

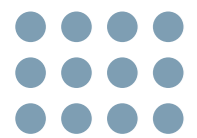
## EGA's technology solutions





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## About EGA

Emirates Global Aluminium is the world's largest 'premium aluminium' producer and the biggest industrial company in the United Arab Emirates outside oil and gas.

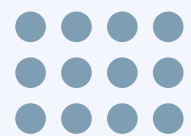
Aluminium is among the world's most versatile metals, our more than 400 global customers transform it into products that make modern life possible - from smartphones and building materials to food packaging and car parts.

EGA employs more than 7,000 people and supplies customers in over 50 countries. Our development since 1970s has taken the UAE from no aluminium production to the fifth largest aluminium-producing country in the world.

We takes pride in our research and technology development, driving growth through our own innovation. This enables EGA to be cost-competitive and environmentally responsible while meeting customer and societal needs.

EGA's Al Taweelah site received certification from the Aluminium Stewardship Initiative (ASI) in May 2019, making EGA the first company in the Middle East to achieve such a certification. EGA Jebel Ali was certified in 2021.





# EGA's technology heritage

EGA has been developing technology in the UAE for over 30 years. Today, our latest technology is amongst the most efficient and competitive in the global aluminium industry. It provides customised and tailor-made solutions for optimising smelters around the world.

Technology Development & Transfer department is staffed by 50 employees, led by technologists and engineers. The team includes a number of experts with between 10 to 45 years of experience in aluminium smelting R&D.

Since 1990, EGA's technology development has more than doubled the size of cell that is technically and commercially viable. Our technology development, and earlier work started in 1980, has reduced the amount of electricity required to produce each tonne of aluminium by 37.5 per cent, improving both cost and environmental performance.

EGA's latest technology, DX+ Ultra, has more than double the productivity of our first D18 technology developed in 1990 from the original technology used to build our Jebel Ali smelter.

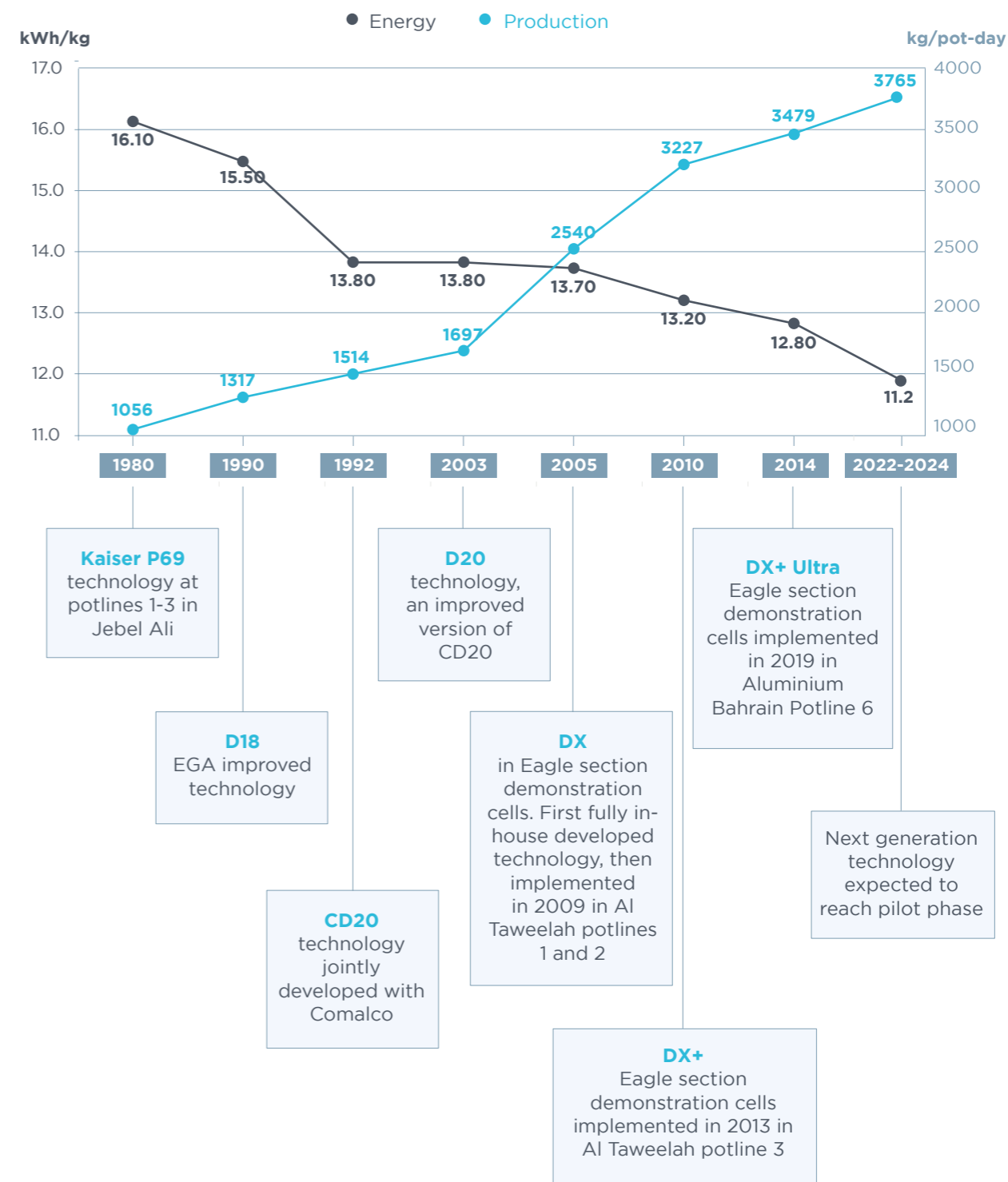
EGA has developed and industrialised eight reduction technologies in greenfield projects and brownfield retrofits. We have used our own technology for every smelter expansion since the 1990s, and have also retrofitted all our older production lines, meaning all 2,843 reduction cells at EGA use EGA technology.

