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# *About CTCN Technical Assistance*

## Training Programme on Energy Efficiency and Self Generation Option

*Strictly Private  
and Confidential  
January 2020*



**CTCN**  
CLIMATE TECHNOLOGY CENTRE & NETWORK

# Agenda

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**Overview of technical assistance** **3**

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**Activities performed** **7**

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**Key findings** **12**

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# *Overview of technical assistance*

## *Strategic context & Need for the study*

Solomon Islands relies primarily on imported fuels to meet its energy needs. Imported fuels account for 28-30% of the country's total imports.

The National Energy Policy states to

- Improve energy efficiency and conservation in all sectors by 10.7% by 2019
- Increase use of renewable energy sources for power generation in urban and rural areas to 50% by 2020

Energy demand of Solomon Water is ~10% of the total energy demand of Solomon Islands

Solomon Islands has committed to reduce its GHG emissions by 12% below 2015 levels by 2025 and 30% below 2015 levels by 2030 compared to Business-As-Usual projection



TA would help Solomon Water in identifying viable Renewable Energy and Energy Efficiency options, include energy efficiency in the procurement stage itself and build technical capabilities

# *Aim of Technical Assistance*



## Assessment of Energy Efficiency and RE options

- Field visit for measurement
- Identify energy conservation opportunities
- Identify self generation options



## Capacity building through on-job training for Solomon Water

- Prepare training modules and operational modules
- On-the –job hands-on-mentoring on EE and RE implementation



## Detail assessments of shortlisted EE and SGO options for Solomon Water

- Technical analysis
- Financial analysis



## Monitoring of impact

- CTCN Monitoring and evaluation template

## *Expected benefits*

### **Environmental Benefits**

- Enhanced energy efficiency
- Improved energy security
- Lower dependence on imported fuels
- Contribution towards climate change mitigation

### **Economic Benefits**

- Reduced operating (energy) cost for Solomon Water
- Increased investments in energy efficiency and renewable energy

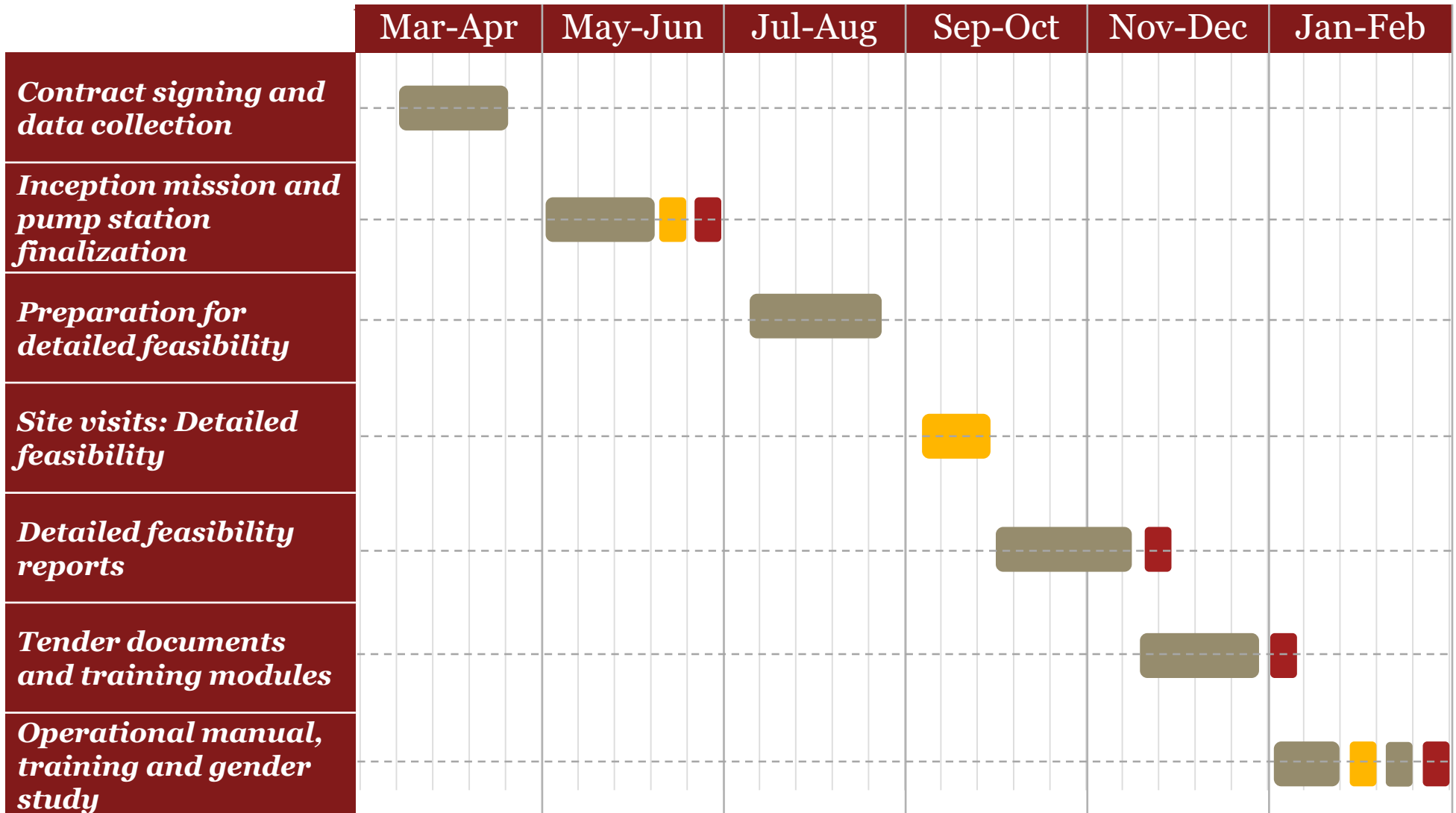
### **Social Benefits**

- Skill enhancement of Solomon Water professionals on EE and RE
- Enhanced profitability leading to availability of funds for increasing water coverage to un-serviced areas

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# *Activities performed*

# Activity timeline



## *Detailed feasibility study*

<b>Sr. No.</b>	<b>Name of pump station</b>	<b>No. of transfer pumps</b>	<b>No. of borewell pumps</b>
1	Titinge	3 (2 R + 1 S)	4 (2 R)
2	Skyline	3 (1 R + 2 S)	4 (2 R)
3	Tuvaruhu JICA	2 (2 R)	3 (3 R)
4	Tuvaruhu SIWA	2 (1 R + 1 S)	2 (2 R)
5	Kwaibala	2 (1 R + 1 S)	0
6	Borderline	3 (2 R + 1 S)	4 (4 R)
7	Tasahe	3 (2 R + 1 S)	4 (4 R)

*Where, R – Run, S – Standby*

*All operational pumps including standby pumps were tested*

# Activities performed at each pump station

## 1. Understanding operational procedures

- Operational cycle/sequence of transfer pumps and bore pumps
- Working out the water balance

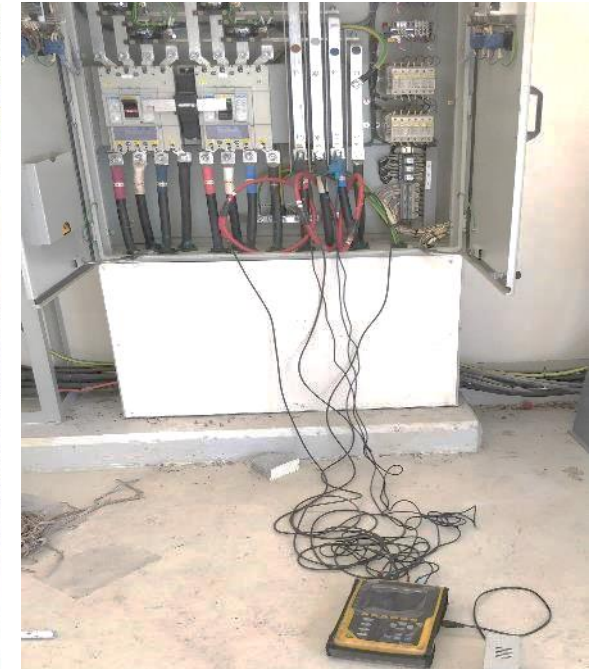
## 2. Conducting pump efficiency assessment

Measurement of following:

- Pump water flow rate
- Suction and discharge pressure
- Power consumption of motor

## 3. Self-generation potential assessment

- Total available area in transfer pump station
- Roof space available
- Effect of shading



## *Few photos of field visits*



**Field visit support  
team from SIWA**

- **Adam**
- **Shaun**
- **Noel**

- **Danny**
- **Livingston**
- **Sam**
- **Moffat**

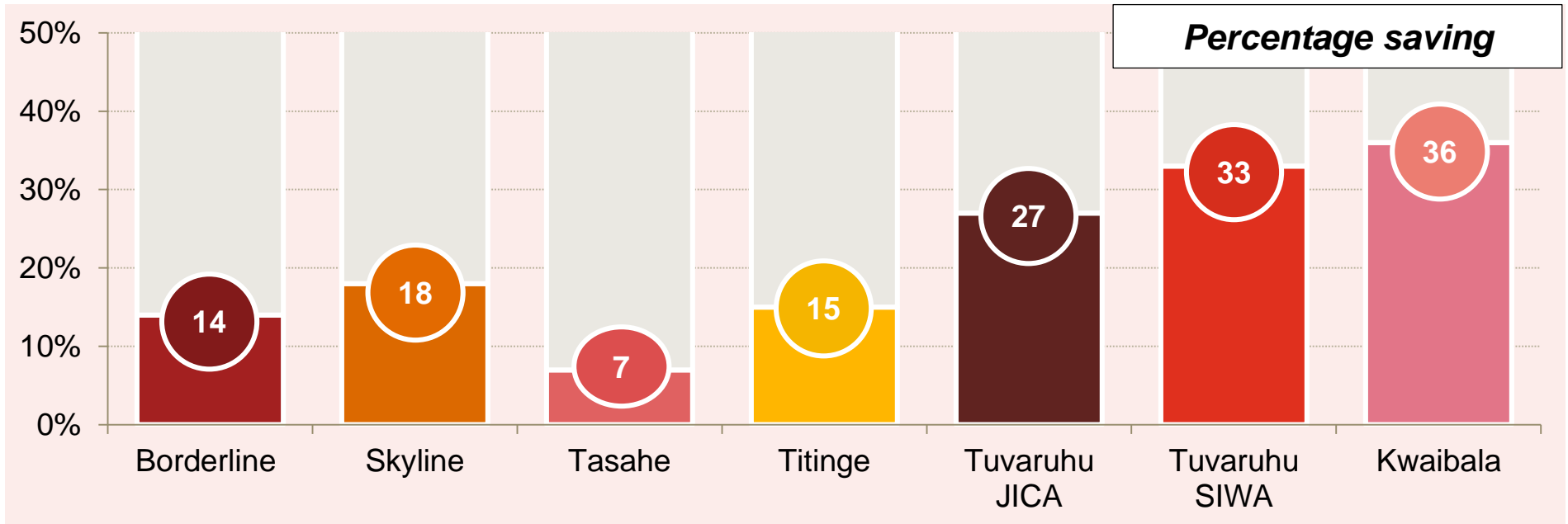
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# *Key findings*

## *Longlist of findings*

- 1 Use of in-efficient pumps*
- 2 Use of non-standard or low rating motors i.e. IE1, IE2*
- 3 Over-sized pumps*
- 4 Worn impeller*
- 5 Clogging of bore well screens*
- 6 No calibration of water flow meters and pressure gauges*
- 7 FTL 36W tube lights*
- 8 Energy Management System*
- 9 Low power factor*
- 10 Potential for Solar PV system*

## Summary of savings identified



**Investment**

**SBD 1.8 million**

**Energy Saving**

**490 MWh/year**

**Monetary Saving**

**SBD 2.7 million/year**

**GHG reduction**

**326 tonne CO<sub>2</sub>/year**

Equivalent to water production of  
**~2400 m<sup>3</sup> per day**

## Self generation potential summary

Daily Global Horizontal Irradiation in kWh/m <sup>2</sup> /day											
Latitude -9.44°, Longitude 159.96°											
Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35

Pump Station	Solar power potential kWp
Borderline	21.8
Skyline	21.8
Tasahe	21.8
Titinge	21.8
Tuvaruhu	97.8
<b>Total</b>	<b>185</b>

**Investment**

**SBD 5 million**

**Conventional Energy Avoided**

**286 MWh/year**

**Annual Monetary Saving**

**SBD 0.77 million**

**Annual GHG reduction potential**

**189 tonne CO<sub>2</sub>**

*Thanks!*



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# *Detailed feasibility study: Methodology*

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*January 2020*



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# Agenda

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**System boundary** **6**

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**Audit methodology** **8**

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# *Need and purpose of energy audit*

# *What is Energy Audit?*

**1**

*Energy Auditing serves to identify all energy usage in a facility and quantifies it according to its discrete functions*

**2**

*Energy Auditing monitors the performance of various energy consuming equipment in a facility and identifies opportunities*

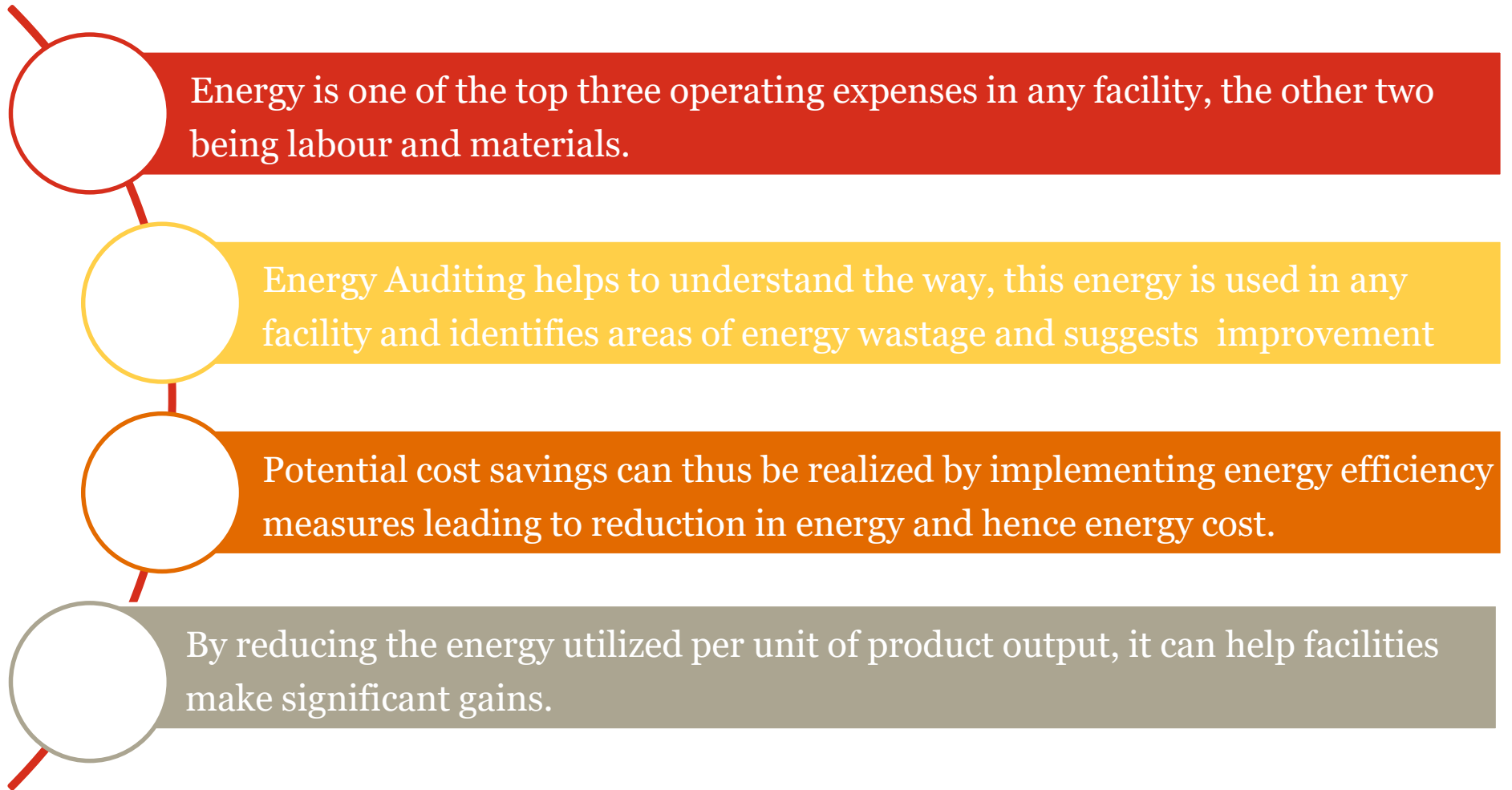
**3**

*Energy auditing helps develop a strategic approach to energy management.*

**4**

*It is key to development of comprehensive energy management programme for any facility.*

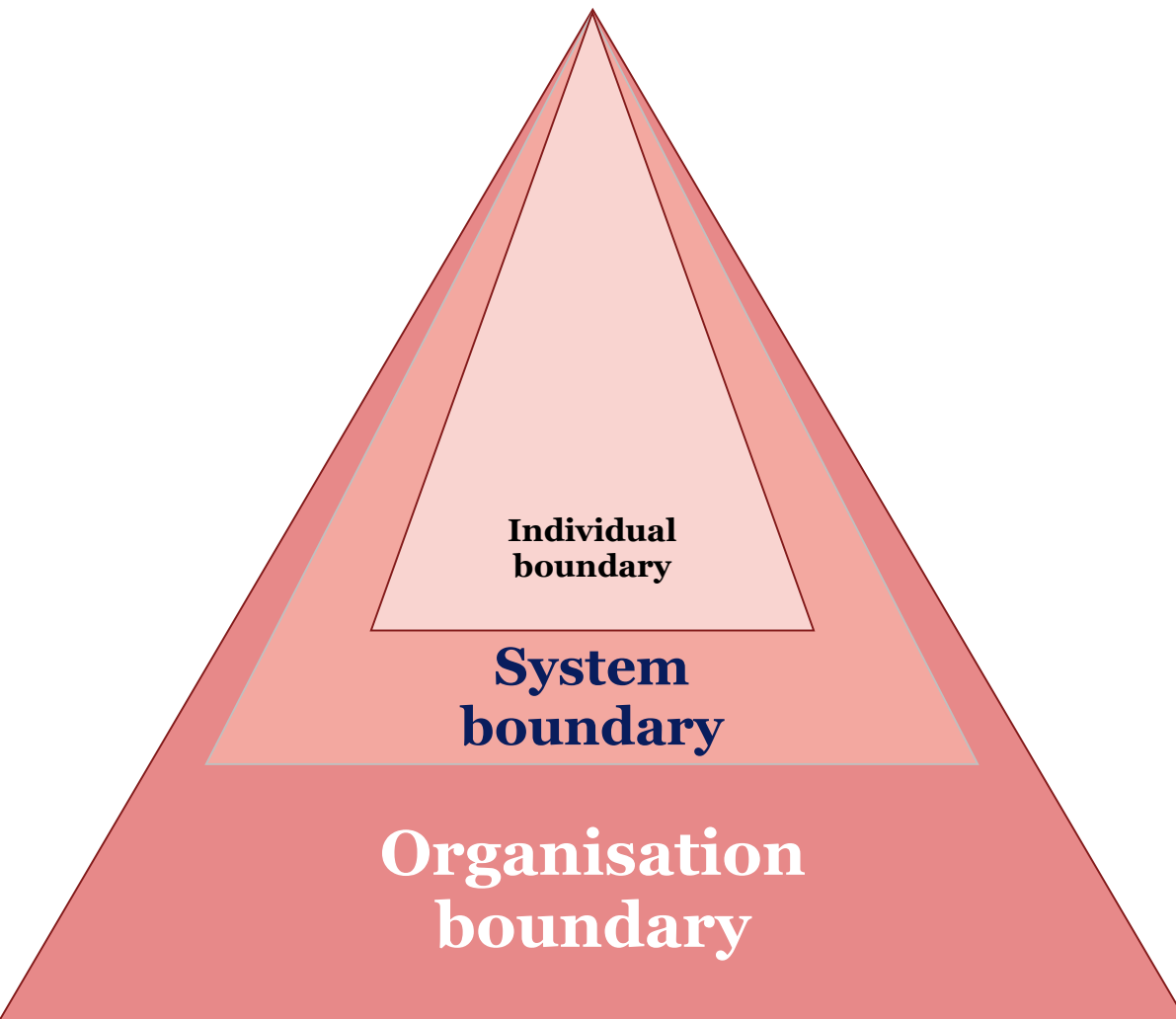
# *Need for Energy Audit*



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# *System Boundary*

# Defining system boundary



**Individual boundary:** Boundary of an equipment

E.g. Pump, light, motor

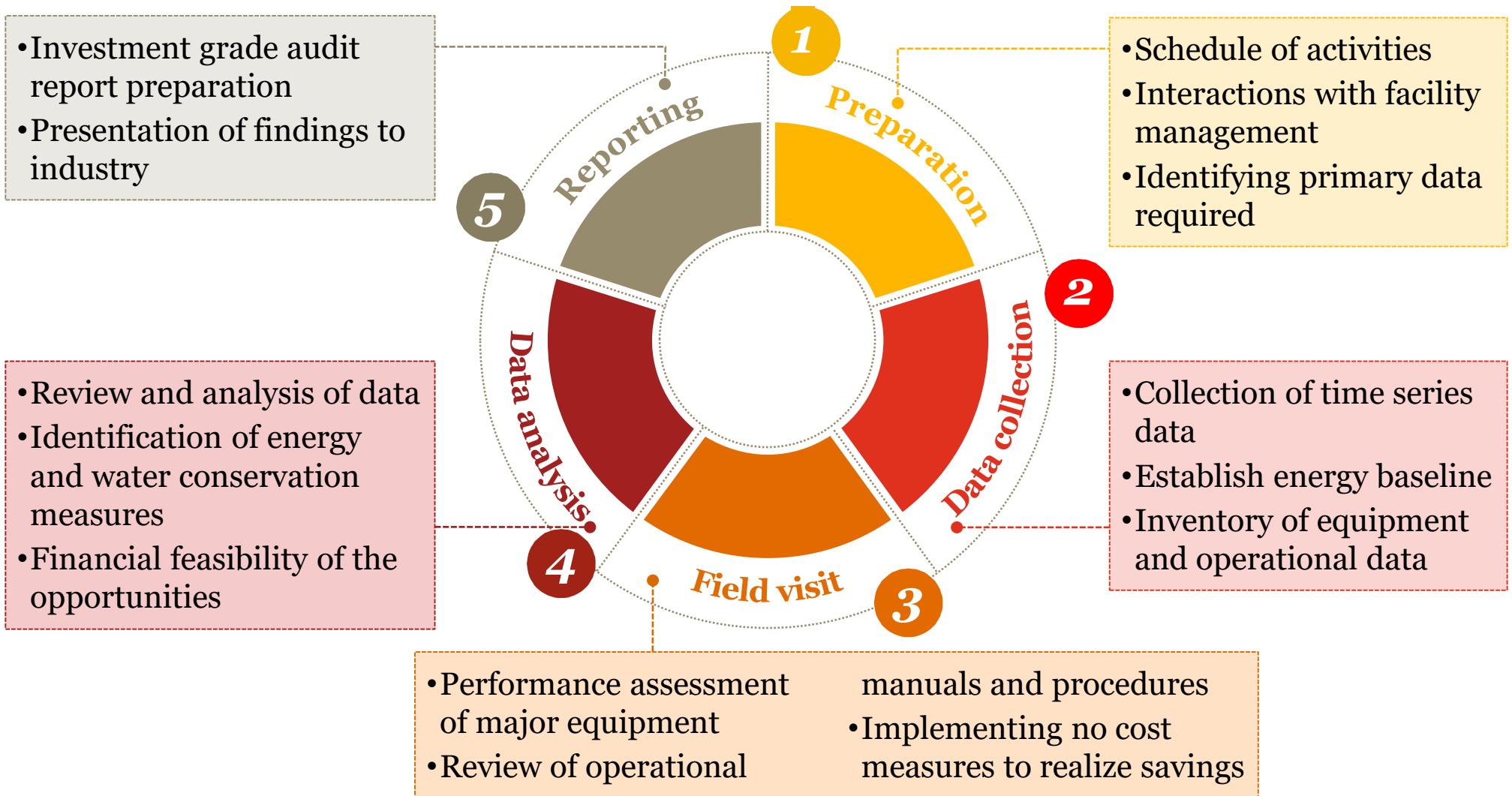
**System boundary:** A group of equipment interacting with each other. E.g. Pumping system

**Organisation boundary:** Physical boundary of the plant/company  
E.g. Water pumping station

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# *Audit Methodology*

# Audit methodology



## *Data collection – Audit questionnaire*

General Information

Energy Profile

Historical consumption data

Historical production data

Major energy consuming equipment details

Assessment of self generation options

### ***Data and Information required from the selected unit(s)***

- Existing technical specifications of the pumps being studied
- Pump capacities
- Number of pumps in operation and standby
- Average hours of operation
- Maintenance (planned and forced)
- Energy consumption



**Audit questionnaire**

***Data collection is very important to know the historical trend of electricity and fuel consumption in the plants as well as collection of data is essential for estimation of energy saving potential***

