EN 410
Energy Management

Gurubalan Annadurai
guru.a@iitb.ac.in

Recap

- MT and R process – Elements, steps
- Regression analysis
- CUMSUM Technique
- Energy benchmarking

Energy Billing

- ***Electricity***
- Fuel
- Steam
- Cold/hot water

Electricity billing rate

- Unlike other utilities (like fuel) – Charges standard and depends on demand, time, consumer type

Electric billing = Customer charge + Electric charge + Fuel adjustment

Flat rate

- Billing according to the amount of electricity
- Fixed customer charge
- Mostly applied to residential and commercial users
- Lower billing rate when compared to industries
- Lower billing rate for a fixed small amount of usage – promotes optimum using and encourage energy efficient equipment or appliances

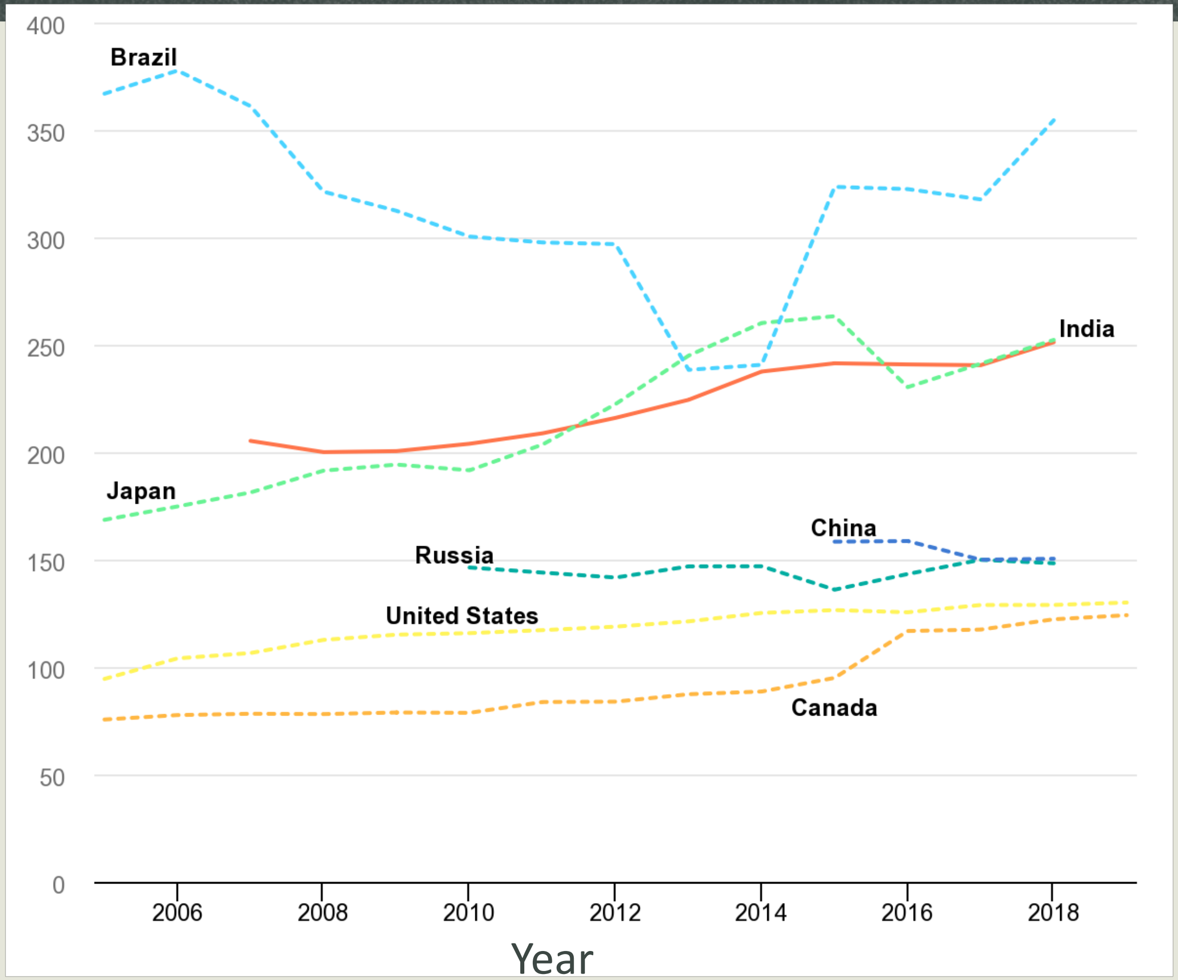
Flat seasonal rate – Similar to flat rate but different electric charge.

