ETM 530/630 DECISION MAKING SPRING 2017

TEAM PROJECT

Application of Decision Making to Evaluate Renewable Energy Alternatives for Hawaii Island

GROUP D

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AGENDA

- KEY DECISION
- INTRODUCTION
- DATA USED
- METHODOLOGY
- MODEL
- FINDINGS
- DISCUSSION
- FUTURE RESEARCH
- REFERENCE

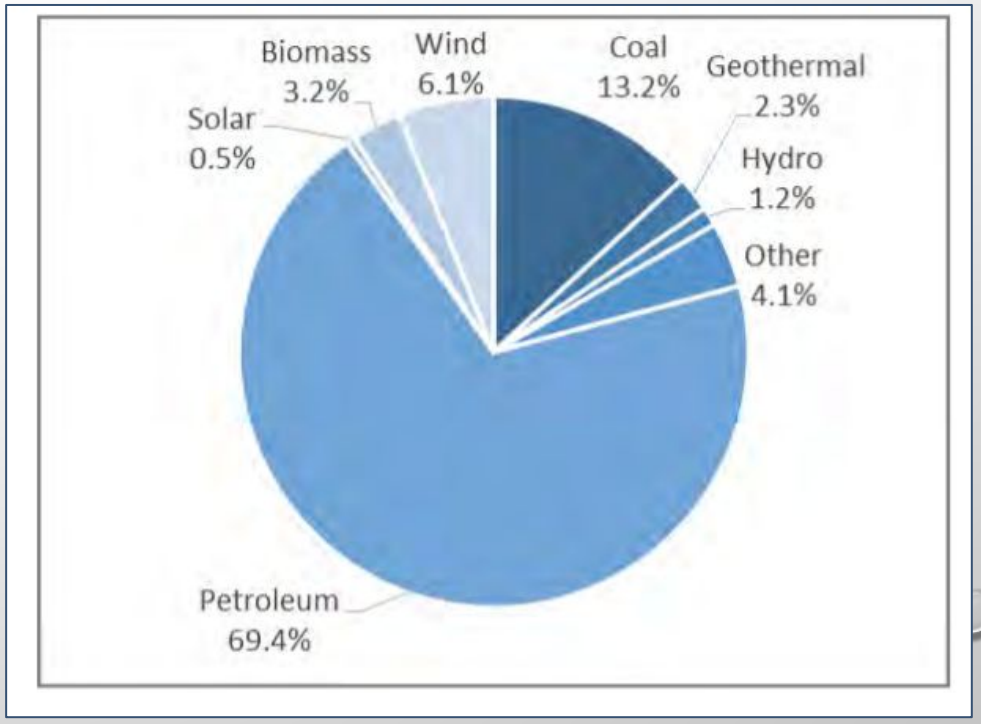
KEY DECISION

To develop a hierarchical decision model (HDM) for evaluating three renewable energy alternatives for Hawaii Island.

INTRODUCTION

Hawaii's goal: using energy efficiency and renewable resources to supply 70% or more of Hawaii's energy needs by 2030 and 100% by 2045 (at 23.4% in 2015) [12]

- Hawaii is the only state in U.S. that depends heavily on oil and coal for its energy needs [13]
- The state is currently using imported oil to meet 95% of the energy demands [12]
- Hawaii's electricity prices are almost two times higher than the U.S. average [13]
- Each of Hawaii's six main islands has its own electrical grid and NOT connected to any other island [13]
- Over the past decade, renewable energy has been increased in all counties of Hawaii [13]



Hawaii Electricity Production by Source in 2015 [13]

