SIEMENS

Power Transmission
and Distribution

Obtaining Low SF_6 Emissions in Germany

4th International Conference on SF_6 and the Environment

Peter Glaubitz, Friedrich Ploeger / Siemens AG, Germany

San Antonio, Texas, USA, November 29th 2006

AGENDA

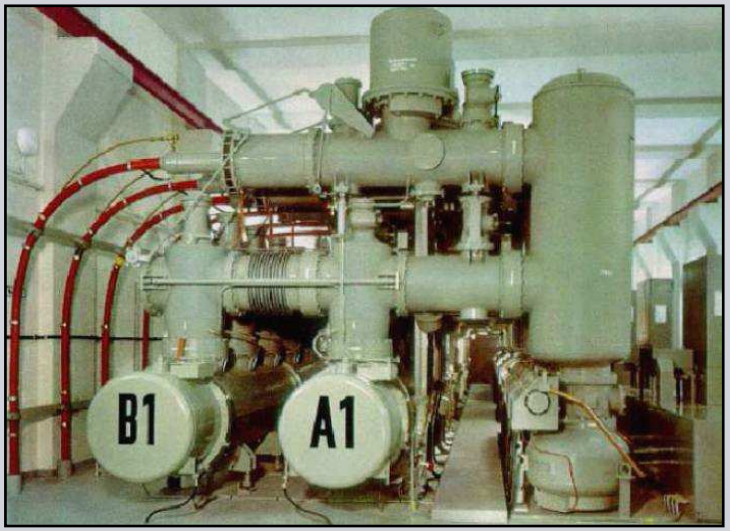
SIEMENS

1. Introduction
2. Recent studies
3. Implementation and results of the Voluntary Commitment and legislation
4. SF_6-Emissions: Field Experience (Utility, Manufacturer)
5. State-of-the-art-Equipment (High Voltage and Medium Voltage)
6. Optimized SF_6-handling equipment and processes
7. Current activities in industry standards
8. Conclusion

1. Introduction
History and Background

SIEMENS

SF_6 has been successfully used since mid **1960`s** by the German Electrical Industry in power equipment for **High Voltage** transmission and distribution of electricity and for **Medium Voltage** distribution since early **1980's** in gas insulated substations, ring main units, circuit breakers and instrument transformers.



Example
GIS 132 kV

2006

1968*

SF_6-electric power equipment represents state-of-the-art technology with respect to its technical features, its economics and safety.
In spite of extensive research no viable alternatives have been found.

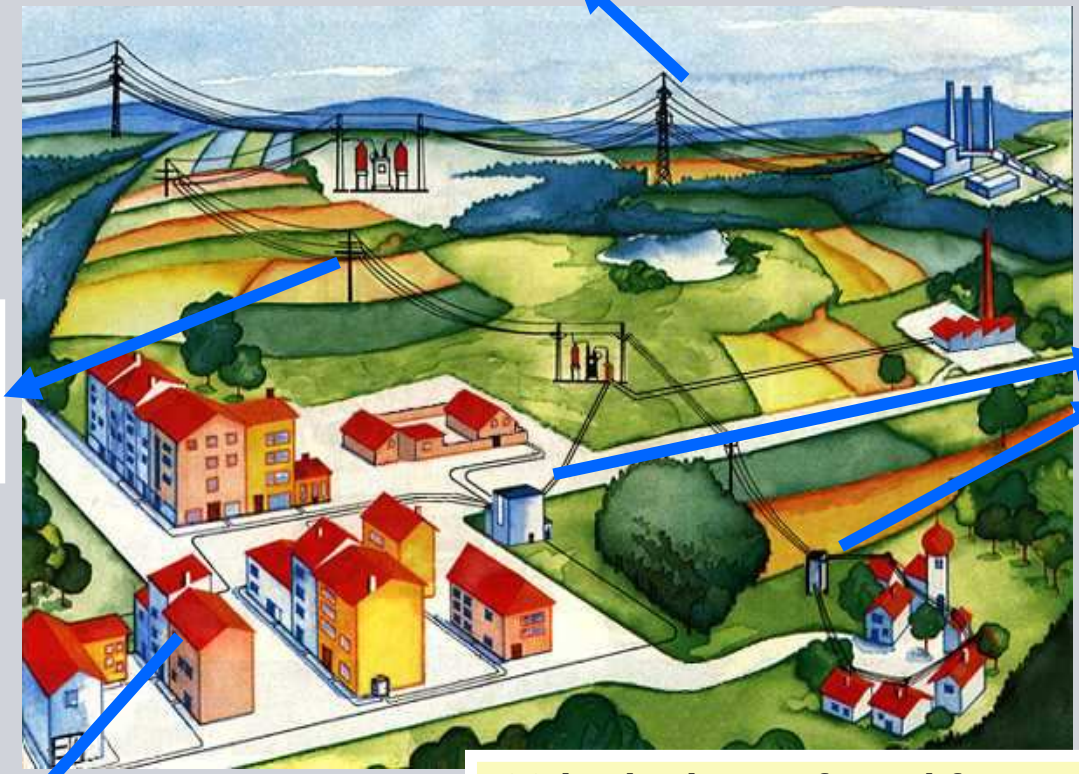
*Source: Siemens 110 kV-switchgear substation Wittenau, Vattenfall Berlin, in service since 1968

1. Introduction

Power Transmission and Distribution in Germany

SIEMENS

Transmission 245 kV **/ 420 kV**



Transmission/ Distribution 123 kV

Distribution 12 kV/**24 kV**/36 kV **Medium Voltage**

Low-voltage 0.23 / 0.40 kV

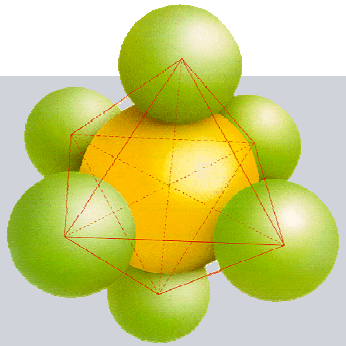
420 kV is the preferred future transmission grid voltage level.

Possible integration of large wind power parks in the north with load centers in the West and South.

1. Introduction

Emissions from SF_6-Switchgear >1 kV in Germany

SIEMENS



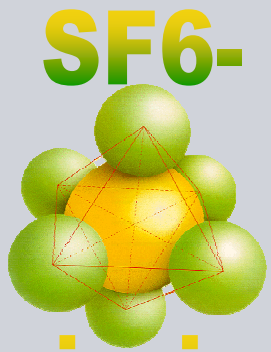
- Contribution to the GHG effect -gross-
  (manufacturing, operation and recycling / disposal)
- Less than 0,04%, including a tenth from medium voltage = 0,004%
  (monitored values)
- Modern high voltage switchgear (above 52 kV) show leakage rates well below 0,5% p.a./gas compartment (closed pressure systems*)
- Modern medium voltage switchgear is sealed for life (sealed pressure systems*) with leakage rates below 0,1% p.a.

Welded containments for MV switchgear show leakage rates <u>far below</u> 0,1% p.a.

