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Ukraine Sustainable Energy Lending Facility

Renewable Energy Technologies

Characteristics and Risks for Consideration during Project Development and Financing

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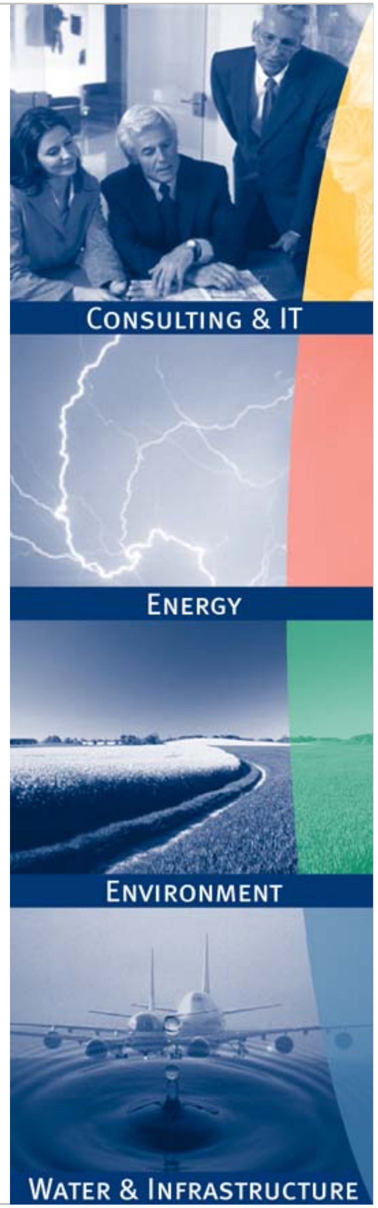

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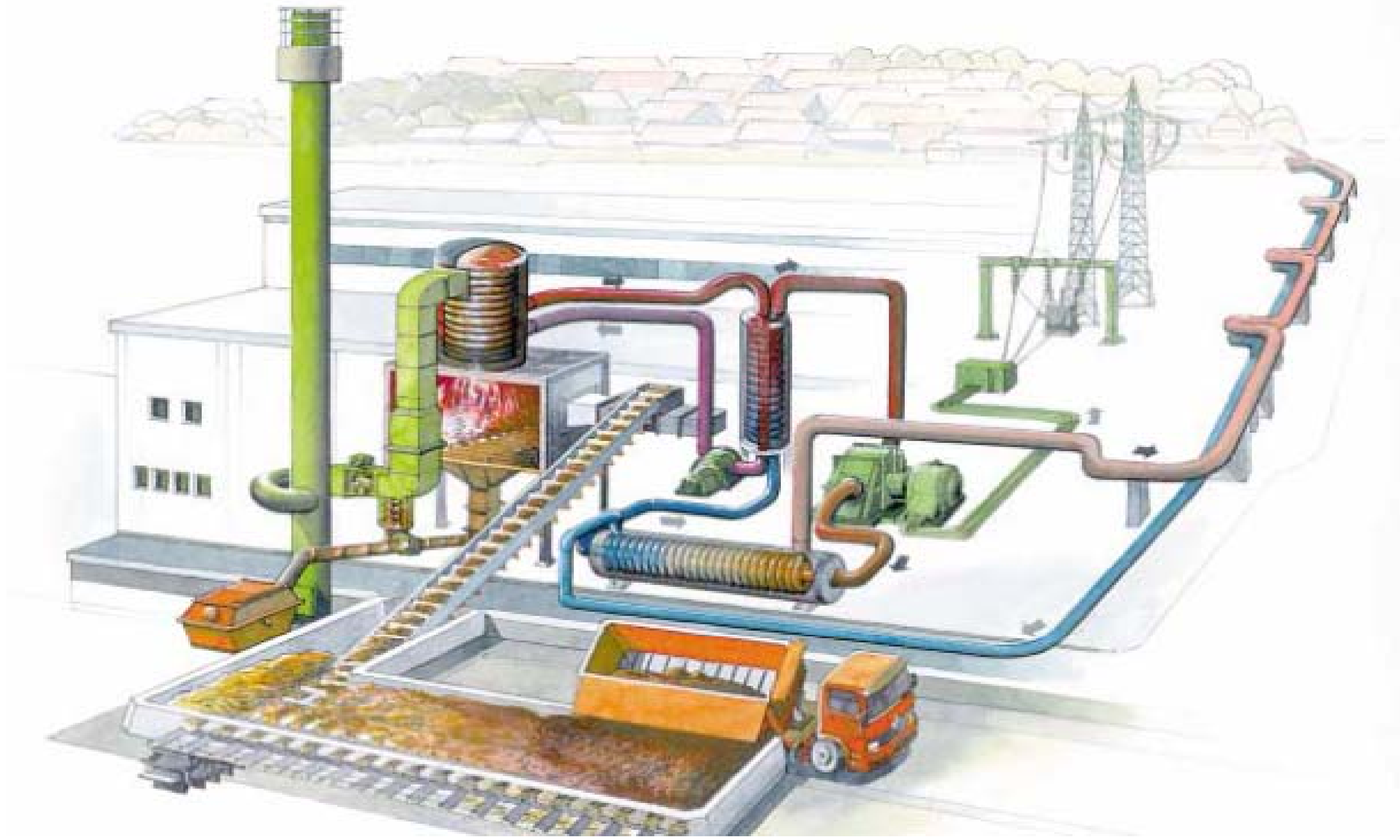
Agenda

- Biomass projects
- Windpower projects
- Photovoltaic solar projects (PV)
- Hydro power projects
- Financial models for renewable projects and risk assessment with Monte Carlo Simulation

Biomass power projects – types

- Steam cycles / steam turbines
- Biogas reactors / reciproking engines
- Gasifications systems / reciproking engines or GT
- ORC and Kalina / turbines
- Biodiesel/bioethanol / reciproking engines

Biomass Steam Plants



Biomass power (steam CHP) - characteristics

- CAPEX moderate to high (2.5 - 5.0 mn EUR/MW)
- CAPEX well predictable (modular standard solutions)
- OPEX high (staff costs)
- Fuel cost high in case of energy crops, wood and pellets
- Well scalable 1 MW - 20 MW, but high economies of scale
- Short planning and construction periods
- Waste heat use for co-generation often required for financial viability
- Site comparatively independent from fuel source; however, viable projects often on-site of biomass-waste producer (saw mill dust, furniture manufacturing wood waste, sunflower husks)

Biomass power (steam CHP) – risks and issues

- Price of energy crops and agricultural commodities
- Local wood supply may dry out due to demand competition from other plants or suppliers move price to the edge
- Low cost boilers suffer from fouling and grate slag
- Heat off-taker may close operation
- Transportation and wood collection costs underestimated in case other plants starts up in the region
- Developing and transition countries: cost of diesel oil determines benefits
- Benefit programs issues for ´multiple fuel boilers: operator uses coal, lignite or peat

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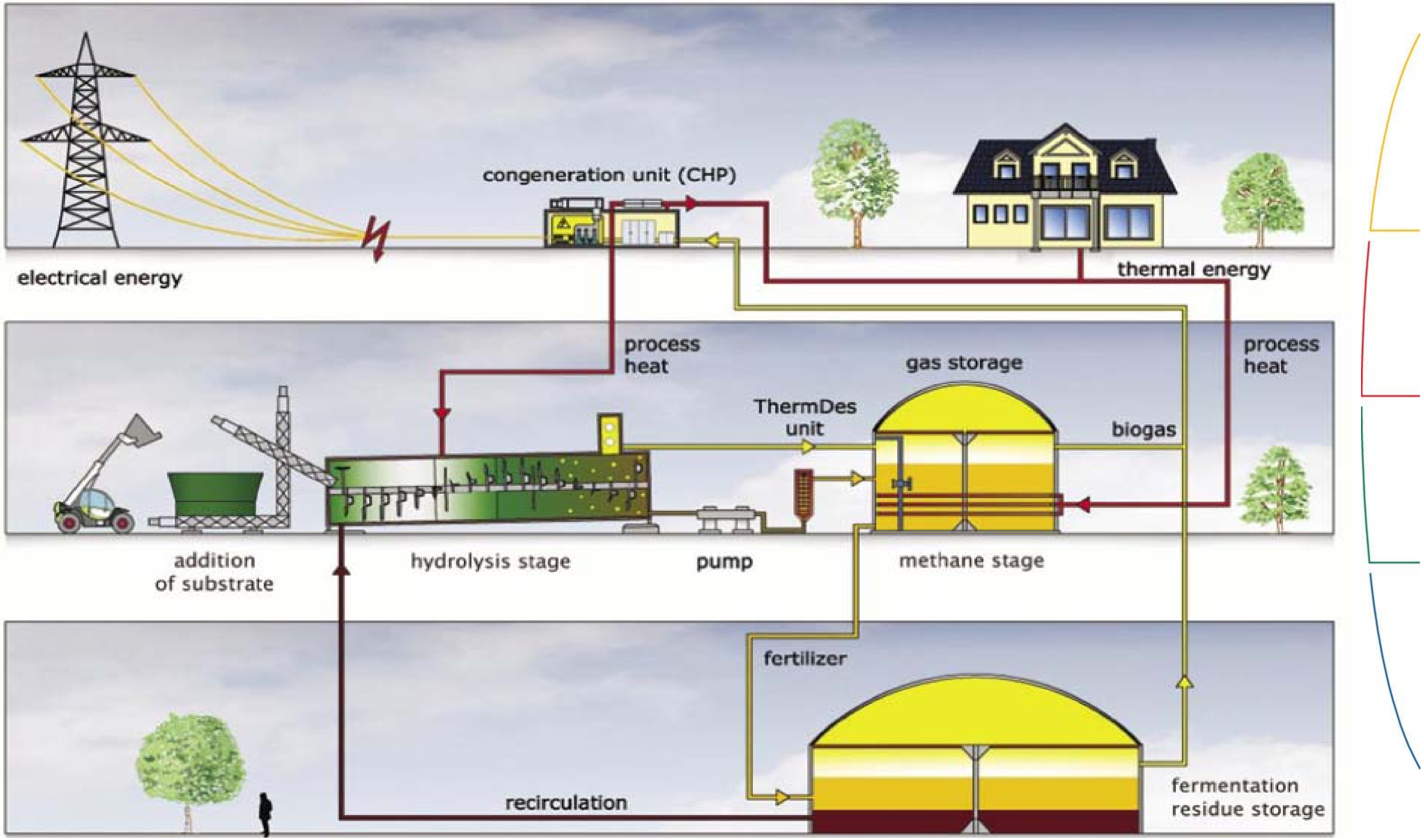
Biomass power - Biogas



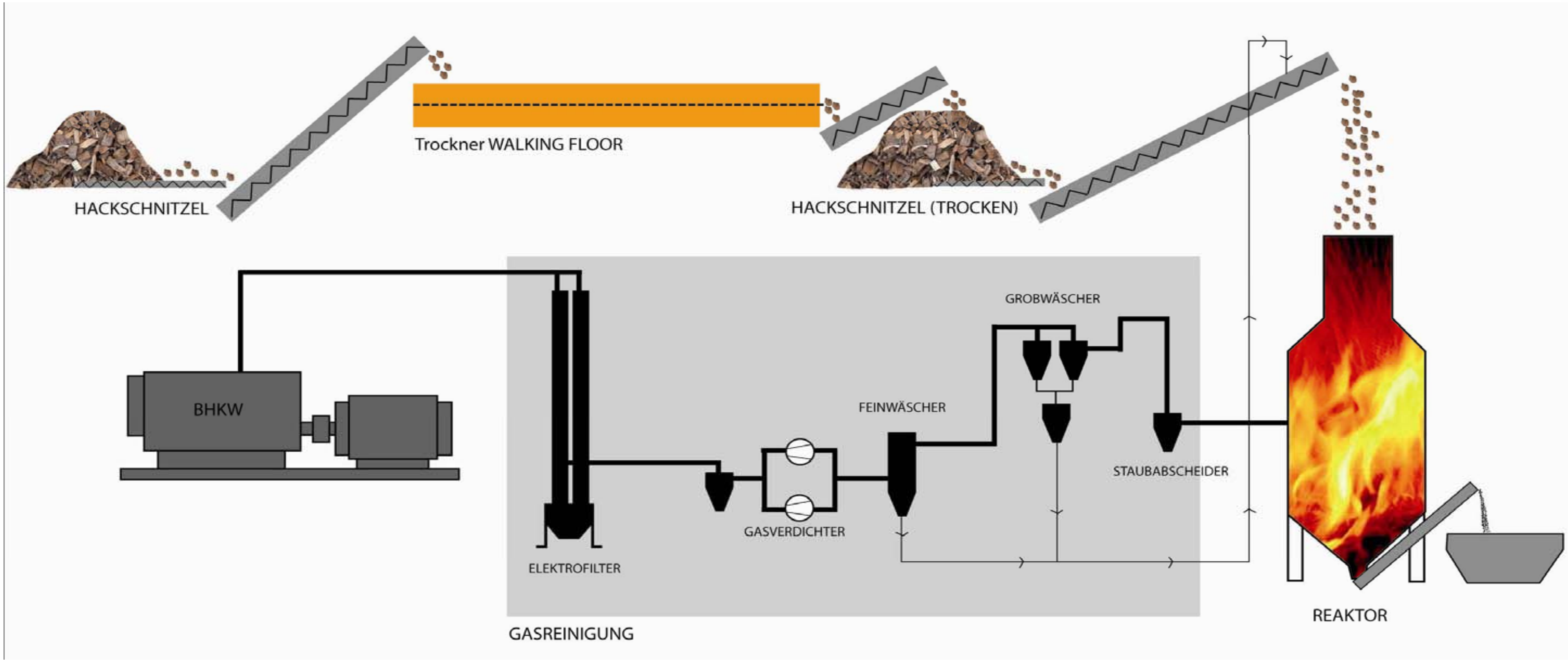
Biogas projects - characteristics

- CAPEX moderate to high (2-4.5 mn EUR/MW)
- CAPEX well predictable (modular standard solutions)
- OPEX very high (reciproking engines, reactor feed systems, own consumption)
- Fuel cost high in case of energy crops
- Well scalable 10 kW - 20 MW
- Short planning and construction periods
- A huge range of co-benefits (smell reduction, ground water protection, fertilizer, jobs in rural areas, efficient use of standby generators)
- Waste heat use for co-generation often required for financial viability but not possible
- Large projects often benefit from CDM

Biogas projects - risks

- Price of energy crops and agricultural commodities
- Fermenter operation requires skills and monitoring which are often underestimated (e.g. Mexico, Moldova)
- Heat off-taker may close operation
- Developing and transition countries: cost of diesel oil determines benefits

Biomass power - Gasification



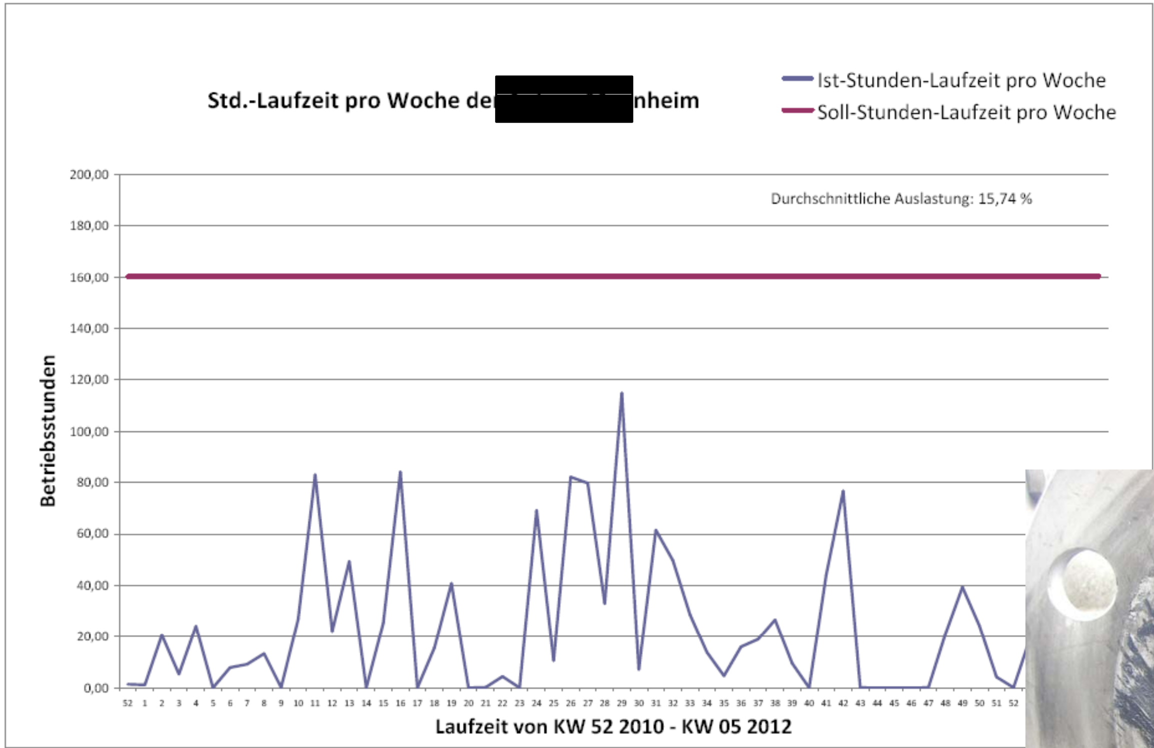
Gasification projects - characteristics

- CAPEX moderate to high (3-5 mn EUR/MW)
- CAPEX well predictable (modular standard solutions)
- OPEX high (staff costs; cleaning)
- Fuel cost high in case of energy crops, wood and pellets
- Well scalable 50 kW - 20 MW, but high economies of scale
- No mass production, technology/designs often unproven
- Short planning and construction periods
- Waste heat use for co-generation often required for financial viability
- Site comparatively independent from fuel source; however, viable projects often on-site of wood-waste producer

Gasification projects - risks

- Unproven design leads often to failed projects
- Track record of supplier is often not bankable (reference list with less than 10 projects)
- Availability often lower than expected (and lower than necessary for a viable project)
- Gasifier not suitable or adjustable for the the respective fuel
- OPEX underestimated (staff costs; cleaning, wear of engines)
- Local wood supply may dry out or suppliers move price to the edge
- Heat off-taker may close operation
- Transportation and wood collection costs underestimated in case other plants starts up in the region

Recent gasification experience…..