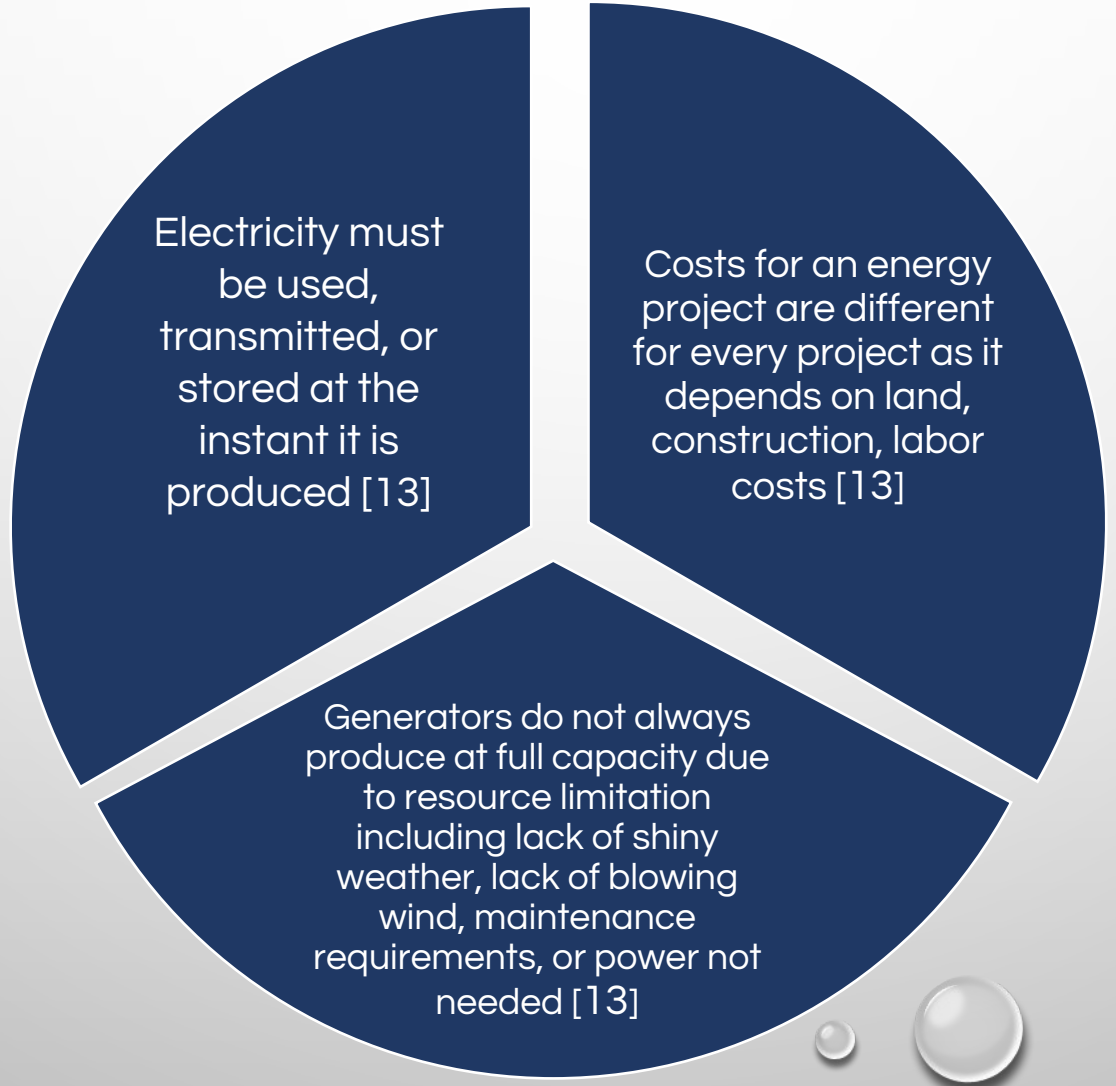
Renewable Energy Options in Hawaii

The islands of Hawaii have abundant natural resources

There are different options for harnessing natural resources to achieve Hawaii's clean energy goals

Options	Main source for producing energy in Hawaii [1]
Bioenergy	Organic materials such as leaves, branches, wood chips, paper, algae
Geothermal	Associated with areas of volcanic activities
Hydroelectric /Hydropower	Flowing water through turbines
Ocean	Waves
Solar	Sun (used in two types of solar thermal and photovoltaic)
Wind	Force of the wind

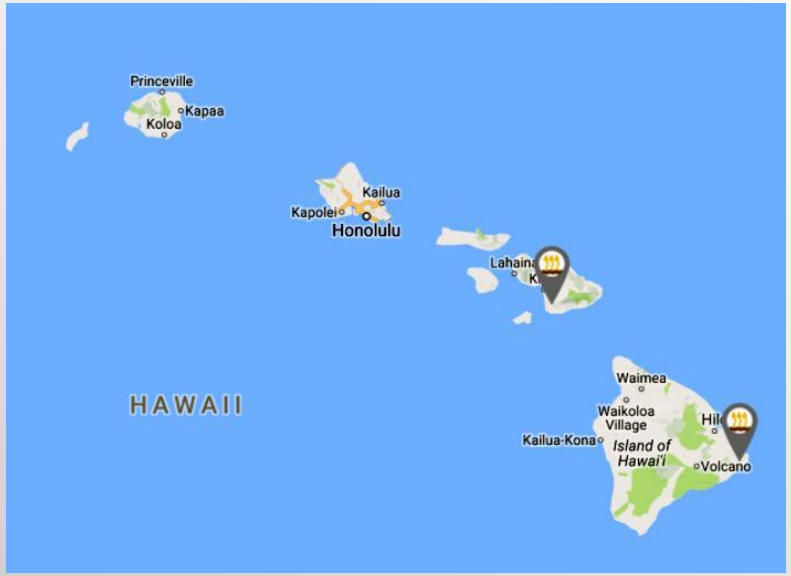
Limitations of Renewable Energy in Hawaii



Renewable Energy Projects in Hawaii

All renewable Energy Projects in Hawaii with different types of technology, until Spring 2017
(Biofuel, Biomass, Geothermal, Hydroelectric, Ocean, Solar, Waste to Energy, and Wind)

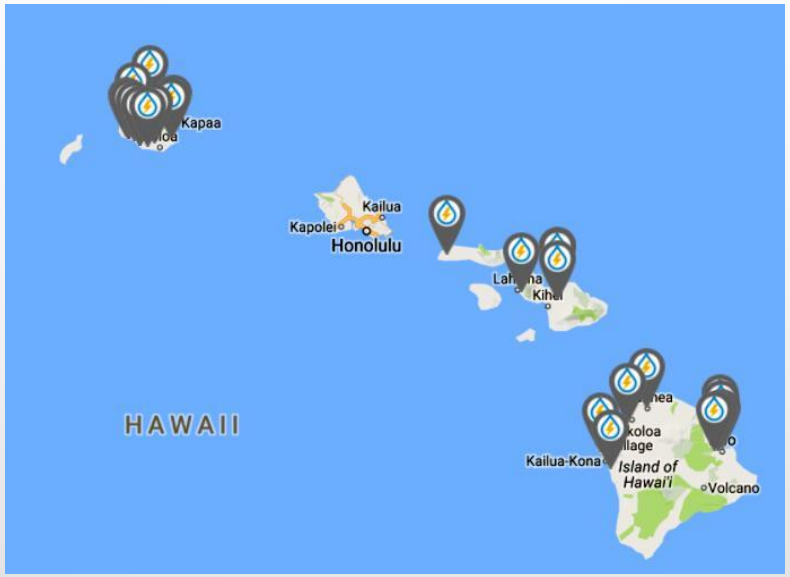
117 Projects (69 Existing +48 proposed/under development)



Geothermal Projects: 2

(1 Existing +1 proposed/under development)

