# Toolbox 1 & 2: Parameter Estimation and Economics

## UCC501 Sustainable Energy, Spring 2014


Instructor:

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LECTURE 6

# $CO_2$ Savings from EV/PV Combo

- Estimate baseline
  - First we need to know how much carbon is contained in gasoline
  - From table 7.1 we can find the H/C atomic ratio for commonly used fossil fuels.
  - For gasoline: H/C = 2.1 - so every gram of gasoline contains 12/(2.1x1+12) g of C. Gasoline
  - For our 100km drive we burn 6l of gasoline or 4.38kg (gasoline density ~0.73kg/l) □3.73 kg of C (631g/l)
  - Assuming complete combustion. We estimate the weight ratio of $CO_2$ (molecular weight: 2x16+12=44) to C:

    44 /12
  - So our emissions for the 100 km drive is:

    44/12 x 3.73= 13.68 kg (or 136g/km)

How much are our savings?

# Lifecycle Emissions of Energy Generation Methods

Lifecycle estimates for electricity generators[a]

| Technology | Capacity/configuration/fuel | Estimate ($gCO_2e$/kWh) |
|---|---|---|
| Wind | 2.5 MW, offshore | 9 |
| Hydroelectric | 3.1 MW, reservoir | 10 |
| Wind | 1.5 MW, onshore | 10 |
| Biogas | Anaerobic digestion | 11 |
| Hydroelectric | 300 kW, run-of-river | 13 |
| Solar thermal | 80 MW, parabolic trough | 13 |
| Biomass | Forest wood Co-combustion with hard coal | 14 |
| Biomass | Forest wood steam turbine | 22 |
| Biomass | Short rotation forestry Co-combustion with hard coal | 23 |
| Biomass | FOREST WOOD reciprocating engine | 27 |
| Biomass | Waste wood steam turbine | 31 |
| Solar PV | Polycrystalline silicone | 32 |
| Biomass | Short rotation forestry steam turbine | 35 |
| Geothermal | 80 MW, hot dry rock | 38 |
| Biomass | Short rotation forestry reciprocating engine | 41 |
| Nuclear | Various reactor types | 66 |
| Natural gas | Various combined cycle turbines | 443 |
| Fuel cell | Hydrogen from gas reforming | 664 |
| Diesel | Various generator and turbine types | 778 |
| Heavy oil | Various generator and turbine types | 778 |
| Coal | Various generator types with scrubbing | 960 |
| Coal | Various generator types without scrubbing | 1050 |

[a] Wind, hydroelectric, biogas, solar thermal, biomass, and geothermal, estimates taken from Pehnt (2006). Diesel, heavy oil, coal with scrubbing, coal without scrubbing, natural gas, and fuel cell estimates taken and Gagnon et al. (2002). Solar PV estimates taken from Fthenakis et al. (2008). Nuclear is taken from this study. Estimates have been rounded to the nearest whole number.

Source: Sovacool 2008

# Commonly applied techno-economic evaluation concepts

- Inflation – Consumer Price Index

- Discount rate

- Evaluation methods:
  - Break-even
  - Net present value
  - Internal rate of return
  - Levelized cost

# Choice of Discount Rate (DR) for Investment Evaluation

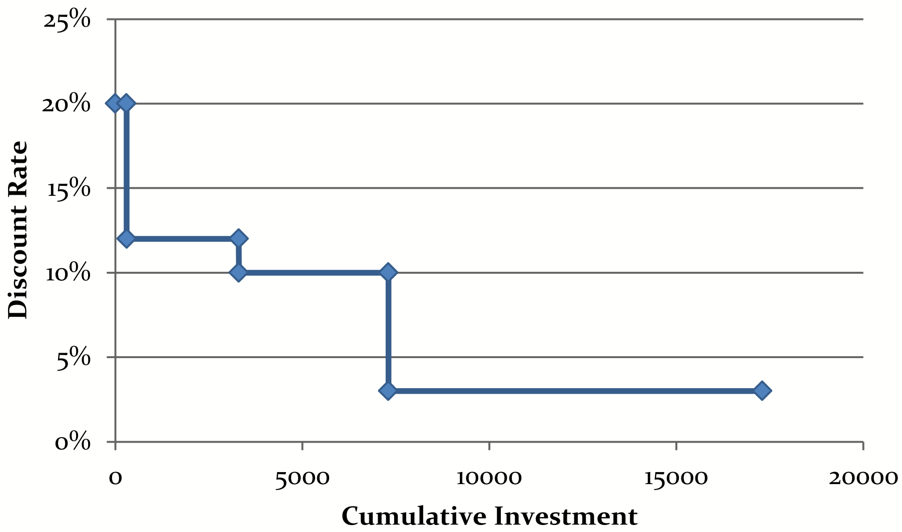
- DR reflects rate at which money can be "productive" = **productivity of capital**
- NOT equivalent to interest
- Example opportunities:
    - Credit Card Debt: $300 at 20%
    - Car Loan: $4000 at 10%
    - Company bond: $3000 at 12%
    - Savings account: 3%

