MAGNUS GEHRINGER AND VICTOR LOKSHA
ESMAP/WORLD BANK GEOTHERMAL TRAINING DAYS
JUNE 2012

Geothermal Handbook: Planning and Financing Power Generation

A Pre-launch

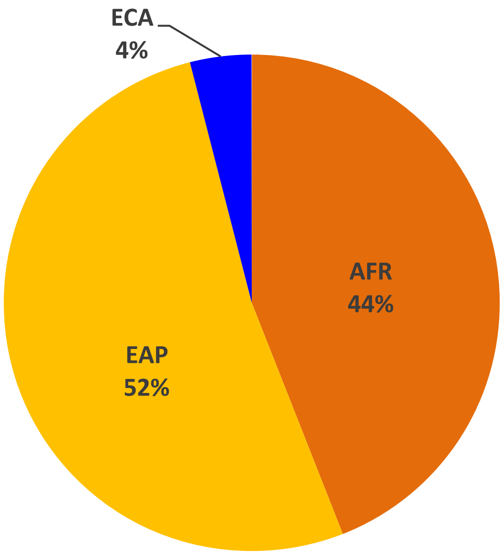
Agenda

- ESMAP AND WORLD BANK GEOTHERMAL PROJECTS IN PAST AND PRESENT
- WHAT IS GEOTHERMAL?
- GEOTHERMAL RESOURCES AND POWER GENERATION GLOBALLY
- RISKS, COSTS AND FINANCING OPTIONS
- ACCELERATING GEOTHERMAL POWER GENERATION IN DEVELOPING COUNTRIES BY A GLOBAL GEOTHERMAL DEVELOPMENT PLAN (GGDP)

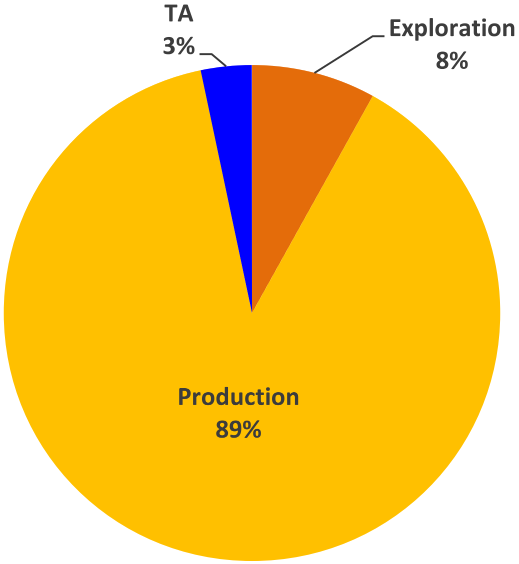
The WBG: Three Decades of Financing Geothermal…

Investment concentrated geographically and in development phase

By Region



By Project Phase



AFR : Djibouti*, Ethiopia, Kenya
EAP: Indonesia, Philippines
ECA: Armenia, Lithuania, Poland (low temperature)

**Grouped under MENA countries within the World Bank*

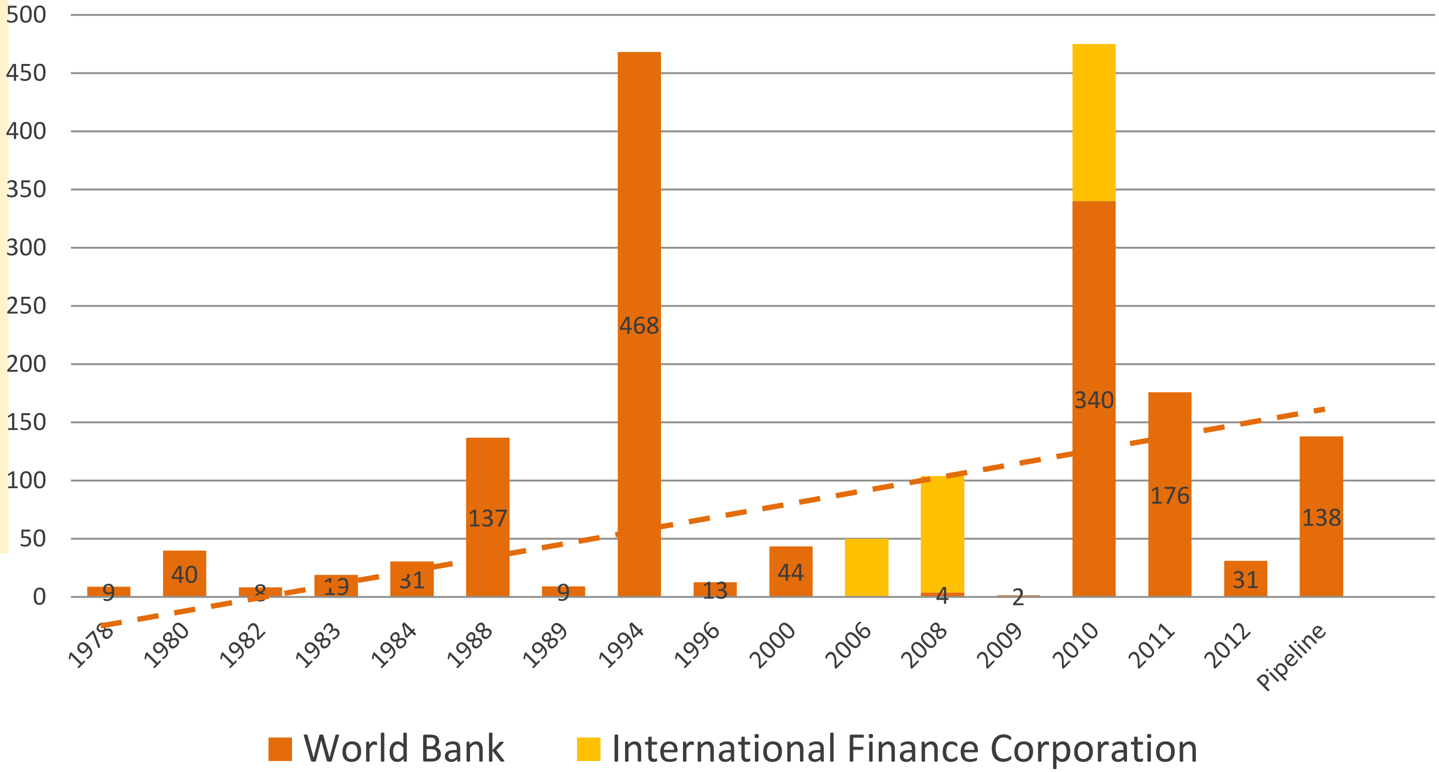
	Exploratory phase	Production phase	TA	Total
AFR	73.72	557.66	22.15	653.53
EAP	44.75	701.64	25.54	771.93
ECA	1.50	56.40	1.50	59.40
Total * (US$ millions)	119.97	1,315.70	49.20	**1,484.86**

**IBRD, IDA, GEF only.*

… Growing Slowly

Geothermal lending modest in World Bank energy lending (<2% over 2007-2012). Investments address resource risk in limited way. Support to private sector still limited.

World Bank Group Lending for Geothermal Energy Development
$ Million, 2010 Constant Price*



** Do not include recent financing from Climate Investment Funds through the World Bank (Indonesia, Ethiopia, Kenya, Turkey)*

ESMAP

- The **Energy Sector Management Assistance Program** (ESMAP) is a global, multi donor technical assistance program aimed at promoting environmentally sustainable energy solutions for poverty reduction and economic growth.
- ESMAP's product lines include targeted technical studies, strategic advice, best practice dissemination, and pre-investment work.
- ESMAP provides technical assistance (TA) in the field of geothermal power generation to Kenya, Ethiopia, Djibouti, Malawi, Rwanda, Central-America, Indonesia and Vanuatu.
- Iceland has recently offered to assist our East-African Client countries in geothermal resource mapping and exploration.

Handbook on Geothermal Power Generation

ESMAP publication by Magnus Gehringer and Victor Loksha

1

Provides advice to developing country Governments & WB staff working on geothermal projects

2

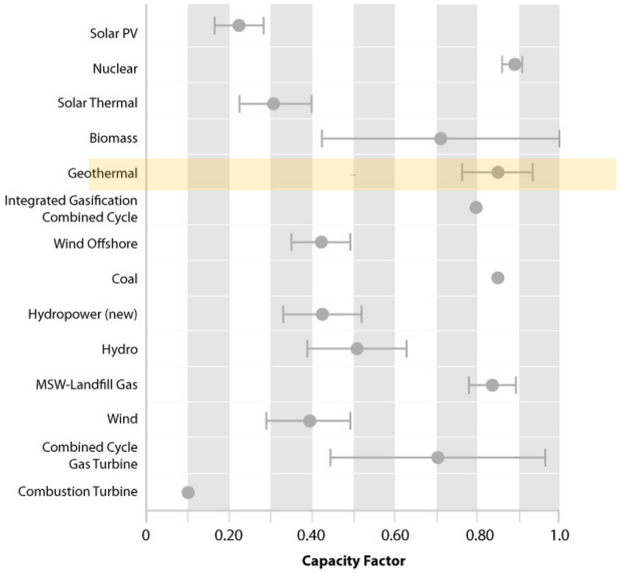
Includes basic issues of geothermal, economic and financial discussions, risks during all project development phases

3

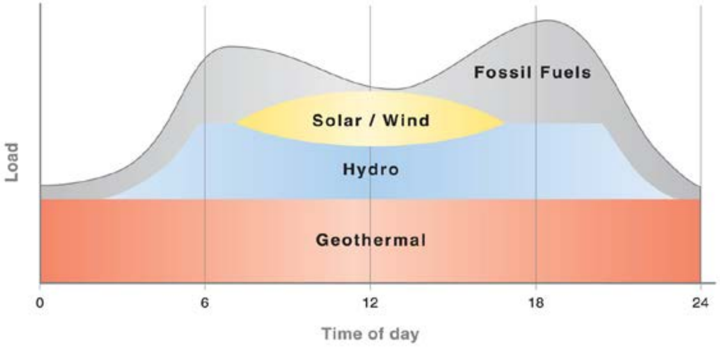
Discusses the role of the public and the private sector

Why Geothermal Energy?

