KAZAKHSTAN UPSTREAM OIL AND GAS
TECHNOLOGY AND R&D ROADMAP

MAY 2013

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A COLLABORATIVE INDUSTRY STRATEGIC FRAMEWORK TO DRIVE THE TECHNOLOGY DEVELOPMENT VISION OF THE KAZAKHSTAN UPSTREAM OIL AND GAS SECTOR

A pragmatic steer for technology development

"I fully support the proposal to develop a roadmap to strengthen local R&D capacity. It is important to know what resources and technologies are needed to meet the challenges, then which [Kazakhstan] institutions and enterprises need to be involved in tackling each challenge, and who has to be trained in the required disciplines."

President Nursultan Nazarbayev emphasises the need for a Kazakhstan upstream oil and gas technology and R&D roadmap at the Foreign Investors' Council in May 2011.

"I firmly believe that technology roadmapping should be adopted by the industry as an integral part of the planning process. It provides decision-makers with a means to identify, evaluate and select the strategic technological objectives that will deliver most value to Kazakhstan. It is a comprehensive tool that increases collaboration, knowledge sharing and new partnerships and reduces the risk of costly investment in less appropriate technology and R&D."

Matthias Bichsel, Projects & Technology Director, Royal Dutch Shell plc

Collective industry effort

I would like to thank those at Shell who took part in this project plus their numerous industry colleagues for their outstanding efforts at every stage of this exciting project. Since the start of this project in 2010 more than 100 industry representatives have contributed to the work, with a total of more than 300 involved in the workshops, interviews and expert panels.

Engagement and collaboration have been the bywords of the roadmapping project as the whole upstream industry has made unprecedented efforts to cast fresh light on the demanding combination of challenges that exists in Kazakhstan.

This was a unique opportunity for R&D organisations in Kazakhstan to interact directly with operators and service companies from oil fields all over the country and to share knowledge and experience.

We should continue the exercise by holding regular expert meetings and by introducing a systematic annual cycle of interaction among the academic community, operators and service companies.

Campbell Keir, Country Chairman, Shell Kazakhstan











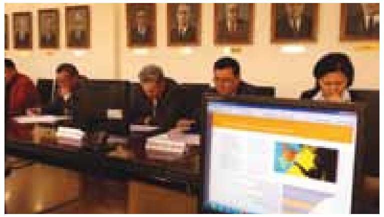


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THERE ARE A LOT OF GOOD IDEAS IN THE REPORT. THE AMOUNT OF WORK DONE IS REMARKABLE AND THE OUTCOMES ARE IMPORTANT (Schlumberger).

I THINK YOUR TEAM HAS DONE AN EXCELLENT JOB OF REDUCING WHAT WAS AN EXTREMELY COMPLEX SET OF ENGAGEMENTS INTO CLEAR RANKED RECOMMENDATIONS – WELL DONE. (Petrofac).

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"A GOOD PIECE OF WORK, IT CAPTURES THE ESSENCE OF THE ISSUES. IT HAS SAVED THE KAZAKHSTAN INDUSTRY YEARS OF WORK AS IT WILL SPEED UP THE GROWTH OF THE LOCAL INDUSTRY (Roadmap Workshop, Sept 2012).

Executive summary

Capital and technology-intensive industry

Oil and gas is among the most capital and technology intensive of all industries, and the role of technology innovation in aiding the discovery of economically viable new reserves and improving the efficiency of resource extraction is critical. Investments in R&D, aimed at supporting vital Kazakh oil and gas projects, will also help to realise the country's broader industrial and economic potential. But for innovation to be effective, research and development priorities must be business-driven and in line with the upstream industry's needs.

In order to help Kazakhstan focus its R&D efforts and to contribute to the government's innovation agenda, Shell undertook to work with the entire industry and to lead the development of the Kazakhstan upstream oil and gas technology and R&D roadmap. A coherent picture of the oil and gas sector is a prerequisite when making high-level decisions. When the industry has to decide which technology alternatives to pursue, how quickly they are needed, or how to coordinate the development of multiple technologies, roadmapping is essential to controlling capital expenditure and ensuring cost-efficient R&D activities.

Following the pragmatic steer from the President of Kazakhstan, Nursultan Nazarbayev, the industry has collectively supported the formulation of technology and research priorities, which is essential to ensuring that common industry challenges are addressed effectively.

Since the start of this initiative in 2010 more that 100 industry representatives have made valuable contributions to the roadmap development – more than 300 industry representatives were involved in the workshops, interviews and expert panels. This was a unique opportunity for Kazakhstan R&D organizations to interact directly with operators and service companies from oilfields throughout the country and to share knowledge and experience and develop a better understanding of the technology challenges faced by the industry. The project has demonstrated the potential for improved knowledge sharing through structured industry forums and workgroups. The academic institutes possess a wealth of knowledge and are passionate about contributing to the oil and gas field developments in Kazakhstan. Improved communication is bound to help unlock the potential that exists within this community.

The roadmapping project achieved a number of important objectives. The industry collectively identified, screened and ranked the main technology challenges based on the potential financial benefits that could result if they are successfully addressed.

Potential technology solutions were also identified and assessed in terms of their impact on solving the challenges and on their attractiveness to the nation, which included consideration of local R&D and industry opportunities.

The fifteen prime challenges identified have a significant value associated with them, assuming appropriate solutions can be implemented in the required timeframe. The challenges were assessed using a standard industry financial model. The categories considered were capex reduction, opex reduction, increased production, increased ultimate recovery, reduced environmental risk and improved personal safety. The indicative values of the fifteen challenges varies between US$2 billion and US$7.5 billion. Clearly the total value of successfully addressing all of the 15 challenges would be several tens of US$ billions.

Technology solutions

Over 230 possible individual technology solutions were identified to address the fifteen prime challenge areas. These individual solutions were grouped, where appropriate. The relative value ranking of these (grouped) solutions was determined on the basis of their likely ease of implementation, local industry opportunities and their power to develop intellectual capacity in Kazakhstan. This solution overview (together with a variety of other output from the project over nearly three years) formed the basis of the fifteen topic roadmaps. The topic roadmaps add detail to the challenges and indicate the best way of overcoming them in the future. It is very clear from these topic roadmaps that there exists a wealth of opportunities for local industry and academia in Kazakhstan – and also a number of areas where skills need to be developed.

The topic roadmaps are technology-focused and they provide guidance for technical developments in the upstream oil and gas industry. It will be important for the academic community, local industry, the operators and service companies to work together now in genuine partnership and to plan ahead to address the challenges facing the industry. Optimising this partnership and the way it works will be of immense benefit to Kazakhstan; the roadmap contains recommendations about how to do this, in terms of R&D focus, local industry opportunities and skills development. One of the next steps will be to undertake a more detailed local capacity assessment in the highest-priority technology areas.

There is a strong argument for the industry adopting technology roadmapping as an integral part of the planning process. It provides decision-makers with a good way of identifying, evaluating and selecting the strategic technological objectives that will deliver most value to Kazakhstan. It is a comprehensive tool that increases collaboration, knowledge-sharing and new partnerships and reduces the risk of costly investment in less appropriate technology and R&D.

The main benefit of technology roadmapping is that it supplies information to help make better technology investment decisions and provides a collaboration framework around which to build links between the industry, government and academia.

Creating a successful alliance of industry members is the key to developing the full spectrum of technologies that future markets will demand – only by working together will technology challenges be converted into technology solutions.

THE MAIN BENEFIT OF TECHNOLOGY ROADMAPPING IS THAT IT SUPPLIES INFORMATION TO HELP MAKE BETTER TECHNOLOGY INVESTMENT DECISIONS.

The main messages

The roadmapping project has gathered and carefully analysed information from a wide range of expert sources – and there has been a strong logic applied to what has been a highly rigorous process.

Important points have emerged throughout the project from the various visits, meetings and workshops. However, the main messages only crystallised at the end of the work, once the challenges facing the upstream oil and gas industry in Kazakhstan, and the solutions to them, had been properly assessed. This is reflected in this document with the main messages fully presented in the last section, 'addressing the challenges'. The section comprises three themes covering R&D focus, industry opportunities and skills development.

In summary

R&D focus – a need for more communication and better planning on a national scale

A wide variety of R&D focus areas were identified during the course of the roadmapping project. Four areas stand out: correlation of NMR core data from SCAL studies with well logs; the use of non-metallic materials in highly corrosive environments; sulphur storage and its applications; and bio- and nano-sensors for environmental monitoring.

It would be reasonable to expect R&D proposals from the Kazakhstan academic community to centre around these areas and, in time, to see Kazakhstan develop strong capabilities in the NMR interpretation of complex rocks, in the use of non-metallic pipelines and in the utilisation of sulphur (sour gas to power was seen as a particularly interesting opportunity in this area). Kazakhstan is already well recognized for its environmental services and, with more R&D, should realistically aim to become an industry leader in this area.

The process of identifying R&D priorities that was begun during the roadmapping project is one that must be carried out on a continuous basis and become more focused and directed. There is a strong case for the establishment of a council at government level, including representatives from industry and the academic community, tasked with national R&D strategy development and planning in Kazakhstan. R&D in Kazakhstan suffers severely from a lack of communication and collaboration, especially between the parties seeking solutions and those able to generate them: one of the more striking features to emerge from the roadmapping project is the relatively poor communication between the upstream oil operators and the Kazakhstan academic community. An organization with authority is needed to control and coordinate upstream oil and gas R&D in Kazakhstan, to provide focus, to determine funding and monitor the outcomes of the work.

It would be realistic to expect the Kazakhstan government/industry R&D planning process to be founded on the established principles used to plan and manage R&D by many large technology-oriented companies. Translated onto a national scale, the process might be run along the following lines:

- The major operators and service companies would each outline their views on the prime challenges faced by their organisations on an annual basis – they would be encouraged to provide information on the nature and status of the challenge, its urgency and the size of the prize.
- The information, once analysed and consolidated, would be made widely available to the academic community and used to shape R&D proposals.
- Good proposals would be likely to feature international and in-country academic partnerships; they would also contain well-developed project cost estimates and timeframes, and go as far as describing technology demonstration and field trials requirements.
- Proposals received positively would be progressed in the first place by (1) a sharing of relevant data and information from the industry side with the R&D proposer and (2) the setting of suitable milestones and key performance indicators.
- Assuming good progress of the work, it would be incumbent on the industry organisation that set the challenge to facilitate field trials of the new technology solution.
- The reasons behind unsuccessful proposals would be made clear and used to drive improvements in the sections of the academic community involved.

The process just outlined addresses a number of the issues judged by participants

in the roadmapping project to be hindering R&D in Kazakhstan – lack of focus, limited collaboration, poor understanding by the academic community of the challenges and the opportunities within the industry, and the difficulty of fixing up field trials were foremost among them. Additional enablers highlighted during the course of the roadmapping project include the provision of guidance to academics on the commercialization of R&D; the relaxation of local content regulations in selected emerging technology areas; measures to ease the import of equipment for R&D purposes and field trials; and a facilitation of visits,

perhaps extended stays, by international technology experts. The establishment of

centres of excellence and technology parks was another measure favoured by many in

the industry. Finally, there was a call for better understanding of international patent law and clearer recognition of intellectual property rights.

Industry opportunities – the need for a sound financial case and business model

Throughout the course of the roadmapping project, attempts were made to gather views on the sort of local companies that could make a positive difference to the way the upstream oil and gas industry operates. After much careful analysis, it was concluded that the most realistic industry opportunities lie in the area of steel and concrete structural design and fabrication, the provision of upstream chemicals and well sand-screen manufacturing.

Further opportunities were highlighted: the manufacture of corrosion-resistant alloys; provision of SCAL services; jack-up rigs for cold climates and ice-scouring design; and sulphur storage, transport and products. However, there were thought to be blocks to progress in each of these cases. The high cost of corrosion-resistant alloys could theoretically be allayed by setting up local production facilities; however, manufacturing (and testing) capabilities in Kazakhstan were thought to be lacking. In the case of SCAL services, for which there is strong local demand, there has been a lot of investment in the last year, but there are further upgrades desired by the operators. There was a good deal of discussion around the subject of jack-up rigs for cold climates and ice-scouring-resistant design. However, technology in these areas is immature globally and both will require a combination of R&D and heavy industry participation to move the technology forward; as such neither offers immediate industry opportunities. Sulphur storage, transportation and products seem like perfect opportunities for Kazakhstan to build local capability. But two critical things must happen before these will be realised. There needs to be overhaul of the regulations surrounding the use of sulphur; and the markets in Kazakhstan need first to be created and grown.

While the roadmapping project has succeeded in identifying real opportunities for local companies in Kazakhstan, in the longer term a more formal and rigorous approach is needed to maintain a continuous flow of similar ideas. Ideally, this ought to be overseen by a strong government/industry council. Its role would be, in the first place, to invite oil and gas operators to provide regular information about their materials, products and services requirements, the scale of these requirements and their timing. This market research would be made available to the relevant international and local companies who would subsequently be invited to put forward local manufacturing and service solutions – ideally with strong local job creation, technology transfer and supply chain development credentials.

A sound financial case and an effective business model (including skills development and training needs and based on, for example, a joint venture, licensing agreement or a wholly foreign-owned, locally registered company) would be a condition of the opportunity gaining government support. For such a process to work, there needs to be good communication and open dialogue between government and industry. There is a widespread view that there needs to be less bureaucracy surrounding the import of goods and equipment and that the business regulatory environment has to become more fluid and transparent and easier to negotiate.

Learning and skills development in Kazakhstan

A strong, consistent message emerged from the roadmapping project that – in common with the oil and gas industry worldwide – there is a shortage of talented graduates in the basic sciences, engineering and mathematics in Kazakhstan. Further, the industry would ideally like to see young people coming forward with qualifications in applied disciplines such as geophysics, reservoir engineering, production technology and production chemistry. There is a similar requirement for more well-trained technicians and skilled workers to perform important roles in construction, and operations and maintenance.

More than one academic made the point that the loss of the best graduates to jobs in other industries and to other countries was also a problem; though, this in one that is perhaps outside the scope of this roadmapping project.

Leading universities in Kazakhstan are undoubtedly producing good graduates, based on a model with some key features:

- high course admittance standards
- well trained staff
- good working links with overseas seats of learning
- degree qualifications certified by leading institutions
- relevant courses devised in collaboration with industry
- visiting lecturers from overseas and industry guest speakers
- internships with leading oil operating and service companies active in Kazakhstan.

More could undoubtedly be done in all of these areas, especially given more funding. One area that stands out is the training and mentoring of staff to raise teaching standards. Post-graduate training was seen as an area with considerable scope for improvement. The teaching of post-graduate courses is an area where industrial involvement is paramount, for example, in providing expert supervisors and access to field data on which to base relevant research studies.

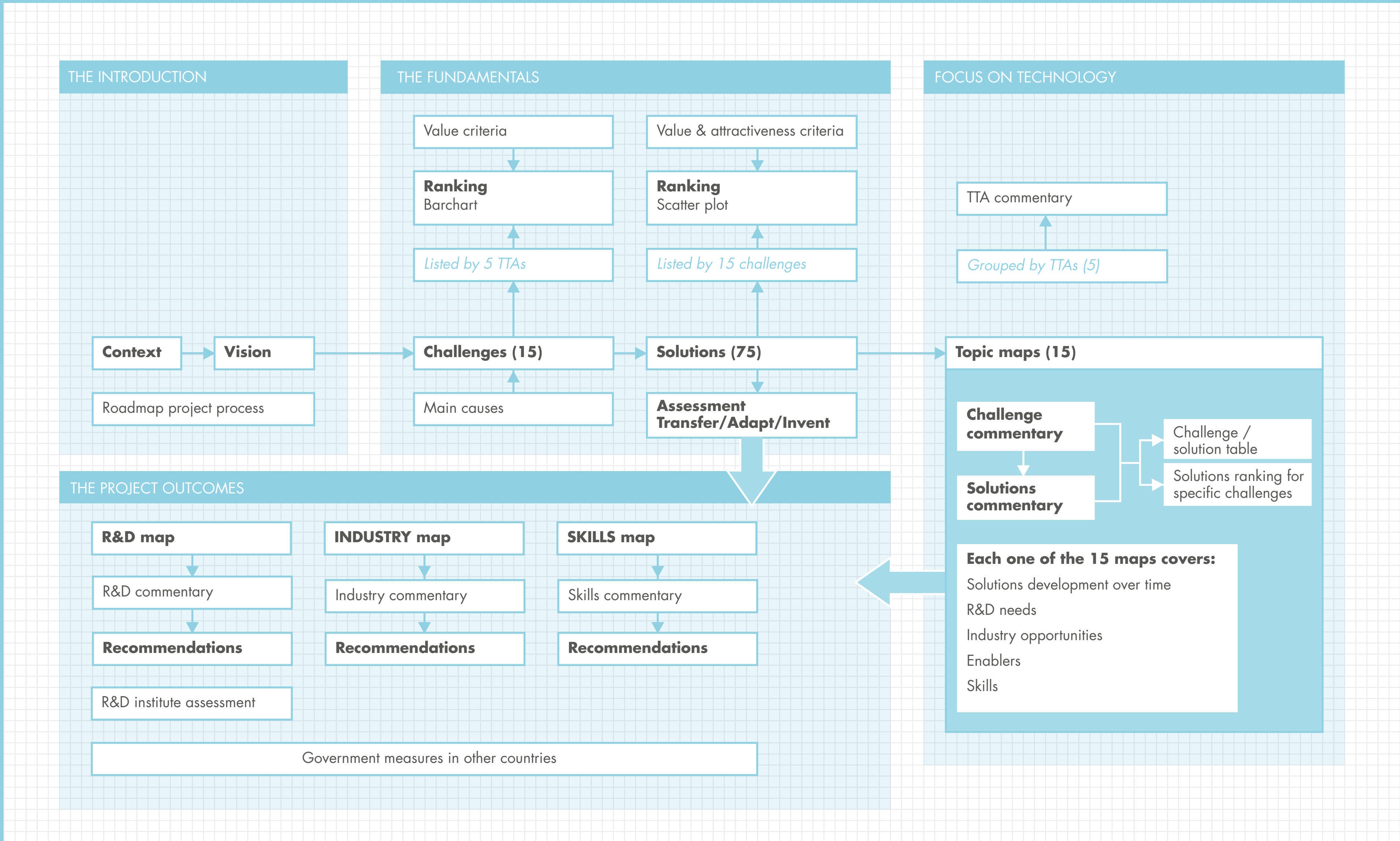
Strengthening the links between the academic community and industry must be a constant objective. There must be a partnership, under government leadership, between academia and industry with the aims being to:

- provide more detail around the question of skills requirements, and bring clarity to the gaps between graduate demand and supply
- increase industry involvement in curriculum development
- create more industrial placements
- raise the involvement of industry professional bodies like the SPE and SEG, who both offer highly relevant skills development programmes
- encourage the holding of technical conferences in Kazakhstan covering the main challenges faced by local operators
- promote the upstream oil and gas industry as an exciting and rewarding place to work.

Contents

Structure of the document

This document is in a format that reflects the way the project has been conducted. First of all there is some context for the roadmap project, notably a list of the key contributors and some of their views on the project. The focus then shifts to the upstream oil and gas industry's ambitions, these based on the vision provided by President Nursultan Nazarbayev. Next there is a section on the roadmap development process, before attention is turned to the technology challenges facing the industry in Kazakhstan – and their possible solutions. The challenges and solutions were assessed in a variety of ways, and the main findings are summarised here. This leads into the topic maps for each of the main challenges. These plot the technology developments deemed necessary to generate the solutions called for by the industry. The roadmap comes full circle, finally, when all of the information generated during the project is examined in light of the key issues outlined at the start – R&D focus, industry opportunities and skills development in Kazakhstan. There are maps for each of these areas, which point the way forward for the upstream oil and gas industry in the country.



The structure of the document

Vision

Direction and reassurance

A good roadmap shows you precisely where you are, where you want to go – and how to get there. It provides direction and constant reassurance that you are on course to reach your objective.

Roadmaps of our highway infrastructure enable you to build a picture of the geographical landscape and help you plot the most efficient path through it. In much the same way, an industry roadmap provides a picture of the complex interconnections and the different layers that make up the industry landscape. Arguably of more value, the roadmap also highlights the challenges and opportunities within a given area and indicates the best way to overcome the former and take advantage of the latter.

The Kazakhstan upstream oil and gas technology and R&D roadmap has been developed within the framework of the Foreign Investors' Council (FIC) with the support of Nursultan Nazarbayev, President of Kazakhstan and Chairman of the FIC.

The roadmapping project, which began in May 2010, has been led by Shell and supported by numerous key stakeholders in the industry. The international operating companies (IOCs), the smaller independent operators and the international service companies (ISCs) working in Kazakhstan have all been heavily involved at some stage. The state oil company KazMunayGas (KMG) and the Kazakh Institute of Oil and Gas (KING) have played vital roles throughout the project, and the county's leading universities and industry organisations have provided further local intelligence. Shell's stance from the beginning has been that this should be a collaborative effort and the outcome should represent the collective view of the entire upstream oil and gas industry in Kazakhstan.

Crystal clear

Crucial to the success of the project was defining an industry goal – a vision – around which to anchor the roadmap.

President Nazarbayev has a crystal clear vision for Kazakhstan. It is one of sustained growth fuelled by a diversified, innovation-led economy that capitalises on the nation's considerable hydrocarbon resource base.

As early as 1997, the President described the oil and gas extraction industry as the "vital base of the country and the starting point from which to begin building Kazakhstan's structural policy."

Participants in the present roadmapping project were keenly aware of the importance placed on the industry by the President when, as part of the project, they advanced their vision for the Kazakhstan upstream sector.

The vision is of an industry that maximises the value of its oil and gas resources through world-class R&D and strong local companies capable of delivering high-quality materials, equipment and services to the international standards demanded by major resource holders and field operators.

Contained within this vision is the need for a strong policy framework and fiscal incentives to encourage technology R&D and innovation in Kazakhstan. Further, there is the expectation that the government and the industry will work closely together to set priorities and indicate where research efforts and resources should focus.

On the issue of technology development, there is broad agreement that it makes sense for Kazakhstan, where possible, simply to adopt upstream technology solutions established elsewhere – to be an astute fast-follower. However, it will also be necessary to take existing technologies and adapt them to meet specific challenges, or, in some cases, to invent new technology, either alone or in collaboration with other organisations around the world.

The vision is also very clear that, assuming Kazakhstan companies respond positively to the opportunities presented to them, they will ultimately be able to compete with the major international technology providers in a range of areas. It must be stressed, however, that underpinning this entire vision, there has to be a drive within Kazakhstan to develop the professional skills and competences essential to maintaining a deep and permanent oil and gas industry resource base within the country.

Roadmap development

Project objective

The objective of the roadmapping project was to take the vision first outlined by the President and later developed by the industry and to formulate a way of realising it. It was to provide a route by which Kazakhstan could elevate its upstream oil and gas industry, ultimately to the benefit of the entire economy.

In more detail, the project set out to:

- improve our understanding of the challenges faced by the Kazakhstan upstream oil and gas industry and thence to prioritise them;
- identify potential solutions to the challenges and examine their implementation in Kazakhstan;
- provide direction and focus for upstream oil and gas R&D efforts within the country;
- highlight opportunities for local companies to contribute more to the upstream industry and thereby grow and develop their businesses nationally and internationally;
- identify areas where further education, training and skills development are required within the Kazakhstan workforce; and
- put forward a series of actions or enablers, many but not all of them government-policy measures, with the power to accelerate progress toward the vision.

Engagement and collaboration have been the bywords of the roadmapping project over the past two to three years, as the whole upstream industry has made unprecedented efforts to cast fresh light on these issues. The work progressed through a series of stages and involved discussions, visits, studies and, not least, highly interactive workshops attended by senior representatives of the many companies and organisations involved in the industry.

ENGAGEMENT AND COLLABORATION HAVE BEEN THE BYWORDS OF THE ROADMAPPING PROJECT OVER THE PAST TWO TO THREE YEARS, AS THE WHOLE UPSTREAM INDUSTRY HAS MADE UNPRECEDENTED EFFORTS TO CAST FRESH LIGHT ON THESE ISSUES.

Stage 1 – challenges and solutions

The roadmapping project began in 2010, when Shell led a technology mapping exercise for the upstream oil and gas industry in Kazakhstan. The aim was to provide guidance and focus for technology development in Kazakhstan, vital to the efficient and sustained growth of the industry. Central to Stage 1 was a workshop bringing together more than 150 experienced professionals from industry, government and academia. Their work led to a list of 15 prime challenges in five technology target areas. Potential solutions, which were eventually distilled to fewer than 50 main ones, were also identified. These challenges and solutions form the foundation of the Kazakhstan upstream oil and gas technology and R&D roadmap.

The main outcomes of this stage were presented to the FIC in May 2011. They are reported in:

Report A issued by Shell (SR.12.13425): Kazakhstan R&D Strategy Mapping Initiative

Stage 2 – assessing the current situation

Stage 2 began with a more detailed analysis by subject matter experts from the IOCs, KING and Kazakhstan's R&D institutes and universities of the challenges and solutions identified in Stage 1.

The same community, reinforced by representatives of the ISCs, then carried out a technology readiness study. This had several objectives: to evaluate the global maturity of the proposed technology solutions; to see how mature the same technology solutions were in Kazakhstan; to assess the feasibility of implementing the solutions in Kazakhstan; to highlight issues that might hinder implementation; and to estimate the amount of time necessary to put solutions in place.

KING provided further valuable input in a detailed report of the main technologies already being applied in Kazakhstan's oil and gas fields.

Finally, a team of experts, mainly from the IOCs, visited universities and R&D facilities across the country in an effort to assess their capabilities, identify opportunities for greater collaboration with the industry and explore potential initiatives designed to support that development.

The main outcomes of this stage were reported in:

Report B issued by Shell (SR.12.13425): Overview of Technology Challenges

Report C issued by Shell (SR.12.13425): Technology Readiness Assessment

Report D issued by Shell (SR.12.13425), created by KING: Technologies Currently Applied in Kazakhstan

Report E issued by Shell (SR.12.13425): R&D Visits Overview

Stage 3 – the way forward

The work of stages 1 and 2 was consolidated in Stage 3 at a workshop in June 2012. The community that began the process in 2010 reconvened (133 attendees on this occasion) to review the mass of information generated up until that point and to form a collective view on the way forward for the industry. For each of the 15 challenges, the workshop participants set technology milestones, defined R&D focus areas and listed local industry opportunities.

The participants at this workshop also looked at the crucial question of enablers: actions with the potential, for example, to ease the import of technology into the country, incentivise R&D and foster wider collaboration with companies and organisations in other countries. Policy measures of this kind used by four other countries, Brazil, China, Malaysia and Norway, were also examined at this stage.

The main outcomes of this stage were reported in:

Report F issued by Shell (SR.12.13425): Roadmap Technical Workshop Report

Stage 4 – outcomes and actions

Stage 4 has been all about convergence and has involved filtering all the information, intelligence and analysis generated during the process in order to develop a clear set of compelling messages for senior policy-makers in Kazakhstan.

This could be viewed as the communication stage of the process, when the accent turned from technology to the question of what best to do next, what actions to take. It was during Stage 4 that the roadmap really began to take shape.

Some of the work was undertaken at two smaller workshops (15–30 participants), which were facilitated by technology roadmapping consultants from the University of Cambridge, UK. Representatives from the IOCs, KING, KMG and the government of Kazakhstan worked together to review the information contained within the six earlier reports (A – F), to strengthen the links between the different layers within the roadmap, to set timelines and to establish technology priorities. The final presentation of the roadmap (as contained in this document) was undertaken mainly by subject matter experts from Shell with the support of a number of individuals and groups from a wide cross-section of the industry.

STAGE 4 HAS BEEN ALL ABOUT CONVERGENCE AND HAS INVOLVED FILTERING ALL THE INFORMATION, INTELLIGENCE AND ANALYSIS GENERATED DURING THE PROCESS IN ORDER TO DEVELOP A CLEAR SET OF COMPELLING MESSAGES FOR SENIOR POLICY-MAKERS IN KAZAKHSTAN.

Challenges

Fundamental to the project

Identifying the common challenges facing the upstream oil and gas industry in Kazakhstan has been a fundamental element of the roadmapping project. Indeed, the early stages of the work focused almost entirely on this issue. Vital to building our understanding were, first, a series of detailed presentations from the IOCs and KMG explaining the difficulties that surround exploration and production in Kazakhstan's main oil provinces. Following these presentations, workshops were held to analyse the reported difficulties and ultimately convert then into a set of agreed challenges. The findings of this early work are covered in Report B, Outline of the Technology Challenges. This report was extensively reviewed by experts from across the industry and subsequently redrafted immediately prior to the June 2012 roadmap technical workshop.

The roadmapping project identified 15 prime technology challenges facing the upstream oil and gas industry in Kazakhstan. These fall into one of five categories, or technical target areas (TTAs), that span the entire upstream industry from the initial exploration for oil and gas, through field development (reservoir and facilities) to production operations.

1	**RESERVOIR CHARACTERISATION**
1.1	Seismic data acquisition and processing
1.2	Reservoir description – geology, rock and fluid interpretation
1.3	Well logging and in-well monitoring
1.4	Core analysis and data interpretation
1.5	Fluid property analysis
2	**FIELD EQUIPMENT**
2.1	Corrosion plus equipment and materials for sour service
2.2	Operating in the ice and during cold weather
2.3	Management of sulphur
3	**FLUID FLOW AND PROCESSING**
3.1	Flow assurance and sand control
3.2	Water management
4	**WELLS AND FIELD MANAGEMENT**
4.1	Drilling and well costs
4.2	Field management: optimised recovery including IOR/EOR
5	**HSE AND OPERATIONS**
5.1	Emergency response and disaster recovery
5.2	Operational HSE risk reduction under sour production conditions
5.3	Environmental impact

The causes of the challenges facing the upstream oil and gas industry in Kazakhstan

The 15 challenges all stem from the same basic factors relating to the subsurface characteristics in Kazakhstan (the geology and hydrocarbon fluid composition) and the conditions on the surface within the country (the geography and the climate).

