For a Global HTR Marketing Initiative

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Abstract – HTRs are at a crossroads in their history. The technology is proven and the current technical developments relatively mastered but the marketing track record is disappointing. This paper comes to the conclusion that an international, collaborative marketing and communication plan must be implemented in order to address the marketing bottleneck of HTRs. The paper reflects about the HTR product specificities, its unique selling points and its positioning against other nuclear designs and gas cogeneration. It summarises the global market status and demonstrates that the global market for HTRs is there, for electricity generation, industrial cogeneration and polygeneration. The paper finally argues that HTR vendors have a shared interest to unite in order to succeed in activating the market demand for HTR, and suggests an action plan for an international collaboration among HTR vendors to market and communicate globally on HTRs and reach together a critical mass of business leads worldwide, a mutually beneficial outcome.

I. INTRODUCTION

High Temperature Reators (HTR) could become an excellent example of a concomitant technological success and marketing turmoil. The technology has been tested several times since the 1960s. Two demonstrators have been built (Fort St Vrain in the US, THTR in Germany) and one is now being built (HTR-PM in China). However, no commercial order has been placed since 40 years. This situation does not originate from a technological failure. On the contrary, HTRs demonstrate very high efficiencies, safety and availability features. This situation can be explained only by an incorrect marketing.

The coexistence of several technologies is common in most industrial sectors. For instance, seawater can be desalinated with thermal or membrane processes, paper pulp can be produced with mechanical, chemical and mechanical-chemical processes, steel can be produced with blast furnaces or plasma processes, hydrogen can be produced by steam-methane reforming, electrolysis or thermo-chemical processes, etc.

Nuclear energy is not an exception. Nuclear electricity can be generated with water reactors, gas reactors, liquid metal reactors, molten salt reactors, etc. Water reactors have emerged as the main nuclear reactor technology in a few decades and diversified into various designs (pressurized heavy water reactors, pressurized water reactors, boiling water reactors, supercritical water reactors, etc.). Fast breeders were tested as early as the 1950s and got a few commercial orders (from States).

The non-emergence of high-temperature reactors may therefore be explained by an incorrect marketing. HTRs did not find so far the right market positioning making the most of its advantages, as far as possible in harmony with other nuclear designs.

This paper aims at addressing this situation from an innovation and marketing perspective, as a representative case for large system innovations. The...
II. THE HTR PRODUCT

This first section discusses what we mean by the “HTR product”. It is a necessary step to define the right marketing strategy. The versatility of HTRs has brought so far an uncertainty regarding the market(s) they should address.

II.A. What can do the “HTR product”?

To reach a successful marketing understanding, the question is not what are the technological features of HTRs but which product functionalities do they offer to which clients. It is like wondering what can be done with a smartphone for the logistics industry rather than which material was taken for the bondings of its graphical chip.

So what are the “HTR product” functionalities? HTRs produce steam at 550°C, and up to 1000°C. At this temperature, electricity can be generated at a high thermal efficiency around 45% to 55%. Steam can also be used for heating industrial processes. HTRs could supply various sectors: pulp and paper, district heating, desalination (below 250°C). At a minimum steam temperature of 550°C, HTR could supply heat to chemicals production, oil refining, fertilisers, and certain non-ferrous metals (250-550°C). At a steam temperature above 800°C, HTRs can be used to produce industrial gases like hydrogen, oxygen and nitrogen. At 1 000°C, HTRs could support the heating of several very high-temperature industrial processes like glassmaking, steelmaking, ceramics or cement [1]. Supplying steam to industrial processes requires the HTR to be located close to the industrial facility.

Like other integrated innovations (e.g. smartphones, cars, etc.), HTRs can create a larger market value by building an ecosystem around them, which will add value to its outputs. This applies especially to the co-location of the production of basic raw materials (hydrogen, oxygen, methanol, etc.). This can create an industrial ecosystem that produces not only steam and electricity, but directly chemicals. This however demands to have infrastructures connecting the HTR plants not only to the power grid and steam networks, but also to industrial gases pipelines and logistics hubs.

