German Biogas Association
Association Allemande du Biogaz
Asociación Alemana de Biogás

Fachverband Biogas e.V.

Safety aspects of biogas plants

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General Manager

Outline

- **Biogas in Germany**
- Hazards on Biogas plants
- Safety requirements and recommendations
- Lessons learnt

German Biogas Association

over 400 honorary experts

Steering Committee

7 members, elected for a 4-year-period

Board of Trustees

Elected honorary spokesmen of regional groups, working groups and advisory boards

Advisory Boards, Working Groups

Advisory boards of plant operators, companies, the legal profession, funders; Working groups for the areas permissions, safety, feeding-in of biogas, environment, heat, waste and fertiliser law

Headquarters in Freising

27 employees, organised in 10 departments

Berlin Office

7 employees

Regional offices (North, South, East, West and Editorial Office Biogas Journal

6 employees

23 Regional groups in Germany

Operators of biogas plants

Providers of feedstock

Research Institutions

4,800 Members

Interested private individuals

Public authorities

Lawyers

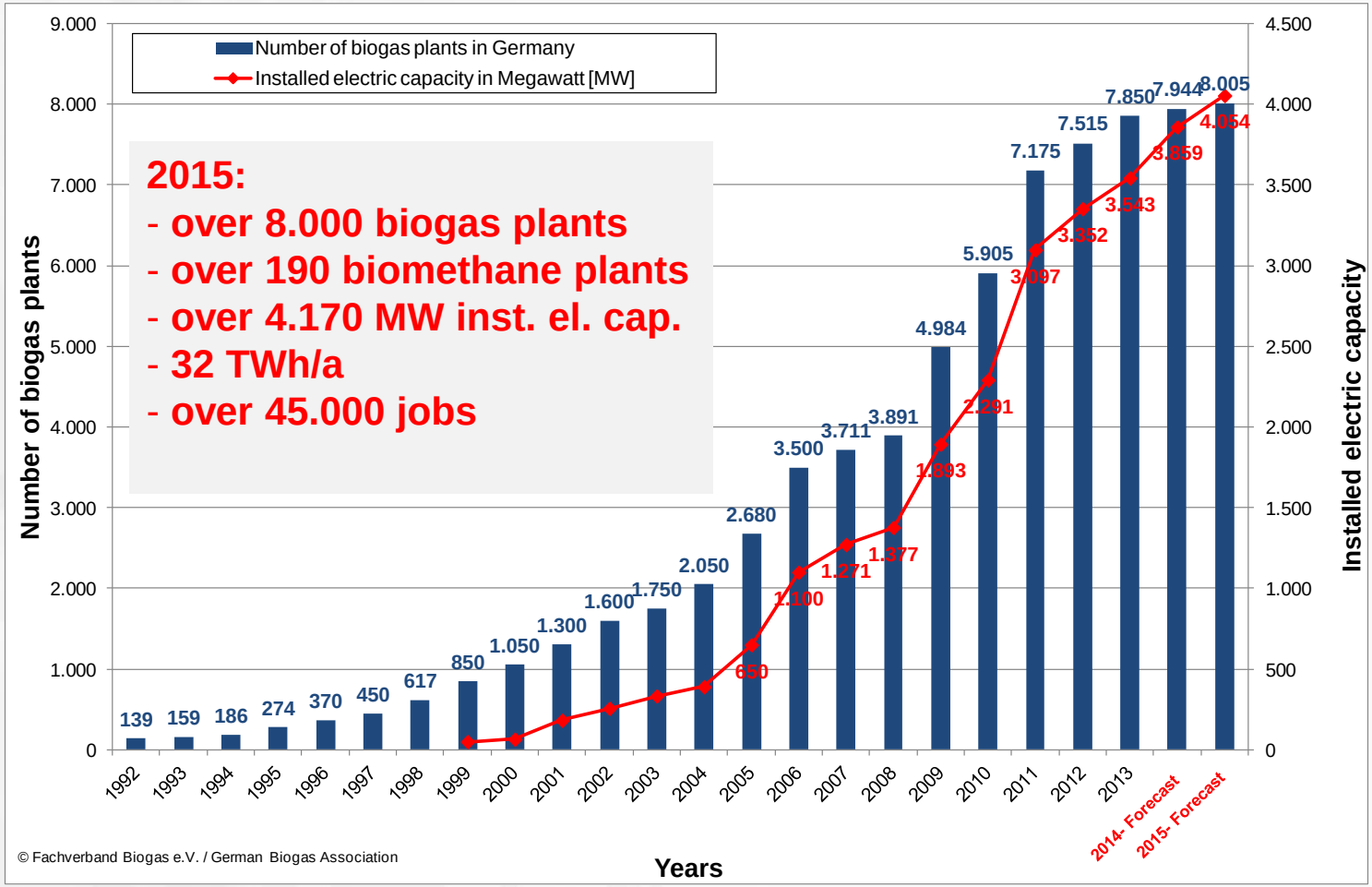
Companies and manufacturers

Corporate finance

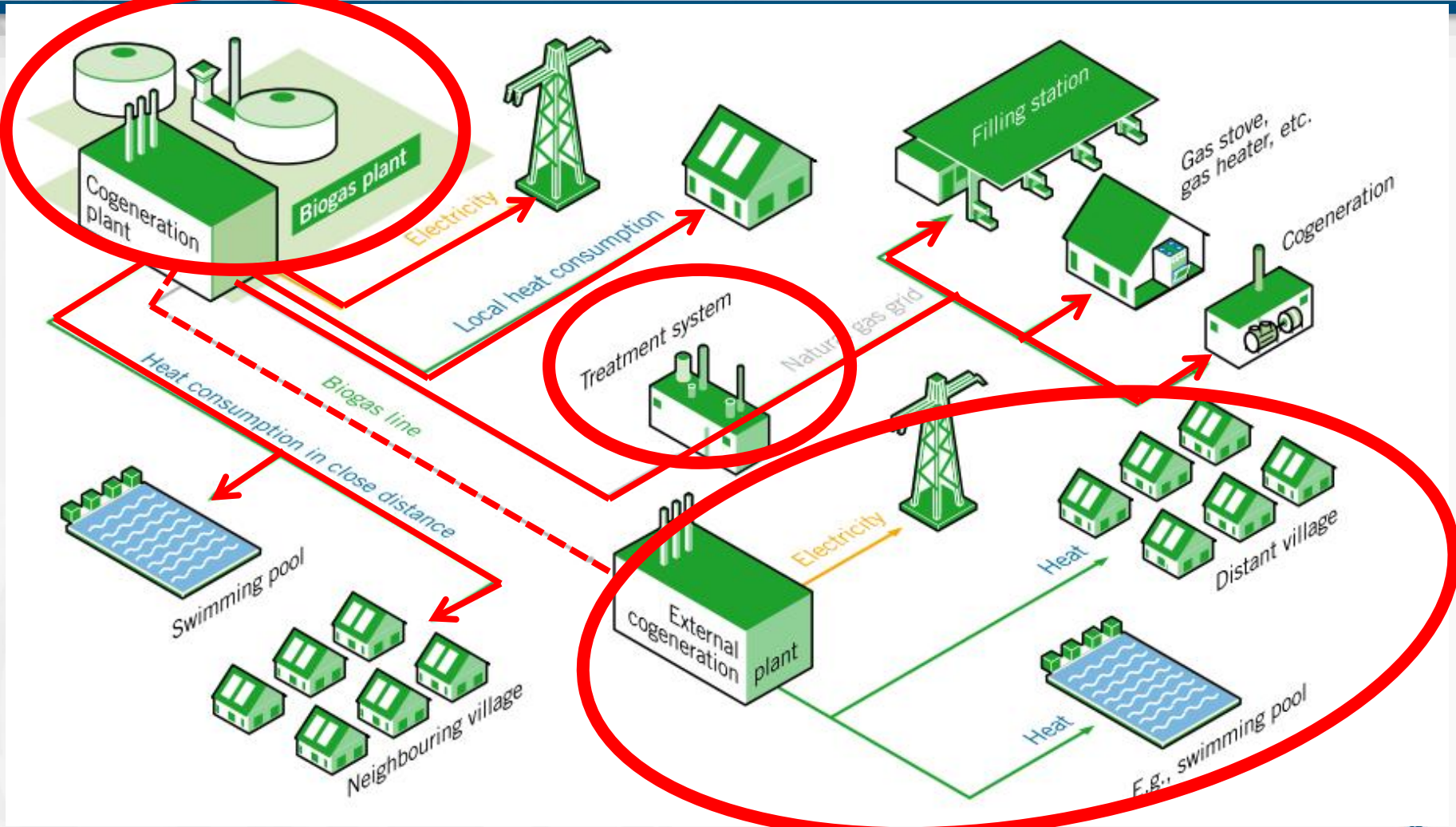
Planners, advisers, laboratories

Member of the European Biogas Association (EBA)

Number of biogas plants in Germany



Fields of Application for Biogas



Outline

- Biogas in Germany
- **Hazards on Biogas plants**
- Safety requirements and recommendations
- Lessons learnt

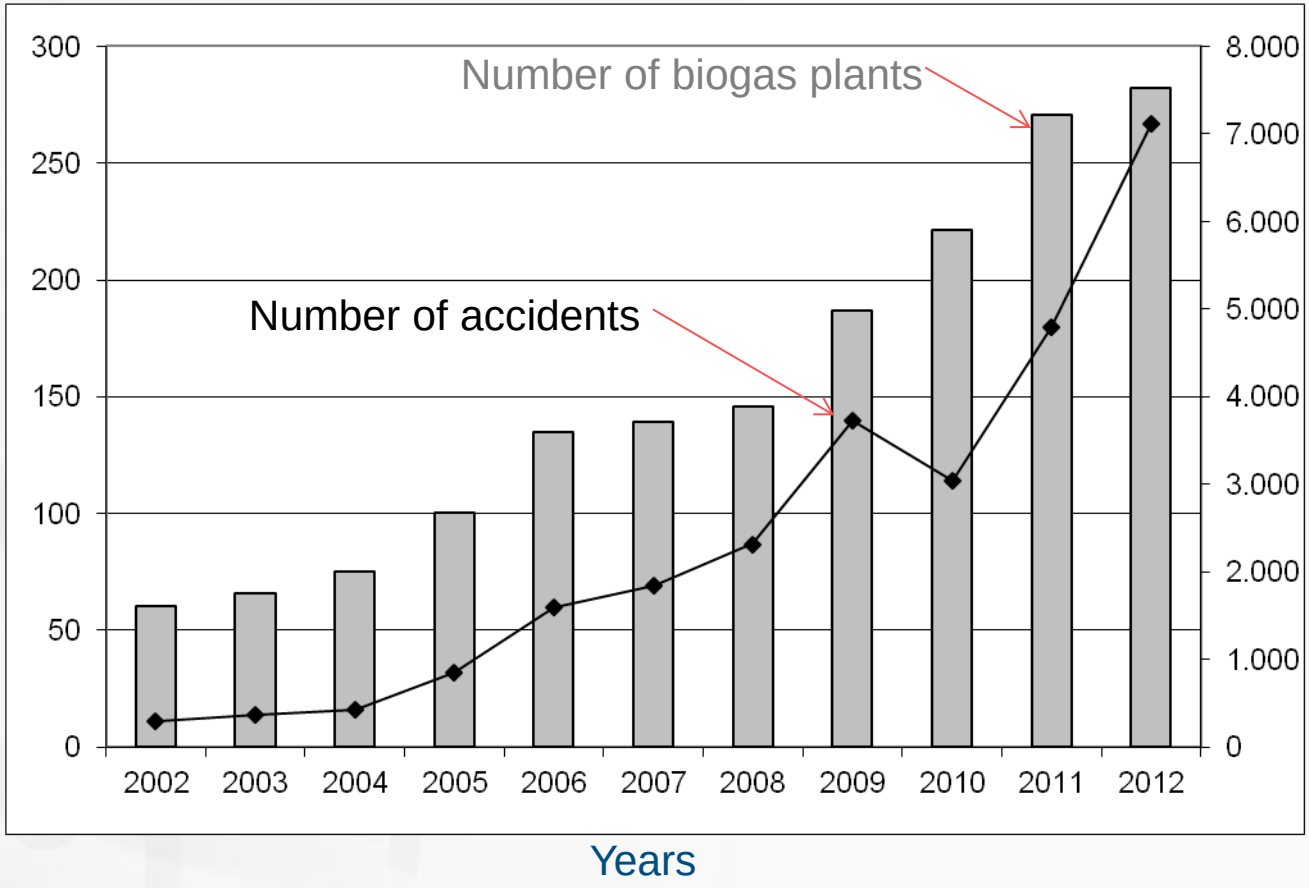
Hazards on biogas plants

Fundamental distinction of hazards:

- **Health hazards**

- **Environmental hazards**

Accidents with injured people on biogas plants



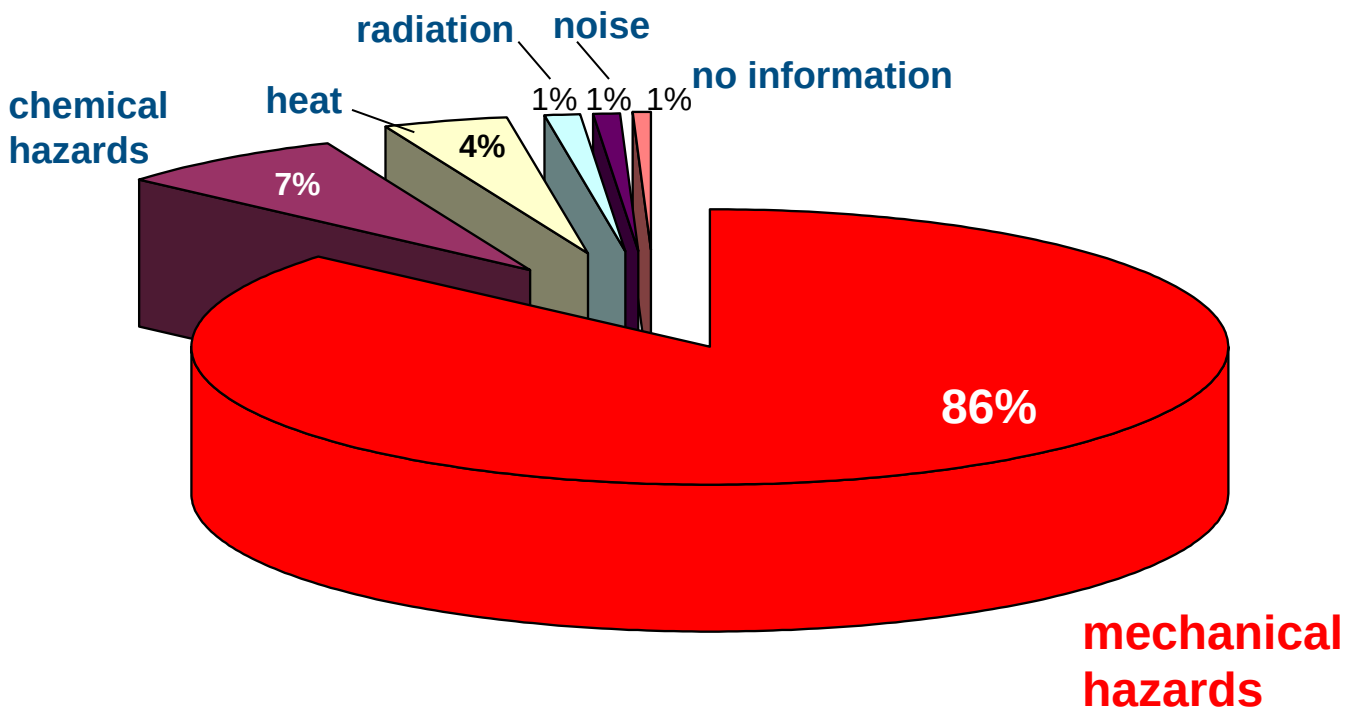
Accidents with injured people

Number of biogas plants in Germany

Source: SVLFG = German Agricultural Occupational Health and Safety Agency

Accidents on biogas plants

Proportion of accidents according to the hazards



Source: SVLFG = German Agricultural Occupational Health and Safety Agency

Health hazards on biogas plants

1. **Hazardous substances:** e.g. infections, sensitizing or toxic effects, viruses, bacteria, acids, trace elements, chemicals ...
2. **Electrical hazards:** e.g. improper use of electric components, damaged electric cable
3. **Mechanical hazards:** e.g. moving parts of machinery, dangerous surfaces…
4. **Crash or falling down:** e.g. into pits, tanks or from buildings and ladders …
5. **Fire hazards:** e.g. hot surfaces, fire
6. **Heat, noise:** e.g. CHP, ...
7. **Gas hazards:** e.g. explosion, suffocation, intoxication…

Mechanical hazards

Health hazards on biogas plants

Crash or falling down:

Falling:

- **into tanks,**
- **from construction area, sla**
  ladder.....

Components of biogas / biomethane

	Biogas	Biomethane (natural gas quality)
Methane (CH_4)	50-75 %	> 97 %
Carbon dioxide (CO_2)	25-45 %	< 3 %
Oxygen (O_2)	2-4 %	< 0.5 %
Hydrogen sulfide (H_2S)	< 0-6,000 ppm	< 5 ppm

ppm = parts per million = 10^{-6} = 0,000 001 %

Gas quality – rawbiogas/Biomethane

component	Symbol	Raw biogas	Biomethane	DVGW 260/262
Methane	CH_4	45 – 70 %	bis 100 %	gem. Brennwert
Hydrogen	H_2	< 200 ppm	< 500 ppm	< 5 %
Carbondioxid	CO_2	30 – 45 %	< 1 – 5 %	< 6 %
Nitrogen	N_2	0 – 2 %	0 – 2 %	k.A.
Oxygen	O_2	0 – 0,5 %	0 – 0,5 %	0,5 % / 3,0 %
Hydrogen-sulfide	H_2S	< 300 mg/Nm³	< 1 mg/Nm³	< 5 mg/Nm³
Sulfur	S	< 50 mg/Nm³	< 1 mg/Nm³	< 30 mg/Nm³
Siloxanes	S_iO_x	< 100 mg/m³	< 1 mg/m³	k.A.
Hydrocarbons	C_xH_y	< 100 ppm v	< 10 ppm v	=Tp Einspeisepkt.
Water	H_2O	gesättigt	< 1 mg/Nm³	=Tp Einspeisepkt
Calorie	$H_{S,N}$	5,5 – 7,5 kWh/Nm³	9 – 11 kWh/Nm³	8,4 – 13,1 kWh/Nm³
Wobbeindex	$W_{S,N}$	5,5 – 10 kWh/Nm³	11 – 15 kWh/Nm³	10,5 – 15,7 kWh/Nm³

Gas hazards – dangerous components of biogas

Carbon Dioxid (CO_2)

- CO_2: colourless, odorless, heavier than air
- MAC[1] 5000 ppm = 0,5 %; dangerous area above 8 Vol. %
- danger of suffocation

Methane (CH_4)

- methan ist colourless, odorless and lighter than air
- danger of suffocation
- **explosive range 4,4 % - 16,5 %**

Oxygen (O_2)

- **O_2-concentration below 18 Vol.-% is dangerous**

[1] maximum allowable concentration

Gas hazards – dangerous components of biogas

Ammonia (NH_3)

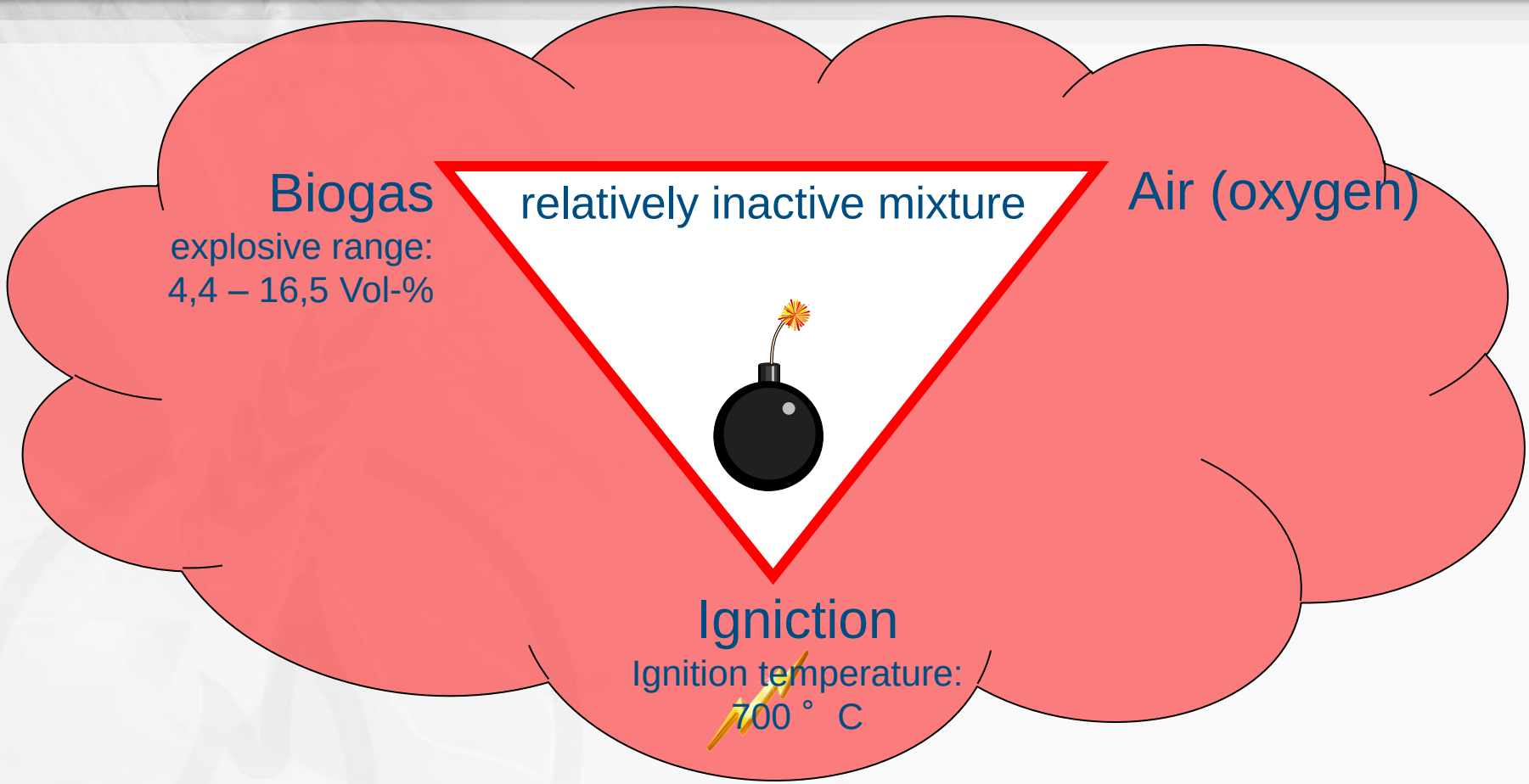
- ammonia is colourless, pungent smelling and lighter than air
- danger of fire 15 % - 30 %
- MAC[1] 20 ppm = 0,002 %
- 30 - 40 ppm = irritation of mucous membranes, respiratory tract and eyes
- **1000 ppm = 0,1 % = difficulty in breathing, unconsciousness**