Subsurface

Complex reservoirs – roughly 80% of Kazakhstan's oil and gas reserves are in sub-salt carbonate or terrigenous sediments with significant heterogeneity. Recent discoveries like Zhanazol, Alibekmola, Urikhtau, Kozhasai, North Truva, Karachaganak, Tengiz, Korolevskoye and Kashagan all fall into this category.

High temperatures and pressures – these are common and certainly exist in the country's largest field, Kashagan.

High H_2S reservoirs – some of the highest reservoir H_2S levels in the world have been recorded in Kazakhstan. Tengiz crude oil contains approximately 0.5% by weight sulphur; the gas is 12.5% H_2S on a molar basis. Kashagan has more than 15% H_2S in the produced gas.

Surface

Transport – there is no sea route into Kazakhstan and so importing some of the latest drilling assets and large items of plant into the country is far from straightforward. Local transport infrastructure in some areas is also in need of improvement.

The natural environment – Kazakhstan experiences massive swings in temperature, with arctic conditions during the winter. Offshore, the challenge in Kazakhstan is working in shallow water, as some advanced exploration techniques do not work well in this situation. (It is ironic that the global industry, of course, sees deepwater as the big challenge.) Additionally, ice formation and very low temperatures at the seabed give rise to subsea infrastructure issues, notably the scouring of oil and gas pipelines.

IDENTIFYING THE COMMON CHALLENGES FACING THE UPSTREAM OIL AND GAS INDUSTRY IN KAZAKHSTAN HAS BEEN A FUNDAMENTAL ELEMENT OF THE ROADMAPPING PROJECT.

Ranking the challenges

In a separate exercise designed by roadmapping specialists from the University of Cambridge, the 15 challenges were ranked by technology experts, according to the impact that addressing them could have on the upstream oil and gas industry in Kazakhstan. Each of the challenges was rigorously assessed for its capacity to:

- reduce capex
- reduce opex
- increase production rate
- increase ultimate recovery
- reduce environmental and reputational risk
- improve personal safety.

Each of the challenges was scored on a scale of 0 – 5 for each of the six criteria and the total score divided by six to give an overall score of between 0 – 5 for each one.

The ranking process, in fact, used a standard industry financial model whereby the impact scores reflect real monetary values, as given in the table below. It is notable that these figures represent the savings or gains likely to be made across all of the fields, ie by the industry as a whole, in Kazakhstan.

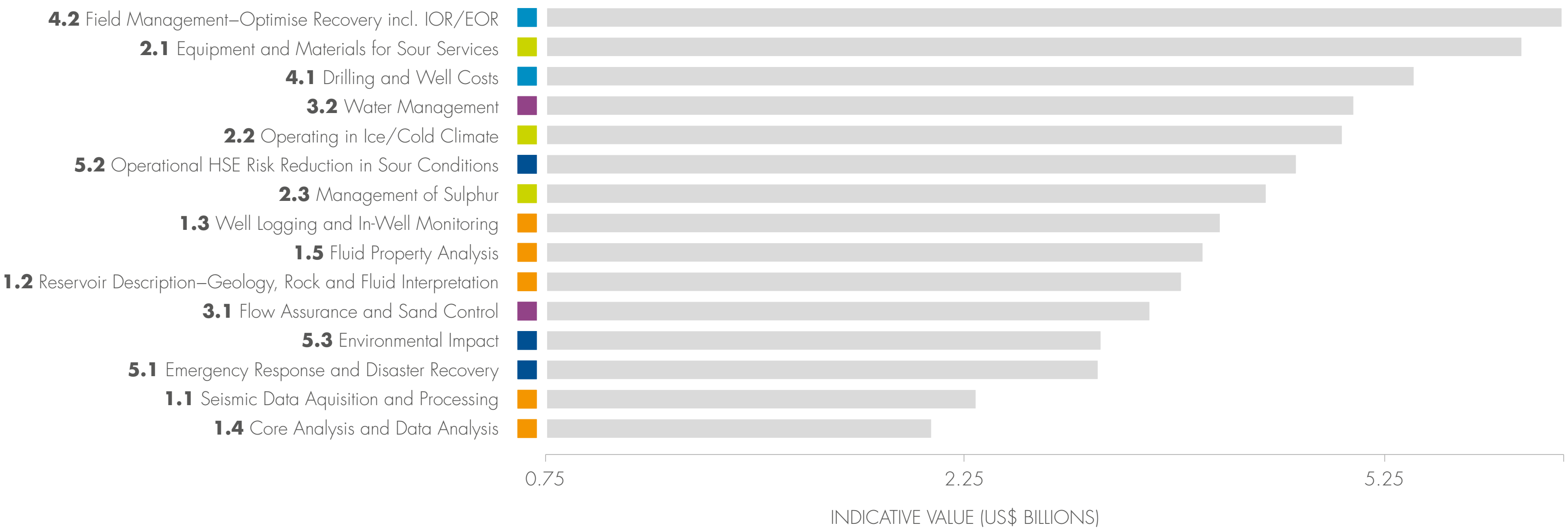
The results of the ranking exercise are shown opposite. It may come as no surprise to find that improved and enhanced oil recovery, equipment and materials for sour service, and drilling and well costs are judged to be the most pressing challenges facing the industry in Kazakhstan. These are followed by water management, cold weather operations, risk reduction in sour operations and the management of sulphur.

Again, using the same financial model, the overall impact scores may be converted to real values. On this basis, addressing successfully the challenge at the top of the ranking could result in a financial reward to Kazakhstan of somewhere in the region of US$ 7.5 billion; the challenge at the bottom of the list somewhere around US$2 billion.

IMPACT	0	1	2	3	4	5
Reduce capex US$ (millions)	No impact	<250	250 – 500	500 – 1250	1250 – 2500	>2500
Reduce opex US$/yr (millions)	No impact	<50	50 – 100	100 – 250	250 – 500	>500
Increase production rate boe/d (thousands)	No impact	<5	5 – 10	10 – 35	35 – 70	>70
Increase recovery boe (millions)	No impact	<15	15 – 30	30 – 90	90 – 180	>180
Reduce environmental risk	No impact	Slight	Minor	Moderate	Major	Gamechanger
Improve personal safety	No impact	Slight	Minor	Moderate	Major	Gamechanger

OVERCOMING ALL 15 CHALLENGES COULD RESULT IN A FINANCIAL REWARD OF TENS OF US$ BILLION.

Ranking the challenges



> IT MAY COME AS NO SURPRISE TO FIND THAT IMPROVED AND ENHANCED OIL RECOVERY, EQUIPMENT AND MATERIALS FOR SOUR SERVICE, AND DRILLING AND WELL COSTS ARE JUDGED TO BE THE MOST PRESSING CHALLENGES FACING THE INDUSTRY IN KAZAKHSTAN.

Technology solutions

The future of the industry

During the course of the roadmapping project, experts from all corners of the industry thought deeply about the 15 prime challenges facing upstream operators in Kazakhstan and came up with a total over 230 possible technology solutions to them.

The future for the upstream oil and gas industry in Kazakhstan is actually all about these solutions – it is the development and implementation of the solutions that will determine how fast and how far the industry progresses in the years ahead.

To help get to grips with these solutions, they were first assessed in terms of their value to the industry and their "attractiveness" within the broader Kazakhstan context, as explained below.

Ranking the solutions by their value and attractiveness

To make the ranking process more manageable, the 230 solutions were consolidated. This resulted in a group of 75 bundled solutions, which form the basis for much of the analysis underpinning this document.

The results of the ranking exercise – undertaken using an industry questionnaire and at a high-level workshop in early 2013 – are shown in the scatter plot opposite. (In fact, some of the 75 solutions were so closely linked they were ranked together and appear as a single point.) A full list of the solutions, to which the scatter plot can be referenced, is provided on pages 27-31.

The value of each of the solutions was computed from the value previously placed on the challenge to which the solution refers, combined with an expert assessment of the impact of that solution on the challenge – high, medium or low.

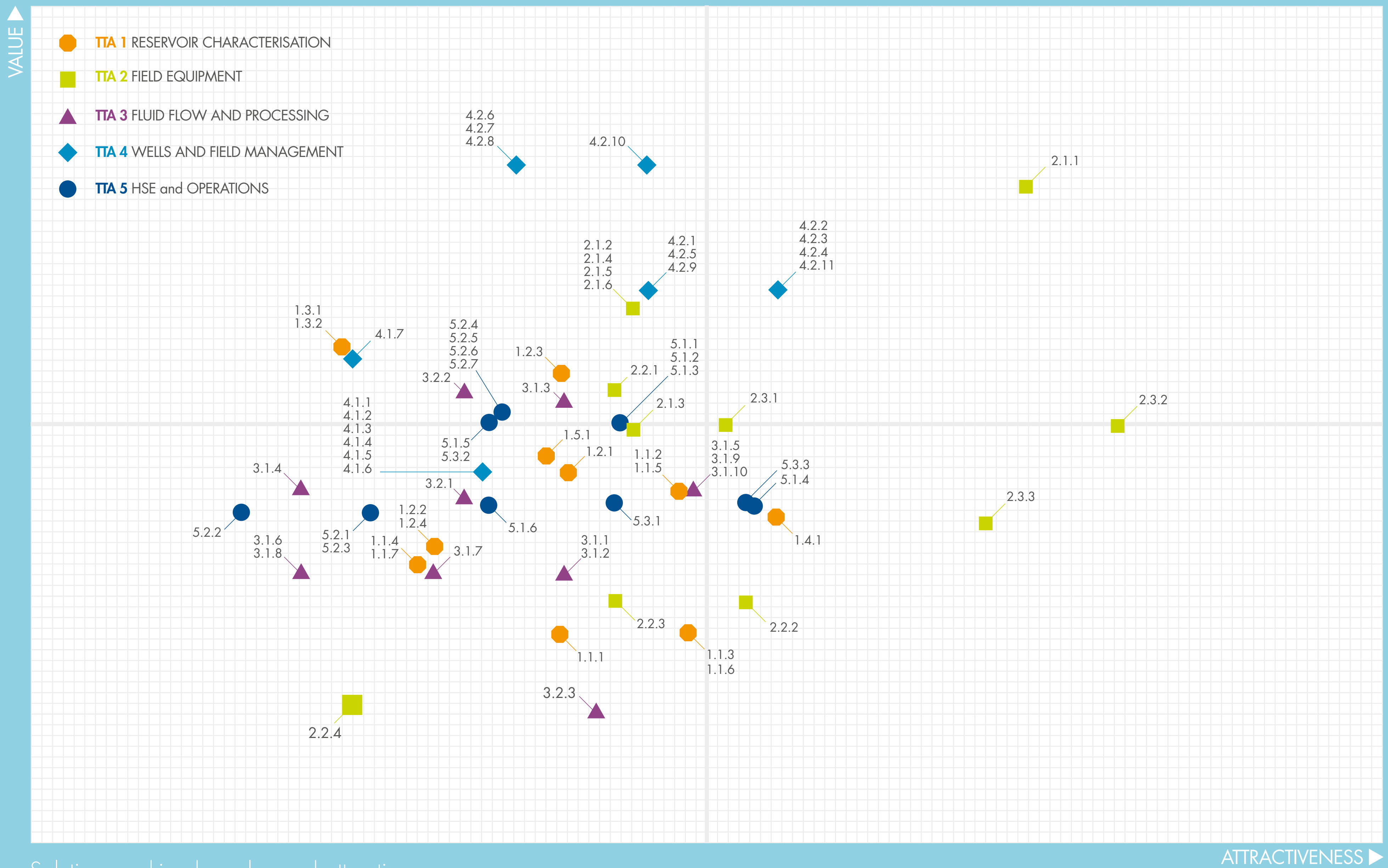
Establishing the broader attractiveness (to Kazakhstan) of the solution involved an assessment that was based on a series of criteria, each worth a maximum of 5 points and each given equal weighting:

- project costs to implement the solution – a low cost being most attractive;
- time to implement the solution – a short time being most attractive;
- opportunities for local industry – the greater the opportunities, the more attractive the solution;
- R&D effort needed to devise the solution – the more R&D effort required, in Kazakhstan, the more attractive the solution;
- the qualifications needed to devise the solution – the more expertise that local people will need to develop, the more attractive the solution.

The last two criteria are perhaps counter-intuitive. The assessment was made on the basis that the more R&D that is needed and the greater the training requirements, the more attractive is the solution. The point is that such solutions serve to raise the intellectual capacity of the nation, ie make Kazakhstan more capable of shaping its own future, at least as far as the oil and gas industry is concerned.

It could be construed that the best solutions for Kazakhstan are those towards the top-right of the chart. However, some solutions are linked; for example, seismic acquisition (1.1.1 & 1.1.2) will enable improved 4D seismic (1.1.4). Hence, care is needed to ensure complete capabilities are developed, not simply point solutions to a challenge. Some solutions appear very attractive; sulphur utilisation (2.3.3), for example. But the market for sulphur products in Kazakhstan will have to be developed in parallel with work in the area. Summarising, this ranking is merely a guide to priorities, and should be followed with care – in fact, all of the solutions here are important to some degree.

> IT IS THE DEVELOPMENT AND IMPLEMENTATION OF THE SOLUTIONS THAT WILL DETERMINE HOW FAST AND HOW FAR THE INDUSTRY PROGRESSES IN THE YEARS AHEAD.



Solutions ranking by value and attractiveness

Assessing the solutions by their mode of implementation in Kazakhstan

Just as important as ranking the solutions by their value and attractiveness was an assessment of what will be needed to implement the solutions in Kazakhstan. Firm input and opinion from across the industry was analysed in order to judge which technologies (1) could be simply brought into the country from outside, (2) could be brought in but would need to be significantly adapted to meet local conditions, or (3) would need considerable research and development in Kazakhstan to make them viable. The results are shown in the tables of the solutions on pages 17-21.

Solutions in category 1 have been described as **transferred** solutions, those in category 2 **adapted** solutions, and those in category 3 **invented** solutions. Now, even transferred solutions are likely to involve some technical input in the early stage of their general deployment. Thus, there is actually a technical R&D capability incline on which the solutions lie. Transferred solutions will need only low technical R&D input; invented solutions will need a high one.

While true innovation is to be commended, it makes great sense, if possible, to take advantage of technology that has been thoroughly researched and developed – and proven in use by others. There is much to be said for being a so-called fast-follower of technology. Powers of invention should be saved for challenges that are unique to Kazakhstan, or where the country has outstanding capabilities.

Depending on the nature of the technology solution, different parties will have roles to play in their implementation. The operating companies, the international service companies, local industry and the academic community may all be involved to some extent or another. Rarely is a single party likely to make an impact on its own, a fact made clear in the table and which reinforces the message that progress in technology terms in Kazakhstan will be fastest when there are good communications and effective collaboration between the various stakeholders in the upstream oil and gas industry.

The assessment is intended to help different parties better understand what is going to be required to bring the Kazakhstan upstream oil and gas industry into line with those in leading countries around the world. Most importantly, it provides an indicator of where effort can best be applied to enhance the implementation of key new technology solutions in Kazakhstan.

The findings of this assessment have been combined with those of the topic mapping exercise to provide the input for the R&D, local industry and skills maps. From these have been derived the main findings of the overall Kazakhstan upstream oil and gas technology and R&D roadmapping project.

The technology solutions and their mode of implementation

1	RESERVOIR CHARACTERISATION	TRANSFER/ ADAPT/ INVENT	OPERATORS	ISCs	LOCAL INDUSTRY	ACADEMIA
1.1	**Seismic data acquisition and processing**					
1.1.1	Seismic acquisition for shallow waters	A		■	■	■
1.1.2	Seismic acquisition for enhanced imaging	T		■	■	■
1.1.3	Non-seismic solutions for reservoir evaluation	A			■	■
1.1.4	4D seismic	A	■	■		■
1.1.5	Seismic processing for improving imaging	T		■	■	■
1.1.6	Integration of seismic & other data	A	■		■	■
1.1.7	Advanced seismic inversion	T	■		■	■
1.2	**Reservoir description – geology, rock and fluid interpretation**					
1.2.1	Basin modeling	A	■			■
1.2.2	Seismically constrained geological models	T	■			■
1.2.3	Integrated static & dynamic models	T	■		■	
1.2.4	Advanced seismic interpretation techniques for subsalt carbonates	A	■		■	■
1.3	**Well logging and in-well monitoring**					
1.3.1	Reservoir characterization (permeability, pressure, contact) and fluid typing using wireline tools	T		■		
1.3.2	In-well monitoring for observing reservoir dynamics	T		■		■
1.4	**Core analysis and data interpretation**					
1.4.1	Special core analysis facilities in Kazakhstan	A			■	■
1.5	**Fluid property analysis**					
1.5.1	Fluid characterisation methods	A			■	■

The technology solutions and their mode of implementation

2	FIELD EQUIPMENT	TRANSFER/ ADAPT/ INVENT	OPERATORS	ISCs	LOCAL INDUSTRY	ACADEMIA
2.1	**Corrosion plus equipment and materials for sour service**					
2.1.1	Corrosion resistant materials for Kazakhstan conditions	A		■	■	■
2.1.2	Fiber optic leak detection techniques	T			■	
2.1.3	Leak reduction and elimination	A		■		■
2.1.4	Control of sulphur production by reinjection	T				■
2.1.5	Sour gas equipment	T			■	■
2.1.6	Local Production of Corrosion inhibition chemicals	A				■
2.2	**Operating in the ice and during cold weather**					
2.2.1	Jack-up rigs capable of working in Arctic conditions all year round	I		■	■	■
2.2.2	Offshore installations to work uninterrupted in Arctic conditions	A			■	■
2.2.3	Numerical analysis for interaction of heavy pipe with ice for ice-scouring	A				■
2.2.4	Ice & weather prediction capabilities	A				■
2.3	**Management of sulphur**					
2.3.1	Sulphur storage	A			■	■
2.3.2	Sulphur separation from crude or gas produced	A				■
2.3.3	Sulphur utilization	A			■	■

The technology solutions and their mode of implementation

3	FLUID FLOW AND PROCESSING	TRANSFER/ ADAPT/ INVENT	OPERATORS	ISCs	LOCAL INDUSTRY	ACADEMIA
3.1	**Flow assurance and sand control**					
3.1.1	3D flow modeling (including multi-phase flow)	A			■	■
3.1.2	Flow assurance modeling and monitoring	A			■	■
3.1.3	Production surveillance and optimization	T	■			■
3.1.4	Multi-phase flow meters (for extreme conditions, self calibrating etc)	A		■		■
3.1.5	Heating for flow assurance	T			■	
3.1.6	Well stimulation (remote stimulation techniques)	A			■	■
3.1.7	Sand control and removal	T		■	■	
3.1.8	Intelligent completions	T		■		
3.1.9	Flow assurance chemicals	T		■	■	■
3.1.10	Mercaptan removal	T		■		
3.2	**Water management**					
3.2.1	Diagnostic evaluation of water source	T		■	■	■
3.2.2	Water control technologies	A		■	■	■
3.2.3	Water clean-up technologies	A			■	■

The technology solutions and their mode of implementation

4	WELLS AND FIELD MANAGEMENT	TRANSFER/ ADAPT/ INVENT	OPERATORS	ISCs	LOCAL INDUSTRY	ACADEMIA
4.1	**Drilling and well costs**					
4.1.1	Casing & liners with improved pressure containment capabilities	T			■	
4.1.2	Drilling through abnormal pressures, high temperatures & H_2S	T		■		
4.1.3	Surface pressure control equipment for improved safety (on land & shallow water)	A		■	■	■
4.1.4	Drilling safety methods	T	■	■	■	
4.1.5	Cost effective drilling techniques	A	■	■		
4.1.6	Directional drilling & reach	T	■	■		
4.1.7	Improved drilling rigs with directional drilling capabilities	A		■		
4.2	**Field management: optimised recovery including IOR/EOR**					
4.2.1	Well stimulation	T		■	■	
4.2.2	Advanced waterflooding & EOR	A	■		■	■
4.2.3	EOR gas injection	T	■		■	■
4.2.4	EOR modeling	A	■		■	■
4.2.5	Water based fracture fluid systems	A		■		
4.2.6	Fracture monitoring & control	T		■		■
4.2.7	In-well monitoring for observing reservoir dynamics	T		■		
4.2.8	In-well monitoring using wireline tools (for integrity & water content)	T		■		
4.2.9	Reservoir monitoring with geo-chemistry & tracers	T		■		
4.2.10	Well (in)flow control	T		■		
4.2.11	Optimised field management	A	■			■

The technology solutions and their mode of implementation

5	HSE AND OPERATIONS	TRANSFER/ ADAPT/ INVENT	OPERATORS	ISCs	LOCAL INDUSTRY	ACADEMIA
5.1	**Emergency response and disaster recovery**					
5.1.1	Quantitative risk assessment & management	A	■		■	■
5.1.2	Emergency response preparation	A	■		■	■
5.1.3	Safety processes & systems	A	■		■	■
5.1.4	Emergency escape vehicles for arctic conditions	A	■			■
5.1.5	Emergency response to oil spills (clean-up, containment, etc)	A	■		■	■
5.1.6	Disaster management – well capping systems etc	T	■	■		
5.2	**Operational HSE risk reduction under sour production conditions**					
5.2.1	Leak reduction & elimination	T		■		
5.2.2	Breathing apparatus (SCBA) for H_2S protection	T			■	■
5.2.3	Leak detection techniques	T		■		
5.2.4	Technology & automation for risk reduction (eg robots, wireless)	I			■	■
5.2.5	SIMOPS methods	T	■			
5.2.6	Facility management	T	■			
5.2.7	Safety certification & independent verification	T	■		■	
5.3	**Environmental impact**					
5.3.1	Chemical & membrane methods for oil-water separation	A			■	■
5.3.2	Emergency response to oil spills	A			■	■
5.3.3	Remote sensing / aerial surveillance	A			■	■

SPECIFIC 'TOPIC ROADMAPS' HAVE BEEN DEVELOPED FROM THE MASS OF INFORMATION GATHERED DURING THE PROJECT FOR EACH OF THE 15 PRIME CHALLENGES FACING THE UPSTREAM OIL AND GAS INDUSTRY IN KAZAKHSTAN.

Introducing the topic maps

Introduction to the topic maps

Specific 'topic roadmaps' have been developed from the mass of information gathered during the project for each of the 15 prime challenges facing the upstream oil and gas industry in Kazakhstan. The maps depict the development of technology solutions to each of the 15 challenges. It is hoped the following explanation will help readers better understand the approach that was taken to producing the maps.

First, a little more detail on the each of the challenges is provided in the text, under the heading 'Challenge commentary'. The 15 challenges are all quite complex and each one contains a number of elements (highlighted using bold text).

Previously, it was explained that during the project over 230 solutions were put forward to the 15 challenges and that these had been consolidated down to a list of 75. These solutions were subsequently ranked and displayed on a scatter plot, which was presented earlier. Each of the topic maps is accompanied by a smaller version of the scatterplot which highlights those solutions that address the particular challenge on which the map is based.

Also accompanying each of the topic maps is a table that lists the different elements of the challenge together with the solutions that address each element of the challenge.

The maps themselves trace the development of the solutions from the current state of technology, on the left-hand side of the map, towards a goal, described on the right-hand side (in a shaded box), considered to be achievable by 2025.

Some of the technology boxes are labelled GAP. This describes technologies that are more mature outside Kazakhstan than in country, or which will require significant adaptation before they can be used effectively under the sort of conditions found in Kazakhstan. More details of this analysis can be found in the project Technology Readiness Report (Report C).

Finally, each of the topic maps has a 'Solutions commentary', which provides some further insight into the information presented in the map.

THE MAPS THEMSELVES TRACE THE DEVELOPMENT OF THE SOLUTIONS FROM THE CURRENT STATE OF TECHNOLOGY, ON THE LEFT-HAND SIDE OF THE MAP, TOWARDS A GOAL, DESCRIBED ON THE RIGHT-HAND SIDE (IN A SHADED BOX), CONSIDERED TO BE ACHIEVABLE BY 2025.

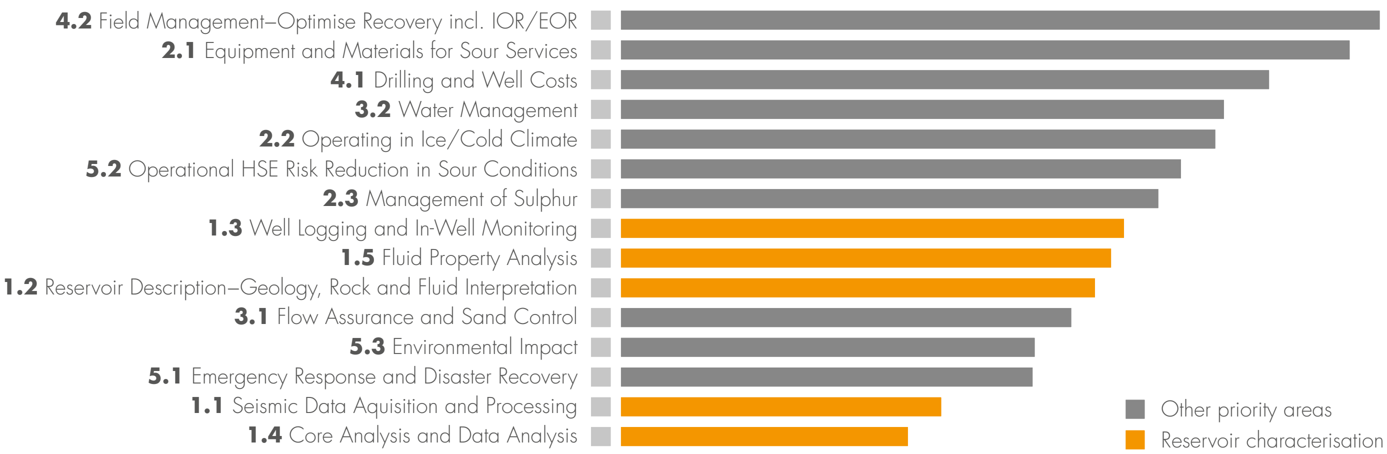
1. Reservoir characterisation

Reservoir characterization is concerned with building an understanding of the subsurface, with the focus on those regions where hydrocarbons are present. It covers not only the rock structures but also the fluids present in them and their distribution and composition. An understanding of the changes occuring over time within the reservoir, as the hydrocarbons and associated liquids are released, is also of the utmost value. Reservoir characterisation is fundamental to all aspects of exploration and production. It determines whether or not a prospect is commercial, it drives the drilling programme and sets the production strategy, something that will invariably change as knowledge and understanding of the reservoir increases.

Seismic surveying, well logging and monitoring, core and fluid analysis, and, of course, reservoir modelling all have a role to play in helping to understand the reservoir and make the best business and operational decisions throughout the life of the field.

Characterising Kazakhstan's complex reservoirs with their generally high levels of heterogeneity is not straightforward. However, it is vital to working out how to maximise production, often involving improved and enhanced oil production techniques – IOR (waterflooding) and EOR.

> CHARACTERISING KAZAKHSTAN'S COMPLEX RESERVOIRS WITH THEIR GENERALLY HIGH LEVELS OF HETEROGENEITY IS NOT STRAIGHTFORWARD



> THE GOAL MUST BE TO BRING KAZAKHSTAN UP TO WORLD-CLASS STANDARDS IN TERMS OF SEISMIC ACQUISITION AND DATA PROCESSING, WHICH WILL THUS LEAD TO INCREASED RESERVES, IMPROVED SWEET-SPOTTING OF RESERVOIRS AND RAISED LEVELS OF HYDROCARBON PRODUCTION.

1.1 Seismic data acquisition and processing

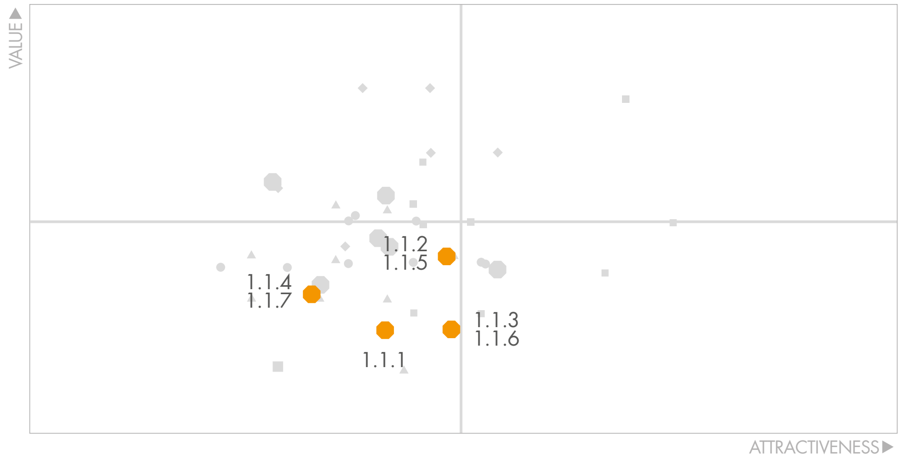
Challenge commentary

The challenge for Kazakhstan in this area is simple: operators need better seismic images of the complex reservoirs that make up the bulk of the nation's reserves.

Most reservoirs in Kazakhstan are in relatively complex carbonate formations that are overlaid by salt. Consequently, **seismic image quality** is a major issue both onshore and offshore. Kazakhstan's biggest field, Kashagan, is a classic case in point. The problem is made worse at Kashagan, as modern high-density and wide-azimuth streamer technology does not work well in shallow water. Poor seismic quality is also observed in clastic reservoirs lying beneath carbonate formations; fields such as Karachaganak and Pearls are known to have this problem. Elimination of water bottom multiples is another issue: these degrade image quality and hamper the use of advanced data processing techniques.

Understanding the heterogeneity common in carbonate reservoirs is a particular challenge. Tengiz and Chinarevskoe, for example, both have adjacent units with quite different porosity and permeability. Determining the distribution of these properties is vital to optimising hydrocarbon recovery; it requires **seismic data with higher lateral and vertical resolution** than is normally achieved in Kazakhstan.

