Future Perspectives of Biogas

沼气行业的前景

Flexible power generation to balance future electricity systems

作为灵活多样的电力生产方式来补充完善未来的电力系统

Dr. Henning Hahn

Fraunhofer IWES

Content 内容

1) Short introduction (Speaker, Fraunhofer Institute)
   简介（发言人、弗劳恩霍夫研究院）
2) Transformation of the energy system
   电力系统的改革
   - Role of energy (electricity) from biomass and biogas?
   - 生物质和沼气能源的重要意义？
3) Technical concepts of a demand-driven biogas supply for (a demand-oriented) balancing power generation.
   (用于支持电力系统的）沼气发电需要考虑的技术性问题
4) Cost analysis and comparison of demand-driven biogas supply concepts
   需求驱动型沼气供应理念的成本分析与比较
5) Conclusion 结语

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3) Technical concepts of a demand-driven biogas supply for balancing power generation.

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5) Conclusion

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弗劳恩霍夫风能与能源系统技术研究院

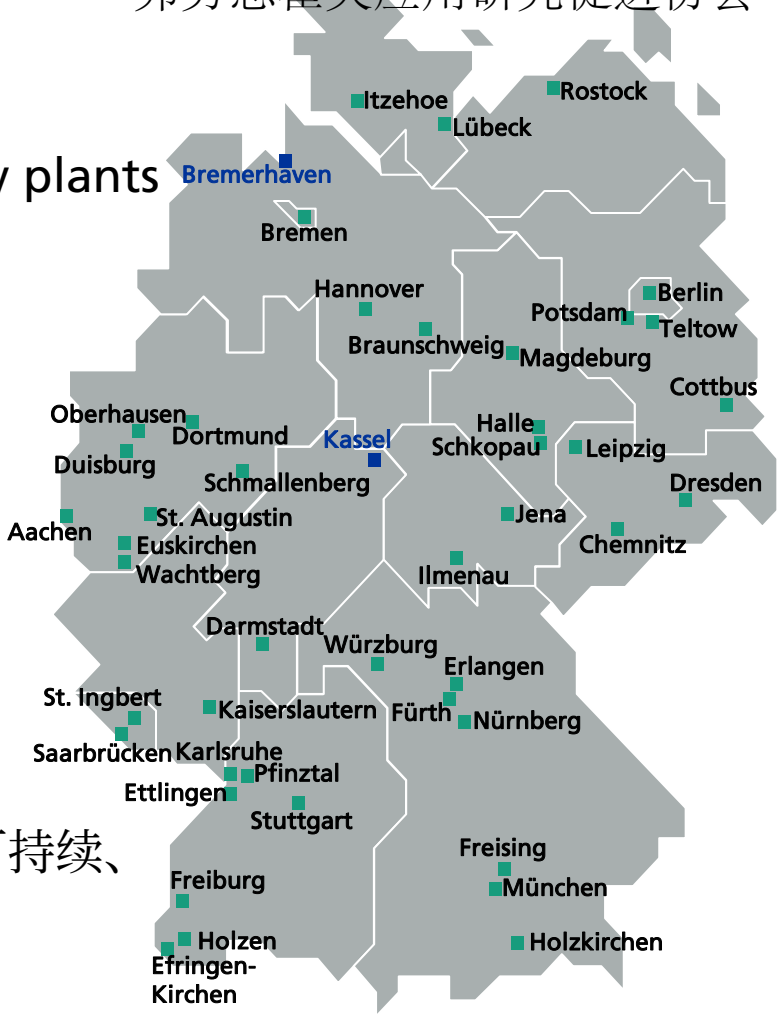
Fraunhofer Gesellschaft
弗劳恩霍夫应用研究促进协会

Main task: 主要职责
Cost efficient wind energy plants

高性价比的风力发电厂

Main task: 主要职责
Integration of RE sources for a sustainable and reliable energy supply

整合利用再生资源，实现可持续、可信赖的电力供给



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Herculean task: „Energiewende“
艰难的挑战：“能源革命”

How to solve it? 如何解决？

Which will be the task of energy from biomass and biogas?

生物质和沼气在能源革命中会起到什么作用？

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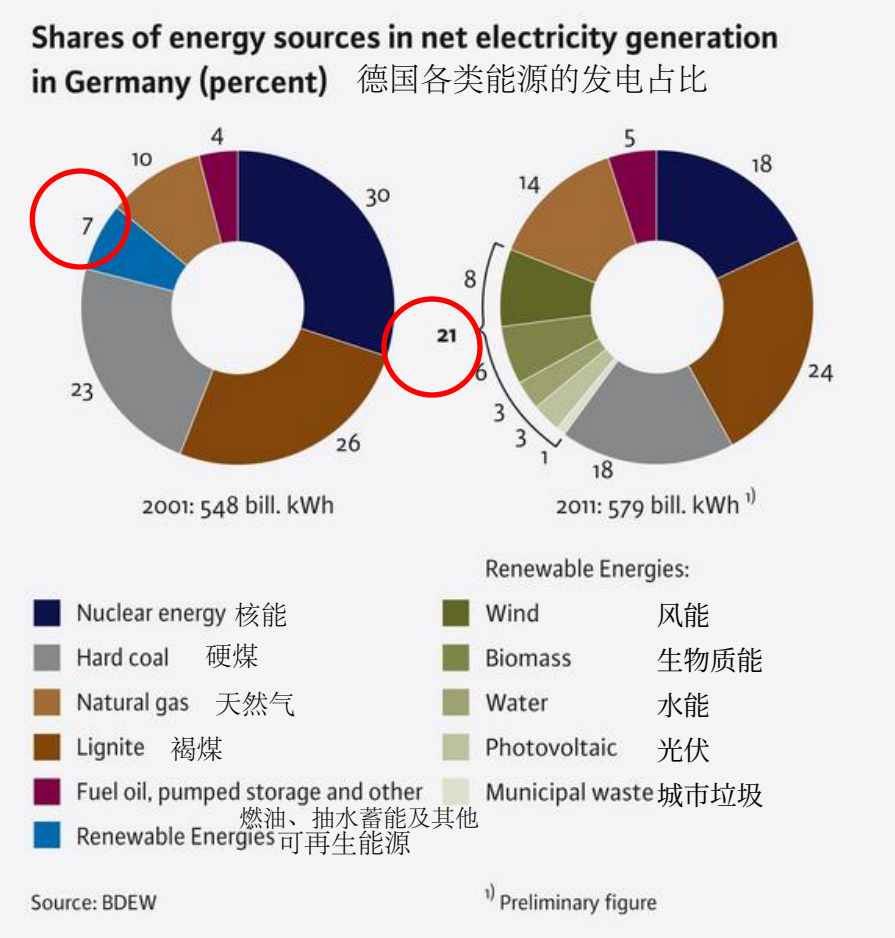
2) 生物质燃料和沼气发电的重要意义

The current status: Energy mix in Germany
电力系统的现状：德国的混合型能源结构



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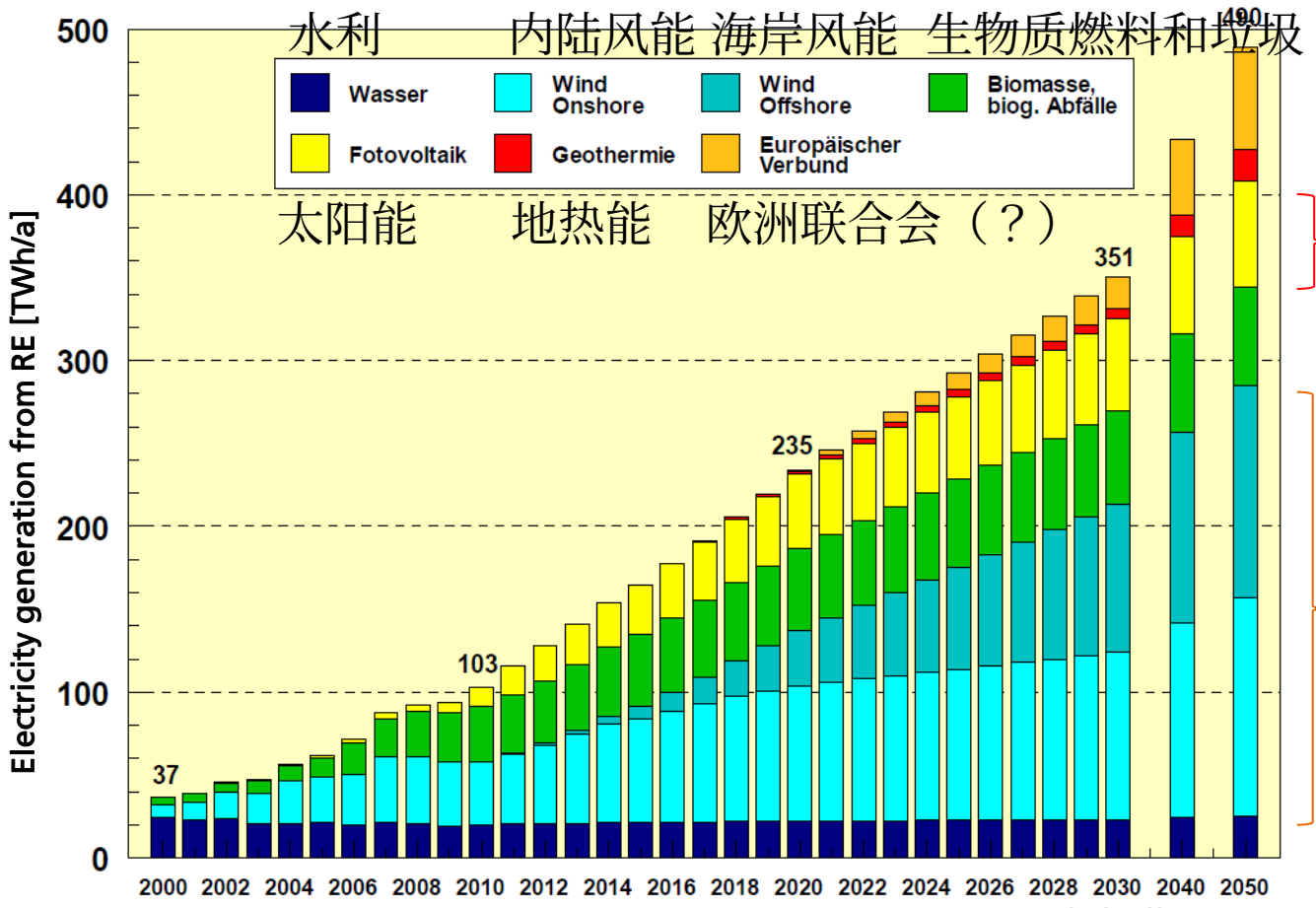
2) 生物质燃料和沼气发电的重要意义

可再生能源发电量[TWh/a]



Source: Langfristszenarien 2011; DLR, IWES

可再生能源发电在能源结构中所占的比率：

- 现在：20%
- 目标2050：80%
- Displayed显示: 100%

进一步发展：

- Main pillar will be fluctuating, weather dependent RE sources
- 不断波动、依赖天气条件的可再生能源将成为能源结构中的主体
- Dynamic expansion of PV and wind energy plants
- 光伏和风能发电厂的动态扩展

-> 不断增加的挑战：
起伏不定的发电能力必须满足不断变化的电力需求。

-> Increased challenges to cover the varying energy demand with fluctuating energies!