E.g. summer electric charge due to substantial use of air conditioners

Residential electricity prices

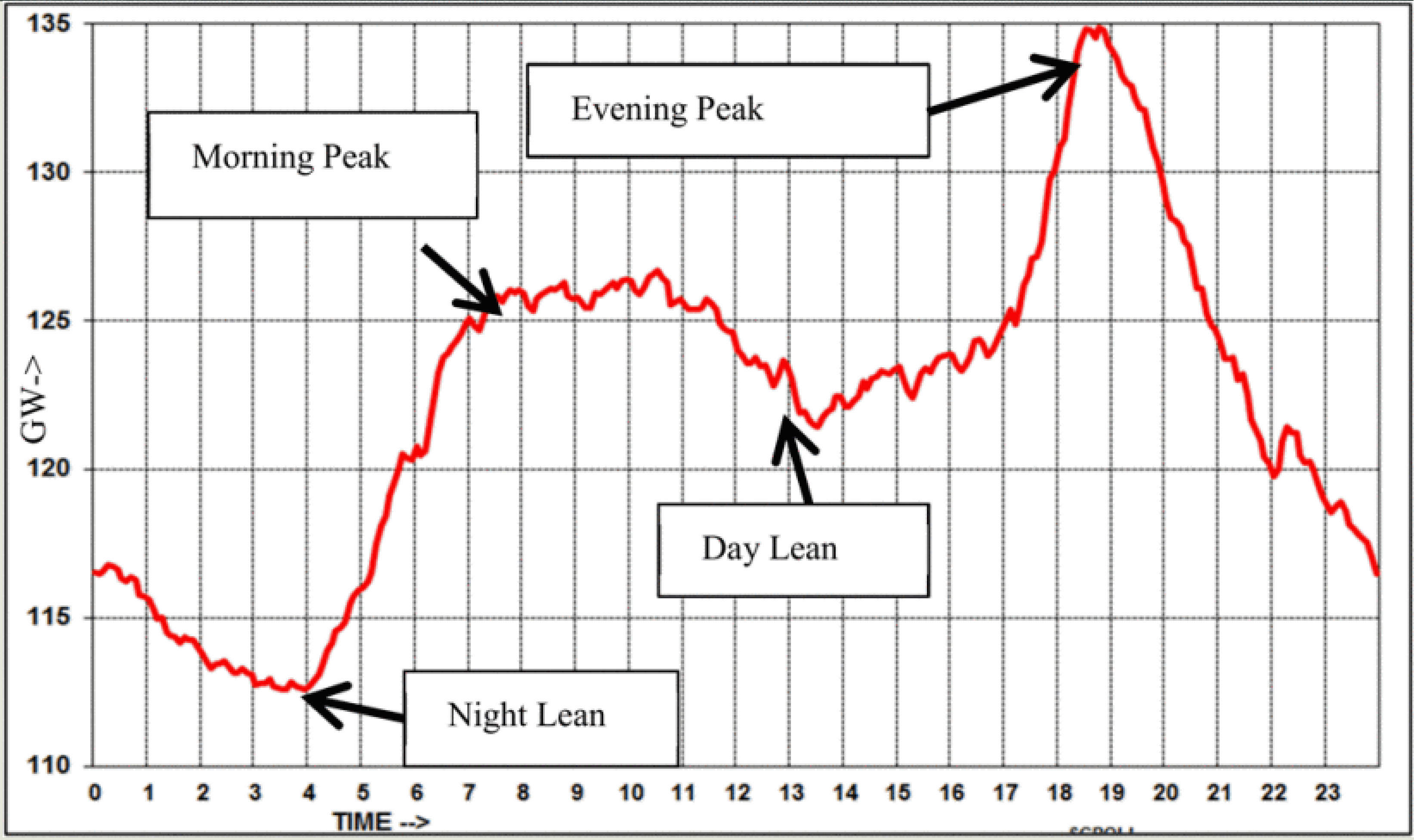
Variation due to fuel source of countries