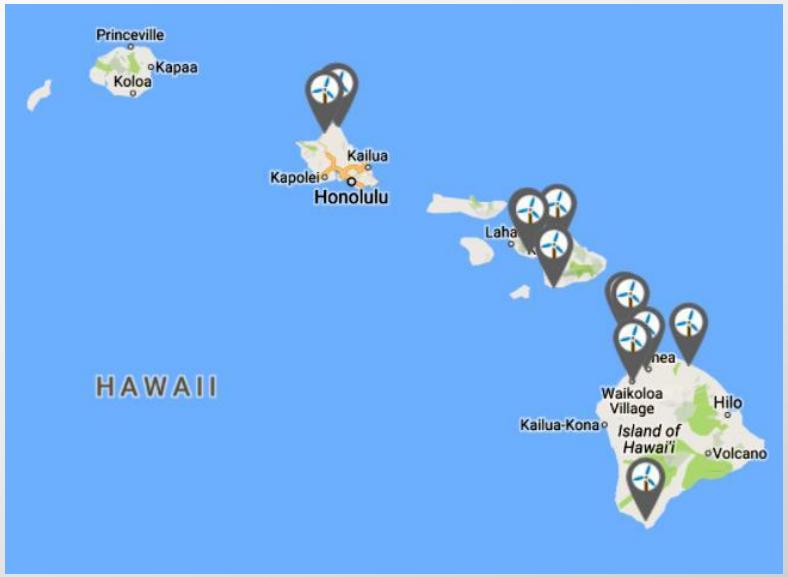
Total Capacity: 38 MW + TBD



Hydroelectric Projects: 29

(21 Existing +8 proposed/under development)

Total Capacity: 68.5 MW (Largest cap 25)



Wind Projects: 13

(9 Existing +4 proposed/under development)

Total Capacity: 229.76 MW (Largest cap 69)

Source: https://energy.ehawaii.gov/epd/public/energy-projects-map.html

DATA USED

- Literature Reviews: based on scholarly articles in identifying the main criteria, sub-criteria, and alternatives

- Experts
  - Two Hawaii professional experts:
    - Veronica Rocha: Renewable energy program manager, Hawaii State Energy Office
    - Saeed Sepasi: Postdoctoral, Hawaii National Energy Institute
  - Four graduate students from PSU

LIST OF ENTITIES
County of Maui, Hawaii, Office of Economic Development
Maui Economic Development Board
Electric Power Research Institute
Hawaii Natural Energy Institute
Hawai'i Energy
Hawaii State Energy Office
National Council for Science and Environment
University of Hawaii

Source: http://hawaiiindependent.net/story/wind-farms-in-hawaii

ALTERNATIVES

Source: http://vibhudhawij.weebly.com/geothermal-energy.html

Source: https://carbonzerohome.org/environment/solutions/

Hydropower in Hawaii

- Hydropower is derived from the force or energy of moving water [17]
- The State of Hawaii has high rainfall, steep temperature gradients between shallow and deep ocean waters, and a favorable wave climate. These resources provide favorable conditions for ocean and hydropower [12]
- Studies have identified 47 potential sites for small-scale hydroelectric projects in Hawaii [13]
- Hydropower produced 3.6% of Hawaii total renewable energy portfolio in 2016 [13]

Wailuku River Hydroelectric built in 1993 for generating 11MW electricity

(Source: Hawaiian Electric, https://www.hawaiianelectric.com/)

Wind Power in Hawaii

- Wind turbines capture the wind's energy with two or three propeller-like blades, which are mounted on a rotor to generate electricity [1] [17]

- Hawaii has one of the most robust and consistent wind regimes in the world, with capacity factors exceeding those commonly found elsewhere [13]

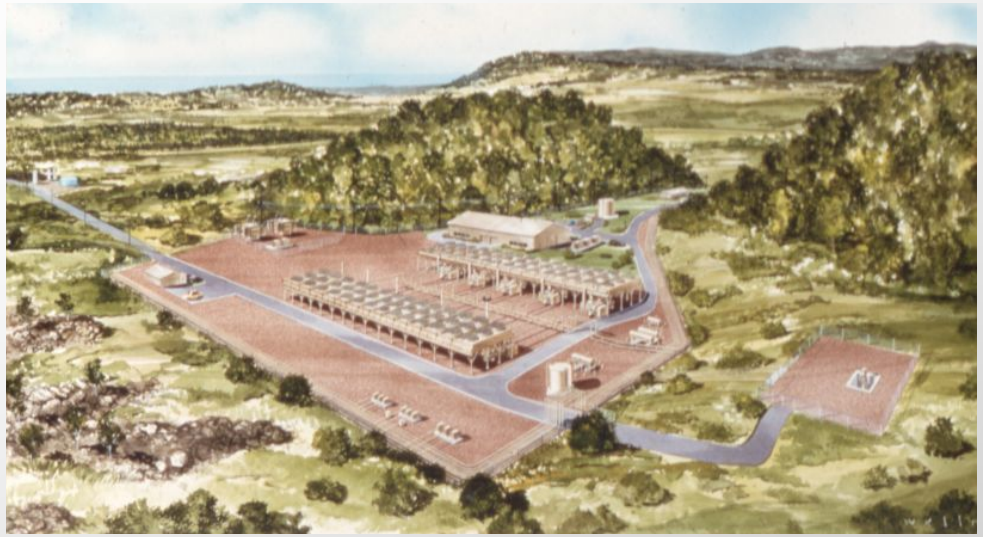
- Wind energy is Hawaii's second utilized renewable energy resource with producing of 27% of Hawaii total renewable energy portfolio in 2016 [13]

Picture of construction Pakini Nui Wind Farm in early 2007, as one of the largest wind farms in Hawaii for generating 21 MW electricity

(Source: Tawhiri Power LLC, http://www.tawhiri.us/)

Geothermal Power in Hawaii

- "Geothermal power is energy generated by heat stored beneath the Earth's surface" [17]
- "Geothermal energy taps the volcanically-heated water and steam that occurs naturally in certain areas in Hawaii, particularly the younger islands of Maui and Hawaii where volcanic activity has been most recent" [1]
- Geothermal energy provided 10.5% of Hawaii total renewable energy portfolio in 2016 [13]



