Integrated system of ash and slag waste disposal

SEPTEMBER 2015
Situation in the Russian market of ash and slag waste

Topicality

Today in Russia there are about 350 power plants and coal-fired CHP plants. Among them there are 172 large ones, each generating over 100,000 tons of ash and slag waste a year. Moreover, about a hundred power plants position themselves as potential ash suppliers.

Annual generation of ash and slag waste in the Russian Federation is about 22 mln* tons. About 4 million tons of ash and slag materials are shipped to the consumer’s market, where dry fly ash is no more than 0.6 million tons, and the rest in the form of hydrated ash and slag mixtures from ash dumps is used in recultivation projects, landscaping and cement manufacturing.

According to different evaluations the ash dumps have accumulated 1.5 to 1.8 billion tons of ash and slag waste. Today 115 power plants have almost empty ash disposal capacities. Such a situation says about the local environmental disasters and inefficient work on these problems in Russia.

On 12 September, 2013, the Government of the Russian Federation made a decision to freeze the power rates since 1 January, 2014. In November, 2013 a decision was made of a four-year programme of annual 10% reduction of the internal cost of energy companies partially owned by the state. Federal Law No. 219 came into effect in January 2015 according to which since 2020 eco-payments will grow 25–100 times.

These factors are affecting the topicality of the ash and slag waste problem solution at the Russian coal-fired power plants and coal-fires CHP plants.

Ash and slag waste generation

≈ 22 000 000 tons

Sale

≈ 4 000 000 tons

* Source: Russian Energy Agency (REA)
Energy industry problems

Historically, the country’s energy sector focused only on one problem: to produce a lot of cheap energy for the country. The problems of waste utilization went to the second place, they were often forgotten. It was expressed also in design solutions. For example, the Reftinskaya power plant generating 5-6 million tons of ash annually still has had only two silos, each by capacity 3000 tons. And they are the largest silos of all coal-fired power plants in Russia. Most power plants have no silo at all to ship ash for consumers and, therefore, no ash distribution system.

There are no weighty reasons which would force power engineering specialists to solve the ash distribution problems. So, in European countries ash disposal areas of coal-fired power plants are illegal, or a fine for each ton of ash sent to an ash disposal area is from 60 euro (Finland) up to 248 euro (Czech Republic).

In Russia this fine is 5–16 rubles for a ton (€ 0.07–0.23). Besides, there is a possibility to include the ash disposal costs in the electric power costs.

Tendencies

In Russia, the power plants privatization objectively forces new private owners to optimize and make the best use of the resources under their control. The competition for key power consumers starts. The second important tendency is the fact that the local authority cease allocation of land plots for ash disposal areas, or they do it with reluctance and at a high price.

The resolution of the Government of the Russian Federation on freezing the natural monopoly rates in 2014 and their growth containment in 2015–2016, dated 12.09.2013, may become the most important factor. The Ministry of Natural Resources of the Russian Federation is working out a question of multiple increase of eco-duties for ash and slag waste dumping.

The environmental legislation is becoming tougher, and it promotes introduction of the best available technologies (FL No. 219 dated 21.07.2014) such as dry ash and slag disposal systems. On 01.08.2014, RF Government Regulation No. 712 “Concerning the procedure of certification of I-IV hazard category wastes” and Order of the Ministry of Natural Resources of Russia No. 792 dated 30.09.2011 “Concerning the procedure of maintaining of the State Cadastre of wastes”, according to which the State Register of waste disposal areas will be formed, came into effect. According to item 6, Article 12, Federal Law No. 89 dated 24.06.1998 “Concerning the waste of manufacturing and consumption”, the waste disposal areas (storage and dumping) enter the State Register of waste disposal areas.

Now, the Federal Service for Supervision of Natural Resource Usage (Rosprirodnadzor) is developing the State Register of waste disposal areas based on the information sent by natural resource users according to the Order of the Ministry of Natural Resources and Environment of the Russian Federation dated 25.02.2010 No. 49. This information was sent to the Rosprirodnadzor Department to include ash and slag deposit areas in the State Register of waste disposal areas. However, the Order of Rosprirodnadzor concerning inclusion of ash and slag deposit areas in the State Register of waste disposal areas No. 479 dated 01.08.2014 does not cover ash disposal areas within human settlements and/or water conservation zones.

Therefore:
1) while the ash disposal area is not included in the State Register of waste disposal areas, its exploitation is forbidden;
2) waste disposal payment will be calculated without decreasing coefficient 0.3, but with a fivefold increasing coefficient.
Total payment for ash and slag waste disposal will be 16 times as much and more.