USD PPP per MWh



Time of use rate

- Depends of the day
- Reducing the peak load and thereby reducing in investing new power plant while increasing trend of demand
- Scheduling the operation (e.g., setting up timer for dishwasher, washing machine etc.)

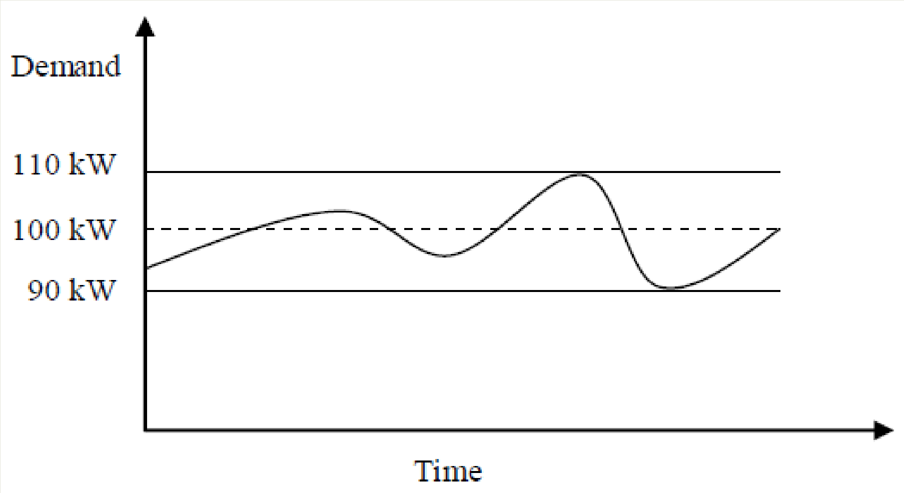


Voltage based billing

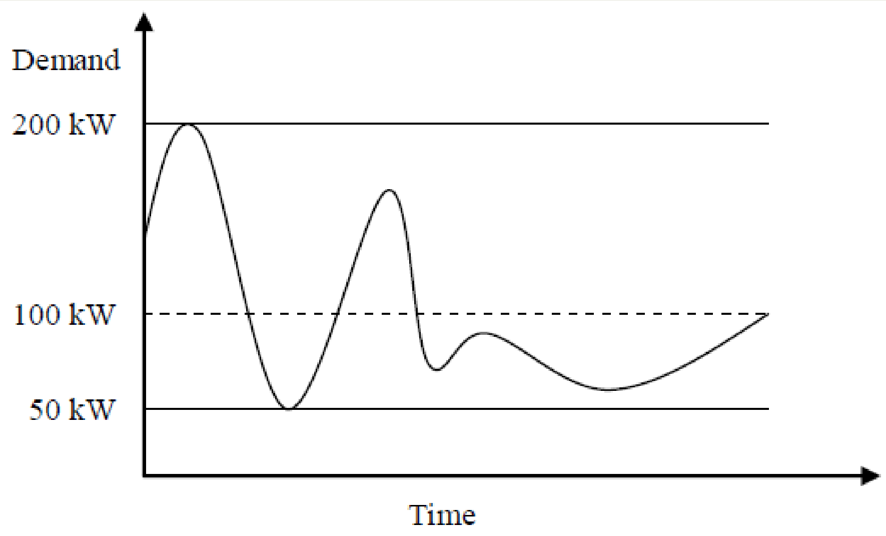
- Lower charge for the industry receives electricity at the transmission voltage rate (>50000 V)
- Maintenance charge for distribution and transformers

Demand Billing

- Additional charges for peak demand in addition to utility charge
- Load factor
- Ratchet rate – Certain % (generally 50) of peak demand of previous 11 or 12 months



Facility A: The utility charges this facility (0.80)(110 kW)($10/kW) = $880 per month for demand billing.



