Unit-3 Notes

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Part-2

energy saving opportunities in hvac and refrigeration system

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Here are some ways to save energy in HVAC and refrigeration systems:

HVAC

- Adjust the temperature: Set the heat to 68°F in the winter and the air conditioner to 78°F in the summer.
- Use a smart thermostat: These devices can learn your preferences and adjust the temperature based on the time of day and occupancy.
- Install programmable controls: Use programmable thermostats to change the temperature throughout the day.
- Seal ducts: Seal your heating and cooling ducts.
- Use ENERGY STAR certified equipment: Consider installing ENERGY STAR certified heating and cooling equipment.
- Tune up your HVAC equipment: Tune up your HVAC equipment yearly.
- Change the air filter: Change your air filter regularly.

Refrigeration

- Choose an energy-efficient model: Choose or upgrade to an energy-efficient model.
- Keep the door closed: Keep the door closed.
- Store food properly: Store food properly and don't put hot food in the fridge.
- Keep it organized: Keep your fridge organized.
- Keep it full: Keep your fridge full.
- Give it space: Give your fridge a cool place and some room to breathe.

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Here are some ways to save energy in HVAC and refrigeration systems:

**HVAC**

- **Maintain**: Regularly clean and replace filters, inspect coils, check refrigerant levels, and lubricate moving parts.
- **Seal and insulate**: Seal leaky ducts and insulate ductwork in unconditioned areas.
- **Optimize airflow**: Ensure supply and return vents are unobstructed and clean vents and registers regularly.
- **Set thermostat**: Set the thermostat to the recommended temperature of 22–25 °C for cooling.
- **Use a smart thermostat**: Install a smart thermostat to help you save energy.
- **Use energy-efficient equipment**: Consider installing ENERGY STAR certified equipment.

**Refrigeration**

- **Choose an energy-efficient model**: Choose or upgrade to an energy-efficient refrigerator.
- **Keep it cool**: Keep your fridge in a cool place with enough room to breathe.
- **Keep the door closed**: Keep the fridge door closed.
- **Keep it organized**: Keep your fridge organized and store food properly.
- **Keep it full**: Keep your fridge full.
- **Avoid hot food**: Don't put hot food in your fridge.

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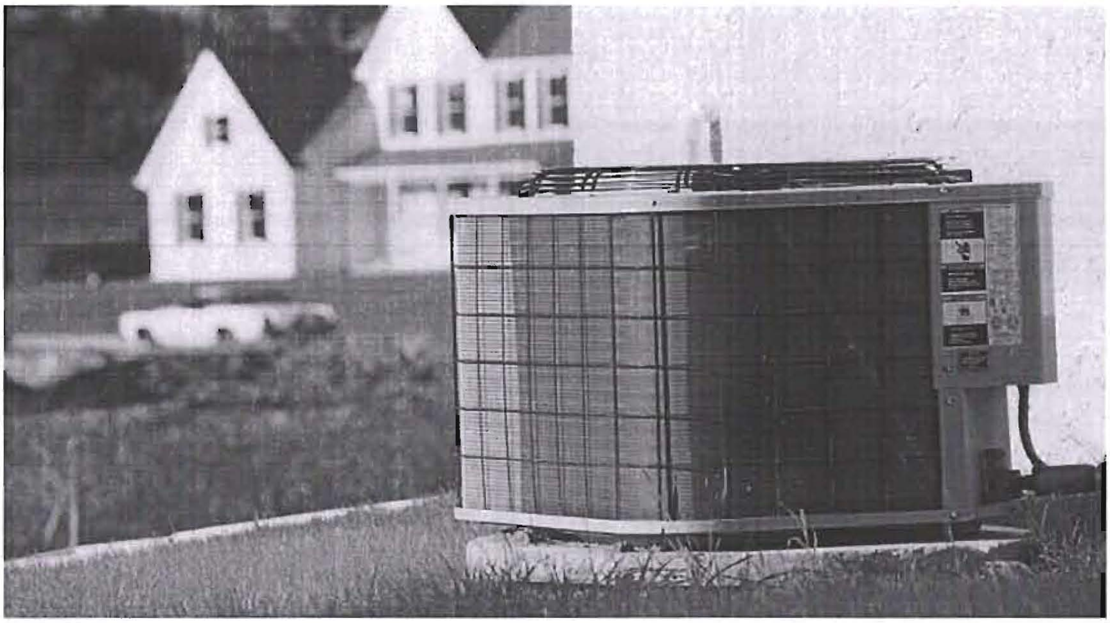
Energy Conservation Opportunities in Refrigeration Systems

# Energy Conservation methods in Refrigeration & HVAC System

*The article discusses about methods through which energy savings can be achieved. Basic refrigeration process, energy efficient selection of chiller, case study of replacement of existing VAR type Chiller with Centrifugal Chiller and other energy conservation opportunities in refrigeration systems are discussed.*

September 18, 2018



Refrigeration process is used in chilled water, brine for processes, ice plants, air conditioning, humidification – moisture removal etc. A generalised method of refrigeration can be explained in block diagram 1.

Refrigeration systems energy balance follows the following method as shown in diagram 2.

Energy efficient chiller has the requirement of Centrifugal Chiller 300 TR and above and 0.6 ~ 0.65 KW/TR.
Screw chiller has 50-200 TR and 0.7 ~ 1.0 KW/TR.
Reciprocating chiller has 10-50 and TR 1.0~1.2 KW/TR
VAR has 50 TR and above and 2000 ~ 2575 Kcal/HR.

**Energy Conservation Opportunities in Refrigeration Systems**

☐ Use water-cooled condensers rather than air-cooled condensers.
☐ Challenge the need for refrigeration, particularly, for old batch rocesses.
☐ Avoid oversizing – match the connected load.
☐ Consider gas-powered refrigeration equipment to minimize electrical demand charges.
☐ Use free cooling to allow chiller shutdown in cold weather.
☐ Use refrigerated water loads in series if possible. Convert firewater or other tanks to thermal storage.
☐ Don't assume that the old way is still the best – particularly, for energyintensive low temperature systems.

☐ Correct inappropriate brine or glycol concentration that adversely affects heat transfer and/or pumping energy. If it sweats, insulate it, but if it is corroding, replace it first.
☐ Make adjustments to minimize hot gas bypass operation.
☐ Inspect moisture/liquid indicators.
☐ Consider change of refrigerant type if it will improve efficiency.
☐ Check for correct refrigerant charge level.
☐ Inspect the purge for air and water leaks.
☐ Establish a refrigeration efficiencymaintenance program. Start with an energy audit and follow-up, then make a refrigeration efficiency-maintenance program a part of your continuous energy management program.

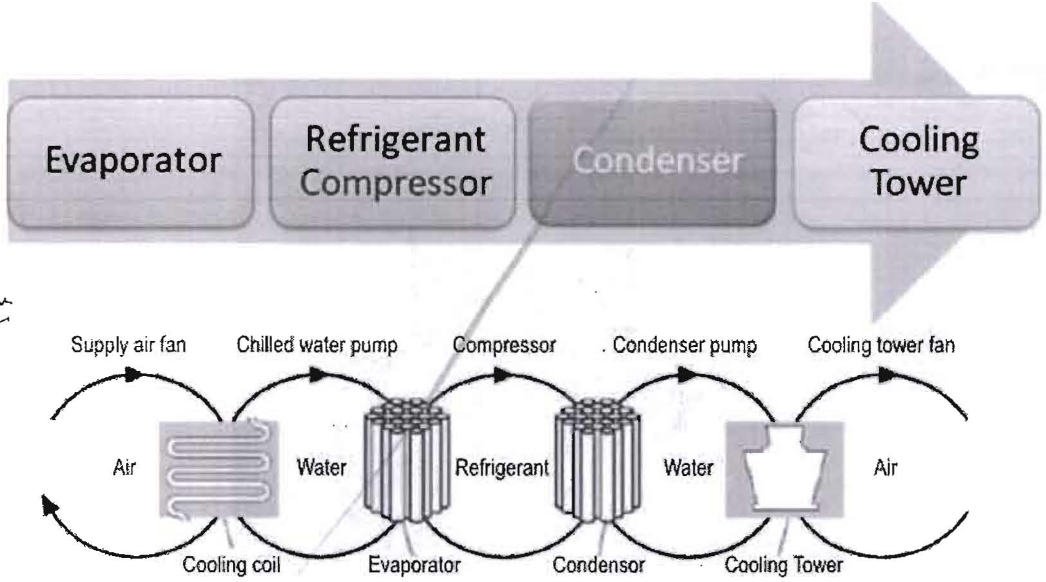


Diagram 1: Method of Refrigeration

**Case Study: Replacement of Existing VAR Type Chiller with Centrifugal Chiller**

Energy Efficient Capacity Selection of Refrigeration and chiller systems may be done by proper selection of load (1200 TR or 300 TR) or by RH (10 HR or 14 HR). Optimum set point temperature (Evaporator) is also important. Having optimum or minimum driving force (temperature difference between set temperature of motive fluid (water and refrigerant temperature) help to achieve highest possible suction pressure at compressor which leads to less energy requirements. Other ENCON opportunities in refrigeration systems are such as

1. Optimise process heat exchange
2. Maintain heat exchanger surfaces
3. Multi-staging systems
4. Matching capacity to system load
5. Capacity control of compressors
6. Multi-level refrigeration for plant needs
7. Chilled water storage
8. System design features

**Energy Conservation opportunities in Chillers**

☐ Increase the chilled water temperature set point if possible. Use the lowest temperature condenser water available that the chiller can handle. (Reducing condensing temperature by 5.5 0C, results in a 20 – 25 per cent decrease in compressor power consumption)

☐ Increase the evaporator temperature (5.50C increase in evaporator temperature reduces compressor power consumption by 20 – 25 per cent)

☐ Clean heat exchangers when fouled. (1 mm scale build-up on condenser tubes can increase energy consumption by 40 per cent)

☐ Optimise condenser water flow rate and refrigerated water flow rate.

☐ Replace old chillers or compressors with new higher-efficiency models.

☐ Use water-cooled rather than aircooled chiller condensers.

☐ Use energy-efficient motors for continuous or near-continuous operation.

☐ Specify appropriate fouling factors for condensers.

☐ Do not overcharge oil.

☐ Install a control system to coordinate multiple chillers.

☐ Study part-load characteristics and cycling costs to determine the mostefficient mode for operating multiple chillers.

☐ Run the chillers with the lowest energy consumption. It saves energy cost, fuels a base load.

☐ Avoid oversizing – match the connected load.

☐ Isolate off-line chillers and cooling towers.

☐ Establish a chiller efficiencymaintenance program. Start with an energy audit and follow-up, then make a chiller efficiency-maintenance program a part of your continuous energy management program.

