THERMOCHEM & WEST JEC RESOURCE EVALUATION SERVICES

Resource evaluation and feasibility studies may be initiated at any point in a project's lifetime, ranging from pre-feasibility studies for exploration drilling of a greenfield resource to full-scale feasibility studies for proven resources, or an expansion to a currently operating field. The 2020 acquisition of Thermochem by the Kyuden Group has allowed collaboration and growth for Thermochem, West Japan Engineering Consultants (West JEC), and Kyuden International Corporation (KIC). This new partnership improves our capabilities in supporting all stages of pre-feasibility and feasibility studies, management of wellfield development, construction, commissioning, and ongoing operations (Figure 1). Thermochem continues to provide geoscience support for conceptual and numerical model development, and the added expertise from West JEC and KIC in the areas of integrated project management for drilling operations, power plant design, as well as financial, economic, environmental, and social impact studies allow for execution of pre-feasibility and resource feasibility studies required in the early stages of project development to secure capital investment.

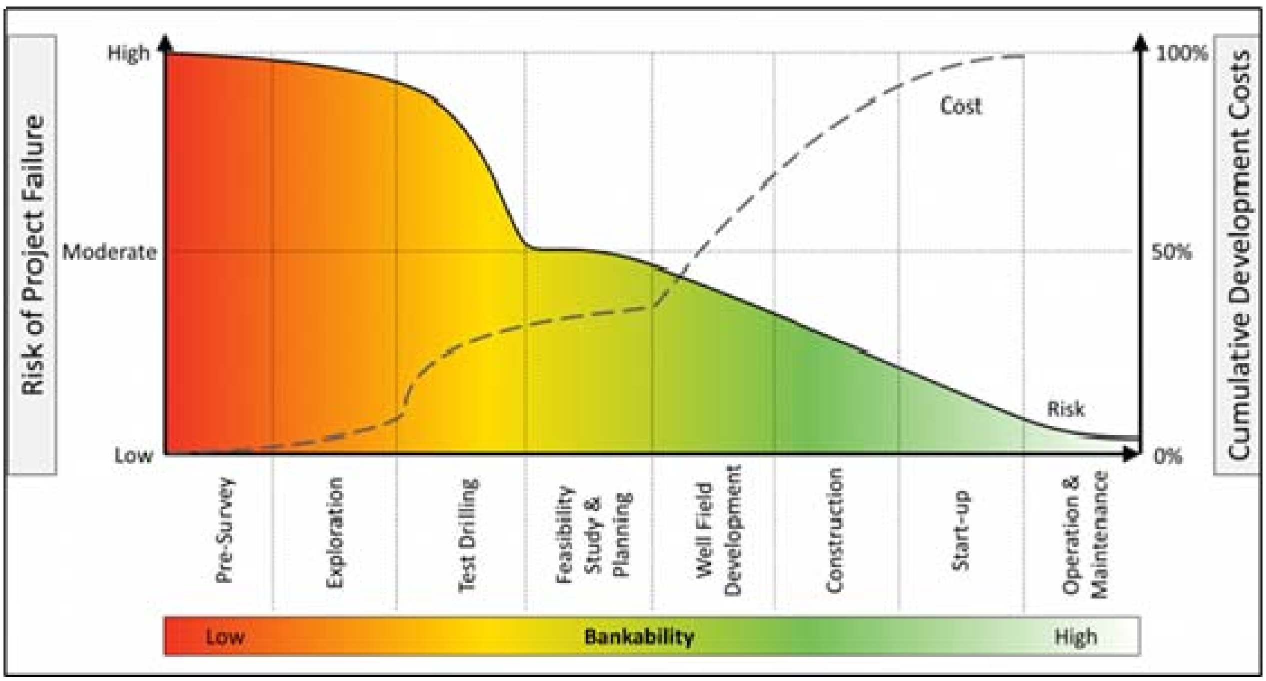

Figure 1. Project risk and cumulative development costs for geothermal project development (World Bank, 2012).

Thermochem utilizes in-house and consultant geoscience and engineering experts to manage geoscience and field surveillance data reviews, data collection and processing, and the development of conceptual and numerical models to support pre-feasibility and feasibility studies carried out in the early stages of project development. The Kyuden Group now offers the combined expertise of Thermochem, West JEC, and KIC for the management of resource evaluation projects through the feasibility study stage, as illustrated in Figure 2.

The preliminary stage of a resource evaluation should consist of a pre-survey data validation study to organize and catalog existing resource data, perform a rigorous review of data quality, identify data gaps and define value added for additional data acquisition, and assess the uncertainties of the geoscience data inputs that will be used to create the resource conceptual models. If it is determined that further data acquisition is required, or if initial exploration studies have yet to be carried out, then Geochemistry, Geology and Geophysics (3G) Exploration Surveys should be conducted in the field to better characterize the resource. The high quality 3G data is then integrated to form a robust conceptual model(s) of the system to be used for defining drilling targets and undertaking resource capacity (MWe) estimates.