Biomass supply contract: Issues to be considered

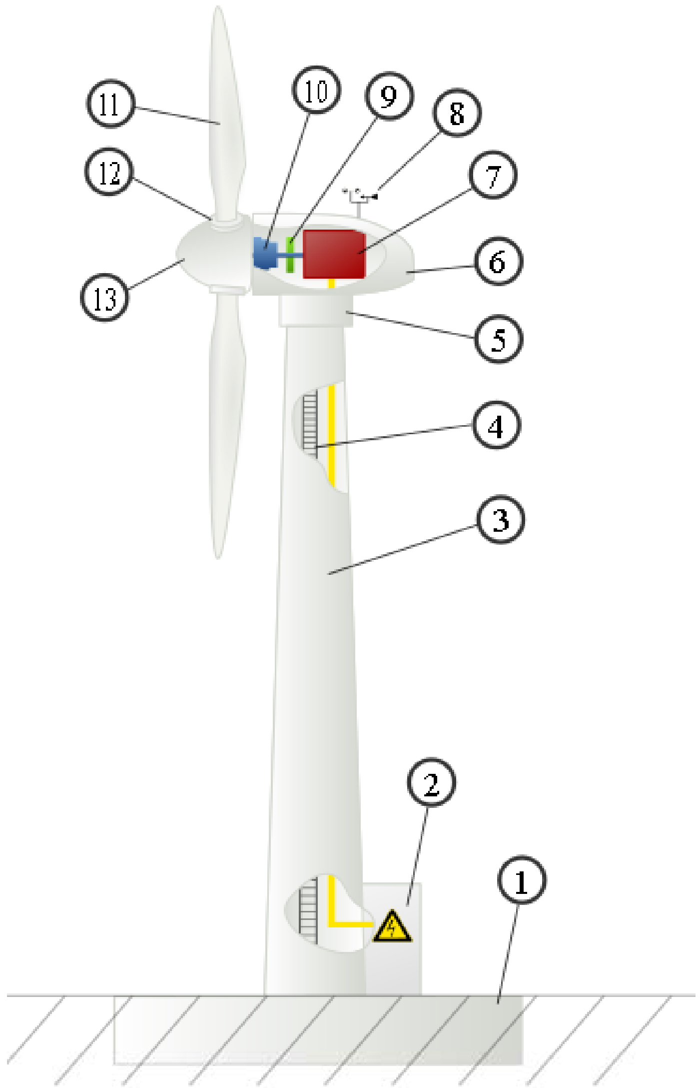
- Natural product: Amount and property of feedstock depends on weather, climate, season.
- Rapid fluctuation in production from one year to another possible.
- No constant quality: Representative samples on delivery, simple laboratory investigation.
- Price adjustment, e.g. to water content.
- Price escalation according to recognized indices
- Spread of supply risk: Several suppliers from different businesses.
- Conformity with “green tariff” requirements.
- Duration of contract: Project finance seeks long term validity. But long term contracts are not usual in farming / forestation.


Wind
Energy

Wind turbine technology

The wind turbine converts the kinetic energy of the wind to mechanical energy and then to electrical energy.

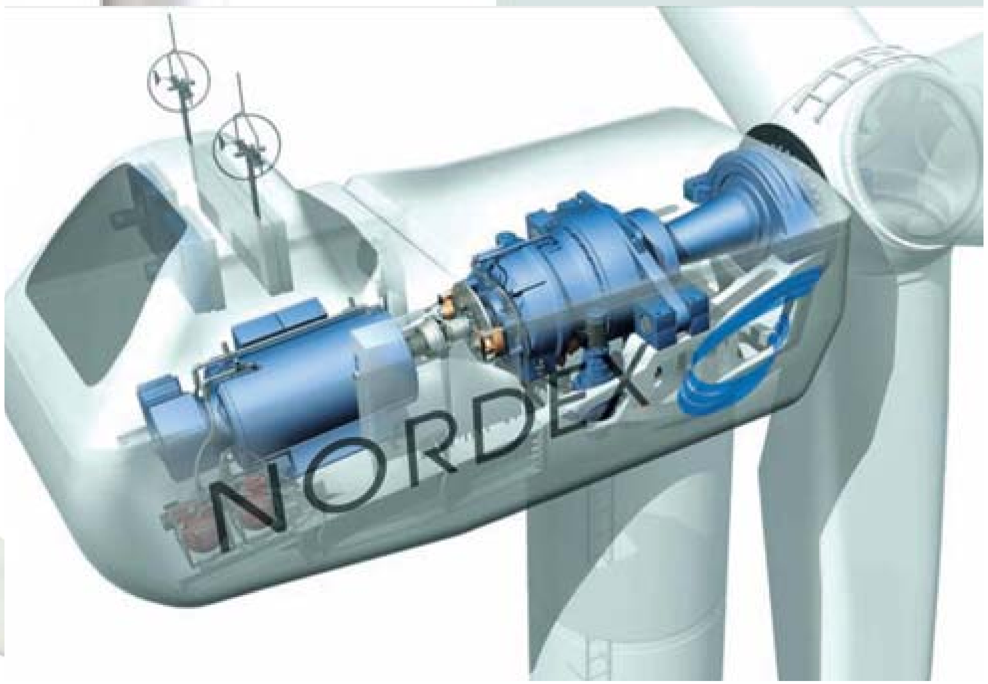
1. **Foundation**
2. **Connection to electric grid**
3. **Tower**
4. **Access ladder**
5. **Wind orientation control**
6. **Nacelle**
7. **Generator**
8. **Anemometer**
9. **Brake**
10. **Gearbox**
11. **Rotor blade**
12. **Blade pitch control**
13. **Rotor hub**



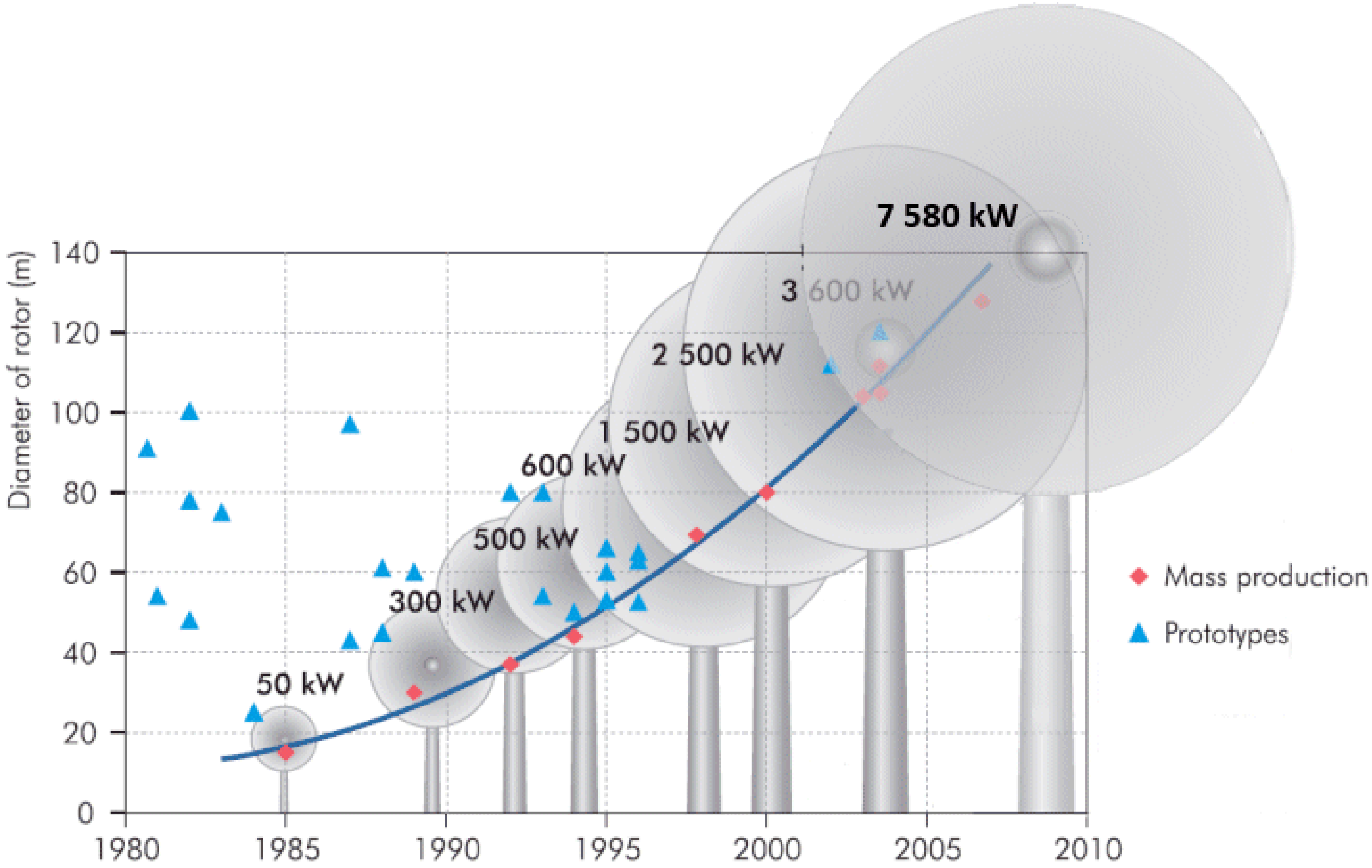
Graphic: A. Nordmann


1 Main carrier
2 Yaw drive
3 Annular generator
4 Blade adapter
5 Rotor hub
6 Rotor blade


Vestas


NORDEX

Wind turbine technology development



Source: International Energy Agency (IEA)

Wind energy - characteristics

- CAPEX moderate to high (turbine costs 0.8 -1 mn EUR/MW; system costs onshore 1.3 – 1.8 mn EUR/MW; offshore 2.4 – 3.5 mn EUR/MW);
- OPEX is low (typical assumptions year 1-10: 2% ; year 10-20: 4% of CAPEX)
- Typical unit sizes offshore 2.0-3.0 MW; onshore 3.6 – 7.5 MW
- Capacity utilisation factors varies strongly with site conditions
- No fuel cost, nor water requirements
- Intermittency issue; in some regions predictable patterns
- Moderate planning and construction periods
- Low economies of scale, modular concept
- Isolated networks: Can be adjusted to demand development in low increments without risking significant increases in specific CAPEX

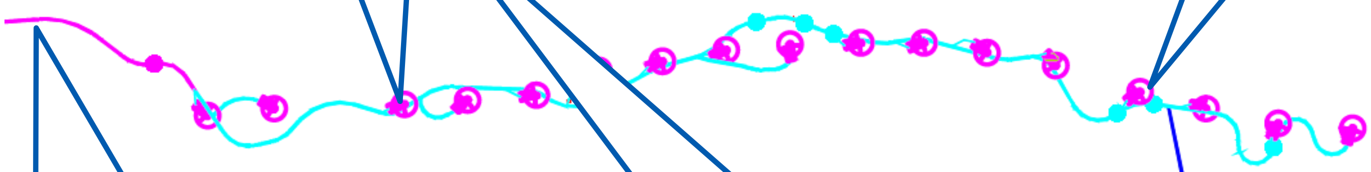
Wind energy – risks and issues

- General risk profile is moderate
- CAPEX overrun risk is low
- Output is well projectable if necessary long term wind studies are performed; however, history of poor wind measurement studies
- OPEX risk is low and predictable; insurance is available, but expensive for new designs/models
- Permitting and environmental risk comparatively high (birds & bats, landscape impact, noise, disco-effect, tourism)
- bird habitats and migration, e.g. annual mortality rate of medium and large birds in Spain is about 0.13 per turbine
- Financial viability depends on green feed in tariff (subsidies) in most power systems due to intermittency
- Future conflict due to network constraints in saturated markets

Key components of a Wind Farm

22 crane platforms for WEC erection
- Cost ~ 0.2 M€
- detail design performed by local subcontractor

22 WECs incl. foundation
- 80 – 95 m rotor ø
- 2.0 – 2.5 MW each
- Cost 50 - 60 M€



21 km of access roads
- Cost ~ 3 M€
- detail design performed by local subcontractor

Substation & MV cabling
- Switchyard
- Transformer 20/110 kV
- ~8 km of MV cabling
- Cost ~4-5 M€

Project development

During the development phase of a wind project concepts for the following areas / components of a wind farm have to be developed:

- **Location and resulting restrictions from**
  - **Ownership of land plots**
  - **Accessibility**
  - **Environmental issues (birds habitats and migration , noise, shadow, impacts during construction)**
- **Wind resource and prospected electricity generation**
- **Wind turbine selection and suitability**
- **Park layout, micrositing (turbine location)**
- **Access roads**
- **Grid connection and electrical design of wind park**
- **Wind turbine erection (availability of equipment)**

Project development – Turbine selection

Wind Study

Restrictions (max. height, boundaries) determine initial layout

IEC class
- Average wind speed
- Extreme wind speed
- Turbulence

Commercial
- Market availability (FiT)
- Delivery time
- Contract conditions
- Price

- Maximizing production
- Minimizing costs
- Restrictions: environmental aspects and land availability
- Shadow and noise

Wind turbine selection (~2-4 models)

Micrositing for selected wind turbines including
- **Layout optimization**
- **Update of energy yield calculation (complete energy yield assessment)**

Project Development – Wind Resource Assessment

Standard wind resource assessment for wind energy:

1. Nearby measurement or mesoscale simulation data for prefeasibility study
2. On-site wind speed measurement for at least 12 months at different heights, temperature measurement
3. Long term correlation with nearby weather stations
4. Extreme wind conditions calculations
5. Turbulence assessment

Measurement and wind regime study

Standards: **- IEC 61400-12**
- MEASNET recommendations

Project Development – Wind Measurement

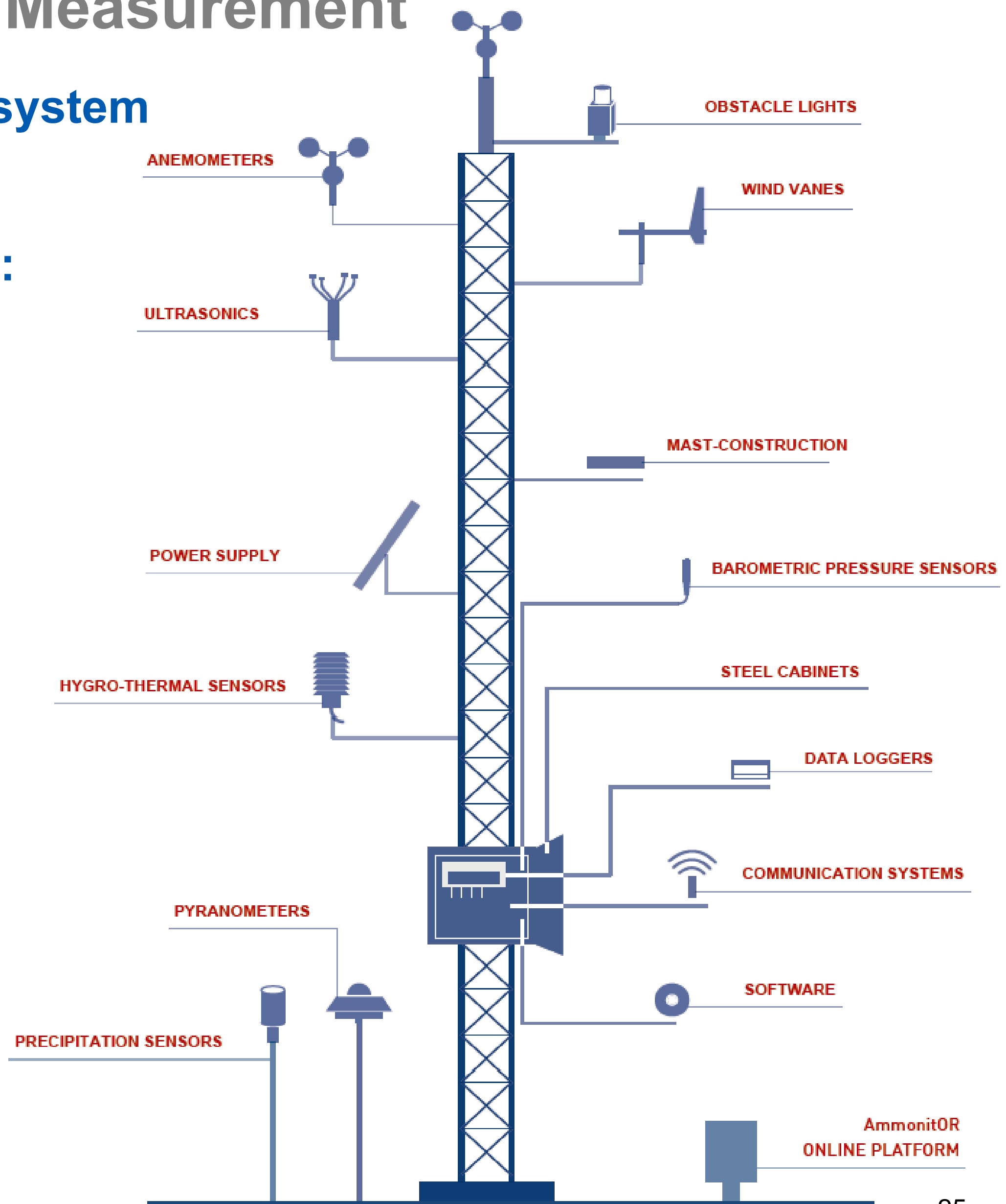
Potential components of a measuring system

Basic components of every system are:

- data logger
- several anemometers
- wind vane(s)
- a hygro-thermal sensor
- an barometric pressure sensor
- power supply (usually solar panels).

Additional optional components:

- a GSM/GPRS data transfer system
- a precipitation sensor
- a pyranometer and
- an obstacle light



Source: Ammonit 2010

Project Development – Wind Measurement

Measurement characteristics:

- At present, two types of masts are primarily in use: lattice masts and telescope masts
- Typical standard height is at present between 80 to 100m ((year 2009), with the latest masts reaching a height of 140m. Recommended at least 2/3 of hub height
- Masts are a specialist constructions and are equipped with sensors, usually mounted prior to erection of the mast
- A steel cabinet containing the data logger, data transfer system, components for the power supply and any additional system components are mounted near the bottom of the tower typically at a height of approx. 6m to make access for thieves or vandals difficult, while allowing maintenance and service access.

