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KVARIT IS COALESCENCE OF ENERGY EFFICIENCY, ENVIRONMENTAL COMPATIBILITY, RESOURCE EFFICIENCY AND ECONOMY

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Abstract. The European IPPC Bureau (2007) is reviewing around 50 techniques for pollution prevention and control in the ceramic manufacturing industry. Therefore, scientists from all over the world are trying to do away with the genetic dependence on the paradigm of past millennia – production of bricks and bloating clay, the main construction materials these days. In today's projects, they try to use various technologies and materials as alternatives. However, all innovative projects reviewed depend on local supplies, which are mostly materials for recycling, whose production is highly volatile and can be seasonal only. Apart from this, these materials use cement as an adhesion agent, and concrete production has always been criticized for multiple reasons.

The proposed project changes all of this. The technical parameters of the projects are much better than the best available technologies (BAT) of the ceramic manufacturing industry. With a very diverse raw material base, the project offers a whole new paradigm for eco-design, opens new horizons for researching new concepts of the future technology that addresses today's challenges and describes an efficient control system. Besides, it helps achieve the following:

- ✓ Stop using fossil fuels (gas, oil);
- ✓ Lower the environmental impact by reducing the emission of greenhouse gases, nitrogen oxides, dust and noise;
- ✓ Save resources (mostly energy, water is not required);
- ✓ Considerably reduce the area of open mines and free more land for agriculture.

Keywords: Kvarit, building materials, eco-design, new paradigm, energy efficiency, resource efficiency, environmental compatibility, economy, research GML 5, innovation TRL-4, markets.

1. A new paradigm for eco-design: porous ceramics from natural clay Shale and Slate

Through a radical departure from conventional engineering practice, this technology brings forward a new paradigm for material eco-design: Maximizing the potentials for ecologically adapted technology development through material selections and process choices in manufacturing, with a potential four-fold improvement in eco-compatibility including reduction in GHG emissions.

Kvarit is an innovative technology [7] which uses natural properties of certain geologic materials and well-known volcanic rocks formed without water and oxygen (such as pumice or volcanic tuff) and capable of increasing their volume as affected by volcanic scoria.

Proposed technology changes a person's view on industrial landscape – due to the lack of dust, noise and bulky productions; this technology is easily transformable, transportable and can be located close to the major construction objects, significantly reducing the transporting of products.

Technological process of the project basically uses electric ovens-moulds, in which the dosed amount of raw material passes through the swelling, silicificiation and formation of the product with predetermined configuration and bulk density (Figure 1).