The design and acquisition of 4D seismic is the other challenge in this technology area. This is not well established in Kazakhstan. An improved capability would be of significant benefit, especially in terms of better understanding the performance of waterflooding operations and the identification of stranded or bypassed zones.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Seismic imaging sub-salt & in carbonates	1.1.1 Seismic acquisition for shallow waters
	1.1.2 Seismic acquisition for enhanced imaging
	1.1.5 Seismic processing for improving imaging
Seismic resolution to determine reservoir characteristics	1.1.1 Seismic acquisition for shallow waters
	1.1.2 Seismic acquisition for enhanced imaging
	1.1.3 Non-seismic solutions for reservoir evaluation
	1.1.5 Seismic processing for improving imaging
	1.1.6 Integration of seismic & other data
	1.1.7 Advanced seismic inversion
Design & acquisition of time-lapse (4D) seismic	1.1.1 Seismic acquisition for shallow waters
	1.1.2 Seismic acquisition for enhanced imaging
	1.1.4 4D seismic

1.1 Seismic data acquisition and processing

Solutions commentary

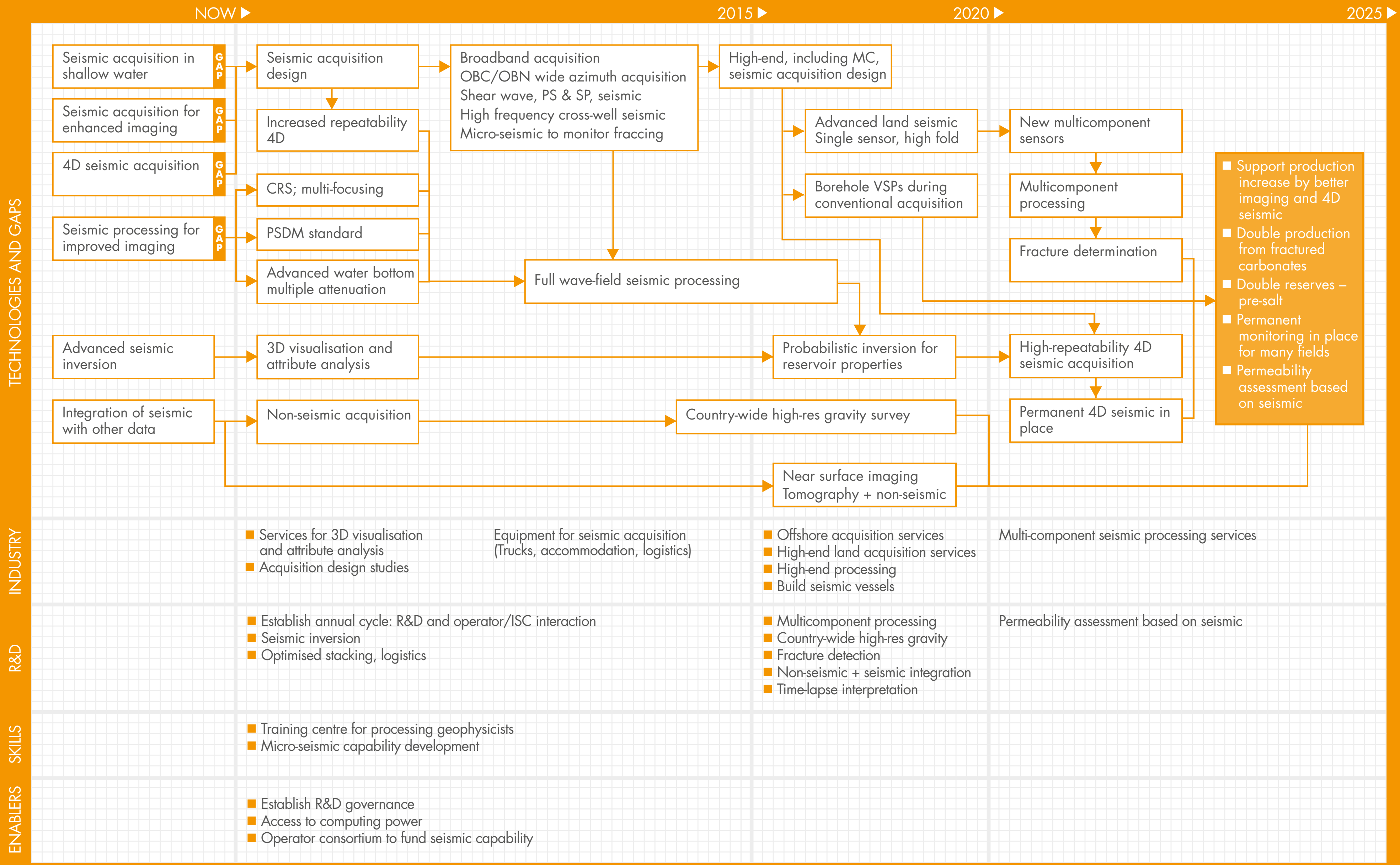
The seismic solutions are grouped into the natural steps of data acquisition, processing and interpretation. The seismic data, where appropriate, are combined with non-seismic data and utilised in a more sophisticated manner over time to provide key information, including fracture orientation and size, high resolution lithology distribution, fluid movements and permeability distribution. This information, which for key fields is expected to be available on demand via permanent monitoring, will significantly impact reserves and production.

In the near term, current global practices need to be transferred into Kazakhstan, in some cases they require adapting before being suitable for use. Some have already been used, but with mixed results and their use has not been widespread. Survey design underpins the seismic capability and source and sensor coverage, together with spatial sampling; all of this needs to be optimized based on the subsurface targets, while being constrained by cost considerations. Irrespective of processing or interpretation capabilities, sub-optimal input field data cannot be rectified. Optimal design will improve existing 4D repeatability, it also will enable broadband, wide-azimuth and other more sophisticated acquisition methods – although these are also likely to require adapting for the shallow waters of the Caspian.

On the processing side common reflection point stacking (CRS) for noise removal, pre-stack depth migration (PSDM) for improved imaging, and advanced water bottom multiple attenuation needs to become standard practice. Significant computer power is required to enable this. With the newer acquisition methods and processing capability growth, full wave-equation-based seismic processing is the near term goal.

The improved data needs to be interpreted with the latest 3D visualisation and attribute analysis packages available. In the mid term, acquisition design will improve further, land seismic should move towards mega-channel, single-sensor, high-fold surveys – providing step changes in land subsurface images, while probabilistic inversion for reservoir properties will become standard.

These developments will be paralleled by wide coverage with non-seismic methods, which when combined with seismic further reduce subsurface uncertainties. All these steps will be further refined in the long term with permanent 4D, multi-component sensors and the ability to determine fractures and infer permeability; thus providing the support for increased production and reserves.



1.1 Seismic data acquisition and processing

THE OBJECT MUST BE TO INCREASE RESERVES AND PRODUCTION THROUGH THE CREATION OF HIGH RESOLUTION RESERVOIR MODELS FORMED BY THE THOROUGH INTEGRATION OF SURFACE AND SUBSURFACE DATA. COUNTRY-WIDE CENTRAL DATABASES CONTAINING INFORMATION ON BASINS, FIELDS AND RESERVOIRS AS WELL AS INCREASED COMPUTING POWER ARE CERTAIN TO BE IMPORTANT FACTORS IN ACHIEVING THIS.

1.2 Reservoir description – geology, rock and fluid interpretation

Challenge commentary

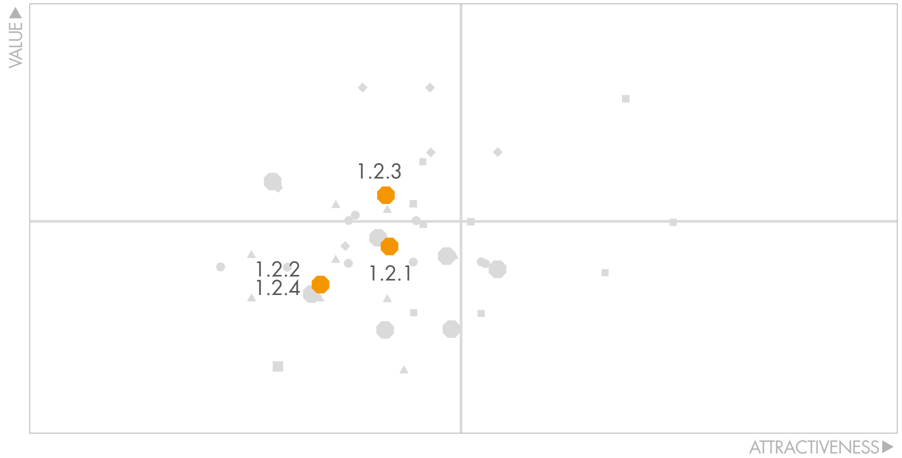
A challenge in Kazakhstan is to improve reservoir modelling, as it this is key to gaining a better understanding of the local petroleum systems and raising hydrocarbon recovery and operational efficiency. Sedimentology, sequence stratigraphy, structural geology, tectonics, palaeoenvironmental studies, palaeography and source rock maturation (all basin-wide disciplines) each have a role to play.

Problems of inadequate **reservoir modelling,** especially high resolution simulations with fine grids, have reported for important fields such as Tengiz, Kashagan, Karachaganak, Uzen, Zhetybay, Kalamkas, Kenkiyak, Kumkol, Kenbay and Nurzhanov.

Part of the problem of reservoir characterisation is the lack of constraints on static and dynamic reservoir models due to the limited geological, matrix and fluid information available. Substandard data interpretation (linked to the complexity of the reservoirs combined with a lack of computing power) is another issue, as is the limited ability to carry out genuinely integrated reservoir modelling (IRM).

The detailed mapping and analysis of tight carbonate reservoirs is a specific challenge – understanding permeability changes occurring as the production rate falls (vital input to EOR studies) could have a huge positive impact on oil and gas production in Kazakhstan.

As noted earlier, waterflooding is common in Kazakhstan, which partly accounts for the high water cuts in many fields. The challenge is therefore to **improve the efficiency of waterflooding,** which requires more detailed subsurface mapping and a better understanding of the water leg within the reservoir.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Reservoir characterisation (matrix & fluids)	1.2.1 Basin modelling
	1.2.2 Seismically constrained geological models
	1.2.3 Integrated static & dynamic models
	1.2.4 Advanced seismic interpretation techniques for subsalt carbonates
Tight reservoirs identification and permeability change during production	1.2.2 Seismically constrained geological models
	1.2.3 Integrated static & dynamic models
	1.2.4 Advanced seismic interpretation techniques for subsalt carbonates
Effective water flooding	1.2.3 Integrated static & dynamic models

1.2 Reservoir description – geology, rock and fluid interpretation

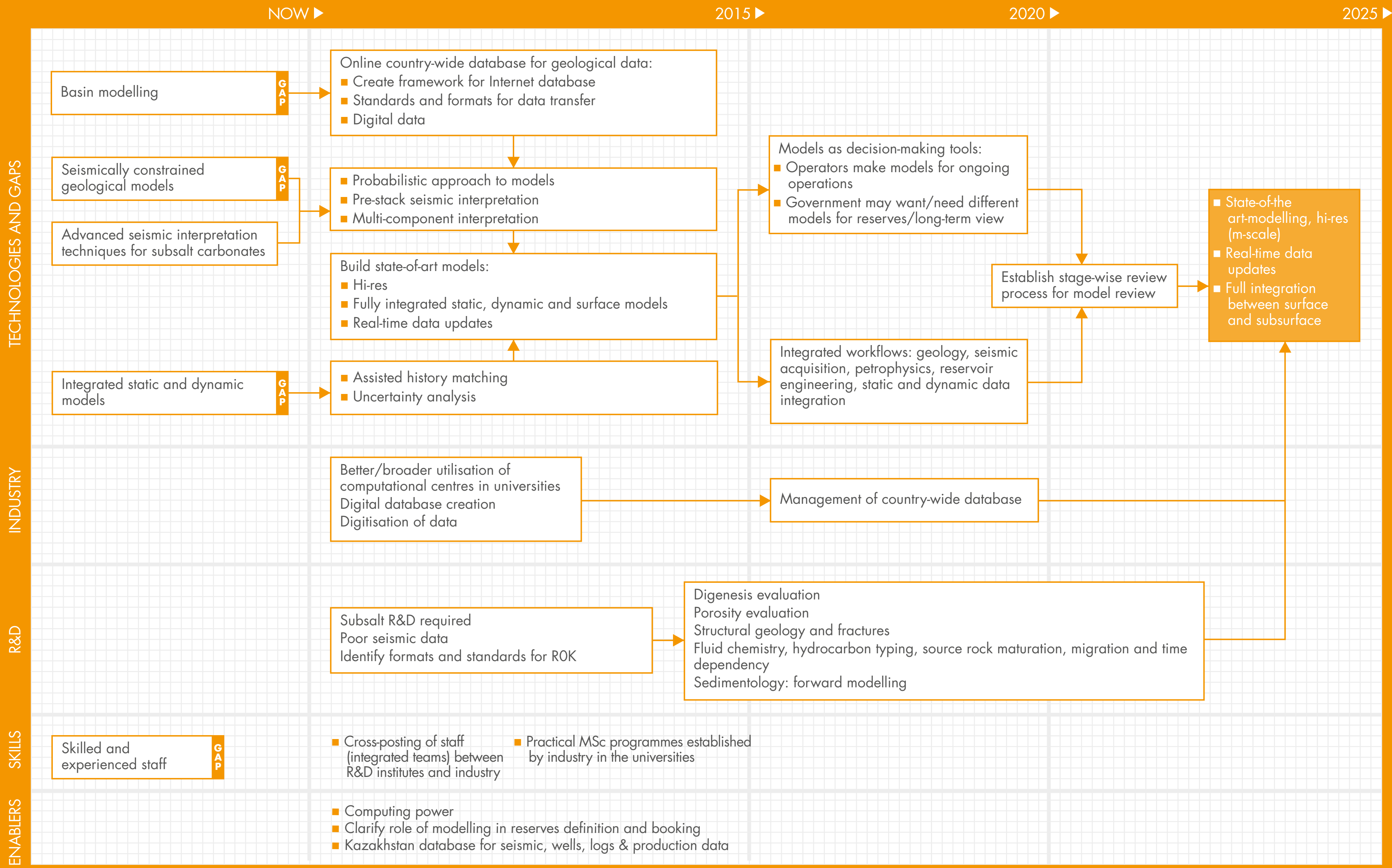
Solutions commentary

The long term goal is to have static and dynamic subsurface models that are consistent, include the full spectrum of spatial coverage and resolution, utilise all the available subsurface data and provide robust subsurface forecasts (including uncertainties).

In the near term, further optimisation of current practices in Kazakhstan is required in basin, seismic-constrained and automated modelling. Basin modelling requires country-wide geological information as input. To enable this, information needs to be shared in digital format, with a clear framework and standards in place. On the seismic side, probabilistic (rather than deterministic) practices need to be widely adopted and a move made towards the use of pre-stack and multi-component data, assuming the seismic is of high enough quality. Assisted history matching using seismic, production and other data also needs to be more widely adopted; the result would be models that are more consistent with the input data and provide uncertainty estimates. All these activities ultimately need to be combined into state-of-the-art models, which are high resolution, fully integrated with all available constraining data, and can be easily updated. Computer power and data in digital form will be key enablers for these activities.

As input data improves in the mid term, these efforts will be further optimised and integrated. The ability to take advantage of the rapidly increasing amount of data should be the objective. The predictive capability of the models will improve, enabling the operators to better manage well and reservoir activities in both the short and long timeframes. Better information will also be provided to the Government to assist national planning activities for the upstream oil and gas industry.

In the longer term, greater consistency between the activities undertaken by the operators will ensure that the information and predicted subsurface behaviour, is rolled upwards in a robust manner to the benefit of the whole industry and, indeed, the nation.



1.2 Reservoir description – geology, rock and fluid interpretation

KAZAKHSTAN HAS THE POWER TO BECOME THE REGIONAL CENTRE OF EXCELLENCE FOR WIRELINE LOGGING AND TO ESTABLISH A PIONEERING POSITION IN IN-WELL MONITORING. ACCESS TO ADVANCED DATA WOULD ENABLE THE INDUSTRY TO GAIN A MUCH DEEPER INSIGHT INTO RESERVOIR PROPERTIES AND BEHAVIOUR BEFORE AND DURING PRODUCTION.

1.3 Well logging and in-well monitoring

Challenge commentary

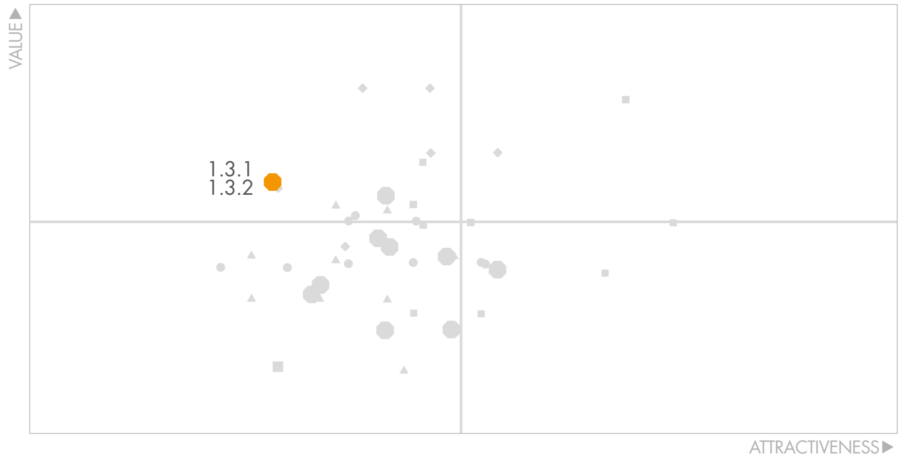
In a number of fields in Kazakhstan, it has been observed that high porosity zones are unable to sustain flow, while low porosity zones produce readily. Chinarevskoe and Kashagan exhibit this behaviour. The reason for this, of course, relates to permeability differences.

The problem is that there is no fundamental relationship that links porosity and permeability. And while porosity information can be derived from standard wireline logging data, permeability can only be calculated from direct measurements of flows and pressure differentials.

Well logging in Kazakhstan is typically undertaken by specialist international service companies, a situation reproduced the world over. However, the nature of the field operations in fractured formations in Kazakhstan, the high-pressure, high-temperature nature of the reservoirs and the sour conditions often lead to sub-optimal results.

Under the circumstances, the acquisition of the sort of data needed to obtain permeability information (using more advanced magnetic resonance tools, wireline formation testers and formation sampling tools) represents a significant challenge.

In-well (continuous, real-time) monitoring, typically using distributed temperature or acoustic sensors and downhole pressure gauges, is a natural extension of wireline logging, but is in its early stages. The challenge lies in selecting the most suitable wells in which to apply the technology and then tailoring the monitoring hardware to the chosen application. In-well monitoring has much to offer in Kazakhstan in terms of improving operators' understanding of reservoir behaviour but there is a lot of work to be done before the industry is in a position to exploit it on a routine basis.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Production tests without testing	1.3.1 Reservoir characterization (permeability, pressure, contact) and fluid typing using wireline tools
Real time in-well monitoring	1.3.2 "In-well monitoring" for observing reservoir dynamics

1.3 Well logging and in-well monitoring

Solutions commentary

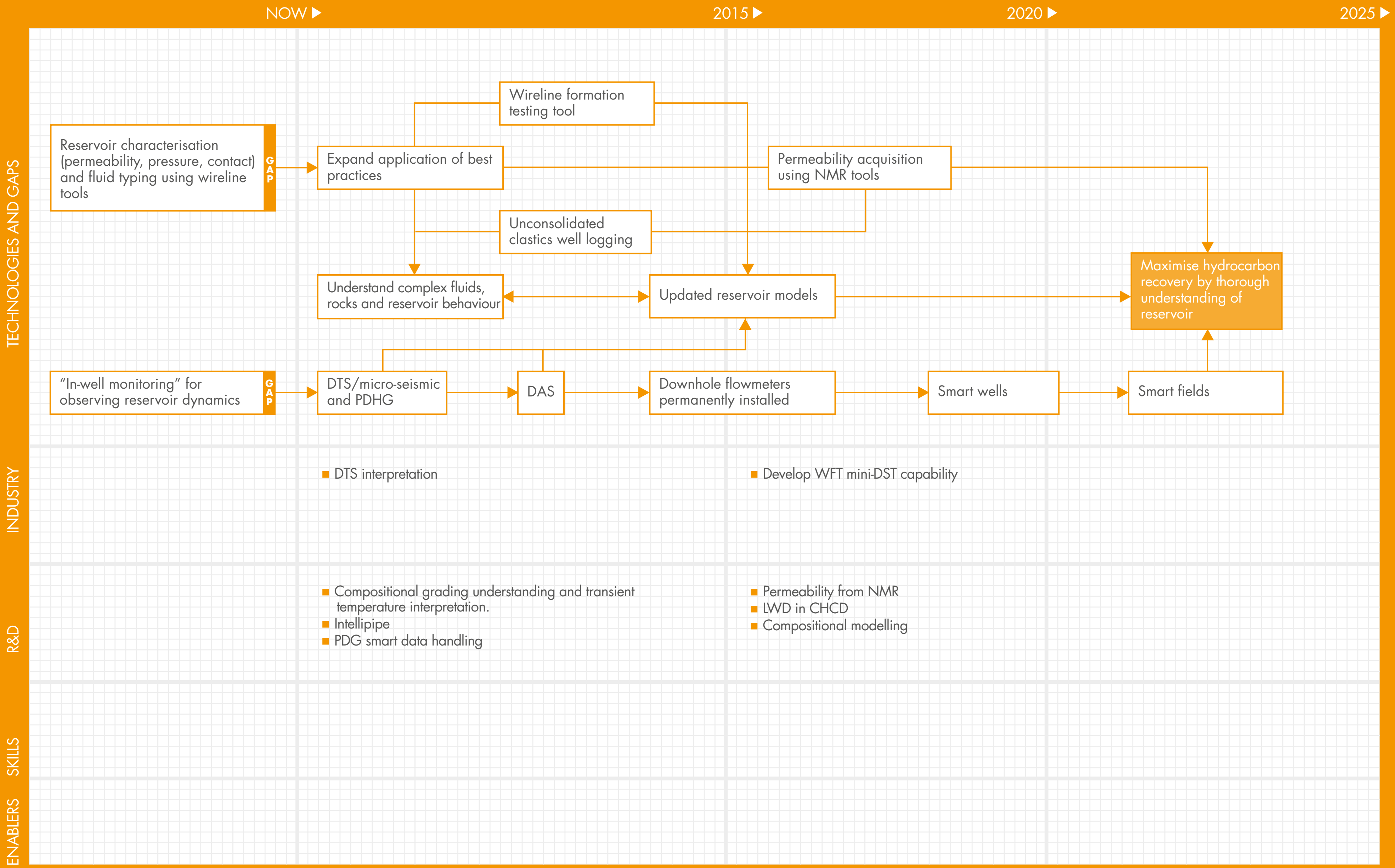
The proposed technology solutions in this area are related to well logging for reservoir characterization and in-well monitoring for gaining a better understanding of reservoir dynamics. Both were judged to be of high value but not necessarily prime candidates for R&D in Kazakhstan.

For reservoir characterization, it is important now that the best practices being applied in some fields in Kazakhstan are applied more broadly and that the available well logging tools are fully utilized. Longer term, the focus should be on the acquisition of better permeability data using specialised wireline tools (for example, NMR), wireline formation testers and samplers. These will all lead to a better understanding of rock and fluid properties and reservoir behaviour, which can then be used to update the reservoir models. Potential local R&D opportunities include support for improved well logging technologies and improved reservoir modelling. This could further lead to local industry opportunities to partner with established well logging service providers and adapt technologies and equipment to Kazakhstan conditions.

Regarding in-well monitoring, there are existing and emerging passive technologies, such as downhole pressure gauges, flux, fiber optics systems (DTS) and microseismic that can be deployed in the near term to acquire real-time data and improve reservoir management and decision-making. Wells need to be set up now with smart sensors; this would open the way for smart fields in which it is possible to react with agility to dynamic changes in the reservoir performance.

As noted elsewhere, technical support for the development of fiber optic systems, adaptation to Kazakhstan conditions, and broad deployment in support of smart wells (and ultimately smart fields) constitutes a potential R&D opportunity.

Extending the local knowledge base in specific disciplines such as reservoir engineering, petrophysics, production technology, well engineering and production chemistry will be necessary before Kazakhstan companies will be able to contribute in this area.



1.3 Well logging and in-well monitoring

> SETTING UP SCAL FACILITIES IN KAZAKHSTAN AND TRAINING STAFF IN THE MOST IMPORTANT TECHNIQUES OUGHT TO BE RELATIVELY STRAIGHTFORWARD – PARTNERSHIPS WITH EXISTING INTERNATIONAL SERVICE PROVIDERS WOULD SEEM A SENSIBLE WAY TO MOVE FORWARD QUICKLY. THE OPPORTUNITY EXISTS FOR KAZAKHSTAN TO BECOME A REGIONAL HUB FOR CORE ANALYSIS SERVICES.

1.4 Core analysis and data interpretation

Challenge commentary

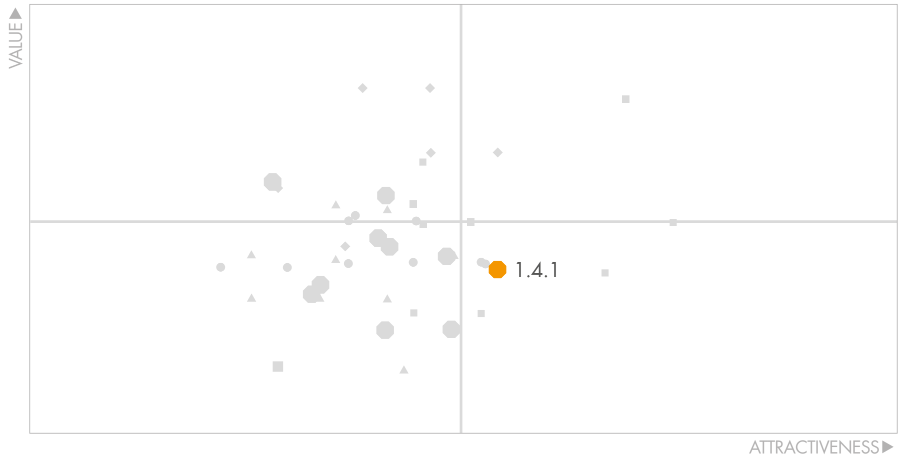
Routine core analysis and special core analysis (SCAL) are key to improving our understanding of oil and gas reservoirs and gaining a true estimate of their reserves. The data from these various analyses drives field development decisions and drilling campaigns.

Unfortunately, **local Kazakhstan capability** in this area is limited and most of the work has to be done overseas, which leads to higher costs, inconvenience, and delays.

Moreover, full or partial cores cannot be exported from Kazakhstan; only limited plugs from the core are allowed out of the country and this takes a long time to arrange. This erodes the value of the core, creates uncertainties with analysis results and severely holds up development decisions.

There is also an inability in Kazakhstan to conduct core displacement tests with live sour fluids. These tests are hazardous and can only be done in Edmonton, Canada. Considering how many large sour fields there are in Kazakhstan, it would make huge sense to bring this technology into the country. It would raise understanding of relative permeability and help determine remaining oil saturations, thus accelerating the development of sour fields.

The challenge is to establish core analysis laboratories in country capable of providing services that match those available internationally. The staff for these **core analysis** laboratories will need to suitably trained; particularly important will be the development of expertise in analysing carbonate reservoir cores and carrying out studies, for example, designed to mimic the acid treatment of these cores at abnormally high temperatures and pressures.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Core analysis infrastructure & equipment	1.4.1 Special core analysis facilities in Kazakhstan
Data analysis capability	

1.4 Core analysis and data interpretation

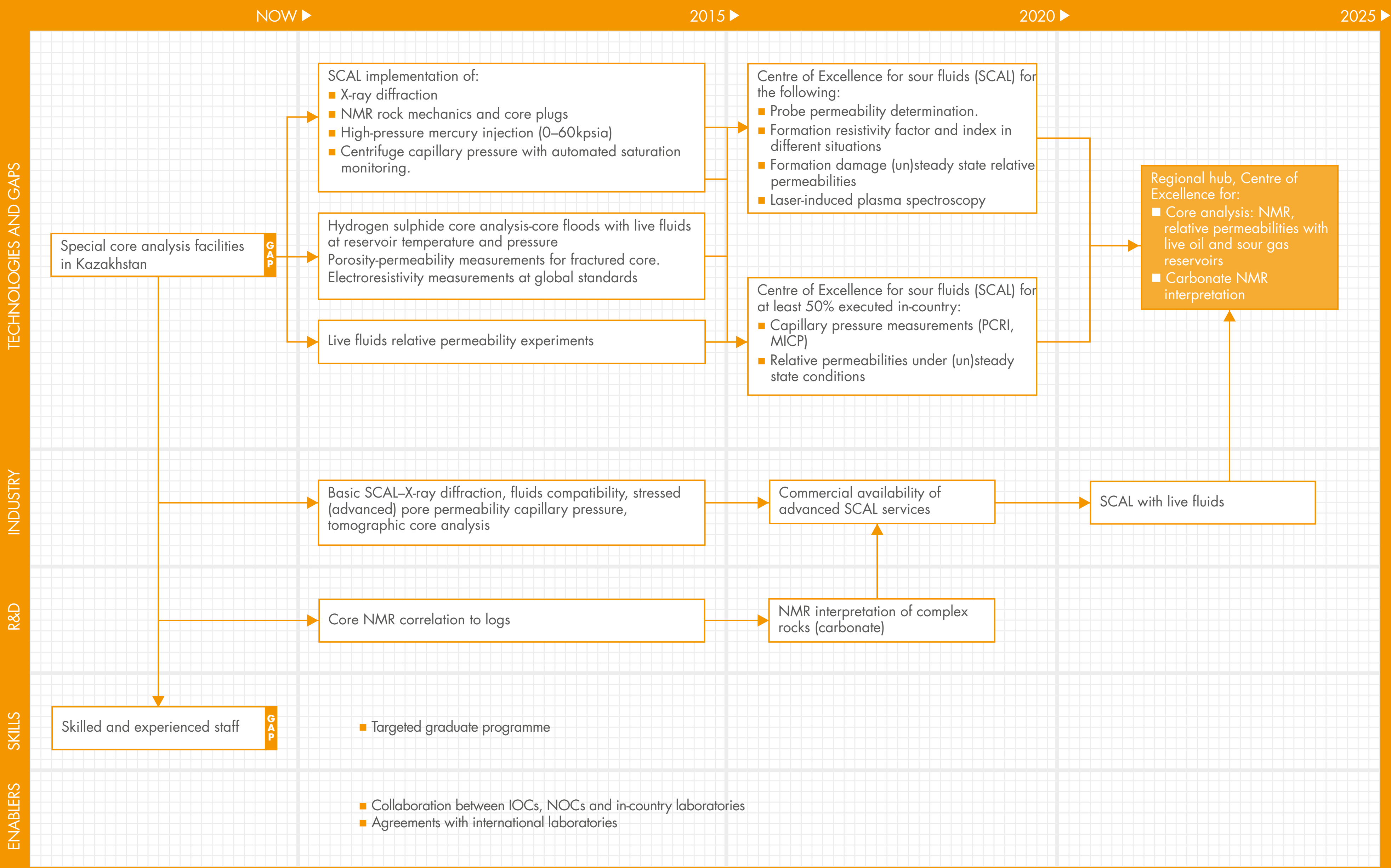
Solutions commentary

There is much to be gained by building a specialised SCAL services capability (focused on the study of sour reservoirs) in Kazakhstan. The country has the potential to become a regional centre for such work, possibly even the world's leading centre in the long term.