Hydrogen Sulfide (H_2S) :

- H_2S is colourless, smelling like rotten eggs
- heavier than air, strong blood and nerve poison
- MAC[1] 10 ppm = 0,001 %
- 50 ppm 0,005 % = irritation of the respiratory tract
- **200 ppm 0,02 % = paralyzed sense of smell**
- **700 ppm 0,07 % = respiratory arrest (death)**

[1] maximum allowable concentration

Explosion hazards – „Explosion Triangle“



Explosion and subsequent fire due to welding

- total loss of 80,000 €
- commissioning of the biogas plant
- no injured persons

Fire in a CHP-building

- fire in a CHP-building
- no injured persons

Explosion / deflagration due to welding

- digester-roof with 20 tons was whirled through the air
- no injured persons

pictures:
Freiw. Feuerwehr Markt Mering

Fire in a gas storage

Frozen gas pipe:

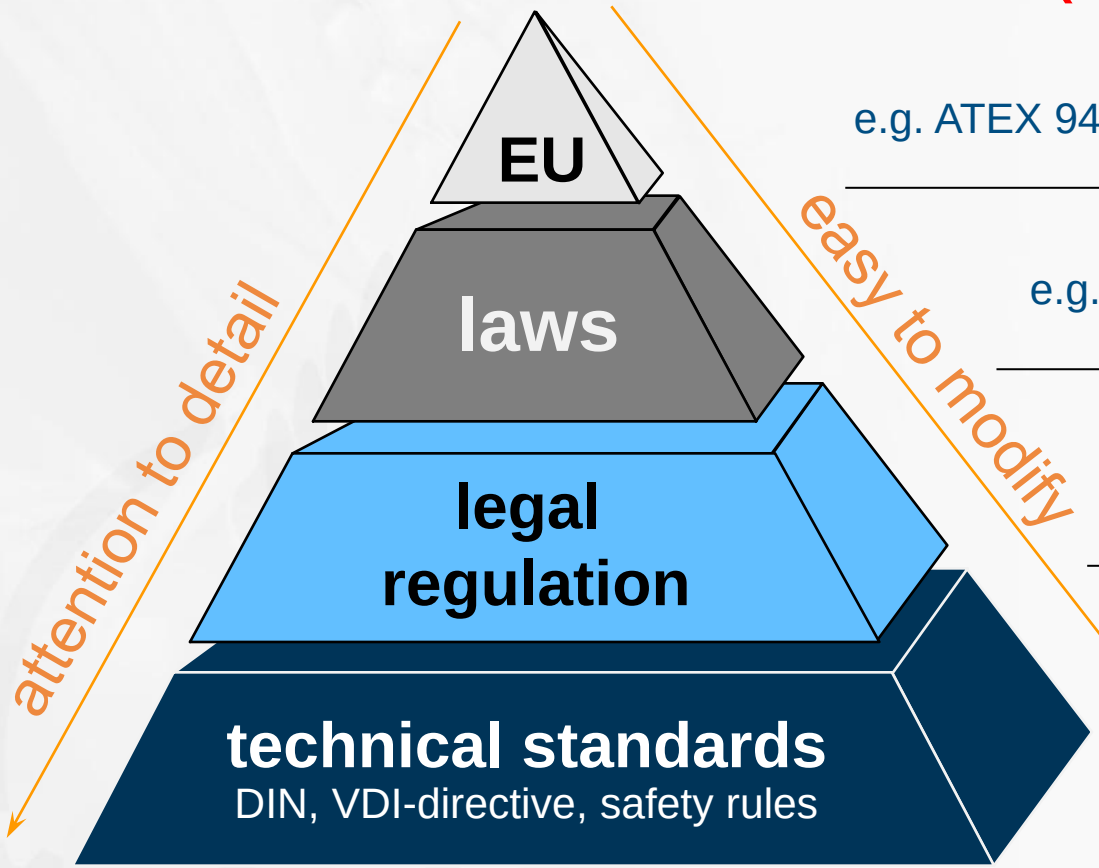
plant operator was trying to thaw the gas line with a heat gun!!!

Outline

- Biogas in Germany
- Hazards on Biogas plants
- **Overview of main safety requirements in Germany**
- Lessons learnt

„Law-pyramid“ (in Germany)

ISO TC 255 (Standardization of biogas)