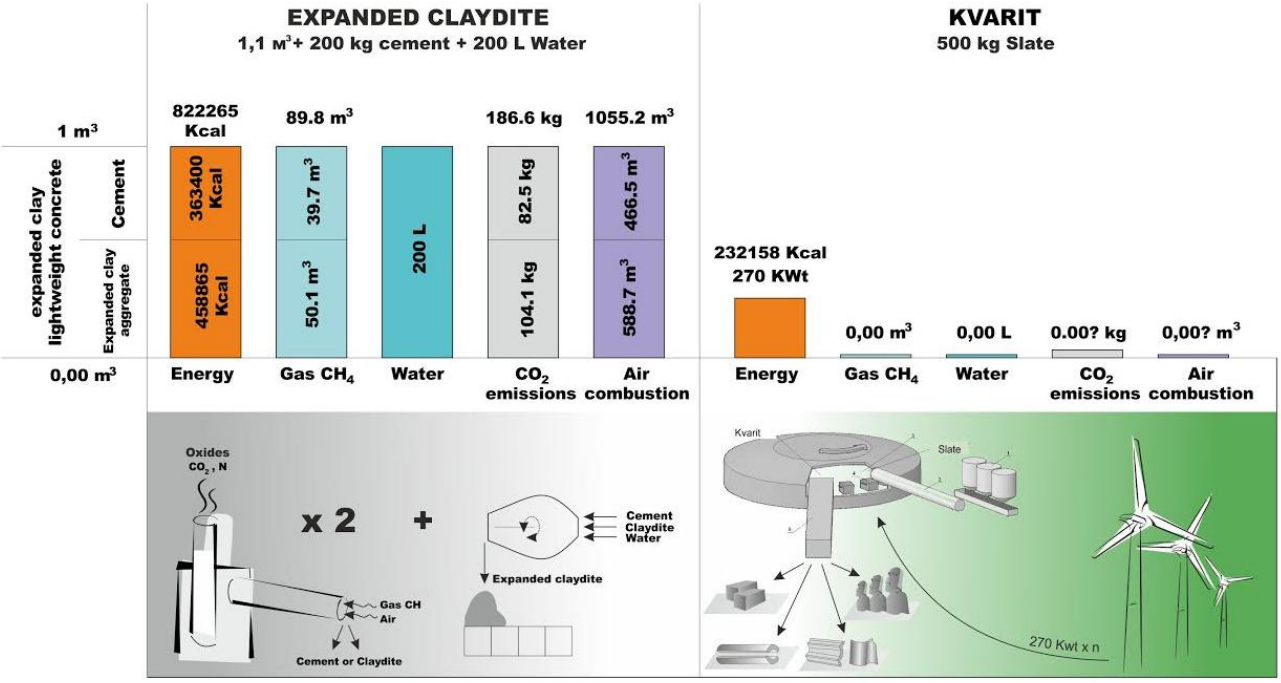

FIGURE 1. Impact categories (top) and production systems (below) for the novel concept of the porous ceramics building material Kvarit (right) in comparison with existing building material Light Expanded Clay Aggregate, Leca or Claydite (left). Numbers presented are based on preliminary calculations that will be assessed in detail during the course of the project, including the impact categories indicated with question marks [1-4, 6].

The proposed technology meets such modern-age challenges as:

- ✓ doing away with exhaustible energy sources (gas, petroleum products);
- ✓ environmental compatibility and sustainability;
- ✓ cost-effective use of resources (i.e. water, cement, lands) suitable for agricultural production;
- ✓ flexible and intellectual production
- ✓ energy efficient technologies and products at the stages of our construction product manufacturing, transporting , operating and processing;
- ✓ cost efficiency.

2. "KVARIT" (thermo-insulating construction material) is the porous ceramics building material

KVARIT itself is a porous ceramic material which can be considered as an intermediary between glass and ceramics. It is formed by means of heating of clay slate and 0.5-20 mm mudstones and usually contains 5% of quartz, 8% of spinel, 3 % of mullite and 84% of X-ray amorphous material. KVARIT can be obtained in closed molds put into a muffle furnace under a temperature of 1150–1250^{0}C (2102–2282^{0}F) and with the use of autoadhesion and filling in of the entire mould. Reference samples obtained in our laboratory have the following specifications: density 370 kg/m3 with compression resistance 10.4 kg/cm2 and density 750 kg/m3 with compression resistance 32.4 kg/cm2. Based on results of our benchmarks with ceramsite concrete B-3.5, we suggest that the use of KVARIT may help to reduce emissions of CO2 and other combustion gases (Table 1).

TABLE 1. Air emissions of combustion products (gm) per kg of output [1- 4, 6]

Air pollution	Lightweight claydite-concrete blocks		"Kvarit"
	Claydite	Cement	
CO_2	245,7	413,52	No data. Presumably, negligible.
H_2O	571,0	325,56	
N_2	1012,0	2209,1	
O_2	14,6	73,0	
In total	1843,3	3021,18	
Source	[1-4, 6]	[1-4, 6]	

Raw material is represented by crushed aggregates from carbon-free clay shale (roofing shale/slate), argillites and other bloating materials of 0.5 to 20 mm fraction, including inter alia: overburden rock and mining production wastes; roofing slate wastes up to 85% at roofing plate manufacturing (Table 2).

TABLE 2. Composition of raw material [1- 5]

	Dagestan	Chelyabinsk	Rostov	Vladikavkaz [4]
SiO_2	57,34	59,16	57	61,73
Al_2O_3	19,68	19,94	20,97	20,23
Fe_3O_4	7,57	8,15	7,57	5,73
TiO_2	0,93	0,7	0,96	0,64
CaO	1,11	1,04	0,63	1,06
MgO	1,64	1,82	1,48	1,99
C_2O_3	1,2	0,32	<0,1	0,2
Na_2O	1,4	1,82	1,16	1,19
K_2O	3,02	2,52	3,71	2,78
P_2O_5	0,22	0,24	0,19	-
C	0,94	<0,1	0,35	-
Other	4,95	4,29	5,98	4,32

Theoretical power consumption is 270 KVA/cbm of production with density 500 kg/cbm. Production of "Kvarit", because of the technological process in a confined space, reduces energy costs. Comparative data are given in Table Calorie per kg of product.