Kazakhstan's complex rocks and fluids dictate the need for special measurements that require the displacement of sour in-situ fluids to be performed on a core from the same formation. These measurements are only available in Canada, which serves as the world's centre of excellence for such measurements.

By adopting such technologies in Kazakhstan, and by the sheer magnitude of its application in Kazakhstan, the country could become, in time, the new centre of excellence for this work.

There are other issues in this area, for example, surrounding solid hydrocarbons (bitumen) present in abundance in the pore space. Core NMR measurements are needed to study this. However, owing to the low porosity of some carbonate rocks in Kazakhstan, NMR logs cannot resolve such issues. More research is needed here; cooperation between IOCs, ISCs and NOCs would be valuable in establishing this work in the top universities in Kazakhstan.



1.4 Core analysis and data interpretation

> JUST AS FOR CORE ANALYSIS, SETTING UP PVT FACILITIES IN KAZAKHSTAN AND TRAINING STAFF IN THE MOST IMPORTANT TECHNIQUES IS AN ACHIEVABLE GOAL. THE OPPORTUNITY AGAIN EXISTS FOR KAZAKHSTAN TO BECOME A REGIONAL HUB FOR WORK OF THIS KIND.

1.5 Fluid property analysis

Challenge commentary

As in the case of core analysis, the challenge is to **create a strong fluid property analysis capability in Kazakhstan:** to establish laboratories, train local staff and develop the expertise necessary to characterise the sort of fluids (notably with high levels of H_2S) commonly encountered by the Kazakhstan upstream industry.

Fluid properties analysis (commonly known as PVT) provides vital information on produced fluids, their phase behaviour in the reservoir rock, and the way they behave when displaced by water or gas.

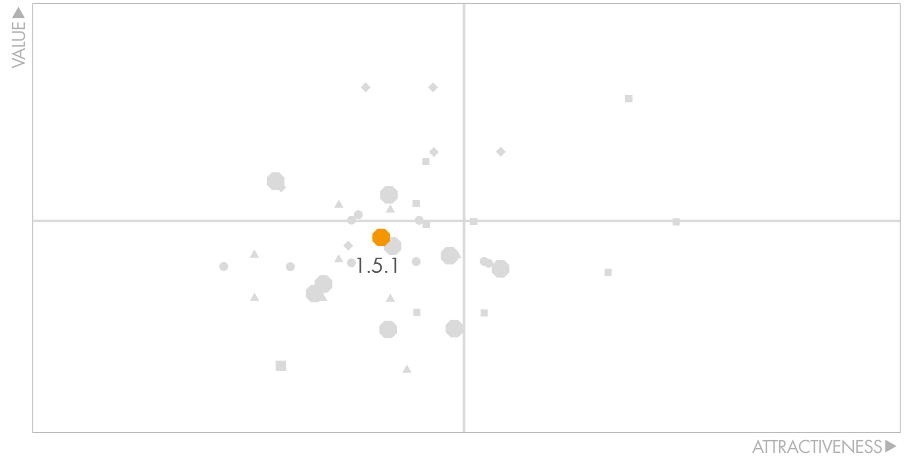
As such PVT data is extremely valuable when designing waterflooding operations. For example, it is particularly pertinent to understand the likelihood of scale formation resulting from the interaction of the injection water and the formation water. Kumkol South and Pearls, for example, face this problem.

PVT information also helps in estimating reserves, forecasting production rates, designing processing facilities and pipelines, and is the basis of calculating the value of the produced fluids to the market. This information is needed at the beginning of the exploration phase in order to determine the optimum development scheme.

A particular challenge in this area is the measurement of sulphur species and mercaptans in the produced stream. The data are very time-sensitive (the compounds decay with time); measurements are affected by very small levels of contamination; and species are easily absorbed by the tanks containing them.

The lack of laboratories capable of making measurements like these soon after the recovery of the fluid samples creates a major problem, which has severe financial implications: facilities can end up being over-designed because of the lack of good information.

As well as developing a PVT capability in Kazakhstan, establishing geochemistry labs in Kazakhstan capable of isotope detection and analysing the origin of hydrocarbons could help immensely in developing accurate basin models, and can also lead to more accurate produced fluids allocation.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Develop a strong fluid characterisation capability in Kazakhstan to avoid the problems connected to the need to export samples for analysis	1.5.1 Fluid characterisation methods; advanced PVT; use of GC.GC and MD.GC techniques

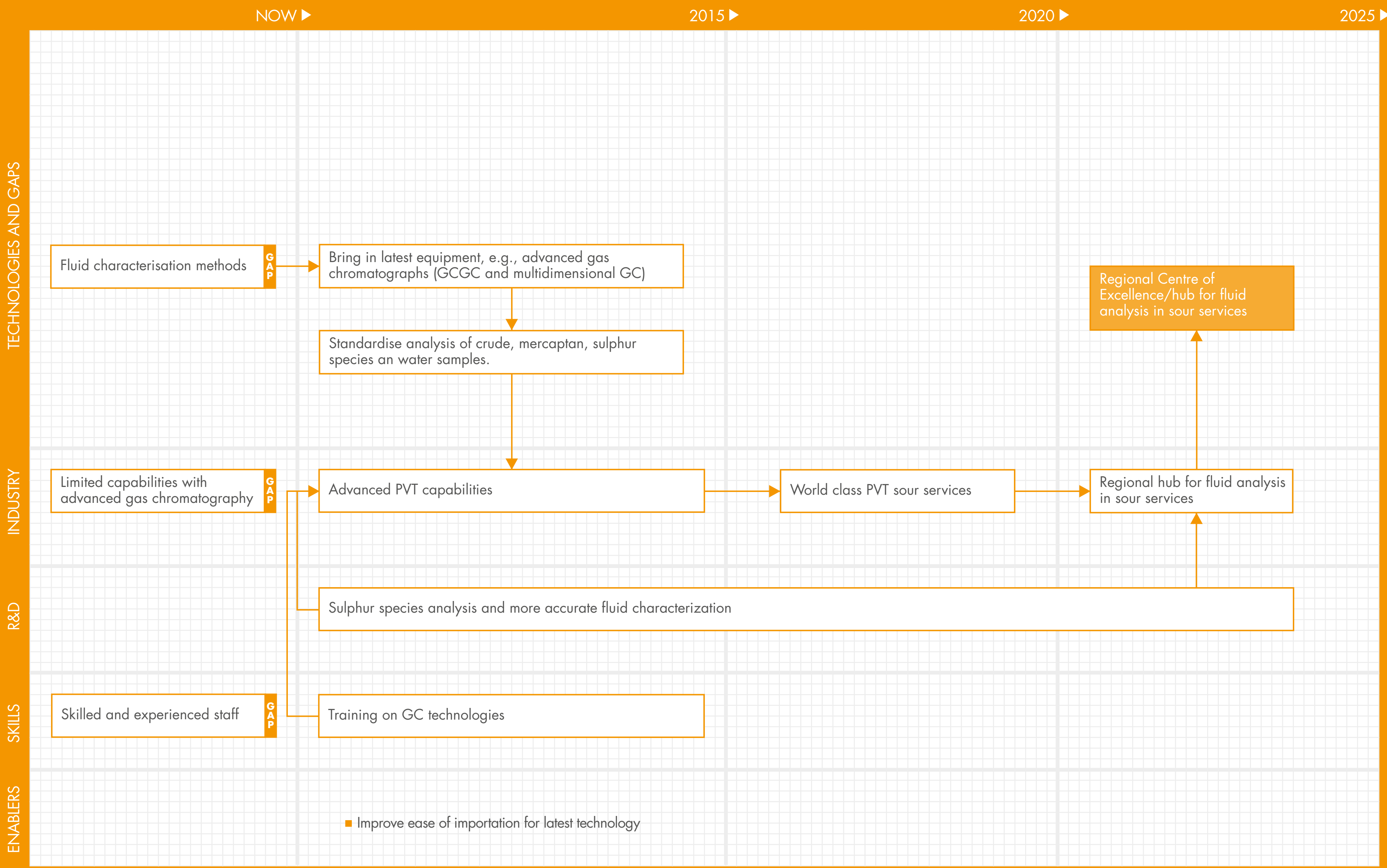
1.5 Fluid property analysis

Solutions commentary

Kazakhstan's super-critical and sour fluids dictate the need for special measurements that require special equipment. These measurements are only available in Canada, which serves as the world's centre of excellence for work in this area. Having the ability to carry out work of this kind in Kazakhstan would provide tremendous benefits and contribute to increased levels of hydrocarbon recovery.

By adopting such technologies in Kazakhstan, and by the sheer magnitude of its application in Kazakhstan, the country has the potential to become a new centre of excellence for fluids and related analysis.

There is another issue in this area connected to the analysis of solid hydrocarbons (bitumen) present in abundance in the pore space. To quantify its source, the latest geochemistry techniques are needed. Exporting samples is not feasible in this case, owing to the need to carry out analyses very quickly after samples are recovered. Cooperation between IOCs, ISCs and local institutes would help in establishing research centres for advanced PVT with sour capabilities and geochemistry studies in Kazakhstan.



1.5 Fluid property analysis

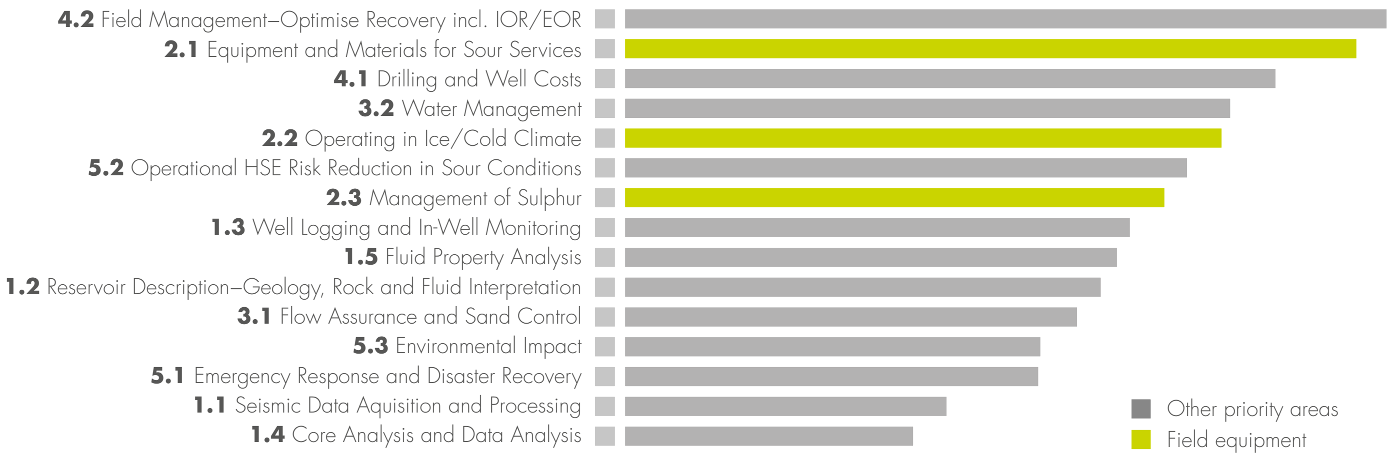
2. Field equipment

Designing and building the production infrastructure required not only to cope with the sour crudes found in Kazakhstan but also to operate in what is a distinctly challenging environment represents a huge challenge.

Corrosion is a constant threat. Drilling is difficult. There are tremendous demands put on offshore structures. And dealing with all of the sulphur produced is one of the biggest issues facing the Kazakhstan upstream oil and gas industry.

The challenges in this area are immediately obvious to anyone with any upstream experience. They affect production directly and continuously, a fact that perhaps explains why they were considered to be among the most important challenges by participants in the roadmapping project.

> THE CHALLENGES IN THIS AREA ARE IMMEDIATELY OBVIOUS TO ANYONE WITH ANY UPSTREAM EXPERIENCE. THEY AFFECT PRODUCTION DIRECTLY AND CONTINUOUSLY



"KAZAKHSTAN HAS THE POWER TO BECOME A LEADER IN INTEGRITY MANAGEMENT FOR SOUR SERVICE, PROVIDING MATERIALS, PRODUCTS AND SERVICES TAILORED TO THE LOCAL ENVIRONMENT AND MEETING THE HIGHEST INTERNATIONAL STANDARDS.

2.1 Corrosion plus equipment and materials for sour service

Challenge commentary

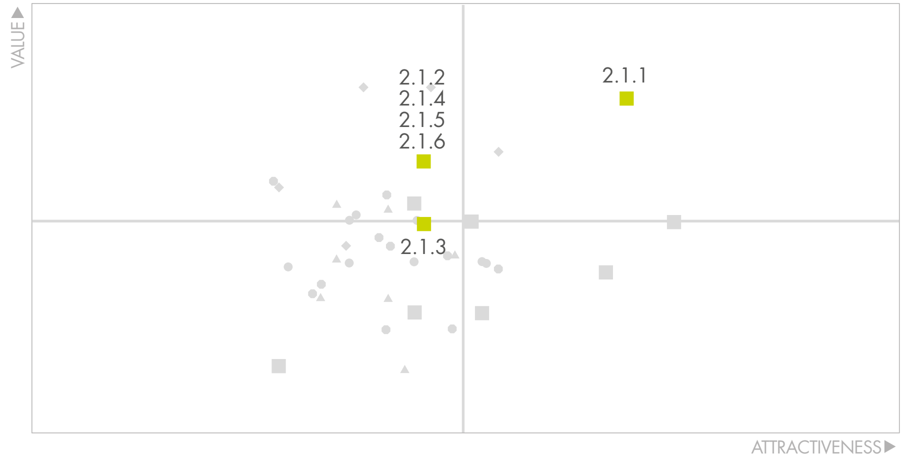
A combination of extreme weather, production streams containing high levels of carbon dioxide and hydrogen sulphide and, in some cases, an offshore environment means that corrosion is a severe challenge for the Kazakhstan oil and gas industry. Uzen, Karamadybas and Zhetybay, all high water cut fields, are known to have problems with production casing integrity, while mature fields like Kumkol South, Tengiz and Korolev are reportedly beset by a variety corrosion-related issues.

Improving **corrosion management** across Kazakhstan's oilfields is a huge challenge. However, the prize is considerable: better management would lead to more efficient operations, improved productivity, and reduced downtime; it would also improve HSE performance.

Effective and early **leak detection** is a specific issue. Kazakhstan needs to have robust systems for leak detection at the surface and downhole that are tailored to work under conditions where H_2S is present.

High pressure, high temperature streams containing extremely high levels of H_2S place enormous **demands on the pumps and compressors used for liquid and, especially, gas reinjection.** Such equipment for sour service is available internationally but conditions in fields such as Kashagan are as extreme as anywhere in the world (15% H_2S). The challenge is take the best available technology, adapt it and apply it in Kazakhstan.

Corrosion-resistant alloys and reinforced polymer materials can provide good containment solutions in demanding production environments and for pipelines carrying aggressive streams. But they are expensive and have long lead times. Kazakhstan needs to develop its own materials science capabilities in this area in order to provide cost-effective and tailored solutions to the corrosion problems faced on a frequent basis by most operators.



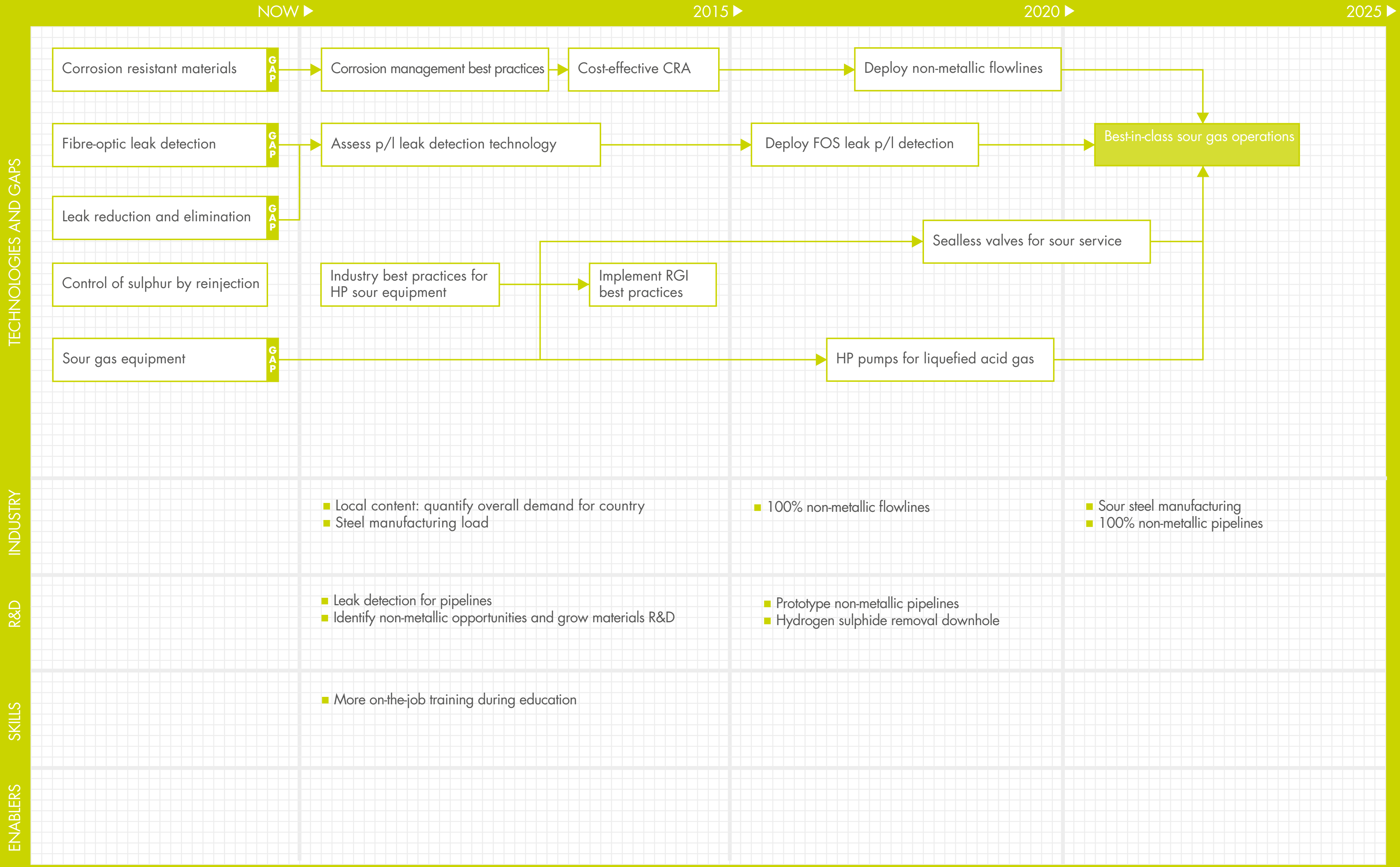
CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Corrosion management methods	2.1.1 Corrosion resistant materials for Kazakhstan conditions
Leak detection	2.1.2 Fiber optic leak detection techniques
	2.1.3 Leak reduction and elimination
High pressure pumps and compressor for sour	2.1.4 Control of sulphur production by reinjection
	2.1.5 Sour gas equipment
Cost effective corrosion resistant materials	2.1.1 Corrosion resistant materials for Kazakhstan conditions
	2.1.6 Local Production of Corrosion inhibition chemicals

Solutions commentary

There were six principal solutions identified to the challenge of dealing with corrosion caused by the processing of sour crudes. Corrosion-resistant materials technology was deemed to have the biggest role to play: the improved availability of non-ferrous and polymer materials – at costs significantly lower than today's – would be of tremendous benefit to the industry. This is reflected in the fact that this solution came out top of the value/attractiveness ranking exercise carried out as part of the roadmapping project. The value element is clear: the safe processing of sour crude is fundamental to the sustainability of the industry, and materials technology is the key to this. The attractiveness of the solution is linked to the ability of the R&D community in Kazakhstan to contribute in this area, and also the opportunities for local industry ultimately to provide the necessary manufacturing capacity. To aid progress in this area, it would make sense first of all to introduce corrosion management best practices from other parts of the world that suffer similar problems to those in Kazakhstan – Canada, for example, could provide valuable lessons for Kazakhstan.

Aside from pure materials technology, the roadmapping project highlighted fiber optic leak detection techniques, leak reduction (using, for example, seal-less valves), improved sour gas processing equipment (notably improved injection pumps) and chemical inhibitors as also being high on the value scale; though, these solutions were deemed rather less attractive as far as their development in Kazakhstan is concerned, being seen as longer-term technologies. There was a feeling among some experts that pipeline leak detection should be pursued in Kazakhstan. This could involve, in the first place, the assessment of available technologies and the provision of services in this area, with research into fiber optic technology being built up subsequently.

The control of sulphur by reinjection of the raw sour gas was also put forward as a high-value solution in this area. While it is already done in the Tengiz field, it is believed that implementing this solution elsewhere will require considerable growth in capabilities. In the first place, the wider adoption of industry best practices around sour gas reinjection equipment and processes probably makes most sense.



2.1 Corrosion plus equipment and materials for sour service

KAZAKHSTAN IS PERFECTLY PLACED TO BECOME A LEADER IN THIS AREA, COMBINING ADVANCED ICE MODELLING AND WEATHER FORECASTING CAPABILITIES WITH SPECIALISED STRUCTURAL ENGINEERING SKILLS AND STRONG, LOCAL, COLD-CLIMATE SUPPORT CENTRES.

2.2 Operating in the ice and during cold weather

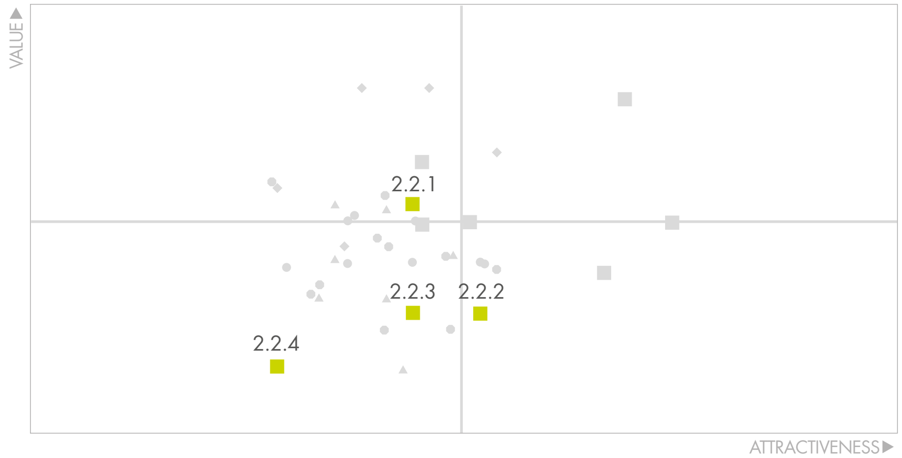
Challenge commentary

Winters in the northern Caspian Sea are like those in the Arctic. The sea is covered by a thick layer of moving ice from December to March and temperatures of -40 C are not uncommon.

Drilling and well intervention during this part of the year requires the construction of artificial islands or the use of ice-strengthened mobile drilling units, both of which are expensive options. The challenge is to optimise the available Arctic drilling technology for use in the Caspian (and improve ice modeling and weather forecasting), so that operations can be conducted all the year round in an efficient, safe and cost-effective manner.

Producing assets like Kashagan suffer during the winter from **ice encroachment over vital plant and equipment.** In the short-term, better and more cost-effective protection structures are needed. Longer-term the solution probably lies in reinforced steel or concrete structures designed specifically for the shallow, icy waters of the Caspian.

Generally, more work needs to be done in areas such as process modularisation (to reduce the need for site work in harsh environments), automation and human factors engineering in order to improve productivity and to **reduce the impact of winter** on the oil and gas industry in Kazakhstan.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Drilling in cold climates	2.2.1 Jack-up rigs capable of working in Arctic conditions all year round
	2.2.2 Offshore installations to work uninterrupted in Arctic conditions
	2.2.4 Ice & weather prediction capabilities
Structures, equipment & facilities suitable for working in cold climates	2.2.2 Offshore installations to work uninterrupted in Arctic conditions
	2.2.3 Numerical analysis for interaction of heavy pipe with ice for ice-scouring
Ability to carry out operations all year round	2.2.2 Offshore installations to work uninterrupted in Arctic conditions

2.2 Operating in the ice and during cold weather

Solutions commentary

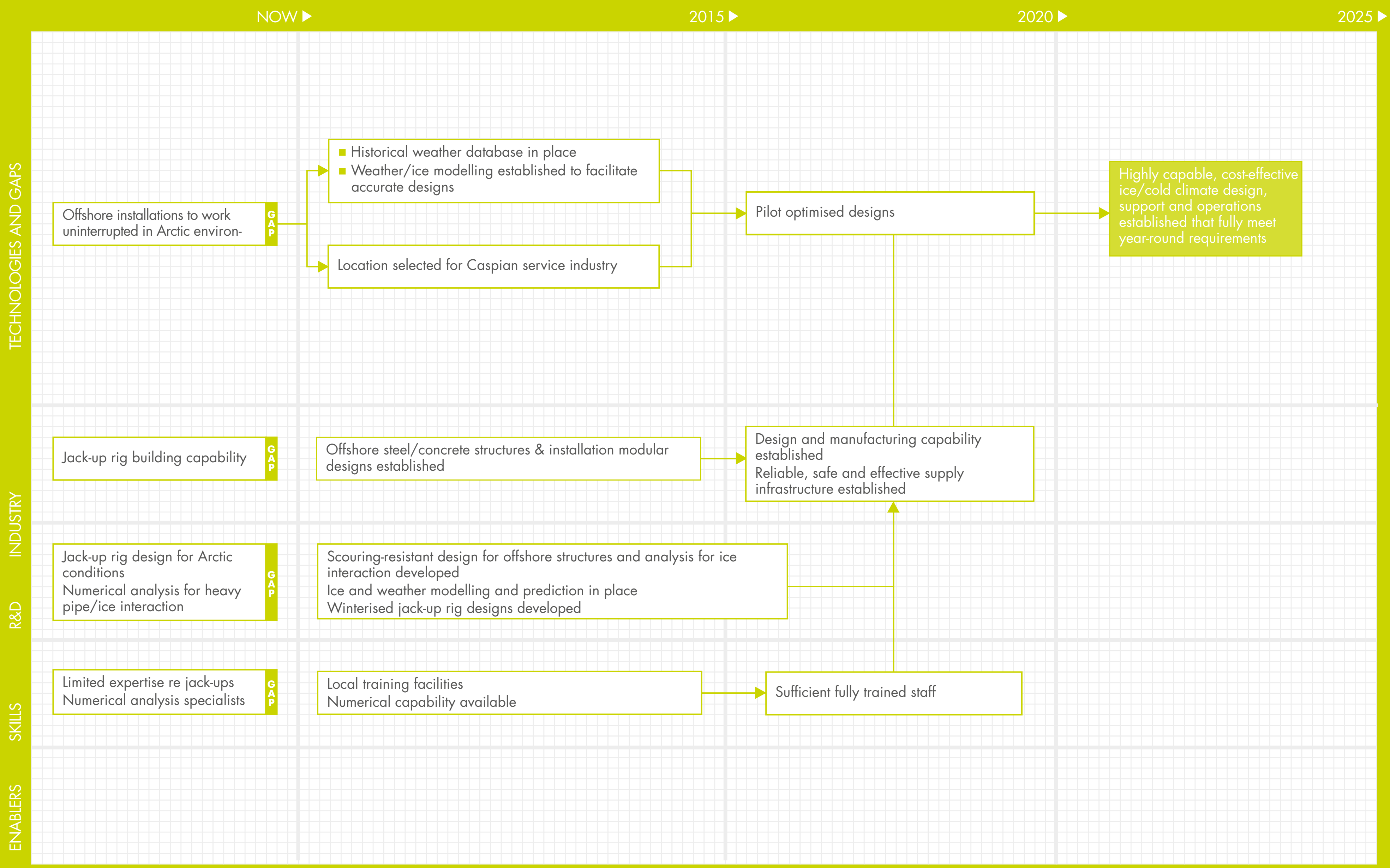
The solutions in this area cover the study, design, construction and operation of ice cold weather drilling and production infrastructure.

