



MATHEMATICS APPLIED IN ENERGY INDUSTRY

**31st Conference of Slovak Mathematicians
Jasna pod Chopkom, Nov. 18 - 21, 1999**



H² natural gas industry

H² classical engineering mathematics

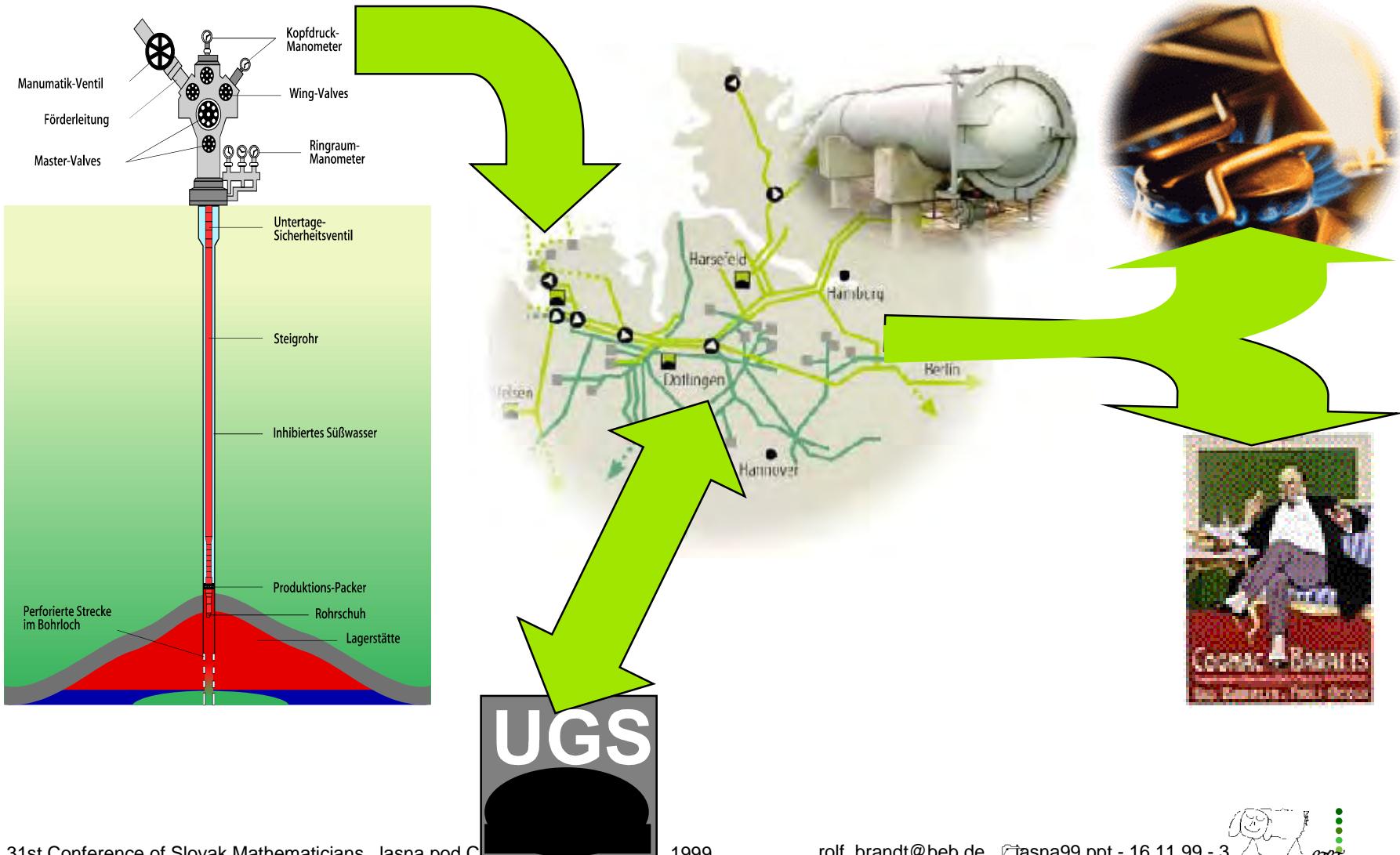
H² AI („modern things“ ...)

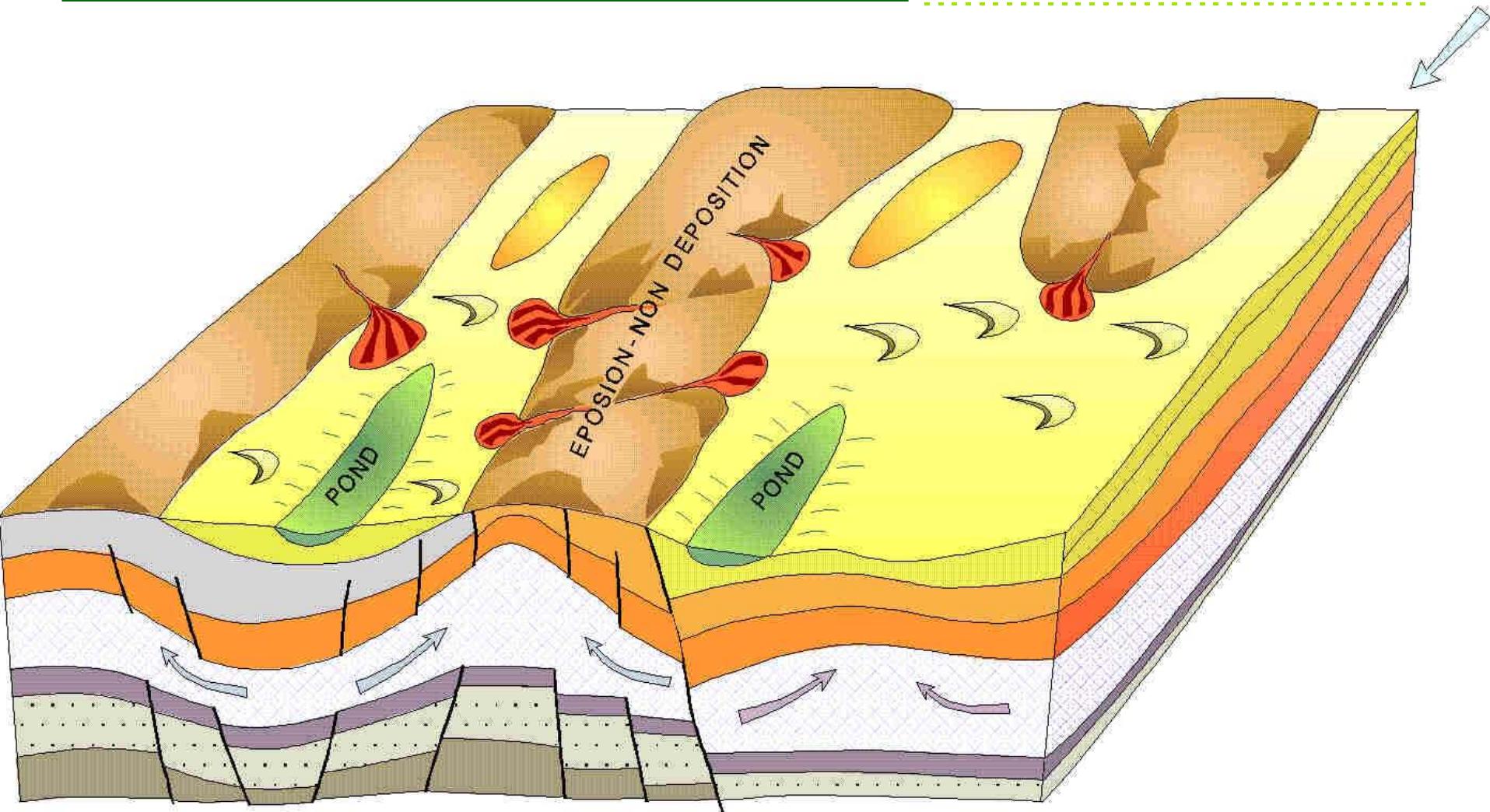
H² category theory / topology /
convergence theory

H² applications / optimisation

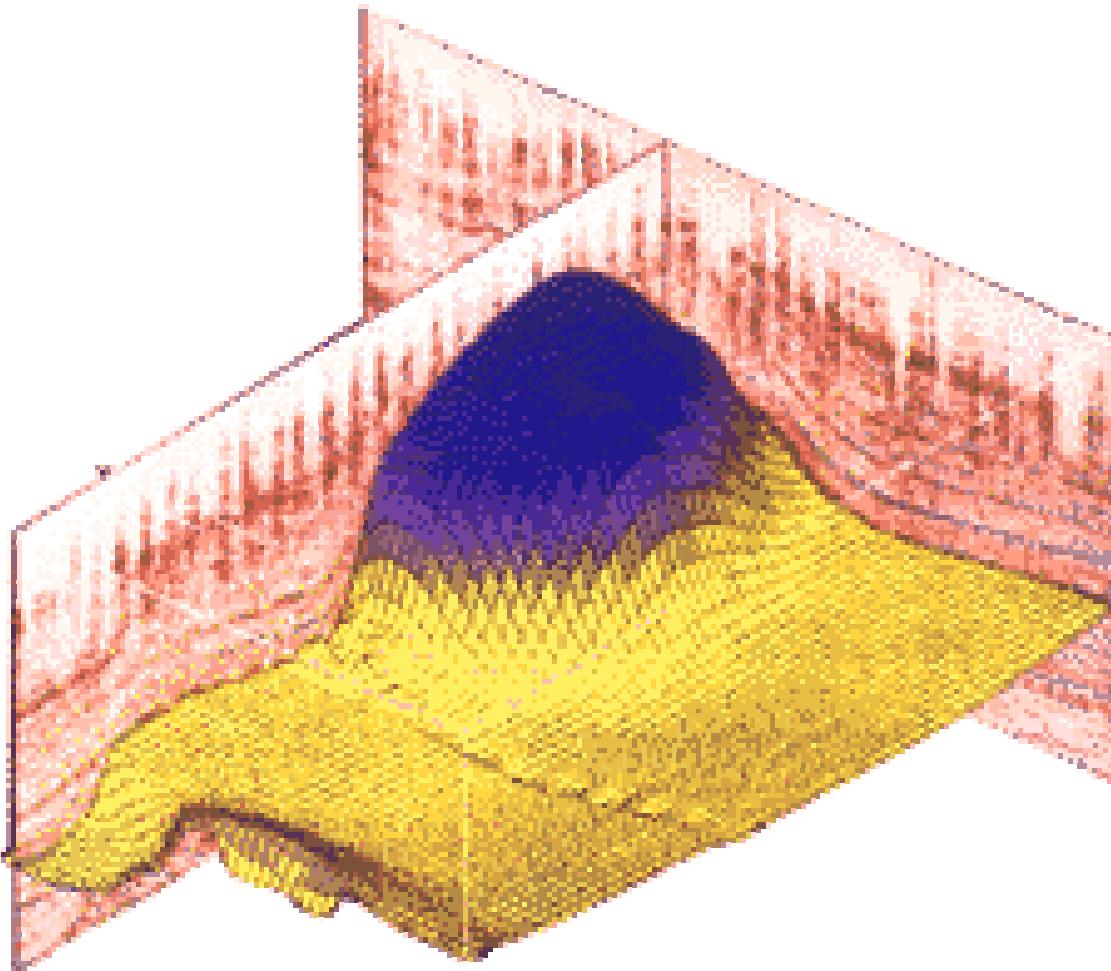


math in the whole chain ...





exploration: 3D seismic

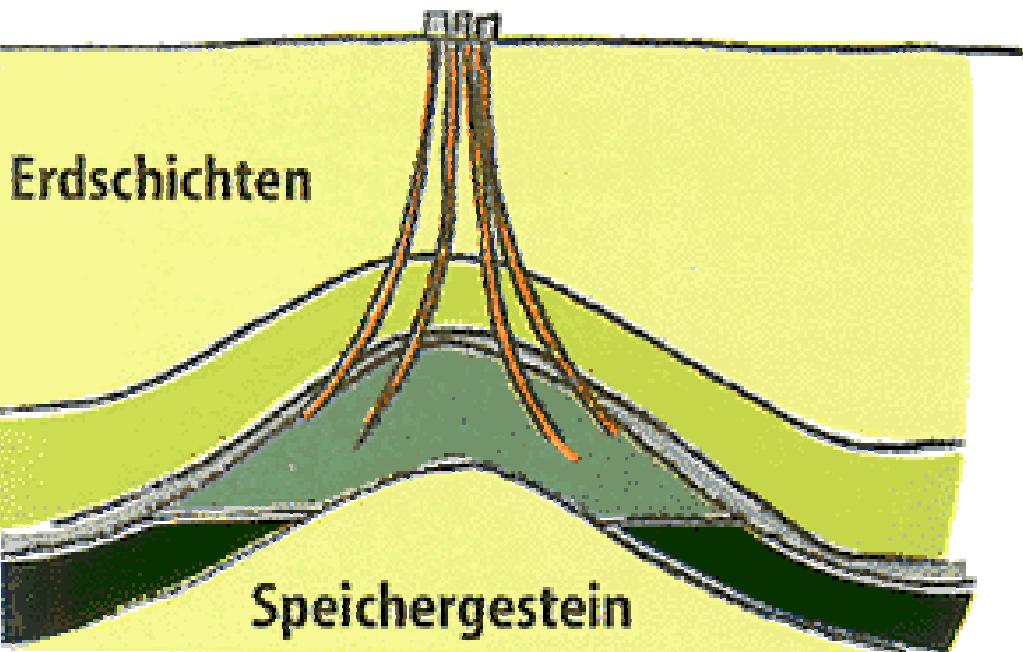


- interpolation algorithms
- number crunching
- visualisation
- today short distances
=> no interpolation ...
- even 4D started



