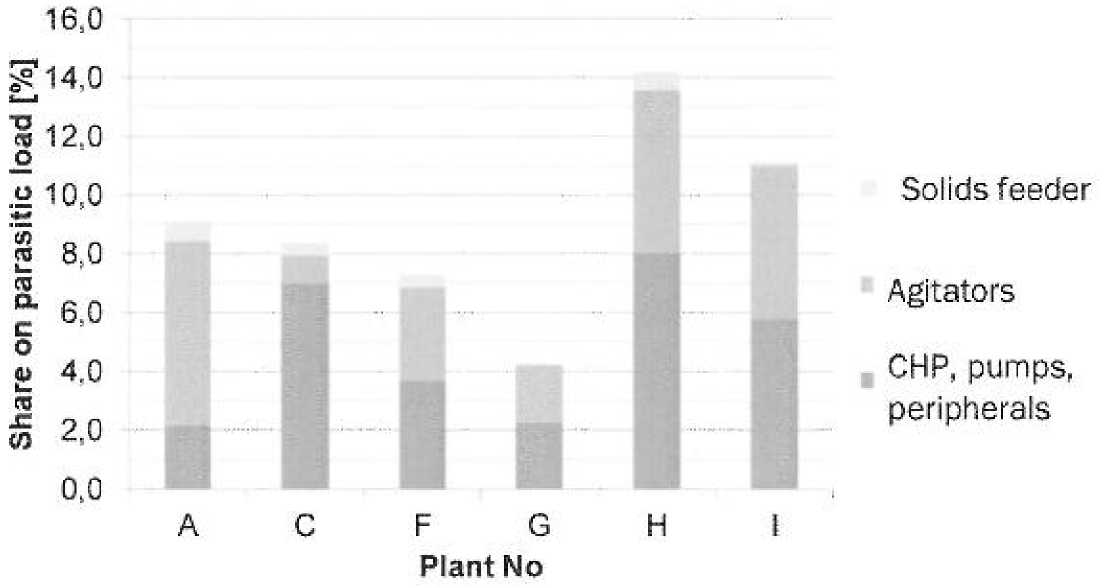
DBFZ

Substrate provisioning		Unit	Average	Min	Max	Share on primary energy [%]
Renewable resources		GJ / ha	18,5	17	20	4,93
Preservation losses		mass %	12	3 - 6	up to 30 %	9,51
Substrate transport (2 to 20 km)	Manure / digestate	MJ / t km	2,8			0,19
	Silage	MJ / t km	7,5			0,54
Transport silo to digester	Maize	kWh / d	73			0,14

Up to 30 % losses during substrate storage
6 % of losses in dry matter

Mixing - Energy consumption

DBFZ



CHP, pumps, peripherals	%	23,9	83,1	50,9	50,3	56,8	52,2
Agitators	%	68,8	11,4	43,3	43,3	38,9	47,0
Solids feeder	%	7,3	5,4	5,8	1,3	4,2	0,9

Source: Bayerische Landesanstalt für Landwirtschaft (LfL) (Hrsg.): Wissenschaftliche Begleitung der Pilotbetriebe zur Biogasproduktion in Bayern. Schriftenreihe ISSN 1611-4159, 1. Auflage, Januar 2010

Operating hours of biogas plants

DBFZ

Year of commissioning	Avg. Operating hours [h/a]	No. of replies	Avg. full-load hours	No. of replies
< 2000	6911	47	5161	49
2000 - 2003	7801	90	6570	94
2004 - 2008	8248	297	7323	287
2009 - 2010	8273	146	7242	132

Operating hours 2011, (data taken from operator survey DBFZ 2011/12)

- Operating hours are an indicator for process failures
- Overall quality of biogas plant is improving
- Losses:
    - Overproduction
    - Malfunctions

Reasons for process failure

DBFZ

Reason	Avg. duration of failure / performance decline [d]	Median [d]	No. of replies
CHP	7,6	4	491
Feeders	5,2	2	319
Agitators	5,8	2	219
Foaming	28,3	3	37
Floating layer	7,8	3	62
Overacidification	11,7	10	52
Other	12,3	5	48

(Source: Operator survey DBFZ 2011/2012, n=577)

- CHP is most common reason for failure
- Efficiency is affected, if biogas can't be utilized
- Statements from operators (operating hours?)

Economic efficiency improvement

Ulrich Keymer
Institut für Betriebswirtschaft
und Agrarstruktur

Loss in silo and storage

Assumptions: 1,800 €/ha cost

Cause	Assessment	Loss	
		% DM	€/ha
Residual respiration	Unavoidable	1 - 2	18 - 36
Digestion	Unavoidable	5 - 10	90 - 180
Silage effluent	Process related	0 - 7	0 - 126
Field loss	Process related	1 - 5	18 - 90
Noxious digestion	Avoidable	0 - 20	0 - 360
Aerobic deterioration	Avoidable	0 - 10	0 - 180
Post-heating	Avoidable	0 - 10	0 - 180
Corn silage		6 - 40	108 - 720

- Compaction: Rolling ≥ 2 min/t; min. weight ≈ pick-up rate [t/h] / 4
- Cover: On the same day, if possible
- Feed: ≥ 2.5 m/week in summer

Source: Thaysen, J., Wie hoch sind die Silierverluste?, BAUERNBLATT 25.08.2012

Need-based electricity production (1)

Assumption: The available cogeneration unit is sold

ACTUAL		
Installed capacity	kW_{el}	500
Electricity generation	kWh/a	4.161.000
Full utilization hours	Vbh	8.322
Annual hours	h	8.760
Capacity utilization	%	95
Useful life	Vbh	67.000
Utilization	%	38
Methane content in biogas	%	53
Gas production	Nm³/h	237
Gas consumption	Nm³/h	237
Available gas storage	m³	750
Management bonus*)	Ct/kWh_{el}	0,20
Marketer's share		
Excess proceeds EPEX from schedule	%	35
Marketing MRL	%	30

*) not considered in the calculation

TARGET		
Operating mode	**Time**	**Hours**
Time window (1) from	8	8
Time window (1) to	16	
Time window (2) from	16	8
Time window (2) to	24	
Total		**16**

Full load operation	**16**	h/d
Requ. output with 16 Vbh/d	**712**	kW_{el}
Planned utilization	**95**	%
Installed capacity	**750**	kW_{el}
Utilization	**41**	%

Required gas storage volume	2.456	m³
Construct. of add. gas storage	**1.706**	**m³**
Biogas need reduced by	80.379	Nm³ CH_4
Saving on substrate cost	**33.766**	**€/a**

Need-based electricity production(1)

Assumption: The available cogeneration unit is sold

Target		
Electricity production	kWh_{el}/a	4.161.000
Conduction & transformation loss	kWh_{el}/a	-41.610
Electricity compensated	kWh_{el}/a	**4.119.390**
Additional acquisition cost		**605.680**
Excess proceeds from flex bonus	€/a	29.575
Savings on substrate cost	€/a	33.766
No general overhaul	€/a	19.393
Additional fixed cost	€/a	-73.176
Additional operating cost	€/a	-2.417
Balance		**7.141**
Possible excess proceeds		
EPEX SPOT auction business*)	€/a	12.604
Marketing of negative MRL*)	€/a	5.577
Less marketing shares	€/a	-6.084
Balance		**12.096**
Total balance	€/a	**19.237**
Overall return		**9,35%**

⇨ New cogen unit P ≈ 461,000 €
Old cogen unit SP= 52,000 €

*) Market data for 2015

Need-based electricity production(2)

Anticipated provision of replacement

Available cogeneration unit remains as stand-by

ACTUAL		
Installed capacity	kW_{el}	500
Electricity generation	kWh/a	4.161.000
Full utilization hours	Vbh	8.322
Annual hours	h	8.760
Capacity utilization	%	95
Useful life	Vbh	67.000
Utilization	%	38
Methane content in biogas	%	53
Gas production	Nm³/h	237
Gas consumption	Nm³/h	237
Available gas storage	m³	750
Management bonus*)	Ct/kWh_{el}	0,20
Marketer's share		
Excess proceeds EPEX from schedule	%	35
Marketing MRL	%	30

