Hydro Power
How Hydropower Works!

- Hydrologic cycle
How Hydropower Works! (ctd…)

- Water from the reservoir flows due to gravity to drive the turbine.
- Turbine is connected to a generator.
- Power generated is transmitted over power lines.
## Top ten countries (in terms of capacity)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>POWER CAPACITY (GWh)</th>
<th>INSTALLED CAPACITY (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAJIKISTAN</td>
<td>527000</td>
<td>4000</td>
</tr>
<tr>
<td>CANADA</td>
<td>341312</td>
<td>66954</td>
</tr>
<tr>
<td>USA</td>
<td>319484</td>
<td>79511</td>
</tr>
<tr>
<td>BRAZIL</td>
<td>285603</td>
<td>57517</td>
</tr>
<tr>
<td>CHINA</td>
<td>204300</td>
<td>65000</td>
</tr>
<tr>
<td>RUSSIA</td>
<td>160500</td>
<td>44000</td>
</tr>
<tr>
<td>NORWAY</td>
<td>121824</td>
<td>27528</td>
</tr>
<tr>
<td>JAPAN</td>
<td>84500</td>
<td>27229</td>
</tr>
<tr>
<td>INDIA</td>
<td>82237</td>
<td>22083</td>
</tr>
<tr>
<td>FRANCE</td>
<td>77500</td>
<td>77500</td>
</tr>
</tbody>
</table>
The Indian Scenario

- The potential is about 84000 MW at 60% load factor spread across six major basins in the country.
- Pumped storage sites have been found recently which leads to a further addition of a maximum of 94000 MW.
- Annual yield is assessed to be about 420 billion units per year though with seasonal energy the value crosses 600 billion mark.
- The possible installed capacity is around 150000 MW (Based on the report submitted by CEA to the Ministry of Power)
The proportion of hydro power increased from 35% from the first five year plan to 46% in the third five year plan but has since then decreased continuously to 25% in 2001. The theoretical potential of small hydro power is 10071 MW. Currently about 17% of the potential is being harnessed. About 6.3% is still under construction.
India’s Basin wise potential

<table>
<thead>
<tr>
<th>Rivers</th>
<th>Potential at 60%LF (MW)</th>
<th>Probable installed capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indus</td>
<td>19988</td>
<td>33832</td>
</tr>
<tr>
<td>Ganga</td>
<td>10715</td>
<td>20711</td>
</tr>
<tr>
<td>Central Indian rivers</td>
<td>2740</td>
<td>4152</td>
</tr>
<tr>
<td>West flowing</td>
<td>6149</td>
<td>9430</td>
</tr>
<tr>
<td>East flowing</td>
<td>9532</td>
<td>14511</td>
</tr>
<tr>
<td>Brahmaputra</td>
<td>34920</td>
<td>66065</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>84044</strong></td>
<td><strong>148701</strong></td>
</tr>
</tbody>
</table>
### Region wise status of hydro development

<table>
<thead>
<tr>
<th>REGION</th>
<th>POTENTIAL ASSESSED (60% LF)</th>
<th>POTENTIAL DEVELOPED (MW)</th>
<th>% DEVELOPED</th>
<th>UNDER DEVELOPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORTH</td>
<td>30155</td>
<td>4591</td>
<td>15.2</td>
<td>2514</td>
</tr>
<tr>
<td>WEST</td>
<td>5679</td>
<td>1858</td>
<td>32.7</td>
<td>1501</td>
</tr>
<tr>
<td>SOUTH</td>
<td>10763</td>
<td>5797</td>
<td>53.9</td>
<td>632</td>
</tr>
<tr>
<td>EAST</td>
<td>5590</td>
<td>1369</td>
<td>24.5</td>
<td>339</td>
</tr>
<tr>
<td>NORTH EAST</td>
<td>31857</td>
<td>389</td>
<td>1.2</td>
<td>310</td>
</tr>
<tr>
<td>INDIA</td>
<td>84044</td>
<td>14003</td>
<td>16.7</td>
<td>5294</td>
</tr>
</tbody>
</table>
## Major Hydropower generating units

