Strategies, Structures and Processes for Owning and Operating an Energy Resource Park

Shaun Tudor
Thesis of 60 ECTS Credits
Master of Science in Sustainable Systems Science
Reykjavik University – Iceland School of Energy
November 2015
Strategies, Structures and Processes for Owning and Operating an Energy Resource Park

Shaun Tudor

Thesis of 60 ECTS credits submitted to the School of Science and Engineering at Reykjavik University in partial fulfillment of the requirements for the degree of

Master of Science in Sustainable System Science
Reykjavik University – Iceland School of Energy
November 2015

Supervisors:

Viðar Helgason, Supervisor
Associate Professor, Reykjavik University

Einar Jón Ásbjörnsson, Co-supervisor
Associate Professor, Reykjavik University

Examiner:
Þórður Vikingur Friðgeirsson
Associate Professor, Reykjavik University
Strategies, Structures and Processes for Owning and Operating an Energy Resource Park

Shaun Tudor

Thesis of 60 ECTS credits submitted to the School of Science and Engineering at Reykjavik University in partial fulfillment of the requirements for the degree of

Master of Science in Sustainable Systems Science

Reykjavik University – Iceland School of Energy

November 2015

Student:

_________________________________________
Shaun Tudor, Reykjavik University MSc Candidate

Supervisors:

_________________________________________
Viðar Helgason, Supervisor

_________________________________________
Einar Jón Ásbjörnsson, Co-supervisor

Examiner:

_________________________________________
Þórður Vikingur Friðgeirsson, Associate Professor
1.1 Abstract

Industrialization has increased the demand for sustainable solutions to business, environmental and social challenges. This demand stems from all sectors of society, and involves decisions of varying magnitude. The dynamic and variable nature of such demand must be answered with an equally interdisciplinary response, involving concerted and proactive interaction between otherwise isolated or unrelated sectors of society.

An Energy Resource Park (ERP) answers such demand through careful and coordinated exploitation of geothermal resources; maximizing utilization of the resource through energy production and cascaded recovery of heat for industrial applications. The concept inspires industrial symbiosis, where previously independent industries exchange heat and waste bi-products, in-turn lowering operating costs and raising each participant’s “bottom line”. The ERP fundamental design includes a high temperature geothermal resource that will be exploited for both is thermal and electric power generation. Waste heat, gases and minerals produced by the power plant are recognized as “Waste to Value” (W2V) streams, and become utilized as inputs to Energy Resource Park “actors”, such as industrial corporations, municipalities, educational institutions, and local residents. The ERP will execute Creating Shared Value (CSV) policies and practices through defined ERP value streams, where independent actors collaborate to achieve shared economic and environmental goals. The ERP mission is driven by core values that aspire to achieve secure, diverse and sustainable economies through development of collaborative communities aiming to achieve zero-waste.

The primary expected ERP societal impacts include: increased sustainable energy development and consumption; job generation (one power plant employs ~50 people, whereas an expanded ERP could employ ~500); competitive edge in market place through lowering operating costs and streamlining waste/energy streams; education opportunities involving universities, technical institutions and corporate clients engaged in courses, seminars and research projects; high standard of living through for all involved and near to
the ERP through rigorous execution of environmental and corporate social responsibility policies.

The ERP is scoped to be integrative cycle-based movement that simultaneously builds sustainable infrastructure and policy in developing countries. When looking at a map of accessible geothermal energy, you can see the resource is prevalent amongst developing countries, lying on tectonic plate fault-lines. It is imperative that such countries develop sustainable infrastructure and policy instead of becoming another fossil fuel dependent state.

The ERP concept is a tested and proven as observed in Suðurnes, Iceland. The Suðurnes Resource Park has integrated multiple industries of varying operation and market share into one unified organization that has proven to be financially viable and whilst preserving the environment.

This thesis is the foundation for a handbook to owning, developing, implementing, and operating an ERP. Comprehensive detail regarding development and operational processes as well as management and ownership strategies will are priority outputs of this research. The long-term mission is to develop ERPs upon existing and new geothermal resources internationally. Ultimately, a global network will assemble independent ERPs to work together in shaping sustainable economic and environmental policies and practices worldwide.

Keywords: geothermal energy, Energy Resource Park, geothermal direct use applications, shared value, waste-2-value, industrial symbiosis
Áætlanir, mannvirki og vinnuferlar í tengslum við eignastýrinu orkugarðs

Shaun Tudor
Nóvember 2015

1.2 Útdráttur

Iðnvæðing hefur leitt til aukinnar eftirspurn síðar að rekja til allra sviða samfélagsins og nær til lausna af öllum stærðargráðum. Eðli þeirra er svo fjölbreytileg að taka þarf þverfaglega nálgun til að svara þeim. Þ.e.a.s. að virk og samhæfð samskipti milli ólíka geira samfélagsins, sem myndu annars ekki vinna saman, eru nauðsynleg.

Orkugarður (e. Energy Resource Park or ERP), sem nýtir jarðhita, getur verið ein slik lausn ef varfærni og samræmdar ægerðir eru hafðar að leiðar ljósi. Hægt er að hámarka nýtingu auðlindarinnar með raforkuframleiðslu og svo beina nýtingu varmaorkunarl á íðnaðar í framhaldi þess. Hugmyndafraðin yfir undir samvinnu milli mismunandi íðnaðargeira sem geta skipst á afurðum sem annars væru öntytt og getur leitt til lækkunar á rekstrarkostnað fyrrirtækjanna. Grundvallar hönnun orkugarðsins er miðuð að háhitasvæði þar sem bæði raforkuframleiðslu og nýting varmaorku fer fram. Varmaorka, gös sem losna úr læðingi og steindir er falla út við keyrsul jarðvarmvirkjunariðarinnar er hægt að flokka sem “Waste to Value (W2V)” afurðir og er litið á þær sem aðföng er tilheyra þeim aðilum sem koma að orkugarðinum og eru í næsta nágrenni. Stefna orkugarðsins mun vera að stuðla að sameiginlegu verðmæti (e. Creating Shared Value or CSV) þessara hagsmunaaðila og mun samstarfði ganga út á það að ná markmiðum í eigin efnahagsmálum og bættum umhverfismálum. Með þessu móti á orkugarðurinn að yta undir stöðugleika, fjölbreytileika og sjálfþærnum gildum í efnahagsmálum og beita sér fyrir söunarlausum samfélagi.

Helstu samfélagslegu áhfrar garðsins eru spáð til að vera: aukin þróun og notkun sjálfþærar orku; sköpun starfa (~50 í tengslum við jarðvarmvirkjun inn allt að 500 í stórum orkugarði); aukin samkeppnishæfni fyrrirtækja vegna lægrí rekstrarkostnaðar og nýtingar á annars önotuðum afurðum (úrgang); námsmöguleikar í tengslum við hákóla, tæknilegar stofnanir og starfsmenn fyrrirtækja sem sækja námskeið, málstofur og rannsóknarverkefni; hætri lifsgæði fyrir alla sem koma að orkugarðinum og á nærliggjandi svæðum vegna stefnumótun fyrrirtækjanna í skylðum gagnvart samfélag og umhverfi.
Orkugarðinum er einnig húsgað sem dríftkraftur til að hvetja þróunarlönd áfram í uppbýggingu á sjálfbærum innviðum og stefnumótum. Jarðhita er helst að finna á flekamótum og í mörgum tilfellum liggja þróunarlönd á þessum svæðum. Þess vegna er mikilvægt að þessi lönd líti til nýtingar á sjálfbærri orku frekar en að bæta við á lista þeirra ríkja sem eru háð jarðefnaeldsneyta.

Þegar hefur verið reynt á þróun orkugarðs á Suðurmesjum og hefur sá garður núð að mynda samstarf milli margra ólíkra íðnaðargreina. Þar hafta fjyriræki komið saman undir einu þaki og þýnt fram á að orkugarðurinn geti gengið upp fjárhagslega og á sama tíma verndað umhverfið.

Þessi ritgerð kynrir til leiks grunninn að uppbýggingu, þróun og rekrustur orkugarðs. Siðan eru lögð fram ítarlegar upplýsingar um þessa þætti og einnig ýmsar sviðsmyndir kynntar um rekrustur og eignarhald á slikum garði. Framtíðarsýnin er sú að orkugarðar verði reistir á núverandi nýttum jarðhitasvæðum og líka að hugmyndin verði líður í fyrirhugudum nýtingarleiðum á jarðhitasvæðum framtíðarinnar. Að lokum er vonast til þess að það skapist alþjóólegt net/kerfi fyrir samskipti og samvinnu milli orkugarða viðs vegar í heiminum. Þannig gætu þau deilt reynslu og þekkingu milli sín og hjálpað hvort öðru að ná því takmarki að skapa sjálfbær vinnuferli og umhverfi um gjörvallan heim.
1.3 Acknowledgements

I am very grateful for the guidance I’ve received throughout my profession, educational and personal life. It is this guidance, combined with my own internal inspiration and creativity that has provided me with a successful career in energy engineering thus far. I’m fortunate to say I can leverage experience acquired throughout my diverse background nearly every day writing this thesis. My B.A. in International Studies and Economics has provided me with a cultural, societal and economic perspective when considering energy decisions at a utility scale; as well as the ability to communicate the gravity of such scenarios, various organizations and functions to parties involved.

Jason Gorak and Jesse Knee provided me with fundamental skills in engineering and managing HVAC projects early in my career with Johnson Controls. Their hands-on direct guidance provided me with a balanced skill set that proved successful as my projects closed out profitable. In 2010 I moved to New York City and began consulting commercial energy performance contracts with Malkin Properties, the owner of the Empire State Building. Mike Ryan and Paul Rode provided valuable insight to both executing retrofit projects in NYC as well as managing high profile client expectations. After a move from one major HVAC firm to another, Schneider Electric stationed me at the World Trade Center Tower 1, where I was exposed to the incredibly complex world of new construction in lower Manhattan. Lee Therrien, the WTC1 automated controls project manager, involved me in programming and commissioning systems, and coordination of associated subcontractors, where continued to refine my technical and communication skills. During 2013 and 2014 my experience thus far allowed me to become a freelance energy consultant, where I worked closely with EN-POWER; a small energy consulting start-up in Manhattan. There I developed new market offerings and value streams for the firm, all the while observing operations of a start-up company and its associated challenges.

Throughout my career as an energy consultant in the building sector of NYC, I found frustration in the limited impact my projects had to the “bigger picture”. The energy retrofit projects I was involved in yield consumption reductions of ~30% at best, meanwhile the majority other buildings on the block remained inefficient, burning considerable amounts of fuel oil as well as operating outdated processes and equipment. I quickly recognized I wanted to improve the “grid” and the generation techniques of primary supply energy. In March 2012
I applied to Reykjavik University, with the goal of understanding and developing geothermal resources in developing countries worldwide.

In July 2014 I moved to Iceland, where Kristín Kristínsdottir and Halla Hrund’s assistance proved very helpful. They’re guidance exceeded my expectations, through general transition assistance, program course selection and facilitating an internship with the Icelandic Geothermal Cluster. Viðar Helgason is the program manager for the cluster, and has provided excellent guidance academically, and professionally, as the internship started in December 2014. Shortly thereafter, the development of the energy resource park concept became full focus and a thesis was identified. Viðar has worked extensively to provide support for my research through engagement of Iceland’s geothermal engineering firms, and continues to provide feedback and support, as I require. I consider myself very lucky, as I can say that I’m working on my dream project with incredibly supportive and inspiring people.

Lastly, I recognize the continuous and ever strengthening core support from my Family. Their unchecked reinforcement for whatever my personal or professional aspirations are has aided in the much-needed confidence for my endeavors.

I cordially thank all of those whom I’ve worked with; past, present, future and continuous, your guidance and support have greatly aided my ability to sustain success despite the face of change.
Table of Contents

1.1 Abstract ........................................................................................................ vi
1.2 Úttráttur ............................................................................................................ Error! Bookmark not defined.
1.3 Acknowledgements .......................................................................................... viii
1.4 List of Figures .................................................................................................... xiii
1.5 List of Tables ..................................................................................................... xiv
1.6 Nomenclature .................................................................................................... xiv

1 Introduction ......................................................................................................... 1
  1.1 Context ........................................................................................................... 2
  1.2 Research Focus ............................................................................................... 3
  1.3 Object of Research .......................................................................................... 3
  1.4 Structure of Research ..................................................................................... 3
  1.5 Graphical Overview of Research .................................................................... 4
  1.6 Methodology .................................................................................................. 5
    1.6.1 Geothermal Review .................................................................................... 5
    1.6.2 Fundamental Ideology ............................................................................... 6
    1.6.3 Ownership, Development and Operation ................................................... 7
  1.7 Geothermal Review ....................................................................................... 8
    1.7.1 General Geothermal Information ............................................................... 8
    1.7.2 Classification of Geothermal Systems ......................................................... 9
    1.7.3 Indirect Geothermal Utilization Overview ................................................ 12
    1.7.4 Indirect Use Value Chain ........................................................................... 14
    1.7.5 Direct Geothermal Utilization Overview .................................................... 15
    1.7.6 Direct Use Value Chain ............................................................................. 20

2 Fundamental Ideology ......................................................................................... 21
  2.1 Core Value Infrastructure ............................................................................... 21
  2.2 Value Propositions .......................................................................................... 23
    2.2.1 Environmental ........................................................................................... 23
    2.2.2 Societal ..................................................................................................... 25
    2.2.3 Economic .................................................................................................. 27
  2.3 Actors .............................................................................................................. 29
    2.3.1 ERP Owner ............................................................................................... 29
    2.3.2 ERP LLC ................................................................................................. 29
    2.3.3 Operation Board ....................................................................................... 29
    2.3.4 Geothermal Power Company .................................................................... 30
    2.3.5 ERP Companies ........................................................................................ 30
    2.3.6 Sector Managers ...................................................................................... 30
    2.3.7 Municipalities ......................................................................................... 30
    2.3.8 Educational Institutions ......................................................................... 30
    2.3.9 Communal and Residential Sectors .......................................................... 31

3 Ownership, Development and Operation .......................................................... 32
  3.1 Ownership Strategies ..................................................................................... 32
    3.1.1 ERP Fund, LLP ........................................................................................ 32
    3.1.2 Geothermal Power Company Ownership ................................................. 38
    3.1.3 Government Ownership ............................................................................ 39
  3.2 Development Strategy - Adaptive Project Framework .................................... 40
    3.2.1 Initiate ..................................................................................................... 41
3.2.2 Scope Phase .......................................................... 48
3.2.3 Design, Spec and Plan............................................... 54
3.2.4 Build .................................................................. 59
3.2.5 Review ................................................................. 62
3.2.6 Monitor and Control ............................................... 64

3.3 Organization and Operation ........................................... 66
3.3.1 Organization Structure ............................................. 66
3.3.2 ERP Management Team and Operation Board Structure ... 67
3.3.3 Operational Value Chain ........................................... 68
3.3.4 Operational Cycle Approach – Scrum Framework and the ERP 69

3.4 Chapter 4: Sector and Cluster Management ....................... 70
3.4.1 Creating Shared Value and Energy Resource Parks ........... 70
3.4.2 Waste to Value ..................................................... 71

4 Closing Statements .......................................................... 72

Bibliography ..................................................................... 73

4.1 Appendix A – Lindal Diagram (Lindal, 1973) ....................... 79
4.2 Appendix B – Direct Use Value Chain .............................. 80
4.3 Appendix C – As-Built Plans and Specifications Requirements ........ 81

1.4 List of Figures

Figure 1: Reykjanes Resource Park Diagram (HS Orka, 2014) .................. 2
Figure 2: Energy Resource Park Greater Research Structure .................... 5
Figure 3: Worldwide distribution of geothermal energy (Glitnir Bank, 2009) .... 8
Figure 4: Natural Hydrothermal Geothermal System diagram (Inforse, 2015) ... 10
Figure 5: Flash Steam Geothermal Power Plant Diagram (Subramaniam, 2012) ... 13
Figure 6: World Cumulative Installed Capacity, 1950-2013 (Roney, 2014) ......... 14
Figure 7: PLN Geothermal Power Value Chain ( PT. PLN. Geothermal, 2009) ...... 15
Figure 8: Energy Resource Park Core Value Infrastructure .......................... 21
Figure 9: ERP Environmental Value Proposition ......................................... 23
Figure 10: ERP Societal Value Proposition ............................................... 25
Figure 11: ERP Economic Value Proposition .............................................. 28
Figure 12: EPC LLP Fund Structure based upon (Barufaldi, 2015) ................. 33
Figure 13: ERP LLP Fund Shared Equity Structure ..................................... 34
Figure 14: ERP LLP Fund Retail Energy Structure ...................................... 35
Figure 15: Geothermal Power Company Owned Structure ......................... 38
Figure 16: Geothermal Power Company + Start-Up Fund Structure ............. 39
Figure 17: Government Owned ERP Structure ............................................ 40
1.5 List of Tables

Table 1: Direct-Use Industrial Drying Applications (Rafferty K., Industrial Processes and the Potential for Geothermal Applications, 2003) ................................................................. 18

Table 2: Suðurnes Resource Park Employment Index (HS Orka, 2014) ........................................... 29

1.6 Nomenclature

ADSCR - Annual Debt Service Cover Ratio
APF - Adaptive Project Framework
CDT - Core Development Team
COS - Conditions of Satisfaction
CSR - Corporate Social Responsibility
CVI - Core Value Infrastructure
DM - Development Manager (ERP Management Team Lead)
EA - Environmental Auditor (ERP Management Team)
EMS - Environmental Management System
ERP - Energy Resource Park
GHG - Green House Gas

Strategies, Structures and Processes for Owning and Operating an Energy Resource Park
Shaun Tudor – MSc Thesis – Iceland School of Energy, Reykjavik University 2015
GO - Generator Operator
GP - General Partner
IRR - Internal Rate of Return
ISO - International Standards Organization
LLC - Limited Liability Corporation
LLP - Limited Liability Partnership
LP - Limited Partner
MR - Municipality Representative
MT - Magneto Telluric
MWe - Megawatt Electric
MWt - Megawatt Thermal
NCG - Non-Condensable Gas
PPP - Private-Public Partnership
ROI - Return on Investment
SDS - Sustainable Development Strategy
TDM - Transmission and Distribution Managers
TEM - Transient Electro Magnetic
WACC - Weighted Average Cost of Capital
WBS - Work Breakdown Structure
1 Introduction

The demand for energy, goods and services is increasing every day throughout the world. Industrialization inherently leads to increased consumption of energy. In recent years political and non-governmental policies aim to reduce mankind’s impact on the climate through reducing carbon dioxide emissions through promotion of renewable or sustainable energy sources and technologies. Despite these international efforts to promote the use of sustainable energy as the primary supply to satisfy the demand, the burning of fossil fuels remains the primary energy source of the world in the 21st century. Combustion of fossil fuels produces high levels of greenhouse gas (GHG) emissions.