II.B. HTR position against other nuclear designs

The “HTR product” functionalities differ from other nuclear designs.

Usual water reactors can produce steam at a maximum temperature of 250°C and a thermal efficiency around 35%. They dedicate fully to electricity generation. The cogeneration potential of water reactors is limited. The only processes that may be supplied are pulp and paper (e.g. Beznau NPP in Switzerland), desalination (e.g. Japanese NPPs), district heating (e.g. Cernovoda NPP in Romania). This temperature is insufficient for most other industrial sectors, except hydrogen for which low-temperature electrolysis could be achieved by water reactors, provided the feasibility and efficiency of this technology is proven. Contrary to HTRs, supplying these sectors would require fresh steam from water reactors and not back-end steam, so the impact on electricity generation is important. Except district heating which requires temperature below 100°C, nuclear cogeneration from water reactors is therefore relatively difficult from a business perspective.

Light water reactors have grown over time from a few hundreds of MWe in the 1960s to now 1,700 MWe for the largest reactor design EPR with the objective to achieve larger economies of scale. Light water reactors have specialised into the production of vast amounts of base load electricity for large, industrialised power markets. The usual clients are nuclear utilities who have the capacity to optimise the operations of such large and complex plants. Emerging countries represent a new market potential but their power grids cannot host very large plants and the local nuclear capabilities must be built up. The latest move initiated by the nuclear industry towards small and medium size reactors (SMR) address these markets.

SMRs encompass several reactor technologies (water, fast breeders, HTRs). They dedicate mostly to electricity generation as semi-base load capacities. SMRs are somehow complementing large water reactors, both to reach new markets in emerging countries and to supplement large water reactors in
industrial markets. Today, water reactors are the reference as regards nuclear electricity and new designs should differentiate from them.

Fast breeders (e.g. sodium-, gas-, lead-cooled, molten salt reactors) can produce steam at a maximum temperature in the range of 350 to 450°C. The thermal efficiency for generating electricity is similar to water reactors. The sectors that can be supplied with fast breeder steam are therefore the same than water reactors (chemicals, refining, etc. require a minimum temperature of 550°C). Fast breeders differentiate from water reactors by enabling to reach an extended fuel independency and to burn certain minor actinides. The market of fast breeders is therefore not purely the generation of electricity, but the national States energy security requirements and long-term sustainability of the wastes from the nuclear industry. This market differs somehow from the one of water reactors.

Where does HTR position then? This question is periodically raised (see for instance [2] and [3]). HTR can generate electricity at a high thermal efficiency with a reactor capacity up to 600 MWt (largest design developed by Areva, ANTARES) with lower volumes and less radioactive wastes per MWh. This puts HTRs in competition for semi-base load electricity with water SMRs. Safety, another feature often brought forward by HTR promoters, represents a market value as it decreases the risk of accidents. However, capturing this value is uneasy. The HTR nuclear safety concept relies on the fuel resistance and retention of fission products, while the current nuclear safety concepts, adapted for water reactors, rely on the assumption that the fuel will break up, so strong safety barriers outside fuel are needed (especially nuclear containment buildings). Licensing HTRs will demand to adapt these concepts and implies a cost. The large uptake of water reactors has thus indirectly set market barriers to competing designs.

On the other hand, HTRs can burn thorium, a complementary resource of uranium, which puts HTRs in competition with fast breeders for the fuel independency.

HTR can produce high-temperature steam, which is unreachable for all other nuclear designs.

**II.C. HTR position against gas technologies**

Gas is the reference technology for industrial cogeneration (especially combined cycle gas turbines). Gas demonstrates a very high flexibility, availability and reliability and can produce steam at high temperatures. However, gas technologies are subject to a large volatility in gas prices, and consequently in production costs. As large-scale gas storage is uneasy and costly, gas cogeneration consumers depend on the secure day-to-day supply of gas, which can be interrupted. Finally, gas technologies emit CO2, which can represent an additional risk in case CO2 taxations are imposed as for instance in Europe [4].

