Energy Ponds - description of the concept

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This document introduces the technological concept which the author baptized **Energy Ponds**. Throughout the body text, links in round parentheses refer to various descriptions of the concept which the author published on his blog: Discover Social Sciences (https://discoversocialsciences.com/ ; see, for example 'The mind-blowing hydro').

Premises – why should anyone bother?

Climate change brings new risks to the European continent, in the form of floods and droughts. We seem to be more at home with the former than with the latter. We are historically familiar with floods, and climate change brings just more of otherwise measurable risks in that respect. The so-called flash floods, connected to sudden downpours of rain, are certainly a new factor. in Europe, we seem to be already on the path of adaptation to floods. Both the currently observed losses – human and financial – and their 10-year, moving average had their peaks between 1960 and 2000. After 2000, Europe seems to have been progressively acquiring the capacity to minimize the adverse impact of floods, and this capacity seems to have developed in cities more than in the countryside. A large part of presently existing urban structures in Europe has been constructed on previously drained and dried wetlands, still, while adapting to recurrent floods, Europeans have to acknowledge the comeback of this specific natural formation (Alfieri et al. 2015[1]; Paprotny et al. 2018[2]).

Adaptation to droughts is something different. In Europe, we are still defining what an actually harmful drought is, with respect to agriculture and water management. Estimation of socio-economic impacts of drought is even harder that it is the case with direct damage they

[1] Alfieri, L., Feyen, L., Dottori, F., & Bianchi, A. (2015). Ensemble flood risk assessment in Europe under high end climate scenarios. Global Environmental Change, 35, 199-212

[2] Paprotny, D., Sebastian, A., Morales-Nápoles, O., & Jonkman, S. N. (2018). Trends in flood losses in Europe over the past 150 years. Nature communications, 9(1), 1985

inflict (Naumann et al. 2015[3]; Vogt et al. 2018[4]; Lu et al. 2019[5]). Droughts happen slowly and insidiously, allowing human adaptation in the meantime, whence very prosaic a problem when estimating the outcomes of droughts on economy: residual errors are correlated Webber et al. (2018[6]). Different metrics are used for detecting drought, and the assessment of drought-related losses heavily depends on the metric used (Lu et al. 2019 op. cit.). Once we account for those methodological disparities, some trends emerge. Europe in general seems to be more and more exposed to long-term drought, and this growing exposure seems to be pretty consistent across various scenarios of climate change. Exposure to short-term episodes of drought seems to be growing mostly under the RCP 4.5 and RCP 6.0 climate change scenarios, a little bit less under the RCP 8.5 scenario. In practical terms it means that even if we, as a civilisation, manage to cut down our total carbon emissions, as in the RCP 4.5. climate change scenario, the incidence of drought in Europe will be still increasing. Stagge et al. (2017[7]) point out that exposure to drought in Europe diverges significantly between the Mediterranean South, on the one hand, and the relatively colder North. The former is definitely exposed to an increasing occurrence of droughts, whilst the latter is likely to experience less frequent episodes. What makes the difference is evapotranspiration (loos of water) rather than precipitation. Europe has been experiencing increasing an incidence of extreme heat events since 1989, and until 2015 it didn't seem to affect adversely the yield of wheat. Still, since 2015 on, there is a visible drop in the output of wheat, apparently compensated by more of other cereals, and accompanied by decreasing crops of potatoes and beets (Eurostat[8], Schills et al. 2018[9]).

The concept

The technological concept of Energy Ponds consists in using the technology of ram pumps, placed in the stream of a river flowing through relatively flat a landscape, so as to create head (elevation), which, in turn, is used to power hydroelectric turbines, and to conduct water into retentive wetlands. This core technology can be optimized with various possible technologies of energy storage - pumped hydro, gravity storage, and batteries – as well as with connections to other sources of power. The economic concept going together with the technology consists in creating a range of financial instruments based on the assumption that future stored energy is a circulating asset endowed with intrinsic utilitarian value, and with extrinsic market price.