As a whole, the power engineering specialists will be forced to look for a way of cost reduction and increase of efficiency of the available assets, which will provoke the interest of power plant owners in investments into ash sale and the available ash disposal areas optimization, as this is a way to extend duration of power plants operation and to improve their profitability.
Reftinskaya state power plant, one of the largest coal-fired power plants in Russia, in June, 2013 launched a new ash disposal system. It is oriented on the ash disposal optimization and hundredfold decrease of a water share in the mixture arriving at an ash disposal area.

If the today’s system, where an ash/water ratio is equal 1:30, allows this hydropower plant to work till 2016, changing the ash/water ratio up to 3:1 will allow to prolong this period till 2040. At the same time, 25% of ash is supposed to be sold in the market.

Two single-section silos by lump-sum storage volume 22 000 m³ and a closed 4.5 km conveyor for transportation of humidified ash mixture to an ash disposal area are installed. The given system is evaluated at 11 billion rubles. Only two of ten power units are connected to the system. In 2012, the Reftinskaya hydropower plant sold about 300 000 tons of ash, in 2013 — about 190 000 tons, in 2014 — 250 000 tons. A similar system is designed at the Beryozovskaya state power plant.

According to conservative evaluations, the potential of the Russian ash and slag materials (ASM) market makes up:

- **Cement market**: ≈ 17 mln tons
- **Recultivation market**: ≈ 5 mln tons
- **Road construction market**: ≈ 10 mln tons
- **Soil deoxidization market**: ≈ 3 mln tons

Total about 35 000 000 tons of ASM yearly*

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* — If there is a product on the market. Conditions for the existence of the product: see page 9.
The design solutions used at the Reftinska-ya state power plant and planned to be introduced at the Beryozovskaya state power plant focus on the optimization of ash disposal at the existing dumps, but not the optimization of the generated ash distribution. Therefore, at the Raftinskaya state power plant, the created complex capacity supposes sale of 25% of ash only. Different commercial properties of ash are ignored, and the technology is designed for mixing all kinds of ash in the same silo, that will result in decrease of sales efficiency and in decrease of stability of quality of the product delivered on the market. The same problems are present in the Beryozovskaya state power plant project.

The reason for such solutions is the fact that in Russia there are no professional organizations which can analyze, design, construct and create a system covering all aspects of ash processing at an individual power plant.

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**Current approaches criticism**

**Low sales reason:**

Power engineering specialists should turn waste into a product. Obligatory conditions of the existence of a product:

1. Stable availability in the market
2. Stability of product parameters

According to:
- GOST 25818-2000
- GOST 31108-2003

**Two basic approaches to the ASW problem:**

"Create the ASW market — then we will do the rest"

"Create a product, that the market needs — then we will buy it"

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**ASM application**

Fly ash application in the construction industry.

- Active mineral additives for additive cement
- Active mineral additives for dry mortars
- Raw materials for artificial concrete aggregate production
- Active mineral additives for concrete and mortars
  - Light concrete
  - Foam & gas concrete
  - Heavy concrete
  - Mortars
- Ceramic items production

**Common effects of ASM application in concrete systems:**

1. Decrease of the concrete system water consumption
2. Structure packing due to:
   - spherical particles
   - small particle size (< 40 mc)
   - chemical composition

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**Two basic approaches to the ASW problem:**

"Create the ASW market — then we will do the rest"

"Create a product, that the market needs — then we will buy it"
Improving the legislation of Russia

Moving to our goal — creation of conditions for distribution of fly ash in Russia — we use an integrated approach participating in efforts to improve design standards for thermal power plants as well as the regulatory framework of the Russian Federation concerning the application of coal combustion products.

Our proposals:

1. **ACCEPTANCE OF A NEW TECHNICAL POLICY**
   which forbids the application of wet ash and slag waste removal and sets a transition to dry ash and slag waste removal aimed at production of ash and slag products and sales to customers, and not at dumping of ash and slag materials in ash dumps.

2. **REVISION OF TECHNICAL REGULATIONS**
   concerning engineering and construction of coal power plants. They must be oriented at:
   2.1 Development of modern coal-fired power generating units of powder-like combustion, which can achieve high efficiency, and their certification for ash and slag materials production;
   2.2 Limited application of boilers with circulatory boiling layer (only in case of positive technological, economic and ecological justification and 100% utilization of ash and slag materials);
   2.3 Implementation of technologies of coal combustion byproducts capture, which are aimed at the creation of materials with consumer properties according to acting standards (20 Russian standards);
   2.4 Increase of ecological payments for dumping of ash and slag waste in ash dumps and gradual elimination of ash dumps;

3. **PROVISION OF PRIORITIES**
   for ash and slag materials sales:
   3.1 Ecological payments should be transferred to special regional sectorial funds for the financing of measures concerning coal combustion byproducts utilization;
   3.2 State subsidies for ash and slag materials long distance railway transportation with the aim to level regional disproportion in coal generation location and construction materials industry demand and also the factor of seasonality in power generation and building materials production.

