Geothermal Project Economics

2024 SPE Europe Energy GeoHackathon

Davis Varghese, CFA
Senior Economist
GaffneyCline™ energy advisory
Baker Hughes

Baker Hughes

ENERGY GeO Hackathon
Society of Petroleum Engineers
#DatafyingEnergy

2024 SPE Europe Energy GeoHackathon

Geothermal education.

Register Here

BootCamps Schedule – Starting October 21, 2024

Oct 21	Croatia – the geothermal energy front - the past, present and future	- Dragutin Domitrović, CEO Calida Acqua
Oct 23	Introduction to the challenge - Data review, handling | interpretation	– Josh Sellars / Mike Gunningham
Oct 24	Geothermal Reservoirs - Geology basics	– Ana Maria Alexandru, Expert Geoscience, OMV
Oct 28	Geothermal Reservoirs - Deciphering the rocks through petrophysics	– Tom Bradley, Sr.Petrophysical Advisor BH
Oct 30	Introduction to Machine Learning and Deep Learning	- Chiara Galimberti, Data & AI Scientist Expert, Eni
Nov 4	Leapfrog – Building a conceptual model	– Josh Sellars, Project Geophysicist, Seequent
Nov 6	Geothermal energy - heat flow quantification	– Yamal Askoul, Global SME Reservoir Engineering, GaffneyCline
Nov 14	Geothermal Field Development Plan - the Approach	– Tim Lines, CEO Geothermal Wells LLC
Nov 15	Geothermal energy - Project economics	– Davis Varghese, Senior Economist GaffneyCline

ALL SESSIONS WILL BE RECORDED AND MADE AVAILABLE TO PARTICIPANTS – Sessions 1,2,3 starting at 15:00 UTC

Geothermal Power Project

A typical geothermal power project has the following components:

- **Geothermal reservoir**
- **Wells**
  - Production well(s), Injection well(s)
  - Well field piping, manifolds, and circulation pump(s)
- **Geothermal power plant**
  - Steam turbine
  - Condenser or cooling tower
  - Circulating water pumps
  - Monitoring equipment
  - Instrumentation and controls
- **Electrical Infrastructure**
  - Transmission line

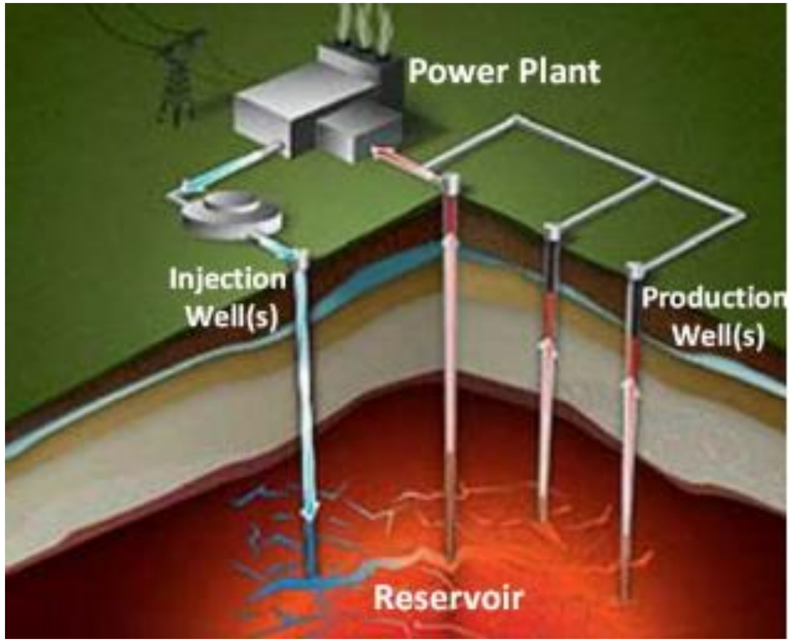
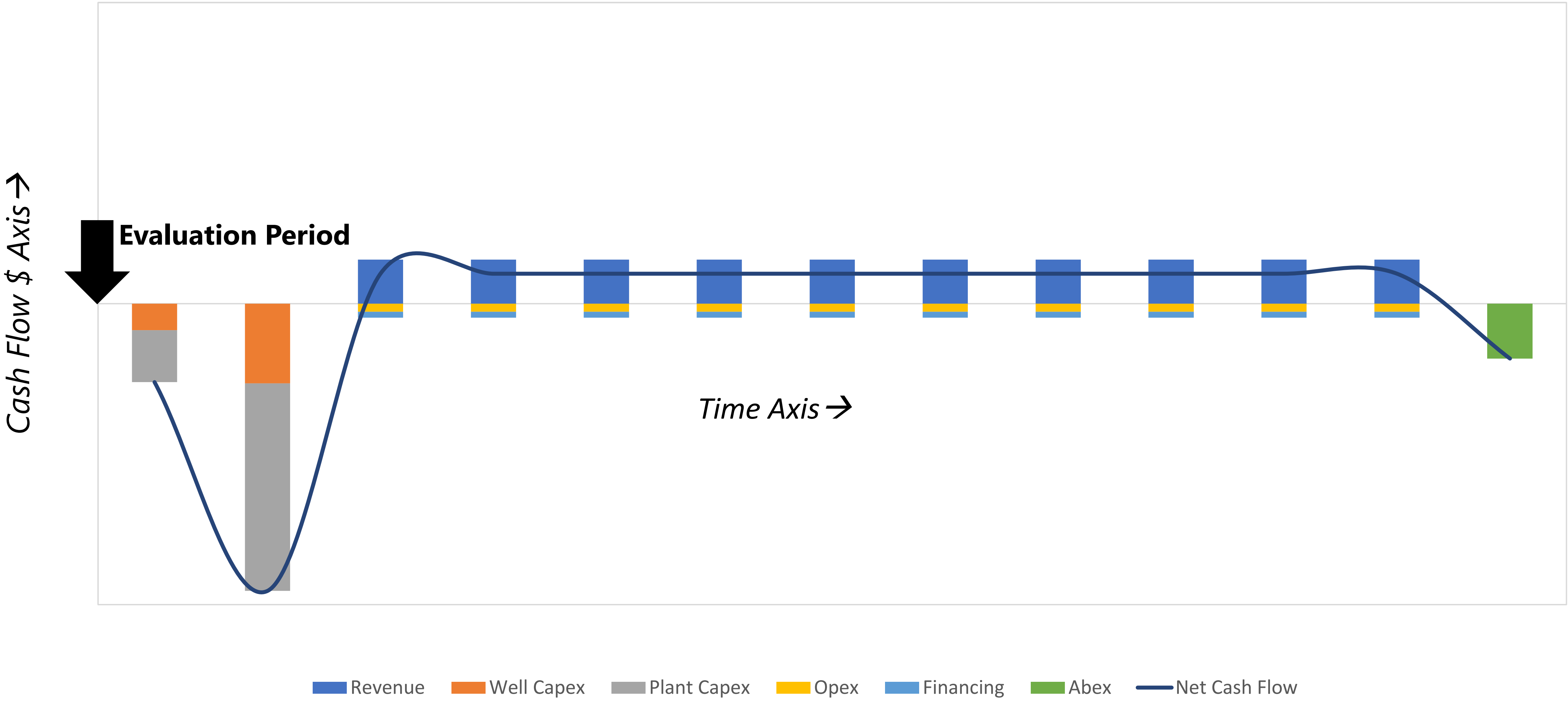