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3 Gustavo Naumann et al. , 2015, Assessment of drought damages and their uncertainties in Europe, Environmental Research Letters, vol. 10, 124013, DOI https://doi.org/10.1088/1748-9326/10/12/124013

4 Vogt, J.V., Naumann, G., Masante, D., Spinoni, J., Cammalleri, C., Erian, W., Pischke, F., Pulwarty, R., Barbosa, P., Drought Risk Assessment. A conceptual Framework. EUR 29464 EN, Publications Office of the European Union, Luxembourg, 2018. ISBN 978-92-79-97469-4, doi:10.2760/057223, JRC113937

5 Lu, J., Carbone, G. J., & Grego, J. M. (2019). Uncertainty and hotspots in 21st century projections of agricultural drought from CMIP5 models. Scientific reports, 9(1), 4922

6 Webber, H., Ewert, F., Olesen, J. E., Müller, C., Fronzek, S., Ruane, A. C., ... & Ferrise, R. (2018). Diverging importance of drought stress for maize and winter wheat in Europe. Nature communications, 9(1), 42-49

7 Stagge, J. H., Kingston, D. G., Tallaksen, L. M., & Hannah, D. M. (2017). Observed drought indices show increasing divergence across Europe. Scientific reports, 7(1), 140-45

8 https://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_production_-_crops last access July 14th, 2019

9 Schils, R., Olesen, J. E., Kersebaum, K. C., Rijk, B., Oberforster, M., Kalyada, V., ... & Manolov, I. (2018). Cereal yield gaps across Europe. European journal of agronomy, 101, 109-120

The purpose (expected outcome) of Energy Ponds is to create better capacity of retaining water, and thus to prevent droughts, together with generation of electricity from renewable sources. Europe in general seems to be more and more exposed to long-term drought, and this growing exposure seems to be pretty consistent across various scenarios of climate change. Even if we, as a civilisation, manage to cut down our total carbon emissions, as in the RCP 4.5. climate change scenario, the incidence of drought in Europe will be still increasing, mostly due to increased evapotranspiration (loss of water), but also as a result of changing patterns in precipitation (Stagge et al. 2017[10]).

The typical natural environment for the implementation of Energy Ponds are flatlands, or even floodplains, located in the collecting basin of a river, possibly with the already occurring re-formation of wetlands. Such as it is studied, the concept is meant to be implemented in Europe, although, of course, other geographical locations are just as possible.

The core technology of Energy Ponds consists in combining ram pumping with hydrogeneration and retention of water in (semi)constructed wetlands, and thus to use the kinetic energy of rivers both for water retention and for generating electricity.

Idea: in case of flood, sudden surge in flow per second in the river can be detected and additional ram pumps can turn on, pumping the excess flow to a retention facility. The retention facility can be modular, so as to absorb more water in the times of flood. Retention facility in rural areas: swamps and similar. Retention facilities in urban, semi-urban and peri-urban areas: Sponge Cities or similar.

The possible optimization of the core technology in Energy Ponds aims at stabilizing, and possibly increasing the power output in the core technology, and consists in adding various forms of energy storage, as well as in connecting them to other sources of power (windmills, photovoltaic etc.).

The technological concept of **Energy Ponds** is outlined graphically in Figure 1. Rivers are the drainpipes of their respective basins, and the first step of the technology in question consists in capturing rainwater as it is already being drained through the local river. An otherwise old technology, used in Europe for hundreds of years, namely that of ram-pumping, is used to pump water from the river, using the kinetic energy of the river itself. The available technology of ram pumps allows an elevation of up to 20 meters, and a distance of up to 3 km.

