Asia-Pacific
Economic Cooperation

Energy and Water Efficiency in Water Supply Workshop Proceedings

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Introduction to Water and Energy Efficiency in Water Supply

Hotel Hilton Hanoi Opera

9th of March 2010

By: Sudha Setty

Asia-Pacific Economic Cooperation

ALLIANCE TO SAVE ENERGY

Creating an Energy-Efficient World

Who are the Alliance to Save Energy?

- Established in 1977; Non-Profit
- Mission: “To promote energy efficiency worldwide to achieve a healthier economy, cleaner environment & greater energy security”
- A leader in energy efficiency in all relevant sectors:
  - buildings
  - industry
  - water
  - utilities
  - appliances
  - transportation
  - research
  - policy
  - education
  - federal government (e.g., FEMP)
- Have implemented water and energy efficiency projects in more than100 cities around the world

What is Watergy?

- Term coined to define the *nexus* between water and energy
- The goal is to provide cost effective water services while reducing energy consumption and protecting the environment

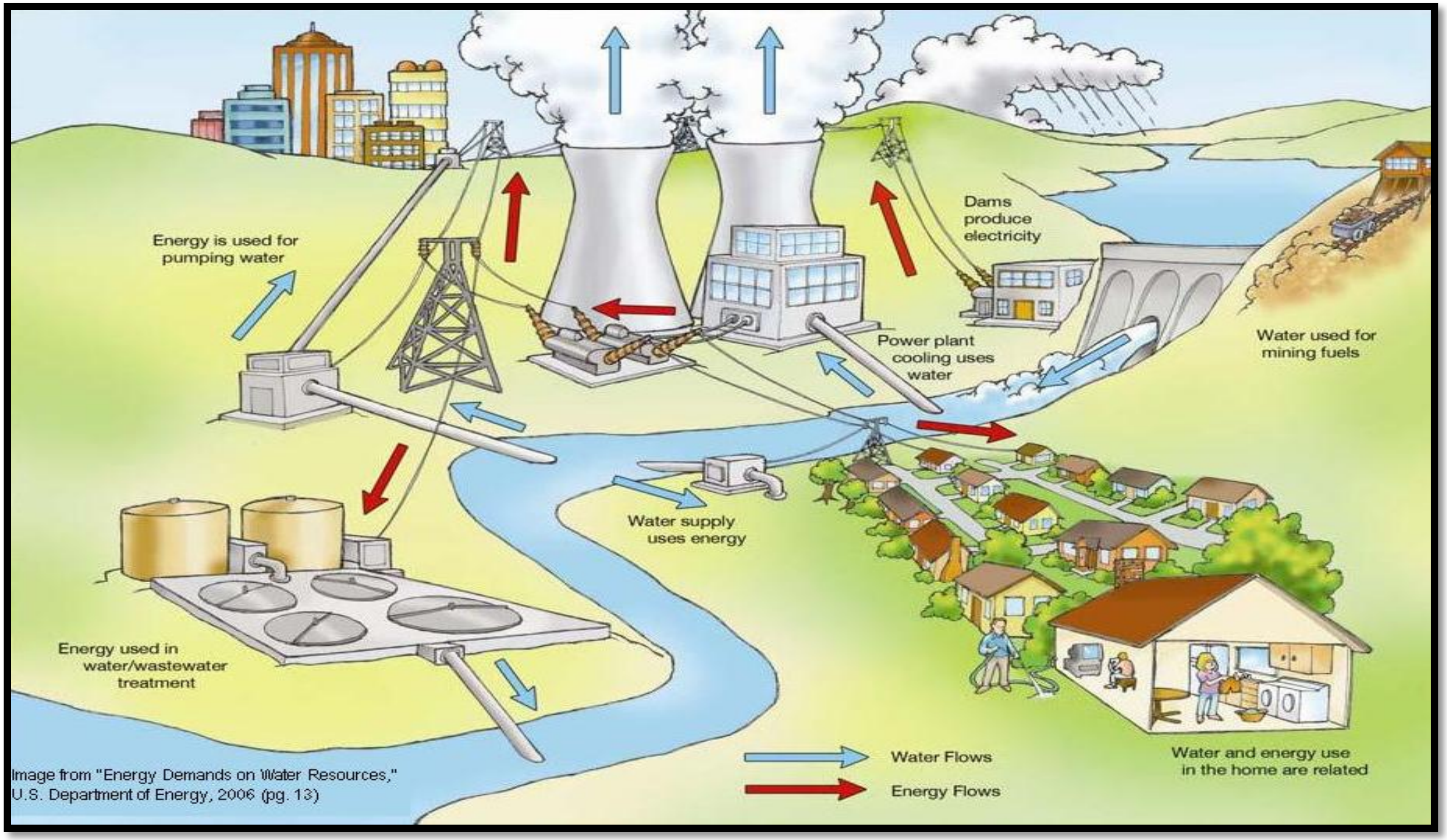


Image from "Energy Demands on Water Resources," U.S. Department of Energy, 2006 (pg. 13)

Components of the Water System that Use Energy

Stage	Operation	Energy-Using Systems
Extraction	Deep well or surface	Pumping systems
Treatment	Chemical & physical	Piston-type dosing pumps, pumping systems, fans, agitators, centrifugal blowers
Between Source and Distribution Network	Sending drinking water to the distribution grid	Pumping systems
	Booster pumping	Pumping systems
Distribution	Distribution to end users	Pumping systems
Storm and Sanitary Sewer Systems	Piping of sewage, rainwater	Pumping systems
	Wastewater treatment and disposal	Pumps, fans, agitators, centrifugal blowers
Support Systems	Support functions of utility building(s)	Lighting systems, HVAC, etc.

Watergy: Current Situation

- The relationship between water and energy is not widely understood or sufficiently exploited.
- Treating water for human consumption and moving treated water to the consumer is an extremely energy-intensive undertaking:
  - Every liter of water that passes through a water system represents a significant energy cost.

For water utilities:

- Globally:
  - Energy among the top 3 costs to water utilities, often coming second after labor costs.
- Developing country cities:
  - Energy generally the most expensive cost of supplying water
  - Often use 50-60% of their budgets to move water around!

Watergy: Leakage Wastes Energy and Water

- Whenever water is lost to leaks, energy and the cost of energy embodied in that water are also lost.
- Many distribution systems around the world are leaky:
  - Even in fully industrialized countries where infrastructure is old
  - Developing countries: 33-50% lost to leaks and system inefficiencies
    - Mexico: 33% of water supplied in many cities is lost before reaching consumer
    - Brazil: 44% lost to leaks and system inefficiencies in some municipalities
    - India: 50% is lost (less in very large cities, can be more in smaller cities)
- Often a misplaced emphasis on end-user conservation!
  - In many countries most water is lost before it reaches the end user.

Watergy: Water Supply & Wastewater Treatment are Infrastructure-Intensive

"Energy and water efficiency can defer and in some cases eliminate the need for additional infrastructure investment"

- More efficient operations in water supply stretch limited water and energy resources by:
  - expanding water access more quickly & inexpensively
  - postponing expensive new construction by maximizing the capacity of existing infrastructure

  Example: in Mexico, the water currently lost to leaks would cover the demand growth for the next 6 yrs, leading to postponed infrastructure development

- Investment decisions in water & wastewater that neglect efficiency have a domino effect, increasing other investments:
  - new power plants
  - extraction & transport of fuel
  - environmental costs (e.g., air emissions)
  - declining reserves of water and hydrocarbon

Watergy: Opportunities

Watergy represents technical and managerial improvements in water and wastewater systems that…

- Provide quality service with a minimum of water & energy;
- Generate significant energy, water and monetary savings; and
- Improve O&M and service at lower cost.

Efficiency improvements in water supply:

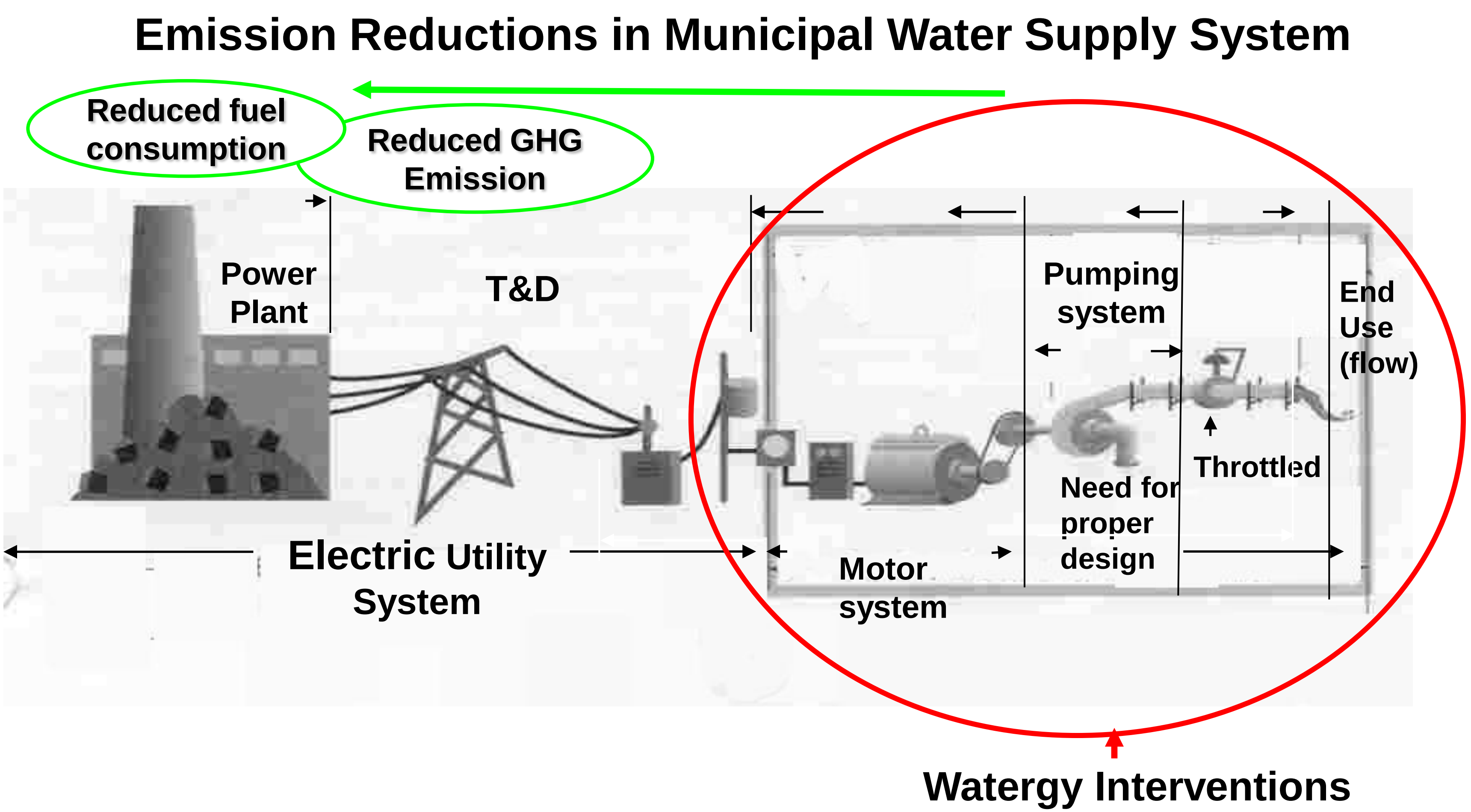
- Cost-effective: paybacks generally from a few months to ~3 yrs
- Savings leave more funds for critical public services
- One of the few cost-effective options available for meeting growing demands for electricity, water & wastewater treatment.

Watergy: Challenges

- Lack of awareness and technical skills to address inefficiencies in utility operations
- Lack of financial resources to implement efficiency interventions
- Difficult to prioritize efficiency needs over service delivery extension
- Decision making processes in local governments are often time consuming and difficult to navigate.
- Most water infrastructure is located underground and leaks can go undetected.
- Management of Non Revenue Water (wasted water) and the implementation of a program to reduce water losses demands a long term approach which often conflicts with municipal budgeting timelines.

Efficiency Interventions in Water Systems

Energy Efficiency Interventions in Water Supply Systems

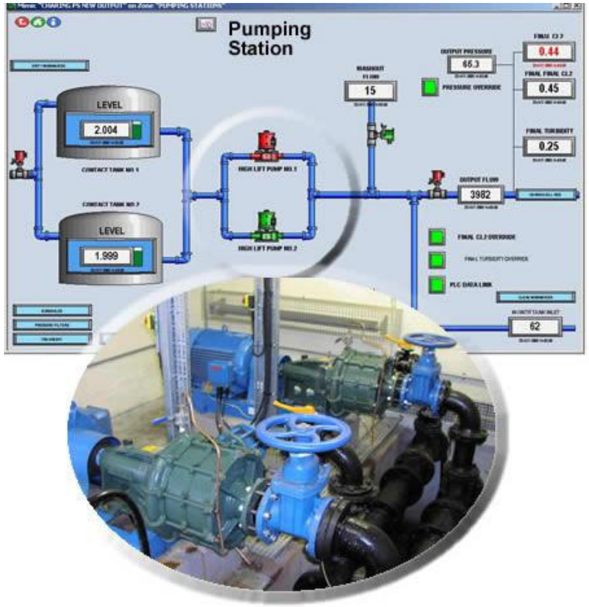


Typical Energy Audit Findings in Pumping Stations

- Inefficient pumps & motors
- Mismatch in head and flow
- Inadequate pipe sizing
- Excess contract demand
- System over design

Cost-Effective Interventions

- Pumps
- Leak Management
- Automated Controls
- Pressure Management
- Metering & Monitoring



Low Cost/ No Cost Efficiency Interventions

- Surrendering of excess contract demand (KVA)
- Improvement of power factor (PF) (0.95)
- Improvement in O&M practices
- Separation of LT & HT Load
- Minor rectification in pump
- Leak detection and repair
- Review of electricity tariff and opting suitable tariff
- Monitor all important system parameters like: motor kW, pump head, flow, temperature

Medium Cost Efficiency Interventions

- Replacement of low efficiency pump set
- Impeller replacement
- Improvement in piping – suction & header
- Installation of energy efficient motors
- Enhancement of contract demand - in case of shortfall

Energy Efficiency Measure Example: Optimizing Pumps

Procurement should be based on *efficiency* not *purchase price!*

- Of a pump's total cost over its lifetime:
  - 3% is for purchase
  - 74% is for energy
- A more efficient pump also has lower maintenance & downtime costs.

Typical Energy Savings in a total pumping system:

- SIZE – proper matching of pump size to load: 10–30%
- SPEED – variable speed drives adjust as needed: 5–50%
- SYSTEM REQUIREMENTS – don't pump more flow and pressure than needed: 5–20%

Pune Watergy Project 2004 Case Study -Background

- City in Western India
- Population of 3.5 million
- Receives water from the Khadakwasala Dam, 12 kms from the city.
- Water was supplied on alternate days.

Pune Watergy Project 2004 - Approach

- Alliance Partnered with Maharashtra State Urban Development Department and Pune Municipal Corporation (PMC) to implement a Watergy project
- Set up Energy Management Cell at PMC
- Carried out system-wide Energy Audit
- Trained 45 Municipal Engineers in energy audit process
- Prioritized and implemented system improvements

Tracking energy savings in Pune

Pune Watergy Project 2004 - Highlights

- Energy Audit Report – Potential of $332,000 as annual savings; investment required $198,000
- 70% of Energy Efficiency measures had payback of less than a year!!
- Pune invested $189,000 and accrued energy savings of $336,000

Energy Savings	Cost savings	Additional water	Emissions avoided
3.8 Million kWh/Year	**US $336,000/Year**	**10% increase in Water Supply**	**38,000 Tons CO2/Year**

Developing Energy Efficiency Projects in Water Supply

Steps and Self Assessment

Steps for Developing Energy Efficiency Projects

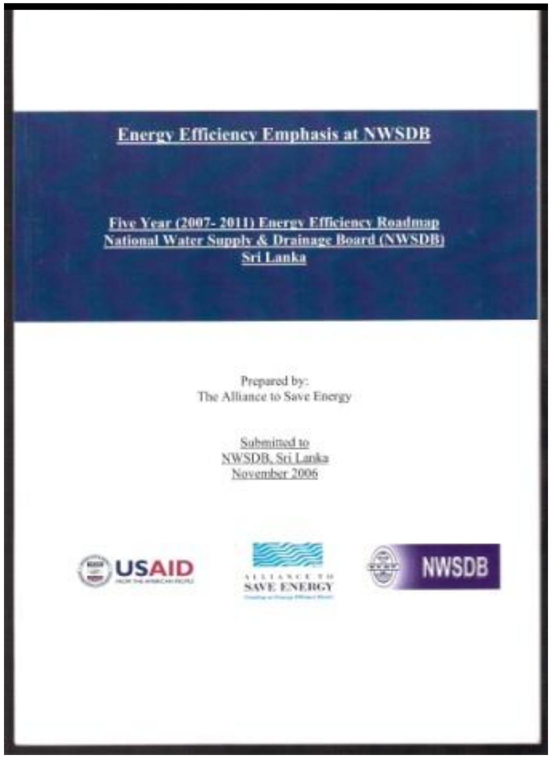
- Buy-in from top management + capacity building
- Set up an Energy Management Cell
- Self assessment to choose the best fit option for undertaking EE program
- Collect baseline information by carrying out a preliminary (walk-through) audit
- Develop and issue a request for Expressions of Interest (EOI)
- Evaluate and shortlist preferred ESCOs/ qualified service providers
- Issue a Request for Proposal (RFP)
- Evaluate the proposals
- Finalize ESCO/ service provider selection
- Award the Investment Grade Audit (IGA) contract
- Finalize EE proposals to be implemented
- Enter into an energy performance contract
- Establish Measurement and Verification (M&V) plan

Buy-in from Top Management and Capacity Building

- Top and middle management buy-in is essential to ensure the success of water and energy efficiency projects.
- Use terms that are familiar to managers:
  - Productivity & efficiency
  - Maintaining high reliability (downtime is expensive)
  - Lower operating costs
  - Improved service
  - Life-cycle costs
- Build capacity at all levels to ensure the sustainability of the project.

National Water Supply & Drainage Board (NWSDB) Sri Lanka

- Developed Five Year (2007-2011) Energy Efficiency Road Map for NWSDB
  - To reduce overall energy expenditure by 15%
  - The Roadmap Action incorporated in the 5 year corporate plan
- Results:
  - Set up an “Energy Saving Unit” in 2004
  - Established specific energy consumption for 150 pumping stations
  - Identified 25 high SEC plants for audit & implementation
  - Introduced ESCOs to NWSDB officials
  - NWSDB allocated Rs. 72 million for EE implementation



Energy Efficiency Emphasis at NWSDB

Five Year (2007- 2011) Energy Efficiency Roadmap
National Water Supply & Drainage Board (NWSDB)
Sri Lanka

Prepared by:
The Alliance to Save Energy

Submitted to
NWSDB, Sri Lanka
November 2006

Self Assessment Guidelines

1. What are the reasons for undertaking the EE project?
2. What are the goals for the project?
3. Is the project feasible?
4. What risks are involved in the project?
5. What type of contract should be used for the project and how should it be financed?

1. What are the Reasons for Undertaking the Project?

- Rising operational cost
- Increase in population
- Increase in demand
- Increasing greenhouse gas (GHG) emissions
- Others?

2. What are the Objectives for the Project?

- Reduce operational cost
- Improve delivery of services
- Rehabilitate existing systems
- Reduce GHG emissions
- Others?

3. Is the Project Feasible?

- Market analysis
  - Size and capacity of the project
- Technical analysis
  - Best solutions to identified problems
- Economical analysis
  - Cost efficiency
- Financial analysis
  - Cost of capital
- Sensitivity analysis
  - Effects of changes to initial assumptions

4. What Risks are Involved in the Project?

- Market fluctuations
  - Misjudged demand, consumption, or prices
- Changes in economic assumptions
  - Inflation, currency devaluation, tax burdens
- Legislative changes
  - E.g., stricter environmental requirements
- Technical risks
  - Risk of technical failures, breakdowns
- Political risk

5. What Type of Contract Should be Used for the Project and How Should it be Financed?

- Energy Services
  - Energy Service Company (ESCO) financing
    - Guaranteed Savings
    - Shared Savings
- Turnkey
  - Municipality borrows from private institutions
  - Municipality self financing (O&M funds)

Introduction to Energy Audit Methods in Water Supply

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By: Pradeep Kumar

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Energy Audit

"An energy audit is an assessment and analysis of energy flows in a process or system, aimed at reducing the amount of energy input into the system without negatively affecting the output(s)."

Objective

The main objective of an energy audit is to explore various possibilities for energy conservation;

Approach

An energy audit requires a thorough and detailed study of every aspect of the system, through the performance of various tests and measurements.

Steps in an Energy Audit

- Collect and analyze historical energy usage.
- Study pumping systems and their operational characteristics.
- Identify potential modifications that will reduce the energy usage and/or cost.
- Perform an engineering and economic analysis of potential modifications.
- Prepare a rank-ordered list of appropriate modifications.
- Prepare a report to document the analysis process and results.

Levels of Assessment

- Level I Assessment – Preliminary Energy Use Analysis & Walk Through Analysis; simple assessment based on available documents and information, physical inspection, and staff interviews to create a baseline and identify obvious energy efficiency measures which are easy to implement
- Level II Assessment – Energy Survey and Analysis; review of data, existing and newly gathered, to identify all energy saving measures and identify high potential measures for further investigation
- Level III Assessment – Detailed Analysis of Capital Intensive Measures; also known as Investment Grade Audit used to give a detailed assessment of costs and benefits derived from capital intensive energy conservation measures

Level I Assessment

- Purpose for undertaking:
  - Gain a full understanding of how energy is being consumed and the associated costs
  - Report on energy use to internal or external stakeholders
  - Find energy conservation programs for immediate and future consideration
  - Identify projects for future energy reduction
  - Set targets for energy reduction
- Results:
  - Baseline of energy use
  - Forecast of future energy use based on current / historical consumption
  - Identification of no/low cost measures for energy reduction
  - List of potential projects for future investigation
  - Detailed benchmarking for accurate comparison to other facilities and own past performance
  - Preparation for next level of assessment

Level II Assessment

- Purpose for undertaking:
  - Desire to take advantage of energy and cost savings from a wider range of projects
  - Creation of a full energy conservation program
- Results:
  - Evaluation of all potential energy conserving operational changes and capital investments available
  - Listing of capital projects that require further investigation prior to implementation
  - Preparation for next level of assessment

Level III Assessment

- Purpose for undertaking:
  - Desire to undertake significant capital projects to improve energy efficiency based on projects identified in previous levels of assessment
  - May include gaining access to external financing under performance contract.
- Results:
  - Detailed information provided so that owners have a high level of confidence in decision making regarding significant capital investment
  - May include implementation of capital intensive EE measures under performance contract.

Method & Approach for Water Systems

- The audit involves carrying out various measurements and analysis of the following systems to assess losses and the potential for energy efficiency improvements:
  - Pumps & Pumping Systems
  - Electrical Systems
  - Electric Drives

Measurement

- Data collection
  - Specifications of pumps and motors
  - Diagram of water distribution air network
  - Water pressure required for the system
  - Number of pumps in operation
  - Design/specified water temperature required
- Water flow rate of pumps at various operating conditions
  - Individual
  - Parallel
- Water flow velocity in pipe lines
- Suction & discharge pressure of pump

Measurement

- Power consumption and motor electrical parameters
  - During individual operation
  - During parallel operation
  - At various valve openings
- Speed
- Flow control methods
- Pipe line status
- Pressure drop in the line
- Operating hours and pump schedule
- Variations in flow requirement

Measurement

- User area operating schedule
- Measurement of water flows to the users
- Segregation of users based on operating hours
- Any modifications carried out in the pumps such as replacement of impeller, trimming of impeller, others
- Operation and maintenance practices

Data Analysis and Energy Conservation Measures (ECMs)

- Full written description of each ECM to include:
  - Existing conditions and data collection approach (snapshot, short-term, or long-term measurement of data)
  - Recommendations. Include discussion of facility operations and maintenance procedures that will be affected by ECM installation and implementation.
- Baseline energy use:
  - Summary of all utility bills
  - Base year consumption and description of how established

Data Analysis and Energy Conservation Measures (ECMs)

- Savings Calculations:
  - Base year energy use and cost
  - Post-retrofit energy use and cost
  - Savings estimates including analysis methodology, supporting calculations, and assumptions used
  - Operations and maintenance savings
  - If manual calculations are employed, formulas, assumptions, and key data shall be stated.

Data Analysis and Energy Conservation Measures (ECMs)

- Cost Estimate:
  - Engineering/design costs
  - Contractor/vendor estimates for labor, materials, equipment; etc
  - Construction management fees
  - Commissioning costs
  - Other costs/fees

Data Analysis and Energy Conservation Measures (ECMs)

- Auditors should consider the following while analyzing potential energy and water saving measures:
  - Comfort and maintenance problems
  - Energy use, loads, proper sizing, efficiencies and hours of operation
  - Current operating condition
  - Remaining useful life
  - Feasibility of system replacement
  - Customer's future plans for equipment replacement or pumping station renovations
  - System operation and maintenance procedures that could be affected
  - Hazardous materials and other environmental concerns

Energy Audit Report Format

- Executive Summary
- Background
- Energy Scenario
- Inventories
- Baseline Parameters & Adjustments
- System Mapping Details
- List of Potential Energy Saving Projects
- Detailed Financial Analysis (Payback, NPV, IRR)
- Details of Approved Projects
- M&V Plan
- Risk Assessments & Mitigation Plan
- Annexure

Investment Grade Energy Audit

How is it different from an energy audit?

Energy Audit

- Background information
- Energy assessment study
- Inventory details
- Energy saving opportunities
  - Estimated energy and cost savings
  - Implementation cost
  - Calculation and analysis
  - Simple payback
  - Appendix
- Measured data
- Appendix and references

Investment Grade Audit

- An investment grade audit is a **technical and economic analysis** of potential energy saving projects in a facility that:
  - Provides information on current energy-consuming equipment operations
  - Identifies technically and economically feasible energy efficiency improvements for existing equipment, and
  - Provides the customer with sufficient information to judge the technical and economic feasibility of the recommended projects.

Investment Grade Audit

Technical Scope of Work, Performance Based Contracts

Scope of Work – IGA & Implementation through performance based contract

1. Investment Grade Audit Phase:
   - Propose detailed projections of energy and cost savings to be obtained as a result of the implementation of the recommended energy efficiency measures (EEMs).
   - Establish energy consumption baseline.
   - Conduct financial and technical risk analysis.

Scope of Work – IGA & Implementation through performance based contract

2. Construction and Implementation Phase:
   - Negotiate Energy Performance Contract based on IGA agreement to define implementation scope of work.
   - Provide design services.
   - Provide equipment procurement and purchasing.
   - Provide construction and construction management services.