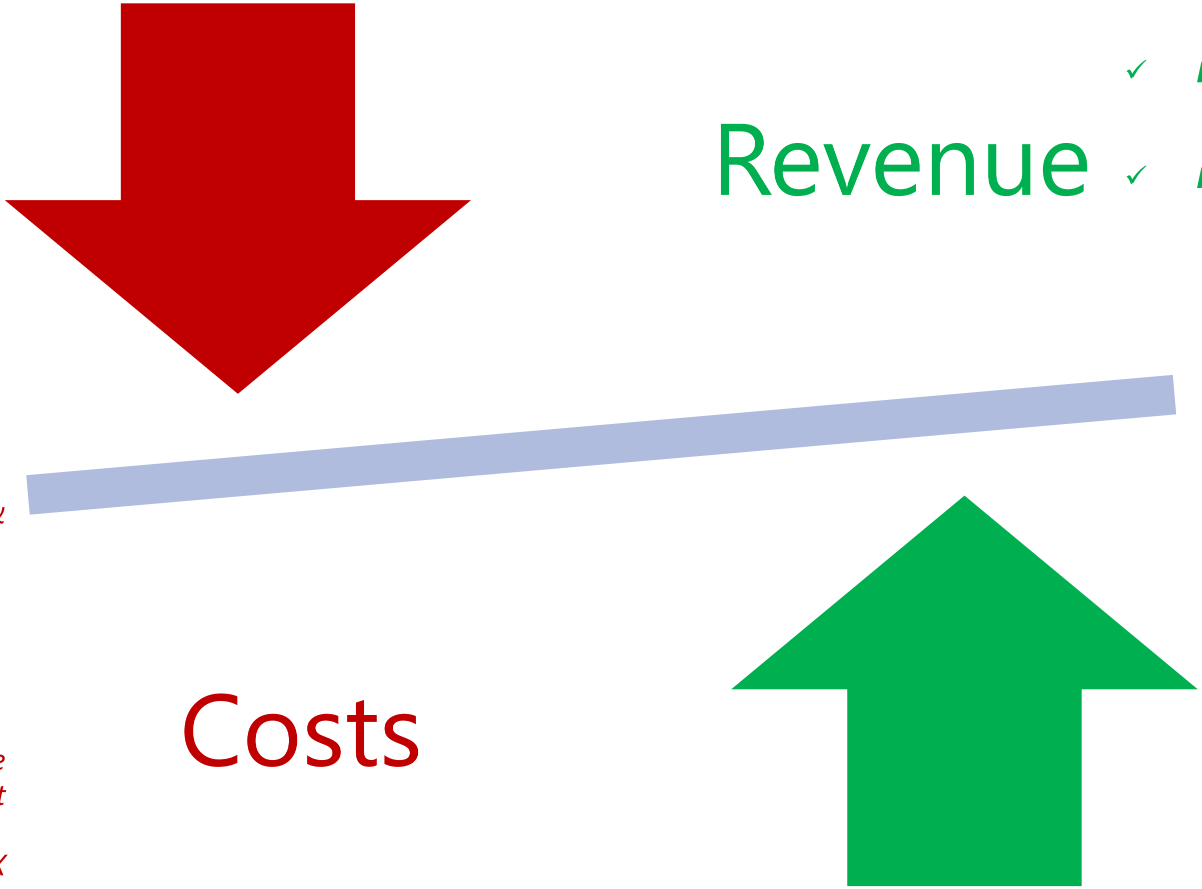
Illustration from the website of the U.S. Department of Energy Geothermal Technologies Office