Picture of the Puna Geothermal Venture, as the only geothermal power plant in Hawaii, for generating 21 MW electricity

(Source: Hawai'i Groundwater and Geothermal Resources Center, https://www.higp.hawaii.edu/hggrc/)

CRITERIA & SUB-CRITERIA

ECONOMIC

This criteria includes capital investments, fixed, and variable cost of the facility [16]

Potential Economic Issues [14]:

- Wind: Onshore wind costs are in the range of fossil electricity costs, offshore costs are higher
- Geothermal: Enhanced geothermal system (EGS) costs are estimates only, obtaining funds can be difficult and costly
- Hydropower: Emerging small/low-head hydro costs unknown

INITIAL COST

Investment cost including civil and structural costs, and purchase and installation of mechanical equipments [4]

OPERATION COST

Refers to the cost incurred in power plant's operations including employees' wages, the funds spent for the energy, the products and services for the energy system operation [15]

MAINTENANCE COST

Aims to prolong energy system life and avoid failures that may lead to its operation suspension [15]

TECHNICAL

Technical factors focus on production efficiency of the generation source [16]

Potential Technical Issues [14]:

- Wind: resource intermittency and variability, operating in a corrosive marine environment and installation of equipment at various water depths (for offshore technology). Grid power system requires constant monitoring and control to balance supply and demand
- Geothermal: EGS technology is not yet commercially available
- Hydropower: resource variability based on annual rain/snow fall

EFFICIENCY

Amount of useful energy obtained from energy resource [15]

RELIABILITY

The performance of the energy supply technology consistent and replicable under expectable circumstances [19]

EASE OF INTEGRATION

connection to the electric power grid [14]

ENVIRONMENTAL

Capturing and converting any energy source—including renewable energy—will have some degree of impact on the environment. [14]

Potential Environmental Issues [14]:

- Wind: Land use, habitat disturbance, bird mortality, and noise
- Geothermal: Water use, land subsidence, and seismicity
- Hydropower: water quality degradation, ecosystem disruption, and animal mortality

REGULATIONS

Federal and state regulations such as clean energy standard [14]

POLLUTION

- It's cleaner, less impact on the environment [6].
- Greenhouse gas emissions, climate change [14]

ECOSYSTEM PROTECTION

- Restore the balance between humans and Mother Nature [6].
- Refers to the potential risk to ecosystems caused by the production of the various projects [14].

SOCIAL

Social aspects were definitely the most important criteria for people's acceptance of energy systems during the past decades [15].

Potential Social Issues for three options:

- Energy continues to be a key factor shaping Hawaii's economy, environment, and standard of living. A stable energy supply is essential to continued prosperity [21]

HEALTH

Health effects of the renewable energy generation [15]

SAFETY

Effects of energy system to society and people [15]

JOB CREATION

Creating more energy system jobs opportunities contributing to the local economy [6][15]

METHODOLOGY

Literature Review and Data Collection

- Main Objective
- Significance
- Criteria
- Sub-criteria
- Alternatives

→

Hierarchical Decision Model Development

- PSU online HDM tool [3]

↓

Expert Judgments Data Collection

- Pairwise comparisons

↓

Expert Judgments Data Review and Aggregate Weights Calculation

- Inconsistency checks
- Disagreement checks
- Delphi
- Average and Normalized Weights