*) not considered in the calculation

TARGET				
Operating modeahrweise	Cogen u. (1) Time	Cogen u. (1) Hours	Cogen u. (2) Time	Cogen u. (2) Hours
Time wind. (1) from	--	0	8	8
Time wind. (1) to	--		16	
Time wind. (2) from	--	0	16	8
Time wind. (2) to	--		24	
Total		**0**		**16**

Full load operation	**0**	**16**	h/d
Requ. output with 16 Vbh/d	**0**	**712**	kW_{el}
Planned utilization	**0**	**95**	**%**
Installed capacity	**500**	**750**	kW_{el}
Utilization	38	41	%

Requ. gas storage volume	2.456	m³
Construct. of add. gas storage	**1.706**	**m³**
Biogas need reduced by	80.379	Nm³ CH_4
Saving on substrate cost	**33.766**	**€/a**

Need-based electricity production(2)

Available cogeneration unit remains as stand-by

Target		
Electricity production	kWh_{el}/a	4.161.000
Conduction & transformation loss	kWh_{el}/a	-41.610
Electricity compensated	kWh_{el}/a	**4.119.390**
Additional acquisition cost		**770.447**
Excess proceeds from flex bonus	€/a	81.250
Savings on substrate cost	€/a	33.766
No general overhaul	€/a	19.393
Additional fixed cost	€/a	-93.050
Additional operating cost	€/a	-11.145
Balance		**30.214**
Possible excess proceeds		
EPEX SPOT auction business*)	€/a	12.604
Marketing of negative MRL*)	€/a	5.577
Less marketing shares	€/a	-6.084
Balance		**12.096**
Total balance	€/a	**42.310**
Overall return		**13,98%**

⇨ New cogen. unit P ≈ 461.000 €

*) Market data for 2015

IE-Directive

- 2010/75/EU → Industrial Emission Directive
- **November 24th, 2010:** Integration of proposal
- **Januar 6th, 2011:** Regulation becomes law
- **Januar 7th, 2011:** Implementation by member states
- **Evaluation:**
  - All activities concerning **IPCC** Directive / codes
  - All combustion plants bigger than **50 MW** (heat input)
  - **Waste incinerators** and production facilities for **titania and drying**
  - Methodological basis for other regulations (*e.g.* regarding best available technology)

MCP-Directive

- MCP = **M**edium **C**ombustion **P**lant
- Developed by **Environment Committee** of the European Parliament
- Part of the **Clean Air Directive** of the EU-Commission presented in December 2013
- **Results presented on July 15th, 2015** after „Trilog"-negotiations of council and parliament
- **Objective:** Reduction of emissions of sulfur dioxide (SO_2), nitric oxide (NO_x) and particulate matter (PM)
  - So-called ELV (Emission Limit Values)
  - Concentration of carbon monoxide (CO) should not rise
- Became effective on December 28th, 2015 → member states to implement any defaults into legislation until December 2017

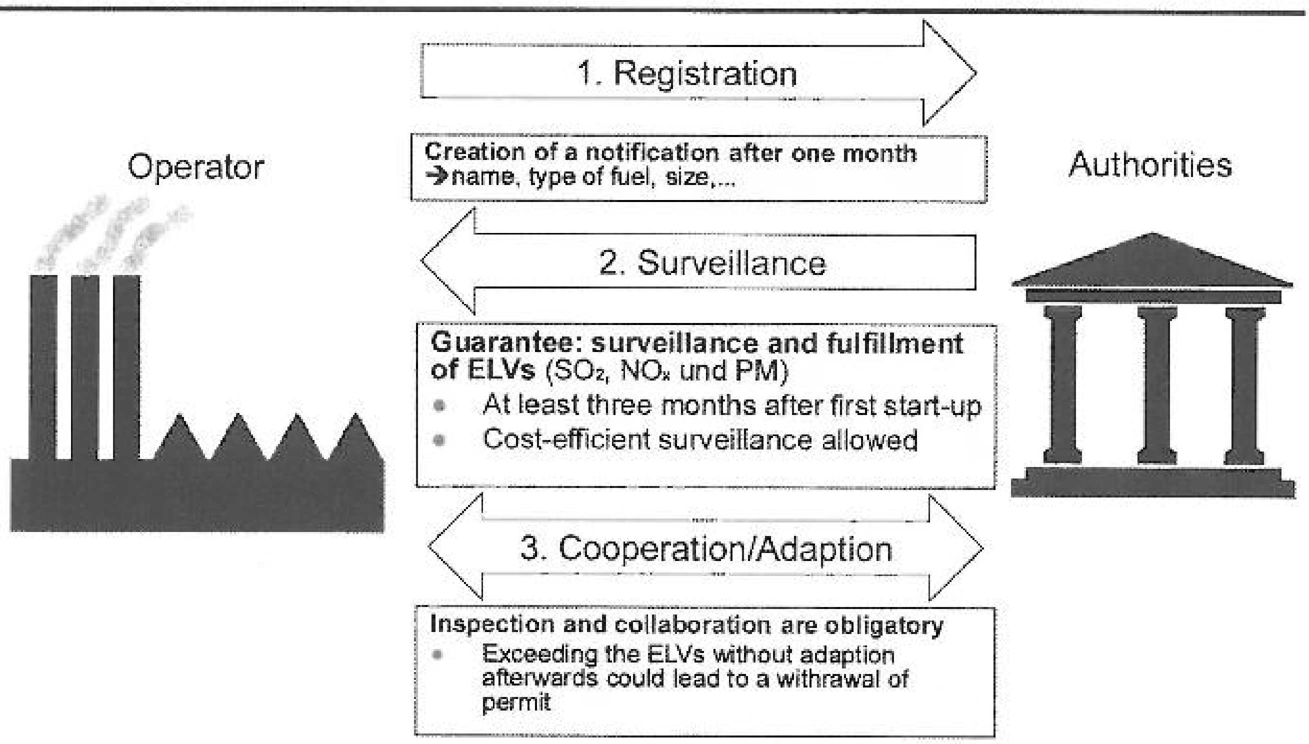
Plants Involved / Emission Limit Values- MCP-Directive

- Definition Art. 3 (5): „Any technical apparatus in which fuels are oxidised in order to use the heat thus generated"
  - All plants with **1 – 50 MW** thermal input (about 150.000 in EU)

- ELVs are differentiated in **tables** for **existing** and **new** plants:
  - Existing MCP (1 – 5 MW und > 5 MW) and new MCP
  - Existing and new engines and gas turbines
  - ***„Existing"*** ≙ all plants comissioned within a year after implementation of the MCP-Directive
  - Compliances: for existing and new plants→ 2025/2030 and December 20th, 2018 respectively

- ELVs are distributed into **six types of fuel**:
  - Solid biomass, other solid fuels, liquid fuels, heavy fuel oil, natural gas and other gaseous fuels

Procedure After MCP-Directive



⇔ Compare with response time for administration according to TA Luft 2002: between three and six months after first start-up

Calculation ELV's - MCP-Directive

- In **mg·m⁻³** based on
  - **Standard conditions** for exhaust fumes: 273,15 K and 101,3 kPa
  - Excluding **water vapor content**
  - **Reference oxygen content:** for combustion plants depending on type of fuel (3 – 6 %) or for engines and gas turbines (15 %)
  - Same for **TA Luft** except for different reference oxygen values (5 % for engines / 15 % für gas turbines)

LfL
Tier und Technik

Development of „TA Luft"

- **1964** first initiated as administrative regulation: "Technical Instructions on Air Quality Control"
- Plants with a **requirement for licence** after **BImSchG**
  - 50.000 plants affected (not only biogas)
    - ⇔ other plants with **building licence** according to "Biogashandbuch" or benchmarks regarding TA Luft Nr. 4
- State of the art / **„best available technology"** (BAT)
- Last modification in 2002
- Limit values according to **type** and **size** of **facility**
- Making of draft law in 2014
  - interdepartmental coordination in 2015
  - Next amendment mid of 2017

LfL
Tier und Technik

ELVs in mg·m^{-3} - International / National

Pollutants for engines (5 % reference oxygen)	TA Luft 2002		MCP-Directive		Draft of TA Luft 2017
	Gas-Otto-engine < 3 MW	Pilot injection engine < 3 MW	Existing engines	New engines	No distinction
CO	1.000	2.000			200
NO_x	500	1.000	507* (Gas-Otto) 1.013* (pilot injection)	507 (alle)*	500
SO_2	311*		160*	107*	89
CH_2O**	60				20 (30 for existing pl. until 01.01.2020)
Particulate matter		20			4
C_nH_m (hydrocarbons)					1.000

*) Original value transformed into a comparable reference oxygen value of 5 %
**) Formaldehyde

- **Expected impact on biogas sector - TA Luft 2017:**
  - **Continous monitoring (<20 MW):** CO, NO_x (without exhaust treatment for NO_x), PM (for pilot injection)
  - **Monitoring yearly (<20 MW):** CH_2O, SO_2, NO_x (without exhaust treatment for NO_x), Staub (for pilot injection)
  - **Gas turbine**: stricter ELVs without any impact on technical adaption (no exhaust treatment necessary)

Impact of EU Legislation on German Legislation

- **The German Federal Environment Ministry** does not plan to modify structure and methodology of its legislation.
  - **IED – BAT-conclusion (emission benchmark) in the Official Journal of EC**: affected plants after four years of implementation
  - **MCP-Directive**: implementation of its defaults into national legislation by member states until end of 2017

- **Discussion over adaptation of TA Luft 2017 (not only CHP)**
  - ELVs, 11x BAT, immission values for particulate matter (PM) from 10 µm ➔ 2,5 µm), carcinogenic substances, etc.

