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Minutes of meeting

Joint meeting between the Industrial Alliance for NNGP and the EUROPAIRS Project

Paris, 13th and 14th October 2010

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the Industrial Alliance for NNGP
and the EUROPAIRS Project***

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EUROPAIRS project – Grant Agreement no. 232651
End-User Requirements for industrial Process heat Applications with Innovative nuclear Reactors for Sustainable energy supply

EC Scientific Officer: Panagiotis Manolatos

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Summary

Minutes of the joint meeting between the Industrial Alliance for NGNP and the EUROPAIRS project which was held on Wednesday 13th and Thursday 14th October 2010

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Executive summary

This summary synthesizes the minutes fully reported in the next parts of the joint meeting held on the 13th and 14th October 2010 between representatives from the US Industrial Alliance for the Next Generation Nuclear Plant project (NGNP), from the EUROPAIRS consortium and from the European Commission.

The Industrial Alliance for NGNP aims at proving the interest of nuclear energy for energy supply to industry, especially to grow the membership of the Alliance and reinforce its position, and at improving the public support by increasing the understanding of the HTR technology.

The EUROPAIRS project aims at identifying the boundary conditions for the coupling between a high temperature reactor and industrial facility by expressing both the end-users requirements and the reactor capabilities and at developing a strong partnership between the nuclear and the heat end-users industries.

The objective of the meeting was to share experience in their areas between both communities and to investigate the potential for a possible transatlantic cooperation.

On the basis of presentations from experts of both groups supported by the European Commission, the attendees discussed the following topics:

- ⇒ The political context in the US and in Europe
- ⇒ The heat markets in the US and in Europe
- ⇒ Objectives and expectations from American and European large heat end-users and nuclear operators
- ⇒ The experience in HTR development and the challenges to address.
- ⇒ The challenges of nuclear cogeneration against the current status (cheap fossil fuels, short amortization periods for gas plants, nuclear acceptance, licensing, fuel cycle), the opportunities (concerns over security of supply and climate change) and the possible actions to demonstrate HTR (ensuring government support, identifying key industries).

The attendees proposed a common strategy and an action list for deploying HTR in Europe and in the US:

- General strategy
 - The demonstration of 2 concepts (prismatic / pebble) could be made over the 2 continents
 - Standardised modular designs should be targeted?
 - Competition between the US and Europe for HTR development may be unnecessary in the demonstration phase?
- Common products of EU-US collaboration
 - Detailed analysis of market opportunities, including economics and societal benefits
 - Cross-review of business plans
 - Elaboration of a common safety case
 - Joint exploration of possible interactions with HTR-10 & HTR
 - Eventually, work on a joint demonstration strategy
 - Joint communication for increased visibility
- Organisation
 - Constitution of a stable European alliance, building on the existing HTR Technical Network and the EUROPAIRS partnership
 - Cross-referencing of end-users or common membership between Europe and the US
 - Exploration of the potential public and private resources in Europe for HTR development

Day 1 (Wednesday 13th October 2010)

1 Introduction

Dominique Hittner (DH, Areva US) welcomed all participants to the meeting.

Fred Moore (FM, Dow Chemicals) and Harri Tuomisto (HT, Fortum) were appointed as co-chairs of the meeting.

Introduction to the Alliance for NGNP (Fred Moore)

Fred Moore reported from the Industrial Alliance for the Next Generation Nuclear Plant project (NGNP). The Alliance is growing with new members having joined. The Alliance was incorporated in 2009 as a non-profit making organisation.

The Alliance aims at proving the interest of nuclear energy for energy supply to industry, especially to grow the membership of the Alliance and reinforce its position, and at improving the public support by increasing the understanding of the HTR technology.

The Alliance lobbies to secure public funding the development of two demo plants, one with a block type core, and one with a pebble bed core. The US government would fund half of one demo plant with a total budget of around \$4bn if the rest being is taken over by industry. Industry is concerned with risk of constructing and operating a demonstration plant for end-user industry and requests a stronger governmental engagement.

Introduction to EUROPAIRS (Edgar Bogusch)

Edgar Bogusch (EB, Areva Germany) presented briefly the EUROPAIRS project. EUROPAIRS is managed by a consortium of 27 partners (nuclear organisations and process heat end users), supported by the European Commission. Its total budget is 1.2 M€. It is expected to have a large strategic impact by initiating an alliance of nuclear and non-nuclear industries for the development of nuclear cogeneration in Europe.

EUROPAIRS aims at identifying the boundary conditions for the coupling between a high temperature reactor and industrial facility by expressing both the end-users requirements and the reactor capabilities. Safety and licensing aspects of this coupling are being evaluated. EUROPAIRS will define a joint roadmap for developing nuclear cogeneration and its application. A strong partnership between the nuclear and the heat end-users industries is to come out of EUROPAIRS.