## *Field study – Steps*

Initial meeting/personnel interview with company officials



```
graph TD; A[Initial meeting/personnel interview with company officials] --> B[Field study and measurements]; B --> C[Areas and equipment to be covered under the Energy Audit]; C --> D[Assessment of Self Generation Options];
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Field study and measurements

Areas and equipment to be covered under the Energy Audit

Assessment of Self Generation Options

## *Field study – Energy audit*

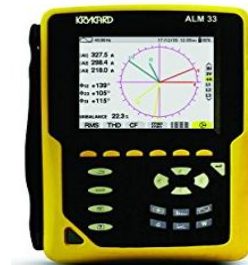
- The team will carry field study to improve energy use efficiency and identify energy conservation measures
- A few instruments used for the study are as follows



Water flow meter



Digital pressure gauge



3  $\Phi$  Power analyser



Thermal Imager

# *Electrical measurement instruments: Power analyser – 3 phase*



# Power analyser – 3 phase

## Suitable working range

Voltage : 0 to 480 volts  
 Current : - 10 to 1,000 Amps

## Measured parameters

- $V_{rms}$ ,  $A_{rms}$
- $V_{peak}$ ,  $A_{peak}$
- Frequency
- Harmonics
- Watt
- VA
- VAR
- VA Harmonics
- VA Unbalance
- Power factor
- DPF
- Energy and energy cost calculations
- Line and phase unbalance
- Transient capture
- Inrush current



## *Power analyser – 3 phase*

### **Applications**

- Energy loss calculations
- System efficiency assessment
- Waveform analysis
- Harmonic analysis
- diagnostic functions for use in substation and industrial power environments
- Automatic transients visualization
- Harmonics and infra-harmonics detection
- Unbalance detection in phases



# ***Water measurement instruments: Ultrasonic flow meter***



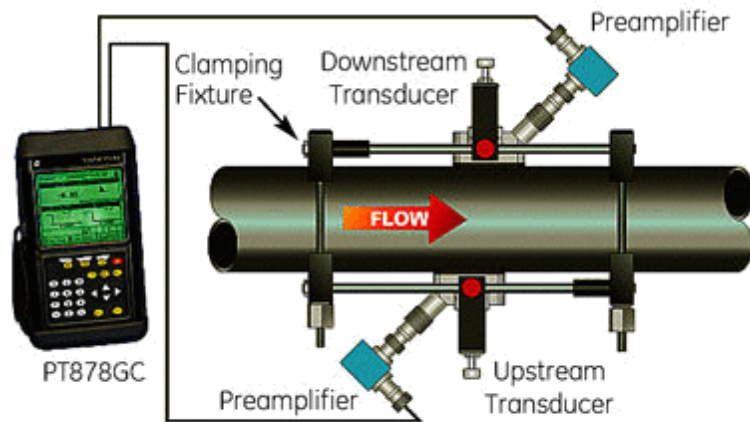
# Ultrasonic flow meter

## Suitable working range

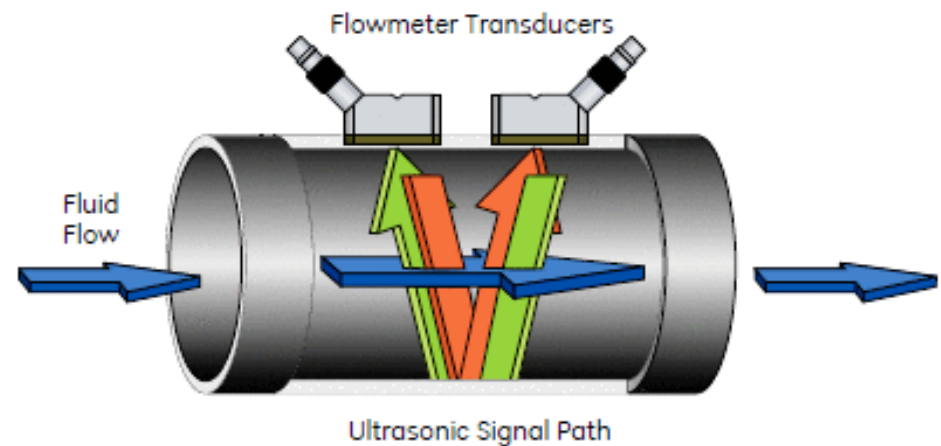
- Operating temperature:  $-20^{\circ}\text{C}$  to  $55^{\circ}\text{C}$
- Range (Bidirectional):  $-40$  to  $40$  ft/s  
( $12.2$  to  $12.2$  m/s)

## Measured Parameter

- Non-intrusive volumetric flow rate measurement
- Flow velocity
- Total quantity of liquid
- Totalized flow and trend data
- Energy flow rate measurement



Typical meter setup for portable clamp-on gas flow



# *Ultrasonic flow meter*

## **Applications**

- Non-intrusive, clamp-on ultrasonic liquid flow meter for chilled and hot water applications
- Monitoring flows of fluids that are homogenous, relatively clean, flowing steadily, and have no gas-phase substance present
- Flow measurement for liquid-
  - Potable water
  - Waste water
  - Crude oil and refined hydrocarbons
  - Diesel and fuel oils
  - Chemicals
  - Beverages
- Water demand analysis, including leaks
- Diagnosing system performance issues like variation in flow and flow direction
- Assessing load variation in heating or cooling systems



# Thermal measurements instruments: Thermal Imaging Camera

## Suitable working range

- -20 to 100 °C / 0 to 280°C

## Measured Parameter

- Temperature gradient
- Surface temperature

## Applications

- Thermal insulation performance assessment
- Hot-spot determination on surfaces
- Electrical safety assessment
- Surface (Radiative) losses assessment
- Suitable for thermal imaging of :
  - Industrial machines & appliances
  - Buildings and structures
  - Furnaces and boilers
- Thermal performances of buildings
- Structural defect detection
- Motor and other equipment performance analysis

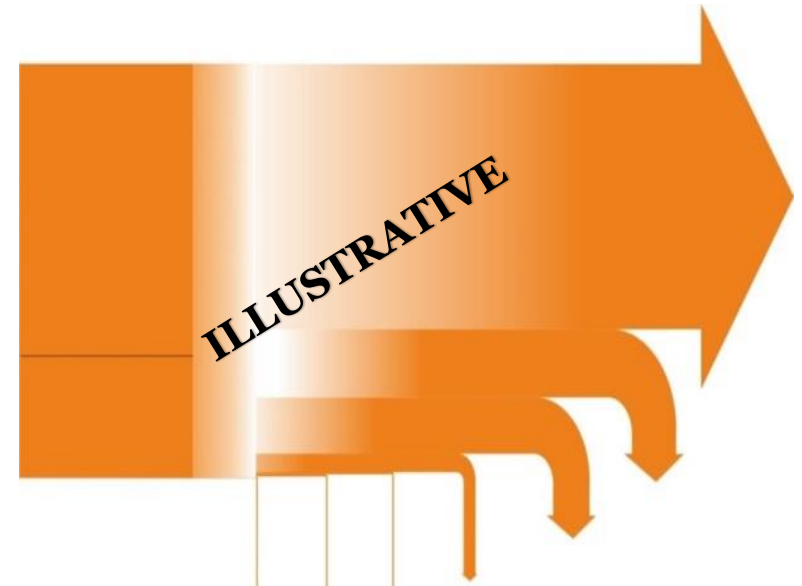


# Data analysis

The project team will make

- Use of its in-house **Microsoft Excel based tools** to assess performance of the equipment and systems.
- Use of proven tools for identification of performance indicators and performance assessment such as **material balance** and **energy balance**.

Design Parameters	Unit	DM pump for Induction Furnace Panel	Coil cooling pump for Induction Furnace	Raw water pump for heat exchanger	ECM Pump replacement
Make		Ajvy	Ajvy	Ajvy	Recommended Pump Specification
Type		Mono-Block	Mono-Block	Mono-Block	Units
Flow rate	m <sup>3</sup> /hour	12.0	14.4	14.4	Flow rate
Head	m	20	40	30	Differential Head
Motor Power	kW	2.2	3.7	3.7	Efficiency
Overall Efficiency	%	40%	34%	54%	Power
					Energy saving
					Operating period
					Annual Energy saving
					Cost saving
					Energy cost per unit
					Annual Monetary Saving
					Investment
					Sample Payback Period
					CO <sub>2</sub> emission avoided



## *Energy Performance Indicators (EnPIs)*

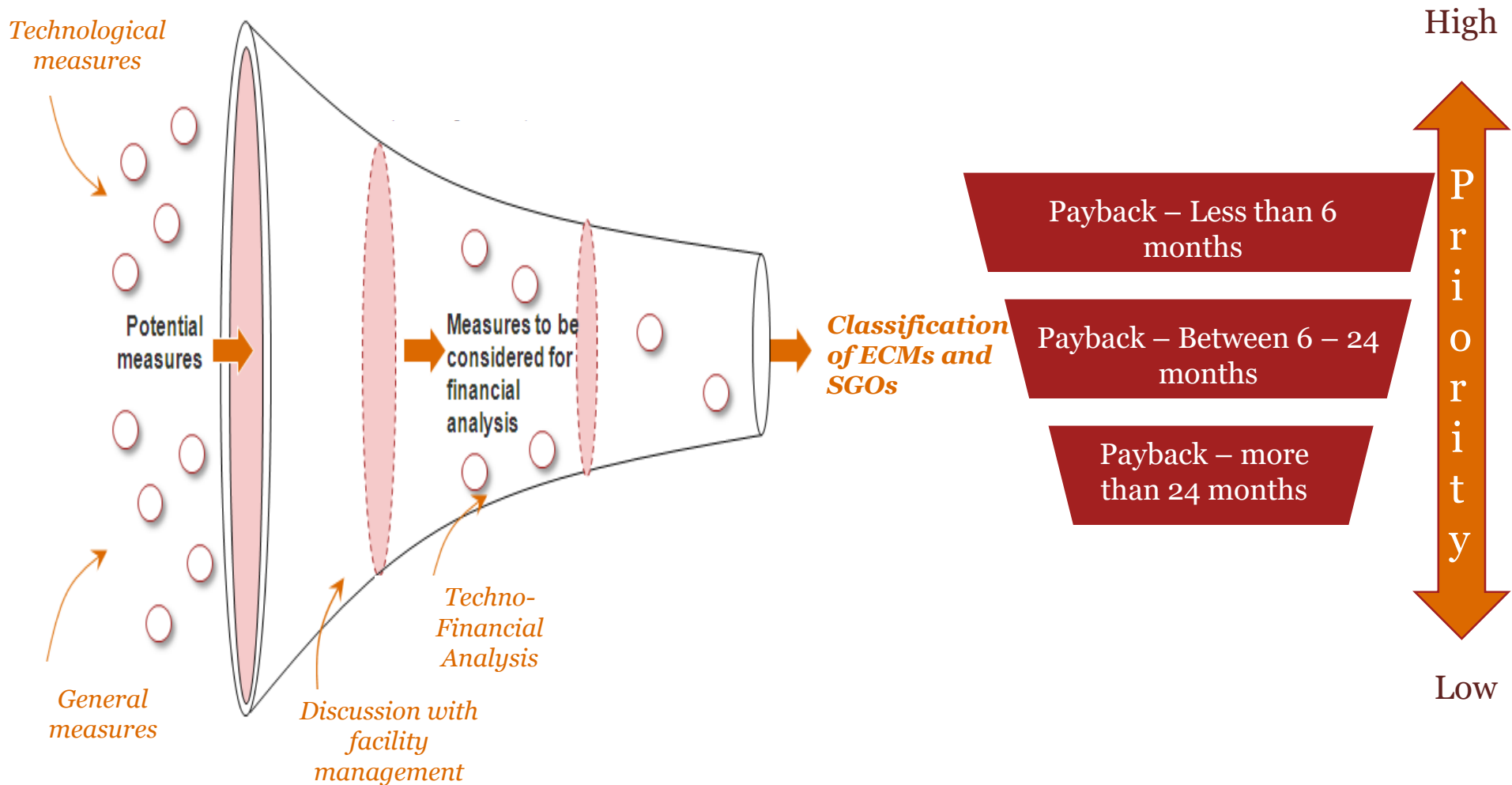
### Energy performance indicators of pump station

EnPIs	Unit
Pump efficiency	%
Specific consumption	kWh/m <sup>3</sup>
Motor loading	%

### Example: EnPI's of Borderline pump station

EnPI	Unit	Value
Efficiency of transfer pump-3	%	71.3
Specific energy consumption of pump station	kWh/m <sup>3</sup>	0.496
Motor loading transfer pump-3	%	66.2

# Filtering and prioritizing 'Energy Conservation Measures and Self Generation measures'



# Report preparation

## Findings

- Establish specific water performance indicators
- Identification of possible Energy Conservation measures and Self-Generation options (ECM & SGO)
- Techno-financial analysis or Cost Benefit Analysis (CBA)
- Estimation of reduction of Greenhouse Gas (GHG) emissions

## Report preparation

- Discuss the findings with plant management
- Prioritization of identified SGO's and ECMs
- List of suitable vendors & technology providers
- Investment grade audit report
- Presentation on audit findings

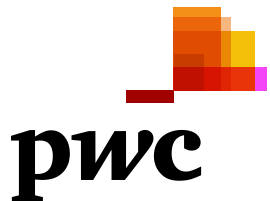
## Investment grade audit report

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**ILLUSTRATIVE**

*Thanks!*



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# *Energy Performance Assessment*

## Training Programme on Energy Efficiency and Self Generation Option

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# *Agenda*

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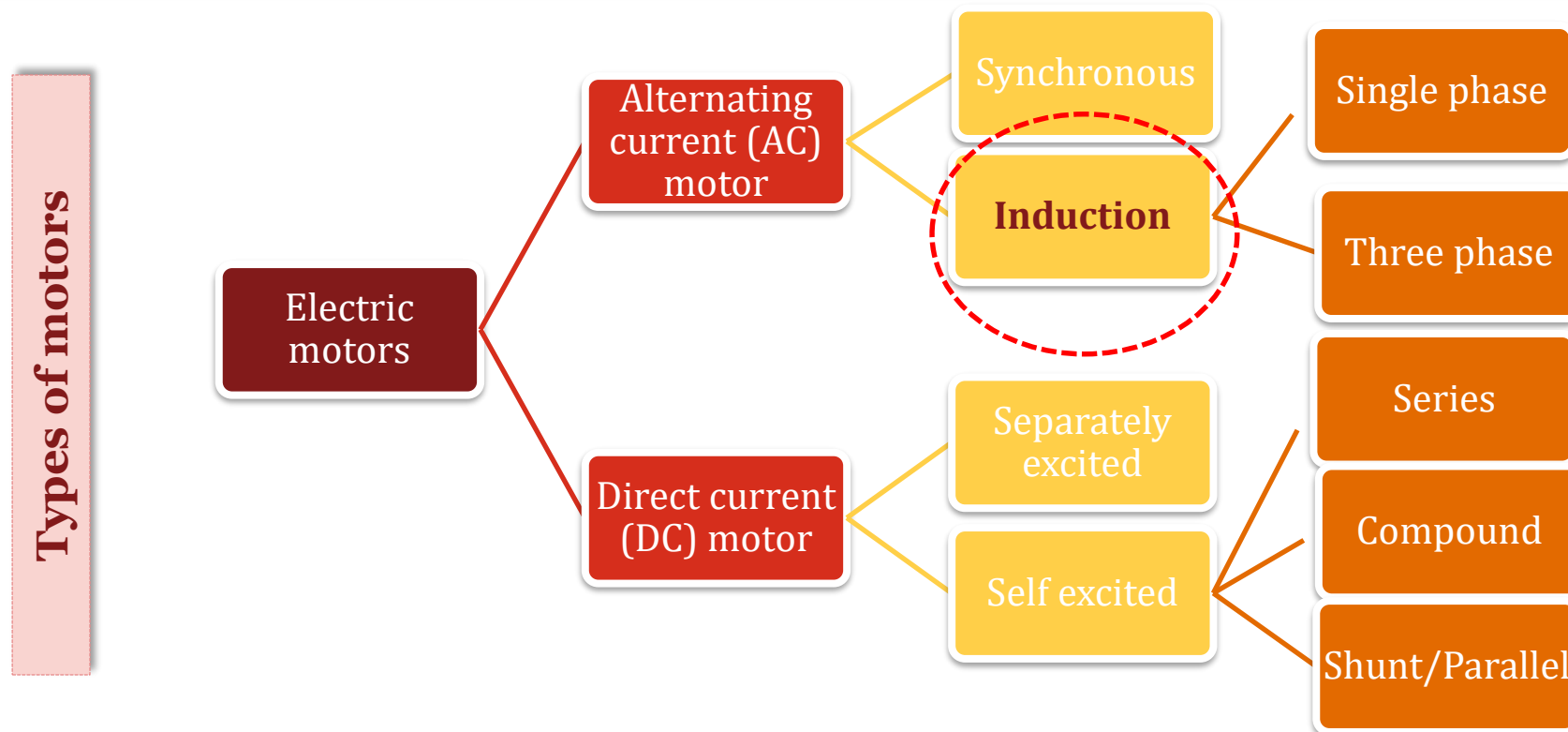
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# *Electric motors*

# Electric motors

**Motors convert electrical energy into mechanical energy by interaction between the magnetic fields set up in the stator and rotor windings**



**Motor driven systems account for ~ 55% of global industrial electricity consumption**

# Performance Evaluation of electric motor

## Input power measurement

Ratio input power and rate power at 100% loading

$$P_i = \frac{V \times I \times PF \times \sqrt{3}}{1000} \quad P_r = hp \times \frac{0.7457}{\eta_r} \quad Load = \frac{P_i}{P_r} \times 100\%$$

$P_i$  = Three Phase power in kW

$V$  = RMS Voltage, mean line to line of 3 Phases

$I$  = RMS Current, mean of 3 phases

$PF$  = Power factor as Decimal






$P_r$  = Input Power at Full Rated load in kW

$hp$  = Name plate Rated Horse Power








$\eta_r$  = Efficiency at Full Rated Load

Load = Output Power as a % of Rated Power

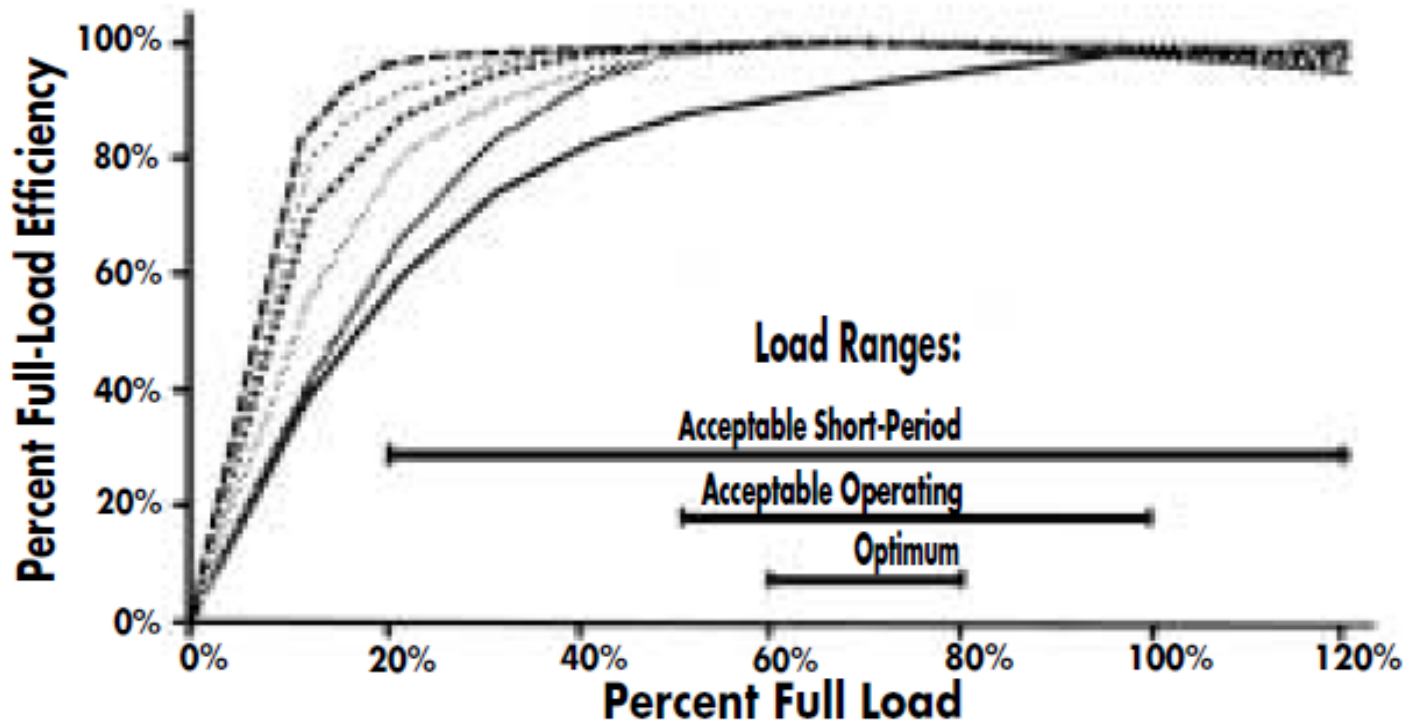
# Electric motors – Energy Efficiency

<p><b>1</b></p> <p><b>Age</b> New motors are more efficient than older ones</p> 	<p><b>2</b></p> <p><b>Capacity</b> Motor efficiency increases with rated capacity</p> 	<p><b>3</b></p> <p><b>Speed</b> High speed are usually more efficient for same capacity</p> 	<p><b>4</b></p> <p><b>Temperature</b> TEFC motors are efficient than Screen Protected Drip Proof</p> 	<p><b>5</b></p> <p><b>Rewind</b> Often asserts efficiency drop of 1-5% when a motor is rewound</p> 	<p><b>Factors affecting energy efficiency of electric motor</b></p>
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## *Energy Efficiency measures in electric motors*

-  *Use high efficiency motors (IE3, IE4)*
-  *Optimum sizing of motor according to load*
-  *Proper selection of capacity for variable load*
-  *Avoid under-loading of motor*
-  *Proper rewinding of motor*
-  *Speed control of induction motor*
-  *Power factor correction by capacitors*