Typical Geothermal Project Cashflow



Project Economics

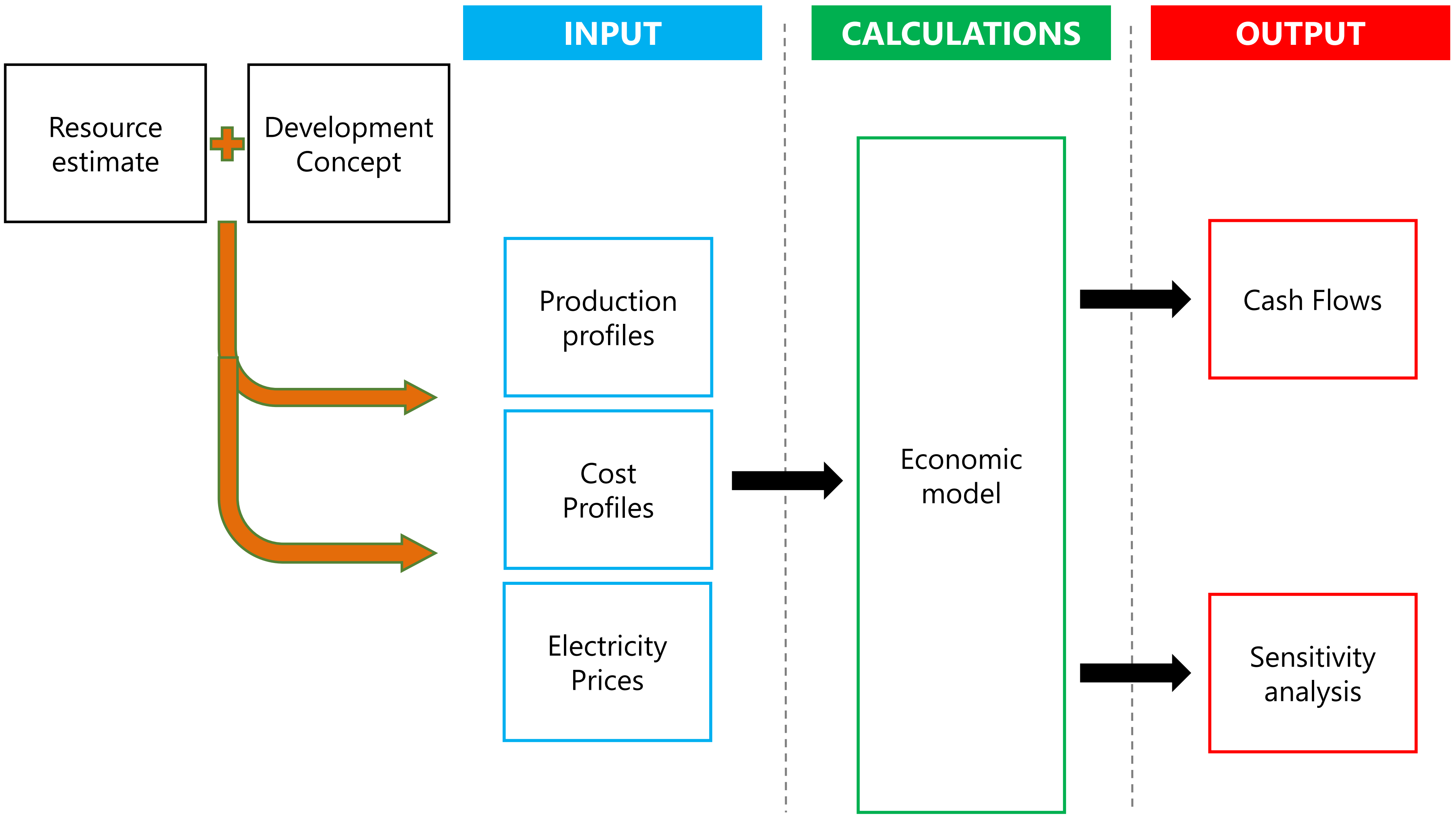
Does it make sense to invest in the Project?



- ✓ ***Production***
  - *Generation capacity (MW)*
  - *Power Plant availability*
- ✓ ***Prices***
  - *Power Purchase Agreement (PPA)*

- ✓ ***CAPEX***
  - *Wells*
  - *Power Plant EPC*
  - *Power Delivery & Integration*
- ✓ ***OPEX***
  - *O&M*
  - *Consumables*
  - *Insurances*
  - *Logistics*
  - *Major Maintenance (overhaul plant equipment every X years)*
  - *Well interventions (every X years)*
  - *G&A expenses*
- ✓ ***Financing Costs***
- ✓ ***Decommissioning***