Geothermal energy, which is exploited by mining thermal energy from the earth’s crust, is a promising energy alternative to fossil fuels. Increasing the use of geothermal energy could help satisfy the growing demand for energy and curb GHG emissions worldwide. There are two types of geothermal energy utilization direct use of the heat and fluids in applications and industrial processes, or indirect use by using the geothermal fluid vapor to drive a turbine for electricity production. Indirect use, or electricity production, is the most common utilization of geothermal energy worldwide, producing 12GWe (Matek, 2014). Unfortunately, the average efficiency of geothermal electricity production is only ~12% efficient, meaning the remaining ~88% of heat extracted is wasted through exhaust. The highest reported conversion efficiency is approximately 21%, at the Darajat vapor-dominated system (Moon & Zarrouk, 2012). An Energy Resource Park utilizes the heat from a geothermal resource in a cascaded fashion, where the high temperature industries utilize the waste heat first. Lower temperature applications receive the discharge from high temperature industries, in a cascaded fashion.

An energy resource park attempts to recover heat lost in electricity production as well as associated waste byproducts to fuel additional industries and processes. An energy resource park however not only improves the efficiency of a renewable energy source, but also increases net value and societal benefits through of a geothermal power plant industrial symbiosis. An ERP generates employment opportunities and integrates diverse business
operations into a common effort towards increased sustainability and profitability through reducing operating costs. (GAMMA, 2015)

1.1 Context

The energy resource park concept is not new or unique. The concept is simple; utilize waste from one process as an input to another. The Suðurnes Resource Park operates with several companies and R&D organizations over the past decade. The Suðurnes Park has experienced success on many levels. HS Orka, the geothermal electricity generator and sole proprietor of the Suðurnes Park, released an official statement of combined revenues within the park, as well as societal and environmental benefits achieved. (HS Orka, 2014)

Figure 1: Reykjanes Resource Park Diagram (HS Orka, 2014)

After several decades of trial and error, the environmental, economic and societal success that the Suðurnes Resource Park has attracted the attention of both existing and new geothermal power plant operators across the globe. On November 18 2014, Ms. Ragnheiður Elin Árnadóttir, Minister of Industry and Commerce signed a Memorandum of Understanding on Iceland’s behalf in relation to cooperation with Nicaragua in the field of renewable energy, especially geothermal power. The agreement is between the Icelandic Ministry of Industry and commerce (ANR) of Iceland and the Ministry of Energy and Mines (MEM) of Nicaragua. President Daniel Ortega of Nicaragua was present and acknowledged the agreement in a speech. In the same meeting ENEL (National Power Company of Nicaragua) and the Icelandic Geothermal Power S.E. signed an agreement on developing a geothermal resource park in the geothermal districts of Masaya, Apoyo and Mombacho.
Usable geothermal energy for electricity generation in these areas has been estimated to be around 363.5 MW. (Baker, 2014)

The demand for an energy resource park in Nicaragua is one example of the attention the concept is receiving internationally. Within Iceland several on-going projects include developing resource parks.

1.2 Research Focus

The energy resource park concept is fundamentally interdisciplinary, it integrates a diverse pool of business, technologies and industrial processes to cooperate and exchange waste and energy. The research for this thesis is therefore interdisciplinary, and will attempt to provide an overview to develop, operate and continuously expand energy resource parks. This thesis is segmented sections; Section 1 Introduction reviews the research and background geothermal information. Section 2 Fundamental Ideology details core values, value proposition, and ERP Actors. Section 3 reviews ERP development, implementation, as well as operational, managerial and ownership strategies of the ERP. Section 4 is reserved for closing statements.

1.3 Object of Research

The research for this thesis will attempt to answer the following questions:

- What is an ERP?
- What applications and processes can be integrated to an ERP?
- What are the economic, social and environmental values of an ERP?
- How does one own, develop, implement and operate and ERP?
- What are the macro impacts of an ERP?

1.4 Structure of Research

This thesis begins with an introduction section, reviewing the research context, focus, object and structure. The introduction also includes a sub-section of geothermal review, which intends to provide background details of the energy source; utilization classifications, related market sectors and ERP associated industries. This review is provides background information about the diverse opportunities that can be utilized within an ERP. These applications will be referred to and built upon in Section 2 and 3 as examples when discussing potential configurations. Section 2 is a theoretical review of an ERP’s value
structure foundation and propositions to society, the environment and economy as well as associated actor classes on a macro scale. The importance of detailing an ERP’s value infrastructure and propositions will be reflected upon in Section 3 where application selection and development decisions are discussed, which highly consider baseline attributes and virtues. Section 3 dives deep into project management processes and approaches to owning, developing and operating an ERP. An ERP’s ownership structure can take various forms, depending on the level of government, Energy Company or private investment. Regardless of ownership strategy, the approach to developing an ERP is assumed to be universal, although slight variations dependent on ownership strategy are considered. Once developed, continuous operation and organization of an ERP are reviewed through use of business illustrations including value chains and organization charts. Continuous expansion and improvement are at the core of an ERP’s value set, so it is important to identify potential obstacles and solutions that might be encountered. Operation of an ERP will also be reflected upon existing management and business initiatives such as Cluster Management, Creating Shared Value and Waste-to-Value strategies. Lastly, macro considerations such as emerging markets, geographic influence, and lobbying for policy or development of an ERP and their associated impacts are hypothesized. A 4th Section draws conclusions and highlights next steps in the research and development of an Energy Resource Park Handbook.

1.5 Graphical Overview of Research

Figure 2: Energy Resource Park Greater Research Structure identifies four major research areas of the ERPH, Fundamental Ideology; Ownership, Development and Operation; Sustainable Resources and Core Business Analyses. This thesis will review background geothermal information, then a comprehensive review of Fundamental Ideology then Ownership, Development and Operation subjects. The Sustainable Resources and Core Business Analysis research areas should be pursued in subsequent efforts following the completion of this thesis.
1.6 Methodology

An Energy Resource Park is a uniquely interdisciplinary operation, which requires and equally if not more interdisciplinary approach to it’s research and development. This thesis primarily focuses on theoretical and practical project management techniques and strategies in relation to an ERP. These topics provide a necessary foundation for quantifying and calculating actual ERP operating variables and outputs, which is not performed in this thesis.

1.6.1 Geothermal Review

To understand opportunities for implementing ERPs, it is important to understand the primary resource that drives an ERP\(^1\). The Geothermal Review section is primarily a literature review of basic geothermal characteristics and principals. The Utilization Overview provides summaries of existing and potential indirect and direct use applications to be integrated to an ERP. These examples rely heavily of existing operations and projects. The indirect use value chain and displayed in Figure 7 is a proven approach to geothermal

\(^{1}\) An Energy Resource Park may use waste heat and water from various sources other than geothermal energy, i.e. aluminum smelters, fossil fuel power plants, and high volume heat intensive industrial process.
utilization as well as oil and gas exploitation. The direct use value chain does not exist in the geothermal business world, per a meeting with Viðar Helgason (Helgason, 2015). The direct use value change was developed from a combination of previous professional experience in project management, proven value chain principals, and unique conditions of the geothermal direct use markets. Although indirect use power production remains at the center of an ERP’s waste-to-value stream, direct uses are widely used throughout the ERP. Initially, all possible direct uses must be identified. Existing lists, and diagrams, illustrations of various direct use strategies such as the Líndal diagram were compared, and combined. Once a comprehensive list of various applications was identified, the list was organized by operating temperature; then associated case studies and literature was collected. For this thesis, projects of note for each application to better explain its function and applicability within the ERP.

1.6.2 Fundamental Ideology

The fundamental ideology section bears investigation of values that pertain to sustainability, environmental conservation, and social progress. As demonstrated throughout this thesis, the attempt is to cast a wide net to cover potential variables and conditions. Chapter 1 highlights five pillars that have expanded upon Albert Albertson’s vision as discussed in Suðurnes Resource Park (Jónsdóttir, 2011). The original concept rings true, and was broadened to increase applicability and apply more detail as to the reach of an ERP’s core value infrastructure, as well as identifying supporting attributes and virtues related to an ERP. Albertson’s original resource park values are as follows:

- Integrated usages of a variety of subjective and objective resources of different nature.
- The Resource Park is to equally accentuate ecological balance, economic prosperity and social progress, doing so it fully supports the sustainable development in society as defined by the Brundtland commission.
- Interdisciplinary cooperation of different entities.
- The Resource Park is to bridge different technical and social cultures.
- Read the Nature—holistic approach to the project—be in the nature.
- The inherent time scale of the Resource Park activities spans centuries.

Chapter 2 reviews current environmental and social policies and their relation to an ERP, further illustrating the aggressive yet realistic approach to behind an ERP’s ability to be executed. Once the value infrastructure is understood, logically a discussion of whom it involves should follow. These policies include CSR and ISO practices and methods, and are widely adopted throughout various industries and entities that would be considered part of an ERP. Chapter 3 identifies actor “classes” that will participate in an ERP. This chapter Strategies, Structures and Processes for Owning and Operating an Energy Resource Park
Shaun Tudor – MSc Thesis – Iceland School of Energy, Reykjavik University 2015
reviews high level details and responsibilities of all associated actor classes active within an ERP. The fundamental ideology is reviewed prior to ownership, development, and operation, because the ERP’s values transcend every level of operation and communication within an ERP.

1.6.3 Ownership, Development and Operation

A variety of resources come into play when designing various ownership strategies as well as a comprehensive process to include the interdisciplinary efforts of an ERP. These resources include proven project management techniques as well as cluster management and shared value initiatives. It is important to note that an attempt at assembling an ERPH has yet to be accomplished, therefore much of the work in this section is a combination of new ideas incorporated with previously mentioned resources. Diagrammatic representations are of my original design, although inspiration is attributed where applicable. Ownership strategies in Chapter 1 rely upon commonly known limited liability tax vehicle structures and arrangements. The relationships between stakeholders at various levels of management within the ERP explore various share and revenue distribution methods, intending to sustainably circulate earnings, endorsing a “team-like” mentality. Five (5) different ownership structures were identified that utilize a proven LLP financial structure that are intended to entice investors with various risk profiles.

The resources used to develop the strategies and processes in Chapter 2 primarily applies the methods and strategies of the Project Management Book of Knowledge (PMBOK) and Robert K. Wysocki’s Effective Project Management to an ERP model; a complex and long-term interdisciplinary energy development project. As mentioned before, the ERP approach is incredibly interdisciplinary, so its associated management strategy is adaptable and scalable. An iterative feedback loop is included to ensure consistency from one project cycle to the next. This chapter merges the Adaptive Project Framework and PMBOK methods with fundamental geothermal exploration and utilization tasks of development, and continuous operation. These geothermal specific tasks and subtasks have been highlighted in my coursework at Icelandic Geo-Survey (ISOR) and Reykjavik University (HR).

Chapters 3 and 4 continues to explore innovative project management techniques in relation to the structure and operation of an ERP; agile methods such as Scrum and Michael Porter’s Value Chain and Shared Value Initiative reflects the core values and functions of an ERP.
1.7 Geothermal Review

This section will introduce general information on geothermal energy and classification. An overview of different characteristics between low and high temperature geothermal fields will be followed by discussion on indirect and direct use applications.

1.7.1 General Geothermal Information

Geothermal energy derives from the exploitation of thermal energy, which is stored in the earth’s crust (Ledru & Huenges, 2010). Since conductive and convective heat transfer is omnipresent in the earth’s mantle, thermal energy is distributed worldwide (Skinner & Murck, 2011). Nonetheless, the distribution of geothermal energy is not uniform and geothermal gradients differ according to geological environment (Bjorlykke, 2010). The geothermal gradient is measured as an increase of temperature per unit of depth. An overview of areas with a steep geothermal gradient, displayed on a world map, can be found in Figure 3. Notice how closely these areas align with tectonic plate boundaries.

![Figure 3: Worldwide distribution of geothermal energy (Glitnir Bank, 2009)](image)

The heat flow rate through the crust is significantly different between terrestrial and oceanic crust. The terrestrial flow rate averages 0.65 W/m² and the flow rate under oceanic crust averages 0.10 W/m². The average temperature gradient ranges from 25°C to 30°C per kilometer, which mainly results from the decay of potassium, uranium and thorium isotopes. (Tester, Drake, & Driscoll, 2012)
The thermal gradient can be influenced locally by intrusions of molten rock (lava) (Tester, Drake, & Driscoll, 2012). The gradient is the steepest at tectonic plate boundaries, where temperature usually rises quickly with increased depth (Burke & Kidd, 1978). People who inhabited these areas were historically among the first to explore the use of geothermal energy. Proof of early use of geothermal energy is present in areas where geothermal fluid reaches the surface of the earth and creates hot springs (Stober, 2013) (Cataldi, S. F. Hodgson, Council, & Association, 1999) (Cataldi & Chiellini, 1995). This utilization of geothermal energy was used for bathing and washing clothes for more than 7000 years (Lund, 2001). Industrial use of geothermal energy, either directly or indirectly for power production, began in the early twentieth century. One of the first industrially exploited geothermal fields was Lardarello in Italy, where electricity was produced from geothermal steam in 1902 (Quick, Michael, & H. Huber, 2010).

Industrial use requires accessibility to the resource. Accessibility is achieved through drilling production wells to a certain depth until the desired temperature is reached. Drilling for geothermal fluid is a major cost factor in geothermal development and is generally more expensive than drilling for oil and gas, economic accessibility is a requirement as well (Glowka, 1997) (Tester & Herzog, 1990) (Milora & Tester, 1976). Development is therefore limited to areas where drilling costs are manageable due to steep geothermal gradients and an ideal geological environment.

1.7.2 Classification of Geothermal Systems

This section of the Introduction focuses on the classification of geothermal systems and gives an overview of the characteristics of four different system types and the fluid enthalpy classifications.

1.7.2.1 Natural Hydrothermal Systems

Natural hydrothermal systems produce geothermal fluid without any added technology. This type of system utilizes a natural heat source, and rocks with enough permeability to allow a convection-dominated system. Natural hydrothermal systems are usually found at tectonic plate boundaries, which have steep geothermal gradients with local high permeability formations (Tester, Drake, & Driscoll, 2012) (Norton, 1984). Water in hydrothermal systems is often of meteoric origin. Water falls as precipitation and percolates through permeable layers until it reaches the heat source (e.g. magmatic intrusion), heats up and travels upward.
towards the earth’s surface (DiPippo, 2005). There are exceptions to this, like the Reykjanes field in Southwestern Iceland, where the geothermal fluid contains seawater as well (Hardardottir, 2011) (Arnorsson, 1978).

In general, natural hydrothermal systems are further divided into two categories: vapor dominated systems and liquid dominated systems (DiPippo, 2005) (Tester, Drake, & Driscoll, 2012). A vapor-dominated system is formed if the pressure of the reservoir allows the geothermal fluid to boil and eventually vaporize. These systems are relatively easy to exploit and seldom occur. When they occur, they might be suitable for base load electricity production. Examples include Geysers in the USA and Larderello in Italy (Gupta, 2006) (Allis, 2000) (Ingesbritsen & Sorey, 1988) (White, Muffler, & Truesdell, 1971) (White, 1974).

Figure 4: Natural Hydrothermal Geothermal System diagram (Inforse, 2015)

A liquid-dominated system is formed if the pressure of the reservoir does not allow the geothermal fluid to boil. These systems are more common than vapor dominated systems, but they are generally more difficult to exploit, because the concentration of total dissolved solids (TDS) in the fluid might foster increased scaling. Scaling can become problematic when flashing between a two-phase flow and a one-phase flow. (Tester, Drake, & Driscoll, 2012) (Gupta, 2006) (White, Muffler, & Truesdell, 1971) (White, 1974).
1.7.2.2 Geo-pressured Systems

Geo-pressured geothermal systems consist of reservoirs filled with sedimentary rock and water which is excluded from exchange with surrounding rocks (Jones, 1970) (Duffield & Wendell, 2003). Rapid precipitation of sediments increases the pressure in the reservoir, which becomes higher than the hydrostatic pressure (Gupta, 2006). The geothermal fluid might be exposed to a pressure up to 600 bar while reaching a temperature of about 180°C (Tester, Drake, & Driscoll, 2012). Generally, geo-pressured systems are assumed to be saturated with methane and have around 100,000 ppm TDS. Geo-pressured systems were first found in the Gulf of Mexico region, where research was carried out during the 1970s and 80s. US research found additional reservoirs in Alaska, California and the Rocky Mountain region (Sanyal, Robertson-Tait, Kraemer, & Buening, 1993) (Blackett & J. Satrape, 1986). These types of systems have been found to be profitable only under very special circumstances. However, technological development might change this in the future (Gupta, 2006) (Wys & Dorfman, 1990).

