Summary

JI TEFRA Project has allowed for avoiding emitting more than half a million ton of CO2 in the course of 5 years, by producing and commercializing binders capable of effectively replacing cement and lime in select geotechnical applications – predominantly in road construction. Realistic cement/lime replacement ratios were ascertained for three TEFRA products, allowing for relatively straightforward determination of the avoided emissions. However, bureaucratic barriers limited scaling up potential of such an approach and all market risks are put solely on the side of project developers – despite the public good achieved through such initiatives.

Introduction

As a party to the UN FCCC Poland has ratified the Kyoto Protocol pledging to reduce its greenhouse gas emission by 6% during the first commitment period (2008-2012) as compared to the base year (1988). Effectively achieved reduction was in fact much higher and reached the level of 30-32% reduction.

Poland is one of the world’s leading producers of hard coal and its power generation sector is heavily dependent on carbon intensive fossil fuels. With its high carbon intensity of GDP, sizeable renewable energy and energy efficiency potential and quickly modernizing economy Poland could offer ample opportunities for JI projects. However, this potential has not been translated into much action. Despite an early start of JI Secretariat the actual number of approved JI projects was and remained small, mostly due to bureaucratic barriers and lack of political commitment.

Broadly defined JI projects can include any co-operative effort of both investing and host parties that result in the reduction of GHG emissions compared to an established baseline. However, Poland has adopted several additional criteria to restrict the categories of projects that could be endorsed as JI. It was required, that the eligible projects should:

- comply with the standards or guidelines adopted by the Conference of the Parties (COP) to the UNFCCC and the Kyoto Protocol;
- be consistent with the National Environmental Policy of Poland, promote the principles of sustainable economic development with optimum natural resource allocation, and bring long-term benefits to Poland;
- ensure cost-effective use of public and private domestic financial resources.
The other additional criteria were as follows:

- For any JI project, it must be possible to estimate ex ante the expected reductions in GHG emissions and monitor ex post the actual reductions in GHG emissions;
- JI projects should not lead to the degradation of other local/regional environmental quality indicators at the expense of achieving GHG emissions reductions. Where proposed JI projects might lead to the increases in other negative environmental impacts (e.g. air pollution, wastewater discharges, or waste disposal), appropriate mitigation measures should be incorporated into the JI project;
- JI projects should directly or indirectly result in cost-effective realization of environmental goals. Where JI projects involve the installation of new capital equipment, they should also lead to a net reduction (or at least no increase) in the facility's costs of meeting current and anticipated environmental standards (e.g. resulting from harmonization with the EU environmental directives and/or other international treaty commitments). Thus, process changes and new technologies that prevent pollution are desirable;
- JI projects should encourage the economical use of natural resources and reuse or recycling of waste materials;
- JI projects should be compatible with, and promote to the greatest extent possible, utilization of modern production processes;
- JI projects should be sensitive to and compatible with macroeconomic policies at national and voivodship (regional) levels and be, to the greatest extent possible, replicable;
- Financial viability of the project partners (the partners may be asked to provide relevant documents to prove it).

As we may clearly see, the above additional restrictive bureaucratic criteria – despite being apparently positive – did not actually bring any new value to the idea of reduction of CO2 emissions, but on the other hand made any project quite much more complicated, burdensome in its initial stages and unlikely for a wider replication. Alas, the practical experience has proven that this was precisely so.

**TEFRA JI Project**

TEFRA (Greek for ‘ash’) Project, involves production and practical use of low-emission hydraulic binders for geotechnical applications, in which the majority – if not totality – of cement or lime is replaced by ashes from coal-based power generation. As these ashes are a byproduct arising during the combustion of coal while generating electricity, their production doesn’t involve practically any additional CO2 emissions, which would have otherwise had to arise, should the traditional binders like cement or lime be used instead – in a business as usual baseline scenario. Seen in this light, ashes from power generation are a valuable resource, utilization of which should be a commonplace practice in the environmentally aware societies.