* see IEC 62271-1 CDV

1. Introduction
Emissions occur at all life cycle stages

SIEMENS



Less than 1/3 of emissions during operation result from leakage

Manufacturing, Testing, Installation, Maintenance and end of life procedures

SF6-leakage of switchgear

Values are well established in IEC, IEEE standards

+

SF6-handling losses

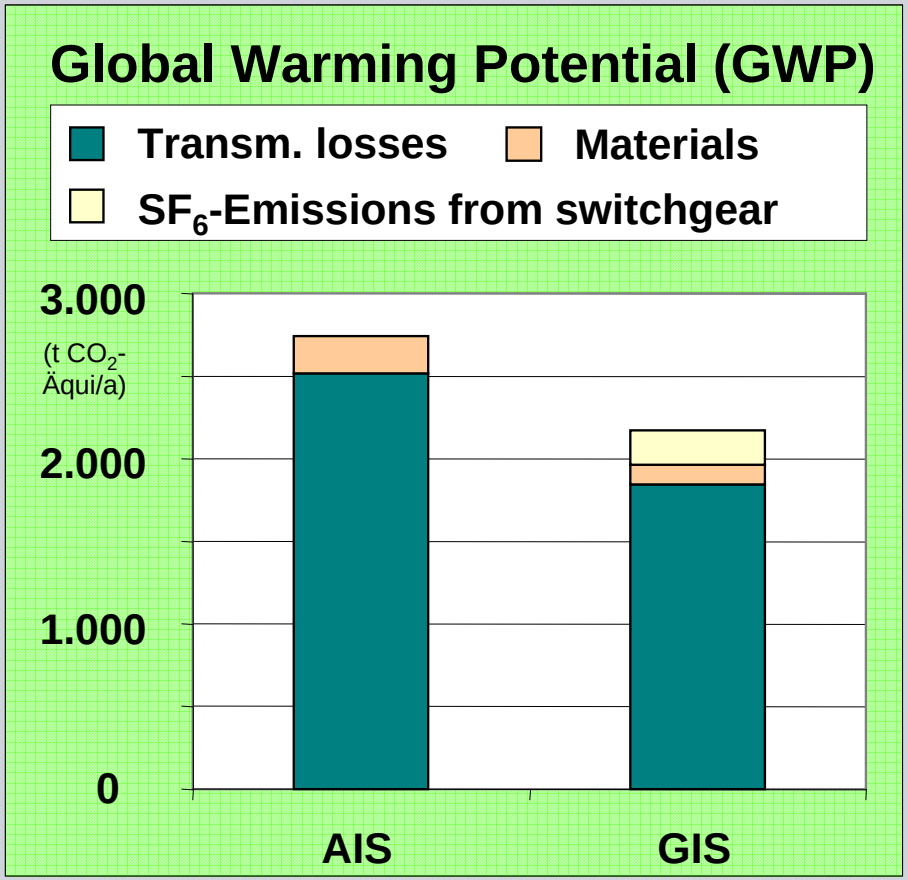
Recommendations are given: e.g. SF_6-handling guide Cigré Nr. 276

Current German activities are concentrating on optimized SF_6-Handling at all life cycle stages

2. Recent studies
Life Cycle Assessment (LCA) - High Voltage 1999

SIEMENS

Results from consideration on system-/ network level in Germany



Similar advantages for SF_6-Technology on other environmental criteria:

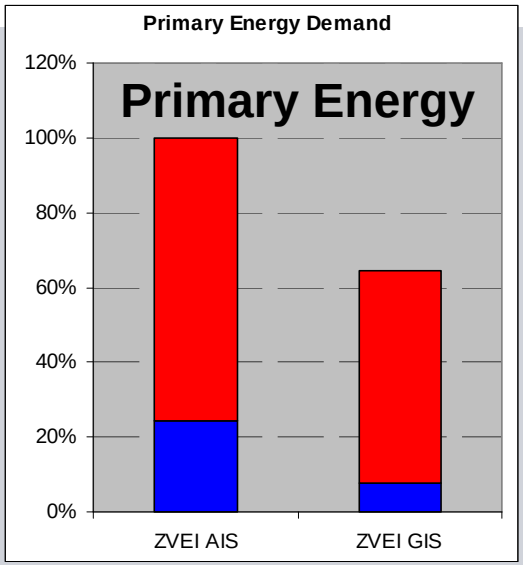
- Acidification (AP*, forest dieback)
- Nitrification (NP*, waters, algae)
- Primary Energy consumption
- Space consumption

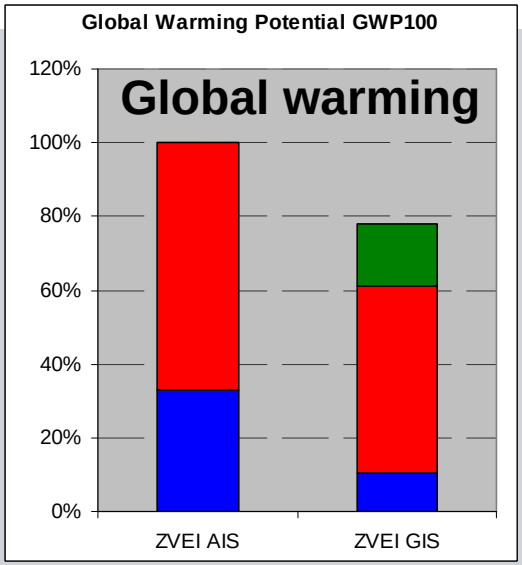
***=Potenzial**

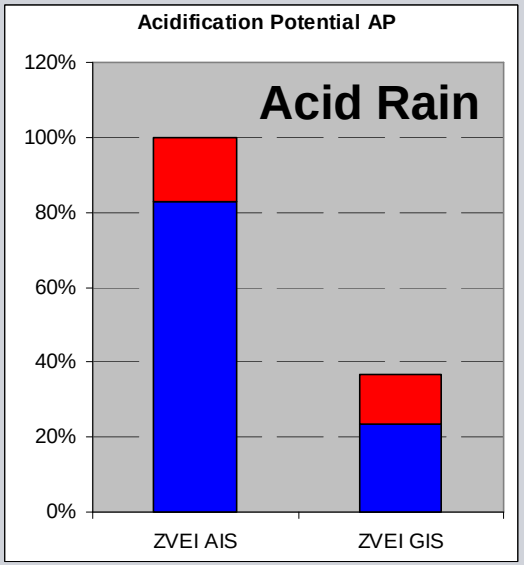
2. Recent studies

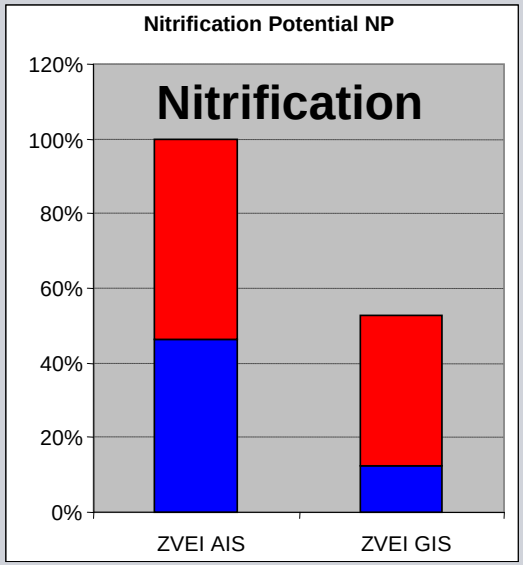
Life Cycle Assessment (LCA) - Medium Voltage 2003

SIEMENS









- Switchgear level only, other components (cables, lines, and transformers) not considered.
- On grid level the advantage for global warming expected to be higher due to additional savings of transmission losses.