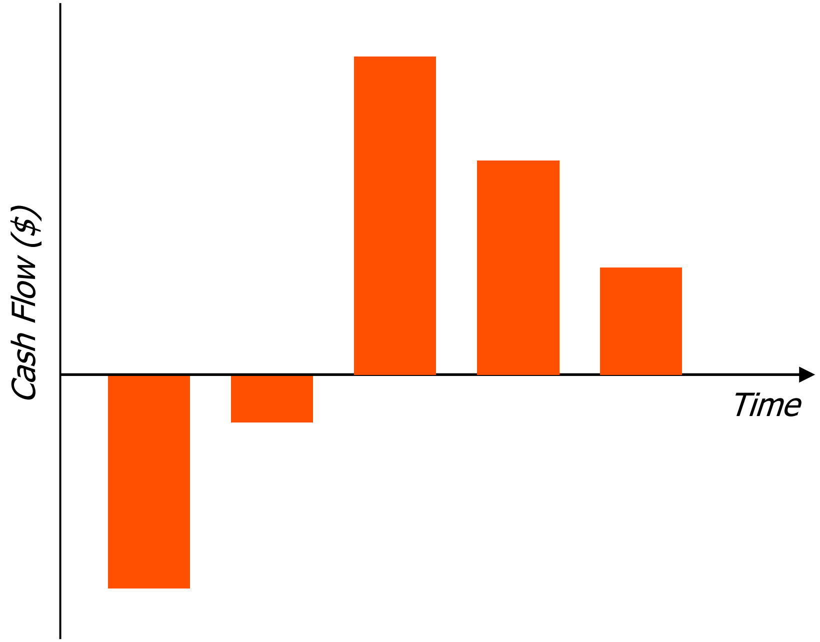
Forecasting Project Cash Flows



What is Cash Flow?

- Cash Flow is the net of revenue received by a company and payments made by a company in a discrete period of time
  - Cash Flow and Net Cash Flow are used interchangeably in this presentation
  - It reflects how much more (or less) money you have at the end of the time period compared to the start
  - Convention: Cash Outflows Negative; Inflows Positive
  - The sum of cash flows is the project's total or cumulative cash flow and the net cash the project is expected to return to the company

Period	Revenue	Cost	Cash Flow
1	0	10	- 10
2	1	3	- 2
3	20	5	15
4	15	5	10
5	10	5	5
Total Cash Flow			18



Gaffney Cline

Time Value of Money Principle

Money available today is worth more than the same amount in the future due to its earning capacity

- Money received today can accrue interest at a bank or be invested into an opportunity to generate additional money, thus a rational investor will prefer money received today over the same sum received in the future.

- A dollar is worth more today than it is tomorrow.

- **Discounted Cash Flow (DCF) analysis** discounts future cash flow estimates to arrive at a present value.

- Each year's net cash flow discounted by a "Discount Factor" to account for Time Value of Money and certain categories of risk.

- Sum of discounted cashflow in each period is the Present Value (or Net Present Value) of the Project.

Gaffney Cline

Present Value and Future Value

- Discounting can be used to estimate the present value or future value of a cash flow
- The value of a project is normally discussed in terms of its Present Value
- To help illustrate the principle though we will start with an example of future value

$$Present\ Value = \frac{Future\ Value}{(1+r)^n}$$

$$Future\ Value = Present\ Value\ \times\ (1+r)^n$$

where:
r = interest/discount rate (%); n = time period (year)

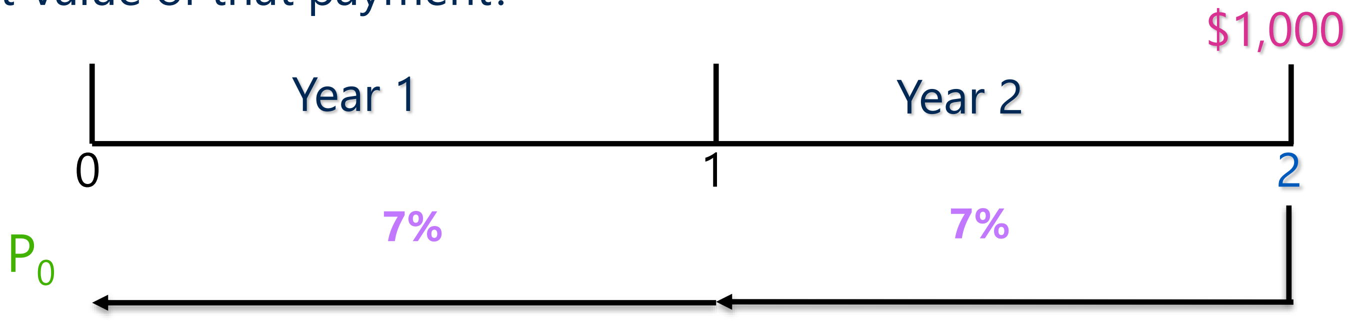
Gaffney Cline

Present Value Example

The Present Value (P_0) is the Future Value of cash (FV) of the cash discounted by an assumed interest rate or rate of return (i) for a number of periods (^{n}):

$$P_0 = FV_n / (1+i)^n$$

E.g.: The bank will pay you $1,000 in 2 years. If you expect a 7% return/interest rate for your money, how much is the Present Value of that payment?