A family of five TEFRA products were taken into account, which were analyzed technically in terms of an effective replacement of cement with flyash, which in turn could be easily converted into an effectively avoided CO2 emissions, using the commonly established emission levels involved with the production of cement and lime, and, of course, demonstrated and verified sales volumes of TEFRA products in question.
In order to arrive at a realistic and balanced – if cautious and conservative when evidence is somewhat weaker – of how much cement each of the TEFRA products is capable of replacing, a thorough technical analysis was undertaken, whose results were since corroborated by the practical experience. Existing body of technical knowledge in many aspects of geotechnical works is usually quite well summarized in technical standards. Such standards capture a commonly agreed technical wisdom pertaining to particular aspects of geotechnical operations, for which TEFRA products were designated. Therefore such standards provide a reliable reference for assessing the amount of cement or lime, which would most likely had to be used if TEFRA products were not applied instead. As the standards usually stipulate performance levels to be achieved by a given geotechnical technology, it is an adequate reference for determining the amounts of TEFRA products necessary for producing those required performance levels.

We will present now briefly three of such analyses in an increasing order of complexity, importance and value-added of a given product.

**TEFRA 15**

This product is a weak binder for treatment of soil before any road and other purpose embankments may be constructed on a poorly bearing grade. Such soils are typically of a clayey nature and therefore lime is more effective than cement in those treatment operations. This doesn’t impact our line of thinking much, as CO2 emissions involved with burning of lime are comparable and even higher than those of cement, so using the cement equivalent is yet another facet of a conservative approach adopted in this project.

The most direct comparison of effectiveness of a binder such as TEFRA 15 versus lime can be found in the Polish Standard PN-S-96011 *Roads for vehicles, Soil stabilization for roads with lime*. In point 2.2.1 thereof it is stated, that, “The composition of the mix depends primarily on the type of both soil and lime and on the function of the stabilized layer. Therefore the percentage addition of lime and water should be individually determined by laboratory tests. Nevertheless, typical amount of lime added (...) for the upper layer of treated subgrade is between 3 and 7% by mass.”

This layer of treated subgrade has been for many years a dominating area of application of TEFRA 15 binder in road structures and was the most relevant for this analysis. Both laboratory test and practical application experience from numerous road construction project implemented in years 2009-11 have demonstrated, that typical amount of TEFRA 15 binder had to be approx. 50% higher than the equivalent amount of lime, which would have yielded the same technical performance of the stabilized soil, and was typically in range of 5 to 10% (m/m). In comparison with typical lime content of between 3 and 7%, this would indicate an average replacement ratio of 0.67, but considering somewhat indirect character of the data used for analysis, eventually it was assumed, that 1 unit of TEFRA 15 replaces 0.6 unit of lime or – expressed differently – for 1 unit of lime 1.67 units of TEFRA 15 are necessary. So using in a geotechnical structure, for example, one ton of TEFRA 15 we may claim savings of CO2 emission of at least 0.6x0.832 Mg (reference Portland clinker CO2 emission) = 0.494 Mg CO2