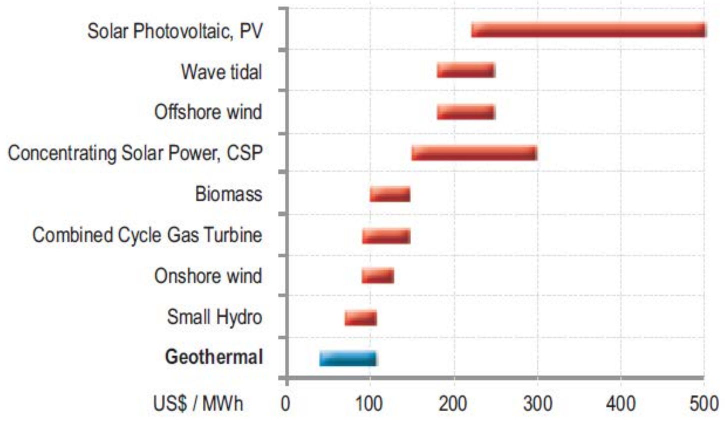
1. Highly reliable electricity



Source: NREL, 2010

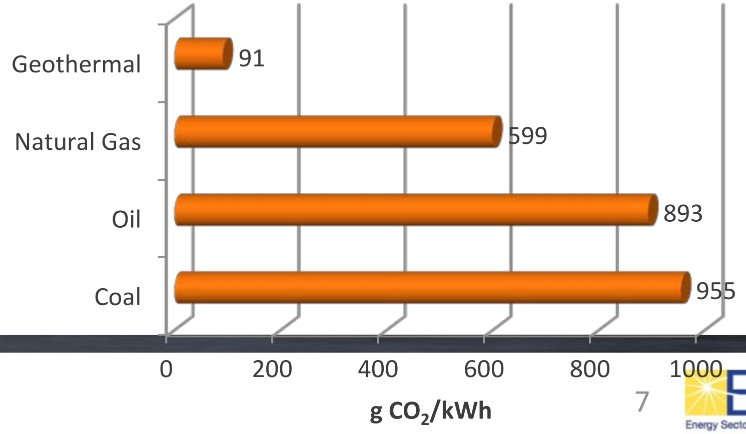


2. Low levelized cost of generation



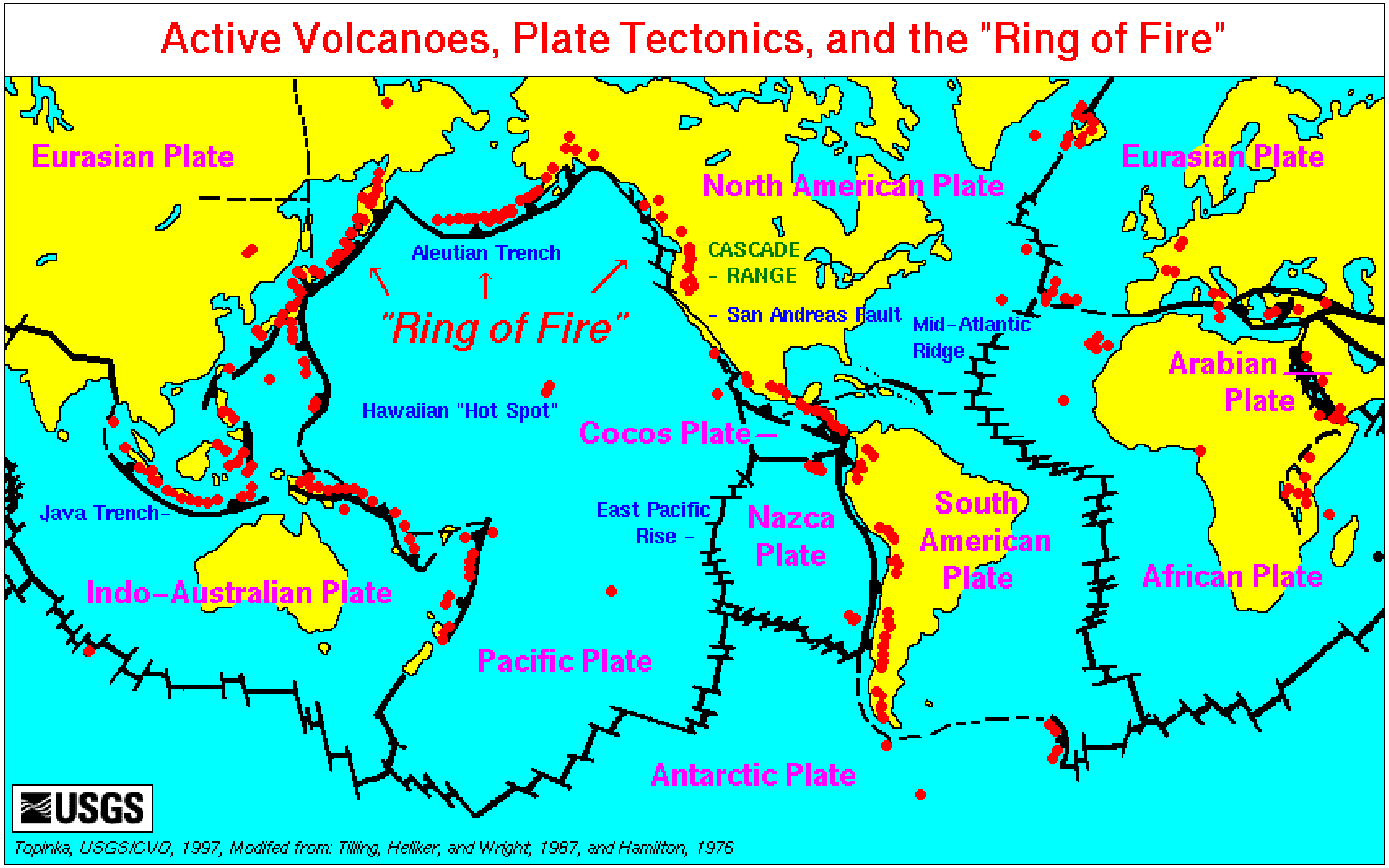
Source: McKinsey

3. Low CO_2 emission factor



Where is Geothermal Energy Found?

About 40 countries possess geothermal potential that theoretically could satisfy their entire electricity demand

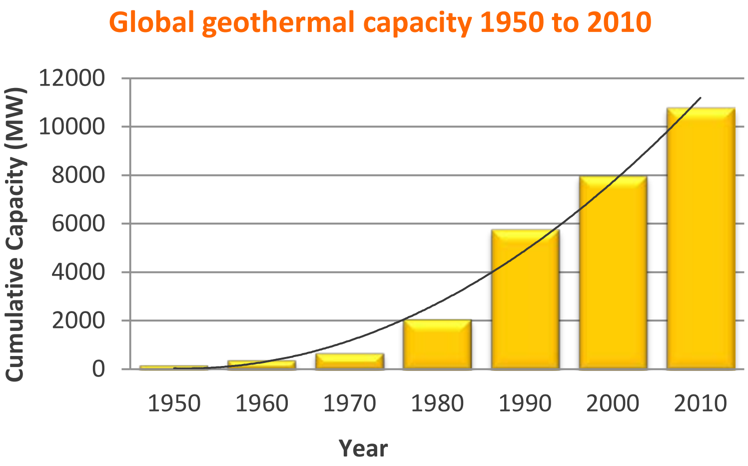


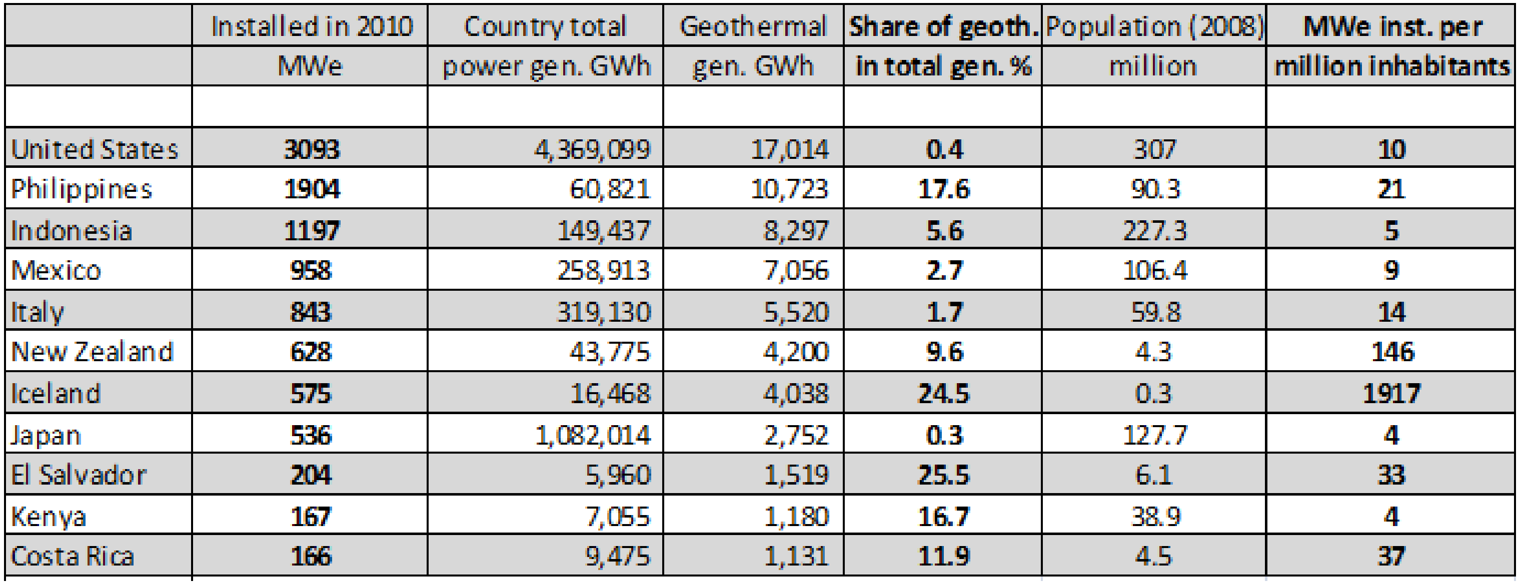
Active Volcanoes, Plate Tectonics, and the "Ring of Fire"

Topinka, USGS/CVO, 1997, Modifed from: Tilling, Heliker, and Wright, 1987, and Hamilton, 1976

Where is Geothermal Energy Utilized?