# Motor efficiency v/s loading



***Recommended range of loading of motor is 50 – 90%***

## *Effect of over-sizing*

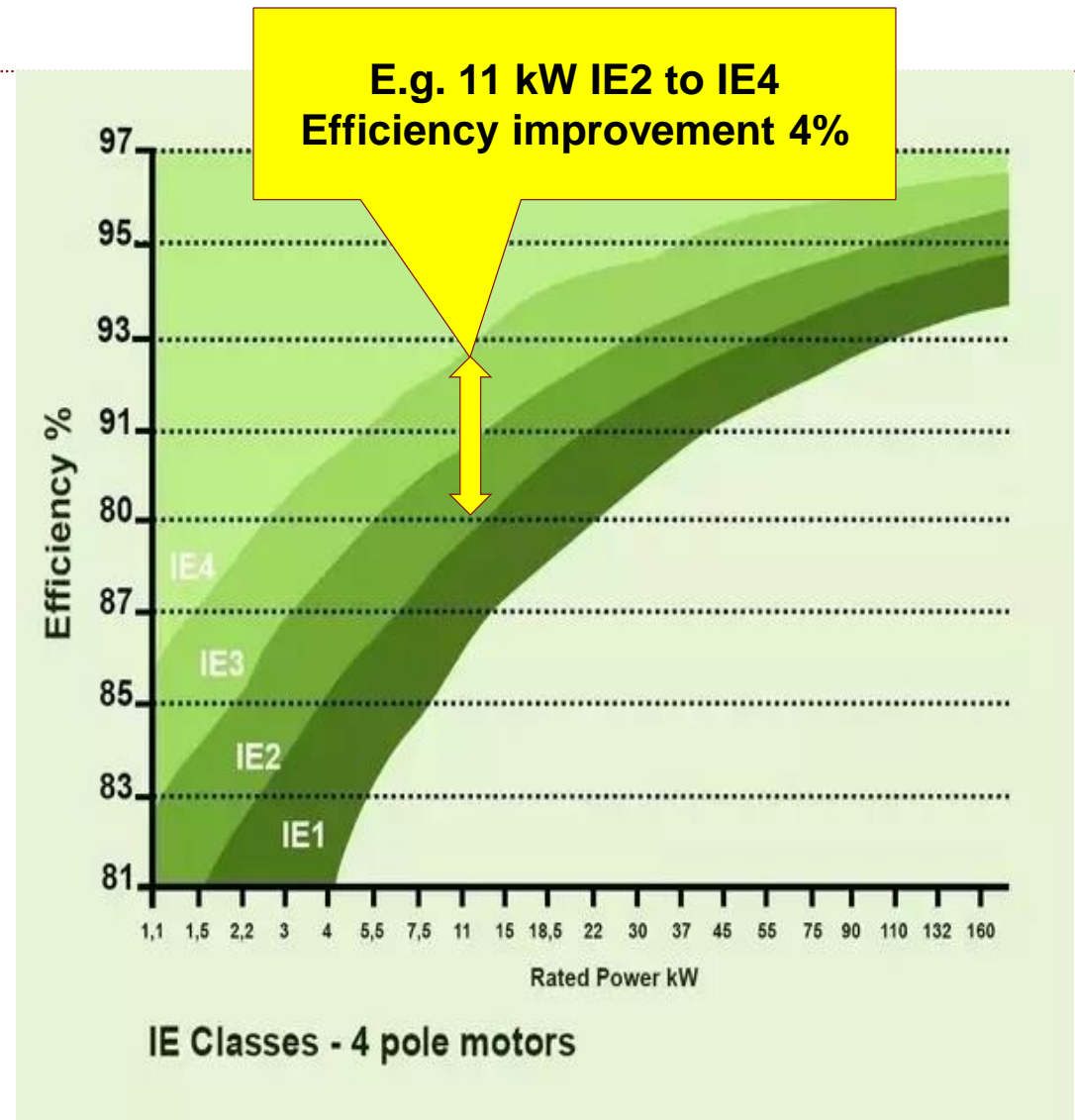
- Operating a higher capacity motor for lower loads reduces efficiency, PF and increase energy consumption
- Following table compares the use of a 7.5 kW, 11kW and 15 kW to meet a 7.5 kW load:

<b>Parameter</b>	<b>Case 1</b>	<b>Case 2</b>	<b>Case 3</b>
Motor Load	7.5 kW (100% load)	11 kW (70% load)	15 kW (50% load)
Required Load	7.5	7.5	7.5
Motor EFF (%)	88	84	79
Motor input kW	8.5	9.0	9.5
Unit consumed, kWh	42,500	45,000	47,500
<b>% increase</b>	<b>-</b>	<b>5.8</b>	<b>11.76</b>

## High efficiency motor

- Reduce intrinsic motor losses
- Efficiency 3-7% higher for entire range of rating (IE4 v/s IE1)
- Cost is higher but quick RoI
- Best to replace when existing motors fail

**Recommended range of loading of motor is 50 – 90%**



# Case study: Soft starter on motor for hydraulic machine

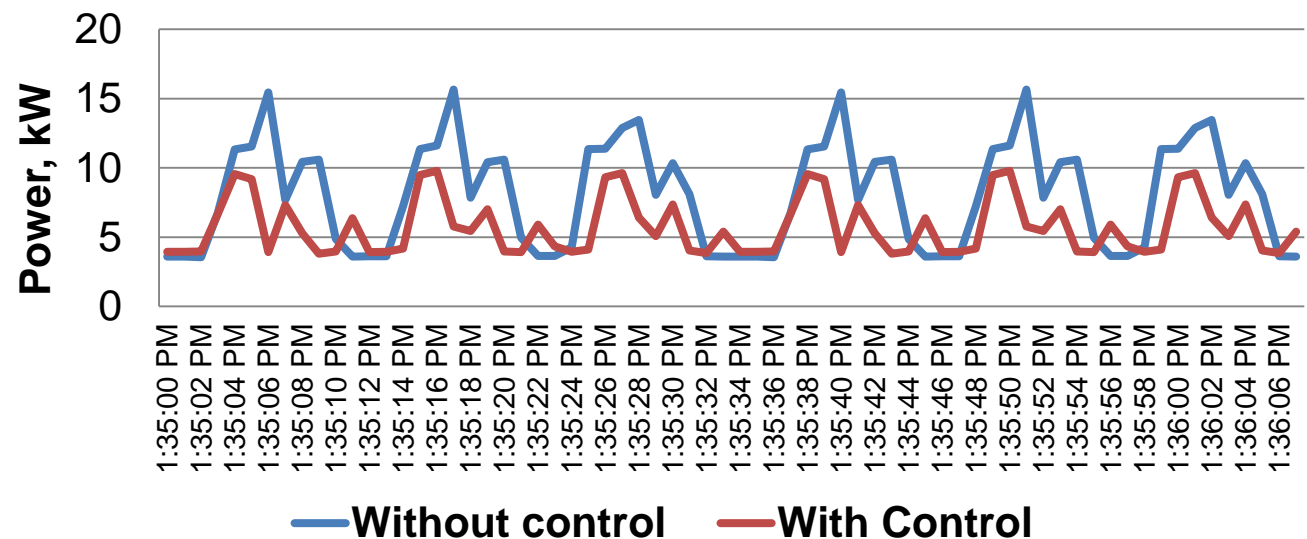
➤ Case of 20 no's. of 180 ton hydraulic press installed in a Sheet metal fabrication industry

## Design Parameters

- Soft starter installed on the motor
- Along with capacitor bank

## Savings

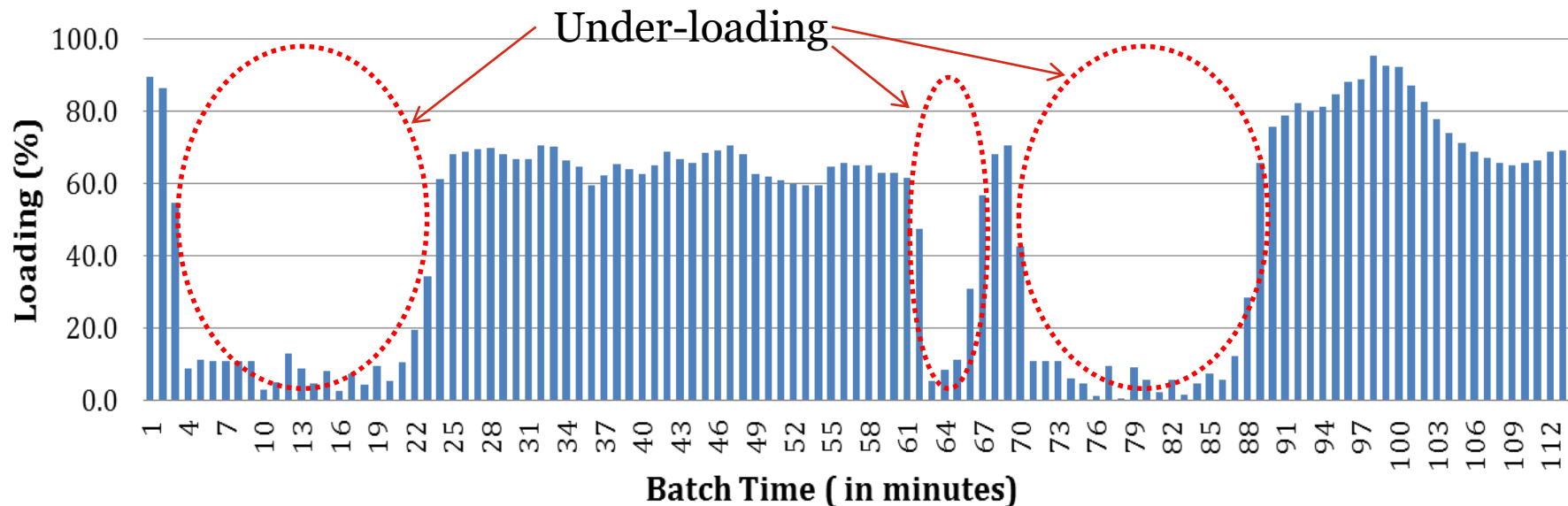
- Annual electricity saving – 2,750 kWh
- Annual monetary savings – USD 362
- Simple payback – 1 months
- Energy savings – 0.5%



**GHG reduction potential: 1.8 t CO<sub>2</sub>/year**

## Case study: Star- delta convertor

➤ Case of metal processing industry with 112 no. induction motors



### Parameters

- Load profile of motor for complete batch – graph above
- Estimated under-loaded duration : 40% of batch time

### Savings

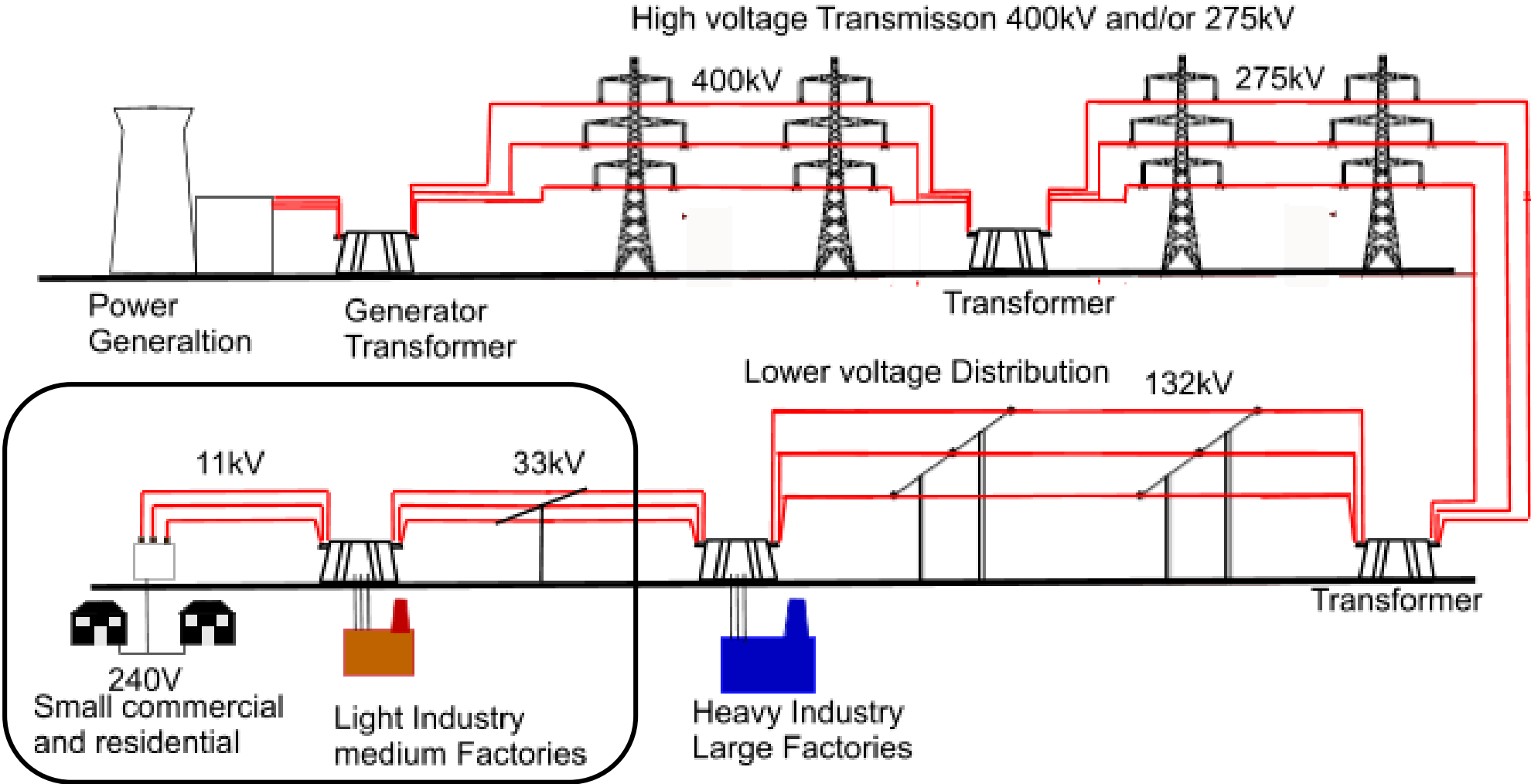
- Annual energy saving – 68,150 kWh
- Annual monetary savings – USD 7900
- Simple payback – 9 months
- Energy savings – 2.8 %

**GHG reduction potential: 45.7 t CO<sub>2</sub>/year**

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# *Electrical system*

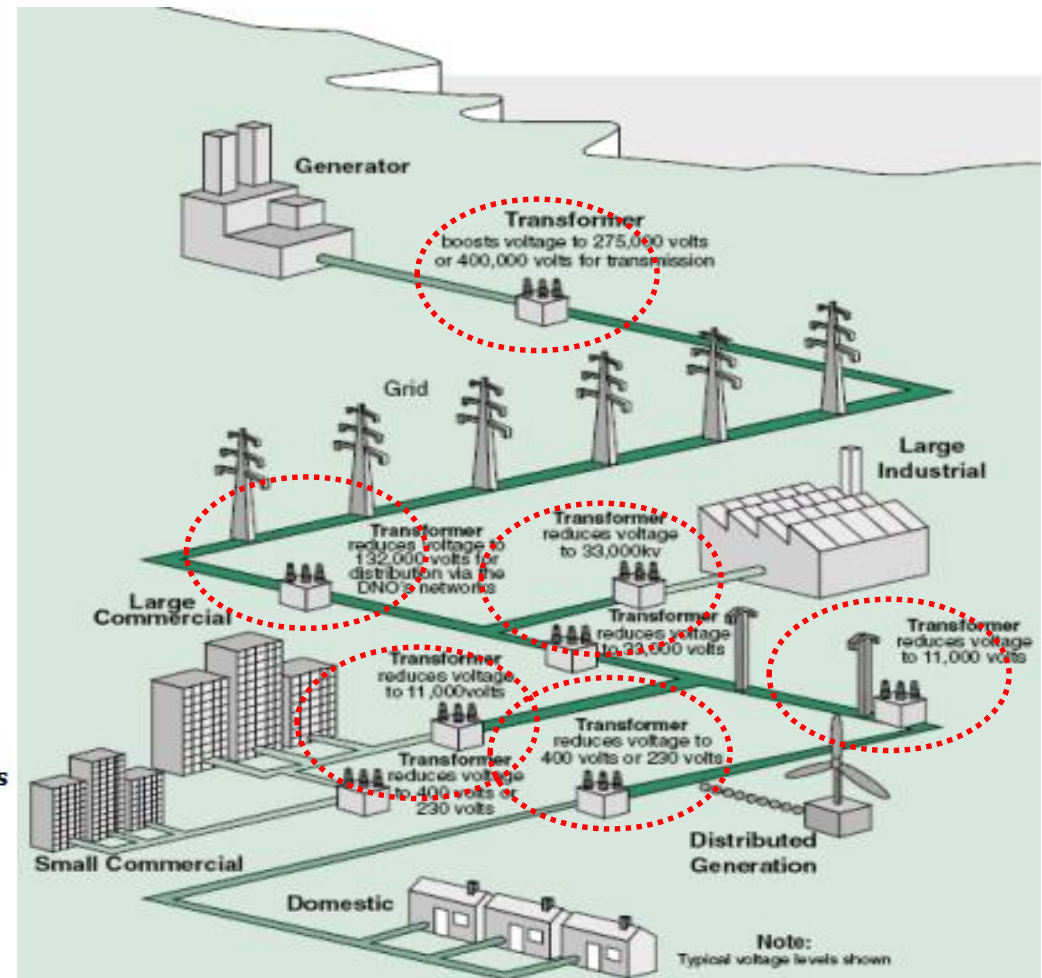
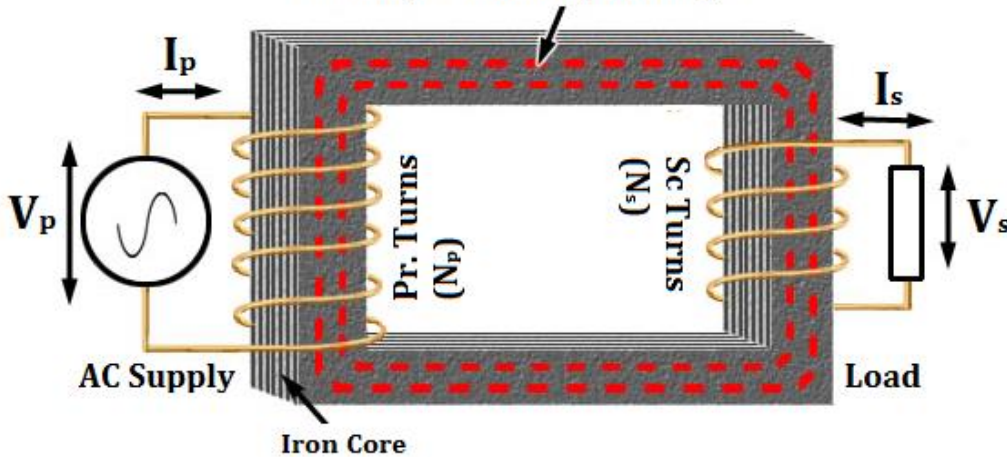
# Electrical system overview



# Transformer

- *Static electrical device that transforms electrical energy from one voltage level to another*
- *Two or more coils linked magnetically but electrically insulated*

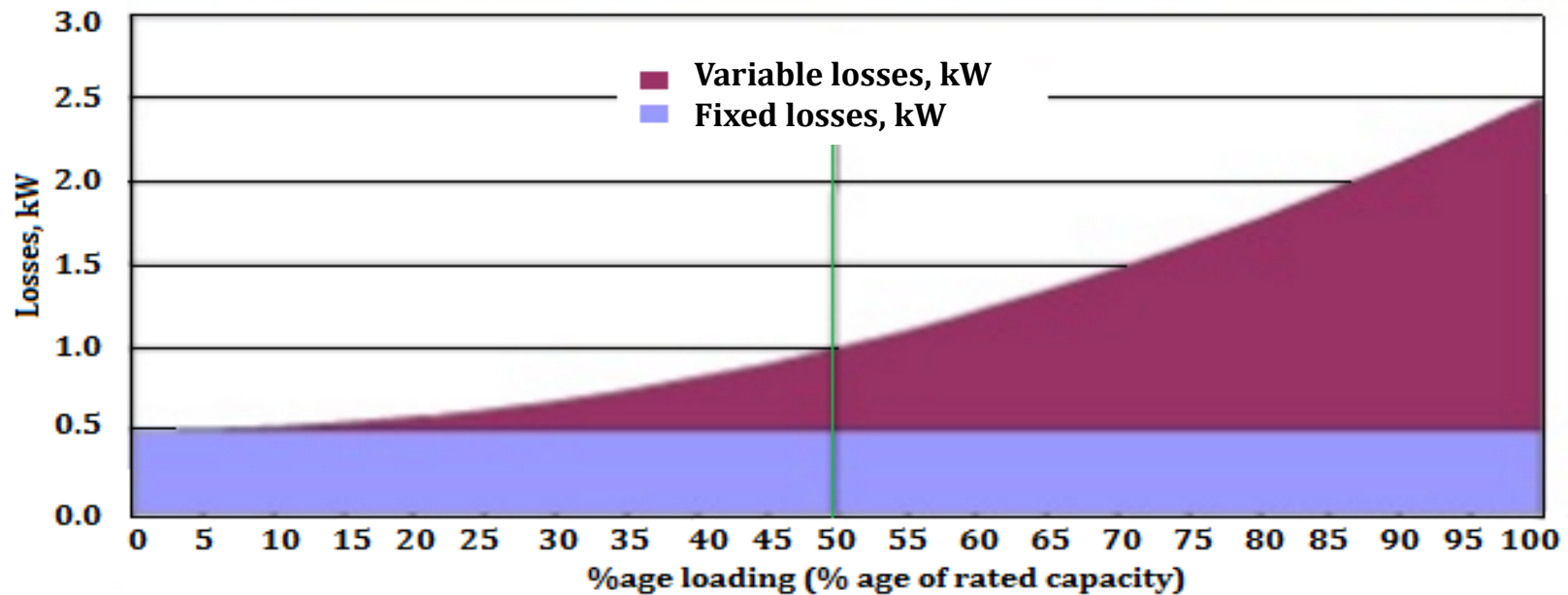
Lines of magnetic Flux linking Primary & Secondary windings



## Performance assessment - Transformer

Transformers can be extremely efficient as there is no mechanical losses

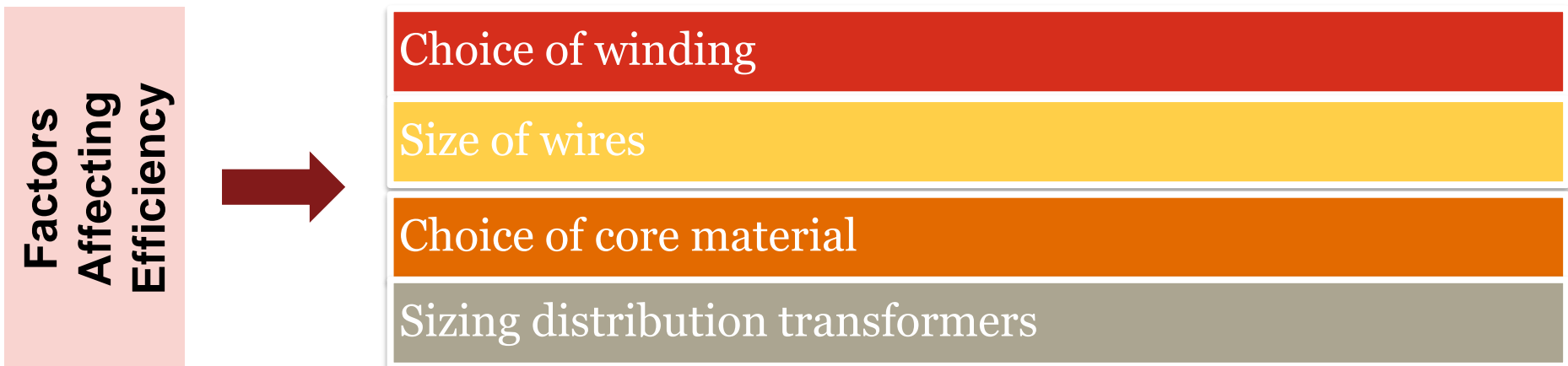
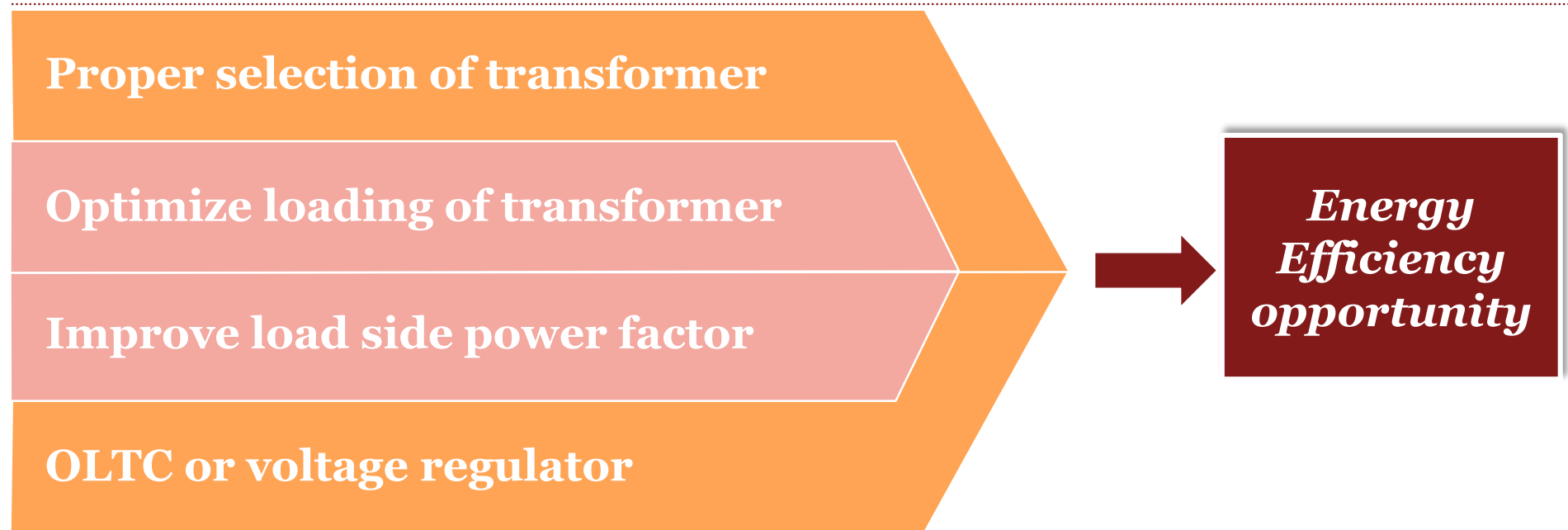
- No Load losses/Core Losses or Iron Losses
- Load Losses/ Copper Losses



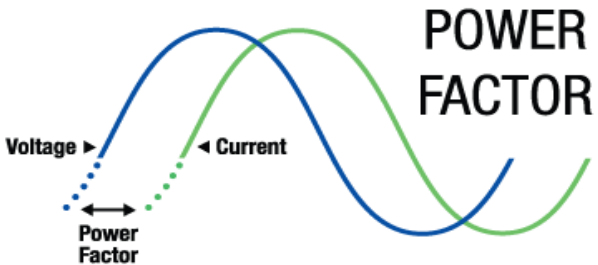
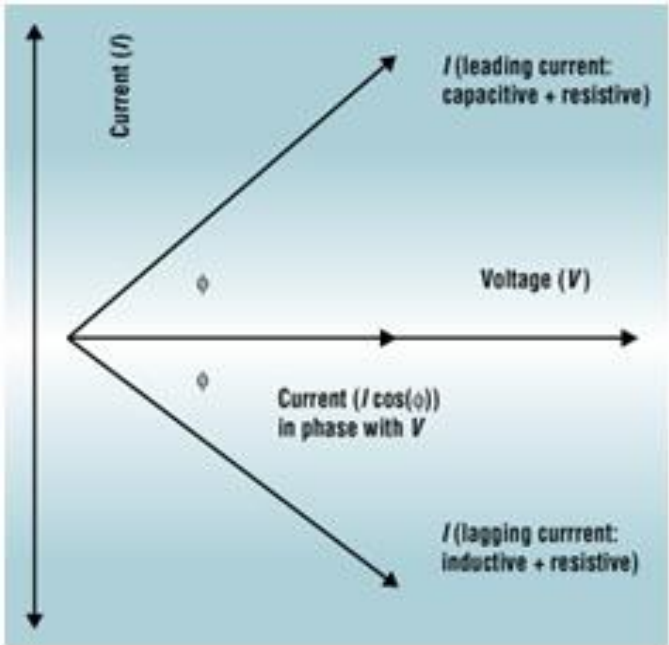
$$P_{TOTAL} = P_{NO-LOAD} + (\% \text{ Load}/100)^2 \times P_{LOAD}$$

$$P_{TOTAL} = P_{NO-LOAD} + (\text{Load KVA}/\text{Rated KVA})^2 \times P_{LOAD}$$

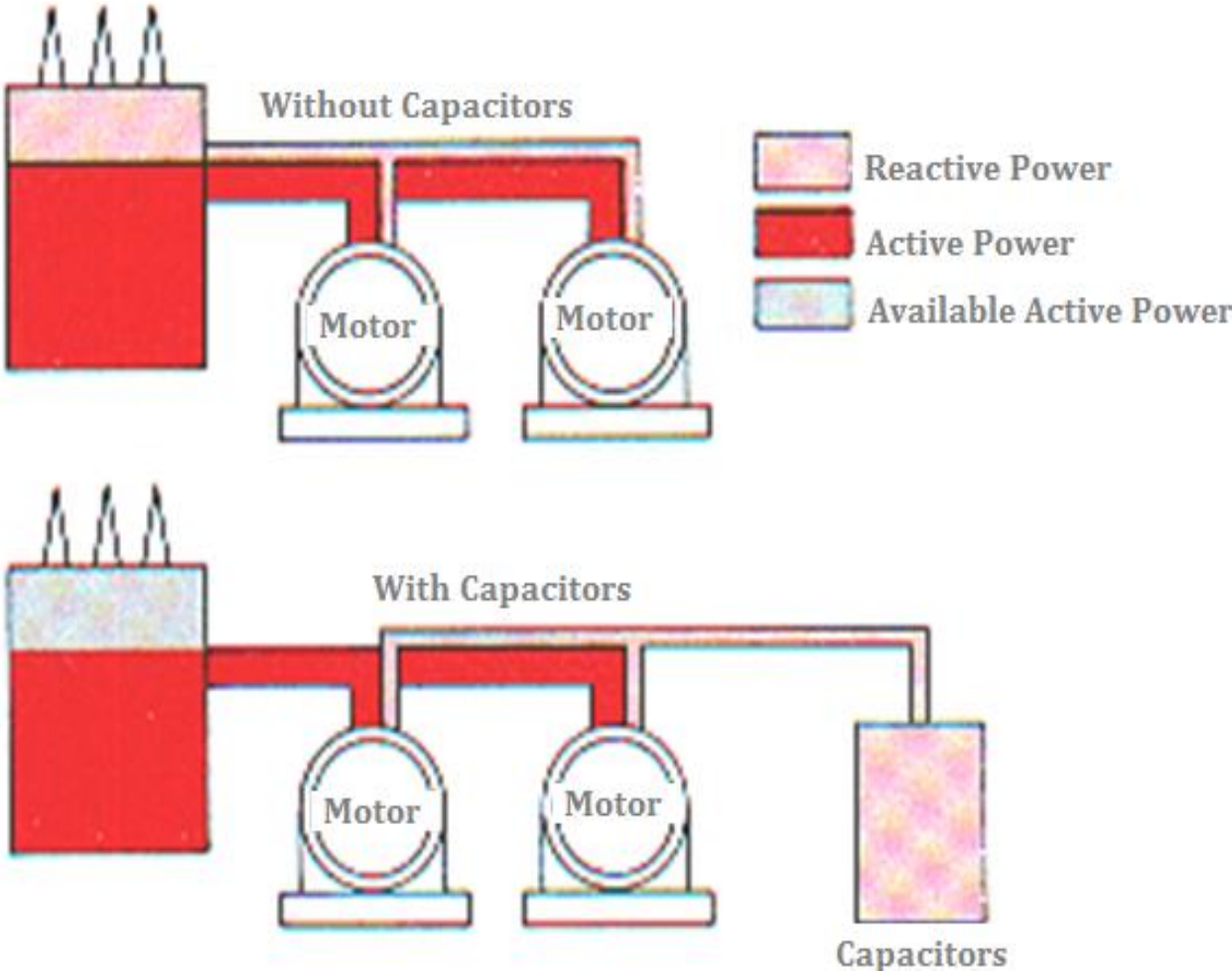
# Energy efficiency opportunities



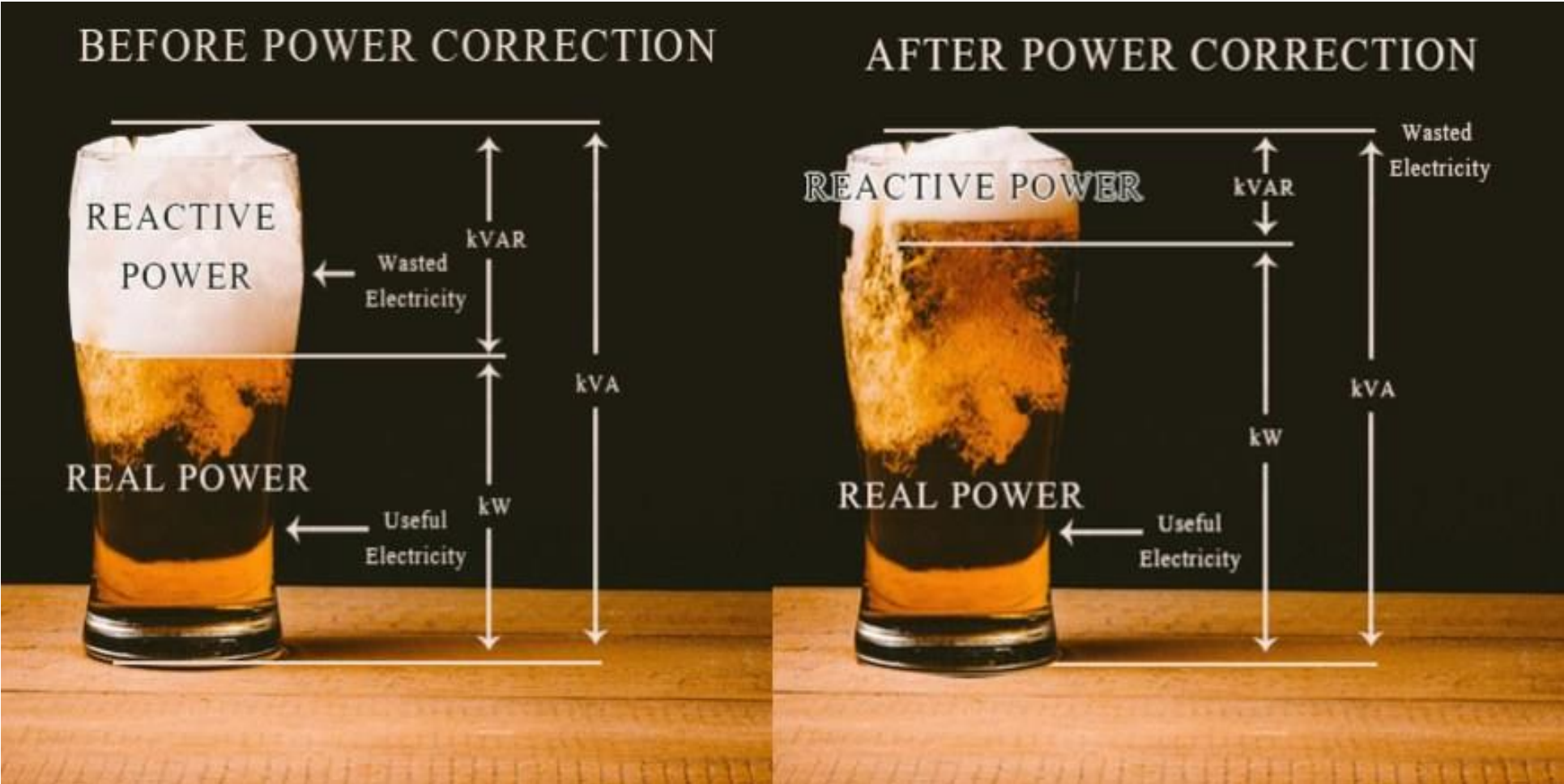
# Power factor



## Power factor correction system



# Power factor



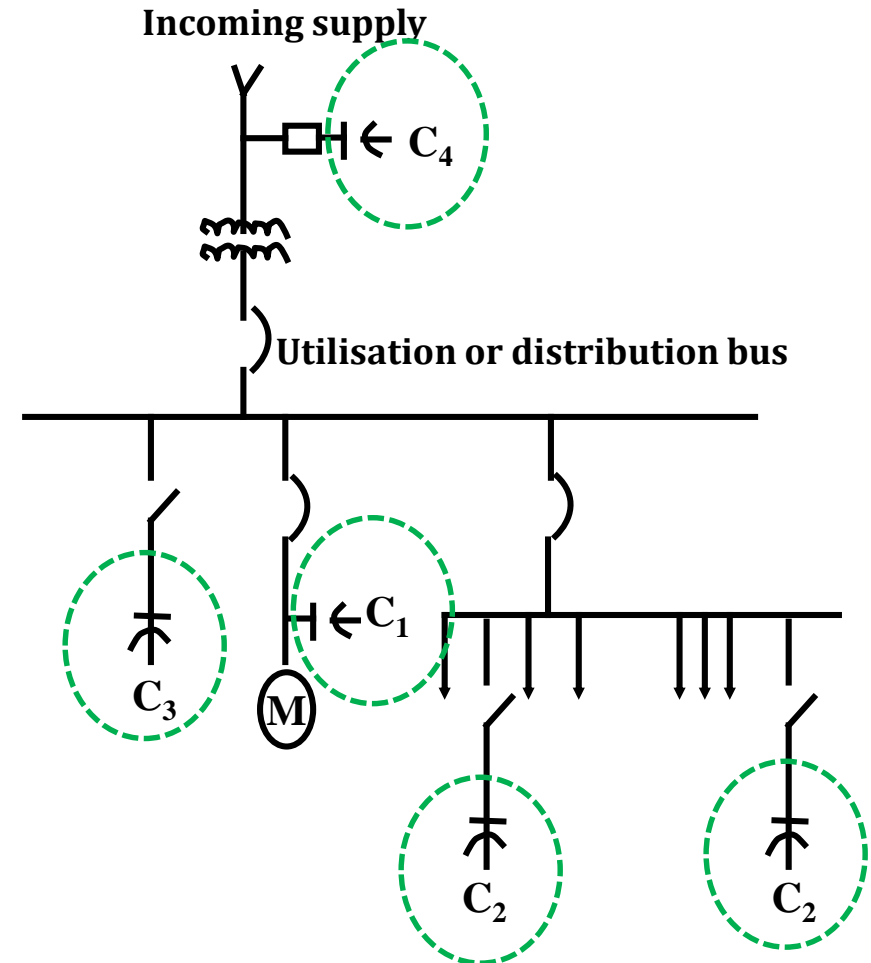
# Installation of power factor correction capacitor

## ➤ Location

- At HT bus / transformer
- LT bus of transformer
- Main sub-plant buses
- Load points

## ➤ How to identified location

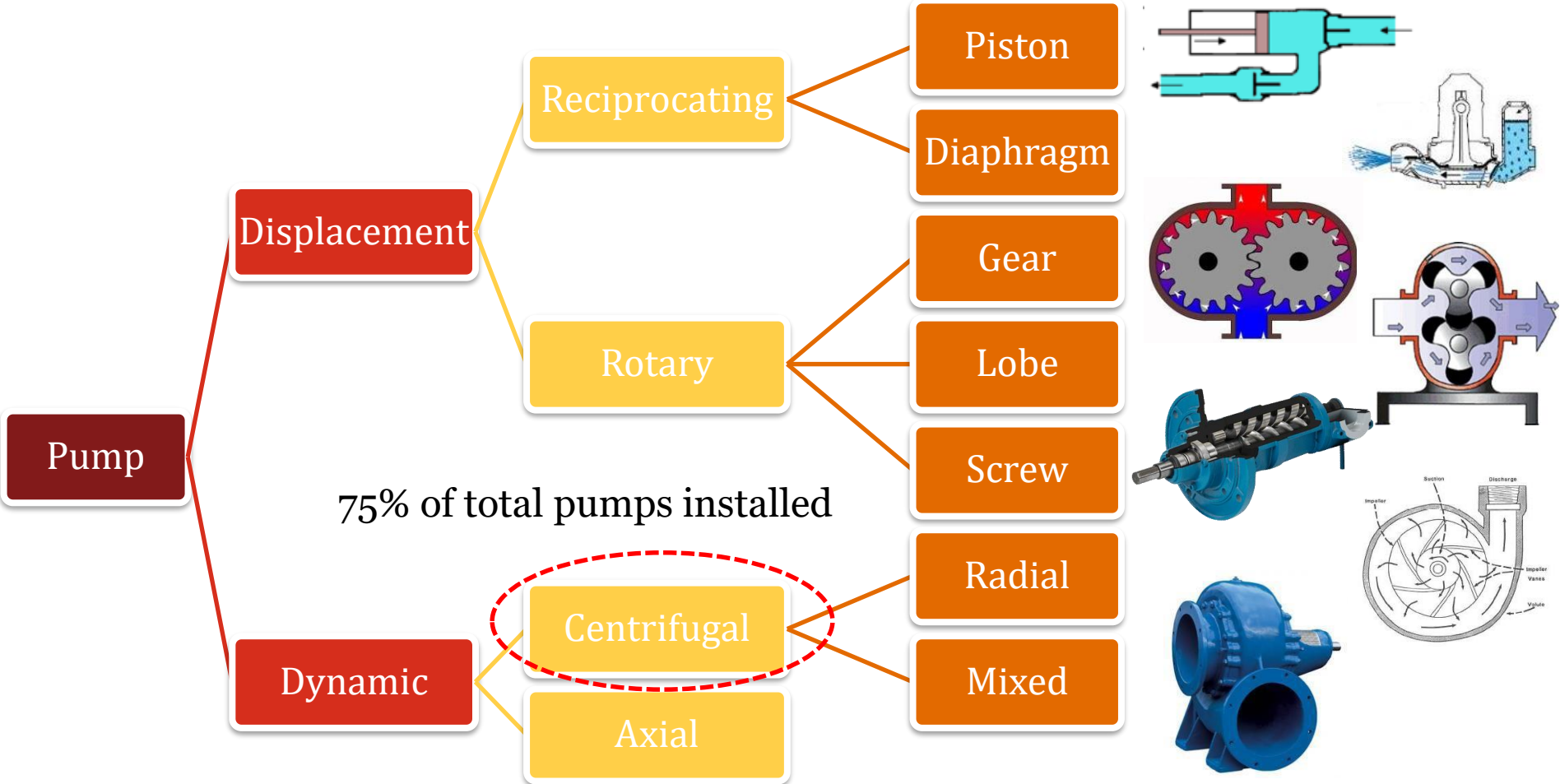
- Identify the sources of low pf loads in plant
- Locate close to end equipment to reduce  $I^2R$  loss
- Release of system capacity(kVA) happens if reactive current is reduced.



---

# *Pumping system*

# Types of pumps



## Overview

- Account for nearly 20% of the world's electrical energy demand
- Has about 25-50% of energy usage in certain industrial plant operations
- Provide services in domestic, commercial & agricultural, waste water & food processing etc.

***To make liquid flow at the needed rate, pressure applied should overcome head losses. They are-***

### ***Static discharge head (hd):***

Is the vertical distance between the pump center line and the point of free discharge.

### ***Friction head (hf)***

Is the head required to overcome the resistance to flow in the pipe and fittings

## Performance evaluation

- Pump efficiency  $\eta = P_H / P_S$
- Pump output is the liquid horsepower delivered by the pump

$$P_H = Q (h_d - h_s) \rho g / 1000$$

$Q$  = fluid flow rate (m<sup>3</sup>/s)

$h_d$  = discharge head (m)

$h_s$  = suction head (m)

$\rho$  = density of fluid (kg/m<sup>3</sup>)

$g$  = acceleration due to gravity

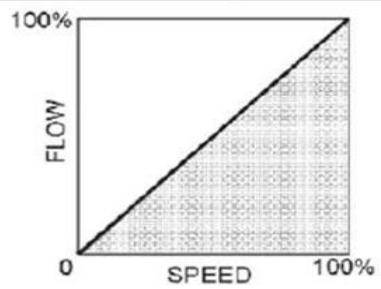
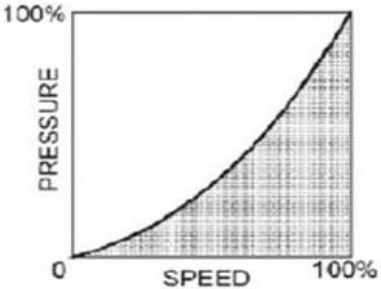
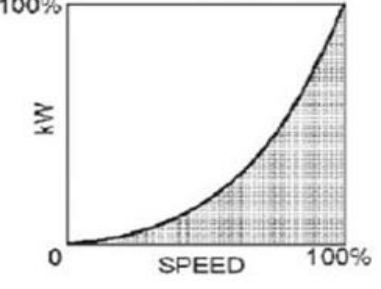
$P_H$  = Hydraulic power

$P_S$  = Shaft power

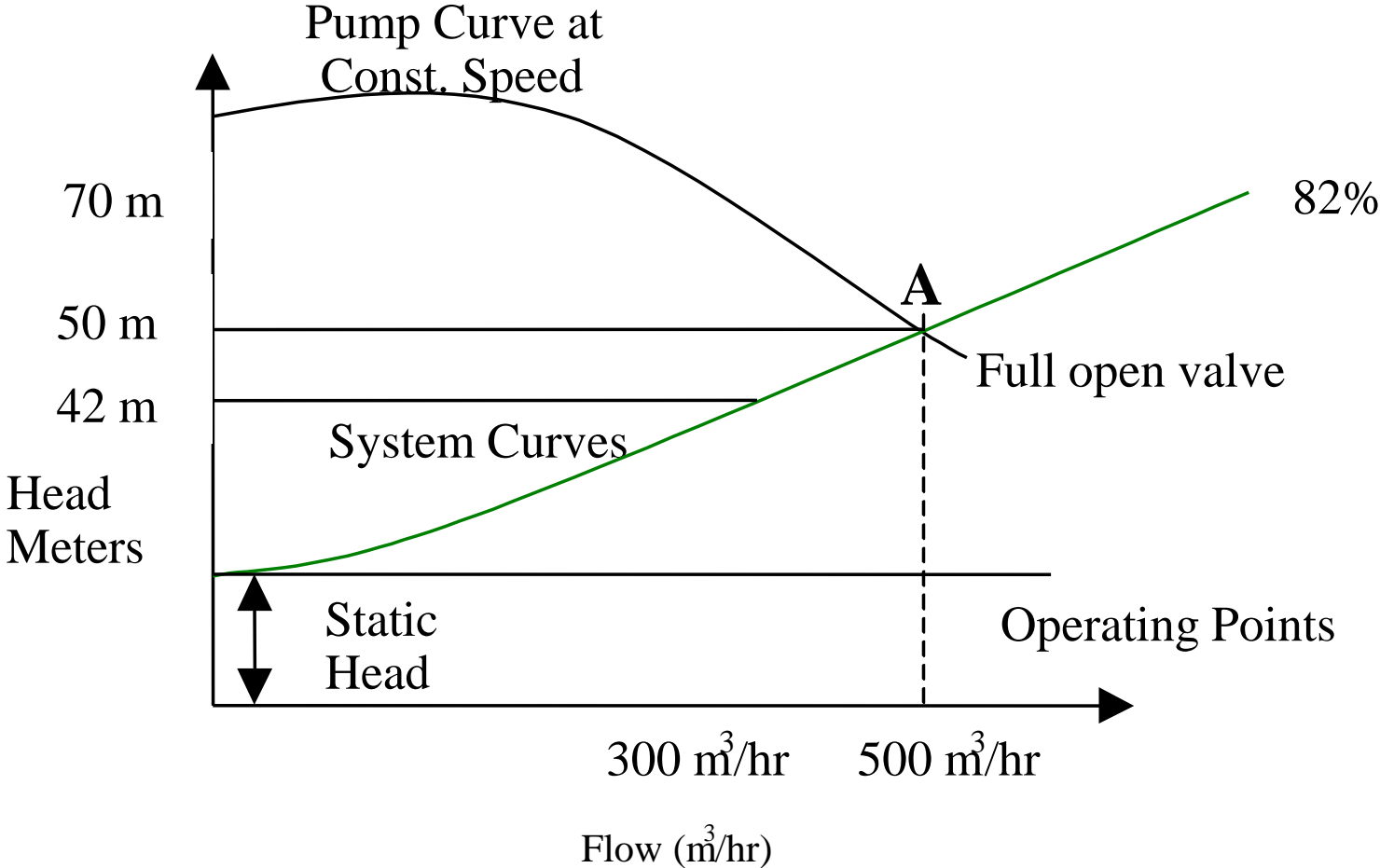
$\eta$  = Efficiency



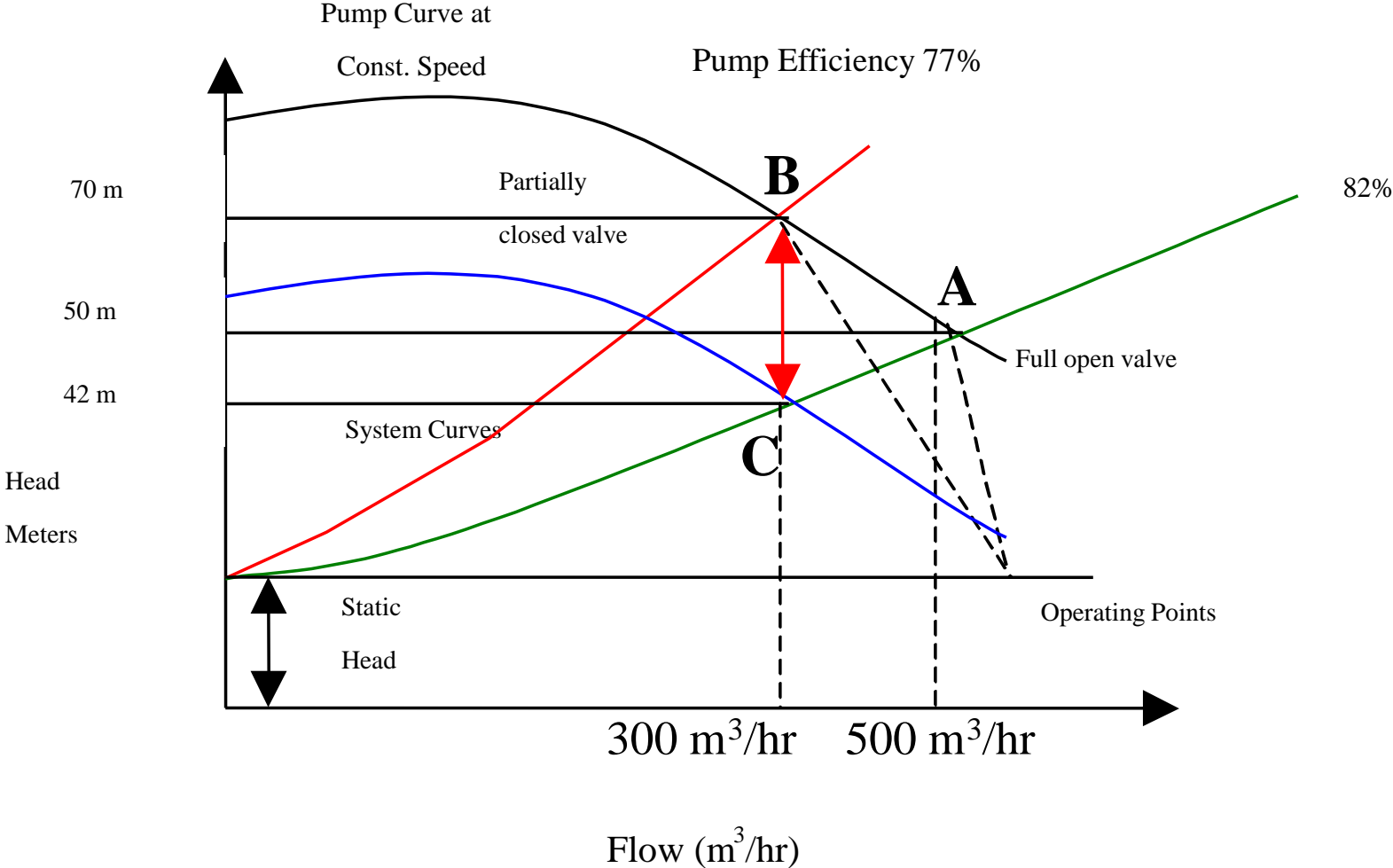
# Affinity laws

Flow $\propto$ Speed	Pressure $\propto$ (Speed) <sup>2</sup>	Power $\propto$ (Speed) <sup>3</sup>
		
$Q_1/Q_2 = N_1/N_2$	$SP_1/SP_2 = N_1^2/N_2^2$	$kW_1/kW_2 = N_1^3/N_2^3$
<p>Varying the RMP by 10% decreases or increases water delivery by 10%</p>	<p>Reducing RPM by 10% decreases the static pressure by 19% and an increase in RPM by 10 % increases the static pressure by 21%</p>	<p>Reducing the RPM by 10% decreases the power requirement by 27% and an increase in RPM by 10% increases power requirement by 33%</p>

# Effect of Throttling



# Effect of Throttling



# *Energy efficiency opportunities*

## Pumps

- Selection of pumps with right specifications
- Control flow rate using speed variations
- Pumps in parallel to meet varying demand
- Eliminate flow control valve
- Eliminate by-pass control
- Start/stop control of pump
- Impeller trimming



*Thanks!*



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# *Energy Efficiency Opportunities*

## Training Programme on Energy Efficiency and Self Generation Option

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# Agenda

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**Transfer pumps** **3**

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**Bore-hole pump** **9**

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**Other areas** **16**

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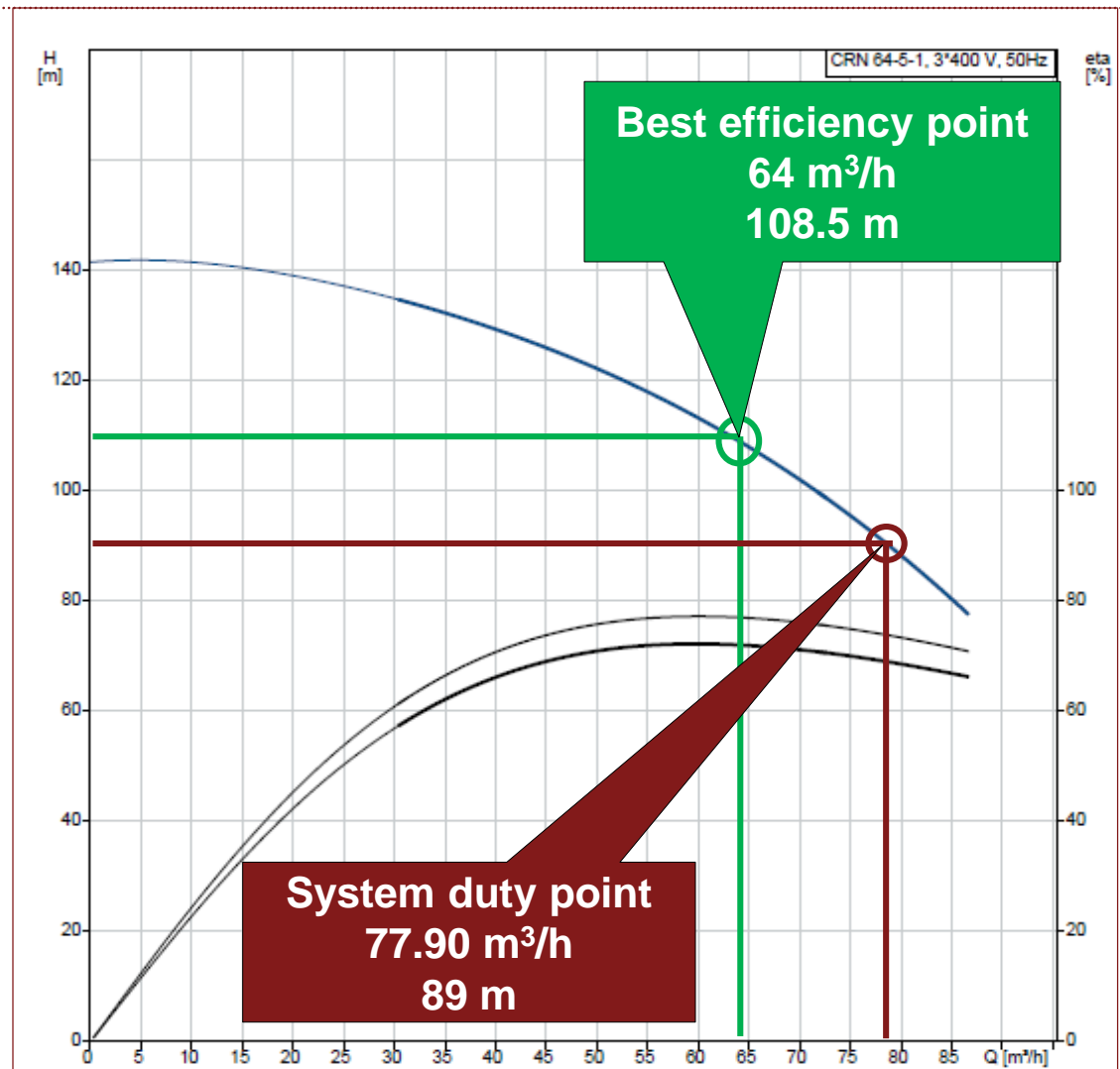
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# *Transfer pumps*

## Sample system and pump curve

### Tasahe Pump Station Transfer Pump

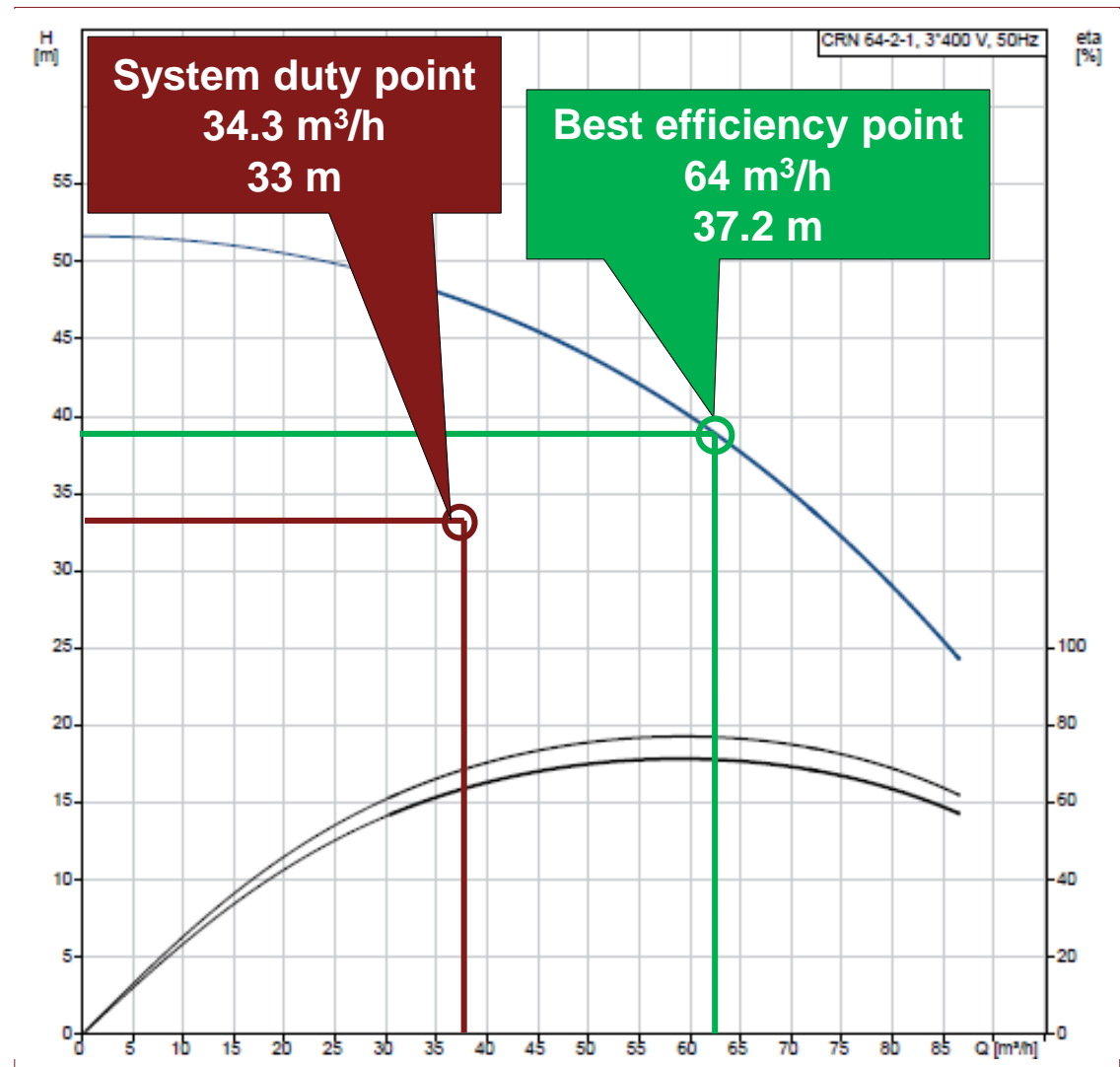
- Designed to deliver 64 m<sup>3</sup>/h at 108.5 m
- The system head was measured to be 89 m
- Flowrate of water delivered by transfer pump was 77.9 m<sup>3</sup>/h
- Operating efficiency of pump was estimated as 79%



# Case of worn impeller

## Borderline Pump Station Transfer Pump

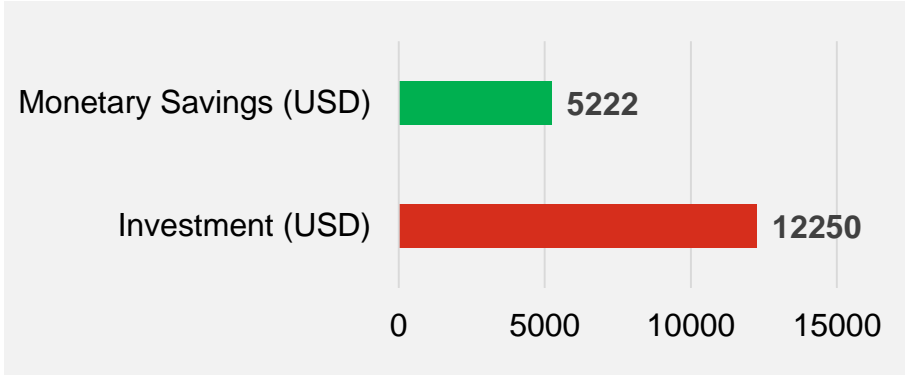
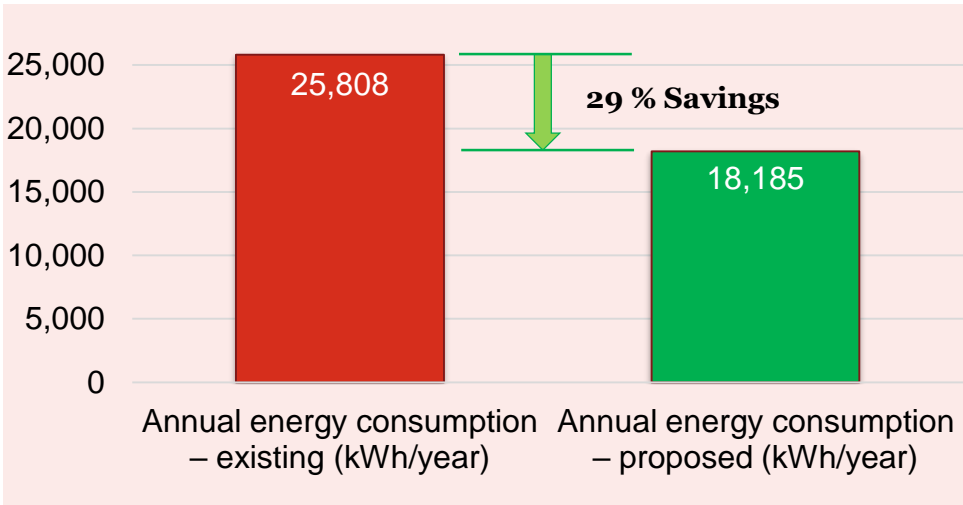
- Designed to deliver 64 m<sup>3</sup>/h at 37.2 m
- The system head was measured to be 33 m at 34.3 m<sup>3</sup>/h
- Operating efficiency of pump was estimated as 48.26 %
- The operating flow is 46.4% less whereas the head is close to the design head suggesting impeller damage



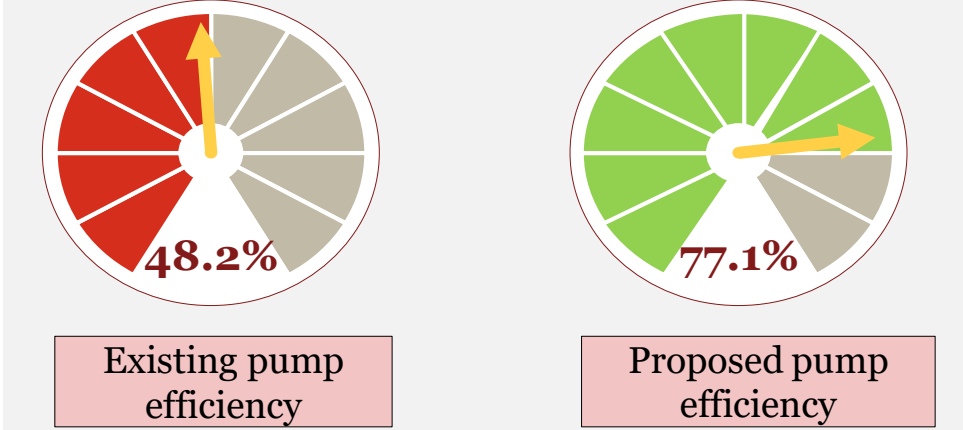
# Case of worn impeller

• An efficient pump was proposed in replacement of the existing pump with a IE 4 motor having an efficiency of 92.6%

Pump Parameter	Value
Flow (m <sup>3</sup> /h)	64
Head (m)	37.2
Pump Efficiency (%)	77.1
Existing motor	IE2
Proposed motor	IE4



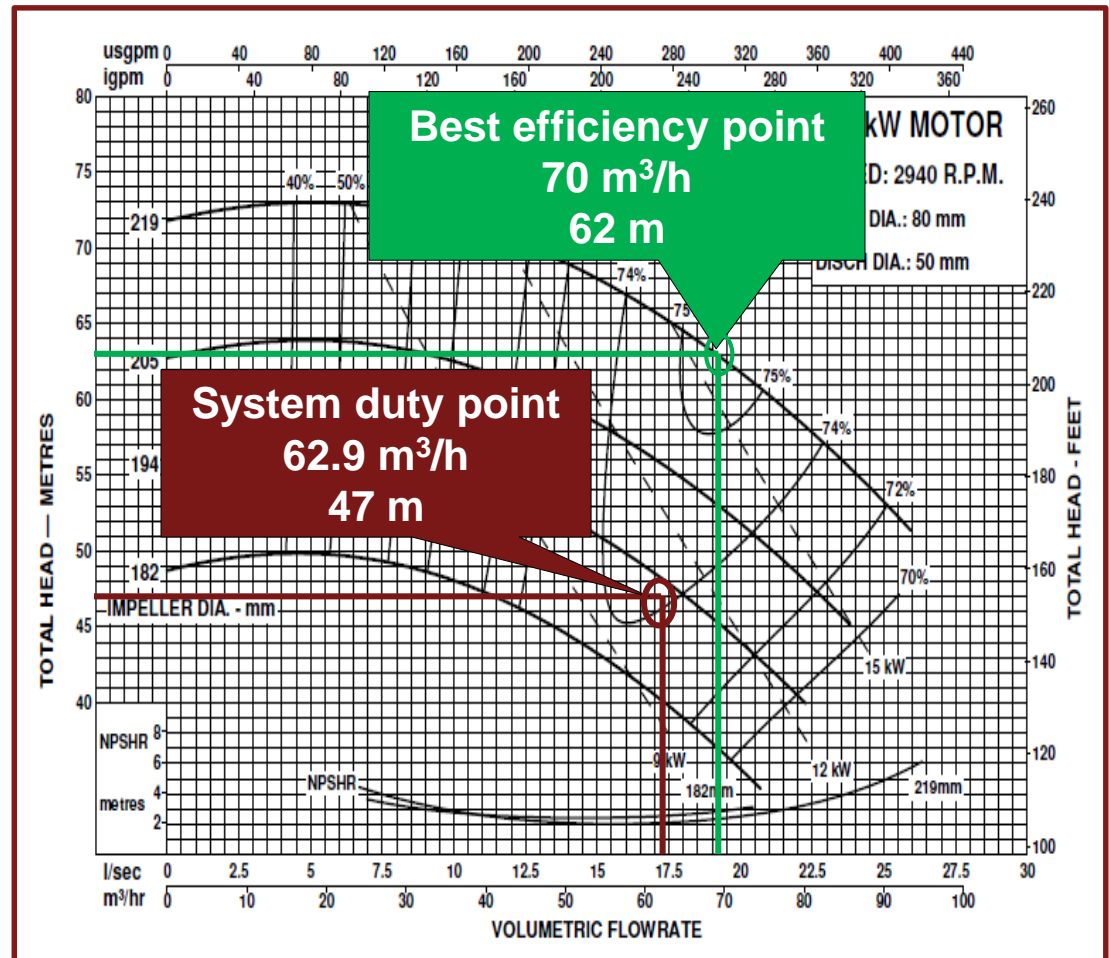
Simple payback for the investment is 2.3 years



# Case of oversized pump

## Tuvaruhu SIWA Pump Station Transfer Pump

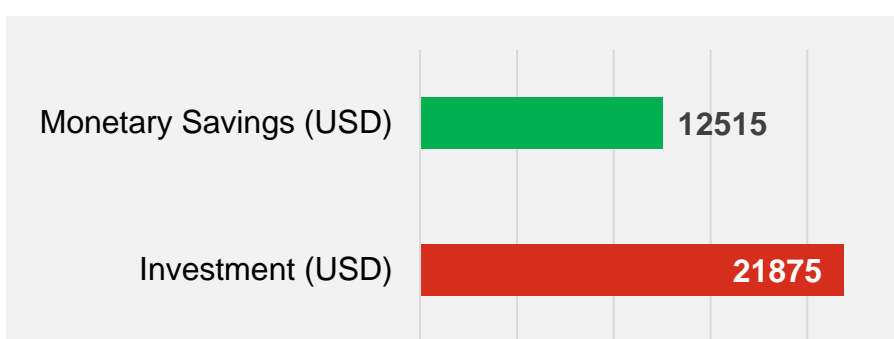
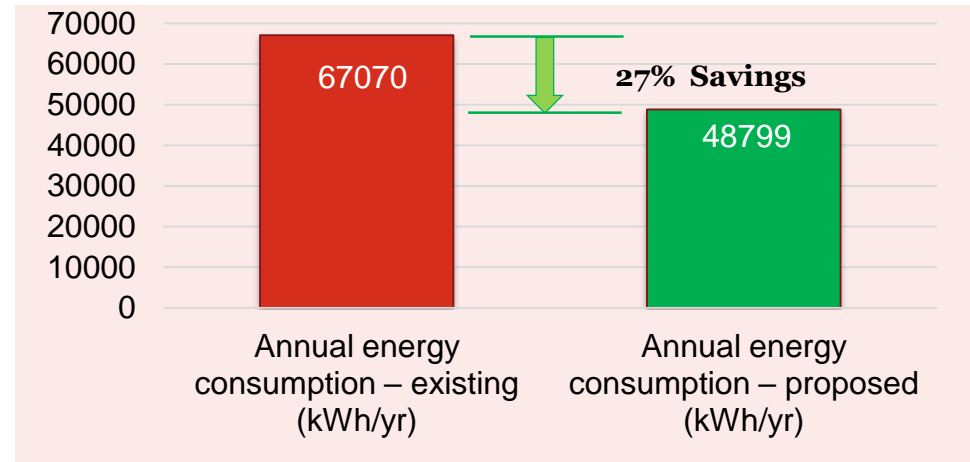
- Designed to deliver 70 m<sup>3</sup>/h at 62 m
- System head was 47 m delivering 62.9 m<sup>3</sup>/h
- Operating efficiency of pump was estimated as 53.75 %
- The inefficiency in the pump is because of an oversized pump installed and ageing of impeller



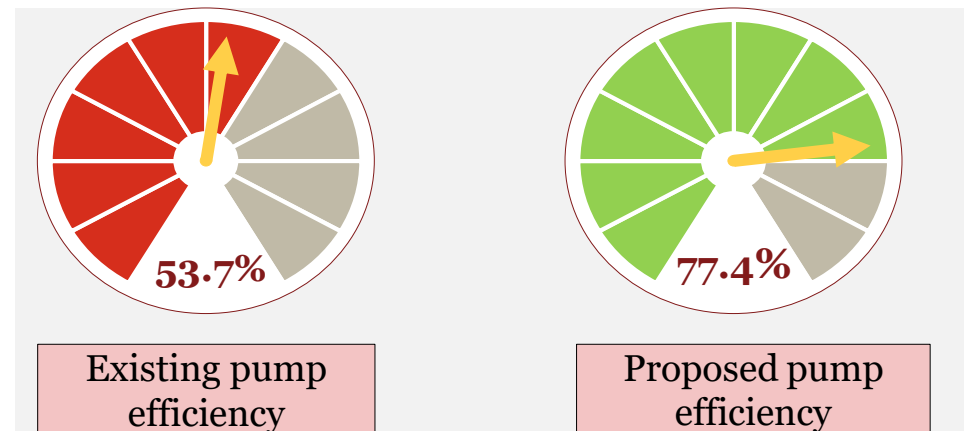
## Case of oversized pump

- An energy efficient pump was proposed as a replacement of the existing pump.