Gas is the main source of energy and raw material for hydrogen production through the largely predominant production route of steam-methane reforming. Chemical clusters and oil refineries use typically steam reformers. Standalone gas plants producing hydrogen and basic raw materials do not exist to our knowledge; steam reformers are usually embedded in pre-existing industrial facilities.

HTR would be mostly complementary to gas. It provides a source of low-carbon heat. Fuel supply is secure and stable in price. Fuel storage for several months of exploitation is easy. However, HTRs are less flexible and available than CCGTs and more costly and risky to build. The creation of a polygeneration capacity using HTR heat could be developed.

**II.D. Summary of the HTR technology landscape**

The positioning of the HTRs against its main competitor technologies can be depicted in the following figure.

Figure 1: Radar graph of the HTR technology landscape

HTR offer, like all nuclear reactors and contrary to gas cogeneration, a low-carbon and secure source of energy, with high construction costs.
HTRs differ from water reactors by offering a high thermal efficiency for the production of electricity, a high level of passive safety features. However, water reactors are clearly easier to license, as the licensing process is adapted for them.

Fast breeders excel for the security of fuel supply and waste reduction. The safety concept has still to be proven.

Gas is leading for cogeneration and are much easier to bring to the market: the licensing process is simpler than for nuclear plants and the construction costs are much lower (the fuel costs induce however a risk during the plant operation). HTRs are the only nuclear reactors able to provide a versatile cogeneration solution. HTRs could even host a poly-generation cluster.

In summary, HTR differentiates from other nuclear reactors especially with the potential for cogeneration for which gas is the reference technology. As HTRs are largely complementary from gas, this segment looks particularly relevant.

HTRs can also offer a high thermal efficiency for power generation and a high level of safety compared to other nuclear reactors.

The main issue for HTRs is to secure the licensing, for which water reactors have a large advance.

It is important to note that the business models for power generation, fuel security and cogeneration are not similar.

Figure 2: Value chain for power generation, fuel security and industrial cogeneration

<table>
<thead>
<tr>
<th>Applications</th>
<th>Power generation</th>
<th>Fuel security</th>
<th>Industrial cogeneration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactors</td>
<td>All reactors</td>
<td>Fast breeders, HTRs</td>
<td>HTRs</td>
</tr>
<tr>
<td>Buyers</td>
<td>Utilities</td>
<td>Utilities</td>
<td>Utilities</td>
</tr>
<tr>
<td>End-users</td>
<td>Power grids</td>
<td>States</td>
<td>Industrial end-users</td>
</tr>
</tbody>
</table>

Power generation is a usual business model: a utility buys a power plant (nuclear or not) and sells the electricity to the grid. The power grid is a liquid market, this means that utilities can sell electricity to numerous, distant customers. As utilities operate in most countries on competitive markets, the business motivations are particularly acute. Utilities must balance the risks (construction, licensing, fuel supply, operation, dismantling...) and the benefits (production costs, flexibility, etc.)

Fuel security and waste reduction address a need expressed mainly by States, which are the “end-users” in this case. The utilities would still buy the plant to generate electricity. As risks to licence, build and operate are high, bringing this technology to the market requires a significant public support.

The business model for industrial cogeneration is also different. Utilities would still have to buy and operate the plant, but the end-users are industrial facilities consuming the heat. Contrary to the electric grid, industrial cogeneration implies that utilities have only one local client. The dependency to the client is therefore high, and represents a business risk. All other risks and benefits are similar. Polygeneration would reduce the market risk by enabling to supply distant customers (e.g. through industrial gas pipelines, trucks...) but the operation of several co-located production processes (a system already well known in chemical clusters) can be complex.

In summary of the applications, industrial cogeneration represents a market potential for HTRs but is a challenging business. Fuel security and waste reduction relate to States’ needs and therefore require State support to bring technologies to the market. Power generation is a mature but highly competitive market, for which the licensing potential of reactors is a crucial pre-requisite.

II.E. The unique selling points of HTRs

In summary of Section II, what can we deduce about the Unique Selling Points of HTR?