4. **PRIORITY MEASURES:**
   4.1 Alteration of VNTP 81 (“Departmental rules for technological design of thermal power plants”) and SNIP II-58-75 (“Building regulations for thermal power plants”);
   4.2 Updates to GOST 25818-91* (“Thermal power plant fly ashes for concretes. Technical specifications”).

Suggestions on improval of GOST 25818-91

On December 2nd, 2014 within the global conference “Reducing energy consumption and CO2 emissions in the cement industry of fast developing economies” global conference, held as part of the XVI International Construction Forum CemEnergy 2014, Andrey Kalachov, Consortium Fenix leader, made a report titled “Problems and solutions in the regulatory framework of the Russian Federation and the European Union concerning the application of coal combustion products”. In his report he highlighted current problems in the regulatory framework of the Russian Federation on the use of fly ash of thermal power plants and took the initiative to make dramatic changes in the Russian standard GOST 25818-91 “CHP plants’ fly ashes for concretes. Specifications”.

The report was received with interest by the participants of the conference, and we hope that this will mark the beginning of the creation of the new Russian standard for handling fly ash, which will be useful for all market participants.

* GOST — Russian state standard
On December 3rd, 2014 at the joint meeting of the RAS** Scientific Council and the Scientific and Technical Board of NP “STC UES” Consortium Fenix presented our proposals for amendments to VNTP 81 “Rules for technological design of thermal power plants” concerning ash removal systems.

Chairman of the RAS Scientific Council on the problems of reliability and safety of large-scale power systems, chairman of the Scientific and Technical Board of NP “STC UES”, corresponding member of RAS professor A.F. Dyakov pointed out that due to the initiative of the Consortium the current joint meeting of the two Councils initiated the development of new engineering standards for thermal power plants.

The Councils decided to approve the initiative of the Consortium and to adopt the proposed changes. To continue work on the development of new engineering standards for thermal power plants in the technical committee TC 016 “Power industry” of Rosstandard under the leadership of JSC “Institute Teploelektroproekt” with the direct participation of Consortium Fenix, with the involvement of industry organizations and Research Institution “MEI”.

### Our proposals for the chemical composition of fly ash requirements and a comparison with the current requirements of GOST 25818-91

<table>
<thead>
<tr>
<th>Proposed requirements</th>
<th>GOST 25818-91</th>
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</thead>
<tbody>
<tr>
<td><strong>Type of ash by CaO content</strong></td>
<td></td>
</tr>
<tr>
<td>Acidic ash</td>
<td>Alkaline ash</td>
</tr>
<tr>
<td>type I</td>
<td>type II</td>
</tr>
<tr>
<td>CaO, %</td>
<td>≤10</td>
</tr>
<tr>
<td>MgO, %</td>
<td>&lt;2.5</td>
</tr>
<tr>
<td>SO₃, %</td>
<td>&lt;3</td>
</tr>
<tr>
<td>NOₓ, ppm</td>
<td>0.04</td>
</tr>
</tbody>
</table>

#### 1) According to the proposal for the requirements to chemical composition of fly ash, fly ashes with CaO, MgO, SO₃, sulphide sulphur, F₂O content higher than that of the table are applicable if there is a positive result in the applicability test.

#### 2) According to the proposal for the requirements to chemical composition of fly ash, fly ashes with loss if ignition level of 5–10% are applicable in ferroconcrete constructions if there is a positive result of the applicability test.

#### 3) According to GOST 25818-91 fly ashes with CaO, MgO, SO₃, loss on ignition content higher than that of the table are applicable if there is a positive result of the applicability test.

#### 4) NOₓ content in fly ash is limited due to workplace safety regulations that allow the migration levels of ammonia into the air not higher than 0.04 mg per m³.

#### 5) According to GOST 25818-91 fly ash that does not meet the standard requirements for dispersion and specific surface area may be used provided that the application of said fly ash provides the desired quality parameters of concrete.
Every ash dump is a local environmental disaster.
Study of physical, mechanical and chemical properties of all kinds of ash and slag of an individual power plant, determination of the factors influencing their stability. Determination of the directions of application of these materials in the industry, construction and agriculture. Forming the product market within 500–1500 km radius from the power plant. Development of specifications and acquisition of certificates of conformity for ash and slag materials generated by an individual power plant.