- **Resulting questions for the biogas sector and TA Luft 2017:**
  - MCP-Directive: member states are allowed to implement stricter ELVs, locally
  - Granting of **exceptions** (more efficient technologies in the future)?
  - Is it still possible to **adapt national ELVs** until implementation?

Rheinland-Pfalz
MINISTERIUM FÜR WIRTSCHAFT, KLIMASCHUTZ, ENERGIE UND LANDESPLANUNG

Labeling

Information about application

Note that recommendations by the official authority have priority

1. Time of application
2. Nutrient availability
3. Application rate
4. Application technique
5. Restrictions on application
6. Risk reduction

Rheinland-Pfalz
STRUKTUR- UND GENEHMIGUNGSDIREKTION NORD

Farm manure labeling – DüMV 2012

Kennzeichnungsbeispiel nach Düngemittelverordnung
vom 05 Dezember 2012

Die Kennzeichnung von Gehalten erfolgt grundsätzlich auf die Frischmasse bezogen. Von dieser Grundregel gibt es nur wenige Ausnahmen; z.B.: Schadstoffgehalte nach Anlage 2 Tabelle 1.4, die auf die Trockenmasse bezogen zu kennzeichnen sind.

Wirtschaftsdünger unter Verwendung von Schweinegülle und Mais

x,xx % N Stickstoff
x,xx % N verfügbarer Stickstoff
x,xx % N Stickstoff tierischer Herkunft

x,xx % P_2O_5 Phosphat
x,xx % K_2O Kaliumoxid

x,xxxx % Cu Kupfer
x,xx % CaO basisch wirksame Bestandteile
.............Nettomasse oder Volumen

> Die Gehalte dürfen zusätzlich in kg/t angegeben werden.

> Angabe zu Spurennährstoffen nur, wenn folgende Gehalte in der TM erreicht sind: 0,01 % B, 0,004 % Co, 0,05 % Cu, 0,1 % Zn. Die Kennzeichnung der Gehalte erfolgt in der Frischmasse.

> Eine Kennzeichnung von Gehalten an basisch wirksamen Bestandteilen ist ab 5 % in der TM vorgeschrieben.
> Die Kennzeichnung der Gehalte erfolgt in der Frischmasse.

Inverkehrbringer / Hersteller:

Ausgangsstoffe: 60 % Schweinegülle (Kat. 2 gem. EG-VO 1069/2009), Mais

Nebenbestandteile: xx,xx % organ. Substanz, x,xxxx % Se Selen
xx mg/kg TM As Arsen

> Eine Kennzeichnung von Gehalten an organischer Substanz ist ab 5 % in der TM vorgeschrieben. Ein Gehalt an Selen ist ab 0,0005 % in der TM auszuweisen.
> Die Kennzeichnung der Gehalte erfolgt jeweils in der Frischmasse.

> Die Gehalte an Schadstoffen gemäß Anlage 2 Tabelle 1.4 sind bei Erreichen / Überschreiten der Kennzeichnungsschwellen in Spalte 2 bezogen auf die TM anzugeben.

Anwendungshinweise:

Sachgerechte Lagerung und Anwendung (z.B.: Düngeverordnung, EG-VO 142/2011 (Organisches Düngemittel / Bodenverbesserungsmittel unter Verwendung von tierischen Nebenprodukten – Zugang für Nutztiere zu den behandelten Flächen während eines Zeitraumes von mindestens 21 Tagen nach der Ausbringung verboten))

Treatment aids for fertilizers

Regulation for treatment aids

1. Up to a concentration of 0.5 %: Identify the purpose of addition;

- e.g.: prepared with conditioning agents,
- Prepared with precipitation agents

2. Higher concentration: additional specification of the substance used

- e.g.: prepared with sulfur as coating substance or vinasse as dust binder
- Prepared with carbonic lime as treatment control agent

Labeling example

– Farm manure with the use of pig slurry and corn -

... % N total nitrogen

.... % N available nitrogen

..... % N nitrogen of animal origin

... % P_2O_5 Phosphate

... % K_2O Potassium oxide

0,0005 % Cu Copper

0,02 % S Sulfur

Net mass or volume .....

Producer / placed on the market by ......

Inputs: 60 % pig slurry and silage corn

With the use of ferrous sulfate for precipitation of sulfur

Notes on application and storage......

Labeling example

Organic NPK fertilizer – liquid 1.8-2.0-2.51

with the use of farm manure (pig slurry), material from the processing of medicinal and aromatic plants (garlic), animal by-products from kitchens and canteens (category 3 according to EV Regulation 1069/2009)

-Digestion residue-

1.80 % N total nitrogen

0.95 % N available nitrogen

2.0 % P_2O_5 total phosphate

2.51 % K_2O total potassium oxide

5 % organic substance, calculated as ignition loss

50 mg/kg DM Ni nickel

Net weight (voluntarily also the volume).....

Producer / placed on the market by......

Labeling example

- **Organic NPK fertilizer – liquid- 1.8-2.0-2.5**
  Storage and application....

  "The restrictions on application and quantity defined in regulations governing waste disposal (AbfKlärV, BioAbfV) must be observed when the fertilizer is applied to agricultural areas."

  "Application requirements: Suitable precautions shall be taken to avoid the uptake by farm animals when the fertilizer is stored, transported or spread in the field."

  "No mixing with animal feed."

  "Organic fertilizer/soil improver prepared using animal by-products – access for farm animals to the treated areas forbidden for a period of at least 21 days after application."

GENERAL CONDITIONS

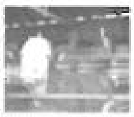
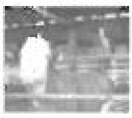
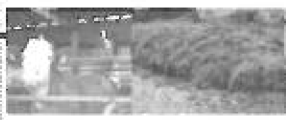
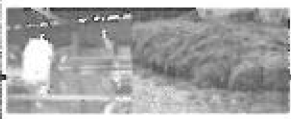
Section 46 EEG 2014 "Digestion of slurry"

- Assumed value : 23.73 CENT/kWh$_{el}$
- Rate under EEG marketing: 23.53 CENT/kWh$_{el}$
- Degression first time from 2016: 23.41 CENT/kWh$_{el}$
- Electricity must be generated at the site of the biogas production plant
- Total installed electrical capacity not to exceed 75 kW$_{el}$
- Per calendar year: ≥ 80 %by wt. slurry EU 1069 **without** poultry

Section 9 EEG 2014 "Technical requirements"

- 150 days of gas-tight dwell time when digesting non-slurry EU 1069
- Construction of new digestion residue store at the site of the biogas plant; must be covered to be technically gas-tight
- No feeding management
- Entry in the plant register
- *Possibly deviating requirements by the approval authority*

VERSIONS CONSIDERED

Substrates	Dwell time in d		Sizes 30 / 50 / 75 kW$_{el}$
	Digester	Store	
100 % Dairy cattle slurry	30	0	
84 % / 16 % dairy cattle slurry / renewable primary products	70	90	 
50% / 34% / 16 % dairy cattle slurry / cow dung / renewable primary products,	70	90	 
90 % / 10 % dairy cattle slurry/ cow dung	50	0/90	

