

# Innovation & technology



**Innovation is a structural and critical requirement for the mining industry.**

**The major challenges we face as a company go beyond our processes and require the generation of solutions, disruptive and innovative technologies.**

Simultaneous execution of complex structural projects within deadlines, agreeing on sustainable development with our neighboring communities, being competitive, increasing productivity, cutting costs and working in maximum safety conditions are part of Codelco's upcoming challenges. We know that achieving these goals requires the generation of innovative solutions for the company's main production processes. Innovating, approaching management differently, and seeking new ways of doing things are essential when it comes to achieving better, more inclusive and sustainable mining practices.

At Codelco we understand that innovation is a structural and critical need for the business. In keeping with this objective, we merged our business and innovation divisions in 2015 while starting to challenge the scientific community, entrepreneurs, innovators, engineers and academics to become a part of building this future and jointly creating advanced technological capacities and solutions in robotics, communications, logistics, safety, sustainability, biotechnology and information technology.

Chairmen's statement

President & CEO's review

Organisation

Corporate profile

Divisions

Highlights

Mineral resources & reserves

Exploration

Investment & projects

**Investment & projects**

Results & market

People & sustainability

Company network

Financial statements

Chairmen's statement

President & CEO's review

Organisation

Corporate profile

Divisions

Highlights

Mineral resources & reserves

Exploration

Investment & projects

Investment & projects

Results & market

People & sustainability

Company network

Financial statements

The new structure also allows us to address a series of business opportunities and to qualify and prioritize innovative initiatives, considering long-term requirements and challenges for the mining business. It is in this sphere that we are designing a more open and interactive innovation management system.

The idea is to attract know-how from different levels because Codelco's transformation is no longer necessary for Chile's development, but represents an opportunity to empower the capacities of universities, research and development centers and companies that supply technologies. We believe that having access to several external creative solutions for the problems of tomorrow in the mining industry will increase the speed and intensity of change and innovation at our company.

### The ThinkCopper contest

Codelco and the Universidad de Chile Mathematical Modeling Center (CMM) created ThinkCopper, the first contest calling for innovative theses in the mining industry, in November. The initiative was framed in the agreement we signed with CMM in June 2015, which will enable to the company to support the development of new knowledge and technologies for the mining industry.

The winning theses encompass areas such as modeling hydraulic transport for solids; using bacteria for the pyrite flotation process using seawater, and detecting minerals that cannot be ground during the crushing process, among others.

### New business and innovation

We invested nearly US\$ 60 million in innovation and technology in 2015, especially for our priority areas for automating mining processes, management of BigData operational information, and the pursuit

of technological breakthroughs for metallurgical and technological processes that will provide solutions to demands for environmental and community sustainability in the mining industry.

Some milestones reached during the year are listed as follows:

### Continuous underground mining

This program is a technological breakthrough that will enable Codelco to increase productivity by 50%, reduce its operating costs by 20% and reduce personnel's exposure to risks.

This is an automated and remotely operated process for continuously and simultaneously extracting ore from different extraction points at underground mines, substantially increasing the pace of mineral extraction. Continuous mining is expected to increase efficiency, reduce dilution and consequently increase economic reserves at deposits. The technology is in the construction phase for industrial validation at the Andina Division.

### Equipment automation

This technology aims to ensure that LHD loading equipment used for underground mining can operate independently during certain activities, such as ore loading and transport, while being remotely operated from a control room, which may be located several kilometers away. This uses cutting-edge technology from other engineering areas in order to reduce operator exposure levels. Industrial testing will be conducted at the El Teniente Division in 2016.

### Hydrometallurgy

In order to reuse treatment capacity that will be made available at solvent extraction and electrowinning plants due to the exhaustion of oxidized ore, the company will explore the treatment of intermediate

Chairmen's statement

President & CEO's review

Organisation

Corporate profile

Divisions

Highlights

Mineral resources & reserves

Exploration

Investment & projects

Investment & projects

Results & market

People & sustainability

Company network

Financial statements



## Codelco's transformation is an opportunity to empower innovation in Chile.

materials such as complex concentrates, white metal and smelter dust, among others. The company has technologies in the experimental testing stage to date.

### **Bioleaching**

BioSigma, a subsidiary of Codelco and JX Nippon Mining & Metals Corp., developed this technology that uses bacteria to extract copper from crushed ore that does not go through this process, which is known as Run of Mine, ROM, with promising results to date. BioSigma technology is currently in the commercial validation stage, the last stage of development.

### **Independent truck operation**

Gabriela Mistral Division operates its entire truck fleet using automatic systems that control truck movement without exposing operators to risks inherent to this activity. This smart technology requires teamwork culture and ongoing training. Gabriela Mistral Division has been a global

pioneer in the creation of this technology and is constantly improving its use by optimizing hardware and software in order to increase productivity and reduce operating costs. In addition, the Division has an advanced training center it uses for training all operators how to work and interact with automatic equipment.