Earlier last decade, EGA decided to start licensing its technology to other aluminium companies. In addition to delivering revenue, technology licensing creates further opportunities to industrialise EGA's innovations, which strengthens continuous technology development processes for the interest of the company and our technology customers.

EGA licenses two flagship technology: products DX+ Ultra reduction technology and our innovative Pot Control System (PCS). In addition, EGA provides technologies and services to support upgrades to existing smelters.

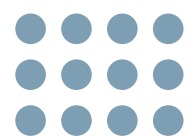
To date, EGA has licensed technology for more than half a million tonnes of installed smelting capacity, outside the UAE.

Evolution of EGA technologies - energy and production





**DX+ Ultra is EGA's latest industrialised technology and was designed to further lower unit capital costs and cell energy consumption.**



# EGA's world leading technologies

## Reduction technology

DX+ Ultra is EGA's latest industrialised technology and was designed to further lower unit capital costs and cell energy consumption.

In comparison with any other technology, it delivers the highest production per square metre of potroom building, reducing the capital costs of construction. It also delivers amongst the lowest specific energy consumption in the smelting industry.

DX+ Ultra technology was first commissioned in 2014 with five demonstration cells at Jebel Ali smelter.

Following a global competitive tender, Aluminium Bahrain (ALBA) selected DX+ Ultra for its Line 6 expansion project, which consists of 424 cells. The first cells were energised in December 2018.

DX+ Ultra is an improved version of EGA's DX+ technology, which was industrialised with 444 cells in Potline 3 at EGA's Al Taweelah smelter. These pots began production in 2013 and now operate at 472 kA. The main new features of DX+ Ultra technology compared to DX+ technology are:

**01 Reduced cell-to-cell centreline distance (6.3 m to 6.0 m)**

**02 Improved busbar design featuring a split riser concept with 30% lower electrical resistance.**

**03 Lower resistance cathode assembly design with copper inserts which is also now implemented in the second generation of DX+ cathodes in Al Taweelah smelter**

**04 Longer anodes, which can also be accommodated in DX+ pots**

Results of ALBA Potline 6 DX+ Ultra performance test at 465 kA compared to the average of all cells.