e.g. ATEX 94/9/EG, ATEX 1999/92/EG, Seveso III

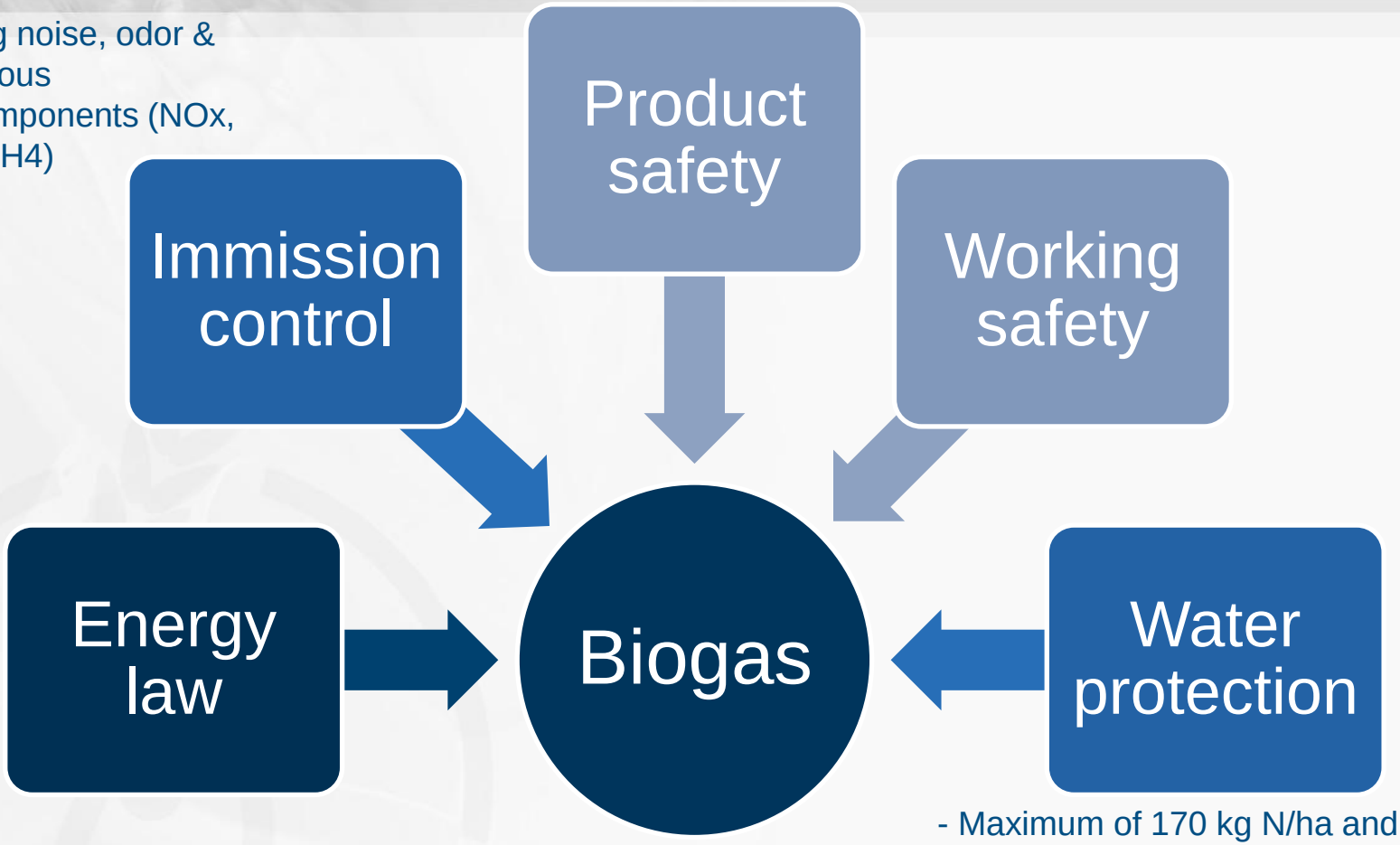
e.g. Occupational Safety and Health Act

e.g. Ordinance on Industrial Safety

e.g. DIN, DVGW G-1030; ….

Main areas of biogas safety

Limiting noise, odor & dangerous gas components (NOx, SOx, CH4)



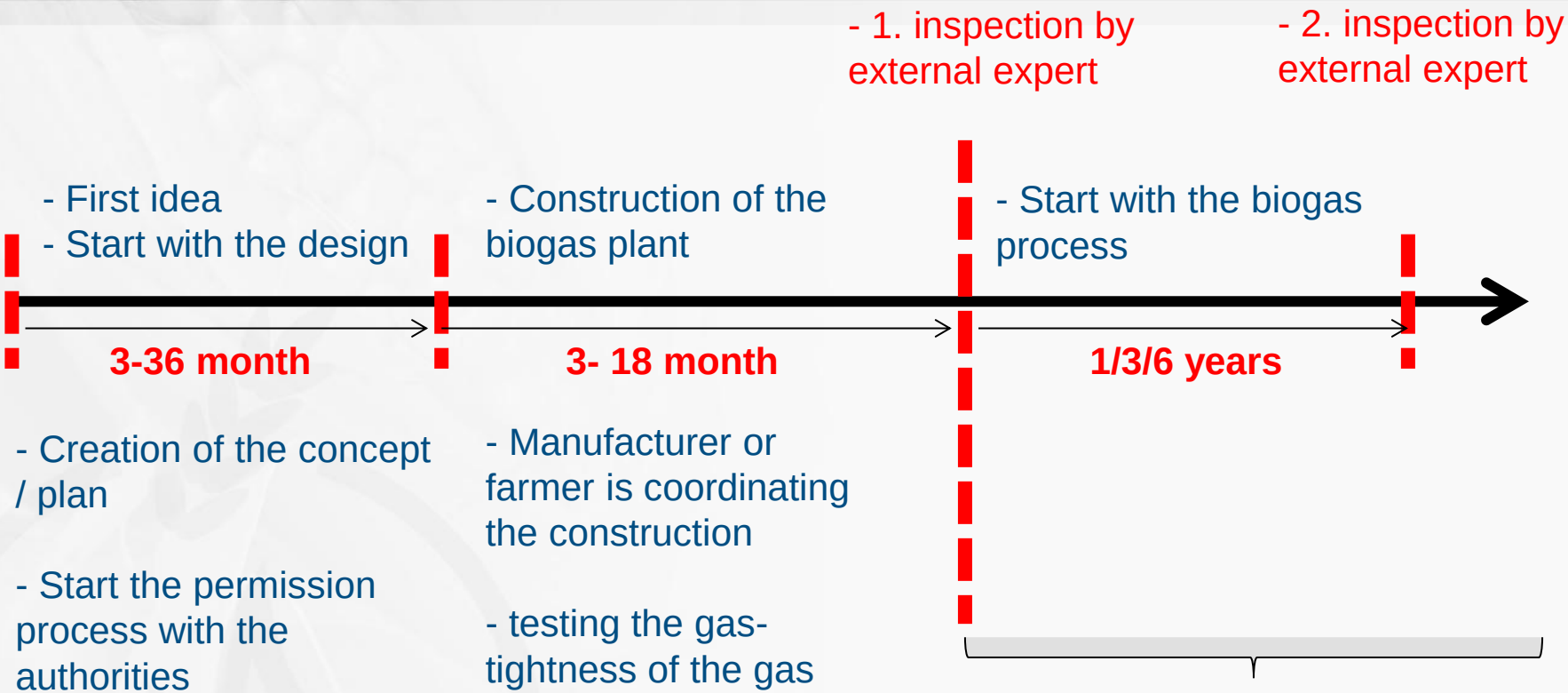
- Maximum of 170 kg N/ha and year
- Requirement of a rampart
- inspections of watertightness

The rampart makes the difference…

Ministeries involved in the biogas plant and work safety in Germany

1.	**Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety**	**Federal Ministry of Labour and Social Affairs**	**Federal Ministry for Economic Affairs and Energy**	**Federal Ministry of Food and Agriculture**
2.	plant safety; environ-mentalism	occupational safety	energy supply	
3.	UBA; KAS; LAI; AISV	BG´S; GAA; LASI; AGS,ABS	Energie-aufsicht; z.B. DVGW	
4.	-Immission control - Water protection - Waste act - Technical Instructions on Air Quality Control / Technical Instructions on Noise Protection: BImSchG; WHG, KreislaufWG, KrWAbfG/AbfKlärV EEWärmeG; UVPG DÜMV; TierNebG; StörfallV	Ordinance on Industrial Safety and Health; German Occupational Safety and Health Act; Ordinance on Hazardous Substances, Ordinance on Biological Agents; Explosion Protection (94/9/EG, 99/92/EG, BGR 104, 11.PSGV) Machinery Directive 06/42/EG; Biogas Safety Rules	Energy Economy Law (EnWG); Gas Network Access Ordinance (GasNZV); Technical Standards of the DVGW (German Technical and Scientific Association for Gas and Water): G 260, G262, VP265, G462, G415, G1030, G469	- Energy crops/ sustainabilty, - Regional value - agricultural laws - greenhouse-gas reduction - …..

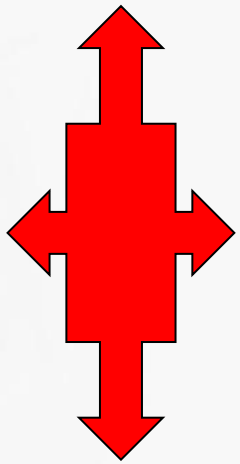
Important stages for the safety on biogas plants



Responsibilities for manufacturers and plant operators

Responsibilities for manufacturers:

- **European Machinery directive (2006/42/EG) = German Product Safety Act**
- **Operating instructions and risk analysis for the product (biogas plant or components)**
- **Declaration of incorporation (e.g. ATEX / Ex-Zone) / installation instructions**
- **Declaration of conformity (CE-mark)**
- **Maintenance instructions**



Responsibilities for plant operators:

- Responsible for the safety on the biogas plant (documentation of the supplier…)
- Create a risk assessment
- Prepare a explosion protection document as part of the risk assessment
- Safety instruction
- Testing of the equipment
- Maintenance
- Create a safety manual for:
  - hazardous materials,
  - machinery etc.
- Create a work instruction for:
  - Cleaning the digester
  - entering pits etc.