Being able to understand and predict the weather and the ice dynamics is the key to effective facility design and construction, as well as year-round operations. The most up-to-date modelling packages need to be adapted – by R&D institutes in Kazakhstan – to deliver the required advanced capabilities. Historical weather databases should provide the initial calibration for the modeling; however, more extensive advanced sensing will be required. A range of sensors will be needed from fiber optic distributed strain sensors on facilities through to differential global position system (DGPS) networks. Significant computing power will be required to support the integration of diverse measurements made at different scales.

Understanding the forces related to ice and weather is important in designing all kinds of structures and equipment. Currently, heavy pipe needs to be extensively armoured and/or deeply buried to avoid damage due to ice scouring. Huge time and cost savings could be realized if the current requirements were to be relaxed based on improved understanding or alternative avoidance mechanisms. Ice-induced movement of jack-up rigs can cause well casing shear and loss of containment. R&D is required to improve the cost effectiveness and operating envelope for drilling and well interventions in Caspian winter operations.

Presently, offshore steel/concrete structures are designed to protect the production facilities from ice encroachment. Alternatively, sacrificial zones are created where ice simply piles before reaching critical equipment. Global best practices in this area should be quickly adopted in Kazakhstan. Longer term, R&D is required to provide more cost effective, movable (modular) ice protection capabilities. Modular design is considered a major component in addressing year round operations, maximising facility uptime and minimising workforce exposure. The solutions range from small-scale plug-and-play components (such as instrument packages that can be quickly replaced when they fail) to large-scale fabricated items (such as a compressor modules). Kazakh companies and academia will need to further develop such technologies.

A Caspian manufacturing and logistics location needs to be selected and developed to realize the ultimate objective of delivering cost effective ice/cold climate equipment and supporting year round operations. The associated workforce needs to be grown to the required numbers and skill levels by 2020.



2.2 Operating in the ice and during cold weather

> KAZAKHSTAN COULD BECOME A RECOGNISED CENTRE OF EXCELLENCE FOR THE MANAGEMENT OF SULPHUR, LEADING THE WAY IN CAPTURE TECHNOLOGY AND ENVIRONMENTALLY-ACCEPTABLE STORAGE SOLUTIONS. A STRONG LOCAL INDUSTRY COULD BE BUILT AROUND THE MANUFACTURE OF SULPHUR PRODUCTS AND THEIR WIDE-SCALE USE IN A RANGE OF OTHER KAZAKHSTAN INDUSTRIES.

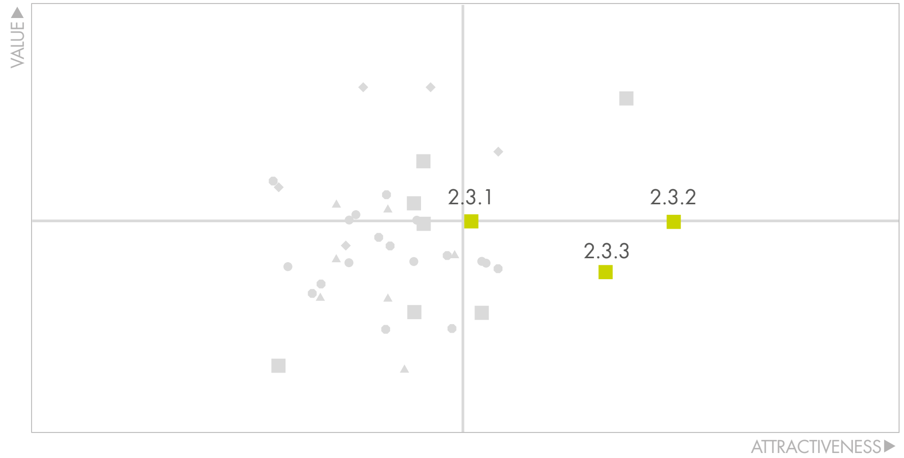
2.3 Management of sulphur

Challenge commentary

Sour oil production from large carbonate reservoirs across Kazakhstan leads to the challenge of dealing with huge volumes of sulphur – its handling, transport and storage are constant issues for most operators. Some sulphur is exported, though global supply outstrips demand and so the market is volatile, at best.

Kazakhstan would benefit greatly from having better solutions to the **capture and long-term storage of sulphur.** While technologies exist around the world, there is room for their improvement and for their better adaptation to the operating conditions and the natural environment in the country.

The **development and local use of sulphur products** presents a significant opportunity for Kazakhstan. Sulphur could be used, for example, to produce chemicals, as an additive for fertilizers, in building materials (sulphur concretes) and in the construction of roads. The challenge for Kazakhstan is both to develop the necessary technologies to manufacture these kinds of products and then to open up the markets for them.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Sulphur capture and storage	2.3.1 Sulphur storage
	2.3.2 Sulphur separation from crude or gas produced
Development of sulphur products, fabrication technology & market	2.3.3 Sulphur utilization

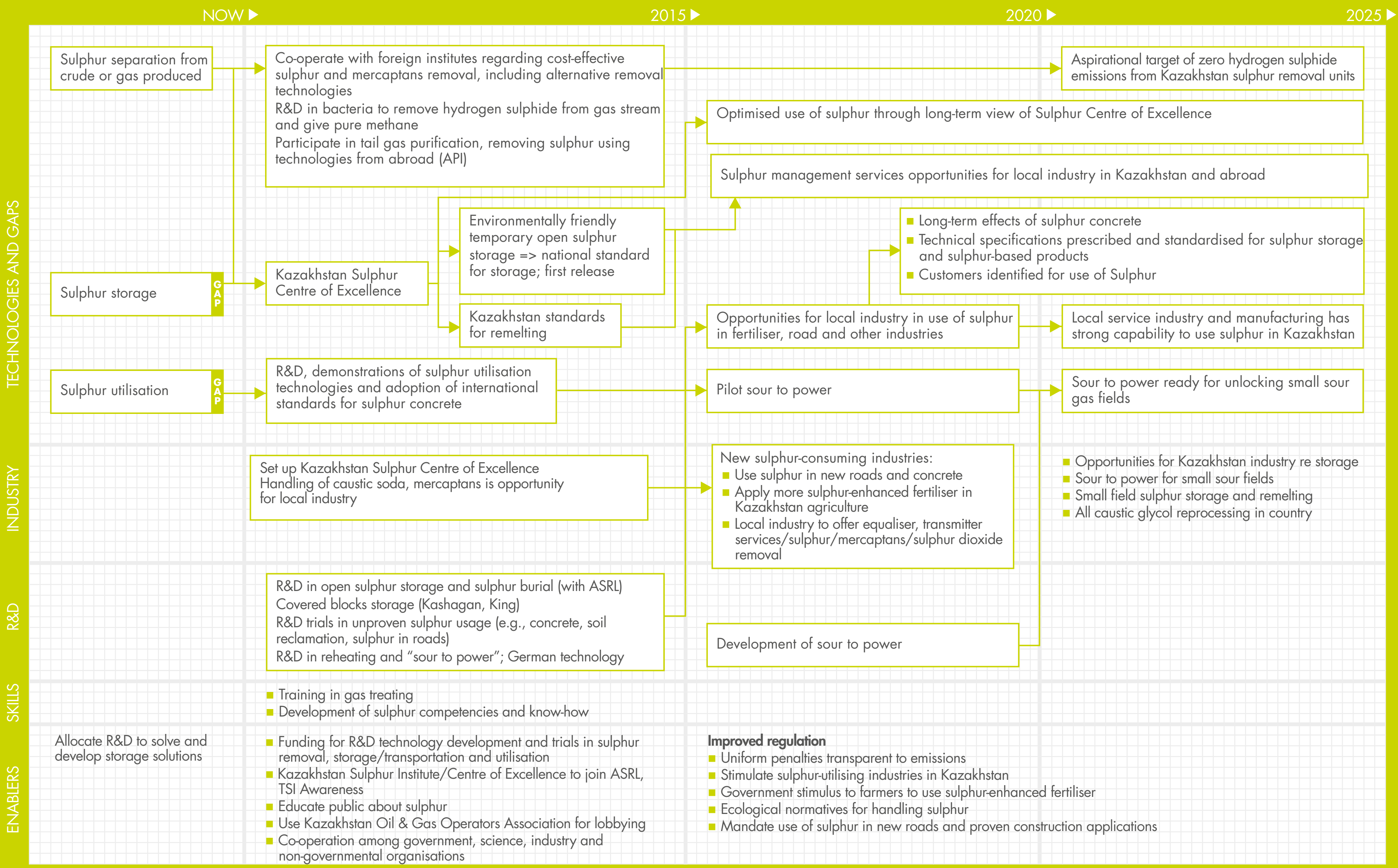
2.3 Management of sulphur

Solutions commentary

The production of elemental sulphur from oil and gas is likely to grow to around 4 million tonnes per annum 10 years from now. Sulphur storage and sulphur utilization remain challenging, while separation of sulphur and mercaptans from oil & gas is reasonably well progressed.

More cost-effective separation technology solutions exist, and emissions could be reduced towards zero through tail gas purification by working with other institutes abroad. The foundation of a Kazakhstan sulphur centre of excellence would be of value in developing fit-for-purpose standards for advanced sulphur separation and storage technologies. These standards for environmentally friendly, temporary sulphur storage could be based on best practices in Canada and other countries with a history of responsible sulphur management, possibly adapted for the harsh Kazakh conditions.

Experience with sulphur storage and re-melting should present opportunities for local industries to develop sulphur management services in Kazakhstan and abroad, such as Russia and Middle East. The biggest challenge is the utilization of the large quantities of produced elemental sulphur. Some sulphur is used for making sulphuric acid and phosphate fertilizers, and it is hoped that these industries will grow further. Some research has taken place by local institutes on sulphur enhanced asphalt and concrete but more R&D and cooperation with global sulphur innovators is needed to accelerate the development of local industries based on these opportunities. As the Kazakhstan construction industry is not used to dealing with sulphur, the government ought to consider adopting fit-for-purpose, international regulations and approval/permit processes regarding the handling and storage of elemental sulphur. This would lower the barriers to growing a rich local sulphur industry. Kazakh entrepreneurs should be encouraged to pilot existing technologies for sulphur enhanced construction materials, and develop new small, medium enterprises. The agriculture sector could benefit from using sulphur-enhanced fertilizers in sulphur-deficient soils and sulphur ameliorant to reclaim waste land with sodic and saline soil for agriculture in large parts of the country. Local R&D in sulphur storage and utilization could make Kazakhstan a front runner in this area. A decision will have to be made on whether know-how and resources should be made available for fundamental and longer-term research into the conversion of sour gas more directly into power.



2.3 Management of sulphur

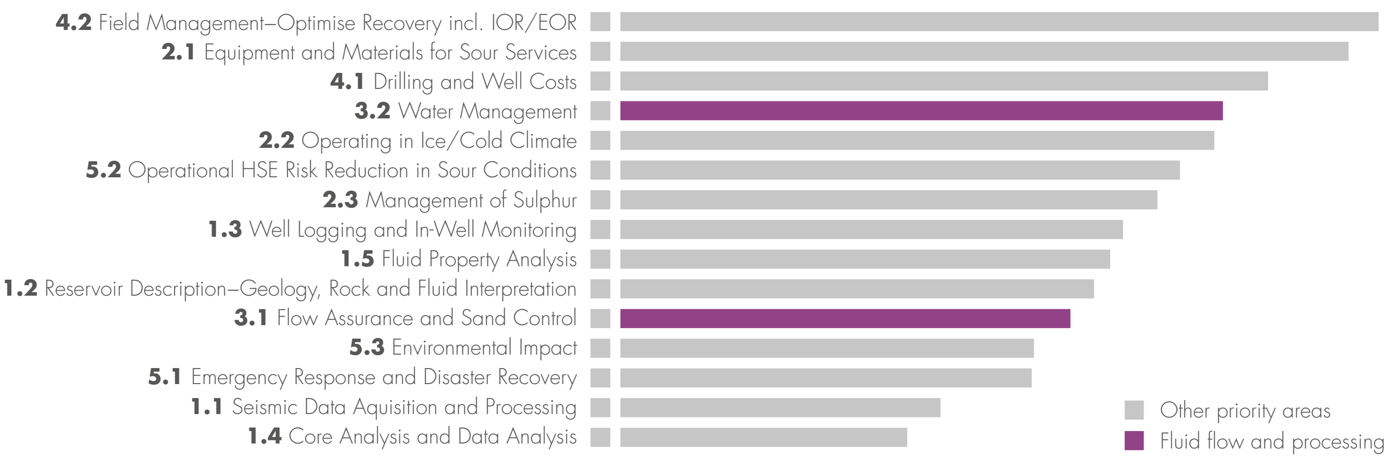
3. Fluid flow and processing

Flow assurance and sand control are issues common to oil and gas production the world over, and Kazakhstan is no exception in this respect. Multiphase flow-related technology appears to be a particular weak spot in Kazakhstan, likewise chemical flow enhancement technology and sand control.

Water management is big problem for many operators who report difficulties indentifying water sources, shutting off water-producing zones and dealing with the high volumes of produced water. Improved completion technology is just one area where effort needs to be made in Kazakhstan.

While flow assurance came towards the bottom of the list of the most important challenges facing the upstream industry in Kazakhstan, water management came close to the top.

WATER MANAGEMENT IS BIG PROBLEM FOR MANY OPERATORS WHO REPORT DIFFICULTIES INDENTIFYING WATER SOURCES, SHUTTING OFF WATER-PRODUCING ZONES AND DEALING WITH THE HIGH VOLUMES OF PRODUCED WATER.



KAZAKHSTAN HAS THE POWER TO BECOME A CENTRE OF EXCELLENCE FOR THE SELECTION AND DEPLOYMENT OF FLOW ASSURANCE TECHNOLOGY ACROSS THE INDUSTRY. MULTIPHASE FLOW MODELLING AND SAND MANAGEMENT EXPERTISE WILL BE KEY.

3.1 Flow assurance and sand control

Challenge commentary

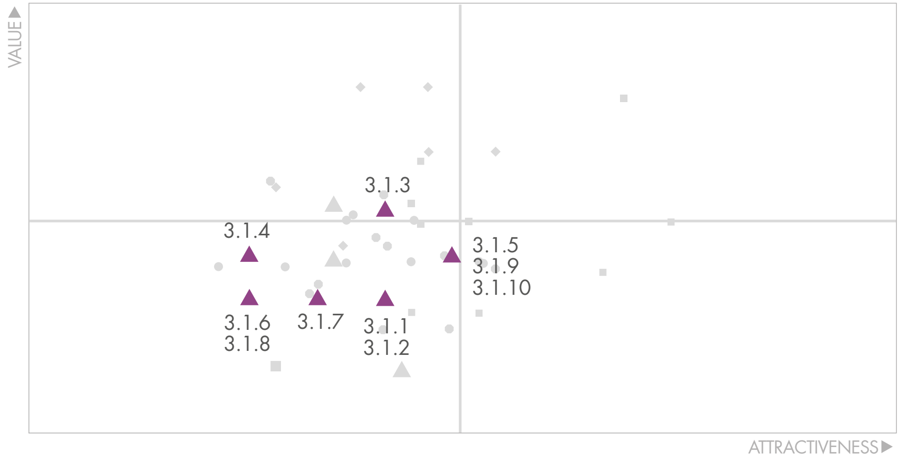
Kazakhstan's upstream oil and gas industry suffers from common flow assurance issues such as hydrate formation, wax deposition and sand production. **Multiphase flow modelling** in both wells and pipelines is another challenge in Kazakhstan: it is a complex discipline and not well developed in country.

Problems have been reported with the selection, deployment and monitoring of flow assurance techniques in a number of fields. Production allocation and pressure monitoring are known to be difficult in the Karachaganak, Kenkiyak, Kumkol South and North Buzachi fields. Flowline metering and monitoring is a challenge in extremely cold weather. And the assessment of permeability changes due to plugging and scaling during production has caused difficulties in the Tengiz, Kenkiyak, Kumkol South, North Buzachi and Karazhanbas fields.

Sand management is a challenge in fields like Karazhanbas, North Buzachi, Zhalgiztobe and Kenkiyak. Operators appear to have given up trying to control sand production, simply dumping sand in special disposal sites. Formation stabilisation to reduce sand production and the processing of sand for industrial applications are both key challenges.

Hydrate, asphaltene and wax deposition and scaling are reported problems in the Kashagan and North Buzachi fields. Paraffin build-up is an issue in fields like UzenMunayGas, Karamandybas and Zhetbay. And scaling due to the reaction between formation water and injected seawater is a common challenge. **Speciality chemicals** are available to tackle all of these problems and also to help break emulsions and improve oil rheology. But they are not routinely used in Kazakhstan owing to the lack of facilities to evaluate their performance and tailor their properties to the local conditions, and the absence of local manufacturing facilities (which puts up their cost).

Finally, **mercaptan removal** is a specific challenge for operators in Kazakhstan. Levels are high, all the necessary technology has to be imported and the process is prohibitively expensive.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Flow assurance methods incl. multiphase flow modelling	3.1.1 3D flow modeling (including multiphase flow)
	3.1.2 Flow Assurance Modelling and Monitoring
	3.1.3 Production surveillance and optimization
	3.1.4 Multiphase flow meters (for extreme conditions, self calibrating etc)
	3.1.5 Heating for Flow Assurance
	3.1.6 Well Stimulation (remote stimulation techniques)
	3.1.8 Intelligent completions
Sand removal and sand control	3.1.7 Sand Control and Removal
Chemicals inhibition	3.1.9 Flow Assurance Chemicals
Mercaptan removal	3.1.10 Mercaptan Removal

3.1 Flow assurance and sand control

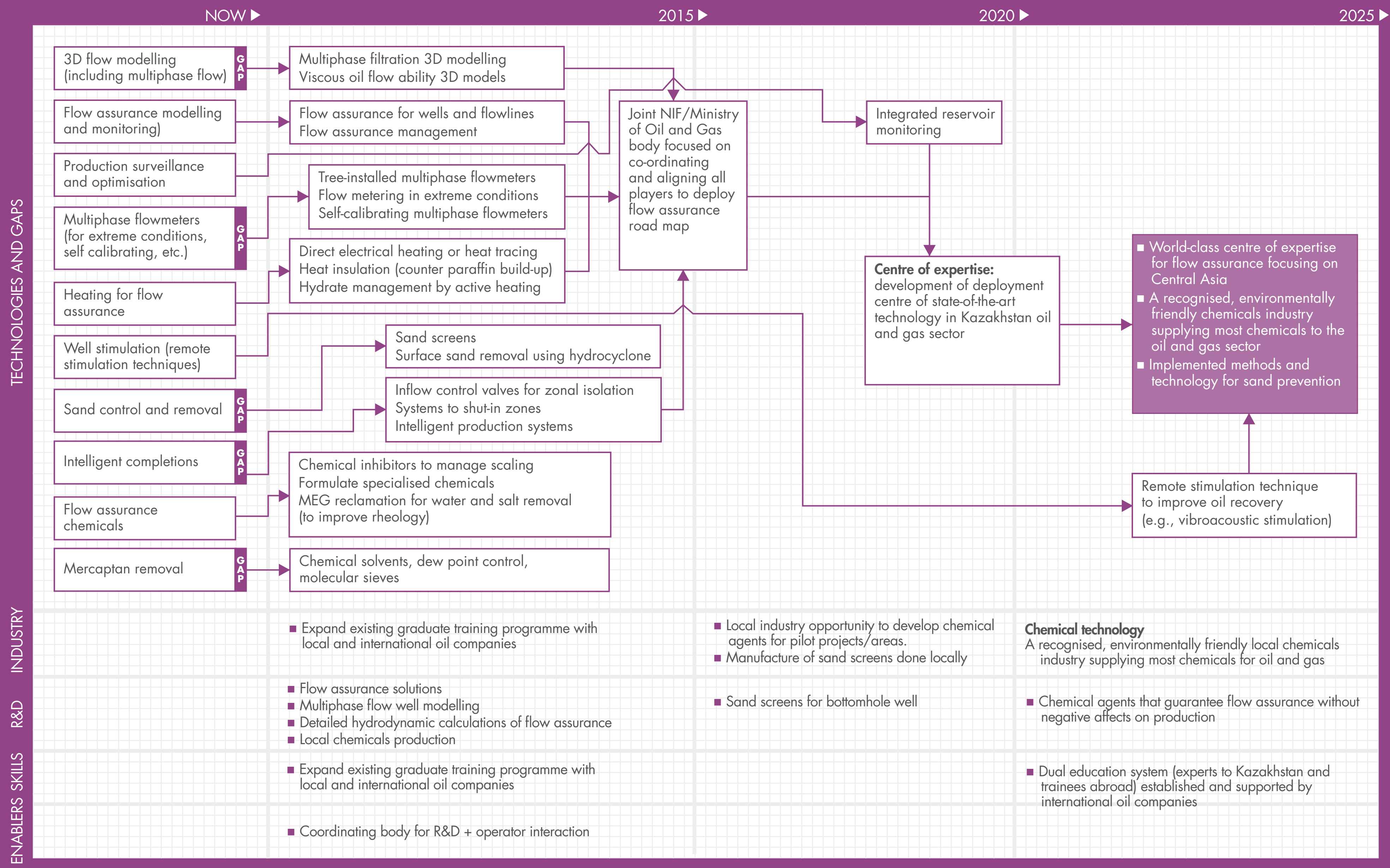
Solutions commentary

There was a series of solutions proposed to this combined challenge of flow assurance and sand control, though nearly all were considered to be in the least favoured value/attractiveness quartile. On the positive side, Kazakhstan was considered to be on a par with other countries in terms of the technology maturity of half of the solutions put forward.

Kazakhstan is well-placed in terms of flow assurance chemical technology and heating-related technology, and while advances will be needed in certain areas such as multiphase flow modelling and metering, the potential exists to create a centre of excellence for flow assurance in Kazakhstan. To some extent, the same applies for sand control.

It is significant that flow assurance chemical production and the manufacture of sand screens were viewed as prime opportunities around which to develop local industries, adding weight to the argument that Kazakhstan could eventually be recognised as one of the leaders in this topic. For this to happen there will clearly need to be a concerted effort to coordinate R&D in a number of related areas, to link the work strongly to the operating community, and to improve the training and development of scientists and engineers in Kazakhstan.

Mercaptan removal was identified as a challenge, and a solution, during the course of the project, which is actually perfectly valid (this is not the only example of this). The technology has to be imported and the process is complex and expensive; simply removing mercaptans from the production stream more easily and cheaply is a perfect objective, a good solution to pursue. This is reflected in its position as one of the most attractive in the list for this area. Though it has to be noted that its attractiveness is partly down to the intellectual capacity needed to make headway in this area. There needs to be some careful thinking before pursuing this particular solution in Kazakhstan, as it is unlikely to provide a quick win.



3.1 Flow assurance and sand control

THE VISION MUST BE OF AN INDUSTRY THAT HAS WATER MANAGEMENT UNDER COMPLETE CONTROL ACROSS ALL OF THE PRODUCING FIELDS IN KAZAKHSTAN. PROCESSES WILL NEED TO BE COST-EFFECTIVE AND ENVIRONMENTALLY FRIENDLY. REAL-TIME DOWNHOLE WATER MONITORING WILL BE IMPORTANT, AS WILL BOTH CHEMICAL AND PHYSICAL SHUT-OFF TECHNOLOGY.

3.2 Water management

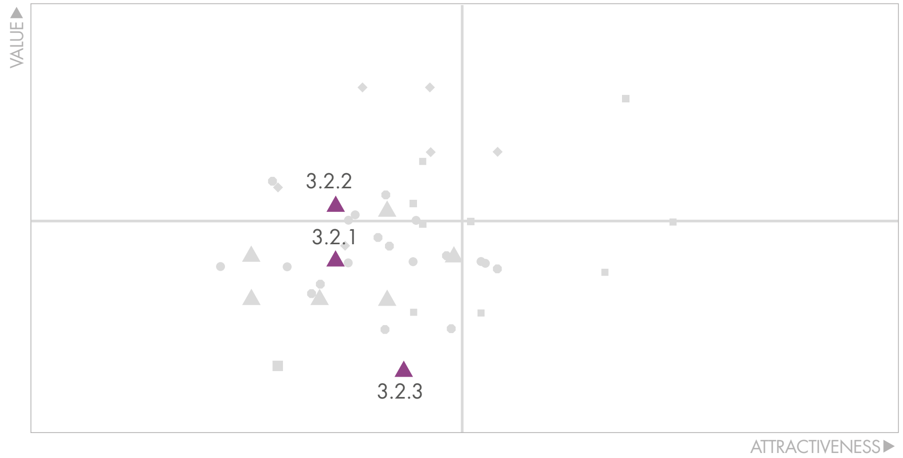
Challenge commentary

Water production associated with channelling, cross flow and coning is common in Kazakhstan because the detection and isolation of water sources is not well developed. High water cuts significantly reduce reservoir recovery levels. Further, the reinjection of produced water is not always straightforward and so disposal becomes a problem. Most water monitoring is confined to wellhead sampling (multiphase metering is rarely used) and so water assessments are often inaccurate, leading to the premature abandonment of wells.

The improved **identification of water source intervals** in wells would be of huge benefit. This is a particularly tough challenge as identification is difficult in complex reservoirs where there is water injection, a situation that is not unusual in Kazakhstan. Under these circumstances, accurate identification requires gathering a wide range of data, its thorough analysis and detailed modelling.

Water shut-off is another challenge, particularly in high water cut fields producing high viscosity oil – North Buzachi is probably the best example of this. Mechanical solutions do not work well where there are complex completions. Additionally, there needs to be good isolation behind the casing (good cement bond) and definite isolation of the water zone in the reservoir (permeability barriers).

The **handling, cleaning and disposal (or recycling) of produced water** is a third problem, especially in fields producing high viscosity crudes, which are difficult to separate. The onus is on the surface facilities needed to produce water of the quality necessary for industrial, agricultural or domestic use. Corrosion management and environmental protection are ever-present concerns for operators.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Identification of water sources	3.2.1 Diagnostic evaluation of water source
Shut-off/isolate water producing intervals	3.2.2 Water control technologies
Treatment/disposal of produced water	3.2.3 Water clean-up technologies

3.2 Water management

Solutions commentary

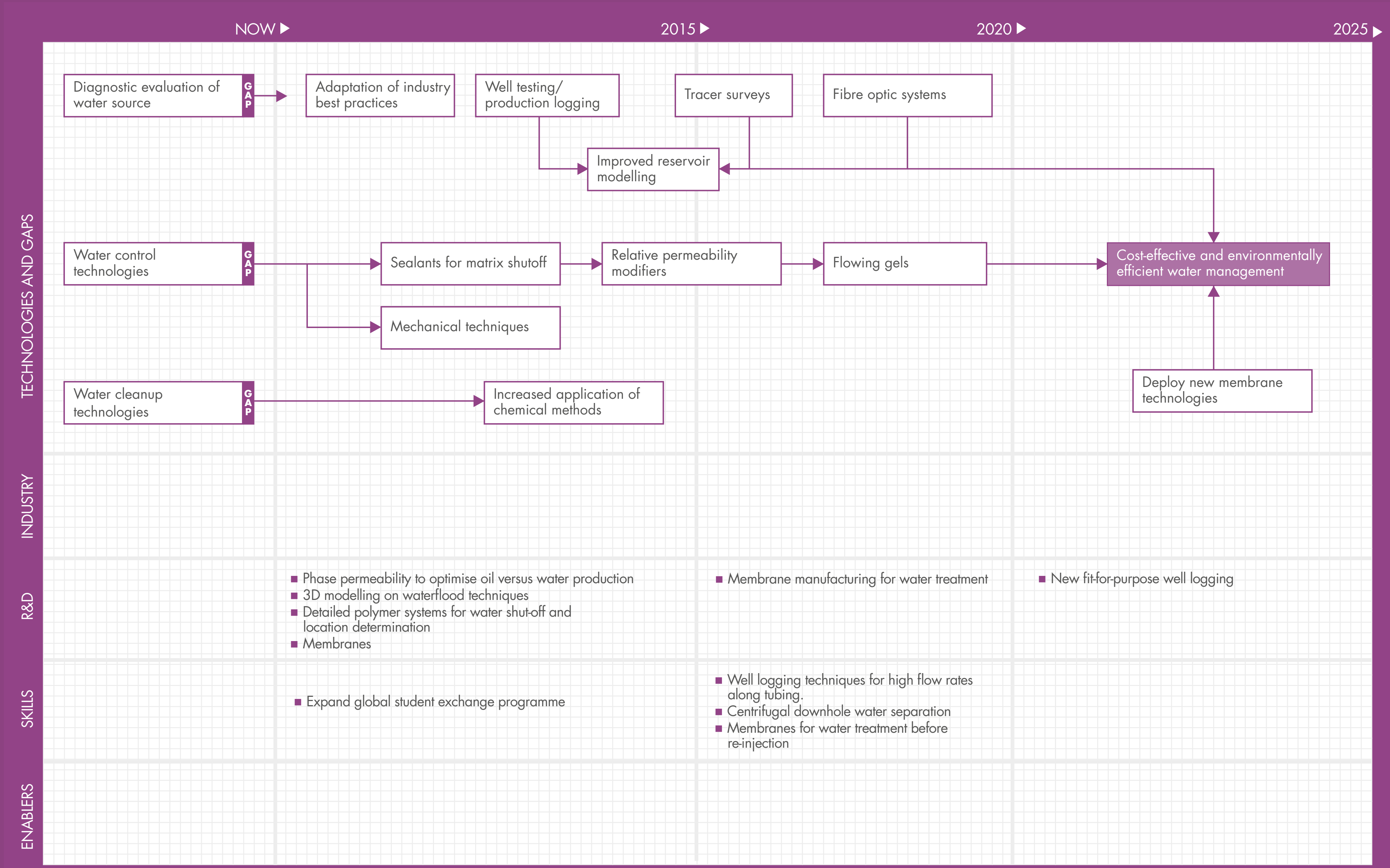
Technology solutions in this area fall into three categories: diagnostic evaluation of water sources; water control technologies; water clean-up technologies.