→

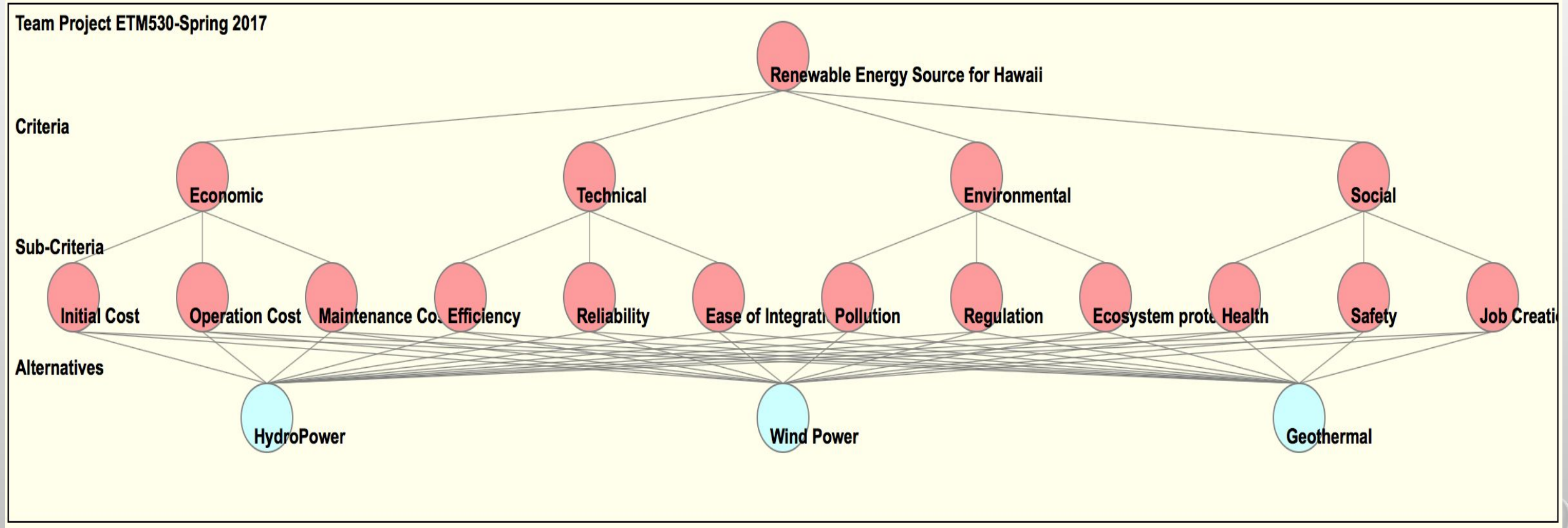
Ranking and Analyses

- Top three sub-criteria
- Top alternative

HDM LITERATURE REVIEW

- Hierarchical Decision Model (HDM)
  - Uses the same basic concept as the Analytic Hierarchical Process (AHP) developed by Saaty [2][5]
  - (AHP) Provides priorities for alternatives based on the experts' judgments [4]
  - An effective quantitative decision-support method to deal with complex multi-attribute decisions [4]
  - The most recognizable methods for subjective approaches [7] [8] [9]
  - The framework is developed based on pair-wise comparisons to quantify expert decisions [4]
  - HDM has been used widely for applications in different fields for the last 25 years [7] [10] [11]

MODEL



Source: http://research1.etm.pdx.edu/hdm2/Model.aspx?id=346f3ae3e1bc9a80/ad6875cbf429aa71

FINDINGS & DISCUSSION

INCONSISTENCY AND DISAGREEMENT

Renewable Energy Source for Hawaii	HydroPower	Wind Power	Geothermal	Inconsistency
EXP1	0.29	0.26	0.45	0.01
EXP2	0.34	0.25	0.41	0
EXP3	0.38	0.20	0.43	0.01
EXP4	0.29	0.41	0.30	0.01
EXP5	0.30	0.54	0.16	0.01
EXP6	0.32	0.16	0.52	0.03
Mean	**0.32**	**0.30**	**0.38**	
Minimum	**0.29**	**0.16**	**0.16**	
Maximum	**0.38**	**0.54**	**0.52**	
Std. Deviation	**0.03**	**0.13**	**0.12**	
Disagreement				**0.091**

AGGREGATE WEIGHTS

Level 1				
Experts	Economic	Technical	Environmental	Social
EXP1	0.34	0.30	0.18	0.18
EXP2	0.22	0.33	0.27	0.18
EXP3	0.24	0.46	0.11	0.20
EXP4	0.25	0.19	0.41	0.15
EXP5	0.29	0.19	0.35	0.16
EXP6	0.25	0.25	0.25	0.25
Average	**0.27**	**0.29**	**0.26**	**0.19**

AGGREGATE WEIGHTS

Level 2					
Sub-Criteria	**Economic**	**Technical**	**Environmental**	**Social**	**Normalized Weight**
Initial Cost	0.41	0.00	0.00	0.00	0.11
Operation Cost	0.30	0.00	0.00	0.00	0.08
Maintenance Cost	0.29	0.00	0.00	0.00	0.08
Efficiency	0.00	0.31	0.00	0.00	0.09
Reliability	0.00	0.42	0.00	0.00	0.12
Ease of Integration	0.00	0.28	0.00	0.00	0.08
Pollution	0.00	0.00	0.27	0.00	0.07
Regulation	0.00	0.00	0.30	0.00	0.08
Ecosystem protection	0.00	0.00	0.44	0.00	0.11
Health	0.00	0.00	0.00	0.43	0.08
Safety	0.00	0.00	0.00	0.38	0.07
Job Creation	0.00	0.00	0.00	0.19	0.04

