PROBLEMS IN EXPLOITATION OF THE AGRICULTURAL PROJECT "GRADINA" IN GEVGELIJA AFTER 10 YEARS OF EXPLOITATION

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ABSTRACT: *Agricultural geothermal project "Gradina" in Gevgelija (Macedonia) is associated with a list of problems during its development. Direct heating system using agressive brine, very long connection line. wrong technical solutions of low-temperature heating systems. weak maintenence, absence of fresh capital etc. resulted in continual "pressure" to overcome the problems and enable profitable production.*

This paper cosists of description of the problems which appeared during the first 10 years of esploitation of the project. Results of several feasibility studies for improving the negative situations are given and justification for reconstruction is discussed. Finally, a trial to make a technical and economic state-of the-art of the project is made and to define the justification of its re-completion and its possible step-by-step realisation. Results are of limited possibility. being based on the influence of economic factors of the country under blockade. However. some of the conclusions of technological nature can be of wider regional (Mediterranean) interest, where such large greenhouse complexes (22.5 ha) are not so often in practice.

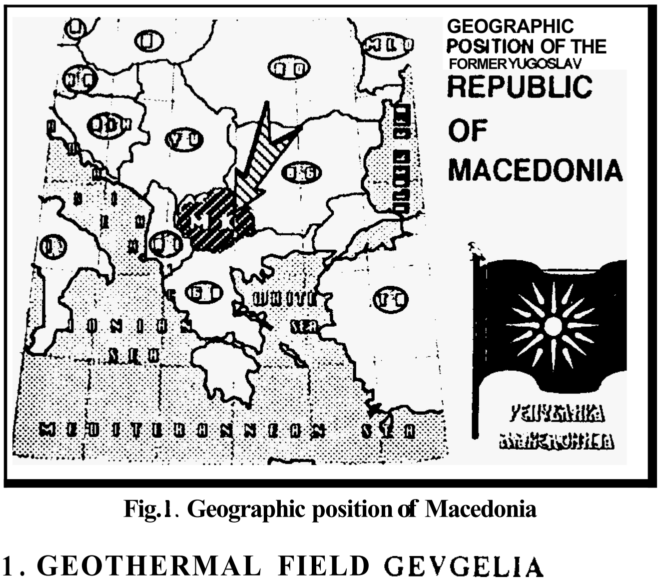

Fig.1. Geographic position of Macedonia

1. GEOTHERMAL FIELD GEVGELIA

Republic of Macedonia (Fig.1) is situated in the central part of the Balkanian Peninsula, along the very favourable geothermal zone that starts in Hungary to the north and Italy to the west, and stretches through Greece down to Turkey and beyond to the East. Unfortunately, it is one of the rare European countries which has not systematically measured terrestial heat flow. However, existing natural springs and exploration results illustrates that it is one of the countries with the richest low-enthalpy geothermal energy resources.

Known geothermal fields are grouped according to the geotectonic divisions in Macedonia (Fig.2). The east and northeast, which part of the Macedonian-Serbian massif characterised by crystalline basement rocks. is much richer than the west and southwest (Bosnian-Serbian-Macedonian geothermal area) which is characterised by limestone. The extreme aggressiveness of the waters of this limestone area makes them unsuitable for practical use as heat sources at this stage of the development of geothermal energy use.

Of the seven geothermal fields identified in the east and northeast of the country (Fig.2). four have been found to be very promising and three of them have been investigated to the stage where practical use is possible.

The Gevgelia Valley is within the river Vardar zone, at the southern part of the country. Three geothermal sites, all near active faults in an area of high seismic activity, have been identified so far.

Fig.2. Location of Gevgelia geothermal field

The *Smokvica* geothermal site was determined after the drilling of 22 boreholes to the depths of between 30 and 850 m (Fig.3). They were all drilled in a highly weathered diabase intrusion, with clay minerals and epidote. The largest aquifer was found at 350-500 m (Fig.4). The maximum total yield by pumping from 4 production wells (Fig.6) is about 180 l/s at an average temperature of 65°C. However, this pumping rate is greater than tlie capacity of tlie reservoir and over-pumping during the initial years resulted with a temperature drop of up to 10 "C (Fig.5). This cooling is believed to be caused by the infiltration of colder water from the surrounding rocks or by downflow of colder water from non-producing wells which are not cemented aiid sealed. The flow of 80 l/s has been found as a realistic maximum of tlie field. without negative influence to the water temperature.

