SOLARPRAXIS
Engineering & Practical Expertise for Renewable Energies

Forum 1

Technology – Mounting and Substructure

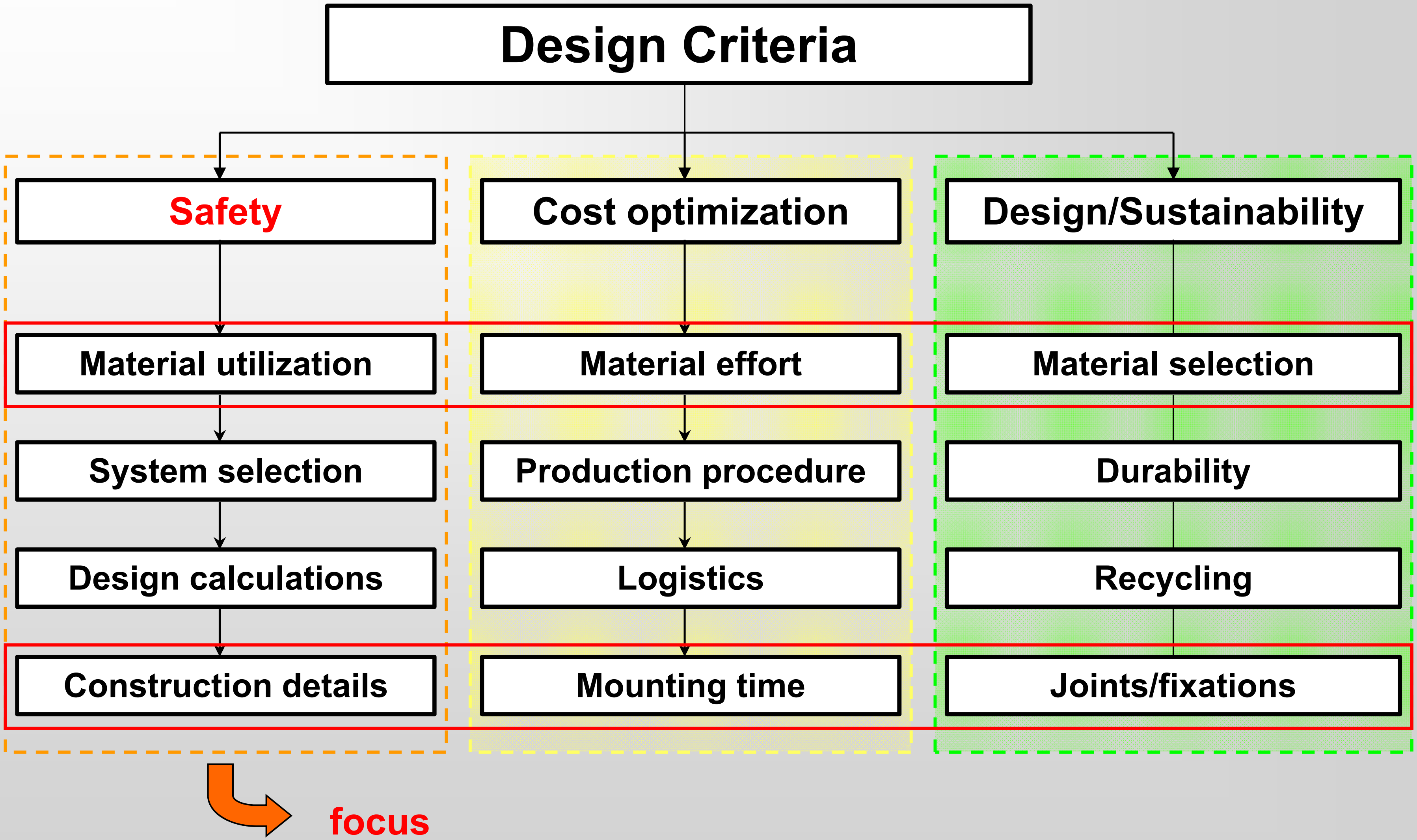
Which mounting systems are suitable for open areas?

25TH/26TH January, Prague, Czech Republic

Overview of topics:

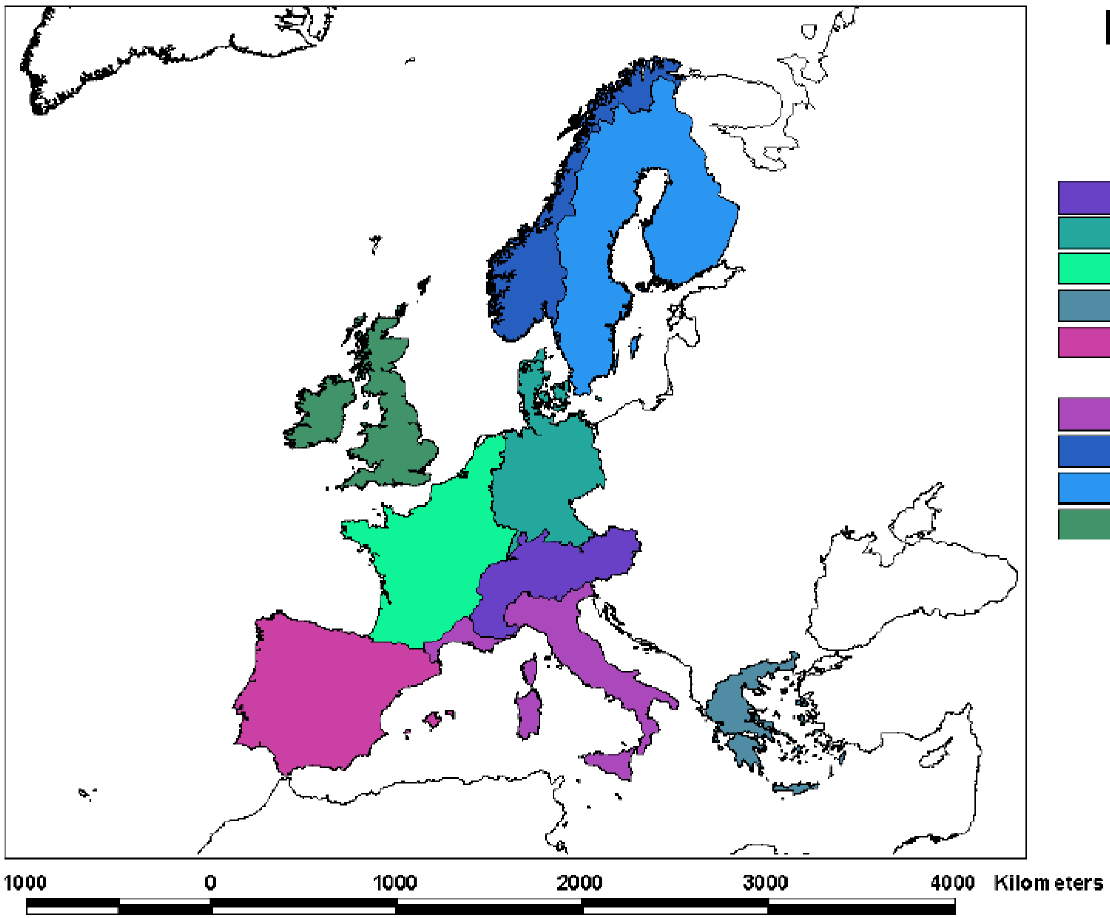
- 1. Introduction
- 2. Load evaluation
- 3. Design calculations
- 4. Decision criteria for a substructure selection
- 5. Foundation concepts
- 6. Mounting progress of different foundation concepts
- 7. Summary