AGGREGATE WEIGHTS

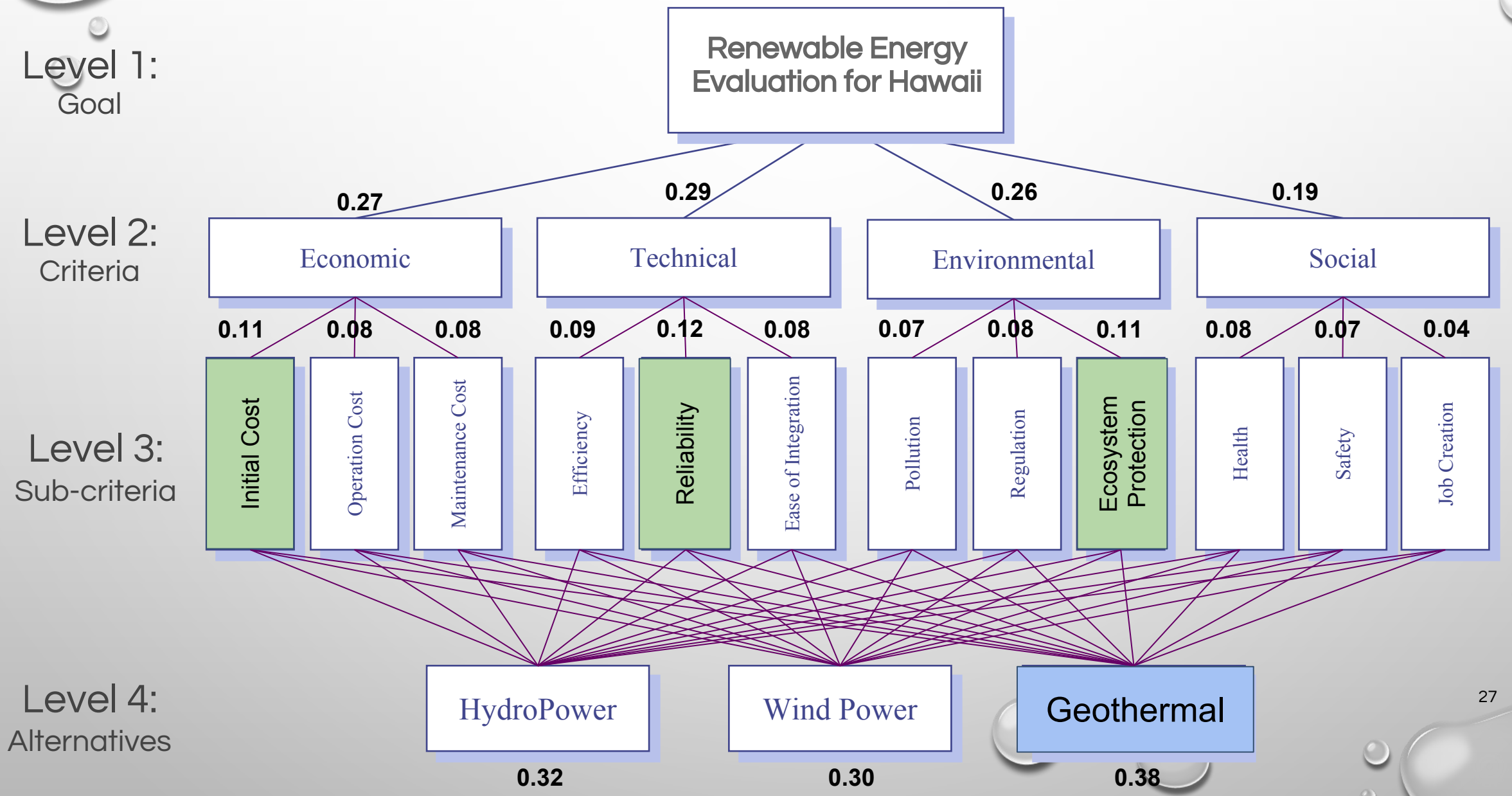
Level 3													
Experts	Source	Initial Cost	Operation Cost	Maintenance Cost	Efficiency	Reliability	Ease of Integration	Pollution	Regulation	Ecosystem protection	Health	Safety	Job Creation
EXP1	HydroPower	0.47	0.20	0.40	0.31	0.21	0.49	0.47	0.08	0.26	0.21	0.11	0.15
	Wind Power	0.23	0.44	0.39	0.21	0.11	0.18	0.18	0.60	0.16	0.09	0.30	0.05
	Geothermal	0.30	0.36	0.21	0.48	0.68	0.33	0.36	0.32	0.58	0.71	0.59	0.80
EXP2	HydroPower	0.49	0.39	0.47	0.14	0.30	0.21	0.35	0.33	0.35	0.44	0.46	0.23
	Wind Power	0.13	0.13	0.16	0.22	0.16	0.15	0.42	0.33	0.41	0.32	0.32	0.15
	Geothermal	0.39	0.49	0.37	0.64	0.54	0.64	0.22	0.33	0.23	0.24	0.22	0.62
EXP3	HydroPower	0.45	0.35	0.52	0.41	0.30	0.37	0.30	0.39	0.40	0.40	0.40	0.32
	Wind Power	0.17	0.16	0.12	0.16	0.17	0.27	0.34	0.24	0.21	0.23	0.24	0.21
	Geothermal	0.38	0.50	0.36	0.43	0.53	0.36	0.36	0.37	0.39	0.38	0.36	0.48
EXP4	HydroPower	0.25	0.32	0.24	0.32	0.29	0.30	0.25	0.31	0.29	0.26	0.31	0.33
	Wind Power	0.45	0.42	0.44	0.40	0.44	0.40	0.42	0.39	0.41	0.39	0.39	0.33
	Geothermal	0.30	0.26	0.31	0.28	0.27	0.30	0.33	0.30	0.30	0.35	0.30	0.33
EXP5	HydroPower	0.32	0.29	0.27	0.31	0.24	0.20	0.21	0.38	0.35	0.29	0.24	0.53
	Wind Power	0.50	0.54	0.59	0.52	0.62	0.67	0.69	0.38	0.53	0.56	0.58	0.32
	Geothermal	0.18	0.17	0.14	0.17	0.14	0.12	0.10	0.24	0.12	0.15	0.17	0.15
EXP6	HydroPower	0.39	0.28	0.29	0.25	0.21	0.22	0.22	0.51	0.67	0.08	0.14	0.22
	Wind Power	0.10	0.13	0.12	0.08	0.05	0.60	0.17	0.09	0.24	0.24	0.13	0.19
	Geothermal	0.50	0.59	0.59	0.67	0.74	0.18	0.62	0.40	0.09	0.69	0.73	0.58

Average	Initial Cost	Operation Cost	Maintenance Cost	Efficiency	Reliability	Ease of Integration	Pollution	Regulation	Ecosystem protection	Health	Safety	Job Creation
HydroPower	0.40	0.31	0.37	0.29	0.26	0.30	0.30	0.33	0.39	0.28	0.28	0.30
Wind Power	0.26	0.30	0.30	0.27	0.26	0.38	0.37	0.34	0.33	0.31	0.33	0.21
Geothermal	0.34	0.40	0.33	0.45	0.48	0.32	0.33	0.33	0.29	0.42	0.40	0.49

AGGREGATE WEIGHTS

Final Result							
Source	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	**Average**
HydroPower	0.29	0.34	0.38	0.29	0.30	0.32	0.32
Wind Power	0.26	0.25	0.20	0.41	0.54	0.16	0.30
Geothermal	0.45	0.41	0.43	0.30	0.16	0.52	0.38

FINAL, QUANTIFIED MODEL



DISCUSSION

- Top three sub-criteria contributing to the result:
  - Reliability (0.12)
  - Initial Cost (0.11)
  - Ecosystem Protection (0.11)

- Final ranking:
  - Geothermal (0.38) - **top alternative**
  - Hydropower (0.32)
  - Wind Power (0.30)

DISCUSSION: Geothermal Analysis

- Reliability: Geothermal promises a firm source of renewable energy [1]

- Initial Cost: Unit Capital Cost is estimated at $2,500/kW to $5,000/kW
  - Geothermal electricity is cheaper than compared to energy from petroleum and other renewable energy [13]