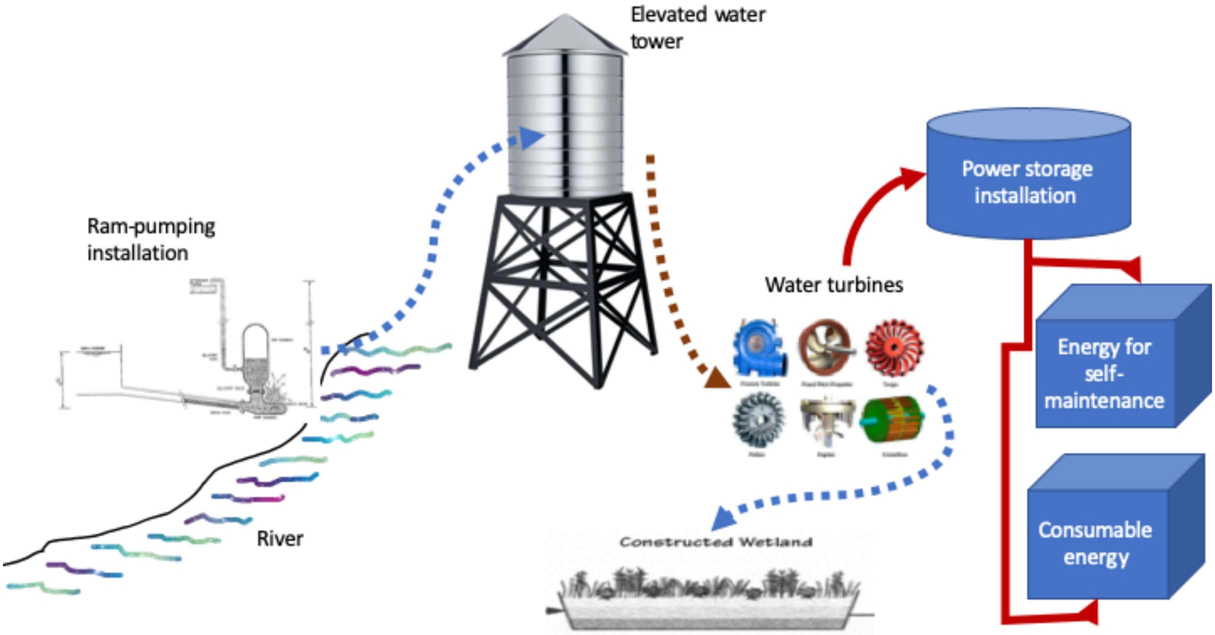
The next step in this technological chain consists in ram-pumping water from rivers into elevated water towers, from which, in the next consecutive step, water falls back to the ground level via a system of covered aqueducts equipped with water turbines. After having passed through turbines, water ends up in swamp-like structures that will retain it. The hydrogenated electricity powers local storage batteries in the first place, which, in turn, self-power the whole system to the extent of necessary (e.g. anti-freezing, digital flow control etc.), and distribute the residual surplus to local consumers of energy.

The combination of ram-pumping with storage in elevated water towers helps overcoming a fundamental weakness of European rivers, as regards hydroelectricity, namely their low head

[10] Stagge, J. H., Kingston, D. G., Tallaksen, L. M., & Hannah, D. M. (2017). Observed drought indices show increasing divergence across Europe. Scientific reports, 7(1), 140-45

(i.e. low denivelation). The amount of hydropower possible to generate from a turbine is proportional to the head of the waterflow. European rivers flow relatively flat and slowly, and yet they convey large masses of water, whence the idea of using that sheer mass to generate a primary push of kinetic energy, just to pump water up. Another limiting factor is the relatively tight, legal protection of riverbeds and riverbanks, either for environmental reasons, or for urbanistic ones. Ram pumps in themselves are relatively light equipment, just as the piping that would channel water to elevated towers. At this point, the concept of Energy Ponds modifies slightly that of water towers. The classical water tower usually collects water from vertical pumping, and lets it flow back down just as vertically. The concept of Energy Ponds returns to the old Roman concept of aqueduct: it assumes spreading the whole structure over a relatively large area, i.e. both the water pipes from ram pumps up, and those from water towers down would be diagonal. The old technological concept of Roman siphon can enrich the structure, so as to exploit the available land surface to create additional piped waterfalls (de Feo et al. 2013[11]). The usage of aqueducts rather that vertical pumping allows transporting water over and across sensitive areas with a minimum of disturbance.

[Figure 1 General description of the Energy Ponds concept]



The target basin for the water pumped from rivers is a swamp-like structure, i.e. a spongy layer – natural or man-made – underground, covered with a superficial layer of relatively thick and short-rooted vegetation. The underlying spongy layer retains water, whilst the superficial vegetal layer prevents or slows down evaporation. It might be important to stress that trees are not really the best idea in this concept. Hydrologically, a tree is a vertical pump: it reaches with its roots deep underground, where it taps into the incumbent water, sucks water into itself and

[11] De Feo, G., Angelakis, A. N., Antoniou, G. P., El-Gohary, F., Haut, B., Passchier, C. W., & Zheng, X. Y. (2013). Historical and technical notes on aqueducts from prehistoric to medieval times. Water, 5(4), 1996-2025

transports it upwards, into branches and leaves, where water evaporates. In the concept of Energy Ponds, trees could serve to stabilize the soil, yet just to that purpose.

We don't necessarily need big water towers in this technology. In some contexts, it could be practical to have them in the circuit, but just sometimes. It is good to split the idea of elevated water towers into two separate solutions: elevation, and elevated storage. Elevation as such serves to use the power of ram pumps to create potential energy in the waterflow. Any elevated tank, in itself, serves to create head in the waterflow, so as to make those hydroelectric turbines work, downstream. At the limit, the capacity of that tank can be just enough to stabilize.