Materials and Manufacture

Ohmic Losses

SF_6 Emissions

2. Recent studies
Conclusions of the European Ecofys Study*

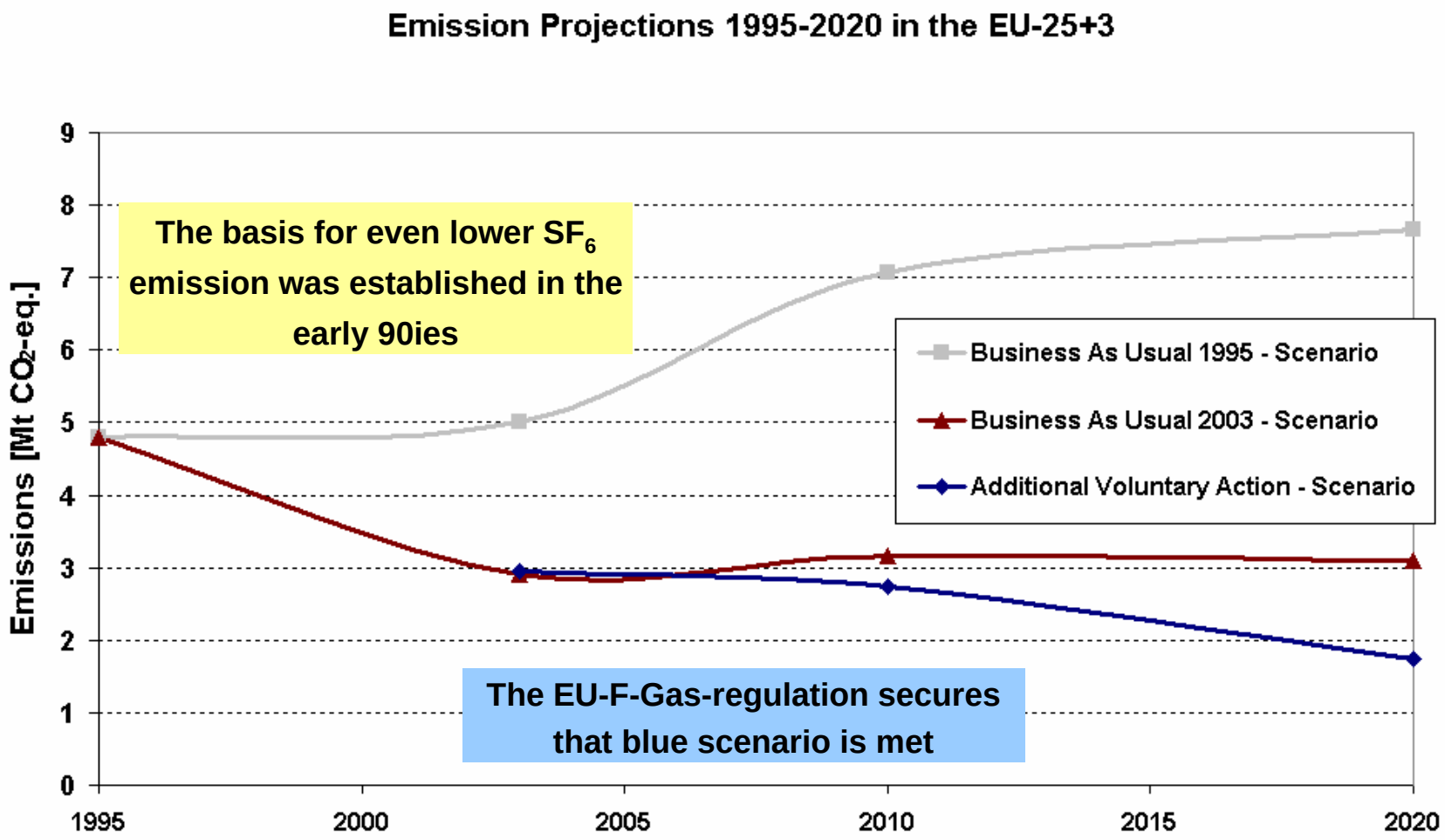
SIEMENS

- **There are no viable alternatives to SF_6 due to its unique properties in transmission and distribution equipment. SF_6 is indispensable for a secure electricity supply.**
- **SF_6-emissions from electrical power equipment contribute less than 0,05% to the total European GHG effect**
- **Voluntary actions resulted in emissions reduction of 40% compared to 1995 (EU 25 + 3 countries)**
- **LCA‘s prove that SF_6-Technology can even relieve the overall balance of GHG emissions from electricity grids**
- **Renewed increase of emissions caused by an increasing SF_6-bank can be prevented by consistent continued voluntary actions by 2020**

*Reductions of SF_6 Emissions from Electrical High and Medium Voltage Equipment in Europe“, Ecofys, 2005, www.capiel-electric.com

2. Recent studies
European Ecofys Study 2005

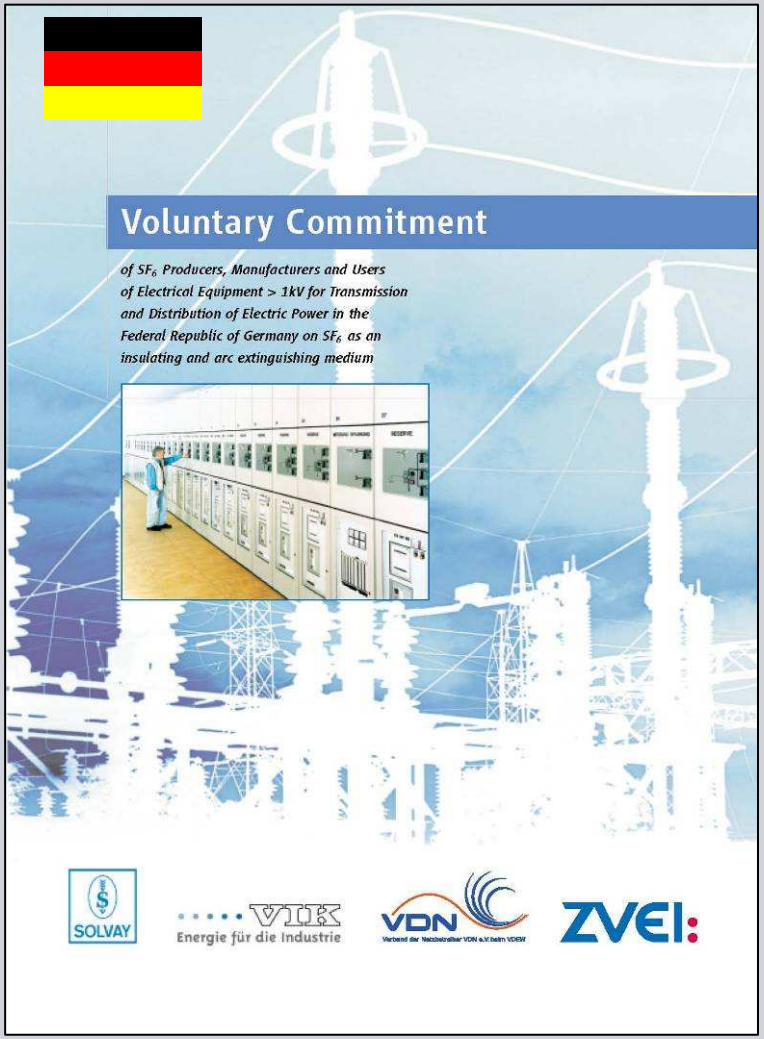
SIEMENS



3. Voluntary Commitment

Implementation of the German Voluntary Commitment

SIEMENS



- **Based on the previous voluntary commitment (1996)**
- **Agreed with and recognized by the German Government in 2005**
- **Scope: Switchgear and Components >1 kV**
- **Quantified and dedicated targets for 2020 by life cycles and responsibilities**
- **Annual monitoring of activity data and emissions according to IPCC 2006 Guidelines for verification**

Mission:
SF_6-emissions should be avoided wherever possible.
The specific quantity of SF_6 used to fulfill functions is to be minimized.

