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Power Electronics: The Key technology for Energy Efficiency and Renewables

What we offer: divisional structure and portfolio

Power Products
Sales: $7.4 billion

Transformers, high- and medium-voltage switchgear, breakers, automation relays

Power Systems
Sales: $4.5 billion

Substations, FACTS, HVDC, HVDC Light, power plant & network automation

Automation Products
Sales: $6.8 billion

Low-voltage products, LV & MV drives, motors, power electronics, and instrumentation

Process Automation
Sales: $5.4 billion

Control systems and application-specific automation solutions for process industries

Robotics
Sales: $1.3 billion

Robots, peripheral devices and modular manufacturing solutions for industry

- Market-leading positions in most key product areas
- Integrated solutions for grid reliability, productivity and energy efficiency
- Robust global value chain to serve established and emerging markets
- Extensive global network of value-added channel partners

* Estimated 2006 revenues, Including internal sales to other divisions

Innovation key to competitive advantage

ABB's current strong market position has been built through consistent R&D investment

- $1.1 billion spent on research and order-related development in 2006, a 10 percent increase compared with 2005
- 6,000 researchers and developers worldwide
- R&D and new product focus in both power and automation:
  - *Energy efficiency (e.g., advanced transmission systems, high-efficiency motors and drives)*
  - *Flexibility and productivity (e.g., automation and control software, wireless communication systems)*

* Comprises Non-order related R&D and order-related development for ABB's five core division and excludes expenditures in Non-core activities

Competence Center Power Electronics

Total ~ 1100 Employees

ABB Power Electronics
ABB MV Drives

Power Electronics Triangle

ABB Corporate Research

ABB Semiconductors

Power Electronics in Switzerland - Turgi

Power Electronics

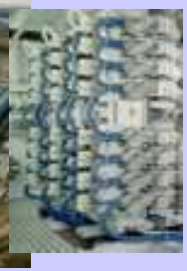
Traction Converters

- Propulsion Converters BORDLINE
- Auxiliary Converters BORDLINE
- Converter Parts & Control
- Rolling Stock OEM's
- Railway Operators

Power Converters

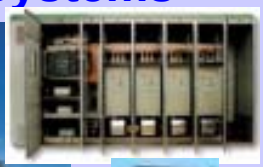
- Static Frequency Convert. up to 100 MW
- Power Quality Systems
- Utilities & Railways

High Power Rectifiers



- Thyribloc / Rectibloc up to 200 kA / 1500 V
- Aluminium Smelters
- Copper, Zinc, Chlorine

Excitation Systems



- UNITROL 1000 / 5000
- Synchrotact 5
- Power Generation
- Synchronous Machines

MV Drives

■ Drive^{IT} ACS 1000	0.3 - 5 MW
■ Drive^{IT} ACS 6000	3 - 27 MW
■ ACS 6000c	14 - 27 MW
■ LCI	2 - 50 MW)

- Cement, Mining & Minerals
- Petrochemical, Oil & Gas
- Marine
- Metals
- Power
- Pulp & Paper
- Water & Wastewater

Electrical Energy - the future demand

- Worldwide eletrical energy demand is fast growing
  - Growth of energy demand at 3.5% per year
  - The installed capacity will grow by 60% until 2020
    - from 4300 GW (2006) to 6700 GW (2020)
    - by 150 to 200 GW per year
- Renewables enabled by Power Electronics
  - Renewables have the potential to reduce the C02 emmissions in power generation (in Europe 20% by 2020)
  - Windpower 2006: new installations 15 GW / year (25% growth rate)
  - Solar Power 2006: new installations at 2 GW / year (50% growth rate)
- Energy efficiency enabled by Power Electronics
  - Variable speed power generation
  - Transmission and distribution (HVDC and FACTS)
  - Variable speed drives
  - Power conversion for rolling stock

EU Council of Ministers 8-9 March 2007

- After a one year process, the EU Council of Ministers agreed upon common target for the European Union to combat Climate Change and securing of supply in future:
  - Renewable energy will cover at least 20 % of the EU's energy demand by 2020.
  - Energy efficiency will be improved by 20 % before 2020
  - Carbon dioxide emissions will be cut by 20 % by 2020
  - Is is enough? Can it be reached?

Energy efficiency along the value chain

- Generation, distribution and industrial processes
  - Primary energy transport
  - Electrical energy conversion efficiency
  - Transmission losses
  - Production processes
  - Equipment efficiency

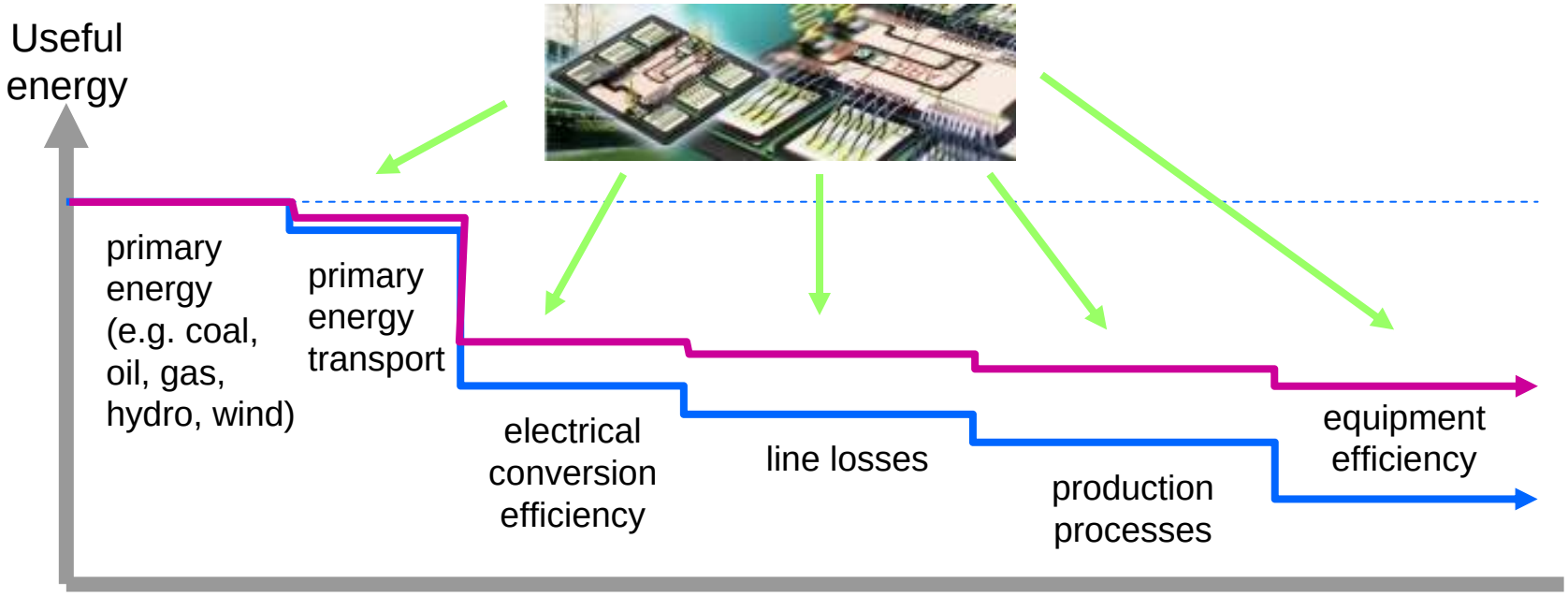
Energy Efficiency & Power Conversion Steps






Potential Power Electronics Contribution

Power Electronics is a cross-cutting technology
that allows saving energy
across all steps of
converting primary energy into goods and life quality