He presented the context of the Sustainable Nuclear Energy Technology Platform (SNETP) and its working group on Nuclear Cogeneration. He also presented the European Strategic Energy Technology Plan (SET Plan) and highlighted the main features of the future European Industrial Initiative for nuclear cogeneration which is envisaged within the SET Plan.

Discussion

Dominique Hittner added that the EUROPAIRS project is founded on a rich historical context, in particular after ten years of renewal of HTR development in Europe, with technology development projects funded by the European Commission since 1998, with the reactor development of Areva

(ANTARES design), with the participation of several European industrial and research organizations in South Africa's PBMR (Pebble Bed Modular Reactor design) and in the Chinese project HTR-PM. PBMR had planned initially to become a EUROPAIRS partner but had to withdraw in August 2010 due to a failing government support.

Ton Baaten (TB, BEC) asked Fred Moore to clarify the reasons for the American chemical industry to be so supportive for HTR. Fred Moore responded that, as regards DOW Chemicals, the support of the company originated from the personal involvement of DOW's CEO who anticipated long-term trend and was concerned with corporate responsibility.

Edgar Bogusch asked for the approach that the Alliance took to develop a common understanding between the nuclear and heat end-user communities. Fred Moore stated that this had not been any problem. Don Halter (ConocoPhillips) added that end-users viewed the heat source as a black box and considered the technical and economic performance only, which improved their acceptance.

Fred Moore wondered how fuel cells were considered in Europe and whether they were felt to have any potential market. Alexandre Bredimas (AB, LGI Consulting) responded that according to IEA scenarios for fuel cells, the uptake of the so-called hydrogen economy would represent an additional 150% of the current consumption of hydrogen in Europe. He added that the European Commission strongly supported the creation of the European Fuel Cells and Hydrogen Joint Undertaking, which had a significant budget and ambitious targets but nuclear technology was not the reference technology.

Philippe Monette (PM, Tractebel Engineering) asked whether DOW could join the EUROPAIRS project. Fred Moore replied that it would be difficult. The team working on HTR integration was sited in the US and DOW had signed a non-disclosure agreement with the other American working parties.

Ludwik Pienkowski (LP, UW Prochem SA) asked for the priority between heat and electricity production. Fred Moore said that the high pressure steam that would not be consumed in a cracker could be used to produce electricity to be fed into the grid. Harri Tuomisto added that the price of electricity can make it advantageous to produce electricity rather than heat depending on the grid features, the market and the competition.

Finis Southworth (FS, Areva US) reported from the US Legislation supporting cogeneration with favourable purchase prices for electricity from CHP plants, which may be a significant support to nuclear cogeneration in the United States.

Werner von Lensa (WvL, FZJ) recalled that Europe and the United States had historically been cooperating, in particular between General Atomics and ABB, and concluded that this cooperation should be revived today.

2 Policy goals

Vision of the US Department of Energy (Phil Hildebrandt)

Phil Hildebrandt (PH, BEA) presented on behalf of Tom O'Connor (US DoE Office of Gas Cooled Reactor Technologies) the vision of the US DoE on HTR. He reported from a gap of between the government and the industry due to political uncertainty.

First, the US did not decide on any reduction objective in greenhouse gases emissions. Second, energy security is a source of concern, especially as regards oil imports from Middle East. Third,

the industrial manufacturing capability and capacity for deploying high temperature nuclear reactors is still unclear.

The Next Generation Nuclear Plant Project was authorised by US Congress via the Energy Policy Act of 2005. From 2006 to 2010, the US government invested \$500 millions in R&D, initial design and early licensing. The risk regarding licensing of advanced reactors is addressed by pre-application interactions with the US Nuclear Regulatory Commission.

He also reported about the latest status of R&D. Significant progress has been achieved with the fabrication of TRISO particle fuel.

A long-term partnership between government and industry is necessary for the design, licensing and construction of the NGNP demonstration reactor but cost sharing remains a key question. The Alliance made a proposal to the DoE and to the Congress in 2009.

The review of designs for Phase II is carried out by US DoE, assisted by the Independent Nuclear Energy Advisory Council. It covers the status, applicability, design requirement, regulatory framework, projected market applications and preliminary economics.

Discussion on the DoE vision

Michael Fütterer (MF, JRC) asked for more details on the energy policy act of 2005, in particular whether building NGNP was considered an obligation. Phil Hildebrandt responded that NGNP was authorised only. A separate bill is necessary to specify the funding of NGNP but this has not been done so far.

Dominique Hittner wondered how to stabilise a partnership with the government over the long term. Phil Hildebrandt suggested an approach similar to the US Department of Defence buying property land and hosting there the construction of an advanced nuclear reactor, as it does for the Hyperion reactor.