- A VFD was installed since there was no pump which was matching the operating requirements of the pump

Pump Parameter	Design	Proposed with VFD
Flow (m <sup>3</sup> /h)	64	57.1
Head (m)	59.8	47.7
Power (kW)	14.4	10.8
Speed (Rpm)	2950	2634
Frequency (Hz)	50	43.9



Simple payback for the investments is 1.9 years



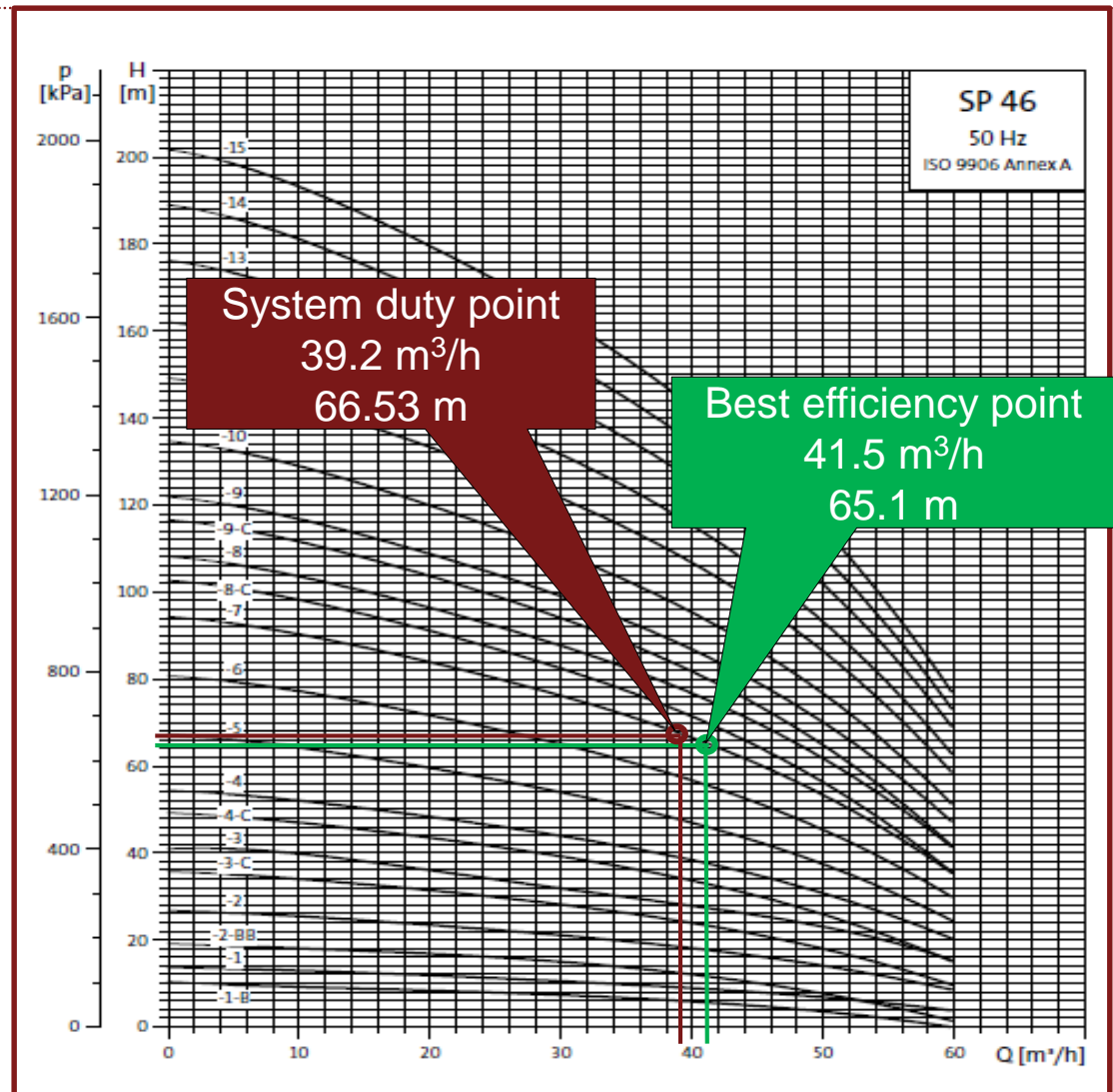
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# *Submersible bore-hole pump*

## Sample system and pump curve

### Tasahe Pump Station Borewell Pump

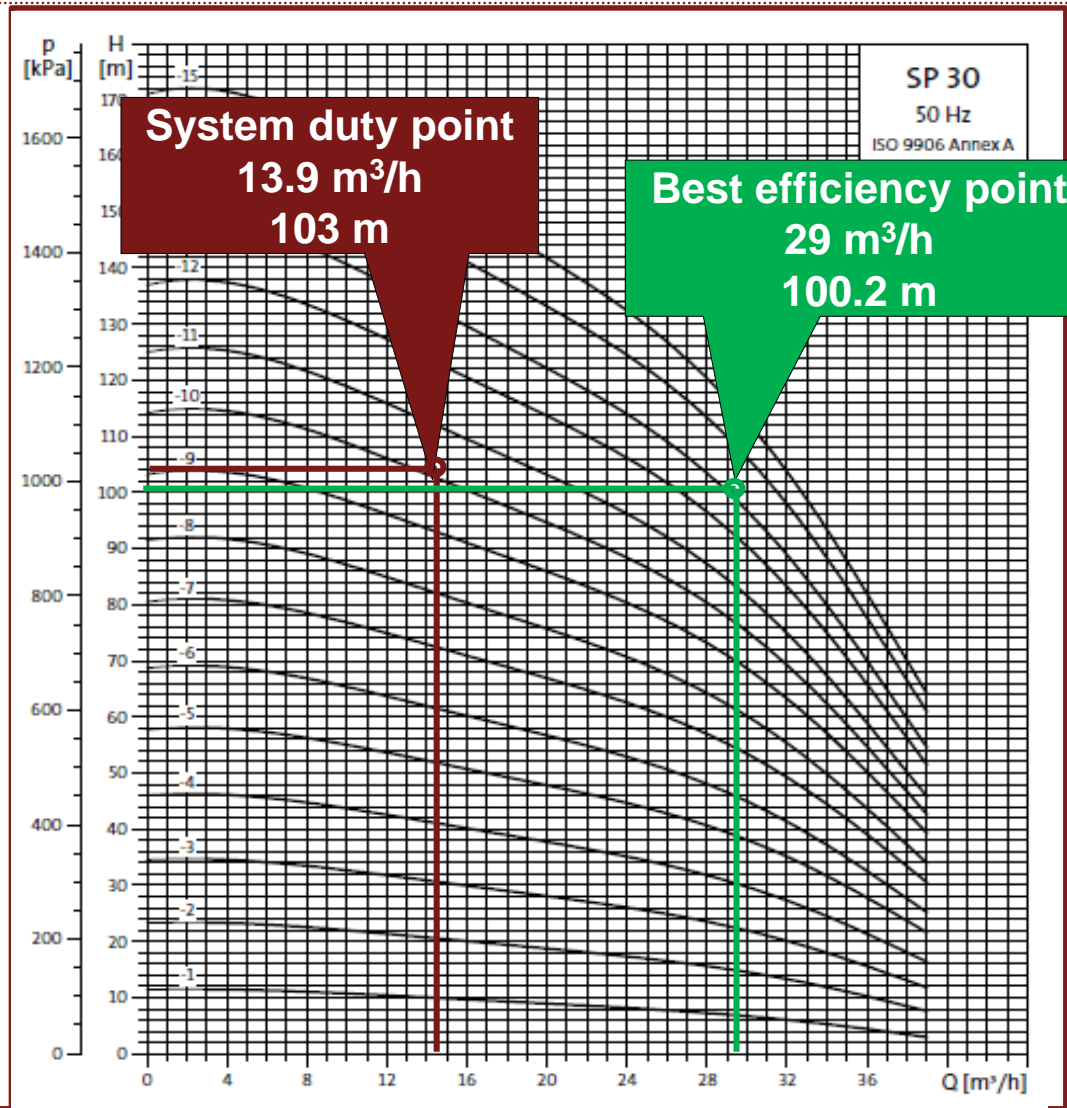
- Designed to deliver 41.5 m<sup>3</sup>/h at 61.5m
- The system head was measured to be 66.53 m
- Flowrate of water delivered by transfer pump was 39.2 m<sup>3</sup>/h
- Operating efficiency of pump was estimated as 71%



# Case of worn impeller

## Tasahe Pump Station Borewell Pump

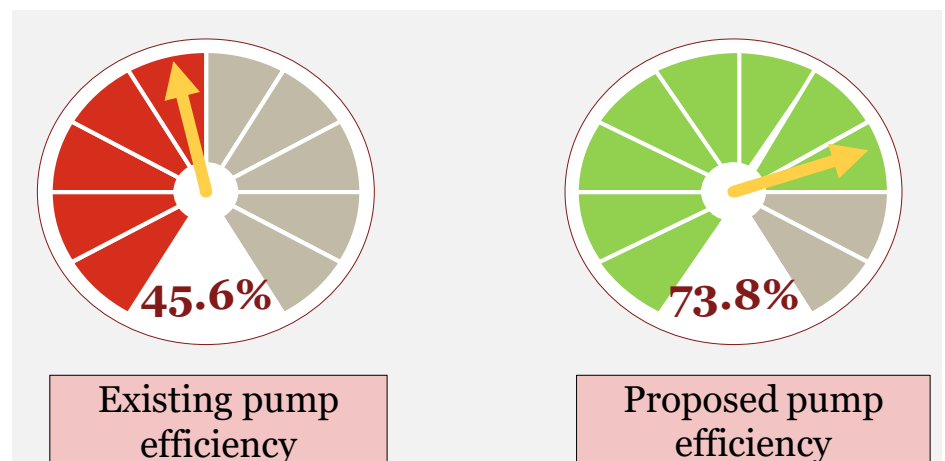
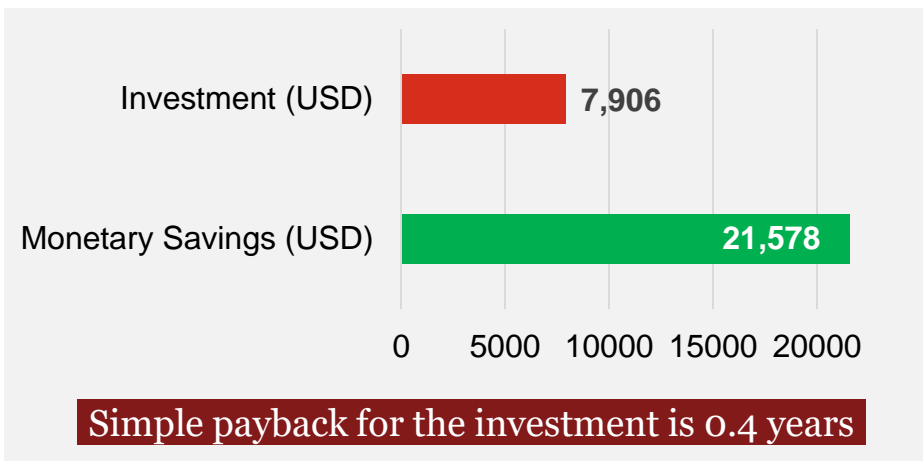
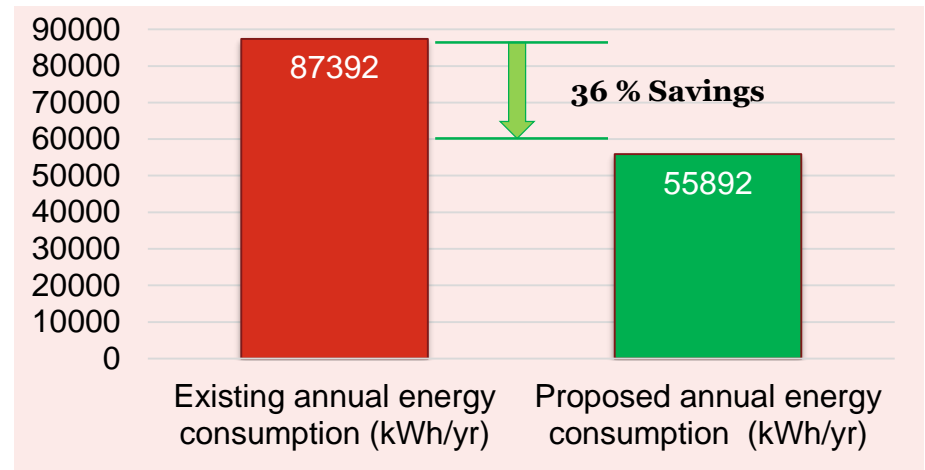
- Designed to deliver 29 m<sup>3</sup>/h at 100.2 m
- The system head was measured to be 103 m at 13.9 m<sup>3</sup>/h
- Operating efficiency of pump was estimated as 45.6 %
- The operating flow is 51 % less whereas the head is close to the design head suggesting impeller damage



## Case of worn impeller

- The recommendation is to replace these pumps with suitable size pumps of better efficiency.

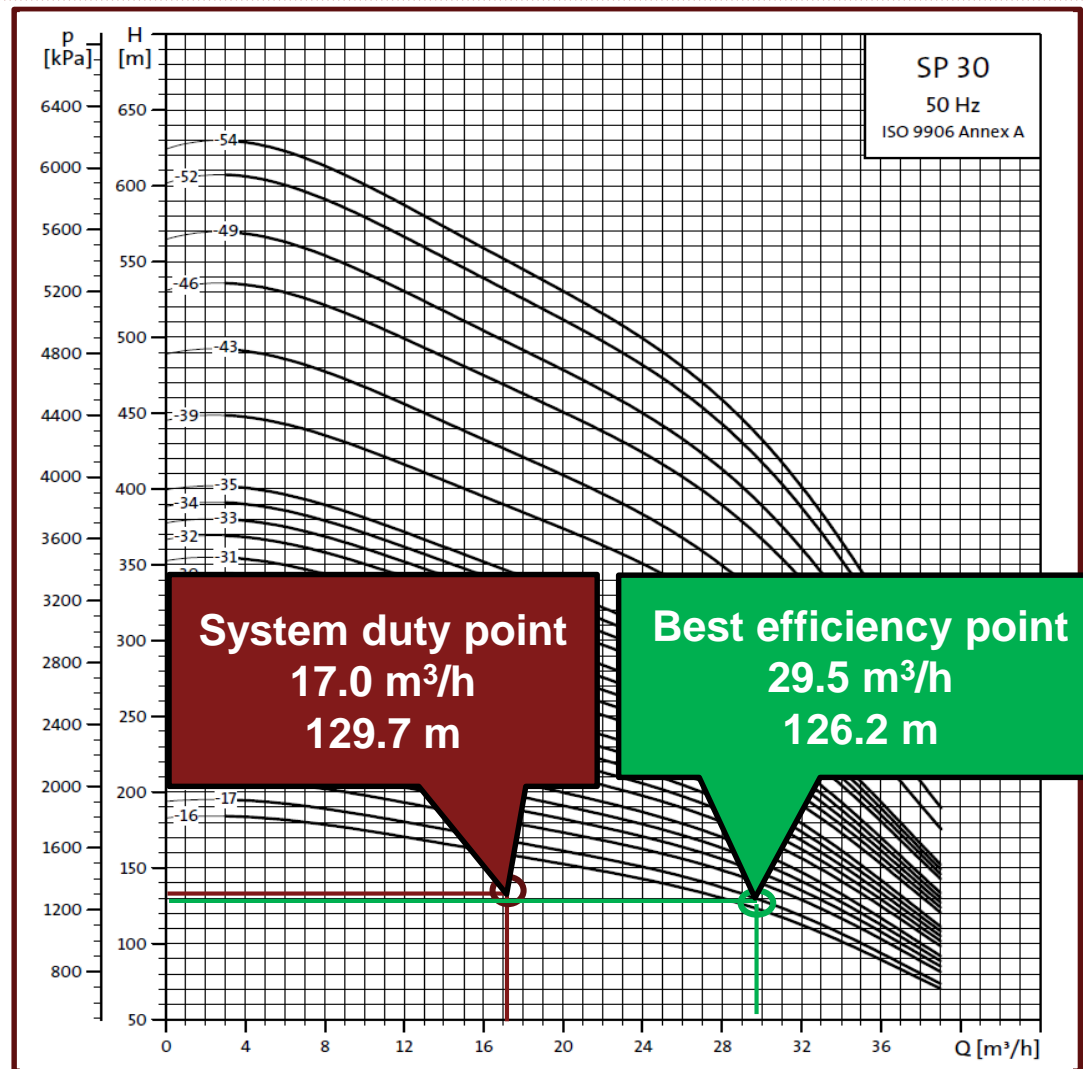
Pump Parameter	Value
Flow (m <sup>3</sup> /h)	30.7
Head (m)	105.0
Pump Efficiency (%)	73.8
Operating hours	10.5



# Case of wear and tear

## Skyline Pump Station Borewell Pump

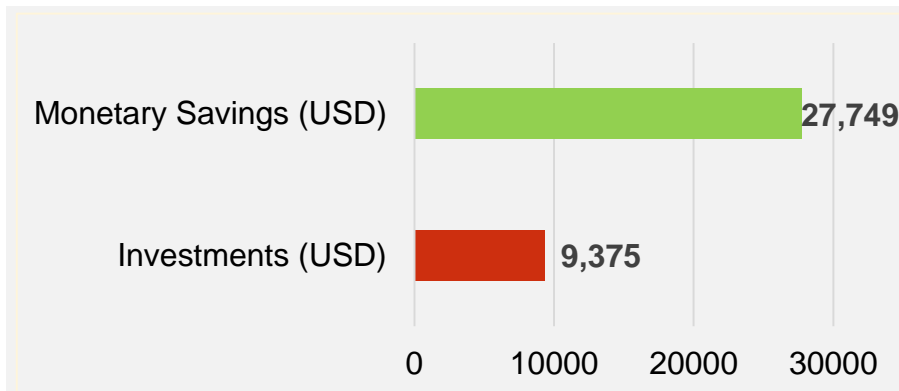
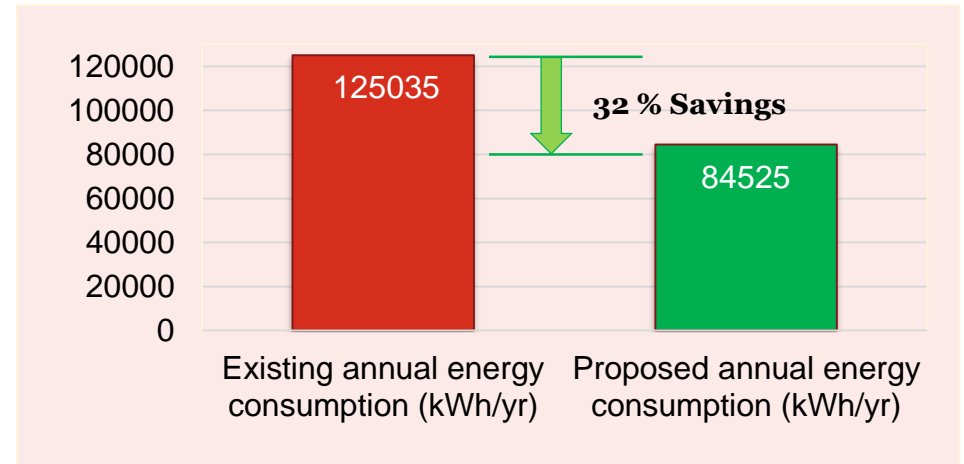
- Designed to deliver 29.5 m<sup>3</sup>/h at 126.2 m
- The system head was measured to be 129.7 m at 17.0 m<sup>3</sup>/h
- Operating efficiency of pump was estimated as 48.9 %
- Operating flow is 42% less whereas head is close to design suggesting impeller damage



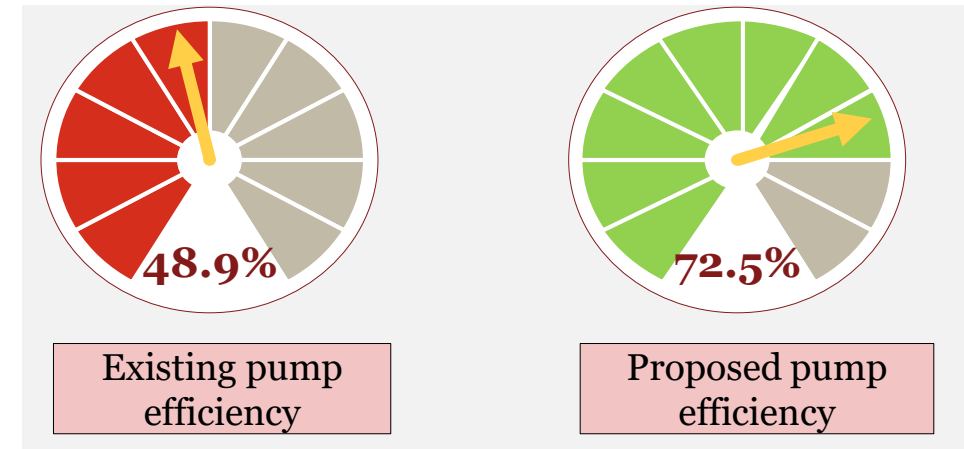
## Case of wear and tear

- An efficient pump was proposed in replacement of the existing pump

Pump Parameter	Value
Flow (m <sup>3</sup> /h)	30.1
Head (m)	130.0
Pump Efficiency (%)	72.50
Operating hours	13



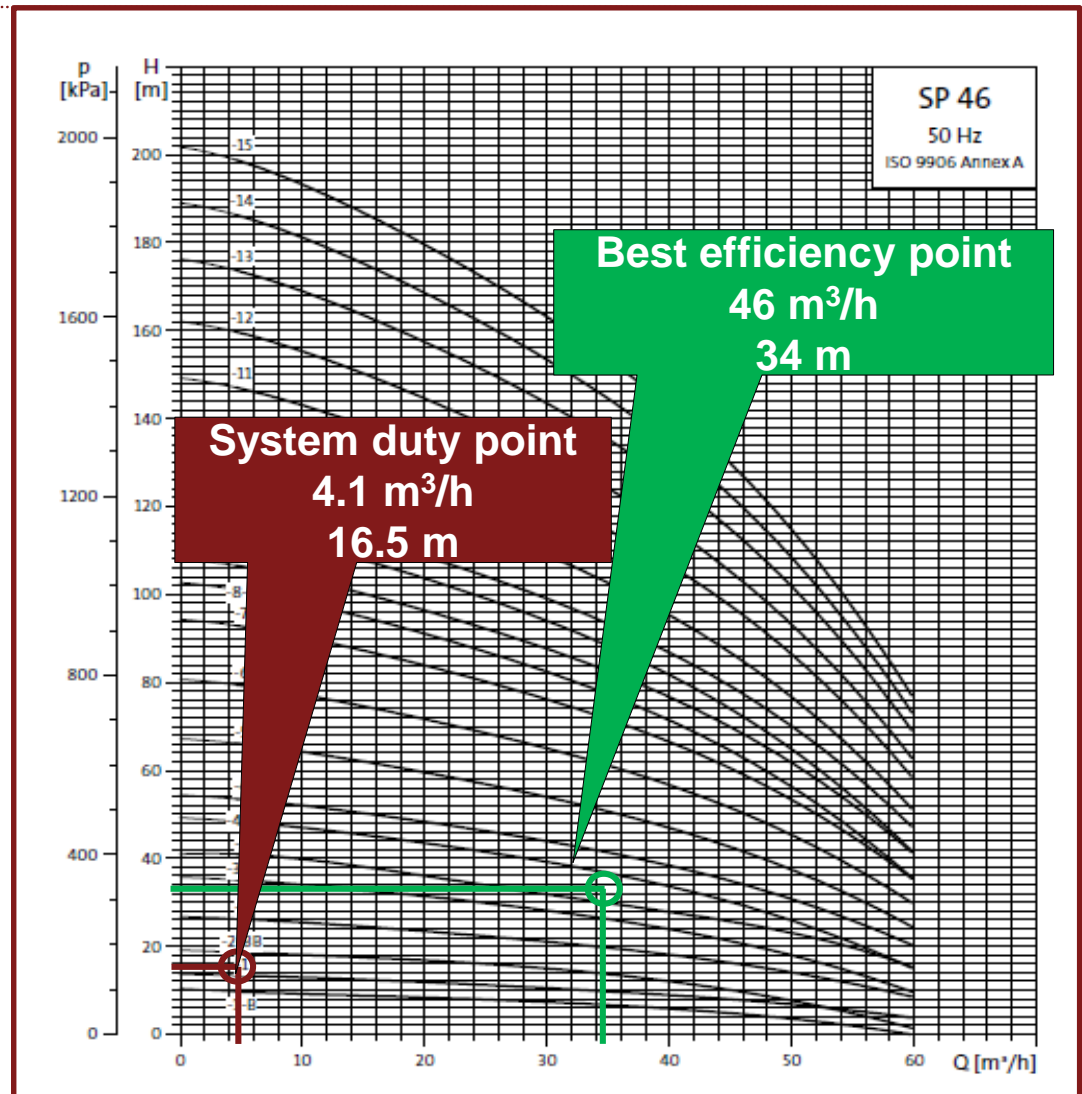
Simple payback for the investment is 0.3 years



## Case of blocked water inlet screen

### Borderline Pump Station Borewell Pump

- Designed to deliver 46 m<sup>3</sup>/h at 34 m
- The pump is operating at 16.5 m head at 4.1 m<sup>3</sup>/h flow with an efficiency 4.8 %
- It appears that the screens for drawing water in this pump are blocked. **This pump should remain off until proper cleaning of the screens.**



---

# *Other areas*

## *Lighting system*

Pump station	Type of fixture	No.	Total Wattage (W)	LED replacement (W)
Titinge	FTL 36W	24	1056	252
Skyline	FTL 36W	24	1056	252
Tuvaruhu JICA	FTL 36W	8	352	126
Tuvaruhu SIWA	FTL 36W	8	352	126
Kwaibala	FTL 36W	4	176	84
Borderline	FTL 36W	24	1056	252
Tasahae	FTL 36W	24	1056	252

The operating hours of lights is very less. Hence, its suggested to replace FTL with LED once the exiting light fails.

## *Lighting system – Case of Solar Tube*

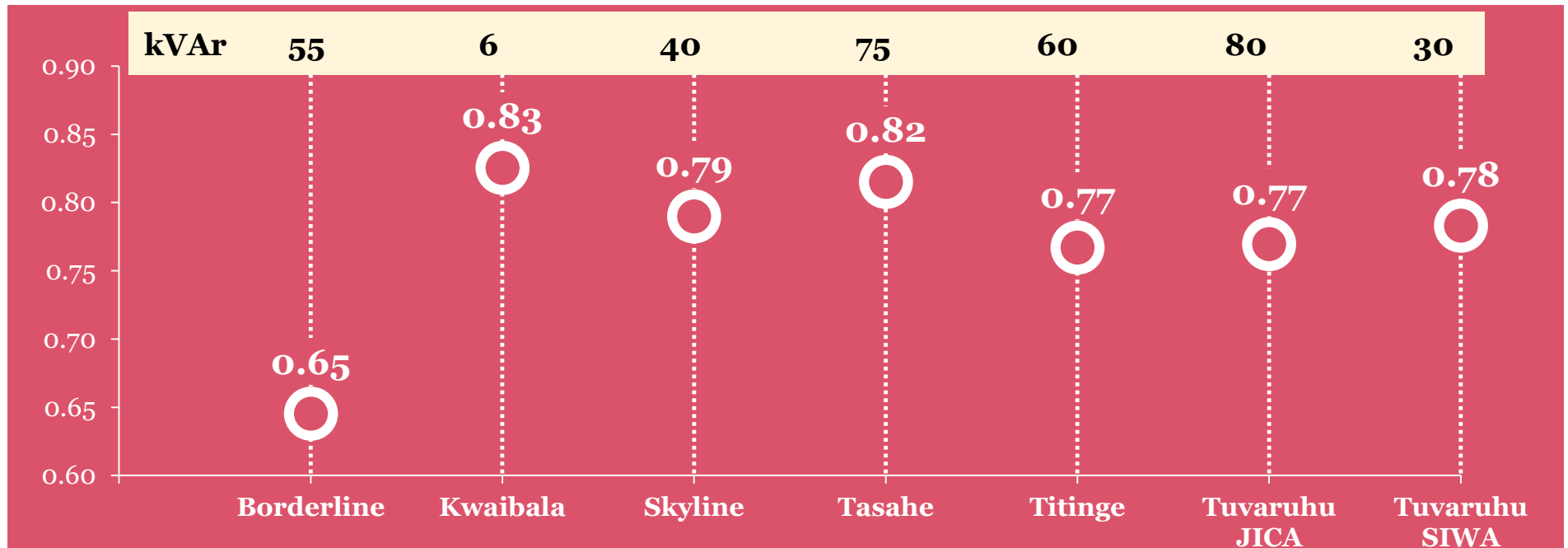
- Case of motor manufacturing industry producing 85 no's. of 1 hp domestic motors per day



### ***Savings***

- Typical – 250 W rating Mercury Vapour Lamps used for shed lighting in factory
- Total of 21 no's. fixtures replaced by solar tubes based reflectors to bring solar light in day time
- Annual electricity saving – 9,450 kWh
- Annual monetary savings – US \$ 1,250
- Simple payback – 3 years
- Energy savings – 25%

## Power factor correction



According to the current tariff structure of SIEA there is no penalty on power factor. However a tariff on PF is likely to be introduced similar to Australia's tariff for PF.

**Total annual penalty USD 31410**

Total investment cost of power factor correction in the seven pumps USD 28,190 with a simple payback period of 0.9 years.

*Thanks!*



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# *Operation and maintenance*

## Training Programme on Energy Efficiency and Self Generation Option

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# *Agenda*

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**Introduction** **3**

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**Types of maintenance** **7**

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**Best operating practices** **13**

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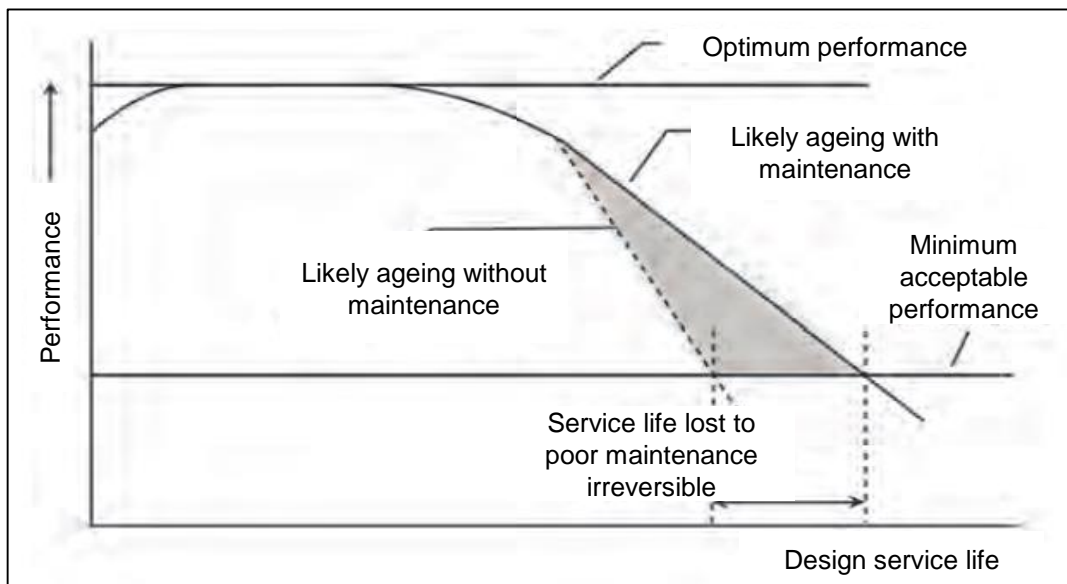
# *Introduction*

## What is O&M?

**Operations and Maintenance** are the decisions and actions regarding the control and upkeep of property and equipment.

These are inclusive, but not limited to

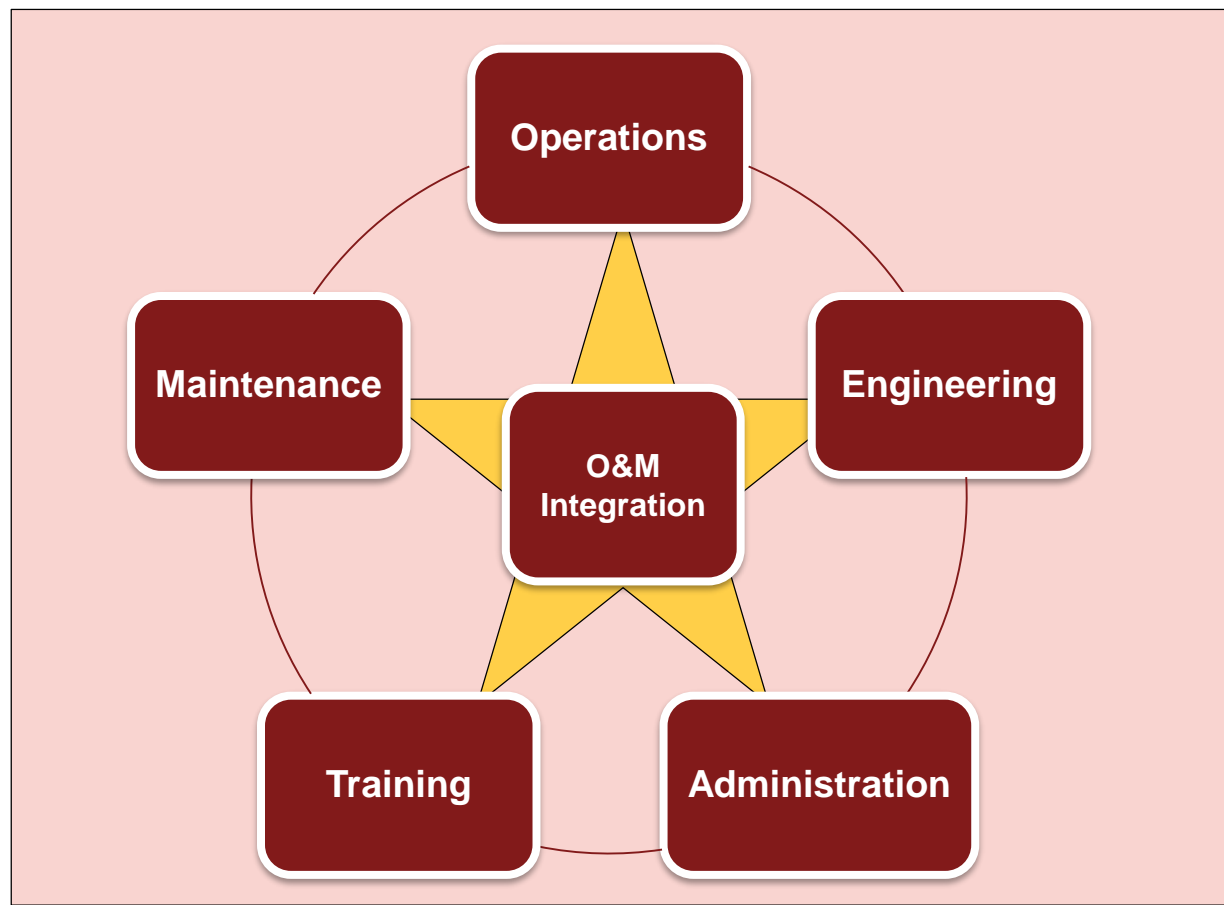
- actions focused on scheduling, procedures, and work/systems control and optimization;
- performance of routine, preventive, predictive, scheduled and unscheduled actions aimed at preventing equipment failure or decline with the goal of increasing efficiency, reliability, and safety.



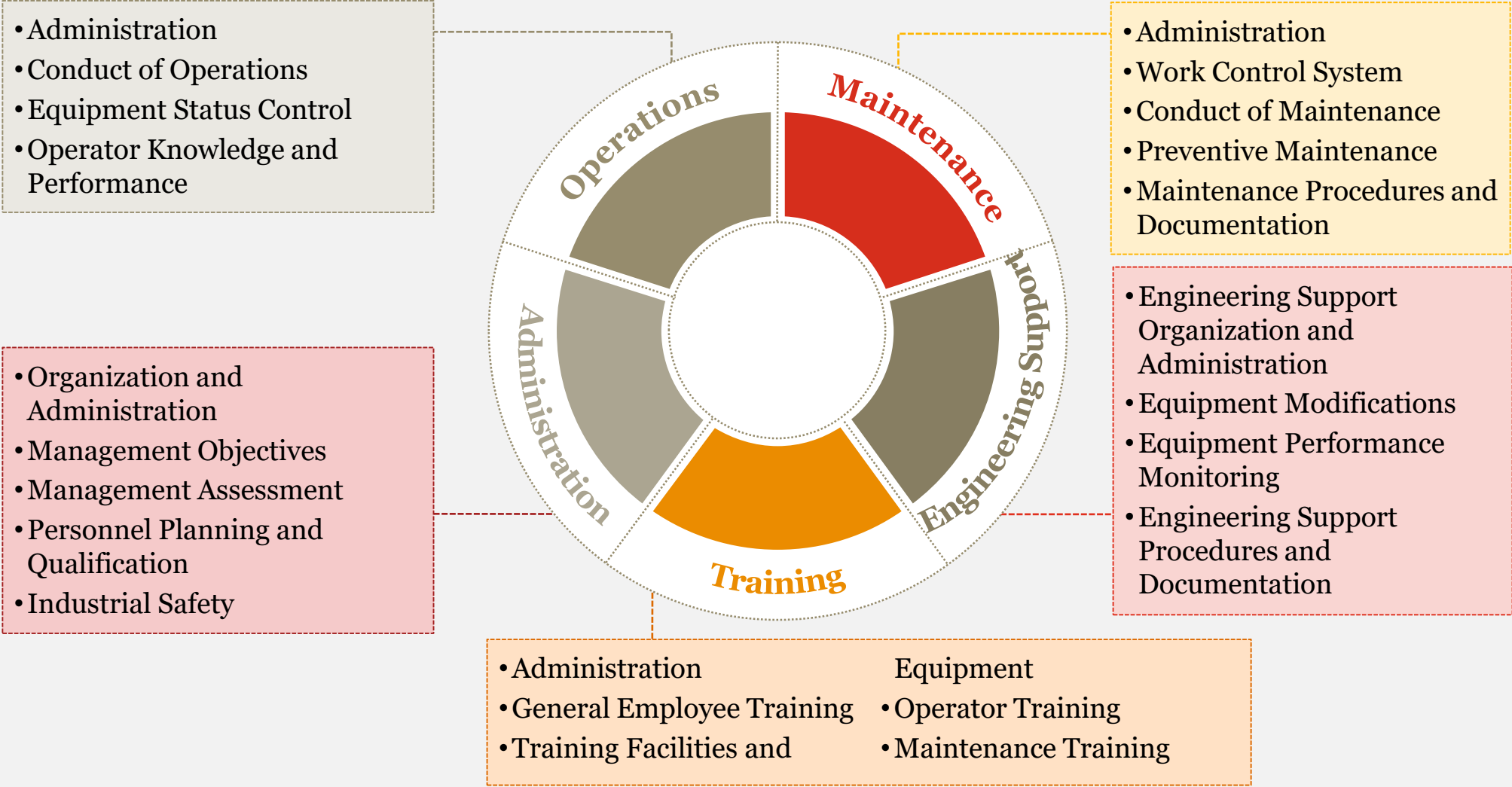
**Effect of adequate and timely maintenance and repairs on service life of a facility**

# *O&M management*

## 5 components of Operations and maintenance management, OMETA



# O&M management

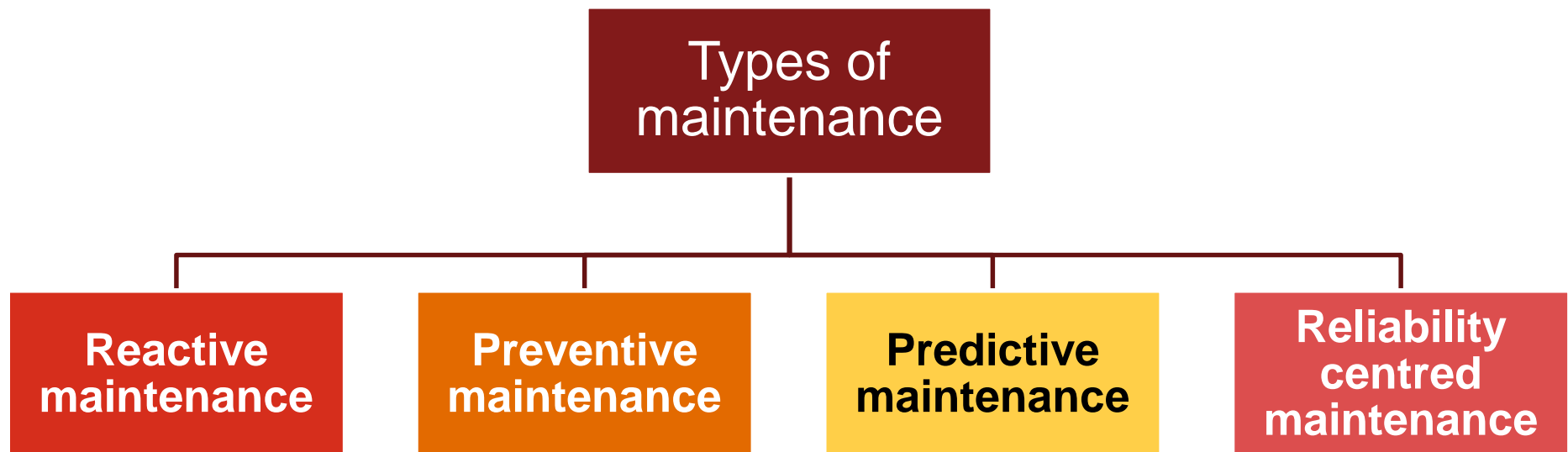


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# *Types of maintenance*

# *Types of maintenance*

**Maintenance is defined as the work of keeping the equipment in proper condition; upkeep.**



# Types of maintenance

## Reliability Centered maintenance

RCM is a systematic approach to evaluate a facility's equipment and resources to best mate the two and result in a high degree of facility reliability and cost-effectiveness.

### Advantages

- Can be the most efficient maintenance program
- Lower costs by eliminating unnecessary maintenance or overhauls
- Minimize frequency of overhauls.
- Reduced probability of sudden equipment failures

### Disadvantages

- Savings potential not readily seen by management
- Can have significant startup cost, training, equipment

## Predictive Maintenance

By observing parameters of the system it is predicted that after some time there will be breakdown of the system. So in that case corrective action is taken as a precautionary measure.

### Advantages

- Increased component operational life/availability.
- Allows for preemptive corrective actions
- Decrease in equipment or process downtime
- Decrease in costs for parts and labor.

### Disadvantages

- Increased investment in diagnostic equipment.
- Increased investment in staff training.
- Savings potential not readily seen by management

# Types of maintenance

## Preventive maintenance

This kind of maintenance is done monthly or any fixed interval of time to prevent any sudden breakdown of machine.

### Advantages

Cost effective in many capital-intensive processes.

Reduced equipment or process failure

Increased component life cycle

Energy savings

### Disadvantages

Catastrophic failures still likely to occur.

Labor intensive

Includes performance of unneeded maintenance

Potential for incidental damage to components

## Reactive Maintenance

Reactive maintenance is basically the “run it till it breaks” maintenance mode. In case of any breakdown immediate maintenance is required to run the system again..

### Advantages

Low cost.

Less staff

### Disadvantages

Inefficient use of staff resources.

Increased labor cost, especially if overtime is needed.

Cost involved with repair or replacement of equipment

Possible secondary equipment or process damage from equipment failure

# Predictive maintenance

**Predictive maintenance attempts to detect the onset of a degradation mechanism with the goal of correcting that degradation prior to significant deterioration in the component or equipment**

## Common predictive technologies assessment

Technologies	Pumps	Electrical motors	Electrical Systems