**TEFRA 25**

This product is a stronger type binder used for significant enhancement of load-bearing capability of higher layers in road and similar type embankments, making them also to certain extent resistant to freezing-thawing cycles typical in performance of such structures exposed to normal weather patterns.
The Polish Standard PN-S-96012 Roads for vehicles, Sub base and capping layer from soil stabilized with cement, in its part 2.2.1 Cement content, states, “The content of cement should be in the range of 4% to 10% (m/m), depending on type and grain size characteristics of soil, cement class and road category.” Further (Table 3) the standard specifies, that the stabilized capping layer should have after 28 days achieve compressive strength in the range of 1.5 to 2.5 MPa. As precisely the use of TEFRA 25 binder in construction of capping layers (top layer of an embankment, under the pavement layers) prevails, it was selected for this analysis. Tests done in 2010 by a specialist road laboratory for the purpose of obtaining a Technical Agreement have demonstrated, that 7% dose of TEFRA 25 yields the compressive strength of the stabilized soil in the range of 1.6-2.4 MPa, which was confirmed by the test runs in many road projects implemented in years 2010-2011. Such a dose represents the exact mathematical mean of the range stipulated by the standard, and technical performance of the stabilized soil matches very well the standard requirements. Theoretically, one might postulate a direct equivalence of TEFRA25 and cement in this area of application, or even claim its superiority, as in clayey soils, where this binder is predominantly used, dosing of cement would need to be higher. However, considering statistical uncertainty resulting from relatively much smaller number of available test results of soil stabilized with this binder in comparison to soil stabilized with cement, it was decided conservatively, that 1 unit of TEFRA25 is replacing 0.7 unit of cement. Additionally, this ratio was further reduced due to the fact, that TEFRA 25 product itself contains up to 10% (m/m) cement, so the final replacement ratio was rounded down to 0.6. Eventually it was assumed, that 1 unit of TEFRA 25 replaces 0.6 cement or – expressed differently – for 1 unit of cement 1.67 units of TEFRA 25 are necessary. Therefore, by using, for example, one ton of TEFRA 25 we may claim savings of CO2 emission of at least 0.6x0.832 Mg (reference Portland clinker CO2 emission) = 0.494 Mg CO2.

TEFRA IN
This product is a binder used for injection treatment of soils, where usually the low water permeability of the treated layer is a key goal, and no particular compressive strength is to be achieved. Similar area of application is the construction of cut-off walls as flood levees and other preventive measures constructed by means of DSM (deep soil mixing) technology. The European Standard PN-EN 12716: 2002 Execution of special geotechnical works – Jet Grouting, in point 6.4 states, “In cement gouts the weight ratio water/cement should be in the range 0.5 to 1.5.” This means, that in practice – depending on the soil and other factors, the standard content of cement in the grout should be in the range of 650-2000kg / 1000 liters of water. Warsaw University of Technology has tested comprehensively a possibility of using FBC (fluidized bed combustion) ash in place of cement in binders for grouts used in injection grouting, achieving average replacement ratio of 0.77, which exceeds the levels suggested by numerous previous research work. This allows for postulating quite substantial replacement ratio of 1 unit TEFRA IN replacing 0.7 unit cement, or – expressed differently – for 1 unit of cement 1.4 units of TEFRA IN are necessary.

It should be noted, that there are also other types of TEFRA products available, which were analyzed for the purpose of this JI Project, but as finally they proved to be not as successful commercially as the above three products, they are not presented here.

Technical aspect

The production facilities for TEFRA products are basically sophisticated mixing plants, and as such have little or no environmental impact in terms of emissions to air, noise, soil and groundwater pollution and waste generation. Formal EIA (environmental impact assessment)
studies preceded operation of these installations, as this is now a normal procedure in Poland leading to an official administrative decision in each case. Currently the Project owner is operating two primary production plants, one in Konin in Central Poland and one in Warsaw.

Fig. 1. Konin Production Plant in Central Poland

The production plant is located in the immediate proximity of large retention silos for fly ash in Konin Power Plant. The installation comprises three constituents silos, 60m3 each and a dosing/mixing unit capable of producing up to 90m3 of product per hour. The ready product is loaded directly to the silo-trucks by a screw conveyor.
Warsaw production plant is located at Żerań Power Plant. As the available land is limited here, the plant is elevated on a steel structure and the ready product is loaded gravitationally from the mixing chamber directly into the silo-trucks parked underneath. The unit has four silos for constituents, 50m³ each, and a dosing/mixing unit with a throughput of 100m³/hour. Currently the FBC ash is brought to the silo by truck.

The production volumes of both plants are dictated first of all by orders from Clients but at times the availability of the ash in the summer peaks of construction season is a limiting factor – since summer is the time of the lowest activity of the power plant because of a lower demand for heat and regularly scheduled repairs of boilers.