NEED LINKED COST

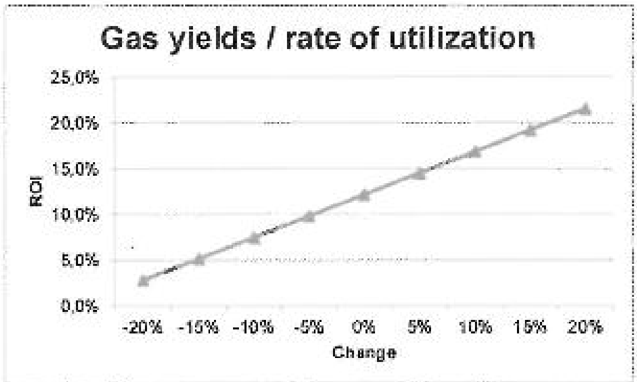
Substrate	Price of basic version free plant	DS/oDS content	Biogas	Methane
	in €/t	*in % by wt.*	*in m^3_NBG/t oDS*	*In % by vol.*
Cattle slurry	0.50	7.5 / 80.0	380	55.0
Cow dung	1.00	25.0 / 85.0	450	55.0
Corn silage	40.00 (silage in silo, covered)	34.0 / 95.0	650	52 .0

Electricity purchasing cost: 20 Cent/kWh
Internal electricity consumption depends on the substrate mix

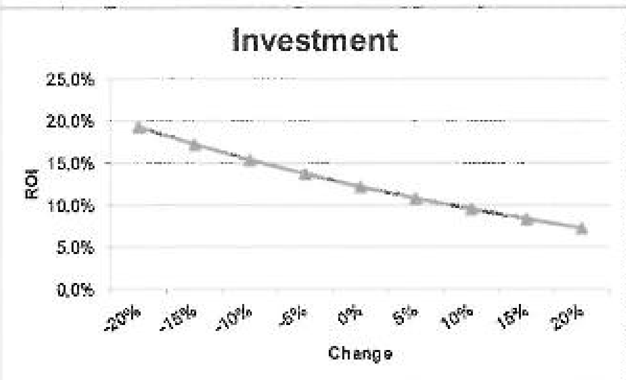
100 % DAIRY CATTLE SLURRY

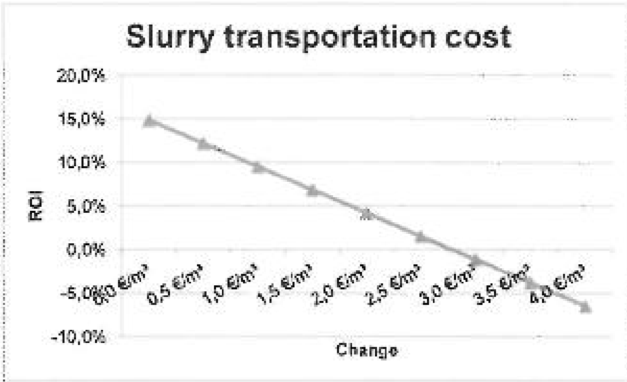
Plant size	Head of cattle	Investment	Profit	Total return on investment
30 kW_{el}	258 LU	240 K€	10 K€/a	12.2 %
50 kW_{el}	397 LU	326 K€	30 K€/a	22.1 %
75 kW_{el}	553 LU	417 K€	57 K€/a	30.9 %
LU = livestock unit				

100 % DAIRY CATTLE SLURRY



Factors of influence; example: 30 kW





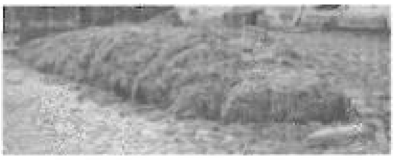
C.A.R.M.E.N.

84% DAIRY CATTLE SLURRY / 16 % RENEWABLES

Plant size	Livestock	Corn	Investment	Profit	ROI
30 kW_{el}	96 LU	462	370K€	- 26 K€/a	-
50 kW_{el}	151 LU	701 t	490 K€	- 19 K€/a	-
75 kW_{el}	213 LU	969 t	590 K€	- 2 K€/a (39 K€/a cost of renewables)	3.3 %
LU = livestock unit					

C.A.R.M.E.N.

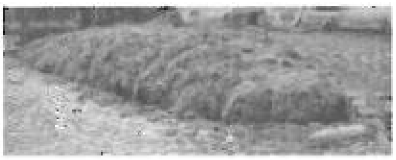
50 % DAIRY CATTLE SLURRY / 34 % COW DUNG / 16 % RENEWABLES


Plant size	Livestock	Corn	Investment	Profit	ROI
30 kW_{el}	39 LU + 665 t/a	303 t	340 K€	-18 K€/a	-
50 kW_{el}	60 LU + 1,025 t/a	466 t	425 K€	- 5 K€/a	-
75 kW_{el}	84 LU + 1,429 t/a	648 t	521 K€	13 K€/a	9.1 %
LU = livestock unit					

C.A.R.M.E.N.

90% DAIRY CATTLE SLURRY / 10% COW DUNG

Plant size	Livestock	Investment	Profit	Return on investment
30 kW_{el}	180 LU + 460 t/a	390 K€	-11 K€/a	
30 kW_{el} w/o GPL		280 K€	2:5 K€/a	
50 kW_{el}	280 LU + 691 t/a	500 K€	6 K€/a	6:5 %
50 kW_{el} w/o GPL		357 K€	23 K€/a	16:8 %
75 kW_{el}	390 LU + 962 t/a	627 K€	30 K€/a	13:5 %
75kW_{el} w/o GPL		423 K€	53 K€/a	29:0 %
LU = livestock unit				

C.A.R.M.E.N.

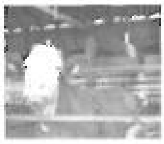
SUMMARY

- Economic efficiency is affected particularly by:
  - Investment
  - Substrate cost (transportation cost)
  - Methane yield, electricity yield

- Take operational and plant safety seriously.

- Small-size plants are also subject to numerous recurrent obligatory inspections and tests

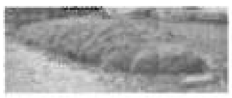
SUMMARY



- Plants digesting only slurry can be financially

viable
  - Ensure high quality
  - Prepare a detailed analysis of the biogas from the slurry

- Slurry / renewables are hardly viable financially



- Plants digesting solid manure from 50 / 75 kW_{el} can be financially viable
  - Solid manure, in particular, must be available on long term at calculated prices!
  - Hygiene requirements are possible

Thank you very much for your attention.

Any questions???

mg(at)carmen-ev.de

C.A.R.M.E.N.

ASSUMPTIONS

Begriff	Festlegung
Abschreibung	auf Basis der zu erwartenden Nutzungsdauer
Anfänglicher Zinssatz	4,0 %
Anlagenbedienung und -reinigung	FNR Leitfaden Biogas 2010 15,00 €/h, bei Feststoffen: + 10'/d
Anschaffung Fahrsiloanlage	Annahme: bereits abgeschrieben
Anschaffungskosten für Behälter und Rührwerke	KTBL Betriebsplanung Landwirtschaft 08/09 mit einem Aufschlag von 10%
Auflagen Hygiene	Annahme: keine zusätzliche Anschaffung bzw. keine zusätzliche jährliche Kosten
Ausbringkosten Gärrest aus Nicht-JGS	0,00 €/m³ - mit Düngerwert verrechnet
Ausbringkosten Gärrest aus JGS	0,00 €/m³, Annahme: muss ohnehin ausgebracht werden
Auslegung BHKW	ca. 8.000 Vbh/a
Betrachtungszeitraum	ein gemitteltes Jahr
BHKW	Gas-Otto
Bürgschaftskosten Rückbau Anlage	0 € p.a.
Eigenstromkosten	0,20 €/kWh$_{el}$
Einspeisung Strom	bis 75 kW$_{el}$ in Niederspannungsseite – keine Anschaffung und keine Transformationsverluste
elektrischer Jahresnutzungsgrad	auf Basis des elektrischen Wirkungsgrad ASUE BHKW Kenndaten
Instandhaltung	umfasst: Inspektion, Wartung und Instandsetzung
Kleinbiogasanlage	Biogasanlage gemäß § 46 EEG 2014
Milchviehgülle, spezifischer Anfall	68 l/GV/d
Unterer Heizwert Methan	9,97 kWh/m³
Versicherung	0,5 % p.a. von Anschaffung
Verzinsung eingelagertes Material	1,5 % von 50 % des eingelagerten Materials
Wärmenutzung	In der Grundvariante keine
Planungskosten	4 % der Anschaffung

C.A.R.M.E.N.