Table 1: Unique Selling Points of HTRs

<table>
<thead>
<tr>
<th>USPs of HTRs</th>
<th>Competition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production of low-carbon, secure, high-temperature steam</td>
<td>/</td>
</tr>
<tr>
<td>Polygeneration cluster</td>
<td>(gas?)</td>
</tr>
<tr>
<td>Fuel supply extension</td>
<td>Fast breeders, but in the future</td>
</tr>
<tr>
<td>Base and semi-base load, low-carbon, secure electricity generation</td>
<td>Water SMRs</td>
</tr>
</tbody>
</table>

HTRs are clearly unique for their capacity to produce high-temperature steam securely and with little carbon emissions. Building on this, polygeneration clusters based on HTR would
represent a breakthrough innovation. However, this market is more challenging than the generation of electricity, in which a direct competition with small and modular water reactors would occur.

III. GLOBAL MARKET SUMMARY
III.A. Overall electricity and industrial heat market estimate

All recent scenarios foresee an increase in the world electricity demand, driven in particular by large countries like China, India, Russia, and Brazil, and more generally emerging regions like Asia, South America and Africa. The electricity demand in Europe, North America and Japan should stagnate until 2035.

Many power capacities will be commissioned in the time window from 2010 to 2040: in the BRIC countries to supply the increasing demand; in industrialised countries to replace ageing capacities, which were built in the 1970s and will be decommissioned in this timeframe.

While the world electricity market benefits from a rich literature, no public world industrial heat market study has, to our knowledge, been published up to now and no comprehensive scenario up to 2035 or 2050 has been developed. The European and United States industrial heat market have been analysed in detail [2], [3]. A first rough guess of the world heat market can be however extrapolated from both studies in proportion of the Gross Domestic Product (GDP).

<table>
<thead>
<tr>
<th></th>
<th>2011 GDP (bnc)</th>
<th>Share of world GDP</th>
<th>Heat market (TWh/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Union</td>
<td>17 552</td>
<td>25%</td>
<td>3 000</td>
</tr>
<tr>
<td>Brazil</td>
<td>2 477</td>
<td>4%</td>
<td>423</td>
</tr>
<tr>
<td>China</td>
<td>7 319</td>
<td>10%</td>
<td>1 251</td>
</tr>
<tr>
<td>India</td>
<td>1 848</td>
<td>3%</td>
<td>316</td>
</tr>
<tr>
<td>Japan</td>
<td>5 867</td>
<td>8%</td>
<td>1 003</td>
</tr>
<tr>
<td>Russia</td>
<td>1 858</td>
<td>3%</td>
<td>318</td>
</tr>
<tr>
<td>United States</td>
<td>15 094</td>
<td>22%</td>
<td>3 600</td>
</tr>
<tr>
<td>World</td>
<td>69 994</td>
<td>100%</td>
<td>11 963</td>
</tr>
</tbody>
</table>

This represents an equivalent installed thermal capacity between 1 500 and 2 100 GWth, notwithstanding the future capacity additions.

III.B. Country summaries

This subsection provides very brief summaries for selected countries in the world.

Asia

China is a fast-growing nuclear country. It has opted for a diversified reactor fleet strategy including pressurised and boiling water reactors, heavy water reactors, fast reactors and high-temperature reactors. China is leading on HTR and has ranked this technology among its highest priorities. It operates the HTR-10 test reactor since 2000 and builds the HTR-PM 200 MWe demonstrator. Several HTR plants should be built subsequently. According to the World Nuclear Association, new build capacities may represent 150-200 GWe.

India is like China a fast-growing economy and has developed an expertise in heavy water and fast reactors to take advantage of its domestic thorium resources and reduce its dependency to uranium imports. HTR can provide an additional and desirable solution to burn the Indian thorium resources. According to the World Nuclear Association, new build capacities may represent 55-60 GWe.

Japan is an advanced industrial country, heavily dependent on energy imports. The country can hardly avoid using nuclear energy. It masters water, fast and high-temperature reactors. The Fukushima accident has weakened the Japanese nuclear industry and pushed forward the need for safety. By 2030, a large share of the Japanese nuclear fleet should be replaced with safer technologies and high-temperature reactors could be a reference solution.
According to the World Nuclear Association, new build capacities may represent 40-50 GWe.