Negorska banjo is characterised by steeply dipping diabases of Tertiary age and by numerous dykes and granite intrusions. Several shallow boreholes, between 20 and 130 m, were drilled in 1983 to delineate the fault that is considered to carry the hot water. During **1984-1985,** two boreholes of **600** m each were drilled. resulting in a total thermal water flow by pumping of 80 l/s at 51 "C. The production horizon seems to be associated with spilites at a very shallow depth of 100 **to 150** m and at the intersections of faults. The newest borehole, drilled to 300 m during **1986** with tlie use of Head-On-Resistivity profiling (applied for the first time in Macedonia), intersected a permeable fault at about 250 m and the water temperature increased to 63 °C.

Gornitchet has not yet been sufficiently explored. 'fhere are two springs yielding 5 l/s tliernial water at 24 "C. Geothermometers indicate that the water has a temperature of 150 "C at depth.

2. DEVELOPMENT OF THE "GRADINA" GEOTHERMAL PROJECT

In the wake of the good results obtained with the

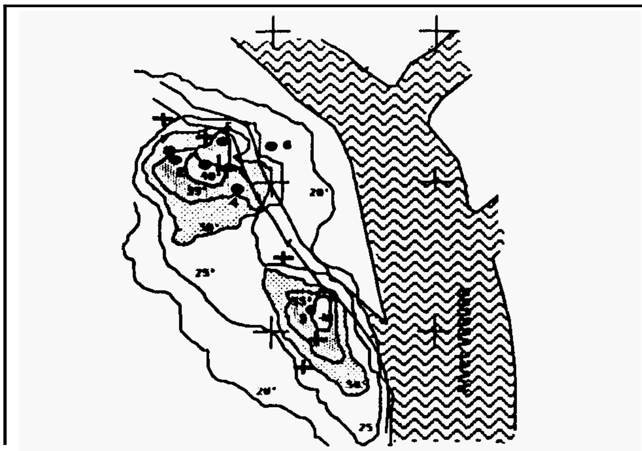

Fig.3. Horizontal temperature distribution of the Smokvica geothermal field

previous Bansko (Strumica geothermal field) and Kotchany geothermal projects. the wave of euphoria in Gevgelia when the first successful borelioles were drilled caused many potential problems to be ignored. Within a year, financing was found. and a connecting pipeline almost 6 km long was built, designed to handle the expected thermal water flowrate of over 300 l/s. All the warnings of scientists aiid specialists that it was too early to draw conclusions and to make technical decisions were ignored, and by 1983/ 1984 the system was in operation.

The direct connection of geotliermal water (Fig.7) to the existing system and boiler plants, combined with a much lower thermal water flow than expected, resulted in the project's total financial failure. The fire tubes in most of the boilers were destroyed by the end of the first season, as were the steel pipes in the heating installation, due to the thermal water aggressiveness (Table 1); the total energy yields were much lower than expected.

Series of investigations were carried out, and a team of energy specialists were involved in trying to find a solution to the problem (Cerepnalkovski et al., **1986). 120 l/s** of thermal water was made available 1986 and 160 l/s in 1987; the system was redesigned (Fig.8) through a process of technological and economical optimisation.

However, it became obvious that orientation towards a highly sophisticated technical solution with incorporation of heat pumps was far from being economically feasible. Neither the concentration of necessary capital has been possible nor the existing agricultural production could pay it.

A new study has been conducted (Popovski et al., 1987) in order to find a possible solution for the situation. Three important conclusions have been made for the future of the project:

1. Technical solution of the project should be simplified (Fig.9) in the way that heat pumps should be avoided;
2. Technology of production should be changed in order to enable payment of additional investments for tlie system reconstruction; and

