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Water for Sana'a and Taiz'z from Solar Desalination at the Red Sea

Proposal for saving Sana'a and Taiz'z
and serving all Yemen

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This document can be found under http://www.trec-eumena.org

Sana'a / Hamburg **November 20th, 2006**

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Executive Summary

Options for resolving the imminent Sana'a water crisis have been investigated. The only lasting solution we found is by seawater desalination using solar energy. There are 2 fundamentally different options:

(1) The desalinated water is pumped to Sana'a ("saving Sana'a solution") or

(2) The vast majority of Sana'a population is relocated to the coasts ("Sana'a relocation solution").

While pumping of water to the elevation of Sana'a (2500 m) is often considered as too expensive, we have compared the costs for a pipe line (option 1) with the costs of building new settlements (option 2). Socially, logistically, financially, politically and internationally, construction of a water pipeline for saving Sana'a is preferable to relocating its population. Building new settlements for around 2 Million relocated people will cost over $35 Billion, while the costs for the pipeline and solar power plant to pump 1 Billion m^3 water per year will require about $6 Billion. This amount is equivalent to the world market value of 2% of the proven Yemeni oil reserves. Desalination costs will be below 1$/$m^3$. Construction of the pipe line can be controlled, while relocation of 2 Million people can lead to frictions and surprises and can induce uncontrollable developments including civil war. Completing the pipeline in time before depletion of the basin is still feasible if the work is started now. Steps towards making a quick start are proposed.

Such a solution would also work for other cities in Yemen with similar water problems. In the case of Taiz'z the considerations are quite similar to those of Sana'a with the difference that constructing a pipe line to Taiz'z is much easier.

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1. The Proposal

The water scarcity of Sana'a, Taiz'z and Yemen

The water supply of the Yemeni Capital Sana'a, already in a poor state right now, is approaching a critical point since more than 80% comes from extracting water from fossil reserves in the geological Sana'a Basin. It is estimated that the basin will be depleted between 2015 - 2020. At that time, about 2.5 Million people may be living in this area. The rechargeable water from precipitation however would be sufficient for at most 400 000 inhabitants with a life style that would be close to water poverty. A rather sudden breakdown of water supply for over 2 Million people would generate a disaster for Sana'a and the Yemen. Since there are no other places in the country that could provide water for 2 million additional people, the imminent depletion of the Sana'a basin would put the whole country into a political stress situation that could endanger the stability of the country if it is unprepared.

The case of Taiz'z is even more pressing. All considerations brought forward for Sana'a do also apply to the case of Taiz'z. The pipe line solution, however, would be much easier since Taiz'z is only 700m above sea level and not 2500m as Sana'a. We therefore discuss here in detail only the more difficult case.

Desalination in Yemen – a necessity for survival

President Abdullah Saleh in recent public addresses has emphasized the necessity of desalination for the future of Yemen. In fact, the Republic of Yemen, having one of the fastest growing population in the world - with 20 Million inhabitants now, an anticipated population of over 60 Millions in 2050, and growth expected to continue beyond that date - is already now living beyond what rechargeable water resources can supply. The dependence on exhaustible fossil water resources is growing. Population will so substantially outgrow the natural water resources of the country in the coming 1 or 2 decades that basic preconditions for life such as water and food would no longer be secure. Under these circumstances there is no question that a substitute for the water currently available from the Sana'a basin will have to come from new sources, i.e. from desalination, and not by take-away from other users. Even if efficiency of water use is enhanced significantly seawater desalination at large scale, i.e. of millions of cubic meters per day, is becoming a question of survival for Yemen.

Encouraged by recent statements of the President, the authors present here their scientific work from the past 2 years on the Sana'a water problem, and propose **a solution for Sana'a in particular and a strategy for Yemen in general,** by desalination of sea water using solar energy.

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Fossil or solar energy for desalination?

Desalination requires seawater, desalination technology and large amounts of energy. Access to seawater is no problem for Yemen. Desalination technology could be built within the country by local labour force at any level of demand. The bottleneck is energy. Since a secure water supply system for Sana'a, and for any other place in Yemen as well, has to function without foreseeable limitations in volume and in duration it must not depend resources that will expire. Even though Yemen is in the lucky situation of having oil and gas fields, of 3 Billion barrels of oil and of 480 Billion m^3 gas according to present estimates, their reach into the future is too limited for a water supply system: with the present production rate the oil reserves will be depleted in about 2022. If gas will take over most of oil services after 2020, it is unlikely that gas supplies will last much beyond 2040, unless new fields are discovered.

The bottom line on energy for desalination is: the domestic fossil reserves may cease to be available after 2040. This will then lead to a nation-wide collapse of water and power supply with fatal implications for the existence of Sana'a and with dramatic implications for the whole country.