Vibration Monitoring/Analysis	Yes	Yes	No
Lubricant, Fuel Analysis	Yes	Yes	No
Wear Particle Analysis	Yes	Yes	No
Bearing, Temperature/Analysis	Yes	Yes	No
Performance Monitoring	Yes	Yes	No
Ultrasonic Noise Detection	Yes	Yes	No

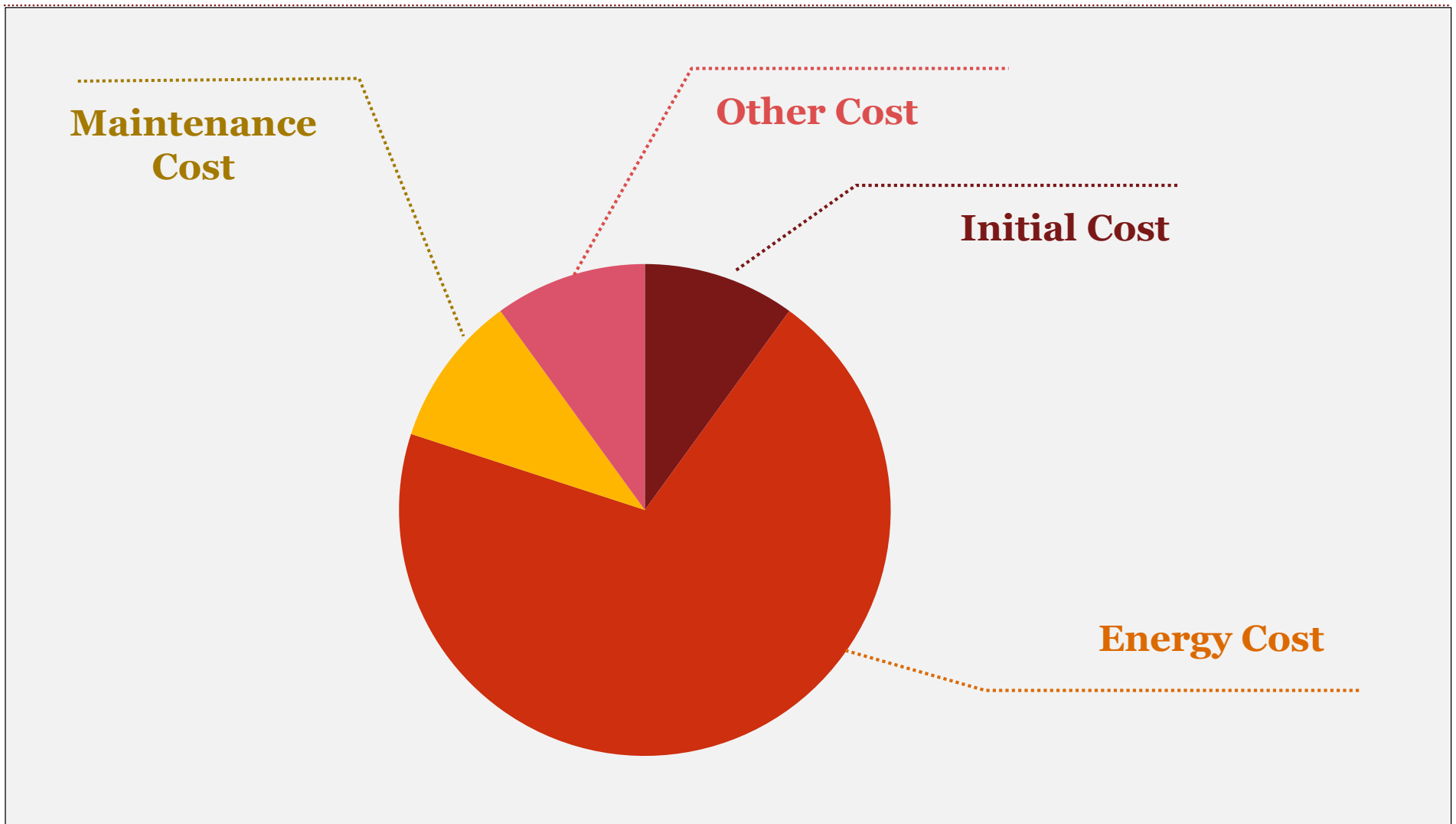
# Predictive maintenance

Technologies	Pumps	Electrical motors	Electrical Systems
Ultrasonic Flow	Yes	No	No
Infrared Thermography	Yes	Yes	Yes
Non-destructive Testing (Thickness)	No	No	No
Visual Inspection	Yes	Yes	Yes
Insulation Resistance	No	Yes	Yes
Motor Current Signature Analysis	No	Yes	No
Motor Circuit Analysis	No	Yes	Yes
Polarization Index	No	Yes	Yes
Electrical Monitoring	No	No	Yes

---

# *Best operating practices*

# *Benefits of efficient pumping system*



# *BOP for pumping system*

Some of  
the best  
practices  
for  
pumping  
system

Use Efficient Flow Control Methods

**01**  
Practice

Avoiding Cavitation in Pump

**02**  
Practice

Location of pump

**03**  
Practice

Proper monitoring and controlling of system

**04**  
Practice

Avoid friction in line

**05**  
Practice

Pumping system design consideration

**06**  
Practice

*Thanks!*



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# *Renewable energy source and potential assessment*

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# *Agenda*

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**Renewable energy sources** **3**

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**Solar feasibility assessment** **17**

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# *Renewable energy sources*

# Renewable energy sources

**Solar**



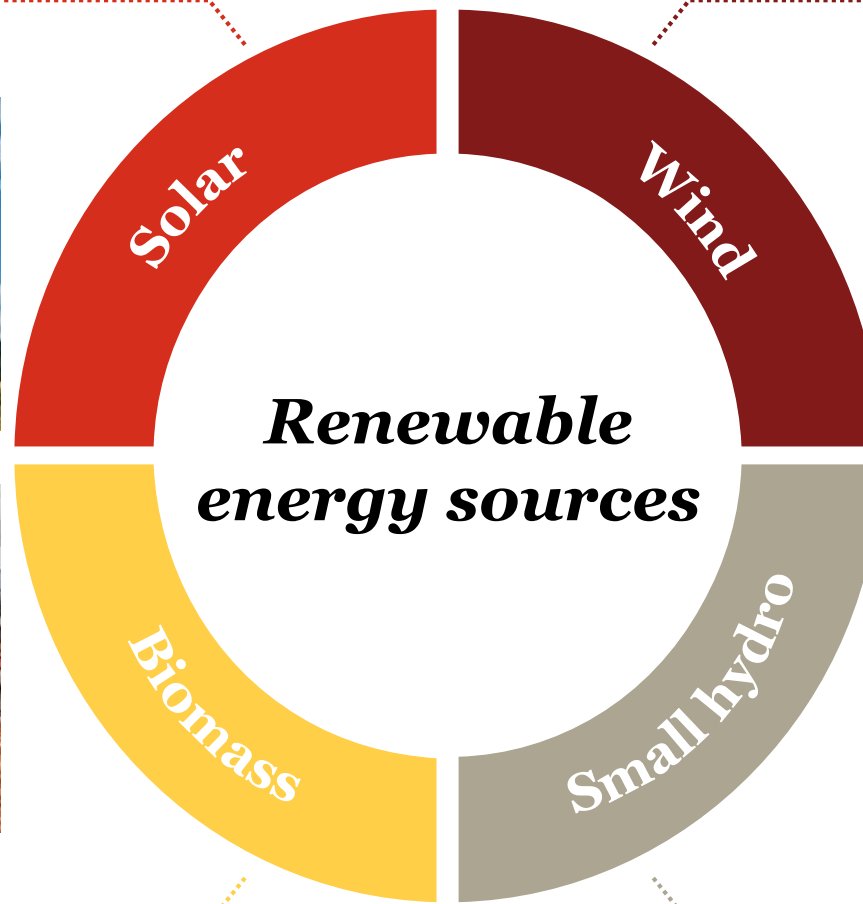
**Wind**



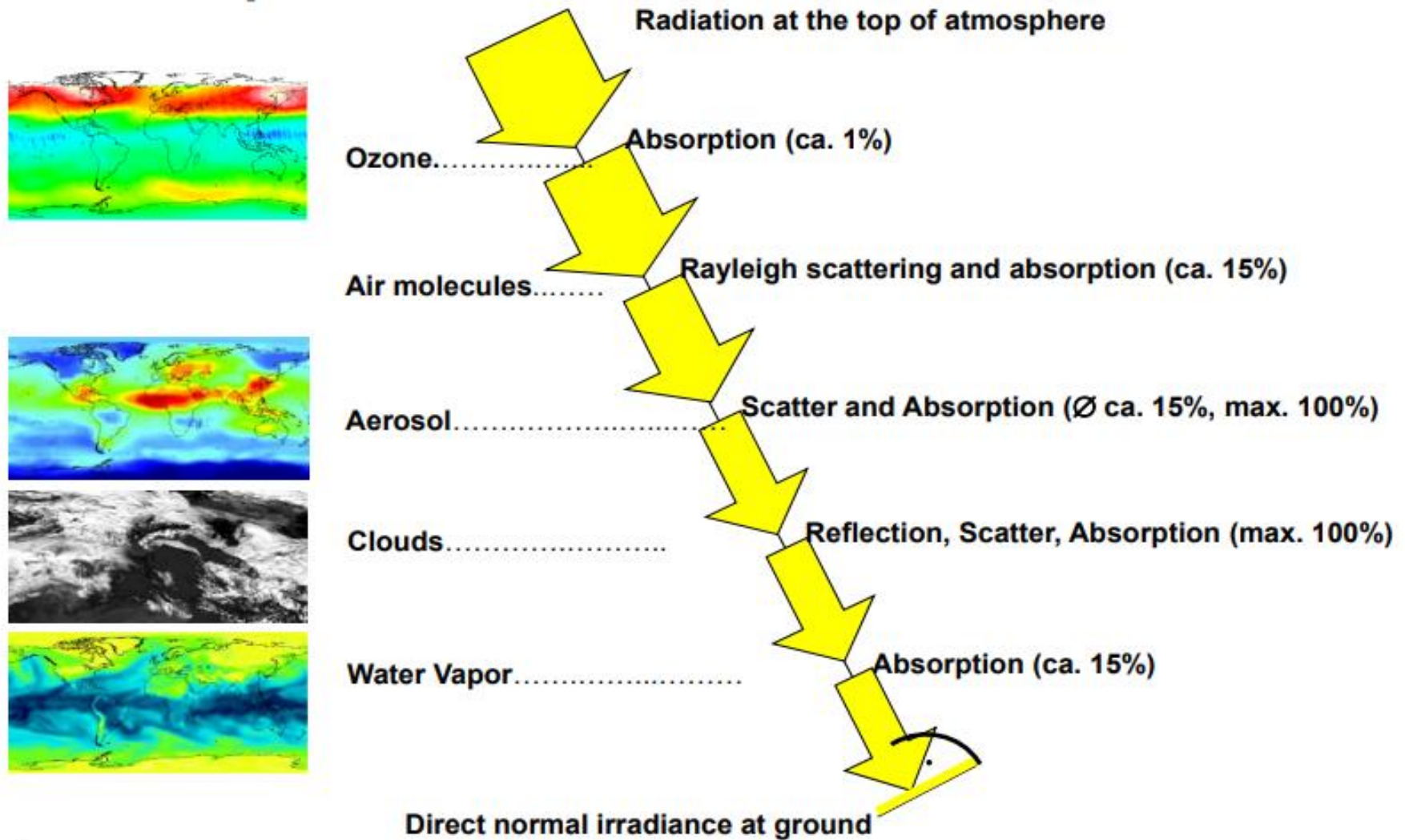
**Biomass**



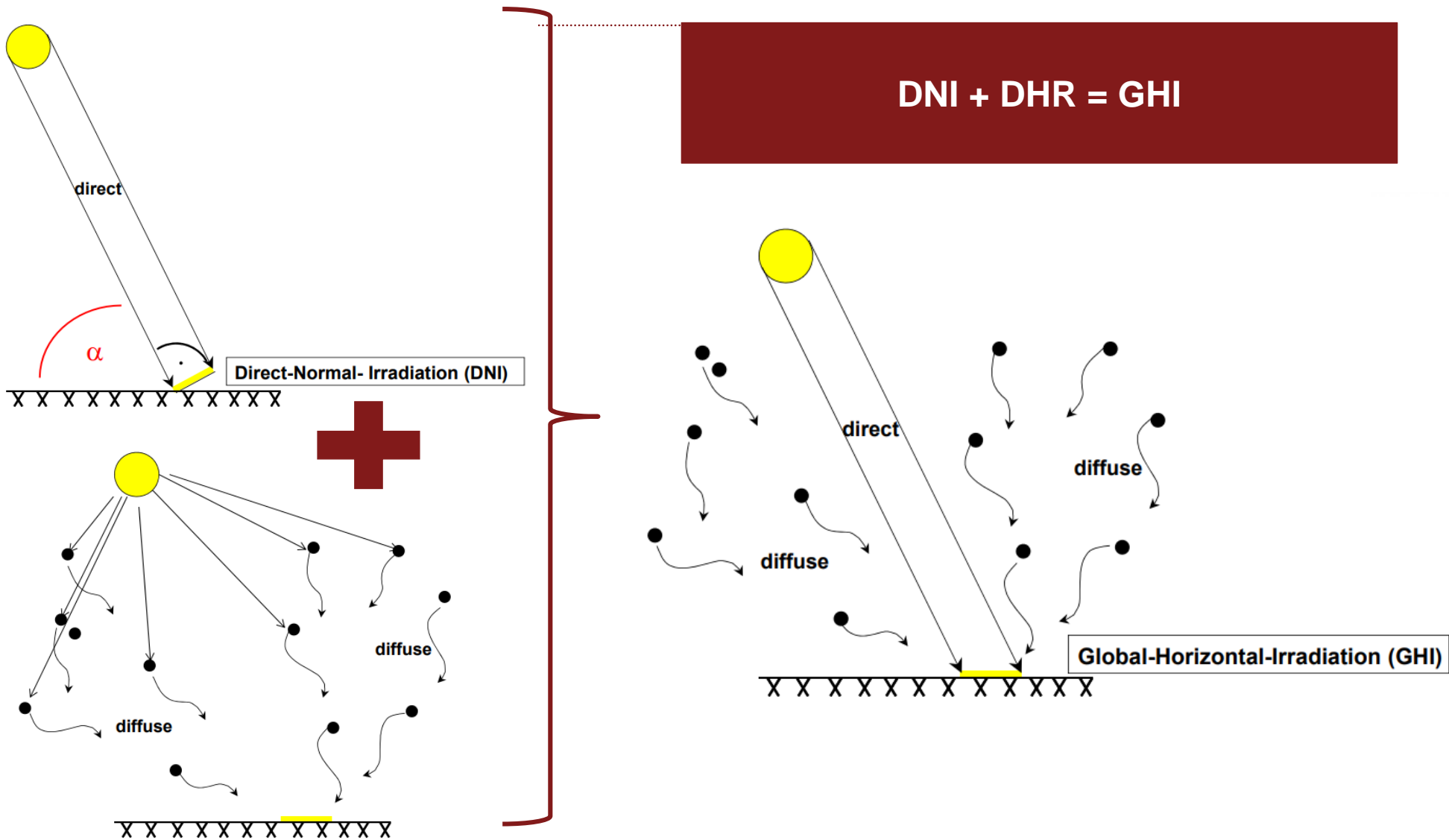
**Small hydro**



# Solar Energy



# Solar Energy

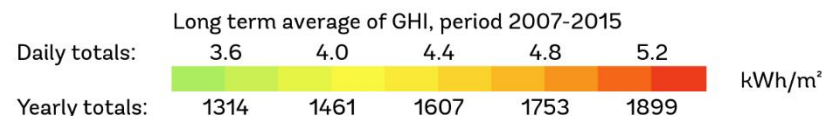


# Solar resource in Solomon Islands

- Geographical location of Solomon Islands (9°S) is good in terms of solar energy potential
- Average global horizontal irradiation in Honiara is about 4.95 kWh/m<sup>2</sup>/day
- Average annual solar yield is about 1542 kWh/kW<sub>p</sub>

SOLAR RESOURCE MAP

## GLOBAL HORIZONTAL IRRADIATION SOLOMON ISLANDS



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# Solar energy harnessing potential assessment

Particular	Unit
Total roof area	m <sup>2</sup>
Roof slope (approximately)	degree
Average roof shaded	% or m <sup>2</sup>
Roof construction (Concrete, polycarbonate, metal sheets, etc.)	
Latitude and longitude of plant location	degree
Elevation	m
Daily solar radiation (average, maximum, minimum)	kWh/m <sup>2</sup> /day

## Solar water heater

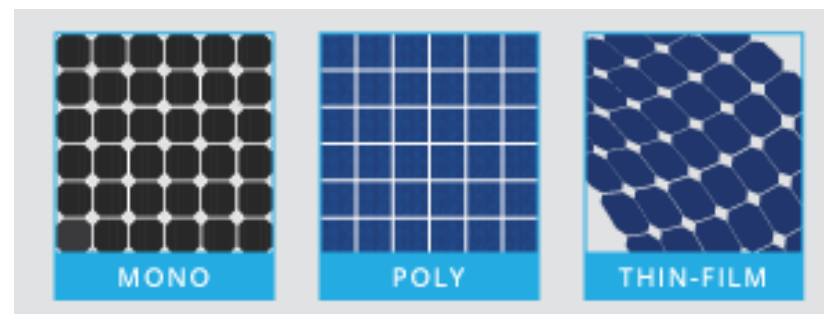


## Solar roof-top PV

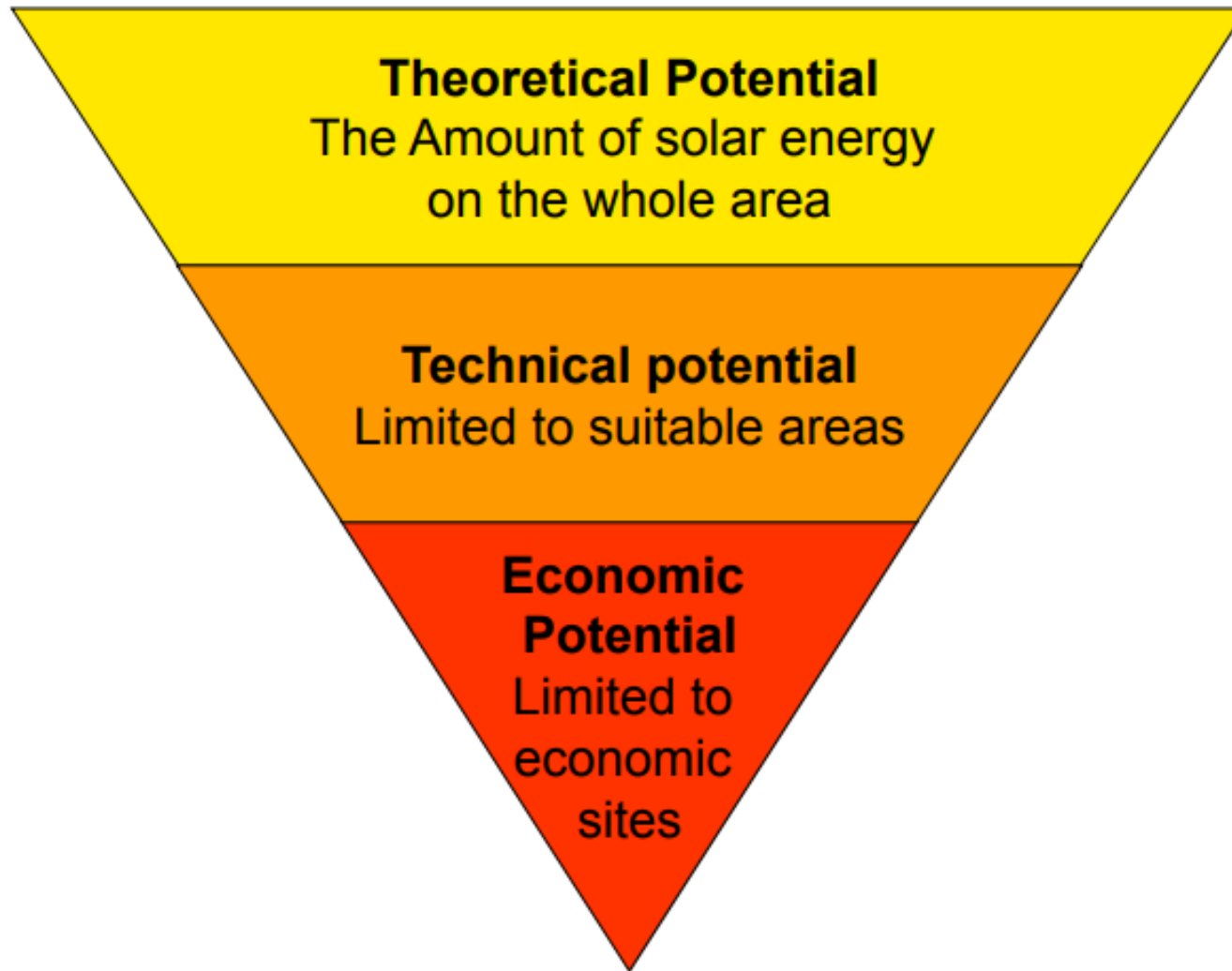


## Solar PV technology

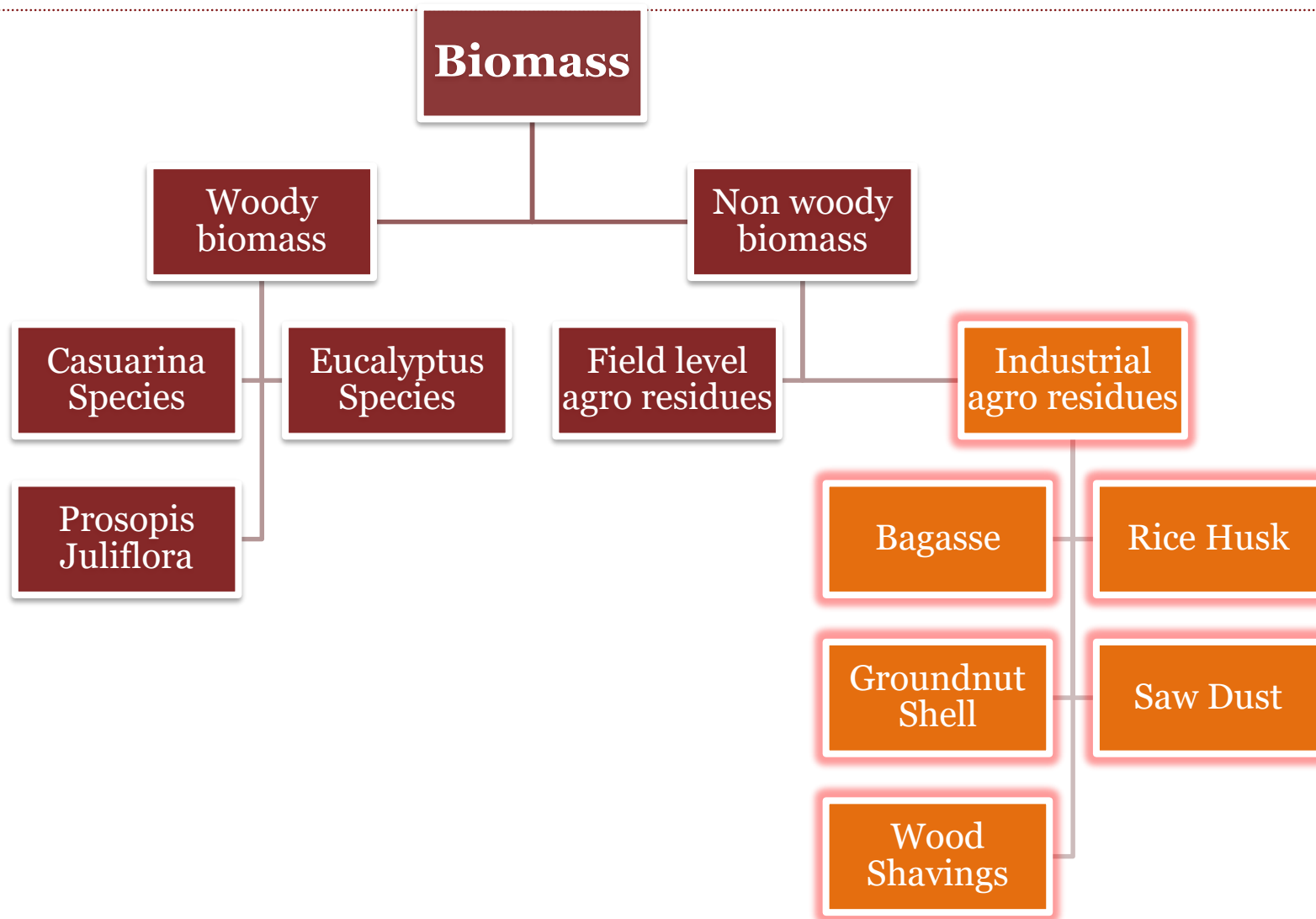
Solar Panel Type	Advantages	Disadvantages
Monocrystalline	– High efficiency/performance	– High cost
Polycrystalline	– Low cost	– Lower efficiency/performance
Thin-film	– Portable and flexible – Lightweight	– Lower efficiency/performance



# *Solar Potential*



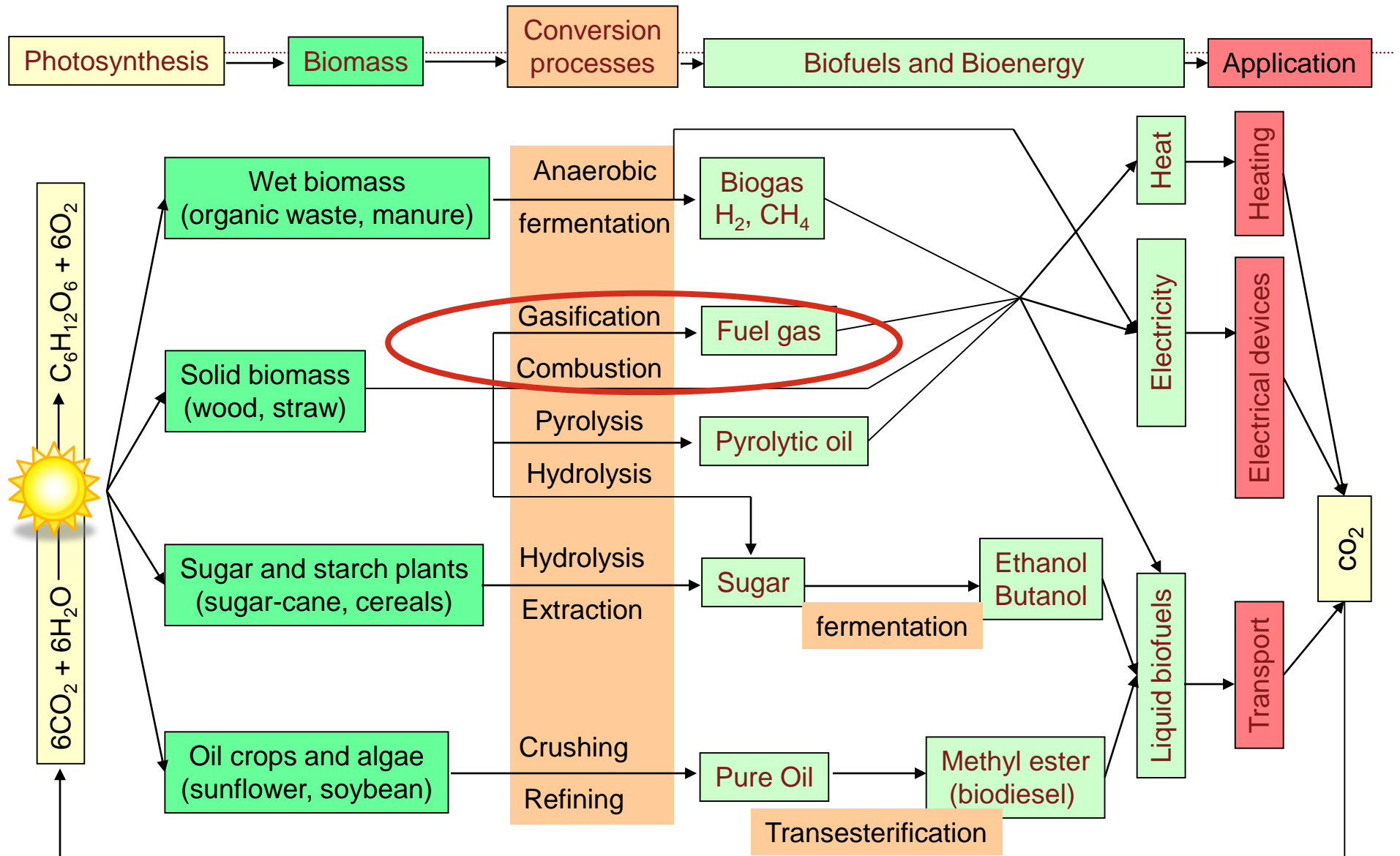
# Biomass resource



## *Biomass resource*



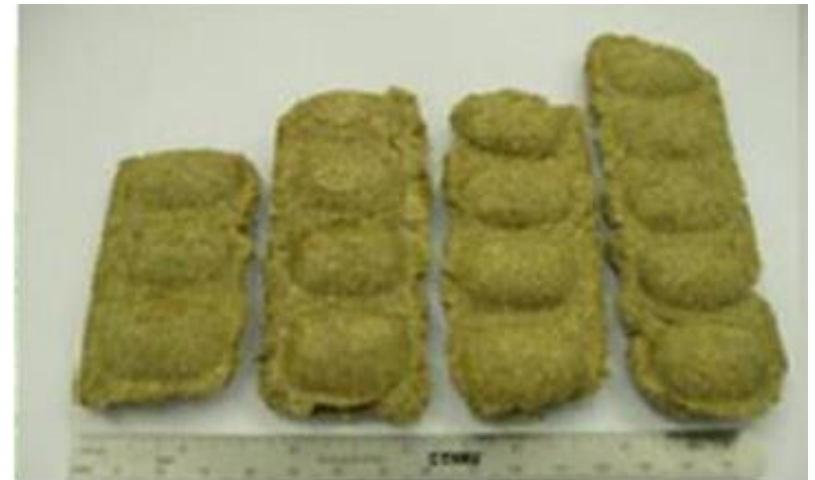
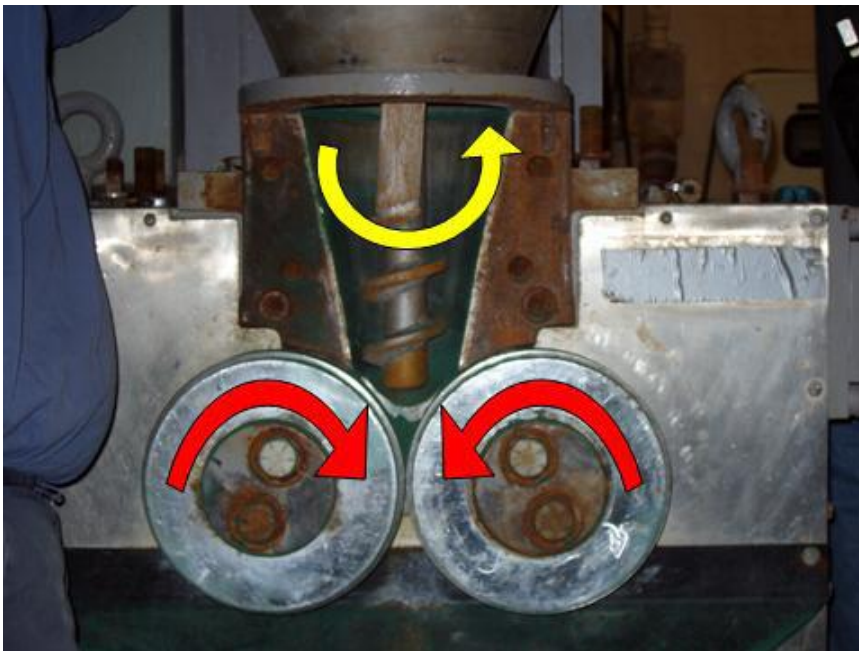
# Biomass to energy



# Briquetting

**Briquettes** and pellets are both products deriving from the densification of a raw material.

**Biomass briquettes** and pellets for fuel use are a product which aims to improve the characteristics of a certain raw material



# *Biomass gasifier*



# Biomass gasifier – Applications

DRYERS	KILNS	FURNACES	PROCESS HEAT	WATER BOILERS
<p><b>Drying applications in farm products, food, and spices industry</b></p> <p>Such tea, coffee, tobacco, and chemical products</p> <p>Temperature requirement: 60-130 °C</p>	<p><b>Baking of tiles, pottery, plaster of Paris, and lime</b></p> <p>Temperature requirement: 700-1000 °C</p>	<p><b>For pre-heating scrap metal such as aluminium, copper, iron, steel and various alloys</b></p> <p>Temperature requirement: 650 – 1100 °C</p>	<p><b>Process industries requiring low-pressure steam</b></p> <p>Such as large scale cooking, textiles, and food processing units such as bakeries and snacks making units</p>	<p><b>Institutional cooking, silk cocoon cooking, fabric dyeing, areca nut boiling, food processing, chemical products, and similar industries</b></p>

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# *Solar feasibility assessment*

# Solar feasibility analysis

Daily Global Horizontal Irradiation in kWh/m <sup>2</sup> /day											
Latitude -9.438°, Longitude 159.959°											
Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35

Particular	Unit	Thin-film	Monocrystalline
Available roof area	m <sup>2</sup>	160	160
Utilization area	m <sup>2</sup>	136	136
Nominal power	kWp	13.6	21.8
Average global horizontal irradiance	kWh/m <sup>2</sup> /day	4.95	4.95
Proposed tilt angle	degree	10	10
Annual solar yield	kWh/year	20974	33620

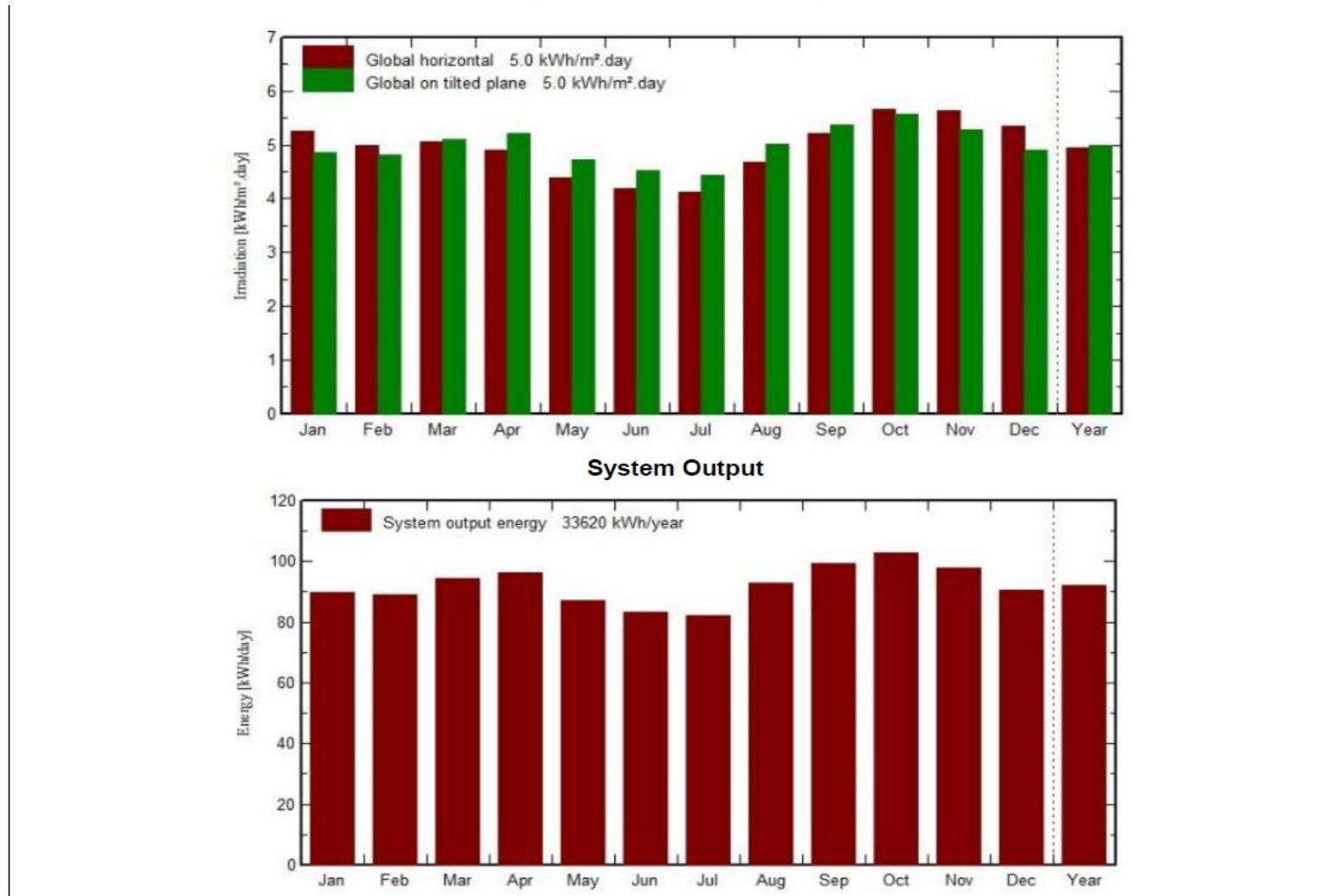
# Solar feasibility analysis – PV Syst snapshot

Definition of Geographical Site													
<b>Geographical Site</b>	Honiara			Country				Solomon Islands					
File New.SIT of 01/10/19 12h40													
<b>Situation</b>	Latitude: -9.45° S						Longitude: 159.96° E						
Time defined as	Legal Time			Time zone UT+11			Altitude: 10 m						
Monthly Meteo values													
	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Hor. Global (kWh/ m <sup>2</sup> day)	5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35	4.95
Extraterrestrial (kWh/ m <sup>2</sup> day)	10.90	10.86	10.49	9.66	8.75	8.23	8.40	9.16	10.06	10.65	10.85	10.85	9.90
Clearness index	0.481	0.459	0.482	0.508	0.502	0.509	0.491	0.510	0.518	0.532	0.520	0.493	0.50
Amb Temp (°C)	27.1	26.9	26.8	27.0	26.8	26.3	26.0	26.0	26.2	26.5	26.7	27.0	26.2
Wind velocity (m/s)	3.7	4.1	3.9	3.6	4.2	5.0	5.9	6.1	5.5	4.7	3.8	3.5	4.5

# Solar feasibility analysis – PV Syst snapshot

Grid System Pre-sizing				
<b>Geographical Site</b>	Honiara	Country	Solomon Islands	
<b>Situation</b>	Latitude --9.45° S		Latitude 159.96° E	
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m	
<b>Collector Plane Orientation</b>	Tilt:10°		Azimuth: 0°	
<b>PV Installation main features</b>				
Module Type		Standard		
Technology		Monocrystalline cell		
Mounting method		Flat roof		
Back ventilation properties		Free Standing		
<b>System characteristics and pre-sizing evaluation</b>				
PV-field nominal power (STC)	Pnom	21.8 kWp		
Collector Area	Acoll	136 m <sup>2</sup>		
Annual energy yield	Eyear	33.6 MWh	Specific yield	1545 kWh/kWp

# Solar feasibility analysis – PV Syst snapshot



*Thanks!*



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# *Performance monitoring of solar power plant*

## Training Programme on Energy Efficiency and Self Generation Option

*Strictly Private  
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January 2020*



**pwc**

# *Agenda*

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**Grid connected solar PV plant** **3**

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**Performance measurement** **7**

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**Business models for Solar roof top** **11**

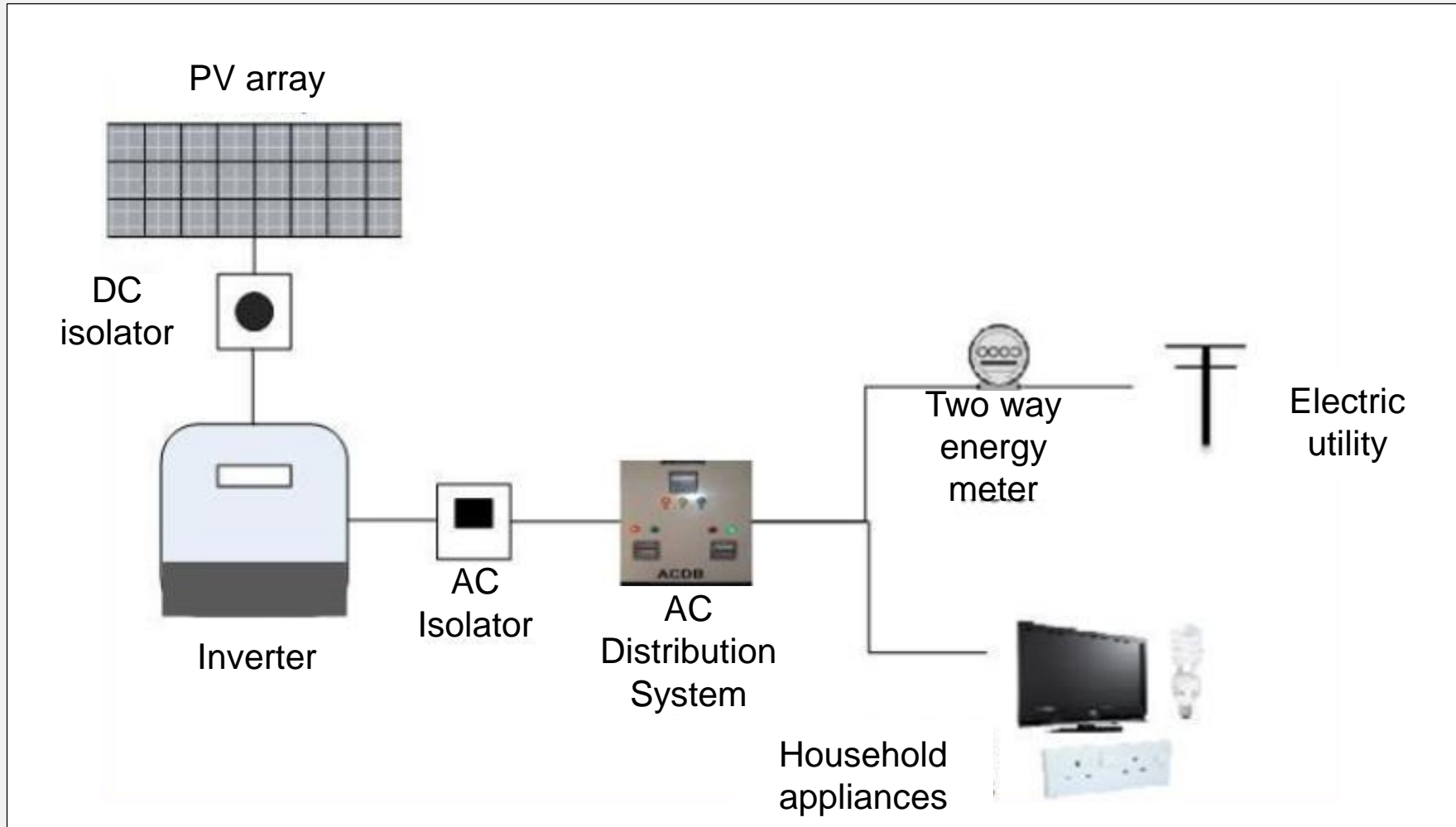
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# *Grid connected solar PV plant*

# Grid connect PV plant

## Typical components of a Solar PV



# Grid connect PV plant

## PV modules

- The PV modules are the devices that actually convert solar energy to electricity. PV modules are made from PV cells, which are most commonly manufactured using silicon



## Inverter

- The inverter in the system converts the DC power into AC power since the PV modules produce DC power and electrical appliances (and the distribution grid) predominantly require AC power