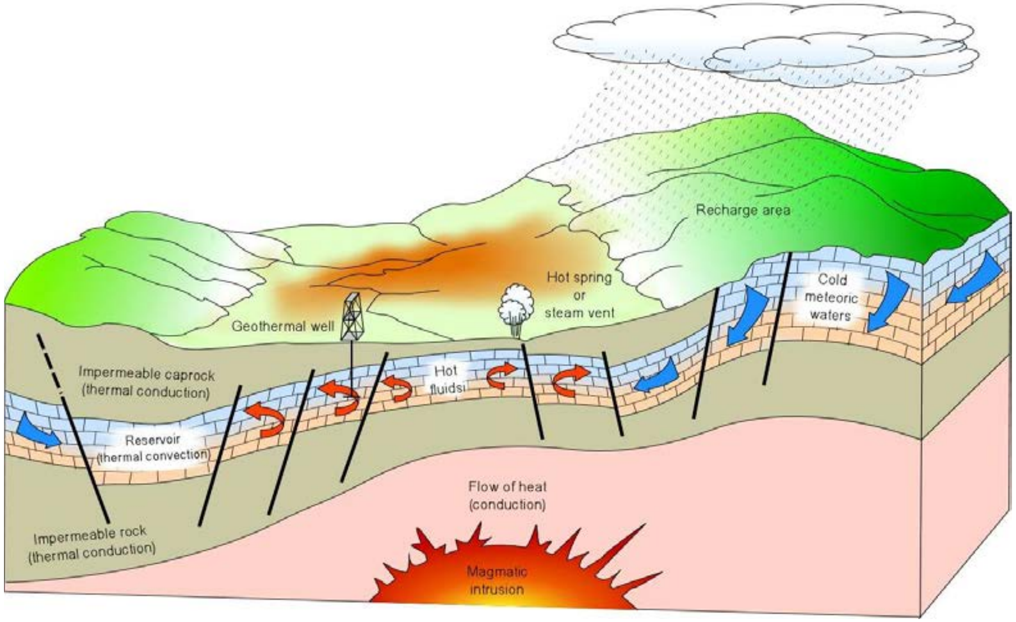
Geothermal energy is underdeveloped. The exploitable geothermal energy potential in several areas is far greater than the current utilization


Global geothermal capacity 1950 to 2010



	Installed in 2010	Country total	Geothermal	Share of geoth.	Population (2008)	MWe inst. per
	MWe	power gen. GWh	gen. GWh	in total gen. %	million	million inhabitants
United States	3093	4,369,099	17,014	0.4	307	10
Philippines	1904	60,821	10,723	17.6	90.3	21
Indonesia	1197	149,437	8,297	5.6	227.3	5
Mexico	958	258,913	7,056	2.7	106.4	9
Italy	843	319,130	5,520	1.7	59.8	14
New Zealand	628	43,775	4,200	9.6	4.3	146
Iceland	575	16,468	4,038	24.5	0.3	1917
Japan	536	1,082,014	2,752	0.3	127.7	4
El Salvador	204	5,960	1,519	25.5	6.1	33
Kenya	167	7,055	1,180	16.7	38.9	4
Costa Rica	166	9,475	1,131	11.9	4.5	37

What is Geothermal Energy? – "Mining Heat"

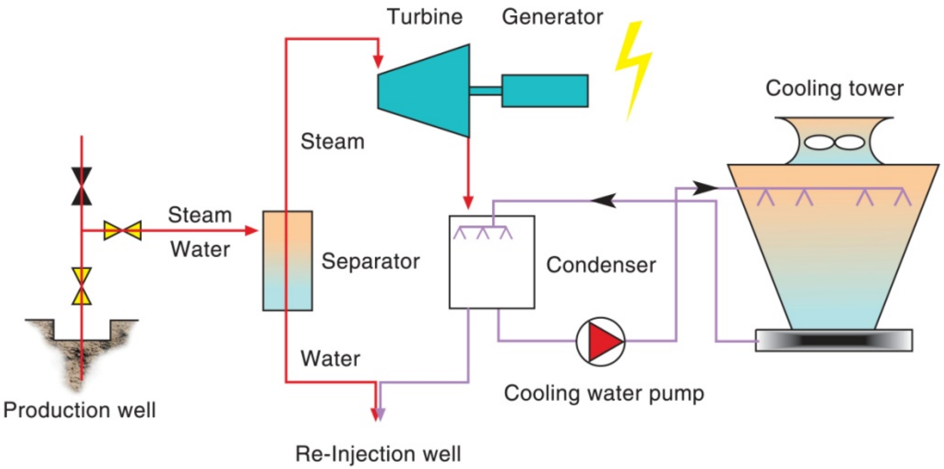


Main components of a volcanic-related system:

- magmatic intrusion
- geothermal reservoir
- fresh water/ precipitation
- geothermal wells

Steam

Power plant



High Up - Front Investment Costs

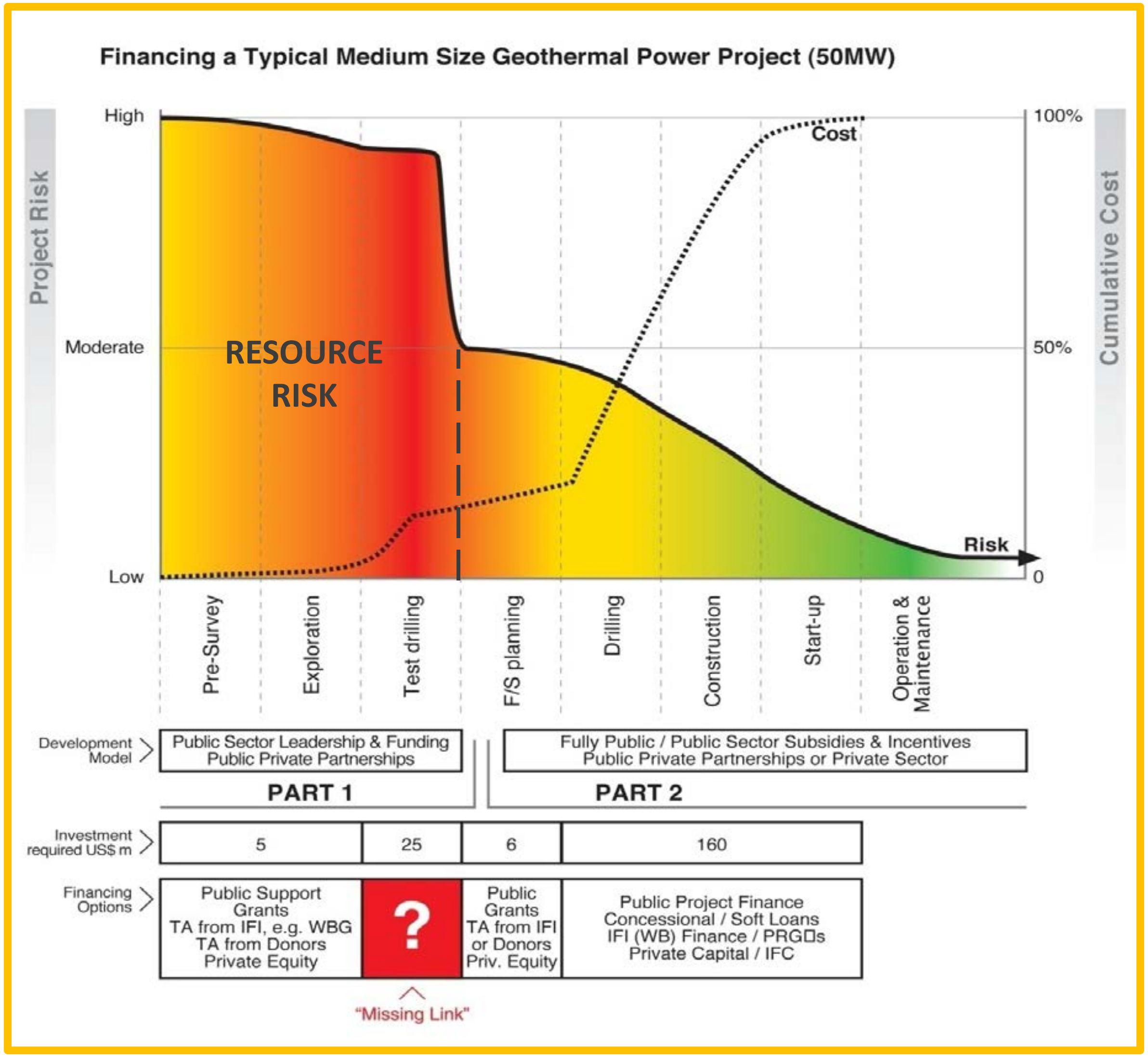
About 10% of the capital costs are at risk as they are incurred up-front to validate the resource

Investment costs for geothermal (50 MW plant)

	Phase / Activity		Low Estimate	Medium Estimate	High Estimate
PART 1	**1**	Preliminary survey, permits, market analysis	1	2	5
	2	Exploration	2	3	4
	3	Test drillings, well testing, reservoir evaluation	11	18	30
PART 2	**4**	Feasibility study, project planning, funding, contracts, insurances, etc.	5	7	10
	5	Drillings (20 boreholes)	45	70	100
	6	Construction (power plant, cooling, infrastructure, etc.) Steam gathering system and substation, connection to grid (transmission)	65 10	75 16	95 22
	7	Start- up and commissioning	3	5	8
		TOTAL	142	196	274
		In million US$ per MW installed	**2.8**	**3.9**	**5.5**

Financing Gap in the Test Drilling Phase

The “missing link” creates a bottleneck which normally only high-middle-income countries are able to overcome

