Small Reactors: Financial analysis

An investment in building a new nuclear power plant must be profitable

Today, interest rates on loans may constitute up to 70% (!) of total capital cost for building large LWRs

Long plant-life is not necessarily beneficial in the financial analysis

Improved quality control and reduced time from order to sales of power are key factors to make nuclear new-build profitable

After this lecture you will be able to:

- **Estimate the net present value of future power sales**
- **Estimate the cost of capital for building a nuclear power plant**
- **Estimate costs for operating small nuclear reactors**

Revenue analysis: Sales of electricity

- The revenue from sales of electricity is either
  - Regulated by government (Higher on average, low fluctuation)
  - Determined by power market (Large fluctuations, often biased by subsidies)

Market	Current [€/MWh]	10 y min [€/MWh]	10 y max [€/MWh]
Nordic	100	0	400
UK	125	20	600
Ontario*	70	40	120
China**	65/102	64/90	66/102

* Ontario data are customer prices at daily mid demand, nuclear plants receive 40 €/MWh.

** Chinese data are customer prices for residents/industry

Net present value

Net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. NPV is used in capital budgeting and investment planning to analyze the profitability of a projected investment or project.
NPV is the result of calculations that find the current value of a future stream of payments, using the proper discount rate. In general, projects with a positive NPV are worth undertaking while those with a negative NPV are not.

- When a utility analyses whether to invest in a new production unit, the **"net present value"** of future profits from sales of electricity is used:

$$NPV(n_{life}, r) = \sum_{n=1}^{n_{life}} \frac{P(n)}{(1+r)^n}$$

net cash inflow-outflows during a single period t

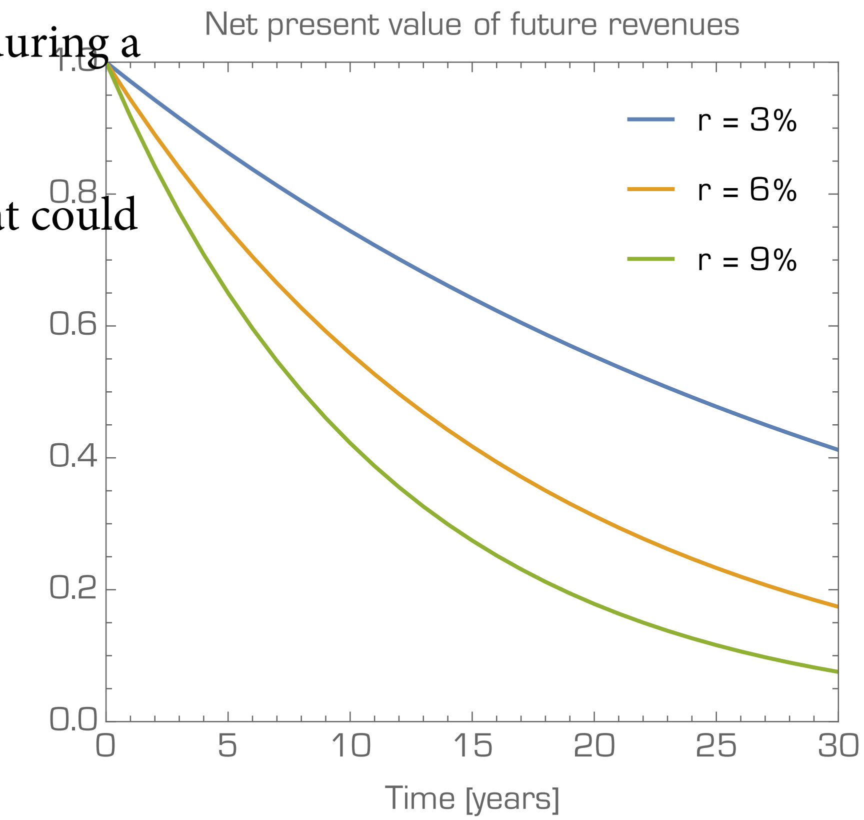
discount rate or return that could be earned in alternative investments

number of time periods

r = cost of capital

n = year of operation

$P(n)$ = profit from operations in year n



Profit = Revenues - OPEX - CAPEX

Money now is worth more than money in the future!