3. Voluntary Commitment

Examples for Participants of the German Voluntary Commitment

SIEMENS

VIK Energie für die Industrie

3M

Die Bahn DB

Ford

VW

BMW

BASF The Chemical Company

Bayer

Coca-Cola GmbH

DaimlerChrysler

Goodyear

ZVEI

Driescher · Wegberg

EGAS

DILO

SOLVAY

Areva

Schneider Electric

ORMAZABAL

TRENCH

ABB

SIEMENS

VDN Verband der Netzbetreiber VDN e.V. beim VDEW

VATTENFALL

e·on

EnBW

RWE

Voluntary Agreement Participation

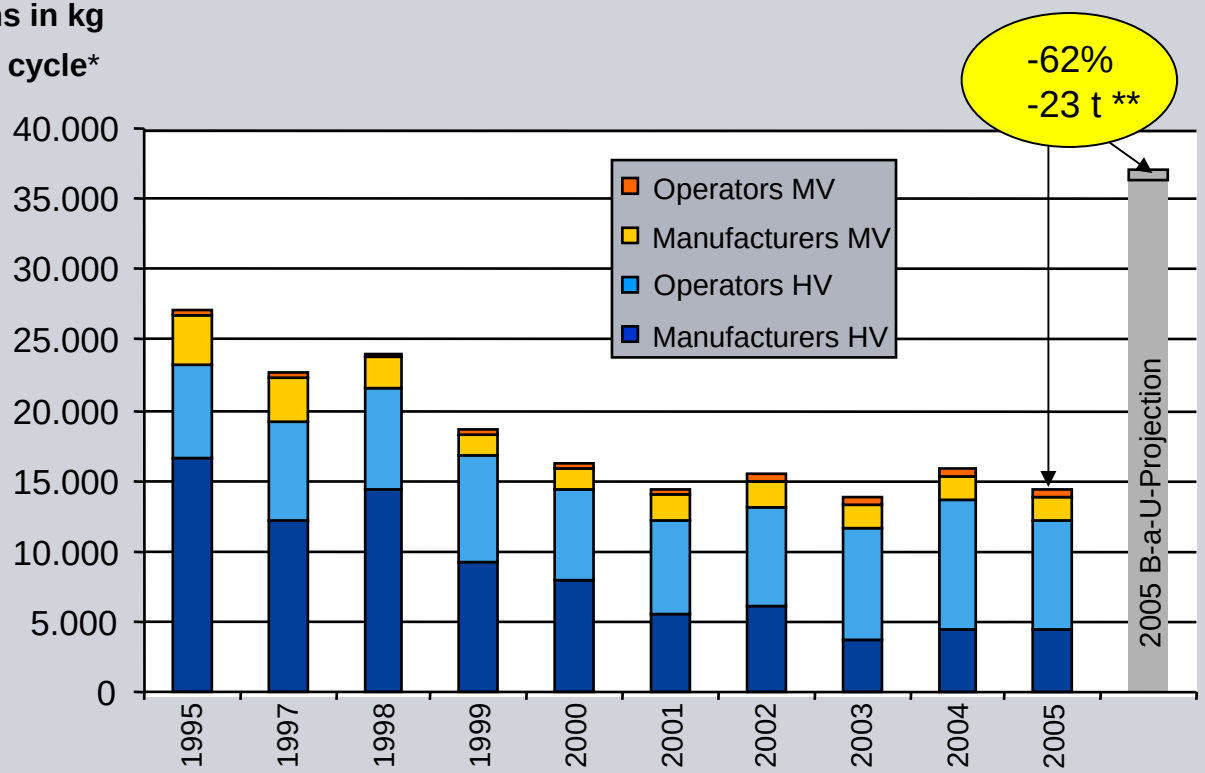
- **100% SF_6 Producer**
- **98% Manufacturer of Electric Power Equipment**
- **100% Operator High Voltage**
- **90% Operator Medium Voltage**

3. Voluntary Commitment

SF_6 Emissions from high and medium voltage switchgear

SIEMENS

SF_6 Emissions in kg from total life cycle*



****Activity data i.e. consumption and banks increased by appr. 40 resp. 70% since 1995**

In spite of significantly increased consumption and banks, emissions have been voluntarily reduced by appr. 50% in absolute values and by over 60% against "Business As Usual"

*Type testing, manufacturing, operation including end-of-life procedures

SIEMENS

3. Voluntary Commitment

Status and targets by life cycle and responsibilities

Subject / Life cycle stage	Status 1995	Status 2005	Target for 2020
1. **Total emission rate (ER) from development, testing and manufacture:** (Commitment by manufacturers)	Ca. 5.5 % p.a.	Ca. 1.3% p.a.	< 1.5 % p.a.
2. **Total ER from 1st installation on site:** (Commitment by manufacturers)	Not assessed	< 0.1 % p.a.	< 0.1 % p.a.
3. **ER from operation including maintenance and repairs** (Commitment by users or their representatives, e.g. manufacturers)	High voltage: Ca. 0.9 % p.a. Medium voltage: Ca. 0.15 % p.a.	High voltage: Ca.0.8% % p.a. Medium voltage: < 0.1 % p.a.	High voltage: Up to 0.6 % p.a. Medium voltage: < 0.1 % p.a.
4. **SF_6 leakage rate from new switchgear installed for operation:** (Commitment by manufacturers and users - relative to the acquisition of new equipment)	High voltage: < 0.5% p.a. Medium voltage: Ca. 0.1% p.a.	High voltage: <0.5%p.a. p.a. Medium voltage: < 0.1% p.a.	High voltage: <0.5%p.a. p.a. Medium voltage: < 0.1% p.a.
5. ER from the post-use phase (recovery/return/disposal from switchgear)	Not assessed	< 2%	< 2%
a. **Recovery (removal):** (Commitment by user resp. manufacturer, when equipment is returned)	Not assessed	< 1.5 %	< 1.5 %
b. **Reuse:** (Commitment by SF_6 producer)	Not assessed	<Ca. 0.1 %	< 0.3 %
c. **Destruction:** (Commitment by SF_6 producer or representative)	Not assessed	Ca. 0.2 %	< 0.5 %

3. Voluntary Commitment

Overview: main measures*

SIEMENS

- **Awareness: Sensitization and Training of staff** (all life cycle stages)
- **Product design and -documentation; improved sealings; gas handling intervals extended to 20 - 25 years, "sealed for life" in medium voltage, adjusted labeling and instructions (manufacturers)**
- **Improved gas handling processes and quality control:**
  - Evacuation to < 20 mbar by modern gas handling units and self-closing valves/couplings (all life cycle stages)
  - Central gas supply systems and application of flow meters for process monitoring (manufacturing)
  - Routine testing: leak detection by applying Helium and/or Integral leak testing of complete units (MV) in large vacuum chambers (manufacturing)
  - Application of high precision leakage detectors for timely repair and/or replacement of leaky equipment (operation)

* for detailed description of measures refer to:

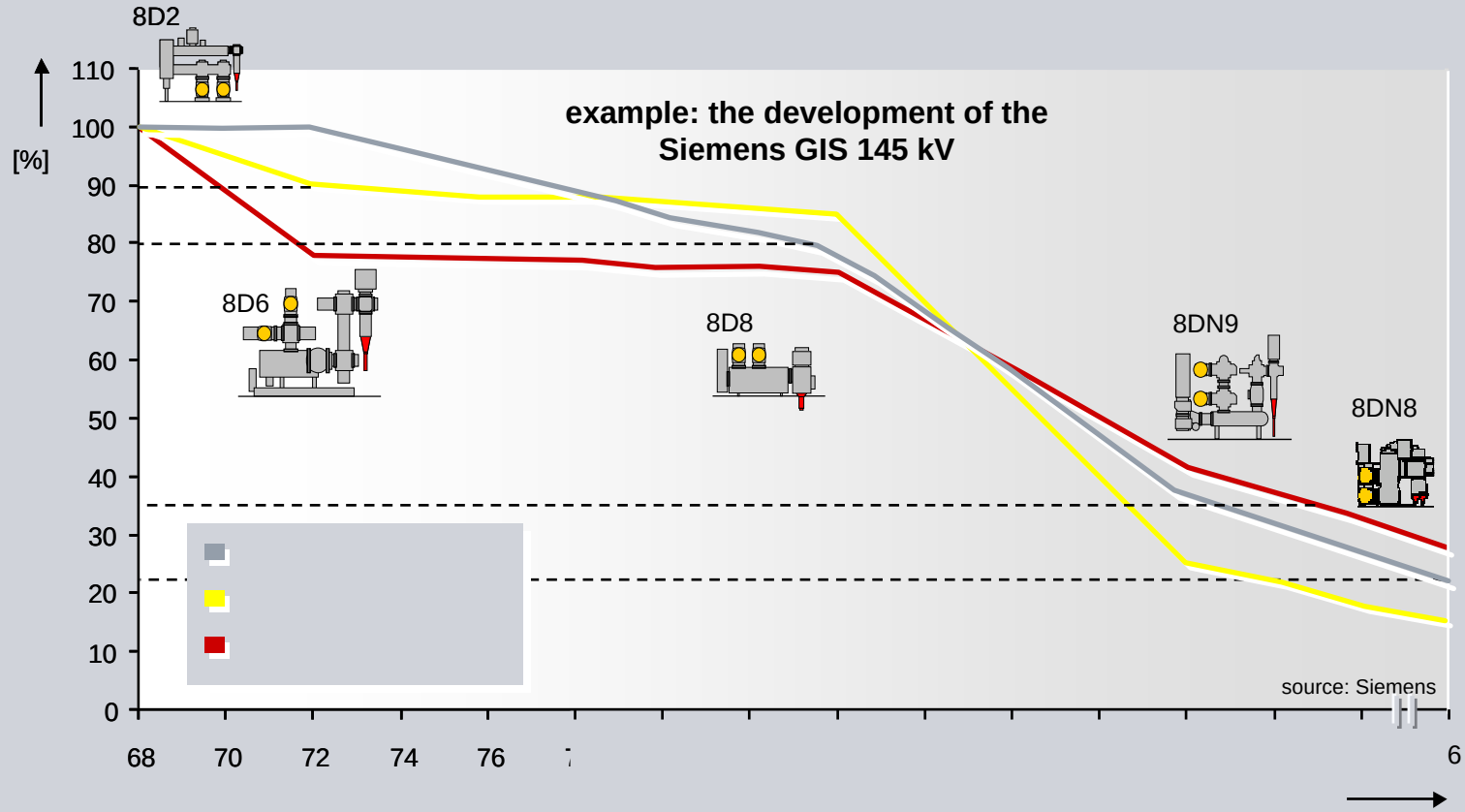
- „The new German monitoring system for SF_6 in electrical equipment for power transmission and distribution, Chapter 3", Ökorecherche, 2006, Winfried Schwarz et al"
- „Reductions of SF_6 emissions from electrical high and medium voltage equipment in Europe, Ecofys, 2005"