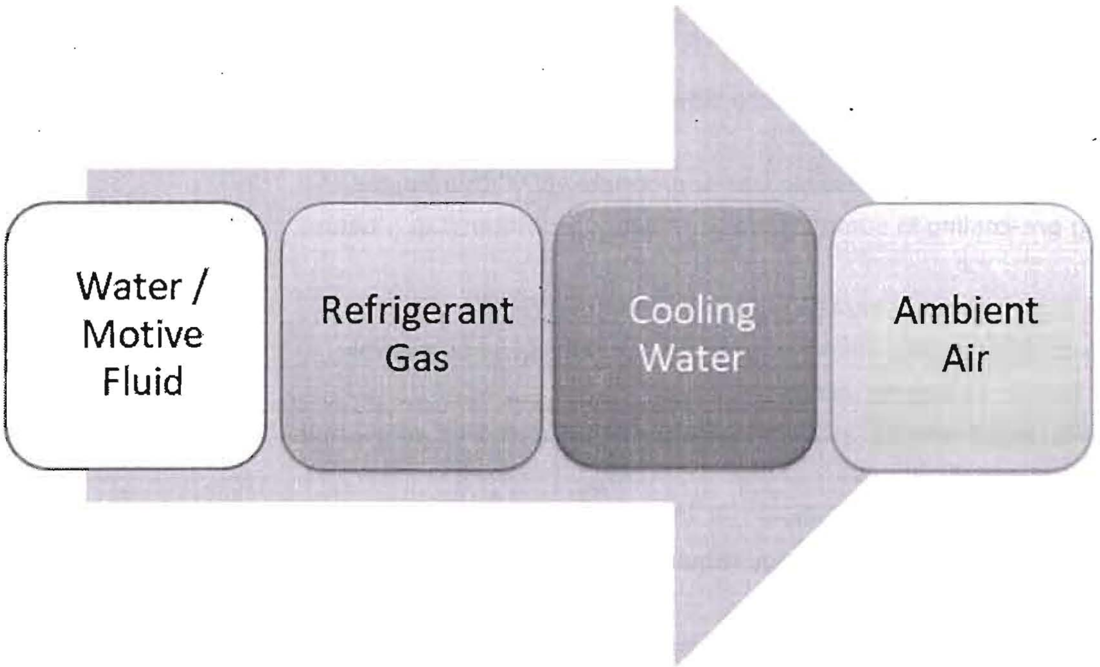



**Diagram 2: Refrigeration systems energy balance**

**HVAC Systems**

HVAC System consists of a chain of components designed to cool or heat, ventilate a specific area while maintaining a defined environmental cleanliness level. Purpose of HVAC system is to To Control/ Maintain Temperature – Heating,
To Purify the Air – Ventilation and
To Control/Maintain Humidity – Air Conditioning.

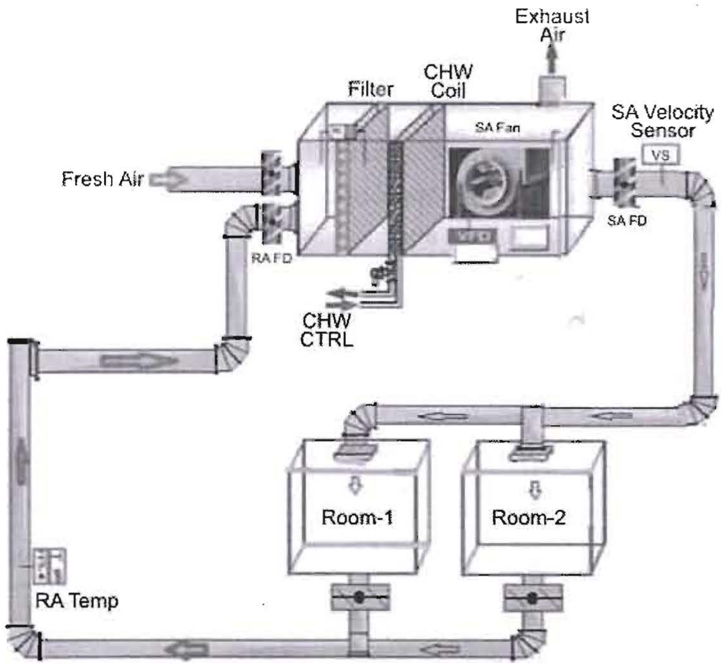
**Case Study: Replacement of Existing VAR Type Chiller with Centrifugal Chiller**

| Type of System | Vapour Absorption Chiller | Centrifugal Chiller |
|---|---|---|
| Capacity | 1000 TR (500 TR x 02 Nos.) | 1000 TR (500 TR x 02 Nos) |
| Input Energy | Heat (Steam) | Power |
| Specific Consumption | 4.33 Kg of Steam / TR | 0.65 KW / TR |
| Total Consumption | 4333 Kg / hour | 650 KW / hour |
| Fuel Consumption (Furnace Oil @ 12.5 Evaporation ratio) | 345 Kg / hour | – |
| Rate of Input Energy | Rs. 40,00 per kg | Rs. 7.00 per KWh |
| Cost of Input Energy | 13800/- | 4550/- |
| Savings in Operating Cost | 9250 Rs. / Hour | |
| % Reduction in Operating Cost | 67% | |

**Energy Conservation Opportunities in HVAC Systems**

☐ Optimum Design (Heat Load and Air Flow Requirements)
☐ Monitoring & Control
☐ Automation
☐ Effective Preventive Maintenance
☐ Minimisation of Heat Energy Losses
☐ Minimisation of Leakage Losses
☐ Energy Efficient HVAC Components
☐ Waste Heat Recovery
☐ Tune up the HVAC control system.
☐ Consider installing a building automation system (BAS) or energy management system (EMS) or restoring an out-of-service one.
☐ Balance the system to minimise flows and reduce blower or fan or pump power requirements.
☐ Eliminate or reduce reheat whenever possible.Use appropriate HVAC thermostat setback. ☐ Use morning pre-cooling in summer and pre-heating in winter (i.e. – before electrical peak hours).
☐ Use building thermal lag to minimise HVAC equipment operating time.
☐ In winter during unoccupied periods, allow temperatures to fall as low as possible without freezing water lines or damaging stored materials.
☐ In summer during unoccupied periods, allow temperatures to rise as high as possible without damaging stored materials.
☐ Improve control and utilisation of outside air.
☐ Use air-to-air heat exchangers to reduce energy requirements for heating and cooling of outside air.
☐ Reduce HVAC system operating hours (e.g. – night, weekend).
☐ Optimize ventilation.
☐ Ventilate only when necessary. To allow some areas to be shut down when unoccupied, install dedicated HVAC systems on continuous loads (e.g. – computer rooms).
☐ Provide dedicated outside air supply to kitchens, cleaning rooms, combustion equipment, etc to avoid excessive exhausting of conditioned air.
☐ Use evaporative cooling in dry climates.
☐ Reduce humidification or dehumidification during unoccupied periods.
☐ Establish an HVAC efficiencymaintenance program. Start with an energy audit and follow-up, then make an HVAC efficiency-maintenance program a part of your continuous

energy management program.
☐ Use atomisation rather than steam for humidification where possible.
☐ Clean HVAC unit coils periodically and comb mashed fins.
☐ Upgrade filter banks to reduce pressure drop and thus lower fan power requirements.
☐ Check HVAC filters on a schedule (at least monthly) and clean/change if appropriate.
☐ Check pneumatic controls air compressors for proper operation, cycling, and maintenance.
☐ Isolate air-conditioned loading dock areas and cool storage areas using high-speed doors or clear PVC strip curtains.
☐ Install ceiling fans to minimise thermal stratification in high-bay areas.
☐ Relocate air diffusers to optimum heights in areas with high ceilings.
☐ Consider reducing ceiling heights.
☐ Eliminate obstructions in front of radiators, baseboard heaters, etc.
☐ Check reflectors on infrared heaters for cleanliness and proper beam direction.
☐ Use professionally-designed industrial ventilation hoods for dust and vapor control.
☐ Use local infrared heat for personnel rather than heating the entire area.
☐ Use spot cooling and heating (e.g. — use ceiling fans for personnel rather than cooling the entire area).
☐ Purchase only high-efficiency models for HVAC window units.
☐ Put HVAC window units on timer control.
☐ Don't oversize cooling units. (Oversized units will short cycle which results in poor humidity control.)
☐ Install multi-fueling capability and run with the cheapest fuel available at the time.
☐ Consider dedicated make-up air for exhaust hoods. (Why exhaust the air conditioning or heat if you don't need to?)
☐ Minimise HVAC fan speeds.
☐ Consider desiccant drying of outside air to reduce cooling requirements in humid climates.
☐ Consider ground source heat pumps.
☐ Seal leaky HVAC ductwork.
☐ Seal all leaks around coils.
☐ Repair loose or damaged flexible connections (including those under air handling units). ☐ Eliminate simultaneous heating and cooling during seasonal transition periods.
☐ Zone HVAC air and water systems to minimize energy use.
☐ Inspect, clean, lubricate, and adjust damper blades and linkages

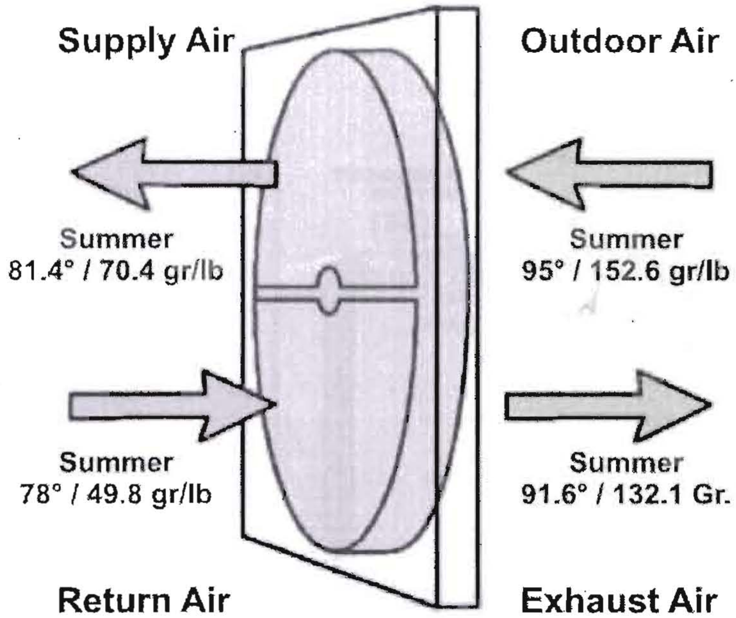


A general lay out of HVAC system

| System | AHU with 100% Fresh Air requirements |
|---|---|
| Capacity | 10000 CFM / 25 TR |
| Ambient Air Temperature | 35°C |
| Room Temperature Requirement | 25°C |
| Exhaust Air Requirement | 27°C |
| Reduction in Fresh Air Temperature by heat transfer between exhaust air & fresh air | 30 – 32 °C |
| % Reduction in Heat Load by Utilization of heat in Exhaust Air | 8.5% - 10 % |