Scope of Work – IGA & Implementation through performance based contract

3. Commissioning, Operation and Monitoring Phase
   - Provide commissioning services.
   - Perform periodic inspection of improvements.
   - Perform routine maintenance of equipment.
   - Develop project-specific measurement & verification plan.
   - Provide staff training on routine maintenance and operation of systems.
   - Provide monitoring, measurement, verification and reporting of performance and savings.

Investment Grade Audit for Performance Based Contracts

Includes:

An energy audit

+

Project financial assessment (NPV, ROI, IRR etc.)

+

Risk assessment

+

Suitable measurement & verification plan

to

Reduce of the level of Uncertainty

Uncertainty

- Performance
  - Will the savings come about?
- Baseline
  - May change, need adjustment
- Energy Price
  - Will fluctuate during the project, how to factor this?
- Delays
  - In construction
  - Commissioning
- Operational conditions
  - Human errors
  - Power quality
  - Water scarcity
  - User intervention
- Addition of loads
  - Added more pumps
  - More water requirements

Uncertainty

- Reported savings values are always estimates because you can't measure what isn't there.
- Uncertainty in the savings value comes from:
  - Uncertainty in performance
  - Uncertainty and changes in usage
  - Uncertainty introduced by estimates
  - Unpredictability in future energy costs
  - Uncertainty in carbon conversion factors

Uncertainty can be

reduced but not **eliminated**…..

How to Reduce Uncertainty

By Allocating Risk– A matrix that details the sharing of risk

Risk & Responsibility Matrix

Risk Assessment

- Types of Risk
- Allocating Risk

Responsibility Allocation

- Financial
- Operational (Usage)
- Performance

Risk & Responsibility Matrix - Overview

Responsibility /Description	Contractor Proposed Approach	Agency Assessment
Performance		
Equipment performance:		
Operations:		
Maintenance & repair:		
Equipment replacement:		
Operational		
Operating hours:		
Load:		
Weather:		
User participation:		

Risk/Responsibility Matrix - Overview

Responsibility /Description	Contractor Proposed Approach	Agency Assessment
Financial		
Interest rates:		
Energy prices:		
Construction costs:		
M&V costs:		
Delays:		
Major changes in facility:		

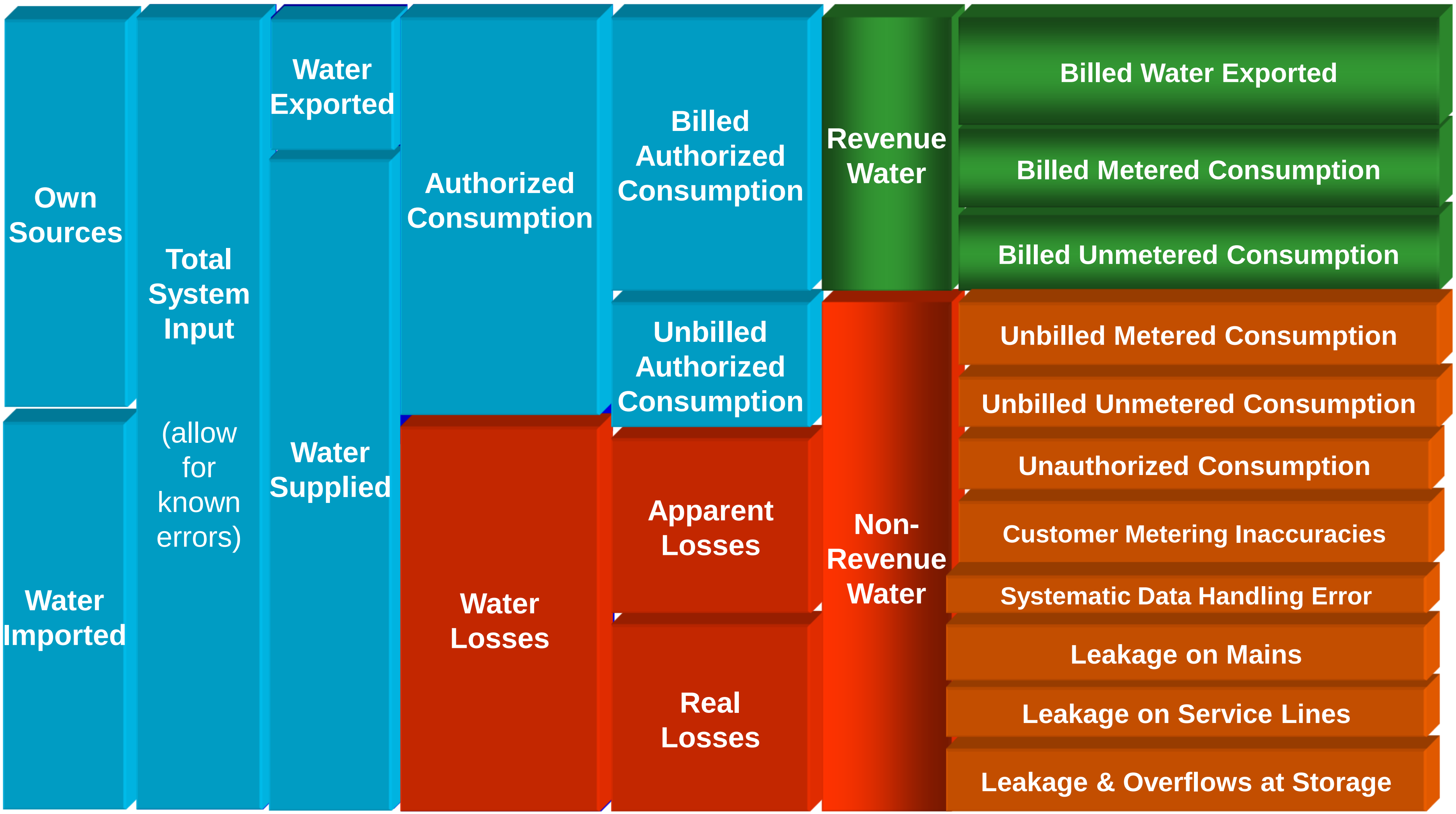
Water Audit Methodology

Purpose – Water Audit

- Promoting water supply efficiency as a standard business practice

- Strong water supply efficiency is evidenced by:
  - Low water leakage losses
  - Minimal unbilled water consumption
  - Minimal unauthorized consumption

Standardizing the Water Audit Method



Source: IWA/AWWA Water Balance

Audit Instruments Used For Measurements

Ultra-Sonic Flow Meter

Application: Flow measurement of Liquids

Non-Contact Tachometer

Application: Speed Measurements

3-Phase Power Analyzer

Application: Measures all Electrical and Harmonic Parameters

Handheld Power Harmonic Analyzer

Application: Measures all Power and Harmonic Parameters

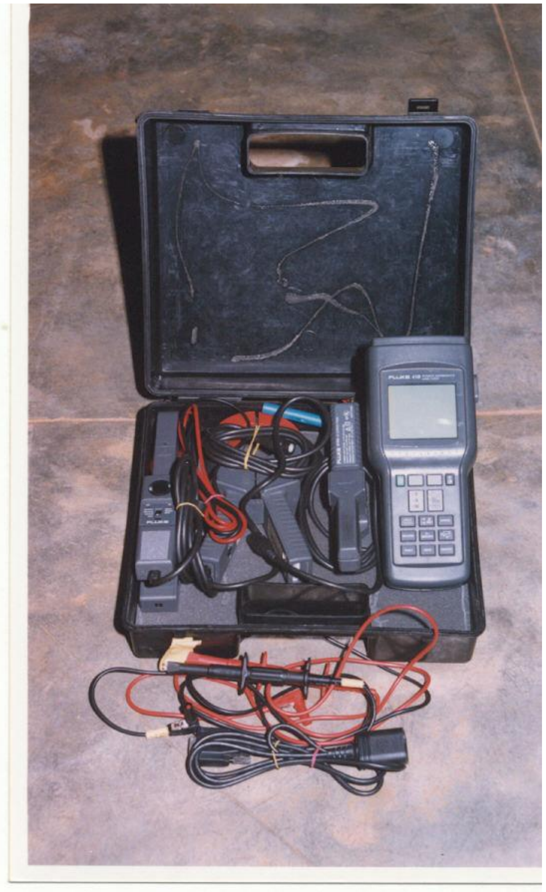
AC/DC Clamp-on Power Meter

Application: Measures all Power Parameters

Ultrasonic Flow Meter

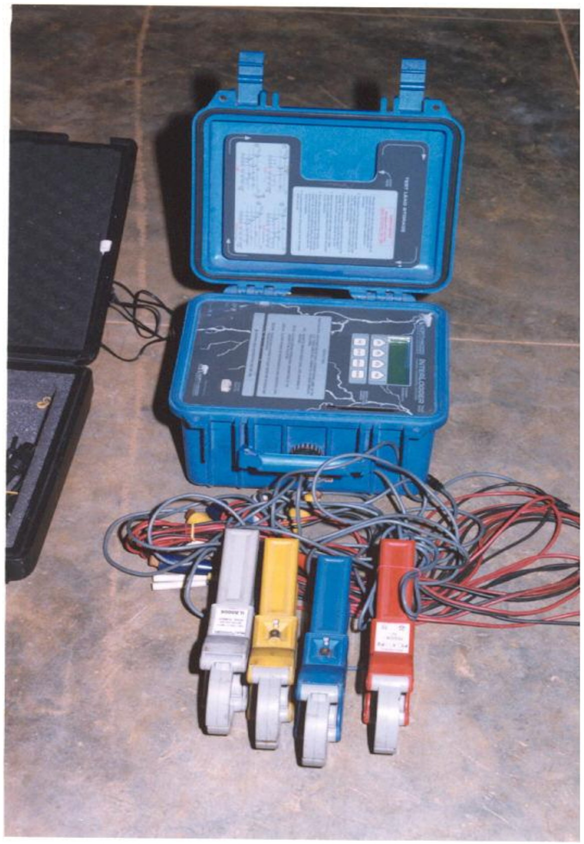
Application: Measures Flow Parameters (discharge, velocity)

Portable Clamp Power Analyser



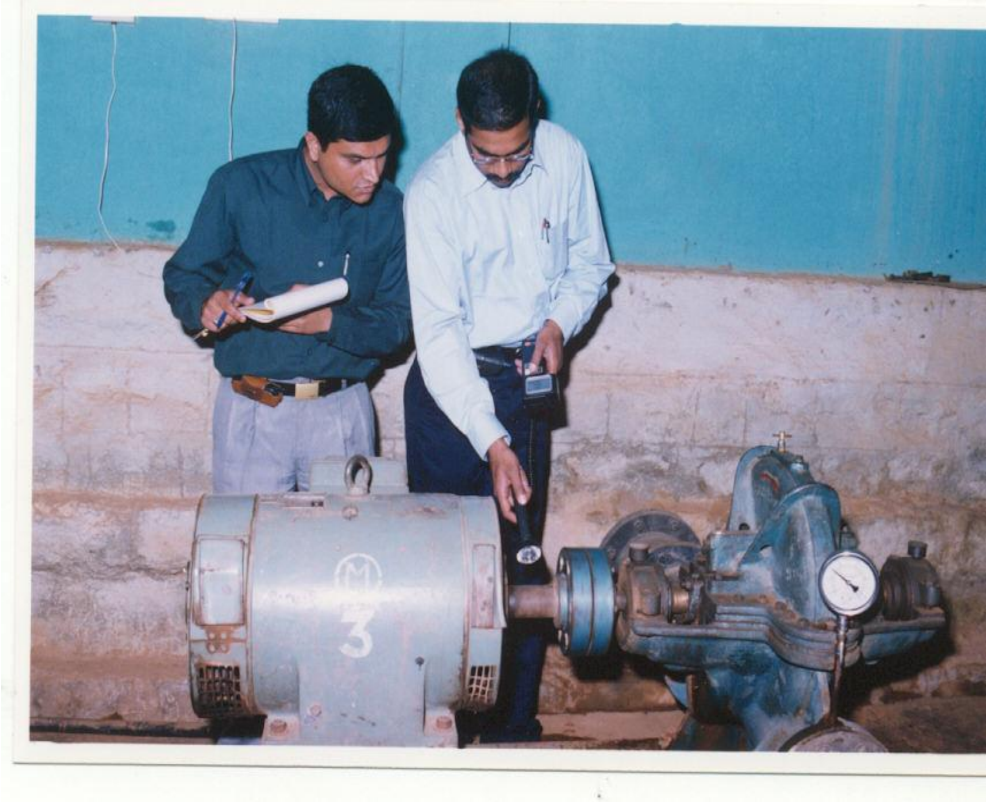
Application: Measures power parameters kW, pf, kVA, Hz, A and V

Portable Load Manager



Application: Measures power parameters kW, pf, kVA, Hz, A and V

Stroboscope

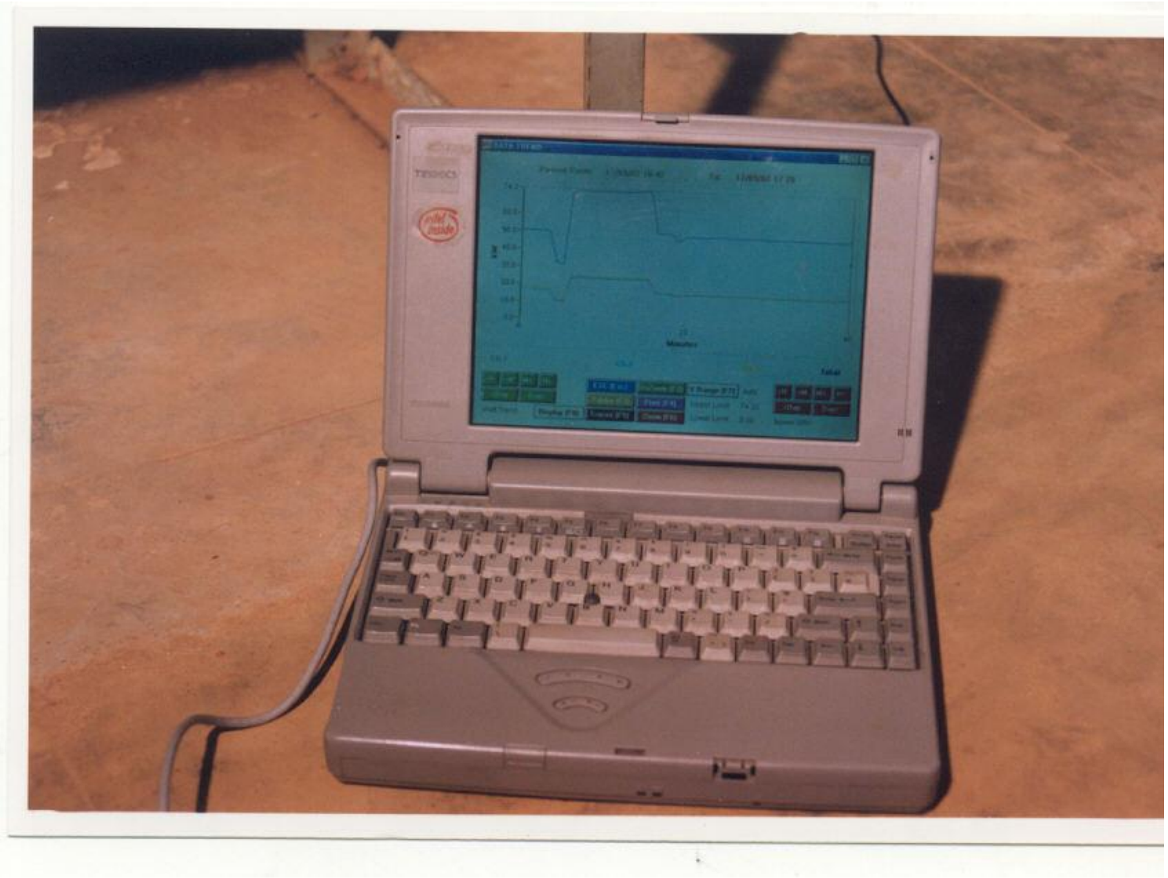


Application: Measures Speed

Pressure Gauge
– Measurement of pressure

Application: Measures Head

Laptops



Application: On line recording and down loading of recording parameters

Credits

- Indian Water Works Association (IWWA)
  http://www.iwwa.info/
- Federal Energy Management Program (FEMP)
  http://www1.eere.energy.gov/femp/
- The Energy and Resource Institute (TERI)
  http://www.teriin.org/

Energy Management In Water Supply Systems
- Pumping Operations

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By: Pradeep Kumar

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Current Scenario in Pumping Systems

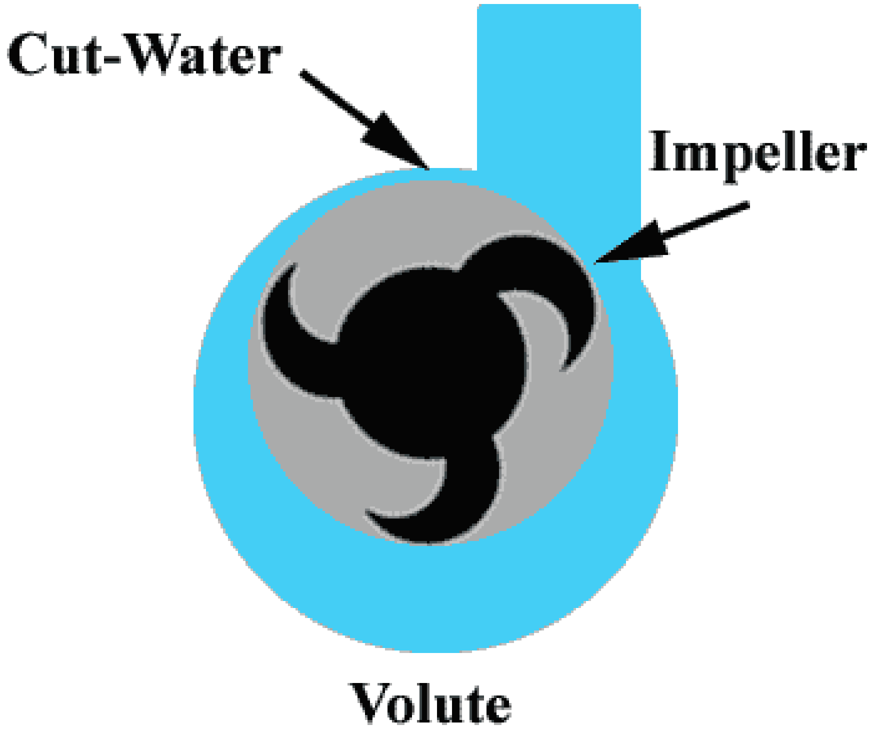
- Pumping systems have often undergone several changes such as:
  - Addition of Load
  - Retrofitting of equipment
    - Shifting of best operating point
  - Changes in the station's headers/piping arrangement
- No or little focus on incorporating energy efficiency parameters at the design stage
- Procurement is based on lowest cost or 'first cost' (L1) NOT on life-cycle cost?

Current Scenario in Pumping Systems

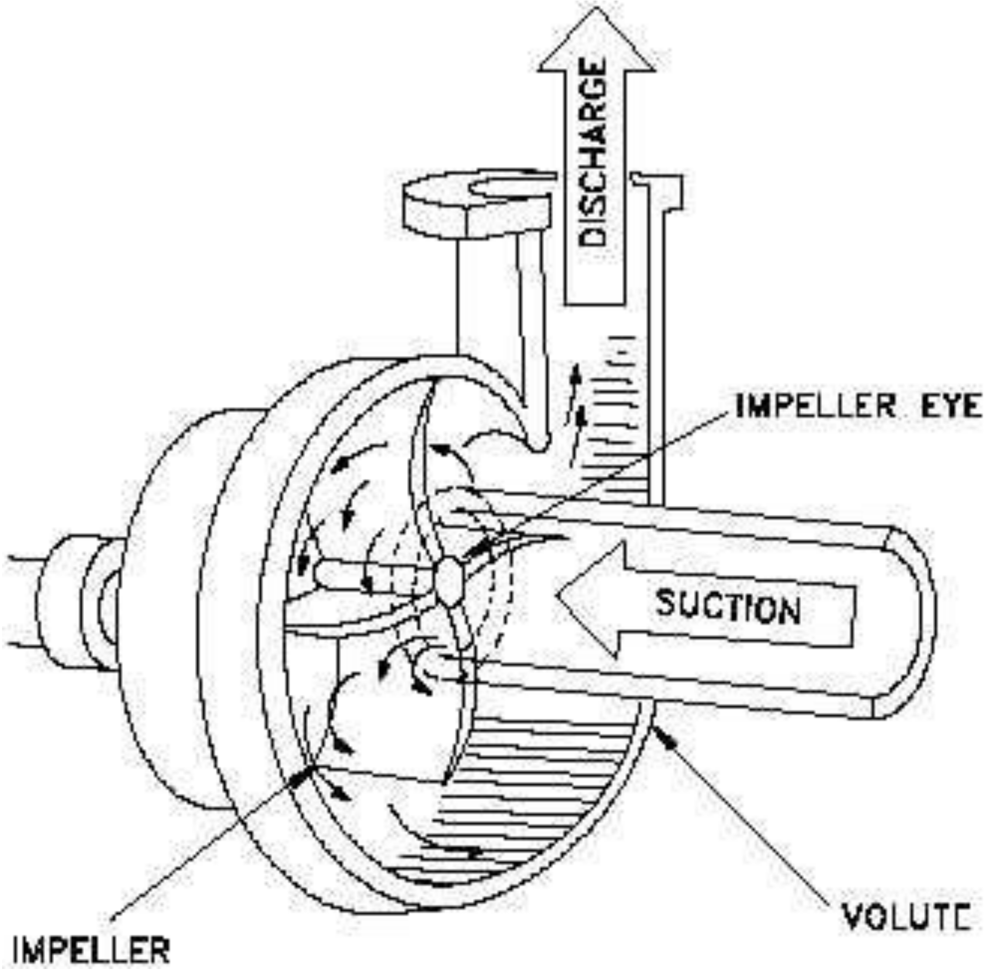
Reasons for poor efficiency in pumping systems

- Over design to cater to future demand or unrealistic use of safety margin factor
- Major retrofits of pumps and other system components
- Changes in operating practices/schedules
- Efficient component NOT installed and/or operated properly
- Inadequate metering and monitoring systems

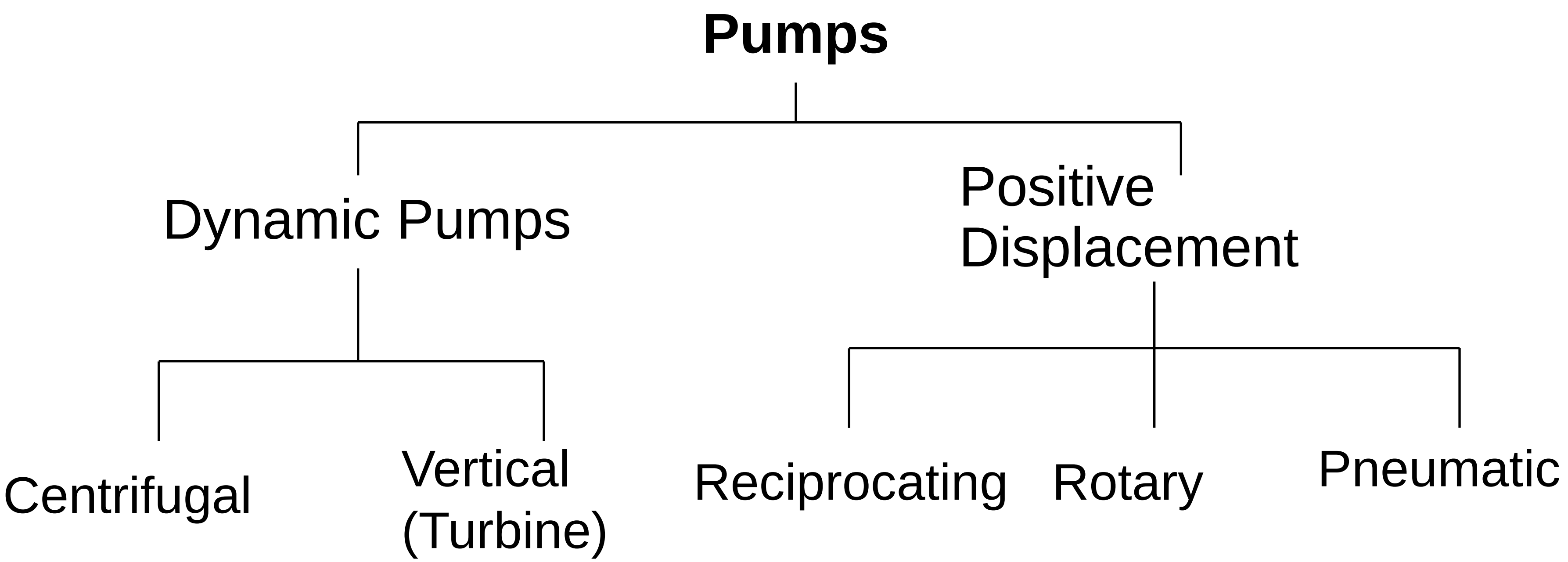
Pumping System



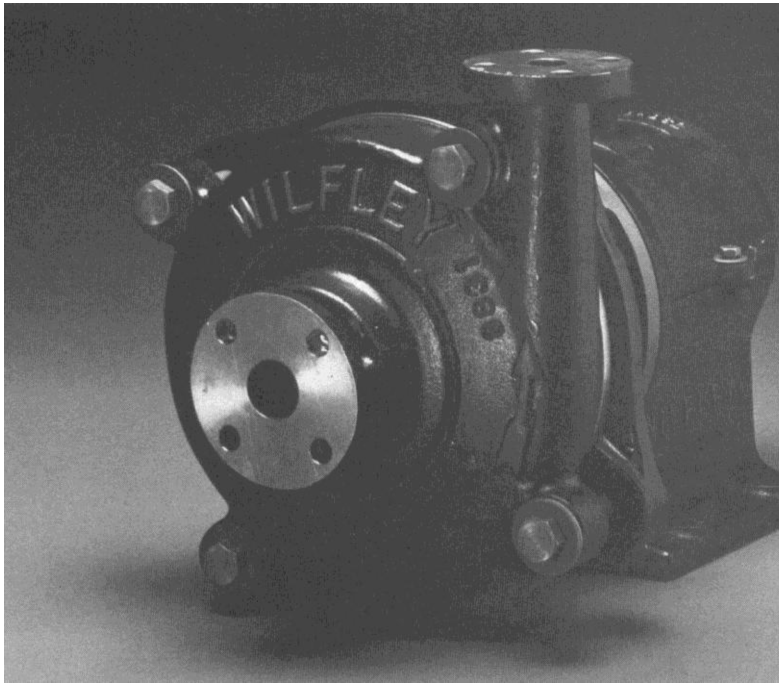
How Pumps Work

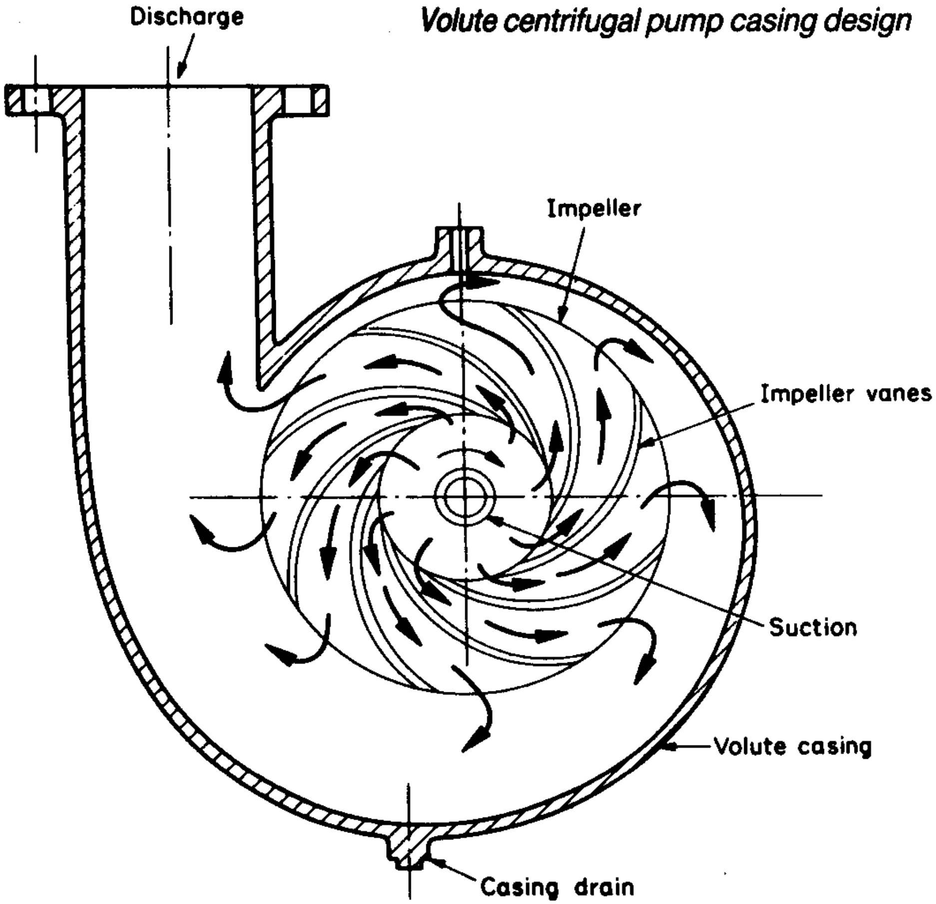


Classification of Pumps



Centrifugal Pumps





Centrifugal Pumps

- Main parts: Impeller and diffuser
- Impellers are generally made of bronze, poly carbonate, cast iron, stainless steal etc.
- The diffuser is also called the volute and houses the impeller
- Velocity is developed as the water flows through the impeller spinning at high speed
- This high velocity is converted into pressure by the diffuser