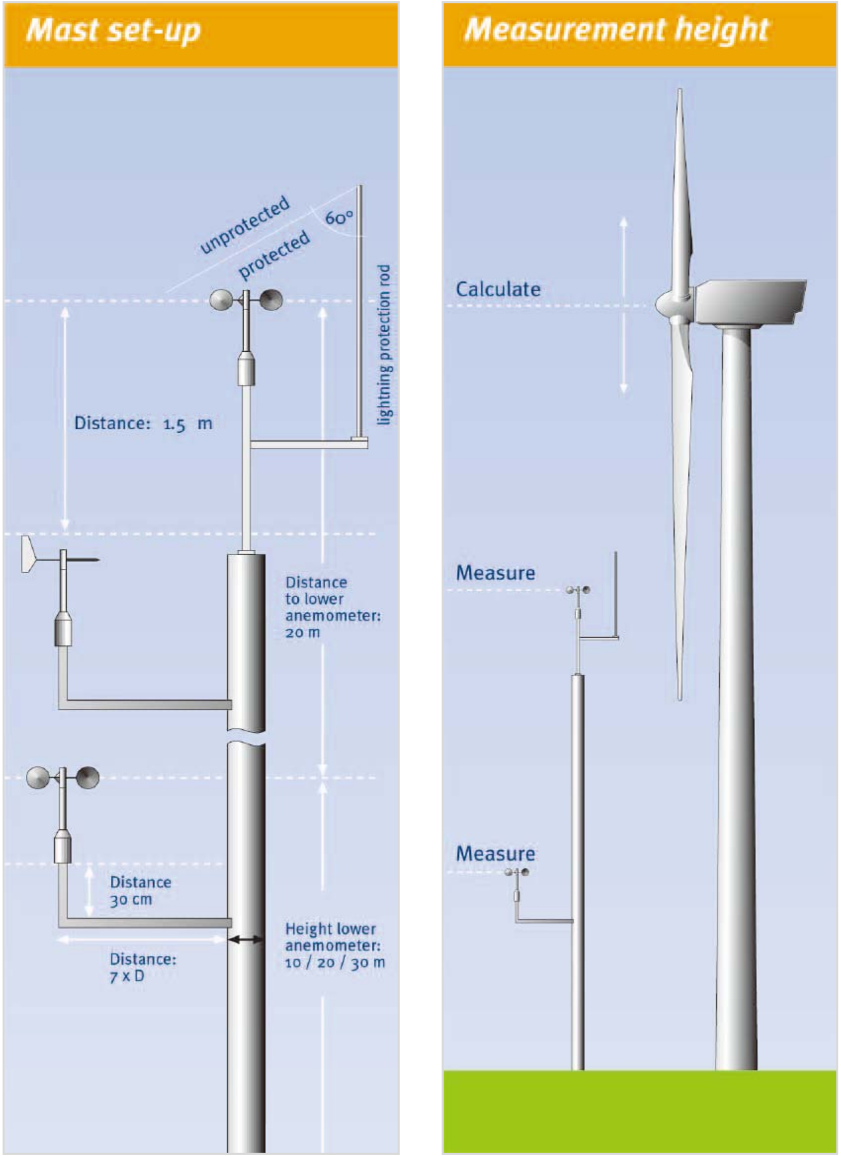
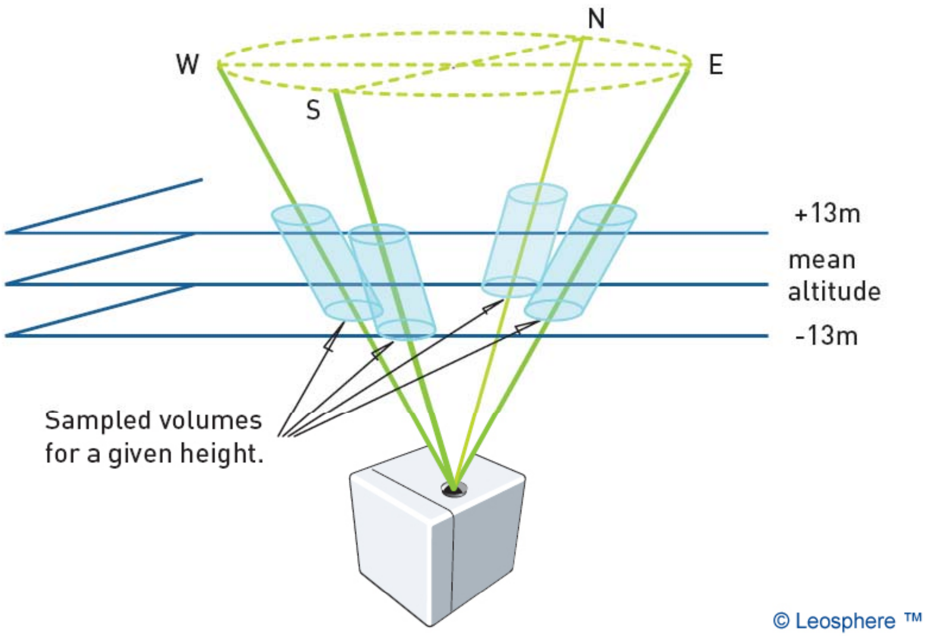


Image: typical measuring system (SCADA)

Source: Ammonit 2010

LIDAR Wind Measurements

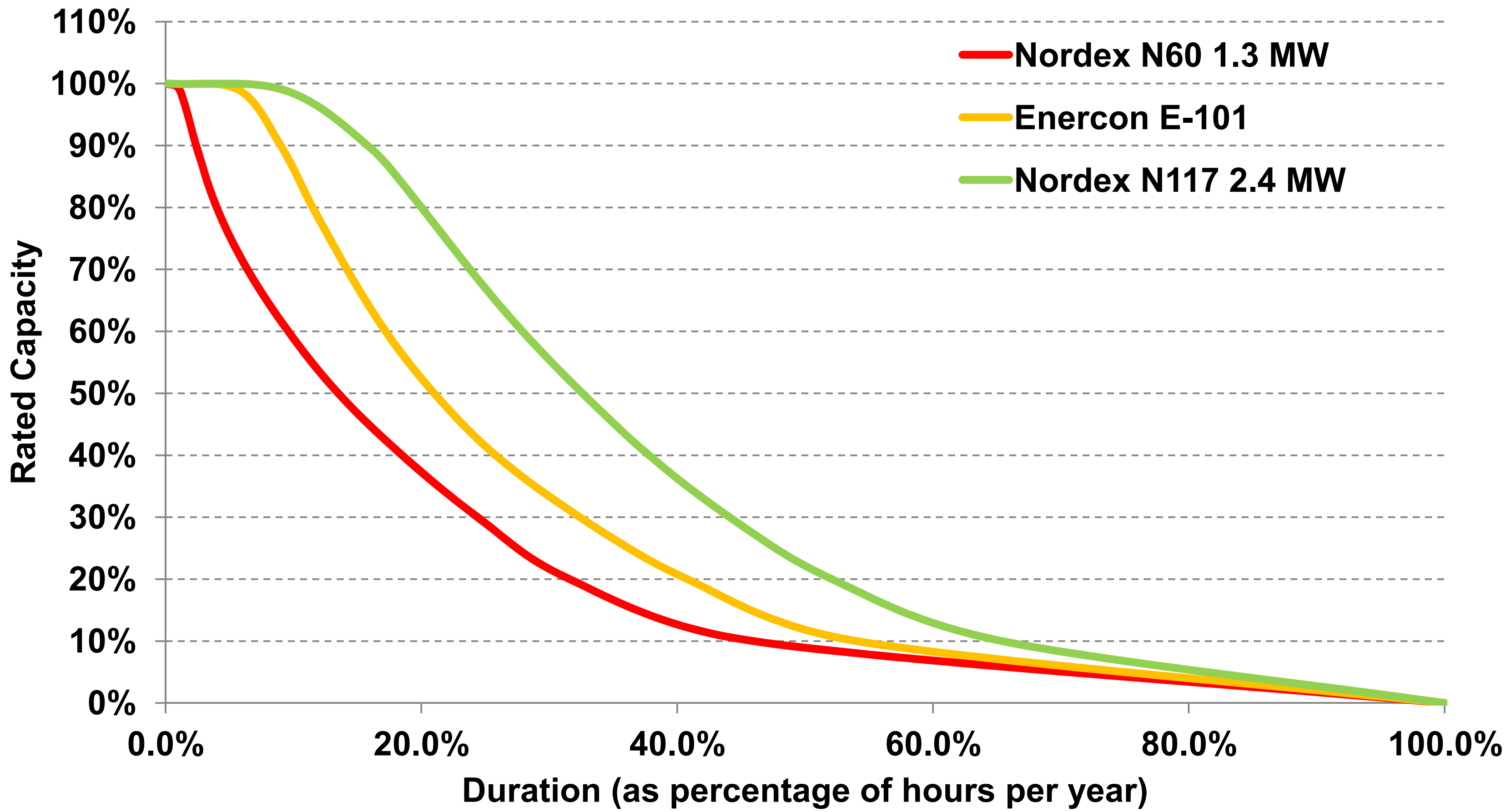


LIDAR (Light Detection And Ranging) is a key technology for detailed wind profiling up to a height of several hundreds of metres. By using a laser, it is possible to obtain wind data at a variety of measurement heights. The advantages over anemometer masts are:

- Ultra portable (< 100 kg)
- Fast installation (< 1 hour)
- Class 1 anemometer matched accuracy
- LIDAR provides the flexibility to measure wind at the hu hight as well as the top of the proposed turbine (full spectrum of rotor diameter)
- Unmatched accuracy in complex terrain with Flow Complexity Recognition.
- LIDAR measurements significantly reduce the uncertainty of yield calculations, a key component of the business plan for a wind farm.

Power Curve and Energy Yield

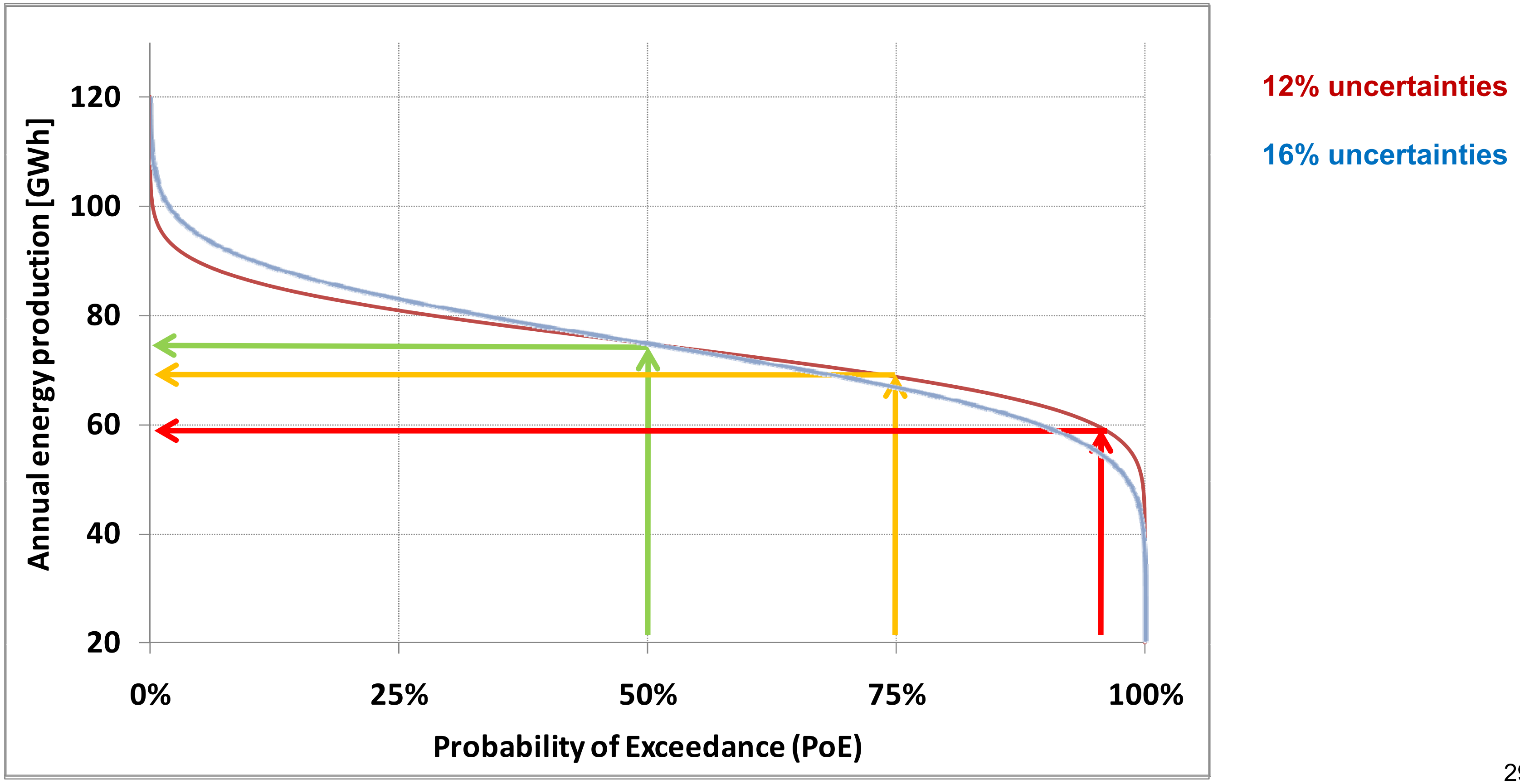
Selection of the suitable wind turbine from energy yield perspective, e.g. the influence of the rotor diameter on the energy yield.



Energy Yield Assessment – Probability of Exceedance

Probability density function is used for calculation of the probability of exceedance (PoE)

- Total uncertainties X annual energy yield = Standard Deviation
- Usual cases are P50 (50% probability), P75 and P90 (90% probability, downside case used by most banks)



Uncertainties in wind analysis

A state of the art energy yield assessment should contain a complete uncertainty analysis. (ISO Guide 98, IEC 61400-12)

Examplary results of an uncertainty assessment

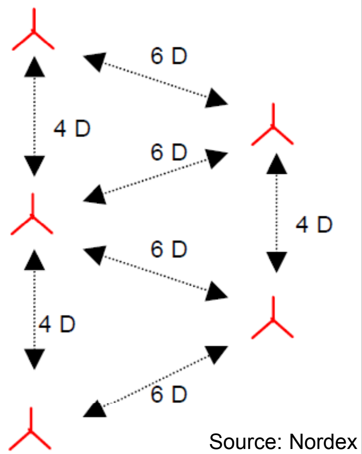
Issue	Uncertainty (%)
Wind measurement, anemometer calibration and data acquisition	4
Long term stability and representativity of met station data	3
Referencing to the long term - seasonal bias	0
Referencing to the long term - method, scatter, wind statistics and discretisation / binning	4
Transfer from measuring heights to hub heights	6
Transfer to the location of the planned turbines (terrain model, wind model and coordinate transformations	6-8
Power curves	3-5
Wake losses	2
Air density	1
Availability	1,5-3
Icing	0,5
Transmission losses, grid downtime and substation downtime	1,5
Total	**12,4-13,1**

Project Development – Wind Farm Layout

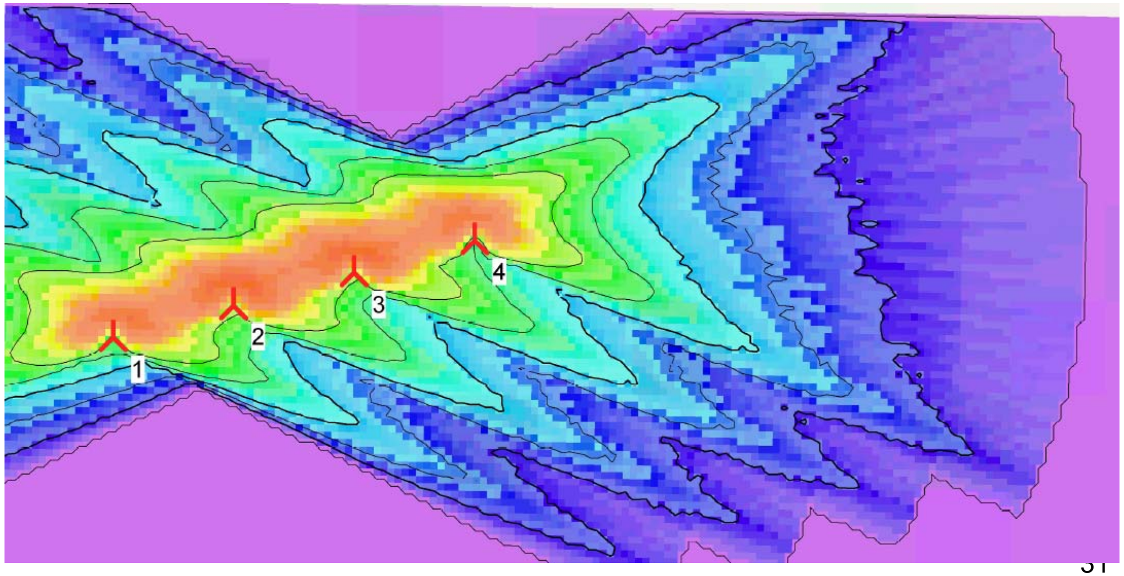
The wind farm layout is designed and optimized with following considerations:

- Minimum distance between turbines (to reduce cabling costs and WTG induced turbulences)
  A commonly applied rule of thumb suggests a minimum distance of 5 rotor diameter in main wind direction and 3 rotor diameter perpendicular to main wind direction.
- Consideration for electrical interconnection and to grid
- Minimize shadow and noise on sensitive areas
- Maximized energy production
- Roads and accessibility
- Land availability and permits

Recommended minimum distances between WTGs



Source: Nordex

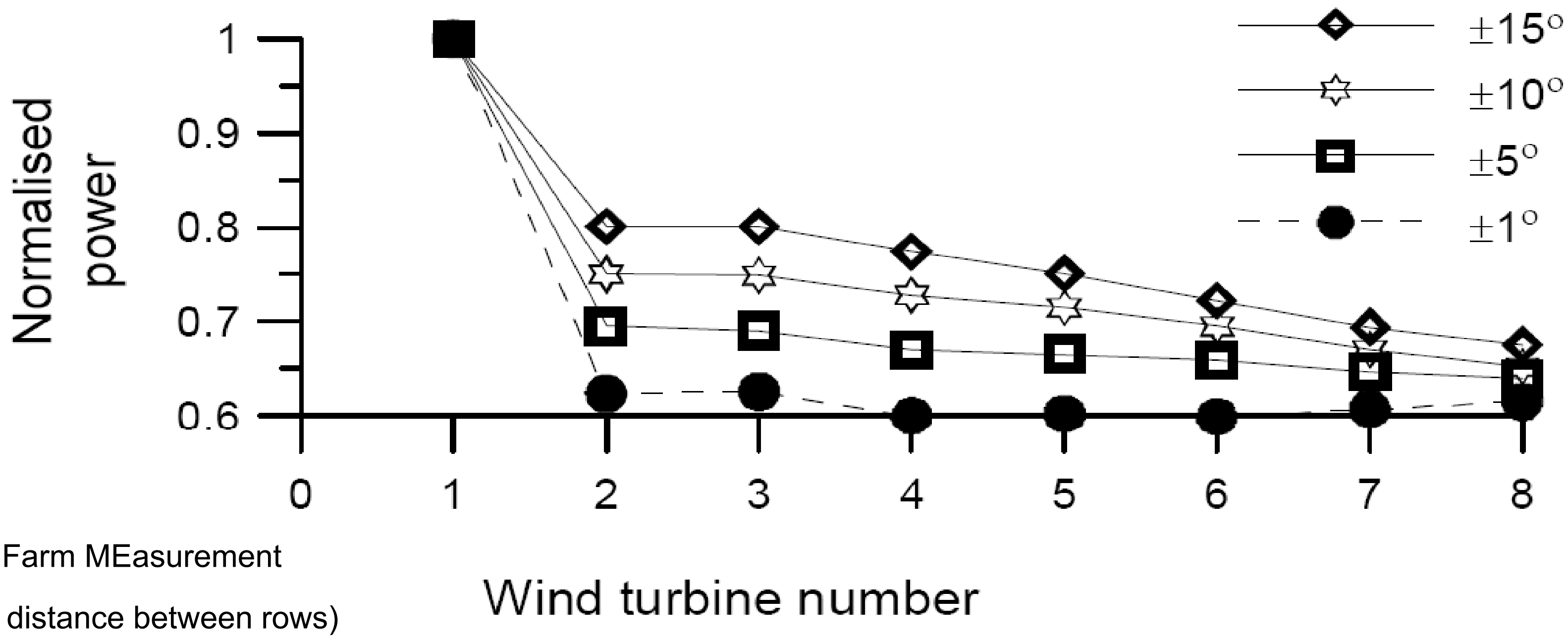


Wake Effects

Wake Effects

Measurements at existing wind farms have shown that

- Wind speed within the wind farm drops < 80% of free stream
- Recovery to ~ 90% occurs within ~ 5 km of wind farm end
- Further recovery over ~ 20 km
- Mitigation measure: increase row distance