- What is the DR for $100, $6000?

□Paying-off debt is a form of investment!

# DR Example

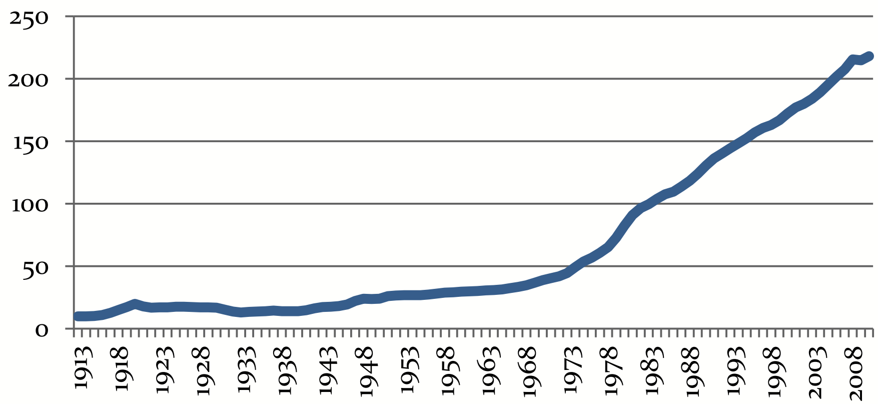
| | Investment | Rate |
|---|---|---|
| Project Alternatives | 300 | 20% |
| | 3000 | 12% |
| | 4000 | 10% |
| | 10000 | 3% |
| Cumulative | 0 | 20% |
| | 300 | 20% |
| | 301 | 12% |
| | 3300 | 12% |
| | 3301 | 10% |
| | 7300 | 10% |
| | 7301 | 3% |
| | 17300 | 3% |




- DR for $100: 20%
- DR for $6000: (300*0.2+3000*0.12+2700*10%)/6000 = 11.5%

# Value of Money - Inflation

- Inflation, Consumer Price Index:
  - ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt - US CPI with 1982 = 100




- Generally, you can work with constant $ if you deal with project costs
  - Revenues may need to be adjusted
  - Inflation complicates calculations, is subject to significant uncertainty and if it is consistently removed, it does not affect comparative evaluations
  - Across studies & estimates always note whether inflation is included

- Even with constant values, there is a “bias” towards the present versus the future:
  - Net Present Value ~ Levelized Cost
  - Accounts for cost of capital and cost of borrowing

# Discount Rate & Inflation

- Comparability

- Factors:
  - Productivity of capital: p% / year
  - CPI (purchasing power): i% / year

- If in constant CPI, dr = p
- If in varying CPI, dr = p + I

- Make a contract to sell PV power at a price 50c/kWh:
  - DR = p + I
- Buy a new more efficient car and save $1000:
  - DR = p (assuming fuel prices vary with inflation)

# Key Points on DR

- Dependent on situation and decision making opportunities
- Not a precise measure
- Always greater (or equal) than low-risk interest rates
- DR = minimum acceptable profitability
  NPV > 0 indicates a good project
- Low DR favors:
  - Capital intensive and longer projects

# Weighted Average Cost of Capital (WACC)

- A basic way for estimating DR

- Current cost of raising money
- Based on estimated returns expected by investors
- Represents a minimum DR (for money raised)
- Does NOT
  - Reflect Opportunity Cost
  - Account for project RISK