3. Voluntary Commitment

Example for reduced switchgear sizes in HV GIS

SIEMENS

The developments within the last decades have led to smaller gas compartments of the switchgear and thus to considerably less used amount of SF_6 at the same performance data.

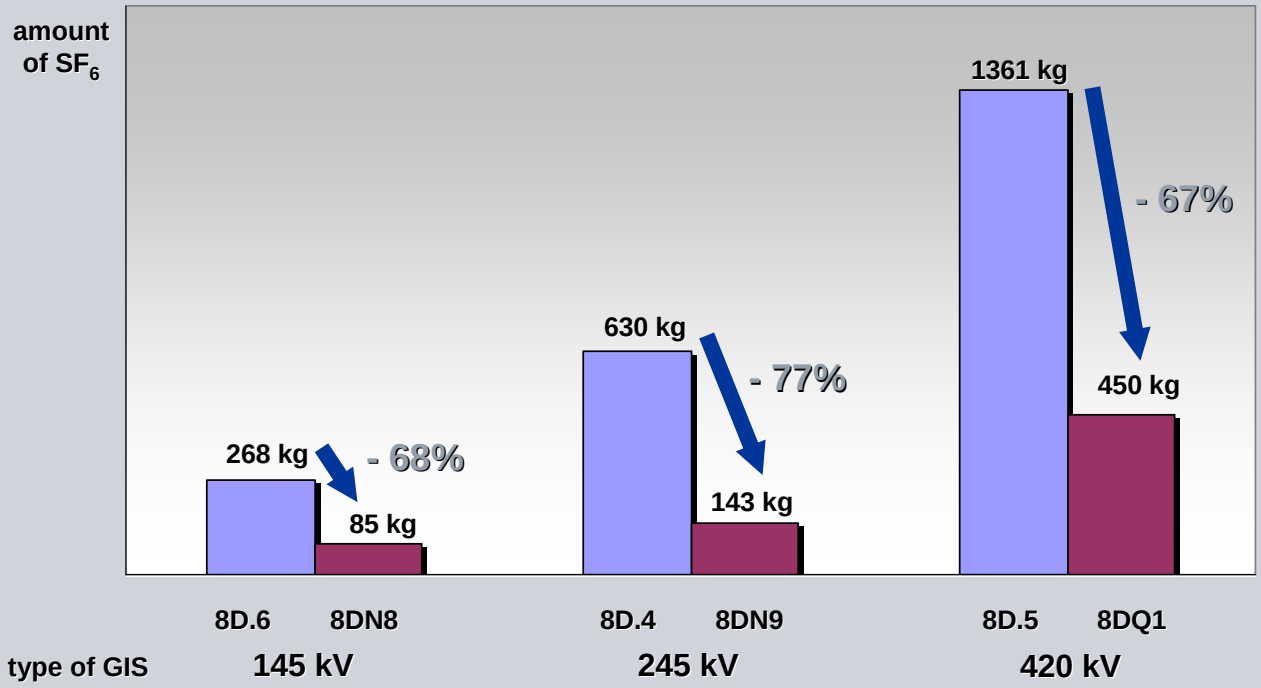


3. Voluntary Commitment

Significant reduced amount of SF_6

SIEMENS

A significant reduction of SF_6 was reached by using modern development tools, new materials and optimized production processes since the introduction of the GIS-technology in 1968.



Siemens GIS

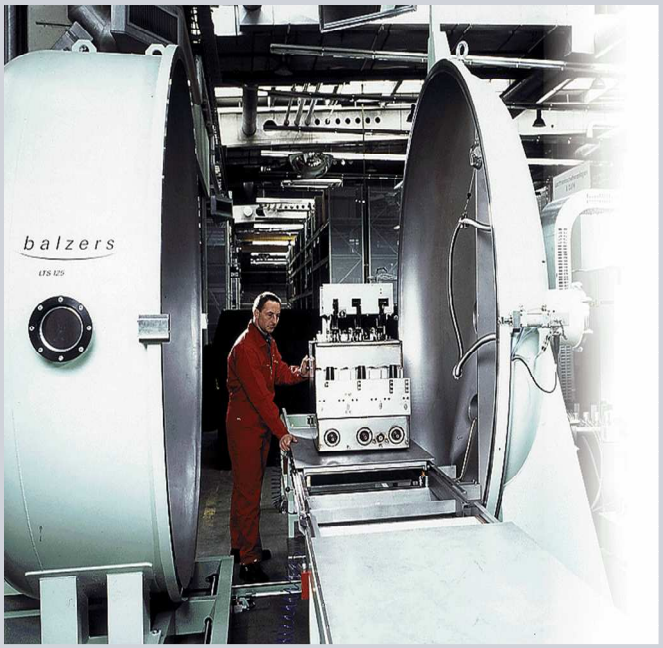
Basis: cable bay with double busbar system including 2 BB DS, 1 L DS, 1 CB, 3 ES

3. Voluntary Commitment

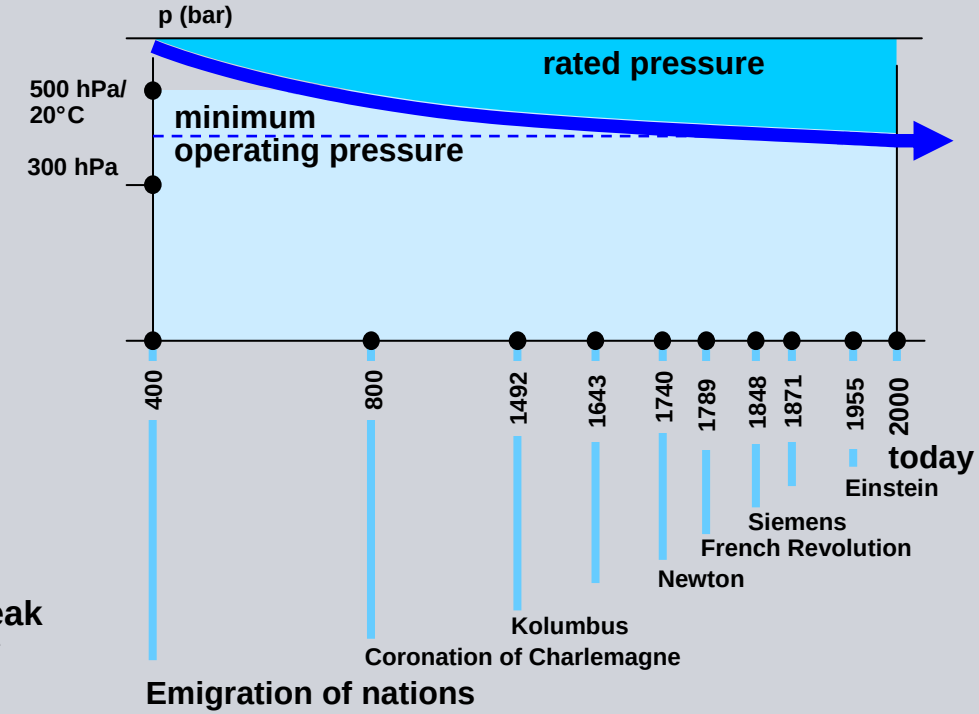
Tightness test of Medium Voltage SF_6 - Switchgear