Energy efficiency along the value chain

- Generation, distribution and industrial processes
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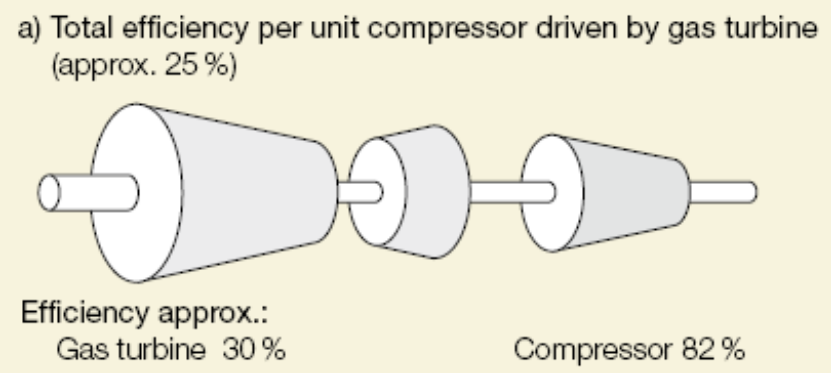
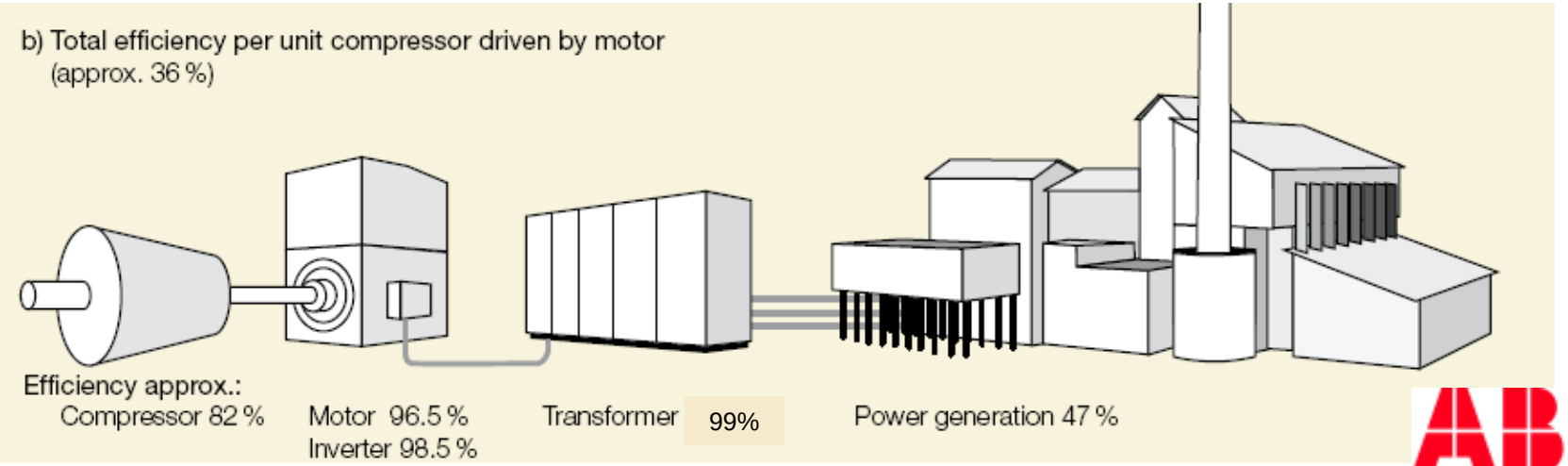
Primary energy transport – Natural gas

- Industrial gas turbine driven variable speed compressor (pipeline or liquefaction of natural gas)



Overall operational efficiency at 25%

- Electrical variable speed drives combined with 100 MW+ power plant improves operational efficiency to 36%



Reference: All electric LNG plants, ABB, 3BHT 490 537 R001

Energy efficiency along the value chain

- Generation, distribution and industrial processes
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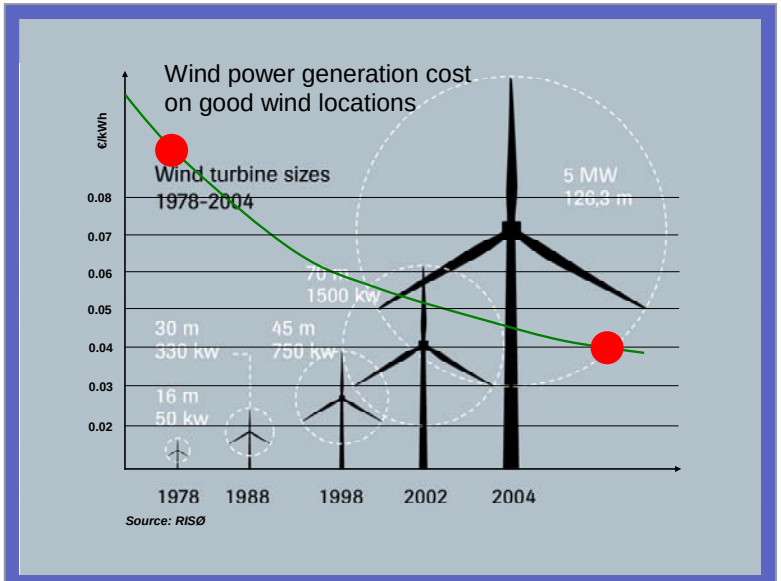
Electrical energy conversion efficiency - Bulk

- 100 MW + gas turbine driven power generation has a primary to electrical energy conversion efficiency of
  - typically 47%
  - up to 55% in a combined cycle plant
  - more than 80% in triple cycle (district heating or water desalination plant)

- Most efficient electrical energy generation is based on
  - Optimized bulk power generation
    - In regards of C02 emmissions nuclear energy is the right choice
  - Utilization of low-temperature heat for heating or industrial processes → to be retrofitted for existing plants
  - Improvement of efficiency of auxiliaries by means of variable speed drives → to be retrofitted for existing plants

Electrical energy conversion efficiency - Wind



Windpower generation costs

5MW Windturbine

The environmental factor

- e.g. climate change, pollution, Kyoto Protocol, clean power initiatives worldwide

Energy demand

- Global demand increasing, new growth economies
- One new coal-fired power plant every week in China

The economy of wind

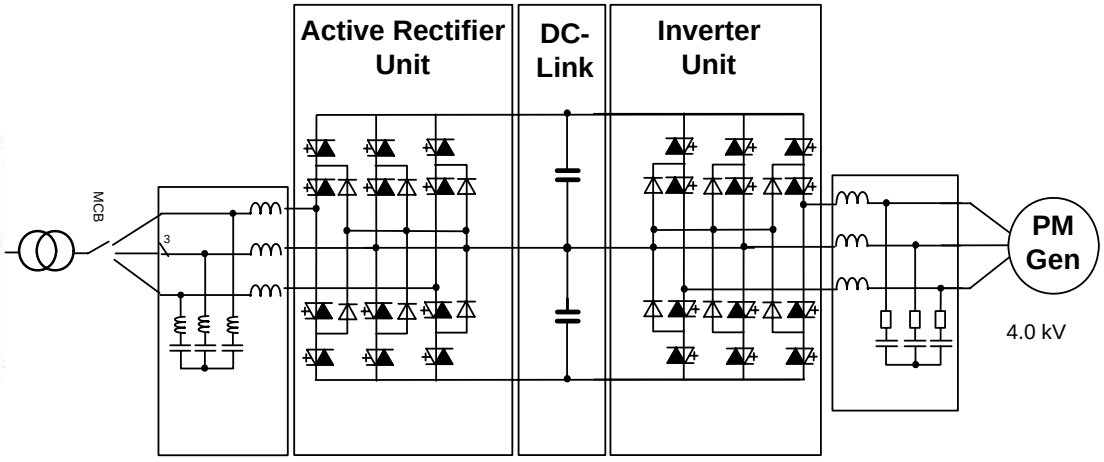
- Average generation cost per kWh has declined by 60% since 1980
- Immune from fuel price spikes, fossil fuel sources are limited

Result

- Wind energy is becoming a mature, global business

PCS6000 - MV converter for wind turbines

- Wind turbine at 5 -10 MW
  - Trend towards full power converter
    - Brushless / no sliprings → substantially longer maintenance cycles
    - Controlled stress on the gear box (Gearless as an option)
  - Trend towards medium voltage
    - MV voltage → Lower (fault) current levels
    - MV semiconductors (IGCT) → Minimum component number