Pump Selection

Important parameters when selecting a pump include:

- required flow and head of fluid
- net positive suction head (NPSH)
- specific gravity and viscosity of fluid
- efficiency of pump
- single or parallel operation

Power Requirement & Efficiency

Hydraulic Power (P_h) : $\dfrac{\text{Flow}\,(m^3/s) \times \text{total head}\,(m) \times \rho\,(kg/m^3) \times g\,(m^2/s)}{1000}$

where, total head: hd – hs (hd - discharge head)

(hs – suction head)

ρ - density of the fluid

g – acceleration due to gravity

Pump shaft power (P_s): $\dfrac{\text{Hydraulic power}, P_h}{\text{Pump efficiency}, \eta_{pump}}$

Electrical input power (P_e): $\dfrac{\text{Pump shaft power}, P_s}{\text{Motor efficiency}, \eta_{motor}}$

Sample Calculation for Pump Efficiency

Flow (Q)	:	110 m^3/h
Head (H)	:	50 m
Input Power to pump (P)	:	20 kW
Application	:	Water

Hydraulic kW is given by:

$$\frac{Q \text{ in } m^3/sec \times \text{Total head in m} \times \text{density in } kg/m^3 \times g \text{ in } m^2/s}{1000}$$

$$= \frac{(110/3600) \times 50 \times 1000 \times 9.81}{1000} = 14.98 \text{ kW}$$

Pump efficiency = Hydraulic kW/Input power to pump

= 14.98 x 100/20

=74.9%

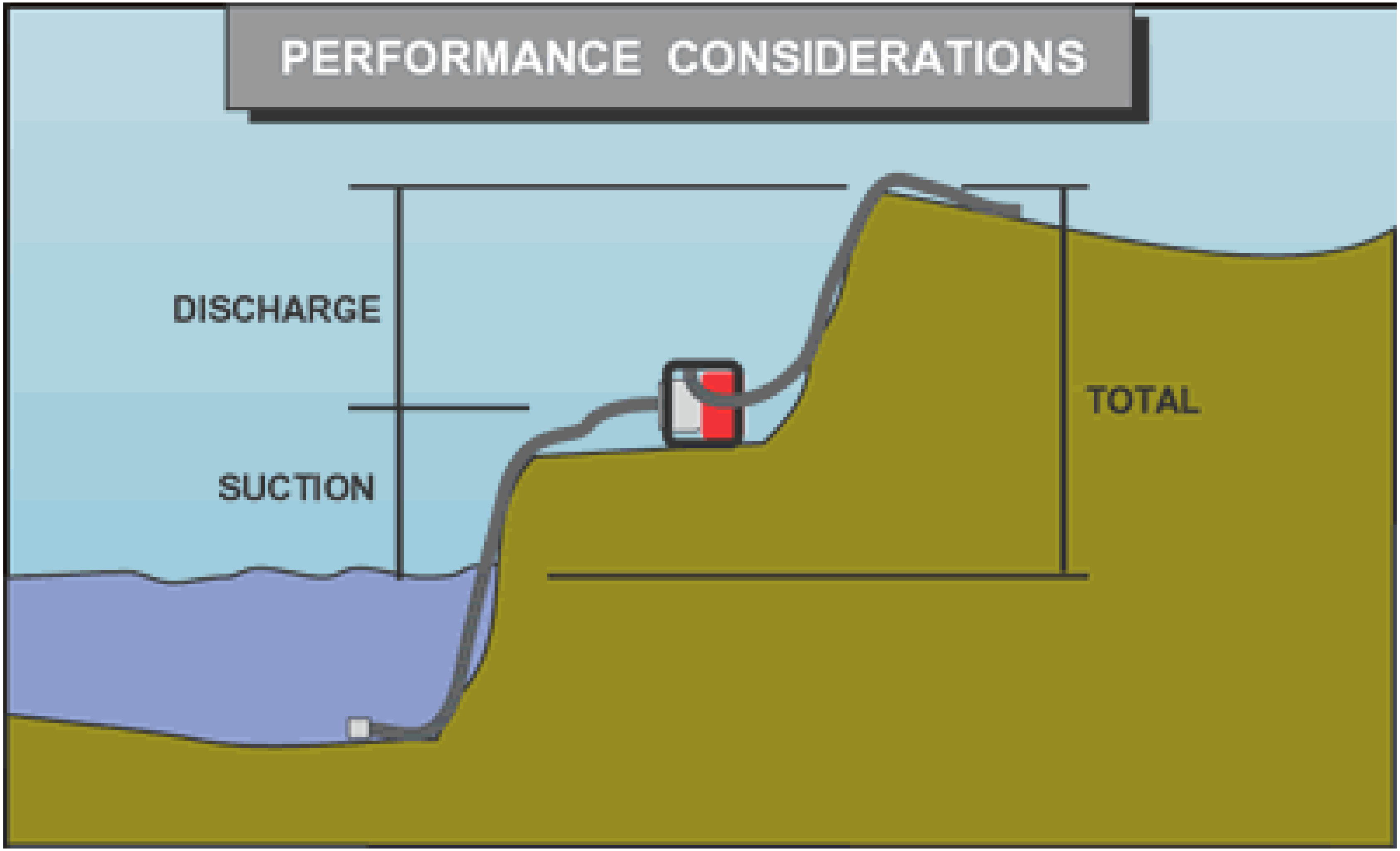
Centrifugal Pumps - Efficiency

Pumps	Peak efficiency (%)
Large (above 30 kW)	Up to 88%
Medium (18 – 30 kW)	70 – 75%
Small (below 18 kW)	50 – 65%

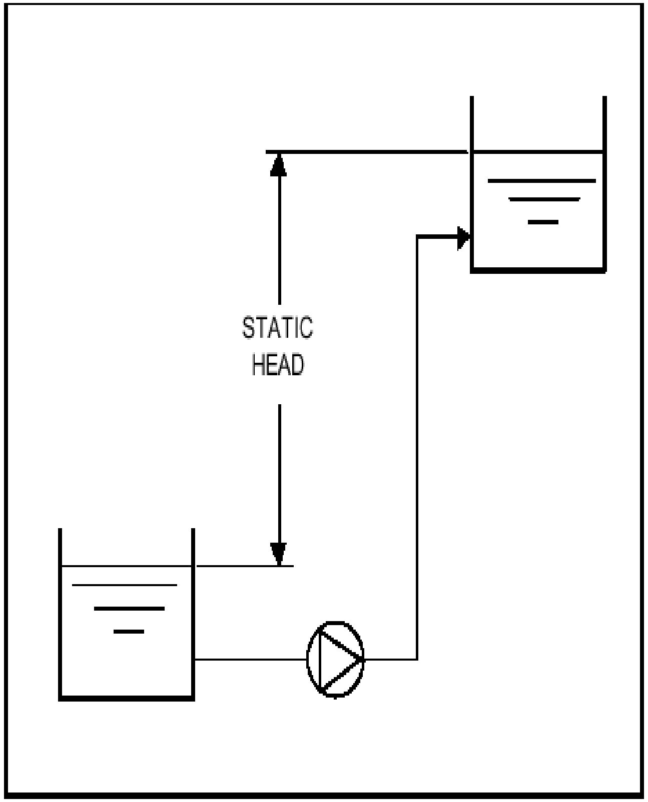
Pumping Loss

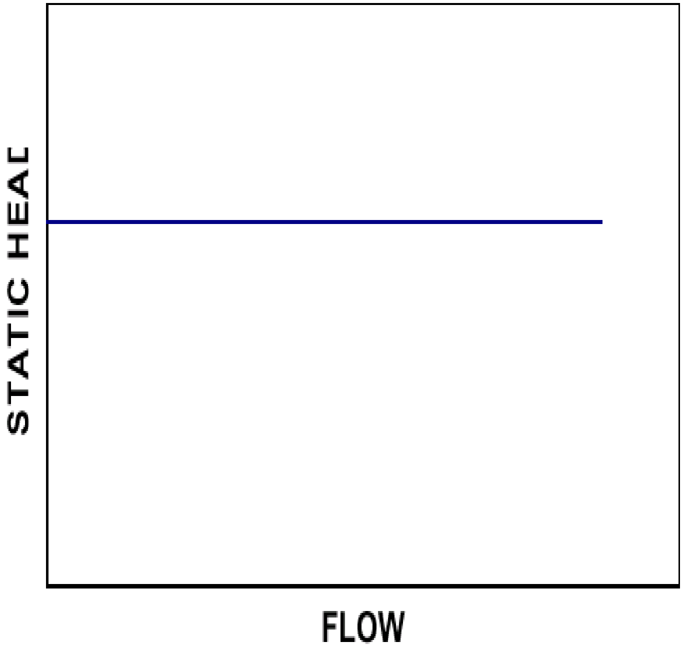
- **Frictional loss**
  - Due to friction and vortex formation over the entire flow passage (Eddy losses arise mainly at entry to the blade passage and in the volute casing.)
- **Leakage loss**
  - Due to fluid flow from discharge to the suction side through the impeller to casing clearance
- **Mechanical loss**
  - Due to friction in bearings and shaft stuffing boxes and friction between the outer surfaces of the impeller and the surrounding liquid

Pumping Operations

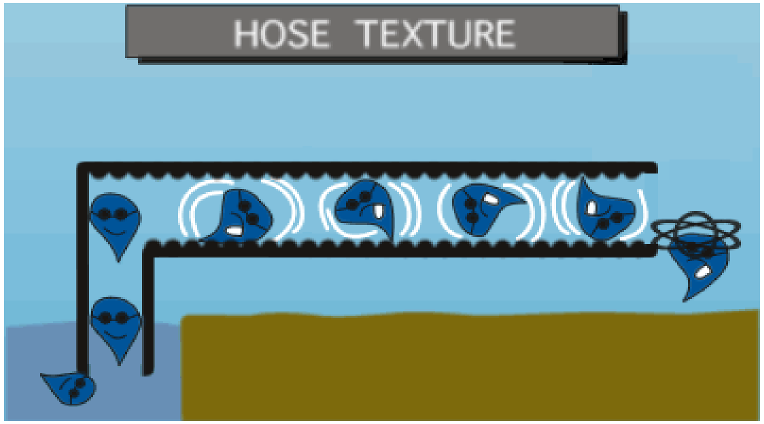

PERFORMANCE CONSIDERATIONS
DISCHARGE
SUCTION
TOTAL

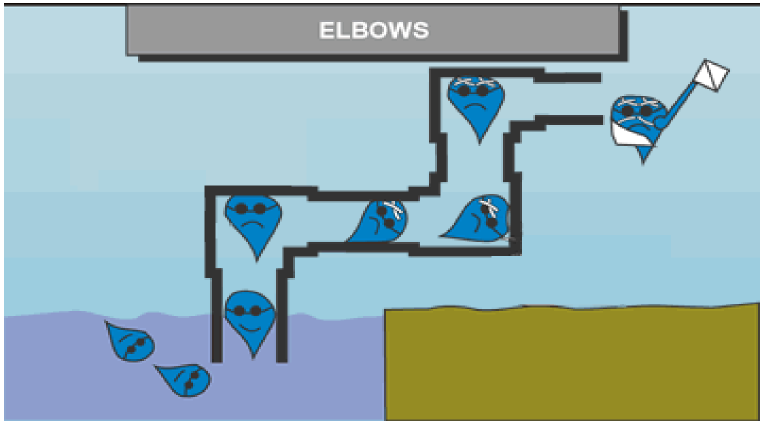
Static Head

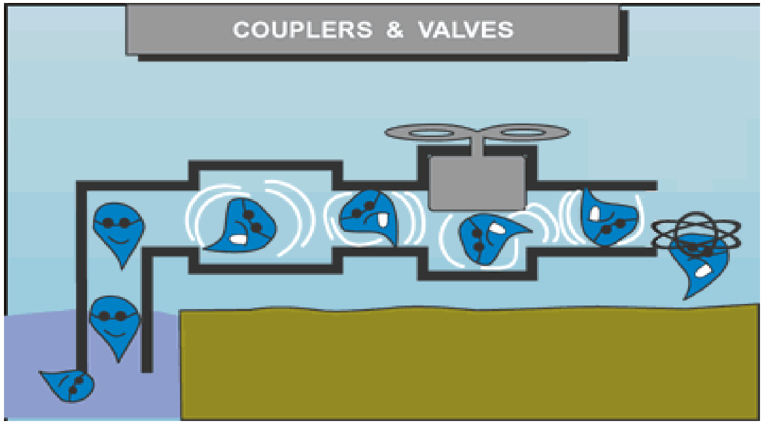


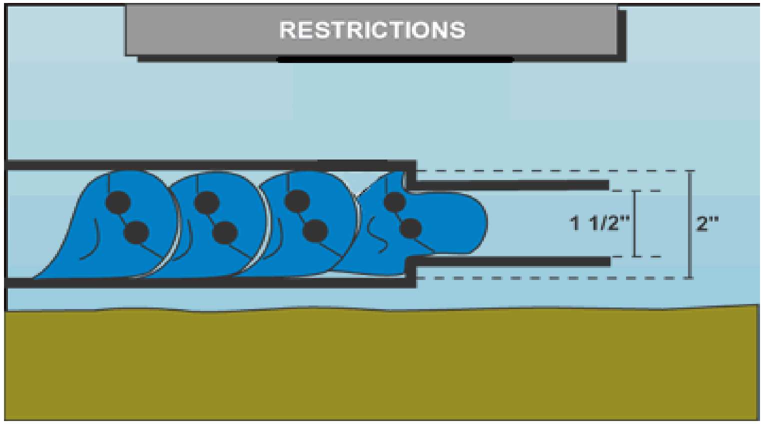


Dynamic / Frictional Effects

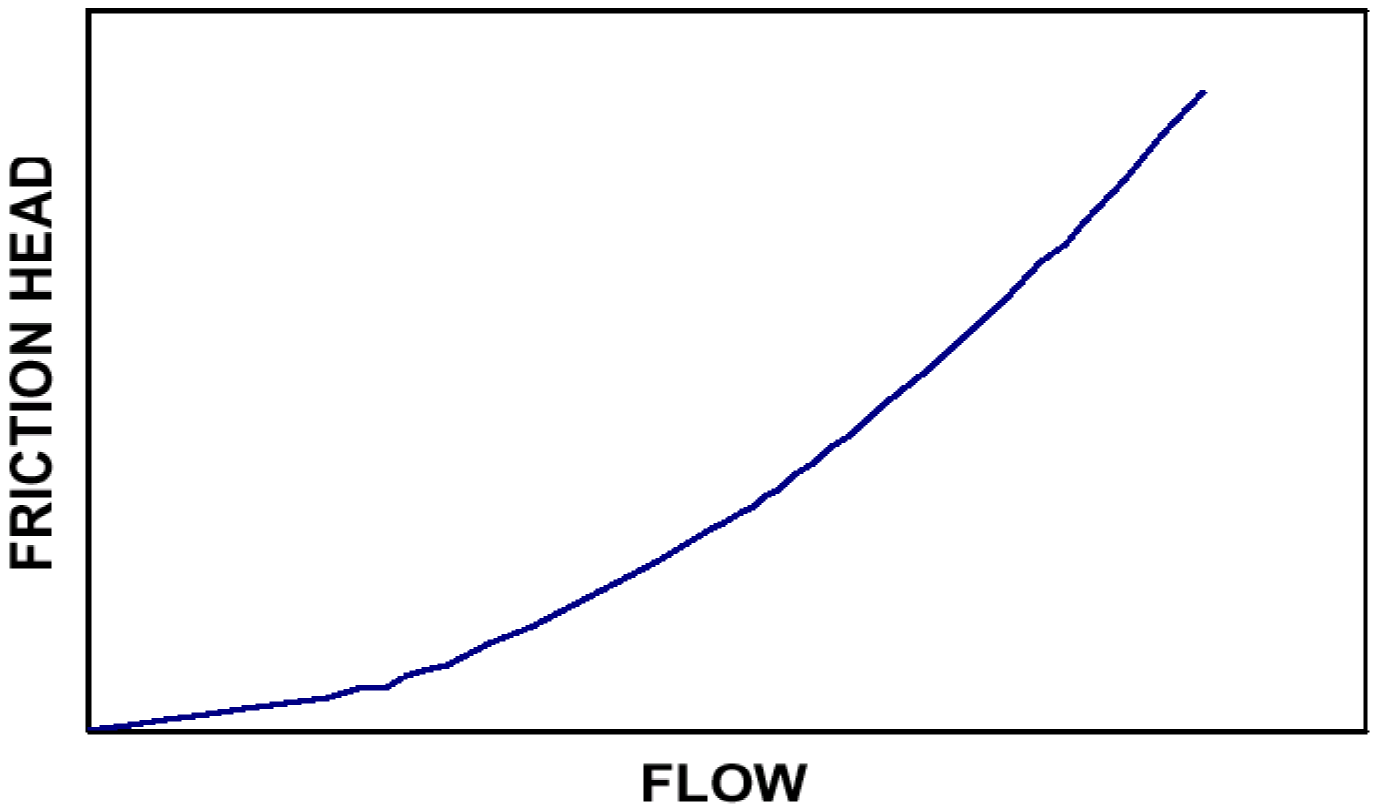




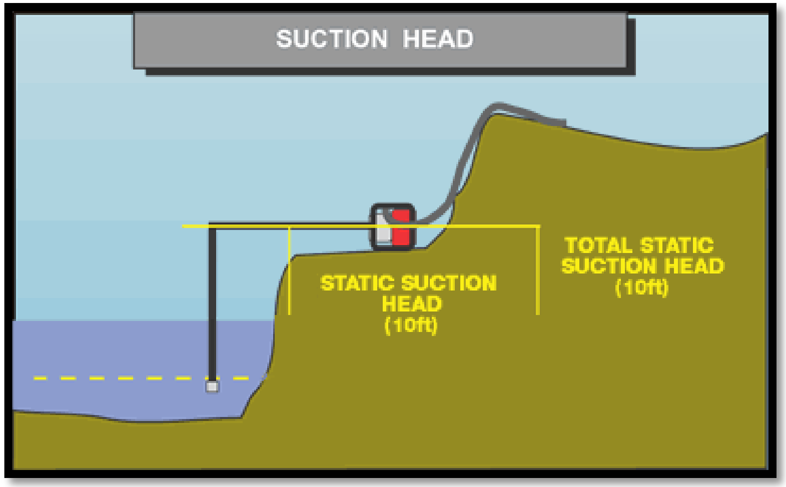


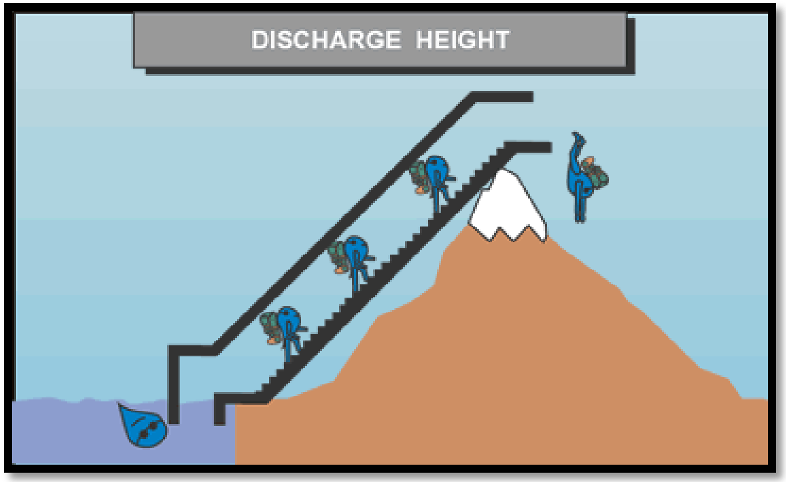


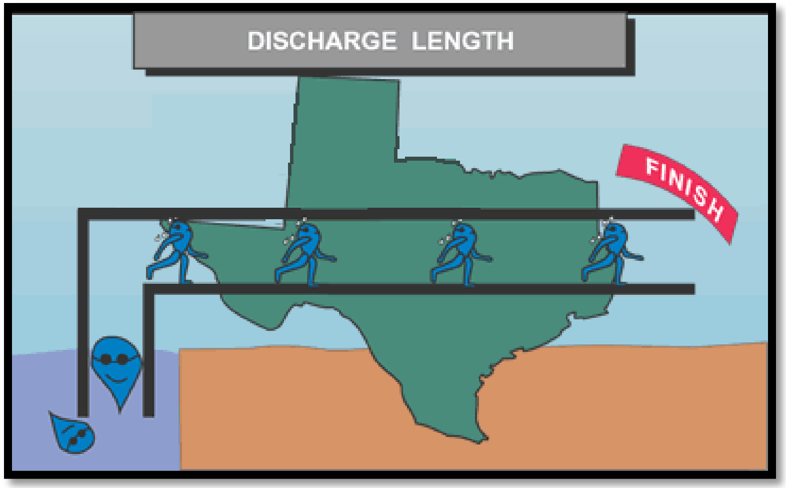
Dynamic Head (friction head)

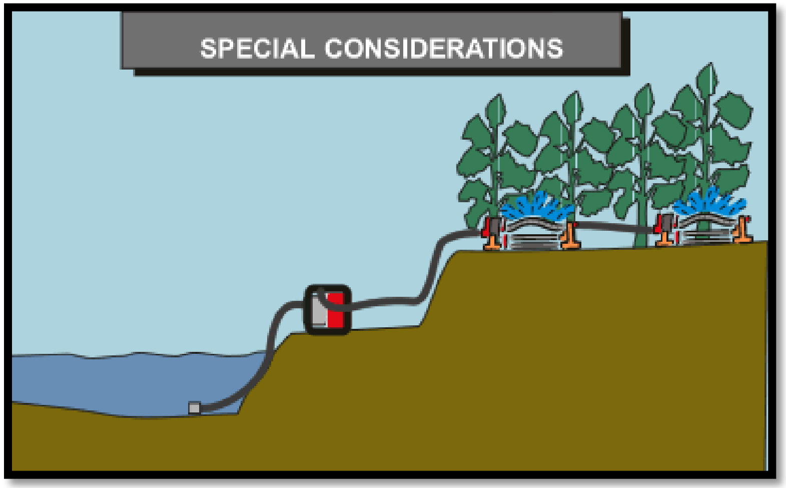


Total Head

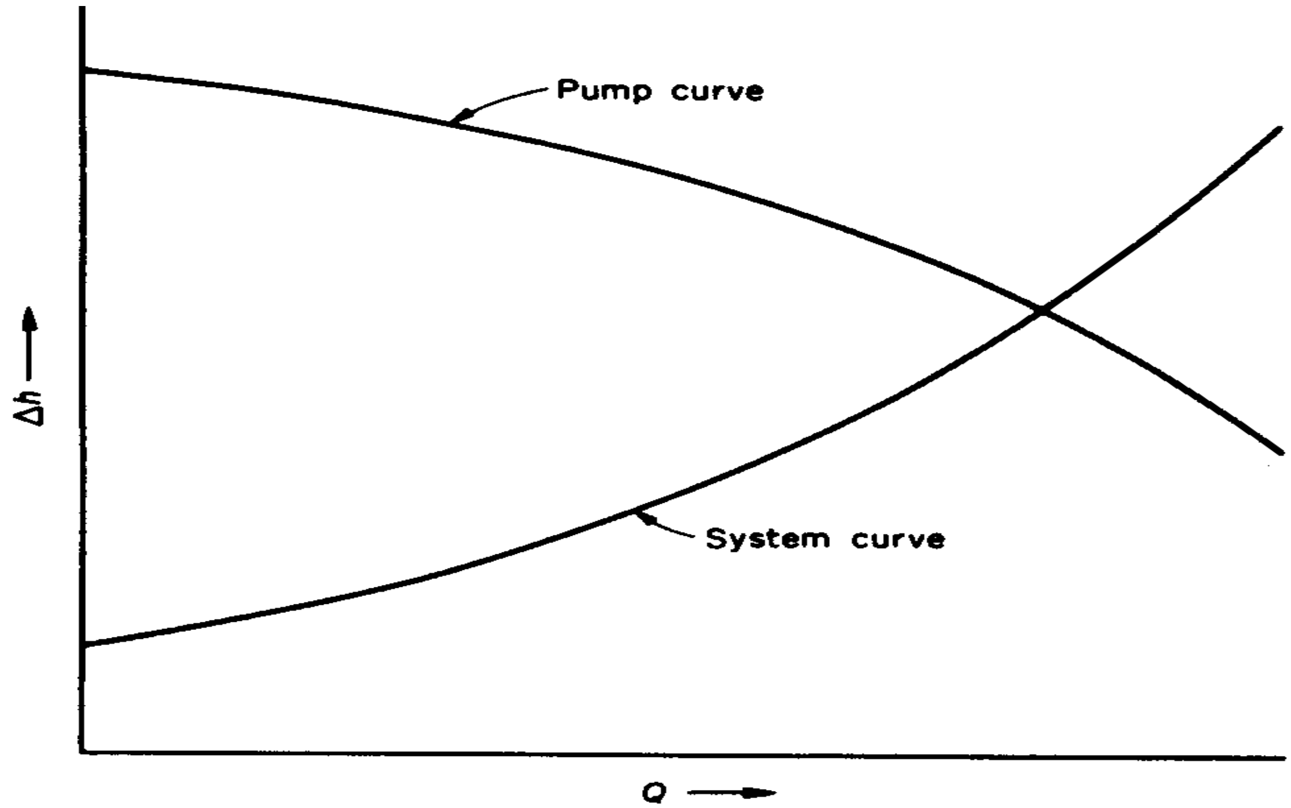

SUCTION HEAD
STATIC SUCTION HEAD (10ft)
TOTAL STATIC SUCTION HEAD (10ft)