### **Rocky massif preconditioning**

We are applying two industrial scale rock-breaking techniques at the site during the process leading up to ore extraction at underground mines. The two technologies are complementary -one uses explosives and the other uses hydraulic force- and have produced good results, enabling prior rock conditioning. The company thus aims to increase productivity by improving rock breaking and material flow toward desired extraction points.

Chairmen's statement

President & CEO's review

Organisation

Corporate profile

Divisions

Highlights

Mineral resources & reserves

Exploration

Investment & projects

Investment & projects

Results & market

People & sustainability

Company network

Financial statements

## Information, telecommunications, automation and robotics

We are driving the Digital Codelco strategy to integrate information technologies, telecommunications, automation and robotics (TICAR) in order to pave the way for new practices with the potential to transform the business. Technologies such as teleoperation of mining equipment, automation of production processes and the incorporation of robotic systems. Robotic systems are applied during high-risk activities or activities requiring physical effort and are tools that blaze a trail toward safer mining that is more committed to the environment, highly efficient and productive.

New technologies have allowed us to redesign mining processes, taking advantage of information that is available in real time and facilities for integrating processes in a homogeneous architecture. More specifically, the incorporation of machine to machine technologies, condition monitoring, big data, analytics y cloud computing paved the way for important advances in 2015 in terms of conceptualizing management and operation centers, monitoring and remote support, highlighting centers being adapted at the El Teniente, Andina and Ministro Hales divisions.

Some important projects executed during this period are listed as follows:

At the automated concentrate plants we standardized 85% of the control systems at our concentrate plants related to instrumentation infrastructure, communication networks, distributed control systems, operation rooms and advanced control and remote operation systems, such as:

- **Chuquicamata:** We improved advanced control strategies in the conventional SAG grinding sections.

We optimized advanced control strategies in the HighCup thickeners and assembled image system cameras for automatic control of the floatation process.

**Ministro Hales:** We added an advanced control system to the thickeners and configured a control system to incorporate remote operation from Santiago for mine dispatch, concentration and roasting processes.

- **Salvador:** We complemented the distributed control system for the plant, incorporating the Los Amarillos tailings plants, filters and hydrometallurgy. In addition, we added advanced controls to the grinding, floatation and tailings thickening processes.
- **Andina:** We kept the advanced control systems stabilized for the concentration process.
- **El Teniente:** We incorporated a distributed control system integrated to the rest of the control systems at the concentrate plant.

In 2016 we will focus on the Chuquicamata Division in order to migrate from its concentrate plant control system and integrate it into the new sustainability projects. With this milestone we will standardize state-of-the-art control systems at our concentrate plants.

## Robotics, teleoperation and automated operation

We designed and built a robotic concentrate sampling system for haul trucks designed for final implementation at the Potrerillos smelter. This solution can be replicated at other divisions. We also built a robotic maxisack monitoring system for the subsidiary Molyb.

At the Andina Division **automated mining application for outdoor operation** project, which considers teleoperation of mining equipment

Chairmen's statement

President & CEO's review

Organisation

Corporate profile

Divisions

Highlights

Mineral resources & reserves

Exploration

Investment & projects

Investment & projects

Results & market

People & sustainability

Company network

Financial statements

in adverse environmental conditions, we successfully completed the second milestone in order to teleoperate a haul truck (CAEX). Improved perception has been made available for WheelDozer and CAEX equipment at the operation.

When training operators to face critical conditions we start developing a high fidelity dynamic simulator to operate the roaster at Ministro Hales. This initiative complements training systems for concentrate plants and the flash furnace.

We also commissioned an advanced control system at the El Teniente Division Converter N° 1 at Caltones, improving operating conditions for the equipment. We also implemented an on-line indicator system to manage processes at Radomiro Tomic, Salvador and the subsidiary Molyb, which integrates information from different operating systems that is essential for decision making.

Finally, a standard tool for formulating metallurgical balances was consolidated at all divisions and in all of their processes.

### Awards

Our subsidiary **BioSigma** was presented the **2015 Avonni Award** in the Mining and Metallurgy category for having successfully industrialized and commercialized the bioleaching process (dissolving copper using bacteria in ore that cannot be exploited using conventional processes). This technology currently produces copper at room temperature using bacteria at the Radomiro Tomic Division.

The concentrate plant automation project at five Codelco divisions was presented the **2015 ICT Corporate Innovation Award**, an annual prize presented by the Information Technology Companies Association (ACTI).



**Our subsidiary BioSigma received the 2015 Avonni Award in the mining and metallurgy category.**