$$P_0 = FV_2 / ((1+i) * (1+i))$$

$$= \$1{,}000 / ((1.07) * (1.07))$$

$$= FV_2 / (1+i)^2 \qquad = \$1{,}000 / (1.07)^2 \qquad = \$873.44$$

Gaffney Cline

Net Present Value (NPV) Calculation Summary

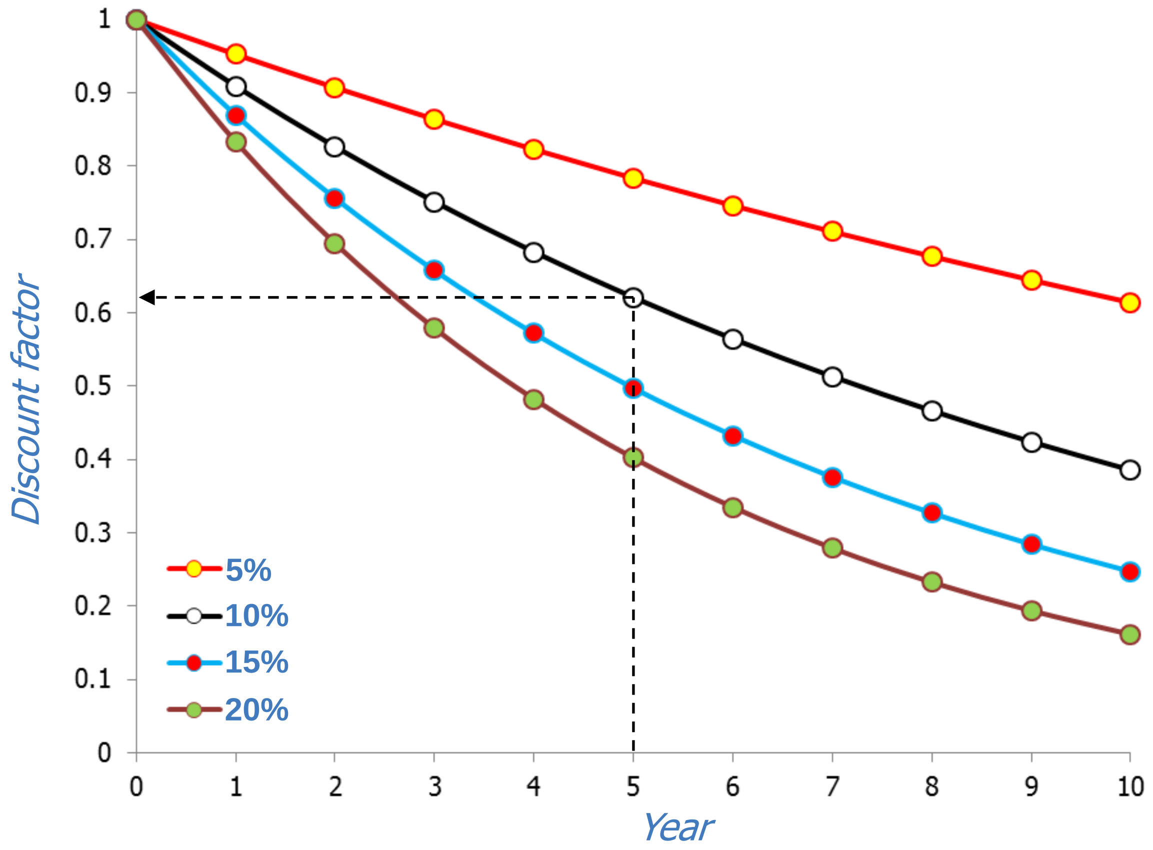
- To value an investment opportunity, net cash flows in future periods are first estimated

- Each year’s cash flow is discounted by the relevant factor based on the discount rate

- Sum of the future discounted cash flows of a project is its **Net Present Value** (NPV)
  - NPV is the most widely used metric to reflect the value of an investment opportunity
  - Must be discounted to the date of evaluation (normally today or current year)
  - NPV is additive between projects and opportunities
  - Positive NPV indicates value is created at that discount rate, Negative value indicates value is destroyed
  - Companies typically make decisions to maximize NPV of their portfolio and projects

Discount Rate and Discount Factor

- Reflects the Cost of Capital i.e., the rate of return expected based on time value of money and certain categories of risk
- Discount factor refers to the level of discounting for the relevant year based on the discount rate.
  - For e.g., discount factor at year 5 using 10% discount rate is 1/(1+10%)^5 = 0.621
- Discount factor applied to individual cash flows to calculate the present value in the relevant year
- Chart highlights the extent to which different discount rates will discount future cash flows
- The higher the discount rate the more the future cash flow is reduced due to discounting



Setting the Discount Rate

- Discount rate is a complex and often debated assumption
  - Relies on many assumptions

- Basic principle is that higher the risk associated with the cash flow; the higher the discount rate
  - A rational investor attempts to maximize the reward while minimizing the risk
  - If an opportunity presents a higher return with a less risky cash flow, it will always be preferred

- The discount rate is meant to adjust for :
  - Time value of money: expected return for an investment with no risk or “Risk Free Return”
  - Systematic risk: risk inherent in the market segment and the market as a whole
  - Unsystematic risk : risks specific to the project

Economic Viability of a Geothermal Project

Discounted Cash Flow (DCF)Analysis

Determines value of the investment today based on future cashflow expectations and discount rate

Levelized Cost of Electricity (LCOE)