<table>
<thead>
<tr>
<th>NAME</th>
<th>STATE</th>
<th>CAPACITY (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHAKRA</td>
<td>PUNJAB</td>
<td>1100</td>
</tr>
<tr>
<td>NAGARJUNA</td>
<td>ANDHRA PRADESH</td>
<td>960</td>
</tr>
<tr>
<td>KOYNA</td>
<td>MAHARASHTRA</td>
<td>920</td>
</tr>
<tr>
<td>DEHAR</td>
<td>HIMACHAL PRADESH</td>
<td>990</td>
</tr>
<tr>
<td>SHARAVATHY</td>
<td>KARNATAKA</td>
<td>891</td>
</tr>
<tr>
<td>KALINADI</td>
<td>KARNATAKA</td>
<td>810</td>
</tr>
<tr>
<td>SRISAILAM</td>
<td>ANDHRA PRADESH</td>
<td>770</td>
</tr>
</tbody>
</table>
## Installed Capacity

<table>
<thead>
<tr>
<th>REGION</th>
<th>HYDRO</th>
<th>THERMAL</th>
<th>WIND</th>
<th>NUCLEAR</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORTH</td>
<td>8331.57</td>
<td>17806.99</td>
<td>4.25</td>
<td>1320</td>
<td>27462.81</td>
</tr>
<tr>
<td>WEST</td>
<td>4307.13</td>
<td>25653.98</td>
<td>346.59</td>
<td>760</td>
<td>31067.7</td>
</tr>
<tr>
<td>SOUTH</td>
<td>9369.64</td>
<td>14116.78</td>
<td>917.53</td>
<td>780</td>
<td>25183.95</td>
</tr>
<tr>
<td>EAST</td>
<td>2453.51</td>
<td>13614.58</td>
<td>1.10</td>
<td>0</td>
<td>16069.19</td>
</tr>
<tr>
<td>N.EAST</td>
<td>679.93</td>
<td>1122.32</td>
<td>0.16</td>
<td>0</td>
<td>1802.41</td>
</tr>
<tr>
<td>INDIA</td>
<td>25141.78</td>
<td>72358.67</td>
<td>1269.63</td>
<td>2860</td>
<td>101630.08</td>
</tr>
</tbody>
</table>
# Region wise contribution of Hydropower

<table>
<thead>
<tr>
<th>REGION</th>
<th>PERCENTAGE</th>
</tr>
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<tbody>
<tr>
<td>NORTH</td>
<td>30.34</td>
</tr>
<tr>
<td>WEST</td>
<td>13.86</td>
</tr>
<tr>
<td>SOUTH</td>
<td>37.2</td>
</tr>
<tr>
<td>EAST</td>
<td>15.27</td>
</tr>
<tr>
<td>NORTH-EAST</td>
<td>37.72</td>
</tr>
<tr>
<td>INDIA</td>
<td>24.74</td>
</tr>
</tbody>
</table>
# Annual gross generation (GWh)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>GROSS GENERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>85/86</td>
<td>51021</td>
</tr>
<tr>
<td>90/91</td>
<td>71641</td>
</tr>
<tr>
<td>91/92</td>
<td>72757</td>
</tr>
<tr>
<td>92/93</td>
<td>69869</td>
</tr>
<tr>
<td>93/94</td>
<td>70643</td>
</tr>
<tr>
<td>94/95</td>
<td>82712</td>
</tr>
<tr>
<td>95/96</td>
<td>72579</td>
</tr>
<tr>
<td>96/97</td>
<td>68901</td>
</tr>
<tr>
<td>97/98</td>
<td>74582</td>
</tr>
<tr>
<td>98/99</td>
<td>82690</td>
</tr>
<tr>
<td>99/2000</td>
<td>80533</td>
</tr>
<tr>
<td>00/01</td>
<td>74346</td>
</tr>
</tbody>
</table>
Annual Gross Generation (GWh)

