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Hydrology and Earth System Sciences Discussions

Interactive comment on "HESS Opinions "Climate, hydrology, energy, water: recognizing uncertainty and seeking sustainability"" *by* D. Koutsoyiannis et al.

D. Koutsoyiannis et al.

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So far the review comments and discussions dealt with scientific premises of hydrology, thus not reflecting the entire content of Koutsoyiannis et al. (2008), which tries to shed light also to technological aspects of water and hydrology and their linkages to energy and sustainability. Therefore, we welcome Montanari's (2008) review comments to other parts of our paper and, in particular, to the role of water in the future, also in relation to hydropower. These comments demonstrate that our paper was perhaps too epigrammatical and that more discussion is needed about these technological aspects.

Montanari states: "First of all, the water use for energy production is far from being

sustainable. We all know how many concerns the use of water raises for the preservation of the environment." We, too, are aware of the environmental concerns about hydropower projects and major water resource development projects, as well as of the critics from the 'green' camp. Hydropower is often presented as unsustainable and hurtful for the environment, whereas, for example nuclear energy has been sometimes characterized as "clean" or even "green" and sustainable. We do not share such views as we tried to explain in Koutsoyiannis et al. (2008). Here, instead of providing our own arguments we prefer to quote a few extracts from Vit Klemes's (2007) recent talk describing his "revelations" in his "hydrological afterlife". His (seemingly old-fashioned and heretic but perhaps post-modern) views on this issue we fully embrace:

"Another important revelation that I was privileged to receive in my hydrological afterlife was that nothing can be green without water – except 'green' politics."

"This leads me to one more important revelation that I can share with you: a new infectious disease has sprung up – a water-born schizophrenia: on the one hand, we are daily inundated by the media with reports about water-caused disasters, from destructive droughts to even more destructive floods, and with complaints that 'not enough is done' to mitigate them; and, on the other hand, attempts to do so by any engineering means – and so far no other similarly effective means are usually available – are invariably denounced as 'rape of nature' (often by people with only the foggiest ideas about their functioning), and are opposed, prevented, or at least delayed by never ending 'environmental assessments and reassessments' ".

"I shall close with a plea to all of you, hydrologists and other water professionals, to stand up for water, hydrology and water resource engineering, to restore their good name, unmask the demagoguery hiding behind the various 'green' slogans. ... [O]ur profession has nothing to be ashamed of – from the times of the ancient Mesopotamia, Greece and Rome to the present, it has done more good for mankind than all its critics combined. This is not a revelation: this is a historical fact."

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Another point of Montanari's criticism is related to our assertion that water and hydropower can play an important role in a future energy scene. Specifically, Montanari states: "I believe that water will hardly be able to play a central role within energy production" and "I think there is an upper limit to water exploitation for energy production and I believe such a limit is already very close... it seems to me that K2008 are overlooking the possible advent of new techniques. What about the possible role played by nuclear energy? What about solar and wind energy? I agree that the ability to produce solar energy and wind energy is related to the presence of water in the climatic system, but I do not think that hydrology is significant within this respect." (Montanari uses K2008 for abbreviating Koutsoyiannis et al., 2008).

To reply to this criticism we must stress four basic technical characteristics of hydropower (with the risk of being pedantic): (1) its high efficiency in energy conversion, which at large-scale power plants may reach 95% (due to very low thermal losses); (2) its ability to be combined with water storage (reservoirs) which allows regulation of the energy production rate; (3) the ability to respond to changes in demand in very short times, of the order of seconds or minutes (as opposed to other conventional, e.g. thermal, power plants, whose response times may be of the order of hours or days); and (4) the potential of installing reversible turbines that work in both directions, either transferring water downstream and thus producing energy, or pumping water upstream and thus consuming energy, or, in other words, storing available electrical energy in the form of potential mechanical energy of water. Characteristics (1) and (3) make hydropower a very special part of an energy system. Hydropower plants greatly contribute to the stability of the entire system and the produced hydroelectric energy has higher economical value than the conventional (thermal) energy (e.g. 100% higher).