**Energy Efficient System Design & Selection**

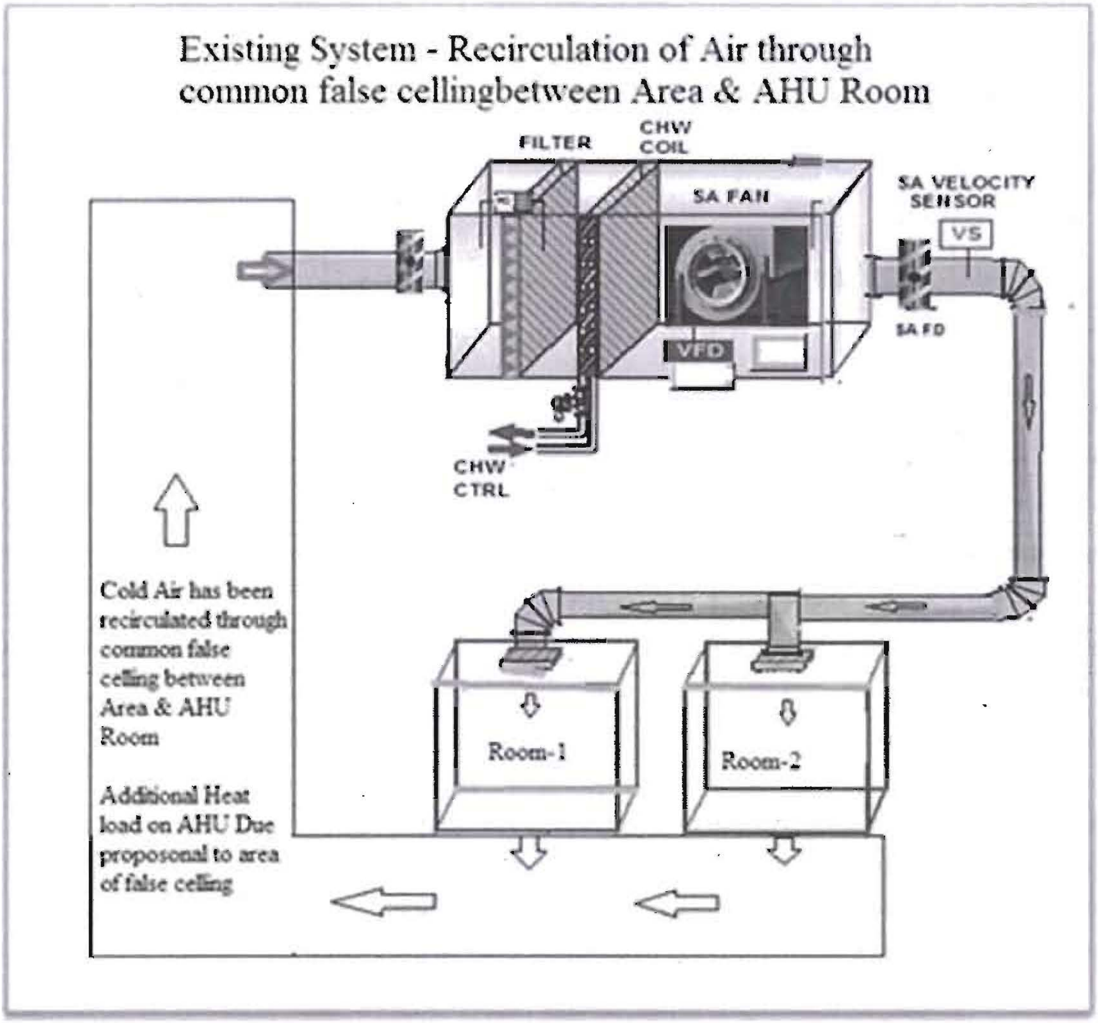
The greatest opportunities for energy efficiency exist at the design stage for HVAC system. HVAC Design should not be tailor made as its operating cost and performance in totally depended on local environmental condition, optimum capacity by considering season variation as well as energy efficiency is the most important part of any pharmaceutical HVAC systems.




**Energy Monitoring & Control System**

An energy monitoring and control system supports the operation of HVAC system by monitoring, controlling and tracking system energy consumption. Such system continuously manages and optimises HVAC System energy Figures of Waste heat recovery and saving energy consumption and indentifying potential technical problem in HVAC system.

Example: For monitoring and control of HVAC, BMS System should be preferred along with configuration of current or power measurement HVAC System also for maintaining room pressure motorised damper should be installed to maintain the required parameter with energy efficiency.




**Figures of Waste heat recovery and saving energy.**

**Automation and Loss Miniminsation**

VFD - Variable Freq Drive.

Installation of VFDs for Air Blower Modulation accordingly air flow requirements will reduce energy consumption at part load operations.

Installation of 2-way or 3-way valves will modulate chilled water flow as per indoor environmental condition which reduce load on chiller.

Heat energy losses from leakages through door and windows lead to lowering energy efficiency in HVAC systems.

**Example:**

- Door Size: 1800 x 1500 (Area = 2.7 sqm),
- Air Velocity: 0.25 – 0.3 m/s, Air Losses = 715 CFM
- If door remains open for 5 sec, Air losses = 60 CFM
- Equivalent Power = 0.08 KWh,  Door Open Frequency = 50 -70 Times / Shift
- Equivalent Power = 4 KWh/Shift

Effluent Treatment Plant
Sewage Treatment Plant

Treated water used in fresh air cooling unit which reduces inlet air temp. (ambient) goes to HVAC. But this air goes to another inlet (even cooler air) which reduces heat load on chilled water cooling coil. This saves power consumption

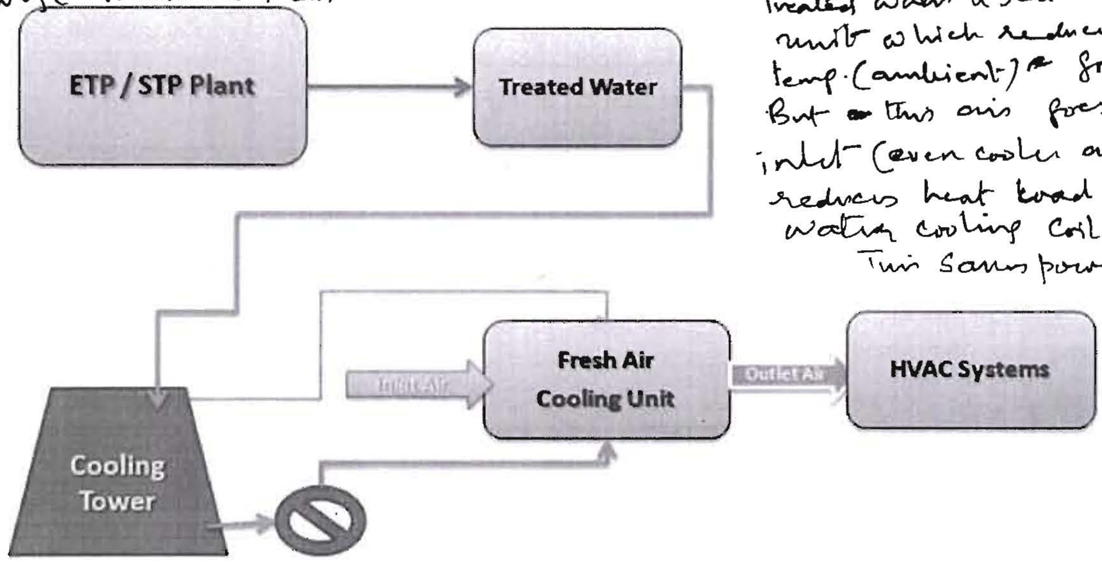



*Figure of Case Study: Evaporative Cooling System*

**Case Study: Waste Heat Recovery**

Utilisation of heat energy available in exhaust air by reducing fresh air temperature through heat transfer between fresh air and exhaust air.

AHU room: air handling unit = heart of central air conditioning. It collects outside air & room air, removes dust & other particles from collected air, adjusts temp & humidity & then supplies air conditioned air to the rooms, thro' ducts

☐ If existing return air is through common false celling area between AHU room and conditioned area, additional load (of above false celling area) approximately 15 to 18 per cent has been added in actual requirement of HVAC System.
☐ Appropriate size of return air duct required which is to be connected ~~with AHU inlet~~ with provision of fresh air duct with damper on both return air as well as fresh air duct.
☐ Fresh air damper and return air damper open or close position to be set accordingly temperature of return air temperature and fresh air temperature.
☐ Lower temperature air intake rate to be increased by setting damper accordingly
☐ Provision of return duct in place of return through false celling for recirculation Type HVAC System.

Dampers are used to freshen return air

**Case Study: Evaporative Cooling System**

**Objective**

☐ Utilisation of ETP/ STP treated water to maintain zero discharge condition and simultaneously utilisation of treated water for fresh air cooling media.

**Principal of Operation**

☐ After being cooled by Cooling Tower Treated Water has been recirculated in fresh air cooling unit to reduce the Inlet Air Temperature (Ambient).
☐ Air Cooled by Fresh Air Cooling System has been supplied to main HVAC Systems . instead of taking fresh air directly at ambient temperature HVAC System have inlet air with reduced temperature than ambient air which in turns reduction of reduction of heat load on chilled water cooling coil, ultimately, saving in power consumption of chilling plant.

**Conclusion**

# What are energy-saving opportunities in the HVAC system

May 30, 2023

## Embrace Smart Thermostats for Precision Control

One of the key energy-saving opportunities in your HVAC system (https://www.globalheatingairconditioning.com/heating-furnace-repair/) lies in embracing smart thermostats. These advanced devices allow for precise temperature control and scheduling, optimizing energy usage. With features like learning algorithms and remote access, smart thermostats enable you to adjust settings based on occupancy patterns, weather conditions, and personal preferences, maximizing comfort while minimizing energy waste.

## Maximize Insulation for Efficient Heating and Cooling



Proper insulation plays a crucial role in improving energy efficiency i
Inadequate insulation leads to heat loss during winter and heat gain
your HVAC system to work harder. By ensuring sufficient insulation in walls, ceilings, floors, and ductwork, you can create a well-insulated envelope that minimizes energy leakage, reduces strain on your HVAC system, and enhances overall efficiency.

# Implement Regular HVAC Maintenance

Regular maintenance is vital for optimizing the energy efficiency of your HVAC system. Neglected systems accumulate dirt, dust, and debris, hindering airflow and reducing efficiency. Schedule routine maintenance tasks, such as cleaning or replacing filters (https://www.globalheatingairconditioning.com/air-conditioning/), inspecting and cleaning coils, checking refrigerant levels, and lubricating moving parts. Properly maintained HVAC systems operate more efficiently, reducing energy consumption and extending equipment lifespan.

# Sealing and Insulating Ductwork

Leaky ductwork is a common culprit of energy waste in HVAC systems. Inspect your ductwork for leaks, gaps, or loose connections and seal them properly to prevent conditioned air from escaping. Additionally, consider insulating ductwork in unconditioned areas, such as attics or crawl spaces, to minimize heat gain or loss. Sealing and insulating ductwork ensures that conditioned air reaches its intended destination efficiently, optimizing energy usage.