SIEMENS

Routine Tightness Testing for and automatic filling of sealed pressure systems



Integral Leak Detection*



Strong Quality Control on manufactured products secures extreme tightness of equipment during its entire service life with high benefit to the environment

*Siemens Medium Voltage SF_6 switchgear factory Frankfurt/Germany

3. Legislation

Impact on "High and Medium Voltage SF_6-Switchgear"

SIEMENS

European Community : The "F-Gas-Regulation"

- In force since July 4th 2006; to be applied from July 4th 2007
- Gas to be properly recovered by certified personnel at end of life to ensure its recycling, reclamation or destruction
- National requirements for training and certification of personnel handling SF_6 to be based on uniform minimum requirements
- Member states to establish emissions reporting systems
- Requirements on product labeling and instructions
- Member states to facilitate cross boarder transport of recovered gas
- The European Industry is closely cooperating with the authorities to ensure appropriate "fine-tuning" of the regulation, based on the existing voluntary industry actions and commitments

4. SF_6 Emissions
Field Experience of utility – Example Vattenfall Berlin

SIEMENS

Siemens 420 kV-GIS, Substation Friedrichshain, Vattenfall Berlin

Installed bays:

420 kV	**53 bays**
110 kV	**454 bays**

Manufacturer:

ABB, AEG / Alstom / Areva, CSE, TRO, Siemens

Siemens has delivered since 1968:

all 53 bays 420 kV
226 bays 110 kV

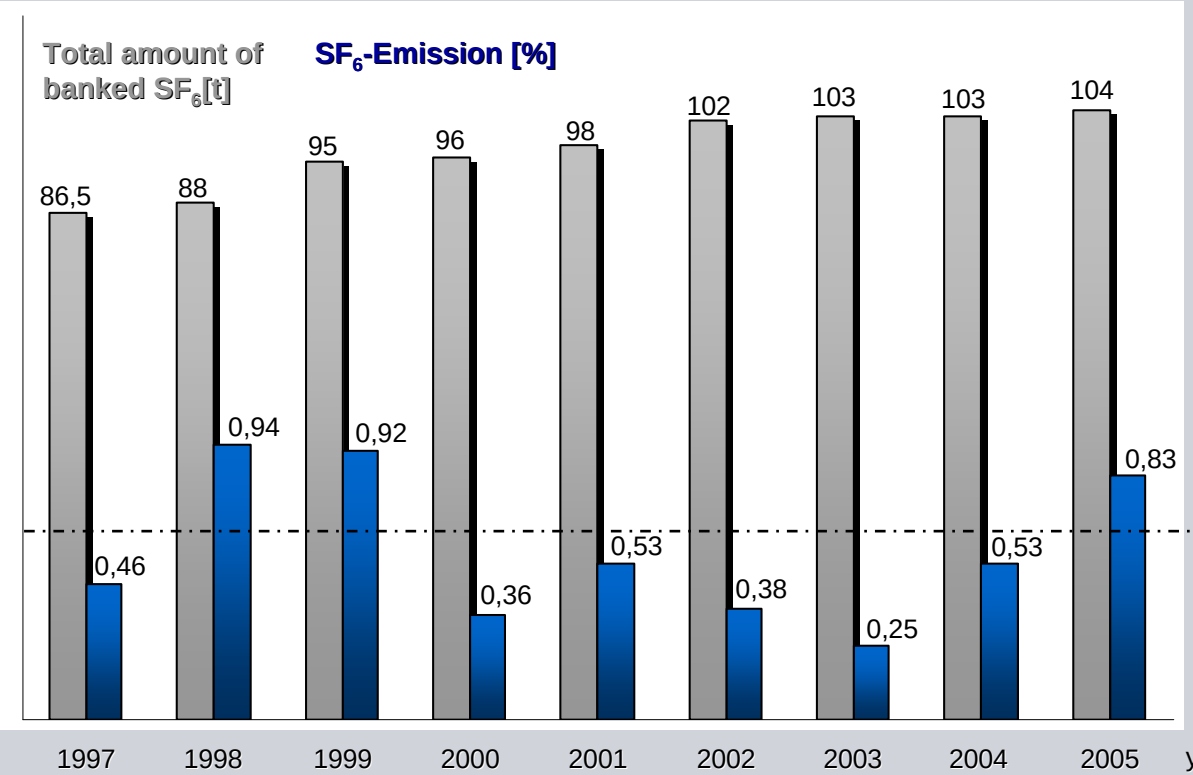
SF_6 electric power equipment overview, appr. 7% of total amount of SF_6 banked in Germany

- **SF_6-Substation** **90**
- **Total amount SF_6 installed** **ca. 104 t**
- **Total amount of gas compartments** **ca. 3300**
- **Smallest gas compartments** **1,8 kg**
- **Largest gas compartments** **1.152 kg**
- **SF_6 leakage rate** **<< 0,5%**

4. SF_6 Emissions

Field Experience of utility – Example Vattenfall Berlin

SIEMENS



Already one measure / incident can influence significantly a very low SF_6 emission level

Average value 0.58%

≈ 0,2%
SF_6-leakage rate

0,4%
SF_6-handling losses

Vattenfall experience: In general the contribution of SF_6-leakage of the equipment is 30%, while the handling losses contribute with 70%.

4. SF_6 Emissions
Field Experience of utility – Example Vattenfall Berlin

SIEMENS

The very low SF_6-emission was reached due to:

- Improvement of maintenance strategy (less openings)
- continuous training of staff (once per month in conjunction with safety-at-work-information)
- using state-of-the-art-handling equipment & quality measurement devices (observing permanently the market for new products)
- Identifying of small SF_6-leakage and immediate repair (regular monitoring, e.g. density sensor, contact manometer in connection with other checking's)

4. SF_6 Emissions

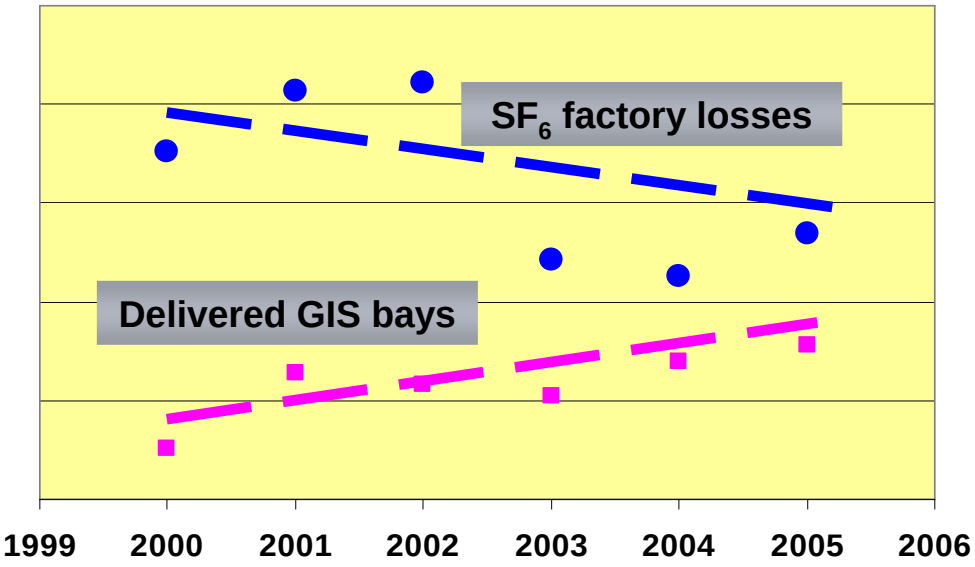
Reduced SF_6 emissions within HV GIS production