Electricity Generation (GWh)

Year

1991  1993  1995  1997  1999  2001
Potential of Small Hydropower

- Total estimated potential of 180000 MW.
- Total potential developed in the late 1990s was about 470000 MW with China contributing as much as one-third total potentials.
- 570 TWh per year from plants less than 2 MW capacity.
- The technical potential of micro, mini and small hydro in India is placed at 6800 MW.
## Small Hydro in India

<table>
<thead>
<tr>
<th>STATE</th>
<th>TOTAL CAPACITY (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARUNACHAL PRADESH</td>
<td>1059.03</td>
</tr>
<tr>
<td>HIMACHAL PRADESH</td>
<td>1624.78</td>
</tr>
<tr>
<td>UTTAR PRADESH &amp; UTTARANCHAL</td>
<td>1472.93</td>
</tr>
<tr>
<td>JAMMU &amp; KASHMIR</td>
<td>1207.27</td>
</tr>
<tr>
<td>KARNATAKA</td>
<td>652.51</td>
</tr>
<tr>
<td>MAHARASHTRA</td>
<td>599.47</td>
</tr>
</tbody>
</table>
Sites (up to 3 MW) identified by UNDP

<table>
<thead>
<tr>
<th>STATE</th>
<th>TOTAL SITES</th>
<th>CAPACITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORTH</td>
<td>562</td>
<td>370</td>
</tr>
<tr>
<td>EAST</td>
<td>164</td>
<td>175</td>
</tr>
<tr>
<td>NORTH EAST</td>
<td>640</td>
<td>465</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1366</strong></td>
<td><strong>1010</strong></td>
</tr>
</tbody>
</table>
TECHNOLOGY
Technology

Hydropower Technology

- Impoundment
- Diversion
- Pumped Storage
Impoundment facility

Transmission lines - conduct electricity, ultimately to homes and businesses.

Dam - stores water.

Penstock - Carries water to the turbines.

Generators - rotated by the turbines to generate electricity.

Turbines - turned by the force of the water on their blades.

Cross section of conventional hydropower facility that uses an impoundment dam.
Dam Types

- Arch
- Gravity
- Buttress
- Embankment or Earth
Arch Dams

- Arch shape gives strength
- Less material (cheaper)
- Narrow sites
- Need strong abutments
Concrete Gravity Dams

- Weight holds dam in place
- Lots of concrete (expensive)
Buttress Dams

- Face is held up by a series of supports
- Flat or curved face
Embankment Dams

- Earth or rock
- Weight resists flow of water
Dams Construction

Diagram showing the components of a dam, including:
- Upstream Cofferdam
- Main Dam
- Downstream Cofferdam
- Diversion Tunnel

Diagram also includes a River flow path.
Diversion Facility

- Doesn’t require dam
- Facility channels portion of river through canal or penstock
**Pumped Storage**

- During Storage, water pumped from lower reservoir to higher one.
- Water released back to lower reservoir to generate electricity.
Pumped Storage

- Operation: Two pools of Water
- Upper pool – impoundment
- Lower pool – natural lake, river or storage reservoir
- Advantages:
  - Production of peak power
  - Can be built anywhere with reliable supply of water

The Raccoon Mountain project
Sizes of Hydropower Plants

- Definitions may vary.
- Large plants: capacity >30 MW
- Small Plants: capacity b/w 100 kW to 30 MW
- Micro Plants: capacity up to 100 kW
Large Scale Hydropower plant
Small Scale Hydropower Plant
Micro Hydropower Plant
Micro Hydropower Systems

- Many creeks and rivers are permanent, i.e., they never dry up, and these are the most suitable for micro-hydro power production
- Micro hydro turbine could be a waterwheel
- Newer turbines: Pelton wheel (most common)
- Others: Turgo, Crossflow and various axial flow turbines
Generating Technologies