Sylvain Menou (SM, Areva France) asked for the incentives for introducing nuclear cogeneration. Phil Hildebrandt responded that today's incentives are the industry anticipation of an increase in energy costs and of the introduction of a price for CO₂, as well as the current price volatility which hinders the business predictability. Yet, the discovery of shale gases will probably make gas cheaper and put on threat the nuclear renaissance in the US. Additionally, the introduction of a CO₂ emissions regulation is the task of the Congress but the timing for decision remains unclear.

Fred Moore added that the economic performance of modular HTRs and their low sensitivity to energy costs would enable the diversification and predictability of energy costs for end-users.

European vision (Marc Deffrennes)

Marc Deffrennes (MD, European Commission DG Energy) presented the context of European energy policy and its founding texts. The first one is the 2007 communication from the European Commission entitled "Energy Policy for Europe" establishing the three objectives for 2020 of 20% reductions in greenhouse gases emissions, 20% share of renewable energies and 20% energy efficiency. The second interesting text is the 2d Strategic Energy Review of 2008 which emphasized the issue of security of supply, but also that 2/3 of the EU electricity in 2020 should be carbon free (compared to 44% today – of which 30% from nuclear) and all EU electricity should be carbon free in 2050.

He also presented the Strategic Energy Technology Plan (SET Plan) issued in 2007 which aims at structuring the European R&D on all low carbon energy technologies. The SET Plan covers all renewable energies, smart grids and nuclear fission energy.

The development of energy technologies under the frame of the SET Plan will be organized around so-called European Industrial Initiatives. The total estimated budget by 2020 is 80 bn€ (equivalent to an average 8 bn€/year) while today's financing for energy technology amounts only to 2-3 bn€/y.

He underlined that the difficulty to get financing for research in nuclear fission in Europe is not only a matter of nuclear acceptance by some Member States but also of competing priority with the vision of the so-called super smart grids concept integrating wind energy from Northern and Southern Europe, hydropower from Scandinavia and Central Europe and solar photovoltaic from Southern Europe and Northern Africa (DESERTEC project), all this coupled with increased and innovative energy storage. Phil Hildebrandt reported a similar energy policy in the US.

Marc Deffrennes detailed then the most significant European forums for nuclear energy, namely the European Nuclear Energy Forum (ENEF), which addresses the political dimension of nuclear energy, the Sustainable Nuclear Energy Technology Platform (SNETP) and the European Technology Platform for Implementing Geological Disposal (IGDTP), which address the R&D dimensions of nuclear fission and geological disposal technologies, and the European Nuclear Safety Regulator Group (ENSREG), which covers the nuclear regulation aspects.

He followed on with the detailed presentation of the European Sustainable Nuclear Industrial Initiative (ESNII), to serve as a model for possible further initiatives. The ESNII Initiative is supported by 13 organisations (nuclear research, nuclear operators, technology providers and engineering companies). The Sodium Fast Reactor (SFR) is the reference technology with a funding request of 5 bn€, followed by the Lead Fast Reactor (1,36 bn€) and Gas Fast Reactor (1,2 bn€). Supporting infrastructures are also covered by ESNII for a budget of 2,65 bn€. The total budget of ESNII is 10,81 bn€. ESNII will be launched officially on the 15 November. In order to secure a room for an Initiative on Nuclear Cogeneration using HTRs, industry needs to build a concept and a detailed implementation plan. What needs to be demonstrated is the coupling between an HTR and an industrial user process. Therefore a user site needs to be defined and the host country involved in order to bring the idea on the table of the SET Plan Governing Bodies. Next year 2011 will be crucial since the EU budget for the period 2014-2020 will be proposed by the Commission to the Council and the Parliament. The timing is therefore tight and the ball is first of all in the camp of industry.

3 Market assessment

Alliance analysis of the US market for HTRs (Phil Hildebrandt)

Phil Hildebrandt summarized the conclusions of the market assessment which was carried out for the US. Fossil fuels represent 83% of the US energy mix. Petroleum is the main energy carrier, followed by natural gas and coal. Renewable energies and nuclear energy play a smaller role.

The main potential industrial applications of high temperature nuclear process heat and electricity in the US would be petrochemical plants (170 plants in the US), petroleum refining (137 plants), fertilizers/ammonia (23), coal-to-liquids synthesis plants (24), hydrogen production and oils sands and shale.

For this market, the total thermal power requirements were found to be:

- 75 GWth for industrial applications (corresponding to a market share of 25%)
- 36 GWth for hydrogen production (25% share of anticipated growth of merchant market)
- 25,8 GWth for oil sands bitumen recovery (25% of projected growth in energy required)

- 249 GWth for coal to transportation fuels (corresponding to a import reduction of 25% compared to 2009)
- 110,4 GWth for electricity production. (10% of the nuclear electrical supply increase to achieve government objectives for emission reductions by 2050.

HTGR were found to provide stable energy prices, secure source and reduced emissions as compared to natural gas and crude oil price volatilities.