The T-O-P principle is the base for safety on biogas plants

priority….

1.	2.	3.
Technical safety measures	**Organizational safety measures**	**Personal protective measures**
▪ substitution of dangerous machinery, hazardous substances ▪ crash protection for the feeder, ▪ work place, ▪ work equipment ▪ …	▪ work organization ▪ procedures ▪ working hours ▪ standby ▪ visual inspection of power tools before each use ▪ ...	▪ qualification ▪ motivation ▪ safety instructions ▪ safety training ▪ personal safety equipment ▪ …

As a matter of principle, in determining protective measures, technical protective measures are to be preferred, for example, the filling of closed systems compared to organizational protective measures, such as, the time separation between human presence and filling procedures. Personal safety measures, such as wearing respiratory equipment, come into use only when other protective measures have been exhausted.

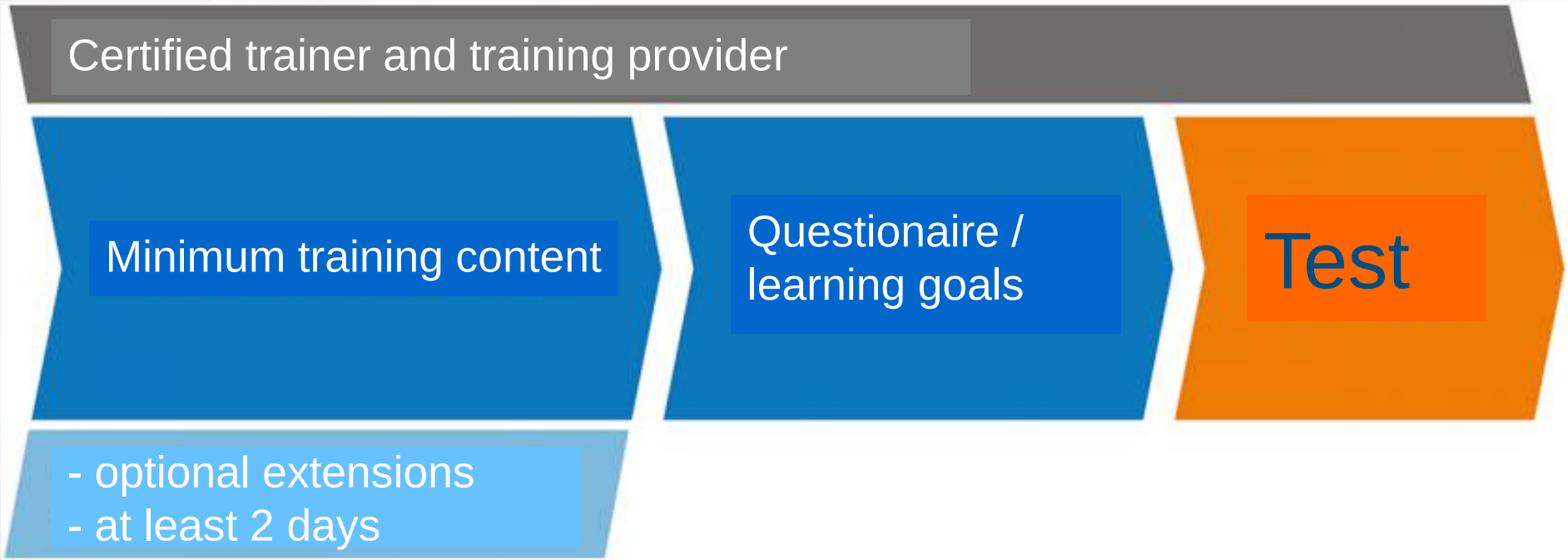
Organizational safety measures - operating instructions and instruction manuals

- The manufacturers introduce products into the market with operating instructions.
- The operating instructions from the component manufacturers must be collected and safely stored from the plant operator.
- For the operation of different resources, equipment, etc., the operator has to provide an instruction manual which includes content such as the operating instructions, as well as information about hazards that result from the installation conditions.
- In addition, special operating states such as startup and shutdown of the system need a specific instruction.
- The employees must be instructed regularly about safe operation, e.g., using the instruction manual.

Organizational safety measures - Biogas Training Network

- Established in 2013
- Founder German Biogas Association
- Training obligation for plant operator (at least 2)
- Implementation of the requirements by the network

Concept – Training Network Biogas



Organizational safety measures - risk assessment

- **The basis for the development of a hazard assessment is to protect and to reduce the exposure to risk and hazards of employees.**

- **The employer must determine, evaluate, and minimize the hazards and must consider the acquired knowledge during:**

  - design and selection of work tools,
  - as well as the design of workplaces, work and production processes, work procedures,
  - and interactions of all of the above .

Organizational safety measures - risk assessment

When is a risk assessment necessary?

- as a first analysis **before start up**
- at regular intervals, in particular:
  - changes to regulations
  - changes in the state of the art
- if facilities are substantially **expanded or rebuilt**,
- in **significant changes** in the *organization* of work,
- after **accidents**, near-accident and diseases.

Organizational safety measures - explosion Protection Document

- **Consequently, all biogas systems are subject to inspection obligations according to § § 15 and 16 of the BetrSichV, regardless of the employment activity or occupation of the workers. => Inspection before the first production of biogas (§ 15) and at latest after 1/3/6 years (§ 16)*.**

- **This implies, in principle, that all biogas plants in Germany need an Explosion Protection Document!**

- **The operator bears the responsibility to ensure that changes to the system are also updated in the documentation, such as, the circuit diagrams, the operating instructions, the Explosion Protection Document, etc.**

*Testing for Ex-safety every 6 years; Additional testing of the equipment, protective systems and devices according to ATEX every 3 years; Additional testing of ventilation systems, gas warning equipment, Inertingsystems every year

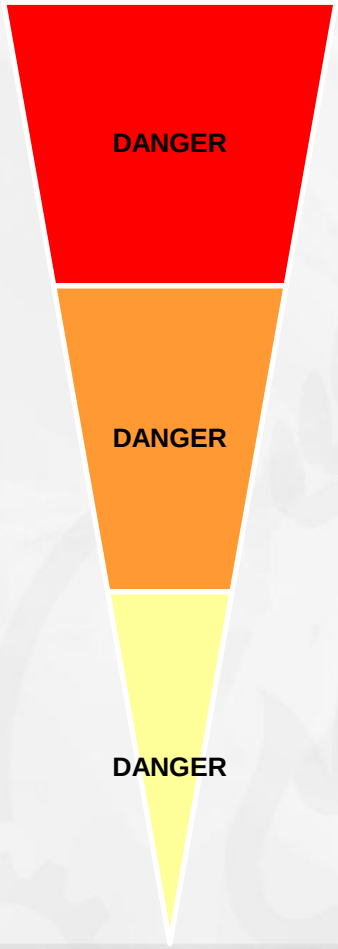
Organizational safety measures - explosion hazards

- Explosion hazards must be determined and assessed. In particular, it must be determined where potentially explosive atmospheres can occur. Potentially explosive areas are to be classified into Ex-zones = Ex-Zone-Document is necessary for all biogas plants!

- Totentially explosive areas must be identified at their entrances by appropriate signage with black lettering on a yellow background.