Introduction

DBFZ

Why „small“ manure based biogas plants?

- Low transportability and decentralised origin
- Energy potential ca. 15 kW per 100 large cattle units (LCU) indoor; (large variation, depending on kind and category of animals, litter, yield, fodder residues integration)
- Single farms in Western Europe typically less than 300 LCU
- Even in Germany less than 30% of manure in use for biogas digestion (mass based)
- Special rules in German EEG, one of the rare possibilities for economic biogas plant realisation in Germany after EEG 2014
- Mass-flows without competition; Strong improvements by digestion (emission reduction, hygiene improvement, nutrient availability)

Enhancement of usability of potential

DBFZ

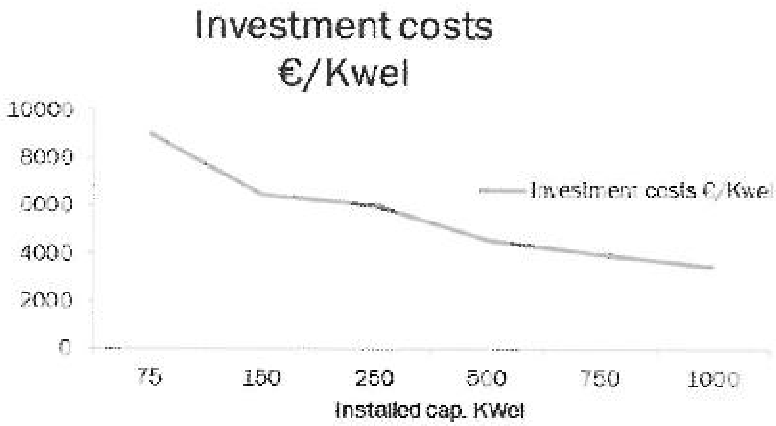
Progressive structural change in West Germany:

- Repeal of milk quota
- > Larger herd sizes on single farms, some in conjunction with specialization (paging young cattle) and increasing milk yield
- >> Autumn cuts and fodder residues are available for biogas production
- But: Even after growing, farms in Western Germany (Western Europe?) are rarely over 200 GV, especially in low mountain
- Regions
- > 20 - 60 kW from manure
- Additional use of energy crops means strong competition for fodder (e.g. silage maize) in such farms

Measures to promote manure use – cost efficient small plants

DBFZ

- Verfügbare wirtschaftliche Anlagengrößen müssen weiter reduziert werden (auch für Exportmärkte)
- Anpassung an typische Herdengrößen von Zukunftsbetrieben



Source: www.fnr.de (Faustzahlen)

Measures to promote manure use – Use of synergy effects

DBFZ

- General integration of biogas utilization into barn planning (e.g. manure scrubber instead of slatted floor)
- Biogas utilization as a necessary measure for new construction of large stables?
- Optimizing agricultural investment promotion
- > biogas production diversifies and secures farm income
- Optimize revenues through use of heat in winter
  - reduce heat requirements of plants, additional use of energy crops only in the winter?

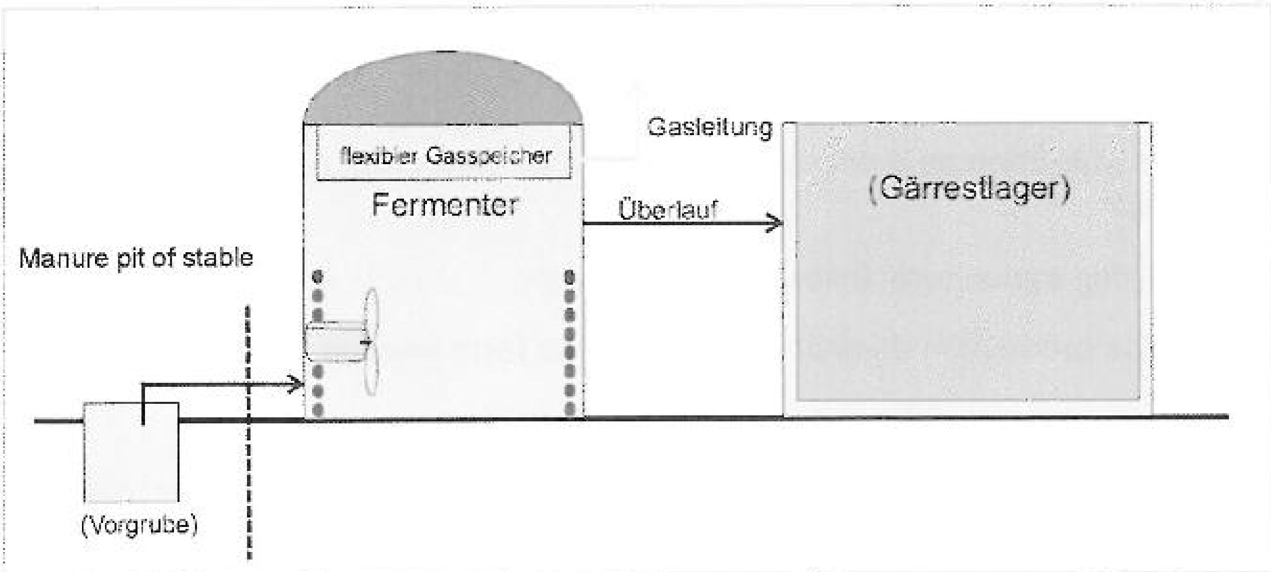
Technical conzepts

DBFZ

- Typically cost reduction by adaptation to local conditions (for example, use of manure collection pit, pumps, slurry storage synergies, joint planning and construction with stable expansion)
- Substrate supply usually by pump
- With larger proportions of solids (solid manure, 20% energy crops) use of screw or special pumps for solids integration

CSTR with submersible mixer and gas storage roof

DBFZ



Cover of digesters

DBFZ

- Most times gas-tight membranes
- Proportion of single-membrane gas storage and solid concrete roofs is higher in the range of 75 kW - class (cost saving, technical reasons)
  - Concrete roofs are easier to install on smaller tanks
  - Often integration of axial stirrers in combination with concrete roofs
  - Easy thermal insulation
- Often release of coverage of digestate storage for cost saving
  - Elevated ammonia emissions
  - No gas storage on digestate tank
  - Redused gas yields, especially with small retention times

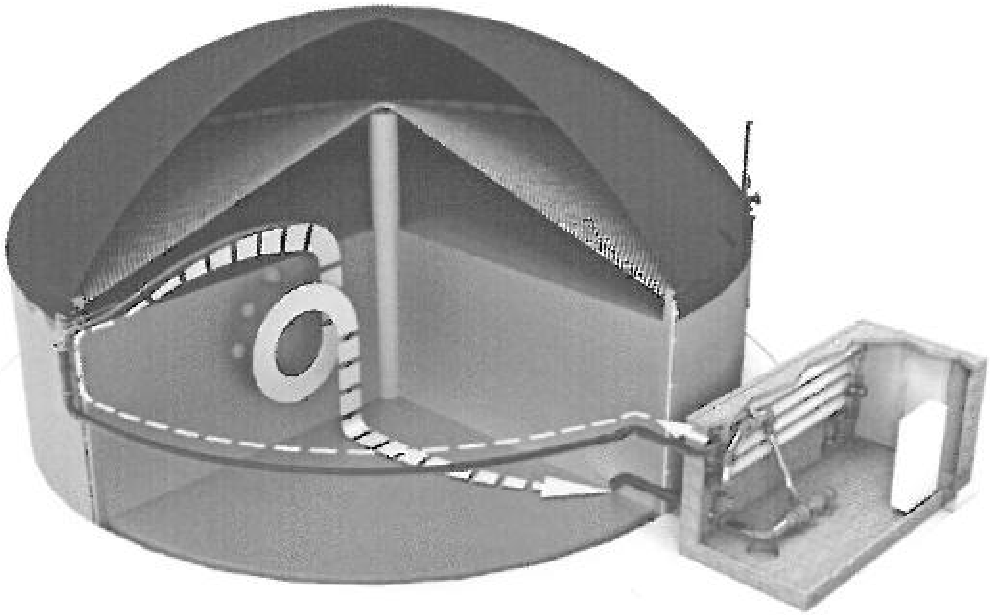
Mixing technology

DBFZ

- Submersible engine stirrers
- Lateral shaft-stirrers with engine outside
- Axial stirrers on concrete top
- Various lengths of shafts, agitator paddel sizes and speed