Horns Rev Wind Farm MEasurement

- Case 1 (7D distance between rows)
- U at first turbine 8.0±0.5 m/s

Data courtesy DTU

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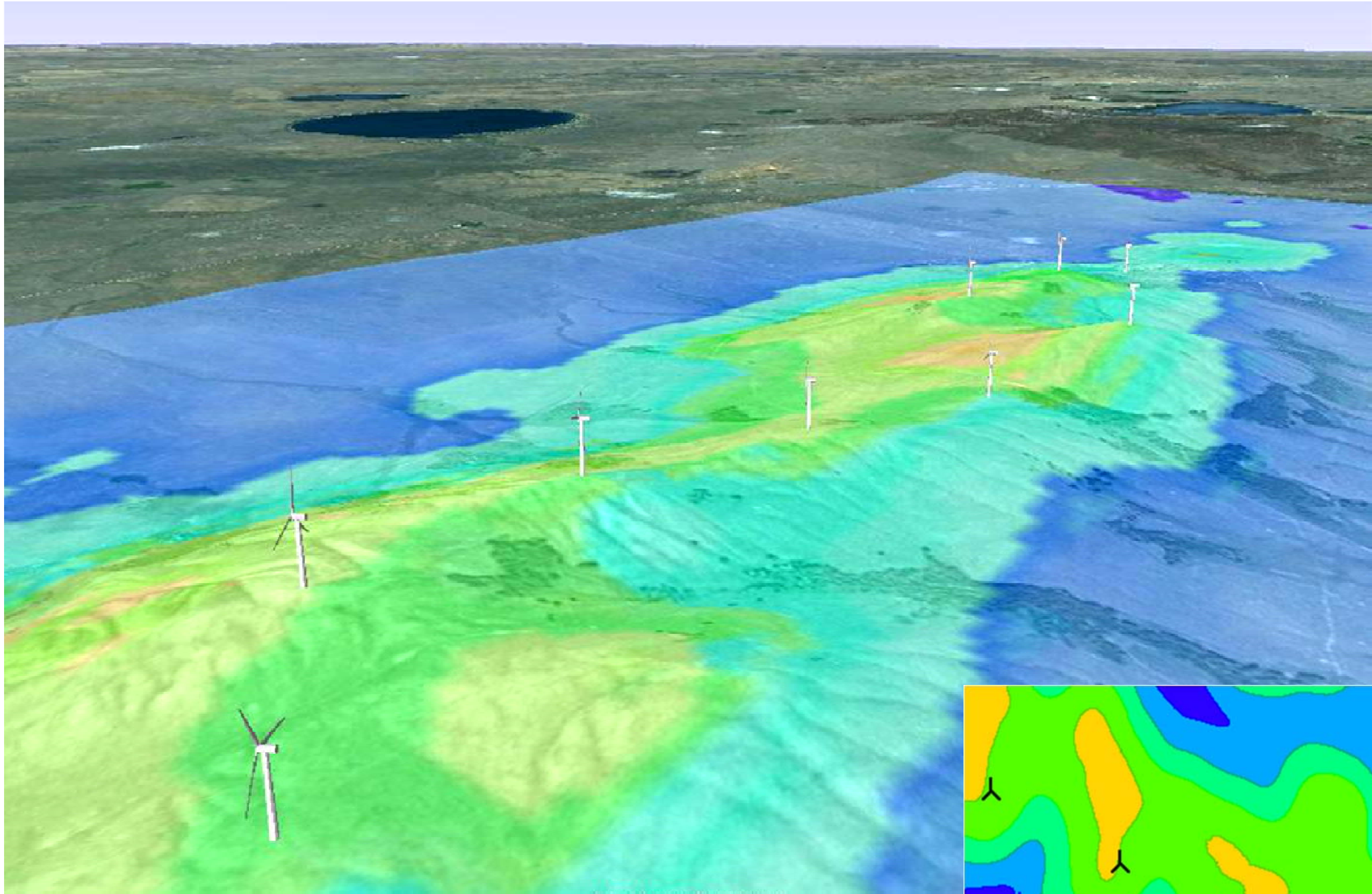
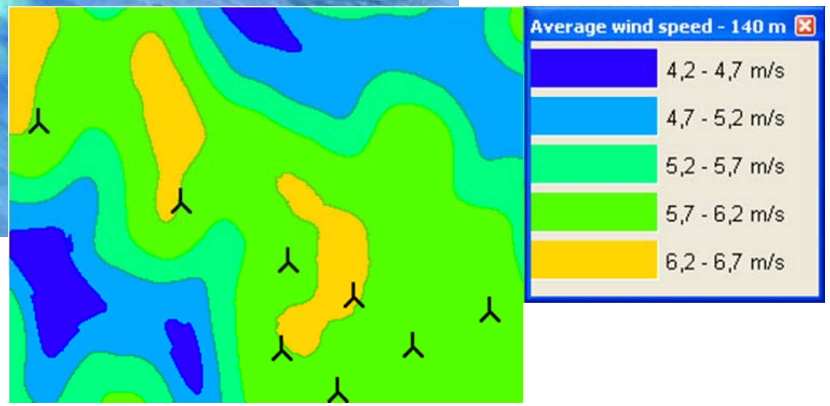
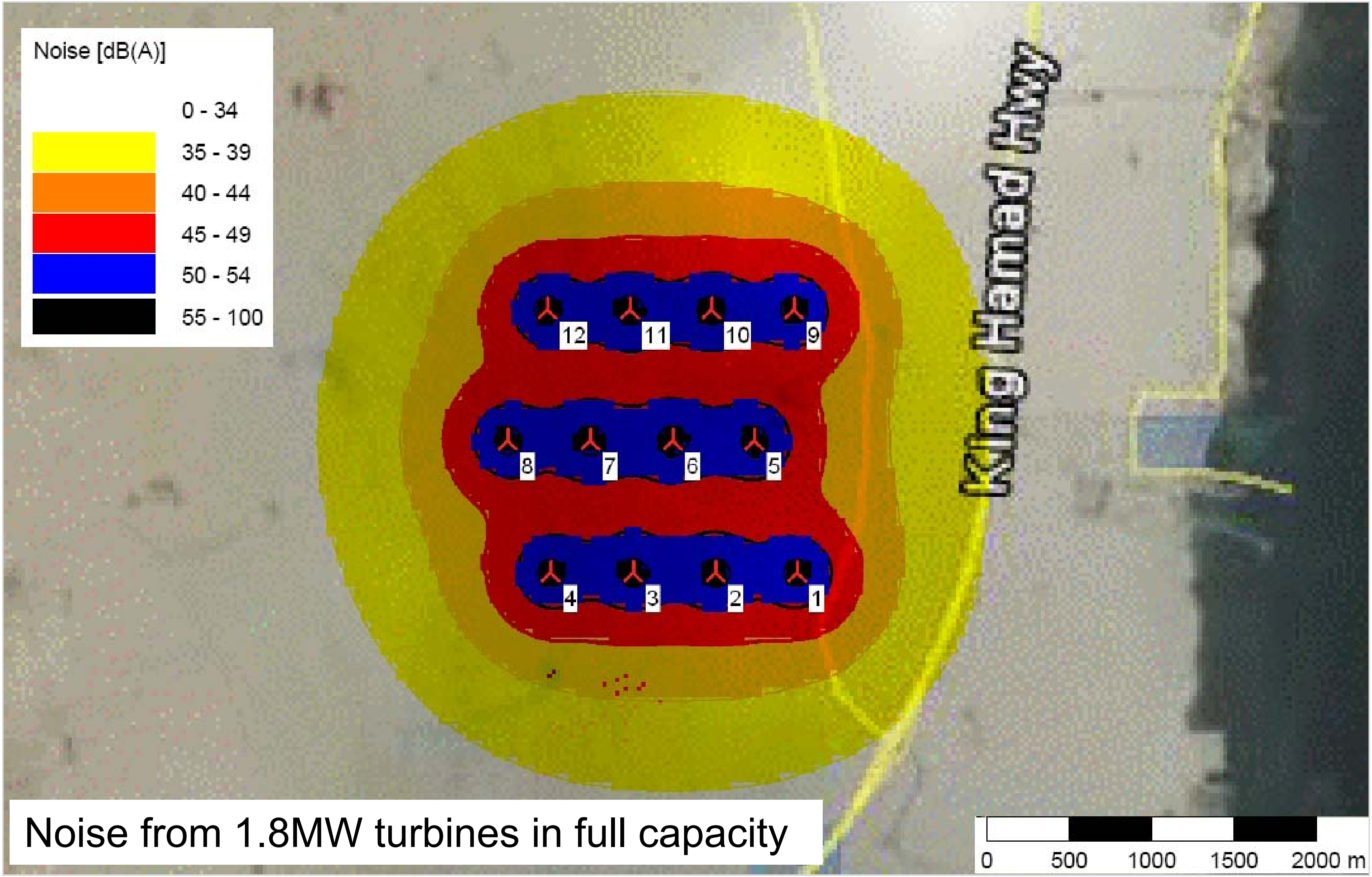
Project Development – Micrositing





Project Development - Noise



Noise from 1.8MW turbines in full capacity

Project development – Access roads

Photos by Paul Anderson

Minimum road requirements are usually specified by wind turbine manufacturers in what concerns:

- **Minimum width on straight roads and turns**
- **Minimum turn inner and outer radius**
- **Clearances around the road**
- **Requirements for axle load**
- **Requirements for areas for cranes and storage**

Considerations for a Procurement Strategy

- **WT Model pre-selection**
  - Models shall be state of the art WT with proven technology and good track of references, best also in the region (bankable WTG model / manufacturer).
  - Type certificates as well as calculated and measured power curves shall be available.
- **Scope of Works / Contract structure**
  - WT manufacturers should be available for “supply and erection” contract.
  - WT Ex-works supply is in principle not recommended.
- **Time line**
  - For WT “supply and erection” some 4-5 weeks should be considered as reference time for the offer.
  - Time for offer preparation in case of EPC contract can be anticipated to be in the order of 2-3 months, with a typical offer validity of 4-5 weeks, a certain extension at the time of negotiations being reasonable to be envisaged.
- **Service contract**
  - WT manufacturer should be available for a long term (i.e. 5-9 years) service and maintenance concept and guaranteed availability (especially for project financed projects).

Due Diligence - Typical Wind Project Risks from the Lender‘s Point of View

- **Average annual energy yield lower than predicted**
  - Review of wind measurements and long-term wind data assumptions
  - Review of the energy yield assessment as to the reliability of the input data, methods and results
  - Consideration of losses
  - Wake Effects, Wake Models
  - inter-annual variability, long-term correlation
- **Technical Design**
  - Evaluation of technical concept such as layout, grid connection, civil works
  - Review of the suitability of the wind turbines to the site (e.g. turbulence, max. wind speed, site complexity, soil conditions)
- **Permit approval risks**
  - Time schedule, duration of permits
  - Special conditions and their fulfillment
  - land-lease agreements, right-of-way, projects in competition
- **Environmental impacts**
  - Special conditions and their fulfillment
  - envisaged Natura 2000 areas
  - noise emissions
  - shadow flicker

Due Diligence - Typical Wind Project Risks from the Lender‘s Point of View

- **Cost overruns (construction, O&M),**
  - Review of cost estimates
  - consideration of contingencies
  - monitoring of budget and time schedule, project steering
- **Deviation from contracted technical performance**
  - Availability reduction
  - Power curve / performance
- **Time Scheduling**
- **Contracts / project agreements including mainly: EPC-Contract, grid connection agreement, PPA, O&M, technical and risk allocation to the project parties / Contracts**
  - Check of adequacy and appropriateness as well as negotiation of the technical warranties and its verification procedures (e.g. performance test, availability, technical characteristics)
  - Liquidated Damages, penalties
  - Review of Project Insurances
- **O&M / Maintenance concept**
  - Supply with spare parts, duration
  - Experience of contractor,
  - Local representation
  - Unscheduled repairs

Due Diligence - Typical Wind Project Risks from the Lender‘s Point of View

- **Project structure**
  - Assessment of project structure and obligations of project parties, transaction structure
  - administrative operation
  - Evaluation of the qualification of involved parties, QC/QA concept

- **Financial performance**
  - Review of financial model input data including
  - project costs and contingencies,
  - revenues,
  - technical input data
  - Assessment of applicability of project within the CDM / JI framework
  - Analysis of project sensitivities / risk assessment
  - Price risks, feed-in tariffs, duration of feed-in tariff

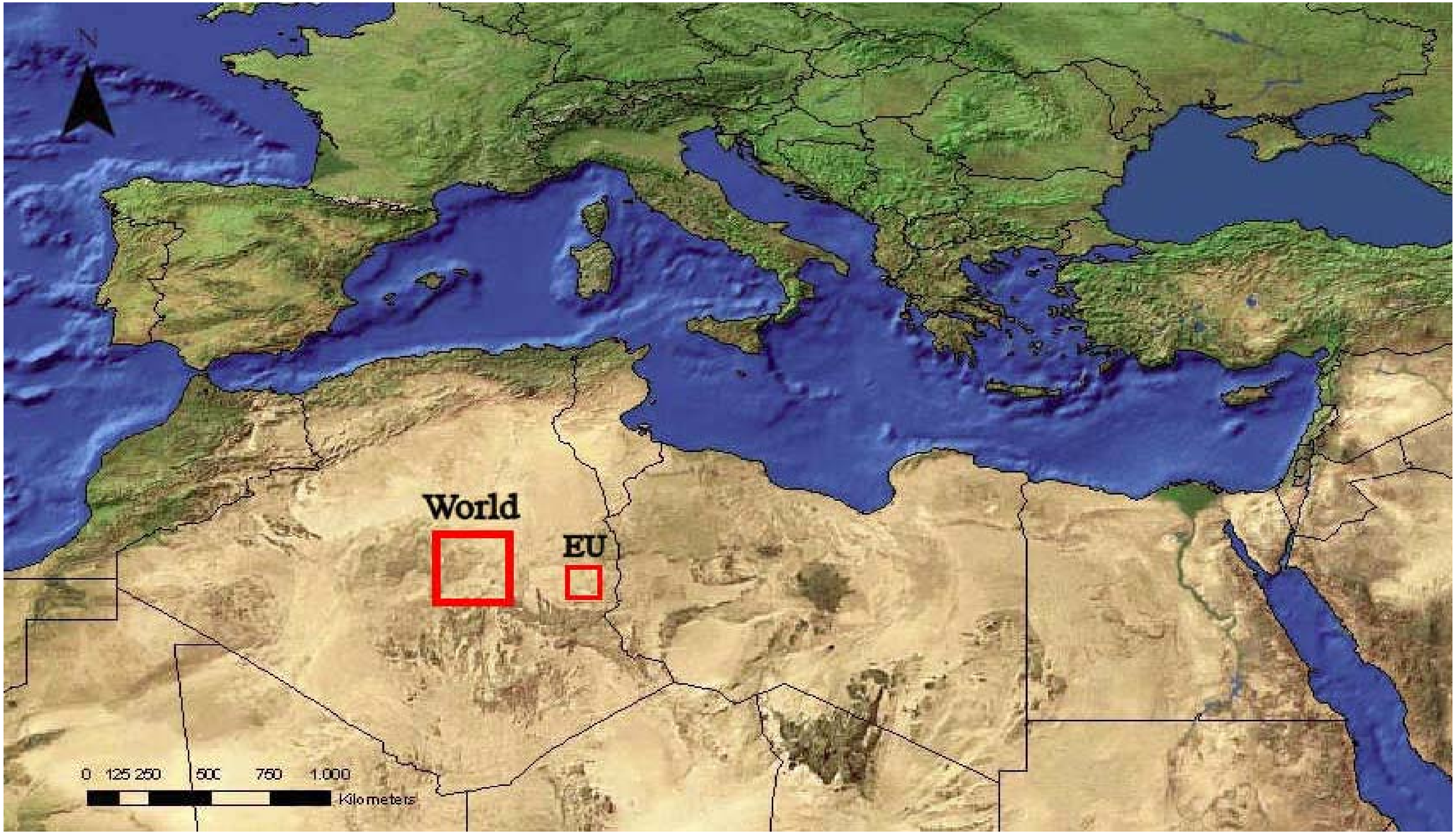
- **Risk Assessment**
  - Summary of risks
  - Monitoring of developments
  - Recommendations and mitigation measures

⟶ **Preparation of a Due Diligence Report**

Maintenance and Insurance Costs

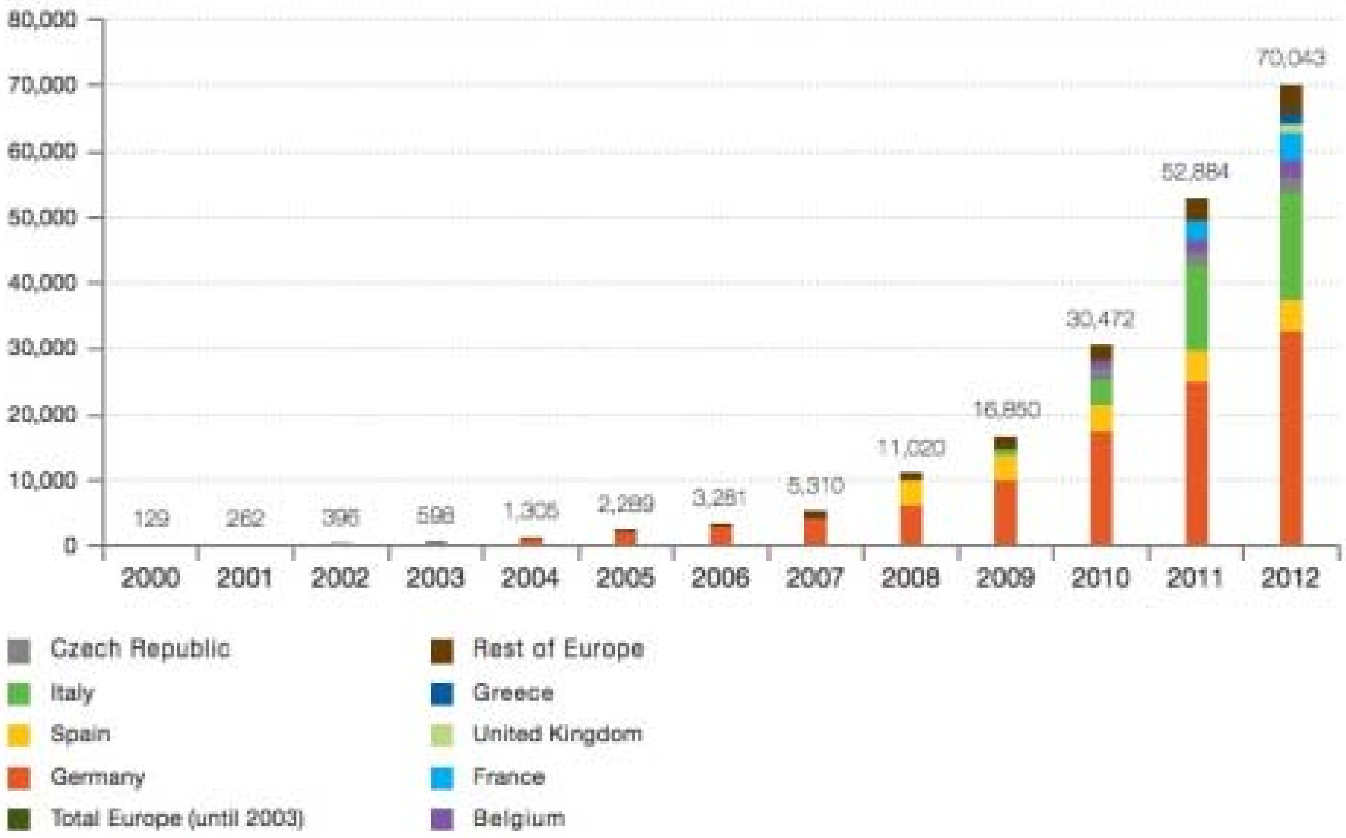
- Maintenace contracts are a key driver of project viability; 25-32% of the life cycle costs are maintenance and ispection costs
- Full service contract from OEM supplier versus service contracts with specialized companies
- Spare parts stock of key components of up to 5% are typical for large projects
- Condition Monitoring Systems become increasingly a tool to avoid severe damage and to reduce operational risk insurance costs
- Trend to industrialized service companies with large spare part stock
- Construction Risk Insurance (Inland Transit, Testing & Commissioning Stage; Advanced Loss of Profits, Phased Operation; • Physical Damage)
- Operational Risks (Mechanical & Electrical Breakdown; Physical Damage; Business Interruption; Liability)