These conditions drew out the idea of creation of an international consortium which will unite the professionals in the energy and building industries.

The synergetic effect of such an association enabled to create a product which, until quite recently, has been absent in the Russian market. This is an integrated system of fly ash processing at a power plant, and we have called it Fenix.

The integrated system of ash and slag materials utilization includes:

1: Research

Study of physical, mechanical and chemical properties of all kinds of ash and slag of an individual power plant, determination of the factors influencing their stability. Determination of the directions of application of these materials in the industry, construction and agriculture. Forming the product market within 500–1500 km radius from the power plant. Development of specifications and acquisition of certificates of conformity for ash and slag materials generated by an individual power plant.

2: Preconstruction works

Development of the technical concept for the system of dry ash and slag removal oriented at 100% sale (and not for dumping) of ash and slag to the consumers using the advanced technologies and equipment. The concept includes selecting coal grades, averaging its parameters, coal preparation, technical proposals to improve coal combustion in boilers, as well as optimization of all factors that affect both the efficiency of the boiler, and the quality of the ash. The feasibility report for construction of a dry ash and slag removal system for a power plant under new construction or reconstruction. Development of the engineering design draft for the dry ash and slag removal system.

3: Design

Creation of the project of the dry ash and slag removal system with binding and adapting of the dry ash and slag removal system’s technological scheme to the particular power plant according to the current conditions and requirements of the customer.

4: Funding

Assistance in credit financing from SBERBANK of Russia for the construction of the dry ash and slag removal system.

5: Construction

Construction of a dry ash and slag removal system using the most advanced and fastest methods in the conditions of a working power plant.

6: Sales

Arrangement of sales of commercial ash and slag to the consumers.

Thus, the power plant gets a solution to the ash and slag waste problem designed according to its features.
Consortium Fenix has developed a fundamental manufacturing scheme for the Dry Ash and slag Removal System oriented at 100% sale of fly ash and slag to the consumers — DARS-100.

The system is designed according to the following principles:

1. **System of coal preparation:**
   - parameter averaging and maintenance of a definite coal milling level.

2. **Stabilization of coal combustion modes:**
   - maintenance of an ignition losses level not higher than 5%;
   - preparation for certification of the power unit for ash and slag manufacturing.

3. **Separating extraction of fly ash** from different fields of electrical filters, cyclone collectors, and extraction of slag from power units.

4. **Ash and slag generation control system** in a laboratory on site which is capable of analyzing up to 4.5 thousand samples annually within one power unit, and to provide the ash consumer properties demanded by the market.

5. **Silos for storage or a multiple-chamber reinforced concrete silo** for ash from different fields of electrical filters with possibility of their controlled mixing with the volume of lump-sum storage not less than the volume of 10-day production of ash and slag materials.

6. **Slag milling system and separate storage.**

7. **Loading system** for cement trucks, railway cement units, big-bag packing and entrucking.

8. **Reserve system of ash and slag disposal** with 30% humidification of ash and slag waste and storage at small ash disposal areas.

DARS-100 fundamental components include a system of ash separate collection from electrical filters or cyclone collectors, an IBAU silo (or multiple silos) for storage and controlled mixing of ash and slag materials, and also a lab and a system of sampling to ensure stability of chemical and physical parameters of the product.

As a whole, these should guarantee the necessary commercial properties of ash.
The schematic diagram of an environmentally friendly coal power plant is based on the concept of a coal thermal power plant, which is an integrated technology platform, generating not only electricity and heat but also quality coal combustion by-products, namely fly ash and mineral fertilizer or gypsum.
System of production of ash and slag products

The consortium key objective is the creation of a system of ash and slag products manufacturing at power plants (working and under construction). It includes:

1. Construction of DARS-100 oriented at 100% sale of ash and slag products.
2. Usage of advanced pneumotransport and labware in DARS-100.
3. Creation of a quality control system for ash and slag products with a laboratory on site, which is integrated in the current scheme of power and heat production.
4. Forming of the market for ash and slag products within a 1500 km radius from an individual power plant.