For these reasons we have investigated the option of solar energy as the basis for a water and energy supply system with long-term security. Our studies show that solar energy (Figures 1, 2) has great potential in Yemen, much larger than would be needed to accommodate the desalination and power generation needs of the country for the foreseeable future. For desalinating and pumping 1 Billion m^3/year, a collector area of about 40 km^2 is needed. We therefore propose **solar power generation and desalination of seawater as the preferred strategy for water and energy security, for Sana'a and for Yemen.**

Other solutions for the Sana'a water problem

There are a number of proposals under discussion for resolving the Sana'a water problem.

1. Transfer water from other fresh water sources to Sana'a. These proposals have two problems: firstly, such resources are insufficient for keeping Sana'a alive. Secondly, all this fresh water is in use already. This proposal implies taking water away from other users. It requires construction of pipelines and pumps, but water scarcity is only shifted from one place to another. This will cost money, will create conflicts and does not provide any additional water. Therefore we dismiss such concepts totally.
2. Reduction or elimination of agriculture in the Sana'a basin: farmers from the Sana'a basin would have to be transferred to other activities with less water demand in the Sana'a region within 10 years, or to be relocated to other regions in Yemen. There are no other activities easily available in Sana'a for people working as farmers now, and there are no regions with unused water in Yemen to where they could be relocated. Desalination

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would be needed as well. Displacement of farmers from their traditional regions will be costly, and legally and socially difficult. Keeping the farmers but stopping irrigation and farming, and make the former farmers live from selling “their” water to the urban population will create social problems, and will collapse when the Sana’a basin approaches depletion – now a few years later.

3. Better water management: this is clearly needed, but does not create new water and will become meaningless when the basin is depleted.

We come to the conclusion that the only real solution for a secure and lasting water supply for Sana’a is seawater desalination based on solar energy.

Water pipeline to Sana’a or relocation of population to the coasts

There two very different options for a solution by desalination:

1. Most of the population of Sana’a is to be relocated to the coast line where desalination will take place (*Sana’a relocation option*), or
2. Desalinated water is to be pumped from the coast line to Sana’a (*Saving Sana’a option*).

Neither of these options is easy or free of cost. In both cases desalination facilities for around 2 million people are needed. The difference in cost between the two options, however, is substantial:

1. The relocation option requires construction of new settlements for 2.1 Million people. Assuming that an average family of 6 people need 100 m^2 of housing then with present prices for housing, $5.500 will be needed for each person, or $12 Billion in total. On top of this comes the community infrastructure (roads, schools, shops, factories etc.) which will cost at least 2 times the private housing investment. The total cost of the relocation option will be then $35 Billion or more.
2. The saving Sana’a option requires the construction of a pipeline with a capacity of around 1 billion m^3/year (cost estimate: $3 Billion), and of solar power plants for pumping the water up to Sana’a (cost extimate: $3 Billion). The estimated cost of these facilities is $6 Billion.

These costs for infrastructure investment are summarized in Table 1. The $6 Billion are equivalent to the world market value of about 2% of the present proven oil reserves of Yemen. The costs for desalination itself, an investment of $5 – $6 Billion $, should be recovered from water sales to the consumers.

Apart from being relatively expensive, the relocation option would be difficult to implement. Both, pipelines and new settlements require long term planning and a lead time for construction of several years prior to the depletion of the Sana’a

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basin. Planning of the pipeline can be started right away, as soon as the most appropriate locations at the Red Sea coast for desalination plants have been identified and the optimal path for the pipeline has been traced. This can be accomplished within 1 year. Planning of new settlements appears to us as a more complex and difficult task, technically and politically.

Further, a project for saving the World Cultural Heritage of Sana'a is likely to attract international support. By contrast, a proposal to relocate the population of Sana'a is more likely to be considered as an internal matter of Yemen.

Race against depletion time

A depletion of the Sana'a basin before completion of the pipeline or of the substitute settlements for displacement, including the necessary desalination facilities might lead to a chaotic situation, in Sana'a and throughout the country. The new water supply system must be operational before the wells begin to fall dry. This may happen as soon as 2015. According to our investigations the water pipeline and a reasonable fraction of the solar power and desalination plants can be ready for operation within 8 years. This implies that the necessary decisions should be made within 2 years from now and that preparatory work should begin immediately, as outlined in Table 2 in the appendix.

No problem would arise if the Sana'a basin begins to fall dry some years after pipeline and desalination facilities go into operation. Any surplus water in a transient period can readily be dumped into the nearly emptied Sana'a basin and raise the water table. A refilled Sana'a basin could serve as a buffer for fluctuations in desalination and in consumption. Also, it would help to ensure security of water supplies in the event of a relatively long shut down of the pipeline for maintenance or repair. However, in the displacement approach it will be a difficult task to select people to leave Sana'a first while some water pumping from the basin is still working. There may be rivalries for the remaining water and fights for who should go and who might stay.