1.7.2.3 Hot Dry Rock

Many locations on Earth have a relatively steep geothermal gradient but have insufficient fluid content or permeability. These systems are called hot dry rock (HDR) formations or enhanced geothermal systems (EGS) (Tester, Drake, & Driscoll, 2012) (DiPippo, 2005) (Gupta, 2006). Given a sufficient borehole depth, such systems are available across the globe - creating a very large resource base. However, access is restricted heavily by economic factors such as drilling and infrastructure cost. (Tester & Herzog, 1990) (Herzog, Tester, & Frank, 1997) Nevertheless, the universal nature of EGS is a promising feature. The technology behind EGS is hydraulic fracturing, a technology well known from the oil and gas industry, where it is employed to access shale oil and gas reservoirs. A partially horizontal injection well is drilled and a mixture of water and chemicals is pumped into the ground at high pressure. The rock formations fracture under the high pressure and create a fairly large surface area for heat exchange. As an application for the geothermal industry, the water is heated up in the hot rock formation and is pumped up through a production well where it can be flashed and its vapor phase can be used for electricity production (Tech Rep, 2006).

1.7.2.4 Magma

In contrast to using a cooling magmatic intrusion as the heat source, as natural hydrothermal systems do, magma systems use a heat source that comes from molten rock. The high
temperature of this heat source is desirable for electricity production; however, the high temperatures could damage the power plant equipment. The Iceland Deep Drilling Project (IDDP) had the goal to drill 4500m into the supercritical zone that was suspected in the Krafla geothermal area, located under the Krafla volcano in northern Iceland. The drilling process was stopped at 2100m when magma with a temperature of 900°C flowed into the borehole (Fridleifsson, Elders, & Albertsson, 2014). Krafla was able to achieve production at a wellhead temperature of 450°C and a superheated dry steam with a pressure of between 40 and 140 bar. This production test had to be stopped after two years due to mechanical failure. (Elders, Fridleifsson, & Albertsson, 2014) The project aims to continue testing the possibilities of using magma as a heat source. Currently a discussion is ongoing whether the Reykjanes geothermal zone in southwestern Iceland is designated the location for IDDP 2 (Fridleifsson, et al., 2014).

1.7.2.5 Geothermal fluid enthalpy classification

The temperature of the geothermal fluid produced by the resource is directly related to the enthalpy classification. The three (3) classifications of enthalpy are identified below:

- Low Enthalpy 4-150
- Medium Enthalpy 150-200
- High Enthalpy 200+

1.7.3 Indirect Geothermal Utilization Overview

The varying characteristics of different geothermal systems account for different uses. This subchapter focuses on the different indirect use applications of geothermal energy.

1.7.3.1 Power Production

One of the most common uses of high temperature geothermal resources is electricity production. Commonly one of the following three power plant types is used (DiPippo, 2005) (Tester, Drake, & Driscoll, 2012):

- Dry steam power plants
- Flashing power plants
- Binary power plants

Dry steam power plants are the simplest design of geothermal power plants and can only be operated in vapor dominated high temperature geothermal fields, and the vapor contain almost no liquid. In ideal conditions the dry steam can be extracted easily and used directly in electricity generation (DiPippo, 2005) (Tester, Drake, & Driscoll, 2012).
Flashing power plants, as shown in Figure 5, are the most common form of geothermal power plants. The geothermal fluid is brought to the surface under pressurized conditions. The pressure is released gradually in a flash tank, which leads to partial vaporization of the fluid. The vapor phase is then used to run a turbine and generate electricity, while the liquid phase might be used for reinjection or further industrial uses such as an Energy Resource Park. Even after multiple flashing stages, a liquid phase usually still exists (DiPippo, 2005) (Tester, Drake, & Driscoll, 2012).

Binary power plants are commonly used when the reservoir temperature is not high enough to produce a vapor phase in the geothermal fluid. The fluid is pumped to the surface and flows through a heat exchanger that transfers the heat to a closed working fluid cycle. The working fluid used has usually a lower boiling point than the geothermal fluid (Intergovernmental Panel on Climate Change, 2014). The working fluid vapor form is used to run a turbine. The
working fluid then condenses and is used again for the next vaporization cycle (Tester, Drake, & Driscoll, 2012) (DiPippo, 2005).

Figure 6: World Cumulative Installed Capacity, 1950-2013 (Roney, 2014)

There is an ongoing discussion whether producing electricity from geothermal resources should be considered sustainable or not. The majority of scientists believe, that if the local resource is exploited at or below the reservoir’s recharge rate, sustainability can be achieved (Evans, Streszov, & Evans, 2009) (Hammons & Gunnarsson, 2008) (European Geothermal Congress, 2007) (Wright, 1998) (Rybach, 2003).

Worldwide, geothermal energy is still a rather small sector of the energy industry, although electricity generation from geothermal power plants is constantly rising. This development is displayed in Figure 6. Furthermore, new technologies ensure a positive outlook for the geothermal industry internationally.

1.7.4 Indirect Use Value Chain

A value chain is a set of activities that a firm performs to deliver valuable products or services to the market. Indirect use value chains are very similar to oil and gas mining value chains, as illustrated in PT. PLN’s value chain for operations in Malaysia in Figure 7.
1.7.5 Direct Geothermal Utilization Overview

Geothermal energy has many direct uses than indirect uses. Historically it has been used for bathing and washing purposes, but as technology continues to develop, more diversified applications are emerging and proving profitable in varied markets. As of 2012, 28 GWt of direct geothermal heating capacity is installed for district heating, space heating, hot spas, industrial processes, desalination and agricultural applications worldwide (Fridleifsson, Ruggero, Huenges, Lund, Ragnarsson, & Rybach, 2008). For a general overview of different uses, the work of Lindal in 1973 is illustrated in Appendix A.

1.7.5.1 Heating, Cooling and Air Conditioning

The first and foremost common application of direct use geothermal energy is district heating. The fluid is either pumped and directly distributed to the end-user or passed through a heat exchanger, which heats a secondary distribution loop. District heating loops in Iceland supply 80°C hot water to it’s end-users. The district heating utility in Reykjavik is one of the largest municipal geothermal district heating service in the world. It started on a small scale in 1930 but has expanded considerably and is now serving 61% of the total population of Iceland with hot water, ~193,000 people (Gunnlaugsson, 2008). Geothermal district heating systems exist throughout the world; including Eastern Europe, India, China, Japan, and New Zealand.

Geothermal steam can be used as the heat source for driving an absorption chiller cooling system. The absorption cycle is a process by which refrigerant effect is produced through the use of two fluids, condenser and chilled water, and steam heat ranging from 180-240°C. A typical configuration utilizes geothermal heat to boil the refrigerant from a lithium bromide solution in the generator. The vapor is condensed back to a liquid state, and then passed to the evaporator across tubes containing fluid to be chilled, or the chilled water inlet. By
maintaining very low pressure in the absorber-evaporator shell, the refrigerant boils at a low temperature, which causes the refrigerant to absorb the heat from the fluid to be cooled, thus lowering it’s temperature, which is then supplied to the end-user as chilled water. The evaporated refrigerant passes into the absorber section where it is mixed with Li Br/H2O solution with a very low water content, which absorbs the vapor from the evaporator section to form a weaker solution (Rafferty K. D., 2015). This process can vary in capacity, and could be utilized to provide chilled water for district cooling and/or cooling intensive facilities such as datacenters, laboratories, and cold storage.

1.7.5.2 Aquaculture Farming

For aquaculture applications, geothermal fluid is passed through a heat exchanger to heat a secondary loop. The secondary loop distributes specific temperature water to specific culture facilities, maximizing the production of the fish stock. In the Salton Sea and Imperial Valley area of southern California, the estimate of the geothermal installed capacity and annual energy use for 15 farms is 85 MWt and 50.1 million kWh/year, or about 66 W/yr/kg of fish. The 15 farms produce ~4.5 million kilograms of catfish, striped bass and tilapia per year. (Rafferty K., Aquaculture in the Imperial Valley - A Geothermal Success Story, 1999)

1.7.5.3 Greenhouse Farming

Greenhouse farming can use geothermal heat and gases in various configurations. Namely, geothermal fluid is either directly pumped to the greenhouse heating equipment, typically under-floor thermal convection piping, radiators or fan powered heating coils (Kiril Poposvki, 2001). CO2 extracted from non-condensable gases exhausted through geothermal electricity production can be introduced to the greenhouse ventilation system, maximizing the crop yield. Optimal grow conditions for specific crops determines the amount of heat and CO2 a greenhouse consumes; and is monitored and controlled through use of automated control valves and ventilation systems. In Hungary, approximately 420 acres (200 ha) of glass and plastic covered greenhouses are heated by geothermal energy. Additionally, 2,500 acres (1,000 ha) of temporarily covered plastic tents of “tunnels” are also utilizing geothermal heat (Ottlik, 1989). Vegetables are grown in about 25% of the greenhouses covered by glass and in 95% of those covered with plastic. The most prevalent vegetables grown are peppers, tomatoes and cucumbers. The remaining greenhouses are used for nursery stock, ornamental and cut flowers. Of the 9 x 1012 kJ/year used in horticulture for heating purposes, 72% (161 million TOE) is recovered from geothermal fluids (Karai, Kocsis, Liebe, Nagy, & Ottlik,
Including all energy use, geothermal fluids provide over 80% of the energy demand at vegetable farms. In Turkey, 565,000 m² of greenhouses consume 131 MWt of geothermal heat.

1.7.5.4 Balneology

Geothermal heat and precipitated minerals can be utilized as revitalizing resources for balneological applications. Spas use the heat for therapeutic exercises and precipitating minerals, such as silica, for treating skin diseases such as psoriasis (Sigurgeirsson & Olafsson, 2015). In Turkey, 195 spas consume 327MWt of geothermal energy (Mertoglu, Bakir, & Kaya, 2003). The Blue Lagoon in Iceland is a 5,000 m² surface pond that receives effluent brine from the nearby Svarsengi power plant at a rate of 42 l/s. The man-made lagoon contains about 6 million liters of brine, between 37-39°C and the hydraulic retention time is about 40 hours (Ragnarsson, 2015). The Blue Lagoon attracted ~700,000 tourists and visitors in 2014, which is over twice the population of the country. (MBL, 2014)

Public swimming pools utilize geothermal heat either directly, by filling the pools and hot pots with treated geothermal fluid, or indirectly through a heat exchanger and secondary loop configuration. The geothermal fluid must be between 20-45°C depending on whether the structure is indoor/outdoor, and the ambient climatic conditions of the area.

1.7.5.5 Agricultural Drying

Agricultural drying provides long-term storage without degradation, early harvesting, which reduces field losses, higher prices of agricultural products and better quality. Drying of agricultural products is performed with the consumption of heat an electricity driving auxiliary equipment. Basic energy requirements are connected to heating the product to suitable temperatures to initiate the process of evaporation. Geothermal heat is exchanged with a heating coil, which warms air to relatively low temperatures (35-80°C) that comes in direct contact with the product. In Gaoyang County, China, a wool drying plant utilizes 95°C geothermal water to dry 280kg/hr of wool on a conveyor belt drier. Another example in Guatemala; an agricultural drying plant dries grains, fruits and vegetables have a capacity of .5 MWt, annually consuming 12.094 TJ/yr at a .787 capacity factor. (Vasilevska, 2015)
1.7.5.6 **Industrial Drying**

As discussed in the agriculture drying section previously, there are many applications where geothermal heat can be used to dry specific materials, chemicals and products. There are three basic methods of convection drying; drying by reheating of the air, drying with recirculation of used air, and a combination of the two. Convective drying types include chamber, tunnel, conveyor, drum, and pneumatic dryers. Table 1 below identifies numerous industrial and agricultural drying products, and their respective operating conditions.

<table>
<thead>
<tr>
<th>Process</th>
<th>Heat Requirement W/Unit</th>
<th>% steam/hw</th>
<th>Temp °C</th>
<th>% of Heat Input&lt;96DegC</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rayon</td>
<td>13739</td>
<td>92/2</td>
<td>121/93</td>
<td>100</td>
<td>per lb. rayon produced</td>
</tr>
<tr>
<td>Acetate</td>
<td>10051</td>
<td>96/4</td>
<td>121/60</td>
<td>100</td>
<td>per lb. acetate produced</td>
</tr>
<tr>
<td>manmade fabric finish</td>
<td>3809</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb. product</td>
</tr>
<tr>
<td>polypropylene</td>
<td>2861</td>
<td>100</td>
<td>127</td>
<td>100</td>
<td>per lb. product</td>
</tr>
<tr>
<td>dipped latex</td>
<td>2216</td>
<td>100</td>
<td>110</td>
<td>100</td>
<td>per lb. latex product</td>
</tr>
<tr>
<td>molded latex</td>
<td>2216</td>
<td>100</td>
<td>116</td>
<td>100</td>
<td>per lb. latex product</td>
</tr>
<tr>
<td>acetylene</td>
<td>1749</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb. acetylene</td>
</tr>
<tr>
<td>acrylics</td>
<td>1484</td>
<td>0/100</td>
<td>82</td>
<td>100</td>
<td>per lb. ac fiber 30wet/70dry</td>
</tr>
<tr>
<td>paper finishing</td>
<td>1436</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb. paper produced</td>
</tr>
<tr>
<td>bldg. paper and board</td>
<td>1277</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb. building paper</td>
</tr>
<tr>
<td>bldg. paper/bard integrated</td>
<td>1235</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb. building paper</td>
</tr>
<tr>
<td>alk/chlorine-mercury</td>
<td>1172</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb. chlorine product</td>
</tr>
<tr>
<td>alk/chlorine-soda ash</td>
<td>1081</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb. NaCO3 product</td>
</tr>
<tr>
<td>SBR rubber</td>
<td>907</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb. product</td>
</tr>
<tr>
<td>wet corn milling</td>
<td>836</td>
<td>100</td>
<td>121/93</td>
<td>100</td>
<td>per lb. corn input</td>
</tr>
<tr>
<td>canned fruit</td>
<td>739</td>
<td>76/24</td>
<td>121/60</td>
<td>100</td>
<td>per can (24/case)</td>
</tr>
<tr>
<td>butyl rubber</td>
<td>733</td>
<td>46/54</td>
<td>121/82</td>
<td>100</td>
<td>per lb. rubber</td>
</tr>
<tr>
<td>saw mills</td>
<td>725</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb. lumber produced</td>
</tr>
<tr>
<td>polybutadiene</td>
<td>663</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb. polybutadiene</td>
</tr>
<tr>
<td>polyisoprene</td>
<td>660</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb. product</td>
</tr>
<tr>
<td>meat packing</td>
<td>640</td>
<td>88/12</td>
<td>121/60</td>
<td>100</td>
<td>per lb.</td>
</tr>
<tr>
<td>phosphoric acid</td>
<td>561</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb.</td>
</tr>
<tr>
<td>canned drinks</td>
<td>517</td>
<td>70/30</td>
<td>121/60</td>
<td>100</td>
<td>per can (24/case)</td>
</tr>
<tr>
<td>potash</td>
<td>322</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb. potash product</td>
</tr>
<tr>
<td>malt beverages</td>
<td>264</td>
<td>52/48</td>
<td>121/85</td>
<td>100</td>
<td>per lb. beverage produced</td>
</tr>
<tr>
<td>photographic film</td>
<td>257</td>
<td>62/38</td>
<td>121/82</td>
<td>100</td>
<td>per lb. film product</td>
</tr>
<tr>
<td>pharmaceutal preps</td>
<td>171</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per $ of sales</td>
</tr>
<tr>
<td>fluid milk</td>
<td>163</td>
<td>100</td>
<td>121</td>
<td>100</td>
<td>per lb.</td>
</tr>
<tr>
<td>cakes/pies</td>
<td>155</td>
<td>89/11</td>
<td>121/82</td>
<td>100</td>
<td>per lb. product</td>
</tr>
</tbody>
</table>
1.7.5.7 Food Processing

Geothermal heat can be utilized in food processing industries beyond aquaculture, agriculture production and drying. Configuration of specialized equipment operating under optimal conditions can be used in the following direct use applications and their respective operating temperatures:

- Fermentation 40°C
- Soft-Drink Carbonation 40-70°C
- Beet sugar extraction 45-90°C
- Pickling 40-100°C
- Canning 50-140°C
- Blanching and cooking 70-100°C
- Milk Pasteurization 70°C
- Whey Condensing 70-90°C
- Drying fish stock 90-95°C

1.7.5.8 Mining and Mineral refinement

The direct-use of geothermal heat to mine metals, non-metallics or minerals must be of high-grade to generate a profit. Geothermal reservoirs that have high-temperature ranges usually also have higher concentrations of metals (gold, copper and silver) due to the large geothermal gradient that mixes with the deep geothermal fluids. Some mining operations use geothermal heat a process called enhanced heap-leaching to recover low-grade metal ores. In order to do this it is necessarily to use a leachate solution on the piles (or heaps hence heap leaching) where the ore is stacked on nonporous pads where it will be collected and taken to a
refinery for more purification. This process is very common in the Western region of the US. After mines are past their operational phase many mines are abandoned. These mines too can be a valuable source, this time through the process of heat mining. Heat mining can be used for district heating and cooling purposes. Direct-use of geothermal waste heat is a great fit for remote areas with extractable metals with access to a geothermal reservoir. (Bakane, 2013)

1.7.5.9 Miscellaneous Applications

As technology continues to advance, and industrial processes become more prone to utilize renewable energy, numerous direct use applications emerge. The following list identifies some of the more miscellaneous applications of using geothermal heat.