Phil Hildebrandt presented then possible business model for HTGR. The owners of the HTGR plant and of the industrial facility (or facilities) consuming nuclear heat are reasonably assumed to be different entities which contract together a long-term purchase energy agreement. The owner of the HTGR plant also contracts with the regional grid for the purchase of excess electricity cogenerated.

In this case and under defined economic assumptions, nuclear electricity is found to be competitive from a natural gas price of \$8,5/MMBtu or from \$4/MMBtu in case CO₂ is assigned a cost of \$50/tCO₂. Similarly, nuclear steam is found to be competitive from a natural gas price of \$7/MMBtu or from \$4/MMBtu in case CO₂ is assigned a cost of \$50/tCO₂.

Hydrogen production via high temperature electrolysis is found to be competitive with the conventional steam methane reforming from a natural gas price of \$13.5/MMBtu or from \$10/MMBtu (respectively \$8/MMBtu) in case CO₂ is assigned a cost of \$50/tCO₂ (respectively \$100/tCO₂).

Key uncertainties on pricing are related to the debt to equity ratio, the internal rate of return and the engineering, procurement and construction costs. The financing term, operating costs and interest rates have a minor impact on pricing uncertainty.

Phil Hildebrandt also presented further concepts of a steam reformer and HTGR HTE integrated plant for hydrogen production and of the gas firing substitution in the gas to ammonia process, as well as their related cost analysis.

Phil Hildebrandt concluded that a large and viable potential market for HTRs has been identified and the economics of each application were evaluated. The results depended on several uncertain assumptions, in particular the future policy for CO₂ emissions, the capital and operating costs of HTR and the financing schemes. A detailed market study would still be required.

European heat market assessment (Alexandre Bredimas)

Alexandre Bredimas presented the results of the draft EUROPAIRS study which aims at quantifying and qualifying the European heat market in general. This first step was required before estimating the potential market for nuclear cogeneration since no precise and reliable data existed previously.

The heat market was estimated via a direct evaluation based on a detailed analysis by industry sector and completed by an indirect calculation from the declared CO₂ emissions under the European Emissions Trading Scheme.

Four markets were investigated:

- the “plug-in” market relates to the heat production already externalized in the form of cogeneration. Nuclear cogeneration could enter this market simply by replacing the existing cogeneration plants and plug into the steam and electricity networks: this is the easiest and most straightforward market for nuclear cogeneration.
- the “extended” market relates to the remaining general heat market; it refers to heat production within industrial facilities supplied by embedded process burners and boilers.

These boilers producing steam are to be differentiated from the cogeneration plants because they represent either necessary back-up capacities or means to burn calorific process off-gases. The “extended” market is of interest for estimating the total heat market existing today in Europe, which is the upper size limit of the market of nuclear cogeneration.

- the “polygeneration” market relates to the co-production near or directly within the nuclear plant of hydrogen and oxygen in particular. This market would be an additional but hypothetical heat market, especially because the production technologies (e.g. oxygen high temperature membranes) are still to be developed. This estimate related only to the existing market, i.e. CTL processes and the market related to the future hydrogen economy were not considered.
- Finally, the part of the “extended” market not yet supplied by cogeneration but which could be so in the future following some adaptation efforts in the end-users processes was estimated. This so-called “pre-heating” market could therefore slip from the “extended” to the “plug-in” market at some point in time. Although this market is today hypothetical, it may represent an additional future potential market for nuclear cogeneration.

Alexandre Bredimas then summarized the main conclusions. First low temperature nuclear cogeneration was already proven and Europe has a good experience, especially in supplying heat for district heating and for isolated industrial end-users.

Second, the current European heat market was found to be very large with a total thermal capacity of 289 to 353 GWth. The heat market is most significant at temperatures below 550°C and above 1 000°C. The main heat consuming sectors are district heating, pulp and paper, chemical clusters, refineries, iron and steel and cement.

30% of this market is externalized, representing a total of 87 to 89 GWth of heat from cogeneration. This market is restricted to temperatures lower than 550°C. Europe was found to have very good infrastructures in place (especially back-up capacities and steam networks) where cogeneration was installed and several high industrial density regions. Some challenges were identified, in particular the flexibility, the average thermal capacity per site and the safe and secure integration of nuclear cogeneration with end-users.

Concerns from European industries on climate policies and energy supply and costs would also favour the emergence of alternative low-carbon technologies.

Polygeneration and pre-heating represent additional heat markets of around 54 GWth. Polygeneration requires to reach process temperatures between 700°C and 1 000°C and to demonstrate the production technologies. Polygeneration offers yet the advantage to access new markets (in particular fuel cells, iron reduction, glass, steel, clean coal technologies). Europe operates interestingly the largest network of industrial gases pipelines in the world and plans to integrate all pipelines into a super European network. This would make possible to site a nuclear cogeneration plant anywhere near the network and supply distant consumers with hydrogen and oxygen.