TABLE 3. Calorie per kg of product

	"Kvarit"	expanded clay lightweight concrete (LC)		
		expanded clay (EC)	expanded clay sand (CS)	cement (C)
Energy consumption for firing	129,62	129,62	129,62	
Energy consumption for evaporation of moisture		233,84	233,84	
Loss of hot product	210,00	210,00	210,00	
The loss of the off-gas		113,00	113,00	
Loss in the environment	147,40 (?)	147,40	147,40	
The loss to the lack of a chemical reaction		12,46	12,46	
Energy consumption for the production of cement				1817,00
In total	487,02	846,32	846,32	1817,00
Source	[4]	[4]	[4]	[2]

(LC) = 1(EC):0,3(CS):0,22(C)=846,32+282,10+0,22x1817=1528,16 kcal

Energy Efficiency "Kvarit" is 1528,16 : 487,02 = 3,14

Product costs are competitive; this conclusion should be made from the following:

1. Technology under review requires no cement.

2. Technology involved provides for no water consumption.

3. Technology involved requires no supplementary facilities to manufacture products.

4. The total energy consumption of 3.14 times less than the theoretical energy requirements for production blocks made from Light Expanded Clay Aggregate (Leca).

3. Obtained product and raw materials

Raw materials for "Kvarit" is widespread around the world: quarries wastes production of slate roof tiles , mudslides and landslides, construction and demolition wastes, slate or shale quarries. There are great careers for slate tiles in the UK, Germany, Spain, USA, Canada, Greenland, China, Russia, Finland and other countries.

"Kvarit" actually is pumice or volcanic tuff with ability to change shape and density. Its primary use is as a thermo-insulating construction material. It may be helpful other areas of usage:

- fire-resistant 1250°C
- used as a natural insulator against heat and cold
- reduce microbial contaminants and airborne fungal carcinogens of indoor environments [9]
- helps to maintain soil moisture
- reduces the need for irrigation
- noncorroding with water, flightless with wind
- anti-skid roads in winter season by providing friction
- makes it easier to draw water from the soil before planting.

The main technical barrier – high temperature – 1250° C.

PHOTO 1. The bulk density of 500 kg/m3


PHOTOS 2-3. The bulk density of 370 kg/m3 (left) and 750 kg/m3 (right)

PHOTOS 4-5. Dimensions

PHOTOS 6-8. Raw materials

Summary:

1. Water is only needed in the production process for flushing muddy raw stock obtained mostly in the drainage areas of the Sulak River in Dagestan and Duruji River in Georgia, and from weathered clay shale rocks.

2. No careful treatment of the fragmented raw stock being required, crushed stone 0.5 mm to 20 mm in size can be used in production processes, even though 60% of it only is used in the traditional (dry) method and 40% discarded as spills and screenings [7].

3. A product of any desired density (in the range of 300-800 kg/m3) can be obtained.

4. There is no need to use open flat areas for quarries, as raw stock can be obtained from overburden removal operations at mining facilities, wastes from roofing slate production, silt in the above-named rivers, and from other sources.

5. Flushing tailings contain humus and dust-like clay shale having up to 3% potassium and can be used for land reclamation.

6. No dust present, the factory can dispense with ventilation and suction equipment, the basic equipment components are so integrated that they can be set up in a workshop having a height of up to 7 meters and all handling and other operations can be performed by overhead cranes of up to 5 metric tons lifting capacity.

7. The process allows maximum use to be made of primary raw stock heating energy to obtain an end product and the process to be monitored and managed at any stage or mode thereof. Electric power used in the material production process facilitates equipment adjustment while the volume weight of a product can be changed quickly within the range of 300 to 800 kg/m3 or over.

4. Problems and prospects

Previously, we applied for a grant of the HORIZON-2020 programme [8-10], but the programme's experts considered that our lead R&D engineer does not have sufficient skills and expertise.

If we obtain a grant, we will be able to perform the following research:

Phase I (R&D):

✓ In-depth study of creation of synthetic pumice and volcanic tuff as well as usage of the autoadhesion processes and additive agents, such as carbon fibre, for adjusting material's attributes
✓ Tribological studies during selection of materials for concrete forms
✓ Studies and certifications of the resulting material
✓ Development of the methodology and technological processes for laboratory production of the material.

Phase II (Pilot):

✓ Launching of a pilot production with average daily output of 1.5-2 m3 and testing of the production equipment with the total throughout of 30,000 thermal cycles a year; the same number of thermal cycles is performed by engine pistons of modern cars in 10 minutes at 3,000 rpm, or at a speed of 80–100 km/h.