1. Introduction



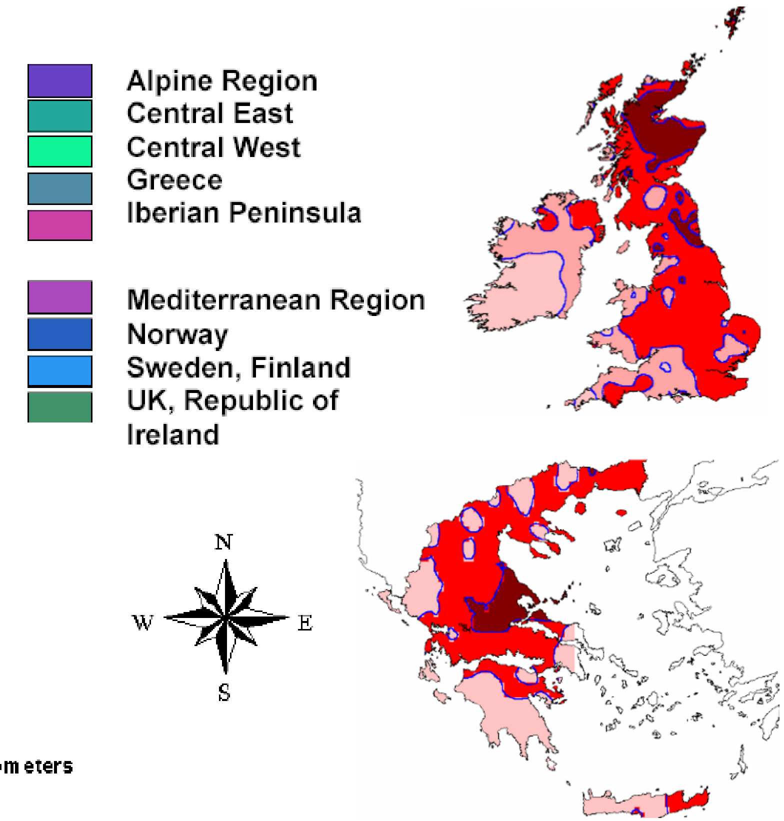
2. Load actions

Climatic Regions



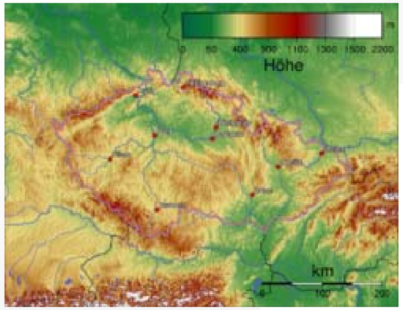
Guidelines provided by EU

Implementation by individual member states

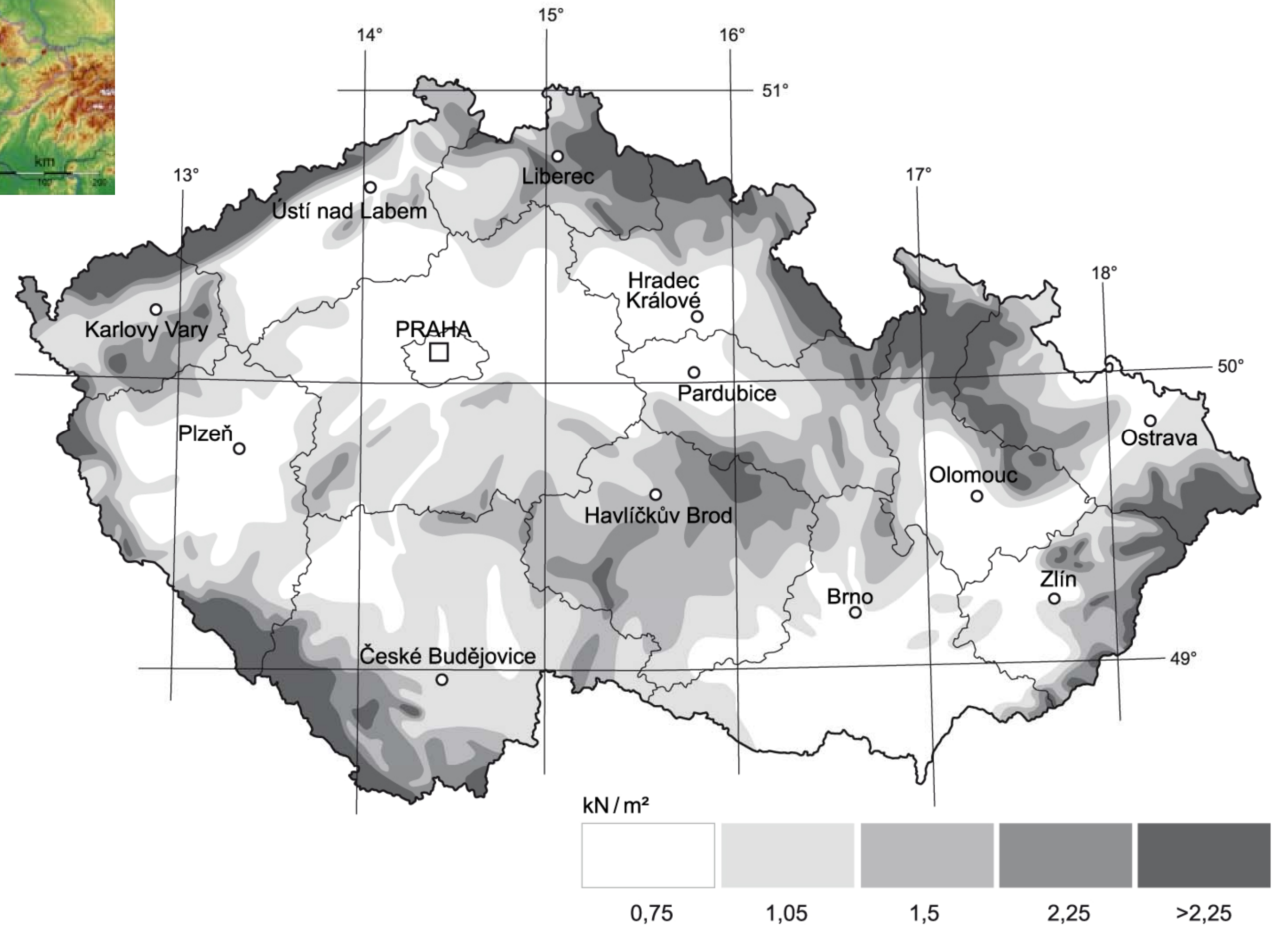


Example: International system for snow load evaluation

Czech Republic   CSN 1991-1-3



Snow loads on the ground



European wind zone map according to Eurocode 1

Basis:

Measurements (188 in D)

