“Sustainability Indicators for Energy Systems to Enhance Decision Making Processes”

25th USAEE/IAEE North American Conference,
September 18 – 21, 2005
Interlocken, Denver / Colorado

T. J. Petrovic and H.-J. Wagner

Chair for Energy Systems and Energy Economics
Ruhr-University Bochum
e-mail: lee@lee.rub.de

- Motivation
- What does „sustainability“ mean for the energy sector?
- Sustainability indicators
- Evaluation of energy systems
- Conclusion

→ Guidance for investment planning

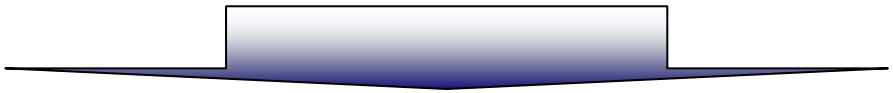
→ Technological impact assessment

→ Future planning (scenarios)

→ Verification: Compliance with political targets?

→ System benchmarking

→ Identification of main research areas

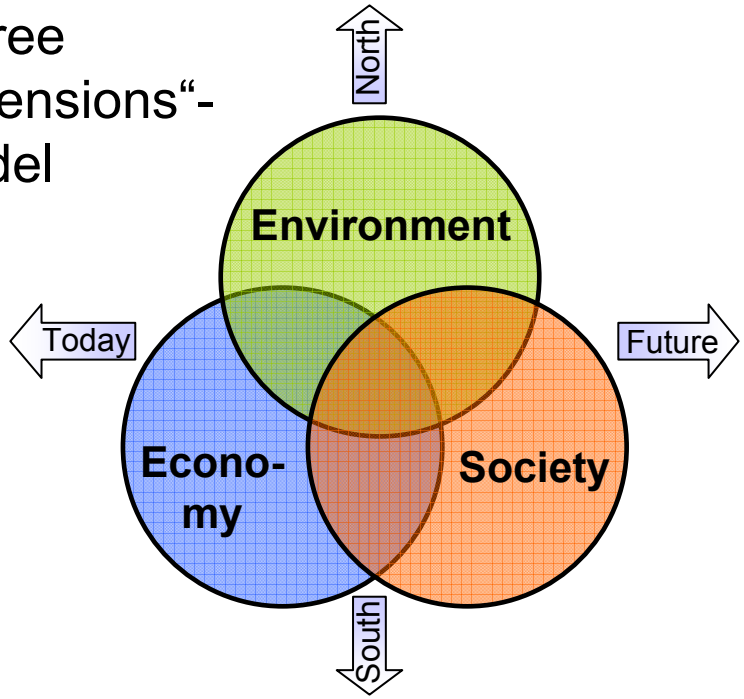


Indicators / Indicator systems

“Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”

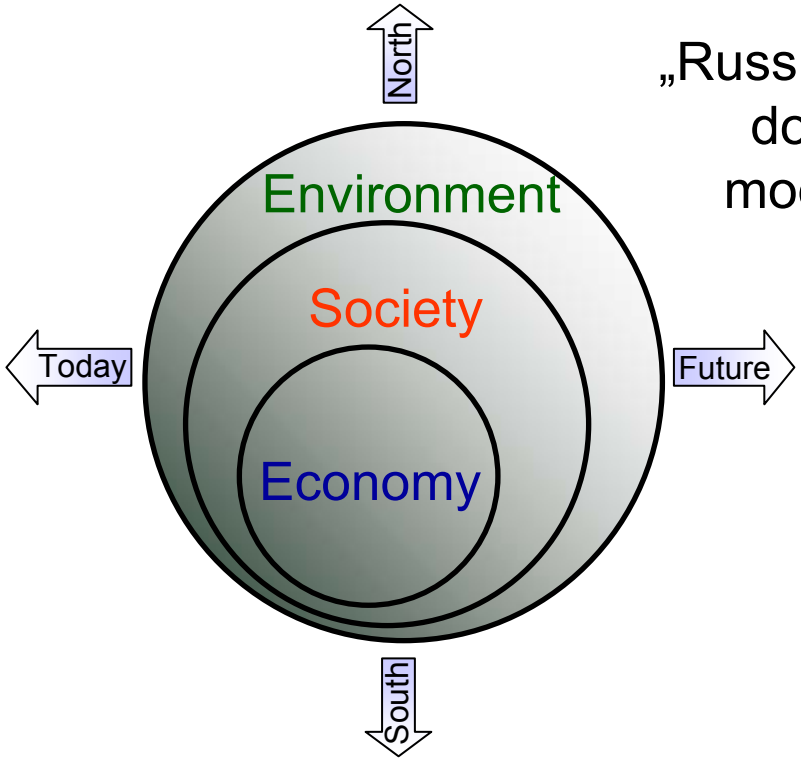
source: UN 1987, p. 54 („Brundtland report“)