DISCHARGE HEIGHT


DISCHARGE LENGTH
FINISH

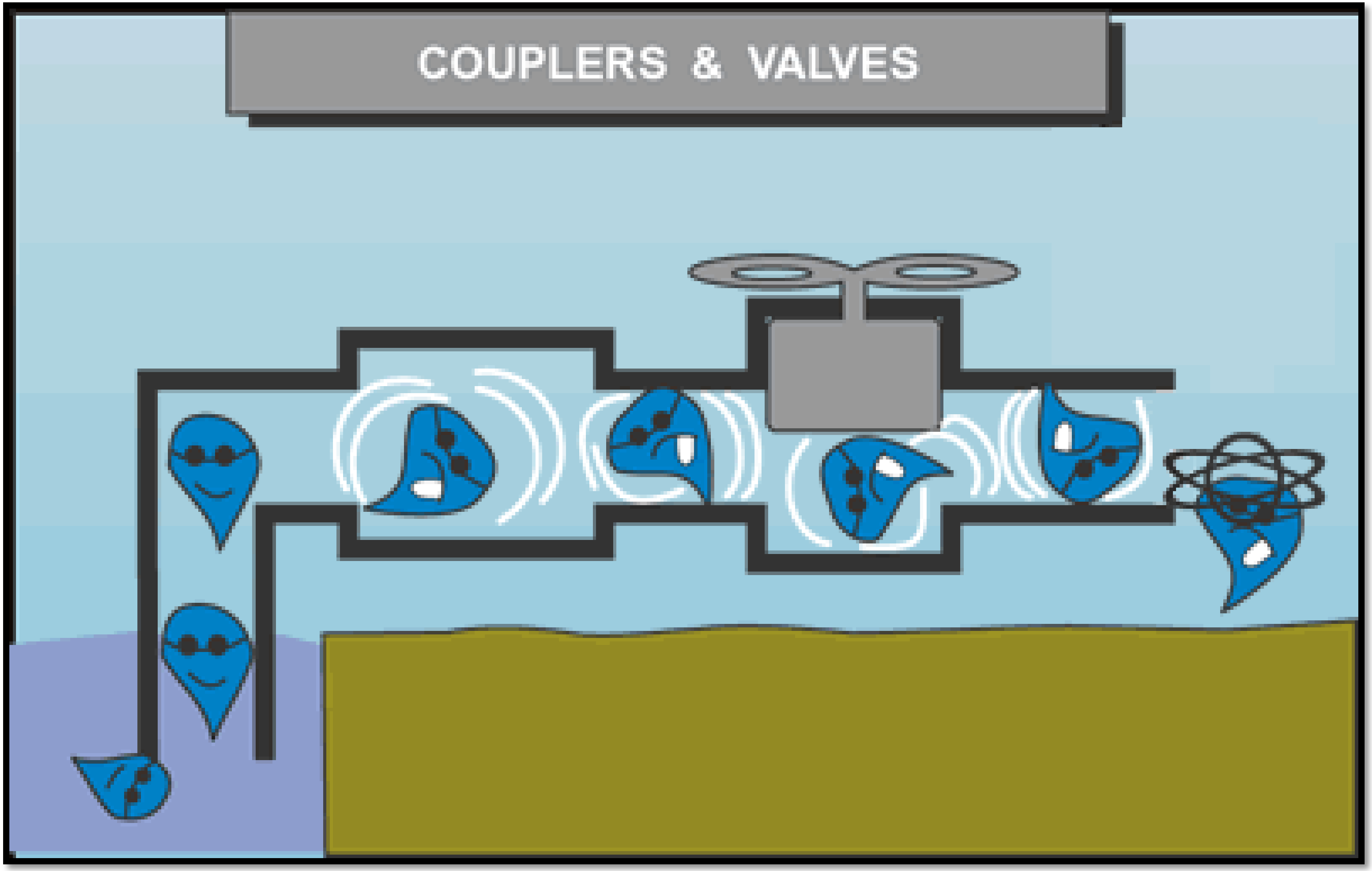

SPECIAL CONSIDERATIONS

Operating Point Defined

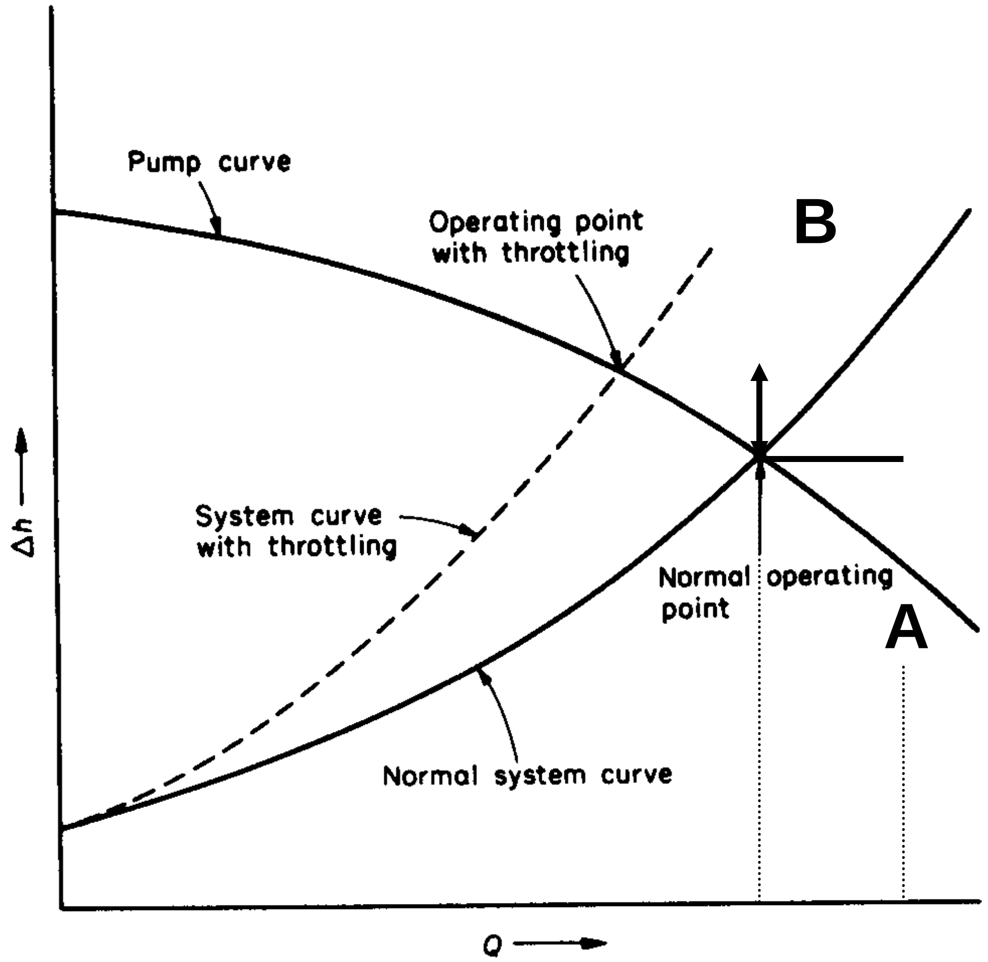


System and pump total head against capacity curves. The intersection of the two curves defines the operating point

Operation with Throttling



Operation with Throttling

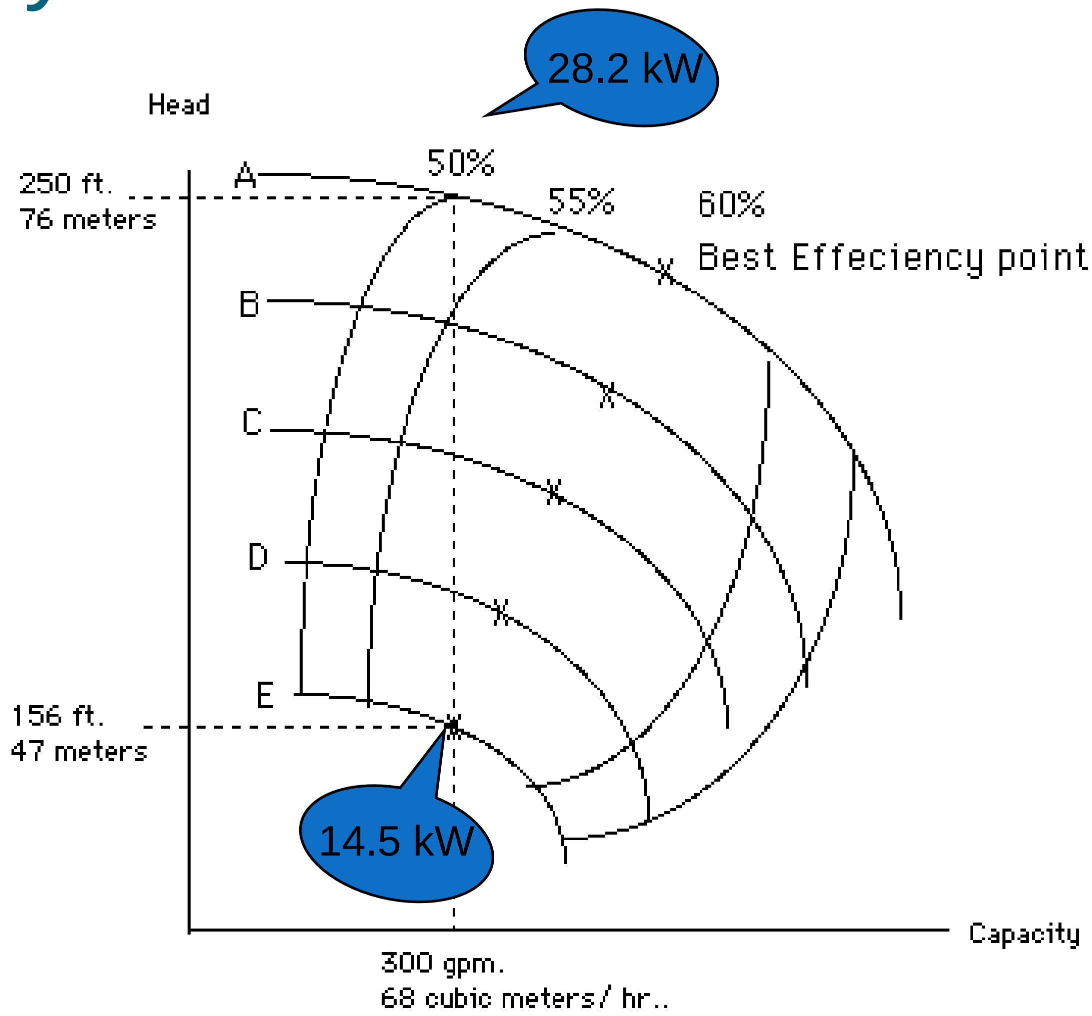


Effect of throttling the discharge valve on the operating point of a centrifugal pump

Example for Throttling Operation

Parameters	Unit	Part A	Part B	Part C
Flow	m^3/hr	500	300	300
Head	M	50	70	42
Power	kW	83	74	45
Efficiency	%	82	77	77
Remarks		Existing pump	Throttling operation	New small pump, trimmed impeller, VSD in use

Efficiency Curves



Pump Parameters for Selection

Required Pump parameters:

Q = 68 m^3/h;   H = 47 m

Selection of pump:

Parameter	**Unit**	**E-pump**	**A-pump**
Flow	m^3/h	68	68
Head	M	47	76
Efficiency	%	60	50
Hydraulic power	kW	8.7	14.0
Shaft power	kW	14.5	28.2

Oversized Pumps

Why are oversized pumps so common?

- Safety margins were added to the original calculations.
  - Several people are involved in the buying decision, each of them afraid of recommending a pump that proves to be too small for the job.
- It was the only pump the dealer had in stock and one was needed immediately. “Special deals" to take the larger size.
  - Capital for equipment is limited so the larger pump appeared to be the only choice.
- Use a pump from spare parts inventory.

Oversized Pumps

The effect of adding safety margins:

- Required flow - 150 LPS – after final calculation
  - Design Engineer – 10-15 % extra – 12% (approx.)
- New Flow - 168 LPS
  - Approval Committee – keeping future demand into consideration – Suggest – 10 % more
- Revised Flow – 185 LPS
  - Purchase Department – In View of better commercial deal supplier suggest higher capacity pump in same price range- again flow increases by 10 - 12 % approx.
- **Final Flow- 207 LPS**
- **Net Increase in Flow – 38 % - at the time of Installation**
- Final effect at operation end - **Throttling** to get reduced flow

Pump Affinity Laws

A. Effect of Change In Speed :

For a constant impeller diameter,

- Flow varies directly as speed
- Pump head varies as the square of speed
- Input power varies as the cube of speed

The Affinity Law for a Centrifugal Pump

Flow:

Q1 / Q2 = N1 / N2

Example:

100 / Q2 = 1750/3500

Q2 = 200 m^3/hr

Head:

H1/H2 = ($N1^2$) / ($N2^2$)

Example:

100 /H2 = 1750^2/ 3500^2

H2 = 400 m

Kilowatts (kW):

kW1 / kW2 = ($N1^3$) / ($N2^3$)

Example:

5/kW2 = 17503 / 35003

kW2 = 40

Pump Affinity Laws

B. Effect of Change in Size :

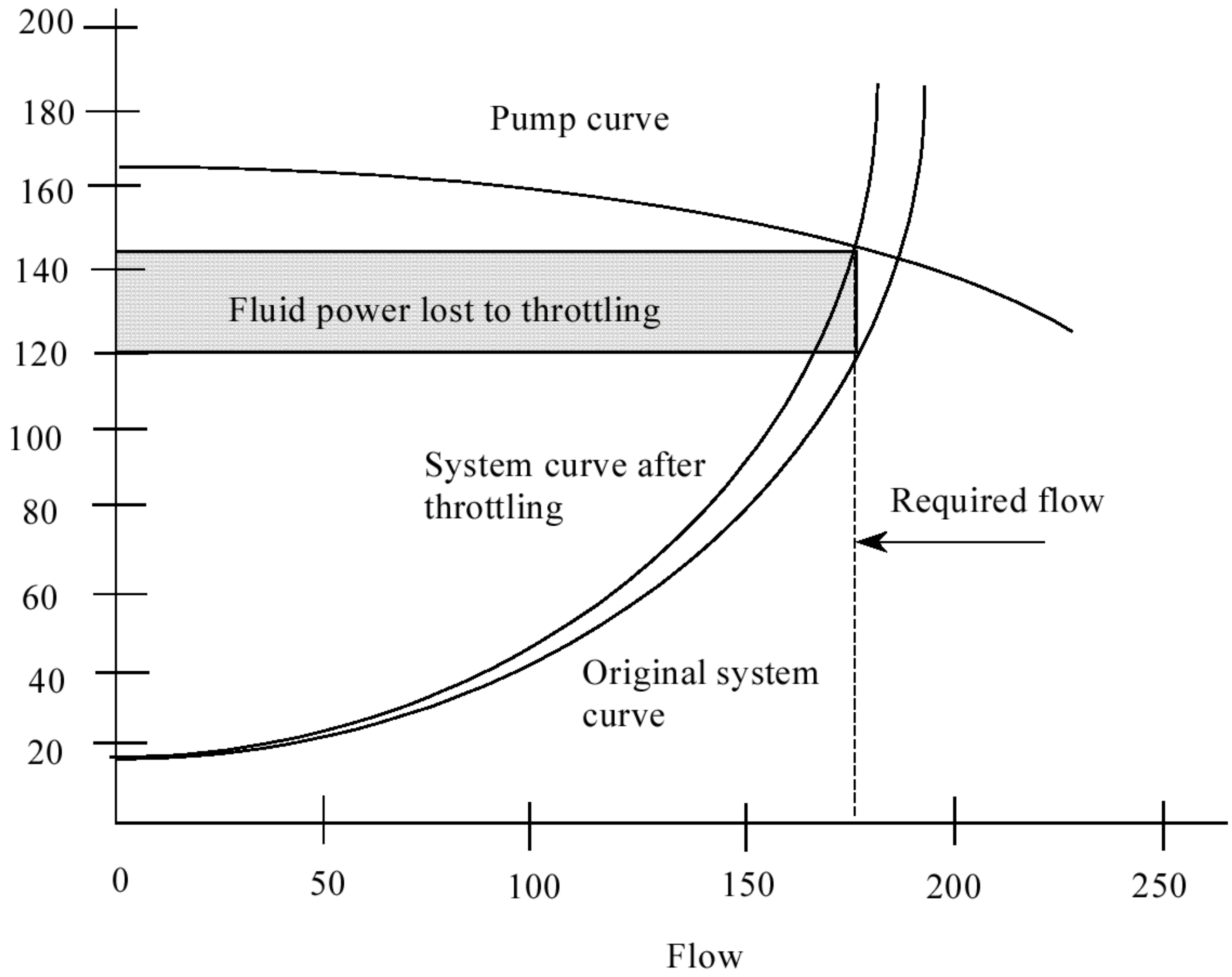
For a given casing with different impellers,

- Flow varies directly as impeller diameter
- Pump head varies as the square of impeller diameter
- Input power varies as cube times the impeller diameter

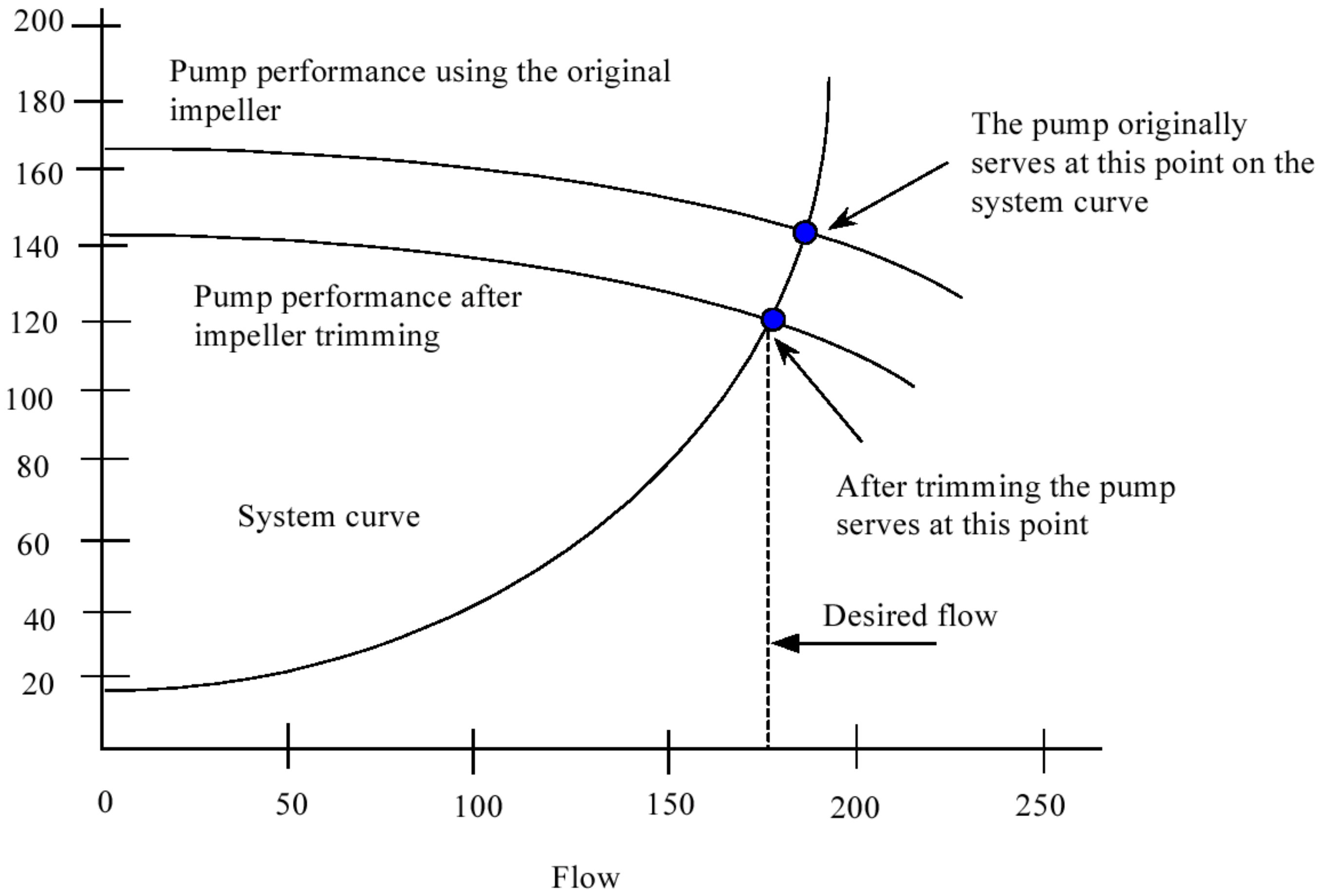
Flow Control Strategies

- Bypass valve
  - Zero savings
- Throttle output
  - Increased system pressure drop
  - Move system curve and reduces efficiency
  - Effect less in flat H-Q curve
- Trim impeller
- Variable speed drive
  - Most efficient
  - Different flow rates without affecting efficiency

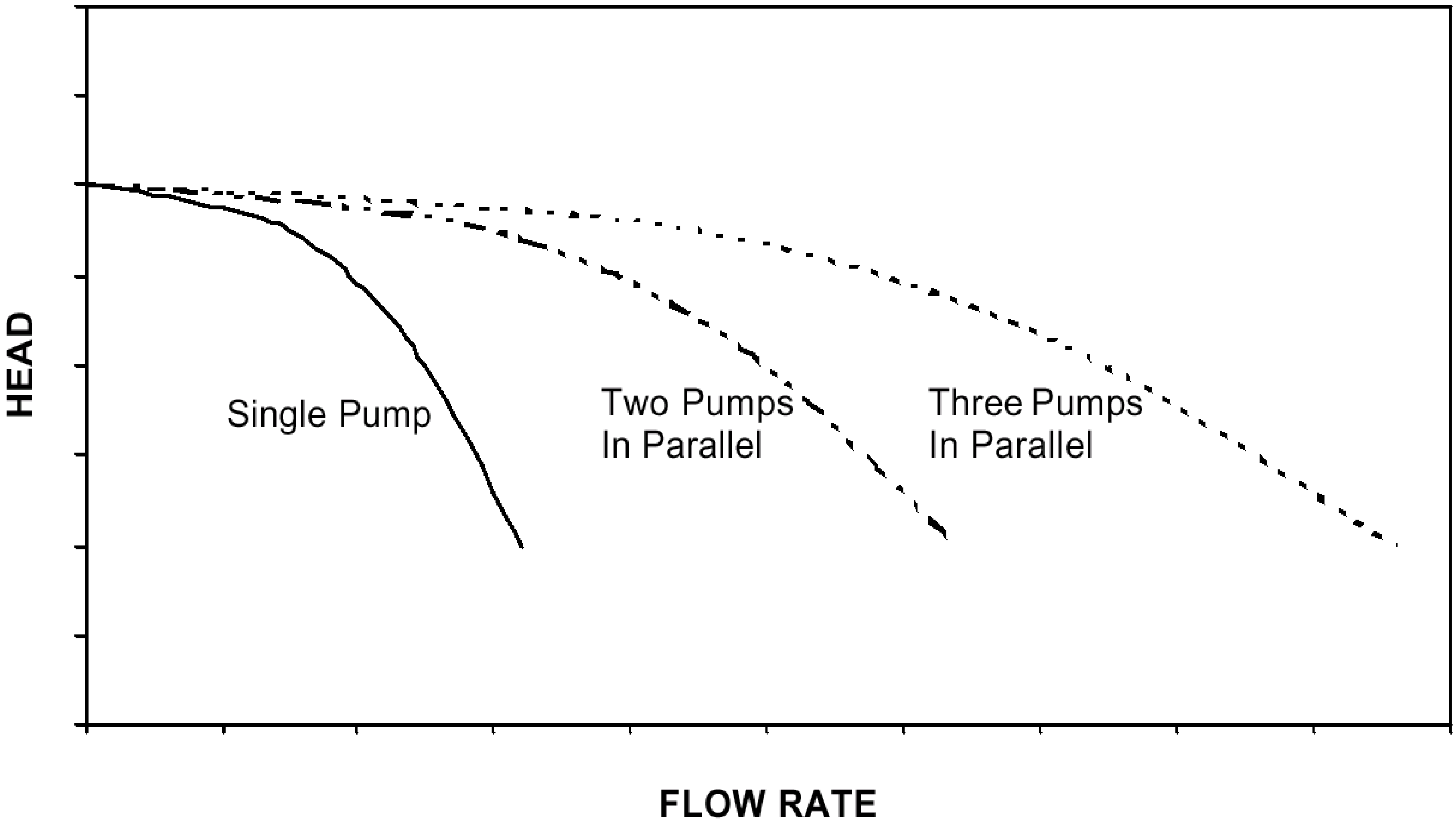
Throttling Before Impeller Trimming



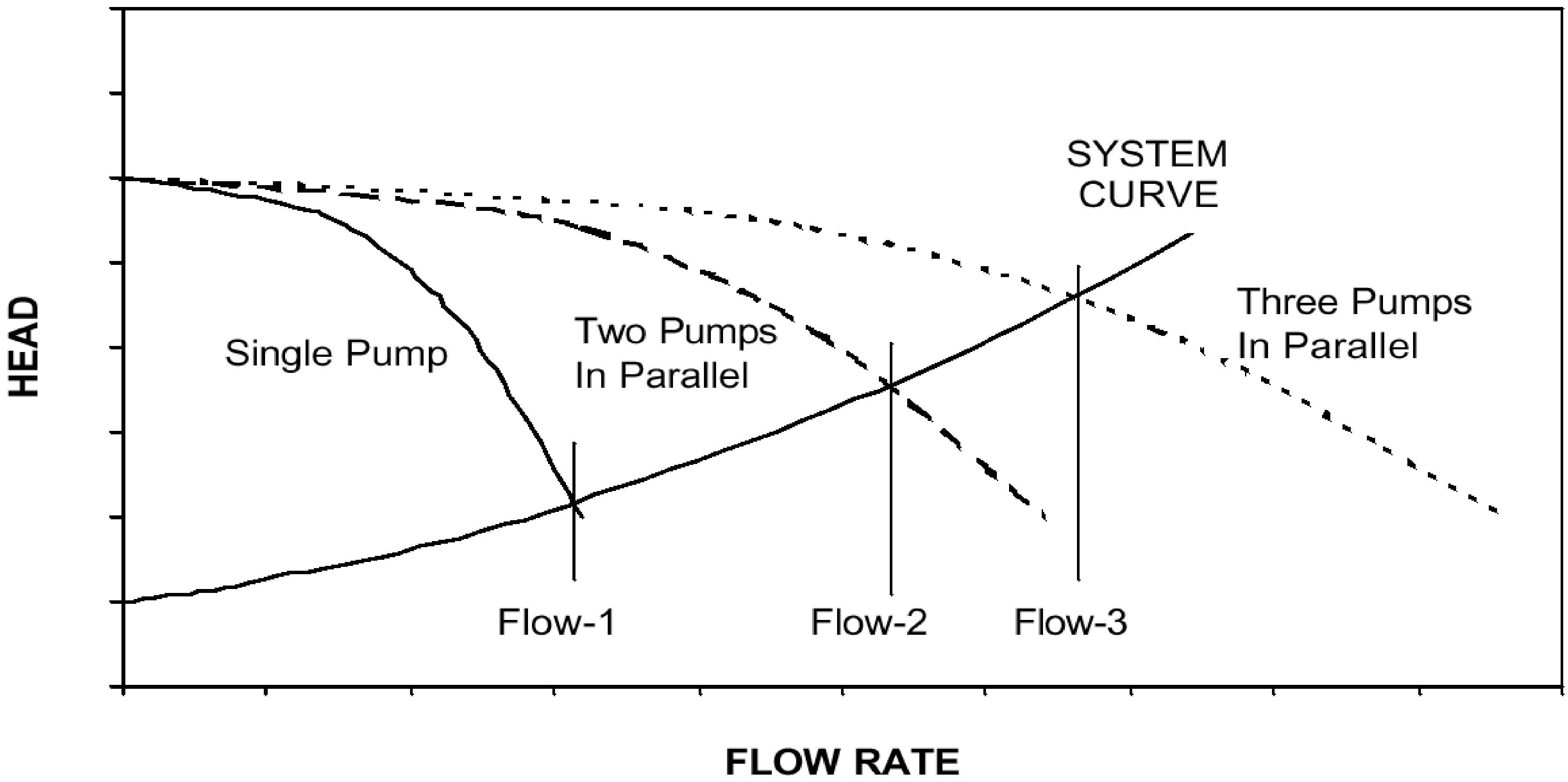
After Impeller Trimming



Parallel Operation of Pumps



Head & Flow Curve for Parallel Operation



Energy Efficiency Measures

- Operate pumps near to best efficiency point .
- Modify pumping system and pump losses to minimize throttling operation.
- Install VFDs in case of variable demand pattern or:
  - Sequenced control of multiple pumps
- Use booster pumps for small load requiring higher pressure.
- Replace old pumps by energy efficient pumps.