Key Performance Indicator	Dx+ Ultra ALBA		
	Oct - Nov 2019	Oct - Nov 2019	Sep 2020- Feb 2021
Duration			
Number of pots	424	30 (performance test pots)	424
Production per pot per day (kg)	3,537*	3,565**	3617
Amperage (kA)	465	465	471.7
Current Efficiency (%)	94.5*	95.2**	95.2
Gross Voltage per pot (V)	4.125*	4.102	4.095
Gross specific energy (kWh/kg Al)	13,009*	12,835**	12,821
Net carbon consumption (kg/t Al)	391***	391	400
Gross carbon consumption (kg/t Al)	550***	550	537
Anode effect frequency (AE/pot-day)	0.034	0.044	0.029
Average anode effect duration (sec)	14.4	16.6	9
Fe (%)	0.089	0.089	0.070
Si (%)	0.030	0.033	0.029

\* After solid metal corrections assumed to be the same as in the performance test group, but no metal inventory measurement was made.

\*\* After inventory and solid metal corrections.

\*\*\* Measured for the performance test pots and assumed to be the same for the full potline.

## Pot Control System (PCS)

EGA's Pot Control System (PCS) consists of state-of-art modern software that runs on off-the-shelf Programmable Logic Controllers (PLC) and Human Machine Interfaces (HMI) supplied by well-established automation equipment manufacturers.

EGA's innovative control logics enable end-users to get all the information required at the Potline to maximise metal production while reducing energy consumption and environmental emissions.

EGA's reduction cell technology controlled by EGA's PCS achieves exceptionally low anode effect frequency and duration, with very low emissions of perfluorocarbon greenhouse gases.

PCS is an integral part of EGA's technologies. Yet due to the standard control system architecture of its design, PCS is flexible for use with any other pot technology and is available for licensing for use in retrofits.

### EGA's PCS softwares includes:

#### Pot Control Logics (DPC®) – adaptable to different pot technologies

- EGA's proprietary Pot Control Logics - DUBAL Pot Controller (DPC®) operates on potlines from 200 to 500 kA, four or five breaker-feeders per pot, and anode current densities from 0.85 A/cm<sup>2</sup> for low energy pots to more than 1 A/cm<sup>2</sup> for high productivity pots.
- In pot instability control, it is capable to differentiate MHD Noise (low frequency) and Anode Noise (high frequency).
- The control logic is developed on standard industrial control system platform supplied by well-established automation manufacturers which provides access to long-term support and maintenance through readily available spare parts.
- DPC® registered at the US Copyright Office in 2015 under number TXu 1-989-474.

#### Pot Operator Interface (DPC-HMI®) – Interactive pot operation

- EGA's proprietary Pot Operator Interface (DPC-HMI®) is a graphical interface application that enables the operator to interact with the pot simply and seamlessly.
- It provides real-time status of the pot conditions, pot control and pot operation parameters through an efficient operator touchscreen.
- DPC-HMI® registered at the US Copyright Office in 2015 under number TXu 1-989-482.

#### Potline Interface Programs (PIP®) – data traffic control system

- EGA's proprietary subsystem (PIP®) is a set of executable programs which are responsible for exchanging data with all the pot control units in the potline.
- It governs the download of the pot parameters and handles the storage of the data.
- It also manages the potline audible alarming system.
- PIP® registered at the US Copyright Office in 2015 under number TXu 1-987-055.

#### Pot Online Terminal System (IPOTS®) – potline command & control centre

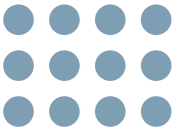
- iPOTS® is EGA's proprietary supervisory control and data acquisition system (SCADA), which provides an overview of the potline status for potroom personnel to monitor live status and control operation parameters remotely.
- It can display a selected group of pots or the whole potline at a glance, viewed in control rooms on large screens or on desktop computers or wireless tablets connected to the network.
- iPOTS provides instantaneous status and graphs at pot level, section level and potline level.
- It also allows modification of pot control parameters for a single pot or a group of pots.
- iPOTS® registered at the US Copyright Office in 2015 under number TXu 1-987-054.

#### Reduction Plant Management System (iRPMS®) – production reporting system

- iRPMS® is EGA's proprietary manufacturing execution system (MES), which is the reporting system for potlines, interfacing with other facilities (Casthouse, Laboratory, Anode Plant, etc.).
- It is used by potline operation personnel to monitor pot and potline process parameters.
- iRPMS provides summarised information at potline and plant level for shifts, days, weeks, months or years. The information is made available by means of numerous reports, tables and graphs.
- iRPMS® registered at the US Copyright Office in 2015 under number TXu 1-987-044.