10-minutes median in 10 m height above ground

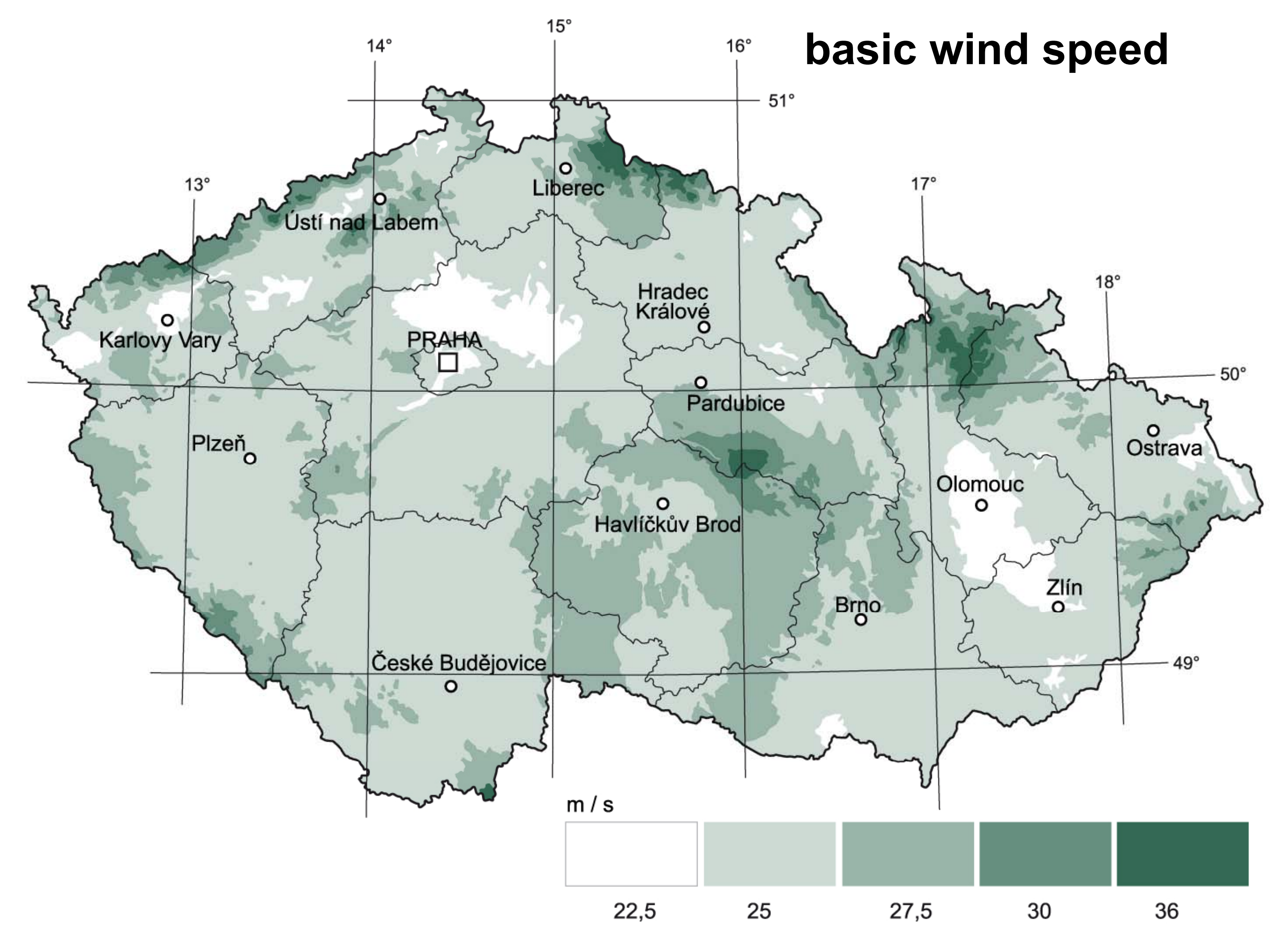
That occurs once every 50 years

Observation period: 40-107 years

Contains no gusts

Applicable for flat, even terrain

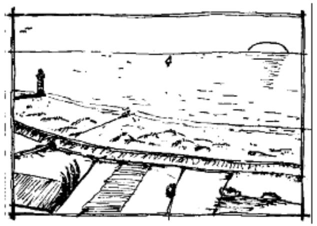
Czech Republic CSN 1991-1- 4



Terrain categories according to Eurocode 1

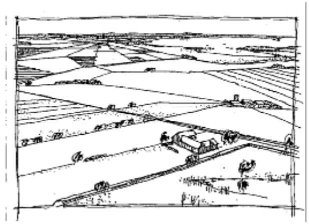
Terrain category 0

Sea, coastal area exposed to the open sea



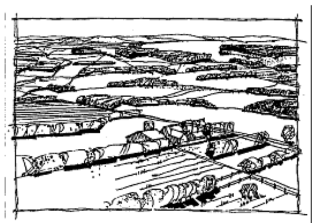
Terrain category I

Lakes or area with negligible vegetation and without obstacles



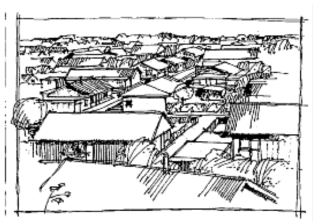
Terrain category II

Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights



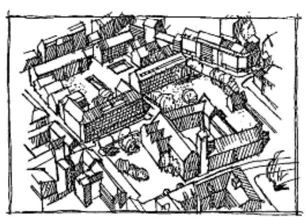
Terrain category III

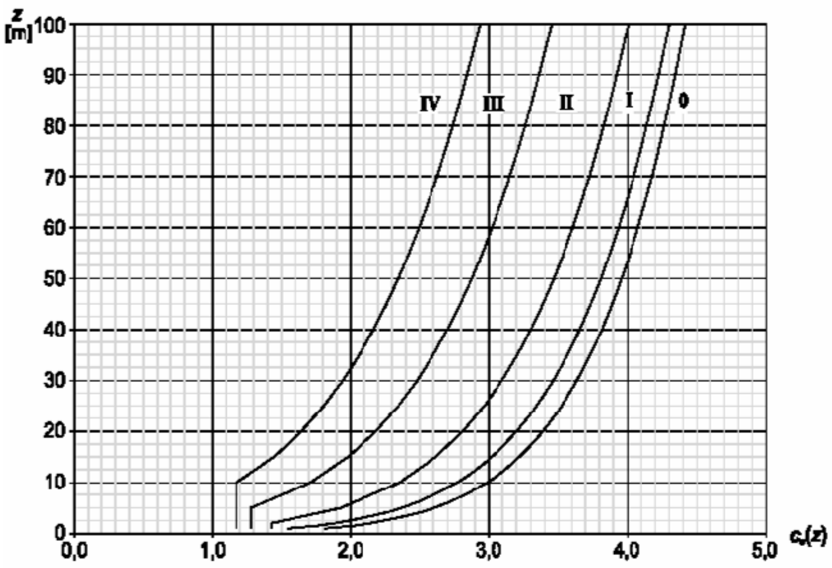
Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)



Terrain category IV

Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m





Basis:

$q_b = {}^1/_2 \cdot \rho \cdot v^2$ (basic pressure)