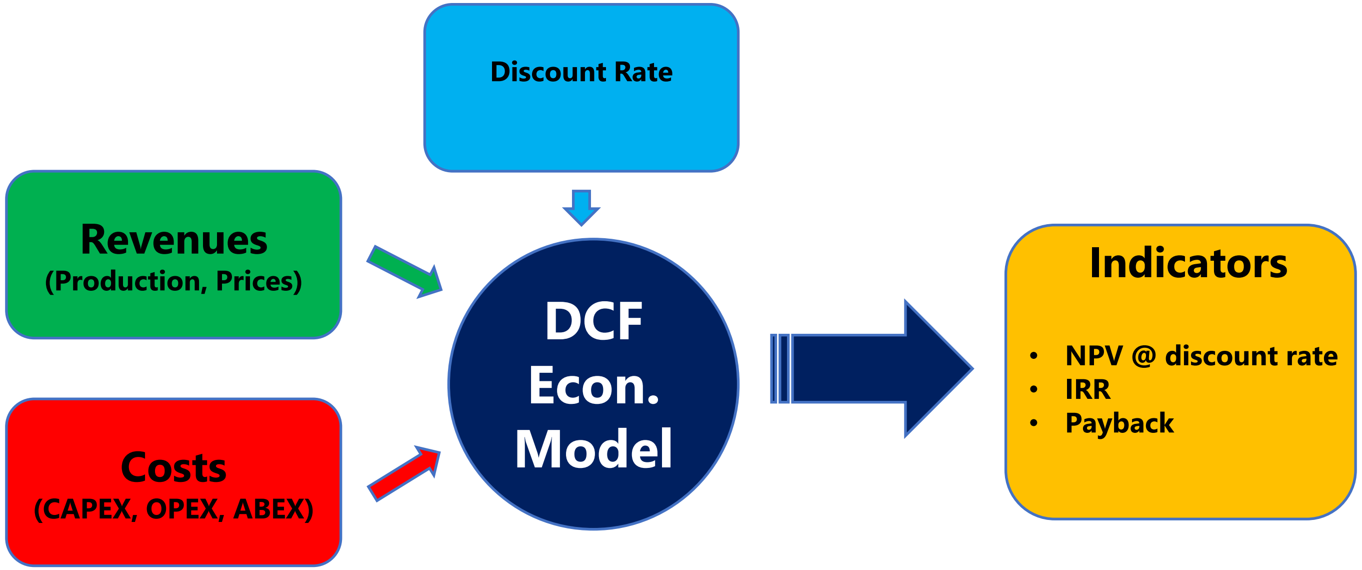
Represents the theoretical minimum electricity price for the project to break-even

DCF Analysis

- Discounted cash flow (DCF) is a valuation method that calculates the value of an investment today, based on cashflows estimates the investment will generate in future.

- To calculate expected future cash flows we need to estimate:

  - ✓ Revenues
  - ✓ Costs



Inputs for DCF Analysis

Revenues

- **Production**
  - Generation capacity (MW)
  - Power Plant availability
- **Prices**
  - Power Purchase Agreement (PPA)

Costs

- **CAPEX**
  - Wells
  - Power Plant EPC
  - Power Delivery & Integration
- **OPEX**
  - O&M
  - Consumables
  - Insurances
  - Logistics
  - Major Maintenance (overhaul plant equipment every X years)
  - Well interventions (every X years)
- **G&A expenses**

Commercial Inputs

- **Discount Rate**

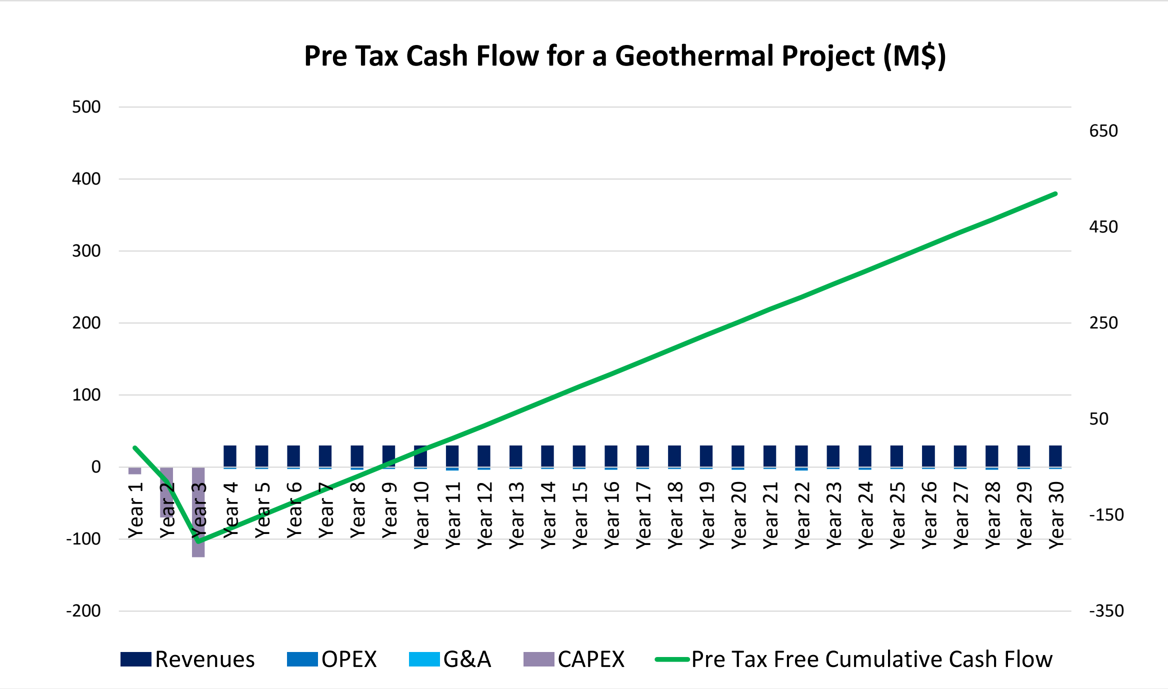
Example of Geothermal Project Inputs (1/2)

Geothermal Project Assumptions		Unit	Value
Plant & PPA assumptions	Nameplate Generation	MW	30
	Delivery Rate	%	90%
	Available Power	MWh	236,520
	Net Energy Sales -PPA-	MWh	200,000
	Power Plant Startup	yr.	Year 4
	Unit Price for Power($/kWh)	$/MWh	150
OPEX	O&M	M$	1.50
	Consumables	M$	0.50
	Parts	M$	0.10
	Insurance	M$	0.15
	Logistics	M$	0.10
	Annual Maintenance	M$	0.25
	Overhaul Cost (per 10 years)	M$	1.0
	Transmission line replacement (per 10 years)	M$	1.0
	Well field interventions (per 4 years)	M$	1.0
G&A	G&A	M$	0.2
CAPEX	Well (Producers & Injectors)	M$	30.0
	Plant Engineering, Procurement, and Construction	M$	150.0
	Power Delivery and Integration	M$	25.0