- Types of Hydro Turbines:
  - Impulse turbines
    - Pelton Wheel
    - Cross Flow Turbines
  - Reaction turbines
    - Propeller Turbines: Bulb turbine, Straflo, Tube Turbine, Kaplan Turbine

- Francis Turbines
- Kinetic Turbines
Impulse Turbines

- Uses the velocity of the water to move the runner and discharges to atmospheric pressure.
- The water stream hits each bucket on the runner.
- No suction downside, water flows out through turbine housing after hitting.
- High head, low flow applications.
- Types: Pelton wheel, Cross Flow
Pelton Wheels

- Nozzles direct forceful streams of water against a series of spoon-shaped buckets mounted around the edge of a wheel.
- Each bucket reverses the flow of water and this impulse spins the turbine.
Pelton Wheels (continued…)

- Suited for high head, low flow sites.
- The largest units can be up to 200 MW.
- Can operate with heads as small as 15 meters and as high as 1,800 meters.
Cross Flow Turbines

- drum-shaped
- elongated, rectangular-section nozzle directed against curved vanes on a cylindrically shaped runner
- “squirrel cage” blower
- water flows through the blades twice
Cross Flow Turbines (continued...)

- First pass: water flows from the outside of the blades to the inside
- Second pass: from the inside back out
- Larger water flows and lower heads than the Pelton.
**Reaction Turbines**

- Combined action of pressure and moving water.
- Runner placed directly in the water stream flowing over the blades rather than striking each individually.
- Lower head and higher flows than compared with the impulse turbines.
Propeller Hydropower Turbine

- Runner with three to six blades.
- Water contacts all of the blades constantly.
- Through the pipe, the pressure is constant.
- Pitch of the blades - fixed or adjustable.
- Scroll case, wicket gates, and a draft tube.
- Types: Bulb turbine, Straflo, Tube turbine, Kaplan.
Bulb Turbine

- The turbine and generator are a sealed unit placed directly in the water stream.
Others...

- Straflo: The generator is attached directly to the perimeter of the turbine.
- Tube Turbine: The penstock bends just before or after the runner, allowing a straight line connection to the generator.
- Kaplan: Both the blades and the wicket gates are adjustable, allowing for a wider range of operation.
Kaplan Turbine

- The inlet is a scroll-shaped tube that wraps around the turbine's wicket gate.
- Water is directed tangentially, through the wicket gate, and spirals on to a propeller shaped runner, causing it to spin.
- The outlet is a specially shaped draft tube that helps decelerate the water and recover kinetic energy.
Francis Turbines

- The inlet is spiral shaped.
- Guide vanes direct the water tangentially to the runner.
- This radial flow acts on the runner vanes, causing the runner to spin.
- The guide vanes (or wicket gate) may be adjustable to allow efficient turbine operation for a range of water flow conditions.
Frances Turbines (continued…)

- Best suited for sites with high flows and low to medium head.
- Efficiency of 90%.
- Expensive to design, manufacture and install, but operate for decades.
**Kinetic Energy Turbines**

- Also called free-flow turbines.
- Kinetic energy of flowing water used rather than potential from the head.
- Operate in rivers, man-made channels, tidal waters, or ocean currents.
- Do not require the diversion of water.
- Kinetic systems do not require large civil works.
- Can use existing structures such as bridges, tailraces and channels.
Hydroelectric Power Plants in India

Baspa II

Binwa
Continued …

Gaj

Nathpa Jakri
Continued…

Rangit

Sardar Sarovar
ENVIRONMENTAL IMPACT
Benefits…

- Environmental Benefits of Hydro
  - No operational greenhouse gas emissions
  - Savings (kg of CO2 per MWh of electricity):
    - Coal 1000 kg
    - Oil 800 kg
    - Gas 400 kg
  - No SO2 or NOX

- Non-environmental benefits
  - flood control, irrigation, transportation, fisheries and
  - tourism.
Disadvantages

- The loss of land under the reservoir.
- Interference with the transport of sediment by the dam.
- Problems associated with the reservoir.
  - Climatic and seismic effects.
  - Impact on aquatic ecosystems, flora and fauna.
Loss of land

- A large area is taken up in the form of a reservoir in case of large dams.