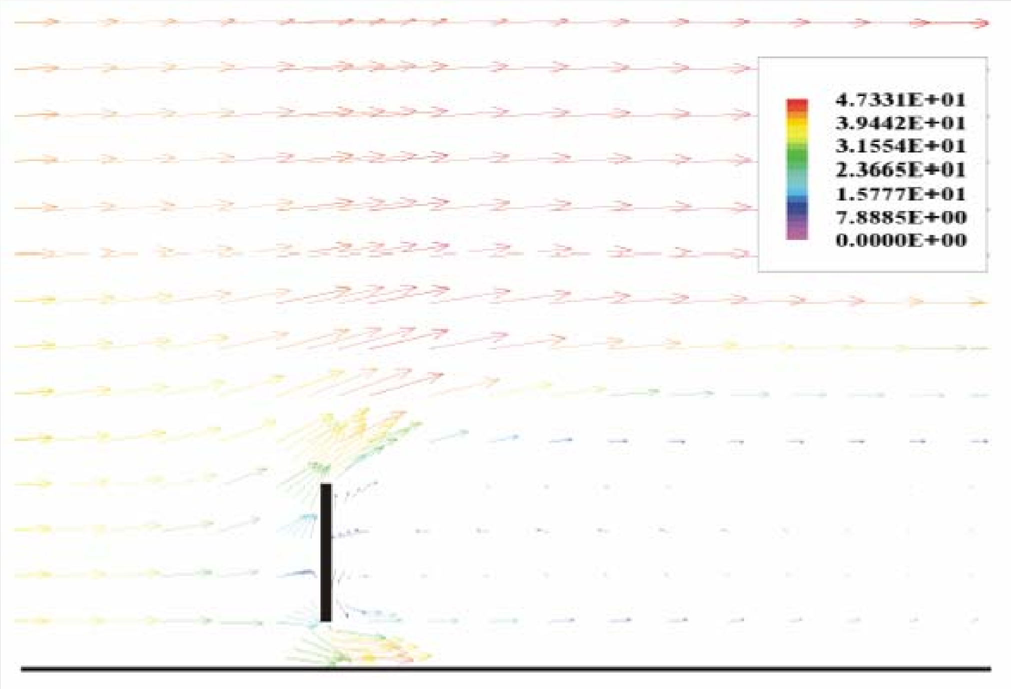
Peak velocity pressure

$q_b(z) = C_e(z) \cdot q_b$

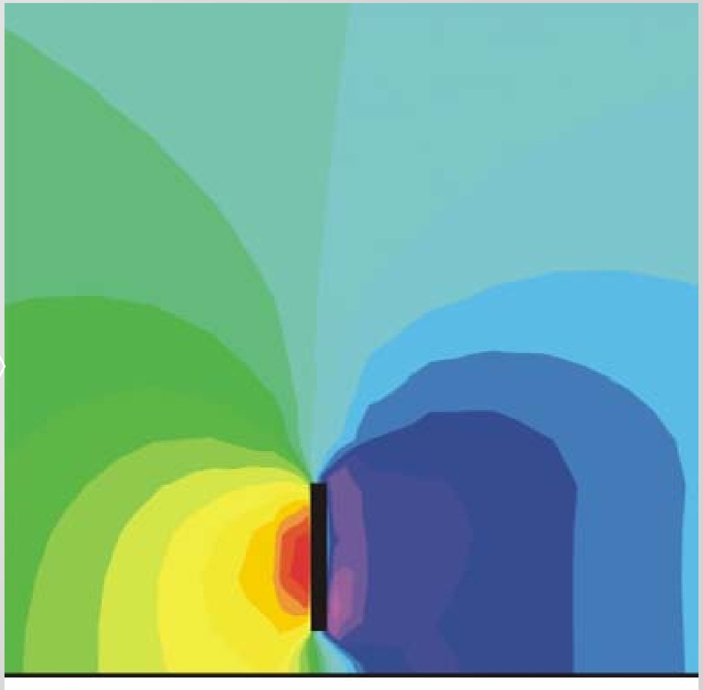
Aerodynamic characteristics

Pressure field if a vertical flow impacts the screen

Strömungsgeschwindigkeiten



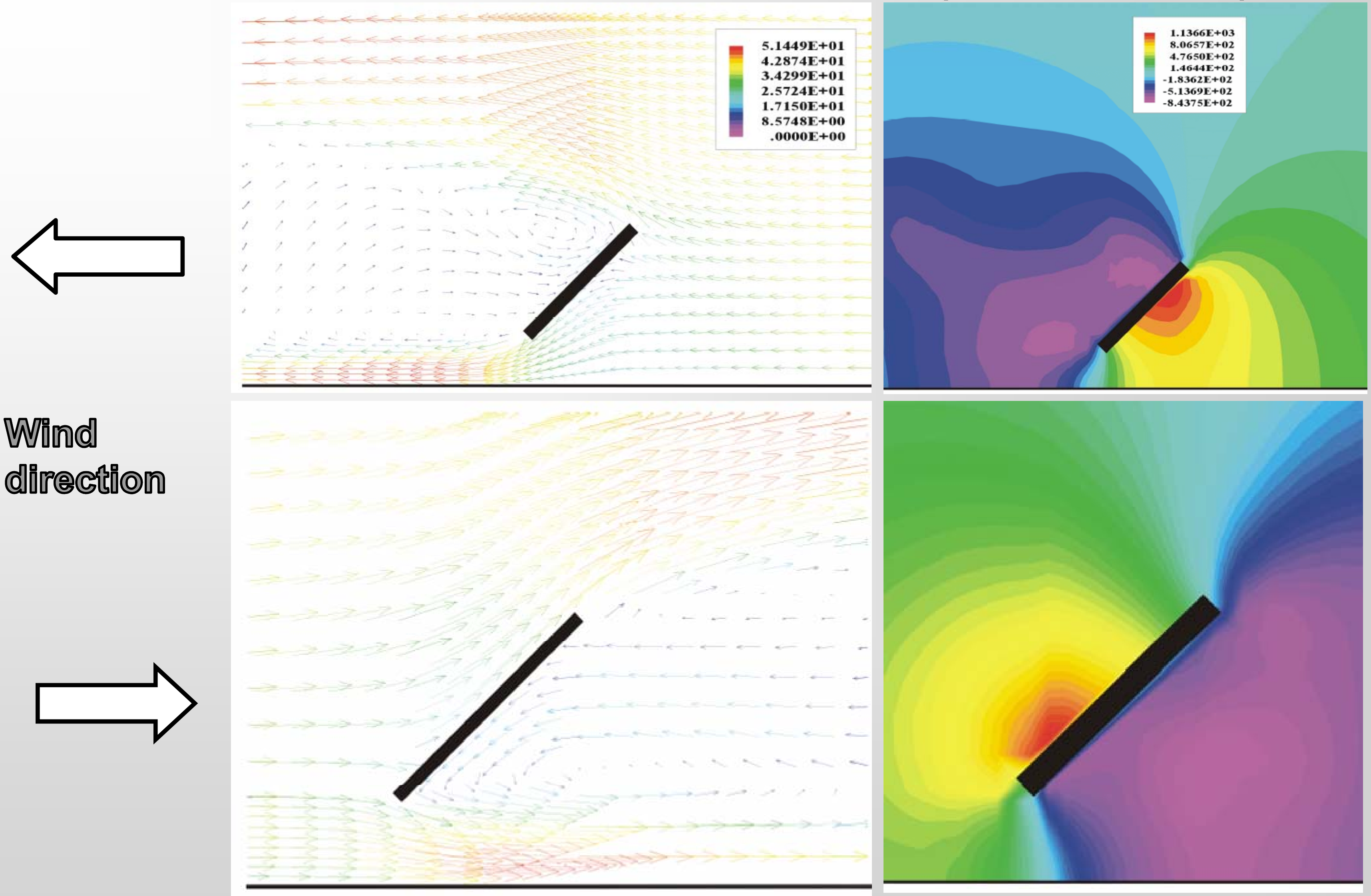
Pressure field (qualitative)



Source: Final report 0327229 A, patronized by the Federal Ministry of Economy and Technology

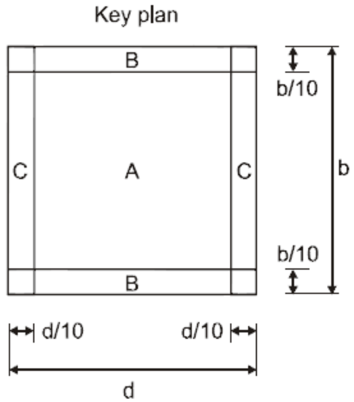
Aerodynamic correlations

(45° inclination)