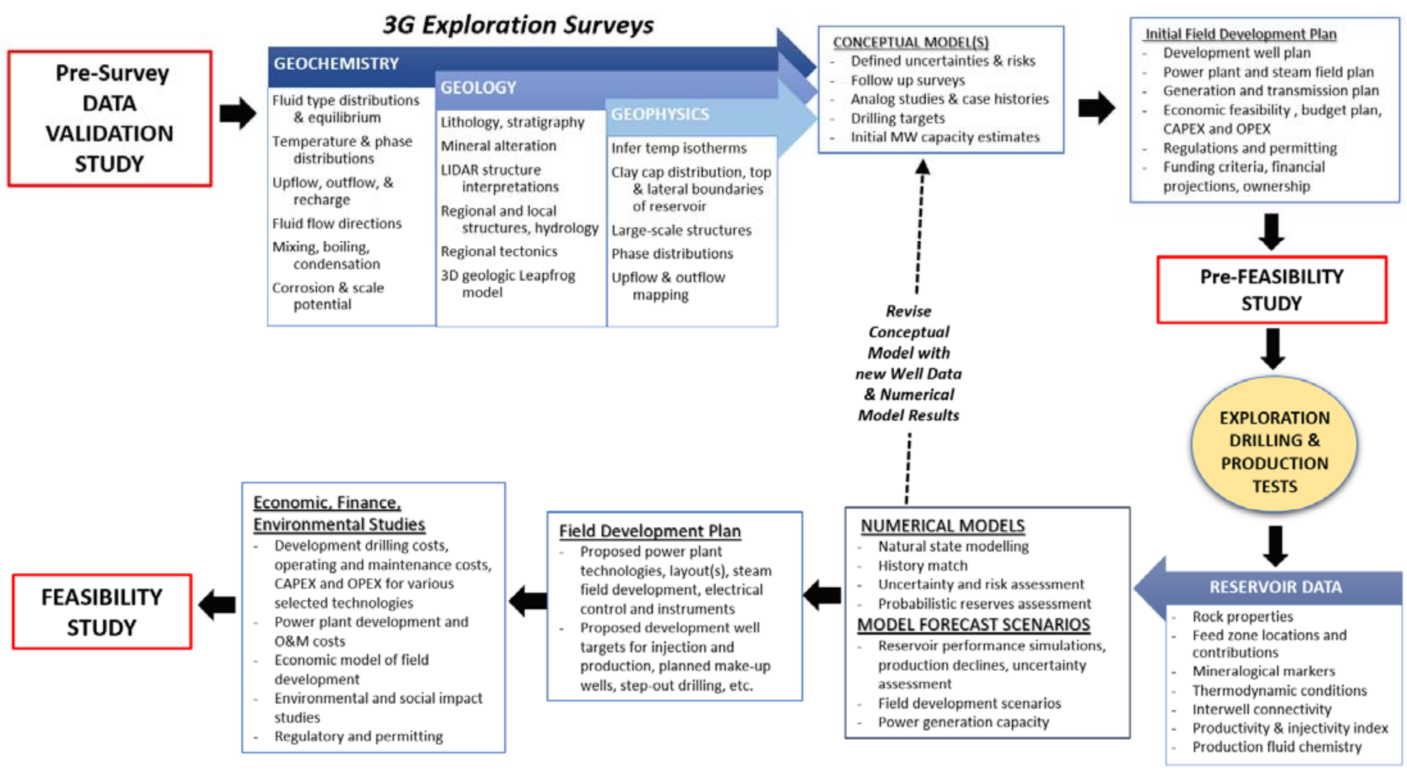

Figure 2. The stages of early project development, from pre-survey data validation studies and exploration surveys, through pre-feasibility studies and exploration drilling, to complete project development feasibility studies.

The conceptual model defines the key components of the geothermal system including the interpreted locations upflow, outflow, and recharge, thermodynamic conditions, permeability structure and primary fluid flow directions, chemical distributions that reflect reservoir processes such as mixing, boiling, or steam condensation, and the lateral and vertical reservoir boundaries. To assist the process of constructing conceptual models, the 3G data can be integrated in 3D space using geologic modeling software, such as Leapfrog, that can then serve as the visualization platform for conceptual model development and well targeting.

The key uncertainties and risks associated with the resource should be identified and quantified as part of the conceptual model development. Resource risks common to developing geothermal fields include insufficient temperature, insufficient permeability, insufficient resource size for an economic development, scaling, corrosion and acidic reservoir fluids. To access these uncertainties and risks, follow-up surveys for additional data acquisition may be warranted prior to exploration drilling. If the uncertainties and risks are not sufficiently clear after further 3G data collection, then they should be addressed by the exploration drilling program (e.g. drilling, production flow testing and geochemical testing to de-risk the possibility of acidic reservoir fluids).