Three
limensions“-
model



ource: SIA 2000, modified

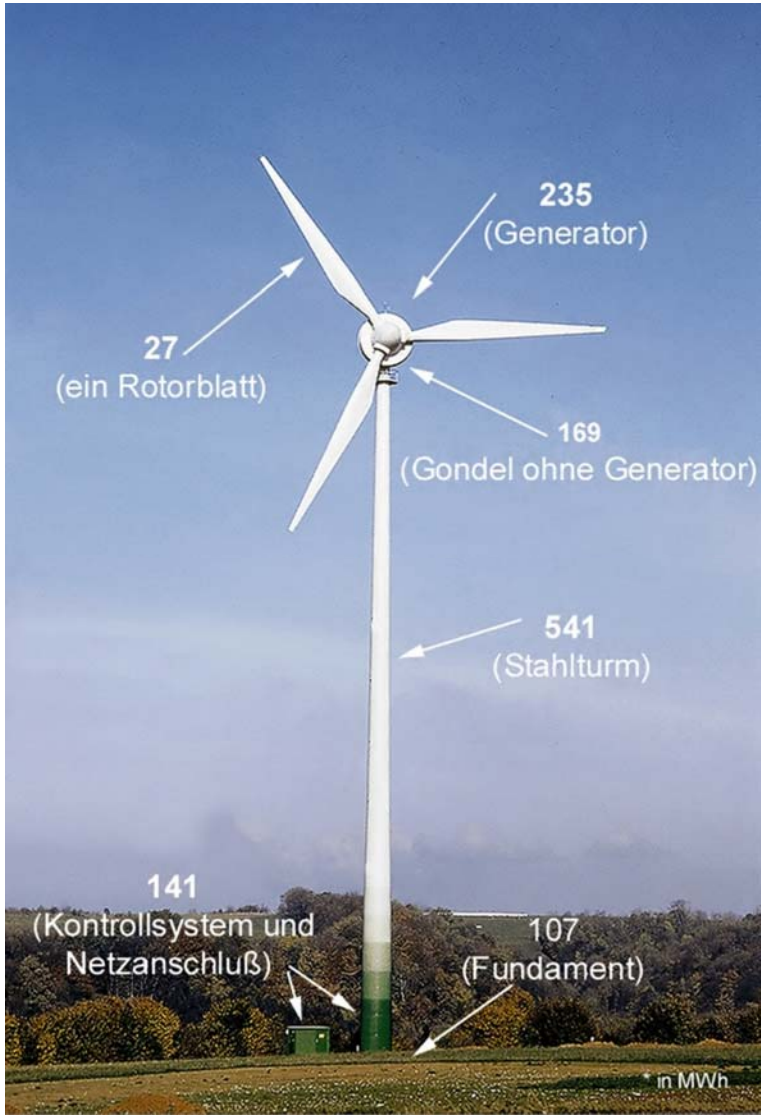
„Russian
doll“-
model



source: Levett 1999, modified

Energy security related risks	➢ Covering supply, technical and economical related risks ➢ Aggregation via measure for concentration tendencies (Hirschman-Herfindahl index)
Cumulated Energy Demand	➢ According to VDI guideline 4600: totality of energetic expenditures ➢ Distinction of sustainable / non-sustainable energy expenditures
Energy Costs	➢ Calculation with annuity method according to VDI guideline 2067 ➢ A 5% discount rate was used.
Gross Employment Effects	➢ Induced by installation of 1.000 MW capacity of a specific technology ➢ Comparison of two scenarios: „business as usual“ vs. „installation“ ➢ Software: MARES*forte*
Usage of Air Resources	➢ Critical air volume that is necessary to attenuate emissions accurate to limits that are defined and regulated by law
Usage of Water Resources	➢ Critical water volume that is necessary to attenuate water based pollutants accurate to limits that are defined and regulated by law
Land Use	➢ Direct land use by energy system and infrastructure ➢ Indirect land use due to visual disturbance of the environment (= buffer area trading off the visual impact)