Complex study of ash and slag waste

Study of ash and slag waste properties and their stability:

1. Determination of the chemical composition and physical-and-mechanical parameters of all kinds of fly ash and fuel slag of boiler aggregates;
2. Determination of parameters and a degree of stability of properties and detection of factors influencing the properties stability of all kinds of fly ash and fuel slag;
3. Study of technical and commercial properties of all kinds of fly ash and fuel slag of boiler aggregates, detection of their application areas in the industry of building materials and technologies;
4. Study of the sanitary-epidemiological, toxic parameters (determination of the hazard class) of fly ash and fuel slag of boiler aggregates.

System of commercial ash and slag products manufacturing:

5. Development of the technological rules for production of commercial ash and slag products based on all kinds of fly ash and fuel slag of boiler aggregates, development of specifications for all commercial ash and slag products;
6. Development of the fly ash and fuel slag quality control system;
7. Certification of commercial ash and slag products;
8. Development of the specification draft for the DARS-100 focused on 100% sale of fly ash and fuel slag to the consumers;

Sales:

9. Study of the commercial ash and slag products market;
10. Declarations of intent to buy ash and slag products from potential consumers.
Conducted works

Consortium members are conducting extensive work researching the Russian market of ash & slag materials and implementing dry ash & slag removal on major energy sites of the country.

Here are the results of the most promising plants.

- Market analysis
- Feasibility study
- ASW research program
- Technical proposals for changes to the ash removal system

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berezovskaya SDPP</td>
<td>TPP-22 Mosenergo</td>
</tr>
<tr>
<td>Verhnetagilskaya SDPP</td>
<td>Gusinozerskaya SDPP</td>
</tr>
<tr>
<td>Kashirskaya SDPP</td>
<td>Cherepetskaya SDPP</td>
</tr>
<tr>
<td>Yerkovetskaya TPP</td>
<td>Novo-Irkutskaya CHP</td>
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<td>Novo-Ziminskaya TPP</td>
<td>Ust-Ilimskaya TPP</td>
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<tr>
<td>TPP-6</td>
<td>TPP-9</td>
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<td>TPP-10</td>
<td>TPP-11</td>
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<td>TPP-12</td>
<td>TPP-16</td>
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<td>Azot JSC, Kemerovo</td>
<td>Trojan Riverside SA</td>
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<td>Novosibirskaya CHP</td>
<td>Energoservice</td>
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<tr>
<td>Chelyabinskaya CHP-2</td>
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### DARS-100 project implementation stages

**by the members of the Fenix Consortium**

<table>
<thead>
<tr>
<th>Executors</th>
<th>Stages and works</th>
<th>Time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PCV</strong></td>
<td>Stage I: Research</td>
<td>15 m</td>
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<tr>
<td></td>
<td>Sampling, research of the applicability of ash and slag</td>
<td>12 m</td>
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<tr>
<td></td>
<td>Design specifications development</td>
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<tr>
<td></td>
<td>Feasibility study, technical requirements for project realization</td>
<td>5 m</td>
</tr>
<tr>
<td></td>
<td>Processing of research results</td>
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<tr>
<td><strong>Cotes</strong></td>
<td>Stage II: Engineering</td>
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<tr>
<td></td>
<td>Elaboration of design documentation</td>
<td>6 m</td>
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<td></td>
<td>Design documentation agreement</td>
<td>3 m</td>
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<tr>
<td></td>
<td>Design documentation state examination</td>
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<td></td>
<td>Elaboration of working documentation</td>
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<tr>
<td><strong>CM Pro</strong></td>
<td>Stage III: Design specification and contract preparation</td>
<td>2 m</td>
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<tr>
<td><strong>PCV</strong></td>
<td>Stage IV: Construction, production and equipment delivery, commissioning</td>
<td>15 m</td>
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<tr>
<td><strong>PCV</strong></td>
<td>Stage V: Marketing</td>
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<tr>
<td><strong>Sberbank</strong></td>
<td>Credit funding</td>
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</tbody>
</table>

### Consortium members

- **ProfCement-Vector** (Saint Petersburg, Russia)
  - Ash supplier, leader of the consortium

- **Cotes Group** (Novosibirsk, Russia)
  - Energy engineering

- **Renaissance Construction** (Turkey & Russia)
  - Construction holding company

- **CM Pro** (Moscow, Russia)
  - Construction industry audit and analytics

- **IBAU HAMBURG** (Germany)
  - Supplier of equipment for storage, transportation and shipment of bulk materials in the cement & mineral industries and thermal power plants

- **Hyprocement Institute** (Saint Petersburg, Russia)
  - Russia’s leading institute of cement industry

Also:
- **Sberbank of Russia**
  - Strategic financial partner

The leader of the consortium is **ProfCement-Vector**, the leading supplier of shale ash in Russia.
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