Integrated course „Energy Economics“
- Financial management -

Chair of Energy Systems | Department of Energy Systems
Technische Universität Berlin

Outline

- Fundamentals of finance
- Time value of money
- Capital structure and cost of capital
- Capital budgeting: NPV method
- NPV vs IRR
- Levelised cost of electricity (LCOE)
- Real options

Reminder: Next class – Thu 26.11.2020

Vortragsreihe „Neue Entwicklungen auf den Energiemärkten“ / Lecture series „New developments on the energy markets“

- Lecture series and discussion on current topics in energy economics and systems
- Language: German / English
- ISIS: Vortragsreihe WiSe 20/21 | Password: Meritorder20

- Introduction of the topics in the class on 26 November 2020
- Topic allocation via ISIS: 26.11.2020 18:00h – 03.12.2020 23.55h
- The dates for your presentation will be announced in due course.

Task 4) Investment appraisal (continued)

There are two power plants as investment options. The data is given below:

	Natural gas power plant	*Hard coal power plant*	*Units*
Capacity	900	900	MW
Efficiency	55	43	%
Investment costs	585	900	Million €
Interest rate	8	8	%
Lifetime	20	20	a
Employees	66	140	Number
Labor costs	60 000	60 000	€/a/employee
O&M costs	4	8	Million €/a
Fuel price	22	14	$€/MWh_{th}$
Emission factor fuel	56	92	$kg\ CO_2\ /\ GJ_{th}$
Full load hours	4 000	5 500	hours/a

a) What are the **specific investment costs** in €/kW of the two options?

b) What are the **(short-term) marginal generation costs**?

c) What are the **annual capital costs**?

d) What are the total annual **fixed costs** per MW installed?

e) What are the **levelised cost of electricity (LCOE)**?

f) What must the **full load hours** of the natural gas power plant be so that the long-term marginal generation costs are equal for both technologies?

Task 4) Investment appraisal

	Natural gas power plant	Hard coal power plant	Units
Capacity (Cap)	900	900	MW
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Investment costs (I_0)	585	900	Million €
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Emission factor fuel	56	92	kg CO_2 / GJ_{th}
Full load hours (FLH)	4 000	5 500	hours/a

There are two power plants as investment options.

e) What are the levelised cost of electricity (LCOE)?

$$LCOE = \frac{C_{fix}}{FLH} + STMGC$$

$$\frac{C_{fix_t}[€]}{Q_t[MWh]} = \frac{C_{fix}[€/MW] \cdot Cap[MW]}{FLH[h] \cdot Cap[MW]}$$

$$LCOE_{NG} = \frac{75144\ €/MW \cdot a}{4000\ h/a} + 40\ €/MWh = 18{,}786 + 40 = 58{,}79\ €/MWh$$

$$LCOE_{coal} = \frac{121\,333\ €/MW \cdot a}{5500\ h/a} + 32{,}56\ \frac{€}{MWh} = 54{,}62\ €/MWh$$

Task 4) Investment appraisal

There are two power plants as investment options.

f) What must the full load hours of the natural gas power plant be so that the long-term marginal generation costs are equal for both technologies?

→ LCOE

$C_{fix\ NG}$	75.144	€/MW/a
$C_{fix\ coal}$	121.333	€/MW/a
$STMGC_{NG}$	40	€/MWh
$STMGC_{coal}$	32,56	€/MWh
FLH_{coal}	5.500	hours/a

$$\frac{C_{fix\,NG}}{FLH_{NG}} + STMGC_{NG} = \frac{C_{fix\,coal}}{FLH_{coal}} + STMGC_{coal}$$