Energy Efficiency Measures

- Replace old motors with energy efficient motors.
- In multiple pump operations, judiciously mix the operation of pumps and avoid throttling.
- Trim impeller for reduced flow and head (practical limitation of 10% reduction in diameter).
- If the head and flow is higher than requirement by 5-15%,
  - The existing impeller should be trimmed to a smaller diameter, or
  - install a new impeller with a smaller diameter
- Monitor all important system parameters: motor kW, pump head, flow, etc

Energy Management in Water Supply Systems
- Motors

APEC
Asia-Pacific
Economic Cooperation

Hotel Hilton Hanoi Opera
9th of March 2010
By: Pradeep Kumar

ALLIANCE TO
SAVE ENERGY
Creating an Energy-Efficient World

Electric Motors

Introduction

- The electric motor is the single largest electricity-using device in the world.
- Implementing efficiency improvements can help avoid the need for expanding electricity supply -- and is a more cost effective & environmentally friendly solution.

Basic Concept of Motor Efficiency

- System analysis
  - Motors are a part of a system
  - Optimize the process

- Integrate measures
  - Focus on integrated packages of savings opportunities rather than isolated measures, since many savings are inter-dependent

Motor Characteristics

Motor Speed

- The speed of a motor is the number of revolutions in a given time frame, typically revolutions per minute (RPM).
- Speed depends on the frequency of the input power and the number of poles.

Synchronous speed (RPM) = 120 x frequency / No. of Poles

Motor Characteristics

Motor Speed

- Actual speed is less than the synchronous speed. The difference between synchronous and full load speed is called slip (measured in %)
- Slip (%) = $\frac{\text{Synchronous Speed} - \text{Full Load Speed}}{\text{Synchronous Speed}} \times 100$
- Theoretically, the speed of an AC motor can be varied infinitely by changing the frequency.
- With the addition of a variable speed drive (VSD), the speed of the motor can be decreased as well as increased.

Motor Characteristics

Power Factor

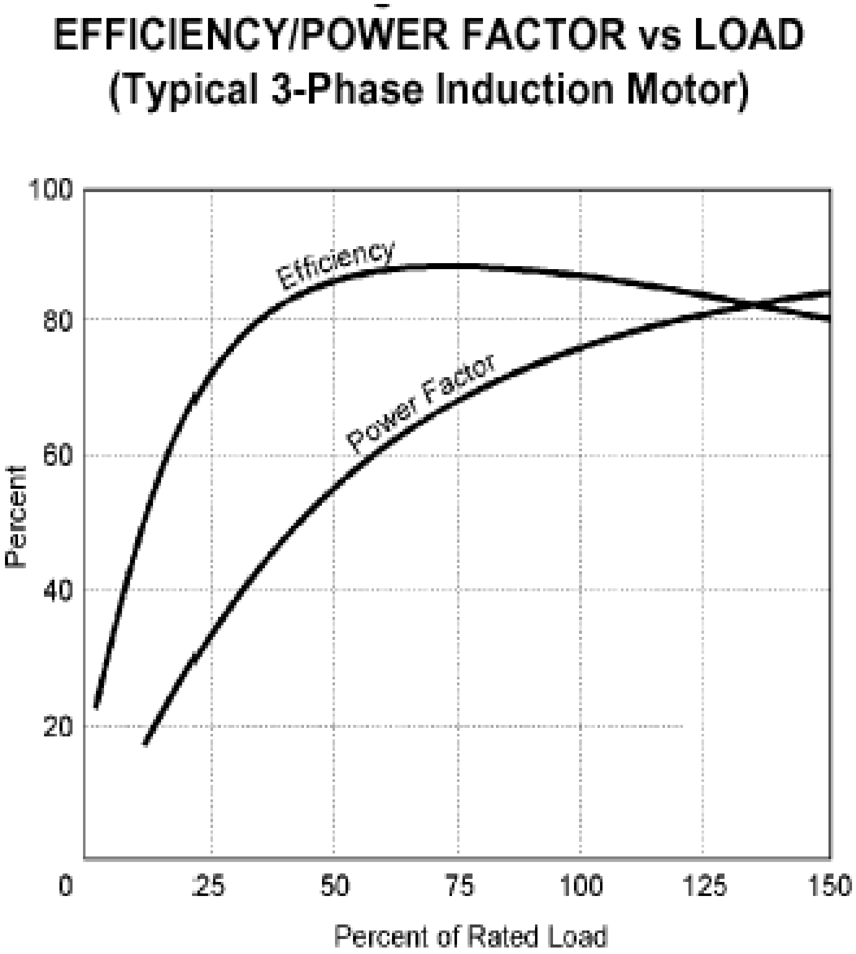
- Power Factor = cosØ = kW/kVA
- As the load on the motor comes down, the magnitude of active current is reduced -- but not the corresponding magnetizing current, which is proportional to the supply voltage. As a result, the Power Factor decreases.

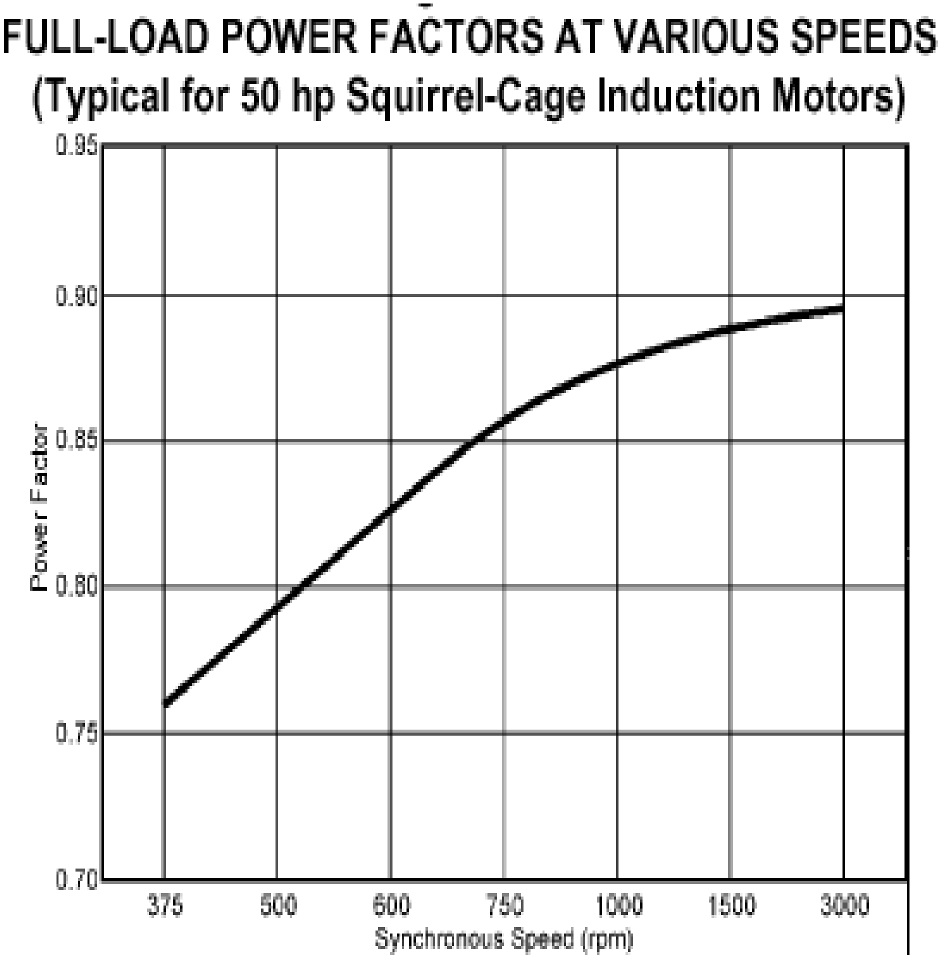
Motor Efficiency (η)

- Two important attributes relating to efficiency of electricity use by motors are:
  - Efficiency – ratio of the mechanical energy delivered at the rotating shaft to the electrical energy input at its terminal
  - Power Factor
- A higher value for η and a PF close to unity are desired for overall efficiency of the system
- Squirrel cage motors are normally more efficient than slip-ring motors.
- Higher speed motors are normally more efficient than lower speed motors.
- Also, motor efficiency increases with the rated capacity.

Motor Efficiency

Effect of load and Speed on Power Factor





Motor Efficiency

- Efficiency of a motor is determined by intrinsic losses that can be reduced only by changes in motor design.
- Intrinsic losses are of two types:
  - **Fixed Losses** – independent of motor load
  - **Variable Losses** – dependent on load

Motor Efficiency

Fixed Losses

- Fixed Losses = Magnetic core losses + F&W (friction and windage) losses
  - F&W losses are caused by friction in the bearings of the motor
- Magnetic core losses = Eddy current losses + Hysteresis losses
- Vary with the core material, and with input voltage

Motor Efficiency

Variable Losses

- Consist of resistance losses in the stator and in the rotor, and miscellaneous stray losses.
- Resistance to current flow in the stator and rotor result in heat generation that is proportional to the resistance of the material and square of the current (I2R).
- Stray losses arise from a variety of sources and are difficult to either measure or calculate, but are generally proportional to the square of the rotor current.

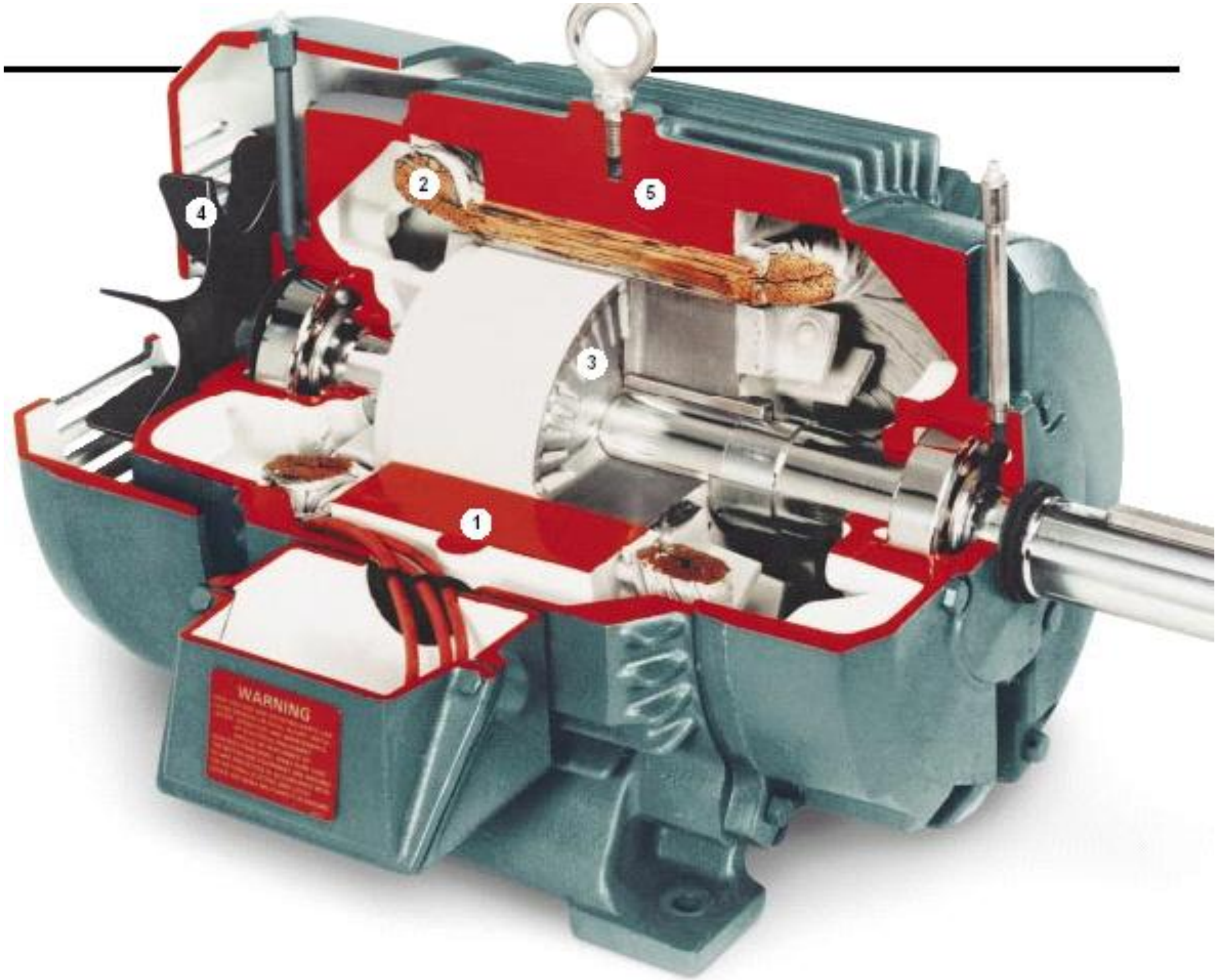
Motor Efficiency

Approximate losses in Motors**

Stator Resistance Loss	-	6.0 %
Rotor Resistance Loss	-	3.5 %
Core Loss	-	3.0 %
- Hysteresis Loss		
- Eddy Current Loss		
Friction & Windage Loss	-	0.7%
Stray Load Loss	-	1.4%
Motor Input	-	100%
Power Delivered at Shaft	-	85.4%

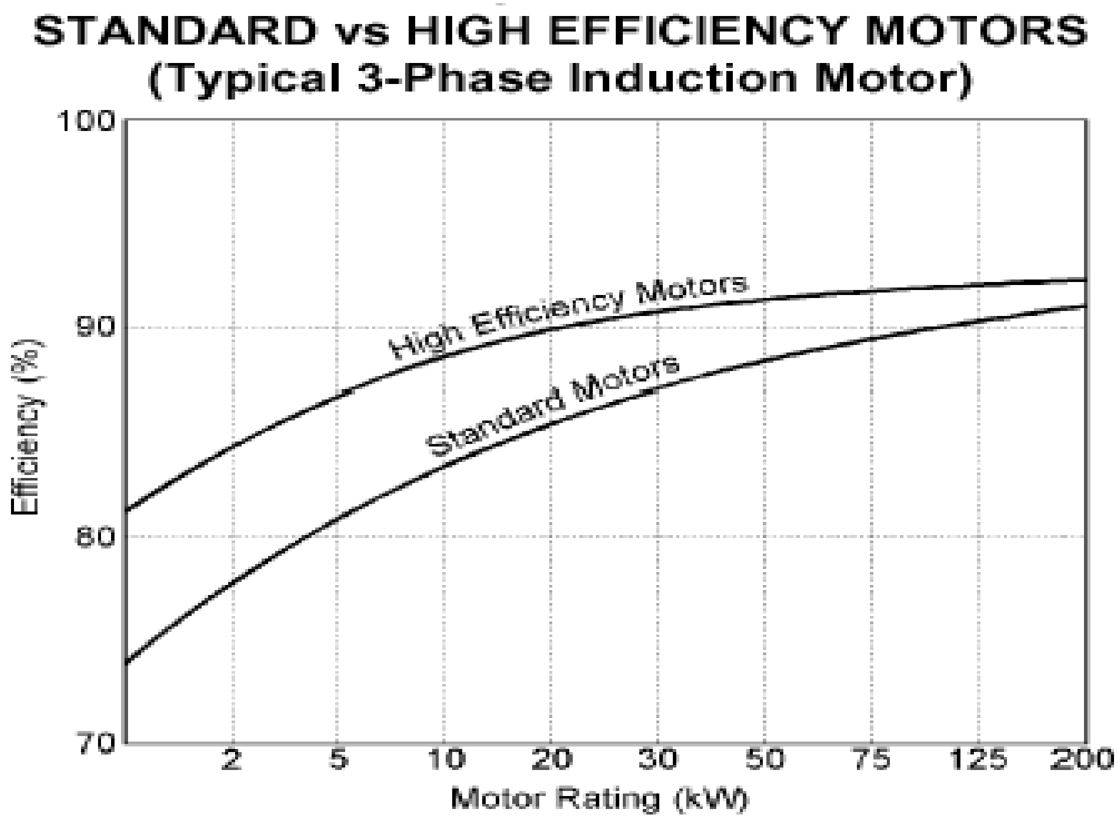
*** approximate values*

Energy Efficient Motors



Energy Efficient Motors

Energy efficient motors incorporate design improvements specifically to increase operating efficiency over standard motor design.



Energy Efficient Motors

- Improvements include:
  - Use of lower-loss silicon steel
  - Longer core (to increase active material)
  - Thicker wires (to reduce resistance)
  - Thinner lamination
  - Reduced air gap between stator and rotor
  - Copper instead of aluminum bars in the rotor
  - Superior bearings, etc.
- Energy efficient motors are designed to operate without loss in efficiency at loads between 75% and 100% of rated capacity.
- The power factor is about the same or may be higher than for standard motors.

Energy Efficient Motors

- Energy efficiency motors:
  - Have lower operating temperatures
  - Have lower noise levels
  - Are less affected by supply voltage fluctuations

- Energy efficient motors cover a wide range of ratings and the full load efficiencies are higher by 3-7%.

Optimizing Motor Performance

- Minimize Voltage Unbalance
  - Balance single phase loads
  - Segregate any single phase loads which disturb the load balance and feed them from a separate line/transformer

- Motor Loading

  Reducing Under-loading
  - Proper sizing
  - Connect to star mode

Optimizing Motor Performance

Calculate Motor Loading

% Loading

= <u>Input power drawn by the motor at existing load x 100</u>

Name plate kW rating/Name plate efficiency

- % Loading

= <u>Input power drawn by the motor at existing load x 100</u>

Name plate $\sqrt{3}$ x V x I x Cosφ rating/Name plate efficiency

Loading should not be estimated as ratio of currents

Manage Variable Load

Adopting control strategies (multi speed motors, fluid couplings and VSD)

Optimizing Motor Performance

Maintenance

- Perform regular inspection for wear in bearings and housings and for dirt/dust in motor ventilating ducts
- Check load conditions
- Lubricate appropriately
- Check periodically for proper alignment of the motor and driven equipment
- Ensure properly sized supply wiring

Optimizing Motor Performance

Motor Re-winding

- Rewinding can affect energy efficiency:
  - Winding and slot design
  - Winding material
  - Insulation thickness
  - Operating temperature

- Measure no-load losses before and after to assess the affect of re-winding

Optimizing Motor Performance

Soft Starters: Background

- At the time of start, an induction motor will develop excess torque than required at full speed.
- At the instant of start-up, there is an unnecessary heavy power surge.
- The sudden impact at start-up on the load, followed by the rapid acceleration to full speed, causes excessive wear on the mechanical drive component:
  - Belts and pulleys
  - Gears and chains
  - Couplings and bearings.
  - Cavitations in pumps etc.

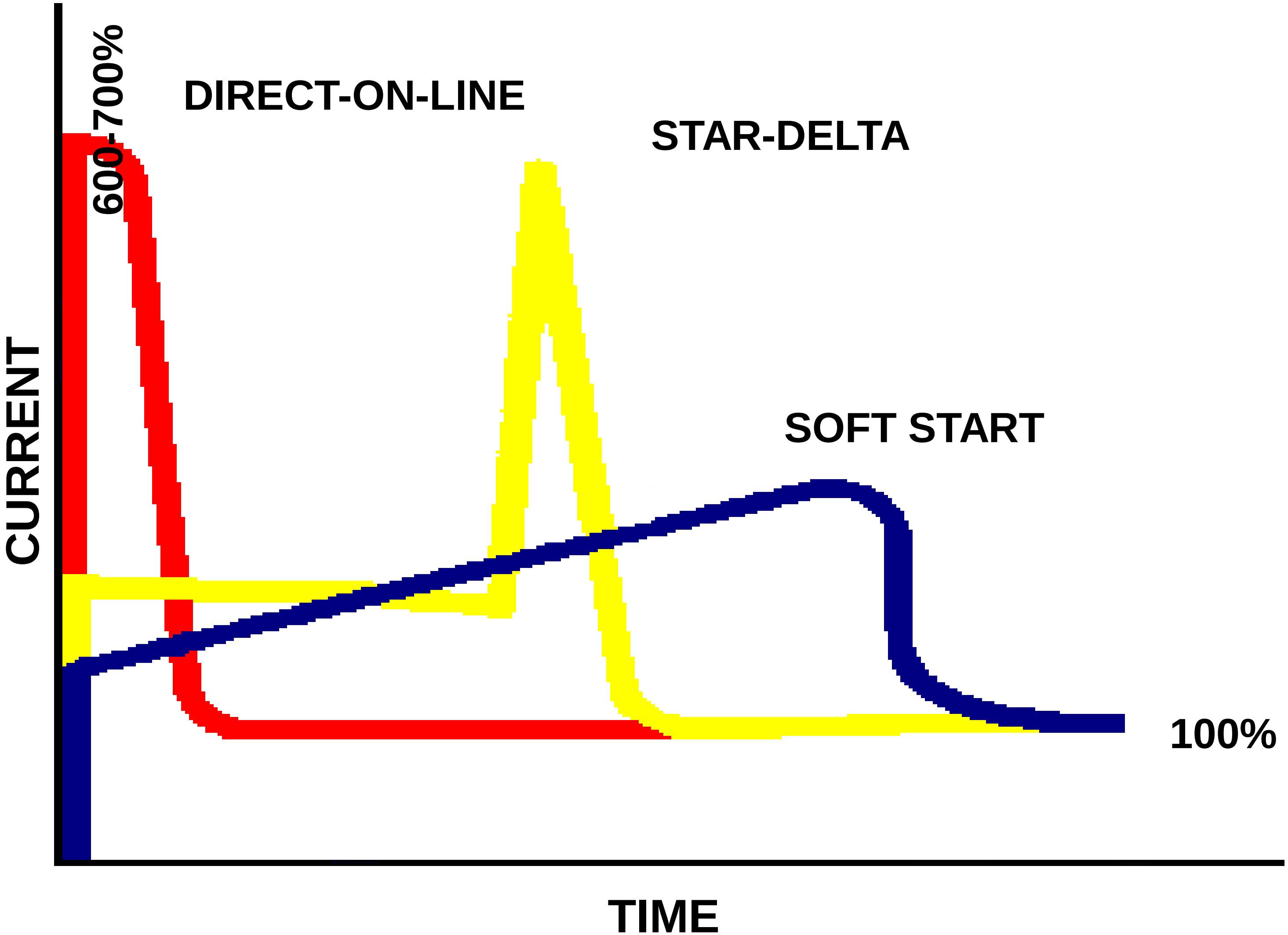
Optimizing Motor Performance

Soft Starters

- Provides controlled delivery of starting current for operation

- Advantages of soft starters:
  - Less mechanical stress
  - Improved power factor
  - Lower maximum demand
  - Less mechanical maintenance