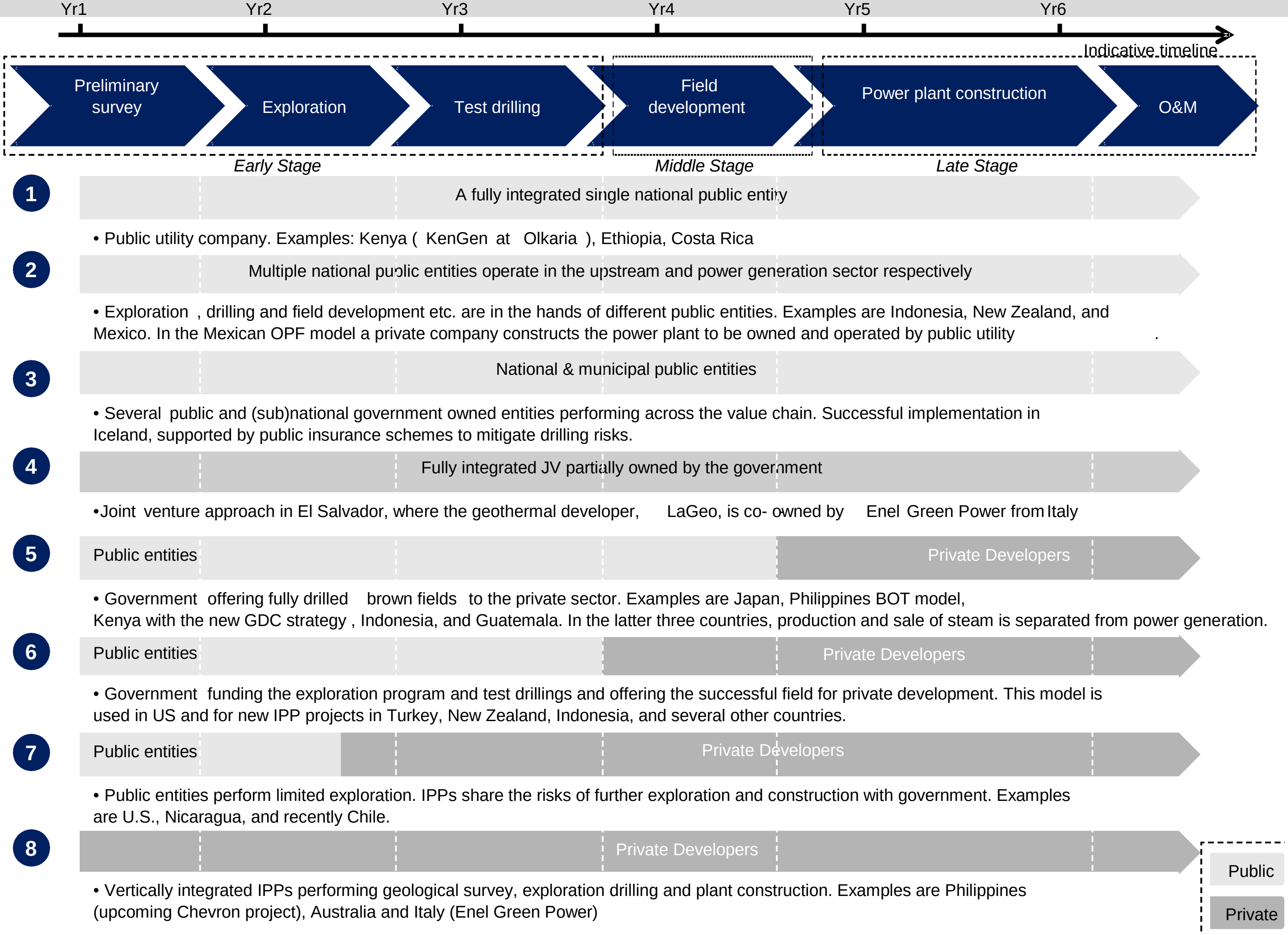


Financing a Typical Medium Size Geothermal Power Project (50MW)

Development Model	Public Sector Leadership & Funding Public Private Partnerships PART 1		Fully Public / Public Sector Subsidies & Incentives Public Private Partnerships or Private Sector PART 2	
Investment required US$ m	5	25	6	160
Financing Options	Public Support Grants TA from IFI, e.g. WBG TA from Donors Private Equity	?	Public Grants TA from IFI or Donors Priv. Equity	Public Project Finance Concessional / Soft Loans IFI (WB) Finance / PRG□s Private Capital / IFC

Models of Geothermal Development,

SHOWING THE IMPORTANCE OF THE PUBLIC SECTOR FOR UPSTREAM PROJECT PHASES



1 A fully integrated single national public entity

- Public utility company. Examples: Kenya (KenGen at Olkaria), Ethiopia, Costa Rica

2 Multiple national public entities operate in the upstream and power generation sector respectively

- Exploration , drilling and field development etc. are in the hands of different public entities. Examples are Indonesia, New Zealand, and Mexico. In the Mexican OPF model a private company constructs the power plant to be owned and operated by public utility .

3 National & municipal public entities

- Several public and (sub)national government owned entities performing across the value chain. Successful implementation in Iceland, supported by public insurance schemes to mitigate drilling risks.

4 Fully integrated JV partially owned by the government

- Joint venture approach in El Salvador, where the geothermal developer, LaGeo, is co- owned by Enel Green Power from Italy

5 Public entities | Private Developers

- Government offering fully drilled brown fields to the private sector. Examples are Japan, Philippines BOT model, Kenya with the new GDC strategy , Indonesia, and Guatemala. In the latter three countries, production and sale of steam is separated from power generation.

6 Public entities | Private Developers

- Government funding the exploration program and test drillings and offering the successful field for private development. This model is used in US and for new IPP projects in Turkey, New Zealand, Indonesia, and several other countries.

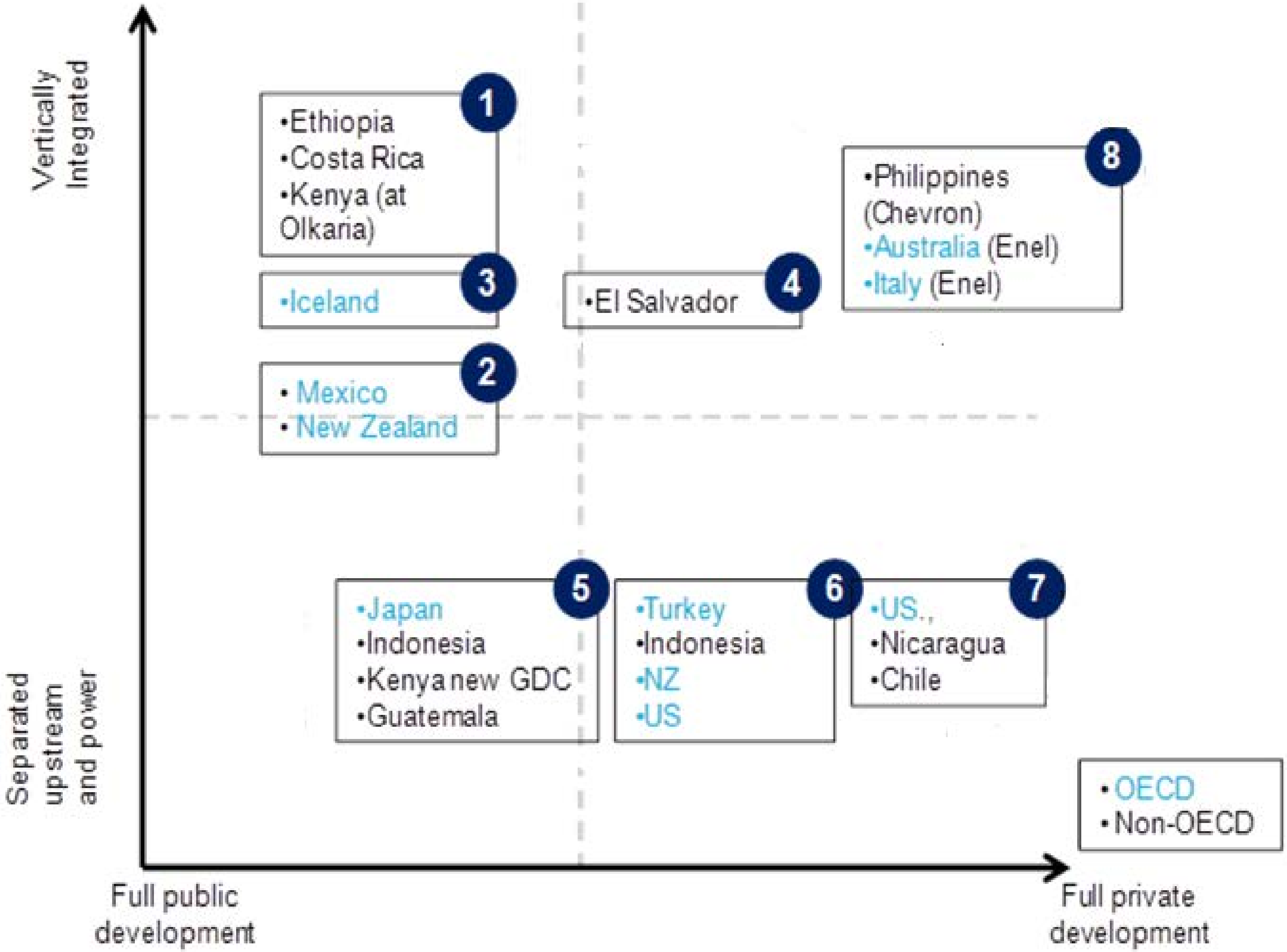
7 Public entities | Private Developers

- Public entities perform limited exploration. IPPs share the risks of further exploration and construction with government. Examples are U.S., Nicaragua, and recently Chile.

8 Private Developers

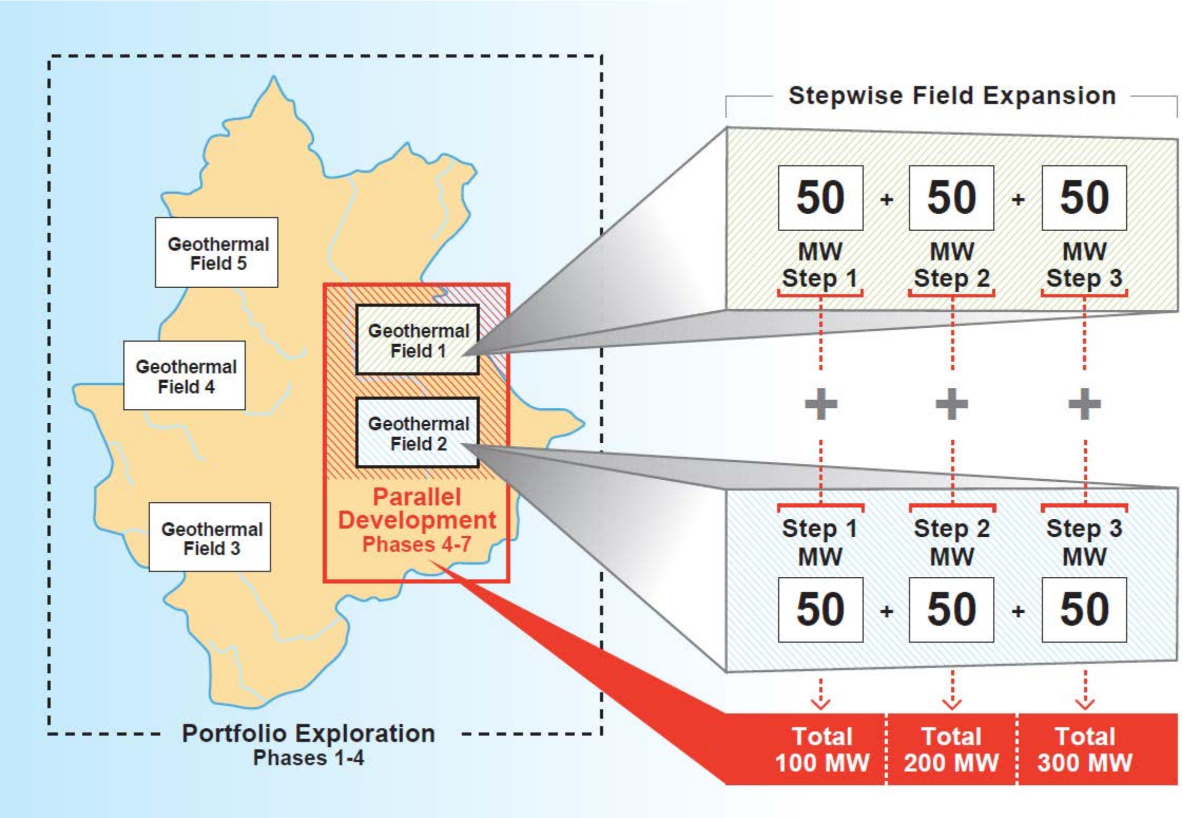
- Vertically integrated IPPs performing geological survey, exploration drilling and plant construction. Examples are Philippines (upcoming Chevron project), Australia and Italy (Enel Green Power)