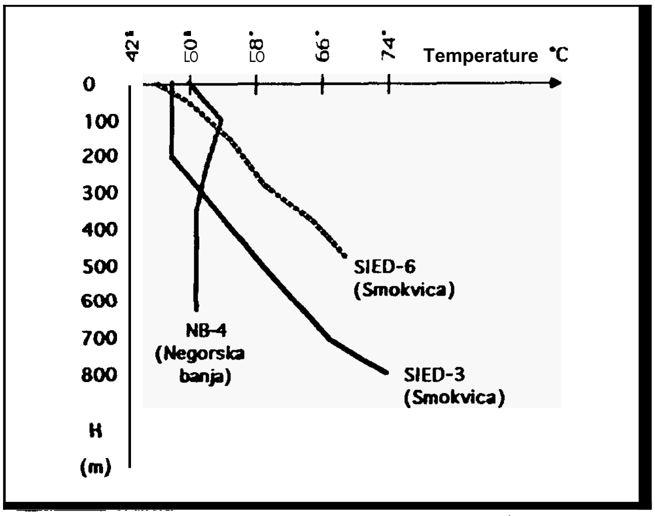

Fig.4. Vertical temperature profile of the most important boreholes

3. The process of reconstruction should go in logical phases. Firstly, a very simple reconstruction should be realised (Fig.10), enabling protection of tlie heating installation. Then, the deaeration and chemical treatment of the water should come, enabling protection of tlie connection pipeline. Further, depending on the realistic project development, other optimizations should be incorporated.

3. ANALYSIS OF CONCEPTUAL AND DESIGN MISTAKES

Both above mentioned studies found the same conceptual and design mistakes of tlie geothermal system technical solution:

3.1. Direct Connection of the System to the Wells

Both, tlie long connection pipe-line (6 km) and heating installatioils of greenhouses have been designed to use tlie thermal water directly. In addition, the thermal water should be heated to higher temperatures in the boilers for climate conditions above heat power of the geothermal energy source.

Taking into account that the thermal water is aggressive because of containing free O_2 and CO_2, resulting in destruction of the heating installation systems in tlie greenhouses and fire pipes in the boilers, during the first year of use. l'he connection pipeline has been harmed at several points. also.

3.2. Use of a heating systeni designed for higher temperature

Technical solution accepted for the reorientation from closed loop system led by heavy oil boilers to thermal water didn't consist of changing tlie heating system.

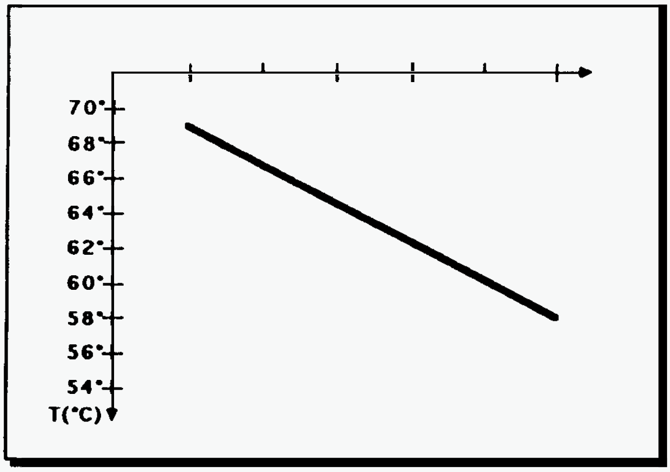

Fig.5. Temperature drop duriig the exploitation

Resulting temperatures in greenhouses couldn't fulfil the demands of the winter season production. Even tlie autumn and spring production have been more or less covered by tlie heat of geotliernial origin, it was quickly obvious that temperature regime of 65/35°C doesn't suit with the installation designed for 110170°C.

3.3. Use of thermal water without degassification

No special measures were designed lor degassification of the thermal water, consisting significant quantity of free O_2 and CO_2.

Resulting air gaps in many parts of the heating installation caused irregular temperature distribution in greenhouses.

3.4. Use of over-dimensioned connection line

The main pipeline of 6 km length has been designed for a flow of 300 l/s, which is far bigger than the 80-120 l/s on disposal.

Resulting in very slow flow of the thermal heating fluid it causes a temperature drop in the line and, in that way, in a decline in available heating power.

3.5. Absence of chemical treatment of thermal water

Complete neglection of the problemme of thermal water aggressiveness (see 3.1) resulted with a quick decay of the heating pipes and fire pipes of the boilers. After only one year of exploitation it became clear that indirect connection should be applied or chemical treatment of thermal water introduced, if intending to use it as heating fluid.