- Leather Tanning 35-60°C
- De-Icing 20-50°C
- Biogas 35-40°C
- Animal Husbandry 40-70°C
- Synthetic Rubber 45-90°C
- Concrete block curing 65-75°C
- Lumber Drying 95-120°C
- Distilling Liquor 100-150°C
- Multi-effect evaporation/concentration of saline solution 120°C
- Pharmaceutical Autoclaving 120°C
- Fresh Water Distillation 130°C
- Ethanol and biofuel process 140-170°C

1.7.6 Direct Use Value Chain

As shown in Figure 7, indirect use value chains are quite common, as they highly resemble traditional oil and gas development value chains. To my knowledge, a Direct Use value chain has yet to be identified, or publicly available. Appendix B – Direct Use Value Chain illustrates a value chain the author developed new to the industry, combining indirect use processes with direct use application conditions. Value chains should include a feedback loop, to ensure iterative communication and review, this is represented by the “Zero-Waste Consultation” segment of the chain.
2 Fundamental Ideology

A detailed guide to development, operation and ownership of an Energy Resource Park (ERP) didn’t exist prior to writing this paper. An ERP is a vastly complex and a long-term project that includes many unique conditions and variables that traditional energy development projects do not address. When thinking of the type of organization an ERP is, consider it much like a commercially operated State without borders; built upon a sustainable core value infrastructure and reliant on success in competitive markets to maintain operation. This section merges the disciplines of project management and finance with fundamental governance theories and ideologies. Therefore, this section is highly theoretical but practical in execution as the core applications and processes included in ERP development and organization are industry tested and proven successful.

![Iterative Ideological Approach](image)

Figure 8: Energy Resource Park Core Value Infrastructure

2.1 Core Value Infrastructure

The idea of the ERP bears strong resemblance to the concept “Symbiosis”, where companies and organizations cooperate with the goal to minimize waste. Such symbiosis can be developed into an “Eco-Industrial Park” or, an Energy Resource Park; a commonality of manufacturing and service companies that are located near each other and seek increased success in the fields of environmental, economic and sociological factors.
The Energy Resource Park ideology is built upon fundamental core values:

1) **Sustainable Economy**: Societal and economic production and consumption practices that do not deplete or destroy natural resources. Companies and communities collaborate to achieve balance between viable economic operation and environmental conservation. The Energy Resource Park’s sustainable practices promote high quality of life, and its vision is intended for generations and centuries to come. The beauty of nature is a resource itself.

2) **Security**: Economic cooperation between companies and communities increases through consumption and production of goods and services through commonly defined values and goals. The ERP’s shared economic perspective ensures sustainable business development locally, yet competitive in the global market. Encouraged inter-industry resource exchanges creatively repurpose waste from one process into energy for another. Security is provided through cooperative economies and energy independence: the ERP’s primary energy source is sustainably generated locally.

3) **Diversity**: Incorporation of independent economic, societal and environmental actors under a unified mission towards common prosperity. From collaboration of symbiotic industries such as greenhouse agriculture and food processing, to ensuring biodiversity in surrounding natural environments, inspiration and innovation through diversity is essential to the Energy Resource Park.

4) **Community**: Interdisciplinary cooperation transcends each sector of the Energy Resource Park through education institutions and community involvement, and by connecting technical and social cultures. Direct involvement between an ERP and local government, organizations and municipalities encourages local and regional economic and environmental priority alignment.

5) **Zero Waste**: Collaboration towards efficient production and consumption, turning one process’s waste into fuel for another. A cascading network of waste energy transfer interconnects previously independent industrial processes, promoting shared economic gains and environmental stewardship. Continuous evaluation of how resources are utilized promotes innovation and exploration of creative and economic relationships. Waste is a valuable resource when managed properly.

The identification and reinforcement of the Energy Resource Park’s core values is integral to successful development, operation and expansion of the park. As discussed later in Section 3, the core values will be reviewed and applied to major decisions made in the ERP. The reflection of the core values ensures longevity of the concept’s purpose and intent. The time scale of the energy resource park exceeds typical project life cycles; as this concept is intend to be executed for many generations to come. At each junction, albeit review and development of a new resource park or a century later when considering a new cluster addition, the core values shall be applied to the decision at hand. Once the proposed action is
checked against the core values, it can proceed towards implementation. It is important to recognize the environments of decisions to make in the future will encounter new challenges and perspectives. In the event the core values require adjustment to meet the modern scenario, an amendment shall be proposed. In the event several ERPs operating across various geographic locations, the proposed amendment shall be circulated amongst global ERP network for review.

2.2 Value Propositions

2.2.1 Environmental

Each actor has an environmental impact manager. Each manager is represented at sector and ERP wide reviews and meetings. The individual actor is responsible for maintaining impact projections and will amend internal policy and operations to adhere to the stipulated Environmental Management System requirements. Figure 9 identifies potential ERP activities and their associated output as related to the ERP environmental value proposition.

![Figure 9: ERP Environmental Value Proposition](image-url)
Policy Framework:

1) The ERP recognizes that every operation results in an environmental impact. In an effort to keep impact to a minimum, all measurable environmental impacts will be monitored and recorded. An annual review will compare the baseline, projected and actual environmental impacts.

2) The ERP ensures that all environmental legal requirements are being met and set stricter standards when appropriate.

3) The ERP promotes environmental awareness among the employees and residents of the ERP and appreciation for the importance of environmental issues by regular training and education.

4) The ERP emphasizes environmentally friendly practices by, among other things, reusing and recycling items associated with our activity as much as feasible but otherwise dispose of those items as appropriate.

5) The ERP should consider the guidelines of the European Union Sustainable Development Strategy (SDS) and ISO 14000 family of environmental standards and continually seek to improve the effectiveness of the ERP environmental management system.

   i) 14001 EMS
   ii) 14004 additional guidance
   iii) 14006 eco-design
   iv) 14031 environmental performance
   v) 14040 LCA
   vi) 14063 environmental communication
   vii) 14051 MFCA
   viii) 14064 GHG accounting and verification
   ix) 14096 carbon footprint
   x) 19011 auditing EMS

This policy framework aims to promote sustainable development that will assure a healthy and sound environment for present and future generations. To achieve this, the code shall be applied so that:

- Human health and the environment are protected against damage and detriment, whether caused by pollutants or other impacts
- Valuable natural and cultural environments are protected and preserved
- Biological diversity is preserved
- The use of land, water and the physical environment in general is managed well in the long term in regards to ecological, social, cultural and economic values
• Reuse and recycling, as well as other management of materials, raw materials and energy, are encouraged so that natural cycles are established and maintained.

2.2.2 Societal
The design of the ERP is intended to yield numerous benefits on a societal level. The Core Value Infrastructure (CVI) foundation is built to support a high standard of living through diverse and sustainable inter-industrial cooperation as well as collaboration with educational institutions and surrounding municipalities. This section will focus on the more “tangible” societal benefits the ERP strives to achieve. The following diagram identifies potential ERP activities and their associated output as related to the ERP societal value proposition.

Figure 10: ERP Societal Value Proposition

2.2.2.1 Education
The ERP integrates various types of education to its design and function. The ERP exports the CVI via educational tourism as well as through educational institutions. The road to sustainability is dynamic, testing theory through application results in costly trials and errors. The ERP intends to share best practices and lessons learned to aid the global movement
towards a sustainable future. The ERP actively incorporates the following educational areas to its operation and service offerings.

2.2.2.1 Tourism – each ERP is to incorporate an eco-tourism cluster or sector, providing accommodation and attractions to demonstrate the CVI within the ERP. Accommodation represents the highest standard in sustainable design and function, and fosters independent interaction with its guests through informational and explanatory signage and kiosks. Tours of ERP operations will reveal what happens behind the scenes and how the ERP concept was developed, implemented and operated.

2.2.2.2 University/Technical Institution – Local and regional universities and technical institutes will be engaged early in the design and development of an ERP. An ERP will collaborate with the universities on research projects to benefit both parties. Such projects include but aren’t limited to expansion decisions and engineering, process/sequence improvement, social and environmental policy, and financial and economic modeling. These projects will alleviate the workload from the Operational Board to the ERP’s benefit, and provide project and thesis based research topics to universities. Additionally, the ERP will offer space for remote classroom instruction and work-study programs that would engage technical, mechanical, and/or electrical focused students with hands-on industry experience. The university students will also have the opportunity to apply for ERP or associated company internships. Actual industry experience for students is imperative for the professional maturation of the student’s skill set and ability to utilize it.

2.2.2.3 Grade School – Informing tomorrow’s generation on sustainable practices is of high importance to the ERP. Field trips, remote classes, and tours will held on a routine basis, and will transcend all grade levels.

2.2.2.4 Community - Community education outreach exists to serve the local populous that is not employed by the ERP, nor is a student available to take advantage previously mentioned contact and interactivity. Community education includes brief seminars explaining the ERP concept, function and future, DIY residential energy efficiency programs, and informational tours.

2.2.2.5 Commercial – Companies both domestic and abroad have the opportunity to enroll in various seminars offered by the ERP. These seminars are turnkey courses instructed on-site, ranging from sustainable engineering practices and technologies to Creating Shared Value or CSR policies and financial exercises. Companies will benefit from the comprehensive of material, as well as the option to witness the material executed in real-time at the ERP.
2.2.2.2 Corporate Social Responsibility and ISO 26000:2010

The ERP endorses and practices Corporate Social Responsibility (CSR) throughout the park, and shares its values with surrounding municipalities. The following outline the key principals and core subjects exercised by the ERP through adherence to ISO 26000.

The Seven Key Principles, advocated as the roots of socially responsible behavior, are:

- Accountability
- Transparency
- Ethical behavior
- Respect for stakeholder interests (stakeholders are individuals or groups who are affected by, or have the ability to impact, the organization's actions)
- Respect for the rule of law
- Respect for international norms of behavior
- Respect for human rights

The Seven Core Subjects are:

- Organizational governance
- Human rights
- Labor practices
- Environment
- Fair operating practices
- Consumer issues
- Community involvement and development

2.2.3 Economic

The ERP’s impact on local, regional and global economies can be positive if the concept is executed properly and maintains close connection to the core value infrastructure. While there is proven economic viability from a business perspective as demonstrated at the Suðurnes Resource Park, this section will primarily discuss the economic impacts on employment opportunities, and their subsequent effects.

2.2.3.1 Employment

It is important to recognize: a successful ERP can employ much more people than a stand-alone geothermal power plant. Table 2 tallies published Suðurnes Resource Park employment indices. HS Veitur and HS Orka are power plant and distribution companies, which include teams dedicated to operating the resource park. The three non-power plant companies have increased the employment opportunities for the Suðurnes region by ~250%. Although there are no other operating resource parks, employment estimates of specific direct use...
Applications can be obtained. This allows the ERP Core Development Team to estimate employment opportunities and associated impact given selected applications. For example, a typical greenhouse (5200 m²) operates with 8 full-time 19 part-time employees (Thomas & Hall, 2010).

Consider a hypothetical agriculture focused ERP based upon Thomas & Hall’s estimates (Thomas & Hall, 2010). The ERP intends to install industrial scale greenhouses (20km²), fish farms, and milk pasteurization in a cascaded fashion from a proven geothermal resource. The greenhouses alone would employ ~30 full-time and 80 part-time employees, and eliminates any regional distribution costs of fresh produce to the employed population and surrounding communities. ERP configurations are endless, and will greatly impact a developing country’s economic performance at both the household level as well as the country’s gross domestic output.

![Figure 11: ERP Economic Value Proposition](image_url)
Table 2: Suðurnes Resource Park Employment Index (HS Orka, 2014)

<table>
<thead>
<tr>
<th>Company</th>
<th># Of Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS Veitur</td>
<td>90</td>
</tr>
<tr>
<td>HS Orka</td>
<td>60</td>
</tr>
<tr>
<td>Blue Lagoon</td>
<td>300</td>
</tr>
<tr>
<td>Stolt Sea Farm</td>
<td>70</td>
</tr>
<tr>
<td>Carbon Recycling International</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>532</strong></td>
</tr>
</tbody>
</table>

2.3 Actors

The ERP organizational structure is sector oriented, ensuring equal representation of each member amongst the variety of operations. The sectors are divided up by function, grouping related industries and companies together. Energy Resource Park involves the following specific “Actor” classes:

2.3.1 ERP Owner

The ERP Owner can take on various forms and organizations and will be discussed in Section 3. A Limited Liability Partnership is composed of investors and general partners who fund and steer the ERP can own an ERP. An ERP can also be solely owned by the power company that owns and operates the power plant, or by the government of which the ERP is located. Regardless of ownership strategy, the ERP owners align investors and assemble the Operation Board, which is quintessential to initiating the development of an ERP.

2.3.2 ERP LLC

The ERP LLC is the executing arm of the ERP Owner. The LLC is comprised of five employees, The ERP Developer Lead, Engineer, Economist, Facilitator, and Environmental Auditor, the only direct employees of the ERP. The ERP LLC responsible for executing the Owner’s ERP objectives, and reports directly to the ERP Owner. The ERP LLC employees are also on the Operation Board.

2.3.3 Operation Board

The Operation Board is a team of professionals appointed by the Owner. The Operational Board is composed of an ERP Management Team as well as additional board members including key actor representatives such as Generator Operator, Transmission and Distribution Managers, Industry Managers, and Municipality Representatives.
2.3.4 Geothermal Power Company
The Geothermal Power Company (GPC) provides heat and power is the primary energy for the ERP. The generator sector also includes the transmission operator. The ERP concept was conceived with geothermal energy bi-products in mind, but also includes other forms of renewable energy generation and integration into the ERP design and operation.

2.3.5 ERP Companies
Independently owned companies are the primary consumers and producers of resources within the ERP. These companies are organized into sectors based upon the type of operation, consumption and production practices. These industrial corporations adhere to a business practice standards through demonstrated environmental conservation and code of conduct. Employing the local population, these companies endorse ERP’s core value infrastructure and quality of life.

2.3.6 Sector Managers
Economic sectors are grouped by operation, consumption and production of specific industries and functions (i.e. aquaculture, industrial drying, biotechnology are different types of cluster sectors within an ERP). Sector managers are elected from within their specific sector to oversee and ensure equal economic participation and competition amongst sector members. Sector managers aim to continually expand and integrate other companies, and actively seek additional utilization of energy, waste and products produced within their sector and the greater ERP.

2.3.7 Municipalities
Local and state level government representatives are engaged through policy lobbying, writing and regulation. Municipality integration ensures alignment and understanding between local government and ERP objectives, as well as operation of the ERP and integrated public facilities. The ERP municipality actor includes incorporation and communication with existing local governmental, economic and societal organizations and functions, providing an economic umbrella over the geographic region. Innovative initiatives towards sustainable expansion of employable workforce and economies are strongly supported by the ERP.

2.3.8 Educational Institutions
Educational institutions ranging from university to elementary levels will utilize the ERP as an extension of the classroom, allowing for hands on interactivity with sustainable
technology and processes. Higher education institutes and laboratories will continuously execute research and development projects for ERP.

2.3.9 Communal and Residential Sectors

The ERP aspires to achieve for economic, environmental, and societal sustainability and prosperity; therefore associated employees and their family’s quality of life and accessibility to nature is quintessential to the livelihood of the ERP. Albeit the consumption and production of energy is industrial by nature; an ERP’s design and daily function aims to continue to inspire future generations, from tourists to residents, to incorporate nature’s beauty as a resource, receives equal importance throughout development and operation of the ERP.
3 Ownership, Development and Operation

3.1 Ownership Strategies

A group of developers and investors collaborate to build an Energy Resource Park. This collaboration of developers and investors become the “Owner” and will be referred to as such throughout this thesis. The group of committed core investors could include but is not limited to private investors, energy companies, development organizations/funds or local governments. The Owner appoints the Operational Board who design, develop and implement projects throughout the ERP.

The Owner receives revenues from selling metered retail energy supply, inter-ERP electrical and waste energy (heat, minerals, gases, etc.) and property/land lease revenues depending on the ownership strategy. Independent companies develop, construct, finance and own their respective sites and systems. They pay the Owner for services and energy, as well as rent for lease of site property. The independent company must consume services and energy provided by the Owner within predetermined ranges. Such ranges ensure proper demand forecasting and production rates required by the power plant.

Several ERP ownership strategies will be discussed in this paper. The infrastructure supporting legal frameworks of such projects will vary from country to country; therefore three potential ownership strategies are discussed in this chapter. It is important to clarify that regardless of the ownership structure, an ERP Management Team and Operational Board will be assembled and manage the ERP’s ongoing operation. It is also important to mention that Owner plays a key role in developing the Conditions of Satisfaction and project financing through formulation of a collective investment vehicle, or ERP Fund, regardless of ownership strategy.

3.1.1 ERP Fund, LLP

3.1.1.1 Fund Structure

An LLP Fund is composed of a two-tier structure, where the first tier is composed of a GP LLC (General Partner) and Investors (Limited Partner), who formulate the ERP Fund, LLP (Limited Partnership). The ERP Fund LLP enters an EPC with a Geothermal Power...
Company and begins the preliminary resource assessment. The ERP Fund LLP then registers the ERP LLC and appoints its employees.

![Diagram](image)

**Figure 12: EPC LLP Fund Structure based upon (Barufaldi, 2015)**

The general/limited partnership model is a common structure amongst pools of investment funds that make up a hedge fund. In this structure the general partner assumes responsibility of operating the fund, while limited partners can make investments into the partnership and are only liable for their paid-in amounts. (Barufaldi, 2015) Typically each ERP Fund LLP will be composed of the following personnel and parties:

- A GP fund manager who manages the investment decisions, trading, reconciliations, valuation and unit pricing.
- A board of directors or trustees who safeguards the assets and ensures compliance with laws, regulations, and rules.
- The LP stakeholders who own (or have rights to) the assets and associated income.

The second component of the two-tiered structure is the general partnership. The proposed ERP structure for this partnership is a limited liability partnership (LLP). An LLC is created as the LLP’s executing arm, and is a flow-through tax entity where investors are limited in liability to the amount of their investment. The general partner’s responsibility is to market and manage fund, and relay decisions to the ERP LLC Management Team and Operation Board through routine meetings and communication.