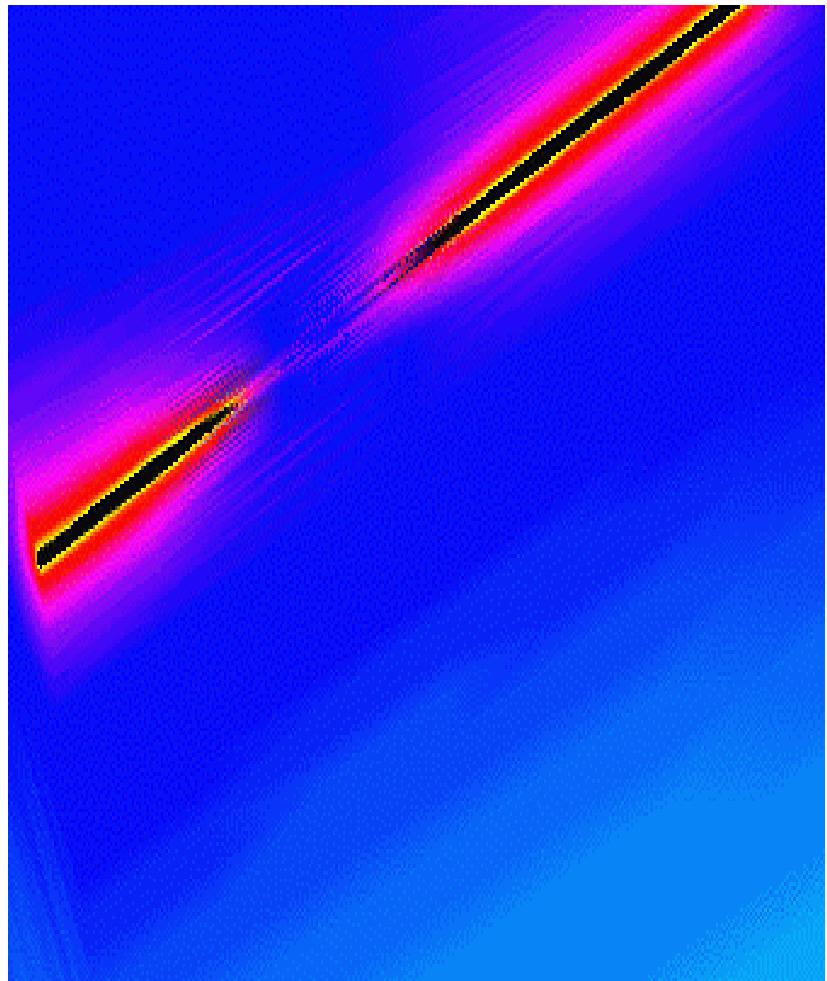
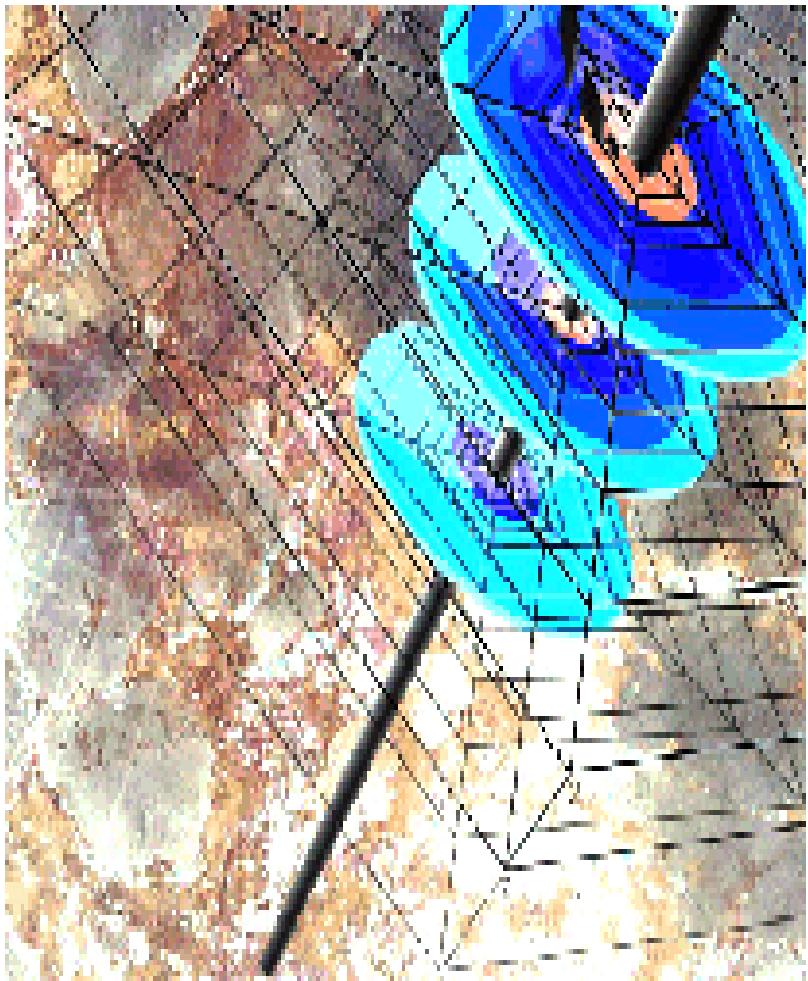
PORENSPEICHER

Bohrung

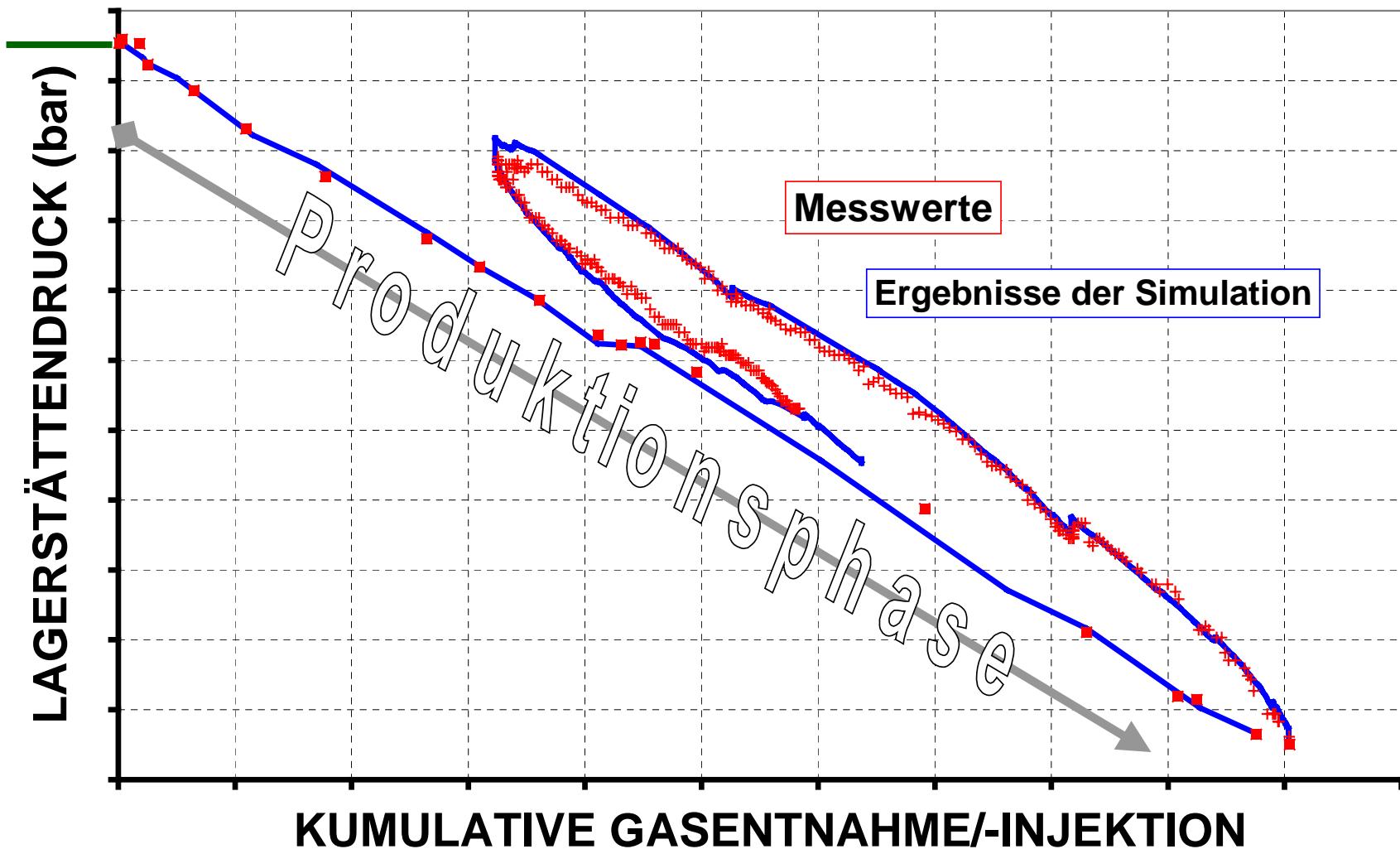


- modelling
- reservoir simulation
- diff. equations
- numerics:
 - linear solver
 - parallelisation
- statistics: correlation analysis, monte carlo, ... determination of reserves, reliability, ...
- interpolation
- optimisers: simplex, some non linear in dev.
- visualisation
- same for pore storages