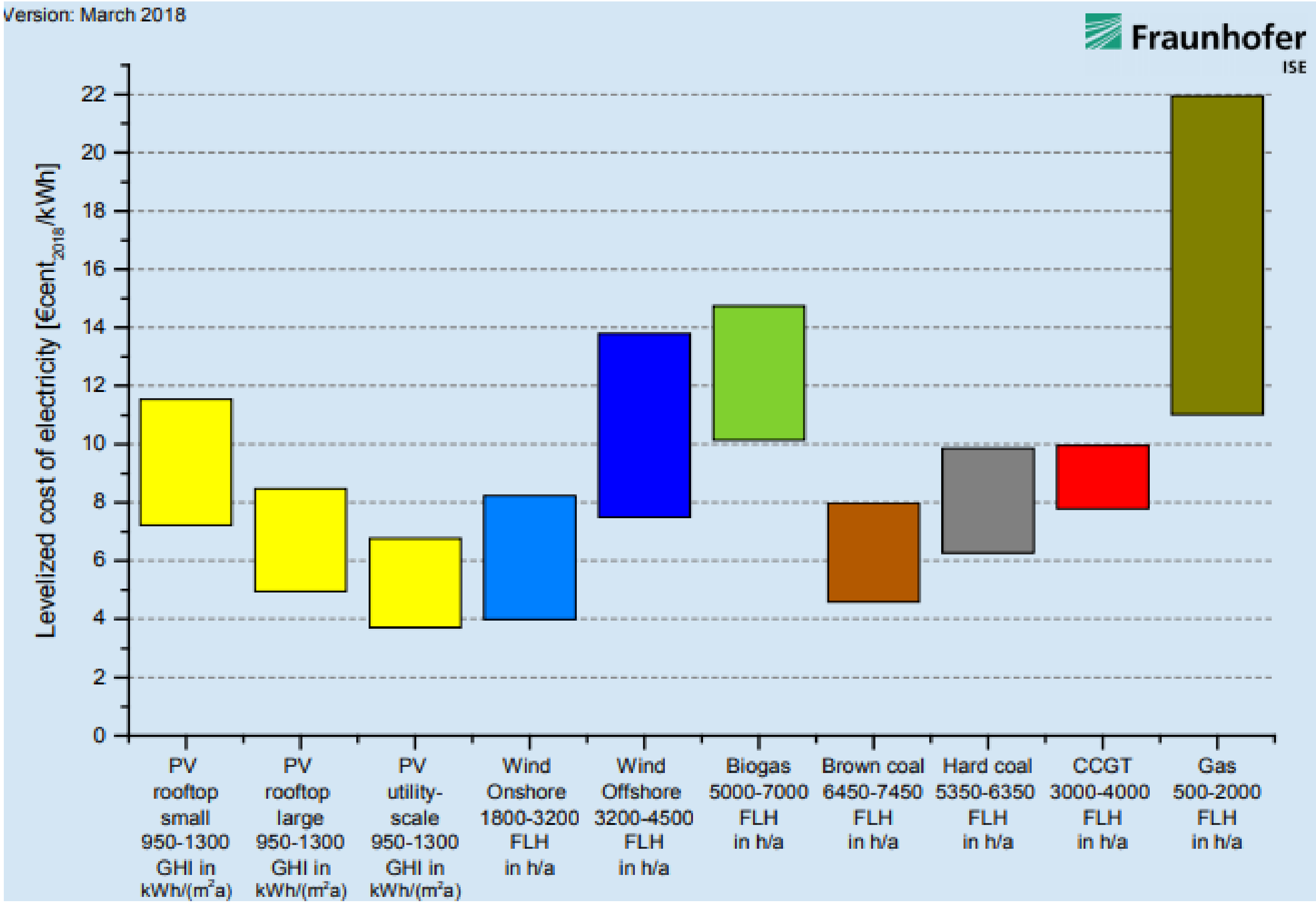
$$\frac{C_{fix\,NG}}{FLH_{NG}} = \frac{C_{fix\,coal}}{FLH_{coal}} + STMGC_{coal} - STMGC_{NG}$$

$$FLH_{NG} = \frac{C_{fix\,NG}}{\frac{C_{fix\,coal}}{FLH_{coal}} + STMGC_{coal} - STMGC_{NG}}$$

$$= \frac{75144\,\frac{€}{MW \cdot a}}{\frac{121.333\,\frac{€}{MW \cdot a}}{5500\,h/a} + 32{,}56\,€/MWh - 40\,€/MWh} = 5161\,h/a$$

(→ €/MWh)

LCOE of renewables and conventional generation at different locations in Germany in 2018



Source: Fraunhofer ISE

What happened?

Shell puts its $9bn Arctic drilling project on ice

Robin Pagnamenta

September 28 2015, 10:25am, The Times

Shell said that exploratory results had been disappointing
GARY BRAASCH/CORBIS

Royal Dutch Shell ordered a retreat from the Arctic yesterday, as it abandoned plans to drill for oil in Alaska's Chukchi Sea, despite forfeiting nearly $9 billion in total costs.

What happened?

FP | by David Fracis | Sep 28,2015:

“The decision to abandon oil exploration at the top of the world is at once both surprising and to be expected. It comes just two months after President Barack Obama signed off on Shell’s operations off the coast of Alaska, and after the company defended its actions to environmental groups.”