Facility B: The utility charges this facility (0.80)(200 kW)($10/kW) = $1600 per month for demand billing.

Demand Billing

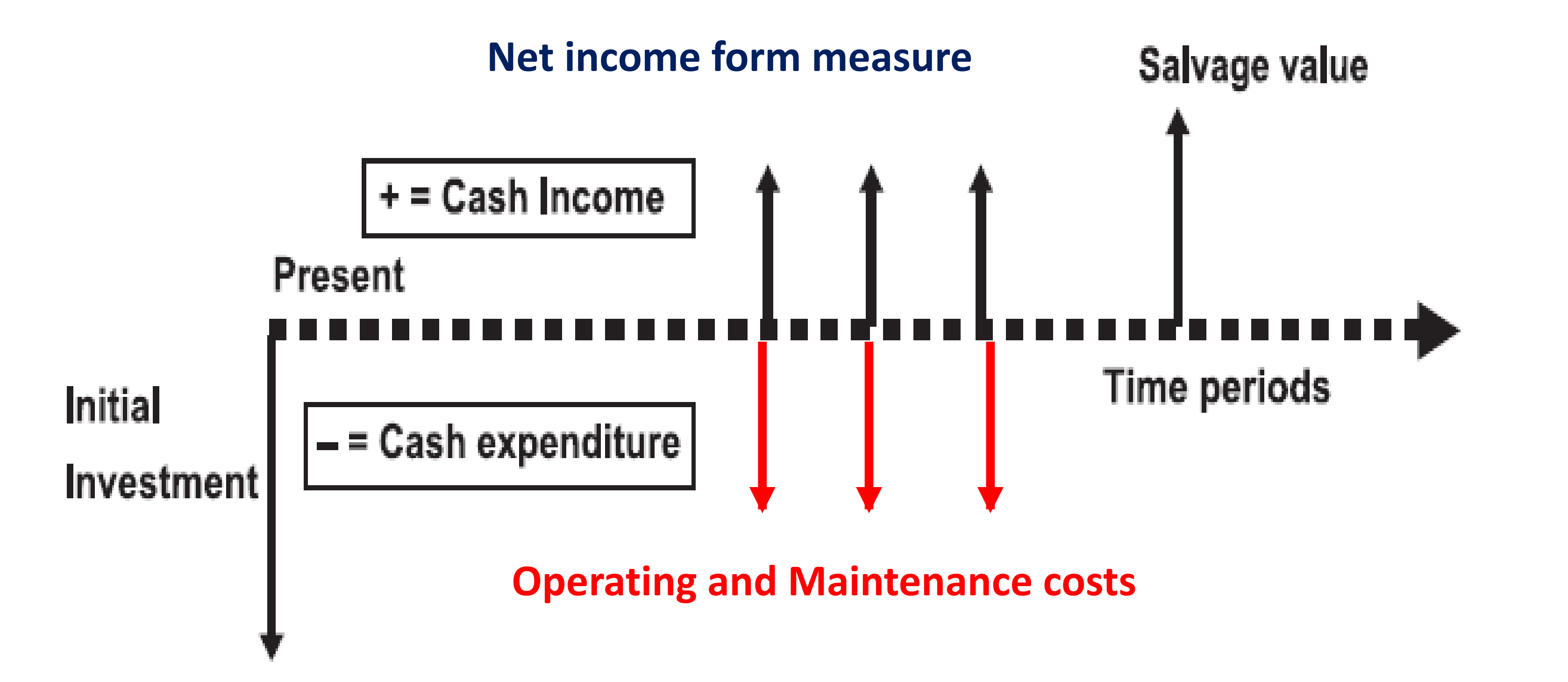
An industrial facility operating 24 hours a day through the week consumes 2.8 million kWh of electricity in April. The demand varies between 3000 kW and 5500 kW during this month. The electrical load supplied by the utility has fluctuated between 2000 kW and 6400 k during the previous 11 months. The demand billing for a given month is based on 50% of peak demand in the previous 11 months. The unit price of electricity is $0.12/kWh and the demand charge is $13/kW. Determine the load factor, consumption charge and percent of demand charge for the month of April.