FEM, pressure drop simulation

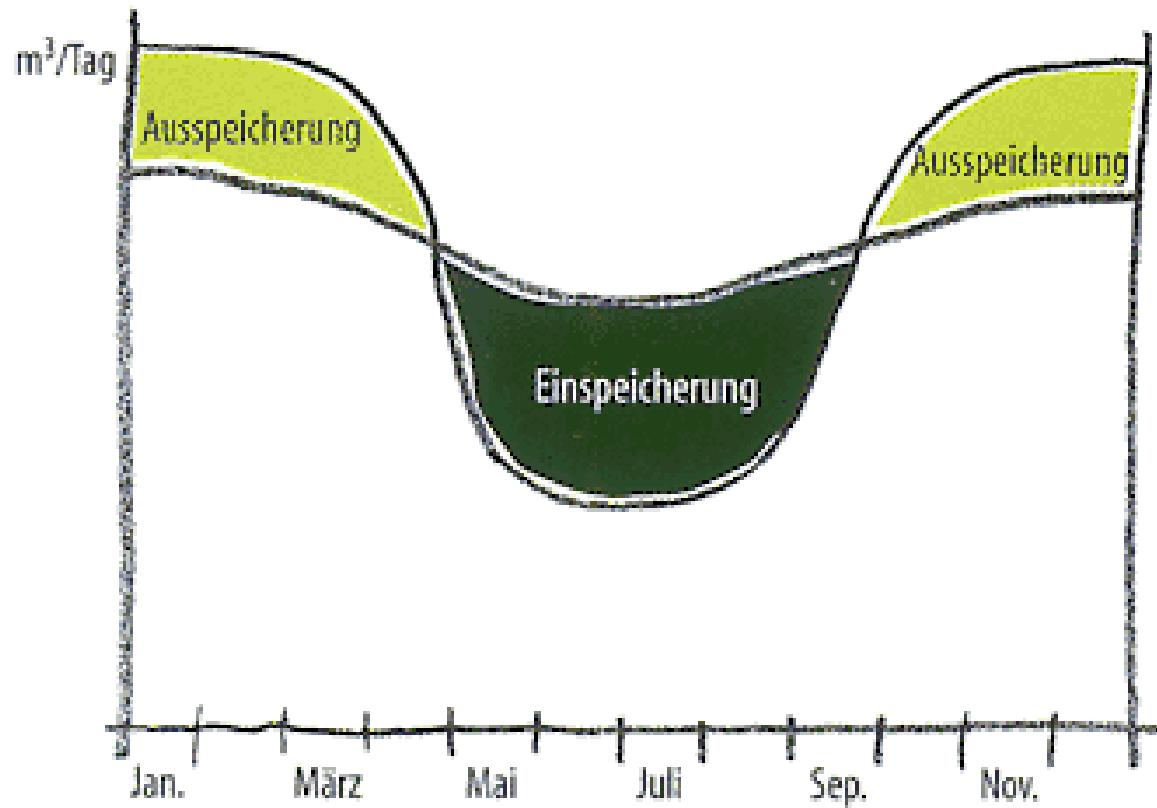


statistics: history match ... UGS



UGS: load balancing

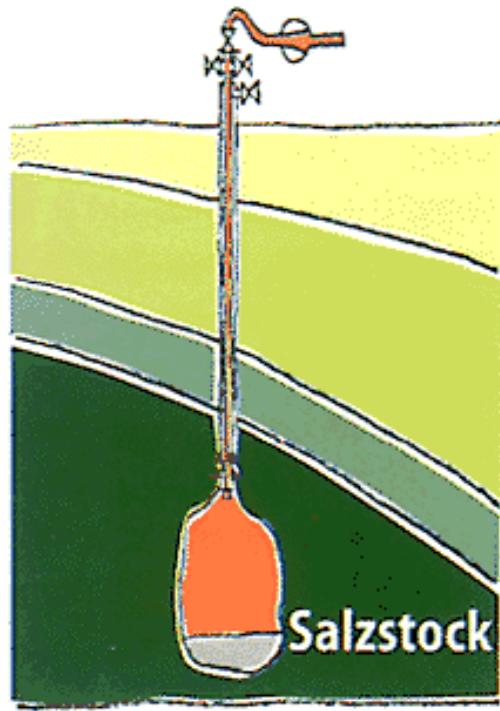
STRUKTURAUSGLEICH DURCH PORENSPEICHER



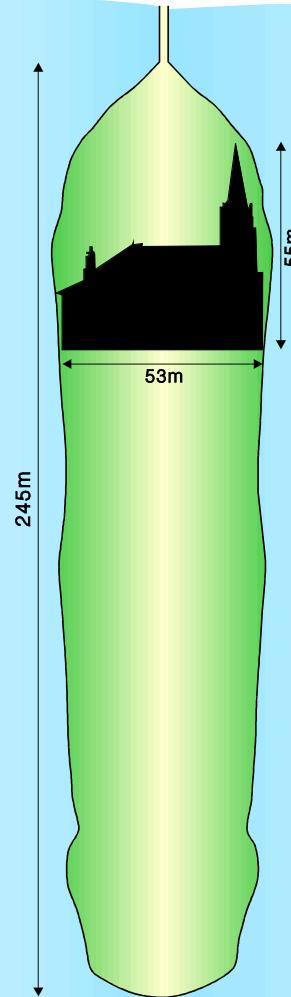
UGS: cavities

- modelling: FEM even for rock mechanics
- simulation: thermodynamics / climate not solved yet

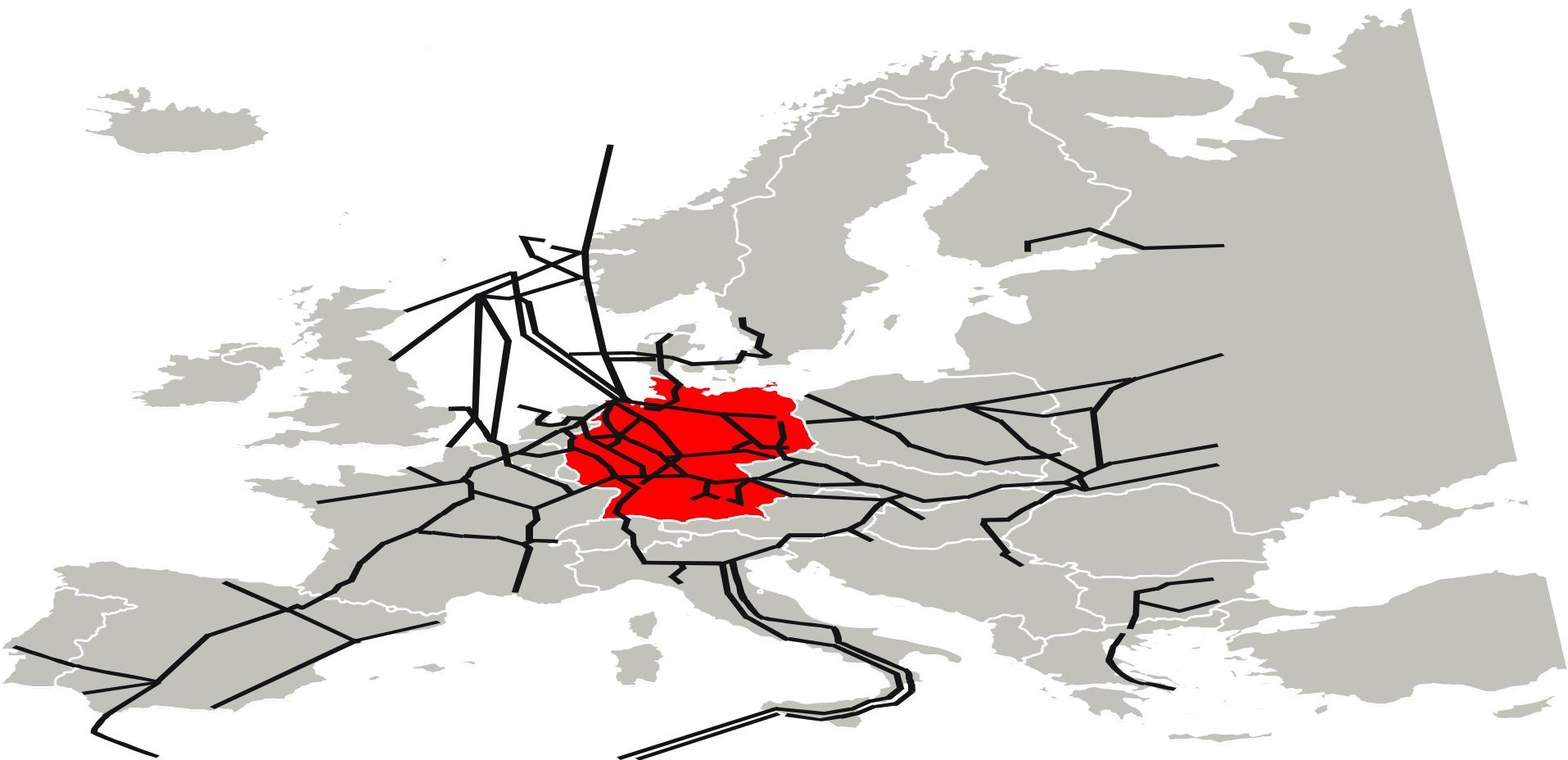
KAVERNENSPEICHER



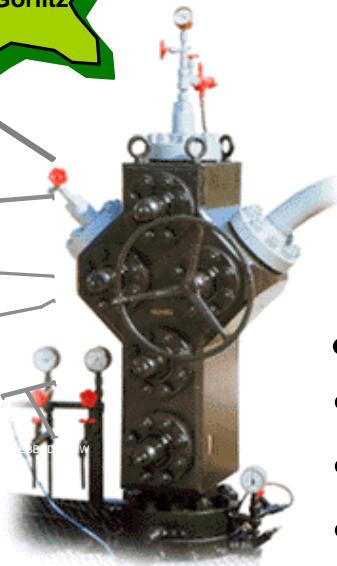
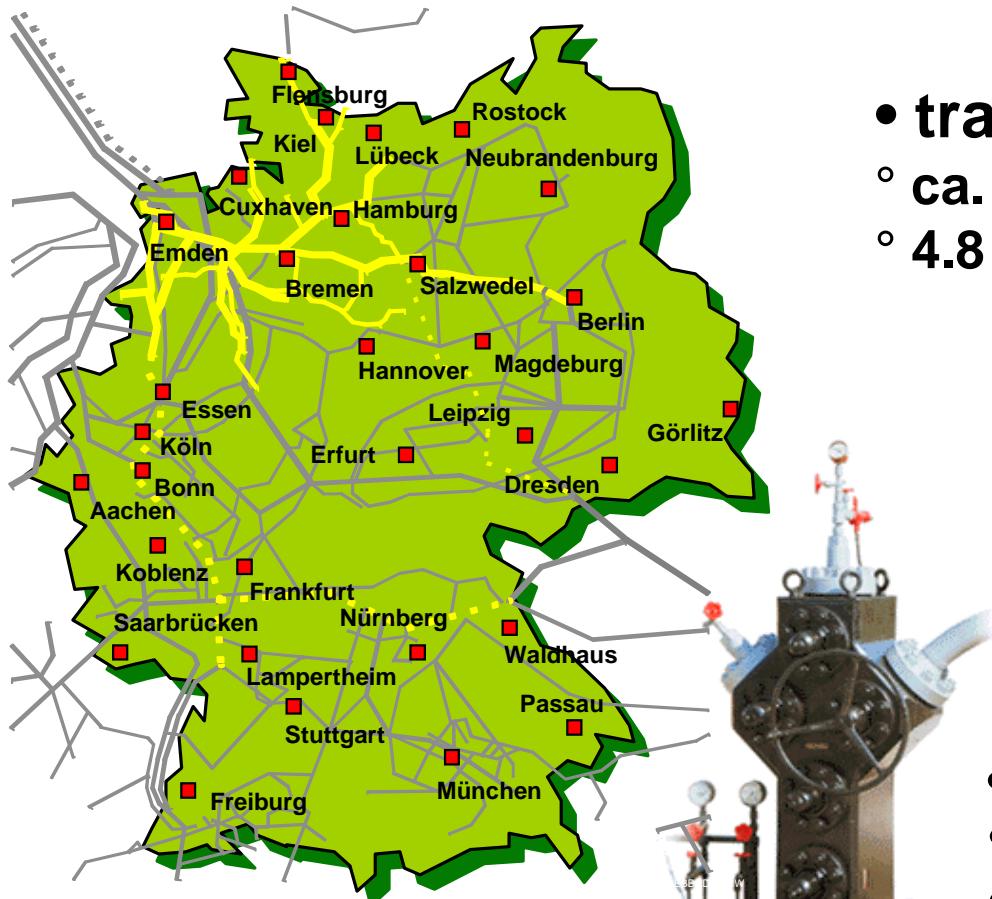
UGS Harsefeld - Kaverne K1 Größenvergleich mit St. Mariae u. Bartholomae