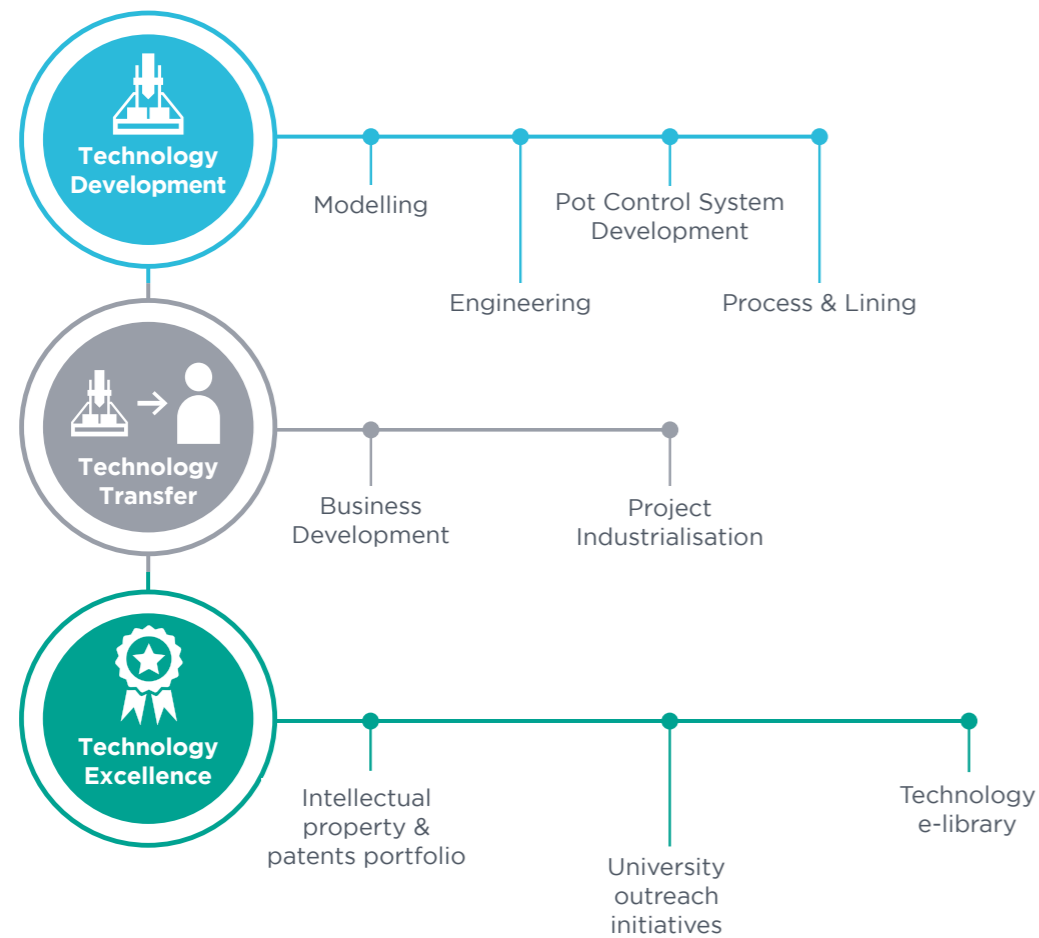
#### Smelter Analytics® – complete smelter summary at a glance

- EGA's proprietary dashboard system (Smelter Analytics®) provides various dashboards, statistics and graphs representing data and information of different parts of the smelter.
- It is an advanced system to analyse smelter performance by interfacing with other facilities (Casthouse, Laboratory, Anode Plant, etc.).
- It is used by smelter management to analyse and take appropriate decisions.
- Smelter Analytics® registered at the US Copyright Office in 2015 under number TXu 1-987-040.



# EGA's technology solutions

EGA's Technology Development & Transfer department is led by a team of functional experts.



## Technology Development

### Modelling

The Modelling team designs new state-of-the-art cell technologies and improves existing technologies. The team has a unique combination of diverse, theoretical and practical knowledge in different areas that contribute to optimal cell design, including thermoelectric, thermomechanical, magneto-hydrodynamics (MHD) and computational fluid dynamics (CFD) modelling, lining material selection, measurement methods and cell operation.