4. TECHNICAL FEASIBILITY OF POSSIBLE OPTIMISATIONS

Mistakes, listed in point 3, could be removed by the application of following technical solutions:

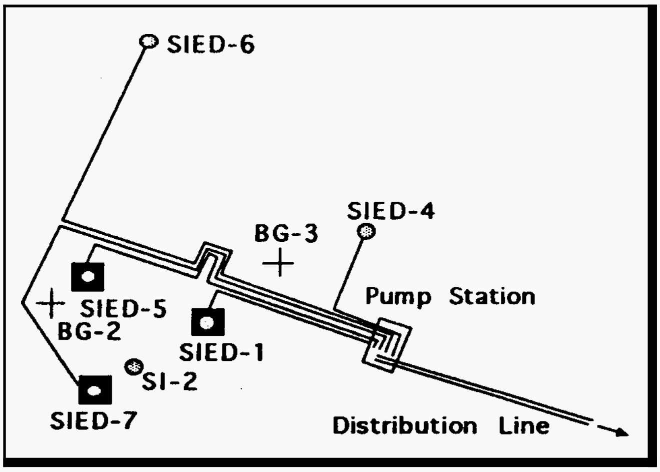

Fig.6. Connections between the exploitation wells

1. Introduction of indirect connection of the heating installations in greenhouses to the geothermal wells, i.e. application of heat-exchanger(s) directly after tlie collection of thermal water from the system of wells;
2. Introduction of heat pumps in order to increase the temperature of heating fluid on disposal and, in that way, to euable proper use of the existing type of heating installation (system of horizontally positioned steel pipes) [Cerepnalkovski]; or to introduce other type of heating installation, convenient for use of low-temperature heating fluid [Popovski];
3. Introduction of a collecting reservoir lor the

tliernial water, equipped with necessary armature for proper degassification, directly after tlie collection of tliernial water from tlie system of wells;

4. Introduction of a large and good thernically insulated lieat accumulator [Popovski] in order to increase the maximal lieat power on disposal and to equalise tlie water flow through tlie over-dimensioned connection pipe-line;

5. Introduction of chemical treatment of the thermal water in tlic system of wells or inmediately after its collection in tlie pump station.

Element	Si02	Na	K	Ca
mg/l	67	405	10	308
Element	Mg	c02	SO4	Cl
mg/l	0.5	30.8	1,340	240

Table 1. Chemistry of tlie geothermal water

5. ECONOMIC FEASIBILITY OF POSSIBLE OPTIMIZATIONS

Taking into account that a large lieatiig system is in question, application of any one of technically feasible optimizations conditions additional large investments. Some of them (chemical treatment) result with liigli esploitation costs of the system. On tlie other hand. character of the user limits the possible maximum level of investments (by its ability to repay tliem in an economically justified time period).

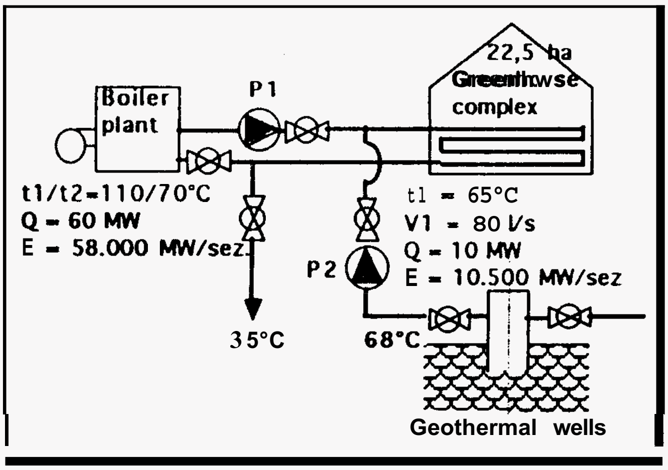

Fig.7. Simplified scheme of the initial geothermal system

The approach of two studies to the determination of economic feasibility of technically feasible solutions lor optimisation has been different:

1. The first one (Cerepnalkovski et al. 1986) looked lor economic feasibility in the increasing of tlie geothermal part of used heat and. in that way, lowering tlic price of tlic heat unit, i.e. by keeping the total heating costs at tlie same level as they are without reconstruction.

2. The second one (Popovski et al., 1987) looked lor economic feasibility in the ability of the production in greenhouses to repay additional investment (and definition of priority of investments in energy installations in comparison with the other necessary ones).