An engineer, procure and construct (EPC) contract is signed with a Geothermal Power Company, a group of investors, developers and power plant operators seeking to develop the resource. The EPC will include specific clauses that allocate minimum amounts of waste from the power plant (i.e. waste heat, gas, water and minerals) to the ERP LLC subsidiary companies in exchange for percentage ownership. Figure 13 illustrates the Geothermal Power Company owning 5-10% of the ERP LLC in exchange for delivery and service of power plant waste to ERP companies. In addition to the GPC ownership benefits, the GPC will also collect interconnection and commodity payments from the ERP subsidiary companies.
Once the resource is proven, the ERP LLC will commence developing companies for to satisfy ERP LLP Conditions of Satisfaction, optimal revenues, and promote sustainable development. A preliminary geothermal resource assessment will estimate reservoir performance and power plant output, including waste heat, gas, water, and minerals. Once the LLC receives the preliminary assessment results, an ERP business case is developed which identifies potential value streams for ERP companies. The sequence of developing ERP ownership is discussed later in this Section.

Figure 13: ERP LLP Fund Shared Equity Structure

Figure 14 below identifies an alternative arrangement of the ERP LLP structure. This structure removes equity investment of the GPC to the ERP LLC, and replaces it with retail energy sales from the GPC to the ERP LLC turnkey companies.

3.1.1.2 Investments

The ERP Fund LLP will primarily fund the development and construction of the ERP LLC, independent companies and industries to be integrated to the ERP and a portion to the
geothermal power plant. The amount invested in the geothermal power plant will be determined between the ERP Fund LLP and the GPC; Figure 13 proposes 1-10%. To incentivize independent companies to join the ERP, the ERP Fund should invest debt and equity into independent company development, construction and interconnection. The level of investment will vary between the ERP LLP and each company, and will be dependent upon the independent company’s willingness to bear debt. ERP Fund investment in independent companies of 10-50% will attract potential ERP members and create shared value, a core objective of the ERP.

3.1.1.3 Debt

The level of debt senior lenders will provide is relative to the level of equity that greatly impacts the project gearing, and will be determined by the variability of the ERP’s cash flow. The greater the degree of riskiness in cash flow, the greater the cushion lenders will need in the forecast of available cash flow beyond what will be needed for debt service. This is necessary to reassure LPs that the debt can be repaid even in a bad-case scenario. LPs will specify their requirement in terms of forward-looking “annual debt service cover ratio”

Figure 14: ERP LLP Fund Retail Energy Structure

| ERP LLP: General and Limited Partners, Investors and Banks. Owns 90-65% of the ERP LLC and 1-10% of the Geothermal Power Company. |
| ERP LLC: ERP Management Team and Operation Board. ERP LLC develops ERP turn-key companies and sells 50-90% of each company to investors and/or external companies |
| Geothermal Power Company: Investors, Developers, and Operators. Owns 90-99% of the geothermal power plant and 100% of the resource assessment costs. |
| Carbon Recycling | Data Center |
| Hotel / Spa | Agriculture |
| Food Processing | Industrial Drying |
| Cosmetics | Biotechnology |
| Aquaculture | Bio Tech |

Turn-key Companies

100% Geothermal Resource Assessment

90-99% Geothermal Power Plant

10-95% EPC Contract

1-10% ERP Fund investment in independent companies of 10-50% will attract potential ERP members and create shared value, a core objective of the ERP.

Figure 14: ERP LLP Fund Retail Energy Structure

3.1.1.3 Debt

The level of debt senior lenders will provide is relative to the level of equity that greatly impacts the project gearing, and will be determined by the variability of the ERP’s cash flow. The greater the degree of riskiness in cash flow, the greater the cushion lenders will need in the forecast of available cash flow beyond what will be needed for debt service. This is necessary to reassure LPs that the debt can be repaid even in a bad-case scenario. LPs will specify their requirement in terms of forward-looking “annual debt service cover ratio”
(ADSCR) above a specified minimum level. The value of the ADSCR will depend in large part on project risk, and therefore variability of cash flows. (Barufaldi, 2015) The following debt classes are reviewed below

3.1.1.3.1 Senior Debt – top-tier funders or capital market investors, also known as senior debt, typically form the largest but not the sole source of the ERP Fund. Seniors lenders enjoy priority in terms of repayment over all other forms of finance.

3.1.1.3.2 Mezzanine Debt – ranks between senior debt and pure equity. Mezzanine debt is subordinated in terms of repayment to senior debt but ranks above equity both for distributions of free cash (priority of each cash inflow and outflow of a project) and in the event of liquidation of the LLP. Since mezzanine debt’s repayment can be affected by poor performance of the LLP, and senior debt takes priority, mezzanine debt typically commands higher returns than senior debt.

3.1.1.3.3 Junior Debt – shareholder or supplementary loans to senior debt from minor investors.

3.1.1.3.4 Grant Funding – Public funds and/or grants can contribute to the ERP Fund and will be managed as an LP

3.1.1.4 Equity

Equity is usually provided by the project sponsors but may also be provided by the contractors who will build and operate the project as well as by financial institutions. A large part of the equity (often referred to as “quasi-equity”) may actually be in the form of shareholder-subordinated debt, for tax and accounting benefits. Since equity holders bear primary risks under an ERP project, they will seek a higher return on the funding they provide. (EPEC, 2015)

3.1.1.5 Fee Structure

There are several fee structures associated with the ownership of the ERP; they include payments and fees within the LLP as well as between the ERP LLP, ERP LLC companies and the Geothermal Power Company. The following fees are examples shown in Figure 13.

3.1.1.5.1 Inter-ERP LLP Fund - The investors typically pay the cost of managing the fee to the general partner. Management and administration of the fund requires expertise and time. A typical management fee is ~2% of the assets managed. An incentive fee for the GP manager can range between 10-20% fund profits may also be included in the fund cash-flow structure. The idea of the incentive fee is to reward the fund manager for good
performance, and if the fund's performance is attractive enough, investors are willing to pay this fee.

3.1.1.5.2 ERP LLP and Geothermal Power Company - The ERP LLP acquires 1-10% ownership of the GPC through debt or equity investment. This aligns financial goals between the throughout the lifetime of the ERP and the power plant. Additionally, In exchange for minimum commodity inputs required by ERP companies, the ERP LLP will sell 5-10% of its ownership of the LLC to the GPC. This will ensure the Geothermal Power Company’s interest in the ERP LLC and subsidiary company’s success, and further incentivize prompt delivery of minimum delivery of required commodities (i.e. heat, gas, water, minerals).

3.1.1.5.3 ERP Companies and Geothermal Power Company - The ERP companies pay several fees to the GPC; which includes an initial interconnection fee and commodity delivery. The amount and frequency of these payments are stipulated in independent contracts between each ERP Company and the GPC. The interconnection fee is the first payment to the geothermal power plant, which is fully responsible for installing necessary equipment to interconnect the company. The following payments are based upon lease of land for the company and how much the company consumes and produces.

3.1.1.5.4 ERP LLP and ERP Companies – Rent and tax will be paid from the ERP companies to the ERP LLP.

3.1.1.6 Term Structure

The following terms are determined by the fund manager, and detailed within the legal contract framework established between the LP and the GP. (Barufaldi, 2015)

3.1.1.6.1 Subscriptions and Redemptions – An investor applies to join a limited partnership through a subscription agreement. The terms of this agreement are defined by the GP, and evaluate the investor’s suitability for investment in the partnership. Redemption occurs in a fixed income security at par or at a premium price, upon maturity or cancellation by the issuer. Redemptions occur at the choice of the investor, however limitations by the issuer may exist such as minimum holding periods. Some funds can have subscriptions and redemptions monthly, while others are quarterly. Subscription and redemption frequency is directly related to the liquidity of the fund. Given the long-term scope of the ERP, subscriptions and redemptions will occur over longer periods, such as every six months to a year or two.

3.1.1.6.2 Lock-Ups – To secure long-term partners, a two year “hard lock-up” commitment is proposed for LP investment in the ERP Fund. A “soft lock” could be introduced, and the penalty for early exit could range from 2-10%.
3.1.2 Geothermal Power Company Ownership

A Geothermal Power Company (GPC) owned ERP currently exists in Suðurnes, Iceland. HS Orka is an energy-retail company providing electrical and thermal energy to the Reykjanes Peninsula and South Iceland. In this configuration, a GPC is the sole proprietor of the ERP, investing equity and debt into the power plant, as well as the ERP’s independent companies. Figure 15 illustrates a structure where the energy company develops and owns ERP LLC.

![Figure 15: Geothermal Power Company Owned Structure](image)

Figure 16 below illustrates an alternative ERP development structure, where the GPC, and potential existing seed-in funding programs establish a start-up fund. The start-up fund is open to new companies, as well as existing companies willing to engage in the ERP start-up fund program. The start-up fund will provide entrepreneurs initial funding to develop turnkey companies for the ERP. Once selected for further development, additional funding may be allocated depending on the COS of the GPC.
3.1.3 Government Ownership

The structure and operation of a government owned ERP is similar to ERP Fund LLP, where the government or state authority occupies the GP role, and has the ability to allocate funding directly, as well as seek external investment through LP agreements. This strategy most likely will be organized as a public-private partnership (PPP) where a government service or private business venture is funded and operated through a partnership of government and one or more private companies.
3.2 Development Strategy - Adaptive Project Framework

The five phases outlined in this chapter follow the Adaptive Project Framework (APF) (Wysocki, 2007) and the PMBOK Process Groups (PMI, 2006). Given the complex nature of developing an ERP, the strategy outlined in this chapter is not revolutionary, rather simple and intuitive, in an attempt to streamline the process. The initiate and scope phases occur once, when launching an ERP; whereas the Plan, Build, Review phases are repeated as a cycle throughout the lifetime of the ERP. The intent of a continuous cycle is to proactively seek feedback for improvements and future developments. Energy and industrial markets fluctuate at varying rates and frequencies. Although the ERP provides its members with energy security, long-term global market cycles are unforeseen. There are two types of APF cycles, which depend on the point in time the ERP is currently in. A Development cycle starts an ERP, or considerable expansion thereof; and Operational Cycles are routine projects maintaining and improving current systems. Operational Cycles utilize the Scrum framework for completing cycle sub-objectives, as discussed in Organization and Operation. The CVI
lays the foundation for on-going adaptation and is reviewed throughout the cyclical execution of the APF as illustrated in the Figure 18.

![Figure 18: Adaptive Project Framework - development strategy phases simplified adopted from (Wysocki, 2007)](image)

The following five phases (Initiate, Scope, Design, Build and Review) are guidelines on to a practical approach for successfully developing, and operating an ERP.

### 3.2.1 Initiate

The Initiate phase is the first of five to starting an ERP in accordance with the Adaptive Project Framework approach. Subsequent APF cycles that continue to develop and expand the ERP will skip the Initiate phase.

![Figure 19: Initiate phase flow diagram based upon (Barufaldi, 2015)](image)

The ERP LLP enters and EPC Contract with a Geothermal Power Company (GPC), an LLC composed of developers, investors and power plant operators. The GPC performs a preliminary geothermal resource assessment. The assessment results allow the ERP LLC to develop a business case for the power plant and ERP companies. Performing the preliminary
Strategies, Structures and Processes for Owning and Operating an Energy Resource Park
Shaun Tudor – MSc Thesis – Iceland School of Energy, Reykjavik University 2015

assessment and business case is expected to take 6-12 months. The preliminary assessment can be completed before assembly of the ERP LLC as commonly seen in brownfield developments.

3.2.1.1 Committed Core Investors Assembly

A group of developers and investors collaborate to build an Energy Resource Park. This collaboration of developers and investors become the “Owner”. The group of committed core investors could include but is not limited to private investors, energy companies, development organizations/funds or local governments. The arrangement of the committed core investors determines the ownership of the ERP as discussed in Ownership Strategies. Regardless of the ownership, the committed core investors are the driving force behind ERP and are responsible for initiating the ERP.

3.2.1.2 Register ERP Fund LLP, LLC entity and legal accounts

The ERP Fund LLP is a vehicle for core investors to buy into developing and operating the ERP. An ERP LLC is a subsidiary entity to the LLP, acting as an executive arm handling contracts and transactions between the LLP and ERP contractors, industrial companies, and any other accounts payable/receivable. An LLC or similar registered organization must be registered between the Owner and the state where the ERP is located. This agreement determines ownership rights and ensures proper development and construction of the park within state regulations and requirements.

3.2.1.3 EPC Contract

A turnkey engineering, procurement and construction contract is signed between the ERP LLP and a prospective Geothermal Power Company. The GPC will perform all associated geothermal and power plant associated functions throughout the lifetime of the ERP. The GPC will perform preliminary and final geothermal resource assessments, as well as own a majority of the power plant costs.

3.2.1.4 Resource Identification, Concession and MOU

An economically and environmentally viable geothermal energy source has been identified. The Owner signs a concession agreement with governing officials to proceed with design of a geothermal power plant and an ERP. A detailed MOU between the Owner and governing officials will follow registration of the ERP LLC entity, and will include the time duration of the concession, typically 30-40 years with the option to renew.
3.2.1.5 Supplementary investors

In the event additional investment is required, the Owner and initial Operation Board will solicit additional sources of investment, including but not limited to private investors, development funds/grants, energy companies, prospective ERP cluster companies, and local governments. The opportunity for additional investors to acquire senior, mezzanine or junior debt may be integrated through additional contract arrangements.

3.2.1.6 Operation Board Assembly

The Operation Board Assembly begins with the Owner formulating and appointing the ERP Management Team. The team is composed of a development manager, facilitator, engineer, environmental auditor and economist; whom remains active and involved in all on-goings of the ERP from the Initiate phase to continuous operation. Once the ERP Management Team is selected, the remaining members of the Operational Board are carefully selected and integrated to complete the Operational Board. The following ERP team member’s role and responsibilities are articulated below:

3.2.1.6.1 ERP Development Manager – ERP Lead

The ERP Development Manager (DM) serves as the team Operation Board lead officer and occupies a variety of responsibilities. The DM is an energy industry experienced project manager capable of managing ERP Management team as well as commercial, educational, R&D and municipality expectations. The DM must be a superb planner; skilled administrator; sensitive and understanding yet firm and driven; gifted engineer; master of communication; unshakeable optimism; and a miser. A long interdisciplinary track record of mechanical, electrical and heat transfer power plant projects is a must. The DM oversees and manages long-term APF cycle goals and objectives. The DM is the primary manager of the Owner’s expectations and demands, which are directly communicated to the ERP team and directed to the facilitator for proper distribution.

3.2.1.6.2 ERP Facilitator

The Facilitator manages and distributes all forms of communication within the Operation Board. A clear and transparent record of communication, agreements, ideas, and expectations is imperative to the success of the ERP and its cycle direction. The Facilitator solicits and distributes information from the Owner to the Operation Board, and from the board to the greater resource park personnel as necessary.
3.2.1.6.3 ERP Engineer

The Engineer is a certified and licensed professional by local, regional and international standards and qualifications. All major developments within the park are either designed or approved by the Engineer. The Engineer designs and assembles all APF cycle engineering documentation. Most of the design and engineering of ERP developments will be completed by the development team, or other subcontractors, but must be reviewed and approved by the Engineer. The Energy Flow Model is designed, calibrated, measured and maintained by the Engineer. The Engineer manages the ERP Process Flow, General Arrangement and One-line diagrams and documents. The Engineer provides oversight and council to sector, generator, transmission, distribution, educational, and municipal actors with regards to ERP projects.

3.2.1.6.4 ERP Economist

The Economist manages all financial activity within the park, not for financial record, but for economical consideration and modeling. Each activity and project is processed and input into an economic model, which the Economist is responsible for designing, calibrating, and maintaining. As APF cycles are completed, the opportunities for further development are input into scenario models, for review of projected economic viability.

3.2.1.6.5 ERP Environmental Auditor

The Environmental Auditor (EA) manages the ERP cycles from an environmental perspective, continuously working with the Engineer and the Economist to minimize negative impact, and produce positive impact. The EA ensures the ERP’s compliance with EU SDS and ISO 14000 standards. The Environmental Model is designed, calibrated, measured and maintained by the EA. The EA also works closely with educational and municipal actors to promote environmental stewardship.

The Operation Board also includes members of private, commercial, educational and municipal backgrounds. The more committed operational board members that are identified in the Initiate phase, the clearer the ERP market approach becomes. Each board member contract includes clear guidelines and expectations of each member and respective organization requirements. A continuous and open channel of communication must be present to ensure transparency and trust between of each member of the Operational Board. Additional members outside the ERP Management Team typically include the following profiles:
3.2.1.6.6 Generator Operator

The generator operator (GO) is an executive level power plant manager specifically assigned to the operation of the geothermal power plant at the core of the ERP. The GO is engaged in the initiate phase to ensure proper allocation of cost and schedule of the ERP development accommodates the GO’s requirements. The GO will be responsible for selecting all associated design, build and commissioning contractors for the power plant. The GO will work closely with the engineer and his design contractor on plant design and ERP general arrangement. Ideally, the same GO will remain in this position throughout the initial development cycles of the ERP, to ensure continuity and consistency in design and maintain alignment with the Conditions of Satisfaction identified in the Scope Phase. It is important to mention that the GO has several clients: members or the ERP, as well as residencies and constituencies in surrounding region, and any additional special industrial contracts or PPAs. The GO must manage the expectations of each client and ensure ample supply of power to each to maintain satisfaction requirements.

3.2.1.6.7 Transmission and Distribution Managers

Transmission and Distribution Managers (TDM) could be the same executive manager as the GO, if the same firm manages both electric and thermal energy distribution. The primary role of the TDM lies outside the ERP, distributing electric and/or thermal energy generated by the power plant to the regional constituents and residencies. The TDM’s secondary role is to provide oversight and support to transmission and distribution interconnections within the ERP. The TDM and associated design subcontractors will “balance” the conditions of expansion both within the ERP and outside regionally; meaning calculating and modeling shifts in demand and supply given various scenarios of integrating new consumers.