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Shell updates on Alaska exploration

Sep 28, 2015

Shell today provides an update on the Burger J exploration well, located in Alaska's Chukchi Sea. The Burger J well is approximately 150 miles from Barrow, Alaska, in about 150 feet of water. Shell safely drilled the well to a total depth of 6800 feet this summer in a basin that demonstrates many of the key attributes of a major petroleum basin. For an area equivalent to half the size of the Gulf of Mexico, this basin remains substantially under-explored.

Shell has found indications of oil and gas in the Burger J well, but these are not sufficient to warrant further exploration in the Burger prospect. The well will be sealed and abandoned in accordance with U.S. regulations.

[…] "Shell continues to see important exploration potential in the basin, and the area is likely to ultimately be of strategic importance to Alaska and the US. However, this is a clearly disappointing exploration outcome for this part of the basin."

Shell will now cease further exploration activity in offshore Alaska for the foreseeable future. This decision reflects both the Burger J well result, the high costs associated with the project, and the challenging and unpredictable federal regulatory environment in offshore Alaska.

Source: www.shell.com

Real options

Cash flows used for calculation under NPV method are future projections and, thus, estimated values.

Uncertainty determining the risk of a project may be resolved during its lifetime.

Flexibility to react to changes is part of investment evaluation.

Financial options theory has been applied to physical investments.

Option is the right to buy [or sell] the underlying asset at a specified price during [or at] a specified time. Option holder pays option premium to option writer.

Real options: Valuating managerial flexibility

„A real option is a right, but not an obligation, to do something for a certain cost within or at a specific time.“ Source: He, 2007.

Options to make adjustments to the project once it is accepted based on new information:

- delay investment until an uncertainty disappears (timing option)
- expand or reduce the scale of the project
- change the input or output of the project
- abandon the project if a pessimistic scenario materialises

Example: oil or gas field with production costs exceeding the current oil/gas price but still valuable with a view to a potential future rise in the price.

Real options: Compared to NPV method

NPV method: more uncertain assets have relatively less economic value → riskier investments are penalised by higher discount rates.

Real options theory: uncertainty means not only possibility of future loss but also opportunity to create value from flexibilities by adapting the project to evolving conditions.

Energy projects:

- long time horizons
- large amounts of capital
- high uncertainty

Valuation complexity vs. Way of thinking

Oil drilling problem: Bayesian decision theory

Consider the problem faced by an oil company that is trying to decide whether to drill an exploratory oil well on a given site. Drilling costs are $200.000. If oil is found, it is worth $800.000. If the well is dry, it is worth nothing. However, the $200.000 cost of drilling is incurred, regardless of the outcome of the drilling.

Suppose that the oil company estimates that the probability that the site has oil ("Wet") is 40%.

Decision	**State of nature**	
	Wet	Dry
Drill Do not drill	600T 0	-200T 0
Prior probability	0,4	0,6

Source: M. Hillier

Real options: Expected pay-off

Expected pay-off = (Probability of success x Pay-off if successful) + (Probability of failure x Pay-off if failure)

In reference to the waste truck excercise in a previous class:

Annual revenue from truck operation of 120.000€ is an expected value.

Alternative 1:	80.000€/a	0,167
Alternative 2:	120.000€/a	0,5
Alternative 3:	140.000€/a	0,333

EV = 80.000€ * 0,167 +120.000€ * 0,5 + 140.000€ * 0,333

Decision tree method

Decision tree method is used for modelling sequential decision problems under uncertainty.