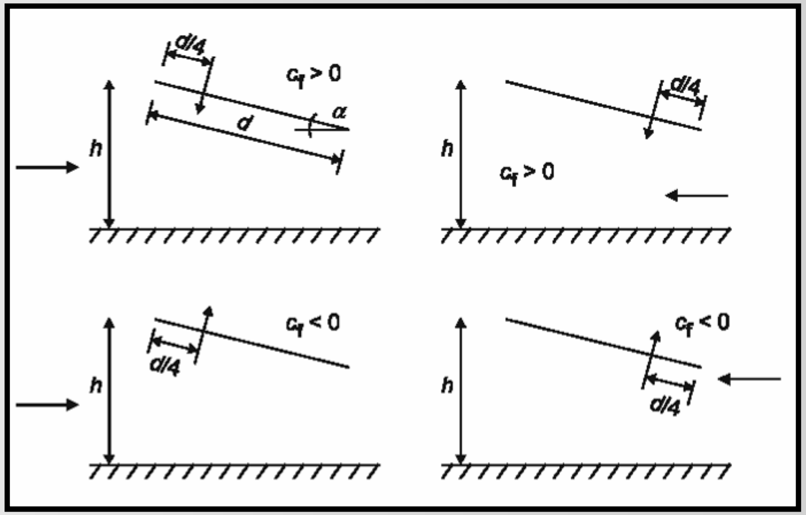


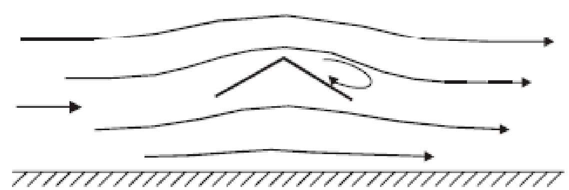
Pressure and force coefficients (DIN EN 1991-1-4)

Net Pressure coefficients $c_{p,net}$

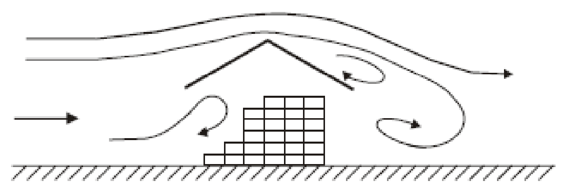


Roof angle α	Blockage φ	Overall Force Coefficients c_f	Zone A	Zone B	Zone C
0°	Maximum all φ	+ 0,2	+ 0,5	+ 1,8	+ 1,1
	Minimum φ = 0	- 0,5	- 0,6	- 1,3	- 1,4
	Minimum φ = 1	- 1,3	- 1,5	- 1,8	- 2,2
5°	Maximum all φ	+ 0,4	+ 0,8	+ 2,1	+ 1,3
	Minimum φ = 0	- 0,7	- 1,1	- 1,7	- 1,8
	Minimum φ = 1	- 1,4	- 1,6	- 2,2	- 2,5
10°	Maximum all φ	+ 0,5	+ 1,2	+ 2,4	+ 1,6
	Minimum φ = 0	- 0,9	- 1,5	- 2,0	- 2,1
	Minimum φ = 1	- 1,4	- 2,1	- 2,6	- 2,7
15°	Maximum all φ	+ 0,7	+ 1,4	+ 2,7	+ 1,8
	Minimum φ = 0	- 1,1	- 1,8	- 2,4	- 2,5
	Minimum φ = 1	- 1,4	- 1,6	- 2,9	- 3,0
20°	Maximum all φ	+ 0,8	+ 1,7	+ 2,9	+ 2,1
	Minimum φ = 0	- 1,3	- 2,2	- 2,8	- 2,9
	Minimum φ = 1	- 1,4	- 1,6	- 2,9	- 3,0
25°	Maximum all φ	+ 1,0	+ 2,0	+ 3,1	+ 2,3
	Minimum φ = 0	- 1,6	- 2,6	- 3,2	- 3,2
	Minimum φ = 1	- 1,4	- 1,5	- 2,5	- 2,8
30°	Maximum all φ	+ 1,2	+ 2,2	+ 3,2	+ 2,4
	Minimum φ = 0	- 1,8	- 3,0	- 3,8	- 3,6
	Minimum φ = 1	- 1,4	- 1,5	- 2,2	- 2,7





Empty, free-standing canopy (φ=0)



Canopy blocked to the downwind eaves by stored goods (φ=1)

Increasing wind loads in case of isolated hills and ridges

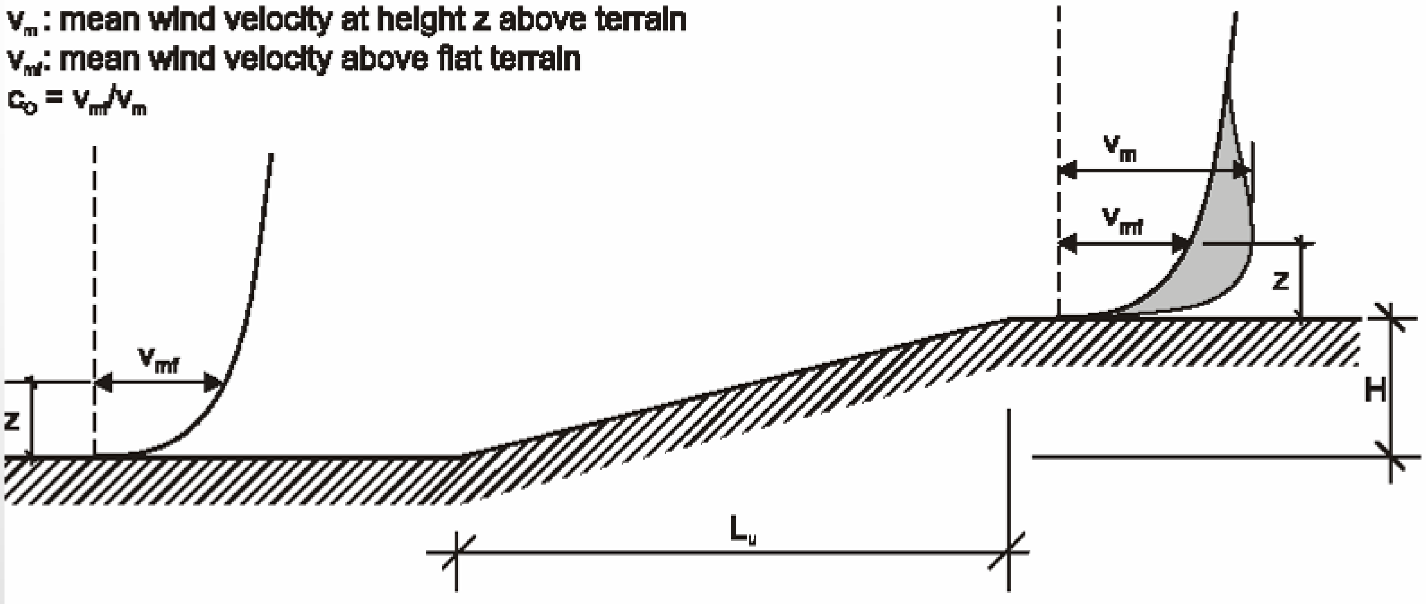


Figure A.1 — Illustration of increase of wind velocities over orography

Increasing wind loads up to 42 % in case of changig topology (isolated hills and ridges)