It is true that we do not examine in our paper the nuclear energy, which we do not regard sustainable (and this is a long discussion that may not have a place in this paper) but it is not true that we do not discuss the solar and wind energy. Quite the opposite. We state: "Renewable energy sources, including hydropower, wind, wave, tidal and

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biofuels, are all based on solar energy. The amount of solar energy should not be underestimated... solar energy reaching Earth in one hour only is equivalent to the current energy use for all human activities in one year... In recent years, significant technological developments have improved the efficiency and reduced the cost of these energy sources ... and their improvement continues at a growing pace. ". We can now regard all renewable energies as proven technologically, commercially and politically (Scheer, 2006) as testified for instance by the great progress in several European countries, and Germany in particular (http://en.wikipedia.org/wiki/Renewable_energy_in_Germany). Montanari also may have overlooked the subsequent paragraph in Koutsoyiannis et al. (2008a), which describes the linkages of all renewable energies with hydropower – or perhaps its meaning was not clear enough. Therefore we clarify this meaning here.

Currently, the fossil fuels (oil, coal) gave us the luxury of a fully controllable and deterministically manageable energy production, with the flip of a switch. This is quite different in renewable sources. We may recall from Homer and Greek tragedies that the Greeks' ships waited motionless for many days in Aulis and finally Agamemnon sacrificed his daughter Iphigenia for a fair wind to start to blow to sail to Troy. The unavailability at the time of demand, the incompliance with the specifications we demand, the high variability, and the unpredictability, are common characteristics in all renewable energies. Hydropower can be an exception, though, if combined with water storage in reservoirs. Water can be stored but wind and solar radiation cannot. However, electric energy produced either by wind turbines or by photovoltaic cells can potentially be stored. Here comes hydropower again, now not as a means for (original) energy production but as a means for energy storage. At a time of excess availability of solar or wind energy, the produced energy could be used in hydropower plants to pump water from downstream to upstream. At times of deficit of solar and wind energy, the upstream stored water can be used to cover the deficit, this time producing energy. This is a very old technology with an efficiency that can reach 90% (for the whole cycle) in large-scale plants.

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It is thus striking that this simple technology of energy storage is not widely known and is not discussed in the media, including popular science magazines, whereas we are inundated by discussions on other lower-efficiency and unproven energy storage technologies such as hydrogen (as a fuel – not to be confused with hydrogen fusion, and not to mention that the hydrogen as a fuel has been often misleadingly presented as an energy resource, while it is just a medium for energy storage). It is more striking that even scientific review articles fail to mention this technology. As we state in Koutsoyiannis et al. (2008a), "In their state of the art review, Crabtree and Lewis (2007) classify the cost effective storage of electricity well beyond any present technology." This is not correct because energy storage through pumped water storage is an old, proven and highly efficient technology.

We hope that with these clarifications, our reasons justifying our statement "Water is going to play a principal role in this future energy scene" have become more understandable. We do not refer just to hydroelectric energy generation, but also to energy storage, in which water is unique among all renewable energies. And this is not at all related "to the presence of water in the climatic system". A question then arises, Is hydrology, the science of water on Earth, going to play an enhanced role in the future? Montanari seems to reply negatively when he states "I do not think that hydrology is significant within this respect". Our answer, however, is positive. Why? Because renewable energies imply a switch from the current "switch-flip" deterministic energy management to a different type of management, where variability and uncertainty of natural (hydrometeorological) elements are dominant. And hydrology, if not isolated from its strong technological and engineering roots, has traditionally a good and close relationship with uncertainty description and management. Perhaps it is the scientific discipline that has studied uncertainty in Nature more and in greater depth than any other discipline. We hope to have made clear that this is the important role we view for hydrology for the future, which is a holistic rather than a reductionist view (to borrow the excellent terms from Savenije, 2008). We subscribe to this view and we do not think that hydrology's ambition should be to produce analytical and insightful calculations of

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