# Companies Options for Raising Capital

- Debt – borrowing
  - Bank loans & bond issues
  - Money received upfront – repaid with interest
  - Explicit benefit of creditors: interest revenue

- Equity – selling (parts of) the company
  - Shareholders gain ownership of the company and certain management rights
  - Company gives up part of future earnings and stock growth
  - Implicit benefit of shareholders: Expect future earnings / growth as dividends and stock prices
  - Most stock trades occur in secondary market (i.e. the company does not receive money)

# Influences on Cost of Money

- Confidence in Company
  - Interest rates vary on perceived risk (more later)
  - Value of shares
- Factors
  - Start-ups have higher cost of money
  - Strategic/financial status
  - Risk (industry & region)

# WACC Calculation

- WACC = $R_{eq}$(Eq%) + $R_{bonds}$(Bond%)
  - Return on Equity is an estimate of future growth & earnings – based on track record and prospects
- Start-up X example:
  - Equity: 1000 shares at \$10 each – $R_{eq}$ = 15%
  - Debt: 500 bonds at \$10 each – $R_{bond}$ = 10%
  - Why the difference?
- WACC = 15%(2/3)+10%(1/3) = 13.33%

# WACC for Established Firms

- WACC = $R_{eq}(E/V) + R_{debt}(D/V)$
- E, V: **<u>MARKET</u>** value of equity and debt
  - $1000 bond paying 10% on face value selling at $1200 will have R = 10% * 1000/1200 = 8.33%
  - Total value of equity = “market capitalization”=(share price)(number of shares outstanding)
- V = D + E

- Company Y example:
  - Debt = 50M – annual servicing = 4 M
  - Stock = 100M – expected return = 20M
- WACC = 20% (2/3) + 8%(1/3) = 16%

# WACC Overview

- Used as a metric:
  - Performance; cost of money over time
  - Comparison; among firms in industry
- Used as a reasonable approximation of DR
  - IF project is average investment without much risk (1000dth Danish wind turbine for Vestas)
- Does *not* account for **project risk**
- Does *not* account for **opportunity cost**

# Evaluation Methods: Break-even

- Break-even: Simplest.
  - Used for rule of thumb evaluations
  - Small projects
  - Does not account for time value of money, financing, etc.

- Example project evaluation:

What is the break even point for buying a Prius?

Hybrid car price premium: \$2000, Fuel Consumption Improvement: 2 l/100km. Gasoline: \$1.5 / l. Driving 15000km / year.

$$BreakEven = \frac{CapitalCost}{AnnualBenefit} = \frac{\$2000}{15000km/yr \times 2\ {}^{l}\!/_{100km} \times \$1.5/l} = 4.44years$$

# Evaluation Methods: Net Present Value

- Net Present Value (NPV): Widespread
  - Depends on discount rate
  - Any project
  - Projects with NPV>0 are adding value
  - Bias against capital intensive projects (see assignment)

$$NPV = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$

- Example project evaluation:

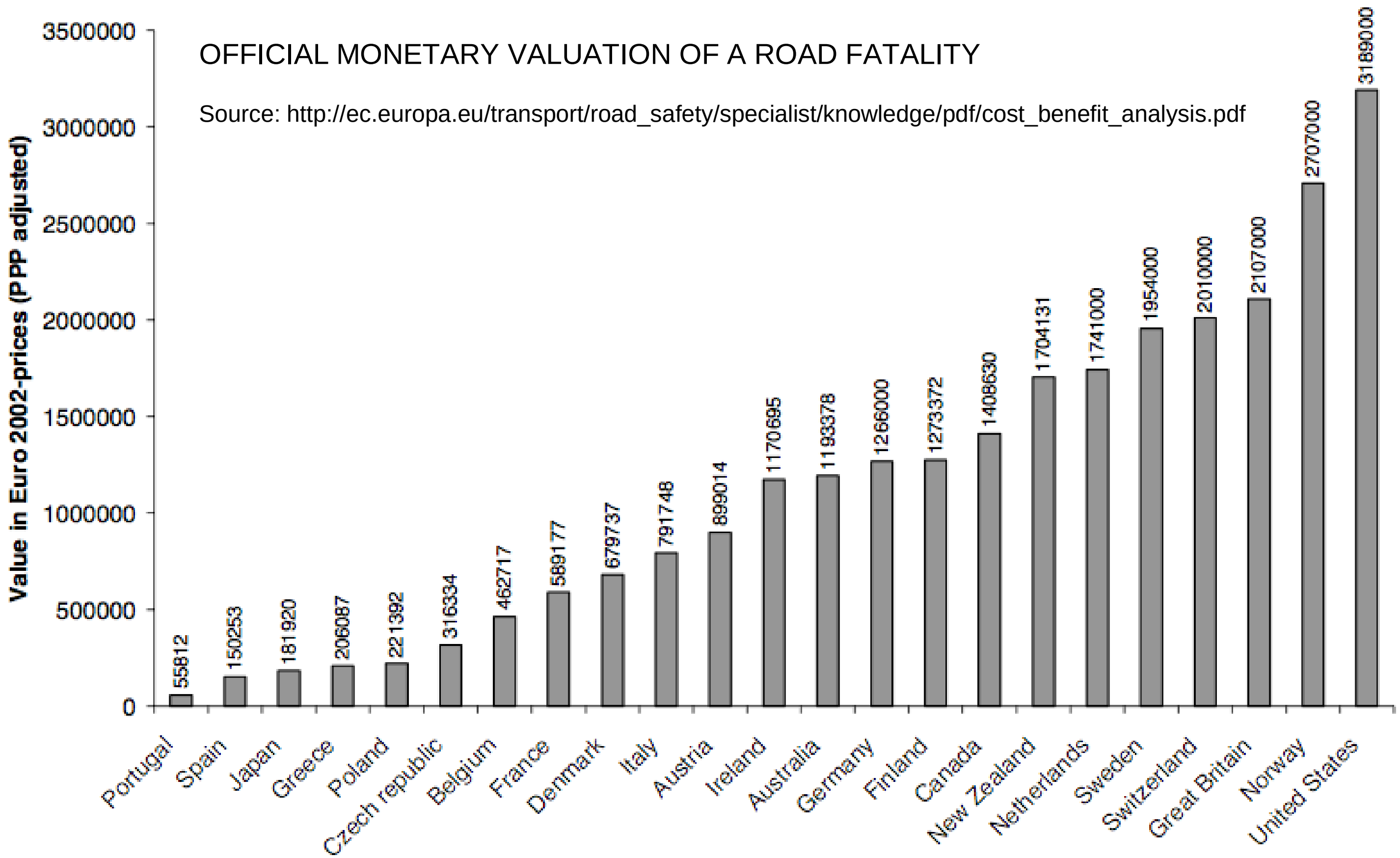
What is the NPV of buying a Prius vs a conventional vehicle?

| | Savings from operation | | | | | | Resale | | |
|---|---|---|---|---|---|---|---|---|---|
| Capital | Y1 | Y2 | Y3 | Y4 | Y5 | Y6 | Y7 | NPV | DR |
| -2000 | 450 | 450 | 450 | 450 | 450 | 450 | 600 | $676.64 | 5% |
| -2000 | 450 | 450 | 450 | 450 | 450 | 450 | 600 | $243.42 | 10% |
| -2000 | 450 | 450 | 450 | 450 | 450 | 450 | 600 | ($62.10) | 15% |

Inflation?

# Extreme NPV 1

- What is the cost of a life in CBA?




- Please remember you don't have to value it monetarily always! What is the alternative option?

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# Extreme NPV 2

- What is a good discount rate for climate change?
- What is a 'good' value for human life?
- For your chosen parameters, what is the value of a human life in 10, 50, 100, 300 years from now?

| | | | |
|---|---|---|---|
| V | 5,000,000 | | |
| r | 0.01 | 0.05 | 0.15 |
| t | | | |
| 10 | 4,526,435 | 3,069,566 | 1,235,924 |
| 50 | 3,040,194 | 436,019 | 4,614 |
| 100 | 1,848,556 | 38,022 | 4 |
| 300 | 252,672 | 2 | 0 |