# Optimize Airflow with Proper Ventilation

Proper airflow is essential for an energy-efficient (https://www.globalheatingairconditioning.com/yearly-maintenanc Ensure that supply and return vents are unobstructed by furniture, c objects. Clean vents and registers regularly to prevent blockages tha Additionally, consider implementing strategies such as zoning or adjusting dampers to optimize airflow to different areas of your home, maximizing comfort and reducing unnecessary energy consumption.

# Consider Energy-Efficient Equipment Upgrades

If your HVAC system is outdated and inefficient, upgrading to energy-efficient equipment can yield substantial energy savings. Look for units with high Seasonal Energy Efficiency Ratio (SEER) ratings for air conditioners and Annual Fuel Utilization Efficiency (https://www.lennox.com/buyers-guide/guide-to-hvac/glossary/annualized-fuel-utilization-efficiency-afue) (AFUE) ratings for furnaces. Energy-efficient equipment utilizes advanced technologies to minimize energy consumption and provide better temperature control, resulting in long-term energy and cost savings.

# Conclusion

Exploring energy-saving opportunities in your HVAC system is a proactive step towards creating a more sustainable and cost-effective home environment. By embracing smart thermostats, maximizing insulation, implementing regular maintenance, sealing and insulating ductwork, optimizing airflow, and considering energy-efficient equipment upgrades, you can significantly reduce energy consumption, lower utility costs, and contribute to a greener future.

Take advantage of these energy-saving strategies and transform your HVAC system into an efficient and environmentally friendly asset for your home.

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# ANNEXURE

## CHECKLIST & TIPS FOR ENERGY EFFICIENCY IN ELECTRICAL UTILITIES

### Electricity

- Optimise the tariff structure with utility supplier
- Schedule your operations to maintain a high load factor
- Shift loads to off-peak times if possible.
- Minimise maximum demand by tripping loads through a demand controller
- Stagger start-up times for equipment with large starting currents to minimize load peaking.
- Use standby electric generation equipment for on-peak high load periods.
- Correct power factor to at least 0.90 under rated load conditions.
- Relocate transformers close to main loads.
- Set transformer taps to optimum settings.
- Disconnect primary power to transformers that do not serve any active loads
- Consider on-site electric generation or cogeneration.
- Export power to grid if you have any surplus in your captive generation
- Check utility electric meter with your own meter.
- Shut off unnecessary computers, printers, and copiers at night.

### Motors

Fast motor – no load → less Egy Consum

- Properly size to the load for optimum efficiency.
  *(High efficiency motors offer of 4 – 5% higher efficiency than standard motors)*
- Use energy-efficient motors where economical.
- Use synchronous motors to improve power factor.
- Check alignment.
- Provide proper ventilation
  *(For every 10°C increase in motor operating temperature over recommended peak, the motor life is estimated to be halved)*
- Check for under-voltage and over-voltage conditions.
- Balance the three-phase power supply.
  (An Imbalanced voltage can reduce 3 – 5% in motor input power)
- Demand efficiency restoration after motor rewinding.
  *(If rewinding is not done properly, the efficiency can be reduced by 5 – 8%)*

Slow motor – Full Load – More Egy

### Drives

- Use variable-speed drives for large variable loads.
- Use high-efficiency gear sets.
- Use precision alignment.
- Check belt tension regularly.
- Eliminate variable-pitch pulleys.
- Use flat belts as alternatives to v-belts.

- Use synthetic lubricants for large gearboxes.
- Eliminate eddy current couplings.
- Shut them off when not needed.

## Fans

- Use smooth, well-rounded air inlet cones for fan air intakes.
- Avoid poor flow distribution at the fan inlet.
- Minimize fan inlet and outlet obstructions.
- Clean screens, filters, and fan blades regularly.
- Use aerofoil-shaped fan blades.
- Minimize fan speed.
- Use low-slip or flat belts.
- Check belt tension regularly.
- Eliminate variable pitch pulleys.
- Use variable speed drives for large variable fan loads.
- Use energy-efficient motors for continuous or near-continuous operation
- Eliminate leaks in ductwork.
- Minimise bends in ductwork
- Turn fans off when not needed.

## Blowers

- Use smooth, well-rounded air inlet ducts or cones for air intakes.
- Minimize blower inlet and outlet obstructions.
- Clean screens and filters regularly.
- Minimize blower speed.
- Use low-slip or no-slip belts.
- Check belt tension regularly.
- Eliminate variable pitch pulleys.
- Use variable speed drives for large variable blower loads.
- Use energy-efficient motors for continuous or near-continuous operation.
- Eliminate ductwork leaks.
- Turn blowers off when they are not needed.

## Pumps

- Operate pumping near best efficiency point.
- Modify pumping to minimize throttling. 6σ → to ensure pump operating within target range of pump curve → checks pump overload, minimise power consumption
- Adapt to wide load variation with variable speed drives or sequenced control of smaller units.
- Stop running both pumps -- add an auto-start for an on-line spare or add a booster pump in the problem area.
- Use booster pumps for small loads requiring higher pressures.
- Increase fluid temperature differentials to reduce pumping rates.
- Repair seals and packing to minimize water waste.

- Balance the system to minimize flows and reduce pump power requirements.
- Use siphon effect to advantage: don't waste pumping head with a free-fall (gravity) return.

### Compressors

- Consider variable speed drive for variable load on positive displacement compressors.
- Use a synthetic lubricant if the compressor manufacturer permits it.
- Be sure lubricating oil temperature is not too high (oil degradation and lowered viscosity) and not too low (condensation contamination).
- Change the oil filter regularly.
- Periodically inspect compressor intercoolers for proper functioning.
- Use waste heat from a very large compressor to power an absorption chiller or preheat process or utility feeds.
- Establish a compressor efficiency-maintenance program. Start with an energy audit and follow-up, then make a compressor efficiency-maintenance program a part of your continuous energy management program.

### Compressed air

- Install a control system to coordinate multiple air compressors.
- Study part-load characteristics and cycling costs to determine the most-efficient mode for operating multiple air compressors.
- Avoid over sizing -- match the connected load.
- Load up modulation-controlled air compressors. (They use almost as much power at partial load as at full load.)
- Turn off the back-up air compressor until it is needed.
- Reduce air compressor discharge pressure to the lowest acceptable setting. *(Reduction of 1 $kg/cm^2$ air pressure (8 $kg/cm^2$ to 7 $kg/cm^2$) would result in 9% input power savings. This will also reduce* compressed air leakage rates by 10%)
- Use the highest reasonable dryer dew point settings.
- Turn off refrigerated and heated air dryers when the air compressors are off.
- Use a control system to minimize heatless desiccant dryer purging.
- Minimize purges, leaks, excessive pressure drops, and condensation accumulation. *(Compressed air leak from 1 mm hole size at 7 $kg/cm^2$ pressure would mean power loss equivalent to 0.5 kW)*
- Use drain controls instead of continuous air bleeds through the drains.
- Consider engine-driven or steam-driven air compression to reduce electrical demand charges.
- Replace standard v-belts with high-efficiency flat belts as the old v-belts wear out.
- Use a small air compressor when major production load is off.
- Take air compressor intake air from the coolest (but not air conditioned) location. *(Every 5°C reduction in intake air temperature would result in 1% reduction in compressor power consumption)*
- Use an air-cooled aftercooler to heat building makeup air in winter.
- Be sure that heat exchangers are not fouled (e.g. -- with oil).

- Be sure that air/oil separators are not fouled.
- Monitor pressure drops across suction and discharge filters and clean or replace filters promptly upon alarm.
- Use a properly sized compressed air storage receiver.
  Minimize disposal costs by using lubricant that is fully demulsible and an effective oil-water separator.
- Consider alternatives to compressed air such as blowers for cooling, hydraulic rather than air cylinders, electric rather than air actuators, and electronic rather than pneumatic controls.
- Use nozzles or venturi-type devices rather than blowing with open compressed air lines.
- Check for leaking drain valves on compressed air filter/regulator sets. Certain rubber-type valves may leak continuously after they age and crack.
- In dusty environments, control packaging lines with high-intensity photocell units instead of standard units with continuous air purging of lenses and reflectors.
- Establish a compressed air efficiency-maintenance program. Start with an energy audit and follow-up, then make a compressed air efficiency-maintenance program a part of your continuous energy management program.

## Chillers

- Increase the chilled water temperature set point if possible.
- Use the lowest temperature condenser water available that the chiller can handle.
  *(Reducing condensing temperature by 5.5°C, results in a 20 – 25% decrease in compressor power consumption)*
- Increase the evaporator temperature
  *(5.5°C increase in evaporator temperature reduces compressor power consumption by 20 – 25%)*
- Clean heat exchangers when fouled.
  *(1 mm scale build-up on condenser tubes can increase energy consumption by 40%)*
- Optimize condenser water flow rate and refrigerated water flow rate.
- Replace old chillers or compressors with new higher-efficiency models.
- Use water-cooled rather than air-cooled chiller condensers.
- Use energy-efficient motors for continuous or near-continuous operation.
- Specify appropriate fouling factors for condensers. Sewage.
- Do not overcharge oil.
- Install a control system to coordinate multiple chillers.
- Study part-load characteristics and cycling costs to determine the most-efficient mode for operating multiple chillers.
- Run the chillers with the lowest operating costs to serve base load.
- Avoid oversizing -- match the connected load.
- Isolate off-line chillers and cooling towers.
- Establish a chiller efficiency-maintenance program. Start with an energy audit and follow-up, then make a chiller efficiency-maintenance program a part of your continuous energy management program.