The team also supports process control and engineering teams in decision making through mathematical modelling to achieve the best KPIs with optimal costs. The modelling team developed DX+ and DX+ Ultra, which are high amperage, low energy reduction cell technologies. In addition, the team worked on the design of brownfield developments within EGA, including D18+ and D20+ technologies, and outside of EGA. The team plays a role of an internal expert in Cell design and Materials.

### Engineering

The Engineering team generates and transforms theoretical concepts into practical designs ready for prototyping. All in-house developed concepts are tested as Proofs of Concept (PoC). While maintaining a high level of confidentiality, the team also manages PoC projects and continue supporting day to day operational and maintenance functions.

The team holds core responsibilities and expertise in delivering studies of EGA's future technologies developed in-house, and protecting EGA's interest in innovation and patenting.

The team also works in optimising the existing in-house developed technologies. This includes developing and detailing all aspects of the cell design parameters as well as tools for starting-up operation. The Engineering team are the focal point at EGA for all technological expertise, material approval, and vendor database expansions. This team also support external technology licensing projects of green and brown field and technology upgrade projects.

Members of the Engineering team work on Autodesk Inventor for 3D and AutoCAD for 2D conceptual designs and 3D printing.

This team serves as technical advisors for other departments providing engineering solutions and suggestions for improvement and plant safety.





### Pot Control System (PCS) Development

The role of the PCS development team is to improve software control logic for new and existing reduction cell technologies.

These improvements aim to enhance process efficiency and minimise harmful emissions and manual interventions in the process. The team also develops control software for prospective projects including continuous anode Current Distribution (CD) monitoring and individual anode control. The team also designs and customises pot control system and logics for adaptation of clients smelters as part of technology PCS upgrade projects.

### Process & Lining

The Process & Lining team is responsible for overseeing demonstration and trial cells performance, validating cell design parameters by monitoring cell lining, validating cell preheat and magnetic models, and monitoring the pot room environment. The Process team also tests and monitors new technologies and measurement tools to ensure that demonstration and trial cells are operating within their design boundaries.

The Process & Lining team provides customers with technical advice, support and documentation, and answers queries related to potlining materials and installation. Its main activities are cathode casting and potlining.

The Process & Lining team prepares the required documentation for customers to be able to estimate cost and successfully construct EGA's technology designs. These range from technical reports and drawings to specifications and procedures.

The cell design, lining materials, required equipment and tools are detailed by the Process & Lining team in collaboration with the Engineering, Modelling, Operations and Process Control teams.

## Technology Transfer

### Business Development

The Business Development team works with existing and potential customers on the commercial aspects of technology licensing and services including contracts negotiations.

The aim of the team is to create value for both EGA and our customers based on in-depth understanding of the aluminium production value-chain, aluminium cost structure and global economics.

### Project Industrialisation

The Project Industrialisation team is involved in all steps of project execution. It is responsible for developing Reduction and Carbon Area technology packages in accordance with the customers' needs, and ensures that these packages follow industry best practice for CAPEX efficient industrial implementation of EGA technology.

It also continuously improves technology packages to meet best practice within the industry.

The Project Industrialisation team provides all technical information required to estimate the CAPEX and OPEX of a green or brownfield smelter, participates in the customer design review, equipment and material selection, manufacturing and construction inspection, and performs conceptual studies for customers who are interested in investing in the aluminium industry.

The team is responsible for implementing EGA technologies at customers' sites. The team has subject matter experts in construction, cell lining, pot commissioning and start-up, and performance testing. These experts are deputed to customer and OEM sites at various milestones to confirm that all aspects of construction and fabrication are within the overall technology specifications and guidelines, and to ensure that the start-up of the reduction cells is conducted based on EGA's recommended best practices.

Additionally, the team stays up-to-date on the latest equipment technology by maintaining good relationships with key equipment and material suppliers.

The Project Industrialisation team works hand in hand with the Technology Development teams during the development of new technologies to review their future industrialisation and ensure a smooth transition to execution team.



### Technology package 1

Provides all the general information for (Reduction area of the smelter). with this information, our customer can perform preliminary feasibility studies to verify if their project has good potential.

EGA can also provide all the general information required for Carbon area in this technology package.