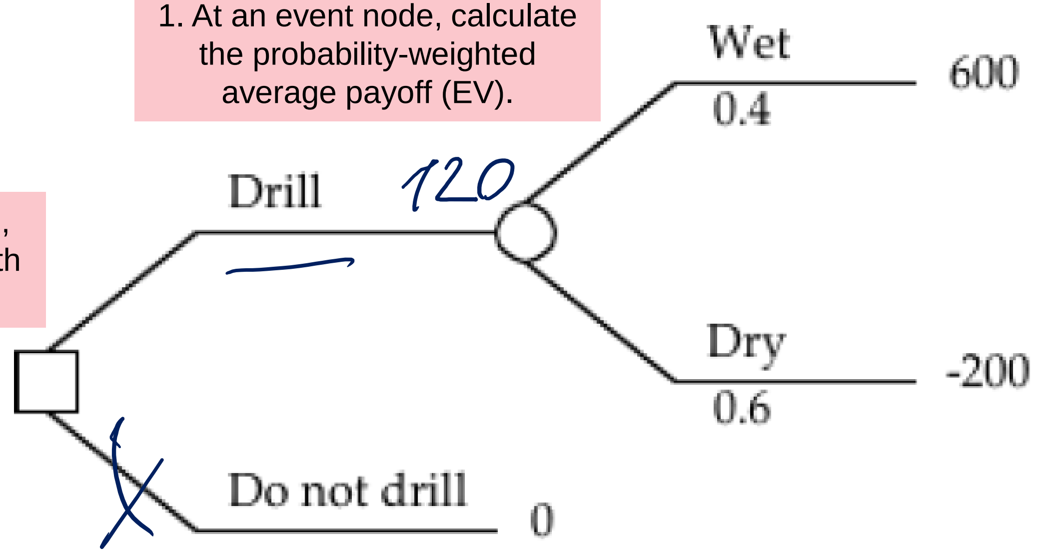
- Decisions — mutually exclusive and collectively exhaustive set of possible alternatives of courses of action
- Events — mutually exclusive and collectively exhaustive set of possible outcomes (states of nature) with assigned probabilities. The sum of probabilities in a set of events is equal to one.
- Payoffs — sum of costs and revenues associated with an alternative

Oil drilling problem: Decision tree solved (rolled-back)

1. At an event node, calculate the probability-weighted average payoff (EV).

2. At a decision node, choose the branch with the highest EV.

120 > 0



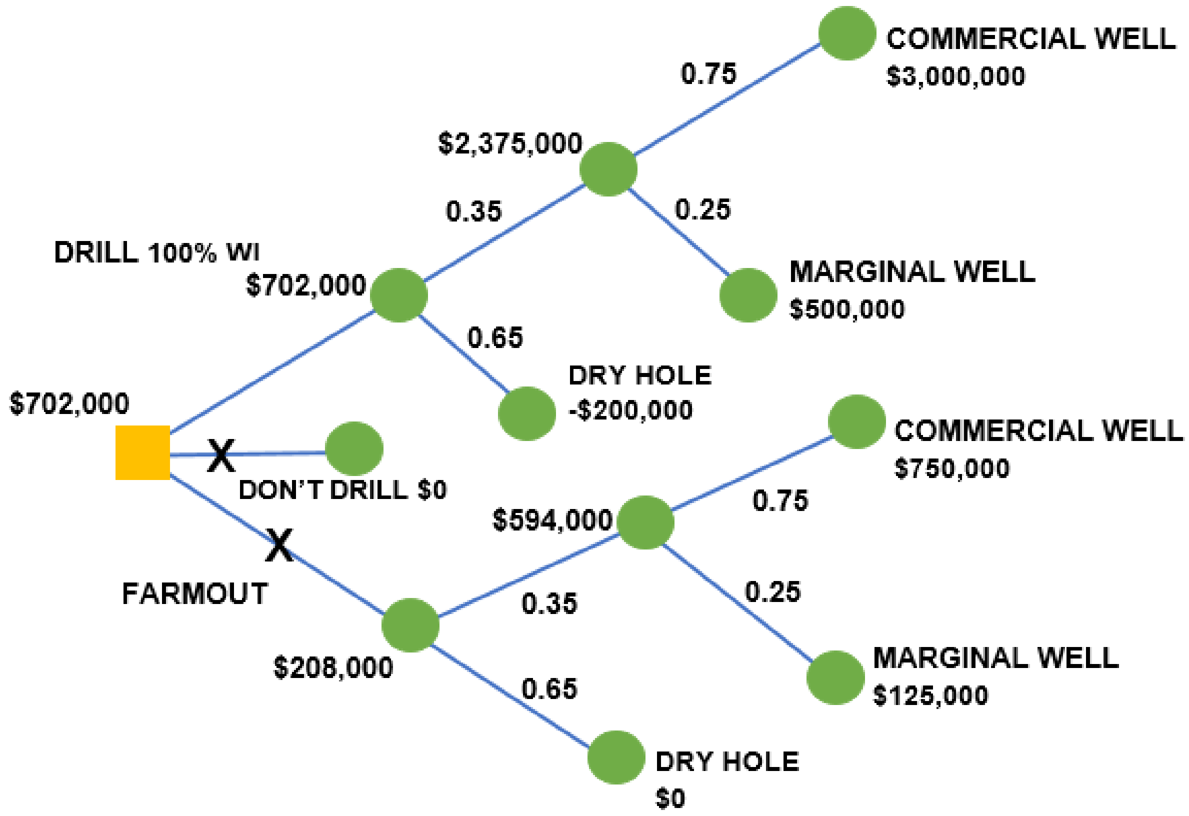
Payoff [Drill]: 600*0,4 + (-200)*0,6 = 240 – 120 = $120T