- Ecosystem Protection: Ecosystem concerns are evaluated and helped through advanced technology and resource understanding [13]

- Further developments on geothermal energy considers environmental impact analysis, proper planning, and community engagement before determining any decision [13]

LIMITATIONS

- **Lack of experts**
  - Some experts that we contacted didn't feel they can provide judgments on some criteria
  - Suggestion to identify panel of experts grouped based in a specific area of expertise

- **Lack of time for experts to evaluate the model**
  - We contacted 30 experts, we received 2 responses (given 10 days to respond)
  - Suggestion to identify experts at the beginning stage of the research project as to give them plenty of time to provide their inputs and also get them involved during the model development stage

FUTURE RESEARCH

- **Sensitivity Analysis.** Final ranking of the alternatives can be sensitive to changes in the model [5], hence for robustness check, a sensitivity analysis is recommended

- Why the number of Geothermal projects in Hawaii is significantly lower compared to Hydropower and Windpower?[22]

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BACKUP

Level-1	Renewable Energy Source for Hawaii
Economic	0.34
Technical	0.30
Environmental	0.18
Social	0.18
Inconsistency	0.03

Level-2	Economic	Technical	Environmental	Social
Initial Cost	0.31	0.00	0.00	0.00
Operation Cost	0.27	0.00	0.00	0.00
Maintenance Cost	0.42	0.00	0.00	0.00
Efficiency	0.00	0.29	0.00	0.00
Reliability	0.00	0.49	0.00	0.00
Ease of Integration	0.00	0.22	0.00	0.00
Pollution	0.00	0.00	0.32	0.00
Regulation	0.00	0.00	0.45	0.00
Ecosystem protection	0.00	0.00	0.24	0.00
Health	0.00	0.00	0.00	0.35
Safety	0.00	0.00	0.00	0.45
Job Creation	0.00	0.00	0.00	0.19
Inconsistency	0.00	0.00	0.00	0.01

Level-3	Initial Cost	Operation Cost	Maintenance Cost	Efficiency	Reliability	Ease of Integration	Pollution	Regulation	Ecosystem protection	Health	Safety	Job Creation
HydroPower	0.47	0.20	0.40	0.31	0.21	0.49	0.47	0.08	0.26	0.21	0.11	0.15
Wind Power	0.23	0.44	0.39	0.21	0.11	0.18	0.18	0.60	0.16	0.09	0.30	0.05
Geothermal	0.30	0.36	0.21	0.48	0.68	0.33	0.36	0.32	0.58	0.71	0.59	0.80
Inconsistency	0.02	0.01	0.00	0.02	0.00	0.02	0.03	0.03	0.02	0.00	0.03	0.00

The final result:

Level-1	Renewable Energy Source for Hawaii
HydroPower	0.29
Wind Power	0.26
Geothermal	0.45
Inconsistency	0.01

Level-1	Renewable Energy Source for Hawaii
Economic	0.22
Technical	0.33
Environmental	0.27
Social	0.18
Inconsistency	0.00

Level-2	Economic	Technical	Environmental	Social
Initial Cost	0.40	0.00	0.00	0.00
Operation Cost	0.33	0.00	0.00	0.00
Maintenance Cost	0.27	0.00	0.00	0.00
Efficiency	0.00	0.27	0.00	0.00
Reliability	0.00	0.40	0.00	0.00
Ease of Integration	0.00	0.33	0.00	0.00
Pollution	0.00	0.00	0.41	0.00
Regulation	0.00	0.00	0.18	0.00
Ecosystem protection	0.00	0.00	0.41	0.00
Health	0.00	0.00	0.00	0.51
Safety	0.00	0.00	0.00	0.31
Job Creation	0.00	0.00	0.00	0.19
Inconsistency	0.00	0.00	0.00	0.00

Level-3	Initial Cost	Operation Cost	Maintenance Cost	Efficiency	Reliability	Ease of Integration	Pollution	Regulation	Ecosystem protection	Health	Safety	Job Creation
HydroPower	0.49	0.39	0.47	0.14	0.30	0.21	0.35	0.33	0.35	0.44	0.46	0.23
Wind Power	0.13	0.13	0.16	0.22	0.16	0.15	0.42	0.33	0.41	0.32	0.32	0.15
Geothermal	0.39	0.49	0.37	0.64	0.54	0.64	0.22	0.33	0.23	0.24	0.22	0.62
Inconsistency	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The final result:

Level-1	Renewable Energy Source for Hawaii
HydroPower	0.34
Wind Power	0.25
Geothermal	0.41
Inconsistency	0.00

Level-1	Renewable Energy Source for Hawaii
Economic	0.24
Technical	0.46
Environmental	0.11
Social	0.20
Inconsistency	0.04

Level-2	Economic	Technical	Environmental	Social
Initial Cost	0.56	0.00	0.00	0.00
Operation Cost	0.28	0.00	0.00	0.00
Maintenance Cost	0.16	0.00	0.00	0.00
Efficiency	0.00	0.25	0.00	0.00
Reliability	0.00	0.53	0.00	0.00
Ease of Integration	0.00	0.23	0.00	0.00
Pollution	0.00	0.00	0.20	0.00
Regulation	0.00	0.00	0.44	0.00
Ecosystem protection	0.00	0.00	0.36	0.00
Health	0.00	0.00	0.00	0.54
Safety	0.00	0.00	0.00	0.29
Job Creation	0.00	0.00	0.00	0.17
Inconsistency	0.00	0.00	0.01	0.03

Level-3	Initial Cost	Operation Cost	Maintenance Cost	Efficiency	Reliability	Ease of Integration	Pollution	Regulation	Ecosystem protection	Health	Safety	Job Creation
HydroPower	0.45	0.35	0.52	0.41	0.30	0.37	0.30	0.39	0.40	0.40	0.40	0.32
Wind Power	0.17	0.16	0.12	0.16	0.17	0.27	0.34	0.24	0.21	0.23	0.24	0.21
Geothermal	0.38	0.50	0.36	0.43	0.53	0.36	0.36	0.37	0.39	0.38	0.36	0.48
Inconsistency	0.01	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01