Pre-heating may be a significant heat market, which would increase with the process temperature. Examples are glassmaking, iron and steel, aluminum, ceramics, lime and cement, which are either neutral towards the heating source, the materials (e.g. syngas) or operate processes at both low and high temperatures. A further detailed analysis to investigate the technical and economic potential of nuclear pre-heating for each industrial sector is yet required.

Discussion on European heat market

Phil Hildebrandt asked whether a business model for HTRs was established. Alexandre Bredimas responded that the study focused on estimating the current total heat market in Europe only as a

pre-requisite to any analysis of the technical and economic potential of nuclear cogeneration. He recalled that no detailed data existed previously.

Scott Nagley (SN, Babcock & Wilcox) wondered whether European companies were concerned with gas supply and costs. Alexandre Bredimas responded that European companies were concerned with gas supply, in particular from Russia, but also with coal (e.g. coking coal in iron and steel), with oil and more generally with all fossil fuels supply and costs in a context of low European energy resources. They felt also the European industrial policies on energy or climate as a source of uncertainty.

Phil Hildebrandt stated that the pre-heating market was found to be not economically interesting in the US. Alexandre Bredimas responded that the economic performance was not investigated but that the pre-heating market could be an additional outlet to nuclear heat, envisioning several industrial consumers around a nuclear cogeneration plant. He took the example of glassmaking which is mostly independent from the heating source and is operating today combined fossil fuel and electric heating furnaces.

Phil Hildebrandt recommended investigating the market for coal-to-liquid which was found to be very large in the US. Alexandre Bredimas agreed but pointed out that CTL processes may not be as economically attractive in Europe as in the US because of higher average production costs (i.e. mining at deep levels, social costs) and lower average qualities of the European coal, which requires significant pre-treatment to remove moisture and impurities.

4 Industry needs: point of view of heat end-users

Europe: End-users general requirements identified in EUROPAIRS (Jacques Ruer)

Jacques Ruer (JR, SAIPEM) reported from the EUROPAIRS investigations on end-users requirements. 3 temperature classes were identified. The temperature class below 600°C would relate to a so-called steam class where steam is used as heating media. Examples are sea water desalination and steam assisted gravity drainage.

The second temperature class between 600°C and 1 000°C would relate to a so-called chemical class. Examples are oil refining, steam methane reforming and ammonia production. The last temperature class would lay above 1 000°C and relate to a so-called mineral class.

He presented some cogeneration scheme that could be applied in each temperature class and concluded that large heat quantities can be found below 600°C, although future hydrogen production may increase heat consumption at higher temperatures. Cogeneration would be an entry point of the general heat market.

Europe: Air Liquide (Francois Fuentes), Tecnimont KT (Gaetano Iaquaniello) and Solvay (Roberto Moron)

Francois Fuentes presented the view of Air Liquide as a potential industrial consumer of nuclear heat. In general, Air Liquide would be interested in a carbon free electricity and high quality heat in large quantities (several hundreds of MWth) but would not be owner and operator of the nuclear plant. Prior to installing a nuclear cogeneration plant, different criteria including reliability, availability and flexibility would need to be demonstrated.

He made also some remarks on nuclear cogeneration. First, the industrial visibility of heat end-users is shorter than the required long-term engagement to build and operate a nuclear reactor. The industrial production base of any heat end-user company evolves following a living situation

which is mostly difficult to foresee. He gave the example of one large production cluster of Air Liquide near Rotterdam which grew very rapidly within one decade.

Second, the lifetime of production units may be shorter than the one of nuclear plant. Third, the industrial gases production units (e.g. H₂, N₂, O₂) have to be located close to the consumers because it requires power for transporting gases through a pipeline so the price may become unattractive from a certain distance.

He added that contracts with consumers were indexed on the cost of energy so it is possible to pass over the cost to consumers only to the extent that they are not forced to delocalize.

Gaetano Iaquaniello (GI, Tecnimont KT) followed on with the presentation of membrane technologies for hydrogen production which would offer the advantage of decreasing the operating temperature for steam reforming from 850-900°C in current steam reformers to 500-650°C. He presented the design for a steam membrane reformer and reported the good results from a pilot project that Tecnimont started in 2010. He specified the required thermal power by site would be 150 to 250 MWth. He suggested to test such a novel technology for coupling with a gas cooled nuclear reactor.

Roberto Moron (RM, Solvay) presented the view of Solvay as a European global player in the chemical industry. He emphasized the high competitiveness of the global market and the increasing constraints put on the chemical industry. All factors led Solvay to set strategic energy objectives for 2020 looking to lower the consumption of primary energy by 20% and to reduce greenhouse gases emissions by 20%. He presented some typical thermal and power demands at Solvay sites (all production sites are supplied with cogeneration plants) which could be compatible with a large HTR. Solvay would therefore be ready to study a demonstration project at one of its plant.