*Project’s robustness*

Considering the years 2008-12, when the JI Project was formally developed, submitted and accepted, its cumulative 5-year impact in terms of the avoided emissions of CO2 was
estimated at 567838 tons. It may be interesting to look at the approximate figures characterizing the two subsequent years of Project life:

<table>
<thead>
<tr>
<th>Year</th>
<th>Product sales t</th>
<th>Cement replaced t</th>
<th>CO2 avoided t</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEFRA 15</td>
<td>66,000</td>
<td>39,600</td>
<td>32947</td>
</tr>
<tr>
<td>TEFRA 25</td>
<td>14,000</td>
<td>8,400</td>
<td>6989</td>
</tr>
<tr>
<td>TEFRA IN</td>
<td>7,000</td>
<td>4,900</td>
<td>4077</td>
</tr>
<tr>
<td>total 2013</td>
<td>87,000</td>
<td>52,900</td>
<td>44,013</td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEFRA 15</td>
<td>80,000</td>
<td>48,000</td>
<td>39,936</td>
</tr>
<tr>
<td>TEFRA 25</td>
<td>7,000</td>
<td>4,200</td>
<td>3,494</td>
</tr>
<tr>
<td>TEFRA IN</td>
<td>28,000</td>
<td>19,600</td>
<td>16,307</td>
</tr>
<tr>
<td>total 2014</td>
<td>115,000</td>
<td>71,800</td>
<td>59,738</td>
</tr>
<tr>
<td>TOTAL</td>
<td>202,000</td>
<td>124,700</td>
<td>103,750</td>
</tr>
</tbody>
</table>

These figures confirm basic robustness of the Project and demonstrate, that it is capable to avoid in a sustainable way significant amounts of CO2 emissions year on year.

**Financial assessment**

TEFRA JI Project is very vulnerable to the fluctuations of financial value of ERU, which is clearly demonstrated by the two values of IRR of the Project: IRR without ERU is 1.10% and with ERU was calculated at 11.68%. The price of ERU over the analyzed period was very volatile and unfortunately at the time of writing this paper was very low indeed. In this light, especially some moves of the European Commission and national bureaucracies seem to be adding to the complexity of this – already complex enough – system of emission certificates trading. Glaring example of this is seen in the procrastination with introducing a CER stabilization reserve by the EC, which might help to keep the unit value at a reasonable level. Given the noble and basic nature of initiatives such as JI Projects as one of the several clean development mechanisms, it is somewhat puzzling, that the market risks are not more closely monitored by the relevant public bodies and if necessary some corrective measures implemented.

**Lessons learned and outlook**

Such projects are a long-haul exercises. In the case of TEFRA JI Project financing was purely private, commercial loan which makes it vulnerable to the ERU price fluctuations. It’s clear, that projects of such nature can actualize financial surplus only over longer periods. For this reason, if we also take into account the earlier mentioned additional bureaucratic barriers, it’s no wonder, that the uptake of such projects was relatively low (in total less than 40 JI projects in Poland).

On the other hand projects as TEFRA JI clearly show, that a serious and long term commitment to environmental issues is not incompatible with market economy mechanisms, and public procurement sphere seems to be key for the growth and sustained presence of such initiatives in routines of public bodies responsible for large infrastructure investments.
A new impulse for reconsideration of such frameworks may come from the ideas of Circular Economy, that seem to be gaining momentum in the EU. They offer a more favorable environment for initiatives aiming at as wide as possible use of anthropogenic minerals in economy – before resorting to the use of virgin resources – which carry with them oftentimes no additional carbon footprints and as such should be the first call of designers, contractors and investing institutions.

Conclusions

- TEFRA JI Project has allowed for successfully avoiding emitting of well over 600 thousand ton of CO2 into the atmosphere using a Joint Implementation mechanism stipulated by the Kyoto Protocol.

- Anthropogenic minerals in general and ashes from power generation in particular, can be used instead of virgin resources in numerous application, which should be a long term priority.

- It is perfectly possible to realistically asses replacement potential and assign CO2 reduction volumes to products, in which ashes are used as binders instead of cement and lime.

- Market mechanisms alone, without adequate political and financial support for such complicated and long term endeavors will lead to only a very limited scope of successful CO2 reductions by such projects.

- Despite all its drawbacks, TEFRA JI Project is an exciting example still holding much of a promise for the future.