3.2.1.6.8 Sector Managers

Sector Managers (SM’s) are executive managers assigned to the local development and operation of a specific company. Depending on the ERP, the sectors could include aquaculture companies, data center service providers, cosmetic R&D, etc. For example, the on-site production and operation manager of a greenhouse would be a single SM. If there were several greenhouse companies in the ERP, the independent companies would consider the operating, production and consumption characteristics of each greenhouse and select the primary producer/consumer as the “Greenhouse Sector Manager”. In this case, the Greenhouse SM is responsible for maintaining the conditions of satisfaction established by
the other member companies within the Greenhouse sector. The number of SMs is dependent of the number of sectors and member companies within the ERP.

3.2.1.6.9 Municipality Representative

The Municipality Representative (MR) is a state official specifically assigned to the region of the country in which the ERP is located. The MR is responsible for maintaining communication between the ERP Operation Board and the state/region officials the ERP serves. The MR engages residential and commercial constituents within the ERP region, and maintains any conditions of satisfaction requested therein. The MR is also responsible for relaying energy policies produced and proposed by the ERP to the region represented. The ERP continues to improve efficiency and sustainability internally, but also externally within the region, state and country it’s located. The MR assists in this effort through review, consultation and distribution of proposed policies to associated state officials.

3.2.1.7 Preliminary Geothermal Resource Assessment

Although a known and proven geothermal resource is slated for development, a comprehensive assessment is required to provide baseline information to the initial concept design of the ERP. The preliminary assessment is prepared by a third party geothermal engineering firm for the Geothermal Power Company, and includes the following results from surface and subsurface exploration surveys and studies:

3.2.1.7.1 Literature Survey – any existing data or research regarding the target reservoir

3.2.1.7.2 Aerial Survey – infrared and aeromagnetic imagery and analysis

3.2.1.7.3 Geologic Mapping – detailed mapping of geological units, structures (tectonics), volcanic structures/history, and thermal manifestations

3.2.1.7.4 Hydrologic Survey – ground water and hydro-geological manifestations

3.2.1.7.5 Geochemical Survey – includes sampling of water and steam from hot springs and fumaroles, sampling from cold springs, analysis of chemical species in water, and gases in steam, geothermometers for water and steam, stable isotope analysis, soil chemical anomaly study, soil diffuse degassing, geothermometry

3.2.1.7.6 Geophysical Survey – thermal methods (soil temperature gradient, heat flux), gravity methods (rock density), rock magnetization, seismic methods (sound velocity, seismicity, geological structure), as well as DC (Schlumberger, Dipole-Dipole), Transient Electro Magnetic TEM (Central-Loop, LOTEM), Magneto Telluric MT (Natural source, controlled source), and Induced Polarization
The preliminary assessment will identify the following components of the geothermal reservoir:

- Temperature of the reservoir
- Permeability (fractures) of the reservoir
- Porosity
- Geological formations and alterations
- Structure and size of reservoir
- Aerial extent of thermal anomaly
- Depth to useful temperatures
- Location of up-flow and outflow zones
- Chemical composition of the fluid
- Evaluate fluid origin, corrosion and scaling potential

3.2.1.8 Business Case

The Business Case utilizes results from the preliminary assessment to estimate economic performance of the proposed ERP as well as associated costs. The business case is utilized to attract additional investors or financial institutions for further development of ERP LLC and subsidiary companies in the Scope Phase. The business case proposal must include the following:

3.2.1.8.1 Legal, Development and Construction Costs – comprehensive cost model and budget for installing the power plant

3.2.1.8.2 Operating Conditions and Costs – expected costs and risks of operating the power plant

3.2.1.8.3 Preliminary Direct and Indirect Market Analysis – existing and projected market conditions of electric and/or thermal energy sales outside the ERP

3.2.1.8.4 Retail Energy Revenue Forecast – detailed revenues and cash flow models

3.2.1.8.5 ERP Feasibility – market analysis and feasibility assessment of assembling and ERP

Initiate Phase Outputs and Documentation:

- ERP Fund LLP
- ERP LLC
- Geothermal Power Company EPC
- Resource Concession Agreement
- Exploration and Development MOU
- Preliminary Geothermal Resource Assessment
- ERP Business Case
3.2.2 Scope Phase

The scope phase sets the direction of the ERP through clearly defined values, conditions of satisfaction, selected contractors and specified plans of implementation.

Figure 20: Scope Phase - Stages, Feedback Loops and Outputs

3.2.2.1 Core Development Team Selection and Assembly

The Core Development Team (CDT) is steered by the ERP management team, operation board members and active Owner members at this point in the APF process. Selection decisions and agreements between ERP Management Team, the Operation Board and selected ERP contractors are finalized and contracts are signed.

Upon project kick-off, which includes the ERP Management Team, additional operation board members and ERP contractors assemble to develop ERP cycles within the Adaptive Project Framework guidelines. The Core Development Team (CDT) includes the following parities:

3.2.2.1.1 ERP Management Team – Development Manager, Facilitator, Engineer, Economist, Environmental Auditor

3.2.2.1.2 Operation Board – Generator Operator, Transmission and Distribution Managers, Cluster Industry Managers, Municipality Representative

3.2.2.1.3 ERP Contractors

- Geological, Geochemical, Geophysical Leads
- Drilling Contractor Lead
- Mechanical Lead
- Structural Lead
- Instrumentation and Controls Lead
• Electrical Lead
• HVAC Lead
• Procurement Lead
• Civil Lead
• Architect Lead
• Landscape Architect Lead

3.2.2.2 Exploration Well Drilling

Exploration drilling is the first step in verifying preliminary surface and subsurface exploration results. Exploration drilling sites are determined based upon assumptions and results presented in the preliminary assessment, and can become production well if the resource meets production requirements. Exploration determines resource lithology (cap-rock, host rock and alteration), temperature gradients, formation temperature and pressure, up-flow and out-flow lineament of resource. Exploration well drilling can occur throughout the development of the ERP as the Owner or GPC wishes, but start as early as possible due to long lead times associated with drilling equipment procurement, installation and laboratory tests. Results of exploration well drilling include:

• Pre-feasibility study
• Site selection appraisal/production well
• Refined data and inputs for conceptual models
• Environmental Impact Assessment inputs and variables

3.2.2.3 Reservoir Engineering, Modeling and Final Geothermal Resource Assessment

A final assessment is completed by the previously contracted third party geothermal engineering firm, but checked and reviewed by an additional third-party firm for verification of calculations and finding accuracy. Modeling geothermal systems helps the CDT understand the physical nature and behavior of the system, quantify reservoir parameters/properties, simulate production response, estimate production potential, and provides resource management tools. The final assessment is expanded upon the previous deliverables of the preliminary assessment in the initiate phase as well as the following:

3.2.2.3.1 Reservoir Engineering – geothermal fluid flow evaluation and predictions

3.2.2.3.2 Reservoir Conceptual Models – developed and maintained by third-party geothermal engineering firm. A computer simulated model illustrating sub-surface and structural geology, relation of geology and permeability, hydrothermal alteration (shape of the system, evolution and present state). The following conceptual models include:
3.2.2.3.2.1 Volumetric Assessment
3.2.2.3.2.2 Monte Carlo Simulation
3.2.2.3.2.3 Numerical Modeling
3.2.2.3.2.4 Dynamic Modeling – simple analytical models, lumped parameter and detailed numerical models
3.2.2.3.2.5 Grid Generation – 2D and 3D grids illustrating reservoir properties

A retaining contract with the third-party geothermal engineering firm will continuously update and maintain all geothermal models throughout the life of the ERP. Model calibration and output delivery will coincide with additional modeling efforts (Energy, Financial, Economic, Environmental) executed by the CDT.

3.2.2.4 Concept Engineering – Value Streams and ERP LLC Companies

Concept Engineering determines which value streams and respective clusters will be integrated into the ERP as well as what metrics can be used to measure the quality or performance of the cluster, based on analysis of market conditions. Value streams may transcend multiple clusters or companies, aligning previously independent company’s objectives towards a shared economic goal. The net value of inter-cluster shared economic goals must be most lucrative for each cluster member individually and include proposed agreements to distribute revenues based upon input and output values of calibrated financial models. This will ensure unbiased, even distribution of revenues per value stream. The following items outline the criteria evaluate for each value stream:

3.2.2.4.1 Risk – quantitative assessment of magnitude of potential loss and the probability
3.2.2.4.2 Complexity – number of steps, actors and interactions within the process
3.2.2.4.3 Duration – short term and long term cycle evaluation
3.2.2.4.4 Business Value – Calibrated financial model
3.2.2.4.5 Dependencies – interaction with additional value streams

The primary output of the concept engineering exercise is development of individual companies, with intent to be sold to external investors or companies interested in acquiring operation and shares in the ERP. The ERP LLC will sell 10-50% of the company to prospective buyers.
3.2.2.5 Concept Engineering – Value Stream Classification and Failure Response Plan (FRP)

The secondary output of the concept engineering exercise is to develop a back up plan in the event a value stream, or inter-ERP operation is not meeting expected performance or begins to fail. As each value stream is identified, they are classified based upon priority requirements set fourth in the conditions of satisfaction. These classifications are determined by a calculated numerical rating issued by a review board. Each value stream investigation is placed in the following classes:

3.2.2.5.1 Class A – 90%+ meets COS and is slated for further development in Design, Spec and Plan Phase.

3.2.2.5.2 Class B – 75-89% nearly meets COS and will be reviewed as primary project in the FRP further developed in the Design, Spec and Plan Phase

3.2.2.5.3 Class C – 60-74% meets some of COS or could become a potential Spin-Off project. These projects are reviewed as secondary projects in the FRP

3.2.2.5.4 Class D – 50-59% meets some of COS but doesn’t warrant further investigation, and are reconsidered in the Review Phase.

Value Stream Failure Response Plan includes an evaluation sequence and review of alternatives should a failure begin to occur. A critical deliverable from each value stream’s performance model are modeled negative scenarios as defined in the risk evaluation and mitigation exercise.

3.2.2.6 Conditions of Satisfaction

A primary function of the COS is to ensure adherence to core value infrastructure and ERP mission towards propagating sustainable economies through iterative expansion and dynamic
inclusion. The ERP COS includes two types of conditions, fundamental and directional. Development of each ERP includes one directional condition and three fundamental conditions. As the directional condition is being defined, decisions and agreements made will be reflected upon the fundamental conditions. Iterative review and incorporation of fundamental conditions assure the ERP future remains connected to its initial concept, to answer the call for sustainable futures for generations to come.

The projected value streams and market share condition is the directional condition. The following two (2) are fundamental conditions of which the directional condition is continuously reflected upon.

3.2.2.6.1 Target Market Share and Value Stream Performance

Projected Value Streams define proposed energy distribution, type of clusters to be integrated to the ERP and integration to the surrounding municipality. This condition includes requirements for engineering documents and models developed in the concept engineering process. The documents include financial assessment that highlights the expected market share throughout the proposed lifetime of each value stream.

3.2.2.6.2 Core Value Infrastructure

As discussed in Core Value Infrastructure, the five core values are Zero Waste, Diversity, Sustainable Economy, Energy Security, and Community. Each value will weigh in on the CDT’s proposed direction and design of the ERP. The intensity of which a specific value impacts the design will vary depending on geographic location, ownership strategy, and proposed direction of ERP general arrangement and integrated clusters.

3.2.2.6.3 CSR and Environmental policies

Corporate Social Responsibility and Environmental Policy adherence is of highest importance. The adapted codes and policies will be revisited at the launch of each development cycle to ensure compliance and frequency requirements are satisfied. As discussed in Value Propositions.

3.2.2.7 ERP Charter

The primary output of the Scope Phase is the ERP Charter, which includes outputs from each scope phase activity. The ERP Charter must include the following documents before proceeding onto the Design, Plan and Spec phase. The ERP Charter is a “live” document, and
is continuously updated throughout each APF phase, and is used as a baseline document of record.

3.2.2.7.1 Turnkey ERP Companies – turnkey companies that developed by the CDT in the Concept Engineering exercise, majority intended to be sold to investors and companies external to the ERP.

3.2.2.7.2 Value Stream Failure Response Plan – a high-level mitigation strategy to reduce risk impact severity and/or probability of occurrence

3.2.2.7.3 Short and Long-term cycle model and schedule – ERP development cycle and projected operational cycle objectives and schedule. Lays framework for subsequent APF cycle outcomes and pace

3.2.2.7.4 Process Flo Diagram – general flow of energy throughout major equipment of the ERP

3.2.2.7.5 General Arrangement and ERP Layout – detailed and scaled drawing of 3D model of piping, mechanical and structural systems

3.2.2.7.6 One-line Diagram – Electrical diagram or 3D model of electrical network and circuits of the ERP

3.2.2.7.7 Education R&D assessment – Throughout the scope phase, involvement and incorporation of Education systems and institutions is considered for the ERP. The R&D Assessment includes identification of potential university/institute based research projects that will benefit both the ERP and educational institution. This assessment must include several projects for university, technical institute, and high school levels.

3.2.2.7.8 Preliminary Environmental Impact Assessment – a formal report procured from a third party contractor analyzing environmental consequences (positive or negative) of the ERP on the existing environment conditions.

3.2.2.7.9 Municipal, Permitting, Legal and Contractual Agreements – copies of ratified agreements and contracts between all associated parties

3.2.2.7.10 Financial pro forma – detailed and modeled financial outputs of projected value stream cash flows, net revenues and taxes. The ERP pro forma will include analysis of the following for each value stream, as well as for the ERP as a whole.

3.2.2.7.10.1 ROI – benefit to the investor resulting from investment in value stream

3.2.2.7.10.2 IRR – a rate of return to determine profitability of the value stream

3.2.2.7.10.3 Risk Analysis – impact and probability assessment

3.2.2.7.10.4 Break-Even Analysis – cost accounting to determine when cost and revenues are equal

3.2.2.8 *Mid-Level Work Breakdown Structure*

Strategies, Structures and Processes for Owning and Operating an Energy Resource Park

Shaun Tudor – MSc Thesis – Iceland School of Energy, Reykjavik University 2015
The Mid-Level WBS is a starting point for the CDT to determine sub-functions of each value stream’s WBS. To determine the priority of such functions, an evaluation of each value stream’s criteria will determine the priority of each function within the WBS. Once value stream priorities have been identified, the CDT and sector members refine the Mid-Level WBS down to the second level. The CDT uses Mid-Level WBS as a planning and project-reporting tool throughout each APF cycle.

Scope Phase Outputs and Documentation:
- Exploration Well Pre-Feasibility Studies
- Final Geothermal Resource Assessment
- Proposed Value Streams
- Conditions of Satisfaction
- ERP Charter
- ERP Companies
- Mid-Level WBS

3.2.3 Design, Spec and Plan

The design, spec and plan phase formulates official documents for constructing the ERP. The phase is comprised of design, modeling and scheduling efforts that are executed concurrently and overseen by the CDT.

3.2.3.1 Low-Level Work Breakdown Structure

An expansion of the Mid-Level WBS, prioritized functionality through each activity level to developed work packages. Scope triangle analysis at each function level: time, cost, and resource availability

3.2.3.2 Baseline Modeling

The CDT develops and maintains ERP models, either in-house or through approved subcontractors. Models are heavily used throughout each phase of the ERP development and operational cycles. Modeling energy, or economics provides several benefits to the ERP CDT, it can forecast scenarios based upon modification of model inputs as well as provide a revision record, allowing for project tracking and reporting. A baseline model is developed for each model, i.e. existing conditions. Then baseline+1 is created, which models the effects of implementing the ERP through the first development cycle. Each model is calibrated throughout the Build and Review phases, then re-baselined once the APF iterative operational cycle begins.
3.2.3.2.1 Energy flow model – The model is a virtual or computerized simulation of the energy flow throughout the ERP. The models primarily focus on gathering system and power plant performance, heat, energy, and waste exchange, metering/billing, life cycle analysis and payback of proposed projects and expenditures.

3.2.3.2.2 Economic model – a theoretical model, representing quantitative relationships between real variables and outputs of the ERP as well as external market conditions and operations.

3.2.3.2.3 Environmental models – include species distribution modeling, predictive habitat distribution modeling, and climate envelope modeling refers to the process of using computer algorithms to predict the distribution of species in geographic space on the basis of a mathematical representation of their known distribution in environmental space. The environment is in most cases represented by climate data.

3.2.3.2.4 Financial model - Financial models include inputs from the ERP Charter Financial Pro Forma for the following applications:

- Business valuation – especially discounted cash flow, but including other valuation problems. Estimates economic value of the Owner’s interest in the ERP.
- Scenario planning and management decision making ("what is"; "what if"; "what has to be done")
- Capital budgeting – consideration of long-term investments such as equipment, plants, products and development projects
- Cost of capital and WACC calculations – minimum return investors expect for providing capital
• Project finance – fund performance analysis
• Portfolio optimization – selection of various assets to integrated to the ERP
• Risk modeling – utilizes market risk, value at risk, historical simulation, extreme value theory techniques to forecast likely losses that would be incurred for a variety of risks.
• Real options – undertake certain business initiatives such as deferring, abandoning, expanding, staging, or contracting a single investment project.
• Mergers and Acquisitions – estimating the future performance of combined entities

3.2.3.2.5 Reservoir models – baseline and calibrated models produced for Final Geothermal Resource Assessment by a third-party geothermal engineering firm. These models are calibrated and maintained by the third-party firm.

3.2.3.3 Design, Plans and Specifications

Detailed mechanical, electrical, structural, architectural, instrumentation/controls, civil and piping plans and specifications are designed and approved for the following ERP systems. The notes associated with each system identify major elements of the design deliverable.