Application of Financing Models in Countries



Investment Portfolio to Reduce Risk

- Portfolio approach to reduce risk
- Multi-country global approach to ensure volume
- Strict selection criteria to limit exposure within single projects
- Identifying options for parallel development of two or more fields to reduce resource risks



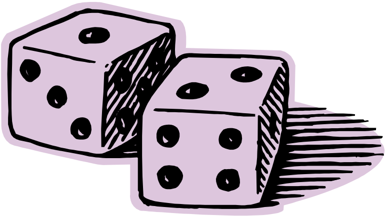
Geothermal Power Generation Costs Observed Internationally, 2010

Country	Project and / or size	US$ cents per kWh	Comments
Costa Rica	4 projects total 200 MW	4 – 5	Figures from ICE
Philippines	Existing total 2,000 MW	4 – 5.5	Privately owned, but mostly built by public companies and then privatized. Own estimate built on utility power purchase price
Indonesia	Total 1,000 MW	4.5 – 7 <9.7	Estimate built on study Tariff ceiling set by government
Ethiopia	Planned 35 MW plant	5 – 8	Estimate
Kenya	Existing 130 MW units Planned 280 MW in 4 units	4.3 - 6.4 < 8	KenGen's Expansion Plan 2008 Tariff ceiling set by government, but 10-20% lower according to Kenyan sources
Iceland	500 MW in large units	3 - 5	Estimate. Power sold to aluminum companies for contract price.
Mexico	960 MW in total	8	Average costs for all units

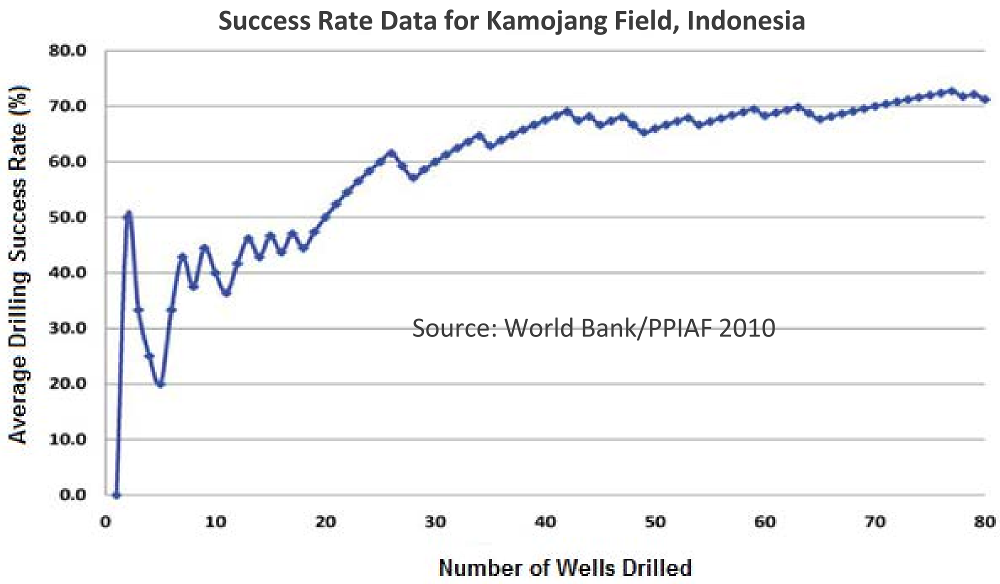
Generation Costs are Competitive…

WHAT IS THE DOWNSIDE?

- Resource/Exploration Risk
- Financing Risks
  - High Upfront Cost
  - Long Lead Time
- Completion/Delay Risk
- Operational Risks
- Off-take Risk and Price Risk
- Regulatory Risk
  - Institutional Capacity Constraints
- Other Risks

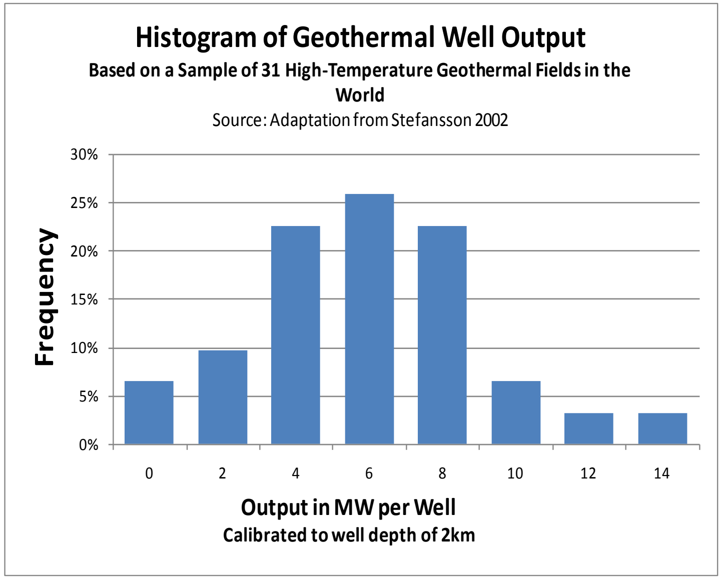


Risks Lead to Uncertainty in Generation Costs



Success Rate Data for Kamojang Field, Indonesia

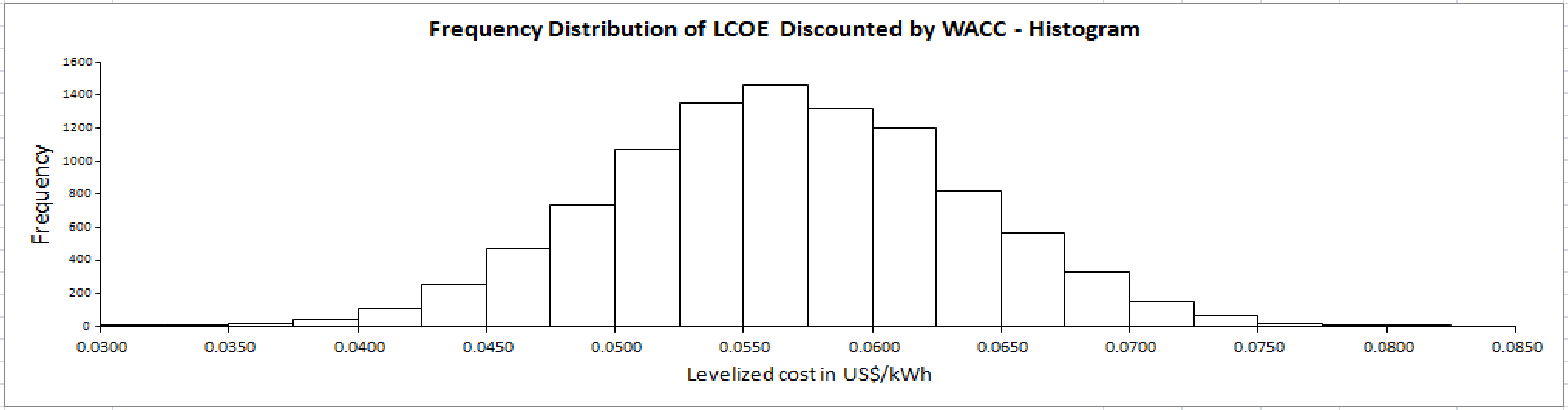
Source: World Bank/PPIAF 2010



Histogram of Geothermal Well Output

Based on a Sample of 31 High-Temperature Geothermal Fields in the World

Source: Adaptation from Stefansson 2002



Frequency Distribution of LCOE Discounted by WACC - Histogram

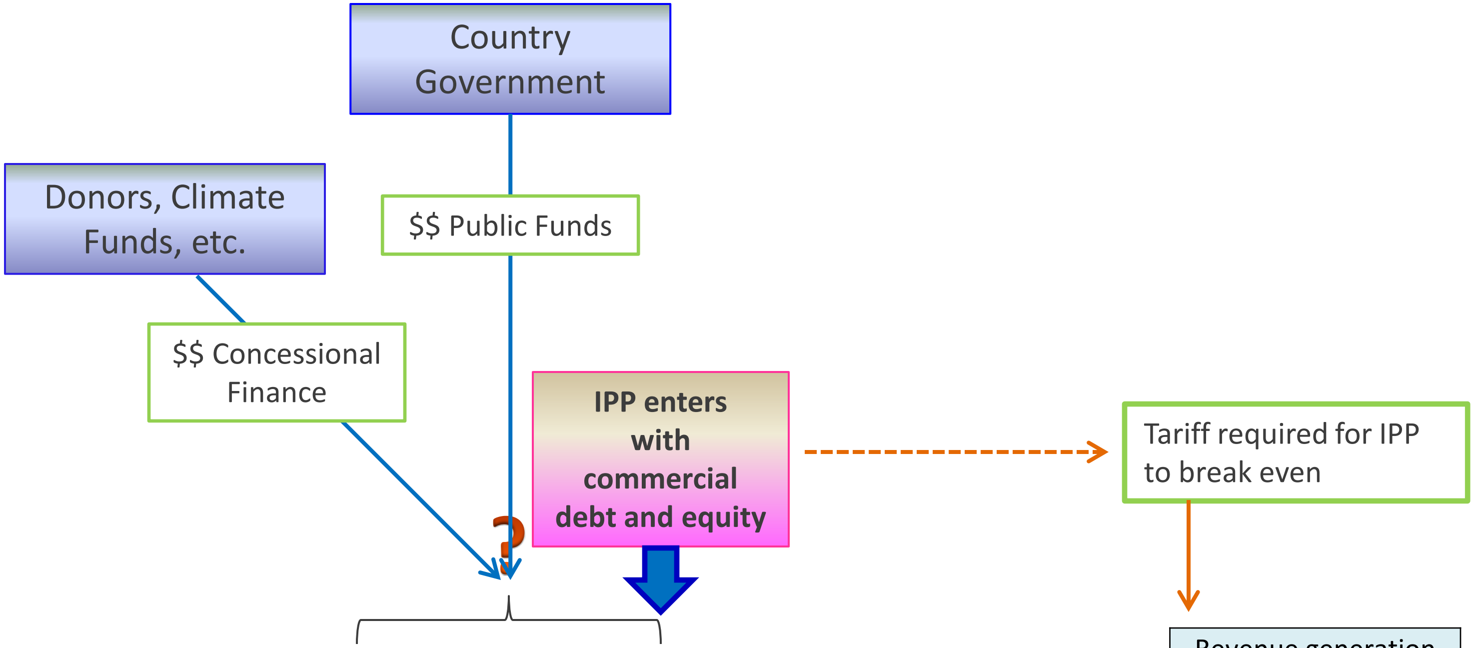
Levelized Cost of Energy (LCOE)