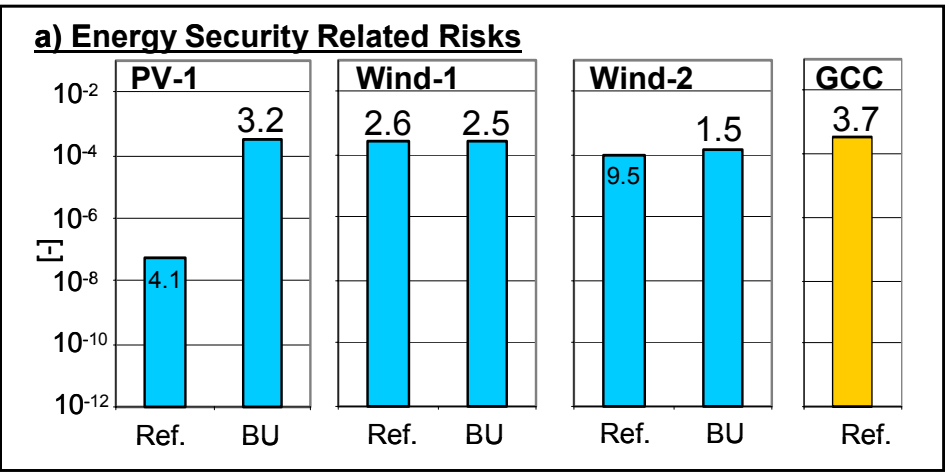
hotovoltaics field system

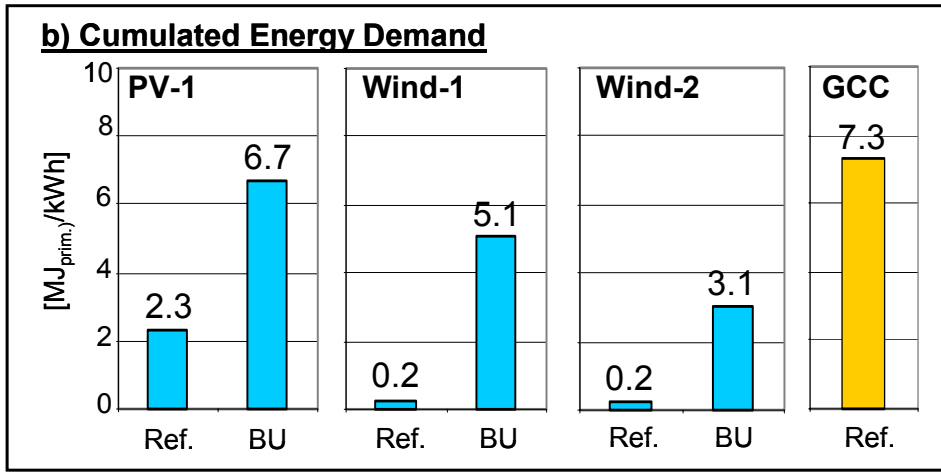


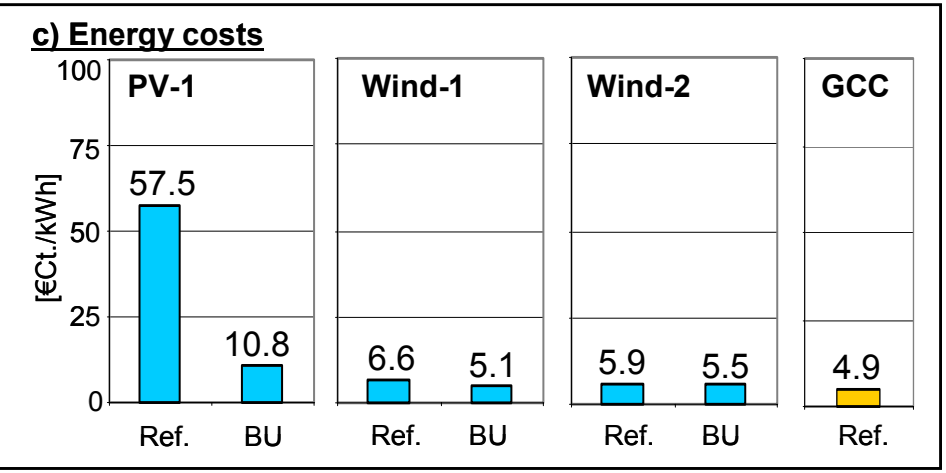
Wind energy converter

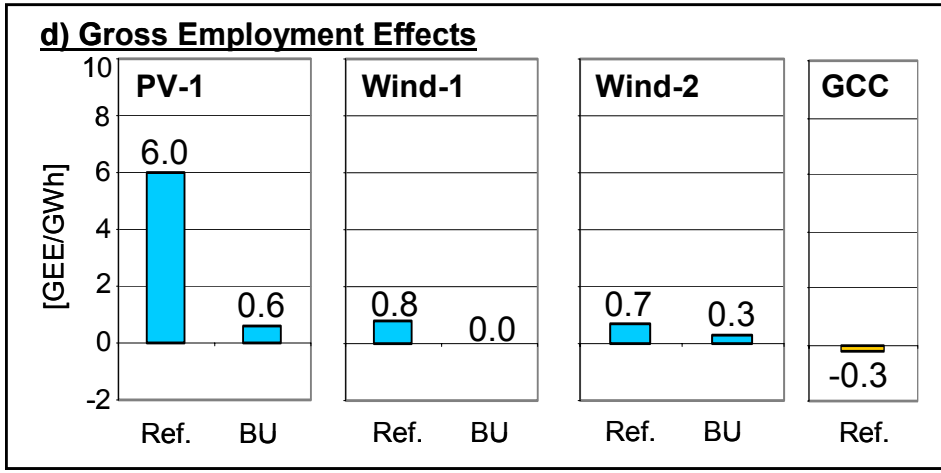
Reference System Specification	PV System field unit	Wind energy converters onshore	 offshore	GCC plant NG fired
Installed capacity [MW]	0.5	1.5	5.0	353.0
Expected lifetime: System (IS*) [a]	20 / (40)	20 / (40)	20 / (40)	30 / (40)
System efficiency [%]	13.2	53.6	47.7	58.0
Solar irradiation [W/m^2]	1,000	-	-	-
Wind speed [m/s]	-	6.5	9.0	-
Capacity factor [%]	8.8	25.1	47.9	79.9
Investment costs (IVC) [€/kW]	5,110	1,250	1,700	1,330
Operational costs p. a. [% of IVC]	0.50	6.0	8.0	3.3