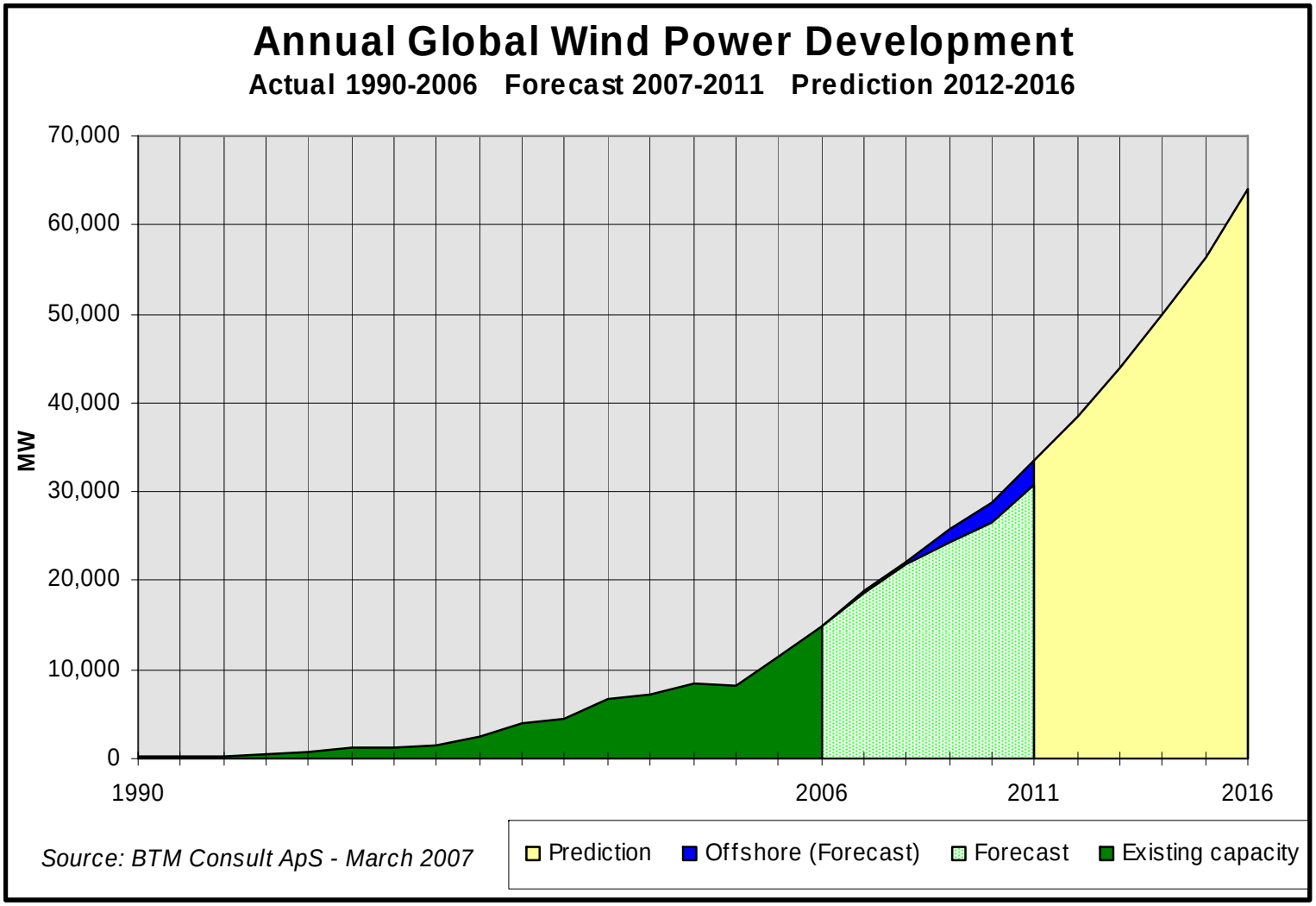
PCS6000 – 5 MW Wind converter

Electrical energy conversion efficiency - Wind

Growth of Wind Power in a World Wide Generation Context

2006	Windpower	Conventional
Growth	26.2%	3.3%
Average asset utilization	25%	50%
Added capacity in 2006	15 GW	126 GW
Added produced energy in 2006	32 TWh **(5%)**	562 TWh **(95%)**

Electrical energy conversion efficiency - Wind



- Windpower growth continues at 15% / year

Electrical energy conversion efficiency - Wind

Wind Power Generation's share of the World-Wide Generation

- Windpower in 2016:
  - 4% of world's installed electricity production
  - 15-20 % of world's yearly added produced energy

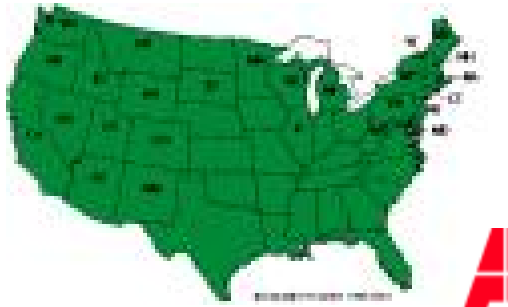
Electrical energy conversion efficiency - Solar

- Hydro power at Itaipu (Brazil)
  - 12’600 MW installed power
  - 80 TWh per year (util. factor = 72%)
  - Dam 200 x 7 km = 1400 km^2
- Solar power in South Europe
  - Solar irradiation 5 kWh/m^2 and day
  - 1400 km^2 equipped with 20 % efficiency solar cells
  - 500 TWh per year
- 380 thousand km^2 of solar cells to cover all world energy

Itaipu dam

Solar cells

Sweden 450 thousand km^2

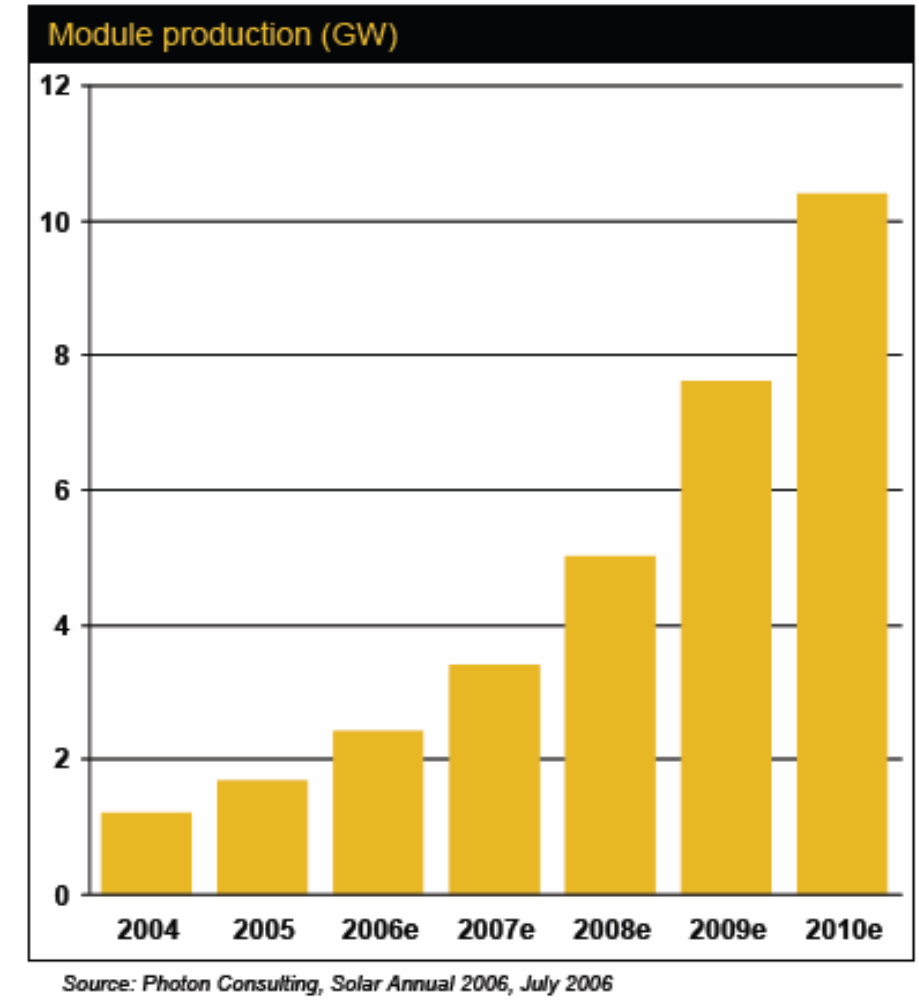


USA 9.6 million km^2

Source: G. Asplund, ABB Power Systems, Sweden

Electrical energy conversion efficiency - Solar

- World production of photovoltaic cells increase very rapidly (40-50% growth rate)