Sprincler technology

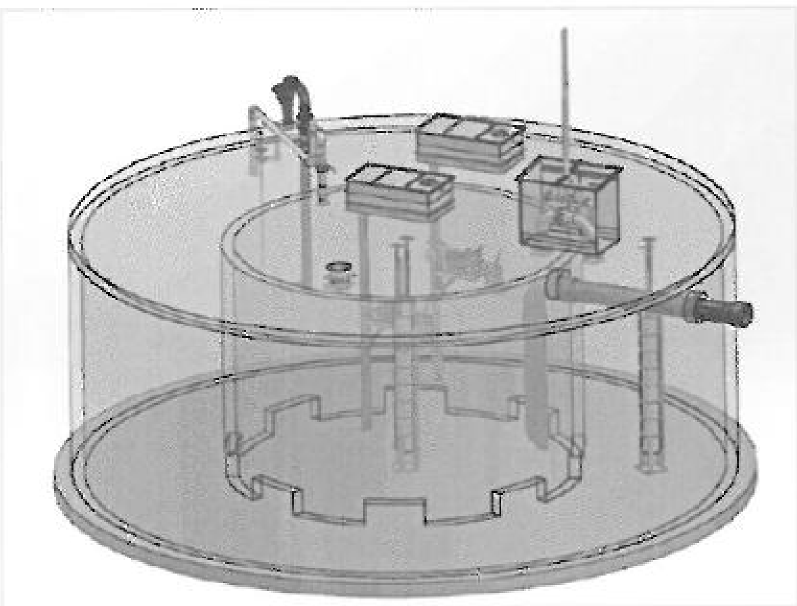
DBFZ



© Sauter
Biogas Gmbh

Pfefferkorn digester

DBFZ



© Bio4Gas EXPRESS GmbH 2014

Slurry digesting plants in practice –

Results of a poll in Baden-Württemberg

Jörg Messner
Staatliche Biogasberatung
Joerg.Messner@lazbw.bwl.de

L A Z B W

Situation in Baden-Württemberg

About 75 biogas plants up to 75 kW have been built in Baden-Württemberg since the beginning of 2012

- Construction:
  - Over 80% with two gas-tight vessels (digester + gas-tight digestion residue store)
  - Over 90% based on the traditional plant concept, i.e., with agitated vessel digesters
  - Only one plant as compact system in a container
- Plant manufacturer:
  - About 55% general contractor (e.g., Novatech, Seiler, Agrikomp, NQ)
  - About 35% "house builder's scheme" (e.g., Dyckhoff, Zintl, Rosenheimer Modell)
  - Less than 10% new providers (e.g., Bio4Gas, Dynaheat)

L A Z B W

Poll among owners

- Targets:
  - Development of recommendations for consultation
  - Verification of known calculation approaches
  - Increased focus on plants under the "house builder's scheme"
- First data collected in fall of 2014
  updated and expanded by a poll in fall of 2015
- Data gathered from 25 plants, all 75 kW rating

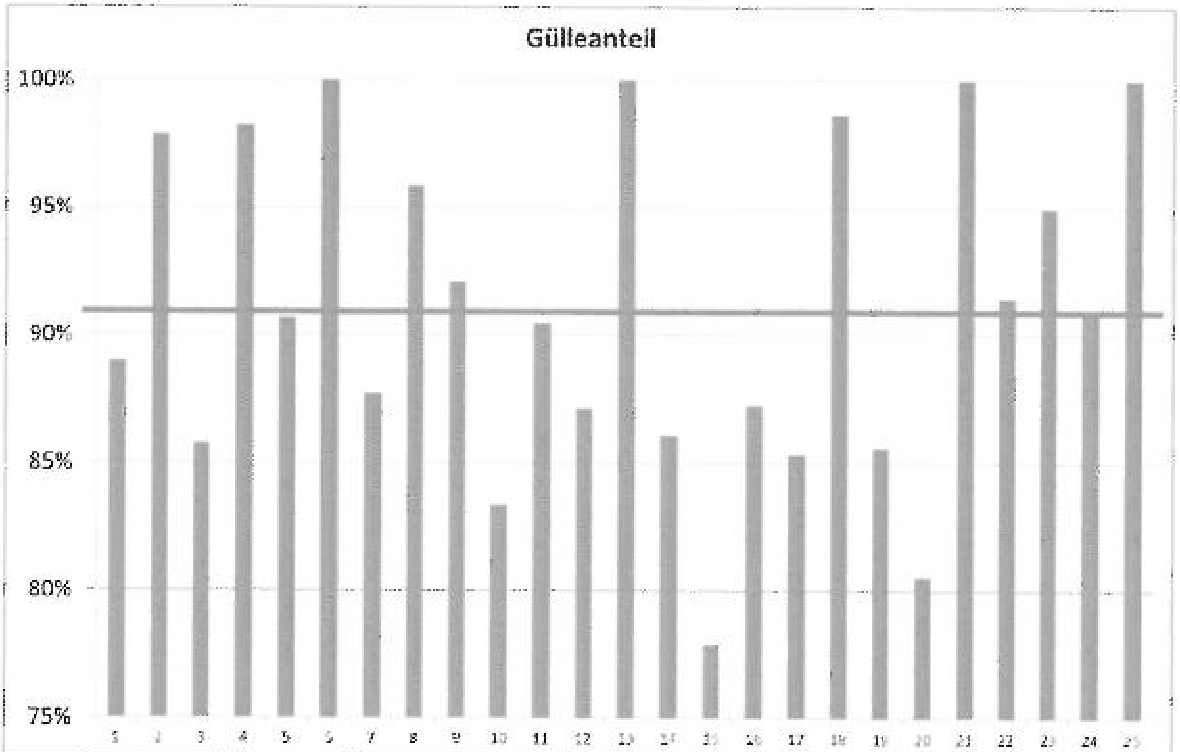
Poll among owners

- Procedure
  - Visits to the plants and collection of data from available documents (logs, accounting, etc.)
  - The assessment was in part based on identical calculation values (AfA depreciation for wear and tear, interest, maintenance, wages, other expenses)
- Problems:
  - Normally slurry volume and quality are not recorded
  - Cost rates for biomass / evaluation of "feed remains"
  - Demarcation between farming and biogas plant (digestion residue store, silage clamp, etc.)
  - In some cases no separate recording of the internal electricity consumption

Results of the poll among owners (24 plants)

Substrate	Number of plants	Average qty./a	Max. qty./a
Cow slurry	22	4,028 t	8,030 t
Pig slurry	5	526 t	4,400 t
Solid manure	23	758 t	3,200 t
Grass silage	12	115 t	850 t
Corn silage	15	259 t	1,100 t
Cereal whole plants	4	39 t	511 t
Cereal grains	5	13 t	137 t
Total quantity/annum		5,788 t	8,578 t
Substrate quantity/day		15.9 t	23.5 t

Results of the poll among owners (25 plants)