### Technology package 2

Provides all the detailed information for the construction of EGA's reduction cells. The detailed information mainly include busbar, potshell, anode assembly, lining and superstructure drawings, specifications and bill of materials.



### Technology package 3

Provides complementary information to Technology package 2 in relation to the auxiliary equipment surrounding the reduction cell.



### Technology package 4

Provides all the procedures for the customer to operate EGA's reduction cell technology. It is generally provided a few months after the project notice to proceed.

**In addition to the delivery of technology packages, the following services are part of a Technology Licensing Agreement with EGA:**

- Expert assistance during engineering, construction, start-up and operation, technology queries and improvement notifications provided throughout the engineering phases in close relation with Project Owner's team and Engineering, Procurement and Construction (EPC) or Engineering, Procurement and Construction Management (EPCM) contractor
- Review of Design Documentation
- Process material analysis
- Technical assistance during commissioning and start-up
- Training of supervisory and operator personnel
- Supervision of performance tests
- Supply of PCS software

**Services are also available in other areas of the smelter as part of Technical Services Agreements:**

- Developing workforce training and IT business solutions
- Strategic material sales to customers
- Technical benchmarking, process optimisation and sharing of best practices for the improvement of smelter operations
- Secondment of experienced personnel

## Technology Excellence

The Technology Excellence team is responsible for EGA's Intellectual property and patents portfolio as well as research and collaboration with academia. The team manages extensive research activities in various fields related to aluminium smelting by working with local and international universities. The Technology Excellence team has established and maintained a successful partnership with world renowned universities including Massachusetts Institute of Technology and University of New South Wales. The team also collaborates with UAE's universities by sponsoring research projects and engaging with undergraduate students. It strives to increase the technical level of EGA staff through involvement in research teams.

The Technology Excellence team protects EGA's Intellectual property by registering EGA's innovations for patents worldwide, and manages EGA's patents portfolio.

Upon request, the technology Excellence team provides technical assistance for testing and adapting new tools and equipment in EGA operations. The team also represents EGA to Governmental agencies including Emirates Scientists Council and the Department of Economic Development. The team runs a knowledge hub for EGA staff providing easy access to books, magazines and technical articles.