…DOES NOT TELL FULL STORY ABOUT INVESTOR'S RISK

- Discounting at public or weighted average cost of capital (WACC) understates required return for an equity investor
- Projects with long lead time (such as geothermal) are especially vulnerable to inadequate discounting of cash flows
- LCOE takes economic cost perspective disregarding financial cost components relevant to equity investor (taxes, depreciation)

- Levelized tariff (LT) calculation based on required return to equity better serves a private investor's purposes
  - LT is the break-even tariff generating required rate of return for an equity investor
  - Free cashflow to equity is the basis for calculation
  - The required rate of return on equity (Re) is the discount rate which may be as high as 25% or more due to high risk premium

Illustration: An Independent Power Producer (IPP) Entering Project After Test Drilling



Country Government

Donors, Climate Funds, etc.

$$ Public Funds

$$ Concessional Finance

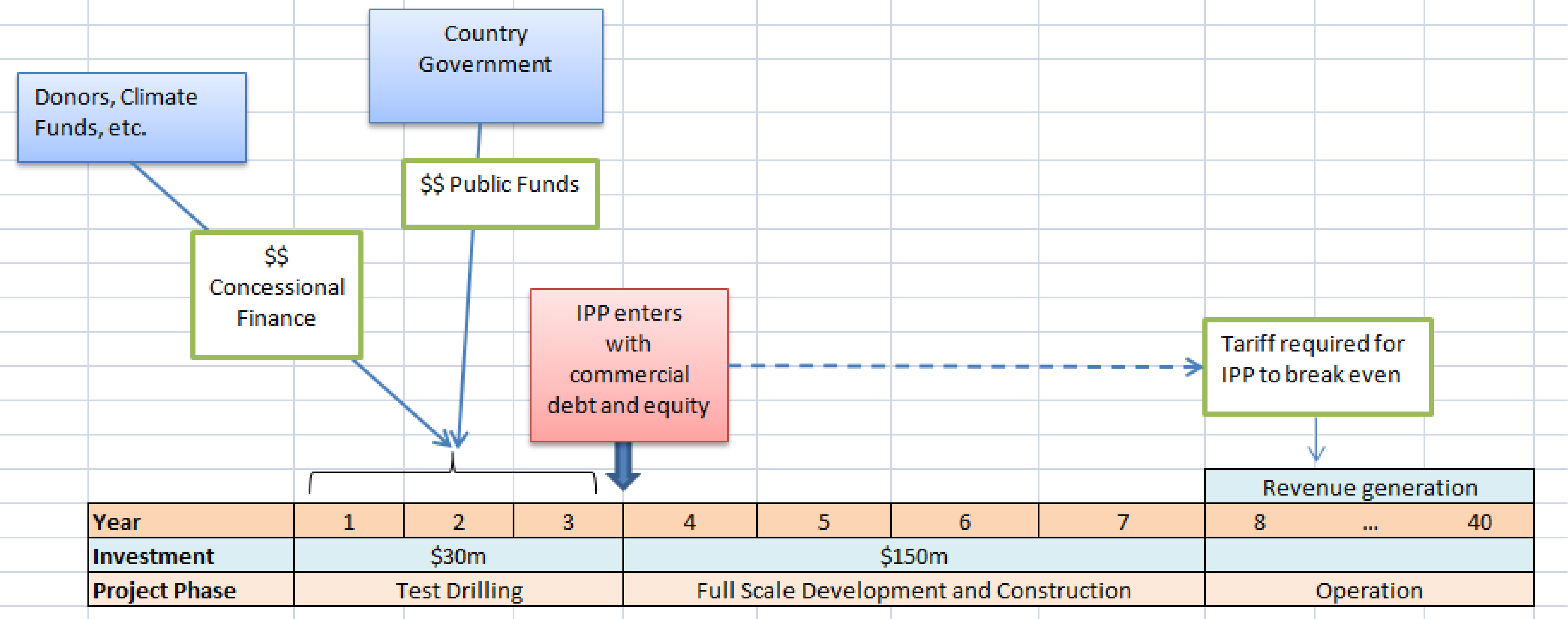
?

IPP enters with commercial debt and equity

Tariff required for IPP to break even

								Revenue generation		
Year	1	2	3	4	5	6	7	8	…	40
Investment	$30m			$150m						
Project Phase	Test Drilling			Full Scale Development and Construction				Operation		

Illustration: An Independent Power Producer (IPP) Entering Project After Test Drilling



Donors, Climate Funds, etc.

$$ Concessional Finance

Country Government

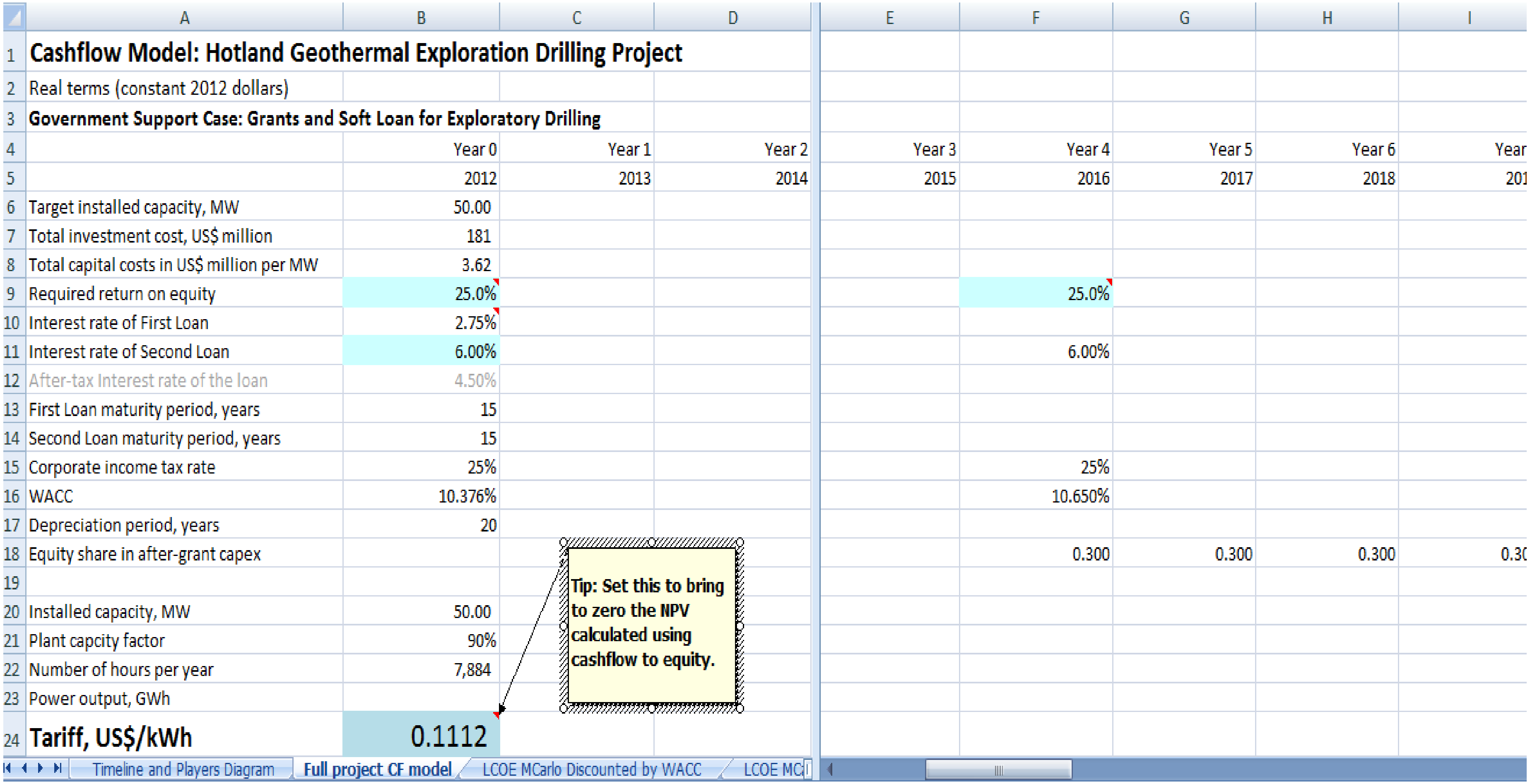
$$ Public Funds

IPP enters with commercial debt and equity

Tariff required for IPP to break even

								Revenue generation		
Year	1	2	3	4	5	6	7	8	...	40
Investment	$30m			$150m						
Project Phase	Test Drilling			Full Scale Development and Construction				Operation		