Solar power plants

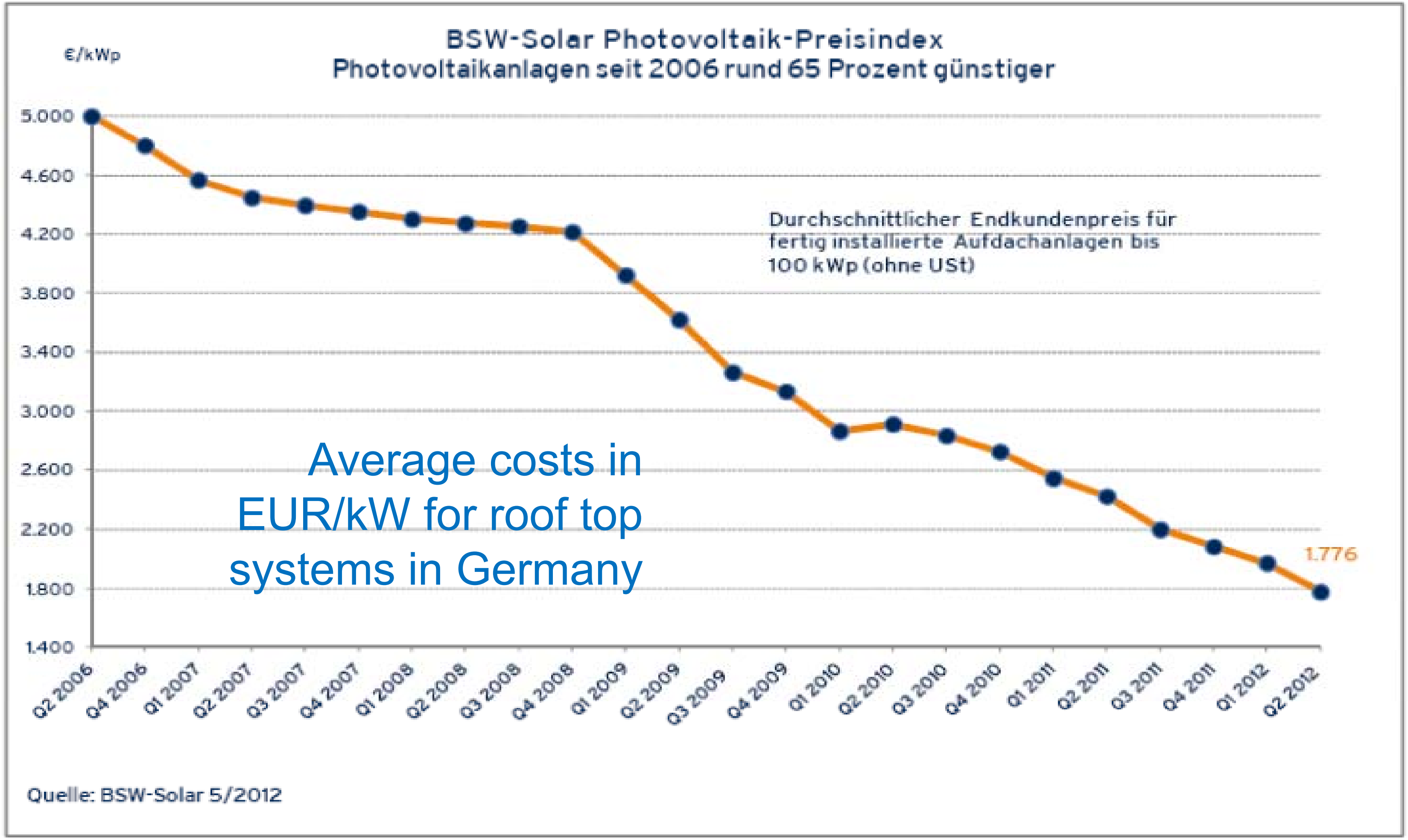


PV solar – the game changer

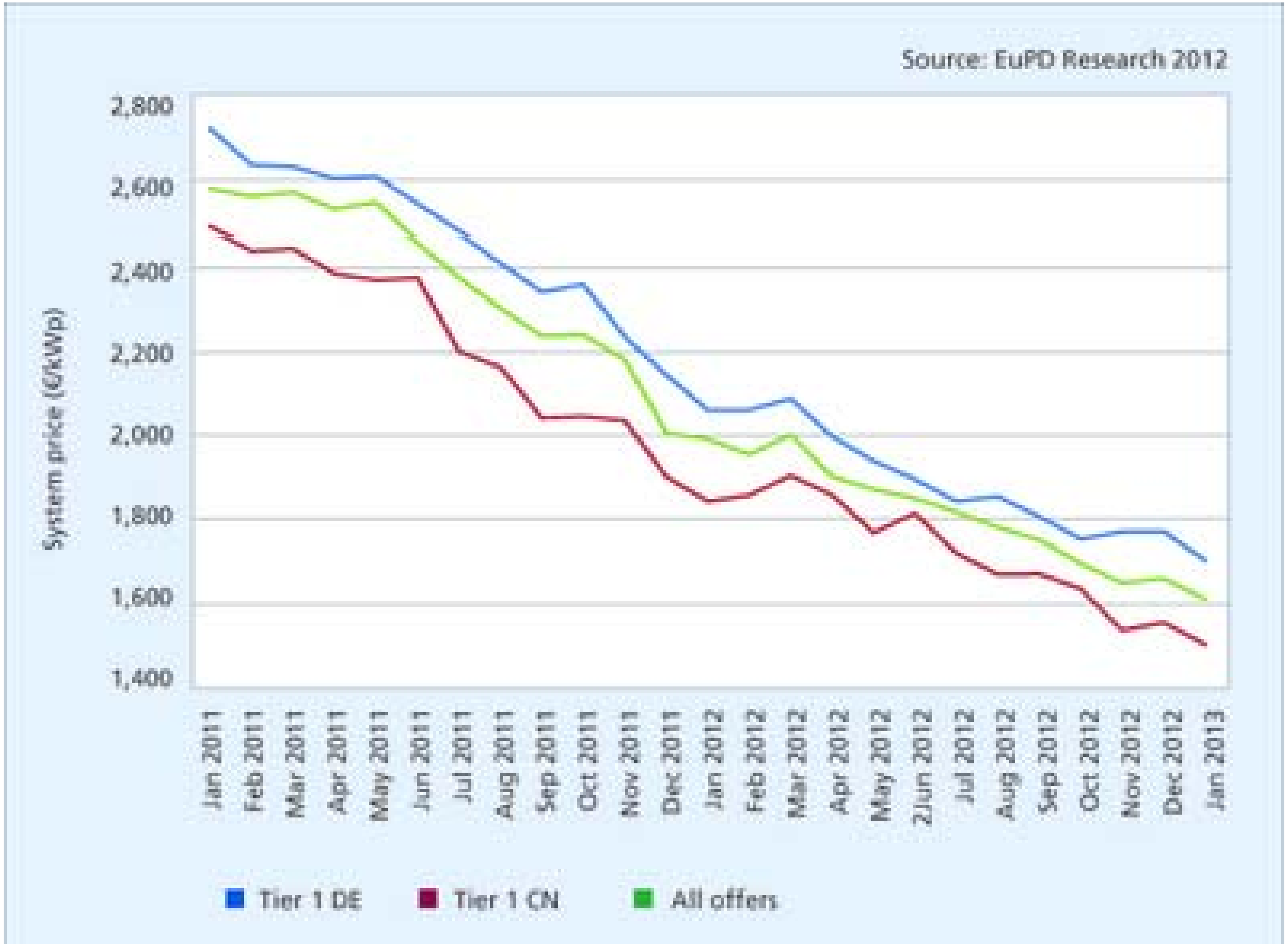
Figure 5 - Evolution of European PV cumulative installed capacity 2000-2012 (MW)



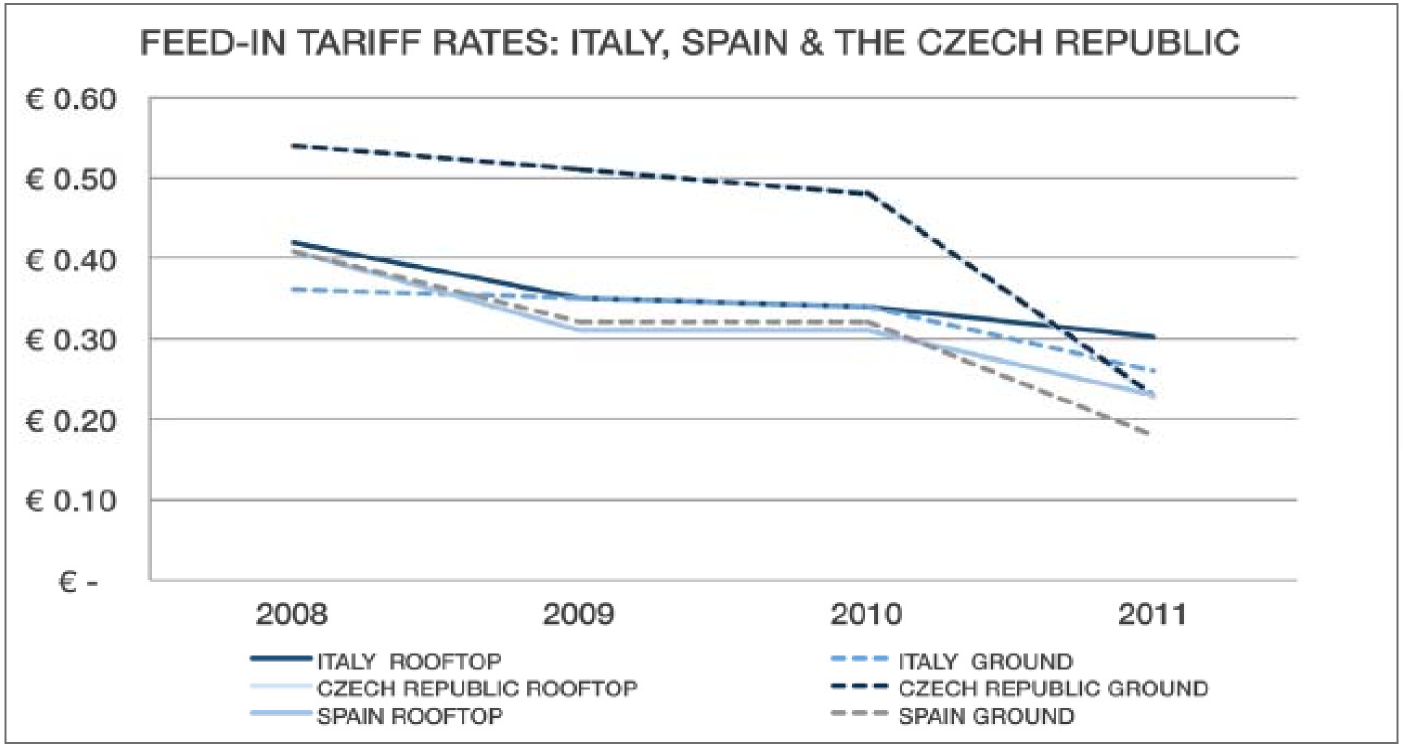
PV solar projects – CAPEX development



PV solar projects – CAPEX development



PV projects – decreasing tariffs



Source: Green Tech Media Research

Types of Solar Cells

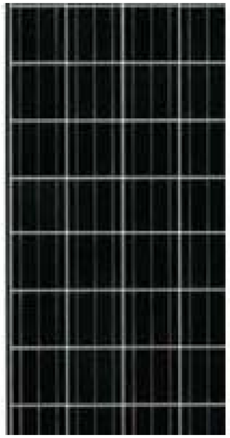
- There are basically two different technologies to manufacture PV solar cells:

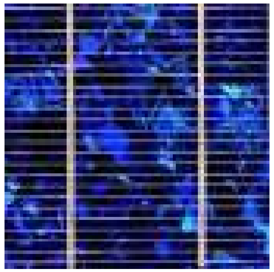
- **Wafer based crystalline silicon solar cells**
  Represent the bulk of the market

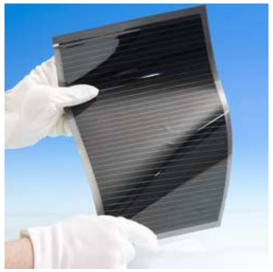
a) Mono-crystalline cells
b) Poly-crystalline cells

- **Thin-film technology**

c) Different materials and deposition processes



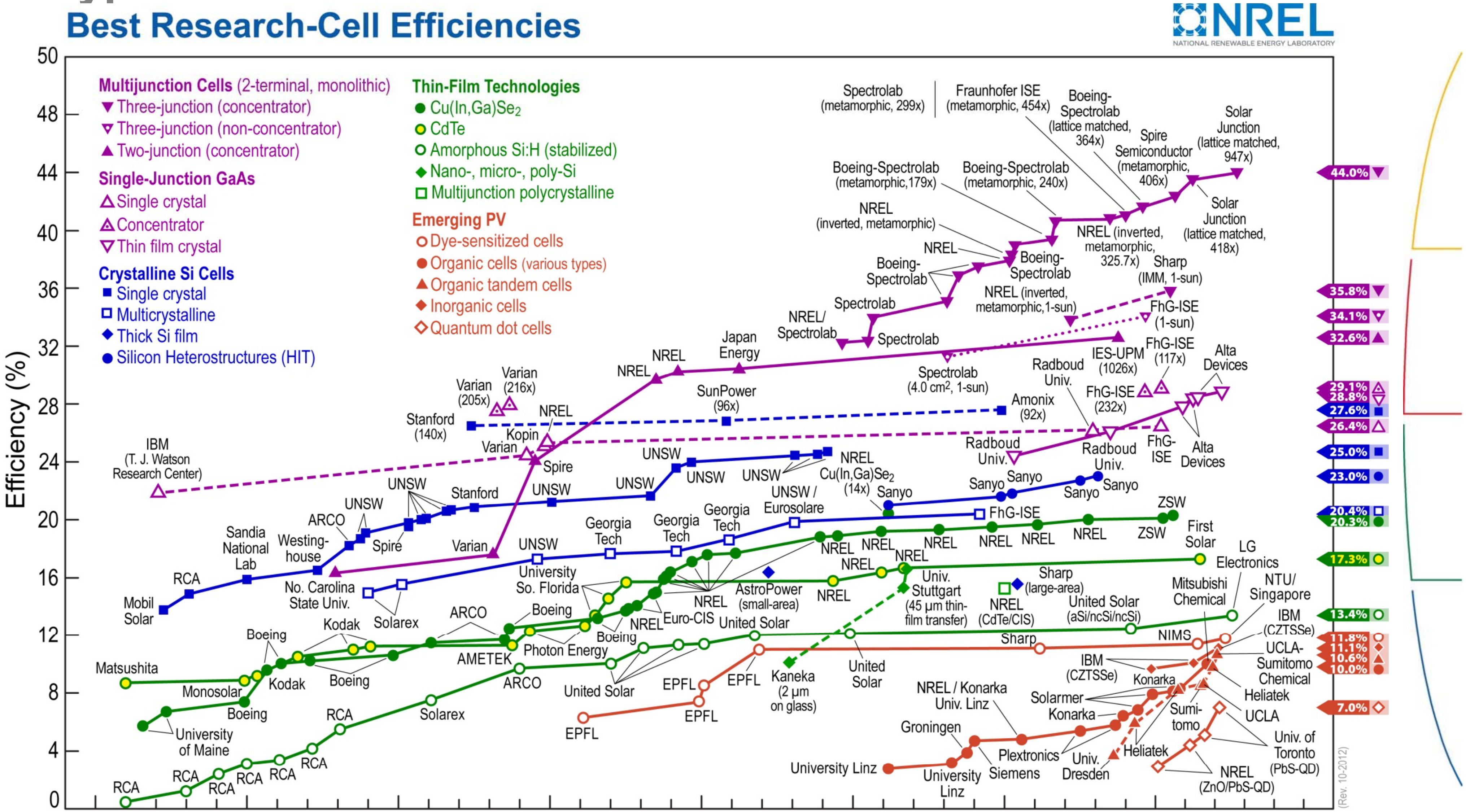






PV projects – collector material

- Mono-crystalline silicon: Most efficient commercial technology (efficiencies of around 16-19.5% (commercial) to 28% (research)
- Multi-crystalline silicon: Cheaper than mono-crystalline silicon but also less efficient. Research cells approach 24% efficiency, and commercial modules approach around 12-16% efficiency.
- Thin film:
  - Cheaper than crystalline silicon but less efficient; various materials
  - CdTe - Cadmium telluride (6-11%)
  - a-Si - Amorphous silicon (5-8%)
  - CIGS/CIS - Copper indium gallium di-selenide (commercial 10-12.7%); but higher output in terms of kWh/kWp
  - Organic PV (OPV) cells (3.5 -10%)

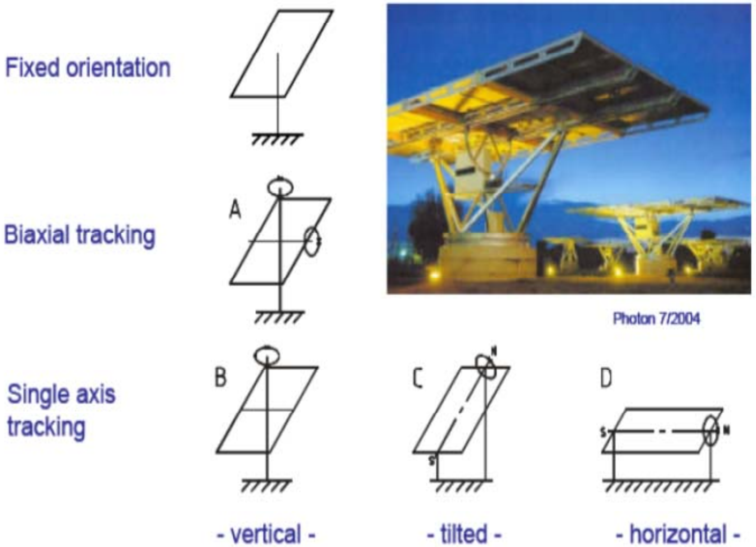
Types of Solar Cells VI – PV Cell Efficiencies