supply grid Europe



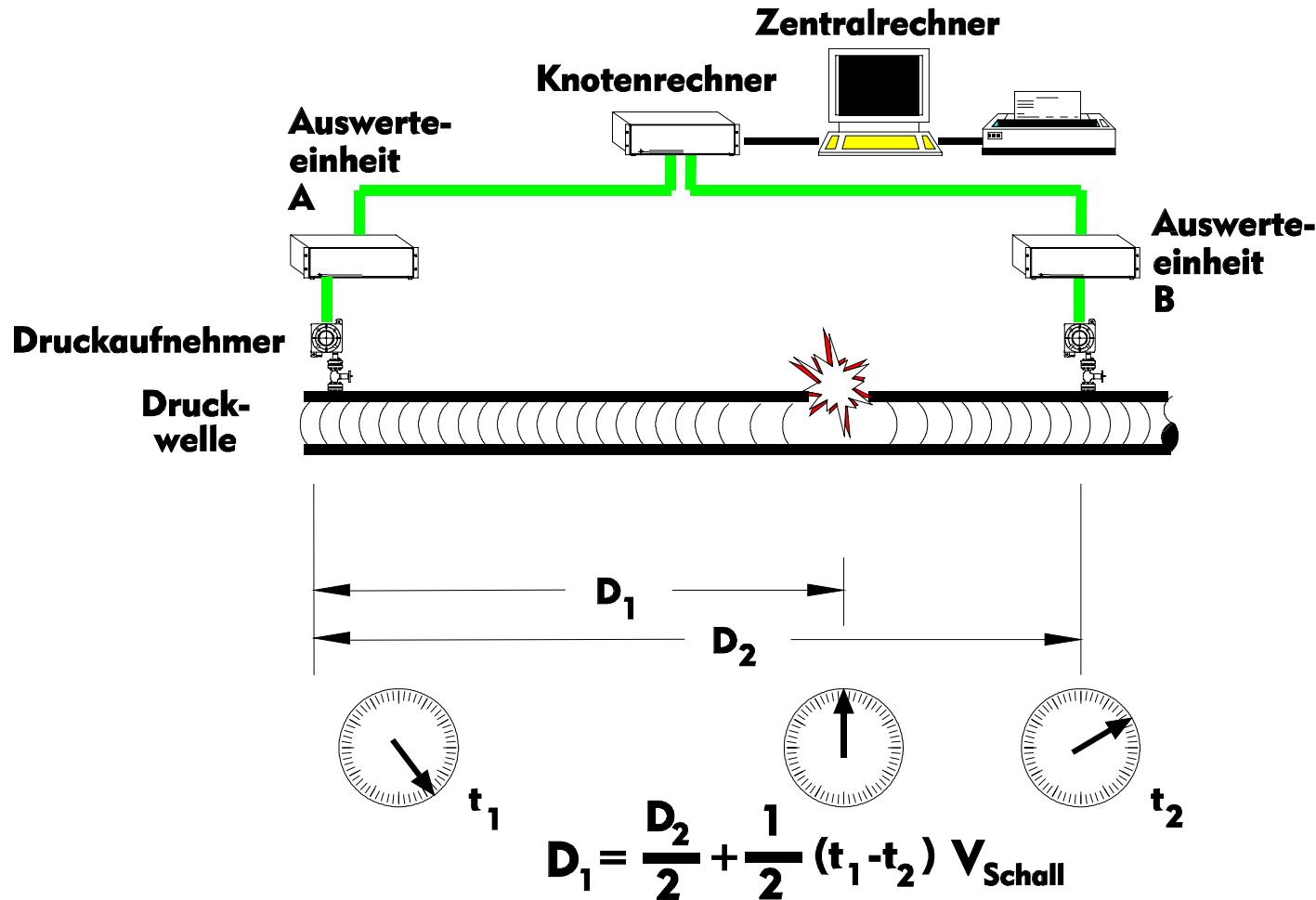
BEB's infrastructure



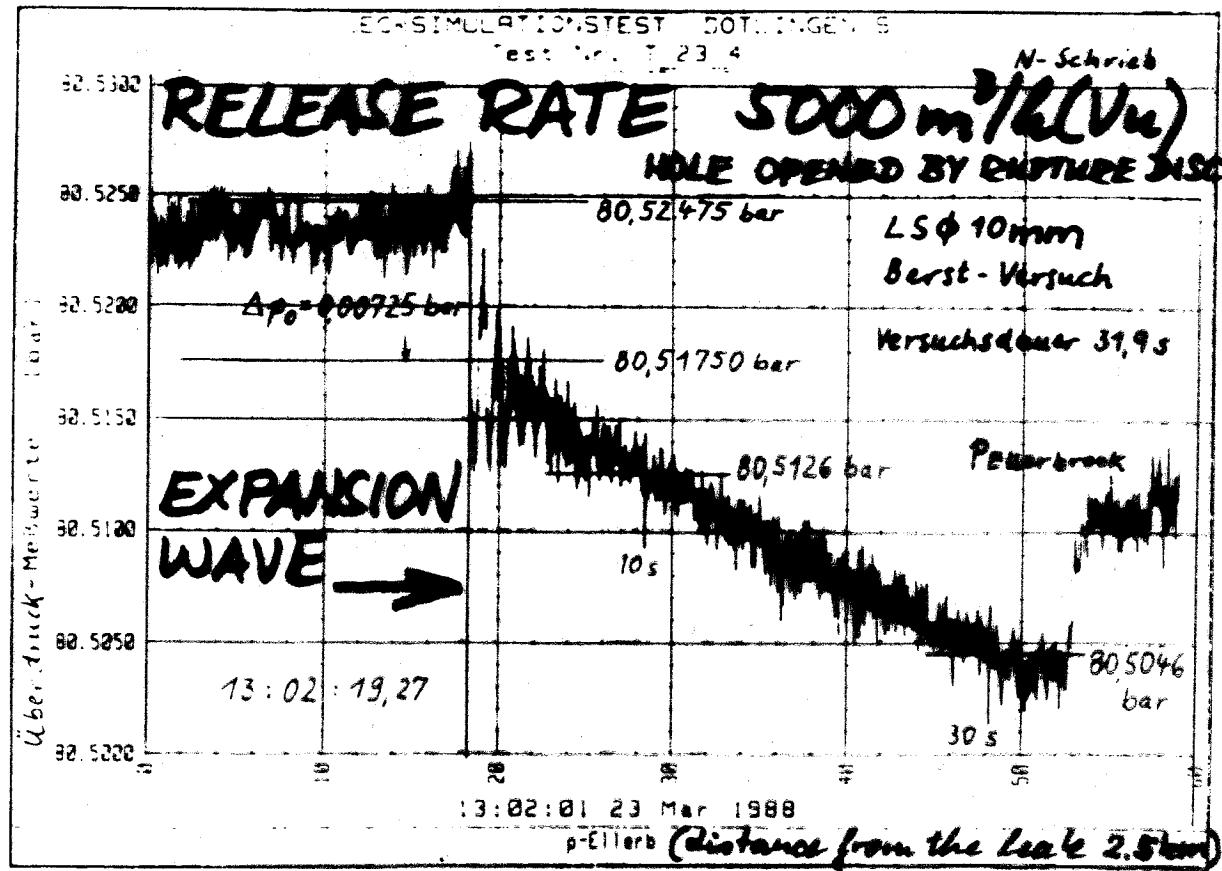
keyfigures 1998

- transported volumes
 - ca. $26 \times 10^9 \text{ m}^3/\text{a}$
 - $4.8 \times 10^6 \text{ m}^3/\text{h}$ (peak)
- transportsystem
 - ca. 3500 km pipelines
 - 7 compressorstations, 19 units
 - 230 stations
- production system
 - ca. 200 wells
 - ca. 1400 km pipelines
- underground storage
 - 2 pore storages
 - 2 cavern locations
 - working gas volume $2.7 \times 10^9 \text{ m}^3$
 - withdrawal cap. $1.8 \times 10^6 \text{ m}^3/\text{h}$

leak detection

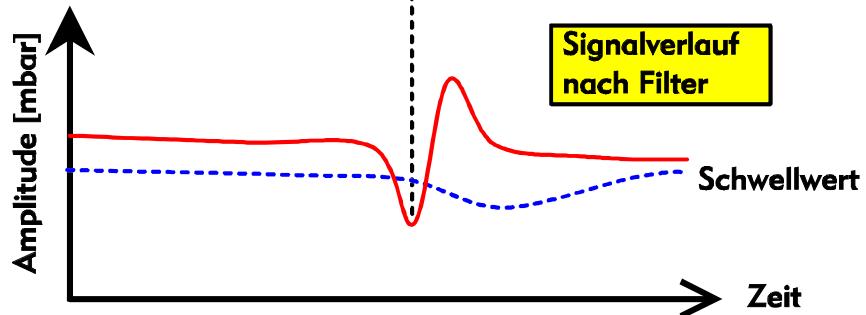
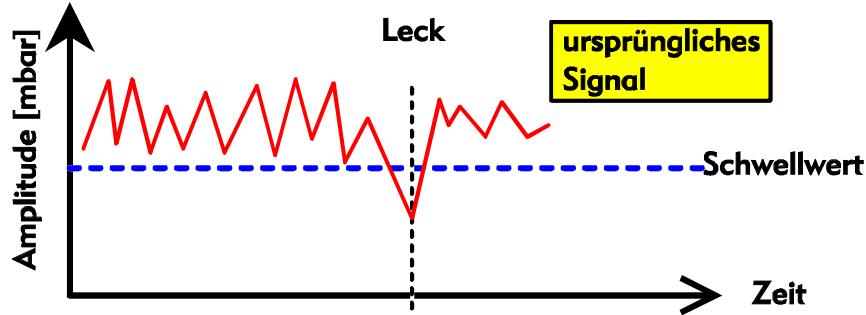


leak detection



12 34" - 14.

leak detection, operating, ...



Digitalfilter :
Ausfiltern von
Störsignalen
Kreuzkorrelation
mit vorgegebenem
Lecksignalprofil

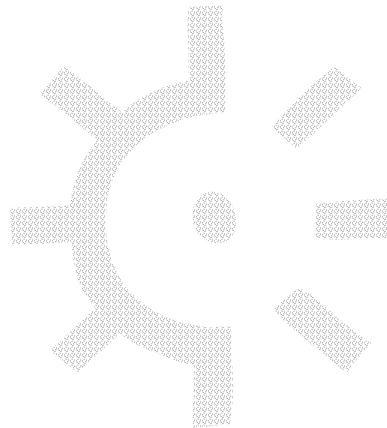
verbesserte
Zeitabfragefolge

dynamische
Schwellwerteinstellung

other techniques in dev.: neuronal nets, rule based systems, adaptive systems, fuzzy control, ... for unmanned operation (smell, sound, ...)

- Kontinuitätsbedingung: Zu einer bestimmten Zeit t wird eine sich in einem abgegrenzten Volumen $V(t)$ befindliche Gasmasse m als ein System kontinuierlich verteilter Massenelemente betrachtet. Von dem Volumen $V(t)$ wird angenommen, daß es ausgefüllt ist und keine Hohlräume besitzt.
- Der Massenerhaltungssatz bzw. die Kontinuitätsgleichung besagt nun, daß in einem abgegrenzten Gasvolumen Masse weder verlorengehen noch entstehen kann.

- Nach dem Newtonschen Grundgesetz der Mechanik (Impulssatz) ist die zeitliche Änderung des Impulses I einer Masse m , die sich in einem abgegrenzten Volumen $V(t)$ befindet gleich der auf das System wirkenden resultierenden Kraft F .



simulation of gas nets

- Mit Hilfe des Massenerhaltungssatzes, des Impulssatzes, der thermischen Zustandsgleichung und den Transportgleichungen gelangt man durch geeignete mathematische Umformungen zu den Leitungsdifferentialgleichungen:

z. Druckänderung

$$\frac{\partial p}{\partial t} + \frac{c^2}{A} \frac{\partial q}{\partial x} = 0$$

(Kontinuitätsgleichung)

örtl. Flußänderung

z. Flußänderung

$$\frac{\partial q}{\partial t} + A \frac{\partial p}{\partial x} + \lambda \frac{c^2}{2 D/A} \frac{|q|q}{p} = 0 \quad (\text{Bewegungsgleichung})$$

örtl. Druckänderung

Rohreibung

- Diese Gleichungen stellen die nichtlinearen, partiellen Leitungsdifferentialgleichungen vom hyperbolischen Typ dar, und sind die Grundlage zur Berechnung der durchströmten Rohrleitungen.



- Durch Diskretisierung (ersetzen von Differentialquotienten durch Differenzenquotienten) des Ortes in der Kontinuitätsgleichung und der Bewegungsgleichung erhält man ein gewöhnliches Differentialgleichungssystem.
- Es gilt nun, ein für die Lösung eines nichtlinearen, steifen Differentialgleichungssystems geeignetes Zeitintegrationsverfahren zu finden.

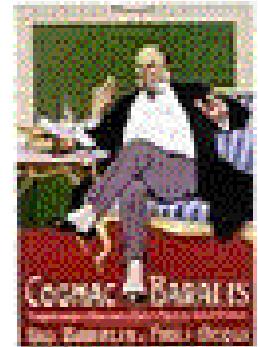


- Das genaueste absolut stabile lineare Mehrschrittverfahren der Ordnung 2 ist die Trapezregel:

$$x_{n+1} - x_n = \frac{h}{2} [f(t_n, x_n) + f(t_{n+1}, x_{n+1})]$$



- \$\$ via polynoms ...
- monte carlo for reliability; open OR methods like „shortest path“: analogue for debottlenecking of topology of a given net and also looking for „most important objects“
- optimisers: simplex, net flow, closed loop
- forecasting: statistics, time series, Box-Jenkins, AI



- H^2 category theory / topology / convergence theory**
- H^2 applications / optimisation**

topology: visualisation, navigation

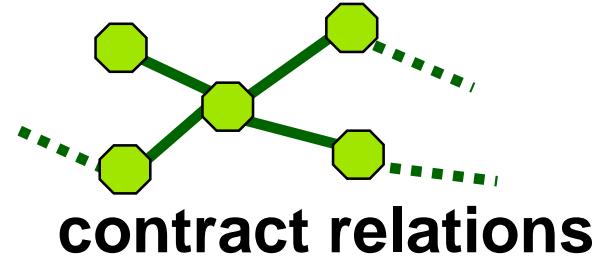
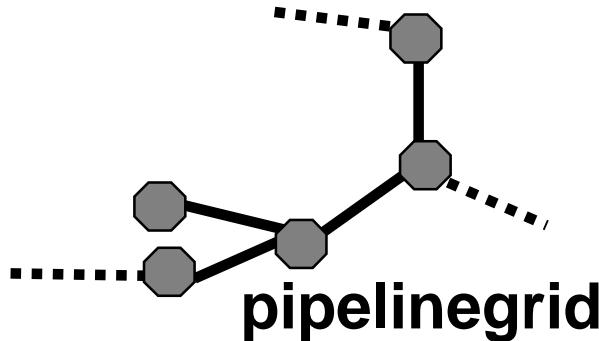
Rechnerunterstützung (möglichst grafisch) so, daß

- ≈ strecken, stauchen, verschieben, ... (verzerren) anordnen, umsortieren, gruppieren, ...
- ≈ Teilnetze einfach konstruier und wählbar
- █ komplexe Netze aus Teilen zusammensetzbare
- ⌘ vereinfachte/abstrahierte Sichten einfach erzeugbar ("Quotientennetze")
- 🖐 diverse Sichten (physikalische & logische:
Pipelinenetz, Vertragsnetz, Tauschbeziehungen, ...) einfacher konstruier-, darstell- und verknüpfbar



weitere Anregungen ??? Alles analog auch für "Daten"