Example of Geothermal Project Inputs (2/2)

	Pre-Tax Cash Flow Geothermal Project ($ Real)	Unit	Total	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Year 26	Year 27	Year 28	Year 29	Year 30
Revenues	**Revenues**	**M$**	**810.00**	**0.00**	**0.00**	**0.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**	**30.00**
	Nameplate Generation	MW		0	0	0	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
	Delivery Rate	%		0%	0%	0%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
	Available Power	MWh		0	0	0	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520	236,520
	Net Energy Sales -PPA-	MWh		0	0	0	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000	200,000
	Unit Price for Power($/kWh)	$/MWh		0	0	0	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Costs	**OPEX**	**M$**	**80.20**	**0.00**	**0.00**	**0.00**	**2.60**	**2.60**	**2.60**	**2.60**	**3.60**	**2.60**	**2.60**	**4.60**	**3.60**	**2.60**	**2.60**	**2.60**	**3.60**	**2.60**	**2.60**	**2.60**	**3.60**	**2.60**	**4.60**	**2.60**	**3.60**	**2.60**	**2.60**	**2.60**	**3.60**	**2.60**	**2.60**
	O&M	M$	40.50	0.00	0.00	0.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
	Consumables	M$	13.50	0.00	0.00	0.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	Parts	M$	2.70	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Insurance	M$	4.05	0.00	0.00	0.00	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	Logistics	M$	2.70	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Annual Maintenance	M$	6.75	0.00	0.00	0.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Overhaul Cost (per 10 years)	M$	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Transmission line replacement (per 10 years)	M$	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Well field interventions (per 4 years)	M$	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00
	G&A	**M$**	**5.4**	**0.0**	**0.0**	**0.0**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
	CAPEX	**M$**	**205.0**	**10.0**	**70.0**	**125.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
	Well (Producers & Injectors)	M$	30.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Plant Engineering, Procurement, and Construction	M$	150.0	10.0	60.0	80.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Power Delivery and Integration	M$	25.0	0.0	10.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pre Tax Free Cash Flow	**M$**	**519.4**	**-10.0**	**-70.0**	**-125.0**	**27.2**	**27.2**	**27.2**	**27.2**	**26.2**	**27.2**	**27.2**	**25.2**	**26.2**	**27.2**	**27.2**	**27.2**	**26.2**	**27.2**	**27.2**	**27.2**	**26.2**	**27.2**	**25.2**	**27.2**	**26.2**	**27.2**	**27.2**	**27.2**	**26.2**	**27.2**	**27.2**
	Pre Tax Free Cumulative Cash Flow	**M$**		**-10.0**	**-80.0**	**-205.0**	**-177.8**	**-150.6**	**-123.4**	**-96.2**	**-70.0**	**-42.8**	**-15.6**	**9.6**	**35.8**	**63.0**	**90.2**	**117.4**	**143.6**	**170.8**	**198.0**	**225.2**	**251.4**	**278.6**	**303.8**	**331.0**	**357.2**	**384.4**	**411.6**	**438.8**	**465.0**	**492.2**	**519.4**

	Unit	Value
NPV10	**M$**	**28.2**
IRR	**%**	**11.9%**



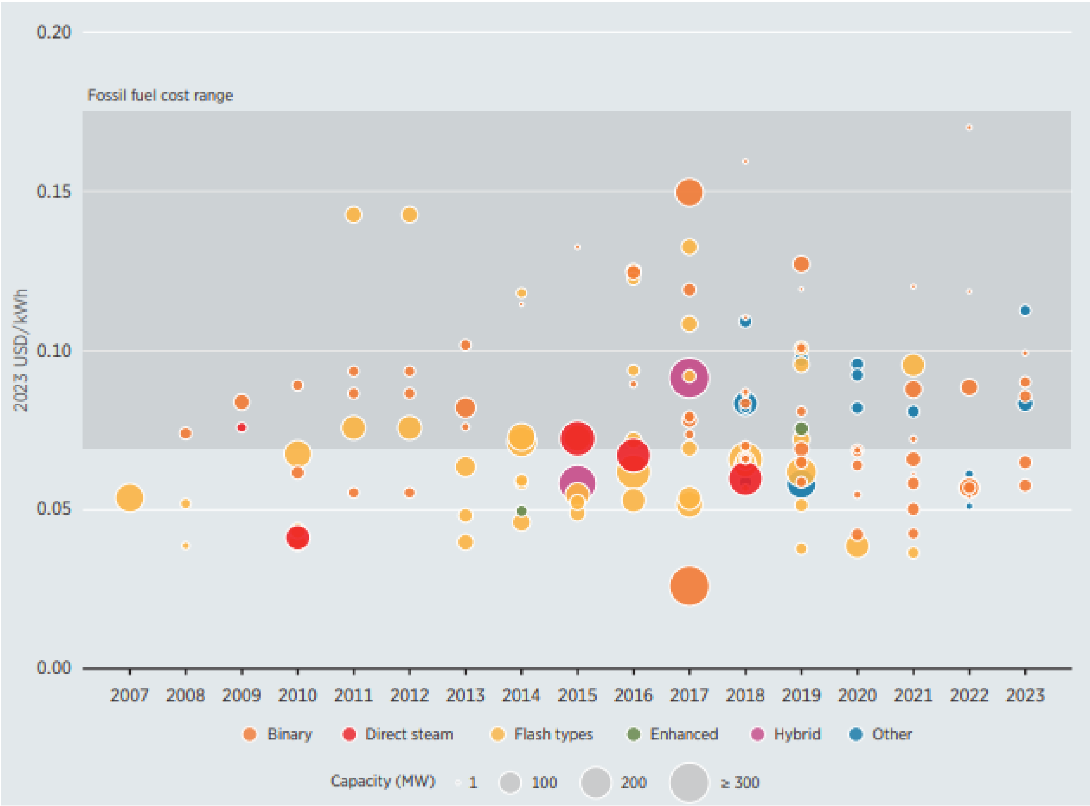
Levelized Cost of Electricity (LCOE)