## HVAC (Heating / Ventilation / Air Conditioning)

- Tune up the HVAC control system.
- Consider installing a building automation system (BAS) or energy management system (EMS) or restoring an out-of-service one.
- Balance the system to minimize flows and reduce blower/fan/pump power requirements.
- Eliminate or reduce reheat whenever possible.
- Use appropriate HVAC thermostat setback.
- Use morning pre-cooling in summer and pre-heating in winter (i.e. -- before electrical peak hours). Thermal lag
- Use building thermal lag to minimize HVAC equipment operating time.
- In winter during unoccupied periods, allow temperatures to fall as low as possible without freezing water lines or damaging stored materials.
- In summer during unoccupied periods, allow temperatures to rise as high as possible without damaging stored materials.
- Improve control and utilization of outside air.
- Use air-to-air heat exchangers to reduce energy requirements for heating and cooling of outside air.
- Reduce HVAC system operating hours (e.g. -- night, weekend).
- Optimize ventilation.
- Ventilate only when necessary. To allow some areas to be shut down when unoccupied, install dedicated HVAC systems on continuous loads (e.g. -- computer rooms).
- ✓ Provide dedicated outside air supply to kitchens, cleaning rooms, combustion equipment, etc. to avoid excessive exhausting of conditioned air.
- Use evaporative cooling in dry climates.
- Reduce humidification or dehumidification during unoccupied periods.
- Use atomization rather than steam for humidification where possible. atomization — Bulk liquid or gas broken into fine particles / fragmentation ↓ high purity, control, improved flow.
- Clean HVAC unit coils periodically and comb mashed fins.
- Upgrade filter banks to reduce pressure drop and thus lower fan power requirements.
- Check HVAC filters on a schedule (at least monthly) and clean/change if appropriate.
- Check pneumatic controls air compressors for proper operation, cycling, and maintenance.
- Isolate air conditioned loading dock areas and cool storage areas using high-speed doors or clear PVC strip curtains.
- Install ceiling fans to minimize thermal stratification in high-bay areas.
- Relocate air diffusers to optimum heights in areas with high ceilings.
- Consider reducing ceiling heights.
- Eliminate obstructions in front of radiators, baseboard heaters, etc.
- Check reflectors on infrared heaters for cleanliness and proper beam direction.
- Use professionally-designed industrial ventilation hoods for dust and vapor control.
- Use local infrared heat for personnel rather than heating the entire area.
- Use spot cooling and heating (e.g. -- use ceiling fans for personnel rather than cooling the entire area).
- Purchase only high-efficiency models for HVAC window units.
- Put HVAC window units on timer control.
- Don't oversize cooling units. (Oversized units will "short cycle" which results in poor humidity control.)

- Install multi-fueling capability and run with the cheapest fuel available at the time.
- Consider dedicated make-up air for exhaust hoods. (Why exhaust the air conditioning or heat if you don't need to?)
- Minimize HVAC fan speeds.
- Consider desiccant drying of outside air, to reduce cooling requirements in humid climates.
- Consider ground source heat pumps.
- Seal leaky HVAC ductwork.
- Seal all leaks around coils.
- Repair loose or damaged flexible connections (including those under air handling units).
- Eliminate simultaneous heating and cooling during seasonal transition periods.
- Zone HVAC air and water systems to minimize energy use.
- Inspect, clean, lubricate, and adjust damper blades and linkages.
- Establish an HVAC efficiency-maintenance program. Start with an energy audit and follow-up, then make an HVAC efficiency-maintenance program a part of your continuous energy management program.

## Refrigeration

- Use water-cooled condensers rather than air-cooled condensers.
- Challenge the need for refrigeration, particularly for old batch processes.
- Avoid oversizing -- match the connected load.
- Consider gas-powered refrigeration equipment to minimize electrical demand charges.
- Use "free cooling" to allow chiller shutdown in cold weather.
- Use refrigerated water loads in series if possible.
- Convert firewater or other tanks to thermal storage.
- Don't assume that the old way is still the best -- particularly for energy-intensive low temperature systems.
- Correct inappropriate brine or glycol concentration that adversely affects heat transfer and/or pumping energy.

  If it sweats, insulate it, but if it is corroding, replace it first.
- Make adjustments to minimize hot gas bypass operation.
- Inspect moisture/liquid indicators.
- Consider change of refrigerant type if it will improve efficiency.
- Check for correct refrigerant charge level.
- Inspect the purge for air and water leaks.
- Establish a refrigeration efficiency-maintenance program. Start with an energy audit and follow-up, then make a refrigeration efficiency-maintenance program a part of your continuous energy management program.

## Cooling towers

- Control cooling tower fans based on leaving water temperatures.
- Control to the optimum water temperature as determined from cooling tower and chiller performance data.
- Use two-speed or variable-speed drives for cooling tower fan control if the fans are few. Stage the cooling tower fans with on-off control if there are many.

- Turn off unnecessary cooling tower fans when loads are reduced.
- Cover hot water basins (to minimize algae growth that contributes to fouling).
- Balance flow to cooling tower hot water basins.
- Periodically clean plugged cooling tower water distribution nozzles.
- Install new nozzles to obtain a more-uniform water pattern.
- Replace splash bars with self-extinguishing PVC cellular-film fill.
- On old counterflow cooling towers, replace old spray-type nozzles with new square-spray ABS practically-non-clogging nozzles.
- Replace slat-type drift eliminators with high-efficiency, low-pressure-drop, self-extinguishing, PVC cellular units.
- If possible, follow manufacturer's recommended clearances around cooling towers and relocate or modify structures, signs, fences, dumpsters, etc. that interfere with air intake or exhaust.
- Optimize cooling tower fan blade angle on a seasonal and/or load basis.
- Correct excessive and/or uneven fan blade tip clearance and poor fan balance.
- Use a velocity pressure recovery fan ring.
- Divert clean air-conditioned building exhaust to the cooling tower during hot weather.
- Re-line leaking cooling tower cold water basins.
- Check water overflow pipes for proper operating level.
- Optimize chemical use.
- Consider side stream water treatment.
- Restrict flows through large loads to design values.
- Shut off loads that are not in service.
- Take blowdown water from the return water header.
- Optimize blowdown flow rate.
- Automate blowdown to minimize it.
- Send blowdown to other uses (Remember, the blowdown does not have to be removed at the cooling tower. It can be removed anywhere in the piping system.)

Blow down → Volume or % of discharge water compared to incoming water & to check high concentration of dissolved solids

- Implement a cooling tower winterization plan to minimize ice build-up.
- Install interlocks to prevent fan operation when there is no water flow.
- Establish a cooling tower efficiency-maintenance program. Start with an energy audit and follow-up, then make a cooling tower efficiency-maintenance program a part of your continuous energy management program.

## Lighting

- Reduce excessive illumination levels to standard levels using switching, delamping, etc. (Know the electrical effects before doing delamping.)
- Aggressively control lighting with clock timers, delay timers, photocells, and/or occupancy sensors.
- Install efficient alternatives to incandescent lighting, mercury vapor lighting, etc. Efficiency (lumens/watt) of various technologies range from best to worst approximately as follows: low pressure sodium, high pressure sodium, metal halide, fluorescent, mercury vapor, incandescent.
- Select ballasts and lamps carefully with high power factor and long-term efficiency in mind.

- Upgrade obsolete fluorescent systems to Compact fluorescents and electronic ballasts
- Consider lowering the fixtures to enable using less of them.
- Consider daylighting, skylights, etc.
- Consider painting the walls a lighter color and using less lighting fixtures or lower wattages.
- Use task lighting and reduce background illumination.
- Re-evaluate exterior lighting strategy, type, and control. Control it aggressively.
- Change exit signs from incandescent to LED.

**DG sets**

- Optimise loading
- Use waste heat to generate steam/hot water /power an absorption chiller or preheat process or utility feeds.
- Use jacket and head cooling water for process needs
- Clean air filters regularly
- Insulate exhaust pipes to reduce DG set room temperatures
- Use cheaper heavy fuel oil for capacities more than 1MW

**Buildings**

- Seal exterior cracks/openings/gaps with caulk, gasketing, weatherstripping, etc.
- Consider new thermal doors, thermal windows, roofing insulation, etc.
- Install windbreaks near exterior doors.
- Replace single-pane glass with insulating glass.
- Consider covering some window and skylight areas with insulated wall panels inside the building.
- If visibility is not required but light is required, consider replacing exterior windows with insulated glass block.
- Consider tinted glass, reflective glass, coatings, awnings, overhangs, draperies, blinds, and shades for sunlit exterior windows.
- Use landscaping to advantage.
- Add vestibules or revolving doors to primary exterior personnel doors.
- Consider automatic doors, air curtains, strip doors, etc. at high-traffic passages between conditioned and non-conditioned spaces. Use self-closing doors if possible.
- Use intermediate doors in stairways and vertical passages to minimize building stack effect.
- Use dock seals at shipping and receiving doors.
- Bring cleaning personnel in during the working day or as soon after as possible to minimize lighting and HVAC costs.

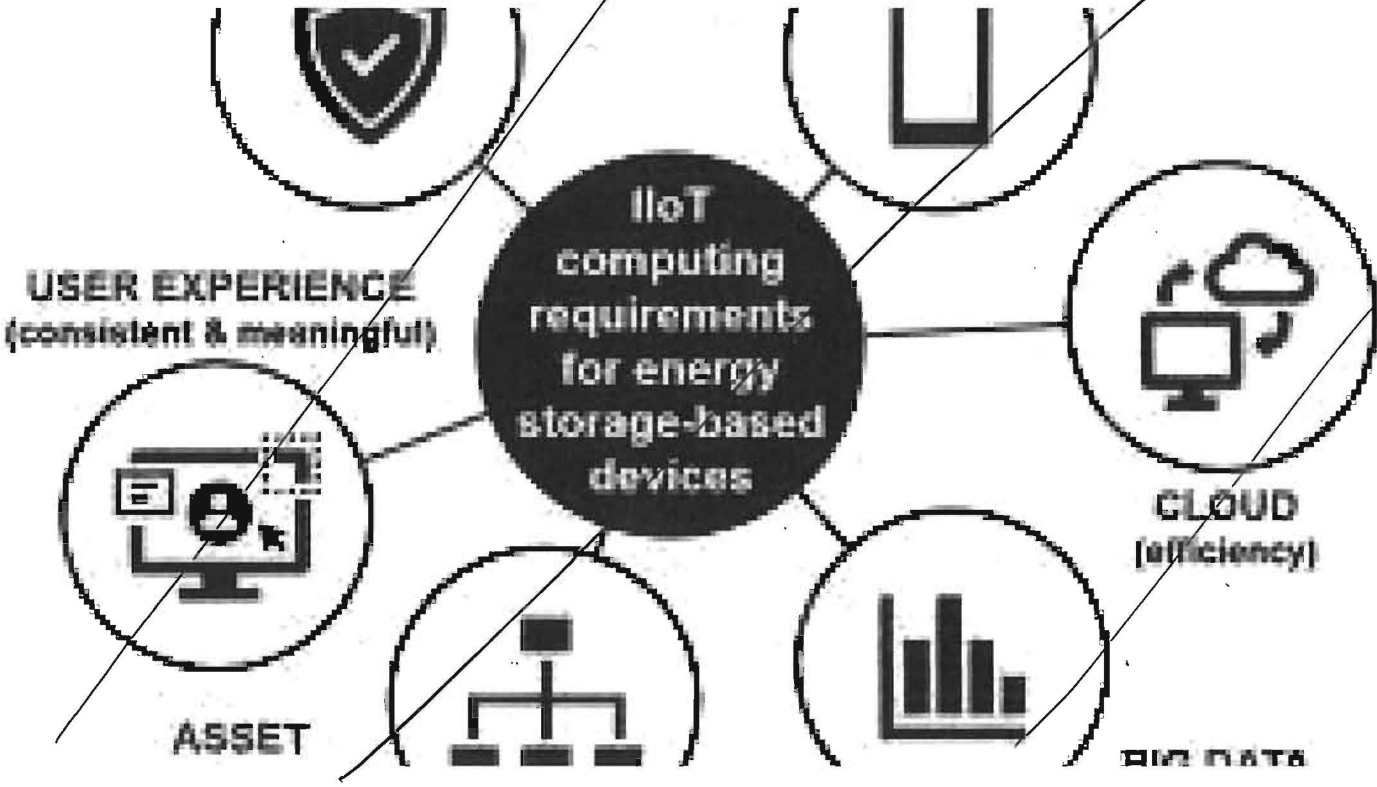
**Water & Wastewater**

- Recycle water, particularly for uses with less-critical quality requirements.
- Recycle water, especially if sewer costs are based on water consumption.
- Balance closed systems to minimize flows and reduce pump power requirements.
- Eliminate once-through cooling with water.
- Use the least expensive type of water that will satisfy the requirement.