## Mounting structure

- The mounting structure, or racking system, is the support structure that holds the PV panels.



## Balance of system

- These consist of cables, switchboards, junction boxes, meters, etc.



## *O&M of grid connected solar PV*

**A typical annual maintenance a grid-connected rooftop solar PV system would include:**

Pre-decided maintenance schedule

Supply of spare parts as required

Replacement of defective modules, inverters, etc.

Maintenance of log sheets for operational detail

Complaint logging and its attending Insurance (machine breakdown insurance, general insurance covering fire, earthquake, etc.)

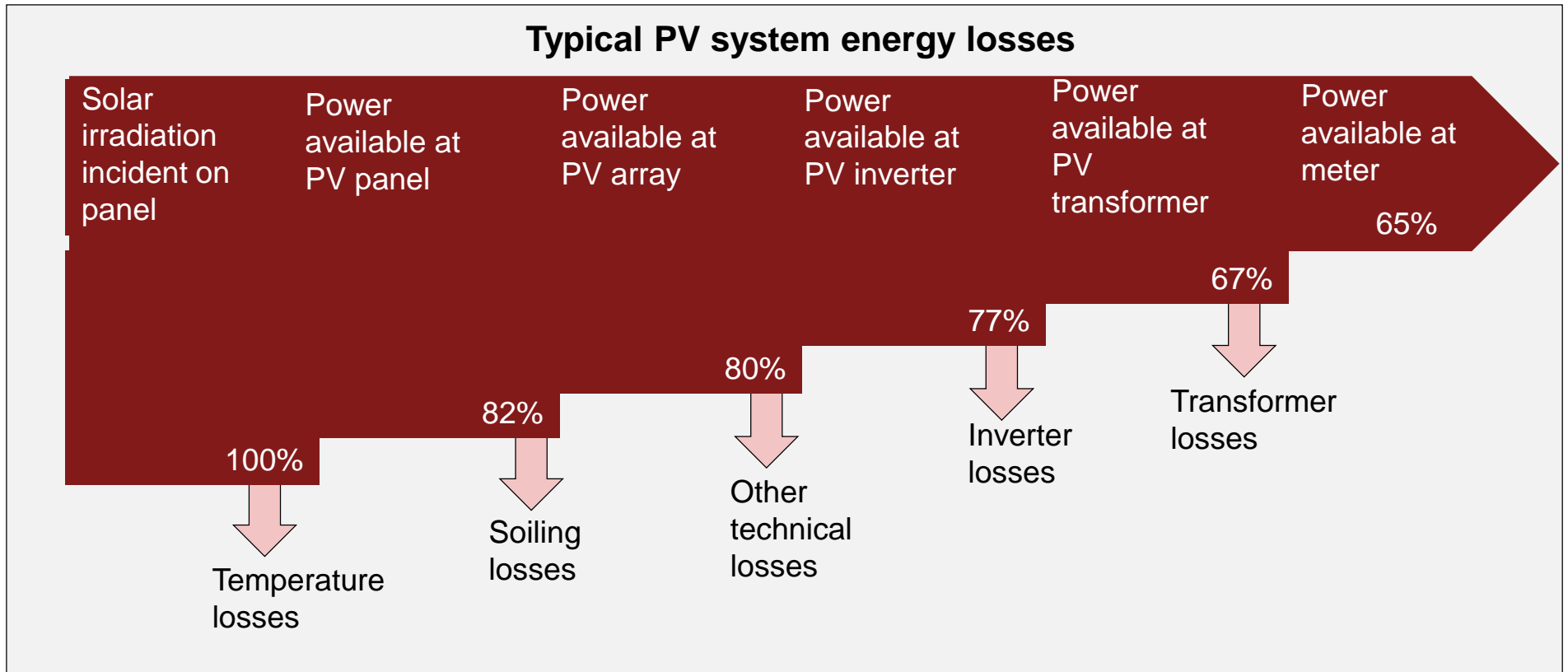
Insurance (machine breakdown insurance, general insurance covering fire, earthquake, etc.)

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# *Performance measurement*

# Performance monitoring

Performance monitoring is essential in the successful operation and maintenance of the system, since it provides the relevant data for fault detection and performance analysis.



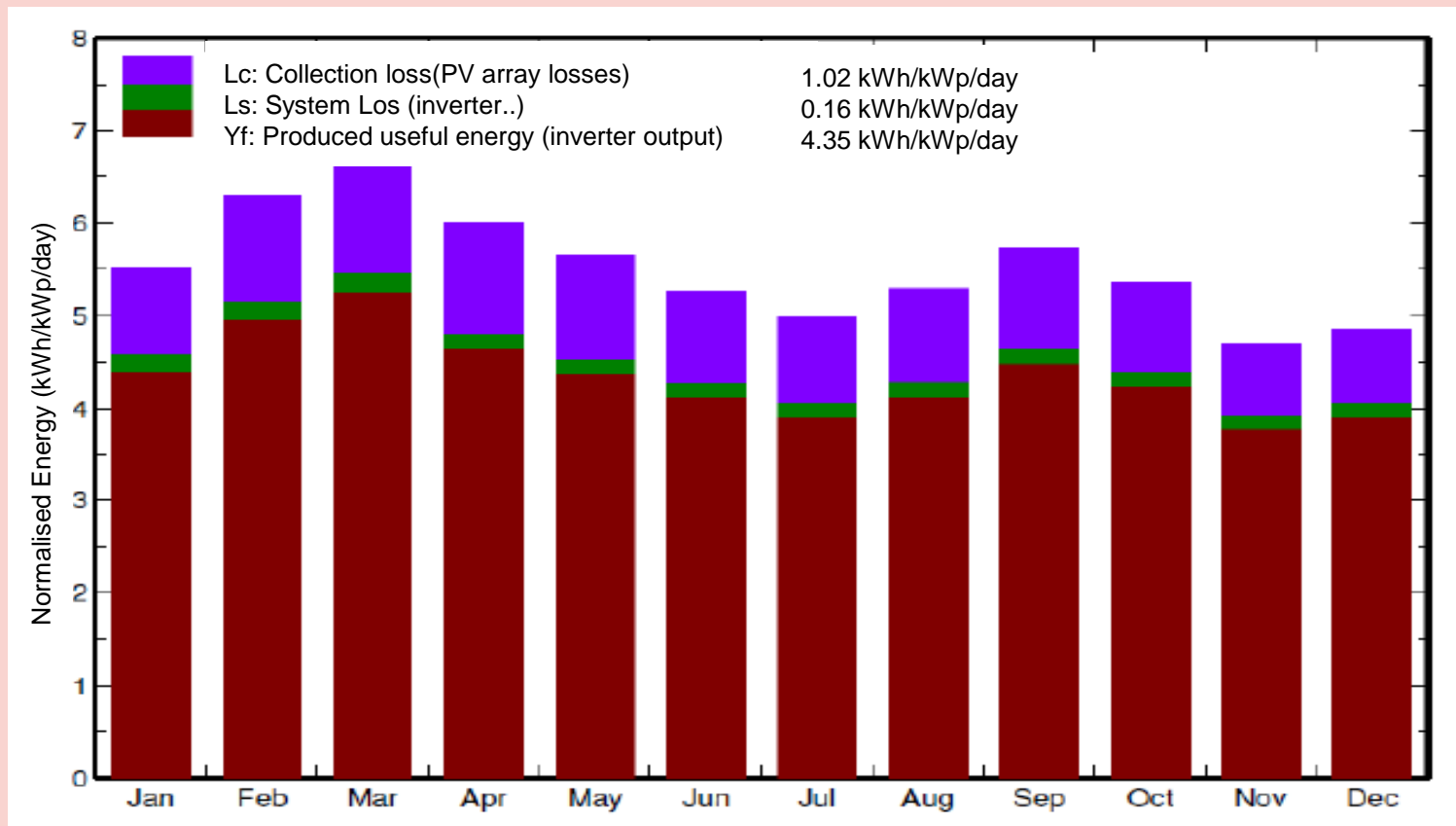
## Generic estimation

**Generic estimations use a small number of parameters to give a crude approximation of the generation performance of a PV system**

Parameter	Description
<b>System size</b>	It is measured in kWp or MWp
<b>Deration (%):</b>	Deration refers to various factors in PV systems which cause power losses, including inverter loss, slight manufacturing inconsistencies in modules, electrical impedance/resistance, temperature, dust and other environmental conditions, aging and maintenance issues
<b>Peak sun hours (hours/day):</b>	Peak sun hours refers to the average hours of full solar radiation (1000 W/m <sup>2</sup> ) received in a day at a location
<b>No. of effective sunshine days in year (days/year):</b>	This refers to the number of days in a year for a location that can be assumed to have full solar radiation (1000 W/m <sup>2</sup> ) for the peak sun hours duration
<b>Module degradation rate (%):</b>	PV modules suffer from degradation, due to a variety of reasons, over the product life, which causes the generation capacity per module to decrease over time; this decrease in generation is captured in an annual degradation rate, usually about 0.2-0.5%

## *PVSYST example*

There are a lot of software products used for planning and design of Solar PV. A sample simulation is using PVSYST is shown.



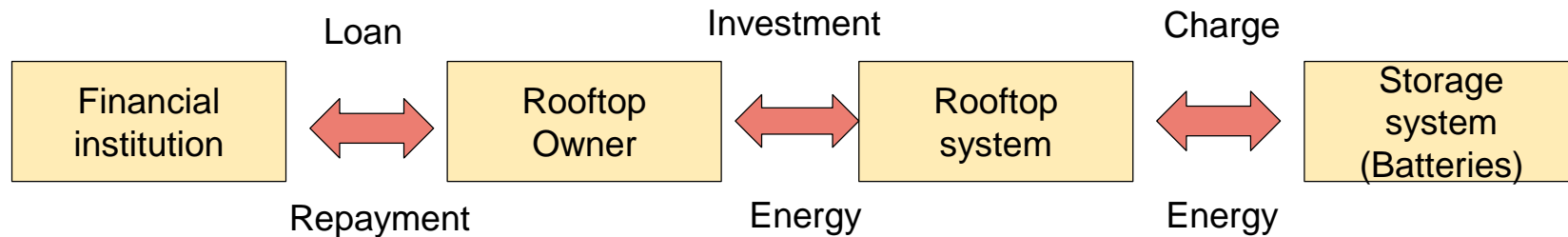
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# *Business models for Solar roof top*

# Self owned business model

**Self owned business models promote investments in Solar rooftop by the consumer either for own use or export to the grid**

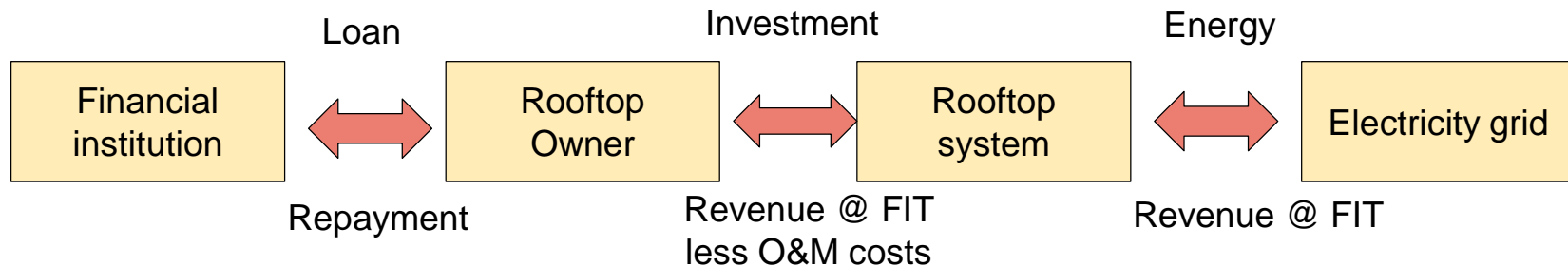
## Captive (off-grid):



Application	Advantages	Disadvantages
Prevalent where grid is not available or very less reliable	Stand alone systems are usually deployed in energy deficient areas	They need storage options coupled to them to satisfy variable demand
Huge application in remote, isolated, semi urban areas which have no or limited access	They act as cleaner and a cheaper options at such locations	There is high cost of energy involved with stand alone solar PV systems

# Gross feed

## Gross feed:

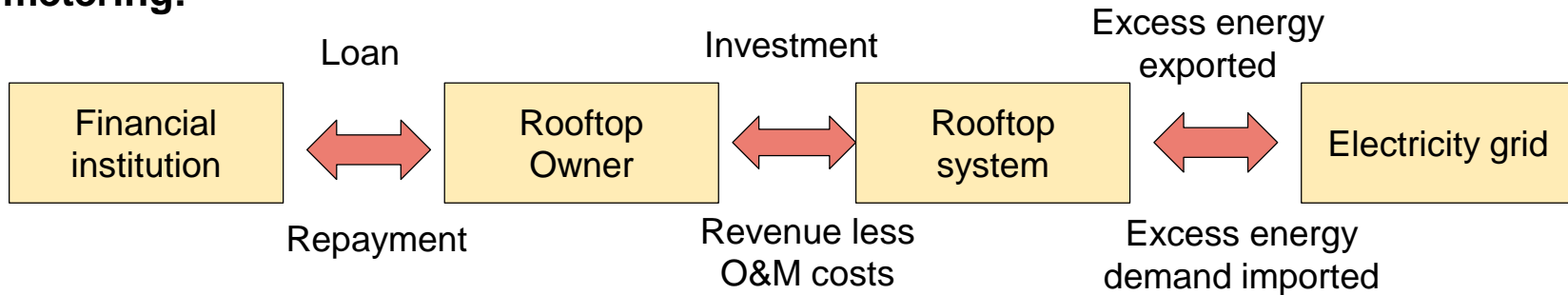


**It consists of grid connected Solar rooftop systems which feed all the energy that is generated back to the grid and are paid feed in-tariff (FiT)**

Application	Advantages	Disadvantages
The key markets to adopt gross FiT approach are only very limited. Eg. France, Germany	Don't need to be coupled with stand alone storage devices	It creates an apparent short term cash flow burden on utilities balance sheet, since it is higher than usual power purchase cost
	Allows entry of new investors	

# Net metering

## Net metering:



- Under this model Solar energy is first consumed by the consumer for internal needs and the surplus is then exported to the grid where it is banked with the utility
- When consumer imports power from grid it is adjusted against the exports

Application	Advantages	Disadvantages
Only useful when consumer tariffs are higher than cost of solar generation.	Does not depend on FiT	Only works for consumers with high grid tariffs
In case tariffs are lower than the model is not feasible	Allows only those consumers to install solar who can afford solar, bringing down cost of Solar	Reduces the net quantum of power sold by utilities to the consumers

## *Third party owned business model*

**Under the third party-owned model, a third party (separate from the consumer [rooftop owner] and the utility) is the owner of the rooftop systems**

**This third party may**

- **lease the rooftop from the rooftop owner**
- **the third party may lease the system to the rooftop owner**

CAPEX	OPEX
<b>Project owned by roof owner/consumer</b>	<b>Project owned by project developer/supplier</b>
<b>Roof owner/consumer responsible for O&amp;M of system after initial 1-2 year period</b>	<b>Roof owner/consumer not responsible for O&amp;M; O&amp;M is responsibility of project developer</b>
<b>Can't be converted to OPEX model at a later date Power to be used for captive consumption; surplus power can be sold to distribution utility</b>	<b>Can be converted into CAPEX at a pre-decided date (option to buy back) Power can be sold to roof owner; Power can be sold to distribution utility; Power can be sold to third party**</b>

*Thanks!*



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# *Financial feasibility and financing options*

## Training Programme on Energy Efficiency and Self Generation Option

*Strictly Private  
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January 2020*



# Agenda

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**Financing Options** **10**

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**Risk analysis** **23**

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# *Financial feasibility analysis*

# *Financial appraisal methods*

*Financial analysis is the process of evaluating projects or investment propositions and identifying the project or investment proposition with the highest potential*

**Simple Payback  
Period (SPP)**

**Discounted Payback  
Period (DPP)**

**Net Present  
Value (NPV)**

**Internal Rate of  
Return (IRR)**

**Return on  
Investment (ROI)**

**Life Cycle Cost  
Analysis (LCCA)**

**Sensitivity  
Analysis**

# Financial Parameters

## Simple Payback

- **Simple Payback** is the amount of time (in years) taken to recover the initial investment in resource efficiency project considering only the net annual savings from the project.

$$\text{Simple payback period} = \frac{\text{Initial Investment}}{\text{Yearly Savings}}$$

- The SP does not consider the savings accrued after the payback has finished.
- **Discounted Payback period (DPP)** is a measure of the amount of time (in years) it takes to recover the initial investment in any project taking into **account the time value of money**.

$$\text{Discounted payback period} = \frac{\text{Initial Investment}}{\text{Discounted Annual Cash Inflows}}$$

## Sensitivity Analysis

- **Sensitivity analysis** is an assessment of risk. Because of the uncertainty in assigning values to the analysis, it is recommended that a sensitivity analysis be carried out - particularly on projects where the feasibility is marginal.

## Return on Investment

- **Return on Investment (ROI)** is an indicator of the “annual return” from the project as a percentage of the capital cost involved in the project.

$$ROI = \frac{\text{Annual net cash flow}}{\text{Capital cost}} \times 100$$

- It does not account for the variable nature of annual net in cashflow and time value of money.

# Financial parameters

## Life Cycle cost analysis

- **The Life cycle cost (LCC)** of any equipment is the total “lifetime” cost to purchase, install, operate, maintain and dispose of that equipment.