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2) 生物质燃料和沼气发电的重要意义

Main challenge 主要挑战

- … will be to synchronize the varying electricity demand with the fluctuating power generation
  起伏不定的电力生产必须满足起伏不定的电力需求。

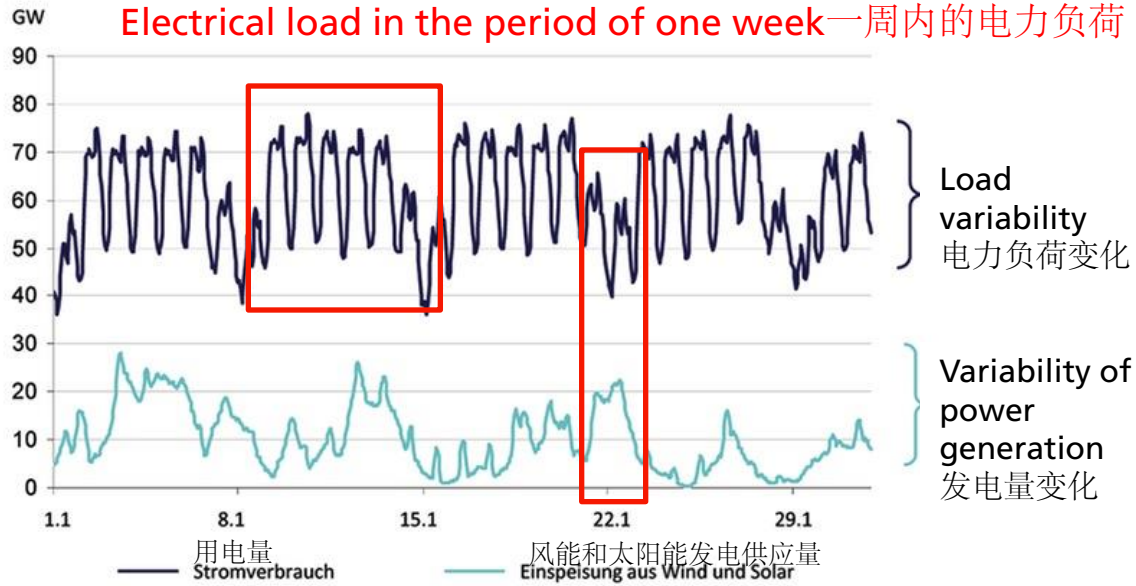

Abb.: Variations of power generation and consumption, January 2012
图： 2012年1月发电与电力消耗的变化

Source: entso-e, eex

Various technical solutions
各类解决方案

Dispatchable power plants
针对性发电

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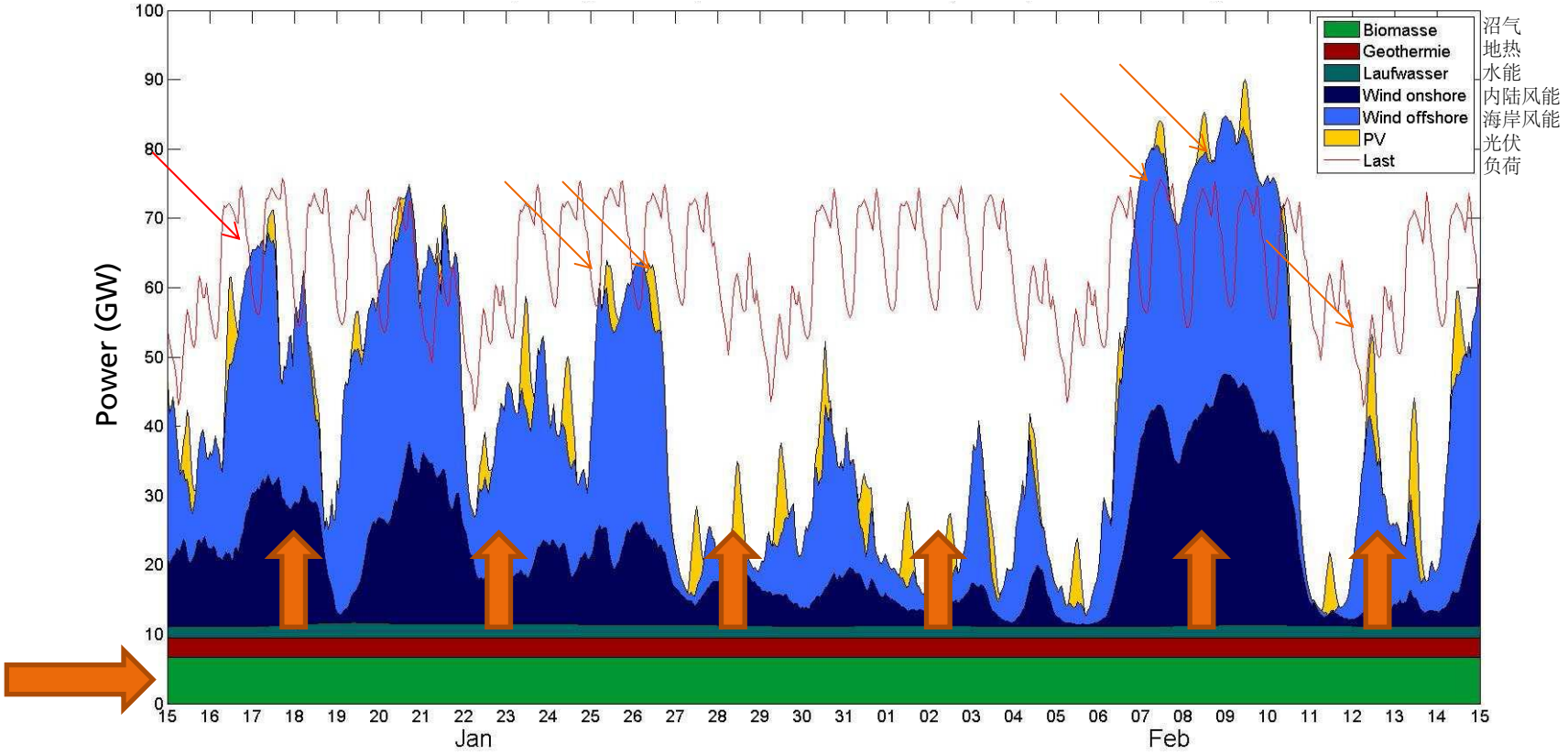
Baseload power generation with biogas!
沼气发电的基底负荷

Power generation from renewable resources and load, January until February 2050 (based on Meteo year 2006)
预计2050年1月至2月期间的可再生能源发电量及负荷



Assumption: Perfect electrical grid, no Must-Run-Units (MRU) necessary

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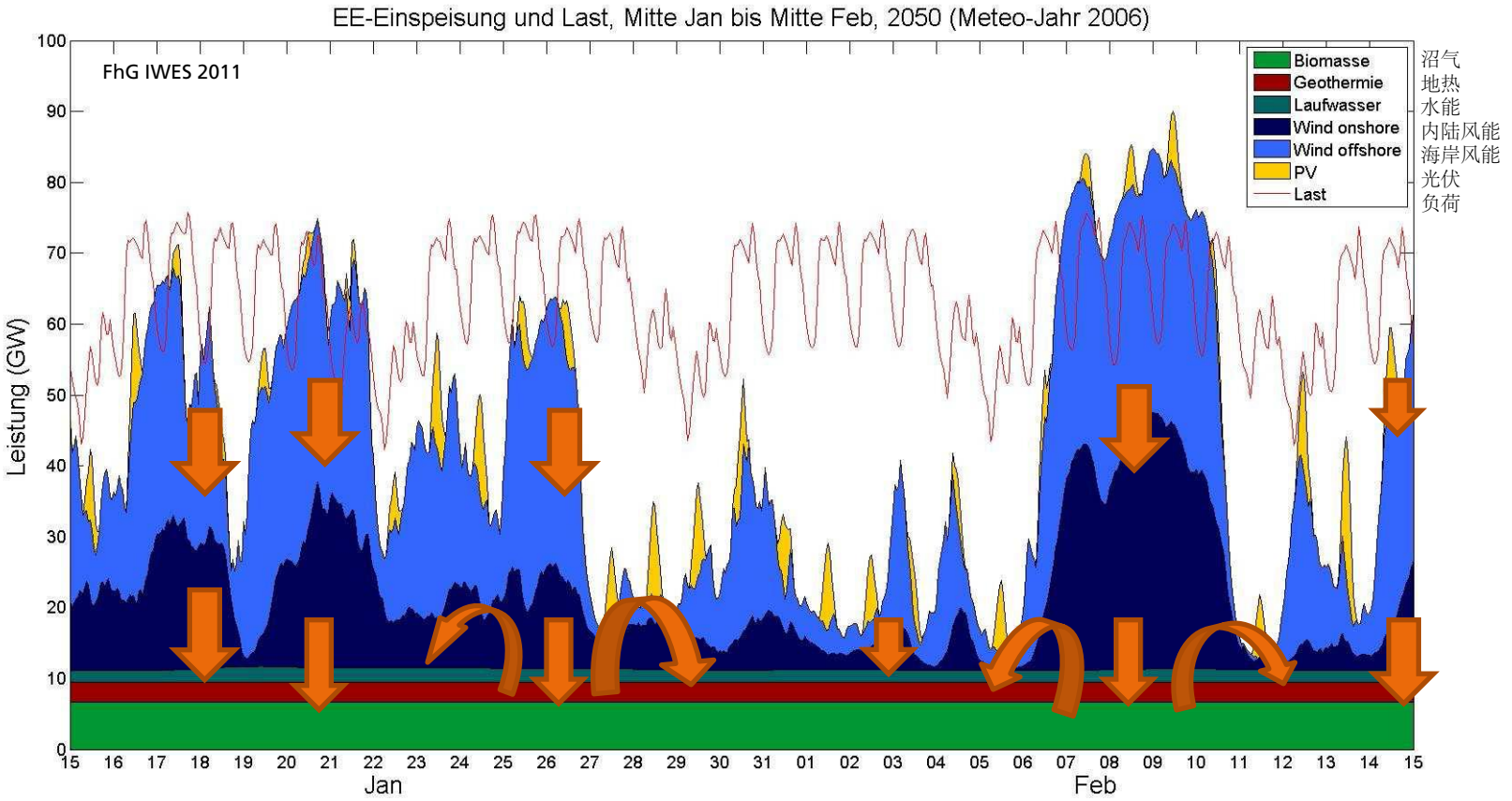
Target is not to waste cheap electricity from fluctuation renewable sources!

主要目的是确保不因为可再生能源电力生产浮动而造成浪费！



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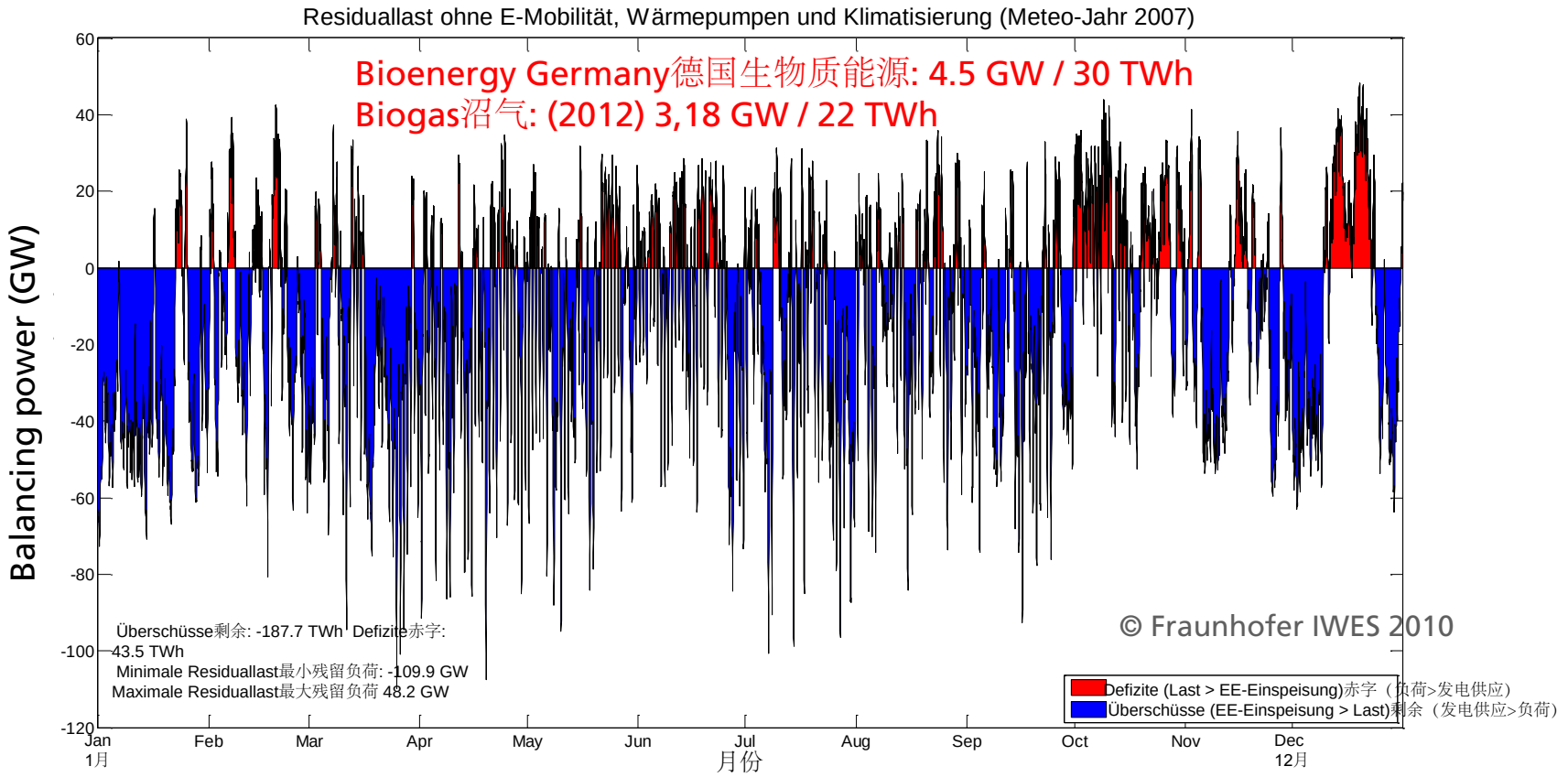
2) 生物质燃料和沼气发电的重要意义

Balancing power demand without e-mobility, heat pumps and air conditioning
(Meteo-year 2007) 电力需求平衡（不含电动交通、热泵和空调）



Source: IWES-calculation for UBA Energy goal 100% electricity from RE

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2) 生物质燃料和沼气发电的重要意义

Advantages of energy from biomass and biogas利用生物质和沼气产生能源的优势:

- Electricity generation is independent of climate influences. 不受气候影响
- Biomass and biogas can be stored and its power can be produced on demand.
  生物质和沼气便于储存，可以更好地根据需求发电

First incentives from the legislator 立法鼓励:

- Direct selling of electricity from RE at the wholesale market 在批发市场直销
- Selling of balance power 售出电力平衡

Preconditions for a demand-driven power generation from biogas:
需求驱动的沼气电力必须满足的先决条件:

A guaranteed biogas supply whenever needed for power generation!
如果要随时实现电力供应，必须保证足够的沼气供应!