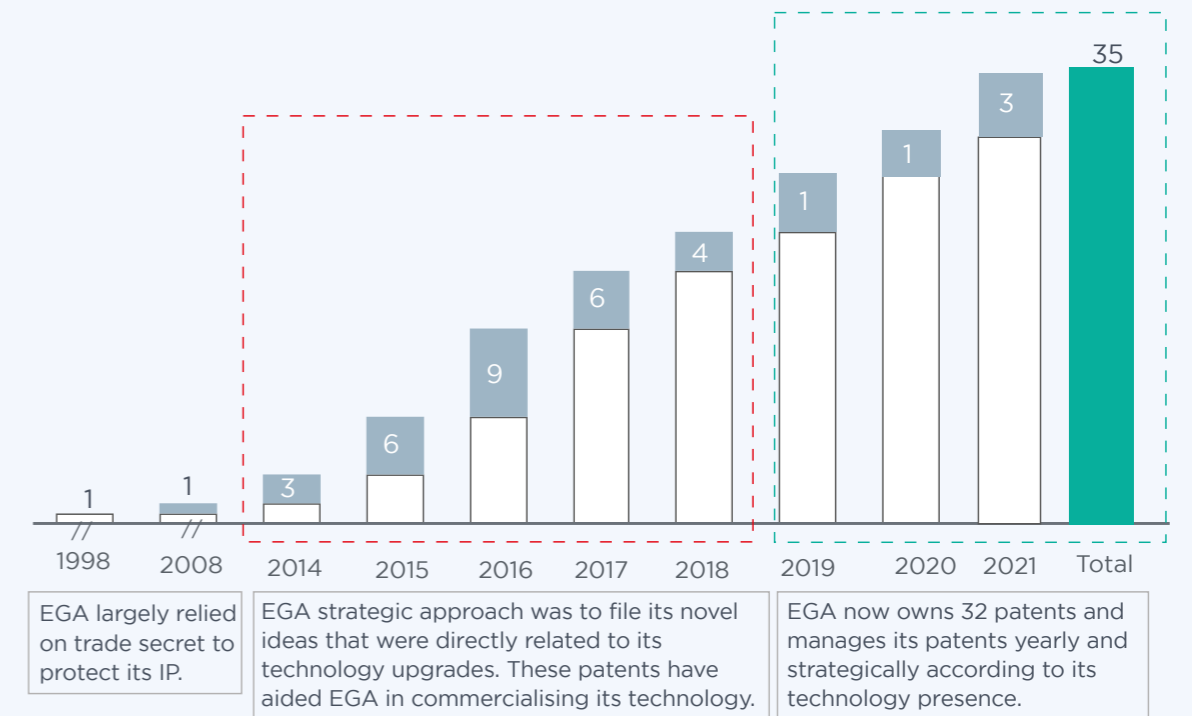
### Intellectual property and patents

Through its 40 years in the Aluminium industry, EGA has been transforming innovative ideas into well-developed smelting technologies. EGA has filed patents under its name since 1998. By the end of 2021, EGA has filed a total of 32 new patents. This number only includes the first filing leading to the priority date. It does not include additional international (PCT), group of countries (such as GCC and Europe) or individual countries filings which has been taking place to protect EGA proprietary Intellectual Property based on EGA technology licensing strategy and monitoring of EGA competitors based on EGA regularly updated Patent Data Base containing more than 3700 Patents in the field of Aluminium smelting. The annual filing program is approved by EGA Intellectual Property and Technology Committee composed of EGA Executive management.

EGA protects its intellectual property by including regularly publishing papers at key aluminium technical conferences (e.g. TMS and ICSOBA), recording copyrights for software (nine copyrights to date) and managing its patents portfolio with the support of a specialised and experienced Patent Attorney.

## The overall patent portfolio of EGA - 2021

Patents filed (UK filings) up to 2021



## Optimising other technologies

EGA has extensive experience from its own potlines of optimising and upgrading existing reduction cells to increase their production capacity and/or reduce their specific energy consumption.

EGA's Technology Development and Transfer department has the capacity to optimise existing potlines of various technologies.

The department can provide a range of technical services with the objective to define the optimum cell modifications and corresponding key operating parameters in order to achieve the expected improved performance in the full upgraded potline. Impact on the anode production and other smelter facilities is studied for the conversion of the full potline.

The department also assesses the viability of EGA's proprietary PCS and offers solutions to work with optimised pots.

EGA always works with the objective of achieving a low investment cost.

Throughout the project, from conceptual design to implementation, the professional and dedicated support of EGA personnel working alongside the client smelter team maximises value to the project stakeholders.



**Performance of technology optimisations at EGA**

KPI	Units	D18 (PL 1-3) (Mar 2014 to July 2015)	D18+ Low Energy Operations (7 Prototype Pots (March to August 2015)	D18+ High Productivity Operations (PL 1-3) (March 2019 to July 2019)
Amperage	kA	205.4	205.0	230.0
Net Specific Energy	kWh/kg Al	14.85	12.61 (-2.24) *	13.43 (-1.42) *
Net Voltage	Volts	4.67	4.02 (-0.65) **	4.25 (-0.42) **
Current Efficiency	%	93.6	95.0 (+1.4) ***	94.2 (+0.6) ***
Daily Prod.	kg/pot-day	1549	1567	1748
AE Frequency	AE/pot-day	0.36	0.01	0.02
AE Duration	sec	21	15	22
Fe	%	0.050	0.056	0.06
Si	%	0.024	0.022	0.021
Net Carbon	kg/t Al	429	—	409