3. Design calculations for PV systems

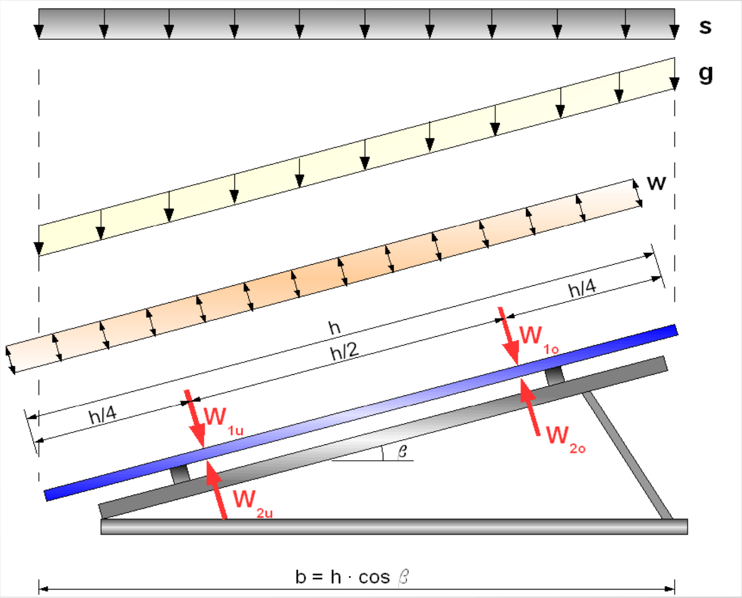
Load combinations

LC 1: 1,35·g + 1,5·s + 0,6·1,5·w

LC 2: 1,35·g + 0,5·1,5·s + 1,5·w

LC 3: 0,9·g + 1,5·w

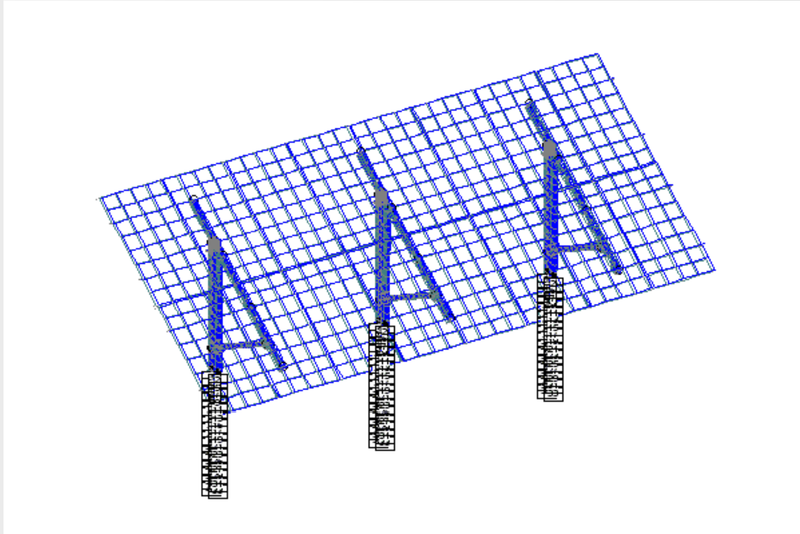
(uplift)

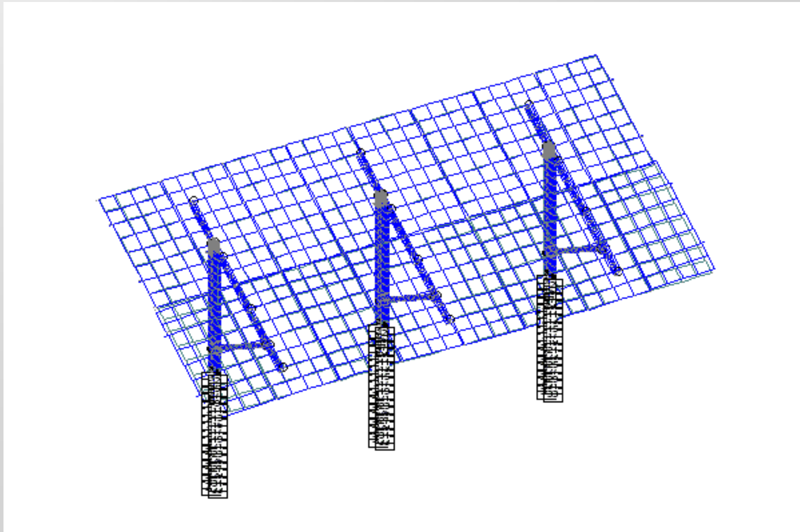


Verifications

- tilting
- dragging
- uplift

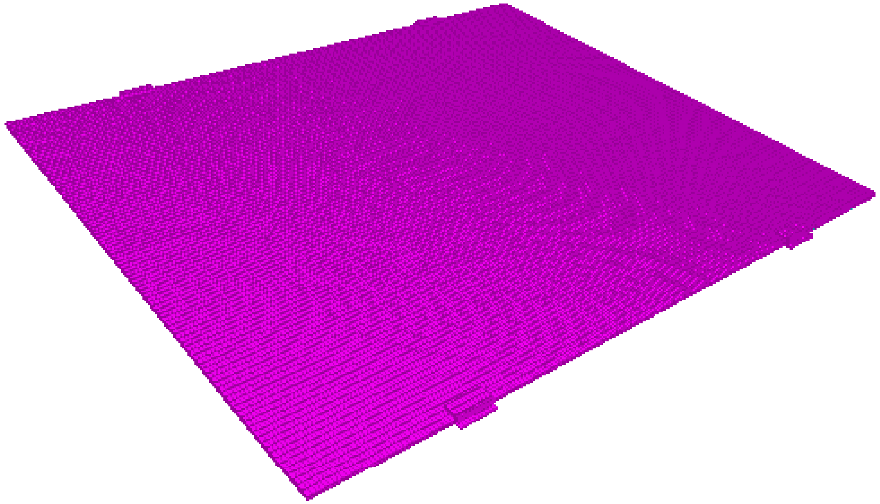
Wind-induced vibrations / seismic design

