MODELLING OPTIMIZATION OF SOLAR SALT PRODUCTION USING EMERGY APPROACH

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What is emergy analysis?

- It transforms all kind of energies needed for a product into equivalents of energy of a single quality (usually solar energy).
- It compares the ratio between invested local and imported, renewable and nonrenewable energy in different processes.

More: http://www.ees.ufl.edu/cep/emergydownloads.asp

Why emergy analysis?

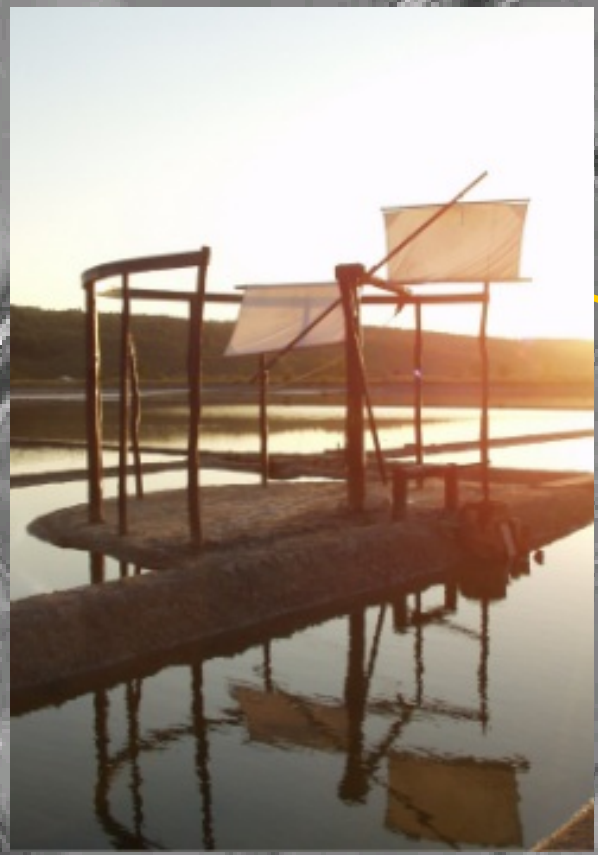
- Evaluates sustainability of the process.
- Tries to put the economy, nature, and society on a common counting base.
- In contrast to other methods (eg. LCA) it results in a single output → easier to compare processes.
- Flexible approach, quite fast.

Problems of emergy analysis:

- Inaccuracy of transformity factors (TFs): some values cannot be directly measured (historical events, social values, information, environmental loading etc.).
- Pre-determined, values of TFs regardless to the particularity of each process (not flexible).
- It is not clear, how individual TFs were calculated.
- Results are snap-shots of the reality.

Study case:

Traditional solar salt producing unit (Museum)



CRYSTALLIZATION STAGE

EVAPORATION STAGE


Formerly extensive production area.
Modified process still operates on nearby salt producing unit.

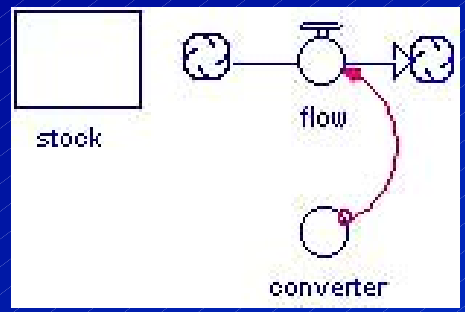
GOALS:

- Comparison of different process variants.
- To define guidelines toward higher sustainability of salt production process.
- To test the appropriateness of selected computer tool for improving the flexibility of the emergy analysis and calculation of TFs for each individual case.

Requirements for a program tool:

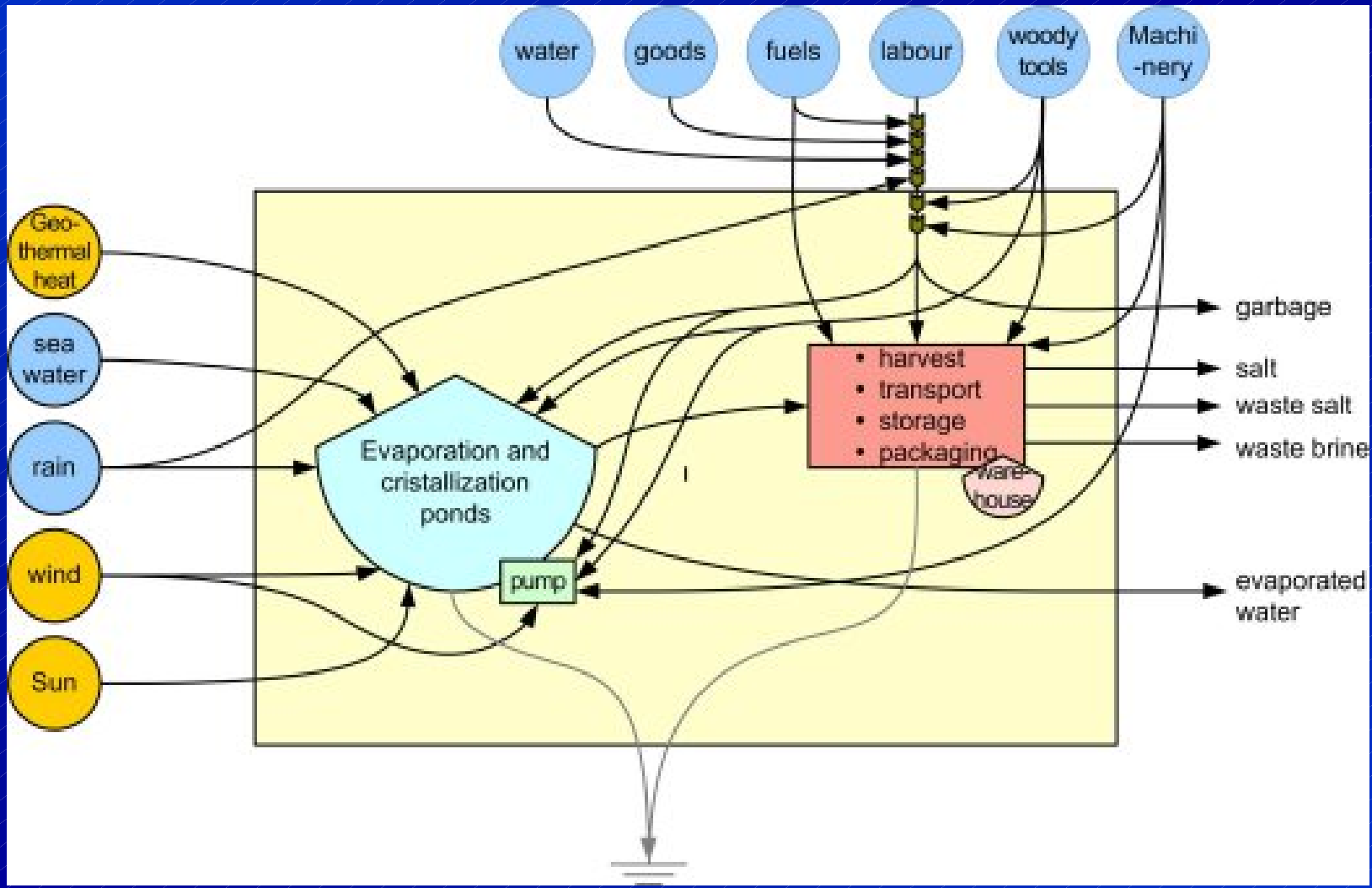
- User friendly.
- Accessible.
- Appropriate for systems analyses.
- Easy to add/remove data, inputs, variables.

STELLA:



- Icon based, graphical software package.
- Essential features are determined in terms of stocks, flows, auxiliary variables and information flows – similar to emergy systems diagrams.

Systems diagram



12-days measurements (July 2003).

Obtained data:

- Meteorological data (wind, precipitation, air temperature, RH, solar radiation, tides…)
- Amount of human work invested.
- Consumption of food, goods, fuel, etc.
- Usage of tools, machinery, buildings.
- Concentrations and T of brine in individual basins through the days.