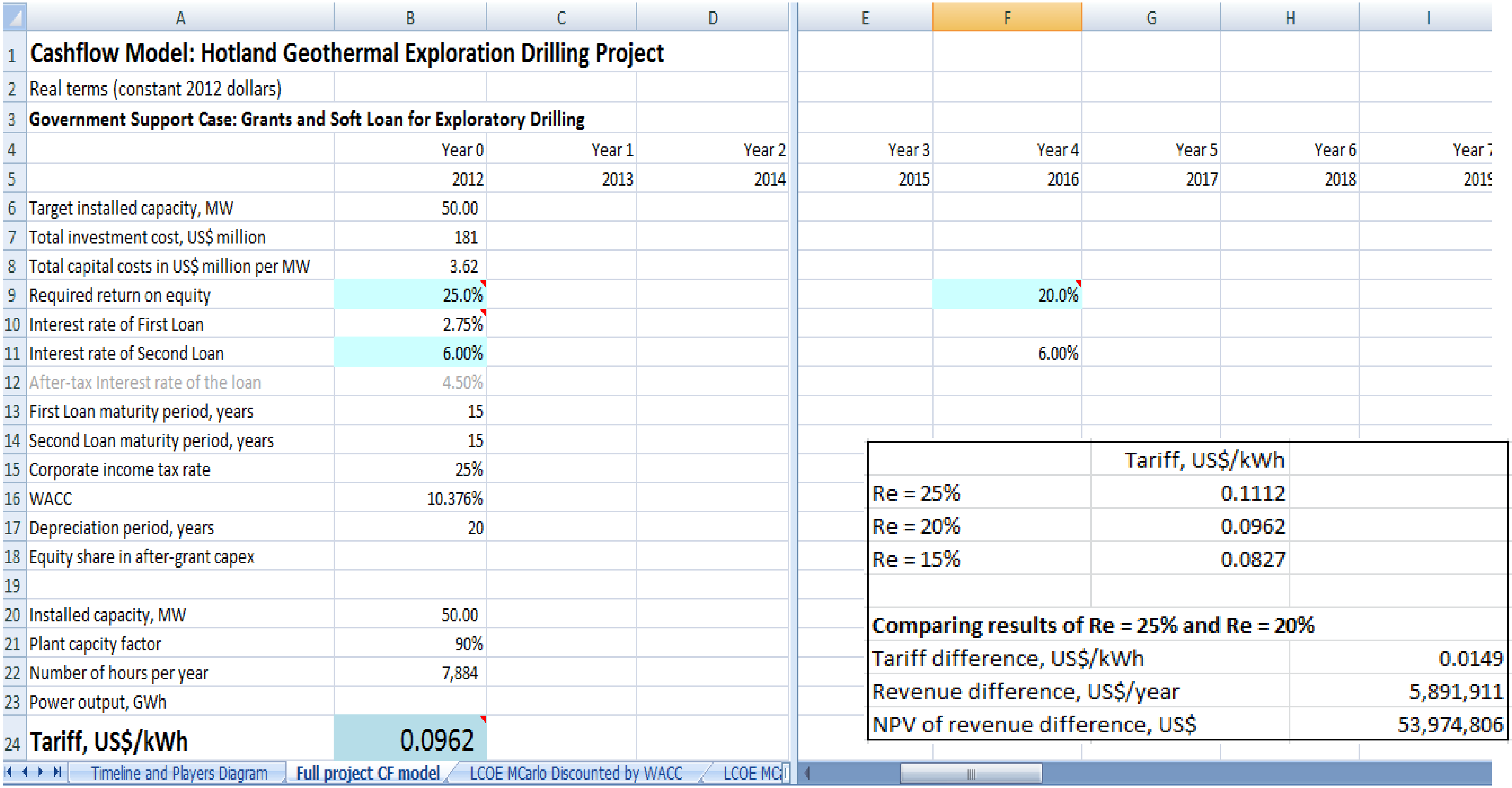
Illustration: An IPP with Re = 25% Entering After Test Drilling



	A	B	C	D	E	F	G	H	I
1	**Cashflow Model: Hotland Geothermal Exploration Drilling Project**								
2	Real terms (constant 2012 dollars)								
3	**Government Support Case: Grants and Soft Loan for Exploratory Drilling**								
4		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year
5		2012	2013	2014	2015	2016	2017	2018	201
6	Target installed capacity, MW	50.00							
7	Total investment cost, US$ million	181							
8	Total capital costs in US$ million per MW	3.62							
9	Required return on equity	25.0%				25.0%			
10	Interest rate of First Loan	2.75%							
11	Interest rate of Second Loan	6.00%				6.00%			
12	After-tax Interest rate of the loan	4.50%							
13	First Loan maturity period, years	15							
14	Second Loan maturity period, years	15							
15	Corporate income tax rate	25%				25%			
16	WACC	10.376%				10.650%			
17	Depreciation period, years	20							
18	Equity share in after-grant capex					0.300	0.300	0.300	0.3
19									
20	Installed capacity, MW	50.00							
21	Plant capcity factor	90%							
22	Number of hours per year	7,884							
23	Power output, GWh								
24	**Tariff, US$/kWh**	0.1112							

Tip: Set this to bring to zero the NPV calculated using cashflow to equity.

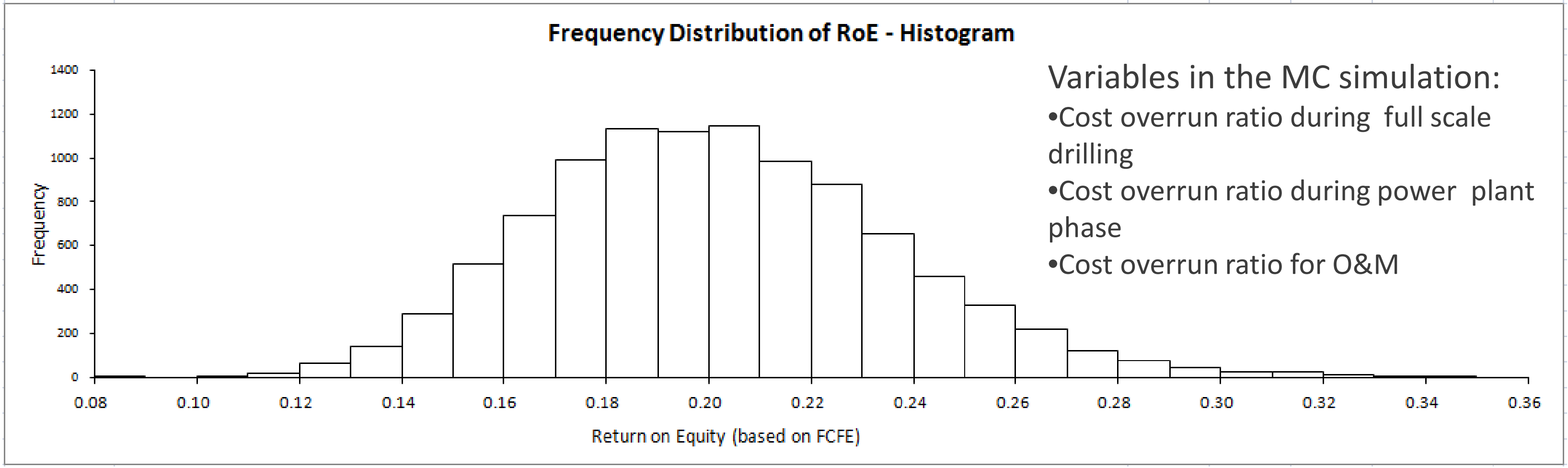
Illustration: An IPP with Re = 20% Entering After Test Drilling



	A	B	C	D	E	F	G	H	I
1	**Cashflow Model: Hotland Geothermal Exploration Drilling Project**								
2	Real terms (constant 2012 dollars)								
3	**Government Support Case: Grants and Soft Loan for Exploratory Drilling**								
4		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year
5		2012	2013	2014	2015	2016	2017	2018	201
6	Target installed capacity, MW	50.00							
7	Total investment cost, US$ million	181							
8	Total capital costs in US$ million per MW	3.62							
9	Required return on equity	25.0%				20.0%			
10	Interest rate of First Loan	2.75%							
11	Interest rate of Second Loan	6.00%				6.00%			
12	After-tax Interest rate of the loan	4.50%							
13	First Loan maturity period, years	15							
14	Second Loan maturity period, years	15							
15	Corporate income tax rate	25%							
16	WACC	10.376%							
17	Depreciation period, years	20							
18	Equity share in after-grant capex								
19									
20	Installed capacity, MW	50.00							
21	Plant capcity factor	90%							
22	Number of hours per year	7,884							
23	Power output, GWh								
24	**Tariff, US$/kWh**	**0.0962**							

	Tariff, US$/kWh	
Re = 25%	0.1112	
Re = 20%	0.0962	
Re = 15%	0.0827	
Comparing results of Re = 25% and Re = 20%		
Tariff difference, US$/kWh		0.0149
Revenue difference, US$/year		5,891,911
NPV of revenue difference, US$		53,974,806

Illustration: Expected Return on Equity (RoE) for an IPP at Tariff of 9.62 US cents/kWh


Frequency Distribution of RoE - Histogram

Variables in the MC simulation:

- Cost overrun ratio during full scale drilling
- Cost overrun ratio during power plant phase
- Cost overrun ratio for O&M