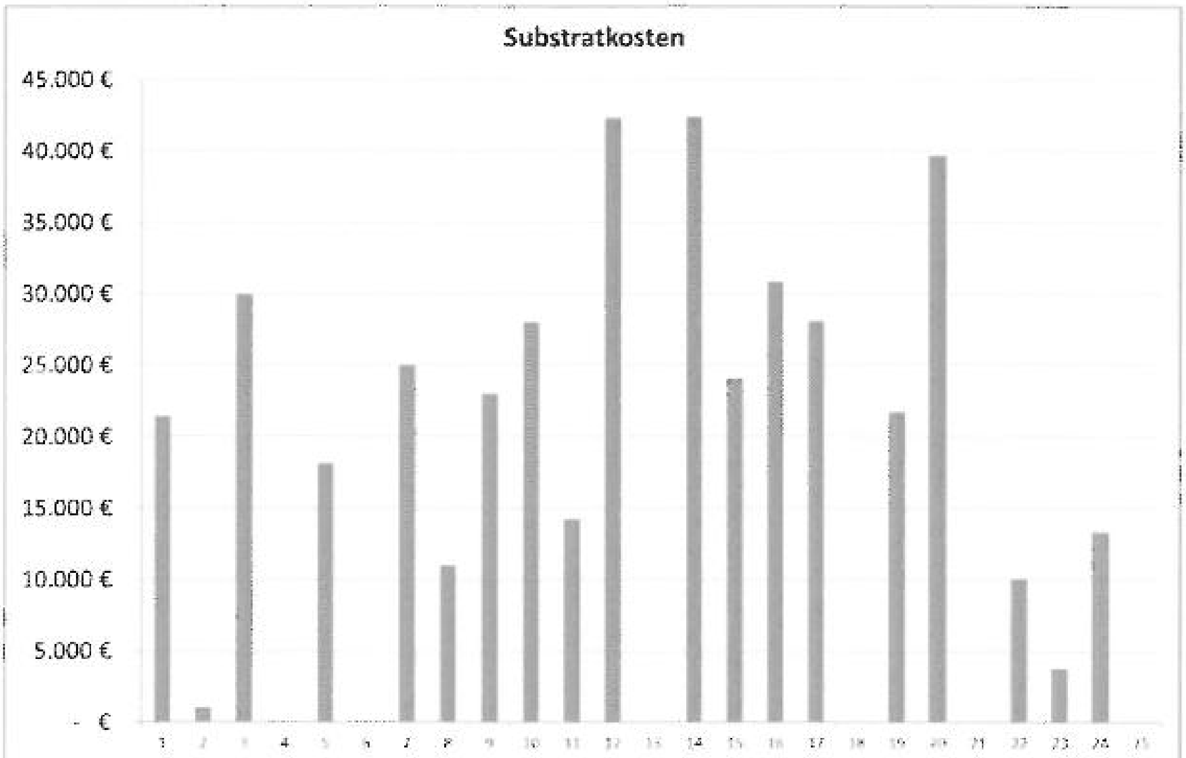
Results of the poll among owners (25 plants)

Capital investment

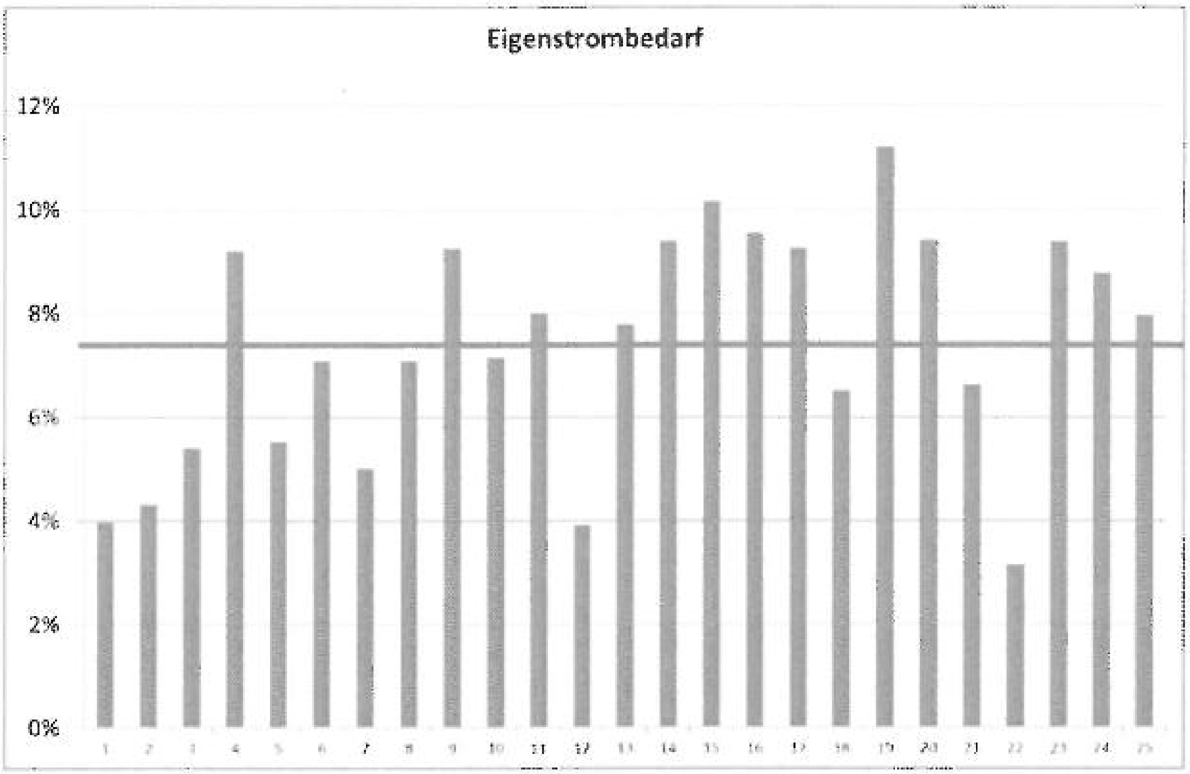
- Mean capital investment: 530,000 €
- Range from €285,000 to €900,000
- What was built?
  - Digester: 100% of all plants
  - Construction of a gas-tight store / post-digester: 62%
  - Gas-tight cover on available store: 30%
  - Transformer: 56%
  - Heat pipeline: 71%
  - Silage clamp: 24%
  - Other expensive construction (long pipelines, water protection authority requirements): 32%

- What was the building model?
  - 11 x general contractor (Ø 8,700 € / KW)
  - 14 x house builder's scheme (Ø 5,800 € / KW)

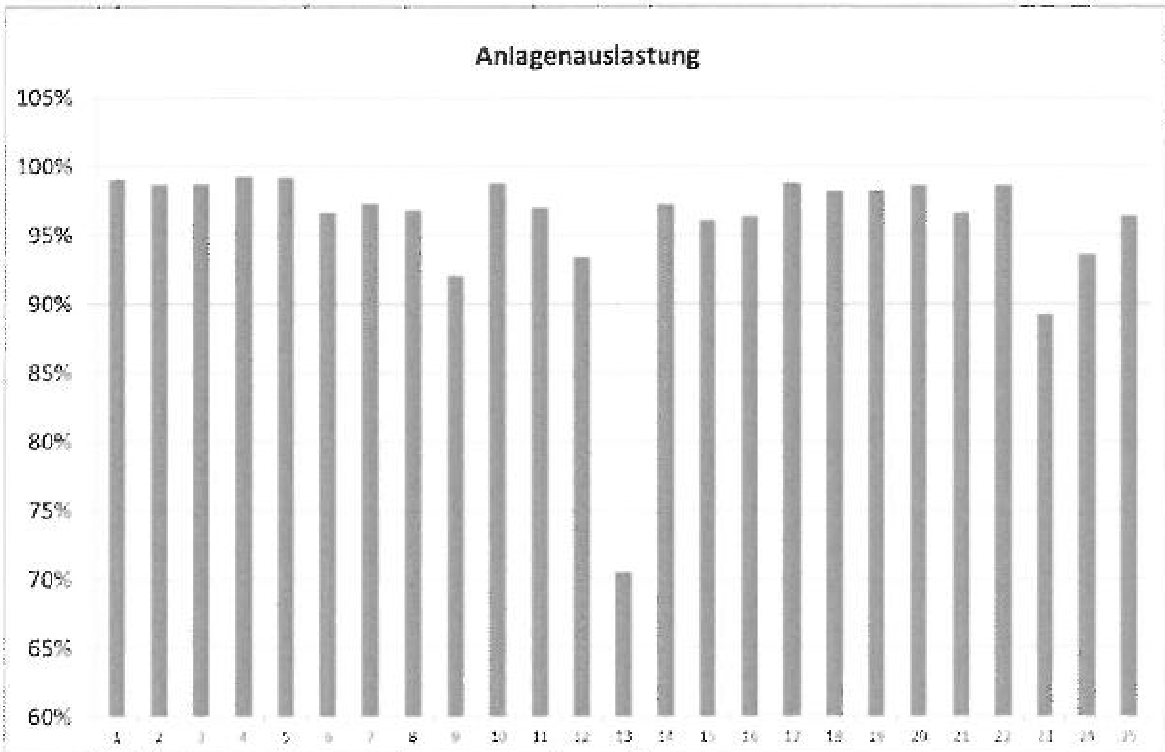
Results of the poll among owners (25 plants)