- Fix water leaks.
- Test for underground water leaks. (It's easy to do over a holiday shutdown.)
- Check water overflow pipes for proper operating level.
- Automate blowdown to minimize it.
- Provide proper tools for wash down -- especially self-closing nozzles.
- Install efficient irrigation.
- Reduce flows at water sampling stations.
- Eliminate continuous overflow at water tanks.
- Promptly repair leaking toilets and faucets.
- Use water restrictors on faucets, showers, etc.
- Use self-closing type faucets in restrooms.
- Use the lowest possible hot water temperature.
- Do not use a heating system hot water boiler to provide service hot water during the cooling season -- install a smaller, more-efficient system for the cooling season service hot water.
- If water must be heated electrically, consider accumulation in a large insulated storage tank to minimize heating at on-peak electric rates.
- Use multiple, distributed, small water heaters to minimize thermal losses in large piping systems.
- Use freeze protection valves rather than manual bleeding of lines.
- Consider leased and mobile water treatment systems, especially for deionized water.
- Seal sumps to prevent seepage inward from necessitating extra sump pump operation.
- Install pretreatment to reduce TOC and BOD surcharges. TOC
- Verify the water meter readings. (You'd be amazed how long a meter reading can be estimated after the meter breaks or the meter pit fills with water!)
- Verify the sewer flows if the sewer bills are based on them

**Miscellaneous**

- Meter any unmetered utilities. Know what is normal efficient use. Track down causes of deviations.
- Shut down spare, idling, or unneeded equipment.
- Make sure that all of the utilities to redundant areas are turned off -- including utilities like compressed air and cooling water.
- Install automatic control to efficiently coordinate multiple air compressors, chillers, cooling tower cells, boilers, etc.
- Renegotiate utilities contracts to reflect current loads and variations.
- Consider buying utilities from neighbors, particularly to handle peaks.
- Leased space often has low-bid inefficient equipment. Consider upgrades if your lease will continue for several more years.
- Adjust fluid temperatures within acceptable limits to minimize undesirable heat transfer in long pipelines.
- Minimize use of flow bypasses and minimize bypass flow rates.
- Provide restriction orifices in purges (nitrogen, steam, etc.).
- Eliminate unnecessary flow measurement orifices.
- Consider alternatives to high pressure drops across valves.
- Turn off winter heat tracing that is on in summer.




# Power electronics and energy efficiency

Kiruthika R
Software Engineer Intern @Wise Work &@Hue Learn | Best Outgoing Student & All Round Performer Awardee -2022,2023,2024 |Full Stack Developer|IEEE| Springer|International Journals-10| Book Chapters -2 |Patents -1



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Power electronics plays a vital role in improving energy efficiency and optimizing power usage in various applications. Power electronic devices and circuits are designed to efficiently convert and control electrical energy, allowing for efficient power management and reducing energy waste. These devices include inverters, converters, rectifiers, and voltage regulators, among others. They are widely used in renewable energy systems, electric vehicles, industrial motor drives, and power supply units. By enabling efficient power conversion, power electronics contribute to reducing energy consumption, minimizing losses, and promoting sustainability in various sectors.

One of the key benefits of power electronics is their ability to facilitate energy-efficient systems. For instance, in renewable energy applications like solar photovoltaic (PV) systems, power electronic converters are used to convert the DC output of solar panels into AC power for grid integration. These converters ensure maximum power extraction from the solar panels and enable optimal power flow based on the grid requirements. Similarly, in motor drive applications, power electronics control the speed and torque of electric motors, enabling precise control and efficient energy usage. By employing power electronics, energy efficiency can be significantly enhanced, leading to reduced energy consumption and lower operating costs.

$LiNbO_3$ → Silicon plat → SiC + GaN (WBG)

Advancements in power electronics technologies continue to drive energy efficiency improvements. Researchers and engineers are constantly exploring new materials, circuit topologies, and control strategies to enhance the performance and efficiency of power electronic devices. For example, wide-bandgap (WBG) semiconductors like silicon carbide (SiC) and gallium nitride (GaN) offer superior properties compared to traditional silicon-based devices, enabling higher switching frequencies, lower losses, and improved efficiency. Additionally, advanced control algorithms and digital signal processing techniques optimize power conversion processes, ensuring precise control and higher efficiency. These ongoing innovations in power electronics hold great promise for achieving even higher levels of energy efficiency and promoting sustainable energy utilization.



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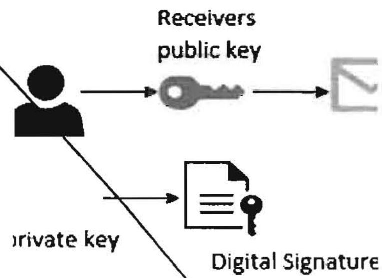

## Introduction To Power Electronics

Renewable energy systems have become a crucial part of our efforts to combat climate change and transition to a sustainable future. These systems harness the power of natural resources such as sunlight, wind, and water to generate clean electricity.

However, to effectively integrate renewable energy into the grid and optimize its performance, we rely on power electronics. In this article, we will explore the role of power electronics in renewable energy systems, the benefits they bring, and the impact they have on our energy future.

## The Role Of Power Electronics In Renewable Energy Systems



Power electronics play a vital role in renewable energy systems by enabling the conversion, control, and management of electrical power. These devices, such as inverters and converters, are responsible for transforming the electricity generated by renewable sources into a form that can be efficiently used or stored.

For example, solar panels produce direct current (DC) electricity, but most appliances and the grid operate on alternating current (AC). Power electronics bridge this gap by converting the DC electricity into AC, making it compatible with our existing infrastructure.

Another critical function of power electronics in renewable energy systems is power conditioning. As renewable energy sources are intermittent and their output can fluctuate, power electronics stabilize the electricity before it is fed into the grid.

They ensure a constant frequency, voltage, and quality of power, improving the reliability and stability of the entire energy system. In addition, power electronics enable the seamless integration of multiple renewable energy sources, such as solar and wind, by synchronizing their outputs and optimizing their performance.

## Benefits Of Using Power Electronics In Renewable Energy Systems

By continuously monitoring and adjusting the operating conditions, they ensure that the energy conversion is optimized, resulting in higher energy yields. This increased efficiency translates into more power being generated from the same resources, making renewable energy systems more economically viable and reducing their environmental footprint.

Furthermore, power electronics enhance the reliability and stability of renewable energy systems. By regulating the voltage and frequency, they prevent fluctuations and disturbances, improving the overall grid performance. This stability is crucial for the successful integration of renewable energy into the existing power infrastructure, minimizing the risk of power outages or disruptions.

Power electronics also protect against overvoltage, overcurrent, and other electrical faults, safeguarding the system and reducing the likelihood of damage.

Additionally, power electronics enable advanced grid functionalities, such as grid-tied inverters with smart grid capabilities. These inverters can communicate with the grid and respond to signals, allowing for dynamic control and grid support services.

For example, they can help stabilize the grid frequency or provide reactive power support when needed. These functionalities enhance the reliability of the grid and enable a smoother transition to a renewable energy-based future.



## Examples Of Power Electronics In Action

The impact of power electronics on renewable energy systems can be seen in various real-world applications. One such example is the use of power electronics in photovoltaic (PV) systems. PV systems convert sunlight into electricity, but the generated DC power needs to be converted into AC for practical use.

Inverters, a type of power electronics device, are used to perform this conversion. They ensure that the PV system operates at its maximum power point, maximizing the energy output. In addition, inverters provide grid synchronization, power quality control, and safety features.

Another example is the integration of power electronics in wind turbines. Wind energy systems rely on power electronics to convert the variable speed and frequency of the wind turbine into a stable electrical output. Power electronics control the rotational speed of the

turbine

## Challenges And Advancements In Power Electronics For Renewable Energy

While power electronics have revolutionized renewable energy systems, there are still challenges to overcome and ongoing advancements in the field. One of the main challenges is the cost of power electronics devices. Although the prices have been decreasing, they still represent a significant portion of the overall system cost. Researchers and manufacturers are striving to develop more cost-effective solutions, such as using new materials, improving manufacturing processes, and increasing production volumes.

Another challenge is the efficiency of power electronic devices. While they have significantly improved over the years, there is still room for enhancement. Higher efficiency means less energy loss during conversion, leading to greater overall system efficiency.



This can be achieved through the development of advanced semiconductor materials and innovative circuit topologies. Additionally, the miniaturization of power electronics devices can improve their efficiency by reducing parasitic losses and improving thermal management.

Advancements in power electronics are also focused on increasing their power density and reliability. Higher power density means that more power can be handled by smaller and lighter devices, enabling compact and efficient designs.

Reliability is crucial for the long-term operation of renewable energy systems, as power electronics devices are exposed to harsh environmental conditions and must withstand high power loads. Research is being conducted to improve device packaging, cooling methods, and fault detection techniques to ensure the reliability and longevity of power electronics in renewable energy systems.

## The Future Of Power Electronics In Renewable Energy Systems

As renewable energy continues to expand its share in the global energy mix, the future of power electronics looks promising. Technological advancements and economies of scale are expected to drive down the cost of power electronics devices, making renewable energy

Additionally, the integration of power electronics with energy storage systems will play a crucial role in the future of renewable energy. Energy storage technologies, such as batteries, allow for the efficient storage and utilization of excess energy generated by renewable sources.

Power electronics enable the bi-directional flow of energy between the storage system and the grid, providing flexibility and grid support services. This combination of power electronics and energy storage will enable a more reliable and resilient energy infrastructure, capable of handling the variability of renewable energy sources.

Solar + wind + Hydro

Furthermore, power electronics will continue to play a vital role in the grid integration of renewable energy. As the share of renewable energy increases, the grid will need to adapt to handle the intermittent nature of these sources.



Power electronics devices, such as grid-tied inverters, will be essential in managing the power flow, maintaining grid stability, and providing grid support services. Advanced control algorithms and communication systems will enable more efficient and intelligent grid operation, facilitating the seamless integration of renewable energy.



## Power Electronics In Electric Vehicles And Transportation

Power electronics also have a significant impact on the electrification of transportation, particularly in electric vehicles (EVs). EVs rely on power electronics for various functions, such as converting the DC power from the battery into AC for the electric motor, controlling the motor speed, and managing the charging process. Power electronics devices, including onboard chargers and motor controllers, are crucial for the efficient and reliable operation of EVs.