*IS: Infrastructure

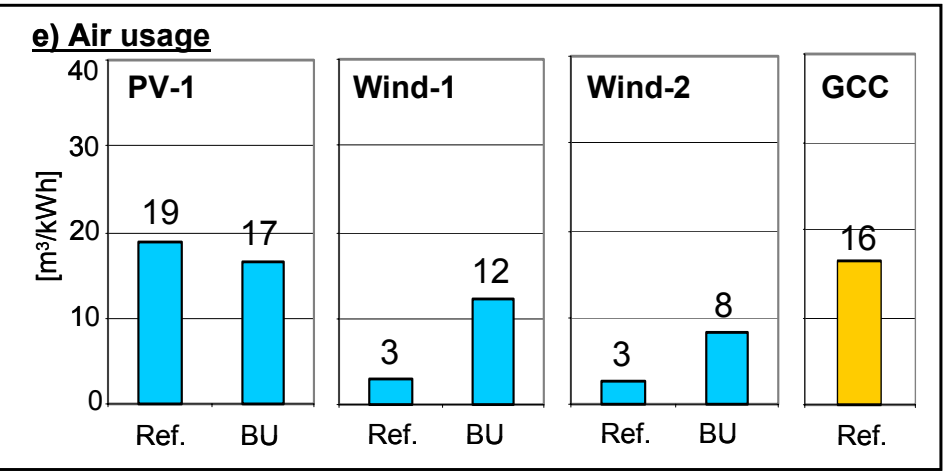


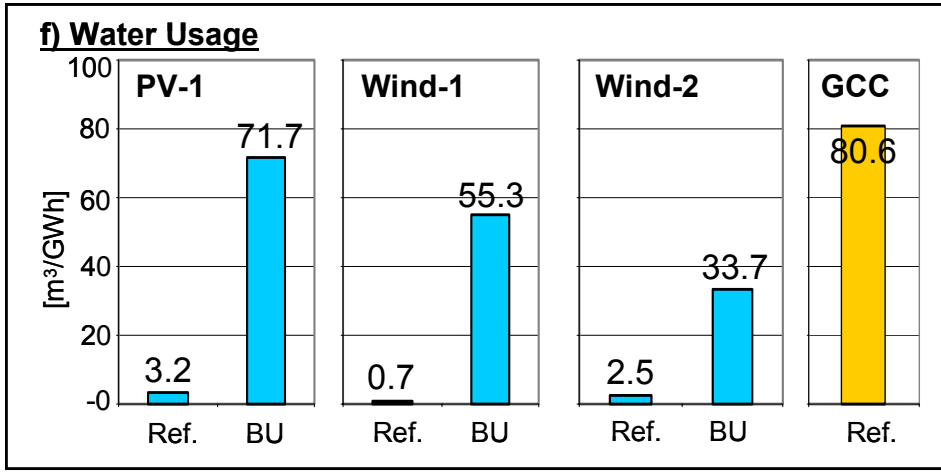


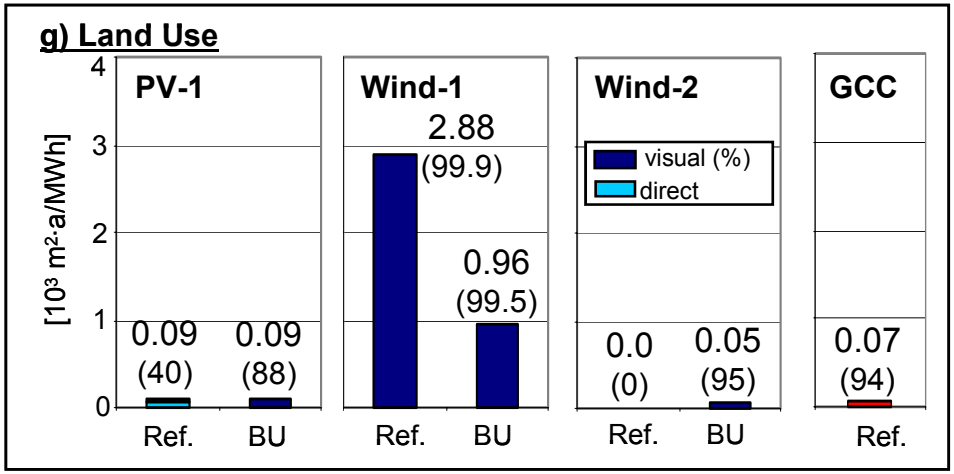




RUHR - UNIVERSITÄT BOCHUM
LEE Lehrstuhl für Energiesysteme und Energiewirtschaft
Prof. Dr.-Ing. H.-J. Wagner







RUHR - UNIVERSITÄT BOCHUM
LEE Lehrstuhl für Energiesysteme und Energiewirtschaft
Prof. Dr.-Ing. H.-J. Wagner

→ Development of transparent procedures for review and selection of sustainability indicators.

→ Gaps concerning the social-economic dimension of sustainability could be closed by new indicators:

- energy security related risks
- gross employment effects.

→ Practicability of the indicator system is guaranteed due to a small number of indicators.

→ Renewable energy systems can clearly contribute to a sustainable development of the energy sector.

→ Strengths and weaknesses regarding individual indicators illustrate need for a diversified structure of the energy system.

→ The integrated view on energy and backup systems laeds to a poorer performance regarding most sustainability indicators.

→ However, the combination of renewable and conventional energy systems is beneficial compared to a stand-alone conventional power plant.

Thank you for your attention!

→ Energy Security Related Risks:
Risks attributed to inconstant renewable energy supplies lie in the same range as geopolitical risks due to natural gas imports (GCC plant).

→ Cumulated Energy Demand:
- energetic expenditures for power generation are lowest for wind energy systems and highest for the GCC plant,
- most of the expenditures for the GCC plant are "non-sustainable".

→ Energy costs:
- wind power generation is almost competitive with GCC plant,
- PV is an order of magnitude more expensive.

→ Employment effects:
- renewable systems show well positive effects,
- a negative effect occurs with the GCC plant.

→ Use of environmental resources (air, water, land):
The indicators show a heterogenic pattern.
- highest air usage attributed with PV systems tracing back to production processes,
- highest water usage attributed with the GCC plant, tracing back to the natural gas chain,
- highest indirect land use associated with the onshore wind facility, caused by visual impact on the environment,
- highest direct land use associated with PV system.