Once the most-likely conceptual model(s) have been agreed by the geoscience team, well pad locations, drilling targets, and well designs can be selected for the exploration drilling campaign. All geoscience and technical information will be compiled at this stage and combined with initial studies for wellfield development plans, power plant technology studies, initial generation and transmission plans, economic and financial feasibility studies, summary of required regulations and permitting for field development, and a review of funding criteria, financial projections, and proposed project ownership. These technical, economic, and project structural components are combined in the pre-feasibility study that can be used to secure funding for the exploration drilling campaign and to carry out the continued feasibility studies for the field development.

The number and types of wells drilled in the exploration drilling program should be tailored to each project with the overall aim of proving the economic viability of developing the geothermal resource for the lowest possible cost. Each exploration well is very important to proving resource characteristics and it is therefore important to undertake thorough well testing programs in order to obtain reservoir data related to the subsurface thermodynamic conditions, rock properties, structural relationships and feed zones, fluid chemistry, and the well production and injection capacities. During the exploration drilling program, the conceptual model will evolve as new drilling and well test results are incorporated, and previously proposed well drilling targets may be updated accordingly.

In general, a numerical model should be constructed following the exploration drilling program. The numerical model should be based on the most likely conceptual model incorporating all available geoscience and reservoir data. The model should be calibrated with production test data, natural state temperature and pressure for each well and any interference testing data to define the natural state model for the system. If a field has been under operation, then the numerical model calibration data is significantly expanded and can include production history matching, interference tests and reservoir tracer tests. Once the natural state model is constructed and calibrated, production forecast simulations are carried out to evaluate the reservoir performance and production sustainability for different field development or operation scenarios. The numerical model and forecasting can be used to conduct detailed sensitivity studies to understand the impact on reservoir performance for a range of parameters (e.g. the level of connectivity between production and injection areas, amount of recharge to the system, and the impacts of these parameters on the pressure and enthalpy evolution of the field with ongoing production).

After exploration drilling is completed, there should be sufficient data to support the feasibility study. The exploration drilling and well test results, updated conceptual model, calibrated numerical model, and production forecast scenarios are then used to create a field development plan, including an evaluation of proposed power plant technologies, steam field development, electrical transmission lines, the proposed development well targets for production and injection, planned make-up well locations and schedule, expansion plans, etc. A financial and economic evaluation for the field development plan must be developed to support the project feasibility, including development drilling, power plant installation, and operations and maintenance costs. In addition to the economic evaluations, additional aspects of the feasibility study include a review of environmental and social impacts, as well as a regulatory and permitting requirements for project development. The feasibility study, or 'bank report,' may then be used to secure capital investment for the complete development of the resource. The project feasibility depends not only on the outcome of the simulated reservoir size and performance from drilling results and numerical model forecast simulations, but also on the feasibility of power plant design, transmission system, economic and financial feasibility, as well as potential environmental and social impacts of the geothermal prospect.

BRIDGING DEVELOPERS AND INVESTORS

The West JEC and KIC team not only bring decades of technical experience to the table, but also routinely serve as a bridge between geothermal project developers and investors during the early stages of project formation, promotion, and financing. The team can support arranging project finance with access to the assistance of financial institutions from Japan to introduce identified promising projects to promote grants or soft loans addressed to governmental institutions of developing countries to execute the initial steps of geothermal development to mitigate risk. Additionally, the team is able to facilitate financial arrangement by accessing the bi-lateral or commercial bank systems of Japan to promote the financing of promising public or public-private partnership projects for the development of geothermal projects. The long history of West JEC and KIC involvement in the international energy sector allows for project exposure to a wide range of private investors to promote partnerships for the development of geothermal projects.

THERMOCHEM RESOURCE TEAM

Thermochem employs in-house geoscientists and consultant experts to carry out resource assessment projects. Details on the key members of our resource assessment team are provided below. Personnel Curriculum Vitae are available on request.

Elisabeth Easley, Project Manager

Thermochem's Geochemistry Manager with 10 years' experience in the geothermal industry. Specializing in geochemistry sampling and analysis methods, interpretation and modeling, development of integrated resource conceptual models, uncertainty and risk assessment, and well targeting. Project Manager for international geothermal resource assessment projects, with significant international experience for exploration surveys, exploration and development drilling campaigns, and geochemical field surveillance programs. Holds an M.Sc. from Colorado School of Mines and speaks intermediate level Spanish and Bahasa Indonesian.

Anna Colvin, Geologist

Geoscientist consultant with 11 years of international experience in geothermal exploration and development. Specializing in geology and hydrothermal alteration, 3D modeling in Leapfrog, geoscience data integration, conceptual model development, resource capacity assessments, and well targeting. Holds an MSc. in Geology from Michigan Technological University. Fluent in English and Spanish.