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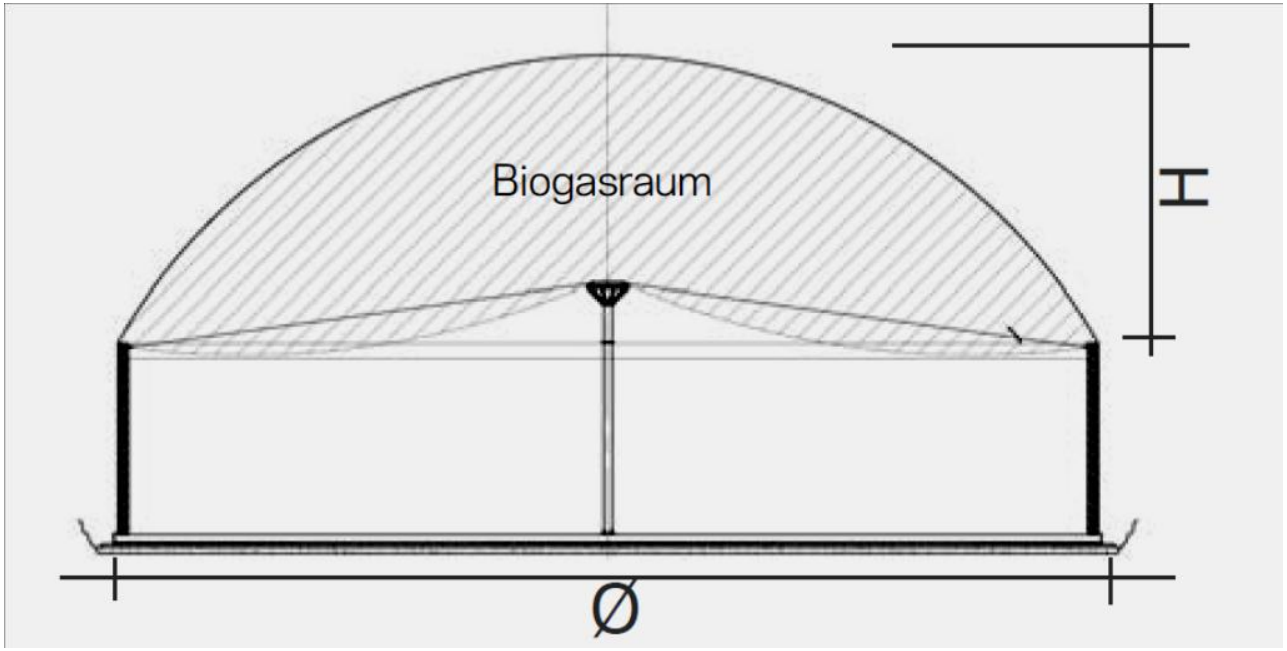
需求驱动的沼气发电需要考虑的技术性问题

2 technical concepts
2大技术理念

Biogas storing 沼气储存

Biogas Storage at a conventional biogas plant
传统沼气厂的沼气存储



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3) Technical concepts for a demand-driven biogas supply
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Biogas storing 沼气储存

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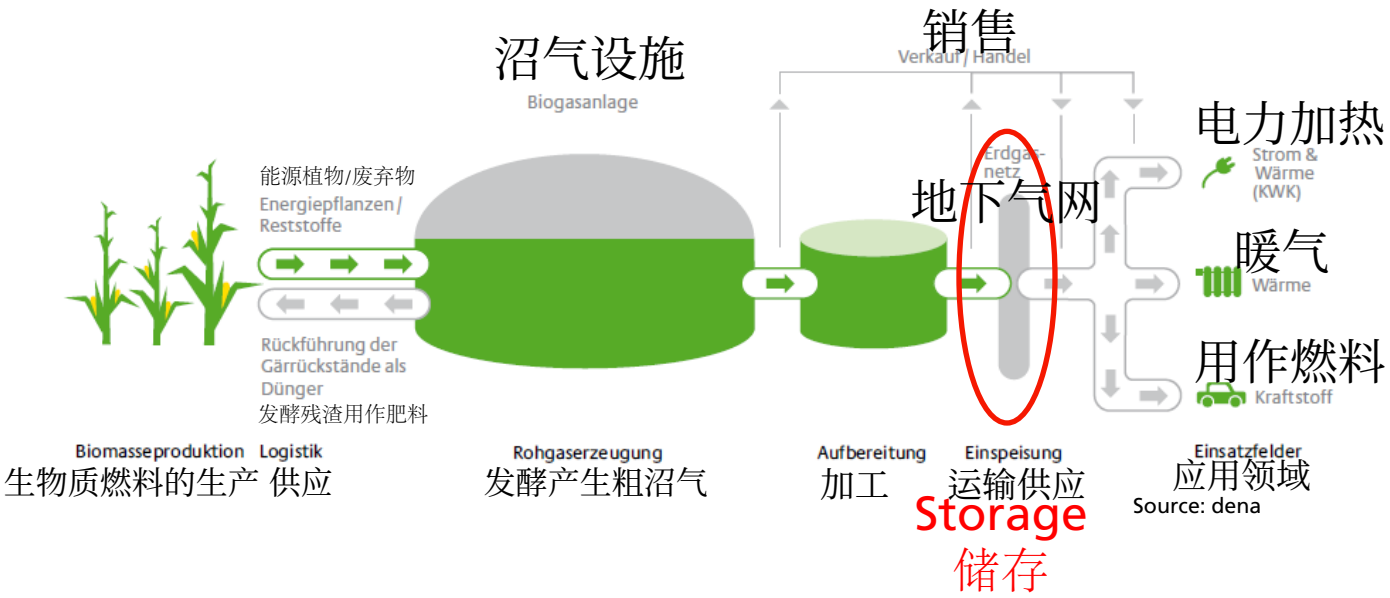
2 technical concepts
2大技术理念

Biogas storing 沼气储存

Biogas upgrading and biomethane grid injection
沼气提纯与生物甲烷并入电网

沼气中含有多种废气，必须经过处理才能得到可燃性极好的甲烷，然后才能被人们用于生产和生活。



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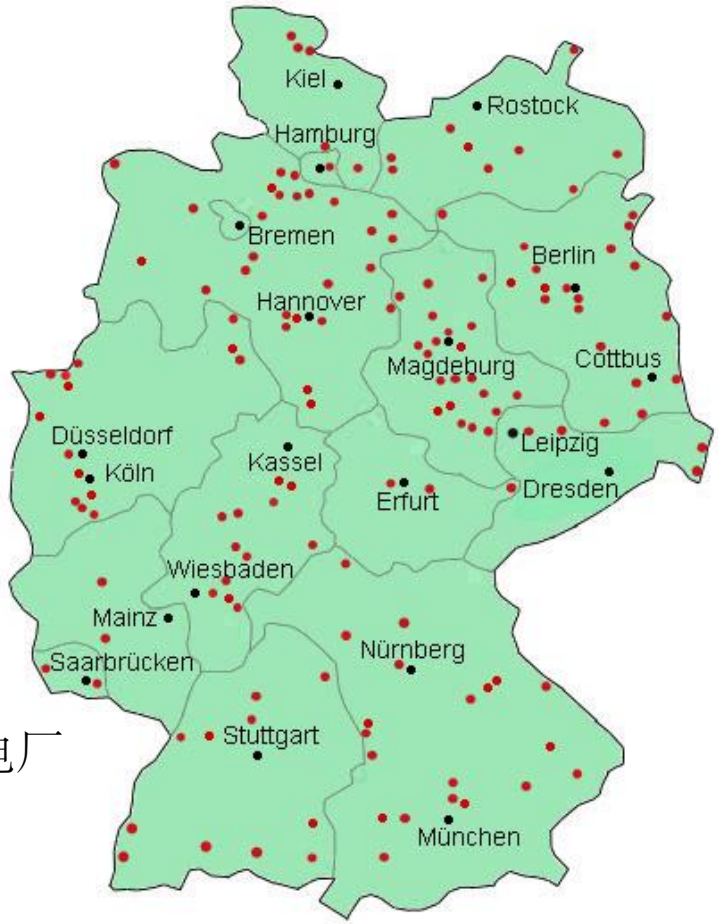
Biogas upgrading and biomethane grid injection
沼气提纯与生物甲烷并入电网

德国沼气提纯与生物甲烷并入电网



Germany德国 2013: 120 plants 120家沼气发电厂

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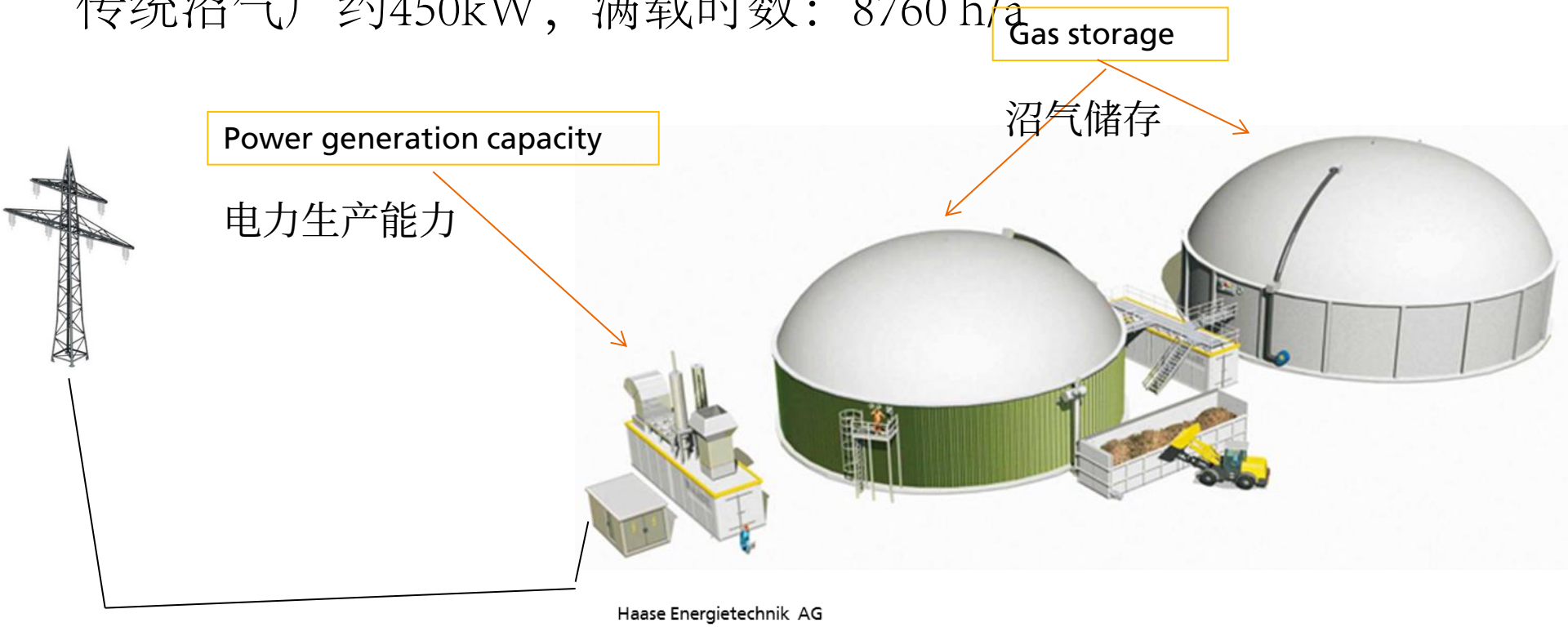
3) Technical concepts for a demand-driven biogas supply
需求驱动的沼气发电供应需考虑的技术性问题

State of the art of demand-driven electricity generation in Germany
德国社会需求驱动的电力生产现状

3) Technical concepts for a demand-driven biogas supply
需求驱动的沼气发电供应需考虑的技术性问题

Conventional biogas plant concept ca. 450 kW, full load hours: 8760 h/a (refered to related power)

传统沼气厂约450kW，满载时数：8760 h/a



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Conventional biogas plant concept ca. 450 kW, full load hours: 8760 h/a (refered to related power)