# Evaluation Methods: IRR

- Internal Rate of Return (IRR):
  - Discount rate for which NPV is 0
  - If IRR > Cost of capital □project adds value
  - Independent of discount rate
  - Any project but can be ambiguous
  - Projects with NPV>0 are considered

- Example project evaluation:

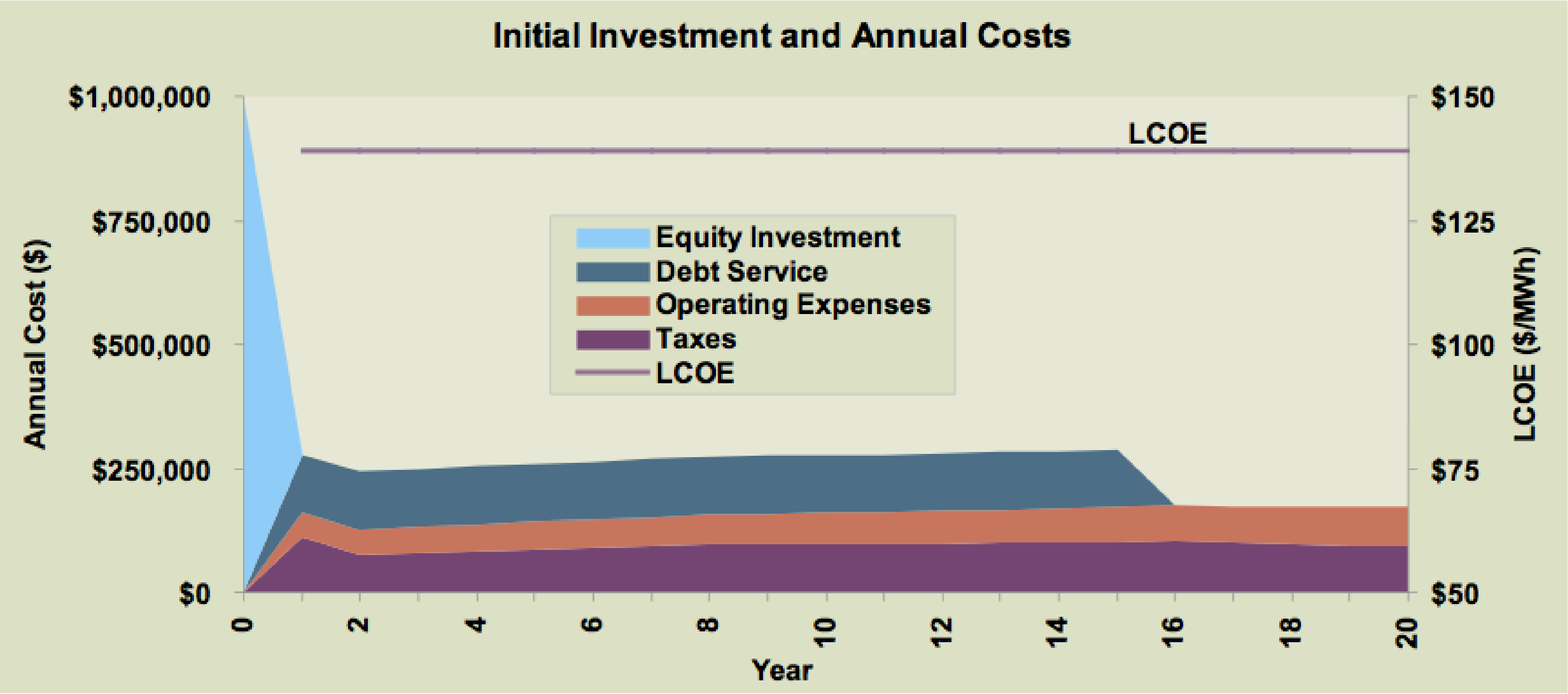
What is the IRR of buying a Prius vs a conventional vehicle?

13.4%

Inflation?

# Levelized Cost of Energy (LCOE)

- **Levelized Cost of Energy (LCOE): constant unit cost** of a payment stream that has the same ***present value*** as the total cost of building and operating a power plant over its lifetime.