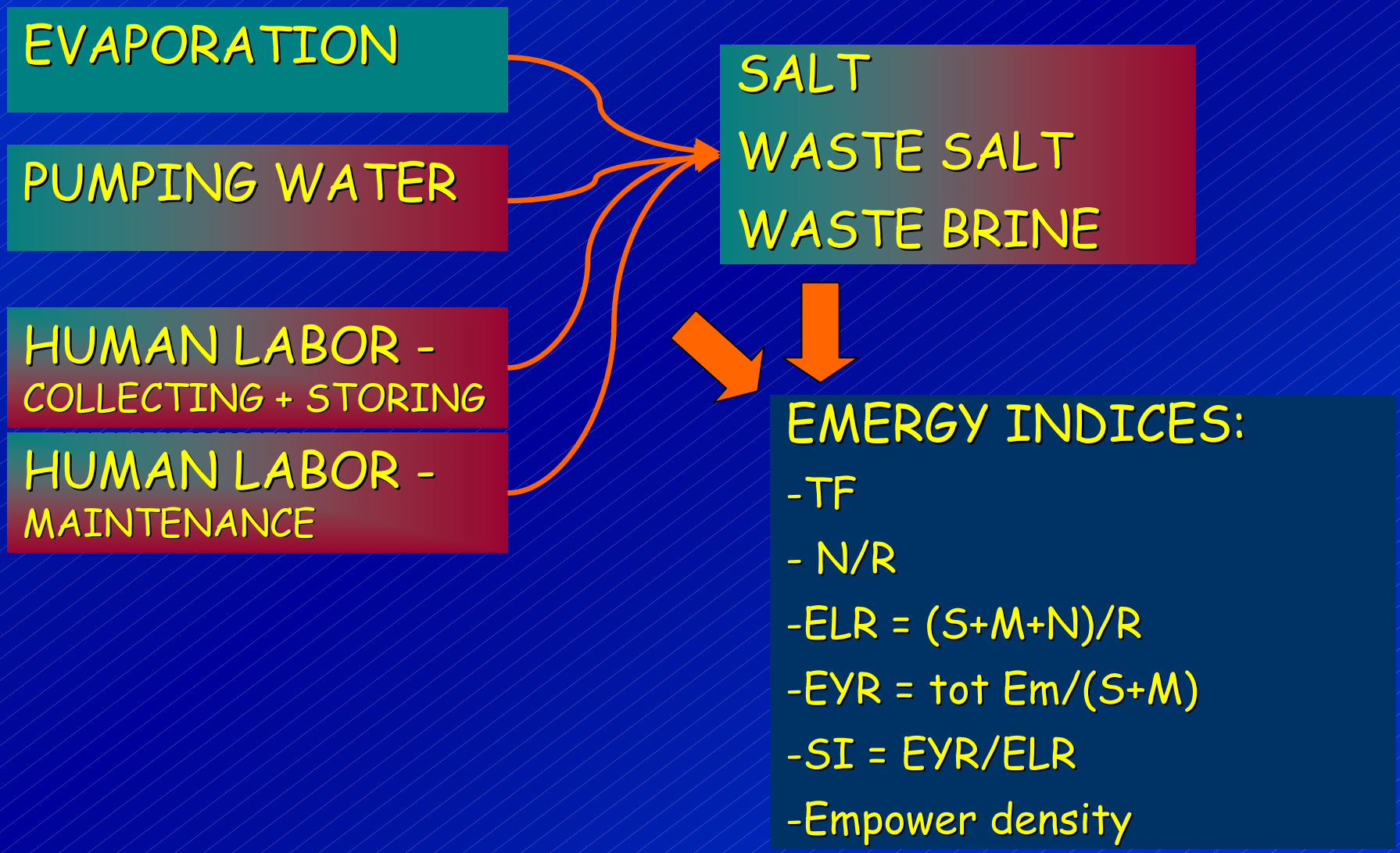
→ Daily evaporation (Penman equation).

→ Emergy analysis of national economy (emergy value per unit of national currency).