Different approach has been caused by the economic situation of greenhouse production in Macedonia in general and the relation between the energy costs of the winter production of vegetables and possible earn of it when realised with old-fashioned production technologies. The most important question has not been how to make a reconstruction which shall enable its repay by the decrease of costs for heating greenhouses. but how to find possibilities for any improvement which can be repaid with the existing production technology.

First concept lias been inmediately found as non feasible. No optimisation has been possible with the *65%* participation of energy costs in tlie production ones. The introduction of new intensive production technologies couldn't enable lowering of that participatiou to the necessary 20-30%.

The second one directed the investigations towards finding tlie economically feasible combinations of necessary improvement of production technology with the removal of design mistakes of heating installations.

It lias beeu found that a complete economically feasible reconstruction of the system was iiot possible. Even tlie most productive teclinologies didn't enable repayment of necessary investment costs for their introduction in combination with proposed reconstruction of tlie geotlieriiial system by the first variant.

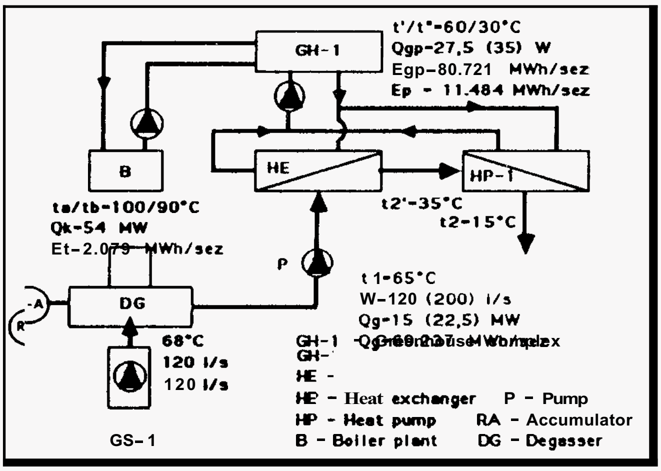

Fig.8. First variant of tlie system optimisation

On tlie other hand, it came that a "medium" sophisticated technological solution with realisation in phases can be economically feasible.

First of all, final technical solutioii of the heating system should not consist heat pumps (Fig.9). Their annual lieat loading factor is to low to be economically feasible. Except that, to introduce large heat accumulators. enabling to cover significant part of the liigli night lieat loadings (day regime-"filling", night regime-"empting"). Four of tlic existing 8 lieavy oil reservoirs of 600 tons each can be easy accomodated for **such** a **purpose**

To introduce a **cheap type** of low-temperature lieatiiig system **to** cover **the** base **lieat** load(corrugated PP pipes laid **on** tlie ground surface). It should be accommodated **to** the requests of the intensive production teclinologies in soil (first phase of reconstruction) **and** in "grodan" (second phase of reconstruction). For lower outside temperatures and peak loadings to use the existing installations (but in closed loops) i.e. fed by the heavy oil boilers and separated from geothermal installations.

To introduce degassification of tlie thermal water (first phase of reconstruction) and system of heat exchangers (second **phase** of reconstruction) in the central pump station, immediately after tlie collection of thermal water from geothermal wells. If necessary **to** introduce also a cliemical treatment of the water (third phase of reconstruction).

Positive financial **results** of each step of the reconstruction should improve **the** ability of the production to cover **the** costs of tlie next phase of it.

5. PRESENT SITUATION

Five years ***ago*** the second variant of optimization **began.** However, tlie development has been very slowe due to tlie whole political **and** economic situation in **the** region. Up **to** now, separation of heating installations lias **been** realised (Fig.10), i.e. corrugated plastic pipes laid on tlic **ground have been** added **to the** steel pipe installation. In that **way**, decay of the second **one** lias been **stopped**. Connection line has been equipped with proper **armature** for degassification and initial degassification in the central **pump** station, too.