In addition to EVs, power electronics are also utilized in other forms of electric transportation, such as electric trains and buses. Power electronics enable the efficient propulsion of these vehicles by controlling the power flow and optimizing the energy conversion. They also facilitate regenerative braking, where the kinetic energy of the vehicle is converted back into electrical energy and stored for later use. This regenerative braking not only improves energy efficiency but also reduces wear on the braking system, enhancing the overall performance and lifespan of the vehicle.

## Conclusion

numerous benefits, including increased energy yields, improved grid stability, and advanced grid functionalities.

Examples of power electronics in action can be seen in photovoltaic systems and wind turbines. However, there are still challenges to overcome and ongoing advancements in the field, focusing on cost reduction, efficiency improvement, power density increase, and reliability enhancement.

The future of power electronics in renewable energy systems looks promising, with further cost reductions, integration with energy storage, and grid integration advancements. Power electronics also play a vital role in the electrification of transportation, particularly in electric vehicles.

With their continued development and deployment, power electronics will continue to shape the renewable energy landscape and pave the way for a sustainable and clean energy future.



## Related Articles

Power Management Strategies for Remote and Off-Grid Locations

The Role of Energy Storage in Grid Stability and Management

~~The Role of Power Management in Sustainable Agriculture Technologies~~



**More on Power Electronics (PE)**

(1) Battery Management System (BMS) for energy solutions

(2) PE devices are manufactured sustainably to reduce hazardous materials, improve recyclability, reduce carbon emissions & help climate change efforts

(3) Helps worldwide in electric transportation & production of renewable egy.

(4) Wide Band Gap (WBG) Semiconductors like SiC & GaN have revolutionized PE, These have wider (higher) bandgap than silicon with results; these materials function at greater voltages frequencies & temp. SiC + GaN devices can sustain many times higher breakdown voltages than silicon devices; enable design of more robust & compact power systems. In WBG materials, intrinsic carrier concentration is low. This reduces leakage currents & power loss during operation

(5) SiC → Thermal conductivity 3 times than that of silicon ⇒ results - better heat dissipation & power density. These properties are useful in Electric Vehicles (EV) & high power industrial equipment

GaN → Very high electron mobility → ideal for RF amplifiers & power supplies

(6) SiC based inverters transform solar & wind energy into electricity with very low losses & with much higher efficiency than silicon inverters

(7) SiC in EV improve power conversion, range & charging time

(8) Challenges of WBG materials — complex to fabricate, costly equipments. Needs reliability testing & standardization to ensure long term performance & safety

(9) PE in wind turbines converters control changing wind generator output & grid compatibility. The converters maximize energy harvest, stabilize voltage & frequency & provide grid oscillatory services

(10) Model Predictive Control (MPC) — An PE algorithm innovation — enhances dynamic response & lowers energy loss in PE converters; Also useful in solar PV inverters & wind turbine converters

(11) Digital Signal Processing (DSP) controllers conduct complex harmonic algorithms for compensation, power factor correction & fault detection for better control & performance & reliability of PE devices

— ... Contd. (P)

(12) PE converters, motor drives use vector control & DTC for real time control (DTC =

(13) Future Trends & challenges in PE

(i) Cheaper manufacturing of WBG Semiconductors

(ii) Artificial Intelligence (AI) & Machine Learning (ML) integration which can easily forsee faults & maximise performance of devices. AI+ML can improve power system efficiency & dependability or complex smart grids & microgrids

(iii) PE advances ensure - charging + discharging cycles, temp. management, battery efficiency + lifespan & help solid state & flow batteries. Also we need to develop advance control algorithms

(14) Modular & scalable design of PE system increases flexibility & adaptation, simplify integration, customization & maintainance. Scalable PE are ideal for renewable energy systems & microgrids needing to expand capacity

(15) Need policy to support regulatory frameworks that promote innovation in guaranteeing safety & reliability standard. Industry stakeholders, regulatory organizations & research institutions need to collaborate

Energy Efficiency ($\eta$) of a system with PE:

$$\eta = E_{util} / E_{in}$$

$E_{util}$ = useful output energy - (Produced by system

$E_{in}$ = Total input energy

Dissipated energy ($E_{diss}$)

$$= E_{in} - E_{util}$$

$$= E_{in} - \eta E_{in}$$

or $\boxed{E_{diss} = E_{in}(1-\eta)}$

Conversion efficiency $\eta_{conv} = E_{out} / E_{in}$

$E_{out}$ = output energy

$$\Rightarrow E_{out} = E_{in}\eta_{conv}$$

$$\boxed{E_{out} = \frac{E_{diss}\eta_{conv}}{1-\eta}}$$

Paper

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# Power Electronics, a Key Technology for Energy Efficiency and Renewables

Peter K. Steimer
ABB Ltd., Power Electronics and MV Drives, CH-5300 Turgi, Switzerland
E-mail: peter.steimer@ch.abb.com

*Abstract – Power Electronics will play a key role in this paradigm shift to more renewable electrical energy and higher energy efficiency in multiple applications including transportation. In electrical energy generation a major shift to renewables as sources of future electrical energy will happen. The political institutions world-wide have the responsibility to create the boundary conditions to accelerate this needed change. Renewables (Wind, Solar, ..) are important future contributors and solar power (photovoltaic or thermal) needs to be taken serious. In regards of energy efficiency we need to focus on efficient bulk power generation including the mandatory use of waste heat for district heating or process industries. This all will ask for a substantial expansion and modernization of the electrical distribution and transmission system with more MVDC and HVDC systems. In industrial processes efficiency improvements can be achieved with a major focus on pump and fan applications. Another 30% of inefficient pump and fan applications need to be converted to variable speed drives to get an average of 40% energy saving in these applications. In regards of transportation up to 30-50% fuel / energy consumption reduction can be achieved with the DC-link based power system to enable efficient hybrid and in the longer term pure electrical solutions in transportation.*

## I. INTRODUCTION

The global demand for electrical energy is growing continuously, at an average rate of 3.3% per year. The installed capacity needs to grow by more than 50% until 2020 from 4400 GW (2007) to 6700 GW (2020). For 2030 the installed electrical power generation capacity will grow by 100%, whereas the worldwide primary energy demand will grow respectively by 55% only [1]. This means new yearly installations of 150 to 200 GW. As the biggest part of today installations have high C02 emissions a paradigm shift is needed. In the future renewable energies and energy efficiency will gain unique attention and will further drive the transition to more electric.

(1) Renewables have the potential to reduce the C02 emissions in power generation substantially. Hydro power contributes today globally about 15% to the total electrical power generation. The target for renwables in Europe is 20% by the year 2020. Besides conventional hydro power the most important renewables are Wind and in the future Solar. In 2007 Windpower has seen new installations [2] of appr. 20 GW at a CAGR of 27%. In the same timeframe Solar power has seen new installations [3] of appr. 3 GW at a CAGR of 50%.

(2) Energy efficiency has the potential to save 20% of the primary energy. Energy efficiency needs to be understood in regards of the total chain from electrical power generation over transmission and distribution down to the end-users.

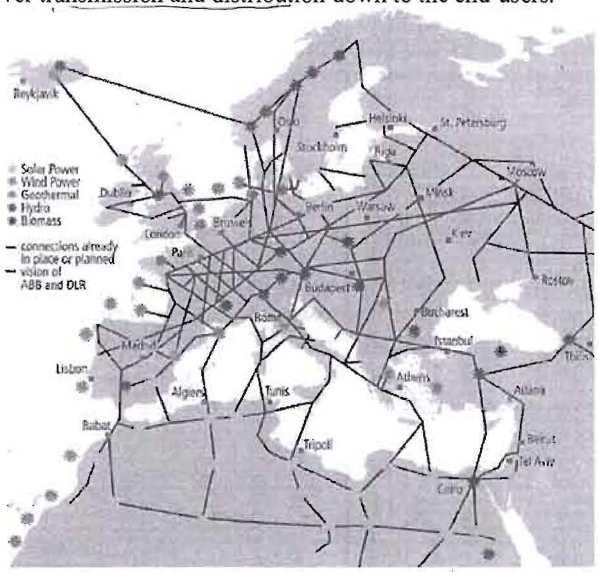

Figure 1: A vision on future integration needs of renewable energies for Europe

To achieve a paradigm shift versus more Renewables and higher Energy efficiency, the electrical energy, in combination with power electronics, will be a future key technology for our environment.

## II. ENERGY EFFICIENCY AND POWER CONVERSION STEPS

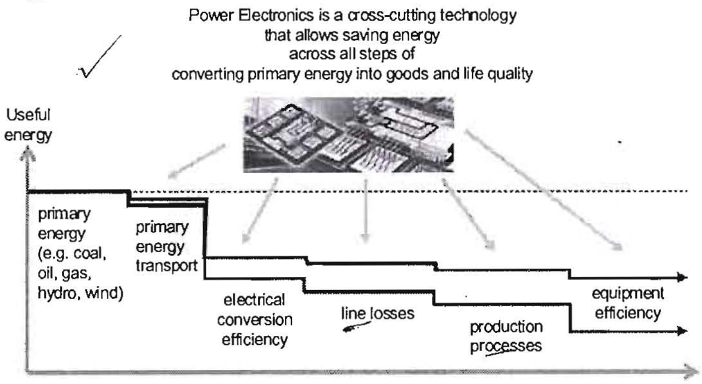


Figure 2: Power conversion steps along the value chain

In regards of energy efficiency it is important to look along the whole value chain, i.e. over the following power conversion steps:

- Primary energy transport
- Electrical energy conversion efficiency
- Transmission and distribution losses
- Production processes
- Equipment efficiency

In regards of the efficient use of the primary energy, which is dominantly fossil fuel based today, each power conversion step needs to be as high efficient as possible (creating as low losses as possible). The different steps should be looked at in detail.

## III. PRIMARY ENERGY TRANSPORT

The energy transport is often requesting a compressor stage either to compress the natural gas for the transport by sea or for the transport by means of a dedicated pipeline.

If a conventional approach of a gas turbine driven compressor is chosen an overall efficiency of only 25% can be achieved [4].

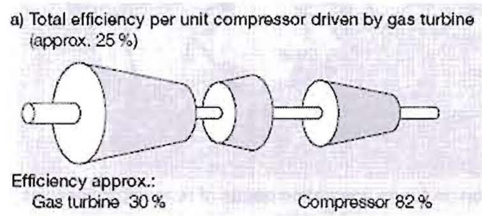


Figure 3: Efficiency of a gas turbine driven compressor

In the case that the electrical variable speed driven compressor solution is chosen an overall efficiency of more than 36% can be achieved. In that case it is important, that the electric power is generated by means of an efficient state-of-the-art bulk power generation station.