South Korea aims at becoming the third largest nuclear reactor and services exporter in the world. The country has a strong domestic nuclear programme including HTR. HTR would diversify the country’s nuclear technology portfolio, secure its energy supply for industry and open the new markets of industrial cogeneration and hydrogen. According to the World Nuclear Association, new build capacities may represent 24-26 GWe.

In general, HTR represents a safe, small-size, competitive energy solution fitting the power grids of South Asian countries. Vietnam is committed to develop nuclear capacities. It has signed agreements with Russia and Japan for them to build and finance 4 GWe of new capacities, and has similar plans with South Korea. Malaysia and Thailand have been considering nuclear energy but with no commitment. According to the World Nuclear Association, new build capacities in these countries may represent 4-6 GWe.

Middle East and Africa

Saudi Arabia has decided a very ambitious industrialisation strategy aiming at developing a world-leading domestic manufacturing industry. The electricity, desalination and industrial heat markets should significantly increase by 2030. Nuclear energy is a priority technology and Saudi Arabia has stated an interest in HTRs. New build capacities may represent 17-20 GWe.

The United Arab Emirates have started an ambitious nuclear programme and selected South Korea as its key nuclear supplier for the Barakah plant. The four units to be supplied will cover a large share of the energy needs of the country but more capacities may be required in the future, for a total of 5-7 GWe.

Contrary to other countries in the region, Jordan is a heavy energy importer. The country is considering nuclear energy to alleviate its energy bill. Despite being a small market in the region, Jordan is pursuing a realistic nuclear programme. Due to the weakness of the power grid, the lack of available cooling water, safe SMRs designs would represent a desirable solution. According to the World Nuclear Association, new build capacities may represent 2-3 GWe.

Turkey has been considering nuclear energy for a long time but its plans were repeatedly postponed and amended. The construction of 4 VVERs and 4 Atmea1 were signed. Turkey is likely to build by 2030 additional capacities in a third site. According to the World Nuclear Association, new build capacities may represent 4-5 GWe.

South Africa operates two nuclear plants and has developed the HTR PBMR design derived from the German HTR-Modul. The government is committed to build significant nuclear capacities by 2030 but would need financial back-up. The country would likely welcome the construction of HTR which would make use of the local HTR expertise. According to the World Nuclear Association, new build capacities may represent 9-10 GWe.

Americas

The United States is a leading country in nuclear technologies. It has hosted the HTR Peach Bottom I test reactor and Fort St. Vrain demonstrator from the 1960s to the 1980s. It has consistently supported the HTR design up to the latest NGNP programme. The recent emphasis put on SMR provides a positive signal for HTR reactors. The US NGNP Industry Alliance including and led by energy-intensive companies supports industrial cogeneration applications for HTR. According to the World Nuclear Association, new build capacities may represent 30-40 GWe.

Canada is the home country of the pressurised heavy water reactor designs. It is also one of the very few countries in the world with a significant experience of nuclear cogeneration. The Bruce nuclear plant has supplied a large industrial park with nuclear heat. Canada’s 19 GWe nuclear fleet will need to be refurbished and fully replaced by 2030. Although Canada is rather focused on water reactor designs, high-temperature reactors could offer a safe alternative, especially for industrial cogeneration in support of the exploitation of Canada’s shale oil and gas reserves. According to the World Nuclear Association, new build capacities may represent 15-25 GWe.

Mexico operates two boiling water reactors supplying a marginal share of the country’s electricity demand. Low gas prices weaken the
business case for new nuclear capacities but the
government has expressed interest in alleviating the
country’s dependency to gas imports. SMRs with
desalination applications may be favoured. Industrial
cogeneration may be an additional interest for the
Mexican heavy industries. According to the World
Nuclear Association, new build capacities may
represent 7-10 GWe.

Brazil is a fast-growing economy. It operates two
PWR units and looks to build new capacities.
Mastering nuclear technologies has been an historic
requirement for Brazil. HTR could provide an
opportunity to build capabilities and to support the
development of the national manufacturing industry.
According to the World Nuclear Association, new
build capacities may represent 10-13 GWe.