Source: Black and Veatch

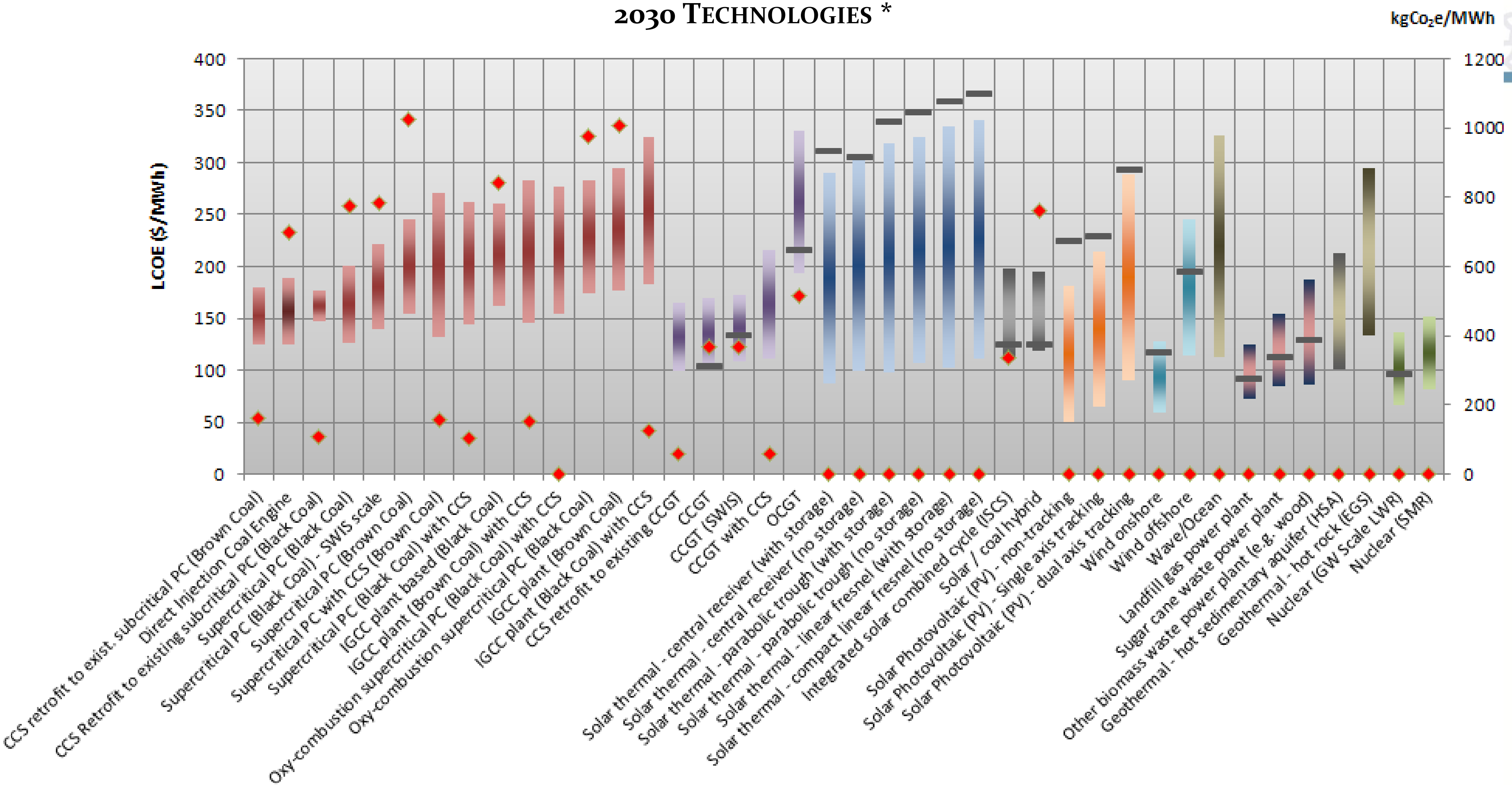
# Levelized Cost Formula

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

- LCOE = Average lifetime levelised electricity generation cost
- $I_t$ = Investment expenditure in the year t
- $M_t$ = Operations and maintenance expenditure in the year t (in calculations, other costs (such as a carbon price) may be added in to this variable or separately)
- $F_t$ = Fuel expenditure in the year t
- $E_t$ = Electricity generation in the year t
- r = Discount rate
- n = Amortisation period