In conclusion

Socially, logistically, financially, politically and internationally a saving of Sana'a by a water pipeline is easier than the relocation of most of its population. The costs for the pipeline and solar power plant to provide water for 2 Million people will amount to about $6 Billion while construction of new settlements for around 2 Million people will cost over $35 Billion. The process of constructing the pipe line can be well controlled, while displacement of 2 Million people can lead to frictions and surprises and can induce uncontrollable developments including civil war. Constructing the pipeline before depletion of the basin is still feasible if preparatory work is started now. In case of Taiz'z, the pipeline solution is relatively simpler and cheaper, and therefore even more preferential over the relocation option.

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2. Getting started

Setting up a Sana'a desalination task force (SDTF)

Implementation of the Sana'a solar water project is mainly an engineering task, once basic parameters, such as time plan, desalination volume and financing have been settled. The main unknown factors at present are the volume of desalinated water to be allocated for irrigation and the expected growth of population in the Sana'a region. For agriculture the cost of water is the critical factor. If the pipeline and power plant construction costs are handled as investments in the public infrastructure of the country, then water costs below 1$/m^3 appear to be possible. An agreement is needed to find out how much fresh or reprocessed desalinated water should be available for agriculture in the Sana'a region and an assessment of the feasibility of providing it.

There are a number of important issues and potential fringe benefits connected with this project that deserve careful consideration. For instance, along the route of the pipe line from the sea shore to Sana'a, outlets could supply water to people who are living there and perhaps serve new settlements. Since solar desalination will become a matter of survival for Yemen, construction of solar collectors can be made a new industry in Yemen. Horticulture in the shade under the collectors could become a new type of agriculture in Yemen (see Fig. 1). The SDTF should have the proper structure and the necessary financial means to come up with solutions to such issues within 1 year.

Pre-feasibility study

The numbers quoted in this proposal are based on studies, sundry information collected from various sources, and assessments. They are good enough to paint a reasonably clear qualitatively picture of the various options, and to identify the best way forward for the future. What is needed now is a more detailed assessment of the feasibility of the proposed project and more precise estimates of costs. To this end a pre-feasibility study needs to be performed. The responsible authorities and members of the SDTF should organize public hearings and other meetings, aiming to define the issues that need to be clarified in a pre-feasibility study up to the end of 2006.

A technology demonstration plant

Independent of the various questions specific to the Sana'a – and also the Taiz'z - project, desalination in Yemen with solar energy is a pressing issue. Therefore, whether or not, or how in detail a pipeline to Sana'a will be built, Yemen should begin to use this technology as a strategic step for its future. To this end, a small scale project should be started without hesitation. It would be good if it were to be located at the Red Sea to gain experience for the larger projects to follow. The water may be used for industrial, residential or agricultural applications. The capacity should be between 5 and 10 Million m^3 per year. This would require an

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investment of $35 to $60 Million, and lead to costs of 1.0 – 1.5 $/m³ desalinated water. In a second stage, this plant could be extended to a capacity of 50 to 100 Million m^3 per year, and with lower costs per m^3. It would be interesting to make use of the solar collector field (about 200 x 300 m^2 in stage 1) consisting of mirror plates concentrating the sun light onto water pipes for steam generation, for agricultural research on plant growth in its shade, by the University of Sana'a. The second stage could already serve for testing collectors largely built in Yemen. Such production could help to reduce costs and found a new industry, and research and development of solar technology in Yemen.

Appendix

Table 1: Comparison of costs estimated for infrastructure

Saving Sana'a option Pumping 1 BCM water for 2.1 Million people (or more) from Red Sea to Sana'a		Sana'a Relocation option Move 2.1 Million people (or more) from Sana'a to new settlements at the coasts	
Item	Billion $	Item	Billion $
Pipeline	3	Housing	12
Solar power plant for pumping	3	Community infrastructure	23
Total	6		35

Table 2: Approximate time schedule

Project	Task	Time
Sana'a solar water project	Constitution of project task force:	July –August 2006
	Project parameter definition	September – December 2006
	Project pre-design study	2007
	Project design	2008, 2009
	Engineering, Procurement and Construction (EPC)	Begin 2010
	First water to Sana'a (partial capacity)	2015
Solar desalination demonstration plant	Parameter definition	July – October 2006
	Design:	Nov. 2006-Dec. 2007
	EPC	2008, 2009
	First water	2010

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Figure 1: Concentrating solar collectors with flat mirror array. Each mirror strip reflects the sunlight to the absorber pipe, in which water is converted into hot steam for a power and desalination plant. The space under the mirrors could be user for horticulture.

Figure 2: Concentrating solar collectors with parabolic trough mirrors to reflect the sunlight to the absorber pipe.