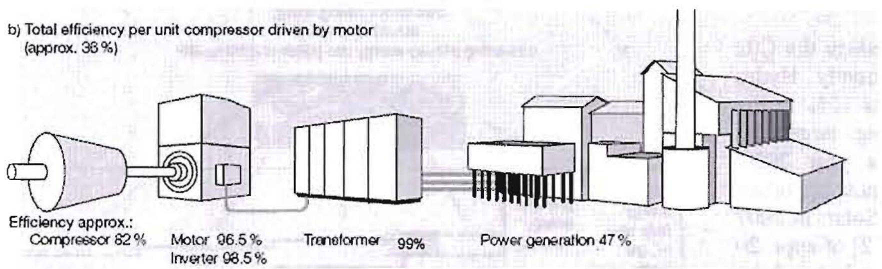


Figure 4: Overall efficiency of a electrically driven compressor

## IV. ELECTRICAL ENERGY POWER CONVERSION EFFICIENCY

### *A. Conventional electrical energy generation*

It is preferable to for generation of electrical energy based on fossil fuel to select the bulk power generation option. Gas turbine based power generation in the 100 MW class and above can achieve a primary to electrical energy conversion efficiency of

- of 47% in a typical arrangement
- up to 55% and higher in a combined cycle plant and
- of more than 80% in triple cycle (for example for district heating or water desalination plant)

Further improvement in regards of C02 emissions can be achieved by

- changeover from coal to natural gas, which has inherently lower C02 emissions
- Carbon capture and storage (CCS) solutions is another future option
- Utilization of nuclear energy

In regards of the overall energy efficiency it is mandatory to utilize the remaining low-temperature heat for heating or industrial processes. Additionally the efficiency of auxiliaries may be improved by means of variable speed drives (for pumps and fans).

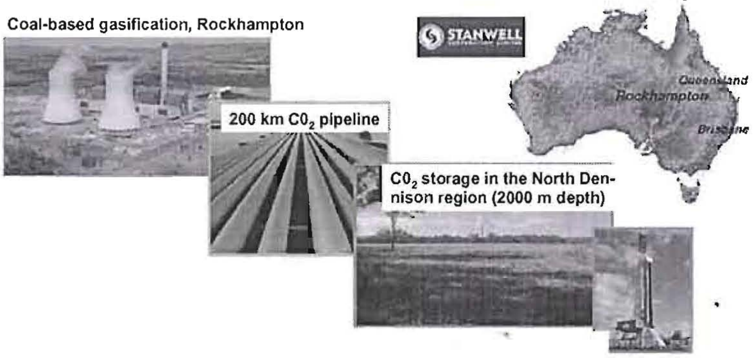


Figure 5: Carbon capture and storage (CCS) solutions for a coal based power plant

In reards of Carbon capture and storage (CCS) solutions the ZeroGen [5] is one of the First CCS pilot plants. It is built in Rockhampton in Australia and utilizes the integration of two proven processes, i.e. coal-based gasification and the carbon capture and storage (CCS). The commissioning is planned for 2010 and the demonstration will end in 2020. This example explains, that the development of these new process technologies need quite some time.

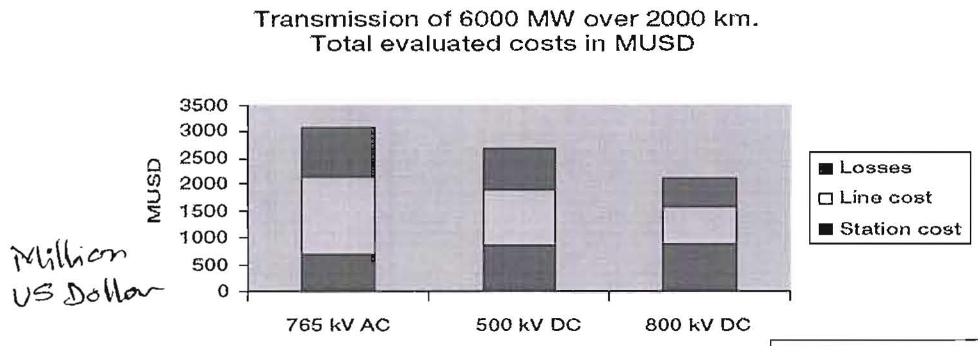


Figure 5: Comparison of HVAC and HVDC transmission systems

DC based system have the advantage of higher efficiency and more throughput power per installed cables compared to AC. Additionally the distribution and transmission system can get invisible as underground cable solutions are simpler to realize.

Additionally it makes in regards of overall energy efficiency a lot of sense to make the power conversion to electrical energy, for example for coal-based power generation, as close to the fossil energy source as possible. The preferred means of energy transportation is the transmission as electrical energy.

## VI. INDUSTRIAL PROCESSES

In regards of industrial processes and related energy efficiency again power electronics can make a considerable contribution ([6] and [7]).

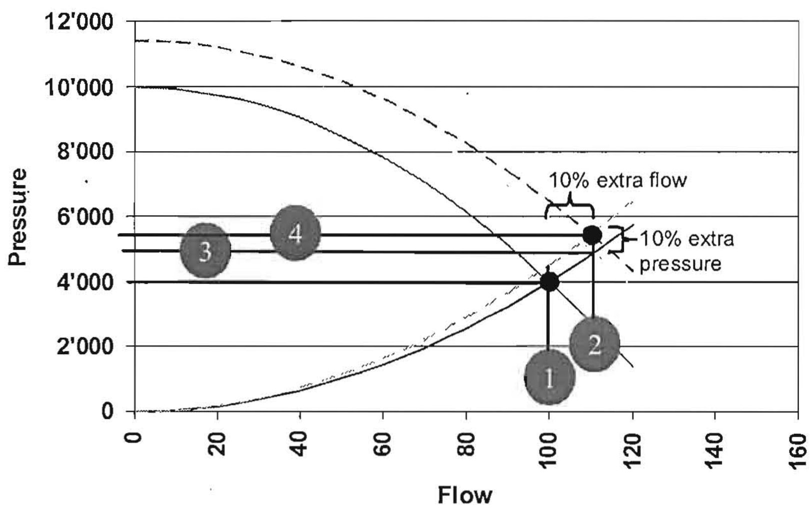


Figure 6: Design of typical pump or fan application with reserves in flow in pressure resulting in 50% oversized motor.

Over all industrial processes the application of power electronics to pumps and fans has the biggest energy saving impact. It is in that respect important to know, that the motor driving pumps and fans are in at least 30% of the applications oversized due to the uncertainty in regards of flow and pressure sizing. The overall global energy saving is huge as can be seen in Table IV.

TABLE IV.

YEARLY SAVINGS IN PUMP AND FAN APPLICATIONS (Global)

| | Yearly Savings |
|---|---|
| Saving of Medium Voltage Drives | 227 TWh |
| - Only 4% are variable speed today<br>- 30% of pumps / fans converted to VSD | |
| Saving of Low Voltage Drives | 1655 TWh |
| - 10 x the installed power of MV motors<br>- Already 30% are variable speed today<br>- 30% of pumps / fans converted to VSD | |
| Total savings of Variable Speed Drives | 1882 TWh |

To put this energy saving into a context, we can say that it would correspond to more than 22 Itaipu Hydro power stations (equivalent to 275 GW of installed capacity with its average asset utilization degree of 75%). We could stop for one year to build any electrical power generation plants.

## VII. TRANSPORTATION

For fossil fuel based transportation systems, i.e. cars, buses, trains, airplanes and ships again the application of power electronics can substantially increase the energy efficiency due to

- higher efficient variable speed power generation
- energy savings for acceleration and deceleration by means of energy storage.

In this approach the DC-linked based power system is the ultimate approach for the highest efficiency.

Based on this concept the following improvements can be achieved:

- 20-30% improvements on the fossil fuel energy engine
- 20-30% improvements due to the hybrid system with energy storage.

Overall energy savings for example for cars in the range of 30 to 50% can be achieved by means of power electronics in combination with energy storage.

The hybrid system will be an intermediate step to the full electrical vehicle, where a further substantial energy efficiency improvement is possible due to the much higher efficiency of bulk power electrical generation.

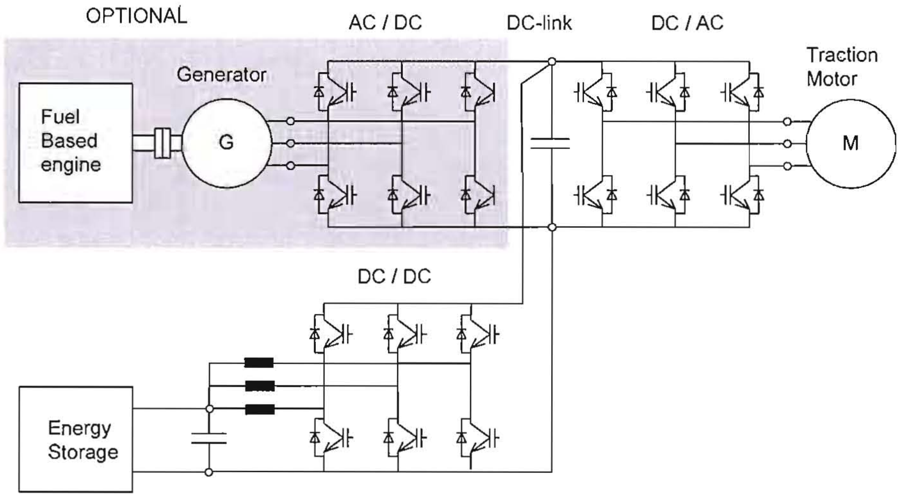


Figure 7: DC-link based power system

## VIII. CONCLUSIONS

It is quite clear, that a major shift to renewables as sources of future electrical energy will happen. The political institutions world-wide have the responsibility to create the boundary conditions to accelerate this needed change. Renewables (Wind, Solar, ..) are important future contributors and solar power (photovoltaic or thermal) needs to be taken very serious. It may develop much faster than expected. At the end it is a simple technology in the application.

In regards of energy efficiency we need to focus on efficient bulk power generation including the mandatory use of waste heat for district heating or process industries. Variable speed drives have to replace overall inefficient industrial gas turbines drivers. Another 30% of pump and fan applications need to be converted to variable speed drives to get an average of 40% energy saving in these applications.

In regards of transportation up to 30-50% fuel / energy consumption reduction can be achieved with the DC-link based power system to enable efficient hybrid and in the longer term pure electrical solutions in transportation (cars, buses, trains,..). Transportation needs to get electrical, wherever possible with the first option for trains.

Overall it is clear, what needs to be done. But we need an effective approach to productize and multiply future solar power solutions, we have to exploit the energy efficiency options, i.e. bulk power generation and variable speed drives for pumps and fans. This all will ask for a substantial expansion and modernization of the electrical distribution and transmission system.

The other challenge will be transportation, where the long-term target is the highest-efficient, pure electrical solution for cars, trains, etc. In the mean time we need to productize intermediate hybrid solutions combined with substantially higher efficient fossil fuel engines.

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energy scene toward a more sustainable future. By strategically using these advances and resolving related issu we may raise the bar for environmental sustainability, dependability, and energy efficiency to unprecedented lev worldwide.





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