Several ways of improving the diagnostic evaluation of water sources were identified for implementation between now and 2025. Most immediately, it was proposed to adopt water source identification technologies and monitoring best practices from some other parts of the world, notably the North Sea and Oman. Further, there should be more frequent well testing and the use of new production logging techniques. Improved well logging, ultimately combined with tracer techniques to determine flow paths, will lead to improved reservoir modeling and enhanced predictive capability. An ultimate target is the deployment of downhole fiber optic systems, which offer the potential for real-time reservoir characterization and rapid zonal isolation to minimize water production.

In the area of water control technology, there are mechanical techniques, as well as sealants, that can be used now for the isolation of water producing zones, though these techniques are not applicable in cases where hydraulic fracturing and complex completions have been used. Longer term, water control can be improved using relative permeability modifiers and flowing gels, but these technologies require further development and testing. As shown in the R&D segment of the roadmap, there are potential local R&D opportunities associated with testing of improved chemicals for matrix sealing and relative permeability modification. Scope was also identified for local service provision - for example, sampling and well logging activities, manufacture of chemicals and well intervention services for water shut-off.

As far as water clean-up technologies are concerned, the near-term opportunity is increased application of established chemical techniques. However, the existing techniques can be quite expensive for high water cuts and are not well suited for separation of water from high viscosity oils. The preferred, longer term solution is likely to be membrane technology, which present a local R&D opportunity since further development is needed. This could lead to local opportunities for design, installation and maintenance of membrane separation equipment.

Provision of the necessary products and services from local sources will depend upon broadening and deepening the local knowledge and skills base.



3.2 Water management

4. Wells and field management

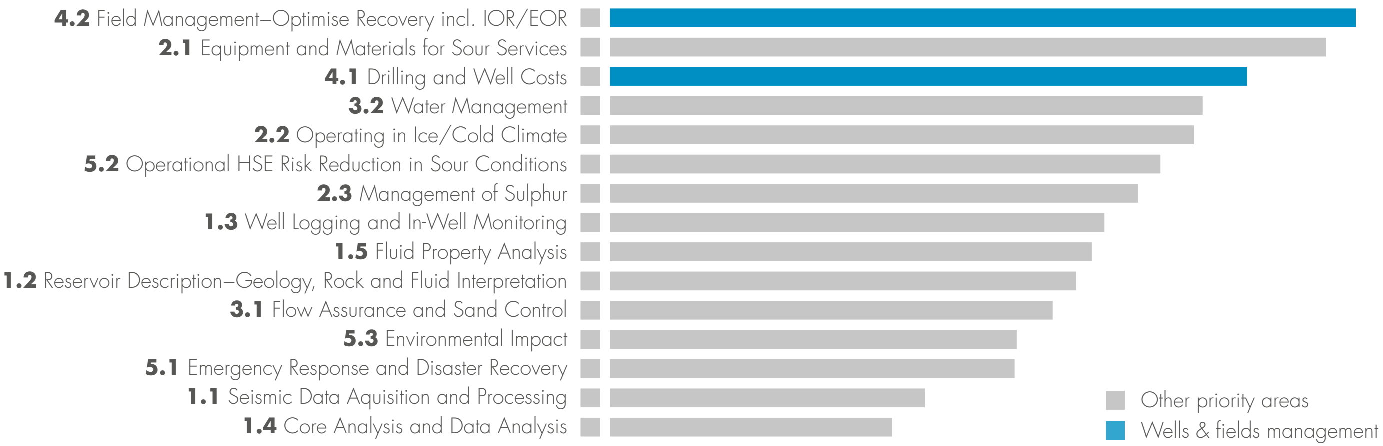
The management of, first, drilling and well construction and, second, production operations has an immense influence on overall field economics.

Reducing the cost of drilling is a huge challenge facing the industry in Kazakhstan, given the practical difficulties surrounding this activity, especially offshore in the winter. Throughout the roadmapping project there was constant reference made to the need for safer and more efficient drilling using winterised rigs.

There was also a clear call for better field management, including the effective deployment of IOR and EOR techniques in Kazakhstan. The industry is making great strides in this respect in other parts of the world and Kazakhstan has ground to make up.

The interest surrounding this technology target area is reflected in the ranking given to the two defined challenges – they were placed first and third in the list of 15.

THROUGHOUT THE ROADMAPPING PROJECT THERE WAS CONSTANT REFERENCE MADE TO THE NEED FOR SAFER AND MORE EFFICIENT DRILLING USING WINTERISED RIGS.



THERE NEEDS TO BE A STEADY REDUCTION IN THE NATION'S RELIANCE ON IMPORTED TECHNOLOGY AND GREATER TECHNOLOGY ADAPTATION TO CREATE DRILLING EQUIPMENT THAT BETTER SUITS LOCAL NEEDS. BY OVERCOMING THE CHALLENGES IN THIS AREA, KAZAKHSTAN STANDS TO BECOME THE DRILLING INDUSTRY LEADER IN THE CASPIAN REGION.

4.1 Drilling and well costs

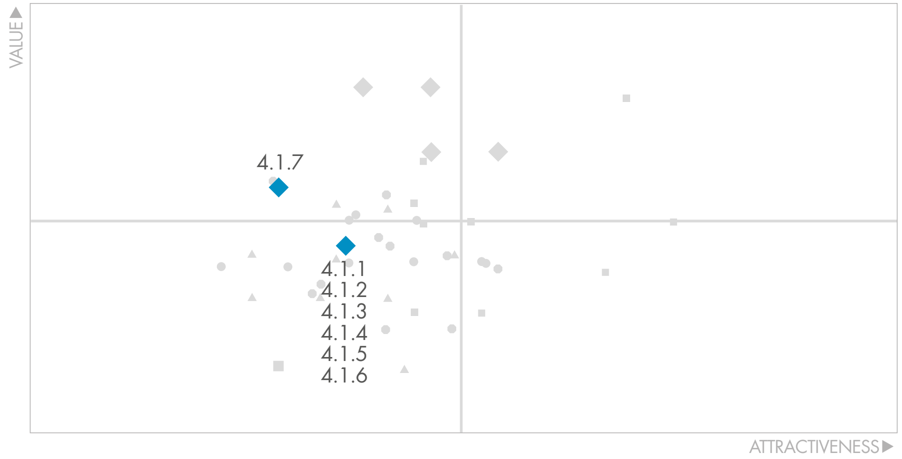
Challenge commentary

Kazakhstan has some of the most complex reservoirs in the world, containing oil and gas at high pressures and temperatures, as well as high levels of H_2S and CO_2. Drilling is always going to be a challenge under these conditions. On top of this, there are the practical and logistical difficulties associated with the limited internal infrastructure in parts of the country, lack of a sea route for drilling equipment into the country and the harsh winters.

Under the circumstances, **rig safety** is a major challenge in Kazakhstan, undertaking exploration or development drilling or well intervention in a manner that reduces the risk to the people involved as well as local communities. The challenge is most acute in fragile formations and where there are issues of well integrity – the Kenkiyak, Korolev, Kumkol South and North Buzachi fields are examples. Casing pressure management is also a safety-related issue in many fields, especially in sedimentary sub-salt reservoirs such as Karachaganak, Kenkiyak, Zhanazhol and Alibekmola.

Drilling through low pressure zones is a widespread challenge, given the prevalence of carbonate reservoirs in Kazakhstan and their tendency to contain cavities (vugs or karsts) or otherwise low mechanical strength rock structures. Mud loss, well bore stability and pipe sticking are common problems in, for example, Karachaganak, Kenkiyak, Kumkol South and North Buzachi.

Given the drilling challenges faced in Kazakhstan, **well costs** are generally high. Drilling in shallow water generally entails the construction of concrete drill pads. But the main cost issues arise from the need to bring every element of the drilling process (rigs, tools and equipment, chemicals and, not least, skilled people) into Kazakhstan. Unsurprisingly, cost over-runs are common: reducing their likelihood is a big challenge.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Rig safety	4.1.1 Casing & liners with improved pressure containment capabilities
	4.1.2 Drilling through abnormal pressures, high temperatures & H_2S
	4.1.3 Surface pressure control equipment for improved safety (on land & shallow water)
	4.1.4 Drilling safety methods
Drilling through low pressures (losses, stability)	4.1.2 Drilling through abnormal pressures, high temperatures & H_2S
Reduce well costs	4.1.5 Cost effective drilling techniques
	4.1.6 Directional drilling & reach
	4.1.7 Improved drilling rigs with directional drilling capabilities

4.1 Drilling and well costs

Solutions commentary

The reduction of drilling costs will play an important role in the development of the oil and gas industry in Kazakhstan. If significant advances can be made, Kazakhstan could realistically become a leader in this area of technology within the Caspian region.

Drilling costs depend on many factors. There is a great deal of drilling carried out in a variety of geological conditions in order to meet the volume of oil production in the Kazakhstan. The uniqueness of the industry in Kazakhstan in terms of reserves complexity is accompanied by the same the same level of challenges in the process of well construction. This is subject to abnormally high and low formation pressures, high temperatures, the presence of salt-bearing strata with strong streaks, plastic rocks and natural brine, as well as the presence of corrosive components (hydrogen sulfide and carbon dioxide) in the reservoir fluids.

The challenges arising in the process of drilling hydrogen-sulfide-containing reservoirs are extremely important. The enormous differences in geological conditions and the distribution of hydrogen sulfide in the formation fluids are important factors in regulating drilling activities. There are key issues surrounding the safety of drilling operations, personal exposure to toxic gases, prevention of metal damage and embrittlement, and violations of drilling techniques.

In order to reduce the cost of drilling under these circumstances, it is necessary to solve the following technical challenges:

1. Selecting optimum well drilling technology and ensuring good-quality well construction without complications (drilling in abnormally high formation pressure, abnormally low formation pressure, high temperatures, hydrogen sulfide).
2. Utilisation of equipment that is resistant to high pressures and multi-mineral and corrosive gas exposure (wellhead blowout preventing equipment, casings, liners etc.).
3. Quality assurance of well casing (high quality cementing, well casings of the required quality).
4. Application of new technologies, such as managed pressure drilling (drilling with a small excess of reservoir pressure, underbalanced drilling), extended reach drilling, gas-liquid drilling etc.
5. Improvement of drilling rigs with regard to their directional drilling capability in the offshore environment (shallow waters).

In order to address the first challenge there are several technical solutions to be implemented between now and 2025. Kazakhstan has vast experience in the construction of wells in the conditions described above. The primary means of regulating the stability of borehole drilling in the complex conditions of western Kazakhstan is through judicious selection of the circulating fluids used. Kazakhstan now needs to build on the results achieved in this area and to carry out further R&D aimed at developing new drilling fluid systems providing a further reduction of drilling costs. Circulating fluids and chemicals used for treatment should be also inert to hydrogen sulfide and have an inhibitory effect. It is essential to develop new chemicals to neutralise hydrogen sulfide, an area where local R&D institutions are reasonably strong.

As for the second challenge, most of the large deposits of the Caspian Basin contain hydrogen sulfide in the formation fluid. Distribution of hydrogen sulfide is confined to specific stratigraphic horizons, where a significant part of the section is represented by carbonate rocks. H2S being a permanent component of oil and gas sub-salt deposits of the Caspian Sea region, it has a highly detrimental effect not only on the metals and grouting materials, but also dramatically changes the properties of drilling fluids.

Operation of drilling and oilfield equipment in hydrogen sulfide deposits is complicated by the corrosive phenomena. The most hazardous form of corrosion is sulfide corrosion cracking of ferrous metal equipment. The steels used for oil and gas equipment must have special properties, for example, ductility, resiliency, chemical composition, and resistance to sulfide corrosion cracking. Particularly vulnerable are joint welds, where the metal has to be heat treated in order to relieve stress and improve its quality.

It should be noted that material selection is important in reducing the chances of sulfide corrosion cracking but that there are still issues around other corrosion processes and hydrogen-induced cracking of the metal. Therefore, to ensure the availability of the necessary equipment for the industry it is important, first of all, to focus R&D efforts (in collaboration with foreign R&D centres) to develop new types of alloys and to produce them domestically by 2025. BOP equipment, boring casing, liners and so forth of good quality are absolutely essential in Kazakhstan.

As for the third challenge, one of the most important issues in the course of well construction is mounting (casing running, and cementing). Poor-quality cementing of wells results in significant costs and delays. The cement should also have high corrosion resistance. Kazakhstan does not produce such cements, but there are factories in Russia that produce special cements with the desired properties. It would make sense to pursue the possibility of setting-up joint ventures with such factories to address this issue with the involvement of local research institutes.

As for the fourth challenge, the improvement of drilling technologies in complex geological conditions is a necessary condition for reducing the cost of well construction in general. The methods describe below are currently not widely used in Kazakhstan, but could be with more research and development.

Managed Pressure Drilling – managed pressure drilling is when the flow from the well is not specifically triggered during drilling, but the pressure profile in the wellbore is precisely controlled using enclosed and high pressure drilling mud recirculation. Instead of relying on a single mass of drilling mud, a managed pressure drilling systems control the well pressure by rotating the BOP head along with the ground pressure equipment controlling the drilling mud returning from the annulus.

4.1 Drilling and well costs

Underbalanced drilling – in the course of underbalanced drilling the emphasis is on protecting layers from damage – particularly in depleted reservoirs with low pressure. Causing flow from the formation during drilling prevents skin effects and the corresponding negative impact on well productivity and reservoir performance. Reduced pressure in the wellbore also increases the penetration rate, extends bit durability and prevents loss of drilling fluid into the formation, and minimises exposure to sticking under the differential pressure. The overall result is an increase in well productivity and reservoir performance. Downhole DDV valves, such as those produced by Weatherford, reduce costs by decreasing the time for round trips, increase productivity by reducing formation damage, improve personal safety and eliminate the need for forced tripping under pressure. The technology of using downhole DDV valve increases the reliability of drilling operations.

Another way to reduce drilling costs is air flushing, which involves the use of humidified air or foam as a drilling mud. This increases the rate of penetration and extends bit durability. Although air flush drilling is considered to be mature in the United States, it is best described as a promising technology in other parts of the world.

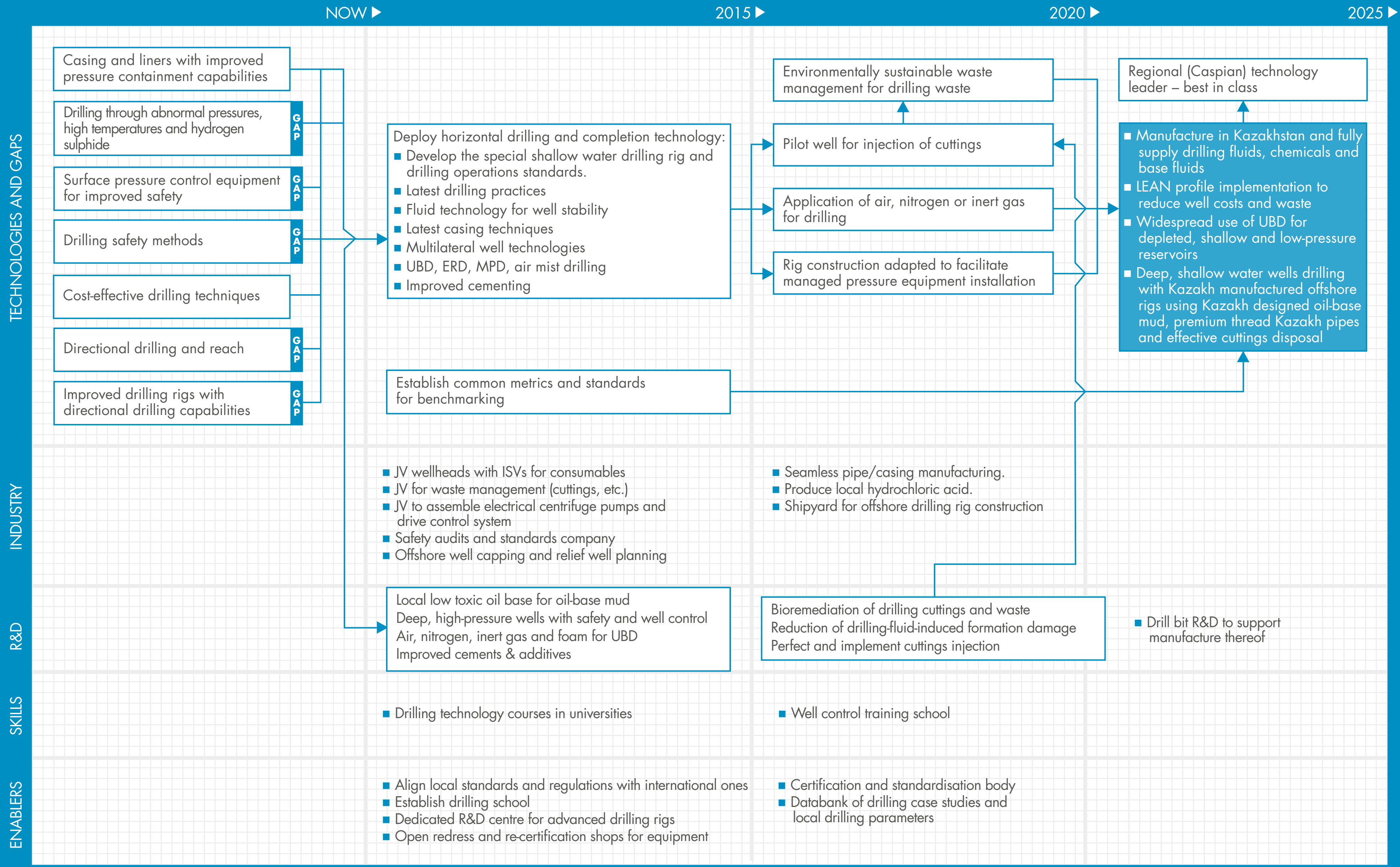
With the injection of nitrogen into the casing, an underbalanced drilling campaign on the Hassi Messaoud field (Algeria) has reduced the time of drilling horizontal wells from approximately 30 days to 12-15 days. Subsequent improvements, for example, blowing nitrogen through the drill string and measuring downhole parameters in the drilling process, has reduced the time even more - down to 10 days.

It is recommended to use these methods in Kazakhstan before 2020. To help the utilisation of such technologies in Kazakhstan fields it will be necessary to conduct appropriate adaptation through local research and development institutes and possibly through the creation of joint ventures with the companies that invented these technologies.

As for the fifth challenge, drilling wells in the Caspian region is difficult owing to issues surrounding the mounting of rigs in shallow water. In order to solve the problem of designing rigs suitable for shallow waters, it will be necessary to streamline the efforts of R&D institutes and design houses or form joint ventures with foreign institutions, with the active participation of the government. The objective must be to bring this effort (design and manufacture of new drilling rigs) to Kazakhstan by 2025.

In order to accelerate the development of the oil and gas industry it will be necessary in the shortest time to fulfill and implement the following actions.

- Create industry joint ventures for the production of wellhead equipment suitable for the conditions in Kazakhstan; the recycling of wastes (sludge etc.); the undertaking of safety audits and management of standards; the rehabilitation and re-certification of equipment etc.
- Research and development should focus on studies of local mineral bases for the development of new chemicals and formulation of drilling fluids; methods for the initial opening of productive strata; new well construction techniques; methods for obtaining and using inert gas well drilling etc.



4.1 Drilling and well costs

"THE ABILITY TO CARRY OUT COMPLEX RESERVOIR MODELLING WILL BE VERY IMPORTANT. SO WILL BE THE INTRODUCTION OF EOR BEST PRACTICES FROM OTHER PARTS OF THE WORLD AND THE ADAPTATION OF THE VARIOUS TECHNOLOGIES TO MATCH THE CONDITIONS FOUND IN INDIVIDUAL FIELDS.

4.2 Field management: optimised recovery including IOR/EOR

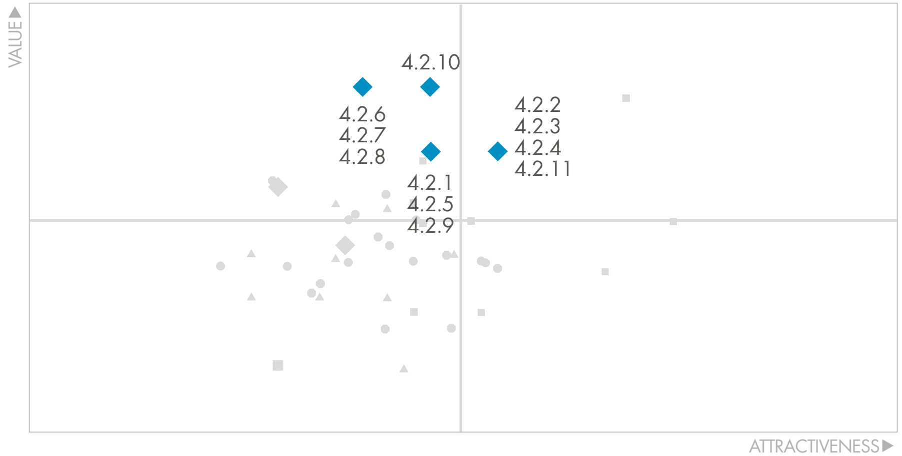
Challenge commentary

Maximising the production and ultimate recovery of oil and gas from existing assets is a constant challenge for operators all around the world. The conditions in Kazakhstan – unusually complex reservoirs, high temperatures and pressures, high H_2S levels and arctic weather conditions – all combine to pose particularly difficult field management problems for even the leading operators.

Waterflooding for improved oil recovery (IOR) is used extensively in Kazakhstan. However, matching the properties of the injection stream with those of the hydrocarbons present in the reservoir and the characteristics of the rock matrix is not easy. Consequently, benefits are often limited and field performance may even decline as a result of this treatment. **Selecting the best enhanced oil recovery (EOR) technique,** or combination of IOR and EOR, is even more fraught and the economics even more likely to prove unsatisfactory. The challenge is to better understand (via data capture, analysis and modelling) the reservoirs and be able to predict more accurately what will happen when water, chemicals, gas or heat are used to enhance hydrocarbon recovery.

EOR is known to be largely ineffective in tight reservoirs, which require stimulation by, for example, fracturing, acid treatment or re-perforation. The challenge here surrounds the modelling, selection, application and monitoring of the chosen **stimulation technique in tight carbonate reservoirs** with few natural fractures, such as the Korolev field.

A third challenge is specifically related to the understanding and **management of coning and water and gas breakthrough** under different depletion profiles, vital to achieving high recovery factors with fewer wells. Problems are particularly acute during the final stages of production, when formation pressure and flow rates fall and water influx increases. Karashaganak, Kenkiyak, Zhanazhol and Alibekmola fields have all experienced problems along these lines.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
EOR techniques	4.2.2 Advanced waterflooding & EOR
	4.2.3 EOR gas injection
	4.2.4 EOR modelling
	4.2.11 Optimised field management
Improved well productivity from tight reservoirs	4.2.1 Well stimulation
	4.2.5 Water based fracture fluid systems
	4.2.6 Fracture monitoring & control
Management of coning, water & gas breakthrough	4.2.7 'In-well monitoring' for observing reservoir dynamics
	4.2.8 'In-well monitoring' using wireline tools (for integrity & water content)
	4.2.9 Reservoir monitoring with geo-chemistry & tracers
	4.2.10 Well (in)flow control

4.2 Field management: optimised recovery including IOR/EOR

Solutions commentary

The ultimate goal in this area is to increase oil production from existing assets through improvements in reservoir engineering.

Stimulation techniques are intended to restore well productivity that has been reduced by bottom-hole zone damage, the result of poor well packing, asphaltene/resin/paraffin deposits, scaling, etc. The objective is to deal with these problems and restore initial production and water intake capacity. Techniques include treatment with hot water, condensate, hydrochloric acid, steam, surfactants etc.

To select the optimal chemical for bottom-hole treatment, a core analysis must be carried out and the bottom-hole zone modelled to test the intended treatment. Based on laboratory results and the modeling work, recommendations can be made for pilot testing, and thereafter a decision made for a wider application.

Fracturing plays an important role in improving productivity. The efficiency of fracturing (i.e., the depth of fracturing, filling of fractures and duration of the effect) is dependent on the selection of the most efficient fracturing fluid. A combination of hydrofracturing, acid treatment and surfactants is usual to achieve the optimum effect. Selecting appropriate wells (with no defects in the casing) is also important – pilot testing should be carried out on selected wells.

Hydrofracturing monitoring, analysis and management of all field operations are mandatory processes. They enable the efficiency of the technology to be determined, the cost of the job to be estimated and deliver G&G studies on estimated ultimate recovery and reservoir behaviour. Based on fracturing monitoring and analysis, the technical and economic feasibility of fracturing the asset can also be determined.

EOR modeling requires input data from laboratory core analysis, deep oil samples, samples from drill sumps (asphaltene/resin/paraffin deposits, scaling, etc.), G&G and other activities.

Based on the results, a model of the bottom-hole zone can be prepared and different EOR options assessed. The selected technique should be tested at the selected location and based on the results a specific EOR technique recommended for deployment.

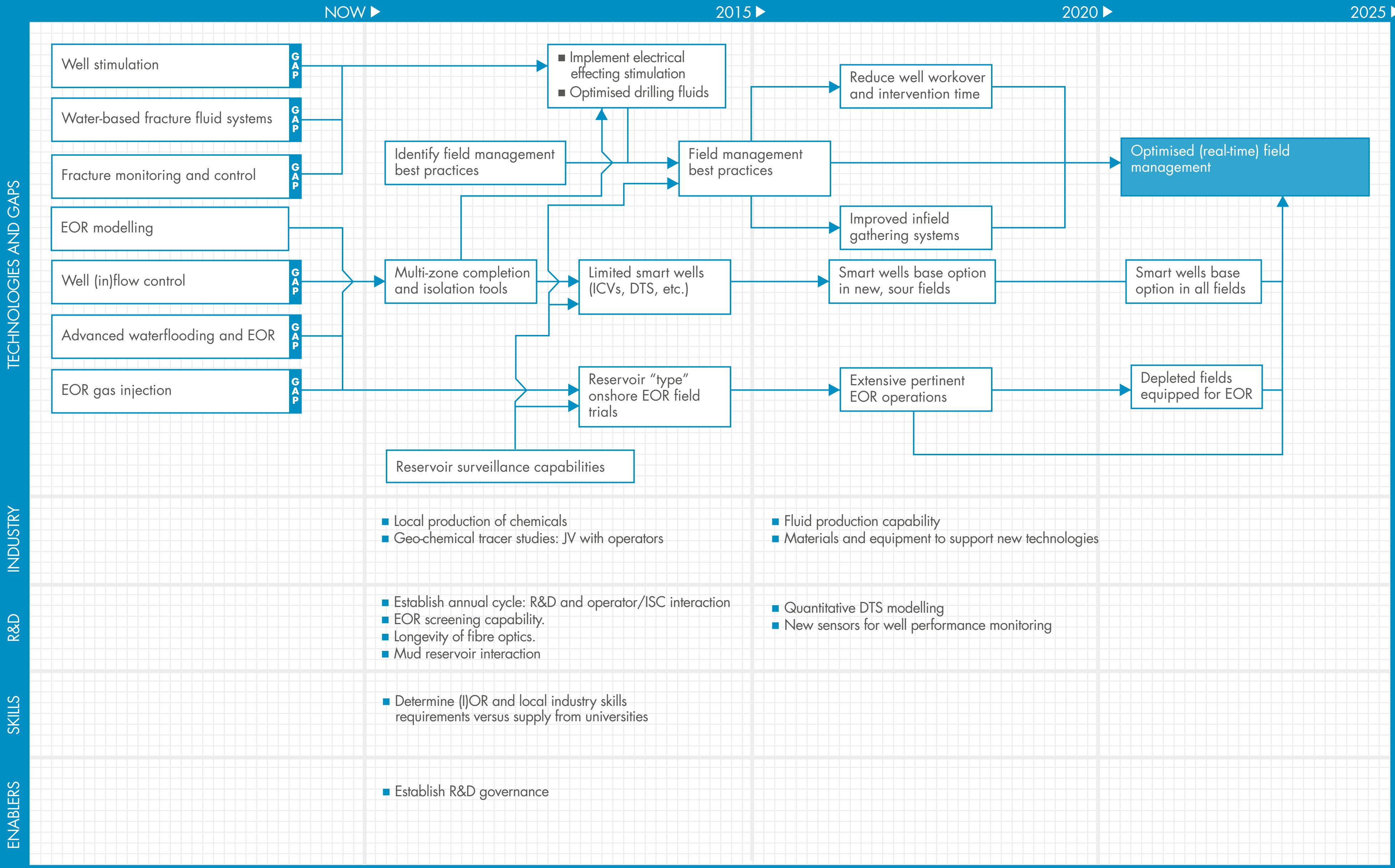
Problems or challenges encountered may vary, for example asphaltene/resin/paraffin deposits, scaling, incomplete perforation of pay zone, plugged drill sump, etc. All of these generally result in well production and water intake capacity decrease. To address these challenges, well intervention will be required, including bottom-hole zone treatment by various fluids, chemicals, re-perforation and additional perforation, drilling (restoring) the drill sump, etc.

The most efficient waterflooding, reservoir pressure maintenance or EOR technique must be selected based on laboratory analysis, reservoir and bottom-hole zone models and pilot tests. Advanced waterflooding is about changing the reservoir pressure maintenance techniques, testing different systems and elements subject to G&G features and heterogeneity.

EOR is based on laboratory analysis, modelling, pilot testing and reviewing the various advanced technologies, including physical, chemical and thermal techniques.

EOR gas injection is a very promising technology, widely deployed in fields around the world. Gases used include associated gas, CO_2, nitrogen, etc.

Technology and chemical have to be selected based on the core analysis, G&G studies, reservoir and dynamic models, pilot testing. Following the results of all tests, and if positive technical and economic factors are achieved, recommendations will be generated for specific injection techniques or combination of techniques.