Motor Starters



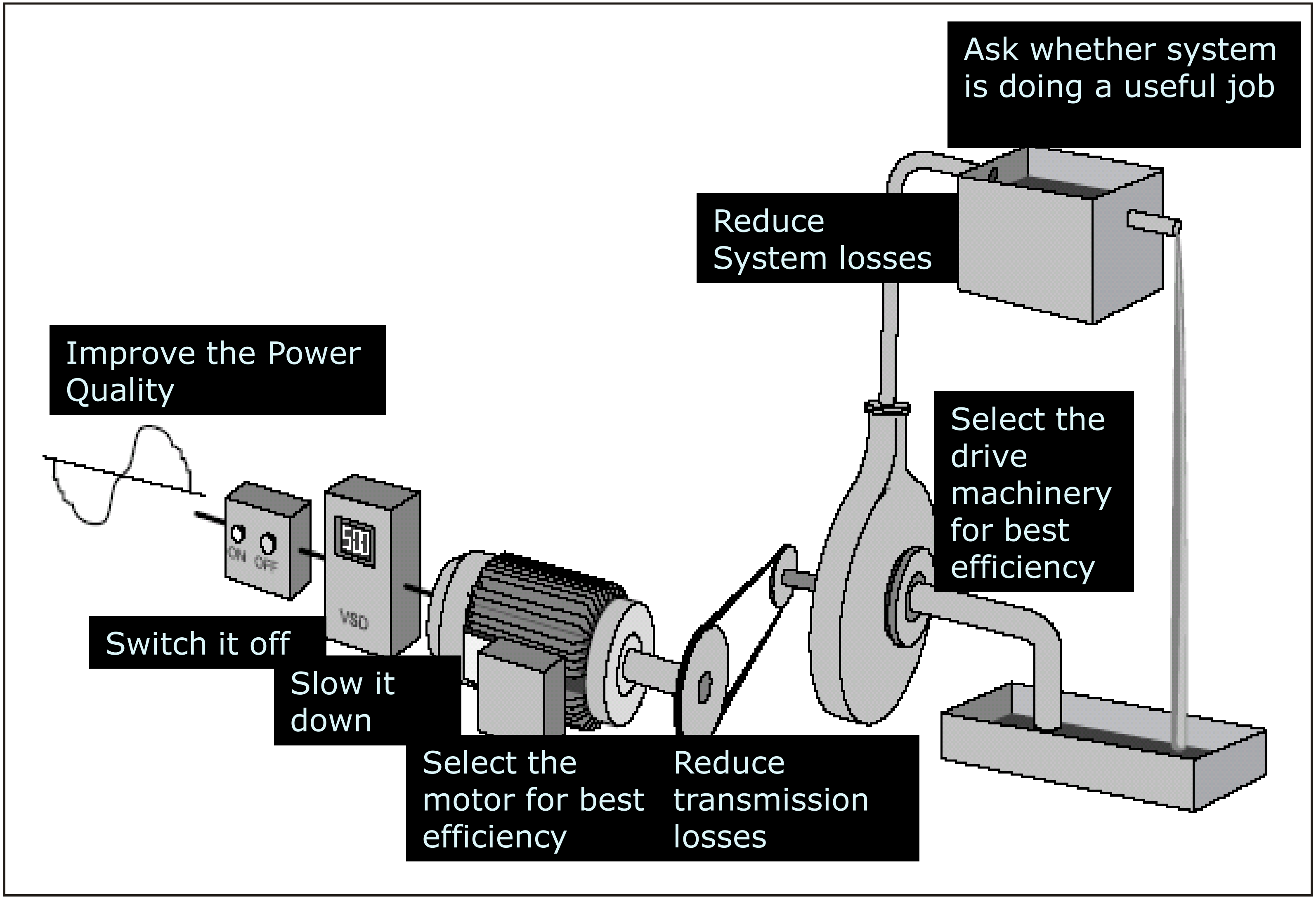
Optimizing System Performance

Other Components that Affect Energy Efficiency

- Gearboxes
  - Worm reduction box approx. 85-90% efficiency
  - Helical reduction box typically 97-98% efficiency

- Belt drives
  - Compared to a “V” belt:
    - Wedge belt gives approx. 2% efficiency improvement
    - Flat/ribbed belt up to 6%

Energy Efficiency Opportunities in Motors



Identification Of Energy Efficiency Measures

Operating motors in STAR Instead of DELTA

- For motors that constantly operate at loads below 40% of rated capacity
- Operating in STAR mode leads to a voltage reduction by a factor of '$\sqrt{3}$'
- Automatic Delta - Star mode of operating, for motors which are loaded from 40% to 80% in different cycles of loading
- This also reduces the torque capacity of the motor

Energy Efficiency Measures

- Use of energy efficient motors as retrofits (replacements) for existing old and rewound motors after a review of motor rewinding practice.
- Use of energy efficient motors for new equipment with proper sizing
- Power factor correction

Energy Efficiency Measures

- Application of soft starters
- Installation of VFDs in case of variable load pattern
- Replacement of gear box and use of fluid coupling / belt drives
- Use of dual speed motors - Application oriented

Energy Management In Water Supply Systems -Electrical Systems

Hotel Hilton Hanoi Opera

9th of March 2010

By: Pradeep Kumar

Asia-Pacific Economic Cooperation

ALLIANCE TO SAVE ENERGY

Creating an Energy-Efficient World

Electrical Energy Management (EEM)

EEM of any pumping station is based on the load estimates and planning of the distribution system.

EEM can be effectively accomplished through:

A. Operational management

B. Load management

Operational Management

Includes:

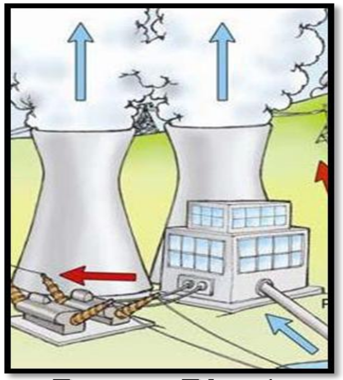
- Energy accounting - Metering of energy consumed
- Monitoring and control
- Housekeeping measures
- Reduction of losses
- End-use minimization
- Equipment operation at optimum capacity
- Selection of most efficient equipment or efficient process for operation
- Use of technology up-grades

Load Management

Includes:

- Demand management
- Transformer load management
- Power factor management

Introduction to Electric Power Supply System



Power Plant

Sub-Station (power up)

↓

High Voltage Transmission Lines

↓

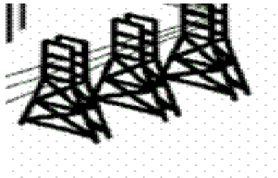
Sub-Station (power down)

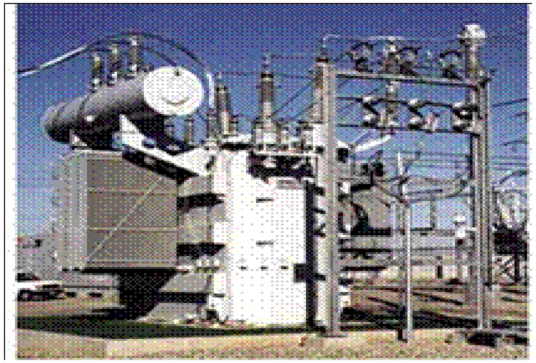
↓

Distribution Transmission Lines

↓

End User (Pumping Stations)





Introduction to Electric Power Supply System: Pumping Station

At the pumping station premises, elements like transformers, switchgears, lines and cables, capacitors and the loading equipment (e.g., motors) form the plant network. Power generation reaches the station with typical technical losses of 17%. (The efficiency of generation and transmission would be 83%.)

In a typical pumping station distribution network, transformer efficiency would be 95%;motor efficiency 90%;mechanical system efficiency 70%.Thus the overall energy efficiency becomes 50%.

(0.83 x 0.95x 0.90 x 0.70 = 0.50, i.e. 50% efficiency)

Hence one unit of energy saved by the end user is equivalent to two units generated in the power plant.

(1Unit / 0.5Eff = 2 Units).

Electrical System

- Electricity billing
- Electrical load management
- Maximum demand control
- Power factor improvement and its benefit
- Selection and location of capacitors
- Transformer losses

Electricity Billing

"The electricity bill is a periodic statement of electricity usage and its cost, issued by the electricity supplying authority to the end user, mentioning the details of electrical energy availed (both entitled and actual), maximum demand, PF, penalties and incentives, taxes, period of usage, last date of payment ,etc."

Based on monthly energy usage and issued every month.

Energy usage by consumers is monitored by energy meters installed at customer premises by electricity-supplying authorities – i.e., utilities.

Electricity Billing

The electricity billing by utilities for pumping stations often involves a two-part tariff structure:

- Capacity (or demand) drawn -- capacity or demand is in kVA (apparent power) or kW terms
- Actual energy drawn during the billing cycle or month

In addition to the above cost components, other components – e.g., Power Factor penalty/incentive, fuel escalation charges, taxes, duties and surcharges, meter rentals -- are also included in the bill.

Electricity Billing

- The energy meter at the consumer end records the maximum demand, kWh, kVAh, & kVArh consumed, power factor.

- Where an analog meter is used, the average power factor of the plant is determined/estimated by taking the ratio of monthly kWh and kVAh recordings.

Electricity Billing

The maximum demand (MD) recorded is not the instantaneous demand drawn, but rather the time-integrated demand over a predefined recording cycle.

As an example, in a pumping station, if the drawl over a recording cycle of 30 minutes is:

300 kVA for 4 minutes;

450 kVA for 12 minutes;

250 kVA for 6 minutes;

280 kVA for 8 minutes;

The maximum demand recorder will be computing MD as:

$$\frac{(300 \times 4) + (450 \times 12) + (250 \times 6) + (280 \times 8)}{30}$$

= 345 kVA

Electrical Load Management

What is Electrical Load Management?

- Electrical load management is the process of scheduling load usage so as to reduce the electricity use during peak load periods.

Why the Need for Electrical Load Management?

- Growth in electricity use, the diversity of end uses, and time of use has led to shortfalls in capacity to meet demand.
- Since capacity addition is costly and a long-term prospect, better load management at the user end helps to minimize peak demands on utility infrastructure and to better utilize power plant capacities.

Electrical Load Management

Why the Need for Electrical Load Management? Cont.

Utilities (Electricity Boards) use power tariff structures to promote better load management by end users through measures such as:

- Time of use tariffs,
- Penalties on exceeding allowed maximum demand,
- Night tariff concessions.

Load management is a powerful means of efficiency improvement for both the end user and the utility.

Demand Management

"Demand management commonly refers to a set of measures taken to reduce the maximum demand of the system without affecting the plant output."

Since demand charges account for a considerable portion of the electricity bill, there is also a need for integrated load management from the user angle to effectively control the maximum demand.

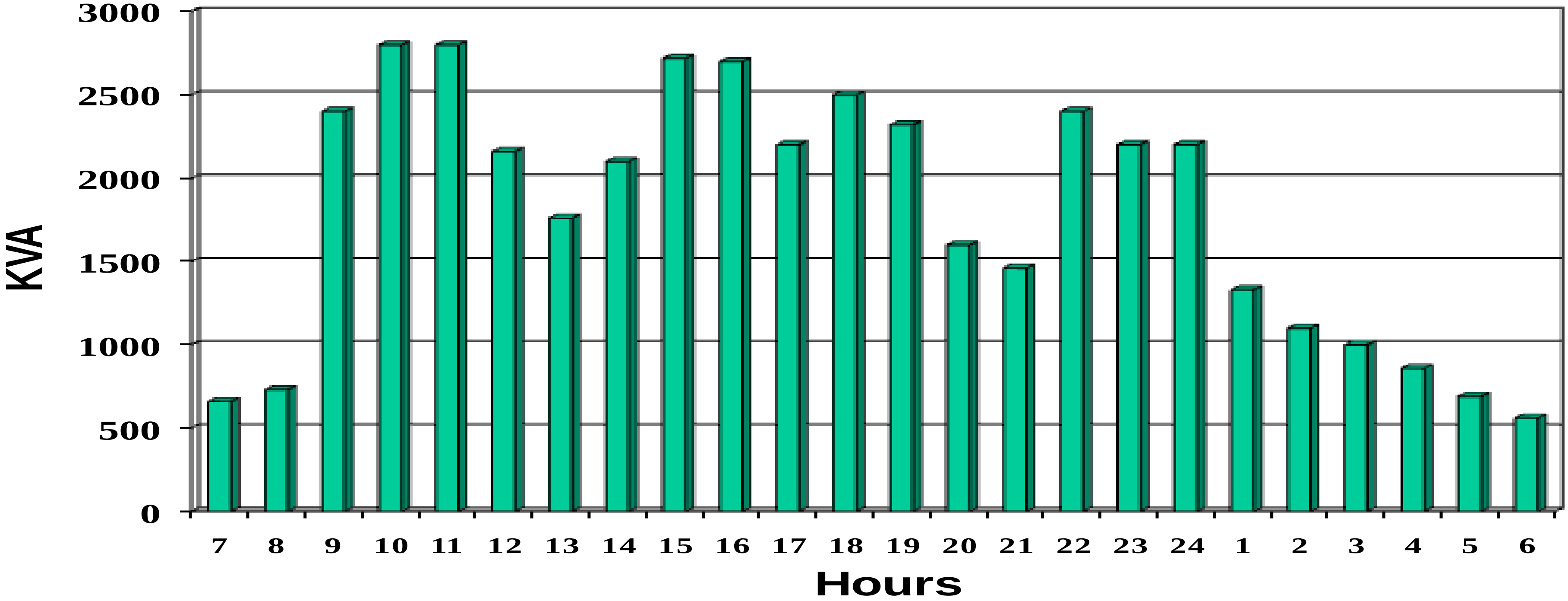
Maximum Demand Control

1. Plot monthly/weekly/daily load curves.
2. Start with the largest time scale.
3. Analyze bill by asking probing questions.
4. Identify measures to control.

Observe Maximum Demand	Identify
Monthly Basis (2-3 year period)	**Demand pattern over year (specific months of more demand)**
Daily basis (one billing period)	**Day of higher demand in a month**
Hourly basis (a typical day)	**Time of the day that Maximum Demand occurs**

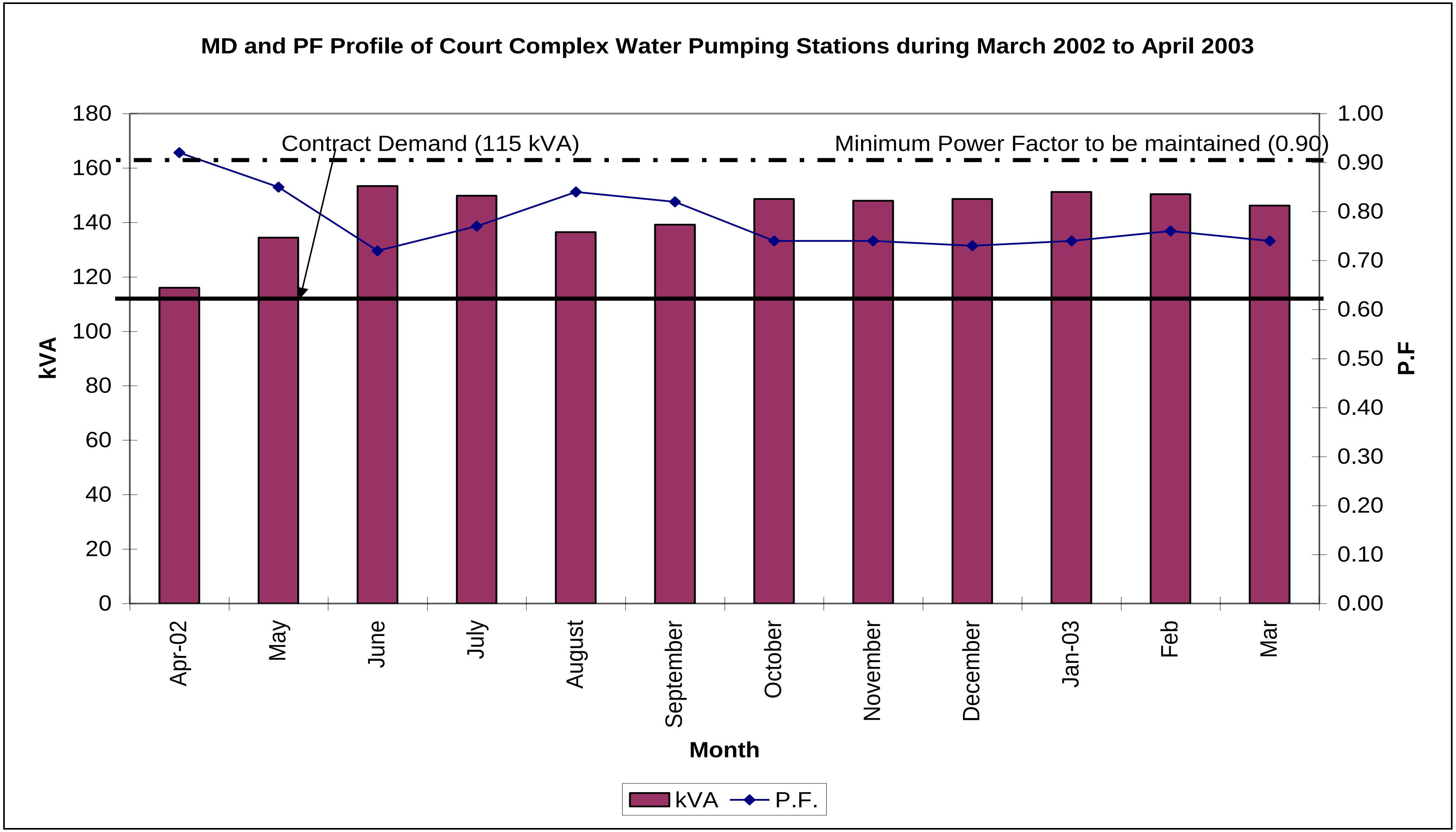
Maximum Demand Control

Daily load curve

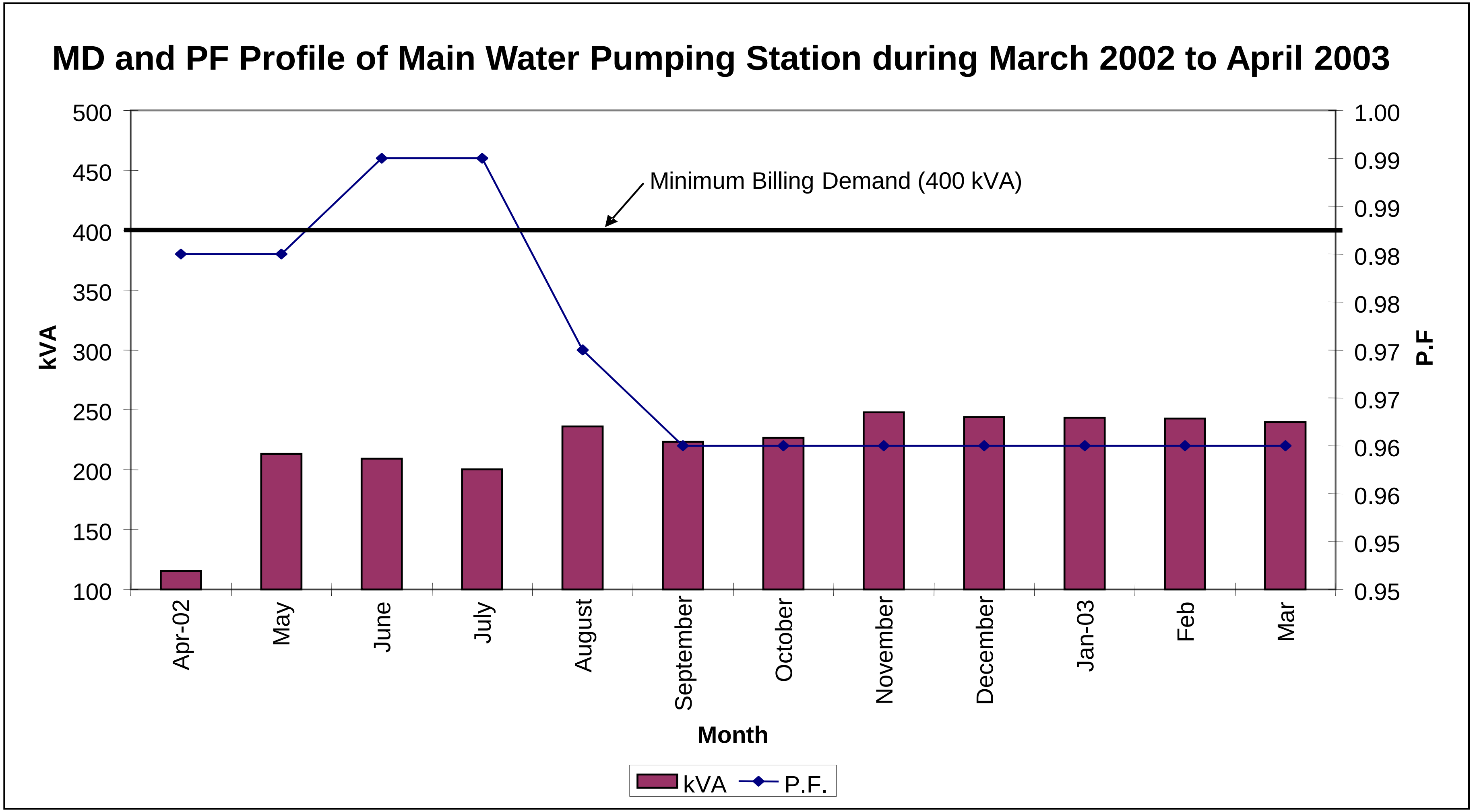


Maximum Demand
(Daily Load Curve,Hourly kVA)

Case # 1: Maximum Demand Profile of a Typical Pumping Station



Case # 2: Maximum Demand Profile of a Typical Pumping Station



Maximum Demand Control

- More closely scrutinize energy bills.
- Identify variations in minimum & maximum of demand in various seasons/conditions.
- Analyze loads contributing to demand peak.
- Identify non-priority loads.
- Determine when MD occurs (time/day).
- Define which loads could be:
    - Re-scheduled
    - Reduced
    - Turned off during peak load time

Methods of Maximum Demand Control

- Manual type
- Load scheduling
- Demand monitoring activity
- Alarm set-up
- Automatic demand controllers
- Energy management system

Power Factor Improvement

Power Factor Basics

To understand power factor, we'll first start with the definition of some basic terms:

KW is Working Power (also called Actual Power, Active Power or Real Power). It is the power that actually powers the equipment and performs useful work.

KVAR is Reactive Power. It is the power that magnetic equipment (transformer, motor and relay) needs to produce the magnetizing flux.

KVA is Apparent Power. It is the "vectorial summation" of KVAR and KW.

Selection of Capacitors

Capacitor sizing can be done using the following equation:

kVAr Rating = kW(Tan Φ Old – Tan Φ New)

where, kVAr rating is the size of the capacitor needed,

kW is the average power drawn,

Φ_{Old} = Existing (Cos^{-1} PF) and

Φ_{New} = Improved (Cos^{-1} PF)

To determine capacitor kVAr requirement for PF correction, several standard charts are available. Using the available chart one can suitably size the capacitor requirement to a desired power factor.

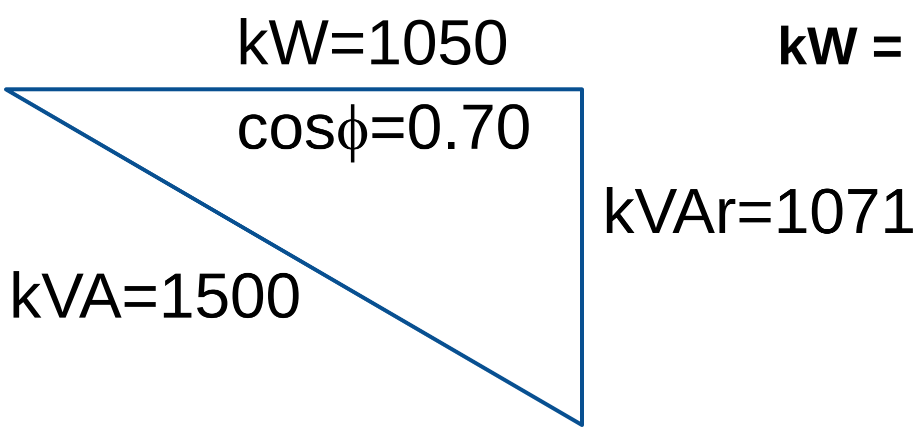
Selection of Capacitors

Problem:

A pumping station has a 2000 kVA rated transformer, loaded to 1500 kVA with pf = 0.70. Calculate the capacitor required to improve pf = 0.90. What is the kVA demand release?

If 1600 kVA is the contract demand & billing demand is 75% of contract demand, what would be the demand savings at Rs 180 per kVA?

Solution:



kW = kVA x PF = 1500 x 0.70= 1050

$kVAr^2 = kVA^2 – kW^2$

$kVAr = \sqrt{1500^2 - 1050^2}$

$= 1071$

Location of Capacitors

- Options:
  - At HT bus / transformer
  - LT bus of transformer
  - Main sub-plant buses
  - Load points
- Hence:
  - Identify the sources of low power factor loads in plant.
  - Locate close to end equipment to reduce I2R loss.
  - Release of system capacity(kVA) happens if reactive current is reduced.

Rating of Transformers

- The kVA rating of the transformer is calculated based on the connected load and a diversity factor that is applicable to the particular industry.
- The diversity factor is defined as the ratio of overall maximum demand of the pumping station to the sum of individual maximum demand of various equipment.
- The diversity factor varies from station to station and depends on various factors such as individual loads, load factor, and future expansion needs of the station. The diversity factor will always be less than one.

Transformer Losses

- Transformer losses consist of two parts:
  - **No-load loss (also called core loss)** is the power consumed to sustain the magnetic field in the transformer's steel core. Core loss occurs whenever the transformer is energized; core loss does not vary with load.
  - **Load loss (also called copper loss)** is associated with full-load current flow in the transformer windings. Copper loss is power lost in the primary and secondary windings of a transformer due to the ohmic resistance of the windings.

Transformer Losses

- Voltage in transformers is regulated by altering the voltage transformation ratio with the help of tapping.
- There are two available methods of tap changing:
  - Off-circuit tap changer: A device fitted in the transformer, which is used to vary the voltage transformation ratio. The voltage levels can be varied only after isolating the primary voltage of the transformer.
  - On load tap changer (OLTC): The voltage levels can be varied without isolating the connected load to the transformer, to minimise the magnetisation losses and to reduce the nuisance tripping of the plant.
- The on-load gear can be put in auto mode or operated manually depending on the requirement. OLTC can be arranged for transformers of size 250 kVA and up. However, the necessity of OLTC below 1000 kVA can be considered after calculating the cost economics.

Credits

- Winrock India

http://www.winrockindia.org/

Energy Management in Water Supply Systems
- Life-Cycle Cost Analysis

Asia-Pacific Economic Cooperation

Hotel Hilton Hanoi Opera

9th of March 2010

By: Pradeep Kumar

ALLIANCE TO SAVE ENERGY

Creating an Energy-Efficient World

What is Life-Cycle Cost (LCC)?

- LCC analysis is a management tool that can help water utilities minimize waste and maximize energy efficiency for many types of systems, including pumping components.

- The LCC of any piece of equipment is the total “lifetime” cost to purchase, install, operate, maintain, and dispose of that equipment.

What is Life-Cycle Cost (LCC)?

- LCC compares the estimated costs of different options taking into account both initial capital costs as well as costs that may be incurred over the life cycle.

- LCC treats design decisions as investments in pumping systems and pumping components.

Life-Cycle Cost Components

The components of a life-cycle cost analysis typically include

- initial cost
- installation and commissioning cost
- energy costs
- operation costs
- maintenance and repair costs
- down time costs
- environmental costs

Steps – Life-Cycle Cost Assessment

Step 1: Select design alternatives to evaluate.