- Discounted unit cost of building and operating an electricity generation asset
- Includes all relevant costs faced by developer such as exploration & drilling costs, capital, operating and maintenance(O&M), decommissioning, financing etc.
- Used to compare different electricity generation technologies
- Represents the minimum electricity price for the project to break-even given the discount rate
- Levelized Cost of Electricity = NPV of Total Costs over Project Life / NPV of Electricity Generated over Project Life

$$LCOE = \frac{\sum_n \frac{Total\ Costs}{(1+r)^n}}{\sum_n \frac{Total\ Electricity\ Generated}{(1+r)^n}}$$

Where n = time-period, r = discount rate

LCOE of Global Geothermal Projects in US$/kWh



https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2024/Sep/IRENA_Renewable_power_generation_costs_in_2023.pdf

Economic Drivers of Geothermal LCOE

- Drilling Costs and Technology Used (drilling depth, lateral wells, temperature etc)
  - Generally, 10-20% of Total Cost; increasing to 20-50% for high temperature fields
- Power Plant Construction Costs
  - In the range of $2.00-$6.00/MW (depending on binary or direct steam or flash plant)
- Operation & Maintenance Costs
  - Higher compared to other renewables like solar & wind; periodic well workovers required to maintain production
- Capacity Factor or Availability Factor or Delivery Rate
  - Geothermal projects generally have high-capacity factors (75-95%)
- Discount Rate Used
  - Depends on various factors such as cost of debt, level of project financing, investor’s required return, project specific risks etc.
  - Ranges from 6% -10%

Example of LCOE Calculation (Representational)

		Unit	TOTAL	1	2	3	4	5	6	7	8	9	10	11	12	13
Denominator	Production Flag		**10**	-	-	1	1	1	1	1	1	1	1	1	1	-
	Nameplate Capacity	*MW*		-	-	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	-
	Availability Rate	*%*		0%	0%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	0%
	Available Supply	*10^3 MWh*	**394**	-	-	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	-
Numerator	Capex - Drilling	*MM$*	**- 11**	- 2.7	- 8.0	-	-	-	-	-	-	-	-	-	-	-
	Capex - Power Plant	*MM$*	**- 26**	- 5.2	- 20.7	-	-	-	-	-	-	-	-	-	-	-
	Opex	*MM$*	**- 8**	-	-	- 0.8	- 0.8	- 0.8	- 0.8	- 0.8	- 0.8	- 0.8	- 0.8	- 0.8	- 0.8	-
	Abex	*MM$*	**- 5**	-	-	-	-	-	-	-	-	-	-	-	-	- 5.5
	Project Finance	*MM$*	**26**	5.5	20.0	-	-	-	-	-	-	-	-	-	-	-
	Finance Repayment	*MM$*	**- 29**	-	-	- 5.7	- 5.7	- 5.7	- 5.7	- 5.7	-	-	-	-	-	-
LCOE Calculation	Discount Factor			0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.47	0.42	0.39	0.35	0.32	0.29
	LCOE Numerator	*MM$*	**33**	2.13	7.10	4.91	4.46	4.06	3.69	3.35	0.37	0.34	0.31	0.28	0.25	1.58
	LCOE Denominator	*10^3 MWh*	**200**	-	-	29.64	26.94	24.49	22.27	20.24	18.40	16.73	15.21	13.83	12.57	-
	LCOE	*$/MWh*	**164**													

Use LCOE with Caution

- LCOE metrics used widely for comparing power projects

- Use caution when comparing LCOE from different sources
  - Input assumptions can have a significant impact

- LCOE can vary widely based on:
  - Discount rates used
  - Real Or Nominal
  - Leveraged or Unleveraged
  - Pre-tax or Post-tax
  - Project Term

Applications of DCF and LCOE

- DCF analysis used when electricity sales price and discount rate(minimum required return) assumptions are known
  - Success Case : NPV @ Discount Rate > 0
  - Positive NPV implies that the project creates value
  - Negative NPV implies project doesn’t meet minimum return criteria
- LCOE used to calculate the minimum electricity price required for project to break-even at the discount Rate
  - Success Case : LCOE < Wholesale Electricity Purchase Price
  - LCOE > Wholesale Electricity Price implies the project is uncompetitive in the market
  - Project competitiveness improved by
    - Upfront capex reduction measures (change in development concept, capital grants, etc)
    - Opex reduction measures (change in development concept, govt support measures etc)
    - Lower cost of debt (reduces discount rate)
    - Higher leverage (reduces discount rate when cost of debt is lower than discount rate)

THANK YOU!

QUESTIONS?