4.2 Field management: optimised recovery including IOR/EOR

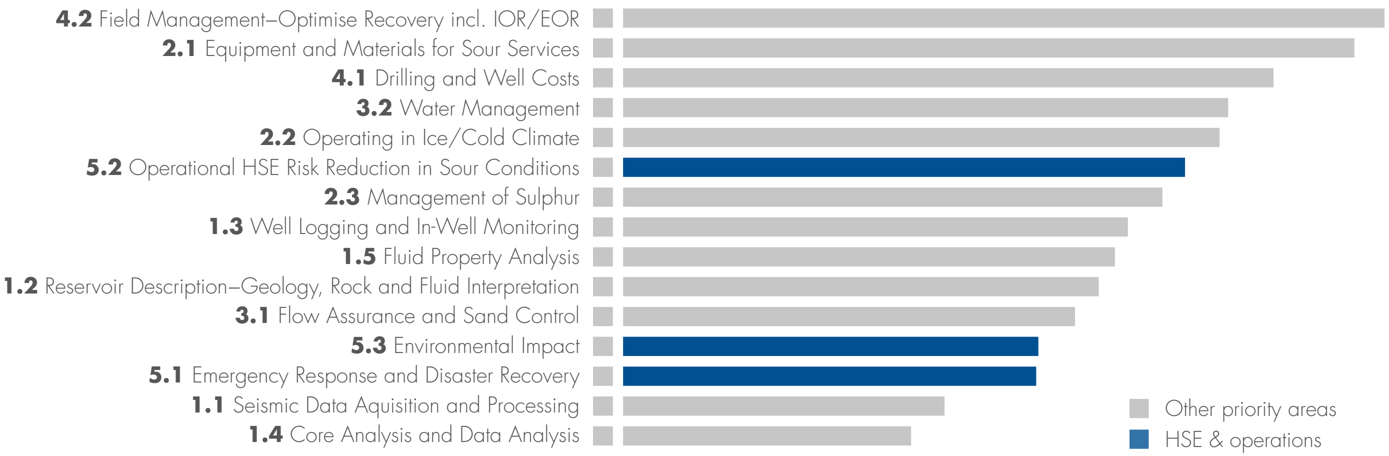
5. HSE and operations

The oil industry is perhaps judged more on its record on health, safety and the environment these days than it is on its exploration and production performance. Serious incidents make the front pages. Inevitably, the 2010 Macondo disaster in the Gulf of Mexico comes to mind; this tragic event not only brought the field operator, BP, to its knees, in both a reputational and a financial sense, but cast a pall over the entire global industry.

The HSE challenge in Kazakhstan is daunting: dealing with production from some of the sourest reservoirs in the world; operating under difficult geographic and climate conditions; and having to work in a region, the north Caspian Sea, where environmental sensitivities run extremely high.

Participants in the roadmapping project, however, placed HSE issues lower down the list of the 15 prime challenges facing the Kazakhstan upstream oil and gas industry. Operational risk reduction in sour conditions is in the top half of the list but emergency response and environmental impact come towards the bottom.

THE HSE CHALLENGE IN KAZAKHSTAN IS DAUNTING: DEALING WITH PRODUCTION FROM SOME OF THE SOUREST RESERVOIRS IN THE WORLD; OPERATING UNDER DIFFICULT GEOGRAPHIC AND CLIMATE CONDITIONS; AND HAVING TO WORK IN A REGION, THE NORTH CASPIAN SEA, WHERE ENVIRONMENTAL SENSITIVITIES RUN EXTREMELY HIGH.



KAZAKHSTAN NEEDS TO REACH A POSITION WHERE IT HAS THE TECHNOLOGY, SYSTEMS AND PEOPLE IN PLACE TO DEAL EFFECTIVELY WITH OPERATIONAL INCIDENTS IN A WAY THAT MINIMISES THEIR IMPACT ON THE PEOPLE INVOLVED AND ALSO THE LOCAL ENVIRONMENT. COLLABORATION WILL BE KEY.

5.1 Emergency response and disaster recovery

Challenge commentary

One of the greatest challenges faced by the oil and gas industry in Kazakhstan is developing effective emergency response plans for what is a highly complex and sensitive environment. Workflows are needed that are sufficiently advanced to overcome the worst possible situations but simple enough to be enacted rapidly and effectively in a relatively remote part of the world with, in some areas, limited infrastructure.

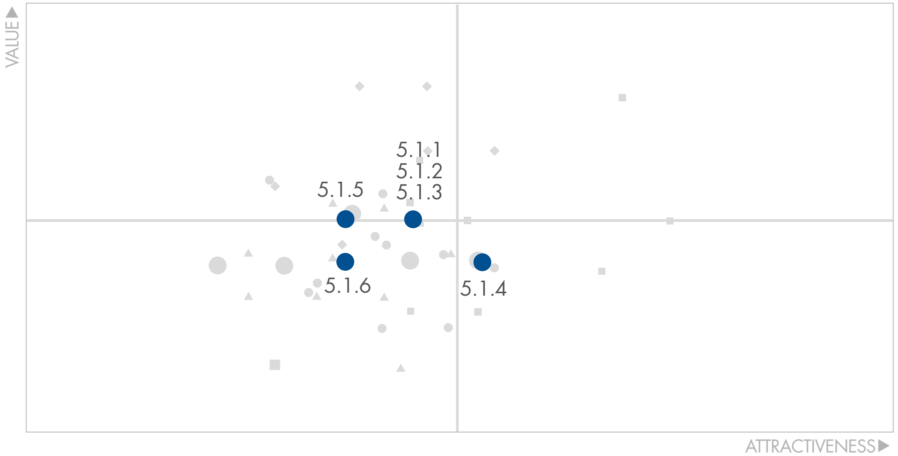
Developing world-class **emergency response plans** for Kazakhstan's offshore oil and gas fields is a challenge not only because of the harsh operating environment during the winter but also because of the large seasonal variation from winter to summer. The problem is made worse by the high levels of H_2S in the production streams. Existing plans need to be bolstered by incorporation of best practices from around the world, more training, better incident reporting, more in-depth safety reviews and greater attention to contingency measures.

There is a specific issue around **escape, evacuation and rescue (EER) vessels** for use in icy seas and under extreme winter conditions.

Improved designs for ice-breaking emergency support vessels, lifeboats and survival craft are required that more closely match the conditions in the shallow water fields of the north Caspian.

Measures to deal with oil spills in ice-covered waters need to be better established. There are concerns over the use of conventional mechanical clean-up techniques, and also the performance of the available dispersants in terms of their effectiveness and their impact on the environment when used in shallow water. Much work is being done in this area globally and Kazakhstan would benefit from taking a more collaborative role.

Finally, the Macondo incident in the Gulf of Mexico, in 2011, focused the industry on the difficulty of **dealing with wells in which pressure control has been lost.** Developing the ability to bring under control a well that is releasing large volume of oil and gas by use of an effective capping system is a challenge that Kazakhstan shares with the rest of the global industry.



CHALLENGE (elements)	TECHNOLOGY SOLUTIONS
Offshore emergency response	5.1.1 Quantitative risk assessment & management
	5.1.2 Emergency response preparation
	5.1.3 Safety processes & systems
Emergency response vessels for ice conditions	5.1.4 Emergency escape vehicles for arctic conditions
Oil clean-up technology & processes	5.1.5 Emergency response to oil spills (clean-up, containment, etc)
Disaster recovery system for Caspian	5.1.6 Disaster management – well capping systems etc

5.1 Emergency response and disaster recovery

Solutions commentary

The three solution groups cover

- HSE management systems (QRA & management, emergency response preparation and safety processes & systems);
- Oil spill/disaster response and mitigation, where well capping systems are normally considered to be required;
- Personnel escape vehicles.

Robust, effective HSE management systems are a critical pre-requisite for operations. The existing systems in Kazakhstan can be further optimised in the near term, for example by:

- Quantitative risk management modelling tools for risk identification.
- Increasing the scope of the oil spill response plan to include:
  - Location of facilities where oil spills are possible;
  - Detailed map of ecologically sensitive areas and review of seasonal sensitivity for each species;
  - List, location and type of equipment, transportation means, materials, personnel and working procedure concerning oil spill response;
  - List of applicable dispersants.
- Incident documentation for collective benefit within and between organizations.
- Mandatory Safety Programs, e.g. STOP.

Mechanical clean-up techniques comprise the physical containment of the oil within natural or man-made barriers, the subsequent removal of the oil from the surface and secondary storage for recovered oil and water.

Chemical dispersants are another addition to the toolkit for cleaning up spills and have proven highly effective in the Arctic. Dispersants are like detergents, designed to enhance the breakup of oil into fine droplets that can then be dispersed and biodegraded in the sea. The use of dispersants offshore is generally recognized as an efficient way of rapidly treating large areas of spilled oil, providing greater protection to shorelines, birds and marine mammals. They can be applied from fixed-wing aircraft, helicopters, and vessels.

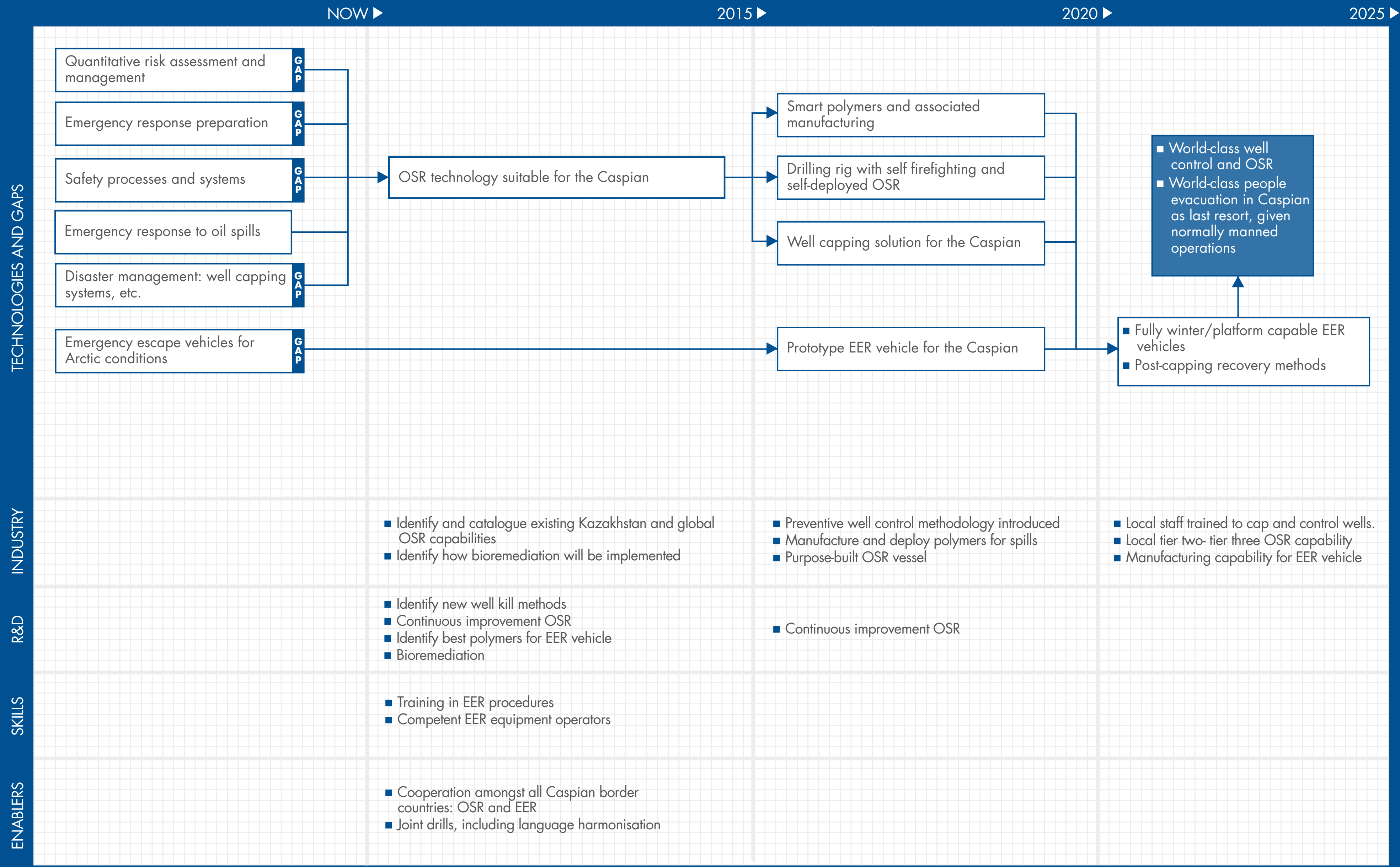
Any required modifications to these technologies to ensure they are applicable in the Caspian should be established in the short term; with the required changes performed by 2020.

In the near/mid term, importing and deploying advanced well capping systems tailored to the shallow water operating environment can help in addressing challenges around disaster recovery for the Caspian. The capping solution will have to also be tailored for surface application, since North

Caspian uses surface blowout preventers. A strategy proposed is to leverage capabilities from the recently established SWRP (subsea well response project) to identify the specific cold weather capping technology required for arctic conditions in Kazakhstan.

Another solution, in the unlikely event of a blowout, is to always plan for a relief well that can pump cement or heavy mud into the original well to cut off the flow.

At present escape and rescue vessels exist, however improved designs are sought that enable craft to operate under all conditions of open water and ice and a large range of water depths. Potential solutions for the North Caspian include the ARKTOS, and Ice Strengthened Lifeboats (ISL). The latter is a specialized ice resistance Totally Enclosed Motor Propelled Survival Craft (TEMPSC) capable of safely operating in ice. After further design work, followed by proto-typing in the medium term, fully winter/platform capable EER vehicles should be available in 2020+.



5.1 Emergency response and disaster recovery

IT WOULD BE REASONABLE TO ENVISAGE A FUTURE IN WHICH UNMANNED OPERATIONS WERE COMMON AND HAD REDUCED PERSONAL RISK TO EXPOSURE TO H_2S BY 50%. ADVANCED MATERIALS TECHNOLOGY AND LEAK DETECTION WOULD ALSO HAVE PLAYED A PART IN REACHING A POINT WHERE KAZAKHSTAN LEADS THE WORLD IN TERMS OF SAFELY PRODUCING OIL AND GAS CONTAINING HIGH LEVELS OF H_2S.

5.2 Operational HSE risk reduction under sour production conditions

Challenge commentary

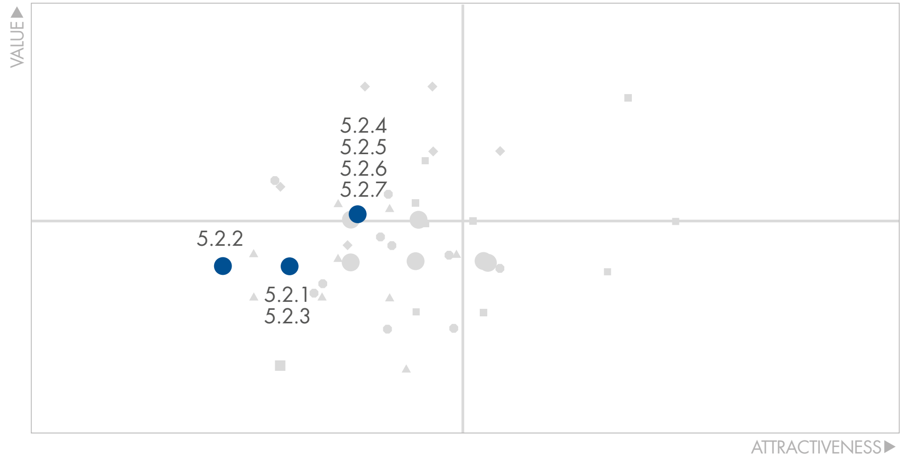
This challenge is all about dealing with the risks to people of operating fields that produce oil and gas with high levels of H_2S.

The **elimination of leaks through better plant design and improved operations** is a big challenge in Kazakhstan. There are benefits to be gained from reducing the number of valves, flanges and instrument intrusions in pipe systems. The greater use of seal-less valves and corrosion-resistant materials is to be encouraged. Risk-based inspection and reliability-centred maintenance have a role to play and there is the simple expedient of separating toxic and non-toxic process areas.

Personal protection equipment to enable people to work comfortably and safely in high-risk areas needs to be improved. There needs to be greater use of the latest, self-contained breathing apparatus with integrated communications capability to enhance operator performance.

Greater use needs to be made of automation, robotics, remote control technology and 3G WiFi communication to **reduce manning levels** in high-risk environments.

Overall, the challenge is to better **manage HSE risk** through, for example, greater use of 3D gas plume modelling, quantitative risk assessment methodology, consequence modelling, SIMOPS analysis and the latest plant integrity management procedures.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Facility design with minimum leak path	5.2.1 Leak reduction & elimination
	5.2.3 Leak detection techniques
	5.2.6 Facility management
H_2S personal protection (eg without cylinders)	5.2.2 Breathing apparatus (SCBA) for H_2S protection
Remote operations, minimum on-site work	5.2.4 Technology & automation for risk reduction (eg robots, wireless)
Managing the HSE risk	5.2.5 SIMOPS methods
	5.2.6 Facility management
	5.2.7 Safety certification & independent verification

5.2 Operational HSE risk reduction under sour production conditions

Solutions commentary

The three solution groups cover

- Personal Protective Equipment (PPE);
- Preventing H_2S leaks;
- Minimising personal exposure.

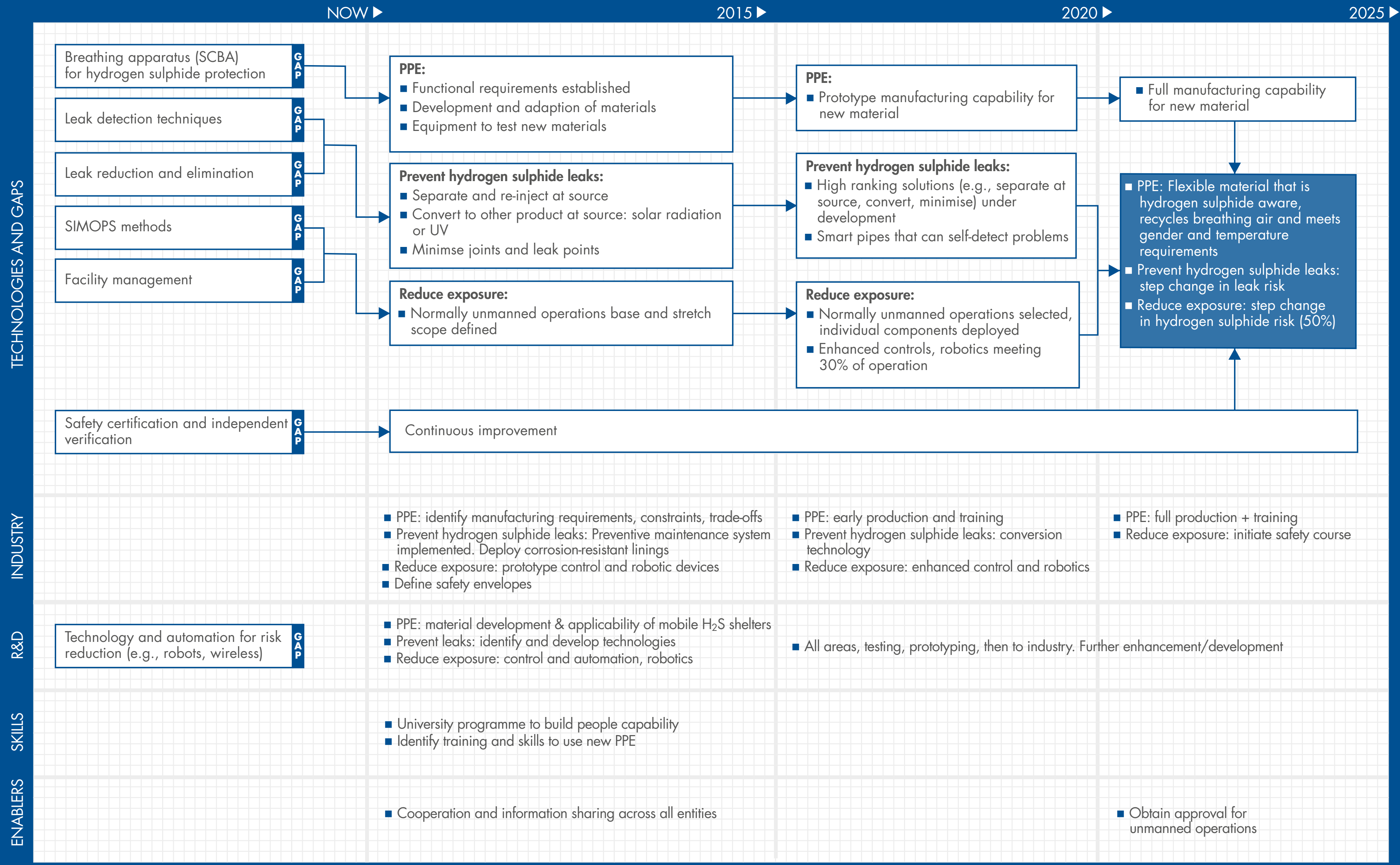
The combination of potentially very high H_2S environments plus extreme climate requires improved personal protective equipment to be developed for locations like Kashagan, allowing efficient, comfortable construction and operational activities to be performed. In the short term the detailed functional specifications need developing utilizing learnings and trials based on next generation H_2S personal protection equipment from other high pressure H_2S regions (Middle East, Canada), eg self-contained breathing apparatus (SCBA) that can support wireless audio and video with noise cancellation software. It is also expected that material capabilities will need establishing in Kazakhstan to enable the new PPE equipment to be supplied from 2020, fulfilling the goal of flexible material that is H_2S aware, recycles breathing air and meets gender and temperature requirements.

The goal with respect to leak mitigation is to have a significant reduction in leak risk and occurrences after 2020. Such a goal needs to be addressed in a holistic manner, ranging from separation, re-injection and utilization of H_2S/Sulphur; to the more conventional reduction and elimination of potential leak points.

For example a large development has upwards of 20,000 valves, 6,000 of which will be in critical positions and all of which are potential leak points. In the near term, the focus should be on reducing exposure via minimising leak paths in design and by separation of toxic versus non-toxic process areas, selective use of isolation valves (driven by Operations Philosophy) and use of non intrusive measurement and inspection methods (driven by condition based maintenance philosophy) .

Investments in R&D in the medium term should focus on address the sealing limitations of existing valves including providing valve functionality with no moving parts, together with 'smart pipes' that can self detect problems via in-built fiber optic sensors or analogous techniques.

The third solution group is focused on reducing manpower exposure, where the goal is to minimize and in selected areas eliminate (normally unmanned) the presence of workers within hazardous areas. Currently in Kazakhstan, oil and gas operations and maintenance activities require manual intervention, some of which are performed using breathing apparatus. Hence, dangerous but high value tasks like fluid sampling are often regretted. In the near-term transfer of technologies and workflows from other parts of the World like Oman and Canada can reduce exposure while the detailed target scope is developed. This is expected to lead in the medium-term to further R&D focused on robotics and automation of operations & maintenance tasks to increase availability. These technologies once deployed are expected to deliver the required step change reduction in manpower exposure.



5.2 Operational HSE risk reduction under sour production conditions

THE GOAL HERE IS SIMPLE. THE CASPIAN ECOSYSTEM MUST BE FULLY RESTORED, MONITORED WITH THE MOST UP-TO-DATE SENSOR AND SATELLITE SURVEILLANCE TECHNOLOGY AND PROTECTED BY THE LATEST WATER TREATMENT AND CLEAN-UP METHODS.

5.3 Environmental impact

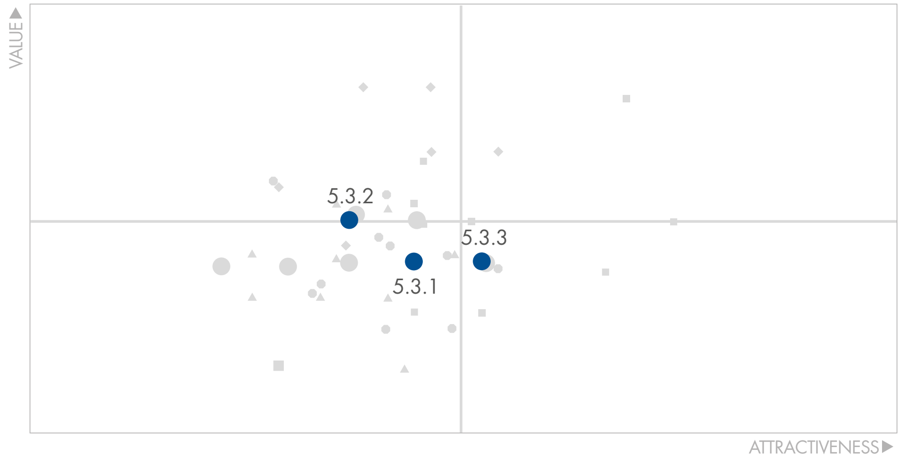
Challenge commentary

The oil and gas industry has to have a sound understanding of the potential impacts of its operations on the natural environment: the surface hydro-geology, the surrounding land and the atmosphere. It is important to be able to forecast and monitor impacts effectively – and to be capable of implementing measures to reduce them.

The **detection and assessment of oil releases, especially beneath ice,** is a challenge in Kazakhstan. Aerial surveillance needs to be improved and better sensors brought into play for accurately tracking the movement of oil volumes in the sea.

Several Kazakhstan oil fields have high water cuts: Kumkol South, for instance, stands at 93%. In cases such as this the challenge is to develop **water separation and clean-up methods** that will deliver water that meets the quality standards for use in industry, agriculture and maybe even domestic applications.

Heavy, viscous oil, such as produced in the Karazhanbas, North Buzachi and Kalamkas fields, poses particularly difficult **separation problems.** The position is improved by heating, but this naturally involves large amounts of energy. Separation and clean up technologies that get around this requirement would be particularly valuable.



CHALLENGE (elements)	**TECHNOLOGY SOLUTIONS**
Oil spill on/under ice	5.3.2 Emergency response to oil spills
	5.3.3 Remote Sensing/Aerial Surveillance
Produced water clean-up methods	5.3.1 Chemical & membrane methods for oil-water separation
Oil water separation methods for viscous oil	5.3.1 Chemical & membrane methods for oil-water separation

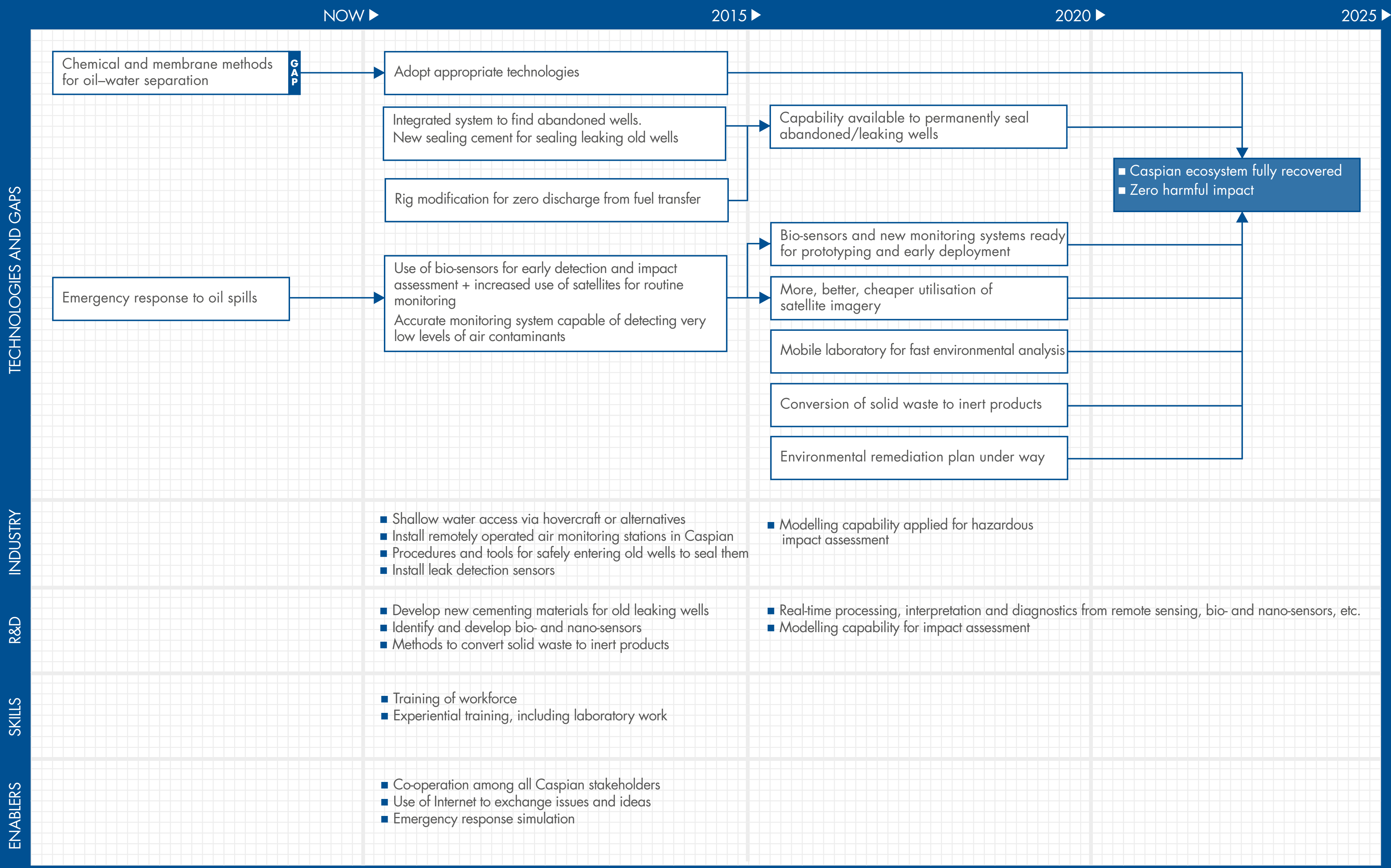
5.3 Environmental impact

Solutions commentary

The goal is to put in place technology systems than provide complete, rapid assessment of the environmental situation and enable full remediation of any past or future contamination of the Caspian ecosystem.

It is expected that membrane technologies will be a critical component in the technology staircase for separating water and (viscous) oil, enabling the full remediation of the Caspian to be achieved; current and future global capabilities should be trialed and adopted with high priority. In parallel the location and sealing (potentially with new cements) of old abandoned wells needs to be rapidly pursued, thereby stopping further legacy contamination. In addition all aspects of current and future operations need to be addressed to stop leaks, for example modifying rigs to avoid discharge during fuel transfer.