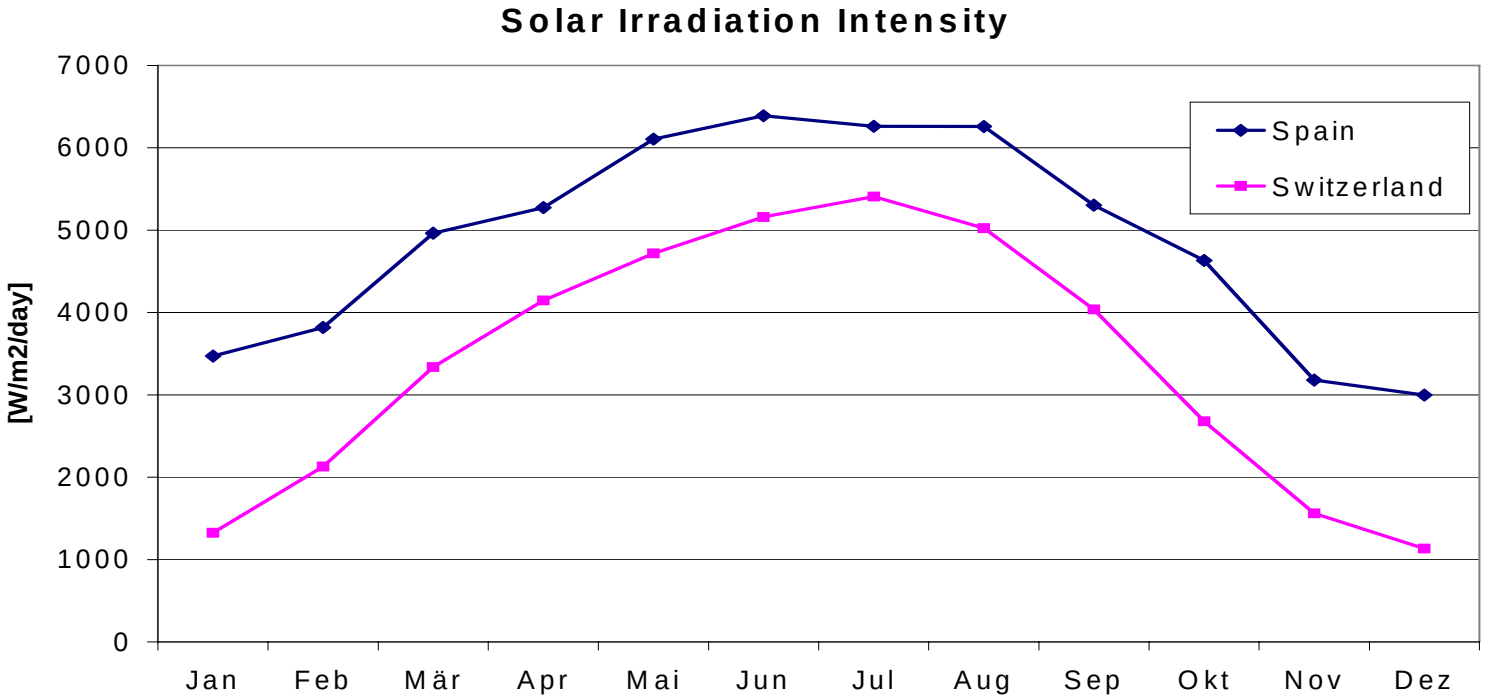
Area needed for Europe's electricity
25000 km^2

Surface of Sahara
9 million km^2

Source: G. Asplund, ABB Power Systems, Sweden

Electrical energy conversion efficiency - Solar

- Spain (1kWp installation)
  - 1500 kWh / year (fixed) or 2100 kWh / year (controlled orient.)
  - 15-25% average utilization factor
- Switzerland (1kWp installation)
  - 1000 kWh / year (fixed) or 1400 kWh / year (controlled orient.)
  - 10-15% average utilization factor (at full power)



Electrical energy conversion efficiency - Solar

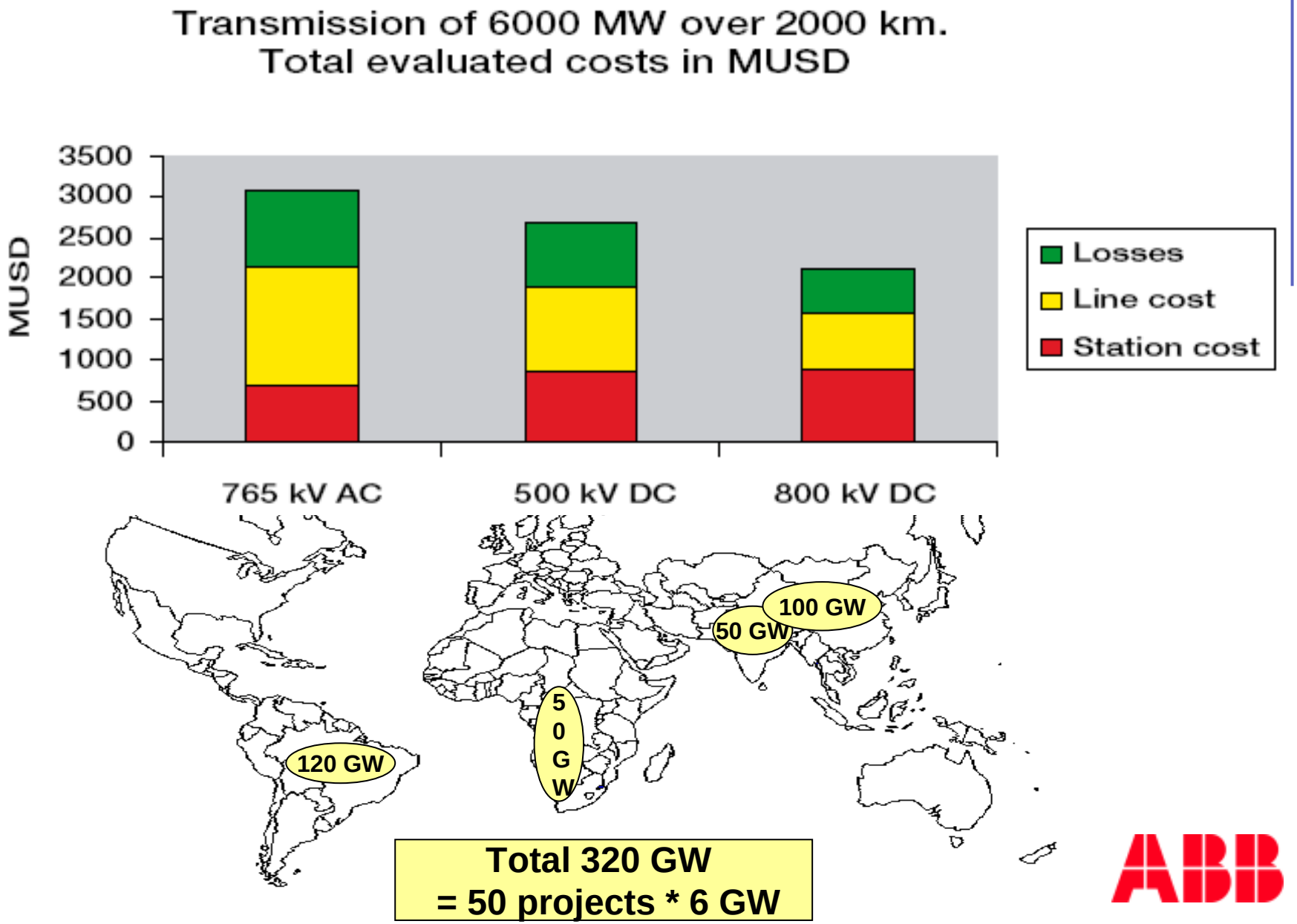
- Simple technology has the potential to spread fast
- Switzerland has 70% of the solar irradiation of Gibraltar
  - Limited basic disadvantage
  - Use orientation intelligence (40% benefit)
- Leadership in Renewables created in the EU
  - €20 billion turnover and
  - 300.000 jobs