Discussion on the statement of Air Liquide, Tecnimont KT and Solvay

Alexandre Bredimas and Ton Baaten introduced the idea of clustering, which levels the issue of the lifetime of individual production units and/or companies by bringing several stakeholders in one production site. These clusters are economically attractive by sharing large energy and utilities infrastructures as well as risks so the living situation of individual companies is leveled. The average number of participants remains stable and the lifetime can be very long (e.g. more than one century for several chemical clusters).

United States: DOW Chemicals (Fred Moore), ConocoPhillips (Don Halter)

Fred Moore pointed out what energy represented for DOW Chemicals. DOW is consuming 0,3% of the world's energy consumption, 80% of which was located in 6 sites. DOW self-generates 4 GWe of electricity as well as 22 million pounds per hour of steam. And large heating loads are further required for direct fired processes.

DOW Chemicals energy strategy structures on energy efficiency, diversification and optimization of hydrocarbon energy and feedstock supplies, development of alternative and renewable energy and feedstock sources (including HTRs) in order to organize for the transition to a low carbon economy.

DOW is interested in HTRs because of their inherent safety, of their neutrality to fuel costs and CO₂ costs.

Don Halter followed on with the position of ConocoPhillips. HTRs, as a large source of low-carbon energy, would be of interest for the recovery of oil from sands by steam assisted gravity drainage.

The shorter lifetime of such sites as compared to nuclear plants (25 years) could be levered by producing electricity with high efficiency.

The second interest would concern cogeneration of steam and electricity for refineries. He gave several examples of refining processes (distillation, upgrading, catalytic reforming, alkylation, gas plant, fluidized catalytic cracker, delayed coking).

Other potential applications of HTRs would cover shale oil, hydrogen production, distillates upgrading and thermal cracking of water.

Day 2 (Thursday 14th October 2010)

5 Industry needs: point of view of nuclear operators

E.ON statement (Benedikt Hecking)

Benedikt Hecking (BH, E.ON Kernkraft) presented E.ON's position. He reported from E.ON's experience of coupling one nuclear power plant (now decommissioned) with a salt refinery. E.ON generally sees its role as a utility which operates plants with a viable business case. The fundamental technology development for cogeneration is seen as task of vendors, academia or state institutions.

Benedikt Hecking concluded that it is in the interest of utilities and researchers to investigate the possible business models (including interface between utility and consumer, competitiveness with fossil fuels, lifetime, time frames, market demand, back-up, acceptance). E.ON announced its willingness to support corresponding projects in the framework of EUROPAIRS.

Fortum statement (Harri Tuomisto)

Harri Tuomisto listed further some possible concerns regarding nuclear cogeneration. First a nuclear reactor may have to be located close to an industrial facility although new heat transport technologies could make it possible to transport heat across several tens of kilometres (cf. Adam & Eva concept in Germany).

Second, the integration with industrial complexes could reveal difficult due to complex energy needs and high availability requirements. Third end-users may be reluctant to build and operate nuclear reactors.

He concluded that a partnership between interested end-users and utilities is necessary to develop business models for nuclear heat supply.

Entergy statement (Finis Southworth on behalf of John Mahoney)

Finis Southworth presented on behalf of John Mahoney the Entergy position. He listed the company's near-term objectives (lifetime extension, new build), mid-term objectives (small modular reactors for electricity production) and long term objectives (high temperature reactors).

6 Challenges to be faced

Lessons from the German experience (Rainer Reimert)

Rainer Reimert (RR, KIT) presented the results from a process oriented engineering study for the process heat from modularised HTR. He summarised the main results for integrating an HTR with the production of heavy crudes, steam reformers, deep crudes conversion, refining, coal gasification, steam methane reforming, iron making, aluminum).

He concluded that the production of heavy crudes, oil production from tar sands and shale, refining, alumina production and sea water desalination could be integrated with an HTR whereas coal gasification, iron ore pelletizing and sintering, ceramics and cement production could be feasible but with more difficulties.

Present challenges and how to address them

Alliance view on business models and financing

Phil Hildebrandt and Finis Southworth discussed the general issues of the business model and the financing of HTRs. They detailed the cost sharing scheme that was proposed to the US government, for a project for the development of first of a kind plant.

Public funding would be required in the first phases of the project to set up a stable framework limiting risk by supporting the licensing, the R&D and the engineering studies. Private companies would then finance in a second stage 100% of the construction of the demonstration plants. Long amortisation periods would mean that profits would be made 25 years later.

Alexandre Bredimas asked for the distribution of the cost sharing scheme between the different industries involved. Finis Southworth responded that from 2010 to 2014 (design phases) nuclear vendors would contribute to the costs whereas all costs from 2014 to 2020 (procurement and construction) would be taken over by the operators/owners.