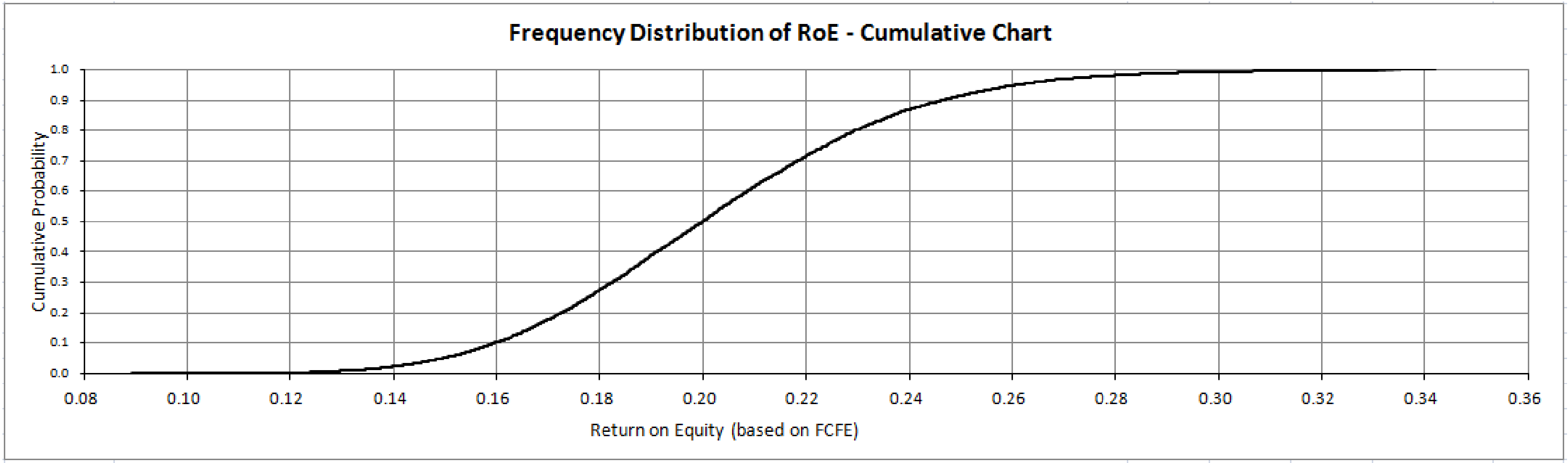
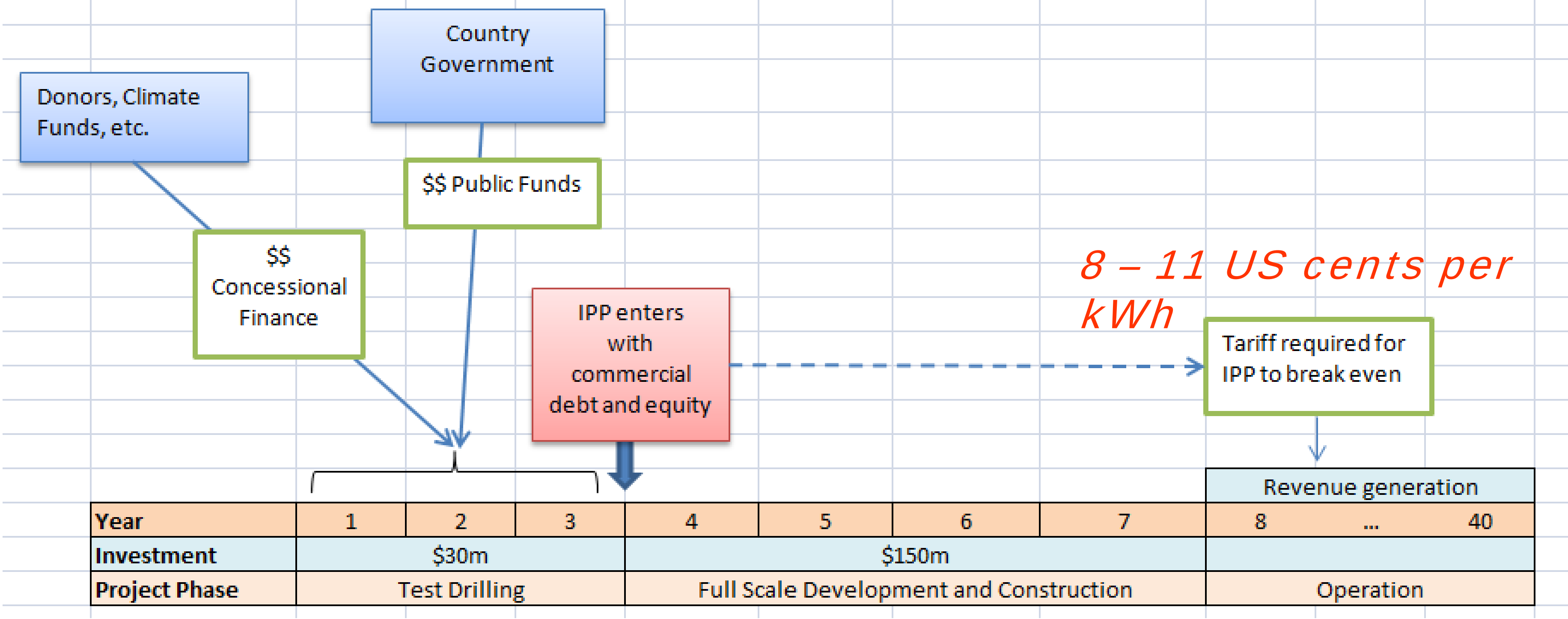

Frequency Distribution of RoE - Cumulative Chart

Illustration: An IPP with Re = 15 – 25% Entering After Test Drilling



Country Government

Donors, Climate Funds, etc.

$$ Public Funds

$$ Concessional Finance

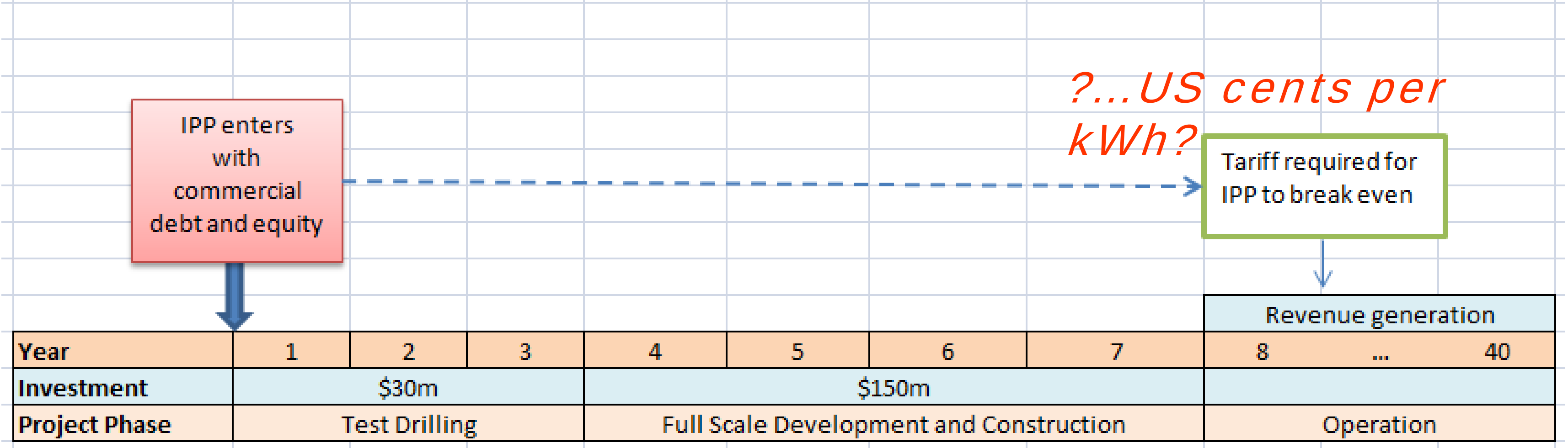
IPP enters with commercial debt and equity

8 – 11 US cents per kWh

Tariff required for IPP to break even

								Revenue generation		
Year	1	2	3	4	5	6	7	8	...	40
Investment	$30m			$150m						
Project Phase	Test Drilling			Full Scale Development and Construction				Operation		

Hypothetical: An IPP with Re = 25% Entering BEFORE Test Drilling



IPP enters with commercial debt and equity

?...US cents per kWh?

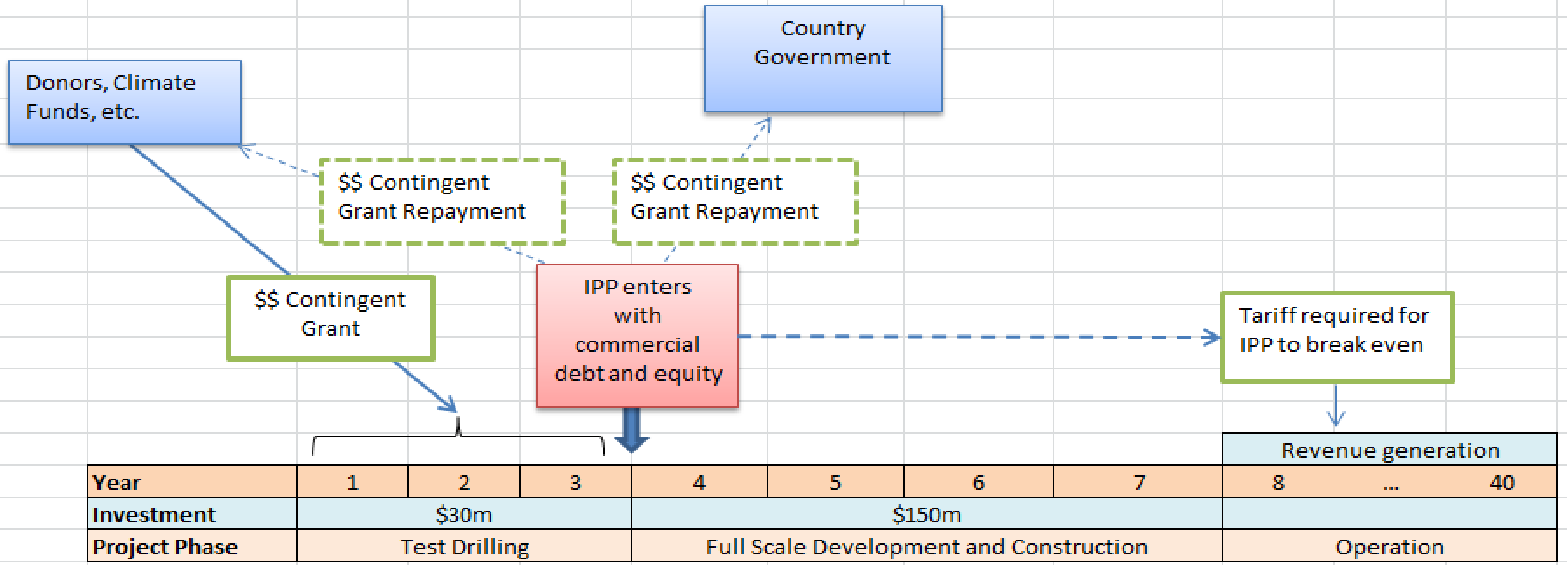
Tariff required for IPP to break even

Revenue generation

Year	1	2	3	4	5	6	7	8	...	40
Investment	$30m			$150m						
Project Phase	Test Drilling			Full Scale Development and Construction				Operation		

- Much higher levelized tariff (LT) is required because:
  - Lead time is longer by 3 years
  - Required rate of return on equity (Re) is higher (25%) due to high risk premium of early entry
  - The $30m cost of exploration is still ahead
  - Result: LT >14 US cents/kWh!

Possibilities for Innovative Concessional Financing from Donors



Year	1	2	3	4	5	6	7	8	...	40
Investment	$30m			$150m						
Project Phase	Test Drilling			Full Scale Development and Construction				Operation		

- Required levelized tariff (LT) is reduced because:
  - Lead time is shorter by 3 years
  - Required rate of return on equity (Re) is lower than 25% and equal to 20% or 15% due to reduced risk
  - Multi-year amortization of contingent grant is possible
  - Some of the $30m cost of exploration may have been pure grant financed making it a sunk cost for the IPP.

Possible Designs for a Donor-supported Geothermal Development Facility

Possible designs for a donor-supported geothermal development facility include:

- a direct capital subsidy/grant facility;
- a contingent grant facility;
- a loan (on-lending) facility; and
- a risk guarantee/insurance facility.

Any of these designs can reduce the private investors' risk and thus reduce the risk premium for the return on equity and the overall cost of capital, opening up new opportunities for scaling up geothermal power.

Energy Sector Management Assistance Program

MAGNUS GEHRINGER:
MGEHRINGER@WORLDBANK.ORG
VICTOR B. LOKSHA:
VLOKSHA@WORLDBANK.ORG

Thank You.

The World Bank | 1818 H Street, NW | Washington DC, USA
www.esmap.com | esmap@worldbank.org