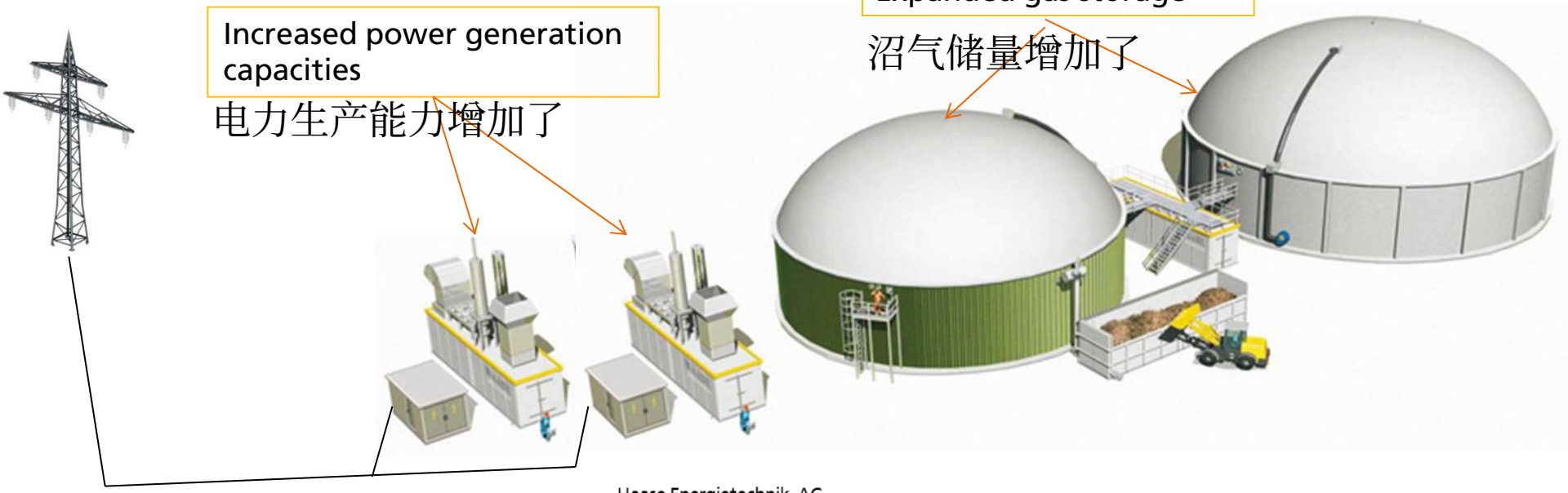
传统沼气厂约450kW，满载时数：8760 h/a

Increased power generation capacities

电力生产能力增加了

Expanded gas storage

沼气储量增加了



Haase Energietechnik AG

Example:
Related power功率: ca. 450 kW,
Installed capacity装机容量: 1000 kW,
Full load hours满载时数:: ca. 4000 h/a

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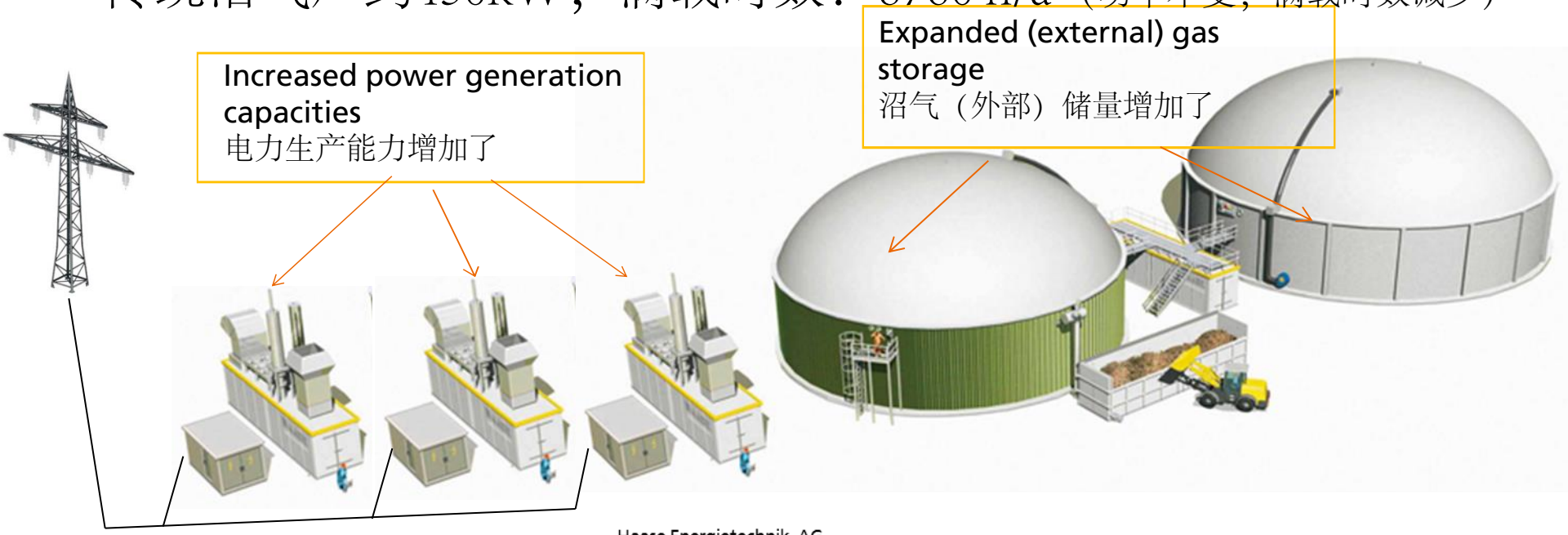
Conventional biogas plant concept ca. 450 kW, full load hours: 8760 h/a (refered to related power)

传统沼气厂约450kW，满载时数：8760 h/a（功率不变，满载时数减少）



Example范例:
Related power功率: ca. 约450 kW,
Installed capacity装机容量: 1500 kW,
Full load hours满载时数: ca. 约2600 h/a

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3) Technical concepts for a demand-driven biogas supply
需求驱动的沼气发电供应需考虑的技术性问题

Demand-driven power generation 需求驱动的发电

Electricity generation from biogas, if there is not enough electricity production from sun and wind energy plants!
如果太阳能和风能无法满足电力需求，那么沼气发电就会弥补电力系统的不足！

Discharging of biogas storages
开放沼气储备

biogas supply
沼气供应与电力系统

3) Technical concepts for a demand-driven biogas supply
需求驱动的沼气发电供应需考虑的技术性问题

Demand-driven power generation 需求驱动的发电

No electricity generation from biogas, if the sun is shining and/or the wind is blowing!
如果太阳能和风能已经可以满足能源需求，那么此时不需要沼气发电！

Filling of biogas storages
积累沼气储备

No biogas supply
沼气不会被用于发电

Haase Energietechnik AG

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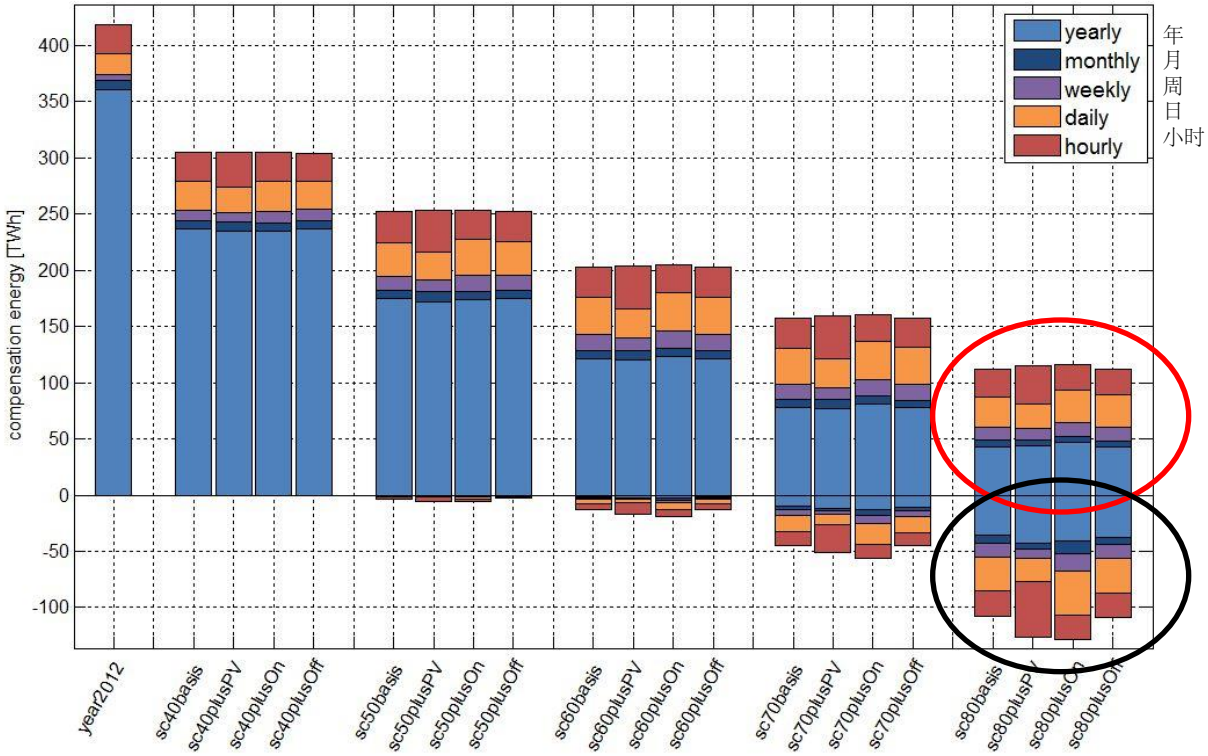
3) Technical concepts for a demand-driven biogas supply
需求驱动的沼气发电供应需考虑的技术性问题

Demand of compensation electricity to cover the residual load

折衷的办法满足电力需求的其他方面



deficits 不足

surpluses 剩余

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3) Technical concepts for a demand-driven biogas supply
需求驱动的沼气发电供应需考虑的技术性问题


Source: KWA Contracting AG


Source: Bontec

2 technical concepts
2大技术理念

Biogas storing 沼气储存

Biogas production on demand
根据需求生产沼气

Source: Triolet

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3) Technical concepts for a demand-driven biogas supply
需求驱动的沼气发电供应需考虑的技术性问题

specific methane yield
沼气每天的产率
cumulative methane yield
沼气的总产率

Variation of substrates 基底的变化

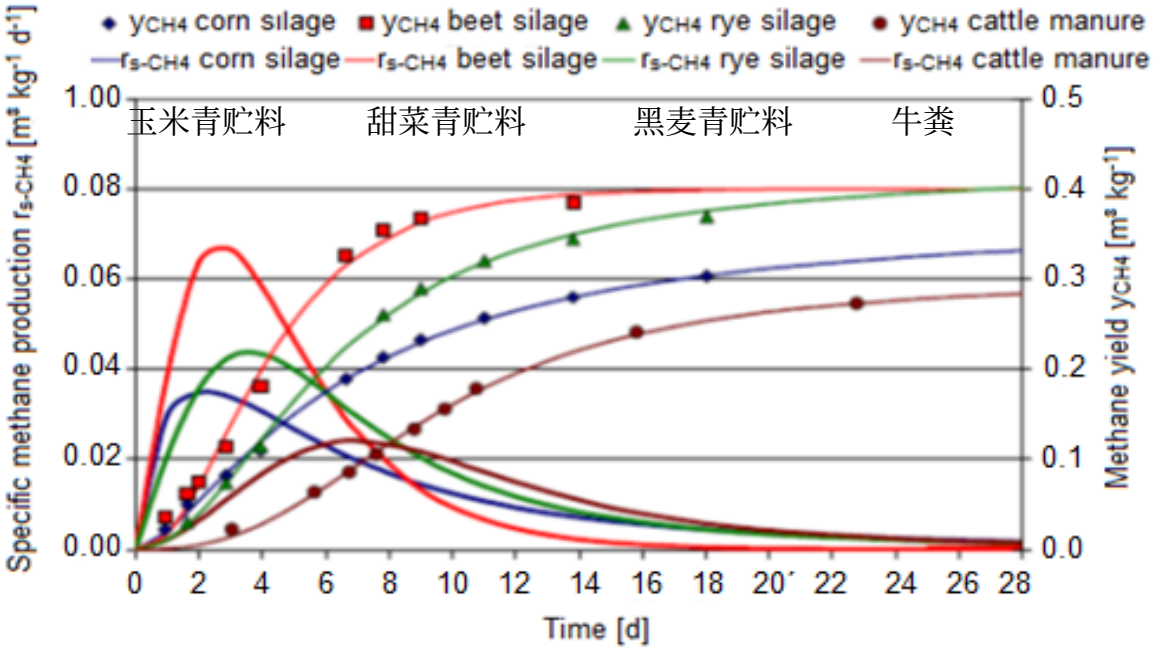

Figure: Specific methane yield and cumulative methane yield from the digestion of cattle manure, corn, rye and beet silage in batch experiments under mesophilic process conditions over a digestion time of 28 days (adapted after Mähnert 2007) (y-CH_4: cumulative methane yield, rs-CH_4: specific methane yield).
沼气的日产率和总产率的对比实验，在特定的对比条件下，经过28天发酵，牛粪、玉米、黑麦、甜菜青贮料会有不同的沼气产率特性曲线。