- Solar in 2016
  - 2-20% of world's yearly added produced energy
    - 2% with yearly growth rate of 20% - LOW assumption
    - 20% with yearly growth rate of 50% - HIGH assumption
  - Will outperform windpower in the long run

Energy efficiency

- Generation, distribution and processes
  - Primary energy transport
  - Electrical energy conversion efficiency
  - Transmission losses
  - Production processes
  - Equipment efficiency

Transmission losses – Ultra High Voltage



Energy efficiency

- Generation, distribution and processes
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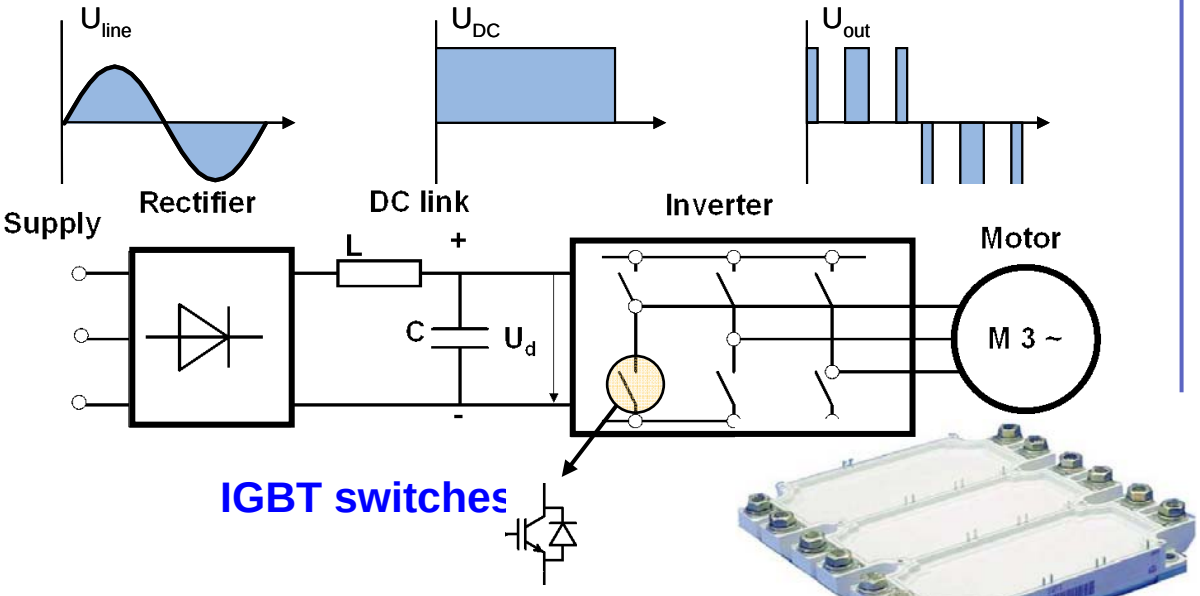
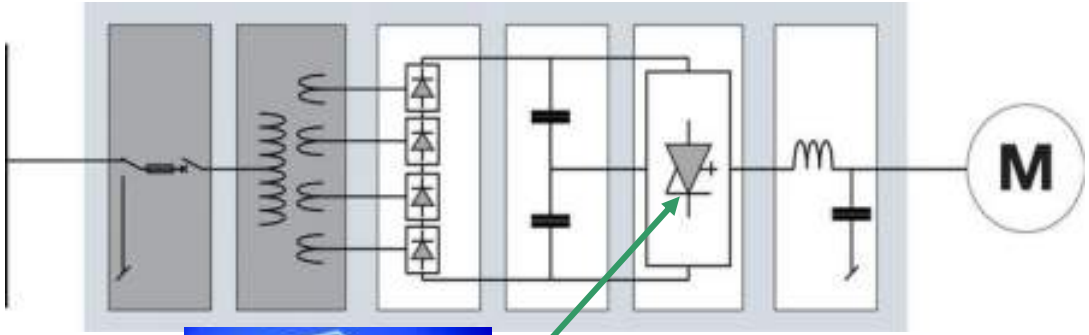
Variable Frequency Drives – VFDs

0.18 to 5600 kW
110 V – 690 V



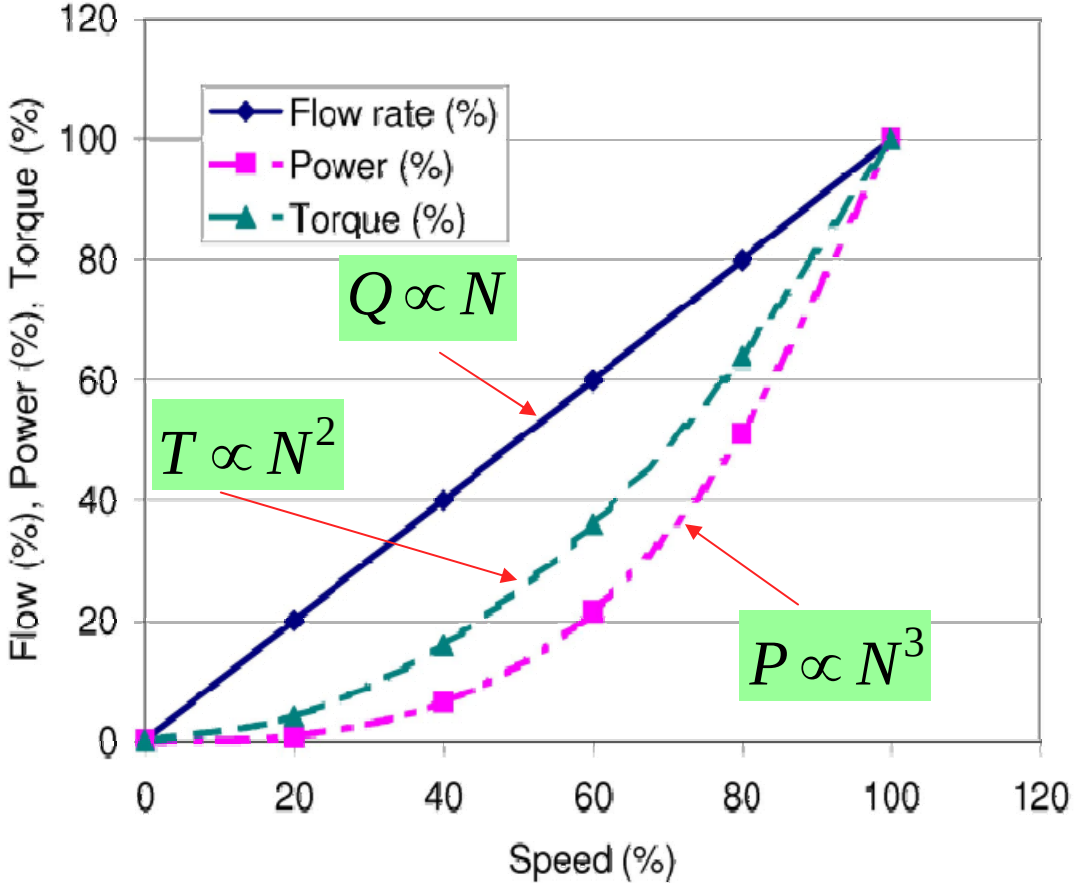
3-27 MW/ 3kV
0.3 – 5 MW/ 2.3/3.3/4kV
2-22MW / 6/6.9 kV



IGCT Switches

Where Can Motor Drives Save The Most?