Source: National Center for Photovoltaics: http://www.nrel.gov/ncpv/

PV - Tracking & Concentration

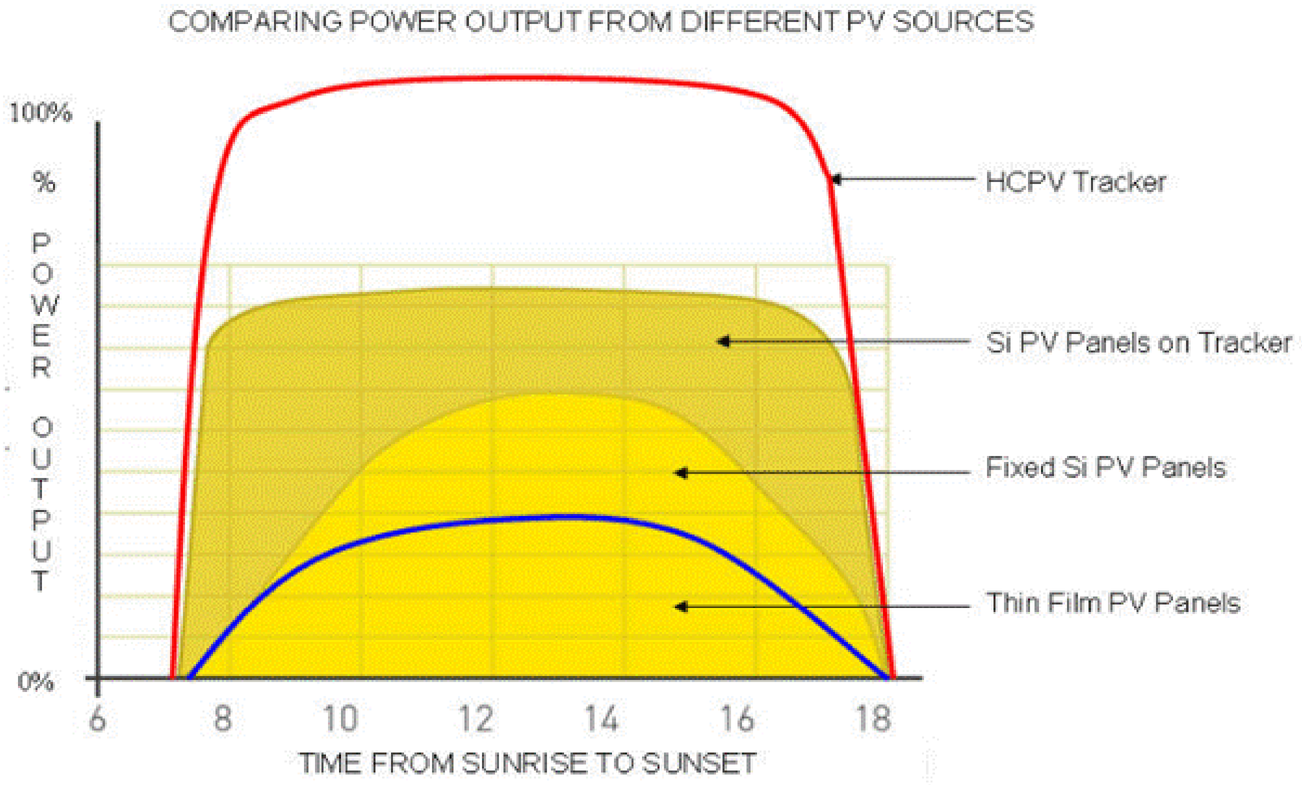
Mounting Concept



Photon 7/2004

	Mean annual radiation gain in Central Europe	Mean annual radiation gain in Southern Europe
Fix, optimum tilt angle	0%	0%
Horizontal N-S axis	12%	17%
30° tilt axis	23%	30%
Vertical axis, module tilt 50°	23%	29%
Biaxial tracking	27%	34%

Power output from different PV systems



www.solarthermalsystem.com

Solar PV projects - characteristics

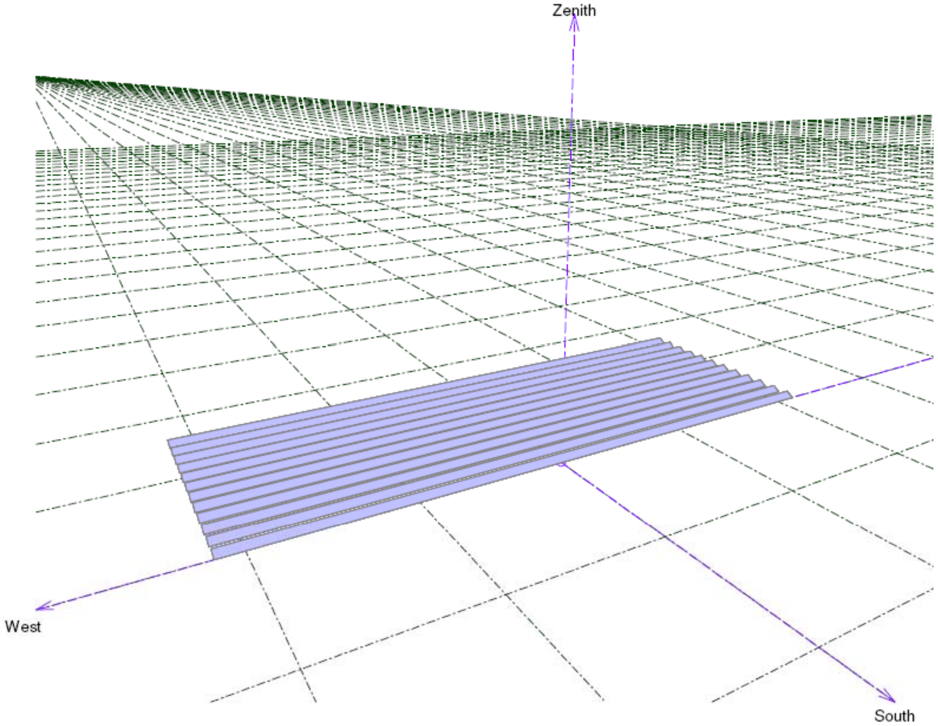
- CAPEX moderate to high (fixed systems 1.2 – 2.0 mn EUR/MWp; tracking systems 1.8 – 4.0 mn EUR/MWp)
- Specific CAPEX (EUR/MW) depends strongly on longitude and radiation
- High specific space requirements (fixed systems 2.5 – 7.0 ha/MWp; tracking systems 4.5 – 8.5 ha/MWp)
- OPEX very low and well predictable for fixed systems; low for tracking systems;
- No fuel and water cost
- Short planning and implementation periods
- Usually no resettlement and environmental impact issues
- Well suited for competitive bidding
- Intermittency issue, no base load capacity; typical annual capacity utilization factors 12-20%
- Intermittency no issue on low and medium penetration levels, in systems with high air conditioning and cooling peaks

PV projects – risks and issues

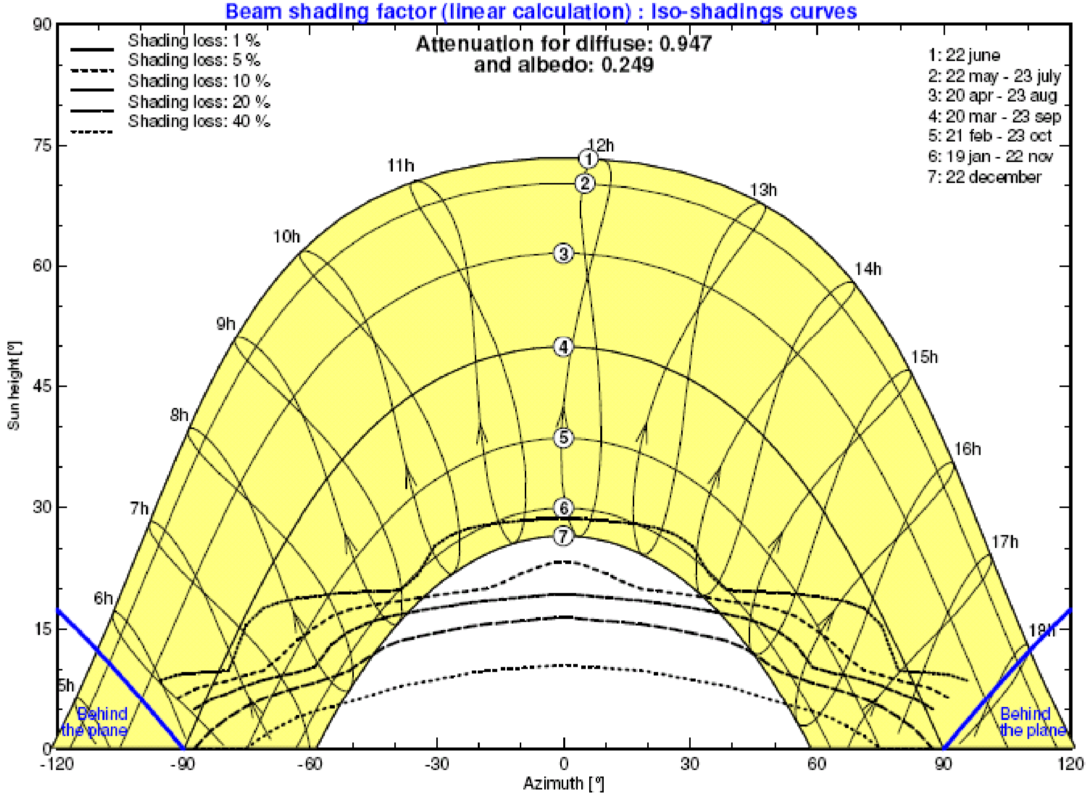
- General risk profile very low
- CAPEX overrun risk is low
- Output is well projectable
- OPEX risk very low and predictable
- Serial manufacturing defaults (look for bankable manufacturers)
- Unit abatement costs in northern countries are high due to intermittency (compared with wind, biomass or hydro)
- Grid parity concept does not cover all aspects of power supply
- Isolated networks: Can be adjusted to demand development in low increments without risking significant increases in specific CAPEX
- Financial viability depends on green feed-in tariff (subsidies) in most power systems, however, this dependency reduces with further capital cost reductions

PV Performance Projection - Example

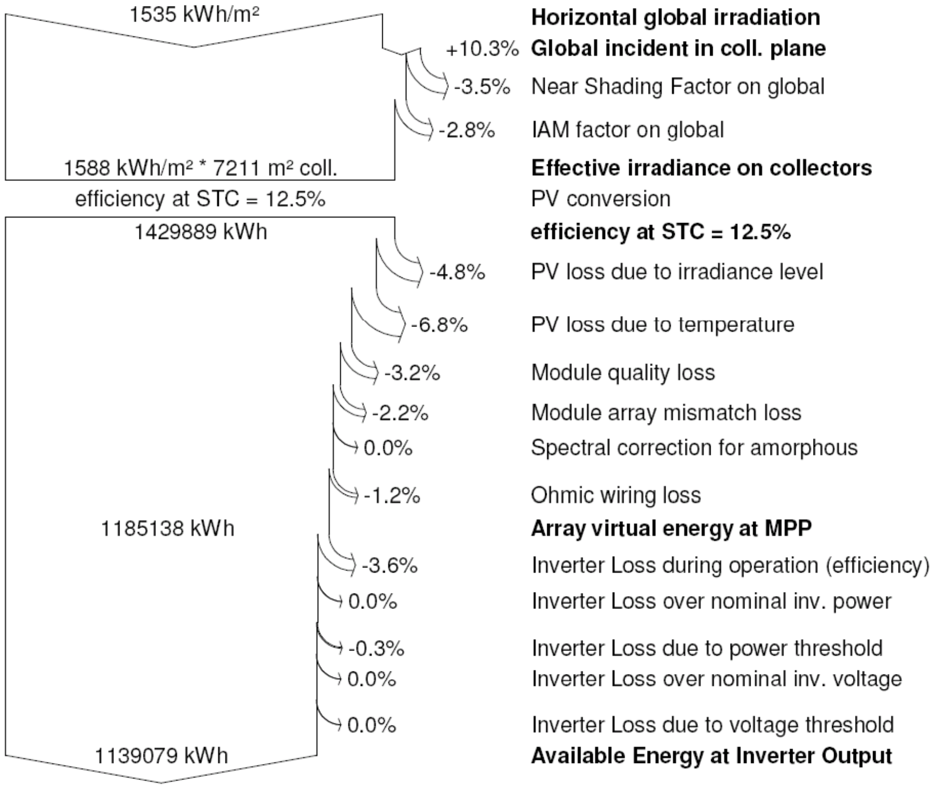
Perspective of the PV-field and surrounding shading scene

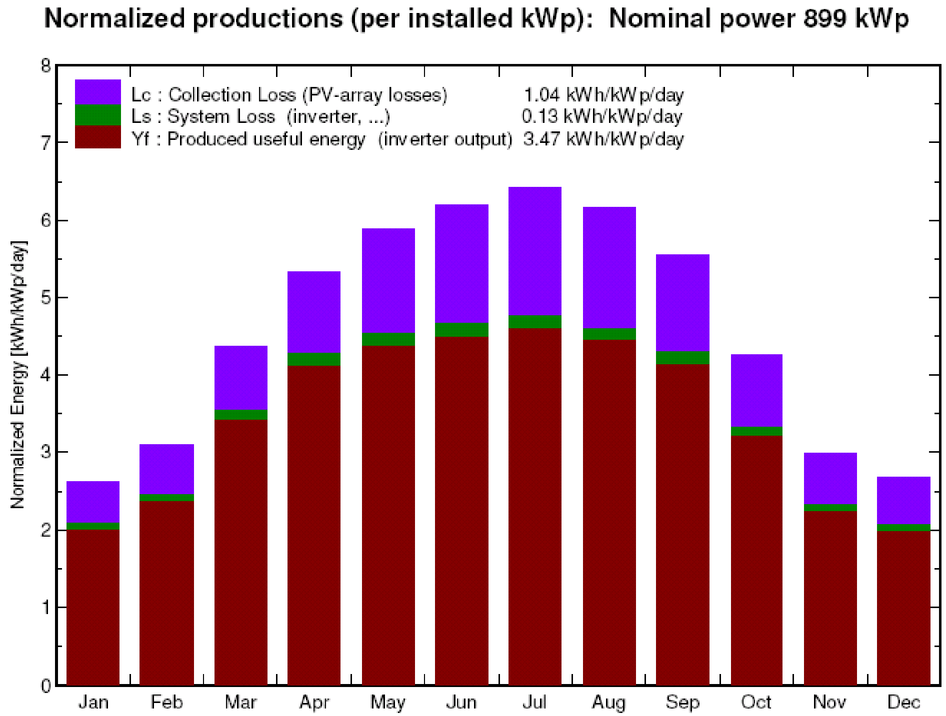


Iso-shadings diagram



PV Performance Projection - Example





Source: Fichtner (fix installation, polycrystalline modules, Italy)

Yield projections – Typical loss parameters

- PVsyst calculated loss parameters for a ground mounted PV power plant in Italy:

Item	%
Near shading factor	-3.4
IAM on Global	-2.9
Irradiance level	-4.8
Temperature losses	-4.9
Soiling losses	-1.1
Module quality	-1.1
Mismatch losses	-1.6
DC wiring losses	-0.9
AC wiring losses	-0.5
Transformer and substation losses	-1.1

Source: Fichtner (fix installation, polycrystalline modules, Italy)

Yield projections – Main simulation results

- PVsyst calculated main simulation results:

Specific Yield [kWh/kWp/a]	Performance Ratio [%]	Energy Production [MWh/a]
1,304	78.2	78,882

- Still to be accounted for:
  - Module degradation (initial and linear)
  - Plant availability
  - Grid availability
- Accordingly reduced specific yield for uncertainty evaluation (degradation normally considered separately in financial models)

Yield projections – Uncertainty evaluation

- Simulation and data uncertainties to be considered:

Duration [years]	1	2	3	4	5	10	20
σ_{Sim}	4.00%	4.00%	4.00%	4.00%	4.00%	4.00%	4.00%
$\sigma_{Irr,acc}$	3.22%	3.22%	3.22%	3.22%	3.22%	3.22%	3.22%
$\sigma_{Irr,ltc}$	3.85%	2.72%	2.22%	1.92%	1.72%	1.22%	0.86%
σ_{Tot}	**6.42%**	**5.81%**	**5.59%**	**5.48%**	**5.41%**	**5.27%**	**5.20%**

- Probability cases for downside scenarios:

Duration [years]	1	2	3	4	5	10	20
Total uncertainty [%]	6.4%	5.8%	5.6%	5.5%	5.4%	5.3%	5.2%
P50	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
P75	95.7%	96.1%	96.2%	96.3%	96.3%	96.4%	96.5%
P90	91.8%	92.6%	92.8%	93.0%	93.1%	93.2%	93.3%
P95	89.4%	90.4%	90.8%	91.0%	91.1%	91.3%	91.4%
P99	85.1%	86.5%	87.0%	87.3%	87.4%	87.7%	87.9%
P50 [kWh/kWp]	1,291	1,291	1,291	1,291	1,291	1,291	1,291
P75 [kWh/kWp]	1,235	1,240	1,242	1,243	1,244	1,245	1,246
P90 [kWh/kWp]	1,185	1,195	1,198	1,200	1,201	1,204	1,205
P95 [kWh/kWp]	1,155	1,168	1,172	1,175	1,176	1,179	1,180
P99 [kWh/kWp]	1,098	1,117	1,123	1,126	1,129	1,133	1,135

Photovoltaic Power Plants – Some Key Figures

Estimates of solar electricity generation for some countries (untracked system):

- Ukraine: 1,200 kWh/kWp
- Spain and Italy: 1,450 kWh/kWp
- France: 1,150 kWh/kWp
- Germany: 900 kWh/kWp

Fix installation or module tracking?