For future communication purposes using the financial flux plots vs. time, Michael Fütterer recommended presenting not only the money spent by government and industry, but also the rather quick return of money and other benefits back to the government incurring through industry investments (taxes, jobs etc.). Given the magnitude of this return the role of industry investment would be better valued and government funding decisions are likely to be facilitated.

Roberto Moron asked for the expected operating costs of an HTR. Finis Southworth responded that it would be in the range \$10-12 / MWh (electric).

Handling IPR issues

Werner von Lensa addressed then the issue of IPR, based on the German experience. It recommended limiting competition in an early stage in order to decrease investment costs and reduce IPR issues. Competition would offer most advantages during the deployment phase.

He also advised to partner with TRISO fuel manufacturers in the design phase as well as graphite producers.

He recalled that the Germany Ministry for Industry had forced the German HTR developers ABB and Siemens to partner in founding HTR GmbH in order to subsidise only one organisation. Any business included a payback of a certain fee to the government.

He questioned whether the Generation IV International Forum could help in managing IP rules, at least in the early phase.

Licensing

Olivier Baudrand (OB, IRSN) presented the results from EUROPAIRS WP 2 on safety and licensing assessment. He recalled that the European context is rather dispersed with each Member State applying its own regulations and the European regulation being low.

He recommended that each part of the coupled system should be approached separately. External hazards induced on the coupling process would have to be included in the safety case of a demonstration plant.

He reported that regulations already define clearly the boundaries of a nuclear site. However, the contamination limits of the heat transfer medium would be stringent because the coupling medium could not be considered as a simple effluent. The risk of tritium contamination exists and could be addressed by existing measures but a cost/benefit analysis according to the objective should be carried out.

Yet, nuclear cogeneration would have to be compared with existing technologies and would need to prove that the risk is not increased (example of French regulation). The possibility of supplying lowly contaminated fluids to industry would need to be discussed with safety and health authorities.

Danger studies for industrial sites already contain scenarios on major accidents which could be integrated in the safety case of a nuclear demonstration plant. There was also experience in France on emergency planning involving commonly chemical and nuclear installations.

Widening the support from end-users industries and utilities

Jacques Ruer made a synthetic presentation in order to launch the discussion. He recalled that nuclear energy was not necessary today, that fossil fuels were still cheap and the related installations are amortised and optimised.

He questioned the industry acceptance of nuclear cogeneration, which requires an adaptation and may be felt as costly and risky from a political, licensing, fuel cycle or planning points of view.

He underlined that the peak oil may happen in the near future and that energy may no longer remain cheap, while security of supply and climate change are concomitantly the source of rising concerns.

He sketched possible actions to demonstrate HTR: ensuring that government and industry agree on the vision of the future, identifying industries at risk which could feel concerned, building a roadmap to help the transition to a low-carbon economy and developing the HTR technology in order to be ready when it will be required.

He wondered whether building a demo plant for an existing industrial facility, with existing cogeneration and back-up capacities would be the right option for limiting the risk of demonstration. In this case, he raised the issue of who would finance this demo plant.

Discussion

As a specific issue, Fred Moore requested that the EU side needs to establish a stable alliance for a long-term partnership at par with the Alliance. The Alliance underlined its drivers for setting up a legal structure (image / membership fees channelled for financing Alliance operations / business with Government).

The European side pointed out that a stable entity has been existing already for the last 10 years in the form of the European High Temperature Reactor Technology Network (HTR-TN) but that a formal legal body had so far been no necessity within Europe. As part of its strategy, HTR-TN had configured a consortium for the EUROPAIRS project with the objective of creating a long-term partnership between nuclear and process heat end-user industries for promoting the development of nuclear cogeneration.

7 The path towards demonstrating HTR cogeneration for industrial applications

A discussion followed the presentations in order to define the potential goals and joint actions that could be found between EUROPAIRS and the Alliance.

- General ideas
 - o Long-term end users' goals seem similar on both sides
 - o The demonstration of 2 concepts (prismatic / pebble) could be made over the 2 continents
 - o Passive safety and proliferation resistance are strong assets to be put forward (e.g. FBI report)
 - o Standardised modular design to be targeted?
 - o Is competition needed at the demonstration phase?

- Common products of EU-US collaboration could include:
 - o Detailed analysis of market opportunities, including economics and societal benefits (carbon footprint, security of supply...)
 - o Cross-review of business plans (refer to Alliance's *Project Implementation Plan* – available from DOE website)
 - o Explore possible strategy for common safety case
 - o Jointly explore possibilities of interaction with HTR-10 & HTTR
 - o Eventually, work on a joint demonstration strategy
 - o Joint communication for increased visibility

- Organisation
 - o Set up a stable European alliance, building on the existing HTR Technical Network and the EUROPAIRS partnership
 - o Cross-referencing of end-users, or common membership, could then be considered
 - o Europe will further explore its potential resources (public / private)

AREVA (US & Europe) will work on the above ideas, and make proposals for the next steps.