$$LCC = C_{ic} + C_{in} + C_e + C_o + C_m + C_s + C_{env} + C_d$$

$C_{ic}$  - initial costs and purchase price,  
 $C_{in}$  - installation and commission cost,  
 $C_e$  - energy costs,  
 $C_o$  - operation costs

$C_m$  - maintenance and repair costs  
 $C_s$  - down time costs,  
 $C_d$  - decommissioning/disposal costs

## IRR and NPV

- **Net Present Value (NPV)** gives the aggregate present value of all the cash flows associated with the project or investment opportunity.

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

$r$  - discount rate,  $n$  - life of project,  $t$  - period  
 $CF_t$  - cash flow occurring at end of period 't'

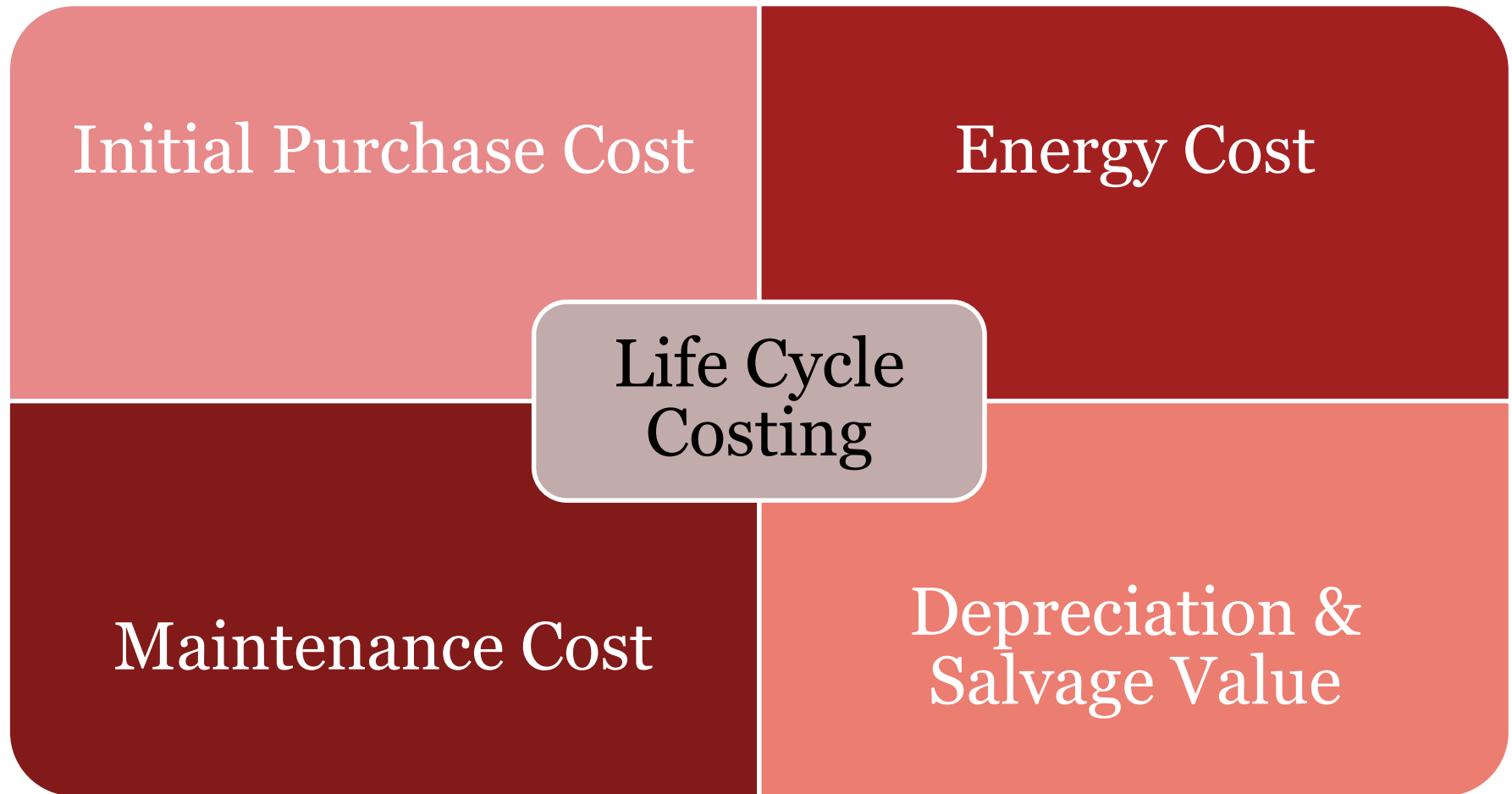
- **Internal Rate of return** is the discount rate at which NPV of the project is zero. This method helps in calculating the rate of return that the investment is expected to yield.

$$0 = \sum_{t=0}^n \frac{CF_t}{((1+r)^t)}$$

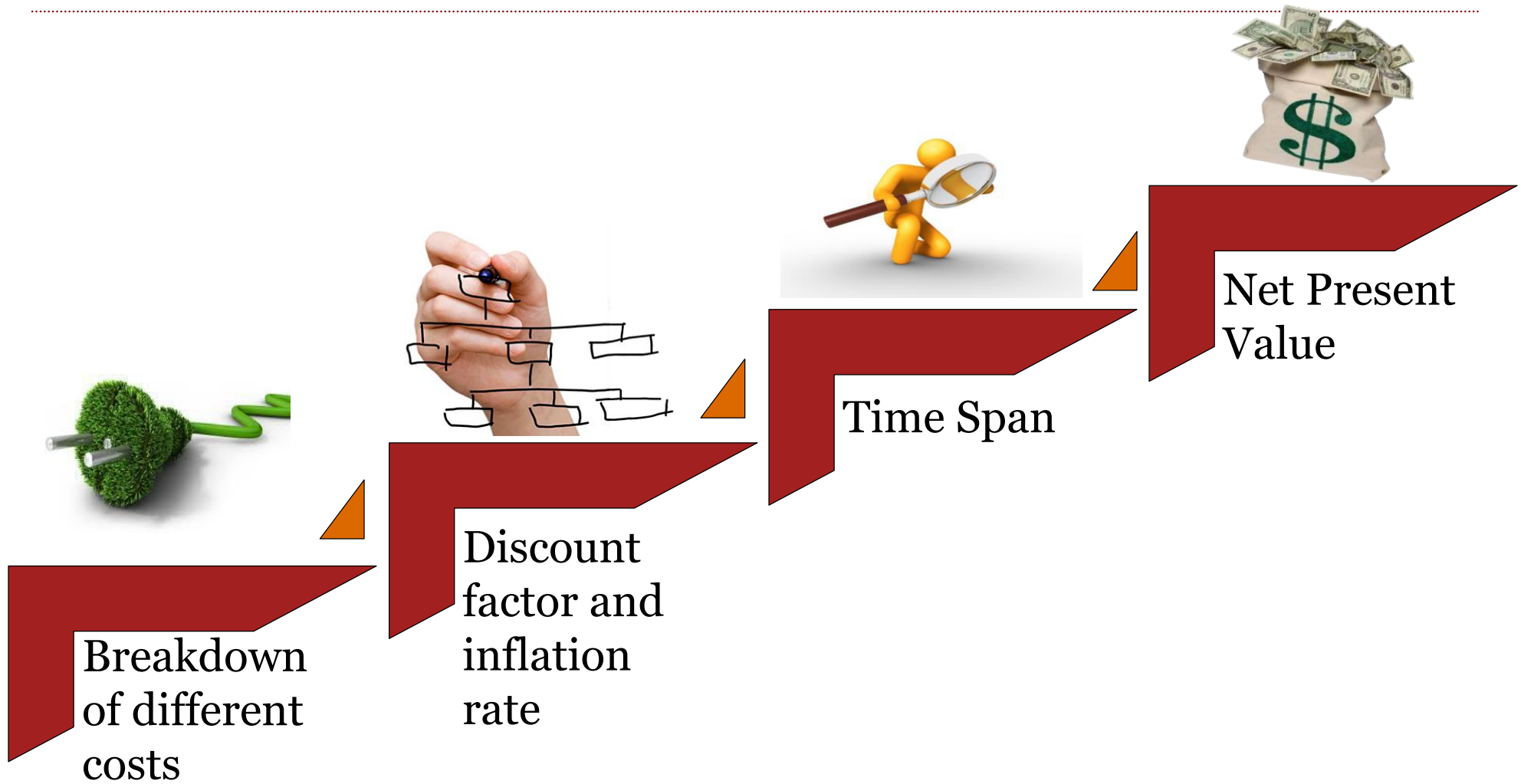
$r$  - Discount rate at NPV=0 is IRR

- NPV for comparison of two different projects and IRR to assess whether or not single project will achieve a target rate of return.

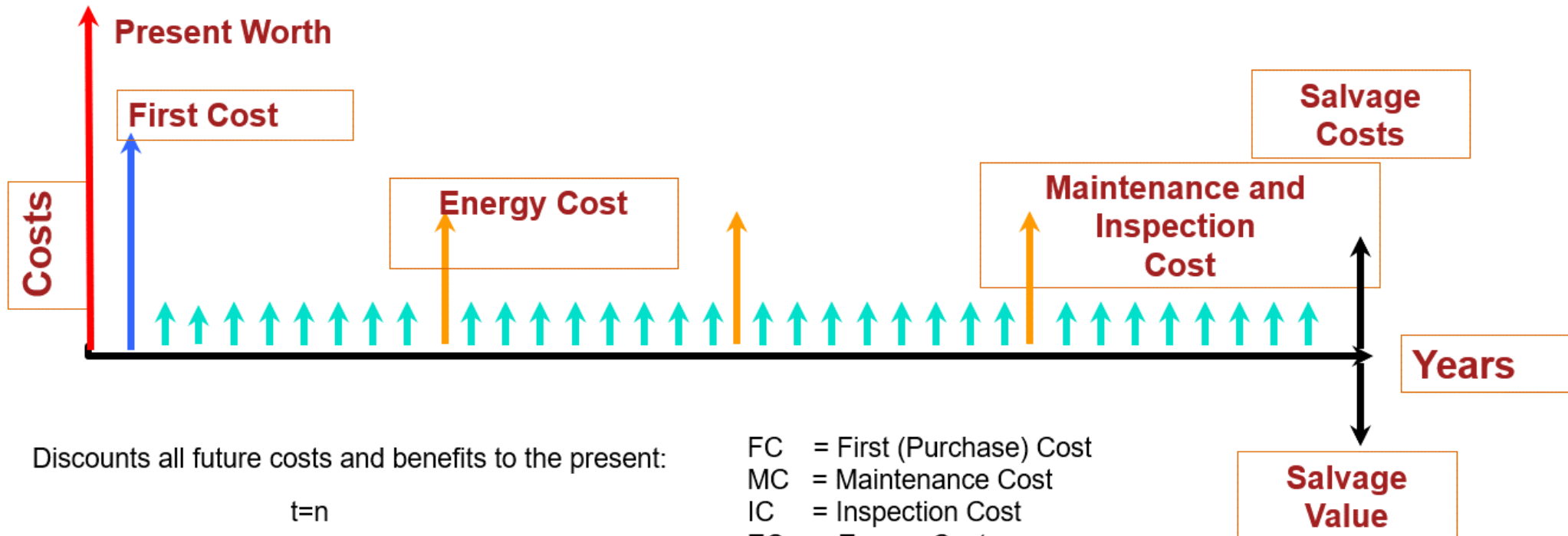
# *Life Cycle Cost*



# Life Cycle Cost Calculation



# Life Cycle Cost Calculation



Discounts all future costs and benefits to the present:

$t=n$

$$PW = FC + \sum_{t=0}^{t=n} pwf [IC+MC+EC] + pwf [S]$$



- FC = First (Purchase) Cost
- MC = Maintenance Cost
- IC = Inspection Cost
- EC = Energy Cost
- S = Salvage Value or Cost
- T = Time Period of Analysis
- pwf = Present Worth Factor

## Life Cycle Case example

**Problem:** The system is a single pump circuit that transports a process fluid containing some solids from a storage tank to a pressurized tank. The plant engineer is experiencing problems with a fluid control valve (FCV) that fails due to erosion caused by cavitation.

**Solution:** (a) Repair the control valve, (b) Change control valve (c) Impeller trimming and (d) Install VFD & remove control valve

LCCA calculation: Comparison of three potential solutions is done based on LCCA as shown below:

Particular	Repair control valve	Change control valve	Impeller trimming	VFD and remove control valve
Investment cost (US \$)	0	5000	2250	21500
Energy cost (US \$/year)	11088	11088	6720	5568
O&M cost (US \$/year)	4500	500	500	1000
Repair cost US \$/ 2 years)	2500	2500	2500	2500
Life time (years)	8	8	8	8
Present value LCC (US \$)	113980	91827	59481	74313

**Option C has the lowest life cycle cost, hence is the preferred solution for the problem**

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# *Financing Options*

# *Financing options*

## Prominent financing options for resource efficiency projects



### **Self-Financing**

The ability of the industry to finance itself through internal funds.



### **Institutional loan**

Multilateral or bilateral organizations which help in the finance large scale development projects.



### **Energy performance contract**

It is an agreement signed with an ESCO involving multiple services related to energy efficiency

# Self Financing

*Financial analysis is the process of financing the projects through internal funds. The industry can finance the energy and water saving proposals which have quick payback and or higher ROI.*

## Direct financial incentive

Assigning a proportion of energy savings to your energy management budget means you have a direct financial incentive to identify and quantify savings arising from your own activities.

## Separately identified returns

Separately identified returns will help the constituent parts of your organization understanding whether they are each getting good value for money through their support for energy management.

## Improved commitment to energy management

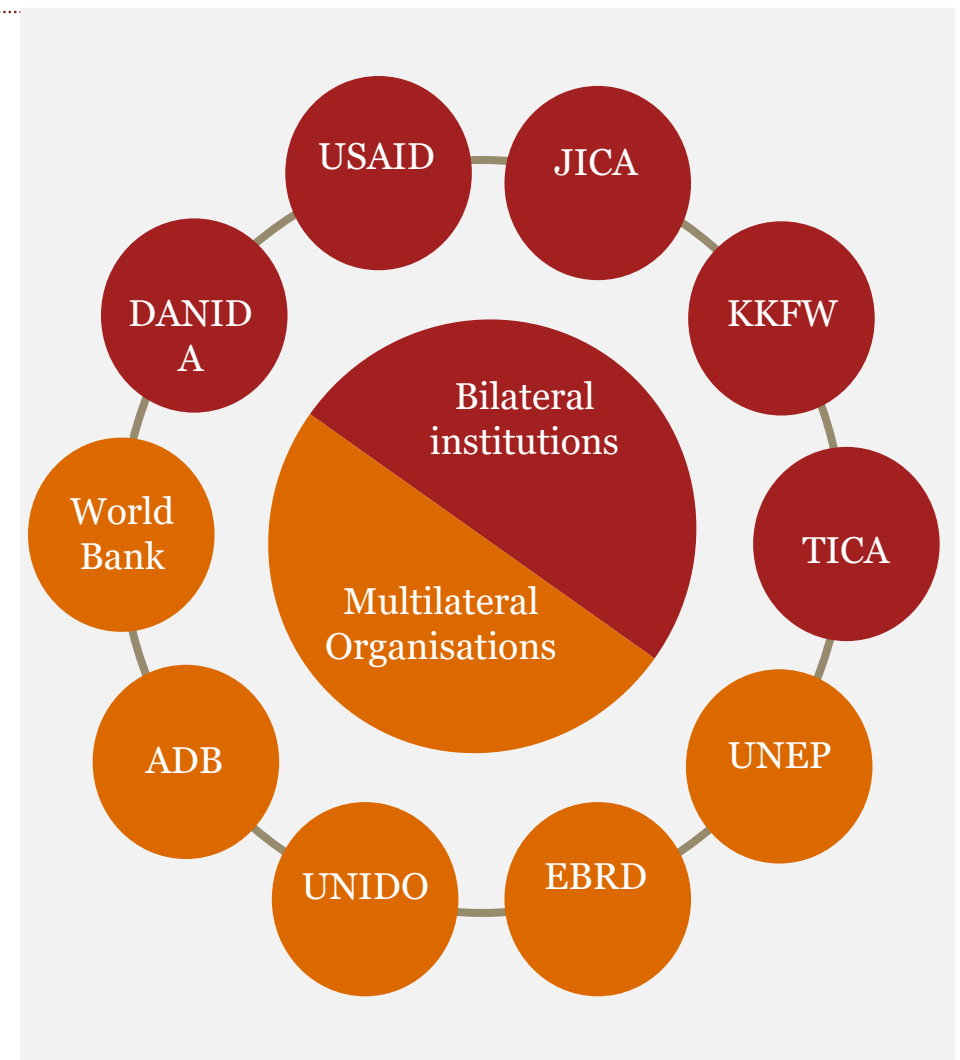
If operated successfully, splitting the savings will improve motivation and commitment to energy management throughout the organization since staff at all levels will see a financial return for their effort or support.

## Independence of energy management function

But the main benefit is on the independence and longevity of the energy management function.

## *Institutional Loan*

- The consumer can sought loan from a bank either nationalized or corporative or international. The form of capital is a term loan where is bank usually demands a collateral for mitigating risk of non-repayment of loan.
- Consumer can combine energy efficiency to develop a funding proposal for a project which could be submitted to either multilateral organizations to seek funds for implementation.



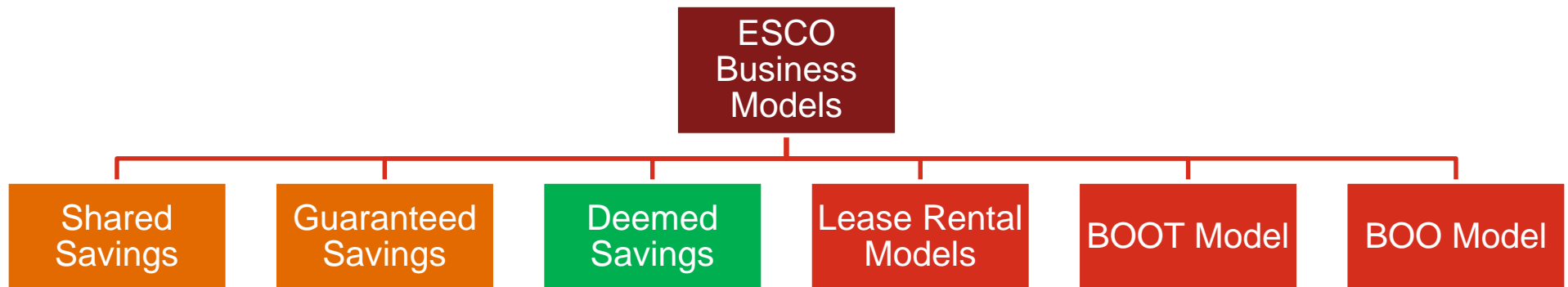
## *Financing mechanisms with ESCO Implementation*

- Energy Service Companies (ESCOs):  
A for Profit Commercial Entity
- ESCOs are profitable commercial entities and provide a range of services and look to derive profits from the amount of energy saved. Although the ESCO business is profitable, it also involves high amounts of risks and demands technical and financial competency.



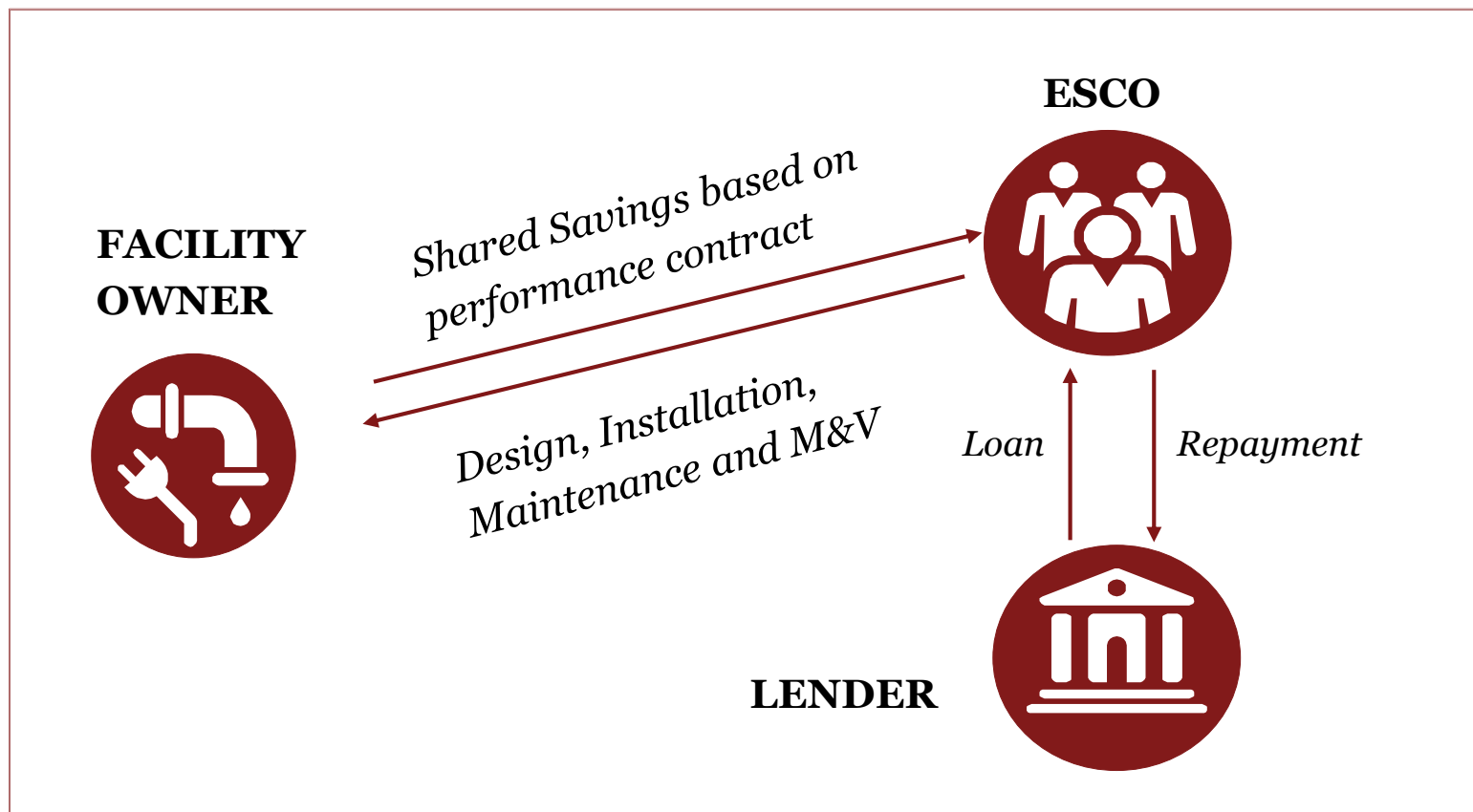
## *Financing models for ESCO Implementation*

ESCOs develop, implement and provide or arrange financing for upfront EE investments for its clients. Repayments from savings allow clients to compensate ESCO’s ongoing savings monitoring, Measurement & Verification (M&V) costs and assumption of risk through EPC or Third-Party Financing. The two common types of Performance-based Contract structures used by ESCOs, called “**Guaranteed Savings**” and “**Shared Savings**”, are widely adopted but there are a few more emerging models which have been described.



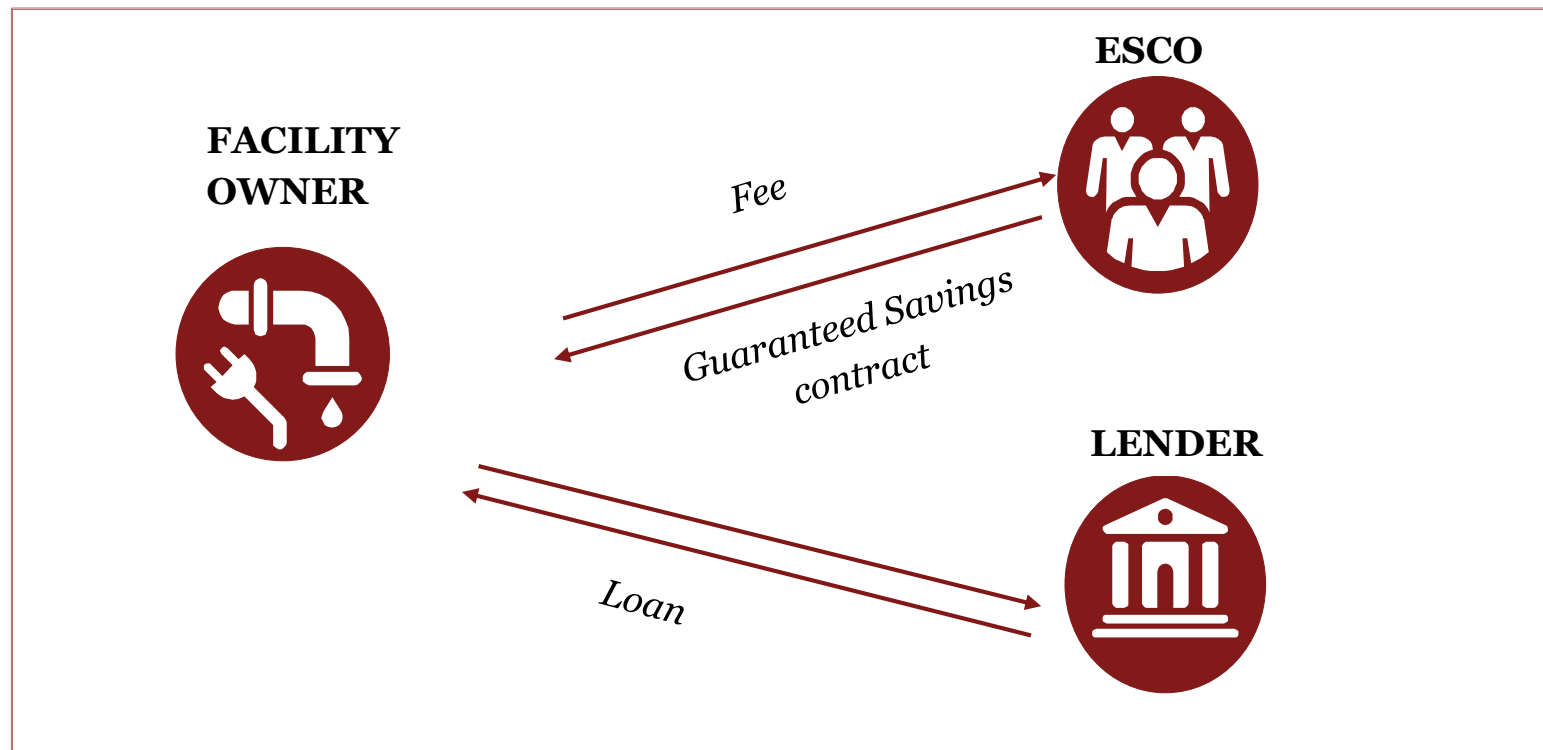
# Shared Savings

Under this model, the ESCO finances the project either through its own funds or by borrowing from a third party. The ESCO takes on the performance risk of the project. The cost savings are divided between the ESCO and customer at a prearranged percentage for an agreed length of time.



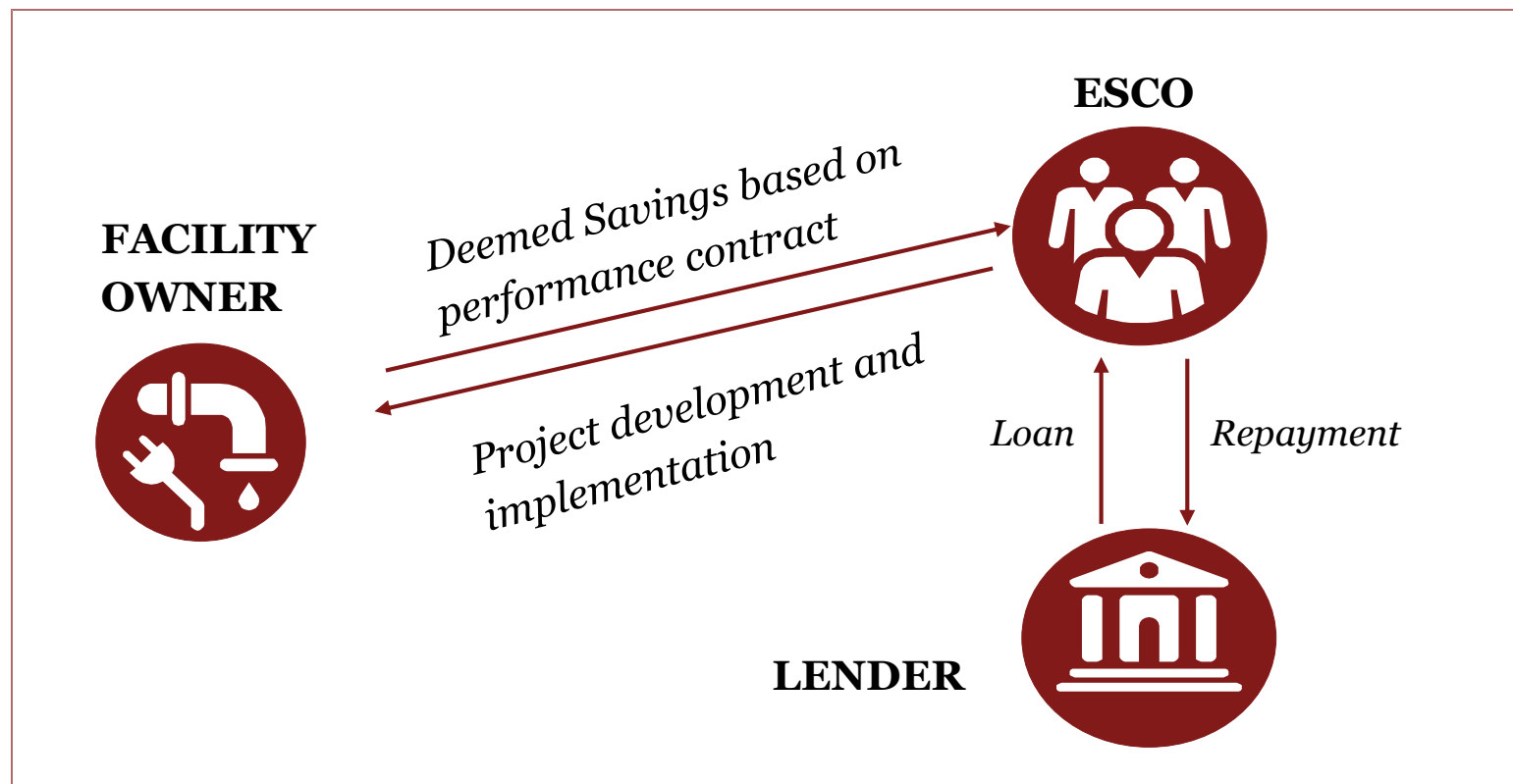
## Guaranteed Savings

In this case, the customer finances the design and installation of the project by borrowing funds from a third party such as a bank or through leasing the equipment. The ESCO has no contractual arrangement with the bank but does assume the project risk and guarantees the energy savings made. If the savings do not reach agreed minimums the ESCO covers the difference; if they are exceeded then the customer agrees to share the savings with the ESCO



## Deemed Savings

Similar to the shared savings model, ESPC will be executed between the ESCO and host facility with a fixed price for services provided and financial agreement will be executed between the ESCO and FI for debt. The former will make loan repayments and interest from host and utility/government payments. The ESCO will execute the agreement between itself and the government or utility, for which it receives payments based on deemed savings.



# *Lease rental, Boot and BOO Model*

## Lease Rental Model

- Supplier installs the equipment and may maintain it. The lease payments are financed by verified savings and the ownership is generally transferred at the end of a lease period. The client (lessee) makes payments of principal and interest; the frequency of payments depends on the contract. The stream of income from the cost savings covers the lease payment.

## BOOT Model

- Build-Own-Operate-Transfer model may involve an ESCO designing, building, financing, owning and operating the equipment for a defined period of time and then transferring this ownership over to the client. Clients enter into long term supply contracts with the BOOT operator and are charged according to the service delivered. The service charge includes capital and operating cost recovery and project profit.