- Tracked systems have a higher demand of construction surface per installed power
- To avoid shading due to increased height of tracking systems compared to fixed mounting
- Additionally tracked systems have always a large shadow as the are aligned to the sun direction
- East/west shadows of fixed mounted systems stay relatively small

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Photovoltaic Power Plants – Exemplary Comparison

	Units	Fixed Mounted		One Axis Tracker		Two Axis Tracker
		thin film	crystalline	horizontal	vertical	
required surface	m²/kWp	19 - 20	16 - 17	45 - 50	45 - 50	45 - 50
specific yield	kWh/ kWp	1,817	1,771	2,193	2,293	2,438
installed capacity	MWp	23.9	29.7	9.3	9.5	10.3
Electricity production (1st year)	GWh/a	43.4	52.7	20.5	21.9	25.0
average energy production	GWh/a	40.3	48.8	18.9	20.2	23.1
CAPEX	Euro/ kWp	1,959	1,947	2,689	2,686	2,726

Module Mounting Systems – Building-Integrated PV

- Photovoltaic modules are integrated into the building envelope
- Dual-purpose to serve as building envelope material and power generator
- Connection possibilities:
  - interfaced with the available utility grid
  - designed as stand-alone, off-grid systems

Grand Valley State University displaying Uni-Solar Thin Film Solar Cells

Solar thermal power plants

- Parabolic trough systems
- Fresnel systems
- Solar tower systems
- Parabolic dish systems

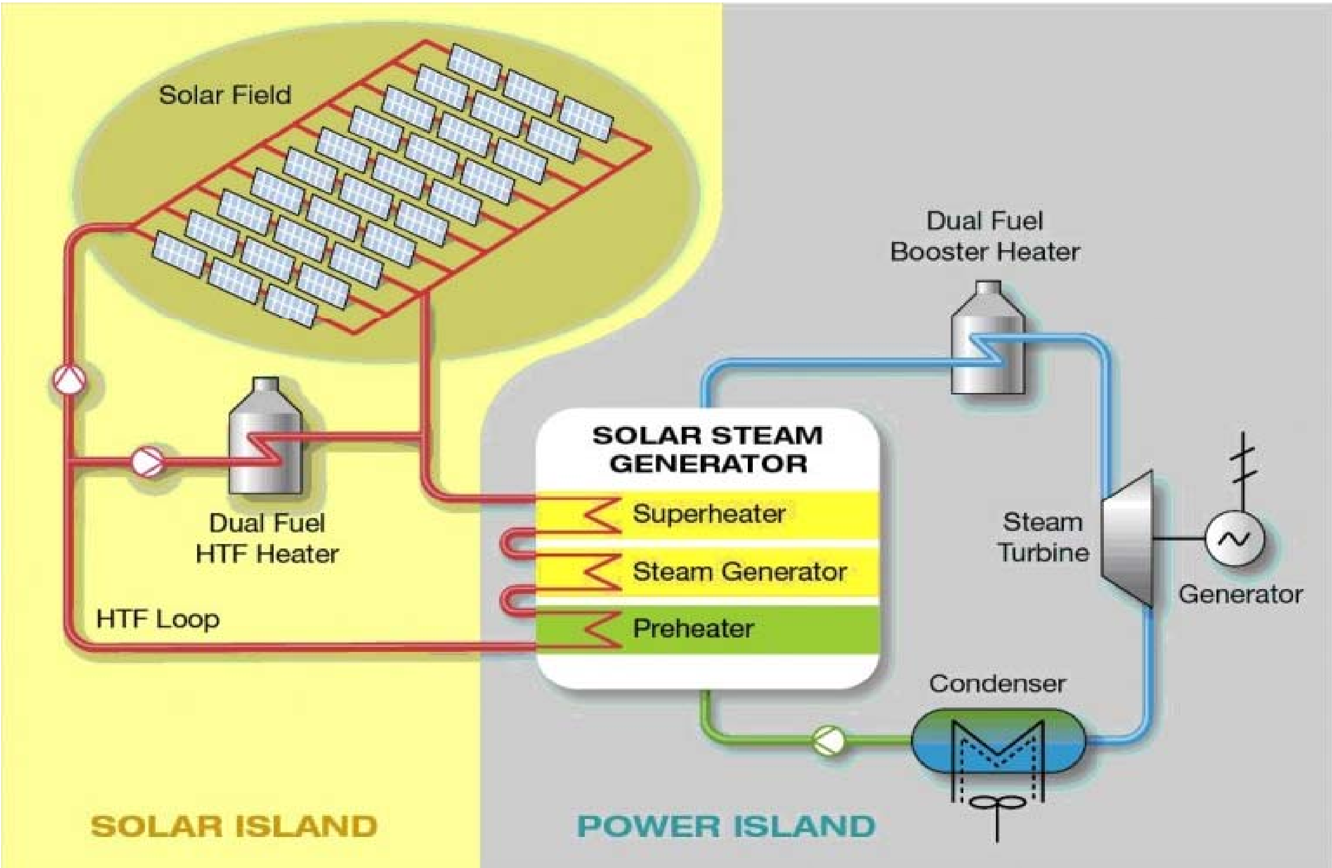
CSP parabolic trough - characteristics

- CAPEX high to very high (no storage 2.8-3.6 mn EUR/MW; with storage 4.3 – 6.5 mn EUR/MW)
- Specific CAPEX depends strongly on longitude / radiation
- Realised capacities 50-300 MW; new projects > 1000 MW
- OPEX low and well predictable
- Frequent sand storms may reduce lifetime and increase OPEX
- No fuel costs; water costs depend on cooling system
- Planning and implementation periods similar to thermal plants
- High specific land demand
- Usually no resettlement and environmental impact issues
- Well suited for competitive bidding
- Intermittency can be mitigated by thermal storage systems; capacity utilisation factors 15-22% without storage; > 40% with storage, hybridisation with fossil energy possible

Solar thermal plants – risks and issues

- General risk profile is low
- CAPEX overrun risk is currently high, due to inexperienced EPC contractors and developers; will change with market development
- Output is well projectable
- OPEX risk low; however, long term experience only from SEGS Kramer Junction (US)
- Financial viability depends on green feed in tariff (subsidies) in most power systems
- Currently strong competition from PV market

CSP plants utility scale – UAE Shams One



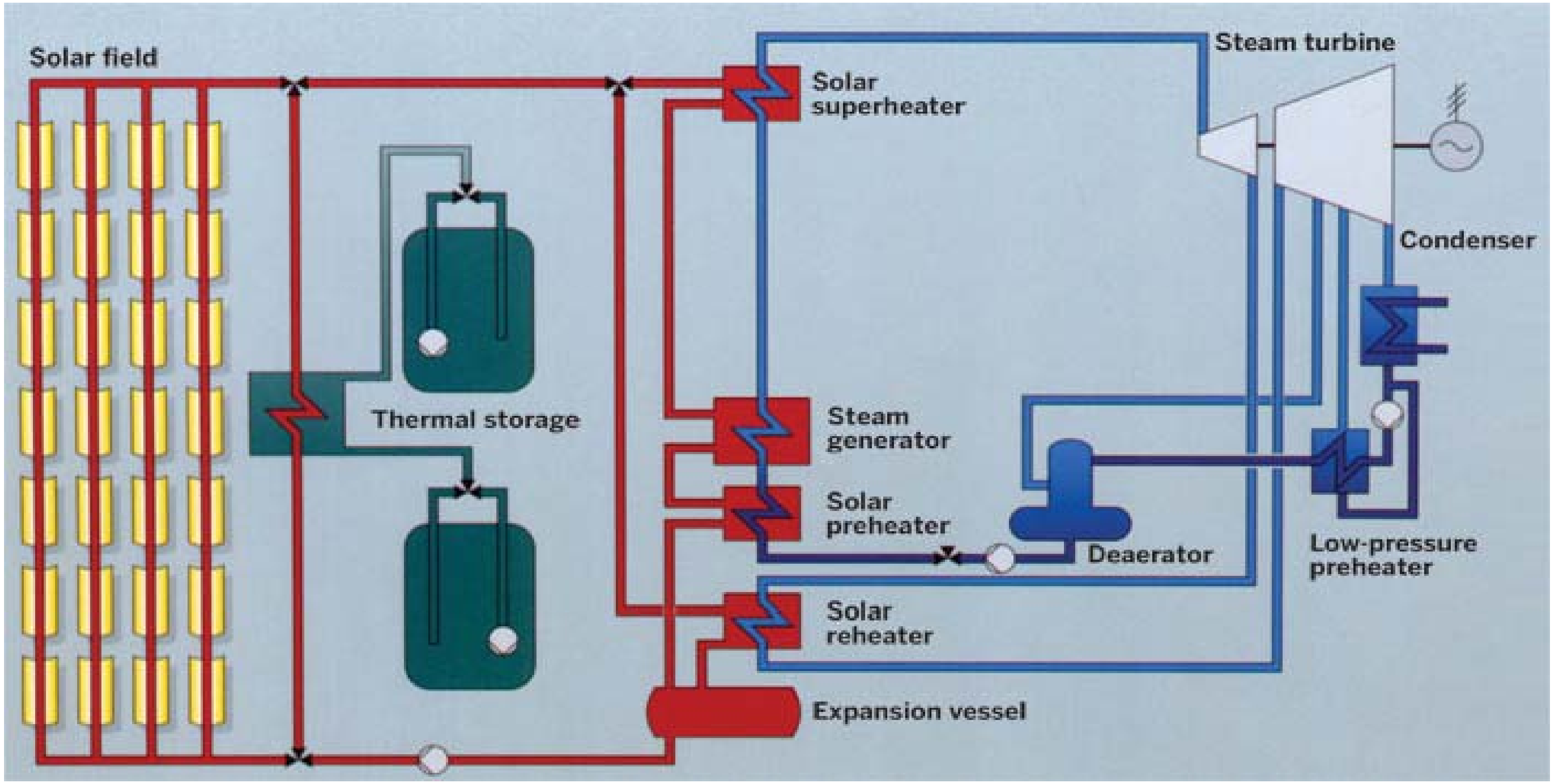
UAE - Shams One - Hybrid CSP Plant 100 MW

CSP plants utility scale – Andasol / Spain

The Andasol Power Plants, the first utility scale parabolic trough power plants in Europe. Located in Southern Spain with a capacity of 150 MW. Andasol includes three power plants (Andasol 1 -3) which were build by a phased implementation of 50 MW per phase. With a net electricity output of around 540 GWh per year and a collector surface area of over 200 ha, Andasol is the largest active solar power plant in Europe.

The three Andasol-plants together are expected to provide approximately half a million people in southern Spain with environmentally friendly solar-generated electricity. They will also contribute to a reliable energy supply and, in particular, cover the demand peaks during the hot summer months.
Each power plant has an electricity output of 50 megawatts and operates with thermal storage. A full thermal reservoir can continue to run the turbines for about 7.5 hours at full-load, even if it rains or long after the sun has set.

CSP plants utility scale – Andasol 150 MW



Andasol CSP Plant 150 MW

CSP plants utility scale – UAE Shams One

UAE - Shams One - Hybrid CSP Plant 100 MW

Comparison of solar options – PV vs CSP

PV advantages over thermal CSP

- PV make use of the global solar irradiation, solar thermal makes use of direct normal solar irradiation
- There are more suitable places for PV as for solar thermal (because solar irradiation requirements)
- PV presents a high degree of flexibility and freedom on installed capacity (sites from several Watts to 1000 MW feasible)
- PV has no water requirements
- PV has lower maintenance requirements.
- No moving parts (or if tracking is selected; PV tracking systems are less complex than for solar thermal).
- State of the art technology with several suppliers of main components; low technology risk

Comparison solar options – PV versus CSP

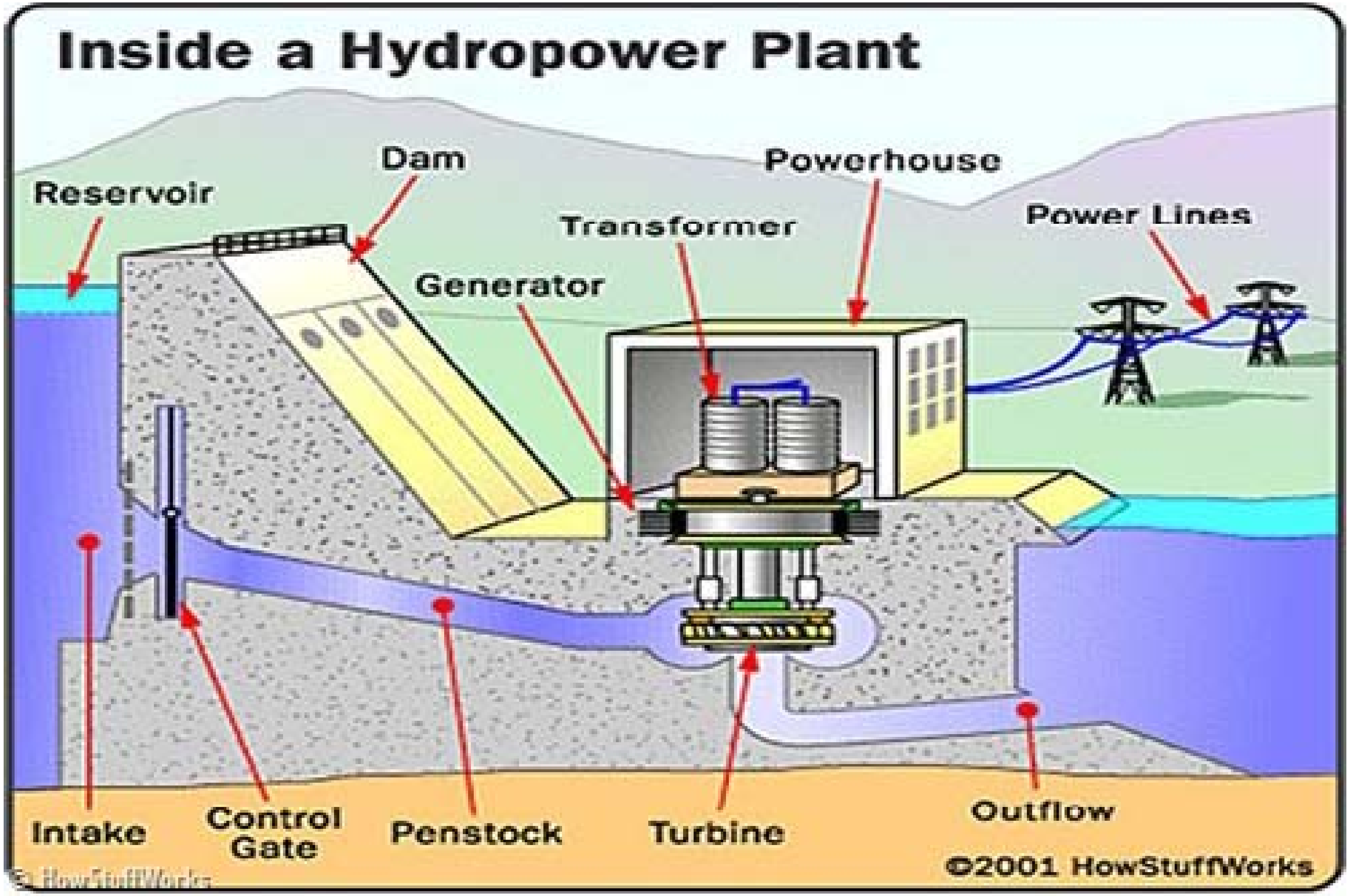
PV disadvantages

- No energy storage economically possible apart from pump-storage hydro; thus intermittency remains an issue
- Energy fluctuation during the year and during the day; hybrid systems require separate technology
- Efficiency of the PV modules decreases with high temperatures

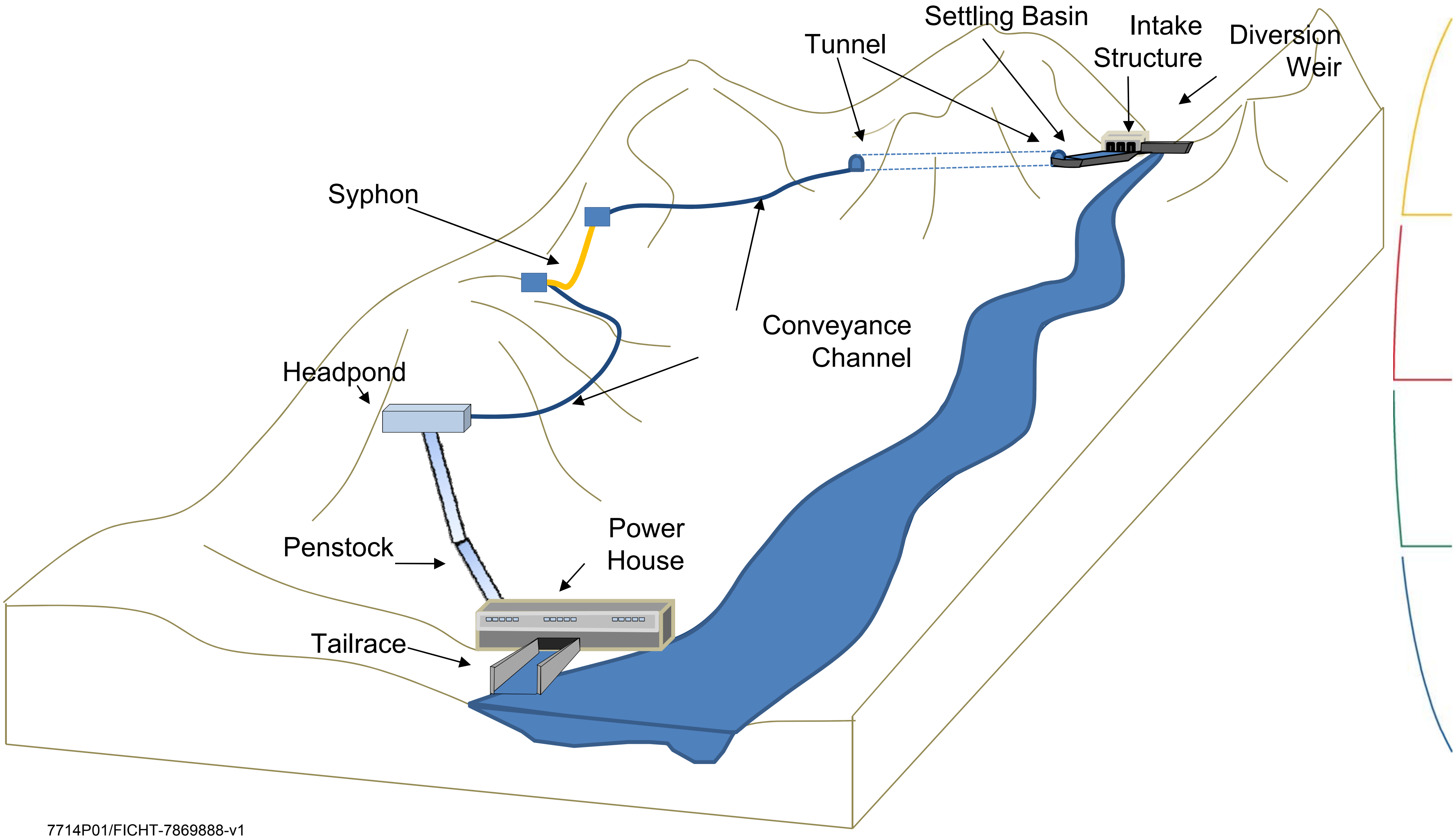
Hydro power projects – types

- Run off river
- Reservoir
- Pump storage
- Cascades

Basic Structures of Hydropower Plants



Basic Structures of Hydropower Plants



Hydro power projects - characteristics

- CAPEX usually high to very high (1 - 6 mn EUR/MW)
- CAPEX often on feasibility analysis level still uncertain (+/- 25%)
- OPEX very low and well predictable (0.3 – 2.0 EUR/MWh)
- No fuel costs
- Large projects often with long planning and construction periods (construction 3-7 years, planning up to 20 years)
- IDC huge portion of CAPEX (> 20% is possible)
- Construction periods prone to delays
- Resettlement and environmental impact issues need careful consideration
- Access roads and interconnection may constitute huge CAPEX portions
- Huge co-benefits in agricultural sector possible (irrigation, fishing)
- Not well suited for competitive bidding (a lot of resources have to be spent before project is sufficiently defined for bidding)
- Base load capacity often only a fraction of total (firm capacity)

Hydro power projects – risks and issues

- CAPEX overrun in most projects

  A World Bank study of 80 hydro projects indicated that final costs exceeded budget in 76 projects. Final costs on half of the projects were at least 25% higher than estimates.
- Construction time has significant impact on IDC
- Hydrology – impact of dry periods and floods often underestimated
- Sedimentation of reservoirs
- Silt (abrasive) erosion on turbines higher than expected
- Lack of cascade planning
- Resistance from local communities and environmental activists delays financial close or start of construction
- Post close resistance damages banks reputation (no model impact)
- Developing countries: High inflation and economic crisis during planning/construction period (CAPEX increases, tariff remains low)

Main Items for Hydropower Planning

As Hydropower is using natural resources a planning of experienced consultants is essential to reduce the main risks like

- Hydrology & Climate (natural flow including flood, sediment transport etc.)
- Topography
- Geological situation
- Earthquake

Additionally the following aspects have to be considered

- Political conditions
- Energy market
- Authorization process with necessary licenses, permits, contracts etc.
- Environmental & Social Assessment based on Equator Principles or similar
- Cultural Issues (Holy sites, archaeological sites etc.)