**Europe and Russia**

The Polish Council of Ministers has formally
endorsed the nuclear programme in January 2014. It
foresees the commissioning of a nuclear power plant
in 2024. The site would be on the Baltic coast.
Poland has started several national research projects
on HTR reactors, which could serve in particular for
industrial cogeneration in replacement of coal and
gas industrial heat production and cogeneration
plants. According to the World Nuclear Association,
new build capacities may represent around 6 GWe.

The United Kingdom needs to quickly replace its
ageing nuclear plants. The country has historically
developed gas-cooled reactors and holds a local
expertise. Even if LWRs are naturally foreseen, HTR could provide an opportunity to use local
suppliers. The latest Electricity Market Reform has
created a favourable context for nuclear financing.
According to the World Nuclear Association, new
build capacities may represent 16-25 GWe.

Russia aims at founding the transformation of its
economy towards higher added value services on the
renovation of the energy sector. It foresees the
construction of all reactor types: water and
supercritical water reactors, lead- and sodium-cooled
fast breeders and HTRs. HTRs are foreseen to
supply heat and power to industrial facilities and to
produce hydrogen. According to the World Nuclear
Association, new build capacities may represent
around 16 GWe.

**III.C. The global HTR market in summary**

In summary, the total market in the selected
countries amount to 410 to 522 GWe. Most of the
new build capacities will take place in a market
window from 2010 to 2030. BRIC, Middle East and
other emerging countries are growing now and
should reach an acme in 2030. Europe, Japan,
Canada and the United States will have to replace
the large amount of power plants commissioned in
the 1960s to 1980s. Lifetime extension programmes
may somehow extend the market window. The new
capacities in industrialised countries will be largely
smaller than emerging countries. For instance, the
expected new builds for China alone would be larger
than the new builds in the United States, Poland,
United Kingdom, Russia and Japan altogether.

It is important to note that the market window for
nuclear new builds in emerging countries has
already opened (say in the 2000s) and should start
slowing down by the 2030s. China is today the sole
country building an HTR demonstrator, to be
commissioned by 2017. Commissioning an HTR in
Europe or in the United States would require around
10 years, in a time period around 2021 to 2023.

**IV. FOR A GLOBAL HTR MARKETING AND
COMMUNICATION PLAN**

**IV.A. Summary of the marketing context**

If we summarise Sections II and III, the world
market for nuclear capacities and for industrial
cogeneration is considerable. The market window
has opened from 2000s and should start to close in
the late 2030s. Most of the new builds will take
place in emerging countries.

HTRs are unique for their capacity to produce
high-temperature, safe, secure, and low-carbon heat.
This clearly indicates the market for industrial
cogeneration as a promising application. This
business is however particularly challenging, as it
involves three key stakeholders (vendor – utility –
industrial heat end-user). The market for fuel
efficiency and waste reduction is not the most
straightforward. The market for power generation is
mature but very competitive.

Bringing HTR to the market (for any application)
has a cost. This cost is common to all HTR designs,
whatever the location. Investments will be necessary at least to:

- Develop the product, capabilities and infrastructures to deliver new build projects in the most secure and competitive manner
- Ensure the licensing of the design in the key markets that are targeted (see section III)

This go-to-market path is comparable to setting a new standard in industry. An illustrative example is the videocassette recording (VCR). In the 1970s, TV recording and its market did not exist. Sony went first to the market with the Betamax standard in 1975 and was soon challenged by JVC’s VHS. Sony believed that consumers would be ready to pay a premium for the higher quality of Betamax cassettes, which were also first to the market. However, it soon became clear that consumers desired longer recording time and lower retail price that VHS offered. As VHS reached a critical mass, consumers started to prefer VHS to ensure compatibility for sharing cassettes, amplified by the brand loyalty to companies who licensed VHS. In 1988, Sony had to market its own VHS machines...

However, history never ends and sometimes repeats. Sony learnt very well the value of setting a global standard in cooperation with competitors, in order to jointly open a same market. Sony collaborated with its competitor Philips for defining successfully the CD standard as early as 1979, merging the work of both companies on laser discs.