Based on results of the conducted studies, technological readiness of the R&D can be levelled up from TRL-3-4 to TRL-7.

The TRL-7 level of technological readiness will significantly increase the overall investment attractiveness and provide excellent opportunities for future commercialization in HORIZON-2020's projects.

The project KVARIT is ready for full-scale results from the local experimentation of the concept are theoretically and experimentally confirmed, and they open the way for full-scale implementation of the concept (GML 5) [11, 12].

Experimental production can be launched on a pilot model of a small-size industrial unit to produce one to two cubic meters of Kvarit items a day with the purpose of obtaining information about the operation of all unit assemblies and components in a commercial manufacturing process to reduce risks when these assemblies and components are used in a full-size project so that any changes in design at the experimental stage may reduce the costs of dealing with problems likely to arise in a large-size plant.

The pilot model will yield valuable scientific knowledge about the processes going on, the properties of equipment materials and manufacturing automation, provide estimates of power requirements and help develop operating instructions and specifications for designing a full-scale plant for quantity production.

The concept of the prototype furnace is shown in Figure 2.

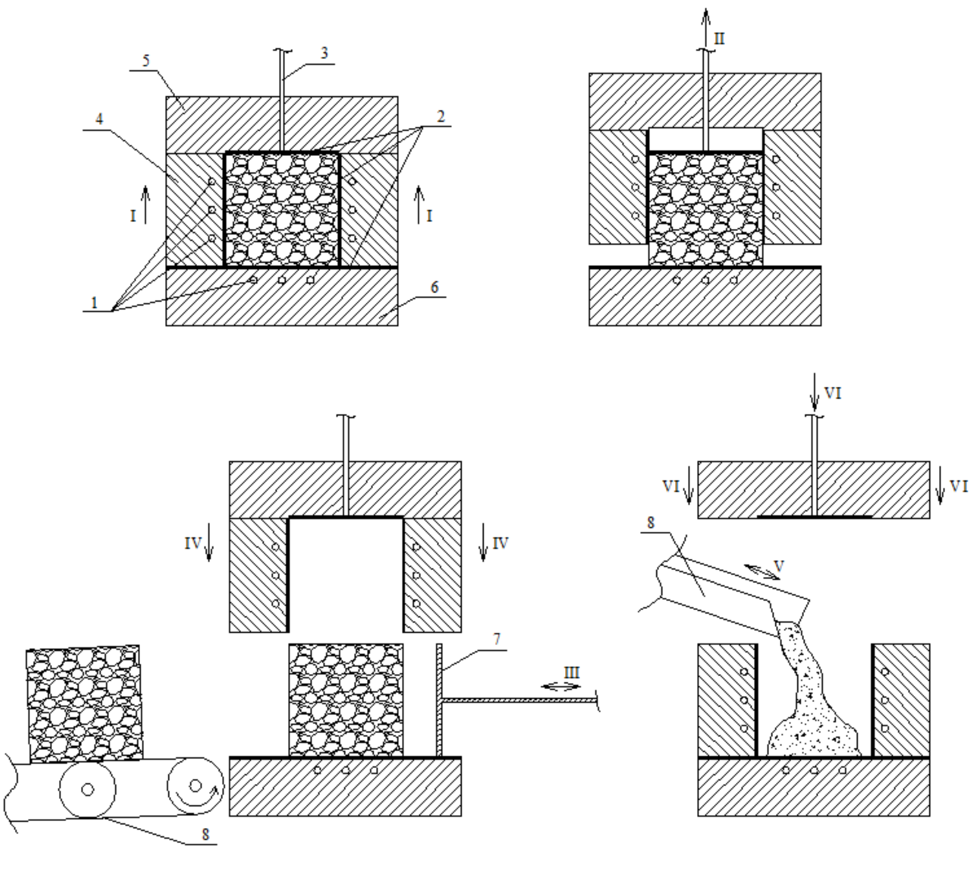

FIGURE 2. The concept of the prototype furnace.

In the experimental production of the product it is necessary to:

1. Carry out a marketing study to establish demand for products made of Kvarit;

2. Certify the product as a structural and heat-insulating building material;

3. To measure the heat and physic-mechanical characteristics of products;

4. Implement full-scale research and nondestructive control of the condition, moisture content, and heat conductivity of the material in wall structures in operation;

5. Establish development of specification;

5. Budget and Financial Structure – It will be adjusted based on R & D

The business plan has been written with consideration for possible costs in Russia and is subject to amendment following research into an experimental production process.