**Note:** D18+ industrial pots are currently operating at 238 kA and had operated at the maximum amperage of 243 kA.

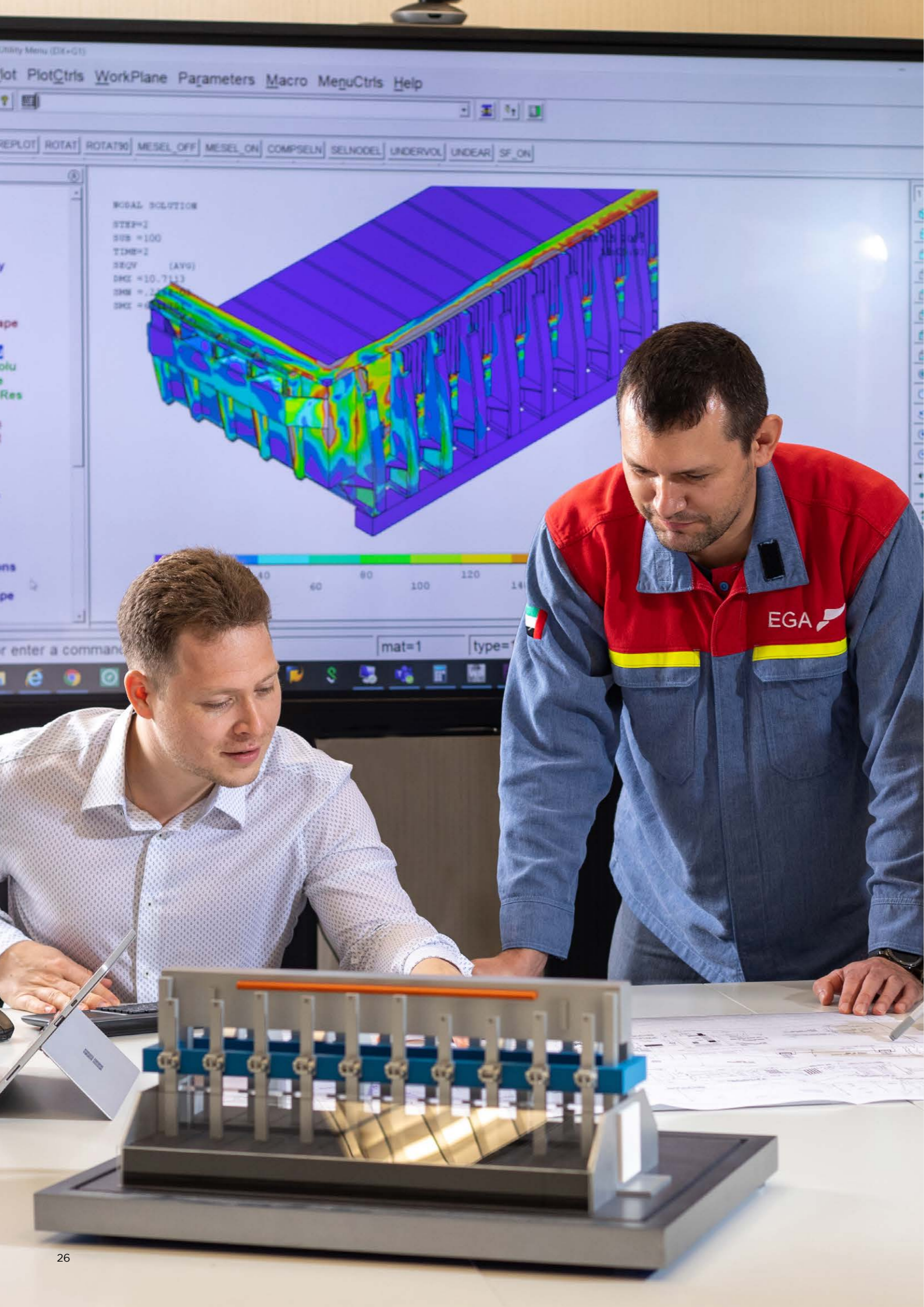
\*Variance of Net Specific energy between D18 vs D18+ (7 prototype and PL 1-3)

\*\*Variance of Net Voltage between D18 vs D18+ (7 prototype and PL 1-3)

\*\*\*Variance of Current Efficiency between D18 vs D18+ (7 prototype and PL 1-3)

KPI	Units	D20 (PL5-2018)	D20+ (PL5-2018)
Amperage	kA	274.9	274.9
Net Specific Energy	kWh/kg Al	14.57	13.14
Net Voltage	Volts	4.488	4.098
Current Efficiency	%	91.8	93.05
Daily Production	kg/pot-day	2033	2061
AE Frequency	AE/pot-day	0.06	0.041
AE Duration	sec	12	14
Fe	%	0.088	0.0839
Si	%	0.028	0.0273
Net Carbon	kg/t Al	430	428





**Emirates Global Aluminium PJSC**

E: [technology@ega.ae](mailto:technology@ega.ae)  
T: +971 4 822 1397/1052