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3) Technical concepts for a demand-driven biogas supply
需求驱动的沼气发电供应需考虑的技术性问题

Variation of substrates and its feeding intervalls
改变投料的间隔和种类

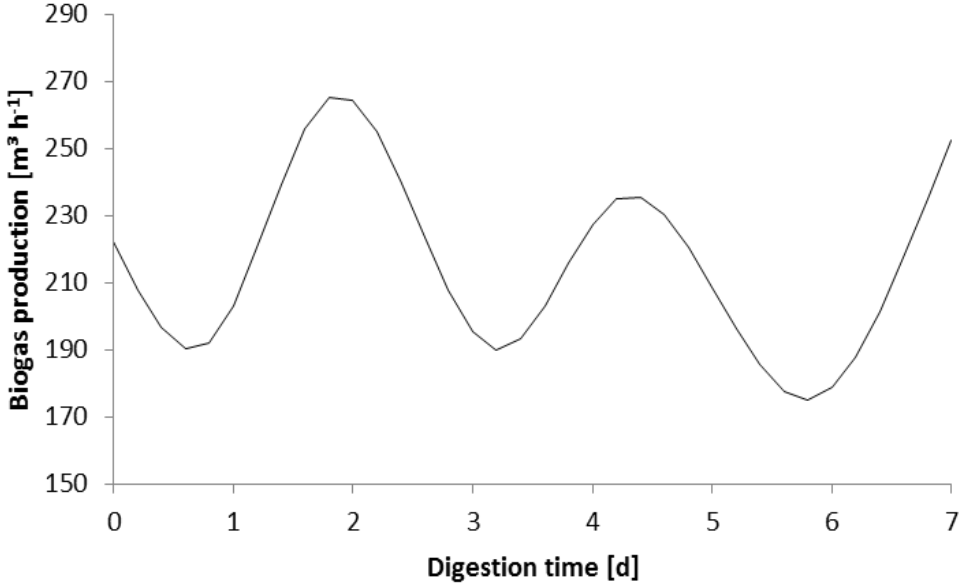

Figure: Simulated flexible biogas production during one week achieved by a variable feeding of manure, maize silage and shredded wheat of a mesophilic driven biogas plant with 500 kW installed electrical baseload power capacity (adapted after Kirchner in Hartmann 2010).

一家装机容量为500kW的中温型沼气厂，投料粪便、玉米青贮料以及小麦秸秆，一周内的模拟弹性沼气产率曲线图

3) Technical concepts for a demand-driven biogas supply
需求驱动的沼气发电供应需考虑的技术性问题


Source: KWA Contracting AG


Source: Bontec

2 technical concepts
2大技术理念

Biogas storing 沼气储存

Biogas production on demand
根据需求生产沼气

Source: Triolet


Source: Meyer Gruppe

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Source: KWA Contracting AG


Source: Bontec

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Biogas production on demand
根据需求生产沼气

Source: Triolet


Source: Meyer Gruppe


Source: Röhring Energieanlagen GmbH

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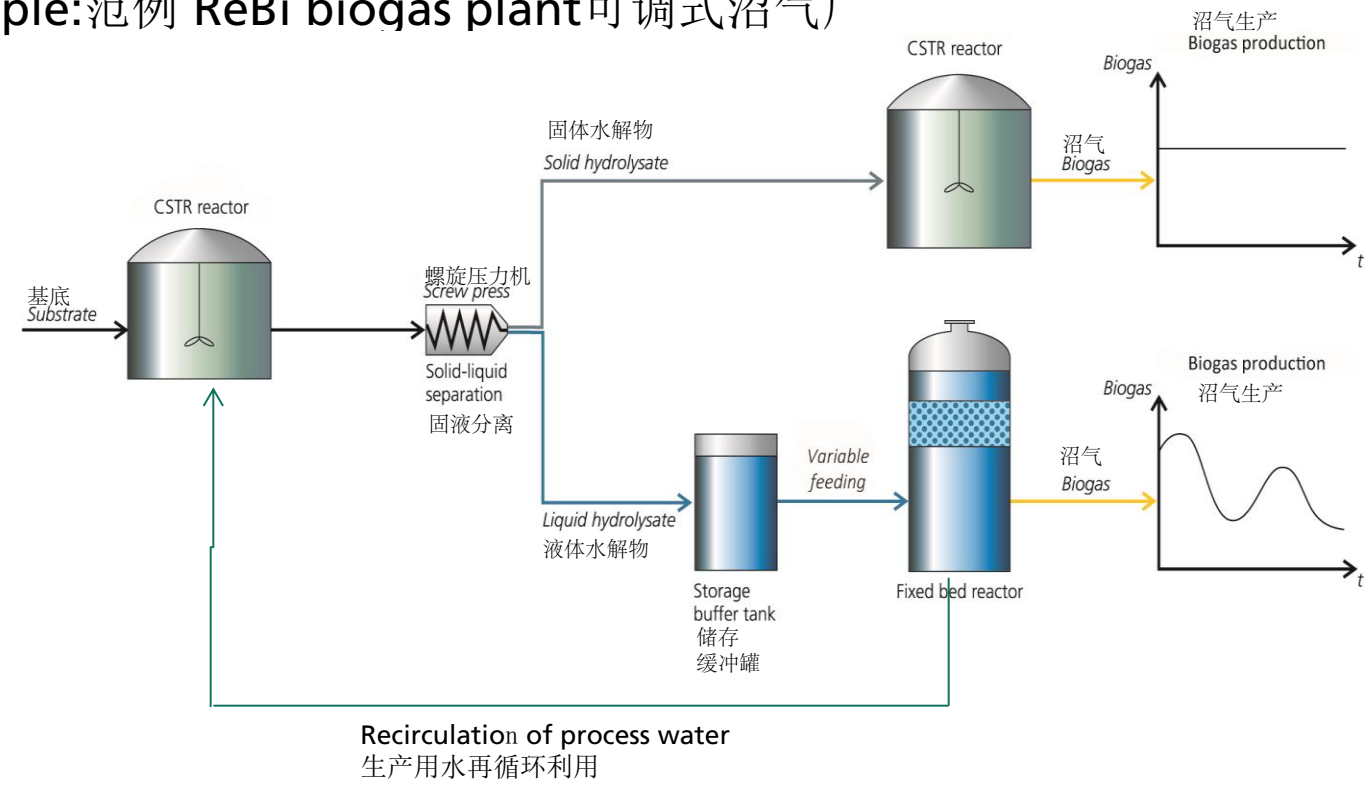
3) Technical concepts for a demand-driven biogas supply
需求驱动的沼气发电供应需考虑的技术性问题

Adapted biogas plant configurations
调整沼气厂的配置

Example:范例 ReBi biogas plant可调式沼气厂



Explanation: ReBi – **Re**gelbare **Bi**ogasanlage (dispatchable biogas plant configuration)

解释：ReBi——可调式沼气厂

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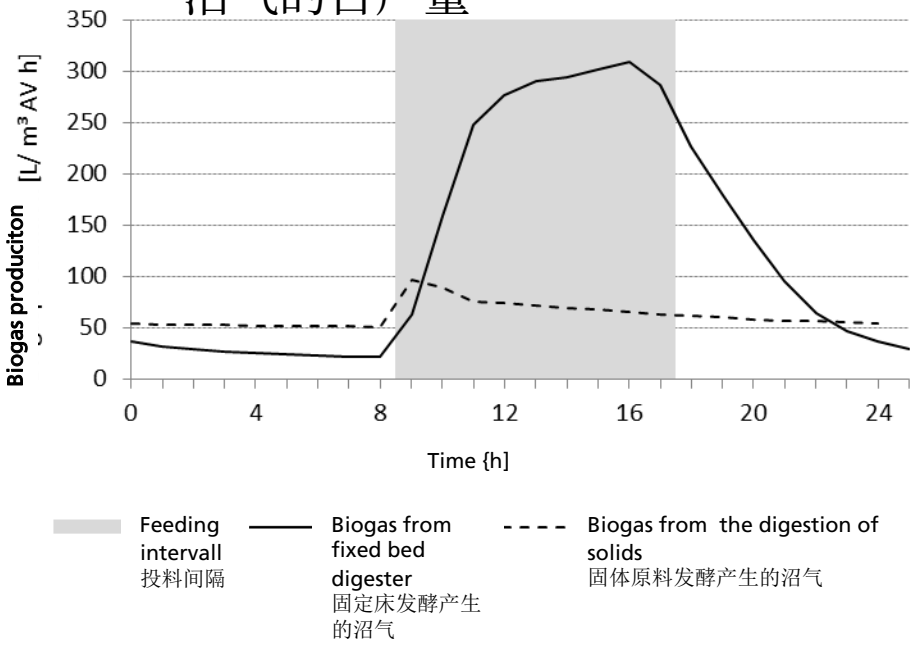
3) Technical concepts for a demand-driven biogas supply
需求驱动的沼气发电供应需考虑的技术性问题

Biogas production on demand with the ReBi biogas plant configuration
根据可调式沼气厂 配置需求生产沼气

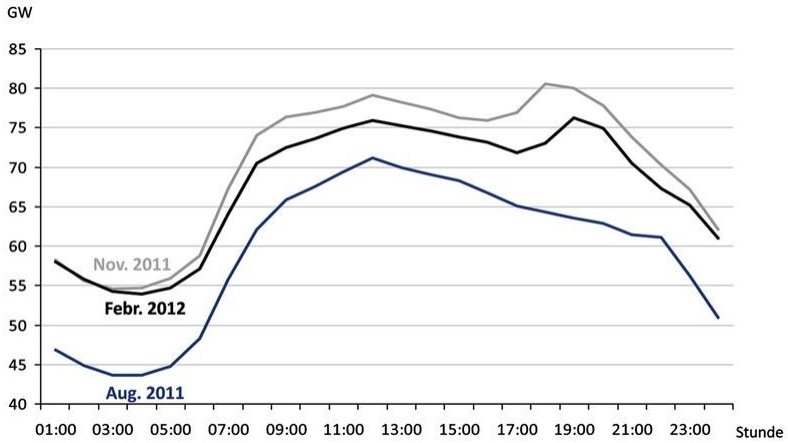
Biogas production in the course of one day

沼气的日产量



Daily electricity consumption in different seasons

（不同季节）电力的日消耗量



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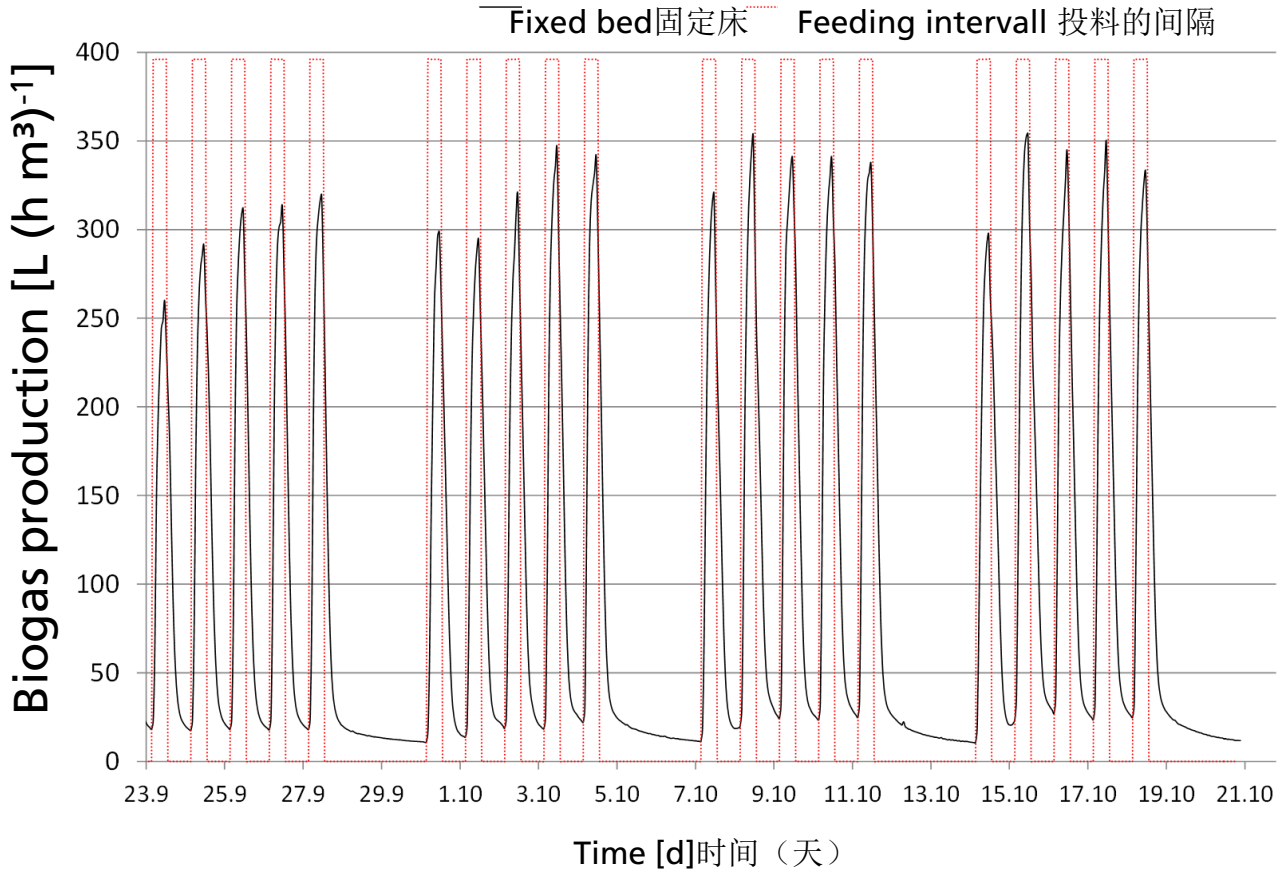