- Pumps, fans, and blowers are the applications with highest saving potential
- Power varies largely as a function of the flow rate

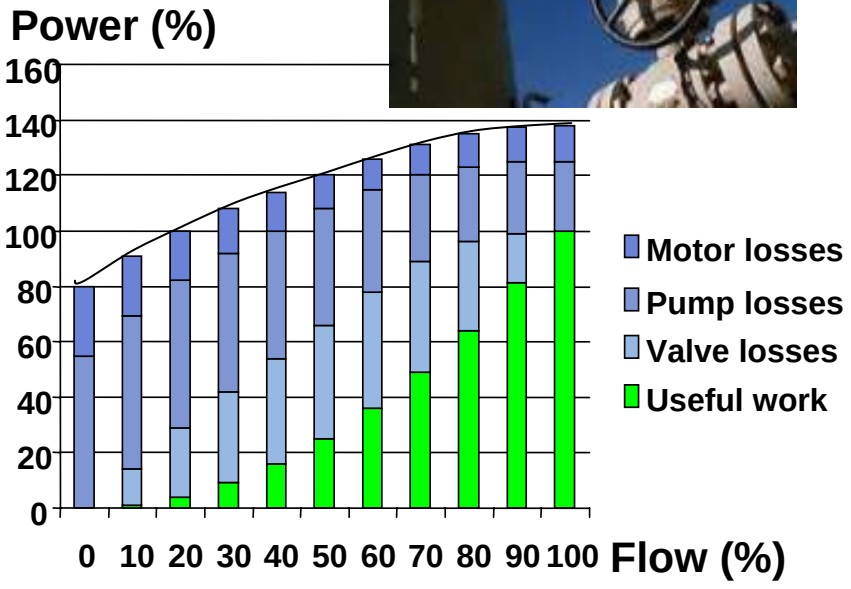


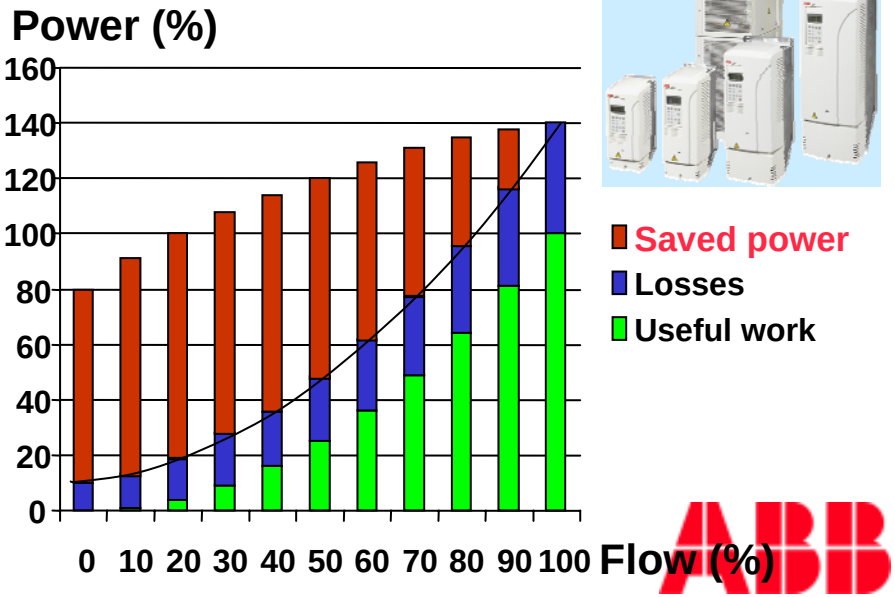
Affinity Laws

Small Flow Reduction ➔ Large Power Reduction

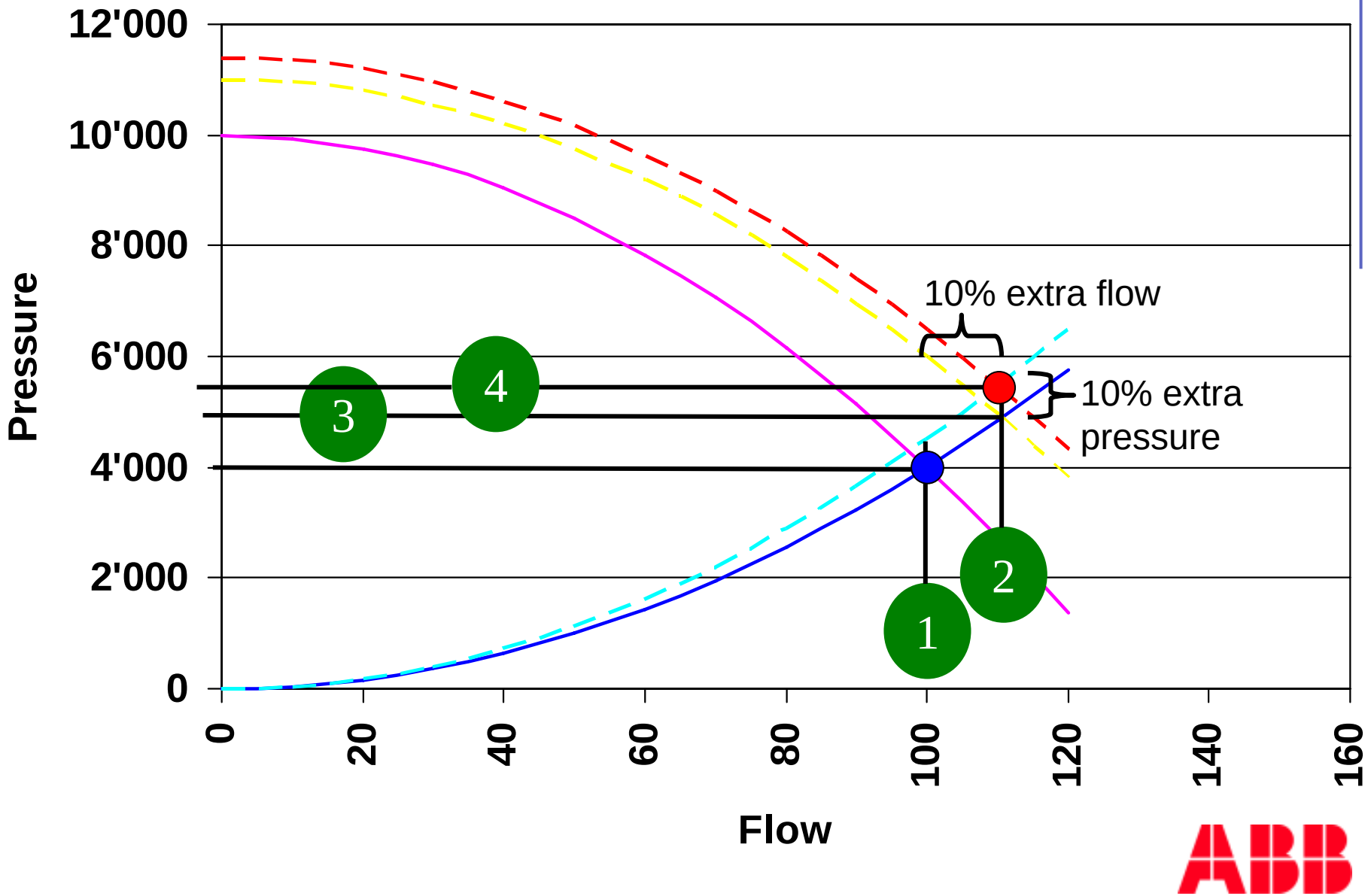
Equipment efficiency – Pumps

- For each 1 EUR spent to purchase a motor, 100 EUR are spent for energy cost during its lifetime
- Many motors still run at fixed speeds, power electronic drives can control the speed of the motor to match output with the needs