- In areas where explosive gas/air mixtures can occur and which are classified as Ex-Zone only special and official accepted devices can be used.

Organizational safety measures - explosion hazards



Ex-Zones

Zone 0

explosive atmosphere **is present continuously, for long periods or frequently. E.g.: overflow protection,** Zone 0 in the pipe and in the area near the overflow

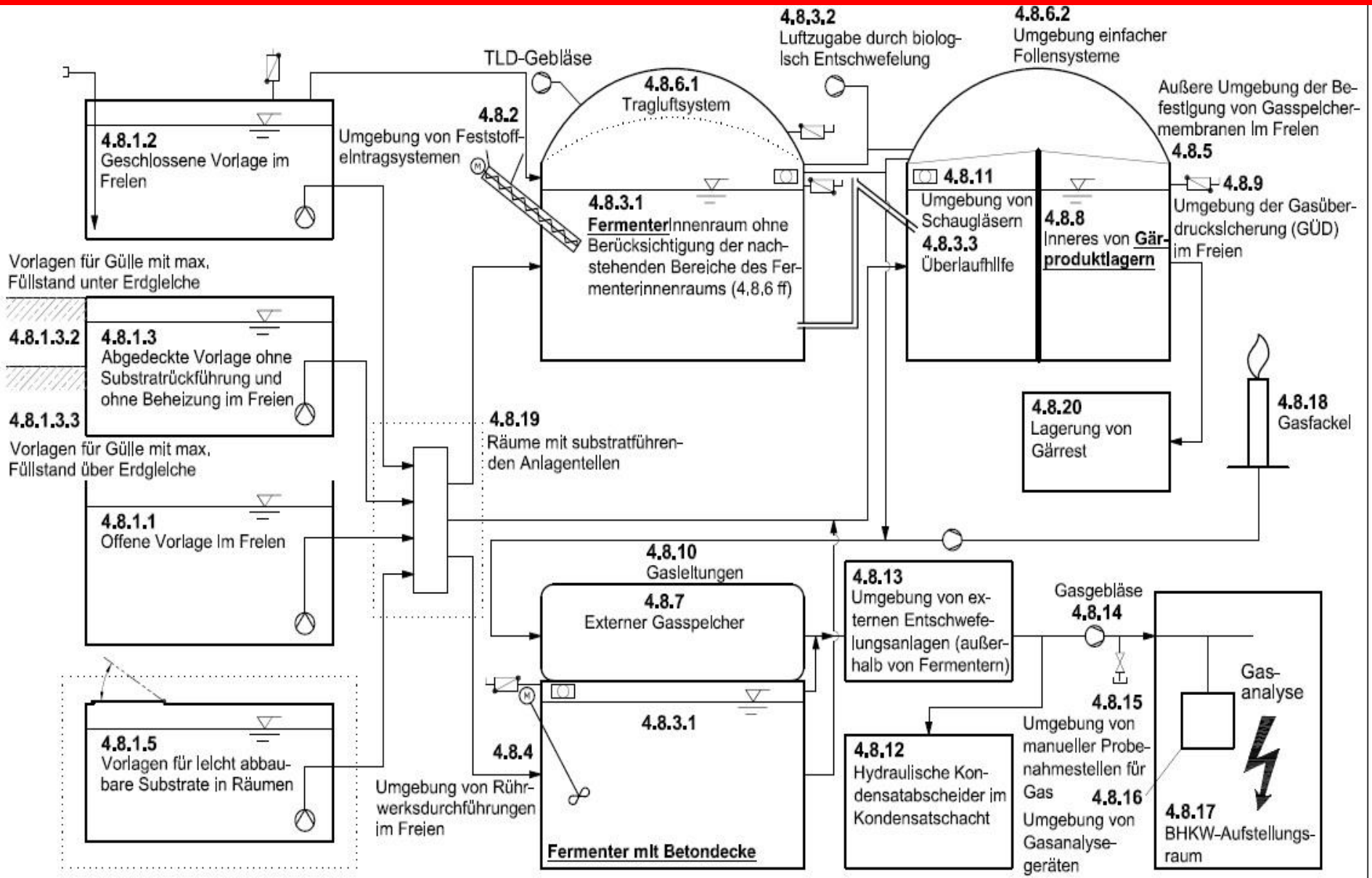
Zone 1 (radius 1 m)

explosive atmosphere **is likely to occur occasionally, in normal operation conditions. E.g. immediate vicinity of manholes into the gas storage tank or on the gas-retaining side of the fermentation tank, and in the vicinity of blow-off systems, pressure relief valves**

Zone 2 (radius 1-3 m)

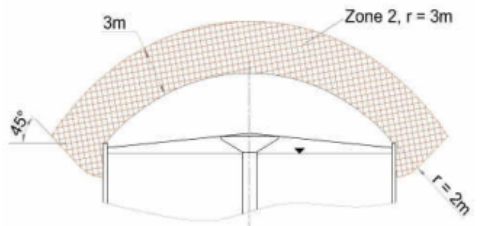
explosive atmosphere **is not likely to occur in normal operation conditions, but if it does occur, it will be for a short period only. E.g. manholes and the interior of the digester, in the vicinity of aeration and ventilation openings of gas storages**

Collection of examples (Ex-Zones on biogas plants) from the employers liability insurance association (BGR 104 – published May 2014)



Example collection of Ex-Zones

- **The plant operator have to use this collection,**
- **But they can differ when the safety is guranteed by other measures.**

Nr,	Beispiel	Merkmale/Bemerkungen/ Voraussetzungen/Hinweise	Schutzmaßnahmen nach TRBS Teil 2	Festlegung der Zonen (Zündquellenvermeidung TRBS 2152 Teil 3)	Schutzmaßnahmen nach TRBS 2152 Teil 4
(Sp.1)	(Sp.2)	(Sp.3)	(Sp. 4)	(Sp. 5)	(Sp. 6)
		kungen wird zeitlich überwiegendes Aufkonzentrieren verhindert.			
4.8.6.2	Single-layer gasstorage	a) Die technische Dichtheit wird erstmalig und wiederkehrend, z.B. Ortung mit Gaskamera und Kontrolle mit schaumbildenden Mitteln oder geeignetem Gasspürgerät, überwacht.	2.4.3.3 2.4.3.5	Keine Zone	Keine
		b) wie a), jedoch ohne wiederkehrende Kontrolle	2.4.3.3	Zone 2: 3m um Folie und 2m nach unten mit 45° siehe Bild, … 	Keine

explosion protection - ATEX directive

- in Ex-Zone 0: devices of category 1
- in Ex-Zone 1: devices of category 1 or 2
- in Ex-Zone 2: devices of category 1, 2 or 3

here: 2 G

Integrated explosion protection

primary Ex-protection

- prevent formation of explosible atmospheres
- substition, inert atmosphere, concentration-limitation, intensive ventilation…

secondary Ex-protection

- preventing the ignition
- Ex-Zoning, preventing sources of ignition, organizational measures…

tertiary Ex-protection

- reduction of explosion consequences
- Personal Safety Equipment (PSA), explosion suppression, explosion pressure resistance.
- => evacuation or enough distance

Explosion / deflagration due to gasleakage

- 1 seriously injured
- approximately 400,000 € property damage

Organizational safety measures - requirement to label

W 21 explosive atmosphere

P 02 fire , smoking etc. are prohibited

W 03 poisonous substances warning sign

P 06 No Admittance Without Authorization

M 03 earprotection

M 09 use safety harness

M 04 use respiratory protection

W 16 biohazard warning sign

W 01 warning flammable substances

Safety needs for small and medium biogas plants - 1

- Every biogas plant needs a emergency gasflare
- Connection points in gas lines for non-stationary equipment, such as, mobile gas flares, must be equipped with shutoff valves.
- Fire Protection: extinguisher according to the fire load
- Digester systems must be equipped at all times with effective safety installations that prevent an inadmissible change of the internal pressure (under- over pressure protection system).