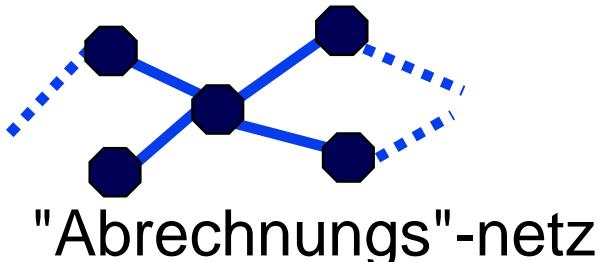
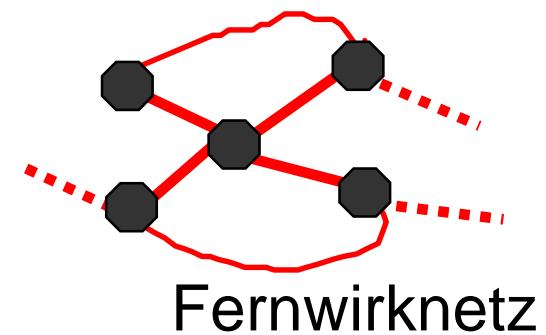
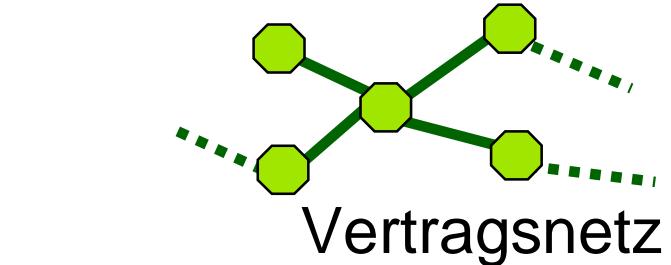
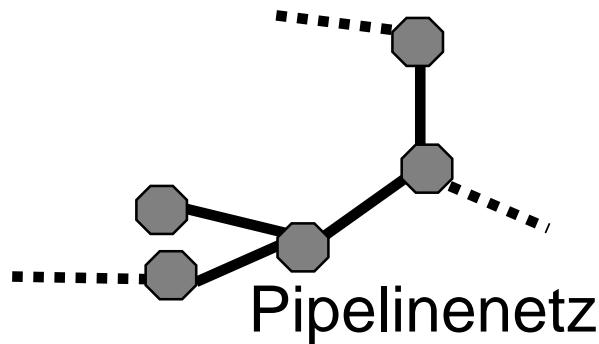
New topological features required:

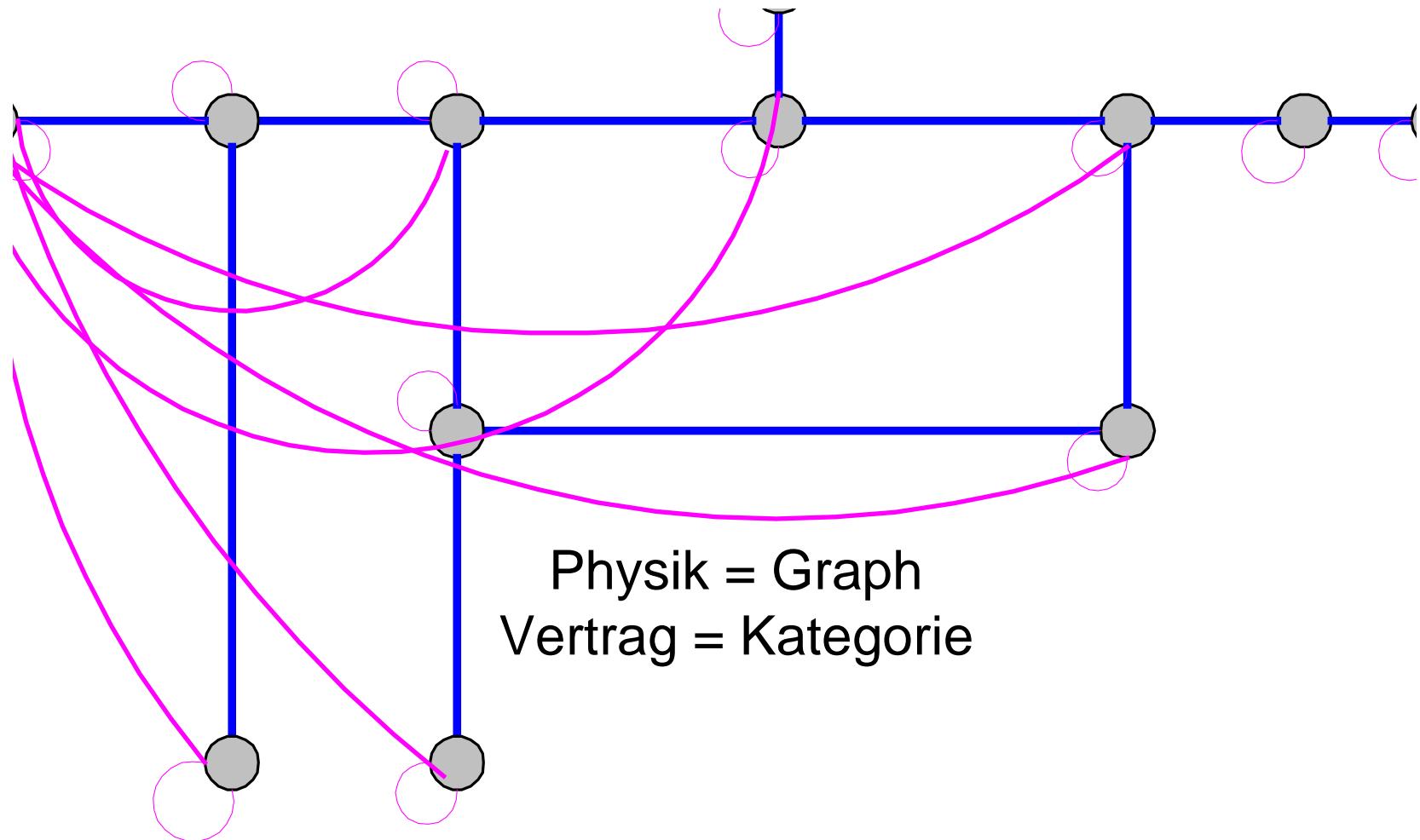
- part of grid (sub spaces)
- product of grids (products)
- simplifying grids (quotients)
- gluing together of grids (coproducts)



topologische-Oberfläche: Objekte

- **Kunden**
- Marktdaten, Prognosen, ...
- Anfragen
- **Verträge**
- Bestellungen
- Bestätigungen
- Disposition
- **Bezug**
- Stationen
- Messschienen
- Leitungen
- Verdichter
- Speicher, ...
- Ferwirktechnik (Router, Adressen, ...)
- **Dispatching: Prozesssteuerung (SCADA, ...)**
- Gasnetzsimulation
- Prognosen
- **Lieferung**
- technische Mengen-/Leistungsermittlung
- Vertragszuordnung (Allokation)
- **Abrechnung, Kassieren**





H² category theory

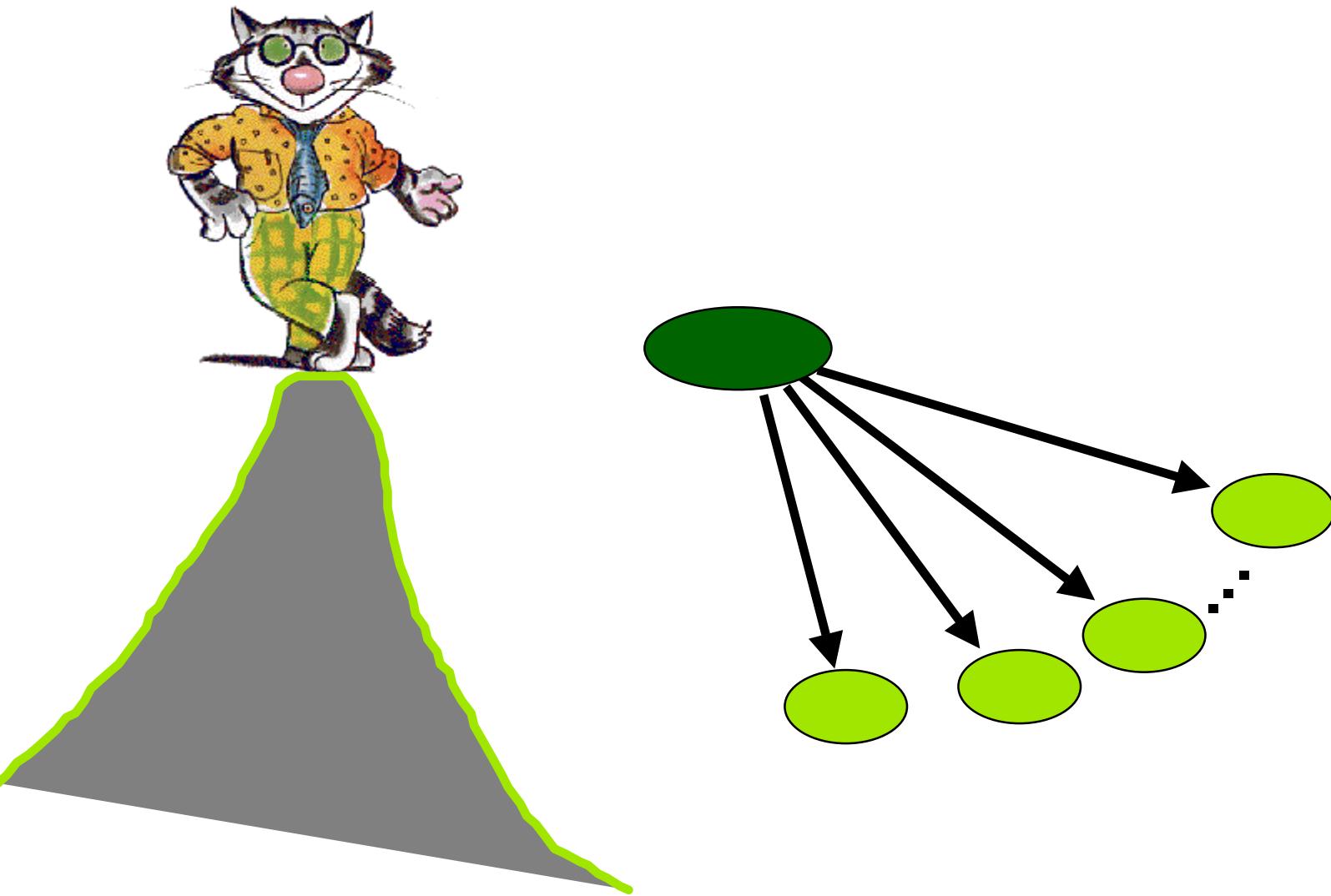
- ❖ topological categories
- ❖ quasitopoi

H² applications / optimisation

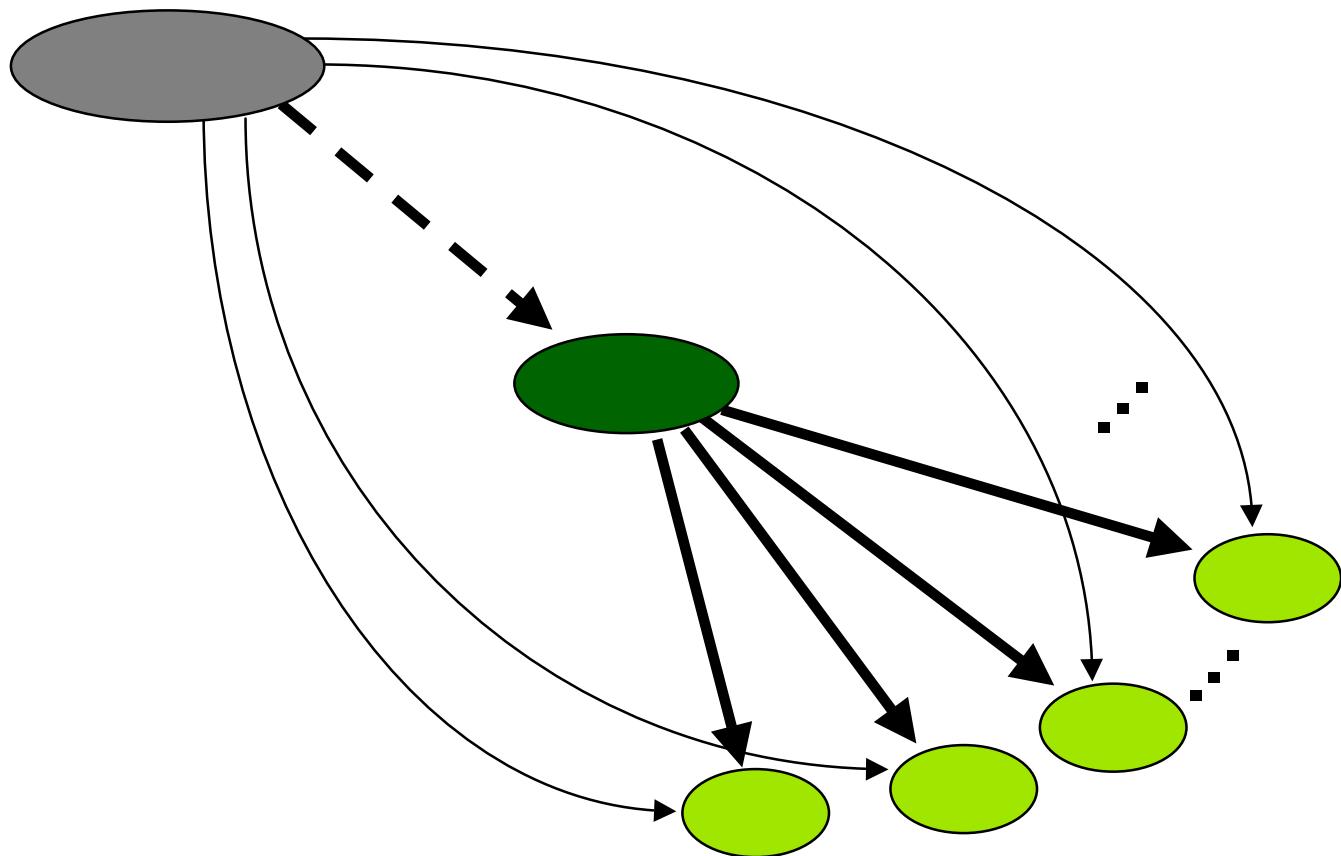
- ❖ load balancing
- ❖ bin packing
- ❖ demand/supply balancing
- ❖ forecasting