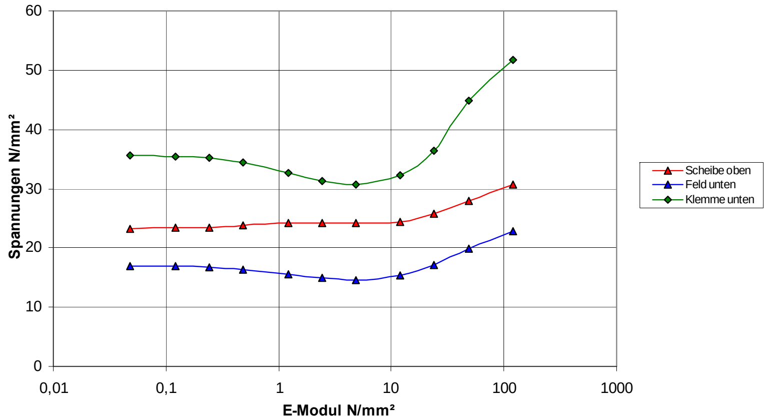


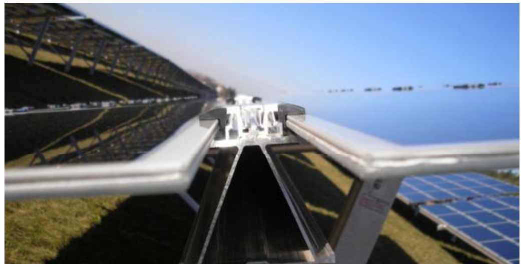


Stress calculations for frameless modules

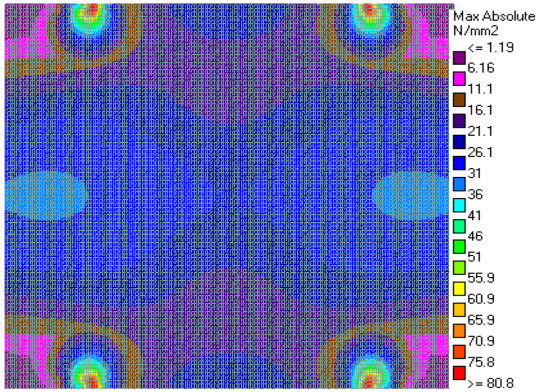
Numerical model

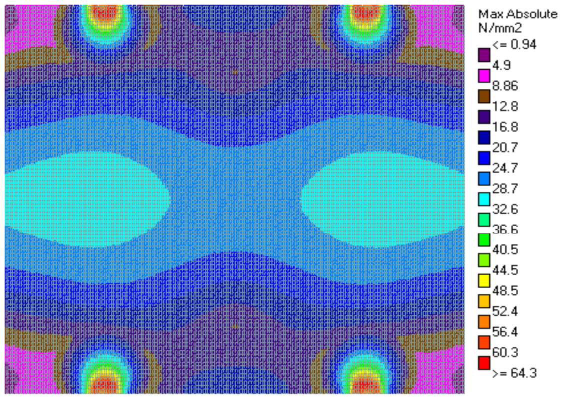


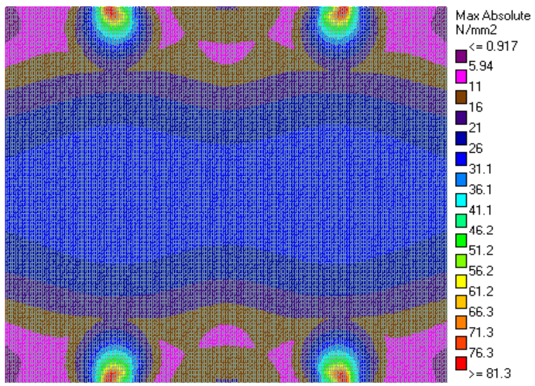




Stress calculations for thin-film modules







Dr. Zapfe GmbH
Ingenieurbüro

4. Decision criteria for substructure selection

Material (dimensioning acc. to basic material standards)

Aluminum

+ low selfweight
+ shaping by extrusion process
+ easy to install (tolerance equalization)
+ remaining value
- floating material prices
- low youngs modulus

Steel

+ availability / well-proven solutions
- corrosion protection
- mounting effort
- high weight

Timber

+ cost-saving for self-mounting
- durability
- contour accuracy

5. Foundation concepts

Pile-driven posts

- Pull-out capacity (vertical)
- Horizontal stiffness
- Bending moment in posts
- Drilling in case of rocks
- Chemical composition (corrosion)

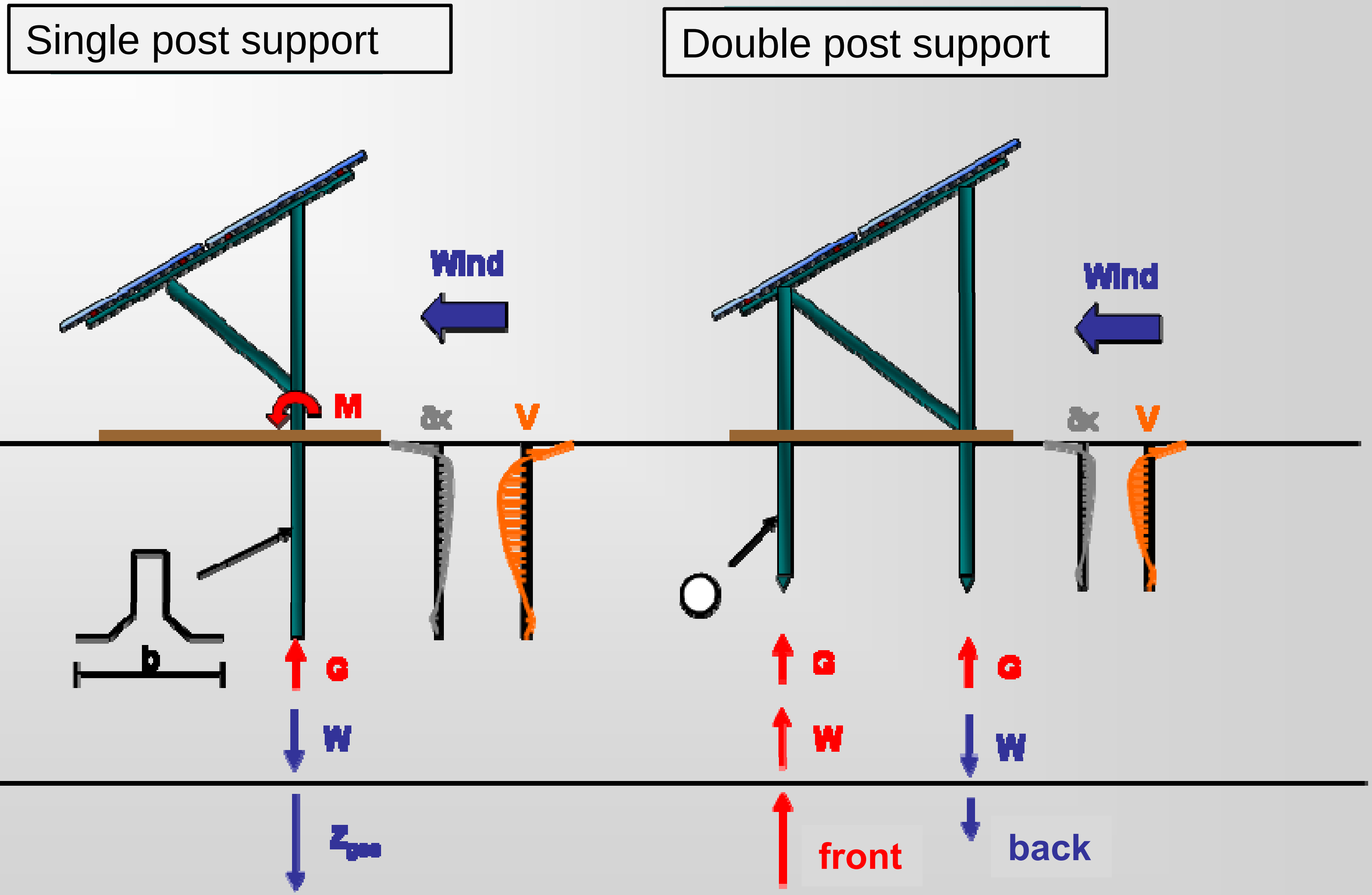
Screw foundations

- Pull-out capacity
- No horizontal stiffness
- Axial forces
- Drilling in case of rocks
- Chemical composition (corrosion)

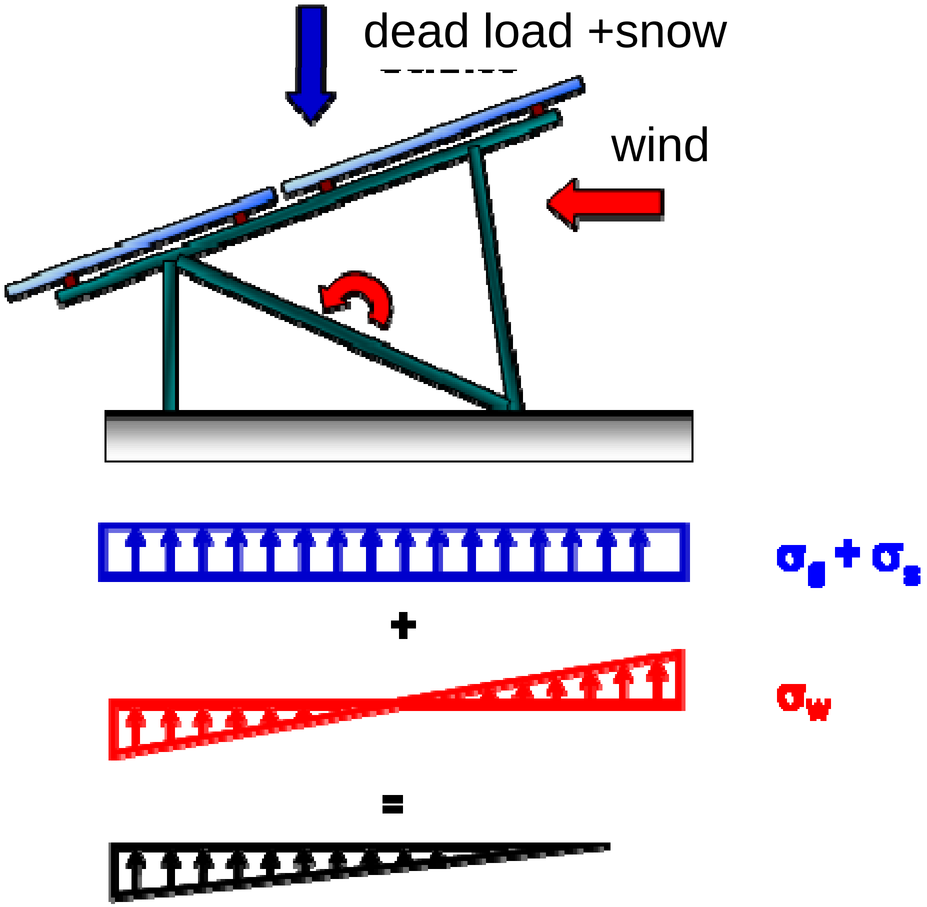
Concrete foundation

- Pressure stability of the soil
- Sensitivity of the top soil towards water
- Aggressive soil