Setting the DVD standard in the 1990s could have become a second format war. Sony and Philips were proposing the Multimedia Compact Disc (MMCD) against the Super Density disc (SD) proposed by Toshiba, Time Warner, Matsushita, Hitachi, Mitsubishi, Pioneer, Thomson and JVC. Representatives from the SD camp asked IBM for advice on the file system. IBM set up in response a Technical Working Group (TWG) made of computer industry experts from IBM, Apple, Microsoft, Sun Microsystems, Dell, and many others. Worried about what started to look like a videocassette format war, TWG voted to boycott both formats unless both camps agreed on a single, consensual standard named DVD in 1995.

This example illustrates well the situation in the nuclear industry. Nuclear designs look much like a standard, as each type of design lock-in the clients (plant operation, organisational structure, safety culture...), the suppliers (industry standards, norms...), the capabilities building (education, training...), etc. The nuclear licensing processes which is to certify the plant safety in general have been adapted to water reactors, creating a standard-like system for nuclear designs to demonstrate similar safety concepts than water reactors. Bringing HTR to the market will demand to adapt the licensing process on the HTR safety concept based on the fuel performance. This additional effort is like overpassing an existing standard.

The situation of HTRs in 2014 looks like the situation of Betamax. A critical mass was reached by water reactors, which have become a reference for nuclear energy in the world.

This comparison does however not apply fully. The nuclear sector can accept several technologies on the market. Other nuclear designs have been licensed (including HTRs) which proves the feasibility.

From another perspective, HTR could draw also inspiration from the CD. CDs were originally developed for music recording (although they could have been used for video recording) in replacement of vinyl discs and audiotapes. This has set for Sony a standard on a new market (audio recording) before getting back to the video recording (by setting the DVD standard). HTR could set a new standard in the market for industrial cogeneration and poly-generation as a way to address more generally the markets for heat and electricity.

So the HTR developers come at a point where the “HTR community” must shift from a failing “Betamax strategy” to a successful “CD strategy”. HTRs must address a specific need and reach the required critical mass worldwide.

IV.B. Why should HTR developers unite on a global marketing strategy now?

It is important to take an historical step-back in order to understand the current situation. The 1990s and 2000s decades have been particularly crucial for HTRs.

Following Chernobyl and the subsequent decline in the demand for new nuclear capacities worldwide, the nuclear sector has undergone a major restructuration worldwide. Numerous mergers, acquisitions and partnerships have taken place in this time period (Areva-KWU-Siemens-Mitsubishi, Combustion Engineering-Westinghouse-BNFL-
Toshiba, GE-Hitachi, etc.). This consolidation has led the two major global nuclear vendors to master several technologies: Areva has a portfolio of designs including water reactors (EPR, KERENA, ATME, submarines...), fast breeders (ASTRID, in collaboration with CEA), and HTRs (HTR-Modul, ANTARES); similarly, Toshiba-Westinghouse masters water reactors (AP1000, ABWR, SCPR, LSBWR, IRIS...), fast breeders (4S...) and HTRs (HTR-500). This timeframe corresponds to the closure of the two HTR demonstrators in the United States and Germany (Fort St Vrain, THTR). With difficult market conditions, both vendors have focused on the products with the shortest, least risky and costly path to market, i.e. water reactors. This strategy, however rationale, undervalue arguably the rich portfolio of reactor products of both vendors.

During these very two decades, Russia transited from the USSR to a liberal economy and the plutonium from Russian nuclear weapons had to be reprocessed. South African vendor PBMR has emerged and disappeared. Japan has commissioned the HTTR test reactor but the population questions the nuclear programme after Fukushima and the Japanese leadership is weakened. China has acquired a global advance following the German HTR technology transfer and leads today the construction of the HTR-PM demonstrator. South Korea is active to set up a nuclear hydrogen programme.

A global market for HTR is perceptible but still to be understood in detail and proven. The path to the market is costly. Nuclear vendors compete fiercely for selling water reactors. The research on HTRs has dramatically decreased since the 1980s, experts start to retire, the transfer of knowledge and skills is unsure, industrial capabilities start to vanish.