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4) Technical concepts of a demand-driven biogas supply

Comparison of the on site biogas storage demand with a biogas production on demand

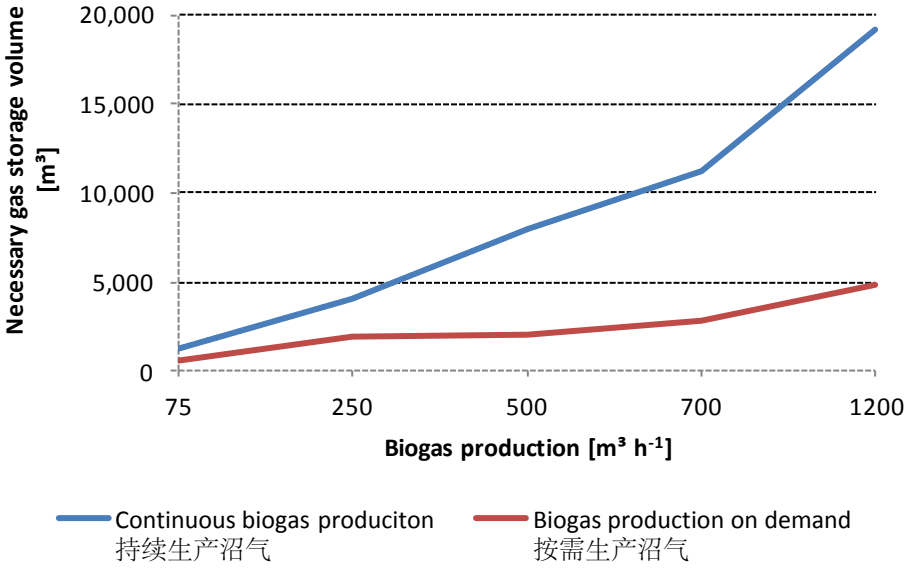
将现场沼气存储需求与沼气生产需求相比较

Advantage of biogas production on demand按需生产沼气的优势：

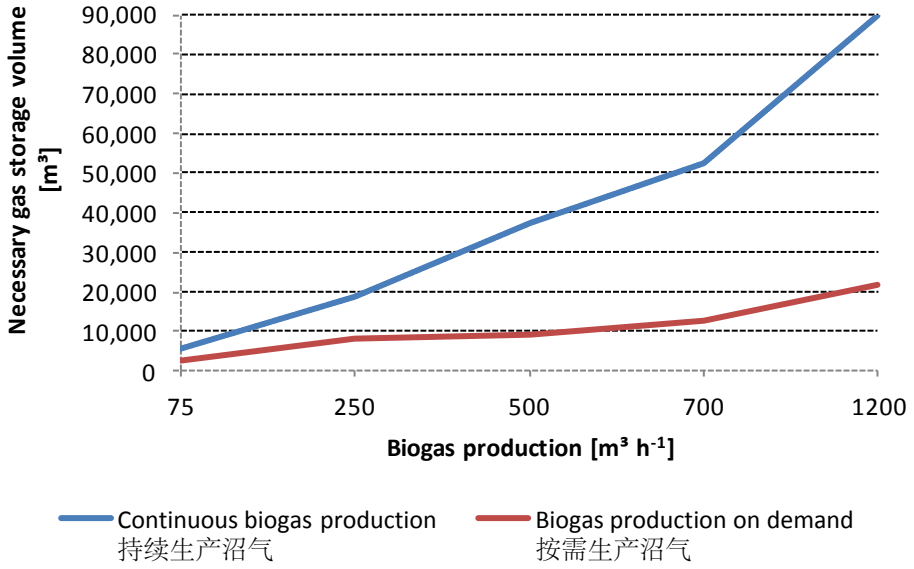
- Reduced necessary biogas storage demand -> reduced investment

  减少必要的沼气存储需求，减少投资
- Increased overall flexibility 增加沼气发电的灵活性

Electricity generation 8h/day
发电 8小时/天



3 days without electricity generation
3天未发电



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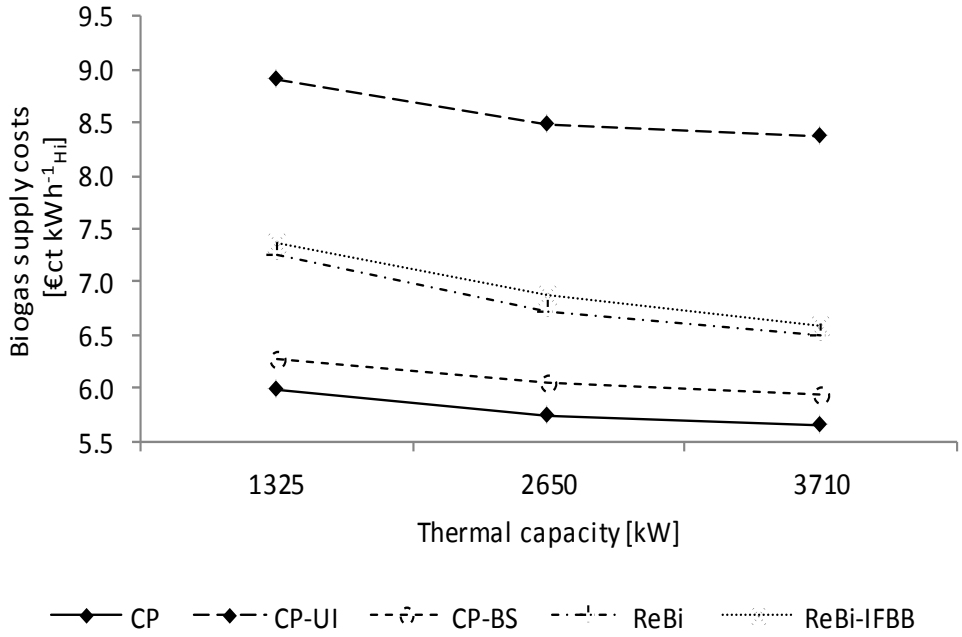
Balance power generation oriented on the daily residual load

根据每日剩余负荷平衡发电

-> Biogas supply at 8 hours per day 每日8小时沼气供应



Additional costs附加成本: ca. 0.3 €ct/kWh

Explanation说明:

CP: conventional biogas plant 常规沼气厂

CP-UI: CP with upgrading to biomethane and grid injection 升级至生物甲烷和电网注入的常规沼气厂

CP-BS: CP with expanded biogas storage 扩充了沼气储备的常规沼气厂

ReBi: Biogas plant configuration for biogas production on demand 按需可调式沼气厂

ReBi-IFBB: ReBi biogas plant configuration with additional digestion of press fluid from the integrated generation of solid fuel and biogas from biomass (Substrate: Grass silage from semi-natural grass land) 对来自固体燃料和生物质沼气综合生产的压流体进行额外发酵的可调式沼气厂（基底：来自半野生草原的牧草青贮）

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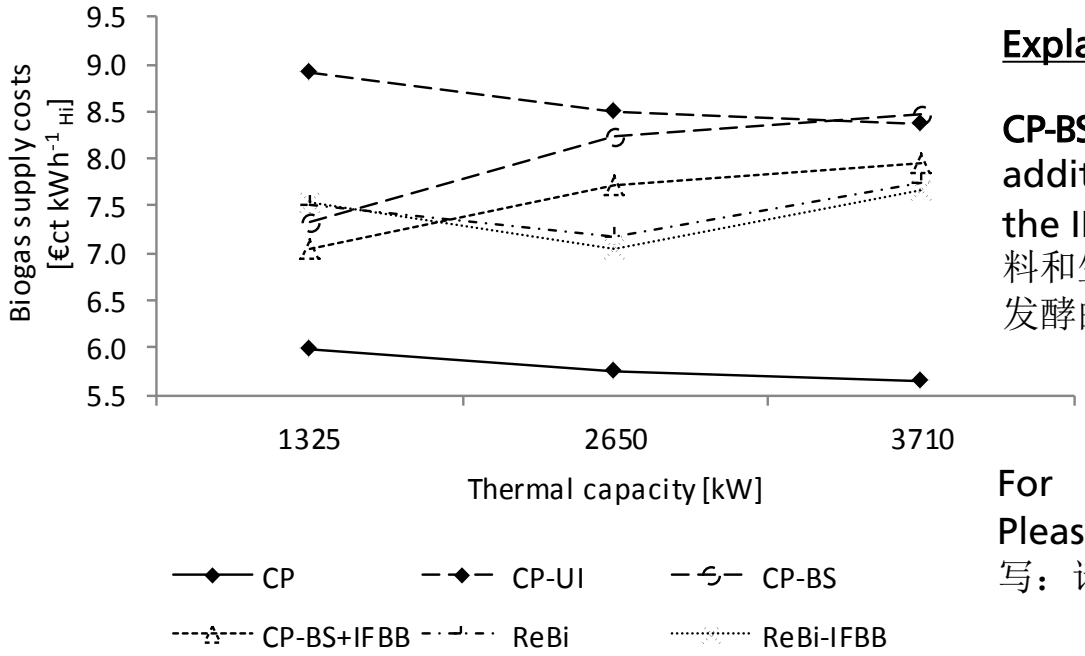
4) Cost analysis and comparison of demand-driven biogas supply concepts 需求驱动型沼气供应理念的成本分析与比较

Balance power generation oriented on the weekly residual load
根据每周剩余负荷平衡发电



Explanation说明:

CP-BS+IFBB: CP-BS with demand oriented addition of easy digestible press fluid from the IFBB technology. 按需可对来自固体燃料和生物质沼气综合生产的压流体进行额外发酵的沼气储备扩充了的常规沼气厂。

For all other abbreviations: Please see previous slide!其他缩写：请参阅前一张幻灯片！

Additional costs附加成本:: ca. 1-2 ct/kWh

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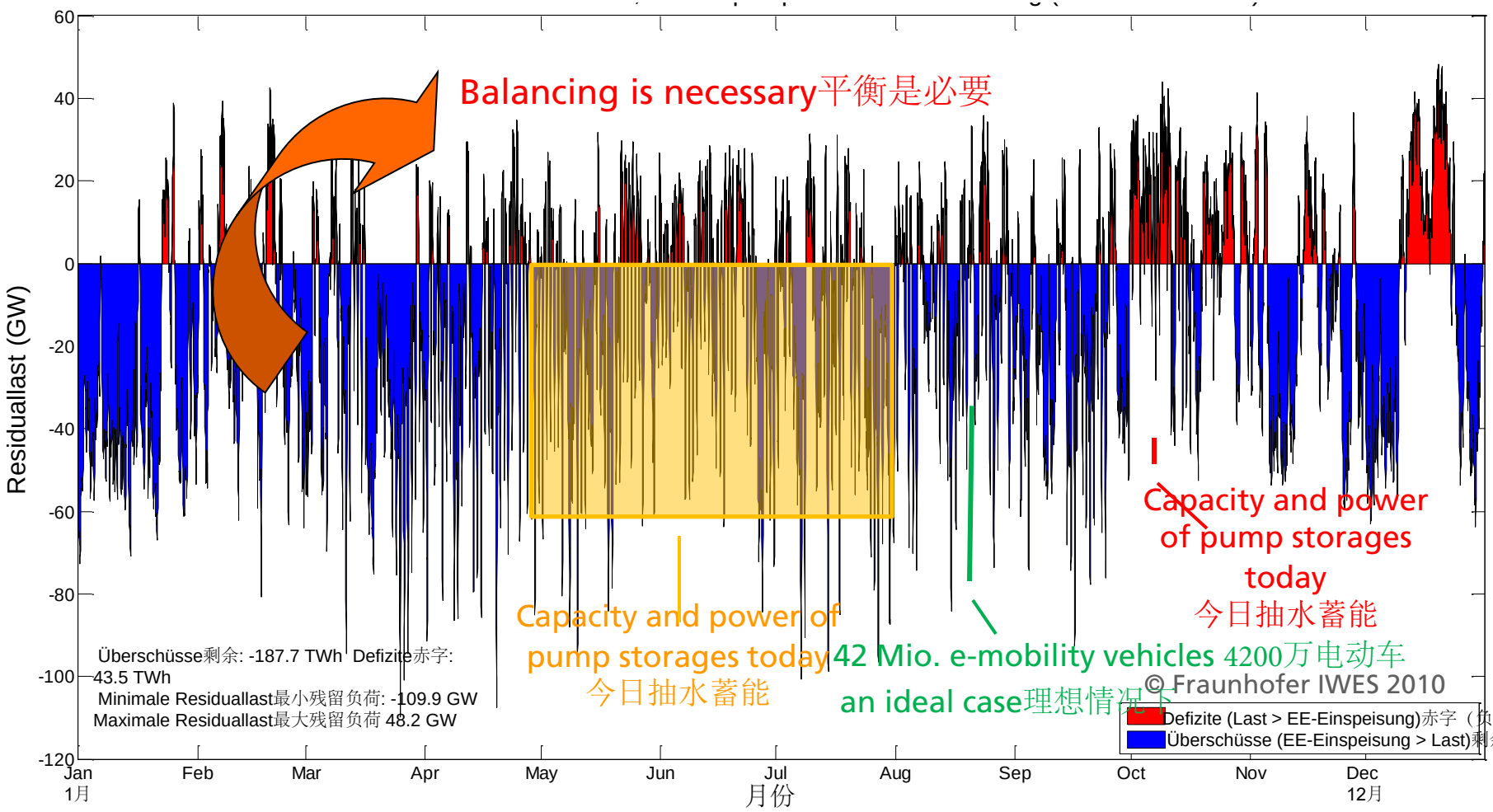
5) Conclusion I 结语（一）