Main topic:

➔ No hydropower plant is exactly like any other!

USELF
Ukraine Sustainable Energy Lending Facility

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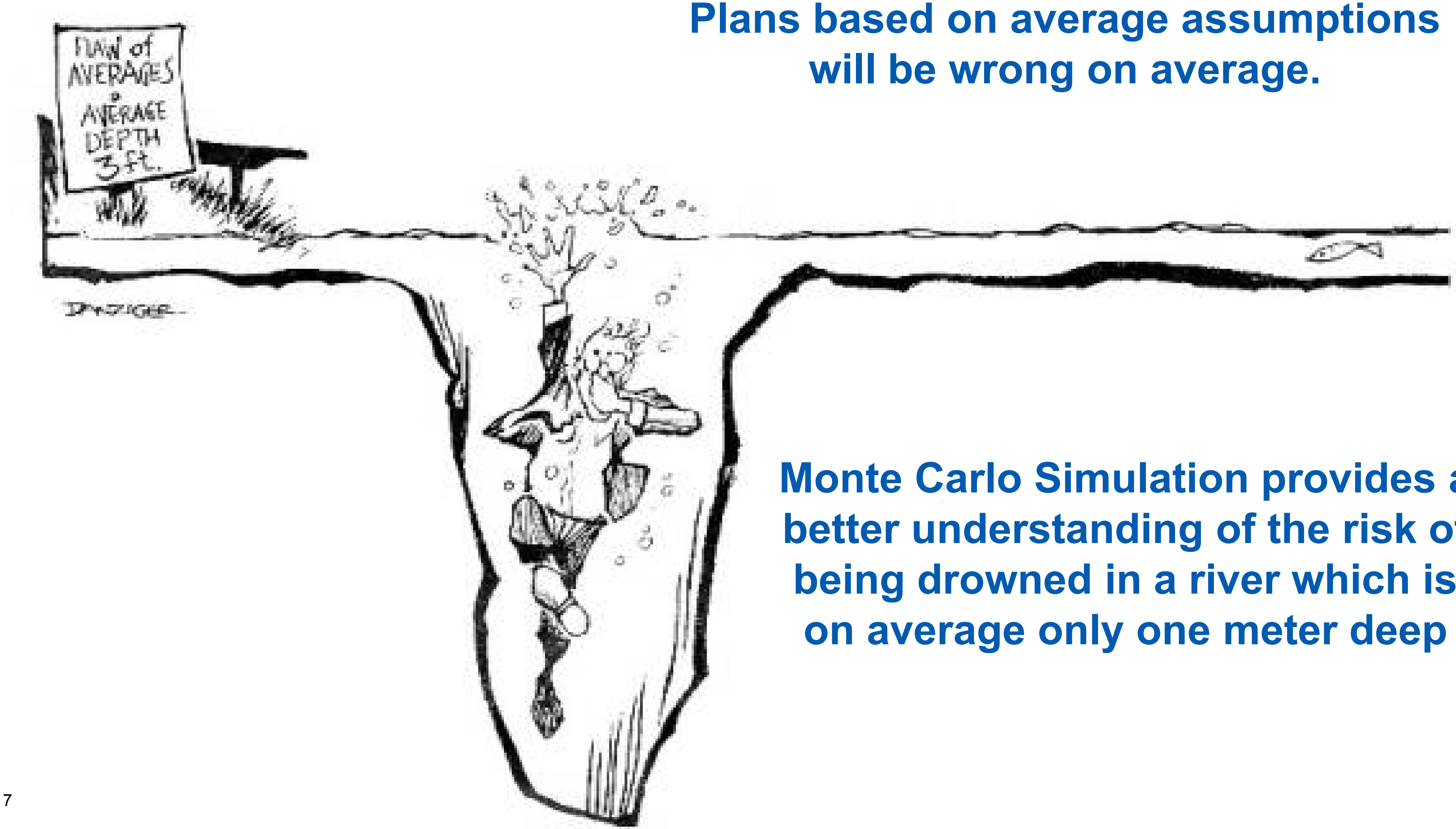
Financial models and risk assessment with Monte Carlo Simulation



Plans based on average assumptions will be wrong on average.

Monte Carlo Simulation provides a better understanding of the risk of being drowned in a river which is on average only one meter deep

Danger of believing too much in models

Alan Greenspan, Financial Times:

"The essential problem is that our models – both risk models and econometric models – as complex as they have become – are still too simple to capture the full array of governing variables that drive global economic reality. A model, of necessity, is an abstraction from the full detail of the real world."

Nicholas Taleb "The Black Swan":

In the not too distant past, say the pre-computer days, projections remained vague and qualitative, one had to make a mental effort to keep track of them, and it was a strain to push scenarios into the future. It took pencils, erasers, reams of paper, and huge wastebaskets to engage in the activity. The activity of projecting, in short, was effortful, undesirable, and marred with self doubt.

But things changed with the intrusion of the spreadsheet. When you put an Excel spreadsheet into computer literate hands, you get projections effortlessly extending ad infinitum. We have become excessively bureaucratic planners thanks to these potent computer programs given to those who are incapable of handling their knowledge.

Financial and economic analysis for renewable energy projects – web resources

- https://financere.nrel.gov/finance/content/CREST-model
- http://www.retscreen.net/ang/home.php
- www.financialmodelling.net
- http://www.financialmodelingguide.com/analytical-tools/financial-management-templates/

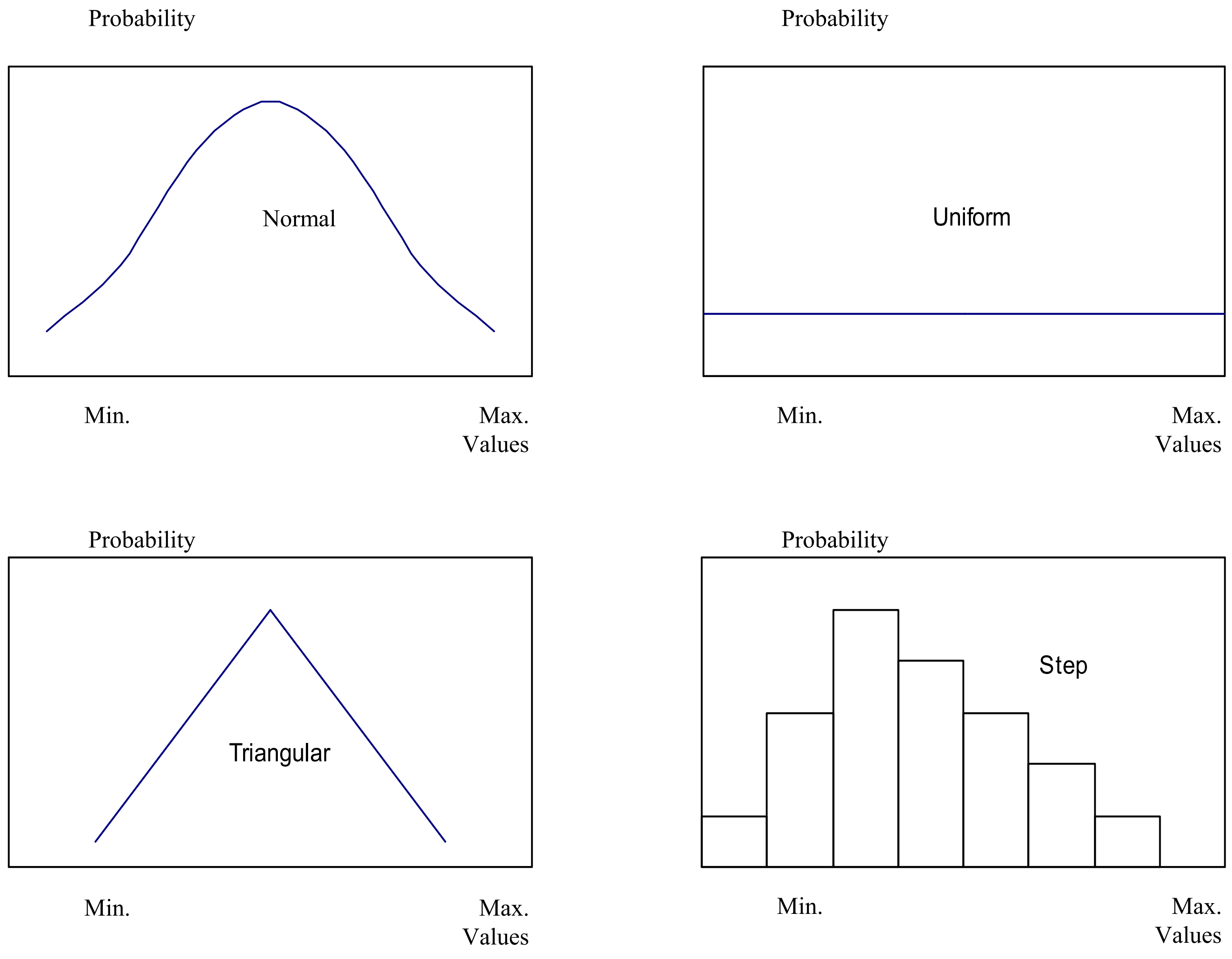
Conventional Approach to Risk Analysis

- Each risk is valued at a singular probability (in %) and a singular impact (delay, additional costs).
- No aggregation of different risk events
- The multiplication of the singular probability with the impact gives the most likely or average expected impact on the project.
- Sample of conventional risk assessment:
  - **Sensitivity 1: High fuel cost scenario:**
    - fuel price inflation +1%; base value + 5 US$/bbl
  - **Sensitivity 2: CAPEX: + 10%**
  - **Sensitivity 3: OPEX: + 0.5 US$/MWh**
  - **Worst Case Scenario: Combination of 1-3**

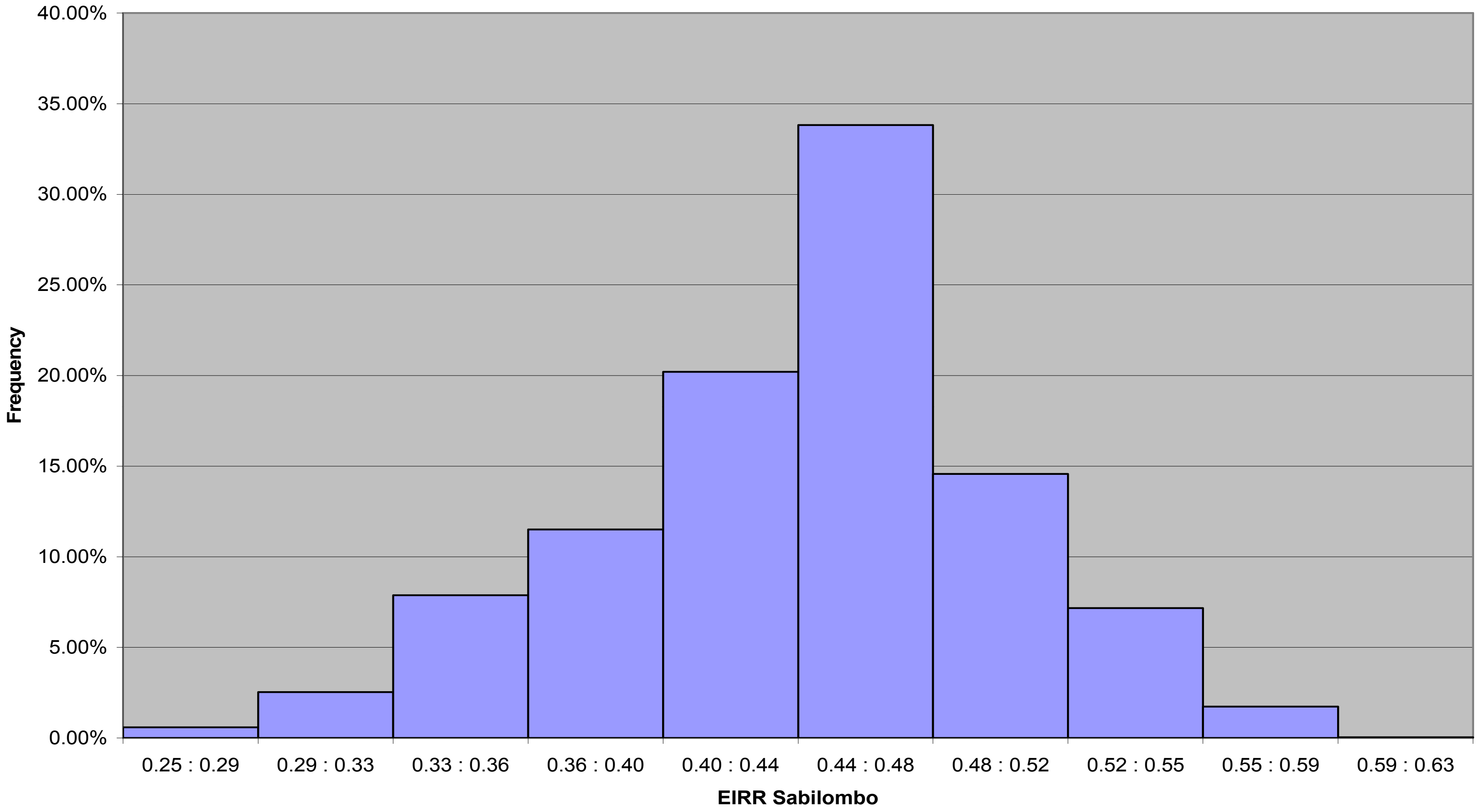
Advantage of Monte Carlo Simulation

- Risk events and the impact of the events can be analysed based on their probability distribution.
- Probability distribution can be derived from historical values or expert opinion
- All project risks can be aggregated in a simulation
- The result is a probability distribution and not a single value, which gives a better idea of the prospective range of results and performance indicators.

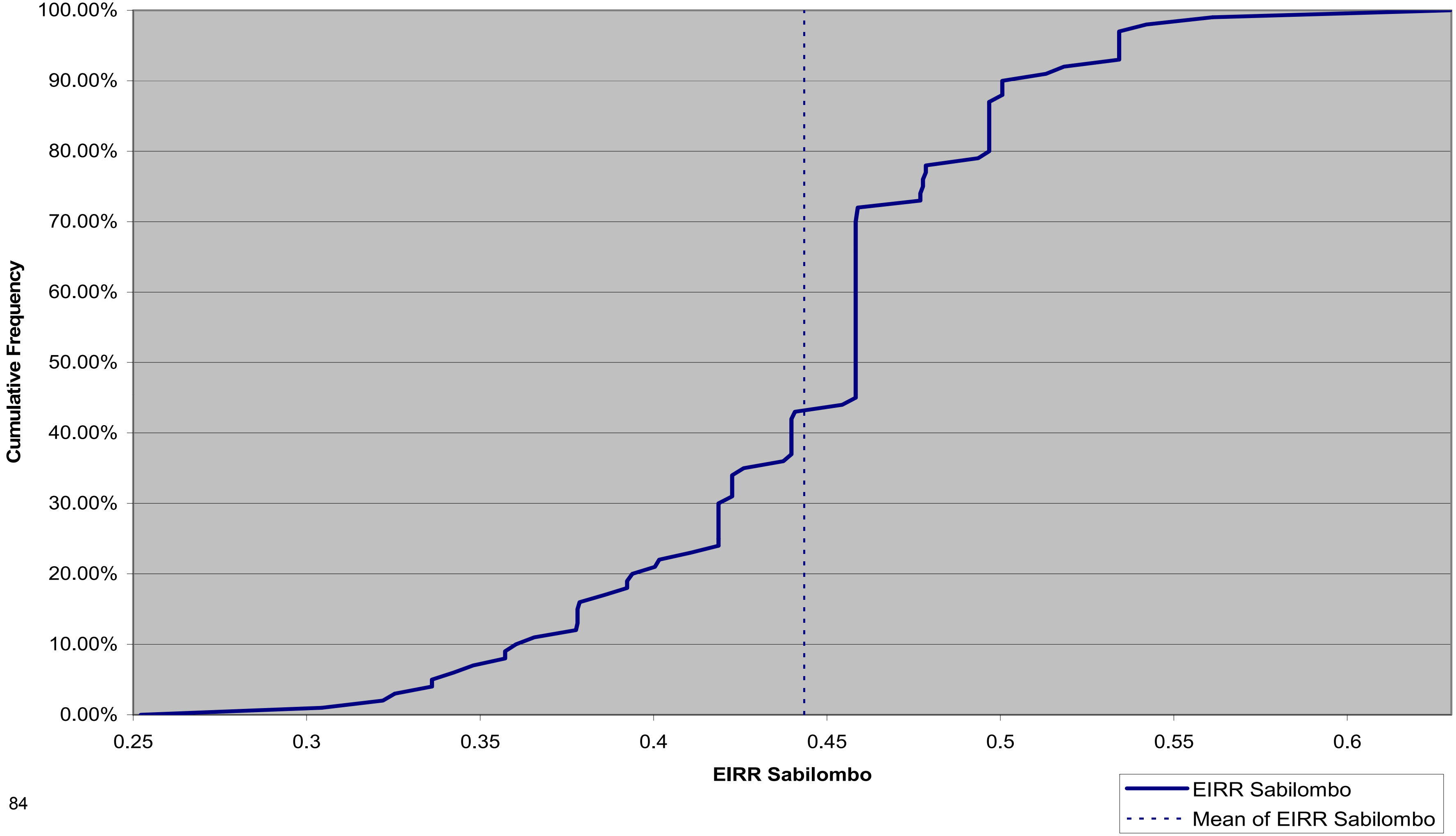
Mostly applied probability distributions



Result of a Monte Carlo Simulation



Result of a Monte Carlo Simulation



Tools for Monte Carlo Simulation

- XLSim AnalyCorp about 150,-- US$
- @Risk 900-1700,-- EUR

References Monte Carlo Simulation

- XLSim AnalyEfron, Bradley and Tibshirani, Robert J. An Introduction to the Bootstrap, Chapman & Hall, New York, 1993.
- Markowitz, H. M. (1959) Portfolio Selection, Efficient Diversification of Investments, 1991 Edition, Blackwell, Cambridge MA.
- Savage, Sam L. Statistical Analysis for the Masses in Statistics and Public Policy, edited by Bruce Spencer, Oxford University Press, 1996. See http://www.stanford.edu/~savage/stat.pdf for a pre-publication draft.
- Decision Making with Insight , - Text and Software, Brooks/Cole—Thomson Learning, Belmont CA 2003.
- INSIGHT.xla Business Analysis Software for Microsoft Excel, - Text and Software, Duxbury Press, Belmont CA 1998.
- The Flaw of Averages, San Jose Mercury News, Soapbox Column, October 8, 2000.
- Blitzograms – Interactive Histograms, Informs Transactions on Education, Vol. 1, Number 2, Fall 2000.
- Simon, Julian L., Resampling: The New Statistics. Resampling Stats, Inc. 1974-1995.
- Simulation Software from other vendors: @RISK and Crystal Ball are two powerful Monte Carlo packages that should be considered if you outgrow XLSim. Extend is a good Discrete Event Simulation package. See the Command Reference for a comparison with XLSim.

Thank you for your attention!

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