Opening fully the global market for HTR will require several countries to host HTR plants. For instance, China alone cannot open the market for HTR plants in Europe and the United States. Europe and the United States have identified a need for cooperation to find common ways to develop and market HTRs.

Continuing on the same path than in the last decades announces a clear market failure for HTR. The positioning of HTR must be clarified in order to address the global market in a coordinated manner. Isolated efforts cannot be visible from potential clients in the world. The two main vendors worldwide need to make the best value of their portfolio of reactor products. Smaller HTR developers (especially Chinese developers) need an international market scope to prepare for exports but also to convince clients internally. The ecosystem around HTR vendors (research centres, universities, safety authorities, suppliers, financiers...) needs a global market visibility to sustain its activities.

Unless HTR developers agree on a concerted global marketing and communication strategy, the critical mass necessary to raise the awareness of several clients in several countries in the short term will not be reached. The demand specifically for HTR must be activated, especially as the market window is open until the 2030s and as the HTR ecosystem in Europe and the United States is weakened. No demand, no market. No market, no return on investment.

**IV.C. What shall HTR developers do?**

Considering the marketing context of HTR today, the obvious objective is to activate the demand for HTR. The market overview indicates that it can be fairly assumed that a demand for HTR exists.

Reasoning backwards, to activate this demand, the awareness of potential clients needs to be raised. Raising the awareness of clients requires a global, coordinated communication that will reach a critical mass and install HTRs as a realistic solution. To agree on a coordinated communication, a clear positioning for HTRs must be agreed upon. All HTR developers will agree on a common positioning only if this positioning satisfies their internal strategy and if a market is indeed identified for this positioning.

So reasoning forward, we suggest the following action plan:

1. Agree on the benefit of setting up an international cooperation for the marketing and communication on HTR in 2014
2. Initiate a collaborative study of the global HTR market for electricity, cogeneration, polygeneration; the market study should be detailed by industrial sector, heat temperatures, and identify business leads globally
3. Agree on the positioning (e.g. focus on industrial cogeneration and polygeneration, extension of the offer for SMR designs, etc.)
4. Define and implement a global marketing and communication plan through usual media; target audiences should be policy makers,
key nuclear utilities, business leads and the general public.

5. Monitor the results and coordinate marketing and communication actions

The marketing and communication on HTRs can only be carried out by nuclear vendors who are to sell their designs. Research centres, universities, component suppliers should support this effort by amplifying this communication. We recommend the creation of a dedicated international organisation gathering HTR vendors to implement this action plan and monitor the achievements.

These ideas remain recommendations to be widely discussed. As of today, the fate of HTR seems however fragile and requires an immediate and ambitious action to secure a global commercial uptake.

V. CONCLUSION

This paper aims at building a wide, cooperative consensus to align the HTR marketing globally. 2014 is a cornerstone year for HTRs. The momentum from the past successes until the 80s starts to decline, after twenty year of restructuration and difficulties in the nuclear sector worldwide.

A strong, coordinated marketing and communication action is crucial to activate the demand for HTR worldwide. Isolated efforts remain inefficient. As long as no commercial plant is ordered, HTR will remain a nice idea. All HTR vendors have a shared interest to succeed in finding a market for the designs they have invested in. The global market window has opened in the 2000s with the nuclear new builds in emerging countries and should expand with the replacement of ageing capacities in industrialised countries. The market window should start shrinking in the 2030s.

Addressing the market demands to clarify the unique selling points of HTRs. What makes HTR unique is their ability to produce high-temperature, low-carbon, secure heat. This HTR heat can usefully complement gas cogeneration and serve as a basis for polygeneration clusters. It can as well be used for high thermal efficiency electricity generation.

In any case, HTRs are in a challenger position in all market segments it could target. Bringing HTRs to their market has a cost and a risk, which concerns all HTR vendors. HTR vendors have a unique and timely opportunity to adopt a new approach to the market through an international marketing and communication collaboration. This is in our opinion the unique way to achieve a critical mass and activate the demand for HTRs. HTR may then become a nice example of strategic, coordinated move for a commercial success.

REFERENCES

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