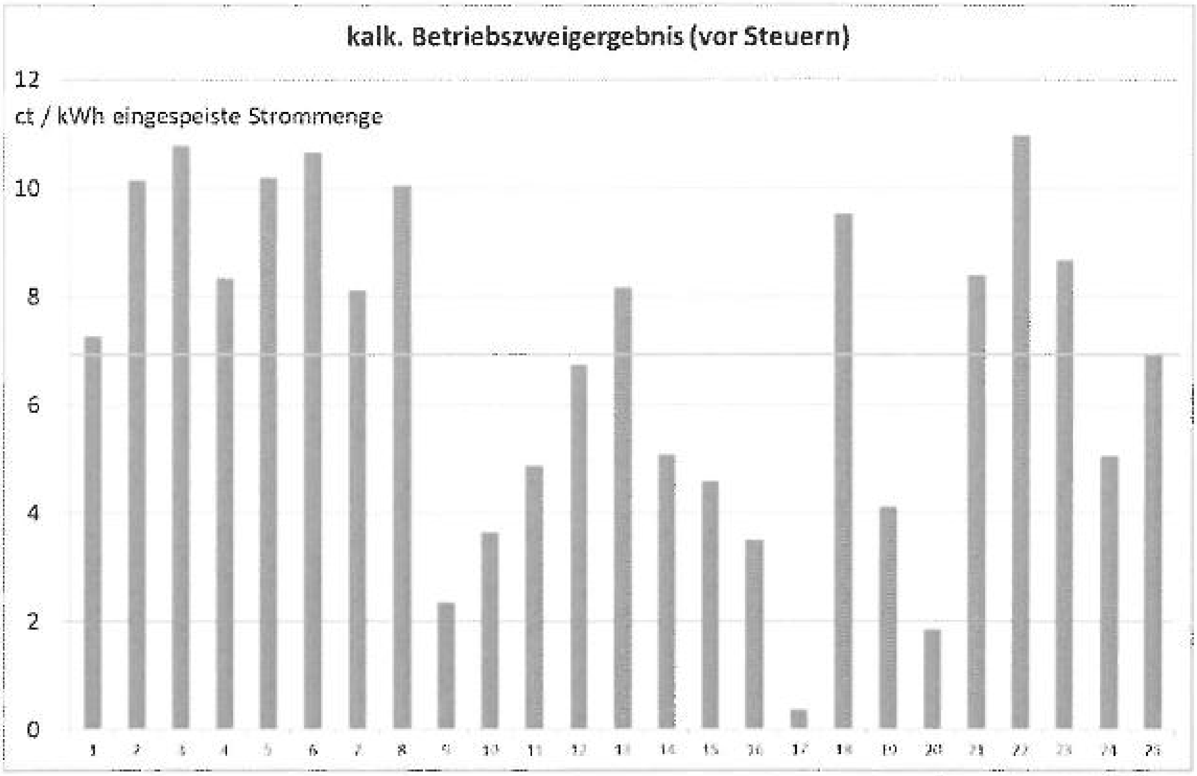
Results of the poll among owners (25 plants)



Results of the poll among owners (25 plants)



Results of the poll among owners (25 plants)

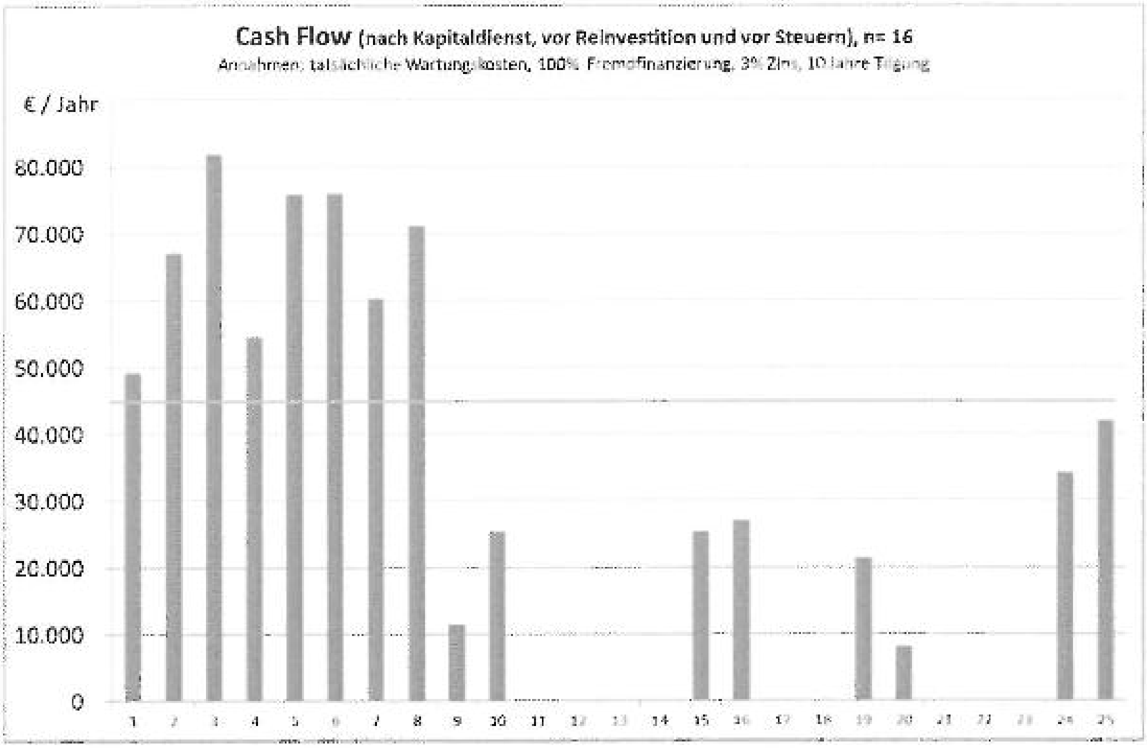


Profitability of two selected plants

		Anlage A	Anlage B
Investitionssumme		285.000 €	624.000 €
Gülleanteil		88%	99%
verkaufte Strommenge	kWh	625.000	605.000
Stromerlös	0,25 €	156.250 €	151.250 €
Kosten (ohne Biomasse)		63.500 €	87.500 €
Kosten Biomassebereitstellung		33.600 €	5.000 €
Gewinn		**59.150 €**	**58.750 €**

Critical factors for the profitability of a plant are the capital investment and the available quantity of slurry / manure

Results of the poll among owners (16 plants)



What is the present situation for builders of a slurry-fed biogas plant?

- Present feeding compensation rate (23.53 ct / kWh) is about 1.5 cent less in comparison with the poll: about 10,000 € / year less earnings for sale of electricity for 75 KW plant
- Capital investments have gone up
- Only plants with a very high proportion of (free) slurry / manure can still operate at a profit, i.e., at least 250 – 300 GV
- Plants of less than 75 KW are profitable only when feeding on 100% slurry / manure
- Proposed new regulations of the AwSV / DüngeVO (drafts):
  - Operation without biogas: min. 6 months slurry store
  - Operation with biogas: min. 9 months digestion residue store

Recommended slurry feeding plant concept

- If possible, two gas-tight vessels (digester + gas-tight store)
- Dwell time (heated) > 60 days with co-digestion of solid manure / renewables
  > 40 days for slurry-only plants
- Total dwell time (gas-tight) > 150 days (exception: slurry-only plants)
- In addition to the gas-tight store, an open end store for cooling of digestion residue. Gas-tight store must not be heated!
- Slurry feeding plants with dwell times of distinctly less than 120 days and without gas-tight digestion residue store can be a cause of increased methane emission. Up to 50% of the energy goes unused.
- Recommended: Traditional plant concept with agitated vessel digester and sufficiently long dwell time in the digester (many years of reliable operation, few cases of disruption, high gas yield)

Conclusion

- The operation of legacy plants is predominantly very good (tried and tested plant concept)
- The profitability fluctuates very widely but is generally better than forecast on the basis of calculations
- The profitability depends strongly on the capital invested as well as on the availability sufficient quantities of slurry or solid manure
- In view of lower EEG compensation, new projects only recommended where conditions are optimum.
- Combination with a high cattle population is ideal
- The traditional plant concept has proved viable and is recommended also for the future