- This leads to inundation of fertile alluvial rich soil in the flood plains, forests and even mineral deposits and the potential drowning of archeological sites.

- Power per area ratio is evaluated to quantify this impact. Usually ratios lesser than 5 KW per hectare implies that the plant needs more land area than competing renewable resources. However this is only an empirical relation.
Climatic and Seismic effects

- It is believed that large reservoirs induce have the potential to induce earthquakes.

- In tropics, existence of man-made lakes decreases the convective activity and reduces cloud cover. In temperate regions, fog forms over the lake and along the shores when the temperature falls to zero and thus increases humidity in the nearby area.
### Some major/minor induced earthquakes

<table>
<thead>
<tr>
<th>DAM NAME</th>
<th>COUNTRY</th>
<th>HEIGHT (m)</th>
<th>VOLUME OF RESERVOIR (m³)</th>
<th>MAGNITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOYNA</td>
<td>INDIA</td>
<td>103</td>
<td>2780</td>
<td>6.5</td>
</tr>
<tr>
<td>KREMASTA</td>
<td>GREECE</td>
<td>165</td>
<td>4650</td>
<td>6.3</td>
</tr>
<tr>
<td>HSINFENKJIANG</td>
<td>CHINA</td>
<td>105</td>
<td>10500</td>
<td>6.1</td>
</tr>
<tr>
<td>BENMORE</td>
<td>NEW ZEALAND</td>
<td>118</td>
<td>2100</td>
<td>5.0</td>
</tr>
<tr>
<td>MONTEYNARD</td>
<td>FRANCE</td>
<td>155</td>
<td>240</td>
<td>4.9</td>
</tr>
</tbody>
</table>
Eutrophication

- In tropical regions due to decomposition of the vegetation, there is increased demand for biological oxygen in the reservoir.
- The relatively constant temperatures inhibit the thermally induced mixing that occurs in temperate latitudes.
- In this anaerobic layer, there is formation of methane which is a potential greenhouse gas.
- This water, when released kills the fishes downstream and creates an unattractive odor. The only advantage is that all these activities are not permanent.
Other problems

- Many fishes require flowing water for reproduction and cannot adapt to stagnant resulting in the reduction in its population.
- Heating of the reservoirs may lead to decrease in the dissolved oxygen levels.
- The point of confluence of fresh water with salt water is a breeding ground for several aquatic life forms. The reduction in run-off to the sea results in reduction in their life forms.
- Other water-borne diseases like malaria, river-blindness become prevalent.
Methods to alleviate the negative impact

- Creation of ecological reserves.
- Limiting dam construction to allow substantial free flowing water.
- Building sluice gates and passes that help prevent fishes getting trapped.
Favorable impact

- Enhanced fishing upstream.
- Opportunities for irrigated farming downstream.
- With the flooding of the forest habitat of the Tsetse fly, the vector of this disease, the problem of Sleeping Sickness has been substantially reduced.
Technological advancements

- Technology to mitigate the negative environmental impact.
  - Construction of fish ways for the passage of fish through, over, or around the project works of a hydro power project, such as fish ladders, fish locks, fish lifts and elevators, and similar physical contrivances
  - Building of screens, barriers, and similar devices that operate to guide fish to a fish way
Continued…

- Evaluating a new generation of large turbines
  - Capable of balancing environmental, technical, operational, and cost considerations

- Developing and demonstrating new tools
  - to generate more electricity with less water and greater environmental benefits
  - tools to improve how available water is used within hydropower units, plants, and river systems

- Studying the benefits, costs, and overall effectiveness of environmental mitigation practices
THANK YOU