Economics

- Any energy efficiency or conservation technique is evaluated by economics in industry
- Capital or Initial cost
- Operating cost
- Maintenance cost
- Scrap value

Cash flow diagram

- **Expenditures:** Negative (downward) arrows
- **Incomes:** Positive (upward) arrows



Metrics of economic analysis

- Time value of money
- Life cycle cost
    - Net present value
    - Levelized annual value
- Payback period

Time value of money

- Value of money changes with interest and inflation
- Simply subtracts the investment with savings during the timeline of project neglects the time value of money

$$F = P(1+i)^n$$ Compound interest

$$P = \frac{F}{(1+i)^n}$$ Relation between present and future values of money

i interest rate or discount rate
n number of time period
P present value of money
F future value of money

Time value of money - Uniform series amount

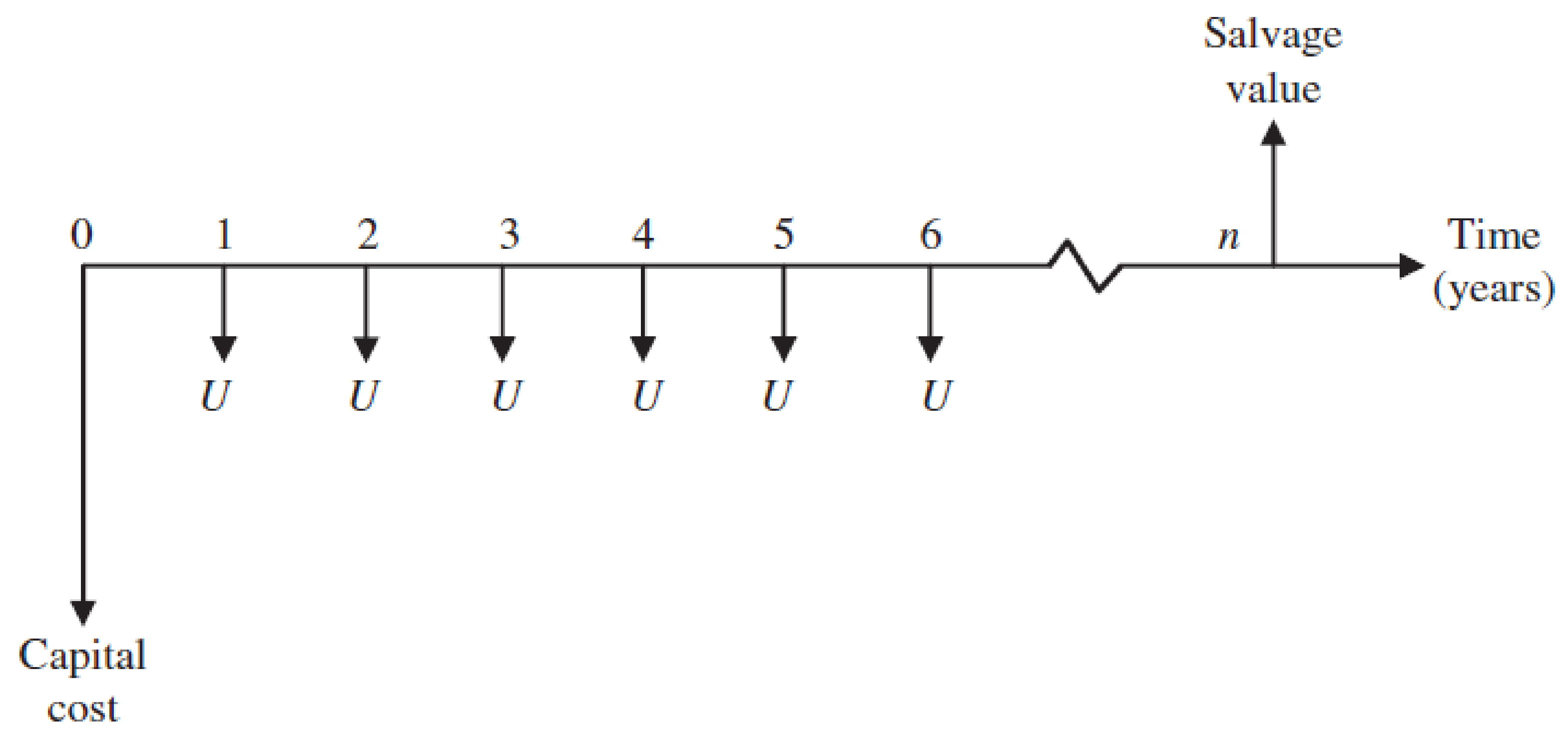
$$U = P\left[\frac{i}{1-(1+i)^{-n}}\right]$$