3.2.3.3.1 Powerhouse – structure design of concrete foundations and structural steel; mechanical equipment (turbines, pumps, cooling towers, condensers, NCG system, heat exchangers etc.) capacity, service and interconnection; instrumentation and controls on equipment, control wiring and monitoring system; electrical specification and interconnect to equipment and power house electrical networks; civil site grade, elevation, and road access; architectural cladding and penetrations; procurement contracts for equipment and material

3.2.3.3.2 Gathering System – pipe flow, line sizing and hydraulics, construction material, fluid service/two-phase flow, operating conditions, steam traps/condensate removal, stress analysis and support design; nozzles and appurtenances design of process connections, level, pressure, temperature instruments, vents, drains, relief connections, inspection ports, platform connections; tank and vessel service, size, material and connection; process Well design, depth, direction, flow rate and capacity. Steam separators flashing calculations, vessel design, brine precipitation/scaling management; Vent/pressure control station valve selection for steam/brine service, control system, hydraulic transients, well control, demisters, silencers and mufflers; demister specifications for desuperheat/scrubbing, turbine inlet steam quality, pressure drop and vessel design.

3.2.3.3.3 Electrical Transmission – design pathway for generated power to outgoing transmission lines both within and external to the ERP, provide power to auxiliary loads, provide
uninterruptible power to critical plant components. Plans and specifications of the following components throughout the ERP: transmission lines, switches, breakers, transformers, generators, instruments, monitoring system, buses, consumption/demand meter network, motors and loads.

3.2.3.3.4 Thermal Distribution – Design for interconnect within and external to the ERP; pipe flow, line sizing and hydraulics, construction material, fluid service, operating conditions, energy meter network, monitoring system stress analysis and support design.

3.2.3.3.5 Cluster Industries – Site location, equipment and interconnect.

3.2.3.3.6 Municipality Interconnect – thermal and electrical interconnections for outgoing energy produced by the ERP; network and access for municipality inputs to the ERP (biomass/solids, waste water, etc.).

3.2.3.3.7 ERP General Arrangement – detailed and scaled map of ERP to include: project design data e.g. location, topography, climate; mechanical lay out above and below grade, piping runs, piping racks, equipment location; civil grade draining, foundations, roads; electrical area classifications, switchgear, cable runs; vessel sizes, turbine size/configuration, condenser size, cooling tower size, pump types and size; cluster and municipality sites and interconnections.

3.2.3.3.7.1 Initial cycle – preliminary development cycles of the APF

3.2.3.3.7.2 Future cycle expansion capacity – forecasted ERP expansion

3.2.3.4 Risk Monitoring and Value Stream Failure Response Plan

Risk is an uncertain event or condition that, if it occurs, has an effect on at least one ERP project objective. Such objectives can include scope, schedule, cost, and quality. A risk may have one or more causes and, if it occurs, it may have one or more impacts. A cause may be a requirement, assumption, constraint, or condition that creates the possibility of negative or positive outcomes. For example, causes could include the requirement of an environmental permit to do work. The risk event is that the permitting agency may take longer than planned to issue a permit. If uncertain events occur, there may be an impact on the project cost, schedule, or performance. Risk conditions could include aspects of the project or organization’s environment that may contribute to project risk, such as immature project management practices, lack of integrated management systems, concurrent multiple projects, or dependency on external participants who cannot be controlled. Such risks are first identified in the Scope Concept Engineering exercise, and then are carefully measured and monitored throughout the remaining phases of the APF cycle. In anticipation of a risk event,
a mitigation strategy is employed called a Value Stream Failure Response Plan. This plan identifies alternative opportunities if a specific value stream encounters a negative risk event. The magnitude of the Response Plan is directly related to the impact of the risk event.

3.2.3.5 Environmental Management System

The design and development of the ERP environmental program in a comprehensive, systematic and planned relies heavily upon outputs from the Baseline Modeling and Plans/Specification stages of the Plan Phase. The ERP Environmental Management System (EMS) is a system and a database which integrates procedures and processes for training of personnel, monitoring, summarizing and reporting of specialized environmental performance information to internal and external stakeholders of the ERP. The ERP EMS is a custom program that integrates and complies with the European Union Sustainable Development Strategy (SDS) and ISO 14001 requirements, as discussed in Value Propositions.

3.2.3.5.1 Environmental Impact Assessment – a third party assessment of predicted environmental consequences (positive and/or negative) of constructing the ERP. The assessment should adhere to and comply minimum requirements stipulated by local environmental authority as well as internal ERP environmental directive requirements.

3.2.3.6 Preliminary Construction Schedule

A product of the Low-Level WBS is a preliminary construction schedule. The WBS develops work packages, which include expected time-lines and critical path analyses, key elements in formulating a project schedule. This project schedule focuses on construction activities, but can also be used to forecast incoming revenue as the powerhouse and cluster industries start-up.

3.2.3.7 Core Development Team Sub-Contractor Selection

The work packages that the Low Level WBS developed allow for detailed insight regarding involved and responsible contractors. The CDT solicits bids biasedly from previously used subcontractors as well as local and minority contractors. The bid packages include relevant plans, specifications and project schedules. The approved bids are reviewed to reduce contractor redundancy and ensure fair distribution of contracts to the contractor market. Meaning, the CDT aims to streamline subcontractor quantity and function, but still provide equal opportunity for numerous subcontracting firms; employing as many contractors as efficiently as possible.

Design, Spec and Plan Phase Outputs and Documentation:
• Low-Level WBS
• Baseline Models
• ERP Plans, Specifications and Schedule
• EMS Plans and Specifications
• Environmental Impact Assessment

3.2.4 Build

The Core Development Team transitions from a design based operation into an executing team when moving into the Build Phase. Design intensive contractors are kept on standby with a retainer in the event clarification of their design is required.

Figure 23: Build Phase flow diagram

3.2.4.1

3.2.4.2 Micro-Level WBS and PM Tracking

The Micro-level WBS provides a reporting and tracking tool for across the entire ERP project. The CDT uses the WBS daily and weekly in managing construction, procurement processes as well as project and subcontractor financials. The CDT iteratively updates the construction schedules and reports at predetermined intervals to the Owner and supplementary stakeholders.

3.2.4.2.1 Construction Schedule – advances, delays, holds, and change orders are reflected in the schedule as report during weekly and monthly construction meetings.
3.2.4.2  Contractor Tracking – Progress and delays at every contractor and subcontractor level are tracked to evaluate performance and evaluate project segment sequencing and procurement strategies.

3.2.4.3  Construction Model Calibration

Each ERP model has unique modeling input/outputs, calculations, and parametric runs. Once sections and systems of the ERP come on-line and are operating per specification, real-time data collected is compared to the model outputs. Each model is modified to match actually installed conditions and processes through updating the Design, Plan, Spec models to match actual operation.

3.2.4.4  Construction and Commissioning

The construction and commissioning phases are expected to be complex, involving many contractors, schedules and interconnectivity therein. For example, a new ERP would involve construction of the power plant gathering system and power house, transmission and distribution throughout ERP, cluster industry sites and interconnection, alternative power generators such as wind turbines or solar panels, roads, security and monitoring systems. The main impact to this phase is the number of cluster sectors to be installed in the development cycle.

Geothermal power plant construction is typically staged, splitting the expected power capacity into 2 or 3 stages of construction. For example, a 90MWe capacity reservoir would be split into 2 stages of exploration and development. Each 45MWe would take ~7 years to develop, ~15 years to exploit the reservoir’s full capacity as seen in the proposed Kárahnjúhkar geothermal power plant. Figure 24, Figure 25 and Figure 26 illustrate typical geothermal power plant development duration in years and incurred costs.
It is important to note the following construction and cost schedule are for development of a geothermal power plant only, not an Energy Resource Park. Depending on the types of sectors to be integrated, scheduling installation and interconnection between steps 6 and 9 of Figure 24 reduce cost of development as the ERP general layout will be complete (no reconstruction costs due to site design changes) and contractors will already on-site, allowing for better direct coordination and communication. Figure 26 below illustrates project costs for a 70MWe Power Plant in Kenya:

<table>
<thead>
<tr>
<th>Project Identification, Desktop review, inception Report and Licensing</th>
<th>$50,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detailed Surface Exploration</td>
<td>$500,000</td>
</tr>
<tr>
<td>Pre-feasibility Study</td>
<td>$10,000</td>
</tr>
<tr>
<td>Exploration Drilling well testing pads and roads (3Wells)</td>
<td>$912,000</td>
</tr>
<tr>
<td>Appraisal Drilling and testing (6 WELLS)</td>
<td>$17,400,000</td>
</tr>
<tr>
<td>Feasibility Study</td>
<td>$100,000</td>
</tr>
<tr>
<td>Design and tender documents</td>
<td>$1,300,000</td>
</tr>
<tr>
<td>Environmental Impact Assessment (EIA)</td>
<td>$100,000</td>
</tr>
<tr>
<td>Production Drilling and Testing</td>
<td>$40,600,000</td>
</tr>
<tr>
<td>Power station &amp; Transmission Construction and supervision</td>
<td>$100,000,000</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>$169,180,000</strong></td>
</tr>
<tr>
<td><strong>COST PER MWe</strong></td>
<td><strong>$2,416,857</strong></td>
</tr>
</tbody>
</table>

3.2.4.5  *As-built specifications and plans*

Accurate and detailed as-built plans and specifications, and commissioning close out documents are the most important deliverables to be received upon construction completion. The University of Minnesota Capital Planning and Project Management has assembled a comprehensive list of As-Built documentation, and is utilized as a primary source in determining ERP as-built requirements. Each contractor and subcontractor must submit as-built plans and specifications as displayed in Appendix C.
Build Phase Outputs and Documentation:
- Calibrated Models
- Construction and Commissioning As-Built specifications and plans

3.2.5 Review
The Review Phase ensures thorough project evaluation through various feedback loops, reviewing each major activity completed in the current APF cycle seeking improvement and more efficient practices for subsequent cycles. Practices and strategies that proved successful will be incorporated for cycles to come, whereas inefficient and unsuccessful efforts will be evaluated and corrected.

3.2.5.1 Review spin-off value streams
Unforeseen disruptions, events and opportunities occur in every project. Opportunities that potentially benefit the ERP greater objectives are considered spin-off value streams. A spin-off value stream is a modification to a planned process, output, or integration that became realized during implementation, commissioning or operation of the ERP. Such a value-stream may be an unpredicted waste product from one process that can be utilized by existing industrial corporations of the ERP as well as new additional prospective industries.

Spin-off value streams are the most organic sources of expanding the ERP. Spin-off feasibility is assessed and entered into the potential project queue for the next APF development cycle. Assessments include evaluation of ease of integration, estimated
energy/waste consumption/production, and financial impacts to both cluster and ERP level net revenues.

3.2.5.2 Modeling – Calibration and Re-baseline

After the system is up and operating, data is recorded, and is used to assess the performance of the value stream when comparing to projected model outputs. This process of comparison, and tuning the model to match actual performance is called a model “true-up”. Once “true-up” is complete, the model becomes the new baseline for the following APF cycle. To begin the “true-up”, the performance of each system in comparison to the projected baseline+1 model, and the associated inputs are then calibrated to ensure the model’s accuracy within +/- 5% actual performance. Actual performance of each system is metered and monitored through a central monitoring system. These monitoring devices are calibrated and recommissioned annually to maintain accuracy within +/-1%.

3.2.5.2.1 Energy flow model – calibration of model to include but not limited to power output, heat/waste transfer, sub/auxiliary system consumption, cluster industry production/consumption, transmission and distribution line losses

3.2.5.2.2 Economic model – calibration to include updated external market prices, indices, stock and fluidity, cluster industry performance and productivity, work force productivity and utilization

3.2.5.2.3 Environmental model – calibration of models to include weather normalization, input true-up of recorded data logging and samples, waste production and reclamation rates, gas and emissions logs, flora and fauna diversity tracking

3.2.5.2.4 Financial model – calibration to include updated data inputs on financial performance from accounting and fund monitoring programs.

3.2.5.2.5 Reservoir models – calibrated and maintained by the third-party geothermal engineering firm, updated performance inputs as wells and systems are commissioned.

3.2.5.3 Environmental Management System audit

Upon start up and commissioning, the EMS is audited to ensure performance and adherence to standards as identified in Value Propositions. Any shortfalls in system performance must be remediated before proceeding onto the next APF cycle.

3.2.5.4 Financial Review
Once the financial models are calibrated, a comprehensive review of the APF financial performance will be performed. The models and associated inputs will be distributed to a third-party financial consulting contractor for review. Once model accuracy is confirmed, a series of review meetings will occur between the Owner, ERP Management Team, Operation Board, Core Development Team and any additional contractors or ERP subsidiary companies as needed. Upon close out of the financial review, any remaining contractor payments will be issued.

3.2.5.5 Education R&D results

As the ERP cycle progresses, educational institutions such as universities or technical institutes can be engaged to perform research on ERP processes and strategies related to current and future cycle objectives. Such research will be evaluated as prior to the following APF cycle, and its results will be considered and incorporated to the next APF cycle if determined to be beneficial to the ERP.

3.2.5.6 Cycle Goals, Objectives and Completion

The initial and modified goals of the APF cycle are discussed and reviewed upon the cycle’s completion. Although the Core Value Infrastructure is continuously reflected upon throughout each APF phase, a final review of all completed objectives will be performed. An evaluation includes identifying successful objectives, and rectifying unsuccessful objectives through corrective and expansion plans to be included in the next cycle.

3.2.5.6.1 Closeout documents – Construction and commissioning as-built plans and specifications, any contract amendments or change-orders

3.2.5.6.2 Reflect progress and direction upon Core Value Infrastructure

3.2.5.6.3 Prepare for next cycle

Review Phase Outputs and Documentation:

- Calibrated Models
- Close-out Documentation
- Spin-off Value Streams and Expansion Plans for next APF Cycle

3.2.6 Monitor and Control

Dedicated personnel in the Core Development Team are required to track, review and regulate the progress and performance of the project, identify any required changes and initiate them. The leader of this group is the ERP Facilitator, and will acquire assistance from
within the CDT or from external consults. This group controls changes and recommends preventative action in anticipation of any problems, monitors ongoing project activities against the baseline ERP documents (ERP Charter and Design, Plan and Spec Docs), and influences factors that could circumvent integrated change control so only approved changes are implemented as prescribed in the PMBOK v4 Chapter 3.6 (PMI, 2006). All approved changes and updates to the ERP are reflected in a revised ERP Charter. This continuous monitoring provides the Owner, ERP Management team and Operational Board with insight into the health of the ERP and identifies areas that require attention proactively. The Monitoring and Controlling process coordinates the entire project effort in the following areas:

3.2.6.1  Monitor and Control Project Work

This is the process of tracking, reviewing and regulating the progress to meet performance objectives throughout each phase of the APF cycle. Monitoring includes status reporting, progress measurement, and forecasting. Performances reports provide information regarding scope, schedule, cost, resources, quality and risk, which are valuable inputs to many other project management processes throughout the development of an ERP.

3.2.6.2  Perform Integrated Change Control

Integrated change control is the process of reviewing all change requests, approving changes and managing changes to the deliverables, organizational process assets, project documents and the ERP charter. Changes of large magnitude will require the Operational Board to review and approve.

3.2.6.3  Verify Scope

Once a milestone, or scope deliverable is achieved, its completeness is verified and documented. Final product is compared with original scope, and analysis of the scope execution is documented.

3.2.6.4  Control Schedule

The team continuously monitors scope progress through routine meetings and automated notifications reporting CDT progress.

3.2.6.5  Control Costs

Controlling costs is the process of monitoring the status of the project to update the project budget and managing changes to the cost baseline. These costs are updated in the ERP Charter.
Charter Financial Pro Forma, and once confirmed they are input into respective financial models.

3.2.6.6 *Perform Quality Control*

Quality Control is the process of monitoring and recording results of executing the quality activities to assess performance and recommend necessary changes.

3.2.6.7 *Report Performance*

Report performance is the process of collecting and distributing performance information including status reports, progress measurements and forecasts.

3.2.6.8 *Monitor and Control Risks*

Monitor and Control Risks is the process of implementing risk response plans, such as the Value Stream Failure Response Plan, tracking identified risks, monitoring residual risks, identifying new risks and evaluating risk process effectiveness through developing the ERP.

3.2.6.9 *Administer Procurements*

Administer Procurements is the process of managing procurement relationships, monitoring ERP contract performance and making changes and corrections as needed.

### 3.3 Organization and Operation

This chapter will identify a potential ERP organizational structure; it’s management, and operational value chain. The organization of an ERP is indicative to its function, and is designed to streamline operation and management within the ERP. The ERP Organization is sector based, where similar operations and industries collaborate to achieve shared goals as determined by the COS in the Scope Phase Concept Engineering exercise. Once developed, an ERP operates under a uniform, yet adaptable value chain; allowing for expansion and adjustments to market conditions.

#### 3.3.1 Organization Structure

Figure 28 below illustrates the potential macro organization of a dynamic and interdisciplinary ERP. Along the top of the figure, primary energy providers and distributors are located. Managers or representatives of each energy provider or distributor are included in the ERP Operation Board. Committed core investors, the ERP LLP, input their COS to the ERP Operation Board, and are reflected by the developed ERP sectors identified below the Operation Board. Each ERP sector manager or representative is included in the Operation Board.
Board. Each sector includes turnkey companies, municipality organizations, and educational institutions, grouped by functionality and operation. Upon development of multiple ERPs globally, a consortium of ERP Global representatives assembles to review individual ERP design, progress, and goals.

Figure 28: ERP Macro Organization Structure

3.3.2 ERP Management Team and Operation Board Structure

Figure 29 illustrates a potential Management and Operation Board structure. This figure identifies key personnel to be included in the Operation Board, and supporting roles just outside of the board. The ERP LLC Management Team is the core of the Operation Board, a group of professionals that are employed by the ERP. Sector companies, organizations, or the Primary Energy Generator companies employ the other roles. In addition to sector managers, the Municipality Sector manager and Regional Fund Managers are included in the Operation Board. Note, every role other than the ERP LLC Management Team is a designated representative from each respective organization or company; the role ID is specific to the representatives’ relationship to the ERP Operation Board.
3.3.3 Operational Value Chain

Once developed and operating, an ERP will organize internal functions to execute an Operational Value Chain, as illustrated in Figure 30. The ERP Operational Value Chain utilizes a proven value chain structure developed by Michael Porter (Porter, Changing Patterns of International Competition, 1986).