Funds can also be raised from partners willing to be involved in the project on a cost-sharing basis.

TABLE 4. Budget and Financial Structure

	Capital funding	**cost**	
1	Construction of manufacture		
1.1	Specifications, agreements, project work, and other functions for	$	320 000
1.2	Construction and installation work	$	500 000
1.3	Commissioning work	$	60 000
1.4	Contingencies	$	300 000
1.5	SUM	**$**	**1 180 000**
2	Equipment		
2.1	Furnaces 64 pcs (20 800 $/piece)	$	1 331 200
2.2	Heating screw conveyor (1000°C)	$	220 000
2.3	Vertical conveyor	$	14 000
2.4	Batch Charger	$	36 000
2.5	Electrical substation (250 000 VA)	$	17 000
2.6	Electric generators (for comparison with other sources)	$	4 000 000
2.7	Overhead crane (3 tn)	$	14 000
2.8	Wheel Loader	$	30 000
2.9	Forklift	$	30 000
2.10	Measuring instruments and industrial automatic	$	150 000
2.11	Other equipment	$	350 000
2.12	**SUM**	**$**	**6 192 200**
3	**Amortization and scheduled maintenance**		
3.1	Equipment amortization 20% =[2.12]*0.2	$	1 238 440
3.2	Scheduled maintenance 2% =[1.5]*0.02	$	23 600
3.3	Equipment parts	$	250 000
3.4	Repair by subcontractor	$	12 000
3.5	**SUM**	**$**	**1 524 040**

4	**Production costs**		
4.1	Raw material 10 000 cbm (42 $/cbm)	$	420 000
4.2	Electric power (2,6-for comparison with other sources)	$	950 000
4.3	Transportation costs	$	40 000
4.4	Diesel fuel	$	20 000
4.5	**SUM**	**$**	**1 430 000**
5	**Salary**		
5.1	Chief of production (1 person)	$	32 000
5.2	Laboratory assistant (1 person)	$	16 000
5.3	Warehouse manager (1 person)	$	24 000
5.4	Operator of automatics (4 people)	$	64 000
5.5	Electrician (2 people)	$	32 000
5.6	Locksmith, mechanic (4 people)	$	50 000
5.7	Driver (2 people)	$	24 000
5.8	Laborer (6 people)	$	60 000
5.9	Contingencies	$	20 000
5.10	**SUM**	**$**	**322 000**
6	**Other costs**		
6.1	Public utility	$	8 000
6.2	Marketing department	$	30 000
6.3	Security	$	36 000
6.4	Legal advice	$	12 000
6.5	Accounting and financial audit	$	35 000
6.6	Insurance	$	30 000
6.7	Contingencies	$	40 000
6.8	**SUM**	**$**	**191 000**
7	**Sales revenue**		
7.1	Blocks 60x30x24cm 50 000 cbm (100 $/cbm)	$	5 000 000
7.2	**SUM**	**$**	**5 000 000**
8	**Operating expenses =[3.5]+[4.5]+[5.10]+[6.8]**	**$**	**3 467 040**
9	**Operating income =[7.2]-[8]**	**$**	**1 532 960**
10	**Corporate tax 20% =[9]*0.2**	**$**	**306 592**
11	**Operating margin =[9]*100%/[7.2]**	**30,66%**	
12	**Payback period =([1.5]+[2.12])/([9]-[10]) (years)**	**6,01**	

6. Proposed markets

1. Production of building blocks made from Light Expanded Clay Aggregat (LECA).

The fact that today´s building materials are so environmentally damaging is the reason why the European Expanded Clay Association (EXCA) is pessimistic about the possibility of implementation of the EU 2020 climate and energy targets (“20-20-20”), and the measure “Reform of the EU Emissions Trading System” (EU ETS) [11]. EXCA produces 7000000 cubic meters expanded clay per year.

Accordingly, equipment and technology will be partially cut production expanding clay and cement.

2. KVARIT Manufacturers can also use the exchange platform for trade, which is like a stock exchange for carbon credits.

3. Whilst the scale of the project is difficult to assess, it has huge potential for development. Brick, at the genetic level, is a leader in construction, but climate change and resource issues may seriously change the situation in this market.

Equipment capacity up to 50 thousand cubic metres per year can replace the brick factories of 20 million pieces per year.

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