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

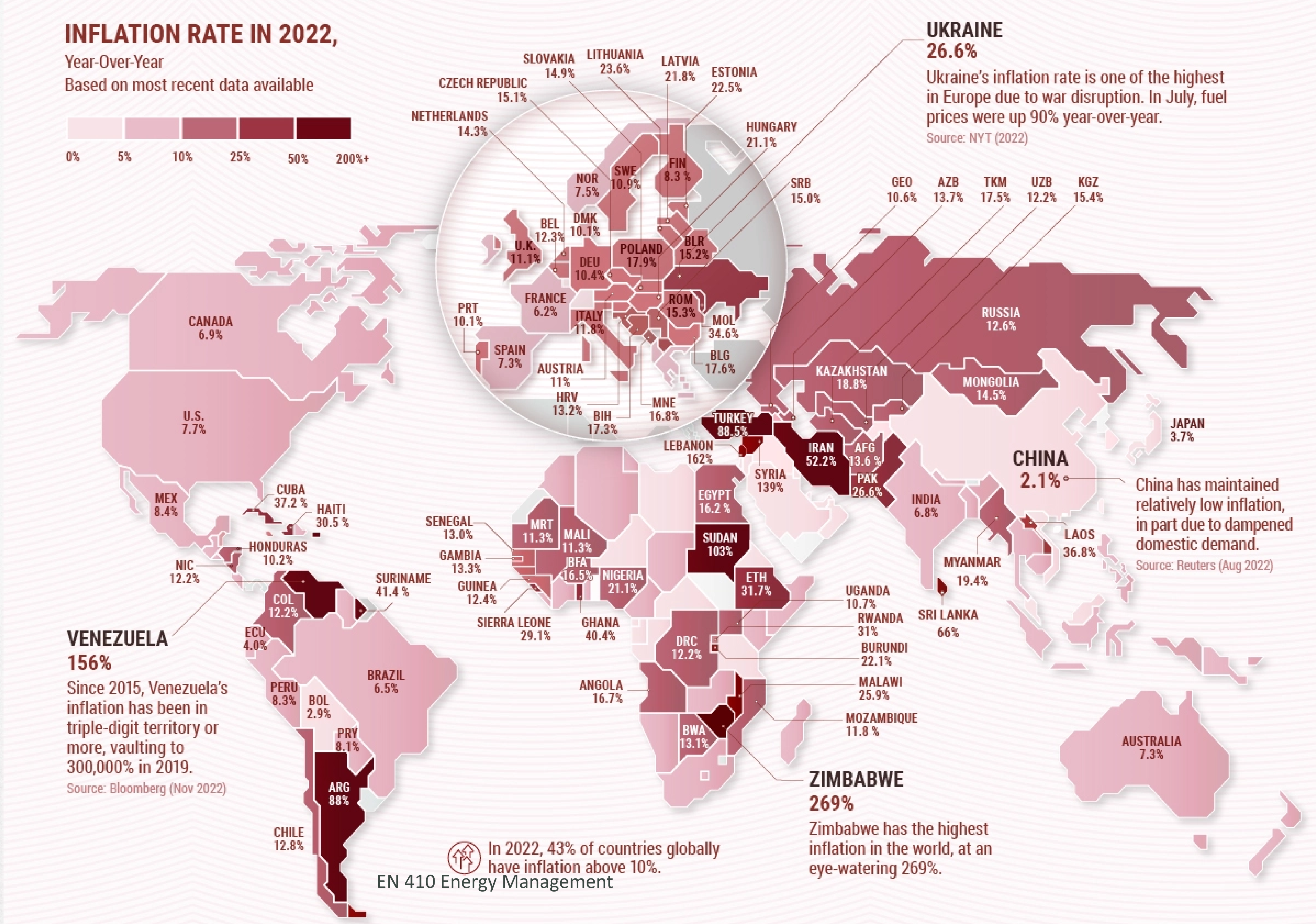
$$F = U\left[\frac{(1+i)^{n}-1}{i}\right]$$