8 Annexes

8.1 Annex 1: agenda

Join meeting between the Industrial Alliance for NNGP and the EUROPAIRS project

Paris, Novotel Les Halles, October 13th-14th

Wednesday October 13th

1. Introduction of the meeting

- 13.30-14.00: Welcome and presentation of participants
14.00-14.15: Introduction: the need for nuclear co-generation, the challenges to be faced, the objectives of the meeting
14.15-14.30: Presentation of the Alliance and of the US context (NGNP...)
14.30-14.45: Presentation of EUROPAIRS and of the local context (European HTR program, SNETP/NC2I, SET-Plan ...)
- Co-chairmen
Fred Moore
Edgar Bogusch

2. The need for nuclear cogeneration

2.1 Policy goals

- 14.45-15.10: Vision of DoE
15.10-15.35: European vision
15.35-15.50 *Coffee break*
- Phil Hildebrandt
Marc Deffrennes

2.2 Market assessment

- 15.50-16.15 Presentation of the Alliance analysis
16.15-16.30 EUROPAIRS market analysis
16.30-16.45 Discussion
- Phil Hildebrandt
Alexandre Bredimas

2.3 Industry needs:

Industry requirements and vision for HTR deployment (priorities, time frame, etc.)

- End-users

- Europe:

- 16.45-17.05 Synthesis of EUROPAIRS work
17.05-17.30 Statements from other European end-users
- Jacques Ruer
Francois Fuentes
Gaetano Iaquaniello
Anton Baaten

- US

- 17.30-17.55 Dow Chemical
17.55-18.20 ConocoPhillips
18.20-18.40 Discussion
- Fred Moore
Don Halter

19.30: *Dinner hosted by AREVA*

Thursday October 14th

2.2 Industry needs (continued):

- Nuclear operators point of view

08.45-09.15 Statements from E.ON, FORTUM, ENERGY

09.15-09.35 Discussion

3. The challenges to be faced

- Lessons from the German experience

09.35-10.05 Presentation

Rainer Reimert

10.05-10.20 *Coffee break*

- Present challenges and how to address them: discussion on each item triggered by a short introduction (5 min) raising the relevant questions

10.20-10.45 Business model for the commercial reactor

The Alliance

10.45-11.10 Financing the demonstrator

The Alliance

11.10-11.35 Handling IP issues

Werner von Lensa

11.35-12.00 Licensing

Olivier Baudrand

12.00-12.25 Widening the support from end-users' industries and utilities

Jacques Ruer

...

12.30-13.45 *Lunch*

4. The path forward for demonstration of HTR co-generation for industrial applications

13.45-15.15 Possibilities of cooperation between the European partnership and the Alliance: discussion on

- Goals
- Joint actions to be performed in the next period
- Discussion of the final resolution

5. Conclusion

15.15-16.00 List of actions & next step

8.2 Annex 2: Attendance to the meeting

Name	Company	Presence
Sander de Groot	NRG	YES
Ludwik Pienkowski	UW Prochem S.A.	YES
Marek Tarka	Prochem S.A.	
Werner von Lensa	Forschungszentrum Jülich	YES
Benedikt Hecking	E.ON	YES
Gaetano Iaquaniello	Tecnimont KT	YES
Francois Fuentes	L'Air Liquide	YES
Philippe Monette	Tractebel Engineering / GDF SUEZ	YES
Anton Baaten	DSM/BEC	YES
Harri Tuomisto	FORTUM	YES
Gérard Griffay	ArcelorMittal	
Philippe Muguerra	SAIPEM SA	YES
Jacques Ruer	SAIPEM SA	YES
Alain Chevalier	AMEC	YES
Michael Fütterer	EC DG JRC	YES
Markus Fendrich	RWE	
Panagiotis Manolatos	European Commission DGRTD	YES
Marc Deffrennes	European Commission DG Energy	YES
Roberto Moron	Solvay	YES
Henri Pailliere	Alstom	YES
Dietrich Knoche	Westinghouse Electric (Germany)	YES
Bismark Tyobeka	IAEA	
Rainer Reimert	Karlsruhe Institute for Technology	YES
Alexandre Bredimas	LGI Consulting	YES
Vincent Chauvet	LGI Consulting	YES
Fred Moore	Dow Chemical	YES
Don Halter	ConocoPhillips	YES
Philip Hildebrand	BEA/INL	YES
Leyla Sandell	Westinghouse Electric (USA)	YES
Scott Nagley	Babcock & Wilcox	YES
Mike Telson	General Atomics	
Sylvain Menou	AREVA (France)	YES
Edgar Bogusch	AREVA (Germany)	YES
Finis Southworth	AREVA (USA)	YES
Dominique Hittner	AREVA (USA)	YES