- In the digester and post digester containers, it must be guaranteed that the fill levels are not exceeded

Safety needs for small and medium biogas plants - 2

- Fill openings, e.g., solids dosing feeders, should be secured so other objects do not fall.

- Gas storage systems must meet the requirements for being gas tight and resistant to pressure, media, UV, temperature, and weather. For the selection of materials, especially for plastic membranes, the following requirements must be met:
  - tensile strength minimum 500 N/5 cm or
  - gas permeability with respect to methane < 1000 cm^3/m^2 x d x bar
  - temperature resistance for the use case (mesophilic, thermophilic digestion process)
  - gas storage must be checked for tightness before being in operation
  - stable to wind/strom and snow

Safety needs for small and medium biogas plants - 3

Ventilation and exhausting of gas storage rooms

Installation rooms for the gas storage must have effective ventilation (cross ventilation). Diagonal ventilation should be attempted. The supply air opening should be placed in the area of the floor, and the exhaust air opening should be placed below the ceiling.

The supply air and exhaust air opening must each have the following minimum cross sections:

Gas Storage Volume	Cross Section for the ventilation
up to 100 m³	700 cm²
up to 200 m³	1,000 cm²
above 200 m³	2,000 cm²

Safety needs for small and medium biogas plants - 4

Safety distances

To avoid mutual impact in the case of damage, preventing flashover to adjacent systems in the case of fire, and for the protection of the gas storage from damage, such as heating as a consequence of fire, safety distances of at least 6 m must be provided in the horizontal direction between the gas storage and adjacent systems, equipment, or buildings (with a height lower than 7.5 m) not belonging to the biogas system, or to pathways or transport paths. For a building height > 7.5 m (gas storage or building not belonging to the system), the following applies:

0.4 x H1 + 3m

The safety distance can be reduced through sufficient earth covering or sufficiently dimensioned safety wall or fire protection insulation (e.g., firewall).

Safety needs for small and medium biogas plants - 5

System control and process control engineering

Control systems with safety functions must be fail-safe if they are not secured by a redundant system, e.g., a mechanical overpressure protection against over-pressure, or e.g., an overflow spillway.

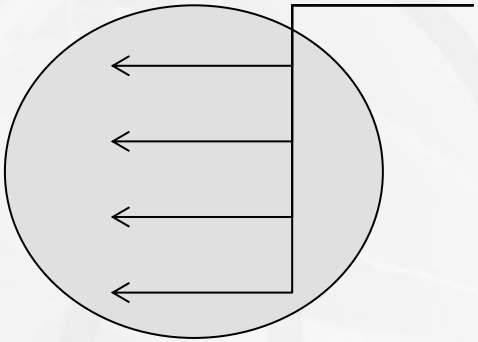
Examples:

- Closing the automatic gas rapid shutoff device at the CHP unit.
- Switching off the corresponding gas compressor.
- Switching off all parts that are not EX-protected in gas-pressurized machine rooms (CHP unit, gas cleaning, etc.).

Safety needs for small and medium biogas plants - 6

Gas processing - desulphurization by air injection in the gas room over the digester

The air-dosing pump must be adjusted so that it delivers at most a volume flow of 6 per cent of the biogas generated in the same time period. The air dosing must be dimensioned so that so that even in the case of a failure of the air flow, no significantly higher quantity of air can be supplied. In the supply to the gas room, a non-return protection (non-return valve) is required, as close to the gas room as possible.



Safety needs for small and medium biogas plants - 7

Biogas pipe - design and material

Gas-carrying lines must be designed according to the generally recognized rules of the technology. The correct production and impermeability must be proven, e.g., by manufacturer's certification.

Pipelines must be resistant to its contents and to corrosion. Pipes that are resistant to biogas are composed of, for example, steel, stainless steel, polyethylene (PE-HD) and PVC-U.

Tip – PVC-U pipes: PVC is not UV-resistant and has a low resistance to impact. For PVC use, correct storage and processing must be observed.

Flashback arrestors must be installed in front of gas-consuming equipment, such as boilers and CHP units, as close to the equipment as possible, corresponding to the instructions of the manufacturer.

Safety needs for small and medium biogas plants - 8

Ventilation of CHP-rooms
Installation rooms must have supply air and exhaust air openings that cannot be closed.

Every biogas plant needs gas-warning device in the CHP-room
Sensing devices should be placed above, depending on the gas properties, in the proximity of possible release sources. The influences of the ventilation and its possibly different operating states must be considered in the placement.

Operating instructions must be written for the case of the alarm being triggered by the gas-warning device or interruptions of the gas-warning device.

Safety needs for small and medium biogas plants - 9

Cutoff CHP

It must be possible to shut off the combined heat and power unit at any time by using an illuminated switch located outside of the installation room. The switch must be labeled permanently and be easily visible with “Emergency Shut-off Switch for Combined Heat and Power Unit ” and must be accessible.

Cutoff for the gas supply

It must be possible to shut off the gas supply to the combined heating and power unit, in the open, outside of the installation room, as close to the CHP unit room as possible. The on and off position must be labeled. The same requirements apply also to electrically-operated shutoff valves.

Shutoff valves

Two shutoff valves must be installed in the gas line in front of each motor aggregate. The valves must automatically close when the motor stops.

Safety needs for small and medium biogas plants - 10

Condensate traps must be easily and safely controllable and operated. In case of. In the case of deeper pits a gas detector must be used, mabe in combination with blower.

Avoiding potential differences in the biogas plant (internal lightening protection)

Feedersystems in closed rooms: at least a fiveold air exchange is necessary

Necessary safety checks:

- leak testing of the biogas leading system: foam, gas detection systems
- corrosion inspection: digester, pipes, wood constructions…
- check of the safety devices: gas detection system in the CHP-room, under- over pressure protection system).

Recommended documentation: risk assessment, Ex-Zone protection document, check of the electric installations, operating instructions, alarm plan, firemen plan,…..

Personal safety equipment (PSE) for all employee

Outline

- Biogas in Germany
- Hazards on Biogas plants
- Safety requirements and recommendations
- **Lessons learnt**

Lessons learnt - 1

- Biogas plants are complex process plants with several hazards.
- The operating staff and the plant owner need professional skills and knowledge. Important is periodic retraining!!!
- Also well-qualified plant designers and manufacturers are required.
- The German biogas plant manufacturers collected over the past 20 years a lot of experience (experience = learn from mistakes!)
- Experienced designers and manufacturers of biogas installations are available. Ideally, they have diverse references.
- Important for a good legal framework is a good running Biogas-Association

Lessons learnt - 2

- Enhanced measures for the standardization of components and materials for biogas plants are in progress (we need definitions of a test-biogas)

- Currently in preparation: development of safety management systems

- Problem in Germany: we have a lot of responsible authorities and too many confusing rules (over 400)

- For the plant operator and the manufacturers, it is hard to be informed on the different regulations.

- Critical is the lack of enforcement of regulations.

Lessons learnt - 3

- Due to some minor defects, the authorities want to make more new regulations.

- Great danger of over-regulation and the disproportionate burden to the operators and manufacturers

- ***Keep it safe and simple!***

The German Biogas Association offers various leaflets and info-papers about safety topics: www.biogas.org

Gracias por la atención!

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