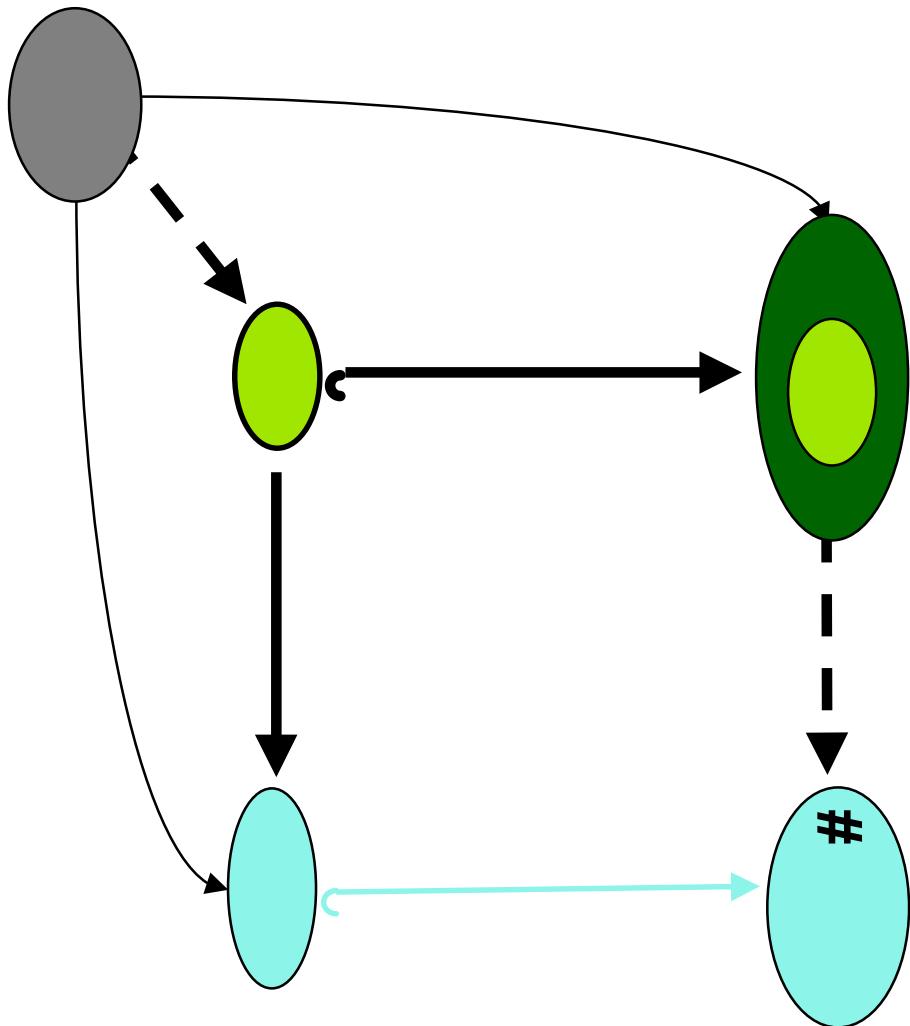
top cats: initial structures



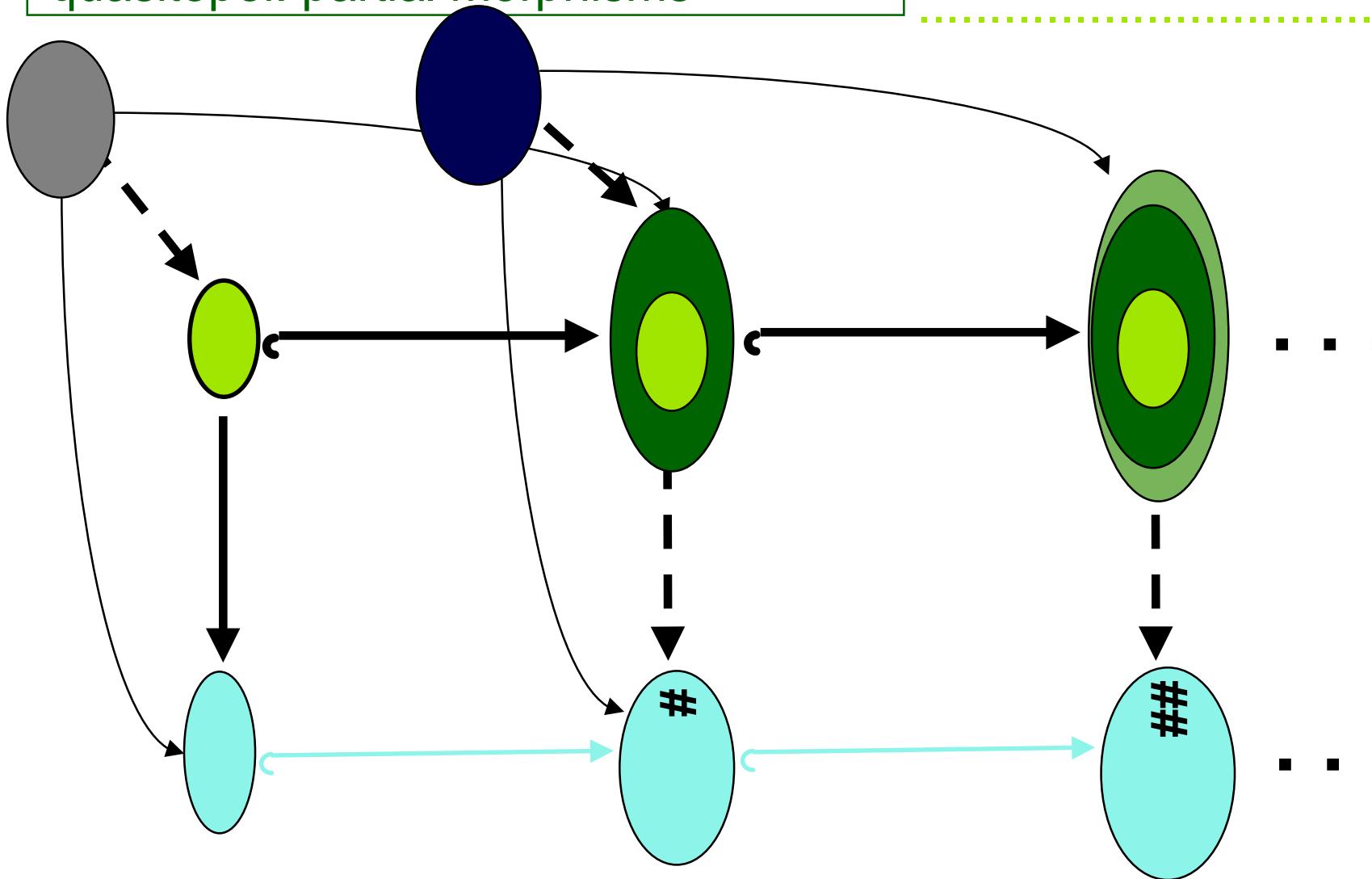
top cats: initial structures



quasitopoi: partial morphisms



quasitopoi: partial morphisms



in practice:

Lim etc.

- ~ look for non idempotent hull operators
- ~ look for "partial knowledge"
R^{STOP} top cat and quasitopos
- ~ look for extensions

**pretopologies have the “build in”
iterative process, in particular
needed, if no direct solutions are
possible and/or known !!!**