$$U = F\left[\frac{i}{(1+i)^{n}-1}\right]$$

U uniform series amount: The periodic income or expenditure



Global inflation



Adjusted interested rate due to inflation (e) and taxation (t)

- Only Inflation $$i_{adj} = \frac{i - e}{i + e}$$

- Inflation and taxation $$i_{adj} = \frac{(1 + t)i - e}{i + e}$$

Energy economy

- Company A installs a heat recovery device that cost \$15000. Energy efficiency calculations indicate that this equipment will save \$3000/YR from the energy it saves for a period of 10 years. The salvage value of the equipment at the end of the 10 years is \$1500.

- Company B takes a different route and invests \$15000 in a savings account.

- The inflation adjusted interest rate (i_{adj}) for both applications is 5%.

- Determine which company is economical after 10 year.

$$F = U\left[\frac{(1+i)^n - 1}{i}\right]$$

$$i_{adj} = \frac{i-e}{i+e}$$

$$F = P(1+i)^n$$

Life cycle cost

- Converting all the costs into one value which is easy for comparison across the projects
- Net present value (NPV) method – Converting all the expenses and benefits over the life cycle into present value, P

$$\text{Net present value (NPV)} = \text{Total benefits in present time} - \text{Total costs in present time}$$

- Leveled annual value method – useful to compare the projects with different timeline

$$\text{Benefit-cost ratio} = \frac{\text{Total benefits in present time}}{\text{Total costs in present time}}$$

Net present value (NPV)

A steam boiler is to installed in an existing gas turbine power plant. The initial cost of the boiler is \$50000. It is estimated that the boiler will save \$10000/yr from the fuel it saves. It will take \$2000/yr to operate and maintain the boiler. The system requires major cleaning after 6 year for a cost of \$7000. The lifetime of the boiler is 12 year and the salvage value is \$3000. The inflation adjusted interest rate for both applications is 4%.

- Draw the cash flow diagram
- Determine the net present value (NPV)
- Recalculate the NPV without considering inflation and interest
- Estimate the benefit to cost ratio
- What is the levelized annual value of this project?

TABLE 11-1 Summary of Basic Equations Used in Economic Analysis

Notation	Equation
P = present value	$F = P(1+i)^n$
F = future value	$P = \dfrac{F}{(1+i)^n}$
U = uniform series amount	$U = P\left[\dfrac{i}{1-(1+i)^{-n}}\right]$
i = interest rate	$P = U\left[\dfrac{1-(1+i)^{-n}}{i}\right]$
n = number of time periods	$U = F\left[\dfrac{i}{(1+i)^n - 1}\right]$
	$F = U\left[\dfrac{(1+i)^n - 1}{i}\right]$

Payback period

- Significantly lower than project timelines
- Two to three years maximum
- Simple payback period

$$n_{spb} = \frac{\text{Investment}}{\text{Annual savings}} = \frac{\text{Investment}}{U} \qquad \left(\frac{\$}{\$/\text{yr}} = \text{yr}\right)$$

- Discounted payback period which includes the time value of money

$$P = U\left[\frac{1-(1+i)^{-n}}{i}\right] \Rightarrow n_{dpb} = \frac{\log\left[1-\left(\frac{P}{U}\right) i\right]^{-1}}{\log(1+i)}$$

Payback period of building insulation

A new insulation is selected for a building as an energy efficiency measure of building which can reduce the heat/cold losses from the building. A natural gas boiler is used in winter for heating and an air-conditioning system is used in summer for cooling. It is estimated that the insulation will reduce the natural gas consumption by 7500 therm in winter and electricity consumption by 50000 kWh in summer. The insulation costs around $60,000 including the material and labour. The unit cost of natural cost and electricity is $1.2/ therm and $0.11/kWh. The interest rate is 6%. Estimate the discounted and simple payback periods.