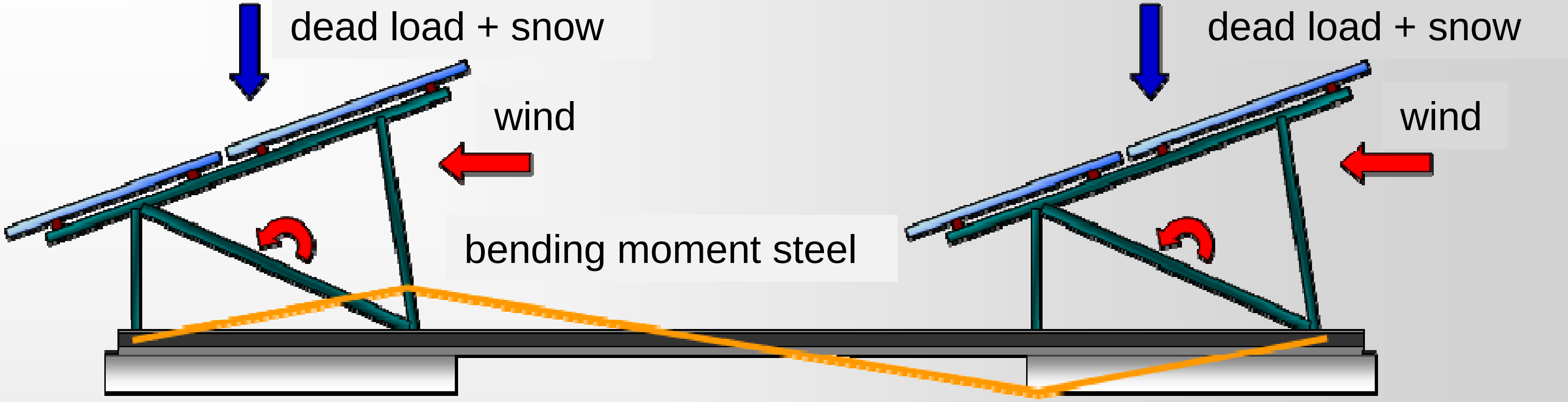
Typical load bearing systems

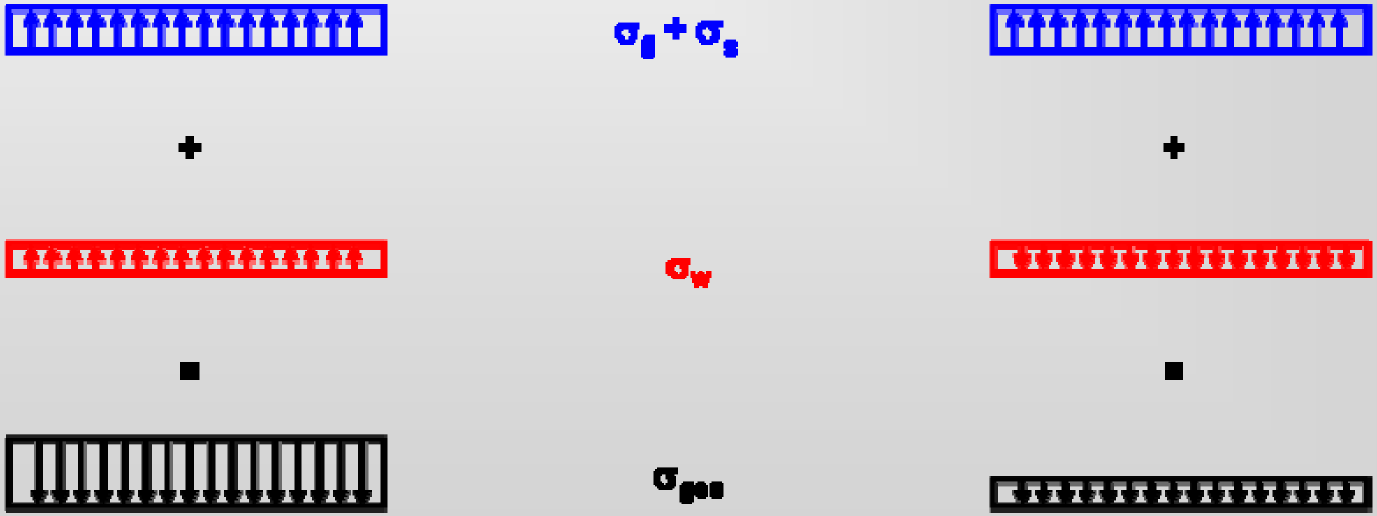


Soil pressure in case of single bearing structures



Soil pressure in case of coupled bearing structures





6. Mounting progress of different foundation concepts

Example 1: Airport Rote Jahne

Module First Solar

- Installation time 3 month
- 92.700 modules
- Optimum soil
- Minimum height 0.8 m (mechanical)
  - structurally optimized
  - terrain care by machines

Chosen System:

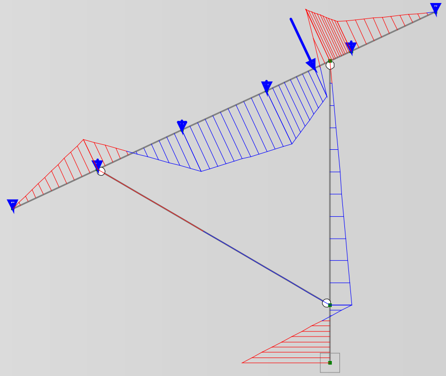
Single post ram foundations

Example 2: Landfill Malsch

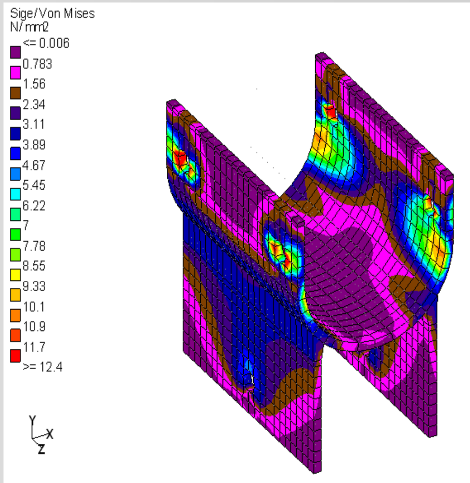
- Installation time 3 months
- 9280 modules
- Bearing capacity of the soil 0,45 KN/m²
- Minimum height 1.2 meters
  - Requirement
  - terrain care by grazing sheep

Chosen System: PvCombi

7. Conclusions



- Design calculations according to national standards
- Safety standards have to be verified for
  - Authorities
  - Insurance
  - Banking



- The suitable system depends on soil contitions
- Ram systems can be mounted significant faster

- Target: Minimum BOS costs
  - Material cost
  - Mounting effort
  - Maintenace over life time


Thanks
for your attention