TOP
topo
but part. morph.
and extreme



H² category theory

- ❖ topological categories
- ❖ quasitopoi

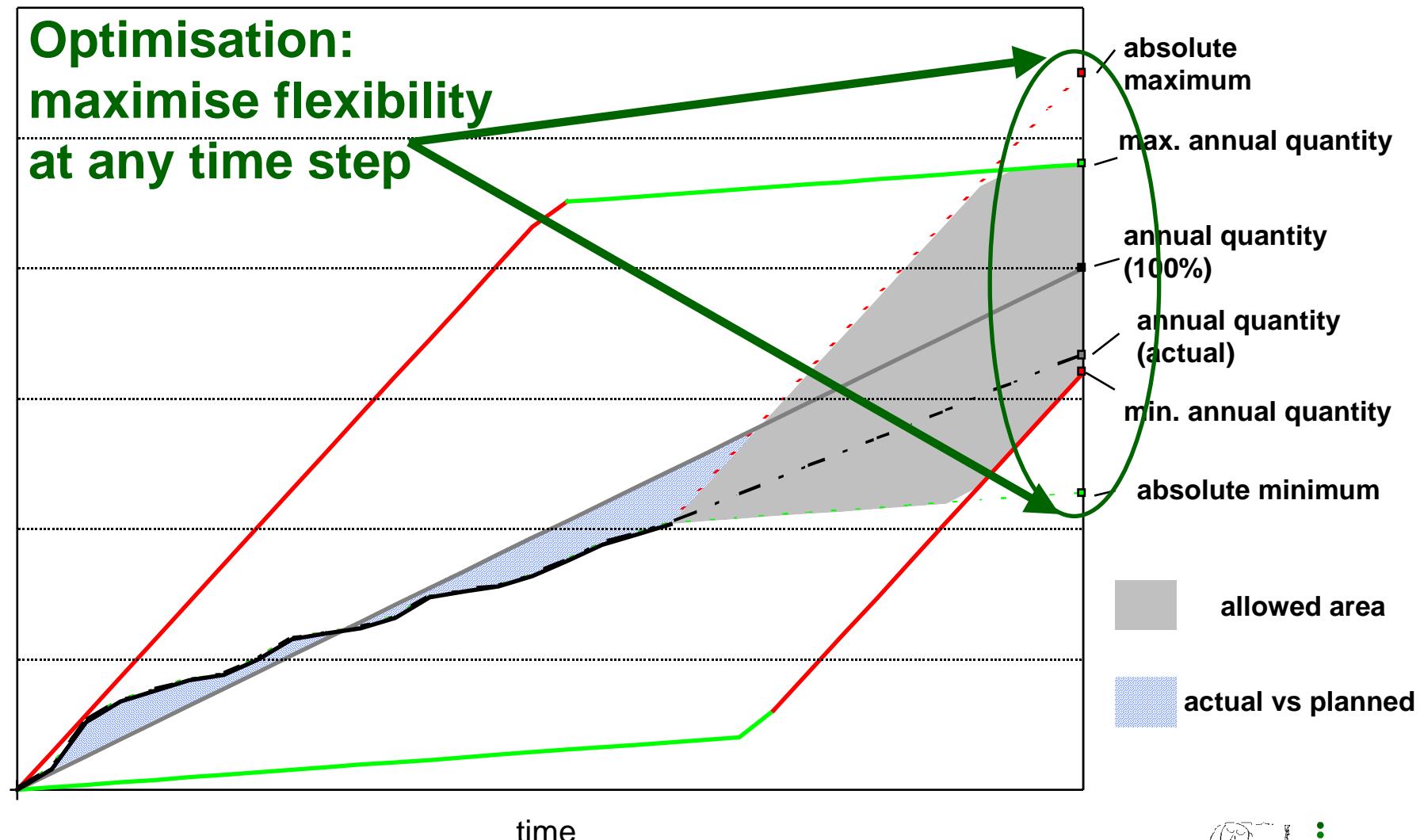
H² applications / optimisation

- ❖ load balancing
- ❖ bin packing
- ❖ demand/supply balancing
- ❖ forecasting



side constraints: production/contracts

**Optimisation:
maximise flexibility
at any time step**



H² category theory

- ❖ topological categories
- ❖ quasitopoi

H² applications / optimisation

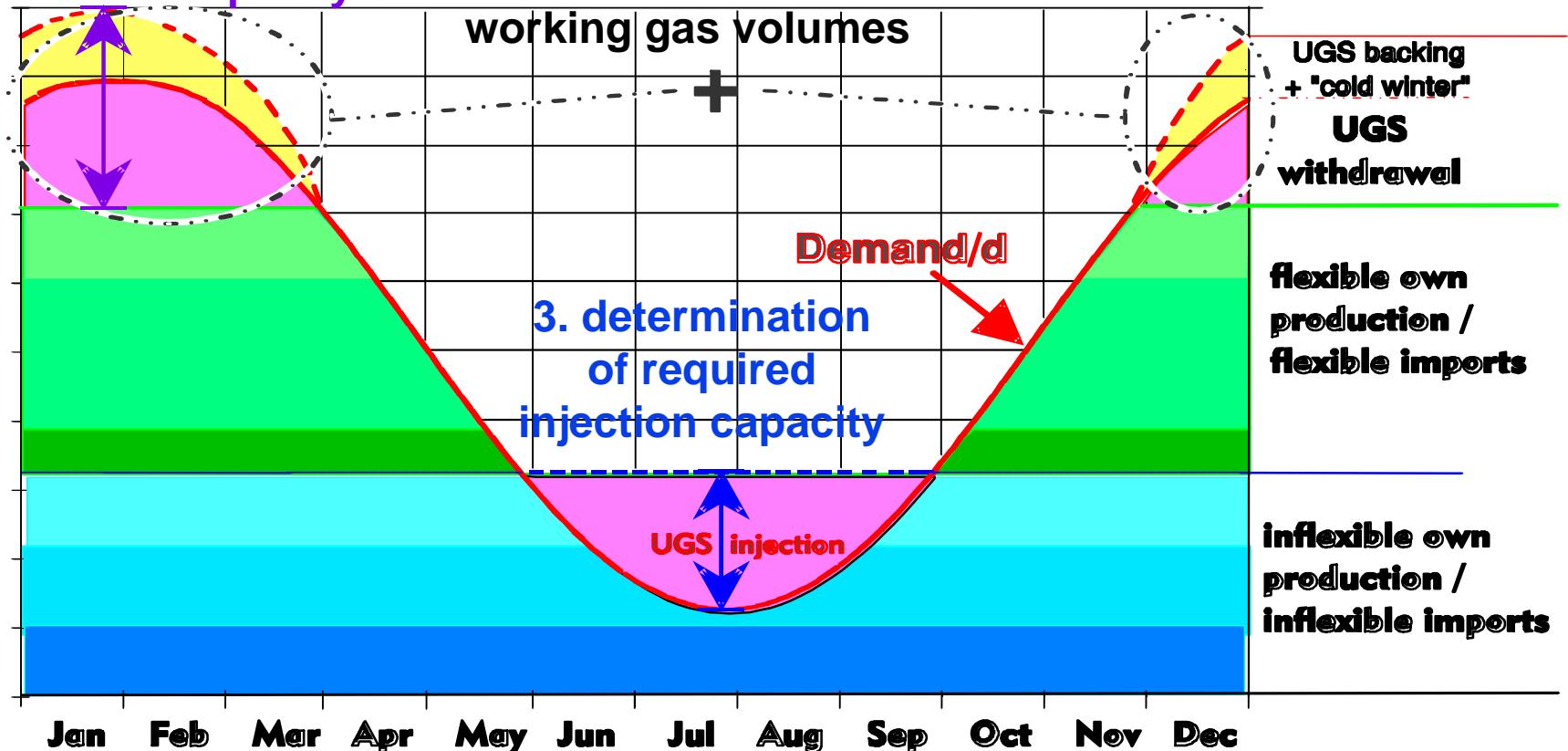
- ❖ load balancing
- ❖ bin packing
- ❖ demand/supply balancing
- ❖ forecasting



2. determination of required withdrawal capacity

1. determination of required working gas volumes

3. determination of required injection capacity



H² category theory

- ❖ topological categories
- ❖ quasitopoi

H² applications / optimisation

- ❖ load balancing
- ❖ bin packing
- ❖ demand/supply balancing
- ❖ forecasting



applications of bin packing

H^2 category theory

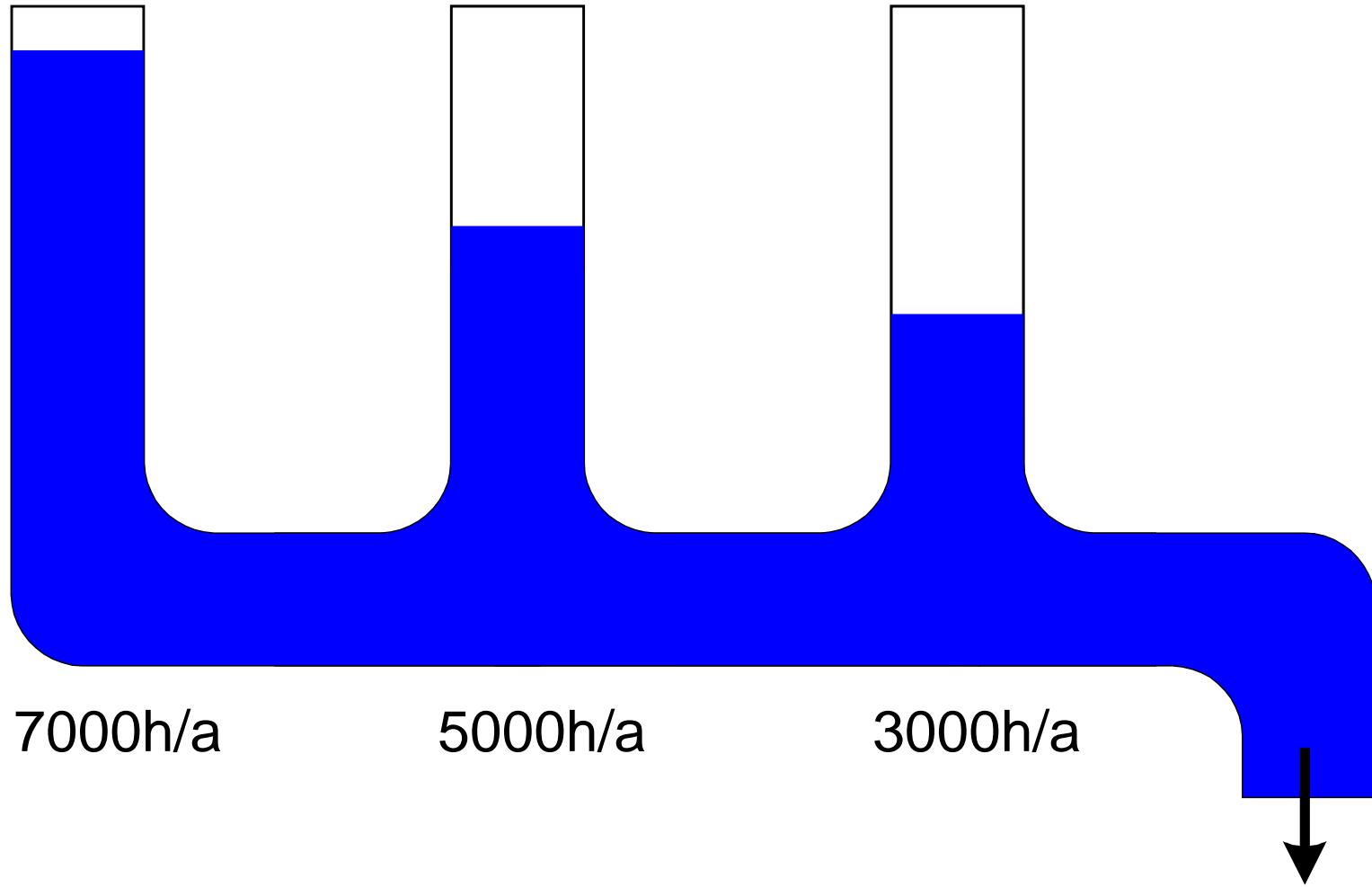
- ❖ topological categories
- ❖ quasitopoi

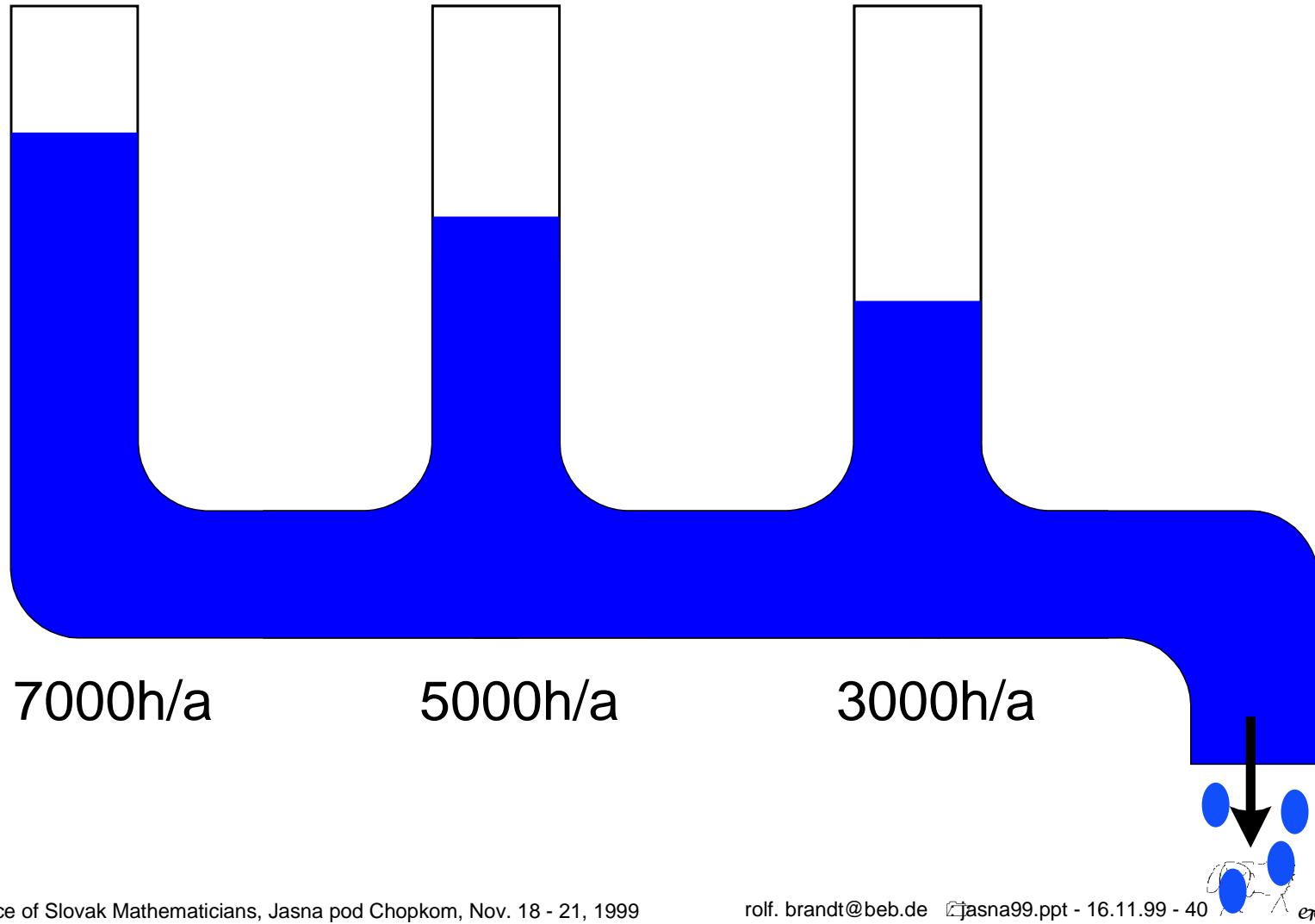
H^2 applications / optimization

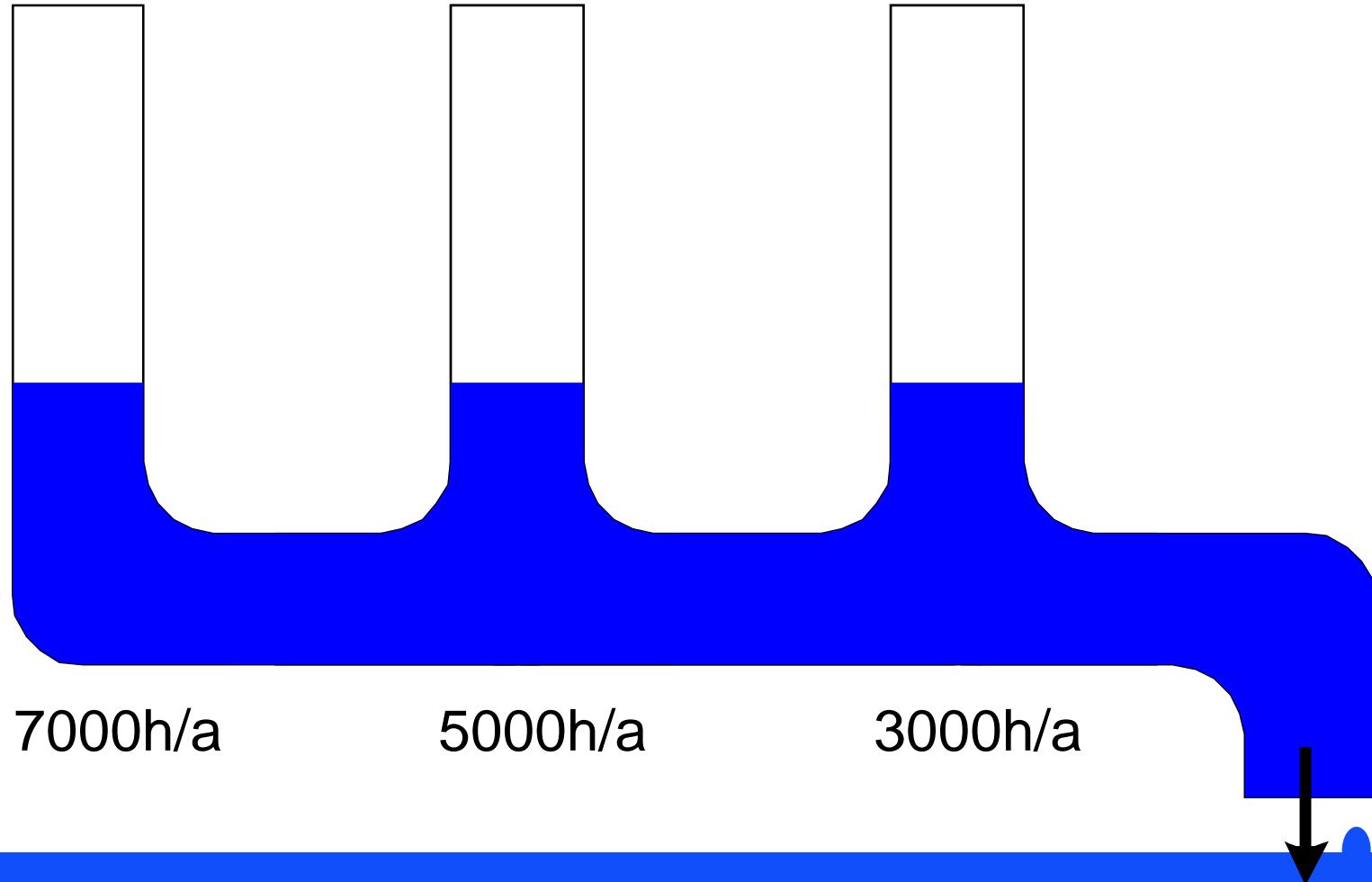
- ❖ load balancing
- ❖ bin packing
- ❖ demand/supply balancing
- ❖ forecasting