BIG Potential as Systems Are Oversized…



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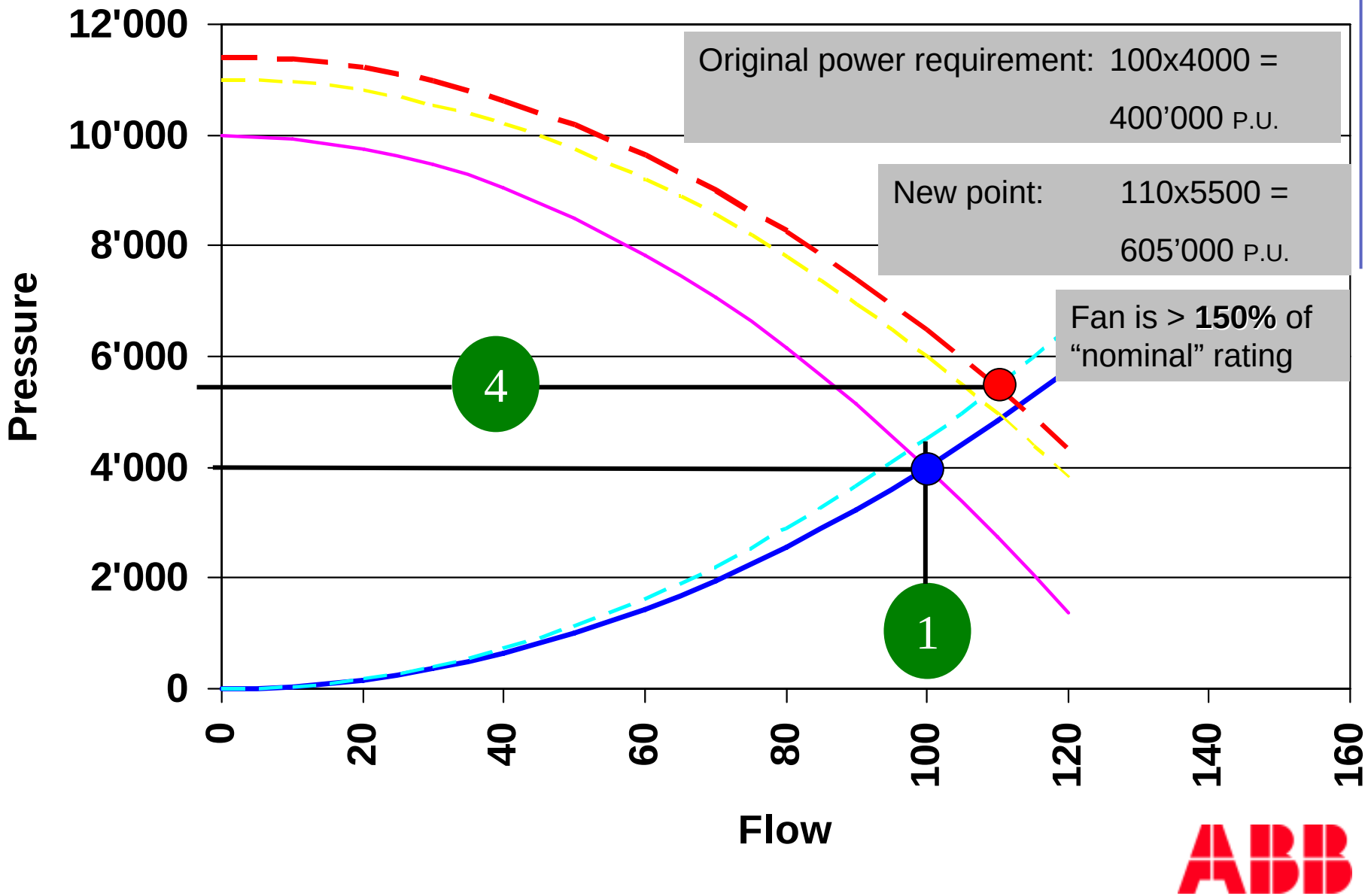


PumpSave

v 4.0.B

Energy saving calculator for pumps

Traditional flow control methods compared to variable speed AC drive control

RESULTS

DATA

PROFILE

ECONOMICS

EQUIPMENT DATA - EXISTING

System Data

Liquid density: 1'000 kg/m³ — Static head: 10 m

Pump Data

Nominal volume flow: 1000 m³/h => 277.8 l/s — Efficiency: 85%

Nominal head: 30 m — Max head: 45 m

Head over open throttling valve: m

Existing flow control method: Throttling control

Motor Data

Supply voltage: 400 V (380/400/415 V)

Motor power: 110 kW — Required motor power: 105.8 kW including 10% safety margin

Motor efficiency: 96.0 %

GENERAL DATA

Calculated by:	PB
Calculated for:	PCIM
Pump ID:	

EQUIPMENT DATA - NEW

Improved flow control by: ABB standard drive (ACS550)

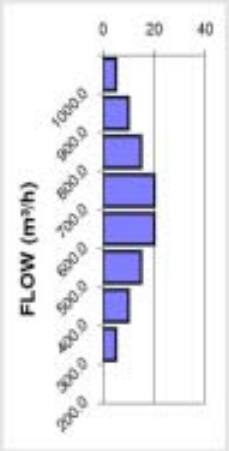
ACS550-01-195A-4

Operating Profile

Annual running time: 5'000 h

5 %	=	250 h	at nom. flow
10 %	=	500 h	at 90% flow
15 %	=	750 h	at 80% flow
20 %	=	1000 h	at 70% flow
20 %	=	1000 h	at 60% flow
15 %	=	750 h	at half flow
10 %	=	500 h	at 40% flow
5 %	=	250 h	at 30% flow
%	=	0 h	at 20% flow

100



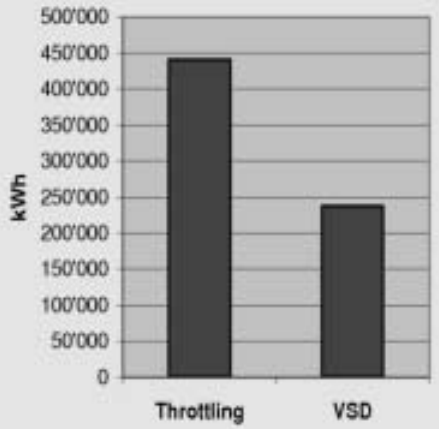
Economic Data

Currency unit	EUR	
Energy price	0.05	EUR/kWh
Investment cost	11'000	EUR
Interest rate	10%	
Service life	10	years

RESULTS

Energy & environmental

Energy Consumed



Saving percentage	46.0 %	
Annual energy consumption:		
with existing control method	440'436	kWh
with improved control method	237'970	kWh
Annual energy saving	202'466	kWh
Annual CO_2 reduction	101'233	kg
CO_2 emission per unit	0.5	kg/kWh

Economic results

Annual money saving	10'123	EUR
Payback period	1.1	years
Net present value (NPV)	51'203	EUR

ABB

Potential Savings - MV Drives worldwide

Installed MV motors	500’000	Motors
Motors used for square torque loads (2/3 of motors)	333’000	Motors
Installed power used to drive square torque loads (1500 kW AVG motor power)	500’000’000	kW
Motors without frequency converters (Less than 4% MV motors have a VFD)	300’000	Motors
30% of these motors have a large energy saving potential	90’000	Motors
Electricity consumption[1]	569	TWh
World wide yearly energy saving potential (40% savings assumed)	227 *) eq. to 35 GW	TWh
The EU-15 saving potential is appr. 20% of above	45 *) eq. to 7 GW	TWh

[1] Assumptions: 2/3 of the motors operate 7500h/yr and 1/3 operate 1850 h/yr. Average load 75% of rated power.

Source: P. Wikström, ABB MV Drives, Switzerland

Potential Savings - Drives worldwide

Yearly Savings

Saving of MV Drives ~ 227 TWh

- Only 4% are variable speed today
- 30% of pumps / fans converted to VSD

Saving of LV Drives ~ 1655 TWh

- 10 x the installed power of MV motors
- Already 30% are variable speed today
- 30% of remaining pumps / fans converted to VSD

Total saving of Variable speed drives ~ 1882 TWh

- 1920 TWh would correspond to more than 22 Itaipu Hydro power stations (equivalent to 275 GW installed capacity)
- Typical payback time: 1-3 years

[1] Assumptions: 2/3 of the motors operate 7500h/yr and 1/3 operate 1850 h/yr. Average load 75% of rated power.