# AUSTRALIAN ENERGY TECHNOLOGY ASSESSMENT 2012

## 2030 TECHNOLOGIES *




**LCOE# includes, where relevant, allowance for:**

- *Carbon Price*
- *$CO_2$ transport and sequestration cost*
- *Plant capital cost (EPC basis) within battery limits*
- *Owners costs excluding interest during construction*
- *Fixed and variable O&M*
- *Fuel costs*
- *Economic escalation factors*

**LCOE excludes:**

- *Decommissioning costs*
- *Project residual value*
- *Network connection costs and augmentation*
- *Effects of taxation*
- *Financing costs*
- *Plant degradation*

**LCOE Sources of Uncertainty**

- *Capital Cost*
- *Operating cost*
- *Fuel cost*
- *Carbon cost*
- *Sequestration cost*

**Legend**

- ◆ **Emission Intensity (kgCO2e/MWh)**
- ▬ **2012 LCOE mid-point (where technology is available in 2012)**

Note: * Default region is NSW except brown coal technologies (VIC) and SWIS scale (as specified)
# Levelised Cost of Electricity (LCOE)

***Source :***
*www.bree.gov.au*

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# Problems with the BREE?

- Fuel cost projections
- Inclusion of finance?
- Decommissioning expenses?

# Levelized Cost: Procedure

- Establish boundaries of system
  - Capital / over night cost, O&M, fuel cost
  - Performance/resource characteristics
  - Cost of capital (debt/equity) and discount rate
  - Taxes, depreciation and tax incentives (if applicable)
  - Inflation (optional)
  - Transmission/integration costs (as applicable – in most cases busbar costs is enough)
  - Externality costs (optional)

# Evaluation Method Examples: Levelized Cost

- Simplified calculation of investment decisions for a 1 GWe nuclear power plant
  - Construction cost: \$2B
  - Construction time: 5 years
  - Lifetime: 40 years
  - Utilization (Capacity Factor): 0.85
  - O&M costs (salaries & repairs): \$100M/yr
  - Fuel Costs (see later)
  - Decommissioning costs: \$0.5B
  - Insurance: Free – state provided

# Capital & Operating Expenses

Capital recovery with annual payment

$$C_{L1} = rP\frac{(1+r)^T}{(1+r)^T - 1}$$

P = \$2B

T = 40+5=45 years

$r = 0.5\,(r_{bond}+r_{equity})=0.5(4.5\%+10.5\%)=7.5\%$

$C_{L1}$=\$156 M / year

Operating: $C_{L2}$= \$100 M / year

Overnight Cost. Engineering Procurement & Construction Cost vs Owner Cost

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# Decommissioning Expenses

- Annuity sinking fund needed for decommissioning over the lifetime of the plant:

$$C_{L3} = D\left[\frac{r}{(1+r)^{40} - 1}\right] = \$2.2M$$

Present Value of a single payment

$$NPV = \frac{P}{(1+r)^n}$$

Present Value of a series payment

$$NPV = P\left[\frac{(1+r)^n - 1}{r(1+r)^n}\right]$$

# Fuel Expenses

- KF = \$2000/kg

- 1GWe plant with fc = 0.8 & n = 0.33 requires annual thermal energy:

$$W_{th} = \frac{f_c P_e T}{n} = \frac{0.8\times10^6 kWe \times 8760}{0.33} = 2.12\times10^{10} kWh$$

- Thermal energy released from 1 kg of fuel:

  $1.08\ 10^6$ $kWh_{th}$

Annual fuel consumption: 19600 kg

$C_{L4}$ = \$39.2M/yr

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# Levelized Cost

- $CL = CL_1 + CL_2 + CL_3 + CL_4 = \$297M / yr$

- Expected wholesale cost of electricity:

$$COE = \frac{100}{8760} \frac{CL(M\$/yr)}{fP_e(GW_e)} = 4.24c/kWh$$

If construction price higher, commercial i, real decommissioning, and increasing fuel price due to scarcity COE > 6.9c/kWh

# What did we miss?

Uncertainties???