Payoff [Do not drill]: $ 0

⇨ Drill

Source: M. Hillier

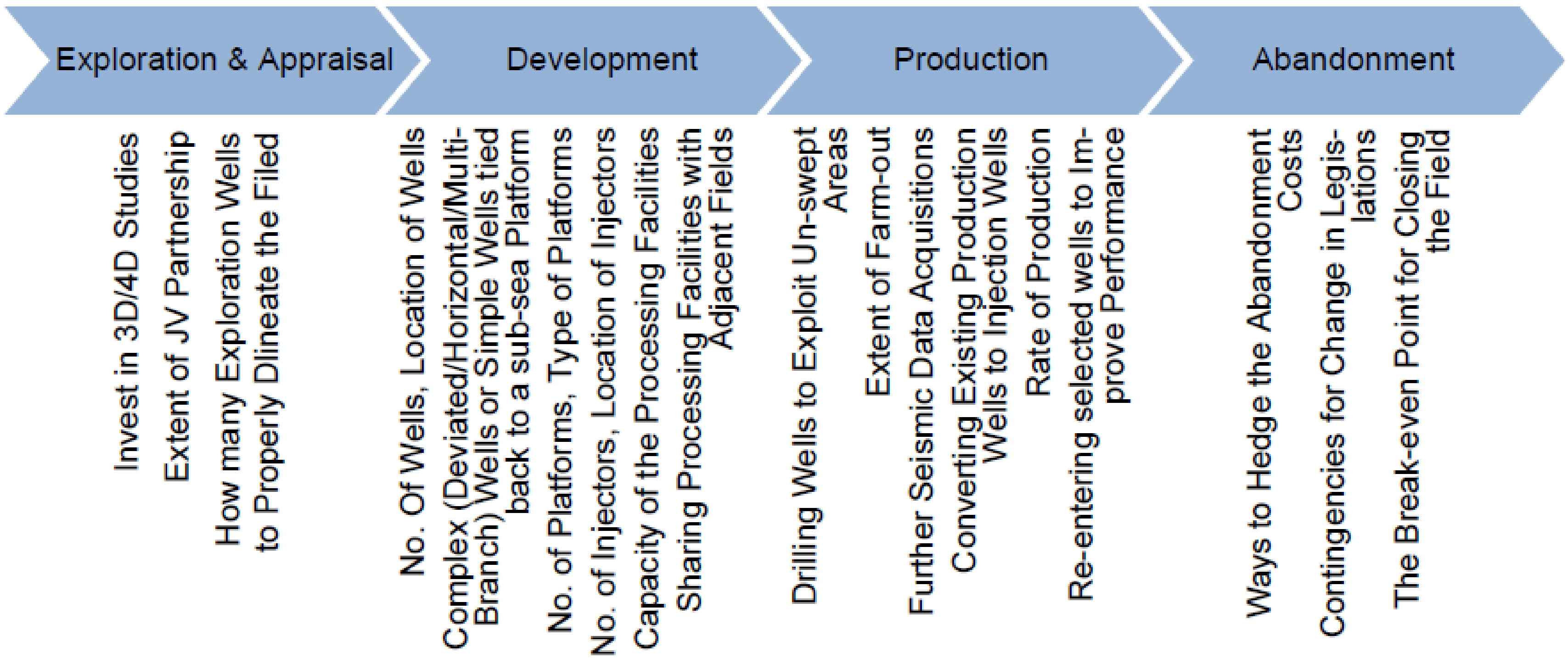
Oil drilling problem: Advanced decision tree



Source: Seba, 2008

Uncertainties in oil drilling

Oil and gas upstream industry is characterised by sequential investments.



Source: Jafarizadeh, Bratvold, 2009

Real options: Application examples

- Oil and gas exploration and production projects
- Developing a new technology → high R&D cost and risk
- Change in regulation, e.g. climate policies → future CO_2 price