Cost of capital

- When financing the purchase of a power unit, a utility may either
  - Sell equity
  - Acquire debt on the financial markets

WACC: Weighted Average Cost of Capital

$$WACC = F_{EQ}\ x\ Cost(Equity) + F_{Debt}\ Cost(Debt)$$

$$Cost(Equity) = R_f + \beta\ (R_m - R_f)$$

$$Cost(Debt) = (1 - R_{tax})\ R_{debt}$$

Cost of Equity

$Cost(Equity) = R_f + \beta\ (R_m\text{-}R_f)$

R_f : Risk free government bond

R_m : Average stock market rate of return

β : Industry/branch related risk factor

www.tradingeconomics.com

UK 10 Y government bond [%]

Yearly stock market rate of return R_m

Index	FTSE	SP500
5y ave	3.8%	18.6 %
10 y ave	12.9 %	16.6 %
65 y ave		10.7%

Beta factor (US data)

Industry	β
Power	0.5
Mining	1.1
Engineering	1.3

Cost of Debt & WACC

$Cost(Debt) = (1\text{-}R_{tax})\ R_{debt}$

$WACC = F_{EQ}\ x\ Cost(Equity) + F_{Debt}\ Cost(Debt)$

Debt cost (US data)

Industry	$(1\text{-}R_{tax})\ R_{debt}$
Power	3,0 %
Mining	5,2 %
Engineering	3,0 %

WACC (US data)

Industry	$WACC$
Power	4,0 %
Mining	7,4 %
Engineering	7,5 %

http://people.stern.nyu.edu/adamodar/New_Home_Page/datacurrent.html

Operational expenditures (OPEX)

- Cost of operation for Forsmark (2018)
- 500 full year equivalent staff/GWe

Category	1 GWe LWR (SEK/MWh)	50 MWe SMR (SEK/MWh)
O & M	74	331
Fuel	48	48
Waste	34	34
Tax	2	2
Electricity	9	9
Total	**167**	424

- Rule of thumb for scaling O & M cost:
- Size of staff for the 50 MWe plant?

$$\frac{Cost(P_{small})}{Cost(P_{large})} \approx \left(\frac{P_{small}}{P_{large}}\right)^{0.5}$$

Cost of construction

- Construction cost of large LWRs today, including cost for interest.

Reactor	Specific cost	Country
EPR-1600	9000 USD/kWe	UK
VVER-1200	5000 USD/kWe	Hungary
APR-1400	4800 USD/kWe	UAE
Hualong-1000	2900 USD/kWe	China

- Rule of thumb for scaling construction cost in the same economic area:

$$\frac{Cost(P_{small})}{Cost(P_{large})} \approx \left(\frac{P_{small}}{P_{large}}\right)^{0.6}$$

- Cost of plant with 50 MWe units ≈ 900 MUSD/unit (VVER & APR data)
- Cost of plant with 200 MWe units ≈ 2000 MUSD/unit (VVER & APR data)