(Note: 1 therm = 100,000 Btu, 1 BTU = 1055 J)

$$n_{spb} = \frac{\text{Investment}}{\text{Annual savings}}$$

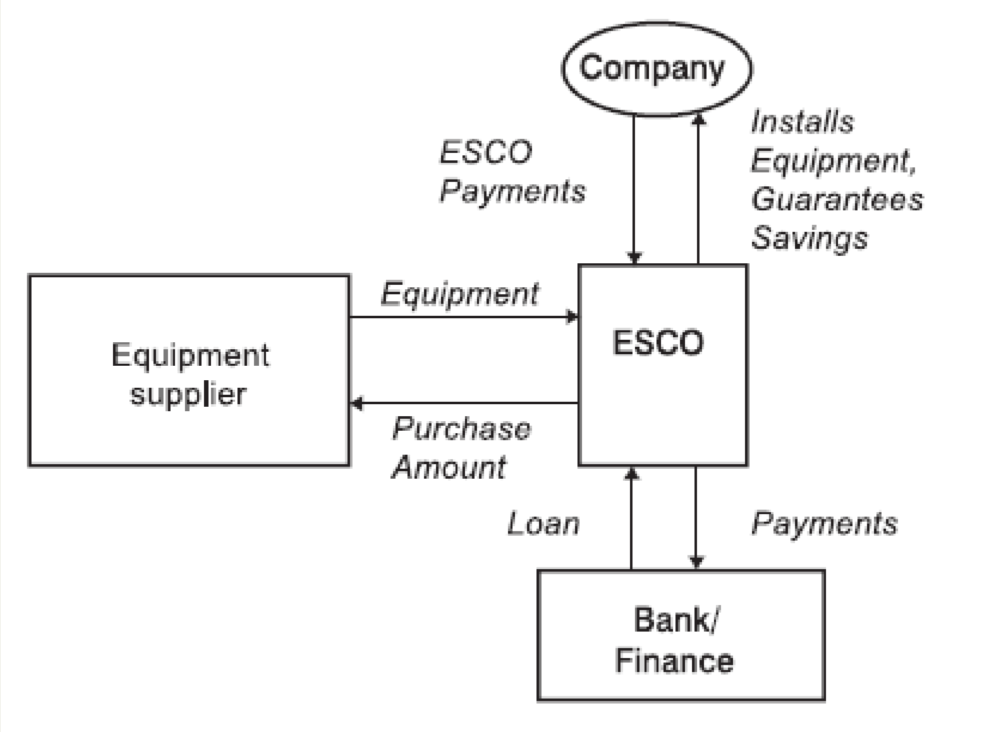
$$n_{dpb} = \frac{\log\left[1 - \left(\frac{P}{U}\right) i\right]^{-1}}{\log(1+i)}$$

Energy performance contractor

- Energy service companies - ESCO
- Assessment, design, construction, installation, management service, financing
- Payment on performance
- Generally risks associated projects taken by ESCO
- Fee type – Fixed fee, Shared savings and Guaranteed savings

Role of ESCO

- Identify the savings potential
- Finical own resources or banking
- Equipment, personal training for operation and maintenance, energy efficient practices
- Monitoring of operation and energy savings
- Measurement and savings verification



Recap

- Cash flow diagram
- Time value of money
- Net present value
- Levelized annual value
- Payback period
- Role of ESCO

References

- K. Gaur, H. Kumar, R. P. K. Agarwal, K. V. S. Baba and S. K. Soonee, "Analysing the electricity demand pattern," *2016 National Power Systems Conference (NPSC)*, 2016, pp. 1-6, doi: 10.1109/NPSC.2016.7858969.
- https://www.visualcapitalist.com/mapped-which-countries-have-the-highest-inflation/