The final result:

Level-1	Renewable Energy Source for Hawaii
HydroPower	0.38
Wind Power	0.20
Geothermal	0.43
Inconsistency	0.01

Level-1	Renewable Energy Source for Hawaii
Economic	0.25
Technical	0.19
Environmental	0.41
Social	0.15
Inconsistency	0.00

Level-2	Economic	Technical	Environmental	Social
Initial Cost	0.38	0.00	0.00	0.00
Operation Cost	0.29	0.00	0.00	0.00
Maintenance Cost	0.33	0.00	0.00	0.00
Efficiency	0.00	0.38	0.00	0.00
Reliability	0.00	0.33	0.00	0.00
Ease of Integration	0.00	0.29	0.00	0.00
Pollution	0.00	0.00	0.28	0.00
Regulation	0.00	0.00	0.29	0.00
Ecosystem protection	0.00	0.00	0.43	0.00
Health	0.00	0.00	0.00	0.28
Safety	0.00	0.00	0.00	0.48
Job Creation	0.00	0.00	0.00	0.24
Inconsistency	0.00	0.00	0.05	0.01

Level-3	Initial Cost	Operation Cost	Maintenance Cost	Efficiency	Reliability	Ease of Integration	Pollution	Regulation	Ecosystem protection	Health	Safety	Job Creation
HydroPower	0.25	0.32	0.24	0.32	0.29	0.30	0.25	0.31	0.29	0.26	0.31	0.33
Wind Power	0.45	0.42	0.44	0.40	0.44	0.40	0.42	0.39	0.41	0.39	0.39	0.33
Geothermal	0.30	0.26	0.31	0.28	0.27	0.30	0.33	0.30	0.30	0.35	0.30	0.33
Inconsistency	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00

The final result:

Level-1	Renewable Energy Source for Hawaii
HydroPower	0.29
Wind Power	0.41
Geothermal	0.30
Inconsistency	0.01

Level-1	Renewable Energy Source for Hawaii
Economic	0.29
Technical	0.19
Environmental	0.35
Social	0.16
Inconsistency	0.03

Level-2	Economic	Technical	Environmental	Social
Initial Cost	0.20	0.00	0.00	0.00
Operation Cost	0.40	0.00	0.00	0.00
Maintenance Cost	0.39	0.00	0.00	0.00
Efficiency	0.00	0.20	0.00	0.00
Reliability	0.00	0.29	0.00	0.00
Ease of Integration	0.00	0.52	0.00	0.00
Pollution	0.00	0.00	0.22	0.00
Regulation	0.00	0.00	0.37	0.00
Ecosystem protection	0.00	0.00	0.40	0.00
Health	0.00	0.00	0.00	0.41
Safety	0.00	0.00	0.00	0.35
Job Creation	0.00	0.00	0.00	0.24
Inconsistency	0.00	0.00	0.04	0.00

Level-3	Initial Cost	Operation Cost	Maintenance Cost	Efficiency	Reliability	Ease of Integration	Pollution	Regulation	Ecosystem protection	Health	Safety	Job Creation
HydroPower	0.32	0.29	0.27	0.31	0.24	0.20	0.21	0.38	0.35	0.29	0.24	0.53
Wind Power	0.50	0.54	0.59	0.52	0.62	0.67	0.69	0.38	0.53	0.56	0.58	0.32
Geothermal	0.18	0.17	0.14	0.17	0.14	0.12	0.10	0.24	0.12	0.15	0.17	0.15
Inconsistency	0.00	0.00	0.02	0.01	0.00	0.05	0.00	0.00	0.00	0.01	0.00	0.02

The final result:

Level-1	Renewable Energy Source for Hawaii
HydroPower	0.30
Wind Power	0.54
Geothermal	0.16
Inconsistency	0.01

Level-1	Renewable Energy Source for Hawaii
Economic	0.25
Technical	0.25
Environmental	0.25
Social	0.25
Inconsistency	0.00

Level-2	Economic	Technical	Environmental	Social
Initial Cost	0.58	0.00	0.00	0.00
Operation Cost	0.25	0.00	0.00	0.00
Maintenance Cost	0.18	0.00	0.00	0.00
Efficiency	0.00	0.45	0.00	0.00
Reliability	0.00	0.45	0.00	0.00
Ease of Integration	0.00	0.10	0.00	0.00
Pollution	0.00	0.00	0.17	0.00
Regulation	0.00	0.00	0.05	0.00
Ecosystem protection	0.00	0.00	0.78	0.00
Health	0.00	0.00	0.00	0.49
Safety	0.00	0.00	0.00	0.40
Job Creation	0.00	0.00	0.00	0.11
Inconsistency	0.05	0.00	0.03	0.01

Level-3	Initial Cost	Operation Cost	Maintenance Cost	Efficiency	Reliability	Ease of Integration	Pollution	Regulation	Ecosystem protection	Health	Safety	Job Creation
HydroPower	0.39	0.28	0.29	0.25	0.21	0.22	0.22	0.51	0.67	0.08	0.14	0.22
Wind Power	0.10	0.13	0.12	0.08	0.05	0.60	0.17	0.09	0.24	0.24	0.13	0.19
Geothermal	0.50	0.59	0.59	0.67	0.74	0.18	0.62	0.40	0.09	0.69	0.73	0.58
Inconsistency	0.00	0.00	0.04	0.10	0.05	0.00	0.00	0.01	0.05	0.06	0.01	0.00

The final result:

Level-1	Renewable Energy Source for Hawaii
HydroPower	0.32
Wind Power	0.16
Geothermal	0.52
Inconsistency	0.03