Energy Use in Industry: Examples

- Replacement of steam turbine by VFD to control blast furnace blower
- Reduced maintenance costs
- Energy savings: 16 GWh/year
- Payback: 2 years

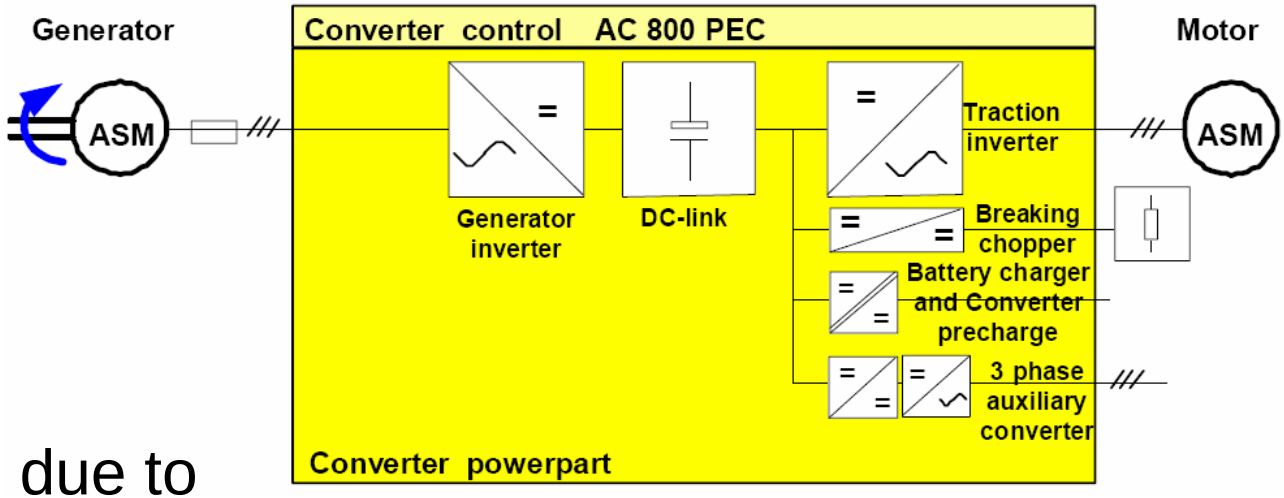
METALS

- Variable speed mixers improved production efficiency & quality
- Reduced noise
- Energy savings of 30%
- Payback: < 2 years

PETRO-CHEMICAL

Equipment efficiency – Transportation

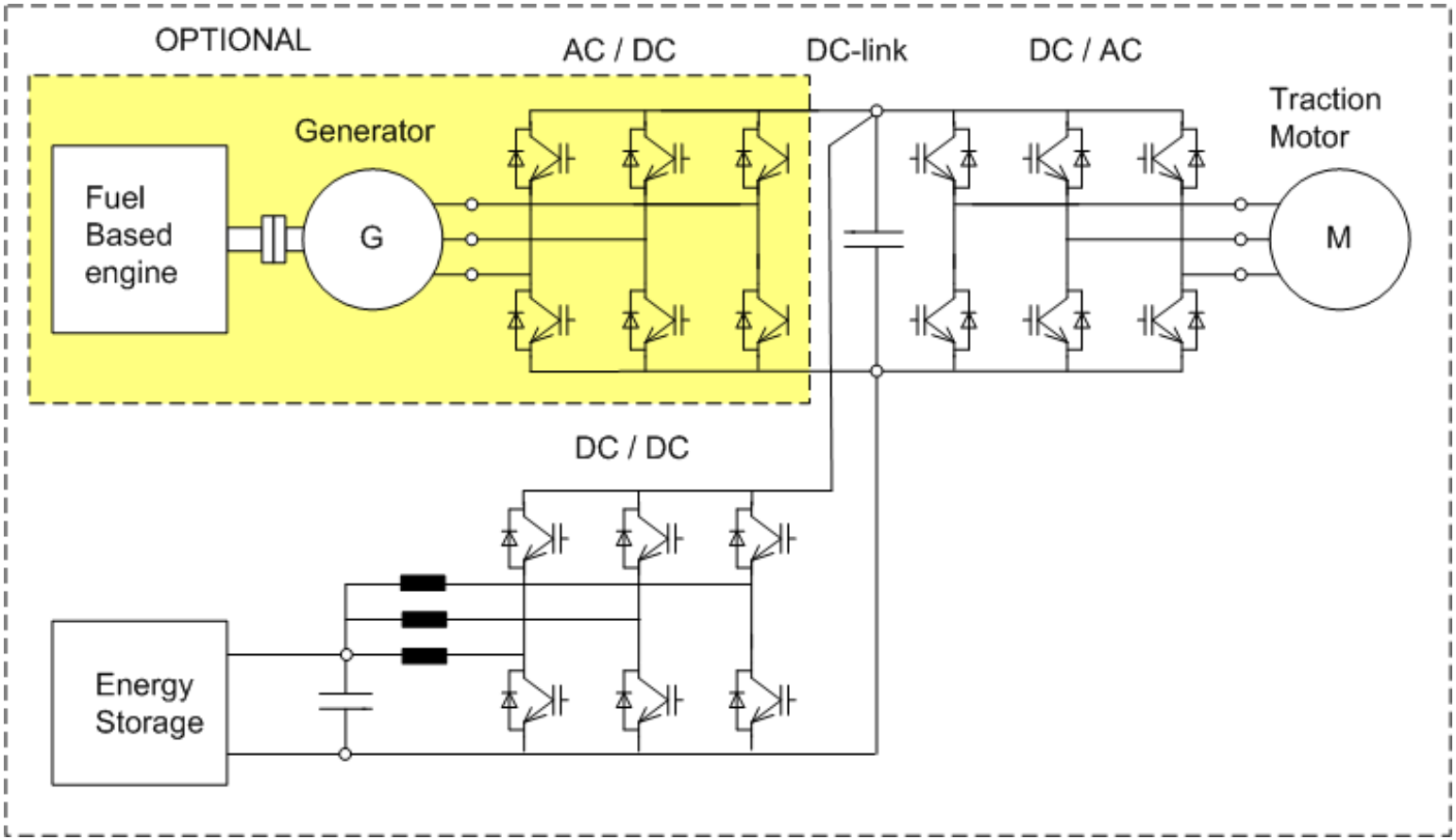
- Common DC-link power systems connect variable speed energy generation, energy storage and traction motor for
  - Cars
  - Buses
  - Trains and
  - Ships



- Energy savings due to
  - Variable speed power generation of fossil fuel based systems
    - up to 30% fuel saving, if used in part load conditions
  - Energy storage for fossil fuel based (and grid supplied) systems
    - 30% fuel saving in acceleration / deceleration mode demonstrated
- This benefits would exist, but are not considered by operators, manufacturers or users

Equipment efficiency – Transportation

- Generically high-efficient DC-link based Power System



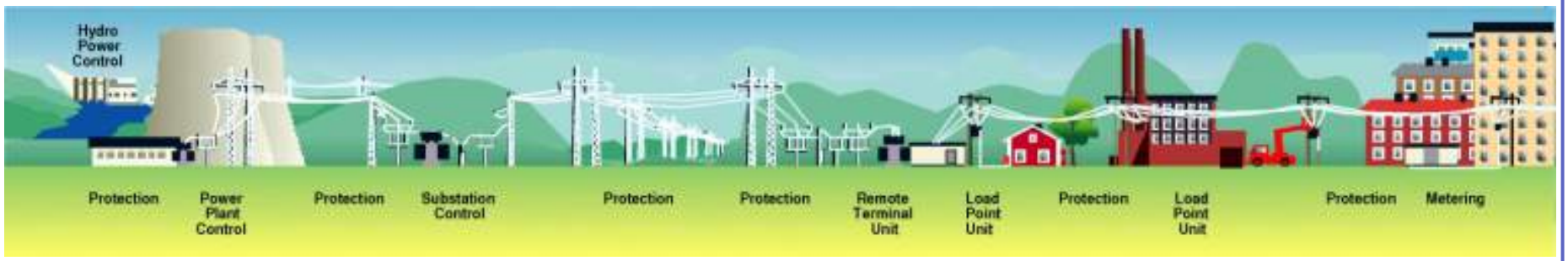
with variable speed power generation and energy storage

- For (hybrid) cars, buses, trains, airplanes, ships, …

We can achieve a lot in the next 10 years…

- Governments have the RESPONSIBILITY to create the boundary conditions to accelerate the needed change
- We Engineers know, WHAT needs to be done for a much more efficient use of energy
- We have ALL the technologies to do it NOW
  - Efficient bulk power generation (nuclear) incl. use of waste heat
  - Variable speed drives to replace industrial gas turbines drivers
  - Renewables (Wind, Solar, ..) are important future contributors
  - SOLAR power to be taken serious, it may develop much faster
  - Another 30% of PUMP and FAN applications need to be converted to Variable speed drives (40% energy saving)
  - Realize 30% (and more) fuel / energy consumption reduction with the DC-link based power system to enable efficient hybrid (or pure electrical) solutions in TRANPORTATION (cars, buses, trains,..)

Power Electronics: A Core Technology Platform



Sustainability | **Supply security** | **Energy Efficiency** | **Productivity** | **Quality of life**

POWER ELECTRONICS IS THE KEY TECHNOLOGY FOR EFFICIENT ENERGY USE AND RENEWABLES

Power and productivity
for a better world™