Capabilities in Kazakhstan to determine the environmental situation are already reasonable, thus building on them offers potential opportunities. In the short term the utilization of satellite remote sensing and multi-spectral sensing from aircraft should be increased, together with adopting bio-sensing technology. Such capabilities should be driven further in the near to medium term by further improvements in the sensitivity of equipment to contaminants, integrated early deployment of more advanced bio-sensing and rapid, mobile analysis laboratories for in-depth spot monitoring.



5.3 Environmental impact

Addressing the challenges

Common themes

The roadmapping project focused heavily on technology, or rather the technology solutions, required to overcome the challenges faced by the upstream oil and gas industry in Kazakhstan. A genuine effort was made to consider challenges across the entire industry: the problems of developing and managing carbonate and clastic reservoirs were examined; onshore and offshore fields were given equal emphasis; and the issues connected with both new and mature fields were taken into account. The findings of this technology-focused part of the project are summarised in the 15 topic maps.

In this section of the roadmap, an attempt has been made to distill the key points of this earlier exercise and to draw out common themes. More significantly, the information has been presented through three different lenses that reflect the fundamental objectives of the project laid down from the start. So, this section contains an R&D focus map, and industry opportunities map and a skills development map. These three maps form the basis for the main conclusions and recommendations of the roadmapping project.

Because they are more relevant at this stage of the roadmap than any other, measures being taken by some other governments around the world to stimulate technology development, boost local industry and raise local skills levels are summarised here. There are perhaps some valuable pointers to the way forward for Kazakhstan in this summary.

Government measures – lessons from some other successful countries

As part of the project, a survey was carried out of measures taken in some other countries, generally led by the government, to accelerate technology development and implementation, build local industries and raise local skill levels. Four countries, in particular, were examined: China, Brazil, Malaysia and Norway. There were some striking similarities in the approaches being taken – a common set of success factors.

The survey clearly showed that effective policies are made up of a mixture of measures: financial and non-financial; specific technology-related and generic; technology supply-side and market-based; and competitive and collaborative.

The main findings of the survey are summarised below, with reference to the three key themes that permeate this roadmap.

> THE INFORMATION HAS BEEN PRESENTED THROUGH THREE DIFFERENT LENSES THAT REFLECT THE FUNDAMENTAL OBJECTIVES OF THE PROJECT LAID DOWN FROM THE START. SO, THIS SECTION CONTAINS AN R&D FOCUS MAP, AND INDUSTRY OPPORTUNITIES MAP AND A SKILLS DEVELOPMENT MAP.

Technology and R&D

- R&D funding needs to be determined and controlled by partnerships between government and industry.
- R&D funding needs to be channelled to specific projects aimed at solving well-defined industry challenges. There should be incentives for researchers and developers to work in areas where there is a strong industry/market need.
- Strong efforts must be made to ensure transparency of the funding exercise, to monitor the progress made and, if necessary, to adjust funding levels.
- Industry technology parks are highly successful in fostering collaboration and cross-fertilisation of ideas.
- Defined centres of excellence work well in providing focal points for research in key areas – they accelerate progress.
- The import of the equipment needed for R&D and technology trials needs to be made easy.
- Visits by international technology experts should be welcomed (and facilitated); they should be encouraged to work with local universities, research institutes and local technology companies.
- International research and development programmes should be promoted; however, the success of such collaborations should be closely monitored to ensure a good return on the investment.
- Intellectual property rights must be fully protected by local legislation (including efficient mechanisms for local registration). It goes without saying that there has to be strict compliance with international patent law.

Local industry

- Raising local content levels makes complete sense in terms of establishing sustainable industries. However, judgement needs to be applied and, in some cases, there must be a longer-term outlook with realistic progressive targets.
- Decisions on the development of local industry have to take into account the market demands and the local supply-side capabilities.
- A mandatory, general approach to local content may be counter-productive, hindering the uptake of newer technology and ultimately limiting local company development.
- The emergence and development of local industries is accelerated by the free flow of information between foreign and local companies, which can be facilitated by government.
- Local industry development requires opportunities are highlighted – and clearly verified – and local capabilities realistically assessed. Good communication is the key to this.

Skills development

- It is a fundamental rule: people learn from what goes on around them; the wider they look, the more they learn. Skills development needs to be an international exercise; strong links with seats of learning in other countries are essential.
- Industry needs to be involved in education and training programmes to help shape curriculums and promote the excitement and rewards of working in areas like oil and gas.

R&D focus

A need for more communication and better planning on a national scale

By comparing the industry-prioritized R&D focus areas (from the latest topic mapping exercise reported earlier plus input gathered throughout the project) with the strengths of the Kazakhstan R&D community (information gained during visits to leading laboratories and institutes), it has been possible to identify the R&D focus areas most likely to bear immediate fruit. Four areas stand out: correlation of NMR core data from SCAL studies with well logs; the use of non-metallic materials in highly corrosive environments; sulphur storage and applications; and bio- and nano-sensors for environmental monitoring.

It would be reasonable to expect R&D proposals from the Kazakhstan academic community to centre around these areas and, in time, to see Kazakhstan develop strong capabilities in the NMR interpretation of complex rocks, in the use of non-metallic pipelines and in the utilisation of sulphur (sour gas to power was seen as a particularly interesting opportunity in this area). Kazakhstan is already well recognized for its environmental services and, with more R&D, should realistically aim to become an industry leader in this area.

The process of identifying R&D priorities that was begun during the roadmapping project is one that must be carried out on a continuous basis and become more focused and directed. There is a strong case for the establishment of a council at government level, including representatives from industry and the academic community, tasked with national R&D strategy development and planning in Kazakhstan.

R&D in Kazakhstan suffers severely from a lack of communication and collaboration, especially between the parties seeking solutions and those able to generate them: one of the more striking features to emerge from the roadmapping project is the relatively poor communication between the upstream oil operators and the Kazakhstan academic community. An organization with authority is needed to control and coordinate upstream oil and gas R&D in Kazakhstan, to provide focus, to determine funding and monitor the outcomes of the work.

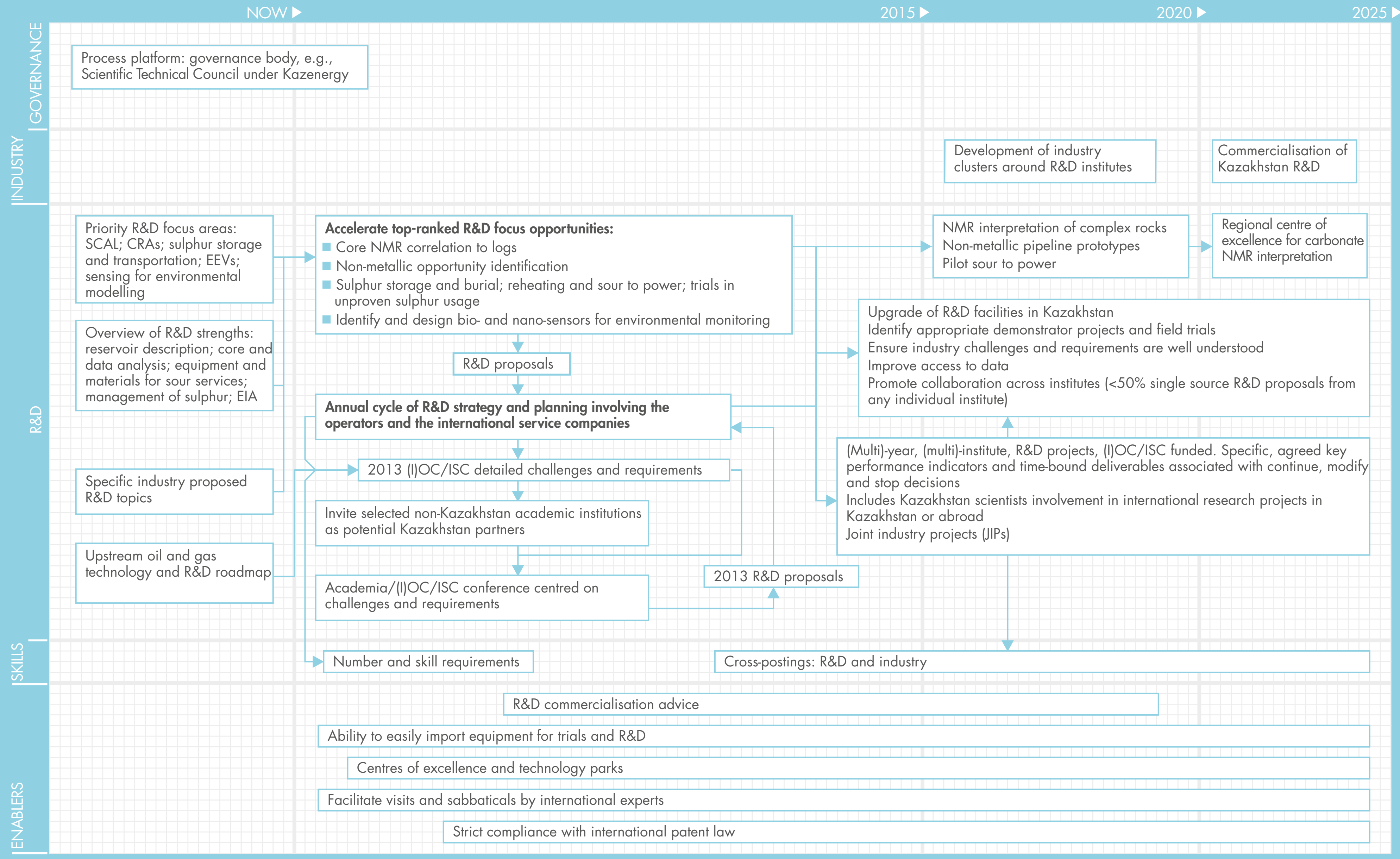
R&D planning

It would be realistic to expect the Kazakhstan government/industry R&D planning process to be founded on the established principles used to plan and manage R&D by many large technology-oriented companies. Translated onto a national scale, the process might be run along the following lines:

- The major operators and service companies would each outline their views on the prime challenges faced by their organisations on an annual basis – they would be encouraged to provide information on the nature and status of the challenge, its urgency and the size of the prize.
- The information, once analysed and consolidated, would be made widely available to the academic community and used to shape R&D proposals.
- Good proposals would be likely to feature international and in-country academic partnerships; they would also contain well-developed project cost estimates and timeframes, and go as far as describing technology demonstration and field trials requirements.
- Proposals received positively would be progressed in the first place by (1) a sharing of relevant data and information from the industry side with the R&D proposer and (2) the setting of suitable milestones and key performance indicators.
- Assuming good progress of the work, it would be incumbent on the industry organisation that set the challenge to facilitate field trials of the new technology solution.
- The reasons behind unsuccessful proposals would be made clear and used to drive improvements in the sections of the academic community involved.

The process just outlined addresses a number of the issues judged by participants in the roadmapping project to be hindering R&D in Kazakhstan – lack of focus, limited collaboration, poor understanding by the academic community of the challenges and the opportunities within the industry, and the difficulty of fixing up field trials were foremost among them.

Additional enablers highlighted during the course of the roadmapping project include the provision of guidance to academics on the commercialization of R&D; the relaxation of local content regulations in selected emerging technology areas; measures to ease the import of equipment for R&D purposes and field trials; and a facilitation of visits, perhaps extended stays, by international technology experts. The establishment of centres of excellence and technology parks was another measure favoured by many in the industry. Finally, there was a call for better understanding of international patent law and clearer recognition of intellectual property rights.



NOW
2015
2020
2025
GOVERNANCE
INDUSTRY
R&D
SKILLS
ENABLERS
Process platform: governance body, e.g., Scientific Technical Council under Kazenergy
Development of industry clusters around R&D institutes
Commercialisation of Kazakhstan R&D
Priority R&D focus areas: SCAL; CRAs; sulphur storage and transportation; EEVs; sensing for environmental modelling
Overview of R&D strengths: reservoir description; core and data analysis; equipment and materials for sour services; management of sulphur; EIA
Specific industry proposed R&D topics
Upstream oil and gas technology and R&D roadmap
Accelerate top-ranked R&D focus opportunities:
Core NMR correlation to logs
Non-metallic opportunity identification
Sulphur storage and burial; reheating and sour to power; trials in unproven sulphur usage
Identify and design bio- and nano-sensors for environmental monitoring
R&D proposals
Annual cycle of R&D strategy and planning involving the operators and the international service companies
2013 (I)OC/ISC detailed challenges and requirements
Invite selected non-Kazakhstan academic institutions as potential Kazakhstan partners
Academia/(I)OC/ISC conference centred on challenges and requirements
2013 R&D proposals
NMR interpretation of complex rocks
Non-metallic pipeline prototypes
Pilot sour to power
Regional centre of excellence for carbonate NMR interpretation
Upgrade of R&D facilities in Kazakhstan
Identify appropriate demonstrator projects and field trials
Ensure industry challenges and requirements are well understood
Improve access to data
Promote collaboration across institutes (<50% single source R&D proposals from any individual institute)
(Multi)-year, (multi)-institute, R&D projects, (I)OC/ISC funded. Specific, agreed key performance indicators and time-bound deliverables associated with continue, modify and stop decisions
Includes Kazakhstan scientists involvement in international research projects in Kazakhstan or abroad
Joint industry projects (JIPs)
Number and skill requirements
Cross-postings: R&D and industry
R&D commercialisation advice
Ability to easily import equipment for trials and R&D
Centres of excellence and technology parks
Facilitate visits and sabbaticals by international experts
Strict compliance with international patent law

R&D focus

Kazakhstan R&D assessment

One of the most critical parts of the roadmapping project was to assess the ability – within Kazakhstan – to perform front-line R&D in support of the upstream oil and gas industry. To make this assessment, visits were made by expert technologists from the major operating companies to 12 different laboratories or institutes.

It would be unfair to publish a direct comparison of the individual laboratories/institutes – indeed the various organisations took part in the exercise on this condition. However, the overall results are still highly revealing.

(Readers may wish to refer to Report E issued by Shell, R&D Visits Overview, for a full account of the assessment.)

The Kazakhstan R&D community scores highly in some key technical areas:

- Geological understanding (of the subsurface in Kazakhstan)
- Field development planning and field engineering
- Sulphur extraction, handing, storage and applications
- Drilling fluids testing
- Flow assurance, corrosion and fluid analysis (though this is strongest in the downstream sector and needs to be transferred upstream)
- 3D modelling (geological and hydrodynamic)
- Waterflood and EOR modelling
- Environmental monitoring (air, water, soil)

The general impression, however, was that the R&D community is being held back by a series of largely non-technical issues, most notably:

- Lack of funds for basic research (as opposed to technical services)
- Yearly tendering for service work prevents long-term investment
- Outdated equipment
- Inadequate links with the upstream industry (poor understanding of the operators' problems and requirements, plus limited access to field data)
- Difficulties in arranging field trials
- Low level of understanding of the technology commercialisation process
- Lack of collaboration between different institutes/laboratories
- Attrition of senior staff – and often a lack of talented people to take their place
- Limited English skills (particularly among more senior staff), which hampers the development of international relationships
- Low level of international patent awareness

Capabilities across the 15 prime challenges

Reservoir characterisation (TTA 1)

There is a moderate overall capability in this area. Kazakhstan is strong in terms of geology and has good subsurface modelling research and service capabilities. In contrast, there is little R&D focus on seismic data acquisition. One area that is developing rapidly is routine and special core analysis and fluid analysis. A lack of awareness of the issues surrounding the handling and processing of high-H_2S streams is a concern.

Field equipment (TTA 2)

Kazakhstan is reasonably well-placed in this area. There are good capabilities in the sulphur management area; ice management and operations is another strength. Field engineering design services are of a high quality. Work on equipment and materials for sour service is lacking focus in the upstream area, however, and relationships with the equipment manufacturers are limited.

Fluid flow and processing (TTA 3)

The assessment exercise highlighted technical weaknesses in this area – at least, in the upstream area. It is notable that flow assurance and water treatment capabilities seem much stronger in the downstream sector; it would make sense to seek to extend this expertise up the oil industry chain.

Wells and field management (TTA 4)

Capabilities in this area are patchy. Most institutes/laboratories are weak but there are some exceptions. A single institute was particularly strong in terms of its drilling-fluid testing expertise; another had a very good understanding of how waterflooding and EOR techniques can be used to optimise recovery; and there were pockets of expertise in dynamic modelling.

HSE and operations (TTA 5)

The Kazakhstan R&D community is remarkably weak – little work is being done – when it comes to emergency response and disaster recovery, and also HSE and operational risk reduction in sour conditions. Environmental impact is another matter: several institutes/laboratories are undertaking good work in this area and are, consequently, in a position to offer competitive environmental impact assessment services.

Visits were made to:

- KING (Astana)
- KazNTU (Almaty)
- KBTU (Almaty)
- KazNIPImunaygas JSC (Aktau)
- Caspian State University – Yessenov (Aktau)
- NIPIneftegas (Aktau)
- CER-Weatherford (Aktau)
- KCR-Zhahan core lab (Atyrau)
- Caspimunaygas (Atyrau)
- Atyrau Institute of Oil and Gas (Atyrau)
- KazPetrotest (Aksai)
- Oilphase-Schlumberger (Atyrau)

During the visits (and through the use of questionnaires) the various laboratories/institutes were assessed using five criteria:

- Breadth of the capabilities and the level of skills available
- Quality of the research being done and the services offered
- Relevance of the work to the upstream oil and gas industry
- Quality of the equipment and facilities
- Ability to undertake computer modelling work.

Industry opportunities

A sound financial case and business model

Throughout the course of this project, attempts were made to gather views on the sort of local companies that could make a positive difference to the way the upstream oil and gas industry operates. At one point, project participants were asked directly to rate the various technology solutions put forward in terms of the strength of the industry opportunities associated with them. The top-ranked solutions are listed in the box at the top left corner of the map.

Below this box is another that contains a list of perceived upstream oil and gas industry strengths in Kazakhstan. (This list is based on an assessment of the maturity of the technology solutions outside and inside Kazakhstan, supplemented by much valuable input from KING.)

A straightforward comparison of the two lists leads to the conclusion that the most realistic industry opportunities lie in the area of steel and concrete structural design and fabrication, the provision of upstream chemicals and sand-screen manufacturing.

Six of the possible opportunities highlighted by project participants have not made it through onto the short list – blocks to progress were thought to exist in these cases. The high cost of corrosion-resistant alloys could theoretically be allayed by setting up local production facilities; however, manufacturing (and testing) capabilities in Kazakhstan were thought to be lacking. Undertaking more R&D in this area is a sensible way forward. In the case of SCAL services, there has been a lot of investment in the last year, but there are further upgrades desired by the operators. Jack-up rigs for cold climates and ice-scouring-resistant design constitute immature technology globally. Both will require a combination of R&D and heavy industry participation to move the technology forward; as such neither offers immediate industry opportunities.

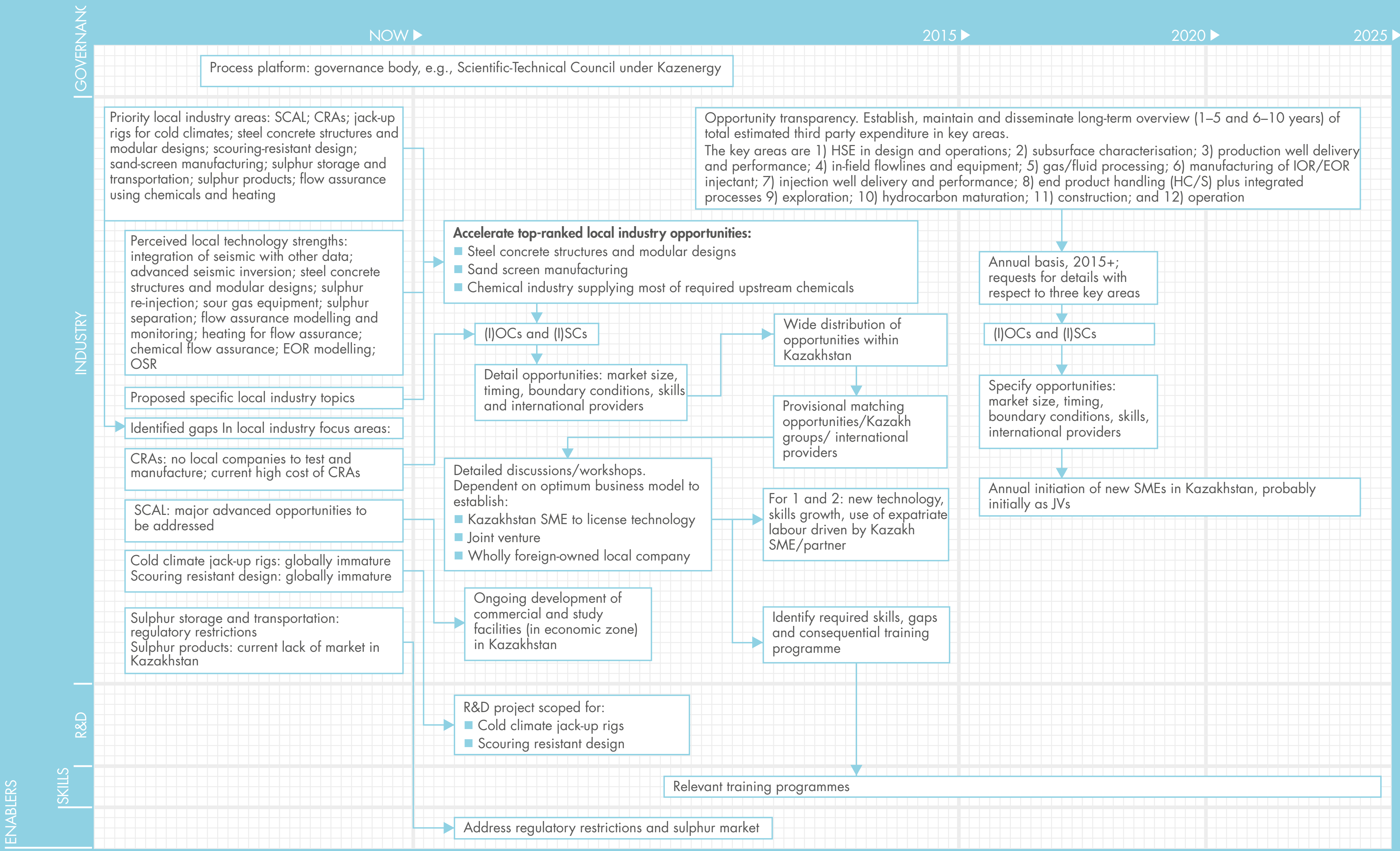
Sulphur storage, transportation and products seem like perfect opportunities for Kazakhstan to build local capability. But two critical things must happen before these will be realised. There needs to be overhaul of the regulations surrounding the use of sulphur; and the markets in Kazakhstan need first to be created and grown.

While the roadmapping project has succeeded in identifying real opportunities for local companies in Kazakhstan, in the longer term a more formal and rigorous approach is needed to maintain a continuous flow of similar ideas. Ideally, this ought to be overseen by a strong government/industry council. Its role would be, in the first place, to invite oil and gas operators to provide regular information about their materials, products and services requirements, the scale of these requirements and their timing. This market research would be made available to the relevant international and local companies who would subsequently be invited to put forward local manufacturing and service solutions – ideally with strong local job creation, technology transfer and supply chain development credentials.

A sound financial case and an effective business model (including skills development and training needs and based on, for example, a joint venture, licensing agreement or a wholly foreign-owned, locally registered company) would be a condition of the opportunity gaining government support.

For such a process to work, there needs to be good communication and open dialogue between government and industry. There is a widespread view that there needs to be less bureaucracy surrounding the import of goods and equipment and that the business regulatory environment has to become more fluid and transparent and easier to negotiate.

> THERE NEEDS TO BE GOOD COMMUNICATION AND OPEN DIALOGUE BETWEEN GOVERNMENT AND INDUSTRY.



Industry opportunities

Skills development

Learning and skills development in Kazakhstan

There was a strong, consistent message from the project participants that – in common with the oil and gas industry worldwide – there is a shortage of talented graduates in the basic sciences, engineering and mathematics. Further, the industry would ideally like to see young people coming forward with qualifications in applied disciplines such as geophysics, reservoir engineering, production technology and production chemistry. There is a similar requirement for more well-trained technicians and skilled workers to perform important roles in construction, and operations and maintenance.

More than one academic made the point that the loss of the best graduates to jobs in other industries and to other countries was also a problem; though, this in one that is perhaps outside the scope of this roadmapping project.

Leading universities in Kazakhstan are undoubtedly producing good graduates, based on a model with some key features:

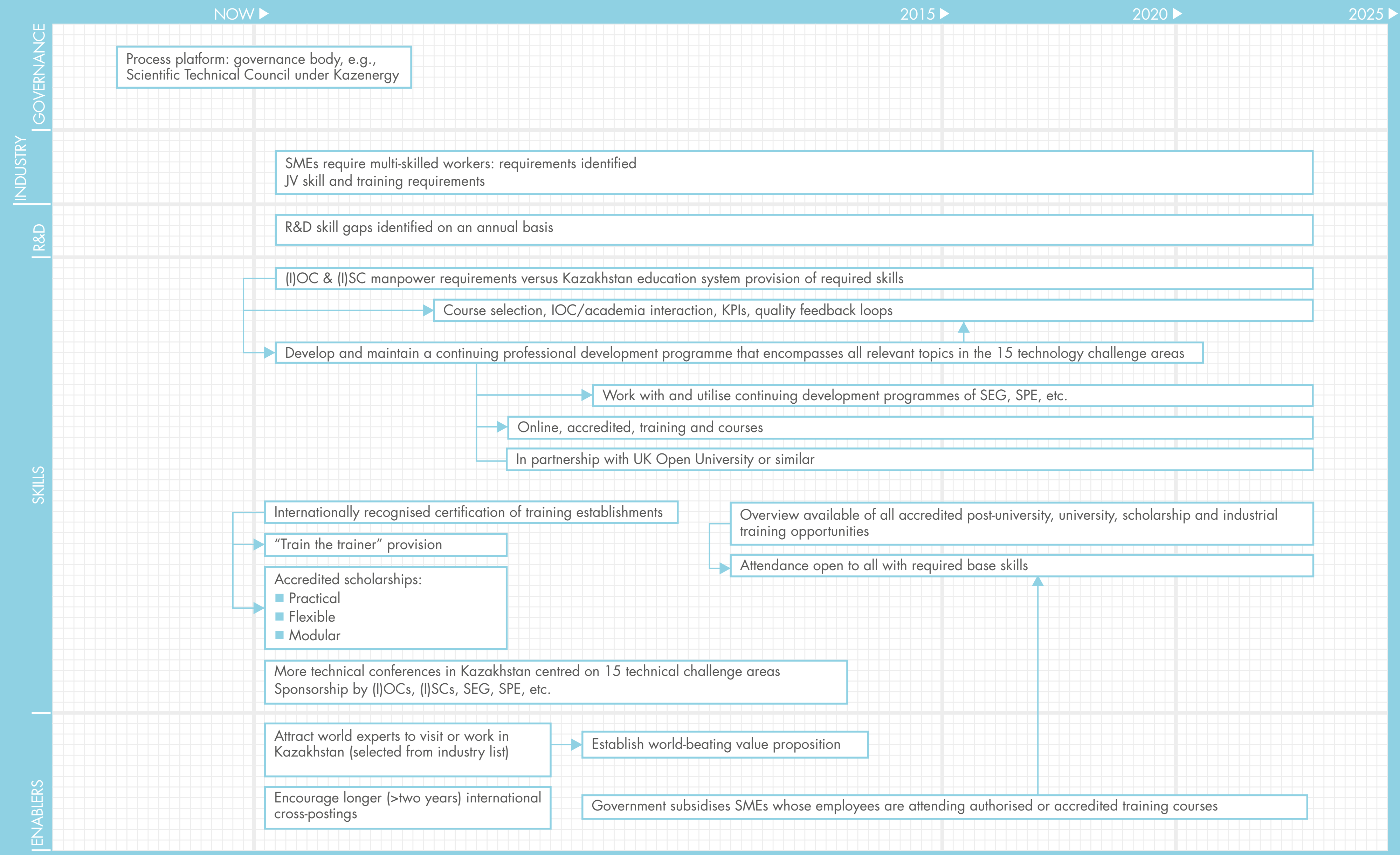
- high course admittance standards
- well trained staff
- good working links with overseas seats of learning
- degree qualifications certified by leading institutions
- relevant courses devised in collaboration with industry
- visiting lecturers from overseas and industry guest speakers
- internships with leading oil operating and service companies active in Kazakhstan.

More could undoubtedly be done in all of these areas, especially given more funding. One area that stands out is the training and mentoring of staff to raise teaching standards. Post-graduate training was seen as an area with considerable scope for improvement. The teaching of post-graduate courses is an area where industrial involvement is paramount, for example, in providing expert supervisors and access to field data on which to base relevant research studies.

Strengthening the links between the academic community and industry must be a constant objective. There must be a partnership, under government leadership, between academia and industry with the aims being to:

- provide more detail around the question of skills requirements, and bring clarity to the gaps between graduate demand and supply
- increase industry involvement in curriculum development
- create more industrial placements
- raise the involvement of industry professional bodies like the SPE and SEG, who both offer highly relevant skills development programmes
- encourage the holding of technical conferences in Kazakhstan covering the main challenges faced by local operators
- promote the upstream oil and gas industry as an exciting and rewarding place to work.

POST-GRADUATE TRAINING WAS SEEN AS AN AREA WITH CONSIDERABLE SCOPE FOR IMPROVEMENT. THE TEACHING OF POST-GRADUATE COURSES IS AN AREA WHERE INDUSTRIAL INVOLVEMENT IS PARAMOUNT, FOR EXAMPLE, IN PROVIDING EXPERT SUPERVISORS AND ACCESS TO FIELD DATA ON WHICH TO BASE RELEVANT RESEARCH STUDIES.



Skills development

Notes