Steve Sewell, Geophysicist

Geoscientist consultant with over 10 years of experience in geothermal resource exploration, development, field operations and research with extensive expertise in design, acquisition, analysis and interpretation of most types of geophysical surveys used in geothermal exploration and field performance monitoring, including MT, TEM, gravity, microearthquake and precision gravity methods. Steve has special expertise in the development of resource conceptual models supporting numerical reservoir simulation, well targeting and resource capacity risk assessment in both volcanic and sedimentary-hosted geothermal resources.

William Cumming, Geoscience Advisor

Consulting geophysicist with 40+ years' experience who provides technical, training and management services for geothermal industry, government and academic clients. Specializing in geothermal resource decision assessment, geophysical applications and professional education.

Rich Gunderson, Geoscience Advisor

Geologist consultant with over 35 years of experience in the geothermal industry working on a broad range of topics, including exploration program planning, execution, and interpretation, resource evaluation, resource risk evaluation, geothermal development planning, exploration, development, and make-up well planning and drilling, and all phases of conceptual model development.

Mauro Parini, Ph.D., Reservoir Engineering Advisor

Geothermal expert with 40 years' experience in geothermal industry. Specialized in geothermal reservoir engineering, mathematical modeling of geothermal reservoirs, resource evaluation, definition and optimization of exploitation strategy, techno-economic feasibility studies of geothermal projects, decision/risk analysis.

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WEST JEC RESOURCE TEAM

West JEC employs in-house geoscientists and engineers to support all stages of resource assessment and geothermal development projects. Details on the key members of the West JEC resource team are provided below. Personnel Curriculum Vitae are available on request.

Enrique Manuel Lima Lobato, Ph.D., Senior Geothermal Engineer

Senior geothermal engineer with over 40 years of experience in geothermal developments. His background in plant engineering and his academic training in geophysics and reservoir engineering permitted him to grow experience along the years participating in many projects around the world in his specific fields of expertise and in the integration of under and overground engineering aspects of geothermal developments. Mr. Lima served as managing director of West JEC and currently as Executive Officer and sub-manager of the Geothermal Division.

Koji Matsuda, Senior Geochemist

Senior geochemist with over 30 years of experience in geothermal developments. Mr. Matsuda has participated in numerous geothermal projects around the world. He has been responsible for geochemical survey execution, review and analysis of geochemical data, evaluation of chemical quality of steam, planning of geothermal power development and resource evaluation for geothermal power plant projects. Currently he is the General Manager of the Geothermal Department under the Geothermal Division of West JEC.

Luis Urzua, Senior Geoscientist

Mr. Urzua is a senior geoscientist with over 20 years of experience in geothermal exploration, resource assessment, commercial evaluation, drilling strategy and operations. He specializes in geothermal geological, geochemical, and geophysical exploration with focus on Magnetotellurics for resource potential estimation. Countries of work experience include Australia, Chile, Peru, Nicaragua, Mexico, Ecuador, Indonesia, Argentina, El Salvador, Costa Rica, Guatemala, Colombia, Malaysia, Kenya, USA, Turkey, Grenada, Saint Lucia and New Zealand.

Mitsuru Honda, Senior Geophysicist

Mr. Mitsuru Honda has over 30 years' experience with West JEC, specializing in geophysics and participating in numerous geothermal projects executing field surveys, data processing, analysis and interpretation of electrical and electromagnetic (MT/CSAMT) surveys, gravity and magnetic surveys in many geothermal projects in Japan, as well as Indonesia, Philippines, Guatemala, Peru, Nicaragua, Ethiopia, Rwanda, Turkey, and others. Mr. Honda is the senior geophysicist of the geothermal department of West JEC responsible for the construction of geophysical and conceptual models.

Yoshio Soeda, Ph.D., Senior Geologist

Dr. Yoshio Soeda has 20 years' experience with West JEC as a geologist. He has participated in numerous geothermal projects in Japan, as well as Indonesia, Philippines, Mexico, Costa Rica, Peru, Kenya, Rwanda, Turkey, and others. His fields of competence include remote sensing, structural geology, surface geological surveys, well geology data acquisition, analysis and interpretation, construction of geological and geothermal conceptual models, well targeting and resource evaluation for geothermal power plant projects.

Hideki Hatanaka, Senior Reservoir & Well Test Engineer

Mr. Hideki Hatanaka is a reservoir engineer and well logging/testing engineer with more than 20 years' experience. He has overseen well logging/testing data analysis and interpretation for many geothermal development projects in Japan and in other countries in Southeast Asia, Latin America, and Africa. His work on well data interpretation is a key element in the construction of geothermal conceptual model and resource assessment.