## BOO Model

- A new public-private partnership (PPP) project model for ESCO business named BOO (build, own, operate) has been emerging in which a private organization builds, owns and operates the energy efficiency of a facility. The government doesn't provide direct funding in this model, but it may offer other financial incentives such as tax-exempt status.

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# *Risk analysis*

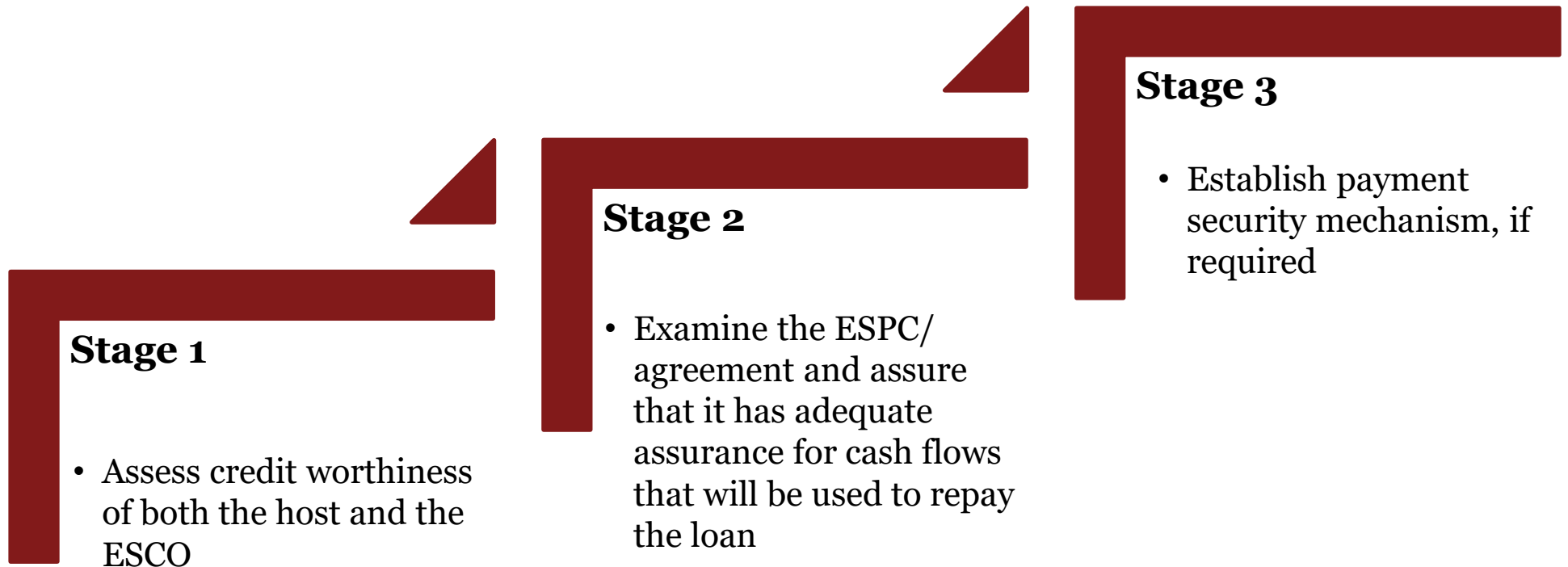
# Risk analysis



# Technical Risk Assessment and Mitigation

Risk (by phase)	Mitigation measure
<p><b>Development phase</b></p> <ul style="list-style-type: none"> <li>• Estimated savings and capital costs not realistic</li> <li>• Host does not implement the project</li> </ul>	<ul style="list-style-type: none"> <li>• Properly prepared IGA; Equipment meets the appropriate design standards, proven technologies are used</li> <li>• Development costs funded or reimbursed by Host</li> </ul>
<p><b>Implementation phase</b></p> <ul style="list-style-type: none"> <li>• Not installed according to IGA specifications</li> <li>• Local regulatory requirements are not met</li> </ul>	<ul style="list-style-type: none"> <li>• Execute design/build contracts with qualified vendors and contractors which include all IGA specifications and appropriate recourse for non performance of the EEPs</li> <li>• Sufficient time has been allocated for permits and licenses</li> </ul>
<p><b>Operation phase</b></p> <ul style="list-style-type: none"> <li>• Equipment does not operate as intended</li> <li>• Savings cannot be measured and verified; Savings are not achieved</li> <li>• Changes in the host facility or operations</li> </ul>	<ul style="list-style-type: none"> <li>• ESPC contains performance guarantees (given by both the ESCO and the equipment suppliers). Include extended warranty coverage in all vendor contracts</li> <li>• Implement M&amp;V plan</li> <li>• Establish energy baseline for easy adjustment to operating changes</li> </ul>

# *Financial Risk assessment and mitigation*



*Thanks!*



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# *Measurement and verification*

## Training Programme on Energy Efficiency and Self Generation Option

*Strictly Private  
and Confidential  
January 2020*



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# *Agenda*

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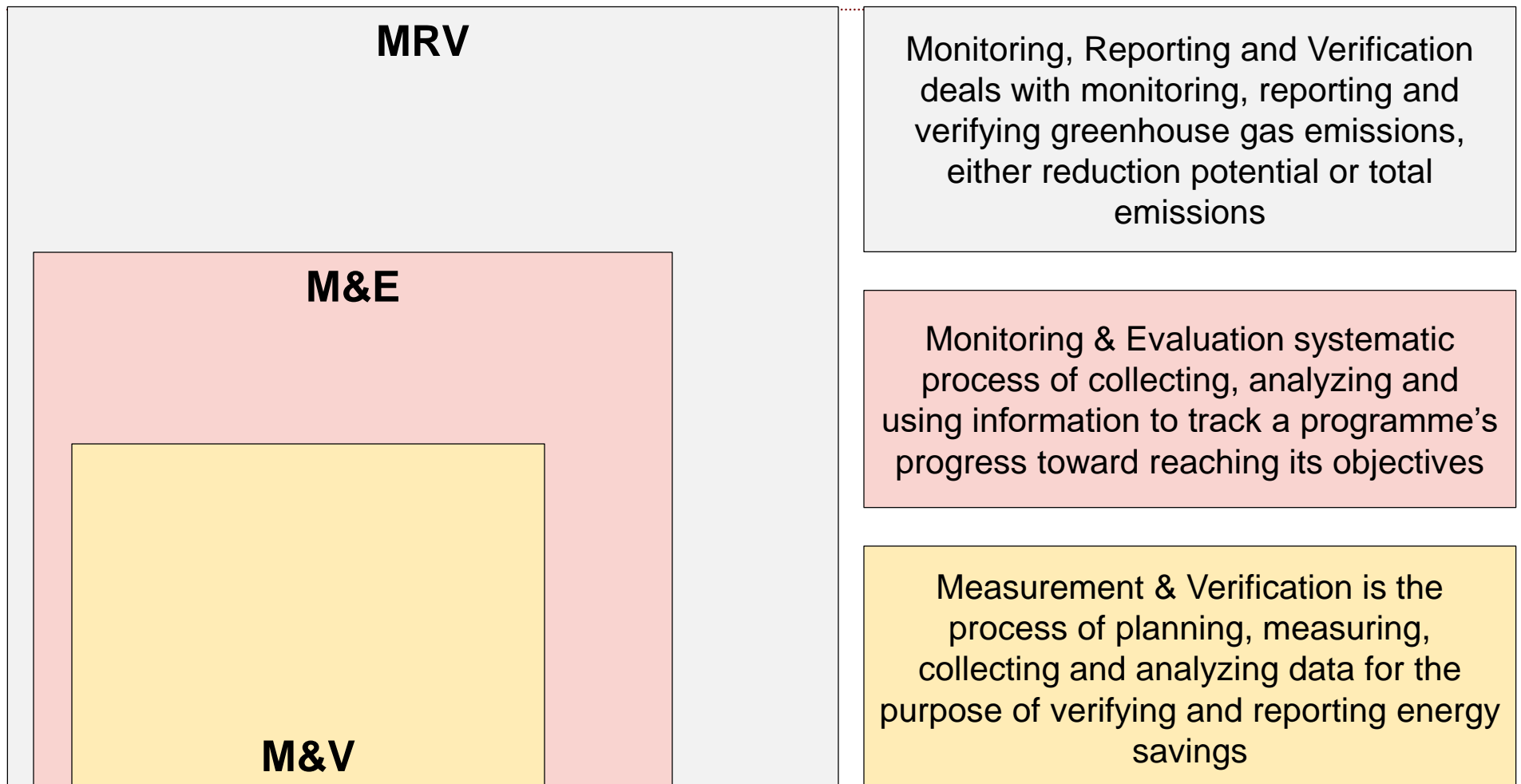
**Relevant examples** **16**

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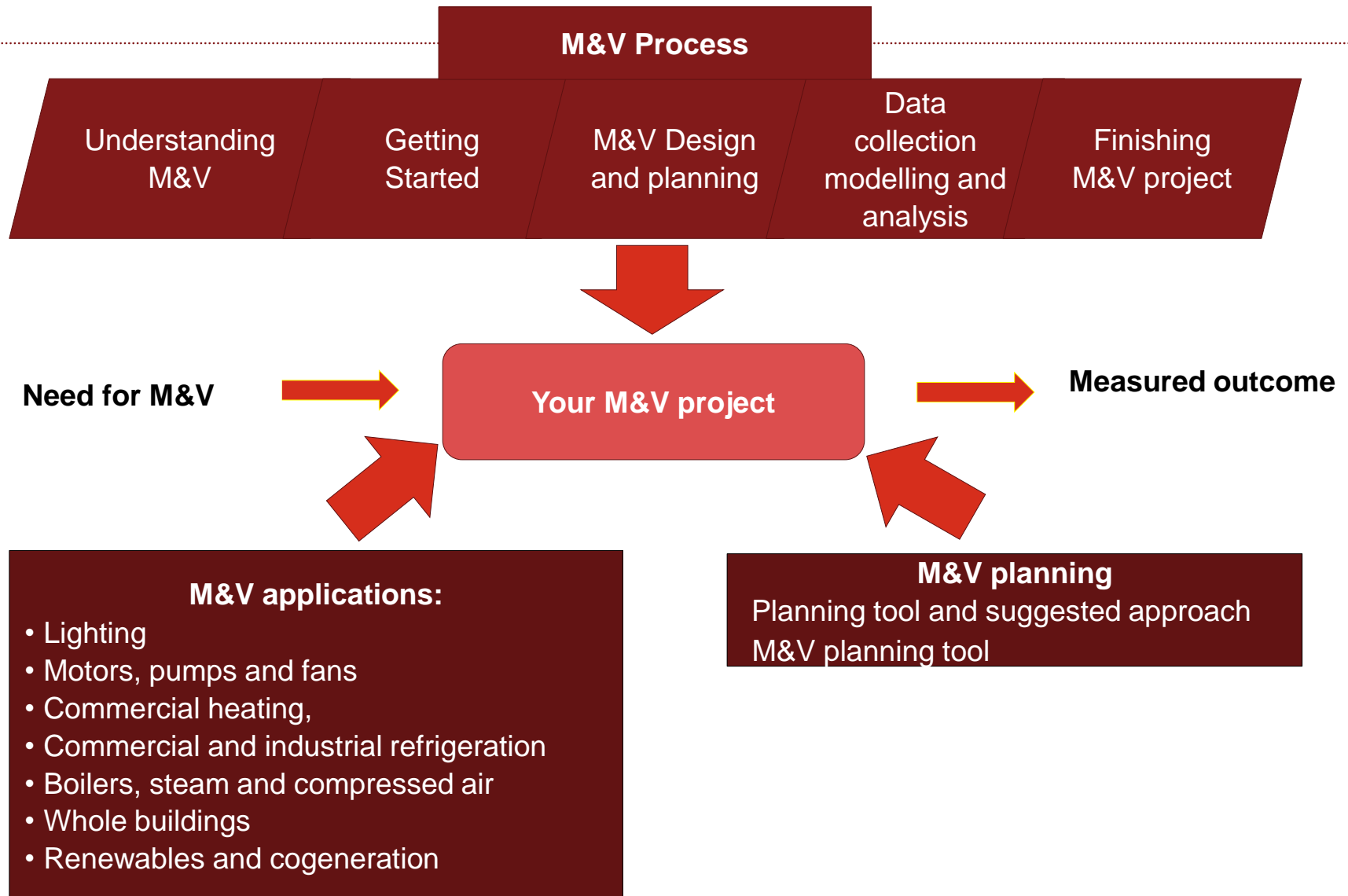
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# *Introduction*

# Introduction



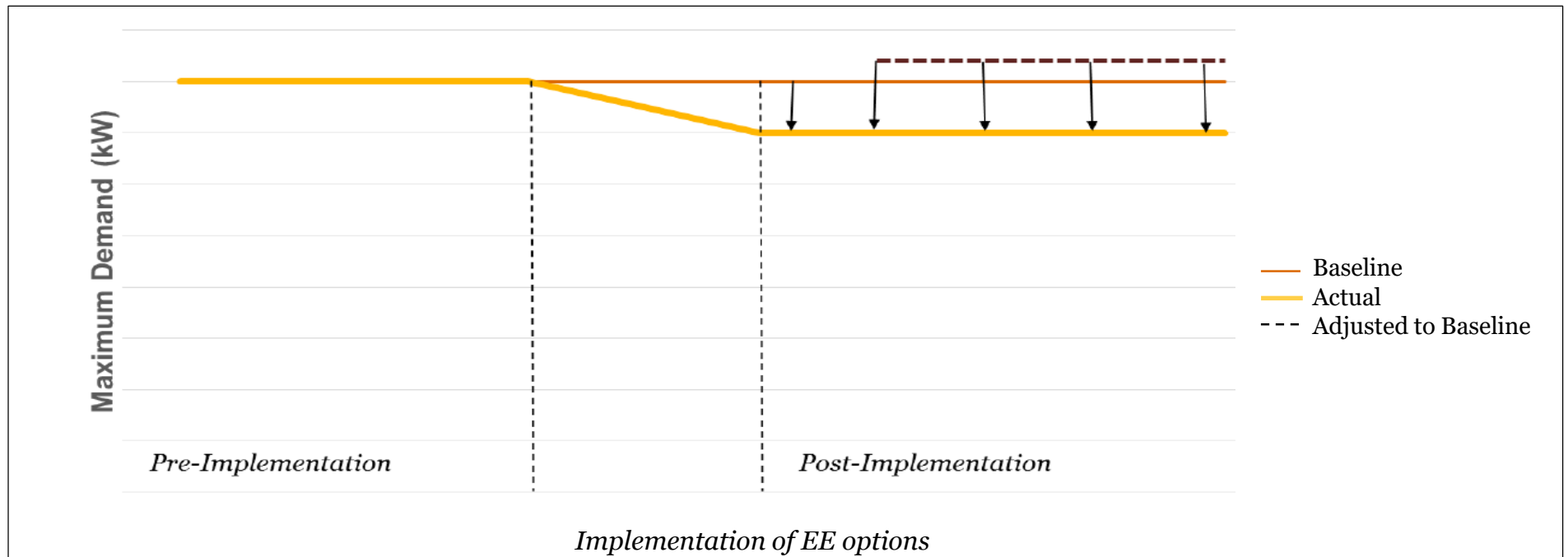
# Introduction



# Introduction

**M&V is the process of quantifying the energy and cost savings resulting from improvements in energy-consuming systems**

$$\text{Savings} = ( \text{Baseline Energy} - \text{Post Installation Energy} ) \pm \text{Adjustments}$$

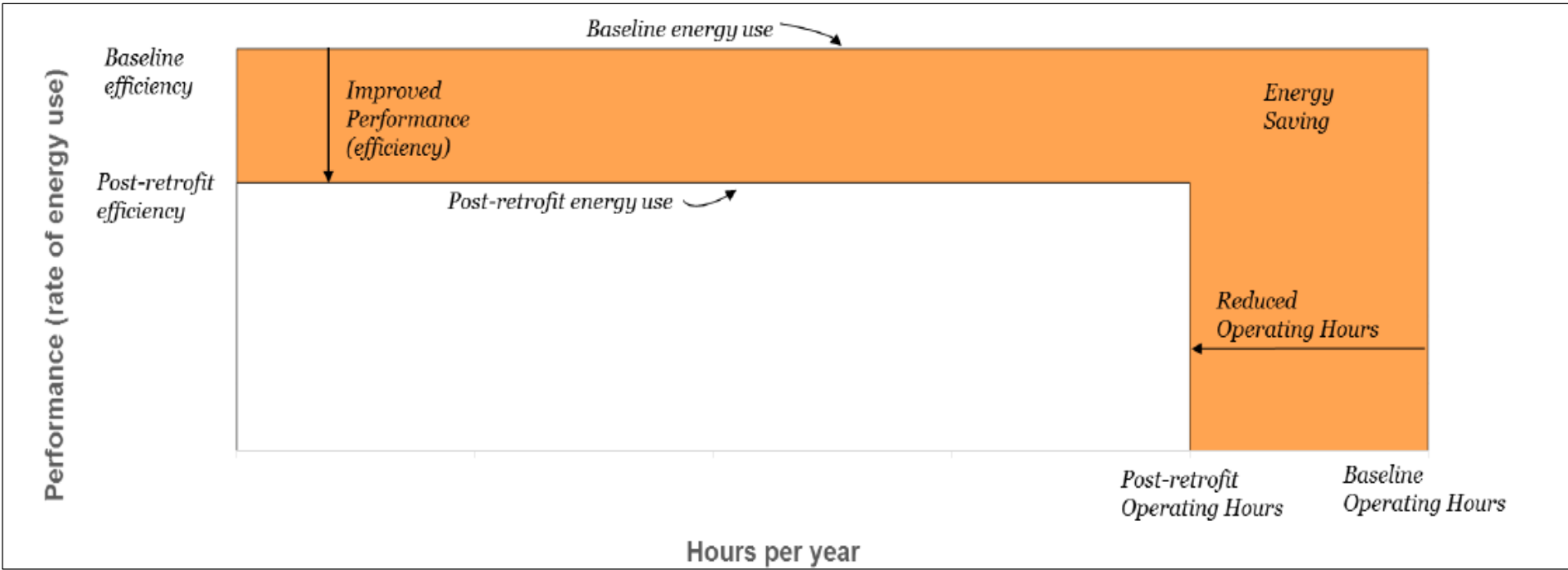


# Introduction

**Both performance and use factors need to be known to determine savings.**

**Diagram depicts the two ways in which total energy consumed has decreased:**

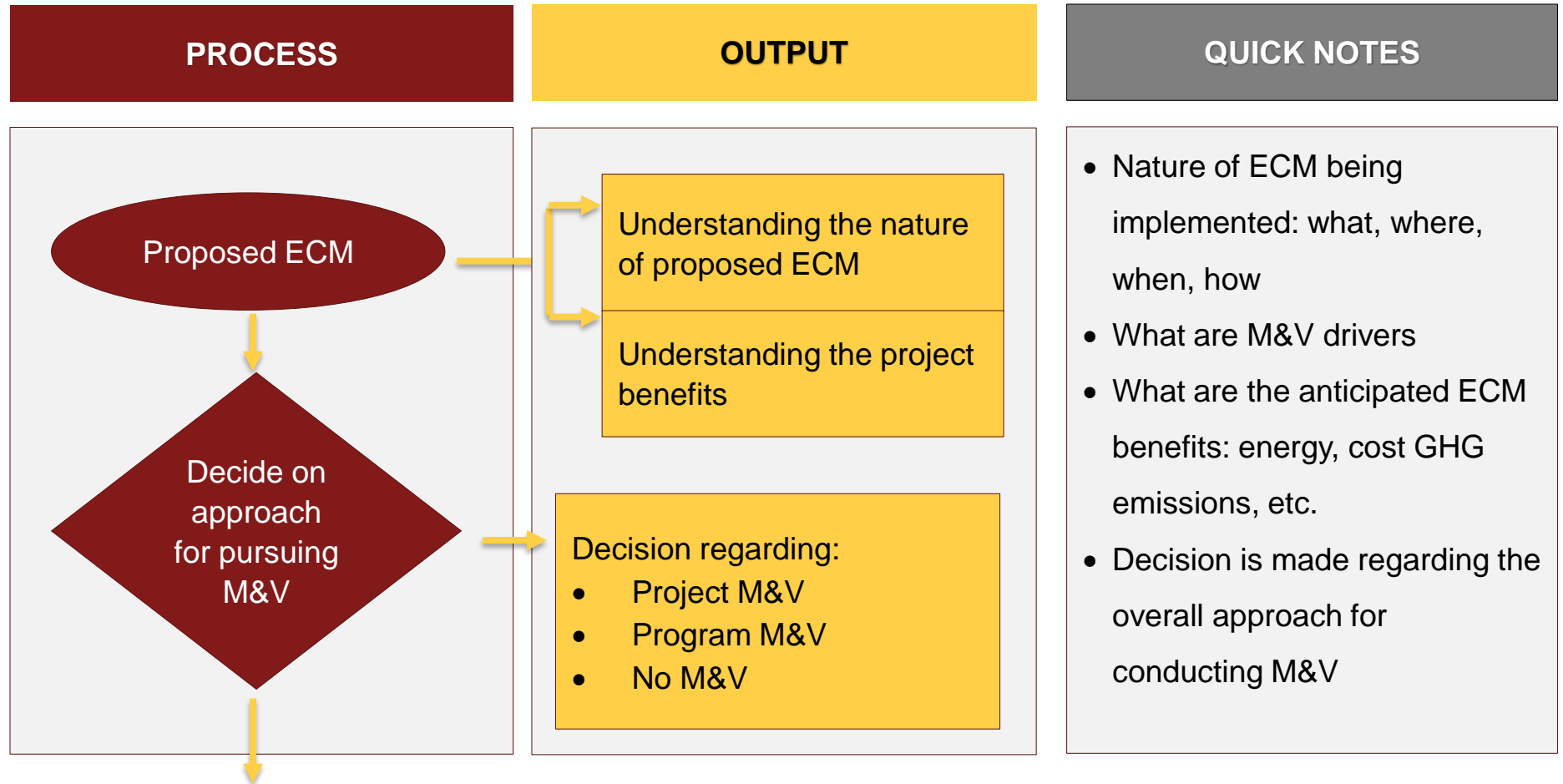
- Reduction in the rate of energy use (increase in performance)
- reductions in use (decrease in operating hours)



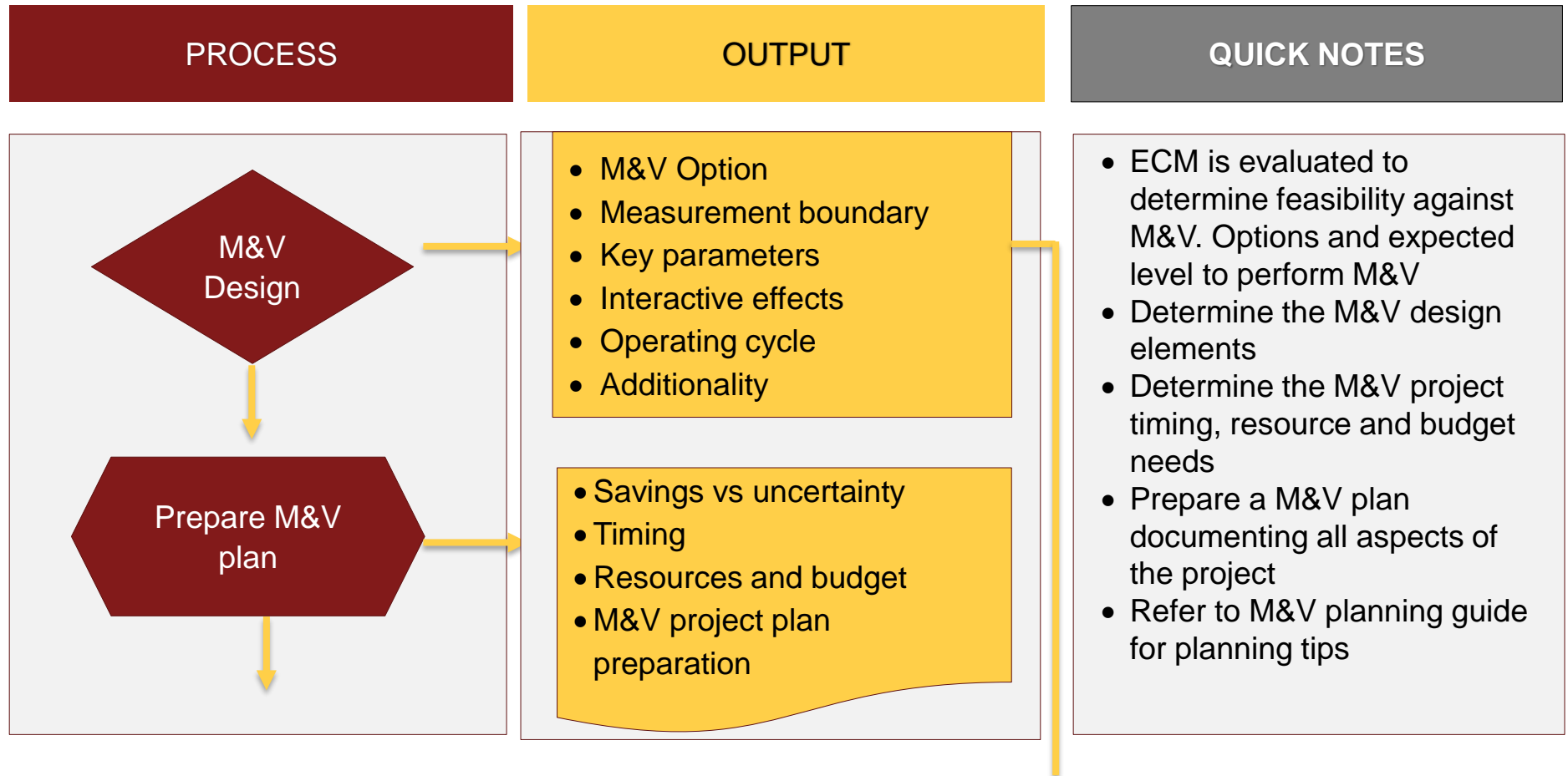
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# *M&V process*

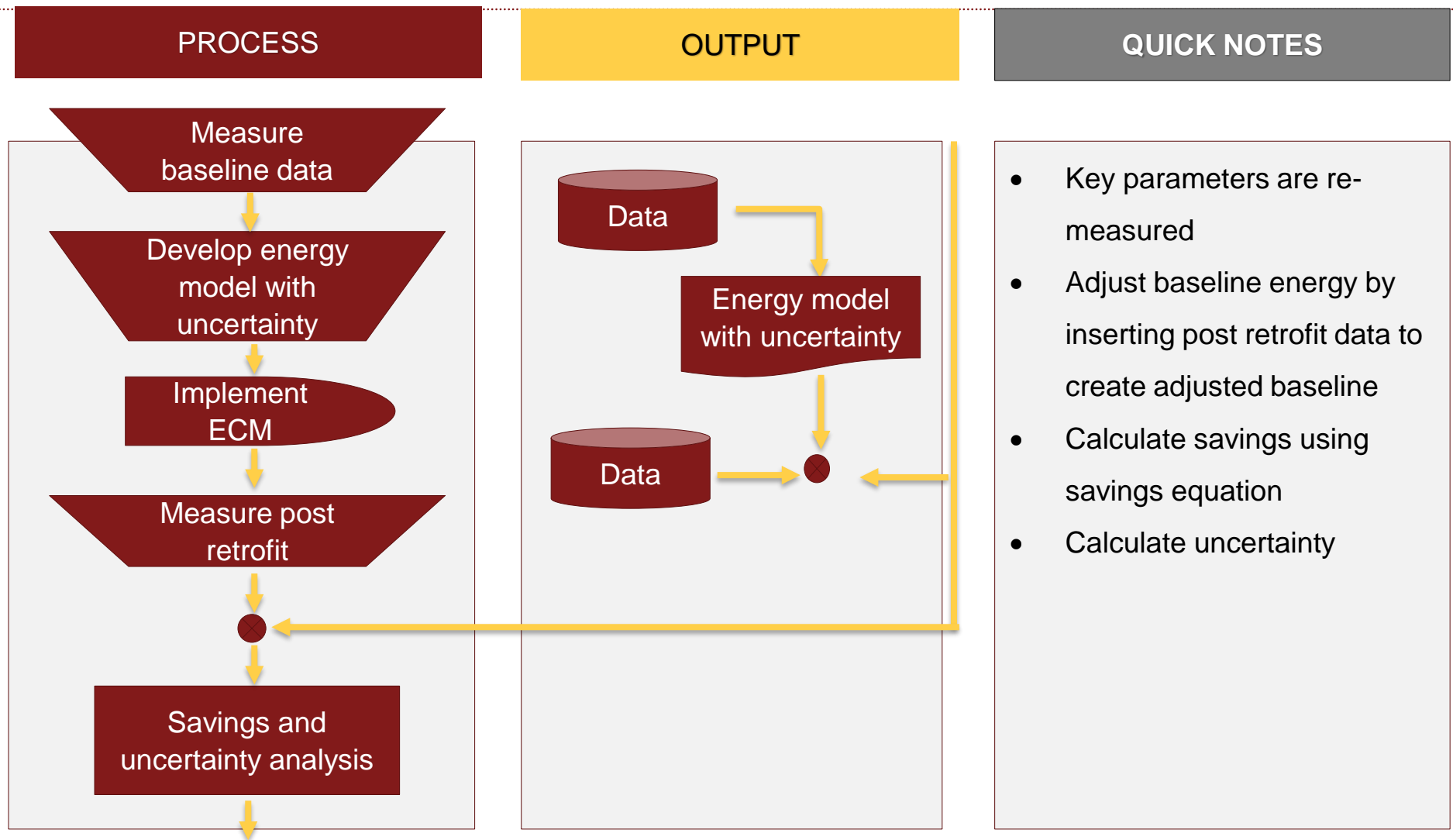
# Getting started



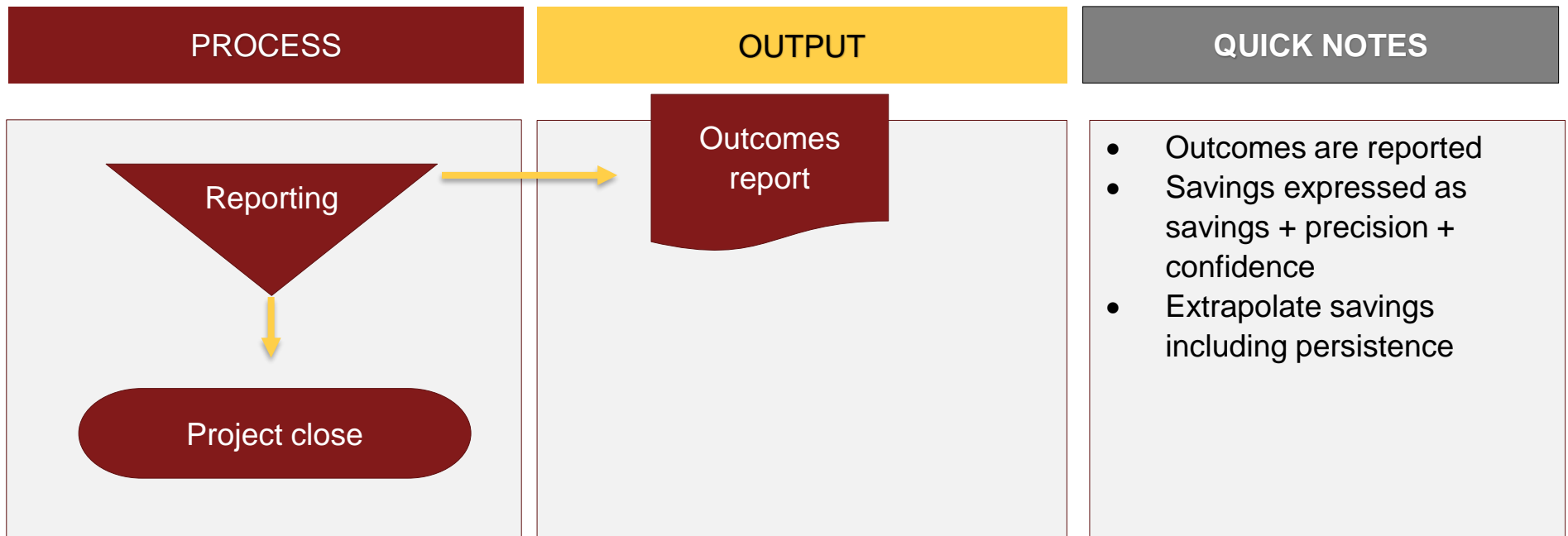
# M&V design and planning



# Data Collection design and modelling



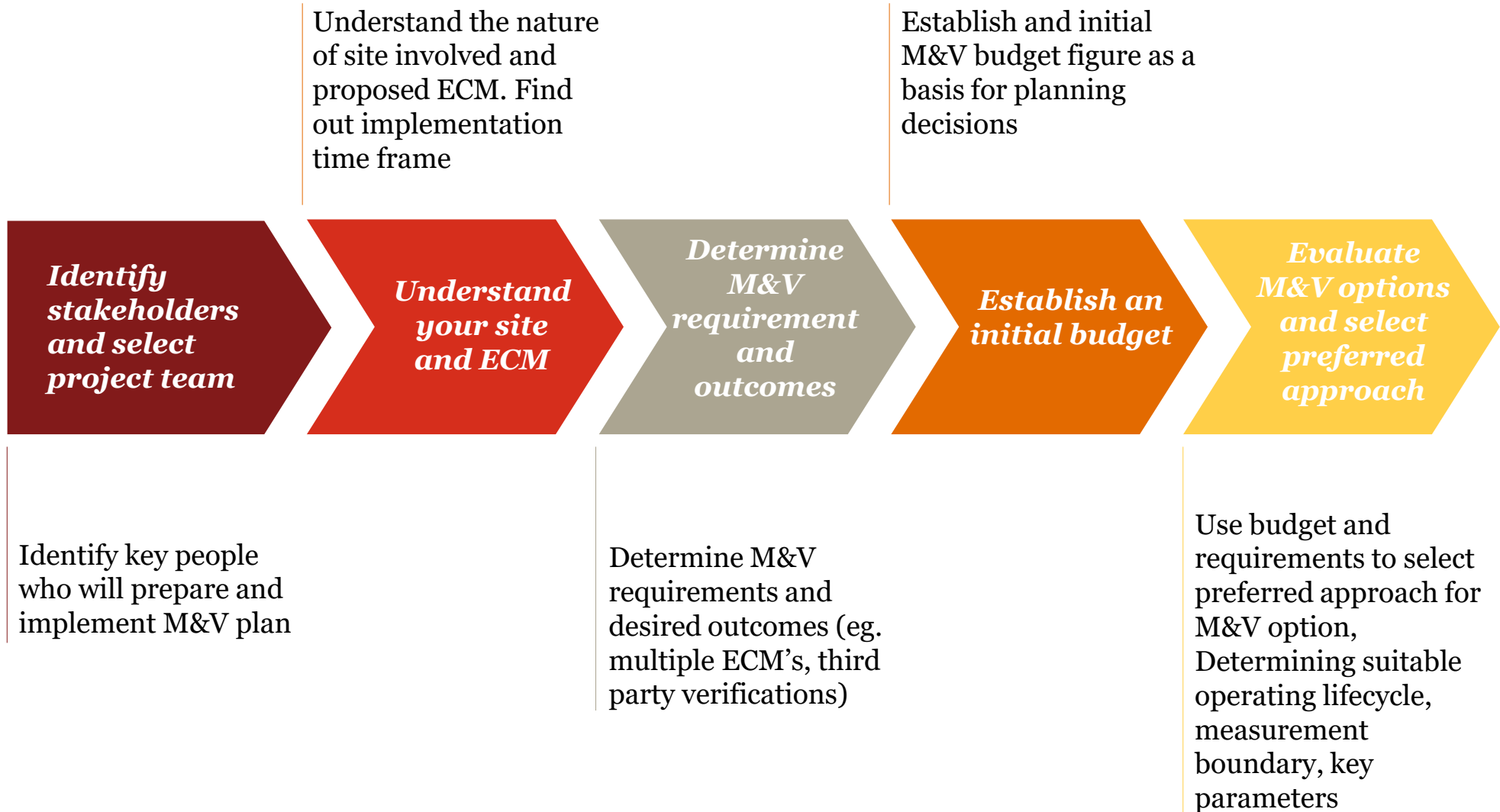
# Finish



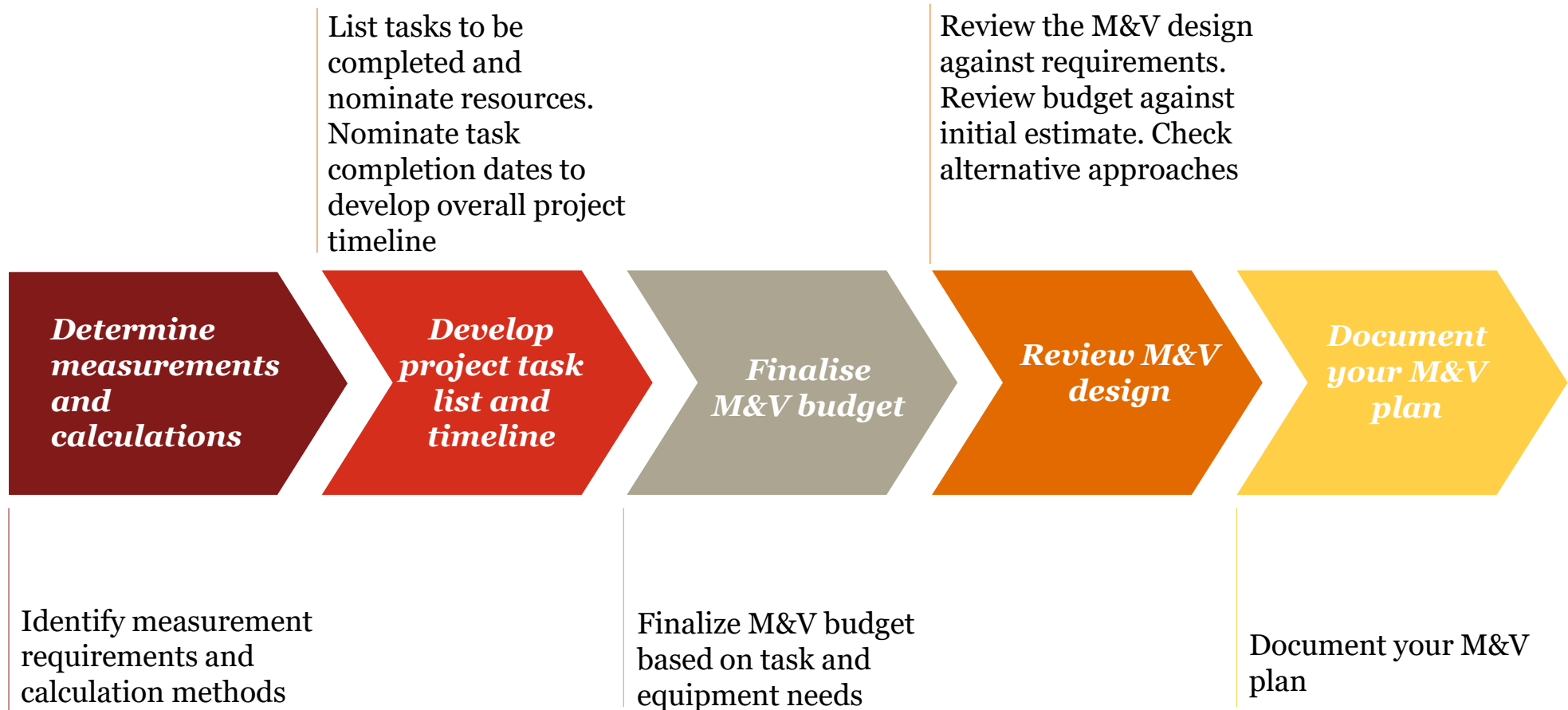
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# *M&V planning*

# Planning



# Planning



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# *Relevant examples*

# Relevant Example

Typical Projects	Key parameters		
	To measure	To estimate	To consider
<p>Changes in efficiency (input power draw versus work output requirement):</p> <ul style="list-style-type: none"> <li>• Replace existing motor with a high efficiency motor.</li> <li>• Matching motor or pump system to actual demand</li> <li>• Installation of variable speed drive</li> <li>• Impeller trimming for oversized pumps</li> <li>• Replacing pump or drive to properly match system demand and/or with higher efficiency.</li> <li>• Reducing pipe pressure losses</li> <li>• Unthrottled valves and change pump or impeller.</li> <li>• Increasing pipe diameters to reduce resistance where appropriate.</li> </ul>	<p>Change in power draw</p>	<ul style="list-style-type: none"> <li>• Work output requirement (e.g. production within in a process environment)</li> <li>• Operating hours</li> <li>• Interactive effects</li> </ul>	<ul style="list-style-type: none"> <li>• Rebalancing to meet system demand</li> <li>• Future plant capacity requirements</li> <li>• Occupant comfort</li> <li>• Interactive effects</li> </ul>

## *Relevant Example*

Typical Projects	Key parameters		
	To measure	To estimate	To consider
<p>Changes in controls:</p> <ul style="list-style-type: none"> <li>• Reduction in plant and equipment operating times.</li> <li>• Occupant push-button activation and timer control (e.g. for supplementary condenser water in meeting rooms).</li> <li>• Installation of sensors to control fan or pump operation (e.g. to control contaminants such as carbon dioxide or carbon monoxide in car parks).</li> <li>• Changes to set points for existing sensors such as indoor dry bulb temperature.</li> </ul>	<p>Operating hours</p>	<ul style="list-style-type: none"> <li>• Changes in power draw</li> <li>• Interactive effects</li> </ul>	<ul style="list-style-type: none"> <li>• Occupant comfort</li> <li>• Interactive effects</li> <li>• Effects on existing motor VSDs</li> </ul>

## Relevant Example

Typical Projects	Key parameters		
	To measure	To estimate	To consider
<p>Combination of operational control and motor or pump efficiency initiatives above and additional initiatives listed below:</p> <ul style="list-style-type: none"> <li>• Installation of additional low-load / multiple pumps to reduce power draw during low demand periods and reduced operating hours for larger pumps.</li> </ul>	<p>Measure the parameter with the biggest impact or uncertainty on the accuracy of the outcome.</p> <p><b>If both are unknown or uncertain, then Option A cannot be used.</b></p>	<p>Estimate or stipulate the remaining key parameters, including:</p> <ul style="list-style-type: none"> <li>• Changes in power draw</li> <li>• Operating hours</li> <li>• Interactive effects</li> </ul>	<ul style="list-style-type: none"> <li>• Rebalancing to meet system demand</li> <li>• Occupant comfort</li> <li>• Interactive Effects</li> <li>• Effects on existing motor VSDs</li> <li>• Choice of Measurement boundary</li> </ul>

## Relevant Example

Typical Projects	Key parameters		
	To measure	To estimate	To consider
All motor or pump projects	Changes in power draw and work output requirement based on independent variables (e.g. operating hours, sensor-based control)	Interactive effects	<ul style="list-style-type: none"> <li>• Rebalancing to meet system demand</li> <li>• Future plant capacity requirements</li> <li>• Occupant comfort</li> <li>• Interactive effects</li> </ul>
All motor or pump projects	<ul style="list-style-type: none"> <li>• Whole facility energy consumption</li> <li>• Independent variables</li> </ul>	Interactive effects	<ul style="list-style-type: none"> <li>• Estimated savings are “large” (&gt;10% of baseline energy)</li> <li>• Rebalancing to meet system Demand</li> <li>• Future plant capacity Requirements</li> </ul>
Projects with no metered baseline	<ul style="list-style-type: none"> <li>• Actual energy consumption</li> <li>• Independent variables</li> </ul>	Simulation input and modelling	<ul style="list-style-type: none"> <li>• Model calibration</li> <li>• Modelling difficulty for certain building types/ECM’s</li> </ul>

*Thanks!*



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