1. 需利用可再生能源发电来平衡风能和太阳能在电力供给中的不稳定状况。
2. 沼气可灵活地按需发电
3. 需求驱动型的沼气生产对平衡电力系统很重要。
4. 沼气发电很经济，可以最低成本短期平衡发电。
5. 灵活的沼气生产对保证长期发电平衡也有很好作用。
6. 对于发电变化性巨大的创新型沼气厂是一次机遇。

- The transformation to an electricity system based on renewable sources is characterized by an increasing need for balancing power in order to compensate power supply from fluctuating sources, such as solar or wind.
- Biomass, more precisely energy from biogas, has the potential to generate electricity flexible on-demand.
- A demand-driven biogas production is vital for balancing power generation and can generally be achieved by biogas storing or flexible biogas production concepts.
- Results of the cost analysis and comparison of biogas supply configurations show that a demand-driven biogas supply for short term balancing power generation can be achieved at the lowest costs by on-site biogas storing.
- Whereas, flexible biogas production concepts are an opportunity to ensure the biogas supply for long-term balancing power generation.
- A demand-driven electricity generation from biogas (biomass) offers substrates which are not commonly used in biogas plants and innovative biogas plant configurations a chance, especially if there a huge variability of electricity production is required.

Balancing power demand without e-mobility, heat pumps and air conditioning (Meteo-year 2007) 电力需求平衡（不含电动交通、热泵和空调）



→ natural gas storage天然气储存 = 1500 to 3000x 所有抽水蓄能 ($\eta_{GT,GuD}$ = 28-55%)

Source: IWES-calculation for UBA Energy goal 100% electricity from RE

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Renewable Gas – Power-to-Gas 可再生气体 - 电力-燃气

energy storage by coupling of electricity and gas grids通过将电力和天然气电网联结进行能量储存 → Technical simulation of photosynthesis 光合作用的模拟技术

POWER NETWORK 电网

NATURAL GAS NETWORK 天然气管网

Wind 风能

Solar 太阳能

Other renewables

其他可再生能源

燃气轮机

Gas turbines, Gas CHP

燃气热电联产

- for Heat 用于供暖
- for Mobility 用于交通

POWER GENERATION 发电

ENERGY STORAGE 储能

Gas storage

燃气储存

H_2O O_2

电解

Electrolysis, H_2-Tank

H_2

甲烷化反应

Methanation

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

CH_4

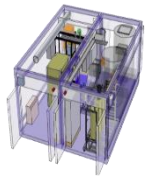
- Atmosphere 大气层
- Biomass, Waste 生物质能，废物

CO_2

CO_2-Tank

CO_2

H_2O



Source: Sterner, 2009
Specht et al , 2010

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Power-to-Gas – combining advantages of the energy grid

electricity grid 电网

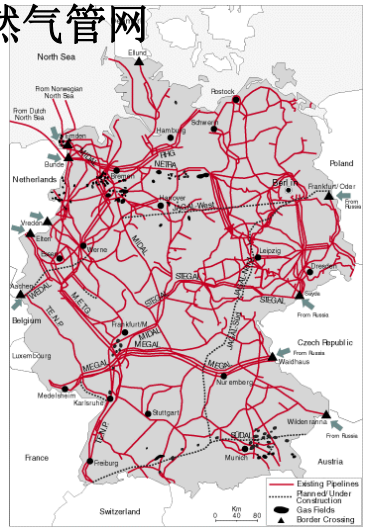
Transmission capacity

single-figure GW
单位数

Storage capacity
输送容量

0,04 TWh_{el}

Natural gas grid 天然气管网



double-figure GW
双位数

220 TWh_{th} + grid

Pros and Cons优缺点

+ high-quality energy 优质能源
  high-price energy 价格高昂
- electricity hardly storable电力难储存
+ direct use is highly efficient可直接使用，很高效
- AC transmission loss交流输电损耗
3-10% / 1000km

+ versatile energy source 多用途能源
  low-price energy 价格低廉
+ major storages 储量大
- high power conversion loss高功率转换损耗
- power transmission 0,5% / 1000 km
  H_2 limit today今日限制:
  2% vehicle汽车;
  1% gas燃气-KW and storage 与储存

Quelle: IWES, 2011

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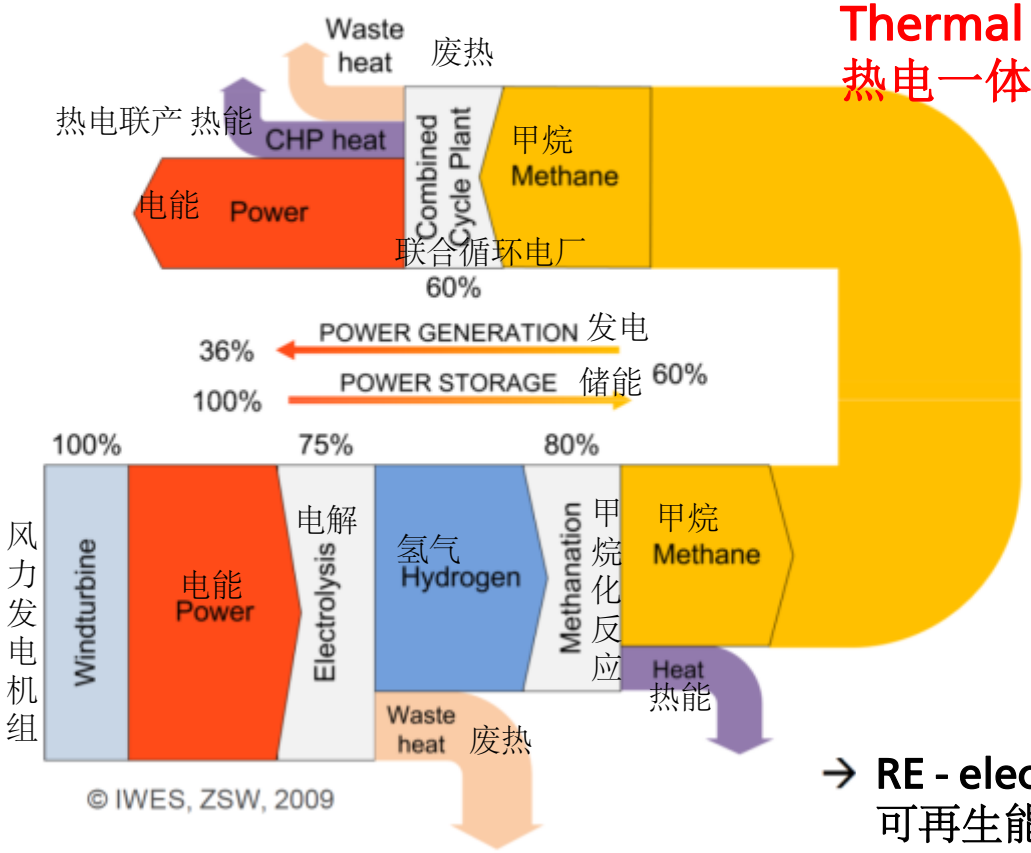
Energy Balances 能源收支

Renewable Gas – electricity-to-gas可再生气体–电–气
efficiency chain 效率链



Thermal Integration in Biogas Plant!
热电一体化沼气厂

Efficiency rates使用率:

60-65 % methane甲烷

35-40 % electricity电

50-60 % CHP热电联产

Vs. 0 % cut-off
Vs. more efficient but limited capacity storage alternatives
更高效，但容量存储有限

→ **RE - electricity becomes primary energy**
可再生能源成为主要能源

Source: Sterner, 2009; Specht et al, 2010

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Biogas as a CO_2-Source
沼气作为CO2来源

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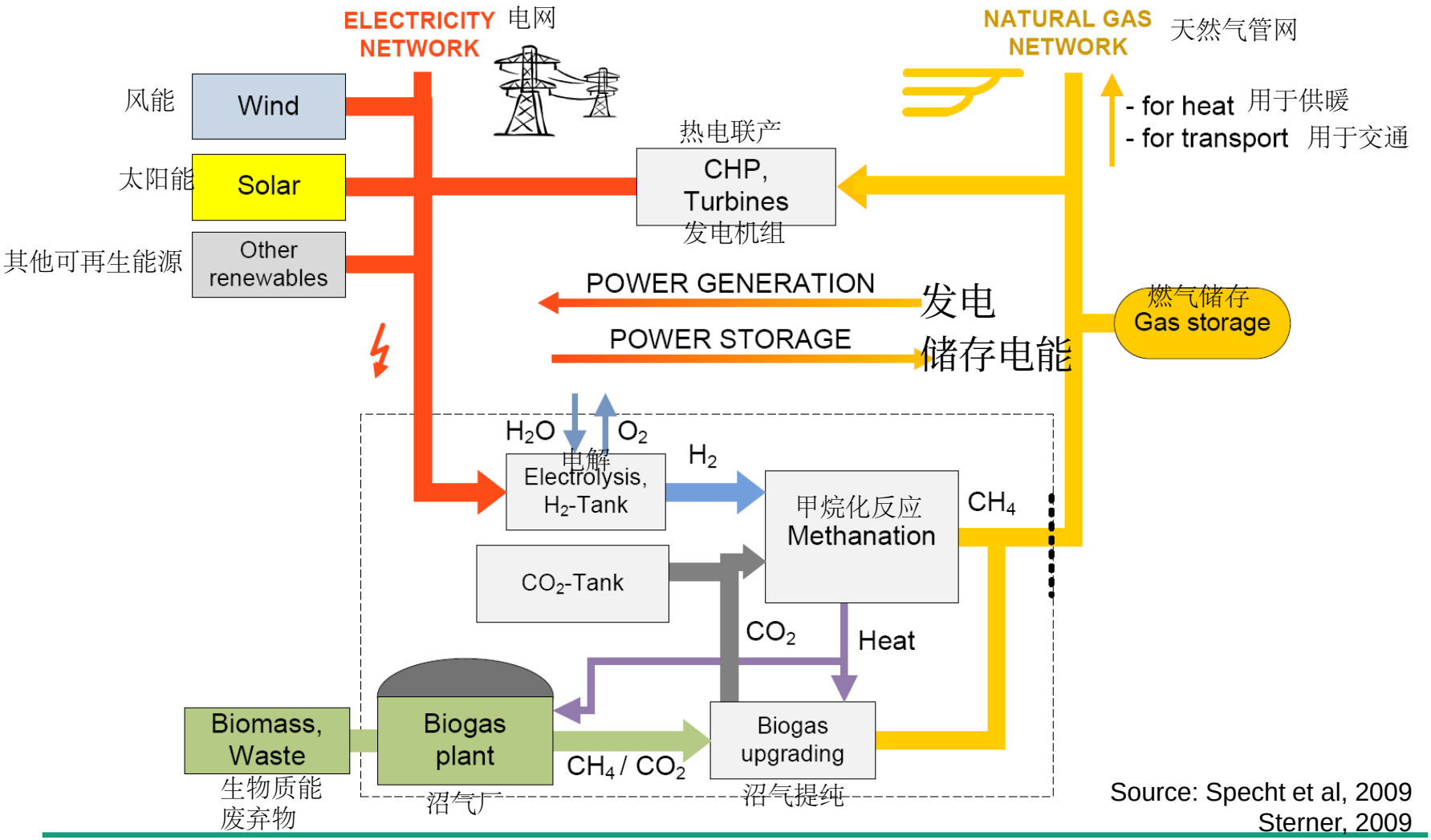
Biogas upgrading as source of CO_2 for methanation