SIEMENS

SF_6 losses within production is minimized by:

- Optimized handling & Sensitive employees
- Use of state-of-the-art SF_6 handling equipment
- High assembly quality (increase FPY)
- High recycling rates of used SF_6

Siemens High Voltage SF_6 electric power equipment factory Berlin/Germany



5. State-of-the-art-Equipment
High Voltage Switchgear

SIEMENS

Gas Insulated Switchgear

Highly Integrated Switchgear HIS®

Life Tank Breaker

Dead Tank Breaker

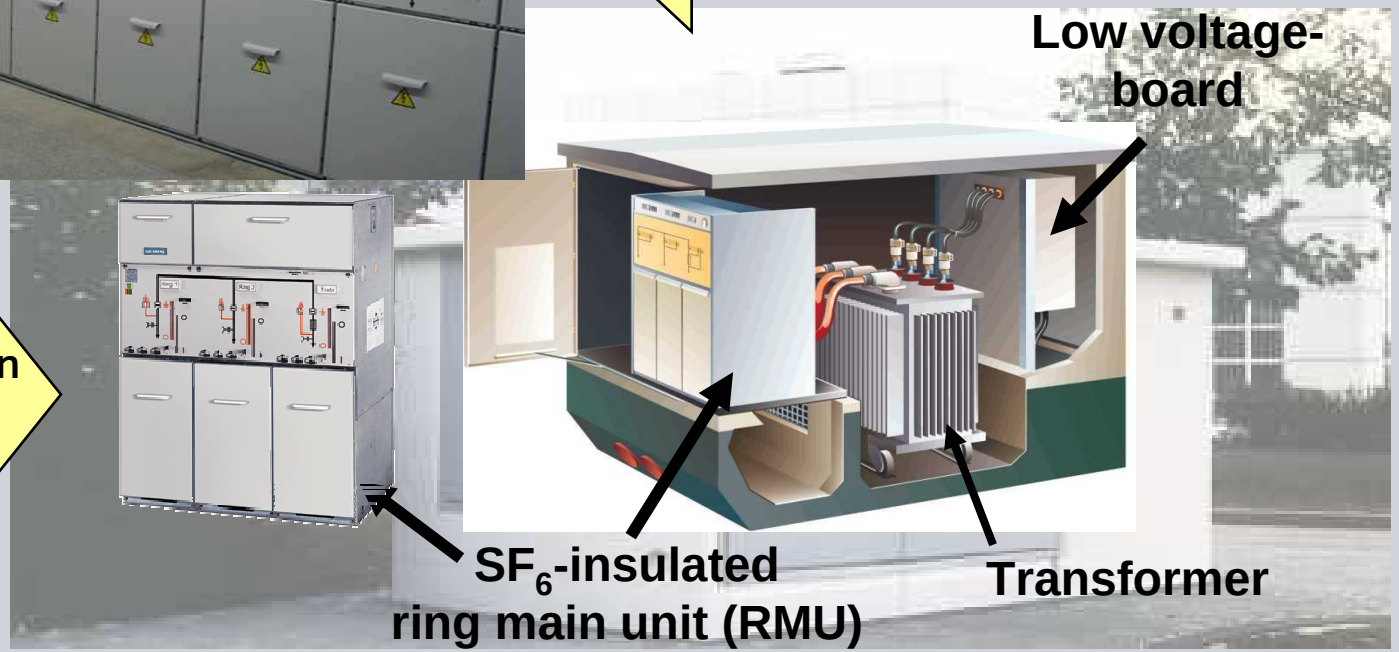
Dead Tank Compact

State-of-the-art High Voltage Electric Power Equipment has got leakage rates well below the required 0,5%/a per gas compartment as required in the international Standards for closed pressure systems

5. State-of-the-art-Equipment
Medium Voltage Switchgear

SIEMENS

SF_6-insulated switchgear with vacuum circuit breakers up to 40,5 kV



Low voltage-board

Compact substation 6 - 24 kV

SF_6-insulated ring main unit (RMU)

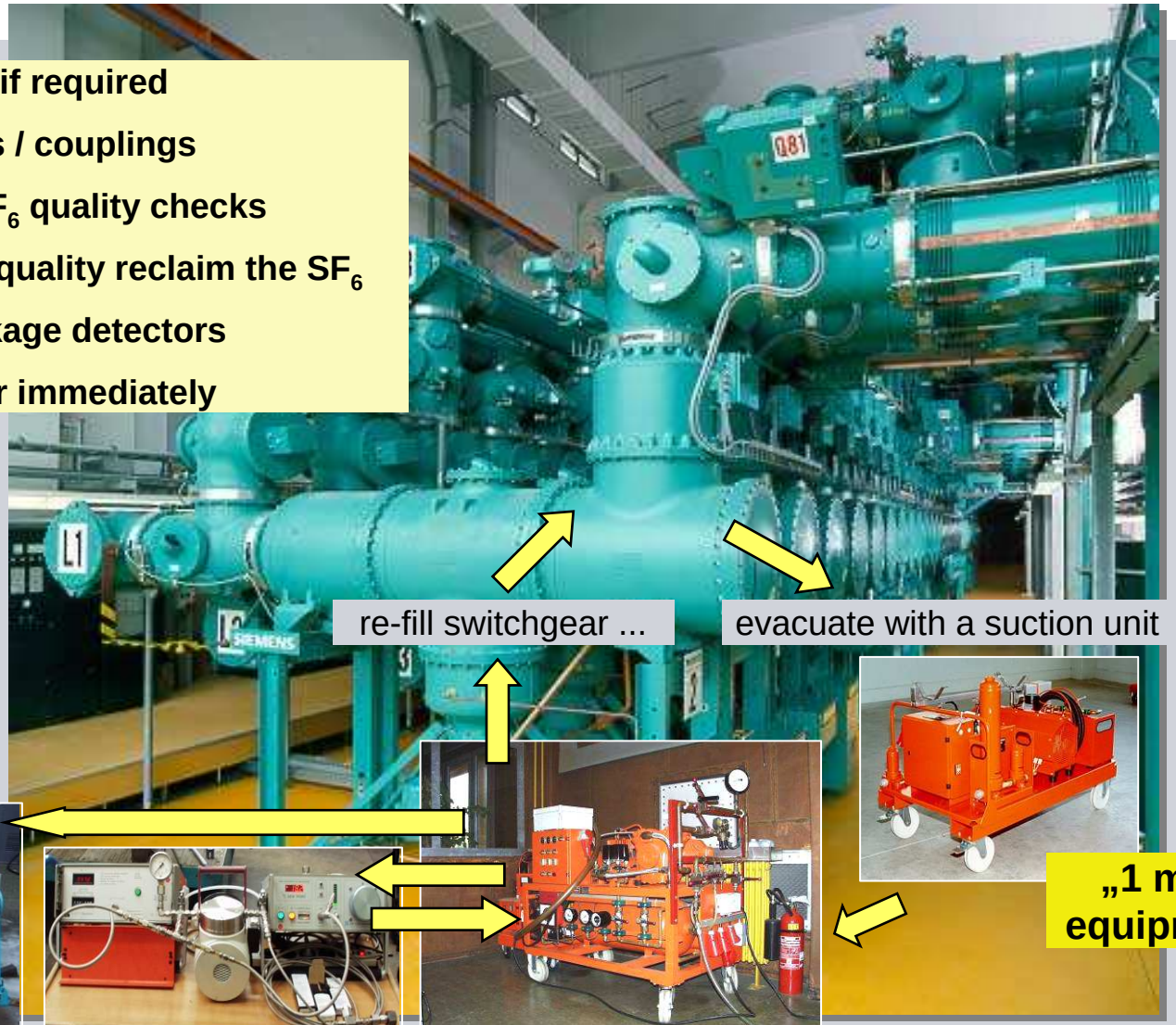
Transformer

Medium voltage switchgear has got leakage rates below resp. far below 0,1 % p.a. It does not require any maintenance / gas handling during operation.