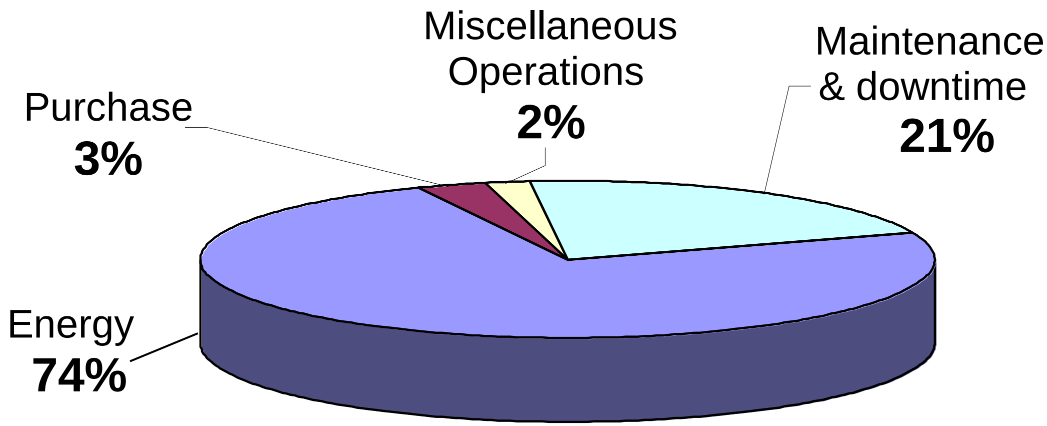
Step 2: Compute the first cost associated with each alternative.

Step 3: Establish the economic life, in years, for each alternative.

Step 4: Determine the annual energy cost and maintenance cost for each alternative.

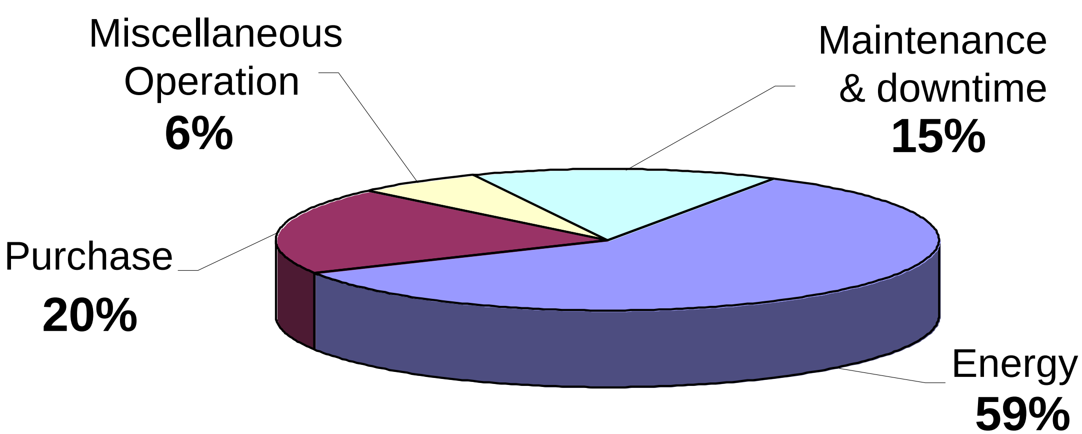
Step 5: Compute the life-cycle cost of each alternative over a period. (use tool, spreadsheet, software)

Life-Cycle Cost
-Efficient vs. Inefficient Pump



Life Cycle Costing: Inefficient Pump

- Purchase Price: $28,000
- 1st Yr Energy Cost: $69,000
- Total in Year One: **$97,000**



Life Cycle Costing: Energy Efficient Pump

- Purchase Price: $56,000
- 1st Yr Energy Cost: $19,600
- Total in Year One: **$75,600**

A Typical LCC Analysis Spreadsheet

Calculation of LCC

System description

Options A and B

	All cost in Euro/USD	
Input:	**Alt. A**	**Alt. B**
- Initial investment cost:	5000	2250
- Installation and commissioning cost:	0	0
- Energy price (present) per kWh:	0.08	0.08
- Weighted average power of equipment in kW:	23.1	14
- Average Operating hours/year:	6000	6000
Energy cost/year (calculated) = Energy price x Weighted average power x Average Operating hours/year	11088	6720
- Operating cost/year:	0	0
- Maintenance cost (routine maintenance/year):	500	500
- Repair cost every 2nd year:	2500	2500
- Other yearly costs:	0	0
- Down time cost/year:	0	0
- Environmental cost:	0	0
- Decommissioning/disposal cost:	0	0
n - Life in years:	8	8
i - Interest rate, %:	8%	8%
p - Inflation rate %:	4%	4%
Output:		
Net present LCC-value:	**91827**	**59481**
of which net present **energy cost** is:	75129	45533
and **routine maintenance cost** is:	3388	3388
of which net present **energy cost %** is:	82%	77%
and **routine maintenance cost %** is:	4%	6%

Financing Options for Water and Energy Efficiency Projects

Asia-Pacific Economic Cooperation

Hotel Hilton Hanoi Opera

9th of March 2010

By: Sudha Setty

ALLIANCE TO SAVE ENERGY

Creating an Energy-Efficient World

Financing an Energy Efficiency Project in Water Supply

- Energy Services
  - Energy Performance Contracts -- Energy Service Company (ESCO) financing
    - Guaranteed Savings
    - Shared Savings
- Turnkey
  - Municipality borrows from private financial institutions or development banks (i.e. ADB, World Bank)
  - Municipality self financing (O&M funds)

What is an ESCO?

- Definition

  An ESCO is a business that develops, installs, maintains, and finances interventions designed to improve the overall efficiency and operational costs for a utility over an agreed period of time.

- The cost of the services provided by the ESCO are included in the project cost and repaid through the generated savings.

Do You Need an ESCO?

- Make a self evaluation of your strengths and weaknesses

Strength/Weakness	If you answer YES	If you answer NO
Do you need help in getting internal buy-in into the project?	Consider an ESCO	Consider contracting out the needed services.
Do you need help in identifying and Implementing projects?	Consider an ESCO. By deciding early to use one, you may reduce project implementation costs and speed up project installation.	Consider contracting out only the necessary services. Use in-house staff where possible.
Do you lack available and/or experienced staff to install and manage the project?	Consider an ESCO with the expertise to ensure timely project implementation.	Use in-house staff where possible and consider contracting out needed services.

Do You Need an ESCO?

Strength/Weakness	If you answer YES	If you answer NO
Do you lack available and experienced staff to maintain the equipment?	Consider an ESCO since it provides these and other services. You can also contract with a maintenance firm.	Use your staff with or without supervision by external energy consultants
Do you lack project financing?	Consider an ESCO to provide financing or to assist you in securing it. ESCOs typically secure financing from third parties such as municipal leasing companies, banks, states.	Use your funds or secure outside funds from municipal leasing companies, banks, states, etc.

Energy Performance Contracting

- Energy Performance Contract
  - A performance-based procurement method and financial mechanism
  - Agreement with an ESCO that will identify, evaluate and implement energy saving opportunities. Improvements will be paid for through utility bills savings.
  - An arrangement where the exact benefits are only known afterwards.
  - Can recognize two types of savings:
    - Energy Cost Savings
    - Energy-Related Cost Savings

Energy Performance Contracting

- Two main types of contracts (combinations and variations exist)
  - **Shared Savings**
    - Financial risk lies with the ESCO, savings are shared between ESCO and water utility for a negotiated period of time
    - Municipality will receive *a certain percentage of the savings* but ESCO *does not guarantee the magnitude* of those savings
  - **Guaranteed Savings**
    - ESCO *guarantees that savings will be sufficient to cover investment cost*, if not the ESCO will pay the difference
    - External financing is brought in by the municipality or ESCO
    - Excess savings can be shared between the municipality and ESCO

Why Use Performance Contracting?

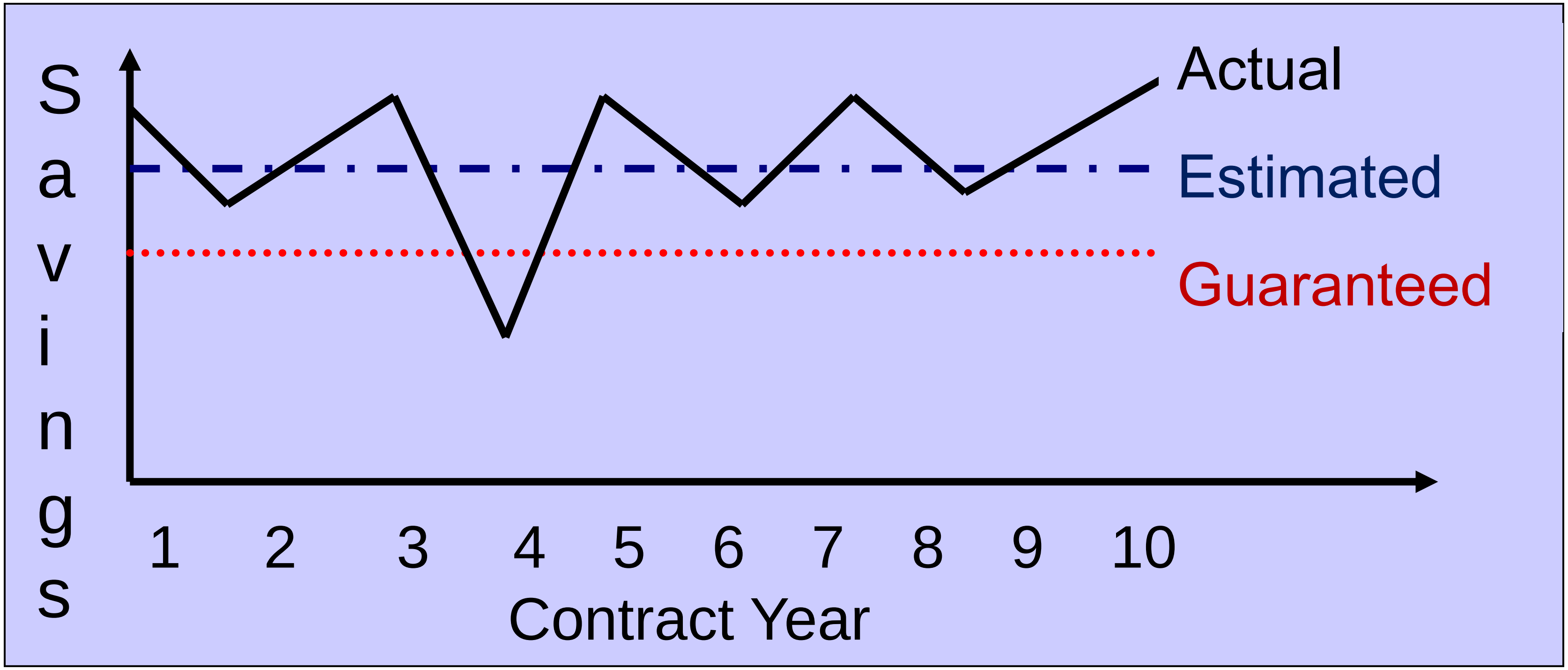
- Excessive energy costs
  - Strong potential for significant savings
- Limited access to capital resources
  - Lengthy project funding cycles
  - Competition with other capital and service needs
- Inadequate, old, or faulty equipment
  - Frequent repairs required/growing backlog of deferred maintenance
  - Underfunded maintenance budget/high costs
- Limited staff resources/expertise
  - Limited staff to bid and manage all phases of project
  - Untrained, high turnover, excessive overtime

Energy Performance Contracts - Benefits

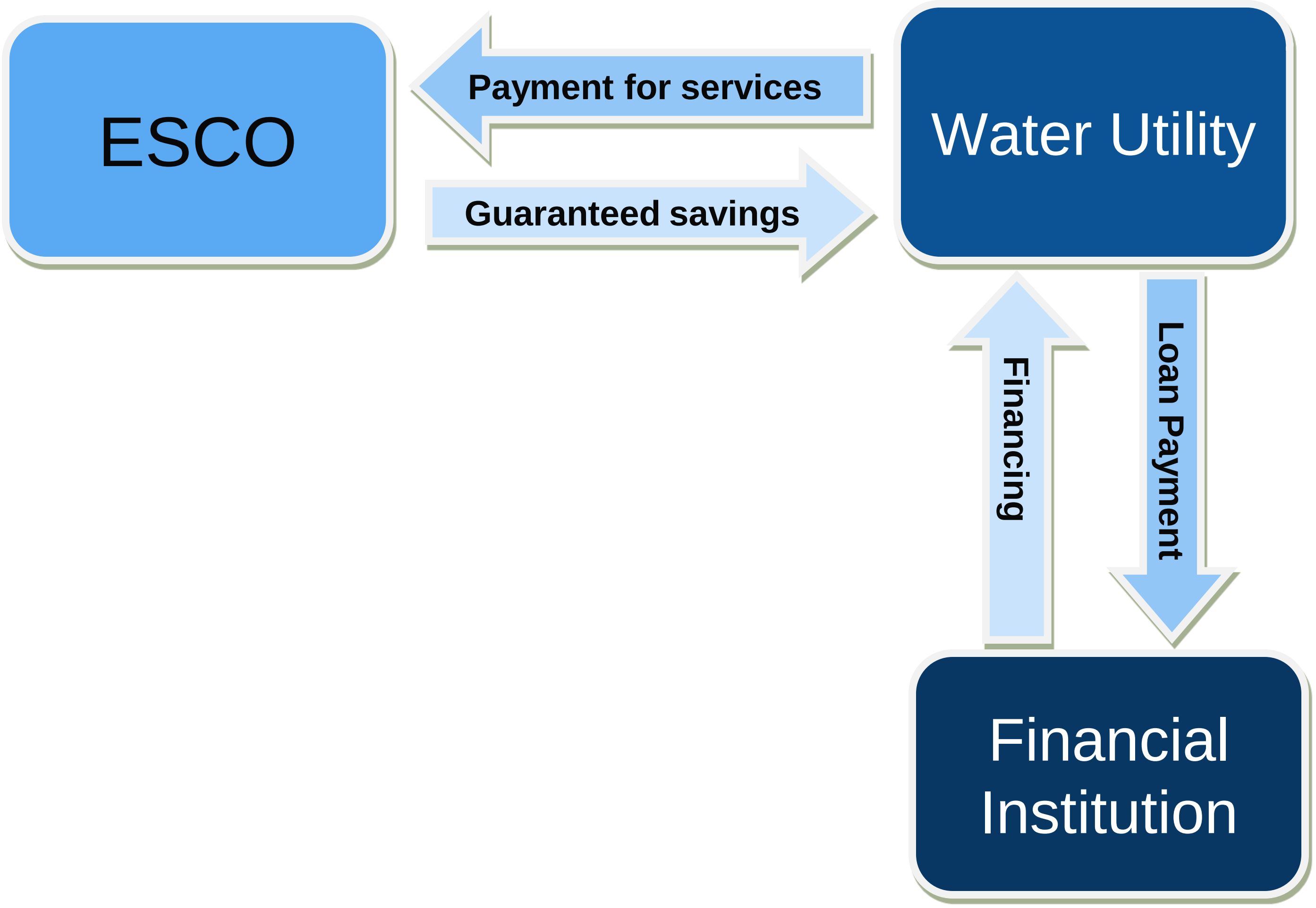
- More budget available for core business
- Decreased repairs and lower maintenance costs
- Improved operational efficiency – reduced energy costs
- Performance guarantees/persistent long-term energy savings
- Financing can be made available
- ESCOs package all services in single contract / single source of accountability
- Technical & operational training opportunities
- Local subcontractors are utilized, benefiting the businesses in the local community

Performance Contracting Under Guaranteed Savings Mechanism

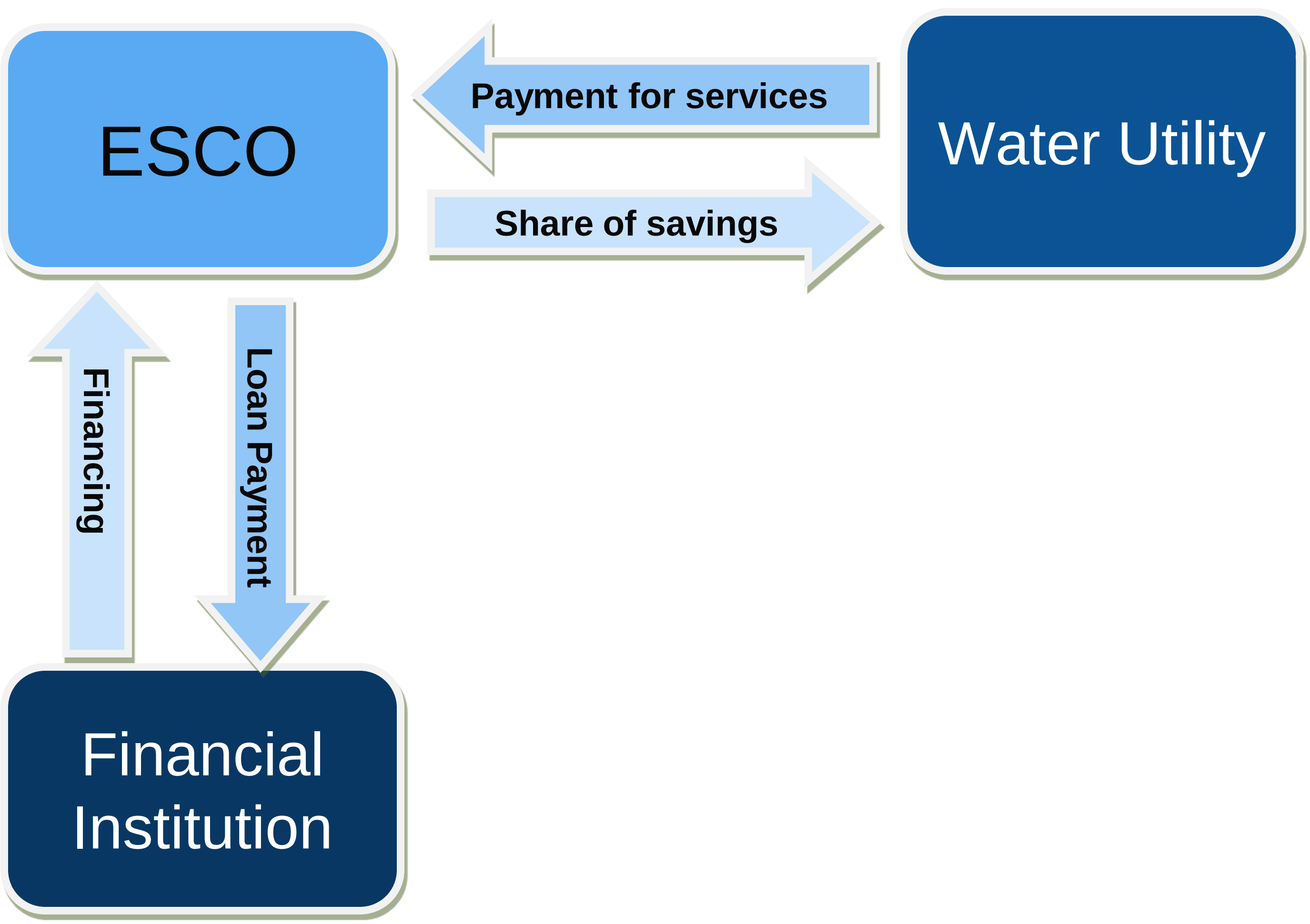
- Actual saving will fluctuate, but should always be greater than the guaranteed amount



Payback Mechanism Under Guaranteed Savings



Payback Mechanism Under Shared Savings



Energy Performance Contracts - Restrictions

- Higher Costs
  - Water utility has to pay for the risk transferred to the ESCO
- Implemented efficiency measures may be restricted to the most profitable and less risky for the ESCO
  - By performing only the cheapest options with the shortest paybacks other worthy options may be left untouched. This may constrain the ability to perform energy upgrades on systems with longer payback periods.
- Risk of losing skills and control
- Complex contracts
- Additional cost due to M&V

Energy Performance Contracts
- Implementation Challenges in India

- Lack of knowledge and awareness about energy performance contract implementation among stakeholders
  - Long project development time
- Availability of financing options
- Payment guarantee mechanisms to ESCOs
- Disputes over quantifying savings resulting from the projects and distrust between the project parties

Case Study: Tamil Nadu 2007-09 - Background

- One of the most urbanized states in India
- Hub for several industrial activities
- Suffers from severe energy and water shortages
- Many inhabitants of the state only enjoy running water for a few hours a day

Objective

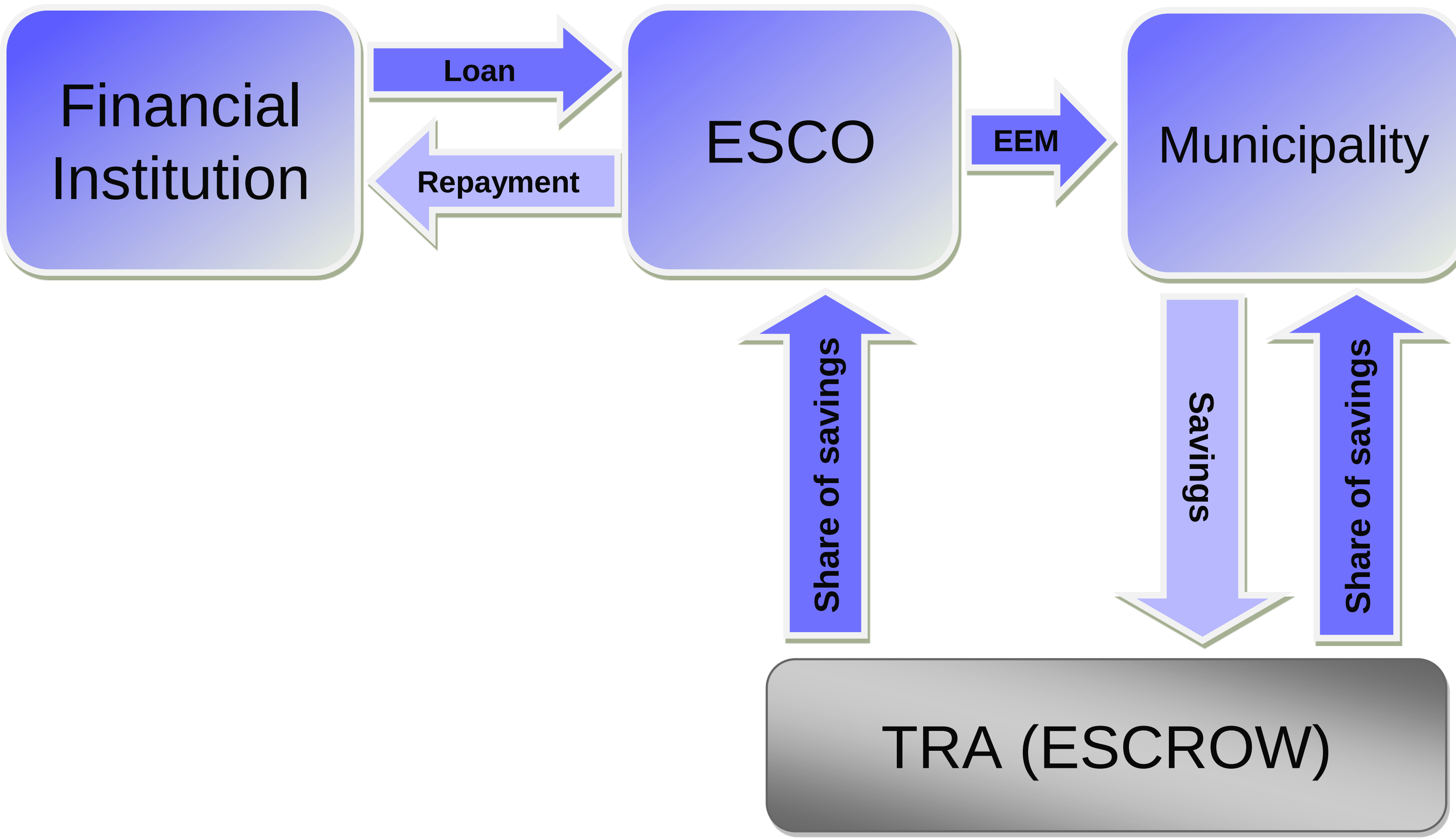
- Create confidence in the use of performance contracts in public sector among all stakeholders by ensuring the success of the Tamil Nadu Municipal Energy Efficiency Program

reeep
renewable energy & energy efficiency partnership

Tamil Nadu 2007-2009
- Addressing Financing Issues

Issues	Solutions
• Availability of Finance to ESCOs • Payment Guarantee Mechanism to ESCOs • ESCO projects in India often falter/fail due to disputes over quantifying energy savings resulting from the project	• TNUIFSL / TNUDF willing to finance ESCOs • Setting up of TRA Account with electricity bill payment escrowed • Using The International Performance Measurement and Verification Protocol (IPMVP)

Tamil Nadu Project Payback Mechanism – Shared Savings



Tamil Nadu 2007-2009 - Highlights

- Partnership with Tamil Nadu Urban Infrastructure Financial Services Limited (TNUIFSL), CMA, ULBs
- Implementing energy efficiency projects in 29 municipalities in water pumping and street lighting
- 2 Energy Service Companies implementing the project
- Bid Evaluation process
  - EOI – 13 responses
  - RFP issued to 8
  - RFP – 6
  - LOI issued to 2 ESCOs
- IGA reports in discussion
- EPC between ESCOs will be signed soon

Estimated Cost savings
US $ 800,000/year

Seeking Financing for Energy Efficiency Projects

A project appraisal normally includes (IREDA, 2007):

- Promoter appraisal
  - The utilities' background, credit worthiness, track record with past dealings with banks, etc.
- Technical appraisal
  - Realistic projected energy savings
  - Which technology will be used, fit with current processes?
- Financial appraisal
  - Review the estimated cost of the project, proposed means of financing, financial and cash flow projections, viability parameters and sensitivity analysis.
- Environmental appraisal
  - Environmental impact such as pollution levels pre- and post-installation
- Legal appraisal
  - All necessary legal documentation completed

Energy Efficiency & Carbon Credits

Clean Development Mechanism and Voluntary Market

Energy Efficiency & Carbon Credits Clean Development Mechanism

- The greenhouse gas emission reductions generated in energy efficiency projects can be traded through the carbon market, and the revenue can contribute to the project's cash flow

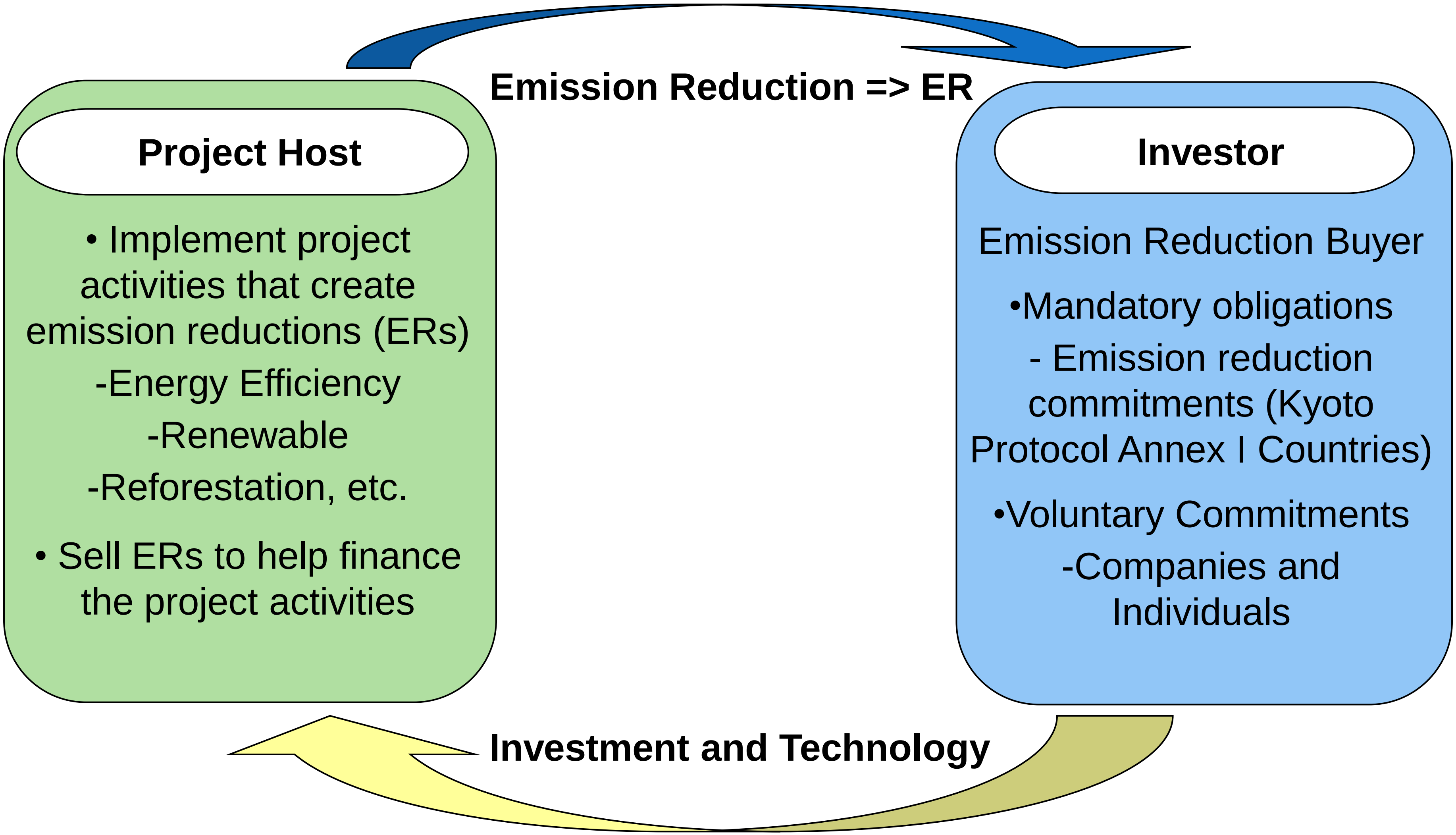
International Carbon Markets

- International trade in GHG reductions is a large and rapidly growing market
- Is motivated by
  - The Kyoto Protocol
  - Regional programs
  - Voluntary initiatives
  - Governments
  - Private companies
  - Individuals

that have collectively committed billions of dollars to buy emission reductions

- Carbon markets have resulted in new capital flows that are supporting sustainable energy and other climate protection activities.