- ❖ wired circuit boards
- ❖ space technology
- ❖ logistics ("decide as late as possible ...")
- ❖ ...
- ❖ balancing of energy grids









H² category theory

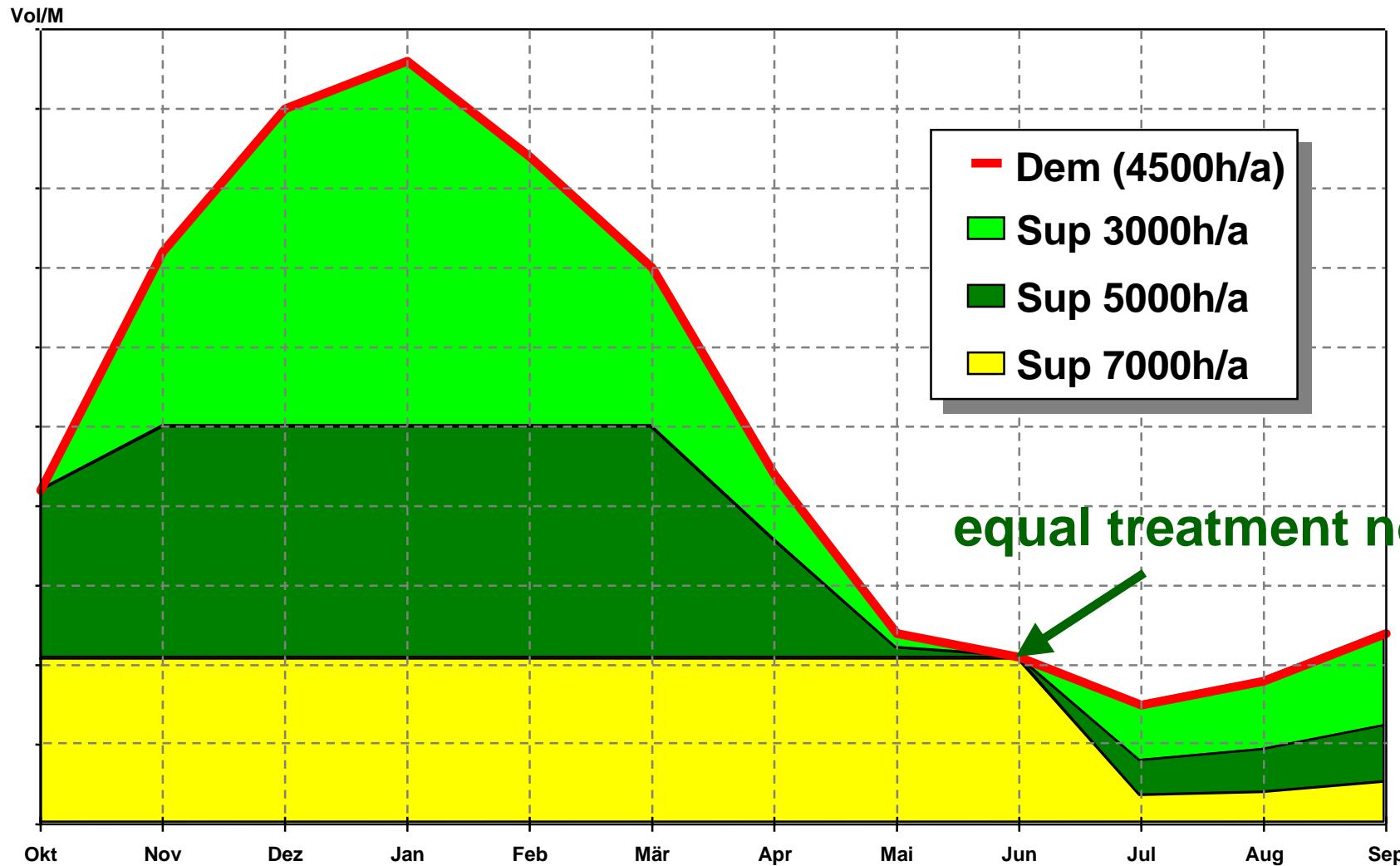
- ❖ topological categories
- ❖ quasitopoi

H² applications / optimisation

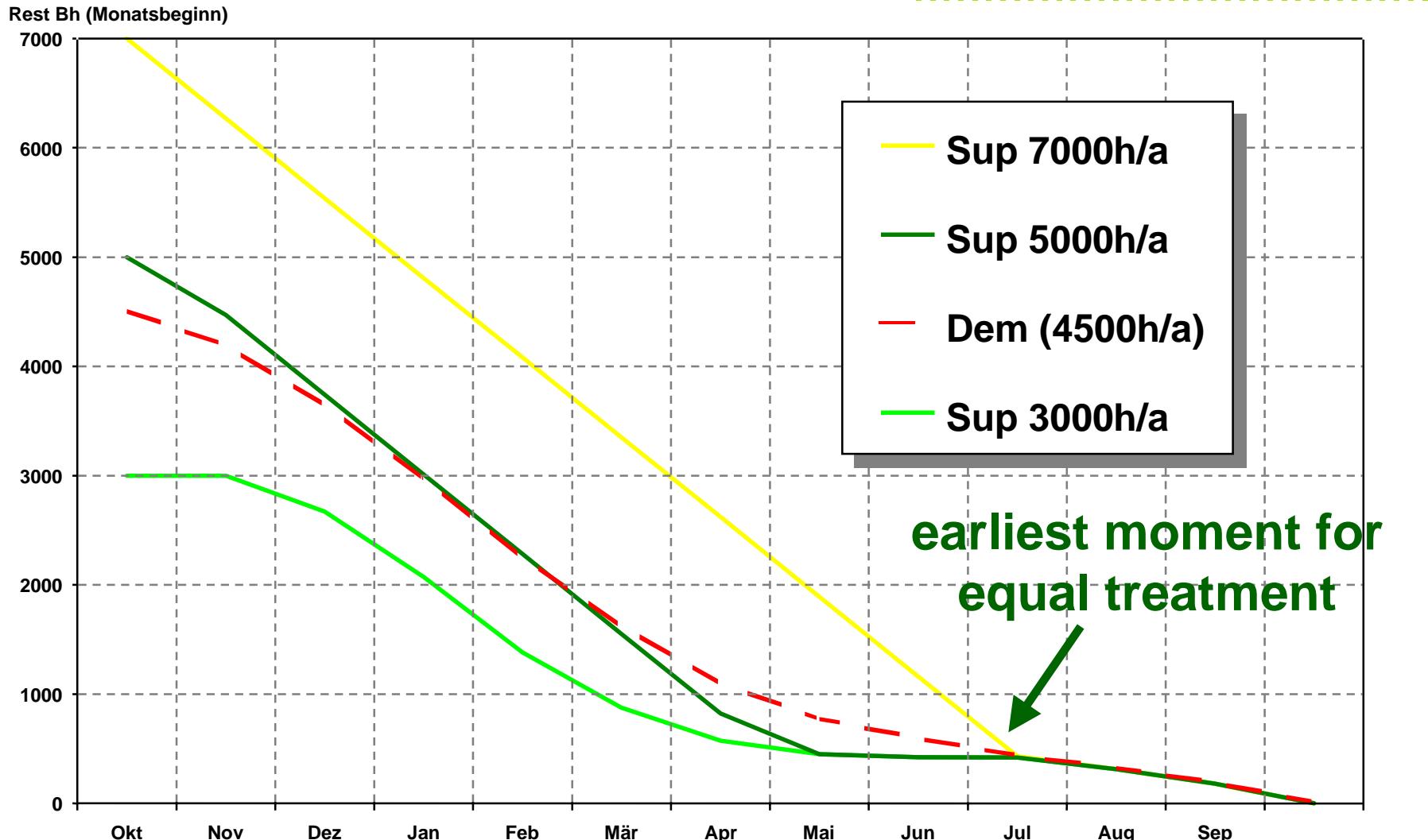
- ❖ load balancing
- ❖ bin packing
- ❖ demand/supply balancing
- ❖ forecasting



demand/supply balancing



equal treatment as soon as possible



H² category theory

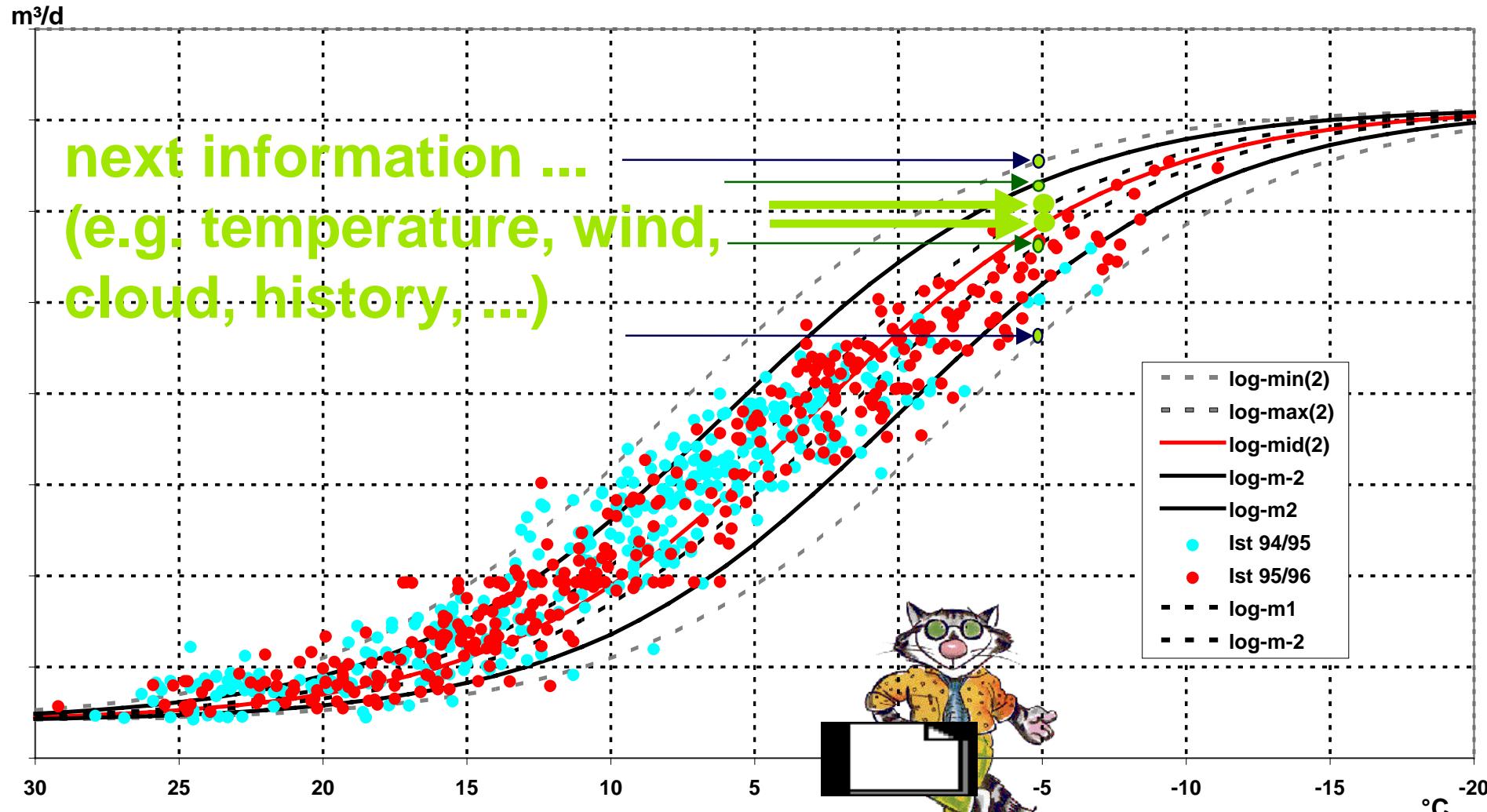
- ❖ topological categories
- ❖ quasitopoi

H² applications / optimisation

- ❖ load balancing
- ❖ bin packing
- ❖ demand/supply balancing
- ❖ forecasting



forecasting energy over temperature



... thank you
for your
kind
attention ...