6. Optimized SF_6 handling equipment and processes

SIEMENS

- **Open equipment only if required**
- **Use selfclosing valves / couplings**
- **Avoid unnecessary SF_6 quality checks**
- **When measuring gas quality reclaim the SF_6**
- **Use sensitive SF_6-leakage detectors**
- **In case of leaks, repair immediately**

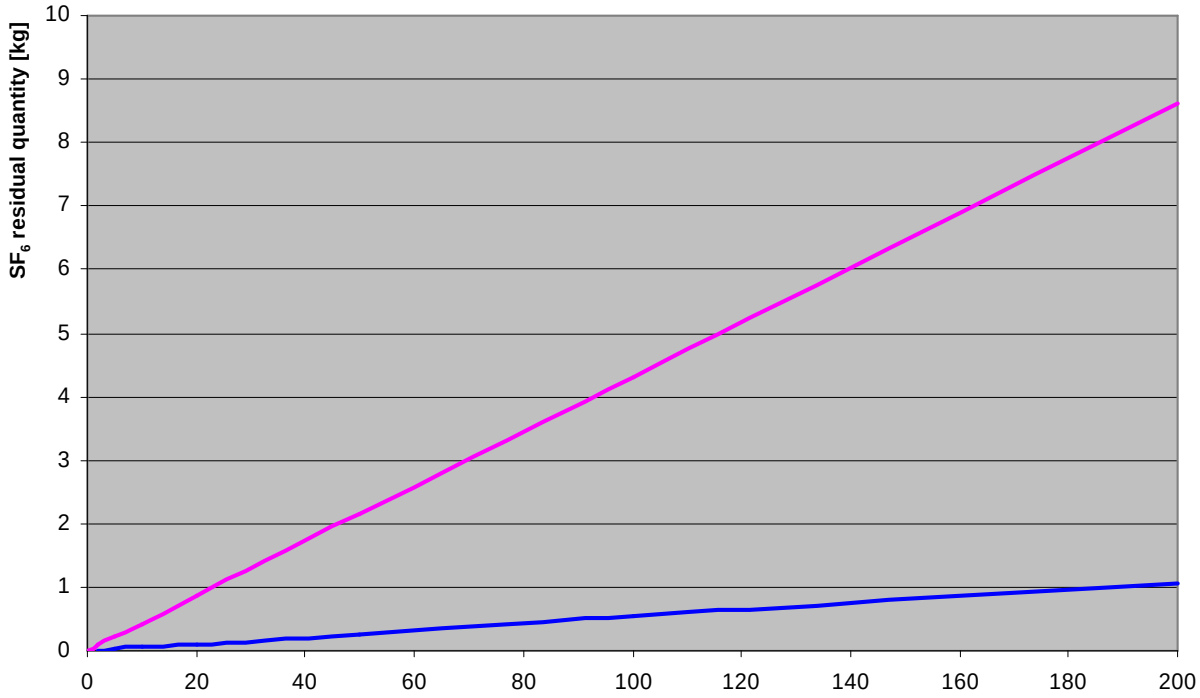


6. Optimized SF_6 handling equipment and processes

SIEMENS

With State-of-the-art-handling equipment SF_6 recovery of each gas compartment till very low pressure (1 - 20 mbar) is possible, thus securing losses of at least less than 2% during maintenance and end of life.

SF_6-residual quantity (emission) dependence on the SF_6 rated filling pressure / compartment size / SF_6 residual pressure



source: Cigré-Guide no. 276, application of table 25; Example: GIS Siemens

420 kV-circuit breaker, 3-pole

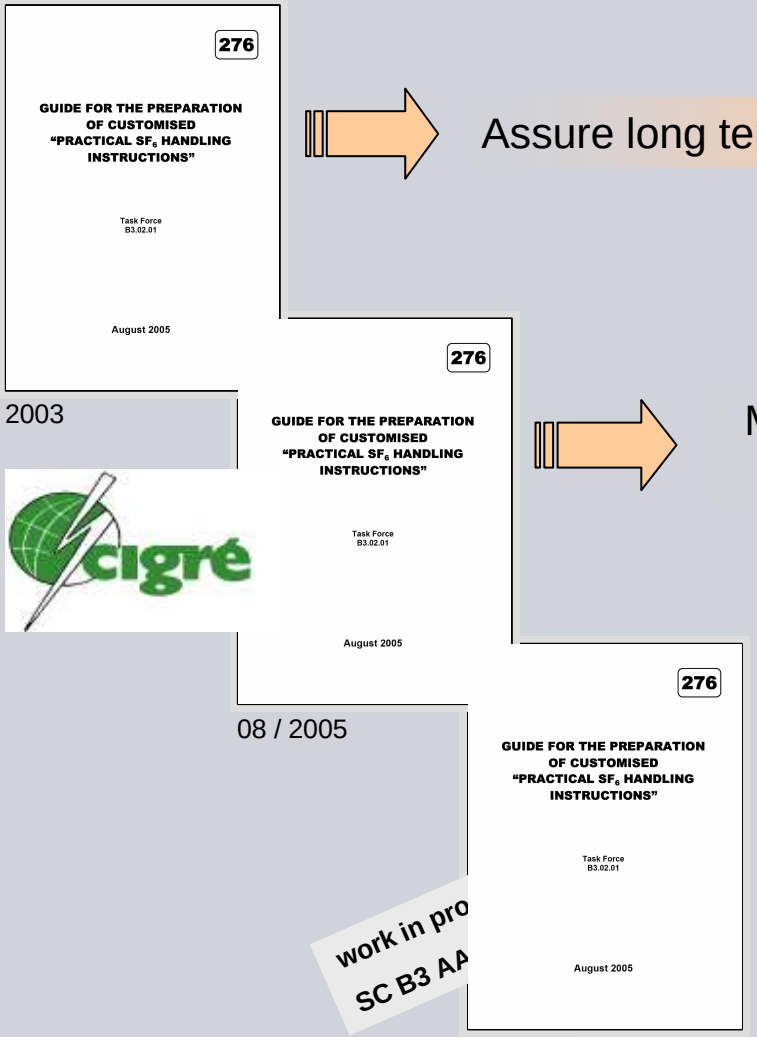
- volume: ca. 7000 l
- working pressure: 6,6 bar abs.
- SF_6-amount: ca. 300 kg
- SF_6-density: 43 g/l

420 kV-disconnector, 3-pole

- volume: ca. 870 l
- working pressure: 4,8 bar abs.
- SF_6-amount: ca. 27 kg
- SF_6-density: 26,7 g/l

7. Current activities in industry standards

SIEMENS



Assure long term use of SF_6

Minimize SF_6 handling losses by state-of-the-art handling

Guarantuee of SF_6 tightness due to state-of-the-art equipment and testing

The CIGRÉ Guide No. 276 will be transferred into the IEC 62271-303. It will serve as reference for Training and Certification requirements of the European F-Gas-Regulation

8. Conclusion

Obtaining Low SF_6 Emissions in Germany

SIEMENS

- Awareness, responsibility and cooperation in the complete “Cradle to Grave” chain is the key
- Environmentally conscious design leads to extremely tight products requiring minimum to no maintenance and gas handling
- State-of-the-art handling equipment, highly qualified personnel together with management commitment ensure that the remaining reduction potential is lifted
- Verification of quantified targets by transparent monitoring establishes trust and helps to minimize impact from legislation
- Successfully implemented actions show that the global warming aspect is manageable and the total balance justifies the sustainable use of state-of-the-art SF_6 technology

SIEMENS

Many thanks for your attention !

For further information please contact:

peter.glaubitz@siemens.com

friedrich.ploeger@siemens.com