Source: Specht et al, 2009
Sterner, 2009

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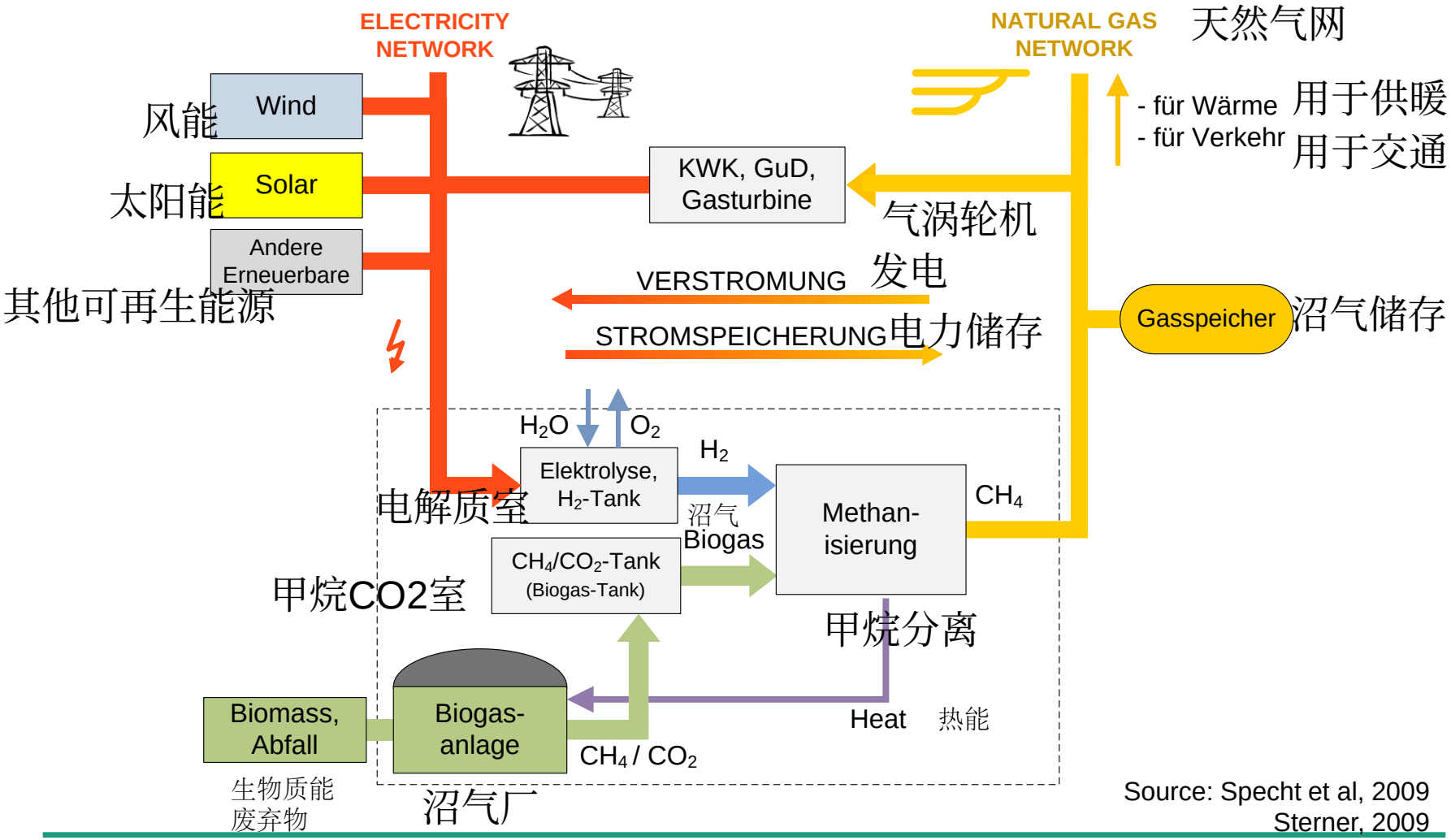
Direct methanation of biogas



Source: Specht et al, 2009
Sterner, 2009

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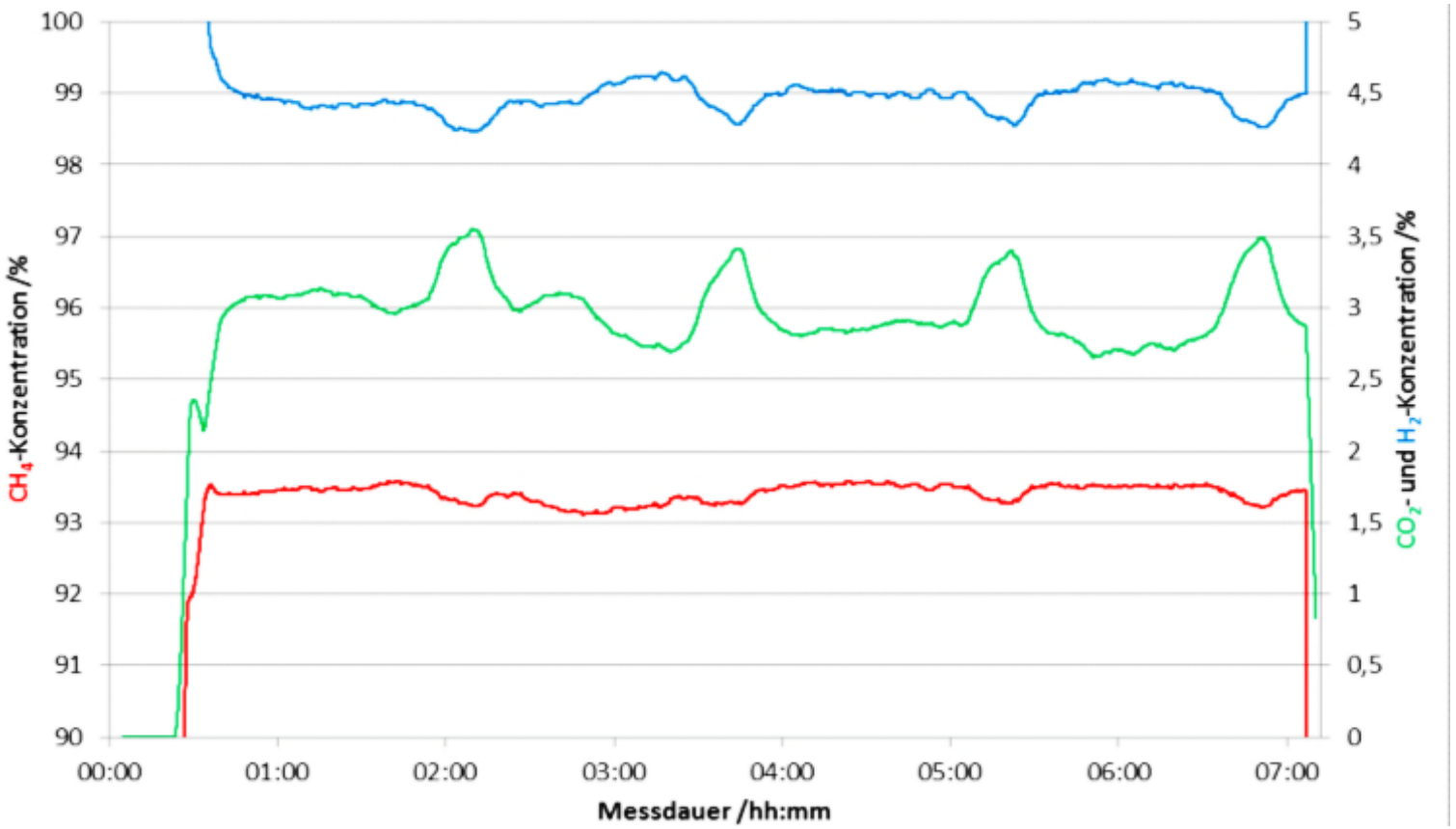
Extract of measurements 测量

Course of the product gas composition at the outlet of the PtG-plant

PtG沼气厂排气口气体成分曲线



- After the start up phase a steady methane content 启动后逐步稳定的甲烷含量> 93 Vol%
- Other components其他成分: 3% CO_2 and ca. 4,5 % H_2
- characterisitcal measurement for the entire operating period整个工作周期特性测量

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Future outlook 展望

- Development of digestion technologies for the treatment of lignin rich material.

-> This would increase the regional biogas potential!
发展发酵技术，以便利用含木质素比较丰富的原料，增加沼气发展的潜力。

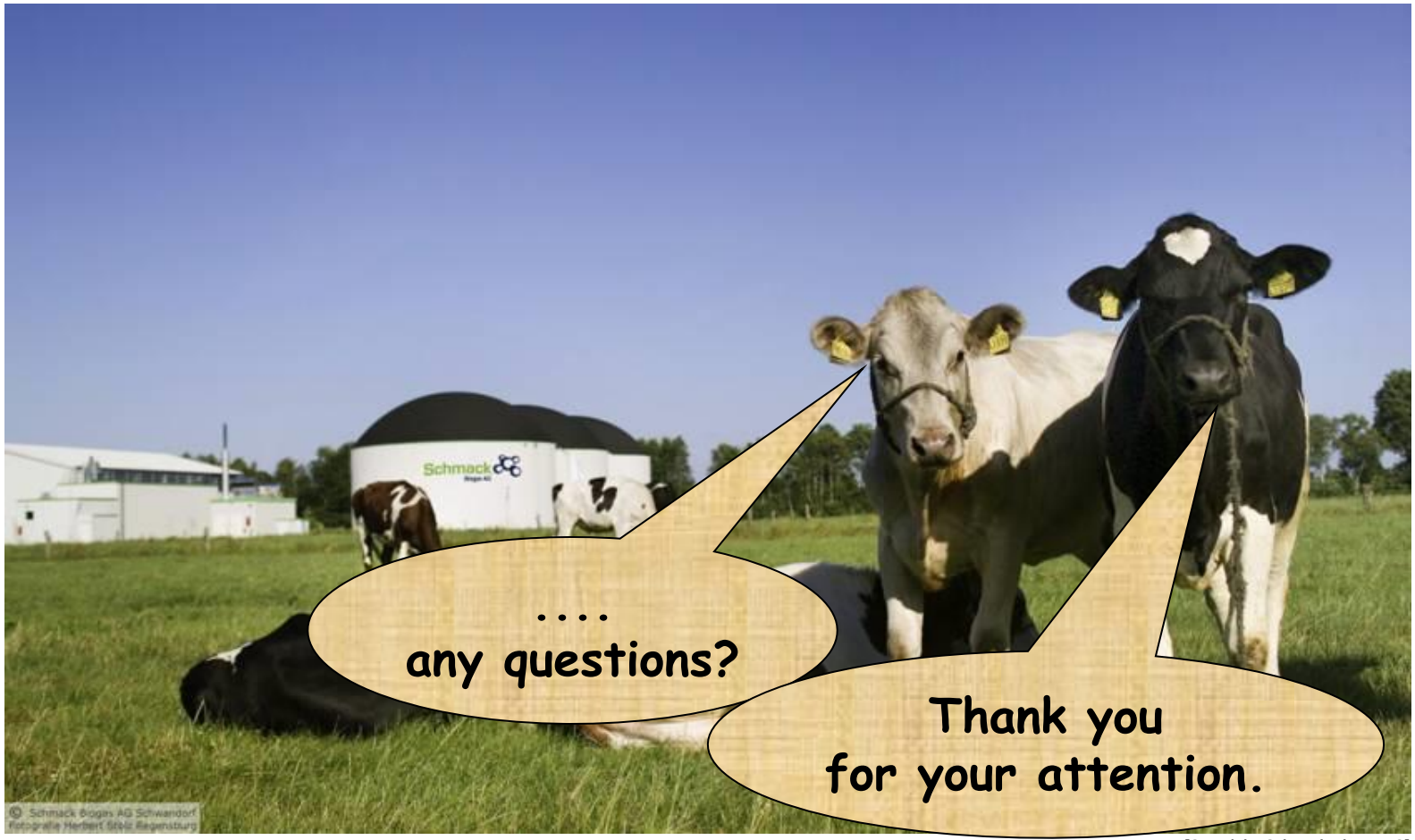
- Development of new biogas plant concepts for flexible biogas production.

-> Necessary biogas storage capacities can be reduced!
运用沼气发电新理念，减少沼气储存设施的投入。

- Biogas plants as back-up units in island systems.

-> Since they are dispatchable power generation units.
沼气发电设施用于岛屿的电力供给，因为他们是可控制的电力生产单元。

The biogas potential worldwide from organic waste materials remained unexploited. Biogas as a source of energy from waste can play a main role, since biomass and biogas can be stored and energy can be generated on demand, in future renewable energy supply systems.
从有机废物中提取的沼气蕴含着巨大潜力。沼气不仅是变废为宝，其便于储存且可按需生产的特性，将使其在未来可再生能源供电系统中发挥重要作用。



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