The ERP Operational Board and subsequent sectors fulfill both Support and Primary activity roles. The Support Activities are defined by the ERP LLP Conditions of Satisfaction (COS), primarily fulfilled by Operation Board members and respective sectors. For example, a Research and Development program established with educational institutions will supplement ERP sector operations with valuable information for further development or expansion. With
Strategies, Structures and Processes for Owning and Operating an Energy Resource Park
Shaun Tudor – MSc Thesis – Iceland School of Energy, Reykjavik University 2015

regards to Market Relationships, a Global ERP representative or Development Manager may export knowledge to a potential market, providing information and support for implementing a new ERP. The output of the value chain is value added less cost, meaning creating shared value by utilizing waste streams reduces operating costs, resulting in higher profit yield for the ERP as a whole.

3.3.4 Operational Cycle Approach – Scrum Framework and the ERP

A variety of project management techniques are required to efficiently operate an ERP. In order to accommodate the complexity of ongoing projects within an ERP, the flexible and adaptable Scrum method is considered. This section reviews the Scrum Guide (Swaber & Sutherland, 2001) and its utilization pertaining to an ERP.

The Scrum method is a framework for developing and sustaining complex projects, and can be utilized within all levels of multi-organization projects; albeit a specific project at the operation board level or just between two companies within the same sector. The Scrum framework consists of Scrum Teams and their associated roles, events, artifacts and rules. The three pillars of Scrum theory are Transparency, Inspection, and Adaptation, which are closely aligned with the supporting attributes and virtues of the ERP core value infrastructure.

Scrum Teams are self-organizing and cross-functional, they include members from all associated organizations in relation to the project’s “Product”; meaning representatives from various companies or organizations within the ERP assemble to execute the project. The Product Owner is responsible for maximizing the value of the product and the work of the Development Team. The Product Owner is the sole person responsible for managing the Product Backlog, which includes specific details and value requirements to complete the project. The Development Team is a group of professionals with varying skillsets and areas of focus required to execute the project, and work closely together and are accountable for executing Product Backlog into Increments of potentially releasable functionality. Lastly the Scrum Master is a “servant-leader” to the Scrum Team and assisting the Product Owner, Development Team and associated organizations or companies through routine communication, coaching, and facilitation of Scrum theory and process. The Scrum Master also works closely with other Scrum Masters within the ERP, to ensure ERP-wide interconnectivity of goals and adherence to the COS. It is important to mention a single
member may be involved in multiple Scrums, depending on the level of involvement and workload each Scrum requires.

Scrum Teams work in “Sprints” which are typically one (1) month long time-boxes, that result in a “done”, useable, potentially releasable product Increment. The Sprint consists of the Sprint Planning Meeting, which highlights Spring Objectives and the Product Backlog items. Daily Scrums are intended to be short meetings, highlighting what is to be achieved within the short-term. At the end of a Sprint, a review is performed evaluating the effectiveness and success of the completed Sprint.

Scrum Masters report to respective representatives within their own organizations, as well as to the ERP Operation Board to report progress and review results. The ERP Management Team carefully reviews and tracks Scrum Sprints, as well as organizes high-level Sprint Objectives that pertain to ERP-wide goals within operational APF cycles. These Scrum “Products” are carefully delegated to specific Scrum Teams, and staged according to the operational APF cycle objectives and priorities.

3.4 Chapter 4: Sector and Cluster Management

This chapter reviews progressive business initiatives that seek optimal business performance whilst operating within progressive environmental and social strategies and agendas.

3.4.1 Creating Shared Value and Energy Resource Parks

Shared value is a management strategy focused on companies creating measurable business value by identifying and addressing social problems that intersect with their business. The shared value framework creates new opportunities for companies, civil society organizations, and governments to leverage the power of market-based competition in addressing social problems. There are three ways in which shared value can be created:

- **Reconceiving products and markets** – Defining markets in terms of unmet needs or social ills and developing profitable products or services that remedy these conditions.
- **Redefining productivity in the value chain** – Increasing the productivity of the company or its suppliers by addressing the social and environmental constraints in its value chain.
- **Local cluster development** – Strengthening the competitive context in key regions where the company operates in ways that contribute to the company’s growth and productivity.

Shared value is not about redistributing value created through philanthropy or about including stakeholders’ values in corporate decisions. Rather, shared value focuses on the creation of
meaningful economic and social value – new benefits that exceed the costs for the business and society. (Porter & Kramer, Creating Shared Value, 2011) (Pfitzer, Bockstette, & Stamp, 2013)

The notion of Shared Value is deeply embedded in the ERP Core Value Infrastructure, through fostering collaboration between diverse industries and regional actors. An ERP is an industrial environment that hosts shared value initiatives, allowing for investors and industries to take part in their own independent initiatives. ERP Turnkey companies are jumpstart shared value initiatives from the start, as their core operation converts waste heat and materials into value a valued product. The turnkey company’s Shared Value initiative typically falls into either the first or second strategies to obtaining shared value, products and markets or productivity in the value chain. For example, when investing into an ERP, a turnkey company may be obtaining new market share, or improving value chain productivity through lower operating and logistic costs. When numerous companies of similar function invest in the ERP, “sectors” or “clusters” are generated, which employs the third section of shared value, local cluster development. Although the shared value initiative is new, and has primarily been adopted by large international firms willing to take the risk, its core business value is replicated in the ERP strategy set forth in this thesis.

3.4.2 Waste to Value

When considering the waste streams of a geothermal power plant, there are numerous outputs that can be cumbersome for the power plant operator, but valuable inputs to other industries and applications. GEORG, a geothermal research group located in Iceland, has identified recognizing and utilizing these waste streams as area for continued research and development. (Ingolfsson, 2014) GEORG’s Waste-2-Value (W2V) workshop aims discussion and research at various geothermal waste streams; including gas treatment, chemical industry, energy efficiency and agricultural cultivation. An ERP has the capacity to operate within all four sections of GEORG’s W2V program, at R&D and industrial production capacities. The entire premise of an ERP is to utilize waste, and could be considered for further development and implementation of the W2V program.
4 Closing Statements

The Energy Resource Park concept is a proven strategy ensuring environmental, economic and social growth within the region and markets it serves. The intent of this thesis is to lay the foundation for a repeatable process to be introduced to developing countries. The design of the processes and practices set forth in this thesis are intended to be universal, and widely applicable across the globe. It is the responsibility of the developed country, to share its success with those still developing. In the case of an ERP, countries experienced in geothermal engineering such as Iceland, USA and New Zealand, must take the initiative to educate and assist in deployment of ERPs in developing countries. Installation of renewable and sustainable systems and infrastructure will not only provide the developing country with energy security and economic growth, but it’ll greater reduce the future emission of GHGs.

The current trends associated with climate change and fossil fuel reserves strongly encourages a new approach to how we live our lives, interact with markets and promotes renewable and sustainable development. The ERP attempts to maximize a resource’s utilization, while simultaneously fostering social and environmental practices to achieve equilibrium with nature. It is nature, and our interaction with it, that should be recognized as a vital resource to our survival and continued progress for generations to come.
Bibliography


MBL (2014, July 11). Double the population of the country to the blue lagoon. *MBL.*


4.1 Appendix A – Líndal Diagram (Lindal, 1973)

Líndal Diagram:
the applications for geothermal resources depending on the temperature.

- 79°C: Digestion in paper pulp (Kraft)
- 180°C: Evaporation of highly concentrated solutions
- 170°C: Refrigeration by ammonia absorption
- 160°C: Heavy water via hydrogen sulphide process
- 150°C: Drying of diatomaceous earth
- 140°C: Drying of fish meal and timber
- 130°C: Alumina via Bayer’s process
- 120°C: Drying farm products (or high rates)
- 110°C: Food canning
- 100°C: Evaporation in sugar canning
- 90°C: Extraction of salts by evaporation and crystallisation
- 80°C: Fresh water distillation
- 70°C: Most multi-effect evaporation
- 60°C: Concentration of saline solution
- 50°C: Refrigeration (medium temperature)
- 40°C: Drying curing of light aggregate cement slabs
- 30°C: Drying of organic materials e.g., seaweed, grass, vegetables etc.
- 20°C: Washing and drying wool
- 10°C: Drying of stock fish
- 0°C: Intense de-icing operations
- 0°C: Space-heating (buildings and greenhouses)
- 0°C: Milk pasteurisation
- 0°C: Refrigeration (lower temperature limit)
- 5°C: Animal husbandry
- 10°C: Greenhouses by combined space
- 15°C: Mushroom growing
- 20°C: Batheology
- 25°C: Soil warming, Swimming pools, Biodegradation, Fermentations
- 30°C: Warm water for year-round mining in cold climates
- 35°C: De-icing
- 40°C: Fish farming
- 45°C: Heat pumps
4.3 Appendix C – As-Built Plans and Specifications Requirements

General Information
Required For All Sheets
1. ERP Project Name and ERP Number
2. Project Team including contact information (also insert team member titles)
3. Drawing issue date
4. Signature certification block
5. Key Plan
6. North arrow for plans
7. Scale, Notes, Symbols, and call-out identification systems
8. CAD Layer Matrix for large or complicated projects
9. Plotting information

Civil Engineering
Civil Survey
1. Civil survey with confirmed benchmarks, right-of-ways, easements, property lines, required setbacks, bearing and distance labels, and construction controls

Environmental Site Plan
1. Coordinated environmental containment and mitigation plan

Grading Plan
1. Proposed contour lines and building footprints

Roads and Topography Plan
1. Proposed pedestrian and vehicular circulation and parking lot plans

Utility Plan
1. Coordinated fire protection and utilities plan

Structural Engineering
Foundation Plan
1. Piles and drilled piers
2. Foundation layout and reinforcing
3. Slab layout, reinforcing, and control joints

Framing Plan
1. Grid pattern, dimensions, and key tags
2. Framing Plan (columns, beams, and joists)
3. Structural bearing and shear walls
4. Scaled layouts, elevations, sections, details, and coordination plans for structural systems as applicable

Architectural
Title Page
1. Project building name, ERP number, and official street address
2. Sheet Index
3. University Project Number (all sheets)
4. Project Team (all sheets)
5. Drawing issue date (all sheets)
6. Signature certification block (all sheets)
7. Location Plan
8. Key Plan (all sheets)
9. Scale, Notes, Symbols, and call-out identification systems (all sheets)
10. Materials, hatching, and other pattern identification symbols key
11. Comprehensive Code Data Block:
a. List all applicable current codes
b. Occupant groups and loads
c. Plumbing fixture analysis (actual and minimums)
d. WAC/SAC analysis
e. Required separation of occupancies
f. Floor area and height/number of stories
g. Allowable square footage and actual square footage
h. Types of construction
i. Fire-resistive rated construction
j. Design loads
k. Frost depth
l. Interior wall and ceiling finish (sprinklered/unsprinklered)

Coordinated Architectural Site Plan
1. Confirmed property lines and required setbacks
2. Comprehensive utility plans
3. Emergency apparatus access and staging plan
4. Life Safety Plan with egress routes and ADA accessibility
5. Construction access, loading, and circulation
6. Construction staging and storage areas
7. Crane and other equipment locations
8. Temporary fencing
9. Storm water and silt controls
10. Construction parking types and locations (obtain Parking and Transportation approval)
11. Landscaping coordination plan
12. Permanent access, loading, and circulation
13. Site lighting coordination plan
14. Permanent fencing coordinated with Landscape Plans
15. Retaining walls coordinated with Landscape Plans
16. Permanent parking stall types and locations (obtain Parking and Transportation approval)
17. Enlarged site details and sections
18. Site signage

Building Plans
1. Demolition plans and details (where required)
2. Selective demolition plans and details (where required)
3. Testing/investigative location plans (where required)
4. Structural plan with column spacing and shear wall locations
5. Scaled floor and roof plans with appropriate dimensions and University room numbers
6. Utility main and entrance locations
7. Mechanical, Electrical, and Telecom Room layouts and coordination plan
8. Recycling Room(s)
9. Janitor Room(s)
10. Door locations with swings
11. Vertical circulation locations and sizes
12. Reflected ceiling plans
13. Show fire separation rated walls on reflected ceiling plans
14. Room materials, casework, and equipment layouts
15. Furniture Plan
16. Lab Equipment Plan
17. Kitchens and Specialty Equipment Plan
18. Classroom requirements and specifications

Elevations
1. Exterior elevations indicating:
   a. Location of fixed and operable windows
   b. Curtain walls and specialty partitions
   c. Doors and access panels
   d. Overall dimensions and floor-to-floor heights
   e. Air intakes and exhausts
   f. Fire apparatus connections and hose bibs
   g. Utility connections and meters
2. Exterior cladding systems finish materials, and colors
3. Exterior architectural lighting and locations
4. Roof profile and finish material(s)
   a. Roof top equipment and screening
   b. Roof access and safety barriers
   c. Rainwater distribution systems
5. Interior elevations of restrooms, major/complicated spaces (e.g. auditoriums, classrooms)

Sections
1. Building sections showing floor-to-floor heights and space relationships (including instructional space elevations)
2. Exterior wall sections
3. Stair, elevator, and shaft sections
4. Sections of major complicated spaces
5. Tunnels

Scaled Details and Schedules
1. Exterior wall details
2. Roof details
3. Floor and floor finish details
4. Wall types
5. Casework details
6. Ceiling details
7. Interior details
8. Significant structural details
9. Door and door frame types
10. Window types
11. Door and window details
12. Door and window schedule
13. Room finish schedule
14. Restroom and plumbing fixture details
15. ADA-required details
16. Specialty walls
17. Specialty equipment

Mechanical

Mechanical Site Plan
1. Coordinated mechanical site plan where applicable

Equipment – spec, location and operation
1. Turbine
2. Compressor
3. Heat Exchanger
4. Cooling Tower
5. Condenser
6. Pump
7. Separator
8. Demister
9. Generator
10. NCG system

Controls and Instrumentation Plan
1. Control/Energy Management system equipment layout plan
2. Thermostats and low-voltage wiring

HVAC Plan
1. HVAC Equipment Plan
2. HVAC Ductwork Plan
3. HVAC Piping Plan
4. Point, Valve, and Damper Schedules

Dust and Fume Collection Systems
1. Dust and Fume Collection Equipment Plan
2. Dust and Fume Ductwork Plan

Steam Systems
1. Steam systems equipment
2. Steam systems condensate piping
3. Steam systems low-pressure piping
4. Steam systems high-pressure piping

Refrigeration Systems
1. Refrigeration equipment
2. Refrigeration piping

Electric Heat and Other Specialty Equipment
1. System description, layout, and coordination plans for specialty systems

Elevations, Sections, Details
1. Scaled layouts, elevations, sections, details, and coordination plans for individual mechanical systems as applicable

Plumbing
Site Plan
1. Coordinated plumbing site plan where applicable

Plumbing Plan
1. Acid, alkaline, and oil waste systems
2. Domestic hot and cold water systems
3. Sanitary drainage
4. Storm drainage system
5. Miscellaneous plumbing equipment
6. Plumbing fixtures
7. Scaled layouts, elevations, sections, details, and coordination plans for individual plumbing systems as applicable
8. Medical gases and tanks
9. Laboratory services

Electrical
Electrical Site Plan
1. Coordinated electrical site plan where applicable

Communication Plan
1. Auxiliary systems (e.g. bell, call, clock, paging, intercom, security, etc.)
2. Sound systems, AV equipment, TV, and other classroom equipment schedules and plans

Grounding Plan
1. Lightning protection systems

Lighting Plan
1. Special, emergency, and exit lighting plans
2. Ceiling, wall, and floor-mounted lighting plans
3. Luminaire identification and schedules
4. Lighting, switching, and circuiting plans

Power Plan
1. Site power plan
2. Power panels and grounding system
3. Power equipment
4. Power switchboards
5. Power circuits, floor raceways, under-carpet, and other power distribution
6. Cable trays, feeders, and buss ways
7. Wall, ceiling, special receptacle, and device plans
8. Emergency power systems

Telecommunications
Site Plan
1. Coordinated telecommunications site plan where applicable

Data Plan
1. Data equipment, distribution, and outlet plan

Telephone Plan
1. Telephone equipment, distribution, and outlet plan

Fire Protection
Sprinkler Plan
1. CO2 system
2. Halon system
3. Standpipe system
4. Sprinkler head and piping system
5. Fire system equipment (hoses and extinguishers)
6. Fire alarm system (including detectors and sensors)
7. Scaled layouts, elevations, sections, details, and coordination plans for individual fire protection systems as applicable

Landscape Architecture
Landscape Site and Planting Plan
1. Coordinated landscape site plan as applicable

Plant and Landscape Materials
1. Existing trees to remain
2. New trees
3. Trees to be removed
4. Other plant materials
5. Rock, bark, mulch
6. Lawn areas

Irrigation System
1. Sprinklers
2. Piping
3. Equipment
4. Coverage
5. Controls

Site Improvements
1. Walks and Steps
2. Fencing
3. Walls
4. Decks and Plazas
5. Site furnishings
6. Other structures
7. Scaled layouts, elevations, sections, details, and coordination plans for individual landscape items as applicable

Project Manual
1. ERP Project Name and Number (all pages)
2. Project Team (all pages)
3. Contract Document issue date (all pages)
4. Signature certification block by professional discipline
5. General Requirements with Bidding Documents
6. Owner provided information available to bidders/proposers where applicable
7. Design Intent Statements for all disciplines (C/S/A/M/E/P/FP etc.)
8. Specifications by current CSI divisions and format
9. Appropriate language for project labor agreement (if necessary)