Carbon Trading Outline



Basics of Carbon Credits

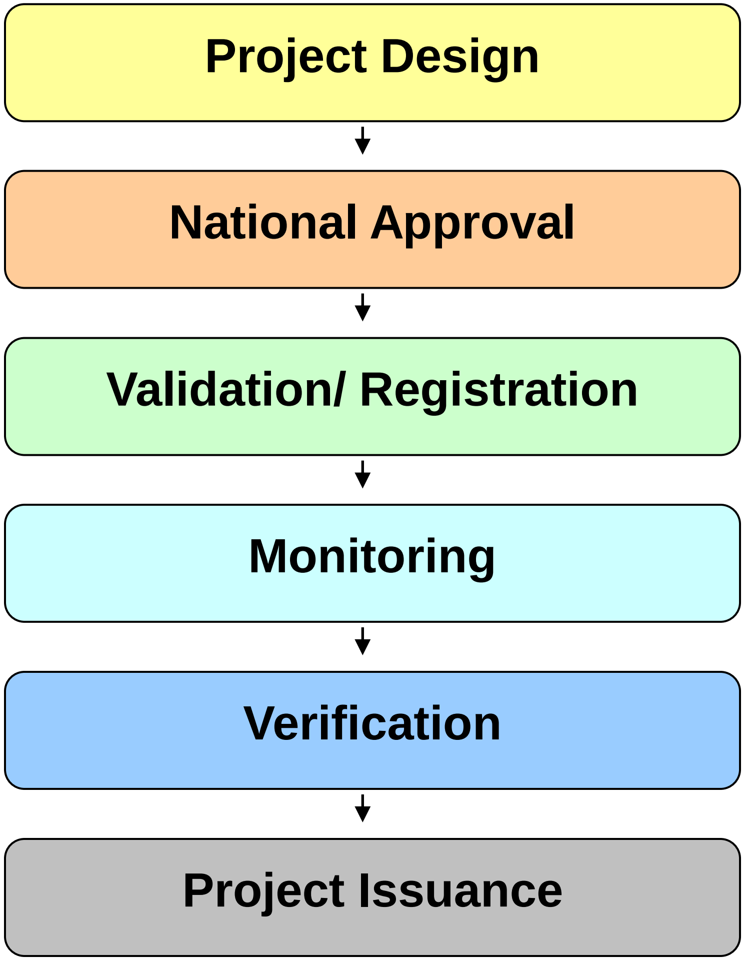
- Carbon trading terms
  - 1 CER = 1 metric ton of CO_2 equivalent GHG reduction.
  - 1 T Co2 ≈1000 Kwh ≈ 1 Mwh
  - In Indian projects 1 Kwh ≈ 0.84-0.89 Kg of CO_2
  - Approximate trading value = @ 15 to 20 USD /CER
- Approved Methodologies available at www.unfccc.int
  - AM 020 – Large scale municipal EE projects (above 60 Gwh)
  - AMS II. C – Small scale projects

Carbon Credits under Clean Development Mechanism

- Developed countries (Annex I countries of Kyoto Protocol) committed to reduce their CO2 emissions
- Developing countries (Non Annex I countries) can take up projects which generate reduction in greenhouse gases
- This reduction in GHG can be sold to Annex I countries to meet their commitment
- Normally larger scale projects

CDM Project - Process

- Feasibility studies
- Project Idea Note and PDD
- PDD => Validation report
- Monitoring protocol and quality assurance protocol
- Monitoring Report, Verification Report and Certification Report
- Request for Issuance => Certificate of Emission Reduction



Parties Involved in CDM stages

Design	• Project Participants
Validation	• Designated Operational Entity (DOE)
Approval	• Designated National Authority (DNA) of host and Annex I country
Registration	• CDM Executive Board
Implementation	• Project Participants
Monitoring & Reporting	• Project Participants
Verification	• Designated Operational Entity (DOE)
Certification	• Designated Operational Entity (DOE) • CDM Executive Board

Voluntary Market

- Companies, individuals, and events buy emission reductions to reduce their carbon footprint
  - not subject to mandatory limitations that wish to offset GHG emissions
- The voluntary market has been very small compared to the regulatory market, but is now growing
- Expectations that voluntary market will become quite substantial

Voluntary Market, Buyers and Sellers

- Buyers include:
  - Companies that buy offsets for their own operations
  - Companies that buy offsets on behalf of their customers, such as airlines & travel agents, automobile & petroleum companies
  - Events such as G8 Summits, World Cup football/soccer
  - Individuals
- Sellers include:
  - Retailers and wholesalers who buy and resell offsets
  - Project developers who develop GHG reducing activities
- Market intermediaries include:
  - Brokers who connect developers and resellers with institutional ER buyers
  - Consultants who help clients select ER suppliers and prepare offsets portfolios

Voluntary Market Standards

- Various standards, certification processes, and emissions registry services do exist but:
  - no universally accepted standard
  - unregulated
- Some standards are now widely recognized and accepted as a designation of credibility:
  - Voluntary Gold Standard
  - GHG Protocol for Project Accounting
  - Climate, Community and Biodiversity Project Design Standards

Voluntary Market Advantages and Disadvantages

Advantages	Disadvantages

Advantages

- Lower transaction costs than CDM
- Less rigorous procedures and standards, suited for smaller scale projects
- Innovative
- Flexible

Disadvantages

- Relatively small
- Lack of transparency
- No formalized procedures, making it less user and investor friendly
- Lower price than CDM project

Energy Accounting, Metering & Monitoring

Hotel Hilton Hanoi Opera

9th of March 2010

By: Pradeep Kumar

Asia-Pacific Economic Cooperation

ALLIANCE TO SAVE ENERGY

Creating an Energy-Efficient World

Energy Accounting

Energy accounting is a process for recording, tracking, and reporting the amount and costs of the various consumable utilities used by commercial-scale facilities. It involves the establishment of a database for storing historical information on:

- Recording
- Tracking
- Reporting

Recording & Tracking

- Energy use (kwh, Kva)
- Water flow (MLD)
- Pressure (head)
  - Pump discharge
  - Header discharge
- Energy expenditure
  - Any other fuel
- Power factor
- Maximum demand
- Operating hrs
- Breakdown / Maintenance details

Energy Accounting

"You cannot manage what you cannot measure"

An energy accounting system can assist municipalities in exposing excessive costs and identifying opportunities for saving money:

- Find billing errors
- Account for usage
- Spot cost trends
- Track cost & usage fluctuations
- Allow comparisons
- Establish utilities budgets quickly and efficiently
- Provide a basis for troubleshooting high usage/costs
- Justify capital expenditures

What Causes Variations in Energy Use?

- Weather
  - Seasonal changes cause increased or decreased water supply during winter or summer
- Operations and schedule changes
- Changes in pumping equipment

Reason for Energy Accounting

- Record and attribute energy consumption and costs.
- Troubleshoot energy problems and billing errors.
- Provide a basis for prioritizing energy capital investments.
- Evaluate energy program success and communicate results.
- Create incentives for energy management.
- Budget more accurately.

Benefits

- Energy accounting by itself does not reduce energy demand or costs. But it is the basis to identify weaknesses and to select and prioritize appropriate measures for the improvement of the energy system.
- Energy accounting can raise the awareness of responsible persons regarding the energy demand of certain uses. This awareness is a necessary first step for carrying out measures to improve system efficiency (sometimes with very little needed investments).
- Reduced energy demand - if the measures are carefully planned and implemented - not only reduces costs, but can also result in environmental benefits (e.g., reduction of emissions).

Key Factors for Successful Implementation of Energy Accounting

- Every person involved in energy accounting should be well-informed about targets and benefits of energy accounting.
- High-level commitment to the implementation of energy accounting will ease cross-department work and communication.
- The implementation of energy accounting will demand financial and personnel resources.

Key Factors

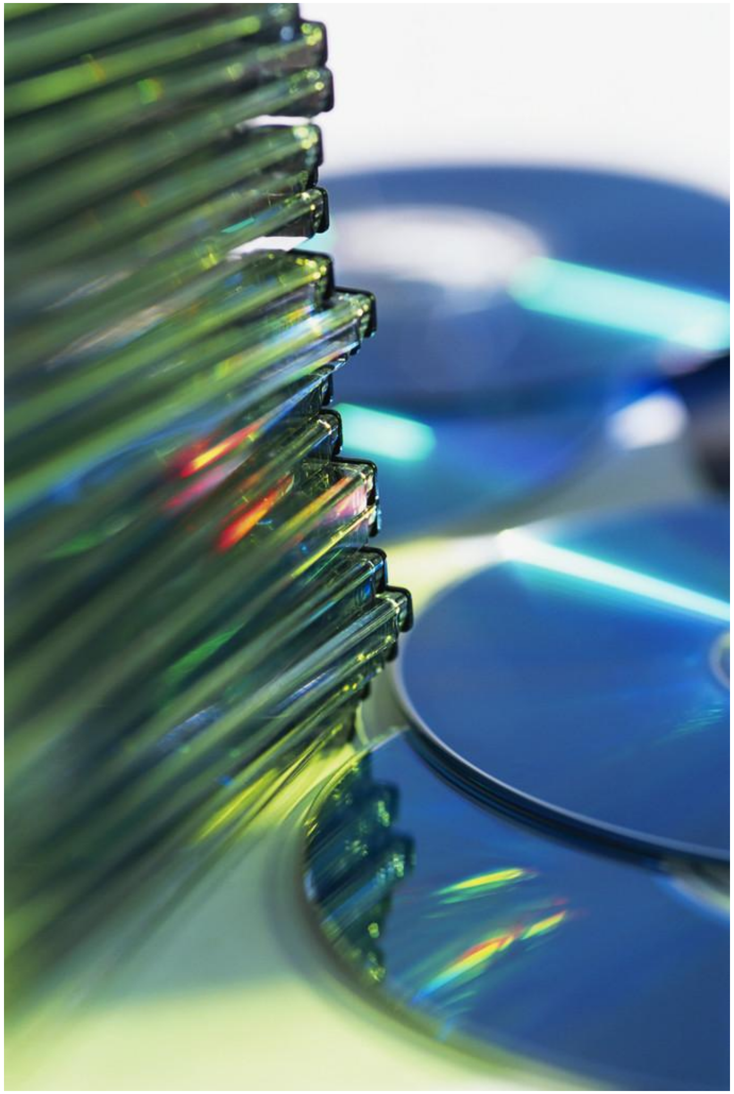
- Benchmarking of different components inside or outside a municipality is only possible with an accurate and standardized collecting method of data.
  - Kwh/M3, Kwh/MLD for Raw water treatment and treated water pumping
  - Maintenance expenses per MLD
- Report the results of the evaluation and explanations - including proposals for improvement measures - to the responsible departments and decision makers regularly.

Energy Accounting Software

- *Specialized Energy Accounting software* is typically employed to develop the historical utilities database and provide the essential analytical tools.
- The software comes in varying levels of sophistication depending on the end-user needs. Basic features include:
  - Importing capability for electronic billing data
  - Graphical reporting features including trending
  - Tabular reporting features including indexing
  - Exporting capability for pasting reports into spreadsheets
  - Utilities budget development with projected utility rate increases

Tips for selecting Software

- Know your applications and needs.
- Examine software demos and documentation.
- Talk to users of the software.
- Know what support you are buying.
- Don't compromise on important features.



Monitoring & Targeting

Monitoring & Targeting (M&T)

- M&T is primarily a management technique that uses energy information as a basis to eliminate wastage, reduce and control the current level of energy use, and improve the existing operating practices .
  - Monitoring: Establishes the existing pattern of energy consumption.
  - Targeting: Identifies the energy consumption level that is desirable, as a management goal to work toward energy conservation.

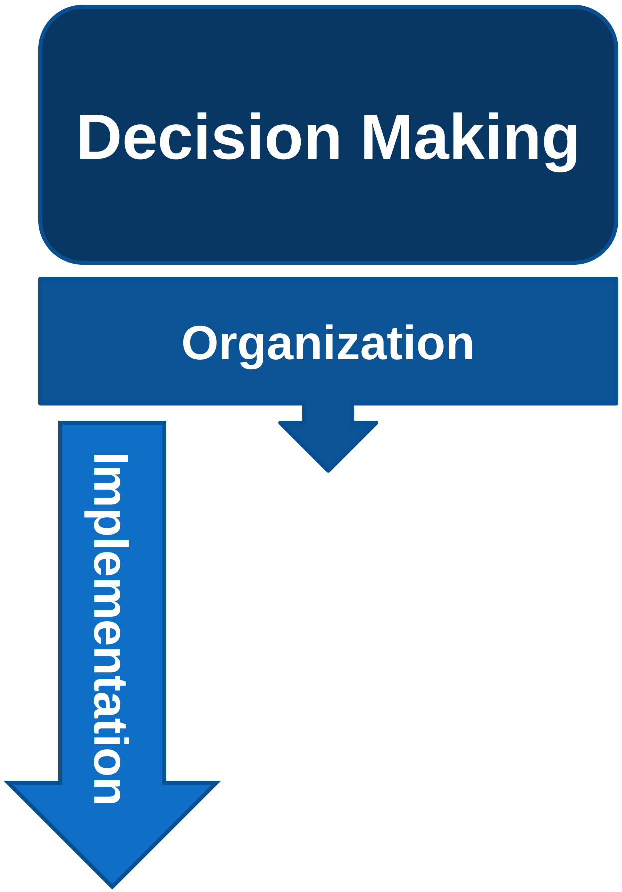
Elements of Monitoring & Targeting System

- Recording
  - Measuring and recording energy consumption
- Analyzing
  - Correlating energy consumption to a measured output, such as production quantity
- Comparing
  - Comparing energy consumption to an appropriate standard or benchmark

Elements of Monitoring & Targeting System

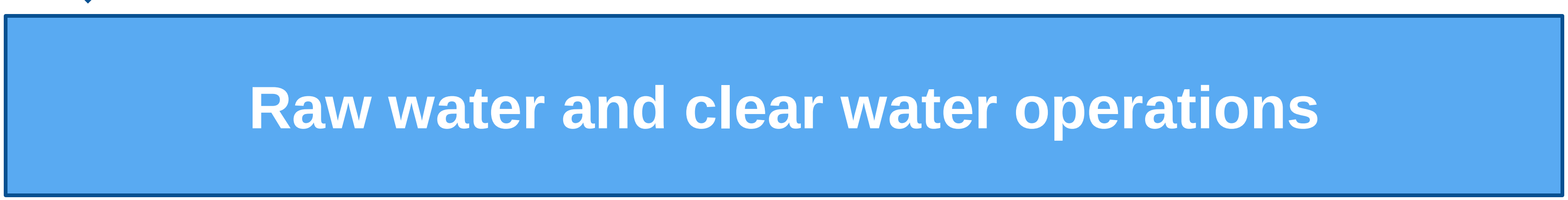
- Setting Targets
  - Setting targets to reduce or control energy consumption
- Monitoring
  - Comparing energy consumption to the set target on a regular basis
- Reporting
  - Reporting the results including any variances from the targets which have been set
- Controlling
  - Implementing management measures to correct any variances that may have occurred

Open Loop Decision Making System

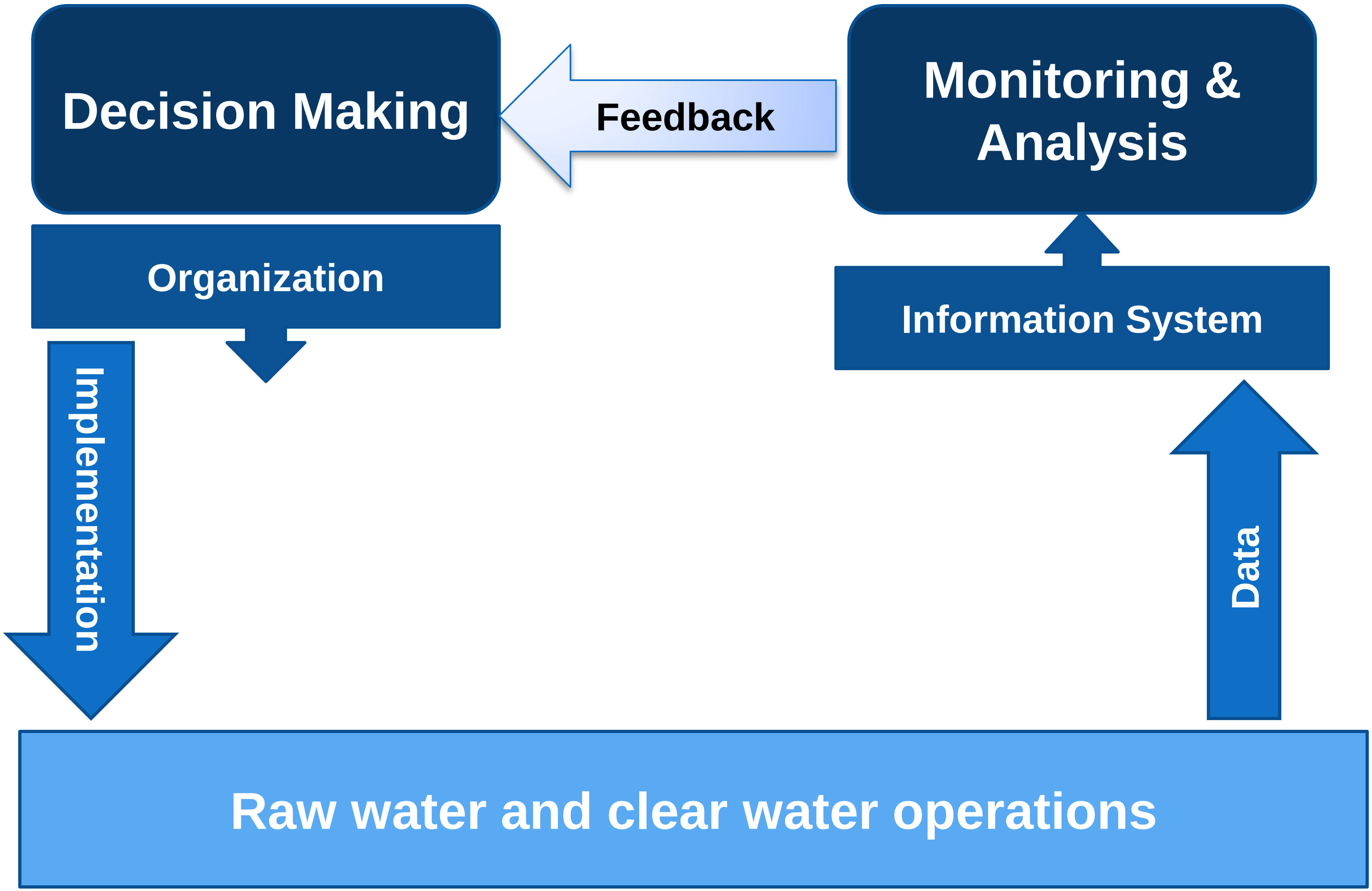


Without a Feedback System

- Lack of understanding of the system effects:
    - Inefficiencies may still exist
    - Operations not being fully optimized



Closed Loop Decision Making System



How Instrumentation Contributes to Cost Reduction

- Energy flow is invisible
- Instruments help to generate accurate and real-time information
- Bring to light operational lapses or inadequacies
- Trigger steps to correct these lapses, leading to optimization and savings

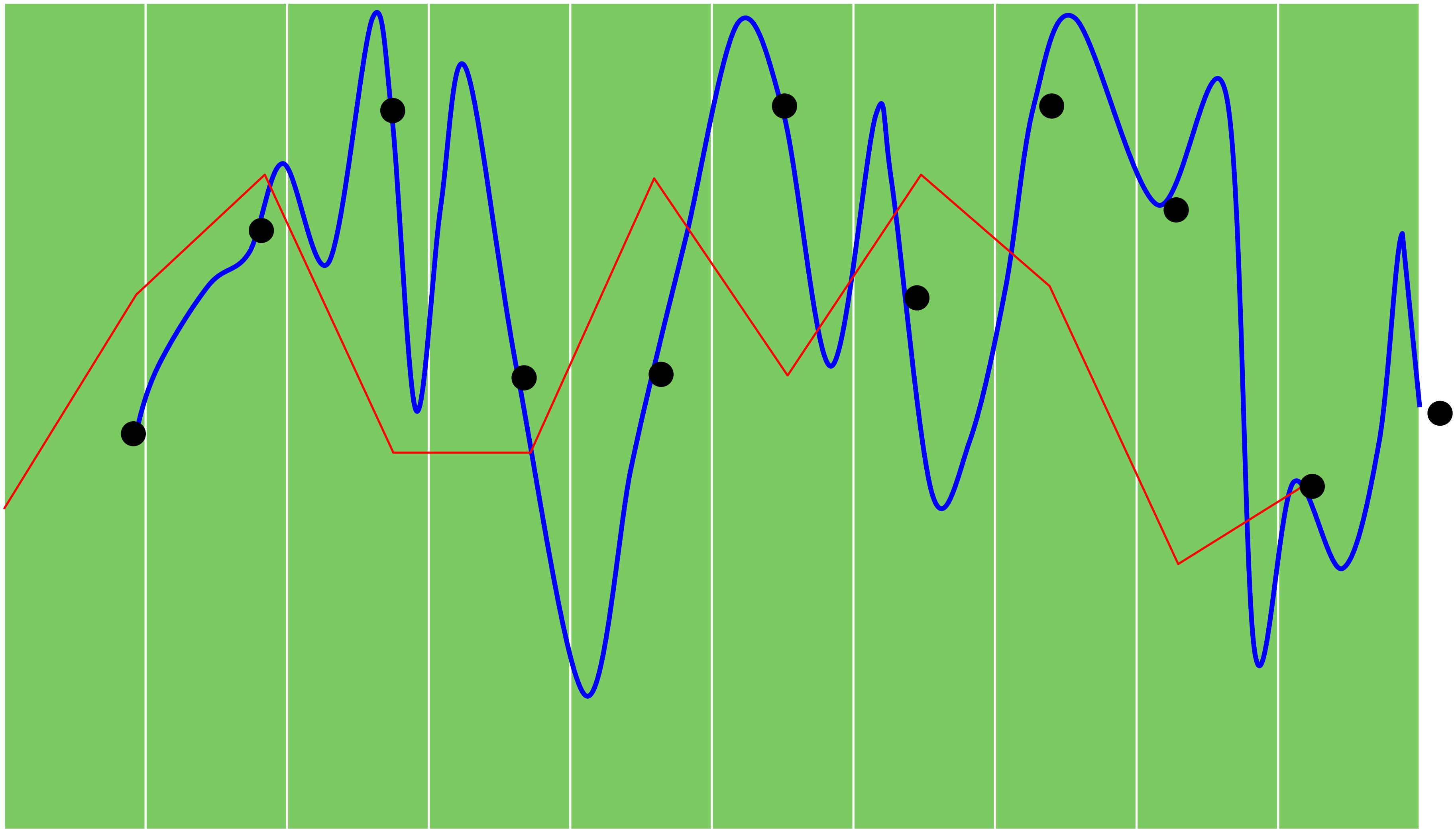
How Instrumentation Contributes to Cost Reduction

- Provide sound basis for management decisions on strategy, targets, investments etc.
- Implementation of these decisions leads to even bigger savings.

Sub Metering

- Sub metering is not expensive
  - Most cases have been under 5% project cost
  - Paybacks are 6 months to 1 yr
- Reduces Uncertainty
  - Able to identifies small data variations

Spot vs. Real-Time Data



Credits

- Conzerv
- Bureau of Energy Efficiency India