Net present value of accumulated profits

$$NPV(n_{life}, r) = \sum_{n=1}^{n_{life}} \frac{P(n)}{(1+r)^n}$$

P(n) = Revenues - OPEX - CAPEX

CAPEX = WACC x Cost of construction

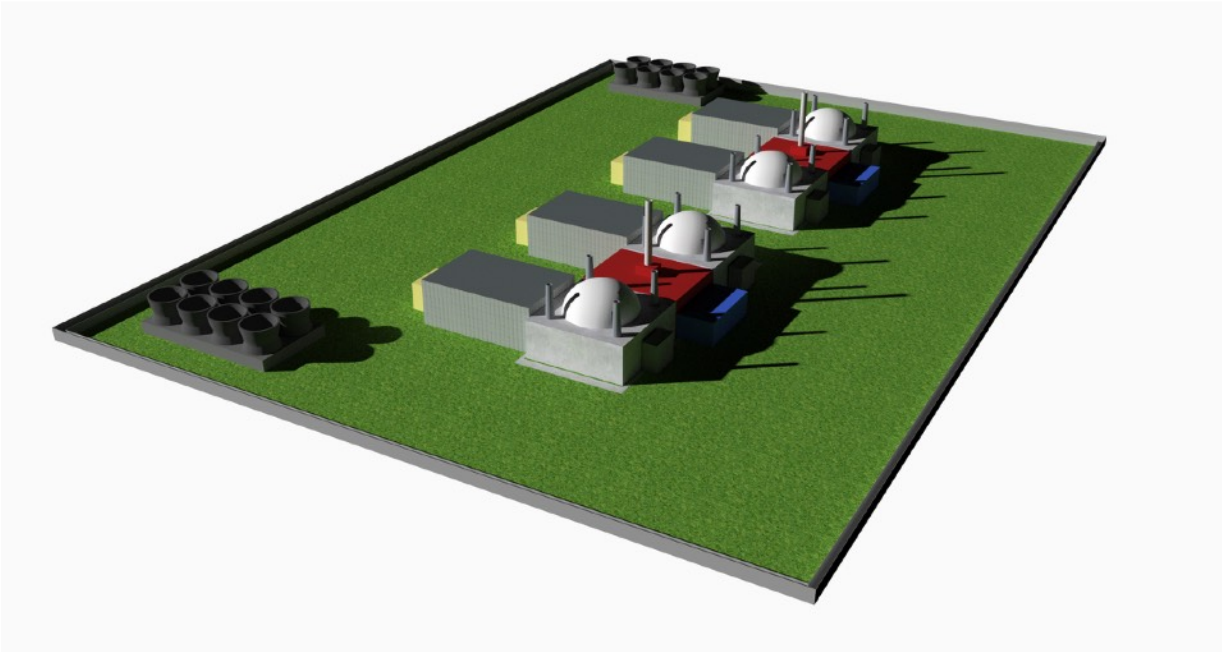
WACC = 5% (European average)

50 MWe: CAPEX = 45 MUSD

200 MWe: CAPEX = 100 MUSD

Power	50 MWe	50 MWe	200 MWe	200 MWe
Power sales [GWh]	394	394	1 578	1 578
Sales price [€/MWh]	40	60	40	60
Revenues [M€]	15,8	23,7	63,1	94,7
OPEX [M€]	17,8	17,8	47,3	47,3
CAPEX [M€]	45,0	45,0	100,0	100,0
Annual profit [M€]	–47,0	5,9	15,8	47,3
WACC	5 %	5 %	5 %	5 %
n_{life} [y]	30	30	30	30
NPV [M€]	–722	91	243	728

Cost analysis: Interest during construction



- Calculate the cost escalation (relative to the ”overnight cost”) due to accumulated interest during construction for
  - One 1 GWe LWR with on-site construction time = 7 years
  - 20 x 50 MWe SMR with on-site construction time = 2 years
- Apply the following WACCs: 5% and 9% (The latter is applied for Hinkley Point C).

Summary questions

- Why are operational costs expected to be higher for SMRs?
- Why are specific construction costs expected to be higher for SMRs?
- Why is accumulated interest during construction expected to be lower for SMRs?

The introduction of new technologies raises the cost significantly, and regulators claim an SMR cost (which cost is not specified) 30% higher than LRs. Additionally, the expected cost reduction determined by factory fabrication is too optimistic because "mass manufacturing" presents problems in the case of very expensive pieces of equipment in a small number. Another aspect to consider is that the creation of a massive assembly line requires a huge amount of capital and could hinder competition driving innovation and cost reduction.