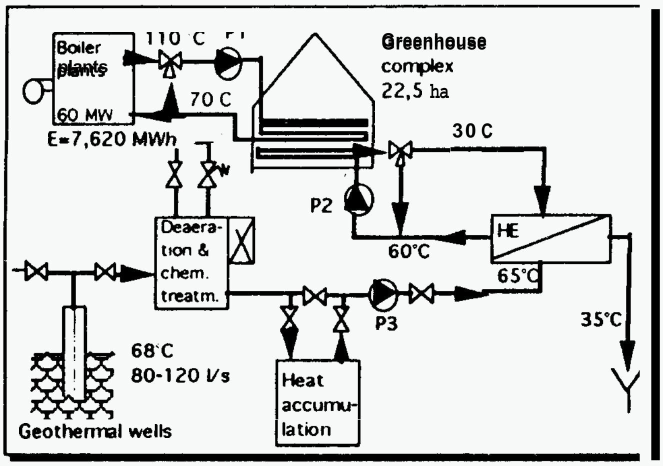

Fig.9. Simplified scheme of the optimised system

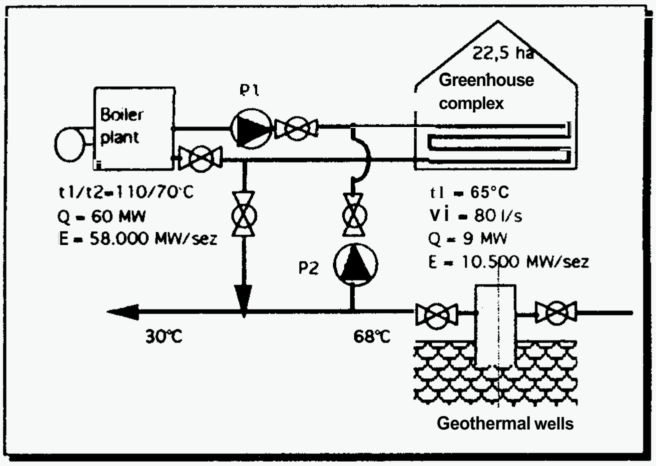

Fig.10. Simplified scheme of the present system

Some trials witli tlie chemical **treatment** of the thermal water liavc been made but without successful final results.

Together with tlic **partial** optimization of tlie energy **systems.** also production technology lias been improved by tlic introduction of drip irrigation system with controlled fertilization of cultivated plants.

Altogether,' it **can** be **stated tliat** the first phase of the planned optimisation has been realised.

6. DISCUSSION

22,5 ha greenhouse complex **"Gradina"** is a rather large heat consumer. Installed power of the heating installation system is about 70 MW and annual heat consumption about 70.000 MWh/sez (depending **on** the chosen production programme and outside climate conditions. It is about 7.000 t/year (initial variant) heavy oil, i.e. 1.800.000 US$/year for a total commercial value of the production of about 2.500.000 US$/year (72% participation).

By the introduction of new low-positioned heating installation. geothermal energy as heating fluid and more intensive production technologies, greenhouse complex decreased the costs of energy to about 1.000.000 US$/year and increased the commercial value of the production **to** about 3.500.000 US$/year (last year before tlie blockade of the country).The participation of energy costs has been decreased to 28,5%. **A** profitable production lias been enabled and further development by finalisation of planned process of optimisation (with a target to reach only 20% participation of the energy costs).

7. CONCLUSIONS

Initial design mistakes, caused by the superficial approach to tlie problem of direct application of geothermal energy, resulted with enormous number of problems in exploitation 01 the geothermal system "Gradina" in Cievgelia (Macedonia). Economic effects of the introduction of **the** "free of charge" euergy source have **been** minimal, if not even negative.

Further development of the project has beeu characterised with continual efforts for removing the mistakes **and** removing negative effects 01them.

Absence of experience and capital **resulted** with two **years** activities directed towards finding the technically and economically feasible **way** to improve the negative situation. Several studies made of different local teams **gave** opposite results which slowed the process of project recoustruction

Finally. the conclusions of the study. made by Popovski and al. (1987). have been accepted (unofficially) and in 1988 active reconstruction began. The first phase of it has been realised until 1991 and gave expected positive results. The project works profitable. Independence of the imported fuel (in a country with reduced supply caused by the blockade of Greece) and reduced participation of energy costs in the total production costs enabled competitive production prices and survival under extremely difficult market conditions.

The owners have neither capital nor organisational possibilities to finalise the reconstruction of the system under the present influencing political and economic conditions. However, positive results of realised part of it give hopes that immediately after their normalisation it shall be finished. It is of particular importance for future of other geothermal projects in Macedonia because if such a "problematic" project can work profitable. then it shall be much easier to find feasible solutions for the others.

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