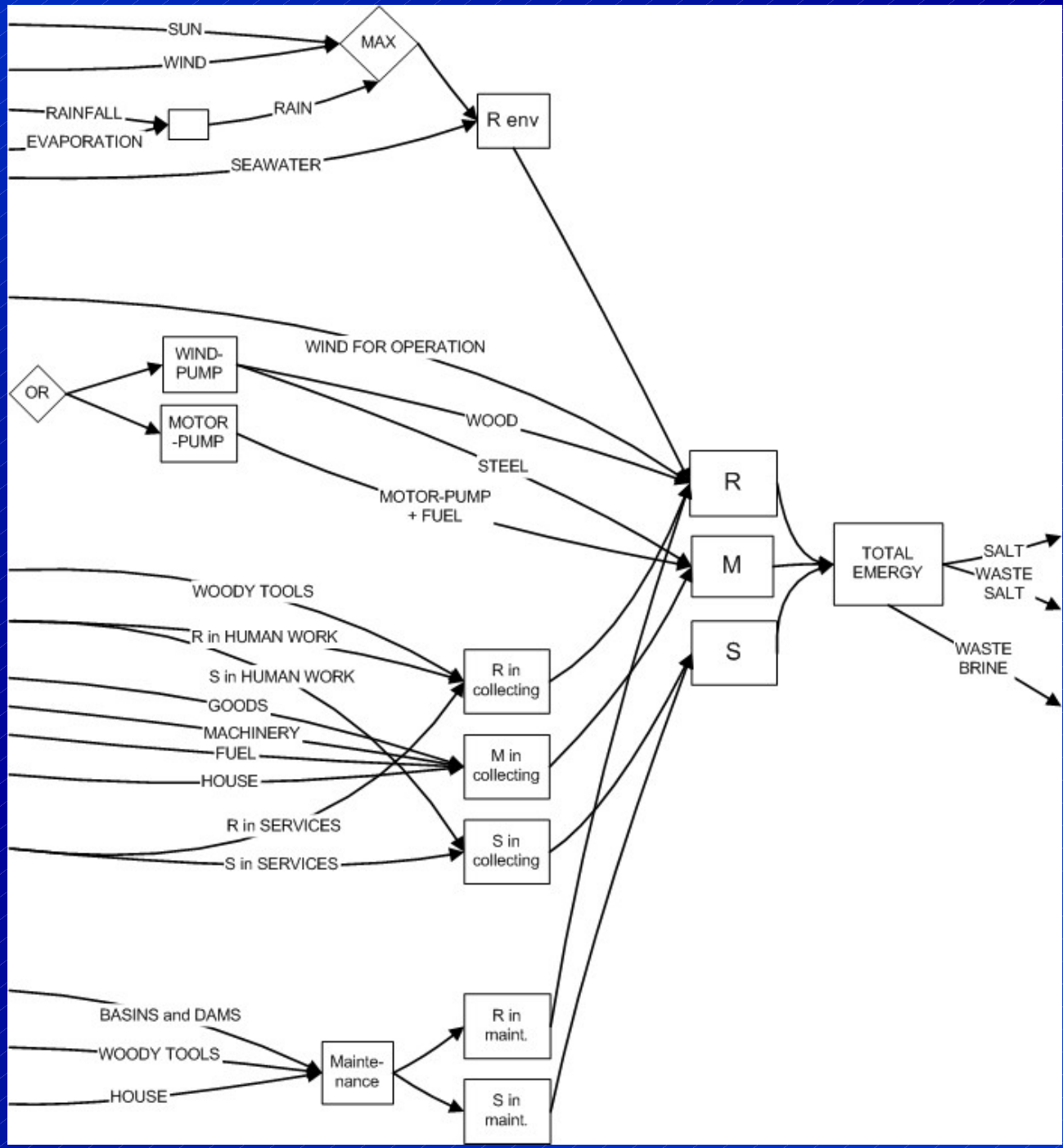
✗ Environmental loading, social values.

✗ Ecological values of the landscape (biodiversity etc.).

Model description



General structure of the model



Model performance

- Variations/oscillations of the most important flows and TFs;
- Sensitivity analysis;

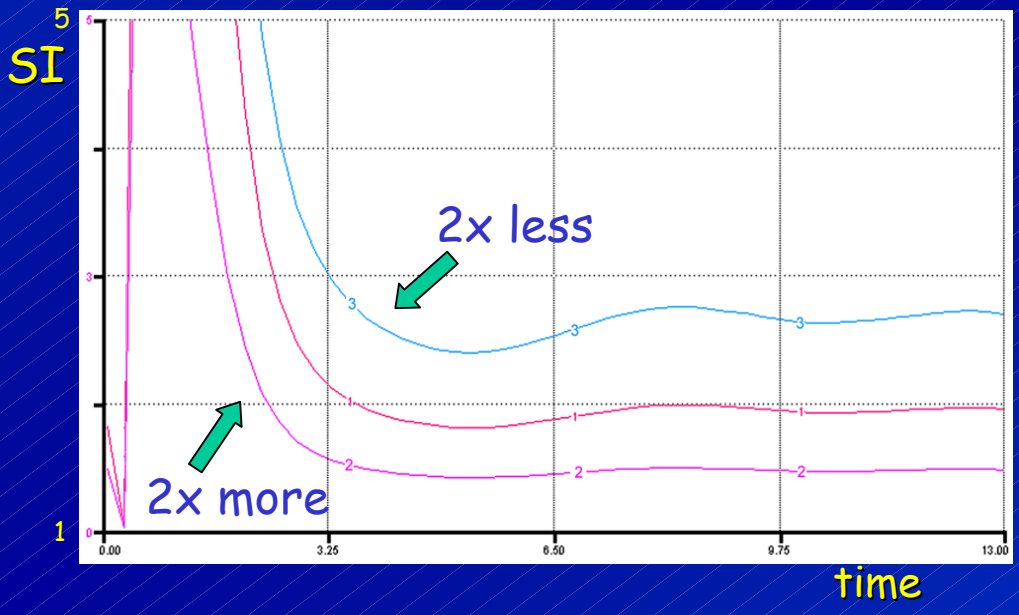
Scenarios:

- Wind-pump/motor-pump;
- Amount of human work;
- % of R in human work;
- Machinery employment & fuel consumption;
- Evaporation intensity & amount of precipitation;
- Changed individual TFs.

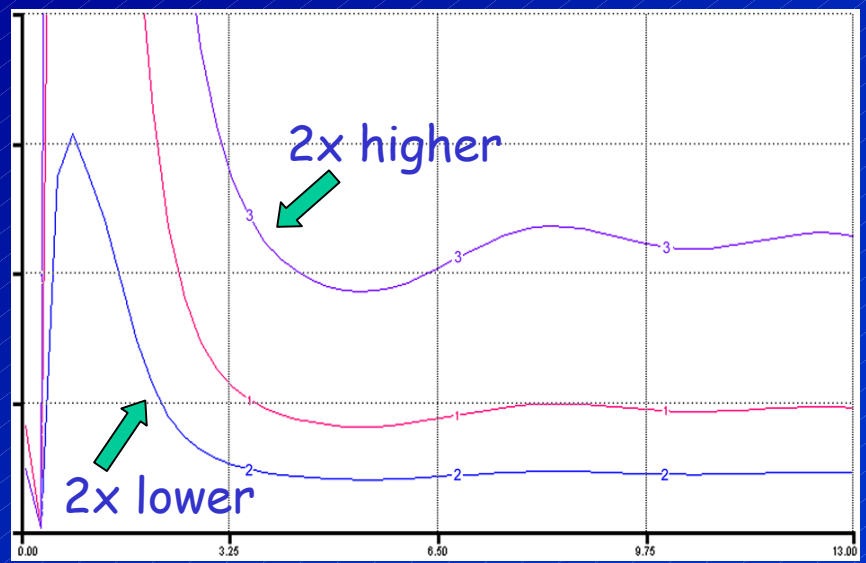
Most important flows and parameters affecting sustainability:

1. Human work and % of R in human work;
2. Meteorological conditions driving evaporation (R);
3. Fuel, machinery.

Human work



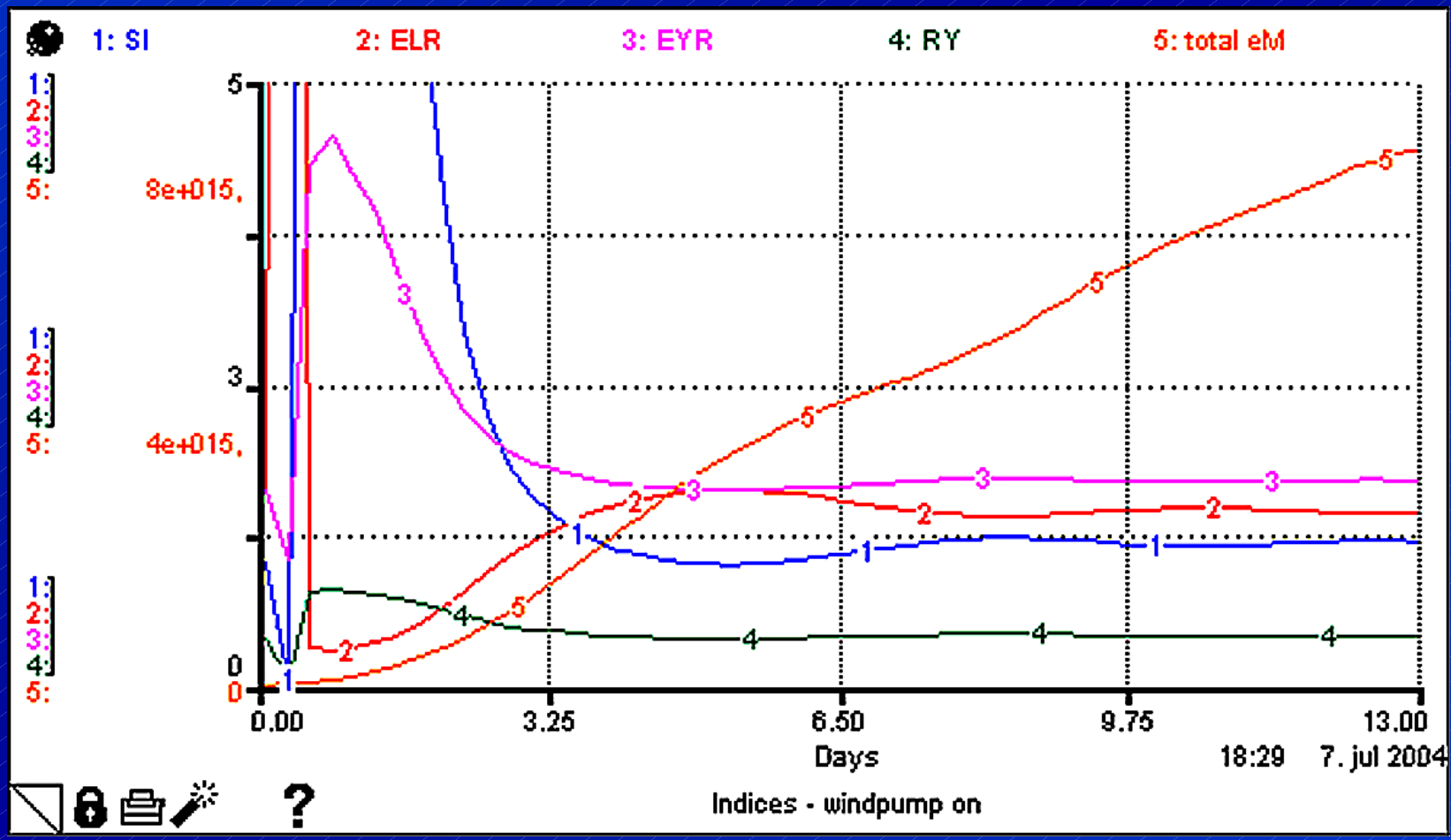
Evaporation



Energy invested into salt production (TF) of salt fluctuates according to:

- human work
- meteorological conditions
- usage of machinery & tools
- fuel and goods consumption
- etc.

The course of emergy indices during the simulation



Comparison of some results

	Original – wind-pump on	Motor-pump on	2x more fuel for motor pump	2x lower evap.	10x more rain	2x more human work	R in human work = 5%	R in human work = 20%
R (seJ) ($*10^{15}$)	2.926	2.922	2.922	1.697	3.126	3.342	2.704	3.369
M (seJ) ($*10^{14}$)	2.037	2.857	3.669	2.037	2.037	2.857	2.037	2.037
S (seJ) ($*10^{15}$)	3.992	3.988	3.988	3.992	3.992	7.762	4.213	3.548
Total eM (seJ) ($*10^{15}$)	7.121	7.196	7.277	5.892	7.321	11.389	7.121	7.121
Total salt (g)	5851188	5851188	5851188	3117185	4109557	5851188	5851188	5851188
TF salt (seJ/g) ($*10^{09}$)	1.046	1.057	1.069	1.624	1.533	1.673	1.046	1.046
N/R	0.070	0.098	0.126	0.120	0.065	0.085	0.075	0.060
ELR	1.434	1.462	1.490	2.473	1.342	2.408	1.634	1.113
EYR	1.697	1.684	1.671	1.404	1.745	1.415	1.612	1.898
SI	1.184	1.151	1.121	0.568	1.300	0.588	0.987	1.704
Empower density (seJ/m^2) ($*10^{11}$)	3.705	3.744	3.786	3.065	3.809	5.925	3.705	3.705

Guidelines for future production:

As our process is highly dependent on meteorological conditions, we cannot determine fixed optimal values for variables, which are under human influence. However, we can identify some general guidelines:

- To optimize (reduce) human work, find optimal combination between machinery use and manual work.
- To avoid dilution at precipitation.
- (To keep the % of R in human work high.)

Conclusions

- Despite some deficiencies Stella offers an opportunity to improve dynamic properties, clearness and flexibility of emergy analysis.
- It is possible to calculate TFs for each individual case.
- It is possible to simply and evidently add new parameters (ecological, social etc. value) to the model.
- Evidence into the fluctuations of individual flows is enabled, whereas future statistical analysis is deficient.


Thank you for your attention!